TM005 - Geotechnical



TM005 Geotechnical

Sevier Watershed Plan and Environmental Assessment
Sevier County, Utah

Jones & DeMille Engineering, Inc.

Project reference: Sevier Watershed Plan
Project number: 60598028

August 12, 2019

Darin Robinson, Principal
1535 South 100 West
Richfield, UT 84701

Quality information

Prepared by	Checked by	Verified by	Approved by
Bryan W. Franke, PE Geotechnical Engineer	Robert W. Snow, PE Senior Geotechnical Engineer	Michael Christianson, PE Senior GeoCivil Engineer	Robert W. Snow, PE Project Manager

Revision History

Revision	Revision date	Details	Authorized	Name	Position
0	06/26/2019	Initial	BWF		
1	08/12/2019	Flat Canyon Elevation 5609 feet	BWF		

Distribution List

# Hard Copies	PDF Required	Association / Company Name

Prepared for:

Jones & DeMille Engineering, Inc.
Darin Robinson, Principal
1535 South 100 West
Richfield, UT 84701

Prepared by:

Bryan W. Franke, PE
Geotechnical Engineer
T: 801.904.4047
M: 801.696.4964
E: bryan.franke@aecom.com

Checked by:

Robert W. Snow, PE
Senior Geotechnical Engineer
T: 801.904.4048
M: 801.661.4905
E: robert.w.snow@aecom.com

AECOM
756 East Winchester Street
Suite 400
Salt Lake City, UT 84107
aecom.com

Table of Contents

1. INTRODUCTION 6
1.1 Scope of Services 6
1.2 Project Description 6
1.3 Site Description 7
1.4 Existing Geotechnical Reports 8
2. SITE CHARACTERIZATIONS 9
2.1 Regional geology 9
2.1.1 Faulting and Mass Movement 10
2.1.1.1 Elsinore Fault 10
2.1.1.2 Bedding-Plane Slip 10
2.1.1.3 Mass Movement Age 11
2.1.2 Local Geology 11
2.1.2.1 Wood Canyon 11
2.1.2.2 Tank Canyon 13
2.1.2.3 Lind Canyon 15
2.1.2.4 Flat Canyon 17
2.2 Geologic Hazards 19
2.2.1 Seismicity 19
2.2.1.1 Seismic Design 19
2.2.1.2 Liquefaction 20
3. FIELD INVESTIGATION AND LABORATORY TESTING 21
3.1 Field Explorations 21
3.2 Site Conditions 24
3.2.1 Wood Canyon 24
3.2.2 Tank Canyon 25
3.2.3 Lind Canyon 26
3.2.4 Flat Canyon 26
3.2.5 Groundwater 26
3.3 Laboratory Testing 27
4. GEOTECHNICAL ANALYSIS 28
4.1 Embankment Geometry 28
4.2 Seepage Analysis 28
4.2.1 Model Parameters 29
4.2.2 Results 29
4.3 Slope Stability Analysis 30
4.3.1 Analysis Cases 30
4.3.1.1 Steady-State Drained Case 30
4.3.1.2 Undrained (End of Construction) Case 31
4.3.1.3 Pseudostatic Case 31
4.3.1.4 Post-Earthquake Case 31
4.3.1.5 Rapid (Instantaneous) Drawdown 31
4.3.2 Material Properties 31
4.3.3 Phreatic Conditions 32
4.3.4 Results 32
4.4 Filter Compatibility 33
4.5 Settlement 33

5. CONCLUSIONS AND RECOMMENDATIONS 34
6. LIMITATIONS 36
7. REFERENCES 37

Tables

Table 1-1. Summary of Debris Basin Geometries Considered for Geotechnical Analysis 7
Table 2-1. Summary of NRCS Seismic Design Parameters 20
Table 2-2. Summary of Utah Administrative Code Seismic Design Parameters 20
Table 3-1. Summary of AECOM Field Explorations 21
Table 3-2. Summary of Selected Laboratory Test Results 27
Table 4-1. Summary of Seepage Model Parameters 29
Table 4-2. Summary of Estimated Toe Drain Discharge 30
Table 4-3. Summary of Required Minimum Factors of Safety 30
Table 4-4. Summary of Selected Unit Weight and Strength Material Properties 32
Table 4-5. Summary of Factors of Safety against Slope Instability 32

Figures

Figure 2-1. Geologic map of Wood Canyon Site (Willis 1994). 13
Figure 2-2. Geologic map of Tank Canyon Site (Willis 1994). 15
Figure 2-3. Geologic Map of Lind Canyon Site (Willis 1994) 16
Figure 2-4. Geologic Map of Flat Canyon Site (Hintze 2003) 17

Photographs

Photo 2-1. Photograph of Exposed Flagstaff Formation, Upper Red Member. 12
Photo 2-2. Photograph of the North Embankment Area of Tank Canyon Site Showing V-Folded Syncline. 14
Photo 2-3. Photograph of the Center Embankment Area of Tank Canyon. 14
Photo 2-4. Photograph of the Center Embankment Area of Lind Canyon 16
Photo 2-5. Photograph of Boulder in Flat Canyon wash. 18
Photo 2-6. Photograph of Flat Canyon Wash. 18
Photo 3-1: View of a Track-Mounted Drill Rig Used for Drilling 23
Photo 3-2: View of a Track-Mounted Excavator Used for Test Pitting 24
Photo 3-3: View of Floor and Wall in Wood Canyon Wash 25

List of Attachments

Attachment A Figures
Attachment B Existing Reports
Attachment C Boring Logs
Attachment D Test Pit Logs
Attachment E Laboratory Test Data
Attachment F Seepage and Slope Stability Results
Attachment G Recommended Filter Bands

1. INTRODUCTION

AECOM Technical Services, Inc., (AECOM) is pleased to provide this geotechnical report presenting findings and recommendations in support of the Sevier Watershed Plan and Environmental Assessment (EA) performed by Jones & DeMille Engineering, Inc., (Jones & DeMille). The purpose of this study was to provide an assessment of geotechnical-related considerations pertaining to the proposed project sites based on our subsurface explorations, laboratory testing, and analysis. The findings and recommendations presented in this report are based on our understanding of the project and encountered surface and subsurface conditions at the project sites.

Based on information provided to us by Jones & DeMille, the general location of each of the basins considered in this report is near the mouths of drainages at Wood Canyon, Tank Canyon, Lind Canyon, and Flat Canyon. The debris basins will reduce peak flows during a flood and capture loose material such as sediment, gravel, boulders, and vegetative debris that are washed out of the canyons during storms. This will greatly reduce the potential for debris to block existing channels and overflow. These improvements will help protect the homes, businesses, roads, and utilities below the basins from damage during a high runoff storm event. AECOM also understands that the proposed design will retain enough storage volume within each basin to provide 100 years of sediment storage and still contain the design inflow.

1.1 Scope of Services

AECOM's geotechnical scope of services for this study included the following:

- Review of available geotechnical data, aerial photographs, and published geologic maps, soil data, and literature.
- Coordination and mobilization for subsurface exploration. Marking existing public utilities was conducted through Blue Stakes of Utah.
- Drilling, test pitting, logging, and sampling of 4 exploratory borings and 12 test pits to depths ranging from 6 to 59 feet near the locations of potential debris basin embankment sites. The purposes of the subsurface explorations were to gather data regarding subsurface conditions and to obtain soil samples for laboratory testing.
- Assignment and performance of laboratory tests to provide physical and engineering properties of subsurface soils, consisting of gradation, Atterberg limits, and modified proctor.
- Compilation and analysis of the accumulated data for seepage, slope stability, settlement, and filter compatibility, for proposed embankment sections.
- Preparation of this report presenting our data, findings, and engineering recommendations.

1.2 Project Description

The project comprises four debris basins in four different canyons including Wood Canyon, Tank Canyon, Lind Canyon, and Flat Canyon. Dam cross sections developed in this report are preliminary in nature to determine project feasibility and require additional investigations and assessments in future designs. Jones & DeMille performed engineering analysis and development of hydrology, sediment and water storage volume, and embankment height. AECOM's understanding of each embankment's proposed location, height, and length, are based on Jones & DeMille's work.

The proposed basin in Wood Canyon would contain the tallest embankment being approximately 65 feet tall and providing approximately 89 acre-feet of storage at the spillway crest. The 100-year sediment storage volume for Wood Canyon would be approximately half of this volume. The embankment in Flat Canyon would be approximately 67 feet tall making this basin in Flat Canyon the largest storage volume at approximately 809 acre-feet. The 100-year

sediment storage volume for Flat Canyon would be approximately half of this at approximately 359 acre-feet of sediment.

The embankments in Tank and Lind Canyons are proposed to be constructed in two segments bisected by existing geologic features. The embankments in Tank and Lind Canyons would be approximately 32 and 30 feet tall, respectively. Tank Canyon would provide approximately 40 acre-feet of storage while Lind Canyon would provide approximately 63 acre-feet of storage at the spillway crest. The 100-year sediment storage volume for these basins would be approximately 50 to 60 percent of this volume. Design plan, section, and profile drawings, which were considered in this report and which were used for supporting geotechnical analysis, are provided in Attachment A.

The embankments are each to be constructed with zoned soils consisting of a clay core, a downstream filter zone with a toe drain, and upstream and downstream shells composed of compacted granular fill from within the basins. The upstream slopes are planned with slopes of 3 horizontal to 1 vertical (3H:1V) and downstream slopes as 2.5H:1V. The crest widths were assumed to be 12 feet wide for preparation of this document; however, during final design, embankment crest widths of at least 14 feet should be considered in accordance with TR-210-60 (Natural Resources Conservation Service [NRCS] 2019) for embankments that more than 25-feet tall and less than 95 feet tall. The basic geometries of each of the analyzed embankments are summarized in Table 1-1.

The Utah Division of Water Rights, Dam Safety, and Natural Resources Conservation Service (NRCS), in accordance with guidelines outlined in TR-210-60 (NRCS 2019), classify dams considering a number of different factors and may include the damage that might occur to existing and future developments as a result of a breach, effect of major infrastructure and utilities, effect of failure on public confidence, site characteristics, and potential for loss of life. Because failure may result in downstream losses to both life and property, impacts to important public utilities and main highways, embankment height, and basin storage volume, these structures are assumed to be high hazard potential facilities.

Table 1-1. Summary of Debris Basin Geometries Considered for Geotechnical Analysis

Debris Basin	Embankment Height (ft)	Crest Elevation (ft)	Spillway Elevation (ft)	100-Year Sediment Elevation (ft)	Design Water Depth at 100 Years (ft)	Crest Width [1] (ft)	Upstream Slope [1] (H:V)	Downstream Slope [1] (H:V)
Wood Canyon [2]	65	5,670	5,662	5,650	12	--	--	--
Flat Canyon	67	5,609	5,599	5,579	22	12	3:1	2.5:1
Tank Canyon	32	5,457	5,449	5,444	5	12	3:1	2.5:1
Lind Canyon	30	5,450	5,442	5,434	8	12	3:1	2.5:1

Notes: ft = feet; H = horizontal; V = vertical, '--' denotes a blank entry

1. The crest width, upstream slope, and downstream slope dimensions shown here were assumed for geotechnical analysis presented in this document. Accordingly, these parameters may not be consistent with NRCS and Utah Dam Safety design recommendations, which are presented elsewhere.
2. It was concluded that the abutments were not suitable for dam construction without significant modification. Accordingly, the following subsections only present analysis and results for Tank Canyon, Lind Canyon, and Flat Canyon, structures; Wood Canyon was excluded from analysis and further consideration.

1.3 Site Description

The proposed basins and drainages are located approximately west of Richfield, Utah, and just west of Interstate Highway 70 (I-70) through Central Utah. The project sites are generally bounded by steep canyon walls at either end of each proposed embankment. Each of the proposed basin sites was accessible by unpaved road and covered with sparse vegetation, generally consisting of brush and grasses. Very few trees were observed.

There are no existing buried facilities that were identified at any of the project sites. However, the Tank and Lind Canyon sites contain existing geologic features bisecting the proposed embankment that support overhead power poles. These poles support power lines overhead across some parts of the proposed embankment footprints. Flat Canyon also has overhead powerlines, but these were not observed in the vicinity of the proposed footprint of the embankment.

1.4 Existing Geotechnical Reports

Schick International, Inc., performed a feasibility-level investigation and prepared a report for flood control basins to mitigate flood damages resulting from discharge from 23 square miles of mountainous area west of Richfield, Utah (Schick International Inc. 1977). This report presented flood plan information along with preliminary hydrologic, geologic, and economic discussion. Deming and Bridges (1976) also prepared a geologic report addressing faulting and seismicity in the area. This report specifically addressed geologic conditions in Flat, Dairy-Rulon Lind, and Tank Canyons. These documents were reviewed and considered in preparation of this geotechnical report. The Schick International Inc. (1977) report is included as an attachment to TM002 and the Deming and Bridges (1976) report is included as Attachment B to this document.

2. SITE CHARACTERIZATIONS

The following sections provide descriptions of regional geology, geologic hazards, and mapped soil conditions for the proposed projects.

2.1 Regional geology

The study area is located west of Richfield, Utah, on the margin between the eastern lower slopes of the Pahvant Range and Sevier Valley and is part of the High Plateaus province of Central Utah. Sevier valley is bounded by active normal faults, Elsinore fault on the west and Sevier fault on the east (Willis 1994). Strata beneath the valley are assumed to be folded into a broad syncline and cut by high angle faults (Elsinore and Sevier). Pahvant Range and Sevier Valley are located in an area of complicated local geology and are located in a transitional zone between highly extended block-faulted terrain of the Basin and Range province (west of Pahvant Range) and the mostly undeformed Colorado Plaueau (east of the Sevier Plateau) (Willis 1994). The study area is located on the western margin of Sevier Valley, a north-south trending valley, formed between the Pahvant Range and Sevier Plateau.

Exposed rocks in the Pahvant Range are Tertiary in age and dip eastward approximately 5-10 degrees (Willis 1994). The study is near the northern edge of the Maryvale volcanic field and may have also received material derived from the Tintic or Thomas-Drum volcanic fields to the northwest. A generalized stratigraphic column is provided in Attachment A and is generally based on the Utah Geological Survey, Open File Report 309 (Willis 1994) and Utah Geological Survey Map 135 (Hintze 2003). Mapped lithologic units in the study area are shown on the generalized stratigraphic column are listed below.

- Osiris Tuff (To) – reddish-brown, moderately ,crystal-rich, densely welded rhyodacitic ash-flow tuff, 23 million years ago (Ma), maximum thickness 200 feet
- Tuff of Albinus Canyon (Ta) – red to gray, crystal poor, densely welded, trachytic ash-flow tuff, 25.3 Ma, maximum thickness 650 feet
- Bullion Canyon Volcanic (Tb), Three Creek Tuff Member (Tbt)– light gray to light brown, crystal-rich, moderately to densely welded dacitic ash-flow tuff, 27 Ma, maximum thickness 720 feet
- Aurora Formation (Tau) – yellow gray to pale brown, bentonitic siltstone and claystone, with thin beds of gray limestone, pebble to cobble conglomerate, fine grained sandstone, contains upwardly increasing amounts of fine grained rhyolitic and reworked volcanic detritus, 38-40 Ma, maximum thickness 1,200 feet
- Crazy Hollow Formation (Tch, Tchs) – brownish orange to brownish red very thin to thin planar bedded fine grained sandstone, siltstone, and mudstones, interbedded, thin to zero southwest of Richfield, Utah, early Oligocene, maximum thickness 350 feet
- Dipping Vat Formation (Tdv) – light gray to pale bluish gray, volcanic clastic sandstone, conglomerate, and reworked volcanic tuff, 35-27 Ma, maximum thickness 600 feet
- Green River Formation (Tg, Tgs)– yellowish gray to pale brown cherty algal and oolitic limestone and dolomite calcareous, fine grained sandstone, early Eocene, maximum thickness 800 feet
- Flagstaff Formation (Tf, Tfuw, Tfur) – pinkish-weathered freshwater limestone, sandstone, siltstone, mudstone, and conglomerate, typically bioturbates, southwest of Pahvant Range lithology is dominated by conglomerate exposure, early Paleocene, maximum thickness 3,500 feet
  - Upper White Member – pale gray, pale purplish gray, or pale yellowish gray, calcareous mudstone, siltstone, sandstone, and sandy limestone, maximum thickness 170 to 185 feet
  - Upper Red Member – dark reddish brown, calcareous mudstone, siltstone, sandstone, with local conglomerate, interbedded, maximum thickness 50 to 162 feet

The bedding planes dip along the eastern margin of the Pahvant Range in an easterly valley making the lower slopes prone to mass movement (landslides and slumps). The entire eastern margin of the Pahvant Range is extensively mapped as mass movement departs. The eastern lower slopes of the Pahvant Range are susceptible to mass movement for the following reasons (Willis 1994):

- The bedrock bedding planes dip 5-10 degrees in easterly direction towards the valley;
- The bedrock consists of alternating layers of fractured permeable and impermeable layers;
- Surface water percolates downward through the fractured permeable bedrock and accumulates on impermeable layers;
- Impermeable layers are largely comprised of fine grained material, inorganic clays, that significantly loses strength when surface of the fine grain layer becomes fully hydrated or saturated; and
- Structural uplift and tilting of the Pahvant Range has developed high topographic relief and has removed down slope support.

Complex landside departs located on the eastern slopes of the Pahvant Range make mapping and structural interpretation challenging and extensive bedding-plane slides and discordant slumps dominate the shallow surficial geology of the area. The landslide and slump blocks vary greatly from highly jumbled large and massive bedrock blocks (several hundred feet across or larger) to jumble brecciated masses with few or no large intact bedrock blocks (Willis 1994). In areas, the bedrock has experienced moderate slumping but still mainly intact and have been mapped over low angle faults or detachments.

2.1.1 Faulting and Mass Movement

Basin and Range faulting in the Sevier Valley likely began as early as early-middle Miocene, approximately 17 million years ago. The Sevier River Formation overlapped rocks now exposed on the range indicating the range did not significantly rise until after its deposition. Faulting along the Pahvant Range likely did not occur until after deposition of the Sevier River Formation, placing the timing of the Pahvant Range uplift from 15 million years ago to 5 million years ago (Willis 1994).

2.1.1.1 Elsinore Fault

The Elsinore fault is located on the eastern flanks of the Pahvant Range and has been intermittently active since Pahvant Range uplift began. The fault is largely concealed beneath active Quaternary alluvial fans and little to no Quaternary fault scarps have been mapped in the area. Alluvial fan depositions along the eastern slopes of the Pahvant Range are very active and rapidly destroy any evidence of faulting along the Elsinore fault (Willis 1994). The fault origination and slip directions along the Pahvant Range may be incompatible with the existence of a major range fault and due to the lack of a preserved quaternary fault scarp, the Elsinore fault has been speculated to be a southeast-facing monocline over a major buried fault at depth (Hecker 1993).

2.1.1.2 Bedding-Plane Slip

Bedding-plane slip is common within the study area and involves movement on low-angle surface detachments toward the Sevier Valley. Bedding-plane slip is concentrated on three main detachment surfaces as listed below (Willis 1994):

- Base of the Upper White Member of the Flagstaff Formation
- Near the base of the Green River Formation
- Near the base of the Aurora Formation

Other bedding surfaces have detached locally through the eastern slopes of the Pahvant Range.

Large landslides have been mapped south of Willow Creek Canyon as QMS and have experienced large and extensive movement down-slope topographically towards the valley. Blocks are highly fractured and disjointed with bedrock beds deformed. Little to no in-place bedding planes remain in this area. The primary detachment is near the base of the Green River Formation (Willis 1994). The detachment is exposed at the surface in the northern part of Cottonwood Creek Canyon and plunges beneath the surface in a southward direction along the front of the mountain range. Southwest of Richfield, the detachment is estimated to be approximately 300 feet below the ground surface and the shallow alluvial fill is thought to be an insufficient buttress to impede slow movement of slump material along the detachment (Willis 1994).

2.1.1.3 Mass Movement Age

The age of landslide and slump movement is not well understood and is poorly constrained. Pedogenic carbonate within the landslide and slump blocks is stage 1 to stage 1+, indicating the movement likely occurred during late Quaternary period. Landsides and slump block movement along the eastern slopes of the Pahvant Range likely occurred during the last glacial wet cycle (15,000 to 25,000 years ago) (Willis 1994). During the last wet cycle in Utah (1983 to 1985) no mass movement was observed along the eastern slopes of the Pahvant Range. This could mean the landslide and slump areas were not extensively monitored during the 1980's or could indicate that movement only occurs over wet-cycle time periods (Willis 1994).

2.1.2 Local Geology

Site specific geology at the four sites studied are dominated by interbedded siltstone, sandstone, mudstone, and weathered volcanics. Landslides and slump blocks, which are present at all sites, dominate the local geology creating jumbled bedrock blocks along the front of the Pahvant Range. The rocks at the sites are highly fractured with slumps and landslide movement towards Sevier valley along low angle detachments. Below are summaries of the sites geology.

2.1.2.1 Wood Canyon

The rocks in Wood Canyon are highly fractured but are relatively undeformed. The bedding-plane detachment is located above the site along the south ride line near the contact between the Flagstaff and Green River formation resulting in relative undeformed bedrock at the site (Photo 2-1: The Upper Red and White Members within Wood Canyon are highly fractured. The Upper Red Member is composed of alternating layers of siltstone and sandstone. Detachment located near the top of the south ridge; Figure 2-1: Approximate embankment location shown with green line. Note the detachment near the top of the south ridge. Map not to scale. North is up.). The bedrock exposed at the site is Upper Red Member of the Flagstaff Formation and is composed of alternating layers of highly fractured siltstone and sandstone. The Upper Red Member forms cliffs along the south side of the canyon which are prone to rock spalling. The site is located approximately 300 feet west of the Elsinore fault. A large alluvial fan has formed at the mouth of Wood Canyon and portions have been mined for sand and gravel. Exposed alluvium in the lower canyon is substantially comprised of debris flow deposits with large boulders.

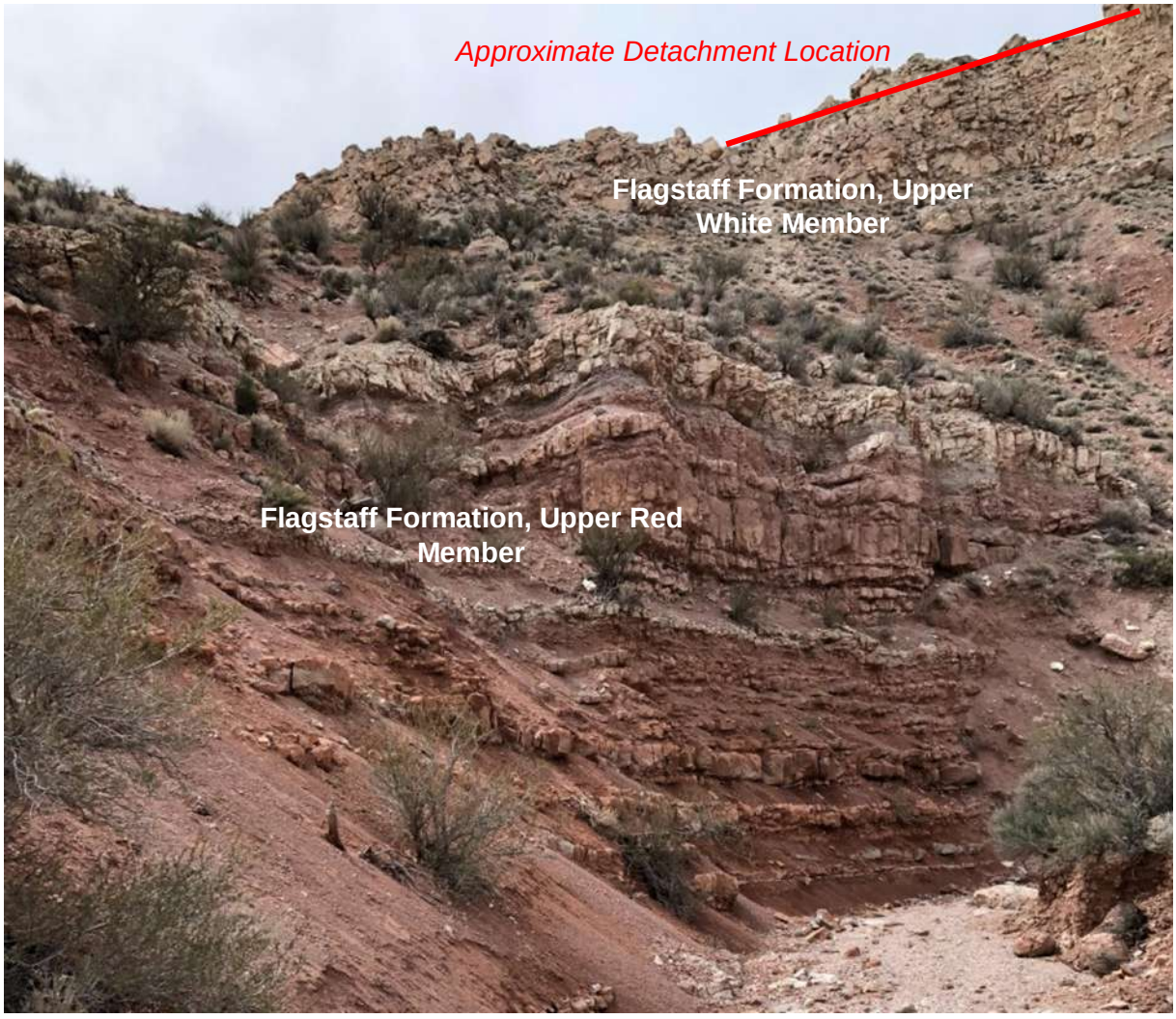


Photo 2-1. Photograph of Exposed Flagstaff Formation, Upper Red Member.

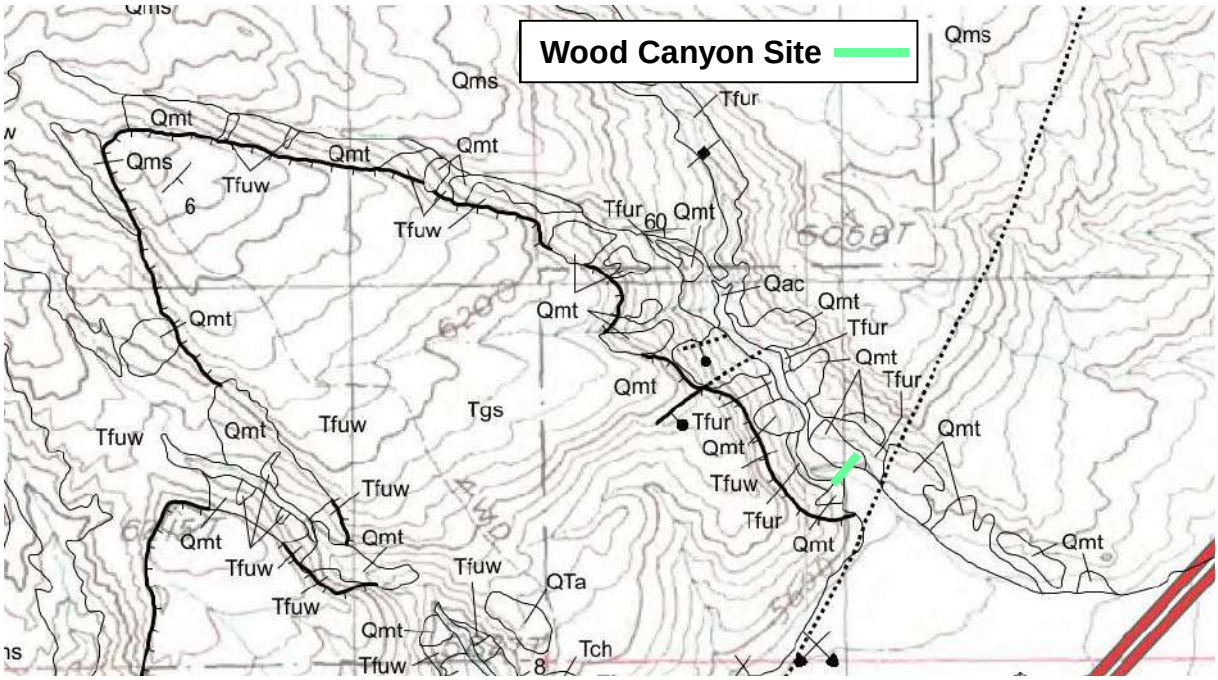


Figure 2-1. Geologic map of Wood Canyon Site (Willis 1994).

2.1.2.2 Tank Canyon

The rocks on both sides and center of Tank Canyon are highly fractured and deformed by a bedding-plane slip along low-angle surface detachments downslope toward the Sevier Valley. The detachment plunges likely in an easterly or southeasterly direction beneath the surface of the Pahvant Range towards the valley. The exact depth of the detachment at Tank Canyon is not known but it is thought to be at least a few hundred feet below ground surface at the site. The bedding planes along the north side of Tank Canyon have been folded into a V-shape syncline (Photo 2-2; Figure 2-2: Approximate embankment locations are shown as green lines. Note the syncline and detachment locations on the map. Map not to scale. North is up.). Directly east of the concrete water tank is small hill comprised of a large detached bedrock block consisting mainly of the Crazy Horse Formation. This detached bedrock block forms the center portion of the dam and the block has been rotated approximately 90 degrees in contrast to the beds on the north and south as seen in Photo 2-3 (Dashed red lines show approximate azimuth or strike of the beds. Hill in the center of Tank Canyon is rotated 90 degrees from the beds on the north and south sides of the canyon. Bedrock in the central hill is detached.). This rotation could indicate the bock is sitting on unconsolidated alluvium or other jumbled bedrock blocks. The site is located approximately 1,800 feet west of the Elsinore fault. The area east and south of the site has been mined for sand and gravel.

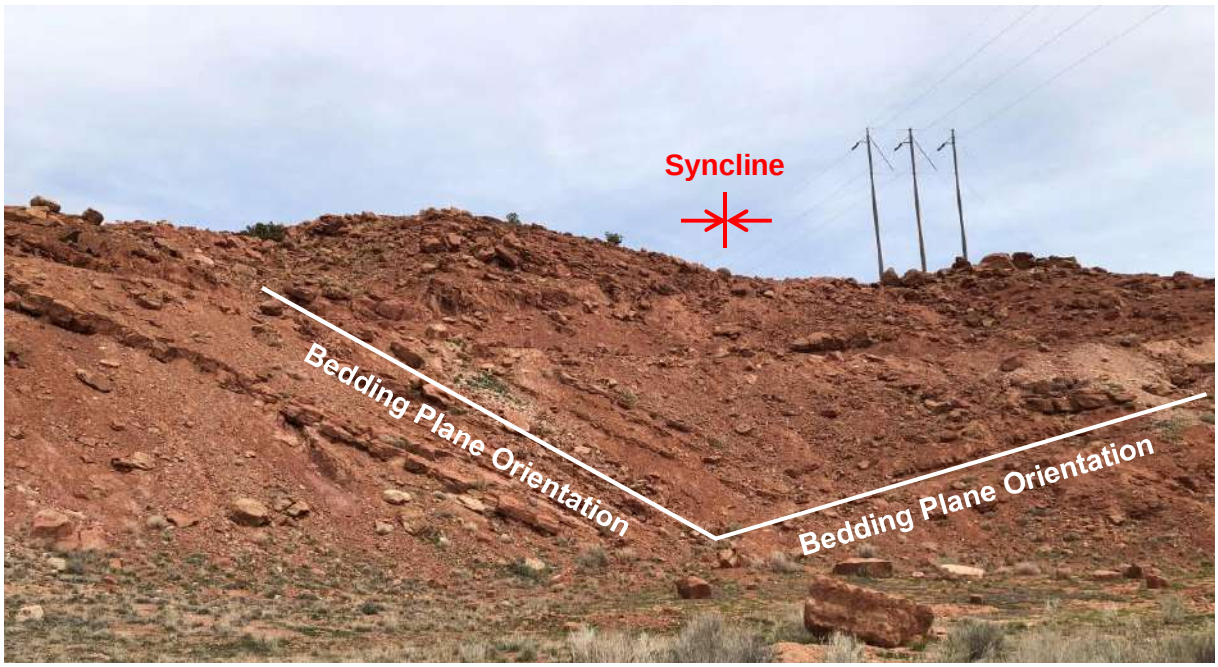


Photo 2-2. Photograph of the North Embankment Area of Tank Canyon Site Showing V-Folded Syncline.



Photo 2-3. Photograph of the Center Embankment Area of Tank Canyon.

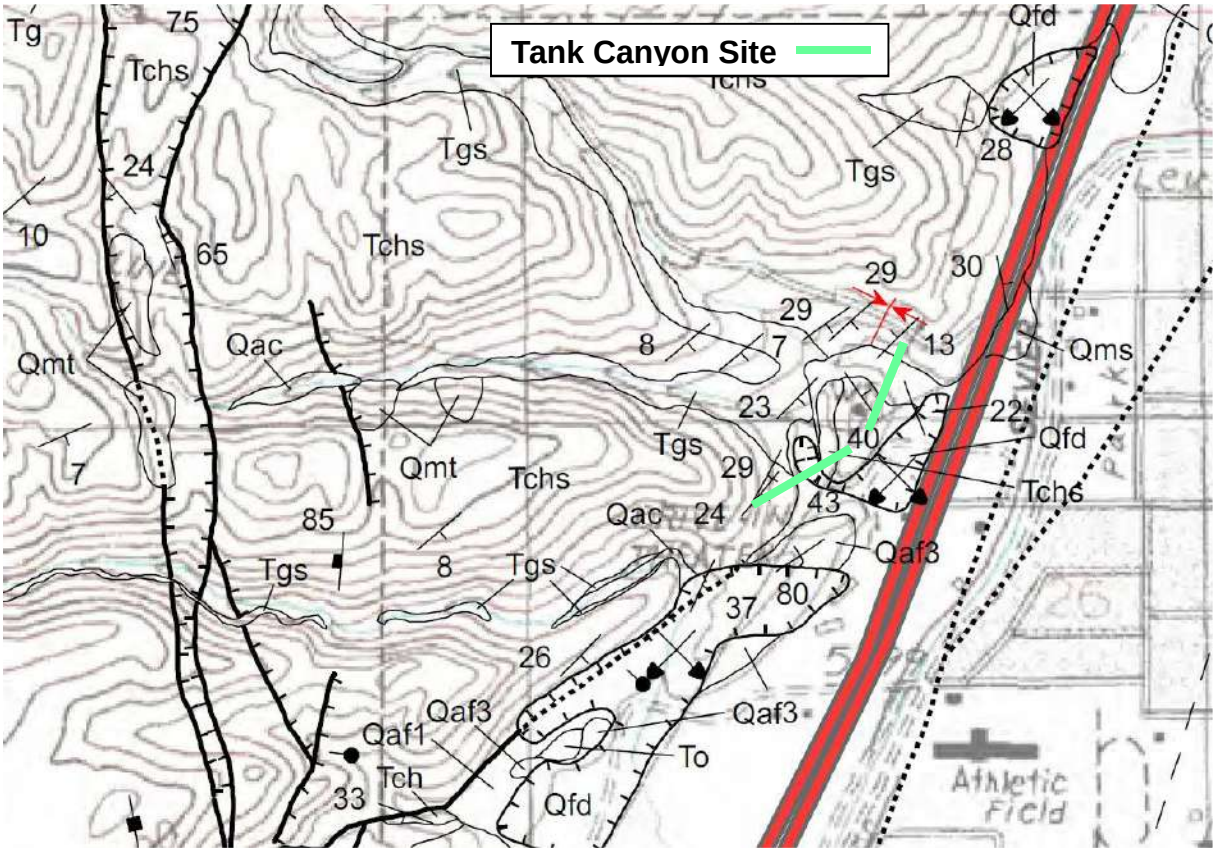


Figure 2-2. Geologic map of Tank Canyon Site (Willis 1994).

2.1.2.3 Lind Canyon

The rocks west of the site in Lind Canyon are highly fractured and deformed by bedding-plane slip along low-angle surface detachments downslope toward the Sevier Valley and are similar to Tank Canyon. The site for Lind Canyon is at the mouth of the canyon located within alluvial deposits (Photo 2-4: The site was formerly mined for sand and gravel and the central hill was mined around it to protect overhead power infrastructure; Figure 2-3: Approximate embankment location shown with green line. Note that the site is located within the footprint of a large former sand and gravel mine. Center point of site is unmined alluvium left to protect overhead power infrastructure. Map not to scale. North is up.). The site is located approximately 1,800 feet west of the Elsinore fault. The site is located within a former sand and gravels mine. Exposed alluvium at the site is substantially comprised of debris flow deposits with very few large boulders. The majority of the alluvium consists of sand and gravel with a minor amount of cobbles.



Photo 2-4. Photograph of the Center Embankment Area of Lind Canyon.

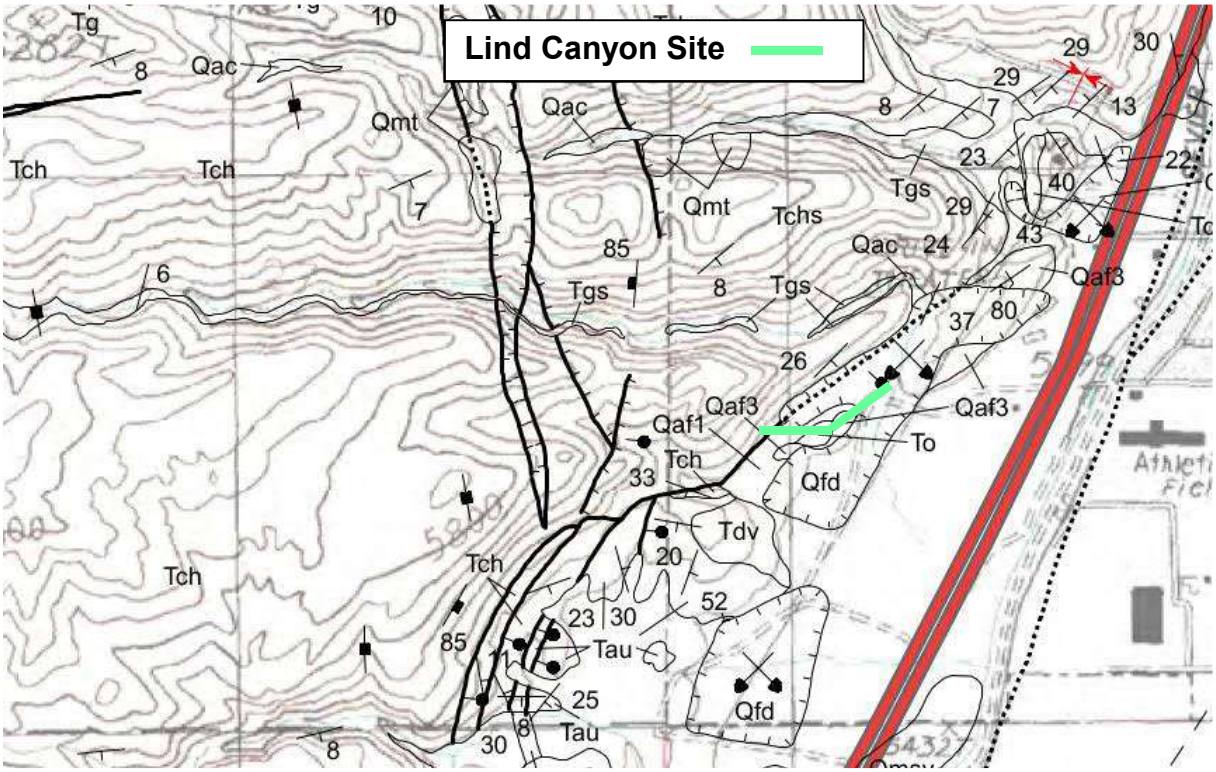


Figure 2-3. Geologic Map of Lind Canyon Site (Willis 1994).

2.1.2.4 Flat Canyon

The rocks within Flat Canyon are highly fractured and deformed by bedding-plane slip and or slumping along low-angle surface detachments downslope toward the Sevier Valley as seen in Figure 2-4 (Map not to scale. North is up.) (Hintze 2003). The detachment plunges likely in an easterly or southeasterly direction beneath the surface of the Pahvant Range towards the valley (Willis 1994). The exact depth of the detachment at Flat Canyon is not known but it is thought to be at least a hundred feet or so below ground surface at the site. The bedding plane slip surface is likely near the base of the Aurora Formation (Hintze 2003). The drainage basin is sufficiently large enough to produce substantial flow during heavy monsoon (August) rain events and has produced flow large enough to transport large boulders downstream to the leading edge of the alluvial fan as seen in Photo 2-5 (Note the large boulder within the channel. Similar boulders are found through Flat Canyon alluvial fan and a larger boulder field has been weathered out between Interstate 70 and the mouth of Flat Canyon.). The exposed rock at the site are Tuff of Albinus Canyon (Tac), a crystal, poorly densely welded trachytic ash-flow tuff and Aurora Formation (Tau), a bentonitic siltstone and claystone with reworked volcanic detritus. Numerous slump and bedding plane detachment surfaces have been mapped along the south side of the canyon. The trachytic ash-flow tuff is substantially more competent with large outcrops present on the north side of the canyon. The southern side of the canyon is dominated by weathered volcanic and bentonitic siltstone and claystone that have slipped or moved downslope towards the Sevier valley (Photo 2-6: Looking south towards numerous bedding plane slip and slump blocks). Some competent trachytic ash-flow tuff is present within the proposed southern embankment area. The site is located approximately 1,800 feet west of the Elsinore fault.

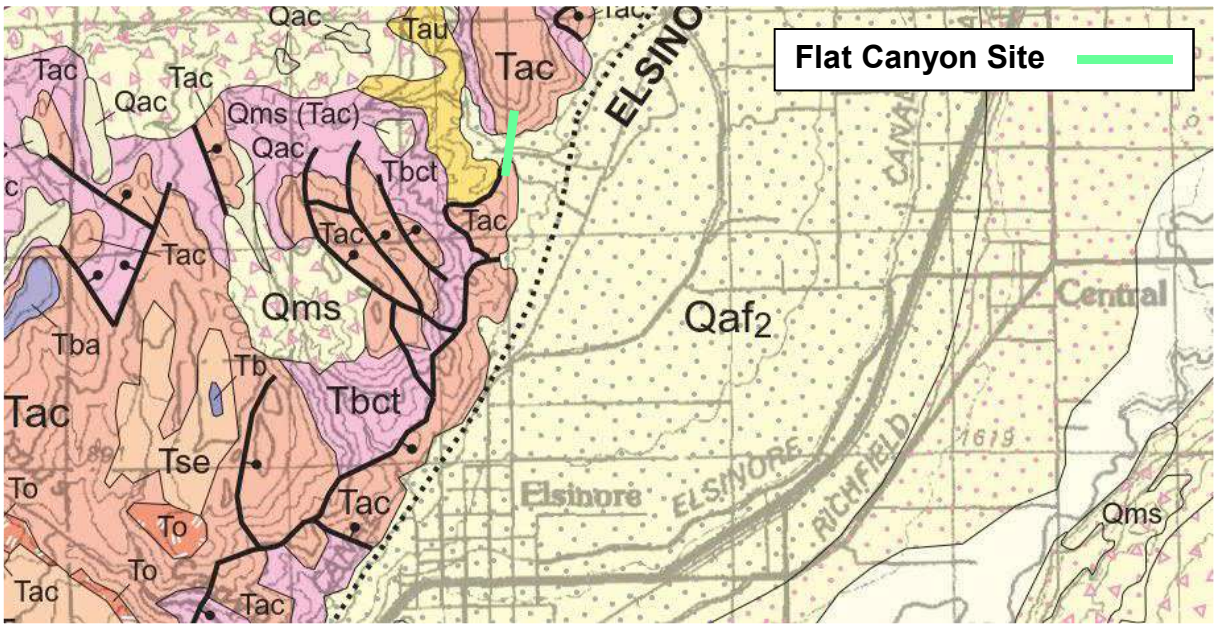


Figure 2-4. Geologic Map of Flat Canyon Site (Hintze 2003).



Photo 2-5. Photograph of Boulder in Flat Canyon wash.



Photo 2-6. Photograph of Flat Canyon Wash.

2.2 Geologic Hazards

A geologic hazard is an adverse geologic condition, which is capable of causing loss or damage to life or property and may occur suddenly or gradually with time. These hazards are often associated with natural disasters, but may also include less devastating, more frequent phenomena. The following subsections provide descriptions of geologic hazards to which the project sites may be subject and discuss potential impacts each hazard may have at the project sites.

2.2.1 Seismicity

The Sevier Valley is located within the Intermountain Seismic Belt (ISB), one of the most seismically active areas in the interior, western United States (US). The east and west margins of the valley are formed by the Elsinore Fault to the west and Sevier Fault to the east. The Elsinore fault is characterized as a normal fault and is mapped to be approximately 28 kilometers long and has a strike north to northeast along the base of the mountains on the west side of the Sevier Valley. The Elsinore fault is mapped to be within 1 mile of each of the proposed debris basin sites. Other minor faults have been mapped in the area that are presumed to be the result of seismic activity associated with the Sevier or Elsinore fault zones. The Sevier and Elsinore faults are the predominant contributors to the seismic hazard at the basin sites.

In recent history, seismic activity and damaging ground motions have been documented (Schick International, Inc. 1977). Plots of earthquake epicenters suggest that the southern portion of the Elsinore fault is the most active portion of the fault; however, evidence of fault movement was also observed in the northern portions of the fault (Deming and Bridges 1976). Deming and Bridges (1976) performed fault mapping and a seismic evaluation for several debris basin sites along the Elsinore fault. They suggest that seismic adjustment is still occurring along the Elsinore fault and the maximum credible earthquake that can be expected from Elsinore fault zone is estimated at 7.4 Richter magnitude. On November 13, 1901, an earthquake with an estimated Richter magnitude of 6.5 or larger occurred and was likely centered near Richfield and was associated with the Elsinore fault. Large surface displacements estimated to be up to 8 feet are also possible. For a full overview of their fault mapping and seismic evaluation, the entire Deming and Bridges (1976) report is provided as Attachment B. The Schick International Inc. (1977) report, which also summarizes the seismic hazard for several of the basins, is also provided as an attachment to TM002.

2.2.1.1 Seismic Design

The NRCS recommends that earthquake loading be considered for all dams (NRCS 2019). According to NRCS design guidelines for earth dams, the maximum deign earthquake (MDE) corresponds to a return period of 10,000 years for high consequence of failure facilities. As a minimum, the NRCS recommends that the operating basis earthquake (OBE) correspond to a return period of 500 years for high consequence of failure facilities. The seismic design parameters associated with the MDE and OBE for the debris basin sites are summarized in Table 2-1.

According to Utah Administrative Code (UAC) Title R655, Chapter 11, Part 5, seismic analysis of dams should include a seismological investigation to determine design ground motions and to consider potential fault rupture. Due to the relative proximity of the basin sites to known mapped active faults, strong ground shaking should be considered. In accordance with UAC, both the maximum credible earthquake (MCE) and OBE should be considered in design. The MCE should be evaluated using both deterministic and probabilistic methods. A deterministic seismic hazard analysis is not within the scope of this work and was not performed for the basin sites; however, probabilistic ground motions for each of the basin sites were developed using the United States Geological Survey (USGS) Unified Hazard Tool for the MCE and OBE having a return period of 5,000 and 200 years, respectively. The seismic design parameters associated with the MCE and OBE for the debris basin sites are summarized in Table 2-2.

Table 2-1. Summary of NRCS Seismic Design Parameters

Location and Event	Peak Ground Acceleration, PGA (g)	Mean Magnitude (-)	Mean Distance (km)	Modal Magnitude (-)	Modal Distance (km)
Wood Canyon MDE	0.49	6.08	9.69	6.5	8.16
Wood Canyon OBE	0.14	5.93	18.97	5.1	9.95
Tank Canyon MDE	0.47	6.13	10.65	6.3	9.19
Tank Canyon OBE	0.14	5.94	19.39	5.1	10.54
Lind Canyon MDE	0.47	6.13	10.65	6.3	9.19
Lind Canyon OBE	0.14	5.94	19.39	5.1	10.54
Flat Canyon MDE	0.47	6.14	10.58	6.5	8.74
Flat Canyon OBE	0.14	5.94	19.25	5.1	10.73

Notes: MCE = “maximum design earthquake”; OBE = “operating basis earthquake” with 500-year return period; km = “kilometers”

Source: United States Geological Survey (USGS) Unified Hazard Tool; Dynamic: Conterminous U.S. 2014 (v.4.1.1) seismic source model: https://earthquake.usgs.gov/hazards/interactive/

Table 2-2. Summary of Utah Administrative Code Seismic Design Parameters

Location and Event	Peak Ground Acceleration, PGA (g)	Mean Magnitude (-)	Mean Distance (km)	Modal Magnitude (-)	Modal Distance (km)
Wood Canyon MCE	0.47	6.23	9.99	6.1	9.1
Wood Canyon OBE	0.1	6.02	23.95	5.1	11.08
Tank Canyon MCE	0.46	6.27	10.55	6.3	9.7
Tank Canyon OBE	0.1	6.01	23.57	5.1	11.01
Lind Canyon MCE	0.46	6.27	10.55	6.3	9.7
Lind Canyon OBE	0.1	6.01	23.57	5.1	11.01
Flat Canyon MCE	0.48	6.26	10.01	6.1	8.91
Flat Canyon OBE	0.1	6.0	22.15	5.1	11.46

Notes: MCE = “maximum considered earthquake”; OBE = “operating basis earthquake” with 200-year return period; km = “kilometers”

Source: United States Geological Survey (USGS) Unified Hazard Tool; Dynamic: Conterminous U.S. 2014 (v.4.1.1) seismic source model: https://earthquake.usgs.gov/hazards/interactive/

Due to the proximity of active faults in the area, the potential for ground fault rupture is relatively high and should be considered in final design. It is possible that active sedimentation at the basin sites may have covered evidence of recent or historical fault rupture activity in the area (Deming and Bridges 1976).

2.2.1.2 Liquefaction

Seismically-induced liquefaction occurs from development of excess pore pressures with earthquake loading, within typically loose, saturated, and cohesionless soils. The generation of excess pore pressures leads to lowered effective stresses within the liquefied soil layer, weakening the soil. Liquefaction effects can include sand boils, settlement, lateral spread, and loss of bearing capacity. Based on the relatively deep groundwater relative to the height of the embankment and the low likelihood that the basin would be filled with appreciable water during an earthquake, liquefaction is not anticipated at any of the project sites and is not considered in any underlying analysis.

3. FIELD INVESTIGATION AND LABORATORY TESTING

The following sections provide a summary of the field investigation, subsurface materials and conditions, and laboratory testing for the project.

3.1 Field Explorations

AECOM performed geotechnical explorations, which included four (4) boreholes and 13 test pits, to assess subsurface conditions at the proposed debris basin sites. The exploration locations were selected for preliminary embankment locations based on information collected during a January 11, 2019, site visit to each of the proposed sites, existing geologic maps and reports, and AECOM's understanding of proposed basin designs. The field explorations were performed between February 19, 2019, and February 23, 2019. The explorations performed at the project sites are summarized in Table 3-1.

Table 3-1. Summary of AECOM Field Explorations

Field Exploration	Ground Surface Elevation (ft)	Total Depth Explored (ft)	Encountered Groundwater Depth (ft)
BH19-WC-01	5,591 [1]	21.0	-- [3]
BH19-TC-01	5,422 [1]	50.3	32
BH19-LC-01	5,423 [1]	21.4	-- [3]
BH19-FC-01	5,571 [1]	59.0	-- [3]
TP19-FC-01	-- [2]	21.0	-- [3]
TP19-FC-02	-- [2]	19.0	-- [3]
TP19-FC-03	-- [2]	21.0	-- [3]
TP19-LC-01	-- [2]	12.0	-- [3]
TP19-LC-02	-- [2]	16.0	-- [3]
TP19-LC-03	-- [2]	25.0	-- [3]
TP19-LC-04	-- [2]	20.0	-- [3]
TP19-TC-01	-- [2]	8.0	-- [3]
TP19-TC-02	-- [2]	15.0	-- [3]
TP19-WC-01	-- [2]	16.0	-- [3]
TP19-WC-02	-- [2]	17.0	-- [3]
TP19-WC-03	-- [2]	6.0	-- [3]
TP19-WC-04	-- [2]	19.0	-- [3]

Notes: ft = feet; '--' denotes a blank entry

3. Ground surface elevation was not surveyed, but was estimated from elevation contours of each site.
4. Ground surface elevation was not surveyed.
5. Groundwater not encountered at the time of exploration.

The drilling was performed by ConeTec, Inc., of Salt Lake City, Utah, under subcontract to AECOM. Exploration locations are indicated on the geotechnical drawings provided in Attachment A. The exploratory borings were advanced using 4.25-inch inner diameter (ID) hollow-stem-auger drilling methods to depths ranging from 21 to 59 feet below the existing ground surface. Drilling equipment included a CME-850 track-mounted drill rig equipped with a two-pronged spade bit.

Penetration resistances were obtained from the number of hammer blows observed to drive a split-spoon standard penetration test (SPT) sampler or a non-standard-size split-spoon, 3-inch outside diameter (OD) sampler. A 140-pound hammer weight was dropped onto the sampler rod helmet from a height of 30 inches using an automatic hammer. The resistance to sampler penetration (blowcount or N-value) is noted as “N” in the logs and refers to the number of hammer blows needed to advance the sampler a distance of 12 inches, beginning after an initial 6 inches of penetration into the subsurface materials (i.e., the number of hammer blows for 18 inches of sampler penetration minus the number of hammer blows for the first 6 inches of penetration). The blowcount at each sample depth was corrected for drilling conditions, rod length, sampler size, hammer energy, and overburden stress to obtain the N_{60} and $(N_1)_{60}$ values. The calibrated average energy transfer ratio for the hammers used on the CME-850 drill rig is 79.2 percent based on relatively recent calibration testing.

Boreholes in Tank, Lind, and Flat Canyons were abandoned using portland cement bentonite grout filling the hole from the bottom of the hole to the ground surface by tremie pipe. The single borehole performed in Wood Canyon encountered an obstruction on one side of the hole at approximately 20 feet, which caused the augers to bind up. Consequently, a test pit was performed at the location of BH19-WC-01, which encompassed the borehole. Because the test pit was performed at this location, grout was not used to abandon the hole.

AECOM engineering personnel observed the subsurface explorations (see Photo 3-1), maintained detailed logs of subsurface conditions encountered, performed visual soil classification, and collected soil samples for laboratory testing. Encountered soils were classified using the Unified Soil Classification System (USCS) at the time of drilling in general accordance with standard procedures described in ASTM D2488 (ASTM Standard D2488 2017). Logs of subsurface conditions encountered in the exploratory borings and a boring log key to symbols and terms are provided in Attachment C.



Photo 3-1: View of a Track-Mounted Drill Rig Used for Drilling

The test pitting was performed by A&D Jensen Contractors, Inc., of Richfield, Utah, under subcontract to Jones & DeMille. Test pits are indicated on the design plan drawings used as the basis for geotechnical analysis, which are provided in Attachment A. The test pitting was performed using a Link-Belt 225 track-mounted excavator with a 22-foot maximum dig depth and maximum heaped bucket capacity of 1.75 cubic yards. AECOM directed the excavator operator to designated test pit locations. Tests pits were abandoned using excavated soils tamped loosely into place.

AECOM engineering personnel observed the test pitting (see Photo 3-2), maintained detailed logs of conditions encountered, performed visual soil classification, and collected soil samples for laboratory testing. Soils encountered in the test pits were classified (USCS) at the time of excavation in general accordance with standard procedures described in ASTM D2488 (ASTM Standard D2488 2017). Logs of conditions encountered in the test pits are provided in Attachment D.



Photo 3-2: View of a Track-Mounted Excavator Used for Test Pitting

3.2 Site Conditions

Generalized descriptions of local stratigraphy and native soil encountered during the field investigation are provided in the following subsections by basin site.

3.2.1 Wood Canyon

The site of the embankment for the debris basin in Wood Canyon is located within a wash at the canyon floor. The wash is about 20 feet wide and about 8 feet deep with approximately vertical sides. Soils visible on the floor and walls of the wash consist of silts, sands, and gravel, with occasional cobbles, boulders, or organic and other debris (see Photo 3-3). Visible wash soils were highly stratified in 3 to 6 inch layers of silt, sand, or gravel, in a loose, visibly unstable, matrix. Voids that were visible on the wall of the wash ranged from about 1/16 inch in diameter to a few inches in diameter. The ground surface outside the wash and some of the canyon slopes are covered with numerous cobbles and boulders up to 5 or 6 feet in diameter. Vegetation consists of desert brush, some sparse grass, and very few trees.



Photo 3-3: View of Floor and Wall in Wood Canyon Wash

Four (4) test pits and one (1) borehole were performed at the Wood Canyon site, two on each side of the wash at the floor of the canyon. BH19-WC-01 was advanced to a depth of 21 feet before refusal of the augers. The test pits were excavated to depths of between 6 and 19 feet. TP19-WC-03 and TP19-WC-04 were excavated until refusal on rock at depths of 6 and 19 feet, respectively; however, the other two test pits did not reach refusal and were extended to the limits of the excavator. Encountered soils were low-plasticity silty to silty, clayey coarse to fine sand and gravel. Encountered rock consisted of highly weathered clay and siltstone. The rock outcroppings exposed on the canyon slopes included sandstone.

3.2.2 Tank Canyon

The embankment for the debris basin in Tank Canyon is located at the site of an abandoned aggregate mining operation. Excavation from the mining operations resulted in the removal of approximately 50 feet of material from within the footprint of the embankment; however, a raised portion of, what appears to be, the original ground surface remains. The ground surface outside the wash and some of the canyon slopes are covered with numerous cobbles and boulders up to 5 or 6 feet in diameter. Vegetation consists of desert brush, some sparse grass, and very few trees.

Two (2) test pits and one (1) borehole were performed at the Tank Canyon site. Test pits were performed at the foundation-abutment contact on either side of the raised surface bisecting the two segments of the proposed embankment. The test pits were excavated to depths of between 8 and 15 feet. TP19-TC-01 and TP19-TC-02 refused on rock. BH19-TC-01 was located near the maximum section of the northern segment of the proposed embankment. It was advanced to a depth of approximately 50 feet where blowcount refusal was reached at the last sample taken at 50 feet. Encountered soils were mainly nonplastic silty fine sand and coarse to fine gravel, but localized shallow (1-2 feet thick) layers of clayey soils were observed near the ground surface. Encountered rock consisted of clay/silt/sandstone and limestone; rock outcroppings exposed on the canyon slopes included sandstone.

3.2.3 Lind Canyon

The embankment for the debris basin in Lind Canyon is also located at the site of an abandoned aggregate mining operation. Historic aerials show that this area was an alluvial fan deposited at the mouth of the canyon. Mining operations resulted in the removal of approximately 30 feet of material over much of the area and from within the footprint of the embankment. A raised portion of, what appears to be, the original ground surface remains intact with a power pole situated on top of it. The ground surface and canyon slopes are covered with numerous cobbles and boulders. Vegetation consists of desert brush, some sparse grass, and very few trees.

Four (4) test pits and one (1) borehole were performed at the Lind Canyon site. Test pits were performed on the southern abutments of each proposed embankment segment, the northern abutment of the northern segment, and within the basin. The test pits were excavated to depths of between 12 and 25 feet. All of the test pits performed encountered cobbles and boulders during excavation. TP19-LC-01 refused at 12 feet because of large cobbles and boulders. TP19-LC-02 encountered boulders less than 4 feet in diameters from approximately 4 to 11 feet below the ground surface before encountering weathered, green gray to brown gray siltstone or clay stone, which was not encountered elsewhere. The remaining test pits encountered very few boulders and only occasional cobbles.

BH19-LC-01 was located near the maximum section of the south segment of the proposed embankment. It was advanced to a depth of approximately 21 feet where auger refusal and blowcount refusal was reached at the last sample taken at 50 feet. Encountered soils were largely nonplastic silty fine sands and coarse to fine gravels, but localized (1-2 feet thick) layers of clayey soils were encountered in the borehole.

In consideration of potential clay borrow sources, AECOM acquired soil samples obtained from sediment contained in nearby Dairy Canyon. This material was classified as silt clay and would likely be suitable for use as a clay core or in surface applications, such as a top soil constituent; however, the soil also contained a significant volume of organics and other debris.

3.2.4 Flat Canyon

The embankment for the debris basin in Flat Canyon is located on a large alluvial fan deposited at the mouth of the canyon. The ground surface is gently sloping from the mouth of the canyon down toward the main highway. At the time of the field investigation, movement at the site was hindered by the wet clayey ground surface. The canyon slopes are covered with numerous cobbles and boulders; large boulders are protruding from, or resting, on the surface in the alluvial fan. Vegetation consists of desert brush, some sparse grass, and no obvious trees.

Three (3) test pits and one (1) borehole were performed at the Flat Canyon site. Test pits were performed within the basin. The test pits were excavated to depths of between 19 and 21 feet. All test pits performed encountered a few cobbles and boulders during excavation. BH19-FC-01 was located near the footprint of the proposed embankment near the middle of the mouth of the canyon. The borehole was advanced to a depth of approximately 59 feet where auger refusal was reached. Encountered soils were largely poorly graded, coarse to fine sands and gravels with low plasticity silts and clays.

In consideration of potential clay borrow sources for use as an embankment core, Jones & DeMille acquired and tested three samples from potential borrow areas within Flat Canyon. Two of the clay borrow area samples were lean clay described as “native red clay,” and one, higher-plasticity fat clay was also identified and tested from flat canyon. The native red clay has suitable plasticity and fines and is likely suitable to use as the embankments clay core. Fat clay tends to be very sensitive to moisture content, which can make it very difficult to place and compact.

3.2.5 Groundwater

The occurrence of groundwater in the Sevier basin is largely within the unconsolidated basin fill material. East of Richfield, groundwater is confined and under artesian conditions (Lambert et al. 1995). Groundwater along the eastern margin of the Pahvant Range is present in both consolidated and unconsolidated aquifer and is largely unconfined (Lambert et al., 1995). The groundwater system within the Sevier Valley is largely interconnected with multiple layers consisting mainly of interbedded clay, silt, sand, and gravel. The consolidated rocks along the western portions of the valley contain limited amounts of groundwater. Ground water discharges from the Flagstaff Formation west of Richfield (Lambert et al. 1995). Generally, the consolidated rock of the Pahvant Range act as groundwater

barrier at depth and localized source of recharge to the shallow unconsolidated valley fill groundwater system. Based on a review of available well logs from Utah Water Rights, depth to groundwater between Richfield and the Pahvant Range varies from 121 to 410 feet below ground surface and is largely found in unconsolidated aquifer.

Shallow groundwater was encountered at approximately 32 feet below ground surface in BH19-TC-01 during the field exploration located in Tank Canyon. None of the other field exploration locations, which were performed in 2019, encountered groundwater. Because shallow groundwater was not observed in other boring during this investigation, the shallow groundwater observed in Tank Canyon at BH19-TC-01 is thought to be likely perched groundwater accumulating on less permeable fine grain layers at depth within the unconsolidated alluvium deposits of Tank Canyon. The source of the water is not known but could be leakage from the municipal water supply concrete tank or discharge of groundwater from the consolidated bedrock aquifer at depth to the unconsolidated sediments of Tank Canyon.

3.3 Laboratory Testing

Laboratory testing was performed by Jones & DeMille, of Richfield, Utah, on selected soil samples, which were collected from the exploratory borings and test pits completed at the project site during the 2019 AECOM field investigation. The laboratory testing program included testing to aid in the classification of on-site soils, to assess physical and engineering properties of tested materials, and included particle-size gradation (mechanical and hydrometer), atterberg limits, and moisture/density relationships (modified proctor). Laboratory test data are summarized in the remarks column of the boring log from which each sample was obtained and more detailed laboratory testing results from the borings located at the project site are provided in Attachment E. Summaries of selected laboratory tests are shown in Table 3-2.

Table 3-2. Summary of Selected Laboratory Test Results

Laboratory Test	Wood Canyon	Tank Canyon	Lind Canyon	Flat Canyon	Clay Core Borrow[1]
Atterberg Limits					
Liquid Limit	NP to 21	NP	NP	NP to 25	25 to 27
Plastic Limit	NP to 17	NP	NP	NP to 20	13
Plasticity Index	NP to 7	NP	NP	NP to 8	12 to 14
Percent Gravel (%)	28.7 to 57.4	0.1 to 40.9	11.9 to 57.3	0.3 to 57.7	13.3 to 14.6
Percent Sand (%)	25.4 to 38.2	38.7 to 57.4	34.3 to 53.9	30.3 to 59.3	21.7 to 21.9
Material passing #200 sieve (%)	15 to 33	19 to 54	7 to 35	12 to 46	63.7 to 64.8
Maximum Dry Density (pcf)	137.7 to 138.6	134	125.4 to 136.5	130.4 to 136.6	--
Optimum Moisture Content (%)	6.7 to 6.9	7.2	6.9 to 10.5	6.8 to 8.3	--

Notes: '--' denotes a blank entry; NP = nonplastic; pcf = pounds per cubic foot;
1. Samples were taken from potential clay core borrow source in Flat Canyon.

4. GEOTECHNICAL ANALYSIS

The following sections provide a summary of the geotechnical analyses performed in support of the Sevier Watershed Plan and EA. Geotechnical analyses included seepage and slope stability, filter compatibility, and settlement.

Prior to the geotechnical analysis performed for this evaluation, a senior geologist and a senior dam engineer visited each of the proposed embankment sites. During the visit of Wood Canyon, it was concluded that the abutments were not suitable for dam construction without significant modification. Accordingly, the following subsections only present analysis and results for Tank Canyon, Lind Canyon, and Flat Canyon structures; Wood Canyon was excluded from analysis and further consideration.

4.1 Embankment Geometry

The typical sections will propose using a clay core, where the top of the core was assumed to begin 3 feet below the crest with side slopes assumed to be 0.25H:1V. The top of the core was assumed to be 8 feet wide and centered along the centerline of the crest. The core extended a distance equal to half the height of the dam for Tank and Lind Canyons and at least 20 feet below the base of the dam for Flat Canyon. The slopes of the core in the cutoff trench were also assumed to be 0.25H:1V. A filter drain, which was approximately 4.5 feet wide, was placed adjacent to the entire height of and downstream of the core. At the base of the embankment, a 3-foot-thick blanket drain extended to a toe trench and drain terminating approximately 6 feet upstream of the downstream toe of the embankment slope.

As an alternative to the traditional clay core option, AECOM also considered a section using an internal filter and gravel drain in place of a core. The top of the filter and gravel drain was assumed to begin 3 feet below the crest with side slopes, both of which sloped toward the downstream end of the dam, assumed to be 0.25H:1V. The top of the filter and gravel was assumed to be 12-feet wide (4-foot-wide filter, 4-foot-wide gravel, and 4-foot-wide filter) with a minimum of a 2-foot-thick filter over the top of the gravel. The drain was completely surrounded by filter material with a minimum thickness of 2 feet measured vertically and 4 feet measured horizontally. The filter and drain system extended a distance equal to 3 feet below the base of the dam. At this depth, a 6-foot-thick blanket filter and gravel drain (2-foot-thick filter, 2-foot-thick gravel, and 2-foot-thick filter) extended to a toe trench and drain terminating approximately 6 feet (measured horizontally) upstream of the downstream toe of the embankment. Approximately half of the drain extending along the base of the embankment was assumed to be below the base of the embankment.

AECOM assumes that a local borrow source will be used to provide soils for construction of the embankment shells and clay core. It is assumed that the embankment shells will be constructed from soils found within each of the proposed basins. Where a clay core is used, AECOM assumed that soil would be obtained from the native red clay borrow area in Flat Canyon. Filter and drain materials were assumed to be sand- and gravel-sized aggregates that would be produced onsite or delivered from an offsite source.

4.2 Seepage Analysis

AECOM estimated steady-state seepage conditions for two representative sections: (1) the embankment in Flat Canyon and (2) the embankment in Tank and Lind Canyons; the embankment at Wood Canyon was excluded from analysis. The representative section for Tank and Lind Canyons was analyzed with two alternatives; one alternative used a clay core and one alternative used a filter and gravel drain system. These sections were selected based on encountered foundation soil types, groundwater conditions, and embankment height. Steady-state seepage conditions were estimated for each section assuming (1) a basin filled with water to the spillway elevation, (2) a basin filled to the spillway elevation and which contains 100 years of sediment, and (3) a basin just after drawdown of the water to the bottom of the basin. The steady-state seepage conditions were estimated using SEEP/W version 8.16.2.14053, which is part of the GeoStudio 2016 software package (GEO-SLOPE International Ltd. 2016a).

Based on information provided by Jones & DeMille regarding the anticipated retention time, each of the basins will experience peak inflows and completely discharge the volume of the reservoir in eight days or less. This period of time is probably insufficient to develop for steady-state seepage conditions within the embankment; however, the potential for obstructed outlet works or sustained inflows, which could prolong this retention period, may result in

steady-state seepage conditions. Accordingly, the results reported and discussed in subsequent subsections are performed under long-term steady-state seepage conditions, which are not anticipated.

4.2.1 Model Parameters

The hydraulic conductivity was assumed using published ranges (Budhu 2010; Das 2011) or assumed based on past experience. Where possible, the selected hydraulic conductivity was checked against correlations using available grain-size distribution data. The anisotropy ratios (k_v/k_h) were assumed. Volumetric water content and hydraulic conductivity functions were estimated using SEEP/W's estimate feature. The hydraulic conductivity function was estimated using the Van Genuchten method as available in SEEP/W. Required inputs include: saturated water content, material type, and residual water content. These parameters were estimated for this analysis and are summarized in Table 4-1 with selected saturated horizontal hydraulic conductivity (k_h) and anisotropy ratio by model material.

Table 4-1. Summary of Seepage Model Parameters

Material	Material Type	Saturated Water Content ft^3/ft^3	Residual Water Content ft^3/ft^3	Anisotropy Ratio (k_v/k_h)	Saturated k_h	
					cm/s	ft/s
Flat Canyon Foundation	Silty Sand	0.35	0.04	0.1	$1.0x10^{-3}$	$3.3x10^{-5}$
Tank/Lind Canyon Foundation	Silty Sand	0.35	0.04	0.1	$1.0x10^{-2}$	$3.3x10^{-4}$
Flat Canyon Embankment Shell	Silty Sand	0.35	0.04	0.1	$1.0x10^{-3}$	$3.3x10^{-5}$
Tank/Lind Canyon Embankment Shell	Silty Sand	0.35	0.04	0.1	$1.0x10^{-2}$	$3.3x10^{-4}$
Embankment Core	Clay	0.45	0.05	0.5	$1.0x10^{-8}$	$3.3x10^{-10}$
Basin Sediments	Silty Clay	0.40	0.04	0.5	$1.0x10^{-5}$	$3.3x10^{-7}$
Filter Drain	Sand	0.30	0.03	1	$1.0x10^{-1}$	$3.3x10^{-3}$
Gravel Drain	Gravel	0.30	0.03	1	$1.0x10^{0}$	$3.3x10^{-2}$

Notes: ft = feet; cm = centimeter; s = seconds

4.2.2 Results

The results of the seepage analysis indicate that the maximum gradient in saturated zones is approximately 2.5-3 for the embankment sections with a clay core, and slightly lower at 2-2.5 for the embankment section with a filter and gravel drain system instead of a clay core.

Estimated discharge from the toe drain, which was modeled in each of the considered sections, is summarized in Table 4-2. The discharge was estimated per unit length of the embankment at the maximum section for the entire length of the embankment is also summarized in Table 4-2. Because the analysis was performed at the maximum section and disregard three-dimensional effects, these values are likely conservative. The reason for the significant disparity between the larger Flat Canyon embankment and the Tank and Lind Canyon embankments with cores is the lower fines content and plasticity of the foundation soil encountered at the Tank and Lind Canyon sites. The 2-stage filter drain scenario has the highest discharge rate. A summary of seepage results is provided in Attachment F.

Table 4-2. Summary of Estimated Toe Drain Discharge

Analysis Section	Estimated Discharge		
	Per Unit Length	Entire Length of Embankment [1]	
	(cfs)	(cfs)	(gpm)
Flat Canyon with Impervious Core	$3.0x10^{-4}$	0.4	160
Tank/Lind Canyons with Impervious Core	$1.2x10^{-3}$	1.2	540
Tank/Lind Canyons with Filter/Gravel Drain	$3.6x10^{-3}$	3.6	1,600

Notes: cfs = cubic feet per second; gallons per minute

1. Tank/Lind Canyon results are separated into two separate embankments and the flow shown here is the combined discharge for the entire length of all embankment structure.

4.3 Slope Stability Analysis

AECOM calculated the factor of safety against slope instability for steady-state drained, undrained (end of construction), rapid (instantaneous) drawdown, pseudostatic, and post-earthquake cases using limit-equilibrium software, SLOPE/W version 8.16.2.14053, which is part of the GeoStudio 2016 software package (GEO-SLOPE International Ltd. 2016b). Spencer's method of slices was used to calculate the factor of safety against slope instability for each section. Analyzed sections were the same sections described in Section 4.2. In accordance with UAC Title R655, Chapter 11, Requirements for the Design, Construction and Abandonment of Dams, all dams should meet or exceed minimum factors of safety under normal loading conditions. Table 4-3 summarizes the required minimum factors of safety by stability case. These are consistent with NRCS design guidelines (NRCS 2019), where a minimum factor of safety is established.

Table 4-3. Summary of Required Minimum Factors of Safety

Loading Case	Required Minimum Factor of Safety
End of Construction	1.3 [1]
Steady-State Drained	1.5
Rapid (Instantaneous) Drawdown	1.2
Pseudostatic	1.0 [2]
Post-Earthquake	1.2 [3]

1. A minimum factor of safety of 1.4 is required for failure surface extending into foundation layers (NRCS 2019).
2. Requirement is only applicable to embankments, foundations, and abutments that are not subject to liquefaction or significant strength loss with a maximum acceleration of 0.2g or 0.35g (clay embankment on clay or rock foundation).
3. Requirement is only applicable to embankments, foundations, and abutments that are subject to liquefaction or significant strength loss with a maximum acceleration. Calculated deformation and settlement of the embankment crest should also be estimated.

Source: Utah Administrative Code Title R655, Chapter 11, Parts 5C and 6A

4.3.1 Analysis Cases

The following slope stability cases were considered in analysis. The NRCS design guidance document recommends that analysis be performed for a flood surcharge case, which uses the reservoir elevation at freeboard hydrograph pool level (NRCS 2019). Because of the nature of the flood, the duration over which the flood is anticipated to occur, and the retention time for flood water, a flood surcharge analysis was not analyzed.

4.3.1.1 Steady-State Drained Case

The steady-state drained case represents the long-term stability due to the phreatic surface coming to steady-state conditions at the spillway elevation. Materials were modeled using effective stress drained shear strength parameters.

4.3.1.2 Undrained (End of Construction) Case

The construction case represents the stability of the embankment following construction. The clay core was considered using undrained strengths for this case. Foundation soils were not considered susceptible to undrained loading. AECOM conservatively assumed that the basin was completely filled with water for an extended period of time immediately after construction. Upstream and downstream failure surfaces were analyzed. Materials were modeled using total stress undrained shear strength parameters.

4.3.1.3 Pseudostatic Case

The pseudostatic case corresponds to an earthquake effect simulated by applying a static horizontal force to the potential sliding mass. The clay core was modeled using peak undrained and all other free-draining materials were modeled using drained shear strength parameters, depending on the materials potential for generating excess pore pressures during loading. Free-draining soils were deemed not susceptible to excess pore pressure generation.

The 10,000-year accelerations were used for these slopes stability analyses in lieu of the MCE, the development of which was beyond the scope of this work. These were above the thresholds provided by UAC for which a pseudostatic analysis is allowed; however, for this level of design, using the 10,000-year return period in conjunction with simplified analysis methods is appropriate. These analyses did not consider the smaller acceleration associated with the OBE. The peak acceleration at the embankment crest was estimated based on published peak transverse crest accelerations as a function of peak transverse base acceleration data (Koester et al. 2000). These crest accelerations were then reduced by approximately 65 percent (Makdisi and Seed 1978). The assumed horizontal seismic coefficient used for all embankments in these analyses was 0.245.

4.3.1.4 Post-Earthquake Case

The post-earthquake case represents the stability with soil strengths after an earthquake. To account for any potential softening of the embankment core, 80 percent of the peak undrained strength was used for post-earthquake load conditions. It is unclear whether the clay core would be saturated or not, but AECOM conservatively assumed the core was saturated during the seismic event. Free-draining soils were deemed not susceptible to post-liquefaction strength loss.

4.3.1.5 Rapid (Instantaneous) Drawdown

The rapid drawdown case represents the stability of an embankment after quickly drawing down the water level in the basin. The rate of drawdown may result in drained or undrained loading of the clay core. Freely-draining soils would be subjected to drained loading. The 3-stage rapid drawdown analysis, which considers the minimum shear strength at any time during drawdown, was used to simulate instantaneous drawdown as implemented by SLOPE/W. Rapid drawdown strength parameters were assumed for this analysis (Duncan and Wright 2005).

4.3.2 Material Properties

Soil unit weights were assumed based on material type and anticipated placement methods or assumed insitu condition. The soil strengths for the foundation soils were based on blowcount correlations and engineering judgement. The soil strengths for embankment soils were selected based on published ranges, engineering judgement, and past experience. AECOM believes that selected values are appropriate for the assumed borrow sources and assumes sufficient compaction effort will be applied during construction. Material properties used for the limit-equilibrium analyses are summarized in Table 4-4 by model material.

Table 4-4. Summary of Selected Unit Weight and Strength Material Properties

Material	Unit Weight (pcf)	Drained Strength		Undrained Strength [1]		Rapid Drawdown Strength	
		ϕ' (deg)	c' (psf)	S_u/σ'_c	Minimum S_u (psf)	ϕ_R (deg)	c_R (psf)
Flat Canyon Foundation	130	33	0	--	--	--	--
Tank/Lind Canyon Foundation	125	30	0	--	--	--	--
Flat Canyon Embankment Shell	130	34	0	--	--	--	--
Tank/Lind Canyon Embankment Shell	125	34	0	--	--	--	--
Embankment Core	125	28	0	0.4	0	16	400
Basin Sediments	115	26	0	0.3	0	16	400
Filter Drain	120	36	0	--	--	--	--
Gravel Drain	120	36	0	--	--	--	--

Notes: pcf = pounds per cubic foot; deg = degrees; psf = pounds per square foot; '--' denotes a blank entry

1. Undrained strength was reduced by 20 percent for post-earthquake analysis.

4.3.3 Phreatic Conditions

For steady-state drained, undrained, and post-earthquake cases, the phreatic conditions resulting from seepage condition (1) was used (see Section 4.2). This represents the full basin under steady-state seepage conditions. Although steady-state seepage conditions are unlikely, they were considered plausible for this analysis. For the pseudostatic analysis, the encountered depth to groundwater from the field exploration was used. This is because of the low likelihood that the earthquake would occur while the debris basin contains water. For the rapid drawdown analyses, the phreatic surfaces resulting from the seepage analyses for seepage conditions (1) to (3) were used (see Section 4.2).

4.3.4 Results

The calculated minimum factors of safety meet or exceed the required minimum factors of safety defined by the State. If the seismic coefficient is increased or full seepage conditions are assumed for the pseudostatic analysis, a flatter slope may be required. A summary of the slope stability results is provided in Attachment F.

Table 4-5. Summary of Factors of Safety against Slope Instability

Analysis Section	Calculated Minimum Factor of Safety [1]									
	End of Construction [1.3]		Drained Steady-State [1.5]		Pseudostatic [1.0]		Post-Earthquake [1.2]		Rapid Drawdown [1.2]	
	Down	Up	Down	Up	Down	Up	Down	Up	Down	Up
Flat Canyon with Impervious Core	1.8	2.9	1.8	2.9	1.2	1.3	1.8	2.8	1.9	2.1
Tank/Lind Canyons with Impervious Core	1.6	2.4	1.7	2.4	1.1	1.2	1.6	2.3	1.8	2.0
Tank/Lind Canyons with Filter/Gravel Drain	-- [2]	-- [2]	1.7	3.1	1.1	1.2	-- [2]	-- [2]	-- [2]	-- [2]

Notes: '--' denotes a blank entry; Down = Downstream Slope; Up = Upstream Slope

1. Minimum required factor of safety, as defined by the State, is shown in brackets.
2. Cohesive materials were not present in this analysis. Consequently, end of construction, post-earthquake, and rapid drawdown analyses were not required.

4.4 Filter Compatibility

Each of the embankments will include a filter and drain system. The sloping filter/chimney drain will consist of filter material designed to minimize the potential for natural cementation and arrest the progression of any internal erosion mechanism. AECOM performed a filter compatibility analysis based on the NRCS guidance document (Natural Resources Convervation Service [NRCS] 2017) for gradation design of sand and gravel filters using field and laboratory available at the time this document was prepared. Selected filter bands and suggested standard aggregate gradations are included in Attachment G.

Based on the preliminary filter compatibility analysis, ASTM C33 Sand [Fine Aggregate (ASTM Standard C33 2018)] may be used as filter material for embankment shells and clay core constructed using the native red clay from Flat Canyon (Zone 1 Filter). ASTM C33 Gravel [Size No. 89 Coarse Aggregate (ASTM Standard C33 2018)] may be used as filter/drain material for a filter constructed of ASTM C33 sand (Zone 2 Filter).

4.5 Settlement

Settlement was estimated using Settle3D 4.008 (Rocscience Inc. 2017) and assuming settlement parameters based on SPT blowcount, experience, soil type, and consistency of soils encountered during this field investigation. Because the foundation soils were cohesionless, constrained moduli were selected to represent soil behavior under new loading. AECOM selected constrained moduli of 3.5-million and 2-million pounds per square foot for Flat Canyon and Tank/Lind Canyon, respectively. Each embankment was modeled assuming a crest width of 12 feet, downstream slopes of 2.5H:1V, upstream slopes of 3H:1V, soil unit weight of embankment material presented in Table 4-4, and an embankment height presented in Table 1-1. The estimated total settlements for Flat and Tank/Lind Canyons were 6-8 and 4-6 inches, respectively. This is immediate settlement that is anticipated during construction.

5. CONCLUSIONS AND RECOMMENDATIONS

AECOM identifies key takeaways and recommendations of this geotechnical evaluation. This section discusses these items, which are to be addressed and considered in final design. The following list summarizes AECOM's key takeaways and recommendations and subsequent paragraphs provide a more detailed explanation of these points:

- The abutments in Wood Canyon are not suitable for dam construction without extensive excavation into the foundation and both abutments, significant grouting of foundation and both abutments, extensive rock characterization, great expense, or relocation.
- AECOM recommends that future field investigations include provisions to locate, sample, and identify soils, which may be susceptible to collapse when wetted.
- Based on drilling conditions encountered during AECOM's 2019 field investigation, air- or mud-rotary drilling methods are recommended for future field investigations in Wood, Lind, and Flat Canyon.
- Because of the frequent cobbles and boulders encountered during the field investigation, the use of CPTs is not recommended as a tool for subsurface characterization.
- Future field investigations should include provisions that support the development of a site-specific seismic hazard analysis, which should include development of the MCE and OBE.
- Dispersive clays should be identified during final design so that they can be treated or avoided altogether.
- Significant effort, which may include fault mapping or trenching, may be necessary during final design to properly assess the seismic hazard for each site.
- AECOM recommends a minimum embankment core width of 10 feet be considered for final design.
- A detailed field investigation of the proposed abutments including packer testing and lugeon analyses is recommended for future design.
- For this preliminary report, the core should be extended into each abutment; 50 feet from the crest of the embankment into each abutment is assumed for Flat Canyon due to the nature of the tuff observed.
- Provisions for Zone 1 and filter placed along the downstream embankment to abutment contact to intercept and control abutment seepage is recommended.
- A depth below the embankment (cutoff) equal to half the height of the embankment (maximum of 20 feet in Flat Canyon) is assumed for a clay core or drain.
- Filter material (Zone 1 Filter) should meet the requirements for ASTM C33 Fine Aggregate or fall within the recommended Zone 1 filter band (presented in Attachment G) compatible with the native red clay core material.
- The gravel drain (Zone 2 Filter) should meet the requirements for ASTM C33 No. 89 Coarse Aggregate or fall within the recommended Zone 2 filter band (presented in Attachment G) compatible with the ASTM C33 Fine Aggregate.
- Hydraulic conductivity testing (ASTM Standard D5084 2016) should be performed on all embankment, core, and filter materials, during final design.
- Thorough foundation preparation, adequate compaction with appropriate compaction equipment, and sufficient quality control testing of embankment soils during placement is necessary during construction.
- The upstream embankment face and spillway should be armored with rip-rap of sufficient gradation and thickness to prevent degradation during the design flood event.

The embankment core zone must have a width of at least 8 feet to provide adequate water retention; however, the NRCS guidance document (NRCS 2019) recommends a minimum zone width of 10 feet. Accordingly, during final design, a minimum core width of 10 feet should be considered. The core of the dam should have 3 feet of cover on the crest of the dam and the center of the clay core should be collocated with the centerline of the embankment crest. To prevent seepage around the embankment, the core should be extended into each abutment, the distance of which will to be established in subsequent designs. For this preliminary report, a value of 50 feet from the crest of the

embankment into each abutment is assumed for Flat Canyon due to the nature of the tuff observed. A depth below the embankment (cutoff) equal to half the height of the embankment (maximum of 20 feet in Flat Canyon) is also assumed.

Unlike ordinary clays that are stable and somewhat resistant to erosion, dispersive clay soils can be highly erosive. Ordinary clays have a flocculated or aggregated structure while the dispersive clays have minute soil particles that are repulsed rather than attracted to one another. The crumb test (ASTM Standard D6572 2013) and double hydrometer (ASTM Standard D4221 2018) usually define this property adequately, but in some cases, pinhole (ASTM Standard D4647 2013) and chemical tests may also be required (NRCS 2017). According to the NRCS filter design guidance document, generally, soils with a crumb dispersion rating of 2 or less and a double hydrometer percentage of dispersive clay less than 30 can be assumed to not contain sufficient dispersive clay to be problematic. AECOM recommends that sufficient testing should be performed on selected clay source materials to adequately characterize its dispersive properties during final design. These types of clays should be identified so that they can be treated or avoided altogether. If dispersive clays are identified, the engineer should reassess the suitability of the clay borrow source, delineate any necessary restrictions to its use, and revise the filter design accordingly.

Detailed abutment characterization is beyond the scope of this investigation and further evaluation of each of the proposed abutments for grouting requirements will be required in subsequent designs. During the visit of Wood Canyon, it was concluded that the abutments were not suitable for dam construction without extensive excavation into the foundation and both abutments, significant grouting of foundation and both abutments, extensive rock characterization, great expense, or relocation. Extensive grouting of the Flat Canyon abutments is anticipated due to the highly fractured nature of the tuff geological formations observed. During final design activities, drilling of the abutments and foundations with packer testing and lugeon analyses will assist engineers to determine the suitability of the abutments for the dams. Excavation into the abutments of 50 feet or more may be necessary to encounter competent rock for grouting to abut the embankment and develop positive cutoff of seepage flows.

Filter material (Zone 1 Filter) should meet the requirements for ASTM C33 Fine Aggregate or fall within the recommended Zone 1 filter band (presented in Attachment G) compatible with the native red clay core material. The chimney filter should be a minimum of 4.5 feet wide (measured horizontally) on the downstream side of the core and a minimum thickness (measured vertically) of 3 feet should be used for the blanket drain. Provisions for Zone 1 and filter placed along the downstream embankment to abutment contact to intercept and control abutment seepage is recommended.

For the alternative filter and gravel drain system considered in Tank and Lind Canyons, the gravel drain (Zone 2 Filter) should meet the requirements for ASTM C33 No. 89 Coarse Aggregate or fall within the recommended Zone 2 filter band (presented in Attachment G) compatible with the ASTM C33 Fine Aggregate. The Zone 1 Filter should be used in conjunction with the Zone 2 Filter to maintain filter compatibility. The Zone 2 Filter material should be encapsulated by Zone 1 Filter material (minimum of 2 feet thick vertically and 4 feet horizontally) and not be placed in direct contact with embankment shell, foundation, or clay core material. To maintain proper seepage conditions during operation, the Zone 1 and 2 filters should be constructed with the dimensions outlined in Section 4.1.

AECOM recommends that hydraulic conductivity testing (ASTM Standard D5084 2016) should be performed on all embankment, core, and filter materials during final design. This data will help characterize seepage flow volumes for sizing of the toe drain and seepage collection systems. Additionally, sufficient samples should be obtained and appropriate testing should be performed to ensure that adequate volumes of Flat Canyon and native red clay are identified, which also have acceptable fines content, plasticity, and permeability.

Based on drilling conditions encountered during AECOM's 2019 field investigation, air- or mud-rotary drilling methods are recommended for future field investigations in Wood, Lind, and Flat Canyon. Rock coring should be anticipated in Wood Canyon, but may also be necessary at any of the other sites. Groundwater was encountered at a depth of approximately 32 feet below the ground surface. Accordingly, mud-rotary drilling methods are recommended for future boreholes in Tank Canyon that are drilled to depths greater than 32 feet. Because of the frequent cobbles and boulders encountered during the field investigation, the use of CPTs is not recommended as a tool for subsurface characterization.

There are a number of soils, including aeolian, alluvial, colluvial, mudflow, residual, and volcanic tuff, which may be susceptible to collapse upon wetting. Typically these soils are found in arid and semiarid regions where soils have

moisture contents less than saturation (Knodel 1992). Alluvial-type collapsible soils are mainly formed by flash flood and mudflows from large precipitation events (Howayek et al. 2011). Such deposits are usually poorly graded and may contain a significant clay fraction. In residual soils, clays, silts, and large cobbles and boulders, high void ratio structures may develop by leaching of soluble and fines from between the larger particles (Howayek et al. 2011). Collapsible soils often have low plasticity fines or are nonplastic (Knodel 1992), have dry unit weight below about 100-110 pounds per cubic foot, and may have very small (pinhole-sized) to moderate voids visible to the naked eye. AECOM did not encounter collapsible soils during the 2019 field investigation. However, voids or other loose materials were observed in the wash in Wood Canyon. Additionally, based on the depositional environment, encountered soils, and observed site conditions, collapsible soils may be present within the footprint of the proposed embankments. AECOM recommends that future field investigations include provisions to locate, sample, and identify soils, which may be susceptible to collapse when wetted.

AECOM performed a preliminary evaluation of the seismic hazards for each of the facilities. The findings of this evaluation are presented in Section 2.2.1. The proposed basin sites are in close proximity to mapped faults and slip zones. Accordingly, significant effort, which may include fault mapping or trenching, may be necessary during final design to properly assess the seismic hazard for each site. Future field investigations should include provisions that support the development of a site-specific seismic hazard analysis, which should include development of the MCE and OBE. Such provisions may include downhole seismic testing or geophysical methods.

Before embankment construction, all vegetation, debris, and all top soil should be stripped and removed from within the footprint of the embankment. Any protruding boulders should be removed and replaced. Any rock outcroppings should be excavated to provide a clean competent surface onto which soil may be compacted. Fills should be compacted to a minimum density of 95% of the maximum dry density based on ASTM D1557 (ASTM Standard D1557 2012) (Modified Proctor). The clay core should be compacted at a moisture content of 1 percent dry and 2 percent wet of optimum. The fill should be compacted in horizontal lifts no more than 6 inches in compacted thickness using a “sheeps-foot” roller for the clay core and vibratory compaction equipment for the embankment shell, filter, and gravel drain materials. Testing for compacted embankment fill, or native silty sand should be conducted at a frequency no less than 3 tests per 2,500 square feet of compacted lift, or 3 tests per lift, whichever is greater.

6. LIMITATIONS

This report was prepared by AECOM and is intended for the sole use by Jones & DeMille. The scope of services performed for this study may not be appropriate to satisfy the needs of other users, and any use or re-use of this document or of the findings, conclusions, or recommendations presented herein is at the sole risk of said user.

Professional judgments, analyses, and evaluations are presented in this report based in part on project discussions, discussion with third parties, file information, information or reports prepared by others and provided by Jones & DeMille and documented in this report, and in part by AECOM experience on similar projects and understanding of the proposed project. This information and its corresponding assumptions, although thought to be reasonable and appropriate, may not prove to be true in the future, including during future design efforts. The conclusions and recommendations of AECOM are conditioned upon this information and its corresponding assumptions described in this report.

There is no evaluation detailed enough to reveal every subsurface condition. Variations may exist and conditions not observed or described in this report may be encountered during construction; however, uncertainties relative to subsurface conditions can be reduced through additional subsurface exploration. This report has been prepared for the use of Jones & DeMille and their designated representatives. The work completed is of a preliminary nature and may not contain sufficient information for the purposes of other parties or for other uses.

AECOM represents that our services were performed within the limits prescribed by the client, in a manner consistent with the level of care and skill ordinarily exercised by other professional consultants under similar circumstances. No other representation to the client, expressed or implied, and no other warranty or guarantee is included or intended.

7. REFERENCES

ASTM Standard C33. (2018). *Standard Specification for Concrete Aggregates*. ASTM International, West Conshohocken, Pennsylvania.

ASTM Standard D1557. (2012). *Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft3 (2,700 kN-m/m3))*. ASTM International, West Conshohocken, Pennsylvania.

ASTM Standard D2488. (2017). *Standard Practice for Description and Identification of Soils (Visual-Manual Procedures)*. ASTM International, West Conshohocken, Pennsylvania.

ASTM Standard D4221. (2018). *Standard Test Method for Dispersive Characteristics of Clay Soil by Double Hydrometer*. ASTM International, West Conshohocken, Pennsylvania.

ASTM Standard D4647. (2013). *Standard Test Methods for Identification and Classification of Dispersive Clay Soils by the Pinhole Test*. ASTM International, West Conshohocken, Pennsylvania.

ASTM Standard D5084. (2016). *Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter*. ASTM International, West Conshohocken, Pennsylvania.

ASTM Standard D6572. (2013). *Standard Test Methods for Determining Dispersive Characteristics of Clayey Soils by the Crumb Test*. ASTM International, West Conshohocken, Pennsylvania.

Budhu, M. (2010). *Soil Mechanics and Foundations*. John Wiley and Sons, Inc., Hoboken, New Jersey.

Das, B. M. (2011). *Principles of Foundation Engineering*. (H. Gowans and T. Altieri, eds.), Cengage Learning, Stamford, Connecticut.

Deming, M. R., and Bridges, B. L. (1976). *Geologic Report of Fault Mapping Findings and Seismic Evaluation for Richfield-West Sevier Watershed*. Sevier County, Utah.

Duncan, J. M., and Wright, S. G. (2005). *Soil Strength and Slope Stability*. John Wiley and Sons, Inc., Hoboken, New Jersey.

GEO-SLOPE International Ltd. (2016a). “GeoStudio 2016 (SEEP/W).” Calgary, Alberta, Canada.

GEO-SLOPE International Ltd. (2016b). “GeoStudio 2016 (SLOPE/W).” Calgary, Alberta, Canada.

Hecker, S., 1993. Quaternary Tectonics of Utah with Emphasis on Earthquake-Hazard Characterization, Utah Geological Survey Bulletin 127.

Hintze, L. F., Fitzhugh, D. D., Rowley, P. D., Cunningham, C. G., Steven, T. A., Willis, G. C., 2003. Geologic Map of the Richfield 30’ X 60’ Quadrangle, Southeast Millard County and Parts of Beaver, Piute, and Sevier Counties, Utah. Utah Geological Survey Map 135.

Howayek, A. El, Huang, P.-T., Bisnett, R., and Santagata, M. C. (2011). “Identification and Behavior of Collapsible Soils.” *Publication FHWA/IN/JTRP-2011/12*, Joint Transportation Research Program, Indiana Department of Transportation and Purdue University, West Lafayette, Indiana.

Knodel, P. C. (1992). *Characteristics and Problems of Collapsible Soils (Report No. R-92-02)*. Denver, Colorado.

Koester, J. P., Sharp, M. K., and Hynes, M. E. (2000). *Technical Bases for Regulatory Guide for Soil Liquefaction*. Vicksburg, Mississippi.

Lambert, P.M., Mason, J. L., and Puchta, R.W., 1995. Hydrology of the Sevier-Sigurd Ground-Water Basin and Other Ground-Water Basins, Central Sevier Valley, Utah. State of Utah Department of Natural Resources, Technical Publication No. 103.

Makdisi, F. I., and Seed, H. B. (1978). “A Simplified Procedure for Estimating Dam and Embankment Earthquake-

Induced Deformations." *Journal of the Geotechnical Engineering Division*, 104(7), 849–867.

Natural Resources Conservation Service [NRCS]. (2017). "Gradation Design of Sand and Gravel Filters." *National Engineering Handbook, Part 633 - Soil Engineering*, United States Department of Agriculture, Washington, D.C., 62.

Natural Resources Conservation Service [NRCS]. (2019). *Technical Release 210-60: Earth Dams and Reservoirs*. United States Department of Agriculture, Washington, D.C.

Rocscience Inc. (2017). "Settle3D." Toronto, Ontario, Canada.

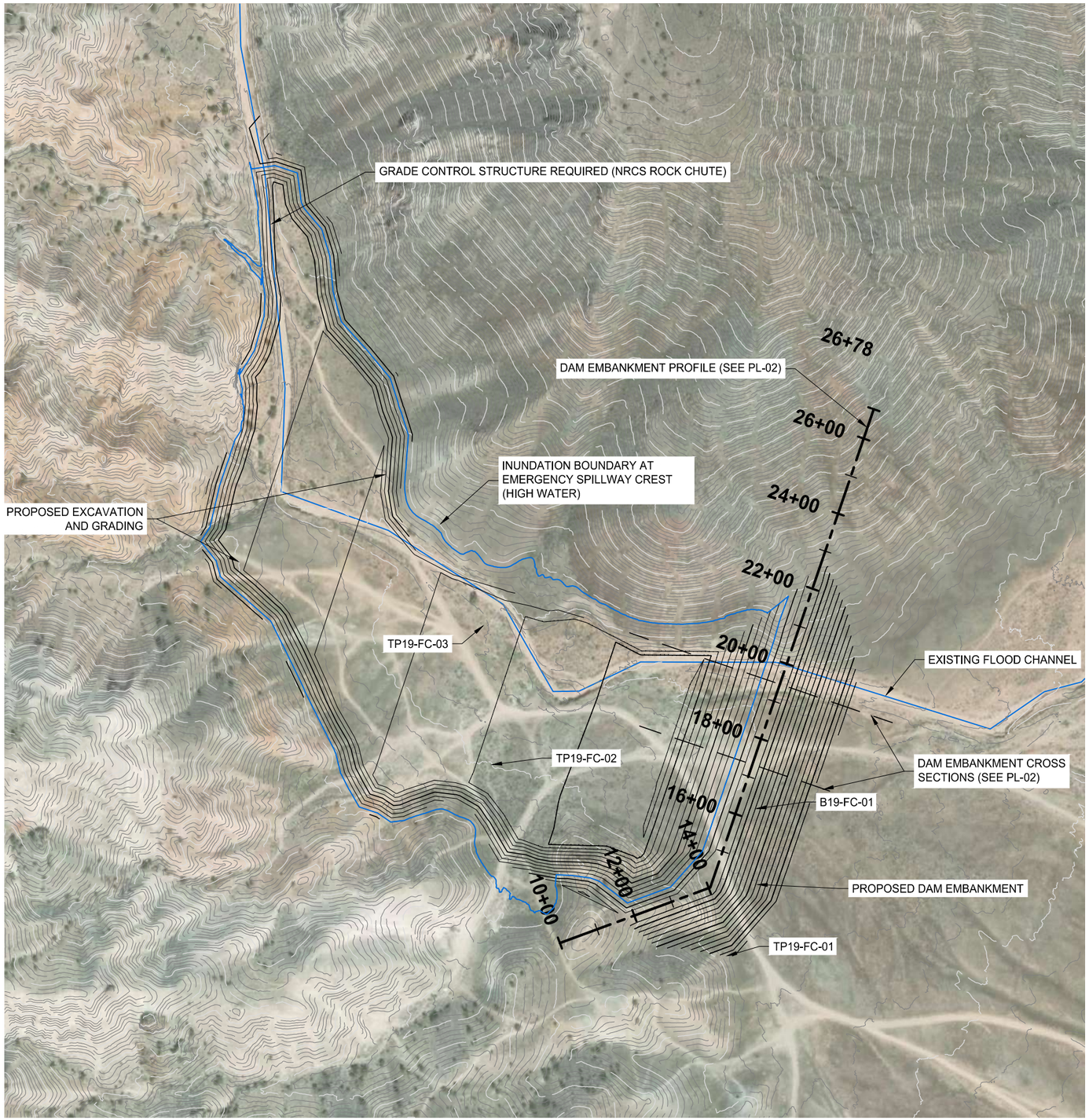
Schick International Inc. (1977). *Richfield Flood Control Feasibility Investigation*. Salt Lake City, Utah.

Willis, G. C., 1994. Interim Geologic Map of the Richfield Quadrangle, Sevier County, Utah, Utah Geological Survey, Open File Report 309.

United States Geological Survey [USGS]. (2014). "Unified Hazard Tool." <https://earthquake.usgs.gov/hazards/interactive/> (May 16, 2019).

United States Geological Survey [USGS]. (2019). "Quaternary Fault and Fold Database for the United States." <https://earthquake.usgs.gov/hazards/qfaults/> (Mar. 28, 2019).

Attachment A. Figures



NOTE: GEOTECHNICAL DESIGN EXHIBIT ONLY. FULL DESIGN DRAWING SET PROVIDED ELSEWHERE WITH ADDITIONAL INFORMATION

N

5 FOOT CONTOUR INTERVAL
SCALE: 1" = 300'

DAM CREST ELEVATION = 5609.0
EMERGENCY SPILLWAY CREST ELEVATION = 5599.0
STORAGE AT EMERGENCY SPILLWAY CREST = 826.9 AC.FT.
EARTHWORK VOLUME OF DAM = 316347 C.Y.



REVISIONS

NO.	DATE	REMARKS

SCALE: 1" = 300'
DWG NAME: H:\JD\Proj\1804-224\dwg\FlatCynLowerGeo.dwg
UPDATED: 8/7/2019
PLOTTED: 8/7/2019

Jones & DeMille Engineering, Inc.
CIVIL ENGINEERING - SURVEYING - TESTING
GIS - ENVIRONMENTAL
1.800.748.5275 www.jonesanddemille.com

APPROVAL RECOMM. PROJECT DESIGN ENGINEER DATE
APPROVED QUALITY MANAGEMENT REVIEW DATE

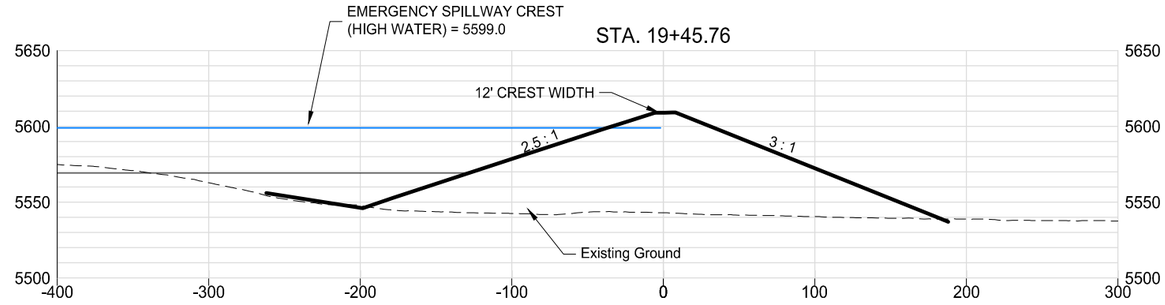
GEOTECHNICAL DESIGN EXHIBIT
FLAT CANYON
PLAN
PROJECT NUMBER: 1804-224

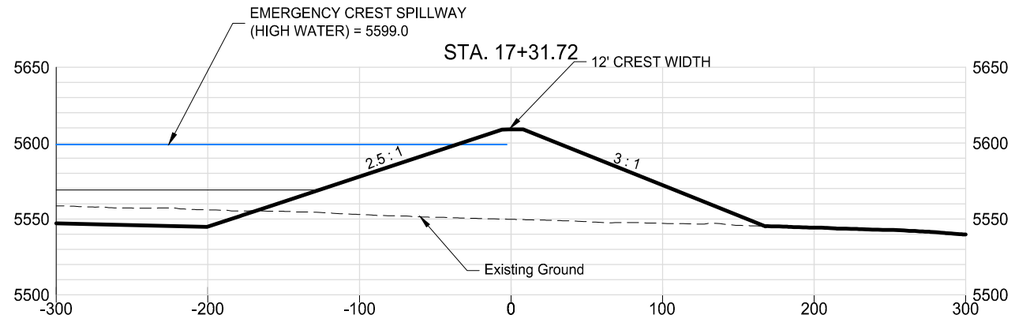
SEVIER
COUNTY

SHEET NO. PL-01

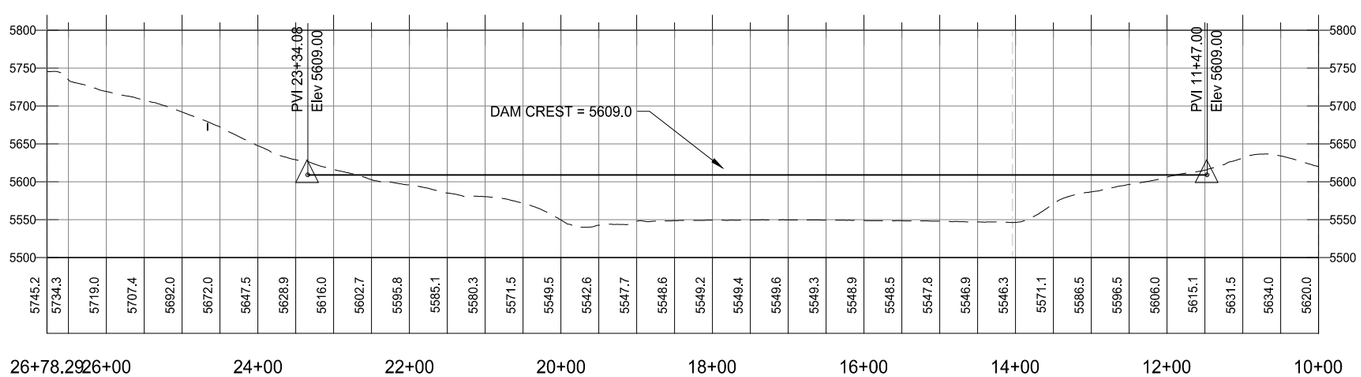
FLAT CANYON CROSS SECTIONS

NOTE: GEOTECHNICAL DESIGN EXHIBIT ONLY.
FULL DESIGN DRAWING SET PROVIDED
ELSEWHERE WITH ADDITIONAL
INFORMATION





FLAT CANYON DAM PROFILE



Jones & DeMille Engineering, Inc.
CIVIL ENGINEERING - SURVEYING - TESTING
GIS - ENVIRONMENTAL
1.800.748.5275 www.jonesanddemille.com

REVISIONS

NO.	DATE	REMARKS

UPDATED: 8/7/2019
PLOTTED: 8/7/2019

DWG NAME: H:\JD\Proj\1804-224\dwg\FlatCynLowerGeo.dwg

SCALE: NTS

APPROVAL RECOMM. PROJECT DESIGN ENGINEER DATE

APPROVED QUALITY MANAGEMENT REVIEW DATE

GEOTECHNICAL DESIGN EXHIBIT

FLAT CANYON

CROSS SECTIONS AND PROFILE

PROJECT NUMBER: 1804-224

SEVIER
COUNTY

SHEET NO. PL-02

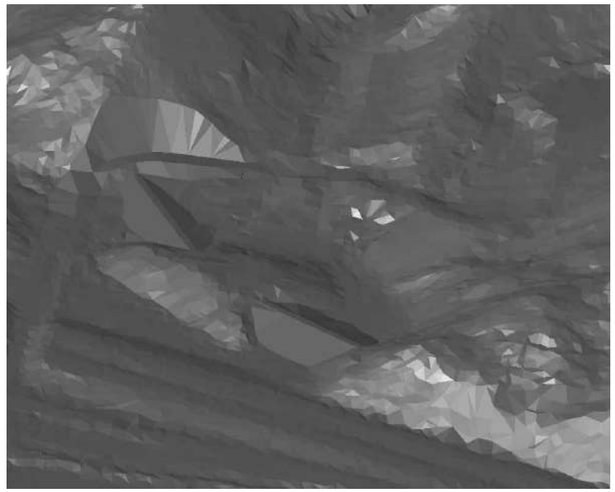


NOTE: GEOTECHNICAL DESIGN EXHIBIT ONLY.
FULL DESIGN DRAWING SET PROVIDED ELSEWHERE WITH ADDITIONAL INFORMATION

N

5 FOOT CONTOUR INTERVAL
SCALE: 1" = 200'

DAM CREST = 5457.0
EMERGENCY SPILLWAY CREST ELEVATION = 5449.0
STORAGE AT EMERGENCY SPILLWAY CREST = 39.6 AC.FT.
EARTHWORK VOLUME OF DAM = 49,150 C.Y.



REVISIONS

NO.	DATE	REMARKS

UPDATED: 8/7/2019
PLOTTED: 8/7/2019

DWG NAME: H:\JD\Proj\1804-224\dwg\TankCynGEO.dwg

SCALE: 1" = 200'

Jones & DeMille Engineering, Inc.
CIVIL ENGINEERING - SURVEYING - TESTING
GIS - ENVIRONMENTAL
1.800.748.5275 www.jonesanddemille.com

APPROVAL RECOMM. PROJECT DESIGN ENGINEER DATE

APPROVED QUALITY MANAGEMENT REVIEW DATE

GEOTECHNICAL DESIGN EXHIBIT

TANK CANYON

PLAN

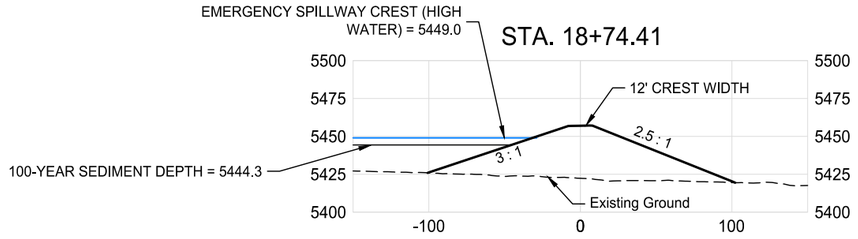
PROJECT NUMBER: 1804-224

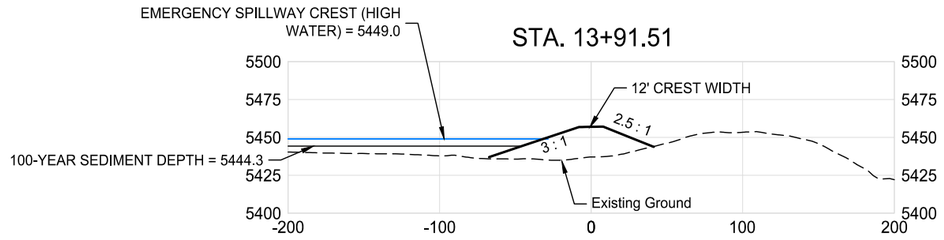
SEVIER
COUNTY

SHEET NO. PL-03

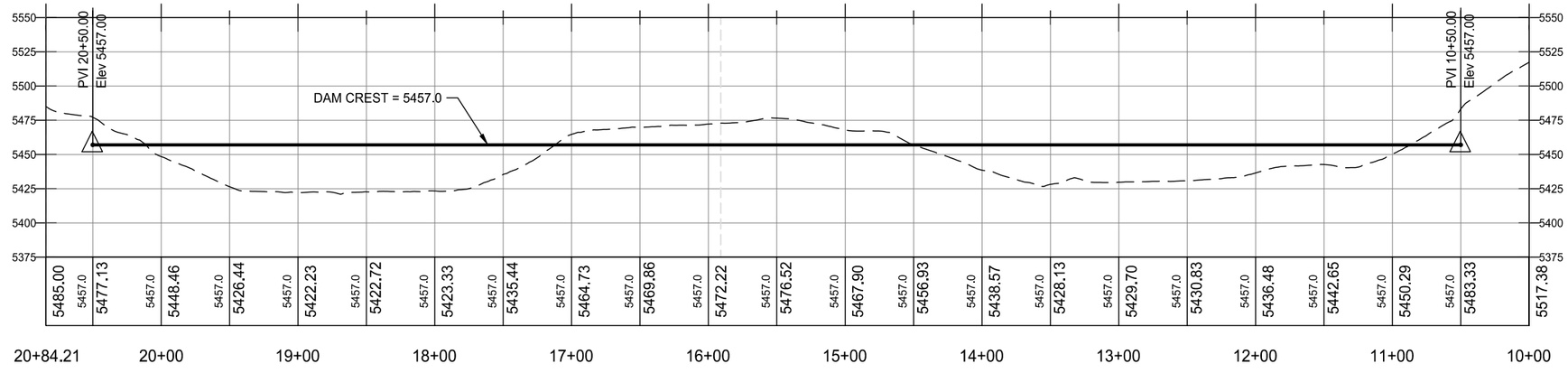
NOTE: GEOTECHNICAL DESIGN EXHIBIT ONLY. FULL DESIGN DRAWING SET PROVIDED ELSEWHERE WITH ADDITIONAL INFORMATION

TANK CANYON DAM CROSS SECTIONS





TANK CANYON DAM PROFILE



REVISIONS

NO.	DATE	REMARKS

SCALE: 1" = 200'

DWG NAME: H:\JD\Proj\1804-224\dwg\TankCynGEO.dwg

UPDATED: 8/7/2019

PLOTTED: 8/7/2019

Jones & DeMille Engineering, Inc.
CIVIL ENGINEERING - SURVEYING - TESTING
GIS - ENVIRONMENTAL
1.800.748.5275 www.jonesanddemille.com

APPROVAL RECOMM: PROJECT DESIGN ENGINEER DATE

APPROVED QUALITY MANAGEMENT REVIEW DATE

GEOTECHNICAL DESIGN EXHIBIT

TANK CANYON

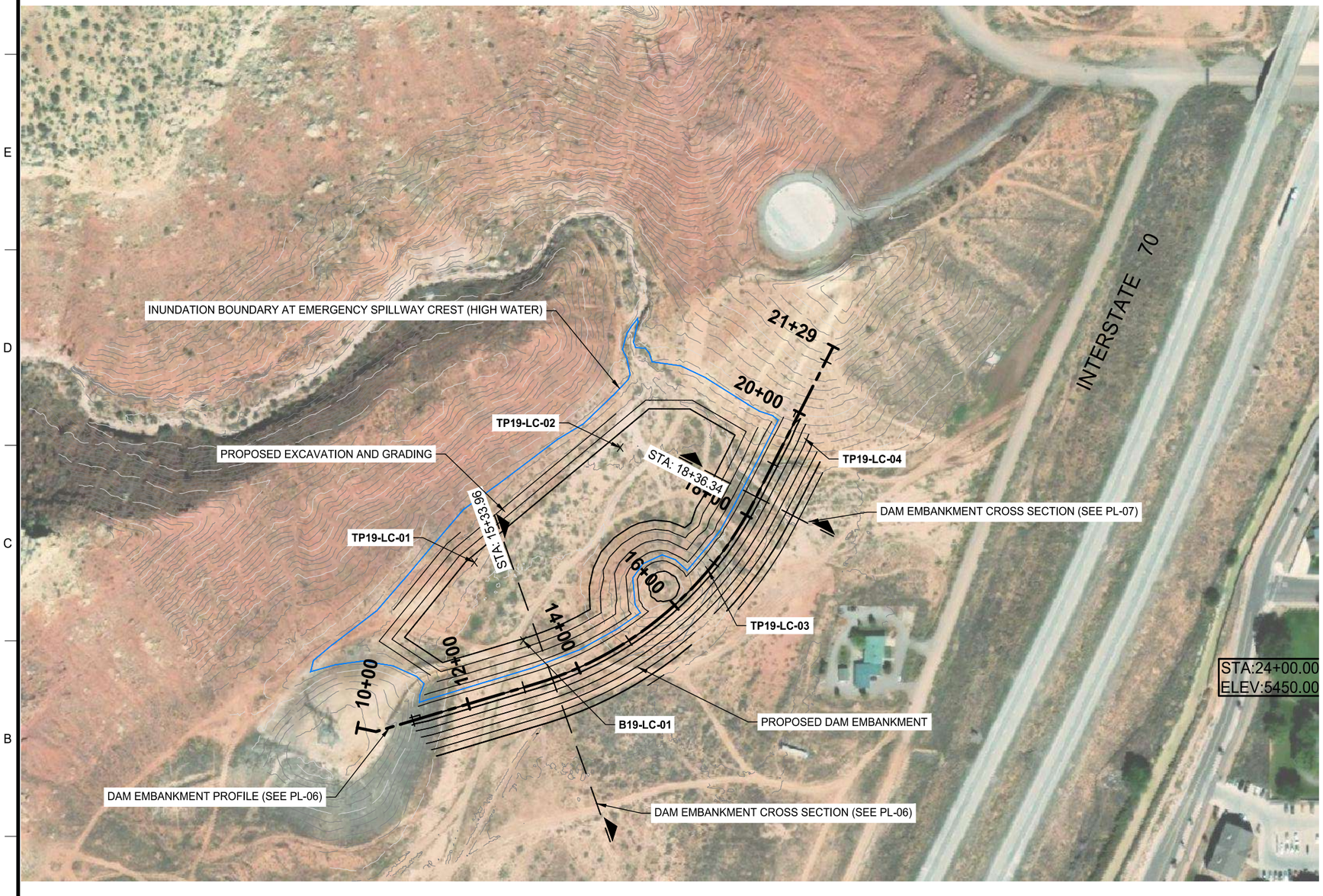
CROSS SECTIONS AND PROFILE

PROJECT NUMBER: 1804-224

SEVIER COUNTY

SHEET NO. PL-04

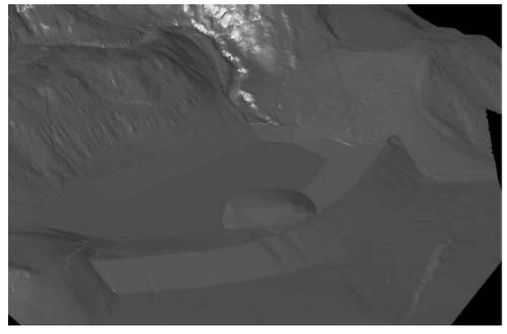
NOTE: GEOTECHNICAL DESIGN EXHIBIT ONLY.
FULL DESIGN DRAWING SET PROVIDED ELSEWHERE WITH ADDITIONAL INFORMATION



N

5 FOOT CONTOUR INTERVAL
SCALE: 1" = 200'

DAM CREST ELEVATION = 5450.0
EMERGENCY SPILLWAY CREST ELEVATION = 5442.0
STORAGE AT EMERGENCY SPILLWAY CREST = 63.4 AC.FT.
EARTHWORK VOLUME OF DAM = 58,272 C.Y.



NO.	DATE	REMARKS

REVISIONS

SCALE: 1" = 200'
DWG NAME: H:\JD\Proj\1804-224\dwg\LindCynGEO.dwg
UPDATED: 8/7/2019
PLOTTED: 8/7/2019

Jones & DeMille Engineering, Inc.
CIVIL ENGINEERING - SURVEYING - TESTING
GIS - ENVIRONMENTAL
1.800.748.5275 www.jonesanddemille.com

APPROVAL RECOMM: PROJECT DESIGN ENGINEER DATE
APPROVED QUALITY MANAGEMENT REVIEW DATE

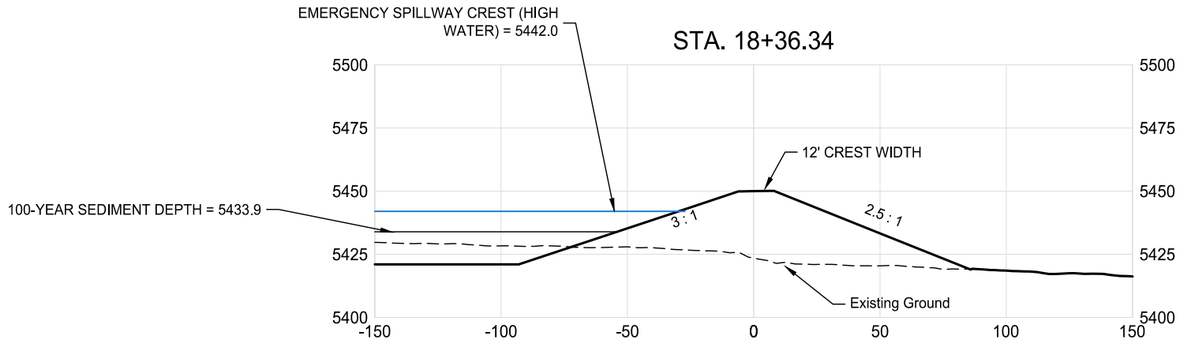
GEOTECHNICAL DESIGN EXHIBIT
LIND CANYON
PLAN
PROJECT NUMBER: 1804-224

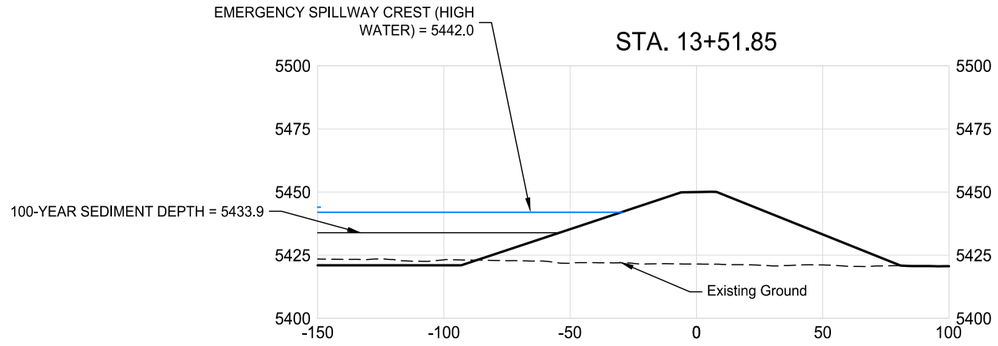
SEVIER
COUNTY

SHEET NO. PL-05

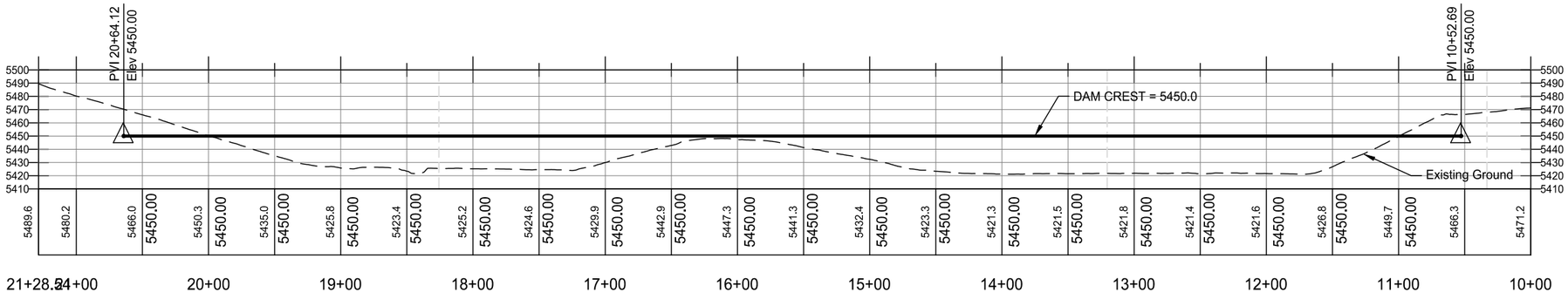
LIND CANYON CROSS SECTIONS

NOTE: GEOTECHNICAL DESIGN EXHIBIT ONLY.
FULL DESIGN DRAWING SET PROVIDED
ELSEWHERE WITH ADDITIONAL
INFORMATION





LIND CANYON DAM PROFILE



NO.	DATE	REMARKS
		REVISIONS

UPDATED: 8/7/2019
PLOTTED: 8/7/2019

DWG NAME: H:\JD\Proj\1804-224\dwg\LindCynGEO.dwg

SCALE: 1" = 200'

Jones & DeMille Engineering, Inc.
CIVIL ENGINEERING - SURVEYING - TESTING
GIS - ENVIRONMENTAL
1.800.748.5275 www.jonesanddemille.com

APPROVAL RECOMM. PROJECT DESIGN ENGINEER DATE
APPROVED QUALITY MANAGEMENT REVIEW DATE

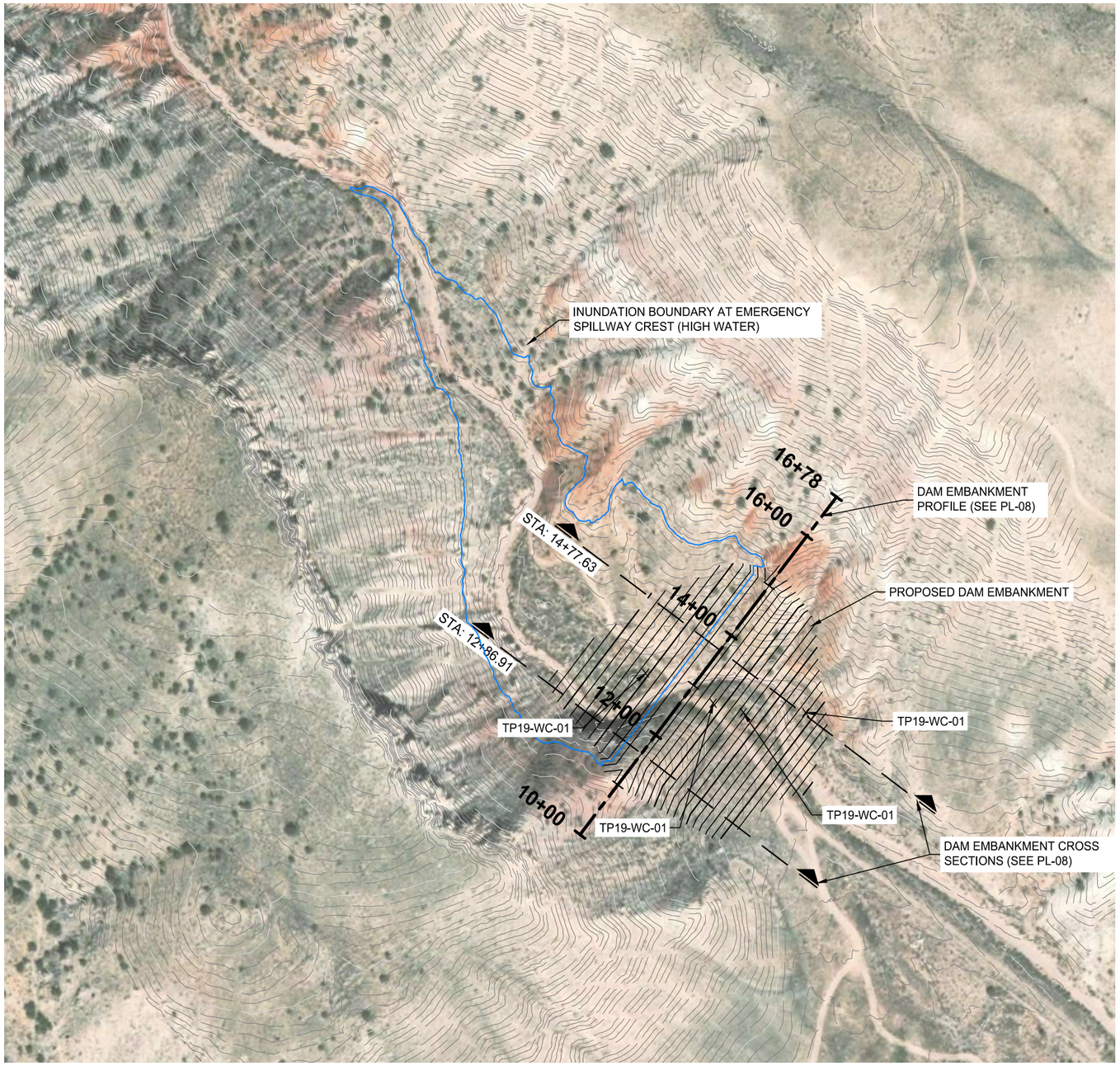
GEOTECHNICAL DESIGN EXHIBIT
LIND CANYON
CROSS SECTIONS AND PROFILE

PROJECT NUMBER: 1804-224

SEVIER
COUNTY

SHEET NO. PL-06

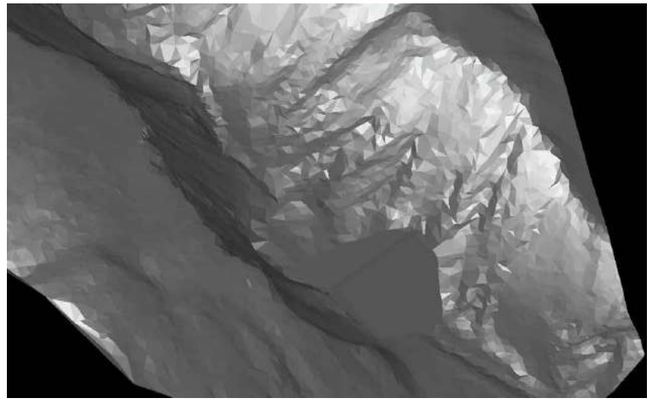
NOTE: GEOTECHNICAL DESIGN EXHIBIT ONLY.
FULL DESIGN DRAWING SET PROVIDED
ELSEWHERE WITH ADDITIONAL
INFORMATION



N

5 FOOT CONTOUR INTERVAL
SCALE: 1' = 200'

DAM CREST ELEVATION = 5670.0
EMERGENCY SPILLWAY CREST ELEVATION = 5662.0
STORAGE AT EMERGENCY SPILLWAY CREST = 88.7 AC.FT.
EARTHWORK VOLUME OF DAM = 152,000 C.Y.



REVISIONS

NO.	DATE	REMARKS

UPDATED: 8/7/2019
PLOTTED: 8/7/2019

DWG NAME: H:\JD\Proj\1804-224\dwg\WoodCynGEO.dwg

SCALE: 1" = 300'

Jones & DeMille Engineering, Inc.
CIVIL ENGINEERING - SURVEYING - TESTING
GIS - ENVIRONMENTAL
1.800.748.5275 www.jonesanddemille.com

APPROVAL
RECOMM. PROJECT DESIGN ENGINEER DATE
APPROVED QUALITY MANAGEMENT REVIEW DATE

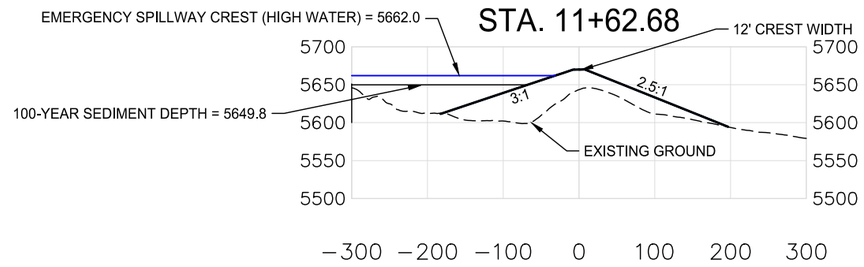
GEOTECHNICAL DESIGN EXHIBIT
WOOD CANYON
PLAN
PROJECT NUMBER: 1804-224

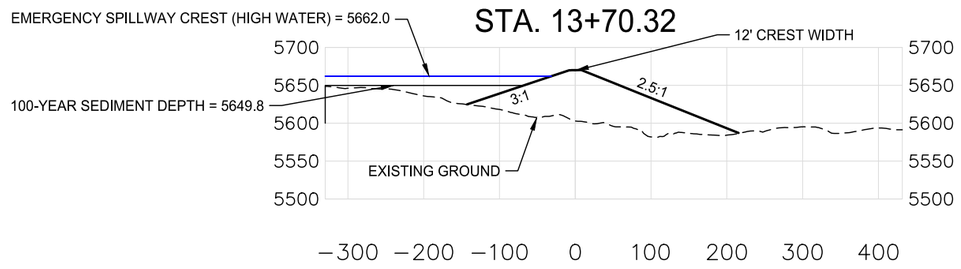
SEVIER
COUNTY

SHEET NO. PL-07

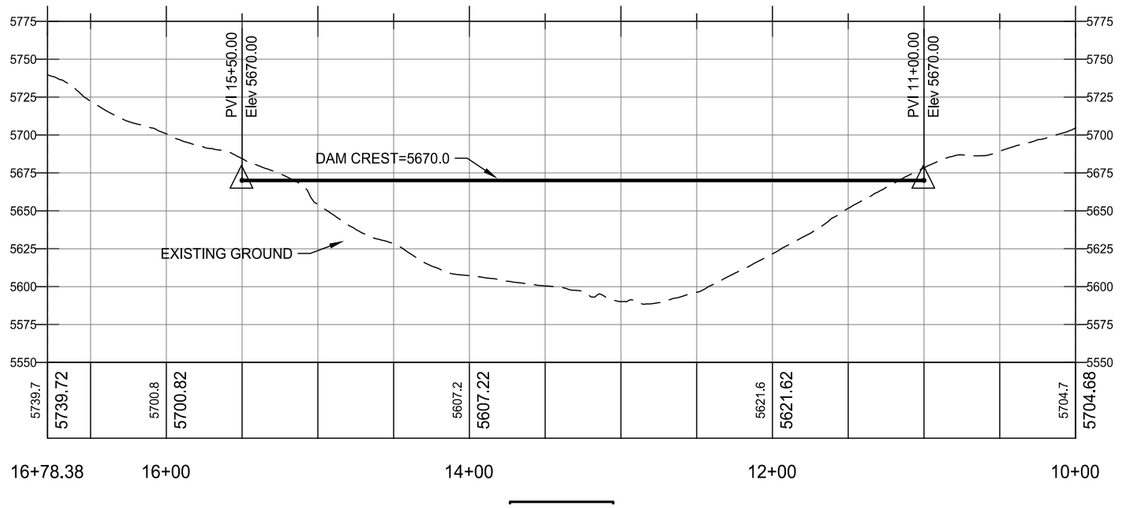
WOOD CANYON DAM CROSS SECTIONS

NOTE: GEOTECHNICAL DESIGN EXHIBIT ONLY. FULL DESIGN DRAWING SET PROVIDED ELSEWHERE WITH ADDITIONAL INFORMATION





WOOD CANYON DAM PROFILE



REVISIONS

NO.	DATE	REMARKS

SCALE: NTS

DWG NAME: H:\JD\Proj\1804-224\dwg\WoodCynGEO.dwg

UPDATED: 8/7/2019
PLOTTED: 8/7/2019

Jones & DeMille Engineering, Inc.
CIVIL ENGINEERING - SURVEYING - TESTING
GIS - ENVIRONMENTAL
1.800.748.5275 www.jonesanddemille.com

APPROVAL RECOMM. PROJECT DESIGN ENGINEER DATE
APPROVED QUALITY MANAGEMENT REVIEW DATE

GEOTECHNICAL DESIGN EXHIBIT
WOOD CANYON
CROSS SECTION AND PROFILE

PROJECT NUMBER: 1804-224

SEVIER
COUNTY

SHEET NO. PL-08

Pahvant Range

Generalized Stratigraphic Column

Period	Epoch	Formations
Quaternary	Holocene & Pleistocene	Younger Alluvial Fan Deposits
		Older Alluvial Fan Deposits
		Mass Movement Talus
		Mass Movement Slides and Sumps
Tertiary	Miocene	Osiris Tuff
	Oligocene	Tuff of Albinus Canyon
		Bullion Canyon Formation, Three Creek Tuff Member
		Aurora Formation
		Crazy Hollow Formation
		Dipping Vat Formation
	Eocene	Green River Formation
		Flagstaff Formation: Upper Member: White Member
		Flagstaff Formation: Upper Member: Red Member
		Flagstaff Formation: Middle Member
		Flagstaff Formation: Lower Member

Description of Map Units

- Qaf$_1$ — Younger alluvial-fan deposit
- Qaf$_2$ — Older alluvial-fan deposit
- Qmt — Mass movements, talus
- Qms — Mass movement, slides and slumps
- To — Osiris Tuff (undivided)
- Tac — Tuff of Albinus Canyon (undivided)
- Tbct — Three Creeks Tuff of Bullion Canyon Volcanics
- Tau — Aurora Formation (undivided)
- Tch, Tchs — Crazy Hollow Formation (undivided)
- Tdv — Dipping Vat Formation (undivided)
- Tg, Tgs — Green River Formation (undivided)
- Tf — Flagstaff Formation (Undivided)
  - Tfuw — Upper White Member of Flagstaff Formation
  - Tfur — Upper Red Member of Flagstaff Formation

Key

- Approximate bedding plane slip surface
- Fault or facture bounding shallow detachment block
- Contact, dashed where approximately located
- High-angle fault, dashed wehre approximately located, dotted where concealed, bar and ball on down-thrown side
- Unconformity
- Strike and dip of bedding
- Gravel or road-fill pit, hachured line shows approximate edge of pit

Sevier Watershed Plan
Richfield, Utah

Generalized Stratigraphic Column

Figure 1

Drafted By: NA | **Date:** May 26, 2019

Reviewed By: Lawrence Cannon | **Project Number:** 60598028

AECOM

Attachment B. Existing Reports

GEOLOGIC REPORT

OF

FAULT MAPPING FINDINGS

AND

SEISMIC EVALUATION

FOR

RICHFIELD-WEST SEVIER WATERSHED

SEVIER COUNTY, UTAH

Prepared by

Michael R. Deming
and
Bob L. Bridges
Geologists
SCS

August 1976

GEOLOGIC REPORT OF FAULT MAPPING FINDINGS

AND SEISMIC EVALUATION FOR

RICHFIELD-WEST SEVIER WATERSHED

SEVIER COUNTY, UTAH

SUMMARY

Detailed fault mapping of the Richfield-West Sevier Watershed between Elsinore and Aurora, Utah, shows that the Elsinore fault zone is active.

Six of seven proposed debris basin sites are located on faults, and the Cottonwood Debris Basin site is also located on a landslide.

Geologic mapping of the Elsinore fault disclosed a zone of intense faulting from Elsinore, Utah, to Denmark Wash, a distance of approximately 22 miles. Width of the zone varies from 1.0 mile near Elsinore to 4 miles near the Cedar Ridge drainages. Two zones or directions of trend were mapped, a northeast zone and a northwest zone. The northwest zone appears to be the most active.

Evidence of recent movement was found in alluvial fan deposits at the mouth of Big Fan Canyon and Dry Red Canyon. Apparent displacement was also found in the fan near Willow Creek.

A search of the seismic record indicates that seismic adjustment is still occurring along the Elsinore fault.

The maximum probable earthquake that can be expected on the Elsinore fault zone during the design life of the project is estimated at 6.5 Richter magnitude.1/ Estimated displacement with an event of 6.5 magnitude is approximately 2 to 4 feet (vertical).

The maximum credible earthquake that can be expected on the Elsinore fault zone is estimated at 7.4 Richter magnitude.1/ Estimated displacement with this event may exceed 8 feet (vertical).

CONCLUSIONS

1. The Elsinore fault zone is active and still undergoing seismic adjustment.

2. An earthquake with a Richter magnitude of 6.5 can be expected during the design life of the project (100 years). The maximum credible earthquake that could be expected on the Elsinore fault is estimated at 7.4 Richter magnitude.

3. Six of seven proposed debris basin sites are located over faults. All of the faults are considered part of an active seismic zone. Displacement could occur along any of the faults associated with the proposed sites.

4. The Flat Canyon, Dairy-Rulon Lind, Tank, Cottonwood, Willow, and North Aurora sites are considered geologically poor locations for construction of dams because of active faults under the proposed embankments.

5. Strong ground motion from earthquakes can also be expected at any of the seven debris basin sites.

6. Part of the foundation and the left abutment of the Cottonwood Debris Basin site is located on a landslide.

7. Plots of earthquake epicenters indicate that the southern portion of the Elsinore fault zone is presently the most active, but all evidence of movement in recent alluvial deposits was observed along the northern portion of the fault zone.

REPORT OF FAULT MAPPING FINDINGS AND SEISMIC EVALUATION BY SITES

Following are individual dam site reports on the seven proposed structures. The reports discuss location of faults with relationships to dam location, findings of the mapping investigation, and conclusions as to geologic suitability of each site. The reports also discuss alternate dam site locations:

FLAT CANYON DEBRIS BASIN SITE

Findings:

Detailed geologic field mapping of faults in the Flat Canyon area disclosed a system of parallel normal faults trending northeast through the Flat Canyon fan along with an associated system trending northwest. The northwest trending faults are responsible for the initial development of Flat Canyon and are about 1 to 1.75 miles in length. Two of the northeast trending faults (N 30-35° E) pass through the debris basin site. They are spaced 450-500 feet apart and are downthrown to the east with an estimated total displacement of 200 feet. Fault length is estimated at 3.5 miles. These faults pass through the wind dikes. The eastern fault passes through the northern wing dike near the P.I. with the main portion of the dam. A third fault is believed to pass approximately 200

feet east of the main centerline of the dam and is over 4.5 miles in length.

All of the faults mapped are part of the Elsinore fault zone. The northeast trending faults appear to form the main stem of the fault zone.

No evidence of recent surface rupture was found in the area even though several large damaging earthquakes have occurred in Elsinore since 1900. Several earthquake epicenters have been plotted within 5 miles of the site. The largest damaging earthquake occurred in 1910 with a Richter magnitude of 6.7. Another quake occurred in 1921 with a magnitude of 6.1. Active sedimentation in the Flat Canyon area has probably covered any evidence of recent activity in the fan, including historical.

Conclusions:

1. The Flat Canyon Debris Basin site is presently located over two normal faults and approximately within 200 feet of a third fault. An additional number of faults have been located within 0.25 miles of the site.

2. The faults passing through the site are part of an active seismic zone. Damage from large magnitude earthquakes has occurred within one mile of the site and possible at the site. Any of the faults could move or areas in between may also be subject to displacement.

3. Moving the debris basin site 3,100 feet downstream (down fan) would move it off of faults mapped during the latest investigation. This might reduce the potential of actual displacement in the dam; however, it would still be subject to strong ground motion from earthquakes on the Elsinore fault. Moving the dam downstream does not completely eliminate the potential for displacement since faults (which could not be mapped) may be concealed by alluvium in the lower fan area.

DAIRY-RULON LIND SITE

Findings:

Northeast trending faults and east-west cross faults have broken the rock beds beneath the proposed site. The northeast trending faults have a total downthrow of approximately 200 feet to the northwest and an average length of 2 miles. The shorter east-west trending cross faults are downthrown both to the north and to the south with approximately 20-30 feet displacement at the site. All of the faults are branches of the Elsinore fault zone. The main Elsinore fault zone is believed to be near the Sevier Valley Canal in this area, and it roughly parallels the axis of the dam.

The dam foundation is underlain by fine to moderately coarse-textured alluvium. Volcanic tuffs, siltstones, shales and sandstones underlie the alluvial cover, which is over 50 feet deep in some areas.

Conclusions:

1. Geologically, the site is unfavorable because of recorded earthquakes in the vicinity. Displacement may occur along one of the several faults, which have broken the rocks beneath the foundation. Also, strong ground motion will occur in the alluvium if movement takes place along the main fault zone.

2. A more favorable site could not be located.

TANK CANYON DEBRIS BASIN SITE

Findings:

1. A series of parallel faults trending N 50° E have broken the rocks in and adjacent to the Tank Canyon Reservoir Basin. These faults range from 1 to over 2 miles long and total downthrow to the east is approximately 250 feet. The fault on the west side of Water Tank Knoll trends diagonally across the axis of the north dam and has a displacement of approximately 25 feet at the site.

2. North-south trending faults are evident along the road near the north end of the north dam. The largest fault trends N 10° E through the reservoir basin and across the axis of the south dam. Displacement along this fault increases to the south, and it probably exceeds 30 feet near the axis of the dam. Sinkholes and large open cracks were observed along the fault north of the old rock quarry, below the Forest Service road.

   An east-west cross fault has apparently broken the rocks along the west side of Water Tank Knoll with a downthrow to the north.

   All of the faults at the site are branches of the Elsinore fault zone.

Conclusions:

1. Part of the north dam is underlain by fractured, cavernous limestone. High water losses are expected from the basin, and this may cause piping of the fill. Geologic conditions can be improved by moving the site approximately 200 feet downstream. Shales, siltstones and sandstones will underlie the embankment in the area; however, they are broken by the east-west trending cross fault.

2. Although the rocks in the south dam are broken by faulting, they are expected to be stable and relatively impervious. The emergency spillway located at the north end of the dam is underlain by fractured broken limestones, which overlie weathered siltstones and

shales. Foundation conditions at the south dam will improved if the south end is moved 50-75 feet downstream.

3. Geologically, the Tank Canyon site is unfavorable because five branches of the Elsinore fault zone are located in the reservoir basin. These branch faults are all considered active because of recorded earthquakes in the vicinity.

4. Ponding water at the site will probably affect the Richfield Spring.

COTTONWOOD DEBRIS BASIN SITE

Findings:

1. The left abutment is composed of moderately consolidated landslide deposits derived mainly from limestones, siltstones, sandstones, and shales. Generally, the deposit is a heterogeneous mixture of poorly graded gravel (broken limestone fragments), silty gravel, clayey gravel, and gravelly clay. Based on information in the drilling logs, over 50 percent of the deposit is estimated to be broken limestone fragments and blocks. The poorly graded gravels are highly pervious and loose. Pockets of weathered shale and siltstone were found at several locations within the landslide mass. The landslide undoubtedly occurred during an earthquake in the area. The slide is younger than the other landslides in the vicinity and is probably less than 500 years old.

2. Rocks at the site are broken by two parallel faults, which trend approximately N 45° E. Both faults trend diagonally across the axis of the proposed dam and join the main Elsinore fault approximately 1 mile to the northeast. The fault on the north is located under the landslide deposit in the left abutment and has a displacement of approximately 30 feet at the site. The fault on the south is located in the right abutment and downstream part of the foundation. This fault extends for over four miles and has a displacement of 75-100 feet at the site.

Conclusions:

1. Geologically, the site is unfavorable for the construction of a dam 110 feet high because of possible settlement and piping in the left abutment and recurring movement along one of the faults, which trends diagonally across the dam axis.

2. A site approximately 600 feet downstream is recommended. A site on the Cottonwood Creek fan just upstream from the hospital is preferred; however, this location has been eliminated in the planning because of land rights and design problems.

3. Because of the recent landslide on the left abutment, unstable rock ledges just upstream from the right abutment, fresh fault scarps in the vicinity, and connection with the main Elsinore fault, the faults mapped at the site are believed to be active.

WILLOW CREEK DEBRIS BASIN SITE

Findings:

Detailed geologic mapping of the Elsinore fault zone, in the Willow Creek area, disclosed intense faulting. The largest number of faults found during the mapping investigation were found at the mouth of Willow Creek Canyon and along the fan. These faults trend northeast (N 30-35° E) and are spaced from 5 to 600 feet apart. Near the mouth of the canyon, faults were so closely spaced that individual faults could not be mapped. Displacement along the fault system is estimated at over 2,000 feet.

Evidence of recent movement was found north of Willow Creek in two places. Both displacements are in alluvial fans, which are estimated to be less than 1,000 years old. One displacement is estimated to be younger than 200 years since it has affected tree roots along the scarp.

Two (2) northeast trending faults pass through the debris basin site. The upper fault has an estimated displacement of 100 feet and the lower fault is displaced approximately 400 feet. In addition, it appears that the upper end of the south wing dike rests on the toe of the Cottonwood-Willow landslide.

Conclusions:

1. The present Willow Creek debris basin site is located over two (2) normal faults. In addition, fourteen (14) or more faults have been mapped within 4,500 feet of the site.

2. Because of the evidence of recent seismic activity, intense faulting in the Willow Creek area and faulting through the basin, the present site is geologically and seismologically a poor location for a debris basin.

3. Site conditions could be improved by relocating the site approximately 1,500 to 2,400 feet downstream. This would somewhat reduce the potential for displacement in the dam, but would not completely eliminate the possibility since faults concealed by alluvium may also exist in this area. The relocation would not eliminate damage caused by ground motion from earthquakes along the Elsinore fault zone.

NORTH AND SOUTH CEDAR RIDGE DEBRIS BASIN SITE

Findings:

Detailed geologic mapping in the North Cedar Ridge-South Cedar Ridge Canyon area indicates that the Elsinore fault zone is primarily located west of the proposed debris basin site. The distance to the closest fault from the proposed centerline is approximately 2,800 feet with the main portion of the fault zone lying approximately 5,000 feet west of the site. The maximum displacement, along the Elsinore fault, occurs west of the site at the mouth of the Cedar Ridge Canyon where an extimated 2,000 feet of vertical separation can be observed.

A northwest-southeast trending fault could possibly pass under the debris basin site, but evidence as to its location is lacking in the active alluvial fan. Good evidence of the northwest-southeast fault crossing of all the northeast trending faults were also lacking, but is suspected.

The Cedar Ridge area is in a transition zone where the northeast trending Elsinore fault zone (N 30-35° E) is intersected by a recently very active fault zone trending northwest (N 20-55° W) to Scipio (may also be part of the Elsinore fault). The crossing of the two fault zones form a cross hatch pattern in the area west of the site. Evidence of the most recent and modern seismic activity was found about 1.5 miles northwest of the site. In addition, earthquake epicenters have been plotted in the same area indicating a high degree of seismic activity.

Displacement in the Cedar Ridge alluvial fans could not be observed, possibly because of active sedimentation.

Conclusions:

1. Evidence of faulting at the North and South Cedar Ridge site is lacking, although one (1) northwest-southeast trending fault is suspected.

2. Although faults were not mapped through the debris basin site, seismic activity and recent fault displacement is more evident in this area than at any other point mapped. The potential for recurrent seismic activity may be highest in this area.

3. The proposed dam probably can be constructed at the proposed site, but is in a highly active seismic area where strong ground motion can be expected. The embankment should be designed with this in mind.

NORTH AURORA DEBRIS BASIN SITE

Findings:

After field mapping of faults near the North Aurora site, the closest displacement appeared to be a northeast trending normal fault approximately 370 feet west of the proposed centerline. However, after reviewing drill hole logs and cross sections done by Neil Murdock (Geologist-Schick International) it appears probable that a northwest to west trending fault crosses the centerline of the dam (perpendicular to axis).

This fault is downthrown to the south and explains the geologic differences in the dam abutments, which is hard to explain by erosion. Estimated displacement along the west trending fault is in excess of 100 feet.

The northeast trending fault upstream of the basin is downthrown to the west with approximately 75 feet of displacement and trends N 50° E. This fault helps form a natural basin. The probable west trending fault through the dam would explain the notch through the northeast trending hogback, which forms the dam site.

The Aurora site is in the more active section of the Elsinore fault and recurrent seismic activity can be expected in this area. Earthquake epicenters have been plotted approximately 2.5 miles southwest of the site. A suspected fresh scarp was also located in the epicenter area. A fault which breaks late Pliocene or early Pleistocene formation was uncovered in a bentonite pit about 4,500 feet northwest of the site.

Surface evidence near Round Valley 8 miles northwest of the site indicates that the northwest to west trending faults have had recent movement and are still undergoing adjustments.

Conclusions:

1. The North Aurora site is in an active seismic area subject to both surface rupture by faulting and ground motion from earthquakes.

2. The probable fault suspected of running through the dam site would have to be confirmed by intense field mapping and possible some additional drilling in the right abutment. If the presence of a west trending fault is confirmed, the present site would be geologically unsound for construction of a debris basin.

REGIONAL SEISMIC SUMMARY

The Richfield-West Sevier Watershed is located near the transition zone between the Basin and Range Province of western Utah and the High Plateaus

of western Utah. The watershed is located on the eastern side of the Pavant Mountains, a Basin and Range type structure. This area is located within the "Intermountain Seismic Belt."[2/] The seismic belt is thought to extend from the Gulf of California into western British Columbia crossing through western Arizona, central Utah, southeast Idaho, western Wyoming, and western Montana (Wollard, 1959).[2/] The seismic system is thought to be a "branch of the active rift system associated with the landward extension of the East Pacific Rise into the North American Continent" (Menard, 1960; Heezen, 1960; Cook, 1962, 1966).[2/]

Major fault zones located within 50 miles of the Richfield region include the Thousand Lake, Hurricane, and Southern Wasatch faults. Major faults within 20 miles of the watershed include the Elsinore, Sevier, and Dry Wash faults. The Elsinore fault zone passes directly through the watershed along the eastern toe of the Pavant Mountains. All of the faults mentioned are considered active faults as the area is still undergoing seismic adjustment.

Numerous earthquake epicenters have been plotted along the Elsinore, Sevier, and Dry Wash faults since the area was settled in the mid 1800's. All three of these faults displace Tertiary strata, and field investigations have revealed Quaternary and modern sediment deposits have been displaced in some localities. Earthquakes with Richter magnitudes less than 1.0 to a maximum of 6.7 have been associated with the three faults. A total of 278 earthquakes have been listed as plotting within a 50-mile (approximately) radius of the site between 1850 and 1975. (See attached epicenter listings).

WATERSHED FAULT MAPPING AND SEISMIC INVESTIGATION

During August of 1976, Bob Bridges and Mike Deming (geologists, Soil Conservation Service) made a detailed mapping study of the Elsinore fault zone. The fault zone passes northeast through the Richfield-West Sevier Watershed along the toe of the Pavant Mountains. The zone was mapped from Elsinore, Utah, north to Denmark Wash (north of Aurora, Utah). The corridor mapped varied from approximately 1 mile wide on the south end to 4 miles wide near the northern end. Purpose of the fault mapping was to determine the relationship between proposed damsite locations and faults, to determine the activity of faults, and to estimate the age or most recent activity occurring along the zone. Large faults outside the watershed were considered less hazardous since the active Elsinore fault zone passes directly through the watershed structure sites.

Faults and other geologic hazards were mapped on 1974 aerial photographs at a scale of 1:24,000. Special aerial photographs used for planning the damsites (at scales of 1 inch equals 1,000 feet and 1 inch equals 500 feet) were also used. Faults were traced on the ground and located on the 1974 photographs. The 1974 photos were later spliced together to

make 1 mosaic of the corridor. Displacement along individual faults was estimated from field investigation. Areas showing recent surface rupture are located on the map.

A paper by Michael C. Schneider, Department of Geology, DePauw University; Geology of the Pavant Mountains West of Richfield, Sevier County, Utah, 1963, and an unpublished PhD thesis by Herman Kenneth Lautenschlager, Ohio State University; and the Geology of the Central Part of the Pavant Range, Utah, 1952, were used for reference.[3 & 4] Guidebook to the Geology of Utah, No. 4, The Transition Between the Colorado Plateaus and the Great Basin in Central Utah, by Edmun M. Speiker, 1949, was also used as a reference.[5]

WATERSHED SEISMIC SUMMARY

General Geology

The Pavant Mountains form a tilted block which dips approximately 12° to the southeast and is bounded on the east and west by normal faults. At the east toe of the mountain range is the Sevier Valley, a structural trough with the Elsinore fault zone, paralleling the east edge and the Sevier fault on the west edge.

Tertiary sedimentary and volcanic rocks comprise all of the exposed outcrops on the eastern dip slope of the Pavant Range with local outcrops of Quaternary-Tertiary sedimentary deposits. Quaternary and modern alluvial deposits cover much of the upper edge of the Sevier Valley along the toe of the range. Beginning with the youngest consolidated deposits, the following stratographic column can be constructed from exposers in the range: Axtell formation - unknown feet thick (sed.); Dry Hollow formation - 150-200 feet thick (vol. and sed.); Bullion Canyon Volcanics - (vol).; Bald Knoll formation - 475 ± feet thick (sed.); Crazy Hollow - 260 ± feet thick (sed.); Green River formation - 56-60 feet thick (sed.); Flagstaff formation - 400-2,300 feet thick (sed.); and North Horn formation - 2,300 ± feet thick (sed.).

Green River and Flagstaff formations are the key stratagraphic marker and structural beds in the watershed. The Green River formation is a light green to gray limestone, which forms on large massive bed in the Richfield area, but in areas where it has been faulted, breaks into blocks and small pieces. The Flagstaff formation is dominantly bright red and purple shales, sandstone, limestone, and conglomerate. The shale in the contact zone between the Flagstaff and overlying Green River formation forms a smooth surface, which in the Cottonwood and Willow Creek areas has allowed the Green River to slide over the Flagstaff formation along the Sevier fault and in places has slid over itself. Movement along the slide plane is thought to have been the

result of dip slope in combination with Seismic activity along the Elsinore fault. Sliding within the Bald Knoll shales is also common.

Past Seismic Activity of the Elsinore Fault Zone

The Elsinore fault zone first appears near Joseph, Utah, and traverses northeast (about N 35° E) along the eastern toe of the Pavant Mountains to the foothills west-southwest of Aurora where a northwest trending fault system intersects the northeast zone. The northwest zone trends N 20° - 55° W and can be traced along the northeast face of the Pavant Mountains to Scipio, Utah. The northwest trending system may be an extension of the Elsinore fault zone.

The northeast trending zone of normal faults traverses from the southern end of the watershed to the Denmark Wash area on the north forming a corridor of deformation about 1/2 to 2 miles wide with 4 to 5 visible parallel faults near Elsinore increasing to as many as 16+ parallel breaks near Willow Creek Canyon. Near the mouth of Willow Creek Canyon, faults were so closely spaced that individual faults could not be mapped.

Faults are spaced from 5 to 800 feet apart along the zone, and displacement ranges from less than 5 to several hundred feet. Displacement along most faults was estimated at 30 to 200 feet. The total combined displacement of the faults is estimated at over 2,000 feet. These parallel faults form a series of steps along the east edge of the Pavant Mountains with most of the downthrown on the east side of each break. Several faults are downthrown to the west forming horst and graben structures, locally. Fault planes that could be observed in the field were nearly vertical (75°+ from horizontal) generally dipping to the southeast but in some cases were vertical. The intensity of faulting appears to decrease both east and west of the corridor mapped; however, alluvial fans and valley fill probably cover faults west of the mapped area.

Isolated outcrops of Tertiary Volcanics and Green River formation east of the main fault scarp indicate that faults probably exist east of the corridor mapped. Isolated outcrops which hold the key to fault locations may exist farther out (west) in the Sevier Valley, but are covered by alluvial fan and Sevier River deposits (valley fill).

Fault length varied from 800 feet to approximately 4 miles, and indications are that longer length faults exist but are obscured by alluvium.

The absence of folding, especially drag folding, indicates that faulting and displacement may have occurred quickly along some faults. This is also indicated by the steep smooth fault scarps.

Displacement increases in the section between Willow Creek and North Cedar Ridge where the northwest zone begins to appear and maximum displacement, estimated at over 2,000 feet, can be observed.

Historic Seismic Activity

A list of 278 earthquake epicenters have been plotted within a 50-mile radius (approximately) of Richfield between 1850 and 1975. About 45 epicenters have been plotted along the Elsinore fault zone between 1850 and 1968. Between 1968 and 1975 earthquakes of Richter magnitude 1.0 to 4.6 have occurred at a rate of one every two years. The last quake of mentionable size to occur was in 1972 and is thought to have occurred along the Elsinore fault zone. The largest seismic event to occur on the Elsinore fault was in 1901 at a Richter magnitude of 6.7. About 35 fore and after shocks were associated with the event. Damage occurred in Elsinore, Richfield and several towns on the west side of the Sevier Valley.

An earthquake of Richter magnitude 6.1 occurred in 1921 on the Elsinore fault with approximately 26 fore and after shocks ranging from 2.0 to 5.5 Richter magnitude. Following is an account of that event taken from Earthquake History of the United States, Publication 41-1, revised edition (through 1970), page 70.[6/]

EARTHQUAKES OF SPETEMBER 29 AND OCTOBER 1, 1921

Epicenter -- Elsinore, Utah
Area affected -- Considerable
Intensity -- Eight
Description -- Elsinore is in Sevier Valley, 150 miles south of Salt Lake City and 5,335 feet above sea level. It is fairly old, and the early houses were built of sun-dried brick and fragments of black basaltic lava. Later houses are of modern construction. At the time of the earthquake, there were about 1,000 inhabitants. The valley is about 5 miles wide and is flanked by abrupt rise of plateaus to several hundred feet.

After several weeks of preliminary tremors, the first sharp shock occurred at 7:12 on September 29. It lasted 7 to 10 seconds, was unaccompanied by noise, and was probably of intensity 8. It threw down scores of chimneys, plaster fell from ceilings, and walls were fractured. Another shock intensity 7 occurred at 19:30 the same day. At 8:32 on October 1, there was another shock like the blow of a great hammer, unaccompanied by noise except from creaking buildings and falling chimneys and was probably of intensity 8. The country was very dry and great clouds of dust arose.

The first shock was strongest at Elsinore but did damage at Richfield and Monroe. The greatest damage was to the Elsinore schoolhouse. Although it was a new two-story brick building, a part of the wall went down and if it had been during school hours there would have been a heavy loss of life. Near by, an old building of rectangular blocks of rock had little damaged. Half the buildings were damaged in some way with chimneys thrown down or otherwise rendered unsafe. Plaster fell

from ceilings, pictures were thrown from the walls. One chimney was twisted through 45°. It is stated that a hot spring with oxide iron in the water ran blood red for a time after the earthquake,

Shocks lasted from September 12 to December 20, the most important being those of October 27, felt sharply at Richfield, and of November 1.

The historic record of the Elsinore fault zone indicates that the fault zone is still quite active and can be expected to remain in that status.

LIST OF DAMAGING EARTHQUAKES
RICHFIELD AREA
(50 Mile Radius)

Date	Location of Greatest Damage
7-31-1873	Beaver
11-14-1901	Richfield, Elsinore
1-12-1910	Elsinore, Richfield
9-29-1921	Elsinore, Richfield, Monroe, Joseph
9-30-1921	Elsinore, Richfield
10- 1-1921	Elsinore
11-18-1945	Glenwood
4-16-1969	Ephraim

Age of The Elsinore Fault Zone

Faulting in the Pavant area has probably been occurring since Precambrian times, but older formations do not outcrop. In Lautenschlager's PhD thesis, he indicates that the last series of large seismic events were quite recent.[4] This is indicated by rupture of all Tertiary formations in the area and by Tertiary-Quaternary deposits, which have been displaced. Many fault scarps appear to be quite recent in that little erosion has taken place and vegetation has not established itself.

Schneider indicates in his paper that northwest-southeast trending faults appear to be younger than the northeast trending zone.[3]

During the field investigation, evidence of recent faulting was observed between Willow Creek and South Cedar Ridge at the mouth of Big Fan Canyon where an alluvial fan, estimated to be less than 1,000 years old, has been displaced and a tree root system affected. This fault movement may have occurred less than 200 years ago. The amount of displacement could not be estimated, but displacement was to the west. Some indication of faulting was noted low on the fans between Willow Creek and South Cedar Ridge, but low sun angle photography are needed to make a better determination.

Moving north from the Willow-South Cedar Ridge area to the mouth of Dry Red Canyon, clear evidence of faulting in the Dry Red alluvial fan was discovered. Displacement was to the west and was estimated at 8 to 10 feet. Downstream approximately 2,200 feet from the alluvial scarp, a sharp fresh break trending N 80° E was found in alluvial material. This break is about 1,500 to 2,000 feet long with a maximum displacement of 30 feet. It was not determined if this is a fresh fault scarp because of gravel excavation in the area but interviewing old time residents may clear this point. If it is a fresh scarp, indications are that it may have occurred within the last 200 years. After reviewing the epicenter plot map (see attached map), one epicenter was located in the area just south of the Dry Red fan, which occurred in 1962. Magnitude of the quake is unknown. The freshness of scarps in the area and epicenter plottings in the same area indicate that this area is active and undergoing adjustment.

Investigating the Maple Grove area about 8 miles northwest of Aurora disclosed a displacement of about 30 feet in an alluvial fan and another fresh scarp in bedrock where vegetation has not yet covered the ruptured surface. Lautenschlager discusses these fresh scarps in his reports that a series of scarplets were found in the Maple Grove to Herbert's Ranch area. The scarplets are mostly in alluvial fans.4/

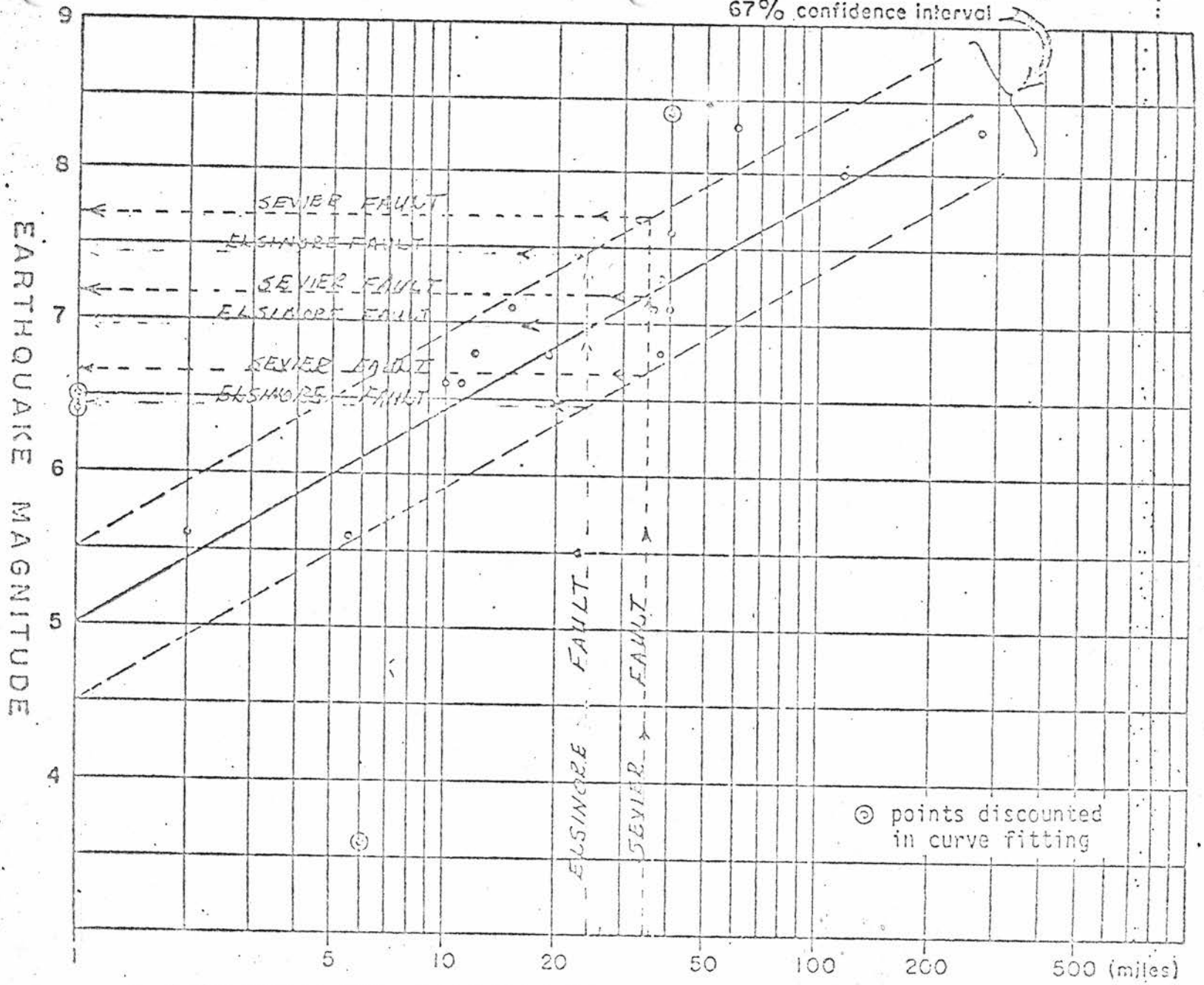
Although plots of epicenters indicate that most seismic activity is occurring along the southern portion of the Elsinore fault zone, evidence of recent surface rupture is more evident from Willow Creek Canyon north. Further, recent surface rupture and most displacement appears to be along the northwest trending fault zone northwest of Aurora. Evidence of displacement in alluvium along the northeast trending zone is most evident between Big Fan Canyon and Dry Red Canyon, but scarps do not appear as fresh as those near Maple Grove along the northwest zone.

ESTIMATING THE MAXIMUM PROBABLE AND MAXIMUM CREDIBLE EARTHQUAKES FOR RICHFIELD-WEST SEVIER WATERSHED

Since two of the most active faults in Utah are located in and near the watershed and their seismic history indicates that they have produced larger quakes than faults within an effecting radius, the Elsinore and Sevier faults were used for obtaining a rough estimate of maximum earthquakes.

Maximum Probable Earthquake (MPE)1/

A Maximum Probable Earthquake (MPE) for the Elsinore fault was roughly estimated, strictly from the one hundred year seismic history of the area (see definitions - end of report). Two earthquakes with Richter magnitudes of 6.0 or greater have occurred within the past one hundred years on the Elsinore and associated fault zone. The largest was of



Earthquake magnitude versus fault rupture length. (From Greensfelder, 1973)

FIG. 1

magnitude 6.7 with an intensity of nine (XI), while the small quake was 6.1 Richter magnitude with an intensity of eight (VIII). Therefore, it appears both logical and possible that events greater than 6.0 could be expected within the next one hundred years. This would give an approximate Maximum Probable Earthquake of Richter magnitude 6.5 for the Elsinore fault.

A study of the historic record for the Sevier fault indicates that the Maximum Probable Earthquake would be somewhat less than can be expected on the Elsinore or at least has not produced as large an earthquake. With this difference in mind, it would appear that the MPE should be the estimated figure for the Elsinore fault. The Elsinore fault should also be used since it is directly related to the proposed structures.

Maximum Credible Earthquake (MCE)[2/]

To derive a rough estimate of the MCE (see definition - end of report) which could be expected, a curve derived by Greensfelder which is published in a report by C. E. Stearns called Seismic Risk Evaluation, September 1974, was used.[1/] This curve was developed for California and although some different types of faults are used to base the evaluation on, it appears to give reasonable estimates of earthquake magnitudes which could be expected. A rupture length of twenty-five miles was used for the Elsinore fault. Fault length shown on the current state geology map was extended to twenty-five miles after tracing the fault further north in field investigations. Going into Greensfelder's curve with a rupture length of twenty-five miles gave a range of about 6.4 to 7.4 in what he calls the sixty-seven percent confidence interval. It appears from the figures obtained from this curve that a value of 7.4 Richter magnitude may be an acceptable estimate MCE for the Elsinore fault.

A rupture length of thirty-five miles was used for the Sevier fault to obtain a MCE magnitude from Greensfelder's curve. The rupture length was obtained from the longest continuous fault line (traced and inferred) shown on the state geology map near Richfield. Values obtained from the curve gave a range of 6.7 to 7.8 Richter magnitude. The value obtained from the lower end of the curve appears higher than the historic record indicates and the upper end of the curve would also appear to be somewhat high.

Evaluation of Data Obtained for the Maximum Probable and Credible Earthquakes

Results obtained form Greensfelder's curve correlates well with historic data as to what the MPE might be for the Elsinore fault.[1/] This is assuming that the lower lines on the curve may correlate somewhat with a one hundred year interval and that the highest line on the curve may represent the largest event that could be expected on a given fault.

Data obtained for the Sevier fault appears too high based on the historic record available. The use of obtained values from Greensfelder's curve should be evaluated in greater detail, but may indicated that the earthquake potential on the Sevier fault is higher than the Elsinore.[1/]

Estimating Displacement on the Elsinore Fault for Maximum Probable and Maximum Credible Earthquakes

Seismic evaluation for the Richfield-West Sevier Watershed takes into consideration two things: (1) strong ground motion and (2) actual surface rupture and displacement where structures rests on faults.

Evidence of recent fault movement (1,000 Years or less) has been confirmed and mapped. This was discussed earlier in the report. Indications from both observed recent activity and the earthquake history of the area show that the Elsinore fault zone is active. To obtain some idea of possible displacement that can be expected along the fault zone the following data has been tabled from faults of similar type.

FAULT NAME	DATE OF EARTHQUAKE	RICHTER MAGNITUDE	MAXIMUM DISPLACEMENT
Hansel Valley Utah	4-12-34	6.6 & 6.0	4 feet from both quakes
Hebgen, Montana	8-17-59	7.1	15 feet
East Cache Fault	8-30-62	5.7	Unknown
Wasatch	9-5-62	5.1	Unknown
Northern Utah Pocatello Valley	4-75	5.6	13 cm's of subsidence

Based on the sketchy information available as to magnitude and displacement, the following rough estimates for expected displacement along the Elsinore fault are proposed. Maximum Probable Earthquake of Richter magnitude of 6.5 could have an expected displacement of 2 to 4 feet. Maximum Credible Earthquake of Richter magnitude of 7.4 could have an expected displacement from 8 to 20 feet.

DEFINITIONS

1. Fault - A fracture or fracture zone along which there has been displacement of the two sides relative to one another parallel to the fracture. The displacement may be a few inches to many miles.

2. Active Fault - A fault that has shown historical activity. Some may be presently active and undergoin creep.

3. Potentially Active Fault - A fault along which no know historical ruptures have occurred. Available evidence indicates geologically recent activity. Estimated recurrence period could be short enough to be of engineering significance. Age of last fault offset should be documented.

4. Inactive Fault - Surface faulting has not occurred in the recent geologic past. Estimated recurrence interval is long enough to be of no engineering significance. Age of last fault offset should be documented.

5. Design Earthquake - It is a specification of the ground motion that a project is required to successfully survive. Successful survival is avoidance of loss of life, acceptable damage and acceptable interruption of service.

6. Maximum Credible Earthquake - The largest earthquake that could ever occur on a given fault. Used as the only design earthquake by the California Department of Water Resources, Division of Dam Safety.

7. Maximum Probable Earthquake - The strongest earthquake most likely to occur during the design life of the project i.e. the 100-year probable earthquake. It is a statistical earthquake.

8. Earthquake Focus - The location of first release of energy located at depth on the fault plane.

9. Earthquake Epicenter - The point on the earth's surface vertically above the focus.

10. Magnitude (or Richter Magnitude) - A measure of the energy of an earthquake at its source. The maximum amplitude of the earthquake waves recorded on a seismogram is transformed to a numerical figure by means of a log scale. Therefore, an increase of one number on the scale (magnitude 4 to 5) represents a tenfold increase in the

size of the earthquake record. One unit of magnitude also represents an increase of thirty-two times the amount of energy released by the quake.

11. Intensity (Modified Mercalli) - Intensity is a rating of the severity of the ground motion at a specific location. The scale of measurement is based on the sensations of persons and upon the physical damage to natural and man-made objects.

Definitions are from Seismic Risk Evaluation, handout document by C.E. Stearns, 1974.[1/]

REFERENCES AND FOOTNOTES

1/ Stearns, C.E. (1974). Seismic Risk Evaluation, Handout document for presentation at the Geologists - Design Engineers workshop in Portland, Oregon, September 9 through 13, 1974.

2/ Cook, K. L., And Smith, Robert B. (1967). Seismicity in Utah, 1850 through June 1965, Bull. Seismological Society Administration, Vol. 57, No. 4, pp. 689-718, 1967.

3/ Schneider, Michael C. (1964). Geology of the Pavant Mountains West of Richfield, Sevier County, Utah, BYU Geology Studies, Vol. II, 12-64.

4/ Lautenschlage, H. K. (1952). The Geology of the Central Part of the Pavant Range, Utah, Ohio State University, unpublished PhD Thesis.

5/ Spieker, Edmund M. (1949). The Transition Between the Colorado Plateaus and the Great Basin in Central Utah, Guidebook to the Geology of Utah, No. 4, Utah Geological Society, Third Impression.

6/ NOAA - Seismic History 1901 to 1973, National Geophysical and Solar - Terrestrial Data Center - EDS - NOAA, Boulder, Colorado.

U.S.D.C., NOAA, Environmental Data Service (1973). Earthquake History of the United States, Publication 41-1, Revised Edition (Through 1970), Environmental Data Service, Boulder Colorado, page 70.

7/ Arabasz, Walter J. (1976). Unpublished seismic data, 1966 to present. University of Utah.

Seismic History
of
Richfield-West Sevier Area
(50 Mile Radius)

YEAR	MO	DAY	HR	MN	SEC	LAT-N	LONG-W	MAG	INT	DEP	S	D	REMARKS
1876	DEC	30	05	15	----	-----	------	3.1	III		W		RICHFIELD COVE CREEK TUSHAR FAULT
1877	JAN	01	--	--	----	-----	------	3.7	IV		W		RICHFIELD FELT 3,000 SQ MI TUSHAR FLT
1877	JAN	15	12	00	----	-----	------	3.1	III		W		SEVIER CITY TUSHAR FAULT 2 SHOCKS
1878	AUG	14	--	--	----	-----	------	4.3	V		W		COVE CREEK HURRICANE FAULT
1878	AUG	15	13	40	----	-----	------	2.0	II		W		COVE CREEK HURRICANE FAULT
1878	AUG	15	14	40	----	-----	------	2.0	II		W		COVE CREEK HURRICANE FAULT
1878	AUG	16	02	44	----	-----	------	3.7	IV		W		COVE CREEK HURRICANE FAULT
1881	AUG	04	04	30	----	-----	------	3.1	III		W		BEAVER HURRICANE FAULT 5 SHOCKS
1881	AUG	04	18	30	----	-----	------				W		BEAVER HURRICANE FAULT
1885	OCT	26	08	00	----	-----	------	3.1	III		W		BEAVER CO FRISCO BEAVER MTN FAULT
1885	OCT	26	09	00	----	-----	------	3.1	III		W		BEAVER CO FRISCO BEAVER MTN FAULT
1885	DEC	17	01	00	----	-----	------	3.7	IV		W		CIRCLEVILLE TUSHAR FAULT
1885	DEC	17	03	20	----	-----	------	3.1	III		W		TEASDALE THOUSAND LAKE FAULT
1887	DEC	05	15	30	----	-----	------	5.5	VII		W		KANAB SEVIER FAULT DAMAGE
1889	DEC	07	11	00	----	-----	------	3.7	IV		W		MANTI THOUSAND LAKE FAULT
1895	JUL	27	22	25	----	-----	------	3.7	IV		W		MT PLEASANT THOUS LAKE FAULT DAMAGE
1899	NOV	10	09	00	----	-----	------	3.7	IV		W		BEAVER HURRICANE FAULT
1901	NOV	14	--	--	----	-----	------	2.0	II		W		RICHFIELD SHOCKS NOV 14 to NOV 30
1901	NOV	14	04	39	----	-----	------	6.7	IX		W		RICHFIELD ABOUT 35 SHOCKS TUSHAR FLT
1902	JUN	01	--	--	----	-----	------	3.1	III		W		BEAVER SEVERAL SHOCKS HURRICANE FLT
1902	JUL	31	07	00	----	-----	------	4.3	V		W		BEAVER CO BEAVER HURRICANE FAULT
1903	JUL	12	16	30	----	-----	------	3.1	III		W		RICHFIELD TUSHAR FAULT
1906	FEB	21	05	30	----	-----	------				W		SEVIER CO ELSINORE TUSHAR FAULT
1910	JAN	10	13	00	----	-----	------	4.9	VI		W		ELSINORE TUSHAR FAULT
1910	JAN	10	13	30	----	-----	------	4.9	VI		W		ELSINORE TUSHAR FAULT
1910	JAN	10	18	45	----	-----	------	4.9	VI		W		ELSINORE TUSHAR FAULT
1910	JAN	10	20	25	----	-----	------	4.9	VI		W		ELSINORE TUSHAR FAULT
1910	JAN	10	21	30	----	-----	------	4.9	VI		W		ELSINORE TUSHAR FAULT

YEAR	MO	DAY	HR	MN	SEC	LAT-N	LONG-W	MAG	INT	DEP	S	D	REMARKS
1910	JAN	11	04	00	----	-----	------	4.9	VI		W		ELSINORE TUSHAR FAULT
1910	JAN	12	03	00	----	-----	------	4.9	VI		W		ELSINORE TUSHAR FAULT DAMAGE
1910	JAN	12	03	15	----	-----	------	4.9	VI		W		ELSINORE TUSHAR FAULT
1913	OCT	20	10	00	----	-----	------	3.7	IV		W		PANGUITCH SEVIER FAULT
1915	OCT	25	17	13	----	-----	------	3.1	III		W		JOSEPH TUSHAR FAULT
1920	AUG	18	08	20	----	-----	------	3.1	III		W		BEAVER HURRICANE FAULT
1921	SEP	12	10	18	----	-----	------	3.7	IV		W		RICHFIELD TUSHAR FAULT
1921	SEP	12	10	22	----	-----	------	3.7	IV		W		RICHFIELD TUSHAR FAULT
1921	SEP	12	13	27	----	-----	------	3.7	IV		W		RICHFIELD TUSHAR FAULT
1921	SEP	13	09	30	----	-----	------	4.3	V		W		RICHFIELD TUSHAR FAULT 2 SHOCKS
1921	SEP	28	--	--	----	-----	------	2.0	II		W		ELSINORE TUSHAR FLT MANY SHOCKS
1921	SEP	29	14	12	----	-----	------	6.1	VIII		W		ELSINORE TUSHAR FAULT DAMAGE
1921	SEP	30	02	30	----	-----	------				W		ELSINORE SEVIER VALLEY
1921	SEP	30	13	30	----	-----	------				W		ELSINORE
1921	OCT	01	02	00	----	-----	------	2.0	II		W		ELSINORE TUSHAR FAULT
1921	OCT	01	15	32	----	-----	------	6.1	VIII		W		ELSINORE TUSHAR FAULT DAMAGE
1921	OCT	01	17	30	----	-----	------	2.0	II		W		ELSINORE TUSHAR FAULT
1921	OCT	02	01	05	----	-----	------	2.0	II		W		ELSINORE TUSHAR FAULT
1921	OCT	04	03	09	----	-----	------	2.0	II		W		ELSINORE TUSHAR FAULT
1921	OCT	04	17	25	----	-----	------	2.0	II		W		ELSINORE TUSHAR FAULT
1921	OCT	08	20	30	----	-----	------	2.0	II		W		ELSINORE TUSHAR FAULT
1921	OCT	10	08	30	----	-----	------	2.0	I		W		ELSINORE TUSHAR FAULT
1921	OCT	10	09	45	----	-----	------	2.0	I		W		ELSINORE TUSHAR FAULT
1921	OCT	15	11	15	----	-----	------	3.1	III		W		ELSINORE TUSHAR FAULT
1921	OCT	15	12	27	----	-----	------	3.1	III		W		ELSINORE TUSHAR FAULT
1921	OCT	27	14	15	----	-----	------	5.5	VII		W		ELSINORE TUSHAR FAULT 2 SHOCKS
1921	DEC	20	09	45	----	-----	------	3.7	IV		W		ELSINORE TUSHAR FAULT
1921	DEC	20	10	35	----	-----	------	3.7	IV		W		ELSINORE TUSHAR FAULT
1921	DEC	20	12	15	----	-----	------	3.7	IV		W		ELSINORE TUSHAR FAULT
1921	DEC	20	13	00	----	-----	------	3.7	IV		W		ELSINORE TUSHAR FAULT
1921	DEC	20	14	50	----	-----	------	3.7	IV		W		ELSINORE TUSHAR FAULT
1921	DEC	20	15	15	----	-----	------	3.7	IV		W		ELSINORE TUSHAR FAULT
1924	JAN	01	23	15	----	-----	------	3.1	III		W		KANE CO ORDERVILLE SEVIER FAULT
1926	MAY	15	19	51	----	-----	------	3.1	III		W		KANE CO ORDERVILLE SEVIER FAULT

YEAR	MO	DAY	HR	MN	SEC	LAT-N	LONG-W	MAG	INT	DEP	S	D	REMARKS
1926	JUN	01	05	20	----	-----	------	2.0	II		W		ORDERVILLE SEVIER FAULT
1926	JUN	05	11	00	----	-----	------	3.1	III		W		ORDERVILLE SEVIER FAULT
1926	JUN	22	03	40	----	-----	------	2.0	II		W		ORDERVILLE SEVIER FAULT
1926	JUN	28	06	00	----	-----	------	2.0	II		W		ORDERVILLE SEVIER FAULT
1926	JUL	12	05	20	----	-----	------	3.1	III		W		ORDERVILLE SEVIER FAULT
1926	JUL	15	--	--	----	-----	------	2.0	II		W		ORDERVILLE SEVIER FAULT
1926	OCT	01	15	15	----	-----	------	3.1	III		W		ORDERVILLE SEVIER FAULT
1926	OCT	14	20	30	----	-----	------	3.1	III		W		ORDERVILLE SEVIER FAULT
1926	OCT	23	00	00	----	-----	------	3.1	III		W		ORDERVILLE SEVIER FAULT
1926	NOV	12	03	40	----	-----	------	3.1	III		W		ORDERVILLE SEVIER FAULT
1926	NOV	16	14	15	----	-----	------	3.1	III		W		ORDERVILLE SEVIER FAULT
1927	MAY	22	05	00	----	-----	------	3.1	III		W		ORDERVILLE SEVIER FAULT
1927	NOV	23	02	45	----	-----	------	2.0	II		W		RICHFIELD TUSHAR FAULT
1927	NOV	23	09	30	----	-----	------	3.1	III		W		ORDERVILLE SEVIER FAULT
1931	MAR	09	04	29	----	-----	------	2.0	II		W		ELSINORE TUSHAR FAULT
1932	MAY	22	06	00	----	-----	------	2.0	I		W		VENICE
1937	FEB	18	04	15	----	-----	------	3.7	IV		W		PANGUITCH, PAROWAN, AND CEDAR CITY
1937	FEB	18	06	30	----	-----	------	3.7	IV		W		PANGUITCH, PAROWAN, AND CEDAR CITY
1937	FEB	18	09	00	----	-----	------	3.7	IV		W		PANGUITCH SEVIER FAULT
1937	FEB	21	08	30	----	-----	------	3.1	III		W		PANGUITCH SEVIER FAULT
1937	FEB	26	01	30	----	-----	------	3.7	IV		W		PANGUITCH SEVIER FAULT
1937	MAR	13	11	40	----	-----	------	2.0	II		W		PANGUITCH SEVIER FAULT
1937	APR	01	04	41	----	-----	------	2.0	II		W		PANGUITCH SEVIER FAULT
1940	NOV	23	13	00	----	-----	------	3.7	IV		W		MANTI THOUSAND LAKE FAULT
1940	NOV	23	13	22	----	-----	------	3.7	IV		W		MANTI THOUSAND LAKE FAULT
1940	NOV	25	12	30	----	-----	------	2.0	II		W		MANTI THOUSAND LAKE FAULT
1940	NOV	25	13	10	----	-----	------	2.0	II		W		MANTI THOUSAND LAKE FAULT
1940	NOV	25	14	25	----	-----	------	3.7	IV		W		MANTI THOUSAND LAKE FAULT
1942	MAR	28	14	10	----	-----	------	3.7	IV		W		CIRCLEVILLE TUSHAR FAULT
1942	MAR	28	16	00	----	-----	------	3.7	IV		W		CIRCLEVILLE TUSHAR FAULT
1942	JUN	04	23	04	----	-----	------	4.3	V		W		SANPETE CO EPHRAIM TO NEPHI
1943	MAR	12	13	45	----	-----	------	3.7	IV		W		EPHRAIM THOUSAND LAKE FAULT
1943	NOV	03	10	30	----	-----	------	4.3	V		W		SEVIER TUSHAR FAULT
1943	NOV	03	12	30	----	-----	------	3.1	III		W		SEVER TUSHAR FAULT

YEAR	MO	DAY	HR	MN	SEC	LAT-N	LONG-W	MAG	INT	DEP	S	D	REMARKS
1943	NOV	04	03	00	----	-----	------	3.1	III		W		SEVIER TUSHAR FAULT
1944	JUN	05	15	45	----	-----	------	2.0	II		W		MONROE SEVIER FAULT
1945	NOV	18	01	15	----	-----	------	4.9	VI		W		GLENWOOD SEVIER FAULT DAMAGE
1948	NOV	04	13	18	----	-----	------	4.3	V		W		MANTI THOUSAND LAKE FAULT
1953	APR	18	05	15	----	-----	------	3.7	IV		C		MONROE
1973	OCT	22	03	00	----	-----	------	4.3	V		C		PANGUITCH DAMAGE
1953	OCT	24	20	50	----	-----	------				C		PANGUITCH
1959	SEP	17	06	20	----	-----	------	3.7	IV		C		MARYSVALE
1961	APR	16	05	02	39.3	39.33	111.65	4.9	VI	4C	U	D	6 MI NW OF EPHRAIM DAMAGE
1961	OCT	15	21	05	01.8	39.25	111.56			20	U	D	SAN PETE CO 6 MI E OF MANTI
1961	OCT	16	19	13	06.5	39.2	111.5			18	C		CENTRAL UTAH
1961	OCT	17	00	59	41.8	39.2	111.5			21	C		CENTRAL UTAH
1961	OCT	17	03	54	39.3	39.23	111.57			20	U	D	SAN PETE CO 5 MI SE OF MANTI
1962	FEB	17	03	29	26.9	38.6	111.6			33	C		NE OF PANGUITCH
1962	JUN	05	22	29	45.0	38.0	112.1			33	C		NE OF PANGUITCH
1962	JUN	08	19	21	27.0	37.5	112.5			33	C		S OF PANGUITCH
1963	JUN	19	08	38	47.6	37.9	112.5	4.2		36	C		NW OF PANGUITCH
1963	NOV	13	06	17	32.8	38.25	112.72	3.8		20	U	D	BEAVER CO 5 MI SW OF BEAVER
1964	JAN	17	00	15	05.1	38.16	112.69			20	U	D	BEAVER CO 8 MI S BEAVER
1964	JAN	17	00	15	37.3	38.18	112.72			20	U	D	BEAVER CO 6 MI S BEAVER
1964	MAR	03	03	24	54.1	38.58	112.28			20	U		SEVIER CO 18 MI SW OF RICHFIELD
1964	MAR	26	22	01	39.1	38.57	112.47	2.4		20	U		MILLARD CO 5 MI E OF COVE FORT
1964	JUL	06	19	27	35.7	38.35	112.27			20	U		PIUTE CO 7 MI SW OF MARYSVALE
1964	AUG	24	01	41	17.6	38.92	112.28			20	U		MILLARD CO 6 MI SE OF FILLMORE
1964	AUG	24	01	51	02.9	38.76	112.23	3.2		20	U	D	MILLARD CO 14 MI NE OF FILLMORE
1964	AUG	24	01	55	37.2	39.09	112.08	3.0		20	U	D	MILLARD CO SCIPIO LAKE
1964	SEP	06	19	03	37.7	39.26	111.59	3.3		20	U	D	SAN PETE CO 3 MI E OF MANTI
1964	SEP	21	00	36	25.9	38.88	112.30	3.4		20	U		MILLARD CO 7 MI OF FILLMORE
1964	OCT	02	20	48	02.4	38.46	112.59			20	U		BEAVER CO 14 MI N OF BEAVER
1964	NOV	29	09	31	41.3	39.33	112.10			20	U		MILLARD CO 25 MI E OF DELTA
1965	FEB	03	20	15	43.9	38.54	112.10			20	U		SEVIER CO 16 MI S RICHFIELD
1965	MAR	16	05	37	14.6	38.66	112.45	3.4		20	U	D	SEVIER CO 21 MI WSW RICHFIELD
1965	MAY	16	19	04	04.6	38.18	112.67	3.4		20	U		BEAVER CO 7 MI S BEAVER
1965	JUN	13	01	41	39.5	38.86	112.12	2.0		20	U	D	SEVIER CO 6 MI NW RICHFIELD

YEAR	MO	DAY	HR	MN	SEC	LAT-N	LONG-W	MAG	INT	DEP	S	D	REMARKS
1965	JUL	05	17	17	08.5	39.30	111.40	2.7		20	U	D	SANPETE CO NEAR EPHRAIM
1965	SEP	10	21	47	46.7	39.40	111.40			20	U		SANPETE CO EAST OF EPHRAIM
1966	APR	23	21	20	30.0	39.50	111.60	2.2		0	U		SANPETE CO MORONI
1968	JAN	16	08	57	19.9	39.40	112.00	2.2		20	U		JUAB CO SEVIER BRIDGE RESERVOIR AREA
1968	JAN	16	09	20	13.3	39.33	112.15	3.1		20	U	D	JUAB CO SEVIER BRIDGE RESERVOIR AREA
1968	JAN	16	09	28	55.4	39.45	111.99	2.1		10	U		JUAB CO SEVIER BRIDGE RESERVOIR AREA
1968	JAN	16	09	39	53.3	39.43	112.01	2.2		20	U	D	JUAB CO SEVIER BRIDGE RESERVOIR AREA
1968	JAN	16	10	38	44.7	39.69	112.16	2.1		20	U		JUAB CO SEVIER BRIDGE RESERVOIR AREA
1968	JAN	17	04	27	15.4	39.33	112.10	2.8		20	U	D	JUAB CO SEVIER BRIDGE RESERVOIR AREA
1968	JAN	17	04	36	01.9	39.53	111.83	2.0		20	U		JUAB CO SEVIER BRIDGE RESERVOIR AREA
1968	JAN	19	11	19	28.5	39.38	112.02	2.4		20	U		JUAB CO SEVIER BRIDGE RESERVOIR AREA

DATE	ORIGIN		LATITUDE		LONGITUDE		UTM-N	UTM-E	DEPTH	MAG	NO	RMS
740120	2500	.58	39	25.58	111	5.09	4363.8834	492.6982	4.64	2.30	5	.05
740125	1326	36.23	39	23.06	111	.87	4359.2191	498.7512	2.00	2.00	5	.30
740208	1632	42.56	39	19.19	111	57.93	4352.5054	418.7704	1.17	1.40	4	.25
740209	1736	4.48	39	22.37	111	1.15	4357,9430	498.3491	2.00	2.40	5	.03
740219	1004	40.89	39	58.05	111	34.53	4424.0986	450.8508	1.30	1.70	5	.28
740220	443	51.55	39	53.96	111	29.25	4416.4882	458.3250	4.69	1.60	7	.23
740220	805	1.54	39	54.57	111	27.78	4417.6053	460.4253	7.00	1.60	6	.33
740222	1515	56.11	39	48.25	111	29.76	4405.9299	457.5397	2.13	1.50	4	.62
740222	1731	28.58	39	51.98	111	16.73	4375.7548	476.0369	2.00	1.30	4	.29
740318	43	54.04	38	36.39	111	39.23	4273.1065	443.0695	7.00	1.70	7	.35
740416	1819	53.85	38	23.96	111	46.91	4250.2060	431.7289	15.02	2.20	6	.34
740515	228	56.99	39	29.22	111	3.67	4370.6144	494.7399	2.00	1.90	5	.23
740517	427	25.78	39	21.57	111	57.76	4356.9050	417.0616	3.12	1.80	5.	.10
740523	907	17.54	39	18.93	111	4.91	4351.5834	492.9453	1.00	2.00	5	.58
740527	1058	30.99	39	25.28	111	1.32	4363.3254	498.1063	2.00	2.10	5	.48
740527	1146	15.21	39	20.42	110	54.60	4354.3398	507.7560	11.64	2.00	4	.22
740528	303	47.73	38	37.61	111	53.42	4275.5359	422.4985	7.00	2.40	6	.53
740529	720	18.92	39	1.11	111	27.99	4318.7250	459.6144	3.48	2.70	5	.12
740712	836	3.78	39	23.48	112	6.76	4360.5864	404.1816	2.61	2.60	6	.31

DATE	ORIGIN		LATITUDE		LONGITUDE		UTM-N	UTM-E	DEPTH	MAG	NO	RMS
740814	1431	30.89	38	40.28	111	56.31	4280.5157	418.3562	10.07	2.70	7	.40
740515	228	56.99	39	29.22	111	3.67	4370.6144	494.7399	2.00	1.90	5	.23
740517	427	25.78	39	21.57	111	57.76	4356.9050	417.0616	3.12	1.80	5	.10
740527	1058	30.99	39	25.28	111	1.32	4363.3254	498.1063	2.00	2.10	5	.48
740528	303	47.76	38	37.61	111	63.42	4275.5359	422.4985	7.00	2.40	6	.53
740529	720	18.92	39	1.11	111	27.99	4318.7250	459.6144	3.48	2.70	5	.12
740412	836	3.78	39	23.48	112	6.76	4360.5864	404.1816	2.61	2.60	6	.31
740722	903	44.21	39	31.77	111	55.04	4375.7310	421.1593	7.00	2.20	7	.37
740814	1431	30.89	38	40.28	111	56.31	4280.5157	418.3562	10.07	2.70	7	.40
740903	1122	51.71	39	48.06	111	35.49	4405.6282	449.3620	7.00	2.10	6	.39
740912	1738	31.67	39	59.87	111	44.61	4427.5713	436.5311	.70	2.30	5	.22
740916	1608	48.31	38	43.98	112	37.70	4288.1993	358.4636	15.43	2.80	7	.20
740920	1454	39.66	38	45.19	112	21.67	4290.0579	381.7204	12.47	2.60	8	.17
741104	507	6.37	38	27.28	112	20.53	4256.9096	382.8873	7.00	2.30	6	.73
741106	1235	24.64	39	27.59	111	2.53	4367.5987	496.3725	7.00	2.20	4	.61
741106	2047	17.74	39	51.48	112	41.40	4413.1537	355.4362	7.00	.40	3	.58
741112	445	46.26	38	24.05	112	12.75	4250.7791	394.1233	7.00	2.40	4	.16
741117	431	55.99	39	11.73	111	28.52	4338.3564	461.8310	2.95	2.40	6	.60
741118	1537	55.78	39	50.91	111	35.96	4410.9045	448.7264	7.00	2.30	10	.21
731118	2317	31.30	39	50.32	111	32.39	4409.7806	453.8104	6.68	2.30	10	.33
741127	9	7.30	39	56.75	112	52.54	4423.2200	339.7580	7.00	1.90	3	.50
741130	1606	.44	39	18.58	112	53.36	4352.6349	337.1048	7.00	3.00	3	.00
741202	2045	24.17	39	12.88	112	5.59	4340.9596	405.6239	1.28	2.40	8	.23
741205	2645	31.47	39	53.50	112	47.91	4417.0718	346.2297	7.00	2.20	3	.46
731210	1313	33.84	39	12.12	112	45.00	4340.4437	348.8876	7.00	1.80	3	.00
741216	956	49.59	39	52.30	111	38.50	4413.5007	445.1235	7.00	.80	0	.34
741117	431	55.99	39	11.73	111	26.52	4338.3564	461.8310	2.95	2.40	6	.60
741118	1537	55.78	39	50.91	111	35.96	4410.9045	448.7267	7.00	2.30	10	.21
741118	2317	31.30	39	50.32	111	32.39	4409.7806	453.8104	6.68	2.30	10	.33
741127	9	7.30	39	56.75	112	52.54	4423.2200	339.7580	7.00	1.90	3	.50
741130	1306	.44	39	18.58	112	53.36	4352.6349	337.1048	7.00	3.00	3	.00
741202	2045	24.17	39	12.88	112	5.59	4340.9596	405.6239	1.28	2.40	8	.23
741206	2645	31.47	39	53.50	112	47.91	4417.0718	346.2297	7.00	2.20	3	.46
741210	1313	33.84	39	12.12	112	45.00	4340.4437	348.8876	7.00	1.80	3	.00

DATE	ORIGIN	LATITUDE	LONGITUDE	UTM-N	UTM-E	DEPTH	MAG	NO	RMS
741213	958 49.59	39 52.30	111 38.50	4413.5007	445.1235	7.00	.80	0	.34
741215	350 19.29	39 55.71	112 7.82	4420.2231	403.4109	7.00	.80	0	.00
731215	1850 5.47	39 49.16	111 49.32	4407.8187	429.6475	9.83	.90	9	.47
741228	1039 13.00	38 26.62	112 23.92	4255.7623	377.9385	11.65	2.10	8	1.15
741225	50 39.05	39 59.72	111 49.46	4427.3546	429.6281	7.00	.70	3	.11
741225	120 37.44	39 58.58	111 47.60	4425.2217	432.2558	7.00	.90	3	.10
741225	204 20.14	39 58.84	111 53.56	4425.7828	423.7782	.97	1.10	6	.14
741225	308 51.85	39 59.73	111 47.60	4427.3490	432.2747	7.00	1.20	3	.25
741225	310 23.95	39 55.60	112 8.16	4420.0258	402.9241	7.00	1.10	3	.20
741225	2348 .91	39 46.96	111 12.27	4403.4461	482.4883	15.12	.90	5	.13
741228	152 35.02	39 52.41	111 8.23	4413.5163	448.2697	4.05	1.20	8	.31
741228	764 11.47	39 58.83	111 49.46	4425.7081	429.6129	7.00	.80	3	.21
741228	917 17.11	39 59.16	111 49.46	4426.3186	429.6185	7.00	1.20	6	.13
741227	1151 58.43	39 58.69	111 52.66	4425.4927	425.0563	.84	.90	4	.10
741231	2210 53.08	39 59.83	111 45.00	4427.5020	435.9756	1.88	2.00	11	.45
750104	2044 40.76	39 37.09	111 14.68	4385.1981	478.9990	7.00	2.20	6	.36
750105	449 51.72	39 24.28	111 3.83	4361.4775	494.5041	2.51	2.60	11	.42
750107	2352 14.12	39 55.61	112 36.79	4420.6723	362.1469	18.22	1.70	5	.09
750110	434 2.67	38 39.50	112 40.26	4279.9801	354.6037	19.16	2.70	5	.51
750112	959 56.52	38 1.79	112 57.92	4210.7426	327.5064	1.27	2.80	7	.50
741225	2348 .91	39 46.96	111 12.27	4403.4461	482.4883	15.12	.90	5	.13
741226	152 35.02	39 62.41	111 8.23	4413.51	488.2697	4.05	1.20	8	.31
741226	734 11.47	39 58.83	111 49.46	4425.70	429.6129	7.00	.80	3	.21
741226	917 17.11	39 59.16	111 49.46	4426.3186	429.6185	7.00	1.20	6	.13
741227	1151 58.43	39 58.69	111 52.66	4425.4927	425.0563	.84	.90	4	.10
741231	2210 53.08	39 59.83	111 45.00	4427.5020	435.9756	1.88	2.00	11	.45
750104	2044 40.76	39 37.09	111 14.68	4386.1981	478.9990	7.00	2.20	6	.36
750105	449 51.72	39 24.28	111 3.83	4361.4775	494.5041	2.51	2.60	11	.42
750107	2352 14.12	39 55.61	112 36.79	4420.6723	362.1469	18.22	1.70	5	.09
750110	434 2.67	38 39.50	112 40.26	4279.9801	354.6037	19.16	2.70	5	.51
750111	1820 24.80	38 4.99	113 25.46	4217.6130	287.3701	1.16	3.00	6	.23
750112	959 56.52	38 1.79	112 57.92	4210.7426	327.5064	1.27	2.80	7	.50
750116	2202 38.39	39 21.31	111 2.30	4355.9830	496.6973	1.03	1.90	5	.50
750115	712 23.59	39 24.79	111 3.68	4362.4205	494.7200	.86	1.40	6	.49

DATE	ORIGIN		LATITUDE		LONGITUDE		UTM-N	UTM-E	DEPTH	MAG	NO	RMS
750115	714	23.96	39	25.16	111	4.80	4363.1061	493.1136	.91	1.60	5	.35
750115	803	53.91	39	35.60	111	10.37	4382.4277	485.1595	3.24	1.60	4	.22
750129	127	35.80	39	22.99	111	7.82	4359.0977	488.7751	.59	2.70	15	.32
750129	200	38.06	39	20.30	111	7.23	4354.1210	489.6153	1.75	2.40	10	.41
750129	234	6.36	39	22.46	111	6.78	4358.1154	490.2667	.20	2.50	10	.19
750129	1724	33.18	39	15.40	112	8.73	4345.6765	401.1647	1.27	2.00	11	.35
750203	1400	5.20	39	26.65	111	52.78	4366.2283	424.3041	3.62	2.20	12	.29
750205	1309	42.20	39	33.52	111	4.07	4378.5684	494.1725	2.33	2.10	8	.12
750207	1619	56.09	39	16.13	112	6.22	4346.9819	404.7907	11.63	1.70	5	.04
750219	314	36.11	39	24.09	112	4.45	4361.6746	407.5106	4.75	2.60	16	.24
750219	1541	47.79	39	18.56	112	4.79	4351.4517	406.9004	1.09	2.10	11	.28
750219	2207	52.48	39	59.99	111	47.60	4427.8300	432.2790	1.48	2.30	7	.52
750222	142	44.45	39	26.91	112	1.20	4366.8365	412.2336	3.44	1.30	5	.33
750225	1817	13.14	39	9.28	112	11.70	4334.4119	396.7444	.52	1.70	7	.27
750207	1819	38.09	39	18.16	112	8.22	4348.9819	404.7907	11.63	1.70	5	.04
750219	314	36.11	39	24.09	112	4.45	4361.6746	407.5106	4.75	2.60	16	.24
750219	1541	47.79	39	18.56	112	4.79	4351.4517	406.9004	1.09	2.10	11	.28
750222	142	44.45	39	26.91	112	1.20	4366.8365	412.2336	3.44	1.30	5	.33
750225	1817	13.14	39	9.28	112	11.70	4334.4119	396.7444	.52	1.70	7	.27
750310	2123	26.96	39	22.77	112	13.37	4359.3958	394.6764	3.89	1.40	6	.25
750311	2130	15.65	39	59.96	111	46.06	4427.7924	434.4698	2.38	2.00	9	.10
750319	2121	3.53	39	58.30	111	43.33	4424.6521	438.3287	7.00	2.30	11	.43
750321	1816	6.04	39	52.42	113	4.29	4415.5798	322.8404	7.00	2.20	12	.42
750310	2123	26.96	39	22.77	112	13.37	4359.3958	394.6764	3.89	1.50	6	.25
750311	2130	15.65	39	59.96	111	46.06	.7924	434.4698	2.38	2.00	9	.10
750317	1818	25.65	39	49.26	113	1.87	4409.6547	326.1753	3.40	1.40	7	.21
750319	2121	3.53	39	58.30	111	43.33	4424.6521	438.3287	7.00	2.30	11	.43
75321	1813	6.04	39	52.42	113	4.29	4415.5798	322.8404	7.00	2.20	12	.42
750327	2302	44.31	39	52.36	113	3.37	4415.4385	324.1493	7.00	1.50	7	.30

DATE	ORIG	TIME	LAT-N	LONG-W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	Q
750718	1658	16.62	39-12.91	111-20.39	7.00*	1.8	8	320	84.3	.42	8.4	3.6	D1
750729	1829	17.38	38-40.49	112-45.01	7.00*	2.1	6	164	114.4	.35	6.1	12.0	D1

DATE	ORIG	TIME	LAT-N	LONG-W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	Q
7508	2043	45.06	39-16.25	111-47.38	7.00*	1.2	7	282	92.6	.29	10.9	4.1	D1
750905	23 1	10.50	39-19.25	111-27.60	7.00*	1.6	6	275	64.7	.28	30.6	4.0	D1
750906	1634	44.54	39-30.26	111-13.79	7.00*	1.6	6	188	38.2	.28	4.2	5.9	D1
750910	839	42.98	38-36.99	112-41.36	7.00*	2.9	8	159	96.0	.35	3.1	2.0	D1
750911	830	31.94	39-20.83	111-29.08	7.00*	2.4	8	153	59.1	.45	2.9	2.9	D1
750926	044	38.70	39-28.36	112-14.03	7.00	1.0	7	177	11.5	.24	3.4	13.8	O1
750928	628	7.72	39-26.31	111-49.93	7.00*	1.2	10	244	29.8	.46	4.5	2.5	D1

YR	DATE	ORIG	TIME	LAT-N	LONG-W	DEPTH	MAG	NO	GAP	DMIN	RMS	Q
75	1005	0155	17.07	39-36.90	111-11.93	7.00*	1.7	9	203	33.8	.22	D
75	1005	0253	55.71	39-35.52	111-13.78	7.00*	2.1	10	209	36.5	.27	C
75	1005	1120	18.17	39-33.30	111-13.73	7.00*	1.4	6	226	36.9	.10	D
75	1006	1550	48.15	39- 9.74	111-29.82	7.00*	3.2	11	169	62.9	.51	D
75	1006	2041	45.68	38-57.69	111-25.83	7.00*	1.6	6	267	77.9	.28	D
75	1009	0142	1.81	39- 3.88	111-28.35	7.00*	1.7	8	181	69.7	.26	C
75	1009	1728	21.22	39-39.09	111- 5.37	7.00*	1.2	5	317	65.7	.16	C
75	1011	1305	23.83	39-40.93	111-10.37	7.00*	1.2	7	189	32.7	.18	C
75	1022	2113	35.12	39-27.59	111-51.84	7.00*	1.4	8	179	27.8	.46	C
75	1104	2318	13.59	39-26.89	111-49.44	7.00*	1.5	14	118	30.7	.50	C
75	1219	1116	51.30	39-31.36	111-15.07	7.00*	1.4	6	235	39.4	.31	D
75	1227	1022	25.64	39-11.10	111-51.95	7.00*	1.1	7	195	34.0	.31	D

Attachment C. Boring Logs

Key to Boring Logs

CONSISTENCY OR CONDITION OF SOILS

Fine-Grained Soils (Silt and Clay): Major portion passing #200 sieve

Relative Consistency	N_{60} SPT, Blows/foot	Shear Strength, tsf	Unconfined Compressive Strength, tsf	Field Behavior
Very Soft	< 2	< 0.13	< 0.25	Easily penetrated several inches by fist
Soft	2 - 4	0.13 - 0.25	0.25 - 0.5	Easily penetrated several inches by thumb
Medium Stiff	5 - 8	0.25 - 0.5	0.5 - 1	Penetrated several inches by thumb with moderate effort
Stiff	9 - 15	0.5 - 1	1 - 2	Readily indented by thumb but penetrated only with great effort
Very Stiff	16 - 30	1 - 2	2 - 4	Readily indented with thumbnail
Hard	> 30	> 2	> 4	Indented with difficulty by thumbnail

Coarse-Grained Soils (Sand and Gravel): Major portion retained on #200 sieve

Apparent Density	$(N_1)_{60}$ SPT, Blows/foot	Relative Density, %	Field Test with 1/2-in Steel Rod
Very Loose	< 5	0 - 20	Very easily penetrated when pushed by hand
Loose	5 - 10	20 - 40	Easily penetrated when pushed by hand
Medium Dense	11 - 30	40 - 70	Easily penetrated when driven with 5-lb hammer
Dense	31 - 50	70 - 85	Penetrated 1 ft with difficulty when driven with 5-lb hammer
Very Dense	> 50	85 - 100	Penetrated less than 3 in. when driven with 5-lb hammer

Particle Size Descriptions for Sand and Gravel

Description	Gravel Size	Sand Size	Size Requirement
Coarse	3-in. to 3/4-in.	#4 to #10 sieve	<30% medium to fine sand or <12% fine gravel
Coarse to medium	- -	- -	<12% fine sand
Medium	- -	#10 to #40 sieve	<12% coarse sand and >30% medium sand
Medium to fine	- -	- -	<30% medium sand or <12% coarse gravel
Fine	3/4-in. to #4 sieve	#40 to #200 sieve	<30% medium sand or <12% coarse gravel
Coarse to fine	- -	- -	>12% of each size

Moisture Conditions

Dry	No indication of moisture, dusty
Slightly Moist	Appears dry, but some moisture present
Moist	Damp but no visible water
Wet	Visible free water

Structure and Layering of Soils

Stratum	>12 inches thick
Layer	1/2 inch to < 12 inches
Seam	1/16 inch to 1/2 inch
Parting	< 1/16 inch
Frequent	More than one per foot
Varved	Frequent alternating layers, seams, or partings of sand, silt, or clay
Pocket	Small erratic deposit
Lens	Non-continuous lenticular deposit

Plasticity of Fine-Grained Soils

Nonplastic	1/8-in thread cannot be rolled at any water content
Low	Thread can barely be rolled and lump cannot be formed when drier than the plastic limit
Medium	Thead is easy to roll with little time required to reach plastic limit. Thread cannot be rerolled after reaching the plastic limit.
High	Considerable time rolling and kneading to reach plastic limit. Thread can be rerolled several times after reaching plastic limit.

Unified Soil Classification System

Major Divisions			Symbols: Graphic	Symbols: Letter
Coarse-Grained Soils: More than 50% of Material is Retained on No. 200 Sieve	Gravels: More than 50% of Coarse Fraction is Retained on No. 4 Sieve	Clean Gravels (little or no fines)		GW
				GP
		Gravels with Fines (appreciable amount of fines)		GM
				GC
	Sands: More than 50% of Coarse Fraction Passes No. 4 Sieve	Clean Sand (little or no fines)		SW
				SP
		Sands with Fines (appreciable amount of fines)		SM
				SC
Fine-Grained Soils: More than 50% of Material Passes No. 200 Sieve	Silts and Clays	Liquid Limit Less than 50		ML
				CL
				OL
	Silts and Clays	Liquid Limit 50, or more		MH
				CH
				OH
Highly Organic Soils				PT

Note: Dual Symbols are used to indicate borderline soil classifications

TYPICAL SAMPLER GRAPHIC SYMBOLS

- 3.25" OD Dames & Moore Sampler
- 3" OD Shelby Tube
- Non-standard Sample
- 2" OD Split Spoon (SPT)
- Piston Sample
- Grab Sample

TYPICAL WATER LEVEL SYMBOLS

- Measured Water Level after minimum of 24 hours
- Estimated or observed water level at time of drilling

KEY TERMINOLOGY

CBR	- California bearing ratio
CONS	- One-Dimensional Consolidation Test
CORR	- Corrosion tests
DS	- Direct shear test
F	- Percent fines by weight passing #200 sieve
G	- Percent gravel by weight
γ_d	- Dry unit weight
$\gamma_{d\text{-}max}$	- Maximum dry unit weight as per ASTM D698 or D1557
LL	- Liquid Limit
N	- Number of blows to drive sampler through the second and third 6-inch soil intervals using a 140-lb hammer dropped 30 inches
N_{60}	- SPT N value corrected for field procedures
$(N_1)_{60}$	- SPT N_{60} value corrected for effective overburden pressure
NP	- Nonplastic
OD	- Outer diameter
PI	- Plasticity index
PP	- Pocket penetrometer
S	- Percent sand by weight
SG	- Specific gravity
SPT	- Standard Penetration Test
SS	- Direct simple shear test
TV	- Torvane
TXCD	- Consolidated drained triaxial test
TXCU	- Consolidated undrained triaxial test
TXCY	- Cyclic triaxial test
TXUU	- Unconsolidated undrained triaxial test
UC	- Unconfined compression test
W	- Moisture content
W_{opt}	- Optimum moisture content associated with ASTM D698 or D1557

Descriptions and layers are interpretive; field descriptions may have been modified to reflect lab test results. Descriptions on these logs apply only at the specific boring locations and at the time the borings were advanced; they are not warranted to be representative of subsurface conditions at other locations or times.

AECOM

Project: 2019 Sevier Watershed Plan
Project Location: Sevier County, UT
Project Number: 60598028

Log of Boring B19-TC-01

Sheet 1 of 2

Date(s) Drilled:	**2/20/2019**	Drill Rig Type:	**CME-850 Track Rig**	Logged By: **BWF**	Checked By: **CJT**
Drilling Contractor:	**Conetec, Inc.**	Hammer Information:	**140-pound Automatic Hammer, 30-inch Drop, ER=79.2%**	Total Depth of Borehole:	**50.25 feet**
Drilling Method: Bit Size/Type:	**Hollow Stem Auger 8" OD/ 4.25" ID 2-Prong Spad Bit**	Borehole Backfill:	**Portland Cement Bentonite Grout**	Surface Elevation:	**5422 feet**
Sampling Method(s):	**18-inch Standard Split Spoon, Modified California with Rings**	Estimated Groundwater Level at Time of Drilling:	**32 feet**	Groundwater Level and Date Measured:	**Not Measured**
Location:	**38.77387° N 112.09958° W**			Survey Datum:	**WGS84**

Elevation feet	Depth, feet	Type	Number	Blows/6inch	SPT N_{60} blowcount	SPT $(N_1)_{60}$ blowcount	Recovery, %	Graphic Log	MATERIAL DESCRIPTION	REMARKS AND OTHER TESTS
	0								Sandy SILT (ML); hard, moist, orange brown, fine sand, fine gravel, low plasticity	
5420										
			S-1	19 21 20 N=41	27	42	67			NP; G=0.1%; S=45.8%; F=54%
	5		S-2	6 7 9 N=16	15	20	61		...very stiff	
5415										
			S-3	14 47 31 N=78	59	72	61		Silty GRAVEL with Sand (GM); very dense, moist, orange brown, fine sand, coarse to fine gravel	G=40.9%; S=40%; F=19%
	10		S-4	11 13 18 N=31	30	35	78		Silty SAND (SM); dense, moist, orange brown	
5410										
	15		S-5	3 5 6 N=11	9	9	39		...less gravel; loose	
5405										
	20		S-6	3 3 3 N=6	7	6	83		...some (trace) gravel; loose, fine sand, fine gravel	G=2.6%; S=57.4%; F=40%
5400										
	25									

AECOM

SLC_GEOTECH_2 Q:\PROJECTS\JONES AND DEMILLE\2019 SEVIER WATERSHED PLAN\400 - TECHNICAL\404 FIELD\GINT\SEVIER WATERSHED PLAN.GPJ GINT LIBRARY FILE - 20180314-UDOT.GLB SLCGEOTECH.GDT 5/16/19

Project: 2019 Sevier Watershed Plan
Project Location: Sevier County, UT
Project Number: 60598028

Log of Boring B19-TC-01

Depth, feet	Elevation feet	SAMPLES Type	Number	Blows/6inch	SPT N_{60} blowcount	SPT $(N_1)_{60}$ blowcount	Recovery, %	Graphic Log	MATERIAL DESCRIPTION	REMARKS AND OTHER TESTS
25	5395		S-7a S-7b	11 30 29 N=59	50	42	78		...with gravel; dense	
									Silty SAND with Gravel (SM); very dense, dry to moist, orange brown; fine sand, coarse to fine gravel, larger particles of rock fractured into spoon	
30	5390		S-8	28 25 38 N=63	73	58	78			NP; G=38.5%; S=38.7%; F=23%
									▽ Poorly Graded SAND (SP); medium dense, wet, orange brown to brown, fine to medium sand	Inferred ground water; significantly softer
35	5385		S-9	9 14 32 N=46	41	31	83		Clayey GRAVEL with Sand (GC); dense, wet, fine to coarse gravel, coarse sand	
									Poorly graded SAND (SP); medium dense, wet, orange brown to brown, fine to coarse sand	
40	5380		S-10	4 8 23 N=31	36	27	78		...with gravel	
45	5375		S-11	26 20 26 N=46	53	38	100		Clayey SAND with Gravel (SC), dense, wet, orange brown to brown, fine to coarse sand, fine to coarse sand	
50	5370		S-12	50/3"	-	-	0		Rock/Boulder	Potentially 2-3 inches of heave in bottom
									End of Boring	Auger Refusal

SLC_GEOTECH_2 Q:\PROJECTS\JONES AND DEMILLE\2019 SEVIER WATERSHED PLAN\400 - TECHNICAL\404 FIELD\GINT\SEVIER WATERSHED PLAN.GPJ GINT LIBRARY FILE - 20180314-UDOT.GLB SLCGEOTECH.GDT 5/16/19

Project: 2019 Sevier Watershed Plan
Project Location: Sevier County, UT
Project Number: 60598028

Log of Boring BH19-FC-01

Date(s) Drilled:	**2/22/2019-2/23/2019**	Drill Rig Type:	**CME-850 Track Rig**	Logged By: **BWF**	Checked By: **CJT**
Drilling Contractor:	**Conetec, Inc.**	Hammer Information:	**140-pound Automatic Hammer, 30-inch Drop, ER=79.2%**	Total Depth of Borehole:	**59 feet**
Drilling Method: Bit Size/Type:	**Hollow Stem Auger 8" OD/ 4.25" ID 2-Prong Spad Bit**	Borehole Backfill:	**Portland Cement Bentonite Grout**	Surface Elevation:	**5571 feet**
Sampling Method(s):	**18-inch Standard Split Spoon, Modified California with Rings**	Estimated Groundwater Level at Time of Drilling:	**Not Encountered**	Groundwater Level and Date Measured:	**Not Measured**
Location:	**38.71081° N 112.14402° W**			Survey Datum:	**WGS84**

Elevation feet	Depth, feet	SAMPLES Type	Number	Blows/6inch	SPT N_{60} blowcount	SPT $(N_1)_{60}$ blowcount	Recovery, %	Graphic Log	MATERIAL DESCRIPTION	REMARKS AND OTHER TESTS
5570	0								Silty SAND with Gravel (SM); very dense, dry, light brown to brown, coarse to fine sand, coarse to fine gravel, with cobbles	
			S-1	3 7 47 N=54	36	55	44			G=26.8%; S=36.6%; F=37%
5565	5		S-2	50/2"	-	-	0			Dust recovered; rock to drill past
									...medium dense, fine gravel	
			S-3	9 10 8 N=18	18	22	67			G=12%; S=51.7%; F=36%
5560	10		S-4	7 13 10 N=23	23	26	44			
5555	15		S-5	32 50/3"	-	-	28		...interbedded strata (1-1.5 ft thick) with gravel; very dense, light brown	
5550	20		S-6	25 34 50/5"	-	-	72		...more gravel	
	25									

AECOM

SLC_GEOTECH_2 Q:\PROJECTS\JONES AND DEMILLE\2019 SEVIER WATERSHED PLAN\400 - TECHNICAL\404 FIELD\GINT\SEVIER WATERSHED PLAN.GPJ GINT LIBRARY FILE - 20180314-UDOT.GLB SLCGEOTECH.GDT 5/16/19

Project: 2019 Sevier Watershed Plan
Project Location: Sevier County, UT
Project Number: 60598028

Log of Boring BH19-FC-01

Elevation feet	Depth, feet	SAMPLES Type	Number	Blows/6inch	SPT N_{60} blowcount	SPT $(N_1)_{60}$ blowcount	Recovery, %	Graphic Log	MATERIAL DESCRIPTION	REMARKS AND OTHER TESTS
	25									
5545			S-7	44 50/3"	-	-	100		...less gravel	G=32.4%; S=47.7%; F=20%
	30									
5540			S-8	42 50/4"	-	-	100			
	35									
5535			S-9	35 50/5"	-	-	91			
	40									
5530			S-10	42 50/5"	-	-	91			G=24.2%; S=52%; F=24%
	45									
5525			S-11	20 31 34 N=65	75	50	83		...fine to medium sand	
	50									
5520			S-12	30 50 50/3"	-	-	67		...some fragments of clayey sand	
									Clayey SAND (SC); medium dense, dry to moist, brown to brown gray, no gravel, fine sand, low plasticity	
	55									

SLC_GEOTECH_2 Q:\PROJECTS\JONES AND DEMILLE\2019 SEVIER WATERSHED PLAN\400 - TECHNICAL\404 FIELD\GINT\SEVIER WATERSHED PLAN.GPJ GINT LIBRARY FILE - 20180314-UDOT.GLB SLCGEOTECH.GDT 5/16/19

Project: 2019 Sevier Watershed Plan
Project Location: Sevier County, UT
Project Number: 60598028

Log of Boring BH19-FC-01

Elevation feet	Depth, feet	SAMPLES Type	Number	Blows/6inch	SPT N_{60} blowcount	SPT $(N_1)_{60}$ blowcount	Recovery, %	Graphic Log	MATERIAL DESCRIPTION	REMARKS AND OTHER TESTS
	55									
5515		S-13		9 11 11 N=22	25	15	78			
		S-14		18 19 23 N=42	49	28	100		...with gravel, moist, fine gravel	LL=25; PI=5; G=0.3%; S=54%; F=46%
									End of Boring	Auger Refusal
5510										
5505										
5500										
5495										
5490										

SLC_GEOTECH_2 Q:\PROJECTS\JONES AND DEMILLE\2019 SEVIER WATERSHED PLAN\400 - TECHNICAL\404 FIELD\GINT\SEVIER WATERSHED PLAN.GPJ GINT LIBRARY FILE - 20180314-UDOT.GLB SLCGEOTECH.GDT 5/16/19

Project: 2019 Sevier Watershed Plan
Project Location: Sevier County, UT
Project Number: 60598028

Log of Boring BH19-LC-01

Sheet 1 of 1

Date(s) Drilled: **2/22/2019**	Drill Rig Type: **CME-850 Track Rig**	Logged By: **BWF**	Checked By: **CJT**
Drilling Contractor: **Conetec, Inc.**	Hammer Information: **140-pound Automatic Hammer, 30-inch Drop, ER=79.2%**	Total Depth of Borehole: **21.4 feet**	
Drilling Method: **Hollow Stem Auger** Bit Size/Type: **8" OD/ 4.25" ID 2-Prong Spad Bit**	Borehole Backfill: **Portland Cement Bentonite Grout**	Surface Elevation: **5423 feet**	
Sampling Method(s): **18-inch Standard Split Spoon, Modified California with Rings**	Estimated Groundwater Level at Time of Drilling: **Not Encountered**	Groundwater Level and Date Measured: **Not Measured**	
Location: **38.76958° N 112.10377° W**		Survey Datum: **WGS84**	

Elevation feet	Depth, feet	SAMPLES Type	Number	Blows/6inch	SPT N_{60} blowcount	SPT $(N_1)_{60}$ blowcount	Recovery, %	Graphic Log	MATERIAL DESCRIPTION	REMARKS AND OTHER TESTS
	0								Silty SAND with Gravel (SM); very dense, dry to moist, orange brown to brown, with cobbles, fine sand, coarse to fine gravel	
5420			S-1	21 60 69 N=129	86	131	100			G=27.5%; S=47.4%; F=25%
	5		S-2	16 18 22 N=40	37	50	78		...dense	
5415			S-3	6 12 19 N=31	23	29	67		...medium dense	
	10		S-4	27 47 37 N=84	63	72	67		...very dense, trending to light orange brown to light brown, coarse to fine sand, coarse to fine gravel	G=36.9%; S=42.8%; F=20%
5410									Lean CLAY with Sand (CL); hard, dry to moist, orange brown	
	15		S-5	15 24 38 N=62	68	69	89			Slow drilling; very hard
5405									Clayey SAND (SC); very dense, dry, orange brown to brown, fine sand	
	20		S-6	19 38 50/5"	-	-	82			
									End of Boring	Auger Refusal
5400										

SLC_GEOTECH_2 Q:\PROJECTS\JONES AND DEMILLE\2019 SEVIER WATERSHED PLAN\400 - TECHNICAL\404 FIELD\GINT\SEVIER WATERSHED PLAN.GPJ GINT LIBRARY FILE - 20180314-UDOT.GLB SLCGEOTECH.GDT 5/16/19

Project: 2019 Sevier Watershed Plan
Project Location: Sevier County, UT
Project Number: 60598028

Log of Boring BH19-WC-01

Sheet 1 of 1

Date(s) Drilled:	**2/20/2019**	Drill Rig Type:	**CME-850 Track Rig**	Logged By: **BWF**	Checked By: **CJT**
Drilling Contractor:	**Conetec, Inc.**	Hammer Information:	**140-pound Automatic Hammer, 30-inch Drop, ER=79.2%**	Total Depth of Borehole:	**21 feet**
Drilling Method: **Hollow Stem Auger** Bit Size/Type: **8" OD/ 4.25" ID 2-Prong Spad Bit**		Borehole Backfill:	**Cuttings**	Surface Elevation:	**5591 feet**
Sampling Method(s):	**18-inch Standard Split Spoon, Modified California with Rings**	Estimated Groundwater Level at Time of Drilling:	**Not Encountered**	Groundwater Level and Date Measured:	**Not Measured**
Location:	**38.79707° N 112.08313° W**			Survey Datum:	**WGS84**

Elevation feet	Depth, feet	SAMPLES Type	Number	Blows/6inch	SPT N_{60} blowcount	SPT $(N_1)_{60}$ blowcount	Recovery, %	Graphic Log	MATERIAL DESCRIPTION	REMARKS AND OTHER TESTS
	0								Silty, Clayey SAND with Gravel (SC-SM); very dense, dry to moist, with cobbles, fine to coarse sand, coarse to fine gravel, low plasticity	
5590			S-1	10 21 39 N=60	40	61	100			
	5		S-2	16 18 20 N=38	35	47	78		...dense	LL=21; PI=6; G=28.7%; S=38.2%; F=33%
5585			S-3	14 34 39 N=73	55	68	67		Silty GRAVEL with Sand (GM); very dense, dry to moist, orange brown, coarse to fine sand, coarse to fine gravel	G=44.3%; S=29.8%; F=26%
	10		S-4	12 18 19 N=37	36	41	69		...dense	
5580			S-5	75/5"	-	-	100		Silty CLAY (CL-ML); very hard, dry, orange brown	
	15		S-6	20 45 50/3"	-	-	60		Weathered Rock/CLAYSTONE; orange brown to dark red	
5575									...streaks of dark olive green color	
	20		S-7	50/3"	-	-	67			
5570									End of Boring	Auger Refusal

AECOM

SLC_GEOTECH_2 Q:\PROJECTS\JONES AND DEMILLE\2019 SEVIER WATERSHED PLAN\400 - TECHNICAL\404 FIELD\GINT\SEVIER WATERSHED PLAN.GPJ GINT LIBRARY FILE - 20180314-UDOT.GLB SLCGEOTECH.GDT 5/16/19

Attachment D. Test Pit Logs

Surface and Shallow Soil Sampling Log

AECOM

Log ID: TP19-FC-01
Datum: WGS84
Latitude: 38.70979°
Longitude: -112.14427° **Elevation:** NM

General Information

Project Number: 60598028	**Project Name:** 2019 Sevier Watershed Plan	**Page:** 1 of 1
Location: Flat Canyon SW of Richfield (southeast test pit 15 ft up on hill)		**Date:** 2/20/2019
Field Investigator: B. Barrett		A&D Jensen Contractors
Sampling Excavation Method: Link-Belt 225 Excavator	**Sampling Method:** Bag, Bucket	
Depth of Excavation: 21 ft	**Depth to Water:** Not Enc.	**Backfill Material:** Excavated Material

Sample Information

Sample Number	Depth (ft)	Lithologic Description	Comments /Analysis Requested
S-1 Bag	0-2	Silty SAND with gravel (SM), slightly moist, some organics, orange brown; few cobbles	
S-2 Bucket	2-21	Poorly graded GRAVEL with clay and sand (GC), slightly moist, orange brown; pockets/layers with higher gravel fraction, few cobbles and boulders, fine sand, coarse to fine gravel, low plasticity	LL=25; PI=8; G=57.7%; S=30.3%; F=12%; $\gamma_{d\text{-}max}$=136.6 pcf; w_{opt}=6.8% (AASHTO T180)

Photograph/Sketch

Description
Right: Note pockets/layers in excavation sidewall with higher gravel fraction Left: Sample piles of excavated material





Recorded By: B. Franke	Date : 05/14/2019	Checked By: C. Tanner	Date: 05/14/2019

Surface and Shallow Soil Sampling Log

AECOM

Log ID: TP19-FC-02
Datum: WGS84
Latitude: 38.71110°
Longitude: -112.14636° **Elevation:** NM

General Information

Project Number: 60598028	**Project Name:** 2019 Sevier Watershed Plan	**Page:** 1 of 1
Location: Flat Canyon SW of Richfield (southern test pit in basin)		**Date:** 2/20/2019
Field Investigator: B. Barrett		A&D Jensen Contractors
Sampling Excavation Method: Link-Belt 225 Excavator	**Sampling Method:** Bag, Bucket	
Depth of Excavation: 19 ft	**Depth to Water:** Not Enc.	**Backfill Material:** Excavated Material

Sample Information

Sample Number	Depth (ft)	Lithologic Description	Comments /Analysis Requested
S-1 Bag	0-2	Silty fine to medium SAND (SM), medium dense, moist, some organics, gray brown; (approx. 15% silt)	
S-2 Bucket	2-19	Silty SAND with gravel (SM), slightly moist, gray brown; few cobbles, coarse to fine sand and gravel, low plasticity	NP; G=26.1%; S=59.3%; F=15%; $\gamma_{d\text{-}max}$=130.4 pcf; w_{opt}=8.3% (AASHTO T180)
	16	…more cobbles, few boulders	

Photograph/Sketch

Description





Recorded By: B. Franke	Date : 05/14/2019	Checked By: C. Tanner	Date: 05/14/2019

Surface and Shallow Soil Sampling Log

AECOM

Log ID: TP19-FC-03
Datum: WGS84
Latitude: 38.71206°
Longitude: -112.14645° **Elevation:** NM

General Information

Project Number: 60598028	**Project Name:** 2019 Sevier Watershed Plan	**Page:** 1 of 1
Location: Flat Canyon SW of Richfield (northern test pit in basin – south of wash)		**Date:** 2/20/2019
Field Investigator: B. Barrett		A&D Jensen Contractors
Sampling Excavation Method: Link-Belt 225 Excavator	**Sampling Method:** Bucket	
Depth of Excavation: 21 ft	**Depth to Water:** Not Enc.	**Backfill Material:** Excavated Material

Sample Information

Sample Number	Depth (ft)	Lithologic Description	Comments /Analysis Requested
S-1 Bucket	0-4	Silty SAND with gravel (SM), moist, orange brown; coarse to fine sand and gravel	G=35%; S=42.1%; F=23%
S-2 Bucket	4-21	Poorly graded GRAVEL with silty clay and sand (GP-GC), slightly moist, orange brown; few cobbles, coarse to fine sand and gravel, low plasticity	LL=20; PI=4; G=56.1%; S=31.9%; F=12%; $\gamma_{d\text{-}max}$=140.8 pcf; w_{opt}=6.2% (AASHTO T180)

Photograph/Sketch

Description



Recorded By: B. Franke	Date : 05/14/2019	Checked By: C. Tanner	Date: 05/14/2019

Surface and Shallow Soil Sampling Log

AECOM

Log ID: TP19-LC-01
Datum: WGS84
Latitude: 38.76995°
Longitude: -112.10407° **Elevation:** NM

General Information

Project Number: 60598028	**Project Name:** 2019 Sevier Watershed Plan	**Page:** 1 of 1
Location: Lind Canyon W of Richfield (southwestern most test pit)		**Date:** 2/19/2019
Field Investigator: B. Franke		A&D Jensen Contractors
Sampling Excavation Method: Link-Belt 225 Excavator	**Sampling Method:** Bucket	
Depth of Excavation: 12 ft	**Depth to Water:** Not Enc.	**Backfill Material:** Excavated Material

Sample Information

Sample Number	Depth (ft)	Lithologic Description	Comments /Analysis Requested
S-1 Bucket	0-1	Sandy Lean CLAY (CL), moist, orange brown; contains gravel, cobbles (3-6” diameter)	
S-2 Bucket	1-12	Poorly graded GRAVEL with silt and sand (GP-GM), moist to dry; cobbles (3-12” diameter), boulders (3-4’ diameter), fine sand, coarse to fine gravel, low plasticity	NP; G=57.3%; S=34.3%; F=7%
		Refusal on boulders/rock	

Photograph/Sketch

Description



Recorded By: B. Franke	Date : 05/14/2019	Checked By: C. Tanner	Date: 05/14/2019

Surface and Shallow Soil Sampling Log

AECOM

Log ID: TP19-LC-02
Datum: WGS84
Latitude: 38.77050°
Longitude: -112.10319° **Elevation:** NM

General Information

Project Number: 60598028	**Project Name:** 2019 Sevier Watershed Plan	**Page:** 1 of 1
Location: Lind Canyon W of Richfield (northwestern most test pit)		**Date:** 2/19/2019
Field Investigator: B. Franke		A&D Jensen Contractors
Sampling Excavation Method: Link-Belt 225 Excavator	**Sampling Method:** Bucket, Bag	
Depth of Excavation: 16 ft	**Depth to Water:** Not Enc.	**Backfill Material:** Excavated Material

Sample Information

Sample Number	Depth (ft)	Lithologic Description	Comments /Analysis Requested
S-1 Bucket	0-3.5	Silty SAND (SM), moist, brown to orange brown; some cobbles (less than 10" diameter), fine sand, coarse to fine gravel, some roots and vegetation	G=14.6%; S=53.9%; F=32%
S-2 Bucket	3.5-10.5	…boulders (less than 4' diameter), low plasticity	NP; G=11.9%; S=52.8%; F=35%; $\gamma_{d\text{-}max}$=125.4 pcf; w_{opt}=10.5% (AASHTO T180)
S-3 Bucket & Bag	10.5-16	Weathered siltstone or claystone, slightly moist, green gray to brown gray	broken into angular 2-4" fragments; effervesces with dilute hydrochloric acid

Photograph/Sketch

Description
Upper Left: Fragments of siltstone/claystone Lower Left: Large boulders removed during excavation Right: sidewall of test pit showing siltstone/claystone at bottom







Recorded By: B. Franke	Date : 05/14/2019	Checked By: C. Tanner	Date: 05/14/2019

Surface and Shallow Soil Sampling Log

AECOM

Log ID: TP19-LC-03
Datum: WGS84
Latitude: 38.76992°
Longitude: -112.10265° **Elevation:** NM

General Information

Project Number: 60598028	**Project Name:** 2019 Sevier Watershed Plan	**Page:** 1 of 1
Location: Lind Canyon W of Richfield (southeastern test pit 10 ft up on hill)		**Date:** 2/19/2019
Field Investigator: B. Franke/B. Barrett		A&D Jensen Contractors
Sampling Excavation Method: Link-Belt 225 Excavator	**Sampling Method:** Bag, Bucket	
Depth of Excavation: 25 ft	**Depth to Water:** Not Enc.	**Backfill Material:** Excavated Material

Sample Information

Sample Number	Depth (ft)	Lithologic Description	Comments /Analysis Requested
S-1 Bag	0-4	Poorly graded SAND with gravel (SP), slightly moist, orange brown	
S-2 Bucket	4-9	Silty GRAVEL with sand (GM), slightly moist, orange brown; fine sand, coarse to fine gravel	G=51.9%; S=34.5%; F=14%
S-3 Bucket	9-25	Silty SAND with gravel (SM), slightly moist, orange brown; few cobbles, fine sand, coarse to fine gravel, low plasticity	NP; G=32.9%; S=51.8%; F=15%

Photograph/Sketch

Description		
Left: Sidewalls of Test pit Right: Location of test pit up on hill		

Recorded By: B. Franke	Date : 05/14/2019	Checked By: C. Tanner	Date: 05/14/2019

Surface and Shallow Soil Sampling Log

AECOM

Log ID: TP19-LC-04
Datum: WGS84
Latitude: 38.77055°
Longitude: -112.10207° **Elevation:** NM

General Information

Project Number: 60598028	**Project Name:** 2019 Sevier Watershed Plan	**Page:** 1 of 1
Location: Lind Canyon W of Richfield (northeast test pit 5 ft up on hill)		**Date:** 2/19/2019
Field Investigator: B. Barrett		A&D Jensen Contractors
Sampling Excavation Method: Link-Belt 225 Excavator	**Sampling Method:** Bucket	
Depth of Excavation: 20 ft	**Depth to Water:** Not Enc.	**Backfill Material:** Excavated Material

Sample Information

Sample Number	Depth (ft)	Lithologic Description	Comments /Analysis Requested
S-1 Bucket	0-20	Silty SAND with gravel (SM), slightly moist, orange brown; some cobbles, few boulders, irregular pockets (approx. 2-4 ft diameter) of fine sand, irregular pockets (approx. 5-10 ft diameter) of coarse to fine gravel with sand, low plasticity	NP; G=39.6%; S=44.6%; F=16%; $\gamma_{d\text{-}max}$=136.5 pcf; w_{opt}=6.9% (AASHTO T180)

Photograph/Sketch

Description
Note pockets of fine sand, pockets of gravel, and large boulder in sidewall of excavation



Recorded By: B. Franke	Date : 05/14/2019	Checked By: C. Tanner	Date: 05/14/2019

Surface and Shallow Soil Sampling Log

AECOM

Log ID: TP19-TC-01
Datum: WGS84
Latitude: 38.77303°
Longitude: -112.10066° **Elevation:** NM

General Information

Project Number: 60598028	**Project Name:** 2019 Sevier Watershed Plan	**Page:** 1 of 1
Location: Tank Canyon W of Richfield (south test pit, on hill north of road)		**Date:** 2/19/2019
Field Investigator: B. Franke		A&D Jensen Contractors
Sampling Excavation Method: Link-Belt 225 Excavator	**Sampling Method:** Bucket	
Depth of Excavation: 8 ft	**Depth to Water:** Not Enc.	**Backfill Material:** Excavated Material

Sample Information

Sample Number	Depth (ft)	Lithologic Description	Comments /Analysis Requested
S-1 Bucket	0-2	Sandy Silty CLAY with gravel (CL-ML), moist, orange brown; contains some cobbles (approx. 6" diameter), some organics/vegetation	
S-2 Bucket	2-8	Silty SAND with gravel (SM), slightly moist, orange brown; contains some cobbles 3-8" diameter, contains rock fragments, fine sand, coarse to fine gravel, low plasticity	NP; G=28.3%; S=43.8%; F=28%; $\gamma_{d\text{-}max}$=134 pcf; w_{opt}=7.2% (AASHTO T180)
		Refusal	

Photograph/Sketch

Description

Left: Location of test pit up on hill

Right: Sidewalls and bottom of test pit; refusal on rock or siltstone/claystone





Recorded By: B. Franke	Date : 05/14/2019	Checked By: C. Tanner	Date: 05/14/2019

Surface and Shallow Soil Sampling Log

AECOM

Log ID: TP19-TC-02
Datum: WGS84
Latitude: 38.77401°
Longitude: -112.10043° **Elevation:** NM

General Information

Project Number: 60598028	**Project Name:** 2019 Sevier Watershed Plan	**Page:** 1 of 1
Location: Tank Canyon W of Richfield (northern most test pit)		**Date:** 2/19/2019
Field Investigator: B. Franke		A&D Jensen Contractors
Sampling Excavation Method: Link-Belt 225 Excavator	**Sampling Method:** Bag	
Depth of Excavation: 15 ft	**Depth to Water:** Not Enc.	**Backfill Material:** Excavated Material

Sample Information

Sample Number	Depth (ft)	Lithologic Description	Comments /Analysis Requested
S-1 Bag	0-2	Sandy lean CLAY with gravel and cobbles (CL), moist, orange brown; contains roots/vegetation	
S-2 Bag	2-6	Matrix supported conglomerate, silty fine grain sand matrix with angular gravel up to 1-inch in diameter, orange brown to brown gray (dark brown matrix, light brown particles)	effervesces with dilute hydrochloric acid
S-3 Bag	6-15	…brown gray with orange brown staining	

Photograph/Sketch

Description		
Left: Sidewalls and bottom of test pit showing fractured rock Right: Location of test pit		

Recorded By: B. Franke	Date : 05/14/2019	Checked By: C. Tanner	Date: 05/14/2019

Surface and Shallow Soil Sampling Log

AECOM

Log ID: TP19-WC-01
Datum: WGS84
Latitude: 38.79701°
Longitude: -112.08300° **Elevation:** NM

General Information

Project Number: 60598028	**Project Name:** 2019 Sevier Watershed Plan	**Page:** 1 of 1
Location: Wood Canyon NW of Richfield (south of wash)		**Date:** 2/20/2019
Field Investigator: B. Barrett		A&D Jensen Contractors
Sampling Excavation Method: Link-Belt 225 Excavator	**Sampling Method:** Bucket	
Depth of Excavation: 16 ft	**Depth to Water:** Not Enc.	**Backfill Material:** Excavated Material

Sample Information

Sample Number	Depth (ft)	Lithologic Description	Comments /Analysis Requested
S-1 Bucket	0-4	Silty GRAVEL with sand (SM), slightly moist, some organics, orange brown; fine sand, coarse to fine gravel, low plasticity	NP; G=53.2%; S=28.2%; F=19%
S-2 Bucket	4-16	Silty, clayey GRAVEL with sand (GC-GM), slightly moist, orange brown; few cobbles and boulders, coarse to fine sand and gravel, low plasticity	LL=21; PI=4; G=47.1%; S=30.4%; F=23%
	9	…1 foot layer of fine SAND with cobbles	

Photograph/Sketch

Description



Recorded By: B. Franke	Date : 05/14/2019	Checked By: C. Tanner	Date: 05/14/2019

Surface and Shallow Soil Sampling Log

AECOM

Log ID: TP19-WC-02
Datum: WGS84
Latitude: 38.79701°
Longitude: -112.08265° **Elevation:** NM

General Information

Project Number: 60598028	**Project Name:** 2019 Sevier Watershed Plan	**Page:** 1 of 1
Location: Wood Canyon NW of Richfield (north of wash)		**Date:** 2/20/2019
Field Investigator: B. Barrett		A&D Jensen Contractors
Sampling Excavation Method: Link-Belt 225 Excavator	**Sampling Method:** Bucket	
Depth of Excavation: 17 ft	**Depth to Water:** Not Enc.	**Backfill Material:** Excavated Material

Sample Information

Sample Number	Depth (ft)	Lithologic Description	Comments /Analysis Requested
S-1 Bucket	0-3	Silty SAND with gravel (SM), slightly moist, some organics, brown	
S-2 Bucket	3-17	Silty, clayey GRAVEL with sand (GC-GM), slightly moist, orange brown; few cobbles and occasional boulders, coarse to fine sand and gravel, low plasticity	LL=21; PI=7; G=57.4%; S=27.8%; F=15%

Photograph/Sketch

Description



Recorded By: B. Franke	Date : 05/14/2019	Checked By: C. Tanner	Date: 05/14/2019

Surface and Shallow Soil Sampling Log

AECOM

Log ID: TP19-WC-03
Datum: WGS84
Latitude: 38.79718°
Longitude: -112.08355° **Elevation:** NM

General Information

Project Number: 60598028	**Project Name:** 2019 Sevier Watershed Plan	**Page:** 1 of 1
Location: Wood Canyon NW of Richfield (TP northwest of wash)		**Date:** 2/20/2019
Field Investigator: B. Barrett		A&D Jensen Contractors
Sampling Excavation Method: Link-Belt 225 Excavator	**Sampling Method:** Bag, Bucket	
Depth of Excavation: 6 ft	**Depth to Water:** Not Enc.	**Backfill Material:** Excavated Material

Sample Information

Sample Number	Depth (ft)	Lithologic Description	Comments /Analysis Requested
S-1 Bag	0-2	Sandy SILT (ML), trace gravel, slightly moist, some organics, orange brown	
S-2 Bucket	2-6	Silty GRAVEL with sand (SM), slightly moist, orange brown; occasional cobbles and boulders, coarse to fine sand and gravel	G=43.1%; S=25.4%; F=32%; $\gamma_{d\text{-}max}$=137.7 pcf; w_{opt}=6.9% (AASHTO T180)
	6+	Siltstone or claystone	unable to penetrate in approx. 3ft x 14ft bottom of excavation

Photograph/Sketch

Description



Recorded By: B. Franke	Date : 05/14/2019	Checked By: C. Tanner	Date: 05/14/2019

Surface and Shallow Soil Sampling Log

AECOM

Log ID: TP19-WC-04
Datum: WGS84
Latitude: 38.79705°
Longitude: -112.08317° **Elevation:** NM

General Information

Project Number: 60598028	**Project Name:** 2019 Sevier Watershed Plan	**Page:** 1 of 1
Location: Wood Canyon NW of Richfield (test pit at location of BH19-WC-01)		**Date:** 2/20/2019
Field Investigator: B. Barrett		A&D Jensen Contractors
Sampling Excavation Method: Link-Belt 225 Excavator	**Sampling Method:** Bag, Bucket	
Depth of Excavation: 19 ft	**Depth to Water:** Not Enc.	**Backfill Material:** Excavated Material

Sample Information

Sample Number	Depth (ft)	Lithologic Description	Comments /Analysis Requested
S-1 Bucket	0-3	Silty SAND with gravel (SM), slightly moist, some organics, orange brown	
S-2 Bucket	3-15	Silty GRAVEL with sand (GM), slightly moist, orange brown; some cobbles, few boulders, fine sand, coarse to fine gravel, low plasticity	NP; G=55.4%; S=27.6%; F=17%; $\gamma_{d\text{-}max}$=138.6 pcf; w_{opt}=6.7% (AASHTO T180)
S-3 Bag	15-19	Weathered clay or claystone, orange brown to dark red; harder with depth	unable to penetrate beyond 19 ft in approx. 3ft x 9ft bottom of excavation
S-4 Bag	17	…Some dark olive green color, fractured to weathered clay/claystone pieces	

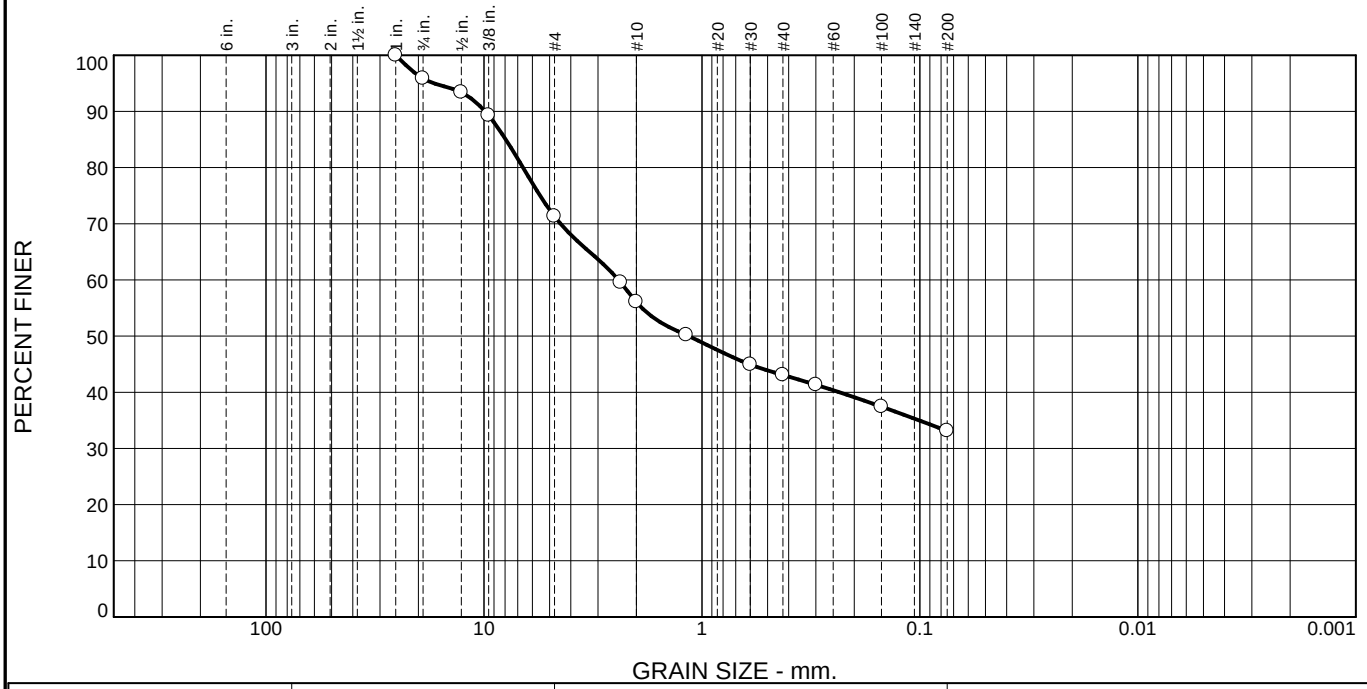
Photograph/Sketch

Description		
Left: Note rock in near end of trench unable to be removed or penetrated Right: Note vertical, relatively smooth sidewall of excavation below approx. 15 ft		

Recorded By: B. Franke	Date : 05/14/2019	Checked By: C. Tanner	Date: 05/14/2019

Attachment E. Laboratory Test Data

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	4.1	24.6	15.2	13.0	10.0	33.1	

Test Results (AASHTO T 27 & AASHTO T 11)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1"	100.0		
3/4"	95.9		
1/2"	93.4		
3/8"	89.3		
#4	71.3		
#8	59.5		
#10	56.1		
#16	50.2		
#30	44.9		
#40	43.1		
#50	41.3		
#100	37.4		
#200	33.1		

* (no specification provided)

Material Description

BH-19, WC-01, Sample 2, 5-6.5'

Atterberg Limits (ASTM D 4318)

PL= 14.5 **LL=** 20.6 **PI=** 6.1

Classification

USCS (D 2487)= SC-SM **AASHTO (M 145)=** A-2-4(0)

Coefficients

D_{90}= 9.8750 D_{85}= 7.9425 D_{60}= 2.4150
D_{50}= 1.1511 D_{30}= D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: 3/1/19 **Date Tested:** 3/5/19

Tested By: Mark Rappleye

Checked By: Mark Rappleye

Title: Lab Manager

Location: BH19 WC-01, S-2
Sample Number: 19-S-051

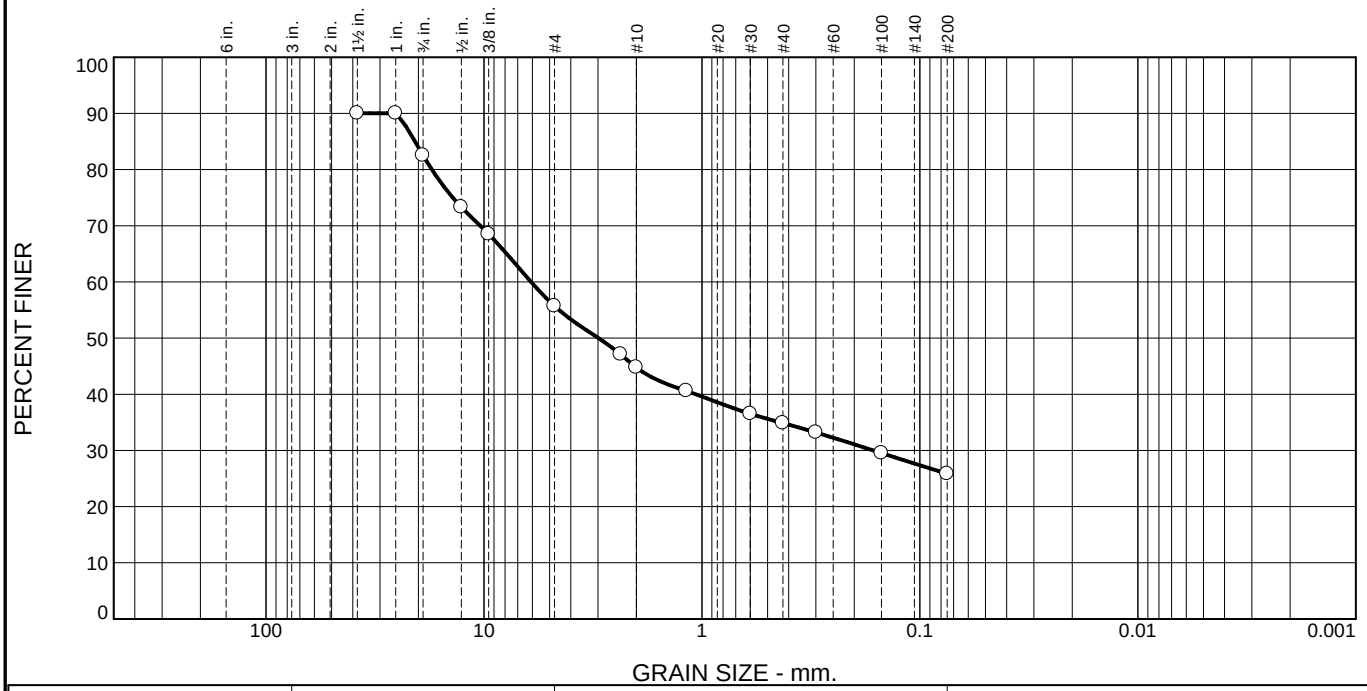
Date Sampled: 2/20/19

JONES & DEMILLE ENGINEERING INC.
Richfield, Utah

Client: Sevier County
Project: Sevier County Watershed Plan & Flood Protection

Project No: 1804-224 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
		26.8	10.9	9.9	9.0	25.9	

Test Results (AASHTO T 27 & AASHTO T 11)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1.5"	90.0		
1"	90.0		
3/4"	82.5		
1/2"	73.3		
3/8"	68.5		
#4	55.7		
#8	47.1		
#10	44.8		
#16	40.6		
#30	36.5		
#40	34.9		
#50	33.2		
#100	29.5		
#200	25.9		

* (no specification provided)

Material Description

BH19 WC-01, Sample 3, 7.5-9

Atterberg Limits (ASTM D 4318)

PL= **LL=** **PI=**

Classification

USCS (D 2487)= **AASHTO (M 145)=**

Coefficients

D_{90}= 25.3680 D_{85}= 20.7254 D_{60}= 6.0805
D_{50}= 2.9854 D_{30}= 0.1639 D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: 3/1/19 **Date Tested:** 3/6/19

Tested By: Mark Rappleye

Checked By: Mark Rappleye

Title: Lab Manager

Location: BH19 WC-01, S-3
Sample Number: 19-S-059

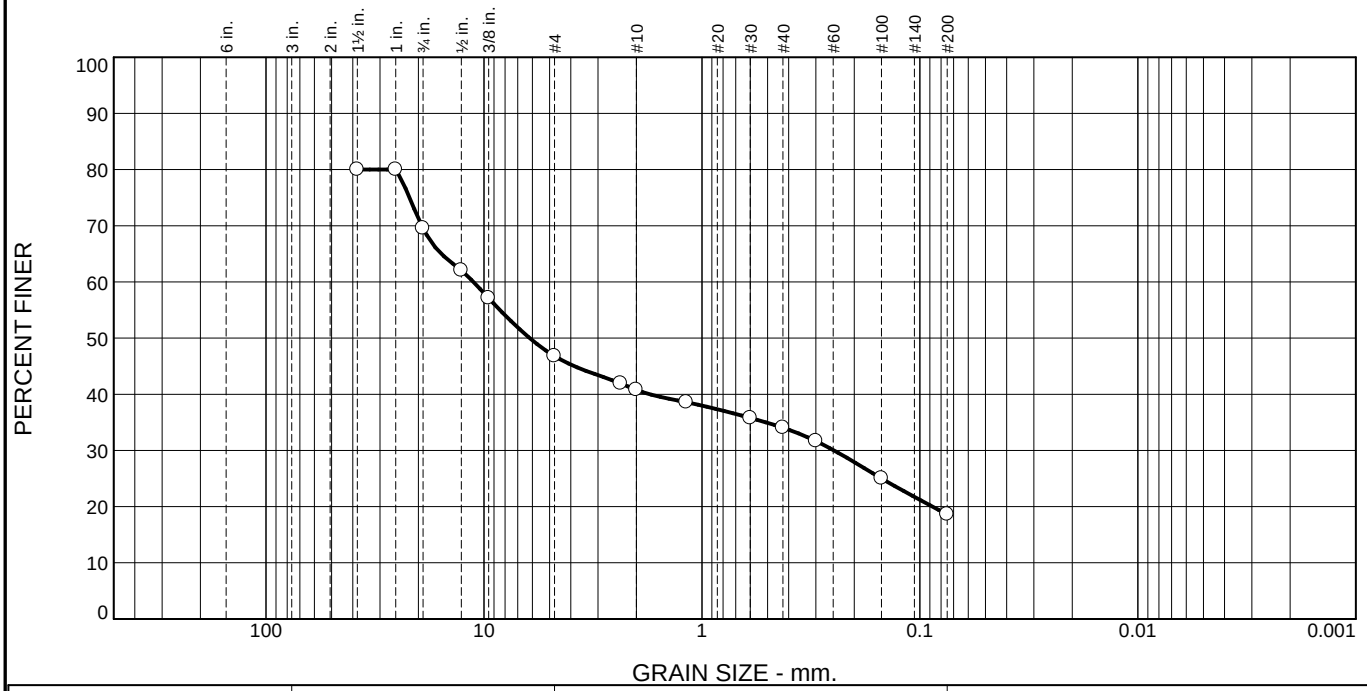
Date Sampled: 2/20/19

JONES & DEMILLE ENGINEERING INC.
Richfield, Utah

Client: Sevier County
Project: Sevier County Watershed Plan & Flood Protection

Project No: 1804-224 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
		22.8	6.0	6.8	15.4	18.6	

Test Results (AASHTO T 27 & AASHTO T 11)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1 1/2"	80.0		
1"	80.0		
3/4"	69.6		
1/2"	62.1		
3/8"	57.1		
#4	46.8		
#8	41.9		
#10	40.8		
#16	38.6		
#30	35.8		
#40	34.0		
#50	31.7		
#100	25.0		
#200	18.6		

* (no specification provided)

Material Description

TP19 WC-01, Sample 1, 0-4'

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= GM **AASHTO (M 145)=** A-1-b

Coefficients

D_{90}= D_{85}= D_{60}= 11.1762
D_{50}= 6.1694 D_{30}= 0.2478 D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: 3/8/2019 **Date Tested:** 3/11/2019

Tested By: Matt Murphree

Checked By: Mark Rappleye

Title: Lab Manager

Location: TP19 WC-01, S-1
Sample Number: 19-S-079

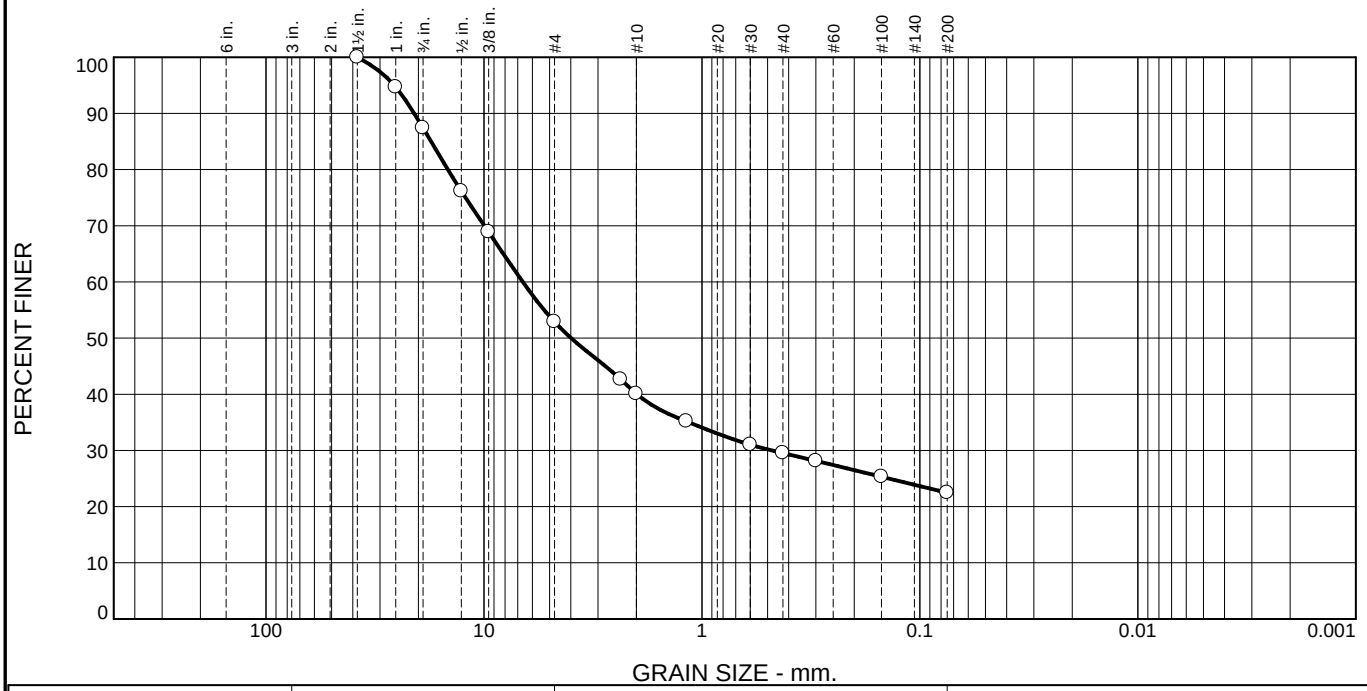
Date Sampled: 2/20/2019

JONES & DEMILLE ENGINEERING INC.
Richfield, Utah

Client: Sevier County
Project: Sevier County Watershed Plan & Flood Protection

Project No: 1804-224 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	12.6	34.5	12.8	10.6	7.0	22.5	

Test Results (AASHTO T 27 & AASHTO T 11)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1.5"	100.0		
1"	94.7		
3/4"	87.4		
1/2"	76.2		
3/8"	68.9		
#4	52.9		
#8	42.7		
#10	40.1		
#16	35.2		
#30	31.0		
#40	29.5		
#50	28.1		
#100	25.3		
#200	22.5		

* (no specification provided)

Material Description

TP19 WC-01, Sample 2, 4-16'

Atterberg Limits (ASTM D 4318)

PL= 17.2 **LL=** 21.1 **PI=** 3.9

Classification

USCS (D 2487)= GC-GM **AASHTO (M 145)=** A-1-b

Coefficients

D_{90}= 20.9113 D_{85}= 17.4925 D_{60}= 6.6388
D_{50}= 3.9835 D_{30}= 0.4771 D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: 2/22/19 **Date Tested:** 3/8/19

Tested By: Mark Rappleye

Checked By: Mark Rappleye

Title: Lab Manager

Location: TP19 WC-01, S-2
Sample Number: 19-S-077

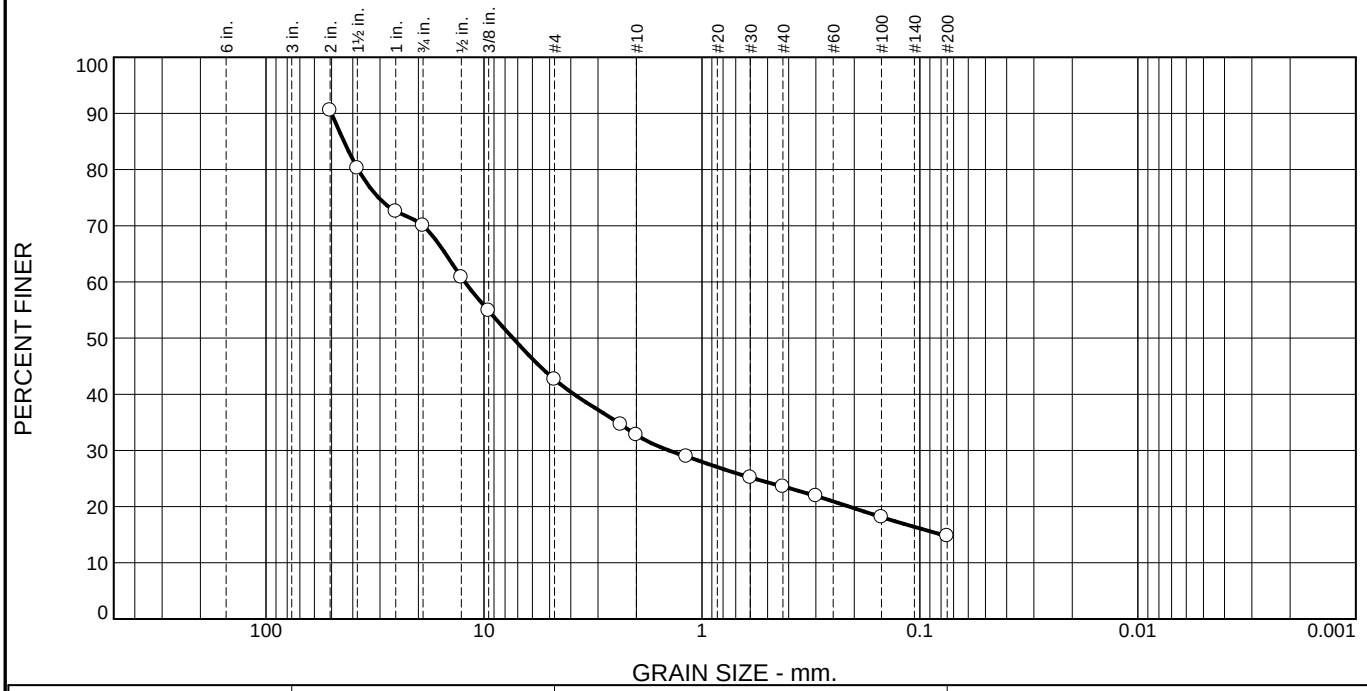
Date Sampled: 2/20/19

JONES & DEMILLE ENGINEERING INC.
Richfield, Utah

Client: Sevier County
Project: Sevier County Watershed Plan & Flood Protection

Project No: 1804-224 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
		27.4	9.8	9.2	8.8	14.8	

Test Results (AASHTO T 27 & AASHTO T 11)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
2"	90.5		
1.5"	80.3		
1"	72.6		
3/4"	70.0		
1/2"	60.8		
3/8"	54.9		
#4	42.6		
#8	34.6		
#10	32.8		
#16	28.9		
#30	25.2		
#40	23.6		
#50	21.9		
#100	18.1		
#200	14.8		

* (no specification provided)

Material Description

TP19 WC-02, S-2, 3-17'

Atterberg Limits (ASTM D 4318)

PL= 14.0 **LL=** 21.4 **PI=** 7.4

Classification

USCS (D 2487)= GC-GM **AASHTO (M 145)=** A-2-4(0)

Coefficients

D_{90}= 50.0858 D_{85}= 43.8782 D_{60}= 12.2542
D_{50}= 7.3715 D_{30}= 1.4167 D_{15}= 0.0790
D_{10}= C_u= C_c=

Remarks

Date Received: 2/22/19 **Date Tested:** 3/18/19

Tested By: Mark Rappleye

Checked By: Mark Rappleye

Title: Lab Manager

Location: TP19 WC-02, S-2
Sample Number: 19-S-080

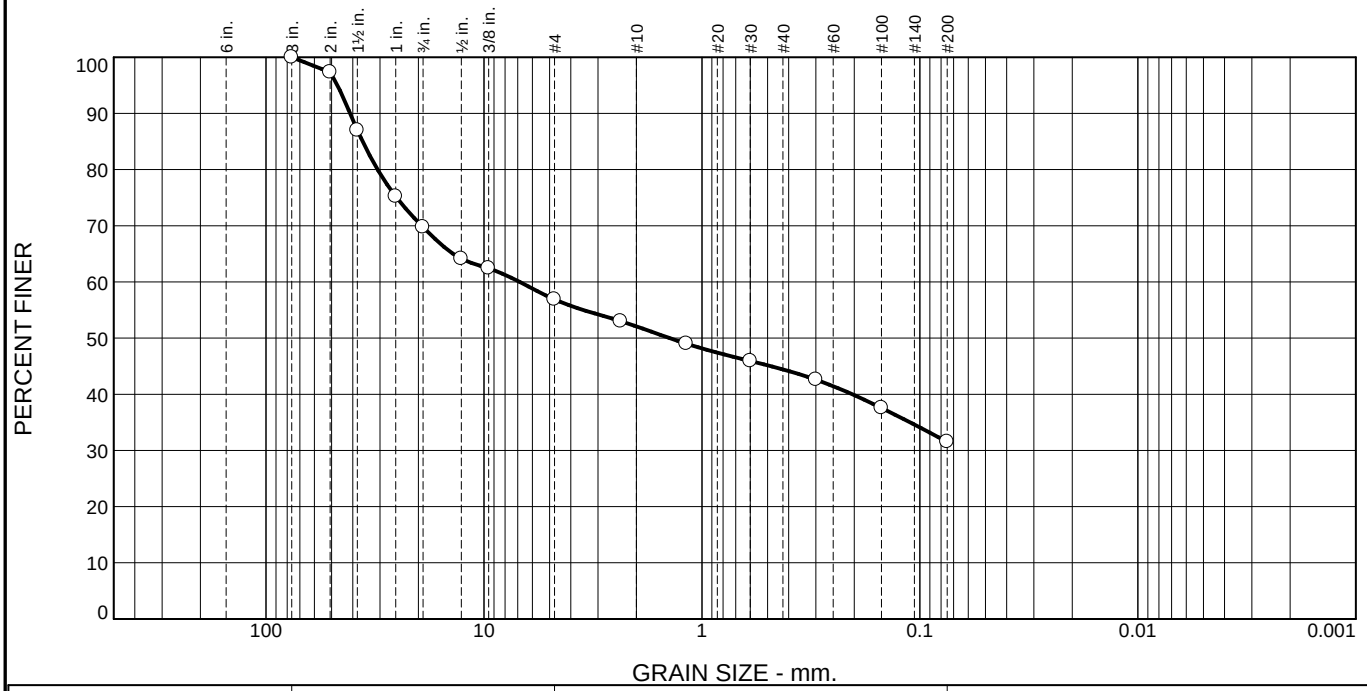
Date Sampled: 2/20/19

JONES & DEMILLE ENGINEERING INC.
Richfield, Utah

Client: Sevier County
Project: Sevier County Watershed Plan & Flood Protection

Project No: 1804-224 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	30.2	12.9	4.8	7.7	12.9	31.5	

Test Results (AASHTO T 27 & AASHTO T 11)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
3"	100.0		
2"	97.3		
1.5"	87.0		
1"	75.2		
3/4"	69.8		
1/2"	64.1		
3/8"	62.4		
#4	56.9		
#8	53.0		
#16	49.0		
#30	45.9		
#50	42.6		
#100	37.6		
#200	31.5		

* (no specification provided)

Material Description

TP19 WC-03, Sample 2, 2-6'

Atterberg Limits (ASTM D 4318)

PL= **LL=** **PI=**

Classification

USCS (D 2487)= **AASHTO (M 145)=**

Coefficients

D_{90}= 41.1435 D_{85}= 36.0499 D_{60}= 6.8658
D_{50}= 1.4074 D_{30}= D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: 2/22/19 **Date Tested:** 3/4/19

Tested By: Mark Rappleye

Checked By: Mark Rappleye

Title: Lab Manager

Location: TP19 WC-03, S-2
Sample Number: 19-S-043

Date Sampled: 2/20/19

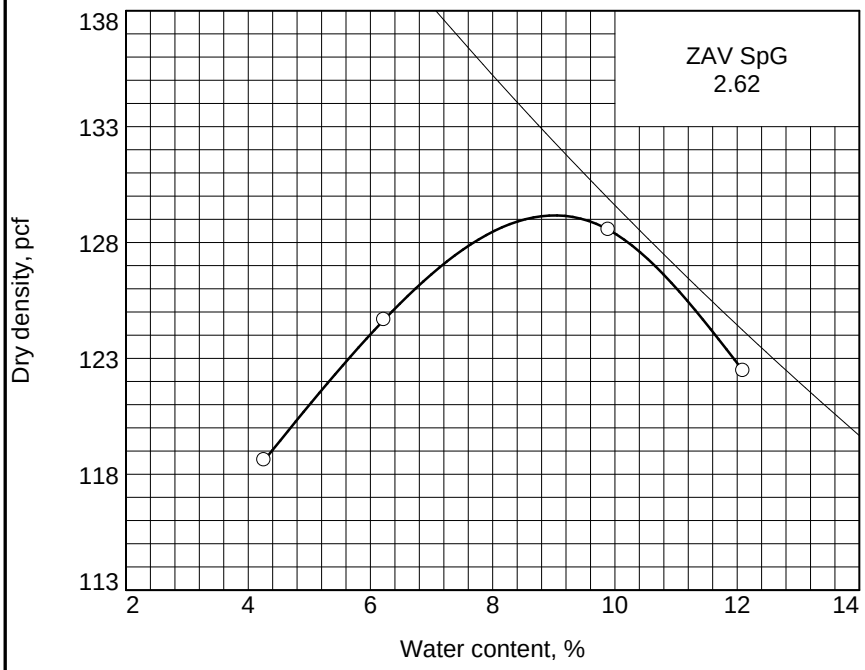
JONES & DEMILLE ENGINEERING INC.
Richfield, Utah

Client: Sevier County
Project: Sevier County Watershed Plan & Flood Protection

Project No: 1804-224 **Figure**

COMPACTION TEST REPORT

Curve No. 043



Preparation Method: -3/4" Material
Rammer: Wt. 10 lb. Drop 18 in.
Type: automatic
Layers: No. five Blows per 56
Mold Size: 0.075 cu. ft.
Test Performed on Material Passing 3/4 in. Sieve

%>3/4 in. 30.2 %<No.200 31.5
Atterberg (D 4318): LL PI
NM (D 2216) Sp.G. (D 854) 2.62
USCS (D 2487)
AASHTO (M 145)
Date: Sampled 2/20/19
Received 2/22/19
Tested 3/4/19
Tested By Mark Rappleye

COMPACTION TESTING DATA
AASHTO T 180-15 Method D Modified
AASHTO T 224-01 Oversize Correction Applied to Final Results

	1	2	3	4	5	6
WM + WS	10707.0	11005.0	11306.0	11170.0		
WM	6500.0	6500.0	6500.0	6500.0		
WW + T #1	868.7	781.9	794.2	914.6		
WD + T #1	842.9	750.6	744.5	842.4		
TARE #1	237.8	247.7	242.3	245.6		
WW + T #2						
WD + T #2						
TARE #2						
MOIST.	4.3	6.2	9.9	12.1		
DRY DENS.	118.6	124.7	128.6	122.5		

SIEVE TEST RESULTS
AASHTO T 27 AASHTO T 11

Opening Size	% Passing	Specs.
3"	100.0	
2"	97.3	
1.5"	87.0	
1"	75.2	
3/4"	69.8	
1/2"	64.1	
3/8"	62.4	
#4	56.9	
#8	53.0	
#16	49.0	
#30	45.9	
#50	42.6	
#100	37.6	
#200	31.5	

ROCK CORRECTED TEST RESULTS

Maximum dry density = 137.7 pcf

Optimum moisture = 6.9 %

Material Description

TP19 WC-03, Sample 2, 2-6'

Remarks:

Project No. 1804-224 **Client:** Sevier County

Project: Sevier County Watershed Plan & Flood Protection

○ **Location:** TP19 WC-03, S-2 **Sample Number:** 19-S-043

Checked by: Mark Rappleye

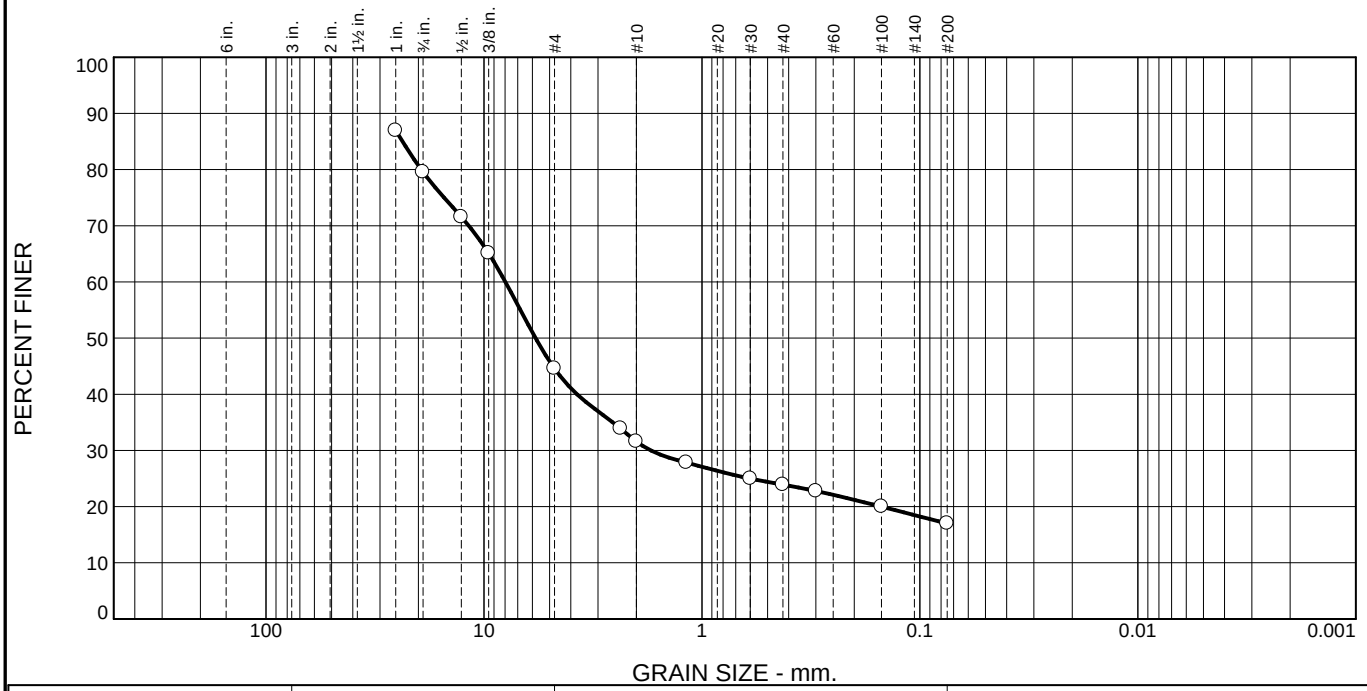
Title: Lab Manager

JONES & DEMILLE ENGINEERING INC.

Richfield, Utah

Figure

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
		35.0	13.0	7.7	6.9	17.0	

Test Results (AASHTO T 27 & AASHTO T 11)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1"	86.9		
3/4"	79.6		
1/2"	71.6		
3/8"	65.1		
#4	44.6		
#8	33.9		
#10	31.6		
#16	27.8		
#30	25.0		
#40	23.9		
#50	22.8		
#100	20.0		
#200	17.0		

* (no specification provided)

Material Description

TP19 WC-04, Sample 2, 3-15'

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= GM **AASHTO (M 145)=** A-1-b

Coefficients

D_{90}= D_{85}= 23.6435 D_{60}= 7.9775
D_{50}= 5.8000 D_{30}= 1.7156 D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: 2/22/19 **Date Tested:** 3/5/19

Tested By: Mark Rappleye

Checked By: Mark Rappleye

Title: Lab Manager

Location: TP19 WC-04, S-2
Sample Number: 19-S-047

Date Sampled: 2/20/19

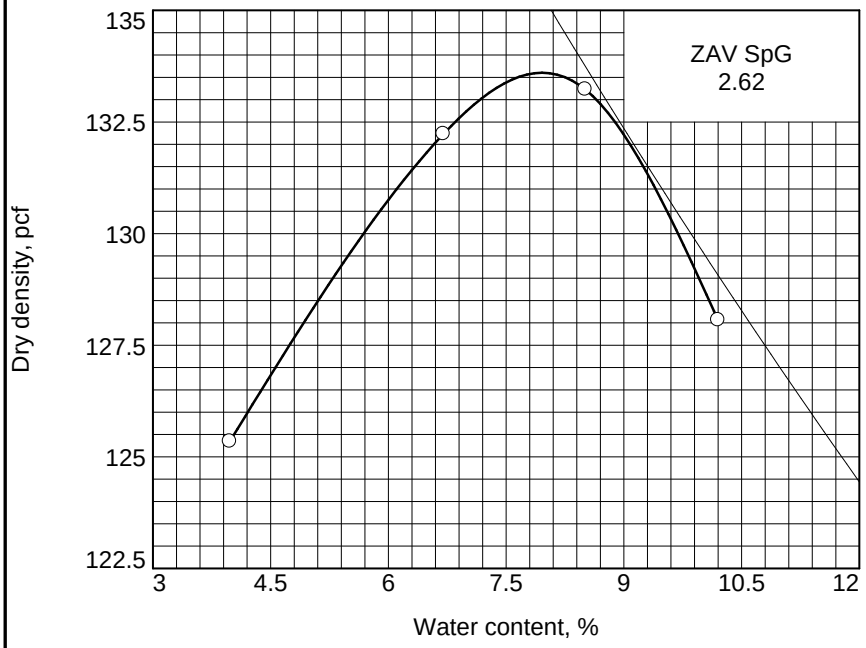
JONES & DEMILLE ENGINEERING INC.
Richfield, Utah

Client: Sevier County
Project: Sevier County Watershed Plan & Flood Protection

Project No: 1804-224 **Figure**

COMPACTION TEST REPORT

Curve No. 047



Preparation Method	-3/4" Material
Rammer: Wt.	10 lb. Drop 18 in.
Type	automatic
Layers: No.	five Blows per 56
Mold Size	0.075 cu. ft.
Test Performed on Material Passing	3/4 in. Sieve
%>3/4 in.	20.4 %<No.200 17.0
Atterberg (D 4318): LL	NV PI NP
NM (D 2216)	Sp.G. (D 854) 2.62
USCS (D 2487)	GM
AASHTO (M 145)	A-1-b
Date: Sampled	2/20/19
Received	2/22/19
Tested	3/5/19
Tested By	Mark Rappleye

COMPACTION TESTING DATA
AASHTO T 180-15 Method D Modified
AASHTO T 224-01 Oversize Correction Applied to Final Results

	1	2	3	4	5	6
WM + WS	10934.0	11300.0	11418.0	11301.0		
WM	6500.0	6500.0	6500.0	6500.0		
WW + T #1	804.4	856.9	886.6	892.9		
WD + T #1	782.7	818.5	837.4	833.5		
TARE #1	237.5	245.6	259.1	251.1		
WW + T #2						
WD + T #2						
TARE #2						
MOIST.	4.0	6.7	8.5	10.2		
DRY DENS.	125.3	132.2	133.2	128.1		

SIEVE TEST RESULTS
AASHTO T 27 AASHTO T 11

Opening Size	% Passing	Specs.
1"	86.9	
3/4"	79.6	
1/2"	71.6	
3/8"	65.1	
#4	44.6	
#8	33.9	
#10	31.6	
#16	27.8	
#30	25.0	
#40	23.9	
#50	22.8	
#100	20.0	
#200	17.0	

ROCK CORRECTED TEST RESULTS

Maximum dry density = 138.6 pcf

Optimum moisture = 6.7 %

Material Description

TP19 WC-04, Sample 2, 3-15'

Remarks:

Project No. 1804-224 **Client:** Sevier County

Project: Sevier County Watershed Plan & Flood Protection

○ **Location:** TP19 WC-04, S-2 **Sample Number:** 19-S-047

JONES & DEMILLE ENGINEERING INC.

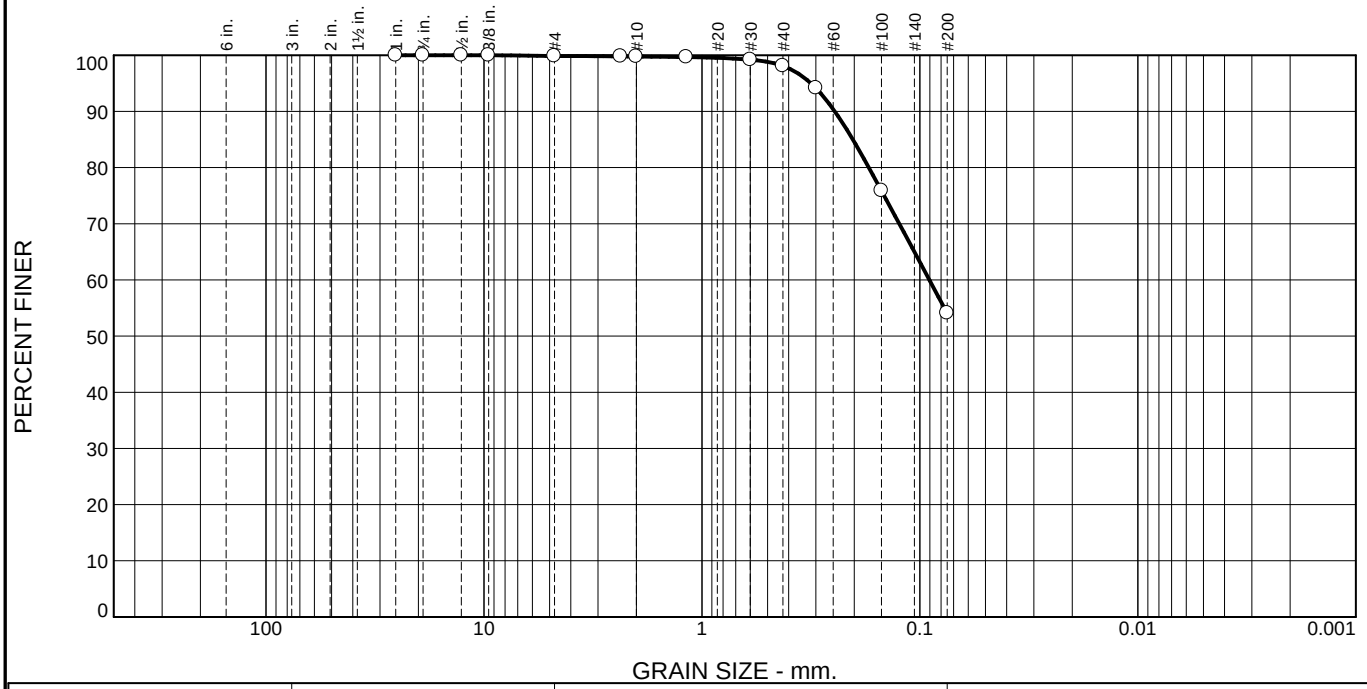
Richfield, Utah

Checked by: Mark Rappleye

Title: Lab Manager

Figure

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.1	0.1	1.7	44.0	54.1	

Test Results (AASHTO T 27 & AASHTO T 11)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1"	100.0		
3/4"	100.0		
1/2"	100.0		
3/8"	100.0		
#4	99.9		
#8	99.8		
#10	99.8		
#16	99.7		
#30	99.2		
#40	98.1		
#50	94.2		
#100	75.9		
#200	54.1		

* (no specification provided)

Material Description

BH19 TC-01, Sample 1, 2.5-4'

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= ML **AASHTO (M 145)=** A-4(0)

Coefficients

D_{90}= 0.2456 D_{85}= 0.2031 D_{60}= 0.0905
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: 3/1/19 **Date Tested:** 3/6/19

Tested By: Matt Murphree

Checked By: Mark Rappleye

Title: Lab Manager

Location: BH19 TC-01, S-1
Sample Number: 19-S-060

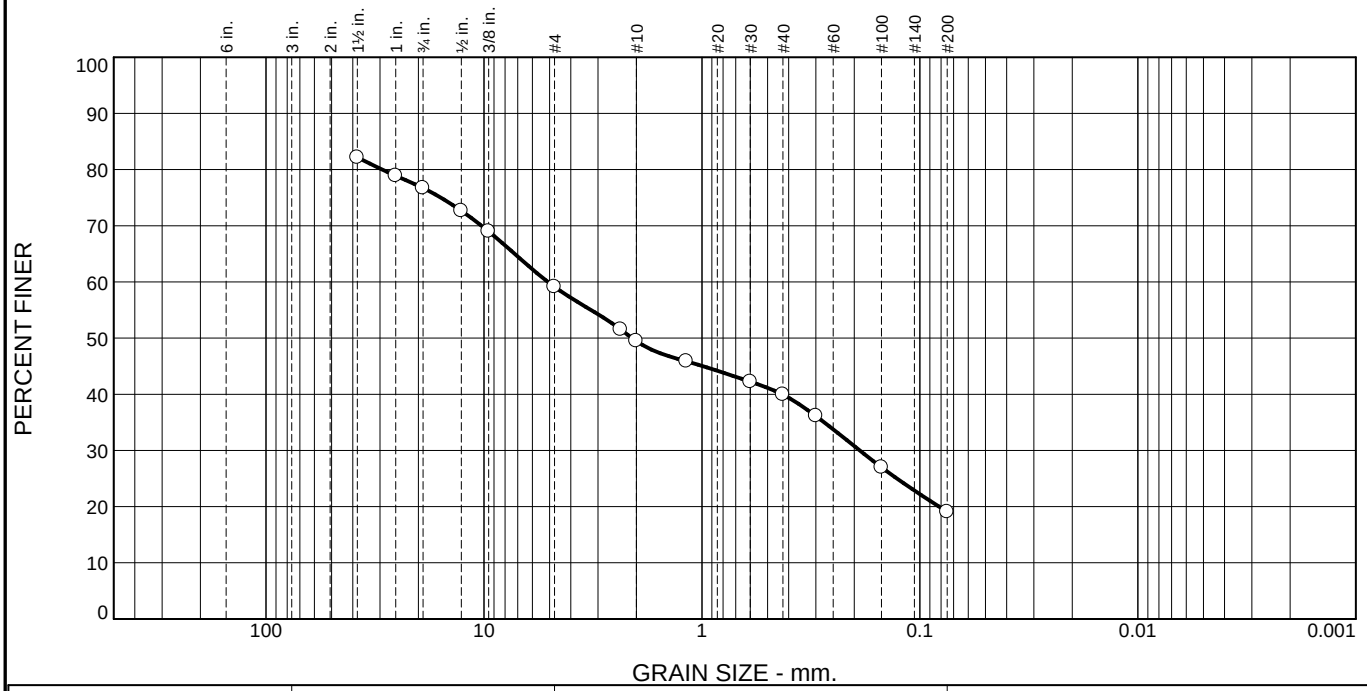
Date Sampled: 2/20/19

JONES & DEMILLE ENGINEERING INC.
Richfield, Utah

Client: Sevier County
Project: Sevier County Watershed Plan & Flood Protection

Project No: 1804-224 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
		17.6	9.6	9.6	20.8	19.1	

Test Results (AASHTO T 27 & AASHTO T 11)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1.5"	82.1		
1"	78.9		
3/4"	76.7		
1/2"	72.7		
3/8"	69.0		
#4	59.1		
#8	51.5		
#10	49.5		
#16	45.9		
#30	42.2		
#40	39.9		
#50	36.1		
#100	27.0		
#200	19.1		

* (no specification provided)

Material Description

BH19 TC-01, Sample 3, 7.5-9'

Atterberg Limits (ASTM D 4318)

PL= **LL=** **PI=**

Classification

USCS (D 2487)= **AASHTO (M 145)=**

Coefficients

D_{90}= D_{85}= D_{60}= 5.0882
D_{50}= 2.0917 D_{30}= 0.1889 D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: 3/1/19 **Date Tested:** 3/5/19

Tested By: Mark Rappleye

Checked By: Mark Rappleye

Title: Lab Manager

Location: BH19 TC-01, S-3
Sample Number: 19-S-052

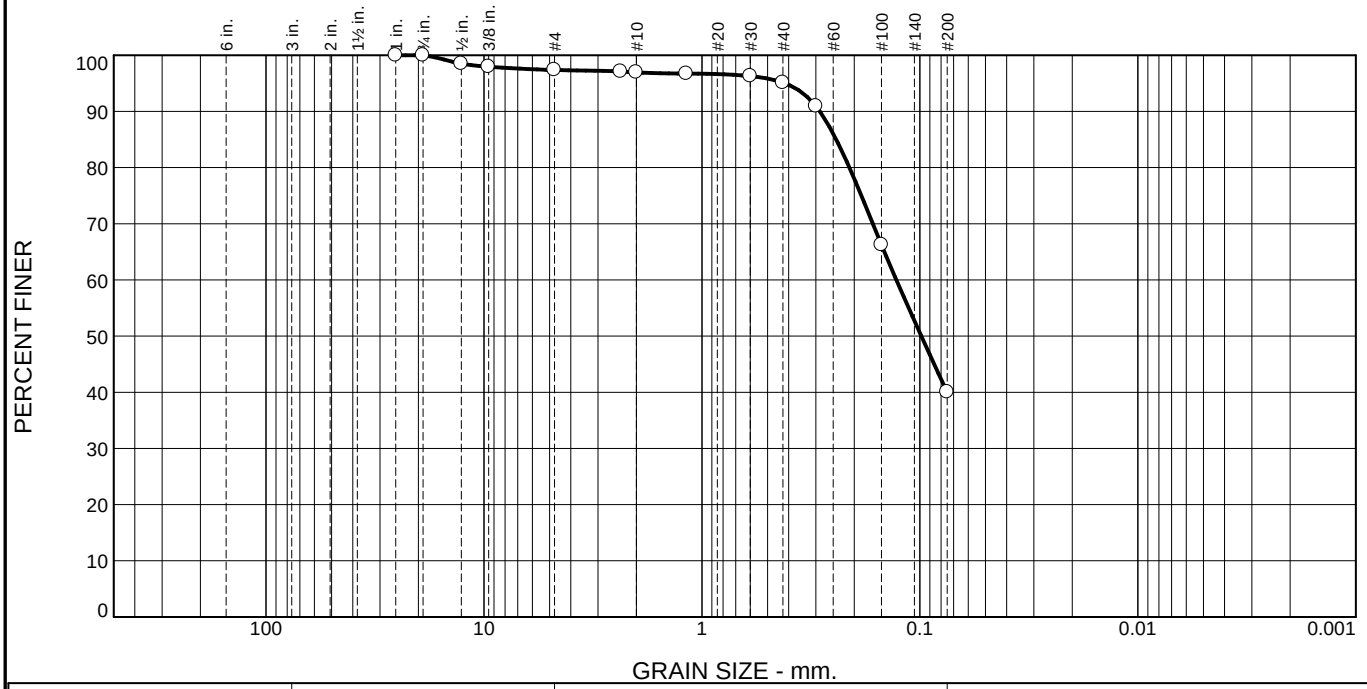
Date Sampled: 2/20/19

JONES & DEMILLE ENGINEERING INC.
Richfield, Utah

Client: Sevier County
Project: Sevier County Watershed Plan & Flood Protection

Project No: 1804-224 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	2.6	0.5	1.8	55.1	40.0	

Test Results (AASHTO T 27 & AASHTO T 11)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1"	100.0		
3/4"	100.0		
1/2"	98.5		
3/8"	98.0		
#4	97.4		
#8	97.1		
#10	96.9		
#16	96.7		
#30	96.3		
#40	95.1		
#50	90.9		
#100	66.2		
#200	40.0		

* (no specification provided)

Material Description

BH 19 TC-01, Sample 6, 20'

Atterberg Limits (ASTM D 4318)

PL= **LL=** **PI=**

Classification

USCS (D 2487)= **AASHTO (M 145)=**

Coefficients

D_{90}= 0.2878 D_{85}= 0.2420 D_{60}= 0.1282
D_{50}= 0.0985 D_{30}= D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: 2/22/19 **Date Tested:** 3/7/19

Tested By: Matt Murphree

Checked By: Mark Rappleye

Title: Lab Manager

Location: BH19 TC-01, S-6
Sample Number: 19-S-067

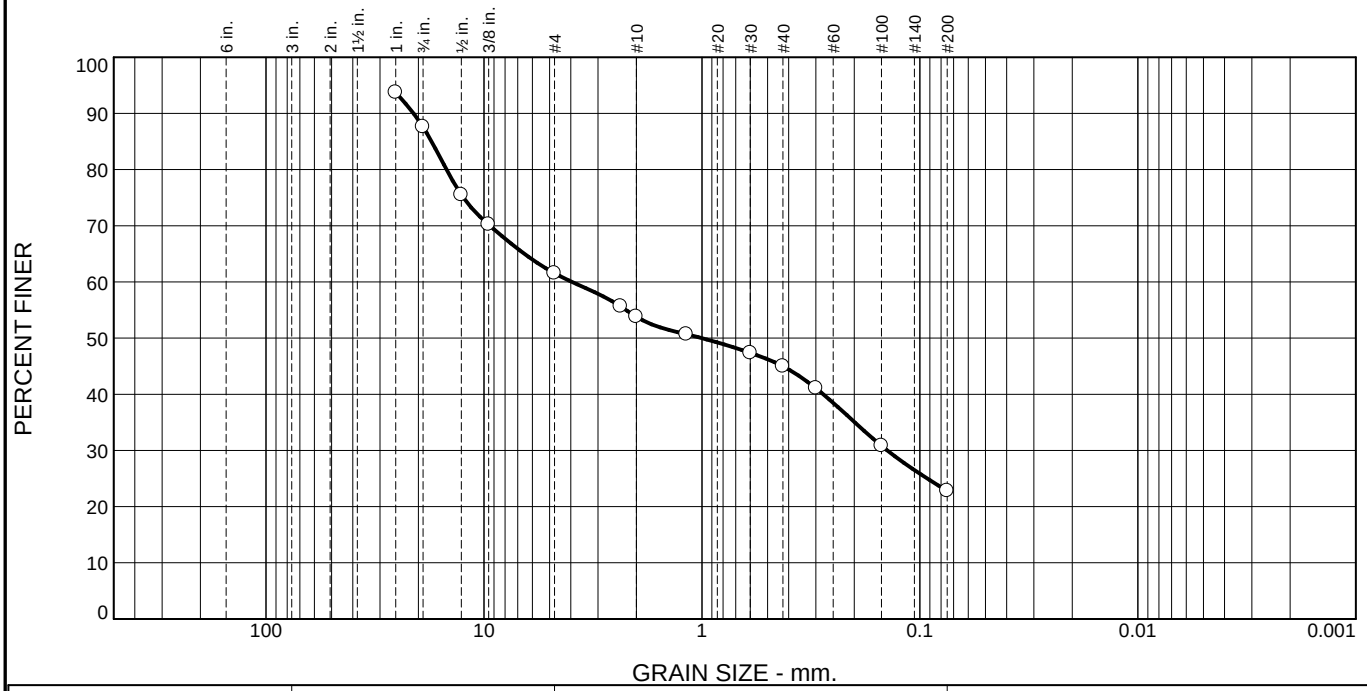
Date Sampled: 2/22/19

JONES & DEMILLE ENGINEERING INC.
Richfield, Utah

Client: Sevier County
Project: Sevier County Watershed Plan & Flood Protection

Project No: 1804-224 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
		26.1	7.7	8.8	22.2	22.8	

Test Results (AASHTO T 27 & AASHTO T 11)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1"	93.7		
3/4"	87.6		
1/2"	75.5		
3/8"	70.2		
#4	61.5		
#8	55.6		
#10	53.8		
#16	50.7		
#30	47.4		
#40	45.0		
#50	41.1		
#100	30.8		
#200	22.8		

* (no specification provided)

Material Description

BH19 TC-01, Sample 8, 30-31.5'

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SM **AASHTO (M 145)=** A-1-b

Coefficients

D_{90}= 21.0409 D_{85}= 17.4049 D_{60}= 3.9503
D_{50}= 1.0034 D_{30}= 0.1412 D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: 3/1/19 **Date Tested:** 3/6/19

Tested By: Matt Murphree

Checked By: Mark Rappleye

Title: Lab Manager

Location: BH19 TC-01, S-8
Sample Number: 19-S-061

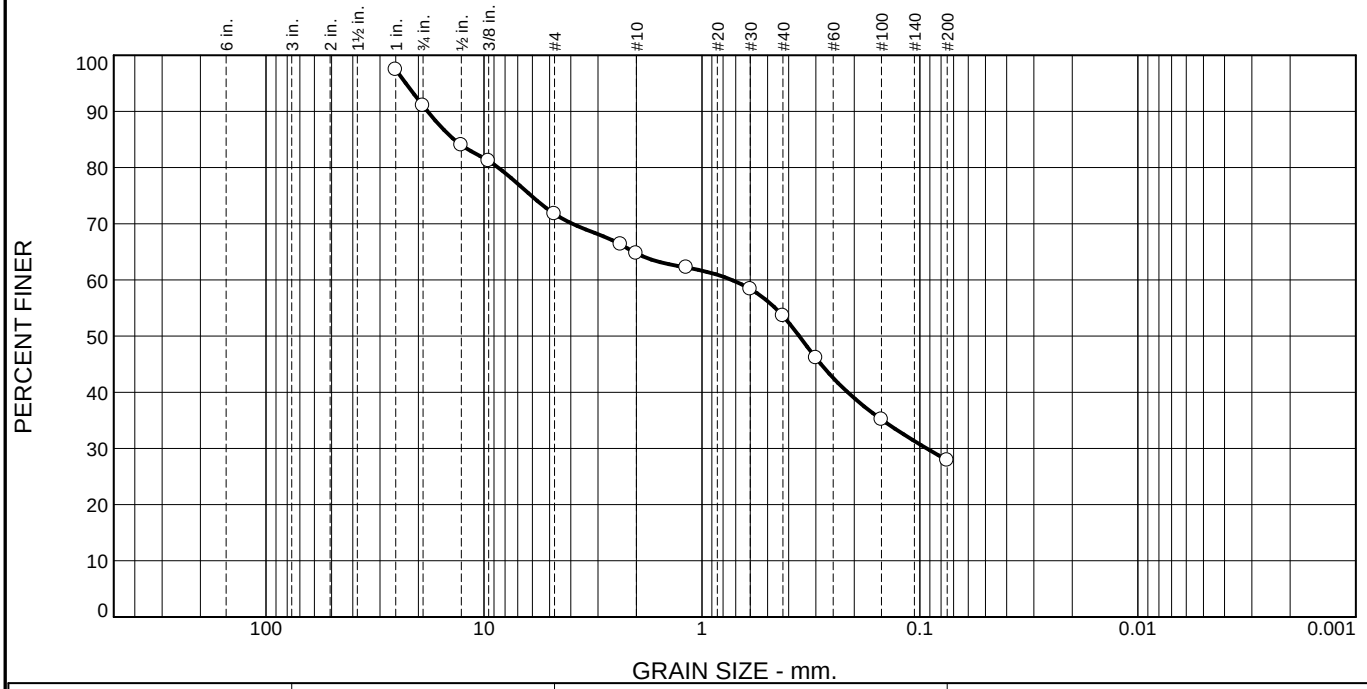
Date Sampled: 2/21/19

JONES & DEMILLE ENGINEERING INC.
Richfield, Utah

Client: Sevier County
Project: Sevier County Watershed Plan & Flood Protection

Project No: 1804-224 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
		19.3	7.0	11.1	25.7	27.9	

Test Results (AASHTO T 27 & AASHTO T 11)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1"	97.4		
3/4"	91.0		
1/2"	84.0		
3/8"	81.2		
#4	71.7		
#8	66.3		
#10	64.7		
#16	62.2		
#30	58.4		
#40	53.6		
#50	46.1		
#100	35.1		
#200	27.9		

* (no specification provided)

Material Description

TP19 TC-01, Sample 2, 2-8'

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SM **AASHTO (M 145)=** A-2-4(0)

Coefficients

D_{90}= 18.1456 D_{85}= 13.7172 D_{60}= 0.7297
D_{50}= 0.3577 D_{30}= 0.0931 D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: 2/22/19 **Date Tested:** 3/4/19

Tested By: Mark Rappleye

Checked By: Mark Rappleye

Title: Lab Manager

Location: TP19 TC-01, S-2
Sample Number: 19-S-044

Date Sampled: 2/20/19

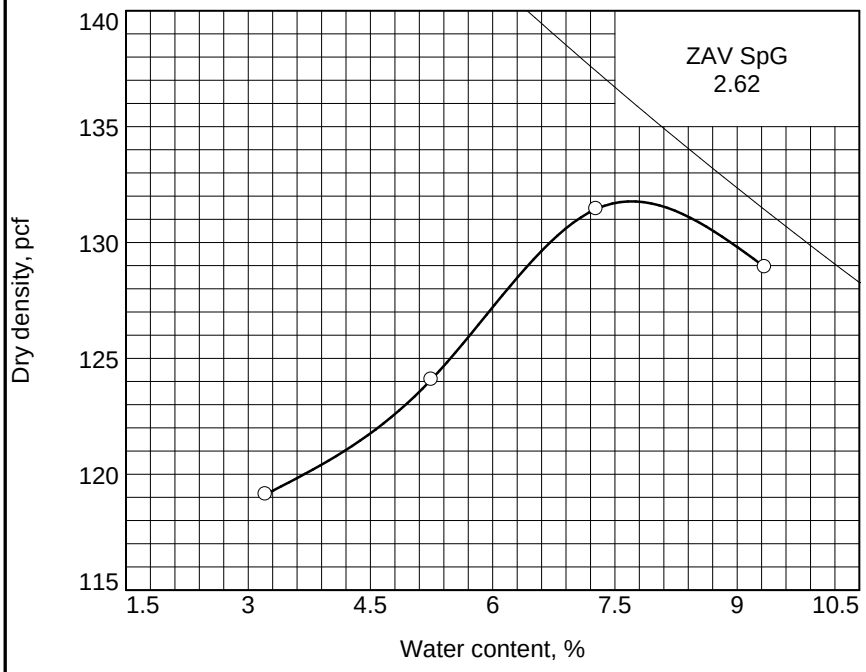
JONES & DEMILLE ENGINEERING INC.
Richfield, Utah

Client: Sevier County
Project: Sevier County Watershed Plan & Flood Protection

Project No: 1804-224 **Figure**

COMPACTION TEST REPORT

Curve No. 044



Preparation Method	-3/4" Material
Rammer: Wt.	10 lb.
Drop	18 in.
Type	automatic
Layers: No.	five
Blows per	56
Mold Size	0.075 cu. ft.
Test Performed on Material Passing	3/4 in. Sieve
%>3/4 in.	9.0
%<No.200	27.9
Atterberg (D 4318): LL	NV
PI	NP
NM (D 2216)	
Sp.G. (D 854)	2.62
USCS (D 2487)	SM
AASHTO (M 145)	A-2-4(0)
Date: Sampled	2/20/19
Received	2/22/19
Tested	3/4/19
Tested By	Mark Rappleye

COMPACTION TESTING DATA
AASHTO T 180-15 Method D Modified
AASHTO T 224-01 Oversize Correction Applied to Final Results

	1	2	3	4	5	6
WM + WS	9915.0	10175.0	10529.0	10528.0		
WM	5732.0	5732.0	5732.0	5732.0		
WW + T #1	850.0	839.7	737.9	831.9		
WD + T #1	831.6	810.1	704.6	782.3		
TARE #1	259.0	246.2	246.7	251.2		
WW + T #2						
WD + T #2						
TARE #2						
MOIST.	3.2	5.2	7.3	9.3		
DRY DENS.	119.1	124.1	131.4	128.9		

SIEVE TEST RESULTS
AASHTO T 27 AASHTO T 11

Opening Size	% Passing	Specs.
1"	97.4	
3/4"	91.0	
1/2"	84.0	
3/8"	81.2	
#4	71.7	
#8	66.3	
#10	64.7	
#16	62.2	
#30	58.4	
#40	53.6	
#50	46.1	
#100	35.1	
#200	27.9	

ROCK CORRECTED TEST RESULTS

Maximum dry density = 134.0 pcf

Optimum moisture = 7.2 %

Material Description

TP19 TC-01, Sample 2, 2-8'

Remarks:

Project No. 1804-224 **Client:** Sevier County

Project: Sevier County Watershed Plan & Flood Protection

○ **Location:** TP19 TC-01, S-2 **Sample Number:** 19-S-044

Checked by: Mark Rappleye

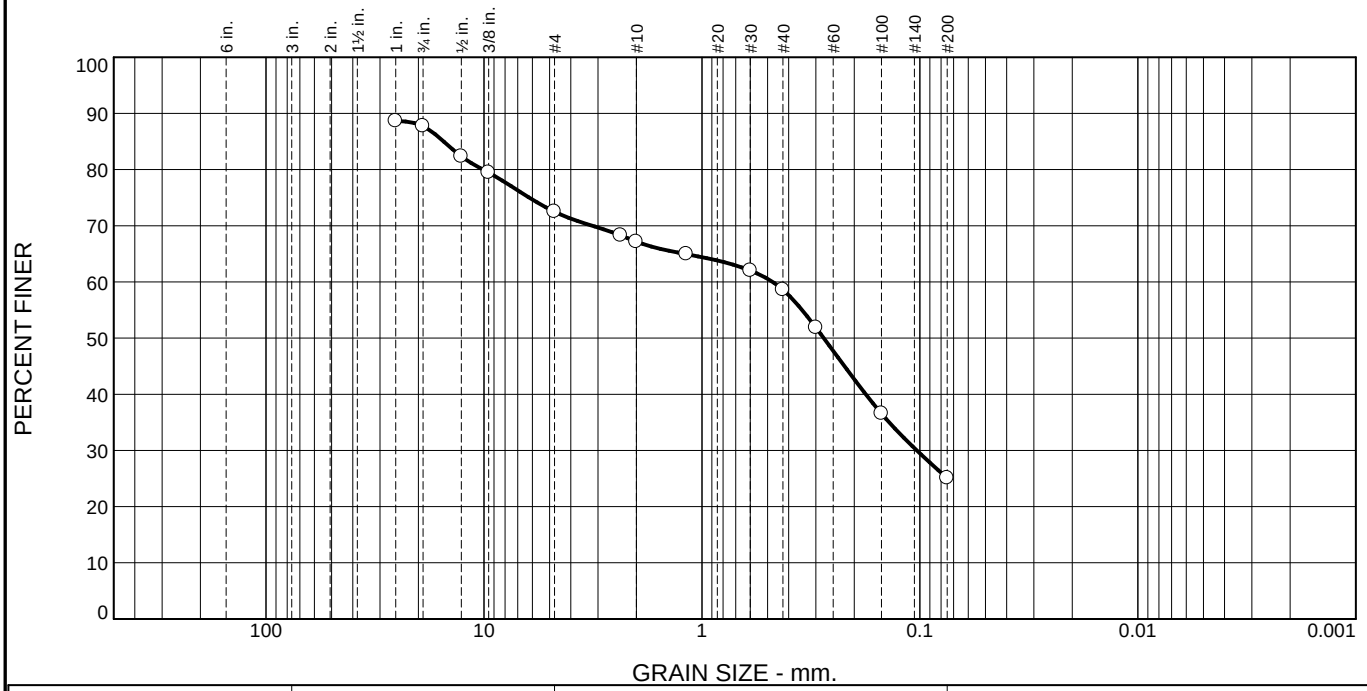
Title: Lab Manager

JONES & DEMILLE ENGINEERING INC.

Richfield, Utah

Figure

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
		15.2	5.3	8.6	33.5	25.1	

Test Results (AASHTO T 27 & AASHTO T 11)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1"	88.7		
3/4"	87.7		
1/2"	82.3		
3/8"	79.5		
#4	72.5		
#8	68.3		
#10	67.2		
#16	64.9		
#30	62.0		
#40	58.6		
#50	51.9		
#100	36.6		
#200	25.1		

* (no specification provided)

Material Description

BH19 LC-01, Sample 1, 2.5-4'

Atterberg Limits (ASTM D 4318)

PL= LL= PI=

Classification

USCS (D 2487)= AASHTO (M 145)=

Coefficients

D_{90}= D_{85}= 15.3055 D_{60}= 0.4737
D_{50}= 0.2760 D_{30}= 0.1034 D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: 2/22/19 **Date Tested:** 3/5/19

Tested By: Mark Rappleye

Checked By: Mark Rappleye

Title: Lab Manager

Location: BH19 LC-01, S-1
Sample Number: 19-S-049

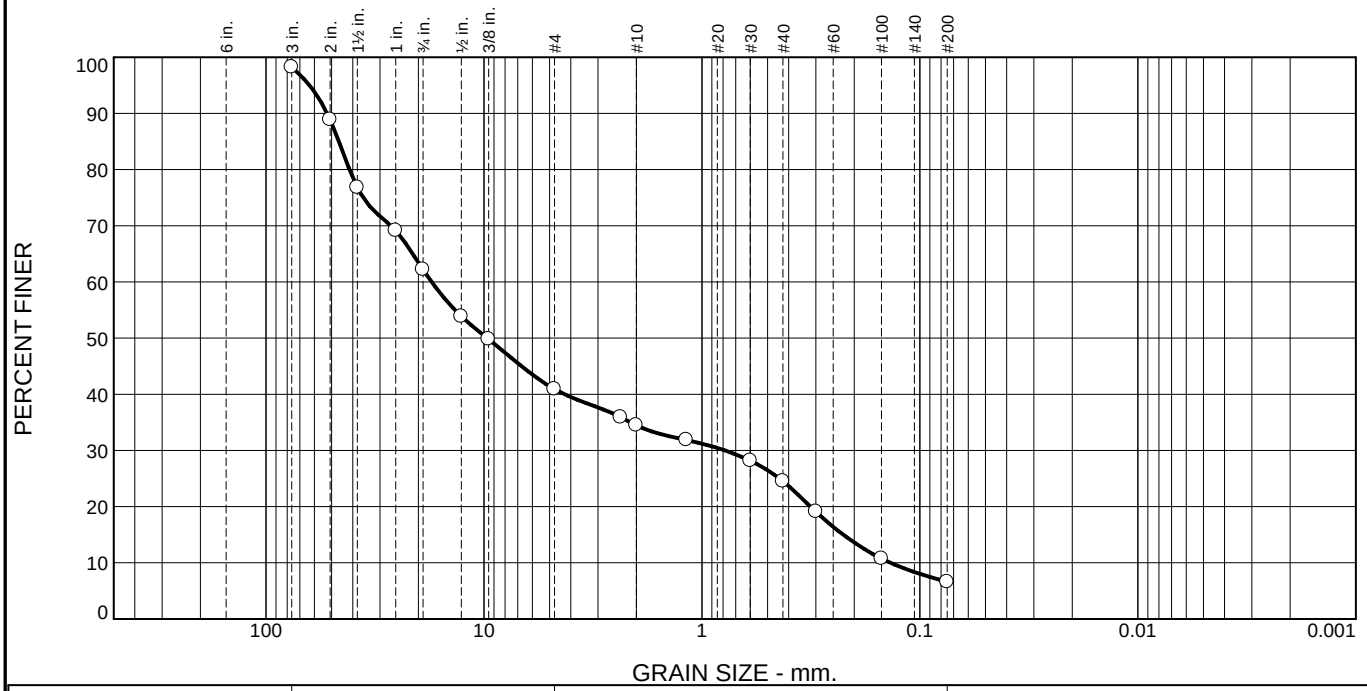
Date Sampled: 2/22/19

JONES & DEMILLE ENGINEERING INC.
Richfield, Utah

Client: Sevier County
Project: Sevier County Watershed Plan & Flood Protection

Project No: 1804-224 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
	36.0	21.3	6.4	10.0	17.9	6.6	

Test Results (AASHTO T 27 & AASHTO T 11)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
3"	98.2		
2"	88.9		
1.5"	76.8		
1"	69.1		
3/4"	62.2		
1/2"	53.9		
3/8"	49.8		
#4	40.9		
#8	35.9		
#10	34.5		
#16	31.9		
#30	28.2		
#40	24.5		
#50	19.1		
#100	10.7		
#200	6.6		

* (no specification provided)

Material Description

TP19 LC-01, Sample 2, 1-12'

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= GP-GM **AASHTO (M 145)=** A-1-a

Coefficients

D_{90}= 52.4006 D_{85}= 46.3281 D_{60}= 17.3957
D_{50}= 9.6586 D_{30}= 0.7849 D_{15}= 0.2246
D_{10}= 0.1366 C_u= 127.33 C_c= 0.26

Remarks

Date Received: 2/19/2019 **Date Tested:** 3/11/2019

Tested By: Matt Murphree

Checked By: Mark Rappleye

Title: Lab Manager

Location: TP19 LC-01, S-2
Sample Number: 19-S-078

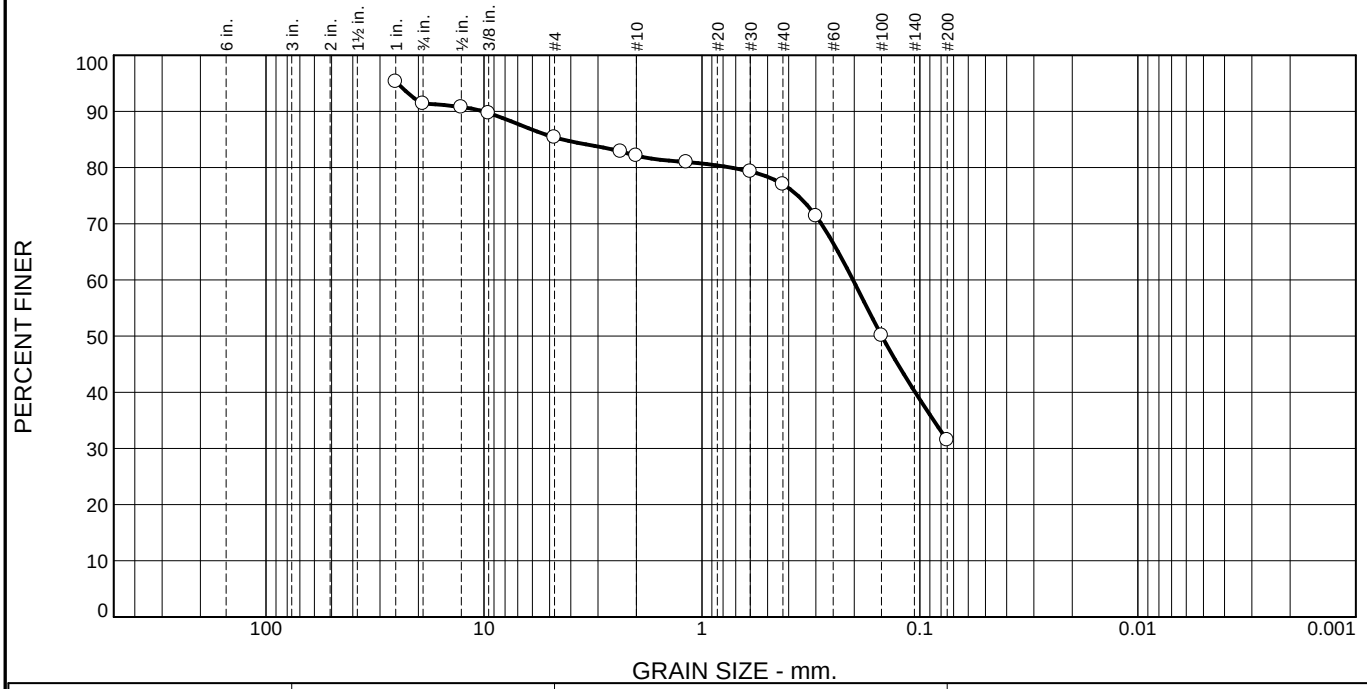
Date Sampled: 2/19/2019

JONES & DEMILLE ENGINEERING INC.
Richfield, Utah

Client: Sevier County
Project: Sevier County Watershed Plan & Flood Protection

Project No: 1804-224 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
		6.0	3.3	5.1	45.5	31.5	

Test Results (AASHTO T 27 & AASHTO T 11)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1"	95.3		
3/4"	91.4		
1/2"	90.7		
3/8"	89.7		
#4	85.4		
#8	82.9		
#10	82.1		
#16	81.0		
#30	79.3		
#40	77.0		
#50	71.4		
#100	50.1		
#200	31.5		

* (no specification provided)

Material Description

TP19 LC-02, Sample 1, 0-3.5'

Atterberg Limits (ASTM D 4318)

PL= **LL=** **PI=**

Classification

USCS (D 2487)= **AASHTO (M 145)=**

Coefficients

D_{90}= 10.0711 D_{85}= 4.3590 D_{60}= 0.2028
D_{50}= 0.1494 D_{30}= D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: 2/22/19 **Date Tested:** 3/7/19

Tested By: Matt Murphree

Checked By: Mark Rappleye

Title: Lab Manager

Location: TP19 LC-02, S-1
Sample Number: 19-S-069

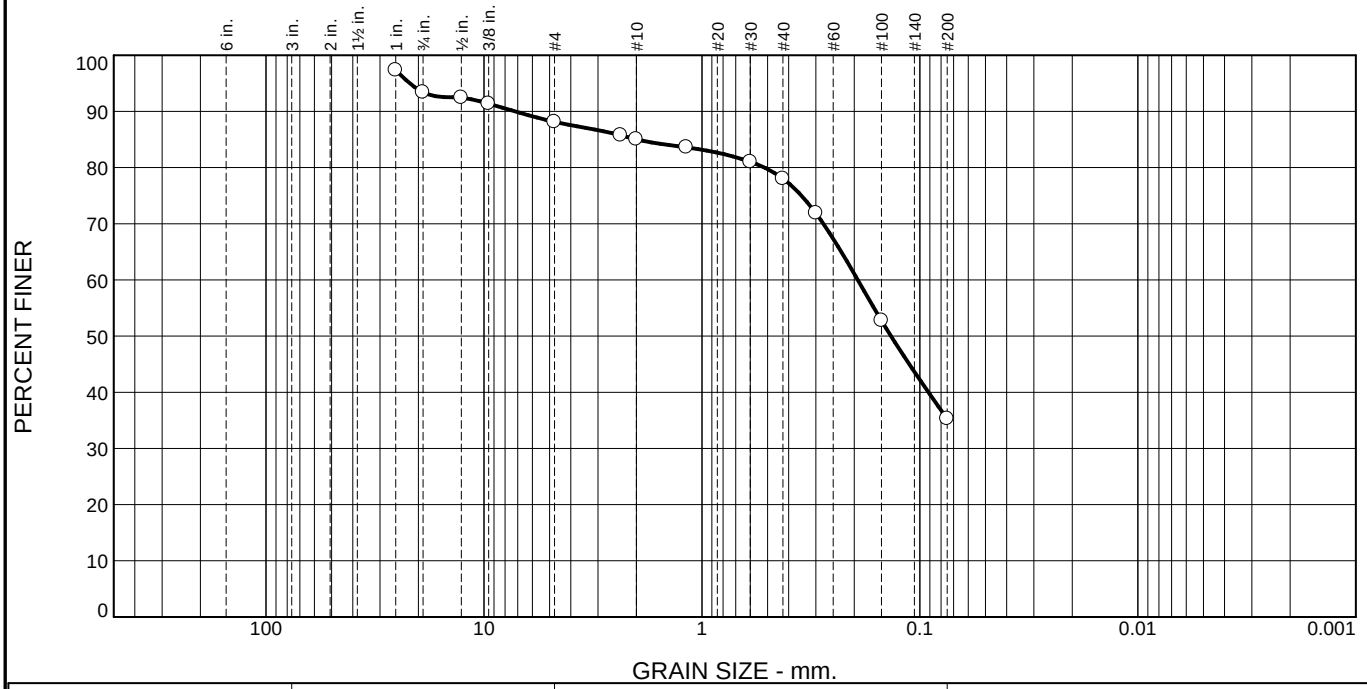
Date Sampled: 2/19/19

JONES & DEMILLE ENGINEERING INC.
Richfield, Utah

Client: Sevier County
Project: Sevier County Watershed Plan & Flood Protection

Project No: 1804-224 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
		5.3	3.1	7.0	42.7	35.3	

Test Results (AASHTO T 27 & AASHTO T 11)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1"	97.3		
3/4"	93.4		
1/2"	92.4		
3/8"	91.4		
#4	88.1		
#8	85.8		
#10	85.0		
#16	83.6		
#30	81.0		
#40	78.0		
#50	71.9		
#100	52.7		
#200	35.3		

* (no specification provided)

Material Description

TP19 LC-02, Sample 2, 3.5-10.5'

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SM **AASHTO (M 145)=** A-2-4(0)

Coefficients

D_{90}= 7.1971 D_{85}= 1.9845 D_{60}= 0.1928
D_{50}= 0.1357 D_{30}= D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: 2/22/19 **Date Tested:** 3/8/19

Tested By: Matt Murphree

Checked By: Mark Rappleye

Title: Lab Manager

Location: TP19 LC-02, S-2
Sample Number: 19-S-072

Date Sampled: 2/19/19

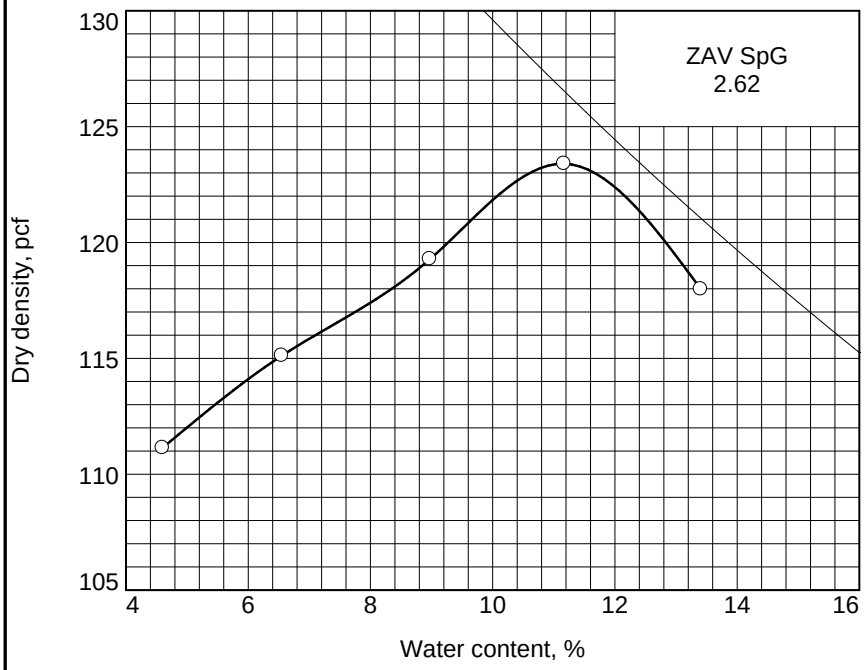
JONES & DEMILLE ENGINEERING INC.
Richfield, Utah

Client: Sevier County
Project: Sevier County Watershed Plan & Flood Protection

Project No: 1804-224 **Figure**

COMPACTION TEST REPORT

Curve No. 072



Preparation Method	-3/4" Material
Rammer: Wt.	10 lb. Drop 18 in.
Type	manual
Layers: No.	five Blows per 56
Mold Size	0.075 cu. ft.
Test Performed on Material Passing	3/4 in. Sieve
%>3/4 in.	6.6 %<No.200 35.3
Atterberg (D 4318): LL	NV PI NP
NM (D 2216)	Sp.G. (D 854) 2.62
USCS (D 2487)	SM
AASHTO (M 145)	A-2-4(0)
Date: Sampled	2/19/19
Received	2/22/19
Tested	3/8/19
Tested By	Mark Rappleye

COMPACTION TESTING DATA
AASHTO T 180-15 Method D Modified
AASHTO T 224-01 Oversize Correction Applied to Final Results

	1	2	3	4	5	6
WM + WS	10454.0	10671.9	10921.1	11165.9	11051.0	
WM	6499.1	6499.1	6499.1	6499.1	6499.1	
WW + T #1	1014.8	934.2	1004.1	1080.8	808.9	
WD + T #1	981.0	891.9	941.5	997.0	742.3	
TARE #1	246.1	246.3	243.9	246.7	245.5	
WW + T #2						
WD + T #2						
TARE #2						
MOIST.	4.6	6.6	9.0	11.2	13.4	
DRY DENS.	111.1	115.1	119.3	123.4	118.0	

SIEVE TEST RESULTS
AASHTO T 27 AASHTO T 11

Opening Size	% Passing	Specs.
1"	97.3	
3/4"	93.4	
1/2"	92.4	
3/8"	91.4	
#4	88.1	
#8	85.8	
#10	85.0	
#16	83.6	
#30	81.0	
#40	78.0	
#50	71.9	
#100	52.7	
#200	35.3	

ROCK CORRECTED TEST RESULTS

Maximum dry density = 125.4 pcf

Optimum moisture = 10.5 %

Material Description

TP19 LC-02, Sample 2, 3.5-10.5'

Remarks:

Project No. 1804-224 **Client:** Sevier County

Project: Sevier County Watershed Plan & Flood Protection

○ **Location:** TP19 LC-02, S-2 **Sample Number:** 19-S-072

Checked by: Mark Rappleye

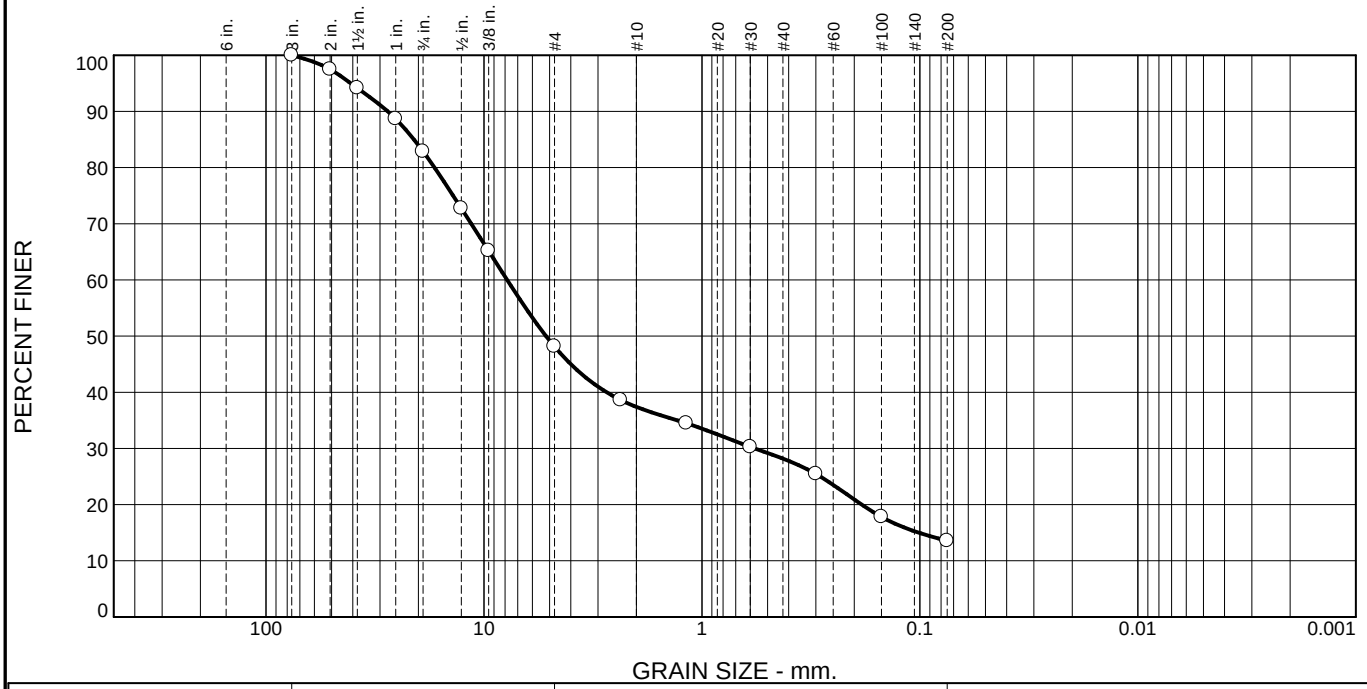
Title: Lab Manager

JONES & DEMILLE ENGINEERING INC.

Richfield, Utah

Figure

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	17.1	34.8	10.7	9.2	14.6	13.6	

Test Results (AASHTO T 27 & AASHTO T 11)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
3"	100.0		
2"	97.5		
1.5"	94.1		
1"	88.7		
3/4"	82.9		
1/2"	72.7		
3/8"	65.2		
#4	48.1		
#8	38.6		
#16	34.5		
#30	30.3		
#50	25.5		
#100	17.8		
#200	13.6		

* (no specification provided)

Material Description

TP19 LC-03, Sample 2, 4-9'

Atterberg Limits (ASTM D 4318)

PL= **LL=** **PI=**

Classification

USCS (D 2487)= **AASHTO (M 145)=**

Coefficients

D_{90}= 27.6285 D_{85}= 20.9668 D_{60}= 7.8300
D_{50}= 5.1955 D_{30}= 0.5732 D_{15}= 0.1012
D_{10}= C_u= C_c=

Remarks

Date Received: 2/22/19 **Date Tested:** 3/4/19

Tested By: Mark Rappleye

Checked By: Mark Rappleye

Title: Lab Manager

Location: TP19 LC-03, S-2
Sample Number: 19-S-048

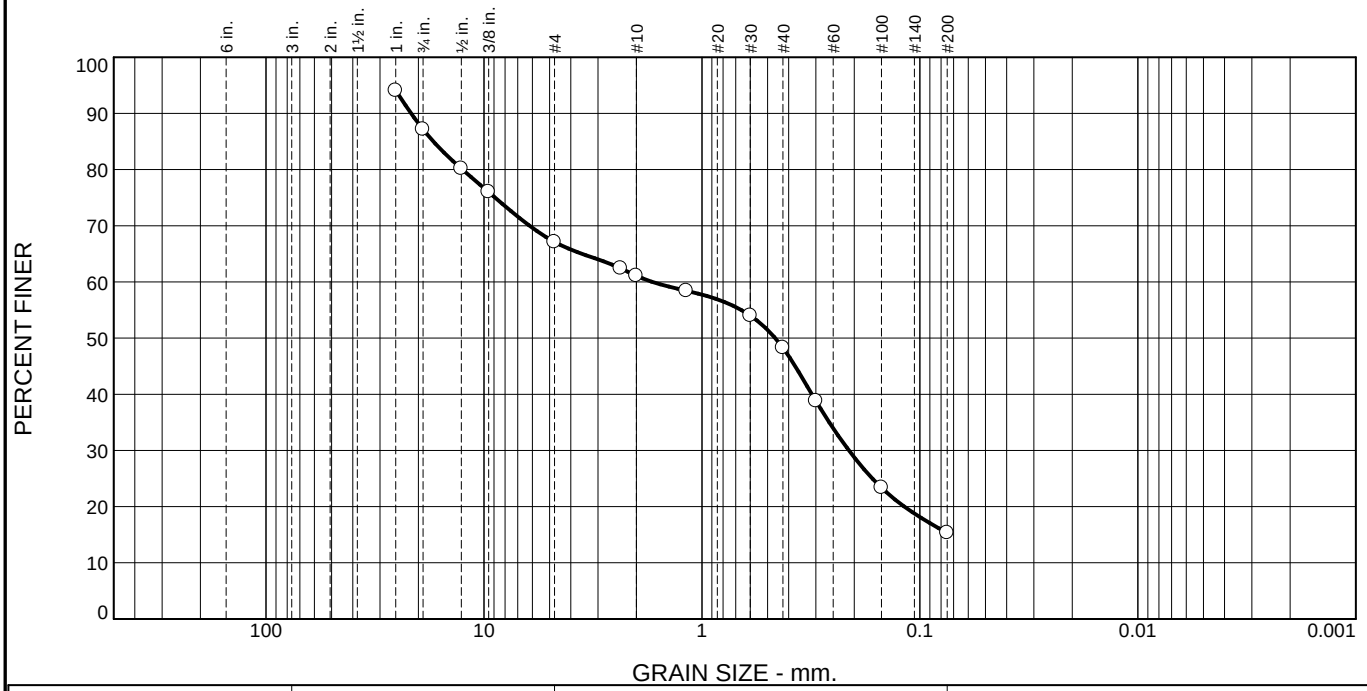
Date Sampled: 2/19/19

JONES & DEMILLE ENGINEERING INC.
Richfield, Utah

Client: Sevier County
Project: Sevier County Watershed Plan & Flood Protection

Project No: 1804-224 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
		20.1	6.0	12.8	33.0	15.3	

Test Results (AASHTO T 27 & AASHTO T 11)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1"	94.1		
3/4"	87.2		
1/2"	80.2		
3/8"	76.0		
#4	67.1		
#8	62.4		
#10	61.1		
#16	58.4		
#30	54.0		
#40	48.3		
#50	38.8		
#100	23.4		
#200	15.3		

* (no specification provided)

Material Description

TP19 LC-03, Sample 3, 9-25'

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SM **AASHTO (M 145)=** A-1-b

Coefficients

D_{90}= 21.5824 D_{85}= 17.0902 D_{60}= 1.6890
D_{50}= 0.4611 D_{30}= 0.2116 D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: 3/1/19 **Date Tested:** 3/5/19

Tested By: Mark Rappleye

Checked By: Mark Rappleye

Title: Lab Manager

Location: TP19 LC-03, S-3
Sample Number: 19-S-053

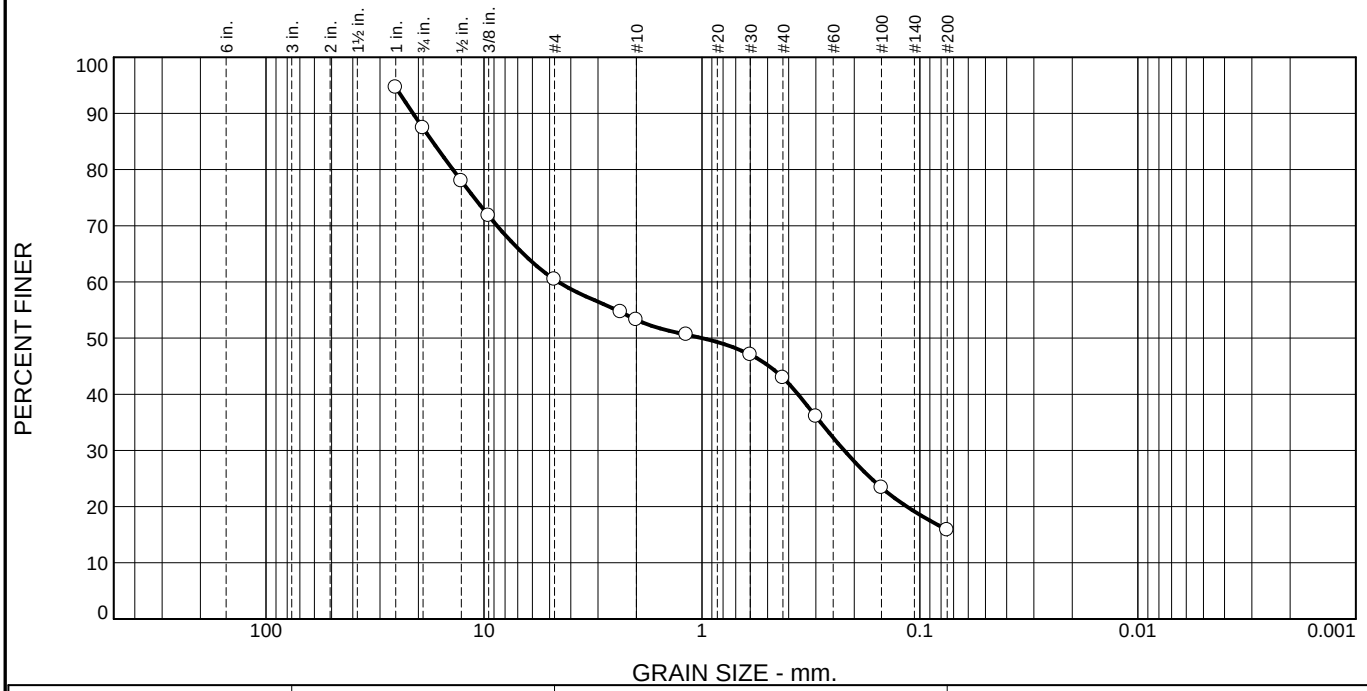
Date Sampled: 2/19/19

JONES & DEMILLE ENGINEERING INC.
Richfield, Utah

Client: Sevier County
Project: Sevier County Watershed Plan & Flood Protection

Project No: 1804-224 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
		27.0	7.1	10.4	27.1	15.8	

Test Results (AASHTO T 27 & AASHTO T 11)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1"	94.6		
3/4"	87.4		
1/2"	78.0		
3/8"	71.8		
#4	60.4		
#8	54.6		
#10	53.3		
#16	50.6		
#30	47.0		
#40	42.9		
#50	36.0		
#100	23.4		
#200	15.8		

* (no specification provided)

Material Description

TP19 LC-04. Sample 1, 0-20'

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SM **AASHTO (M 145)=** A-1-b

Coefficients

D_{90}= 21.1584 D_{85}= 17.2405 D_{60}= 4.5623
D_{50}= 1.0000 D_{30}= 0.2224 D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: 2/22/19 **Date Tested:** 3/6/19

Tested By: Matt Murphree

Checked By: Mark Rappleye

Title: Lab Manager

Location: TP19 LC-04, S-1 **Date Sampled:** 2/19/19
Sample Number: 19-S-055

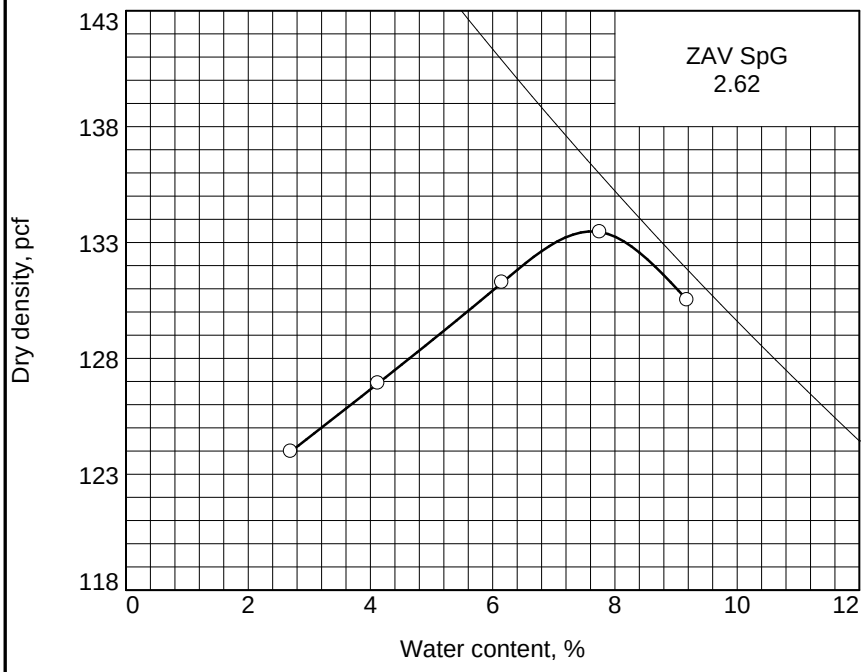
JONES & DEMILLE ENGINEERING INC.
Richfield, Utah

Client: Sevier County
Project: Sevier County Watershed Plan & Flood Protection

Project No: 1804-224 **Figure**

COMPACTION TEST REPORT

Curve No. 055



Preparation Method	-3/4" Material
Rammer: Wt.	10 lb. Drop 18 in.
Type	automatic
Layers: No.	five Blows per 56
Mold Size	0.075 cu. ft.
Test Performed on Material Passing	3/4 in. Sieve
%>3/4 in.	12.6 %<No.200 15.8
Atterberg (D 4318): LL	NV PI NP
NM (D 2216)	Sp.G. (D 854) 2.62
USCS (D 2487)	SM
AASHTO (M 145)	A-1-b
Date: Sampled	2/19/19
Received	2/22/19
Tested	3/6/19
Tested By	Matt Murphree

COMPACTION TESTING DATA
AASHTO T 180-15 Method D Modified
AASHTO T 224-01 Oversize Correction Applied to Final Results

	1	2	3	4	5	6
WM + WS	10063.2	10227.5	10472.2	10623.8	10579.5	
WM	5731.7	5731.7	5731.7	5731.7	5731.7	
WW + T #1	988.4	1023.2	1086.2	973.2	1001.1	
WD + T #1	968.8	992.4	1038.2	920.9	937.6	
TARE #1	242.2	245.6	258.3	246.7	246.0	
WW + T #2						
WD + T #2						
TARE #2						
MOIST.	2.7	4.1	6.2	7.8	9.2	
DRY DENS.	124.0	126.9	131.3	133.5	130.5	

SIEVE TEST RESULTS
AASHTO T 27 AASHTO T 11

Opening Size	% Passing	Specs.
1"	94.6	
3/4"	87.4	
1/2"	78.0	
3/8"	71.8	
#4	60.4	
#8	54.6	
#10	53.3	
#16	50.6	
#30	47.0	
#40	42.9	
#50	36.0	
#100	23.4	
#200	15.8	

ROCK CORRECTED TEST RESULTS

Maximum dry density = 136.5 pcf

Optimum moisture = 6.9 %

Material Description

TP19 LC-04. Sample 1, 0-20'

Remarks:

Project No. 1804-224 **Client:** Sevier County

Project: Sevier County Watershed Plan & Flood Protection

○ **Location:** TP19 LC-04, S-1 **Sample Number:** 19-S-055

Checked by: Mark Rappleye

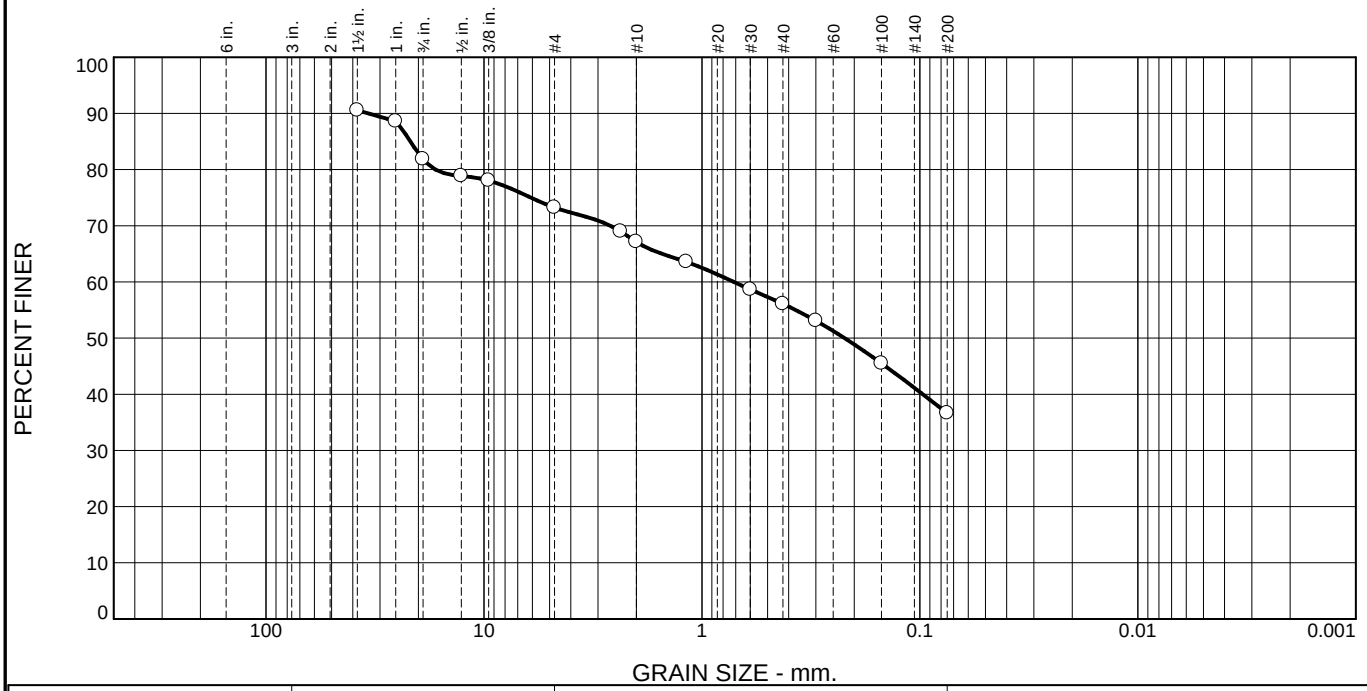
Title: Lab Manager

JONES & DEMILLE ENGINEERING INC.

Richfield, Utah

Figure

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
		8.7	6.1	11.0	19.5	36.6	

Test Results (AASHTO T 27 & AASHTO T 11)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1.5"	90.5		
1"	88.6		
3/4"	81.9		
1/2"	78.9		
3/8"	78.1		
#4	73.2		
#8	69.0		
#10	67.1		
#16	63.6		
#30	58.7		
#40	56.1		
#50	53.1		
#100	45.5		
#200	36.6		

* (no specification provided)

Material Description

BH19 FC-01, Sample 1, 2.5-4'

Atterberg Limits (ASTM D 4318)

PL= **LL=** **PI=**

Classification

USCS (D 2487)= **AASHTO (M 145)=**

Coefficients

D_{90}= 33.9894 D_{85}= 21.7562 D_{60}= 0.7148
D_{50}= 0.2217 D_{30}= D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: 3/1/19 **Date Tested:** 3/6/19

Tested By: Matt Murphree

Checked By: Mark Rappleye

Title: Lab Manager

Location: BH19 FC-01, S-1
Sample Number: 19-S-063

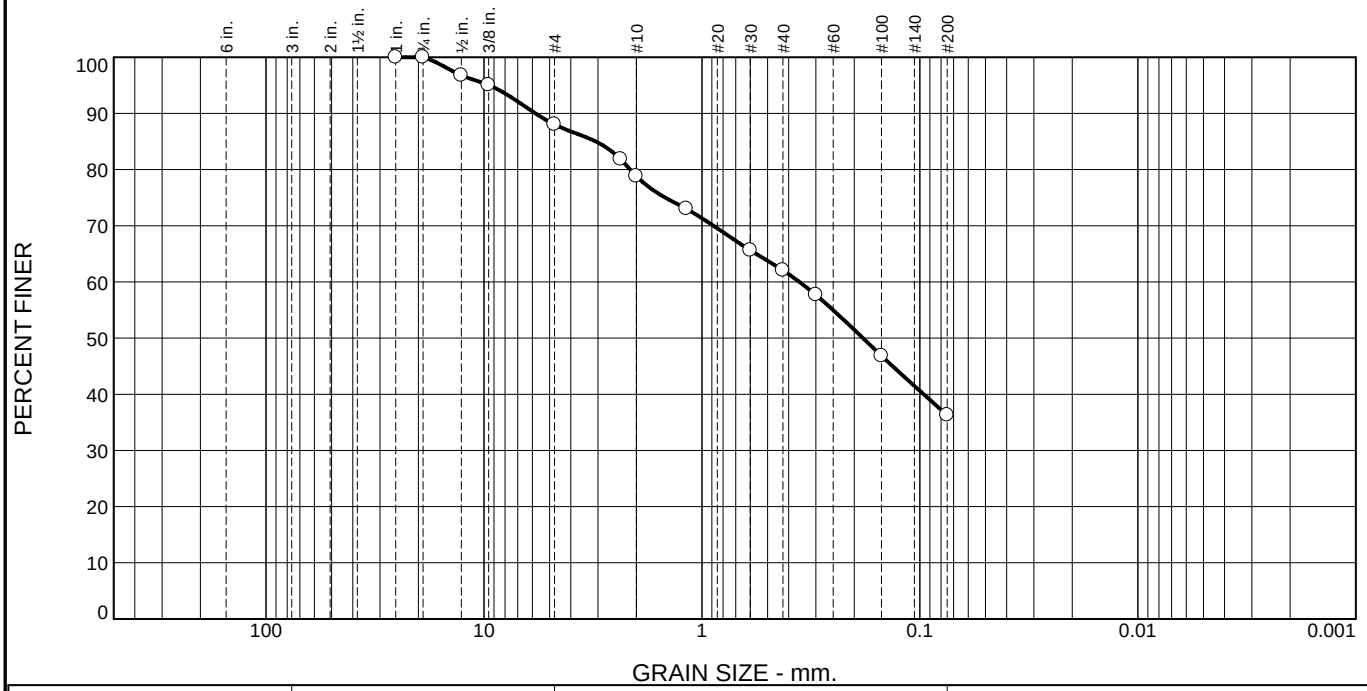
Date Sampled: 2/22/19

JONES & DEMILLE ENGINEERING INC.
Richfield, Utah

Client: Sevier County
Project: Sevier County Watershed Plan & Flood Protection

Project No: 1804-224 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	12.0	9.2	16.7	25.8	36.3	

Test Results (AASHTO T 27 & AASHTO T 11)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1"	100.0		
3/4"	100.0		
1/2"	96.8		
3/8"	95.1		
#4	88.0		
#8	81.8		
#10	78.8		
#16	73.0		
#30	65.6		
#40	62.1		
#50	57.7		
#100	46.8		
#200	36.3		

* (no specification provided)

Material Description

BH19 FC-01, Sample 3, 7.5-9'

Atterberg Limits (ASTM D 4318)

PL= LL= PI=

Classification

USCS (D 2487)= AASHTO (M 145)=

Coefficients

D_{90}= 5.8068 D_{85}= 3.0662 D_{60}= 0.3570
D_{50}= 0.1825 D_{30}= D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: 3/1/19 **Date Tested:** 3/6/19

Tested By: Mark Rappleye

Checked By: Mark Rappleye

Title: Lab Manager

Location: BH19 FC-01, S-3
Sample Number: 19-S-058

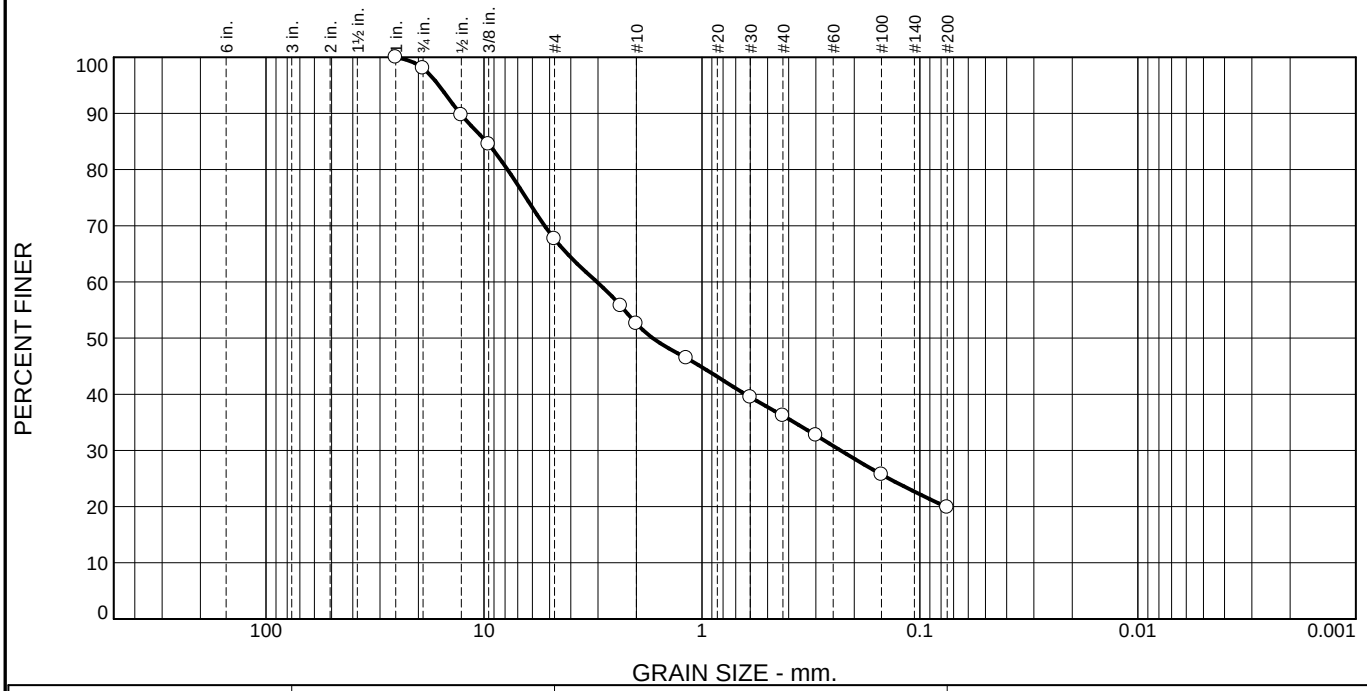
Date Sampled: 2/22/19

JONES & DEMILLE ENGINEERING INC.
Richfield, Utah

Client: Sevier County
Project: Sevier County Watershed Plan & Flood Protection

Project No: 1804-224 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	1.9	30.5	15.0	16.4	16.3	19.9	

Test Results (AASHTO T 27 & AASHTO T 11)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1"	100.0		
3/4"	98.1		
1/2"	89.7		
3/8"	84.5		
#4	67.6		
#8	55.8		
#10	52.6		
#16	46.5		
#30	39.5		
#40	36.2		
#50	32.7		
#100	25.7		
#200	19.9		

* (no specification provided)

Material Description

BH19 FC-01, Sample 7, 25-26'

Atterberg Limits (ASTM D 4318)

PL= **LL=** **PI=**

Classification

USCS (D 2487)= **AASHTO (M 145)=**

Coefficients

D_{90}= 12.8761 D_{85}= 9.7718 D_{60}= 3.0336
D_{50}= 1.6822 D_{30}= 0.2309 D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: 3/1/19 **Date Tested:** 3/6/19

Tested By: Matt Murphree

Checked By: Mark Rappleye

Title: Lab Manager

Location: BH19 FC-01, S-7
Sample Number: 19-S-062

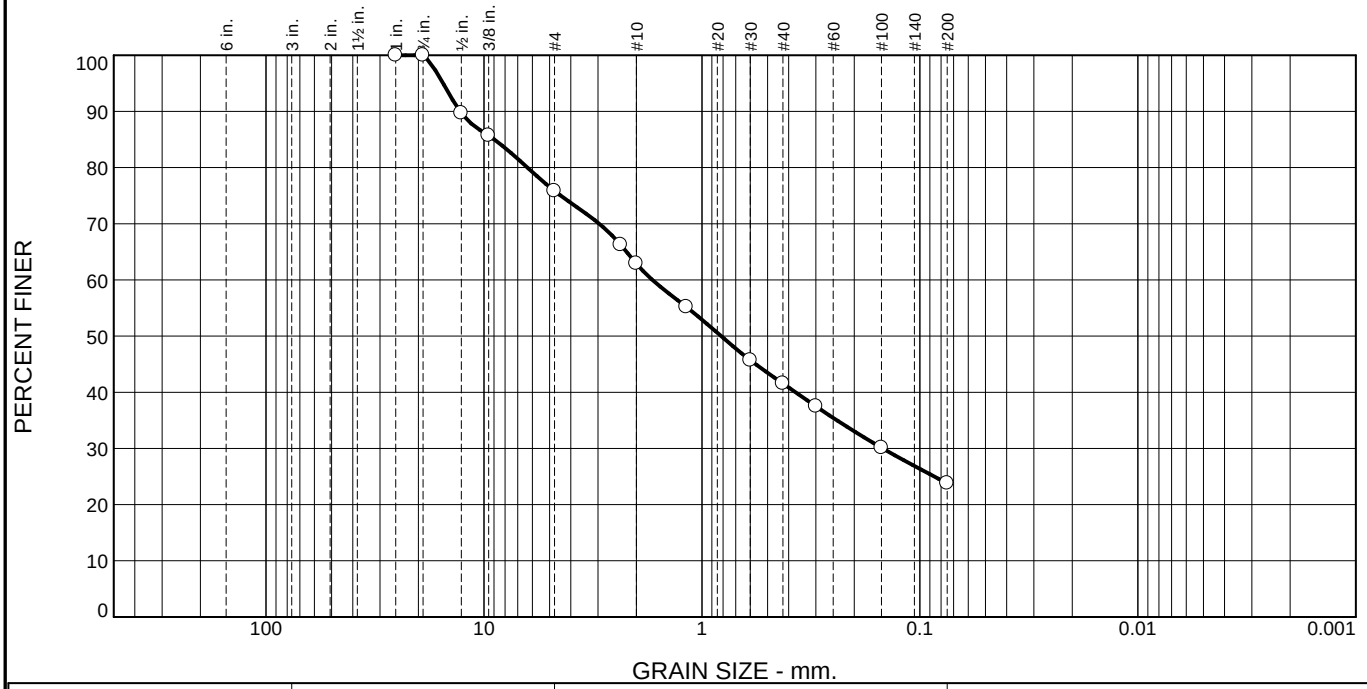
Date Sampled: 2/23/19

JONES & DEMILLE ENGINEERING INC.
Richfield, Utah

Client: Sevier County
Project: Sevier County Watershed Plan & Flood Protection

Project No: 1804-224 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	24.2	12.9	21.3	17.8	23.8	

Test Results (AASHTO T 27 & AASHTO T 11)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1"	100.0		
3/4"	100.0		
1/2"	89.7		
3/8"	85.7		
#4	75.8		
#8	66.3		
#10	62.9		
#16	55.2		
#30	45.7		
#40	41.6		
#50	37.5		
#100	30.1		
#200	23.8		

* (no specification provided)

Material Description

BH19 FC-01, Sample 10, 40-41'

Atterberg Limits (ASTM D 4318)

PL= **LL=** **PI=**

Classification

USCS (D 2487)= **AASHTO (M 145)=**

Coefficients

D_{90}= 12.8676 D_{85}= 8.9696 D_{60}= 1.6881
D_{50}= 0.8169 D_{30}= 0.1481 D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: 2/23/19 **Date Tested:** 3/7/19

Tested By: Mark Rappleye

Checked By: Mark Rappleye

Title: Lab Manager

Location: BH19 FC-01, S-10
Sample Number: 19-S-068

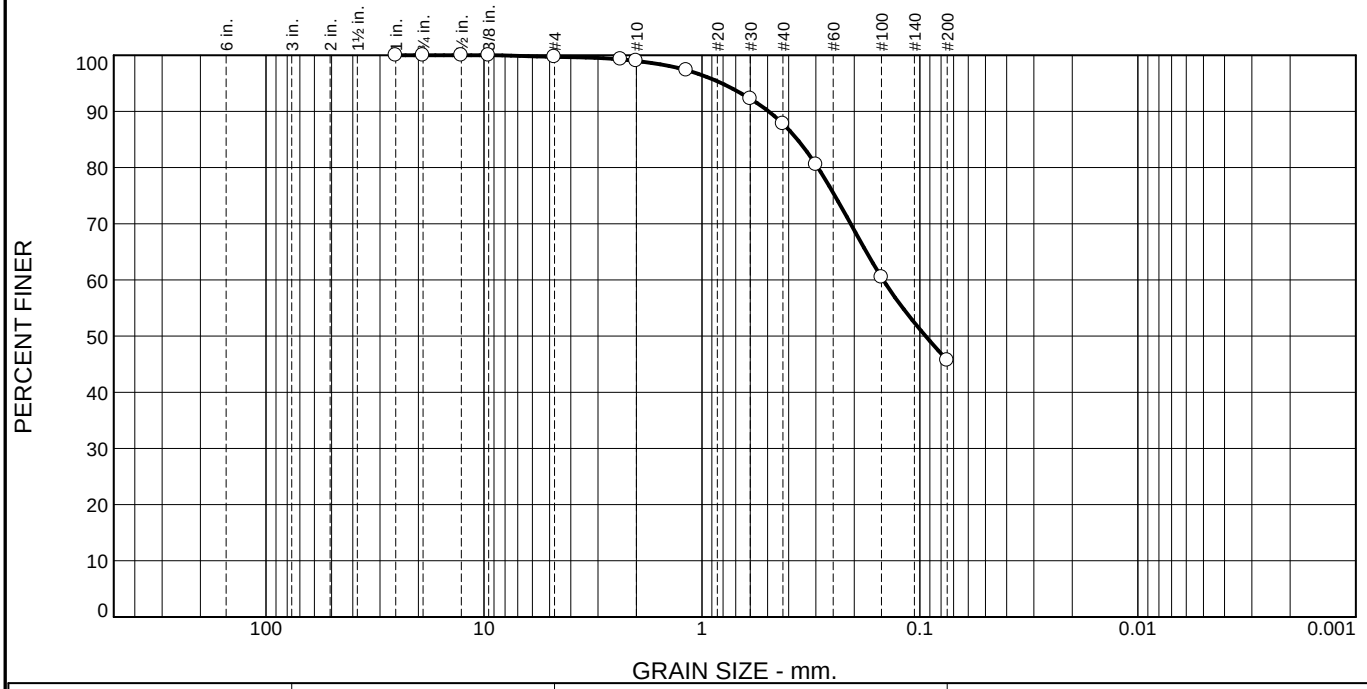
Date Sampled: 2/23/19

JONES & DEMILLE ENGINEERING INC.
Richfield, Utah

Client: Sevier County
Project: Sevier County Watershed Plan & Flood Protection

Project No: 1804-224 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.3	0.7	11.2	42.1	45.7	

Test Results (AASHTO T 27 & AASHTO T 11)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1"	100.0		
3/4"	100.0		
1/2"	100.0		
3/8"	100.0		
#4	99.7		
#8	99.3		
#10	99.0		
#16	97.4		
#30	92.3		
#40	87.8		
#50	80.5		
#100	60.5		
#200	45.7		

* (no specification provided)

Material Description

BH19 FC-01, Sample 14, 57.5-59'

Atterberg Limits (ASTM D 4318)

PL= 19.8 **LL=** 24.8 **PI=** 5.0

Classification

USCS (D 2487)= SC-SM **AASHTO (M 145)=** A-4(0)

Coefficients

D_{90}= 0.4941 D_{85}= 0.3647 D_{60}= 0.1473
D_{50}= 0.0941 D_{30}= D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: 3/1/19 **Date Tested:** 3/5/19

Tested By: Mark Rappleye

Checked By: Mark Rappleye

Title: Lab Manager

Location: BH19 FC-01, S-14
Sample Number: 19-S-050

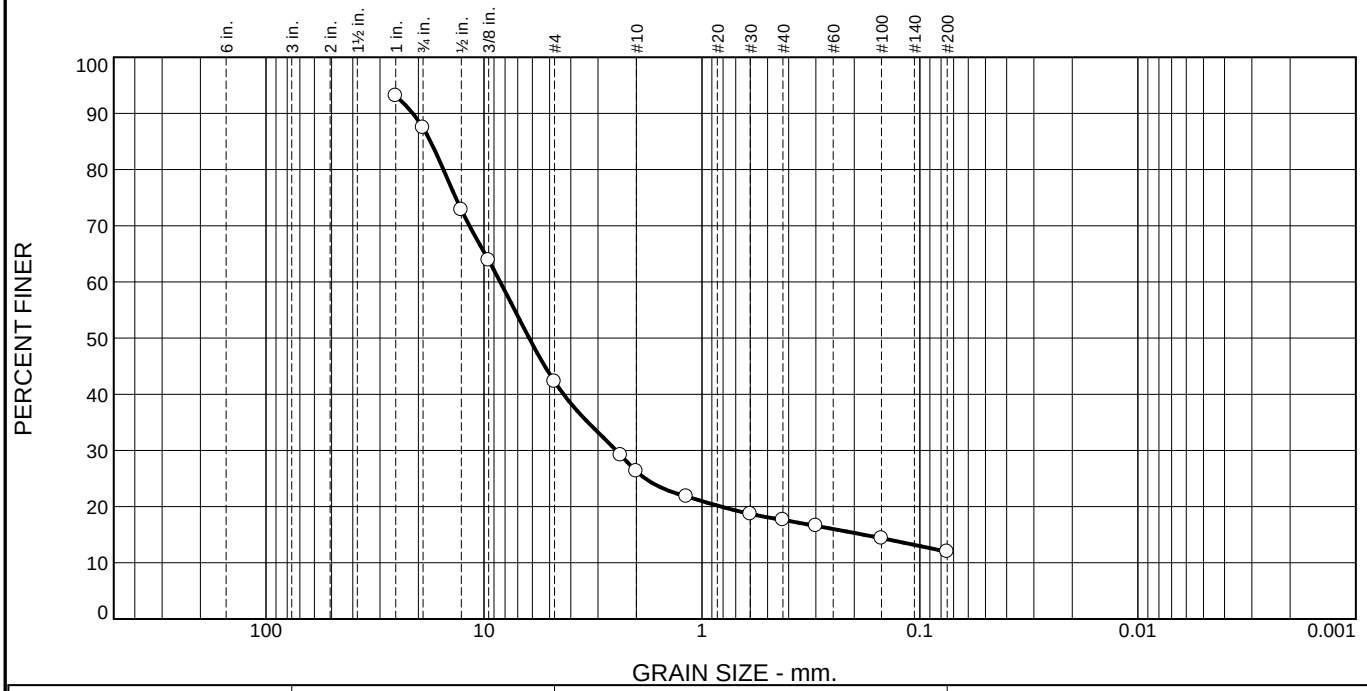
Date Sampled: 2/23/19

JONES & DEMILLE ENGINEERING INC.
Richfield, Utah

Client: Sevier County
Project: Sevier County Watershed Plan & Flood Protection

Project No: 1804-224 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
		45.2	16.0	8.7	5.6	12.0	

Test Results (AASHTO T 27 & AASHTO T 11)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1"	93.1		
3/4"	87.5		
1/2"	72.8		
3/8"	63.9		
#4	42.3		
#8	29.2		
#10	26.3		
#16	21.8		
#30	18.7		
#40	17.6		
#50	16.6		
#100	14.4		
#200	12.0		

* (no specification provided)

Material Description

TP19 FC-01, Sample 2, 2-21'

Atterberg Limits (ASTM D 4318)

PL= 16.7 **LL=** 25.1 **PI=** 8.4

Classification

USCS (D 2487)= GP-GC **AASHTO (M 145)=** A-2-4(0)

Coefficients

D_{90}= 21.1791 D_{85}= 17.5957 D_{60}= 8.4260
D_{50}= 6.2049 D_{30}= 2.4730 D_{15}= 0.1816
D_{10}= C_u= C_c=

Remarks

Date Received: 2/22/19 **Date Tested:** 3/7/19

Tested By: Matt Murphree

Checked By: Mark Rappleye

Title: Lab Manager

Location: TP19 FC-01, S-2
Sample Number: 19-S-070

Date Sampled: 2/20/19

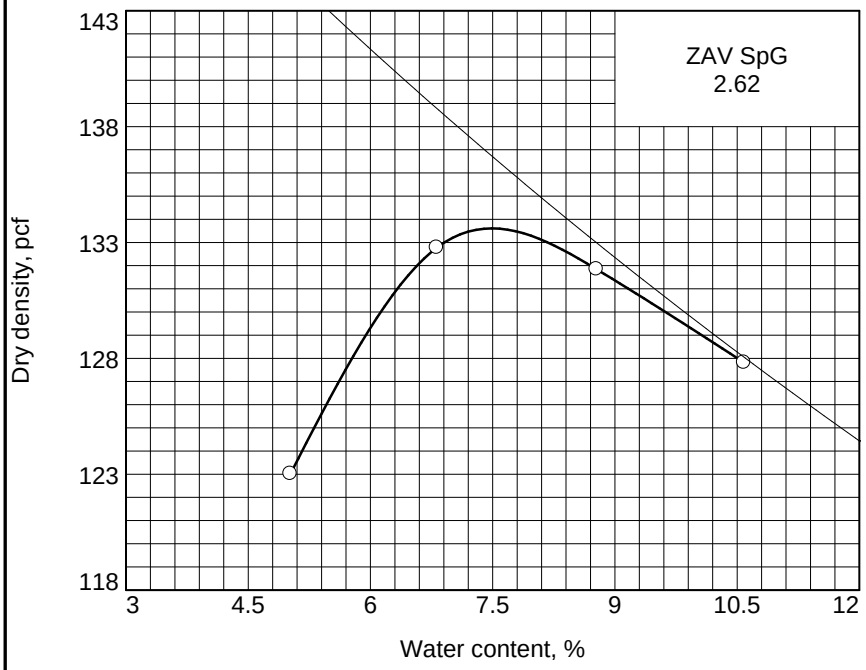
JONES & DEMILLE ENGINEERING INC.
Richfield, Utah

Client: Sevier County
Project: Sevier County Watershed Plan & Flood Protection

Project No: 1804-224 **Figure**

COMPACTION TEST REPORT

Curve No. 070



Preparation Method	-3/4" Material
Rammer: Wt.	10 lb. Drop 18 in.
Type	automatic
Layers: No.	five Blows per 56
Mold Size	0.075 cu. ft.
Test Performed on Material Passing	3/4 in. Sieve
%>3/4 in.	12.5 %<No.200 12.0
Atterberg (D 4318): LL	25.1 PI 8.4
NM (D 2216)	Sp.G. (D 854) 2.62
USCS (D 2487)	GP-GC
AASHTO (M 145)	A-2-4(0)
Date: Sampled	2/20/19
Received	2/22/19
Tested	3/7/19
Tested By	Matt Murphree

COMPACTION TESTING DATA
AASHTO T 180-15 Method D Modified
AASHTO T 224-01 Oversize Correction Applied to Final Results

	1	2	3	4	5	6
WM + WS	10894.7	11324.2	11378.3	11308.0		
WM	6499.4	6499.4	6499.4	6499.4		
WW + T #1	949.0	993.1	1158.1	1052.4		
WD + T #1	915.0	945.2	1084.5	975.2		
TARE #1	237.5	242.3	245.6	245.8		
WW + T #2						
WD + T #2						
TARE #2						
MOIST.	5.0	6.8	8.8	10.6		
DRY DENS.	123.0	132.8	131.8	127.8		

SIEVE TEST RESULTS
AASHTO T 27 AASHTO T 11

Opening Size	% Passing	Specs.
1"	93.1	
3/4"	87.5	
1/2"	72.8	
3/8"	63.9	
#4	42.3	
#8	29.2	
#10	26.3	
#16	21.8	
#30	18.7	
#40	17.6	
#50	16.6	
#100	14.4	
#200	12.0	

ROCK CORRECTED TEST RESULTS

Maximum dry density = 136.6 pcf

Optimum moisture = 6.8 %

Material Description

TP19 FC-01, Sample 2, 2-21'

Remarks:

Project No. 1804-224 **Client:** Sevier County

Project: Sevier County Watershed Plan & Flood Protection

○ **Location:** TP19 FC-01, S-2 **Sample Number:** 19-S-070

Checked by: Mark Rappleye

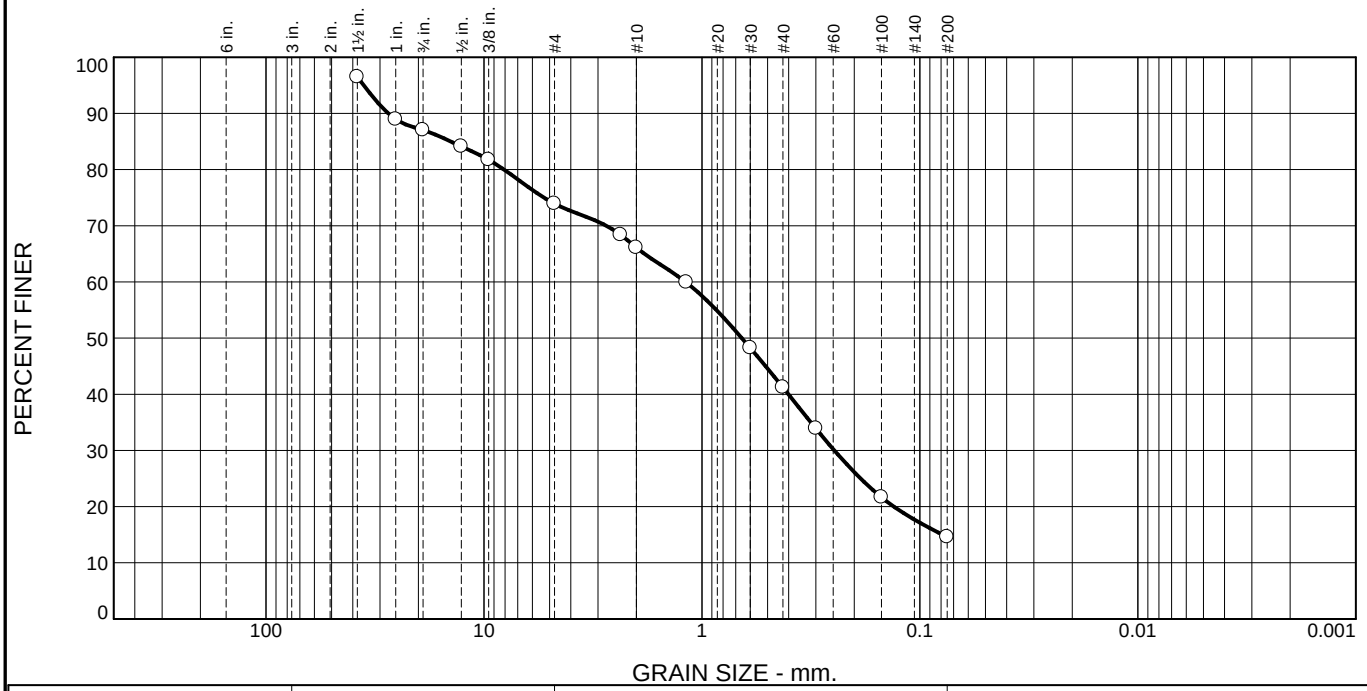
Title: Lab Manager

JONES & DEMILLE ENGINEERING INC.

Richfield, Utah

Figure

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
		13.1	7.8	24.9	26.6	14.6	

Test Results (AASHTO T 27 & AASHTO T 11)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1.5"	96.5		
1"	89.0		
3/4"	87.0		
1/2"	84.1		
3/8"	81.7		
#4	73.9		
#8	68.4		
#10	66.1		
#16	59.9		
#30	48.2		
#40	41.2		
#50	33.9		
#100	21.7		
#200	14.6		

* (no specification provided)

Material Description

TP19 FC-02, Sample 2, 2-19'

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SM **AASHTO (M 145)=** A-1-b

Coefficients

D_{90}= 27.4905 D_{85}= 14.2083 D_{60}= 1.1878
D_{50}= 0.6565 D_{30}= 0.2469 D_{15}= 0.0787
D_{10}= C_u= C_c=

Remarks

Date Received: 2/22/19 **Date Tested:** 3/7/19

Tested By: Mark Rappleye

Checked By: Mark Rappleye

Title: Lab Manager

Location: TP19 FC-02, S-2
Sample Number: 19-S-065

Date Sampled: 2/20/19

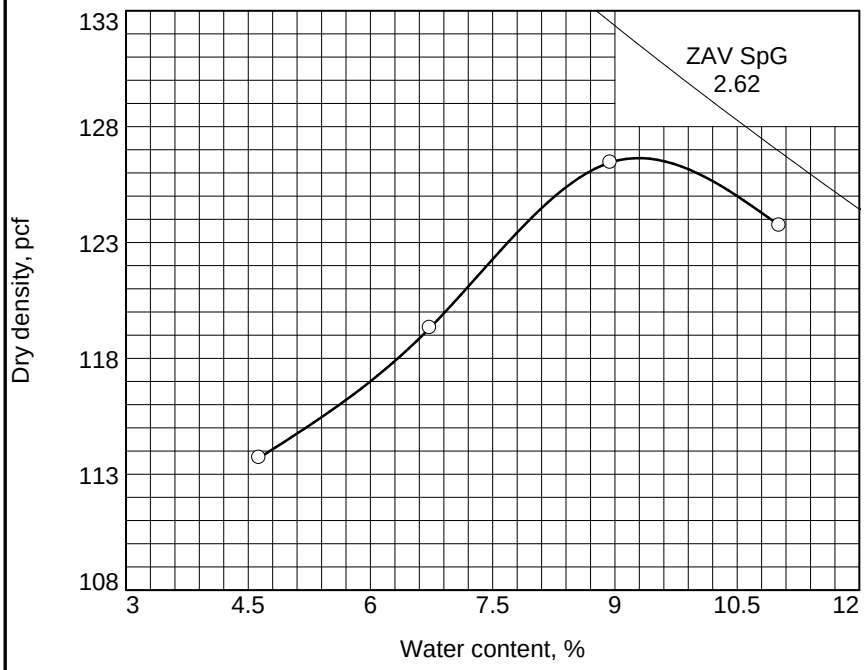
JONES & DEMILLE ENGINEERING INC.
Richfield, Utah

Client: Sevier County
Project: Sevier County Watershed Plan & Flood Protection

Project No: 1804-224 **Figure**

COMPACTION TEST REPORT

Curve No. 065



Preparation Method	-3/4" Material
Rammer: Wt.	10 lb. Drop 18 in.
Type	automatic
Layers: No.	five Blows per 56
Mold Size	0.075 cu. ft.
Test Performed on Material Passing	3/4 in. Sieve
%>3/4 in.	13.0 %<No.200 14.6
Atterberg (D 4318): LL	NV PI NP
NM (D 2216)	Sp.G. (D 854) 2.62
USCS (D 2487)	SM
AASHTO (M 145)	A-1-b
Date: Sampled	2/20/19
Received	2/22/19
Tested	3/7/19
Tested By	Matt Murphree

COMPACTION TESTING DATA
AASHTO T 180-15 Method D Modified
AASHTO T 224-01 Oversize Correction Applied to Final Results

	1	2	3	4	5	6
WM + WS	9778.6	10063.0	10417.6	10404.2		
WM	5730.9	5730.9	5730.9	5730.9		
WW + T #1	920.5	913.2	922.4	998.7		
WD + T #1	890.6	870.6	867.3	925.3		
TARE #1	245.6	237.6	251.3	259.1		
WW + T #2						
WD + T #2						
TARE #2						
MOIST.	4.6	6.7	8.9	11.0		
DRY DENS.	113.7	119.3	126.5	123.7		

SIEVE TEST RESULTS
AASHTO T 27 AASHTO T 11

Opening Size	% Passing	Specs.
1.5"	96.5	
1"	89.0	
3/4"	87.0	
1/2"	84.1	
3/8"	81.7	
#4	73.9	
#8	68.4	
#10	66.1	
#16	59.9	
#30	48.2	
#40	41.2	
#50	33.9	
#100	21.7	
#200	14.6	

ROCK CORRECTED TEST RESULTS

Maximum dry density = 130.4 pcf

Optimum moisture = 8.3 %

Material Description

TP19 FC-02, Sample 2, 2-19'

Remarks:

Project No. 1804-224 **Client:** Sevier County

Project: Sevier County Watershed Plan & Flood Protection

○ **Location:** TP19 FC-02, S-2 **Sample Number:** 19-S-065

Checked by: Mark Rappleye

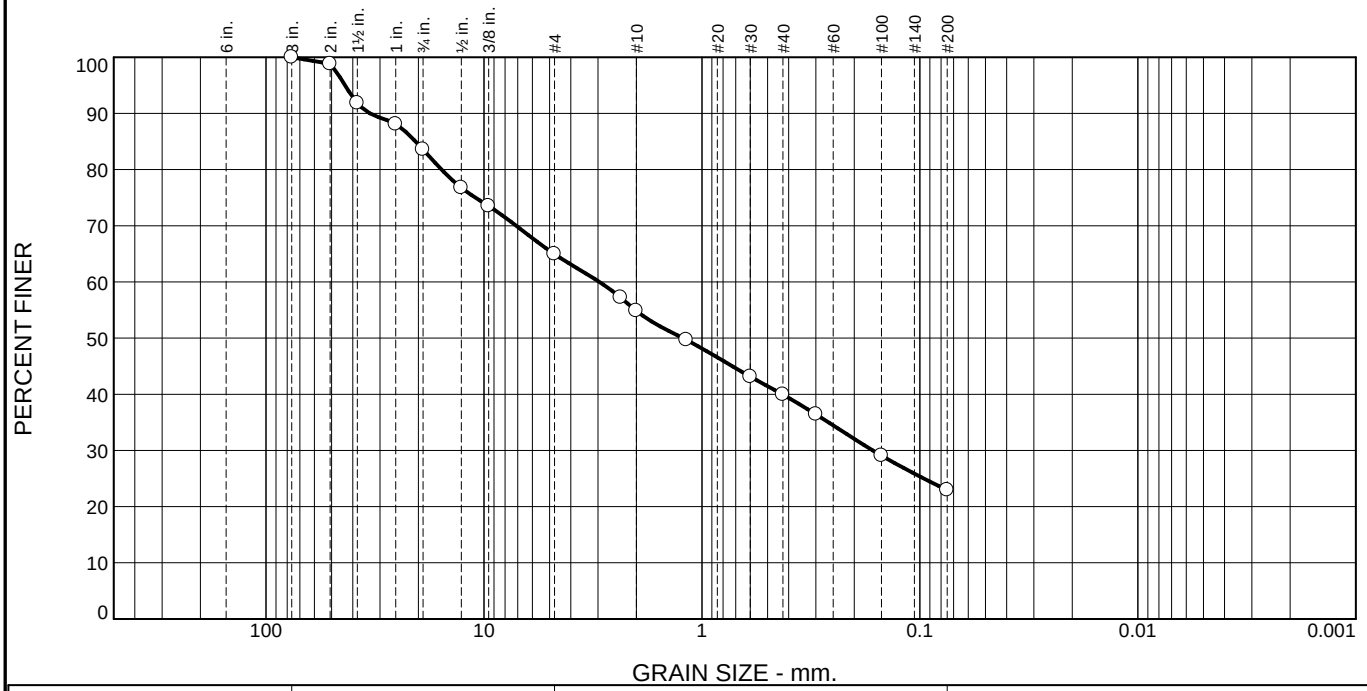
Title: Lab Manager

JONES & DEMILLE ENGINEERING INC.

Richfield, Utah

Figure

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	16.4	18.6	10.1	15.0	17.0	22.9	

Test Results (AASHTO T 27 & AASHTO T 11)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
3"	100.0		
2"	98.8		
1.5"	91.8		
1"	88.1		
3/4"	83.6		
1/2"	76.8		
3/8"	73.5		
#4	65.0		
#8	57.2		
#10	54.9		
#16	49.7		
#30	43.1		
#40	39.9		
#50	36.4		
#100	29.1		
#200	22.9		

* (no specification provided)

Material Description

TP19 FC-03, Sample 1, 0-4'

Atterberg Limits (ASTM D 4318)

PL= **LL=** **PI=**

Classification

USCS (D 2487)= **AASHTO (M 145)=**

Coefficients

D_{90}= 33.3846 D_{85}= 20.6039 D_{60}= 2.9585
D_{50}= 1.2232 D_{30}= 0.1644 D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: 2/22/19 **Date Tested:** 3/5/19

Tested By: Mark Rappleye

Checked By: Mark Rappleye

Title: Lab Manager

Location: TP-19 FC-03, S-1
Sample Number: 19-S-054

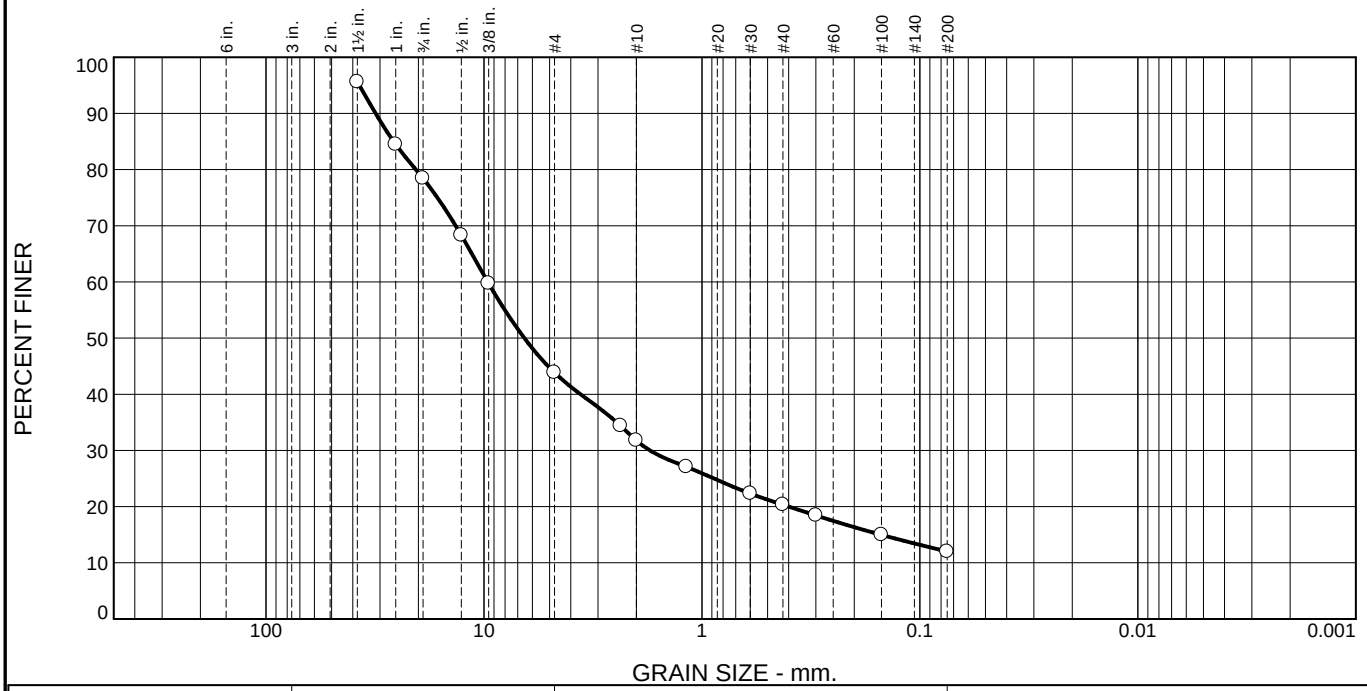
Date Sampled: 2/20/19

JONES & DEMILLE ENGINEERING INC.
Richfield, Utah

Client: Sevier County
Project: Sevier County Watershed Plan & Flood Protection

Project No: 1804-224 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
		34.6	12.1	11.5	8.3	12.0	

Test Results (AASHTO T 27 & AASHTO T 11)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1.5"	95.6		
1"	84.5		
3/4"	78.5		
1/2"	68.3		
3/8"	59.7		
#4	43.9		
#8	34.4		
#10	31.8		
#16	27.1		
#30	22.3		
#40	20.3		
#50	18.4		
#100	15.0		
#200	12.0		

* (no specification provided)

Material Description

TP19 FC-03, Sample 2, 4-21'

Atterberg Limits (ASTM D 4318)

PL= 16.2 **LL=** 19.9 **PI=** 3.7

Classification

USCS (D 2487)= GP-GC **AASHTO (M 145)=** A-1-a

Coefficients

D_{90}= 31.4380 D_{85}= 25.9844 D_{60}= 9.6105
D_{50}= 6.5292 D_{30}= 1.7315 D_{15}= 0.1512
D_{10}= C_u= C_c=

Remarks

Date Received: 2/22/19 **Date Tested:** 3/6/19

Tested By: Mark Rappleye

Checked By: Mark Rappleye

Title: Lab Manager

Location: TP19 FC-03, S-2
Sample Number: 19-S-056

Date Sampled: 2/20/19

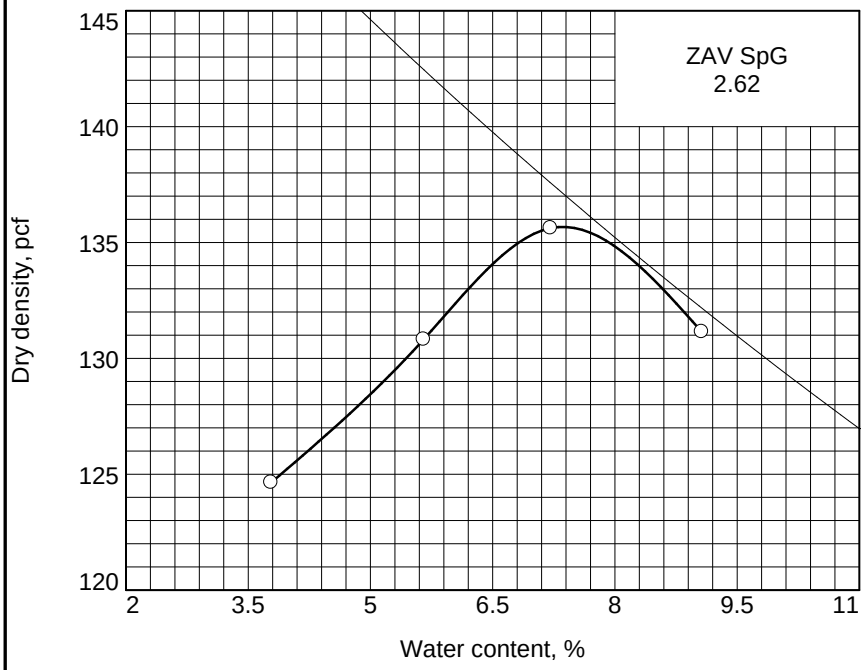
JONES & DEMILLE ENGINEERING INC.
Richfield, Utah

Client: Sevier County
Project: Sevier County Watershed Plan & Flood Protection

Project No: 1804-224 **Figure**

COMPACTION TEST REPORT

Curve No. 056



Preparation Method	-3/4" Material
Rammer: Wt.	10 lb. Drop 18 in.
Type	automatic
Layers: No.	five Blows per 56
Mold Size	0.075 cu. ft.
Test Performed on Material Passing	3/4 in. Sieve
%>3/4 in.	21.5 %<No.200 12.0
Atterberg (D 4318): LL	19.9 PI 3.7
NM (D 2216)	Sp.G. (D 854) 2.62
USCS (D 2487)	GP-GC
AASHTO (M 145)	A-1-a
Date: Sampled	2/20/19
Received	2/22/19
Tested	3/6/19
Tested By	Matt Murphree

COMPACTION TESTING DATA
AASHTO T 180-15 Method D Modified
AASHTO T 224-01 Oversize Correction Applied to Final Results

	1	2	3	4	5	6
WM + WS	10900.2	11201.2	11446.0	11365.2		
WM	6499.4	6499.4	6499.4	6499.4		
WW + T #1	1011.6	1042.1	991.3	1045.1		
WD + T #1	983.7	999.4	941.2	978.8		
TARE #1	246.2	244.0	246.6	247.5		
WW + T #2						
WD + T #2						
TARE #2						
MOIST.	3.8	5.7	7.2	9.1		
DRY DENS.	124.6	130.8	135.6	131.1		

SIEVE TEST RESULTS
AASHTO T 27 AASHTO T 11

Opening Size	% Passing	Specs.
1.5"	95.6	
1"	84.5	
3/4"	78.5	
1/2"	68.3	
3/8"	59.7	
#4	43.9	
#8	34.4	
#10	31.8	
#16	27.1	
#30	22.3	
#40	20.3	
#50	18.4	
#100	15.0	
#200	12.0	

ROCK CORRECTED TEST RESULTS

Maximum dry density = 140.8 pcf

Optimum moisture = 6.2 %

Material Description

TP19 FC-03, Sample 2, 4-21'

Remarks:

Project No. 1804-224 **Client:** Sevier County

Project: Sevier County Watershed Plan & Flood Protection

○ **Location:** TP19 FC-03, S-2 **Sample Number:** 19-S-056

Checked by: Mark Rappleye

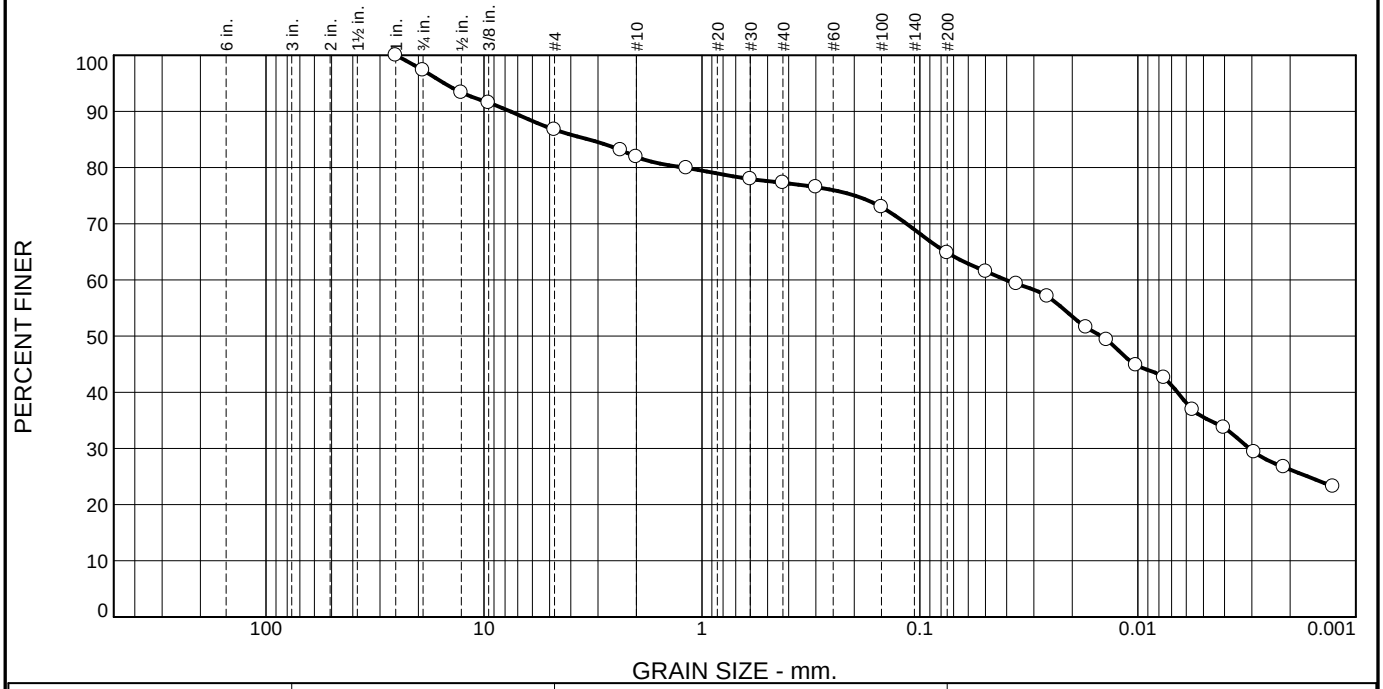
Title: Lab Manager

JONES & DEMILLE ENGINEERING INC.

Richfield, Utah

Figure

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	2.7	10.6	4.8	4.6	12.5	29.3	35.5

Test Results (AASHTO T 27 & AASHTO T 11)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1"	100.0		
3/4"	97.3		
1/2"	93.4		
3/8"	91.6		
#4	86.7		
#8	83.1		
#10	81.9		
#16	79.9		
#30	78.0		
#40	77.3		
#50	76.5		
#100	73.0		
#200	64.8		
0.0498 mm.	61.5		
0.0360 mm.	59.3		
0.0260 mm.	57.1		
0.0173 mm.	51.6		
0.0139 mm.	49.3		
0.0102 mm.	44.8		
0.0076 mm.	42.6		
0.0056 mm.	36.9		
0.0040 mm.	33.7		
0.0029 mm.	29.3		
0.0021 mm.	26.7		
0.0013 mm.	23.2		

* (no specification provided)

Material Description

Native Red Clay

Atterberg Limits (ASTM D 4318)

PL= 13.4 **LL=** 27.2 **PI=** 13.8

Classification

USCS (D 2487)= CL **AASHTO (M 145)=** A-6(6)

Coefficients

D_{90}= 7.5700 D_{85}= 3.3121 D_{60}= 0.0403
D_{50}= 0.0147 D_{30}= 0.0031 D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: 4/6/19 **Date Tested:** 4/22/19

Tested By: Matt Murphree

Checked By: Mark Rappleye

Title: Lab Manager

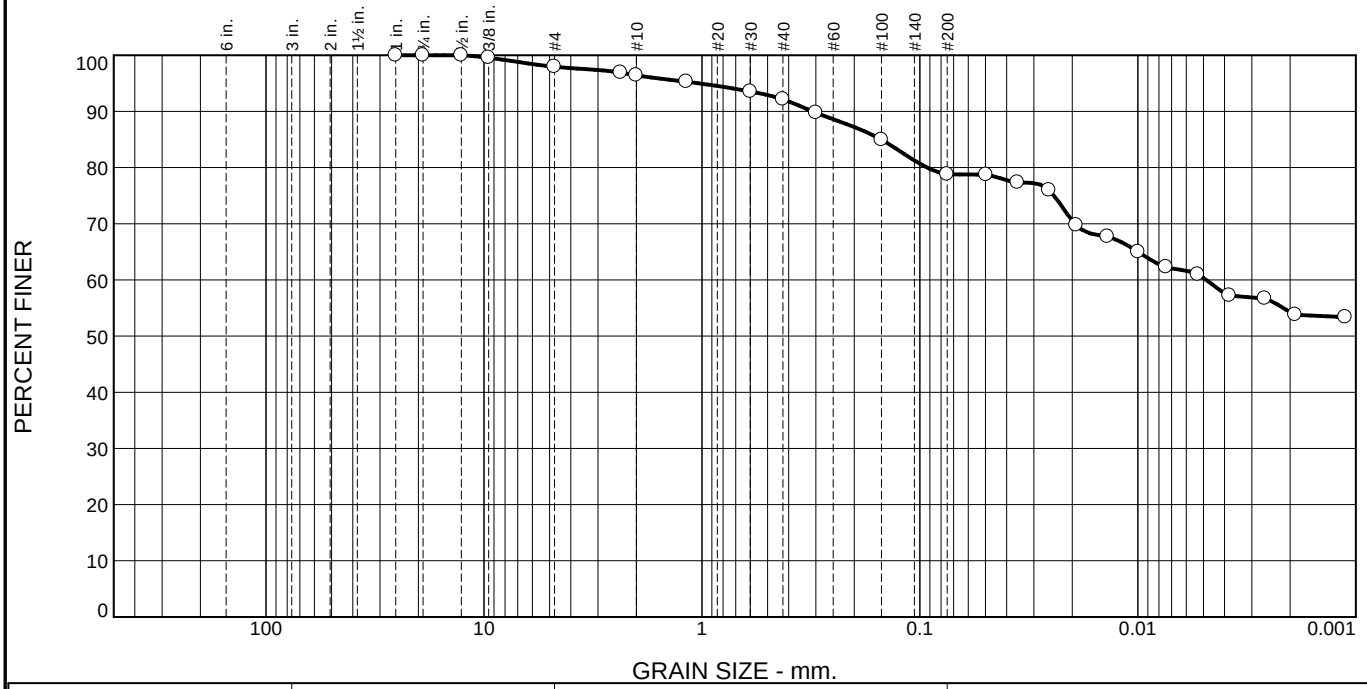
Location: Flat Canyon **Date Sampled:** 4/5/19
Sample Number: 19-S-166

JONES & DEMILLE ENGINEERING INC.
Richfield, Utah

Client: Sevier County
Project: Sevier County Watershed Plan & Flood Protection

Project No: 1804-224 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	2.0	1.6	4.3	13.3	18.4	60.4

Test Results (AASHTO T 27 & AASHTO T 11)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1"	100.0		
3/4"	100.0		
1/2"	100.0		
3/8"	99.6		
#4	98.0		
#8	96.9		
#10	96.4		
#16	95.3		
#30	93.5		
#40	92.1		
#50	89.8		
#100	85.0		
#200	78.8		
0.0497 mm.	78.7		
0.0356 mm.	77.4		
0.0255 mm.	76.0		
0.0192 mm.	69.7		
0.0138 mm.	67.7		
0.0100 mm.	65.0		
0.0074 mm.	62.3		
0.0053 mm.	61.0		
0.0038 mm.	57.2		
0.0026 mm.	56.7		
0.0019 mm.	53.8		
0.0011 mm.	53.4		

* (no specification provided)

Material Description

Native Clay Site - West of Elsinore

Atterberg Limits (ASTM D 4318)

PL= 18.0 **LL=** 67.5 **PI=** 49.5

Classification

USCS (D 2487)= CH **AASHTO (M 145)=** A-7-6(41)

Coefficients

D_{90}= 0.3102 D_{85}= 0.1506 D_{60}= 0.0049
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: 2/27/19 **Date Tested:** 3/1/19

Tested By: Mark Rappleye

Checked By: Mark Rappleye

Title: Lab Manager

Location: Flat Canyon (West of Elsinore)
Sample Number: 19-S-040

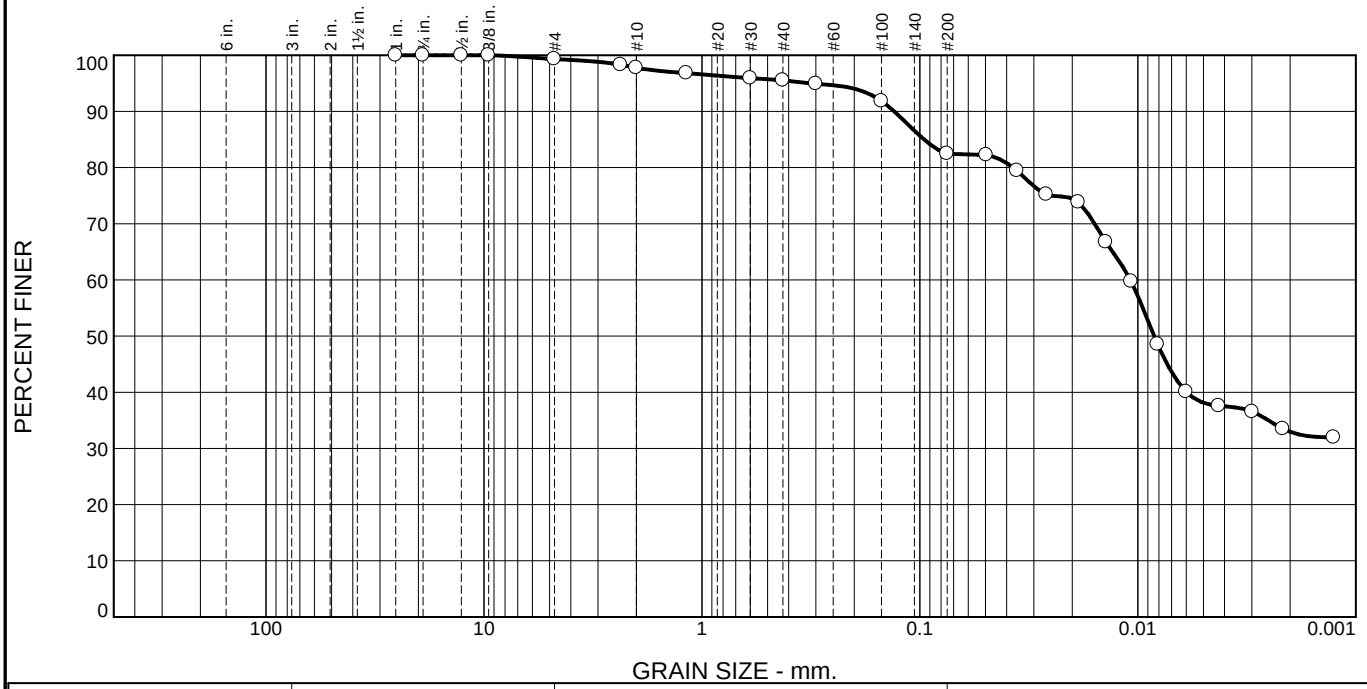
Date Sampled: 2/27/19

JONES & DEMILLE ENGINEERING INC.
Richfield, Utah

Client: Sevier County
Project: Sevier County Watershed Plan & Flood Protection

Project No: 1804-224 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.7	1.5	2.3	13.0	44.4	38.1

Test Results (AASHTO T 27 & AASHTO T 11)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1"	100.0		
3/4"	100.0		
1/2"	100.0		
3/8"	100.0		
#4	99.3		
#8	98.3		
#10	97.8		
#16	96.8		
#30	95.9		
#40	95.5		
#50	94.9		
#100	91.8		
#200	82.5		
0.0495 mm.	82.2		
0.0359 mm.	79.4		
0.0262 mm.	75.2		
0.0188 mm.	73.8		
0.0140 mm.	66.7		
0.0107 mm.	59.7		
0.0081 mm.	48.5		
0.0060 mm.	40.1		
0.0043 mm.	37.6		
0.0030 mm.	36.5		
0.0022 mm.	33.5		
0.0013 mm.	32.0		

* (no specification provided)

Material Description

Native Clay Site - West of Aurora

Atterberg Limits (ASTM D 4318)

PL= 13.5 **LL=** 45.6 **PI=** 32.1

Classification

USCS (D 2487)= CL **AASHTO (M 145)=** A-7-6(26)

Coefficients

D_{90}= 0.1311 D_{85}= 0.0957 D_{60}= 0.0108
D_{50}= 0.0084 D_{30}= D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: 2/27/19 **Date Tested:** 3/1/19

Tested By: Mark Rappleye

Checked By: Mark Rappleye

Title: Lab Manager

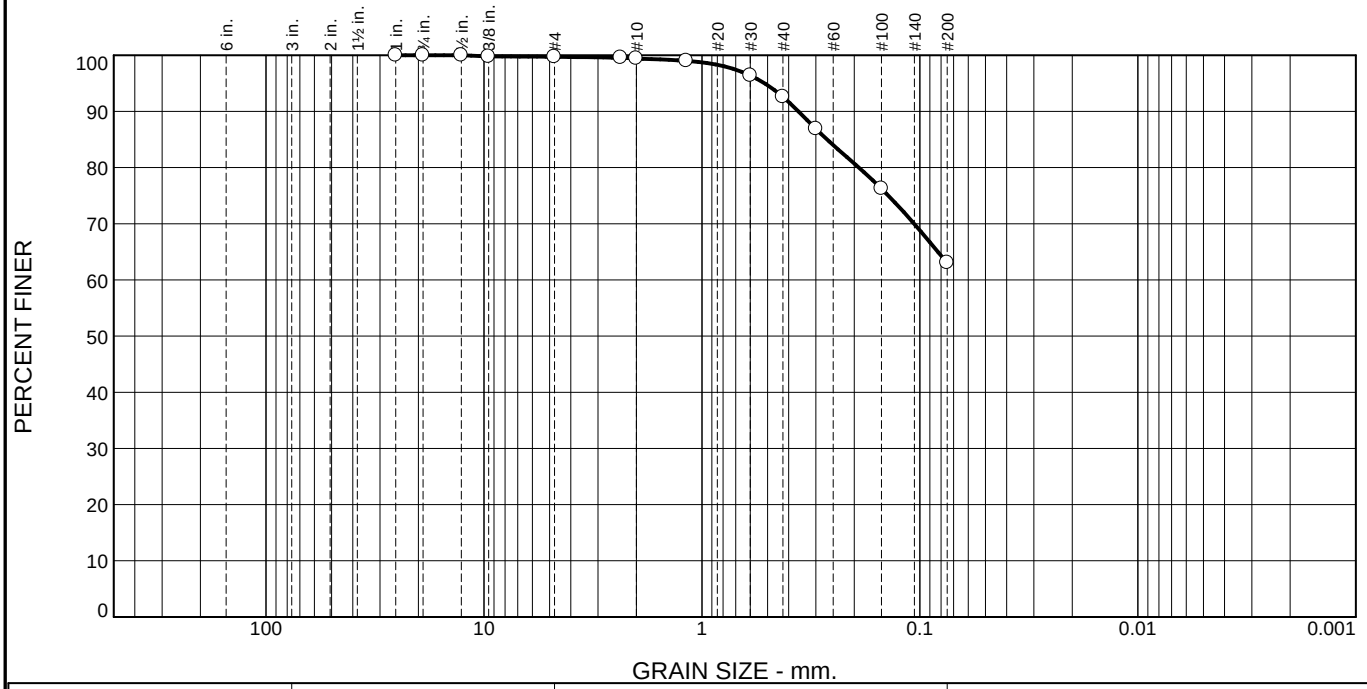
Location: West of Aurora (Above Water Tank) **Date Sampled:** 2/27/19
Sample Number: 19-S-041

JONES & DEMILLE ENGINEERING INC.
Richfield, Utah

Client: Sevier County
Project: Sevier County Watershed Plan & Flood Protection

Project No: 1804-224 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.3	0.3	6.8	29.6	63.0	

Test Results (AASHTO T 27 & AASHTO T 11)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1"	100.0		
3/4"	100.0		
1/2"	100.0		
3/8"	99.8		
#4	99.7		
#8	99.6		
#10	99.4		
#16	99.0		
#30	96.4		
#40	92.6		
#50	86.9		
#100	76.2		
#200	63.0		

* (no specification provided)

Material Description

TP19 DC-01, Sample 1 (Combined with DC-02)

Atterberg Limits (ASTM D 4318)

PL= 20.2 **LL=** 24.0 **PI=** 3.8

Classification

USCS (D 2487)= CL-ML **AASHTO (M 145)=** A-4(0)

Coefficients

D_{90}= 0.3608 D_{85}= 0.2665 D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: 2/22/19 **Date Tested:** 3/5/19

Tested By: Mark Rappleye

Checked By: Mark Rappleye

Title: Lab Manager

Location: TP19 DC-01, S-1 (Dairy Canyon) **Date Sampled:** 2/21/19

Sample Number: 19-S-046

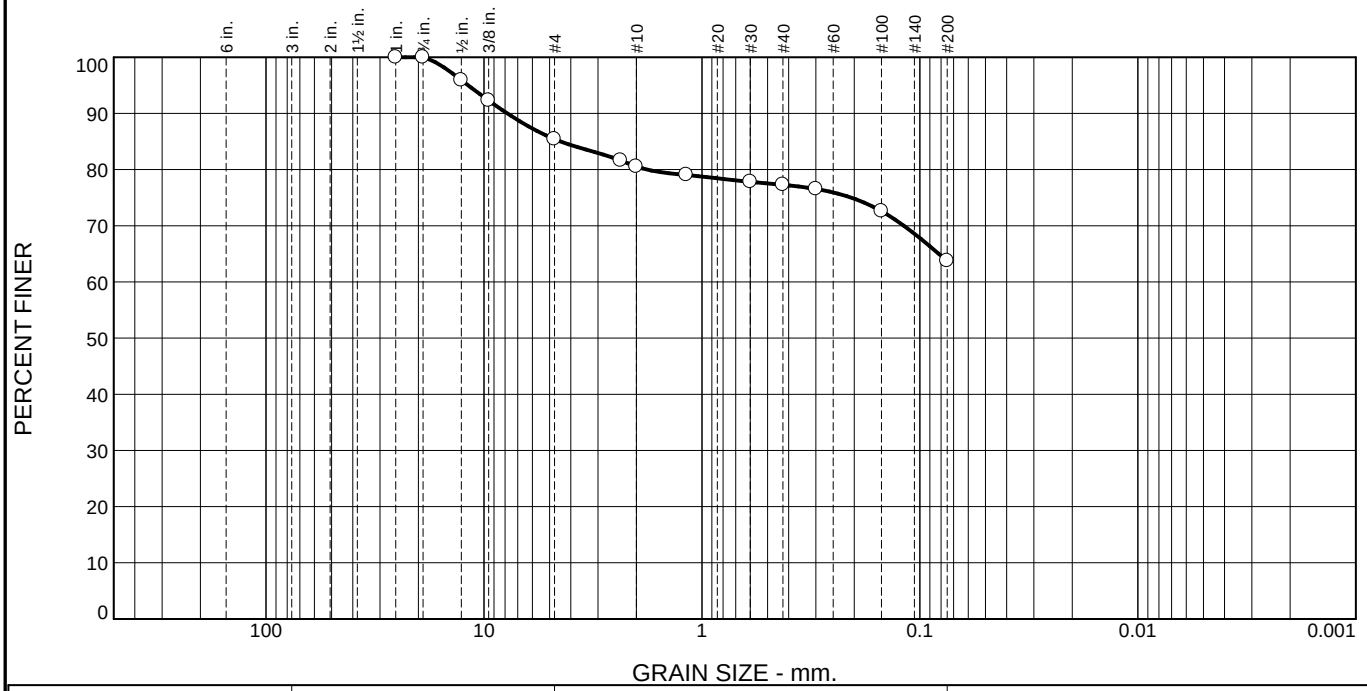
JONES & DEMILLE ENGINEERING INC.
Richfield, Utah

Client: Sevier County

Project: Sevier County Watershed Plan & Flood Protection

Project No: 1804-224 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	14.6	4.8	3.3	13.6	63.7	

Test Results (AASHTO T 27 & AASHTO T 11)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1"	100.0		
3/4"	100.0		
1/2"	95.9		
3/8"	92.3		
#4	85.4		
#8	81.6		
#10	80.6		
#16	79.0		
#30	77.8		
#40	77.3		
#50	76.6		
#100	72.6		
#200	63.7		

* (no specification provided)

Material Description

Red Native Silty/Clay

Atterberg Limits (ASTM D 4318)

PL= 12.8 **LL=** 25.7 **PI=** 12.9

Classification

USCS (D 2487)= CL **AASHTO (M 145)=** A-6(5)

Coefficients

D_{90}= 7.8084 D_{85}= 4.4517 D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: 4/5/19 **Date Tested:** 4/10/19

Tested By: Mark Rappleye

Checked By: Mark Rappleye

Title: Lab Manager

Location: Flat Canyon
Sample Number: 19-S-123

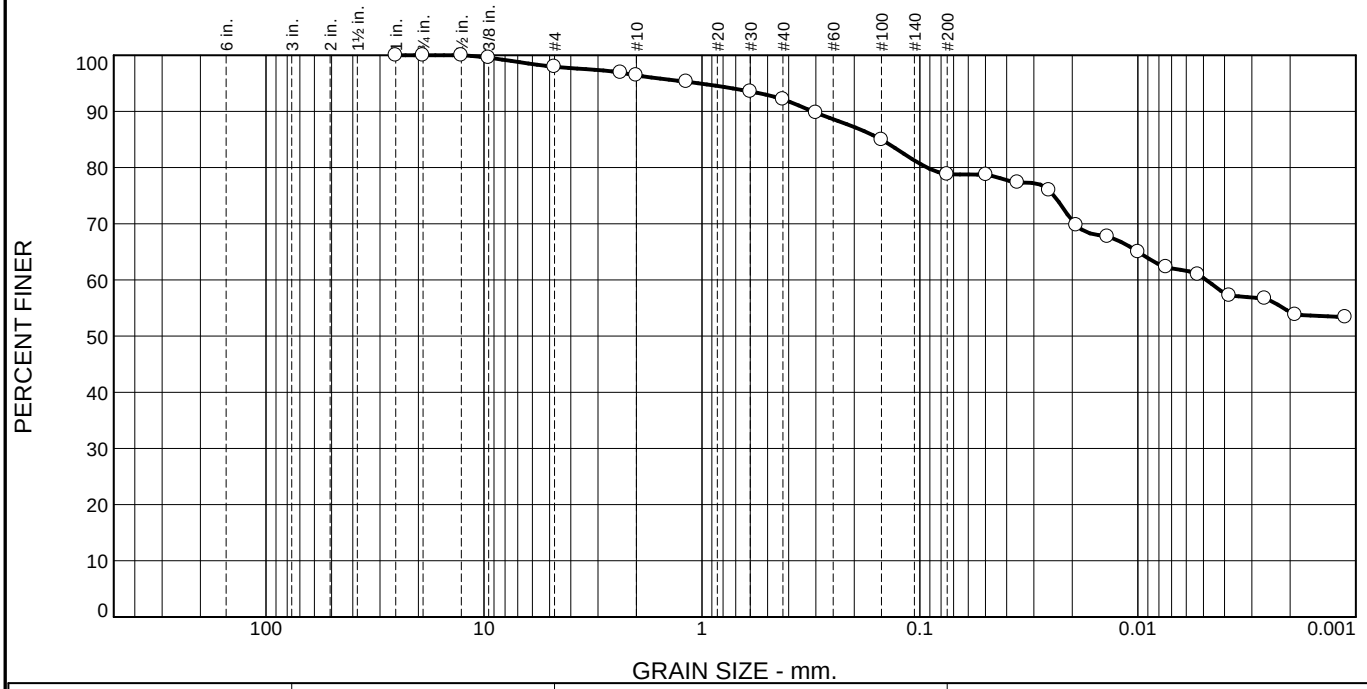
Date Sampled: 4/5/19

JONES & DEMILLE ENGINEERING INC.
Richfield, Utah

Client: Sevier County
Project: Sevier County Watershed Plan & Flood Protection

Project No: 1804-224 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	2.0	1.6	4.3	13.3	18.4	60.4

Test Results (AASHTO T 27 & AASHTO T 11)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1"	100.0		
3/4"	100.0		
1/2"	100.0		
3/8"	99.6		
#4	98.0		
#8	96.9		
#10	96.4		
#16	95.3		
#30	93.5		
#40	92.1		
#50	89.8		
#100	85.0		
#200	78.8		
0.0497 mm.	78.7		
0.0356 mm.	77.4		
0.0255 mm.	76.0		
0.0192 mm.	69.7		
0.0138 mm.	67.7		
0.0100 mm.	65.0		
0.0074 mm.	62.3		
0.0053 mm.	61.0		
0.0038 mm.	57.2		
0.0026 mm.	56.7		
0.0019 mm.	53.8		
0.0011 mm.	53.4		

* (no specification provided)

Material Description

Native Clay Site - West of Elsinore

Atterberg Limits (ASTM D 4318)

PL= 18.0 **LL=** 67.5 **PI=** 49.5

Classification

USCS (D 2487)= CH **AASHTO (M 145)=** A-7-6(41)

Coefficients

D_{90}= 0.3102 D_{85}= 0.1506 D_{60}= 0.0049
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: 2/27/19 **Date Tested:** 3/1/19

Tested By: Mark Rappleye

Checked By: Mark Rappleye

Title: Lab Manager

Location: Flat Canyon (West of Elsinore)
Sample Number: 19-S-040

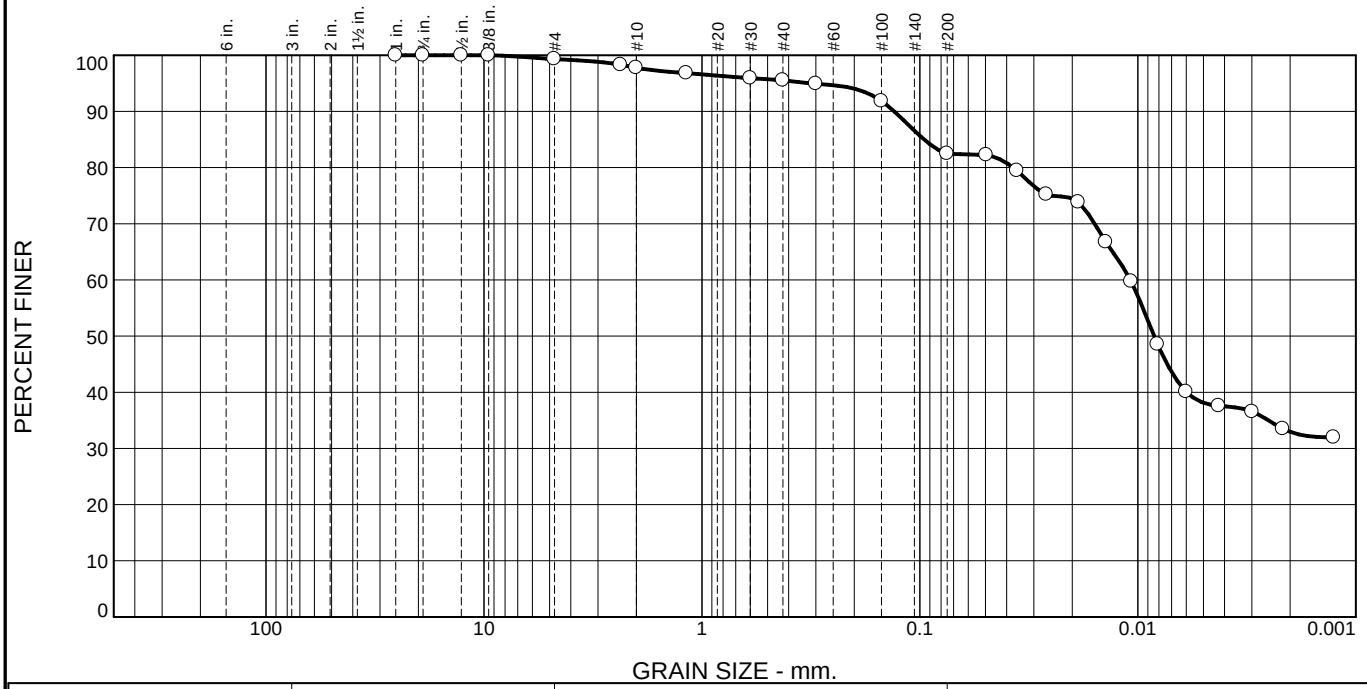
Date Sampled: 2/27/19

JONES & DEMILLE ENGINEERING INC.
Richfield, Utah

Client: Sevier County
Project: Sevier County Watershed Plan & Flood Protection

Project No: 1804-224 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.7	1.5	2.3	13.0	44.4	38.1

Test Results (AASHTO T 27 & AASHTO T 11)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1"	100.0		
3/4"	100.0		
1/2"	100.0		
3/8"	100.0		
#4	99.3		
#8	98.3		
#10	97.8		
#16	96.8		
#30	95.9		
#40	95.5		
#50	94.9		
#100	91.8		
#200	82.5		
0.0495 mm.	82.2		
0.0359 mm.	79.4		
0.0262 mm.	75.2		
0.0188 mm.	73.8		
0.0140 mm.	66.7		
0.0107 mm.	59.7		
0.0081 mm.	48.5		
0.0060 mm.	40.1		
0.0043 mm.	37.6		
0.0030 mm.	36.5		
0.0022 mm.	33.5		
0.0013 mm.	32.0		

* (no specification provided)

Material Description

Native Clay Site - West of Aurora

Atterberg Limits (ASTM D 4318)

PL= 13.5 **LL=** 45.6 **PI=** 32.1

Classification

USCS (D 2487)= CL **AASHTO (M 145)=** A-7-6(26)

Coefficients

D_{90}= 0.1311 D_{85}= 0.0957 D_{60}= 0.0108
D_{50}= 0.0084 D_{30}= D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: 2/27/19 **Date Tested:** 3/1/19

Tested By: Mark Rappleye

Checked By: Mark Rappleye

Title: Lab Manager

Location: West of Aurora (Above Water Tank) **Date Sampled:** 2/27/19
Sample Number: 19-S-041

JONES & DEMILLE ENGINEERING INC.
Richfield, Utah

Client: Sevier County
Project: Sevier County Watershed Plan & Flood Protection

Project No: 1804-224 **Figure**

Attachment F. Seepage and Slope Stability Results

Name	Model	K-Function	Ky'/Kx' Ratio	Rotation (°)	Vol. WC. Function
01-SM with Gravel [All]	Saturated / Unsaturated	SM with Gravel	0.1	0	SM with Gravel
02-Core [Drained]	Saturated / Unsaturated	Core	0.5	0	Core
03-Filter Drain [All]	Saturated / Unsaturated	Filter Drain	1	0	Filter Drain
05-Embankment Shell [All]	Saturated / Unsaturated	SM with Gravel	0.1	0	SM with Gravel

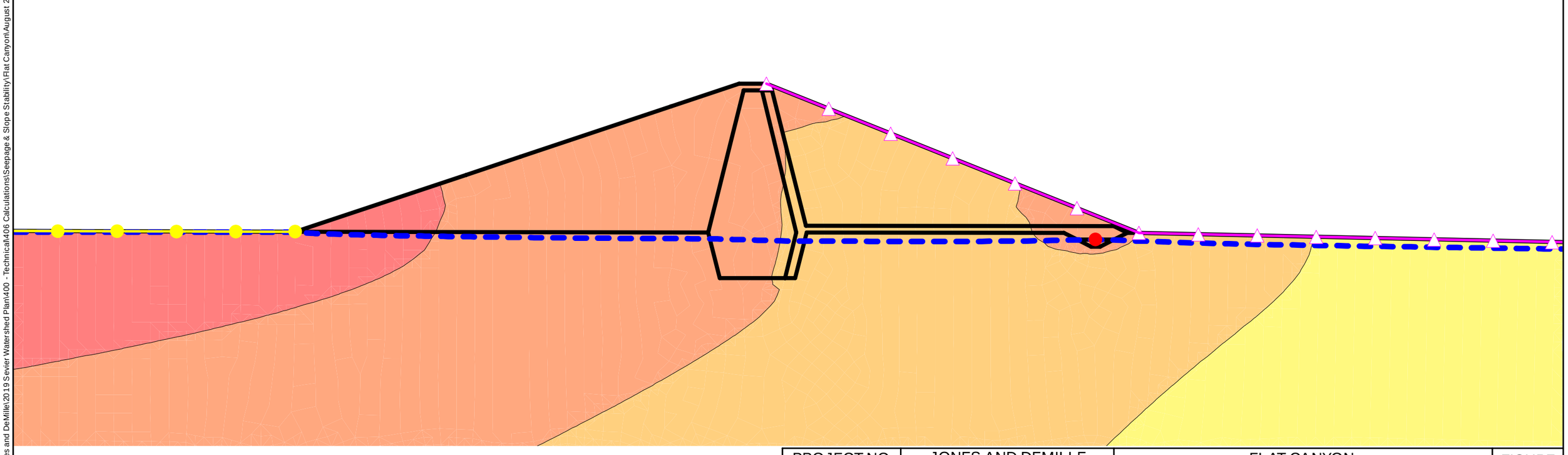
Name: Total Head

Contour parameter: Total Head ft

Starting Contour Value: 5,520 ft

Ending Contour Value: 5,544 ft

Increment by: 2 ft



SOFTWARE VERSION: SEEP/W v. 8.16.2.14053
METHOD: Steady-State
Scale: 1:500.71685

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	FLAT CANYON MAXIMUM SECTION	FIGURE 1
AECOM	SEVIER COUNTY, UTAH	EMPTY SEEPAGE RESULTS	

Q:\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Flat Canyon\August 2019 Rev\Flat Canyon.gsz 8/9/2019 4:58:56 PM

Name	Model	K-Function	Ky'/Kx' Ratio	Rotation (°)	Vol. WC. Function
01-SM with Gravel [All]	Saturated / Unsaturated	SM with Gravel	0.1	0	SM with Gravel
02-Core [Drained]	Saturated / Unsaturated	Core	0.5	0	Core
03-Filter Drain [All]	Saturated / Unsaturated	Filter Drain	1	0	Filter Drain
05-Embankment Shell [All]	Saturated / Unsaturated	SM with Gravel	0.1	0	SM with Gravel

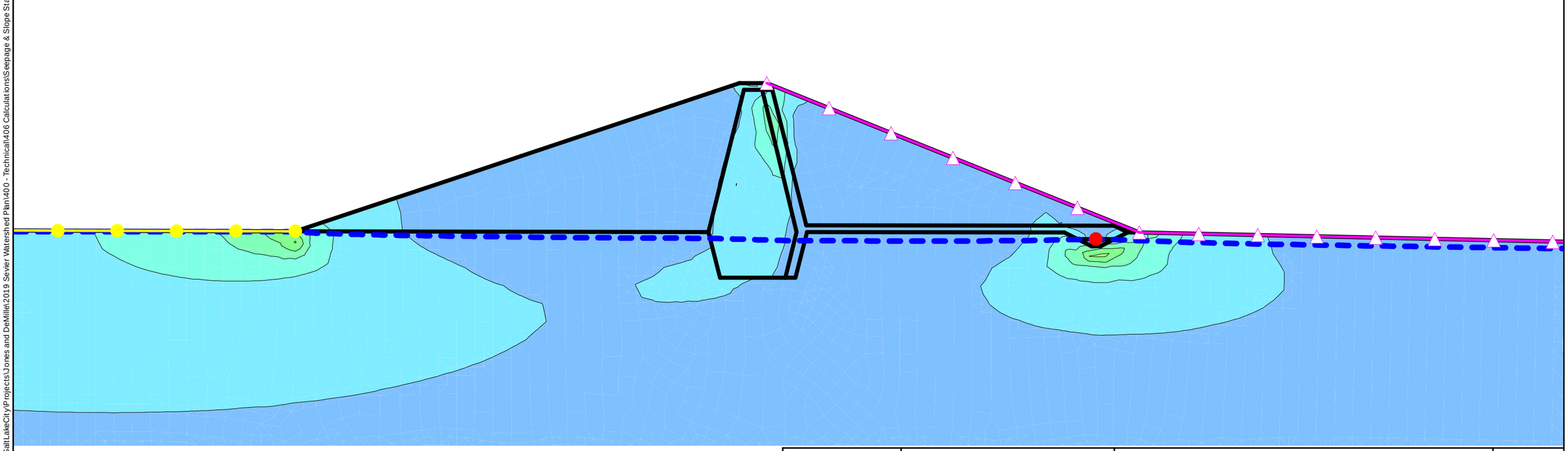
Name: Gradients

Contour parameter: XY-Gradient

Starting Contour Value: 0

Ending Contour Value: 0.22

Increment by: 0.02



SOFTWARE VERSION: SEEP/W v. 8.16.2.14053
METHOD: Steady-State
Scale: 1:500.71685

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	FLAT CANYON MAXIMUM SECTION	FIGURE 2
AECOM	SEVIER COUNTY, UTAH	EMPTY SEEPAGE GRADIENTS	

\\urssaltlakecity\SaltLakeCity\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Flat Canyon\August 2019 Rev\Flat Canyon.gsz 8/9/2019 4:58:56 PM

Name	Model	K-Function	Ky'/Kx' Ratio	Rotation (°)	Vol. WC. Function
01-SM with Gravel [All]	Saturated / Unsaturated	SM with Gravel	0.1	0	SM with Gravel
02-Core [Drained]	Saturated / Unsaturated	Core	0.5	0	Core
03-Filter Drain [All]	Saturated / Unsaturated	Filter Drain	1	0	Filter Drain
05-Embankment Shell [All]	Saturated / Unsaturated	SM with Gravel	0.1	0	SM with Gravel

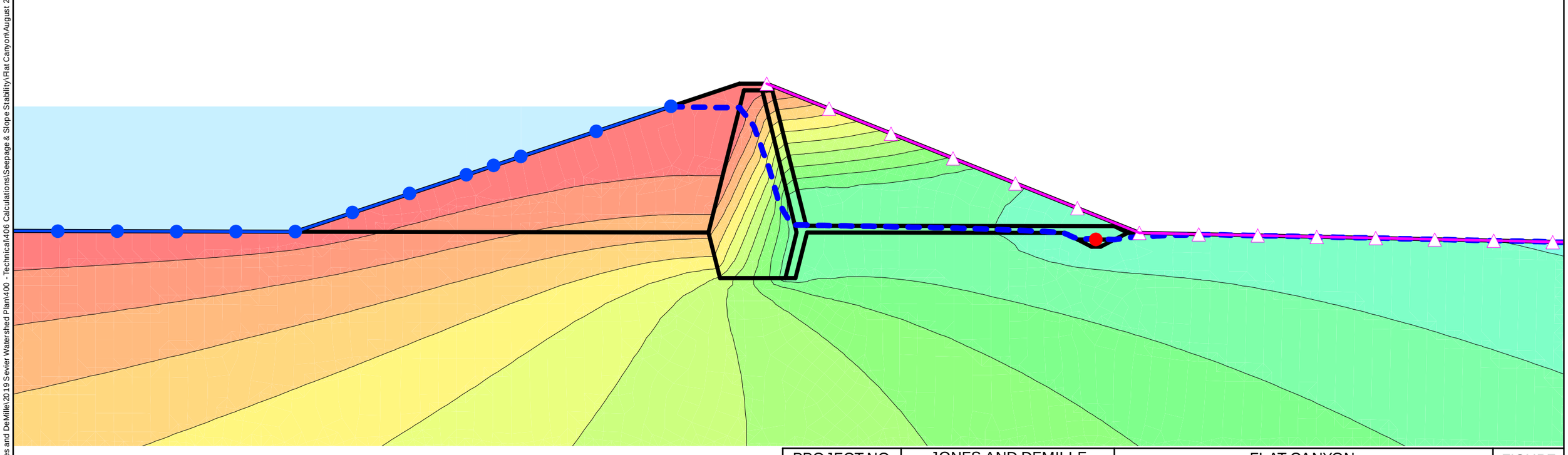
Name: Total Head

Contour parameter: Total Head ft

Starting Contour Value: 5,520 ft

Ending Contour Value: 5,600 ft

Increment by: 5 ft



SOFTWARE VERSION: SEEP/W v. 8.16.2.14053
METHOD: Steady-State
Scale: 1:500.71685

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	FLAT CANYON MAXIMUM SECTION	FIGURE 3
AECOM	SEVIER COUNTY, UTAH	FULL SEEPAGE RESULTS	

Q:\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Flat Canyon\August 2019 Rev\Flat Canyon.gsz 8/9/2019 4:58:56 PM

Name	Model	K-Function	Ky'/Kx' Ratio	Rotation (°)	Vol. WC. Function
01-SM with Gravel [All]	Saturated / Unsaturated	SM with Gravel	0.1	0	SM with Gravel
02-Core [Drained]	Saturated / Unsaturated	Core	0.5	0	Core
03-Filter Drain [All]	Saturated / Unsaturated	Filter Drain	1	0	Filter Drain
05-Embankment Shell [All]	Saturated / Unsaturated	SM with Gravel	0.1	0	SM with Gravel

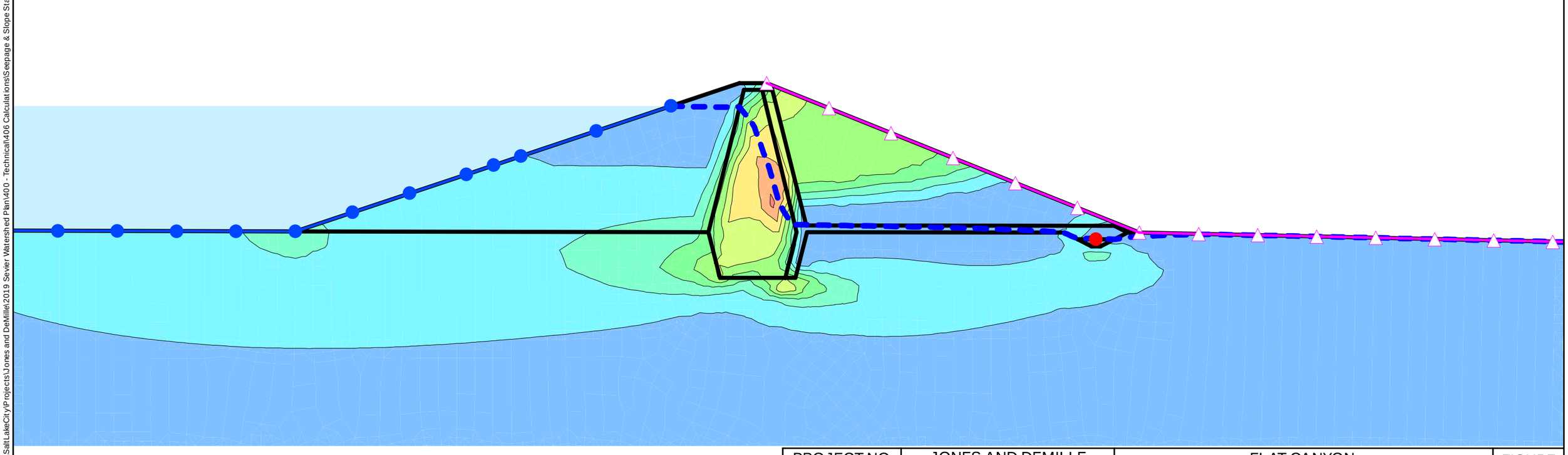
Name: Gradients

Contour parameter: XY-Gradient

Starting Contour Value: 0

Ending Contour Value: 1.8

Increment by: 0.2



SOFTWARE VERSION: SEEP/W v. 8.16.2.14053
METHOD: Steady-State
Scale: 1:500.71685

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	FLAT CANYON MAXIMUM SECTION	FIGURE 4
AECOM	SEVIER COUNTY, UTAH	FULL SEEPAGE GRADIENTS	

\\urssaltlakecity\SaltLakeCity\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Flat Canyon\August 2019 Rev\Flat Canyon.gsz 8/9/2019 4:58:56 PM

Name	Model	K-Function	Ky'/Kx' Ratio	Rotation (°)	Vol. WC. Function
01-SM with Gravel [All]	Saturated / Unsaturated	SM with Gravel	0.1	0	SM with Gravel
02-Core [Drained]	Saturated / Unsaturated	Core	0.5	0	Core
03-Filter Drain [All]	Saturated / Unsaturated	Filter Drain	1	0	Filter Drain
04-Basin Sediment [Drained]	Saturated / Unsaturated	Sediment	0.1	0	Sediment
05-Embankment Shell [All]	Saturated / Unsaturated	SM with Gravel	0.1	0	SM with Gravel

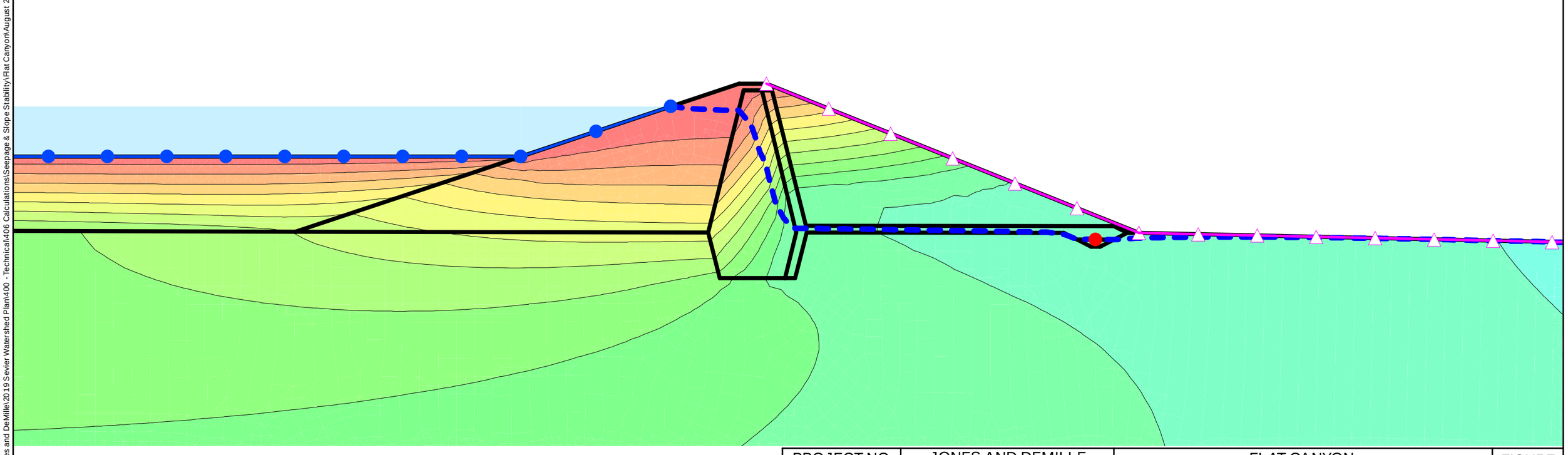
Name: Total Head

Contour parameter: Total Head ft

Starting Contour Value: 5,520 ft

Ending Contour Value: 5,600 ft

Increment by: 5 ft



SOFTWARE VERSION: SEEP/W v. 8.16.2.14053
METHOD: Steady-State
Scale: 1:500.71685

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	FLAT CANYON MAXIMUM SECTION	FIGURE 5
AECOM	SEVIER COUNTY, UTAH	SEDIMENT FILLED SEEPAGE RESULTS	

Q:\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Flat Canyon\August 2019 Rev\Flat Canyon.gsz 8/9/2019 4:58:56 PM

Name	Model	K-Function	Ky'/Kx' Ratio	Rotation (°)	Vol. WC. Function
01-SM with Gravel [All]	Saturated / Unsaturated	SM with Gravel	0.1	0	SM with Gravel
02-Core [Drained]	Saturated / Unsaturated	Core	0.5	0	Core
03-Filter Drain [All]	Saturated / Unsaturated	Filter Drain	1	0	Filter Drain
04-Basin Sediment [Drained]	Saturated / Unsaturated	Sediment	0.1	0	Sediment
05-Embankment Shell [All]	Saturated / Unsaturated	SM with Gravel	0.1	0	SM with Gravel

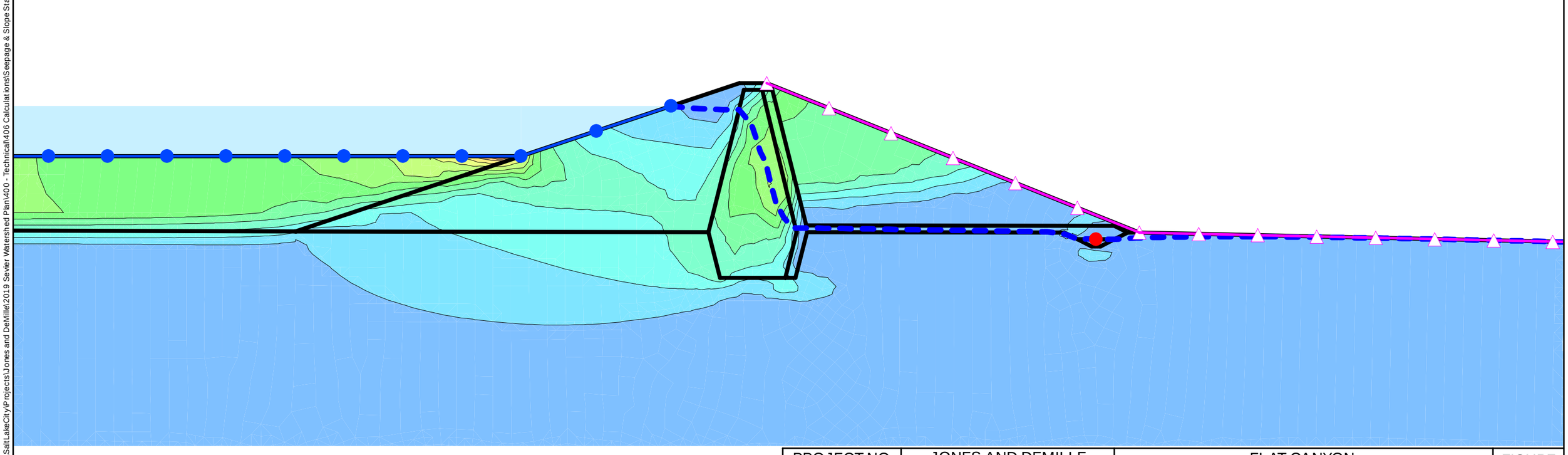
Name: Gradients

Contour parameter: XY-Gradient

Starting Contour Value: 0

Ending Contour Value: 2.6

Increment by: 0.2

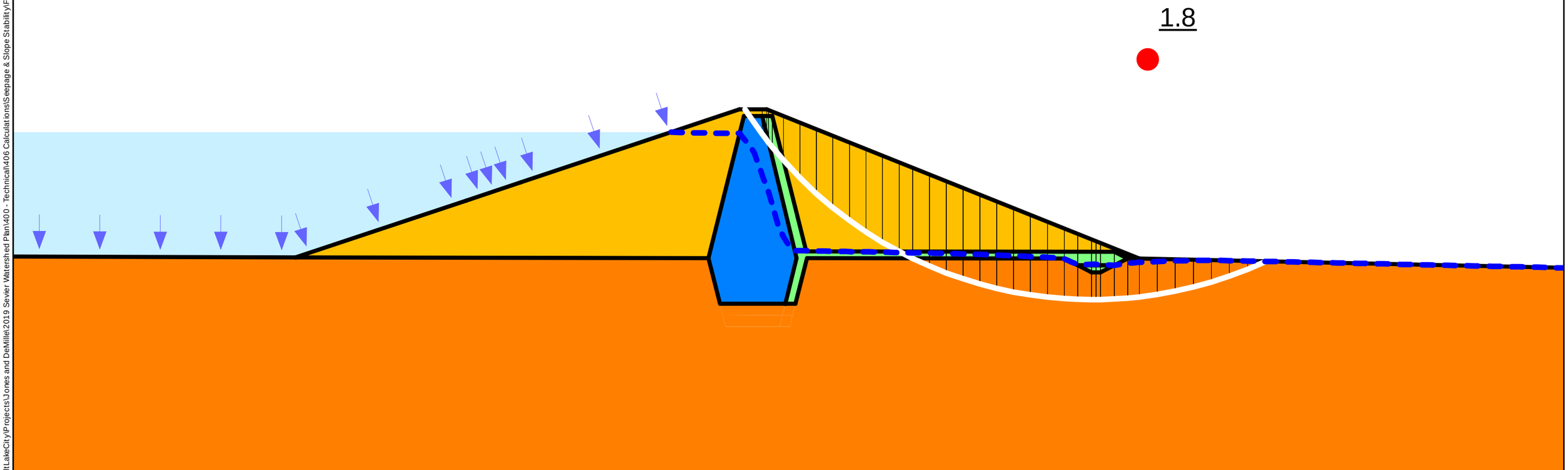


SOFTWARE VERSION: SEEP/W v. 8.16.2.14053
METHOD: Steady-State
Scale: 1:500.71685

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	FLAT CANYON MAXIMUM SECTION	FIGURE 6
AECOM	SEVIER COUNTY, UTAH	SEDIMENT FILLED SEEPAGE GRADIENT	

\\urssaltlakecity\SaltLakeCity\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Flat Canyon\August 2019 Rev\Flat Canyon.gsz 8/9/2019 4:58:56 PM

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	01-SM with Gravel [All]	Mohr-Coulomb	130	0	33	0
	02-Core [Drained]	Mohr-Coulomb	125	0	28	0
	03-Filter Drain [All]	Mohr-Coulomb	120	0	36	0
	05-Embankment Shell [All]	Mohr-Coulomb	130	0	34	0

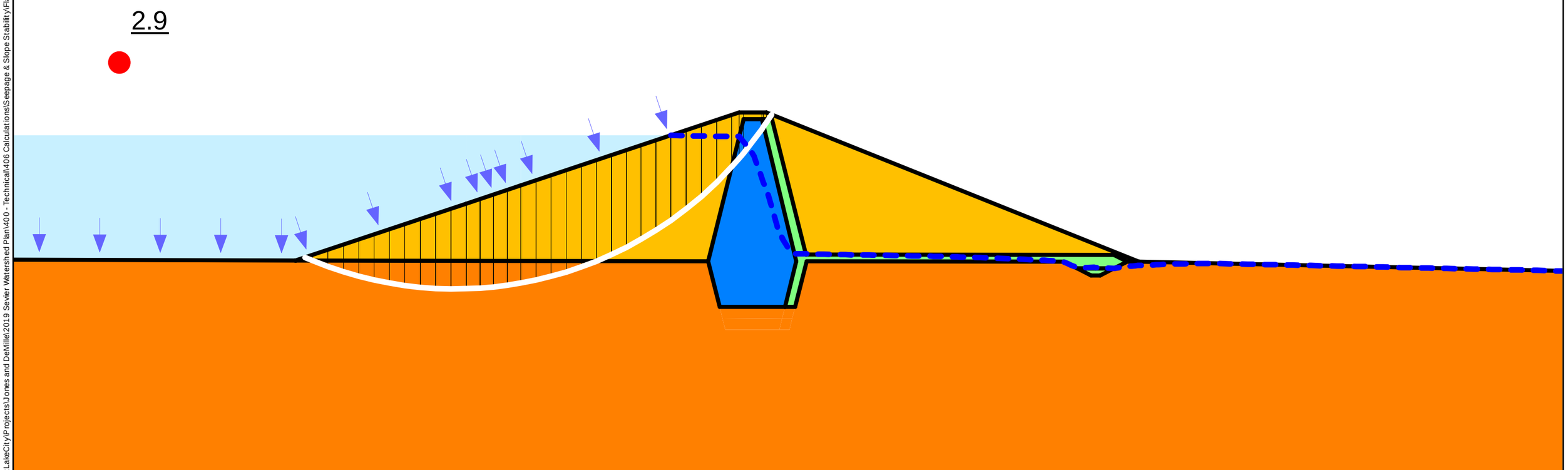


SOFTWARE VERSION: SLOPE/W v. 8.16.2.14053
METHOD: Spencer
Scale: 1:500.71685

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	FLAT CANYON MAXIMUM SECTION	FIGURE 7
AECOM	SEVIER COUNTY, UTAH	DOWNSTREAM - DRAINED	

\\urssaltlakecity\SaltLakeCity\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Flat Canyon\August 2019 Rev\Flat Canyon.gsz 8/9/2019 5:36:31 PM

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	01-SM with Gravel [All]	Mohr-Coulomb	130	0	33	0
	02-Core [Drained]	Mohr-Coulomb	125	0	28	0
	03-Filter Drain [All]	Mohr-Coulomb	120	0	36	0
	05-Embankment Shell [All]	Mohr-Coulomb	130	0	34	0

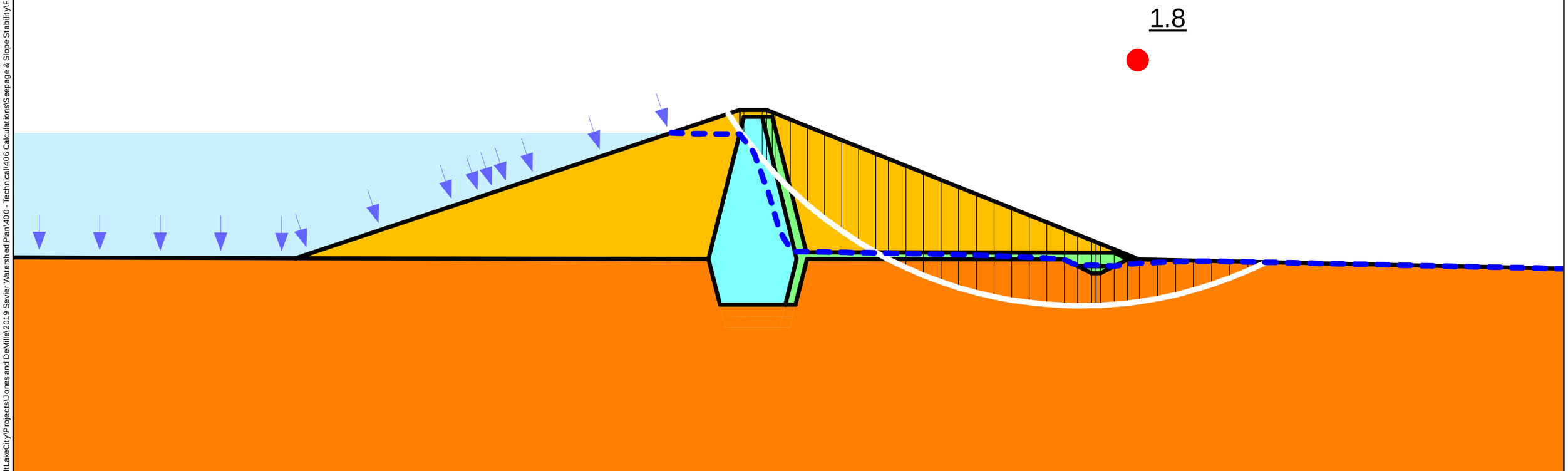


SOFTWARE VERSION: SLOPE/W v. 8.16.2.14053
METHOD: Spencer
Scale: 1:500.71685

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	FLAT CANYON MAXIMUM SECTION	FIGURE 8
AECOM	SEVIER COUNTY, UTAH	UPSTREAM - DRAINED	

\\urssaltlakecity\SaltLakeCity\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Flat Canyon\August 2019 Rev\Flat Canyon.gsz 8/9/2019 5:36:31 PM

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	01-SM with Gravel [All]	Mohr-Coulomb	130	0	33	0
	02-Core [Undrained]	Mohr-Coulomb	125	0	21.8	0
	03-Filter Drain [All]	Mohr-Coulomb	120	0	36	0
	05-Embankment Shell [All]	Mohr-Coulomb	130	0	34	0

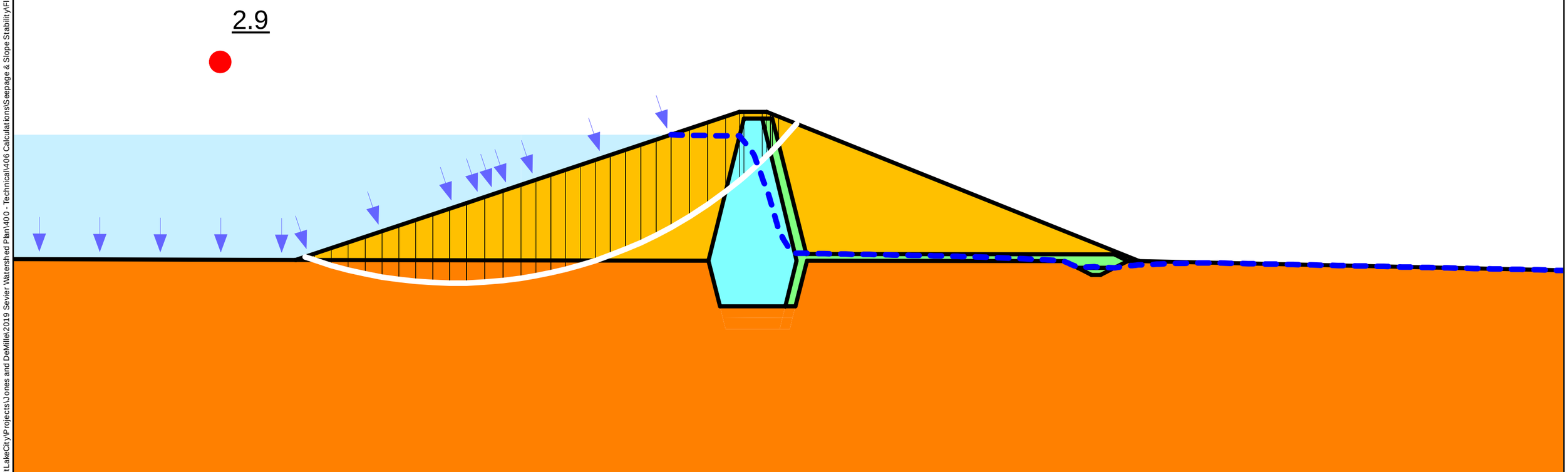


SOFTWARE VERSION: SLOPE/W v. 8.16.2.14053
METHOD: Spencer
Scale: 1:500.71685

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	FLAT CANYON MAXIMUM SECTION	FIGURE 9
AECOM	SEVIER COUNTY, UTAH	DOWNSTREAM - UNDRAINED	

\\urssaltlakecity\SaltLakeCity\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Flat Canyon\August 2019 Rev\Flat Canyon.gsz 8/9/2019 5:36:31 PM

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	01-SM with Gravel [All]	Mohr-Coulomb	130	0	33	0
	02-Core [Undrained]	Mohr-Coulomb	125	0	21.8	0
	03-Filter Drain [All]	Mohr-Coulomb	120	0	36	0
	05-Embankment Shell [All]	Mohr-Coulomb	130	0	34	0



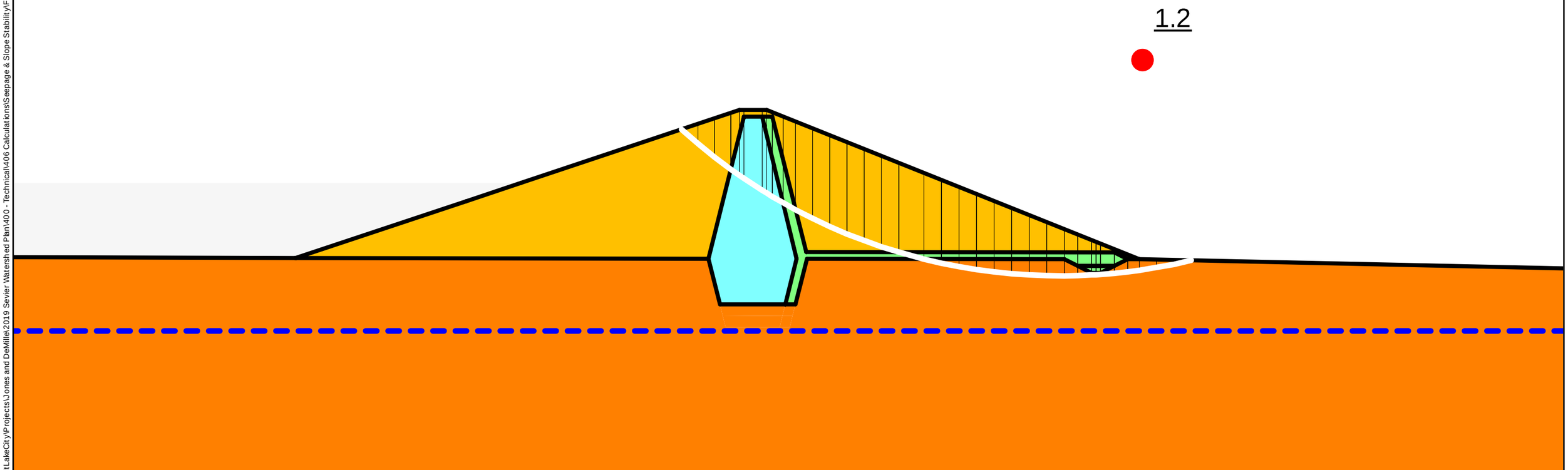
SOFTWARE VERSION: SLOPE/W v. 8.16.2.14053
METHOD: Spencer
Scale: 1:500.71685

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	FLAT CANYON MAXIMUM SECTION	FIGURE 10
AECOM	SEVIER COUNTY, UTAH	UPSTREAM - UNDRAINED	

\\urssaltlakecity\SaltLakeCity\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Flat Canyon\August 2019 Rev\Flat Canyon.gsz 8/9/2019 5:36:31 PM

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Piezometric Line
	01-SM with Gravel [All]	Mohr-Coulomb	130	0	33	0	1
	02-Core [Undrained]	Mohr-Coulomb	125	0	21.8	0	1
	03-Filter Drain [All]	Mohr-Coulomb	120	0	36	0	1
	05-Embankment Shell [All]	Mohr-Coulomb	130	0	34	0	1

Horz Seismic Coef.: 0.245



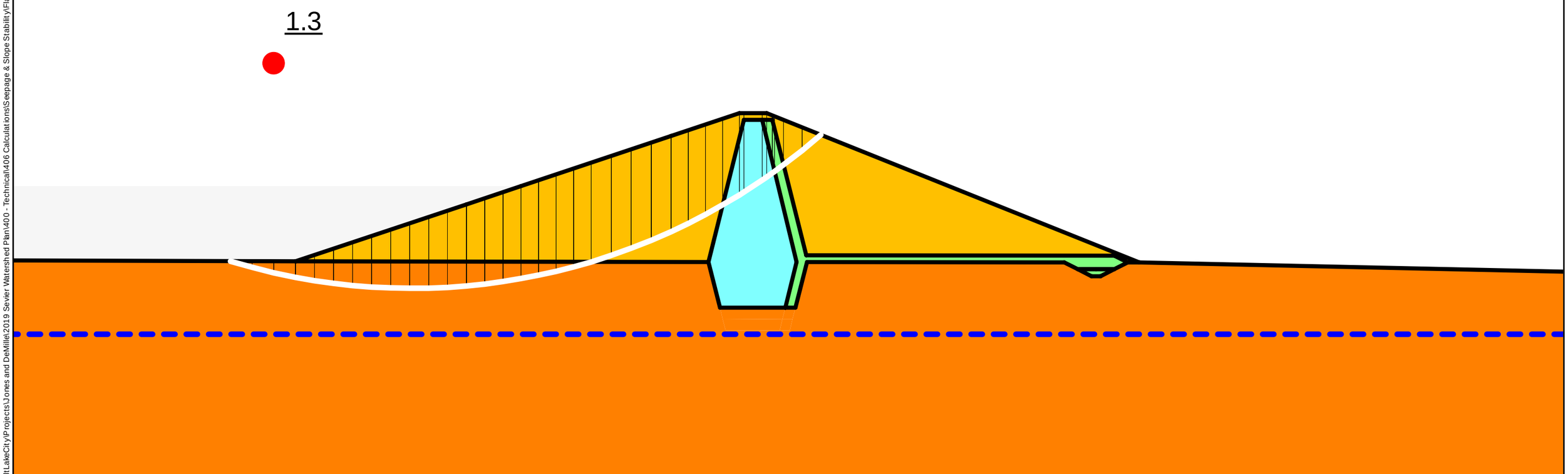
SOFTWARE VERSION: SLOPE/W v. 8.16.2.14053
METHOD: Spencer
Scale: 1:500.71685

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	FLAT CANYON MAXIMUM SECTION	FIGURE 11
AECOM	SEVIER COUNTY, UTAH	DOWNSTREAM - PSEUDOSTATIC	

\\urssaltlakecity\SaltLakeCity\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Flat Canyon\August 2019 Rev\Flat Canyon.gsz 8/8/2019 5:01:28 PM

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	01-SM with Gravel [All]	Mohr-Coulomb	130	0	33	0
	02-Core [Undrained]	Mohr-Coulomb	125	0	21.8	0
	03-Filter Drain [All]	Mohr-Coulomb	120	0	36	0
	05-Embankment Shell [All]	Mohr-Coulomb	130	0	34	0

Horz Seismic Coef.: 0.245

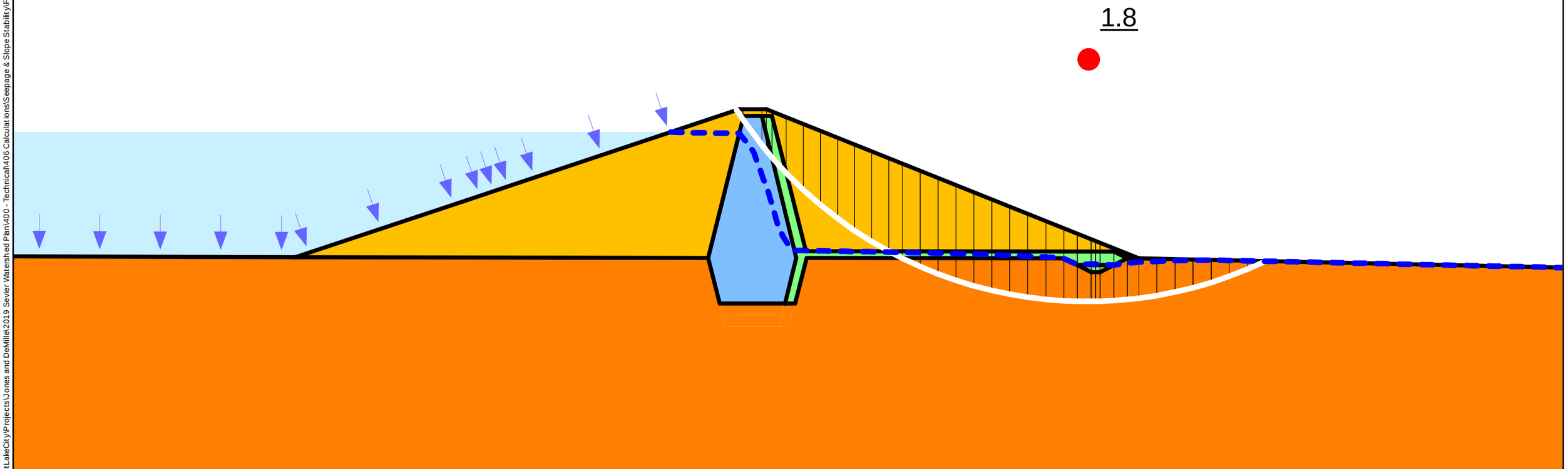


SOFTWARE VERSION: SLOPE/W v. 8.16.2.14053
METHOD: Spencer
Scale: 1:500.71685

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	FLAT CANYON MAXIMUM SECTION	FIGURE 12
AECOM	SEVIER COUNTY, UTAH	UPSTREAM - PSEUDOSTATIC	

8/8/2019 4:56:37 PM
\\urssaltlakecity\SaltLakeCity\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Flat Canyon\August 2019 Rev\Flat Canyon.gsz

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	01-SM with Gravel [All]	Mohr-Coulomb	130	0	33	0
	02-Core [Post-Earthquake]	Mohr-Coulomb	125	0	17.4	0
	03-Filter Drain [All]	Mohr-Coulomb	120	0	36	0
	05-Embankment Shell [All]	Mohr-Coulomb	130	0	34	0

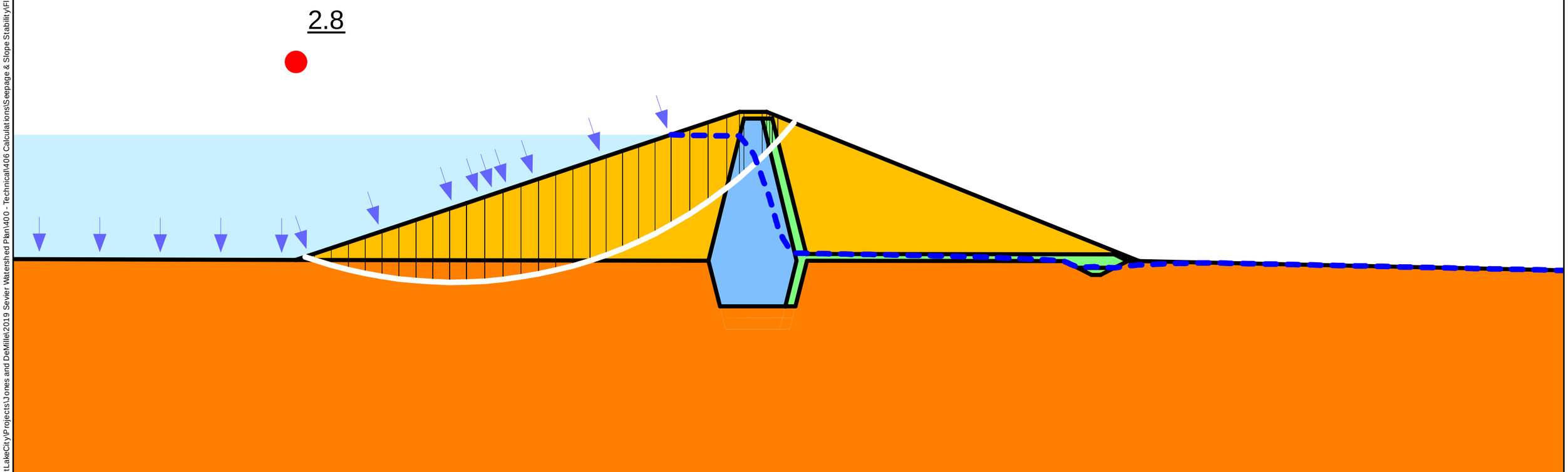


SOFTWARE VERSION: SLOPE/W v. 8.16.2.14053
METHOD: Spencer
Scale: 1:500.71685

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	FLAT CANYON MAXIMUM SECTION	FIGURE 13
AECOM	SEVIER COUNTY, UTAH	DOWNSTREAM - POST-EARTHQUAKE	

\\urssaltlakecity\SaltLakeCity\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Flat Canyon\August 2019 Rev\Flat Canyon.gsz 8/9/2019 5:36:31 PM

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	01-SM with Gravel [All]	Mohr-Coulomb	130	0	33	0
	02-Core [Post-Earthquake]	Mohr-Coulomb	125	0	17.4	0
	03-Filter Drain [All]	Mohr-Coulomb	120	0	36	0
	05-Embankment Shell [All]	Mohr-Coulomb	130	0	34	0

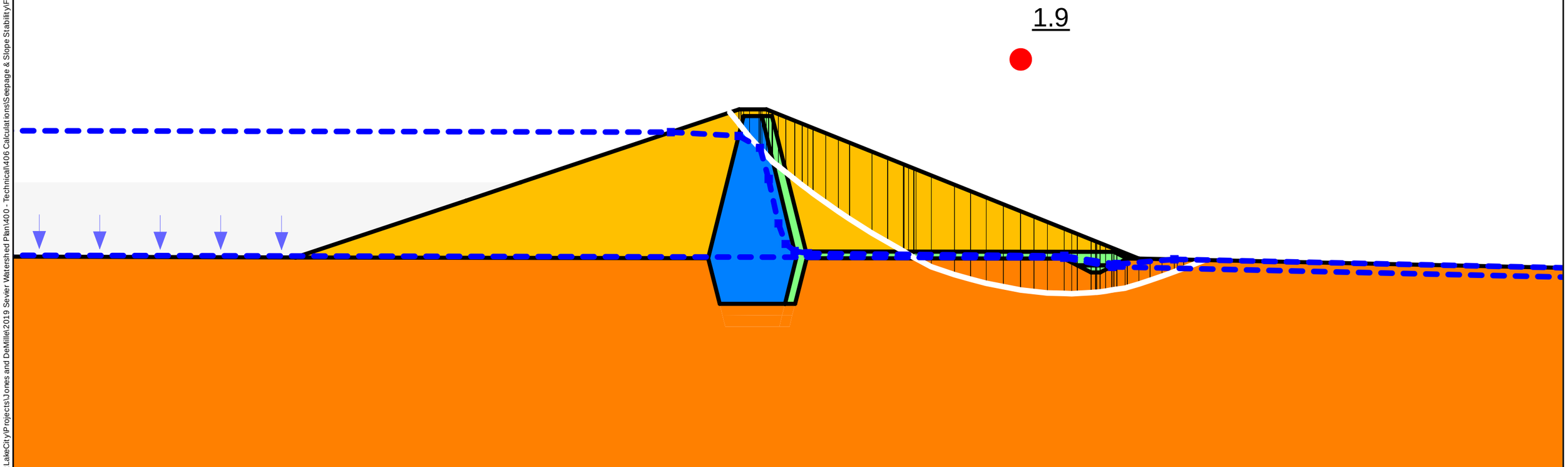


SOFTWARE VERSION: SLOPE/W v. 8.16.2.14053
METHOD: Spencer
Scale: 1:500.71685

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	FLAT CANYON MAXIMUM SECTION	FIGURE 14
AECOM	SEVIER COUNTY, UTAH	UPSTREAM - POST-EARTHQUAKE	

\\urssaltlakecity\SaltLakeCity\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Flat Canyon\August 2019 Rev\Flat Canyon.gsz 8/9/2019 5:36:31 PM

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Cohesion R (psf)	Phi R (°)	Piezometric Line	Piezometric Line After Drawdown
	01-SM with Gravel [All]	Mohr-Coulomb	130	0	33	0	0	0	1	2
	02-Core [Drained]	Mohr-Coulomb	125	0	28	0	400	16	1	2
	03-Filter Drain [All]	Mohr-Coulomb	120	0	36	0	0	0	1	2
	05-Embankment Shell [All]	Mohr-Coulomb	130	0	34	0	0	0	1	2

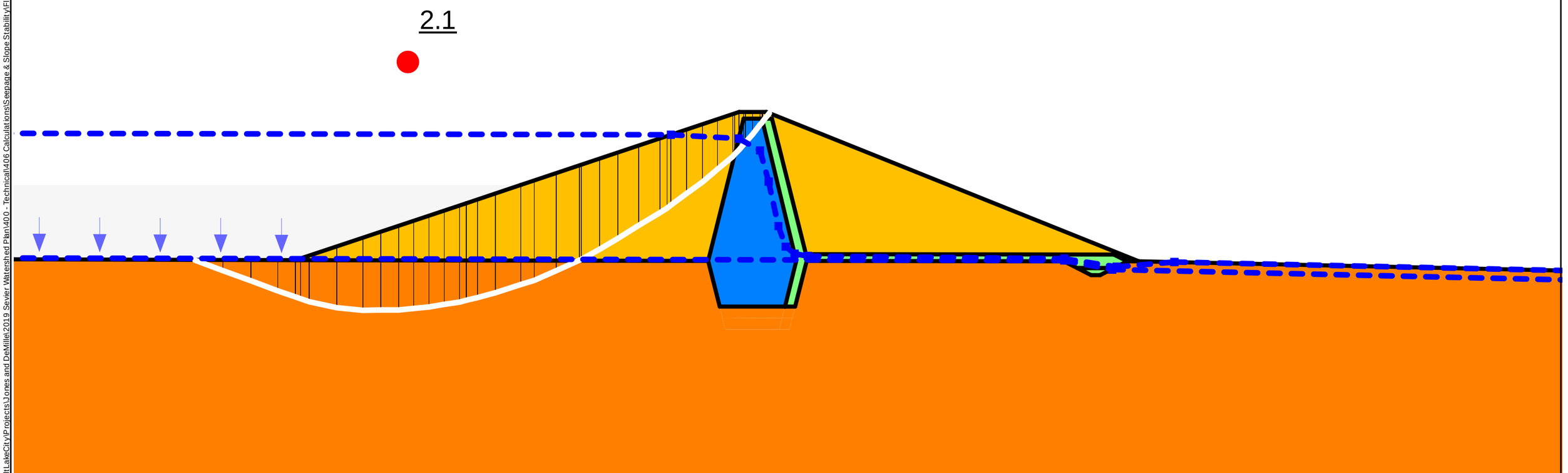


SOFTWARE VERSION: SLOPE/W v. 8.16.2.14053
METHOD: Spencer
Scale: 1:500.71685

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	FLAT CANYON MAXIMUM SECTION	FIGURE 15
AECOM	SEVIER COUNTY, UTAH	DOWNSTREAM - RAPID DRAWDOWN	

\\urssaltlakecity\SaltLakeCity\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Flat Canyon\August 2019 Rev\Flat Canyon.gsz 8/9/2019 8:33:39 AM

Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Cohesion R (psf)	Phi R (°)	Piezometric Line	Piezometric Line After Drawdown
01-SM with Gravel [All]	Mohr-Coulomb	130	0	33	0	0	0	1	2
02-Core [Drained]	Mohr-Coulomb	125	0	28	0	400	16	1	2
03-Filter Drain [All]	Mohr-Coulomb	120	0	36	0	0	0	1	2
05-Embankment Shell [All]	Mohr-Coulomb	130	0	34	0	0	0	1	2



SOFTWARE VERSION: SLOPE/W v. 8.16.2.14053
METHOD: Spencer
Scale: 1:500.71685

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	FLAT CANYON MAXIMUM SECTION	FIGURE 16
AECOM	SEVIER COUNTY, UTAH	UPSTREAM - RAPID DRAWDOWN	

\\rrs\saltlakecity\SaltLakeCity\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Flat Canyon\August 2019 Rev\Flat Canyon.gsz 8/9/2019 8:43:25 AM

Color	Name	Model	K-Function	Ky'/Kx' Ratio	Rotation (°)	Vol. WC. Function
	01-SM with Gravel [All]	Saturated / Unsaturated	SM with Gravel	0.1	0	SM with Gravel
	02-Core [Drained]	Saturated / Unsaturated	Core	0.5	0	Core
	03-Filter Drain [All]	Saturated / Unsaturated	Filter Drain	1	0	Filter Drain
	05-Embankment Shell [All]	Saturated / Unsaturated	SM with Gravel	0.1	0	SM with Gravel

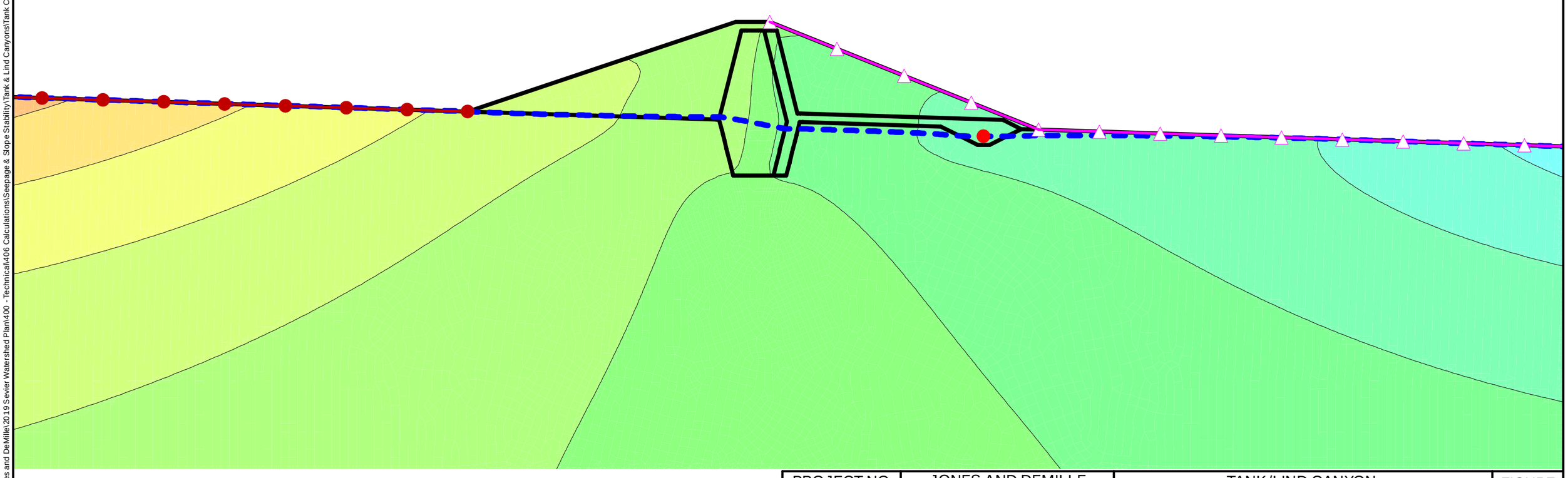
Name: Total Head

Contour parameter: Total Head ft

Starting Contour Value: 5,408 ft

Ending Contour Value: 5,436 ft

Increment by: 2 ft



SOFTWARE VERSION: SEEP/W v. 8.16.2.14053
METHOD: Steady-State
Scale: 1:400.57348

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	TANK/LIND CANYON MAXIMUM SECTION	FIGURE 17
AECOM	SEVIER COUNTY, UTAH	EMPTY SEEPAGE RESULTS	

Q:\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Tank & Lind Canyons\Tank Canyon.gsz 5/21/2019 9:50:16 AM

Color	Name	Model	K-Function	Ky'/Kx' Ratio	Rotation (°)	Vol. WC. Function
	01-SM with Gravel [All]	Saturated / Unsaturated	SM with Gravel	0.1	0	SM with Gravel
	02-Core [Drained]	Saturated / Unsaturated	Core	0.5	0	Core
	03-Filter Drain [All]	Saturated / Unsaturated	Filter Drain	1	0	Filter Drain
	05-Embankment Shell [All]	Saturated / Unsaturated	SM with Gravel	0.1	0	SM with Gravel

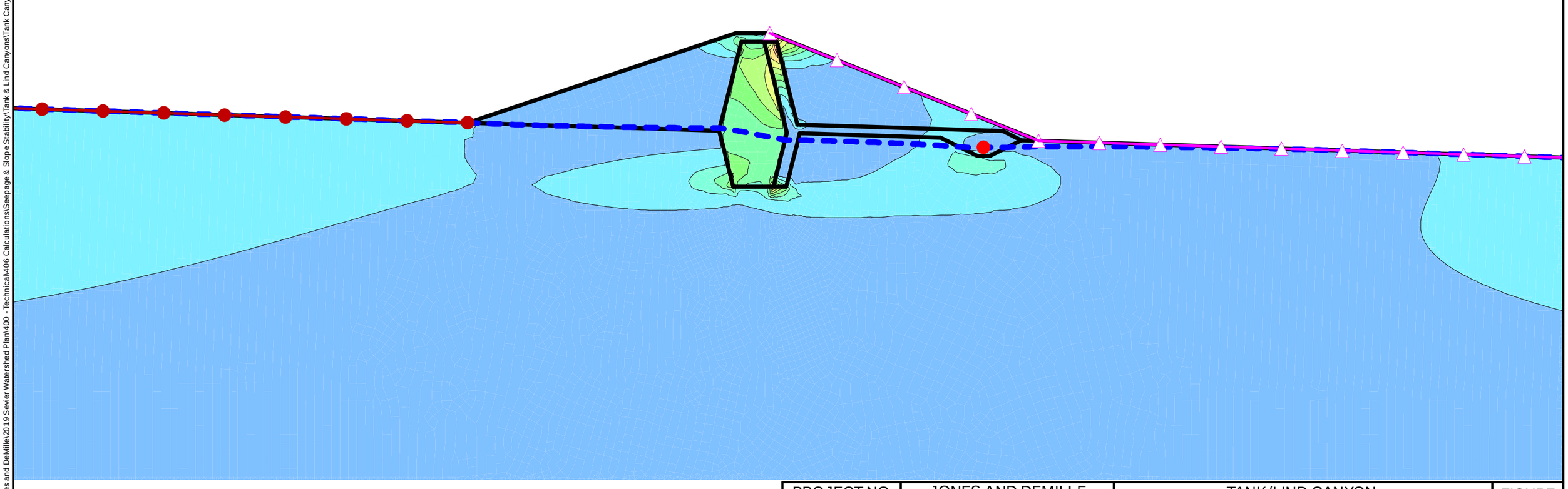
Name: Gradients

Contour parameter: XY-Gradient

Starting Contour Value: 0

Ending Contour Value: 0.5

Increment by: 0.05



SOFTWARE VERSION: SEEP/W v. 8.16.2.14053
METHOD: Steady-State
Scale: 1:400.57348

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	TANK/LIND CANYON MAXIMUM SECTION	FIGURE 18
AECOM	SEVIER COUNTY, UTAH	EMPTY SEEPAGE GRADIENT	

Q:\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Tank & Lind Canyons\Tank Canyon.gsz 5/21/2019 9:50:16 AM

Color	Name	Model	K-Function	Ky'/Kx' Ratio	Rotation (°)	Vol. WC. Function
	01-SM with Gravel [All]	Saturated / Unsaturated	SM with Gravel	0.1	0	SM with Gravel
	02-Core [Drained]	Saturated / Unsaturated	Core	0.5	0	Core
	03-Filter Drain [All]	Saturated / Unsaturated	Filter Drain	1	0	Filter Drain
	05-Embankment Shell [All]	Saturated / Unsaturated	SM with Gravel	0.1	0	SM with Gravel

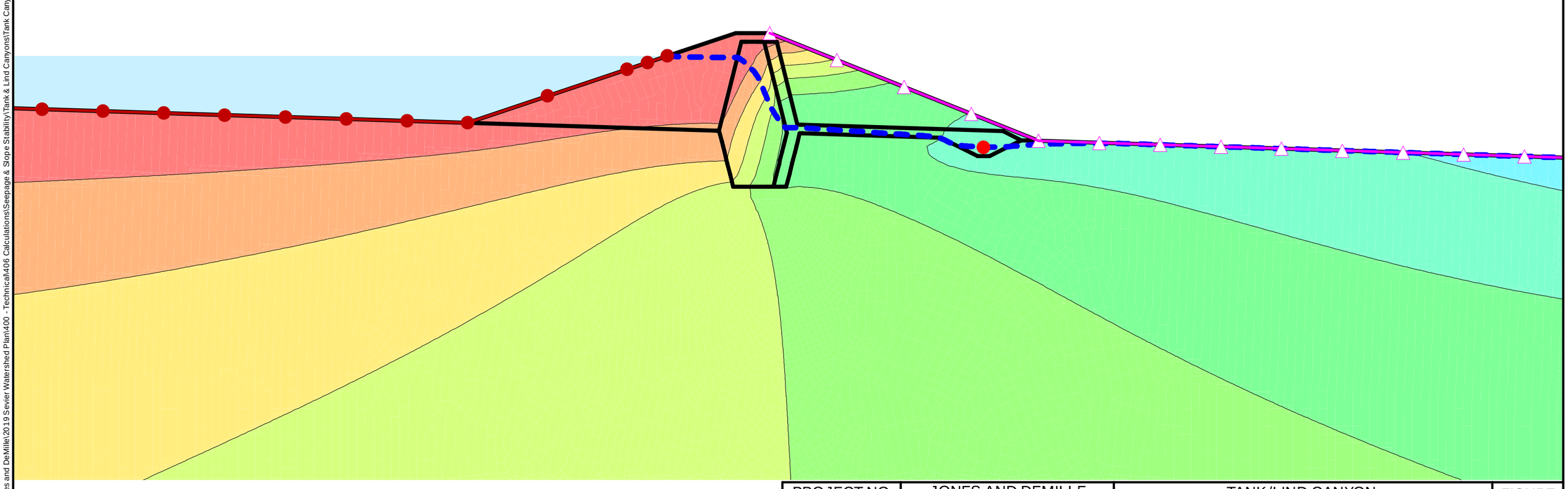
Name: Total Head

Contour parameter: Total Head ft

Starting Contour Value: 5,405 ft

Ending Contour Value: 5,450 ft

Increment by: 5 ft



SOFTWARE VERSION: SEEP/W v. 8.16.2.14053
METHOD: Steady-State
Scale: 1:400.57348

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	TANK/LIND CANYON MAXIMUM SECTION	FIGURE 19
AECOM	SEVIER COUNTY, UTAH	FULL SEEPAGE RESULTS	

Q:\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Tank & Lind Canyons\Tank Canyon.gsz 5/21/2019 9:03:11 AM

Color	Name	Model	K-Function	Ky'/Kx' Ratio	Rotation (°)	Vol. WC. Function
	01-SM with Gravel [All]	Saturated / Unsaturated	SM with Gravel	0.1	0	SM with Gravel
	02-Core [Drained]	Saturated / Unsaturated	Core	0.5	0	Core
	03-Filter Drain [All]	Saturated / Unsaturated	Filter Drain	1	0	Filter Drain
	05-Embankment Shell [All]	Saturated / Unsaturated	SM with Gravel	0.1	0	SM with Gravel

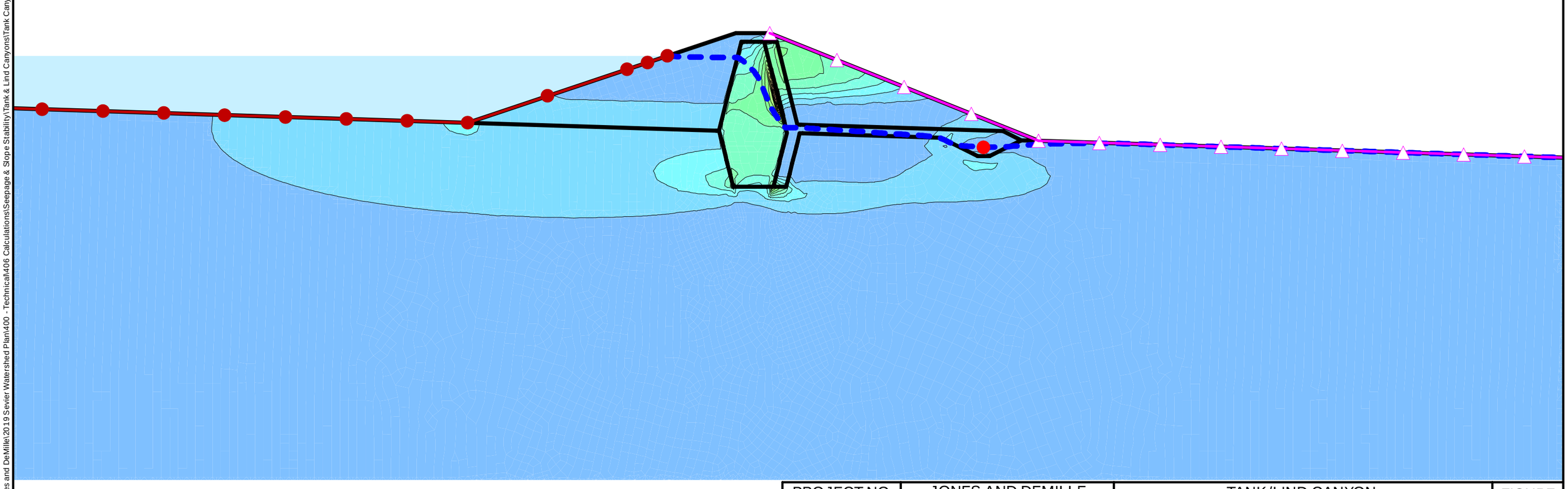
Name: Gradients

Contour parameter: XY-Gradient

Starting Contour Value: 0

Ending Contour Value: 3.2

Increment by: 0.2



SOFTWARE VERSION: SEEP/W v. 8.16.2.14053
METHOD: Steady-State
Scale: 1:400.57348

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	TANK/LIND CANYON MAXIMUM SECTION	FIGURE 20
AECOM	SEVIER COUNTY, UTAH	FULL SEEPAGE GRADIENT	

Q:\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Tank & Lind Canyons\Tank Canyon.gsz 5/21/2019 9:03:11 AM

Color	Name	Model	K-Function	Ky'/Kx' Ratio	Rotation (°)	Vol. WC. Function
	01-SM with Gravel [All]	Saturated / Unsaturated	SM with Gravel	0.1	0	SM with Gravel
	02-Core [Drained]	Saturated / Unsaturated	Core	0.5	0	Core
	03-Filter Drain [All]	Saturated / Unsaturated	Filter Drain	1	0	Filter Drain
	04-Basin Sediment [Drained]	Saturated / Unsaturated	Sediment	0.1	0	Sediment
	05-Embankment Shell [All]	Saturated / Unsaturated	SM with Gravel	0.1	0	SM with Gravel

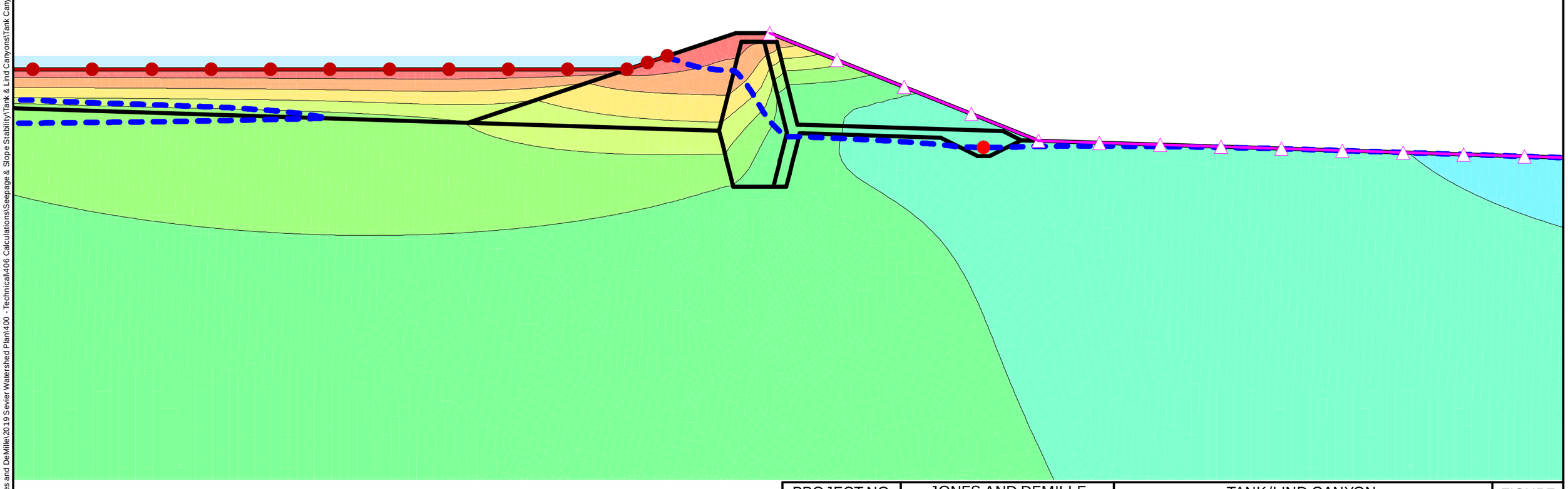
Name: Total Head

Contour parameter: Total Head ft

Starting Contour Value: 5,405 ft

Ending Contour Value: 5,450 ft

Increment by: 5 ft



SOFTWARE VERSION: SEEP/W v. 8.16.2.14053
METHOD: Steady-State
Scale: 1:400.57348

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	TANK/LIND CANYON MAXIMUM SECTION	FIGURE 21
AECOM	SEVIER COUNTY, UTAH	SEDIMENT FILLED SEEPAGE RESULTS	

Q:\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Tank & Lind Canyons\Tank Canyon.gsz 5/21/2019 9:03:11 AM

Color	Name	Model	K-Function	Ky'/Kx' Ratio	Rotation (°)	Vol. WC. Function
	01-SM with Gravel [All]	Saturated / Unsaturated	SM with Gravel	0.1	0	SM with Gravel
	02-Core [Drained]	Saturated / Unsaturated	Core	0.5	0	Core
	03-Filter Drain [All]	Saturated / Unsaturated	Filter Drain	1	0	Filter Drain
	04-Basin Sediment [Drained]	Saturated / Unsaturated	Sediment	0.1	0	Sediment
	05-Embankment Shell [All]	Saturated / Unsaturated	SM with Gravel	0.1	0	SM with Gravel

Name: Gradients

Contour parameter: XY-Gradient

Starting Contour Value: 0

Ending Contour Value: 3.4

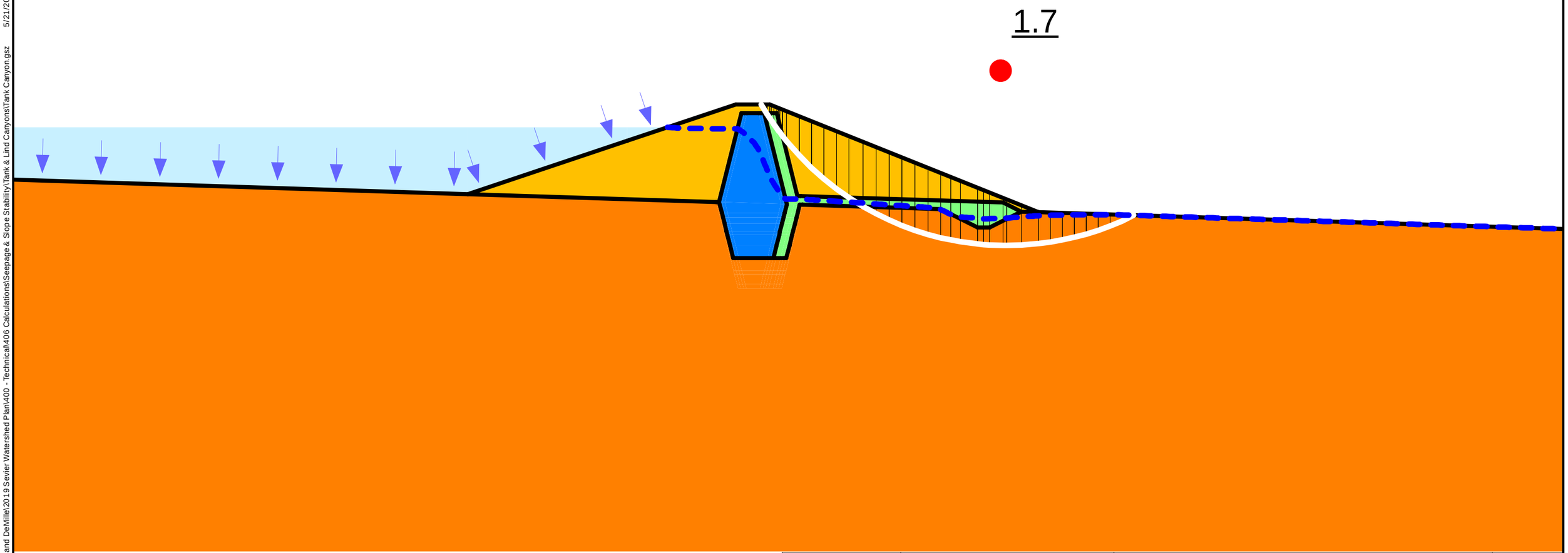
Increment by: 0.2

SOFTWARE VERSION: SEEP/W v. 8.16.2.14053
METHOD: Steady-State
Scale: 1:400.57348

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	TANK/LIND CANYON MAXIMUM SECTION	FIGURE 22
AECOM	SEVIER COUNTY, UTAH	SEDIMENT FILLED SEEPAGE GRADIENT	

Q:\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Tank & Lind Canyons\Tank Canyon.gsz 5/21/2019 9:03:11 AM

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	01-SM with Gravel [All]	Mohr-Coulomb	125	0	30	0
	02-Core [Drained]	Mohr-Coulomb	125	0	28	0
	03-Filter Drain [All]	Mohr-Coulomb	120	0	36	0
	05-Embankment Shell [All]	Mohr-Coulomb	125	0	34	0

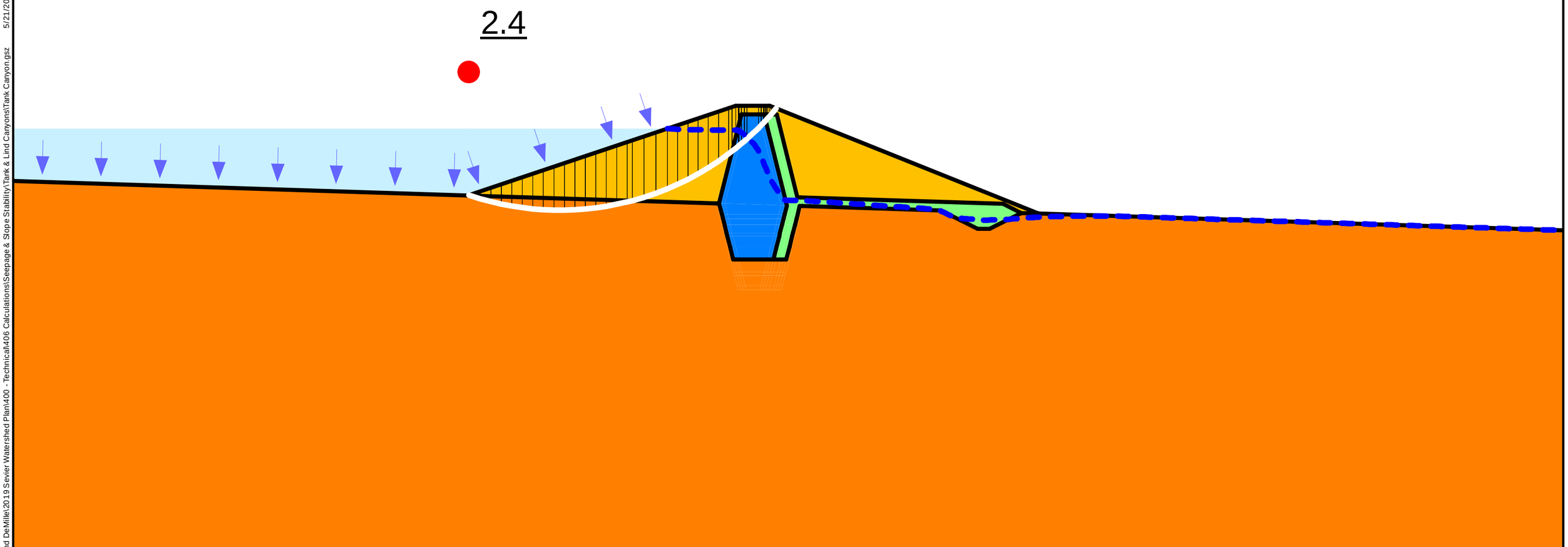


SOFTWARE VERSION: SLOPE/W v. 8.16.2.14053
METHOD: Spencer
Scale: 1:400.57348

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	TANK/LIND CANYON MAXIMUM SECTION	FIGURE 23
AECOM	SEVIER COUNTY, UTAH	DOWNSTREAM - DRAINED	

Q:\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Tank & Lind Canyons\Tank Canyon.gsz 5/21/2019 9:03:11 AM

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	01-SM with Gravel [All]	Mohr-Coulomb	125	0	30	0
	02-Core [Drained]	Mohr-Coulomb	125	0	28	0
	03-Filter Drain [All]	Mohr-Coulomb	120	0	36	0
	05-Embankment Shell [All]	Mohr-Coulomb	125	0	34	0

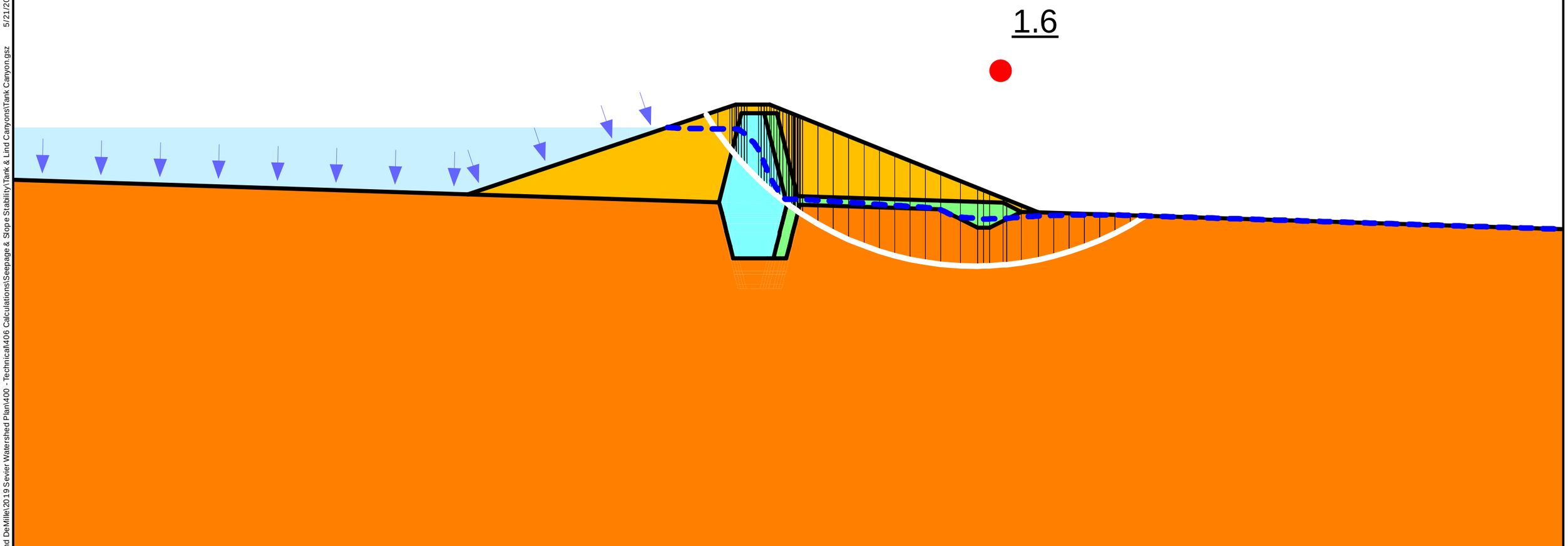


SOFTWARE VERSION: SLOPE/W v. 8.16.2.14053
METHOD: Spencer
Scale: 1:400.57348

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	TANK/LIND CANYON MAXIMUM SECTION	FIGURE 24
AECOM	SEVIER COUNTY, UTAH	UPSTREAM - DRAINED	

Q:\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Tank & Lind Canyons\Tank Canyon.gsz 5/21/2019 9:03:11 AM

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	01-SM with Gravel [All]	Mohr-Coulomb	125	0	30	0
	02-Core [Undrained]	Mohr-Coulomb	125	0	21.8	0
	03-Filter Drain [All]	Mohr-Coulomb	120	0	36	0
	05-Embankment Shell [All]	Mohr-Coulomb	125	0	34	0



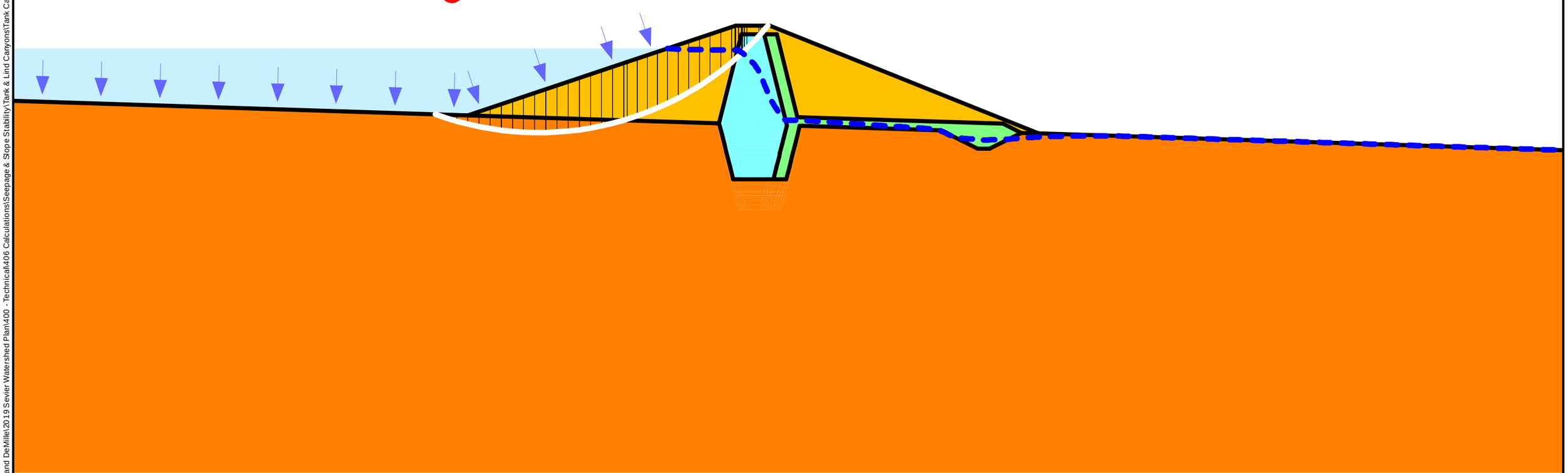
SOFTWARE VERSION: SLOPE/W v. 8.16.2.14053
METHOD: Spencer
Scale: 1:400.57348

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	TANK/LIND CANYON MAXIMUM SECTION	FIGURE
AECOM	SEVIER COUNTY, UTAH	DOWNSTREAM - UNDRAINED	25

Q:\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Tank & Lind Canyons\Tank Canyon.gsz 5/21/2019 9:03:11 AM

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	01-SM with Gravel [All]	Mohr-Coulomb	125	0	30	0
	02-Core [Undrained]	Mohr-Coulomb	125	0	21.8	0
	03-Filter Drain [All]	Mohr-Coulomb	120	0	36	0
	05-Embankment Shell [All]	Mohr-Coulomb	125	0	34	0

2.4

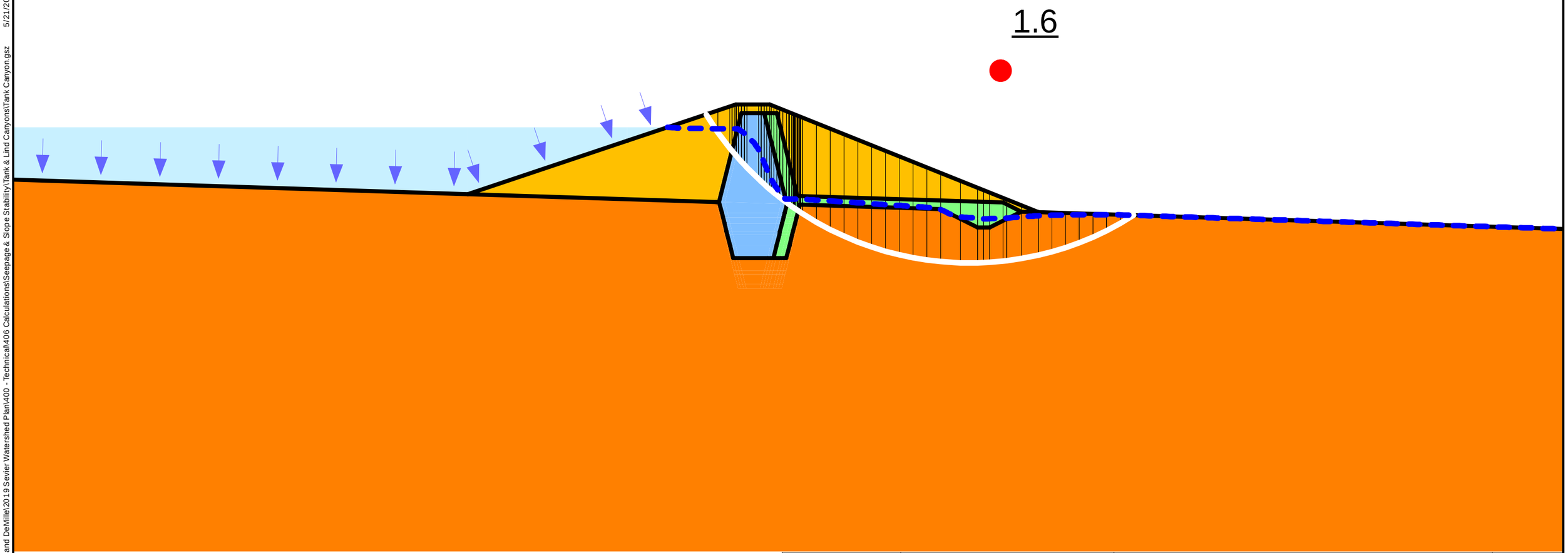


SOFTWARE VERSION: SLOPE/W v. 8.16.2.14053
METHOD: Spencer
Scale: 1:400.57348

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	TANK/LIND CANYON MAXIMUM SECTION	FIGURE 26
AECOM	SEVIER COUNTY, UTAH	UPSTREAM - UNDRAINED	

Q:\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Tank & Lind Canyons\Tank Canyon.gsz 5/21/2019 9:03:11 AM

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	01-SM with Gravel [All]	Mohr-Coulomb	125	0	30	0
	02-Core [Post-Earthquake]	Mohr-Coulomb	125	0	17.4	0
	03-Filter Drain [All]	Mohr-Coulomb	120	0	36	0
	05-Embankment Shell [All]	Mohr-Coulomb	125	0	34	0



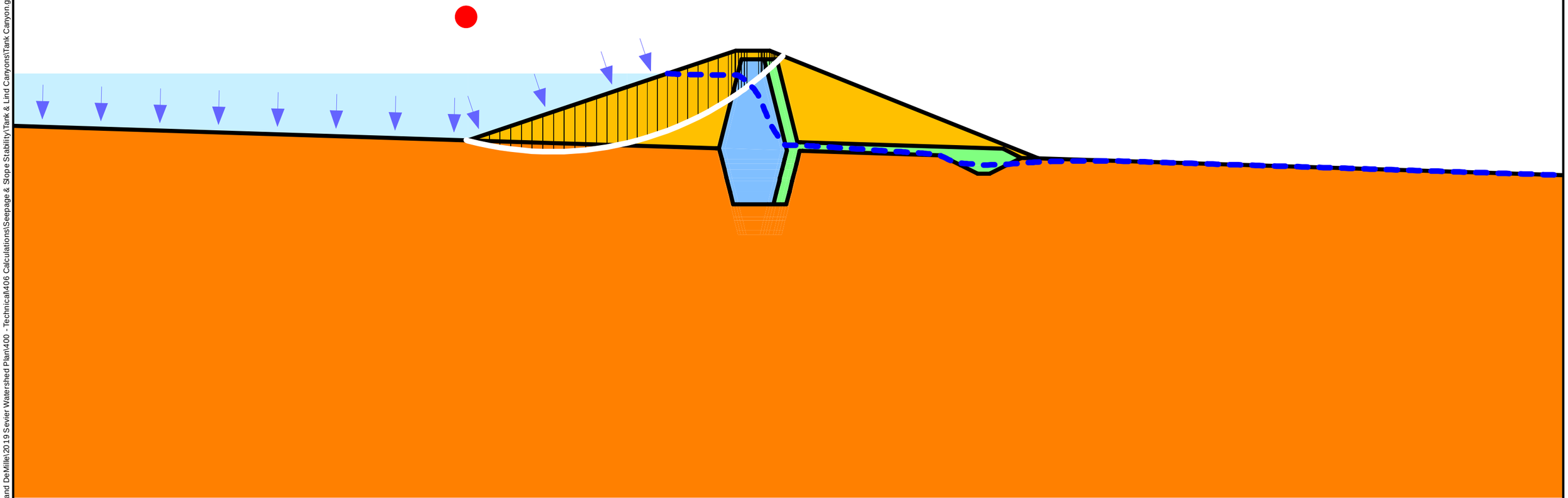
SOFTWARE VERSION: SLOPE/W v. 8.16.2.14053
METHOD: Spencer
Scale: 1:400.57348

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	TANK/LIND CANYON MAXIMUM SECTION	FIGURE 27
AECOM	SEVIER COUNTY, UTAH	DOWNSTREAM - POST-EARTHQUAKE	

Q:\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Tank & Lind Canyons\Tank Canyon.gsz 5/21/2019 9:03:11 AM

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	01-SM with Gravel [All]	Mohr-Coulomb	125	0	30	0
	02-Core [Post-Earthquake]	Mohr-Coulomb	125	0	17.4	0
	03-Filter Drain [All]	Mohr-Coulomb	120	0	36	0
	05-Embankment Shell [All]	Mohr-Coulomb	125	0	34	0

2.3



SOFTWARE VERSION: SLOPE/W v. 8.16.2.14053
METHOD: Spencer
Scale: 1:400.57348

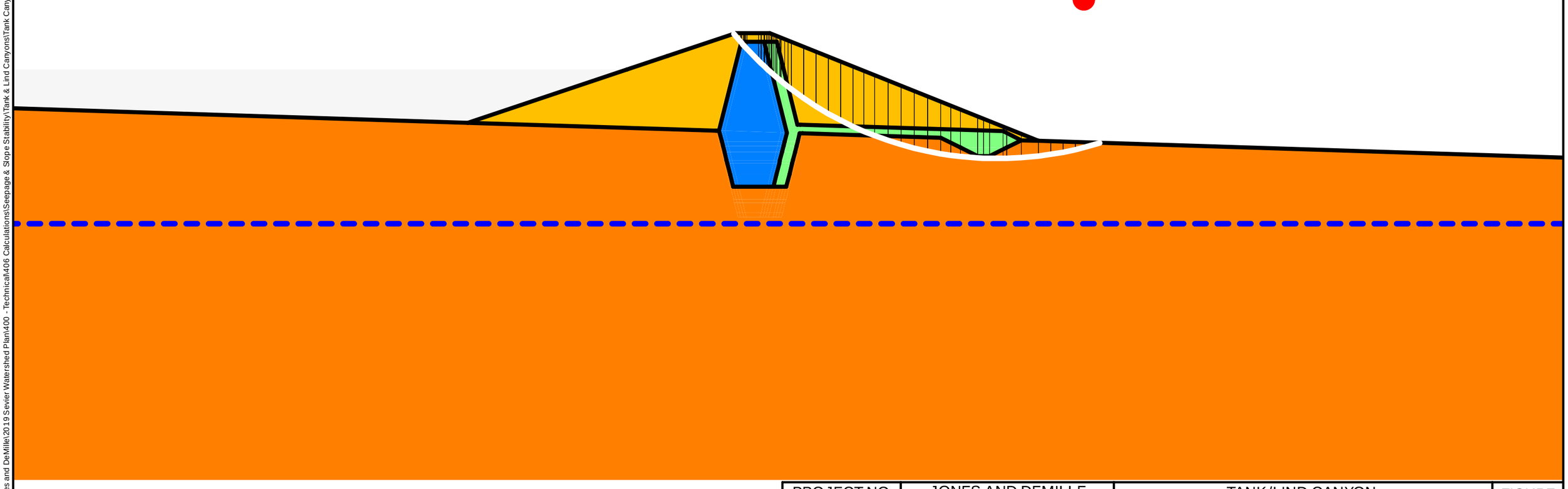
PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	TANK/LIND CANYON MAXIMUM SECTION	FIGURE 28
AECOM	SEVIER COUNTY, UTAH	UPSTREAM - POST-EARTHQUAKE	

Q:\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Tank & Lind Canyons\Tank Canyon.gsz 5/21/2019 9:03:11 AM

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Piezometric Line
	01-SM with Gravel [All]	Mohr-Coulomb	125	0	30	0	1
	02-Core [Drained]	Mohr-Coulomb	125	0	28	0	1
	03-Filter Drain [All]	Mohr-Coulomb	120	0	36	0	1
	05-Embankment Shell [All]	Mohr-Coulomb	125	0	34	0	1

Horz Seismic Coef.: 0.245

1.1



SOFTWARE VERSION: SLOPE/W v. 8.16.2.14053
METHOD: Spencer
Scale: 1:400.57348

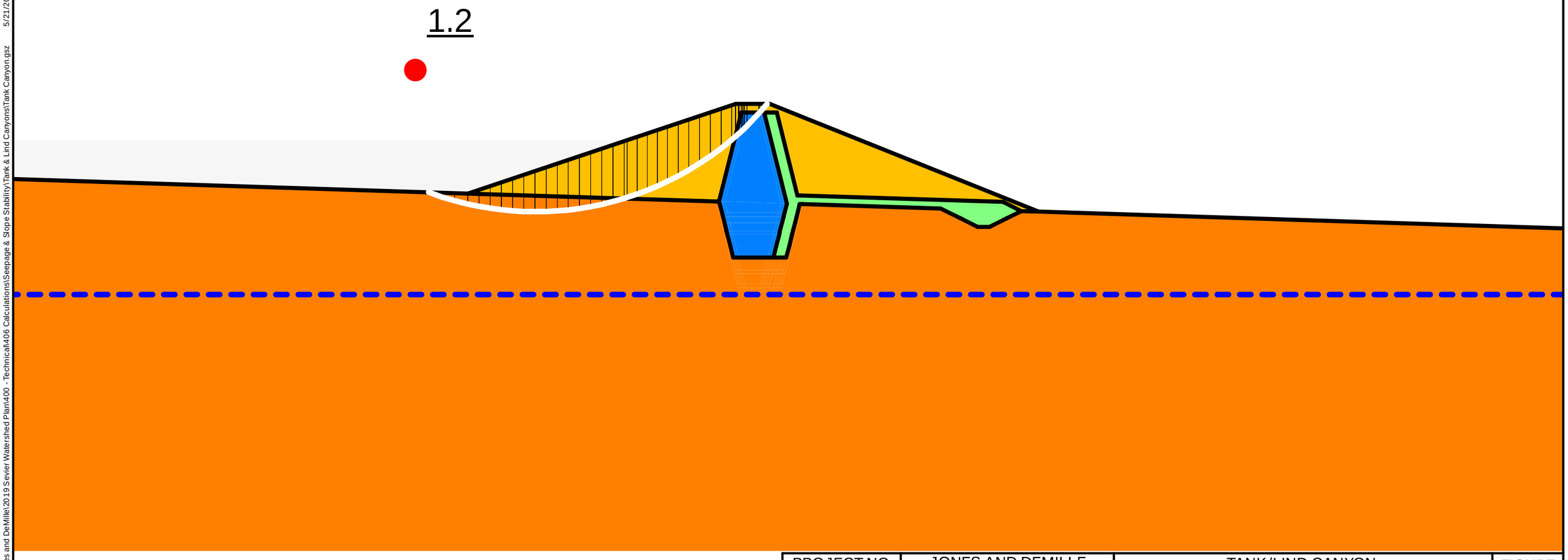
PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	TANK/LIND CANYON MAXIMUM SECTION	FIGURE 29
AECOM	SEVIER COUNTY, UTAH	DOWNSTREAM - PSEUDOSTATIC	

Q:\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Tank & Lind Canyons\Tank Canyon.gsz 5/21/2019 9:03:11 AM

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Piezometric Line
	01-SM with Gravel [All]	Mohr-Coulomb	125	0	30	0	1
	02-Core [Drained]	Mohr-Coulomb	125	0	28	0	1
	03-Filter Drain [All]	Mohr-Coulomb	120	0	36	0	1
	05-Embankment Shell [All]	Mohr-Coulomb	125	0	34	0	1

Horz Seismic Coef.: 0.245

1.2



SOFTWARE VERSION: SLOPE/W v. 8.16.2.14053
METHOD: Spencer
Scale: 1:400.57348

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	TANK/LIND CANYON MAXIMUM SECTION	FIGURE 30
AECOM	SEVIER COUNTY, UTAH	UPSTREAM - PSEUDOSTATIC	

Q:\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Tank & Lind Canyons\Tank Canyon.gsz 5/21/2019 9:03:11 AM

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Cohesion R (psf)	Phi R (°)	Piezometric Line	Piezometric Line After Drawdown
	01-SM with Gravel [All]	Mohr-Coulomb	125	0	30	0	0	0	1	2
	02-Core [Drained]	Mohr-Coulomb	125	0	28	0	400	16	1	2
	03-Filter Drain [All]	Mohr-Coulomb	120	0	36	0	0	0	1	2
	05-Embankment Shell [All]	Mohr-Coulomb	125	0	34	0	0	0	1	2

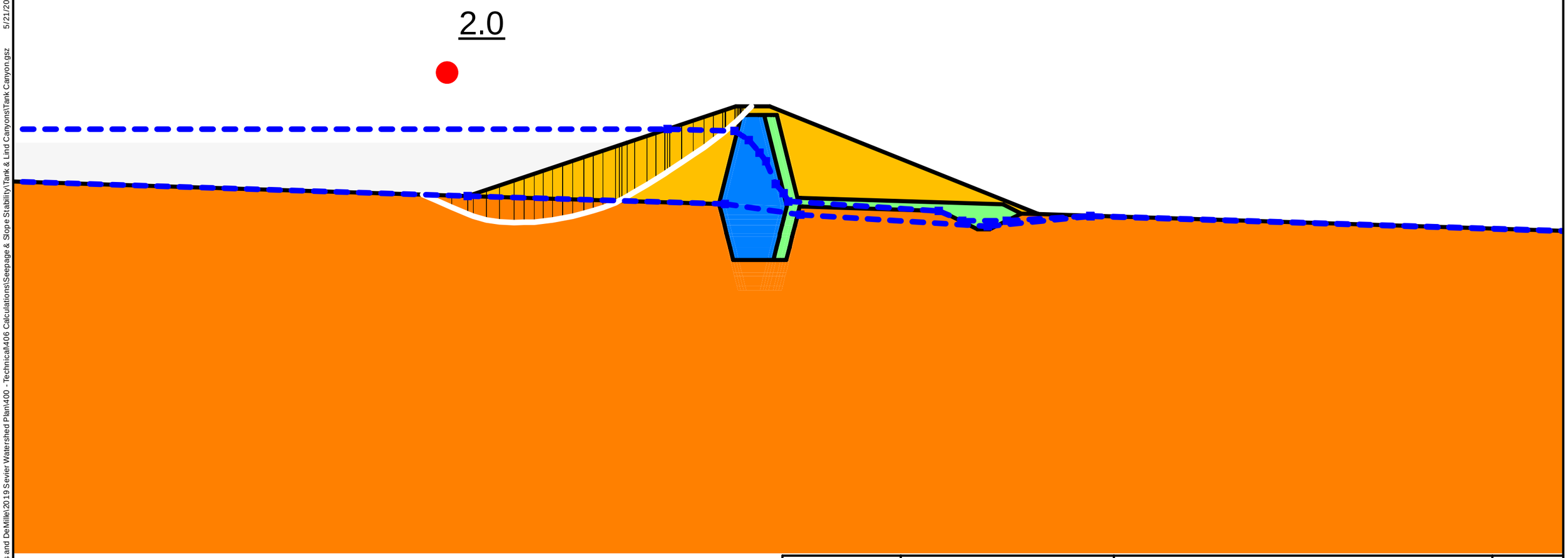
1.8

SOFTWARE VERSION: SLOPE/W v. 8.16.2.14053
METHOD: Spencer
Scale: 1:400.57348

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	TANK/LIND CANYON MAXIMUM SECTION	FIGURE 31
AECOM	SEVIER COUNTY, UTAH	DOWNSTREAM - RAPID DRAWDOWN	

Q:\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Tank & Lind Canyons\Tank Canyon.gsz 5/21/2019 9:03:11 AM

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Cohesion R (psf)	Phi R (°)	Piezometric Line	Piezometric Line After Drawdown
	01-SM with Gravel [All]	Mohr-Coulomb	125	0	30	0	0	0	1	2
	02-Core [Drained]	Mohr-Coulomb	125	0	28	0	400	16	1	2
	03-Filter Drain [All]	Mohr-Coulomb	120	0	36	0	0	0	1	2
	05-Embankment Shell [All]	Mohr-Coulomb	125	0	34	0	0	0	1	2



SOFTWARE VERSION: SLOPE/W v. 8.16.2.14053
METHOD: Spencer
Scale: 1:400.57348

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	TANK/LIND CANYON MAXIMUM SECTION	FIGURE 32
AECOM	SEVIER COUNTY, UTAH	UPSTREAM - RAPID DRAWDOWN	

Q:\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Tank & Lind Canyons\Tank Canyon.gsz 5/21/2019 9:03:11 AM

Color	Name	Model	K-Function	Ky'/Kx' Ratio	Rotation (°)	Vol. WC. Function
	01-SM with Gravel [All]	Saturated / Unsaturated	SM with Gravel	0.1	0	SM with Gravel
	03-Filter Drain [All]	Saturated / Unsaturated	Filter Drain	1	0	Filter Drain
	03-Gravel Drain [All]	Saturated / Unsaturated	Gravel Drain	1	0	Gravel Drain
	05-Embankment Shell [All]	Saturated / Unsaturated	SM with Gravel	0.1	0	SM with Gravel

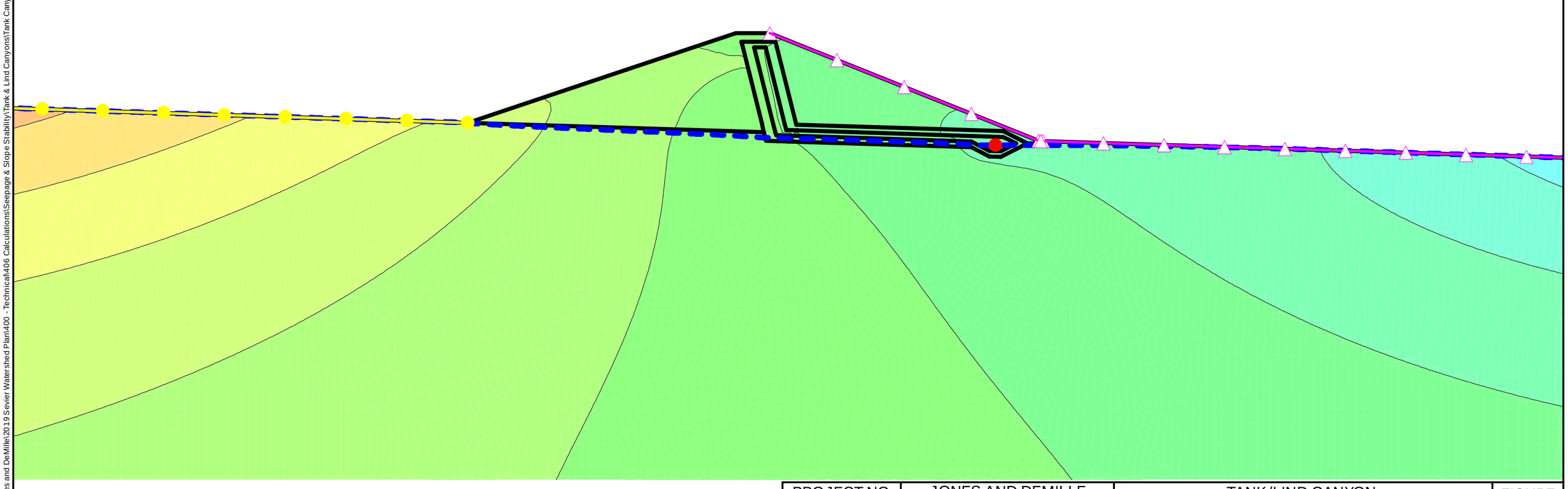
Name: Total Head

Contour parameter: Total Head ft

Starting Contour Value: 5,408 ft

Ending Contour Value: 5,436 ft

Increment by: 2 ft



SOFTWARE VERSION: SEEP/W v. 8.16.2.14053
METHOD: Steady-State
Scale: 1:400.57348

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	TANK/LIND CANYON MAXIMUM SECTION	FIGURE 33
AECOM	SEVIER COUNTY, UTAH	EMPTY SEEPAGE RESULTS	

Q:\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Tank & Lind Canyons\Tank Canyon_Drain.gsz 5/20/2019 2:11:21 PM

Color	Name	Model	K-Function	Ky'/Kx' Ratio	Rotation (°)	Vol. WC. Function
	01-SM with Gravel [All]	Saturated / Unsaturated	SM with Gravel	0.1	0	SM with Gravel
	03-Filter Drain [All]	Saturated / Unsaturated	Filter Drain	1	0	Filter Drain
	03-Gravel Drain [All]	Saturated / Unsaturated	Gravel Drain	1	0	Gravel Drain
	05-Embankment Shell [All]	Saturated / Unsaturated	SM with Gravel	0.1	0	SM with Gravel

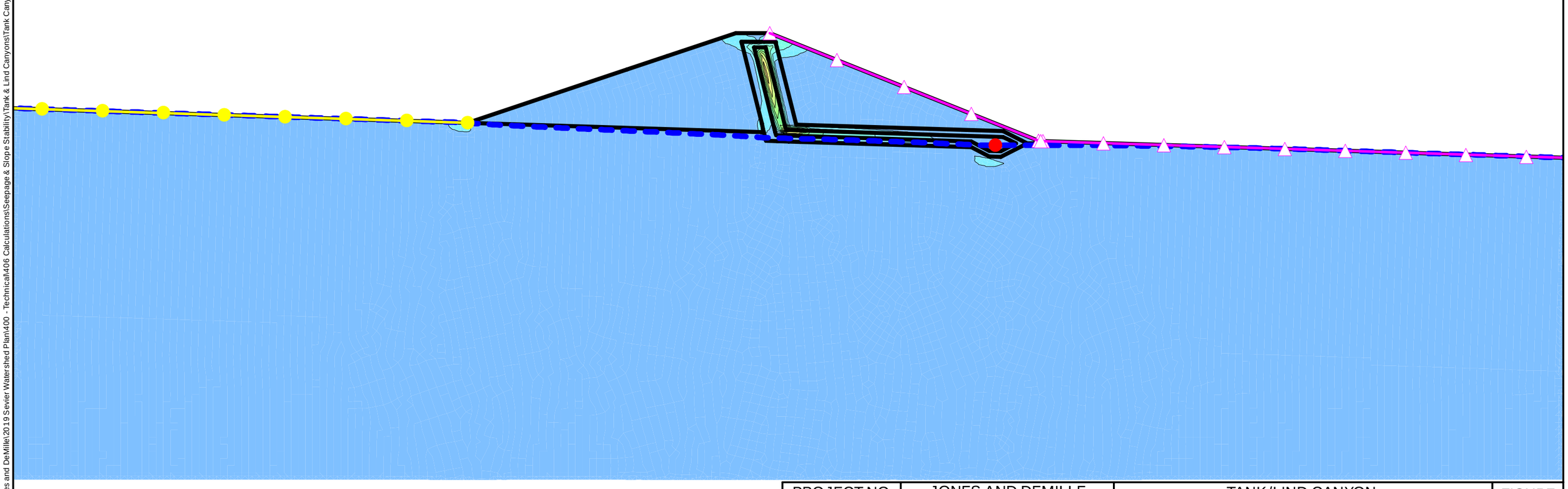
Name: Gradients

Contour parameter: XY-Gradient

Starting Contour Value: 0

Ending Contour Value: 1.1

Increment by: 0.1



SOFTWARE VERSION: SEEP/W v. 8.16.2.14053
METHOD: Steady-State
Scale: 1:400.57348

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	TANK/LIND CANYON MAXIMUM SECTION	FIGURE 34
AECOM	SEVIER COUNTY, UTAH	EMPTY SEEPAGE GRADIENT	

Q:\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Tank & Lind Canyons\Tank Canyon_Drain.gsz 5/20/2019 2:11:21 PM

Color	Name	Model	K-Function	Ky'/Kx' Ratio	Rotation (°)	Vol. WC. Function
	01-SM with Gravel [All]	Saturated / Unsaturated	SM with Gravel	0.1	0	SM with Gravel
	03-Filter Drain [All]	Saturated / Unsaturated	Filter Drain	1	0	Filter Drain
	03-Gravel Drain [All]	Saturated / Unsaturated	Gravel Drain	1	0	Gravel Drain
	05-Embankment Shell [All]	Saturated / Unsaturated	SM with Gravel	0.1	0	SM with Gravel

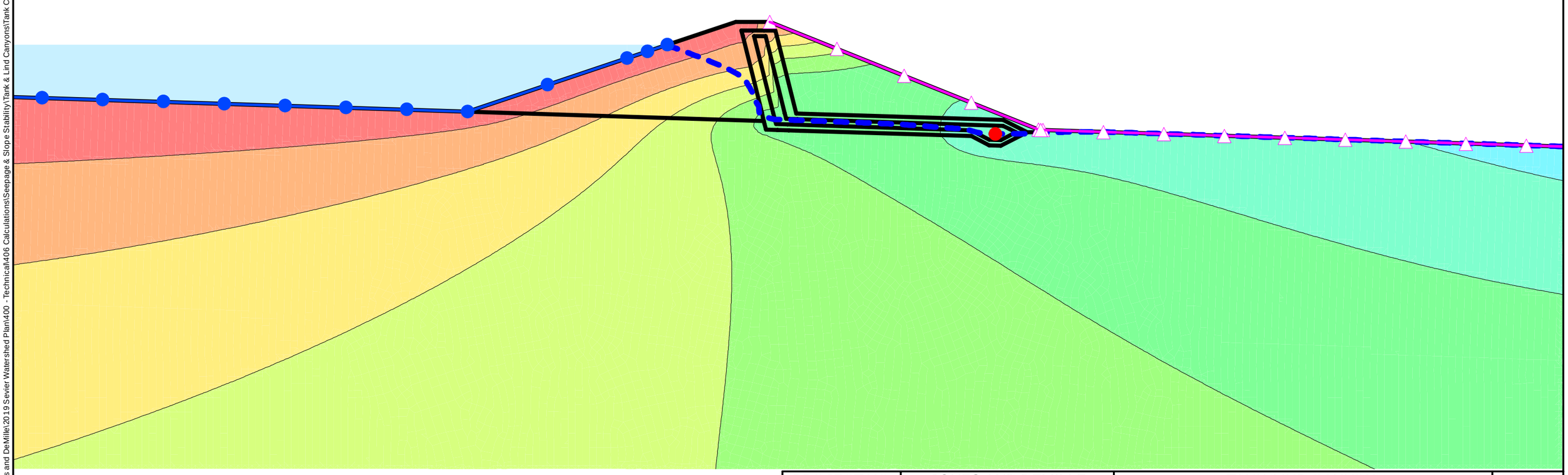
Name: Total Head

Contour parameter: Total Head ft

Starting Contour Value: 5,405 ft

Ending Contour Value: 5,450 ft

Increment by: 5 ft



SOFTWARE VERSION: SEEP/W v. 8.16.2.14053
METHOD: Steady-State
Scale: 1:400.57348

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	TANK/LIND CANYON MAXIMUM SECTION	FIGURE 35
AECOM	SEVIER COUNTY, UTAH	FULL SEEPAGE RESULTS	

Q:\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Tank & Lind Canyons\Tank Canyon_Drain.gsz 5/20/2019 2:11:21 PM

Color	Name	Model	K-Function	Ky'/Kx' Ratio	Rotation (°)	Vol. WC. Function
	01-SM with Gravel [All]	Saturated / Unsaturated	SM with Gravel	0.1	0	SM with Gravel
	03-Filter Drain [All]	Saturated / Unsaturated	Filter Drain	1	0	Filter Drain
	03-Gravel Drain [All]	Saturated / Unsaturated	Gravel Drain	1	0	Gravel Drain
	05-Embankment Shell [All]	Saturated / Unsaturated	SM with Gravel	0.1	0	SM with Gravel

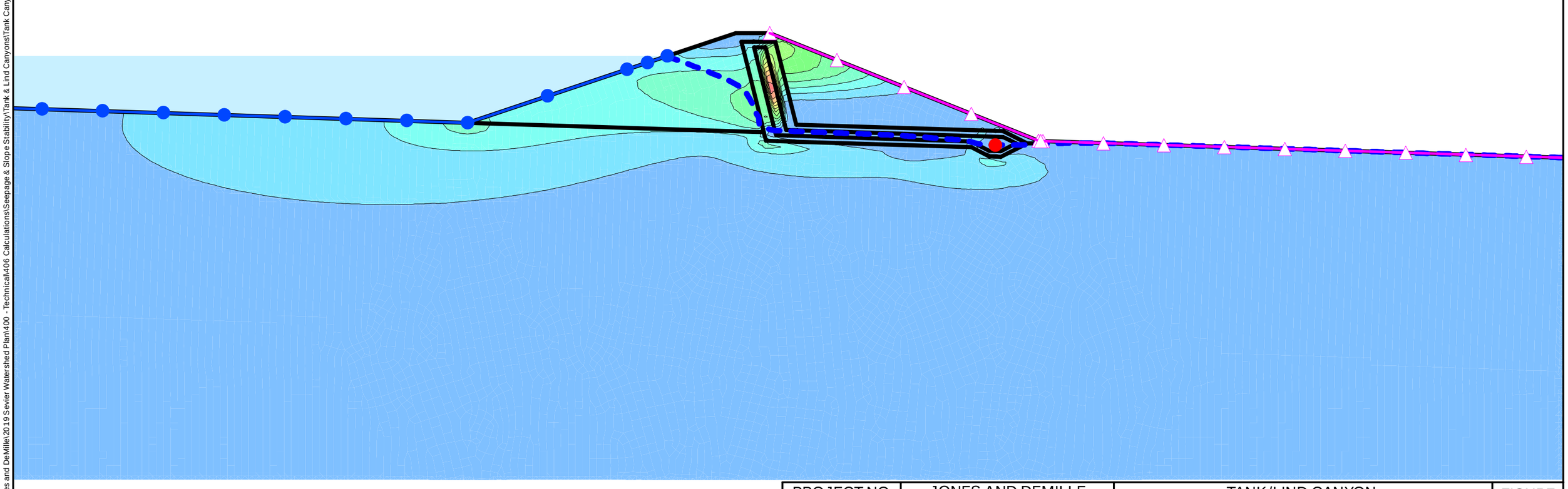
Name: Gradients

Contour parameter: XY-Gradient

Starting Contour Value: 0

Ending Contour Value: 2.6

Increment by: 0.2



SOFTWARE VERSION: SEEP/W v. 8.16.2.14053
METHOD: Steady-State
Scale: 1:400.57348

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	TANK/LIND CANYON MAXIMUM SECTION	FIGURE 36
AECOM	SEVIER COUNTY, UTAH	FULL SEEPAGE GRADIENT	

Q:\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Tank & Lind Canyons\Tank Canyon_Drain.gsz 5/20/2019 2:11:21 PM

Color	Name	Model	K-Function	Ky'/Kx' Ratio	Rotation (°)	Vol. WC. Function
	01-SM with Gravel [All]	Saturated / Unsaturated	SM with Gravel	0.1	0	SM with Gravel
	03-Filter Drain [All]	Saturated / Unsaturated	Filter Drain	1	0	Filter Drain
	03-Gravel Drain [All]	Saturated / Unsaturated	Gravel Drain	1	0	Gravel Drain
	04-Basin Sediment [Drained]	Saturated / Unsaturated	Sediment	0.1	0	Sediment
	05-Embankment Shell [All]	Saturated / Unsaturated	SM with Gravel	0.1	0	SM with Gravel

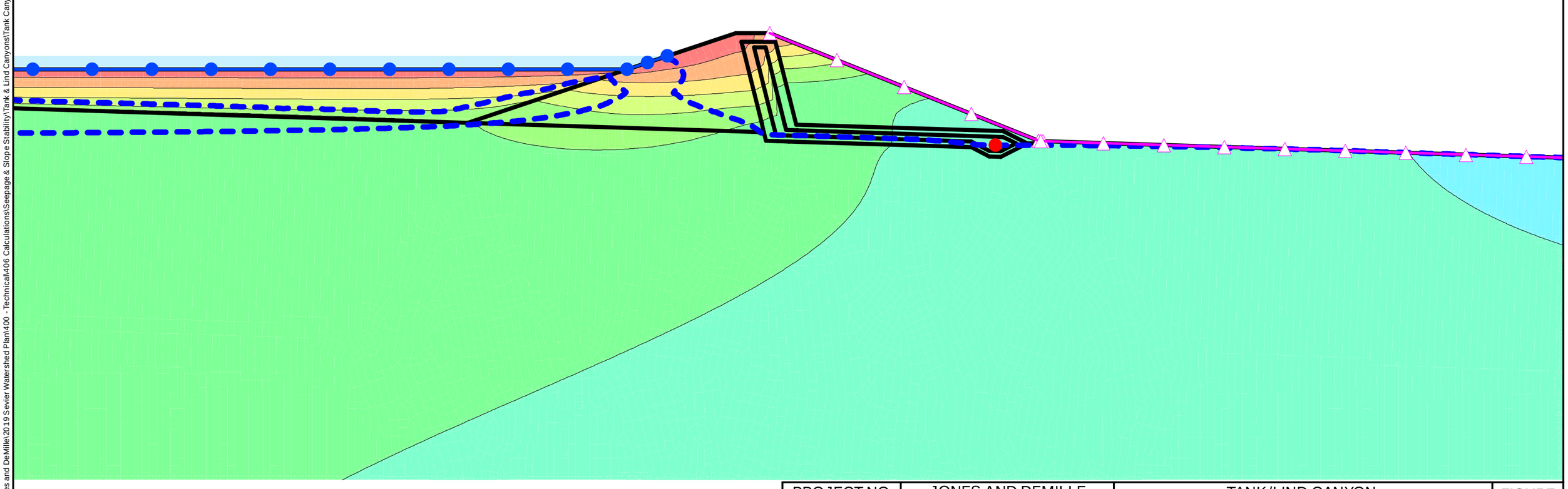
Name: Total Head

Contour parameter: Total Head ft

Starting Contour Value: 5,405 ft

Ending Contour Value: 5,450 ft

Increment by: 5 ft



SOFTWARE VERSION: SEEP/W v. 8.16.2.14053
METHOD: Steady-State
Scale: 1:400.57348

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	TANK/LIND CANYON MAXIMUM SECTION	FIGURE 37
AECOM	SEVIER COUNTY, UTAH	SEDIMENT FILLED SEEPAGE RESULTS	

Q:\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Tank & Lind Canyons\Tank Canyon_Drain.gsz 5/20/2019 2:11:21 PM

Color	Name	Model	K-Function	Ky'/Kx' Ratio	Rotation (°)	Vol. WC. Function
	01-SM with Gravel [All]	Saturated / Unsaturated	SM with Gravel	0.1	0	SM with Gravel
	03-Filter Drain [All]	Saturated / Unsaturated	Filter Drain	1	0	Filter Drain
	03-Gravel Drain [All]	Saturated / Unsaturated	Gravel Drain	1	0	Gravel Drain
	04-Basin Sediment [Drained]	Saturated / Unsaturated	Sediment	0.1	0	Sediment
	05-Embankment Shell [All]	Saturated / Unsaturated	SM with Gravel	0.1	0	SM with Gravel

Name: Gradients

Contour parameter: XY-Gradient

Starting Contour Value: 0

Ending Contour Value: 4.5

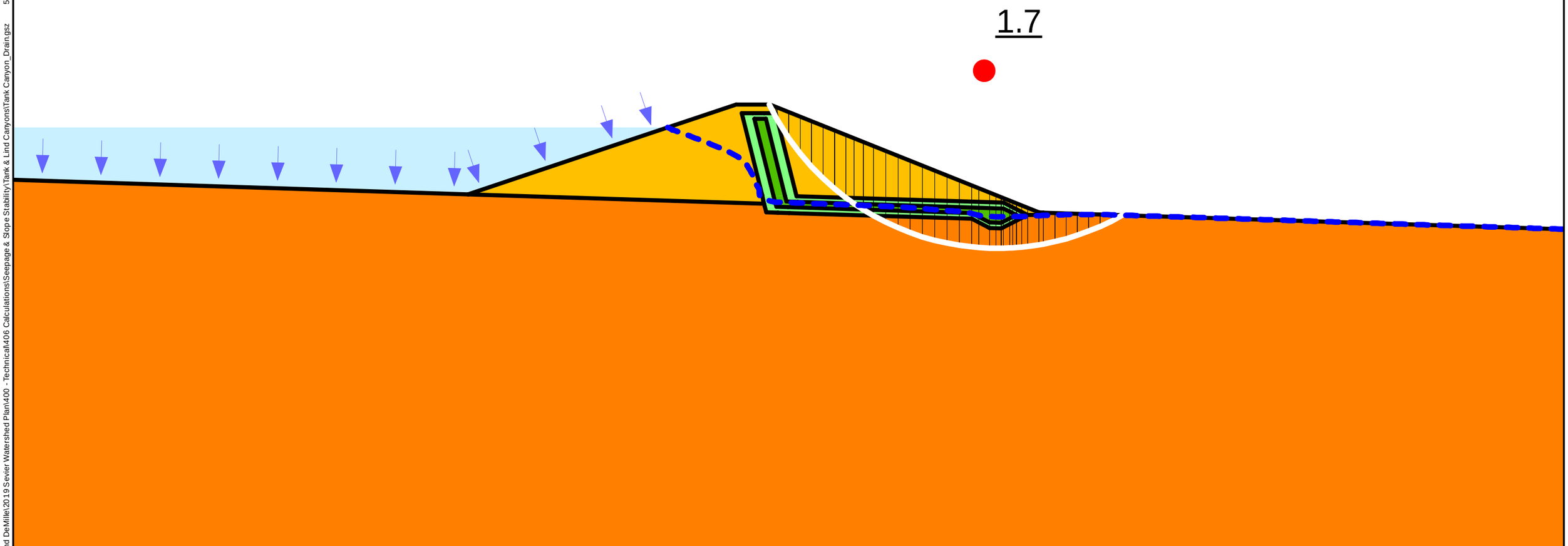
Increment by: 0.5

SOFTWARE VERSION: SEEP/W v. 8.16.2.14053
METHOD: Steady-State
Scale: 1:400.57348

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	TANK/LIND CANYON MAXIMUM SECTION	FIGURE 38
AECOM	SEVIER COUNTY, UTAH	SEDIMENT FILLED SEEPAGE GRADIENT	

Q:\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Tank & Lind Canyons\Tank Canyon_Drain.gsz 5/20/2019 2:11:21 PM

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	01-SM with Gravel [All]	Mohr-Coulomb	125	0	30	0
	03-Filter Drain [All]	Mohr-Coulomb	120	0	36	0
	03-Gravel Drain [All]	Mohr-Coulomb	120	0	36	0
	05-Embankment Shell [All]	Mohr-Coulomb	125	0	34	0



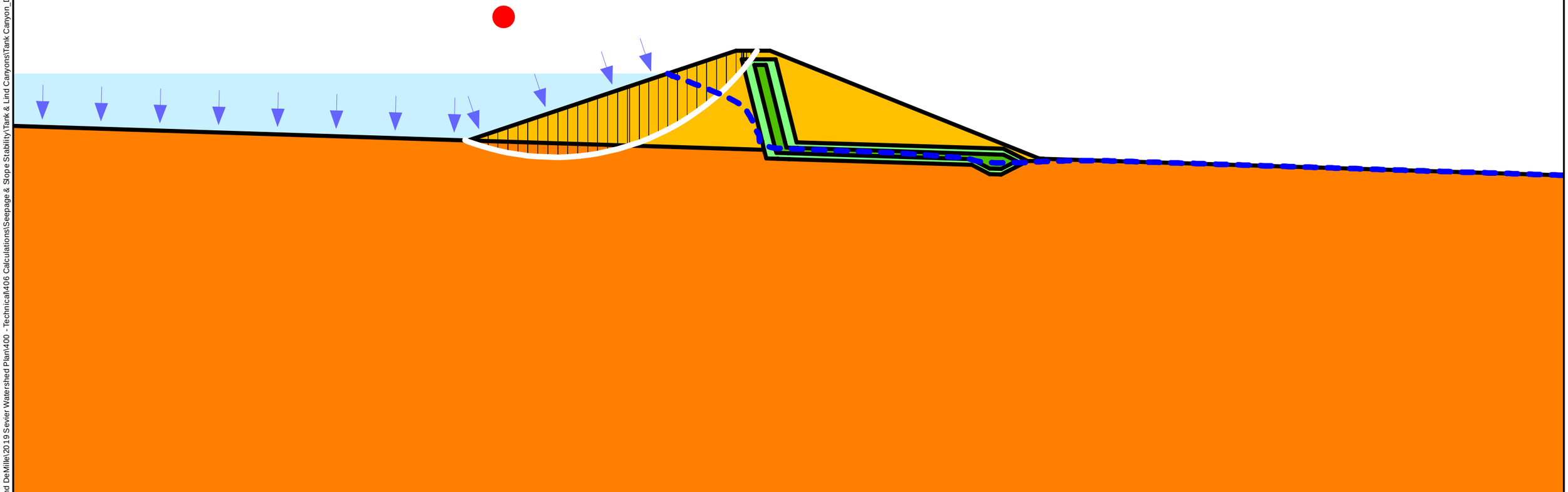
SOFTWARE VERSION: SLOPE/W v. 8.16.2.14053
METHOD: Spencer
Scale: 1:400.57348

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	TANK/LIND CANYON MAXIMUM SECTION	FIGURE 39
AECOM	SEVIER COUNTY, UTAH	DRAINED - DOWNSTREAM	

Q:\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Tank & Lind Canyons\Tank Canyon_Drain.gsz 5/20/2019 4:19:37 PM

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	01-SM with Gravel [All]	Mohr-Coulomb	125	0	30	0
	03-Filter Drain [All]	Mohr-Coulomb	120	0	36	0
	03-Gravel Drain [All]	Mohr-Coulomb	120	0	36	0
	05-Embankment Shell [All]	Mohr-Coulomb	125	0	34	0

3.1



SOFTWARE VERSION: SLOPE/W v. 8.16.2.14053
METHOD: Spencer
Scale: 1:400.57348

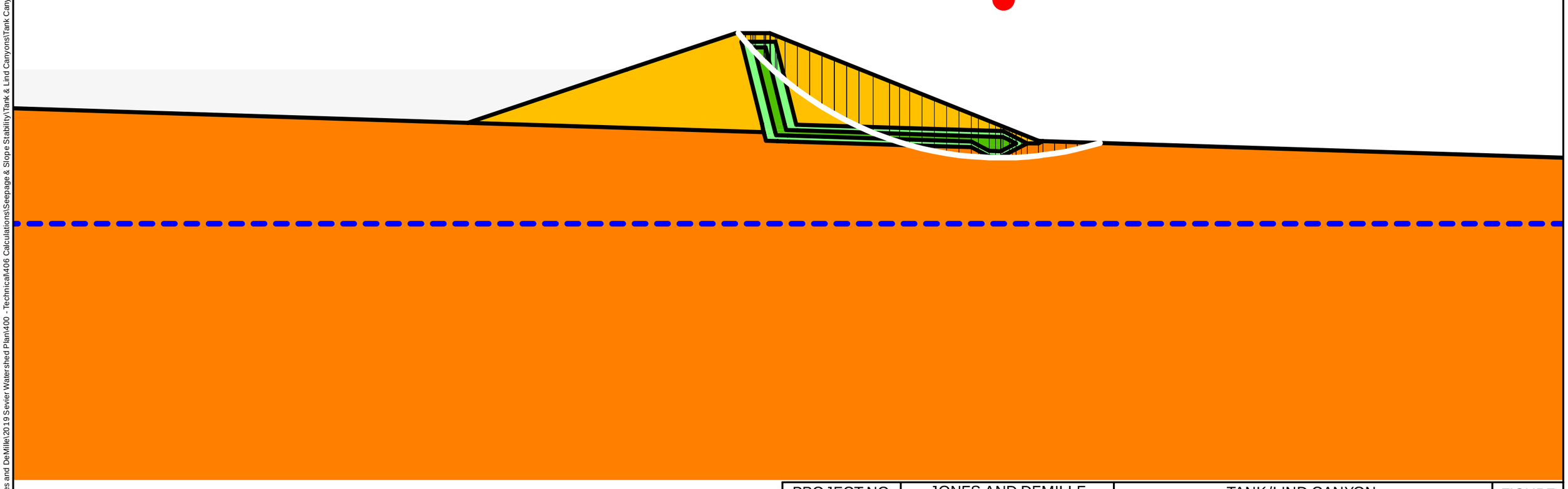
PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	TANK/LIND CANYON MAXIMUM SECTION	FIGURE 40
AECOM	SEVIER COUNTY, UTAH	DRAINED - UPSTREAM	

Q:\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Tank & Lind Canyons\Tank Canyon_Drain.gsz 5/20/2019 4:19:37 PM

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Piezometric Line
	01-SM with Gravel [All]	Mohr-Coulomb	125	0	30	0	1
	03-Filter Drain [All]	Mohr-Coulomb	120	0	36	0	1
	03-Gravel Drain [All]	Mohr-Coulomb	120	0	36	0	1
	05-Embankment Shell [All]	Mohr-Coulomb	125	0	34	0	1

Horz Seismic Coef.: 0.245

1.1



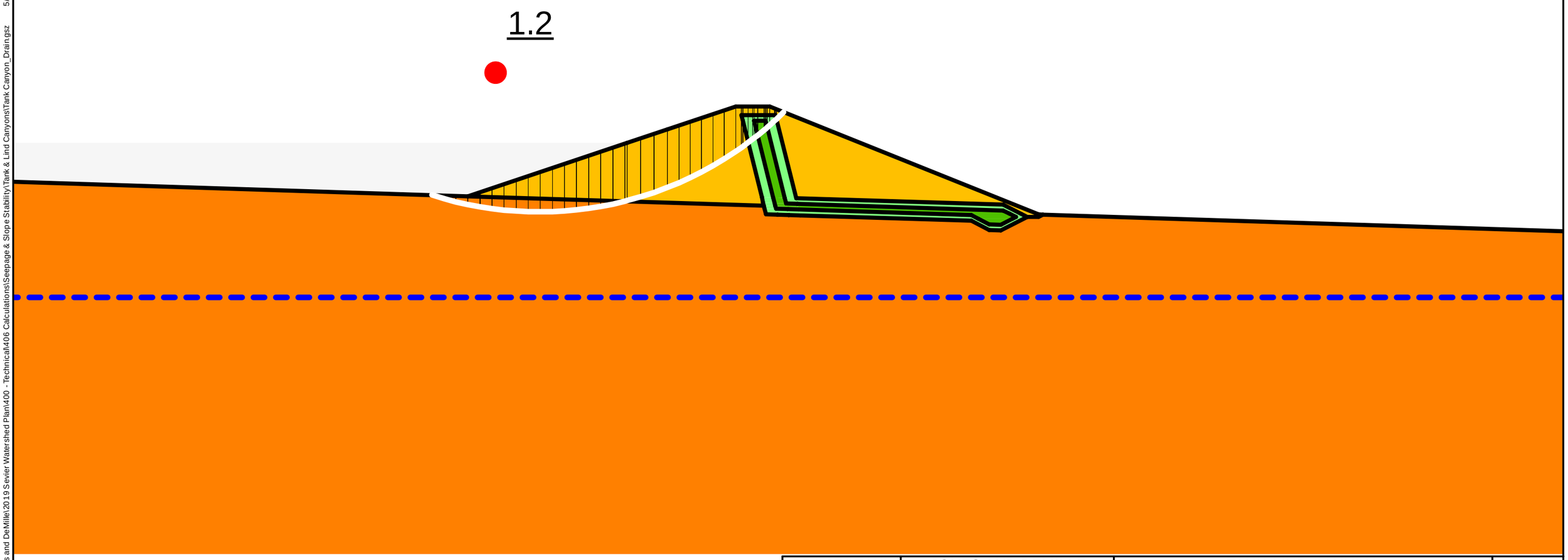
SOFTWARE VERSION: SLOPE/W v. 8.16.2.14053
METHOD: Spencer
Scale: 1:400.57348

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	TANK/LIND CANYON MAXIMUM SECTION	FIGURE 41
AECOM	SEVIER COUNTY, UTAH	PSEUDOSTATIC - DOWNSTREAM	

Q:\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Tank & Lind Canyons\Tank Canyon_Drain.gsz 5/20/2019 4:07:18 PM

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Piezometric Line
	01-SM with Gravel [All]	Mohr-Coulomb	125	0	30	0	1
	03-Filter Drain [All]	Mohr-Coulomb	120	0	36	0	1
	03-Gravel Drain [All]	Mohr-Coulomb	120	0	36	0	1
	05-Embankment Shell [All]	Mohr-Coulomb	125	0	34	0	1

Horz Seismic Coef.: 0.245

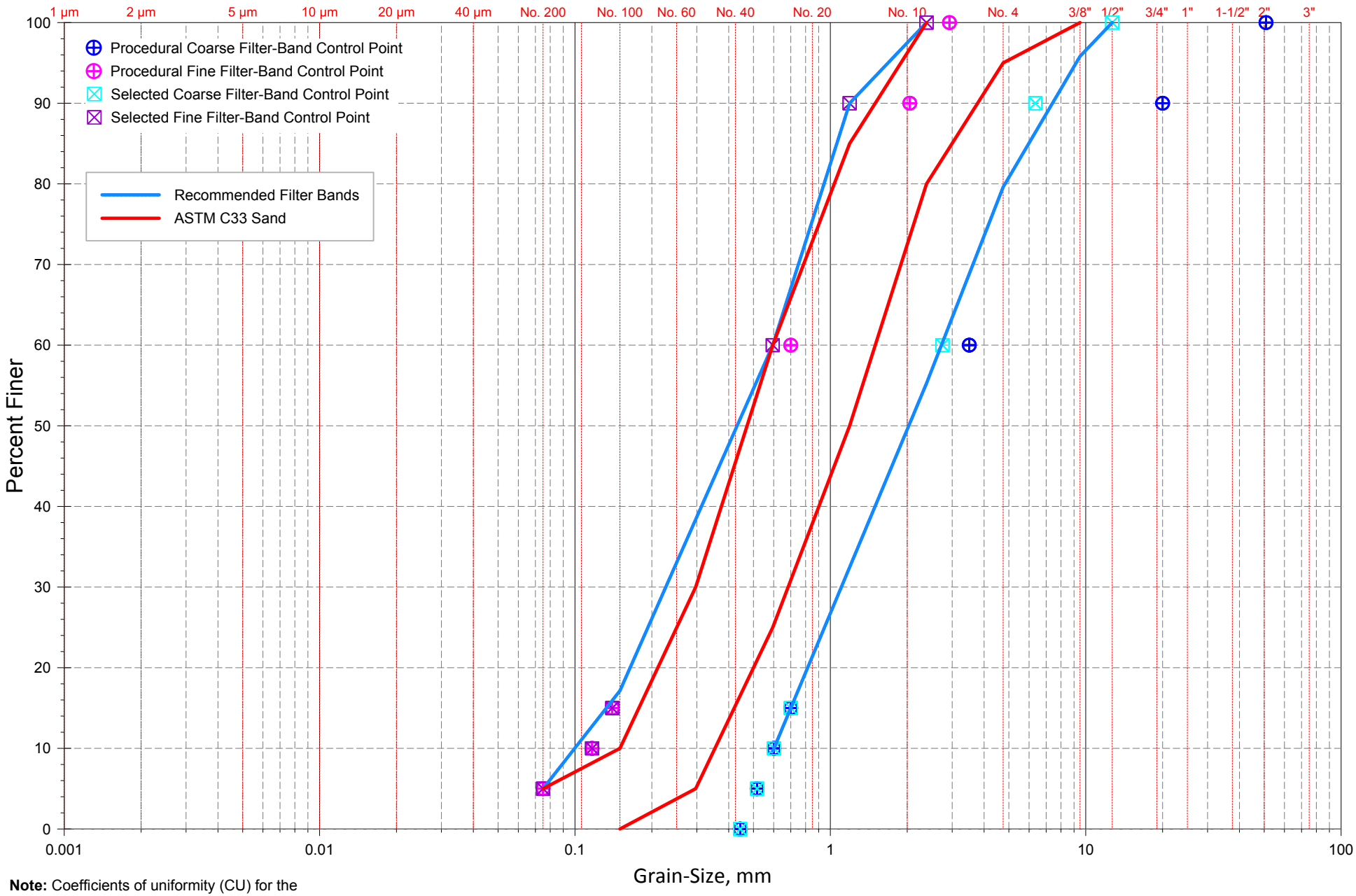


SOFTWARE VERSION: SLOPE/W v. 8.16.2.14053
METHOD: Spencer
Scale: 1:400.57348

PROJECT NO. 60598028	JONES AND DEMILLE ENGINEERING	TANK/LIND CANYON MAXIMUM SECTION	FIGURE 42
AECOM	SEVIER COUNTY, UTAH	PSEUDOSTATIC - UPSTREAM	

Q:\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Seepage & Slope Stability\Tank & Lind Canyons\Tank Canyon_Drain.gsz 5/20/2019 4:07:18 PM

Attachment G. Recommended Filter Bands



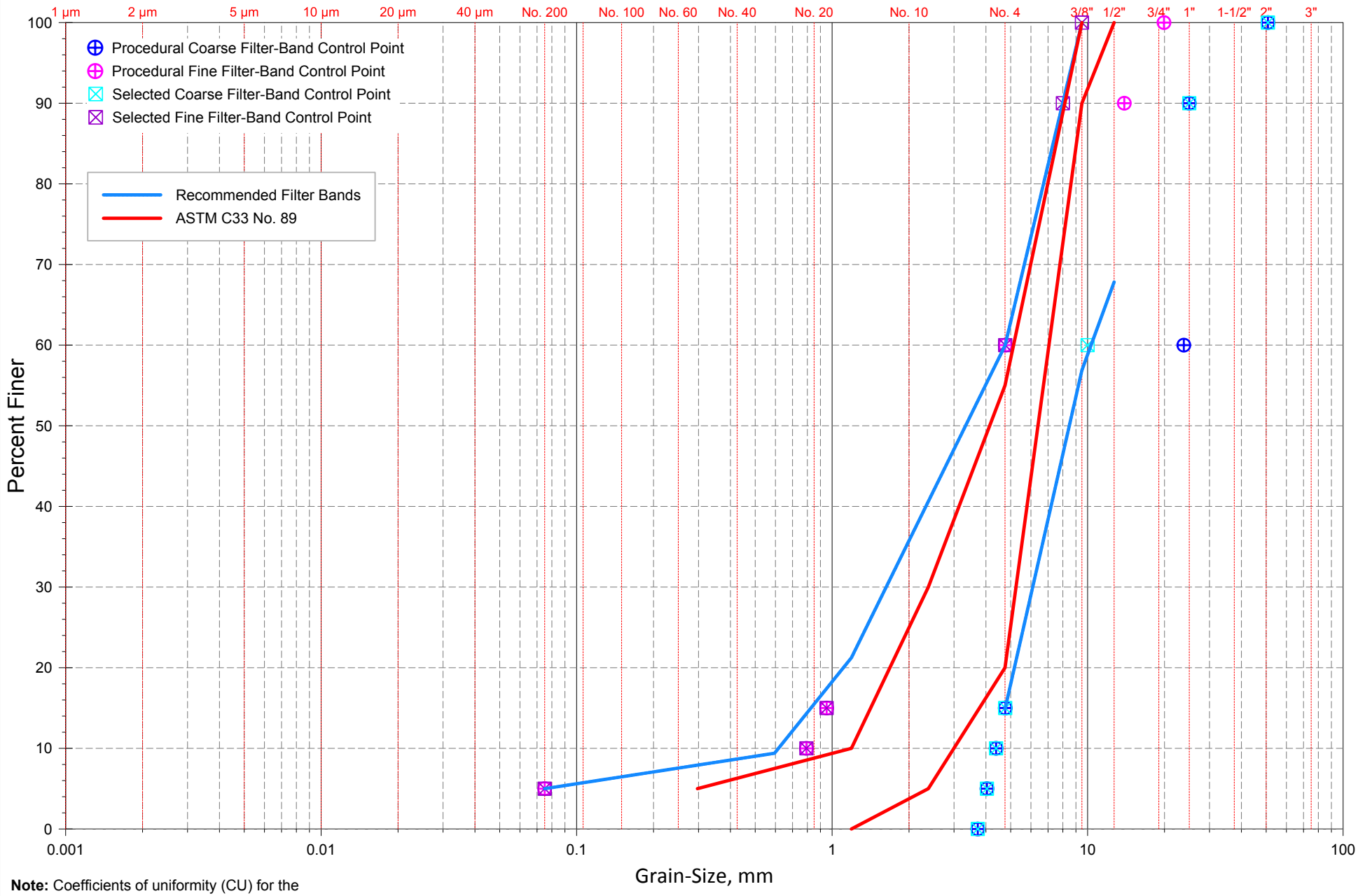
Note: Coefficients of uniformity (CU) for the recommended fine and coarse filter bands are 5.96 and 4.53, respectively.

Method: Natural Resources Conservation Service [NRCS]. (2017). "Gradation Design of Sand and Gravel Filters." *National Engineering Handbook, Part 633 - Soil Engineering*, United States Department of Agriculture, Washington, D.C., 62.

PROJECT NO. 60598028	JONES & DEMILLE ENGINEERING	ZONE 1 FILTER RECOMMENDED FILTER BAND SHOWING ASTM C33 Sand	FIGURE 1
AECOM	SEVIER COUNTY, UTAH		

05/23/2019 2:28 PM

Q:\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Filter Compatibility\STEP 10 - Filter Bands.grf



Note: Coefficients of uniformity (CU) for the recommended fine and coarse filter bands are 7.71 and #VALUE!, respectively.

Method: Natural Resources Convervation Service [NRCS]. (2017). "Gradation Design of Sand and Gravel Filters." *National Engineering Handbook, Part 633 - Soil Engineering*, United States Department of Agriculture, Washington, D.C., 62.

PROJECT NO. 60598028	JONES & DEMILLE ENGINEERING	ZONE 2 FILTER RECOMMENDED FILTER BAND SHOWING ASTM C33 No. 89	FIGURE 2
AECOM	SEVIER COUNTY, UTAH		

05/23/2019 2:27 PM

Q:\Projects\Jones and DeMille\2019 Sevier Watershed Plan\400 - Technical\406 Calculations\Filter Compatibility\ASTM C33 Sand Filter\STEP 10 - Filter Bands.grf

TM006 – Economic Analysis

Table of Contents

1.0 Overview 1
2.0 Economic Evaluation Procedures, Assumptions, and Methods 2
2.1 Structure-Related Damages 2
2.2 Agriculture-Related Damages 9
2.3 Economic Analysis Benefits, Costs, and Results 16
3.0 References 20

Tables

Table 1-1. Description of the With-Project Alternative 1
Table 1-2. Benefit-Cost Analysis Summary 1
Table 2-1. Structures Inventoried 4
Table 2-2. Assumed Foundation Heights 4
Table 2-3. RS Means Replacement Values and Depreciation Rates 5
Table 2-4. Contents Value as a Percent of Structure Value 7
Table 2-5. Summary of Residential Debris Costs 9
Table 2-6. Crops in Study Area 10
Table 2-7. Crop Progress 10
Table 2-8. HEC-FIA Assumptions 12
Table 2-9. Crop Plant Data Assumptions 12
Table 2-10. Crop Damages from 1 to 3 days of Inundation 15
Table 2-11. Planting and Production Costs per Acre 15
Table 2-12. Average Crop Yield and Average Production Value 16
Table 2-13. Likelihood of Flooding by Month 16
Table 2-14. Number of Buildings Protected for the 0.2-percent-annual-probability Flood Event 17
Table 2-15. Structure-Related Benefits by Flood Event and Structure Type (in thousands) 17
Table 2-16. Average Annual Structure-Related Benefits 18
Table 2-17. Breakdown of Agricultural Land Inundated by Crop (acres) 18
Table 2-20. Cost Breakdown 19
Table 2-21. Benefit-Cost Analysis Summary 19

1.0 Overview

AECOM Technical Services, Inc. (AECOM) conducted economic analyses for the identified alternative of the Richfield-West Sevier Watershed Plan. This technical memorandum presents National Economic Development (NED) benefits that were developed following guidance in the *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (U.S. Water Resources Council 1983). The primary benefit categories evaluated were agricultural benefits and community (residential and non-residential structures, roads and bridges, other infrastructure) flood risk management benefits.

This memorandum describes the methods used to quantify damages avoided for the identified alternative (hereafter with-project alternative). Table 1-1 describes the with-project alternative.

Table 1-1. Description of the With-Project Alternative

Component	Description
Flat Canyon Debris Basin	Construct a debris basin near the mouth of Flat Canyon
South Flood Channel	Construct a channel to divert floodwaters from Flat Canyon
North Flood Channel	Construct a channel to divert floodwaters from Flat Canyon

Economic feasibility for a with-project alternative is determined by comparing the average annual benefits to the average annual costs. If the average annual benefits for a with-project alternative exceed the average annual costs, then the alternative is considered economically feasible. The economic analysis considers the no-action scenario (hereafter without-project alternative) as the baseline condition, which does not have any benefits or costs associated with it. Changes resulting from implementation of a with-project alternative in relation to the without-project alternative would be measured as a benefit or a dis-benefit.

The analyses of benefits associated for the with-project alternative include damage reduction to residential and nonresidential structures (e.g., residential, commercial, religious facility, government), contents, automobiles, agriculture, and debris removal.

The benefit categories represent damage reduction from future flooding and are evaluated in average annual terms. The flood damage reduction analysis uses inundation models for eight flood recurrence intervals, which are the 50-percent- (2-year), 20-percent- (5-year), 10-percent- (10-year), 4-percent- (25-year), 2-percent- (50-year), 1-percent- (100-year), 0.5-percent- (200-year), and 0.2-percent- (500-year) annual-probability flood events, to estimate future damages from flooding within the study area.

Benefits and costs over the period of analysis were annualized to allow for a direct comparison of average annual benefits to average annual costs. The benefits and costs were evaluated using a 2025 price level over a 102-year period of analysis (2 years of construction and 100-year evaluation period). The costs and benefits were annualized over the 100-year evaluation period using a 3.0 percent discount rate. Table 1-2 outlines the average annual benefits and costs for the with-project alternative and summarizes the analysis results.

Table 1-2. Benefit-Cost Analysis Summary

Alternative	Average Annual Benefits	Average Annual Costs	Benefit-Cost Ratio	Net Benefits
With-Project Alternative	$1,757,000	$685,000	2.6:1.0	$1,072,000

Notes: 2025 price level, annualized over the 100-year evaluation period using a 3.0% discount rate.

The following sections discuss the types of evaluations and methods used in the economic analysis.

2.0 Economic Evaluation Procedures, Assumptions, and Methods

The analyses of damages associated with the alternatives include damages or costs incurred for a range of benefit categories. The benefits evaluated include damage reductions to residential and nonresidential structures and contents, automobiles and agriculture, and debris removal. Damages to structures and contents typically account for the most damages that result from a flood event, and therefore, form the foundation of the economic analyses. Damages were estimated using custom-built economic models.

2.1 Structure-Related Damages

Knowledge of existing residential and nonresidential development located in a floodplain is essential when evaluating a flood-risk-management project. Structure-related damages assessed include damages to residential and nonresidential structures, contents, and automobiles, and debris removal. The methods used to assess structure damages are described in this section.

2.1.1 Structure Inventory

A structure inventory was undertaken to estimate the residential and nonresidential structures located in the study area, which serves as the base data for the economic analysis. The structure inventory comprises residential (with and without basements) and nonresidential structures that are within the area of inundation based on the hydrologic and hydraulic (H&H) models. Data from the Sevier County Assessor's Office were utilized as the basis for the structure inventory.

In addition, a 50-foot buffer was used in calculating relative flood depths from the flood inundation models. This was done to ensure the analysis captures the flooding that would affect structures that are partially flooded (i.e., partial building flooding that does not cover the address point near the center of the building) as well as to better represent the two-dimensional (2D) modeling result (i.e., the 2D model accounts for the hydraulics of water moving around building obstructions, and therefore reported water surface elevations vary between the middle and outer boundary of a structure footprint).

Structures that could be inundated during the 0.2-percent-annual probability flood event (the maximum flood extent assessed) were inventoried. A summary of the structures included in the inventory is provided in

Table 2-1, which provides a breakdown of the number of structures potentially vulnerable to the 0.2-percent-annual-probability flood event by structure type.

Table 2-1. Structures Inventoried

Structure Type	Count
Apartments	86
Convenience Store	1
Fast Food	1
Grocery Store	6
Industrial - Light	14
Manufactured	27
Medical Office	8
Non-Fast Food	11
Office - One Story	70
Recreation	2
Religious Facility	10
Residential – One Story, Basement	113
Residential – One Story, No Basement	487
Residential – Two Story, Basement	5
Residential – Two Story, No Basement	13
Retail - Clothing	28
Retail - Electronics	16
Schools	4
Service Station	21
Split Level – Basement	4
Split Level – No Basement	5
Warehouse – Non-Refrigerated	15
Total	**947**

The analysis estimated the mean adjacent ground elevation of each residential and nonresidential structure by overlaying the 50-foot-buffered centroid of each address point, which was found to generally be near the center of the structure footprints on LiDAR data. The first-floor elevation (FFE) of each structure was estimated based on adding the ground elevation and an assumed foundation height. Table 2-2 lists the foundation height assumptions used to estimate the FFE (ground elevation plus foundation height) of each structure.

Table 2-2. Assumed Foundation Heights

Structure Type	Foundation Height (Feet Above Ground Level)
Nonresidential	0.5
Residential, no basement	1
Residential, basement	1.5

Detailed data from the Sevier County Assessor's Office were used to determine structure characteristics. The tax assessor listed multiple valuation components (e.g., land, improvement) for each parcel. To avoid including land values when accounting for damages to residential and nonresidential structures,

the value listed under the improvement component in the tax assessor data was used as a proxy for the depreciated replacement value of each structure. For the structures in the analysis that did not have tax appraisal information available (e.g., schools), depreciated replacement values were estimated by multiplying the value per square foot assigned to each building type, as estimated using RS Means data, by the square footage of the total main area of the building. Depreciation rates were obtained from the Federal Emergency Management Agency (FEMA) Final Methodology Evaluation and Recommendations guidance (FEMA 2012). Table 2-3 lists the RS Means replacement values and the associated depreciation rates for each building type.

Table 2-3. RS Means Replacement Values and Depreciation Rates

Building Type	Replacement Value ($/sq. ft.)	Depreciation Rate
Apartments	$187	33.2%
Office – One Story	$214	31.9%
Fast Food	$199	31.9%
Non-Fast Food	$203	31.9%
Recreation	$177	31.9%
Religious Facility	$167	31.8%
Schools	$175	32.0%
Convenience Store	$121	31.9%
Grocery Store	$145	30.3%
Service Station	$200	31.3%
Medical Office	$240	34.7%
Warehouse – Non-Refrigerated	$133	31.3%
Retail – Electronics	$148	31.9%
Retail – Clothing	$148	31.9%
Protective Services	$189	31.9%
Industrial – Light	$116	31.3%
Residential – One Story, No Basement	$100	38.8%

The content value for each structure was estimated based on the structure's depreciated replacement value and the content-to-structure value ratio (CSVR) for the assigned building class.

Table 2-4 quantifies contents value as a percent of the building depreciated replacement value for each building class.

Table 2-4. Contents Value as a Percent of Structure Value

Building Class	CSVR (percent of structure's depreciated replacement value)
Apartments	12%
Convenience Store	38%
Fast Food	30%
Grocery Store	79%
Industrial – Light	44%
Medical Office	66%
Non-Fast Food	25%
Office – One Story	20%
Recreation	28%
Religious Facility	7%
Residential – One Story, No Basement	100%
Residential – One Story, Basement	100%
Residential – Two Story, No Basement	100%
Residential – Two Story, Basement	100%
Retail – Clothing	51%
Retail – Electronics	74%
Manufactured	100%
Schools	8%
Service Station	77%
Split Level – No Basement	100%
Split Level – Basement	100%
Warehouse – Non-Refrigerated	43%

Source: USACE 2019
Note: Split the difference between pre-engineered and engineered contents to building ratio values.

The methods used to calculate structure, contents, automobile, and debris removal damages are described in the following sections.

2.1.2 Structure and Content Damages

Each structure was assigned a depth-damage function (DDF) that estimates an economic loss as a percentage of the value of the structure based on the building class and depth of flooding. DDFs were sourced from the U.S. Army Corps of Engineers (USACE) Economic Guidance Memorandum (EGM) 04-01 (USACE 2003). DDFs for nonresidential buildings were sourced from FEMA's Benefit-Cost Analysis Toolkit (FEMA 2019). Because the DDFs estimate damages at 1-foot intervals, straight-line interpolation was used to estimate damages in 0.1-foot intervals.

Within each DDF, the ratios of damage for the building and its contents are provided in 1-foot increments. The analysis uses the depth of inundation to calculate the percent damage to each building per flood recurrence interval, which was then multiplied by the building depreciated replacement value to estimate the building damages. Similarly, the analysis uses the depth of inundation to calculate the percent damage to contents per flood recurrence interval, which was then then multiplied by the contents value to estimate the content damages.

2.1.3 Automobiles

The damages to automobiles were determined using the USACE EGM 09-04 (USACE 2009). In accordance with the guidance, the elevation of each automobile was assumed to be the mean ground elevation estimated at each building. The damages to vehicles at residences depends on the following: the average number of vehicles per household and the percentage of vehicles that are likely to be at the residence at the time the flood waters reach the property.

In 2016, the median number of vehicles per household in Sevier County, Utah, was two (Data USA 2019). As suggested by the guidance, the average vehicle value was obtained from Edmunds. According to the Edmunds Used Car Market Report (Edmunds 2018), the average retail value for used vehicles was $24,400 (adjusted to 2025 dollars using GDP deflator).

The length of potential warning time and the access to a safe evacuation route to a flood-free location were considered to estimate the percentage of vehicles that would likely remain in the flood-prone location. For Sevier County, the analysis assumes that the warning time would be less than 6 hours; therefore, 50.5 percent of the vehicles in the flood area would be evacuated according to USACE EGM 09-04 and 49.5 percent would remain.

Because only those vehicles not used for evacuation can be included in the damage calculations, an adjusted average vehicle value of $24,200 ($24,400 x 2 x 0.495) was assigned to each individual residential building record. The analysis calculates automobile damages for each flood recurrence interval.

2.1.4 Debris Removal

Debris can accumulate from flood damage, requiring effort to bring damaged materials to the street for pickup and removal. The costs associated with debris removal were estimated based on guidance from the USACE (2018). Costs associated with debris removal were assumed to be incurred based on building damages for the purposes of this analysis.

The debris removal costs were monetized for each residential building inundated in the analysis. Debris removal costs were estimated for residential structures with and without a basement. The debris cost per residential structure includes the hauling cost, tipping fee, and labor to remove debris and break it into pieces that could be hauled to the street for pickup.

FEMA has estimated 25 to 30 cubic yards of debris for a home without a basement and 45 to 50 cubic yards for a home with a basement. Assuming 1 ton of mixed debris has a volume of 4 cubic yards, the average volume for each building type equates to about 6.9 tons for a home without a basement and 11.9 tons for a home with a basement (FEMA 2010). Thus, 5 tons of debris is estimated for the basement level of a home.

The cost to load and haul away debris was estimated using the average labor cost per cubic yard of $31.30 ($125 per ton) from the Homewyse Debris Removal Cost Calculator (Homewyse, 2019, updated to 2025 dollars). The tipping fee of $31 per ton for the Sevier County Landfill was used in place of the disposal cost. The analysis assumes a debris removal cost of $156 per ton (2025 dollars).

Using the Homewyse Debris Removal Cost Calculator (2019), the number of labor hours to break down debris and move it from the building site to the street was estimated to be 1.4 hours for every cubic yard of debris. Because homeowners are forgoing other activities to clean up debris, including work and leisure, the opportunity cost was used to value this time. The value of time was estimated using the 2017 median household income for Sevier County from the Census and updating to 2025 dollars using

the GDP Deflator before dividing by 2,080 hours to get $31.28 per hour per household, which represents the hourly opportunity cost of work per household (White House OMB). For leisure time, an opportunity cost of $20.85 was assigned based on the common practice used in economics literature to value recreation time as a fraction of the wage. In literature, this fraction ranges from one-third of the wage to the full wage; therefore, a fraction of two-thirds was used to estimate the opportunity cost of leisure. Finally, during the flood aftermath, owners were assumed to forego recreation time two-thirds of the time and forego work one-third of the time, for an average value of time of $24.33 per hour (2025 dollars). Table 2-5 presents the average cost of debris removal from a flooded residential building.

Table 2-5. Summary of Residential Debris Costs

Building Description	Cubic Yards of Debris	Average Tons of Debris	Debris Removal – Labor and Tipping	Labor Value	Total Debris Costs
Residential – No Basement	25 to 30	6.9	$1,000	$900	$2,000
Residential – Basement	45 to 50	11.9	$1,800	$1,600	$3,400
Basement Level Only	20	5	$700	$700	$1,400

Notes: 2025 price level, monetary values rounded to the nearest hundred.

2.2 Agriculture-Related Damages

Knowledge of existing agricultural land located in a floodplain is essential when evaluating flood-risk-management measures. Part of the analysis includes estimating the benefits of the with-project alternative based on a reduction in agricultural damages. Agricultural impacts assessed include economic losses due to crop damage and canal maintenance. The analysis is based on the timing, duration, and extent of flooding. This section describes the methods used to estimate agricultural damages in the analysis.

2.2.1 Flood Impacts

Flood damage to crops can result in replanting, fertilizing, additional spraying, and reduced crop yields. A flood occurring prior to the start of field preparation may cause damages (e.g., reduced yields) from delay of seeding. However, due to uncertainty, these damages were not captured in the model. Following a damaging flood that occurs near the beginning of the growing season, a farmer would likely rework the land and replant the same or a substitute crop to minimize loss. Variable production costs for a replanted crop are usually higher than those without a flood because additional fertilizer must be applied to offset loss of soil fertility, herbicides are often required to combat weed infestation, and additional preparation of seed beds is required. For a flood occurring too late in the season to replant, the damages are represented as the reduction of gross crop revenue from crop damage. The analysis assumes that damages to turfgrass (sod farms located in the area) were entirely from sedimentation, because turfgrass cannot be harvested after sediment has been deposited on it. Other crops were assumed to not experience damages from sedimentation because the agricultural land in the study area is far enough from the canyons that any sediment deposited would likely be fine materials that would not result in crop damages.

Seasonal crop damage curves were developed to calculate weighted average damage per acre of flooded agricultural land. Current normalized prices were used when available to counteract the

frequent short-term fluctuations of crop prices (Utah State University 2019).[1] Total crop damages per acre amount to the difference between the expected net income without a flood and the net income with a flood as well as additional planting and production costs incurred. Damages to pastures were limited to the replacement costs of the damaged fencing.

2.2.2 Crops in Study Area

Utah Department of Water Resources (UDWR) Water Related Land Use (2019) data were obtained for the region to identify the percentage of inundated land that is used for agriculture at each flood recurrence interval. The data were also used to identify which crops are grown in the study area and the percent of agricultural land they account for. Table 2-6 identifies the crops grown in the study area and the percent each crop makes up compared to total acres harvested.

Table 2-6. Crops in Study Area

Crop	Percent of Acres Planted
Alfalfa	53%
Corn (Silage)	9%
Pasture	35%
Turfgrass	3%

2.2.3 Crop Progress for Utah Crops

Prior to estimating crop damages associated with a flood occurring in each month, crop progress was estimated for crops grown in Sevier County. USDA's National Agricultural Statistics Service (NASS) information was obtained to determine the months in which crops were planted and harvested. Table 2-7 identifies the months in which corn is planted and harvested. Pastures were not accounted for because the damages to pastures included in the analysis are limited to damages to fencing that encloses the pasture. Damages to pastures do not include a loss in production value.

Table 2-7. Crop Progress

Crop	Progress	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Corn	Planted				20%	70%	10%						
	Harvested										50%	50%	

2.2.4 Crop Damage Analysis

The crop progress data for Utah crops identified in Table 2-7 were used to extract crop DDFs from the USACE Hydrologic Engineering Center – Flood Impact Analysis software (HEC-FIA). Necessary inputs to obtain DDFs include first plant date, full yield date, last planting date, and end of harvest date.

[1] Corn – silage price estimates were sourced from the silage price calculator for Box Elder County, which were provided in 2013 dollars and adjusted to 2025 dollars using the GDP deflator. 2006 Corn – silage prices for Sevier County, the most recent year available, were compared to 2006 corn – silage prices for Box Elder County to demonstrate prices were consistent statewide. Turfgrass unit prices were not used in the analysis.

Table 2-8 provides definitions for each input as defined in the HEC-FIA User's Manual (USACE 2012) and the respective assumption used in the analysis.

Table 2-8. HEC-FIA Assumptions

Date/Days	HEC-FIA Definition	Assumption
First Plant Date	First date that the crop can be planted.	First day of the earliest month in which crops were planted in Utah.
Full Yield Date	Latest date that the crop can be planted and still reach full maturity.	One month prior to the Last Planting date.
Last Planting Date	Latest date that the crop can be planted with a reduction in yield.	Last day of latest month in which crops were planted in Utah.
End of Harvest Date	Last date that the crop is harvested, after which little damage can be incurred.	Last day of final month in which crops are harvested.
Dryout Period (days)	Number of days after a flood has receded before the soil is sufficiently dry so replanting can begin. FIA automatically adds 7 days on to the dryout period to allow for re-cultivation of the fields.	The default value in HEC-FIA. Default includes a period of 3 days for dryout and 7 days for recultivation for a 10-day period following inundation before crops can be replanted.

The data in Table 2-7 were used to make the crop planting and harvesting date assumptions shown in Table 2-9, which were then used to extract the appropriate DDFs from HEC-FIA.[2]

Table 2-9. Crop Plant Data Assumptions

Crop	First Plant Date	Full Yield Date	Last Planting Date	End of Harvest Date
Corn	April 1	May 31	June 30	November 30

HEC-FIA provided damage estimates in “Initial % Crop Loss” values, which represent an estimate of the percentage of the mature crop value that is expected to be reported as damaged if the crop was planted on the First Plant Date. Initial % Crop Loss values depend on the date on which a flood event occurs and factors crop plant data into its estimates. HEC-FIA also categorizes crop damages as a percentage of crop yield for flood events lasting 0, 3, 7, and 14 days based on the vulnerability of the crop to flood damage. Straight-line interpolation was used to estimate total crop damages as a percent of crop yield for flood events lasting 1 and 2 days. Figure 2-1 is a screenshot of corn’s crop loss function during the month of April as generated by HEC-FIA.

[2] Crop progress assumptions for turfgrass farms were obtained from a phone conversation with Sevier County turfgrass farm owner. Consequently, crop progress data for turfgrass farms were not entered into HEC-FIA.

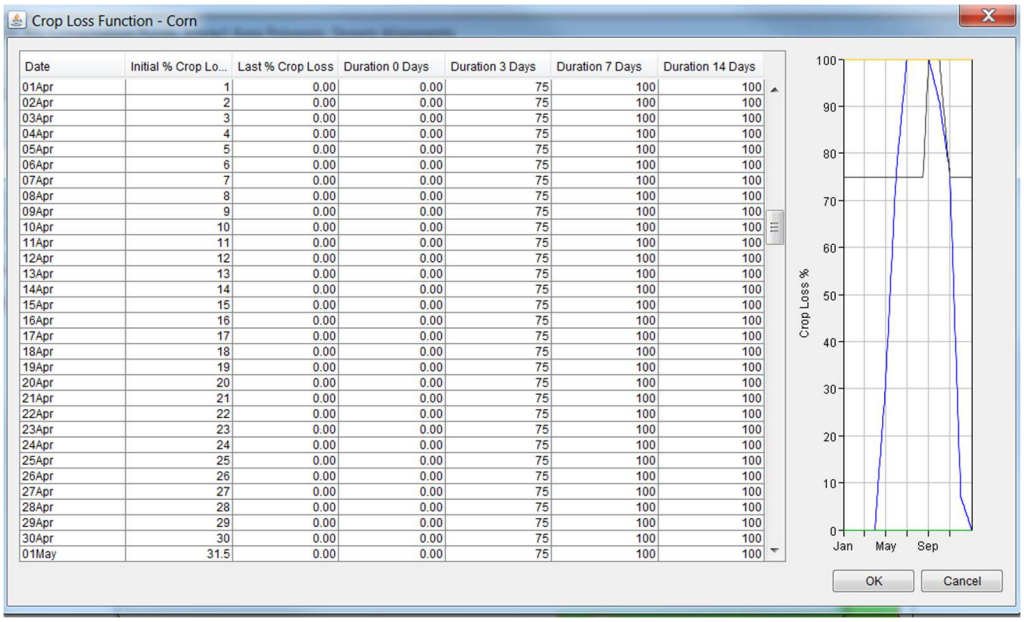


Figure 2-1. Crop Loss Function – Corn

Finally, the Initial % Crop Loss estimates were multiplied by expected damages from flood events lasting 0, 1, 2, and 3 days. The analysis also multiplied the Initial % Crop Loss and the Last % Crop Loss estimates by the estimated damages from flood events lasting 1 and 2 days, which were calculated using straight-line interpolation. Initial % Crop Loss estimates were multiplied by expected damages by flood duration to estimate the crop damages from flooding each day of the calendar year. Then, DDFs from HEC-FIA were averaged over each month to estimate crop damages by month.

Crop damages for alfalfa, one of the primary crops grown in the study area, were estimated using a different method. Alfalfa is a perennial crop that is typically replanted every three to five years. In the study area, it is common to cut and harvest alfalfa three times per year (June, July, and September), with each cutting providing about a third of the total harvest for the year.

While alfalfa is not considered to be tolerant of flooding, it can withstand short periods of flooding (i.e., a couple of days) without major damage. However, due to the sediment and velocity of the floodwater in the study area, it is estimated that 50 percent of the flooded acres would need to be replanted following a flood event with no harvestable crop until the following year for all of the inundated area.[3] The remaining acreage of flooded crop that was not severely impacted by flooding would not need to be replanted but would not be harvestable for the remainder of the year. This would allow the plant roots time to recover, to grow through any sediment, and to wash the sediment from the plants themselves. It is assumed that full production would resume the following year.

[3] Alfalfa analysis based on discussions with project engineers who have experience farming in the region.

Table 2-10 provides the crop damage assumptions for 1 to 3 days of inundation.

Table 2-10. Crop Damages from 1 to 3 days of Inundation

Crop (Duration of Inundation)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alfalfa (1 day)	0%	0%	0%	100%	100%	100%	67%	33%	33%	0%	0%	0%
Alfalfa (2 days)	0%	0%	0%	100%	100%	100%	67%	33%	33%	0%	0%	0%
Alfalfa (3 days)	0%	0%	0%	100%	100%	100%	67%	33%	33%	0%	0%	0%
Corn silage (1 day)	0%	0%	0%	4%	13%	22%	25%	27%	32%	24%	10%	0%
Corn silage (2 days)	0%	0%	0%	8%	27%	44%	50%	55%	64%	48%	20%	0%
Corn silage (3 days)	0%	0%	0%	12%	40%	66%	75%	82%	95%	72%	29%	0%
Pasture* (1 day)	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Pasture* (2 days)	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Pasture* (3 days)	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Turfgrass** (1 day)	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Turfgrass** (2 days)	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Turfgrass** (3 days)	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

*For pasture, the analysis assumes that the entire portion of a fence that has been inundated must be replaced. Consequently, flood damages are 100% per acre inundated.

**Crop damage assumptions for turfgrass farms are based on a phone conversation with a Sevier County turfgrass farm owner and were not obtained using HEC-FDA. The analysis assumes that damages to turfgrass are a result of sedimentation, and any flood event at any time of the year will require complete replanting regardless of the crop's progress. Any flood event will result in 100% damages and 100% replant for all inundated land, as the turf cannot be harvested after sediment has been deposited on it following a flood event.

2.2.5 Crop Planting and Production Prices

To monetize crop damages, the analysis estimated direct (variable) costs and indirect (fixed) costs for alfalfa and corn, estimated by acre, using data on budgets by commodity sourced from Utah State University's Crop and Livestock Budgets (2019) based on estimates for Sevier County. Direct costs include items such as fertilizer, herbicides, seed, equipment operations, labor, and crop insurance. Indirect costs include items such as equipment, management, cash rent, and liability insurance. Additional planting costs per acre were seed, fertilizer, equipment operating expenses, and crop insurance. Also, during the growing season three additional sprays of herbicide would be required after flooding. Replanting costs for pasture account for the costs to replace the damaged fencing, rather than costs associated with replanting a crop. Replanting cost for turfgrass farms was estimated based on a phone conversation with a Sevier County turfgrass farm owner. Table 2-11 lists estimates for crop replanting and production costs per acre for all crops in the study area.

Table 2-11. Planting and Production Costs per Acre

Item	Crop (2025$)			
	Alfalfa	Corn	Pasture	Turfgrass**
Seed	$28	$66	N/A	N/A
Herbicides	$80	$187	N/A	N/A
Fertilizer	$31	$97	N/A	N/A
Trucking	$17	$45	N/A	N/A
Crop Insurance	$19	$22	N/A	N/A
Replanting Cost (per acre)	**$95**	**$229**	**$30***	**$4,278**
Additional Production Cost (per acre)	**$80**	**$187**	**$0**	**$0**

* Account for the costs to replace the damaged fencing, rather than costs associated with replanting a crop.

** Replanting cost for turfgrass farms was estimated based on a phone conversation with a Sevier County turfgrass farm owner.

The analysis assumes replanting would occur following any flood event that occurred in a month in which the damaged crop could be replanted (i.e., before the last plant date). Acres replanted were assumed to equal acres damaged in the flood event.

2.2.6 Crop Production Value

To complete the assessment of agricultural flood damages, production values of each crop per acre were estimated by multiplying the average yield by the normalized price per unit. Yields per acre were obtained from the Utah State University Crop Budgets (2019). Normalized prices for alfalfa were sourced from NASS (2018) and Utah Department of Agriculture and Food (2018). Normalized prices for corn were obtained from the Utah State University Corn Silage Price Calculator. The average production value of turfgrass per acre was estimated by a Sevier County turfgrass farm owner. The production value of pasture per acre was not considered in the analysis. Agricultural prices were standardized to be the value per bushel. Table 2-12 displays the average crop yield and average production value per acre for all crops in the analysis.

Table 2-12. Average Crop Yield and Average Production Value

Item	Crop (2025$)			
	Alfalfa	Corn – Silage	Pasture	Turfgrass*
Average yield (bushel/acre)	130	196	N/A	N/A
Normalized prices (per bushel)	$6.53	$9.97	N/A	N/A
Average production value per acre	$850	$1,950	N/A	$8,020

*Average production value of turfgrass farms ranges from $0.04 to $0.31 per square foot based on a phone conversation with a local turfgrass farm owner. The analysis assumes the production value of turfgrass farms is $0.16 per square foot.

2.2.7 Likelihood of Flooding by Month

The next step was to determine the likelihood of a flood occurring each month. The probability that a flood event would occur in a month was estimated from monthly precipitation data for Sevier County between 1987 and 2017 from the National Oceanic and Atmospheric Administration (NOAA 2019). Average monthly precipitation values were divided by the total average annual precipitation to calculate the percentage of precipitation that occurs each month. The percentage of precipitation per month was used as a proxy for the likelihood of a flood event occurring (see Table 2-13).

Table 2-13. Likelihood of Flooding by Month

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
8%	8%	10%	10%	8%	4%	8%	9%	8%	10%	7%	9%

An Excel-based model was developed to estimate the average annual agricultural damages for the with- and without-project scenarios. The model incorporates the factors presented above and H&H data that estimates the agricultural acres flooded by duration for eight flood recurrence intervals (50-, 20-, 10-, 4-, 2-, 1-, 0.5-, and 0.2-percent-annual-probability flood events).

2.3 Economic Analysis Benefits, Costs, and Results

The following sections summarize benefits quantified in the analysis.

2.3.1 Structure-Related Benefits

The with-project would result in structure-related benefits that result from a reduction in inundation. Table 2-14 lists the number of structures protected.

Table 2-14. Number of Buildings Protected for the 0.2-percent-annual-probability Flood Event

Alternative	Buildings Inundated under Without-Project Scenario	Buildings Inundated under With-Project Scenario	Buildings Protected
With-Project Alternative	947	0	947

Structure-related benefits include damage reductions to structures, contents, automobiles, and debris removal. Structure-related benefits evaluated are summarized by recurrence interval and structure type in Table 2-15.

Table 2-15. Structure-Related Benefits by Flood Event and Structure Type (in thousands)

Structure Type	Annual Probability							
	50%	20%	10%	4%	2%	1%	0.5%	0.2%
Apartments	$0	$0	$0	$0	$0	$15,358	$15,672	$15,767
Convenience Store	$0	$0	$0	$0	$0	$211	$216	$216
Fast Food	$0	$0	$0	$0	$0	$54	$54	$54
Grocery Store	$0	$458	$458	$475	$492	$3,392	$3,463	$3,480
Industrial - Light	$0	$0	$0	$5	$11	$771	$782	$791
Manufactured	$0	$0	$0	$0	$10	$1,570	$1,593	$1,616
Medical Office	$0	$0	$0	$0	$0	$412	$415	$418
Non-Fast Food	$0	$0	$0	$0	$0	$3,986	$3,993	$3,993
Office - One Story	$0	$131	$131	$141	$151	$4,775	$4,818	$4,826
Recreation	$0	$0	$0	$0	$0	$717	$776	$776
Religious Facility	$0	$0	$0	$0	$0	$4,331	$4,343	$4,343
Residential – One Story, Basement	$0	$246	$260	$466	$559	$9,972	$10,026	$10,061
Residential – One Story, No Basement	$0	$0	$19	$72	$127	$28,689	$28,929	$29,017
Residential – Two Story, Basement	$0	$0	$0	$0	$0	$375	$375	$379
Residential – Two Story, No Basement	$0	$0	$0	$0	$0	$615	$619	$622
Retail - Clothing	$0	$0	$0	$0	$0	$472	$477	$477
Retail - Electronics	$0	$0	$0	$0	$0	$444	$453	$454
Schools	$0	$0	$0	$0	$0	$3,609	$3,615	$3,615
Service Station	$0	$79	$79	$82	$85	$1,490	$1,499	$1,508
Split Level – Basement	$0	$0	$0	$0	$0	$221	$222	$222
Split Level – No Basement	$0	$0	$0	$12	$15	$129	$130	$131
Warehouse - Non-Refrigerated	$0	$243	$243	$264	$286	$905	$938	$965
Total	**$0**	**$1,158**	**$1,190**	**$1,517**	**$1,736**	**$82,497**	**$83,409**	**$83,731**

Average annual structure-related benefits are summarized in Table 2-166.

Table 2-166. Average Annual Structure-Related Benefits

Alternative	Structure Related Benefits
With-Project Alternative	$1,492,000

Note: 2025 price level.

2.3.2 Agriculture-Related Benefits

To estimate agricultural losses, H&H data estimated agricultural land inundated for each flood recurrence interval. Each with-project scenario would result in a reduction in inundation of agricultural lands. Table 2-177 summarizes total agricultural land inundated for the 1-percent-annual-probability flood event and the 0.2-percent-annual-probability flood event by crop.

Table 2-177. Breakdown of Agricultural Land Inundated by Crop (acres)

Crop	1-Percent-Annual Probability	0.2-Percent-Annual Probability
Alfalfa	1,340	1,480
Corn (Silage)	240	270
Pasture	880	980
Turfgrass	80	90
Total	**2,540**	**2,820**

A summary of agricultural land protected from the 1-percent- and 0.2-percent-annual probability flood events is provided in

Table 2-118.

Table 2-18. Area of Agricultural Land Protected (acres)

Alternative	1-Percent-Annual Probability			0.2-Percent-Annual Probability		
	Agricultural land inundated - without-project	Agricultural land inundated – with-project	Agricultural land protected	Agricultural land inundated - without-project	Agricultural land inundated – with-project	Agricultural land protected
With-Project Alternative	2,540	0	2,540	2,820	0	2,820

Note: Acreage inundated is rounded to the nearest ten.

Table 19 summarizes the average annual agriculture-related benefits, which include damage reductions to crops and sediment reductions.

Table 2-19. Average Annual Agriculture-Related Benefits

Alternative	Agriculture-Related Benefits
With-Project Alternative	$265,000

2.3.3 Cost Analysis

Average annual NED costs associated with with-project alternative include costs for design and construction and operations and maintenance (O&M). Interest during construction was included in the average annual cost calculation. Table 2-180 shows the cost breakdown.

Table 2-180. Cost Breakdown

Alternative	Total Implementation Costs	Average Annual O&M	Average Annual Costs
With-Project Alternative	$20,629,000	$12,000	$685,000

Notes: 2025 price level, annualized over the 100-year evaluation period using a 3.0% discount rate, average annual cost includes interest during construction, costs are rounded to the nearest thousand.

2.3.4 Results of Economic Analysis

The NED plan is the federally assisted project measures that provide for the greatest net economic benefits. Table 2-191 summarizes the average annual benefits, average annual costs, and the benefit-cost ratio.

Table 2-191. Benefit-Cost Analysis Summary

Alternative	Average Annual Benefits	Average Annual Costs	Benefit-Cost Ratio	Net Benefits
With-Project Alternative	$1,757,000	$685,000	2.6:1.0	$1,072,000

Notes: 2025 price level, annualized over the 100-year evaluation period using a 3.0% discount rate, values may not sum due to rounding.

3.0 References

Data USA. 2019. Sevier County, UT. https://datausa.io/profile/geo/sevier-county-ut#housing. Accessed 3-15-2019.

Edmunds. 2018. Used Car Market Quarterly Report; Q3 2018. https://www.edmunds.com/industry-center/data/used-car-market-quarterly-report.html.

Federal Emergency Management Agency (FEMA). 2010. Debris Estimation Field Guide; FEMA 329. Available at: https://www.fema.gov/pdf/government/grant/pa/fema_329_debris_estimating.pdf (accessed 1-17-2024).

——. 2012. Final Methodology Evaluation and Recommendations, Revisions to the Depreciation Methodology in the Substantial Damage Estimator (SDE) Version 2.0.

——. 2019. Benefit-Cost Analysis Toolkit, Version 6.0. https://www.fema.gov/media-library/assets/documents/179903.

Homewyse. 2019. Cost to Remove Construction Debris. https://www.homewyse.com/services/cost_to_remove_construction_debris.html.

National Oceanic and Atmospheric Administration (NOAA). 2019. National Centers for Environmental Information: Climate at a Glance County Time Series. https://www.ncdc.noaa.gov/cag/county/time-series/UT-041/tavg/1/4/1987-2017?base_prd=true&firstbaseyear=1901&lastbaseyear=2000.

U.S. Army Corps of Engineers (USACE). 2003. Economic Guidance Memorandum (EGM) 04-01, Generic Depth-Damage Relationships for Residential Structures with Basements. Available at: https://planning.erdc.dren.mil/toolbox/library/EGMs/egm04-01.pdf (accessed 1-17-2024).

——. 2009. Economic Guidance Memorandum, 09-04, Generic Depth-Damage Relationships for Vehicles. Available at: https://planning.erdc.dren.mil/toolbox/library/EGMs/egm09-04.pdf (accessed 1-17-2024).

——. 2012. HEC-FIA Flood Impact Analysis, User's Manual. Version 2.2. Available at: https://www.hec.usace.army.mil/software/hec-fia/documentation/HEC-FIA_22_Users_Manual.pdf (accessed 1-17-2024).

——. 2018. Souris River Basin Flood Risk Management Draft Feasibility Report With Integrated Environmental Assessment; Bottineau, McHenry, Renville, and Ward Counties, North Dakota. Appendix E: Economics. https://www.mvp.usace.army.mil/Portals/57/docs/Civil%20Works/Flood%20Risk%20Management/Souris%20River/Appendix%20E%20Economics.pdf?ver=2018-11-19-105908-867.

——. 2019. Hydrologic Engineering Center – Flood Damage Reduction Analysis (HEC-FDA), Version 1.4.2. Default Values. https://www.hec.usace.army.mil/software/hec-fda/.

U.S. Department of Agriculture National Agricultural Statistics Service (NASS). 2018. Normalized Prices. http://www.ers.usda.gov/data-products/normalized-prices.aspx.

——. 2019. Crop Progress and Condition in Utah, 2019. Available at: https://www.nass.usda.gov/Charts_and_Maps/Crop_Progress_&_Condition/2019/UT_2019.pdf (accessed 1-17-2024).

U.S. Water Resources Council (USWRC). 1983. Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies.

Utah Department of Agriculture and Food (UDAF). 2018. Annual Report. Available at: https://ag.utah.gov/documents/2018AgriculturalStatistics (accessed 1-17-2024).

Utah Department of Water Resources. 2019. Water Related Land Use. https://gis.utah.gov/data/planning/water-related-land/.

Utah State University. 2019. Crop and Livestock Budgets. https://extension.usu.edu/boxelder/agriculture_natural_resources/crop_livestock_budgets.

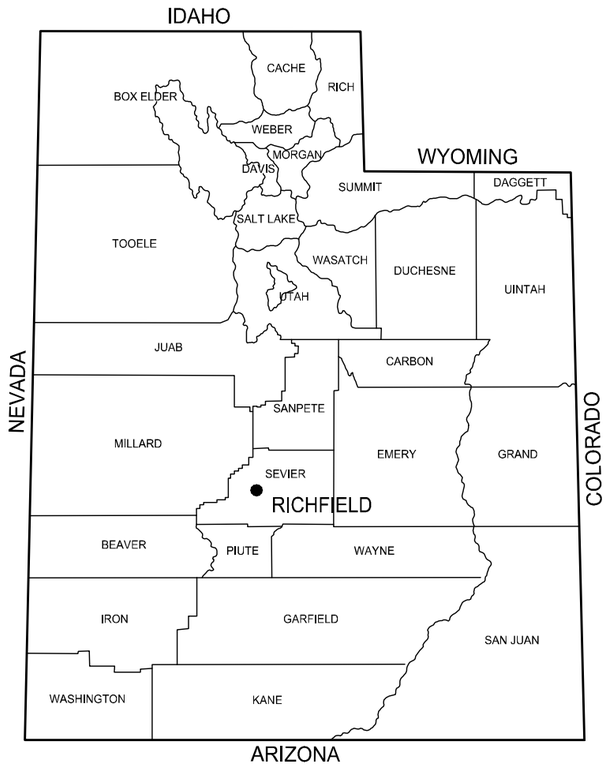
White House Office of Management and Budget (OMB). Historical Tables. Table 10.1 – Gross Domestic Product and Deflators Used in the Historical Tables: 1940-2021. https://www.whitehouse.gov/omb/budget/Historicals.

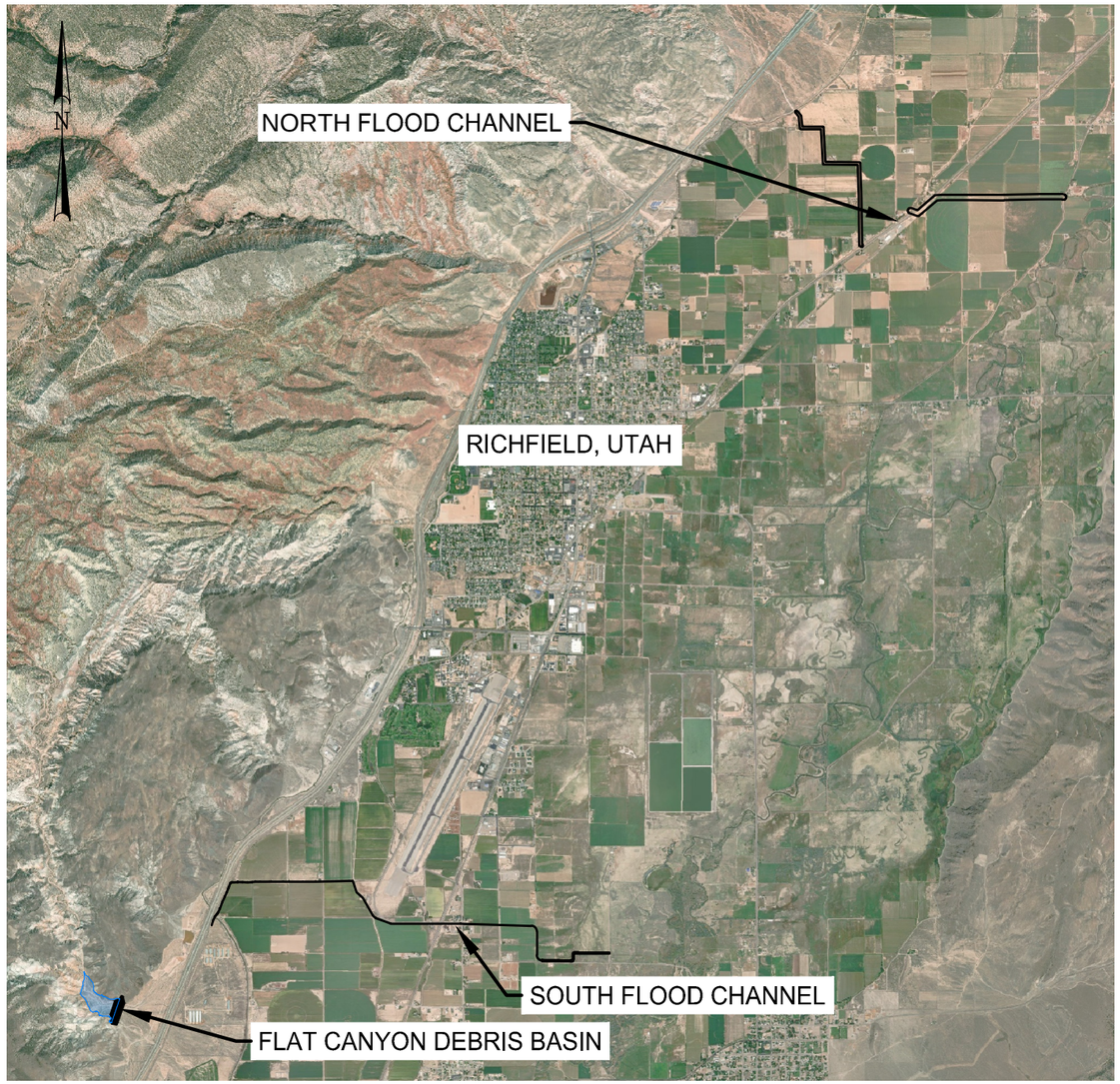
TM007 – Conceptual Design Drawings

SEVIER COUNTY NRCS WATERSHED PLAN

SEVIER COUNTY, UTAH

2025

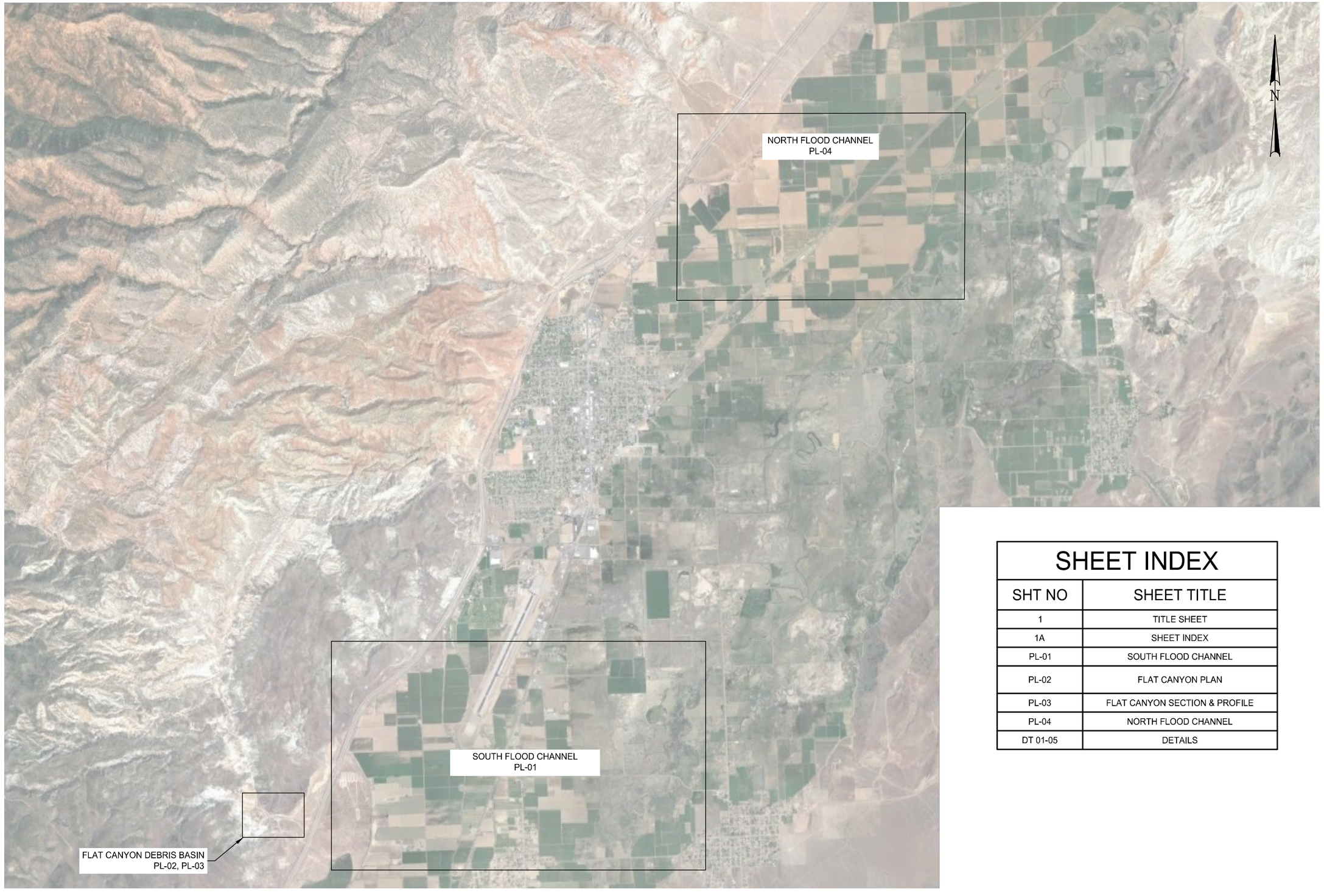




VICINITY MAP

Jones & DeMille Engineering, Inc.
CIVIL ENGINEERING - SURVEYING - TESTING
GIS - ENVIRONMENTAL
- infrastructure professionals -
1.800.748.5275 www.jonesanddemille.com

h:\t\proj\1884-224\dwg\title



SHEET INDEX

SHT NO	SHEET TITLE
1	TITLE SHEET
1A	SHEET INDEX
PL-01	SOUTH FLOOD CHANNEL
PL-02	FLAT CANYON PLAN
PL-03	FLAT CANYON SECTION & PROFILE
PL-04	NORTH FLOOD CHANNEL
DT 01-05	DETAILS

REVISIONS

NO.	DATE	REMARKS

SCALE: NONE

DWG NAME: H:\JD\Proj\1804-224\dwg\Title.dwg

UPDATED: 5/14/2025
PLOTTED: 5/14/2025

Jones & DeMille Engineering, Inc.
CIVIL ENGINEERING - SURVEYING - TESTING
GIS - ENVIRONMENTAL
1.800.748.5275 www.jonesanddemille.com

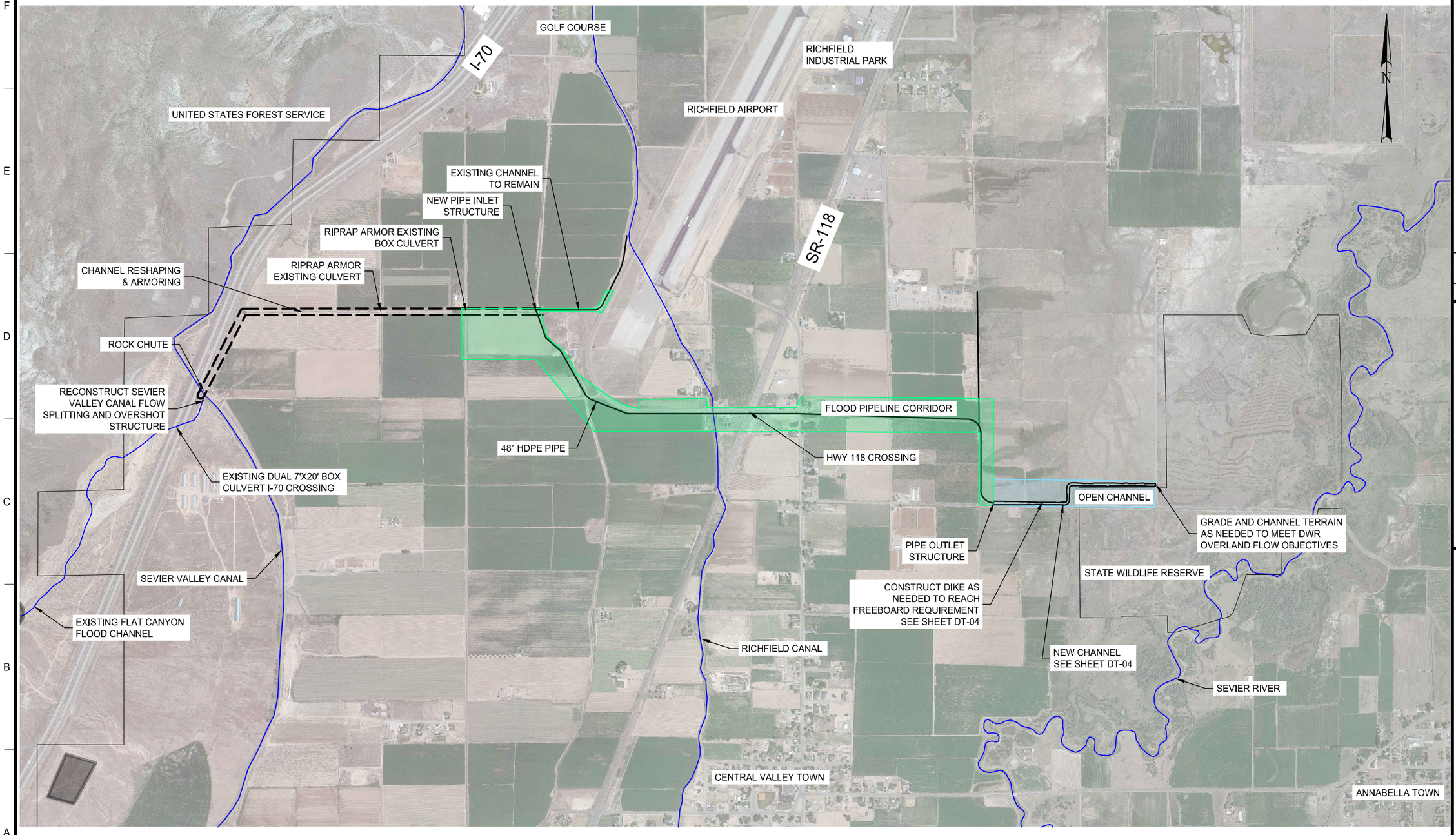
APPROVAL RECOMM: PROJECT DESIGN ENGINEER DATE

APPROVED QUALITY MANAGEMENT REVIEW DATE

SEVIER COUNTY
SEVIER COUNTY NRCS WATERSHED PLAN
SHEET INDEX
PROJECT NUMBER: 1804-224

SEVIER
COUNTY

SHEET NO. 1A



REVISIONS

NO.	DATE	REMARKS

UPDATED: 5/14/2025
PLOTTED: 5/14/2025

DWG NAME: H:\JD\Proj\1804-224\dwg\FltMCynFldChnl.dwg

SCALE: NONE

Jones & DeMille Engineering, Inc.
CIVIL ENGINEERING - SURVEYING - TESTING
GIS - ENVIRONMENTAL
1.800.748.5275 www.jonesanddemille.com

PROJECT DESIGN ENGINEER DATE
APPROVAL RECOMM.
QUALITY MANAGEMENT REVIEW DATE
APPROVED

SEVIER COUNTY

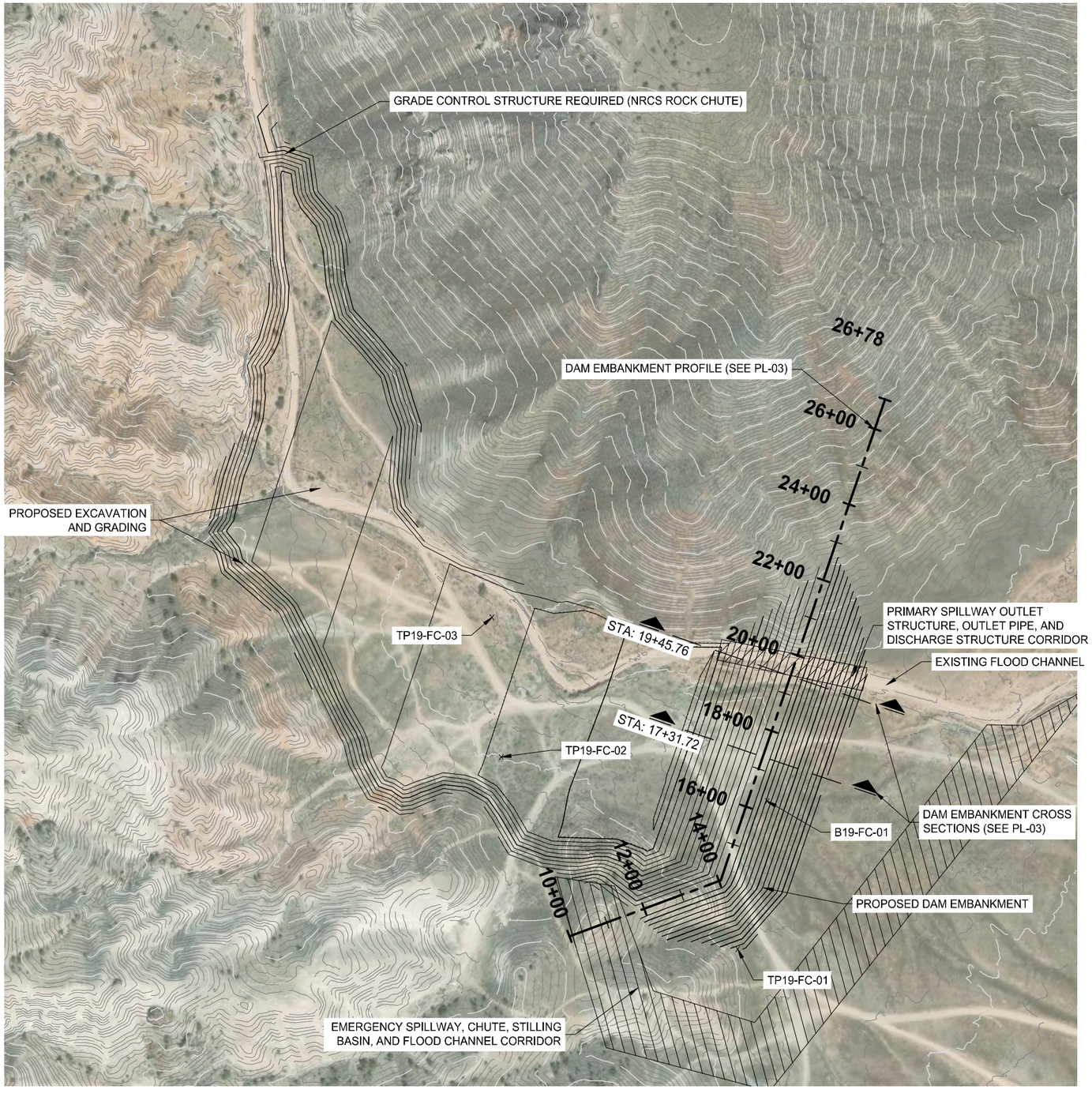
SEVIER COUNTY NRCS WATERSHED PLAN

SOUTH FLOOD CHANNEL

PROJECT NUMBER: 1804-224

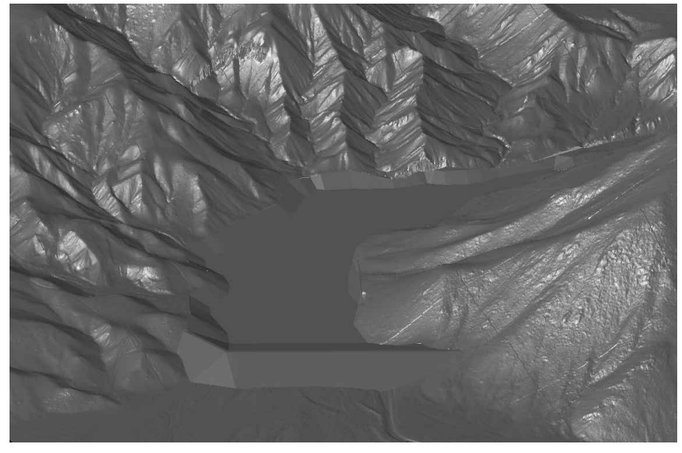
SEVIER
COUNTY

SHEET NO. PL-01



5 FOOT CONTOUR INTERVAL
SCALE: 1" = 300'

DAM CREST ELEVATION = 5,609.0
EMERGENCY SPILLWAY CREST ELEVATION = 5,599.0
STORAGE AT EMERGENCY SPILLWAY CREST = 826.9 AC.FT.
100-YEAR SEDIMENT ELEVATION =
100-YEAR SEDIMENT STORAGE = 359.0 AC. FT.
EMBANKMENT EARTHWORK VOLUME = 313723 CY
TOTAL APPROXIMATE EMBANKMENT HEIGHT = 73.0



REVISIONS

NO.	DATE	REMARKS

SCALE: 1" = 300'
DWG NAME: H:\JD\Proj\1804-224\dwg\FlatCynLower.dwg
UPDATED: 5/14/2025
PLOTTED: 5/14/2025

Jones & DeMille Engineering, Inc.
CIVIL ENGINEERING - SURVEYING - TESTING
GIS - ENVIRONMENTAL
1.800.748.5275 www.jonesanddemille.com

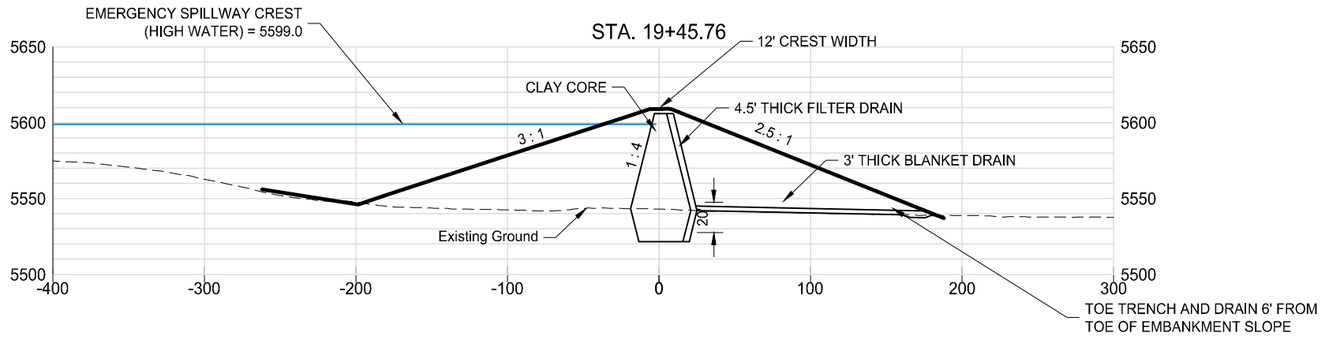
APPROVAL RECOMM: PROJECT DESIGN ENGINEER DATE
APPROVED QUALITY MANAGEMENT REVIEW DATE

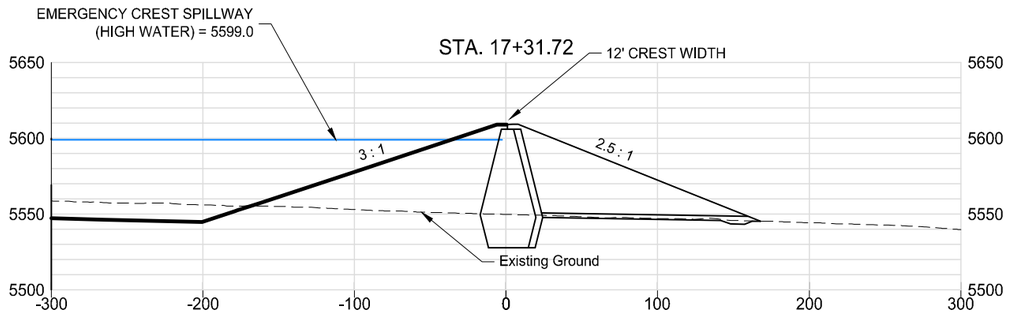
SEVIER COUNTY WATERSHED PLAN
FLAT CANYON
PLAN
PROJECT NUMBER: 1804-224

SEVIER COUNTY

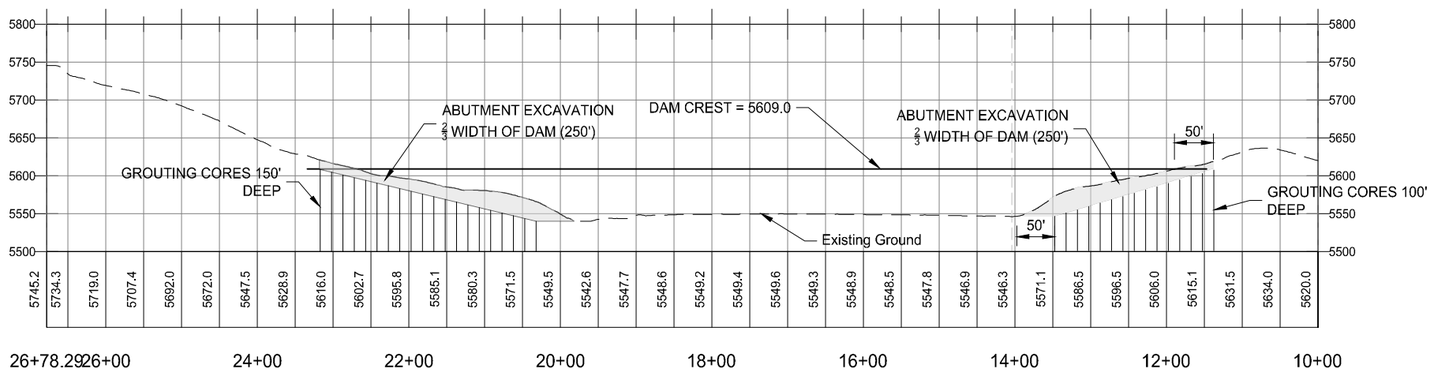
SHEET NO. PL-04

FLAT CANYON CROSS SECTIONS





FLAT CANYON DAM PROFILE



REVISIONS

NO.	DATE	REMARKS

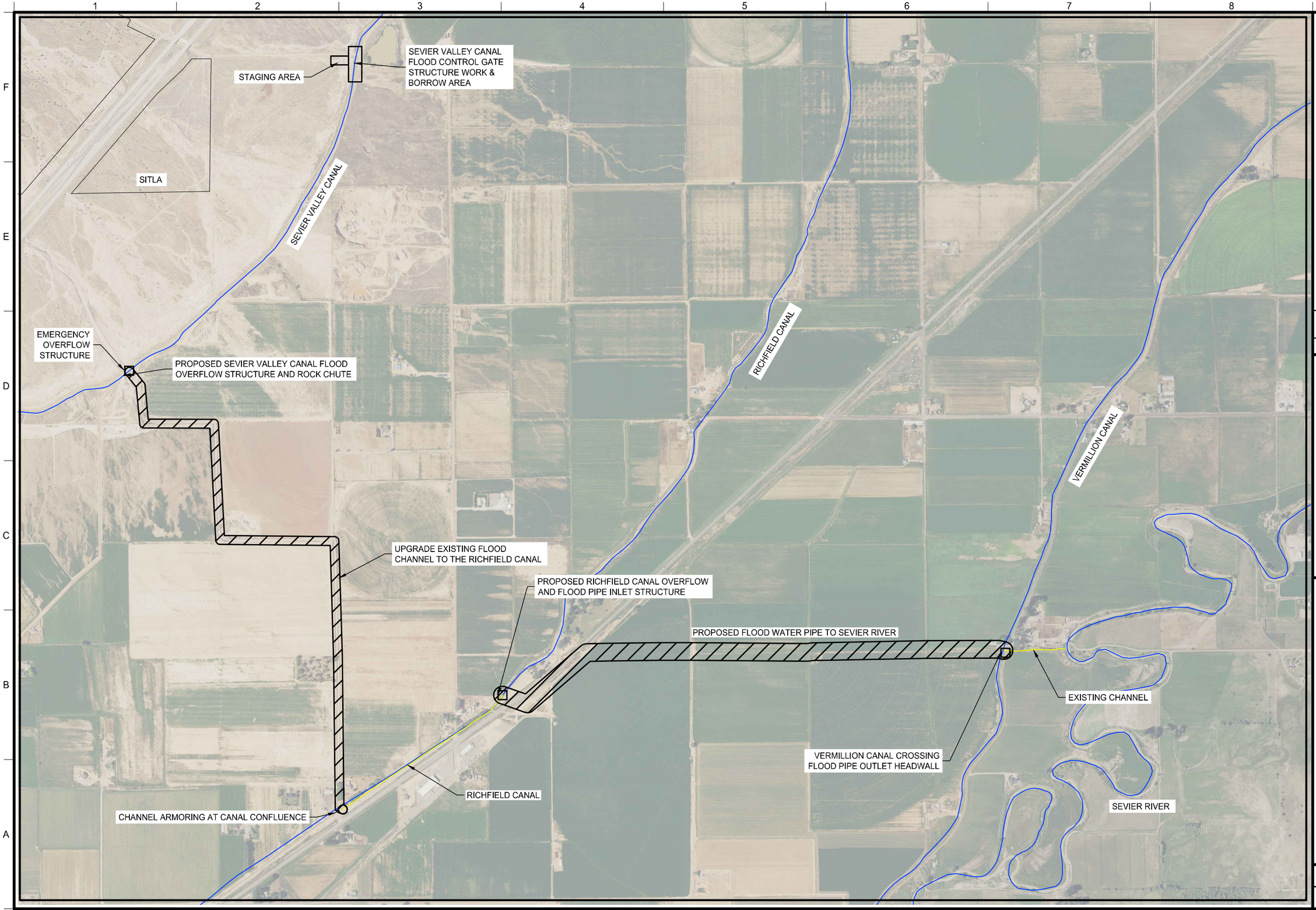
UPDATED: 5/14/2025
PLOTTED: 5/14/2025
DWG NAME: H:\JD\Proj\1804-224\dwg\FlatCynLower.dwg
SCALE: NTS

Jones & DeMille Engineering, Inc.
CIVIL ENGINEERING - SURVEYING - TESTING
GIS - ENVIRONMENTAL
1.800.748.5275 www.jonesanddemille.com

APPROVAL RECOMM: PROJECT DESIGN ENGINEER DATE
APPROVED QUALITY MANAGEMENT REVIEW DATE

SEVIER COUNTY WATERSHED PLAN
FLAT CANYON
CROSS SECTIONS AND PROFILE
PROJECT NUMBER: 1804-224

SEVIER
COUNTY
SHEET NO. PL-05



REVISIONS

NO.	DATE	REMARKS

SCALE: 1" = 1000'

DWG NAME: H:\JD\Proj\1804-224\dwg\WoodCyn\Civil

UPDATED: 5/14/2025

PLOTTED: 5/14/2025

Jones & DeMille Engineering, Inc.
CIVIL ENGINEERING - SURVEYING - TESTING
GIS - ENVIRONMENTAL
1.800.746.5275 www.jonesanddemille.com

APPROVAL RECOMM: PROJECT DESIGN ENGINEER DATE

APPROVED QUALITY MANAGEMENT REVIEW DATE

SEVIER COUNTY

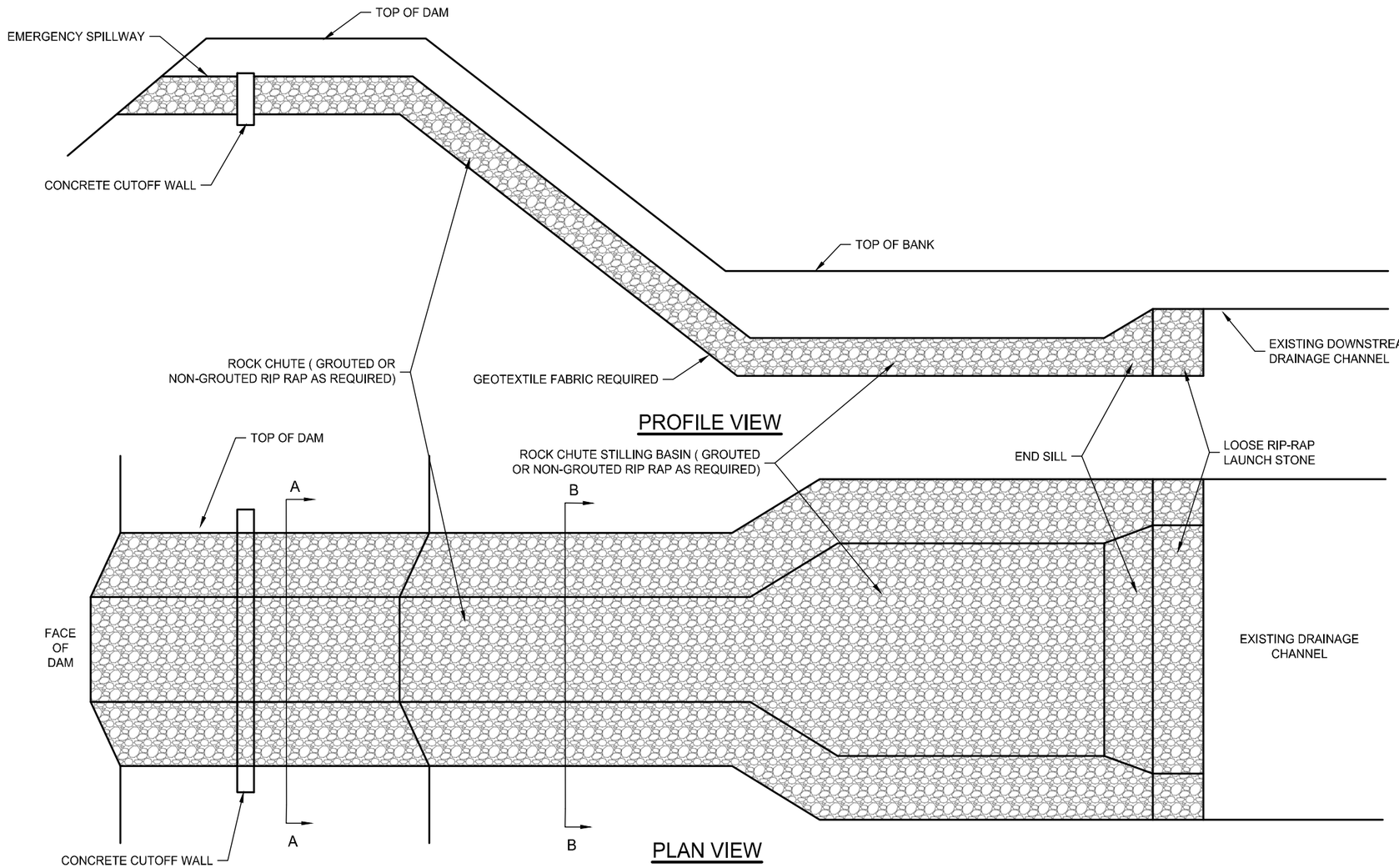
SEVIER COUNTY WATERSHED PLAN

NORTH FLOOD CHANNEL

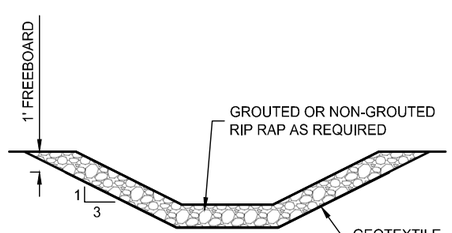
PROJECT NUMBER: 1804-224

SEVIER COUNTY

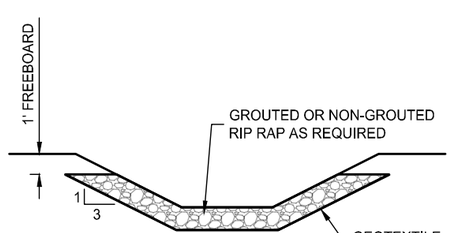
SHEET NO. PL-04



TYPICAL DAM SPILLWAY ROCK CHUTE DETAIL



A-A
ROCK CHUTE
CROSS SECTION



B-B
ROCK CHUTE
CROSS SECTION

REVISIONS

NO.	DATE	REMARKS

UPDATED: 5/14/2025
PLOTTED: 5/14/2025

DWG NAME: H:\JD\Proj\1804-224\dwg\details.dwg

SCALE: NTS

Jones & DeMille Engineering, Inc.
CIVIL ENGINEERING - SURVEYING - GIS - ENVIRONMENTAL
1.800.748.5275 www.jonesanddemille.com

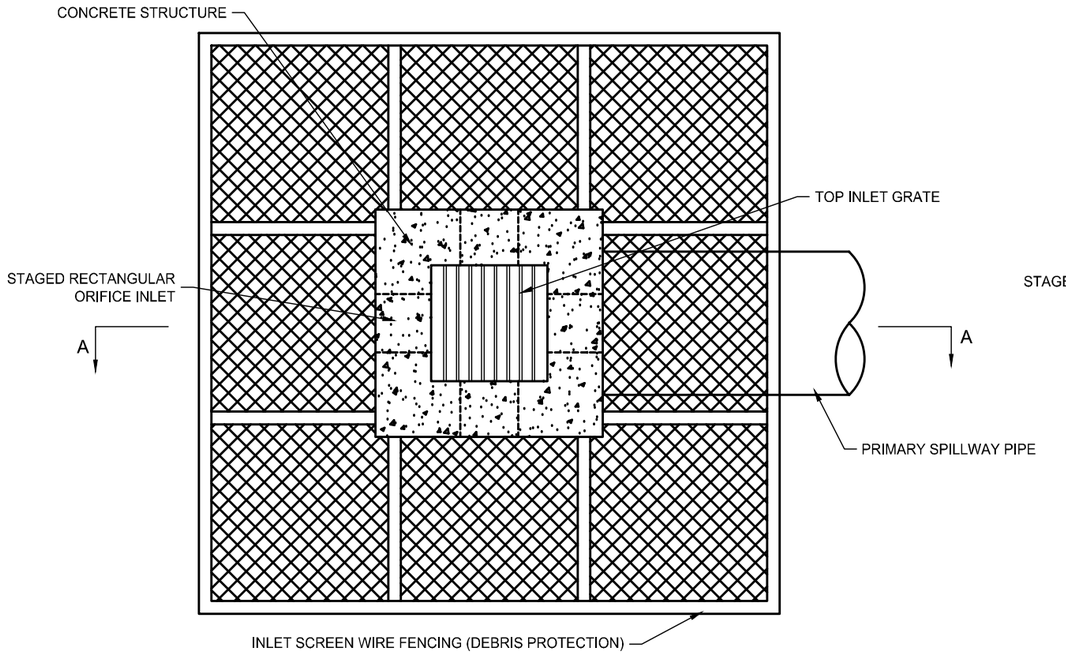
APPROVAL RECOMM. PROJECT DESIGN ENGINEER DATE
APPROVED QUALITY MANAGEMENT REVIEW DATE

TYPICAL ROCK CHUTE
SEVIER COUNTY NRCS WATERSHED PLAN
DETAIL

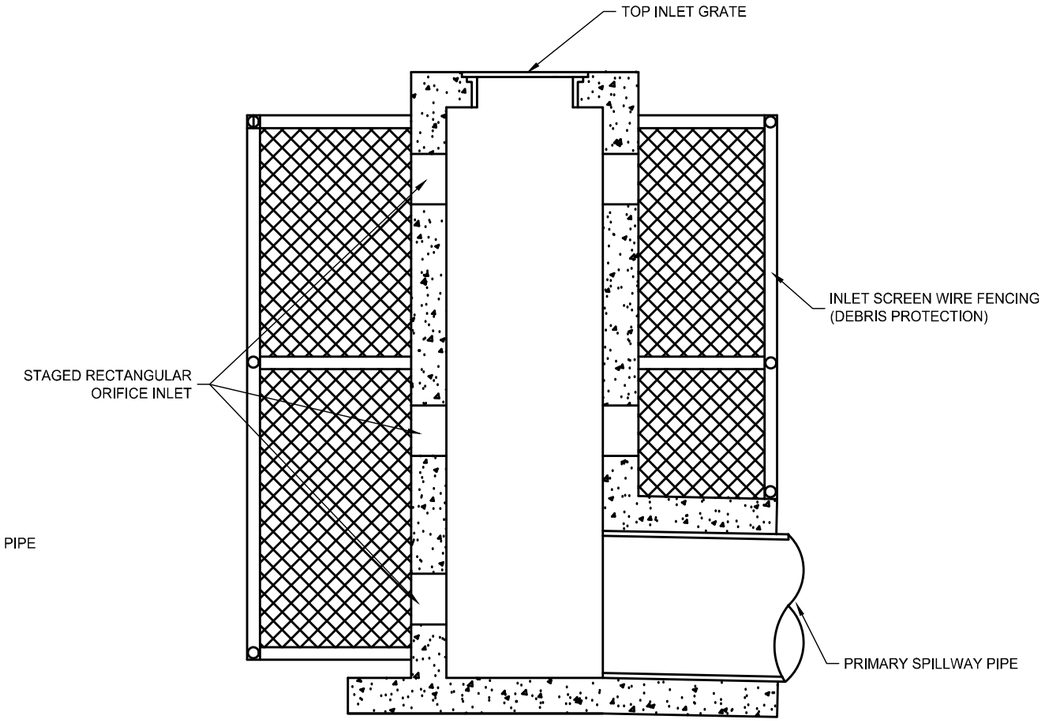
PROJECT NUMBER: 1804-224

SEVIER
COUNTY

SHEET NO. DT-01



PLAN



SECTION A-A

TYPICAL PRIMARY SPILLWAY RISER OUTLET DETAIL

REVISIONS

NO.	DATE	REMARKS

SCALE: NTS

DWG NAME: H:\JD\Proj\1804-224\dwg\details.dwg

UPDATED: 5/14/2025

PLOTTED: 5/14/2025

Jones & DeMille Engineering, Inc.
CIVIL ENGINEERING - SURVEYING - TESTING
GIS - ENVIRONMENTAL
1.800.748.5275 www.jonesanddemille.com

PROJECT DESIGN ENGINEER DATE

QUALITY MANAGEMENT REVIEW DATE

APPROVAL RECOMM.

APPROVED

TYPICAL PRIMARY SPILLWAY RISER OUTLET

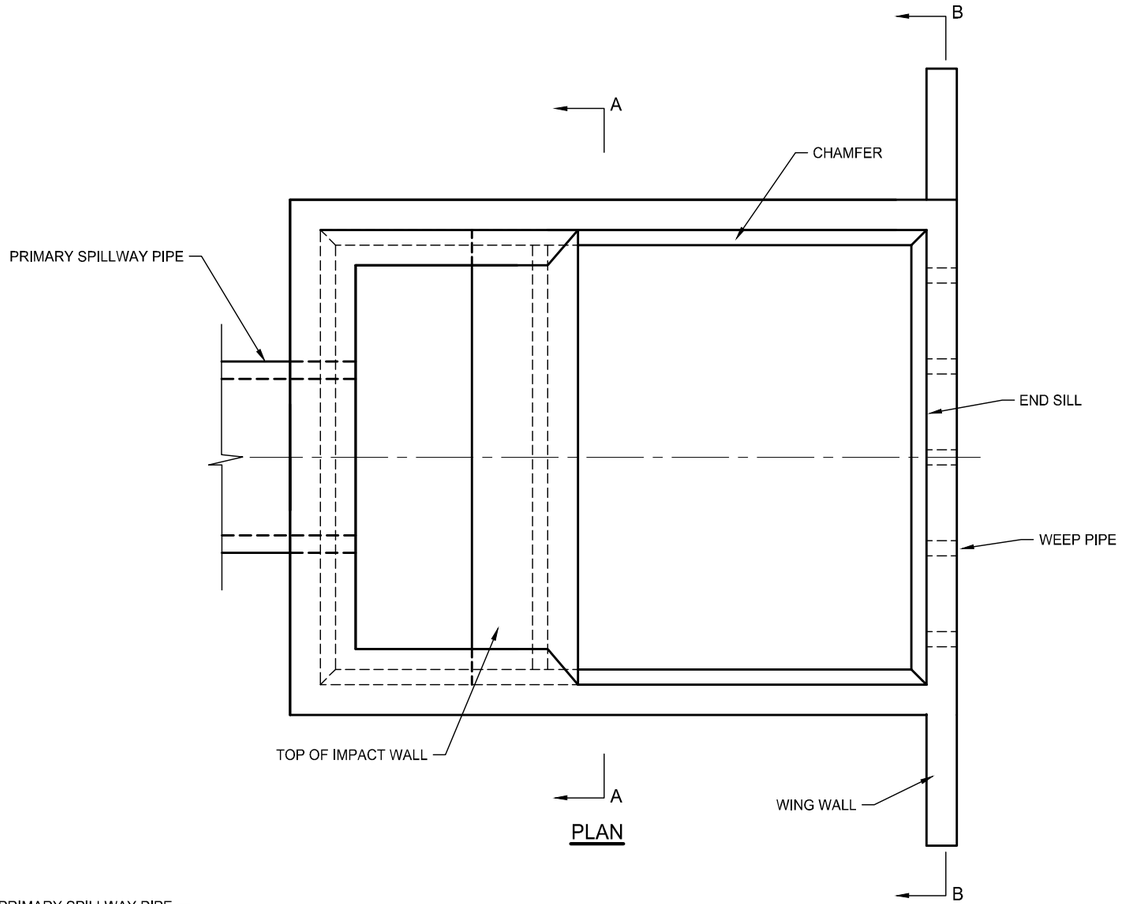
SEVIER COUNTY NRCS WATERSHED PLAN

DETAIL

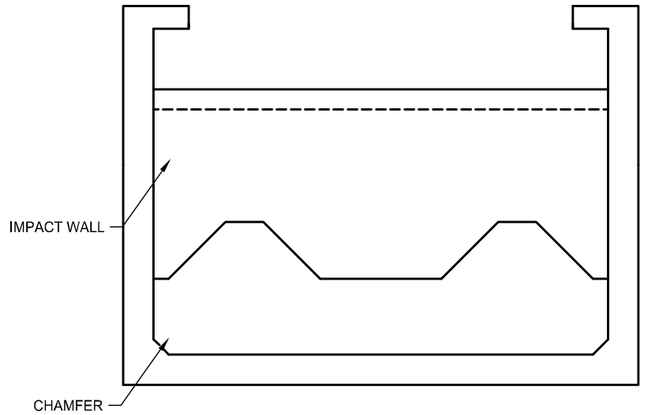
PROJECT NUMBER: 1804-224

SEVIER COUNTY

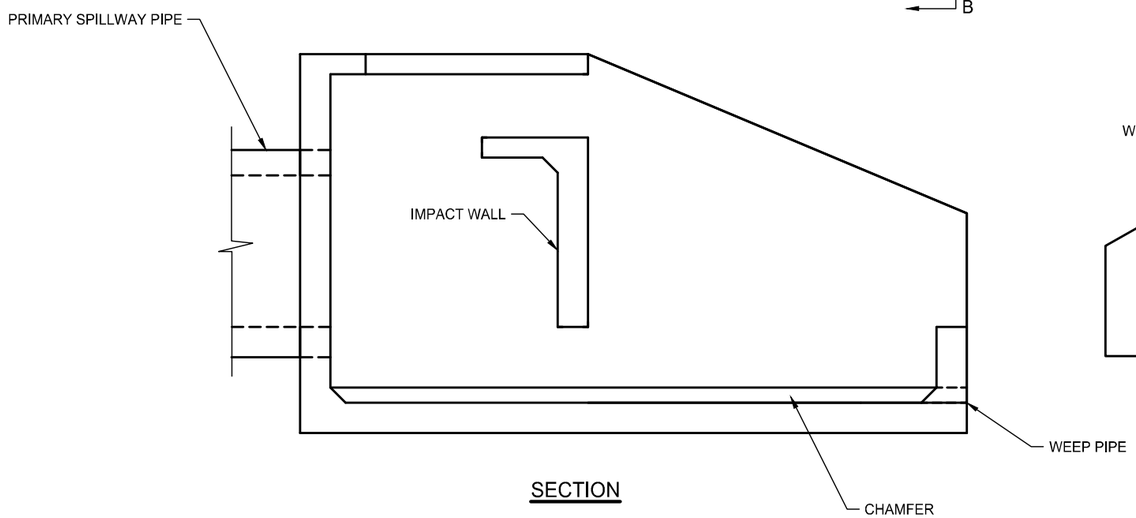
SHEET NO. DT-02



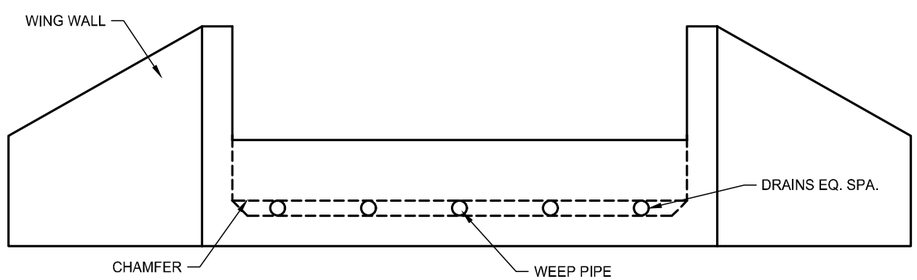
PLAN



SECTION A-A



SECTION



SECTION B-B

TYPICAL PRIMARY SPILLWAY OUTLET IMPACT BASIN DETAIL

REVISIONS

NO.	DATE	REMARKS

SCALE: NTS

DWG NAME: H:\JD\Proj\1804-224\dwg\details.dwg

UPDATED: 5/14/2025

PLOTTED: 5/14/2025

Jones & DeMille Engineering, Inc.
CIVIL ENGINEERING - SURVEYING - TESTING
GIS - ENVIRONMENTAL
1.800.748.5275 www.jonesanddemille.com

APPROVAL RECOMM. PROJECT DESIGN ENGINEER DATE

APPROVED QUALITY MANAGEMENT REVIEW DATE

TYPICAL PRIMARY SPILLWAY OUTLET IMPACT BASIN

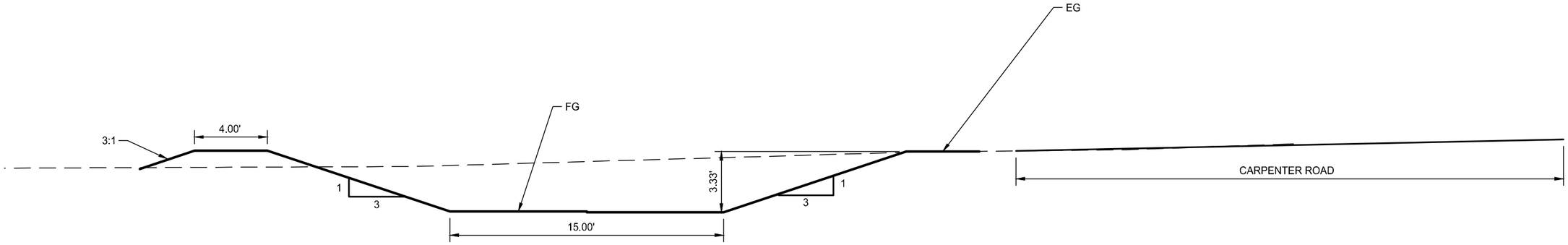
SEVIER COUNTY NRCS WATERSHED PLAN

DETAIL

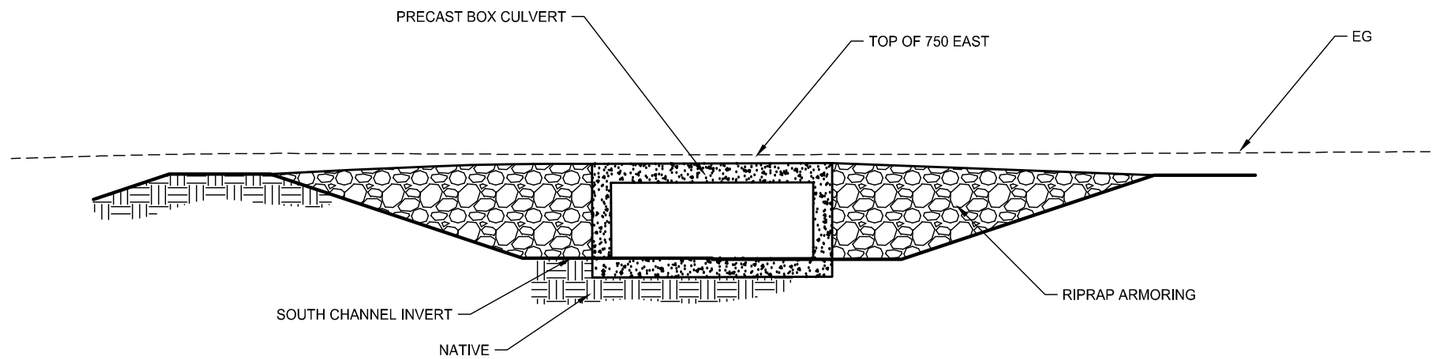
PROJECT NUMBER: 1804-224

SEVIER COUNTY

SHEET NO. DT-03



NEW SOUTH CHANNEL AND DIKE DETAIL



NEW SOUTH CHANNEL BOX CULVERT DETAIL

NO.	DATE	REMARKS

REVISIONS

SCALE: 1" = 6'

DWG NAME: H:\JD\Proj\1804-224\dwg\WoodCynChnl.dwg

UPDATED: 5/14/2025

PLOTTED: 5/14/2025

Jones & DeMille Engineering, Inc.
CIVIL ENGINEERING - SURVEYING - TESTING
GIS - ENVIRONMENTAL
1.800.748.5275 www.jonesanddemille.com

APPROVAL RECOMM: PROJECT DESIGN ENGINEER DATE

APPROVED QUALITY MANAGEMENT REVIEW DATE

SEVIER COUNTY WATERSHED PLAN

WOOD CANYON FLOOD CHANNEL

DETAIL

PROJECT NUMBER: 1804-224

SEVIER COUNTY

SHEET NO. DT-04

TM008 – Costs

1.0 Introduction

There are significant flooding issues in Sevier County in and around the Richfield City area. The proposed solutions to mitigate these issues involve the construction of several detention/debris basins, flood channels, and overflow structures. The feasibility of constructing debris basins at Flat Canyon, Lind Canyon, Tank Canyon, and Wood Canyon were evaluated. A smaller sediment/debris trap structure was also considered at the mouth of Wood Canyon. The final alternative only includes the construction of a debris basin at Flat Canyon. The project would also require existing flood channels to be improved and extended, as the channels would receive attenuated flood waters from other hydraulic structures.

2.0 Project Costs

Project costs were estimated from similar, local projects. A 30% construction contingency factor was applied to the total construction estimate to account for unknown or unforeseen costs and to account for price increases. The total costs are shown in Table 1. Detailed costs for each alternative are included in Attachment A.

Table 1. Total Costs for Project Components

Component	Total Project Cost Estimate
Flat Canyon Detention Basin	$14,504,000
South Flood Channel	$3,231,000
North Flood Channel	$2,894,000
TOTAL	**$20,629,000**

3.0 O&M Costs

3.1 Flat Canyon and North and South Flood Channels

The need for maintenance of the debris basins would be identified in regular detailed inspections (required by Utah Dam Safety) and during cleaning of the principal outlet trash racks after every storm event that activates the principal outlet. The condition of fences, spillways, inlet and outlet works, and other major elements would also be addressed after each inspection. If identified during inspections, deep-rooted vegetation would be removed from the embankment.

The flood channel and inlet and outlet structures would be inspected at the same interval as the debris basins. Flood debris or rooted invasive vegetation that affects channel capacity would be removed, and erosion damage would be repaired when identified. Trash racks would be cleaned after flood flow events. Stormwater pipeline maintenance would include inspection and cleaning of pipeline inlet trash racks during and after every flood-flow event. Access manholes would be accessed annually to quantify sediment deposition; where necessary, sediment would be removed from pipeline segments with sewer vacuum truck equipment. Manhole covers would be repaired, replaced, or re-installed on an as-needed basis. The combined post-project conditions annual O&M costs were estimated for Flat Canyon and the North and South Flood Channel to be approximately $12,000. All annual O&M cost estimates are shown in Table 2.

Table 2. O&M Cost Estimates for the Project Components

Component	Existing Annual O&M Estimate	Post-Project Annual O&M Estimate
Flat Canyon and North and South Flood Channels	-	$12,000

Attachment A. Alternatives 30% Design Cost Estimates

Owner: Sevier County
Project: Sevier County Watershed Plan-EA
Date: 05-30-2025
PM: Darin Robinson, PE

Jones & DeMille Engineering
1-800-748-5275
www.jonesanddemille.com

ENGINEER'S OPINION OF PROBABLE COST: FLAT CANYON DETENTION BASIN

Item Description	Unit	Estimated Units	Unit Price	Price
Contractor Mobilization	L.S.	1	$ 1,050,000.00	$ 1,050,000
Traffic Control	L.S.	1	$ 15,000.00	$ 15,000
Storm Water Controls & SWPPP	L.S.	1	$ 20,000.00	$ 20,000
Compacted Embankment (Fill)	C.Y.	366,123	$ 7.00	$ 2,562,861
Basin Material Removal (Cut)	CY	539,926	$ 2.00	$ 1,079,852
Import Material for Embankment	CY	28,000	$ 10.00	$ 280,000
Basin Excess Material Hauling & Disposal	CY	100,578	$ 5.00	$ 502,892
Detention Basin Clay Core	C.Y.	64,000	$ 15.00	$ 960,000
Foundation Cutoff Trench/Keyway Excavation	C.Y.	23,200	$ 12.00	$ 278,400
Abutment Excavation (Earth)	CY	57,000	$ 6.00	$ 342,000
Abutment Excavation (Rock Ex)	CY	40,000	$ 20.00	$ 800,000
Grouting Abutment Treatment (150' Depth)	FT	225	$ 1,860.00	$ 418,500
Grouting Abutment Treatment (100' Depth)	FT	294	$ 1,240.00	$ 364,560
Clearing and Grubbing	Acre	30	$ 1,000.00	$ 30,000
Existing Construction Access Road Improvements	L.F.	1,500	$ 24.00	$ 36,000
Primary Outlet Structure	L.S	1	$ 150,000.00	$ 150,000
Secondary Spillway Concrete Cutoff Wall	Each	1	$ 30,000.00	$ 30,000
Secondary Spillway & Chute Grouted Riprap	C.Y.	5,000	$ 40.00	$ 200,000
Grout for Riprap	C.Y.	1,500	$ 300.00	$ 450,000
Primary Outlet Discharge Structure	Each	1	$ 20,000.00	$ 20,000
Secondary Energy Dissipation Structure	Each	1	$ 50,000.00	$ 50,000
Onsite Riprap Screening, Sorting and Stockpiling	C.Y.	1,500	$ 15.00	$ 22,500
Offsite Riprap Mining, Screening, Sorting and Hauling	C.Y.	3,500	$ 25.00	$ 87,500
Embankment Field Fence	L.F.	1,200	$ 10.00	$ 12,000
Gate	Each	2	$ 500.00	$ 1,000
Seeding	Acre	30	$ 700.00	$ 21,000
Outlet Pipe Sand Filter with Drain	L.F.	73	$ 210.00	$ 15,330
Chimney and Toe Drain	C.Y.	31,000	$ 50.00	$ 1,550,000
Outlet Pipe	L.F.	400	$ 180.00	$ 72,000
Concrete Encasement	L.F.	400	$ 250.00	$ 100,000
OHV Bypass Trail	L.S.	1,000	$ 20.00	$ 20,000
			Construction Subtotal	**$ 11,541,395**
Contingency 12.25%	L.S.	1	$ 1,413,000.00	$ 1,413,000
			TOTAL PROBABLE CONSTRUCTION COST	**$ 12,954,000**
ENGINEERING AND PROFESSIONAL SERVICES				
Design Engineering	L.S.	1	$ 808,000.00	$ 808,000
Construction Engineering	L.S.	1	$ 578,000.00	$ 578,000
Design survey, investigation, and technical coordination	L.S.	1	$ 30,000.00	$ 30,000
			Engineering and Professional Services Subtotal	**$ 1,416,000**
Administration	L.S.	1	$ 129,540.00	$ 129,540
Real Property Rights	L.S.	0	$ -	$ -
Final Environmental Permitting	L.S.	1	$ 4,000.00	$ 4,000
			TOTAL PROBABLE PROJECT COST	**$ 14,504,000**

Owner: Sevier County
Project: Sevier County Watershed Plan-EA
Date: 05-30-2025
PM: Darin Robinson, PE

Jones & DeMille Engineering
1-800-748-5275
www.jonesanddemille.com

ENGINEER'S OPINION OF PROBABLE COST: NORTH FLOOD CHANNEL

Item Description	Unit	Estimated Units	Unit Price	Price
Mobilization	L.S.	1	$ 207,000.00	$ 207,000
Traffic Control	L.S.	1	$ 12,000.00	$ 12,000
SWPPP	L.S.	1	$ 1,500.00	$ 1,500
Sevier Valley Flood Overflow Structure	L.S.	1	$ 130,000.00	$ 130,000
Sevier Valley Canal Flood Control Gate and Appurtenances	Each	1	$ 210,000.00	$ 210,000
Flood Channel Upgrade Type 1 (to Richfield Canal)	C.Y.	7,100	$ 5.00	$ 35,500
Grouted Riprap Protection (Rock Only)	C.Y.	400	$ 50.00	$ 20,000
Grout for Riprap	C.Y.	280	$ 300.00	$ 84,000
Richfield Canal Flood Overflow and Flood Pipe Inlet Structure	L.S.	1	$ 200,000.00	$ 200,000
Hwy 118 Crossing (ADS Culvert)	L.F.	200	$ 200.00	$ 40,000
Flood Water Pipe (48" ADS Smooth Culvert)	L.F.	6,700	$ 175.00	$ 1,172,500
84" Flood Pipe Access Manhole	Each	7	$ 8,000.00	$ 56,000
Flood Pipe Outlet Headwall Structure	Each	1	$ 25,000.00	$ 25,000
Hwy 118 Crossing (Road repairs & associated work	L.F.	150	$ 250.00	$ 37,500
Canal Crossing Structure (Vermillion Canal)	L.S.	1	$ 10,000.00	$ 10,000
Cultural Mitigation	L.S.	1	$ 20,000.00	$ 20,000
Existing Irrigation Facility Relocation	L.S.	1	$ 15,000.00	$ 15,000
			Construction Subtotal	**$ 2,276,000**
Contingency 12.25%	L.S.	1	$ 279,000.00	$ 279,000
			TOTAL PROBABLE CONSTRUCTION COST	**$ 2,555,000**
ENGINEERING AND PROFESSIONAL SERVICES				
Design Engineering	L.S.	1	$ 160,000.00	$ 160,000
Construction Engineering	L.S.	1	$ 114,000.00	$ 114,000
Design survey, investigation, and technical coordination	L.S.	1	$ 23,000.00	$ 23,000
			Engineering and Professional Services Subtotal	**$ 297,000**
Administration	L.S.	1	$ 25,550.00	$ 25,550
Real Property Rights - Utility Relocations	L.S.	1	$ 15,000.00	$ 15,000
Final Environmental Permitting	L.S.	1	$ 1,000.00	$ 1,000

TOTAL PROBABLE CONSTRUCTION COST $ 2,894,000

Owner: Sevier County
Project: Sevier County Watershed Plan-EA
Date: 05-30-2025
PM: Darin Robinson, PE

Jones & DeMille Engineering
1-800-748-5275
www.jonesanddemille.com

ENGINEER'S OPINION OF PROBABLE COST: SOUTH FLOOD CHANNEL

Item Description	Unit	Estimated Units	Unit Price	Price
Mobilization	L.S.	1	$ 229,000.00	$ 229,000
Traffic Control	L.S.	1	$ 10,000.00	$ 10,000
SWPPP	L.S.	1	$ 1,500.00	$ 1,500
Canal Overshot Flood Structure	L.S.	1	$ 130,000.00	$ 130,000
Stilling Basin/Rock Chute	L.S.	1	$ 30,000.00	$ 30,000
Existing Channel Reshaping and Armoring	C.Y.	7,900	$ 5.00	$ 39,500
48" HDPE - DR26 (80 psi) Pipe (1X 7680' Segment)	L.F.	7,680	$ 200.00	$ 1,536,000
New Channel Excavation	CY	10,815	$ 13.00	$ 140,595
Levee	CY	100	$ 35.00	$ 3,500
Utility and Drainage Obstacle	LS	1	$ 50,000.00	$ 50,000
Removal of Channel Spoil	C.Y.	11,000	$ 5.00	$ 55,000
84" Storm Drain Manhole	Each	8	$ 8,000.00	$ 64,000
8'x3' Precast Box Culvert	LF	30	$ 2,000.00	$ 60,000
Culvert Riprap Armoring	CY	50	$ 100.00	$ 5,000
Pipe inlet and flow splitter (near airport)	L.S.	1	$ 90,000.00	$ 90,000
Hwy 118 Crossing (Road repairs & associated work)	L.F.	125	$ 250.00	$ 31,250
Cultural Mitigation	L.S.	1	$ 20,000.00	$ 20,000
Existing Irrigation Facility Relocation	L.S.	1	$ 18,000.00	$ 18,000
			Construction Subtotal	**$ 2,513,345**
Contingency 12.25%	L.S.	1	$ 308,000.00	$ 308,000
			TOTAL PROBABLE CONSTRUCTION COST	**$ 2,821,000**
ENGINEERING AND PROFESSIONAL SERVICES				
Design Engineering	L.S.	1	$ 198,000.00	$ 198,000
Construction Engineering	L.S.	1	$ 142,000.00	$ 142,000
Design survey, investigation, and technical coordination	L.S.	1	$ 26,000.00	$ 26,000
			Engineering and Professional Services Subtotal	**$ 366,000**
Administration	L.S.	1	$ 28,210.00	$ 28,210
Real Property Rights - Utility Relocations	L.S.	1	$ 15,000.00	$ 15,000
Final Environmental Permitting	L.S.	1	$ 1,000.00	$ 1,000
			TOTAL PROBABLE PROJECT COST	**$ 3,231,000**

TM009 – Hazard Classifications

Table of Contents

1.0 Introduction 1
2.0 Dam Breach Analysis 1
2.1 Dam Breach Parameters 1
2.2 Hydraulic Modeling (HEC-RAS 2D) 1
3.0 Dam Breach Analysis Results 2
3.1 Flat Canyon 2
4.0 References 3

Attachments

Attachment A. TR-60 Dam Breach Parameters
Attachment B. Inundation Maps

Tables

Table 1-1. Hazard Classifications 1
Table 2-1. Peak Breach Flows 1
Table 2-2. Manning's n Values by Land Cover Type 2

1.0 Introduction

NRCS Technical Release 210-60 (TR-60; 2019) and Utah Code 73-5a-106 (1996) outline the criteria for dam hazard classifications in the watershed area. The criteria are summarized in Table 1-1.

Table 1-1. Hazard Classifications

Hazard Classification	NRCS TR-60 (2019)	Utah Dam Safety (1996)
Low	Dams in rural or agricultural areas where failure may damage farm buildings, agricultural land, or township and country roads.	Those dams which, if they fail, would cause minimal threat to human life, and economic losses would be minor or limited to damage sustained by the owner of the structure.
Significant/Moderate	Dams in predominantly rural or agricultural areas where failure may damage isolated homes, main highways or minor railroads, or interrupt service of relatively important public utilities.	Those dams which, if they fail, have a low probability of causing loss of human life, but would cause appreciable property damage, including damage to public utilities.
High	Dams where failure may cause loss of life or serious damage to homes, industrial and commercial buildings, important public utilities, main highways, or railroads.	Those dams which, if they fail, have a high probability of causing loss of human life or extensive economic loss, including damage to critical public utilities.

2.0 Dam Breach Analysis

2.1 Dam Breach Parameters

Per Utah Administrative Code R655-10 (2016), the hazard classification for a dam shall be determined using a dam breach analysis with the reservoir level at the spillway crest. This scenario is also known as a sunny-day breach condition. For this analysis, the sunny-day condition is considered to be when the reservoir level is equal to the auxiliary spillway crest. For TR-60, this is also known as the static failure mode.

The peak breach flows and dam breach hydrographs for Flat Canyon (see Attachment A) were developed using TR-60 and Soil Conservation Service TR-66 (1985) guidelines. The peak breach flows for the Flat Canyon detention basin is shown in Table 2-1.

Table 2-1. Peak Breach Flows

Debris Basin Name	Peak Breach Flow (cfs)
Flat Canyon	71,789

2.2 Hydraulic Modeling (HEC-RAS 2D)

The U.S. Army Corps of Engineers (USACE) River Analysis System (HEC-RAS 5.0.7) software was used to complete the hydraulic modeling (USACE 2019). HEC-RAS was used to create a 2D model simulating the dam breach hydrographs and inundated flood areas. This section outlines the development and parameters of the 2D model.

2.2.1 Terrain Data

The best available elevation surface data for the area was obtained from the Utah Automated Geographic Reference Center (AGRC 2019). The terrain is a 1-meter resolution LiDAR surface from 2018, and the datum is NAVD 88.

2.2.2 Surface Roughness

Land cover types were based on aerial imagery to determine the surface roughness of the terrain data. The land cover types and corresponding Manning's n values that were used in the HEC-RAS model are shown in Table 2-2.

Table 2-2. Manning's n Values by Land Cover Type

Land Cover Type	Value
Agricultural Field	0.06
None - Vegetated Soil	0.025
Parks and Recreational Areas	0.04
Residential Areas	0.075
Roads	0.025

2.2.3 2D Mesh Parameters

A computational grid, or mesh, was created for the HEC-RAS 2D model. The cells of the grid measured 50 feet by 50 feet. Break lines were also used to capture important terrain features such as channel centerlines and major roads.

Time steps for the model were selected to maintain a Courant number of approximately 1.0. Several time steps were considered for a sensitivity analysis to ensure stable, accurate results.

2.2.4 Culverts

Several Utah Department of Transportation (UDOT) culverts with diameters ranging from 24 to 60 inches cross beneath I-70 downstream of Flat Canyon (UDOT 2017). It was important to model the culverts into the HEC-RAS geometry to accurately model how the breach flows would distribute beyond I-70. Culverts with 36-inch diameters were assumed to be clogged with debris and sediment and were therefore excluded from the model. An existing UDOT underpass on I-70 downstream of Flat Canyon was modeled as a large box culvert since it was missing from the 2018 LiDAR surface. The location of the culverts and underpass included in the model are shown in the inundation maps found in Attachment B.

2.2.5 Boundary Conditions

The dam breach hydrographs (see Attachment B) were used for the unsteady flow data boundary conditions at the proposed detention basin locations. Downstream boundary conditions were located on the Sevier River and were modeled using a normal depth approach.

3.0 Dam Breach Analysis Results

An inundation map from the dam breach analysis for the Flat Canyon detention basin is provided in Attachment B. The inundation map includes approximate arrival times of the flood wave for several major roads.

3.1 Flat Canyon

Due to the large alluvial fan at the mouth of Flat Canyon, the dam breach analysis resulted in breach flows going north, east, and south of the canyon. To the north, the breach flows cross under I-70 through existing UDOT culverts and flow toward the Richfield Municipal Airport. The breach flows continue

northeast until they are impounded by Annabella Road. To the east, the breach flows cross under I-70 through the existing underpass and flood across agricultural fields and Central Valley before entering the Sevier River floodplain. To the south, the model shows breach flows overtop I-70 (at depths of approximately 1-2 feet) and flow across Elsinore before reaching the Sevier River floodplain.

Several residential homes and other infrastructure (including Elsinore's fire station) within Elsinore, Central Valley, and surrounding communities are within the dam breach inundation boundary of the Flat Canyon debris basin. Based on the modeling results, it is recommended the Flat Canyon debris basin receive a hazard rating of **high hazard** for both NRCS and Utah Dam Safety criteria as shown in Table 1-1.

4.0 References

Automated Geographic Reference Center (AGRC). 2019. Utah Automated Geographic Reference Center. https://gis.utah.gov/data/. Accessed 6-5-2019.

Natural Resources Conservation Service (NRCS). 2019. Technical Release 210-60: Earth Dams and Reservoirs (TR-60).

Soil Conservation Service. 1985. Technical Release 210-66: Simplified Dam-Breach Routing Procedure (TR-66).

U.S. Army Corps of Engineers. 2019. River Analysis System (HEC-RAS), Version 5.0.7. Hydrologic Engineering Center. March 2019.

Utah Administrative Code (UAC). 2016a. R655-10: Dam Safety Classifications, Approval Procedures and Independent Reviews.

Utah Department of Transportation (UDOT). 2017. UDOT Data Portal. https://data-uplan.opendata.arcgis.com/. Accessed 4-12-2017.

Utah Code. 1996. 73-5a-106 – Dams classified according to hazard and use.

Attachment A. TR-60 Dam Breach Parameters

Dambreach Hydrographs via TRs 60 & 66 NRCS guidance

version 3, July 2018

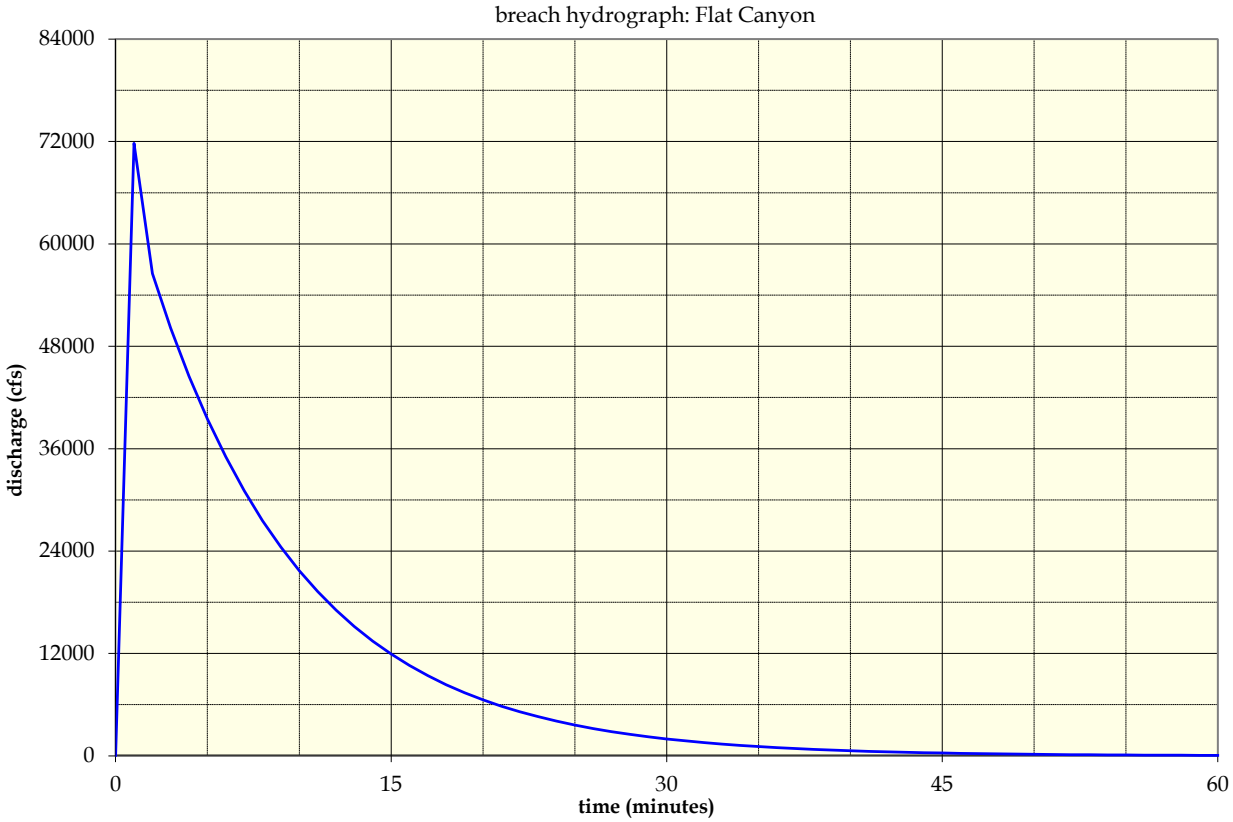
Failure Mode: Static

Input data required:

Dam: Flat Canyon

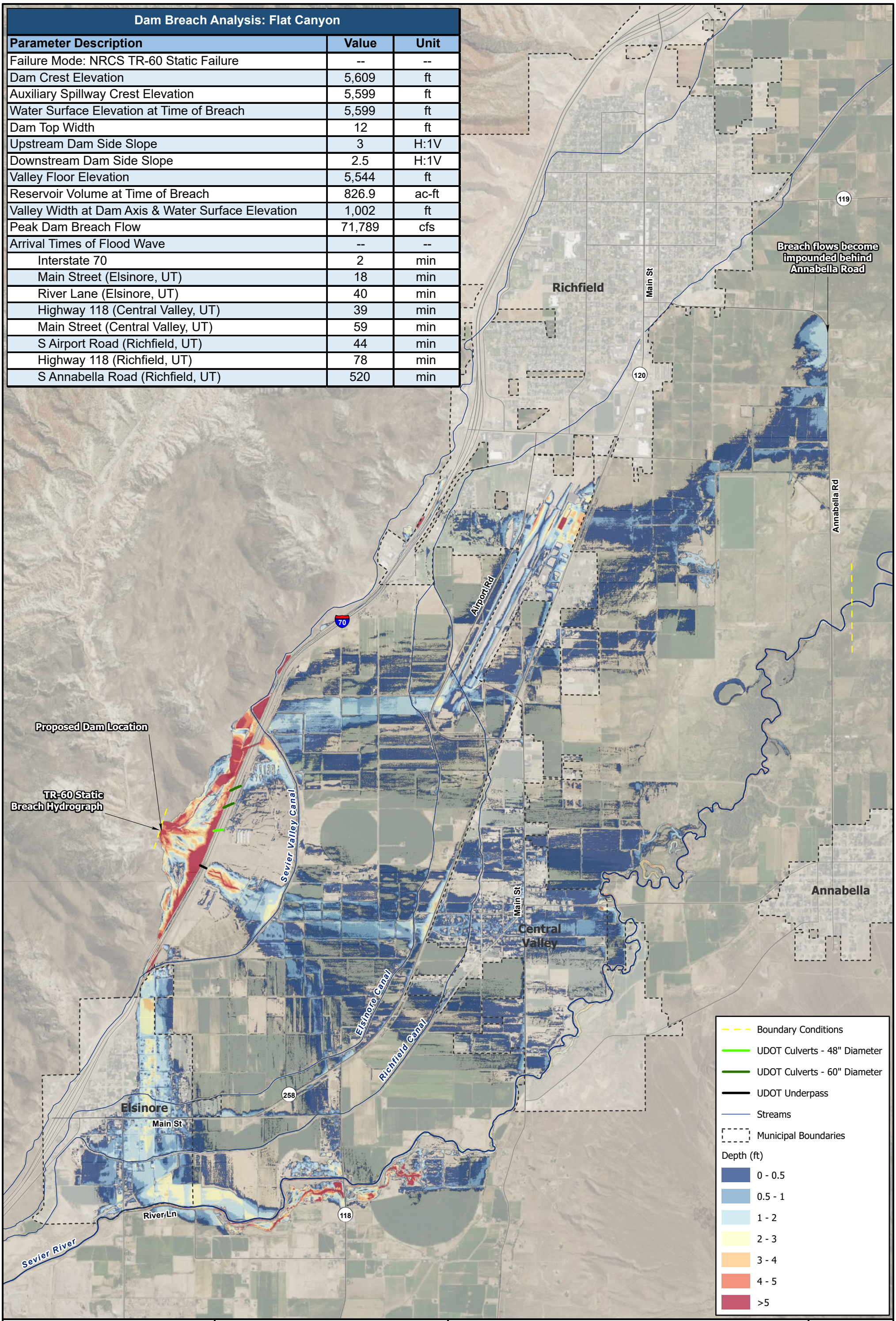
data	variable	explanation
5609	crestEL	dam crest elevation
5599	wsEL	w.s. elev at time of breach
12	TW	dam top width (feet)
3	SSup	dam side slope (upstream, SSup:1)
2.5	SSdn	dam side slope (downstream, SSdn:1)
5544	floorEL	valley floor elev (see note)
826.9	Vs	resv vol at time of breach (acre-feet)
1002	L	valley width at dam axis & w.s. elev (feet)
	ELwave	top of wave berm elevation
	Wwave	width of top of wave berm feet
	SSwave	wave berm side slope (SSwave:1)
	ELstab	top of stability berm elevation
	Wstab	width of top of stability berm (feet)
	SSstab	stability berm side slope (SSstab:1)
1	ts	timestep (minutes) for breach hydrograph

output		**breach hydrograph**	
variable	**results**	**time (min)**	**Q (cfs)**
T	635	0	0
(L < T)?	N	1	**71789**
H_w	55	2	56518
Q_1	107791	3	50148
(H_w < 103)?	Y	4	44496
Awave	0	5	39481
Astab	0	6	35031
A	12399	7	31083
Br	4	8	27579
Q_2	6359	9	24471
Q_{min}	71789	10	21713
(Q_2 < Q_{min})?	Y	11	19266
(Q_2 > Q_1)?	N	12	17094
(Q_1 < Q_{min})?	N	13	15168
Q_{max}	**71789**	14	13458


breach hydrograph: Flat Canyon
84000
72000
60000
48000
36000
24000
12000
0
discharge (cfs)
0
15
30
45
60
time (minutes)

Attachment B. Inundation Maps

Dam Breach Analysis: Flat Canyon		
Parameter Description	**Value**	**Unit**
Failure Mode: NRCS TR-60 Static Failure	--	--
Dam Crest Elevation	5,609	ft
Auxiliary Spillway Crest Elevation	5,599	ft
Water Surface Elevation at Time of Breach	5,599	ft
Dam Top Width	12	ft
Upstream Dam Side Slope	3	H:1V
Downstream Dam Side Slope	2.5	H:1V
Valley Floor Elevation	5,544	ft
Reservoir Volume at Time of Breach	826.9	ac-ft
Valley Width at Dam Axis & Water Surface Elevation	1,002	ft
Peak Dam Breach Flow	71,789	cfs
Arrival Times of Flood Wave	--	--
Interstate 70	2	min
Main Street (Elsinore, UT)	18	min
River Lane (Elsinore, UT)	40	min
Highway 118 (Central Valley, UT)	39	min
Main Street (Central Valley, UT)	59	min
S Airport Road (Richfield, UT)	44	min
Highway 118 (Richfield, UT)	78	min
S Annabella Road (Richfield, UT)	520	min



N

0 1,500 3,000 Feet

Jones & DeMille Engineering

- Shaping the Quality of Life -

800.748.5275 www.jonesanddemille.com

Sevier County

Sevier County Watershed Plan
Dam Breach Analysis: Flat Canyon

Map Name: H:\JD\Proj\1804-224\Design\GIS\Projects\Hydraulics and Hydrology\1804-224_HH\1804-224_HH.aprx - EXH_Dam_Breach_01_Flat_Canyon

Project Number: 1804-224 | Drawn by: JWW 03-21 | Last Edit: 03/30/2021

Sevier County

Scale: 1" = 3,000'

1