CEDAR CITY WEST SIDE DRAINAGE MASTER PLAN

Prepared for:

U.S. Army Corps of Engineers,
Cedar City,
Iron County, and
Central Iron County Water Conservancy District

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June 2008

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INTRODUCTION

Purpose

This report has been prepared as part of the West Side Drainage Master Plan Project, a project jointly funded by Cedar City, Iron County, Central Iron County Water Conservancy District, and the U.S. Army Corps of Engineers. The primary purpose in completing this study is to identify drainage and flood control improvements needed in the area west of I-15 near Cedar City, Utah. A secondary goal of the project was to evaluate the feasibility of implementing a long-term groundwater recharge project utilizing water from Coal Creek. Both of these issues are addressed in subsequent sections of this report.

This report compiles the results of the major work tasks associated with the contractual scope of services for this project, which included:

- Utilizing information from previous studies to estimate the 100-year flood discharges relative to existing conveyance capacities of drainage facilities west of I-15 near Cedar City.
- Preparing a technical memorandum to address alternative flood control improvements and develop a conceptual runoff management plan for the study area.
- Preparing a technical memorandum to evaluate the feasibility of utilizing runoff from Coal Creek to develop a long-term groundwater recharge project in the study area.

A meeting was held on April 28, 2008 to review the preliminary results and recommendations documented in a capacity figure and two draft technical memorandums that were previously prepared. The draft technical memorandums are included in Appendix A with a copy of the meeting notes. The comments received during that meeting were then addressed and this report was prepared to documents the results of the study.

SECTION 2
BACKGROUND INFORMATION

Background Information

The Cedar Valley is located along the eastern margin of the Great Basin at the transition between the Basin and Range and Colorado Plateau Physiographic Provinces (reference 1). The Cedar Valley Drainage Basin varies in elevation from about 5,300 feet (above mean sea level) on the valley floor to about 10,400 feet on the plateau to the east and covers an area of approximately 570 square miles. Average annual precipitation in the drainage basin varies from about 10.6 inches on the valley floor to about 35 inches near the headwaters of Coal Creek in the Markagunt Plateau. Coal Creek, with a drainage area of approximately 80 square miles, is the largest perennial stream (and the only gaged stream) in Cedar Valley (reference 2). Coal Creek is a very dynamic landform, experiencing significant active bank erosion, sediment deposition, and head-cutting.

The average annual runoff from the Coal Creek drainage basin is 24,600 acre-feet, most of which is generated from snowmelt in the higher elevations of the watershed (reference 3).

Cedar City is located on alluvial deposits conveyed from Coal Creek and other drainage basins over thousands of years. Coal Creek and other east-side drainages have been sources of many significant flooding events since the settlement of Cedar City. Much of the flooding from these events has occurred west of I-15, in areas that have historically been agricultural and where periodic flooding was expected and created little or no structural damage. There have been several flood control improvement projects constructed on the east side of I-15 in Cedar City to eliminate or minimize alluvial fan flood hazards and provide facilities to safely convey the 100-year flood to areas west of I-15. Cedar City recently completed another flood control project east of I-15 on Coal Creek to increase channel capacity to convey the FEMA 100-year flood safely through the city. West of I-15, Coal Creek and other open channels have historically been used primarily as irrigation facilities. Diversions are generally operated to convey water to agricultural lands. However, during large runoff events, flood discharges can exceed the limited capacities of the irrigation facilities and cause shallow flooding on the historic agricultural lands. Development pressure west of I-15 has increased significantly over the past 20 years. The new development in this area has made periodic flooding of the historic fields unacceptable. The need to identify storm water management procedures and facilities to minimize flooding west of I-15 is the major issue driving this study.

Most of the water in Coal Creek is diverted into a fairly complex system of ditches and used for irrigation. The water is diverted into ditches or canals based on priority water rights defined by the Coal Creek Decree filed in 1922. Stream-flow less than 102.02 cfs is distributed in accordance with the decree. Flows in excess of that amount are distributed to low priority rights filed after 1903 (reference 2). During periods of extra high runoff resulting from snowmelt or intense canyon cloudburst events, water from Coal Creek that is not utilized for irrigation may be conveyed to Quichapa Lake or Rush Lake, two terminal playa lakes in Cedar Valley. There is not enough data available to estimate amount and frequency of runoff events that result in water being conveyed to these two playa lakes. However, reported lake stage observations from years with drainage basin snowpack well above average, like 1983 and 2005, indicates that extended periods of high runoff can result in significant increases in lake stages, inundating lands and property that is normally dry.

Previous studies have shown that Coal Creek channel seepage losses that could contribute to groundwater recharge between the USGS stream-flow gage 10242000 and Main Street in Cedar City are minimal. It is believed that fine-grained sediment eroded from the watershed during thunderstorms has settled into the sands and gravels along the channel bed, significantly decreasing seepage losses.

Groundwater from the aquifer in the unconsolidated basin fill of Cedar Valley is withdrawn for irrigation and municipal uses. The level of the water table in the Cedar City area has been steadily declining over the past 50 years. Therefore, there is great interest by water users in the area to develop means of increasing aquifer recharge to stabilize the average annual water levels in the aquifer.

Hydrology

Coal Creek experiences high runoff during periods of spring snowmelt as well as in response to summer cloudburst events. The FEMA-accepted 100-year flood hydrology for both Coal Creek and Fiddler's Canyon Creek is presented in Table 1.

Table 1
Magnitudes of FEMA 100-year Floods[1]

Coal Creek 100-year Snowmelt	2,000 cfs
Coal Creek 100-year Cloudburst	5,550 cfs
Fiddler's Canyon Creek (AMC 3) [2]	805 cfs

Notes:

1 - Discharge Locations at Respective Canyon Mouth

2 - Discharge Computed from AMC 3 (nearly saturated) soil moisture conditions at beginning of design storm. Computed discharge from AMC 2 (average) soil moisture conditions at beginning of design storm is 430 cfs.

As shown in Table 1, there are distinct differences between the two types of flood events that occur on Coal Creek. Snowmelt floods generally have high discharges with diurnal fluctuations which usually occur over one to three weeks. Cloudburst floods have short durations, typically just a few hours, and have significantly higher peak discharges than snowmelt events. The flood discharge data summarized in Table 1 for Coal Creek were developed using a statistical analysis of 75 years of annual peak discharge records from the United States Geological Survey stream gage (10242000). The 100-year discharge for Fiddler's Canyon Creek was developed using a rainfall-runoff model in conjunction with a USGS regional regression equation.

Erosion and Sediment Deposition

Over geologic time Coal Creek runoff has been the driving force to the formation of an alluvial fan in the Cedar City area. That fan extends from its apex at the mouth of Cedar Canyon to the valley floor to the west. Coal Creek is still a very active alluvial stream that transports large volumes of eroded sediment from the mountain watershed and canyon channel banks to the Cedar Valley. It has been estimated that Coal Creek yields an annual average of approximately 54.4 acre-feet (88,000 cubic yards) of sediment (reference 4). The highest sediment loads are conveyed during periods of high runoff. The slope of the ground surface on this alluvial fan decreases in the westward direction. This means that the larger and coarser alluvial deposits can be found on the eastern, steeper portion of the fan. Finer grained deposits are located on the flatter portion of the fan. Field observations of sediment deposits indicate that the groundwater recharge is much more efficient in areas east of Airport Road than in areas west of Airport Road. Fine-grain soils and natural topographic depressions have created Quichapa Lake and Rush Lake in areas west and north of Airport Road, far away from the alluvial fan apex, where seepage losses are minimal.

Safety Issues Associated with Hazardous Wildlife Attractants Near Airports

This study evaluates the feasibility of utilizing existing or abandoned gravel mining areas west of I-15 for either storm water detention/retention facilities or groundwater recharge/infiltration facilities. The sites that are most suitable for these purposes are near the Cedar City Airport. Bodies of open surface water can attract wildlife that can create hazards for aircraft. Airports that have received Federal assistance for construction must comply with the standards, practices, and recommendations contained in the Federal Aviation Administration (FAA) Advisory Circular (AC) No. 150/5200-33A, Hazardous Wildlife Attractants on or near Airports. That circular identifies recommended land use practices on or near airports that potentially attract hazardous wildlife.

The FAA recommends a separation distance of at least 5,000 feet between air operation areas and hazardous wildlife attractants for airports that serve piston-powered aircraft and a minimum separation distance of 10,000 feet for airports that serve turbine-powered aircraft. Since sites best suited for both storm water detention/retention and groundwater recharge are located within 5000 feet of the Cedar City Airport, Cedar City, Iron County, Central Iron County Water Conservancy District, and the airport operators will need to develop management plans to minimize wildlife hazards in the area in compliance with local, state and federal regulations to properly support the operation of floodwater and groundwater recharge management facilities in this area. The FAA hazardous wildlife management recommendations associated with open water bodies near airports includes the following:

- Detention/retention basins should be designed to allow a maximum 48-hour detention time.
- Detention/retention facilities should remain completely dry between rainfall events (featuring no dead storage).
- Detention/retention (and other water holding) facilities should be steep-sided, narrow, and linearly shaped.
- Where it is not possible to place storm water management facilities outside the recommended separation distances, physical barriers such as bird balls, wires grids, pillows, or netting should be placed between the airport and the water management facilities.
- All vegetation in or around the water management facilities that provide food or cover for hazardous wildlife should be eliminated.
- Where soil conditions allow, utilize buried storm water infiltration systems to dispose of runoff.

FAA regulations require that airport operators and other entities that sponsor water management projects near airports consult with and get approval from the appropriate FAA regional Airports Division Office before any detention/retention or groundwater recharge facility can be constructed within the required clear zones, previously designated, or before installing any physical barriers over the open water facilities.

SECTION 3
EVALUATION OF STORM DRAINAGE AND FLOOD CONTROL FACILITIES

Existing Drainage Facilities and Problem Areas

Coal Creek conveys runoff from Cedar Canyon through Cedar City to the Woodbury Split, located just east of I-15. The Woodbury Split is a bifurcation structure that diverts a portion of the Coal Creek stream into the Quichapa Channel. A detailed review of historic aerial photographs of the area indicates that a well-defined Coal Creek channel that could convey water from large floods to Rush Lake, in the area west of I-15, has not existed in recent history. This means that historically, large runoff events would cause shallow flooding over large areas west of I-15. Most of that water likely percolated into the ground. As previously mentioned, some Coal Creek flood water from large runoff events likely reached Rush Lake, north of Cedar City. The existing reach of the lower Coal Creek channel between the Airport Split (shown in Figure 1) and Mid Valley Road was constructed in more recent years.

The Quichapa Channel was constructed to convey irrigation water as far west as the Bud Bauer diversion (see Figure 1) and excess irrigation and flood water to Quichapa Lake. The primary hydraulic problems and flood conveyance issues associated with Coal Creek and the Quichapa Channel include the following:

- Inadequate Channel Capacities
- Combined Irrigation and Flood Control Facilities
- Sediment Deposition
- Erosion During High Discharges

Each of these items will be discussed in detail below.

Inadequate Channel Capacities
Channel capacities and stream gradients on both Coal Creek and the Quichapa Channel decrease in the downstream direction. The constructed and maintained reach of the Coal Creek channel currently ends just north of Mid Valley Road where most of the water conveyed to that point then sheet flows to the north. Figure 2 summarizes the hydraulic capacities for the sections of Coal Creek and the Quichapa Channel located in the study area. The information in Figure 2 was compiled from hydraulic computer models developed as part of a Digital Flood Insurance Rate Map project that is currently being sponsored by the State of Utah and the Federal Emergency Management Agency (FEMA) (reference 5). Hydraulic model output for Coal Creek and the Quichapa Channel used in this analysis is included in Appendix B. Figures A-1 and A-2, included in Appendix C present hydraulic profiles developed for both Coal Creek and the Quichapa Channel. Those profiles illustrate how the channel slopes decrease in the downstream direction as well as where sediment deposition has occurred upstream of existing bridges and culverts, and where scour and head-cutting have occurred downstream of bridges and culverts.

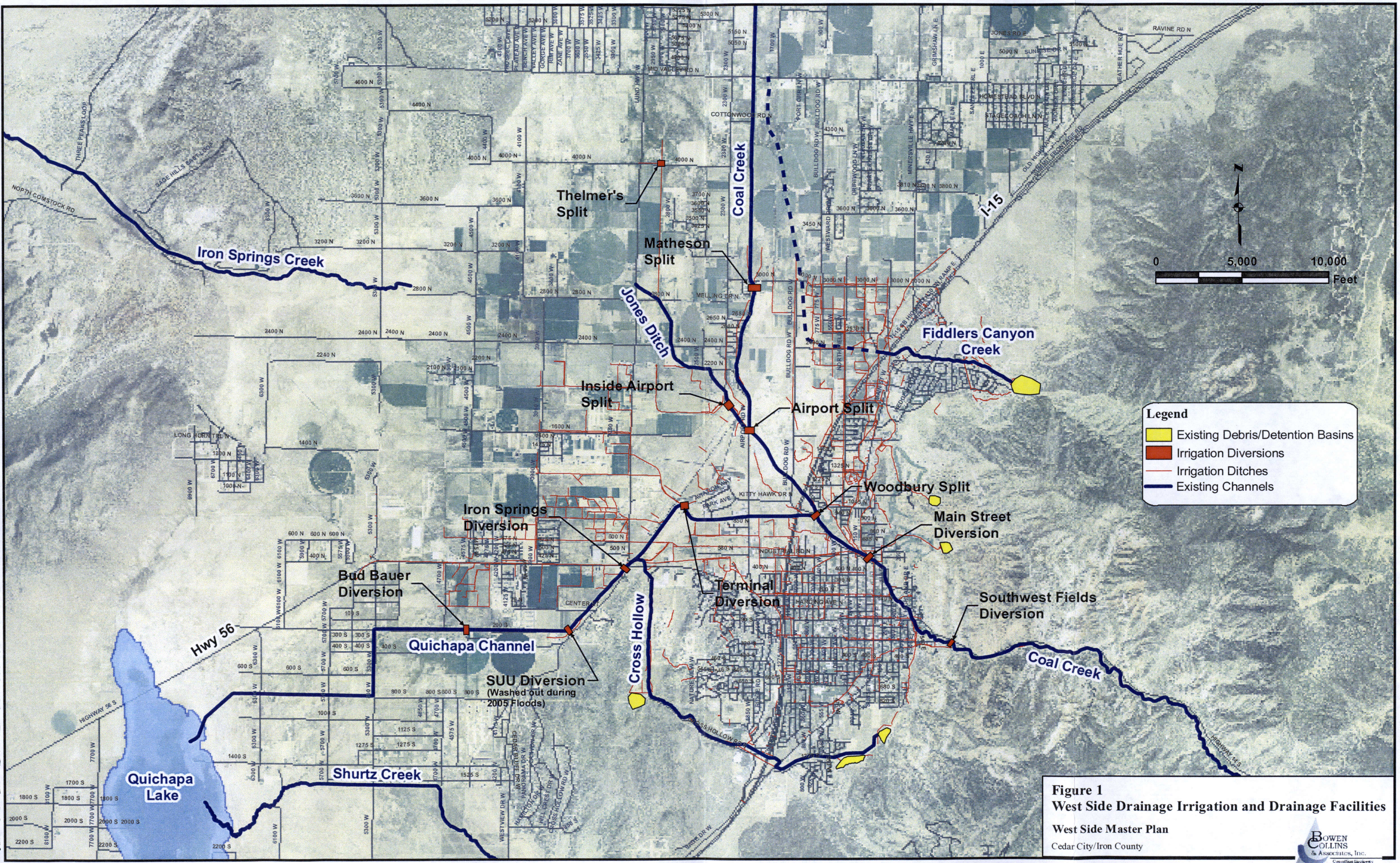

Figure 1
West Side Drainage Irrigation and Drainage Facilities

West Side Master Plan

Cedar City/Iron County

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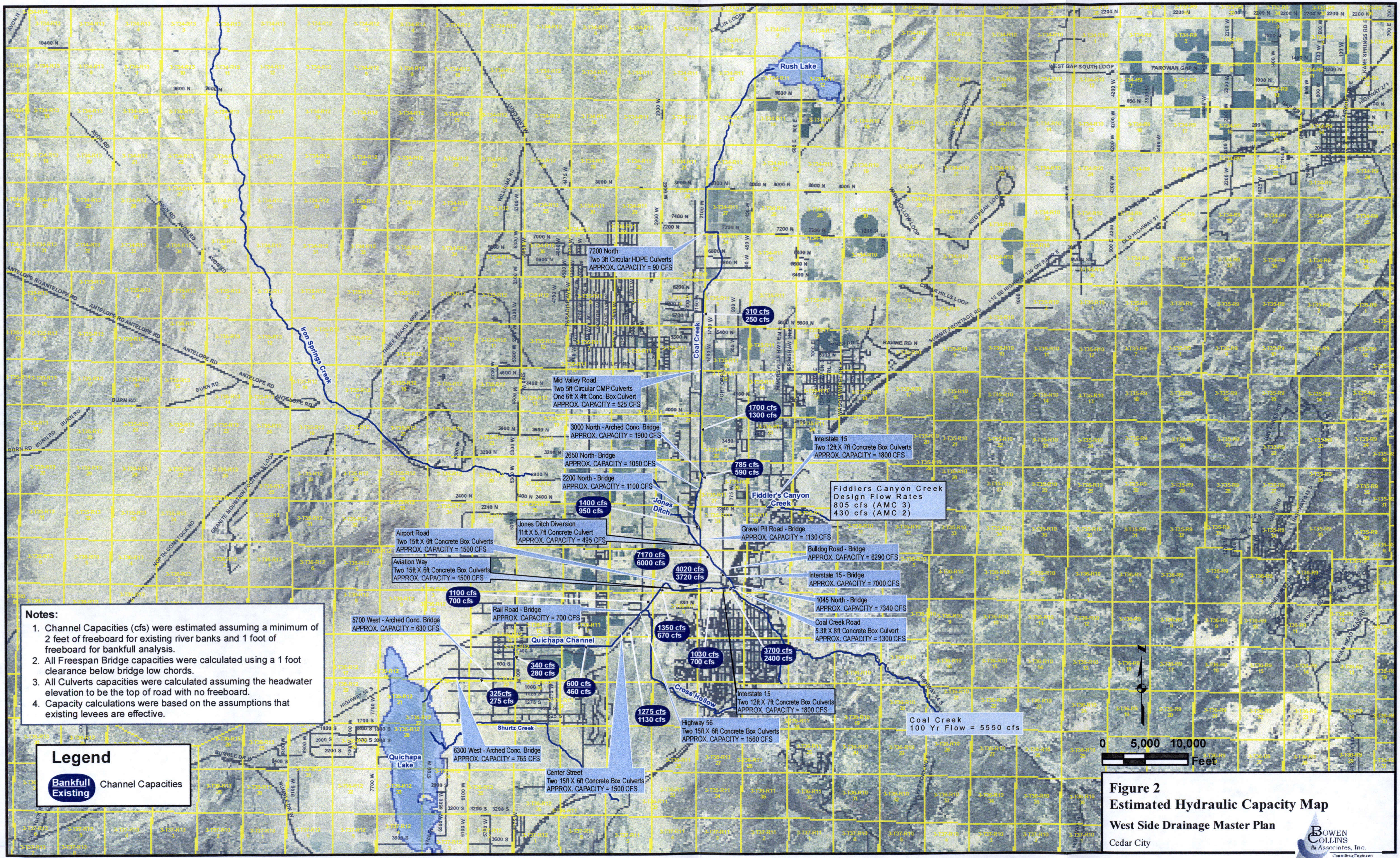

Notes:

1. Channel Capacities (cfs) were estimated assuming a minimum of 2 feet of freeboard for existing river banks and 1 foot of freeboard for bankfull analysis.
2. All Freespan Bridge capacities were calculated using a 1 foot clearance below bridge low chords.
3. All Culverts capacities were calculated assuming the headwater elevation to be the top of road with no freeboard.
4. Capacity calculations were based on the assumptions that existing levees are effective.

Legend

Bankfull / Existing — Channel Capacities

Figure 2
Estimated Hydraulic Capacity Map

West Side Drainage Master Plan

Cedar City

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As Figure 2 indicates, the capacity of the reach of Coal Creek between the Jones Ditch Diversion (Airport Split) and Mid Valley Road varies from 590 to 1300 cfs. North of Mid Valley Road, the existing capacity of the channel is less than 300 cfs. Most of the existing bridges can only convey about 1100 cfs. *This means that the area west of I-15 will experience significant flooding during large flood events.*

Figure 2 also indicates that at bankfull conditions, the Quichapa Channel can only convey between 1000 and 1100 cfs to the SUU farm, where the channel capacity reduces to less than 500 cfs. The area along this channel is also susceptible to some flooding as well as significant erosion potential during periods of high discharge.

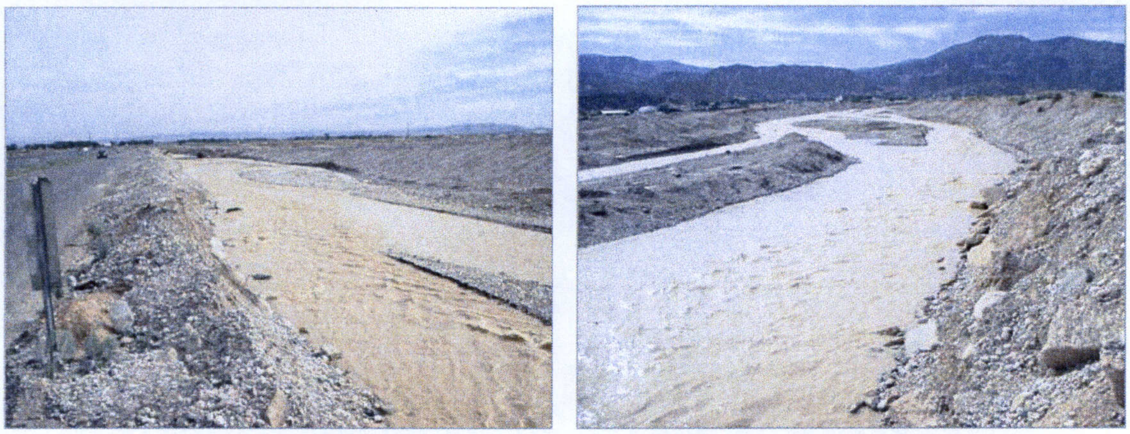
Another thing to consider for future planning is the likelihood that most of the irrigation diversion structures off of both of these channels will be abandoned as the area develops. This will require that more water be conveyed in the main channels during flood events. *It is clear that both channels west of I-15 need significant improvements if they are to serve as flood control facilities in the future.*

Combined Irrigation and Flood Control Facilities

Historically Coal Creek and the Quichapa Channel have been used to convey irrigation water to land west of I-15 for agricultural proposes. Runoff coming from Cedar Canyon and the mountains east of Cedar City ends up in these irrigation facilities. Therefore, flooding during large runoff events was common because neither the reach of Coal Creek west of I-15 nor the Quichapa Channel were designed or constructed to serve as flood control facilities. Flooding events as recent as 2005 have caused significant damage to lower Coal Creek and the Quichapa Channel, including significant erosion damage and the destruction of at least two irrigation diversion structures.

Sediment Deposition

As mentioned previously, Coal Creek conveys a substantial sediment load during periods of high runoff. Since the stream gradients of both Coal Creek and the Quichapa channel decrease significantly decrease west of I-15, the sediment conveying capacities of the channels also decrease. This causes sediment deposition problems in the lower Coal Creek and Quichapa channels. Gravel deposition tends to occur near I-15. Sand deposition occurs in more downstream reaches of both channels, where the stream gradient further decreases. Regular dredging and sediment removal activities are performed in the areas of significant deposition in an effort to maintain flood conveyance capacity in these channels. The dredged material has typically been placed on the existing channel banks. Below are some photographs that illustrate how officials have historically managed the sediment deposition problems.



Areas of Sediment Dredging on Coal Creek near Airport Road

Erosion

Scour and head-cutting commonly occur just downstream of existing bridges and culverts along the Coal Creek channel west of I-15 and the Quichapa Channel. This is due to the fact that the majority of the bridges and culverts in downstream reaches of the channels have limited capacity. The limited capacities cause backwater upstream of the culverts, resulting in sediment deposition, and then head-cutting downstream of existing bridge and culverts. Below are some photographs that show head-cutting downstream of culverts on Coal Creek and the Quichapa Channel.

Head-cut and Erosion on Coal Creek Downstream of the Mid Valley Road Culvert

Head-cut and Erosion on the Quichapa Channel Downstream of the 6300 West Culvert

Photograph Showing Vertical Banks and Scour on the Quichapa Channel, Looking Downstream from the 6300 West Culvert

Recommended Drainage System Improvements

This report section identifies recommend flood control improvements and runoff management plans for Coal Creek, the Quichapa Channel, and Fiddler's Canyon Creek west of I-15. To address the problems identified in the previous section, the following recommendations will be discussed:

- Modifying the Woodbury Bifurcation Structure
- Utilizing Existing Gravel Pits as Detention/Retention Facilities During Cloudburst Floods
- Constructing Channel Improvements on Coal Creek and the Quichapa Channel
- Implementing Sediment Management Activities
- Preserving and Acquiring Future Storm Water Corridors
- Extending the Fiddler's Canyon Channel to Coal Creek
- Constructing a Trail System adjacent to the Flood Control Channels.

Each of these recommendations is addressed in this section and illustrated on Figure 3.

Modifying the Woodbury Bifurcation Structure

The Woodbury Split is a historic bifurcation structure located on Coal Creek just upstream of I-15. This structure is only 26.5 feet wide and can only convey about 2,200 cfs before the channel upstream of the structure begins to overtop. This non-mechanical bifurcation structure was designed with physical attributes to divert about 45 percent of the water in Coal Creek to the Quichapa Channel when more than 300 cfs is flowing in the creek. When less than 300 cfs is flowing in Coal Creek, approximately 60 percent of the water in the creek is diverted into the Quichapa Channel. When more than 2,200 cfs is flowing in Coal Creek, less than 45 percent of the total flow can be diverted into the Quichapa Channel due to overtopping of the channel and bifurcation wall on the diversion structure. In addition, the Quichapa Channel culvert that crosses under I-15 can only convey 1,800 cfs. Documentation showing the percentages of the historic split was provided by Iron County and is included in Attachment 1.

In addition to the capacity problems, the Woodbury Split structure has also been damaged and eroded from large flood events and the high sediment load. Below are some photographs showing the existing Woodbury Split structure.

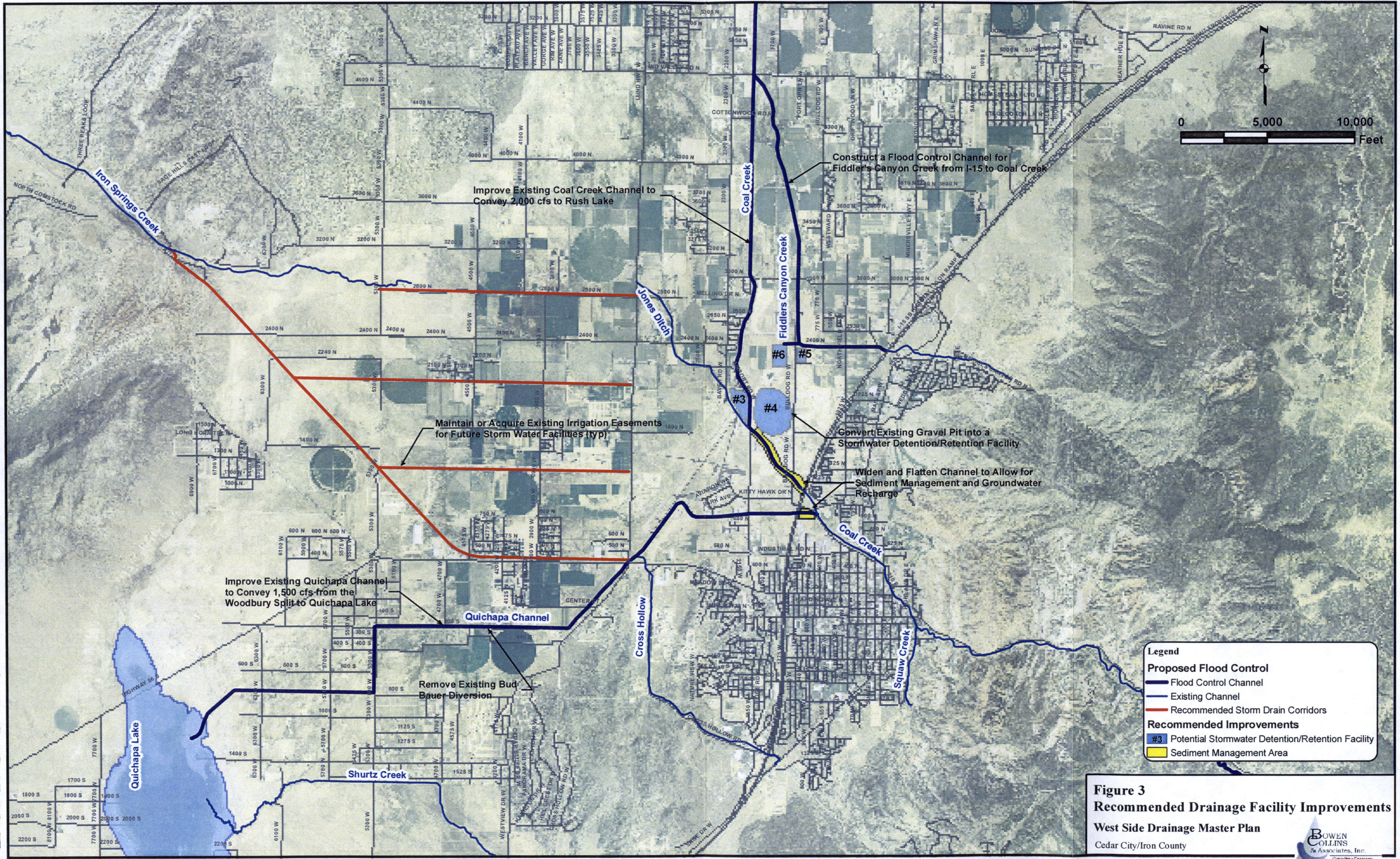


Figure 3
Recommended Drainage Facility Improvements
West Side Drainage Master Plan
Cedar City/Iron County

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Woodbury Split Diverting Runoff into the Quichapa Channel (to the right)

Erosion and Structural Damage on the Woodbury Bifurcation Structure

It is recommended that the existing Woodbury Split be replaced with a new bifurcation structure that has the capacity to safely convey the 100-year design flood of 5550 cfs. This will require a much wider structure in addition to some levee construction. Irrigators would like the new structure to have the ability regulate the water in both channels, with the ability to divert the entire stream into one channel or the other when there is less than 400 cfs flowing in Coal Creek.

This would require adding something like crest gates to the new structure. Planning and design discussions have taken place with personnel from Cedar City, Iron County, and the downstream irrigators regarding the features and operation of the new bifurcation structure during large flood events. Personnel from both Cedar City and Iron County want to reconstruct the Woodbury Split to match the historic diversion percentages of 45 percent to the Quichapa Channel and 55 percent to Coal Creek to avoid liability issues associated with changing the characteristics of the existing structure and potentially making flooding worse on one channel or the other. However, 45 percent of the 100-year cloudburst flood (2,500 cfs) cannot be diverted to the Quichapa Channel without significant improvements every culvert and channel reach on that channel. Therefore, as part of the recommended flood control management plan, it is recommended that the new diversion provide means that will limit the amount of water that can be diverted into the Quichapa Channel to a maximum of 1,500 cfs. The remaining discharge should remain in the main Coal Creek channel.

Utilizing Existing Gravel Pits as Detention/Retention Facilitation During Cloudburst Floods

Two existing gravel pits adjacent to Coal Creek and two existing gravel pits adjacent to Fiddler's Canyon Creek for have been identified for potential use as either storm water detention/retention facilities or groundwater recharge basins. Those sites are shown on Figure 3. The estimated available detention/retention storage volumes associated with those four basins are presented in Table 2.

Table 2
Detention/Ground Water Recharge Basin Storage Volumes

Detention Basin Site	Adjacent Location	Estimated Maximum Detention Volume (ac-ft)
3	Coal Creek	110
4*	Coal Creek	720
5	Fiddler's Canyon Creek	270
6	Fiddler's Canyon Creek	500

* Utilization of this gravel pit for detention would be limited until it is mined out by Western Rock.

A rainfall-runoff model developed for the Coal Creek watershed estimates the peak discharge from a 100-year 3-hour cloudburst design storm to be approximately 5,560 cfs, and a total runoff volume of 1,665 acre-feet. That model was also utilized to estimate the impacts that detention/retention basins of various sizes could have on peak discharges on Coal Creek, downstream of the Woodbury Split and any large detention facilities. In performing this analysis, it was assumed that 40 percent of the Coal Creek discharge, up to a maximum of 1,500 cfs, would be diverted into the Quichapa Channel, and the remaining discharge would be conveyed to a location west of I-15 where discharges in excess of varying threshold values would be diverted into large detention/retention facilities to reduce the peak discharge and required design capacity in the lower reach of Coal Creek. Table 3 provides information that illustrates how detention/retention on Coal Creek would affect peak discharges downstream of a detention/retention basin diversion.

Table 3
Information that Illustrates How Detention Volume Can Affect Various 100-Year Flood Maximum Discharges in Coal Creek

Maximum Discharge Downstream of Detention Diversion (cfs)	Estimated Required Detention Volume Needed to Attenuate to the Maximum Discharge Value (ac-ft)
750	670
1,000	575
1,500	415
2,000	290
2,500	190
3,000	105
3,500	40
4,050	0

The information presented in Table 3 indicates that if no detention/retention facilities are constructed to attenuate the peak cloudburst flood on the main Coal Creek channel west of the Woodbury Split, the downstream channel would have to be designed to convey 4,050 cfs to safely convey the 100-year cloudburst flood if no detention/retention facilities are constructed. If a diversion structure is constructed to divert any discharge in excess of 2,000 cfs into a detention/retention facility with at least 290 acre-feet of detention storage, the channel conveyance capacity below the diversion for the 100-year design storm could be reduced to 2,000 cfs. These gravel pit basins could possibly be converted into detention/retention basins to reduce downstream flooding and reduce the magnitude of channel improvements required to safely convey the 100-year flood through the study area. Constructing a new detention/retention facility that could create periodic open water hazards would need to be done in compliance with the FAA requirements referenced earlier in this report.

During times of high runoff, when water in excess of needed irrigation demands is flowing in the creek, one or more of the gravel pits could potentially be utilized for groundwater recharge. However, due to the sediment loads in the water during periods of high discharge that could plug off the natural gravel formation, reducing infiltration rates, it is not recommended that discharge from large cloudburst events be diverted into groundwater recharge basins. The options of using the existing gravels pits as groundwater recharge basins will be discussed in more detail later in this report.

Much thought should be given to the design of the diversion and inlet structures associated with any detention facilities to eliminate the possibility of initiating a head-cut that could propagate upstream. It is also recommended that the proposed diversion structure, which will divert the floodwater into the basin, should be designed to allow cleaner water to continue downstream diverting most of the debris and sediment into the detention facilities.

Constructing Channel Improvements on Coal Creek and the Quichapa Channel

Coal Creek Channel. It is recommended that the channel and all culverts and bridges on Coal Creek between the Airport Split and Rush Lake be constructed to have a minimum capacity of 2,000 cfs. This would give Coal Creek the ability to safely convey the entire 100-year snowmelt flood as well as an attenuated 100-year cloudburst flood. It is not practical to construct a flood control channel with the capacity to convey a 100-year cloudburst flood to Rush Lake. The cloudburst events are flashy in nature and the peak flows from the 100-year cloudburst event could be attenuated by converting existing gravel pits or other area to detention facilities.

Quichapa Channel

The following improvements are recommended for implementation along the Quichapa Channel:

- Construct improvements to provide a safe conveyance capacity of 1500 cfs from the Woodbury Split to Quichapa Lake. These improvements will include replacing undersized culverts and bridges, enlarging the existing open channel, and providing erosion protection on the channel bed and banks.

- Maintain the Quichapa Channel as a flood control facility, eliminating any diversions that restrict capacity or cause sediment deposition.

- Remove the Bud Bauer Diversion to eliminate the existing capacity restriction. The existing diversion has very little capacity, and due to the backwater created by the size and elevation of the diversion, it has caused a lot of sediment to be deposited in the larger flood channel upstream. This sediment should be removed to attain the design conveyance capacity of the channel.

- Reconstruct the Southern Utah University Diversion structure that failed during the 2005 flood near its original location. However, it should be designed to be a low-flow diversion that will not significantly reduce channel capacity in the area during periods of high discharge or cause sediment deposition problems similar to those that exist at the Bud Bauer Diversion. Water from this new diversion, after being conveyed through a sedimentation structure, should also be used to supply water to the Bud Bauer property via a pipeline or open ditch. This will allow the existing Bud Bauer diversion, which currently creates significant capacity and sedimentation problems, to be removed.

Looking Upstream at the Bud Bauer Diversion

Looking Upstream at the Quichapa Channel from the Bud Bauer Diversion

Implementing Sediment Management Activities

As previously mentioned, it has been estimated that Coal Creek yields an annual average of approximately 54.4 acre-feet (88,000 cubic yards) of sediment (reference 1). The highest sediment loads are conveyed during periods of high runoff. Deposited sediment is removed from the Coal Creek channels on a regular basis. Due to the alluvial nature of the Coal Creek watershed and the declining gradients of the Coal Creek and Quichapa channels downstream of the Woodbury Split, those channels will always require some channel maintenance. It is recommended that a flat reach of stream channel be constructed on each channel, as shown in Figure 3, for the purpose of sediment management. These wide, flat sections of open channel would decrease channel velocities and flow depths and thus reduce sediment-carrying capacities of the channels, inducing sedimentation in these locations. As part of these sediment management channels, a compound channel could be constructed to convey irrigation water in a low flow channel, leaving a larger channel to convey water from larger runoff events. Since the decreasing channel slopes will not allow the transported sediment to be conveyed to either Quichapa Lake or Rush Lake, inducing sediment deposition at selected locations is believed to be more convenient and cost effective to manage and maintain.

It is recommended that a sediment management area be constructed on Coal Creek between I-15 and Airport Road, and that a sediment management area be constructed on the Quichapa Channel between the Woodbury Split and I-15. Local contractors could be retained to remove sediment and maintain these areas. Most of the material that would be removed from these sediment management areas could be processed and sold for use on construction projects.

Preserving and Acquiring of Future Storm Water Corridors

Currently there are many irrigation easements throughout the study area. As the west side continues to develop, these irrigation easements will need to be preserved for future storm water corridors. Figure 3 shows four main storm water corridors that should be preserved and acquired to allow runoff from future development to be conveyed to Iron Springs Creek.

Extending Fiddler's Canyon Channel to Coal Creek

In 2000, Cedar City constructed a debris/detention basin at the mouth of Fiddler's Canyon. The City also constructed an open channel from the debris/detention basin to the east side of I-15. Currently flood water from Fiddler's Canyon Creek west of I-15 flows overland to about 775 West where it turns to the north following an existing topographic depression. There are two existing gravel pits adjacent to where the floodwater turns to the north. These gravel pits also have the potential to be utilized as detention/groundwater recharge basins. Along with the utilization of the gravel pits as detention/groundwater recharge, a flood control channel, similar to the channel constructed upstream of I-15, should be constructed from the west side of I-15 to connect to Coal Creek just upstream of Mid Valley Road. The location of the proposed flood control channel associated with Fiddler's Canyon Creek is shown on Figure 3. Constructing this new channel will also provide a facility to collect and convey runoff from proposed development in this area.

Constructing a Trail System adjacent to the Flood Control Channels

The proposed and improved flood control channel corridors have the potential to be incorporated into a City and County trail system, similar to the trail system that currently exists along Coal Creek. Levees will likely be required improvements to safely convey the design flood in Coal Creek. These levees, along with the flood channels, will require regular maintenance. A pedestrian/bike path could potentially be utilized as a maintenance access to the levees and channel. If a pedestrian/bike path is to be constructed on top of a levee and incorporated into the trail system, the top width should be designed accordingly (up to 20 feet of UDOT funds are used). If the maintenance access is desired on the landside toe of a levee, an additional easement with a minimum width of 14-feet should be acquired.

SECTION 4
GROUNDWATER RECHARGE PROJECT FEASIBILITY AND RECOMMENDATIONS

In the spring of 2005 record snowpack in the mountains east of Cedar City produced 84,270 acre-feet (reference 2) of runoff from the Coal Creek watershed, more than 3.4 times the average annual runoff from that drainage basin. In an effort to reduce anticipated flooding west of I-15 and maximize groundwater recharge during the 2005 high runoff period, Central Iron County Water Conservancy District completed a groundwater recharge pilot project that diverted water from Coal Creek into the Bulldog gravel pit. That pilot project proved to be successful and Central Iron County Water Conservancy District officials are now interested in developing long-term groundwater recharge projects (reference 6). They plan to work with representatives from Iron County, Cedar City, and local irrigation companies in developing a groundwater recharge plan that will benefit all these stakeholders. The issues that will need to be addressed in implementing a recharge project include:

- Water rights and associated permits
- Managing sediment and debris
- Design and maintenance issues

Each of these issues are addressed in this report section. The issue of addressing safety issues associated with hazardous wildlife attractants near airports was mentioned previously.

Water Rights And Associated Permits

One or more permits will have to be obtained from the State Engineer's Office before a long-term groundwater recharge project can be implemented. The first required State permit would be a Groundwater Recharge Permit. However, it should be noted that before beginning the permitting process, the sponsoring agency or individual must have the legal rights to the water that is to be used for groundwater recharge. If the agency desires to utilize the recharge project to create a groundwater right for beneficial use, then a Groundwater Recovery Permit must also be obtained from the State Engineer. The recovery of groundwater will not be addressed as part of this project. In the process of obtaining one or both of these permits, a detailed evaluation will have to be performed to describe how the recharge and recovery system will be operated and maintained and all impacts, both positive and negative, will have to be evaluated. If any federal funds are utilized in developing a groundwater recharge project, it is likely that either an environmental assessment or an environmental impact study will have to be completed to meet NEPA requirements.

Managing Sediment And Debris

Since most of the low-flow water rights are linked to irrigation and stock watering, it is likely that the only time that surface water from Coal Creek can be made available for utilization in a groundwater recharge project will be during periods of high runoff from snowmelt and cloudburst events (i.e., when there is more that 1,000 cfs in the creek). During periods of high runoff, Coal Creek runoff water also transports a high sediment load. For the purposes of this report, two types of sediment are identified as being conveyed with runoff water: wash load and bed load. Wash load is the fine-grained sediment that the flowing water can easily convey in large quantities (usually suspended in the water) and is limited by its availability in the watershed and channel banks. The coarser part of the sediment load, commonly known as bed load (i.e., coarse sands, gravels, and cobble), is more difficult for flowing water to move and is limited in discharge rate by the transporting ability of the stream (i.e., water depth and velocity).

It is recommended that sedimentation basins be constructed upstream of any groundwater recharge basin to allow the bed load and as much of the wash load as is feasible to settle out of the runoff and minimize maintenance and management of the recharge basins. These sedimentation basins will have to be designed and constructed in a manner that will allow the deposited sands and gravels to be easily removed on a regular basis. In Technical Memorandum No. 1, it was recommended that the reach of Coal Creek between I-15 and Airport Road and the reach of the Quichapa Channel between Coal Creek Road and I-15 be purchased, revised, and modified so that they can be perpetually utilized to collect coarser sediments. Additional sedimentation facilities should also be constructed upstream of infiltration/recharge facilities. Potential locations for groundwater recharge facilities are shown in Figure 4.

Design and Maintenance Issues

In designing and constructing any groundwater recharge facilities, it is recommended that the following issues be thoroughly addressed and considered:

- If existing inactive gravel pits are used as recharge basins, the basin inlet facilities must be designed to prevent erosion and head-cutting in the inlet channel facilities as well as bank erosion in the recharge basin.
- Any diversions to recharge basins that are constructed in the main Coal Creek channel should avoid creating backwater in the Coal Creek channel. Diversions should divert both water and the associated sediment load out of the main channel to appropriate sedimentation basin facilities generally described above. New diversions can create significant sediment deposition and/or erosion problems if are not designed and operated properly.
- Convenient access should be provided to sedimentation facilities and recharge facilities for maintenance purposes.
- The properties to be utilized as sedimentation and recharge facilities should be purchased by the sponsoring agency of the groundwater recharge project.
- The bottom elevation of any recharge basin should be maintained below basement or lowest floor elevations of structures within 1,000 feet of the recharge basin.

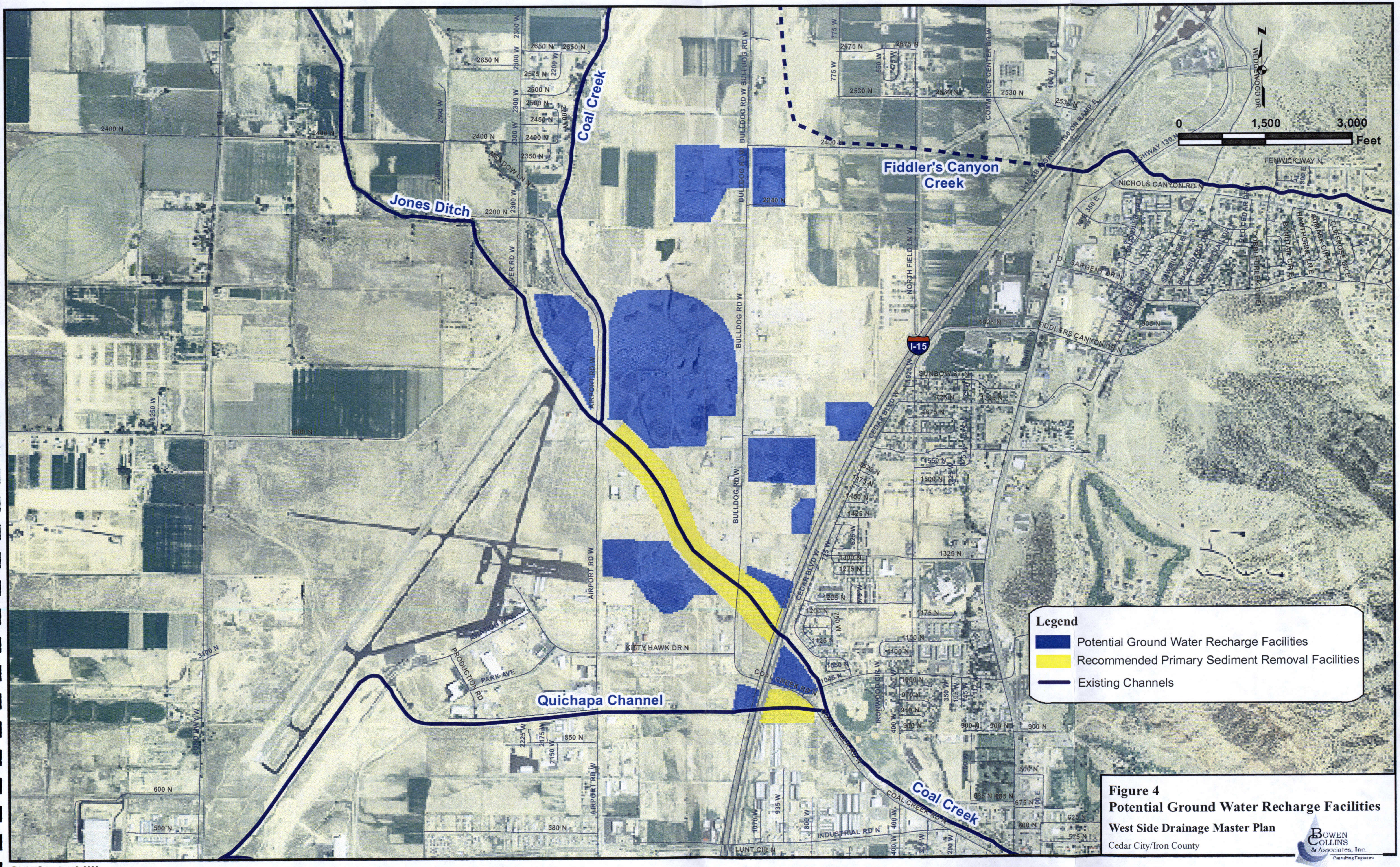

Figure 4
Potential Ground Water Recharge Facilities
West Side Drainage Master Plan
Cedar City/Iron County

Bowen Collins & Associates, Inc.

Printing Date: June 9, 2008
File: P:\Cedar City\West Side Master Plan\GIS\Projects\TM_2\GWRBasins.mxd

- Sedimentation basin and recharge basin owners should contract with one or more local gravel pit owners to remove sediment that is deposited during the operation of those facilities. If the sands and gravels removed from these facilities are made available to the pit owners in exchange for its removal, it is likely that the maintenance of these basins can be accomplished for little to no cost.

- Fine-grained wash load sediments will likely accumulate on the bottom of recharge basins over time. This will significantly reduce the seepage rate and require periodic removal of sediment to clean and restore the native infiltration characteristics of the soils. If deep gravel pits are utilized, it is likely that significant seepage and recharge would also occur through the walls or banks of the gravel pits. It is also likely that materials on the on the banks or walls of the gravel pits will also need to be cleaned to maintain desired infiltration rates.

- The diversion structures to any groundwater recharge facility should be manually operated. Due to the extreme sediment and debris loads produced during cloudburst floods, it is not recommended that water from those events be diverted into infiltration basins. It is likely that the fine-grained sediments in that runoff will settle in the infiltration basins and significantly reduce the infiltration rates, creating major maintenance issues and potential wildlife hazards near the airport. Only runoff from snowmelt events should be diverted into groundwater recharge facilities.

- If storm water detention/retention facilities are constructed, they should be totally separate from any groundwater recharge facilities for the reasons previously mentioned.

- Any open water management facility within the FAA-designated clear zones must be designed in accordance with FAA regulations and approved by the FAA Regional Airports Division Office.

Recommendations and Conclusions

Based on the 2005 pilot test results and the interest of local agencies, it appears that the development of a long-term groundwater recharge project in the study area is feasible. However, additional studies and analyses will be required before such a project can be implemented. Those additional studies should address the following issues:

- FAA regulations and approvals associated with hazardous wildlife attractants on or near airports.

- The availability of surface water rights for use in recharging groundwater.

- State groundwater recharge permitting requirements.

- A smaller-scale multi-year groundwater recharge pilot project should be implemented to determine the ultimate feasibility of a long-term recharge project and to identify design and operation and maintenance issues that should be addressed in the design and operation of a the full-scale recharge project.

- Consultations between the sponsoring groundwater recharge agency, the airport operator and the appropriate FAA regional Airports Division Office.

SECTION 5
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