Final Report

SALT LAKE COUNTY DEPARTMENT OF PUBLIC WORKS
Flood Control & Engineering Division

Copper Creek Drainage Master Plan

Contract # PP13110C

DECEMBER 2014

Prepared for:

SALT LAKE COUNTY

Prepared by:

CH2MHILL

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Electronic PDF copy of the final report and native HEC-HMS Model files

1.0 Acknowledgements

CH2M HILL recognizes and appreciates the cooperation and assistance provided by the Salt Lake County Department of Public Works, Engineering and Flood Control, and in particular, Kade Moncur and Brent Beardall. On behalf of Salt Lake County, CH2M HILL also expresses thanks to staff from Kennecott Land for their cooperation with site visits.

2.0 Introduction and Background

The Copper Creek drainage basin is located generally on unincorporated Salt Lake County land, west of Herriman City, and between Midas and Butterfield Creeks. Unspecified flooding problems have occurred in the general area during the past 10 years. The drainage basin associated with Copper Creek drain toward populated and developing areas of Herriman City. Most of the land in the drainage basin is currently agricultural, with some mining operations and undeveloped Kennecott property as well. Residential development in the basin is a strong possibility in the future. The channel associated with Copper Creek is well defined in the western portions of the drainage basin, but essentially disappears toward the eastern end of the catchment. The Engineering and Flood Control division of Salt Lake County has been proactive in planning for the various rivers, streams, creeks, and canals in their jurisdiction. Although previous larger-scale studies have been completed for the southwest quadrant of Salt Lake County, some watercourses require additional assessment in the form of an individual master plan. Salt Lake County retained CH2M HILL to assist them with such a master plan for the Copper Creek drainage.

3.0 Project Purpose and Objectives

In support of Salt Lake County's responsibilities with Copper Creek, the goals of this study are to:

- Obtain and review existing information regarding existing and future land use and zoning.
- Perform field analysis in support of the hydrologic assessment via site visits.
- Using a Hydrologic Engineering Center–Hydrologic Modeling System (HEC-HMS) model, generate storm hydrographs and peak discharges by completing a refined and more refined hydrology study of the Copper Creek drainage basin than what was provided with the 2002 Southwest Canal and Creek Study (SWCCS). The model and study area terminates at 6000 West, also known as Mustang Trail Way.
- In consultation with County staff, and in consideration of future development trends, determine logical alternatives for the conveyance of Copper Creek flows, which may include the reestablishment of the historical channel path, providing detention capacity, or other channel or pipe conveyance options.
- Provide preliminary hydraulic calculations to support a preliminary design and the construction plans to be developed later by others.
- Provide a preliminary cost estimate for the selected alternative.

4.0 Previous Studies and Works

The following previous works were reviewed as part of this assessment:

- 2002 Southwest Canal and Creek Study (SWCCS)
- 2004 Butterfield Creek to Midas Creek Connection and Channel Improvements, Project # FV 01-0325
- Kennecott Utah Copper (KUC) Park at Lark Drainage design and construction drawings
- Land planning and zoning data provided by Herriman City and Salt Lake County via Master Plans and General Plans, which among other items included Herriman City's 2020 Land Use Plan and the 2008 Salt Lake County Southwest Community Plan.

Other sources of data used in the preparation of this study included:

- Site visits and field work
- Reviews of Geographic Information System (GIS) data provided by the Utah Automated Geographic Reference Center (AGRC) and other sources
- Historical aerial photographs, dating back to 1977, which were provided by Salt Lake County and Google Earth.

5.0 Existing Site Conditions

As shown on Exhibit 1, the study portion of the Copper Creek drainage basin spans from KUC and U-111 to the west and terminates at an existing inlet structure located at 6000 West and Herriman Parkway (an extension of 12600 South), which is near a residential neighborhood and the Herriman City Cemetery. No County or City storm drain systems exist in the Copper Creek drainage between Highway U-111 and 6000 West. An overhead power corridor crosses north/south at Herriman City (about 6400 West). Remnants of a small historical detention or debris basin can be found adjacent to the power corridor and are visible on some historical aerial photographs, USGS topographic quadrangle maps, and in contour datasets.

Copper Creek can be found on the Lark Quadrangle (Salt Lake County #15), generally drains from west to east, and is bounded on the north and south between the Midas Creek and Butterfield Creek basins, respectively (see Exhibit 1). The headwaters found west of U-111 are on private land owned and operated by KUC. Due to KUC cutoff walls, retention ponds, canals, and ditches, the drainage area west of U-111 is limited. A dirt access road used by Kennecott Land as a haul road connecting to the Daybreak development forms much of the northern boundary of the catchment.

Land in the drainage basin is primarily used for agricultural purposes using contoured row crops, with minor portions used as residential, dirt roads, KUC mining property, or some natural undisturbed areas. Most of the land in the Copper Creek drainage is believed to be privately owned or used by farmers and Kennecott Land. As shown on Exhibit 2, Salt Lake County has reported that a portion of land located east of the power corridor within Herriman City boundaries is being reserved for a future junior high school.

A Federal Emergency Management Agency (FEMA) floodplain (Zone A) exists along the eastern portions of Copper Creek in the study area and is shown in Exhibit 1. This Special Flood Hazard Area denotes the *approximate* existing limits of flooding for the 100-year flood (1 percent chance flood) and may warrant modification as additional improvements are made to the creek.

Copper Creek is an intermittent wash without base flows. Portions of Copper Creek have a defined channel with a top width of approximately 55 feet, a side slope of slightly steeper than 3H:1V, a depth of up to approximately 10 feet, and a longitudinal slope exceeding 2.5 percent in some locations. The channel and surrounding land becomes flatter as the creek progresses downstream, with the defined creek entirely disappearing east of about 7000 West. It is possible that KUC operations have cut off drainage area that historically flowed to Copper Creek, and with diminished flows, sedimentation or farming has caused the creek to lose its definition in this area.

Two culverts drain Copper Creek and its north fork beneath U-111. Copper Creek itself drains through a concrete/HDPE pipe and the north fork drains via a 48-inch corrugated metal pipe (CMP).

A Salt Lake County drainage inlet structure was completed along Copper Creek at 6000 West near the Herriman City Cemetery, as noted in Exhibit 1 and Exhibit 2. This inlet structure is part of other improvements recommended in Table 6-10 of the 2002 SWCCS and detailed out in the Salt Lake County construction drawings for the pipe and channel improvements from Butterfield Creek to Midas Creek (Project # FV 01-0325). These plans show a 66-inch Reinforced Concrete Pipe (RCP) with a design capacity of 425 cubic feet per second (cfs). With 200 cfs coming from Butterfield Creek itself (per SWCCS project MC-1 from Figure 8-6A of the 2002 SWCCS), an allotment of 225 cfs is left for the Copper Creek discharges.

Site photographs taken in October 2013 can be found in Appendix A.

6.0 Approach and Methodology

6.1 Basin Delineation

The total drainage area for Copper Creek and tributary to its terminus at 6000 West is 1,119 acres (1.75 square miles), with individual sub-basin areas listed in Table 6-2 and Table 6-3. As shown on Exhibit 1, existing concentration points and their associated sub-basins were selected at key roadway crossings, channel confluences, and other borders such as the Herriman City limits. The watershed terminus for this study is at 6000 West. Basin delineations for the existing condition were based on 2-foot contours generated from AGRC 1.25-meter Digital Elevation Models (DEM) developed using Light Detection and Ranging (LIDAR) technology, field visits, and aerial photography. Field visits included time spent on KUC property, which took into account cutoff walls, canals, ditches, retention ponds, and development that has occurred since the 2002 SWCCS. Basin boundaries were validated with the automated delineations provided by the National Stream Stats (NSS) program. It is noted that limited drainage area comes from KUC mine property west of U-111. Spatially, the overall catchment for this study was roughly equivalent to Basins 187, 188, and 191 in the 2002 SWCCS (these aforementioned three basins encompassed a total of 1,126 acres, as compared to the total 1,119 acres used for this study).

KUC recently constructed the “Park at Lark” employee parking lot west of U-111. A pond receiving discharge from the parking lot was shown on the County-approved drainage plans to infiltrate or retain the full runoff from the 100-year 24-hour design event. A smaller KUC detention pond adjacent to U-111, which receives a relatively small catchment area, has a substantial permanent pool volume. Due to these two ponds and their design capacity, this area was not included in the Copper Creek basin area.

6.2 Precipitation

Per the Scope of Work and at the request of the County, multiple rainfall events of various return periods, durations, depths, and distributions were assessed for this study, and are listed in Table 6-1. The 100-year 3-hour event was originally included for purpose of comparison with SWCCS results, but since became the basis for channel design in this study.

For consistency with the 2002 SWCCS, total storm depths were taken from the SWCCS Valley South area, Salt Lake County’s TRC map data, or by using a centroidal point precipitation value from NOAA Atlas 14 if necessary.

The 100-year Modified Farmer-Fletcher (MFF) temporal distributions used in the 2002 SWCCS HEC-HMS model were also used for this analysis. The MFF distribution inserts a one-hour first-quartile event after the first 30 minutes of the overall 3-hour storm event, with the remaining time periods using a steady precipitation rate (intensity).

Due to the more macroscopic nature of the 2002 Southwest Canal and Creek Study, some Depth-Area-Reduction (DAR) factors had been used based on literature found in the 1983 Salt Lake City Hydrology Manual, which used a 30 percent reduction in aerial rainfall due to the size of the Midas Creek watershed. However, per the limited acreage being analyzed for this study, no Depth-Area-Reduction factors were applied.

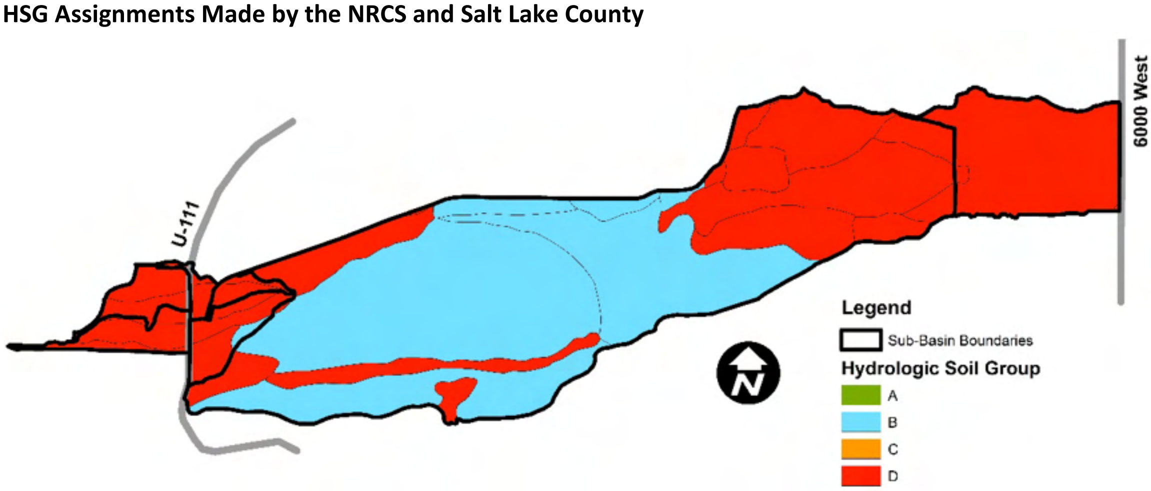
TABLE 6-1
Design Storm Events Assessed in this Study

Return Period (years)	Duration (hours)	Temporal Distribution	Total Rainfall Depth (inches)	Total Rainfall Source
100	24	SCS Type II	2.60	Salt Lake County TRC Report
100	3	MFF per 2002 SWCCS	1.77	2002 SWCCS
50	24	SCS Type II	2.39	NOAA Atlas 14
10	6	MFF per 2002 SWCCS	1.37	Salt Lake County TRC Report
10	3	MFF per 2002 SWCCS	1.20	2002 SWCCS
2	6	MFF per 2002 SWCCS	0.88	Salt Lake County TRC Report
2	3	MFF per 2002 SWCCS	0.71	NOAA Atlas 14

6.3 Hydrologic Soil Type

As it relates to surface runoff, NRCS soil survey data was reviewed using several data sources and formats. These sources included the original 1974 SCS soil survey, TR-55 publications, the online NRCS Web Soil Survey (WSS), and the detailed GIS SSURGO dataset. The majority of the basin is classified by the NRCS as Hydrologic Soil Group (HSG) B or D. It is noted that the more general STATSGO data appears to have been used for the 2002 Southwest Canal and Creek Study, which characterized most of this area as HSG B and some as HSG C. Upon a review of all soils data and in consultation with Salt Lake County Flood Control staff, the soil map unit corresponding with the sloping Dry Creek-Copperton association (DPD) was changed from HSG D, as currently assigned by the NRCS, to HSG B. This change resulted in decreased curve numbers and peak discharges that were viewed by the County to better reflect actual runoff conditions in this area. The HSG assignments used for this study are shown in Figure 6-1.

FIGURE 6-1
HSG Assignments Made by the NRCS and Salt Lake County



6.4 Land Use and Land Cover

As it relates to surface runoff, recent aerial photography and other data sources were inspected and reviewed to determine current land use and land cover. These are shown graphically in Figures 6-2, 6-3, and 6-4. The assessment of land cover in the Copper Creek drainage tributary to 6000 West is summarized as follows:

- **Cultivated/agricultural land.** Land use in the overall watershed is predominantly agricultural. Row crops are contoured, but do not appear to be generally fallow (a fallow classification would have resulted in higher curve numbers and it was felt by the County that this may over-estimate runoff rates). Remotely sensed datasets from 2001 and GAP USGS studies describe these areas as pasture/hay, cultivated crops, herbaceous agricultural vegetation, and some smaller portions as grassland/herbaceous. For the purposes of assigning individual curve numbers, these lands were matched up to an average of the TR-55 land uses of (1) cultivated agricultural lands using contoured row crops with good crop residue, and (2) agricultural lands being used as pasture, grasslands, or range in good condition.
- **Undeveloped areas.** Some lesser portions of the overall watershed can be described as undeveloped or undisturbed natural land. Remotely sensed datasets from 2001 and GAP USGS studies describe these areas as shrub/scrub. KUC owns some western portions of the Copper Creek drainage basin, which include some paved and natural undisturbed areas. All of these undeveloped areas were matched to the TR-55 category for herbaceous arid/semi-arid rangeland with a mixture of grasses, weeds, and low-growing brush in a “good” vegetative condition.
- **Roadways.** The Copper Creek drainage basin includes a few graded dirt roads and some paved surfaces. These were matched to the TR-55 land cover categories for dirt roads and paved roads, respectively.
- **Residential areas.** A residential area is located inside the Herriman City boundary, and was matched to a TR-55 land use consistent with urban residential districts with half-acre lots (25 percent impervious assumed per TR-55).

FIGURE 6-2
USGS GAP Land Cover and Land Use Study Descriptors Overlaid with the Existing Sub-basins

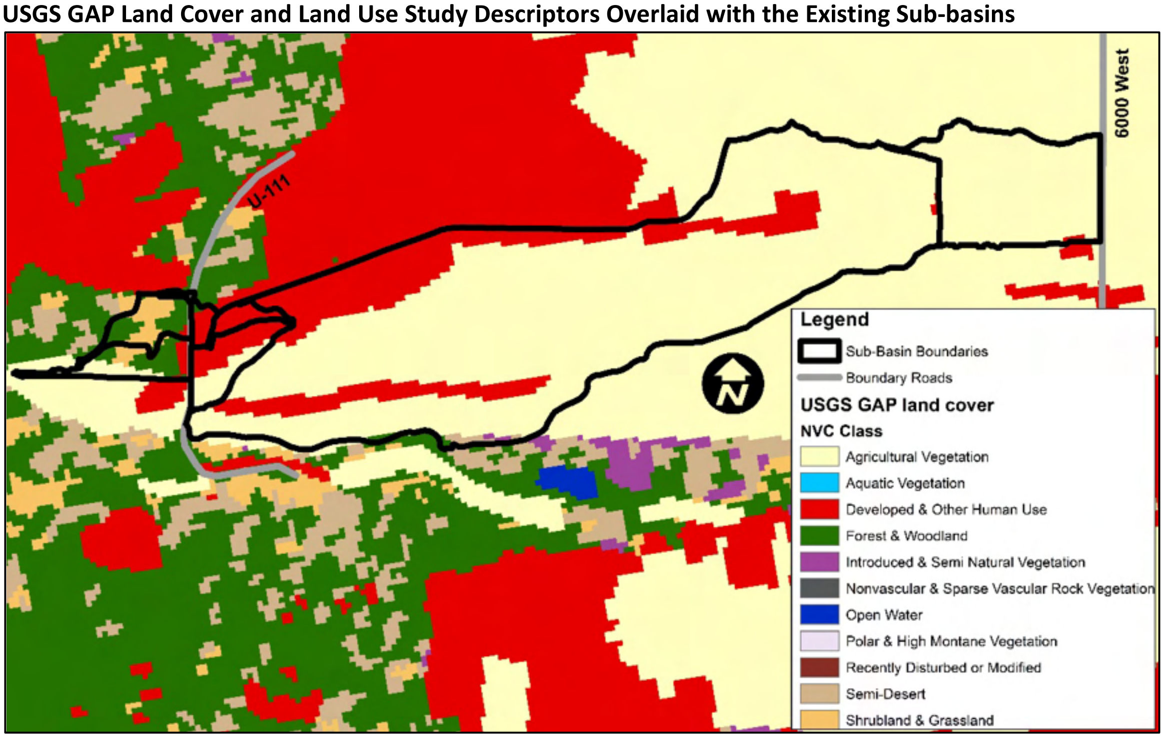


FIGURE 6-3
USGS Land Cover and Land Use Study Descriptors Overlaid with the Existing Sub-basins

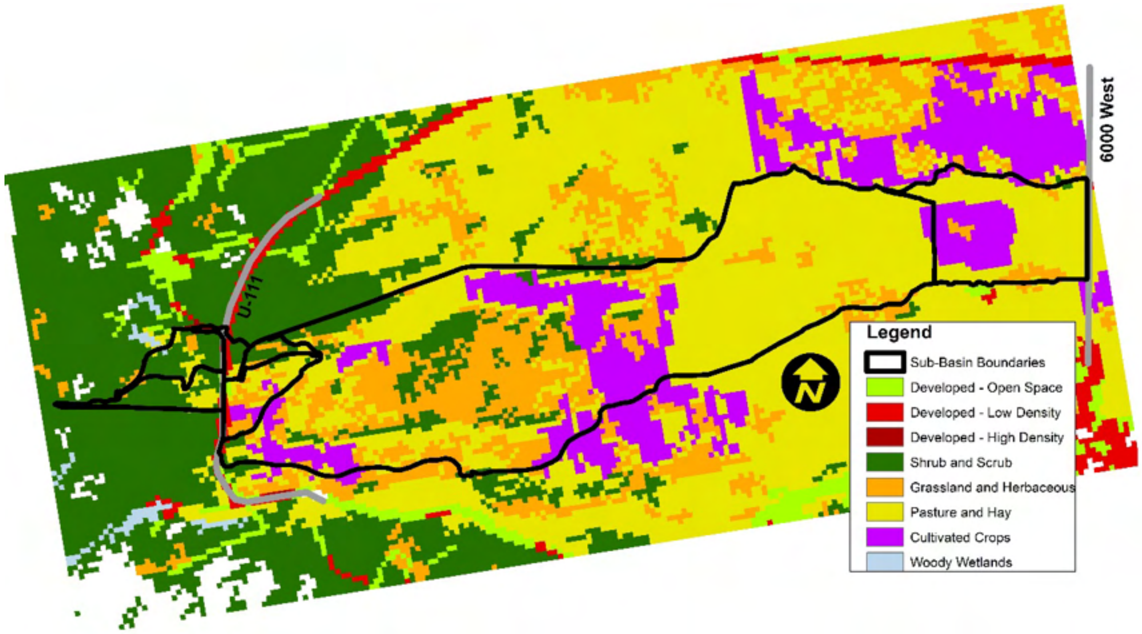


FIGURE 6-4
Final Existing-condition Land Cover and Land Use Assignments Based on USGS Data, Aerial Photography, and Field Work, Overlaid with the Existing Sub-basins

To better understand future land use conditions, Herriman City's 2020 Land Use Plan and Salt Lake County's 2008 Southwest Community Plan were reviewed. Furthermore, both Salt Lake County and Herriman City provided future land use planning and zoning GIS data that appears to match each other in most cases, and is shown in Figure 6-5 and Figure 6-6. From Figure 6-5, it can be seen that the overall Copper Creek drainage area is zoned for agricultural/residential use in the eastern portion found in Herriman City and a north/south split of heavy industrial and agricultural in the remaining western portions. From Figure 6-6, the watershed is listed for low or medium-density residential, with Kennecott mining land remaining as-is and with limited open space at the eastern edge in Herriman City. It is believed that much of the land in the Copper Creek drainage will be developed by Kennecott Land in the future. Land use maps provided by Salt Lake County or Herriman City can be found in Appendix C.

FIGURE 6-5
Salt Lake County and Herriman City Zoning Units

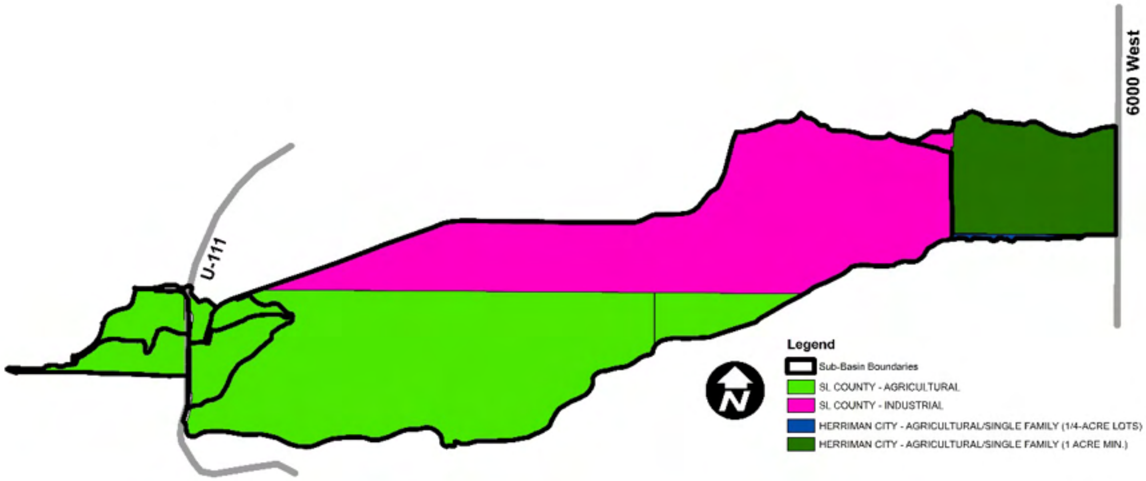


FIGURE 6-6
Salt Lake County and Herriman City Future Land Use

Based on conversations with County Flood Control staff as well as Greg Baptist with the County Planning and Development Services Division, future development within the Copper Creek drainage basin will be required to limit allowable peak stormwater discharges to 0.2 cfs-acre for the 100-year 24-hour storm event (which is intended to mimic predeveloped conditions). However, full development and build out of the Copper Creek watershed is not necessarily expected for some time. Due to developer requirements to maintain existing discharge rates through development, the runoff rates associated with the proposed condition and the associated channel improvements assumed as such.

6.5 Infiltration and Abstractions

To be consistent with the 2002 SWCCS, the SCS curve number method was used in this study to determine losses to rainfall. Based on the previously-discussed land use/cover, soils data, and individual curve number assignments from TR-55, final composite curve number values are listed in Table 6-2 and Table 6-3 for existing and proposed conditions, respectively.

TABLE 6-2
Composite Curve Numbers and Basin Areas for each Existing Copper Creek Sub-basin

Basin ID	Basin Name	Basin Area		CCN
		Square Miles	Acres	
1	Upper Copper Creek North Fork—KUC	0.041	26.2	86
2	Upper Copper Creek—KUC	0.047	29.9	86
3	Upper Copper Creek North Fork—West	0.013	8.3	87
4	Upper Copper Creek North Fork—East	0.016	10.3	84
5	Upper Copper Creek	0.051	32.5	83
6	Middle Copper Creek	1.363	872.5	74
7	Lower Copper Creek	0.218	139.7	83
		1.749	1,119.4	

TABLE 6-3
Composite Curve Numbers and Basin Areas for each Proposed Copper Creek Sub-basin

Basin ID	Basin Name	Basin Area		CCN
		Square Miles	Acres	
1	Upper Copper Creek North Fork—KUC	0.041	26.2	86
2	Upper Copper Creek—KUC	0.047	29.9	86
3	Upper Copper Creek North Fork—West	0.013	8.3	87
4	Upper Copper Creek North Fork—East	0.016	10.3	84
5	Upper Copper Creek	0.051	32.5	83
6A	Middle Copper Creek A	0.509	325.8	70
6B	Middle Copper Creek B	0.529	338.6	72
6C	Middle Copper Creek C	0.161	103.2	82
6D	Middle Copper Creek D	0.164	105.0	83
7	Lower Copper Creek	0.218	139.7	83
		1.749	1,119.4	

6.6 Travel Time and Routing

Travel time calculations were made using the standard TR-55 approach for time of concentration, and then by converting to lag times using a factor of 0.6. Detailed calculations for each existing and proposed sub-basin can be found in Appendix B. To be consistent with the 2002 SWCCS, the Muskingham-Cunge method of stream routing using stream length, slope, roughness (Manning’s n), and side slope, was used to route hydrographs from one design point to the next.

6.7 Other Analysis Assumptions

Assumptions made for this analysis included the following:

- Runoff return period is equal to the rainfall return period.
- Design storm rainfall is spatially uniform across the entire watershed.
- Average soil moisture conditions (Antecedent Runoff Condition II) was assumed to exist before the beginning of the modeled rainfall events, with an initial abstraction equal to 0.2 of the storage at saturation.

7.0 Hydrologic Modeling Results

HEC-HMS v3.4 was used to model the precipitation-runoff response of the existing and proposed Copper Creek watershed. Native electronic model files, along with a graphical topologic tree matching Exhibit 1 and Exhibit 2, can be found on the accompanying CD. Estimated peak discharges resulting from the HEC-HMS hydrographs for existing at various locations within the drainage basin are listed in Table 7-1. Proposed condition flows are shown in Table 7-2 and Table 9-1.

TABLE 7-1
Peak Discharges for Existing Conditions from the HEC-HMS Model

	Existing Condition Peak Discharges													
	100-yr 3-hr MFF		100-yr 24-hr SCS Type II		50-yr 24-hr SCS Type II		10-yr 6-hr MFF		10-yr 3-hr MFF		2-yr 6-hr MFF		2-yr 3-hr MFF	
Location	cfs	cfs/ acre	cfs	cfs/ acre	cfs	cfs/ acre	cfs	cfs/ acre	cfs	cfs/ acre	cfs	cfs/ acre	cfs	cfs/ acre
U-111 culvert (Copper Creek North Fork)	30	1.16	49	1.87	43	1.63	11	0.43	12	0.44	3	0.11	2	0.08
U-111 culvert (Copper Creek)	43	1.45	63	2.12	55	1.84	15	0.49	17	0.56	4	0.13	3	0.09
Kennecott Land Access/ Haul Road	38	1.11	64	1.85	56	1.61	15	0.42	15	0.43	4	0.10	3	0.08
Copper Creek Confluence	112	1.04	192	1.79	166	1.55	39	0.36	41	0.39	9	0.09	7	0.06
Power Corridor/Herriman City boundary	221	0.23	457	0.47	375	0.38	66	0.07	63	0.06	8	0.01	7	0.01
6000 West	272	0.24	541	0.48	445	0.40	85	0.08	77	0.07	11	0.01	8	0.01

TABLE 7-2
Peak Discharges for Proposed Conditions from the HEC-HMS Model

	Proposed Condition Peak Discharges													
	100-yr 3-hr MFF		100-yr 24-hr SCS Type II		50-yr 24-hr SCS Type II		10-yr 6-hr MFF		10-yr 3-hr MFF		2-yr 6-hr MFF		2-yr 3-hr MFF	
Location	cfs	cfs/ acre	cfs	cfs/ acre	cfs	cfs/ acre	cfs	cfs/ acre	cfs	cfs/ acre	cfs	cfs/ acre	cfs	cfs/ acre
Power Corridor/Herriman City boundary	50	0.48	86	0.82	73	0.70	18	0.17	18	0.17	4	0.04	2	0.02
6000 West	105	0.43	176	0.72	149	0.61	39	0.16	38	0.16	9	0.04	5	0.02

As expected, the SCS Type II distributions produce the higher-highest peak discharges than the MFF distributions due to the higher excessively intense rainfall intensity. That is expected during the middle few hours of the overall day-long storm. Although the hydrologic calculations developed in this assessment are more detailed than those developed for Midas Creek in the 2002 SWCCS, a comparison was made using storms common to both analyses for the purpose of awareness of any differences and the magnitude of such (see Table 7-3). It is noted that the peak discharge per unit area from this study is about 0.07 and 0.24 cfs/acre for the 10- and 100-year events, respectively. This is compared to 0.01 and 0.04 cfs/acre from the 2002 SWCCS for the identical 10- and 100-year events, respectively. This difference may be partially explained by the fact that the overall area-weighted CCN for this study was 76, compared to 65 in the SWCCS. It should be noted, that one of the 265-acre Copper Creek sub-basins in the 2002 SWCCS HEC-HMS model produced a relatively low total peak discharge of 0.3 cfs (0.001 cfs/acre) for the 10-year 3-hour event.

TABLE 7-3
Comparison of Existing Peak Discharges at 6000 West between this Study and the 2002 SWCCS

Study	Total Basin Acreage	10-year 3-hour		100-year 3-hour		Average Area weighted CCN
		cfs	cfs/acre	cfs	cfs/acre	
2002 SWCCS (peak discharge sum for basins 187, 188, and 191)	1,126	6.3	0.01	50	0.04	65
Copper Creek Drainage Master Plan	1,119	77	0.07	272	0.24	76

8.0 Proposed Recommendations

Alternative options discussed with the County included stream restoration only, detention, and piping options. Although each option was considered, discussions with Salt Lake County, which included a review of discharge rates and the capacity of the existing storm drain inlet at 6000 West, resulted in the decision to divert the upstream portion of the Copper Creek drainage basin to Midas Creek. As described below, this would involve three different types of channel improvements.

- **Restore Main Copper Creek Channel.** As shown in Exhibit 2, the main incised channel of Copper Creek begins to disappear around Station 105+00. At this point, grading is proposed to transition from the existing channel to a new channel (proposed Channels A and C, totaling approximately 2,400 feet). The horizontal alignment and pathway of this new channel was selected by considering topography, property lines, and data showing the historical alignment of the previous Copper Creek channel. As shown in Exhibit 2, the existing channel and ground in this area is relatively steep as it exceeds 3 percent longitudinal slope in some areas.
- **Interception Channel.** As shown in Exhibit 2, the topography of the Copper Creek basin upstream of the school property is somewhat flat and does not include a discernable water course. As such, a relatively large fraction of the Copper Creek watershed bypasses the historical drainage path of Copper Creek and drains via sheet flow toward the school property. An interception channel approximately 1,500 feet in length is proposed to capture most of this runoff and convey it to Copper Creek (as proposed Channel B). This interception channel still leaves a smaller portion of the watershed west of the school property line not being intercepted into the proposed channel, which would instead continue to flow east toward the school area. At such time when the school property is developed, these flows could be collected in another interception channel and conveyed via an underground pipe (along with runoff from the school property itself) toward the existing inlet structure at 6000 West.
- **Diversion Channel.** As shown in Exhibit 2, a 900-foot diversion channel is proposed to convey the aforementioned portions of the Copper Creek watershed north toward Midas Creek (proposed Channel D). The horizontal alignment and pathway of this diversion channel was selected by considering topography, property lines, and data showing the historical alignment of the previous channel. As this channel crosses a low-spot associated with a minor gully (near Station 130+00), suitable excavated channel material should be properly placed and compacted on the eastern edge of the channel to contain flows and provide the required freeboard.

  The 2002 SWCCS had already proposed the diversion of Copper Creek into Midas Creek, which has since been constructed via SWCCS project MC-1 and Salt Lake County Project # FV 01-0325. However, the currently proposed diversion location is further upstream than the completed diversion, which would result in additional flow in Midas Creek for about 2 miles.

  Approximately 872 acres of the Copper Creek drainage basin would produce an estimated 100-year 3-hour peak discharge of 194 cfs to Midas Creek, which drains about 7,248 acres at that location. Since the diverted areas from Copper Creek represents only about 12 percent of the total, the increases in discharge may be acceptable. During final design, a hydraulic analysis using software such as the Hydrologic Engineering Center– River Analysis System (HEC-RAS) should be developed to confirm that the additional discharges from Copper Creek will not cause an unacceptable downstream rise in water surface or increase in scour potential to Midas Creek or structures such as the bridge at 6000 West.

As development occurs in the future, roadway bridges or culverts would be used to span these proposed channels as is currently done on other County watercourses in the area (e.g., Midas Creek).

9.0 Design Criteria and Channel Geometry

For this level of analysis, the proposed channel design concepts described in this report were guided by the following design criteria as discussed with Salt Lake County. Associated calculations can be found in Appendix D and a summary of results in Table 9-1.

- Despite the fact that hydrographs and peak discharges were to be developed for a variety of storm events, the 100-year 3-hour storm event ultimately formed the basis of facility design.
- As shown on Exhibit 3, proposed channel cross-sections are trapezoidal with a 5-foot base width. Per County direction, side slopes would be no steeper than 2H:1V and the required freeboard for the design storm event is 1 foot.
- Uniform flow and normal depth calculations were used for this stage of preliminary design. Flow velocities were kept relatively consistent along the channel segments to help minimize excessive sediment deposition. The average velocity for the main channel segments with rip rap lining are between 4.15 and 4.27 ft/s. The completed stream segments will need to be monitored for periodic cleanout of sediment.
- In some locations, proposed and existing channel grades exceed 3 percent. Based on the peak discharges for the design storm, erosion and scour due to velocities would otherwise exceed 9 ft/s and be erosive without the armoring and roughness the rip rap can provide. The FHWA Hydraulic Toolbox v4.1 was used with the shear stress methods of HEC-15 to help size rip rap for stable channel design and produce Manning's roughness values (n) based on depth and stone size. Depending upon channel segment, a County Class I (D_{50} of 6 inches) or Class III (D_{50} of 12 inches) is recommended.

TABLE 9-1
Summary of Proposed Channel Improvement Hydrology and Hydraulics

Channel	Approximate Peak Discharge (cfs)	Slope (%)	Roughness (Manning's n)	Proposed Lining	Normal depth (ft)	Average Velocity (ft/s)	Froude #	Flow Regime
A	132	3.78	0.066	Loose rip rap, Class III (D_{50} = 12")	1.32	4.15	0.74	Subcritical
B	42	1.50	0.064	Loose rip rap, Class I (D_{50} = 6")	1.66	3.05	0.49	Subcritical
C	154	2.07	0.076	Loose rip rap, Class III (D_{50} = 12")	3.18	4.27	0.53	Subcritical
D	194	1.26	0.072	Loose rip rap, Class III (D_{50} = 12")	3.86	3.95	0.45	Subcritical

10.0 Cost Estimate

A preliminary cost estimate is provided in Table 10-1 to assist the County in project and budgetary planning. The cost data shown below does not include demolition of existing structures (if any), utility relocation (if any), permitting such as a preparation of a Stormwater Pollution Prevention Plan (SWPPP), a maintenance road (if desired), engineering design fees, dewatering due to groundwater (which is assumed to be deep), ROW/easements, land acquisition costs, construction staking, shrink/swell factors, or dust control. Also, most if not all of the excavated channel material may be able to be placed on the east edge of the north/south portions channel segments. This would save hauling and disposal costs. If not feasible or desired, perhaps the haul distance could be minimal since so much of the drainage basin has yet to be developed.

This cost estimate includes many assumptions and should be considered as “Rough Order of Magnitude.” The estimate is based on approximate quantities and unit prices currently available at the time they were prepared. Although unit prices were reviewed with the County, actual prices and quantities may vary substantially due to a number of circumstances including limited available data, field conditions, availability and cost of materials, methods, timing, weather, and inflation. No cost guarantee is expressed or implied.

TABLE 10-1
Cost Estimate for Copper Creek Channel Improvements

Item	Quantity	Unit	Unit Price	Cost
Mobilization (10%)	1	LS	$118,262	$115,015
Clearing/Grubbing	15.3	ACRE	$2,905	$44,447
Rip Rap	3,247	CY	$65	$211,055
Separation Geotextile	13,923	SY	$5	$69,615
Channel Excavation and Grading	27,705	CY	$15	$415,575
Over-excavation for Rip Rap	3,247	CY	$30	$97,410
Haul to Waste (short distance)	30,952	CY	$8	$247,616
Seeding	13.0	ACRE	$1,800	$23,472
Temporary Erosion Control (silt fence)	10,239	LF	$4	$40,956
Contingency (30%)	1	LS	$390,263	$379,548
			TOTAL	**$1,644,709**

11.0 Final Design

In addition to what is discussed in this report, detailed design efforts to follow by others should include consideration of the following elements:

- A review of property boundaries and consultation with property owners and other stakeholders should occur to help plan the final configuration of each new channel segment. Right-of-way (ROW) and easement requirements should be reviewed.
- Riprap sizing and channel design should be confirmed with final design profiles, hydraulic calculations, and model results.
- Potential utility conflicts should be identified and mitigated.
- Slope stability and geotechnical considerations should be addressed.
- Water quality and permitting requirements should be met.
- Changes to the FEMA floodplain mapping should be considered.

Exhibits

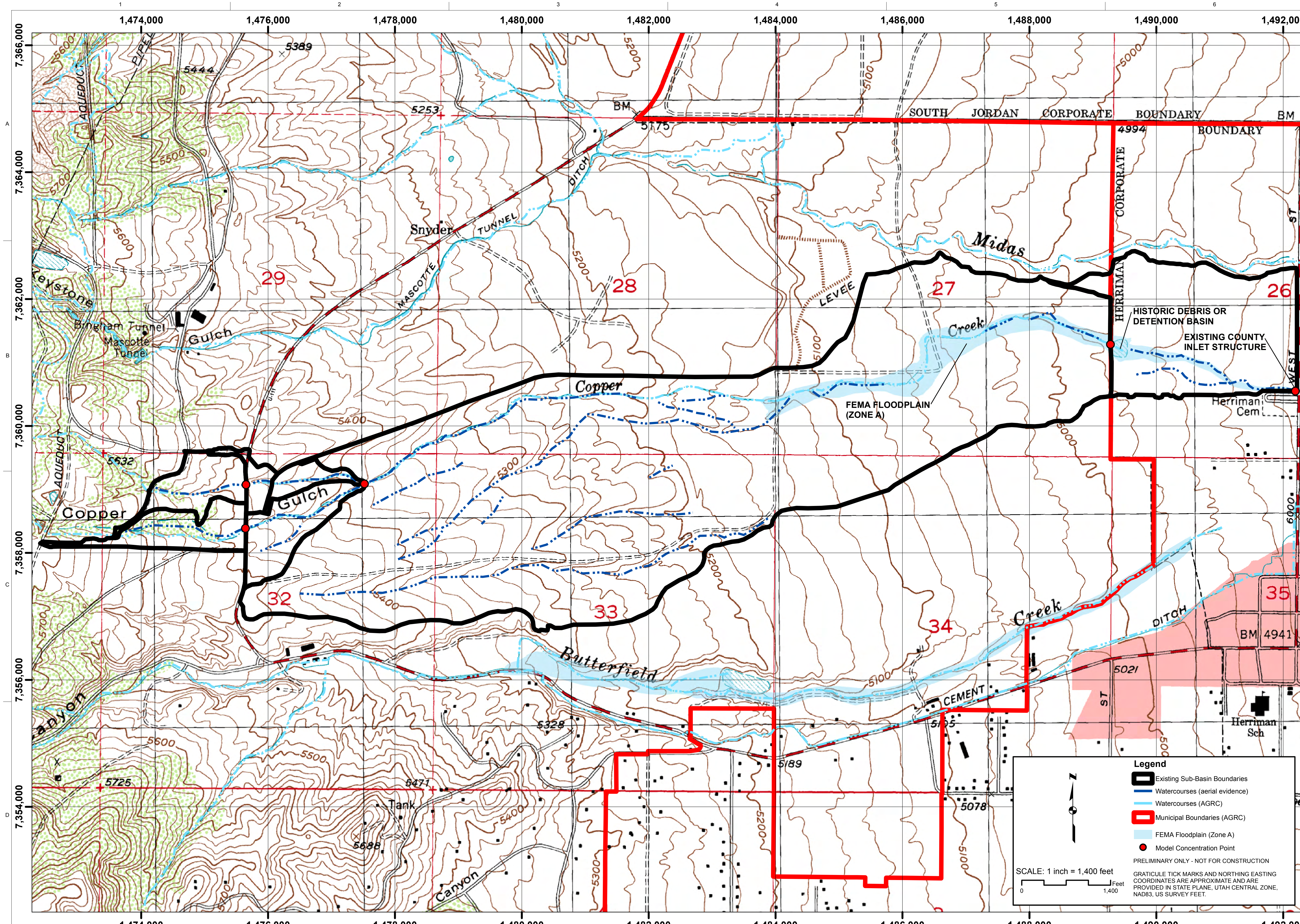


EXHIBIT 1
COPPER CREEK WATERSHED - EXISTING CONDITIONS

SALT LAKE COUNTY
DEPARTMENT OF PUBLIC WORKS
FLOOD CONTROL & ENGINEERING DIVISION
COPPER CREEK DRAINAGE MASTER PLAN

CH2MHILL

SALT LAKE COUNTY

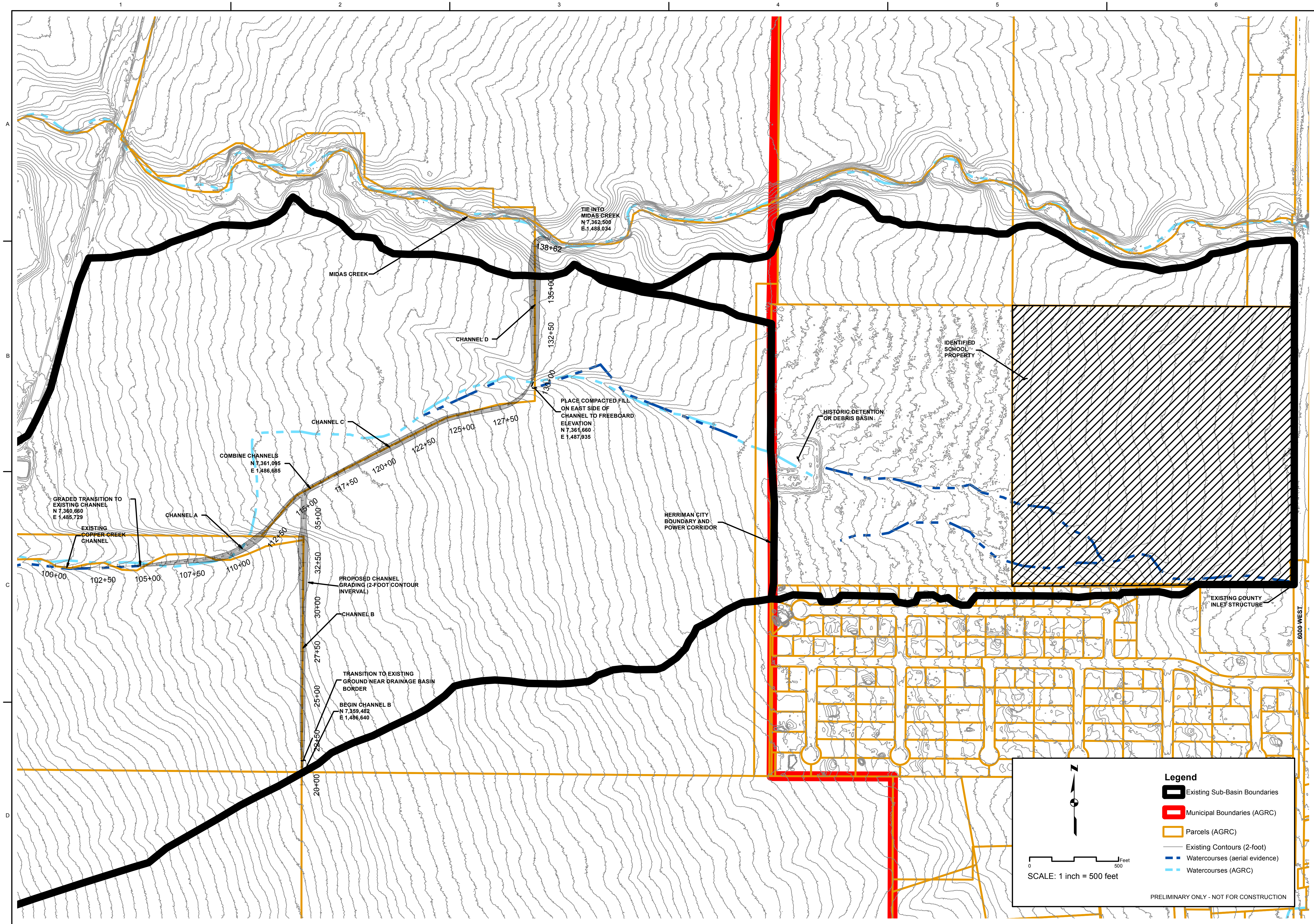
NO.	DATE	REVISION	BY	APVD

DSGN
DR
CHK
APVD

VERIFY SCALE

DATE
PROJ
DWG
SHEET of

Exhibit 1 - 11x17.mxd



CH2MHILL

SALT LAKE COUNTY
DEPARTMENT OF PUBLIC WORKS
FLOOD CONTROL & ENGINEERING DIVISION
COPPER CREEK DRAINAGE MASTER PLAN

SALT LAKE COUNTY

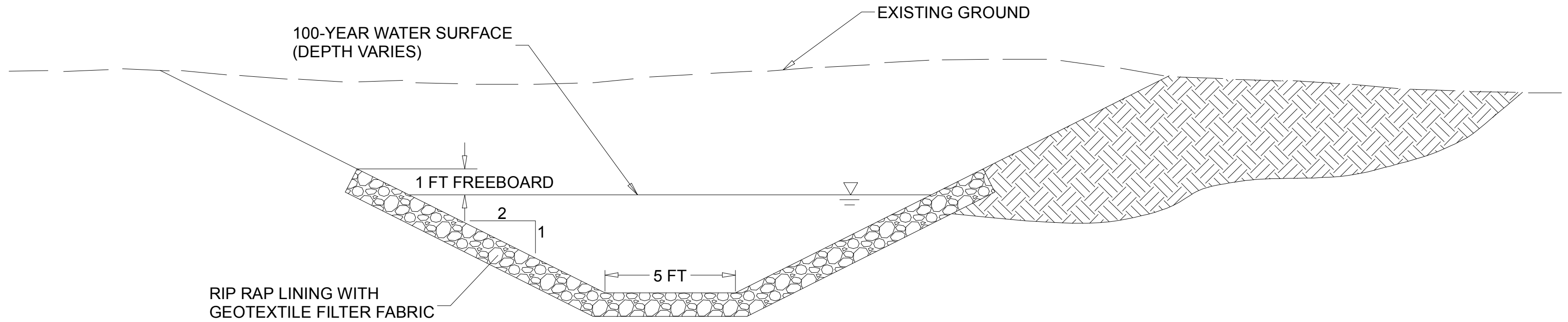
EXHIBIT 2
PROPOSED CHANNEL IMPROVEMENTS - PLAN VIEW

NO.	DATE	REVISION	BY	APVD
DSGN	DR	CHK	APVD	

VERIFY SCALE

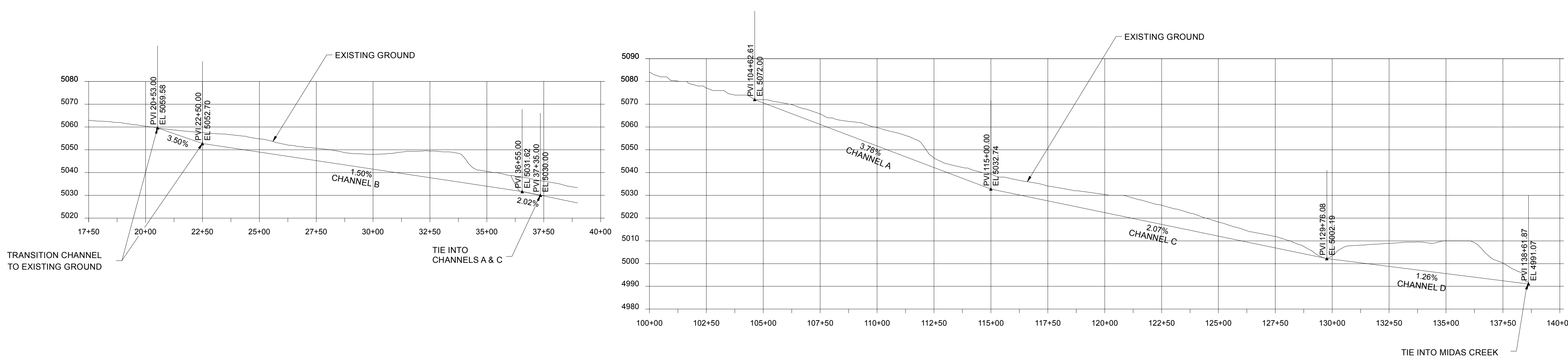
DATE
PROJ
DWG
SHEET of

Exhibit 2 - 11x17.mxd



1 - TYPICAL CHANNEL SECTION

NOT TO SCALE



2 - CHANNEL PROFILES

HORIZONTAL SCALE: 1" = 500'
VERTICAL SCALE: 1" = 50'

PRELIMINARY ONLY - NOT FOR CONSTRUCTION

CH2MHILL

SALT LAKE COUNTY
DEPARTMENT OF PUBLIC WORKS
FLOOD CONTROL & ENGINEERING DIVISION
COPPER CREEK DRAINAGE MASTER PLAN

EXHIBIT 3
PROFILES AND
CROSS-SECTION

SALT LAKE COUNTY

NO.	DATE	REVISION	BY	APVD

DSGN | DR | CHK | APVD

VERIFY SCALE

DATE
PROJ
DWG
SHEET of

Exhibit 3 - 11x17.mxd

Appendix A
Site Photographs

Photograph 1, taken on October 2, 2013, looking east toward 6000 West, with the Herriman Cemetery shown on the right.

Photograph 2, taken October 2, 2013, looking east toward 6000 West. The drainage inlet structure designed as part of SWCCS project MC-1 to receive Copper Creek flows, which are then conveyed via pipe and channel to Midas Creek. Capacity of pipe as shown on the County construction drawings is 225 cfs.


Photograph 3, taken on October 2, 2013, near the power line corridor and looking west toward KUC.


Photograph 4, taken on October 2, 2013, and looking east toward 6000 West. Residential homes border a portion of the Copper Creek watershed.


Photograph 5, taken on October 30, 2013, and looking west toward KUC showing the outlet of the existing 48-inch CMP draining the north fork of Copper Creek beneath U-111.

Photograph 6, taken on October 30, 2013, and looking west toward KUC and showing the HDPE pipe outlet draining Copper Creek proper beneath U-111. This pipe appears to be concrete on the upstream end.

Appendix B
Travel Time Calculations

Salt Lake County - Copper Creek - Basin 1

Reach 1 - Sheet Flow Segment			
Length	L =	102	ft
Reach Start Elevation	Elev=	5,628.0	ft
Reach End Elevation	Elev=	5,610.0	ft
Average slope	S_o =	*0.1770*	ft/ft
Manning's roughness	n =	0.240	
2-yr, 24-hr rainfall depth	P =	1.370	in.
Travel Time	t_t =	*9.24*	min.

$$t_t = 60\left(\frac{0.007\,(nL)^{0.8}}{(P)^{0.5}\,S^{0.4}}\right)$$

Reach 2 - Shallow Concentrated Flow Segment			
Length	L =	159	ft
Reach Start Elevation	Elev=	5,610.0	ft
Reach End Elevation	Elev=	5,592.0	ft
Average Slope	S_o =	*0.1129*	ft/ft
Paved or unpaved?		UNPAVED	
Manning's Coefficient		16.1345	
Average velocity	v =	*5.42*	ft/s
Travel Time	t_t =	*0.49*	min.

$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

where,
$v_x = (20.3282)S^{0.5}$ for paved surfaces, or,
$v_x = (16.1345)S^{0.5}$ for unpaved surfaces

Reach 3 - Open Channel Flow Segment			
Length	L =	1,207	ft
Reach Start Elevation	Elev=	5,592.0	ft
Reach End Elevation	Elev=	5,558.0	ft
Average Slope	S_o =	*0.0282*	ft/ft
Manning's roughness	n =	0.018	
Channel side slope (z:1 => H:V)	z =	6	
Channel base width	b =	0	ft
Channel depth	y =	4.59	ft
Cross-sectional area	A =	*126.58*	ft^2
Wetted Perimiter	P_w =	*55.88*	ft
Hydraulic radius	R_h =	*2.27*	ft
Velocity	v =	*23.90*	ft/s
Travel Time	t_t =	*0.84*	min.

$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

Reach 4 - Open Channel Flow Segment			
Length	L =	597	ft
Reach Start Elevation	Elev=	5,558.0	ft
Reach End Elevation	Elev=	5,508.0	ft
Average Slope	S_o =	*0.0837*	ft/ft
Manning's roughness	n =	0.045	
Channel side slope (z:1 => H:V)	z =	3	
Channel base width	b =	0	ft
Channel depth	y =	6.07	ft
Cross-sectional area	A =	*110.52*	ft^2
Wetted Perimiter	P_w =	*38.39*	ft
Hydraulic radius	R_h =	*2.88*	ft
Velocity	v =	*19.34*	ft/s
Travel Time	t_t =	*0.51*	min.

$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

Reach 5 - Open Channel Flow Segment			
Length	L =	620	ft
Reach Start Elevation	Elev=	5,508.0	ft
Reach End Elevation	Elev=	5,470.0	ft
Average Slope	S_o =	*0.0613*	ft/ft
Manning's roughness	n =	0.045	
Channel side slope (z:1 => H:V)	z =	1	
Channel base width	b =	0	ft
Channel depth	y =	10.00	ft
Cross-sectional area	A =	*100.06*	ft^2
Wetted Perimiter	P_w =	*28.29*	ft
Hydraulic radius	R_h =	*3.54*	ft
Velocity	v =	*18.98*	ft/s
Travel Time	t_t =	*0.54*	min.

$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

Time of Concentration =	**12**	**minutes**
	0.194	**hours**
Lag time (0.6tc)	7	

Salt Lake County - Copper Creek - Basin 2

Reach 1 - Sheet Flow Segment

Length	L =	69	ft
Reach Start Elevation	Elev=	5,709.0	ft
Reach End Elevation	Elev=	5,704.0	ft
Average slope	S_o =	*0.0726*	ft/ft
Manning's roughness	n =	0.011	
2-yr, 24-hr rainfall depth	P =	1.370	in.
Travel Time	t_t =	*0.82*	min.

$$t_t = 60\left(\frac{0.007\,(nL)^{0.8}}{(P)^{0.5}\,S^{0.4}}\right)$$

Reach 2 - Shallow Concentrated Flow Segment

Length	L =	505	ft
Reach Start Elevation	Elev=	5,704.0	ft
Reach End Elevation	Elev=	5,666.0	ft
Average Slope	S_o =	*0.0752*	ft/ft
Paved or unpaved?		UNPAVED	
Manning's Coefficient		16.1345	
Average velocity	v =	*4.42*	ft/s
Travel Time	t_t =	*1.90*	min.

$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

where,

$v_x = (20.3282)S^{0.5}$ for paved surfaces, or,

$v_x = (16.1345)S^{0.5}$ for unpaved surfaces

Reach 3 - Open Channel Flow Segment

Length	L =	2,316	ft
Reach Start Elevation	Elev=	5,666.0	ft
Reach End Elevation	Elev=	5,506.0	ft
Average Slope	S_o =	*0.0691*	ft/ft
Manning's roughness	n =	0.018	
Channel side slope (z:1 => H:V)	z =	7	
Channel base width	b =	0	ft
Channel depth	y =	1.50	ft
Cross-sectional area	A =	*15.80*	ft^2
Wetted Perimiter	P_w =	*21.25*	ft
Hydraulic radius	R_h =	*0.74*	ft
Velocity	v =	*17.81*	ft/s
Travel Time	t_t =	*2.17*	min.

$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

Reach 4 - Open Channel Flow Segment

Length	L =	581	ft
Reach Start Elevation	Elev=	5,506.0	ft
Reach End Elevation	Elev=	5,478.0	ft
Average Slope	S_o =	*0.0482*	ft/ft
Manning's roughness	n =	0.045	
Channel side slope (z:1 => H:V)	z =	7	
Channel base width	b =	0	ft
Channel depth	y =	1.50	ft
Cross-sectional area	A =	*15.80*	ft^2
Wetted Perimiter	P_w =	*21.25*	ft
Hydraulic radius	R_h =	*0.74*	ft
Velocity	v =	*5.95*	ft/s
Travel Time	t_t =	*1.63*	min.

$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

Time of Concentration =	**7**	**minutes**
	0.109	**hours**
Lag time (0.6tc)	4	

Salt Lake County - Copper Creek - Basin 3

Reach 1 - Sheet Flow Segment

Length	L =	100	ft
Reach Start Elevation	Elev=	5,536.0	ft
Reach End Elevation	Elev=	5,534.8	ft
Average slope	S_o =	*0.0123*	ft/ft
Manning's roughness	n =	0.011	
2-yr, 24-hr rainfall depth	P =	1.370	in.
Travel Time	t_t =	*2.24*	min.

$$t_t = 60\left(\frac{0.007\,(nL)^{0.8}}{(P)^{0.5}\,S^{0.4}}\right)$$

Reach 2 - Shallow Concentrated Flow Segment

Length	L =	727	ft
Reach Start Elevation	Elev=	5,534.8	ft
Reach End Elevation	Elev=	5,488.0	ft
Average Slope	S_o =	*0.0644*	ft/ft
Paved or unpaved?		PAVED	
Manning's Coefficient		20.3282	
Average velocity	v =	*5.16*	ft/s
Travel Time	t_t =	*2.35*	min.

$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

where,
$v_x = (20.3282)S^{0.5}$ for paved surfaces, or,
$v_x = (16.1345)S^{0.5}$ for unpaved surfaces

Reach 3 - Open Channel Flow Segment

Length	L =	285	ft
Reach Start Elevation	Elev=	5,488.0	ft
Reach End Elevation	Elev=	5,456.0	ft
Average Slope	S_o =	*0.1121*	ft/ft
Manning's roughness	n =	0.018	
Channel side slope (z:1 => H:V)	z =	7	
Channel base width	b =	0	ft
Channel depth	y =	1.50	ft
Cross-sectional area	A =	*15.80*	ft^2
Wetted Perimiter	P_w =	*21.25*	ft
Hydraulic radius	R_h =	*0.74*	ft
Velocity	v =	*22.69*	ft/s
Travel Time	t_t =	*0.21*	min.

$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

Reach 4 - Open Channel Flow Segment

Length	L =	246	ft
Reach Start Elevation	Elev=	5,456.0	ft
Reach End Elevation	Elev=	5,444.0	ft
Average Slope	S_o =	*0.0488*	ft/ft
Manning's roughness	n =	0.045	
Channel side slope (z:1 => H:V)	z =	1	
Channel base width	b =	0	ft
Channel depth	y =	10.00	ft
Cross-sectional area	A =	*100.06*	ft^2
Wetted Perimiter	P_w =	*28.29*	ft
Hydraulic radius	R_h =	*3.54*	ft
Velocity	v =	*16.93*	ft/s
Travel Time	t_t =	*0.24*	min.

$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

Time of Concentration =	**5**	**minutes**
	0.084	**hours**
Lag time (0.6tc)	3	

Salt Lake County - Copper Creek - Basin 4

Reach 1 - Sheet Flow Segment

Length	L =	34	ft
Reach Start Elevation	Elev=	5,462.0	ft
Reach End Elevation	Elev=	5,458.0	ft
Average slope	S_o =	*0.1172*	ft/ft
Manning's roughness	n =	0.240	
2-yr, 24-hr rainfall depth	P =	1.370	in.
Travel Time	t_t =	*4.55*	min.

$$t_t = 60\left(\frac{0.007\,(nL)^{0.8}}{(P)^{0.5}\,S^{0.4}}\right)$$

Reach 2 - Shallow Concentrated Flow Segment

Length	L =	531	ft
Reach Start Elevation	Elev=	5,458.0	ft
Reach End Elevation	Elev=	5,448.0	ft
Average Slope	S_o =	*0.0188*	ft/ft
Paved or unpaved?		UNPAVED	
Manning's Coefficient		16.1345	
Average velocity	v =	*2.21*	ft/s
Travel Time	t_t =	*4.00*	min.

$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

where,

$v_x = (20.3282)S^{0.5}$ for paved surfaces, or,

$v_x = (16.1345)S^{0.5}$ for unpaved surfaces

Reach 3 - Open Channel Flow Segment

Length	L =	1,512	ft
Reach Start Elevation	Elev=	5,448.0	ft
Reach End Elevation	Elev=	5,367.0	ft
Average Slope	S_o =	*0.0536*	ft/ft
Manning's roughness	n =	0.045	
Channel side slope (z:1 => H:V)	z =	1	
Channel base width	b =	0	ft
Channel depth	y =	10.00	ft
Cross-sectional area	A =	*100.06*	ft^2
Wetted Perimiter	P_w =	*28.29*	ft
Hydraulic radius	R_h =	*3.54*	ft
Velocity	v =	*17.74*	ft/s
Travel Time	t_t =	*1.42*	min.

$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

Time of Concentration =	**10**	**minutes**
	0.166	**hours**
Lag time (0.6tc)	6	

Salt Lake County - Copper Creek - Basin 5

Reach 1 - Sheet Flow Segment			
Length	L =	82	ft
Reach Start Elevation	Elev=	5,509.0	ft
Reach End Elevation	Elev=	5,507.0	ft
Average slope	S_o =	*0.0244*	ft/ft
Manning's roughness	n =	0.011	
2-yr, 24-hr rainfall depth	P =	1.370	in.
Travel Time	t_t =	*1.46*	min.

$$t_t = 60\left(\frac{0.007\,(nL)^{0.8}}{(P)^{0.5}\,S^{0.4}}\right)$$

Reach 2 - Shallow Concentrated Flow Segment			
Length	L =	705	ft
Reach Start Elevation	Elev=	5,507.0	ft
Reach End Elevation	Elev=	5,454.0	ft
Average Slope	S_o =	*0.0751*	ft/ft
Paved or unpaved?		UNPAVED	
Manning's Coefficient		16.1345	
Average velocity	v =	*4.42*	ft/s
Travel Time	t_t =	*2.66*	min.

$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

where,
$v_x = (20.3282)S^{0.5}$ for paved surfaces, or,
$v_x = (16.1345)S^{0.5}$ for unpaved surfaces

Reach 3 - Open Channel Flow Segment			
Length	L =	807	ft
Reach Start Elevation	Elev=	5,454.0	ft
Reach End Elevation	Elev=	5,410.0	ft
Average Slope	S_o =	*0.0545*	ft/ft
Manning's roughness	n =	0.03	
Channel side slope (z:1 => H:V)	z =	3	
Channel base width	b =	0	ft
Channel depth	y =	10.00	ft
Cross-sectional area	A =	*300.19*	ft^2
Wetted Perimiter	P_w =	*63.27*	ft
Hydraulic radius	R_h =	*4.74*	ft
Velocity	v =	*32.66*	ft/s
Travel Time	t_t =	*0.41*	min.

$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

Reach 4 - Open Channel Flow Segment			
Length	L =	1,102	ft
Reach Start Elevation	Elev=	5,410.0	ft
Reach End Elevation	Elev=	5,367.0	ft
Average Slope	S_o =	*0.0390*	ft/ft
Manning's roughness	n =	0.045	
Channel side slope (z:1 => H:V)	z =	1	
Channel base width	b =	0	ft
Channel depth	y =	10.00	ft
Cross-sectional area	A =	*100.06*	ft^2
Wetted Perimiter	P_w =	*28.29*	ft
Hydraulic radius	R_h =	*3.54*	ft
Velocity	v =	*15.14*	ft/s
Travel Time	t_t =	*1.21*	min.

$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

Time of Concentration =	**6**	**minutes**
	0.096	**hours**
Lag time (0.6tc)	3	

Salt Lake County - Copper Creek - Basin 6

Reach 1 - Sheet Flow Segment			
Length	L =	100	ft
Reach Start Elevation	Elev=	5,485.0	ft
Reach End Elevation	Elev=	5,480.0	ft
Average slope	S_o =	*0.0501*	ft/ft
Manning's roughness	n =	0.240	
2-yr, 24-hr rainfall depth	P =	1.370	in.
Travel Time	t_t =	*15.07*	min.

$$t_t = 60\left(\frac{0.007\,(nL)^{0.8}}{(P)^{0.5}\,S^{0.4}}\right)$$

Reach 2 - Shallow Concentrated Flow Segment			
Length	L =	495	ft
Reach Start Elevation	Elev=	5,480.0	ft
Reach End Elevation	Elev=	5,445.0	ft
Average Slope	S_o =	*0.0706*	ft/ft
Paved or unpaved?		UNPAVED	
Manning's Coefficient		16.1345	
Average velocity	v =	*4.29*	ft/s
Travel Time	t_t =	*1.93*	min.

$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

where,

$v_x = (20.3282)S^{0.5}$ for paved surfaces, or,

$v_x = (16.1345)S^{0.5}$ for unpaved surfaces

Reach 3 - Open Channel Flow Segment			
Length	L =	1,644	ft
Reach Start Elevation	Elev=	5,445.0	ft
Reach End Elevation	Elev=	5,358.0	ft
Average Slope	S_o =	*0.0529*	ft/ft
Manning's roughness	n =	0.045	
Channel side slope (z:1 => H:V)	z =	6	
Channel base width	b =	0	ft
Channel depth	y =	1.00	ft
Cross-sectional area	A =	*6.00*	ft^2
Wetted Perimiter	P_w =	*12.17*	ft
Hydraulic radius	R_h =	*0.49*	ft
Velocity	v =	*4.74*	ft/s
Travel Time	t_t =	*5.78*	min.

$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

Reach 4 - Open Channel Flow Segment			
Length	L =	2,982	ft
Reach Start Elevation	Elev=	5,358.0	ft
Reach End Elevation	Elev=	5,242.0	ft
Average Slope	S_o =	*0.0389*	ft/ft
Manning's roughness	n =	0.045	
Channel side slope (z:1 => H:V)	z =	7	
Channel base width	b =	0	ft
Channel depth	y =	1.50	ft
Cross-sectional area	A =	*15.75*	ft^2
Wetted Perimiter	P_w =	*21.21*	ft
Hydraulic radius	R_h =	*0.74*	ft
Velocity	v =	*5.34*	ft/s
Travel Time	t_t =	*9.31*	min.

$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

Reach 5 - Open Channel Flow Segment			
Length	L =	2,874	ft
Reach Start Elevation	Elev=	5,242.0	ft
Reach End Elevation	Elev=	5,142.0	ft
Average Slope	S_o =	*0.0348*	ft/ft
Manning's roughness	n =	0.045	
Channel side slope (z:1 => H:V)	z =	5	
Channel base width	b =	0	ft
Channel depth	y =	2.00	ft
Cross-sectional area	A =	*20.00*	ft^2
Wetted Perimiter	P_w =	*20.40*	ft
Hydraulic radius	R_h =	*0.98*	ft
Velocity	v =	*6.08*	ft/s
Travel Time	t_t =	*7.88*	min.

$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

Reach 6 - Open Channel Flow Segment			
Length	L =	2,894	ft
Reach Start Elevation	Elev=	5,142.0	ft
Reach End Elevation	Elev=	5,069.0	ft
Average Slope	S_o =	*0.0252*	ft/ft
Manning's roughness	n =	0.045	
Channel side slope (z:1 => H:V)	z =	5	
Channel base width	b =	0	ft
Channel depth	y =	2.50	ft
Cross-sectional area	A =	*31.25*	ft^2
Wetted Perimiter	P_w =	*25.50*	ft
Hydraulic radius	R_h =	*1.23*	ft
Velocity	v =	*6.01*	ft/s
Travel Time	t_t =	*8.03*	min.

$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

Reach 7 - Open Channel Flow Segment			
Length	L =	1,696	ft
Reach Start Elevation	Elev=	5,069.0	ft
Reach End Elevation	Elev=	5,029.0	ft
Average Slope	S_o =	*0.0236*	ft/ft
Manning's roughness	n =	0.045	
Channel side slope (z:1 => H:V)	z =	20	
Channel base width	b =	0	ft
Channel depth	y =	1.50	ft
Cross-sectional area	A =	*45.00*	ft^2
Wetted Perimiter	P_w =	*60.07*	ft
Hydraulic radius	R_h =	*0.75*	ft
Velocity	v =	*4.18*	ft/s
Travel Time	t_t =	*6.76*	min.

$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

Reach 8 - Open Channel Flow Segment			
Length	L =	2,356	ft
Reach Start Elevation	Elev=	5,029.0	ft
Reach End Elevation	Elev=	4,976.0	ft
Average Slope	S_o =	*0.0225*	ft/ft
Manning's roughness	n =	0.045	
Channel side slope (z:1 => H:V)	z =	3	
Channel base width	b =	0	ft
Channel depth	y =	3.00	ft
Cross-sectional area	A =	*27.00*	ft^2
Wetted Perimiter	P_w =	*18.97*	ft
Hydraulic radius	R_h =	*1.42*	ft
Velocity	v =	*6.27*	ft/s
Travel Time	t_t =	*6.26*	min.

$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

Time of Concentration =	**61**	**minutes**
	1.017	**hours**
Lag time (0.6tc)	37	

Salt Lake County - Copper Creek - Basin 6A

Reach 1 - Sheet Flow Segment

Length	L =	100	ft
Reach Start Elevation	Elev=	5,494.0	ft
Reach End Elevation	Elev=	5,490.0	ft
Average slope	S_o =	*0.0401*	ft/ft
Manning's roughness	n =	0.240	
2-yr, 24-hr rainfall depth	P =	1.370	in.
Travel Time	t_t =	*16.48*	min.

$$t_t = 60\left(\frac{0.007\,(nL)^{0.8}}{(P)^{0.5}\,S^{0.4}}\right)$$

Reach 2 - Shallow Concentrated Flow Segment

Length	L =	1,600	ft
Reach Start Elevation	Elev=	5,490.0	ft
Reach End Elevation	Elev=	5,400.0	ft
Average Slope	S_o =	*0.0563*	ft/ft
Paved or unpaved?		UNPAVED	
Manning's Coefficient		16.1345	
Average velocity	v =	*3.83*	ft/s
Travel Time	t_t =	*6.97*	min.

$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

where,

$v_x = (20.3282)S^{0.5}$ for paved surfaces, or,

$v_x = (16.1345)S^{0.5}$ for unpaved surfaces

Reach 3 - Open Channel Flow Segment

Length	L =	3,950	ft
Reach Start Elevation	Elev=	5,400.0	ft
Reach End Elevation	Elev=	5,234.0	ft
Average Slope	S_o =	*0.0420*	ft/ft
Manning's roughness	n =	0.045	
Channel side slope (z:1 => H:V)	z =	6	
Channel base width	b =	0	ft
Channel depth	y =	1.00	ft
Cross-sectional area	A =	*6.00*	ft^2
Wetted Perimiter	P_w =	*12.17*	ft
Hydraulic radius	R_h =	*0.49*	ft
Velocity	v =	*4.23*	ft/s
Travel Time	t_t =	*15.58*	min.

$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

Reach 4 - Open Channel Flow Segment

Length	L =	2,432	ft
Reach Start Elevation	Elev=	5,234.0	ft
Reach End Elevation	Elev=	5,032.0	ft
Average Slope	S_o =	*0.0831*	ft/ft
Manning's roughness	n =	0.045	
Channel side slope (z:1 => H:V)	z =	2	
Channel base width	b =	10	ft
Channel depth	y =	1.50	ft
Cross-sectional area	A =	*19.50*	ft^2
Wetted Perimiter	P_w =	*16.71*	ft
Hydraulic radius	R_h =	*1.17*	ft
Velocity	v =	*10.55*	ft/s
Travel Time	t_t =	*3.84*	min.

$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

Time of Concentration =	**43**	**minutes**
	0.714	**hours**
Lag time (0.6tc)	26	

Salt Lake County - Copper Creek - Basin 6B

Reach 1 - Sheet Flow Segment

Length	L =	100	ft
Reach Start Elevation	Elev=	5,485.0	ft
Reach End Elevation	Elev=	5,480.0	ft
Average slope	S_o =	*0.0501*	ft/ft
Manning's roughness	n =	0.240	
2-yr, 24-hr rainfall depth	P =	1.370	in.
Travel Time	t_t =	*15.07*	min.

$$t_t = 60\left(\frac{0.007\,(nL)^{0.8}}{(P)^{0.5}\,S^{0.4}}\right)$$

Reach 2 - Shallow Concentrated Flow Segment

Length	L =	495	ft
Reach Start Elevation	Elev=	5,480.0	ft
Reach End Elevation	Elev=	5,445.0	ft
Average Slope	S_o =	*0.0706*	ft/ft
Paved or unpaved?		UNPAVED	
Manning's Coefficient		16.1345	
Average velocity	v =	*4.29*	ft/s
Travel Time	t_t =	*1.93*	min.

$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

where,

$v_x = (20.3282)S^{0.5}$ for paved surfaces, or,

$v_x = (16.1345)S^{0.5}$ for unpaved surfaces

Reach 3 - Open Channel Flow Segment

Length	L =	1,644	ft
Reach Start Elevation	Elev=	5,445.0	ft
Reach End Elevation	Elev=	5,358.0	ft
Average Slope	S_o =	*0.0529*	ft/ft
Manning's roughness	n =	0.045	
Channel side slope (z:1 => H:V)	z =	6	
Channel base width	b =	0	ft
Channel depth	y =	1.00	ft
Cross-sectional area	A =	*6.00*	ft^2
Wetted Perimiter	P_w =	*12.17*	ft
Hydraulic radius	R_h =	*0.49*	ft
Velocity	v =	*4.74*	ft/s
Travel Time	t_t =	*5.78*	min.

$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

Reach 4 - Open Channel Flow Segment

Length	L =	2,982	ft
Reach Start Elevation	Elev=	5,358.0	ft
Reach End Elevation	Elev=	5,242.0	ft
Average Slope	S_o =	*0.0389*	ft/ft
Manning's roughness	n =	0.045	
Channel side slope (z:1 => H:V)	z =	7	
Channel base width	b =	0	ft
Channel depth	y =	1.50	ft
Cross-sectional area	A =	*15.75*	ft^2
Wetted Perimiter	P_w =	*21.21*	ft
Hydraulic radius	R_h =	*0.74*	ft
Velocity	v =	*5.34*	ft/s
Travel Time	t_t =	*9.31*	min.

$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

Reach 5 - Open Channel Flow Segment

Length	L =	2,874	ft
Reach Start Elevation	Elev=	5,242.0	ft
Reach End Elevation	Elev=	5,142.0	ft
Average Slope	S_o =	*0.0348*	ft/ft
Manning's roughness	n =	0.045	
Channel side slope (z:1 => H:V)	z =	5	
Channel base width	b =	0	ft
Channel depth	y =	2.00	ft
Cross-sectional area	A =	*20.00*	ft^2
Wetted Perimiter	P_w =	*20.40*	ft
Hydraulic radius	R_h =	*0.98*	ft
Velocity	v =	*6.08*	ft/s
Travel Time	t_t =	*7.88*	min.

$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

Reach 6 - Open Channel Flow Segment

Length	L =	2,894	ft
Reach Start Elevation	Elev=	5,142.0	ft
Reach End Elevation	Elev=	5,069.0	ft
Average Slope	S_o =	*0.0252*	ft/ft
Manning's roughness	n =	0.045	
Channel side slope (z:1 => H:V)	z =	5	
Channel base width	b =	0	ft
Channel depth	y =	2.50	ft
Cross-sectional area	A =	*31.25*	ft^2
Wetted Perimiter	P_w =	*25.50*	ft
Hydraulic radius	R_h =	*1.23*	ft
Velocity	v =	*6.01*	ft/s
Travel Time	t_t =	*8.03*	min.

$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

Reach 7 - Open Channel Flow Segment

Length	L =	939	ft
Reach Start Elevation	Elev=	5,069.0	ft
Reach End Elevation	Elev=	5,050.0	ft
Average Slope	S_o =	*0.0202*	ft/ft
Manning's roughness	n =	0.045	
Channel side slope (z:1 => H:V)	z =	20	
Channel base width	b =	0	ft
Channel depth	y =	1.50	ft
Cross-sectional area	A =	*45.00*	ft^2
Wetted Perimiter	P_w =	*60.07*	ft
Hydraulic radius	R_h =	*0.75*	ft
Velocity	v =	*3.87*	ft/s
Travel Time	t_t =	*4.04*	min.

$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

Reach 8 - Open Channel Flow Segment

Length	L =	912	ft
Reach Start Elevation	Elev=	5,050.0	ft
Reach End Elevation	Elev=	5,030.0	ft
Average Slope	S_o =	*0.0219*	ft/ft
Manning's roughness	n =	0.045	
Channel side slope (z:1 => H:V)	z =	2	
Channel base width	b =	10	ft
Channel depth	y =	3.00	ft
Cross-sectional area	A =	*48.00*	ft^2
Wetted Perimiter	P_w =	*23.42*	ft
Hydraulic radius	R_h =	*2.05*	ft
Velocity	v =	*7.89*	ft/s
Travel Time	t_t =	*1.93*	min.

$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

Time of Concentration =	**54**	**minutes**
	0.899	**hours**
Lag time (0.6tc)	32	

Salt Lake County - Copper Creek - Basin 6C

Reach 1 - Sheet Flow Segment

Length	L =	100	ft
Reach Start Elevation	Elev=	5,112.0	ft
Reach End Elevation	Elev=	5,108.0	ft
Average slope	S_o =	*0.0401*	ft/ft
Manning's roughness	n =	0.240	
2-yr, 24-hr rainfall depth	P =	1.370	in.
Travel Time	t_t =	*16.48*	min.

$$t_t = 60\left(\frac{0.007\,(nL)^{0.8}}{(P)^{0.5}\,S^{0.4}}\right)$$

Reach 2 - Shallow Concentrated Flow Segment

Length	L =	4,626	ft
Reach Start Elevation	Elev=	5,108.0	ft
Reach End Elevation	Elev=	5,004.0	ft
Average Slope	S_o =	*0.0225*	ft/ft
Paved or unpaved?		UNPAVED	
Manning's Coefficient		16.1345	
Average velocity	v =	*2.42*	ft/s
Travel Time	t_t =	*31.87*	min.

$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

where,

$v_x = (20.3282)S^{0.5}$ for paved surfaces, or,

$v_x = (16.1345)S^{0.5}$ for unpaved surfaces

Reach 3 - Open Channel Flow Segment

Length	L =	610	ft
Reach Start Elevation	Elev=	5,004.0	ft
Reach End Elevation	Elev=	4,991.0	ft
Average Slope	S_o =	*0.0213*	ft/ft
Manning's roughness	n =	0.045	
Channel side slope (z:1 => H:V)	z =	2	
Channel base width	b =	10	ft
Channel depth	y =	3.00	ft
Cross-sectional area	A =	*48.00*	ft^2
Wetted Perimiter	P_w =	*23.42*	ft
Hydraulic radius	R_h =	*2.05*	ft
Velocity	v =	*7.78*	ft/s
Travel Time	t_t =	*1.31*	min.

$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

Time of Concentration =	**50**	**minutes**
	0.828	**hours**
Lag time (0.6tc)	30	

Salt Lake County - Copper Creek - Basin 6D

Reach 1 - Sheet Flow Segment			
Length	L =	100	ft
Reach Start Elevation	Elev=	5,058.0	ft
Reach End Elevation	Elev=	5,055.0	ft
Average slope	S_o =	*0.0301*	ft/ft
Manning's roughness	n =	0.240	
2-yr, 24-hr rainfall depth	P =	1.370	in.
Travel Time	t_t =	*18.49*	min.

$$t_t = 60\left(\frac{0.007\,(nL)^{0.8}}{(P)^{0.5}\,S^{0.4}}\right)$$

Reach 2 - Shallow Concentrated Flow Segment			
Length	L =	2,886	ft
Reach Start Elevation	Elev=	5,055.0	ft
Reach End Elevation	Elev=	4,978.0	ft
Average Slope	S_o =	*0.0267*	ft/ft
Paved or unpaved?		UNPAVED	
Manning's Coefficient		16.1345	
Average velocity	v =	*2.64*	ft/s
Travel Time	t_t =	*18.25*	min.

$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

where,
$v_x = (20.3282)S^{0.5}$ for paved surfaces, or,
$v_x = (16.1345)S^{0.5}$ for unpaved surfaces

Reach 3 - Open Channel Flow Segment			
Length	L =	588	ft
Reach Start Elevation	Elev=	4,978.0	ft
Reach End Elevation	Elev=	4,976.0	ft
Average Slope	S_o =	*0.0034*	ft/ft
Manning's roughness	n =	0.045	
Channel side slope (z:1 => H:V)	z =	5	
Channel base width	b =	10	ft
Channel depth	y =	2.00	ft
Cross-sectional area	A =	*40.00*	ft^2
Wetted Perimiter	P_w =	*30.40*	ft
Hydraulic radius	R_h =	*1.32*	ft
Velocity	v =	*2.31*	ft/s
Travel Time	t_t =	*4.24*	min.

$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

Time of Concentration =	**41**	**minutes**
	0.683	**hours**
Lag time (0.6tc)	25	

Salt Lake County - Copper Creek - Basin 7

Reach 1 - Sheet Flow Segment

Length	L =	92	ft
Reach Start Elevation	Elev=	5,004.0	ft
Reach End Elevation	Elev=	5,002.0	ft
Average slope	S_o =	*0.0218*	ft/ft
Manning's roughness	n =	0.240	
2-yr, 24-hr rainfall depth	P =	1.370	in.
Travel Time	t_t =	*19.70*	min.

$$t_t = 60\left(\frac{0.007\,(nL)^{0.8}}{(P)^{0.5}\,S^{0.4}}\right)$$

Reach 2 - Shallow Concentrated Flow Segment

Length	L =	453	ft
Reach Start Elevation	Elev=	5,002.0	ft
Reach End Elevation	Elev=	4,992.0	ft
Average Slope	S_o =	*0.0221*	ft/ft
Paved or unpaved?		UNPAVED	
Manning's Coefficient		16.1345	
Average velocity	v =	*2.40*	ft/s
Travel Time	t_t =	*3.15*	min.

$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

where,

$v_x = (20.3282)S^{0.5}$ for paved surfaces, or,

$v_x = (16.1345)S^{0.5}$ for unpaved surfaces

Reach 3 - Open Channel Flow Segment

Length	L =	3,592	ft
Reach Start Elevation	Elev=	4,992.0	ft
Reach End Elevation	Elev=	4,915.0	ft
Average Slope	S_o =	*0.0214*	ft/ft
Manning's roughness	n =	0.045	
Channel side slope (z:1 => H:V)	z =	50	
Channel base width	b =	0	ft
Channel depth	y =	1.00	ft
Cross-sectional area	A =	*49.74*	ft^2
Wetted Perimiter	P_w =	*99.76*	ft
Hydraulic radius	R_h =	*0.50*	ft
Velocity	v =	*3.04*	ft/s
Travel Time	t_t =	*19.70*	min.

$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

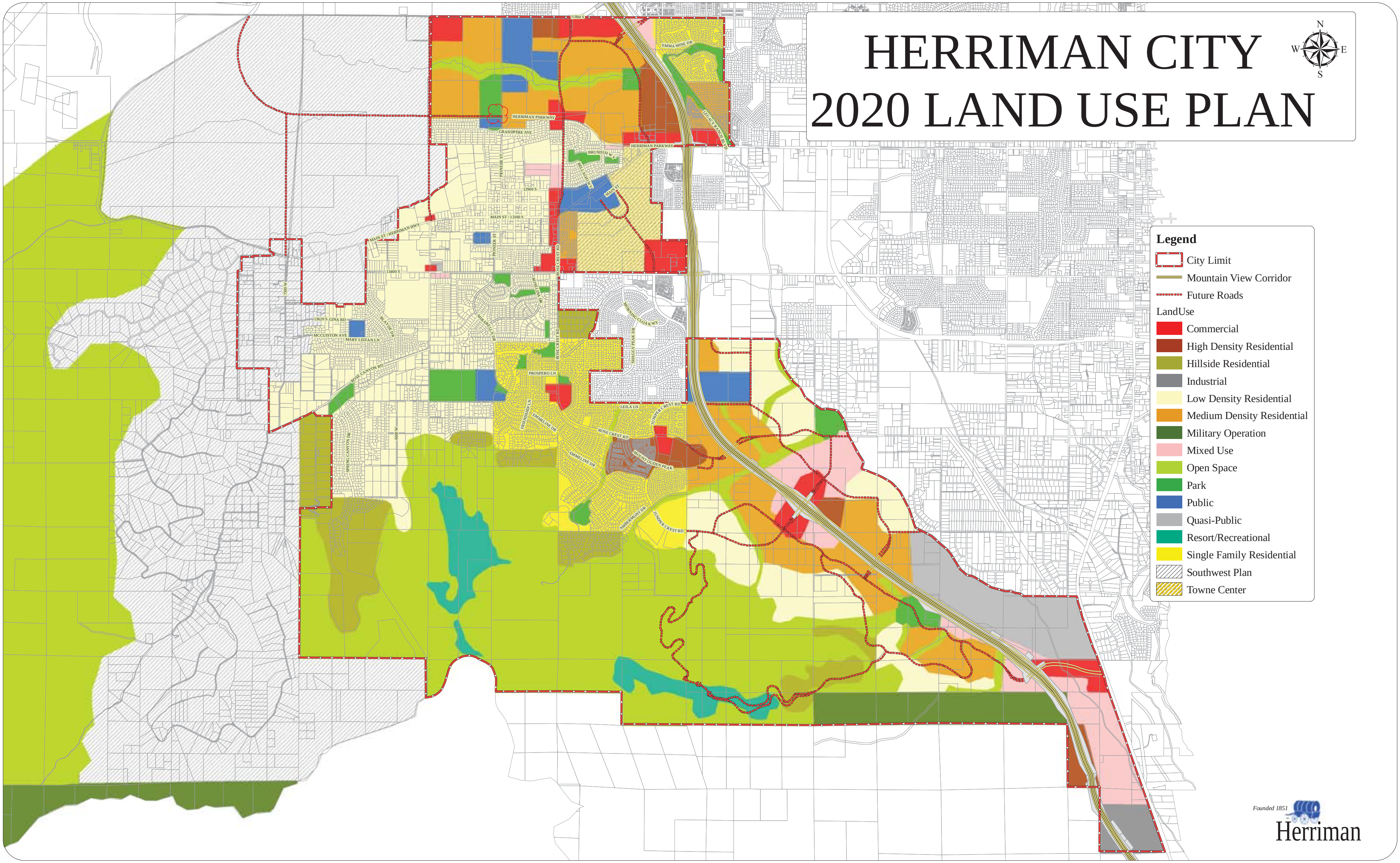
Reach 4 - Open Channel Flow Segment

Length	L =	1,066	ft
Reach Start Elevation	Elev=	4,915.0	ft
Reach End Elevation	Elev=	4,912.0	ft
Average Slope	S_o =	*0.0028*	ft/ft
Manning's roughness	n =	0.045	
Channel side slope (z:1 => H:V)	z =	6	
Channel base width	b =	0	ft
Channel depth	y =	1.00	ft
Cross-sectional area	A =	*5.97*	ft^2
Wetted Perimiter	P_w =	*12.13*	ft
Hydraulic radius	R_h =	*0.49*	ft
Velocity	v =	*1.09*	ft/s
Travel Time	t_t =	*16.28*	min.

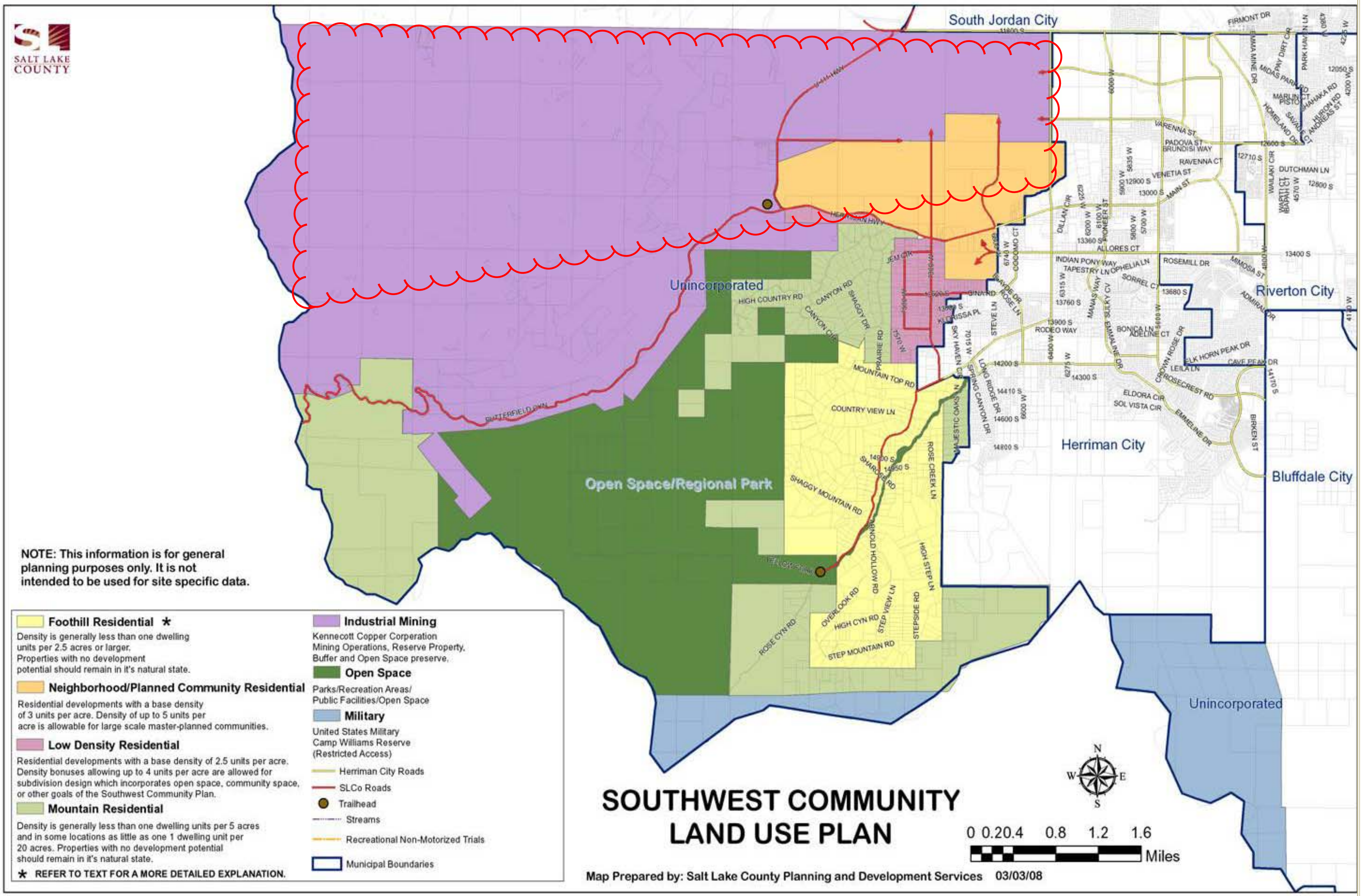
$$t_t = \left(\frac{L}{(3600\,v_x)}\right)60$$

Time of Concentration =	**59**	**minutes**
	0.980	**hours**
Lag time (0.6tc)	35	

Appendix C
Land Use Maps


HERRIMAN CITY
2020 LAND USE PLAN
N
W
E
S
Legend
City Limit
Mountain View Corridor
Future Roads
LandUse
Commercial
High Density Residential
Hillside Residential
Industrial
Low Density Residential
Medium Density Residential
Military Operation
Mixed Use
Open Space
Park
Public
Quasi-Public
Resort/Recreational
Single Family Residential
Southwest Plan
Towne Center
Founded 1851
Herriman

Map 1: Southwest Community Plan



Appendix D
Hydraulic Calculations

Hydraulic Analysis Report

Project Data

Project Title:

Designer:

Project Date: Wednesday, June 25, 2014

Project Units: U.S. Customary Units

Notes:

Channel Lining Analysis: Channel Lining Design Analysis - Channel A

Notes:

Lining Input Parameters

Channel Lining Type: Riprap, Cobble, or Gravel

D50: 1 ft

Riprap Specific Weight: 165 lb/ft^3

Water Specific Weight: 62.4 lb/ft^3

Riprap Shape is Angular

Safety Factor: 1

Calculated Safety Factor: 1.20093

Lining Results

Angle of Repose: 41.7 degrees

Relative Flow Depth: 0.982516

Manning's n method: Bathurst

Manning's n: 0.0660686

Channel Bottom Shear Results

V*: 1.26871

Reynold's Number: 104249

Shield's Parameter: 0.08836

shear stress on channel bottom: 3.11925 lb/ft^2

Permissible shear stress for channel bottom: 9.06574 lb/ft^2

channel bottom is stable

Stable D50: 0.413205 ft

Channel Side Shear Results

K1: 0.802

K2: 0.740307

Kb: 0

shear stress on side of channel: 3.11925 lb/ft^2

Permissible shear stress for side of channel: 6.71143 lb/ft^2

Stable Side D50: 0.447639 lb/ft^2

side of channel is stable

Channel Lining Stability Results

the channel is stable

Channel Summary

Report for channel

Channel Analysis: Channel Analysis

Notes:

Input Parameters

Channel Type: Trapezoidal

Side Slope 1 (Z1): 2.0000 ft/ft

Side Slope 2 (Z2): 2.0000 ft/ft

Channel Width: 5.0000 ft

Longitudinal Slope: 0.0378 ft/ft

Manning's n: 0.0661

Flow: 42.0000 cfs

Result Parameters

Depth: 1.3224 ft

Area of Flow: 10.1098 ft^2

Wetted Perimeter: 10.9141 ft

Average Velocity: 4.1544 ft/s

Top Width: 10.2897 ft

Froude Number: 0.7386

Critical Depth: 1.1117 ft

Critical Velocity: 5.2303 ft/s

Critical Slope: 0.0722 ft/ft

Critical Top Width: 9.4468 ft

Calculated Max Shear Stress: 3.1193 lb/ft^2

Calculated Avg Shear Stress: 2.1849 lb/ft^2

Channel Lining Analysis: Channel Lining Design Analysis - Channel C

Notes:

Lining Input Parameters

Channel Lining Type: Riprap, Cobble, or Gravel

D50: 1 ft

Riprap Specific Weight: 165 lb/ft^3

Water Specific Weight: 62.4 lb/ft^3

Riprap Shape is Angular

Safety Factor: 1

Calculated Safety Factor: 1.24891

Lining Results

Angle of Repose: 41.7 degrees

Relative Flow Depth: 2.03783

Manning's n method: Blodgett

Manning's n: 0.0762887

Channel Bottom Shear Results

V*: 1.45554

Reynold's Number: 119601

Shield's Parameter: 0.0982429

shear stress on channel bottom: 4.1056 lb/ft^2

Permissible shear stress for channel bottom: 10.0797 lb/ft^2

channel bottom is stable

Stable D50: 0.508696 ft

Channel Side Shear Results

K1: 0.802

K2: 0.740307

Kb: 0

shear stress on side of channel: 4.1056 lb/ft^2

Permissible shear stress for side of channel: 7.46209 lb/ft^2

Stable Side D50: 0.551088 lb/ft^2

side of channel is stable

Channel Lining Stability Results

the channel is stable

Channel Summary

Report for channel

Channel Analysis: Channel Analysis

Notes:

Input Parameters

Channel Type: Trapezoidal

Side Slope 1 (Z1): 2.0000 ft/ft

Side Slope 2 (Z2): 2.0000 ft/ft

Channel Width: 5.0000 ft

Longitudinal Slope: 0.0207 ft/ft

Manning's n: 0.0763

Flow: 154.0000 cfs

Result Parameters

Depth: 3.1785 ft

Area of Flow: 36.0982 ft^2

Wetted Perimeter: 19.2147 ft

Average Velocity: 4.2661 ft/s

Top Width: 17.7140 ft

Froude Number: 0.5267

Critical Depth: 2.2834 ft

Critical Velocity: 7.0496 ft/s

Critical Slope: 0.0808 ft/ft

Critical Top Width: 14.1337 ft

Calculated Max Shear Stress: 4.1056 lb/ft^2

Calculated Avg Shear Stress: 2.4267 lb/ft^2

Channel Lining Analysis: Channel Lining Design Analysis - Channel D

Notes:

Lining Input Parameters

Channel Lining Type: Riprap, Cobble, or Gravel

D50: 1 ft

Riprap Specific Weight: 165 lb/ft^3

Water Specific Weight: 62.4 lb/ft^3

Riprap Shape is Angular

Safety Factor: 1

Calculated Safety Factor: 1.19647

Lining Results

Angle of Repose: 41.7 degrees

Relative Flow Depth: 2.40174

Manning's n method: Blodgett

Manning's n: 0.0715058

Channel Bottom Shear Results

V*: 1.25132

Reynold's Number: 102820

Shield's Parameter: 0.0874402

shear stress on channel bottom: 3.03433 lb/ft^2

Permissible shear stress for channel bottom: 8.97137 lb/ft^2

channel bottom is stable

Stable D50: 0.404674 ft

Channel Side Shear Results

K1: 0.802

K2: 0.740307

Kb: 0

shear stress on side of channel: 3.03433 lb/ft^2

Permissible shear stress for side of channel: 6.64157 lb/ft^2

Stable Side D50: 0.438397 lb/ft^2

side of channel is stable

Channel Lining Stability Results

the channel is stable

Channel Summary

Report for channel

Channel Analysis: Channel Analysis

Notes:

Input Parameters

Channel Type: Trapezoidal

Side Slope 1 (Z1): 2.0000 ft/ft

Side Slope 2 (Z2): 2.0000 ft/ft

Channel Width: 5.0000 ft

Longitudinal Slope: 0.0126 ft/ft

Manning's n: 0.0715

Flow: 194.0000 cfs

Result Parameters

Depth: 3.8593 ft

Area of Flow: 49.0848 ft^2

Wetted Perimeter: 22.2593 ft

Average Velocity: 3.9523 ft/s

Top Width: 20.4372 ft

Froude Number: 0.4494

Critical Depth: 2.5774 ft

Critical Velocity: 7.4123 ft/s

Critical Slope: 0.0689 ft/ft

Critical Top Width: 15.3095 ft

Calculated Max Shear Stress: 3.0343 lb/ft^2

Calculated Avg Shear Stress: 1.7338 lb/ft^2

Channel Lining Analysis: Channel Lining Design Analysis - Channel B

Notes:

Lining Input Parameters

Channel Lining Type: Riprap, Cobble, or Gravel

D50: 0.5 ft

Riprap Specific Weight: 165 lb/ft^3

Water Specific Weight: 62.4 lb/ft^3

Riprap Shape is Angular

Safety Factor: 1

Calculated Safety Factor: 1.00016

Lining Results

Angle of Repose: 41.15 degrees

Relative Flow Depth: 2.36996

Manning's n method: Blodgett

Manning's n: 0.0640199

Channel Bottom Shear Results

V*: 0.894716

Reynold's Number: 36759.1

Shield's Parameter: 0.047

shear stress on channel bottom: 1.55131 lb/ft^2

Permissible shear stress for channel bottom: 2.4111 lb/ft^2

channel bottom is stable

Stable D50: 0.321752 ft

Channel Side Shear Results

K1: 0.802

K2: 0.733562

Kb: 0

shear stress on side of channel: 1.55131 lb/ft^2

Permissible shear stress for side of channel: 1.76869 lb/ft^2

Stable Side D50: 0.35177 lb/ft^2

side of channel is stable

Channel Lining Stability Results

the channel is stable

Channel Summary

Report for channel

Channel Analysis: Channel Analysis

Notes:

Input Parameters

Channel Type: Trapezoidal

Side Slope 1 (Z1): 2.0000 ft/ft

Side Slope 2 (Z2): 2.0000 ft/ft

Channel Width: 5.0000 ft

Longitudinal Slope: 0.0150 ft/ft

Manning's n: 0.0640

Flow: 42.0000 cfs

Result Parameters

Depth: 1.6574 ft

Area of Flow: 13.7808 ft^2

Wetted Perimeter: 12.4121 ft

Average Velocity: 3.0477 ft/s

Top Width: 11.6295 ft

Froude Number: 0.4934

Critical Depth: 1.1119 ft

Critical Velocity: 5.2288 ft/s

Critical Slope: 0.0677 ft/ft

Critical Top Width: 9.4477 ft

Calculated Max Shear Stress: 1.5513 lb/ft^2

Calculated Avg Shear Stress: 1.0392 lb/ft^2

Selected Profile: FHWA Profile (read-only)

Culvert Assessment Profiles

Culvert Assessment Profile Name: Standard (read-only)

Maximum Excavation Depth: 20 ft

Maximum Shallow Cover: 4 ft

Maximum Small Pipe Size: 36 in

Minimum Manned Entry Size: 48 in

Riprap Classes

Riprap Name: CLASS I

Riprap Class: I

The following values are an 'average' of the size fraction range for the selected riprap class.

d100: 12 in

d85: 9 in

d50: 6.5 in

d15: 4.5 in

Riprap Name: CLASS II

Riprap Class: II

The following values are an 'average' of the size fraction range for the selected riprap class.

d100: 18 in

d85: 13 in

d50: 9.5 in

d15: 7 in

Riprap Name: CLASS III

Riprap Class: III

The following values are an 'average' of the size fraction range for the selected riprap class.

d100: 24 in

d85: 17 in

d50: 12.5 in

d15: 9 in

Riprap Name: CLASS IV

Riprap Class: IV

The following values are an 'average' of the size fraction range for the selected riprap class.

d100: 30 in

d85: 21 in

d50: 15.5 in

d15: 10.5 in

Riprap Name: CLASS V

Riprap Class: V

The following values are an 'average' of the size fraction range for the selected riprap class.

d100: 36 in

d85: 25.5 in

d50: 18.5 in

d15: 13 in

Riprap Name: CLASS VI

Riprap Class: VI

The following values are an 'average' of the size fraction range for the selected riprap class.

d100: 42 in

d85: 30 in

d50: 21.5 in

d15: 15 in

Riprap Name: CLASS VII

Riprap Class: VII

The following values are an 'average' of the size fraction range for the selected riprap class.

d100: 49.5 in

d85: 35 in

d50: 25.5 in

d15: 17.5 in

Riprap Name: CLASS VIII

Riprap Class: VIII

The following values are an 'average' of the size fraction range for the selected riprap class.

d100: 60 in

d85: 42.5 in

d50: 31.5 in

d15: 22 in

Riprap Name: CLASS IX

Riprap Class: IX

The following values are an 'average' of the size fraction range for the selected riprap class.

d100: 72 in

d85: 51 in

d50: 38 in

d15: 26 in

Riprap Name: CLASS X

Riprap Class: X

The following values are an 'average' of the size fraction range for the selected riprap class.

d100: 84 in

d85: 59.5 in

d50: 44.5 in

d15: 31 in

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