2013 SURPLUS CANAL LEVEE EVALUATION

Prepared for:
Salt Lake County

SALT LAKE COUNTY

Prepared by:
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CHAPTER 1
INTRODUCTION

INTRODUCTION

The levees along the Surplus Canal do not currently meet Federal Emergency Management Agency (FEMA) levee certification criteria defined in the Code of Federal Regulations (CFR) 65.10 using the current effective FEMA base flood magnitude of 4,500 cfs. In addition, in the summer of 2012 the United States Army Corps of Engineers (USACE) completed a field investigation of the levees and identified multiple deficiencies with varying degrees of severity. Salt Lake County (County) hired Bowen, Collins & Associates, Inc. (BC&A) to complete a detailed evaluation of the Surplus Canal that focuses primarily on the levees that were constructed to keep floodwater inside the canal. The purpose of this study is to identify, for planning purposes, recommended improvements that will correct identified levee deficiencies and allow the levees to become certified by FEMA for flood control purposes.

BACKGROUND HISTORY

Surplus Canal Design Criteria

Surplus Canal was originally constructed in the 1890s to reduce flood potential along the reach of the Jordan River that passes through Salt Lake City by diverting floodwater in the Jordan River into the Surplus Canal. The head of the Surplus Canal is on the Jordan River just north of 2100 South Street in Salt Lake County. The canal traverses to the northwest and conveys water toward the Great Salt Lake. The Surplus Canal was enlarged by the USACE in the early 1960s and levees were constructed along both banks. The basic USACE design criteria for the canal are summarized below.

- **Mill Creek to North Point Diversion** - The design discharge of the Surplus Canal is 3,300 cubic feet per second (cfs) from the Mill Creek confluence with the Jordan River at about 2850 South to the North Point Canal Diversion at about 200 South. Through this canal reach, the levees on both sides of the canal were constructed with “semi-compacted” earth fill with the west levee being designed to have three feet of freeboard at the design discharge and east levee being designed to have five feet of freeboard.

- **North Point Diversion to Goggin Drain** - The design discharge of the Surplus Canal is 2,000 cfs from the North Point Canal Diversion to the Goggin Drain. Through this canal reach, both levees were constructed with “uncompacted” fill and designed to have five feet of freeboard at the design discharge rate. The design slope was 0.0 percent through this reach.

The USACE and the County have signed an agreement that assigns operating and maintenance responsibilities of the Surplus Canal and its levees to Salt Lake County.
Major Flood Events

Areas adjacent to rivers and streams in Northern Utah, including the Jordan River, experienced significant flooding in the springs of 1983 and 1984. USGS stream flow records included in Appendix A indicate that the historic recorded peak discharge in the Surplus Canal just downstream of the Jordan River diversion and regulating structure was 4,410 cfs on June 1, 1984. Even though the Surplus Canal was not designed for a flood of that magnitude, the Surplus Canal levees did not overtop or fail. Floodwaters did impound on the low chord of several bridge crossings, and the channel was near bank full at several locations. Following the 1980s flood events, Salt Lake County has periodically performed maintenance dredging in the canal channel to remove sediment deposits in an effort to maintain the hydraulic capacity and levee freeboard associated with the original USACE design.

Utah Lake Compromise Agreement

The Jordan River is a highly regulated river. Streams tributary to Utah Lake are also highly regulated by reservoirs and diversions. The Jordan River conveys water from Utah Lake to the Great Salt Lake. Discharges from Utah Lake into the Jordan River are regulated by the 1985 Utah Lake Compromise Agreement. That legal agreement dictates how water is released into the Jordan River based on the water level of Utah Lake and the discharge in the Jordan River at 2100 South in Salt Lake County. The three key operating/release parameters are as follows:

1. If the level of Utah Lake is below the defined “compromise elevation,” the gates at the Utah Lake Outlet are closed or regulated or pumped to meet downstream demands from canal companies.

2. If the level of Utah Lake is above the defined “compromise elevation,” the gates at the Utah Lake Outlet are fully opened and water is discharged into the Jordan River unregulated.

3. If the flow rate in the Jordan River at 2100 South exceeds 3,400 cfs, or is anticipated to exceed 3,400 cfs, the regulating gates at the Utah Lake Outlet can be regulated in an effort to keep the peak discharge at 2100 South to 3,400 cfs.

This regulating option would most likely be exercised to control the peak discharge in the Jordan River that results from inflows from Big Cottonwood Creek, Little Cottonwood Creek, and Mill Creek when the water surface elevation at Utah Lake is significantly above the compromise elevation. Since it takes about 24 hours for water released from Utah Lake to reach 2100 South in Salt Lake County, snowpack, weather forecasts, and peak discharges in the Surplus Canal all have to be carefully monitored and timed to limit the peak discharge in the Surplus Canal to about 3,400 cfs.

The option to close or regulate the gates at the Utah Lake outlet in an effort to limit peak discharges at 2100 South to 3,400 cfs has not yet been exercised. During the spring runoff event of 2011, the peak discharge in the Surplus Canal reached 3,880 cfs, exceeding 3,400 cfs for a period less than 24 hours. Conversations with the County indicated that the flow at 2100 South was closely monitored, but was not limited using the Utah Compromise Agreement because of the short duration of the peak flow and
because field monitoring of the Surplus Canal levees did not show signs of distress or danger.

A copy of the Utah Lake Compromise Agreement can be found in Appendix B.

Canal Relocations

A significant portion of the reach of the Surplus Canal adjacent to the Salt Lake City International Airport (Airport), between the North Point Canal Diversion and the Goggin Drain, has been relocated to accommodate Airport expansion projects. The most recent of these canal relocation projects was completed the 1990s. Those projects maintained the 3,300 cfs design capacity with levees that have at least three feet of freeboard.

STUDY AREA

The study area for this project includes the entire Surplus Canal and a short reach of the Jordan River. The study area extends from the confluence of Mill Creek with the Jordan River to the point where the Surplus Canal discharges into the Goggin Drain, as shown in Figure 1-1. The study area matches the study area of the 2012 USACE Levee inspection report.

NEED FOR STUDY

The FEMA Flood Insurance Study (FIS) for the reach of the Jordan River from the Utah County line to 2100 South Street in Salt Lake County was updated in the early 1990s, following the large flood events of 1983 and 1984. As part of that FIS update, the flood hydrology for the Jordan River and the Surplus Canal was modified. The revised FEMA hydrology study estimated the one-percent-annual-chance flood (100-year flood) on the Jordan River just below the Mill Creek confluence to be 4,700 cfs, a flood magnitude that is significantly higher than the 3,300 cfs that was used as the canal design discharge. That FEMA FIS did not include analyzing the Surplus Canal.

FEMA is currently in the process of updating the Flood Insurance Rate Maps (FIRMs) in Salt Lake County. In recent years, for floodplain mapping purposes, FEMA has been very stringent in requiring that flood control levees meet specific certification criteria in order for them to be considered to provide flood protection on FIRMs. FEMA regulations require that minimum freeboard requirements and certain geotechnical criteria associated with embankment foundation seepage and stability be satisfied to meet levee certification criteria. If freeboard or geotechnical criteria cannot be met, FEMA guidelines and specifications require that the floodplain maps be developed using two assumed conditions. The first is that a levee would be an effective flood control structure. The second is that the levee is nonexistent, assuming that it would not function properly for its intended use. The most conservative result from those two analyses is typically used to define special flood hazard areas on Flood Insurance Rate Maps. This approach was used to develop draft floodplain maps for the area along the Surplus Canal. In accordance with FEMA Guidelines and Specifications, the FEMA study contractor completed a floodplain analysis assuming that the east levee was nonexistent in three areas along the canal because the existing levee does not meet minimum freeboard criteria for the one-percent annual chance flood.
with a magnitude of 4,700 cfs. The resulting preliminary floodplain shown in Figure 1-2, if adopted, would place many structures in a FEMA special flood hazard area (SFHA) and would require many property owners to purchase flood insurance. This could have a negative financial impact on many people.

FEMA recently updated their Guidelines and Specifications in regards to mapping the landward side of uncertified levees. The mapping technique discussed in the previous paragraph can still be used for uncertified levees. However, FEMA now also allows the flood hazard of the landward side of uncertified levees to be mapped as a Zone D. FEMA defines a Zone D floodplain as “areas where there are possible but undetermined flood hazards.” Because Zone D is an unknown flood hazard, mortgage companies are not federally mandated to require the purchase of a flood insurance policy. However, mortgage companies can still require that property owners purchase a flood insurance policy. The flood insurance rates for property owners in a Zone D floodplain are relatively high because the flood hazard is not defined.

If FEMA designates the landward side of the levee along the Surplus Canal to be a Zone D flood hazard, it is likely that one or more mortgage companies will require property owners to purchase flood insurance. Because of the high rates associated with the Zone D flood hazard, there will be a significant negative financial impact on many people.

This study includes a detailed technical analysis of the Surplus Canal and its levees to identify the improvements and associated costs that are needed to bring them into compliance with FEMA Levee Certification Requirements presented in CFR 65.10 and USACE levee requirements. This report also addresses the critical deficiencies identified in the 2012 USACE Levee Inspection Report, as those deficiencies also need to be remedied.

**SCOPE OF SERVICES**

BC&A was retained to complete the following major tasks for this detailed evaluation of the Surplus Canal:

- **Task 1:** Collect and Review Existing Information
- **Task 2:** Field Reconnaissance
- **Task 3:** Field Survey Hydraulic Structures
- **Task 4:** Perform Bathymetric Survey
- **Task 5:** Inventory and Document Existing Surplus Canal Right-of-Way
- **Task 6:** Develop Hydraulic Computer Model
- **Task 7:** Complete a Geotechnical Investigation
- **Task 8:** Identify Levee and Maintenance Deficiencies
- **Task 9:** Evaluate and Recommend Measures to mitigate Deficiencies
- **Task 10:** Cost Estimates
- **Task 11:** Prepare Design Study Report
The results of the work associated with completing these tasks are presented in this report. Questions associated with this report may be addressed to Craig Bagley P.E., CFM, who served as project manager.
CHAPTER 2
REVIEW OF EXISTING CONDITIONS

Several sources of data regarding the existing conditions of the Surplus Canal levees were collected and analyzed as part of this project. Some of those data sets included topographic data, right-of-way (ROW) data, bathymetric survey of the canal, field survey data of bridges and canal and levee features, and field reconnaissance observations. The 2012 USACE Periodic Inspection Report No. 1 for the Surplus Canal Levee Systems was reviewed. That report is discussed in this chapter as well. The purpose of this chapter is to summarize the existing general conditions of the Surplus Canal channel and levees.

2012 USACE LEVEE INSPECTION REPORT

In 2012, the USACE completed a detailed inspection of both levees along the Surplus Canal in the study area. A report entitled “2012 USACE Periodic Inspection Report No. 1 for the Surplus Canal Levee Systems” was released that documented levee deficiencies based on the USACE guidelines. The levee deficiencies were divided into four categories: Acceptable (A), Minimally Acceptable (MA), Unacceptable (U), and Not Applicable (NA). There are several types of deficiencies discussed that fall into the A, MA, and NA categories. Though the report describes each of the levee deficiencies, it does not provide an exact location of a deficiency unless it falls into the unacceptable category. Because the A and MA items are not of immediate concern and the locations of those deficiencies were not provided, this report will only summarize the deficiencies identified in the 2012 USACE report that fall into the unacceptable category.

Figure 2-1 shows the approximate location of the Unacceptable deficiencies identified in the USACE report. A brief description and recommended improvement for each type of USACE unacceptable deficiency is documented in Table 2-1.

Each of the deficiencies identified by the USACE will need to be mitigated per USACE recommendations. The penetrations (included in the Encroachments deficiencies) and the Salt Lake City storm drain outfalls will need a flap gate or other closure device prior to FEMA certifying the levee. It is recommended that providing the penetrations and outfalls with closure devices be given priority to facilitate proper function and certification of the levees.

Chesterfield Drain

The Chesterfield Drain discharges into the Jordan River about 1,450 feet downstream of the Mill Creek confluence. The Chesterfield Drain is listed in the inspection report as a USACE deficiency. The USACE design drawings indicate that the Chesterfield Drain was originally intended to discharge into the Surplus Canal. Because it was part of the original design, the Chesterfield Drain should not be treated as USACE penetration deficiency.
Table 2-1
Summary of USACE Unacceptable Deficiencies

<table>
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<th>Type</th>
<th>Definition</th>
<th>Recommended Mitigation Measure</th>
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<tr>
<td>Vegetation Growth</td>
<td>Vegetation growth that can conceal underlying embankment problems, root systems, or harbor animals</td>
<td>The vegetation needs to be removed per USACE standards</td>
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<td>Miscellaneous Encroachments</td>
<td>Encroachments consist of trash, debris, signs, gates, fences, fire hydrants, overhead utilities, utilities that pass through both levees, or other structures on or near a levee.</td>
<td>The miscellaneous encroachments need to be either permitted or relocated</td>
</tr>
<tr>
<td>Penetration</td>
<td>A pipe that penetrates a levee and discharges into the Surplus Canal</td>
<td>A permit and a closure device is needed (flap gate or similar)</td>
</tr>
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<td>Sod Cover</td>
<td>Lack of sod cover or rills</td>
<td>Rills need to be filled and the levee needs the appropriate sod cover (typically 75 to 100 percent sod cover) and/or other slope protection</td>
</tr>
<tr>
<td>Depression/Rutting</td>
<td>Depressions or rutting caused by maintenance vehicles, settlement, sinkholes, etc.</td>
<td>All depressions or ruts should be filled and repaired</td>
</tr>
<tr>
<td>Riprap/Bank Protection</td>
<td>Riprap appears to be dumped and spaced in a random manner with thick vegetation growing between the rocks</td>
<td>Design drawings need to be provided to the USACE indicating that riprap was installed correctly or the “dumped rock” needs to be replaced with an engineered riprap that can provide the necessary slope protection, and the vegetation needs to be removed</td>
</tr>
<tr>
<td>High Risk Flood Hazard</td>
<td>A high-risk flood hazard is one of the deficiencies listed above that is “Likely prevent performance in the next flood event.” A brief description of each High Risk Flood Hazard deficiency is found on Figure 2-1</td>
<td>The High Risk Flood Hazard deficiencies should be given the highest priority and fixed per USACE standards</td>
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MAJOR UTILITY CROSSINGS AND PENETRATIONS

Salt Lake City Public utilities department provided a GIS shapefile, which included major irrigation, storm drain, water and sewer pipes that either cross or discharge into the Surplus Canal. The storm drainpipes that penetrate the levee and discharge into the Surplus Canal are shown on Figure 2-1. Those penetrations that do not have flap gates and permits need to have them installed or acquired. The Salt Lake City Utilities that cross the Surplus Canal and do not require closure devices are shown in Figure 2-1 for informational purposes only.
SURVEY AND MAPPING DATA

This section discusses the data collection and analysis associated with topography, survey, and field reconnaissance. The purpose of the topographic and survey analysis was to determine the sedimentation in the Canal, and to compare the condition of the Canal today to the original USACE design drawings.

Topography and Aerial Photography

Topographic and aerial photographic mapping along the Surplus Canal were collected from the Utah Automated Geographic Reference Center (AGRC). The aerial photography was the 2012 High Resolution Imagery and the topography is the bare earth LIDAR data from 2006 with 1-foot contours. Above-water channel cross sections of the Surplus Canal levee and overbank were also field surveyed at about 1000-foot intervals. The survey data was compared to the AGRC topographic mapping data and found to be accurate within 0.5 feet in most areas, which was considered adequate for this study. The aerial photography, topography and the surveyed cross sections were used to define the approximate top and the approximate outside toe of the existing levees. Figure 2-2 shows the approximate top of levee and outside toes of the levees.

Field Survey

Field survey data was collected at each structure that crosses the Jordan River and Surplus Canal in the study area. The survey collected the following data at each structure: high cord elevation, low chord elevation, channel invert, deck elevation, structure width, number of piers, erosion protection, and photographs of each of the structures. The data collected from the field survey and topographic mapping were used to develop the hydraulic computer model of the Surplus Canal (see Chapter 3). Field visits were also made to observe general conditions, view USACE deficiencies, and identify general concerns as well. The notes from the field survey are included in Appendix C. Photographs are included in Appendix D.

Bathymetric Survey

A bathymetric survey of the bottom of the Surplus Canal was completed along the Surplus Canal within the study area. The bathymetric survey was converted to a Digital Elevation Model (DEM), and combined with the 2006, one foot, bare earth LIDAR data from AGRC. The combined DEM was used in this analysis. The purpose of collecting the bathymetric survey was to define the existing underwater channel conditions, define areas of significant sediment deposition or erosion in the canal, and to compare the current channel geometry to the original USACE design geometry.

Original Design Drawings

The design drawings from the USACE developed in the 1950s and 1960s were reviewed and are included in Appendix E. The original design bottom width of the channel was: 100 feet from the Confluence at Mill Creek to the Jordan River Diversion; 60 feet between the Jordan River Diversion and North Temple Road; and 85 feet between North Temple Road and the Goggin...
Drain. As with most manmade channels, the canal was designed to have a prismatic, trapezoidal cross section. In addition to the original design drawings, the canal relocation drawings for the airport expansions were reviewed. The dredging plan after the 1980s floods was also reviewed. The canal relocation drawings and 1980s dredging plan were reviewed to analyze past sedimentation and/or erosion and so they could be compared to the existing channel geometry.

**Results**

Existing cross sections of the canal developed using recently collected bathymetric survey data were superimposed on the original canal design cross sections, and, where available, 1980s field surveyed cross sections, as shown on Figure 2-3. In addition, a profile of the Surplus Canal based on the bathymetric survey was superimposed on the original design channel as shown in Figure 2-4. As can be seen from Figures 2-3 and 2-4, the elevation of the canal bottom is consistently lower than the design elevation through most sections of the Surplus Canal. In addition, the existing channel is wider. The canal-side banks are generally steeper than the design section and are showing signs of instability. The deeper, wider channel is the result of dredging activities. Dredging that has widened the channel or over-steepened the canal banks have resulted in creating some canal bank stability issues.

**EASEMENTS AND ROW**

Surplus Canal easement and ROW data provided by the Salt Lake County Surveyor’s Office were reviewed. The results of this analysis are documented in this section.

**Surplus Canal Easements & ROW**

The Salt Lake County Surveyor’s office compiled available recorded easement and ROW data associated with the Surplus Canal. The approximate boundaries of the ROW were provided to BC&A as a GIS shapefile. Although the original design drawings identify ROW widths and boundaries along the entire original alignment of the Surplus Canal, the ROW data provided by the County did not include ROW boundaries for the entire Surplus Canal. Recorded easements or ROW for some sections of the canal could not be found. The ROW shapefile provided by the County was overlaid onto digital 2012 aerial photographs to identify where development (buildings, parking lots, etc.) has encroached into the Surplus Canal ROW. Development encroachments are shown in Figure 2-2.

As Figure 2-2 indicates, there are multiple development encroachments in the Canal ROW. There are also areas where the outside toe of the levee may not be located within the ROW. The following is a discussion of each of these issues:

- **Development Encroachments** – There are several buildings, parking lots, fences, and other development-related encroachments within the Surplus Canal ROW. Most of the development encroachments were unknown to the County and were not properly permitted. Those encroachments that are not permitted will need to be permitted. It is also important to note that the encroachment deficiencies identified as part of the USACE are not the same as the development encroachments shown on Figure 2-1.
• **Levee Outside ROW** – The toe of the existing levee may be located outside of the canal ROW in multiple locations. Typically, the top of the levee is 12 feet wide, and the landside of the levee slopes at a 3:1 until it intersects the existing ground surface. There are several areas where the top of the levee is wider than 12 feet, or the landside of the levee is much flatter than 3:1. There are also areas where fill has been placed on the outside of the levee, making it appear as though the toe of the levee is outside the ROW. These areas may or may not be a problem depending on the property owner it affects.

**CONCLUSIONS AND RECOMMENDATIONS**

Based on the surveys, field reconnaissance, ROW information, review of existing data, and the associated analyses, the following conclusions and recommendations can be made.

1. **USACE Report** – The USACE identified multiple deficiencies on the Surplus Canal levees. Those deficiencies will need to be remedied in accordance with USACE guidelines and standards.

2. **Levee Penetrations** – Storm drainpipes that penetrate the levees should be provided with closure devices per FEMA standards to prevent river water from flooding land behind the levee enclosure. This action should be given a high priority to increase performance of the levee during a flood event and to facilitate certifying the levees.

3. **Levee Toe Outside ROW** – There are several locations where the outside toe of the levee may be outside Surplus Canal ROW. Because this is a ROW deficiency, the recommendation to this issue can be found in the next bullet item (ROW Data). To complete the recommended improvements to the Surplus Canal Levees, additional ROW and/or easements do not need to be acquired (see conclusions and results in Chapter 3).

4. **ROW Data** – There are two sections of the Surplus Canal where recorded ROW data could not be located. The first section of the canal that is missing ROW data is located between USACE station 200+00 and 224+00 on the left side of the canal. The issue can be resolved by securing a recorded easement. Therefore, it is recommended that a recorded easement be secured in that area prior to completing any future levee improvements. The second section is approximately 2.5 miles long and adjacent to the Salt Lake City International Airport (Airport) starting at the North Point Canal Flume. The original Surplus Canal alignment had an easement through the Airport at one time, but following the most recent canal relocation projects at the Airport, an updated easement or ROW was apparently not recorded. Salt Lake City and Salt Lake County worked together during the design and construction of the Canal relocation project. It appears that on updated easement may not have been obtained because the Airport is a public facility owned by Salt Lake City. It is recommended that a maintenance easement be created and formalized through this reach of the canal.

5. **Development Encroachments** – There are several buildings, fences, parking lots, and miscellaneous development encroachments within the canal ROW. It is recommended that the development encroachments within the canal ROW be relocated or properly permitted. In addition, field observations indicated that in at least one location, a water line and fire hydrant were installed in or near a portion of the canal levee. It is also recommended that the County coordinate with development review staff at West Valley
City and Salt Lake City to ensure that any construction activities in or near the Surplus Canal Levees be reviewed and permitted by Salt Lake County. This issue should be placed on a development review checklist in both cities; otherwise, the County will have a difficult time knowing when projects could impact the levees.

6. **Maintenance-Dredging** – The comparison of the recent bathymetric survey data to the original design cross sections and profile indicates that the Surplus Canal is deeper and wider today than when it was originally constructed, due in large part, to over-dredging. Channel dredging activities have destabilized the toe of the canal bank, which has also made the reaches of the canal banks unstable. To stabilize the canal banks, it is recommended that the canal banks be laid back at a 2:1 design side slope and that future channel dredging be performed in a manner that will not destabilize the banks. Furthermore, it is recommended that the sediment deposition be monitored on the canal bottom and that careful dredging be performed as needed to maintain the channel bottom to within plus 0.5 or minus 1.5 feet below the design elevation. The widened channel cross sections can be maintained if the over-steepened, unstable slopes are laid back to a 2H:1V slope.

7. **Sedimentation Monitoring** – The bathymetric survey that was performed for this study provides a good baseline for existing conditions. Similar bathymetric surveys should be used on a regular basis in the future to monitor sediment deposition, scour erosion, and dredging activities to the limits recommended above.

8. **Remove Jordan River Diversion Structure Walkway** – The Jordan River diversion structure is located at the head of Surplus Canal. The structure includes a 5-foot tall ogee weir and a pedestrian walkway that is supported by vertical steel columns or piers. The columns were designed so that stop logs could be placed on the upstream face of the structure to divert water down the Lower Jordan River for Water Right purposes. However, Salt Lake County personnel indicated that they know of only one instance when the stop logs slots were used to divert water to the Lower Jordan River. It was used to divert water during the summer to facilitate a construction project, not for the original intention of water rights. During field visits, it was observed that several of the steel support columns are nearly totally rusted away. The potential failure of this structure poses a significant safety threat for both personal safety and flooding. The structure also catches a substantial amount of debris during flood events due to the close spacing of the piers. Furthermore, there is a pedestrian bridge approximately 300 feet downstream and 2100 South approximately 300 feet upstream of the diversion structure, making the walkway on the diversion structure redundant. For safety and flood control reasons, it is recommended that the steel walkway and the vertical piers be repaired or removed from the diversion structure.

9. **Scour Holes** – The bathymetric survey indicated that two major scour holes exist on the Surplus Canal: one immediately downstream of the Jordan River Diversion; the other immediately downstream of the North Point Canal Diversion (see Figure 2-4). The deep scour holes create a potential threat to the regulation structures. They have also caused canal slope stability problems that increase the potential for failure of the canal banks and Surplus Canal levees. It is recommended that these scour holes are filled and that the channel bottom and banks be armored to protect the structure and adjacent levees.
10. **Non-Existent Levees** – During field visits, it was observed that several structures adjacent to the levee were constructed after fill was placed on the landside of the levee. Areas where buildings were constructed on top of fill are often high enough to be out of the regulatory floodplain. Adjacent to some areas where fill was placed behind the original levee, lots exist where no fill has been placed, creating a checkerboard pattern of filled and unfilled lots behind the levee along the canal. There is no discernable landside toe of the levee in some areas that have been filled, as shown in Figure 2-2. Though it may seem like levees would only need to be constructed in areas where adjacent buildings are not above the floodplain, it is important to remember that to meet FEMA levee certification criteria, a levee needs to be continuous and tie into natural high ground with freeboard. To create a continuous levee, the levees will need to be raised along the Surplus Canal to provide needed freeboard and to keep unfilled areas out of the regulatory floodplain. The height that the levees need to be raised is discussed in Chapter 3.
CHAPTER 3
HYDRAULIC ANALYSIS

A hydraulic computer model of the reach of the Surplus Canal that extends from the Mill Creek Confluence with the Jordan River to the Goggin Drain was developed utilizing topographic data, bathymetric survey data, aerial photographs, and other data in Chapter 2. The purpose of the model was to estimate levee and structure freeboard conditions over a range of discharge rates and conditions. Version 4.1.0 of the HEC-RAS computer program developed by the USACE of was used to perform the hydraulic modeling of the Surplus Canal. The HEC-GeoRAS extension within ArcGIS (version 10.2) was utilized to create a HEC-RAS geometry file. The purpose of this chapter is to describe the model development, calibration efforts, modeling results, conclusions and recommendations associated with the hydraulic analysis.

MODEL DEVELOPMENT

This section outlines the general methodology and approach used to complete the hydraulic modeling tasks for this project.

Basic Information

Data acquisition and hydraulic model development tasks were completed in accordance with FEMA Guidelines and Specifications.

Downstream Boundary Conditions

At the downstream limit of the study area the Surplus Canal bifurcates into a canal for the Duck Club (which is not supposed to take more than 300 cfs) and the Goggin Drain. The Goggin Drain regulating/drop structure contains regulating gates and a weir. It was constructed at the head of the Goggin Drain that connects the Surplus Canal to the Goggin Drain. A normal depth calculation with an energy slope of 0.00022 ft/ft was entered into the model immediately upstream of the regulating structure and the Duck Club Canal as the downstream boundary condition. The boundary condition was verified using a discharge rating curve based on the Goggin Drain regulating structure design drawings with the gates open and the maximum allowable flow to the Duck Club Canal.

Topographic Data

A DEM was developed using bathymetric survey data and the 2006 LIDAR data from AGRC. The canal DEM was used in conjunction with HEC-GeoRAS to develop cross section geometric data needed for this model. Field survey data of hydraulic structures was used to develop the bridge geometry data.

Manning’s “n” Values and Expansion/Contraction Coefficients

Values for channel overbank roughness coefficients, or Manning’s “n” coefficients, were estimated based on field observations, aerial photography and engineering judgment. As a
general rule, Manning’s “n” values were selected that would result in subcritical flow conditions. The Manning’s “n” value used for the overbank was 0.050, and 0.030 for the channel. Those Manning’s “n” values are within an acceptable range that reflect the channel conditions.

The expansion and contraction coefficients for channel cross sections are 0.1 and 0.3 respectively. At cross sections that are immediately upstream or downstream of a bridge or hydraulic structure, these coefficients were increased to 0.3 and 0.5, respectively.

Stream Layout and Cross-section Locations

The Surplus Canal centerline location was digitized using the ArcGIS software and the 2012 High Resolution Orthophotography (HRO). Stream cross sections for the Surplus Canal hydraulic model were located at intervals of about 500 feet.

Ineffective Flow Areas

The ineffective flow area options were used in HEC-RAS in cross sections immediately upstream and downstream of hydraulic structures in accordance with FEMA modeling guidelines.

Regulating Structures

There are two regulating structures in the Surplus Canal study area: the Jordan River Diversion (just south of 2100 South) and the North Point Canal (at about 200 South) diversion structure.

- **Jordan River Diversion:** The Jordan River Diversion is an Ogee Crest Spillway used to back-up water for the Lower Jordan River regulating structure. The stop log slots on the vertical steel piers have not been used in many years. The Jordan River Diversion was modeled as an inline structure with a spillway with vertical piers and no stop logs.

- **North Point Canal Diversion:** The North Point Canal diversion structure diverts flow from the Surplus Canal to the North Point Canal for irrigation purposes. The structure has two radial gates, and several stop logs bays. Most of the time the North Point Diversion Structure gates are closed and stop logs are in place to raise the water surface to a level when irrigation water can be diverted into the North Point Canal. Based on the diversion structure operations manual the stop logs are removed and the gates are opened during flood events, or during the winter when irrigation water is not needed. The North Point Canal diversion structure was modeled with stop logs and with the gates closed during the normal operation (median annual flow); and without stop logs and gates fully opened during flood events (USACE design flow, FEMA design flow, flooding of 1984, 1983, and 2011).

MODEL CALIBRATION

A computer simulation was performed after the hydraulic parameters were developed and input into the computer model. Output from the simulation was compared to the available calibration data. This section describes the calibration data and the model calibration efforts.
1983 and 1984 Flooding

Water surface elevations were collected at various structures along the Surplus Canal in the field on November 1, 1983 and May 19, 1984. Flow rates from those specific days were collected from the USGS website (3,800 cfs in 1984 and 1,351 cfs in 1983, See Appendix A) and input into the model. The model output indicated that the water surface elevations were as much as one foot below the field data, which is outside the acceptable calibration range. As discussed in Chapter 2, the capacity of the channel has been increased due to over-dredging which has made the channel deeper and wider. After cross sections based on 1984 channel geometry were entered into the hydraulic model, the difference between the model water surface elevation and the field data was less the 0.2 feet. Therefore, the difference between the 2013 bathymetric survey data and the model results was attributed to the increased capacity of the channel.

2011 Calibration

Streams and rivers along the Wasatch front experienced high peak discharges in the spring of 2011. The peak flow rate during the 2011 flood occurred on June 19, 2011 at 3,290 cfs. A model was developed using the 2011 peak flow rate and the bathymetric survey data which was collected in 2013. The profile of that model was reviewed with Salt Lake County personnel and they indicated the model reasonably simulated conditions they observed in 2011.

MODELED SCENARIOS

After completing the model development and calibration, multiple model scenarios were evaluated using varied channel geometry and discharges to evaluate levee freeboard along the Surplus Canal. This section describes the parameters for the separate model scenarios.

Channel Geometry

Two channel geometry conditions were analyzed as part of the evaluation. They include: Existing channel geometry based on the recently-collected bathymetric data and a modified version of the bathymetric data.

- **Existing Geometry** – The DEM that included the bathymetric survey and the 2006 LIDAR data was the basis for the existing geometry used in some of the miscellaneous scenarios.

- **Modified Bathymetric Survey** - As discussed in Chapter 2, it has been recommended that the canal banks be laid back to a 2:1 side slope to avoid bank stability problems. Also, it has been recommended that the canal bottom be allowed to accumulate sediment to within plus 0.5 or minus 1.5 feet below the USACE design elevation. A geometry file was developed in the HEC-RAS model that represented the Surplus Canal after those recommendations have been implemented. Because the recommended improvements will slightly decrease the existing channel capacity, the improved channel parameters were used in three of the modeling scenarios because they will provide a conservative estimate of the channel capacity and freeboard for channel conditions that change over
time with sediment deposition. The USACE design invert plus 0.5 feet should be the maximum allowable invert elevation before dredging in the future.

Scenario One: USACE Design Discharge

The first model scenario that was simulated used the USACE design flow rates with the modified bathymetric survey. The purpose of this scenario was to determine if the levees along the Surplus Canal could meet the original USACE freeboard requirements. The USACE design drawings show the design flow rates for the Surplus Canal as 3,300 cfs between Mill Creek and the North Point Diversion and 2,000 cfs downstream of the North Point Diversion.

Scenario Two: FEMA Design Discharge

The second scenario that was simulated included the 100-year flood from the updated FIS report with the modified bathymetric survey. The purpose of this scenario was to determine whether the levees along the Surplus Canal could meet FEMA freeboard requirements for the 100-year flood event. The modified channel geometry was used for this scenario.

The FEMA FIS indicates that the 100-year flood event is 4,700 cfs on the Jordan River at the Mill Creek Confluence. Based on flow data from the USGS and the FEMA FIS report, the Jordan River Diversion diverts approximately 200 cfs during major flood events. Therefore, downstream of the Jordan River Diversion, the 100-year flood event in the Surplus Canal is approximately 4,500 cfs. The water surface elevations estimated using this discharge rate were used to determine if FEMA freeboard requirements for the levees are met along the Surplus Canal. Appendix F includes a copy of the FEMA FIS Summary of Discharges.

Scenario Three: Median Annual Discharge

The third scenario that was developed included the median annual flow rate and the modified 2013 bathymetric survey. The purpose of this scenario was too provide water surface elevations for the geotechnical study to be used in the seismic stability analysis.

The Median Annual flow was estimated to be 237 cfs and was estimated using data from the years 2002 to 2011. The median flow was calculated for each year then averaged over the last 10 years. The highest and lowest years were removed from the final average.

Miscellaneous Scenarios

There were also other scenarios or miscellaneous scenarios that were set up and run in the HEC-RAS model. The existing 2013 bathymetric survey was combined with each of the following flow rates: USACE Original Design Flow (3,300 cfs and 2,000 cfs), FEMA 100-year Flood event (4,700 cfs and 4,500 cfs), Median Annual Flow Rate (237 cfs), the 2011 flood peak flow (3,290 cfs), and the flow rates on November 1, 1983 (1,351 cfs) and May 19, 1984 (3,800 cfs). Additional scenarios included the modified bathymetric survey with each of the following flow rates: 2011 peak flow and the flow rates on November 1, 1983 and May 19, 1984.
Though each of the miscellaneous scenarios was simulated with the model, results were not included in the freeboard analysis. Profiles of each of the miscellaneous scenarios have been included in Figure 3-1 for informational purposes.

RESULTS AND CONCLUSIONS

The results and conclusions of each of the model scenarios are described in this section.

Scenario One: USACE Design Discharge

The water surface elevations from Scenario One were compared to the elevation of the top of the levees along the Surplus Canal. The levee freeboard results are illustrated on Figure 3-2.

As can be seen from Figure 3-2, there is at least three feet of freeboard for the majority of the west levee and at least five feet of freeboard for the majority of the east levee, which is consistent with the USACE design criteria. There are a few sections of the levee where settlement and wind erosion may have decreased the elevation of the top of the levee, resulting in a little less freeboard than the original design drawings indicate. But there are only a few of those sections, and the levee freeboard is within a foot of the original design elevations. It is also important to note that the original design flow of 3,300 cfs was similar to the peak flow in 2011. During the 2011 runoff event the Surplus Canal, levees did not overtop and the levees had adequate freeboard based on model results and conversations with the County. The Scenario One HEC-RAS profile can be found on Figure 3-1.

Scenario Two: FEMA Design Discharge

The water surface elevations from Scenario Two model simulation were compared to the elevation of the top of the levees along the Surplus Canal. The levee freeboard is illustrated on Figure 3-3.

As Figure 3-3 indicates, the levees along the Surplus Canal consistently do not have the standard 3 feet minimum freeboard to meet FEMA levee criteria. The east levee has an average of 1-2 feet of freeboard between Mill Creek and the South Bound Airport Terminal Drive, while the west has an average of 0-1 feet of freeboard between Mill Creek and the South Bound Airport Terminal Drive. Downstream of the Airport Terminal Drive, where the Surplus Canal turns away from the Airport, the majority of both levees has 3 feet or more freeboard, and do not need to be modified. The section of the Surplus Canal 3,000 feet upstream of the Goggin Drain only has an average of 1-2 feet of freeboard.

Levee freeboard at structures was also analyzed as part of this scenario. FEMA criteria indicate that an additional foot of levee freeboard (for a total of 4 feet of freeboard) is required 100 feet upstream and downstream of each structure. A summary of the 100-year water surface elevation, the low chord, the deck elevation, upstream west levee elevation, and the existing levee freeboard at each structure is presented in Table 3-1.
As the data in Table 3-1 indicates, the upstream west levee of the structures has between 0.0 and 2.5 feet of freeboard, and does not meet FEMA levee freeboard criteria. The levee at each of the structures will need to be raised to meet FEMA levee criteria. Table 3-1 also indicates that the 100-year water surface on several structures will impound on the low chord, which is consistent with the field data collected in the flooding from 1984. During the 1984 flood event, the peak flow in the Surplus Canal was 4,410 cfs, which is one of highest peak discharge on record in the Surplus Canal, and is close to the 100-year event. During that event, some of the structures on the Surplus Canal did have water impounded on their low chords, but neither the structures nor the levees overtopped. The HEC-RAS profile for this scenario is shown in Figure 3-1.
Table 3-1  
Summary of Existing Freeboard on the Upstream Side of Structures with 4,500 cfs Discharge Rate

<table>
<thead>
<tr>
<th>Name</th>
<th>100-year WS (ft)</th>
<th>Low Chord Elevation (ft)</th>
<th>Clearance Between Low Chord &amp; 100-year WS (ft)</th>
<th>West Levee Elevation at Structure (ft)</th>
<th>Levee Freeboard Upstream of Structure (ft)</th>
<th>Structure Deck Elevation (ft)</th>
<th>Clearance Between Structure Deck Elevation and 100-year WS (ft)</th>
<th>Floodwall Needed to Contain Flood Event?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedestrian Bridge at approximately 2300 South¹</td>
<td>4237.0</td>
<td>4236.5</td>
<td>-0.5</td>
<td>4237.5</td>
<td>0.5</td>
<td>4237.0</td>
<td>0.0</td>
<td>No</td>
</tr>
<tr>
<td>UTA Crossing at approximately 2300 South</td>
<td>4236.8</td>
<td>4242.3</td>
<td>5.7</td>
<td>4237.3</td>
<td>0.5</td>
<td>4252.7</td>
<td>15.9</td>
<td>No</td>
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<td>SR-201</td>
<td>4236.6</td>
<td>4235.1</td>
<td>-1.5</td>
<td>4237.2</td>
<td>0.6</td>
<td>4244.7</td>
<td>8.1</td>
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</tr>
<tr>
<td>2100 South</td>
<td>4236.4</td>
<td>4232.1</td>
<td>-4.3</td>
<td>4237.1</td>
<td>0.7</td>
<td>4248.0</td>
<td>11.6</td>
<td>No</td>
</tr>
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<td>Jordan River Diversion¹</td>
<td>4235.6</td>
<td>4237.0</td>
<td>1.4</td>
<td>4263.8</td>
<td>1.2</td>
<td>4237.2</td>
<td>1.6</td>
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<td>4238.8</td>
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<td>4233.8</td>
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<td>4236.5</td>
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<td>1.9</td>
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<td>23.4</td>
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<td>5.8</td>
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<td>Railroad Bridge At Approximately 700 South</td>
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<td>4231.4</td>
<td>0.8</td>
<td>4232.0</td>
<td>1.4</td>
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<td>Railroad Bridge Upstream of 500 South</td>
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<td>4230.1</td>
<td>0</td>
<td>4232.1</td>
<td>2.0</td>
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</tr>
<tr>
<td>500 South</td>
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<td>4231.0</td>
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<td>4230.1</td>
<td>0.2</td>
<td>4239.2</td>
<td>9.3</td>
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<td>1.8</td>
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<td>4227.4</td>
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¹ Structure does not penetrate levees, and does not need 4 feet of freeboard
² Structure does not need a floodwall if Golf Course is allowed to flood
³ Elevation is field surveyed and will need to be confirmed prior to design.
⁴ The Structure Deck Elevation is the elevation at which water would start to flow over the structure
⁵ If clearance between Low Chord and 100-yr WS is negative, then water is impounding on the Low Chord
⁶ If clearance between Deck Elevation and 100-yr WS is negative, then water is overtopping the structure
Scenario Three: Annual Median Discharge

The model results from the annual median flow simulation indicate that the water surface in the canal is normally controlled by the regulation of the North Point Diversion Structure. As mentioned previously, the gates at the North Point Diversion are closed during normal operations. Even with the gates closed, the water surface elevations associated with the median flow are below the natural ground surface so water will not be impounded water on the Surplus Canal levees. The water surface elevations estimated from this scenario are used for the Geotechnical Seismic analysis, and will be discussed in Chapter 4 of this report. The HEC-RAS profile for this scenario is shown in Figure 3-1.

RECOMMENDATIONS

This section will describe the recommendations based on the hydraulic analysis. Conceptual cost estimates for the recommendations will be provided in Chapter 5.

Raise Levees

The levees on both sides of the Surplus Canal should be raised to provide at least 3.5 feet of freeboard to meet FEMA criteria for a 100-year flood event of 4,700 cfs and 4,500 cfs. The additional 0.5 feet of freeboard above the FEMA criteria is recommended to allow for some variation in construction, to allow for potential settlement and impacts from sediment deposition. The geotechnical analysis indicates that there could be up to 0.5 feet of levee settlement after construction. Figure 3-4 shows the proposed top of levee with 3.5 feet of freeboard. As can be seen from Figure 3-4, most of the needed levee raising can be accomplished within the established Surplus Canal ROW. The east levee will need to be raised between 1 and 2 feet between Mill Creek and the Airport Terminal Drive, and the west levee will need to be raised between 2 and 3 feet in that same area. The raised levees should also serve as maintenance access roads for the Surplus Canal, similar to the existing levees. Figure 3-5 shows a typical improved cross section with the proposed levees raised and the canal banks laid back shown. Raising the levees will change the design freeboard criteria for the levees and may require review and approval of the USACE. It is also important to note that based on the preliminary analysis, raising the levees will not require obtaining additional ROW or easements.

Structures

Table 3-1 indicates the top elevations of several structures are not four feet above the 100-year water surface elevation. For discussion purposes, those structures that will be separated into the following groups: Pedestrian Bridges, Redwood Road & Terminal Drive, Regulating Structures, Railroad Bridges and the Wing Point Golf Course Structures.

Pedestrian Bridges. The deck elevations of the pedestrian bridges at approximately 2300 South and downstream of 2100 South are not four feet above the 100-year water surface elevation. The low deck elevations should not affect the 100-year regulatory floodplain because the levees on both sides of the bridges are continuous and will contain the 100-year flow in the channel after the levees have been raised. Therefore, if the levees are raised to provide the needed freeboard,
the bridges will not need to be modified to meet FEMA levee freeboard requirements. However, access ramps will need to be constructed from the top of the raised levees to the bridge deck to provide pedestrian access.

**Redwood Road & Terminal Drive.** Bridges at North Bound Terminal Drive and the Redwood Road Bridge have a low deck elevation relative to the water surface elevation. Floodwalls that are at least 4 feet above the 100-year water surface elevation will need to be constructed on the upstream and downstream side of the bridges that tie into the recommended improvements. The floodwalls will serve as a continuation of the levees along the Surplus Canal and will contain the 100-year flood event.

**Regulating Structures.** Similar to the pedestrian bridges, the deck elevations of the Jordan River Diversion and North Point Diversion are not four feet above the 100-year water surface elevation. The levees on both sides of the structures are continuous and will contain the 100-year flow in the channel after the levees have been raised. Therefore, if the levees adjacent to the structure are raised to provide the needed freeboard, then the structures will not need to be modified to meet FEMA levee freeboard requirements. The scour holes downstream of both of the regulating structures will need to be filled and stabilized to protect the structure and the levee on either side of the canal.

**Railroad Bridges.** There are four railroad bridges that cross the Surplus Canal that are not high enough to serve as a continuation of the Surplus Canal levees with freeboard. The locations of the railroad bridges are: upstream of 1700 South, approximately 700 South, upstream of 500 South, and upstream of I-80. Photos of the railroad bridges can be found in Appendix D. Constructing a floodwall on the bridges to serve as a continuation of the Surplus Canal levees (with freeboard) may not be a viable option. The railroad bridges may not be wide enough to construct a floodwall. The option of installing a floodwall on the railroad bridges will need to be discussed with Union Pacific to see how much clearance between the train and the floodwall would be needed, and also to determine if Union Pacific would be open to a floodwall on their railroad bridge.

If floodwalls cannot be constructed on the railroad bridges, the levees upstream and downstream of the bridges cannot be certified. If the levees are not certifiable, then the regulatory floodplain will be mapped as though the levees do not exist. The result is that several large commercial developments out by the airport would be added to the regulatory floodplain. The regulatory flooding would likely be shallow overland flow and mapped as Zone AO or Shaded Zone X on the Flood Insurance Rate Map. Zone AO flooding is shallow sheet flow that averages as deeper than one foot deep; it also requires the purchase of flood insurance. Shaded Zone X flooding is shallow sheet flow that averages as less than one foot deep; it does not require the purchase of flood insurance. A detailed floodplain analysis will need to be completed if the levees at these railroad bridges cannot be certified. It is important to note that although properties might be mapped as being in the regulatory floodplain due to freeboard deficiencies, they might not actually flood during a 100-year flood event. Future building constructed in these areas should be elevated and graded to minimize flood risk and to reduce potential flood insurance requirements and rates.
Wing Point Golf Course Structures. There are two structures near the Wing Point Golf Course that do not have the necessary freeboard at adjacent levees for FEMA certification purposes: the Wing Point Golf Course Bridge and the North Point Canal Flume. Improving those structures would be costly and would only protect the Golf Course. Since the Golf Course is mostly open space and contains no critical structures, it is recommended that the west levee between the North Point Diversion and Terminal Drive not be modified and allow the Golf Course to be mapped in the regulatory floodplain due to freeboard deficiencies. The following are recommendations in regards to each of the Wing Point Golf Course Structures.

Wingpoint Golf Course Bridge – Raise the levee on the east side of the Surplus Canal near this bridge. A continuous levee on the east side of the Surplus Canal is needed to keep a significant portion of the Airport and several businesses to the east of the Airport out of the regulatory floodplain and/or shallow flooding hazard zone. The road immediately east of the canal that leads to the golf course will need to be raised and incorporated into the improved east canal levee.

North Point Canal Flume - The levee on the north side of the North Point Canal will need to be raised to meet minimum FEMA levee freeboard requirements so that airport facilities can remain outside of the regulatory floodplain. If the north levee is raised, the flume will not need to be modified.

Chesterfield Drain

The area directly north of the Chesterfield Drain that is generally bounded by the Jordan River, the Chesterfield Drain, Brighton Canal and 2100 South is currently in the FEMA 100-year regulatory floodplain because the west levee on the Jordan River does not have 3 feet of freeboard. To remove this area from the floodplain, a levee could be constructed on the North Side of the Chesterfield Drain that connects into the natural ground to the west of the Surplus Canal (near Lester Street). The west levee on the Jordan River would also need to be raised as shown on Figure 3-3. This alternative would protect the structures north of the Chesterfield Drain and remove them from the regulatory Flood Zones AE and AH. The Flood Zone AE is riverine flooding with a base flood elevation, while Flood Zone AH is riverine flooding that is usually in the form of ponding that is 1 to 3 feet deep. Structures in either Flood Zones AE or AH are required to purchase a flood insurance policy. The nature preserve to the south of the Chesterfield Drain is lower than the 100-year water surface and would be included in the regulatory floodplain, which should not be a problem. The homes to the west of the nature preserve are at a higher elevation, and should be out of the regulatory floodplain. A floodplain analysis would need to be completed to confirm that only the nature preserve will be affected. Figure 3-6 shows the Chesterfield Drain recommended improvement.

Potential Exception to FEMA Freeboard Criteria

As stated previously, FEMA standard levee criteria indicates that a levee must have at least 3 feet of freeboard with an additional foot of freeboard 100 feet upstream and downstream of each structure to meet certification criteria. FEMA regulations allow exceptions to the minimum riverine freeboard requirement. If “appropriate engineering analyses demonstrating adequate
protection with a lesser freeboard” (FEMA CFR 65.10) is submitted with a request for an exception to the minimum freeboard requirement, then the minimum freeboard requirement can be reduced to 2 feet. Some of the required engineering analyses need to include an assessment of statistical confidence limits of the 100-year discharge; source, potential and magnitude of debris, sediment and ice accumulation; etc.

It is recommended that an exception to the standard levee criteria for the Surplus Canal Levees be requested from FEMA. The Jordan River and Surplus Canal are highly regulated rivers. Part of the Utah Lake Compromise agreement specifies that if discharge in the Jordan River at 2100 South exceeds 3,400 cfs then the flow from Utah Lake into the Jordan River may be regulated such that the combined flow at 2100 South does not exceed 3,400 cfs. Sediment has not significantly accumulated on the bottom of the Surplus Canal due to the diligence of the maintenance crew responsible for the Surplus Canal. Other engineering analysis would also be completed that would justify to FEMA an exception to the levee criteria.

If the freeboard exception is obtained from FEMA, the levees along the Surplus Canal would need 1 foot less freeboard for the study area; the recommended improvement would be to raise the levees to 2.5 feet above the 100-year water surface along the Surplus Canal. This would represent a significant cost savings to the County during construction of the new levees.

**Consider Revising Jordan River Hydrology**

It may be possible to utilize the Utah Lake Compromise Agreement to revise the FEMA flood hydrology associated with the Surplus Canal. The Utah Lake Compromise Agreement states that if the flow rate in the Jordan River at 2100 South exceeds 3,400 cfs, the gates at the Utah Lake Outlet can be regulated in an effort to keep the peak discharge at 2100 South to 3,400 cfs. The 100-year discharge rate of 4,500 cfs was estimated without consideration of the Utah Lake Compromise Agreement. If the regulating feature of the Comprise Agreement is considered in a hydrologic analysis, then it may be possible to request that FEMA reduce magnitude of the base flood downstream of the Mill Creek confluence with the Jordan River. Reducing the magnitude of the base flood could have significant impacts to improvements needed to mitigate problems associated with levee and bridge freeboard issues and the associated shallow floodplains located near those deficient areas. The option of revising the Jordan River hydrology downstream of the Mill Creek confluence could be considered if Salt Lake County personnel feel confident in the monitoring of Surplus Canal discharges, uncertainty in the timing and peak inflows from Little Cottonwood Creek, Big Cottonwood Creek, and Mill Creek as well as issues associated with potential sediment deposition.
CHAPTER 4
GEOTECHNICAL ANALYSIS

A geotechnical study was completed by Gerhart Cole Incorporated as part of this project. The purpose of the geotechnical study was to determine if the levees along the Surplus Canal meet FEMA and USACE geotechnical requirements and to provide recommendations that would bring the levees into compliance with FEMA levee criteria. As part of the project they performed field reconnaissance, drilled test holes, collected soil samples, completed laboratory analyses, performed stability analyses and provided conclusions and recommendations. For a full review of the geotechnical analysis, see the report developed by Gerhart Cole included in Appendix E. The purpose of this chapter is to summarize the work performed, analyses, conclusions and recommendations of the geotechnical study.

DRILLING AND LAB WORK

Sixteen test holes were drilled along the Surplus Canal levee at approximately 0.5 mile intervals. Testing at each of the holes included:

- Drilling and Sampling
- In-situ constant-head permeability testing
- In-situ borehole shear testing

Test hole locations are shown on Figure 4-1.

Laboratory tests included: Particle-Size Analysis; Moisture Content, Content of Soil, Rock and Soil-Aggregate Mixtures; Density of Soils in Place; Testing for Liquid Limit, Plastic Limit, and Plasticity Index. The laboratory tests results for the geotechnical study were used to evaluate the levees.

ANALYSES

Levee and channel stability analyses and calculations were performed for 65 cross sections, spaced at average intervals of approximately 700 feet. Analyses were completed on the existing levee and on the proposed levee. Stability analyses were performed for: steady state seepage, sudden drawdown, and end of construction. Additional analysis included seismic analyses and settlement. This section discusses each analysis individually.

Additionally, laboratory results from USACE tests holes drilled in 1958 were evaluated and organized as part of the geotechnical study. Data including Atterberg Limits and Sensitivity vs Effective Stress Relationships are summarized in the Geotechnical Report.

Settlement

The settlement analysis was performed to assess anticipated ranges of settlement as embankments are raised to minimum freeboard requirement. The results of the settlement
analysis indicated that there could be up to 6 inches of combined primary and secondary settlement if the levees are raised about 4 feet. Site specific analysis should be performed in areas that require more than 4 feet of fill to raise levee to the required elevation.

**Seismic**

The USACE requires that the seismic analysis if the 100-year earthquake probabilistic peak ground accelerations (PGA) be greater than 0.1 gravity (g). The seismic analysis indicated that the PGA was not more than 0.1g. Therefore, no detailed seismic analysis is required. Furthermore, the median water surface elevation is consistently below the toe of the levees. If the levees were to seismically fail while conveying the median flow rate of 237 cfs, the Canal operation would be unaffected until water surface elevations in the Canal exceeded the elevation of the natural ground.

**Steady State Seepage**

USACE criteria required that the minimum acceptable long term Factor of Safety (FS) for steady state seepage conditions at the 100-year flood stage is 1.4. The existing and proposed levees on the Surplus Canal meet the USACE steady state seepage FS.

**Steady State Canal Bank Stability**

The canal bank stability was analyzed at the median annual water surface elevation. The USACE bank stability FS requirement is 1.4. The majority of the existing left canal bank and a portion of the right bank do not meet steady state stability USACE criteria. The canal banks will need to be stabilized by decreasing their slope to a maximum of 2H:1V.

**Sudden Drawdown**

For this analysis, pore pressures in the embankment and foundation were approximated assuming the water surface decreases from the 100-year event to the median annual event. The acceptable FS for sudden drawdown ranges from 1.0 to 1.2, based on USACE criteria. The Surplus Canal levee meets sudden drawdown USACE stability criteria.

**End of Construction**

The minimum acceptable FS for end of construction stability is 1.3 based on USACE requirements. An end of construction stability test assesses the stability of the foundation and levee materials immediately after fill has been added to the levee before the pore pressure drains. The Surplus Canal levee meets end of construction USACE stability criteria for areas where less than 4 feet of fill will added to the levee. If more than 4 feet of fill will be placed on the existing levee, then additional analysis is recommended.
CONCLUSIONS

The following is a summary of the conclusions regarding the Surplus Canal Geotechnical Study.

1. Existing canal levees need to be raised to meet minimum freeboard criteria required by FEMA regulations (CFR 65.10) based on existing FEMA flood hydrology.

2. Minimum FS are not met for existing canal banks under steady state flood seepage conditions using the existing FEMA flood hydrology. Areas not meeting minimum FS criteria are primarily located along the west canal bank and associated with over-steeping of canal side slopes from maintenance dredging. In some areas, the bank stability has the potential to impact the stability and FS associated with the levees.

3. Proposed levee modifications which include raising embankment up to 4 feet in height with canal side slopes and embankment slopes graded to match initial design criteria (i.e. 2H:1V canal side and 3H:1V landward side slopes) meet USACE minimum stability standards for:
   a. Steady State Seepage Full Flood Stage (Long Term) Stability
   b. Sudden Drawdown Stability
   c. End of Construction Stability
   d. Earthquake Stability

4. Stability analyses suggest that reaches of existing canal banks with side slopes steeper than 2H:1V (the original design side slope) adjacent to the canal levees should be cut back to match the original design side slope to meet canal side minimum stability requirements for the levees; specifically under sudden draw down conditions. In general, critical slip / slope surfaces for the sudden draw down conditions do not intersect the levee geometries but rather the over steepened portions of the canal banks. There is the potential that canal levee stability requirements could be met without regrading the canal banks to match 2H:1V. The stability analyses did not address leaving the over-steepened canal side slopes “as-is”; however, such analyses can be performed if the County wishes to evaluate the impacts of not stabilizing the canal banks to determine if that could impact future levee stability. Preliminary analysis of the “do nothing” option suggests there is a potential to meet stability requirements while leaving canal side slope geometry “as-is”.

   However, engineering judgment suggests that the over steepened canal banks should be stabilized to reduce potential problems associated with instability and erosion.

5. Settlement analyses show that a target fill height of 3.5 feet of freeboard will meet the 3 foot minimum freeboard requirement following estimated primary and secondary settlement for fill heights up to 4 feet.

6. Areas where the levees are raised in excess of 4 feet or where ROW or other geometric constraints precluded target levee design slopes (i.e. 2H:1V canal side and 3H:1V landward side slopes) will require additional analysis and/or site specific sampling and testing.

7. If the recommendations summarized about and identified in the Geotechnical Data Report are incorporated into future levee improvement projects, it is believed that the
levees will meet FEMA and USACE certification requirements with respect to levee stability, steady-state seepage, and settlement.

RECOMMENDATIONS

The following is a summary of the recommendations regarding the Surplus Canal Geotechnical Study.

1. It is recommended that the side slopes of the canal banks steeper than 2H:1V be cut back to match the original design side slope of 2H:1V to stabilize the banks and protect the levees. A typical cross section showing the stabilized canal slope and raised levees is shown in Figure 3-5. The HEC-RAS cross sections in Appendix G also show the existing side slopes and the proposed side slope of 2:1.
CHAPTER 5
SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

If the recommendations in this report are implemented, than the levees along the Surplus Canal should meet FEMA levee certification criteria. After the levees are certified and appropriate floodplain mapping work is complete, the regulatory floodplain associated with the Surplus Canal will be contained within the levees. The previous chapters have provided recommendations to certify the levee. The purpose of this chapter is to summarize the conclusions and recommendations from previous chapters and also to present cost estimates.

CONCLUSIONS AND RECOMMENDATIONS

Based on the USACE inspection report, field survey data, field reconnaissance, ROW, review of the existing data, the hydraulic analysis, and the geotechnical analysis, the following conclusions and recommendations can be made.

2.1 USACE Report

The USACE identified multiple deficiencies on the Surplus Canal levees. Those deficiencies will need to be remedied in accordance with USACE guidelines and standards.

2.2 Levee Penetrations

Pipes that penetrate the levees should be provided a closure valve per FEMA standards. To provide an added level of protection requested by Salt Lake City, it is recommended that the closure valve be provided by with an additional back-up closure valve. This action should be given a high priority to increase performance of the levee during a flood event and to facilitate certifying the levee.

2.3 Levee Toe Outside ROW

There are several locations where the outside toe of the levee is not within the Surplus Canal ROW. Because this is a ROW deficiency, the recommendation to this issue can be found in the next bullet item (ROW Data). To complete the recommended improvements to the Surplus Canal Levee, additional ROW and/or easements do not need to be acquired (see conclusions and results in Chapter 3).

2.4 ROW Data

There are two sections of the Surplus Canal where recorded ROW data could not be located. The first section of the canal that is missing ROW data is located between USACE station 200+00 and 224+00 on the left side of the canal. The issue can be resolved by securing a recorded easement. Therefore, it is recommended that a recorded easement be secured in that area prior to completing any future levee improvements. The second section is approximately 2.5 miles long and adjacent to the Salt Lake City International Airport (Airport) starting at the North Point Canal Flume. The original Surplus Canal alignment had an easement through the Airport at one time, but following the most recent canal relocation projects at the Airport, an
updated easement or ROW was apparently not recorded. Salt Lake City and Salt Lake County worked together during the design and construction of the Canal relocation project. It appears that an updated easement may not have been obtained because the Airport is a public facility owned by Salt Lake City. It is recommended that a maintenance easement be created and formalized through this reach of the canal.

2.5 Development Encroachments

There are several buildings, fences, parking lots, and miscellaneous development encroachments within the canal ROW. It is recommended that the development encroachments within the canal ROW be relocated or properly permitted. In addition, field observations indicated that in at least one location, a water line and fire hydrant were installed in or near a portion of the canal levee. It is also recommended that the County coordinate with development review staff at West Valley City and Salt Lake City to ensure that any construction activities in or near the Surplus Canal Levees be reviewed and permitted by Salt Lake County. This issue should be placed on a development review checklist in both cities; otherwise, the County will have a difficult time knowing when projects could impact the levees.

2.6 Maintenance-Dredging

The comparison of the recent bathymetric survey data to the original design cross sections and profile indicates that the Surplus Canal is deeper and wider today than when it was originally constructed, due in large part, to over-dredging. Channel dredging activities have destabilized the toe of the canal bank, which has also made the reaches of the canal banks unstable. To stabilize the canal banks, it is recommended that the canal banks be laid back at a 2:1 design side slope and that future channel dredging be performed in a manner that will not destabilize the banks. Furthermore, it is recommended that the sediment deposition be monitored on the canal bottom and that careful dredging be performed as needed to maintain the channel bottom to within plus 0.5 or minus 1.5 feet below the design elevation. The widened channel cross sections can be maintained if the over-steepened, unstable slopes are laid back to a 2H:1V slope.

2.7 Sedimentation Monitoring

The bathymetric survey that was performed for this study provides a good baseline for existing conditions. Similar bathymetric surveys should be used on a regular basis in the future to monitor sediment deposition, scour erosion, and dredging activities to the limits recommended above.

2.8 Remove Jordan River Diversion Structure Walkway

The Jordan River diversion structure is located at the head of Surplus Canal. The structure includes a 5-foot tall ogee weir and a pedestrian walkway that is supported by vertical steel columns or piers. The columns were designed so that stop logs could be placed on the upstream face of the structure to divert water down the Lower Jordan River for Water Right purposes. However, Salt Lake County personnel indicated that they know of only one instance when the stop logs slots were used to divert water to the Lower Jordan River. It was used to divert water during the summer to facilitate a construction project, not for the original intention of water rights. During field visits, it was observed that several of the steel support columns are nearly
totally rusted away. The potential failure of this structure poses a significant safety threat for both personal safety and flooding. The structure also catches a substantial amount of debris during flood events due to the close spacing of the piers. Furthermore, there is a pedestrian bridge approximately 300 feet downstream and 2100 South approximately 300 feet upstream of the diversion structure, making the walkway on the diversion structure redundant. For safety and flood control reasons, it is recommended that the steel walkway and the vertical piers be repaired or removed from the diversion structure.

2.9 Scour Holes

The bathymetric survey indicated that two major scour holes exist on the Surplus Canal: one immediately downstream of the Jordan River Diversion; the other immediately downstream of the North Point Canal Diversion (see Figure 2-4). The deep scour holes create a potential threat to the regulation structures. They have also caused canal slope stability problems that increase the potential for failure of the canal banks and Surplus Canal levees. It is recommended that those scour holes are filled and that the channel bottom and banks be armored to protect the structure and adjacent levees.

2.10 Non-Existent Levees

During field visits, it was observed that several structures adjacent to the levee were constructed after fill was placed on the land side of the levee. Areas where buildings were constructed on top of fill are often high enough to be out of the regulatory floodplain. Adjacent to some areas where fill was placed behind the original levee, lots exist where no fill has been placed, creating a checkerboard pattern of filled and unfilled lots behind the levee along the canal. There is no discernable landside toe of the levee in some areas that have been filled, as shown in Figure 2-2. Though it may seem like levees would only need to be constructed in areas where adjacent buildings are not above the floodplain, it is important to remember that to meet FEMA levee certification criteria, a levee needs to be continuous and tie into natural high ground with freeboard. To create a continuous levee, the levees will need to be raised along the Surplus Canal to provide needed freeboard and to keep unfilled areas out of the regulatory floodplain. The height that the levees need to be raised is discussed in Chapter 3.

3.1 Raise Levees

The levees on both sides of the Surplus Canal should be raised to provide at least 3.5 feet of freeboard to meet FEMA criteria for a 100-year flood event of 4,700 cfs and 4,500 cfs. The additional 0.5 feet of freeboard above the FEMA criteria is recommended to allow for some variation in construction, to allow for potential settlement and impacts from sediment deposition. The geotechnical analysis indicates that there could be up to 0.5 feet of levee settlement after construction. Figure 3-4 shows the proposed top of levee with 3.5 feet of freeboard. As can be seen from Figure 3-4, most of the needed levee raising can be accomplished within the established Surplus Canal ROW. The east levee will need to be raised between 1 and 2 feet between Mill Creek and the Airport Terminal Drive, and the west levee will need to be raised between 2 and 3 feet in that same area. The raised levees should also serve as maintenance access roads for the Surplus Canal, similar to the existing levees. Figure 3-5 shows a typical improved cross section with the proposed levees raised and the canal banks laid back shown.
Raising the levees will change the design freeboard criteria for the levees and may require review and approval of the USACE. It is also important to note that based on the preliminary analysis, raising the levees will not require obtaining additional ROW or easements.

3.2 Structures

Table 3-1 indicates the top elevations of several structures are not four feet above the 100-year water surface elevation. For discussion purposes, those structures that will be separated into the following groups: Pedestrian Bridges, Redwood Road & Terminal Drive, Regulating Structures, Railroad Bridges and the Wing Point Golf Course Structures.

3.2.1 Pedestrian Bridges. The deck elevations of the pedestrian bridges at approximately 2300 South and downstream of 2100 South are not four feet above the 100-year water surface elevation. The low deck elevations should not affect the 100-year regulatory floodplain because the levees on both sides of the bridges are continuous and will contain the 100-year flow in the channel after the levees have been raised. Therefore, if the levees are raised to provide the needed freeboard, the bridges will not need to be modified to meet FEMA levee freeboard requirements. However, access ramps will need to be constructed from the top of the raised levees to the bridge deck to provide pedestrian access.

3.2.2 Redwood Road & Terminal Drive. Bridges at North Bound Terminal Drive and the Redwood Road Bridge have a low deck elevation relative to the water surface elevation. Floodwalls that are least 4 feet above the 100-year water surface elevation will need to be constructed on the upstream and downstream side of the bridges that tie into the recommended improvements. The floodwalls will serve as a continuation of the levees along the Surplus Canal and will contain the 100-year flood event.

3.2.3 Regulating Structures. Similar to the pedestrian bridges, the deck elevations of the Jordan River Diversion and North Point Diversion are not four feet above the 100-year water surface elevation. The levees on both sides of the structures are continuous and will contain the 100-year flow in the channel after the levees have been raised. Therefore, if the levees adjacent to the structure are raised to provide the needed freeboard, then the structures will not need to be modified to meet FEMA levee freeboard requirements. The scour holes downstream of both of the regulating structures will need to be filled and stabilized to protect the structure and the levee on either side of the canal.

3.2.4 Railroad Bridges. There are four railroad bridges that cross the Surplus Canal that are not high enough to serve as a continuation of the Surplus Canal levees with freeboard. The locations of the railroad bridges are: upstream of 1700 South, approximately 700 South, upstream of 500 South, and upstream of I-80. Photos of the railroad bridges can be found in Appendix D. Constructing a floodwall on the bridges to serve as a continuation of the Surplus Canal levees (with freeboard) may not be a viable option. The railroad bridges may not be wide enough to construct a floodwall. The option of installing a floodwall on the railroad bridges will need to be discussed with Union Pacific to see how much clearance between the train and the floodwall would be needed, and also to determine if Union Pacific would be open to a floodwall on their railroad bridge.
If floodwalls cannot be constructed on the railroad bridges, the levees upstream and downstream of the bridges cannot be certified. If the levees are not certifiable, then the regulatory floodplain will be mapped as though the levees do not exist. The result is that several large commercial developments out by the airport would be added to the regulatory floodplain. The regulatory flooding would likely be shallow overland flow and mapped as Zone AO or Shaded Zone X on the Flood Insurance Rate Map. Zone AO flooding is shallow sheet flow that averages as deeper than one foot deep; it also requires the purchase of flood insurance. Shaded Zone X flooding is shallow sheet flow that averages as less than one foot deep; it does not require the purchase of flood insurance. A detailed floodplain analysis will need to be completed if the levees at these railroad bridges cannot be certified. It is important to note that although properties might be mapped as being in the regulatory floodplain due to freeboard deficiencies, they might not actually flood during a 100-year flood event. Future building constructed in these areas should be elevated and graded to minimize flood risk and to reduce potential flood insurance requirements and rates.

3.2.5 Wing Point Golf Course Structures. There are two structures near the Wing Point Golf Course that do not have the necessary freeboard at adjacent levees for FEMA certification purposes: the Wing Point Golf Course Bridge and the North Point Canal Flume. Improving those structures would be costly and would only protect the Golf Course. Since the Golf Course is mostly open space and contains no critical structures, it is recommended that the west levee between the North Point Diversion and Terminal Drive not be modified and allow the Golf Course to be mapped in the regulatory floodplain due to freeboard deficiencies. The following are recommendations in regards to each of the Wing Point Golf Course Structures.

Wingpoint Golf Course Bridge – Raise the levee on the east side of the Surplus Canal near this bridge. A continuous levee on the east side of the Surplus Canal is needed to keep a significant portion of the Airport and several businesses to the east of the Airport out of the regulatory floodplain and/or shallow flooding hazard zone. The road immediately east of the canal that leads to the golf course will need to be raised and incorporated into the improved east canal levee.

North Point Canal Flume - The levee on the north side of the North Point Canal will need to be raised to meet minimum FEMA levee freeboard requirements so that airport facilities can remain outside of the regulatory floodplain. If the north levee is raised, the flume will not need to be modified.

3.3 Chesterfield Drain

The area directly north of the Chesterfield Drain that is generally bounded by the Jordan River, the Chesterfield Drain, Brighton Canal and 2100 South is currently in the FEMA 100-year regulatory floodplain because the west levee on the Jordan River does not have 3 feet of freeboard. To remove this area from the floodplain, a levee could be constructed on the North Side of the Chesterfield Drain that connects into the natural ground to the west of the Surplus Canal (near Lester Street). The west levee on the Jordan River would also need to be raised as shown on Figure 3-3. This alternative would protect the structures the north of the Chesterfield Drain and remove them from the regulatory Flood Zones AE and AH. The Flood Zone AE is riverine flooding with a base flood elevation, while Flood Zone AH is riverine flooding that is
usually in the form of ponding that is 1 to 3 feet deep. Structures in either Flood Zones AE or AH are required to purchase a flood insurance policy. The nature preserve to the south of the Chesterfield Drain is lower than the 100-year water surface and would be included in the regulatory floodplain, which should not be a problem. The homes to the west of the nature preserve are at a higher elevation, and should be out of the regulatory floodplain. A floodplain analysis would need to be completed to confirm that only the nature preserve will be affected. Figure 3-6 shows the Chesterfield Drain recommended improvement.

3.4 Potential Exception to FEMA Freeboard Criteria

As stated previously, FEMA standard levee criteria indicates that a levee must have at least 3 feet of freeboard with an additional foot of freeboard 100 feet upstream and downstream of each structure to meet certification criteria. FEMA regulations allow exceptions to the minimum riverine freeboard requirement. If “appropriate engineering analyses demonstrating adequate protection with a lesser freeboard” (FEMA CFR 65.10) is submitted with a request for an exception to the minimum freeboard requirement, then the minimum freeboard requirement can be reduced to 2 feet. Some of the required engineering analyses need to include an assessment of statistical confidence limits of the 100-year discharge; source, potential and magnitude of debris, sediment and ice accumulation; etc.

It is recommended that an exception to the standard levee criteria for the Surplus Canal Levees be requested from FEMA. The Jordan River and Surplus Canal are highly regulated rivers. Part of the Utah Lake Compromise agreement specifies that if discharge in the Jordan River at 2100 South exceeds 3,400 cfs then the flow from Utah Lake into the Jordan River may be regulated such that the combined flow at 2100 South does not exceed 3,400 cfs. Sediment has not significantly accumulated on the bottom of the Surplus Canal due to the diligence of the maintenance crew responsible for the Surplus Canal. Other engineering analysis would also be completed that would justify to FEMA an exception to the levee criteria.

If the freeboard exception is obtained from FEMA, the levees along the Surplus Canal would need 1 foot less freeboard for the study area; the recommended improvement would be to raise the levees to 2.5 feet above the 100-year water surface along the Surplus Canal. This would represent a significant cost savings to the County during construction of the new levees.

3.5 Consider Revising Jordan River Hydrology

It may be possible to utilize the Utah Lake Compromise Agreement to revise the FEMA flood hydrology associated with the Surplus Canal. The Utah Lake Compromise Agreement states that if the flow rate in the Jordan River at 2100 South exceeds 3,400 cfs, the gates at the Utah Lake Outlet can be regulated in an effort to keep the peak discharge at 2100 South to 3,400 cfs. The 100-year discharge rate of 4,500 cfs was estimated without consideration of the Utah Lake Compromise Agreement. If the regulating feature of the Comprise Agreement is considered in a hydrologic analysis, then it may be possible to request that FEMA reduce magnitude of the base flood downstream of the Mill Creek confluence with the Jordan River. Reducing the magnitude of the base flood could have significant impacts to improvements needed to mitigate problems associated with levee and bridge freeboard issues and the associated shallow floodplains located near those deficient areas. The option of revising the Jordan River hydrology downstream of the
Mill Creek confluence could be considered if Salt Lake County personnel feel confident in the monitoring of Surplus Canal discharges, uncertainty in the timing and peak inflows from Little Cottonwood Creek, Big Cottonwood Creek, and Mill Creek as well as issues associated with potential sediment deposition.

4.1 Raise Levees

Existing canal levees need to be raised to meet minimum freeboard criteria required by FEMA regulations (CFR 65.10) based on existing FEMA flood hydrology.

4.2 Existing Canal Bank Stability

Minimum FS are not met for existing canal banks under steady state flood seepage conditions using the existing FEMA flood hydrology. Areas not meeting minimum FS criteria are primarily located along the west canal bank and associated with over-steepening of canal side slopes from maintenance dredging. In some areas, the bank stability has the potential to impact the stability and FS associated with the levees.

4.3 Proposed Levee Stability

Proposed levee modifications which include raising embankment up to 4 feet in height with canal side slopes and embankment slopes graded to match initial design criteria (i.e. 2H:1V canal side and 3H:1V landward side slopes) meet USACE minimum stability standards for:

a. Steady State Seepage Full Flood Stage (Long Term) Stability
b. Sudden Drawdown Stability
c. End of Construction Stability
d. Earthquake Stability

4.4 Proposed Canal Banks

Stability analyses suggest that reaches of existing canal banks with side slopes steeper than 2H:1V (the original design side slope) adjacent to the canal levees should be cut back to match the original design side slope to meet canal side minimum stability requirements for the levees; specifically under sudden draw down conditions. In general, critical slip / slope surfaces for the sudden draw down conditions do not intersect the levee geometries but rather the over steepened portions of the canal banks. There is the potential that canal levee stability requirements could be met without regrading the canal banks to match 2H:1V. The stability analyses did not address leaving the over-steepened canal side slopes “as-is”; however, such analyses can be performed if the County wishes to evaluating the impacts of not stabilizing the canal banks to determine if that could impact future levee stability. Preliminary analysis of the “do nothing” option suggests there is a potential to meet stability requirements while leaving canal side slope geometry “as-is”.

However, engineering judgment suggests that the over steepened canal banks should be stabilized to reduce potential problems associated with instability and erosion.
4.5 Settlement

Settlement analyses show that a target fill height of 3.5 feet of freeboard will meet the 3 foot minimum freeboard requirement following estimated primary and secondary settlement for fill heights up to 4 feet.

4.6 Possible Additional Analysis

Areas where the levees are raised in excess of 4 feet or where ROW or other geometric constraints precluded target levee design slopes (i.e. 2H:1V canal side and 3H:1V landward side slopes) will require additional analysis and/or site specific sampling and testing.

4.7 FEMA and USACE Certification

If the recommendations summarized about and identified in the Geotechnical Data Report are incorporated into future levee improvement projects, it is believed that the levees will meet FEMA and USACE certification requirements with respect to levee stability, steady-state seepage, and settlement.

4.8 Modify Canal Bank

It is recommended that the side slopes of the canal banks steeper than 2H:1V should be cut back to match the original design side slope of 2H:1V to stabilize the banks and protect the levees. A typical cross section showing the stabilized canal slope and raised levees is shown in Figure 3-5. The HEC-RAS cross sections in Appendix D also show the existing side slopes and the proposed side slope of 2:1.

COST ESTIMATE

For cost estimating purposes, the Surplus Canal was divided into four sections, as shown on Figure 5-1. A conceptual construction cost estimate of the recommended Surplus Canal levee improvements for each section is presented in Tables 5-1 through 5-10. Tables 5-1 through 5-5 summarize the cost estimates for the recommended improvements to raise the levees to 3.5 feet of freeboard.

Table 5-1
Cost Estimate - Section 1 (Mill Creek to SR-201)
Scenario - Raise Levees to Provide 3.5 Feet of Freeboard

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Units</th>
<th>Unit Cost</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
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<td>Stabilize Canal Banks</td>
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<td>$15</td>
<td>$177,861</td>
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<tr>
<td>Floodwall</td>
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<td>LF</td>
<td>$150</td>
<td>$360,000</td>
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<tr>
<td>Estimated Contingency</td>
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<td>LS</td>
<td>30%</td>
<td>$217,490</td>
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<tr>
<td>Total:</td>
<td></td>
<td></td>
<td></td>
<td><strong>$940,000</strong></td>
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</tbody>
</table>
Table 5-2
Cost Estimate - Section 2 (SR-201 to I-215)
Scenario - Raise Levees to Provide 3.5 Feet of Freeboard

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Units</th>
<th>Unit Cost</th>
<th>Cost</th>
</tr>
</thead>
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<td>Seeding</td>
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<td>Stabilize Canal Banks</td>
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Table 5-3
Cost Estimate - Section 3 (I-215 to North Point Canal Diversion)
Scenario - Raise Levees to Provide 3.5 Feet of Freeboard

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Units</th>
<th>Unit Cost</th>
<th>Cost</th>
</tr>
</thead>
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<td>Seeding</td>
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<td>EA</td>
<td>$100,000</td>
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<tr>
<td>Stabilize Canal Banks</td>
<td>23,800</td>
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<td>$15</td>
<td>$364,419</td>
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Table 5-4
Cost Estimate - Section 4 (North Point Canal Diversion to Goggin Drain)
Scenario - Raise Levees to Provide 3.5 Feet of Freeboard

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Units</th>
<th>Unit Cost</th>
<th>Cost</th>
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</thead>
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<tr>
<td>Seeding</td>
<td>72,800</td>
<td>SF</td>
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<td>$36,400</td>
</tr>
<tr>
<td>Stabilize Canal Banks</td>
<td>42,000</td>
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<td>$15</td>
<td>$643,093</td>
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<tr>
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<td>LS</td>
<td>30%</td>
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<td>$1,720,000</td>
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### Table 5-5

**Cost Estimate – Summary of Each Section**  
**Scenario - Raise Levees to Provide 3.5 Feet of Freeboard**

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Units</th>
<th>Unit Cost</th>
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</tr>
</thead>
<tbody>
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Tables 5-6 through 5-10 summarize the cost estimates for the recommended improvements to raise the levees to 2.5 feet of freeboard.

### Table 5-6

**Cost Estimate - Section 1 (Mill Creek to SR-201)**  
**Scenario – Raise Levees to Provide 2.5 Feet of Freeboard**

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Units</th>
<th>Unit Cost</th>
<th>Cost</th>
</tr>
</thead>
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<tr>
<td>Seeding</td>
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<td>$33,557</td>
</tr>
<tr>
<td>Stabilize Canal Banks</td>
<td>11,616</td>
<td>LF</td>
<td>$15</td>
<td>$177,861</td>
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<td>Floodwall</td>
<td>2,400</td>
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<td>Estimated Contingency</td>
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### Table 5-7

**Cost Estimate - Section 2 (SR-201 to I-215)**  
**Scenario - Raise Levees to Provide 2.5 Feet of Freeboard**

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Units</th>
<th>Unit Cost</th>
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</tr>
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<td>Seeding</td>
<td>81,698</td>
<td>SF</td>
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<td>Railroad Bridge Modification</td>
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<td>EA</td>
<td>$100,000</td>
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</tr>
<tr>
<td>Stabilize Canal Banks</td>
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<td>$216,508</td>
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<tr>
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<td>LS</td>
<td>30%</td>
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### Table 5-8
Cost Estimate - Section 3 (I-215 to North Point Canal Diversion)
Scenario - Raise Levees to Provide 2.5 Feet of Freeboard

<table>
<thead>
<tr>
<th>Item</th>
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<th>Cost</th>
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</thead>
<tbody>
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<td>$100,000</td>
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<td>$15</td>
<td>$364,419</td>
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### Table 5-9
Cost Estimate – Section 4 (North Point Canal Diversion to Goggin Drain)
Scenario - Raise Levees to Provide 2.5 Feet of Freeboard

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Units</th>
<th>Unit Cost</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
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<tr>
<td>Seeding</td>
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<td>$36,400</td>
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<td>Stabilize Canal Banks</td>
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<td>LF</td>
<td>$15</td>
<td>$643,093</td>
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<td>LS</td>
<td>30%</td>
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### Table 5-10
Cost Estimate – Summary of Each Section
Scenario - Raise Levees to Provide 2.5 Feet of Freeboard

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Units</th>
<th>Unit Cost</th>
<th>Cost</th>
</tr>
</thead>
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<td>$820,000</td>
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<td>Section 2</td>
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<td>LS</td>
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<td></td>
<td></td>
<td><strong>$4,330,000</strong></td>
</tr>
</tbody>
</table>