Bruce Canyon Reservoir

# 30% Design Report

## Huerfano County Water Conservancy District

January 31, 2020

AG JOB No. 18-117

*Prepared by*:

Applegate Group, Inc.

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# INTRODUCTION

The Huerfano County Water Conservancy District (HCWCD) retained Applegate Group, Inc. (Applegate Group) to complete the 30% design for Bruce Canyon Reservoir described herein. The work was funded with a Colorado Water Conservation Board (CWCB) Water Plan Grant for 30% design for a new Bruce Canyon Dam and an enlarged Maria Stevens Reservoir. The grant was approved by the CWCB in May 2019. The scope of work was generally to 1) complete 30% design for the two dams, 2) discuss the 30% design with the Colorado Division of Water Resources – Dam Safety Branch, and 3) identify information needed for the upcoming 50% design phase.

Previous studies were completed that are specific to the storage needs of the Cucharas Basin are summarized as follows:

1. Applegate Group and Parsons Water completed a Cucharas Basin Collaborative Storage Study in June 2017 with the objectives of 1) determining storage needs in the Cucharas Basin and 2) completing a reconnaissance level study and screening of potential storage sites to meet the storage needs. This reconnaissance level study was based on limited geotechnical data found in a literature search and did not include a field geotechnical investigation. The final deliverable included a concept-level design and associated cost estimate for five recommended storage sites.
2. Cesare, Inc. (Cesare) completed a November 2018 reconnaissance level geotechnical investigation for five sites identified in the June 2017 report. This study included field investigations, site-specific geotechnical drilling, and laboratory analyses.

The concept level designs from the June 2017 reconnaissance level study were used as a starting point for the 30% design scope completed for this report. In general, the update from the June 2017 concept level design to 30% design level was to update the concept level design based on the geotechnical data and recommendations summarized in the November 2019 geotechnical report. Additionally, input from the Colorado Division of Water Resources – Dam Safety Branch was incorporated into the 30% design.

Deliverables for the Bruce Canyon 30% design phase include 1) revised design drawings, and 2) an updated Opinion of Probable Cost. This information will be used as the foundation for future design phases. Design procedures and revisions to concept phase design are summarized in the following sections.

# GEOTECHNICAL INVESTIGATION

## SUMMARY

Cesare, Inc. (Cesare) completed a preliminary geotechnical evaluation of the Bruce Canyon site. The dam site is located in an east-west valley intersected by a volcanic dike extending from the northwest to the southeast. Cesare's scope of work was to provide geotechnical and geological information, technical constraints and preliminary design recommendations. Cesare explored subsurface conditions by drillings borings and excavating test pits at the approximate locations as shown in Figure 1. Soil and bedrock were sampled during drilling using a modified California sampler. Sampling locations and results of penetration tests are shown on the boring log profiles on page 4 (Figure 2). Note elevations as indicated on Figure 2 are approximate and based on the 5-meter DEM data used for design, and field survey was not performed. Soils encountered at the site consist of interbedded sandy clays and clayey sand to depths of approximately 14 to 18 feet below ground surface (bgs) in the valley (borings BC-1 and BC-2, respectively) and 1-5 at the abutments (borings BC-4 and BC-3, respectively). The exploratory test pits excavated upstream of the proposed dam confirmed the presence of clayey material which may be suitable borrow material for the embankment. Soil at the site overlies predominantly sandstone and claystone bedrock. Groundwater was encountered 8 to 10 feet bgs during the investigation.

At borings BC-2 and BC-4, bedrock was cored to determine rock quality and Packer testing was performed to evaluate permeability (i.e., hydraulic conductivity). Packer testing measures the horizontal flow component of in situ permeability. Cesare estimated vertical flow to be approximately one order of magnitude less than horizontal flow. The averaged hydraulic conductivity for the cored intervals was reported to be on the order of $10^{-6}$ centimeters per second (1 foot per year) for both bore locations indicating a relatively impervious foundation. The Bureau of Reclamation generally describes soils with permeabilities less than 1 ft/yr as impervious[1]. Packer test results are summarized in Table 1 below.

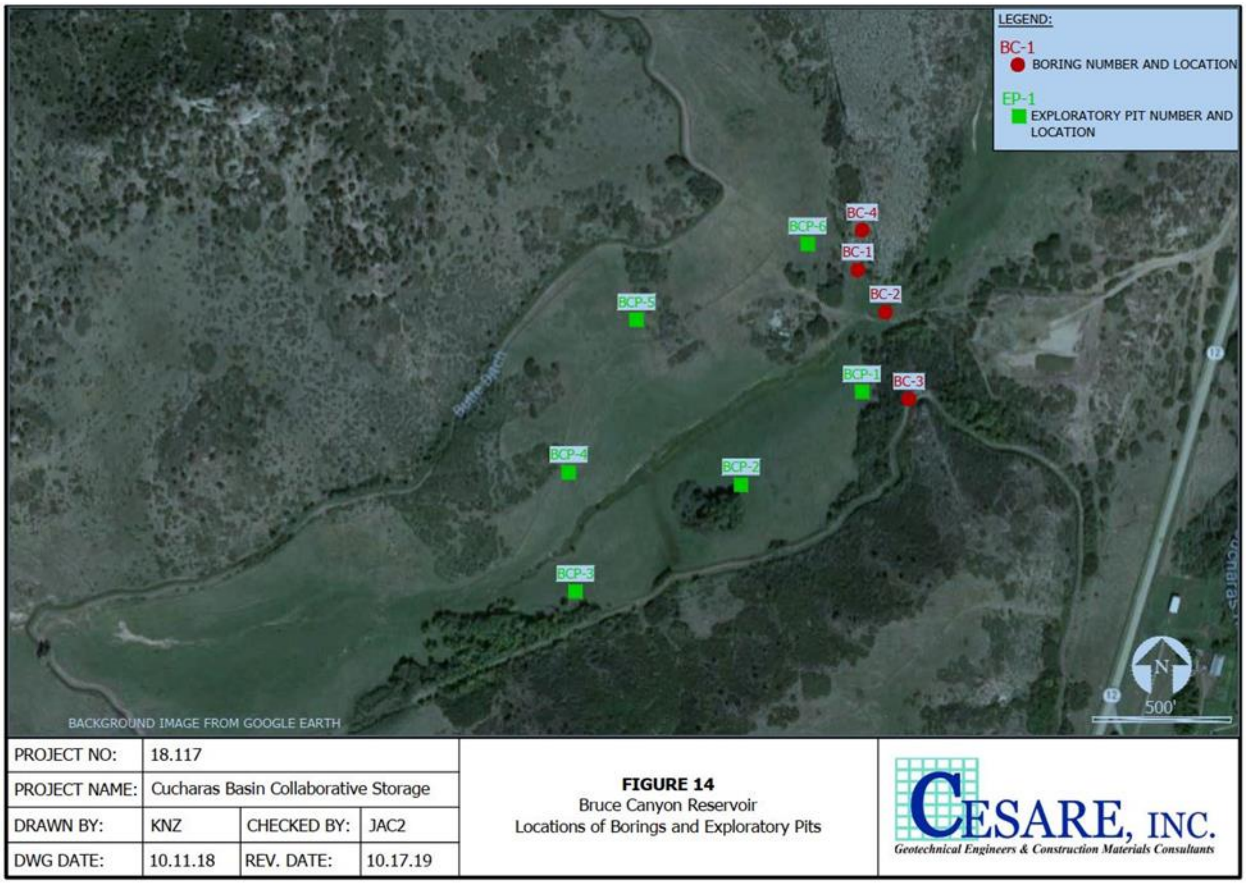

Figure 1. Boring and Test Pit Locations

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[1] Design of Small Dams, U.S. Dept. of the interior, Bureau of Reclamation

| Boring | Interval Tested | | Averaged Hydraulic Conductivity (cm/sec) |
|---|---|---|---|
| | Depth (ft) | Elevation (ft) | |
| BC-2 | 25 to 51 | 7339 to 7313 | $6.4 \times 10^{-6}$ |
| | 35 to 51 | 7329 to 7313 | $2.8 \times 10^{-5}$ |
| BC-4 | 13 to 40 | 7395 to 7368 | $3.2 \times 10^{-6}$ |
| | 20 to 40 | 7388 to 7368 | $1.4 \times 10^{-5}$ |
| | 30 to 40 | 7378 to 7368 | $3.7 \times 10^{-5}$ |

Table 1. Packer Test Results

Cesare also performed stability and seepage analysis on the preliminary embankment sections for each dam site. Permeability and strength values used for the analysis were based on soil classifications, published values and Cesare's experience with the design of dams. Results of the stability analysis for Bruce Canyon are summarized in the Table 2 below. Results of the seepage analysis are discussed in the following section.

| Analysis | Factor of Safety | | Required Factor of Safety |
|---|---|---|---|
| | Block | Circular | |
| Full, steady state, downstream | 1.88 | 1.57 | 1.5 |
| Transient upstream* | 1.29 | 1.33 | 1.2** |

* Rapid drawdown
**Lowest factor of safety

Table 2. Stability Analysis Results

## GEOTECHNICAL RECOMMENDATIONS

Based on results of the investigation, Cesare provided the following recommendations regarding the Bruce Canyon dam site:

1. The dam alignment should be shifted upstream of the volcanic dike based on seepage and stability concerns.
2. Additional geotechnical investigation at the north abutment is necessary to further evaluate stability and permeability.
3. A positive cutoff should extend 25 to 30 feet below existing grade with the cutoff extending 10 to 15 feet into competent bedrock.
4. Consolidation testing should be performed on the overburden soils to evaluate settlement potential.
5. Additional geotechnical investigation is necessary to evaluate the suitability of native clay soils for embankment construction and confirm availability of the supply of borrow material.

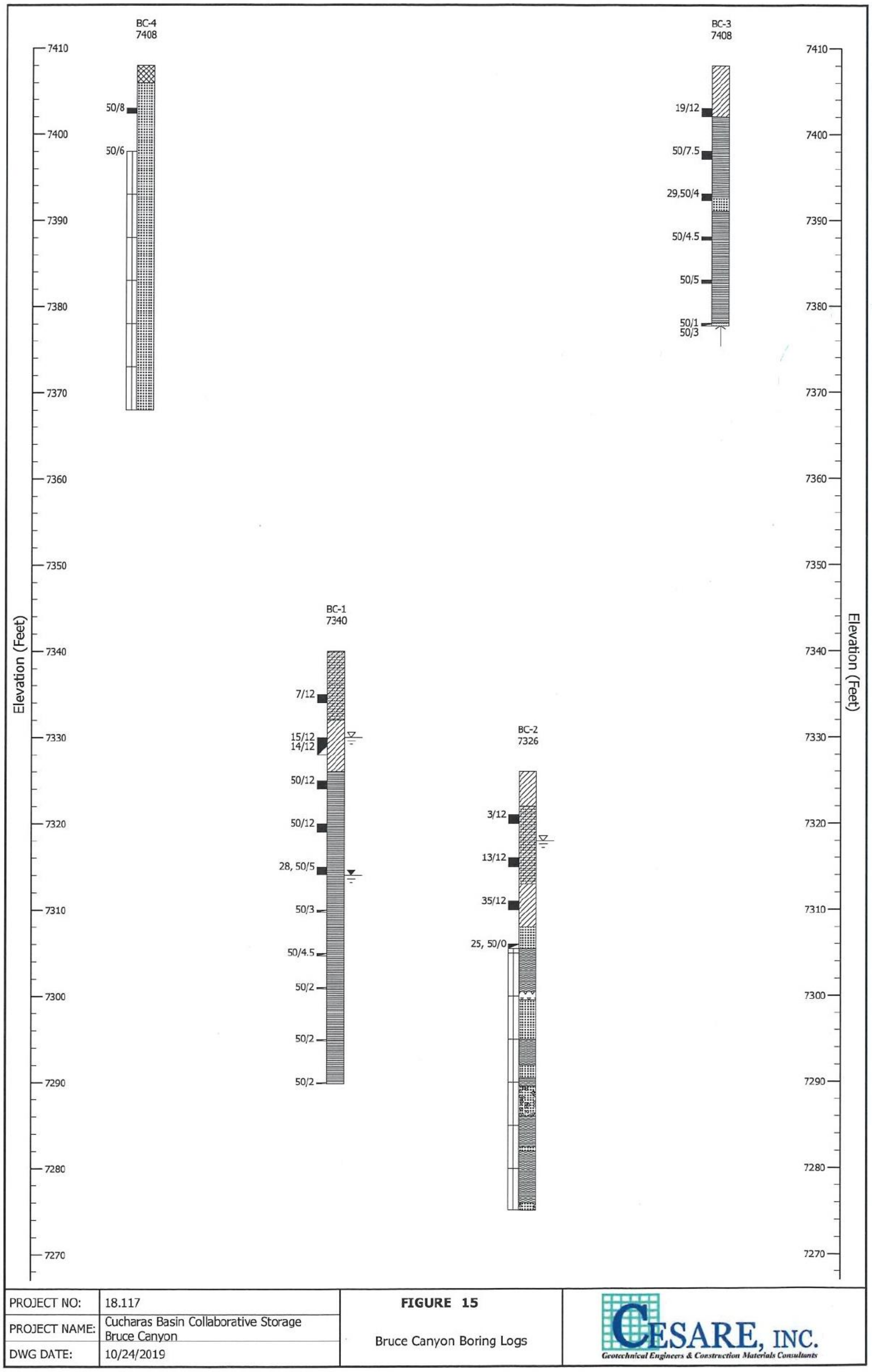

Figure 2. Boring Log

# DESIGN COMPONENTS

## SUMMARY

30% design was developed based on geotechnical data provided by Cesare and includes the following components:

1. Spillway design based on the estimated Inflow Design Flood (IDF).
2. Low-level outlet design to provide the ability make regular releases from the reservoir and draw down water levels for maintenance or emergency purposes.
3. Foundation design to address seepage/stability concerns associated with site geology.
4. Filter design to address seepage/stability concerns associated with native soils.
5. 30% design drawings consisting of a cover sheet, site plan and typical section details.
6. Engineer's Opinion of Probable Cost for construction of a homogeneous earthen embankment dam.

## SPILLWAY DESIGN

Bruce Canyon Dam will have an 80-foot wide riprap lined emergency spillway capable of passing the Inflow Design Flood (IDF) with more than 1 foot of residual freeboard (assuming a discharge coefficient of 3.00). The spillway will provide 3 feet of freeboard between its invert and the dam crest, and will extend approximately 1,200 feet from the dam crest at the north abutment through the existing volcanic dike to the east. The spillway will drop about 100 vertical feet across this distance with a maximum slope of approximately 1.5H:1V. The spillway will be lined with 18-inch riprap (D50) approximately 3 feet thick. Spillway velocities are estimated to range from 4 ft/s to 9.8 ft/s (based on Manning's equation for normal depth) during the IDF event. The rip rap will be installed on 18 inches of Type II (CDOT Class A) bedding to prevent erosion or undercutting of the spillway at high flows. The following paragraphs summarize the procedure used to estimate the IDF.

The Inflow Design Flood (IDF) was updated for the 30% design, based on Colorado Dam Safety's Rules and Regulations for Dam Safety and Construction that became effective January 1, 2020. The IDF prescriptive method for spillway sizing was used to identify the proposed Bruce Canyon dam as a "High Hydrologic Hazard" resulting in a critical rainfall of the 0.01% Annual Exceedance Probability (AEP). The High Hydrologic Hazard determination was based on the Bureau of Reclamation's Consequence Estimating Methodology. The proposed dam would be constructed approximately 2.5 miles upstream of the Town of La Veta, and a dam breach would discharge to the Cucharas River and flood approximately 60% of the Town. This was based on an assumed 2-foot flow depth through the Town, and an analysis of the Cucharas River valley using Google Earth. Maximum flow velocity through Town was assumed to be 15 feet per second, resulting a depth x velocity product of 30 feet squared per second. The associated fatality rate for a dam breach was estimated using the Bureau of Reclamation's case history data identified for cases with adequate warning and partial warning (Figure 2 in RCEM – Reclamation Consequence Estimating Methodology, July 2015). The resulting range of suggested limit for the fatality rate was 0 to 0.001. The number of fatalities resulting from a Bruce Canyon Dam breach was then calculated as the Town population (779 people), times 60% area that would be flooded, times the 0.001 fatality rate (assuming the maximum rate of the range), or a result of 0.47 fatalities. The life loss potential of less than 1 resulted in a "High Hydrologic Hazard" and a 0.01% AEP critical rainfall.

The precipitation best estimate was then determined using the MetPortal[2] online tool from the Colorado-New Mexico Regional Extreme Precipitation Frequency Study. The Mesoscale Storm with Embedded

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[2] https://conm-reps-gui.shinyapps.io/metportal/

Convection (MEC) storm was determined to be the most likely precipitation event for the area, as it is a convective warm-season storm with embedded convective cells (thunderstorms), typical of the Huerfano County area. The resulting 6-hour precipitation best estimate of 5.26 inches was determined, which was scaled up by a 7 percent atmospheric moisture factor as required in Dam Safety's rules effective January 1, 2020. The final resulting precipitation value used was 5.63 inches. A runoff model was not created at this design level, but will be completed for the hydrology report at the future 50 percent design stage. Rather, a 0.01% AEP of 132 cfs determined using USGS Streamstats was scaled using the ratio of the MetPortal precipitation value (5.63 inches) to the corresponding maximum 6-hour precipitation 100-year annual recurrence interval from the USGS Streamstats[1] (3.15 inches). The resulting IDF was 236 cfs for the 0.54 square mile drainage basin.

## EMBANKMENT DRAINS

30% design plans include an inclined chimney drain as well as blanket drain to filter and convey possible seepage. The proposed drain system is intended to prevent the migration of soil particles within the dam embankment which could ultimately lead to a piping failure; this system will also protect against the potential for differential settlement of the foundation. The larger drain system will incorporate a two-stage toe drain which will filter, collect and discharge seepage from the embankment. Design for the two-stage filter will be completed for 50% design, and will likely incorporate a perforated PVC or HDPE drainpipe enveloped in a coarse aggregate and surrounded by filter media (e.g., fine aggregate such as C33 sand). A filter compatibility analysis will be completed at the 50% design phase to evaluate local borrow materials and identify suitable aggregates for filter and drain materials. The inclined configuration of the chimney drain was selected over a vertical configuration based on constructability and estimated costs. Construction details for the drain system will be developed at the 50% design phase.

## OUTLET WORKS

The outlet works will consist of a 24-inch concrete encased ductile iron pipe (DIP). The outlet would be operated by low-level sluice gate operated from the dam crest. Applegate completed stage-discharge calculations to confirm that the 24-inch outlet pipe is capable of drawing down the reservoir 5 feet in 5 days. Calculations showed that the 24-inch pipe will be capable of drawing down the reservoir 5 feet in approximately 17 hours. A 24-inch concrete encased DIP standpipe will regulate normal pool of the reservoir at elevation 7402.90, providing approximately 2 feet of freeboard between normal water surface elevation (WSEL) and the emergency spillway crest. At normal pool, the maximum discharge is calculated to be approximately 80 cfs. Construction details for concrete encasement of the outlet pipe (and standpipe), a trash rack at the upstream invert, and the proposed USBR stilling basin will be completed for the 50% design. Figure 3 on the following page shows the drawdown curve for the dam and Figure 4 provides the stage-discharge relationship for the proposed outlet pipe.

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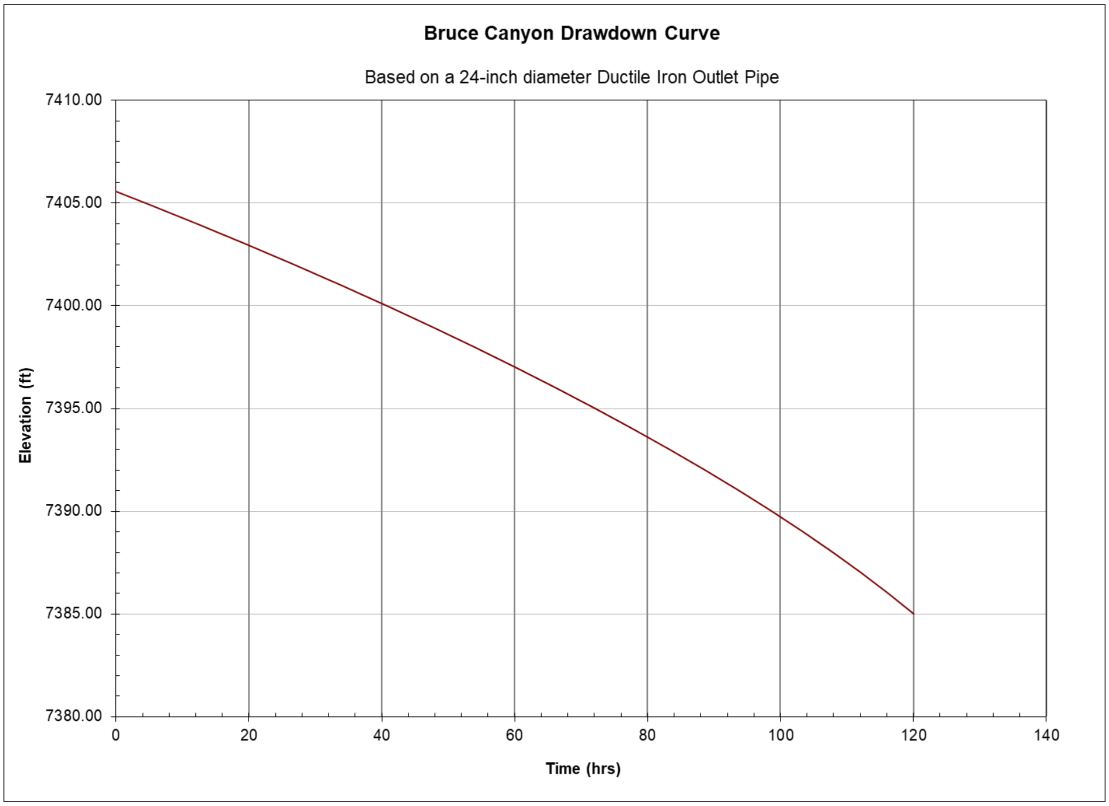


Figure 3. Draw Down Curve for Bruce Canyon Dam

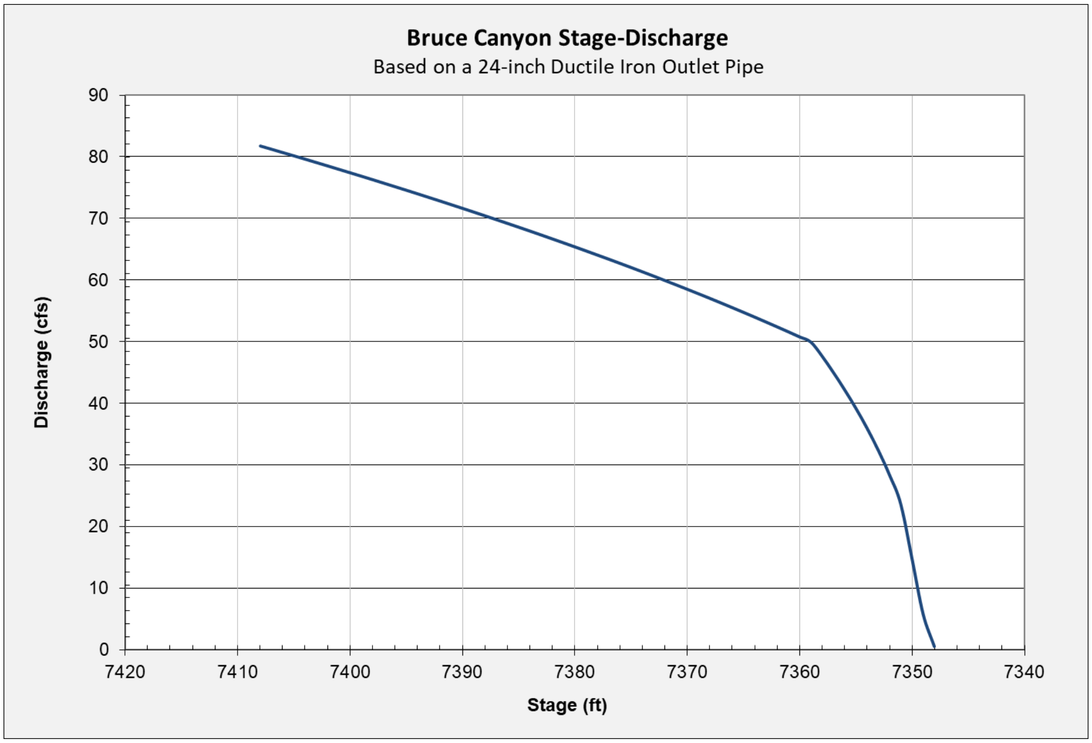


Figure 4. Stage Discharge Curve for the Bruce Canyon Dam

### FOUNDATION PREPARATION AND KEYWAY DESIGN

30% design plans incorporate Cesare's recommendation to move the dam alignment upstream of the existing volcanic dike, based on the geotechnical properties of the dike. The current design (see Appendix B for plans) shows the downstream toe of the embankment upstream of the dike. In addition, design assumes the following will be completed for foundation preparation:

1. Overexcavation of the majority of soft soils overlying bedrock will be completed as part of the proposed keyway. Excavated material will be replaced with moisture-conditioned embankment material and compacted.
2. Construction of a positive cutoff extending a minimum of 3-feet in low-permeability bedrock; the proposed keyway will be 10-feet wide at its base with 3H:1V side slopes and an estimated depth of 25 feet at the max cross section of the dam.

## ENGINEER'S OPINION OF PROBABLE COST

A summary of the updated Opinion of Probable Cost is included on the following page. The full cost estimate is included in Appendix C. The primary components driving project costs are earthwork and construction of the drain system. Costs for earthwork assume suitable borrow material (of sufficient quality and quantity) exists in the reservoir for construction of the embankment, and that material excavated for the keyway can be processed for use as a cutoff. As discussed, additional geotechnical investigation is necessary to confirm the suitability (and availability) of native materials in the reservoir area. Note that quantities for excavation, backfill and other filter materials were approximated based on depth to bedrock encountered in the borings completed by Cesare, assumed excavation limits and dam geometry. Project costs are summarized in Table 4 below.

| | |
|---:|---:|
| Construction Subtotal | $17,936,700 |
| Contingency (20%) | $3,587,300 |
| Construction Total | $21,524,000 |

Table 4. Summary of Project Costs

## SUMMARY

The proposed Bruce Canyon Dam would provide approximately 910 acre-feet of total storage at normal pool (approximately 1,010 acre-feet to spillway crest). Based on 30% design, the dam would be 80 feet in height, extending approximately 1200 feet from north abutment to south abutment and roughly 540 feet from upstream toe to downstream toe. The dam would be founded on bedrock, with an approximately 25-foot deep clay cutoff extending at least 3 feet into sandstone and claystone bedrock. Estimated costs are primarily driven by earthwork costs and filter drain construction. Based on 30% design quantities, storage would cost approximately $23,650 per acre-foot.

Dam design for the Bruce Canyon site was shifted from a zoned earthen embankment dam to a homogeneous earthen embankment based on Cesare's geotechnical investigation, which indicated significant borrow potential for native material in the proposed reservoir area. The dam's alignment was also moved upstream of the existing volcanic dike due to seepage and stability concerns associated with the feature. The emergency spillway was rerouted away from the toe of the dam and through the volcanic dike, based on dam safety concerns and potential effects on the dam associated with high flows running through the emergency spillway.

The following additional information is necessary to further design, and is proposed to be completed at the 50% design stage:

1. Full topographic survey of the dam site and proposed inundation area.
2. Additional geotechnical investigation to obtain more information on the following:
    a. Location and depth to low-permeable bedrock (as well as estimated hydraulic conductivity) along the dam alignment and specifically at the north abutment.
    b. Suitability (as well as availability) of native clay soils in reservoir area for embankment construction.
    c. Settlement potential of overburden soils encountered during test pit excavation.
3. Design and specific cost estimates for key dam infrastructure such as the chimney and blanket drains, toe drain, and outlet works.

# APPENDIX A

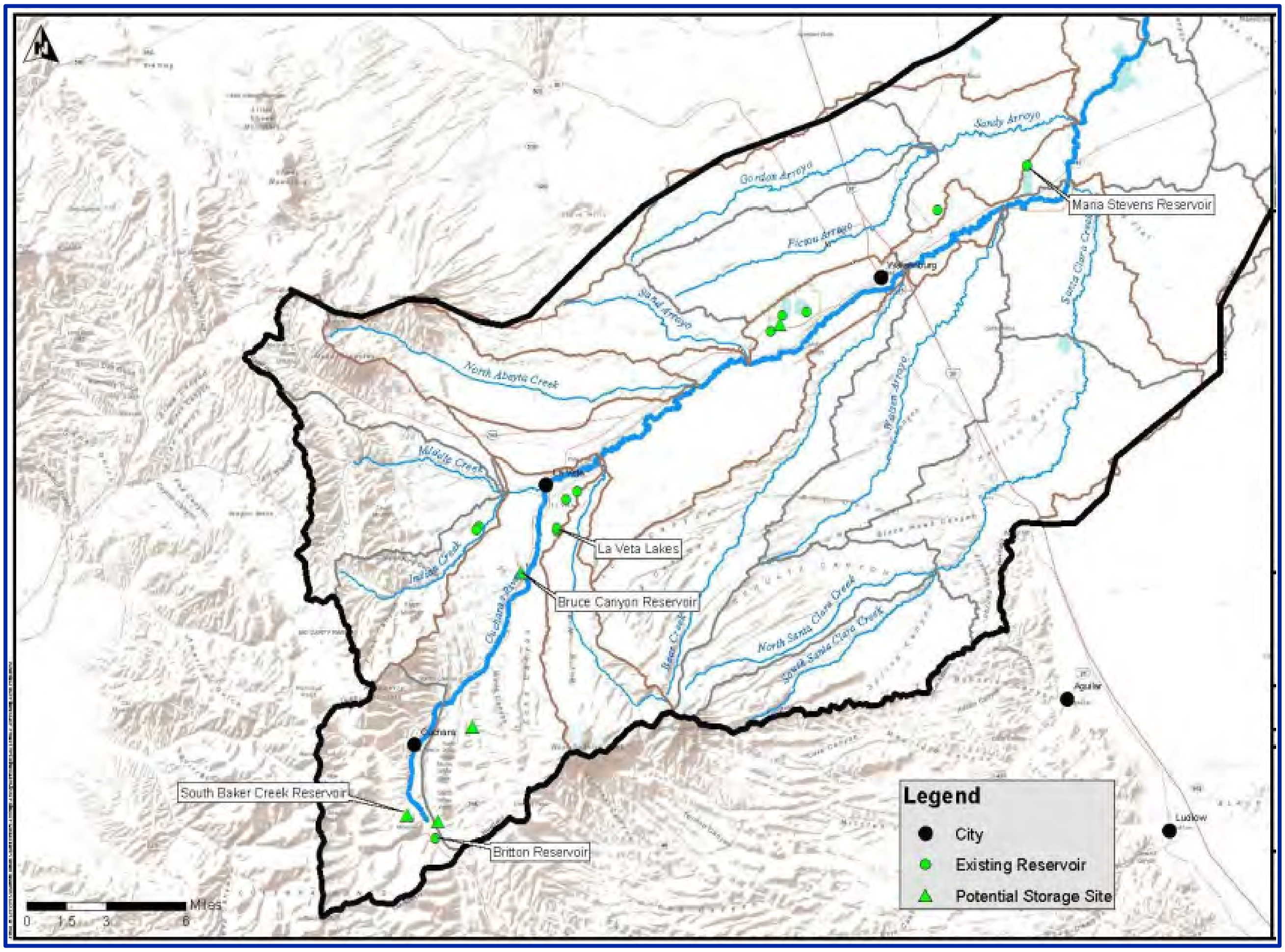
# GEOTECHNICAL REPORT

CESARE, INC.

*Geotechnical Engineers & Construction Materials Consultants*

# PRELIMINARY GEOTECHNICAL EVALUATION

Cucharas Basin Collaborative Storage
Huerfano County, Colorado



**Report Prepared for:**

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**Denver, CO 80234**

**Project No. 18.117.A**
**November 7, 2019**

CESARE, INC.
*Geotechnical Engineers & Construction Materials Consultants*

# PRELIMINARY GEOTECHNICAL EVALUATION
## Cucharas Basin Collaborative Storage
## Huerfano County, Colorado

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**Report Prepared by:**

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# 1. INTRODUCTION

Cesare, Inc. (Cesare) completed a preliminary geotechnical evaluation of five proposed sites under consideration for constructing one or more permanent water storage reservoirs for the Cucharas Collaborative Storage (CCS). CCS is a group of stakeholders requiring additional long term water storage for municipal and agricultural needs. The five preferred alternative sites were selected from an initial 50 potential sites. Cesare's scope of work was to provide geotechnical and geological information, technical constraints, and preliminary design recommendations, as necessary, to allow site selection for new and/or enlarged water storage.

# 2. PROJECT DESCRIPTION

The overall project consists of developing increased permanent water storage capacity. The reservoirs are intended to provide municipal water for Cucharas Sanitation and Water District, Town of La Veta, and the City of Walsenburg in drought years. In addition, various farmers managing about 11,000 irrigable acres require water during most years. The total present and future demands were estimated at about 12,980 acre feet per year (AFY) and 33,673 AFY, respectively. Requirements for a 3 year drought were estimated at about 3,630 TO 3,670 AFY for municipal and about 15,000 AFY for irrigation.

Applegate Group, Inc. (Applegate) performed initial screening of almost 50 sites during the first phase of the overall project resulting in recommending the five sites considered for this work. Applegate developed conceptual plans for each site to prepare initial construction requirements and costs. Cesare performed a preliminary evaluation of each of the five sites, including limited geology, field exploration, laboratory analysis, and engineering analysis. The results are to assess the technical constraints as they apply to the economic constraints. Cesare also prepared recommendations for additional exploration and analysis that may be necessary for site selection, given that final design will require detailed evaluation in field, laboratory, and engineering phases.

## 2.1 BRITTON

The Britton site is just downstream from two existing ponds, about 3 miles south of Cuchara, Colorado. The preliminary plans call for a new zoned earth fill embankment of about 48 feet in average height at its maximum section. The reservoir ponding area is the planned borrow area. The two existing ponds would be inundated by the new reservoir.

## 2.2 BRUCE CANYON

The Bruce Canyon site is about 2-1/2 miles southwest of La Veta, Colorado. It is a relatively broad valley cut perpendicularly by a volcanic dike that was incised by a perennial drainage creating a relatively narrow draw. Preliminary plans call for a new zoned earth fill embankment within the draw, about 77 feet in average height at its maximum section. The planned borrow source is the reservoir ponding area.

## 2.3 LA VETA LAKES

La Veta Lakes is the site of two small existing reservoirs about 1/2 mile south of La Veta, Colorado. Preliminary plans call for two homogeneous earth fill embankments, a north and a south, to combine the two lakes into one and increase the total reservoir capacity. The new embankment and raises will be about 5 feet at their maximum sections. The planned borrow is the small embankment between the two ponds.

### 2.4 MARIA STEVENS

Maria Stevens is an existing reservoir about 6-1/2 miles northeast of Walsenburg, Colorado. The preliminary plans call for two zoned earth fill embankments, a new western and a raised southern, to increase the reservoir's capacity. The new western embankment extends along the majority of the existing reservoir's west side and continues around its north side, just past its northeast corner. The south embankment parallels State Highway 10 (SH10) to its south. The raises will be about 5 feet average height at their maximum sections. The planned borrow is from an area east of the reservoir.

### 2.5 SOUTH BAKER

The South Baker site is about 2 miles southwest of Cuchara, Colorado. Preliminary plans call for a zoned earth fill embankment, about 66 feet average height at its maximum section. The planned borrow source is the reservoir ponding area.

## 3. SITE CONDITIONS

### 3.1 BRITTON

The Britton site is located about 3 miles south of Cuchara, Colorado. It is a steep walled valley, generally trending downward in slope from southeast to northwest. The valley is heavily forested on both sides with the trees thinning near the valley's flowline at the proposed dam centerline. State Highway 12 (SH12) is located about 200 feet west of the proposed southernmost dam abutment.

The valley does not appear to carry either perennial or intermittent stream runoff, other than specific storm runoff. Two existing ponds about 500 feet upstream of the proposed dam centerline were holding water at the time of our field exploration. No other free water was visible. Cesaree noted no bedrock outcrops at the site at the time of our field exploration.

### 3.2 BRUCE CANYON

The Bruce Canyon site is located about 2-1/4 miles south of La Veta, Colorado. It is at the confluence of two relatively broad valleys; one at higher elevation to the north and the other at lower elevation to the south. The southern, lower, valley will provide the reservoir water storage. It generally trends downward in a gentle slope from southwest to northeast.

The confluence tapers to pass through a relative narrow draw formed by an ephemeral drainage through a ridgeline made prominent by the volcanic dike protruding from it. The proposed dam location is within this draw. The ridgeline flanks comprising the draw, slope moderately on both sides. The northern slope is moderately to sparsely vegetated with small conifer trees and low brush. The southern slope is moderately to heavily forested, primarily with conifer and some deciduous trees. SH12 is located about 1/4 mile to the southeast of the proposed dam location.

The valley carries an ephemeral stream. The existing Marker Lake is about 1/4 mile northeast, Hayes Reservoir is about 1 mile north, and Butte Reservoir is about 1 mile northwest of the dam location. No other free water was visible at the time of our field exploration. Butte Ditch forms the perimeter of the proposed storage area with its alignment near the terminus of the proposed south abutment embankment. The ditch was dry at the time of this evaluation.

Sandstone was exposed in the ridge forming the proposed dam location. Bedrock outcrops also include the dike in the ridge forming the dam location, Goemmer Butte, and a lesser peak that are all of volcanic origin. Goemmer Butte and the lesser peak are about 3/4 mile and 1/2 mile northwest of the proposed dam location, respectively.

### 3.3 LA VETA LAKES

The La Veta Lakes site is located about 1/2 mile south of La Veta, Colorado. The two lakes covering this site are west and below the crest of a low hill. The hill slopes downward gently to moderately away from the crest in all directions. The ground surface around the lakes generally slopes downward to the west and southwest.

The northern lake appears to have been created through excavation. The southern lake appears the same but also has low embankments on its west, south, and partial southern east sides. The hill is sparsely vegetated with small trees and bushes. A sparse to heavy growth of native grasses surrounds the lakes. The lakes were holding water at the time of our field exploration.

The Cucharas River is less than 1/2 mile west of the lakes. Wahatoya Creek is a separate drainage about 3/4 of a mile east of the lakes. Wahatoya and Daigre Reservoirs are about 1 to 1-1/2 miles northeast of the lakes. A small unnamed reservoir is about 1/2 mile northeast of the lakes. Cesaree noted bedrock outcrops on the hill's peak and numerous other locations around the hill and its edges at the time of our field exploration.

### 3.4 MARIA STEVENS

The Maria Stevens site is an existing lake located about 4-1/2 miles northeast of Walsenburg, Colorado along SH10. County Road 120 (CR120) extends north from SH10 about 800 feet west of the lake's edge. General topography ranges from relatively flat to rolling and incised by various streams and drainages. The existing reservoir is within a shallow draw that drains to the north. The ground surface slopes gently upward to the east and west from the lake. Low embankments are on both the lake's northern and southern ends creating the reservoir. SH10 trends easterly, parallel to and about 50 feet from the south embankment. Several residences, buildings, roads, and parking exist along the lake's west side along with three boat launch ramps. Vegetative cover consists of a heavy growth of native grasses and weeds with some small trees and bushes.

Cucharas River is about 900 feet south of the lake, with no structural connection between the two. Duran Ditch parallels the lake's western edge about 200 feet to the west. Cucharas Reservoir begins about 3 miles northeast of the lake, with the Cucharas Dam about 6-1/4 miles to the northeast. Cesaree noted no bedrock outcrops on or near the site at the time of our field exploration.

### 3.5 SOUTH BAKER

The South Baker site is located about 2 miles south of Cuchara, Colorado. It is within a secondary valley of a relatively broad east and west trending valley. An isolated east-west trending ridge divides the secondary valley from the large valley and at its eastern end near the mountain forming the large valley's southern side. The proposed dam location is in the secondary valley, an estimated 500 feet upstream of the crotch of the large/secondary valleys.

At the dam location, the secondary valley is steep walled, heavily forested on both sides, with the trees thinning to a narrow open meadow in the valley's bottom that widens to the west. The valley slopes downward from west to east at moderate slope. SH12 is located about a 1/4 mile northeast of the proposed dam centerline.

The valley appears to carry an intermittent stream that was flowing at the time of our field explorations. No other free water was visible nor were rock outcrops visible at the time of our field exploration.

## 4. GEOLOGIC CONDITIONS

The Spanish Peaks/Cucharas region is geologically part of the Raton Basin in southern Colorado. The La Veta syncline is one of the large landscape features in this area. The syncline is a fold that includes a sequence of sedimentary units representing rocks of Paleozoic, Mesozoic, and Tertiary ages. The fold has steeply dipping beds on its west limb bounded on the west by the Sangre de Cristo Mountains and a gently dipping limb on the eastern side where the sedimentary units flatten toward the plains. The Spanish Peaks are prominent features of intrusive igneous rock found along the axis of the syncline fold. These tertiary intrusions are stocks, plugs, laccoliths, sills, and radiating dikes that cut through the sedimentary units as Johnson (1969)[1] indicates.

### Sedimentary Rock

Paleozoic sedimentary rocks outcrop on the western side of the La Veta syncline. The units are from the Pennsylvanian/Permian Sangre de Cristo group; red and gray conglomerate, arkose, sandstone, siltstone, shale, and gray limestone. These units are north-south striking and create higher elevation ridges and steep valleys because of their resistance to erosion.

Mesozoic sedimentary units' outcrop on the western (steeply dipping to near vertical) and eastern side (gently dipping to flat lying) of the syncline axis. This sequence includes the Jurassic Morrison Formation, Dakota Sandstone, Carlile Shale, Niobrara Formation, Pierre Shale, Trinidad Sandstone, and the Raton Formation. These units have sandstone, siltstone, shale, limestone, as well as coal, chalk, and gypsum beds. Because of their variable resistance to weathering and erosion, the steeply dipping beds create ridges and hogbacks that strike generally north-south on the western side of the La Veta syncline.

The axial units of the La Veta syncline include the Tertiary Poison Canyon Formation, the Cuchara Formation, and the Huerfano Formation. These are arkosic conglomerate and sandstone, siltstone, and shale. The Cuchara Formation is sandstone and claystone. The Huerfano Formation is shale and sandstone. Each of these units is unconformable with the unit below. These units are elevated due

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[1] Johnson, R.B., 1969. Geologic map of the Trinidad quadrangle, south-central Colorado. US Geological Survey, Miscellaneous Geologic Investigations Map I-558. Map Scale 1:250,000.

to the intrusion of the West and East Spanish Peaks and essentially drape over the flanks of the stocks.

Johnson observed that throughout the Spanish Peaks region, the competent sedimentary rocks, such as conglomerate, sandstone, and limestone are highly jointed, but noted the effect of contact metamorphism on the sedimentary rocks is generally not significant. Locally bleached sandstone and baked shale adhere to the walls of some of the smaller intrusive bodies, and the shale has been altered to slate or phyllite. Near the intrusive mass of West Spanish Peak, conglomerates, sandstone, and shale beds have been altered to conglomeratic quartzite, hornfels, and slate which are more resistant rock units.

### Igneous Rock

The intrusive igneous bodies of the Spanish Peaks cut through and across the sedimentary sequence and fold structure of the La Veta syncline. The softer sedimentary rocks were subsequently weathered and eroded away to reveal the more resistant radiating dikes, sills, laccoliths, and plugs of silicic, intermediate, and basic composition. There are several references for the types of igneous intrusions and the mineralogy of the different intrusive events in Penn 1992[2] and 1994[3]. The most common rock compositions are monzonite and syenite porphyries. More mafic rocks are prevalent farther from the two peaks. The East Spanish Peak stock and some radial dikes are granite and granodiorite. Basaltic rocks most commonly form sills, dikes, and plugs distal to the two peaks. The dikes vary from 3 to 100 feet in thickness and are exposed for distances of up to 12 miles.

A portion of the Trinidad geologic quadrangle map[1] in Figure 1 shows the locations of the five project sites. Four of the five study sites are located in the central and western portions of the La Veta syncline fold and Spanish Peaks intrusions. Maria Stevens is the only site located on the gently dipping eastern side of the fold on the plains.

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[2] Penn, B. S., Snee, L. W., and Wendlandt, R. F., 1992, 40Ar/39Ar geochronologic constraints on the intrusive history of the Spanish Peaks area in south-central Colorado (abs.): American Geophysical Union Fall Meeting, EOS, v. 73, no. 43, p. 657.

[3] Penn, B. S., 1994, An investigation of the temporal and geochemical characteristics, and the petrogenetic origins of the Spanish Peaks intrusive rocks of south-central Colorado: Ph. D. thesis T-4323, Colorado School of Mines, Golden, Colorado, 198p.

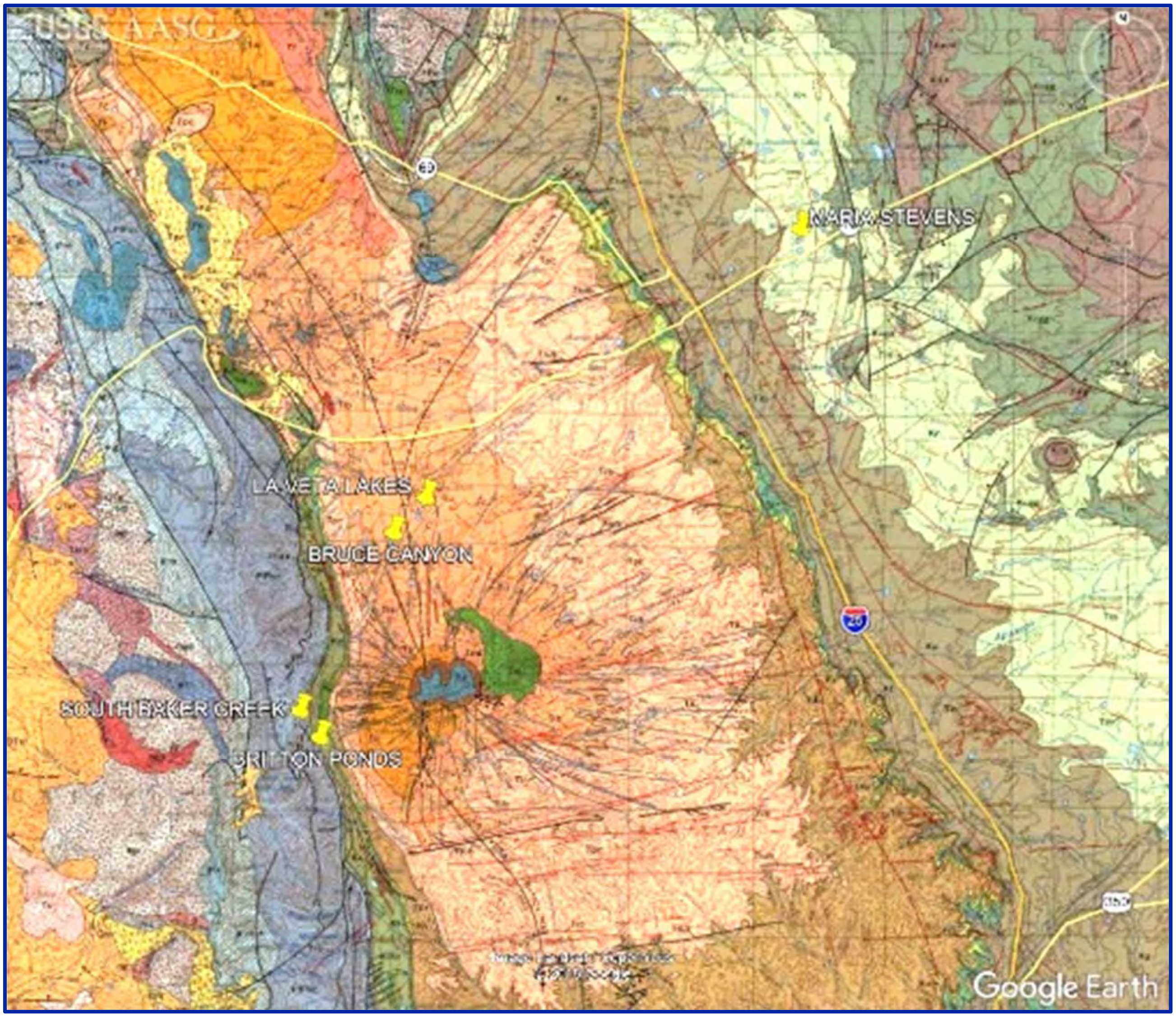

**FIGURE 1. Geologic map showing the five study site locations. The La Veta syncline axis trends southeast to northwest and along the fold axis are the East and West Spanish peak intrusions and radiating dikes. The Maria Stevens site is north and east of the Cucharas area on the gently dipping east limb of the fold.**

## Mapped Hazards

According to the Colorado Landslide Inventory Map[4], only three landslides have been identified and mapped in the area of the subject dam locations (Figure 2). These landslides were mapped from aerial imagery and due to the scale (1:250K), smaller landslides may not be included in the inventory. These landslides are located southwest of the Town of La Veta in the Mesozoic sedimentary rock section. None of the study sites are near these mapped landslides but they are in a similar geologic and topographic setting.

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[4] Colorado Geologic Survey, Colorado Landslide Inventory, 2018. (http://coloradogeologicalsurvey.org/geologic-hazards/landslides/colorado-landslide-inventory/)

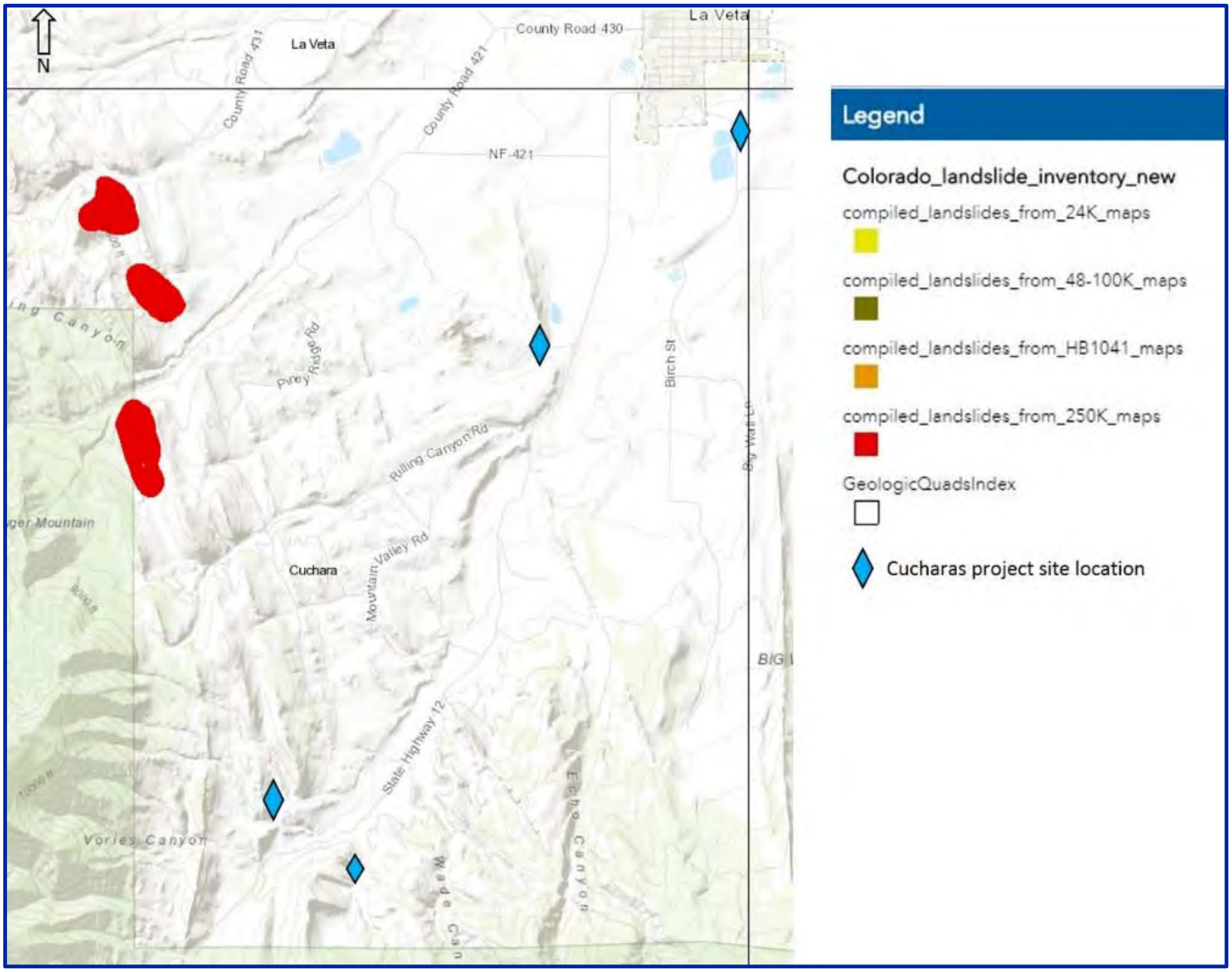

**FIGURE 2. Mapped landslides in the Cucharas region from the Colorado landslides inventory. The red polygons are landslide areas digitized from 1:250,000 scale USGS mapping in the mid 1970's by Colton and others on 1 degree by 2 degree quadrangles. This map may not represent all landslides in the area.**

Seismic hazards are low in the project area; however, earthquakes have occurred in the region, mainly south of the project area. Mapped earthquakes and percent chance of damage are shown on the USGS[5] (Figure 3). The project sites fall into the less than 1% chance of damage area mapped by the USGS. This indicates, should an earthquake occur, there is a very low risk of damage from an event that will affect any of the project sites.

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[5] United States Geologic Survey; Colorado Area Seismicity (1973-8/14/2017). (https://earthquake.usgs.gov/earthquakes/byregion/colorado/CO_2017_damagemap.pdf)

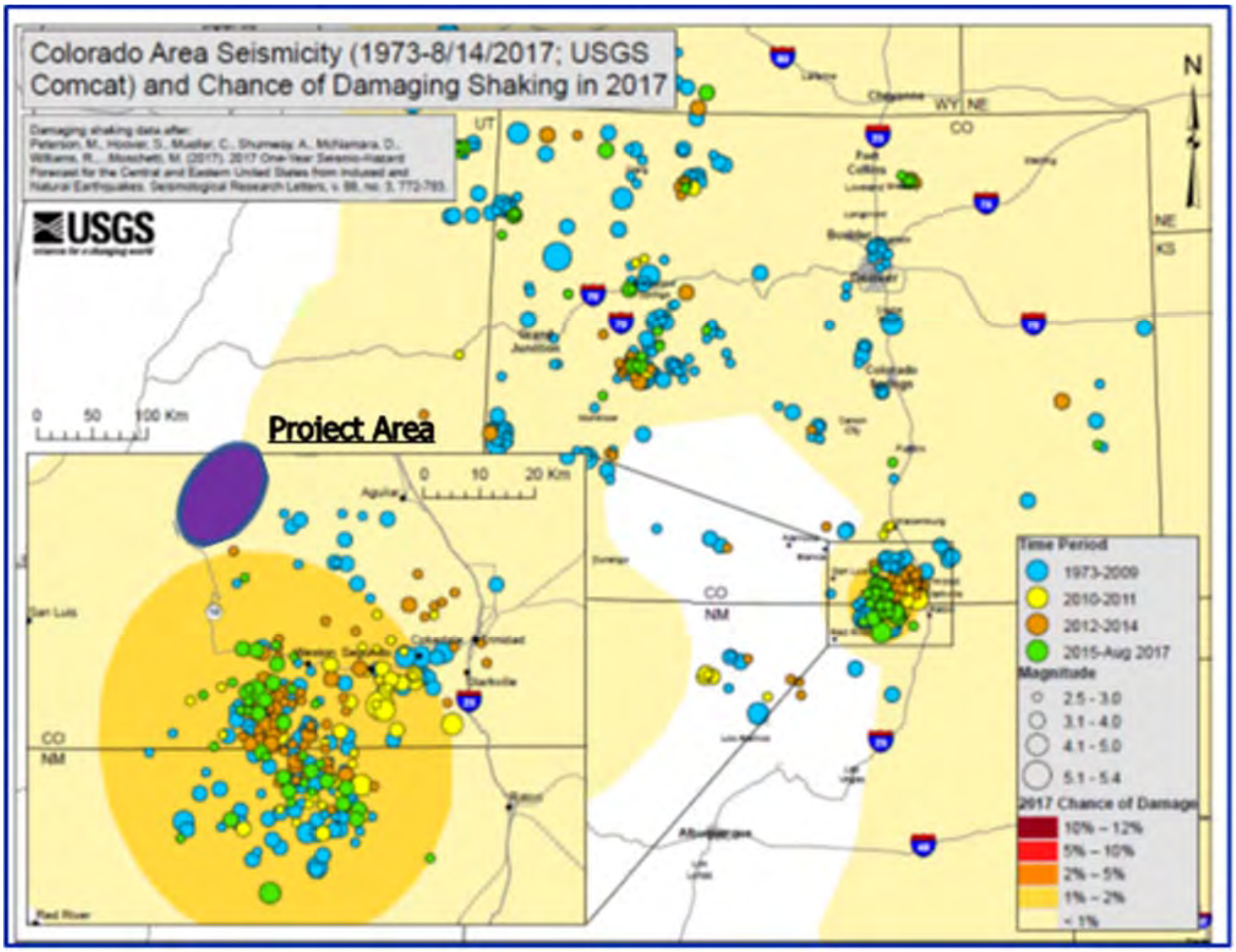

**FIGURE 3. Colorado seismicity from the USGS earthquakes hazards program. There is very low seismic risk for the project area.**

### 4.1 BRITTON

The Britton site is located south of Baker Creek on the east side of SH12 (Figure 4). The site is north of two existing ponds on the South Fork of the Cucharas River. The drainage is a northwest trending valley which is located on the contact between the Sangre de Cristo Formation and the steeply dipping Morrison/Ralston Creek Formation and is bounded on the east by a hogback ridge of Dakota Sandstone. The Morrison/Ralston Creek Formation in this area is described as a variegated maroon shale, gray limestone, red siltstone, gypsum, and gray sandstone. The Dakota is a buff sandstone, buff conglomeratic sandstone, and dark gray shale.

**FIGURE 4. Britton Ponds project site (topographic and Google Earth images) is located southeast of the Baker Creek site, east of SH12 and north of Cucharas Pass. Britton Ponds is on the South Fork of the Cucharas River. The drainage occupies a northwest trending valley.**

Geologic hazards at this site are minimal. The fracture nature of the sedimentary bedrock may lead to seepage and weathering along the fractures and bedding planes. This could result in a modification of drainage patterns.

## 4.2 BRUCE CANYON

The Bruce Canyon site is located southwest of the Town of La Veta off SH12. The potential dam site is upstream of an intrusive dike that strikes northwest to southeast, cutting through the Cuchara Formation that comprises the valley rock (Figure 5). The low valley drains an ephemeral creek through the dike and Butte Ditch runs around the periphery at an elevation of 7,420 feet. Goemmer Butte is west of the valley. Goemmer Butte is a volcanic plug intruded into the Cuchara Formation and exhibits the only evidence in the immediate vicinity of Spanish Peaks for magma venting to the surface. A crescent shaped body of eruptive breccia is well exposed on the south and west sides of the butte. The Eocene aged Cuchara Formation exposed here represents its lowermost part. Typically, the formation is arkosic, conglomeratic, and cross bedded, found in fining upward alluvial cycles. The mudstones are drab brown to red. There are prominent pebbles and cobbles in the sandstone and red mudstone helps distinguish the unit in this area (Penn, 1996[6]).

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[6] Penn, B.S., Lindsey, D.A. and Thompson, R.A., 1996. Tertiary igneous rocks and Laramide structure and stratigraphy of the Spanish Peaks region, south-central Colorado: Road log and descriptions from Walsenberg to La Veta (first day) and La Veta to Aguilar (second day.

**FIGURE 5. Bruce Canyon project site (topographic and Google Earth images) is located southwest of the Town of La Veta, west of CR12. Bruce Canyon is an east-west valley cut through by a north-south trending intrusive dike. There is an ephemeral spring and an irrigation ditch in the project area. Goemmer Butte is a prominent volcanic feature west of the project site.**

Geologic hazards at Bruce Canyon are rockfall and landslides. The vertical face of the intrusive dike is a source area for rockfall into the project area (Figure 6). Even so, rockfall is not expected to affect the project adversely as there is little evidence of rockfall near the proposed abutment locations, the evidence indicates rocks that have fallen are not large, and rocks would likely fall into the reservoir, as opposed to on the embankment. The slopes on either side of the valley have the potential for downslope movement (Figure 7). Because of the interbedded and fractured nature of the sedimentary rock units in this area, the slope stability could be affected by infiltration and movement of water along fractures and bedding planes, increased weathering, and reduced strength along discontinuities.

**FIGURE 6. Intrusive dike on the northeast side of the site. A potential source for rockfall into the project area.**

**FIGURE 7. Bruce Canyon project site. View looking north from the south side of the project area. Steep hill slopes on either side of the valley have the potential for downslope movement due to the fractured and interbedded nature of the sedimentary rock units.**

## 4.3 LA VETA LAKES

The La Veta Lakes project site is located due south of the Town of La Veta. It is about 80 to 120 feet higher in elevation than the town center. The Cuchara Formation consists of red, pink, and white sandstone, and red, gray, and tan claystone and underlies the site. There are small intrusions of igneous material southwest of the site. La Veta Lakes are fed by a piped diversion from the Cucharas River. They occupy a relatively flat area slightly higher than the valley floor (Figure 8). Geologic hazards for this area are minimal. There is no significant geologic hazard.

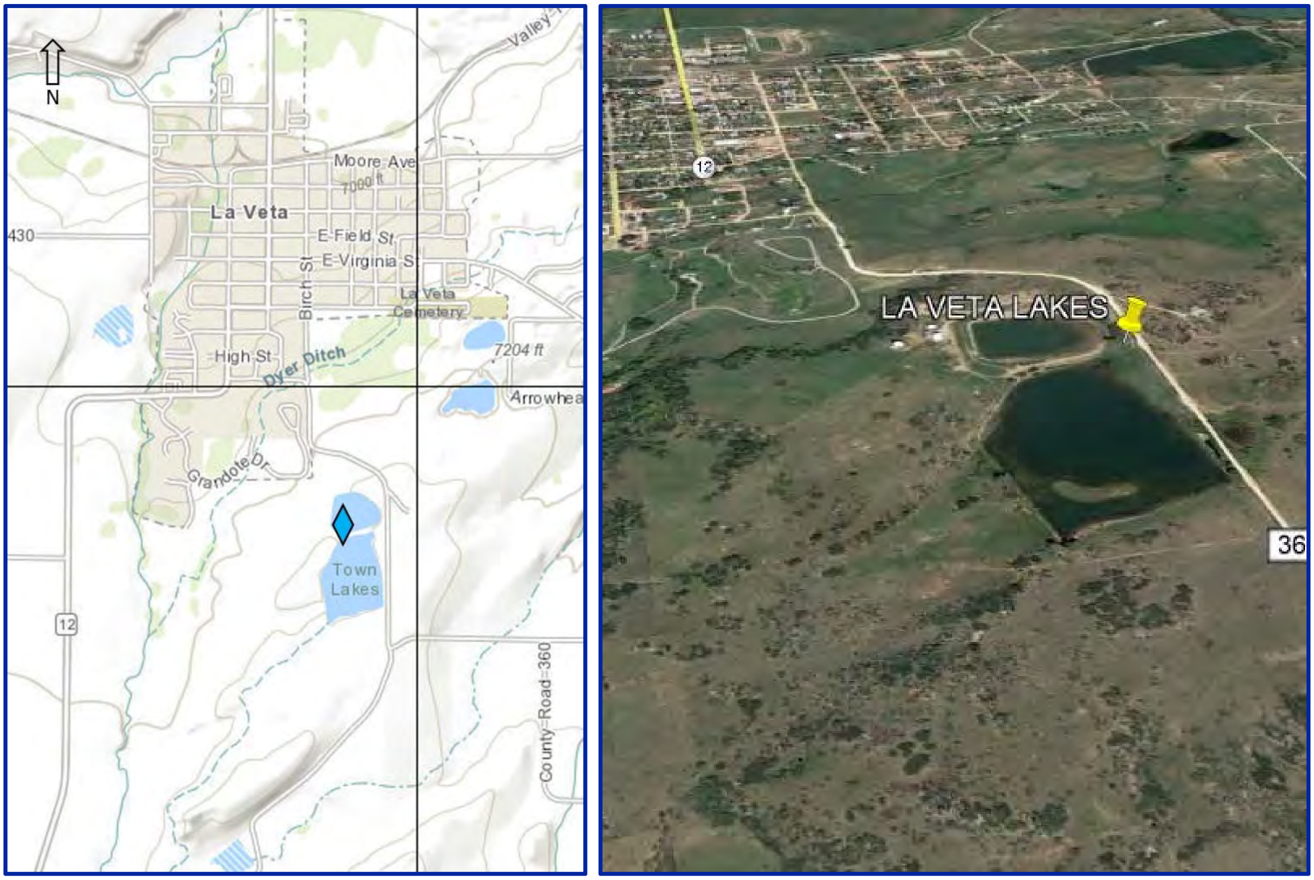

**FIGURE 8. La Veta Lakes project site (topographic and Google Earth images) is located just south of the Town of La Veta and about 100 feet above the valley in elevation. La Veta Lakes is a water storage area that is fed by a piped diversion from the Cucharas River. The site is in the middle of the La Veta syncline and is underlain by the Tertiary Cuchara Formation.**

## 4.4 MARIA STEVENS

Located east of Walsenburg on the north side of SH10, Maria Stevens Reservoir occupies a low point between two low ridges to the west and east (Figure 9). Geologically, the units in this area are the Niobrara Formation and the Pierre Shale. The Niobrara is Cretaceous age limestone with chalk layers. The Pierre Shale is Cretaceous age dark gray fissile siltstone and shale. Because of the location of Maria Stevens in the small topographic swale, it is interpreted that the Niobrara has been eroded in this area and the bedrock below the topsoil is the Pierre shale. Notably, on the ridge northwest of the site, there are several sand and gravel quarries indicating that fluvial erosion and deposition likely stripped the Niobrara from the surface as rivers crossed the area. A geologic hazard that may impact the project is possible sinkholes that may develop in buried limestone units.

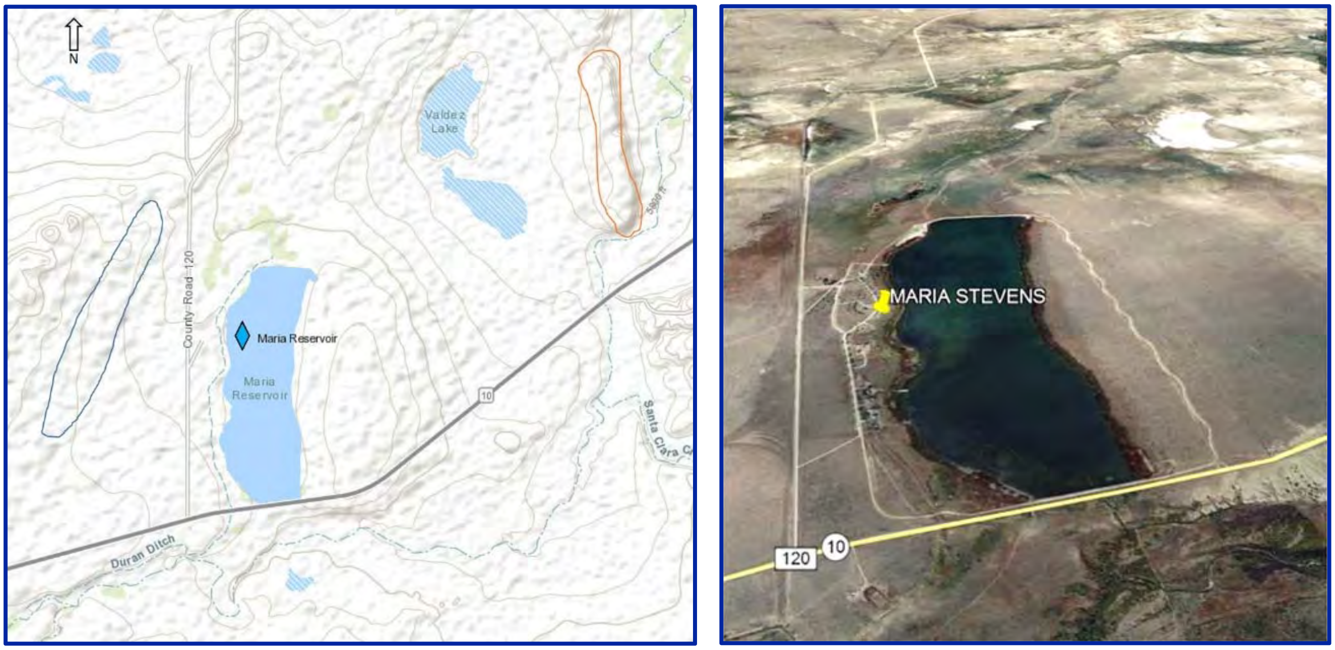

**FIGURE 9. Location and topography of Maria Stevens Reservoir (topographic and Google Earth images). Walsenburg is west, via SH10. The circled area on the left of the topographic map is a gravel ridge. The circled area on the right of this map is a ridge of Cretaceous Carlile shale, Greenhorn limestone, and Graneros Shale consisting of dark gray shale, gray limestone, and gray shale. The reservoir sits in a low point underlain by Pierre shale.**

## 4.5 SOUTH BAKER

The South Baker project site is located southwest of the Bruce Canyon site, west of CR12, north of Cucharas Pass (Figure 10). South Baker Creek is in a southwest–northeast trending valley with South Baker Creek and is a tributary of the South Fork of the Cucharas River. The South Baker Creek drainage is bounded on the north side by a small ridge and to the south by Boyd Mountain. The sedimentary units of this area are the Pennsylvanian Permian Sangre de Cristo Formation. Characterized by red and gray conglomerate, arkose, sandstone, siltstone, shale, and gray limestone. The variety of units in this formation suggests that there are variable weathering and erosion patterns in the steeply dipping unit. Boyd Mountain is well vegetated. Slope instability of the flank of Boyd Mountain is a potential hazard.

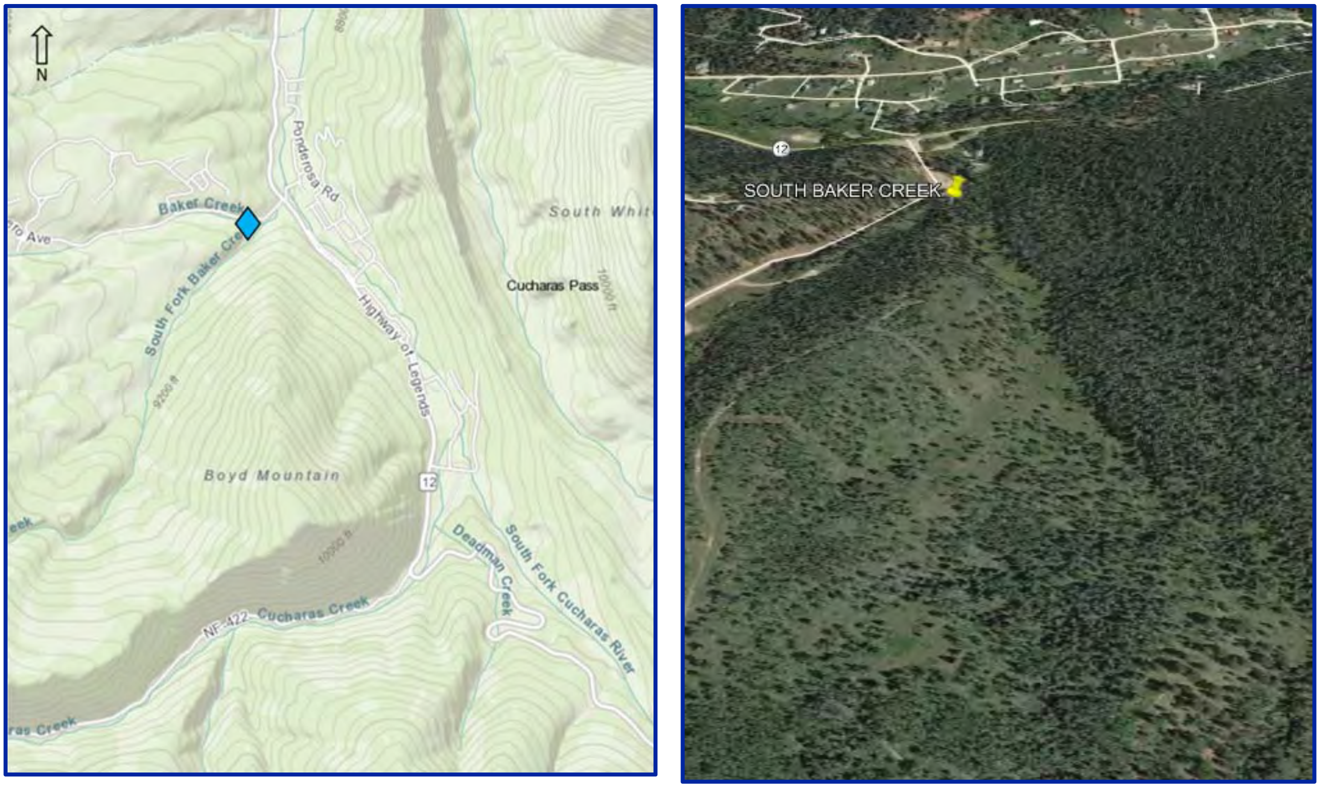

**FIGURE 10. South Baker Creek project site (topographic and Google Earth images) is located southwest of the Bruce Canyon site, west of SH12, north of Cucharas Pass. South Baker Creek is a southwest–northeast trending valley with South Baker Creek becoming a tributary of the South Fork of the Cucharas River at the mouth of the valley. Google Earth image is an oblique image looking east down the creek drainage.**

## 5. FIELD EXPLORATION

### 5.1 BORINGS

Cesare explored subsurface conditions at each site by drilling borings at the locations indicated in Figures 11, 14, 17, 19, and 22. Table 1 presents the number of borings drilled at each site.

**TABLE 1. Borings Drilled**

| Site | Borings Drilled |
|---|---|
| Britton | 2 |
| Bruce Canyon | 4 |
| La Veta Lakes | 7 |
| Maria Stevens | 6 |
| South Baker | 5 |

Abutment inaccessibility was an issue at the sites with relatively steep, heavily forested, slopes including the Britton, Bruce Canyon, and South Baker sites. Cesare drilled only two borings at the Britton site due to inaccessibility of the abutment locations; one in the general maximum dam section area and one close to the toe of the eastern abutment. Cesare drilled a boring at the maximum section location and near the toe of the north abutment at the Bruce Canyon site. A dirt road traversed the Bruce Canyon southern abutment allowing access to that boring location. We drilled the approximate maximum section location and the toes of both northern and southern abutments at the South Baker site. In August 2019, Cesare returned to the Bruce Canyon and South Baker sites to perform additional drilling at abutment boring locations after access roads were constructed. Cesare drilled the north abutment at the Bruce Canyon 30 feet into bedrock. Cesare drilled both abutments at the South Baker site to bedrock contact at the north abutment and 20 feet into bedrock at the south abutment.

Borings were advanced using a CME 550 track mounted drill rig equipped with 6 inch diameter, continuous flight, hollow stem auger and HQ and NX wireline coring equipment. ODEX casing driving was used at one location. Soil and bedrock were sampled to practical auger refusal at designated intervals using a modified California sampler which is driven into the soil by dropping a 140 pound hammer through a free fall of 30 inches. The modified California sampler is a 2.5 inch outside diameter by 2 inch inside diameter device lined with thin brass tubes to recover relatively undisturbed samples. A penetration test is the procedure to drive the modified California sampler into the soil and to record the number of blows required to do so. The number of blows required for the sampler to penetrate 12 inches gives an indication of the consistency or relative density of the soil encountered. Results of the penetration tests and locations of sampling are presented on the Boring Logs profiles, Figures 12, 15, 18, 20, and 23. Individual logs are presented in Appendix A.

At a minimum of one boring per site, the bedrock was cored using HQ or NX wireline coring equipment. Wireline equipment includes drill steel and a core barrel comprised of an inner and outer barrel. The drill steel is thin walled pipe threaded at both ends that is connected, as necessary, to reach coring depths. The outer core barrel is larger diameter than the drill steel with a cutting edge on the bottom that cuts an annular space 3.78 inches in outside diameter and 2.5 inches inside diameter for HQ and cuts annular space of 2.375 inches in outside diameter and 1.75 inch inside diameter for NX. The inner barrel is a metal tube that is held stationary inside the outer barrel and holds the core sample as it is cut from the rock mass. The inner core barrel is retrieved from the outer core barrel by a thin cable attached to it, without removing the drill steel or outer barrel. During coring, the recovered core was continuously logged, wrapped in plastic sheeting or tubing, and stored in partitioned core boxes. Photographs of the cores are presented in Appendix B.

After coring completion, Cesare tested the bedrock in all cored intervals for in situ permeability using the Packer test. The Packer test consists of sealing the cored hole with a single inflatable rubber Packer at a specific depth and pumping water in a pipe through the Packer into the remaining open boring below. This procedure was started at selected heights above the cored bottom and then the Packer unit was raised to a second interval, with testing completed at each interval. During testing, Cesare recorded the flow into the interval in gallons, the time interval pumped in minutes, the pumping pressure, and the flow meter's height above ground. The pumping pressures were increased and decreased incrementally to provide a range of conditions to evaluate seepage. Based on these measurements, Cesare calculated the permeability for each pumping pressure increment. We performed Packer testing in Borings B-2, BC-2, BC-4, LVL-1, LVL-3, LVL-5, MS-1, MS-3, MS-5, and SB-2. Results of the Packer tests are summarized in Table 2.

**TABLE 2. Averaged Packer Test Results**

| Boring | Interval Tested | | Averaged Hydraulic Conductivity (cm/sec) |
|---|---|---|---|
| | Depth (feet) | Elevation* (feet) | |
| B-2 | 23.5 to 40.0 | 9210.5 to 9194.0 | 9.4E-4 |
| | 32.0 to 40.0 | 9202.0 to 9194.0 | 1.6E-3 |
| BC-2 | 25.0 to 51.0 | 7339.0 to 7313.0 | 6.4E-6 |
| | 35.0 to 51.0 | 7329.0 to 7313.0 | 2.8E-5 |
| BC-4 | 13.0 to 40.0 | 7395.0 to 7368.0 | 3.2E-6 |
| | 20.0 to 40.0 | 7388.0 to 7368.0 | 1.4E-5 |
| | 30.0 to 40.0 | 7378.0 to 7368.0 | 3.7E-5 |
| LVL-1 | 19.0 to 40.0 | 7259.0 to 7238.0 | 3.3E-5 |
| | 29.0 to 40.0 | 7249.0 to 7238.0 | 2.7E-6 |
| LVL-3 | 5.5 to 40.5 | 7279.0 to 7243.5 | 2.3E-4 |
| | 22.5 to 40.5 | 7261.5 to 7243.5 | 3.4E-4 |
| LVL-5 | 19.0 to 41.0 | 7260.0 to 7238.0 | 2.5E-5 |
| | 29.0 to 41.0 | 7250.0 to 7238.0 | 8.9E-6 |
| MS-1 | 29.0 to 41.0 | 5896.0 to 5884.0 | 2.6E-7 |
| | 35.0 to 41.0 | 5890.0 to 5884.0 | 8.1E-7 |
| MS-3 | 33.5 to 50.0 | 5887.5 to 5971.0 | 2.0E-6 |
| MS-5 | 29.0 to 41.0 | 5996.0 to 5984.0 | 2.7E-5 |
| | 35.0 to 41.0 | 5990.0 to 5984.0 | 1.9E-6 |
| SB-2 | 19.0 to 51.0 | 8839.0 to 8807.0 | 5.0E-4 |
| | 35.0 to 51.0 | 8823.0 to 8807.0 | 8.9E-6 |

*Estimated

## 5.2 EXPLORATORY TEST PITS

To evaluate potential borrow material for construction, Cesare explored the ponding areas, or nearby areas, of each site with exploratory backhoe pits. A John Deere 225D excavator was used for most of the pits, excavating to depths of about 8 to 10 feet or penetration refusal on coarse material or bedrock. Our field personnel logged the material exposed in the pit excavations and recovered representative samples of the soil encountered. The pit locations are presented in Figures 11, 14, 17, 19, and 22. The pit log profiles are presented in Figures 13, 16, 21, and 24. We did not excavate exploratory pits at the La Veta Lakes site due to the very shallow bedrock that would refuse backhoe excavation.

# 6. LABORATORY ANALYSIS

Cesare performed laboratory testing on representative samples recovered during the subsurface investigation. The tests performed were for classification of material, evaluation of engineering properties, correlation of subsurface material, and development of analysis criteria. A summary table of laboratory test results and the individual tests are shown in Appendix C.

### 6.1 CLASSIFICATION TESTING

Bulk samples and California samples collected from borings and exploratory pits were used for classification testing. Tests were performed on both overburden soil and bedrock material. Classification testing results were coupled with the geologic origin of the material to aid in the selection of foundation and embankment analysis parameters. We performed 54 gradation and Atterberg limits tests for classification.

### 6.2 TIMED CONSOLIDATION TESTS (ASTM D2435)

Cesare conducted timed consolidation tests on existing fill soil and native overburden soil from the Maria Stevens site to evaluate the potential consolidation of the material under increased loading. Samples were inundated with water at 0.125 kips per square foot (ksf). The applied load was progressively doubled to a maximum pressure of approximately 4 ksf. We performed no rebound cycle or unloading after the maximum loading.

### 6.3 SWELL/CONSOLIDATION TESTS (ASTM D4546)

Cesare performed a swell/consolidation test on a sample from Exploratory Pit BCP-5 to evaluate the collapse potential of the native soil due to the presence of abundant voids or vugs in the larger pieces of material. The sample was trimmed from a small block in the bulk sample, loaded to 500 psf, and inundated with water. The sample collapsed 9.9% when wetted, indicating very high collapse potential. No rebound cycle or unloading was performed after the maximum loading.

## 7. SUBSURFACE CONDITIONS

Subsurface conditions of each site are described in the following sections. More complete descriptions of the subsoil and groundwater is shown in the boring and exploratory pit log profiles in Figures 12, 13, 15, 16, 18, 21, 21, 23, and 24 and the individual boring logs in Appendix A. These observations represent conditions at the time of field exploration and may not be indicative of other times or other locations. Groundwater can be expected to fluctuate with variations of seasons, irrigation, water level in the rivers and lakes, and weather.

### 7.1 BRITTON

The borings indicated the soil underlying the embankment consisted of about 15 to 20 feet of interbedded sandy clays, clayey sands, and poorly to well graded gravels with silt and sand, overlying weathered to fresh claystone bedrock. The claystone extended to depths of about 22 to 38 in Borings B-2 and B-1, respectively. We encountered sandstone below the claystone that extended to the remaining depths explored.

Cesare encountered groundwater during drilling at depths of 29-1/2 and 10-1/2 feet in Borings B-1 and B-2, respectively. We backfilled the borings upon drilling completion and made no additional groundwater measurements.

The exploratory pits indicated about 5 to 8 feet of silty, clayey, and relatively clean sands, at which depths the backhoe refused. Exceptions were Pits BP-2 and BP-4 in which we encountered silty gravels at depths of about 6-1/2 and 4 feet, respectively, that extended to the remaining depths explored.

## 7.2 BRUCE CANYON

The soil underlying the Bruce Canyon site consisted of interbedded sandy clays and clayey sands to depths of about 14 feet in Boring BC-1 near the north abutment, 18 feet in BC-2 in the valley, about 5-1/2 feet in BC-3 on the south abutment, and less than 1 foot in BC-4 on the north abutment. The soil overlies claystone bedrock in the south abutment and sandstone in the valley and on the north abutment that extend to the remaining depths explored. We noted occasional relatively thin lenses of sandstone in the claystone in BC-3 and a thin lens of claystone in the sandstone in B-4.

Cesare encountered groundwater during drilling at depths of 10 and 8 feet in Borings BC-1 and BC-2, respectively. We did not encounter groundwater in BC-3 or BC-4 during drilling. We backfilled the borings upon drilling completion and made no additional groundwater measurements.

The exploratory pits encountered interbedded silty, clayey, and silty/clayey sands and sandy clays to the depths explored. We encountered groundwater in BCP-1 at about 9-1/2 feet.

## 7.3 LA VETA LAKES

Cesare encountered fill to depths of about 3 to 11 feet in Borings LVL-1 and LVL-4 through LVL-6. LVL-1 was located at the north side of the north lake, LVL-4 and LVL-5 were at the west side of the lake at the south end, and LVL-6 was at the east side of the lake near its south end. At the central portion of the project site, generally between the two lakes, we encountered native sandy clays to depths of about 1-1/2 to 3 feet in Borings LVL-2, LVL-3, and LVL-7. We encountered interbedded claystone and sandstone below the soil that extended to the remaining depths explored.

Cesare encountered groundwater during drilling at depths of 2-1/2 to 4 feet in Borings LVL-1 and LVL-4 through LVL-7. We did not encounter groundwater in LVL-2 or LVL-3. We backfilled the borings upon drilling completion and made no additional groundwater measurements.

Based on the drilling results, we did not excavate exploratory pits at this site due to the shallow bedrock.

## 7.4 MARIA STEVENS

Cesare's borings indicated the soil underlying the site consisted primarily of sandy clay to depths of about 6-1/2 to 28 feet below the ground surface. Exceptions were in Borings MS-1, MS-2, and MS-6, in which we encountered weathered claystone to 5 feet, interbedded sands and clays to 16-1/2 feet, and fill to 7 feet, respectively. We encountered claystone below the soil in all borings except MS-2 and MS-6, in which we encountered sandstone and shale, respectively. Where encountered, the claystone extended to 22-1/2 to 27 feet in Borings MS-1, MS-3, MS 4, and MS-5 and the depth explored of 34-1/2 feet in MS-2. The shale extended to the remaining depths explored in the remainder of the borings.

Cesare encountered groundwater during drilling at depths of 6 to 25 feet in all borings. We backfilled the borings upon drilling completion and made no additional groundwater measurements.

The exploratory pits indicated about 3 to 5 feet of sandy clays over shales extending to the depth explored of about 6 to 8 feet. Considering the backhoe penetrated the shale, it is likely excavatable with typical earthwork construction equipment.

### 7.5 SOUTH BAKER

The soil underlying the South Baker site in the valley's lower elevations consisted of interbedded silty, clayey, and relatively clean sands, with lesser amounts of sandy clay to depths of 7 to 22 feet. Sandstone directly underlies the soil and extended to depths of 14-1/2 feet and 41 feet in Borings SB-1 and SB-2 and the depth explored of 17 feet in SB-3. Claystone was encountered below the sandstone in SB-1 and SB-2 that extended to about 27 feet and the depth explored of 51 feet, respectively. Sandstone was found underlying the claystone in SB-1 that extended to the remaining depth explored of 29 feet.

The soil encountered at the north abutment consisted of silty sand and clayey gravel to a depth of about 10 feet. Sandstone underlies the soil that extended to the depth explored of about 14-1/2 feet. At the south abutment, we encountered sandy clays with increasing gravel and cobble contents with depth that extended to about 12 feet overlying a mixture of sand, gravel, cobbles, and boulders with a maximum size particle of about 5 feet. The soil overlay interbedded claystone and sandstone that extended to the remaining depth explored of about 70 feet.

The zone of very coarse material that was encountered in SB-4 at the south abutment could be glacial moraine; however, it is more likely landslide material. The drilling progress indicated it was unconsolidated, with blow counts varying from 35 blows for 12 inches to 50 blows for 7 inches on large particles. We cored through this zone with poor recovery between apparently large hard boulders, in which we had good recovery.

Cesare encountered groundwater during drilling at depths of 3 and 4 feet in Borings SB-2 and SB-3, respectively. We encountered no groundwater in SB-1, SB-4, and SB-5. We backfilled the borings upon drilling completion and made no additional groundwater measurements.

The exploratory pits indicated about 1-1/2 to 3 feet of silty, clayey, and silty/clayey sand overlying silty, clayey, and relatively clean gravels extending to the depths explored of 4 to 9 feet. An exception was SBP-4, in which we encountered sandstone at about 5-1/2 feet that extended to about 8 feet, the depth explored.

## 8. ANALYSIS

Cesare reviewed the conceptual embankment sections, field exploration results, and laboratory analysis to perform an initial evaluation of the five sites. After discussions with Applegate, we removed the La Veta Lakes and the South Baker sites from further consideration due to the lack of low permeability borrow material at these sites. Our review of these two sites is presented in Section **9. LOCATION DISCUSSIONS.**

Our analysis included performing stability and seepage analysis on the preliminary embankment sections provided to us. For any permanent water storage embankment, one must evaluate the embankment's stability, while holding water to its design capacity on a long term basis. Other scenarios that may impact its stability, such as rapid drawdown of the stored water, shaking from earthquakes, and deterioration of the supporting soil and/or bedrock, also require stability evaluation. One must also evaluate water seepage through the embankment as it reduces the strength of most soil and causes additional forces within the embankment that reduces its stability during any of the aforementioned scenarios.

Cesare performed the analysis using the GeoStudio 2018 Suite produced by Geo-Slope International, Inc. of Calgary, Canada. The suite integrates all facets of various modeling types that allows the results of one analysis to be used directly by other analyses. More specifically, the programs used for our analysis were SEEP/W and SLOPE/W that allowed seamless analysis by initially analyzing seepage that was subsequently used in the slope stability.

Due to the very soft conditions at the Maria Stevens site, Cesare performed a strain based settlement analysis under the applied loads. We based this analysis on the timed consolidation tests performed in our laboratory. We used the Naval Facilities Engineering Command (NAVFAC) Design Manual 7.1[7] to evaluate the embankment influence at varying depths.

## 8.1 MATERIAL PARAMETERS

### 8.1.1 Seepage Parameters

Cesare used soil permeability values based on material types, published values, and our experience with these types of projects. Based on the exploration and laboratory results, the material encountered on any one site did not vary significantly in their gradations, specifically regarding their clay contents. As a result, specifically evaluating zoned embankments was not necessarily appropriate. Even so, we attempted to do so considering the material encountered, specific to their individual locations.

Some of the Packer test results presented in Table 2 indicated variation in bedrock hydraulic conductivity in the same boring ranging from 1 to 2 orders of magnitude. These variations likely relate to fracture flow, at least in the unweathered bedrock. The sandstones encountered generally varied in condition, ranging from nonindurated and unlikely to exhibit fracture flow, to moderately to well indurated and likely to exhibit fracture flow.

Fracture flow in the fresher claystone is unlikely to be uniform below the embankment, such that the claystone would be consistently relatively permeable. Work by Zhang[8] (2013) and others indicate claystone fractures tend to close under increased loading and when wetted. Cesare's opinion is a conservative approach considering fracture flow during the reservoir life is appropriate.

To be conservative, we used the highest bedrock hydraulic conductivity of each site, specific to the location. For the most part, the Packer testing indicated that the higher permeabilities existed in the upper portion of the bedrock. Using the higher permeability is, therefore, appropriate. Packer testing typically measures the horizontal flow component of in situ permeability. Cesare estimated the vertical

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[7] Soil Mechanics, Desgn Manual 7.1; Department of the Navy, Naval Facilities Engineering Command; May 1982

[8] Zhang, C.-L. Experimental Evidence for Self-sealing of Fractures in Claystone. J. Phys. Chem. Earth (2011), doi:10.1016/ j.pce.2011.07.030.

flow will likely be one order of magnitude lower, thus, the ratio of vertical to horizontal permeabilities would be 0.1.

The material requiring seepage parameters for analysis include the embankment fill, native soil, and the unweathered bedrock. The values used are presented in Table 3.

**TABLE 3. Permeability Parameters**

| | Britton | | Bruce Canyon | | Maria Stevens | |
|---|---|---|---|---|---|---|
| **Material** | **Saturated Hydraulic Conductivity (cm/sec)** | **Saturated Hydraulic Conductivity (ft/sec)** | **Saturated Hydraulic Conductivity (cm/sec)** | **Saturated Hydraulic Conductivity (ft/sec)** | **Saturated Hydraulic Conductivity (cm/sec)** | **Saturated Hydraulic Conductivity (ft/sec)** |
| Embankment core | 1.00E-04 | 3.28E-06 | 1.00E-04 | 3.28E-06 | 1.00E-04 | 3.28E-06 |
| Embankment shell | 1.00E-04 | 3.28E-06 | 1.00E-03 | 3.28E-05 | | |
| Native soil, clayey | | | | | 1.00E-06 | 3.28E-08 |
| Native soil, granular | 3.35E-01 | 1.10E-02 | 3.35E-01 | 1.10E-02 | | |
| Existing fill, clayey | | | | | 1.00E-06 | 3.28E-08 |
| Unweathered claystone | 5.00E-05 | 1.64E-06 | | | 3.00E-05 | 9.84E-07 |
| Unweathered sandstone | 8.99E-04 | 2.95E-05 | 2.80E-05 | 9.20E-07 | | |
| Cutoff | 1.00E-07 | 3.28E-09 | | | | |

Blanks indicate the soil were not pertinent to our analysis.

### 8.1.2 Strength Parameters

Based on our testing, experience, and judgement, we present the strength parameters assigned to the various embankment and foundation material in Table 4.

**TABLE 4. Stability Analysis Strength Parameters**

| Material | Friction Angle (degrees) | Cohesion (psf) | Remarks |
|---|---|---|---|
| Embankment core | 25 | 25 | Predominantly clayey sand/sandy clay |
| Embankment shell | 25 | 25 | Predominantly clayey sand/sandy clay |
| Native clay | 15 | 0 | Maria Stevens supporting surface |
| Claystone | 0 | 3,000 | Fresh |
| Sandstone | 0 | 3,000 | Fresh |
| Native soil | 25 | 25 | Predominantly silty sand |
| Slope protection | 40 | 10 | Riprap with sand bedding |

## 8.2 SEEPAGE RESULTS

Cesare analyzed the embankment sections for Britton, Bruce Canyon, and Maria Stevens sites for steady state through the embankment at full pond. We analyzed rapid drawdown within the reservoir considering a rate of 1 foot per day, as it is a generally accepted upper bound of the preferred design range. The rapid drawdown (transient) analysis provides a phreatic surface, or wetted front, through the embankment at each daily time step.

## 8.3 STABILITY RESULTS

Cesare analyzed the downstream slopes considering full pool and steady state seepage. We analyzed the upstream slope during rapid drawdown at each time step. We did not analyze any slopes considering end of construction, residual bedrock strength, or pseudo seismic forces, as these scenarios are not considered critical to site selection but must be considered during final design. Stability analysis result figures are presented in Appendix D.

### 8.3.1 Britton Stability Results

Results of our stability for this site are presented in Table 5 and include the State Engineer's requirements.

**TABLE 5. Britton Stability Analysis Results**

| Analysis | Factor of Safety | | Required Factor of Safety |
|---|---|---|---|
| | Block | Circular | |
| Full, steady state, downstream | 1.92 | 1.90 | 1.5 |
| Transient upstream* | 1.01 | 1.47 | 1.2** |

* Rapid drawdown
**Lowest factor of safety

The above results indicate the downstream slope provides a factor of safety against sliding well within the State Engineer's requirements. They also indicate the upstream slope requires flattening and/or adding a drain system to allow rapid pore pressure release.

### 8.3.2 Bruce Canyon Stability Results

Results of our stability for this site are presented in Table 6 and include the State Engineer's requirements.

**TABLE 6. Bruce Canyon Stability Analysis Results**

| Analysis | Factor of Safety | | Required Factor of Safety |
|---|---|---|---|
| | Block | Circular | |
| Full, steady state, downstream | 1.88 | 1.57 | 1.5 |
| Transient upstream* | 1.29 | 1.33 | 1.2** |

* Rapid drawdown
**Lowest factor of safety

The results indicate the downstream slope provides a factor of safety against slope failure within the State Engineer's requirements. They also indicate the upstream slope is appropriate.

### 8.3.3 La Veta Lakes Stability Results

Cesare did not perform stability analyses for La Veta Lakes.

### 8.3.4 Maria Stevens Stability Results

Results of our stability for this site are presented in Table 7 and include the State Engineer's requirements.

**TABLE 7. Maria Stevens Stability Analysis Results**

| Analysis | Factor of Safety | | Required Factor of Safety |
|---|---|---|---|
| | Block | Circular | |
| **West embankment** | | | |
| Full, steady state, downstream | 1.17 | 1.46 | 1.5 |
| Transient upstream* | 0.81 | 1.19 | 1.2** |
| **South embankment** | | | |
| Full, steady state, downstream | 1.44 | 1.47 | 1.5 |
| Transient upstream* | 1.77 | 1.69 | 1.2** |

* Rapid drawdown
**Lowest factor of safety

Regarding the west embankment, the results indicate the downstream slope provides a factor of safety against slope failure much less than the State Engineer's requirements and will require flattening and/or improving the subgrade. They also indicate the upstream slope requires flattening and/or a adding a drain system to allow rapid pore pressure release.

Regarding the south embankment, the results indicate the downstream slope provides a factor of safety against slope failure just less than the State Engineer's requirements and may require flattening and/or improving the subgrade. They also indicate the upstream slope is conservative at 5:1, horizontal to vertical (H:V).

### 8.3.5 South Baker Stability Results

Cesare did not perform stability analyses for the South Baker site due to the relatively high permeability of the bedrock underlying the proposed dam site and the general scarcity of low permeability material encountered during our field exploration.

## 9. LOCATION DISCUSSIONS

The discussions below present general assessments of the conditions encountered at each of the sites. The seepage and stability analyses are based on our experience with similar material considering the preliminary nature of these evaluations. The comments on the seepage and slope appropriateness are based on these assumptions and would change when considering material and site conditions based on detailed exploration and specific testing.

### 9.1 BRITTON

Cesare's geologic evaluation indicated geologic hazards are minimal. The fracturing in the sedimentary bedrock may lead to seepage and weathering along the fractures and bedding planes. The gravels and relatively clean sands encountered in the soil overburden would require cutting off below the embankment. Notwithstanding the evaluation, little is known about the site specific geologic conditions. Detailed geologic mapping must be performed.

Packer tests performed were within the sandstone below the claystone indicating permeability rates of about 1E-3 cm/sec, a relatively high rate. The claystone encountered below the soil and above the sandstone may be appropriate to provide the embedment for the cutoff if found to be of sufficient thickness. This would require additional evaluation, including drilling and testing for permeability and evaluating the claystone's continuity. If the claystone also exhibits a high permeability, a deep cutoff may be required. Since the claystone zone encountered in B-2 in the maximum section was about 2 to 5 feet thick and sandstone was below to the remaining depth explored, the required cutoff may extend to over 40 feet.

In our opinion, a slurry cutoff wall as proposed in the concept design has risks associated with the post construction evaluation of the slurry wall construction. Evaluating the effectiveness of a slurry cutoff requires impounding water behind it, which cannot be accomplished until the embankment is constructed. If a there is a leak in the slurry wall, repair would require excavating through the constructed embankment. We would recommend, at minimum, an open cut cutoff trench extending through permeable zones and at least 5 feet into low to nonpermeable material.

The exploratory pits within the reservoir area indicated about 5 to 8 feet of soil over assumed bedrock. The soil encountered appeared lenticular, making them potentially difficult to segregate into the appropriate zones. The more clayey material classified as clayey to silty/clayey sands with about 30% passing the #200 screen are often sufficient to provide a relatively impervious core. Both issues require specific permeability testing and seepage analysis. More extensive exploration in the reservoir area must be performed to verify sufficient quantities of the low permeability material exist. The material requires specific permeability testing.

Cesare was not able to access the abutments with our drilling equipment; thus, we do not have a clear understanding of their subsurface conditions at these locations. The geology is expected to be consistent regarding the types of material present; however, we have insufficient detail to provide accurate information on types of material and their in situ characteristics. To do so would require providing drill rig access to the abutments along the abutment slope at the dam crest elevation. A high percentage of dam failures are from seepage and/or piping through the abutments and/or abutment/embankment interface.

The stability analysis results presented in Section **8.3.1 Britton Stability Results** indicate the downstream slope may be conservative and could be steepened, depending on the material used. The upstream slope requires flattening to possibly 3:1, H:V, or flatter. Once the embankment material is identified in the reservoir area, additional laboratory and engineering analysis must be performed.

### 9.2 BRUCE CANYON

In Cesare's opinion, the dam centerline location should be upstream of the volcanic dike, such that the downstream embankment toe will be at or near the dike. The dike is highly fractured and therefore, has a high permeability. As such, placing the dike within the embankment could lead to seepage issues. Our geologic evaluation indicated the geologic hazards include landslides within the abutment bedrock material. When considering a potential landslide within the abutment material, the remediation could include excavating to a zone below the potential slide surface and constructing the embankment at that surface. If appropriate low permeability material is removed in this excavation, it can be reused as embankment fill. The landslide impact could be significant and requires a more detailed evaluation that would include geologic mapping, drilling and coring, and testing.

The borings indicated sandstone bedrock in the north abutment and claystone with interbedded sandstone zones in the south abutment, representing potential steeply dipping bedrock conditions. The northern abutment exhibited a large sandstone outcrop that likely indicates a harder zone of the sandstone encountered in our boring. The boring at the maximum section exhibited highly interbedded claystone/shale and sandstone. In our opinion, these claystone conditions in the south abutment will more likely impact slope stability in landslides than the sandstone. The highly interbedded claystone/shale and sandstone below the maximum section will have an effect on seepage below the dam, likely greater than the abutments. To properly evaluate this and the landslide potential would require additional drilling on the south abutment, including coring the bedrock to provide a continuous stratigraphy and condition profile. In situ permeability testing would also be required.

Packer tests indicated the permeabilities ranged from 3.7E-5 to 3.2E-6 cm/s. We consider these values typical of the bedrock in Colorado on which permanent water storage dams are often constructed. Although not considered ideal, these values are considered acceptable and can be managed in design and construction with deeper cutoffs, as necessary. The conceptual design indicated a cutoff trench excavated into the native soil. The boring logs for BC-2 indicated the soil is about 18 feet deep, with low permeability mudstone beginning at about 20 feet. This indicates an appropriate cutoff would possibly be 25 to 30 feet, at minimum, considering the cutoff extending about 10 to 15 feet into bedrock. The depth of cutoff must be based on the stratigraphy and continuity of the lower permeability bedrock and seepage flow path length analysis.

The soil encountered overlying the bedrock ranged from low to moderate blow counts, indicating soft or very loose to stiff or medium dense. This soil has the potential to consolidate significantly under surcharge loading. In addition, the more granular material likely has relatively high permeabilities. This would require detailed testing and analysis to evaluate values. This material can be excavated from below the embankment and replaced with embankment material and excavating a cutoff into bedrock to alleviate these issues. To evaluate whether removing them and placing a cutoff to bedrock, or constructing a cutoff trench and allowing the embankment to settle, requires consolidation testing and analysis to properly evaluate settlement potential.

The exploratory pits indicated about 8 to 10 feet of clayey material, including both clays and clayey sands. This indicates substantial borrow potential for the embankment. The material is such that a homogeneous embankment may be possible. More extensive exploration in the reservoir area must be performed to verify sufficient quantities of the low permeability material for embankment construction. This material requires specific permeability testing. This exploration would also be required to evaluate material quantities for shell material.

The swell/consolidation test performed on a sample from this site exhibited 9.9% collapse when wetted under load. This indicates some of the soil within the reservoir is susceptible to collapse when wetted in its natural condition. This will likely impact structural support and potentially slope stability where it is encountered around the reservoir’s inundated perimeter. This material can be used for embankment construction, as it would be wetted and compacted.

The results for our stability analysis are presented in Section **8.3.2 Bruce Canyon Stability Results.** They indicate the downstream and upstream slopes appear appropriate for the conditions modeled. Specific soil mechanics testing on the potential embankment material must be performed to evaluate embankment stability. Stability analysis must be performed using the site specific strength and seepage characteristics.

## 9.3 LA VETA LAKES

Cesare's geologic evaluation indicated minimal geologic hazards. Constructing on the existing embankments is considered an issue at this site. The existing fill classified as sandy clay or silty/clayey sand that exhibited relatively low blow counts, indicating they are soft and compressible. Although the preliminary embankment sections indicated about 3 to 4 feet of new fill, consolidation would likely occur. The extent requires additional consolidation testing and settlement analysis. Mitigation of these would be similar to the Maria Stevens discussion in Section **9.4 MARIA STEVENS**.

The La Veta Lakes site exhibited shallow sandstone with relatively little overburden, particularly the material that was considered the primary source for the new embankment. Although we encountered about 3 feet of clay fill at the surface of the separation dike, the bedrock would be the primary embankment material. Since we did not penetrate the subsurface sufficiently, additional exploration is required, likely by coring, to verify quantities. Specific testing for remolded permeability and strength characteristics would be required.

The sandstone material would likely require significant preparation to use as embankment fill, requiring reducing the maximum particle size to less than 6 inches. As the material is granular, the slopes would require updated seepage and stability analysis, as the remolded parameters would likely significantly impact the possible slopes.

The remolded material's permeability could be acceptable; however, if not, it may require amendment with bentonite. An alternative is importing impervious material or placing an impervious upstream surface, such as hot mix asphalt.

Due to the complications described above with using the sandstone for borrow, Cesare did not perform stability or seepage analysis on this site.

## 9.4 MARIA STEVENS

Cesare's geologic evaluation indicated the geologic hazards include sinkholes in the limestone units. The discussion presented in Section **4.4 MARIA STEVENS** indicated the limestone was likely eroded and is no longer extant. We did not encounter any limestone within the depths we drilled. This may require more detailed geologic mapping and drilling deeper to further evaluate these conditions.

We encountered about 11 feet of relatively clean sands in Boring MS-2 above the claystone bedrock. We anticipate this material would exhibit a relatively high permeability in its present condition. It will likely require extending a cutoff trench below the embankment. With the low embankment height, a slurry cutoff trench may be appropriate.

The existing fill and native soil are clay and typically very soft to soft. This soil is weak, resulting in high consolidation potential and very low strengths. Our settlement analyses indicated potential settlement of about 3 inches under the proposed south embankment loads. The timed consolidation tests indicated the settlement would occur relatively rapidly upon load application.

Managing the settlement could include constructing the new embankment to be as flexible as possible and overbuilding the crest height to compensate for the settlement. This is difficult in that the main portion of the embankment will experience settlement and the abutments will not undergo as much, creating internal stresses in the embankment. Potential piping would become an issue that would require a downstream filter and drain. These types of drains are fairly typical but would require enough space between the embankment and the highway.

The stability analyses indicated calculated factors of safety were well below the State Engineer’s requirements for the west embankment steady state and rapid drawdown and somewhat below for the south embankment steady state. Densifying, thus strengthening, the supporting soil would remediate both stability and settlement issues. An alternative is to flatten the slopes for stability issues, with settlement issues remaining to be addressed.

Improving the supporting soil by excavation and recompaction is a more conservative approach for both stability and settlement issues but considered a much lower risk alternative. This approach requires removing the soft material to a firm base, moisture conditioning by drying or wetting, as necessary, to a moisture content equal to or above optimum moisture content, and then compacting to at least 94% and not more than 98% of maximum dry density as determined by ASTM D698. We estimated depths of excavation of about 14 feet for the west embankment and 24 feet for the south embankment would be required. Borrow material could also be used to replace the native soil.

Our stability analysis results indicated the west embankment’s slopes require flattening to an estimated 4:1, H:V, if the subgrade soil is not improved. Constructing an upstream graded filter and drain system may allow a steeper upstream slope.

The south embankment’s downstream slope requires flattening to an estimated 3.5:1, H:V, if the supporting soil is not improved. The upstream slope can be reduced, possibly to an estimated 4:1, H:V, and likely more, if the subgrade soil is densified. Steepening the slope may require a graded filter and drain system.

The exploratory pits indicated 3 to 5 feet of clay over claystone/shale to 6 to 8 feet. This denotes potentially adequate borrow material for homogeneous embankment construction. A zoned embankment as proposed in the conceptual design would require importing the shell material. A downstream blanket drain and possibly a chimney drain within a homogeneous embankment would require importing the filter and drain material, but much less of it. Specific soil mechanics testing on the potential embankment material must be performed to evaluate embankment stability. Stability analysis must be performed using the site specific strength and seepage characteristics.

## 9.5 SOUTH BAKER

Cesare's geologic evaluation indicated the geologic hazards include potential slope instability due to the steeply dipping bedrock along the Boyd Mountain flanks. Boring SB-4 on the south abutment exhibited about 50 feet of unconsolidated soil overlying bedrock. This unconsolidated material is likely landslide rubble but requires further evaluation to determine its condition, including a more detailed evaluation of geologic mapping, drilling, sampling, and coring. We could not perform Packer tests in the underlying bedrock. Construction would include removing the unconsolidated material to bedrock contact and  excavating a cutoff below it.

The boring at the north abutment toe exhibited a claystone zone, while the other two borings indicated sandstone bedrock. At the north abutment, we encountered about 10 feet of soil overburden, overlying sandstone. Both abutments must be further explored with associated in situ permeability testing.

The soil overburden in the lower valley elevations exhibit very low blow counts with a very shallow water table and would likely consolidate considerably under the embankment. The Packer test results in SB-2 indicated the upper portion of the bedrock is a much higher permeability than the lower portion at the maximum section and would require a cutoff. For this site, we would recommend excavating the overburden soil to bedrock contact over the entire embankment base. A cutoff trench should then be excavated to least 20 feet deep.

The South Baker site exhibited a relatively small amount of low permeability overburden soil to construct a zoned embankment, as depicted in the conceptual section. Although we encountered about 1-1/2 to 3 feet of clayey material at the surface within the reservoir area, most of the soil is granular and would require amendment with clay or importing a low permeability material. An external low permeability zone, such as asphalt pavement, is another alternative. These alternatives are generally more costly.

The proposed cutoff shown in the preliminary cross section appears to be a slurry cutoff trench. This method has been used successfully in reclaimed gravel pit reservoirs; however, the slurry for this type of cutoff is typically made with onsite excavated impervious material amended with a relatively small percentage of bentonite clay. As there is little impervious material onsite, the slurry would require amendment with imported clay, which may not be cost effective.

In our opinion, a slurry cutoff wall as proposed in the concept design has risks associated with the post construction evaluation of the slurry wall construction. Evaluating the effectiveness of a slurry cutoff requires impounding water behind it, which cannot be accomplished until the embankment is constructed. If a there is a leak in the slurry wall, repair would require excavating through the constructed embankment. We would recommend, at minimum, an open cut cutoff trench extending through permeable zones and at least 5 feet into low permeable material.

Applegate has suggested a roller compacted concrete dam as another alternative. This alternative has the benefit of allowing use of lower quality rock for aggregate used for normal concrete. This would require quarry sites to be evaluated for material, quality, and quantity. This type of embankment requires a sound foundation and must be placed on sound bedrock that would likely require deeper excavation than for an earthfill embankment. To properly evaluate this type of embankment, the local rock must be evaluated and a source selected based on its engineering properties for use in concrete. A mix design using the proposed rock must be performed to evaluate strength before stability analysis can be performed.

Considering the above discussion regarding the lack of low permeability material and the cutoff requirements, we did not analyze seepage and stability. Specific soil mechanics testing on the potential embankment material must be performed to evaluate embankment stability. Stability analysis must be performed using the site specific strength and seepage characteristics.

## 10. GEOTECHNICAL RISK

The concept of risk is an important aspect of any geotechnical evaluation. The primary reason for this is that the analytical methods used by geotechnical engineers are generally empirical and must be tempered by engineering judgment and experience, therefore, the solutions or recommendations presented in any geotechnical evaluation should not be considered risk free, and more importantly, are not a guarantee that the interaction between the soil and the proposed construction will perform as predicted, desired, or intended. The engineering evaluations presented in the preceding sections constitute our best estimate of those measures that are necessary to assess the sites regarding the ability to design and construct embankments that perform in a satisfactory manner. These evaluations are based on the information generated during this evaluation and our experience in working with these conditions.

## 11. LIMITATIONS

This report has been prepared for the exclusive use of our client for specific application to the project discussed and has been prepared in accordance with generally accepted geotechnical engineering practices. No warranties, either expressed or implied, are intended or made. In the event that changes in the nature, design, or location of the project as outlined in this report are planned, the conclusions contained in this report shall not be considered valid unless Cesare reviews the changes and either verifies or modifies the conclusions of this report in writing.

The borings drilled for this evaluation were located to obtain a reasonably accurate picture of underground conditions for evaluation purposes. Variations frequently occur from these conditions which are not indicated by the borings. These variations are sometimes sufficient to necessitate modifications in the evaluation. Much more detailed field exploration must be performed for design purposes, the extent of which depends on the specific site.

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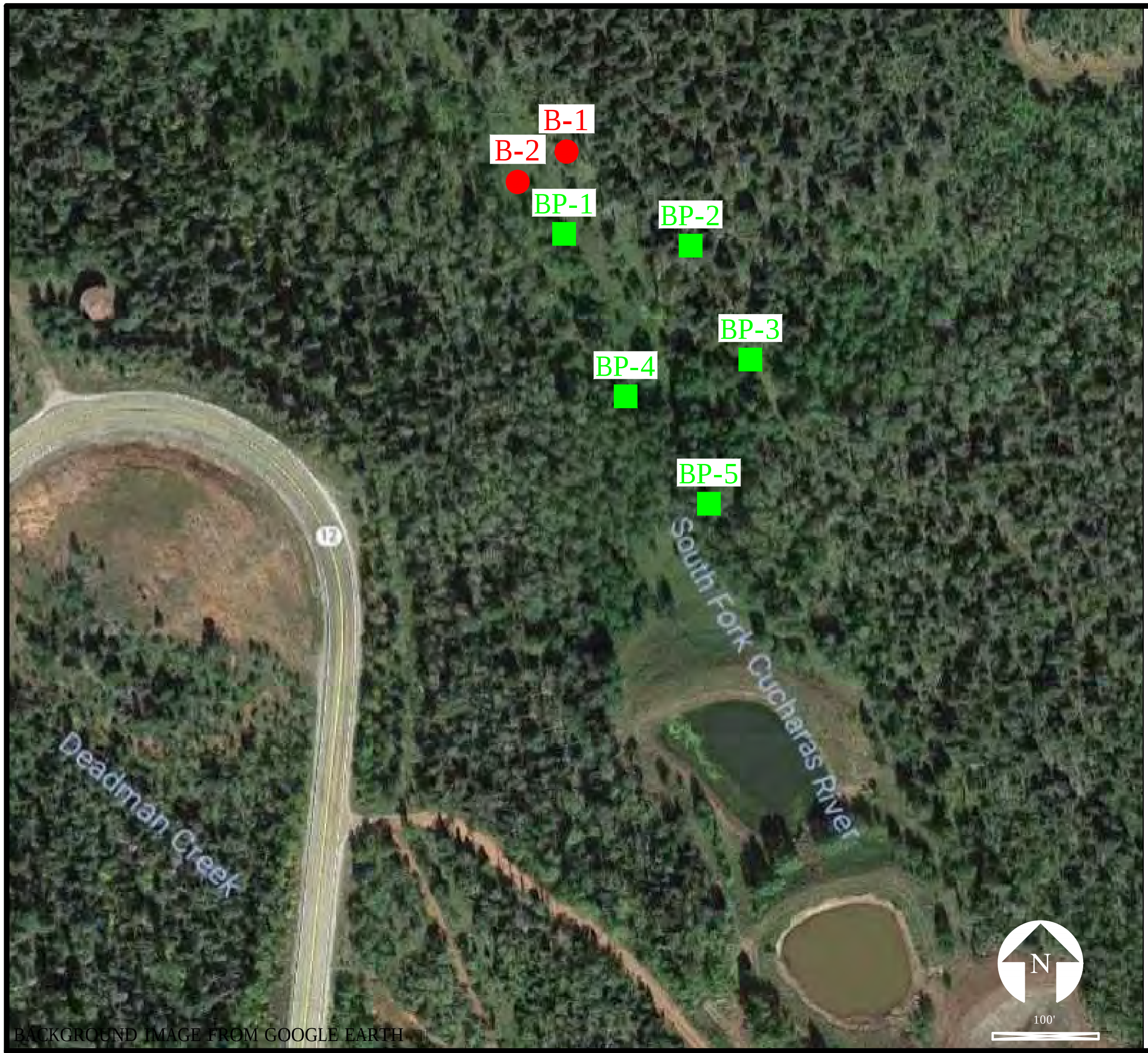

LEGEND:

| | |
|---|---|
| B-1 ● | BORING NUMBER AND LOCATION |
| BP-1 🟩 | EXPLORATORY PIT NUMBER AND LOCATION |

| | | | |
|---|---|---|---|
| PROJECT NO: | 18.117 | | |
| PROJECT NAME: | Cucharas Basin Collaborative Storage | | |
| DRAWN BY: | KNZ | CHECKED BY: | JAC2 |
| DWG DATE: | 10.12.18 | REV. DATE: | 11/1/18 |

FIGURE 11
Britton
Locations of Borings and Exploratory Pits

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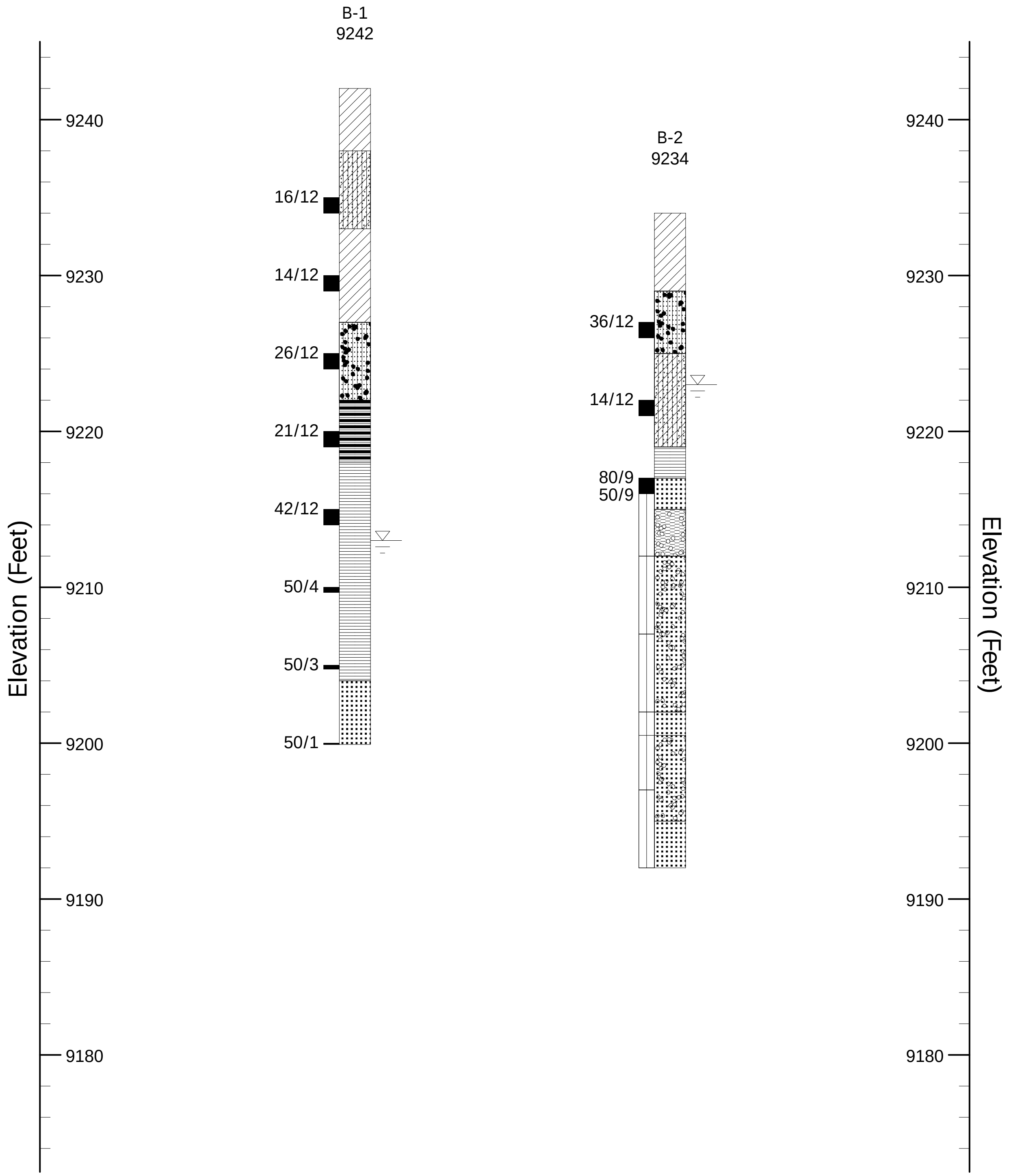
*Geotechnical Engineers & Construction Materials Consultants*

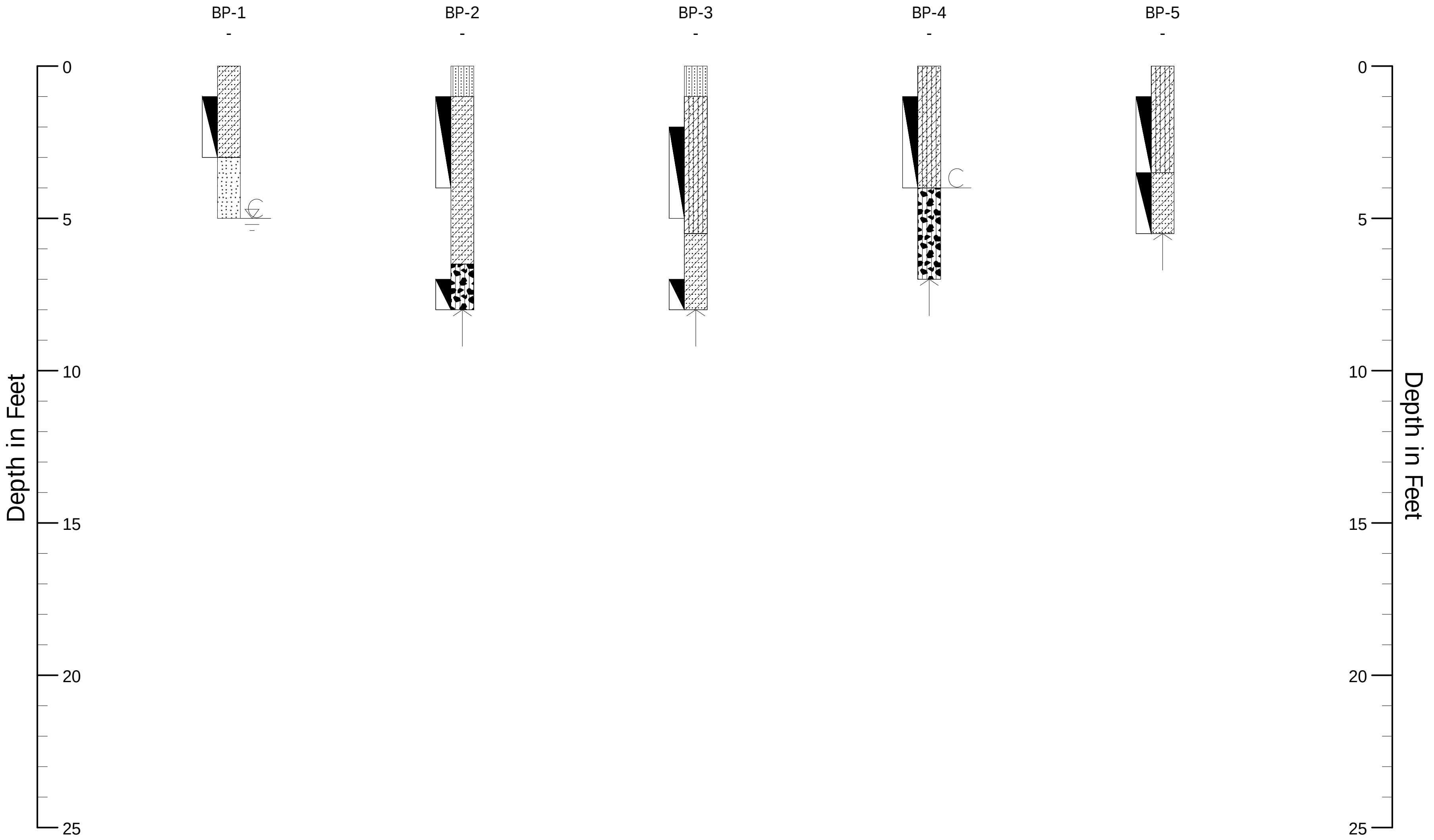


## FIGURE 12

Britton Boring Logs

| | |
|---|---|
| PROJECT NO: | 18.117 |
| PROJECT NAME: | Cucharas Basin Storage Collaborative |
| DWG DATE: | 10/28/2018 |

CESARE, INC.
*Geotechnical Engineers & Construction Materials Consultants*



| | |
|---|---|
| PROJECT NO: | 18.117 |
| PROJECT NAME: | Cucharas Basin Storage Collaborative |
| DATE: | 10/28/2018 |

**FIGURE 13**

Britton Exploratory Pit Logs

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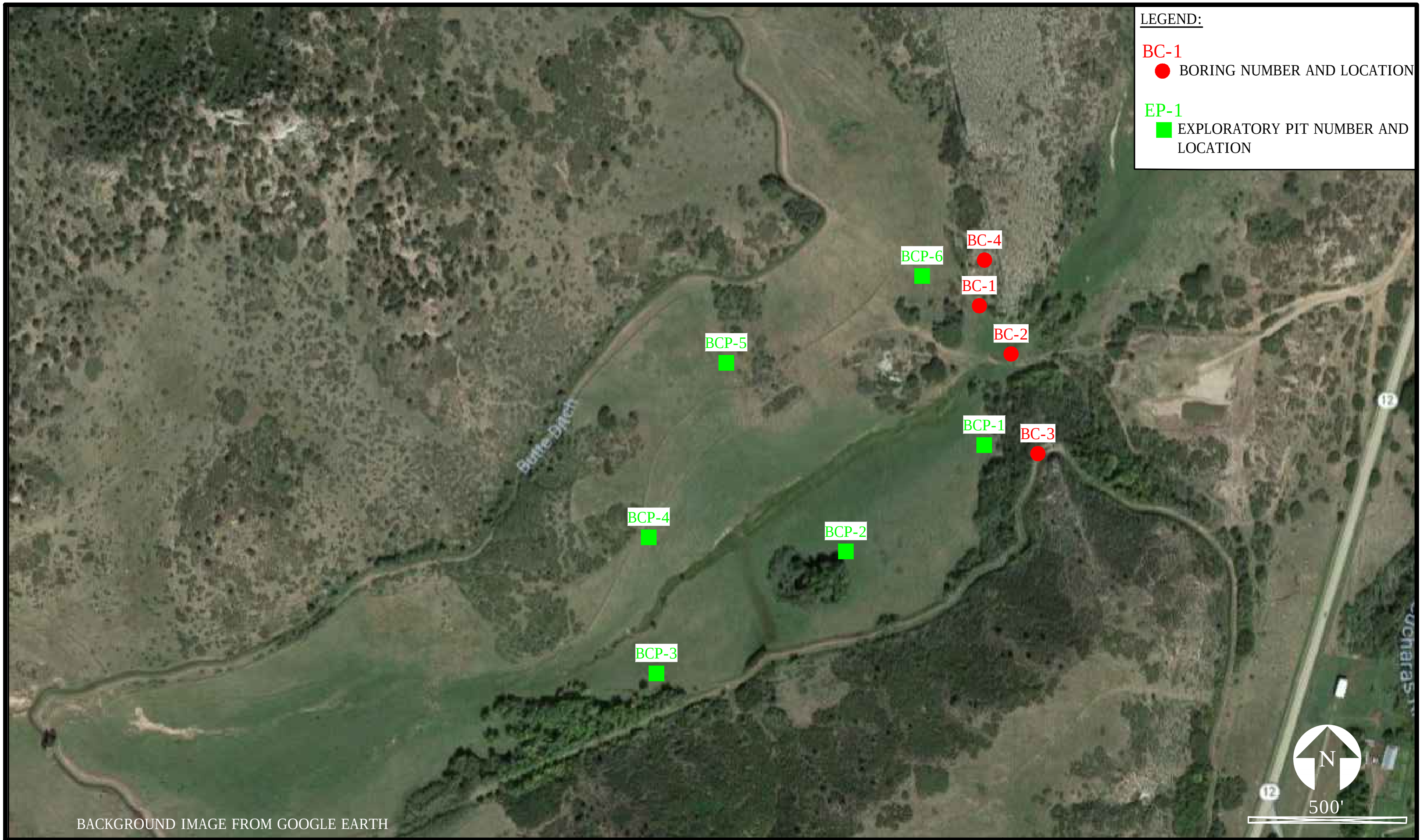


LEGEND:

BC-1
● BORING NUMBER AND LOCATION

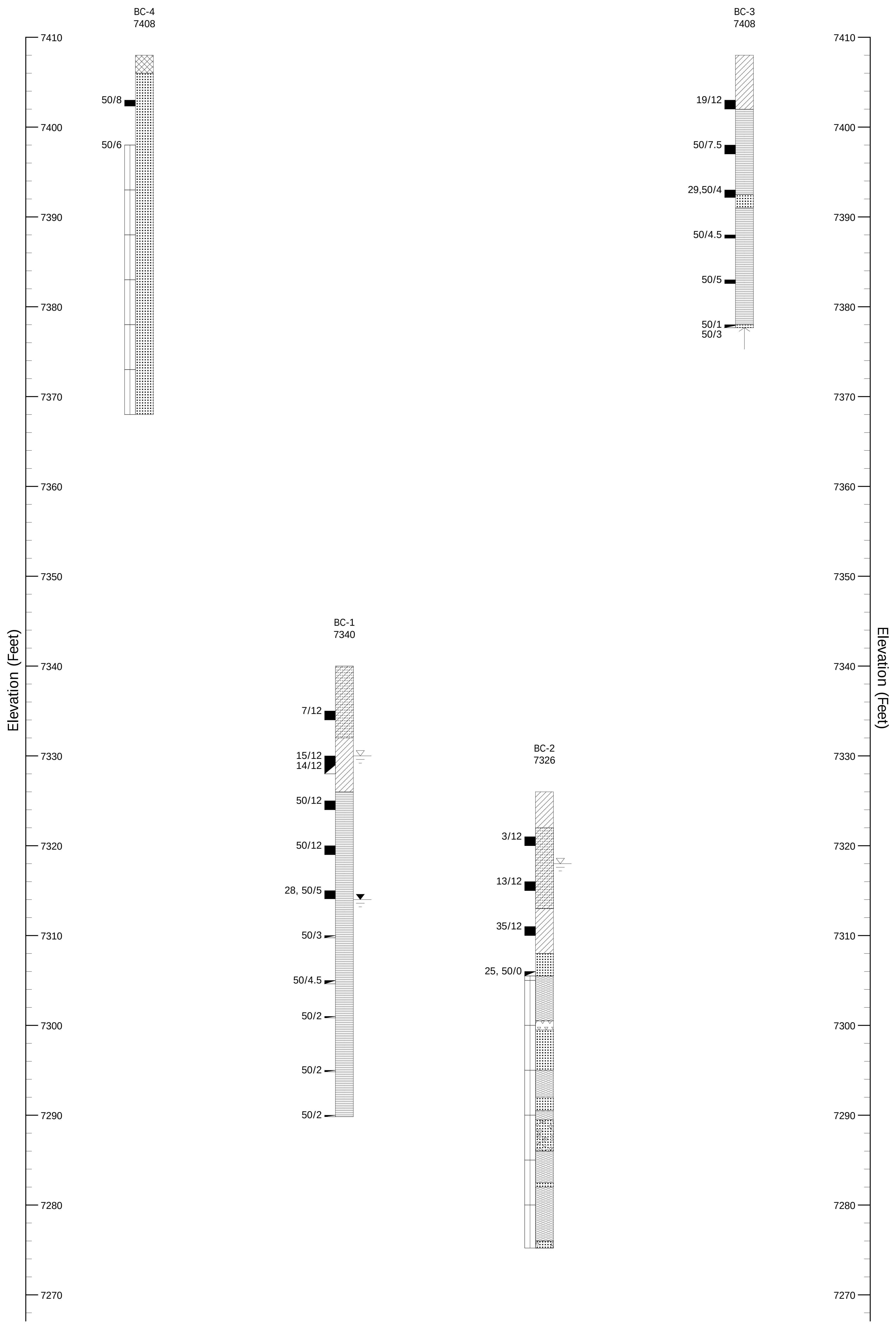
EP-1
🟩 EXPLORATORY PIT NUMBER AND LOCATION

BACKGROUND IMAGE FROM GOOGLE EARTH

| | | | |
|---|---|---|---|
| PROJECT NO: | 18.117 | | |
| PROJECT NAME: | Cucharas Basin Collaborative Storage | | |
| DRAWN BY: | KNZ | CHECKED BY: | JAC2 |
| DWG DATE: | 10.11.18 | REV. DATE: | 10.17.19 |

FIGURE 14
Bruce Canyon Reservoir
Locations of Borings and Exploratory Pits

CESARE, INC.
*Geotechnical Engineers & Construction Materials Consultants*



PROJECT NO: 18.117

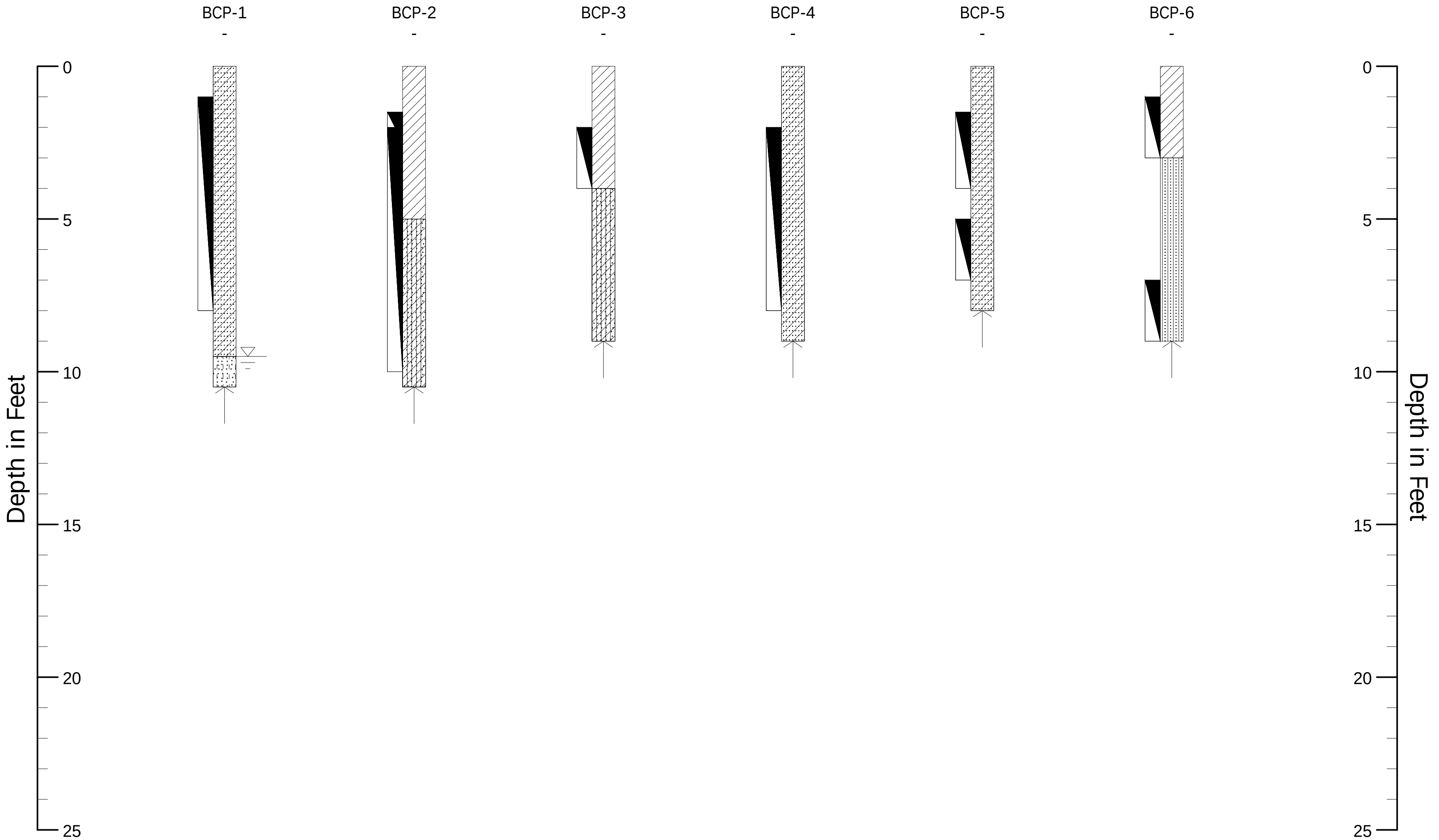
PROJECT NAME: Cucharas Basin Collaborative Storage
Bruce Canyon

DWG DATE: 10/24/2019

**FIGURE 15**

Bruce Canyon Boring Logs

CESARE, INC.
Geotechnical Engineers & Construction Materials Consultants



| | |
|---|---|
| PROJECT NO: | 18.117 |
| PROJECT NAME: | Cucharas Basin Collaborative Storage |
| DATE: | 10/28/2018 |

**FIGURE 16**

Bruce Canyon Exploratory Pit Logs

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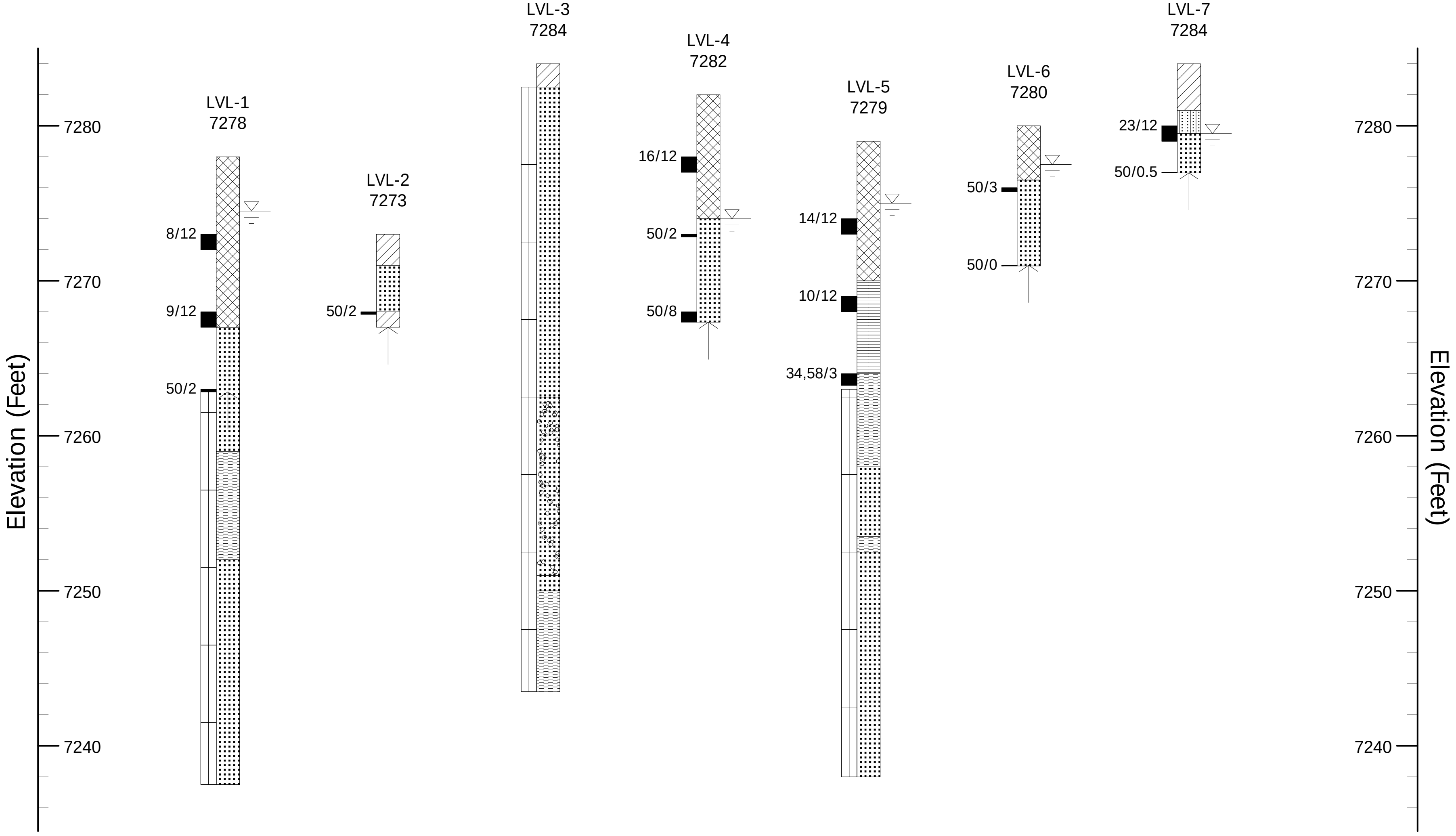
FIGURE 17
La Veta Lakes
Locations of Borings

| | | | |
|---|---|---|---|
| PROJECT NO: | 18.117 | | |
| PROJECT NAME: | Cucharas Basin Collaborative Storage | | |
| DRAWN BY: | KNZ | CHECKED BY: | JAC2 |
| DWG DATE: | 10.12.18 | REV. DATE: | -- |

CESARE, INC.
*Geotechnical Engineers & Construction Materials Consultants*



| | |
|---|---|
| PROJECT NO: | 18.117 |
| PROJECT NAME: | Cucharas Basin Collaborative Storage |
| DATE: | 10/28/2018 |

**FIGURE 18**

La Veta Lakes Boring Logs

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W:\2018\Centennial\18.100\18.117.C Cucharas Basin Collaborative Storage\ACAD\Maria Stevens Reservoir\Maria Stevens Reservoir Boring and Exploratory Pit locations.dwg 11/1/2018 4:18 PM

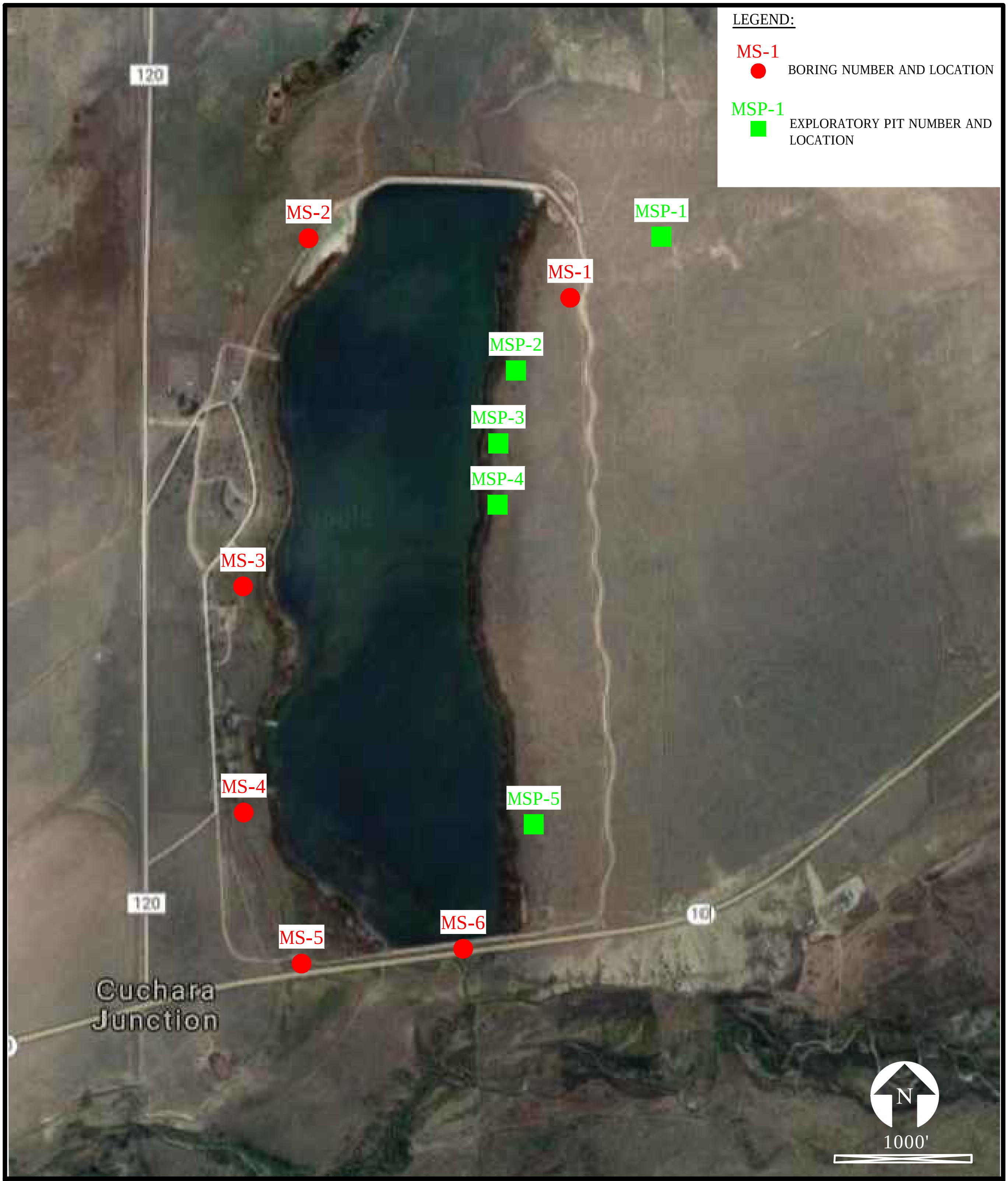

FIGURE 19
Maria Stevens
Locations of Borings and Exploratory Pits

| | | | |
|---|---|---|---|
| PROJECT NO: | 18.117 | | |
| PROJECT NAME: | Cucharas Basin Collaborative Storage | | |
| DRAWN BY: | KNZ | CHECKED BY: | JAC2 |
| DWG DATE: | 10.12.18 | REV. DATE: | -- |

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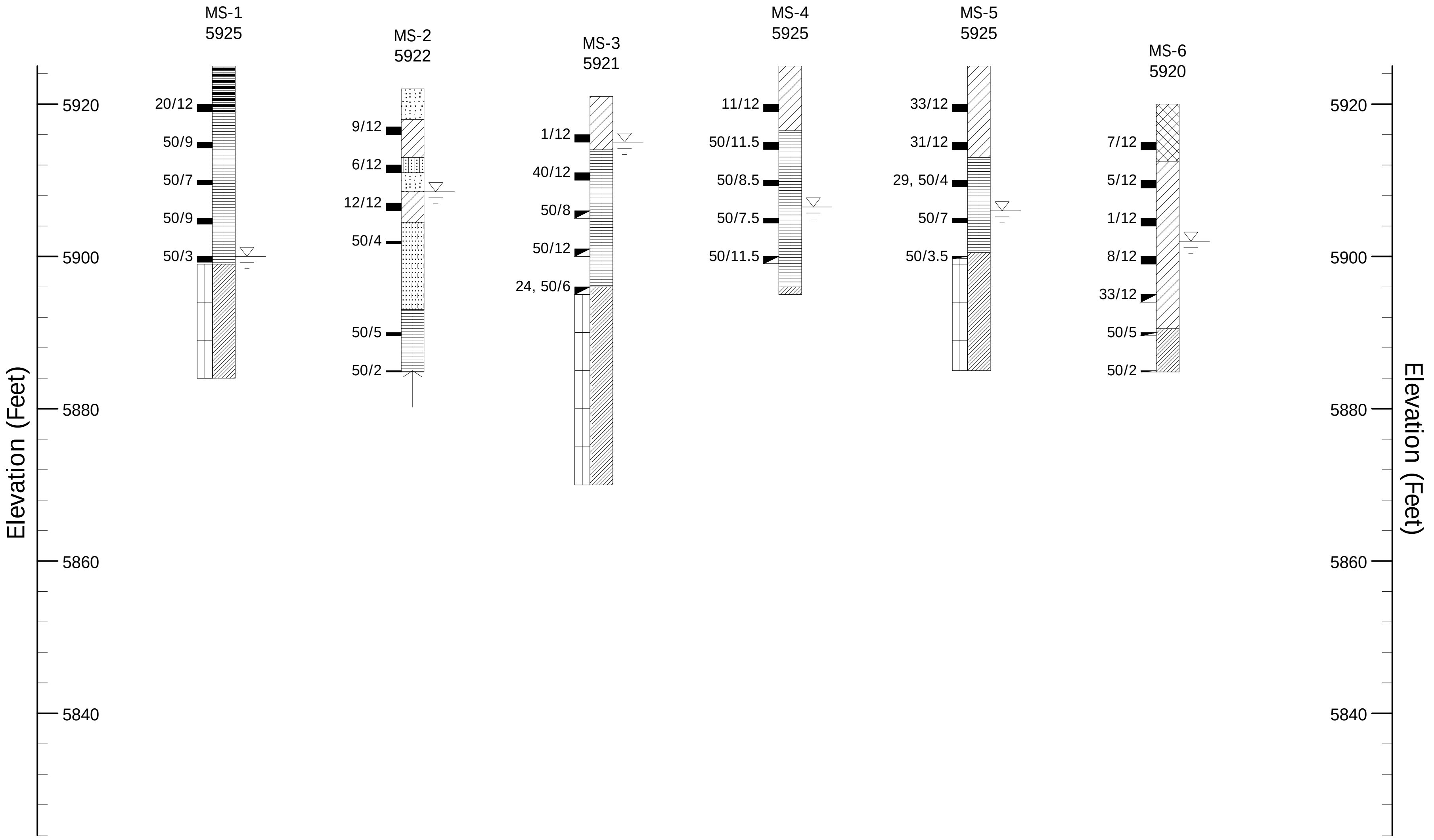

| | | |
|---|---|---|
| PROJECT NO: | 18.117 | **FIGURE 20**<br>Maria Stevens Boring Logs |
| PROJECT NAME: | Cucharas Basin Collaborative Storage | |
| DATE: | 10/30/2018 | |

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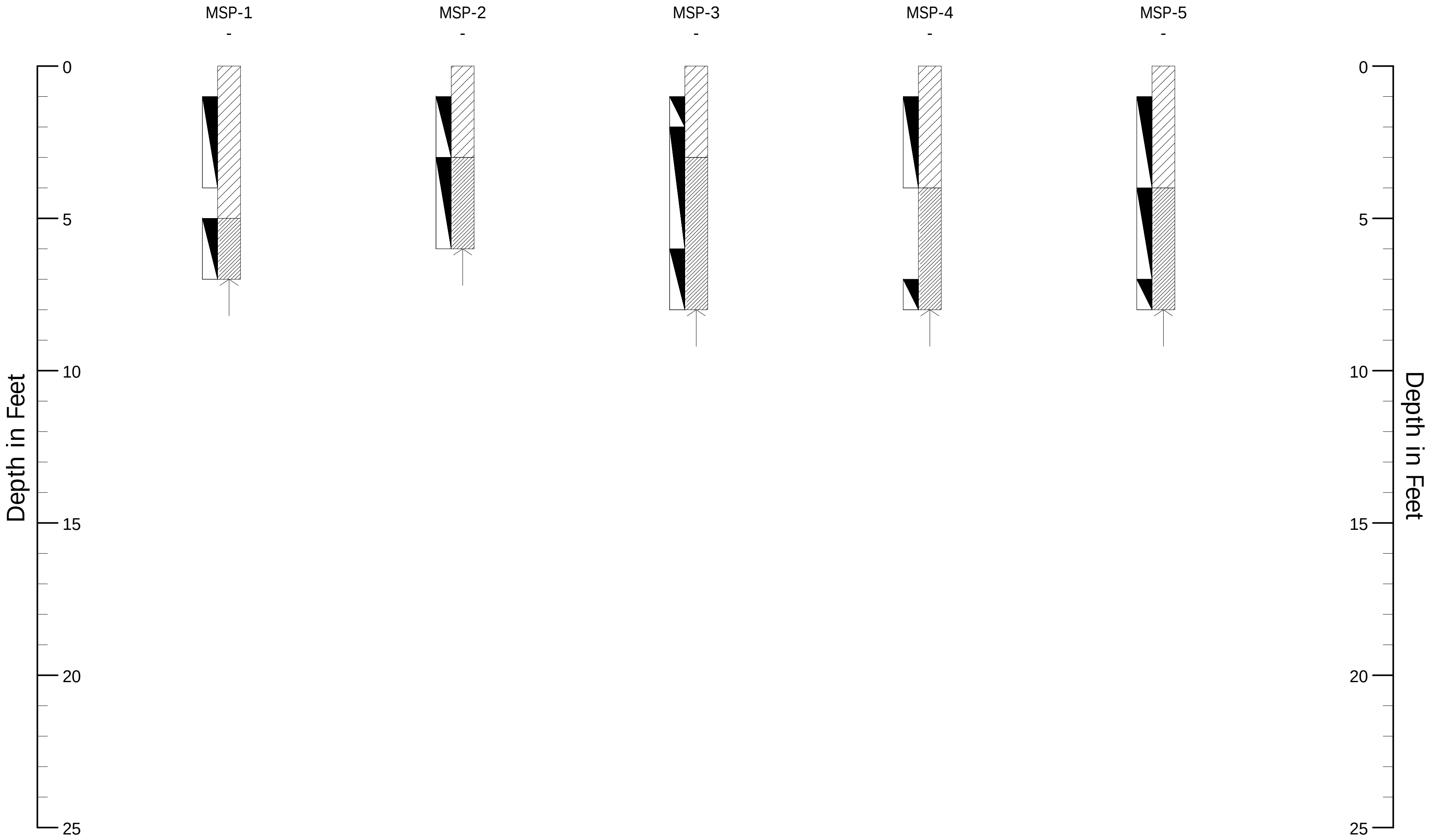

| | |
|---|---|
| PROJECT NO: | 18.117 |
| PROJECT NAME: | Cucharas Basin Collaborative Storage |
| DATE: | 10/28/2018 |

**FIGURE 21**

Maria Stevens Exploratory Pit Logs

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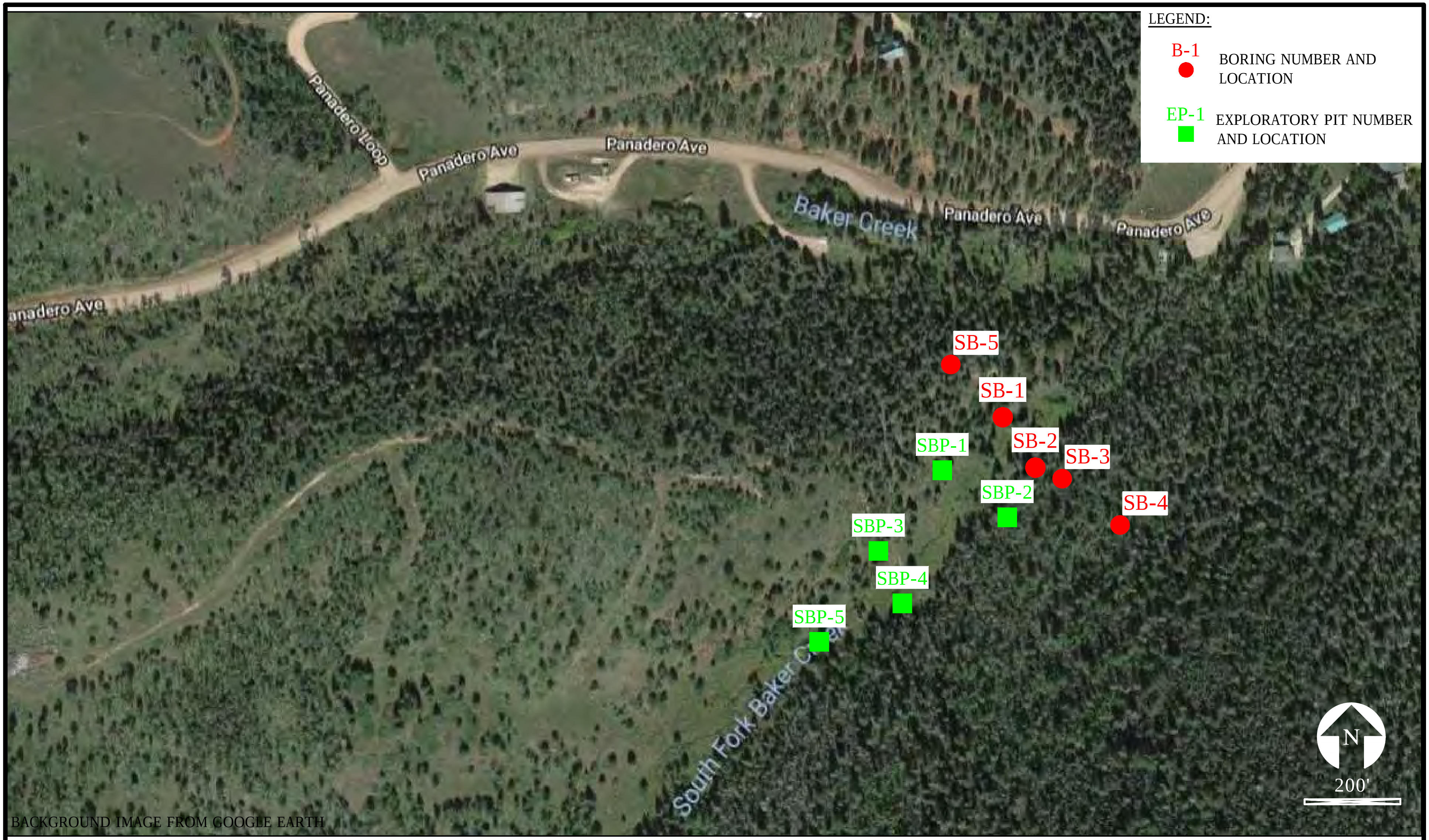
W:\2018\Centennial\18.100\18.117.C Cucharas Basin Collaborative Storage\ACAD\South Baker Creek\South Baker Creek Boring and Exploratory Pit locations.dwg 10/17/2019 12:35 PM



| | | | |
|---|---|---|---|
| PROJECT NO: | 18.117 | | |
| PROJECT NAME: | Cucharas Basin Collaborative Storage | | |
| DRAWN BY: | KNZ | CHECKED BY: | JPC2 |
| DWG DATE: | 10.12.18 | REV. DATE: | 10.17.19 |

FIGURE **22**
South Baker
Locations of Borings and Exploratory Pits

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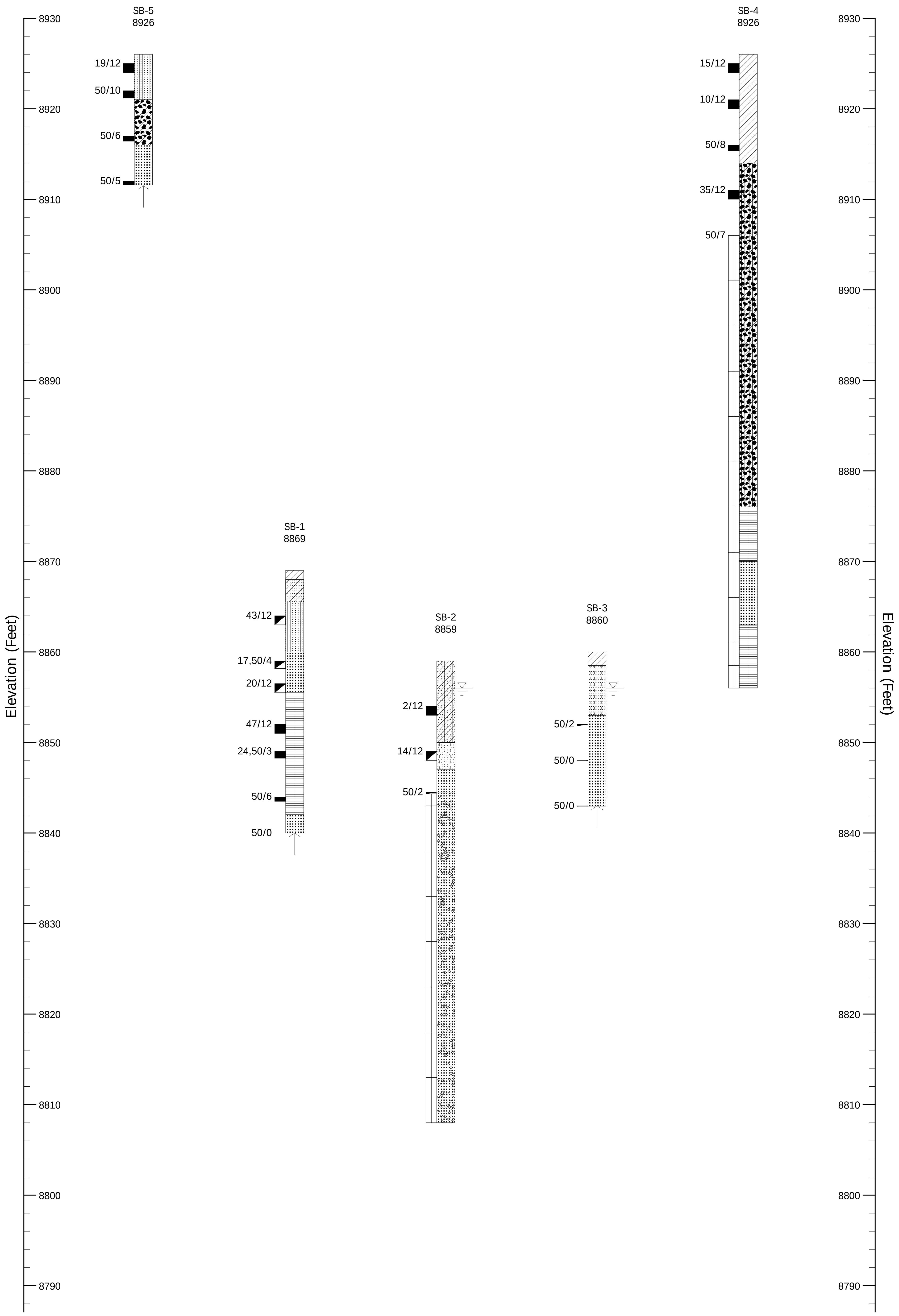

| | | |
|---|---|---|
| PROJECT NO: | 18.117 | **FIGURE 23** |
| PROJECT NAME: | Cucharas Basin Collaborative Storage | South Baker Boring Logs |
| DWG DATE: | 11/6/2019 | |

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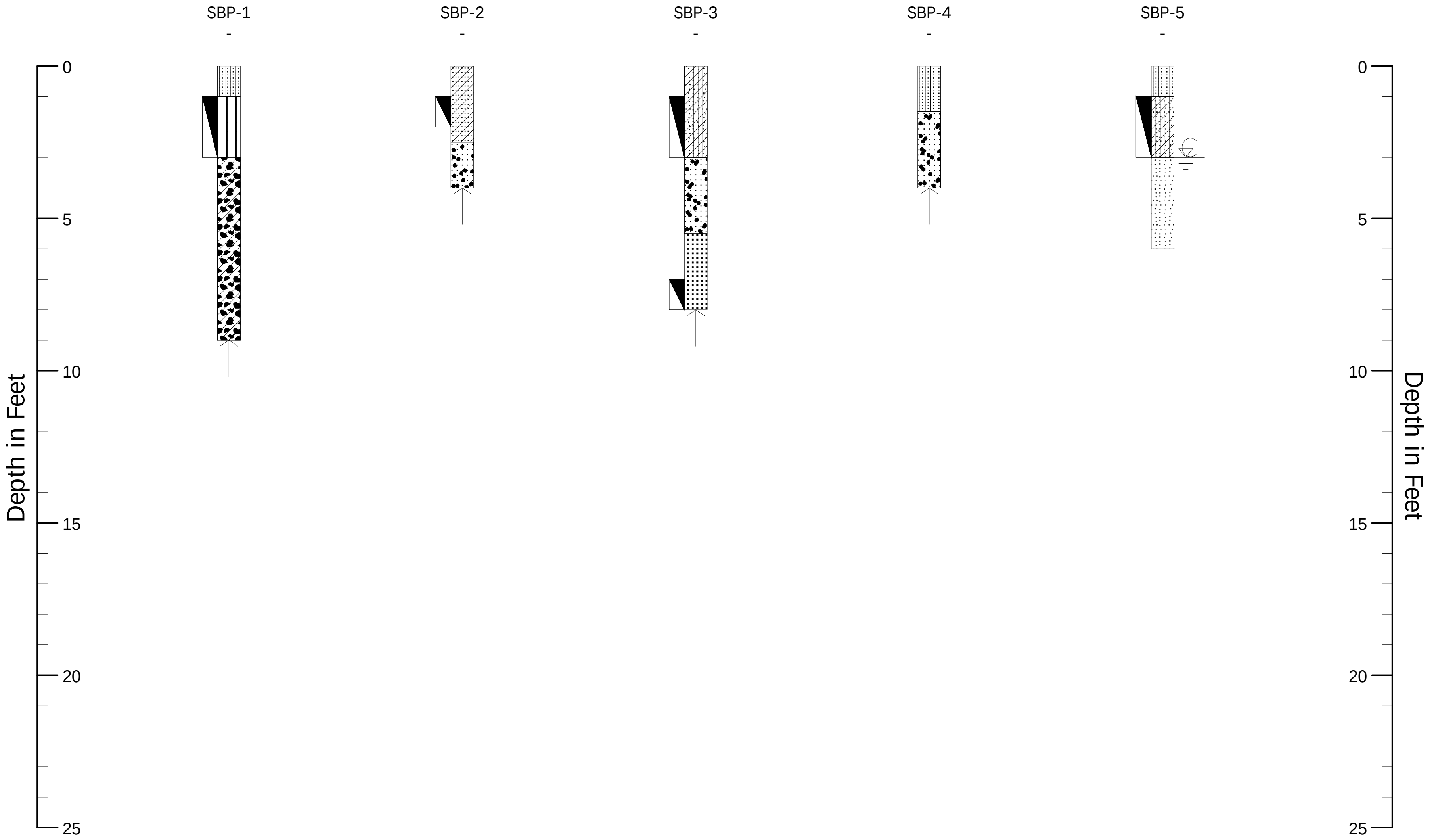

| | |
|---|---|
| PROJECT NO: | 18.117 |
| PROJECT NAME: | Cucharas Basin Collaborative Storage |
| DATE: | 10/28/2018 |

**FIGURE 24**

South Baker Exploratory Pit Logs

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# APPENDIX A

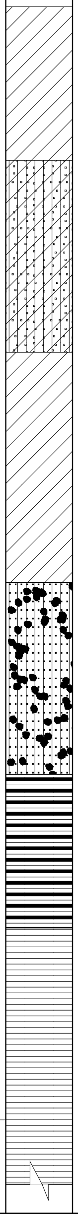
## Individual Boring Logs

# LOG OF BORING

## B-1

PROJECT Cucharas Basin Storage Collaborative
PROJECT NUMBER 18.117
DATE STARTED 8/10/18
DATE COMPLETED 8/10/18
LOGGED BY J. Edwards
DRILLED BY HRL
DRILL RIG CME-55
DRILL METHOD

APPROXIMATE GROUND ELEVATION 9242
DEPTH TO BEDROCK 24
TOTAL DEPTH 42.08
REFUSAL
DEPTH TO WATER / DATE
29 8/10/18



| DEPTH (ft) | FRACTURE LOG | GRAPHIC LOG | MOISTURE dry | moist | sat | DESCRIPTION | BLOWS/FT | CORE NO. | RECOVERY (%) | RQD (%) | HARDNESS | DRILLING NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | CLAY, silty to with sand, moist, roots in upper 18 inches, reddish brown. | | | | | | |
| 5 | | | | | | 4 ft.<br>SAND, silty, clayey, moist medium dense, reddish brown. | 16/12 | | | | | |
| 10 | | | | | | 9 ft.<br>CLAY, sandy, moist, stiff, reddish brown. | 14/12 | | | | | Smoother drilling from 9' |
| 15 | | | | | | 15 ft.<br>GRAVEL, with silt and sand, moist, medium dense, reddish brown. | 26/12 | | | | | Hard, boulder at 15'<br>Sandy |
| 20 | | | | | | 20 ft.<br>CLAYSTONE, weathered, moist to wet, occasional thin sandstone partings, dark red. | 21/12 | | | | | Smoother, firm |
| 25 | | | | | | 24 ft.<br>CLAYSTONE, medium hard to very hard, slightly moist to wet, occasional thin sandstone partings, dark red. | 42/12 | | | | | Harder at 24' |
| 30 | ▽ | | | | | | | | | | | Very hard at 29' |

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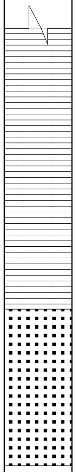
# LOG OF BORING

| PROJECT | PROJECT NO. | BORING NO. |
|---|---|---|
| Cucharas Basin Storage Collaborative | 18.117 | **B-1** |



| DEPTH (ft) | FRACTURE LOG | GRAPHIC LOG | MOISTURE dry | MOISTURE moist | MOISTURE sat | DESCRIPTION | BLOWS/FT | CORE NO. | CORE RECOVERY (%) | CORE RQD (%) | CORE HARDNESS | DRILLING NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 50/4 | | | | | |
| 35 | | | | | | | | | | | | Soft at 34' and 35' |
| | | | | | | | 50/3 | | | | | |
| | | | | | | 38 ft.<br>SANDSTONE, moist to wet, very hard, gray to red. | | | | | | Harder and more dry at 38' |
| 40 | | | | | | | | | | | | |
| | | | | | | | 50/1 | | | | | |
| 45 | | | | | | | | | | | | |
| 50 | | | | | | | | | | | | |
| 55 | | | | | | | | | | | | |
| 60 | | | | | | | | | | | | |
| 65 | | | | | | | | | | | | |

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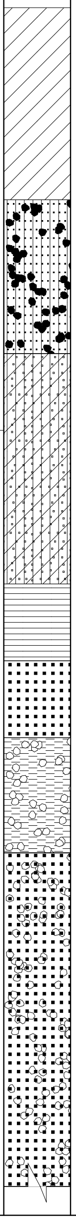
# LOG OF BORING

## B-2

| | | | |
|---|---|---|---|
| PROJECT | Cucharas Basin Storage Collaborative | APPROXIMATE GROUND ELEVATION | 9234 |
| PROJECT NUMBER | 18.117 | DEPTH TO BEDROCK | 14' |
| DATE STARTED | 8/9/18 | TOTAL DEPTH | 18.5 |
| DATE COMPLETED | 8/9/18 | REFUSAL | |
| LOGGED BY | J. Edwards | | |
| DRILLED BY | HRL | DEPTH TO WATER / DATE | |
| DRILL RIG | CME-55 | 11 | 8/9/18 |
| DRILL METHOD | ODEX, HQ core | | |



| DEPTH (ft) | FRACTURE LOG | GRAPHIC LOG | MOISTURE dry | MOISTURE moist | MOISTURE sat | DESCRIPTION | BLOWS/FT | CORE NO. | CORE RECOVERY (%) | CORE RQD (%) | CORE HARDNESS | DRILLING NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | CLAY, sandy, moist, medium stiff, roots in upper 12 inches, reddish brown. | | | | | | |
| 5 | | | | | | 5 ft.<br>GRAVEL, with silt and sand, moist to wet, dense, reddish brown. | 36/12 | | | | | |
| 9 | | | | | | 9 ft.<br>SAND, silty, clayey, wet, medium dense, organic smell at 12-1/2 feet, cobbles at 14 feet, dark red. | 14/12 | | | | | |
| 15 | | | | | | 15 ft.<br>CLAYSTONE, silty, moist, hard to very hard, dark red. | | | | | | |
| 17 | | | | | | 17 ft.<br>SANDSTONE, silty, soft, fine to medium grained, massive bedding, red brown. 18'-19' tan to olive clasts | 80/9<br>50/9 | 1<br>2 | 100<br>88 | 0<br>29 | H7<br>H7 | |
| 19 | | | | | | 19 ft.<br>MUDSTONE, soft, massive bedding, red brown. With calcareous gray concretions 1/8" - 1/2" in diamter. | | | | | | |
| 22 | | | | | | 22 ft.<br>SANDSTONE, slity, conglomeratic, soft, fine grained, massive bedding, dark red brown. With occasional tan to olive gray sandstone clasts. | | 3 | 77 | 100 | H5 | |
| 25 | | | | | | SANDSTONE, conglomeratic, medium hard, coarse grained, massive bedding, with tan clasts in a red brown matrix. | | 4 | 80 | 100 | H3-H5 | |
| 30 | | | | | | | | | | | | |

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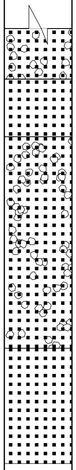
# LOG OF BORING

PROJECT Cucharas Basin Storage Collaborative

PROJECT NO. 18.117

BORING NO. **B-2**



| DEPTH (ft) | FRACTURE LOG | GRAPHIC LOG | MOISTURE dry | MOISTURE moist | MOISTURE sat | DESCRIPTION | BLOWS/FT | CORE NO. | CORE RECOVERY (%) | CORE RQD (%) | CORE HARDNESS | DRILLING NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 32 ft.<br>SANDSTONE, medium hard to hard, coarse grained, massive bedding, tan to red brown. | | 5 | 100 | 83 | H3 | |
| 35 | | | | | | 33.5 ft.<br>SANDSTONE, conglomeratic, medium hard, massive bedding, with 1/8" - 1/2" pink to tan clasts in red brown matrix. | | 6 | 55 | 22 | H3-H7 | |
| | | | | | | | | 7 | 73 | 55 | H3-H7 | |
| 40 | | | | | | 39 ft.<br>SANDSTONE, moderately hard, predominately coarse grained, with gravel, massive bedding, red brown to tan. | | | | | | |
| 45 | | | | | | | | | | | | |
| 50 | | | | | | | | | | | | |
| 55 | | | | | | | | | | | | |
| 60 | | | | | | | | | | | | |
| 65 | | | | | | | | | | | | |

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# LOG OF BORING

# BC-1

| | | | |
|---|---|---|---|
| PROJECT | Cucharas Basin Collaborative Storage | APPROXIMATE GROUND ELEVATION | 7340 |
| PROJECT NUMBER | 18.117 | DEPTH TO BEDROCK | 28 |
| DATE STARTED | 8/6/18 | TOTAL DEPTH | 50.17 |
| DATE COMPLETED | 8/7/18 | REFUSAL | |
| LOGGED BY | H. Brunkal | | |
| DRILLED BY | HRL | DEPTH TO WATER / DATE | |
| DRILL RIG | CME-55 | 10 | 8/6 |
| DRILL METHOD | HSA & HQ Core | 26 | 8/7 |

| DEPTH (ft) | FRACTURE LOG | GRAPHIC LOG | MOISTURE | | | DESCRIPTION | BLOWS/FT | CORE | | | | DRILLING NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | dry | moist | sat | | | NO. | RECOVERY (%) | RQD (%) | HARDNESS | |
| 0 | | | | | | SAND, clayey, moist, loose, dark brown. | 7/12 | | | | | |
| 10 | ▽ | | | | | 8 ft.<br>CLAY, sandy, moist, stiff, low calcareous, dark brown. | 15/12<br>14/12 | | | | | |
| 20<br>30<br>40 | ▼ | | | | | 14 ft.<br>CLAYSTONE, slightly moist to very moist, medium hard, very calcareous, moderately indurated from 28.5', dark brown to reddish brown, olive to gray. | 50/12<br>50/12<br>28, 50/5<br>50/3<br>50/4.5<br>50/2<br>50/2 | | | | | |
| 50<br>60 | | | | | | Stopped HSA and sampling at 50.2'. | 50/2 | | | | | |

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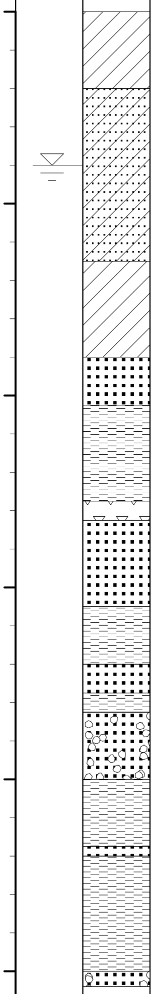
# LOG OF BORING

## BC-2

| | | | |
|---|---|---|---|
| PROJECT | Cucharas Basin Collaborative Storage | APPROXIMATE GROUND ELEVATION | 7326 |
| PROJECT NUMBER | 18.117 | DEPTH TO BEDROCK | 18 |
| DATE STARTED | 8/2/18 | TOTAL DEPTH | 51 |
| DATE COMPLETED | 8/2/18 | REFUSAL | |
| LOGGED BY | J Edwards | | |
| DRILLED BY | HRL | DEPTH TO WATER / DATE | |
| DRILL RIG | CME-55 | 8 | 8/2/18 |
| DRILL METHOD | 6.5" | | |



| DEPTH (ft) | DESCRIPTION | BLOWS/FT |
|---|---|---|
| 0 | CLAY, sandy, moist to wet, very soft, dark brown. | |
| 4 ft. | SAND, clayey, to with gravel, very loose to medium dense, wet, dark brown. | 3/12<br>13/12 |
| 13 ft. | CLAY, sandy, hard, moist, medium calcareous, brown. | 35/12 |
| 18 ft. | SANDSTONE, clayey, moderately hard to very hard, moist, gray.<br>SANDSTONE, moderatly hard, moderately weathered, medium grained, massive bedding, tan. | 25, 50/0 |
| 20.5 ft. | MUDSTONE, soft, moderately to highly weathered, massive bedding, dark gray to gray brown to chocolate brown.<br>Calcareous, orange staining along fractures | |
| 25.5 ft. | Breccia 25.5' - 26.5' | |
| 26.5 ft. | SANDSTONE, moderately hard, fine grained, massive bedding, calcareous, arkosic, dark red brown. | |
| 31 ft. | MUDSTONE, soft, massive bedding, dark red brown. | |
| 34 ft. | SANDSTONE, moderately hard, fine grained, massive bedding, calcareous, with occasional fossil debris, dark gray to red brown. | |
| 35.5 ft. | MUDSTONE, soft, massive bedding, dark red brown. | |
| 36.5 ft. | SANDSTONE, silty, conglomeratic, soft, fine grained, massive bedding, dark red brown to olive gray. With occasional 1/8" - 1/4" clasts.<br>SANDSTONE, conglomeratic, moderately hard, fine grained, massive bedding, dark red brown to olive gray. With occasional 1/8" - 1/4" clasts.<br>SANDSTONE, silty, conglomeratic, soft, fine grained, massive bedding, dark red brown to olive gray. With occasional 1/ 8" - 1/4" clasts. | |
| 40 ft. | MUDSTONE, soft, massive bedding, calcareous, dark red brown. | |
| 43.5 ft. | SANDSTONE, soft to moderately hard, fine grained, massive bedding, calcareous, dark red brown. | |
| 44 ft. | MUDSTONE, soft, highly altered, massive bedding, dark red brown.<br>47'-49' Olive gray to tan, mottled | |
| 50 ft. | SANDSTONE, conglomeratic, soft, highly altered, fine grained, massive bedding, mottled dark red brown to olive gray to yellow brown. | |
| | Stopped coring at 50.8' | |

| CORE NO. | RECOVERY (%) | RQD (%) | HARDNESS |
|---|---|---|---|
| 1 | 100 | 0 | H3 |
| 2 | 100 | 48 | |
| 3 | 100 | 100 | H4 |
| 4 | 100 | 40 | H4 |
| 5 | 100 | 74 | H6, H5 |
| 6 | 70 | 54 | H6 |
| 7 | 100 | 67 | H6 |

DRILLING NOTES

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# LOG OF BORING

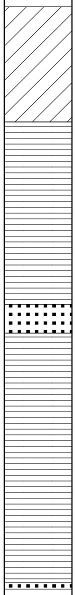
## BC-3

PROJECT Cucharas Basin Collaborative Storage
PROJECT NUMBER 18.117
DATE STARTED 8/7/18
DATE COMPLETED 8/7/18
LOGGED BY H. Brunkal
DRILLED BY HRL
DRILL RIG CME-55
DRILL METHOD 6.5"

APPROXIMATE GROUND ELEVATION 7408
DEPTH TO BEDROCK 10
TOTAL DEPTH 50.25
REFUSAL
DEPTH TO WATER / DATE
dry 8/7/18

DEPTH (ft) | FRACTURE LOG | GRAPHIC LOG | MOISTURE: dry, moist, sat | DESCRIPTION | BLOWS/FT | CORE: NO., RECOVERY (%), RQD (%), HARDNESS | DRILLING NOTES

Depth scale: 0, 10, 20, 30, 40, 50, 60



CLAY, sandy, slightly moist, very stiff, medium calcareous, brown.

6 ft.
CLAYSTONE, sandy, slightly moist, hard, low calcareous, dark reddish brown.

15.5 ft.
SANDSTONE, silty, clayey, slightly moist, very hard, dark red brown.

17 ft.
CLAYSTONE, sandy, slightly moist, very hard, medium calcareous, dark brown.

30 ft.
SANDSTONE, slightly moist, very hard, very calcareous, very indurated, maroon.

Stopped HSA and sampling at 30.3.

BLOWS/FT:
19/12
50/7.5
29,50/4
50/4.5
50/5
50/1
50/3

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# LOG OF BORING

## BC-4

| | |
|---|---|
| PROJECT Cucharas Basin Collaborative Storage | APPROXIMATE GROUND ELEVATION 7408 |
| PROJECT NUMBER 18.117 | DEPTH TO BEDROCK 0.5 |
| DATE STARTED 8/29/19 | TOTAL DEPTH 40 |
| DATE COMPLETED 8/30/19 | REFUSAL |
| LOGGED BY I. Campbell | |
| DRILLED BY Dakota | DEPTH TO WATER / DATE |
| DRILL RIG CME 45 Track Mounted | None |
| DRILL METHOD | |

| DEPTH (ft) | FRACTURE LOG | GRAPHIC LOG | MOISTURE | | | DESCRIPTION | BLOWS/FT | CORE | | | | DRILLING NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | dry | moist | sat | | | NO. | RECOVERY (%) | RQD (%) | HARDNESS | |
| 0 | | | | | | FILL: DRILL PAD, SANDSTONE | | | | | | |
| | | | | | | 2 ft.<br>SANDSTONE, silty, hard, unweathered, moderately fractured, banded to thickly bedded, dark gray. | | | | | | |
| | | | | | | | 50/8 | | | | | |
| 10 | | | | | | SANDSTONE, silty, hard, unweathered, intact to moderately fractured, banded to thickly bedded, light tan. | 50/6 | 1 | 67 | 67 | | |
| | | | | | | Coarse grain lense at 13 feet. | | 2 | 100 | 100 | | |
| 20 | | | | | | Hard, slightly weathered, slightly to highly fractured, banded to thickly bedded, iron staining in joints with hydrothermal quartz, light tan. | | 3 | 100 | 100 | | |
| | | | | | | | | 4 | 98 | 98 | | |
| 30 | | | | | | Hard to moderately hard, slightly to moderately weathered, slightly to intensely fractured, banded to thickly bedded, light tan to gray. | | 5 | 97 | 73 | | |
| | | | | | | Thin lense of claystone at 34 feet. | | 6 | 97 | 75 | | |
| 40 | | | | | | Stopped Coring at 40 feet. | | | | | | |
| 50 | | | | | | | | | | | | |
| 60 | | | | | | | | | | | | |

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# LOG OF BORING

# LVL-1

| | |
|---|---|
| PROJECT Cucharas Basin Collaborative Storage | APPROXIMATE GROUND ELEVATION 7278 |
| PROJECT NUMBER 18.117 | DEPTH TO BEDROCK 11 |
| DATE STARTED 8/13/18 | TOTAL DEPTH 40.5 |
| DATE COMPLETED 8/13/18 | REFUSAL |
| LOGGED BY J Edwards | |
| DRILLED BY HRL | DEPTH TO WATER / DATE |
| DRILL RIG CME-55 | 3.5 8/13/18 |
| DRILL METHOD 8", 3.5" | |

| DEPTH (ft) | FRACTURE LOG | GRAPHIC LOG | MOISTURE | | | DESCRIPTION | BLOWS/FT | CORE | | | | DRILLING NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | dry | moist | sat | | | NO. | RECOVERY (%) | RQD (%) | HARDNESS | |
| 0 | | | | | | FILL; CLAY, sandy, to SAND, clayey, medium stiff to stiff (clay), to loose (sand), slightly moist to wet, low to high plasticity, dark brown; SAN clayey, loose, slightly moist to wet, low to high plasticity (clay), dark brown. | | | | | | |
| | ▽ | | | | | | | | | | | |
| 5 | | | | | | | 8/12 | | | | | |
| 10 | | | | | | | 9/12 | | | | | |
| | | | | | | 11 ft.<br>SANDSTONE, silty to clayey, wet, weathered to very hard, brown to black. | | | | | | Hard drilling @ 11', harder drilling at 13' |
| 15 | | | | | | SANDSTONE, moderately hard, slightly weathered, predominately medium-grained, intact, massive, arkosic, red brown to orange brown to tan. | 50/2 | 1 | 94 | 83 | H3 | |
| | | | | | | | | 2 | 100 | 72 | H3 | |
| | | | | | | SANDSTONE, with clay, soft, moderately weathered, predominately fine grained, laminated to banded cross-beds, olive to orange to brown to tan.<br>SANDSTONE, moderately hard, moderately weathered, predominately coarse grained, arkosic, medium cross-beds, tan pink to yellow brown. | | | | | | |
| 20 | | | | | | 19 ft.<br>MUDSTONE, soft, predominately fine grained, massive, red brown. | | | | | | |
| | | | | | | | | 3 | 100 | 100 | H6/<br>H4/H3 | |
| 25 | | | | | | | | | | | | |
| | | | | | | 26 ft.<br>SANDSTONE, moderately hard, predominately medium grained, arkosic, medium cross-beds, intact, tan to red to brown. | | 4 | 100 | 100 | H3,H6,<br>H3 | |
| | | | | | | SANDSTONE, moderately hard, predominately fine grained, intact, massive, with occasional fossil fragments, calcareous, gray to pink to brown. | | | | | | |
| 30 | | | | | | | | | | | | |

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# LOG OF BORING

| PROJECT | PROJECT NO. | BORING NO. |
|---|---|---|
| Cucharas Basin Collaborative Storage | 18.117 | **LVL-1** |

| DEPTH (ft) | FRACTURE LOG | GRAPHIC LOG | MOISTURE dry | MOISTURE moist | MOISTURE sat | DESCRIPTION | BLOWS/FT | CORE NO. | CORE RECOVERY (%) | CORE RQD (%) | CORE HARDNESS | DRILLING NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 5 | 100 | 100 | H3,H4,<br>H6 | |
| 35 | | | | | | | | | | | | |
| | | | | | | | | 6 | 100 | 100 | H3 | |
| 40 | | | | | | | | | | | | |
| 45 | | | | | | | | | | | | |
| 50 | | | | | | | | | | | | |
| 55 | | | | | | | | | | | | |
| 60 | | | | | | | | | | | | |
| 65 | | | | | | | | | | | | |

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# LOG OF BORING

## LVL-2

| | |
|---|---|
| PROJECT Cucharas Basin Collaborative Storage | APPROXIMATE GROUND ELEVATION 7273 |
| PROJECT NUMBER 18.117 | DEPTH TO BEDROCK 2 |
| DATE STARTED 8/15/18 | TOTAL DEPTH 6 |
| DATE COMPLETED 8/15/18 | REFUSAL |
| LOGGED BY J Edwards | |
| DRILLED BY HRL | DEPTH TO WATER / DATE |
| DRILL RIG CME-55 | |
| DRILL METHOD 4" SSA | |

| DEPTH (ft) | FRACTURE LOG | GRAPHIC LOG | MOISTURE dry | MOISTURE moist | MOISTURE sat | DESCRIPTION | BLOWS/FT | CORE NO. | CORE RECOVERY (%) | CORE RQD (%) | CORE HARDNESS | DRILLING NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | ▨ | | | | CLAY, sandy, stiff, moist, reddish brown. | | | | | | |
| | | ▦ | | | | 2 ft.<br>SANDSTONE, silty, very hard, slightly moist, tan. Claystone parting at 4 feet. | | | | | | |
| 5 | | ▨ | | | | 5 ft.<br>CLAY, sandy, slightly moist, low plasticity, calcareous, tan. | 50/2 | | | | | |
| 10 | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | |
| 25 | | | | | | | | | | | | |
| 30 | | | | | | | | | | | | |

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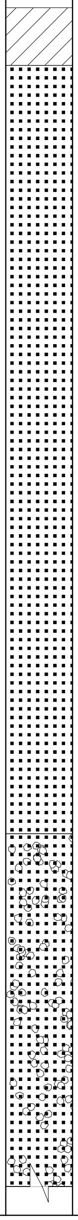
# LOG OF BORING

## LVL-3

| | | | |
|---|---|---|---|
| PROJECT | Cucharas Basin Collaborative Storage | APPROXIMATE GROUND ELEVATION | 7284 |
| PROJECT NUMBER | 18.117 | DEPTH TO BEDROCK | 1.5 |
| DATE STARTED | 8/13/18 | TOTAL DEPTH | 40.5 |
| DATE COMPLETED | 8/14/18 | REFUSAL | |
| LOGGED BY | J Edwards | | |
| DRILLED BY | HRL | DEPTH TO WATER / DATE | |
| DRILL RIG | CME-55 | | |
| DRILL METHOD | 4.25" HSA and HQ Core | | |



| DEPTH (ft) | FRACTURE LOG | GRAPHIC LOG | MOISTURE dry | MOISTURE moist | MOISTURE sat | DESCRIPTION | BLOWS/FT | CORE NO. | CORE RECOVERY (%) | CORE RQD (%) | CORE HARDNESS | DRILLING NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | CLAY, sandy, with gravel, medium stiff, slightly moist, brown. | | | | | | |
| | | | | | | 1.5 ft.<br>SANDSTONE, moderately hard, medium grained, laminated to parting cross-beds, weakly calcareous, tan to yellow brown.<br>Tight to very tight fractures 1.5'-4' and 6.5'-7.5'. Dark red staining along bedding / fracture surfaces 1.5'-2.5'. | | 1 | 92 | 42 | H3 | |
| 5 | | | | | | Very coarse grained sand, massive bedding | | 2 | 100 | 53 | H3,H2 | |
| 10 | | | | | | Medium grained sand, banded to medium cross-beds. 3" clast divides coarse-grained interval above from medium grained interval below at 10'. | | 3 | 100 | 95 | H3, H5 | |
| 15 | | | | | | SANDSTONE, medium hard, highly weathered, medium grained, tight to very tight joints/fractures, thinly cross-bedded, olive gray to tan.<br>14.5'-15.5' zone of brown orange staining, with occasional thin beds of black organic material. | | | | | | |
| | | | | | | SANDSTONE, moderately hard, slightly weathered, coarse grained, massive bedding, calcareous, tan to olive gray. | | 4 | 73 | 27 | H3, H5 | |
| 20 | | | | | | SANDSTONE, soft, fine grained, massive bedding, calcareous, red brown. | | | | | | |
| | | | | | | 21.5 ft.<br>SANDSTONE, silty, conglomeratic, soft, fine grained, parting to thin horizontal beds, calcareous, occasional fossil debris, dark red brown. With occasional clasts 1/8" - 1". | | 5 | 100 | 87.5 | H5 | |
| 25 | | | | | | | | 6 | 100 | 100 | H5 | |
| 30 | | | | | | | | | | | | |

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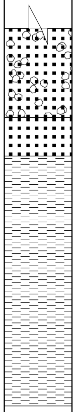
| LOG OF BORING | PROJECT<br>Cucharas Basin Collaborative Storage | PROJECT NO.<br>18.117 | BORING NO.<br>LVL-3 |
|---|---|---|---|

| DEPTH (ft) | FRACTURE LOG | GRAPHIC LOG | MOISTURE | | | DESCRIPTION | BLOWS/FT | CORE | | | | DRILLING NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | dry | moist | sat | | | NO. | RECOVERY (%) | RQD (%) | HARDNESS | |
| | |  | | | | | | 7 | 100 | 100 | H5,H3,<br>H6 | |
| | | | | | | 33 ft.<br>SANDSTONE, soft, fine grained, massively bedded, weakly calcareous, dark red brown. | | | | | | |
| 35 | | | | | | 34 ft.<br>MUDSTONE, sandy, conglomeratic, soft, massive bedding, calcareous, dark red brown. | | | | | | |
| | | | | | | | | 8 | 94 | 100 | H6,H3 | |
| | | | | | | 38.5' - 40.5' Mottled olive gray clasts | | | | | | |
| 40 | | | | | | Fossil debris | | | | | | |
| 45 | | | | | | | | | | | | |
| 50 | | | | | | | | | | | | |
| 55 | | | | | | | | | | | | |
| 60 | | | | | | | | | | | | |
| 65 | | | | | | | | | | | | |

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# LOG OF BORING

## LVL-4

| | | | |
|---|---|---|---|
| PROJECT | Cucharas Basin Collaborative Storage | APPROXIMATE GROUND ELEVATION | 7282 |
| PROJECT NUMBER | 18.117 | DEPTH TO BEDROCK | 8 |
| DATE STARTED | 8/15/18 | TOTAL DEPTH | 14 |
| DATE COMPLETED | 8/15/18 | REFUSAL | |
| LOGGED BY | J. Edwards | | |
| DRILLED BY | HRL | DEPTH TO WATER / DATE | |
| DRILL RIG | CME-55 | 8 | 8/15/18 |
| DRILL METHOD | 4" | | |

| DEPTH (ft) | FRACTURE LOG | GRAPHIC LOG | MOISTURE dry | MOISTURE moist | MOISTURE sat | DESCRIPTION | BLOWS/FT | CORE NO. | CORE RECOVERY (%) | CORE RQD (%) | CORE HARDNESS | DRILLING NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | ▨ | | | | FILL: CLAY, sandy, stiff, slightly moist, dark brown. | | | | | | |
| 5 | | ▨ | | | | | 16/12 | | | | | |
| | ▽ | ⁘ | | | | 8 ft.<br>SANDSTONE, silty, clayey, wet, very hard, greenish gray. | | | | | | |
| 10 | | ⁘ | | | | | 50/2 | | | | | |
| 15 | | | | | | | 50/8 | | | | | |
| 20 | | | | | | | | | | | | |
| 25 | | | | | | | | | | | | |
| 30 | | | | | | | | | | | | |

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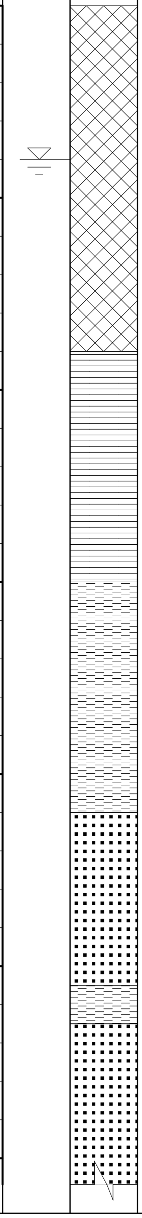
# LOG OF BORING

## LVL-5

| | |
|---|---|
| PROJECT Cucharas Basin Collaborative Storage | APPROXIMATE GROUND ELEVATION 7279 |
| PROJECT NUMBER 18.117 | DEPTH TO BEDROCK 9 |
| DATE STARTED 8/14/18 | TOTAL DEPTH 41 |
| DATE COMPLETED 8/14/18 | REFUSAL |
| LOGGED BY J Edwards | |
| DRILLED BY HRL | DEPTH TO WATER / DATE |
| DRILL RIG CME-55 | 4 8/14/18 |
| DRILL METHOD 8" HSA, 3.5" HQ Wireline | |



| DEPTH (ft) | DESCRIPTION | BLOWS/FT | CORE NO. | CORE RECOVERY (%) | CORE RQD (%) | CORE HARDNESS | DRILLING NOTES |
|---|---|---|---|---|---|---|---|
| 0 | FILL: CLAY, sandy, slightly moist, stiff, some concrete debris and organics in upper 3-1/2 feet, brown to dark brown. | | | | | | |
| 5 | | 14/12 | | | | | |
| | 9 ft.<br>CLAYSTONE, sandy, severely weathered to 14', very moist to moist., reddish brown. | | | | | | |
| 10 | | 10/12 | | | | | |
| 15 | 15 ft.<br>MUDSTONE, soft, massive, calcareous, red brown. | 34,58/3 | | | | | |
| | | | 1 | 100 | 0 | H3 | |
| | MUDSTONE, soft, massive, red brown with calcareous olive clasts. | | 2 | 100 | 100 | h6 | |
| 20 | | | | | | | |
| | 21 ft.<br>SANDSTONE, moderately hard, fine to medium grained, massive bedding, red brown to gray brown, mottled, with occasional calcareous olive spots. | | 3 | 100 | 100 | H5,H3,<br>H5 | |
| | Fracture with wavy sides | | | | | | |
| 25 | 25.5 ft.<br>MUDSTONE, soft, massive bedding, calcareous, red brown.<br>Fracture with wavy sides | | | | | | |
| | 26.5 ft.<br>SANDSTONE, soft, fine to medium grained, calcareous, gray red brown. | | 4 | 100 | 100 | H3 | |
| 30 | SANDSTONE, moderately hard, fine grained, banded cross-beds, weakly | | | | | | |

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# LOG OF BORING

| PROJECT | PROJECT NO. | BORING NO. |
|---|---|---|
| Cucharas Basin Collaborative Storage | 18.117 | **LVL-5** |

| DEPTH (ft) | FRACTURE LOG | GRAPHIC LOG | MOISTURE dry | MOISTURE moist | MOISTURE sat | DESCRIPTION | BLOWS/FT | CORE NO. | CORE RECOVERY (%) | CORE RQD (%) | CORE HARDNESS | DRILLING NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | calcareous, trace soft sediment deformation, light gray to dark gray. | | | | | | |
| | | | | | | | | 5 | 100 | 97 | H3 | |
| | | | | | | At 33.5' fracture along weak layer, up to 1/4" clay between surfaces. | | | | | | |
| 35 | | | | | | | | | | | | |
| | | | | | | | | 6 | 100 | 100 | H3 | |
| | | | | | | SANDSTONE, moderately hard, coarse-grained, thinly laminated to parting bedding , light gray pink to tan.<br>Banded to thin cross-beds. | | | | | | |
| 40 | | | | | | | | | | | | |
| 45 | | | | | | | | | | | | |
| 50 | | | | | | | | | | | | |
| 55 | | | | | | | | | | | | |
| 60 | | | | | | | | | | | | |
| 65 | | | | | | | | | | | | |

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# LOG OF BORING

# LVL-6

| | |
|---|---|
| PROJECT Cucharas Basin Collaborative Storage | APPROXIMATE GROUND ELEVATION 7280 |
| PROJECT NUMBER 18.117 | DEPTH TO BEDROCK 3.5 |
| DATE STARTED 8/15/18 | TOTAL DEPTH 9 |
| DATE COMPLETED 8/15/18 | REFUSAL |
| LOGGED BY J Edwards | |
| DRILLED BY HRL | DEPTH TO WATER / DATE |
| DRILL RIG CME-55 | 2.5 8/15/18 |
| DRILL METHOD 4" | |

| DEPTH (ft) | FRACTURE LOG | GRAPHIC LOG | MOISTURE | | | DESCRIPTION | BLOWS/FT | CORE | | | | DRILLING NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | dry | moist | sat | | | NO. | RECOVERY (%) | RQD (%) | HARDNESS | |
| 0 | | ▨ | | | | FILL: CLAY, sandy, stiff, moist, dark brown. | | | | | | |
| | ▽ | ▨ | | | | | | | | | | |
| | | ⁙ | | | | 3.5 ft.<br>SANDSTONE, very hard, moist to wet fine to medium grained, gray | 50/3 | | | | | Slow to advance in and out of fractures |
| 5 | | ⁙ | | | | | | | | | | |
| | | | | | | | 50/0 | | | | | |
| 10 | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | |
| 25 | | | | | | | | | | | | |
| 30 | | | | | | | | | | | | |

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# LOG OF BORING

## LVL-7

| | |
|---|---|
| PROJECT Cucharas Basin Collaborative Storage | APPROXIMATE GROUND ELEVATION 7284 |
| PROJECT NUMBER 18.117 | DEPTH TO BEDROCK 4.5 |
| DATE STARTED 8/15/18 | TOTAL DEPTH 7 |
| DATE COMPLETED 8/15/18 | REFUSAL |
| LOGGED BY J Edwards | |
| DRILLED BY HRL | DEPTH TO WATER / DATE |
| DRILL RIG CME-55 | 4.5 8/15/18 |
| DRILL METHOD 4" | |

| DEPTH (ft) | FRACTURE LOG | GRAPHIC LOG | MOISTURE dry | MOISTURE moist | MOISTURE sat | DESCRIPTION | BLOWS/FT | CORE NO. | CORE RECOVERY (%) | CORE RQD (%) | CORE HARDNESS | DRILLING NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | CLAY, sandy, stiff, slightly moist, with fine organics, dark brown. | | | | | | |
| | | | | | | 3 ft.<br>SAND, silty, medium dense, slightly moist, dark brown. | 23/12 | | | | | |
| 5 | | | | | | 4.5 ft.<br>SANDSTONE, silty to clayey, weathered, slightly moist, tan. | | | | | | |
| | | | | | | | 50/0.5 | | | | | |
| 10 | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | |
| 25 | | | | | | | | | | | | |
| 30 | | | | | | | | | | | | |

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# LOG OF BORING

# MS-1

PROJECT Cucharas Basin Collaborative Storage
APPROXIMATE GROUND ELEVATION 5925
PROJECT NUMBER 18.117
DEPTH TO BEDROCK 25
DATE STARTED 8/4/18
TOTAL DEPTH 41
DATE COMPLETED 8/4/18
REFUSAL
LOGGED BY H. Brunkal
DRILLED BY HRL
DEPTH TO WATER / DATE
DRILL RIG CME-55
25 8/4/18
DRILL METHOD HSA, HQ Core

| DEPTH (ft) | FRACTURE LOG | GRAPHIC LOG | MOISTURE | | | DESCRIPTION | BLOWS/FT | CORE | | | | DRILLING NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | dry | moist | sat | | | NO. | RECOVERY (%) | RQD (%) | HARDNESS | |
| 0 | | ▤ | | | | CLAYSTONE, sandy, weathered, slightly moist, moderately calcareous, dark tan. | | | | | | |
| 5 | | ▤ | | | | | 20/12 | | | | | |
| | | ▤ | | | | 6 ft.<br>CLAYSTONE, sandy, hard to very hard, slightly moist, calcareous, with sandstone gravel at 15 feet, olive to dark gray. | | | | | | |
| 10 | | ▤ | | | | | 50/9 | | | | | |
| 15 | | ▤ | | | | | 50/7 | | | | | |
| 20 | | ▤ | | | | | 50/9 | | | | | |
| 25 | ▽ | ▤ | | | | | 50/3 | 1 | 100 | 0 | H3 | |
| | | ▨ | | | | 26 ft.<br>SHALE, moderately hard, intact, thin (up to 1/16") dark mud layers interlaminated with lighter colored wavy fossil debris rich layers (up to 1/2"), with soft sediment deformation, bioturbaded, calcareous, light gray to dark gray. | | 2 | 100 | 87 | 3 | |
| 30 | | ▨ | | | | Moderately tight fractures along bedding (28' and 30'), with up to 1/4" of clay | | | | | | |

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# LOG OF BORING

| PROJECT | PROJECT NO. | BORING NO. |
|---|---|---|
| Cucharas Basin Collaborative Storage | 18.117 | **MS-1** |

| DEPTH (ft) | FRACTURE LOG | GRAPHIC LOG | MOISTURE dry | MOISTURE moist | MOISTURE sat | DESCRIPTION | BLOWS/FT | CORE NO. | CORE RECOVERY (%) | CORE RQD (%) | CORE HARDNESS | DRILLING NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ▨ | | | | between surfaces. | | 3 | 100 | 89 | 3 | |
| 35 | | ▨ | | | | | | | | | | |
| | | ▨ | | | | | | 4 | 98 | 57 | 3 | |
| 40 | | ▨ | | | | Sandstone lens at 39 feet, silty, up to 3/4" thick, olive colored, with orange staining on top and bottom. | | | | | | |
| 45 | | | | | | | | | | | | |
| 50 | | | | | | | | | | | | |
| 55 | | | | | | | | | | | | |
| 60 | | | | | | | | | | | | |
| 65 | | | | | | | | | | | | |

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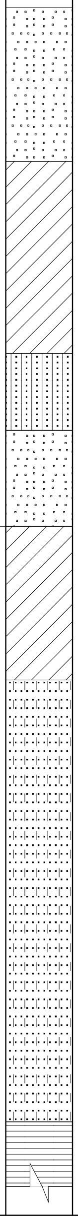
# LOG OF BORING

## MS-2

| | |
|---|---|
| PROJECT Cucharas Basin Collaborative Storage | APPROXIMATE GROUND ELEVATION 5922 |
| PROJECT NUMBER 18.117 | DEPTH TO BEDROCK 32 |
| DATE STARTED 8/6/18 | TOTAL DEPTH 37.17 |
| DATE COMPLETED 8/6/18 | REFUSAL |
| LOGGED BY H. Brunkal | |
| DRILLED BY HRL | DEPTH TO WATER / DATE |
| DRILL RIG CME-55 | 13.5 8/6/18 |
| DRILL METHOD HSA | |



| DEPTH (ft) | FRACTURE LOG | GRAPHIC LOG | MOISTURE dry | MOISTURE moist | MOISTURE sat | DESCRIPTION | BLOWS/FT | CORE NO. | CORE RECOVERY (%) | CORE RQD (%) | CORE HARDNESS | DRILLING NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | SAND, with clay, loose, wet, brown. | | | | | | |
| 5 | | | | | | 4 ft.<br>CLAY, sandy, moist, stiff, very calcareous, brown. | 9/12 | | | | | |
| 10 | | | | | | 9 ft.<br>SAND, silty, loose, moist, very calcareous, brown. | 6/12 | | | | | |
| | | | | | | 11 ft.<br>SAND, poorly graded, with gravel, medium dense, wet, brown. | | | | | | |
| 15 | ▽ | | | | | 13.5 ft.<br>CLAY, sandy, wet, stiff, vary calcareous, dark brown. | 12/12 | | | | | |
| 20<br>25 | | | | | | 17.5 ft.<br>SAND, with silt and gravel, very dense, wet, brown. | 50/4 | | | | | |
| 30 | | | | | | 29 ft.<br>CLAYSTONE, weathered to very hard, very moist, dark olive to black. | | | | | | |

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# LOG OF BORING

PROJECT
Cucharas Basin Collaborative Storage

PROJECT NO.
18.117

BORING NO.
**MS-2**

| DEPTH (ft) | FRACTURE LOG | GRAPHIC LOG | MOISTURE |  |  | DESCRIPTION | BLOWS/FT | CORE |  |  |  | DRILLING NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | dry | moist | sat |  |  | NO. | RECOVERY (%) | RQD (%) | HARDNESS |  |
|  |  |  |  |  |  |  | 50/5 |  |  |  |  |  |
| 35 |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  | 50/2 |  |  |  |  |  |
| 40 |  |  |  |  |  |  |  |  |  |  |  |  |
| 45 |  |  |  |  |  |  |  |  |  |  |  |  |
| 50 |  |  |  |  |  |  |  |  |  |  |  |  |
| 55 |  |  |  |  |  |  |  |  |  |  |  |  |
| 60 |  |  |  |  |  |  |  |  |  |  |  |  |
| 65 |  |  |  |  |  |  |  |  |  |  |  |  |

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# LOG OF BORING

## MS-3

| | |
|---|---|
| PROJECT Cucharas Basin Collaborative Storage | APPROXIMATE GROUND ELEVATION 5921 |
| PROJECT NUMBER 18.117 | DEPTH TO BEDROCK 26 |
| DATE STARTED 8/3/18 | TOTAL DEPTH 26 |
| DATE COMPLETED 8/3/18 | REFUSAL |
| LOGGED BY H Brunkal | |
| DRILLED BY HRL | DEPTH TO WATER / DATE |
| DRILL RIG CME-55 | 6 8/3/18 |
| DRILL METHOD HSA and HQ Core | |

| DEPTH (ft) | FRACTURE LOG | GRAPHIC LOG | MOISTURE | | | DESCRIPTION | BLOWS/FT | CORE | | | | DRILLING NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | dry | moist | sat | | | NO. | RECOVERY (%) | RQD (%) | HARDNESS | |
| 0 | | ▨ | | | | CLAY, with sand, very soft, moist, organics in upper 1 foot, slightly calcareous, dark brown. | | | | | | |
| 5 | | ▨ | | | | | 1/12 | | | | | |
| 6 | ▽ | ▨ | | | | | | | | | | |
| 7 | | ▤ | | | | 7 ft.<br>CLAYSTONE, slightly moist to very moist, medium hard to very hard, calcareous, olive to dark olive. | | | | | | |
| 10 | | ▤ | | | | | 40/12 | | | | | |
| 15 | | ▤ | | | | | 50/8 | | | | | |
| 20 | | ▤ | | | | | 50/12 | | | | | |
| 25 | | ▨ | | | | 25 ft.<br>SHALE, moderately hard, intact, thinly laminated, with occasional soft sediment deformation, with occasional bioturbation, with occasional fossil fragments, calcareous, dark gray. | 24, 50/6 | 1 | 0 | 0 | | |
| | | ▨ | | | | | | 2 | 100 | 56 | H3 | |
| 30 | | | | | | | | | | | | |

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# LOG OF BORING

PROJECT
Cucharas Basin Collaborative Storage

PROJECT NO.
18.117

BORING NO.
**MS-3**

| DEPTH (ft) | FRACTURE LOG | GRAPHIC LOG | MOISTURE | | | DESCRIPTION | BLOWS/FT | CORE | | | | DRILLING NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | dry | moist | sat | | | NO. | RECOVERY (%) | RQD (%) | HARDNESS | |
| | | ▨ | | | | | | 3 | 100 | 68 | H3 | |
| | | ▨ | | | | At 34' - fracture at 45 degree angle with up to 1/4" clay between surfaces. | | | | | | |
| 35 | | ▨ | | | | | | | | | | |
| | | ▨ | | | | | | 4 | 100 | 100 | H3 | |
| 40 | | ▨ | | | | | | | | | | |
| | | ▨ | | | | | | 5 | 80 | 96 | H3 | |
| 45 | | ▨ | | | | | | | | | | |
| | | ▨ | | | | | | 6 | 100 | 100 | H3 | |
| 50 | | ▨ | | | | | | | | | | |
| 55 | | | | | | | | | | | | |
| 60 | | | | | | | | | | | | |
| 65 | | | | | | | | | | | | |

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# LOG OF BORING

## MS-4

| | | | | |
|---|---|---|---|---|
| PROJECT | Cucharas Basin Collaborative Storage | APPROXIMATE GROUND ELEVATION | 5925 | |
| PROJECT NUMBER | 18.117 | DEPTH TO BEDROCK | 29 | |
| DATE STARTED | 8/5/18 | TOTAL DEPTH | 24.3 | |
| DATE COMPLETED | 8/6/18 | REFUSAL | | |
| LOGGED BY | H. Brunkal | | | |
| DRILLED BY | HRL | DEPTH TO WATER / DATE | | |
| DRILL RIG | CME-55 | 18.5 | 8/5/18 | |
| DRILL METHOD | HSA | | | |

| DEPTH (ft) | FRACTURE LOG | GRAPHIC LOG | MOISTURE dry | MOISTURE moist | MOISTURE sat | DESCRIPTION | BLOWS/FT | CORE NO. | CORE RECOVERY (%) | CORE RQD (%) | CORE HARDNESS | DRILLING NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | ▨ | | | | CLAY, sandy, stiff, slightly moist, medium calcareous, brown. | | | | | | |
| 5 | | ▨ | | | | | 11/12 | | | | | |
| 8.5 | | ▤ | | | | 8.5 ft.<br>CLAYSTONE, hard, slightly moist to wet, very calcareous, olive to dark olive, gray to black. | | | | | | |
| 10 | | ▤ | | | | | 50/11.5 | | | | | |
| 15 | | ▤ | | | | | 50/8.5 | | | | | |
| 18.5 | ▽ | ▤ | | | | | | | | | | |
| 20 | | ▤ | | | | | 50/7.5 | | | | | |
| 25 | | ▤ | | | | | 50/11.5 | | | | | |
| 29 | | ▨ | | | | 29 ft.<br>SHALE, lignite partings, | | | | | | |
| 30 | | | | | | | | | | | | |

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# LOG OF BORING

## MS-5

| | |
|---|---|
| PROJECT Cucharas Basin Collaborative Storage | APPROXIMATE GROUND ELEVATION 5925 |
| PROJECT NUMBER 18.117 | DEPTH TO BEDROCK 24.5 |
| DATE STARTED 8/4 | TOTAL DEPTH 40 |
| DATE COMPLETED 8/4 | REFUSAL |
| LOGGED BY H. Brunkal | |
| DRILLED BY HRL | DEPTH TO WATER / DATE |
| DRILL RIG CME-55 | 19 8/4 |
| DRILL METHOD HSA and HQ Core | |

| DEPTH (ft) | FRACTURE LOG | GRAPHIC LOG | MOISTURE dry | MOISTURE moist | MOISTURE sat | DESCRIPTION | BLOWS/FT | CORE NO. | CORE RECOVERY (%) | CORE RQD (%) | CORE HARDNESS | DRILLING NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | ▨ | | | | CLAY, sandy, slightly moist, hard, very calcareous, dark tan to olive. | | | | | | |
| 5 | | ▨ | | | | | 33/12 | | | | | |
| 10 | | ▨ | | | | | 31/12 | | | | | |
| | | ▤ | | | | 12 ft.<br>CLAYSTONE, slightly moist, very hard, very calcareous, olive to dark olive. | | | | | | |
| 15 | | ▤ | | | | | 29, 50/4 | | | | | |
| | ▽ | ▤ | | | | | | | | | | |
| 20 | | ▤ | | | | | 50/7 | | | | | |
| 25 | | ▨ | | | | 24.5 ft.<br>SHALE, moderately hard, intact, slightly weathered, thinly laminated, calcareous, with occasional soft sediment deformation, with occasional fossil fragments, with occasional bioturbation, dark gray. | 50/3.5 | 1 | 80 | 0 | | |
| | | ▨ | | | | | | 2 | 100 | 76 | R3 | |
| 30 | | ▨ | | | | | | | | | | |

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# LOG OF BORING

| PROJECT | PROJECT NO. | BORING NO. |
|---|---|---|
| Cucharas Basin Collaborative Storage | 18.117 | **MS-5** |

| DEPTH (ft) | FRACTURE LOG | GRAPHIC LOG | MOISTURE | | | DESCRIPTION | BLOWS/FT | CORE | | | | DRILLING NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | dry | moist | sat | | | NO. | RECOVERY (%) | RQD (%) | HARDNESS | |
| | | ▨ | | | | SHALE, same as above, but not weathered. | | 3 | 98 | 100 | R3 | |
| 35 | | ▨ | | | | | | | | | | |
| | | ▨ | | | | | | 4 | 100 | 100 | R3 | |
| 40 | | | | | | | | | | | | |
| 45 | | | | | | | | | | | | |
| 50 | | | | | | | | | | | | |
| 55 | | | | | | | | | | | | |
| 60 | | | | | | | | | | | | |
| 65 | | | | | | | | | | | | |

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# LOG OF BORING

## MS-6

| | | | |
|---|---|---|---|
| PROJECT | Cucharas Basin Collaborative Storage | APPROXIMATE GROUND ELEVATION | 5920 |
| PROJECT NUMBER | 18.117 | DEPTH TO BEDROCK | 29.5 |
| DATE STARTED | 8/5/18 | TOTAL DEPTH | 35.17 |
| DATE COMPLETED | 8/5/18 | REFUSAL | |
| LOGGED BY | H. Brunkal | | |
| DRILLED BY | HRL | DEPTH TO WATER / DATE | |
| DRILL RIG | CME-55 | 18 | 8/5/18 |
| DRILL METHOD | HSA & HQ Core | | |

| DEPTH (ft) | FRACTURE LOG | GRAPHIC LOG | MOISTURE | | | DESCRIPTION | BLOWS/FT | CORE | | | | DRILLING NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | dry | moist | sat | | | NO. | RECOVERY (%) | RQD (%) | HARDNESS | |
| 0 | | ▩ | | | | FILL: CLAY, sandy, moist, medium stiff, moderately calcareous, brown to dark brown. | | | | | | |
| 5 | | ▩ | | | | | 7/12 | | | | | |
| | | ▨ | | | | 7.5 ft.<br>CLAY, sandy, moist to very moist, very soft to hard, moderately calcareous, with gravel lenses at 25 feet, light to dark brown to olive. | | | | | | |
| 10 | | ▨ | | | | | 5/12 | | | | | |
| 15 | | ▨ | | | | | 1/12 | | | | | |
| | ▽ | ▨ | | | | | | | | | | |
| 20 | | ▨ | | | | | 8/12 | | | | | |
| 25 | | ▨ | | | | | 33/12 | | | | | |
| | | ▨ | | | | 29.5 ft.<br>SHALE, sandy, very moist, very hard, calcareous, dark olive to black. | | | | | | |
| 30 | | | | | | | 50/5 | | | | | |

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# LOG OF BORING

| PROJECT | PROJECT NO. | BORING NO. |
|---|---|---|
| Cucharas Basin Collaborative Storage | 18.117 | **MS-6** |

| DEPTH (ft) | FRACTURE LOG | GRAPHIC LOG | MOISTURE dry | MOISTURE moist | MOISTURE sat | DESCRIPTION | BLOWS/FT | CORE NO. | CORE RECOVERY (%) | CORE RQD (%) | CORE HARDNESS | DRILLING NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | ▨ |  |  |  |  |  |  |  |  |  |  |
| 35 |  |  |  |  |  |  | 50/2 |  |  |  |  |  |
| 40 |  |  |  |  |  |  |  |  |  |  |  |  |
| 45 |  |  |  |  |  |  |  |  |  |  |  |  |
| 50 |  |  |  |  |  |  |  |  |  |  |  |  |
| 55 |  |  |  |  |  |  |  |  |  |  |  |  |
| 60 |  |  |  |  |  |  |  |  |  |  |  |  |
| 65 |  |  |  |  |  |  |  |  |  |  |  |  |

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# LOG OF BORING

## SB-1

| | |
|---|---|
| PROJECT Cucharas Basin Collaborative Storage | APPROXIMATE GROUND ELEVATION 8869 |
| PROJECT NUMBER 18.117 | DEPTH TO BEDROCK 9 |
| DATE STARTED 8/12/18 | TOTAL DEPTH 29 |
| DATE COMPLETED 8/12/18 | REFUSAL |
| LOGGED BY J. Edwards | |
| DRILLED BY HRL | DEPTH TO WATER / DATE |
| DRILL RIG CME-55 | |
| DRILL METHOD 8' | |

| DEPTH (ft) | FRACTURE LOG | GRAPHIC LOG | MOISTURE dry | MOISTURE moist | MOISTURE sat | DESCRIPTION | BLOWS/FT | CORE NO. | CORE RECOVERY (%) | CORE RQD (%) | CORE HARDNESS | DRILLING NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | CLAY, sandy, soft, slightly moist, dark brown. | | | | | | |
| | | | | | | 1 ft.<br>SAND, clayey, moist, medium dense, reddish brown. | | | | | | |
| | | | | | | 3.5 ft.<br>SAND, silty, with gravel, moist, dense, dark red brown. | 43/12 | | | | | |
| 10 | | | | | | 9 ft.<br>SANDSTONE, clayey, moist, weathered, very dense, dark red brown. Grades to GRAVEL, poorly graded, with silt and sand, slightly moist, medium dense, reddish brown. | 17,50/4<br>20/12 | | | | | |
| | | | | | | 13.5 ft.<br>CLAYSTONE, with sand, slightly moist to moist, moderately hard to very hard, reddish brown to gray. | 47/12<br>24,50/3<br>50/6 | | | | | |
| 20 | | | | | | | | | | | | |
| | | | | | | 27 ft.<br>SANDSTONE, moist, very hard, reddish brown. | | | | | | |
| 30 | | | | | | Stopped HSA and sampling at 29'. | 50/0 | | | | | |
| 40 | | | | | | | | | | | | |
| 50 | | | | | | | | | | | | |
| 60 | | | | | | | | | | | | |

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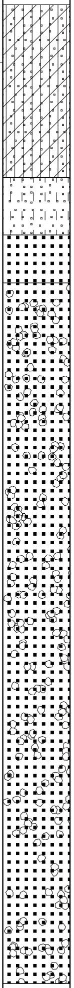
# LOG OF BORING

## SB-2

| | |
|---|---|
| PROJECT Cucharas Basin Collaborative Storage | APPROXIMATE GROUND ELEVATION 8859 |
| PROJECT NUMBER 18.117 | DEPTH TO BEDROCK 12 |
| DATE STARTED 8/11/18 | TOTAL DEPTH 51 |
| DATE COMPLETED 8/11/18 | REFUSAL |
| LOGGED BY J. Edwards | |
| DRILLED BY HRL | DEPTH TO WATER / DATE |
| DRILL RIG CME-55 | 3 8/11/18 |
| DRILL METHOD HSA & HQ Core | |

| DEPTH (ft) | FRACTURE LOG | GRAPHIC LOG | MOISTURE | | | DESCRIPTION | BLOWS/FT | CORE | | | | DRILLING NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | dry | moist | sat | | | NO. | RECOVERY (%) | RQD (%) | HARDNESS | |
| 0 | ▽ |  | | | | SAND, silty, clayey, moist to wet, very loose, dark brown. | 2/12 | | | | | |
| 10 | | | | | | 9 ft.<br>SAND, poorly graded, with silt and gravel, very loose, wet, dark brown to black with organics. | 14/12 | | | | | |
| | | | | | | 12 ft.<br>SANDSTONE, wet, very hard, tan to gray. Thickly interbedded with claystone below 33 feet. | 50/2 | 1 | 89 | 38 | | |
| | | | | | | 14.5 ft.<br>SANDSTONE, conglomeratic, moderately hard, medium sand to 1" gravel - sized grains, thin to medium cross-beds, red brown to pink gray. | | 2 | 100 | 80 | | |
| 20 | | | | | | | | 3 | 95 | 83 | | |
| | | | | | | | | 4 | 100 | 97 | | |
| 30 | | | | | | SANDSTONE, silty, conglomeratic, soft, predominately fine grained, massive bedding, red brown matrix, with occasional calcareous olive gray clasts. | | 5 | 100 | 63 | | 8" gray sandstone boulder |
| | | | | | | | | 6 | 100 | 60 | | |
| 40 | | | | | | Predominately matrix 38.5'-47' | | 7 | 100 | 90 | | |
| | | | | | | | | 8 | 100 | 80 | | |
| 50 | | | | | | Stopped coring at 51'. | | | | | | |
| 60 | | | | | | | | | | | | |

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# LOG OF BORING

## SB-3

| | |
|---|---|
| PROJECT Cucharas Basin Collaborative Storage | APPROXIMATE GROUND ELEVATION 8860 |
| PROJECT NUMBER 18.117 | DEPTH TO BEDROCK 7 |
| DATE STARTED 8/10/18 | TOTAL DEPTH 17 |
| DATE COMPLETED 8/11/18 | REFUSAL |
| LOGGED BY J. Edwards | |
| DRILLED BY HRL | DEPTH TO WATER / DATE |
| DRILL RIG CME-55 | 4 8/11/18 |
| DRILL METHOD 4" | |

| DEPTH (ft) | FRACTURE LOG | GRAPHIC LOG | MOISTURE | | | DESCRIPTION | BLOWS/FT | CORE | | | | DRILLING NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | dry | moist | sat | | | NO. | RECOVERY (%) | RQD (%) | HARDNESS | |
| 0 | | | | | | CLAY, sandy, slightly moist, very soft, dark brown. | | | | | | |
| | ▽ | | | | | 1.5 ft.<br>SAND, well graded, with silt and gravel, moist to wet, loose to medium dense, reddish brown. | | | | | | |
| | | | | | | 7 ft.<br>SAMDSTONE, wet, very hard, reddish brown. | 50/2 | | | | | |
| 10 | | | | | | | 50/0 | | | | | |
| | | | | | | Stopped HSA and sampling at 17'. | 50/0 | | | | | |
| 20 | | | | | | | | | | | | |
| 30 | | | | | | | | | | | | |
| 40 | | | | | | | | | | | | |
| 50 | | | | | | | | | | | | |
| 60 | | | | | | | | | | | | |

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# LOG OF BORING

## SB-4

PROJECT Cucharas Basin Collaborative Storage

PROJECT NUMBER 18.117

DATE STARTED 8/26/19

DATE COMPLETED 8/28/19

LOGGED BY I. Campbell

DRILLED BY Dakota

DRILL RIG CME 550

DRILL METHOD 8"

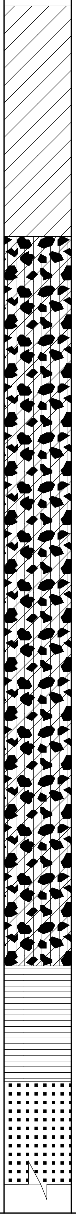
APPROXIMATE GROUND ELEVATION 8926

DEPTH TO BEDROCK 50

TOTAL DEPTH 70

REFUSAL

DEPTH TO WATER / DATE

| DEPTH (ft) | FRACTURE LOG | GRAPHIC LOG | MOISTURE | | | DESCRIPTION | BLOWS/FT | CORE | | | | DRILLING NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | dry | moist | sat | | | NO. | RECOVERY (%) | RQD (%) | HARDNESS | |
| 0 | |  | | | | CLAY, sandy, grades to with gravel, cobbles noted, slightly moist, stiff to hard, red brown (CL, A-4). | | | | | | |
| | | | | | | | 15/12 | | | | | |
| | | | | | | | 10/12 | | | | | |
| 10 | | | | | | | 50/8 | | | | | |
| | | | | | | 12 ft.<br>CLAY, with gravel, cobbles, and boulders, hard, red | | | | | | |
| | | | | | | | 35/12 | | | | | |
| 20 | | | | | | | 50/7 | 1 | 23 | 13 | | |
| | | | | | | SANDSTONE, boulder about 3 feet in diameter. | | 2 | 42 | 12 | | |
| 30 | | | | | | | | 3 | 65 | 32 | | |
| | | | | | | | | 4 | 15 | 0 | | |
| 40 | | | | | | | | 5 | 22 | 0 | | |
| | | | | | | | | 6 | 0 | 0 | | |
| 50 | | | | | | 50 ft.<br>CLAYSTONE, conglomeratic, soft, slightly weathered, highly to intensely fractured, massive bedding, red. | | 7 | 68 | 47 | | |
| | | | | | | | | 8 | 47 | 15 | | |
| | | | | | | 56 ft.<br>SANDSTONE, medium hard, slightly weathered, moderately to highly fractured, thickly bedded, red. | | | | | | |
| 60 | | | | | | | | 9 | 78 | 38 | | |

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# LOG OF BORING

| PROJECT | PROJECT NO. | BORING NO. |
|---|---|---|
| Cucharas Basin Collaborative Storage | 18.117 | **SB-4** |

| DEPTH (ft) | FRACTURE LOG | GRAPHIC LOG | MOISTURE dry | MOISTURE moist | MOISTURE sat | DESCRIPTION | BLOWS/FT | CORE NO. | CORE RECOVERY (%) | CORE RQD (%) | CORE HARDNESS | DRILLING NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 63 ft.<br>CLAYSTONE, soft, slightly weathered, moderately to highly fractured, thickly bedded, red. | | 10 | 53 | 0 | | |
| | | | | | | | | 11 | 90 | 70 | | |
| 70 | | | | | | Stopped coring at 70'. | | | | | | |
| 80 | | | | | | | | | | | | |
| 90 | | | | | | | | | | | | |
| 100 | | | | | | | | | | | | |
| 110 | | | | | | | | | | | | |
| 120 | | | | | | | | | | | | |
| 130 | | | | | | | | | | | | |

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# LOG OF BORING

# SB-5

| | |
|---|---|
| PROJECT Cucharas Basin Collaborative Storage | APPROXIMATE GROUND ELEVATION 8926 |
| PROJECT NUMBER 18.117 | DEPTH TO BEDROCK 10 |
| DATE STARTED 8/29/19 | TOTAL DEPTH 14.42 |
| DATE COMPLETED 8/29/19 | REFUSAL |
| LOGGED BY I. Campbell | |
| DRILLED BY Dakota | DEPTH TO WATER / DATE |
| DRILL RIG CME 55 Track Mounted | |
| DRILL METHOD 8" | |

| DEPTH (ft) | FRACTURE LOG | GRAPHIC LOG | MOISTURE | | | DESCRIPTION | BLOWS/FT | CORE | | | | DRILLING NOTES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | dry | moist | sat | | | NO. | RECOVERY (%) | RQD (%) | HARDNESS | |
| 0 | | ░ | | | | SAND, silty, with gravel and cobbles, slightly moist, medium dense, gray (SM, A-4). | 19/12<br>50/10 | | | | | |
| | | ▓ | | | | 5 ft.<br>GRAVEL, with sand and cobbles, clayey, very dense, slightly moist, gray (GC, A- 2-4). | 50/6 | | | | | |
| 10 | | ⠿ | | | | 10 ft.<br>SANDSTONE, hard, slightly weathered, highly fractured, thickly bedded, gray. | | | | | | |
| | | | | | | Stopped HSA and sampling at 14.4'. | 50/5 | | | | | |
| 20 | | | | | | | | | | | | |
| 30 | | | | | | | | | | | | |
| 40 | | | | | | | | | | | | |
| 50 | | | | | | | | | | | | |
| 60 | | | | | | | | | | | | |

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# APPENDIX B

## Core Photographs

**Photo 1. LVL-5 from 15 to 25 feet.**

**Photo 2. LVL-5 from 25 to 34.5 feet.**

**Photo 3. LVL-5 from 34.5 to 41 feet.**

**Photo 4. B-2 from 17 to 28 feet.**

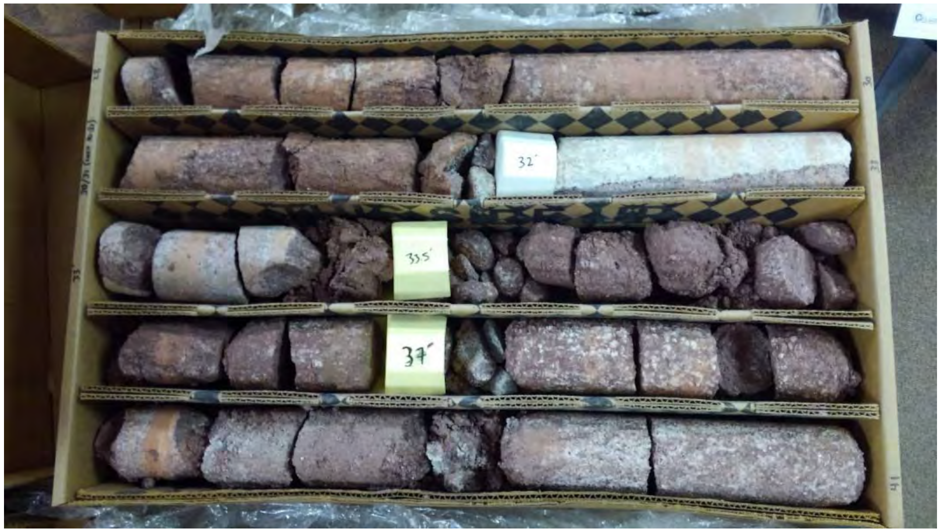

**Photo 5. B-2 from 28 to 41 feet.**

**Photo 6. B-2 from 41 to 42 feet.**

**Photo 7. SB-2 from 14.5 to 24 feet.**

**Photo 8. SB-2 from 24 to 33 feet.**

**Photo 9. SB-2 from 33 to 41 feet.**

**Photo 10. SB-2 from 41 to 51 feet.**

**Photo 11. BC-2 from 20 to 30 feet.**

**Photo 12. BC-2 from 30 to 37.2 feet.**

**Photo 13. BC-2 from 37.2 to 48.9 feet.**

**Photo 14. BC-2 from 48.9 to 50.8 feet.**

**Photo 15. LVL-3 from 1.5 to 11.5 feet.**

**Photo 16. LVL-3 from 11.5 to 21.5 feet.**

**Photo 17. LVL-3 from 21.5 to 31 feet.**

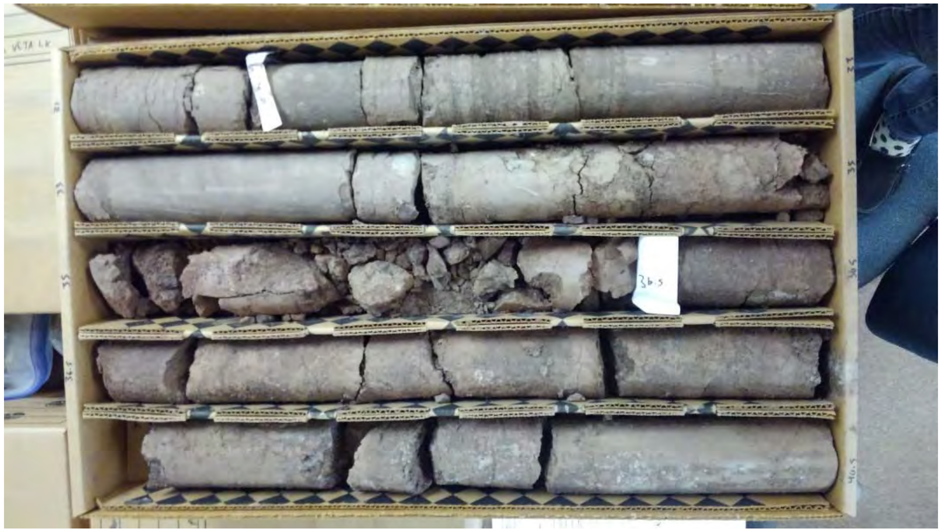

**Photo 18. LVL-3 from 31 to 40.5 feet.**

**Photo 19. MS-3 from 26 to 35.6 feet.**

**Photo 20. MS-3 from 35.6 to 44.5 feet.**

**Photo 21. MS-3 from 44.5 to 50 feet.**

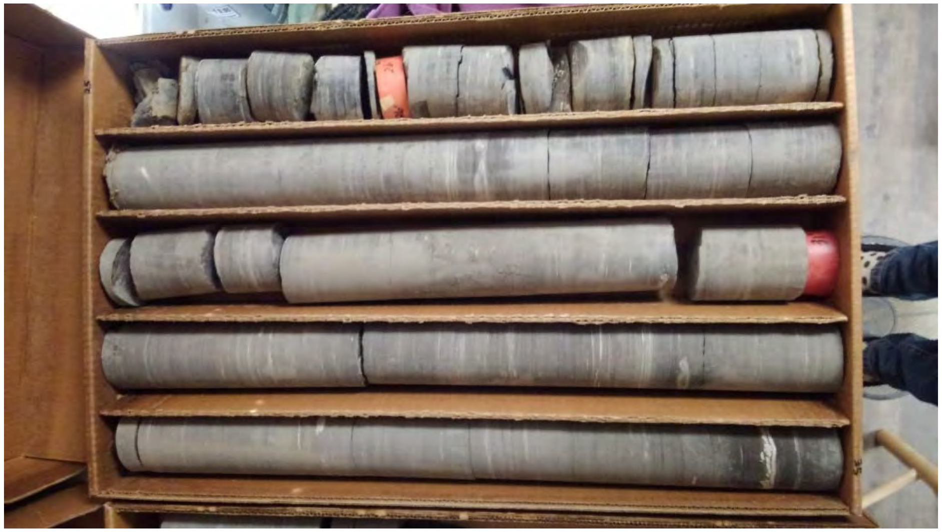

**Photo 22. MS-5 from 25 to 35 feet.**

**Photo 23. MS-5 from 35 to 40 feet.**

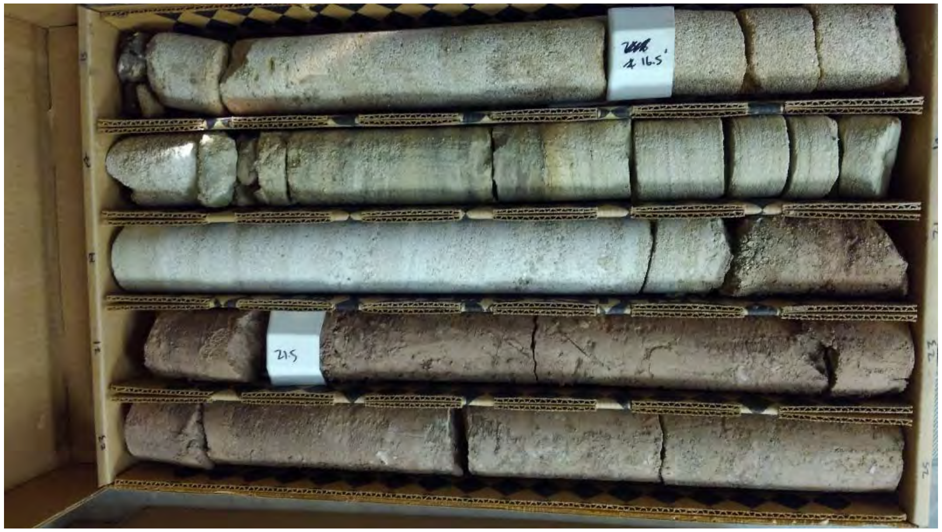

**Photo 24. LVL-1 from 15 to 25 feet.**

Photo 25. LVL-1 from 25 to 34 feet.

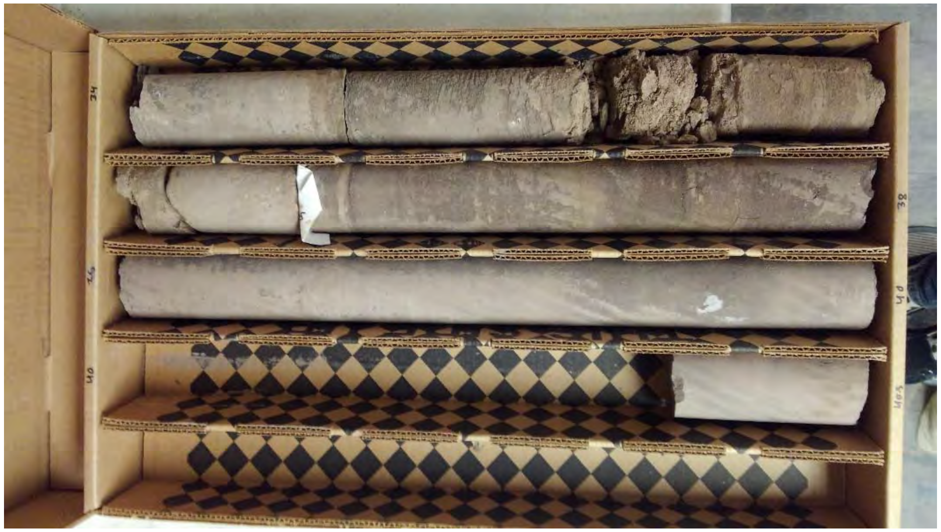

Photo 26. LVL-1 from 34 to 40.5 feet.

Photo 27. MS-1 from 25 to 34.6 feet.

Photo 28. MS-1 from 34.6 to 41 feet.

**Photo 29. SB-4 from 20 to 25 feet.**

**Photo 30. SB-4 from 25 to 27.5 feet.**

**Photo 31. SB-4 from 27.5 to 30 feet.**

**Photo 32. SB-4 from 30 to 31.5 feet.**

**Photo 33. SB-4 from 31.5 to 33 feet.**

**Photo 34. SB-4 from 33 to 35 feet.**

**Photo 35. SB-4 from 35 to 40 feet.**

**Photo 36. SB-4 from 40 to 45 feet.**

**Photo 37. SB-4 from 50 to 55 feet.**

**Photo 38. SB-4 from 55 to 60 feet.**

**Photo 39. SB-4 from 60 to 65 feet.**

**Photo 40. SB-4 from 65 to 67.5 feet.**

Photo 41. SB-4 from 67.5 to 69 feet.

Photo 42. SB-4 from 69 to 70 feet.

Photo 43. BC-4 from 10 to 15 feet.

Photo 44. BC-4 from 15 to 20 feet.

**Photo 45. BC-4 from 20 to 25 feet.**

**Photo 46. BC-4 from 25 to 30 feet.**

**Photo 47. BC-4 from 30 to 35 feet.**

**Photo 48. BC-4 from 35 to 40 feet.**

# APPENDIX C

## Laboratory Test Results

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## SUMMARY OF LABORATORY TEST RSULTS

Cucharas Basin Collaborative Storage
Project No. 18.117

| Sample Location | | Natural Dry Density (pcf) | Natural Moisture Content (%) | Gradation | | | Atterberg Limits | | Swell/Consolidation | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Boring | Depth (feet) | | | Gravel (%) | Sand (%) | Silt/ Clay (%) | Liquid Limit (%) | Plasticity Index (%) | Inundation Pressure (psf) | Volume Change (%) | Swell Pressure (psf) | Permeability (cm/s) | Material Type |
| B-1 | 7 | | 6.5 | 26 | 52 | 21.2 | 19 | 4 | | | | | SAND, silty, clayey (SC-SM, A-2-4) |
| B-1 | 17 | | 3.2 | 65 | 27 | 8.3 | NV | NP | | | | | GRAVEL, poorly graded, with silt and sand (GP-GM, A-1-b) |
| B-2 | 7 | | 6.9 | 63 | 28 | 8.7 | NV | NP | | | | | GRAVEL, well graded, with silt and sand (GW-GM, A-1-a) |
| B-2 | 12 | | 17.7 | | 81 | 19.4 | 24 | 4 | | | | | SAND, silty, clayey (SC-SM, A-2-4) |
| BP-1 | 1 to 3 | | 4.5 | 16 | 56 | 28.3 | 31 | 9 | | | | | SAND, clayey, with gravel (SC, A-2-4(0)) |
| BP-3 | 2 to 5 | | 1.8 | 1 | 65 | 34.2 | 21 | 5 | | | | | SAND, silty, clayey (SC-SM, A-2-4) |
| BP-5 | 3.5 to 5 | | 7.4 | 34 | 34 | 32.6 | 30 | 12 | | | | | SAND, clayey, with gravel (SC, A-2-6(0)) |
| BC-1 | 5 | | 11.5 | | 67 | 33.3 | 22 | 6 | | | | | SAND, clayey (SC, A-2-4(0)) |
| BC-1 | 25 | | 12.3 | | 39 | 60.8 | 40 | 16 | | | | | CLAY, sandy, lean (CL, A-6(8)) |
| BC-2 | 5 | | 27.0 | | 54 | 46 | 30 | 17 | | | | | SAND, clayey (SC, A-6(4)) |
| BC-2 | 10 | | 16.0 | 17 | 52 | 30.7 | 23 | 7 | | | | | SAND, clayey, with gravel (SC, A-2-4(0)) |
| BC-3 | 5 | | 5.4 | 1 | 70 | 29.1 | 24 | 6 | | | | | SAND, silty, clayey (SC-SM, A-2-4(0)) |
| BC-3 | 15 | | 4.6 | | 56 | 43.7 | 24 | 4 | | | | | SAND, silty, clayey (SC-SM, A-4(0)) |
| BC-4 | 10 | | 6.1 | | 23 | 76.7 | 30 | 11 | | | | | CLAY, lean, with sand (CL, A-6(7)) |
| BCP-1 | 1 to 8 | | 3.0 | | 53 | 46.6 | 27 | 11 | | | | | SAND, clayey (SC, A-6(2)) |
| BCP-2 | 2 to 10 | | 4.1 | | 65 | 34.6 | 23 | 6 | | | | | SAND, silty, clayey (SC-SM, A-2-4) |
| BCP-4 | 2 to 8 | | 1.9 | | 64 | 36.0 | 25 | 9 | | | | | SAND, clayey (SC, A-4) |
| BCP-5 | 2 to 8 | 82.8 | 5.1 | 9 | 48 | 43.5 | 29 | 12 | 500 | -9.9 | N/A | | SAND, clayey (SC, A-6(2)) |
| BCP-6 | 7 to 9 | | 4.1 | | 76 | 23.6 | NV | NP | | | | | SAND, silty (SM, A-2-4) |
| LVL-1 | 15 | | 10.7 | | 59 | 40.6 | 24 | 5 | | | | | SAND, silty, clayey (SC-SM, A-4) |
| LVL-4 | 9 | | 16.1 | | 63 | 36.7 | 23 | 6 | | | | | SAND, silty, clayey (SC-SM, A-4) |
| LVL-5 | 5 | | 14.0 | | 48 | 52.5 | 37 | 20 | | | | | CLAY, sandy, lean (CL, A-6(7)) |
| LVL-7 | 4 | | 4.3 | 1 | 63 | 36.3 | 19 | 5 | | | | | SAND, silty, clayey (SC-SM, A-4) |
| MS-1 | 10 | | 9.6 | 5 | 26 | 69.4 | 30 | 14 | | | | | CLAY, sandy, lean (CL, A-6(7)) |
| MS-1 | 20 | | 7.4 | 11 | 30 | 58.5 | 31 | 16 | | | | | CLAY, sandy, lean (CL, A-6(6)) |
| MS-2 | 10 | | 7.8 | 2 | 77 | 21.1 | NV | NP | | | | | SAND, silty (SM, A-2-4) |

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# SUMMARY OF LABORATORY TEST RSULTS

Cucharas Basin Collaborative Storage
Project No. 18.117

| Sample Location | | Natural | Natural | Gradation | | | Atterberg Limits | | Swell/Consolidation | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Boring | Depth (feet) | Dry Density (pcf) | Moisture Content (%) | Gravel (%) | Sand (%) | Silt/ Clay (%) | Liquid Limit (%) | Plasticity Index (%) | Inundation Pressure (psf) | Volume Change (%) | Swell Pressure (psf) | Permeability (cm/s) | Material Type |
| MS-2 | 20 | | 16.5 | 17 | 76 | 6.8 | NV | NP | | | | | SAND, well graded, with silt and gravel (SW-SM, A-1-b) |
| MS-3 | 5 | | 24.5 | | 20 | 79.9 | 39 | 20 | | | | | CLAY, lean, with sand (CL, A-6(15)) |
| MS-4 | 10 | | 11.8 | | 10 | 90.4 | 35 | 20 | | | | | CLAY, lean (CL, A-6(17)) |
| MS-5 | 10 | | 12.3 | | 12 | 87.8 | 35 | 17 | | | | | CLAY, lean (CL, A-6(14)) |
| MS-6 | 5 | 113.1 | 14.0 | | | | | | 50 | 0.3 | 315 | | FILL: CLAY, sandy, lean (CL, A-6) |
| MS-6 | 10 | 91.3 | 25.9 | 1 | 28 | 70.2 | 32 | 15 | 50 | 0.3 | 125 | | CLAY, sandy, lean, with organics (CL, A-6(8)) |
| MS-6 | 15 | 95.3 | 25.2 | | | | | | 50 | 0.1 | 64 | | CLAY, sandy, lean (CL, A-6) |
| MS-6 | 20 | 106.9 | 19.5 | | | | | | 50 | 0.8 | 605 | | CLAY, sandy, lean (Cl, A-6) |
| MS-6 | 25 | | 14.4 | 1 | 30 | 68.1 | 30 | 11 | | | | | CLAY, sandy, lean (CL, A-6(5)) |
| MSP-2 | 1 to 3 | | 6.4 | 1 | 30 | 68.6 | 36 | 13 | | | | | CLAY, sandy, lean (CL, A-6(8)) |
| MSP-4 | 2 to 4 | | 5.3 | 1 | 24 | 74.7 | 37 | 16 | | | | | CLAY, sandy, lean (CL, A-6(11)) |
| MSP-5 | 1 to 4 | | 5.7 | 6 | 28 | 66.3 | 35 | 19 | | | | | CLAY, sandy, lean (CL, A-6(10)) |
| MSP-5 | 4 to 7 | | 3.6 | 8 | 29 | 62.9 | 33 | 16 | | | | | CLAY, sandy, lean (CL, A-6(7)) |
| SB-1 | 5 | | 7.6 | 31 | 47 | 22.5 | 19 | 2 | | | | | SAND, silty, with gravel (SM, A-1-b(0)) |
| SB-1 | 12.5 | | 0.3 | 52 | 37 | 10.7 | NV | NP | | | | | GRAVEL, poorly graded, with silt and sand (GP-GM, A-1-b) |
| SB-1 | 20 | | 8.7 | | 27 | 72.5 | 30 | 11 | | | | | CLAY, lean, with sand (CL, A-6(6)) |
| SB-2 | 10 | | 10.3 | 42 | 47 | 11.3 | NV | NP | | | | | SAND, poorly graded, with silt and gravel (SP-SM, A-1-b) |
| SB-3 | 5 | | 5.6 | 27 | 62 | 11.1 | NV | NP | | | | | SAND, well graded, with silt and gravel (SW-SM, A-1-b) |
| SB-4 | 5 | | 15.5 | | 46 | 54.3 | 26 | 9 | | | | | CLAY, sandy, lean (CL, A-4(2)) |
| SB-4 | 15 | | 6.0 | 23 | 28 | 49.1 | 24 | 8 | | | | | CLAY, sandy, lean, with gravel (CL, A-4(1)) |
| SB-4 | 55 | | | | | | | | | | | 3.63.E-09 | CLAYSTONE, sandy |
| SB-5 | 1 | | 6.3 | 4 | 56 | 40.4 | 19 | 2 | | | | | SAND, silty (SM, A-4) |
| SBP-1 | 1 to 3 | | 2.4 | 1 | 49 | 50.3 | 25 | 5 | | | | | CLAY, silty, with sand (CL-ML, A-4(0)) |
| SBP-3 | 1 to 3 | | 2.0 | 3 | 63 | 33.6 | 24 | 4 | | | | | SAND, silty, clayey (SC-SM, A-2-4(0)) |
| SBP-3 | 6 to 8 | | 6.0 | | 78 | 21.3 | 28 | 9 | | | | | SAND, clayey (SC, A-2-4(0)) |
| SBP-5 | 1 to 3 | | 6.1 | | 58 | 41.3 | 27 | 6 | | | | | SAND, silty, clayey (SC-SM, A-4(0)) |

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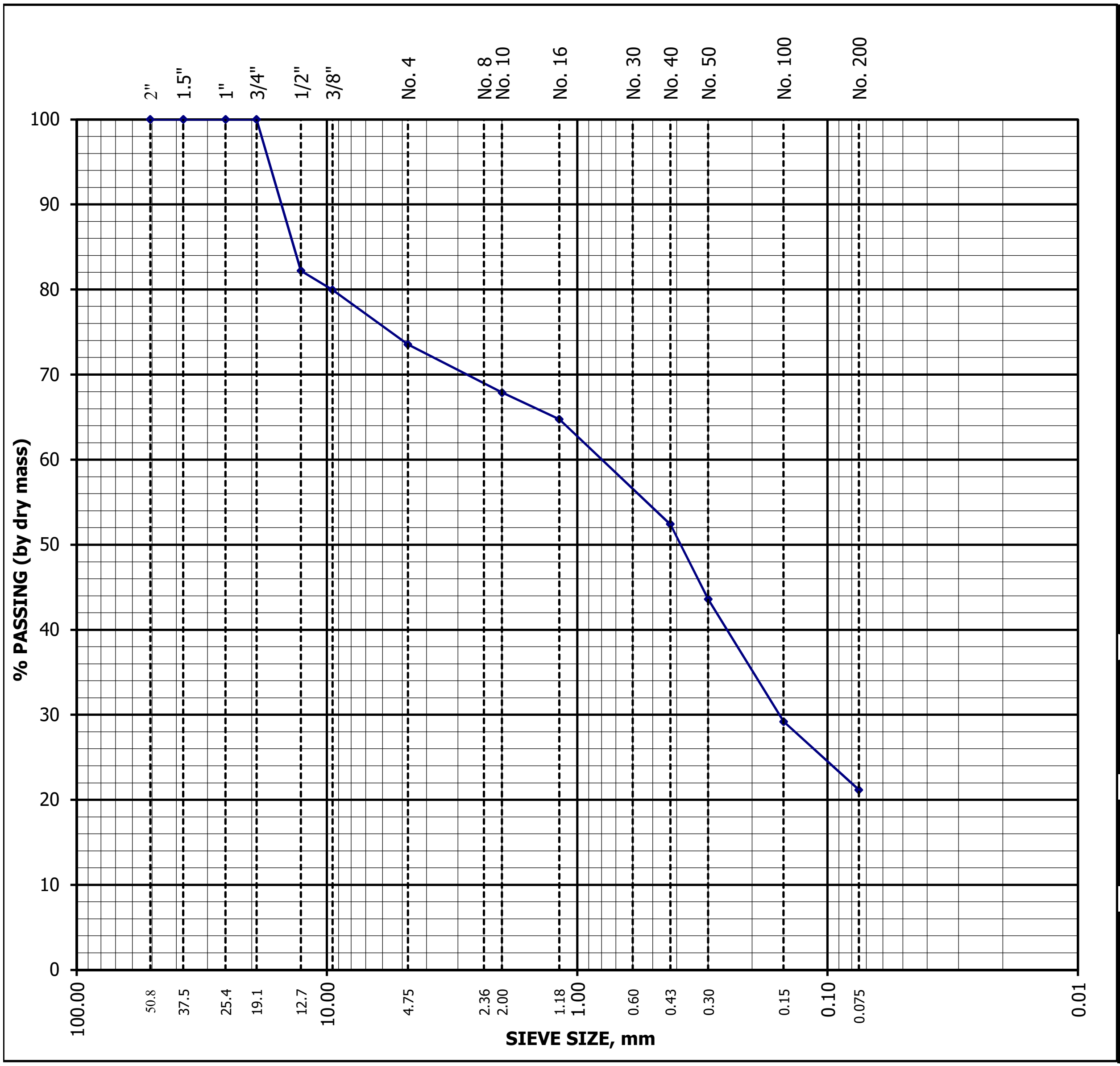
# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822891
Sample Location: B-1 at 7'
Visual Description: SAND, silty, clayey, reddish brown

Date: 8-Sep-18
Technician: J. Holiman
Reviewer: J. Crystal

**AASHTO M 145 Classification:** **A-2-4** **Group Index:** **(0)**
**Unified Soil Classification System**
**(ASTM D 2487):** **(SC-SM) Silty, clayey sand**



| **Sieve Size** | **% Passing** |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | 100 |
| 1/2" | 82 |
| 3/8" | 80 |
| #4 | 74 |
| #8 | |
| #10 | 68 |
| #16 | 65 |
| #30 | |
| #40 | 52 |
| #50 | 44 |
| #100 | 29 |
| #200 | 21.2 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 6.5 |
| D, pcf: | |

| | |
|---|---|
| **LL** | 19 |
| PL | 15 |
| **PI** | 4 |

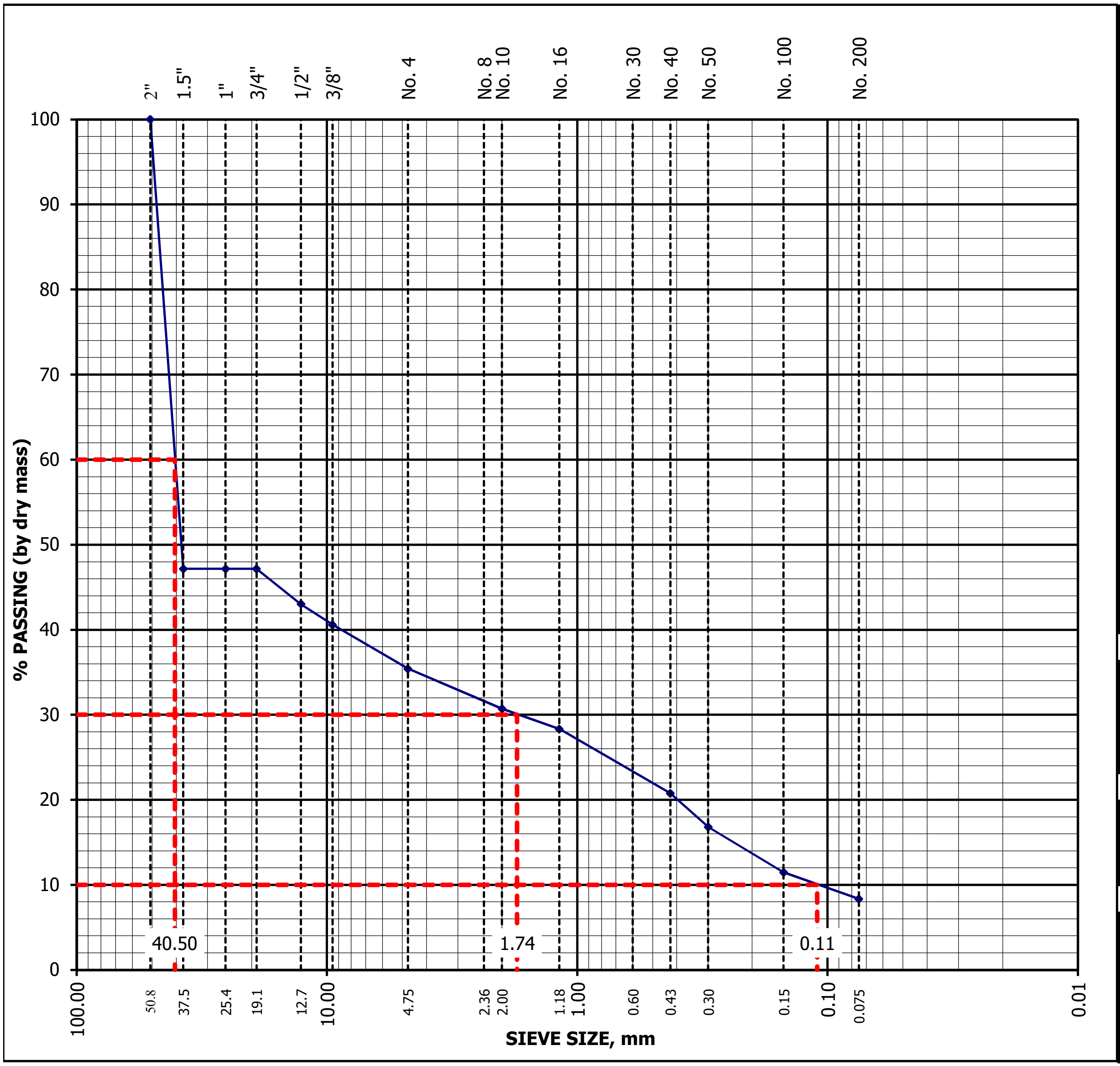
| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822892
Sample Location: B-1 at 17'
Visual Description: GRAVEL, with silt and sand, reddish brown

Date: 8-Sep-18
Technician: J. Holiman
Reviewer: J. Crystal

**AASHTO M 145 Classification:** **A-1-a** **Group Index:** **0**
**Unified Soil Classification System (ASTM D 2487):** **(GP-GM) Poorly graded gravel with silt and sand**



| Sieve Size | % Passing |
|---|---|
| | |
| | |
| | |
| 2" | 100 |
| 1.5" | 47 |
| 1" | 47 |
| 3/4" | 47 |
| 1/2" | 43 |
| 3/8" | 41 |
| #4 | 35 |
| #8 | |
| #10 | 31 |
| #16 | 28 |
| #30 | |
| #40 | 21 |
| #50 | 17 |
| #100 | 11 |
| #200 | 8.3 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 3.2 |
| D, pcf: | |

| | |
|---|---|
| **LL** | NV |
| PL | NP |
| **PI** | NP |

| | |
|---|---|
| $D_{60}$ | 40.50 |
| $D_{30}$ | 1.74 |
| $D_{10}$ | 0.11 |
| **Cu** | **368.18** |
| **Cc** | **0.68** |

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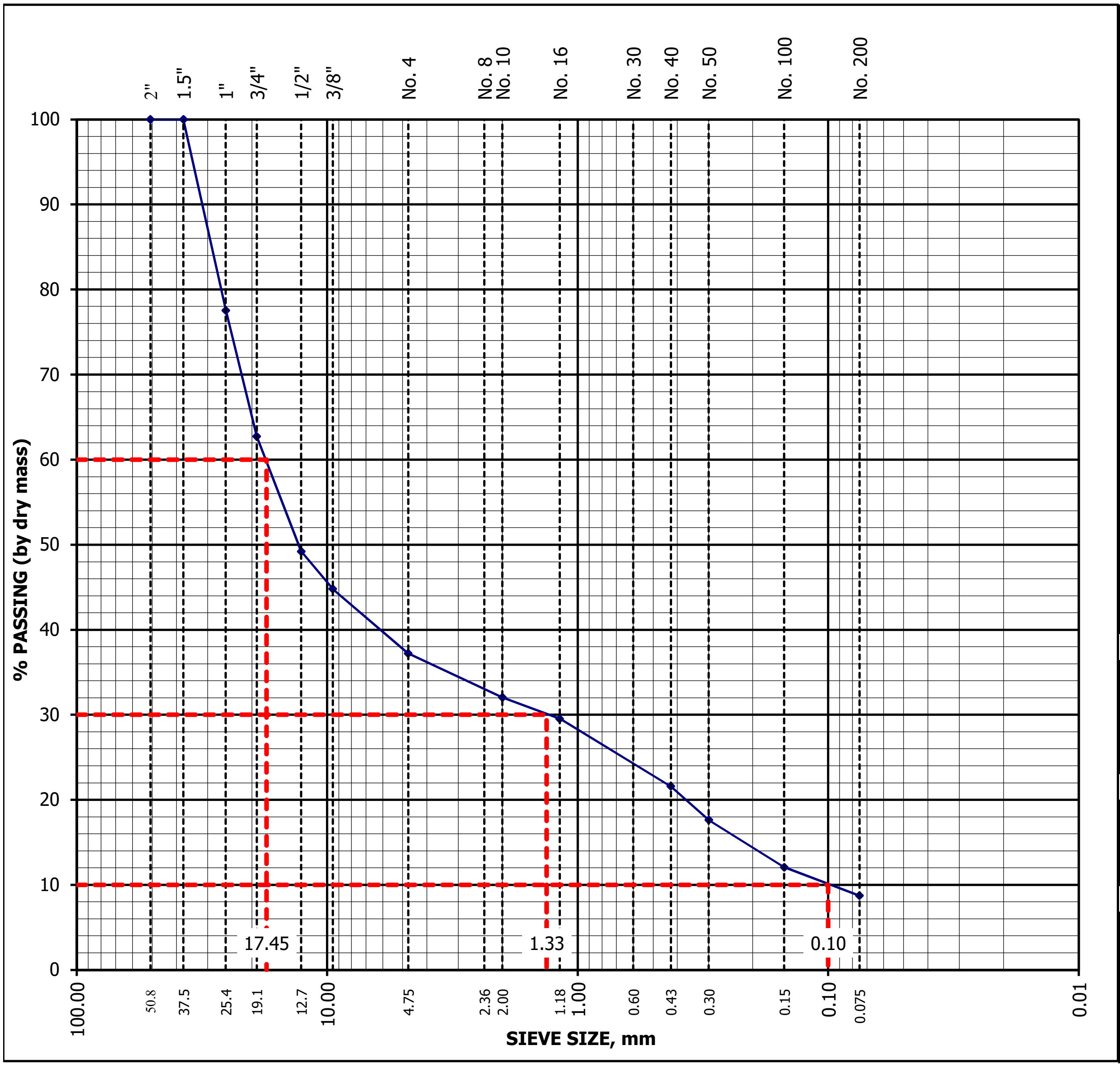
## GRADATION PLOT - SOIL & AGGREGATE

| | | | |
|---|---|---|---|
| Project Number: | 18.117, Applegate Group | Date: | 5-Sep-18 |
| Project Name: | Cucharas Basin Collaborative Storage | Technician: | J. Weinerth |
| Lab ID Number: | 1822893 | Reviewer: | J. Crystal |
| Sample Location: | B-2 at 7' | | |
| Visual Description: | GRAVEL, with silt and sand, red brown | | |

**AASHTO M 145 Classification:** A-1-a **Group Index:** 0

**Unified Soil Classification System (ASTM D 2487):** (GW-GM) Well graded gravel with silt and sand



| **Sieve Size** | **% Passing** |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | 100 |
| 1" | 78 |
| 3/4" | 63 |
| 1/2" | 49 |
| 3/8" | 45 |
| #4 | 37 |
| #8 | |
| #10 | 32 |
| #16 | 30 |
| #30 | |
| #40 | 22 |
| #50 | 18 |
| #100 | 12 |
| #200 | 8.7 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 6.9 |
| D, pcf: | |

| | |
|---|---|
| **LL** | NV |
| PL | NP |
| **PI** | NP |

| | |
|---|---|
| $D_{60}$ | 17.45 |
| $D_{30}$ | 1.33 |
| $D_{10}$ | 0.10 |
| **Cu** | **####** |
| **Cc** | **1.01** |

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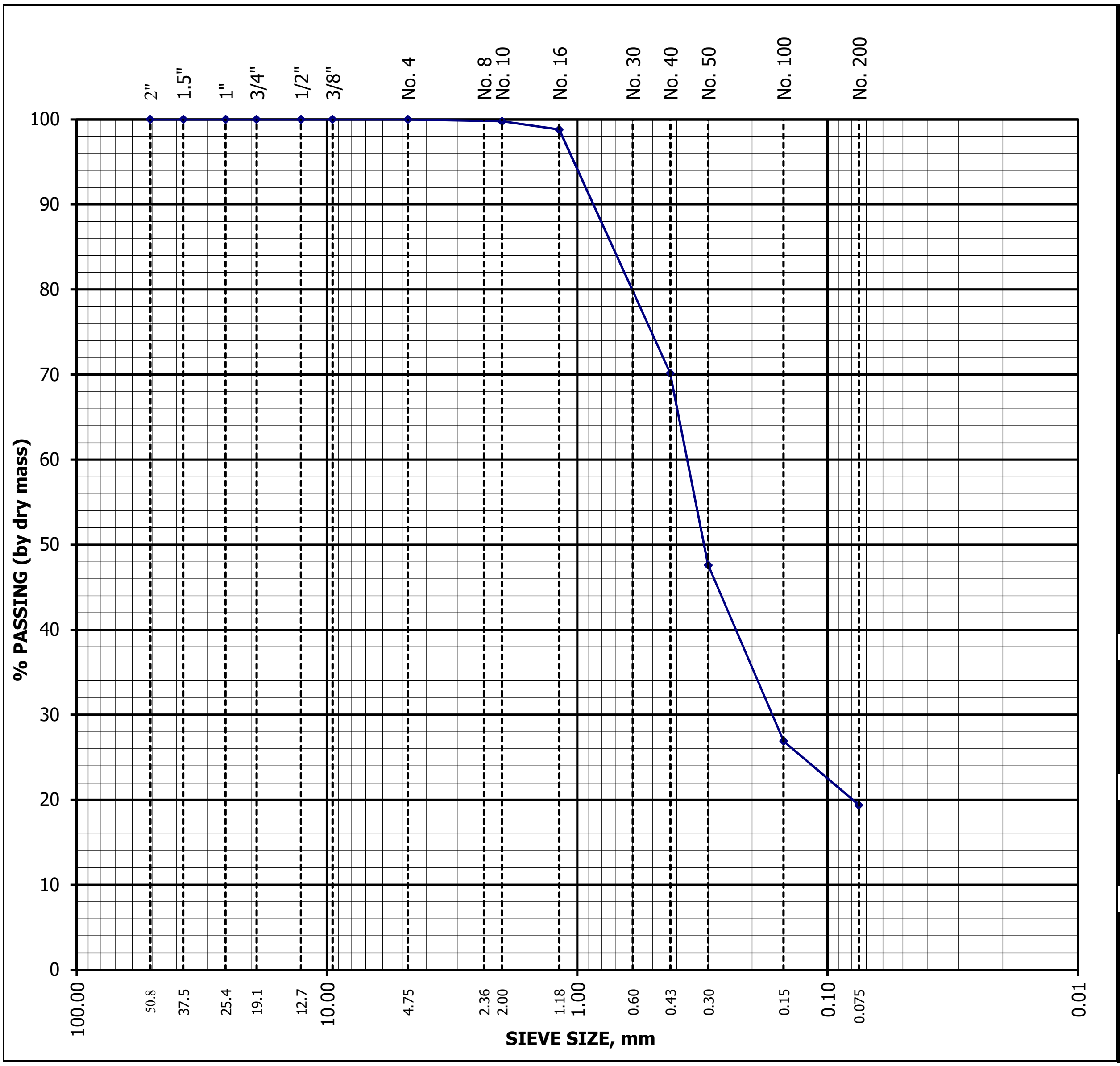
# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822894
Sample Location: B-2 at 12'
Visual Description: SAND, clay, silty, reddish brown

Date: 8-Sep-18
Technician: J. Holiman
Reviewer: J. Crystal

**AASHTO M 145 Classification:** **A-2-4** **Group Index:** **(0)**
**Unified Soil Classification System (ASTM D 2487):** **(SC-SM) Silty, clayey sand**



| **Sieve Size** | **% Passing** |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | |
| 1/2" | |
| 3/8" | |
| #4 | 100 |
| #8 | |
| #10 | 100 |
| #16 | 99 |
| #30 | |
| #40 | 70 |
| #50 | 48 |
| #100 | 27 |
| #200 | 19.4 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 17.7 |
| D, pcf: | |

| | |
|---|---|
| **LL** | 24 |
| PL | 20 |
| **PI** | 4 |

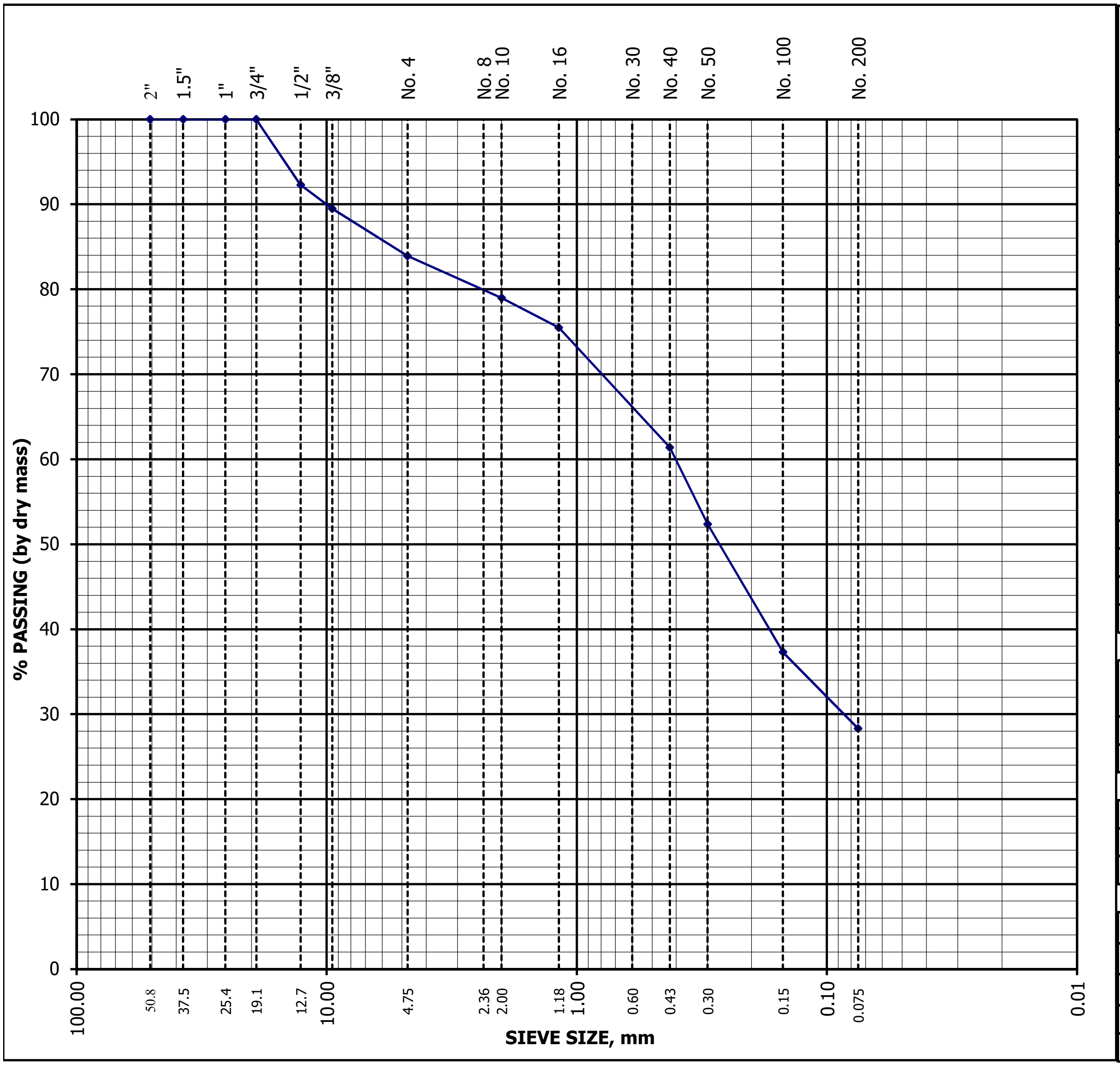
| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822649
Sample Location: BP-1 at 1' to 3'
Visual Description: SAND, clay with gravel, brown

Date: 25-Sep-18
Technician: J. Crystal
Reviewer: J. Holiman

**AASHTO M 145 Classification:** **A-2-4** **Group Index:** **(0)**
**Unified Soil Classification System (ASTM D 2487):** **(SC)** **Clayey sand with gravel**



| **Sieve Size** | **% Passing** |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | 100 |
| 1/2" | 92 |
| 3/8" | 89 |
| #4 | 84 |
| #8 | |
| #10 | 79 |
| #16 | 76 |
| #30 | |
| #40 | 61 |
| #50 | 52 |
| #100 | 37 |
| #200 | 28.3 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 4.5 |
| D, pcf: | |

| | |
|---|---|
| **LL** | 31 |
| PL | 22 |
| **PI** | 9 |

| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

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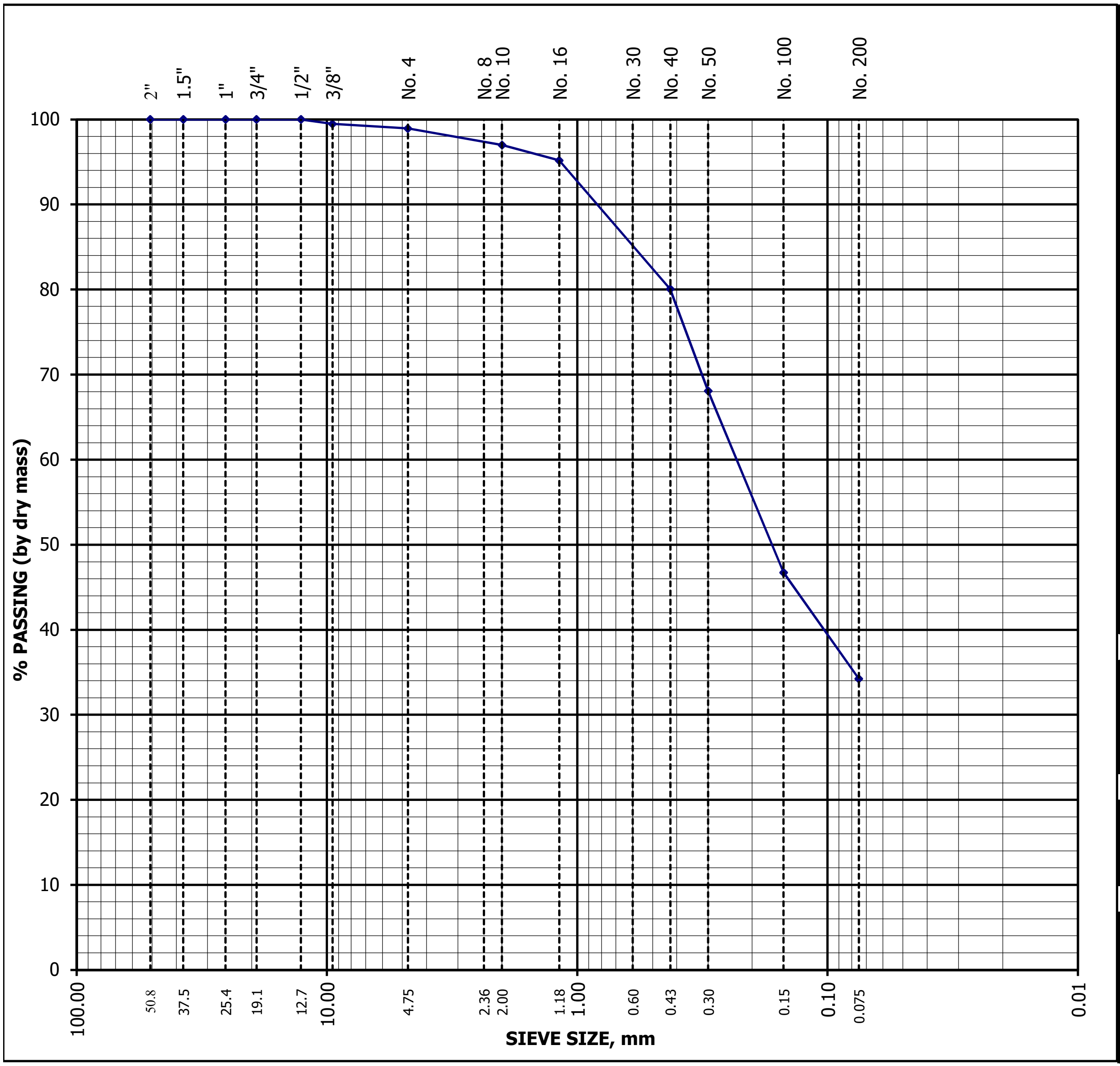
# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822650
Sample Location: BP-3 at 2' to 5'
Visual Description: SAND, silty, clayey, brown

Date: 25-Sep-18
Technician: J. Holiman
Reviewer: J. Crystal

**AASHTO M 145 Classification:** **A-2-4** **Group Index:** **(0)**
**Unified Soil Classification System (ASTM D 2487):** **(SC-SM) Silty, clayey sand**



| Sieve Size | % Passing |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | |
| 1/2" | 100 |
| 3/8" | 99 |
| #4 | 99 |
| #8 | |
| #10 | 97 |
| #16 | 95 |
| #30 | |
| #40 | 80 |
| #50 | 68 |
| #100 | 47 |
| #200 | 34.2 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 1.8 |
| D, pcf: | |

| | |
|---|---|
| **LL** | 21 |
| PL | 16 |
| **PI** | 5 |

| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

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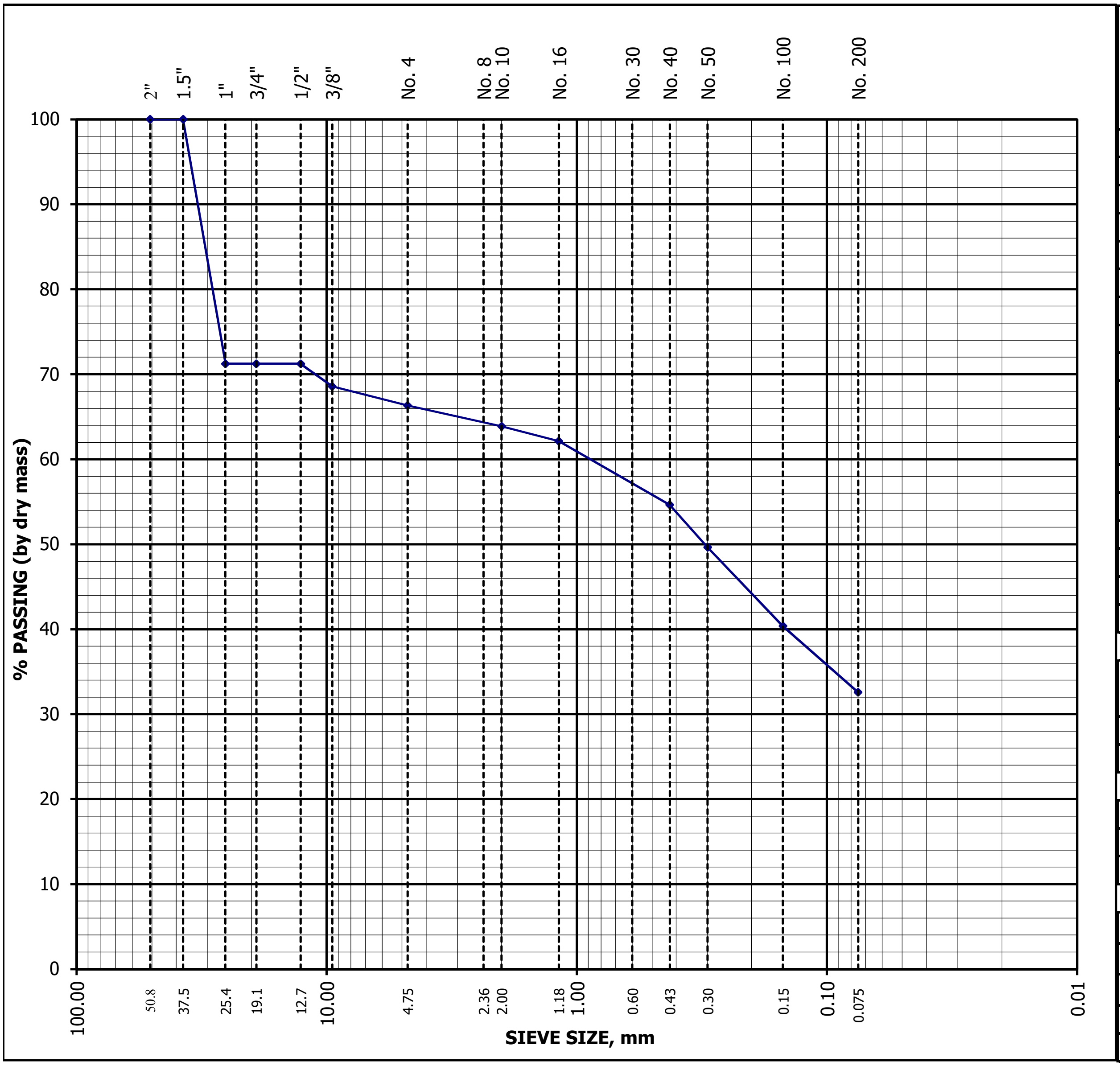
# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822651
Sample Location: BP-5 at 3.5' to 5'
Visual Description: SAND, clayey, with gravel, red brown

Date: 6-Oct-18
Technician: J. Holiman
Reviewer: J. Crystal

**AASHTO M 145 Classification: A-2-6 Group Index: (0)**
**Unified Soil Classification System**
**(ASTM D 2487): (SC) Clayey sand with gravel**



| **Sieve Size** | **% Passing** |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | 100 |
| 1" | 71 |
| 3/4" | 71 |
| 1/2" | 71 |
| 3/8" | 69 |
| #4 | 66 |
| #8 | |
| #10 | 64 |
| #16 | 62 |
| #30 | |
| #40 | 55 |
| #50 | 50 |
| #100 | 40 |
| #200 | 32.6 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 7.4 |
| D, pcf: | |

| | |
|---|---|
| **LL** | 30 |
| PL | 18 |
| **PI** | 12 |

| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

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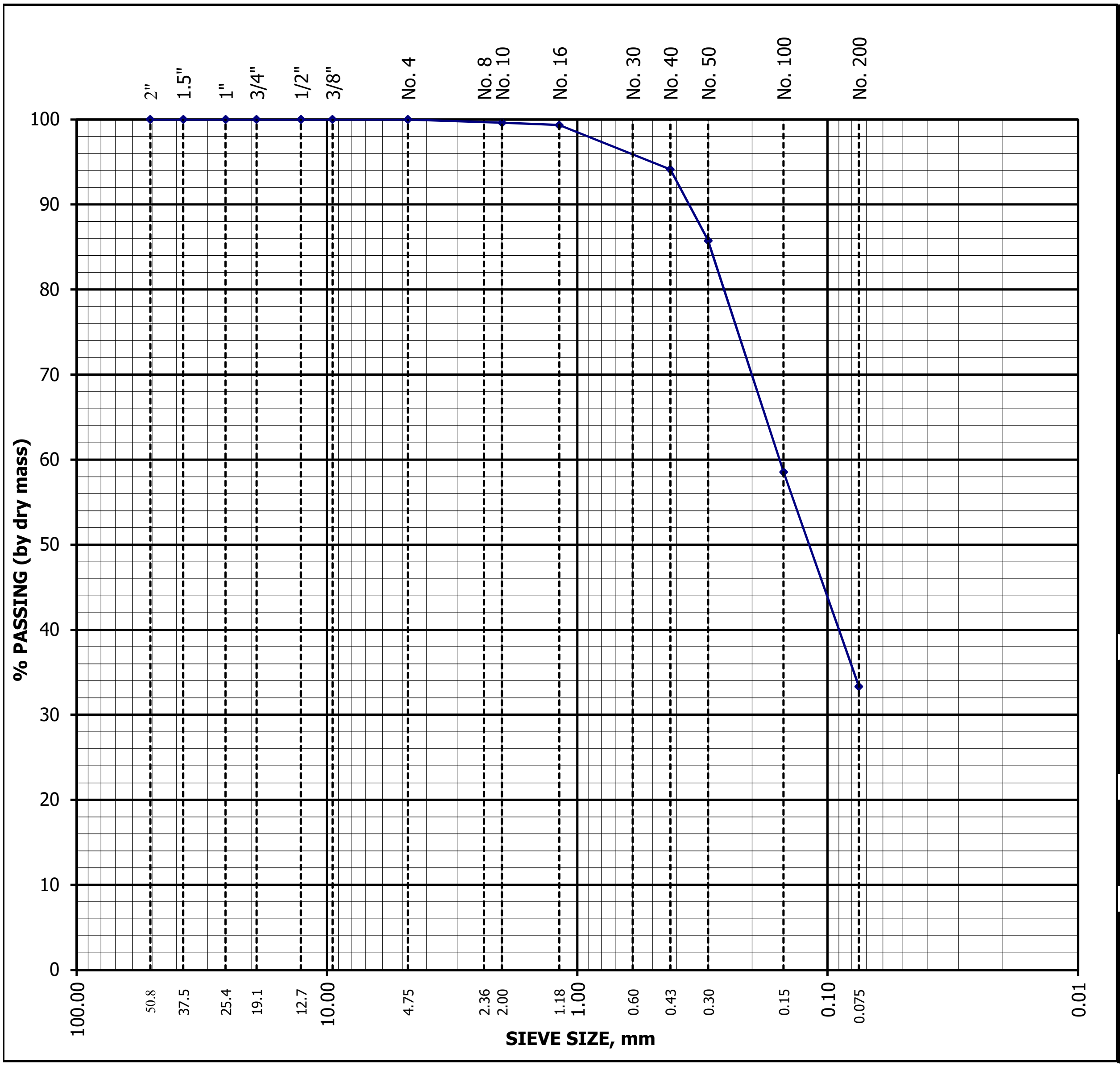
# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822871
Sample Location: BC-1 at 5'
Visual Description: SAND, clayey, brown

Date: 5-Sep-18
Technician: J. Weinerth
Reviewer: J. Crystal

**AASHTO M 145 Classification:** **A-2-4** **Group Index:** **(0)**
**Unified Soil Classification System (ASTM D 2487):** **(SC)** **Clayey sand**



| Sieve Size | % Passing |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | |
| 1/2" | |
| 3/8" | |
| #4 | 100 |
| #8 | |
| #10 | 100 |
| #16 | 99 |
| #30 | |
| #40 | 94 |
| #50 | 86 |
| #100 | 59 |
| #200 | 33.3 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 11.5 |
| D, pcf: | |

| | |
|---|---|
| **LL** | 22 |
| PL | 16 |
| **PI** | 6 |

| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

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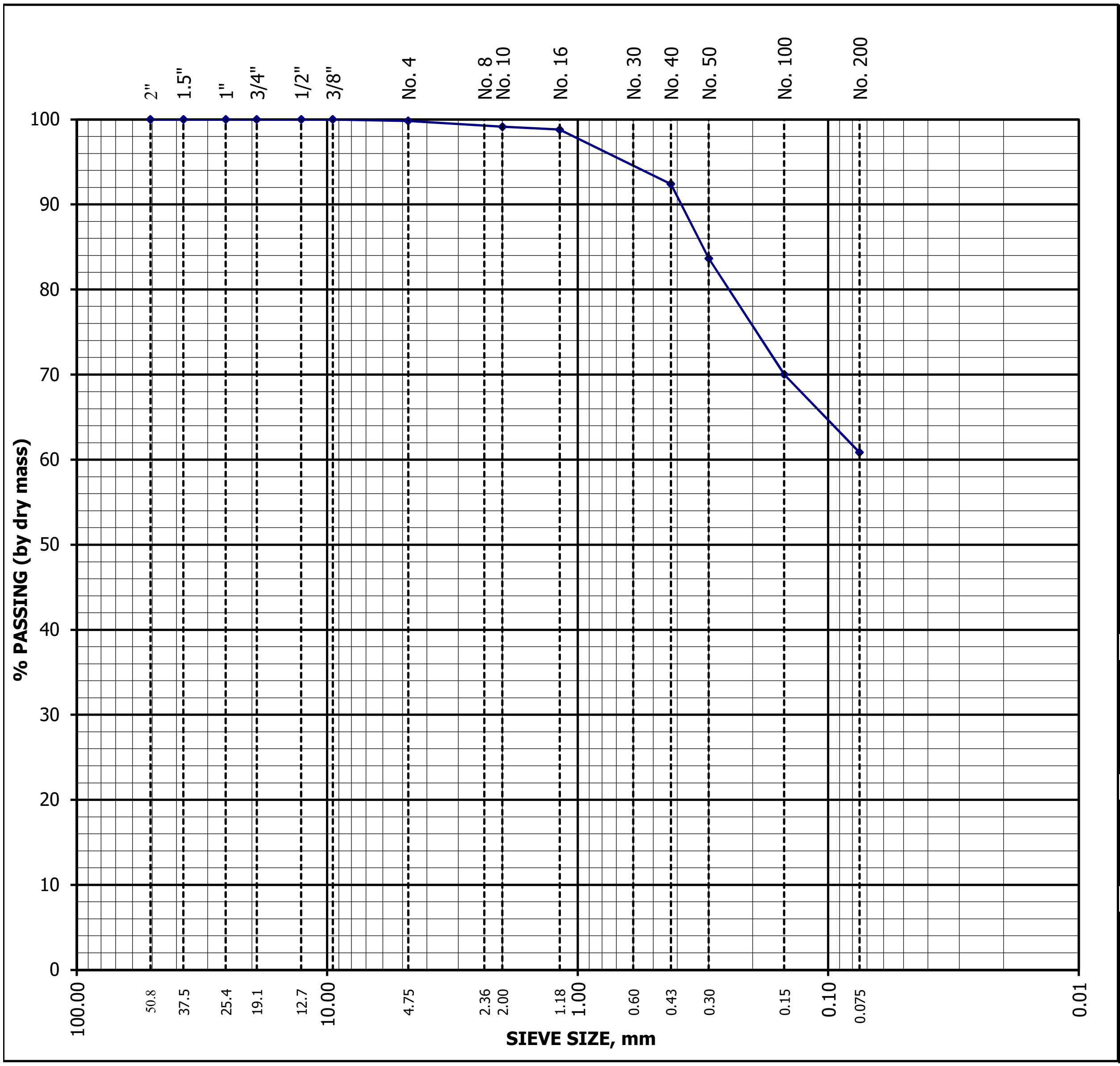
## GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822872
Sample Location: BC-1 at 25'
Visual Description: CLAYSTONE: CLAY, sandy, red

Date: 5-Sep-18
Technician: J. Weinerth
Reviewer: J. Crystal

**AASHTO M 145 Classification:** **A-6** **Group Index:** **8**
**Unified Soil Classification System (ASTM D 2487):** **(CL)** **Sandy lean clay**



| **Sieve Size** | **% Passing** |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | |
| 1/2" | |
| 3/8" | 100 |
| #4 | 100 |
| #8 | |
| #10 | 99 |
| #16 | 99 |
| #30 | |
| #40 | 92 |
| #50 | 84 |
| #100 | 70 |
| #200 | 60.8 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 12.3 |
| D, pcf: | |

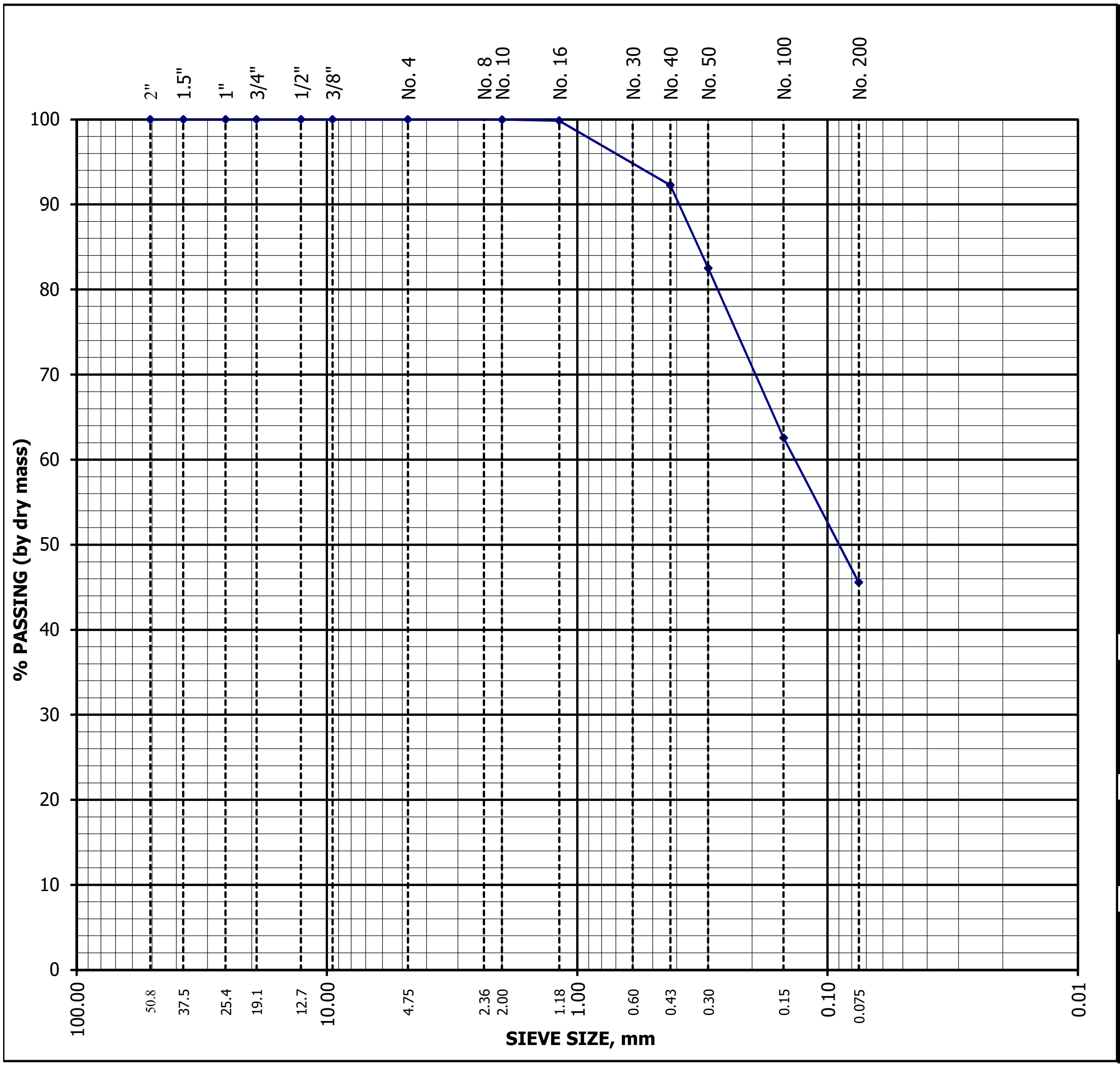
| | |
|---|---|
| **LL** | 40 |
| PL | 24 |
| **PI** | 16 |

| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Date: 5-Sep-18
Project Name: Cucharas Basin Collaborative Storage
Technician: J. Weinerth
Lab ID Number: 1822873
Reviewer: J. Crystal
Sample Location: BC-2 at 5'
Visual Description: SAND, clayey, brown

**AASHTO M 145 Classification:** **A-6** **Group Index:** **4**
**Unified Soil Classification System (ASTM D 2487):** **(SC)** **Clayey sand**



| **Sieve Size** | **% Passing** |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | |
| 1/2" | |
| 3/8" | |
| #4 | |
| #8 | |
| #10 | 100 |
| #16 | 100 |
| #30 | |
| #40 | 92 |
| #50 | 83 |
| #100 | 63 |
| #200 | 45.6 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 27.0 |
| D, pcf: | |

| | |
|---|---|
| **LL** | 30 |
| PL | 13 |
| **PI** | 17 |

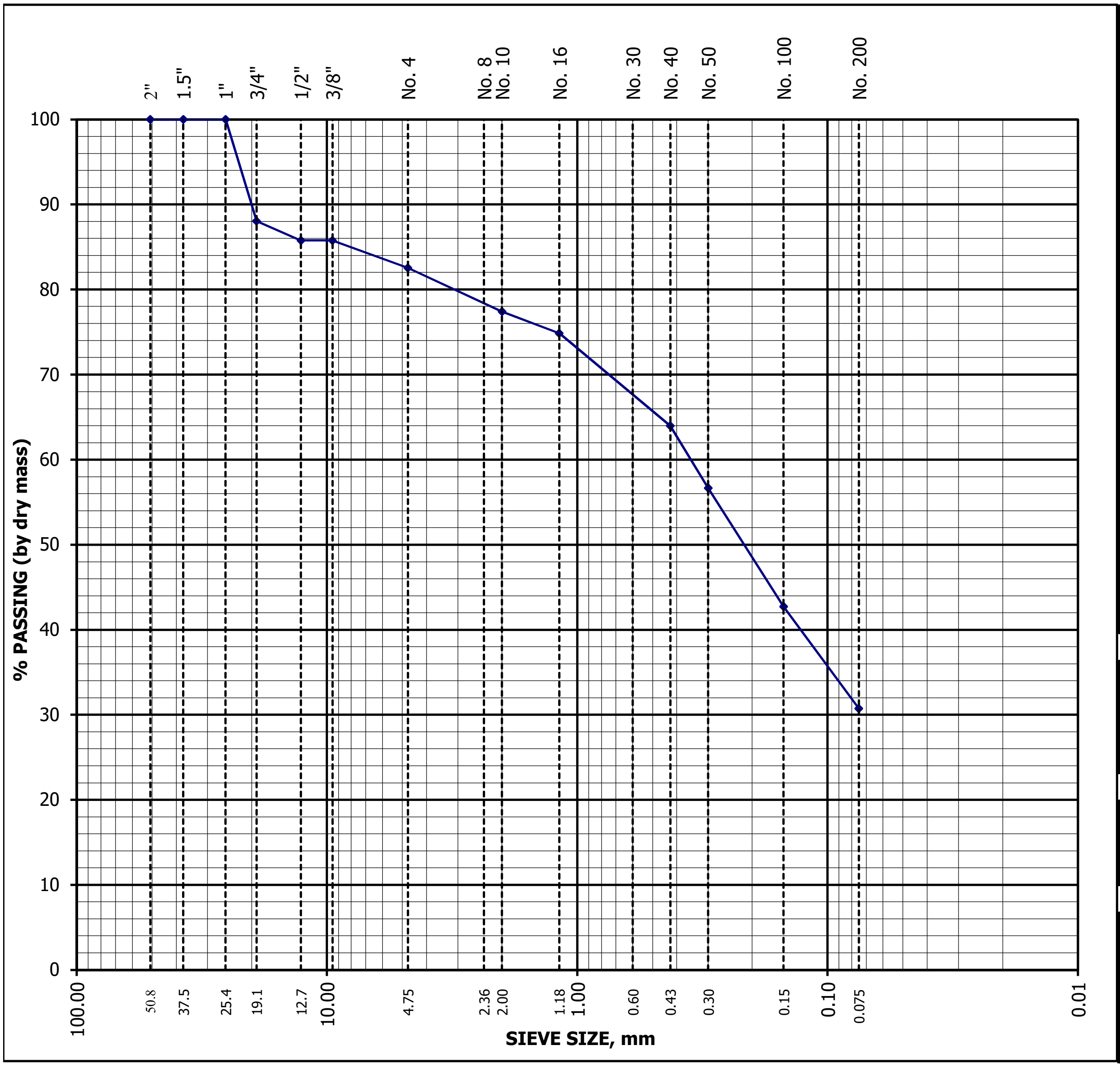
| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822874
Sample Location: BC-2 at 10'
Visual Description: SAND, clayey, with gravel, brown

Date: 5-Sep-18
Technician: J. Weinerth
Reviewer: J. Crystal

**AASHTO M 145 Classification:** **A-2-4** **Group Index:** **(0)**
**Unified Soil Classification System (ASTM D 2487):** **(SC)** **Clayey sand with gravel**



| Sieve Size | % Passing |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | 100 |
| 3/4" | 88 |
| 1/2" | 86 |
| 3/8" | 86 |
| #4 | 83 |
| #8 | |
| #10 | 77 |
| #16 | 75 |
| #30 | |
| #40 | 64 |
| #50 | 57 |
| #100 | 43 |
| #200 | 30.7 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 16.0 |
| D, pcf: | |

| | |
|---|---|
| **LL** | 23 |
| PL | 16 |
| **PI** | 7 |

| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

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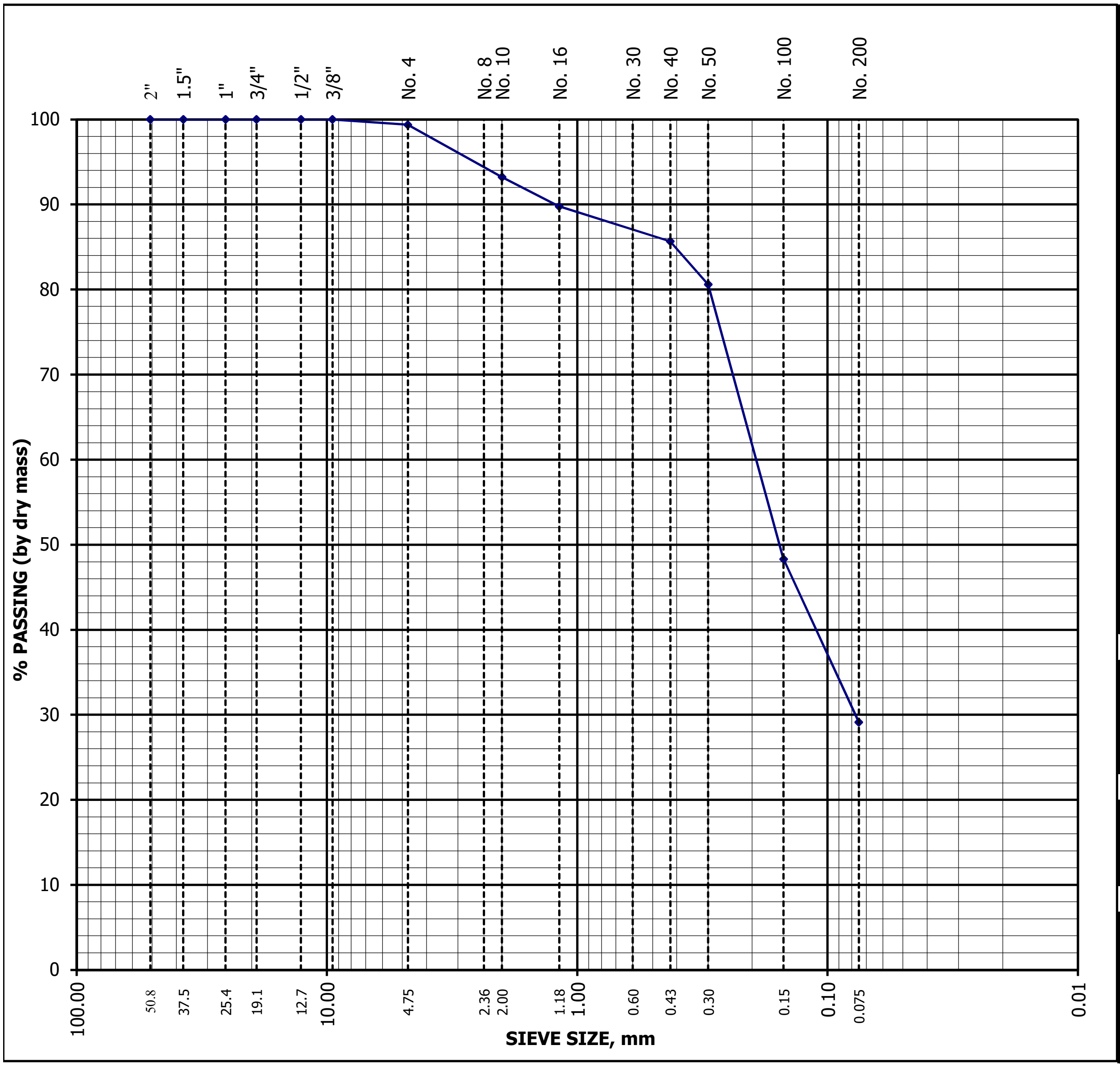
# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822875
Sample Location: BC-3 at 5'
Visual Description: SAND, silty, clayey, brown

Date: 5-Sep-18
Technician: J. Weinerth
Reviewer: J. Crystal

**AASHTO M 145 Classification: A-2-4 Group Index: (0)**
**Unified Soil Classification System (ASTM D 2487): (SC-SM) Silty, clayey sand**



| Sieve Size | % Passing |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | |
| 1/2" | |
| 3/8" | 100 |
| #4 | 99 |
| #8 | |
| #10 | 93 |
| #16 | 90 |
| #30 | |
| #40 | 86 |
| #50 | 81 |
| #100 | 48 |
| #200 | 29.1 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 5.4 |
| D, pcf: | |

| | |
|---|---|
| **LL** | 24 |
| PL | 18 |
| **PI** | 6 |

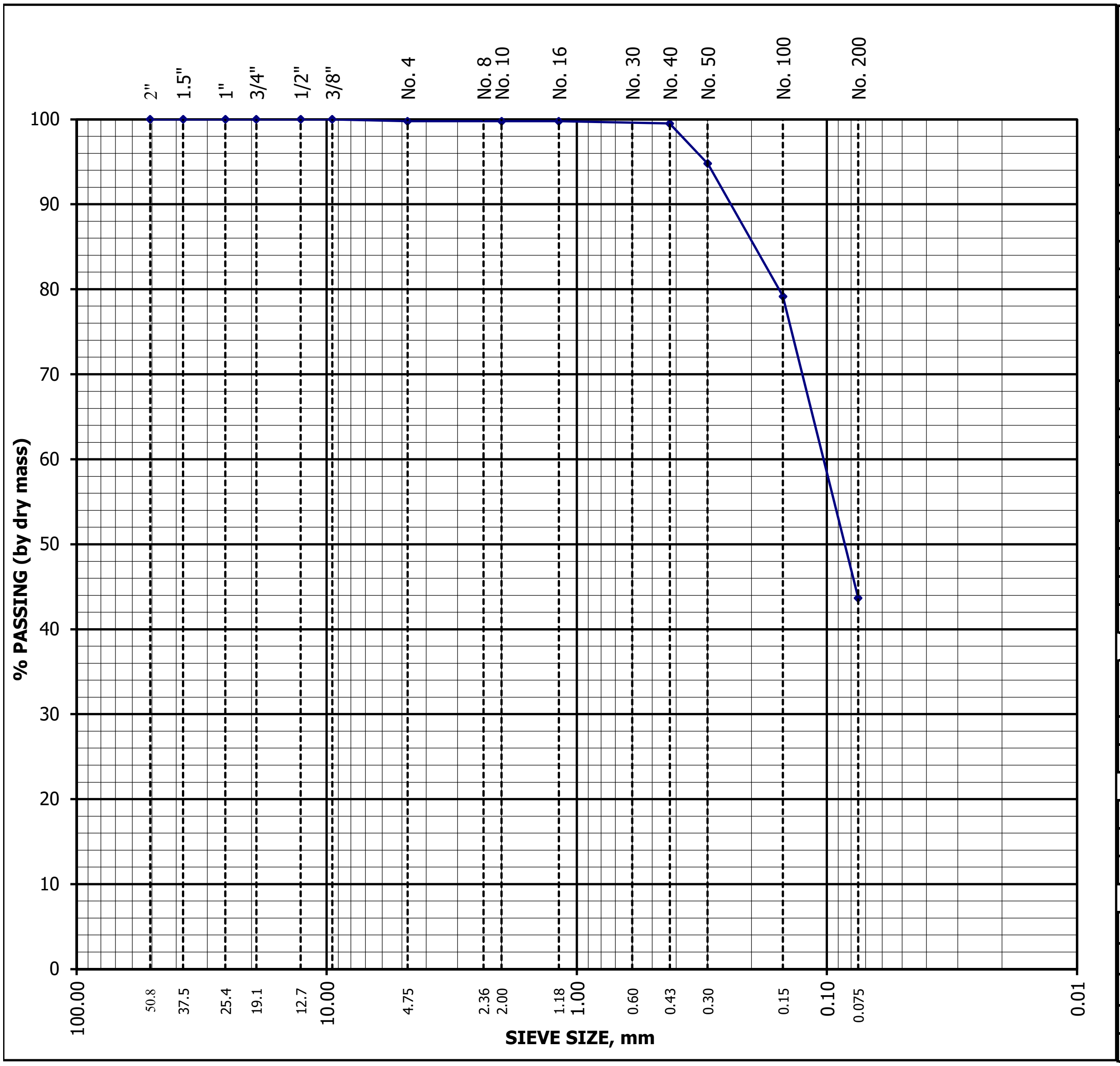
| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

## GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822876
Sample Location: BC-3 at 15'
Visual Description: SANDSTONE, silty, clayey, brown

Date: 5-Sep-18
Technician: J. Weinerth
Reviewer: J. Crystal

**AASHTO M 145 Classification:** **A-4** **Group Index:** **(0)**
**Unified Soil Classification System (ASTM D 2487):** **(SC-SM) Silty, clayey sand**



| Sieve Size | % Passing |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | |
| 1/2" | |
| 3/8" | 100 |
| #4 | 100 |
| #8 | |
| #10 | 100 |
| #16 | 100 |
| #30 | |
| #40 | 99 |
| #50 | 95 |
| #100 | 79 |
| #200 | 43.7 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 4.6 |
| D, pcf: | |

| | |
|---|---|
| **LL** | 24 |
| PL | 20 |
| **PI** | 4 |

| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

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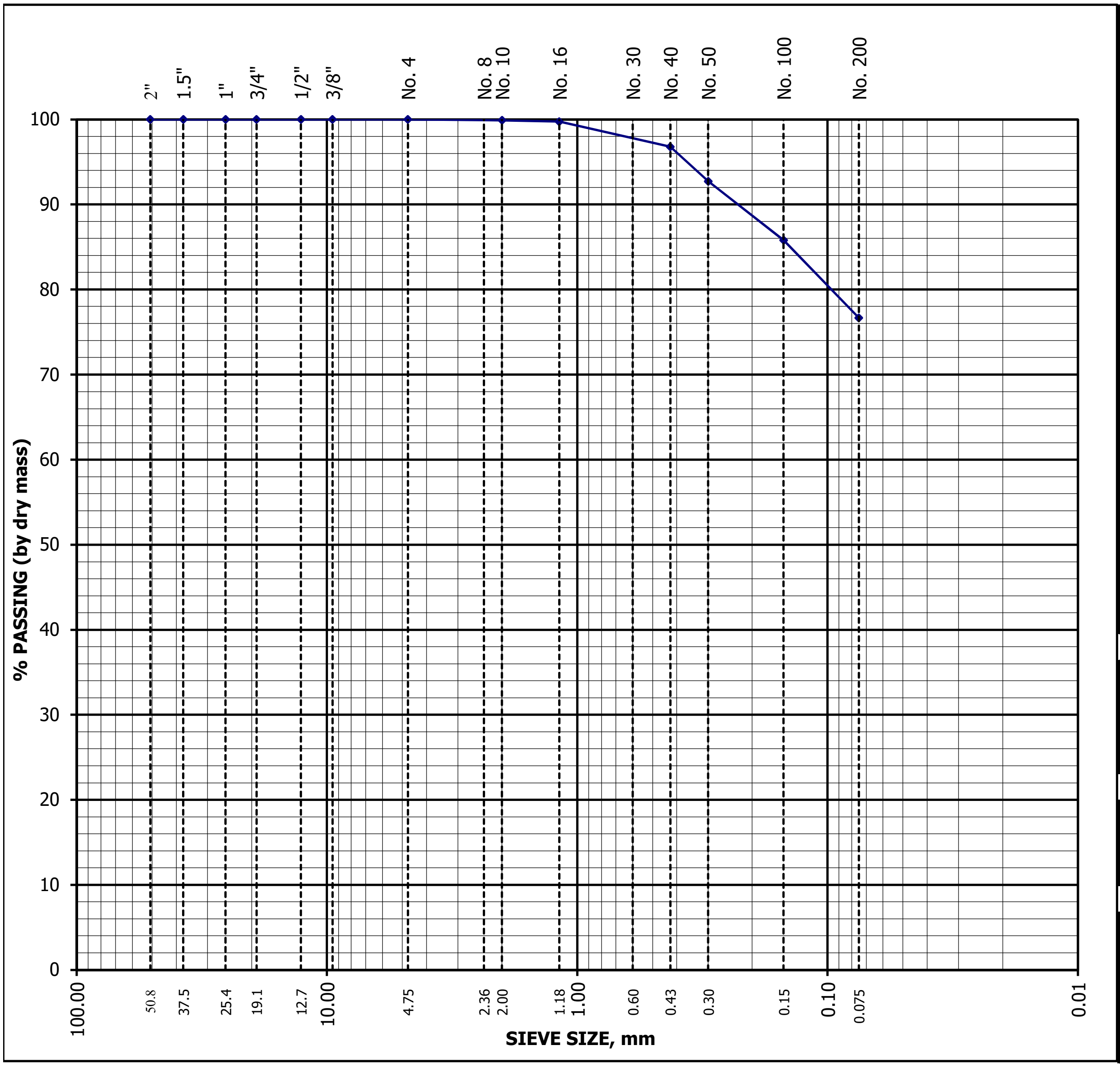
# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Date: 9-Sep-19
Project Name: Cucharas Basin Collaborative Storage
Technician: C. Zoetewey
Lab ID Number: 1921469
Reviewer: J. Crystal
Sample Location: BC-4 at 10'
Visual Description: CLAY, with sand, brown

**AASHTO M 145 Classification:** **A-6** **Group Index:** **7**
**Unified Soil Classification System (ASTM D 2487):** **(CL)** **Lean clay with sand**



| Sieve Size | % Passing |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | |
| 1/2" | |
| 3/8" | |
| #4 | 100 |
| #8 | |
| #10 | 100 |
| #16 | 100 |
| #30 | |
| #40 | 97 |
| #50 | 93 |
| #100 | 86 |
| #200 | 76.7 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 6.1 |
| D, pcf: | |

| | |
|---|---|
| **LL** | 30 |
| PL | 19 |
| **PI** | 11 |

| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

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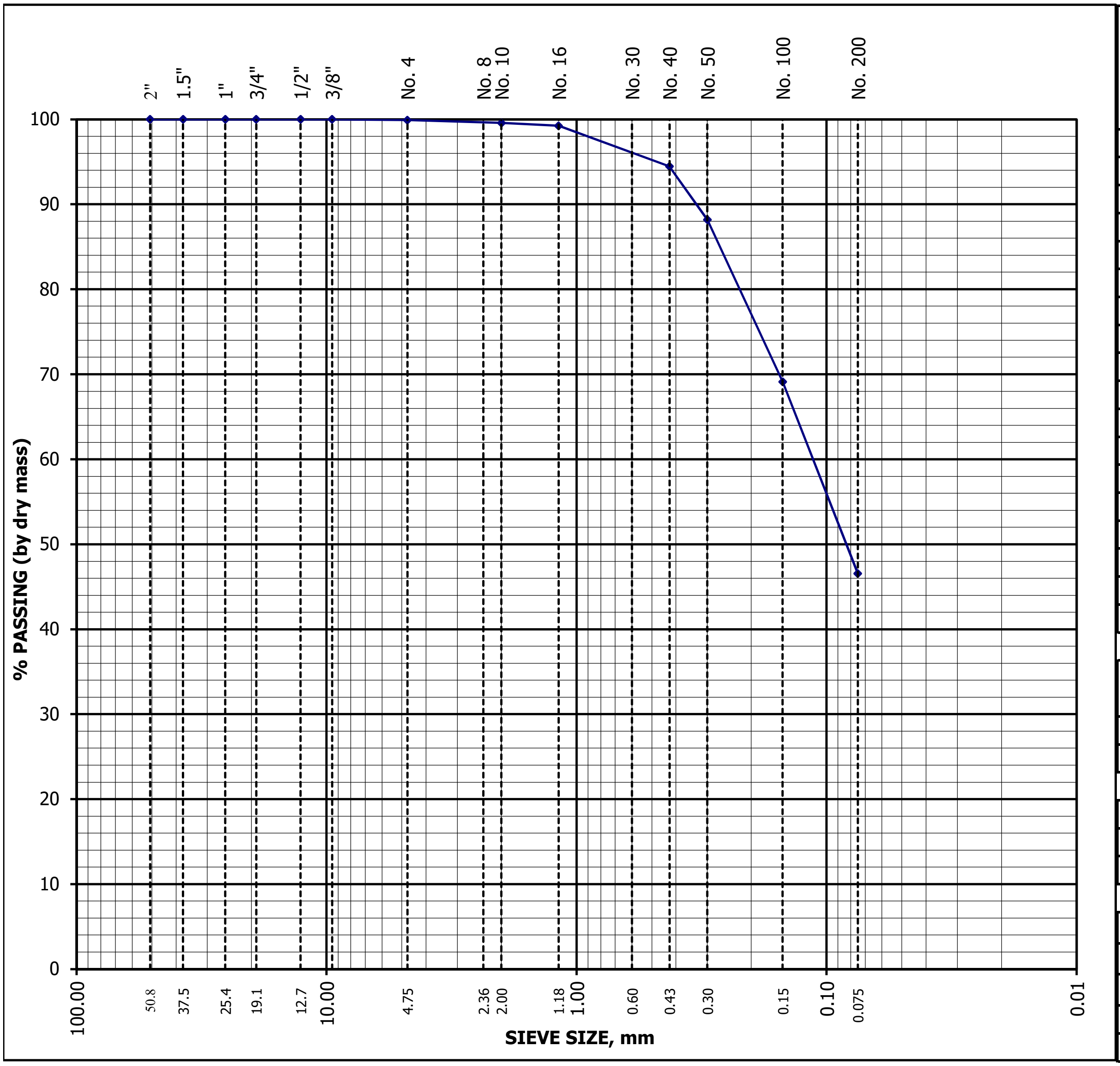
**Phone 303-220-0300 • www.cesareinc.com**

# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822652
Sample Location: BCP-1 at 1' to 8'
Visual Description: SAND, clayey, brown

Date: 25-Sep-18
Technician: J. Holiman
Reviewer: J. Crystal

**AASHTO M 145 Classification:** **A-6** **Group Index:** **2**
**Unified Soil Classification System (ASTM D 2487):** **(SC)** **Clayey sand**



| **Sieve Size** | **% Passing** |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | |
| 1/2" | |
| 3/8" | 100 |
| #4 | 100 |
| #8 | |
| #10 | 100 |
| #16 | 99 |
| #30 | |
| #40 | 94 |
| #50 | 88 |
| #100 | 69 |
| #200 | 46.6 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 3.0 |
| D, pcf: | |

| | |
|---|---|
| **LL** | 27 |
| PL | 16 |
| **PI** | 11 |

| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

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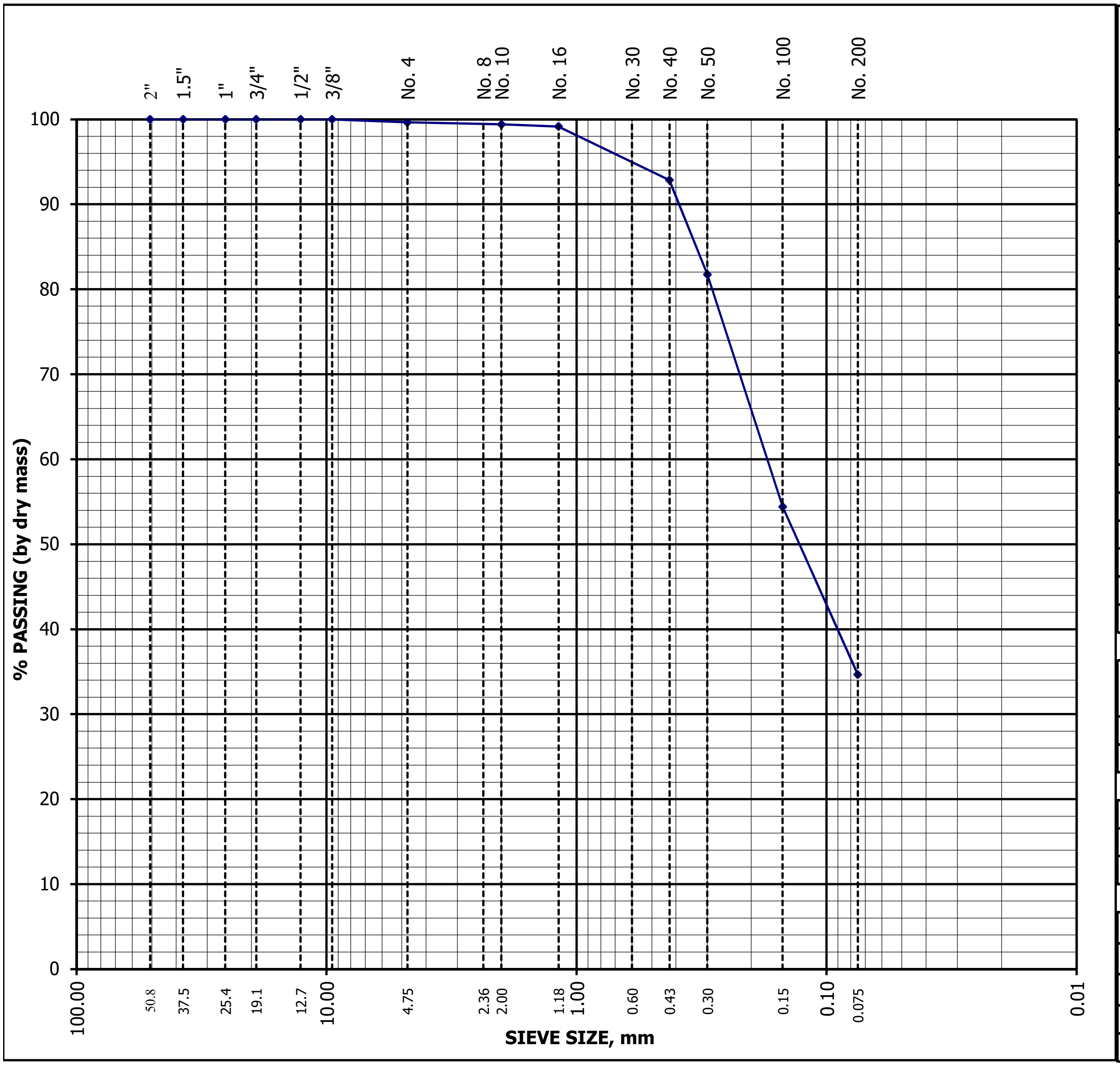
# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822653
Sample Location: BCP-2 at 2' to 10'
Visual Description: SAND, silty, clayey, brown

Date: 25-Sep-18
Technician: J. Holiman
Reviewer: J. Crystal

**AASHTO M 145 Classification:** **A-2-4** **Group Index:** **(0)**
**Unified Soil Classification System (ASTM D 2487):** **(SC-SM) Silty, clayey sand**



| **Sieve Size** | **% Passing** |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | |
| 1/2" | |
| 3/8" | 100 |
| #4 | 100 |
| #8 | |
| #10 | 99 |
| #16 | 99 |
| #30 | |
| #40 | 93 |
| #50 | 82 |
| #100 | 54 |
| #200 | 34.6 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 4.1 |
| D, pcf: | |

| | |
|---|---|
| **LL** | 23 |
| PL | 17 |
| **PI** | 6 |

| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

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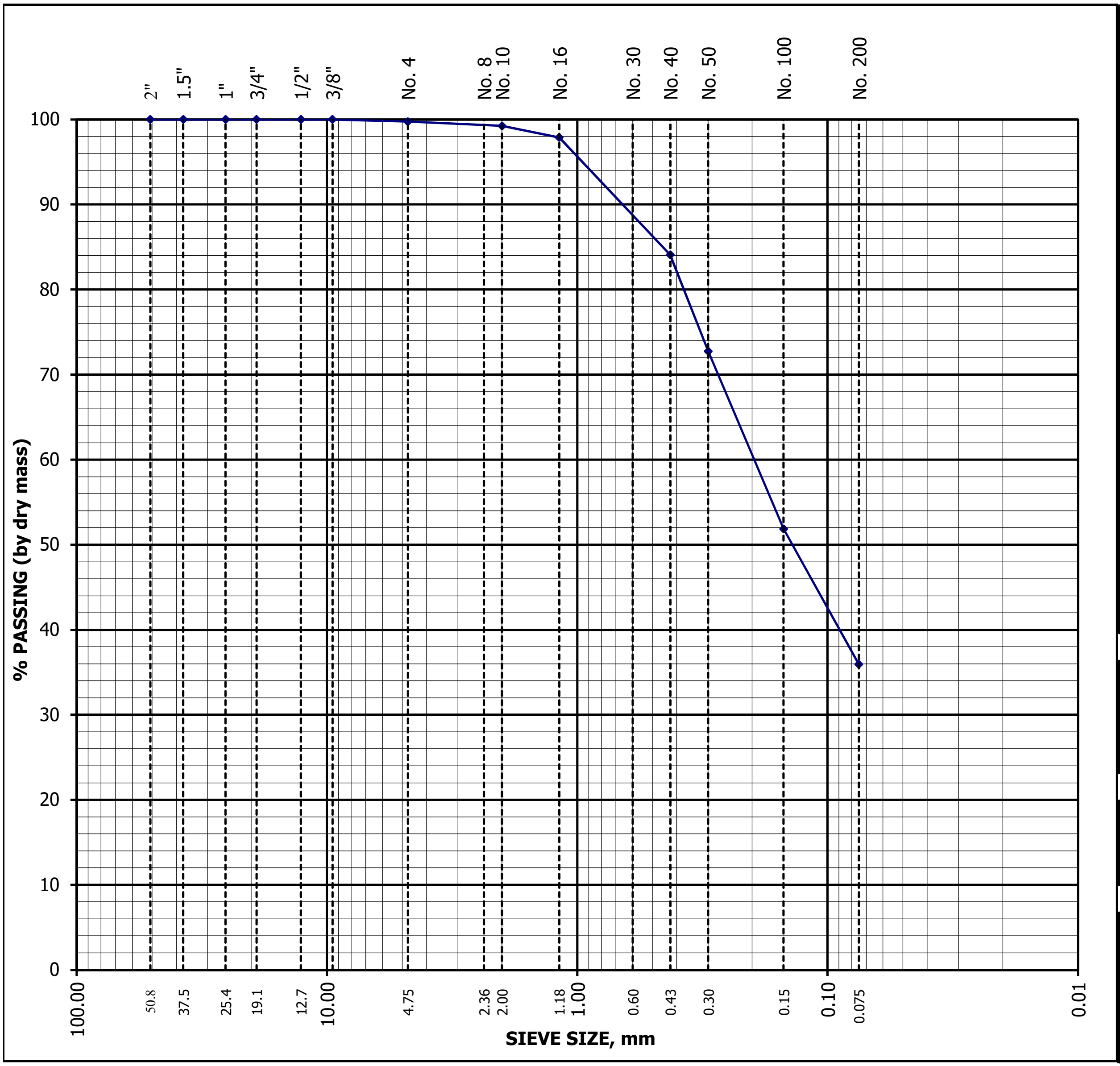
# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822654
Sample Location: BCP-4 at 2' to 8'
Visual Description: SAND, clayey, red brown

Date: 25-Sep-18
Technician: J. Holiman
Reviewer: J. Crystal

**AASHTO M 145 Classification:** **A-4** **Group Index:** **(0)**
**Unified Soil Classification System (ASTM D 2487):** **(SC)** **Clayey sand**



| Sieve Size | % Passing |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | |
| 1/2" | |
| 3/8" | 100 |
| #4 | 100 |
| #8 | |
| #10 | 99 |
| #16 | 98 |
| #30 | |
| #40 | 84 |
| #50 | 73 |
| #100 | 52 |
| #200 | 36.0 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 1.9 |
| D, pcf: | |

| | |
|---|---|
| **LL** | 25 |
| PL | 16 |
| **PI** | 9 |

| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

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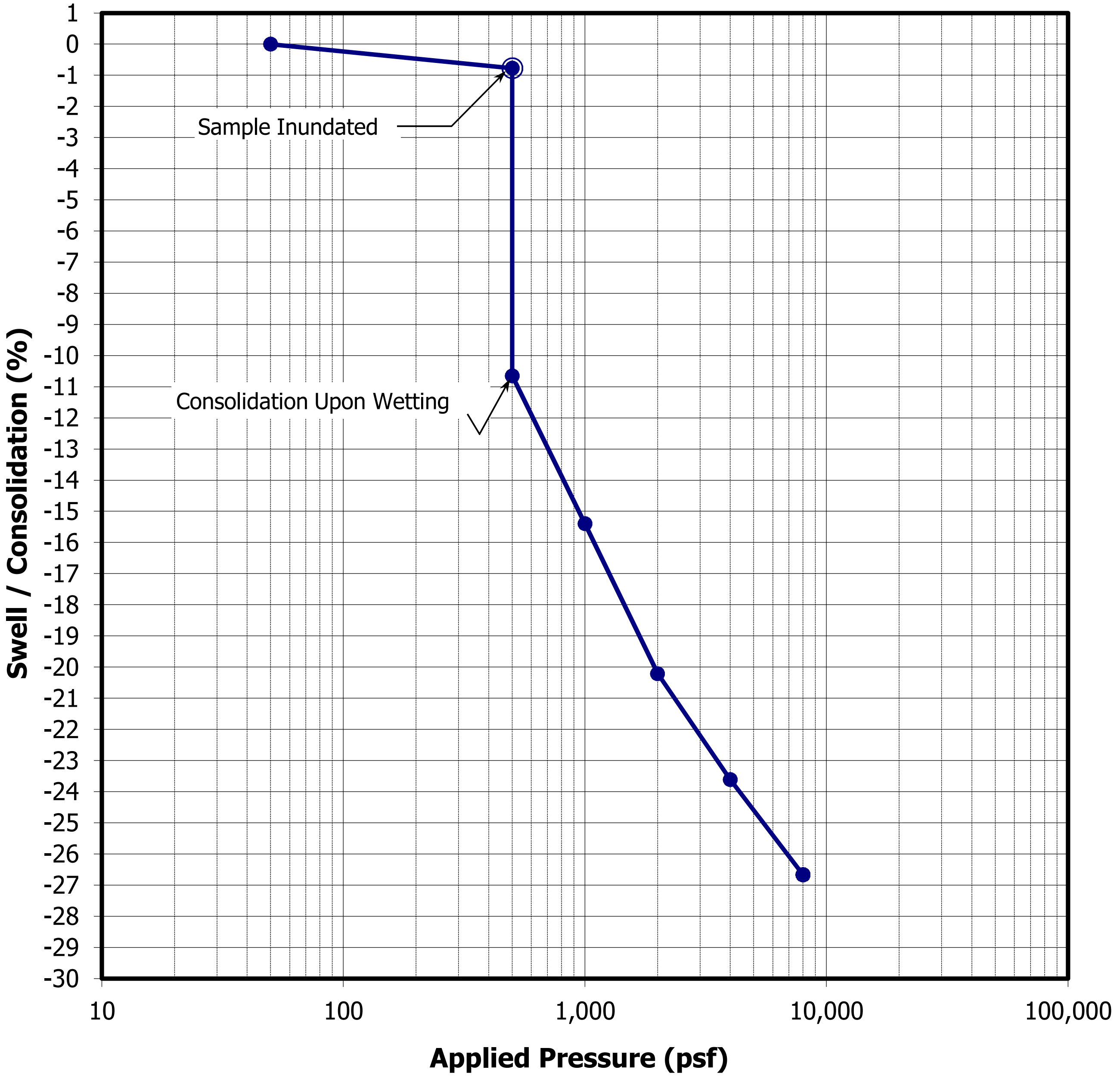
## SWELL/CONSOLIDATION PLOT



| Sample Location | Sample Depth (feet) | Lab ID Number: 1822500<br>Visual Description of Sample | Dry Density (pcf) | Moisture Content (%) | Inundation Pressure (psf) | Volume Change (%) | Swell Pressure (psf) |
|---|---|---|---|---|---|---|---|
| BCP-5 | 0 to 8 | CLAY, sandy, brown | 82.8 | 5.1 | 500 | -9.9 | N/A |

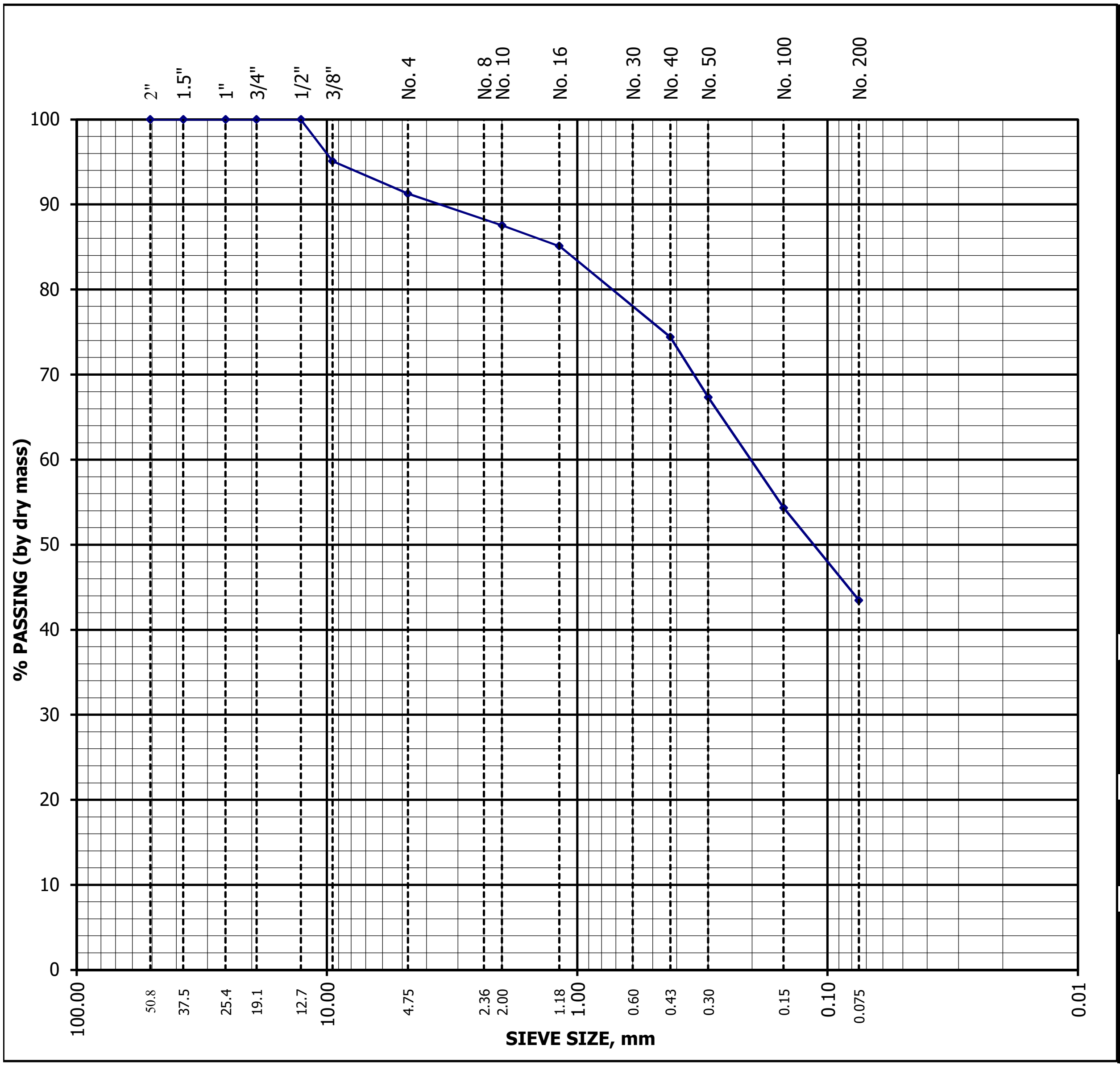
| | | | |
|---|---|---|---|
| **Client:** | **Applegate Group** | **Project No.:** | **18.117** |
| **Project:** | **Cucharas Basin Collaborative Storage** | **Figure:** | **1822500** |

# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822655
Sample Location: BCP-5 at 2' to 8'
Visual Description: SAND, clayey, reddish brown

Date: 7-Oct-18
Technician: G. Hoyos
Reviewer: J. Crystal

**AASHTO M 145 Classification:** **A-6** **Group Index:** **2**
**Unified Soil Classification System (ASTM D 2487):** **(SC) Clayey Sand**



| **Sieve Size** | **% Passing** |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | |
| 1/2" | 100 |
| 3/8" | 95 |
| #4 | 91 |
| #8 | |
| #10 | 88 |
| #16 | 85 |
| #30 | |
| #40 | 74 |
| #50 | 67 |
| #100 | 54 |
| #200 | 43.5 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 11.8 |
| D, pcf: | |

| | |
|---|---|
| **LL** | 29 |
| PL | 17 |
| **PI** | 12 |

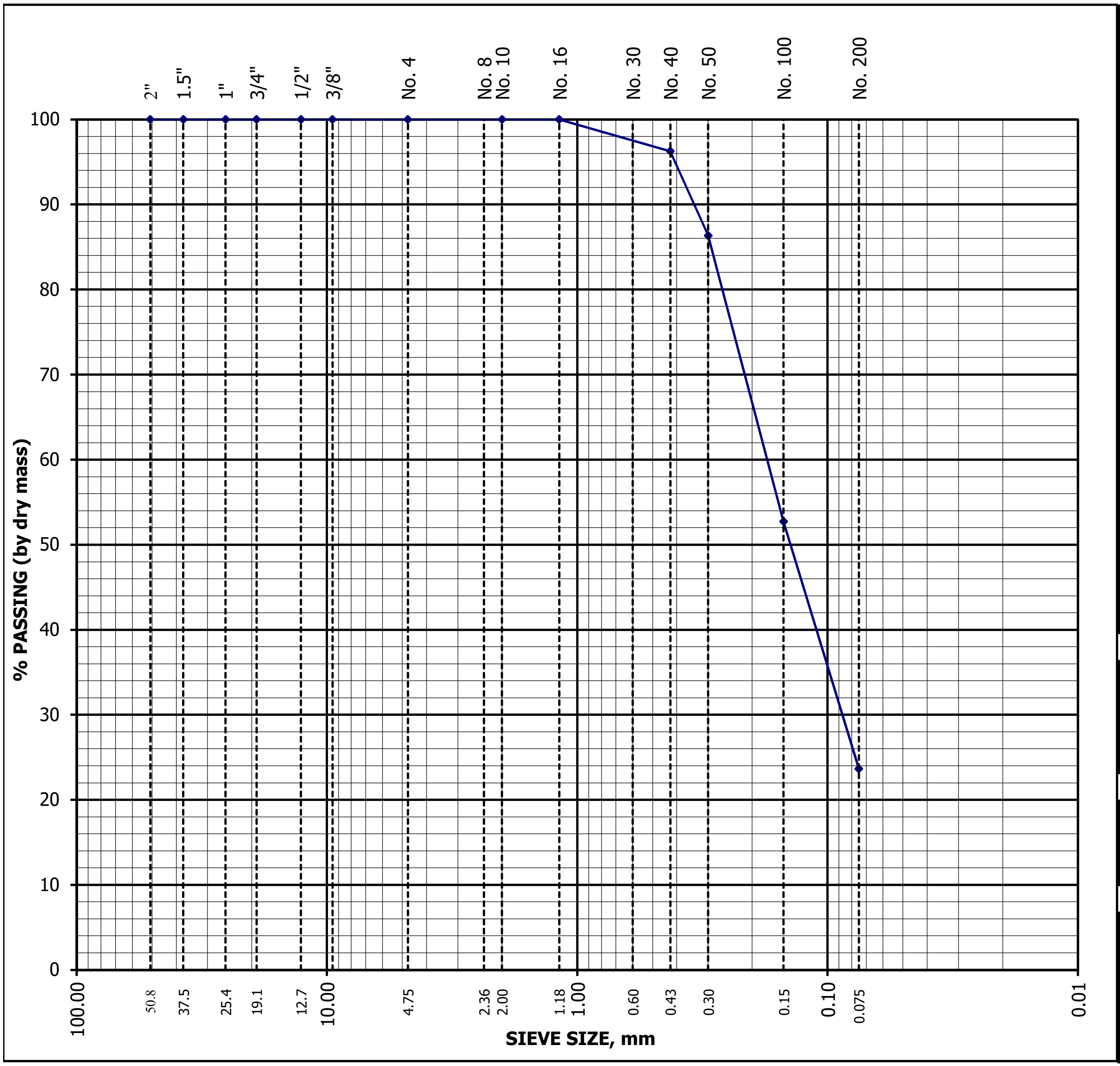
| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822656
Sample Location: BCP-6 at 7' to 9'
Visual Description: SAND, silty, brown

Date: 6-Oct-18
Technician: J. Holiman
Reviewer: J. Crystal

**AASHTO M 145 Classification:** **A-2-4** **Group Index:** **0**
**Unified Soil Classification System (ASTM D 2487):** **(SM) Silty sand**



| **Sieve Size** | **% Passing** |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | |
| 1/2" | |
| 3/8" | |
| #4 | |
| #8 | |
| #10 | |
| #16 | 100 |
| #30 | |
| #40 | 96 |
| #50 | 86 |
| #100 | 53 |
| #200 | 23.6 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 4.1 |
| D, pcf: | |

| | |
|---|---|
| **LL** | NV |
| PL | NP |
| **PI** | NP |

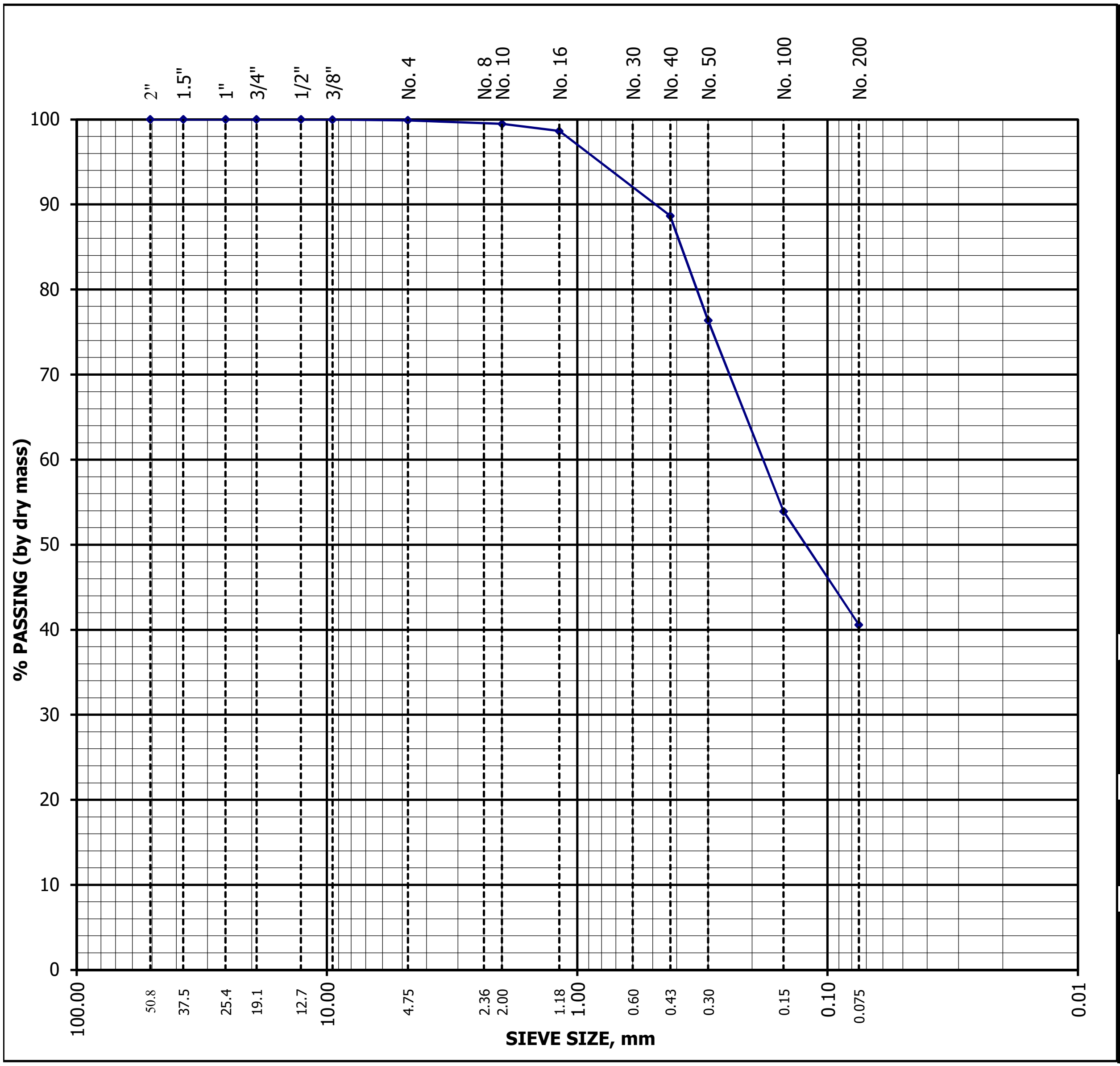
| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822895
Sample Location: LVL-1 at 15'
Visual Description: SAND, silty, clayey, brown

Date: 8-Sep-18
Technician: J. Holiman
Reviewer: J. Crystal

**AASHTO M 145 Classification:** **A-4** **Group Index:** **(0)**
**Unified Soil Classification System**
**(ASTM D 2487):** **(SC-SM) Silty, clayey sand**



| Sieve Size | % Passing |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | |
| 1/2" | |
| 3/8" | 100 |
| #4 | 100 |
| #8 | |
| #10 | 99 |
| #16 | 99 |
| #30 | |
| #40 | 89 |
| #50 | 76 |
| #100 | 54 |
| #200 | 40.6 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 10.7 |
| D, pcf: | |

| | |
|---|---|
| **LL** | 24 |
| PL | 19 |
| **PI** | 5 |

| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

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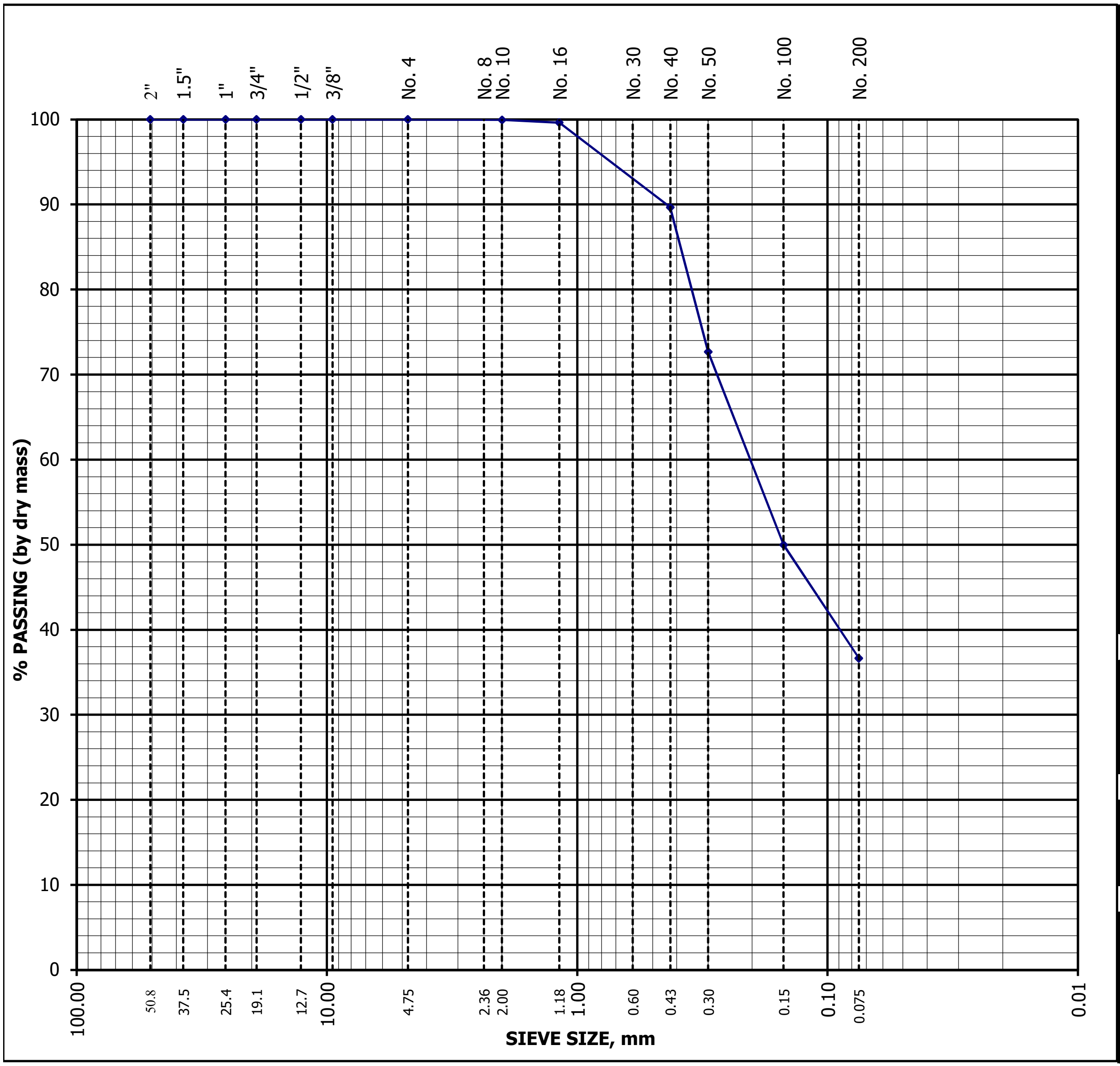
# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822896
Sample Location: LVL-4 at 9'
Visual Description: SAND, clay, silty, reddish brown

Date: 8-Sep-18
Technician: J. Holiman
Reviewer: J. Crystal

**AASHTO M 145 Classification:** **A-4** **Group Index:** **(0)**
**Unified Soil Classification System**
**(ASTM D 2487):** **(SC-SM) Silty, clayey sand**



| **Sieve Size** | **% Passing** |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | |
| 1/2" | |
| 3/8" | |
| #4 | 100 |
| #8 | |
| #10 | 100 |
| #16 | 100 |
| #30 | |
| #40 | 90 |
| #50 | 73 |
| #100 | 50 |
| #200 | 36.7 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 16.1 |
| D, pcf: | |

| | |
|---|---|
| **LL** | 23 |
| PL | 17 |
| **PI** | 6 |

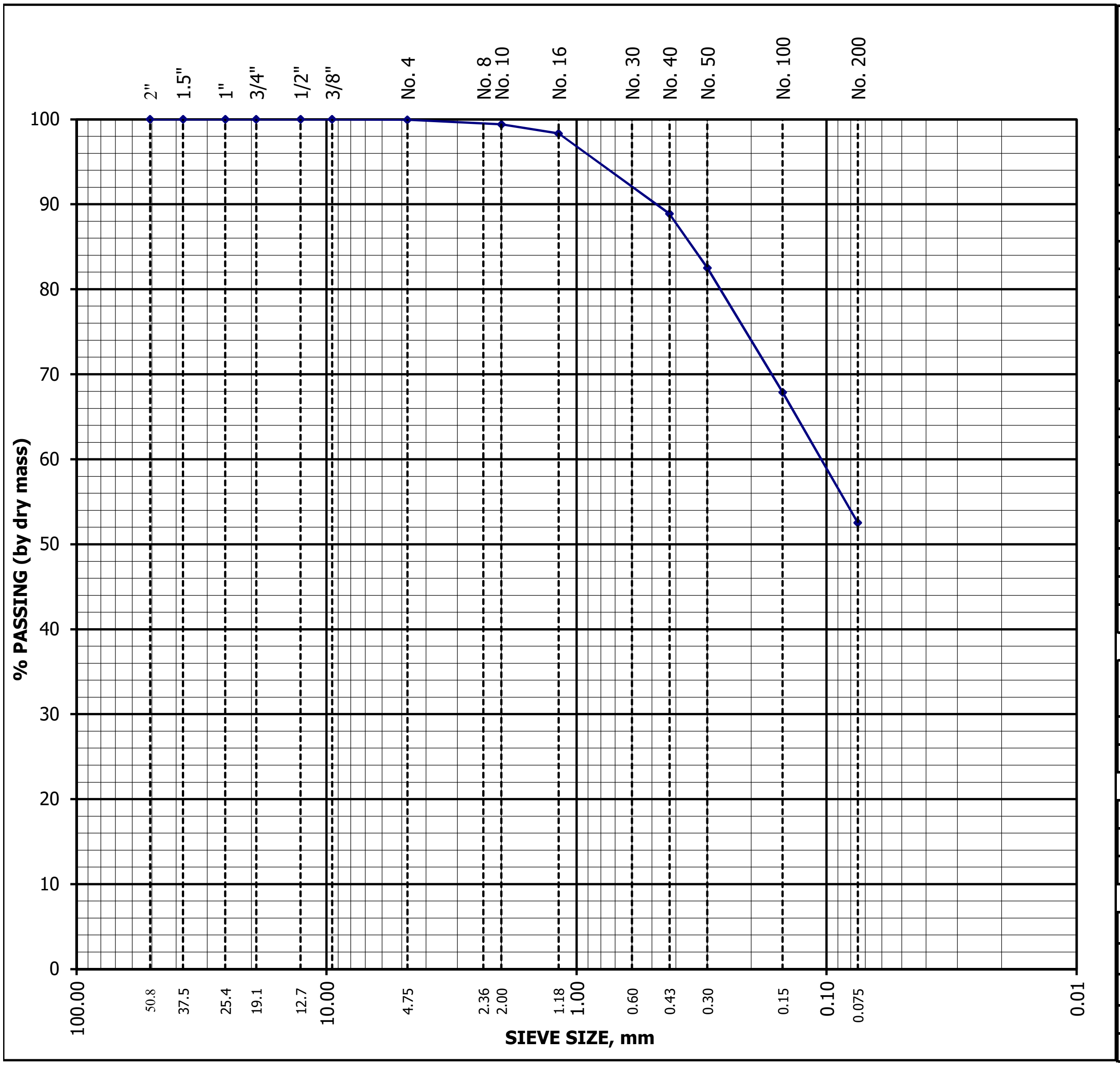
| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822897
Sample Location: LVL-5 at 5'
Visual Description: CLAY, sandy, brown

Date: 8-Sep-18
Technician: J. Holiman
Reviewer: J. Crystal

**AASHTO M 145 Classification:** **A-6** **Group Index:** **7**
**Unified Soil Classification System (ASTM D 2487):** **(CL)** **Sandy lean clay**



| **Sieve Size** | **% Passing** |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | |
| 1/2" | |
| 3/8" | 100 |
| #4 | 100 |
| #8 | |
| #10 | 99 |
| #16 | 98 |
| #30 | |
| #40 | 89 |
| #50 | 83 |
| #100 | 68 |
| #200 | 52.5 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 14.0 |
| D, pcf: | |

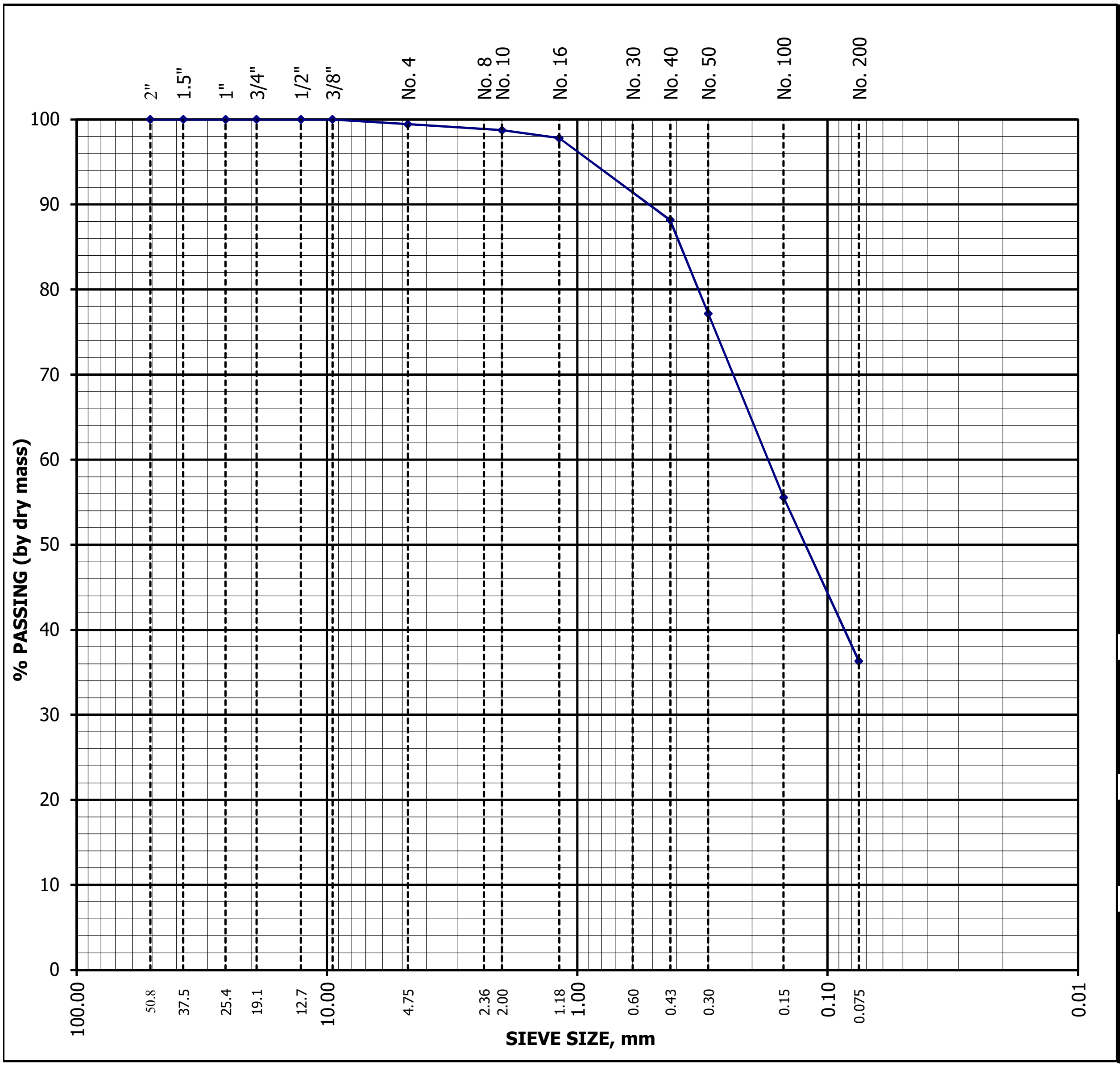
| | |
|---|---|
| **LL** | 37 |
| PL | 17 |
| **PI** | 20 |

| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Date: 8-Sep-18
Project Name: Cucharas Basin Collaborative Storage
Technician: J. Holiman
Lab ID Number: 1822898
Reviewer: J. Crystal
Sample Location: LVL-7 at 4'
Visual Description: SAND, silty, clayey, brown

**AASHTO M 145 Classification:** **A-4** **Group Index:** **(0)**
**Unified Soil Classification System**
**(ASTM D 2487):** **(SC-SM) Silty, clayey sand**



| Sieve Size | % Passing |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | |
| 1/2" | |
| 3/8" | 100 |
| #4 | 99 |
| #8 | |
| #10 | 99 |
| #16 | 98 |
| #30 | |
| #40 | 88 |
| #50 | 77 |
| #100 | 56 |
| #200 | 36.3 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 4.3 |
| D, pcf: | |

| | |
|---|---|
| **LL** | 19 |
| PL | 14 |
| **PI** | 5 |

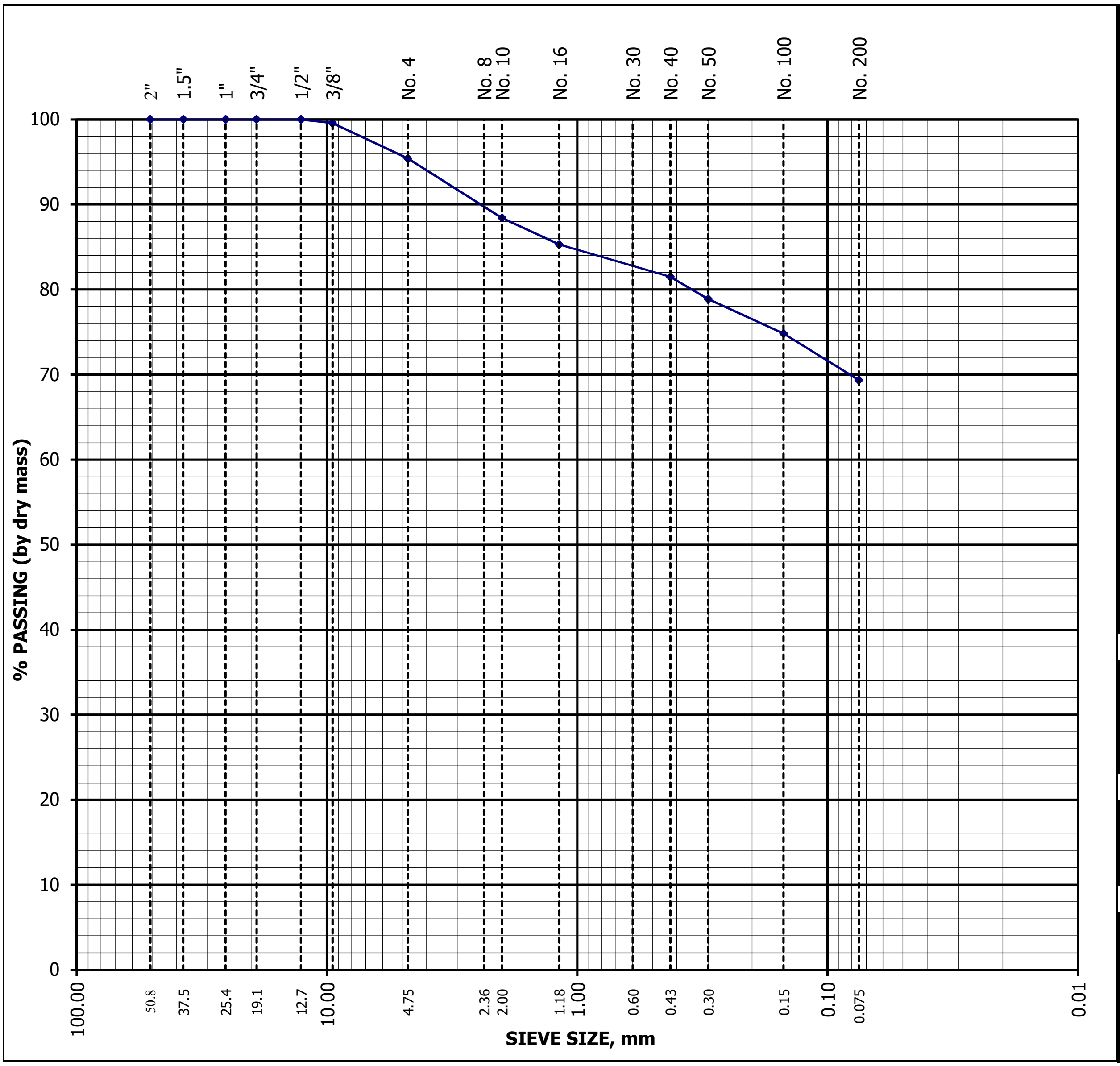
| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822877
Sample Location: MS-1 at 10'
Visual Description: CLAY, sandy, brown

Date: 8-Sep-18
Technician: J. Holiman
Reviewer: J. Crystal

**AASHTO M 145 Classification:** **A-6** **Group Index:** **7**
**Unified Soil Classification System (ASTM D 2487):** **(CL)** **Sandy lean clay**



| **Sieve Size** | **% Passing** |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | |
| 1/2" | 100 |
| 3/8" | 100 |
| #4 | 95 |
| #8 | |
| #10 | 88 |
| #16 | 85 |
| #30 | |
| #40 | 82 |
| #50 | 79 |
| #100 | 75 |
| #200 | 69.4 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 9.6 |
| D, pcf: | |

| | |
|---|---|
| **LL** | 30 |
| PL | 16 |
| **PI** | 14 |

| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

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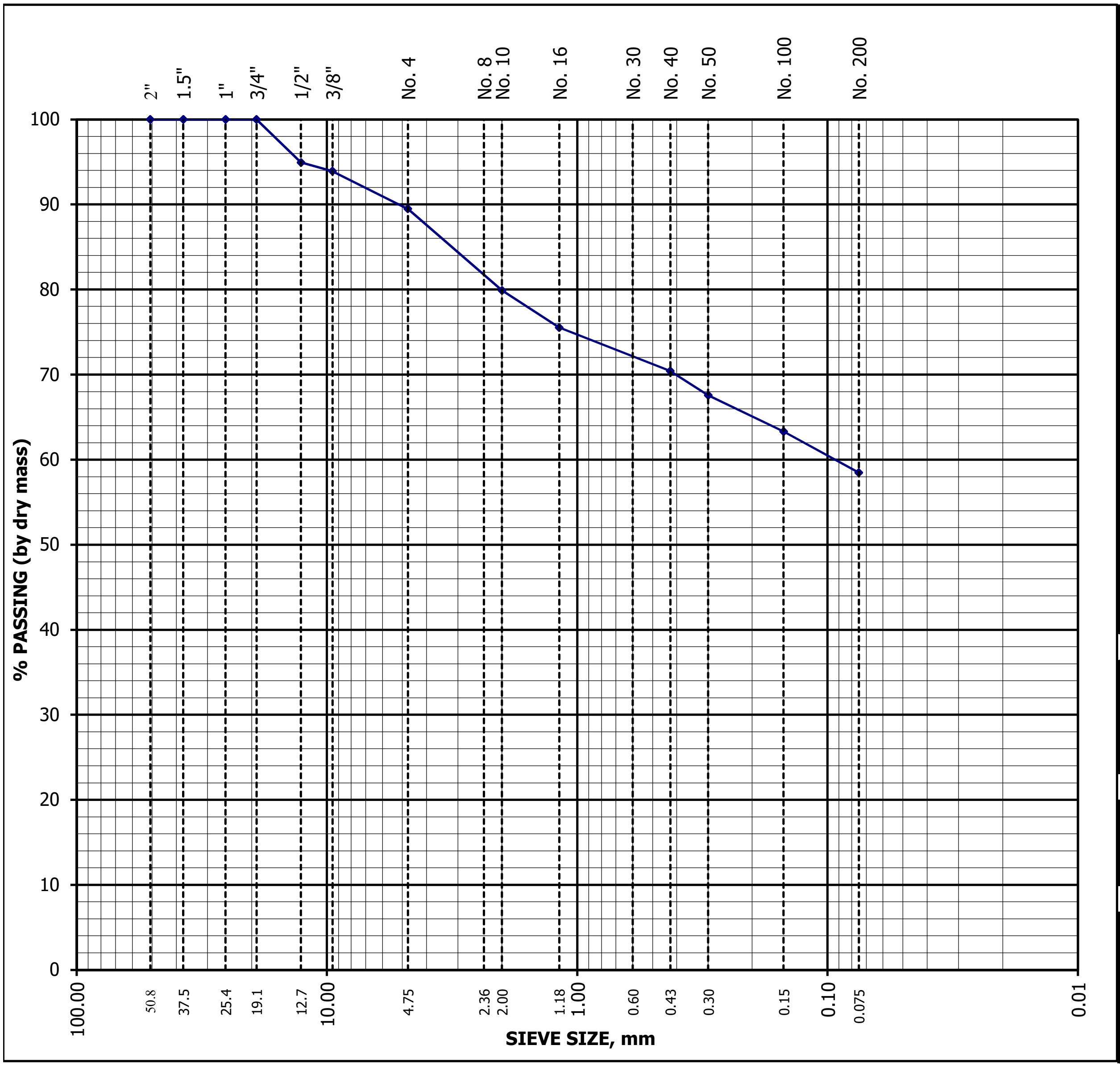
# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822878
Sample Location: MS-1 at 20'
Visual Description: CLAY, sandy, brown

Date: 8-Sep-18
Technician: J. Holiman
Reviewer: J. Crystal

**AASHTO M 145 Classification:** A-6 **Group Index:** 6
**Unified Soil Classification System (ASTM D 2487):** (CL) Sandy lean clay



| Sieve Size | % Passing |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | 100 |
| 1/2" | 95 |
| 3/8" | 94 |
| #4 | 89 |
| #8 | |
| #10 | 80 |
| #16 | 76 |
| #30 | |
| #40 | 70 |
| #50 | 68 |
| #100 | 63 |
| #200 | 58.5 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 7.4 |
| D, pcf: | |

| | |
|---|---|
| **LL** | 31 |
| PL | 15 |
| **PI** | 16 |

| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

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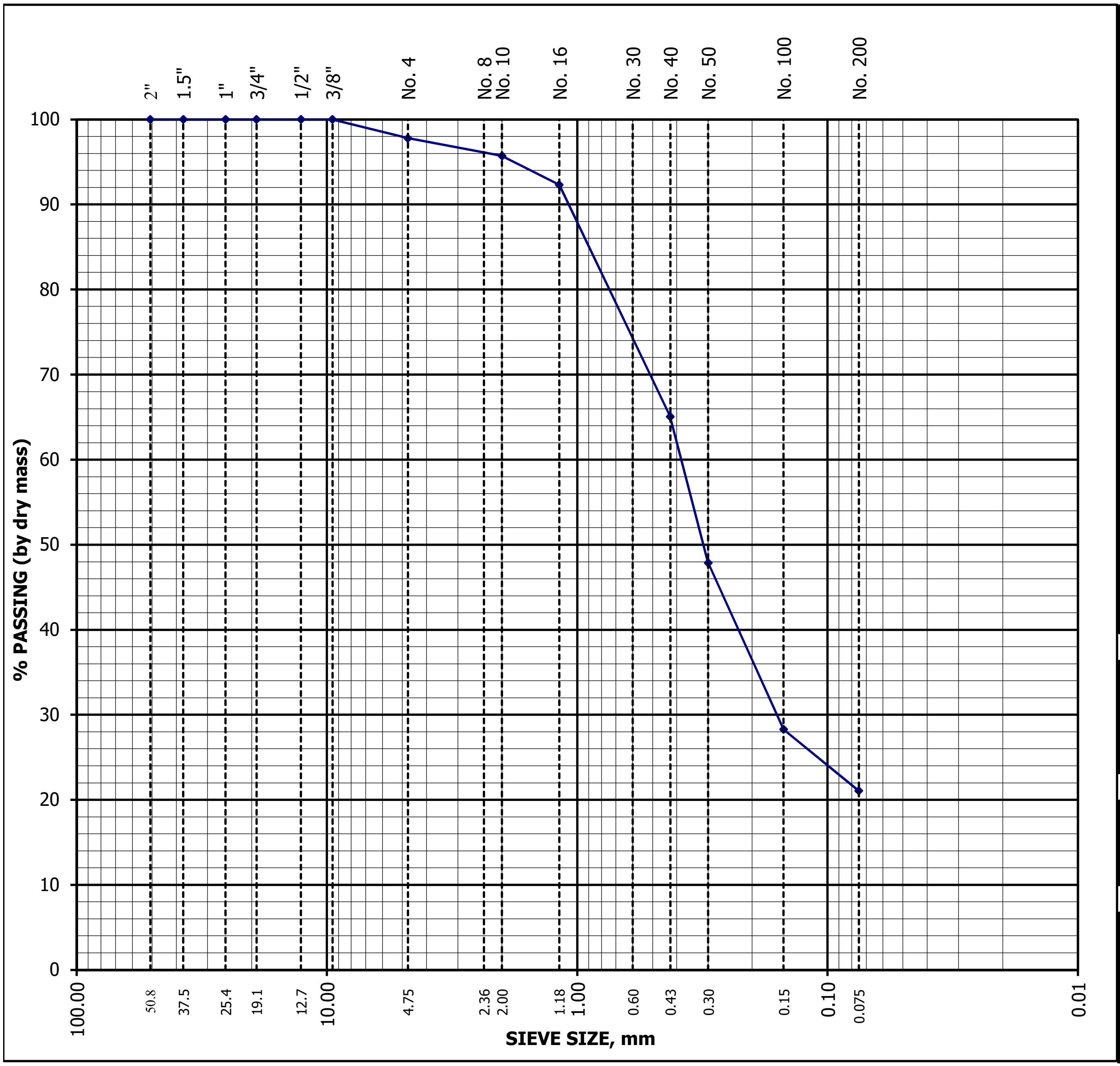
# GRADATION PLOT - SOIL & AGGREGATE

| | | | |
|---|---|---|---|
| Project Number: | 18.117, Applegate Group | Date: | 8-Sep-18 |
| Project Name: | Cucharas Basin Collaborative Storage | Technician: | J. Holiman |
| Lab ID Number: | 1822879 | Reviewer: | J. Crystal |
| Sample Location: | MS-2 at 10' | | |
| Visual Description: | SAND, silty, brown | | |

**AASHTO M 145 Classification:** **A-2-4** **Group Index:** **0**

**Unified Soil Classification System (ASTM D 2487):** **(SM) Silty sand**



| Sieve Size | % Passing |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | |
| 1/2" | |
| 3/8" | 100 |
| #4 | 98 |
| #8 | |
| #10 | 96 |
| #16 | 92 |
| #30 | |
| #40 | 65 |
| #50 | 48 |
| #100 | 28 |
| #200 | 21.1 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 7.8 |
| D, pcf: | |

| | |
|---|---|
| **LL** | NV |
| PL | NP |
| **PI** | NP |

| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

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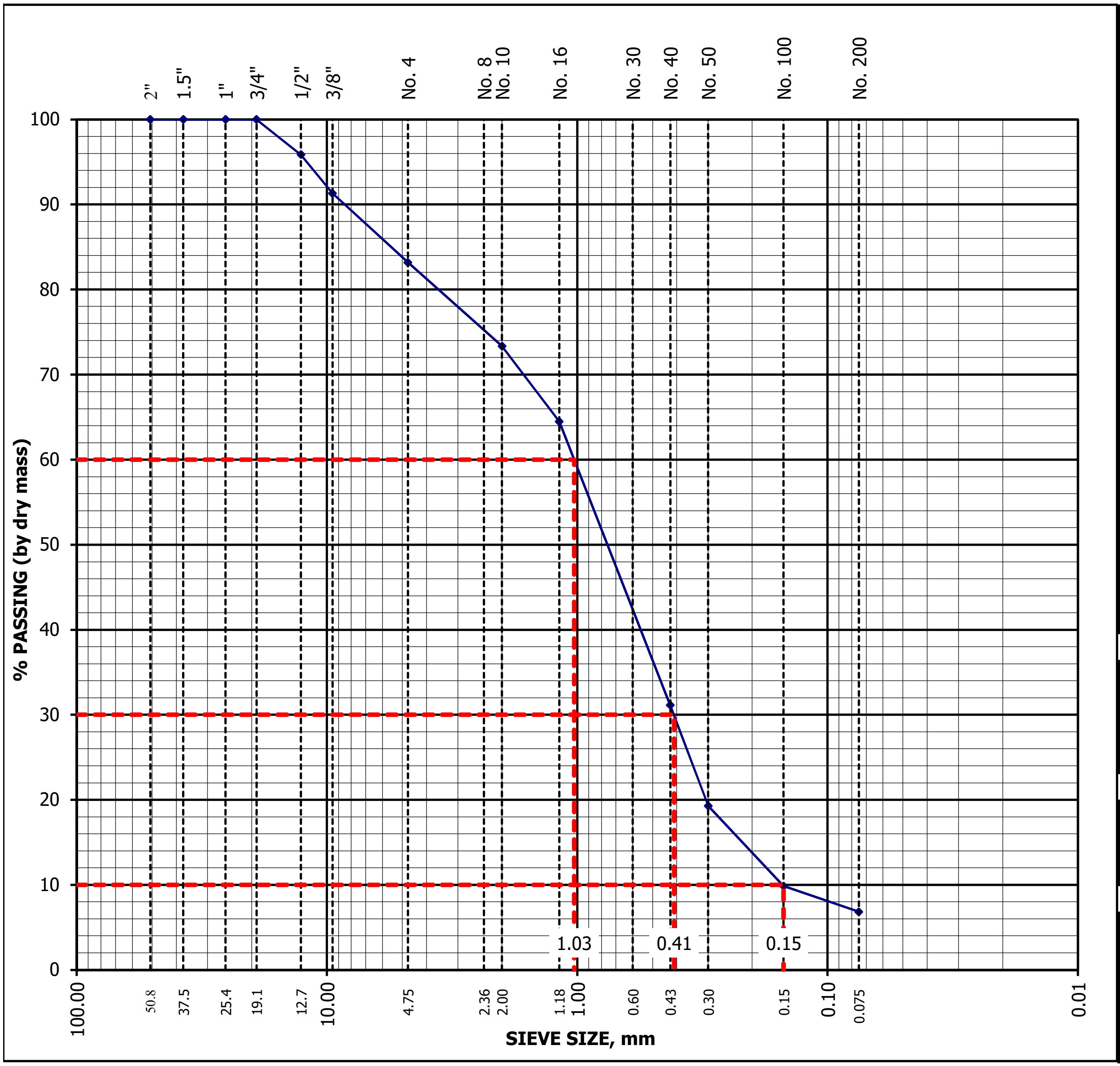
# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822880
Sample Location: MS-2 at 20'
Visual Description: SAND, with silt and gravel, brown

Date: 5-Sep-18
Technician: J. Weinerth
Reviewer: J. Crystal

**AASHTO M 145 Classification: A-1-b Group Index: 0**
**Unified Soil Classification System**
**(ASTM D 2487): (SW-SM) Well-graded sand with silt and gravel**



| **Sieve Size** | **% Passing** |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | 100 |
| 1/2" | 96 |
| 3/8" | 91 |
| #4 | 83 |
| #8 | |
| #10 | 73 |
| #16 | 64 |
| #30 | |
| #40 | 31 |
| #50 | 19 |
| #100 | 10 |
| #200 | 6.8 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 16.5 |
| D, pcf: | |

| | |
|---|---|
| **LL** | NV |
| PL | NP |
| **PI** | NP |

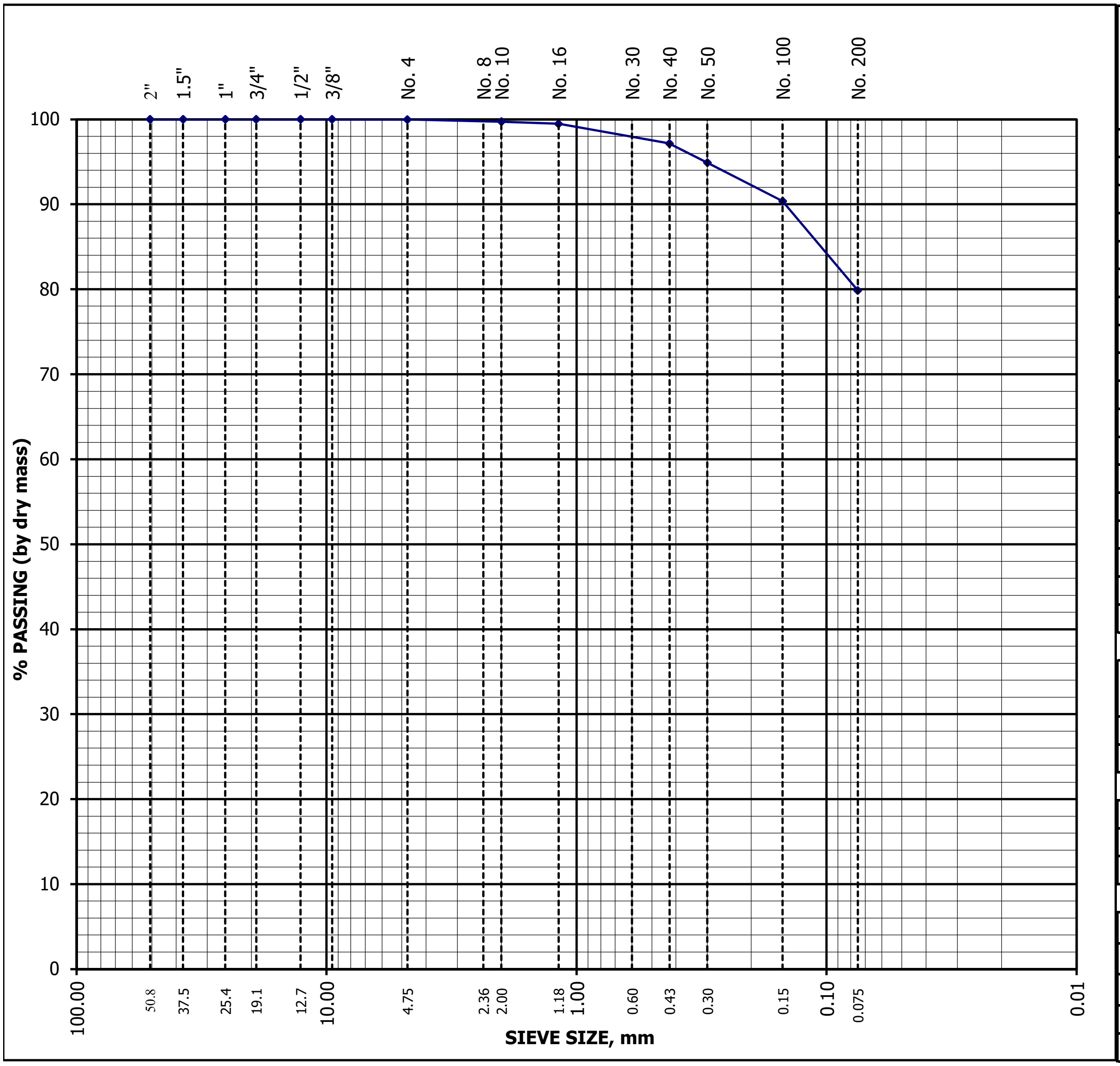
| | |
|---|---|
| $D_{60}$ | 1.03 |
| $D_{30}$ | 0.41 |
| $D_{10}$ | 0.15 |
| **Cu** | **6.87** |
| **Cc** | **1.09** |

# GRADATION PLOT - SOIL & AGGREGATE

| | | | |
|---|---|---|---|
| Project Number: | 18.117, Applegate Group | Date: | 8-Sep-18 |
| Project Name: | Cucharas Basin Collaborative Storage | Technician: | J. Holiman |
| Lab ID Number: | 1822881 | Reviewer: | J. Crystal |
| Sample Location: | MS-3 at 5' | | |
| Visual Description: | CLAY, with sand, brown | | |

**AASHTO M 145 Classification:** A-6 **Group Index:** 15

**Unified Soil Classification System (ASTM D 2487):** (CL) Lean clay with sand



| Sieve Size | % Passing |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | |
| 1/2" | |
| 3/8" | |
| #4 | 100 |
| #8 | |
| #10 | 100 |
| #16 | 99 |
| #30 | |
| #40 | 97 |
| #50 | 95 |
| #100 | 90 |
| #200 | 79.9 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 24.5 |
| D, pcf: | |

| | |
|---|---|
| **LL** | 39 |
| PL | 19 |
| **PI** | 20 |

| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

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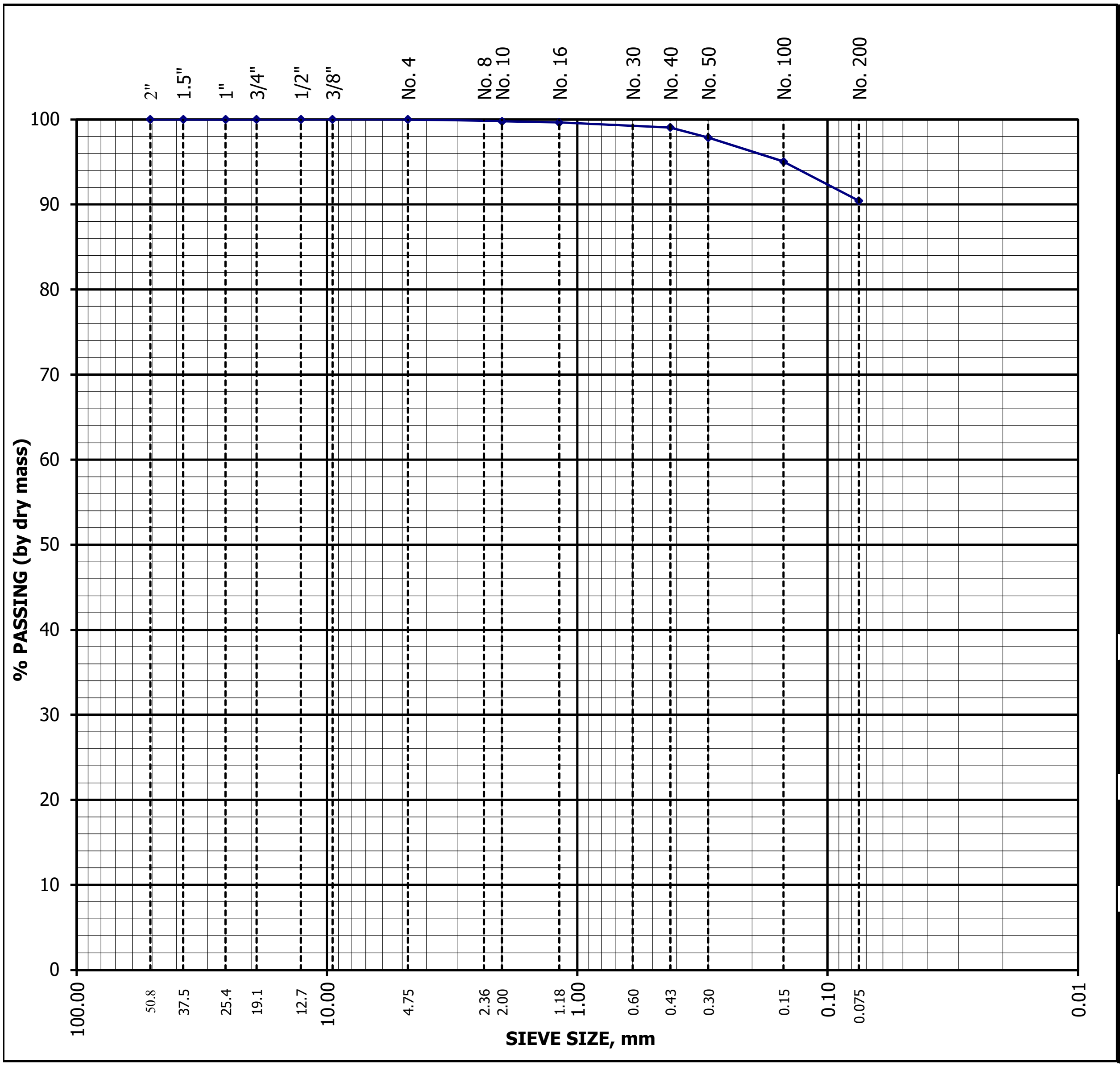
# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822882
Sample Location: MS-4 at 10'
Visual Description: CLAY, brown

Date: 8-Sep-18
Technician: J. Holiman
Reviewer: J. Crystal

**AASHTO M 145 Classification:** **A-6** **Group Index:** **17**
**Unified Soil Classification System (ASTM D 2487):** **(CL) Lean clay**



| **Sieve Size** | **% Passing** |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | |
| 1/2" | |
| 3/8" | |
| #4 | 100 |
| #8 | |
| #10 | 100 |
| #16 | 100 |
| #30 | |
| #40 | 99 |
| #50 | 98 |
| #100 | 95 |
| #200 | 90.4 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 11.8 |
| D, pcf: | |

| | |
|---|---|
| **LL** | 35 |
| PL | 15 |
| **PI** | 20 |

| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

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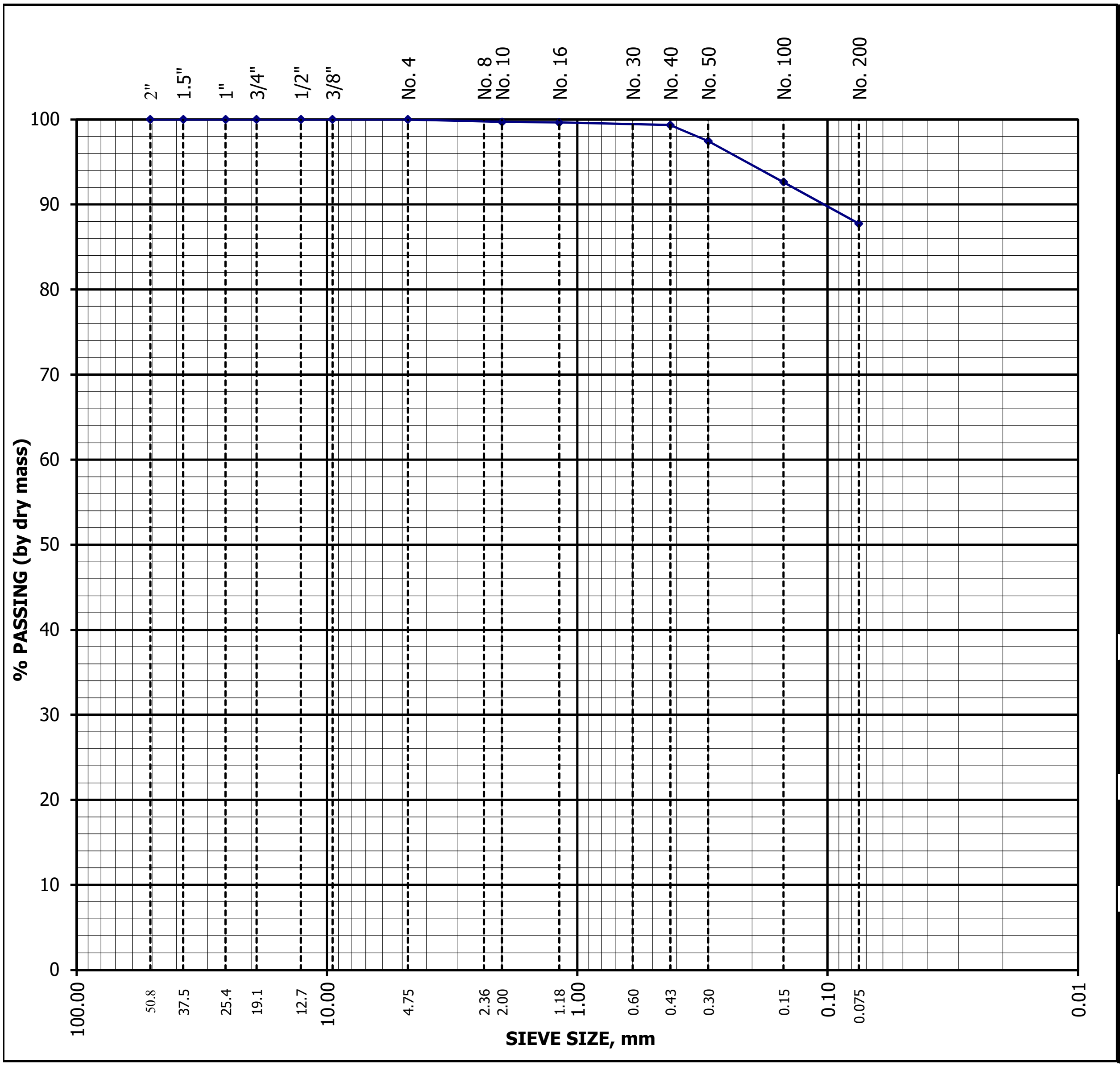
# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822883
Sample Location: MS-5 at 10'
Visual Description: CLAY, brown

Date: 8-Sep-18
Technician: J. Holiman
Reviewer: J. Crystal

**AASHTO M 145 Classification:** **A-6** **Group Index:** **14**
**Unified Soil Classification System (ASTM D 2487):** **(CL)** **Lean clay**



| **Sieve Size** | **% Passing** |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | |
| 1/2" | |
| 3/8" | |
| #4 | 100 |
| #8 | |
| #10 | 100 |
| #16 | 100 |
| #30 | |
| #40 | 99 |
| #50 | 97 |
| #100 | 93 |
| #200 | 87.8 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 12.3 |
| D, pcf: | |

| | |
|---|---|
| **LL** | 35 |
| PL | 18 |
| **PI** | 17 |

| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

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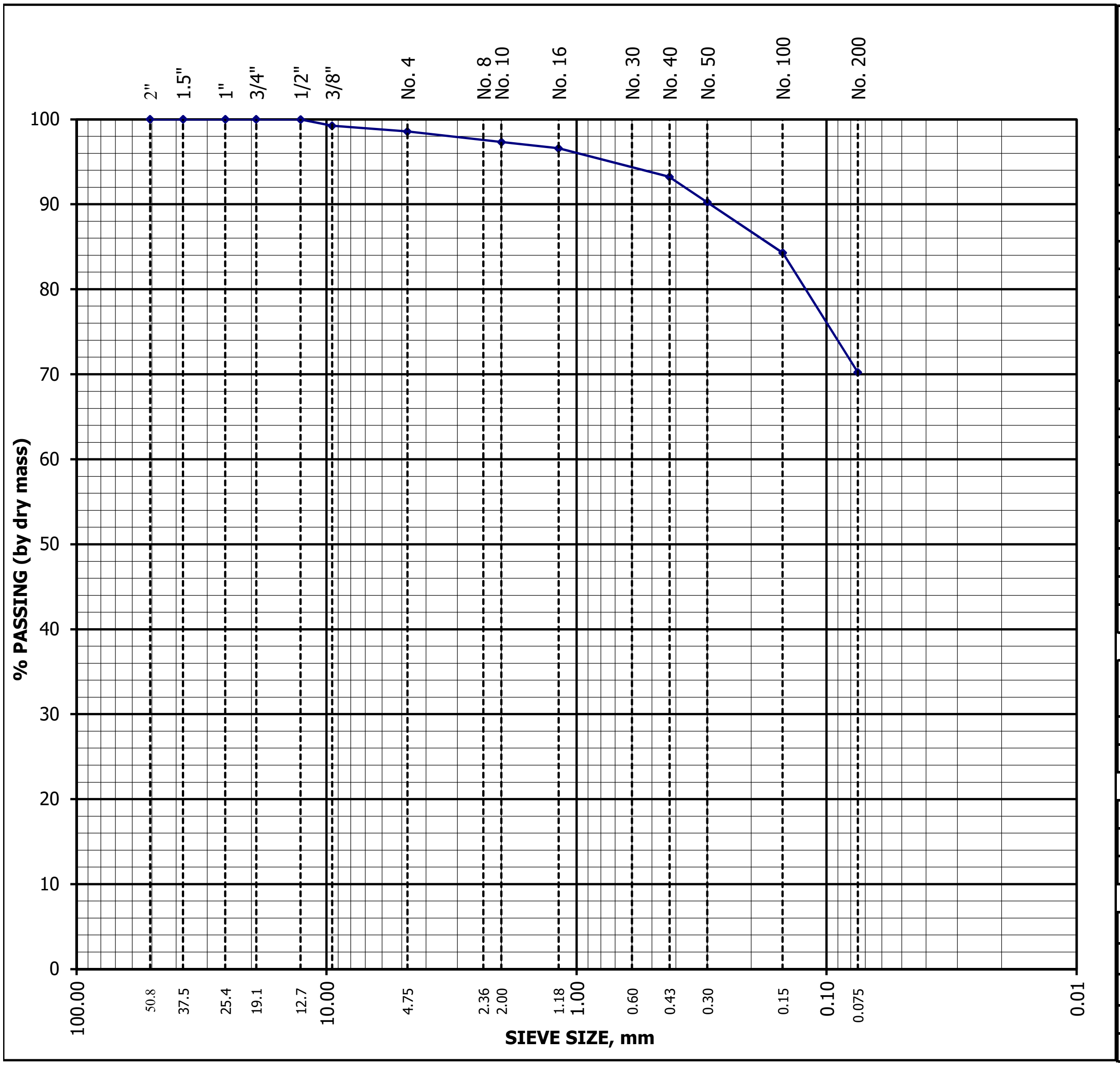
# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822884
Sample Location: MS-6 at 10'
Visual Description: CLAY, sandy, brown

Date: 8-Sep-18
Technician: J. Holiman
Reviewer: J. Crystal

**AASHTO M 145 Classification:** **A-6** **Group Index:** **8**
**Unified Soil Classification System (ASTM D 2487):** **(CL) Sandy lean clay**



| **Sieve Size** | **% Passing** |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | |
| 1/2" | 100 |
| 3/8" | 99 |
| #4 | 99 |
| #8 | |
| #10 | 97 |
| #16 | 97 |
| #30 | |
| #40 | 93 |
| #50 | 90 |
| #100 | 84 |
| #200 | 70.2 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 18.2 |
| D, pcf: | |

| | |
|---|---|
| **LL** | 32 |
| PL | 17 |
| **PI** | 15 |

| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

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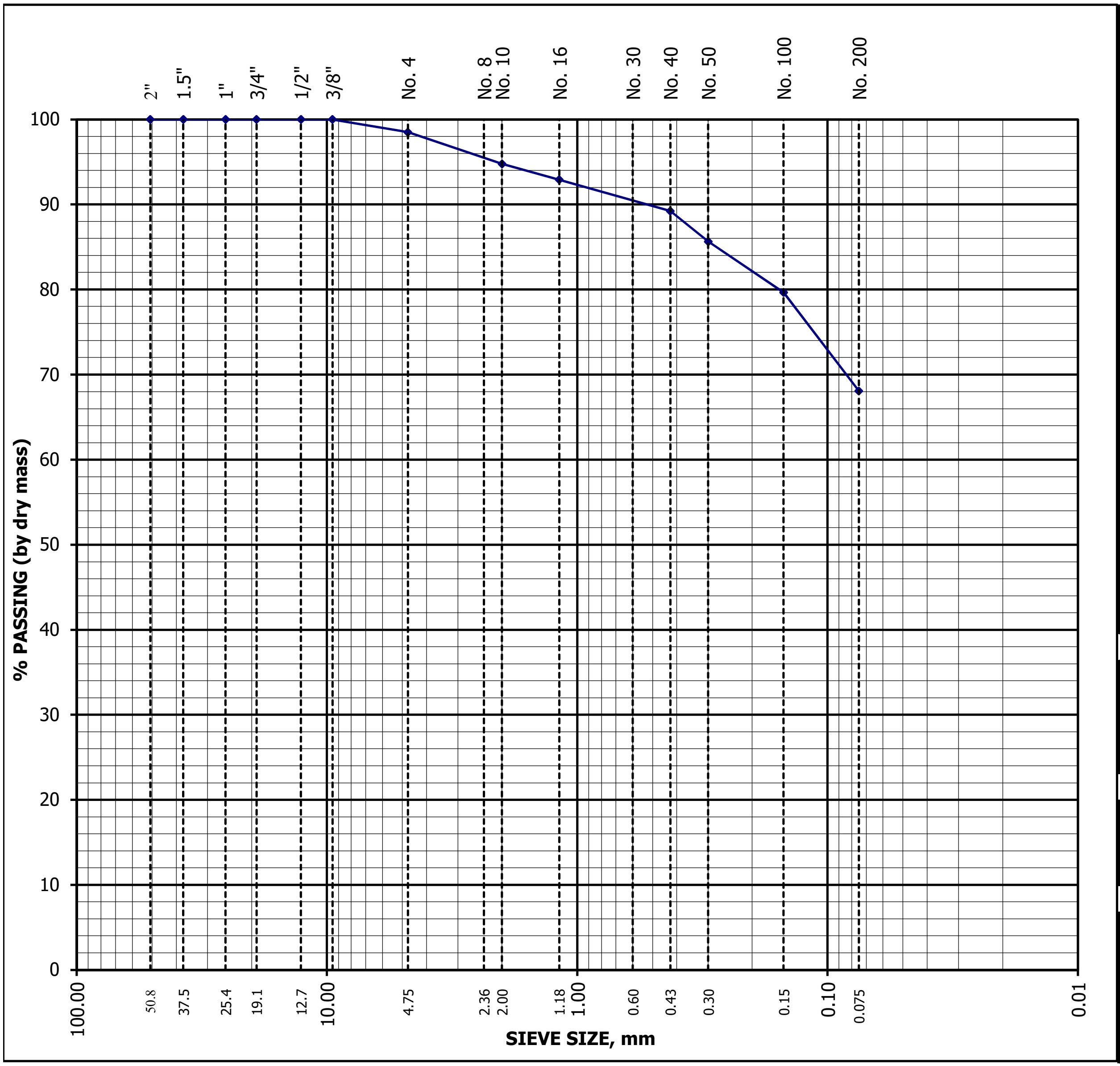
# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822885
Sample Location: MS-6 at 25'
Visual Description: CLAY, sandy, brown

Date: 5-Sep-18
Technician: J. Weinerth
Reviewer: J. Crystal

**AASHTO M 145 Classification:** **A-6** **Group Index:** **5**
**Unified Soil Classification System**
**(ASTM D 2487):** **(CL)** **Sandy lean clay**



| **Sieve Size** | **% Passing** |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | |
| 1/2" | |
| 3/8" | 100 |
| #4 | 99 |
| #8 | |
| #10 | 95 |
| #16 | 93 |
| #30 | |
| #40 | 89 |
| #50 | 86 |
| #100 | 80 |
| #200 | 68.1 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 14.4 |
| D, pcf: | |

| | |
|---|---|
| **LL** | 30 |
| PL | 19 |
| **PI** | 11 |

| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

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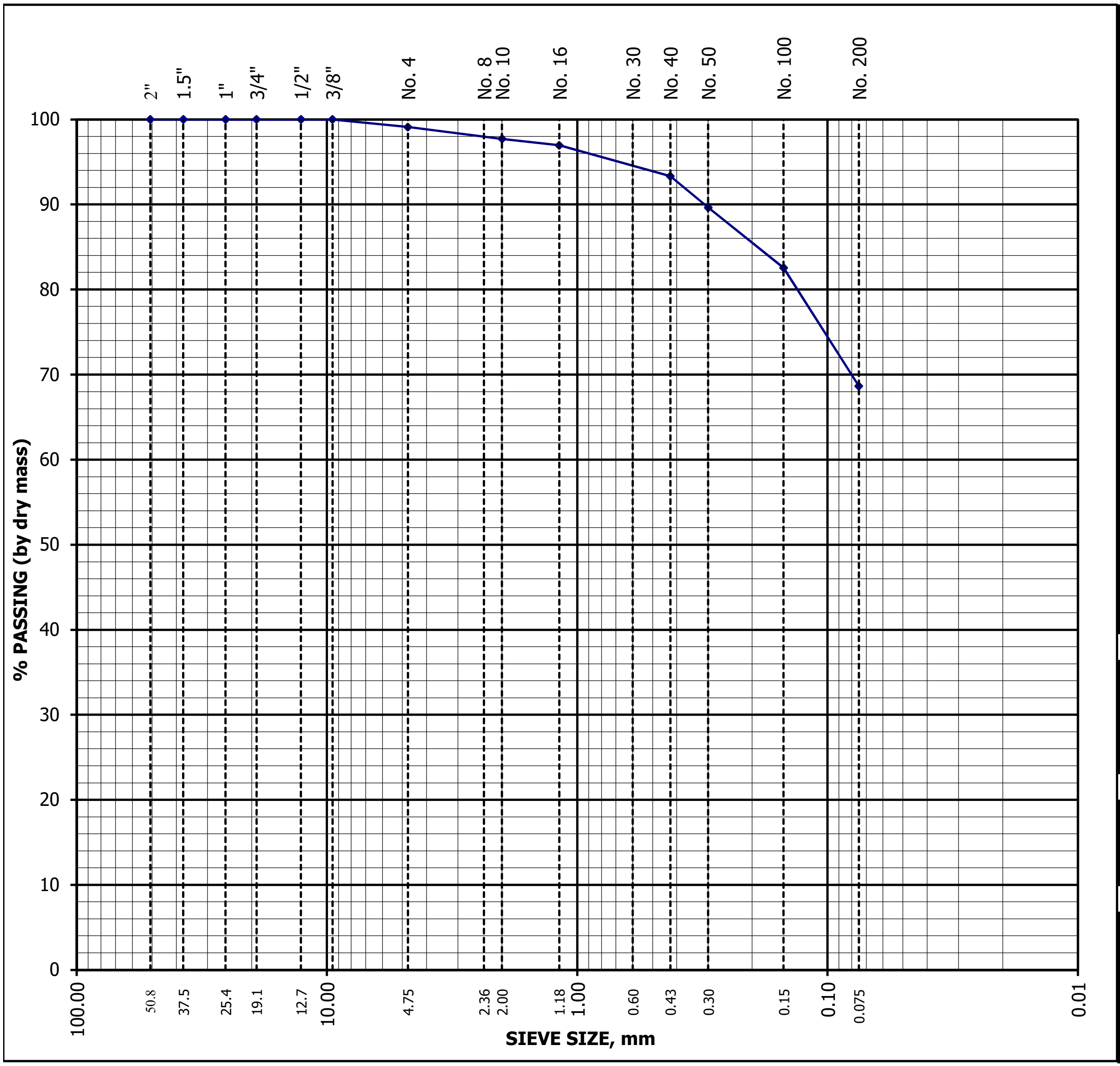
# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822641
Sample Location: MSP-2 at 1' to 3'
Visual Description: CLAY, sandy, light brown

Date: 21-Sep-18
Technician: J. Holiman
Reviewer: J. Crystal

**AASHTO M 145 Classification:** **A-6** **Group Index:** **8**
**Unified Soil Classification System (ASTM D 2487):** **(CL)** **Sandy lean clay**



| **Sieve Size** | **% Passing** |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | |
| 1/2" | |
| 3/8" | 100 |
| #4 | 99 |
| #8 | |
| #10 | 98 |
| #16 | 97 |
| #30 | |
| #40 | 93 |
| #50 | 90 |
| #100 | 83 |
| #200 | 68.6 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 6.4 |
| D, pcf: | |

| | |
|---|---|
| **LL** | 36 |
| PL | 23 |
| **PI** | 13 |

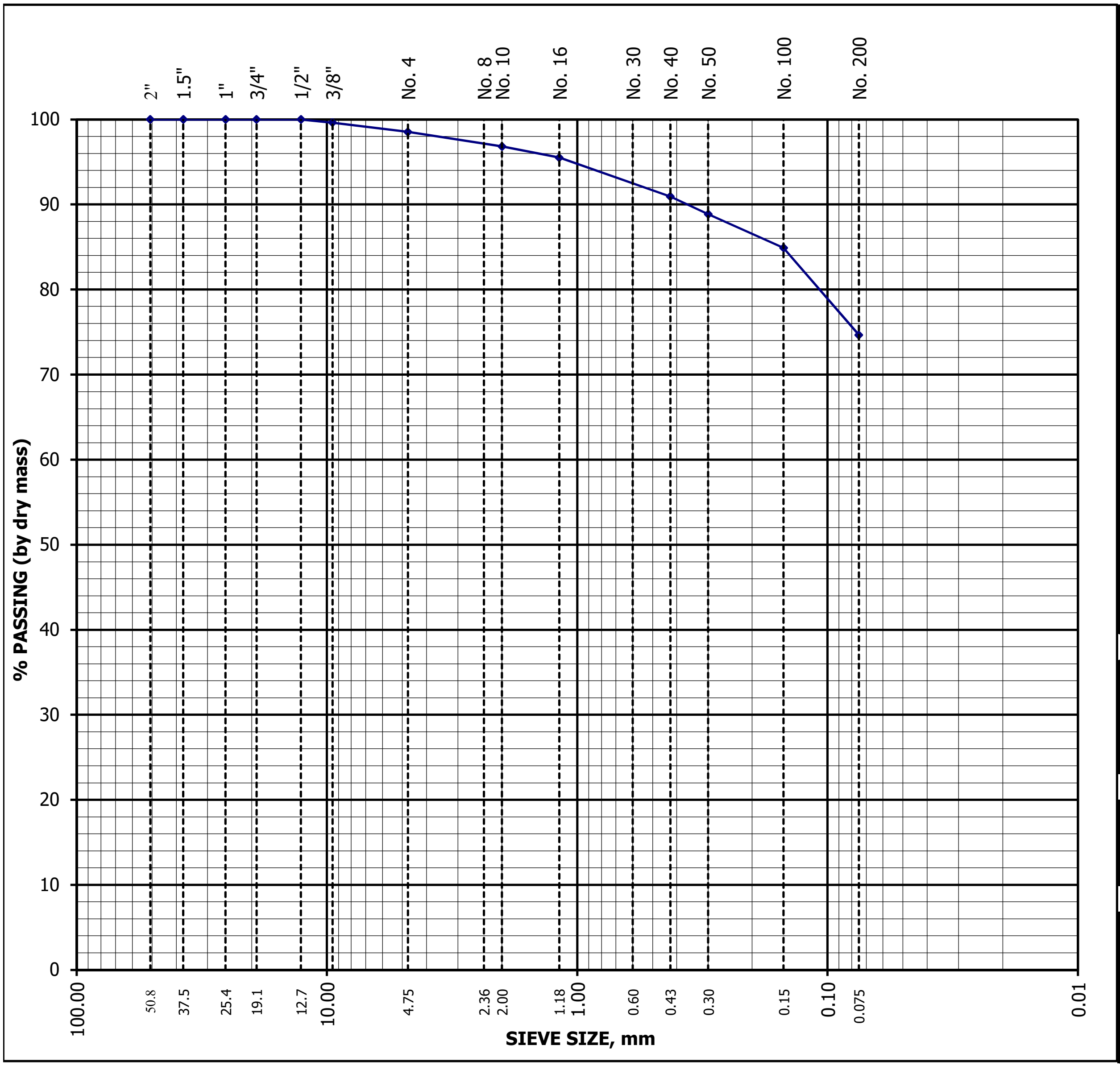
| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822642
Sample Location: MSP-4 at 1' to 4'
Visual Description: CLAY, with sand, brown

Date: 7-Oct-18
Technician: G. Hoyos
Reviewer: J. Crystal

**AASHTO M 145 Classification:** **A-6** **Group Index:** **11**
**Unified Soil Classification System (ASTM D 2487):** **(CL)** **Lean clay with sand**



| Sieve Size | % Passing |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | |
| 1/2" | 100 |
| 3/8" | 100 |
| #4 | 99 |
| #8 | |
| #10 | 97 |
| #16 | 96 |
| #30 | |
| #40 | 91 |
| #50 | 89 |
| #100 | 85 |
| #200 | 74.7 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 5.3 |
| D, pcf: | |

| | |
|---|---|
| **LL** | 37 |
| PL | 21 |
| **PI** | 16 |

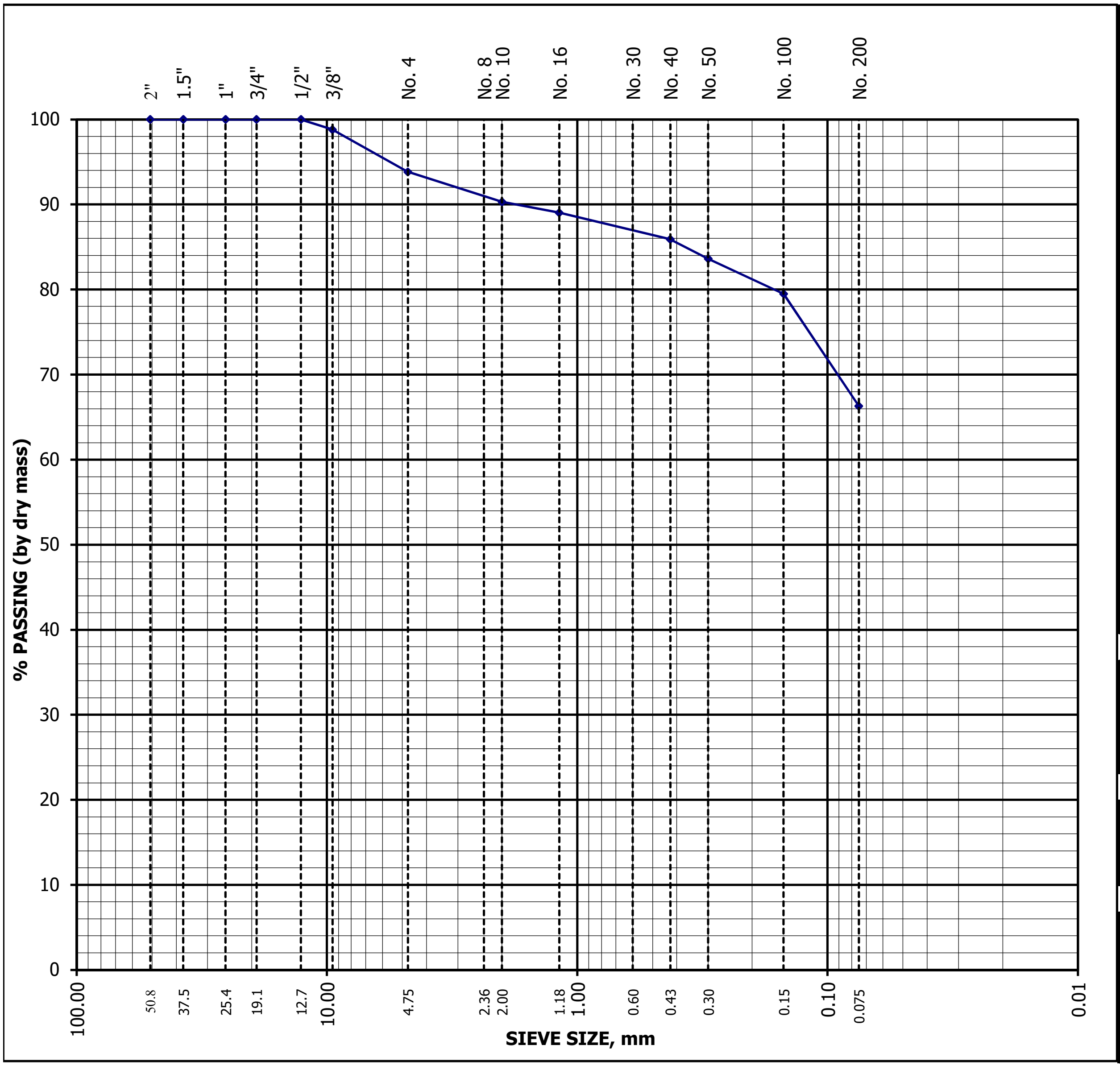
| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822643
Sample Location: MSP-5 at 1' to 4'
Visual Description: CLAY, sandy, brown

Date: 21-Sep-18
Technician: J. Holiman
Reviewer: J. Crystal

**AASHTO M 145 Classification:** **A-6** **Group Index:** **10**
**Unified Soil Classification System (ASTM D 2487):** **(CL)** **Sandy lean clay**



| Sieve Size | % Passing |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | |
| 1/2" | 100 |
| 3/8" | 99 |
| #4 | 94 |
| #8 | |
| #10 | 90 |
| #16 | 89 |
| #30 | |
| #40 | 86 |
| #50 | 84 |
| #100 | 79 |
| #200 | 66.3 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 5.7 |
| D, pcf: | |

| | |
|---|---|
| **LL** | 35 |
| PL | 16 |
| **PI** | 19 |

| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

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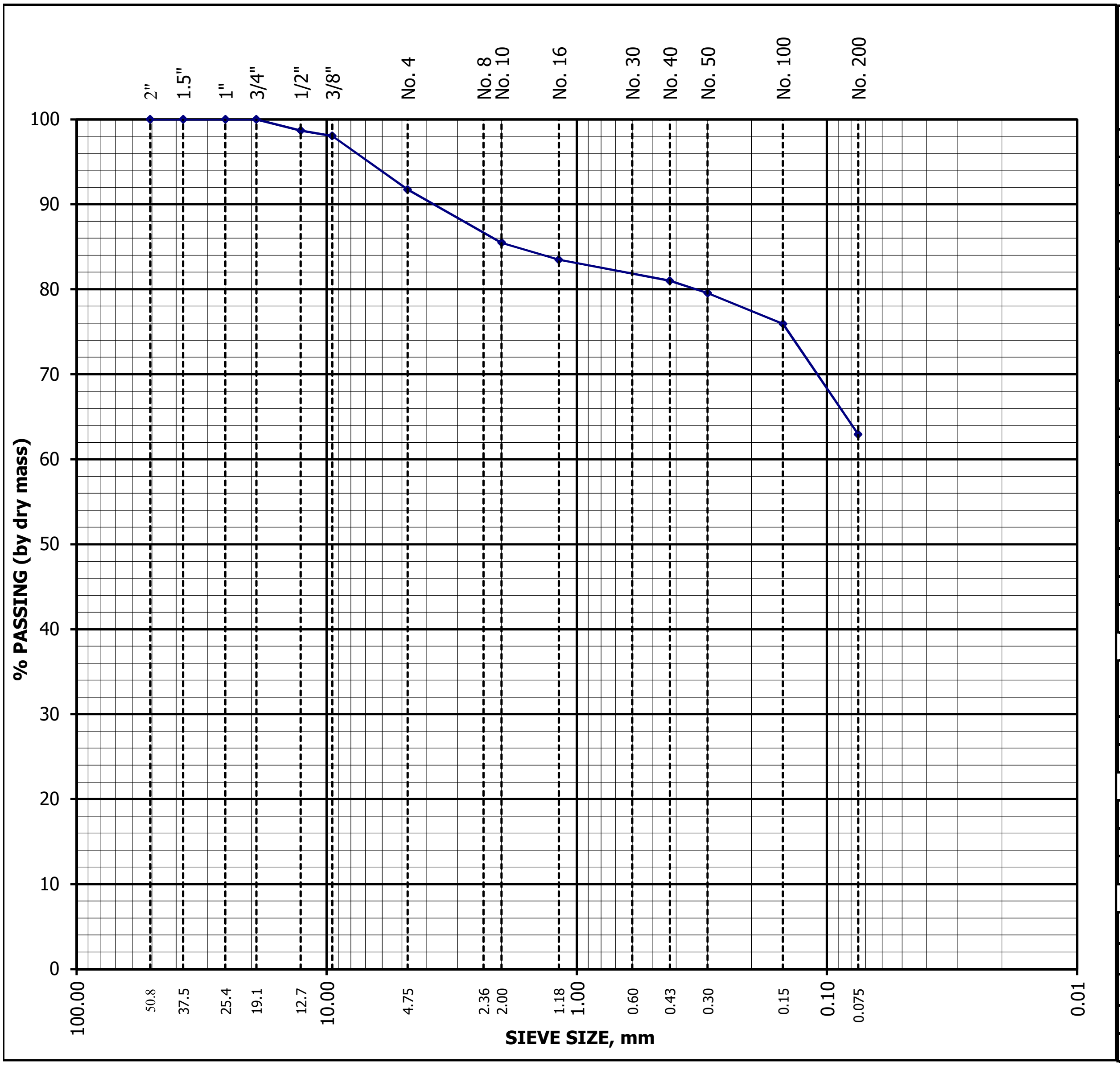
# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822644
Sample Location: MSP-5 at 4' to 7'
Visual Description: CLAYSTONE, sandy, brown

Date: 21-Sep-18
Technician: J. Holiman
Reviewer: J. Crystal

**AASHTO M 145 Classification:** **A-6** **Group Index:** **7**
**Unified Soil Classification System (ASTM D 2487):** **(CL)** **Sandy lean clay**



| **Sieve Size** | **% Passing** |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | 100 |
| 1/2" | 99 |
| 3/8" | 98 |
| #4 | 92 |
| #8 | |
| #10 | 85 |
| #16 | 83 |
| #30 | |
| #40 | 81 |
| #50 | 80 |
| #100 | 76 |
| #200 | 62.9 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 3.6 |
| D, pcf: | |

| | |
|---|---|
| **LL** | 33 |
| PL | 17 |
| **PI** | 16 |

| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

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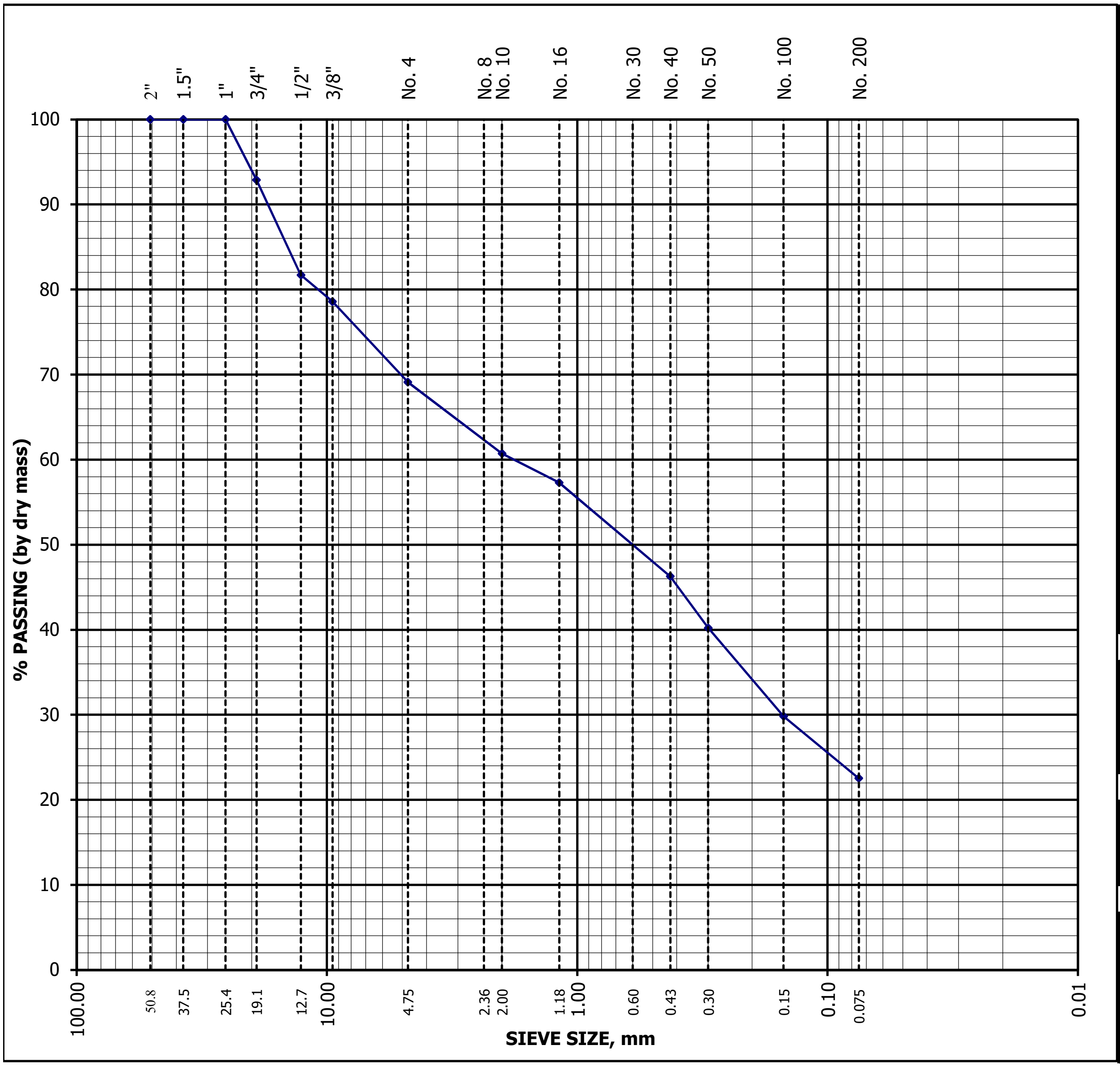
# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Date: 12-Sep-18
Project Name: Cucharas Basin Collaborative Storage
Technician: G. Hoyos
Lab ID Number: 1822886
Reviewer: J. Crystal
Sample Location: SB-1 at 5'
Visual Description: SAND, silty, with gravel, red

**AASHTO M 145 Classification:** **A-1-b** **Group Index:** **(0)**
**Unified Soil Classification System**
**(ASTM D 2487):** **(SM)** **Silty sand with gravel**



| **Sieve Size** | **% Passing** |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | 100 |
| 3/4" | 93 |
| 1/2" | 82 |
| 3/8" | 79 |
| #4 | 69 |
| #8 | |
| #10 | 61 |
| #16 | 57 |
| #30 | |
| #40 | 46 |
| #50 | 40 |
| #100 | 30 |
| #200 | 22.5 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 7.6 |
| D, pcf: | |

| | |
|---|---|
| **LL** | 19 |
| PL | 17 |
| **PI** | 2 |

| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

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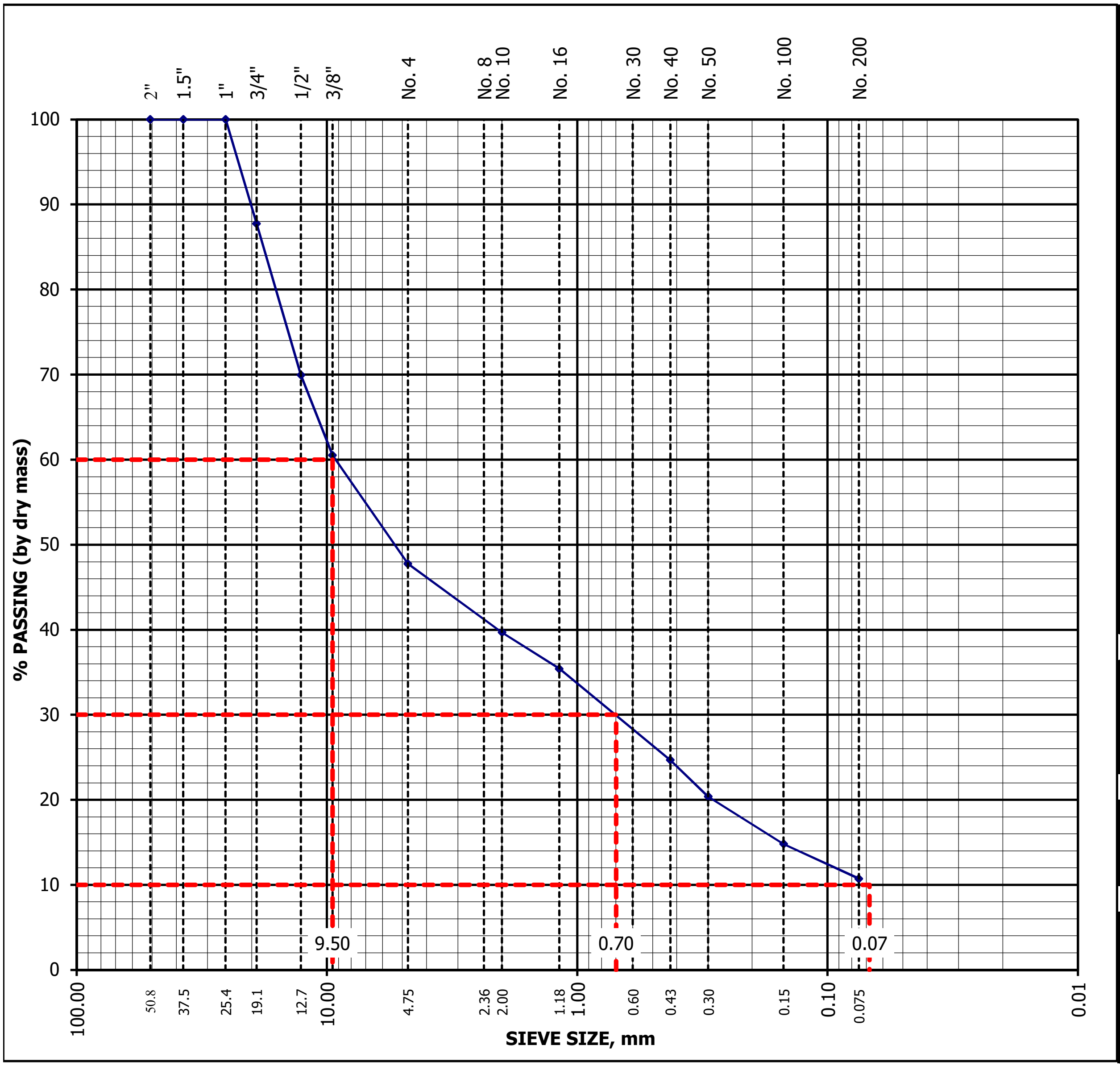
# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822887
Sample Location: SB-1 at 12.5'
Visual Description: Gravel, with silt, with sand, pink

Date: 5-Sep-18
Technician: J. Weinerth
Reviewer: J. Crystal

**AASHTO M 145 Classification:** **A-1-b** **Group Index:** **0**
**Unified Soil Classification System (ASTM D 2487):** **(GP-GM) Poorly graded gravel with silt and sand**



| Sieve Size | % Passing |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | 88 |
| 1/2" | 70 |
| 3/8" | 61 |
| #4 | 48 |
| #8 | |
| #10 | 40 |
| #16 | 35 |
| #30 | |
| #40 | 25 |
| #50 | 20 |
| #100 | 15 |
| #200 | 10.7 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 0.3 |
| D, pcf: | |

| | |
|---|---|
| **LL** | NV |
| PL | NP |
| **PI** | NP |

| | |
|---|---|
| $D_{60}$ | 9.50 |
| $D_{30}$ | 0.70 |
| $D_{10}$ | 0.07 |
| **Cu** | **139.71** |
| **Cc** | **0.76** |

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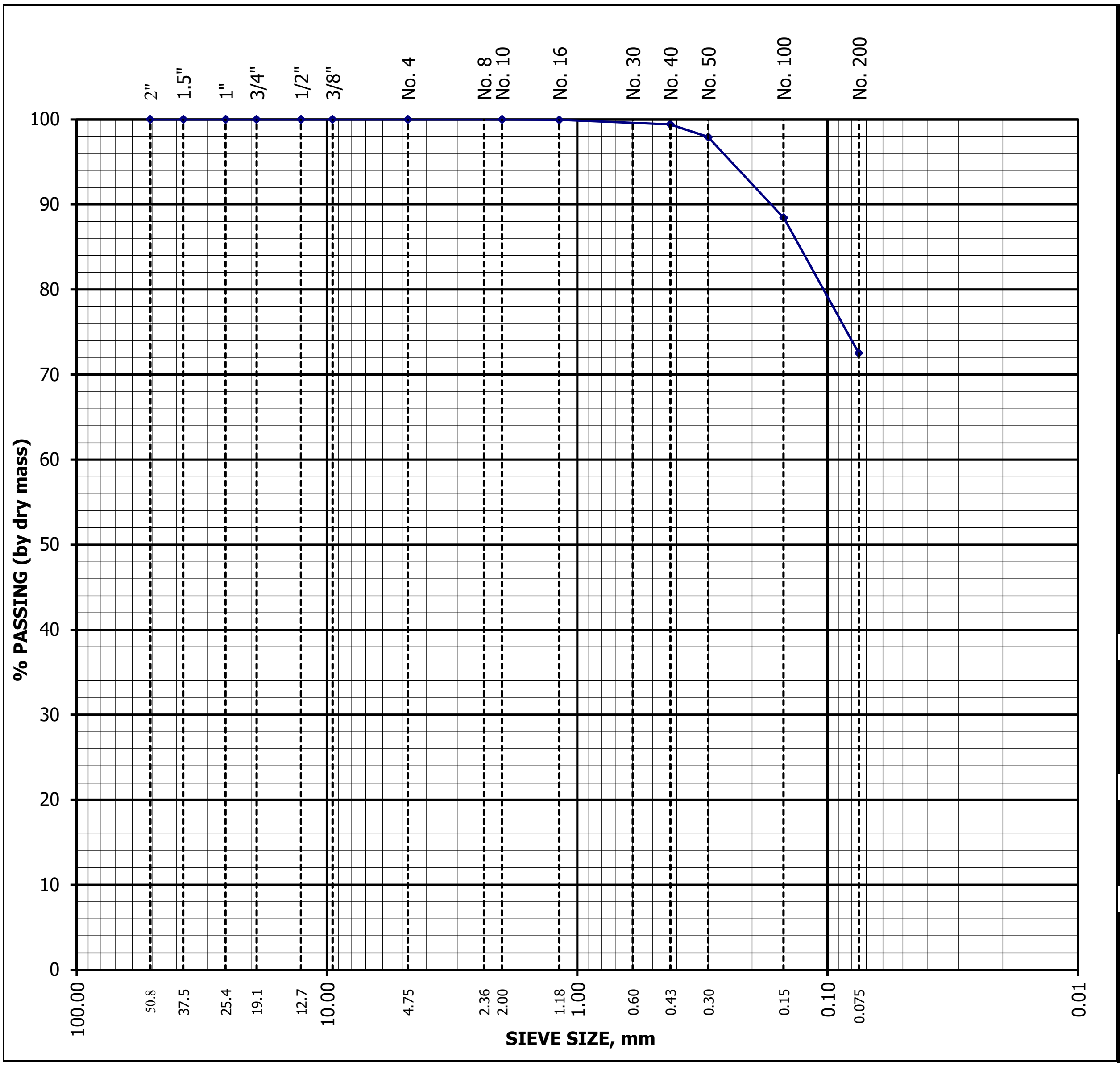
# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822888
Sample Location: SB-1 at 20'
Visual Description: CLAY, with sand, red

Date: 8-Sep-18
Technician: J. Holiman
Reviewer: J. Crystal

**AASHTO M 145 Classification:** **A-6** **Group Index:** **6**
**Unified Soil Classification System (ASTM D 2487):** **(CL)** **Lean clay with sand**



| Sieve Size | % Passing |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | |
| 1/2" | |
| 3/8" | |
| #4 | |
| #8 | |
| #10 | 100 |
| #16 | 100 |
| #30 | |
| #40 | 99 |
| #50 | 98 |
| #100 | 88 |
| #200 | 72.5 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 8.7 |
| D, pcf: | |

| | |
|---|---|
| **LL** | 30 |
| PL | 19 |
| **PI** | 11 |

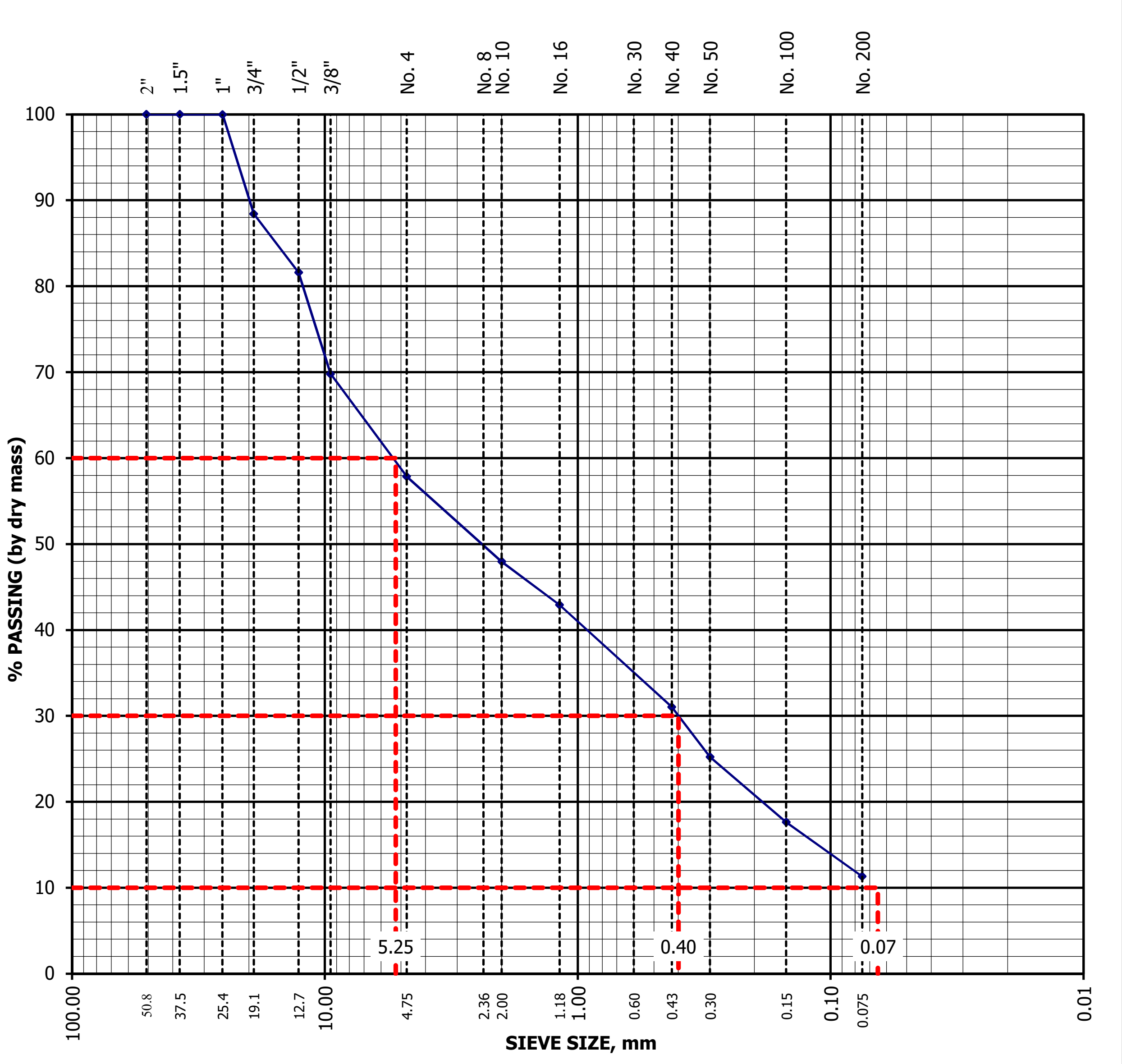
| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

# GRADATION PLOT - SOIL & AGGREGATE

| | | | |
|---|---|---|---|
| Project Number: | 18.117, Applegate Group | Date: | 5-Sep-18 |
| Project Name: | Cucharas Basin Collaborative Storage | Technician: | J. Weinerth |
| Lab ID Number: | 1822889 | Reviewer: | J. Crystal |
| Sample Location: | SB-2 at 10' | | |
| Visual Description: | SAND, with silt and gravel, red brown | | |

**AASHTO M 145 Classification:** **A-1-b** **Group Index:** **0**

**Unified Soil Classification System**
**(ASTM D 2487):** **(SP-SM) Poorly graded sand with silt and gravel**



| **Sieve Size** | **% Passing** |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | 100 |
| 3/4" | 88 |
| 1/2" | 82 |
| 3/8" | 70 |
| #4 | 58 |
| #8 | |
| #10 | 48 |
| #16 | 43 |
| #30 | |
| #40 | 31 |
| #50 | 25 |
| #100 | 18 |
| #200 | 11.3 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 10.5 |
| D, pcf: | |

| | |
|---|---|
| **LL** | NV |
| PL | NP |
| **PI** | NP |

| | |
|---|---|
| $D_{60}$ | 5.25 |
| $D_{30}$ | 0.40 |
| $D_{10}$ | 0.07 |
| **Cu** | **80.77** |
| **Cc** | **0.47** |

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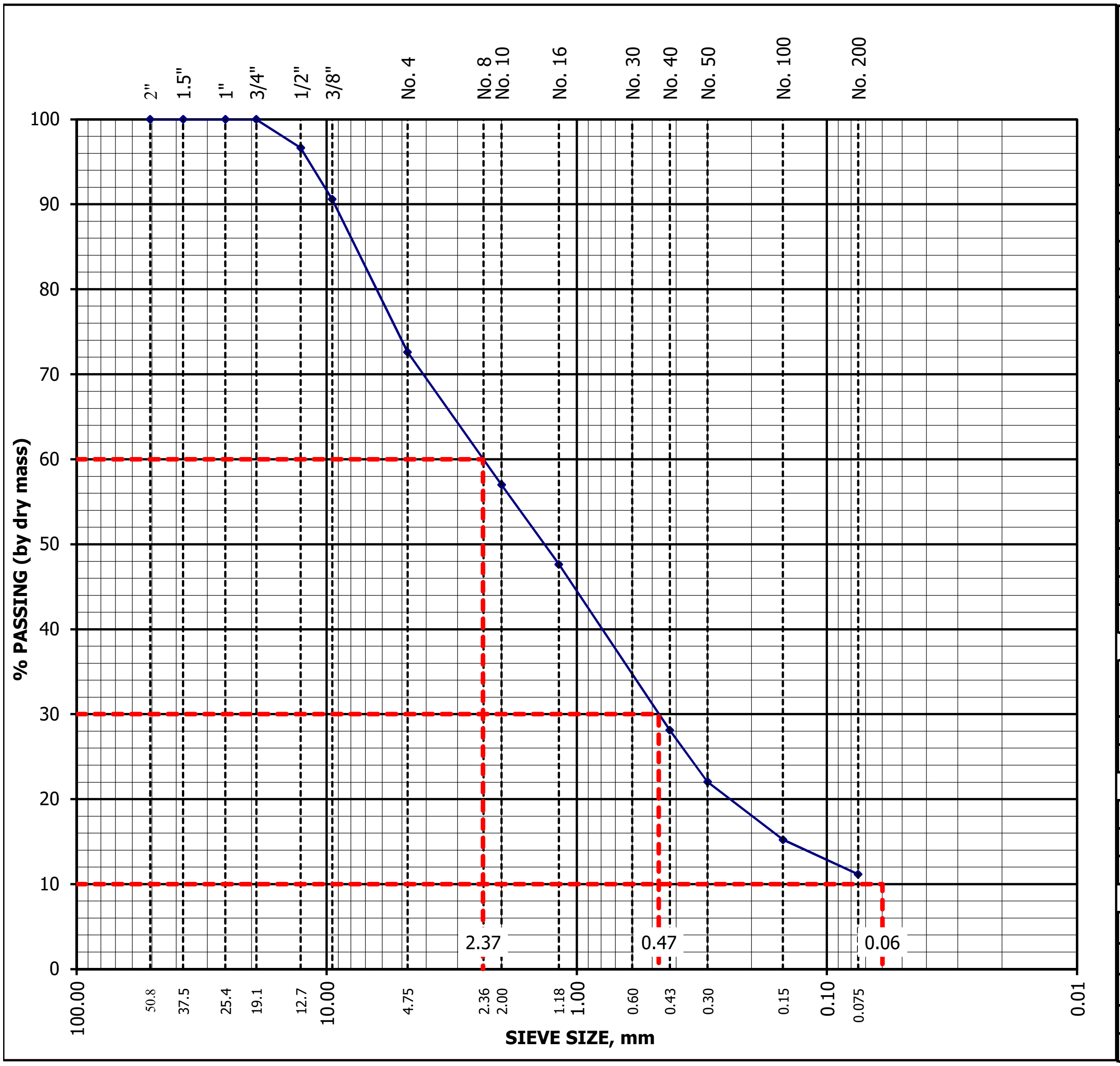
# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822890
Sample Location: SB-3 at 5'
Visual Description: SAND, with silt and gravel, red

Date: 12-Sep-18
Technician: G. Hoyos
Reviewer: J. Crystal

**AASHTO M 145 Classification:** **A-1-b** **Group Index:** **0**
**Unified Soil Classification System (ASTM D 2487):** **(SW-SM) Well graded sand with silt and gravel**



| **Sieve Size** | **% Passing** |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | 100 |
| 1/2" | 97 |
| 3/8" | 91 |
| #4 | 73 |
| #8 | |
| #10 | 57 |
| #16 | 48 |
| #30 | |
| #40 | 28 |
| #50 | 22 |
| #100 | 15 |
| #200 | 11.1 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 5.6 |
| D, pcf: | |

| | |
|---|---|
| **LL** | NV |
| PL | NP |
| **PI** | NP |

| | |
|---|---|
| $D_{60}$ | 2.37 |
| $D_{30}$ | 0.47 |
| $D_{10}$ | 0.06 |
| **Cu** | **39.50** |
| **Cc** | **1.55** |

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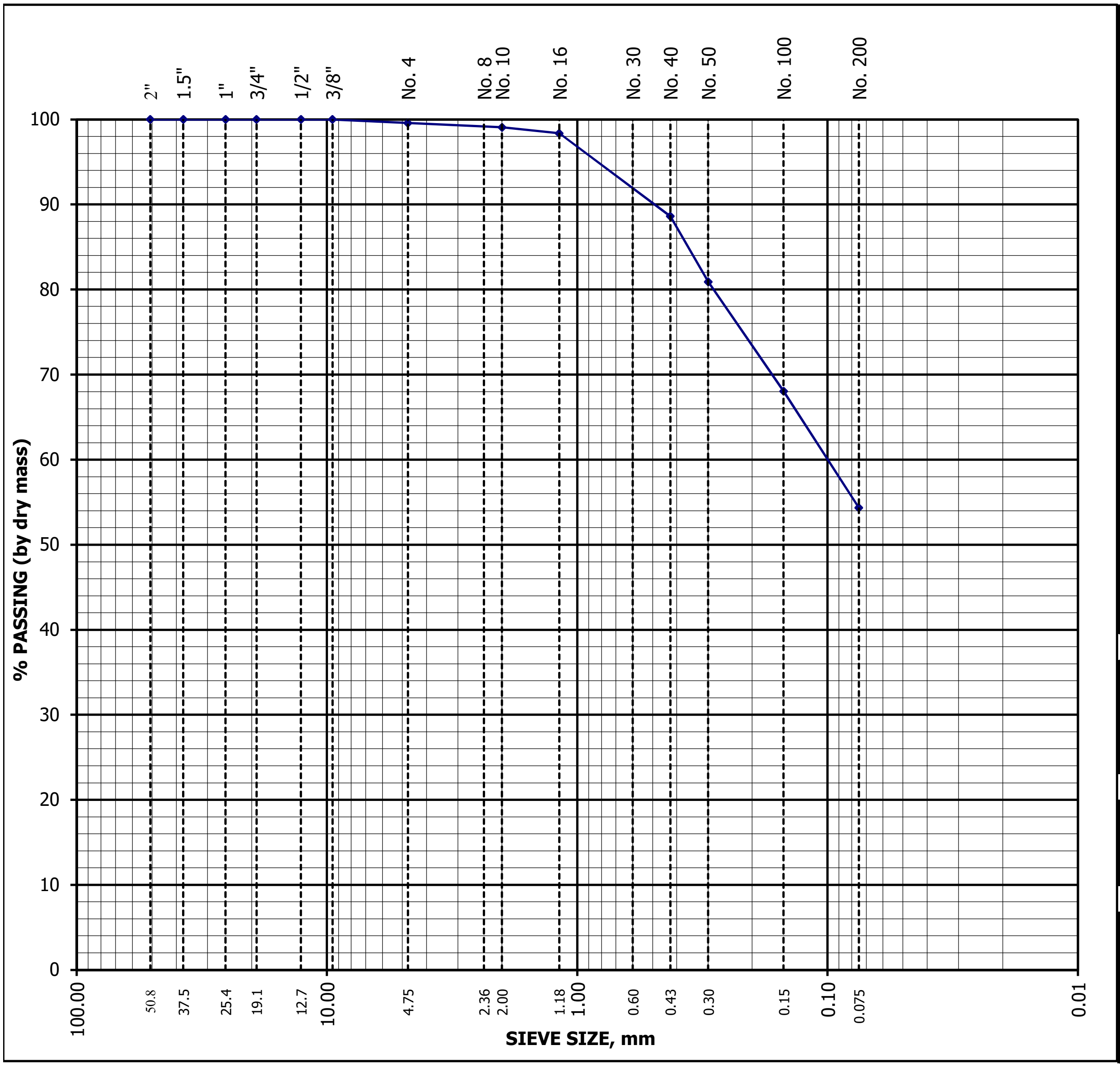
## GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1921465
Sample Location: SB-4 at 5'
Visual Description: CLAY, sandy, brown

Date: 9-Sep-19
Technician: C. Zoetewey
Reviewer: J. Crystal

**AASHTO M 145 Classification:** **A-4** **Group Index:** **2**
**Unified Soil Classification System**
**(ASTM D 2487):** **(CL)** **Sandy lean clay**



| Sieve Size | % Passing |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | |
| 1/2" | |
| 3/8" | 100 |
| #4 | 100 |
| #8 | |
| #10 | 99 |
| #16 | 98 |
| #30 | |
| #40 | 89 |
| #50 | 81 |
| #100 | 68 |
| #200 | 54.3 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 15.5 |
| D, pcf: | |

| | |
|---|---|
| **LL** | 26 |
| PL | 17 |
| **PI** | 9 |

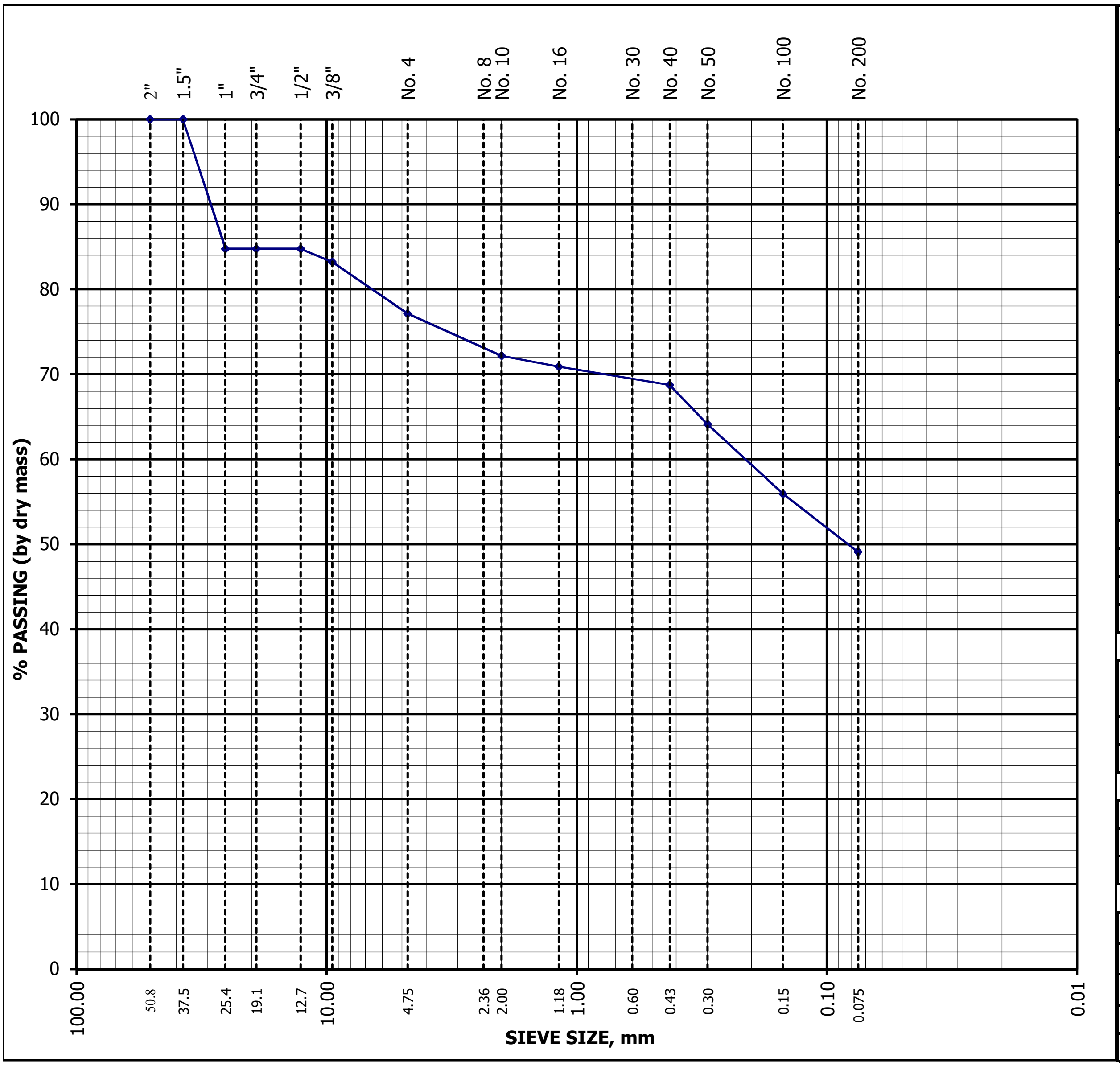
| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

## GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1921466
Sample Location: SB-4 at 15'
Visual Description: CLAY, sandy, with gravel, reddish brown

Date: 9-Sep-19
Technician: C. Zoetewey
Reviewer: J. Crystal

**AASHTO M 145 Classification:** **A-4** **Group Index:** **1**
**Unified Soil Classification System (ASTM D 2487):** **(CL)** **Sandy lean clay with gravel**



| Sieve Size | % Passing |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | 100 |
| 1" | 85 |
| 3/4" | 85 |
| 1/2" | 85 |
| 3/8" | 83 |
| #4 | 77 |
| #8 | |
| #10 | 72 |
| #16 | 71 |
| #30 | |
| #40 | 69 |
| #50 | 64 |
| #100 | 56 |
| #200 | 49.1 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 6.0 |
| D, pcf: | |

| | |
|---|---|
| **LL** | 24 |
| PL | 16 |
| **PI** | 8 |

| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

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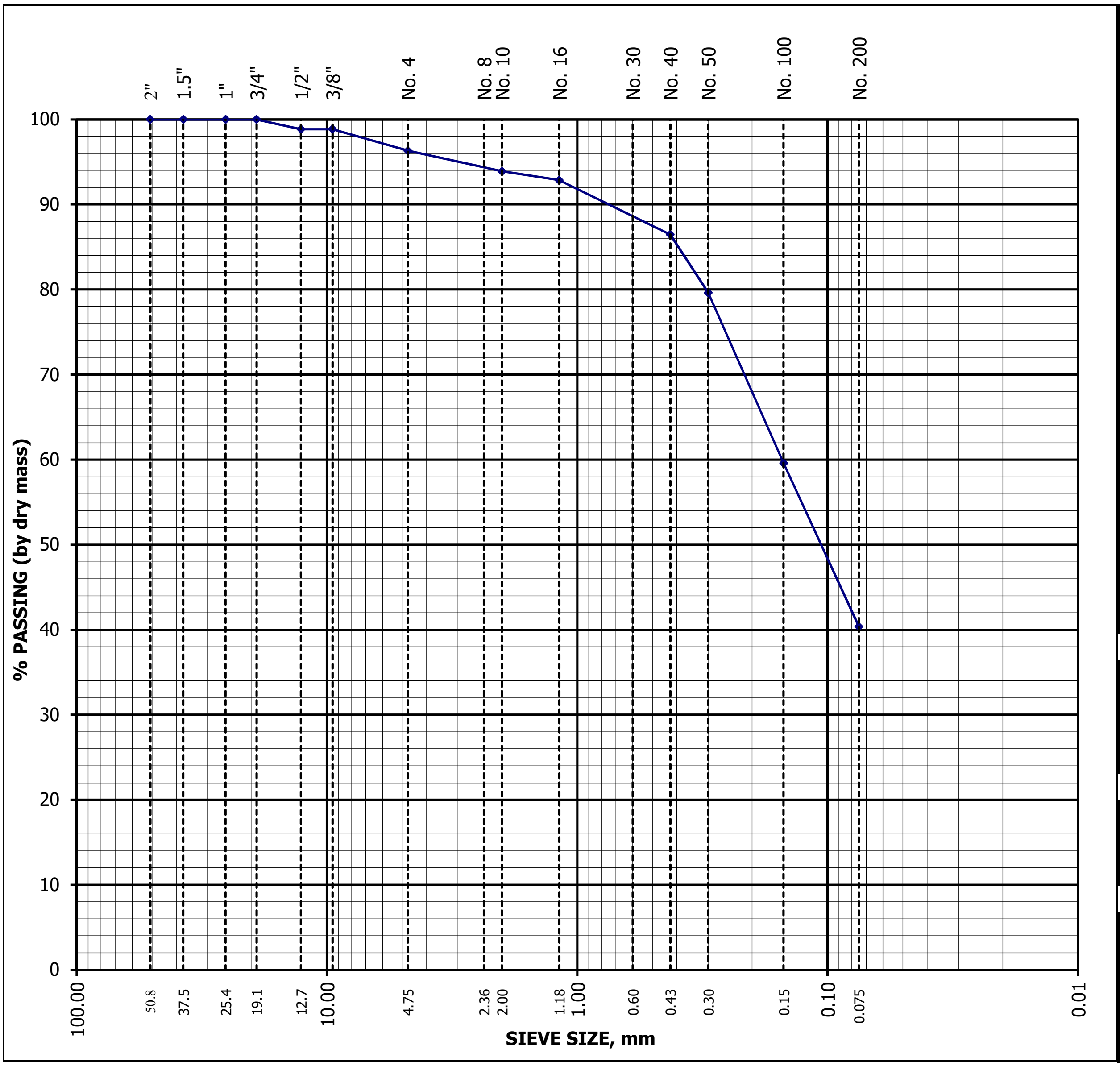
# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1921468
Sample Location: SB-5 at 1'
Visual Description: SAND, silty, reddish brown

Date: 9-Sep-19
Technician: C. Zoetewey
Reviewer: J. Crystal

**AASHTO M 145 Classification:** **A-4** **Group Index:** **(0)**
**Unified Soil Classification System (ASTM D 2487):** **(SM)** **Silty sand**



| Sieve Size | % Passing |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | 100 |
| 1/2" | 99 |
| 3/8" | 99 |
| #4 | 96 |
| #8 | |
| #10 | 94 |
| #16 | 93 |
| #30 | |
| #40 | 86 |
| #50 | 80 |
| #100 | 60 |
| #200 | 40.4 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 6.3 |
| D, pcf: | |

| | |
|---|---|
| **LL** | 19 |
| PL | 17 |
| **PI** | 2 |

| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

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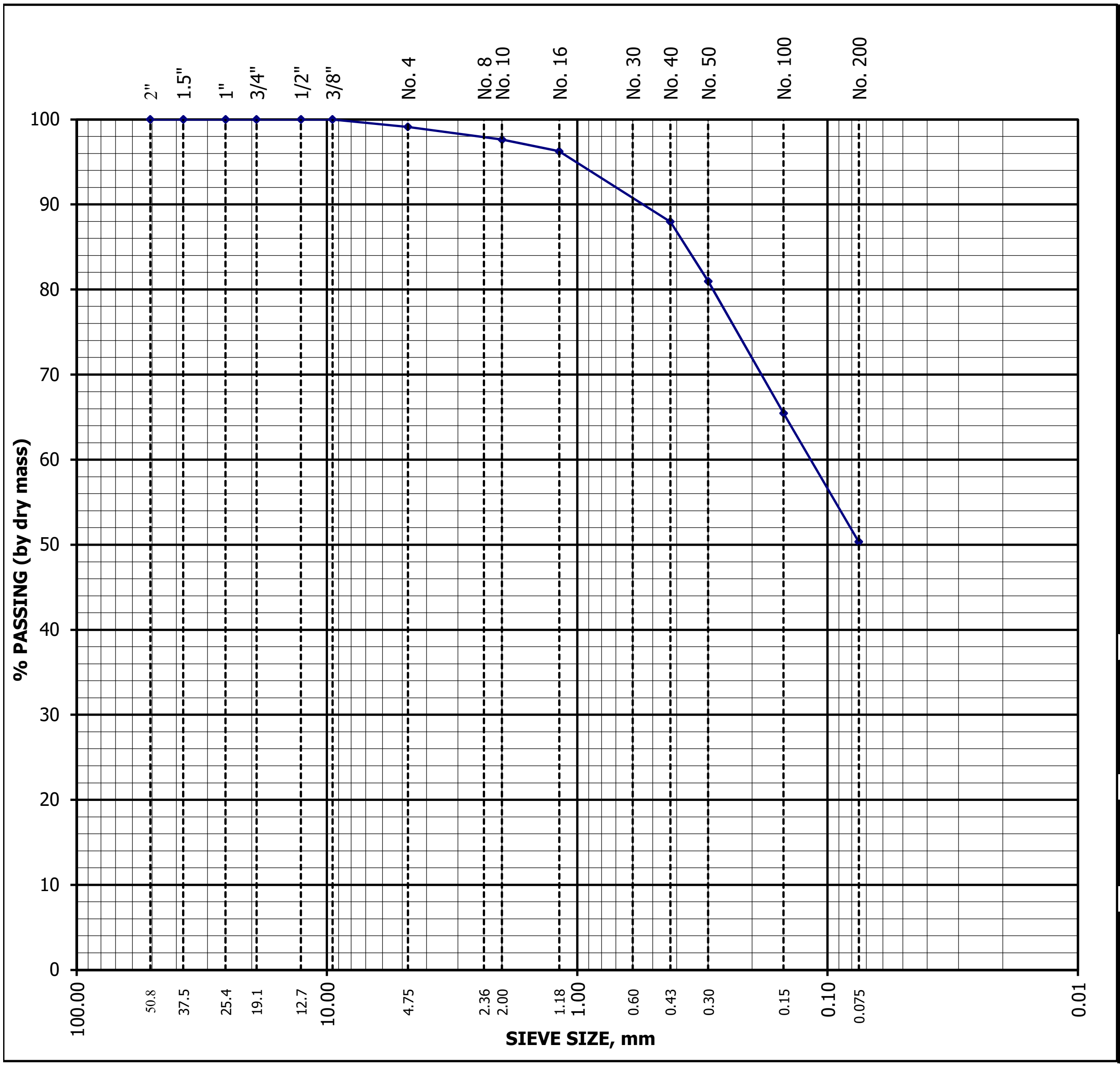
# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822645
Sample Location: SBP-1 at 1' to 3'
Visual Description: CLAY, sandy, red

Date: 21-Sep-18
Technician: J. Holiman
Reviewer: J. Crystal

**AASHTO M 145 Classification:** **A-4** **Group Index:** **0**
**Unified Soil Classification System**
**(ASTM D 2487):** **(CL-ML) Silty clay with sand**



| **Sieve Size** | **% Passing** |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | |
| 1/2" | |
| 3/8" | 100 |
| #4 | 99 |
| #8 | |
| #10 | 98 |
| #16 | 96 |
| #30 | |
| #40 | 88 |
| #50 | 81 |
| #100 | 65 |
| #200 | 50.3 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 2.4 |
| D, pcf: | |

| | |
|---|---|
| **LL** | 25 |
| PL | 20 |
| **PI** | 5 |

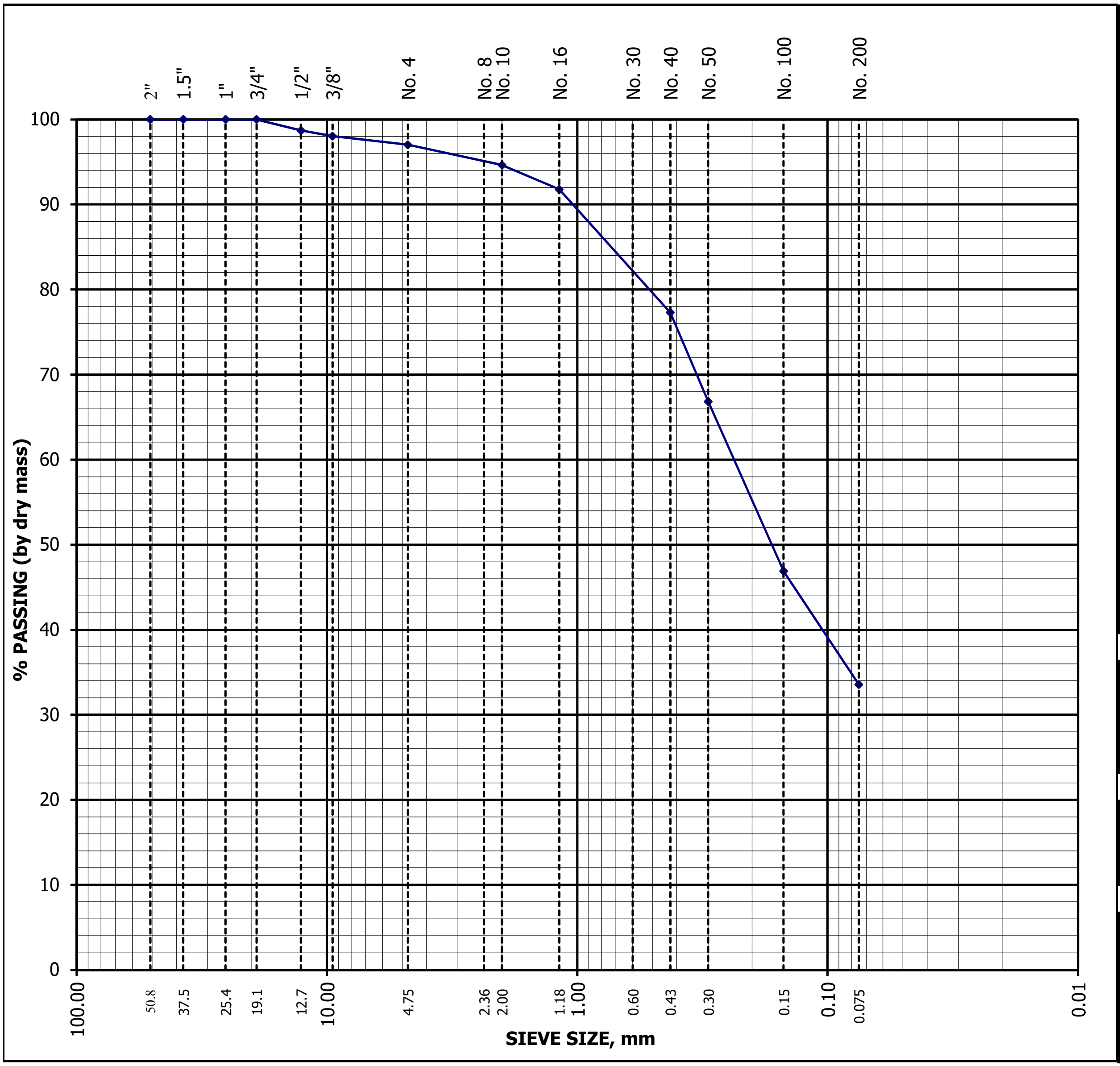
| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822646
Sample Location: SBP-3 at 1' to 3'
Visual Description: SAND, clayey, with silt, brown

Date: 25-Sep-18
Technician: J. Holiman
Reviewer: J. Crystal

**AASHTO M 145 Classification:** A-2-4 **Group Index:** (0)
**Unified Soil Classification System (ASTM D 2487):** (SC-SM) Silty, clayey sand



| Sieve Size | % Passing |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | 100 |
| 1/2" | 99 |
| 3/8" | 98 |
| #4 | 97 |
| #8 | |
| #10 | 95 |
| #16 | 92 |
| #30 | |
| #40 | 77 |
| #50 | 67 |
| #100 | 47 |
| #200 | 33.6 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 2.0 |
| D, pcf: | |

| | |
|---|---|
| **LL** | 24 |
| PL | 20 |
| **PI** | 4 |

| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

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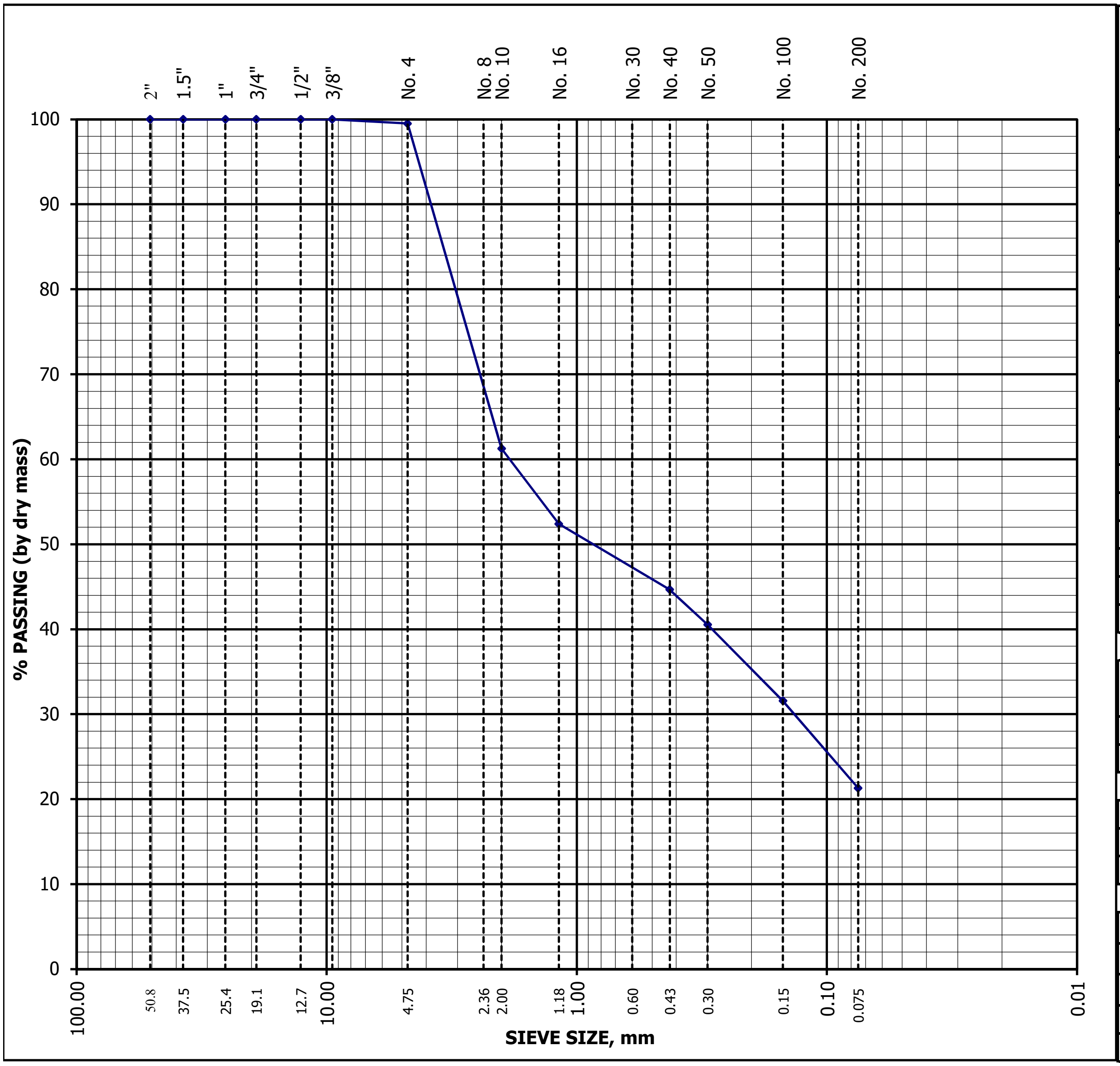
# GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822647
Sample Location: SBP-3 at 6' to 8'
Visual Description: SAND, clayey, red brown

Date: 6-Oct-18
Technician: J. Holiman
Reviewer: J. Crystal

**AASHTO M 145 Classification: A-2-4 Group Index: (0)**
**Unified Soil Classification System**
**(ASTM D 2487): (SC) Clayey sand**



| **Sieve Size** | **% Passing** |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | |
| 1/2" | |
| 3/8" | 100 |
| #4 | 100 |
| #8 | |
| #10 | 61 |
| #16 | 52 |
| #30 | |
| #40 | 45 |
| #50 | 41 |
| #100 | 32 |
| #200 | 21.3 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 6.0 |
| D, pcf: | |

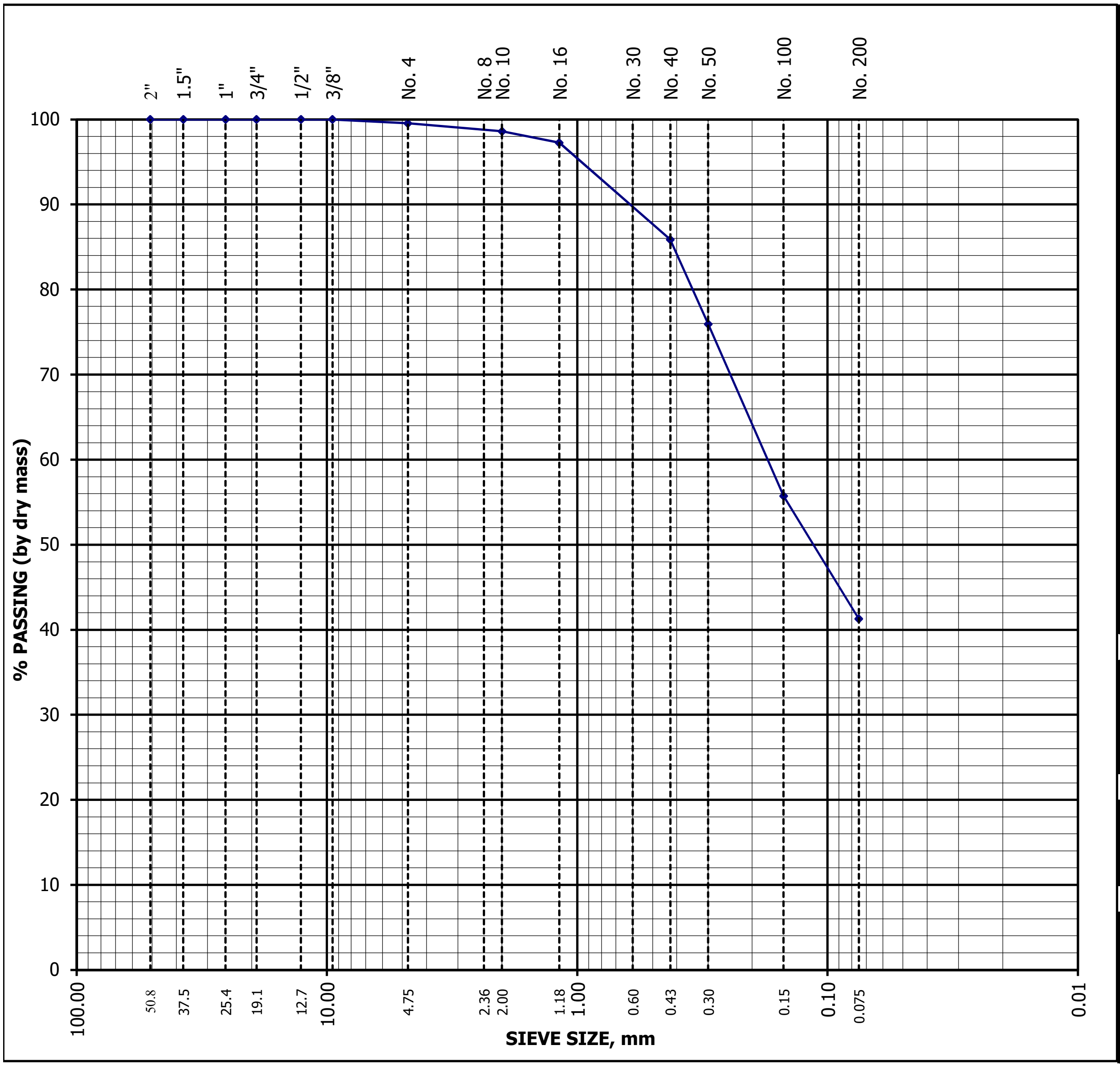
| | |
|---|---|
| **LL** | 28 |
| PL | 19 |
| **PI** | 9 |

| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

## GRADATION PLOT - SOIL & AGGREGATE

| | | | |
|---|---|---|---|
| Project Number: | 18.117, Applegate Group | Date: | 25-Sep-18 |
| Project Name: | Cucharas Basin Collaborative Storage | Technician: | J. Holiman |
| Lab ID Number: | 1822648 | Reviewer: | J. Crystal |
| Sample Location: | SBP-5 at 1' to 3' | | |
| Visual Description: | SAND, silty, clayey, brown | | |

**AASHTO M 145 Classification:** A-4 **Group Index:** (0)
**Unified Soil Classification System**
**(ASTM D 2487):** (SC-SM) Silty, clayey sand



| Sieve Size | % Passing |
|---|---|
| | |
| | |
| | |
| 2" | |
| 1.5" | |
| 1" | |
| 3/4" | |
| 1/2" | |
| 3/8" | 100 |
| #4 | 100 |
| #8 | |
| #10 | 99 |
| #16 | 97 |
| #30 | |
| #40 | 86 |
| #50 | 76 |
| #100 | 56 |
| #200 | 41.3 |

| Moisture (M) & Density (D) | |
|---|---|
| M, %: | 6.1 |
| D, pcf: | |

| | |
|---|---|
| **LL** | 27 |
| PL | 21 |
| **PI** | 6 |

| | |
|---|---|
| $D_{60}$ | |
| $D_{30}$ | |
| $D_{10}$ | |
| **Cu** | |
| **Cc** | |

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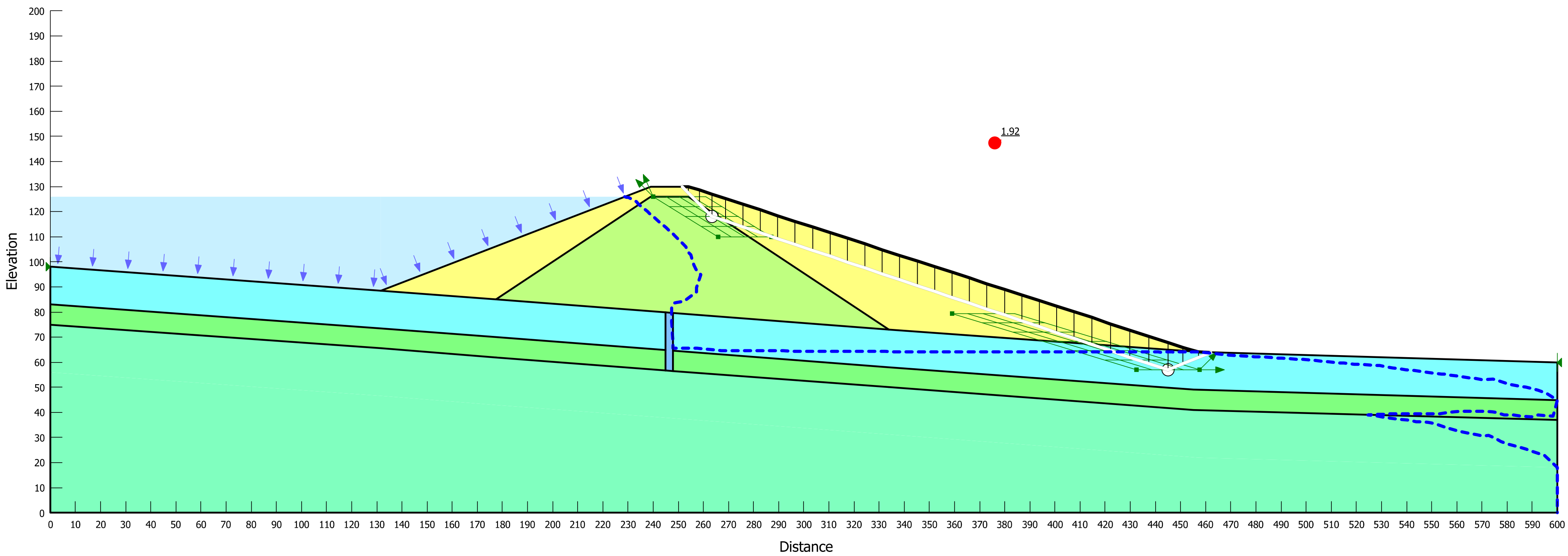
# APPENDIX D

## Stability Analysis Results

# CUCHARAS BASIN COLLABORATIVE STORAGE
# PROJECT NO. 18.117

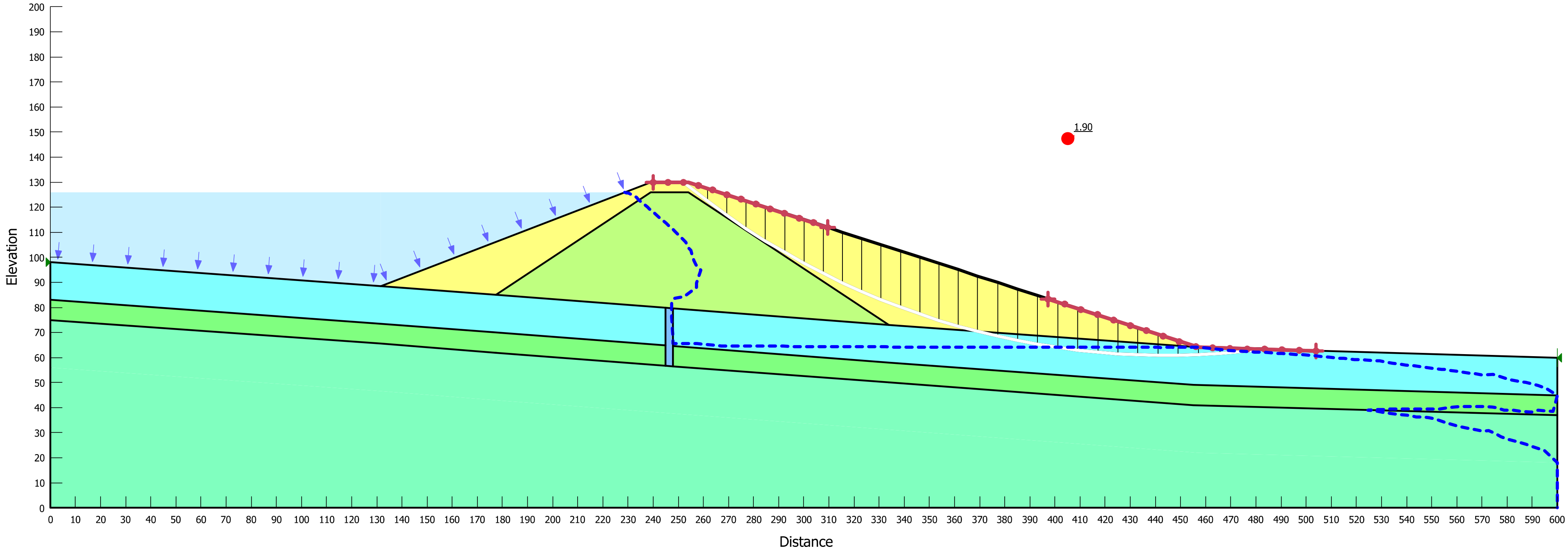


| Color | Name | Model | Unit Weight (pcf) | Cohesion' (psf) | Phi' (°) | Phi-B (°) |
|---|---|---|---|---|---|---|
| 🟩 | **Claystone** | **Mohr-Coulomb** | **135** | **3,000** | **0** | **0** |
| 🟩 | **Core** | **Mohr-Coulomb** | **125** | **25** | **30** | **0** |
| 🟦 | **Cutoff** | **Mohr-Coulomb** | **125** | **10** | **11** | **0** |
| 🟦 | **Overburden** | **Mohr-Coulomb** | **130** | **10** | **30** | **0** |
| 🟩 | **Sandstone** | **Mohr-Coulomb** | **140** | **3,000** | **0** | **0** |
| 🟨 | **Shell** | **Mohr-Coulomb** | **132** | **25** | **30** | **0** |

## Steady State Seepage Stability, Block Failure

## Britton

# CUCHARAS BASIN COLLABORATIVE STORAGE
# PROJECT NO. 18.117

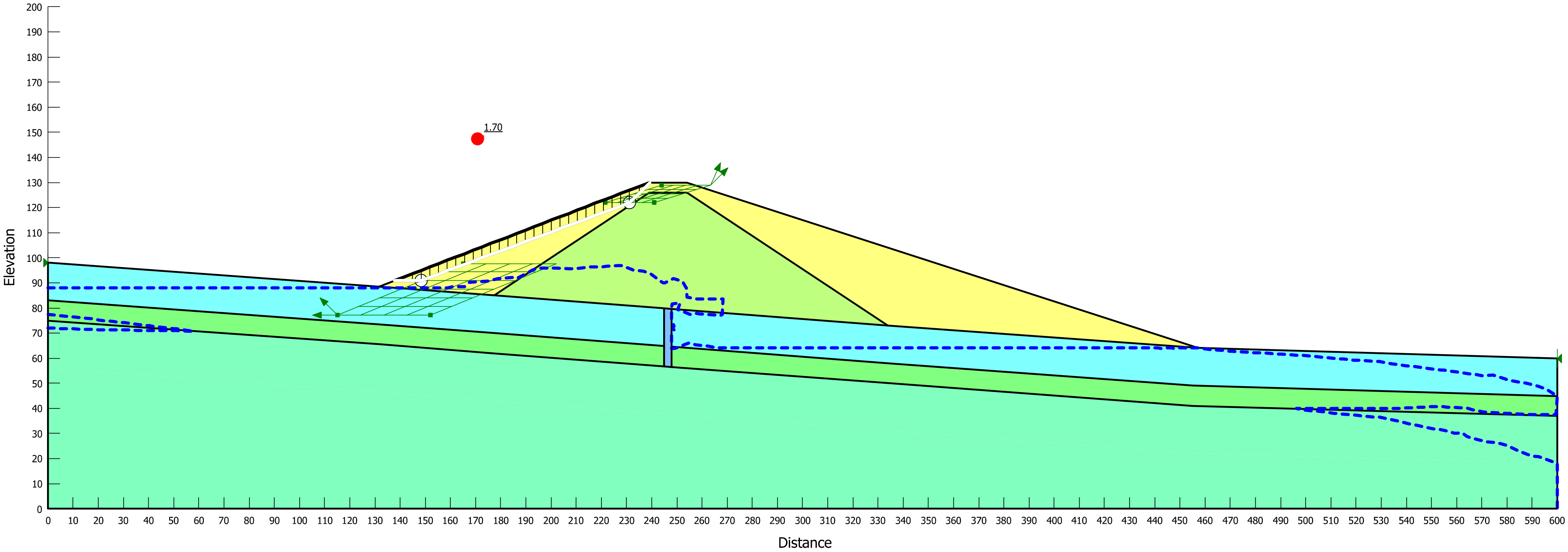


| Color | Name | Model | Unit Weight (pcf) | Cohesion' (psf) | Phi' (°) | Phi-B (°) |
|---|---|---|---|---|---|---|
| 🟩 | **Claystone** | **Mohr-Coulomb** | **135** | **3,000** | **0** | **0** |
| 🟩 | **Core** | **Mohr-Coulomb** | **125** | **25** | **30** | **0** |
| 🟦 | **Cutoff** | **Mohr-Coulomb** | **125** | **10** | **11** | **0** |
| 🟦 | **Overburden** | **Mohr-Coulomb** | **130** | **10** | **30** | **0** |
| 🟩 | **Sandstone** | **Mohr-Coulomb** | **140** | **3,000** | **0** | **0** |
| 🟨 | **Shell** | **Mohr-Coulomb** | **132** | **25** | **30** | **0** |

## Steady State Seepage Stability, Circular Failure

## Britton

# CUCHARAS BASIN COLLABORATIVE STORAGE
# PROJECT NO. 18.117

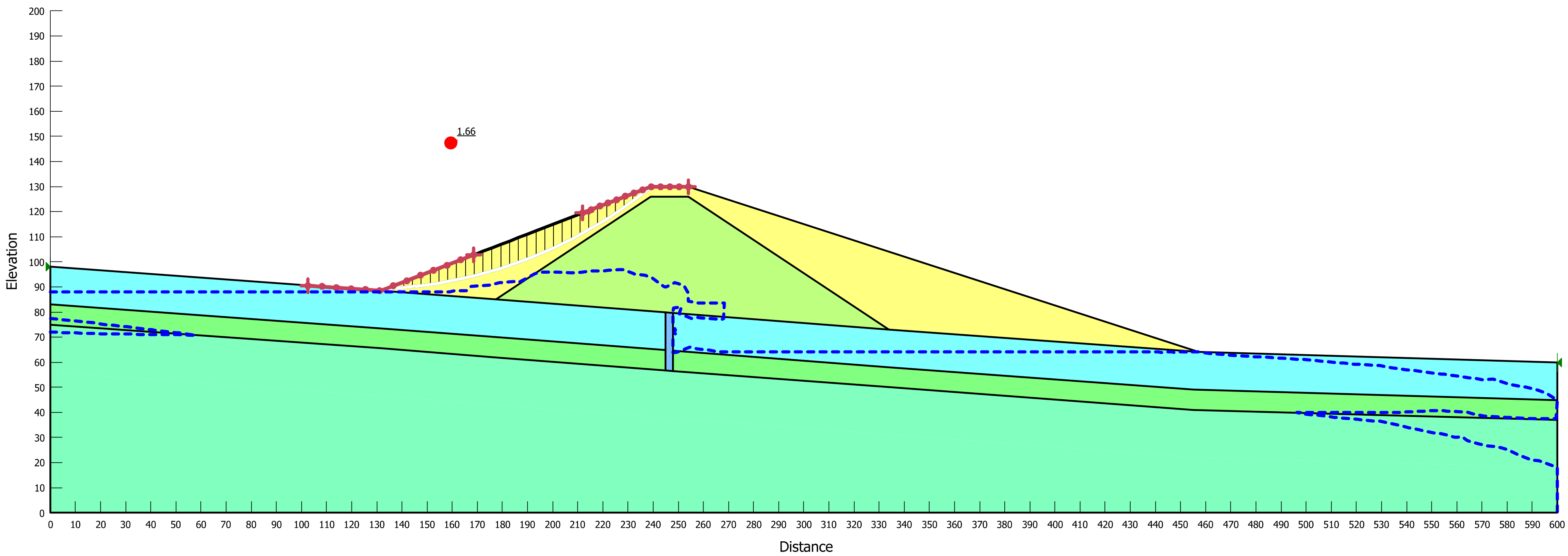


| Color | Name | Model | Unit Weight (pcf) | Cohesion' (psf) | Phi' (°) | Phi-B (°) |
|---|---|---|---|---|---|---|
| 🟩 | **Claystone** | **Mohr-Coulomb** | **135** | **3,000** | **0** | **0** |
| 🟩 | **Core** | **Mohr-Coulomb** | **125** | **25** | **30** | **0** |
| 🟦 | **Cutoff** | **Mohr-Coulomb** | **125** | **10** | **11** | **0** |
| 🟦 | **Overburden** | **Mohr-Coulomb** | **130** | **10** | **30** | **0** |
| 🟩 | **Sandstone** | **Mohr-Coulomb** | **140** | **3,000** | **0** | **0** |
| 🟨 | **Shell** | **Mohr-Coulomb** | **132** | **25** | **30** | **0** |

## Transient Seepage Stability, Block Failure, Eleventh Day

**Britton**

# CUCHARAS BASIN COLLABORATIVE STORAGE
# PROJECT NO. 18.117

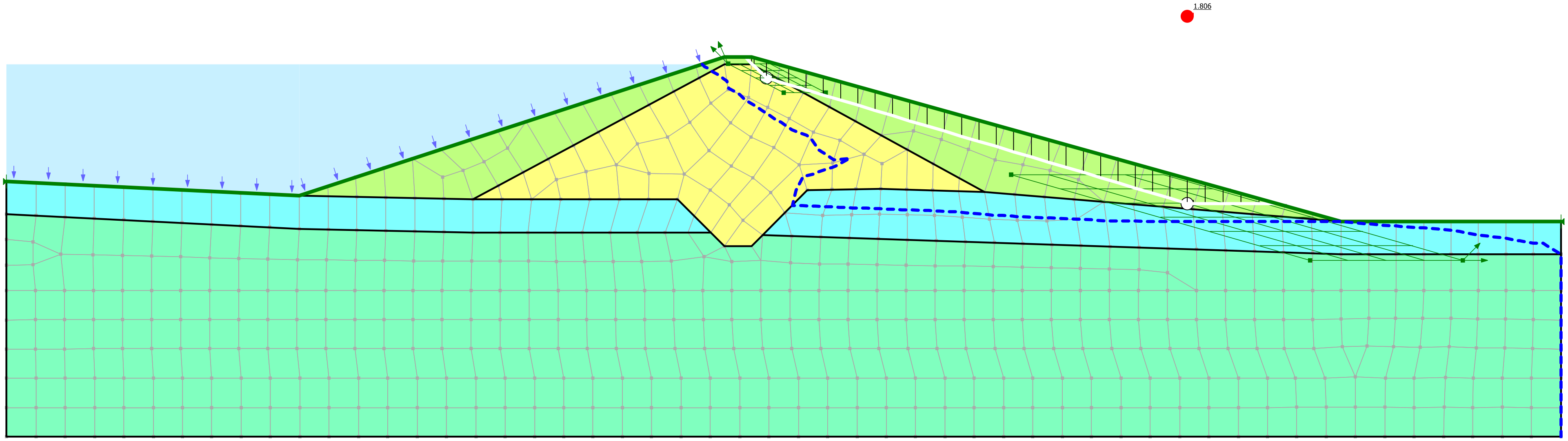


| Color | Name | Model | Unit Weight (pcf) | Cohesion' (psf) | Phi' (°) | Phi-B (°) |
|---|---|---|---|---|---|---|
| 🟩 | **Claystone** | **Mohr-Coulomb** | **135** | **3,000** | **0** | **0** |
| 🟩 | **Core** | **Mohr-Coulomb** | **125** | **25** | **30** | **0** |
| 🟦 | **Cutoff** | **Mohr-Coulomb** | **125** | **10** | **11** | **0** |
| 🟦 | **Overburden** | **Mohr-Coulomb** | **130** | **10** | **30** | **0** |
| 🟩 | **Sandstone** | **Mohr-Coulomb** | **140** | **3,000** | **0** | **0** |
| 🟨 | **Shell** | **Mohr-Coulomb** | **132** | **25** | **30** | **0** |

**Transient Seepage Stability, Circular Failure, Twentieth Day**

**Britton**

# CUCHARAS BASIN COLLABORATIVE STORAGE
## PROJECT NO. 18.117

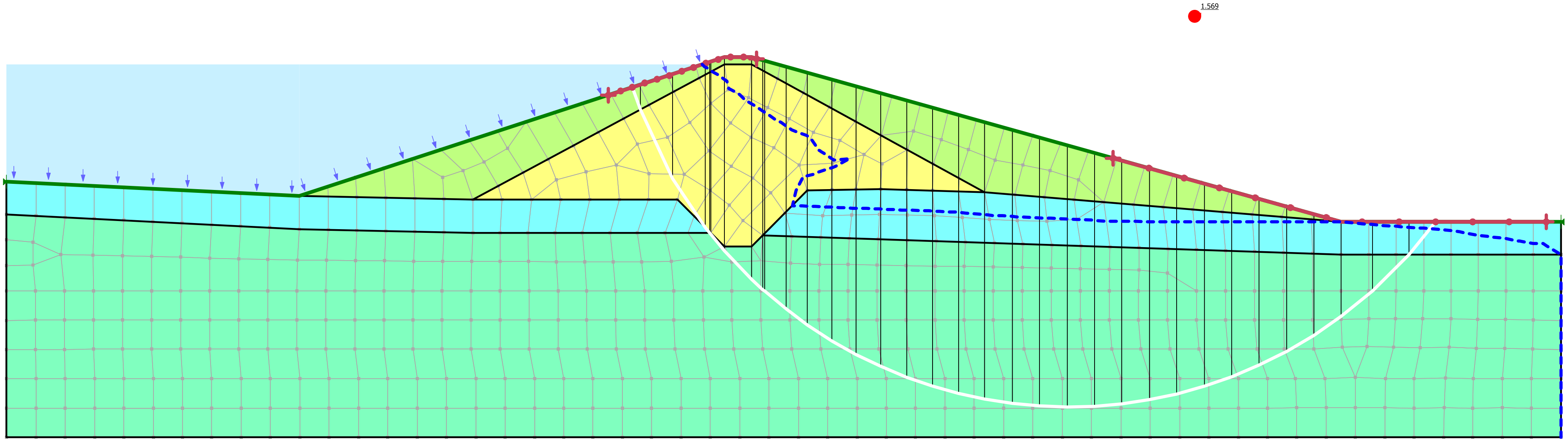


| Color | Name | Model | Unit Weight (pcf) | Cohesion' (psf) | Phi' (°) | Phi-B (°) |
|---|---|---|---|---|---|---|
| 🟨 | Core | Mohr-Coulomb | 125 | 25 | 25 | 0 |
| 🟦 | Gravel | Mohr-Coulomb | 132 | 10 | 35 | 0 |
| 🟩 | Sandstone | Mohr-Coulomb | 140 | 3,000 | 0 | 0 |
| 🟩 | Shell | Mohr-Coulomb | 125 | 25 | 25 | 0 |

**Steady State Seepage Stability, Block Failure**

**Bruce Canyon**

# CUCHARAS BASIN COLLABORATIVE STORAGE
## PROJECT NO. 18.117

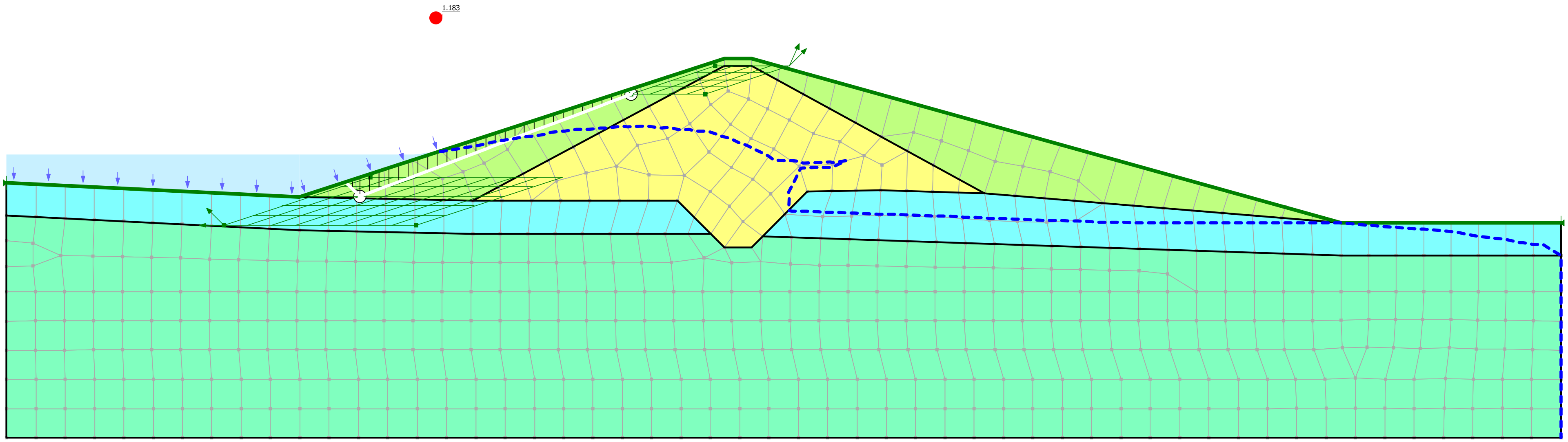


| Color | Name | Model | Unit Weight (pcf) | Cohesion' (psf) | Phi' (°) | Phi-B (°) |
|---|---|---|---|---|---|---|
| 🟨 | Core | Mohr-Coulomb | 125 | 25 | 25 | 0 |
| 🟦 | Gravel | Mohr-Coulomb | 132 | 10 | 35 | 0 |
| 🟩 | Sandstone | Mohr-Coulomb | 140 | 3,000 | 0 | 0 |
| 🟩 | Shell | Mohr-Coulomb | 125 | 25 | 25 | 0 |

**Steady State Seepage Stability, Circular Failure**

**Bruce Canyon**

# CUCHARAS BASIN COLLABORATIVE STORAGE
## PROJECT NO. 18.117

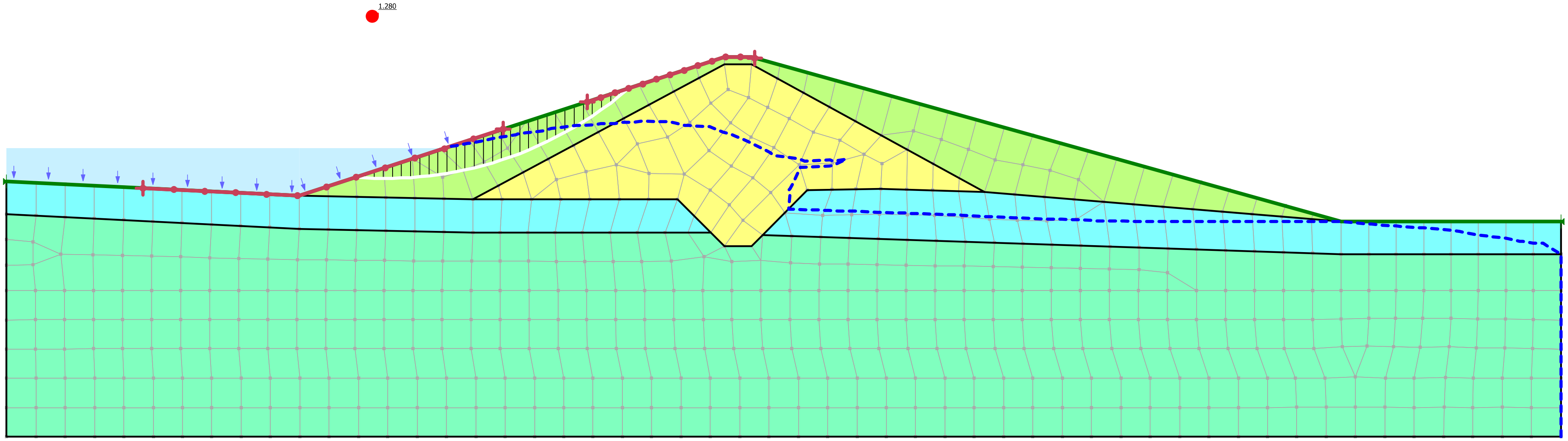


| Color | Name | Model | Unit Weight (pcf) | Cohesion' (psf) | Phi' (°) | Phi-B (°) |
|---|---|---|---|---|---|---|
| 🟨 | Core | Mohr-Coulomb | 125 | 25 | 25 | 0 |
| 🟦 | Gravel | Mohr-Coulomb | 132 | 10 | 35 | 0 |
| 🟩 | Sandstone | Mohr-Coulomb | 140 | 3,000 | 0 | 0 |
| 🟩 | Shell | Mohr-Coulomb | 125 | 25 | 25 | 0 |

**Transient Seepage Stability, Block Failure, 52nd Day**

**Bruce Canyon**

# CUCHARAS BASIN COLLABORATIVE STORAGE
# PROJECT NO. 18.117

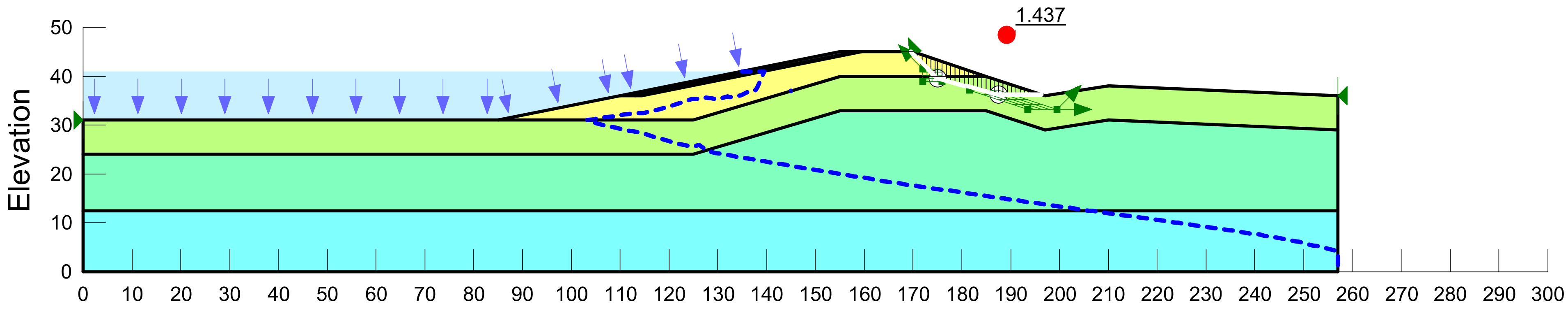


| Color | Name | Model | Unit Weight (pcf) | Cohesion' (psf) | Phi' (°) | Phi-B (°) |
|---|---|---|---|---|---|---|
| 🟨 | Core | Mohr-Coulomb | 125 | 25 | 25 | 0 |
| 🟦 | Gravel | Mohr-Coulomb | 132 | 10 | 35 | 0 |
| 🟩 | Sandstone | Mohr-Coulomb | 140 | 3,000 | 0 | 0 |
| 🟩 | Shell | Mohr-Coulomb | 125 | 25 | 25 | 0 |

**Transient Seepage Stability, Circular Failure, 48th Day**

**Bruce Canyon**

# CUCHARAS BASIN COLLABORATIVE STORAGE
## PROJECT NO. 18.117

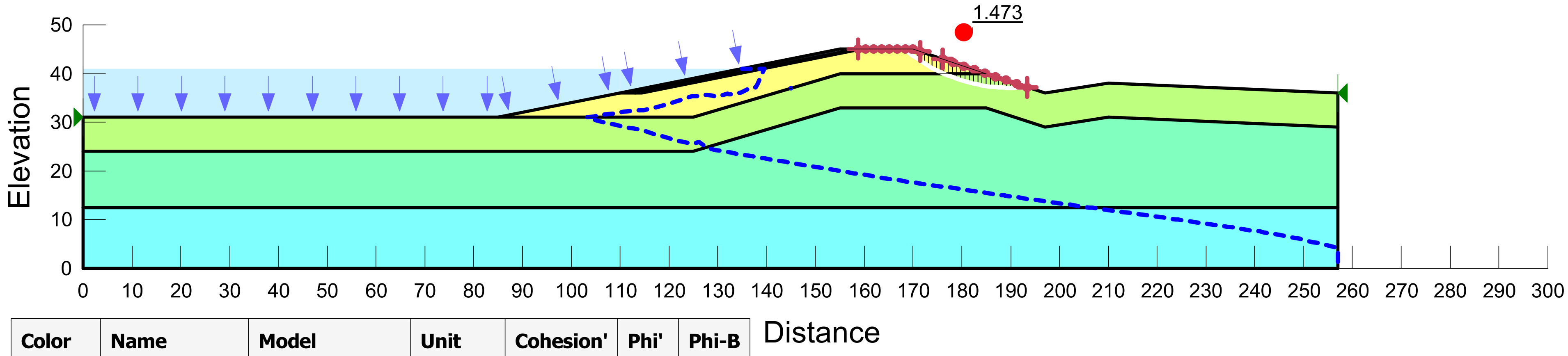


| Color | Name | Model | Unit Weight (pcf) | Cohesion' (psf) | Phi' (°) | Phi-B (°) |
|---|---|---|---|---|---|---|
| 🟨 | Clay Embankment | Mohr-Coulomb | 125 | 25 | 25 | 0 |
| 🟦 | Claystone | Mohr-Coulomb | 135 | 3,000 | 0 | 0 |
| 🟩 | Existing Fill | Mohr-Coulomb | 115 | 10 | 20 | 0 |
| 🟩 | Native Clay | Mohr-Coulomb | 115 | 10 | 15 | 0 |
| 🟦 | Rip Rap | Mohr-Coulomb | 135 | 10 | 40 | 0 |
| 🟩 | Sand Bedding | Mohr-Coulomb | 125 | 10 | 30 | 0 |

**Steady State Seepage Stability, Block Failure**

**Maria Stevens South**

# CUCHARAS BASIN COLLABORATIVE STORAGE
## PROJECT NO. 18.117

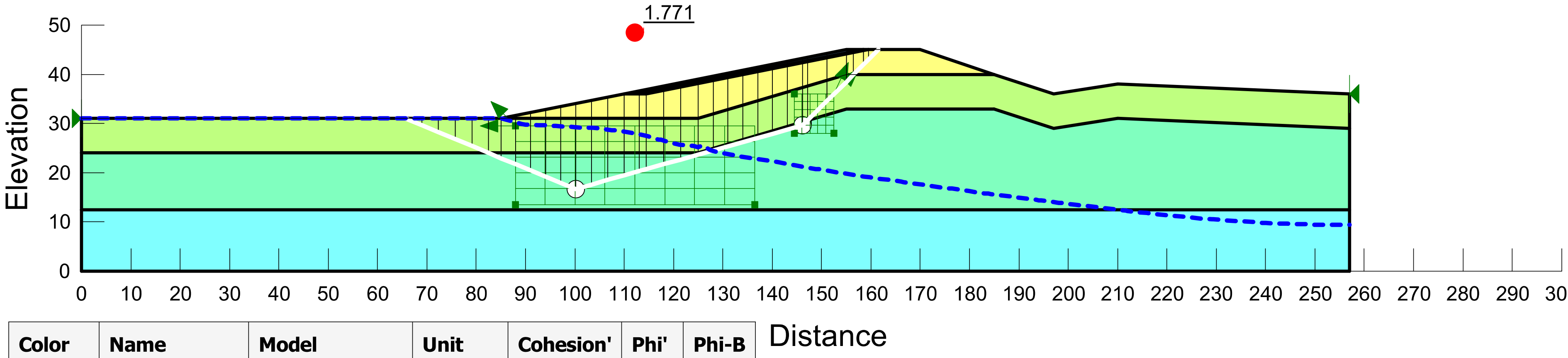


| Color | Name | Model | Unit Weight (pcf) | Cohesion' (psf) | Phi' (°) | Phi-B (°) |
|---|---|---|---|---|---|---|
| 🟨 | Clay Embankment | Mohr-Coulomb | 125 | 25 | 25 | 0 |
| 🟦 | Claystone | Mohr-Coulomb | 135 | 3,000 | 0 | 0 |
| 🟩 | Existing Fill | Mohr-Coulomb | 115 | 10 | 20 | 0 |
| 🟩 | Native Clay | Mohr-Coulomb | 115 | 10 | 15 | 0 |
| 🟦 | Rip Rap | Mohr-Coulomb | 135 | 10 | 40 | 0 |
| 🟩 | Sand Bedding | Mohr-Coulomb | 125 | 10 | 30 | 0 |

**Steady State Seepage Stability, Circular Failure**

**Maria Stevens South**

# CUCHARAS BASIN COLLABORATIVE STORAGE
# PROJECT NO. 18.117

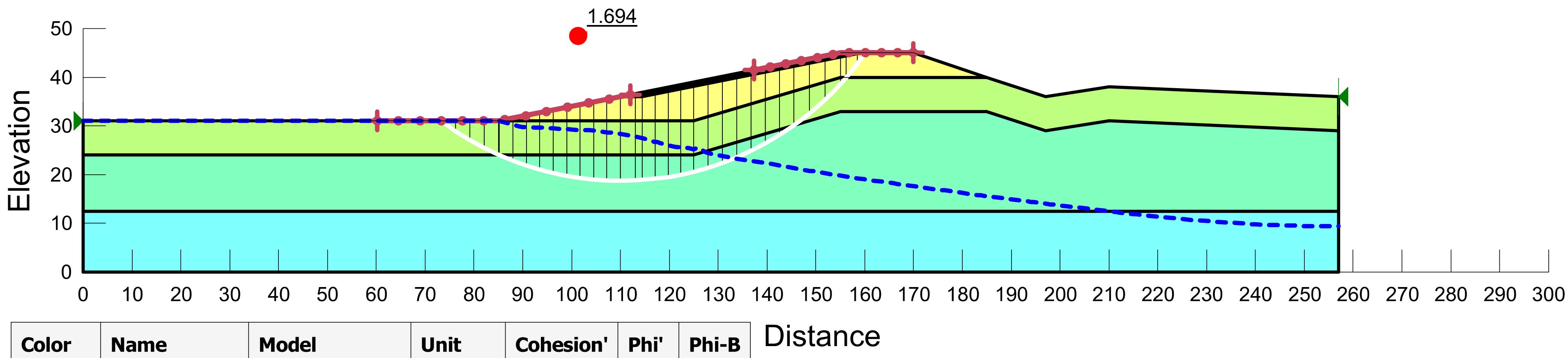


| Color | Name | Model | Unit Weight (pcf) | Cohesion' (psf) | Phi' (°) | Phi-B (°) |
|---|---|---|---|---|---|---|
| 🟨 | **Clay Embankment** | **Mohr-Coulomb** | **125** | **25** | **25** | **0** |
| 🟦 | **Claystone** | **Mohr-Coulomb** | **135** | **3,000** | **0** | **0** |
| 🟩 | **Existing Fill** | **Mohr-Coulomb** | **115** | **10** | **20** | **0** |
| 🟩 | **Native Clay** | **Mohr-Coulomb** | **115** | **10** | **15** | **0** |
| 🟦 | **Rip Rap** | **Mohr-Coulomb** | **135** | **10** | **40** | **0** |
| 🟩 | **Sand Bedding** | **Mohr-Coulomb** | **125** | **10** | **30** | **0** |

**Transient Seepage Stability, Block Failure, Tenth Day**

**Maria Stevens South**

# CUCHARAS BASIN COLLABORATIVE STORAGE
# PROJECT NO. 18.117

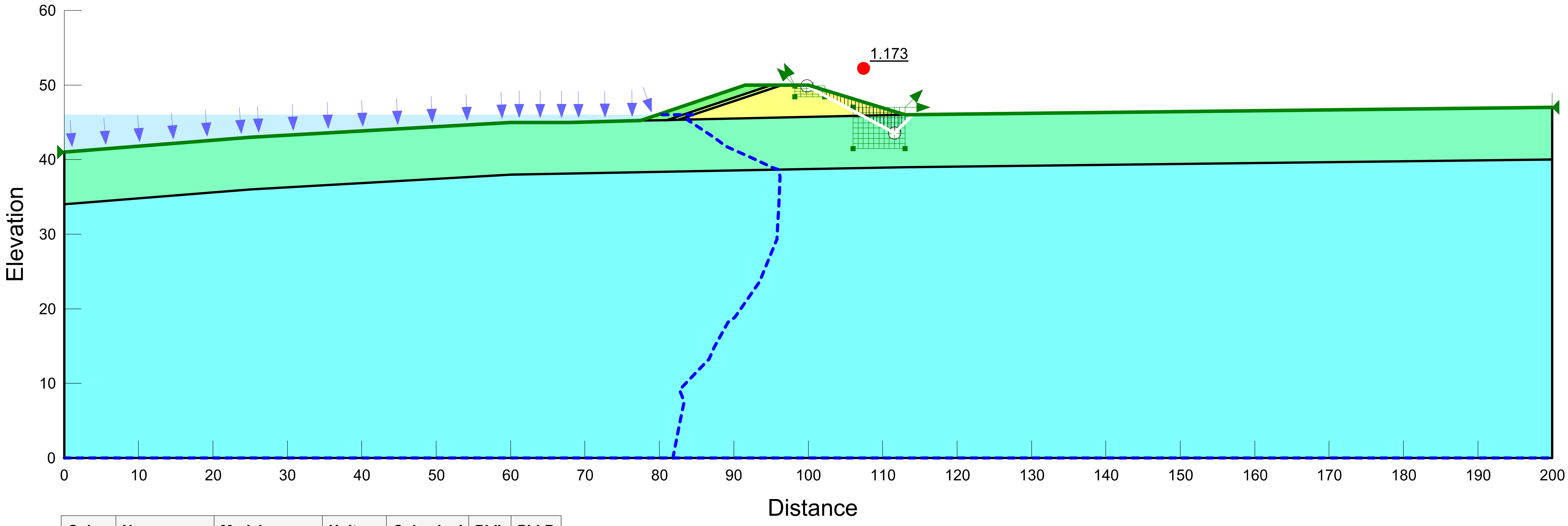


| Color | Name | Model | Unit Weight (pcf) | Cohesion' (psf) | Phi' (°) | Phi-B (°) |
|---|---|---|---|---|---|---|
| 🟨 | Clay Embankment | Mohr-Coulomb | 125 | 25 | 25 | 0 |
| 🟦 | Claystone | Mohr-Coulomb | 135 | 3,000 | 0 | 0 |
| 🟩 | Existing Fill | Mohr-Coulomb | 115 | 10 | 20 | 0 |
| 🟩 | Native Clay | Mohr-Coulomb | 115 | 10 | 15 | 0 |
| 🟦 | Rip Rap | Mohr-Coulomb | 135 | 10 | 40 | 0 |
| 🟩 | Sand Bedding | Mohr-Coulomb | 125 | 10 | 30 | 0 |

**Transient Seepage Stability, Circular Failure, Tenth Day**

**Maria Stevens South**

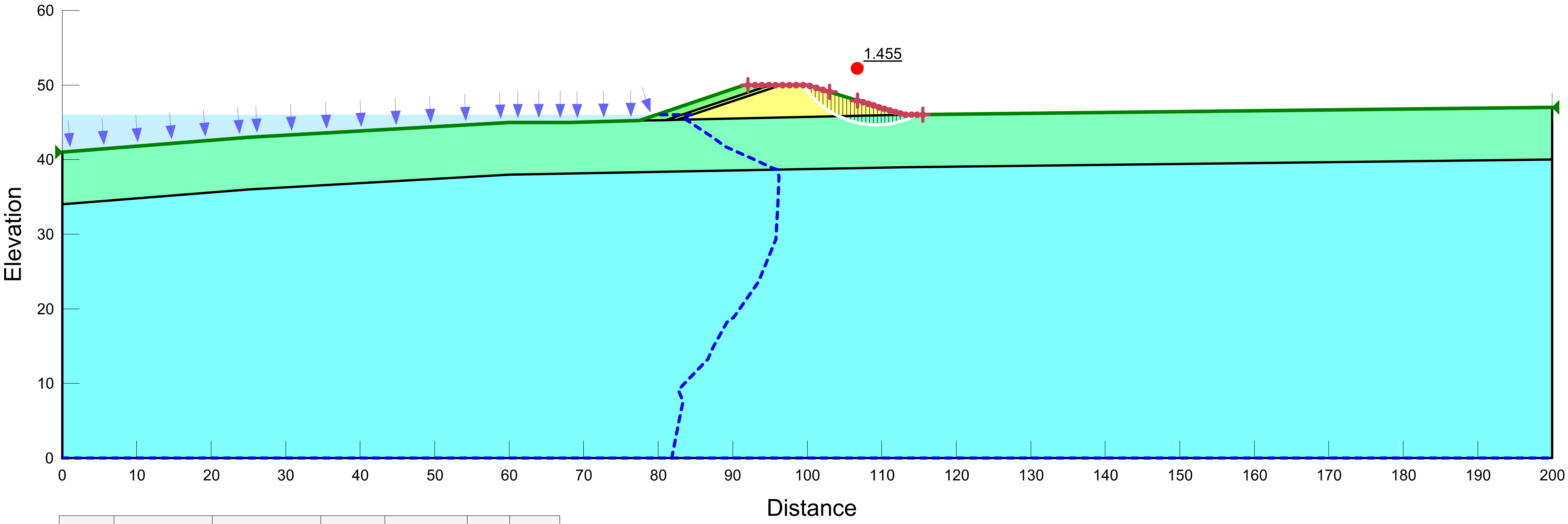
## CUCHARAS BASIN COLLABORATIVE STORAGE
## PROJECT NO. 18.117



| Color | Name | Model | Unit Weight (pcf) | Cohesion' (psf) | Phi' (°) | Phi-B (°) |
|---|---|---|---|---|---|---|
| 🟨 | Clay Embankment | Mohr-Coulomb | 125 | 25 | 25 | 0 |
| 🟦 | Claystone | Mohr-Coulomb | 135 | 3,000 | 0 | 0 |
| 🟩 | Native Clay | Mohr-Coulomb | 115 | 0 | 15 | 0 |
| 🟩 | Rip Rap | Mohr-Coulomb | 135 | 10 | 40 | 0 |
| 🟩 | Sand Bedding | Mohr-Coulomb | 125 | 10 | 30 | 0 |

Steady State Seepage, Block Failure Stability Analysis
Maria Stevens West.gsz
10/24/2018 1:159

# CUCHARAS BASIN COLLABORATIVE STORAGE
# PROJECT NO. 18.117



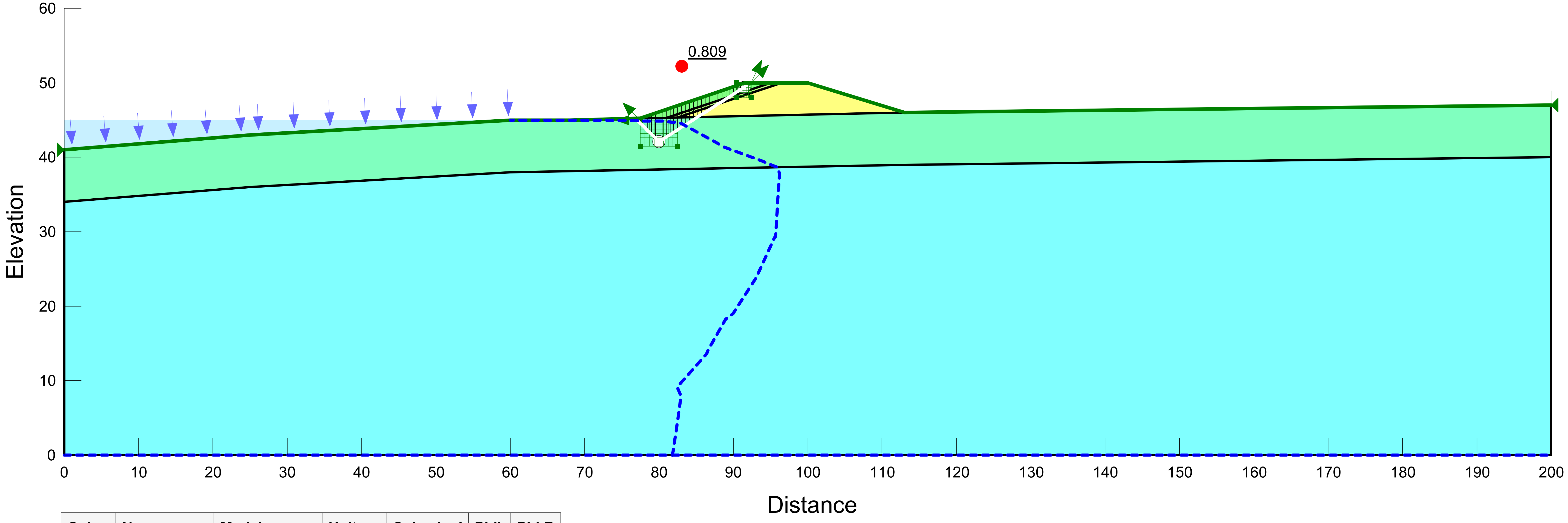
| Color | Name | Model | Unit Weight (pcf) | Cohesion' (psf) | Phi' (°) | Phi-B (°) |
|---|---|---|---|---|---|---|
| 🟨 | Clay Embankment | Mohr-Coulomb | 125 | 25 | 25 | 0 |
| 🟦 | Claystone | Mohr-Coulomb | 135 | 3,000 | 0 | 0 |
| 🟩 | Native Clay | Mohr-Coulomb | 115 | 0 | 15 | 0 |
| 🟩 | Rip Rap | Mohr-Coulomb | 135 | 10 | 40 | 0 |
| 🟩 | Sand Bedding | Mohr-Coulomb | 125 | 10 | 30 | 0 |

Transient Seepage, First Day Circular Failure Stability Analysis

Maria Stevens West.gsz

10/24/2018 1:159

## CUCHARAS BASIN COLLABORATIVE STORAGE
## PROJECT NO. 18.117



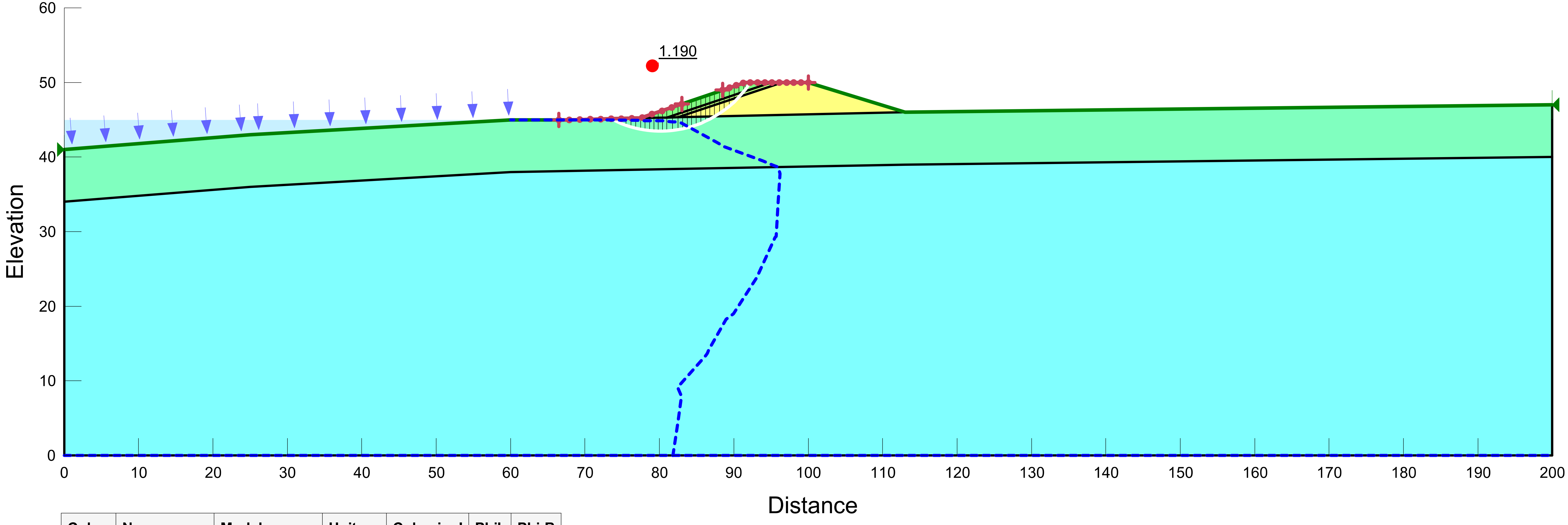
| Color | Name | Model | Unit Weight (pcf) | Cohesion' (psf) | Phi' (°) | Phi-B (°) |
|---|---|---|---|---|---|---|
| 🟨 | Clay Embankment | Mohr-Coulomb | 125 | 25 | 25 | 0 |
| 🟦 | Claystone | Mohr-Coulomb | 135 | 3,000 | 0 | 0 |
| 🟩 | Native Clay | Mohr-Coulomb | 115 | 0 | 15 | 0 |
| 🟩 | Rip Rap | Mohr-Coulomb | 135 | 10 | 40 | 0 |
| 🟩 | Sand Bedding | Mohr-Coulomb | 125 | 10 | 30 | 0 |

Transient Seepage, First Day Circular Failure Stability Analysis

Maria Stevens West.gsz

10/24/2018 1:159

## CUCHARAS BASIN COLLABORATIVE STORAGE
## PROJECT NO. 18.117



| Color | Name | Model | Unit Weight (pcf) | Cohesion' (psf) | Phi' (°) | Phi-B (°) |
|---|---|---|---|---|---|---|
| 🟨 | Clay Embankment | Mohr-Coulomb | 125 | 25 | 25 | 0 |
| 🟦 | Claystone | Mohr-Coulomb | 135 | 3,000 | 0 | 0 |
| 🟩 | Native Clay | Mohr-Coulomb | 115 | 0 | 15 | 0 |
| 🟩 | Rip Rap | Mohr-Coulomb | 135 | 10 | 40 | 0 |
| 🟩 | Sand Bedding | Mohr-Coulomb | 125 | 10 | 30 | 0 |

Transient Seepage, First Day Circular Failure Stability Analysis

Maria Stevens West.gsz

10/24/2018 1:159

# APPENDIX B

# 30% DESIGN DRAWINGS

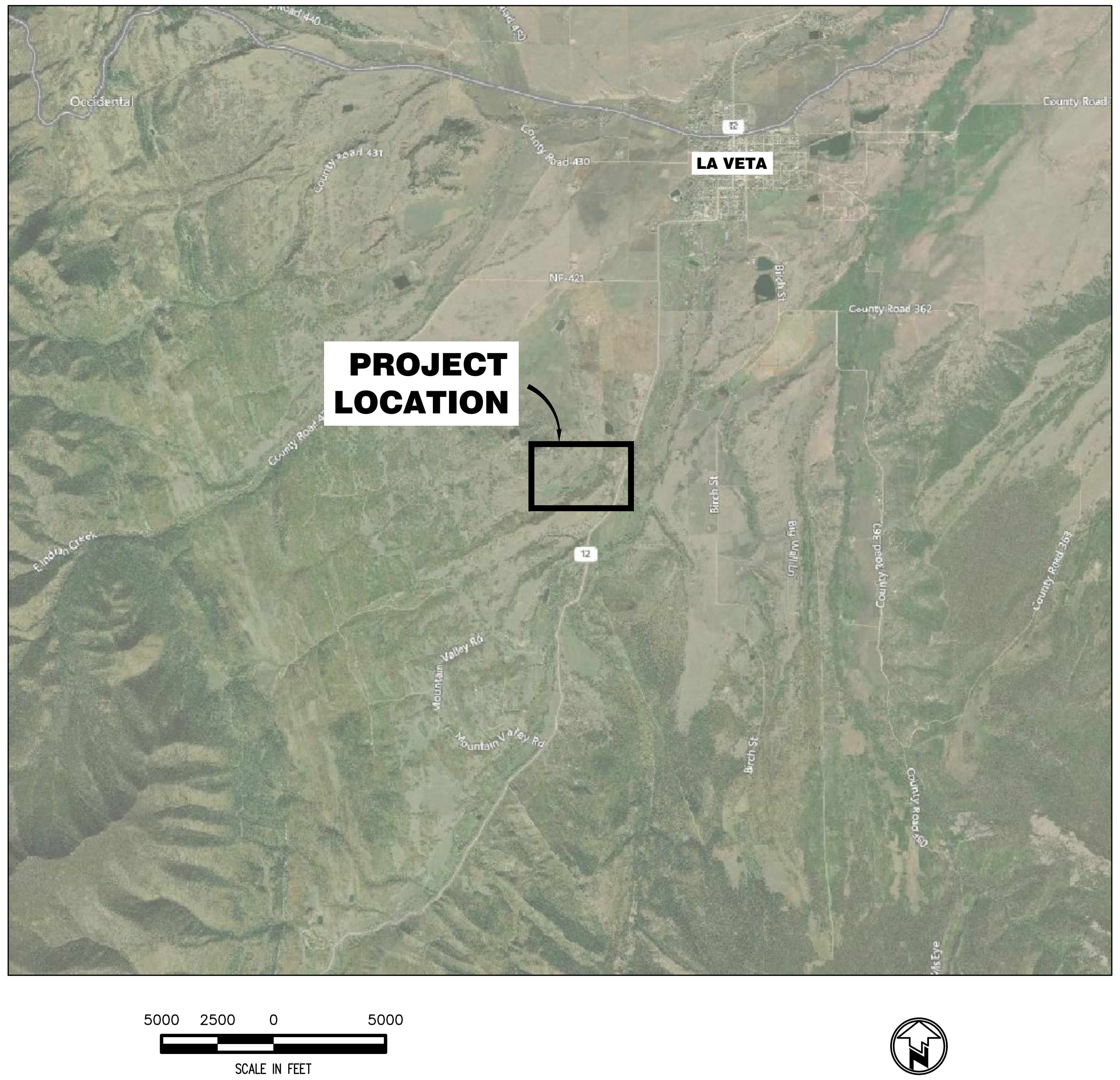
# CUCHARAS COLLABORATIVE
# BRUCE CANYON DAM
# CONSTRUCTION PLANS
# HUERFANO COUNTY, COLORADO

## JANUARY, 2020

**OWNER:** HUERFANO COUNTY WATER
CONSERVANCY DISTRICT
P.O. BOX 442
LA VETA, CO 80155
(719) 989-7259

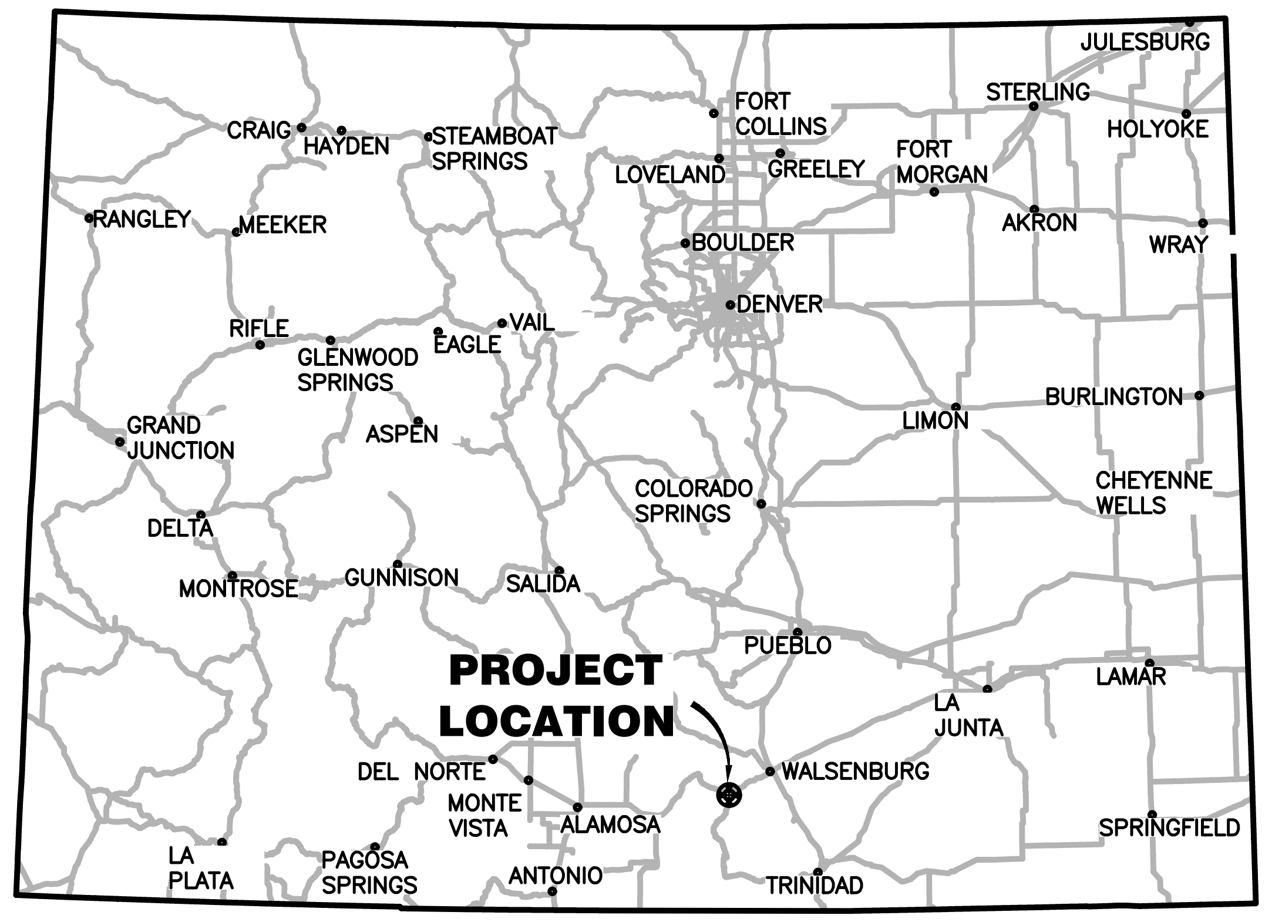
**ENGINEER:** APPLEGATE GROUP, INC.
1490 W. 121st AVENUE
SUITE 100
DENVER, CO 80234
(303) 452-6611

**VICINITY MAP**
SCALE 1" = 5000'



Sheet List Table

| Sheet Number | Sheet Title |
|---|---|
| 1 | COVER SHEET |
| 2 | SITE PLAN |
| 3 | DAM PLAN AND PROFILE |
| 4 | SPILLWAY PLAN AND PROFILE |
| 5 | GEOTECHNICAL DATA |



**LOCATION MAP**
NOT TO SCALE

**30% DESIGN**

I hereby certify that these plans for the Bruce Canyon Dam were prepared by me or under my direct supervision for the Cucharaes Collaborative.

_______________________________Colo. PE No. 43364
Steven A. Smith, P.E.

30% DESIGN DRAWINGS:
NOT FOR CONSTRUCTION

**Applegate Group, Inc.**
Water Resource Advisors for the West
1490 West 121st Ave., Suite 100
Denver, CO 80234
(303) 452-6611
Fax: (303) 452-2759
email: info@applegategroup.com Website: www.applegategroup.com

**PROPOSED BRUCE DAM LOCATION**

**COVER SHEET**

**CUCHARAS COLLABORATIVE**

REVISIONS

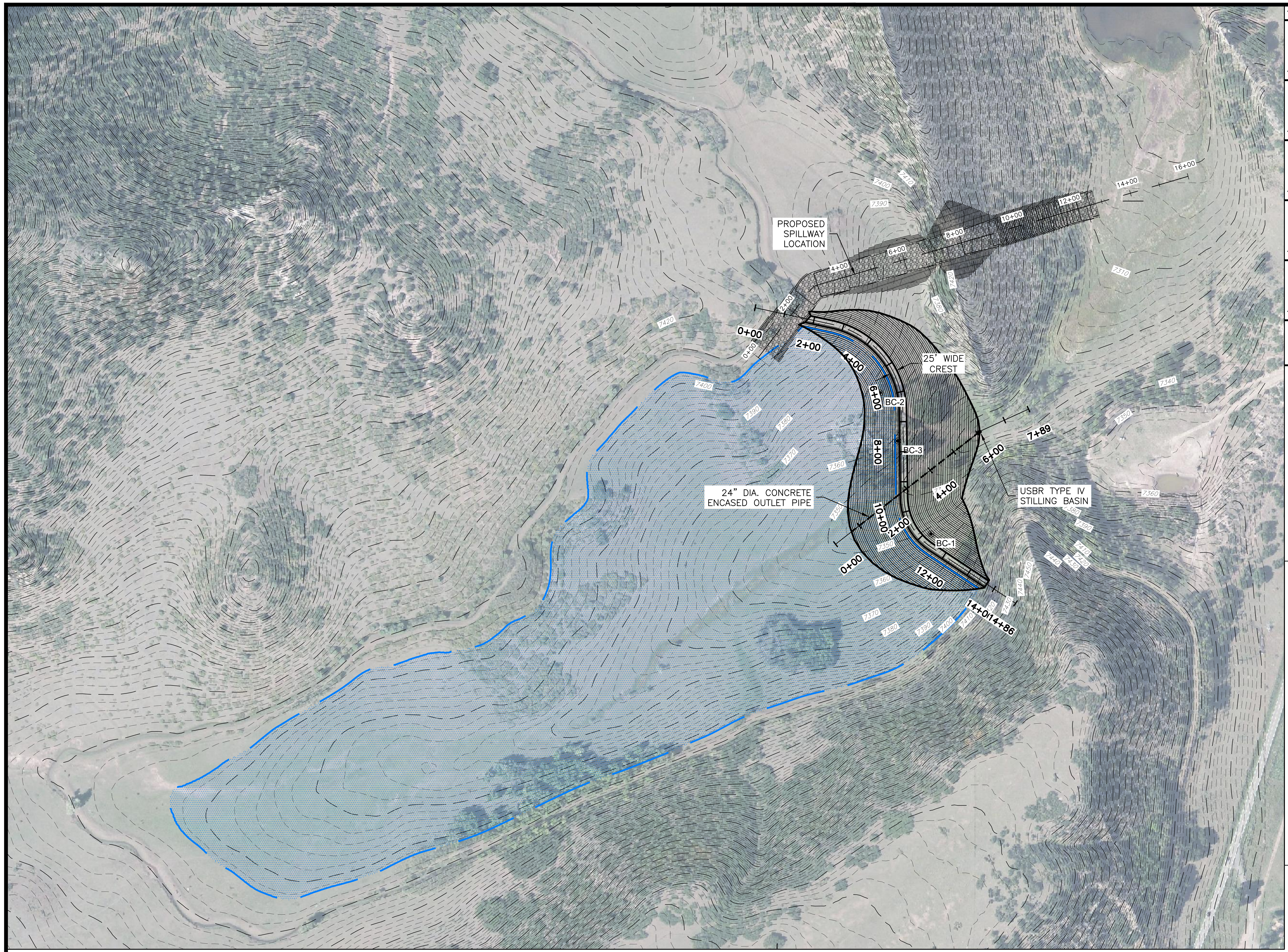
| NO | DATE | BY | CHK'D | DESCRIPTION |
|---|---|---|---|---|
| | | | | |

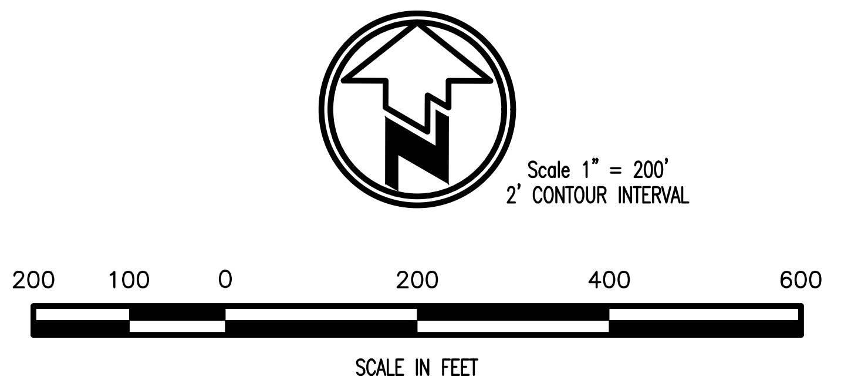
Date: 30/JAN/20
Job No: 16-106
Drawn: LD
Design:
Checked:
Scale: As Noted

Sheet: **1**
Of:

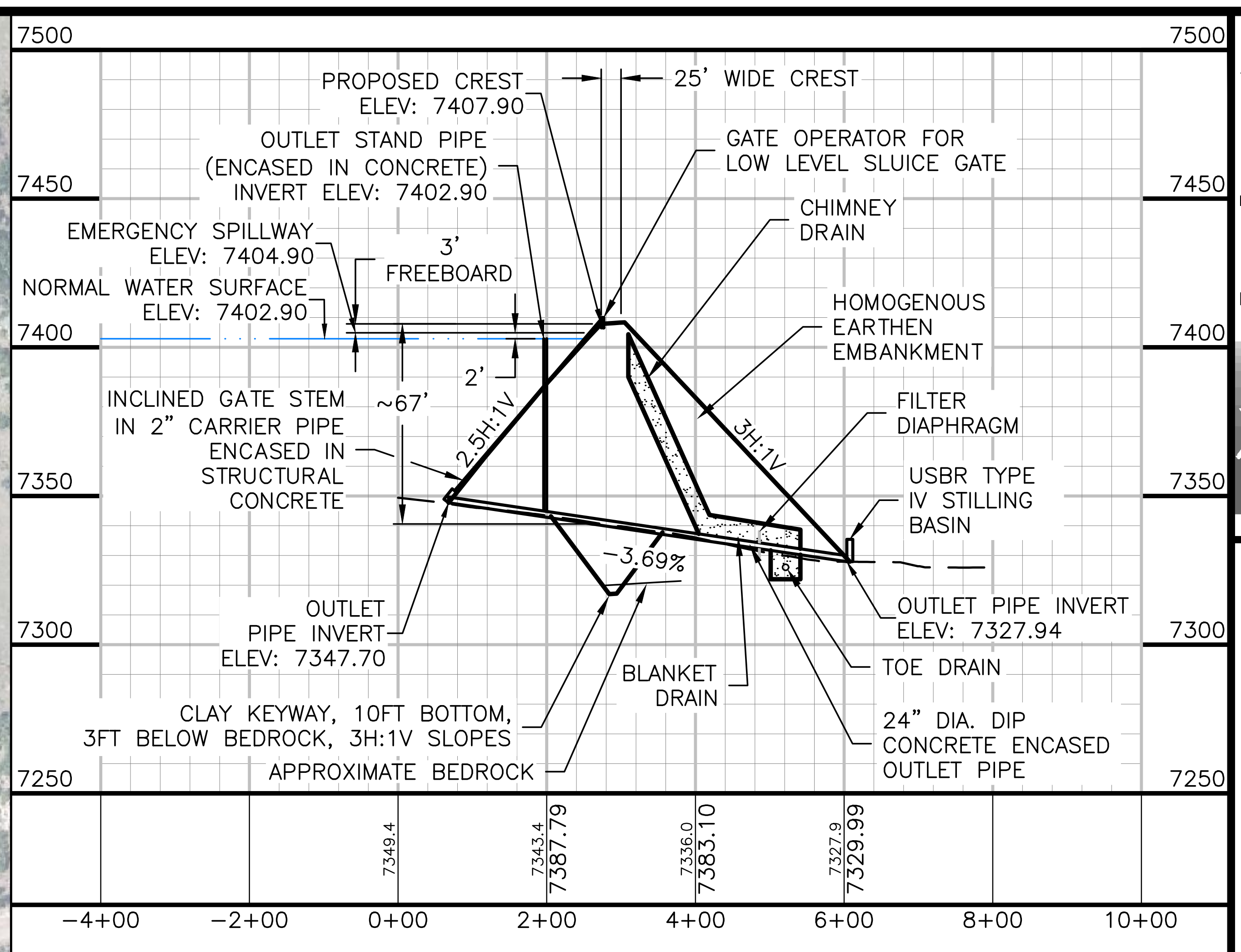
**Filing No.** **C-**

Plot Date: 01/29/20-8:20pm, Plotted by:mtkid, Drawing Path: N:\16106 Cucharas Study\Drawings\Plan Set\Bruce\Drawing Name:Bruce Cover exhibit.dwg



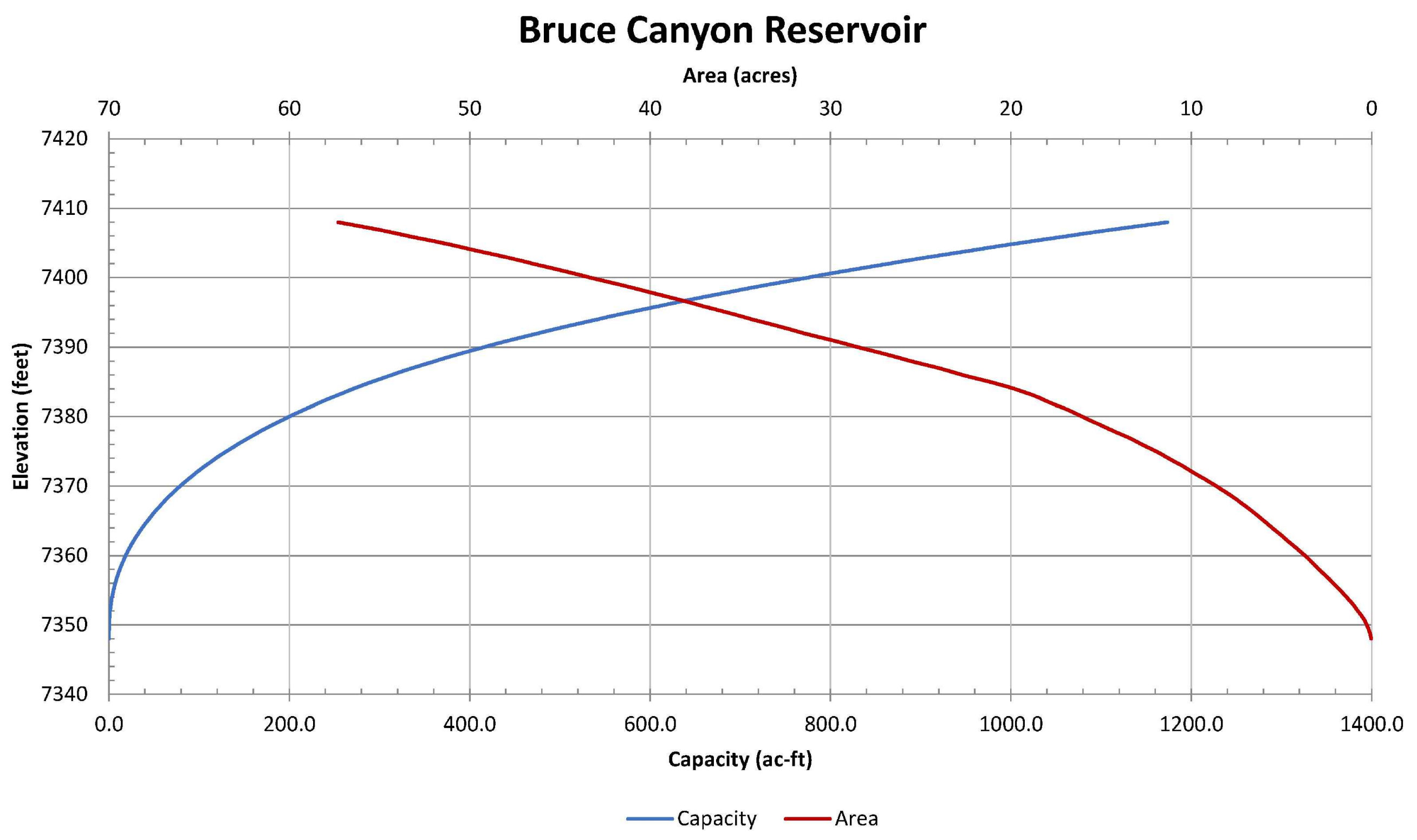


30% DESIGN DRAWINGS
NOT FOR CONSTRUCTION



TYPICAL DAM SECTION

SCALE 1" = 200'
1" = 50' VER



| Elevation (ft) | Areas (ac) | Capacity (ac-ft) |
|---|---|---|
| 7348 | 0.02 | 0.0 |
| 7349 | 0.12 | 0.1 |
| 7350 | 0.27 | 0.3 |
| 7351 | 0.47 | 0.6 |
| 7352 | 0.76 | 1.2 |
| 7353 | 1.05 | 2.1 |
| 7354 | 1.4 | 3.4 |
| 7355 | 1.74 | 4.9 |
| 7356 | 2.14 | 6.9 |
| 7357 | 2.51 | 9.2 |
| 7358 | 2.93 | 11.9 |
| 7359 | 3.3 | 15.0 |
| 7360 | 3.71 | 18.5 |
| 7361 | 4.14 | 22.4 |
| 7362 | 4.61 | 26.8 |
| 7363 | 5.05 | 31.7 |
| 7364 | 5.52 | 36.9 |
| 7365 | 5.97 | 42.7 |
| 7366 | 6.45 | 48.9 |
| 7367 | 6.94 | 55.6 |
| 7368 | 7.46 | 62.8 |
| 7369 | 8.01 | 70.5 |
| 7370 | 8.62 | 78.8 |
| 7371 | 9.25 | 87.7 |
| 7372 | 9.92 | 97.3 |
| 7373 | 10.55 | 107.6 |
| 7374 | 11.26 | 118.5 |
| 7375 | 11.94 | 130.1 |
| 7376 | 12.74 | 142.4 |
| 7377 | 13.48 | 155.5 |
| 7378 | 14.38 | 169.4 |

| Elevation (ft) | Areas (ac) | Capacity (ac-ft) |
|---|---|---|
| 7379 | 15.2 | 184.2 |
| 7380 | 16.05 | 199.9 |
| 7381 | 16.86 | 216.3 |
| 7382 | 17.84 | 233.7 |
| 7383 | 18.71 | 251.9 |
| 7384 | 19.83 | 271.2 |
| 7385 | 21.18 | 291.7 |
| 7386 | 22.69 | 313.6 |
| 7387 | 24.04 | 337.0 |
| 7388 | 25.56 | 361.8 |
| 7389 | 26.98 | 388.0 |
| 7390 | 28.49 | 415.8 |
| 7391 | 29.94 | 445.0 |
| 7392 | 31.47 | 475.7 |
| 7393 | 32.88 | 507.9 |
| 7394 | 34.34 | 541.5 |
| 7395 | 35.75 | 576.5 |
| 7396 | 37.2 | 613.0 |
| 7397 | 38.65 | 650.9 |
| 7398 | 40.16 | 690.3 |
| 7399 | 41.69 | 731.2 |
| 7400 | 43.29 | 773.7 |
| 7401 | 44.85 | 817.8 |
| 7402 | 46.46 | 863.5 |
| 7403 | 48.07 | 910.7 |
| 7404 | 49.79 | 959.6 |
| 7405 | 51.51 | 1010.3 |
| 7406 | 53.39 | 1062.7 |
| 7407 | 55.24 | 1117.1 |
| 7408 | 57.3 | 1173.3 |
| 7408 | 56.95 | 1172.7 |

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Denver, CO 80234
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Fax: (303) 452-2759
email: info@applegategroup.com Website: www.applegategroup.com

# PROPOSED BRUCE DAM LOCATION

## SITE PLAN

## CUCHARAS COLLABORATIVE

| NO | DATE | BY | CHK'D | DESCRIPTION |
|---|---|---|---|---|
| | | | | |

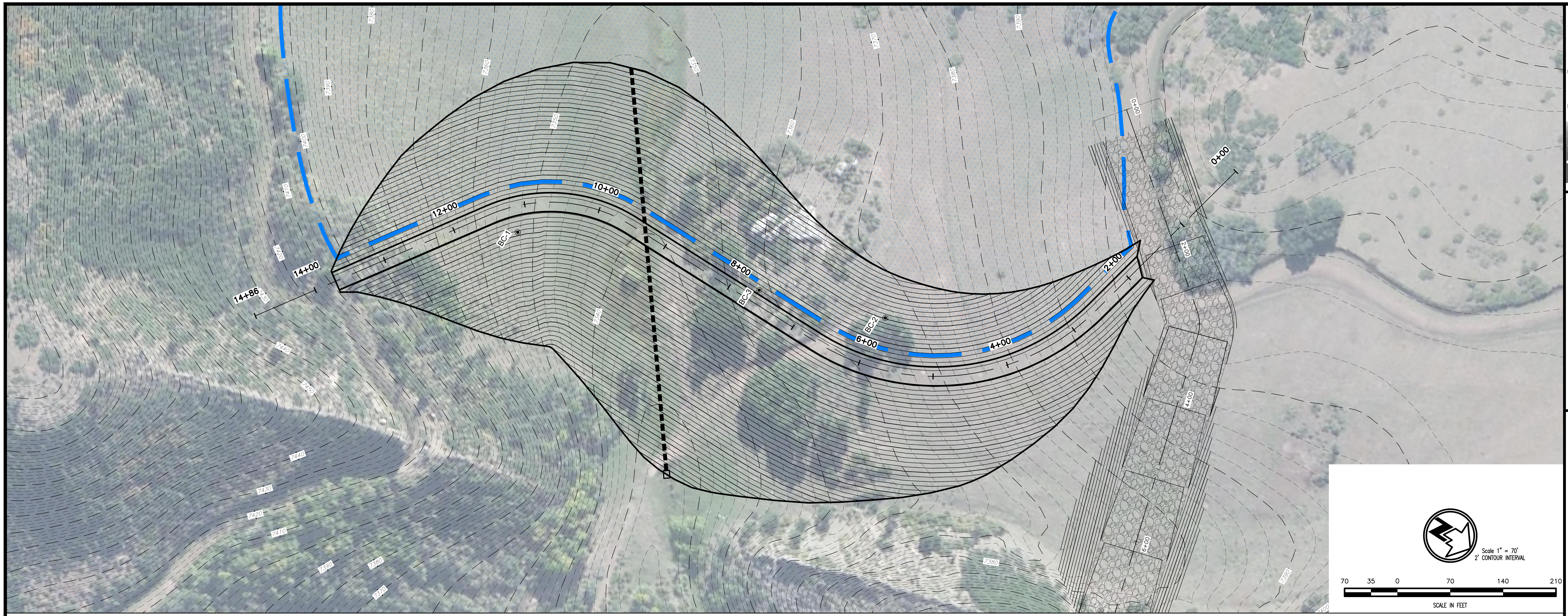
REVISIONS

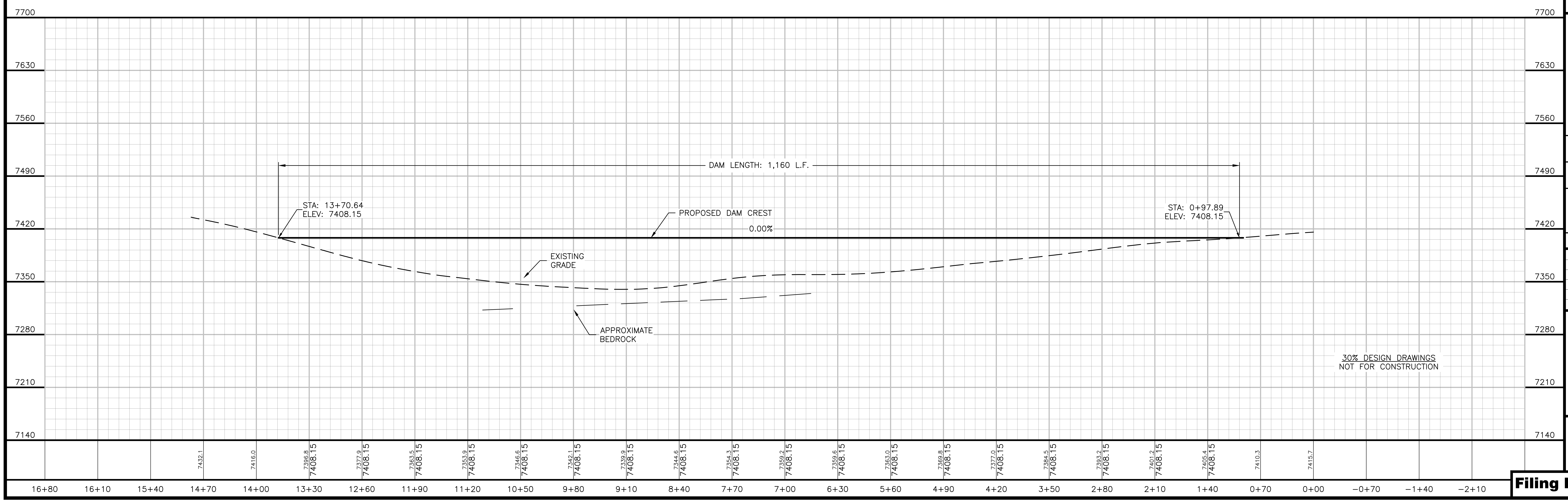
Date: 30/JAN/20
Job No: 16-106
Drawn: LD
Design:
Checked:
Scale: 1" = 200'

Sheet: **2**
Of:

**Filing No.** C-

Plot Date: 01/29/20-8:21pm, Plotted by:mtkid, Drawing Path: N:\16106 Cucharas Study\Drawings\Plan Set\Bruce\Drawing Name:Bruce Dam Site exhibit.dwg





30% DESIGN DRAWINGS
NOT FOR CONSTRUCTION

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Denver, CO 80234
(303) 452-6611
Fax: (303) 452-2759
email: info@applegategroup.com Website: www.applegategroup.com

# PROPOSED BRUCE DAM LOCATION

## DAM PLAN AND PROFILE

## CUCHARAS COLLABORATIVE

| NO | DATE | BY | CHK'D | DESCRIPTION |
|---|---|---|---|---|
| | | | | |

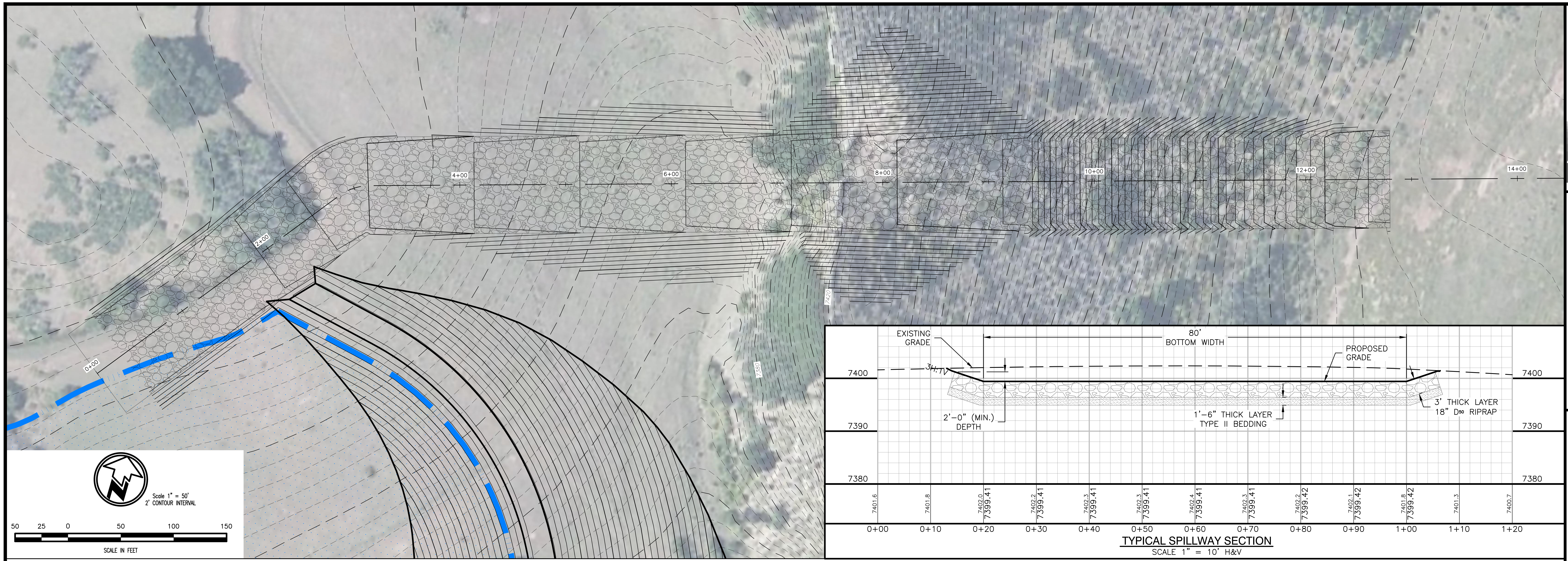
REVISIONS

Date: 30/JAN/20
Job No: 16-106
Drawn: LD
Design:
Checked:
Scale: 1" = 70'

Sheet: **3**
Of:

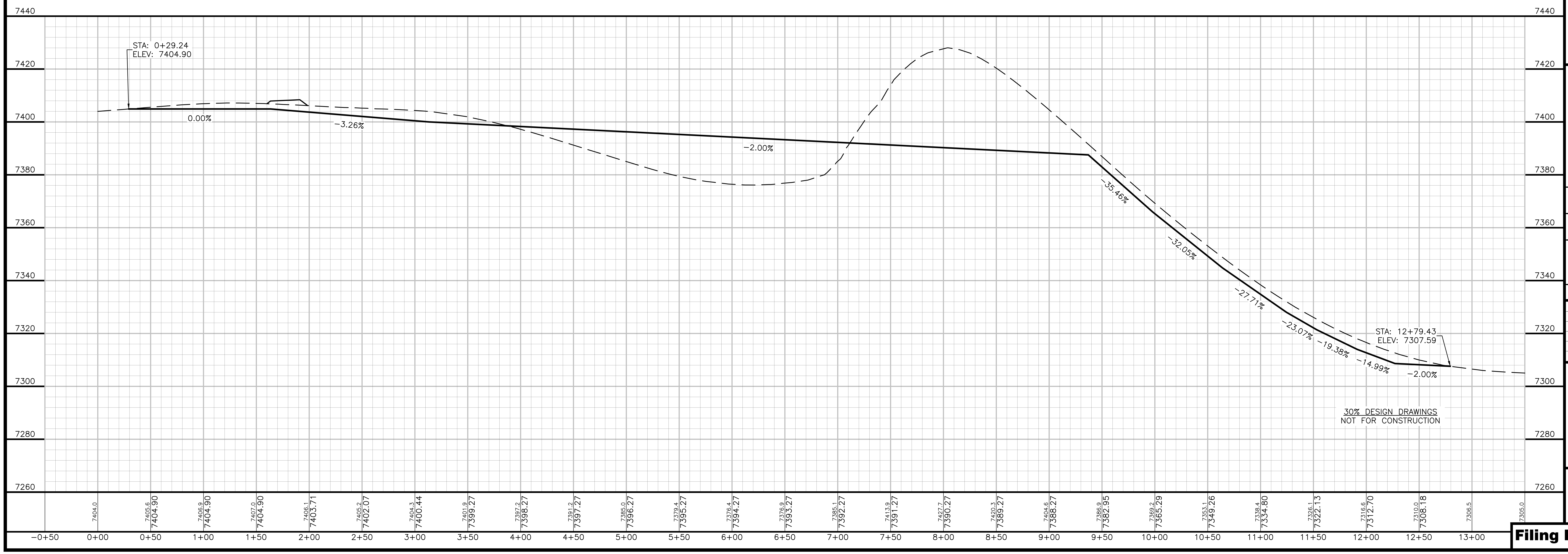
**Filing No.** **C-**

Plot Date: 01/29/20-8:21pm, Plotted by:mtkid, Drawing Path: N:\16106 Cucharas Study\Drawings\Plan Set\Bruce\Drawing Name:Bruce Dam Site exhibit.dwg



TYPICAL SPILLWAY SECTION

SCALE 1" = 10' H&V



30% DESIGN DRAWINGS
NOT FOR CONSTRUCTION

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(303) 452-6611
Fax: (303) 452-2759
email: info@applegategroup.com Website: www.applegategroup.com

## PROPOSED BRUCE DAM LOCATION

## SPILLWAY PLAN AND PROFILE

## CUCHARAS COLLABORATIVE

| NO | DATE | BY | CHK'D | DESCRIPTION |
|---|---|---|---|---|
| | | | | |

REVISIONS

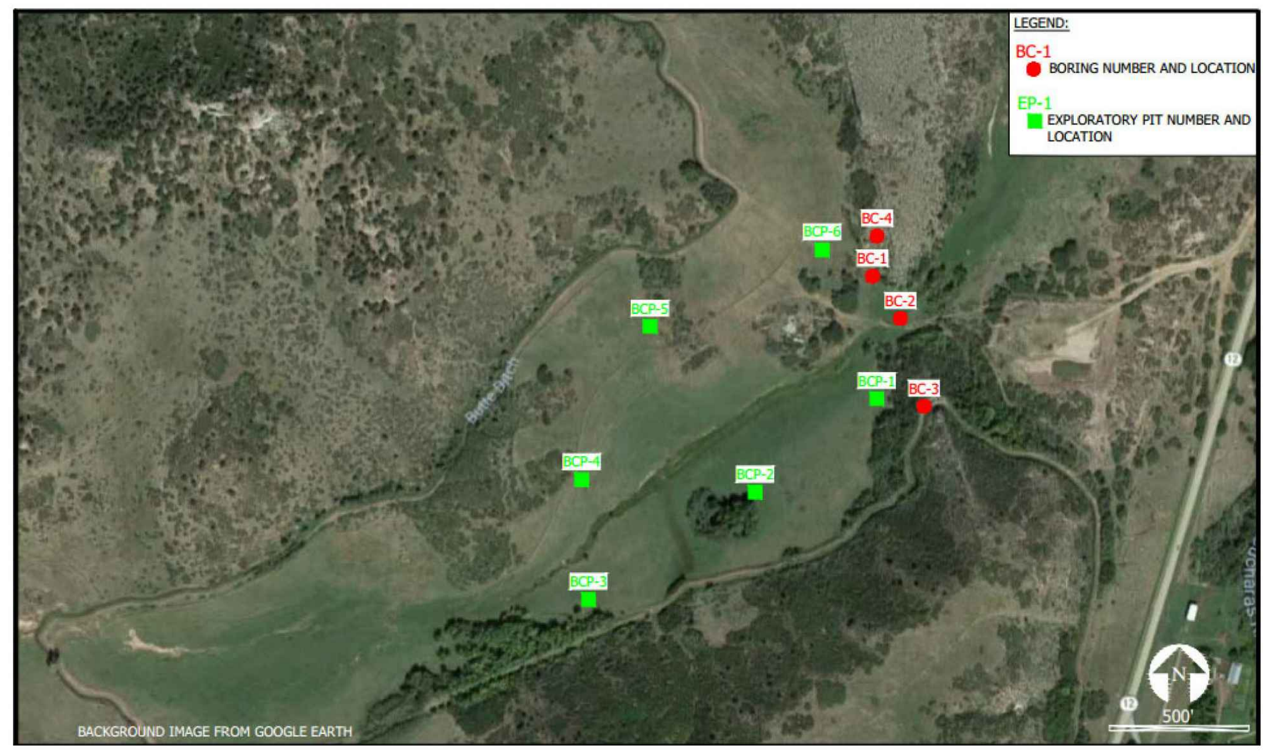
| | |
|---|---|
| Date: | 30/JAN/20 |
| Job No: | 16-106 |
| Drawn: | LD |
| Design: | |
| Checked: | |
| Scale: | 1" = 50' |

Sheet: 4

Of:

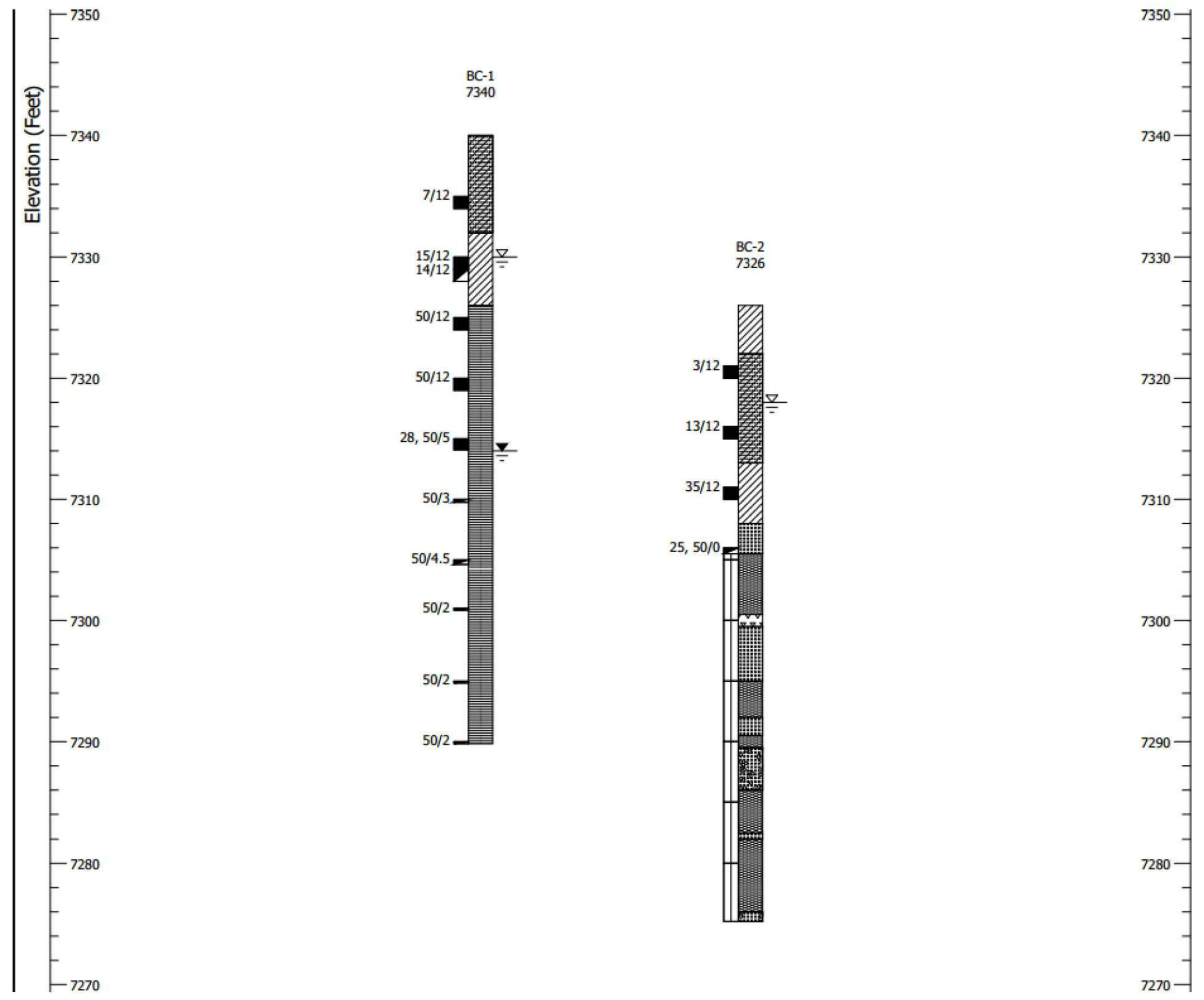
**Filing No.** C-

Plot Date: 01/29/20-8:21pm, Plotted by:mtkid, Drawing Path: N:\16106 Cucharas Study\Drawings\Plan Set\Bruce\Drawing Name:Bruce Dam Site exhibit.dwg

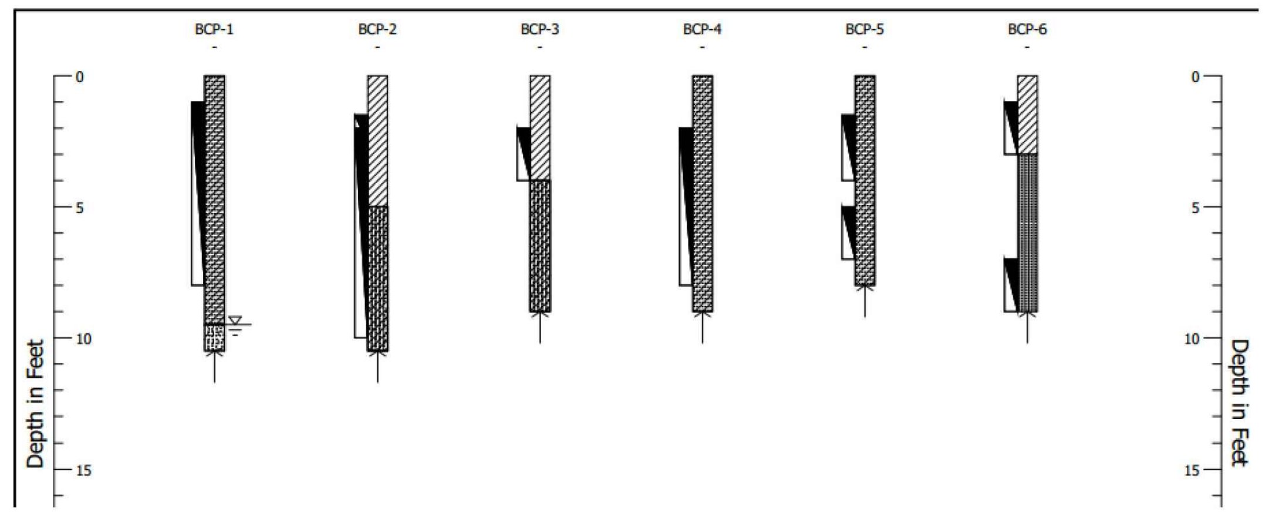


Boring and Exploratory Pit Location Map for Bruce Canyon

Abutment Borings at Bruce Canyon



Valley Borings at Bruce Canyon



Exploratory Pits at Bruce Canyon

**Applegate Group, Inc.**

Water Resource Advisors for the West

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Denver, CO 80234
(303) 452-6611
Fax: (303) 452-2759
email: info@applegategroup.com Website: www.applegategroup.com

# PROPOSED BRUCE DAM LOCATION

## geotechnical data

**CUCHARAS COLLABORATIVE**

REVISIONS

| NO | DATE | BY | CHK'D | DESCRIPTION |
|---|---|---|---|---|
| | | | | |

Date: 30/JAN/20
Job No: 16–106
Drawn: LD
Design:
Checked:
Scale: As Noted

Sheet: **5**
Of:

**Filing No. C-**

Plot Date: 01/29/20–8:21pm, Plotted by:mtkid, Drawing Path: N:\16106 Cucharas Study\Drawings\Plan Set\Bruce\Drawing Name:Bruce Dam Geotech exhibit.dwg

# APPENDIX C

# ENGINEERING OPINION OF PROBABLE COST

# Engineers Opinion of Probable Construction Cost (30% Design)

**Applegate Group, Inc.**

1490 W. 121st Ave. Suite 100
Denver, CO 80234
Phone: (303) 452-6611
Fax: (303) 452-2759

## Bruce Canyon Reservoir

### (Excluding Deferred Maintenance Costs)

Job No. : 18-117
By: SAS/DAB
Date: 1/31/2020
Client: Cucharas Collaborative

| Description of Work | Item | Item Description | Units | Quantity | Unit Cost | Total Cost |
|---|---|---|---|---|---|---|
| **Construction of a Large, Significant Hazard Dam** | | **Administration** | | | | |
| | *1a* | Mobilization | % | | 5% | $ 838,200 |
| | *1b* | Bonds and Permits | % | | 2% | $ 335,300 |
| | | **Site Preparation** | | | | |
| | *2a* | Dewatering and Water Control | LS | 1 | $ 90,000 | $ 95,000 |
| | *2b* | Clearing and Grubbing | AC | 9 | $ 15,000 | $ 135,000 |
| | *2c* | Erosion and Sediment Control | LS | 1 | $ 20,000 | $ 20,000 |
| | *2d* | Construction Surveying | LS | 1 | $ 20,000 | $ 20,000 |
| | *2e* | Geotechnical Investigation | LS | 1 | $ 15,000 | $ 15,000 |
| | | **Earthwork** | | | | |
| | *3a* | Stripping and Stockpiling Topsoil | CY | 14,520 | $ 8 | $ 116,200 |
| | *3b* | Excavation (Cut) & Stockpiling Embankment Material (Native) | CY | 300,300 | $ 12 | $ 3,603,600 |
| | *3c* | Excavation (Cut) for Foundation Cutoff | CY | 79,500 | $ 12 | $ 954,000 |
| | *3d* | Backfill/Compaction (Engineered) for Dam Embankment | CY | 338,900 | $ 15 | $ 5,083,500 |
| | *3e* | Backfill/Compaction (Engineered) for Foundation Cutoff/Keyway | CY | 79,500 | $ 15 | $ 1,192,500 |
| | *3f* | Excavation (Cut) for Emergency Spillway Channel | CY | 38,600 | $ 12 | $ 463,200 |
| | *3g* | Furnish and Place 18" D50 Riprap for Emergency Spillway | CY | 19,400 | $ 95 | $ 1,843,000 |
| | *3h* | Furnish and Place Type II Granular Bedding for Emergency Spillway | CY | 9,700 | $ 125 | $ 1,212,500 |
| | | **Dam Structures and Outlet Works** | | | | |
| | *4a* | Furnish and Place 24" Ductile Iron Encased Outlet Conduit Pipe | LF | 540 | $ 500 | $ 270,000 |
| | *4b* | Furnish and Place Structural Concrete for Inclined Gate Stem | CY | 20 | $ 1,200 | $ 24,000 |
| | *4c* | Furnish and Place 24" Sluice Gate for Low-Level Outlet | LS | 1 | $ 20,000 | $ 20,000 |
| | *4d* | Furnish and Place Concrete Encased Outlet Standpipe | LF | 60 | $ 500 | $ 30,000 |
| | *4e* | Furnish and Place Type VI Stilling Basin | LS | 1 | $ 20,000 | $ 20,000 |
| | *4f* | Furnish and Place Low Level Outlet Trashrack | LS | 1 | $ 3,000 | $ 3,000 |
| | *4g* | Furnish and Place Chimney and Blanket Drain | CY | 15,000 | $ 90 | $ 1,350,000 |
| | *4h* | Furnish and Place Two-Stage Filter Drain at Toe | LF | 1,000 | $ 80 | $ 80,000 |
| | | **Site Reclamation** | | | | |
| | *5a* | Seeding | AC | 9.0 | $ 7,500 | $ 67,500 |
| | *5b* | Place topsoil | CY | 14,520 | $ 10 | $ 145,200 |
| | | | | | | |
| | | | | | | |
| | | *Construction Subtotal* | | | | **$ 17,936,700** |
| | | Contingency | **%** | | 20% | $ 3,587,300 |
| | | **Construction Total** | | | | **$ 21,524,000** |
| | | Permitting | % | | 2.5% | $ 538,100 |
| | | Land Acquisition | AC | 7.5 | $ 5,000 | $ 37,500 |
| | | Engineering | LS | 1 | $ 150,000 | $ 150,000 |
| | | Construction Observation | LS | 1 | $ 80,000 | $ 80,000 |
| | | Annual O&M Costs | LS | 1 | $ 20,000 | $ 20,000 |
| | | ***Total*** | | | | **$ 22,349,600** |