South Baker Creek Dam

30% Design Report

Huerfano County Water Conservancy District

January 30, 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 South Baker Creek dam described herein. The work was funded with a Colorado Water Conservation Board (CWCB) Water Supply Reserve Fund grant for 30% design for a new South Baker Creek dam. The grant was approved by the CWCB in May 2019. The scope of work was generally to 1) collect geotechnical data at the abutment locations for the South Baker Creek and Bruce Canyon dams, 2) complete 30% design for the South Baker Creek dam, 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 which 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. Cesare completed additional geotechnical field investigations in 2019, and updated their geotechnical report in December 2019.

Concept design for the South Baker Creek dam site proposed a zoned earthen embankment that would be classified as a high hazard dam according to Dam Safety regulations. Based on additional geotechnical investigation (and laboratory testing) completed by Cesare at the South Baker Creek site in 2018 and 2019, it was determined that a zoned earthen embankment dam may not be feasible due to concerns over slope stability and the lack of suitable clay borrow material at the site. Results of the 2019 investigation performed by Cesare are summarized in the following sections. As an alternative to a zoned earthen embankment dam, Applegate evaluated a roller-compacted concrete (RCC) gravity dam as an alternative for the 30% design phase. Roller-compacted concrete is considered an economical alternative to traditional concrete gravity dams as it allows the use of lower quality rock and aggregate and requires less cement. RCC dams can also be constructed more quickly than traditional concrete gravity dams (and earthen embankment dams) and require less labor due to the mechanized methods of construction.

As part of the 30% design phase, Applegate completed the following tasks:

1. Review of new geotechnical information based on borings, test pits, and laboratory analysis completed by Cesare in 2019.
2. A static overturning and stability analysis to determine approximate dimensions for a typical dam cross section.
3. Gradation analysis of native overburden materials to evaluate suitability for RCC mix design.
4. Hydraulic analysis for spillway and outlet design.
5. Development of 30% design plans incorporating preliminary grading, typical section details, and updated elevation-area-capacity data.

6. Revised cost estimate based on assumed concrete quantities and unit costs for the construction of small RCC dams obtained from the United States Army Corps of Engineers (USACE) and the United States Bureau of Reclamation (USBR).
7. Discussion with the Colorado Division of Water Resources (DWR) Dam Safety Branch regarding 30% design plans.

Deliverables for the South Baker Creek 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 completed 5 borings along the proposed dam alignment and excavated 5 exploratory test pits in the reservoir basin. Three (3) borings were drilled in 2018 at the toe of the north and south abutments (SB-1 SB-2, and SB-3) and at the approximate location of the maximum dam section. After an access road was constructed in summer 2019, two additional borings were drilled at the north and south abutments (SB-4 and SB-5). Figure 1 shows approximate locations of the completed borings and exploratory test pits.

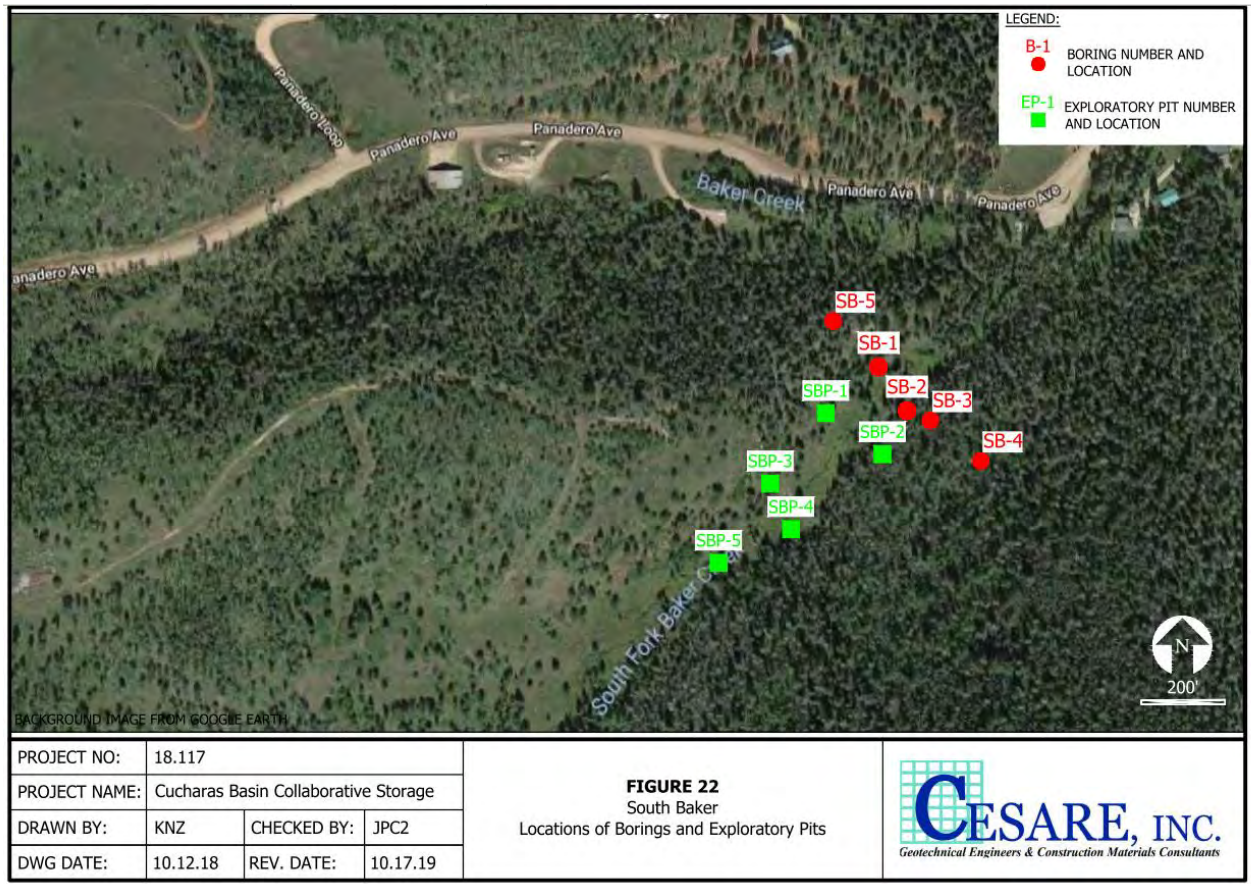


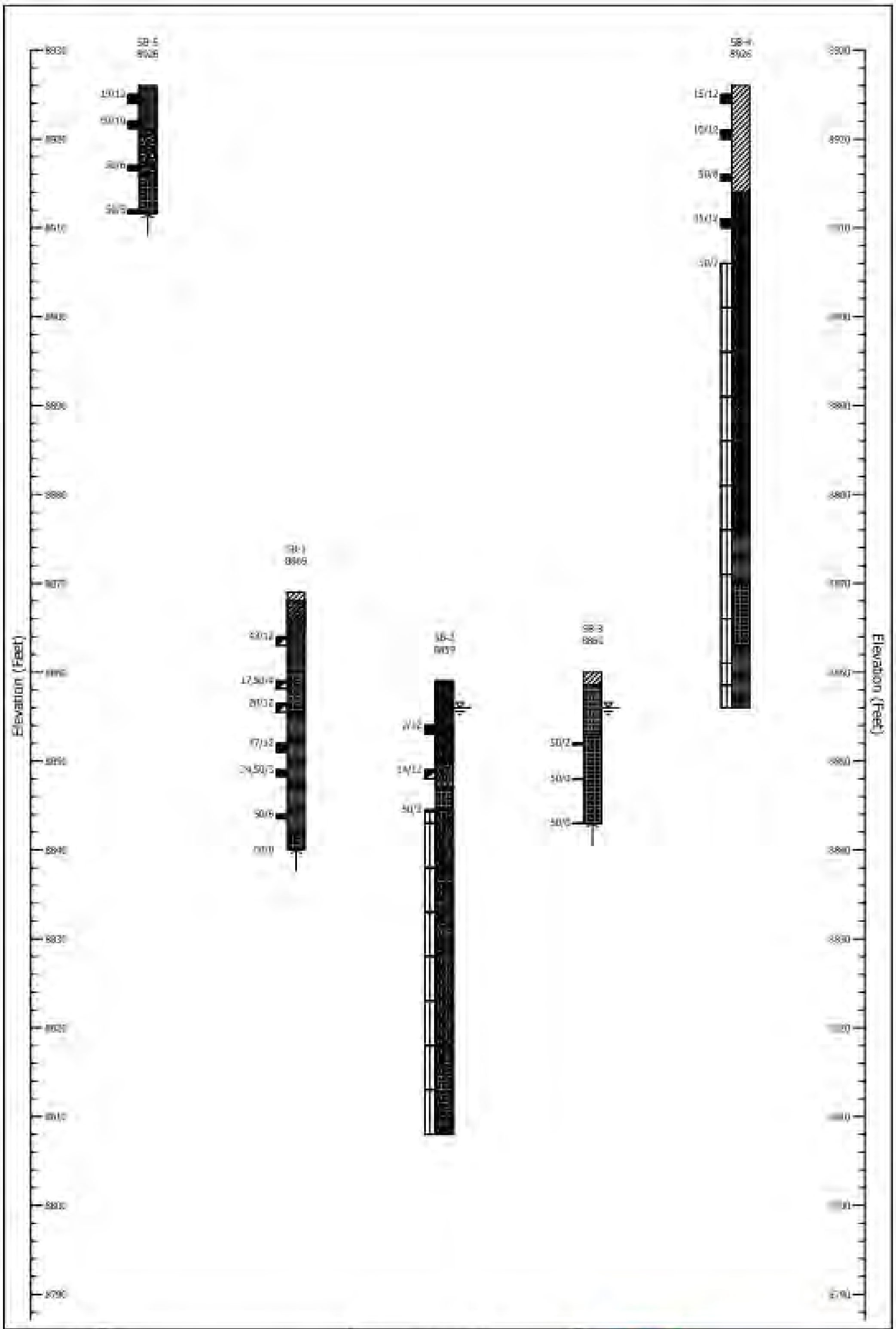
FIGURE 1. BORING AND TEST PIT LOCATIONS

Soil and bedrock were sampled at designated intervals during drilling using a modified California sampler. Locations of sampling and results of penetration tests are shown on the boring log profiles included with Cesare's report. Figure 2 provides a lithologic summary for the five borings completed at the site. Note that the elevations shown are approximate and are based on the 5-meter DEM data used for design; field survey was not performed. Borings SB-1 through SB-3 indicated soils consisting of interbedded silty, clayey and relatively clean sands (with lesser amounts of sandy clay to depths between 7 and 22 feet below ground surface (bgs)), overlying predominantly sandstone bedrock with claystone observed between 13 and 27 feet bgs at SB-1. Depth to bedrock in borings SB-1 through SB-3 ranged from 7 to 12 feet bgs. At the north abutment, boring SB-5 encountered silty sand and clayey gravel to a depth of 10 feet overlying hard, weathered sandstone bedrock. At the south abutment, boring SB-4 encountered sandy clays with increasing gravel and cobble content was observed to a depth of 12 feet overlying a mix of sand, gravel and cobbles to approximately 50 feet. Interbedded claystone and sandstone was encountered between 50 and 70 feet bgs.

At two boring locations, SB-2 and SB-4, bedrock was cored to evaluate rock quality. Packer testing was also performed at SB-2 to estimate permeability. Table 1 summarizes results of the Packer test at SB-2.

	Interval Tested		**Averaged Hydraulic Conductivity (cm/sec)**
Boring	**Depth (ft)**	**Elevation (ft)**	
SB-2	19 to 51	8839 to 8807	5.0×10^{-4}
	35 to 51	8823 to 8807	8.9×10^{-6}

Table 1. Packer Test Results



PROJECT NO:	18.117
PROJECT NAME:	Cucharas Basin Collaborative Storage
DWG DATE:	11/6/2019

FIGURE 23

South Baker Boring Logs

CESARE, INC.

FIGURE 2. BORING LOGS

Exploratory test pits were excavated to evaluate the suitability of borrow material for construction. Materials encountered in the test pits were logged during excavation and samples were collected for lab analysis. The test pits generally indicated about 1.5 to 3 feet of silty, clayey sand overlying silty, clayey and relatively clean gravels extending to an approximate depth of 4 to 9 feet below ground surface. Gradation plots for the test pit samples collected are included in the geotechnical report provided in Appendix A.

RECOMMENDATIONS

Based on results of the site investigation and laboratory analysis, Cesare recommended removing the South Baker Creek earthen embankment dam alternative from further evaluation due to the lack of low-permeable borrow materials present at the site. Stability analyses for an earthen embankment dam at the site were not performed for this reason and due to the high permeability of the bedrock encountered. Potential geologic hazards associated with the site include slope instability. Boring SB-4 at the south abutment encountered approximately 50 feet of unconsolidated soil overlying bedrock which is likely landslide material. A summary or Cesare's recommendations are outlined below:

1. Additional geotechnical investigation is necessary at the north and south abutments to further evaluate permeability.
2. Overburden soils should be excavated to bedrock contact over the entire embankment base; a cutoff trench should then be excavated to a depth of at least 20 feet below top of bedrock.
3. An open-cut cutoff trench is recommended over a slurry wall due to the lack of low-permeable materials onsite. The cutoff should extend at least 5 feet into low-permeable materials.
4. Additional geotechnical investigation is necessary to identify potential borrow materials for construction of a roller-compacted concrete (RCC) dam and evaluate their suitability for RCC mix design.
5. Seepage and stability analyses should be performed for the RCC alternative following additional geotechnical investigation at the site.

GRADATION ANALYSIS FOR RCC MIX DESIGN

One benefit of RCC dams is that it typically permits the use of lower quality aggregate as opposed to conventional concrete gravity dams. Applegate reviewed results of lab testing performed by Cesare on samples collected from borings and test pits to evaluate the suitability of native materials for RCC dam construction. Gradation plots for sampled materials were compared to a typical aggregate gradation band for small RCC dams[1]. Figure 3 compares gradation plots for soil samples collected from borings SB-1 through SB-3 to the typical gradation band referenced above. These samples were determined to be most compatible with the recommended gradation band. The comparison indicates that coarse aggregate would need to be imported (either purchased commercially or from another borrow site) to achieve a gradation within the typical band. It is possible that a 3:1 blend of native sands encountered in borings SB-1 through SB-3 and a coarse aggregate similar to AASHTO #467 stone would meet the recommended gradation band. Figure 4 shows the proposed 3:1 aggregate blend utilizing #467 stone. Estimated additional costs associated with importing aggregate for the RCC mix have been incorporated in the updated Opinion of Probable Cost. Note that additional geotechnical investigation should be completed to identify other potential borrow sources, confirm the suitability of native materials for use as RCC aggregate, and estimate required quantities.

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[1] Portland Cement Association - Design Manual for Small RCC Dams, 2003, Schnabel Engineering Associates, Inc.

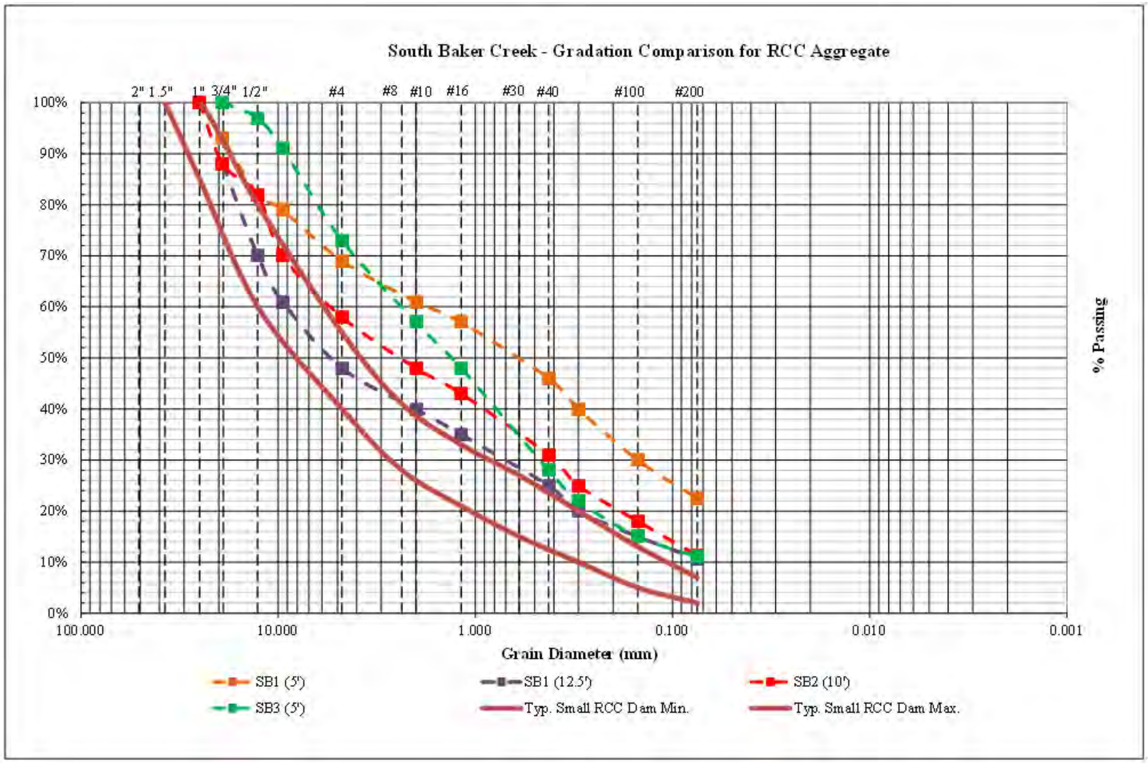

Figure 3. S. Baker Creek Gradation Comparison

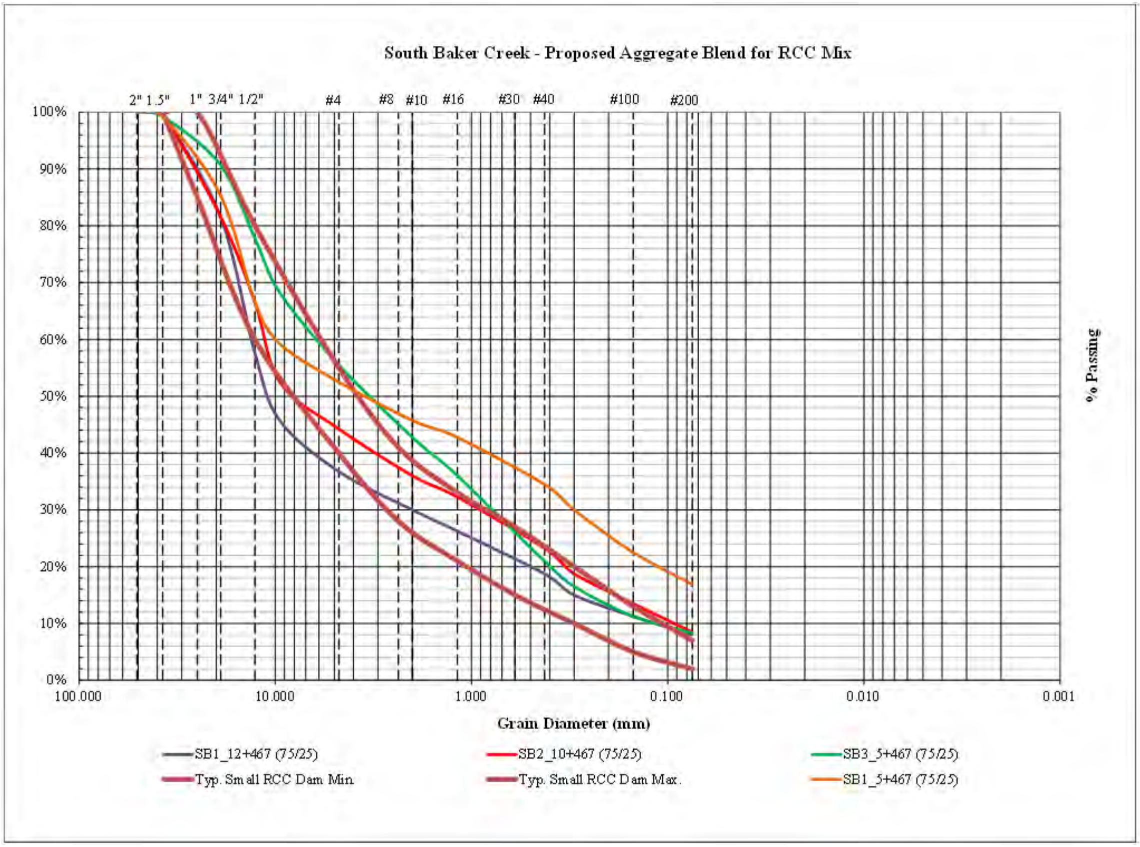

Figure 4. Proposed Aggregate Blend for RCC Mix

DESIGN COMPONENTS

30% design for a South Baker Creek RCC dam was completed based on site-specific geotechnical data collected between 2018 and 2019 and consists of the following components:

1. Overturning and stability analysis to determine the required dimensions to sufficiently resist overturning and sliding forces.
2. Spillway design based on estimated discharges associated with the Inflow Design Flood (IDF) and Probable Maximum Flood (PMF).
3. Low-level outlet design to provide the ability to make low-level releases from the reservoir and draw down water levels for maintenance or emergency purposes.
4. Gradation analysis to determine the suitability of native materials for RCC mix design.
5. Foundation design to address seepage and stability concerns at the site identified by Cesare.
6. 30% design drawings consisting of a cover sheet, site plan, and typical dam section.
7. Engineer's Opinion of Probable Cost for construction of an RCC gravity dam.

ELEVATION-AREA-CAPACITY

The South Baker Creek RCC dam would have a maximum capacity of 117 acre-feet and a maximum inundation area of 4.92 acre-feet. The maximum capacity and inundation area were based on the RCC dam dimensions, and the southern property boundary. It is noted that the capacity for the RCC dam would be about 5 acre-feet less than the 122 acre-foot earthen embankment alternative conceived of in the conceptual design stage.

TABLE 1. ELEVATION AREA CAPACITY TABLE FOR RCC DAM ALTERNATIVE

Height (ft)	Elevation	Area (ac)	Capacity (ac-ft)
28	8896	2.04	30.3
29	8897	2.11	32.4
30	8898	2.19	34.6
31	8899	2.27	36.8
32	8900	2.36	39.1
33	8901	2.45	41.5
34	8902	2.55	44.0
35	8903	2.64	46.6
36	8904	2.74	49.3
37	8905	2.83	52.1
38	8906	2.94	55.0
39	8907	3.04	57.9
40	8908	3.15	61.0
41	8909	3.25	64.2
42	8910	3.37	67.5
43	8911	3.48	71.0
44	8912	3.61	74.5
45	8913	3.73	78.2
46	8914	3.86	82.0
47	8915	3.98	85.9
48	8916	4.11	90.0
49	8917	4.24	94.1
50	8918	4.37	98.4
51	8919	4.50	102.9
52	8920	4.64	107.4
53	8921	4.78	112.1
54	8922	4.92	117.0

*Minimum pool as established by CPW

OVERTURNING AND STABILITY ANALYSIS

Applegate completed a static stability and overturning analysis to determine the required dimensions for an RCC dam at the South Baker Creek site. The analysis followed procedures outlined in the U.S. Army Corps of Engineers Gravity Dam Design Engineer Manual (EM-1110-2-2200) and evaluated three basic loading conditions at two dam sections: a maximum overflow section and a maximum non-overflow section. The overflow section incorporates the proposed spillway, and the non-overflow section is based on total height to dam crest. The three loading conditions analyzed for 30% design are summarized in Table 2 as defined by the Corps of Engineer Manual for Gravity Dam Design.

Table 2. Loading Conditions Considered for RCC Dam Overturning and Stability Analysis

	Loading Condition No. 2	Loading Condition No. 3	Loading Condition No. 5
Description	Usual - Normal Operating	Unusual - Flood Discharge	Unusual - Normal with Earthquake
Loads	Pool - spillway crest	Pool - spillway conveying IDF	Pool - spillway crest
	No tailwater	Tailwater pressure	Earthquake acceleration (0.05g)
	Uplift (full hydrostatic)	Uplift (full hydrostatic)	Uplift (full hydrostatic)
	Ice pressure	No ice pressure	No ice pressure

Seismic forces were based on an assumed peak ground acceleration (PGA) of 0.05g, which is conservative based on the estimated PGA associated with the Operational Base Earthquake (50% probability of exceedance in 100 years or an average return period of 144 years) which was calculated using the USGS Unified Hazard Tool. Seismic forces were calculated following procedure from the Bureau of Reclamation's Design of Small Dams. Ice pressure was based on a 10,000 lb/ft load and a thickness of 2 feet. Full hydrostatic uplift was assumed for all loading conditions as the dam will not include any internal drains (internal drains may need to be considered at subsequent design phases, depending on final dam height). A concrete cutoff wall will extend into low-permeable bedrock. For sliding stability calculations, the angle of internal friction for sandstone bedrock was assumed to be 27 degrees and cohesion between the RCC and bedrock was estimated to be 20 psi.

Based on results of the analysis, the dam will meet required Factors of Safety against sliding and overturning for all loading conditions analyzed with the following dimensions:

Structural Height (leveling pad to crest)	82 feet
Total Storage	117 acre-feet
Crest Width	20 feet
Freeboard	4 feet
Downstream Slope	0.8H:1V
Length (along centerline)	98 feet

Table 3 summarizes the calculated Factors of Safety against overturning and sliding as well as the approximate location of resultant forces acting on the base of the dam for all loading conditions. The table also includes requirements for FOS and resultant location as consistent with U.S. Army Corps and Bureau of Reclamation design standards. Note that a detailed overturning and stability analysis should be completed during subsequent design phases based on the following information:

1. Results of additional geotechnical investigation(s) including refined values for cohesive strength, friction angle(s) and RCC compressive strength.
2. Extreme Loading Conditions including seismic forces based on the Maximum Credible Earthquake (MCE) at the site.
3. Revised dimensions based on design modifications.

CONCRETE

The dam will be constructed of roller-compacted concrete with a conventional concrete facing. 30% design assumes that the concrete will be installed with traditional form liners. However, other methods for installing concrete facing may be evaluated during later stages of design. It is assumed that the RCC will be mixed on-site during construction and that minimal aggregate will need to be imported to meet strength requirements. Applegate recommends that additional geotechnical investigation be completed to develop an RCC mix design prior to proceeding with subsequent phases of design. The costs summarized below reflect this assumption. The spillway, spillway training walls, and stilling basin (as well as encasement for the outlet pipe and gate stem) will be reinforced concrete.

Loading Condition No.2 - Usual

	Overturning FOS	Sliding FOS	Sliding FOS (Required)	Resultant Force Location (feet from dam face)	Resultant Force Location (Required)
Max Overflow	3.1	2.3	2.0	55.9	32.7 - 65.3 (middle 1/3)
Max Non-Overflow	2.4	2.4	2.0	46.9	32.7 - 65.3 (middle 1/3)

Loading Condition No.3 - Unusual

	Overturning FOS	Sliding FOS	Sliding FOS (Required)	Resultant Force Location (feet from dam face)	Resultant Force Location (Required)
Max Overflow	2.0	2.3	1.7	45.1	24.5 - 73.5 (middle 1/2)
Max Non-Overflow	2.0	2.3	1.7	45.4	24.5 - 73.5 (middle 1/2)

Loading Condition No.5 – Unusual with Earthquake

	Overturning FOS	Sliding FOS	Sliding FOS (Required)	Resultant Force Location (feet from dam face)	Resultant Force Location (Required)
Max Overflow	1.9	2.1	1.7	44.2	24.5 – 73.5 (middle ½)
Max Non-Overflow	2.1	1.9	1.7	45.1	24.5 – 73.5 (middle ½)

Table 3. Calculated Factors of Safety and Resultant Locations

SPILLWAY DESIGN

The South Baker Creek dam will have a 60-ft combined spillway that will function as both the service spillway and the emergency spillway. The spillway will regulate normal pool and also have the capacity to pass the Inflow Design Flood (IDF) with almost 3 feet of residual freeboard. A discharge coefficient of 3.00 was used to estimate flow depths across the spillway resulting from the IDF.

The 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 South Baker 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 miles upstream of the Town of Cuchara, and a dam breach would discharge to the Cucharas River and flood approximately 60% of the Town. This was based on an assumed 3-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 in a depth x velocity product of 45 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[2]. The resulting range of suggested limit for the fatality rate was 0.00002 to 0.003. The number of fatalities resulting from a South Baker Creek Dam breach was then calculated as the Town of Cuchara population (150 people), times 60% area that would be flooded, times the 0.003 fatality rate (conservatively assuming the maximum rate of the fatality range), or a result of 0.27 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 online tool from the Colorado-New Mexico Regional Extreme Precipitation Frequency Study[3]. The Mesoscale Storm with Embedded 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 4.23 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 4.53 inches. A runoff model was not created at this design level, but may be completed for the hydrology analysis in subsequent design stages. Rather, a 0.01% AEP of 125 cfs determined using USGS Streamstats was scaled using the ratio of the MetPortal precipitation value (4.53 inches) to the corresponding maximum 6-hour precipitation 100-year annual recurrence interval from the USGS Streamstats[4] (3.33 inches). The resulting IDF was determined to be approximately 170 cfs for the approximately 2.14 square mile drainage basin.

Reinforced concrete training walls approximately 3 feet in height will extend from the spillway crest to the stilling basin at the downstream toe of the dam. The training walls will contain flows resulting from the IDF and would contain spillway discharge within a 60-foot wide section of the downstream dam face. The 20-foot long by 60-foot wide stilling basin was sized based on approximate flow velocities resulting from the design discharges. Note the stepped downstream face of the dam will provide additional energy dissipation, however, these forces were not calculated or accounted for at the 30% design stage. The stilling basin will have 5-foot high walls with a low-flow weir opening in the downstream wall for releases made through the low-level outlet. Construction details for the spillway training walls and stilling basin will be developed during later stages of design based on further hydraulic analysis.

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[2] Figure 2 in RCEM – Reclamation Consequence Estimating Methodology, July 2015

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

[4] https://streamstats.usgs.gov/ss/

OUTLET WORKS

The outlet works will consist of a 24-inch ductile iron concrete encased outlet pipe. The outlet will regulate low-level releases through a 24-inch sluice gate which will be operated from the dam crest. The gate stem will be enclosed in a carrier pipe running along the upstream face of the dam and encased in concrete. 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 indicate that the 24-inch pipe will be capable of drawing down the reservoir 5 feet in only 2 hours. Figure 5 shows the drawdown curve for the proposed outlet configuration. The maximum discharge is estimated to be approximately 90 cfs at full storage. Baffle blocks will be constructed in the stilling basin for energy dissipation during rapid drawdown of the reservoir. Construction details for concrete encasement of the outlet pipe and gate stem, as well as trash rack and stilling basin baffle blocks will be developed during later stages of design.

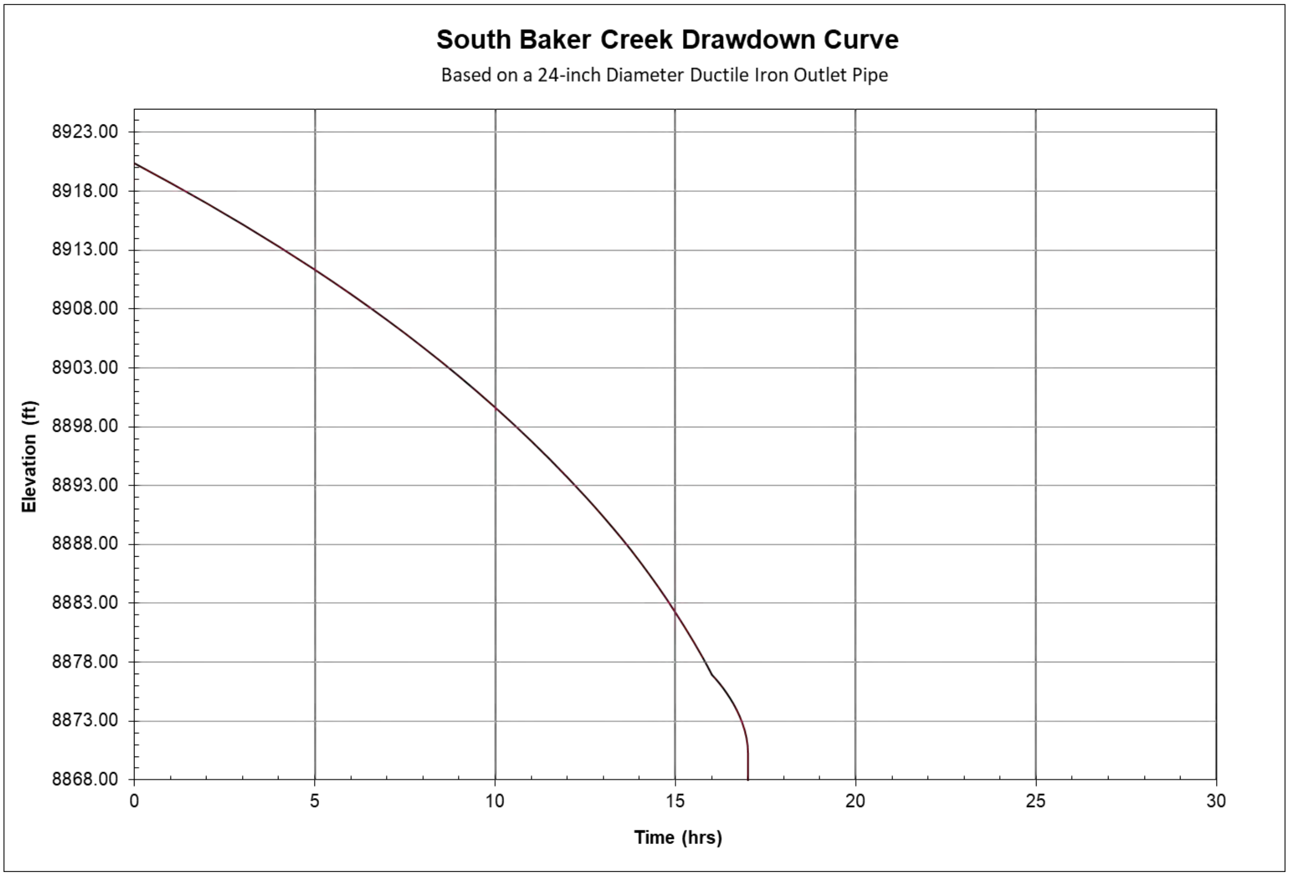


Figure 5. South Baker Creek Drawdown Curve

FOUNDATION PREPARATION AND CUTOFF WALL DESIGN

Based on Cesare's recommendations, 30% design assumes foundation preparation for construction of the RCC dam will consist of the following:

1. Excavation to bedrock contact along the longitudinal length of the dam (north abutment to south abutment).
2. Construction of a concrete cutoff wall extending a minimum of 5 feet into competent, low-permeability bedrock.
3. Placement of leveling concrete over an 80-foot long area at bedrock contact to fill potential voids in the bedrock and provide a base for starting RCC lifts.

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 the roller-compacted concrete (RCC) and the concrete facing. Unit costs for RCC and conventional concrete facing are based on industry cost data for the construction of small RCC dams in the U.S. RCC costs assume that construction water and suitable aggregate are available onsite or in close proximity to the project area. Based on Cesare's investigation, the cost estimate assumes that coarse aggregate will need to be imported to meet typical gradation requirements for RCC aggregate. For 30% design, Applegate has incorporated this cost based on the estimated quantity necessary for a 3:1 blend with native materials (encountered in borings SB-1 through SB-3) and a nominal import cost. As discussed, additional geotechnical information is necessary to confirm the suitability of native materials for RCC mix design and identify other potential borrow areas.

Note quantities for excavation, concrete and other fill materials were approximated based on depth to bedrock encountered in the borings completed by Cesare, assumed excavation limits and dam geometry. The cost estimate does not include estimated costs for the offsite disposal of excess cut material not used for RCC; it is assumed that this material could be disposed of onsite or in a nearby uplands with nominal haul costs. Project costs are summarized in Table 4. The resulting unit cost for the 117 acre-foot reservoir would be approximately $73,000 per acre-foot.

Construction Subtotal	$6,748,800
Contingency (20%)	$1,350,000
Construction Total	$8,098,800
Permitting	$202,500
Land Acquisition	$21,000
Engineering	$135,000
Construction Observation	$70,000
Annual O&M Costs	$20,000
Total	**$8,547,300**

Table 4. Summary of Project Costs

SUMMARY

The proposed South Baker Creek RCC dam would provide approximately 117 acre-feet of total storage. Based on 30% design, the dam would be 82 feet in height, extending approximately 550 feet from north abutment to south abutment and roughly 100 feet from upstream face to downstream wall of the proposed stilling basin. The dam would be founded on bedrock, with an approximately 20-foot deep concrete cutoff wall extending into sandstone and claystone bedrock. Construction costs are primarily driven by concrete costs; based on 30% design quantities, storage would cost approximately $73,000 per acre-foot.

Dam design for the South Baker Creek site was changed from a zoned earthen embankment dam to a roller-compacted concrete gravity dam, based on results of Cesare's geotechnical investigations which indicated a lack of low-permeability material at the site that would be available for construction of zoned earthen embankment dam. A roller-compacted concrete dam was selected as an alternative as construction allows for the use of lower quality rock and aggregate.

The following additional information is recommended if the South Baker Creek site is moved to further design phase(s):

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).
    b. Extent of landslide material at south abutment, including lateral extent upstream, downstream, and into the abutment areas.
    c. Suitability of native materials for RCC and the identification of potential borrow sources for import.

The RCC dam alternative for the South Baker Creek dam site is technically feasible, based on the 30 percent design and geotechnical data available at the time of this report. However, the 30 percent design indicates a high cost per acre-foot of storage capacity that should be considered by the project proponents.

APPENDIX A

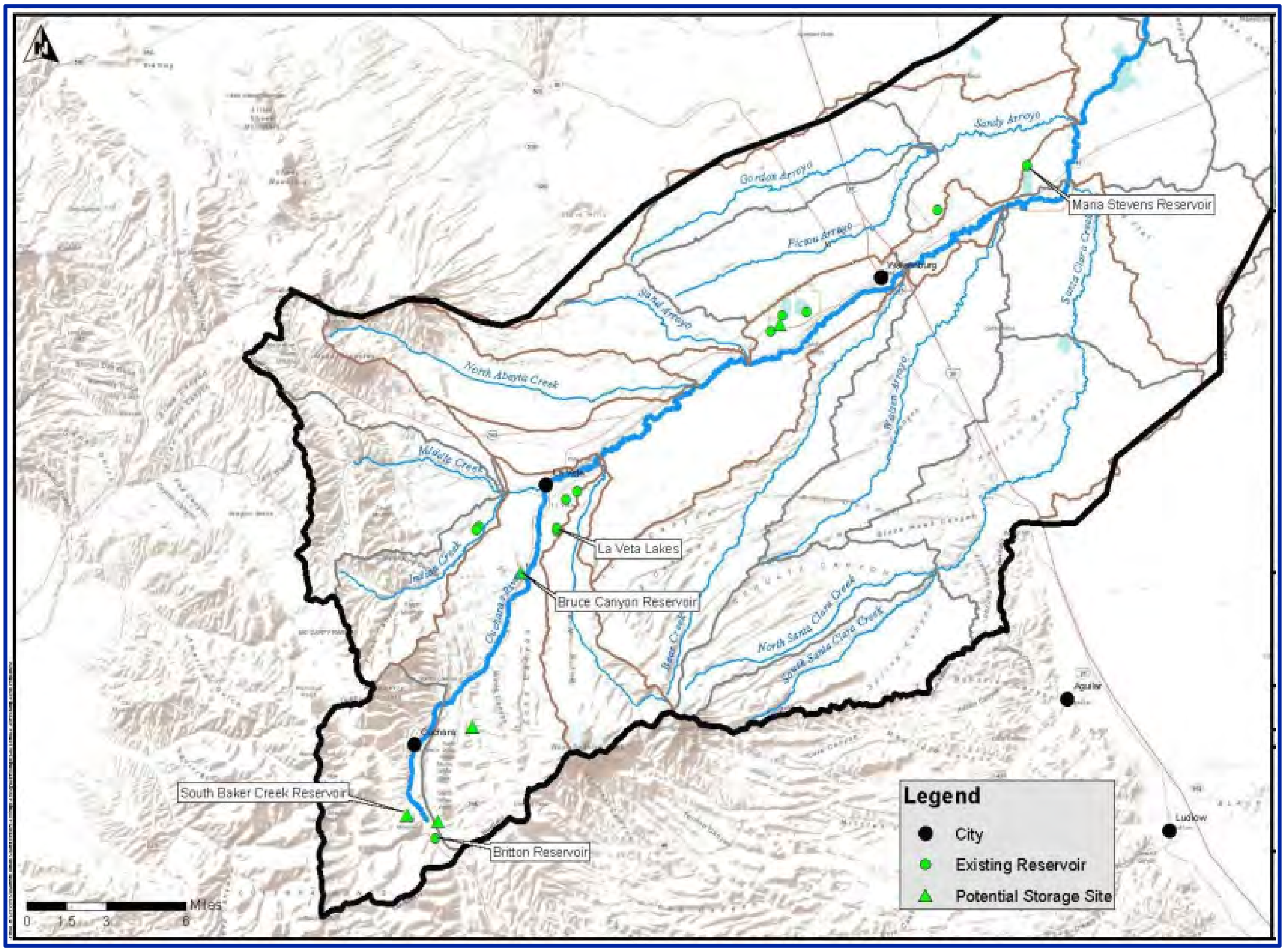
2019 GEOTECHNICAL REPORT

CESARE, INC.

Geotechnical Engineers & Construction Materials Consultants

PRELIMINARY GEOTECHNICAL EVALUATION

Cucharas Basin Collaborative Storage
Huerfano County, Colorado



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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

Report Prepared for:

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November 7, 2019

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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.

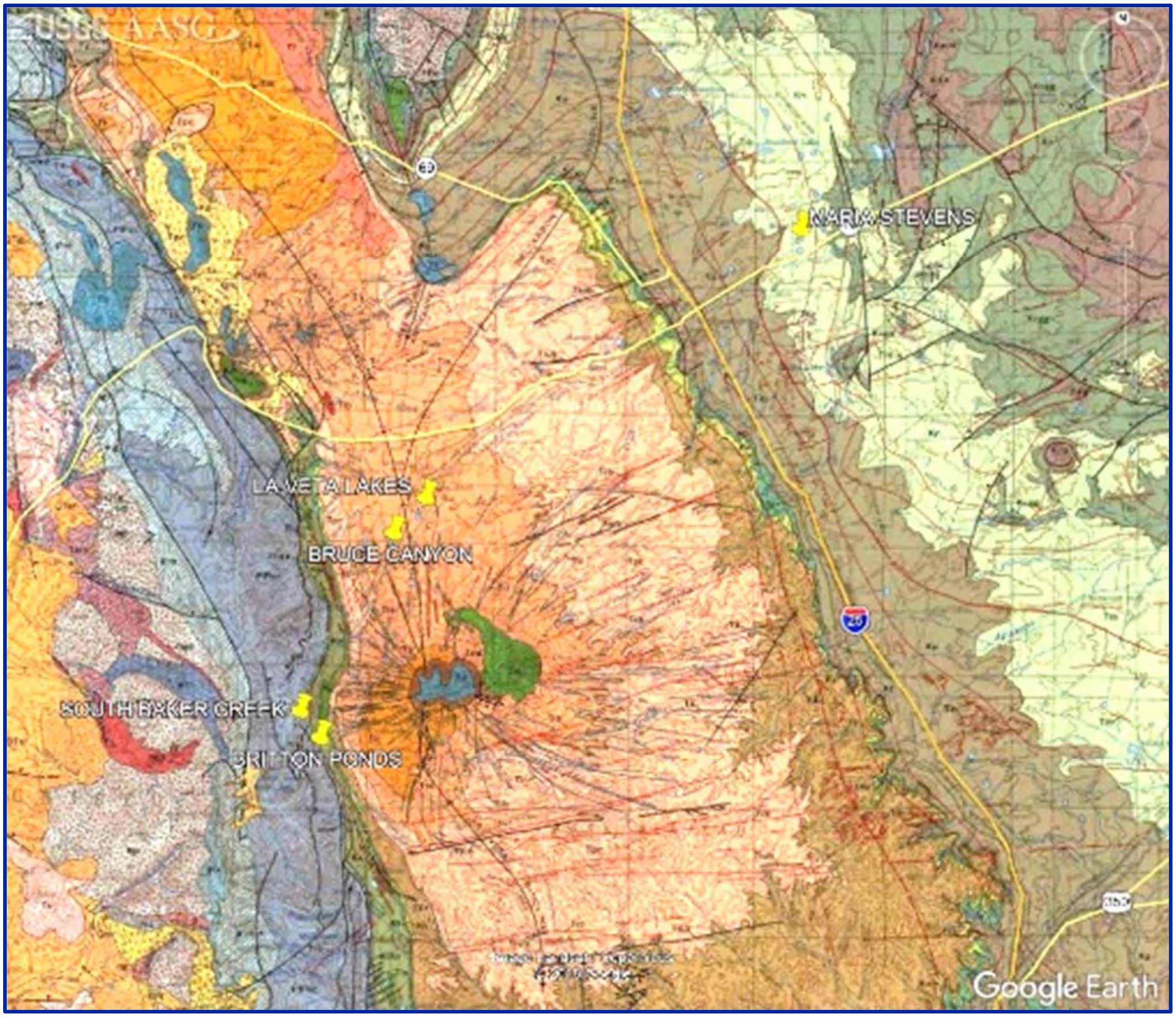

FIGURE 1. Geologic map showing the five study site locations. The La Veta syncline axis trends southeast to northwest and along the fold axis are the East and West Spanish peak intrusions and radiating dikes. The Maria Stevens site is north and east of the Cucharas area on the gently dipping east limb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

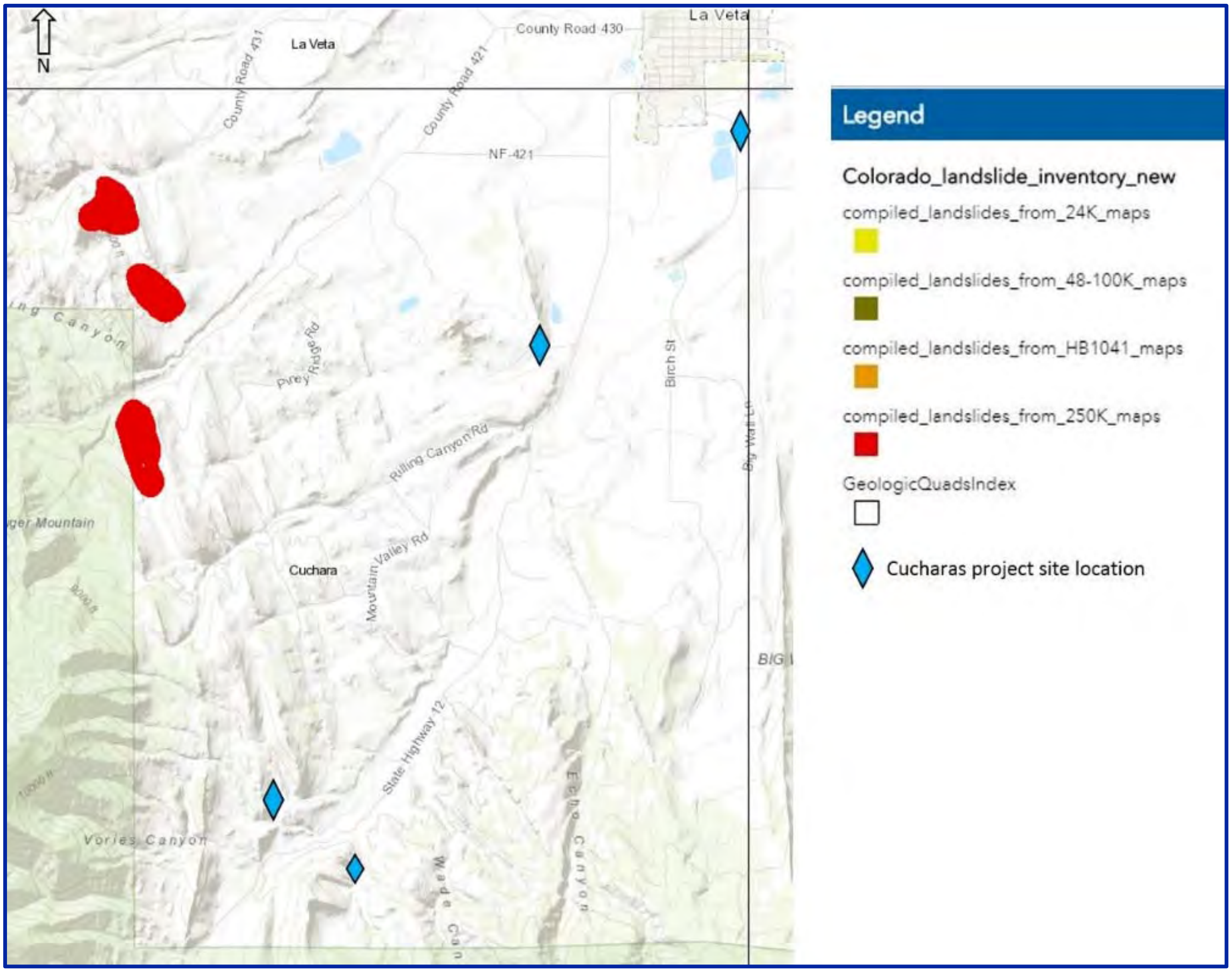

FIGURE 2. Mapped landslides in the Cucharas region from the Colorado landslides inventory. The red polygons are landslide areas digitized from 1:250,000 scale USGS mapping in the mid 1970's by Colton and others on 1 degree by 2 degree quadrangles. This map may not represent all landslides in the area.

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)

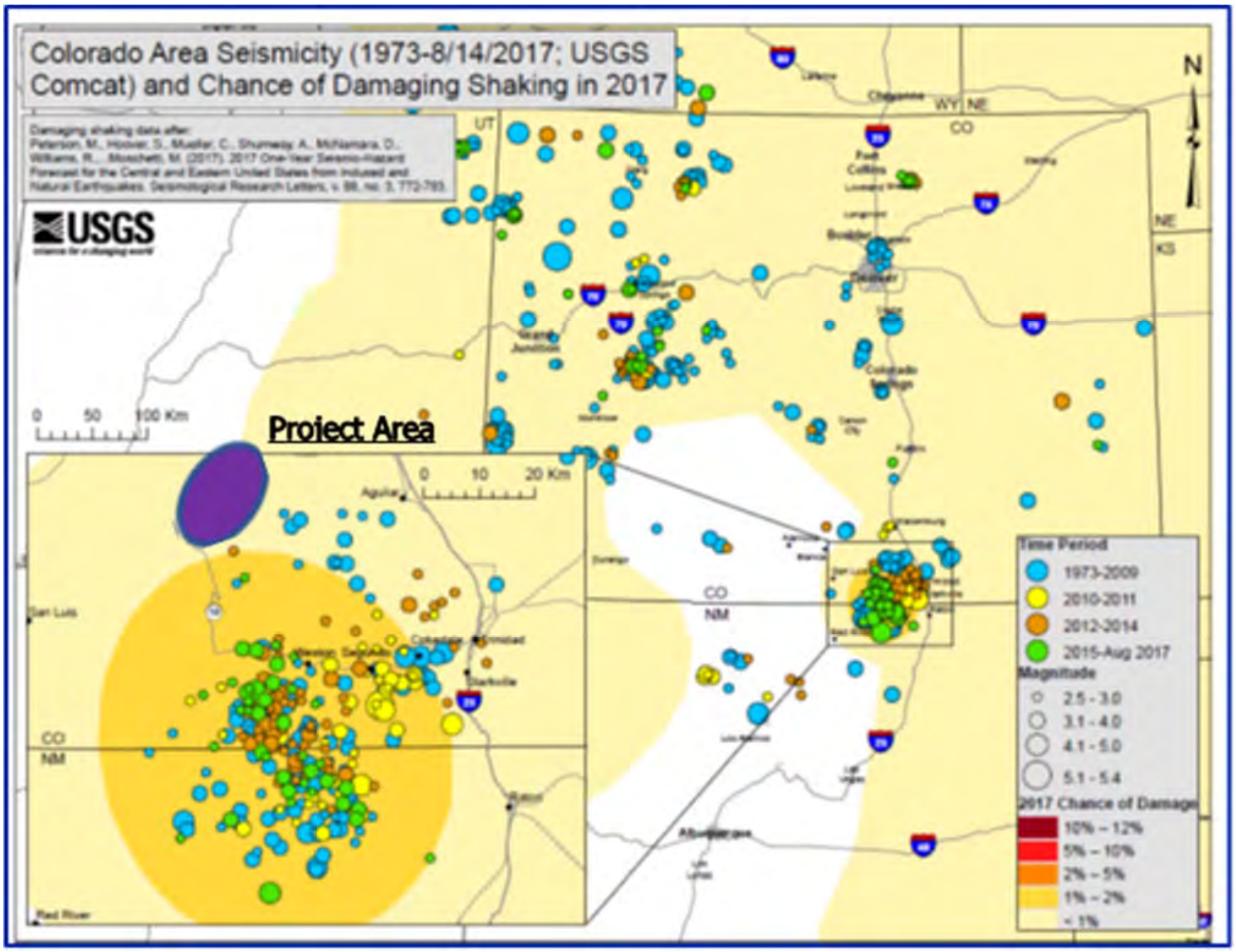

FIGURE 3. Colorado seismicity from the USGS earthquakes hazards program. There is very low seismic risk for the project area.

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.

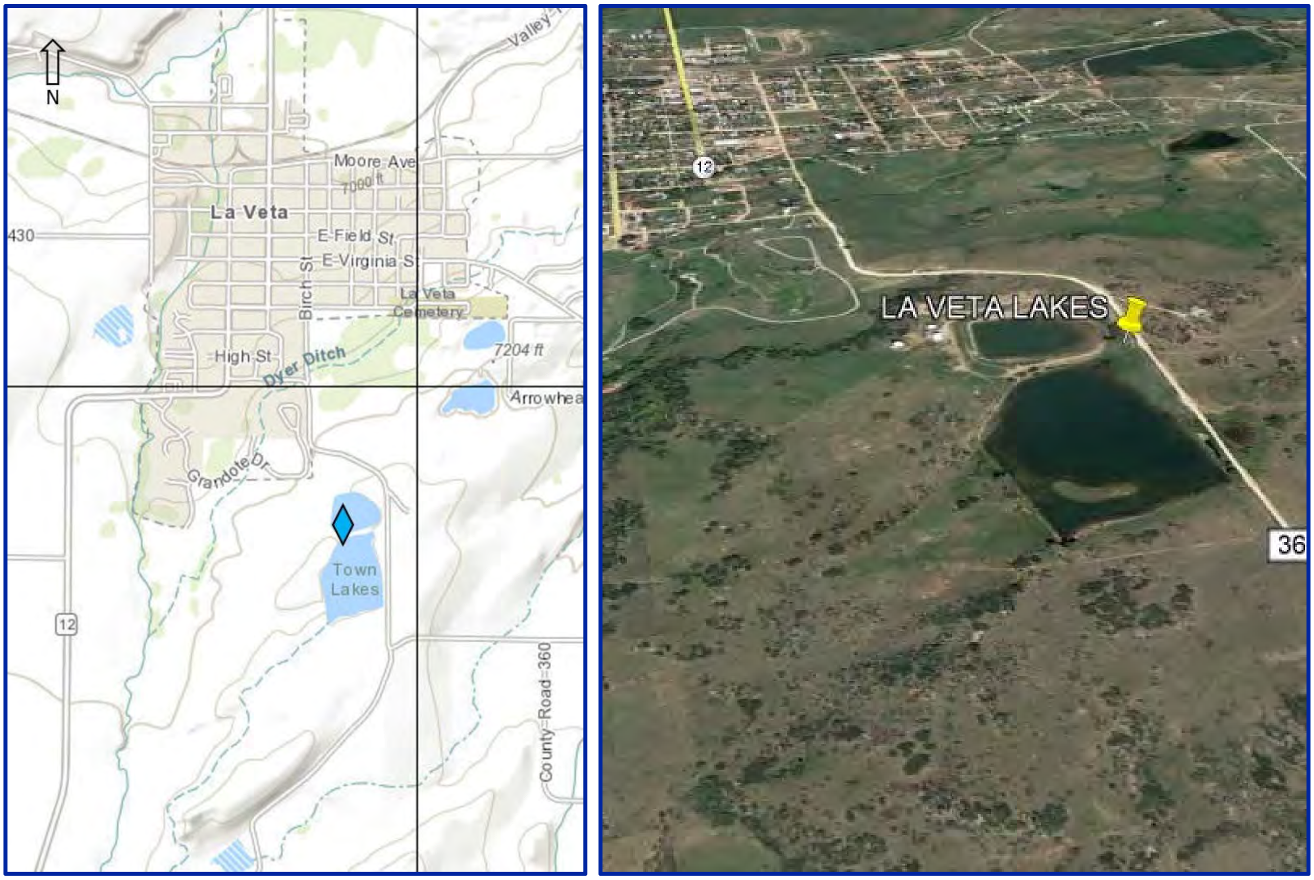

FIGURE 8. La Veta Lakes project site (topographic and Google Earth images) is located just south of the Town of La Veta and about 100 feet above the valley in elevation. La Veta Lakes is a water storage area that is fed by a piped diversion from the Cucharas River. The site is in the middle of the La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

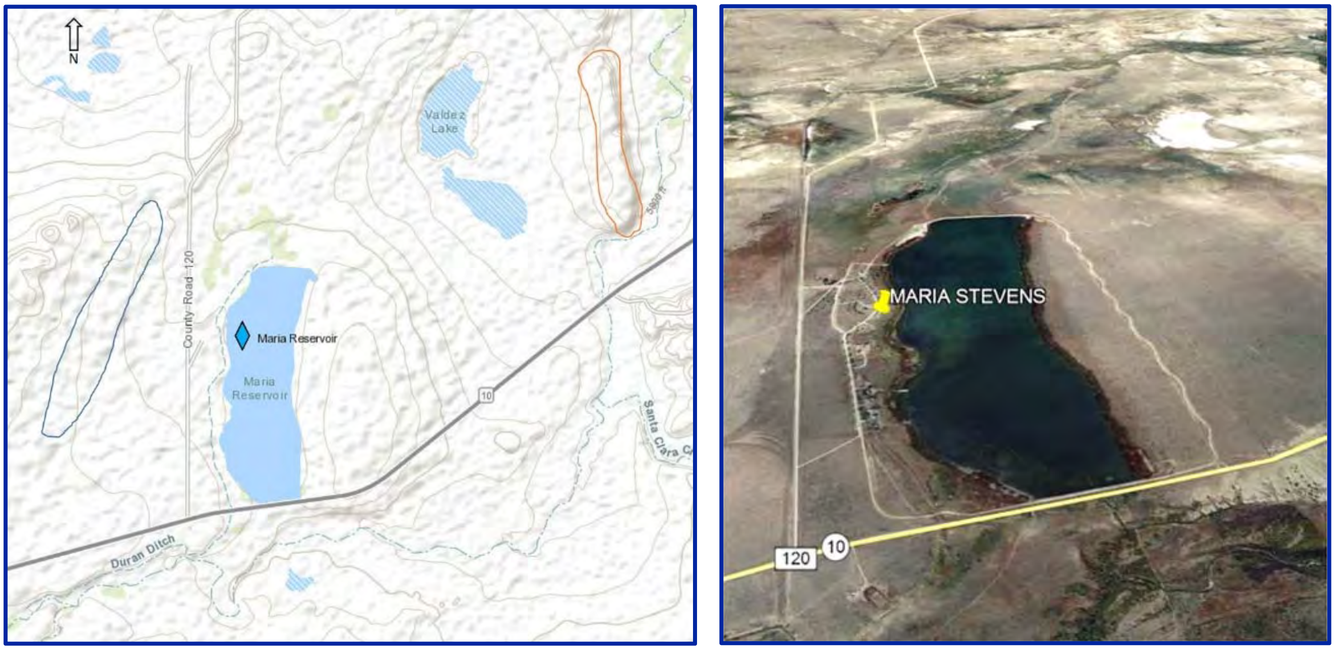

FIGURE 9. Location and topography of Maria Stevens Reservoir (topographic and Google Earth images). Walsenburg is west, via SH10. The circled area on the left of the topographic map is a gravel ridge. The circled area on the right of this map is a ridge of Cretaceous Carlile shale, Greenhorn limestone, 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.

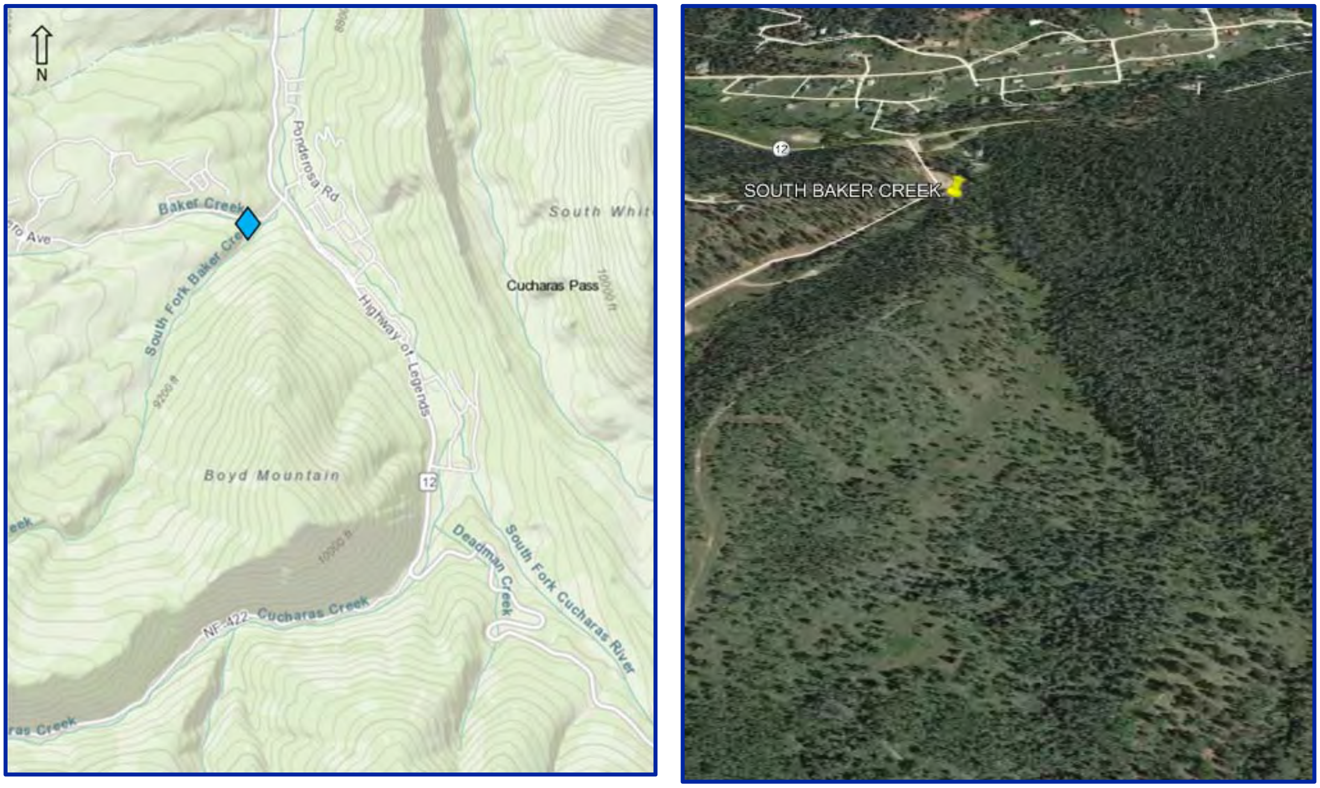

FIGURE 10. South Baker Creek project site (topographic and Google Earth images) is located southwest of the Bruce Canyon site, west of SH12, north of Cucharas Pass. South Baker Creek is a southwest–northeast trending valley with South Baker Creek becoming a tributary of the South Fork of the Cucharas 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

Material	Britton		Bruce Canyon		Maria Stevens	
	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

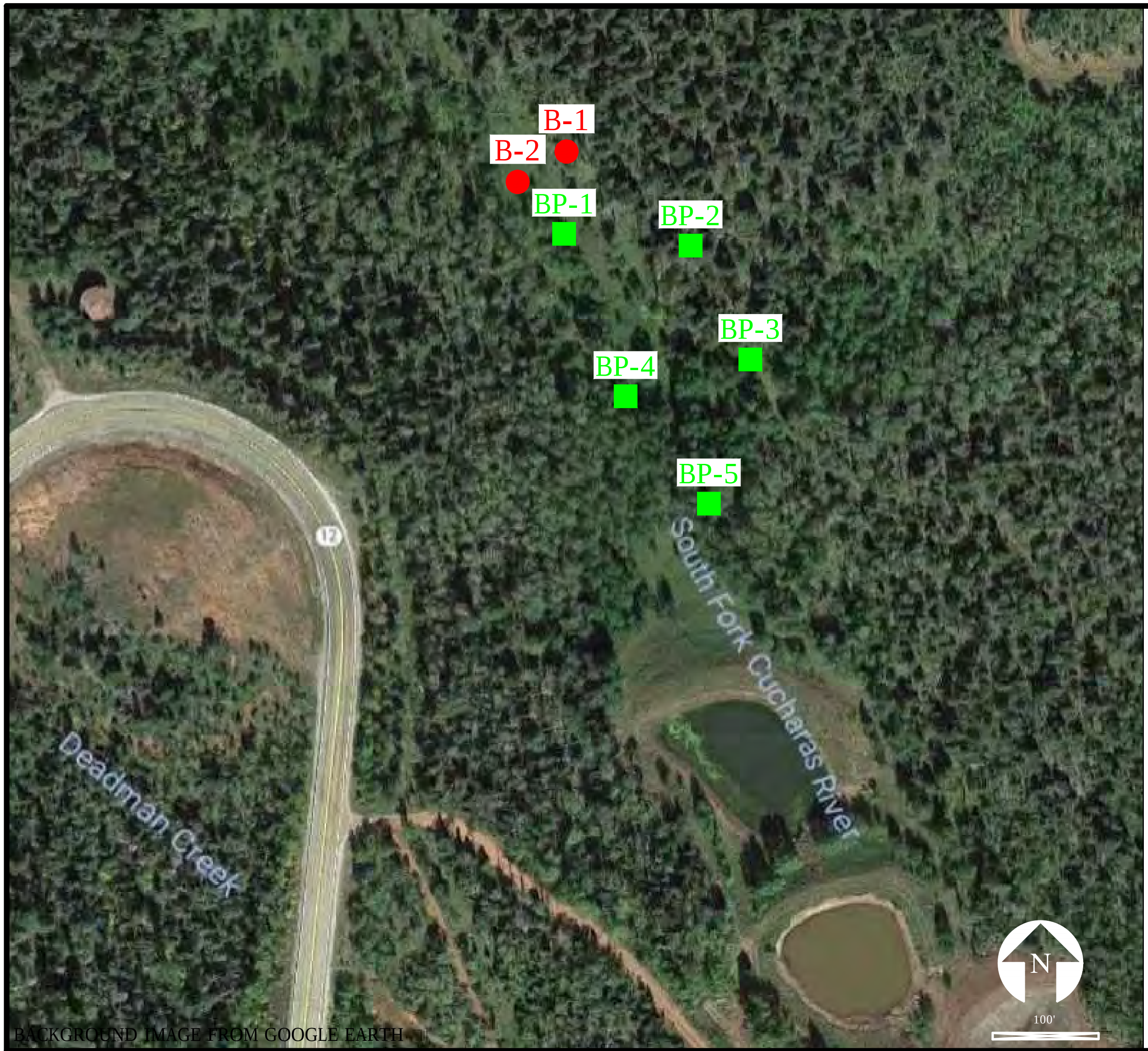
The concept of risk is an important aspect of any geotechnical evaluation. The primary reason for this is that the analytical methods used by geotechnical engineers are generally empirical and must be tempered by engineering judgment and experience, therefore, the solutions or recommendations presented 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.

W:\2018\Centennial\18.100\18.117.C Cucharas Basin Collaborative Storage\ACAD\Britton Reservoir\Britton Reservoir Boring and Exploratory Pit Locations.dwg 11/1/2018 11:16 AM



BACKGROUND IMAGE FROM GOOGLE EARTH

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

CESARE, INC.
Geotechnical Engineers & Construction Materials Consultants

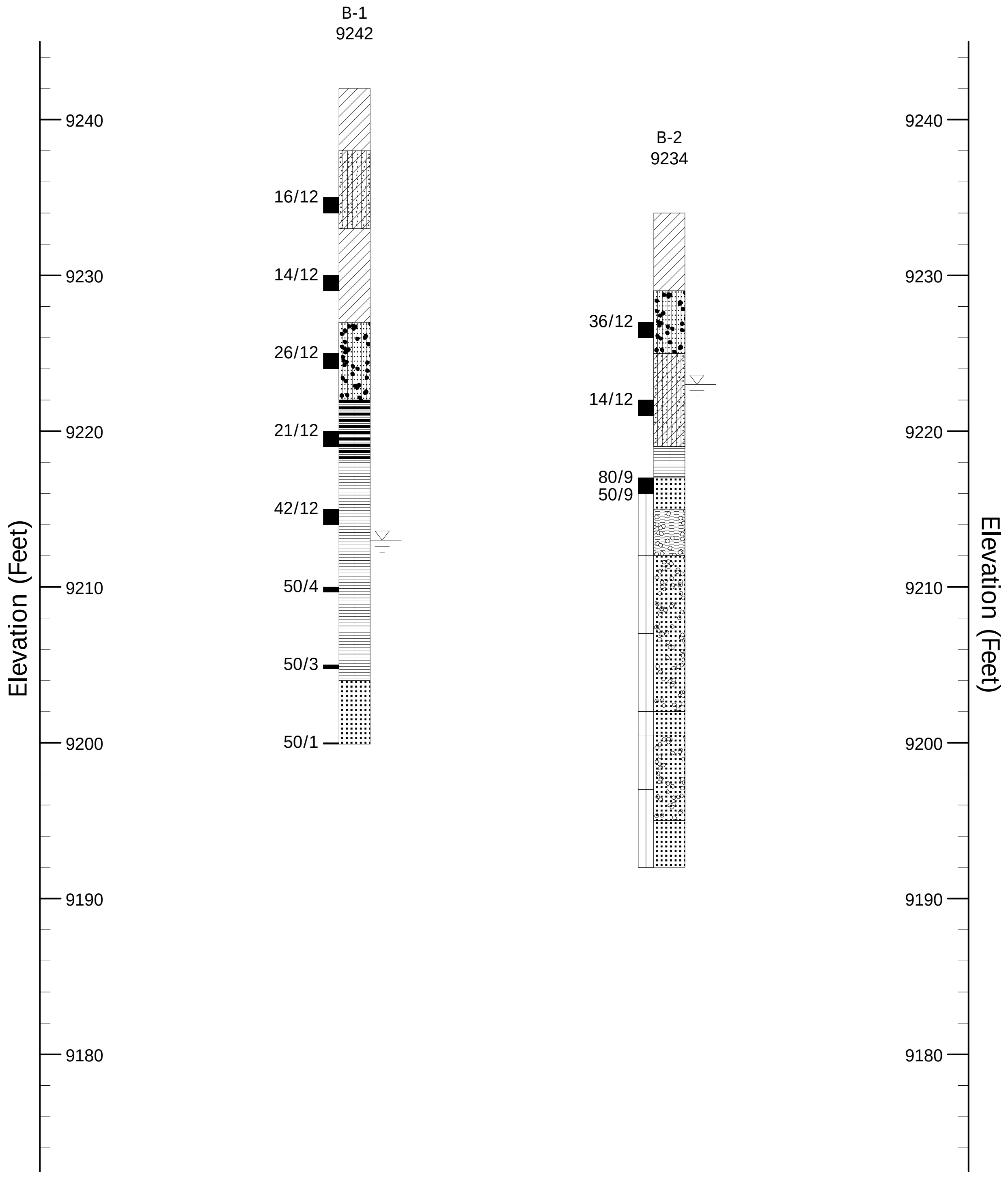
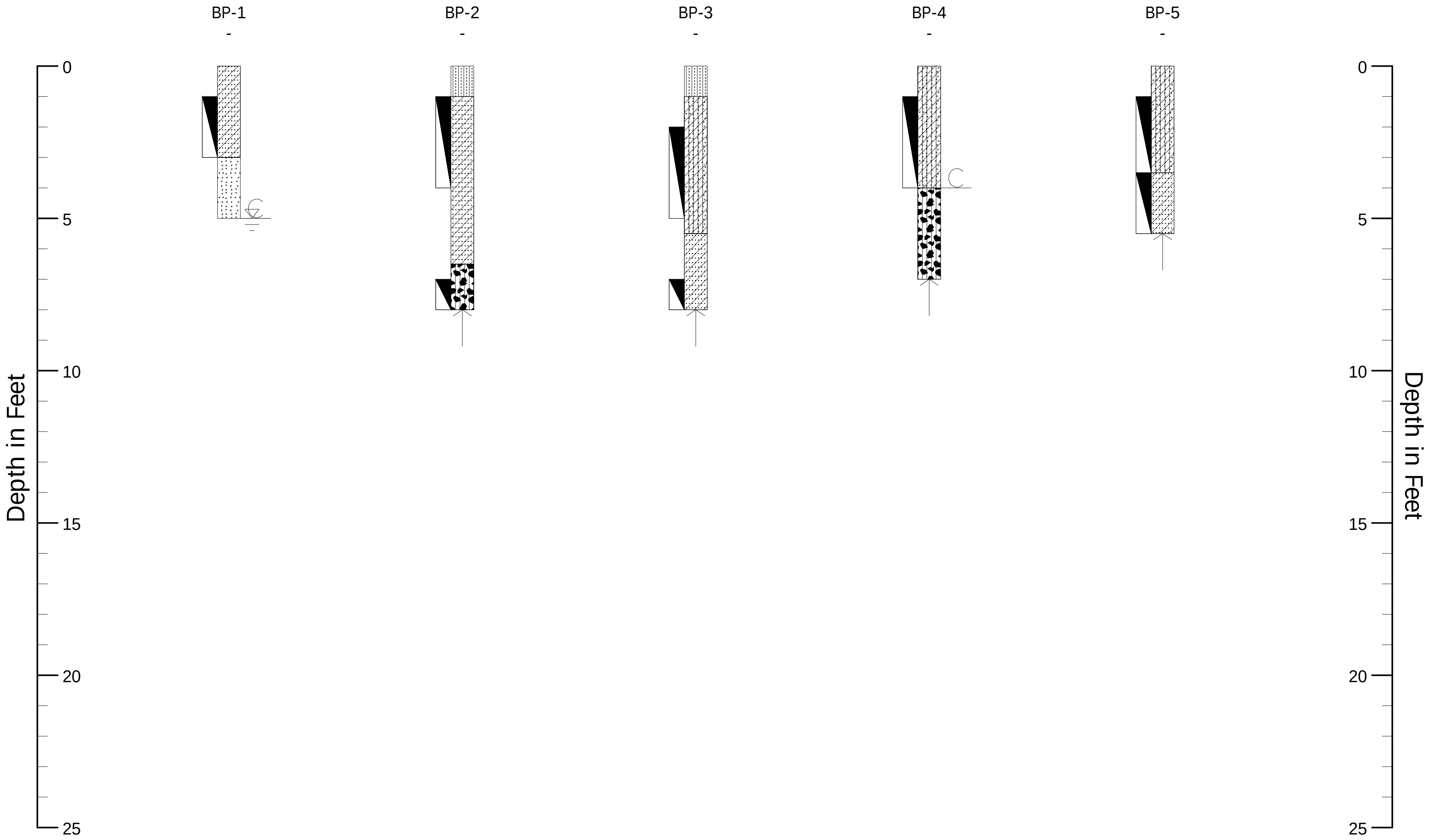


FIGURE 12

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

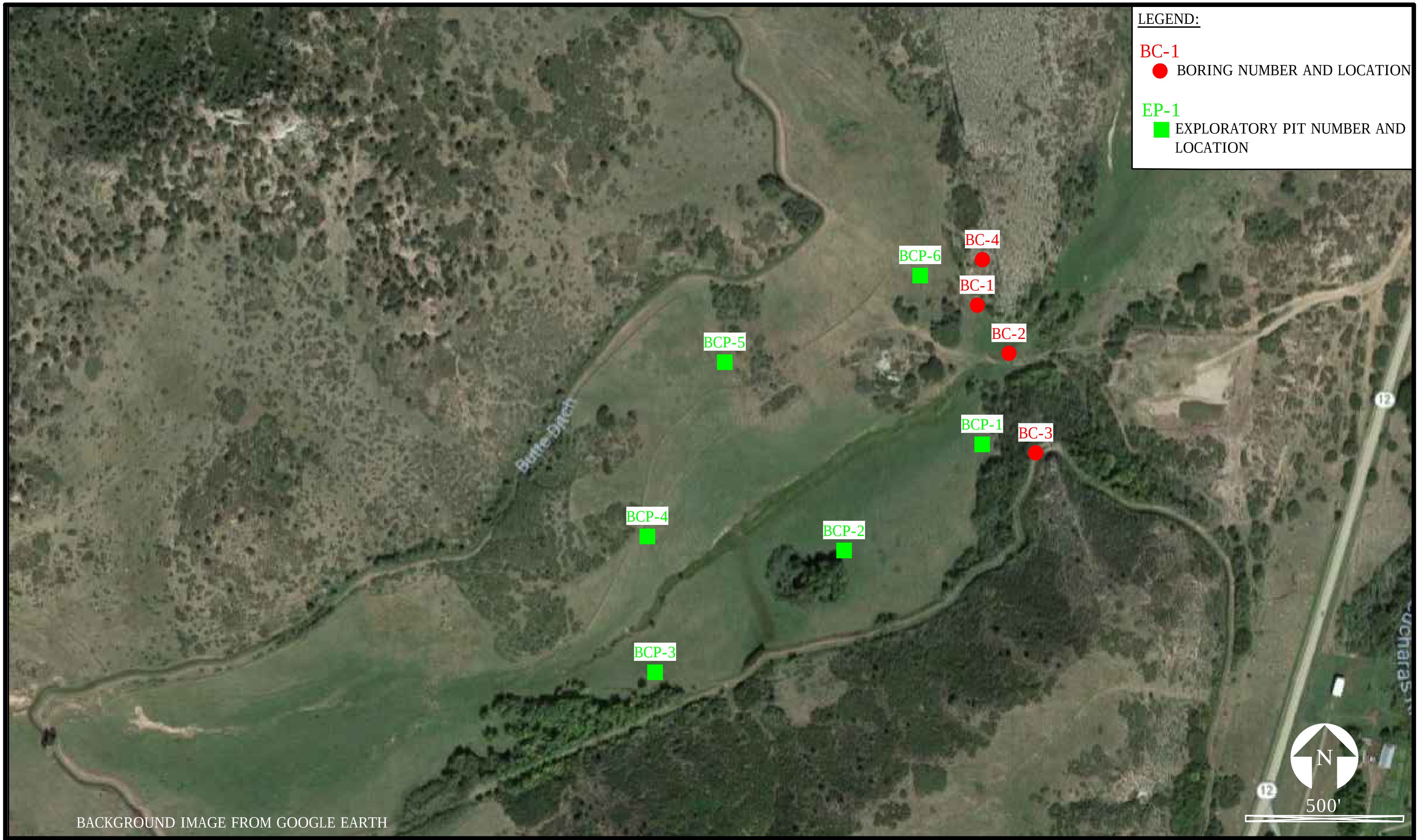
FIGURE 13

Britton Exploratory Pit Logs

CESARE, INC.

Geotechnical Engineers & Construction Materials Consultants

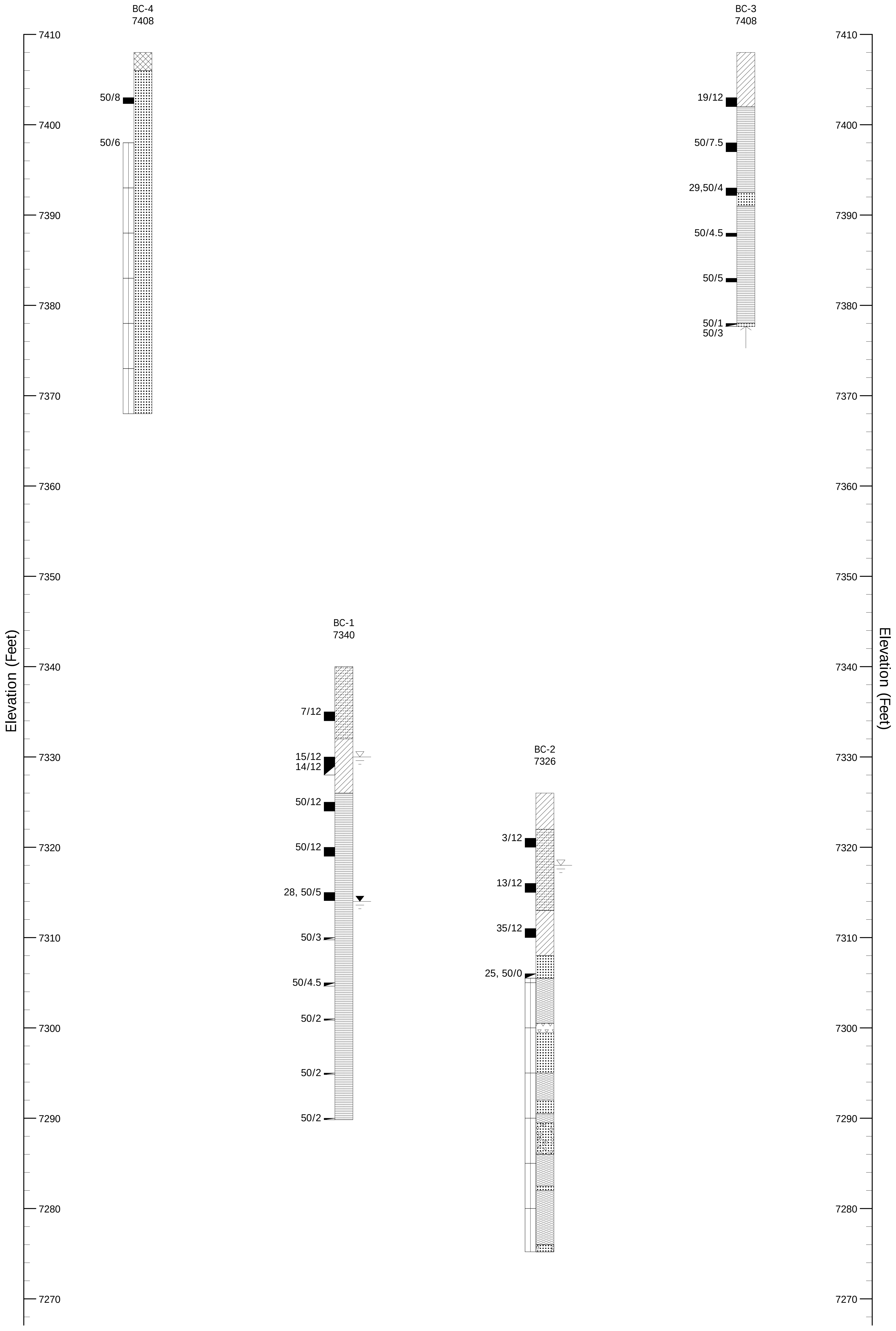
W:\2018\Centennial\18.100\18.117.C Cucharas Basin Collaborative Storage\ACAD\Bruce Canyon\Bruce Canyon Boring and Exploratory Pit locations.dwg 10/17/2019 8:03 AM



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

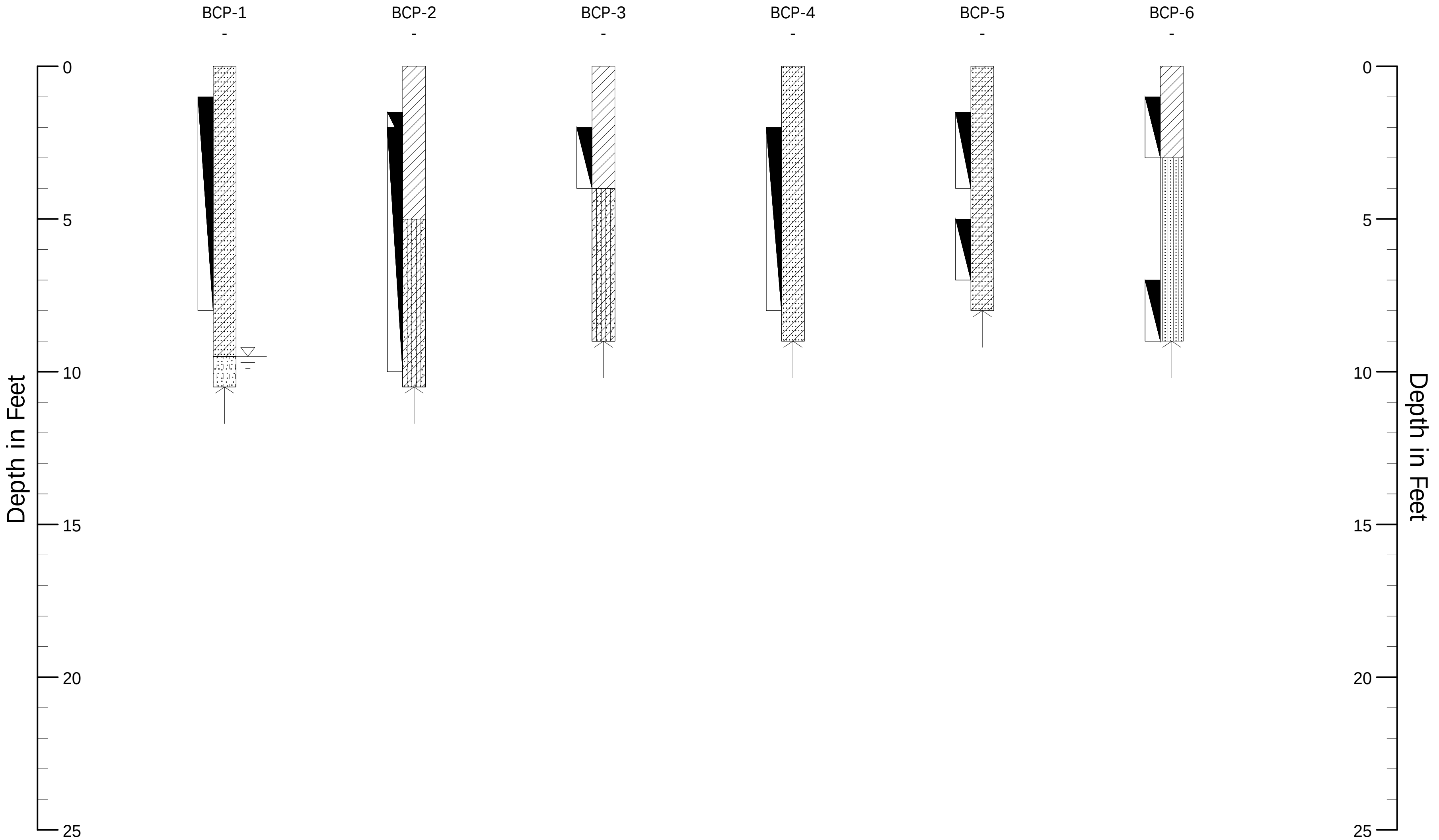


PROJECT NO:	18.117
PROJECT NAME:	Cucharas Basin Collaborative Storage Bruce Canyon
DWG DATE:	10/24/2019

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

CESARE, INC.
Geotechnical Engineers & Construction Materials Consultants

W:\2018\Centennial\18.100\18.117.C Cucharas Basin Collaborative Storage\ACAD\La Veta\LA Veta Boring locations.dwg 11/1/2018 4:16 PM

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.
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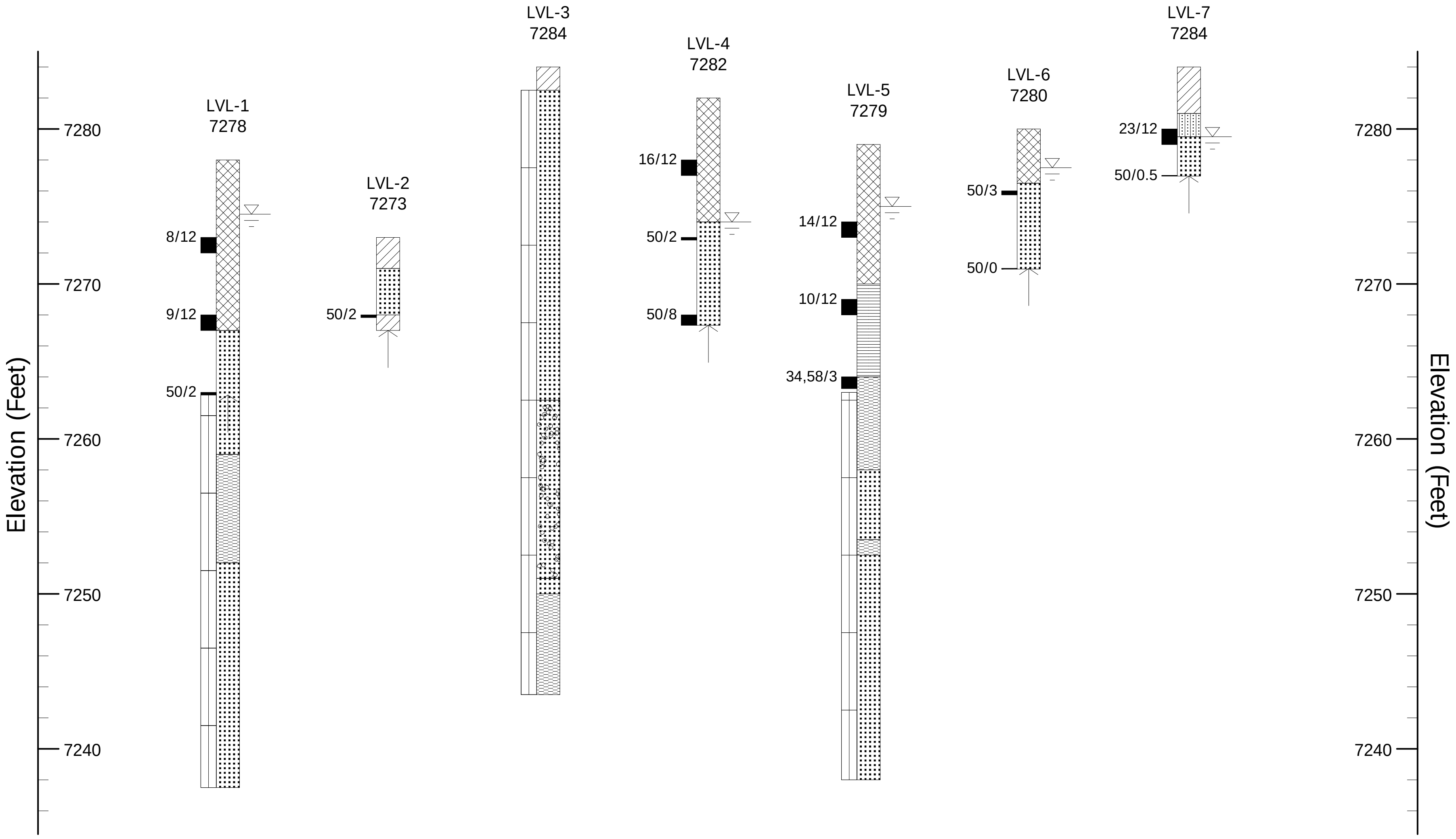


PROJECT NO:	18.117
PROJECT NAME:	Cucharas Basin Collaborative Storage
DATE:	10/28/2018

FIGURE 18

La Veta Lakes Boring Logs

CESARE, INC.
Geotechnical Engineers & Construction Materials Consultants

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

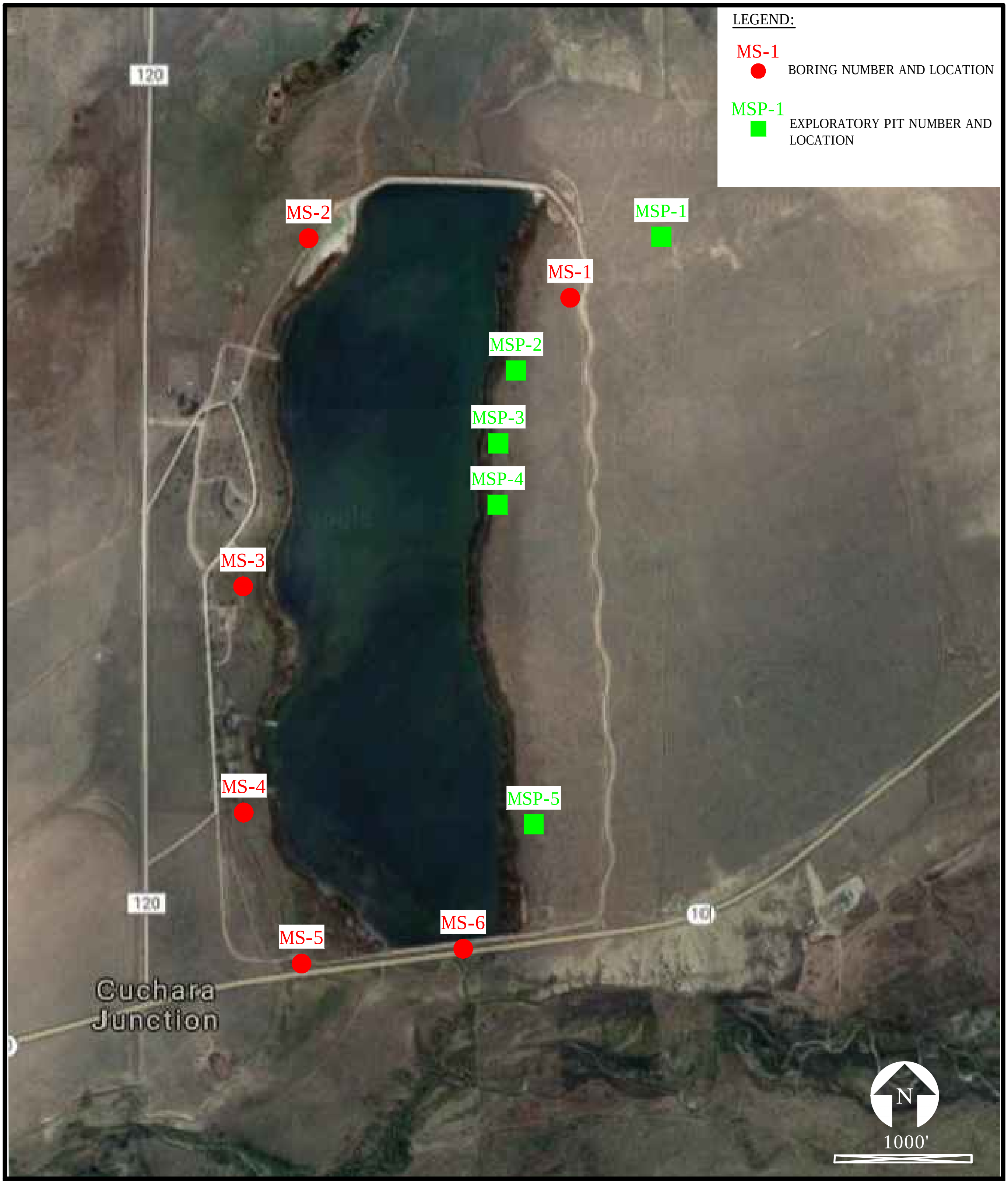
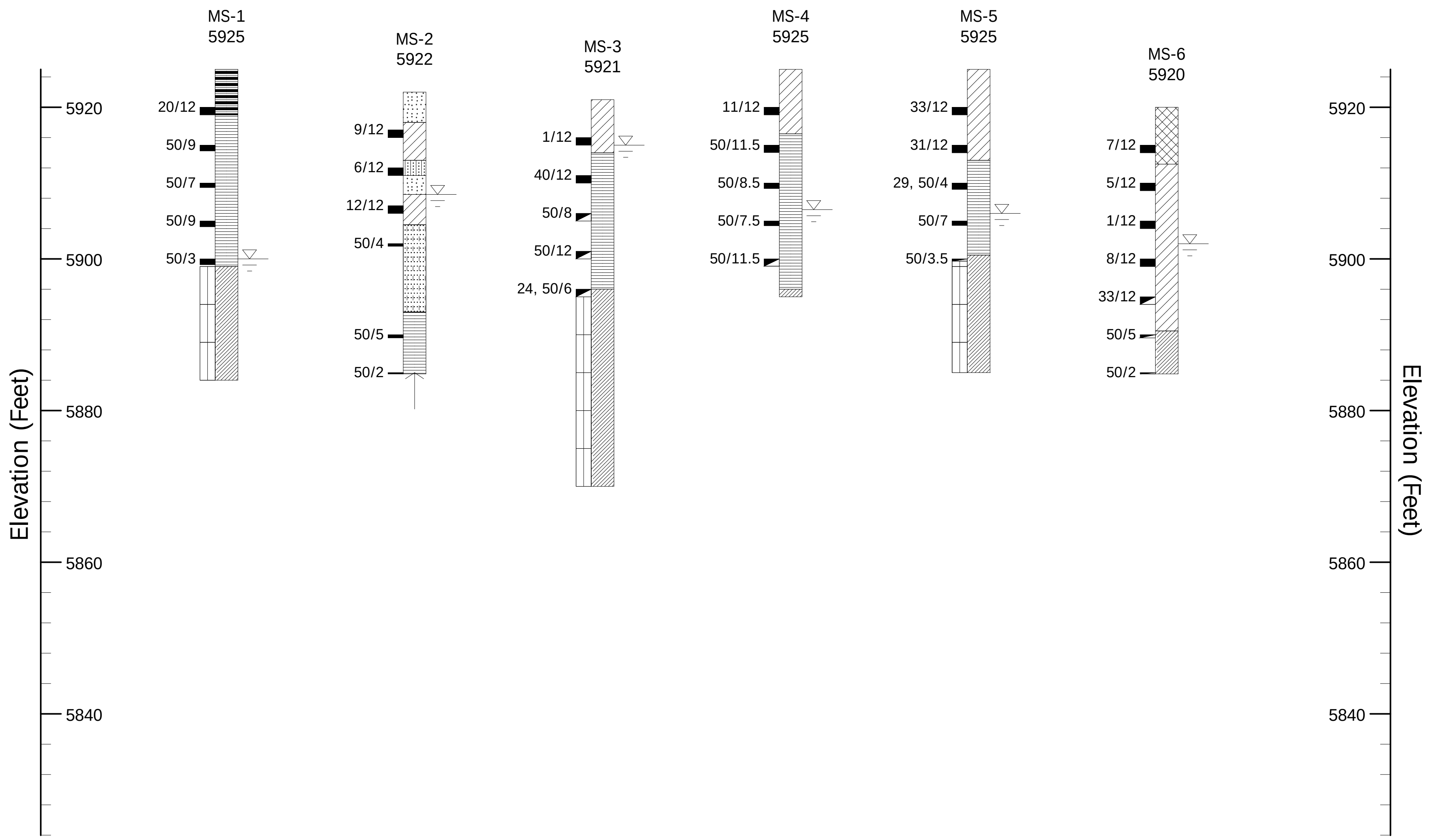


FIGURE 19
Maria Stevens
Locations of Borings and Exploratory Pits

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

CESARE, INC.
Geotechnical Engineers & Construction Materials Consultants



PROJECT NO: 18.117

PROJECT NAME: Cucharas Basin Collaborative Storage

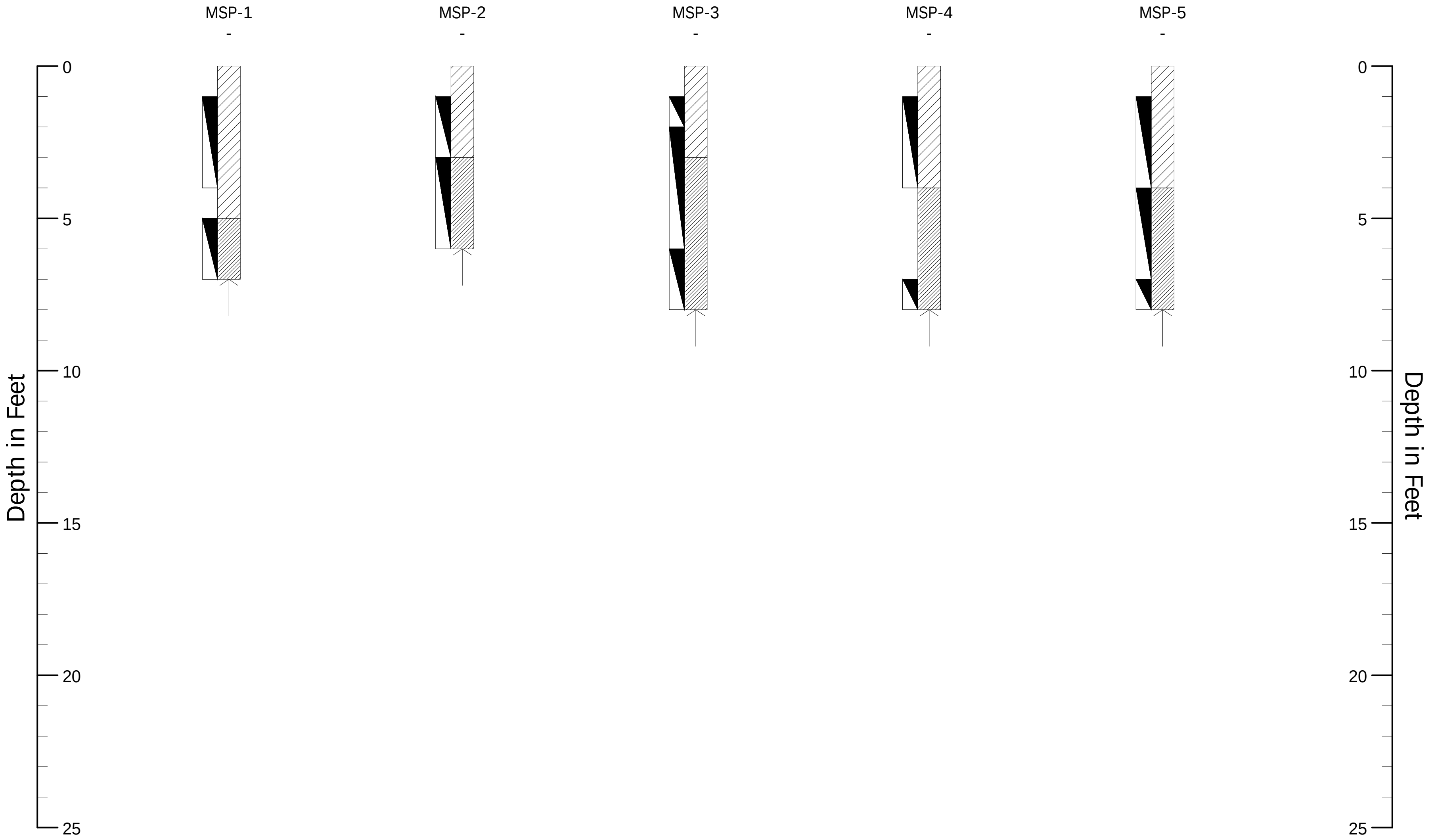
DATE: 10/30/2018

FIGURE 20

Maria Stevens Boring Logs

CESARE, INC.

Geotechnical Engineers & Construction Materials Consultants



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

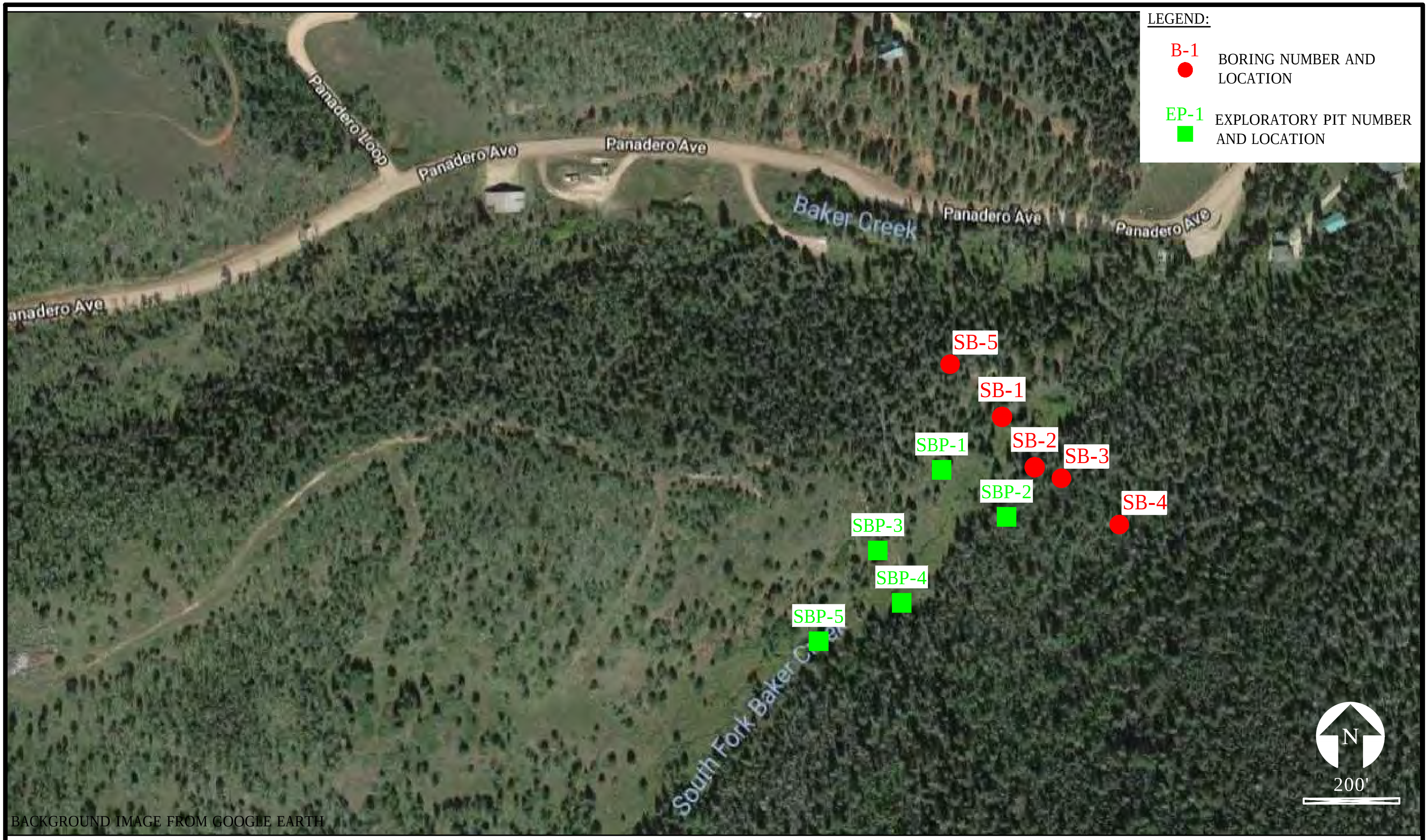
FIGURE 21

Maria Stevens Exploratory Pit Logs

CESARE, INC.

Geotechnical Engineers & Construction Materials Consultants

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

CESARE, INC.
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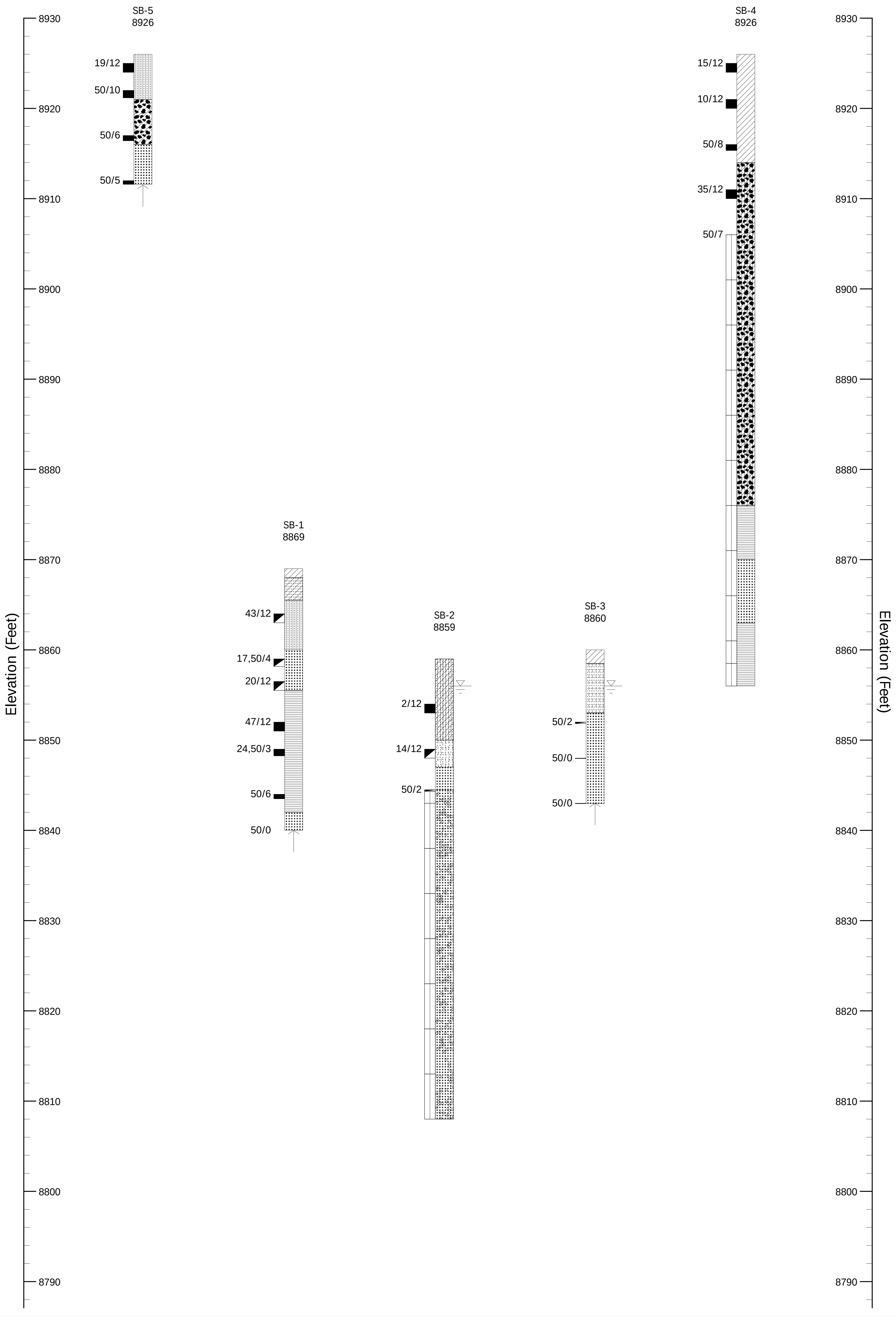
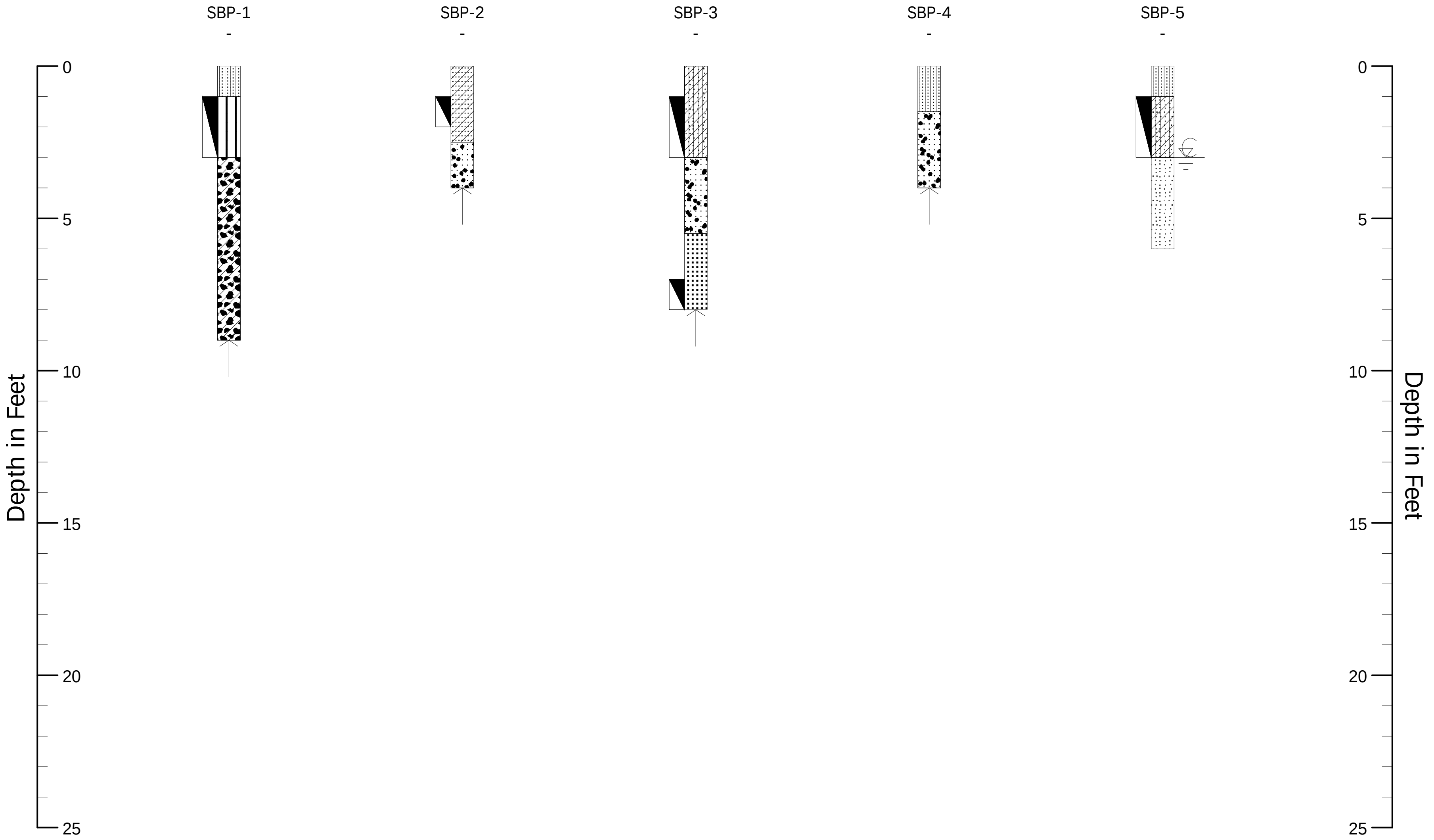


PROJECT NO:	18.117
PROJECT NAME:	Cucharas Basin Collaborative Storage
DWG DATE:	11/6/2019

FIGURE 23

South Baker Boring Logs

CESARE, INC.
Geotechnical Engineers & Construction Materials Consultants



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

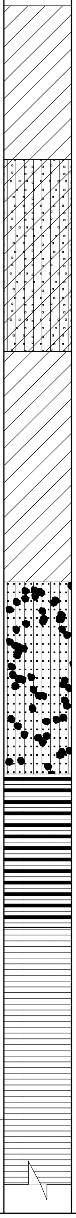
Individual Boring Logs

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. SAND, silty, clayey, moist medium dense, reddish brown.						
							16/12					
10						9 ft. CLAY, sandy, moist, stiff, reddish brown.						Smoother drilling from 9'
							14/12					
15						15 ft. GRAVEL, with silt and sand, moist, medium dense, reddish brown.						Hard, boulder at 15'
							26/12					Sandy
20						20 ft. CLAYSTONE, weathered, moist to wet, occasional thin sandstone partings, dark red.						Smoother, firm
							21/12					
25						24 ft. CLAYSTONE, medium hard to very hard, slightly moist to wet, occasional thin sandstone partings, dark red.						Harder at 24'
							42/12					
30	▽											Very hard at 29'

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CESARE INC.

LOG OF BORING

PROJECT Cucharas Basin Storage Collaborative

PROJECT NO. 18.117

BORING NO. **B-1**

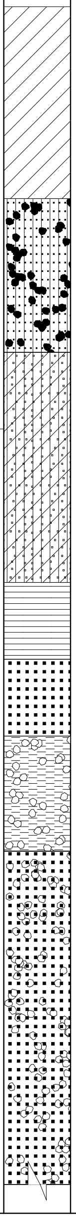
DEPTH (ft)	FRACTURE LOG	GRAPHIC LOG	MOISTURE dry	MOISTURE moist	MOISTURE sat	DESCRIPTION	BLOWS/FT	CORE NO.	CORE RECOVERY (%)	CORE RQD (%)	CORE HARDNESS	DRILLING NOTES
							50/4					
												Soft at 34' and 35'
35												
							50/3					
						38 ft. SANDSTONE, moist to wet, very hard, gray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

CESARE, INC.
Geotechnical Engineers & Construction Materials Consultants

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			DESCRIPTION	BLOWS/FT	CORE				DRILLING NOTES
			dry	moist	sat			NO.	RECOVERY (%)	RQD (%)	HARDNESS	
0						CLAY, sandy, moist, medium stiff, roots in upper 12 inches, reddish brown.						
5						5 ft. GRAVEL, with silt and sand, moist to wet, dense, reddish brown.						
							36/12					
						9 ft. SAND, silty, clayey, wet, medium dense, organic smell at 12-1/2 feet, cobbles at 14 feet, dark red.						
10												
	▽											
							14/12					
15						15 ft. CLAYSTONE, silty, moist, hard to very hard, dark red.						
						17 ft. SANDSTONE, silty, soft, fine to medium grained, massive bedding, red brown. 18'-19' tan to olive clasts	80/9	1	100	0	H7	
							50/9	2	88	29	H7	
						19 ft. MUDSTONE, soft, massive bedding, red brown. With calcareous gray concretions 1/8" - 1/2" in diamter.						
20												
						22 ft. 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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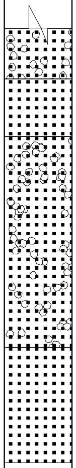
CESARE INC.

LOG OF BORING

PROJECT Cucharas Basin Storage Collaborative

PROJECT NO. 18.117

BORING NO. **B-2**



DEPTH (ft)	FRACTURE LOG	GRAPHIC LOG	MOISTURE			DESCRIPTION	BLOWS/FT	CORE				DRILLING NOTES
			dry	moist	sat			NO.	RECOVERY (%)	RQD (%)	HARDNESS	
						32 ft. SANDSTONE, medium hard to hard, coarse grained, massive bedding, tan to red brown.		5	100	83	H3	
35						33.5 ft. 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. SANDSTONE, moderately hard, predominately coarse grained, with gravel, massive bedding, red brown to tan.						
45												
50												
55												
60												
65												

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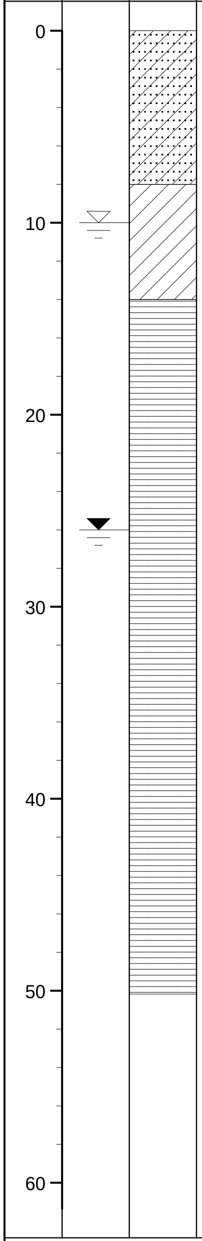
LOG OF BORING

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
DRILL RIG CME-55
DRILL METHOD HSA & HQ Core

DEPTH TO WATER / DATE

10	8/6
26	8/7



MOISTURE dry	MOISTURE moist	MOISTURE sat	DESCRIPTION	BLOWS/FT	CORE NO.	CORE RECOVERY (%)	CORE RQD (%)	CORE HARDNESS	DRILLING NOTES
			SAND, clayey, moist, loose, dark brown.	7/12					
			8 ft. CLAY, sandy, moist, stiff, low calcareous, dark brown.	15/12 14/12					
			14 ft. 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 50/12 28, 50/5 50/3 50/4.5 50/2 50/2					
			Stopped HSA and sampling at 50.2'.	50/2					

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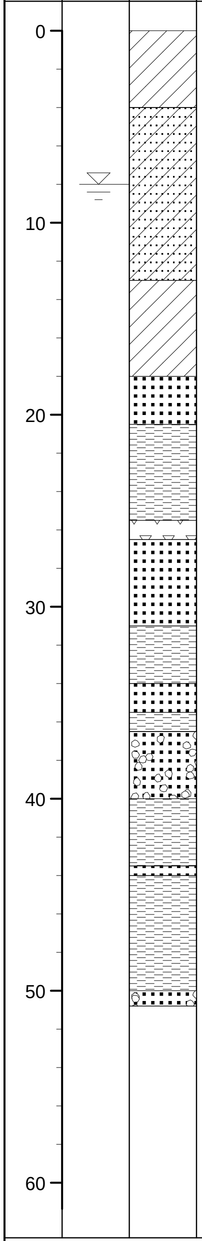
LOG OF BORING

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"		



MOISTURE: dry | moist | sat

DESCRIPTION
CLAY, sandy, moist to wet, very soft, dark brown.
4 ft. SAND, clayey, to with gravel, very loose to medium dense, wet, dark brown.
13 ft. CLAY, sandy, hard, moist, medium calcareous, brown.
18 ft. SANDSTONE, clayey, moderately hard to very hard, moist, gray. SANDSTONE, moderatly hard, moderately weathered, medium grained, massive bedding, tan.
20.5 ft. MUDSTONE, soft, moderately to highly weathered, massive bedding, dark gray to gray brown to chocolate brown. 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. SANDSTONE, conglomeratic, moderately hard, fine grained, massive bedding, dark red brown to olive gray. With occasional 1/8" - 1/4" clasts. 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. 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'

BLOWS/FT
3/12
13/12
35/12
25, 50/0

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
APPROXIMATE GROUND ELEVATION 7408
PROJECT NUMBER 18.117
DEPTH TO BEDROCK 10
DATE STARTED 8/7/18
TOTAL DEPTH 50.25
DATE COMPLETED 8/7/18
REFUSAL
LOGGED BY H. Brunkal
DRILLED BY HRL
DEPTH TO WATER / DATE
DRILL RIG CME-55
dry 8/7/18
DRILL METHOD 6.5"

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
0						CLAY, sandy, slightly moist, very stiff, medium calcareous, brown.	19/12					
10						6 ft. CLAYSTONE, sandy, slightly moist, hard, low calcareous, dark reddish brown.	50/7.5 29,50/4					
						15.5 ft. SANDSTONE, silty, clayey, slightly moist, very hard, dark red brown.						
20						17 ft. CLAYSTONE, sandy, slightly moist, very hard, medium calcareous, dark brown.	50/4.5 50/5					
30						30 ft. SANDSTONE, slightly moist, very hard, very calcareous, very indurated, maroon.	50/1 50/3					
						Stopped HSA and sampling at 30.3.						
40												
50												
60												

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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. 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												

CESARE, INC.

Geotechnical Engineers & Construction Materials Consultants

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

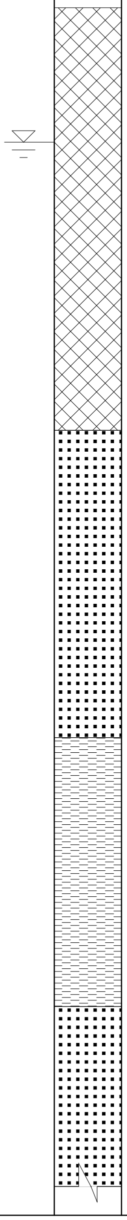
DRILLED BY HRL

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 dry	MOISTURE moist	MOISTURE sat	DESCRIPTION	BLOWS/FT	CORE NO.	CORE RECOVERY (%)	CORE RQD (%)	CORE HARDNESS	DRILLING NOTES
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. 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	
						SANDSTONE, with clay, soft, moderately weathered, predominately fine grained, laminated to banded cross-beds, olive to orange to brown to tan. SANDSTONE, moderately hard, moderately weathered, predominately coarse grained, arkosic, medium cross-beds, tan pink to yellow brown.		2	100	72	H3	
20						19 ft. MUDSTONE, soft, predominately fine grained, massive, red brown.						
								3	100	100	H6/ H4/H3	
25												
						26 ft. SANDSTONE, moderately hard, predominately medium grained, arkosic, medium cross-beds, intact, tan to red to brown.		4	100	100	H3,H6, 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, 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			DESCRIPTION	BLOWS/FT	CORE				DRILLING NOTES
			dry	moist	sat			NO.	RECOVERY (%)	RQD (%)	HARDNESS	
0		▨				CLAY, sandy, stiff, moist, reddish brown.						
		⠿				2 ft. SANDSTONE, silty, very hard, slightly moist, tan. Claystone parting at 4 feet.						
5		▨				5 ft. CLAY, sandy, slightly moist, low plasticity, calcareous, tan.	50/2					
10												
15												
20												
25												
30												

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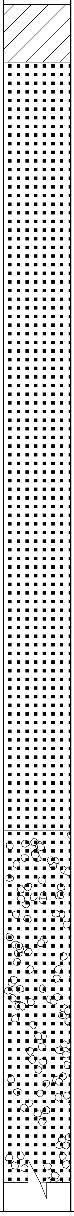
LOG OF BORING

LVL-3

PROJECT Cucharas Basin Collaborative Storage
PROJECT NUMBER 18.117
DATE STARTED 8/13/18
DATE COMPLETED 8/14/18
LOGGED BY J Edwards
DRILLED BY HRL
DRILL RIG CME-55
DRILL METHOD 4.25" HSA and HQ Core

APPROXIMATE GROUND ELEVATION 7284
DEPTH TO BEDROCK 1.5
TOTAL DEPTH 40.5
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, with gravel, medium stiff, slightly moist, brown.						
						1.5 ft. SANDSTONE, moderately hard, medium grained, laminated to parting cross-beds, weakly calcareous, tan to yellow brown.		1	92	42	H3	
						Tight to very tight fractures 1.5'-4' and 6.5'-7.5'. Dark red staining along bedding / fracture surfaces 1.5'-2.5'.						
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. 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. 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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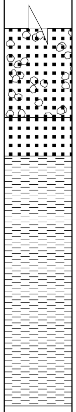
LOG OF BORING

PROJECT	PROJECT NO.	BORING NO.
Cucharas Basin Collaborative Storage	18.117	**LVL-3**



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
								7	100	100	H5,H3, H6	
						33 ft. SANDSTONE, soft, fine grained, massively bedded, weakly calcareous, dark red brown.						
						34 ft. MUDSTONE, sandy, conglomeratic, soft, massive bedding, calcareous, dark red brown.						
35												
								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	▽	░				8 ft. SANDSTONE, silty, clayey, wet, very hard, greenish gray.						
10		░					50/2					
15							50/8					
20												
25												
30												

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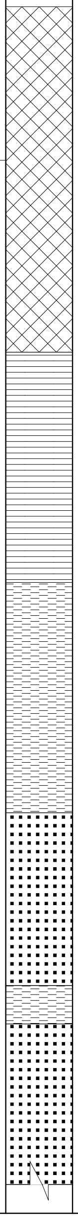
LOG OF BORING

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)	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, slightly moist, stiff, some concrete debris and organics in upper 3-1/2 feet, brown to dark brown.						
	▽											
5							14/12					
						9 ft. CLAYSTONE, sandy, severely weathered to 14', very moist to moist., reddish brown.						
10							10/12					
15						15 ft. MUDSTONE, soft, massive, calcareous, red brown.	34,58/3					
								1	100	0	H3	
								2	100	100	h6	
						MUDSTONE, soft, massive, red brown with calcareous olive clasts.						
20												
						21 ft. 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, H5	
						Fracture with wavy sides						
25						25.5 ft. MUDSTONE, soft, massive bedding, calcareous, red brown. Fracture with wavy sides						
								4	100	100	H3	
						26.5 ft. SANDSTONE, soft, fine to medium grained, calcareous, gray red brown.						
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			DESCRIPTION	BLOWS/FT	CORE				DRILLING NOTES
			dry	moist	sat			NO.	RECOVERY (%)	RQD (%)	HARDNESS	
						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. 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 dry	MOISTURE moist	MOISTURE sat	DESCRIPTION	BLOWS/FT	CORE NO.	CORE RECOVERY (%)	CORE RQD (%)	CORE HARDNESS	DRILLING NOTES
0		▨				FILL: CLAY, sandy, stiff, moist, dark brown.						
	▽	▨										
3.5 ft.		⁙				SANDSTONE, very hard, moist to wet fine to medium grained, gray	50/3					Slow to advance in and out of fractures
5		⁙										
9							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			DESCRIPTION	BLOWS/FT	CORE				DRILLING NOTES
			dry	moist	sat			NO.	RECOVERY (%)	RQD (%)	HARDNESS	
0						CLAY, sandy, stiff, slightly moist, with fine organics, dark brown.						
3 ft.						SAND, silty, medium dense, slightly moist, dark brown.	23/12					
4.5 ft.	▽					SANDSTONE, silty to clayey, weathered, slightly moist, tan.						
7							50/0.5					

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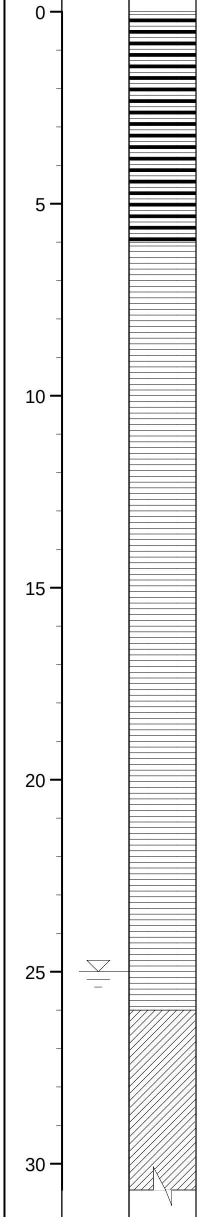
LOG OF BORING

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 dry	MOISTURE moist	MOISTURE sat	DESCRIPTION	BLOWS/FT	CORE NO.	CORE RECOVERY (%)	CORE RQD (%)	CORE HARDNESS	DRILLING NOTES
0						CLAYSTONE, sandy, weathered, slightly moist, moderately calcareous, dark tan.						
5							20/12					
6 ft.						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.						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. Moderately tight fractures along bedding (28' and 30'), with up to 1/4" of clay		2	100	87	3	
30												

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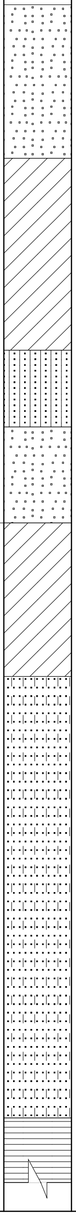
LOG OF BORING	PROJECT Cucharas Basin Collaborative Storage	PROJECT NO. 18.117	BORING NO. **MS-1**

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

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. CLAY, sandy, moist, stiff, very calcareous, brown.	9/12					
10						9 ft. SAND, silty, loose, moist, very calcareous, brown.	6/12					
	▽					11 ft. SAND, poorly graded, with gravel, medium dense, wet, brown.						
15						13.5 ft. CLAY, sandy, wet, stiff, vary calcareous, dark brown.	12/12					
20 25						17.5 ft. SAND, with silt and gravel, very dense, wet, brown.	50/4					
30						29 ft. CLAYSTONE, weathered to very hard, very moist, dark olive to black.						

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LOG OF BORING

PROJECT	PROJECT NO.	BORING NO.
Cucharas Basin Collaborative Storage	18.117	**MS-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
							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. 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. 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		
26								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			DESCRIPTION	BLOWS/FT	CORE				DRILLING NOTES
			dry	moist	sat			NO.	RECOVERY (%)	RQD (%)	HARDNESS	
0		▨				CLAY, sandy, stiff, slightly moist, medium calcareous, brown.						
5		▨					11/12					
		▤				8.5 ft. CLAYSTONE, hard, slightly moist to wet, very calcareous, olive to dark olive, gray to black.						
10		▤					50/11.5					
15		▤					50/8.5					
	▽	▤										
20		▤					50/7.5					
25		▤					50/11.5					
		▨				29 ft. SHALE, lignite partings,						
30												

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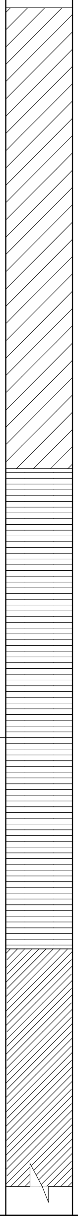
LOG OF BORING

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	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. CLAYSTONE, slightly moist, very hard, very calcareous, olive to dark olive.						
15						29, 50/4					
	▽										
20						50/7					
					24.5 ft. SHALE, moderately hard, intact, slightly weathered, thinly laminated, calcareous, with occasional soft sediment deformation, with occasional fossil fragments, with occasional bioturbation, dark gray.						
25						50/3.5	1	80	0		
							2	100	76	R3	
30											

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LOG OF BORING

PROJECT
Cucharas Basin Collaborative Storage

PROJECT NO.
18.117

BORING NO.
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 dry	MOISTURE moist	MOISTURE sat	DESCRIPTION	BLOWS/FT	CORE NO.	CORE RECOVERY (%)	CORE RQD (%)	CORE HARDNESS	DRILLING NOTES
0						FILL: CLAY, sandy, moist, medium stiff, moderately calcareous, brown to dark brown.						
5							7/12					
7.5						7.5 ft. 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					
18	▽											
20							8/12					
25							33/12					
29.5						29.5 ft. 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. SAND, clayey, moist, medium dense, reddish brown.						
						3.5 ft. SAND, silty, with gravel, moist, dense, dark red brown.	43/12					
10						9 ft. 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 20/12					
20						13.5 ft. CLAYSTONE, with sand, slightly moist to moist, moderately hard to very hard, reddish brown to gray.	47/12 24,50/3 50/6					
30						27 ft. SANDSTONE, moist, very hard, reddish brown. Stopped HSA and sampling at 29'.	50/0					
40												
50												
60												

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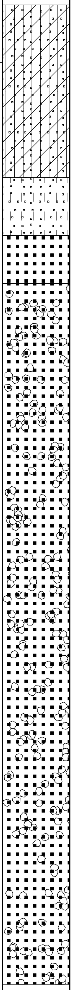
LOG OF BORING

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)	DESCRIPTION	BLOWS/FT	CORE NO.	RECOVERY (%)	RQD (%)	HARDNESS	DRILLING NOTES
0	SAND, silty, clayey, moist to wet, very loose, dark brown.	2/12					
10	9 ft. SAND, poorly graded, with silt and gravel, very loose, wet, dark brown to black with organics.	14/12					
	12 ft. SANDSTONE, wet, very hard, tan to gray. Thickly interbedded with claystone below 33 feet.	50/2	1	89	38		
20	14.5 ft. SANDSTONE, conglomeratic, moderately hard, medium sand to 1" gravel - sized grains, thin to medium cross-beds, red brown to pink gray.		2	100	80		
			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		
50			8	100	80		
60	Stopped coring at 51'.						

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LOG OF BORING

SB-3

PROJECT Cucharas Basin Collaborative Storage
PROJECT NUMBER 18.117
DATE STARTED 8/10/18
DATE COMPLETED 8/11/18
LOGGED BY J. Edwards
DRILLED BY HRL
DRILL RIG CME-55
DRILL METHOD 4"

APPROXIMATE GROUND ELEVATION 8860
DEPTH TO BEDROCK 7
TOTAL DEPTH 17
REFUSAL
DEPTH TO WATER / DATE
4 8/11/18

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. SAND, well graded, with silt and gravel, moist to wet, loose to medium dense, reddish brown.						
10		⁞				7 ft. SAMDSTONE, wet, very hard, reddish brown.	50/2 50/0					
						Stopped HSA and sampling at 17'.	50/0					
20												
30												
40												
50												
60												

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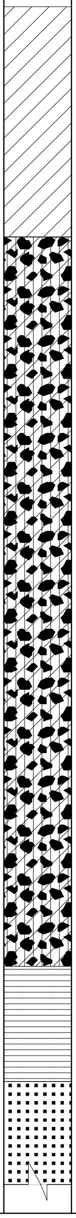
LOG OF BORING

SB-4

PROJECT Cucharas Basin Collaborative Storage	APPROXIMATE GROUND ELEVATION 8926
PROJECT NUMBER 18.117	DEPTH TO BEDROCK 50
DATE STARTED 8/26/19	TOTAL DEPTH 70
DATE COMPLETED 8/28/19	REFUSAL
LOGGED BY I. Campbell	
DRILLED BY Dakota	DEPTH TO WATER / DATE
DRILL RIG CME 550	
DRILL METHOD 8"	



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. 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. CLAYSTONE, conglomeratic, soft, slightly weathered, highly to intensely fractured, massive bedding, red.		7	68	47		
								8	47	15		
						56 ft. 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. 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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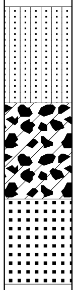
LOG OF BORING

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 50/10					
						5 ft. GRAVEL, with sand and cobbles, clayey, very dense, slightly moist, gray (GC, A- 2-4).	50/6					
10						10 ft. SANDSTONE, hard, slightly weathered, highly fractured, thickly bedded, gray.	50/5					
						Stopped HSA and sampling at 14.4'.						
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.

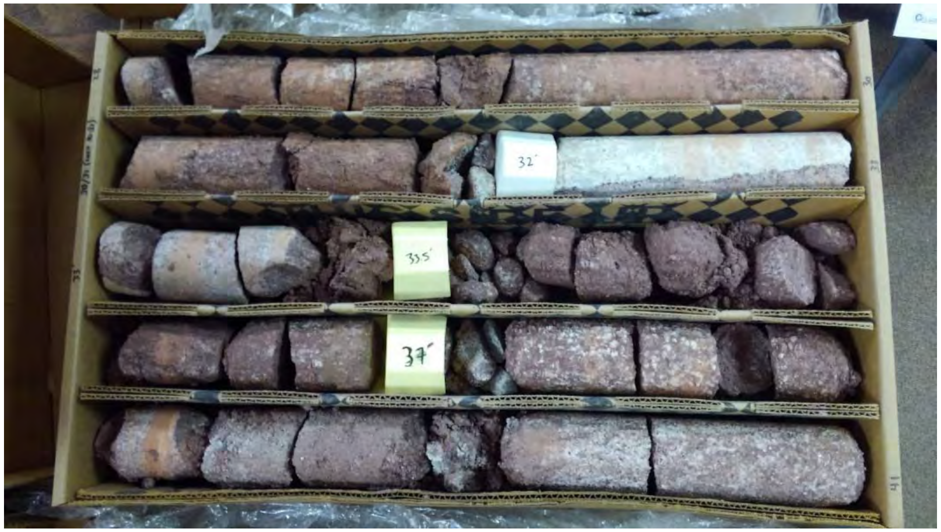

Photo 5. B-2 from 28 to 41 feet.

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.

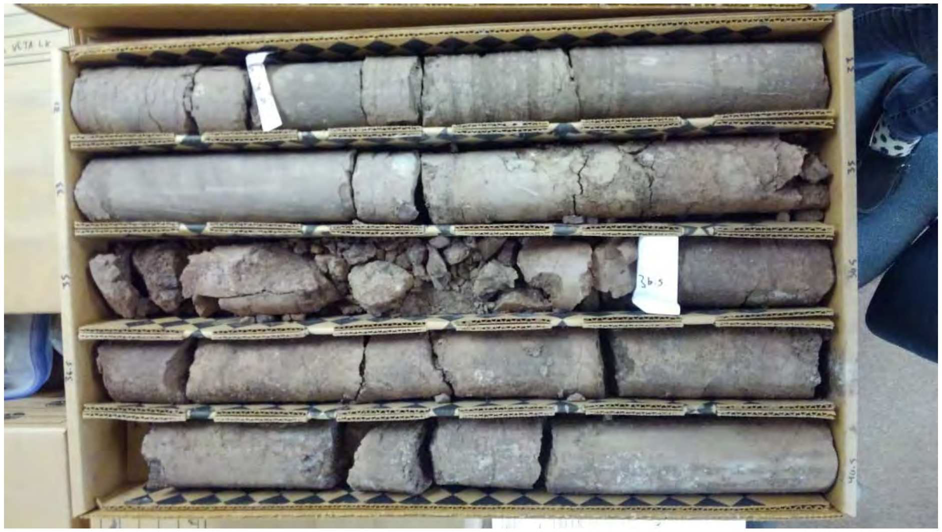

Photo 18. LVL-3 from 31 to 40.5 feet.

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.

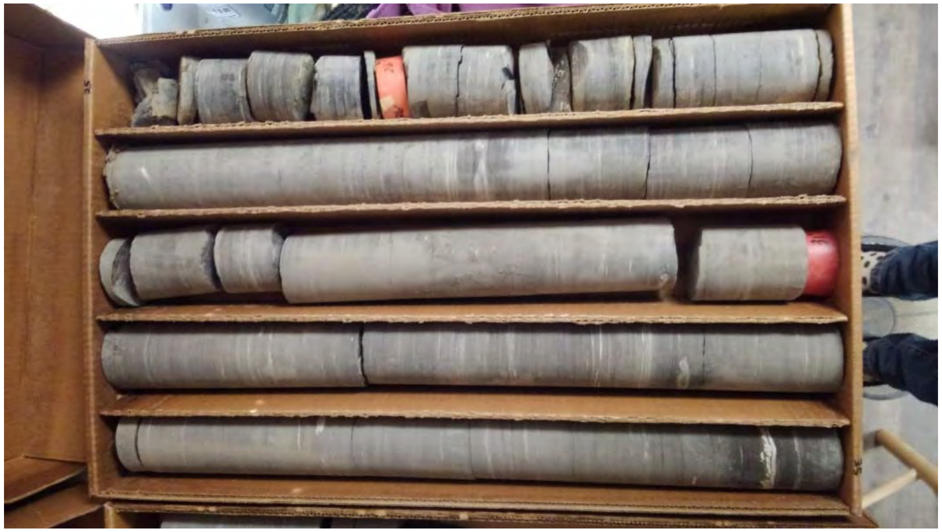

Photo 22. MS-5 from 25 to 35 feet.

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

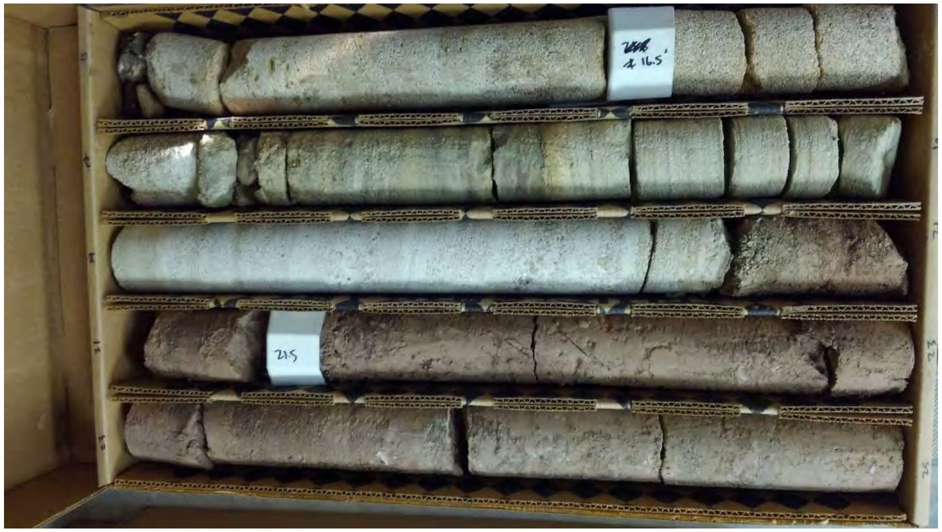

Photo 24. LVL-1 from 15 to 25 feet.

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

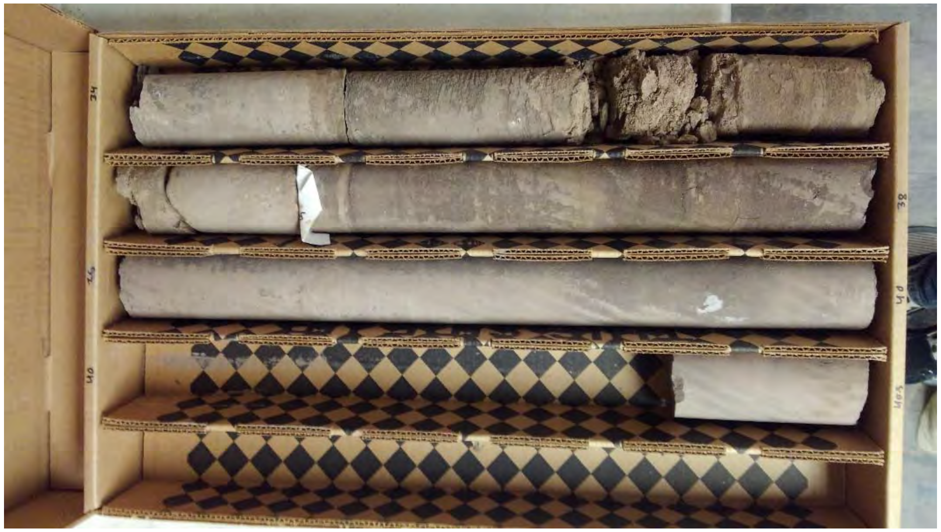

Photo 26. LVL-1 from 34 to 40.5 feet.

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

CESARE, INC.
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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)

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				Material Type
Boring	Depth (feet)			Gravel (%)	Sand (%)	Silt/ Clay (%)	Liquid Limit (%)	Plasticity Index (%)	Inundation Pressure (psf)	Volume Change (%)	Swell Pressure (psf)	Permeability (cm/s)	
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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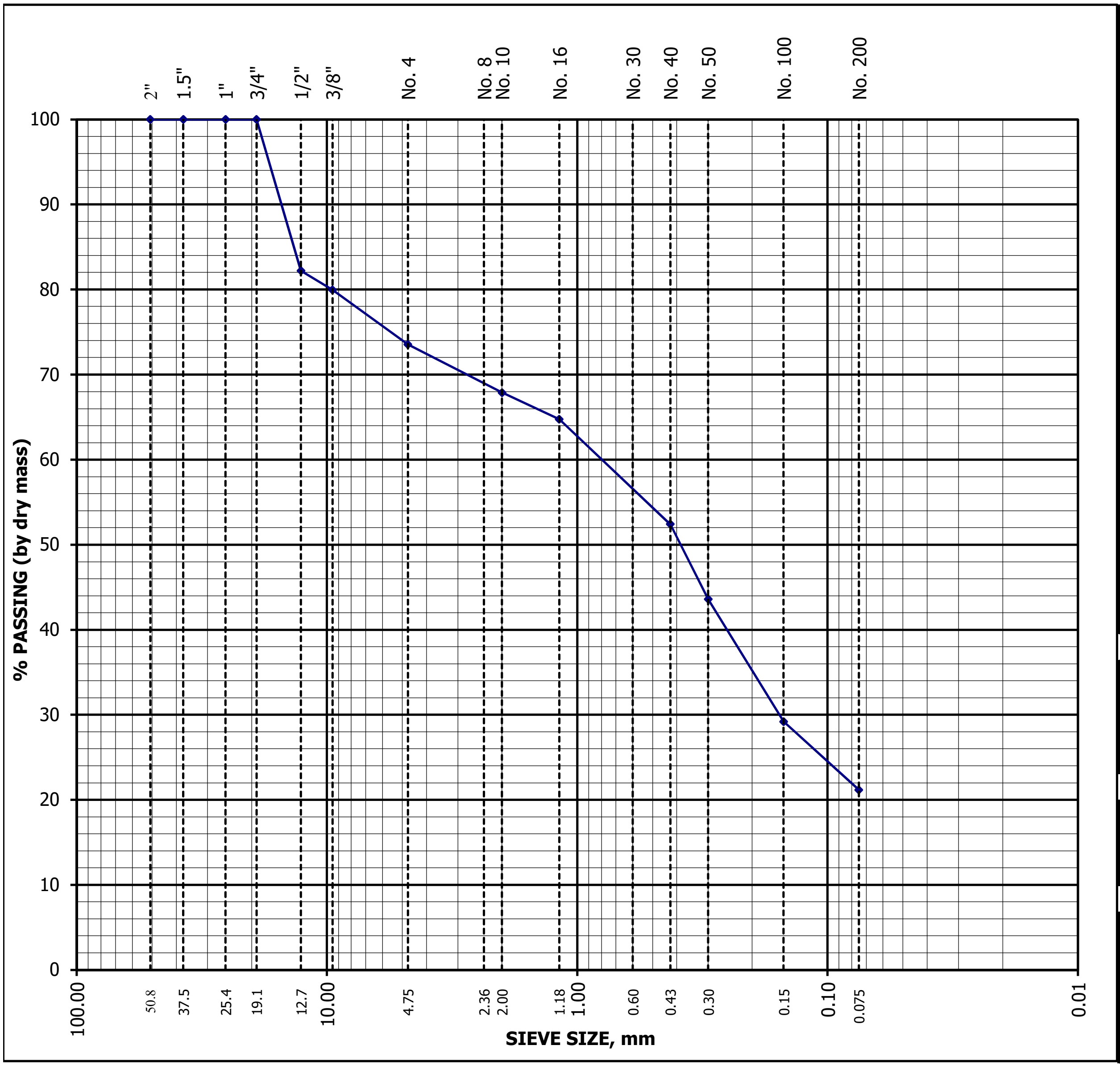
GRADATION PLOT - SOIL & AGGREGATE

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	

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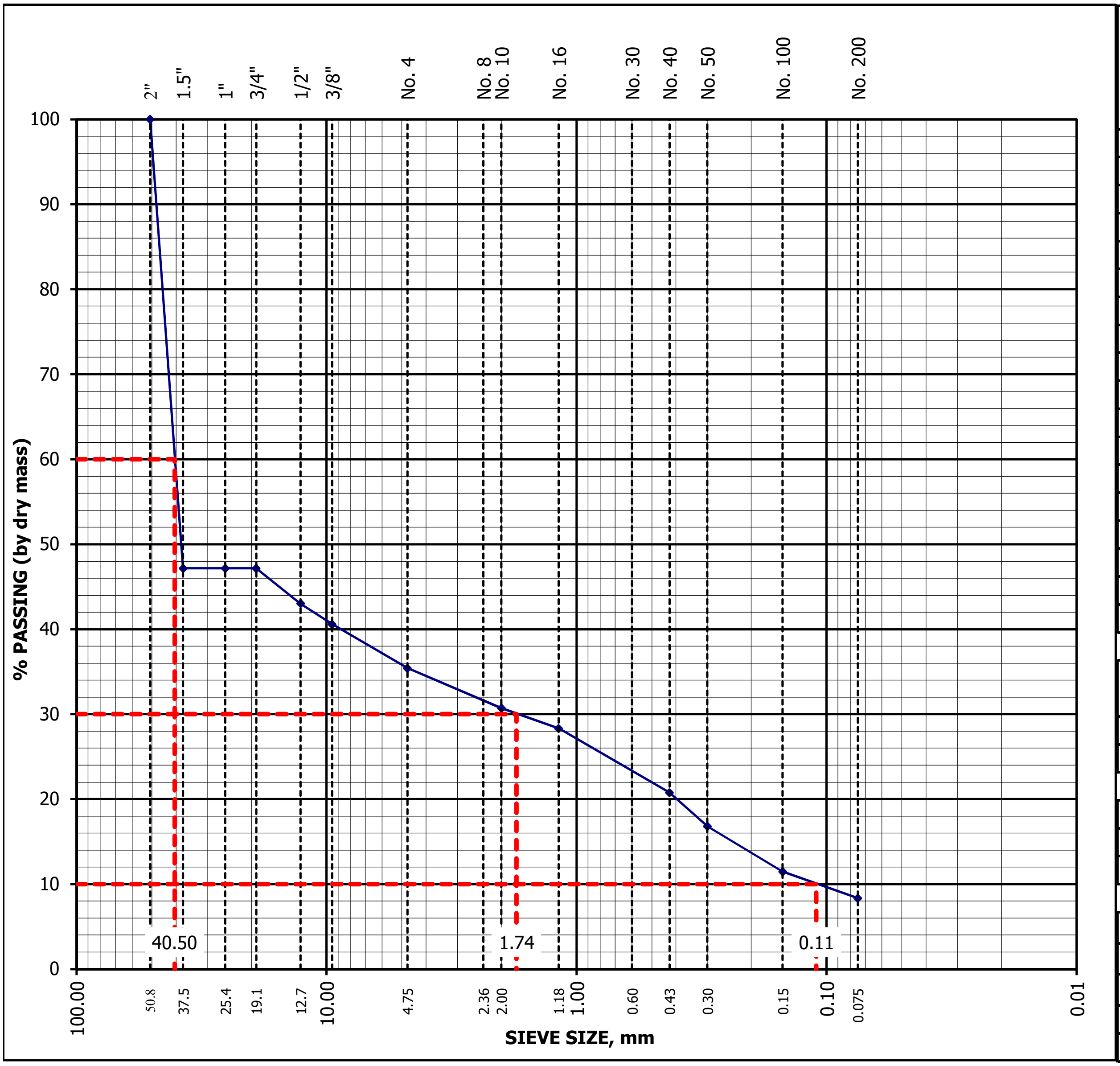
GRADATION PLOT - SOIL & AGGREGATE

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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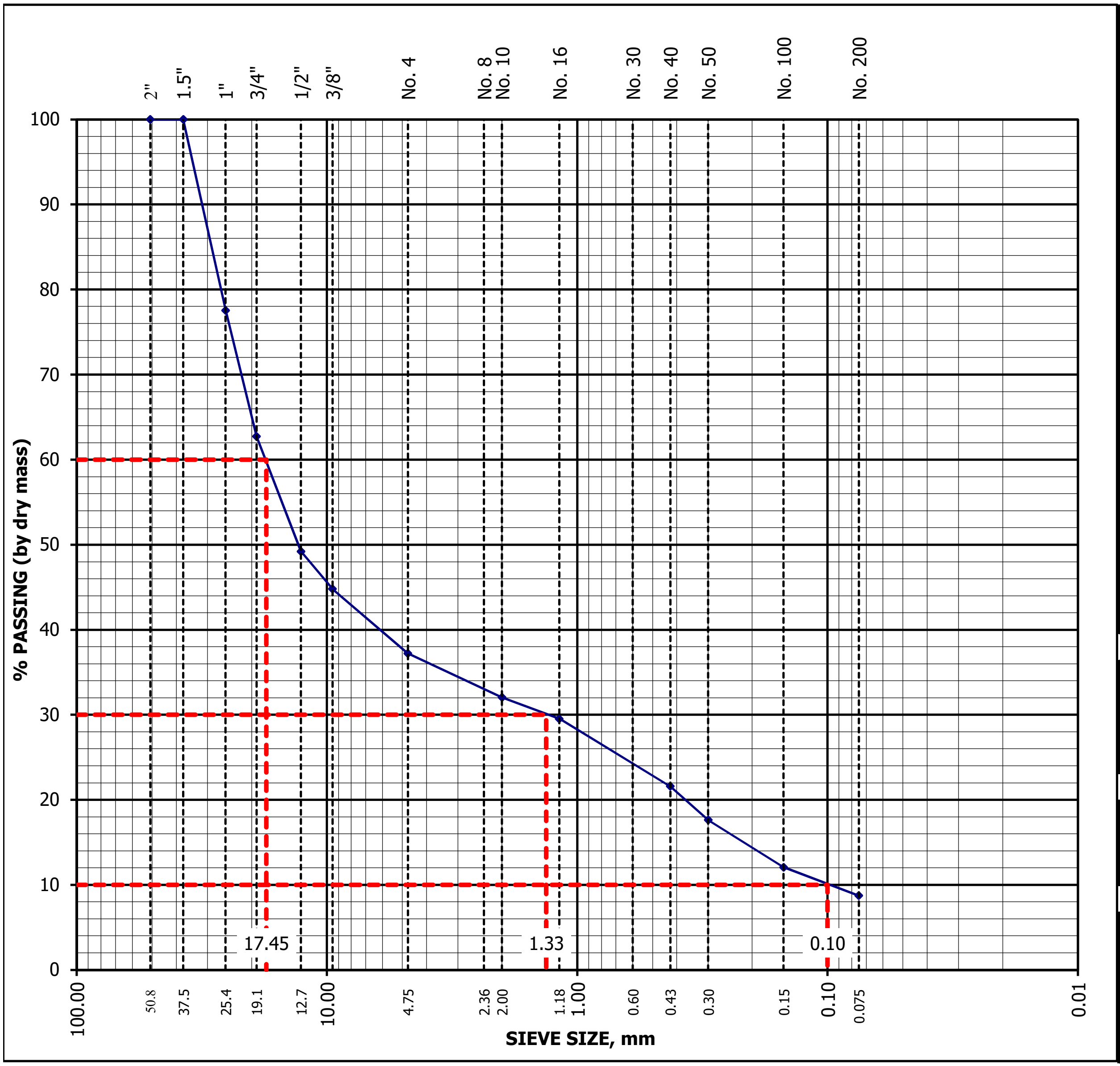
GRADATION PLOT - SOIL & AGGREGATE

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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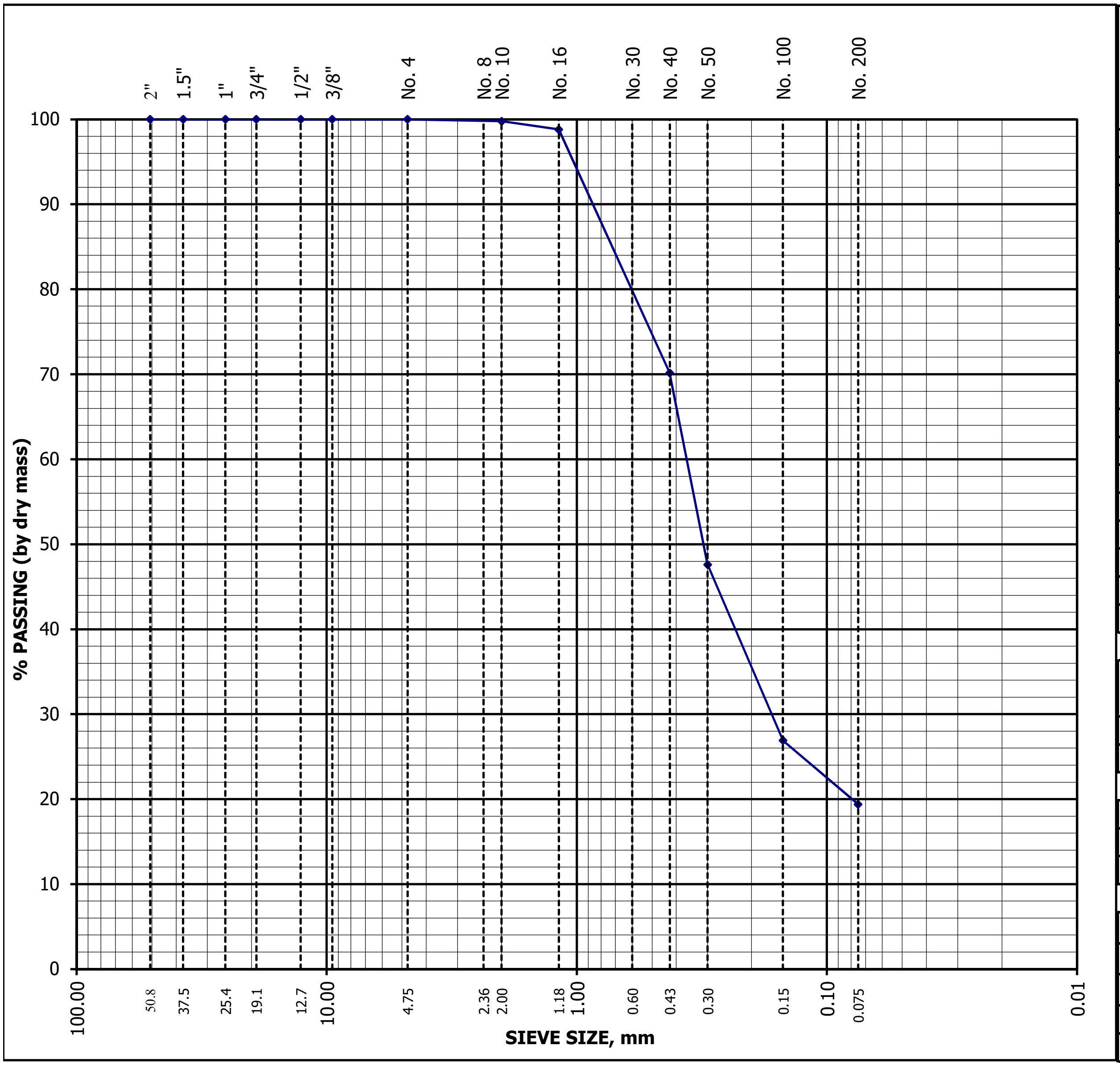
GRADATION PLOT - SOIL & AGGREGATE

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	

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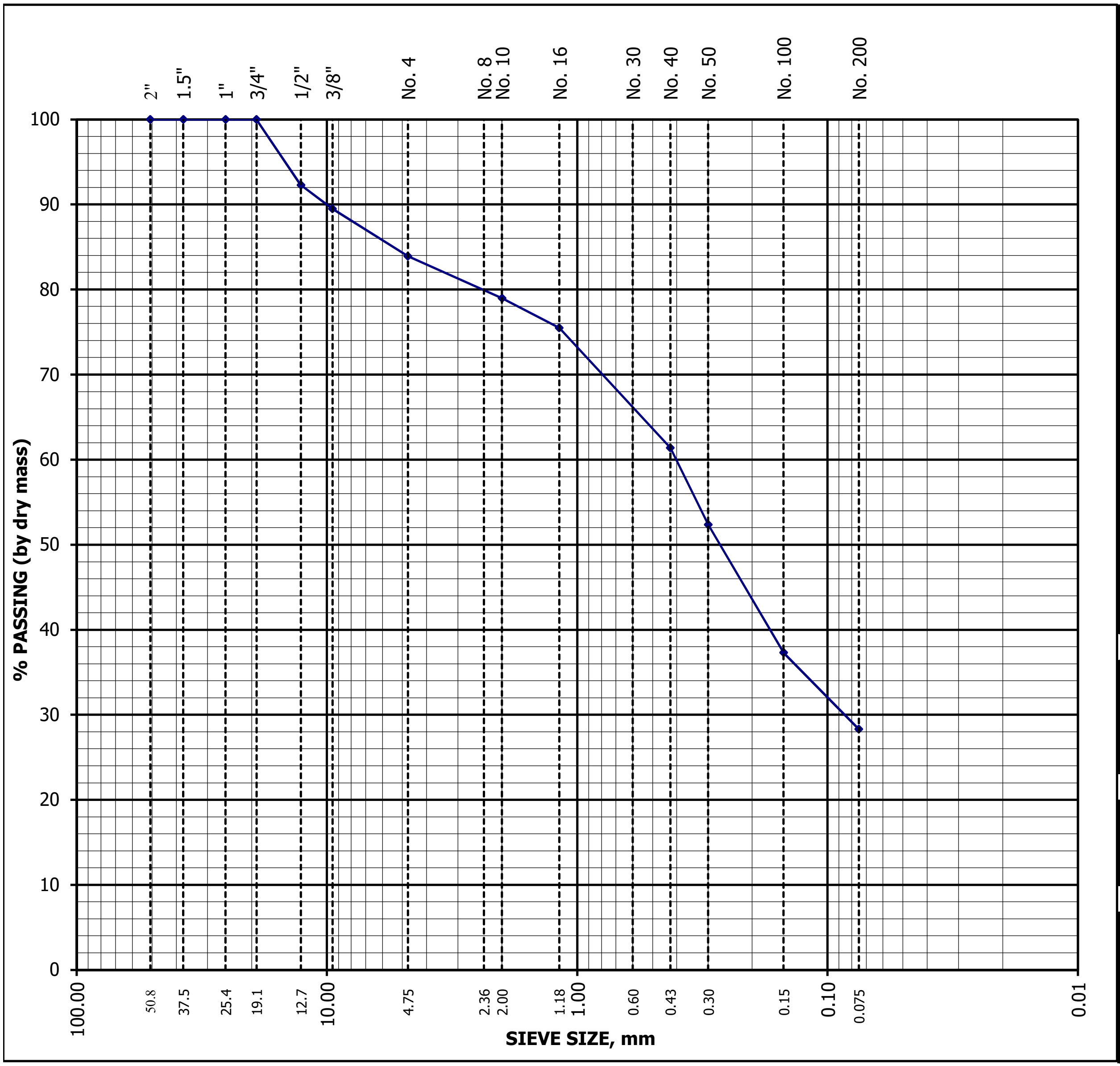
GRADATION PLOT - SOIL & AGGREGATE

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

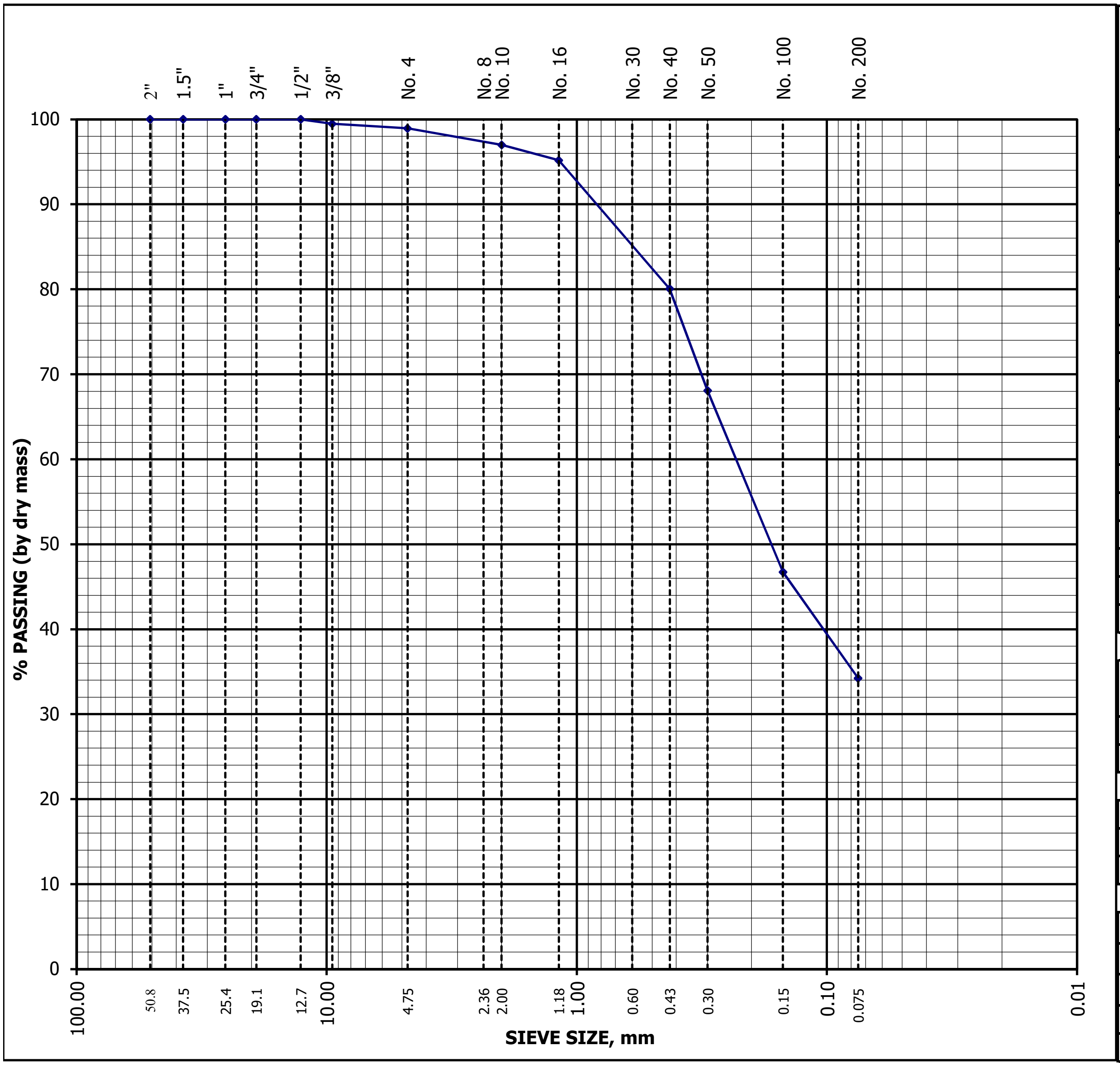
D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

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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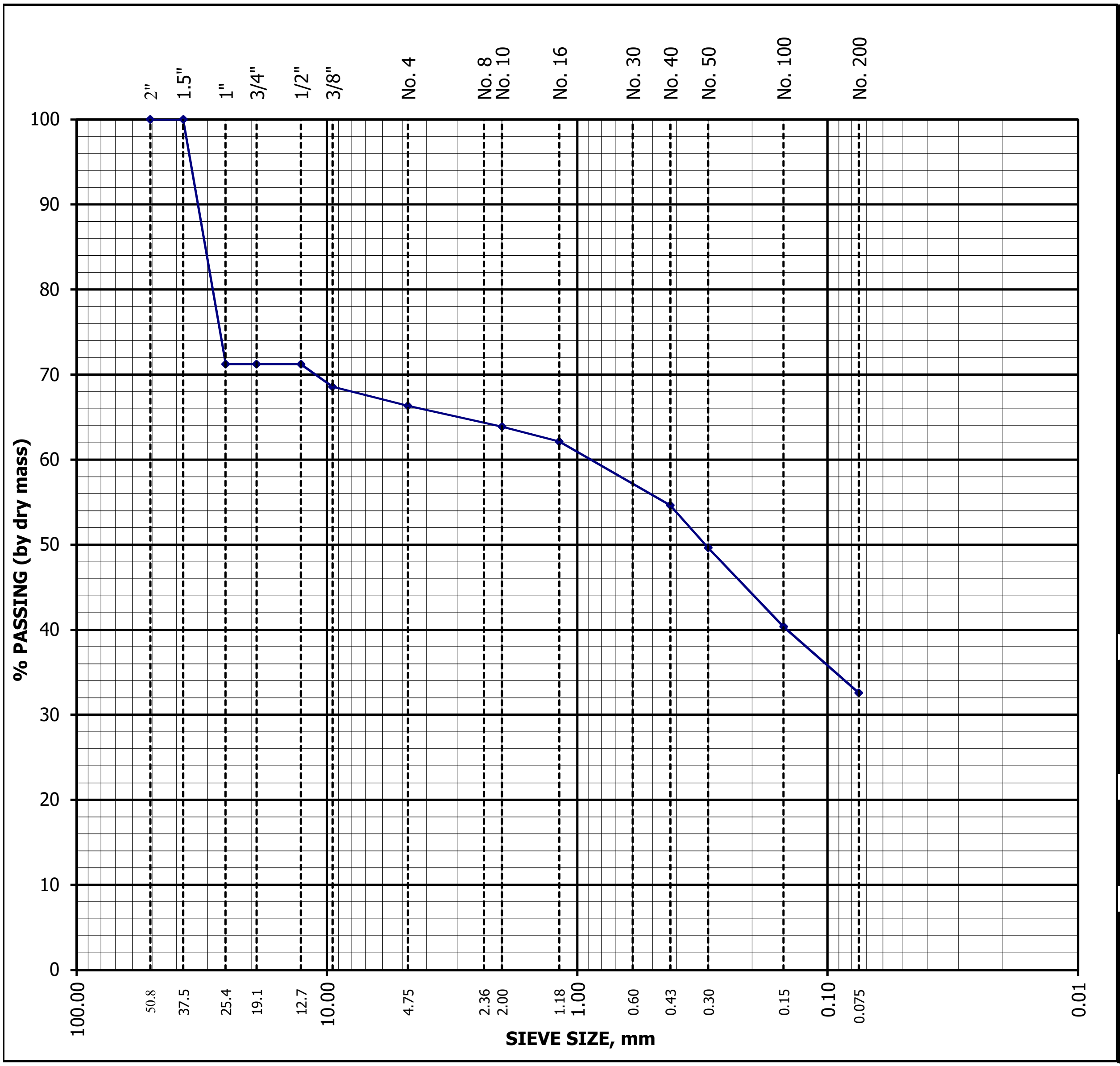
GRADATION PLOT - SOIL & AGGREGATE

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

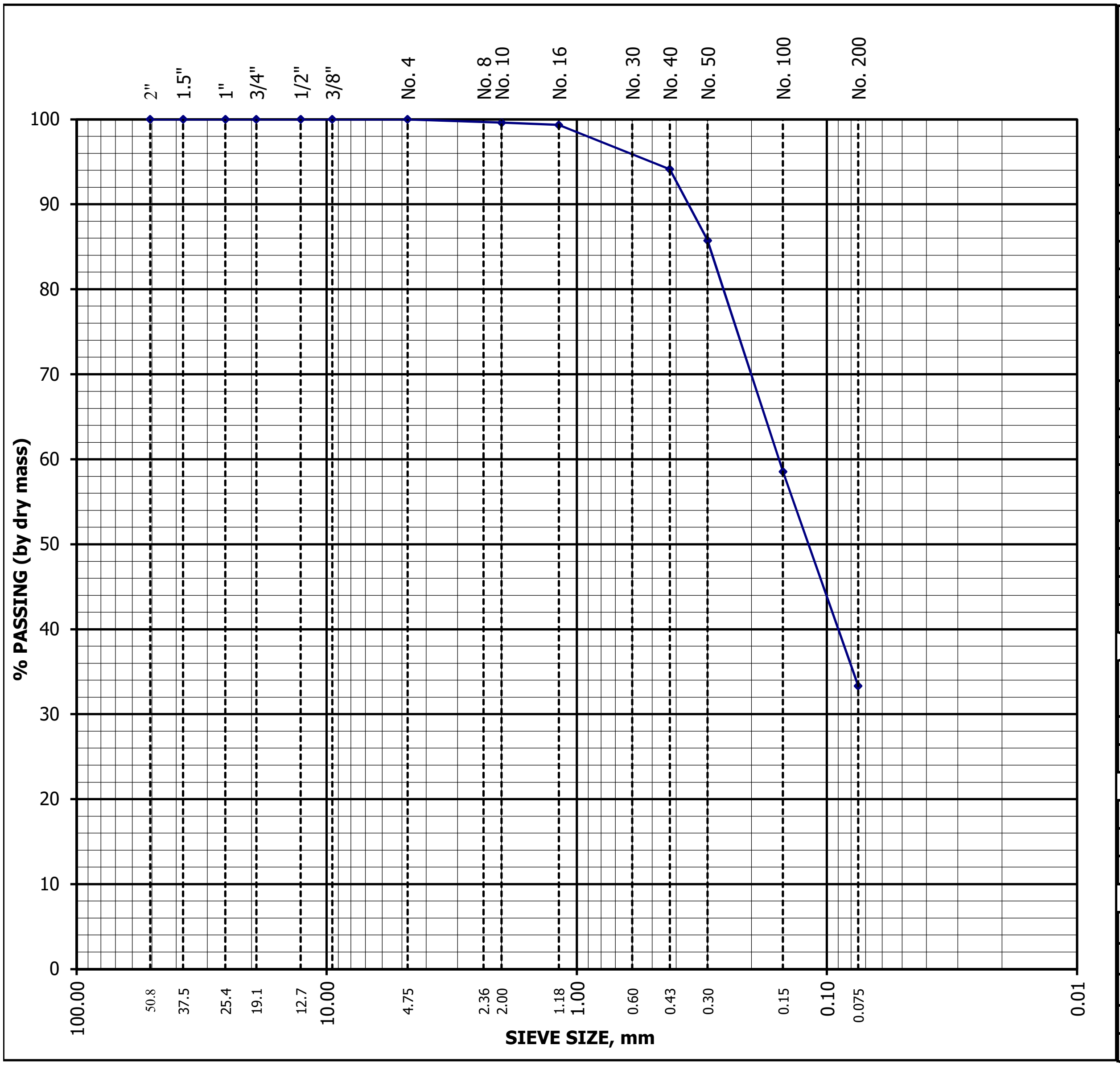
D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

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

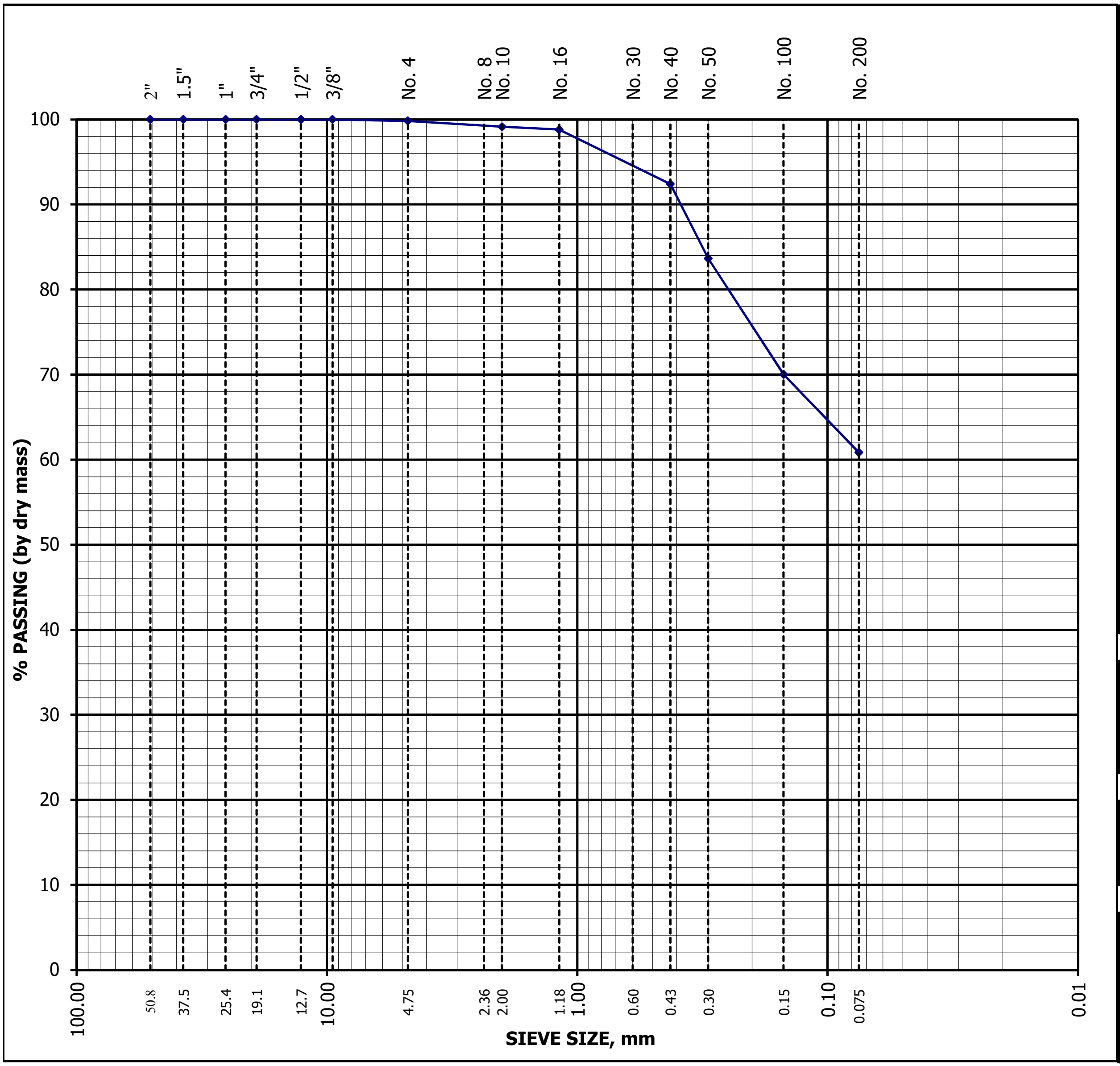
D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

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:	1822872	Reviewer:	J. Crystal
Sample Location:	BC-1 at 25'		
Visual Description:	CLAYSTONE: CLAY, sandy, red		

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	

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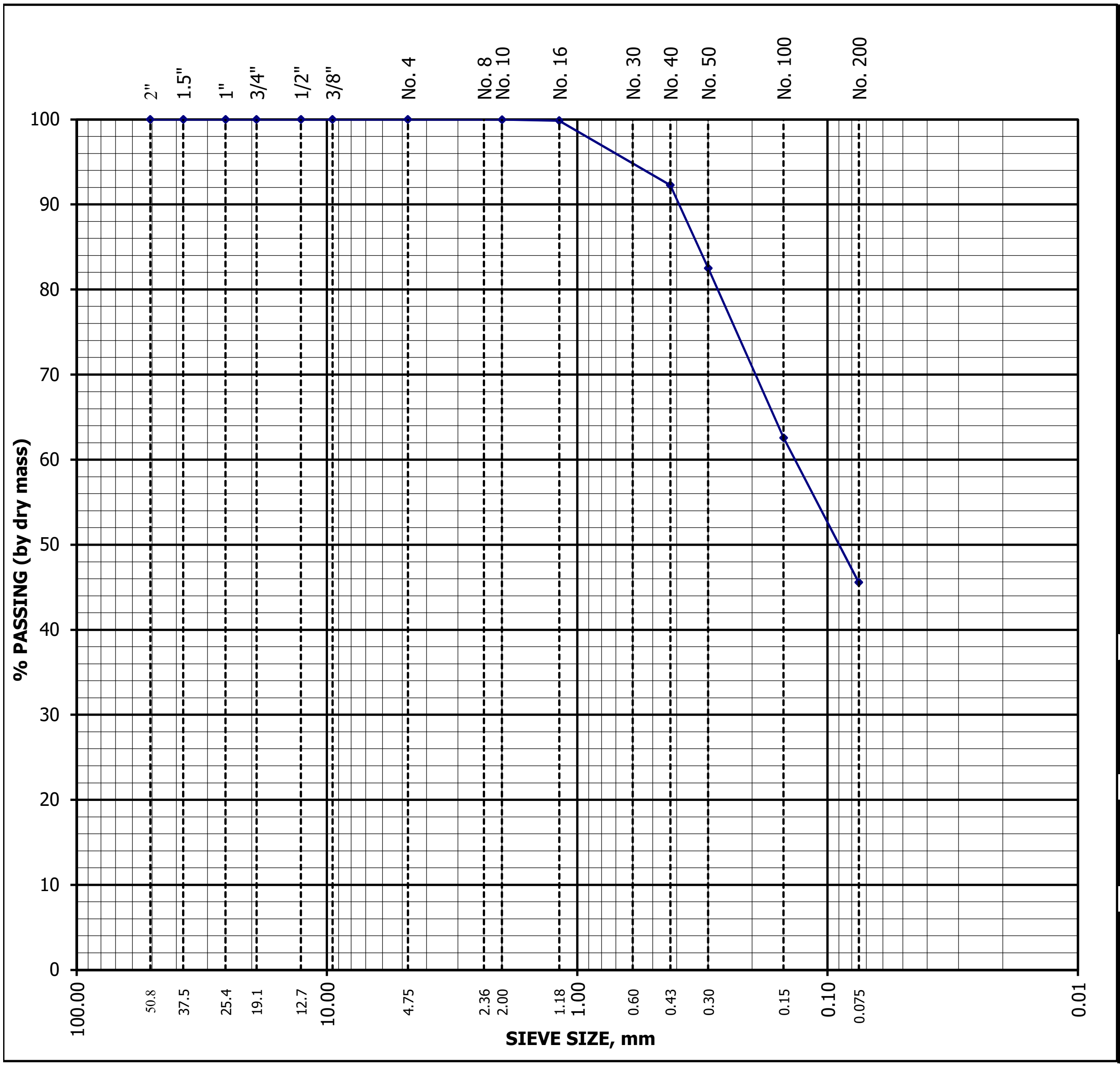
GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822873
Sample Location: BC-2 at 5'
Visual Description: SAND, clayey, brown

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

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	

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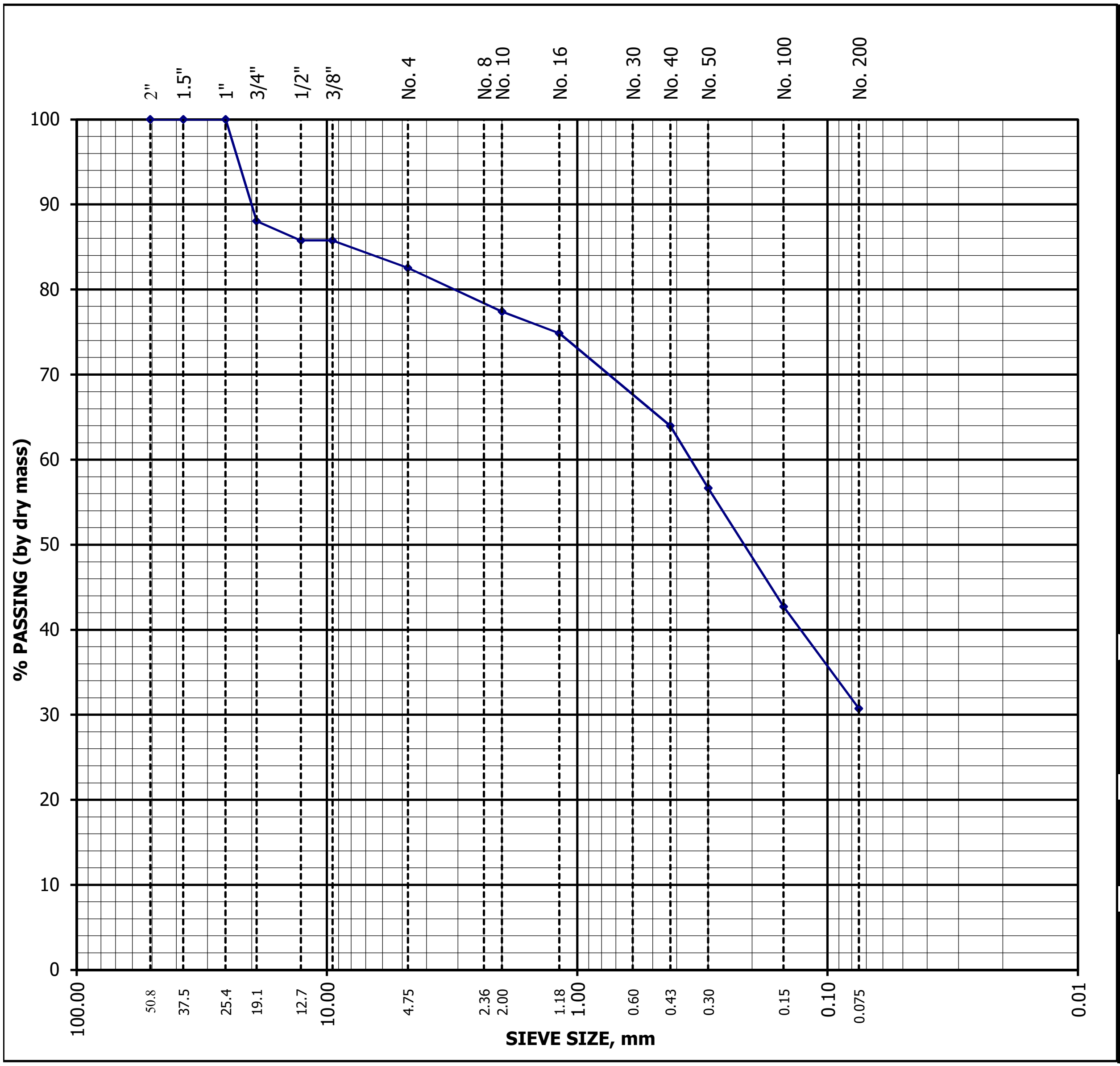
GRADATION PLOT - SOIL & AGGREGATE

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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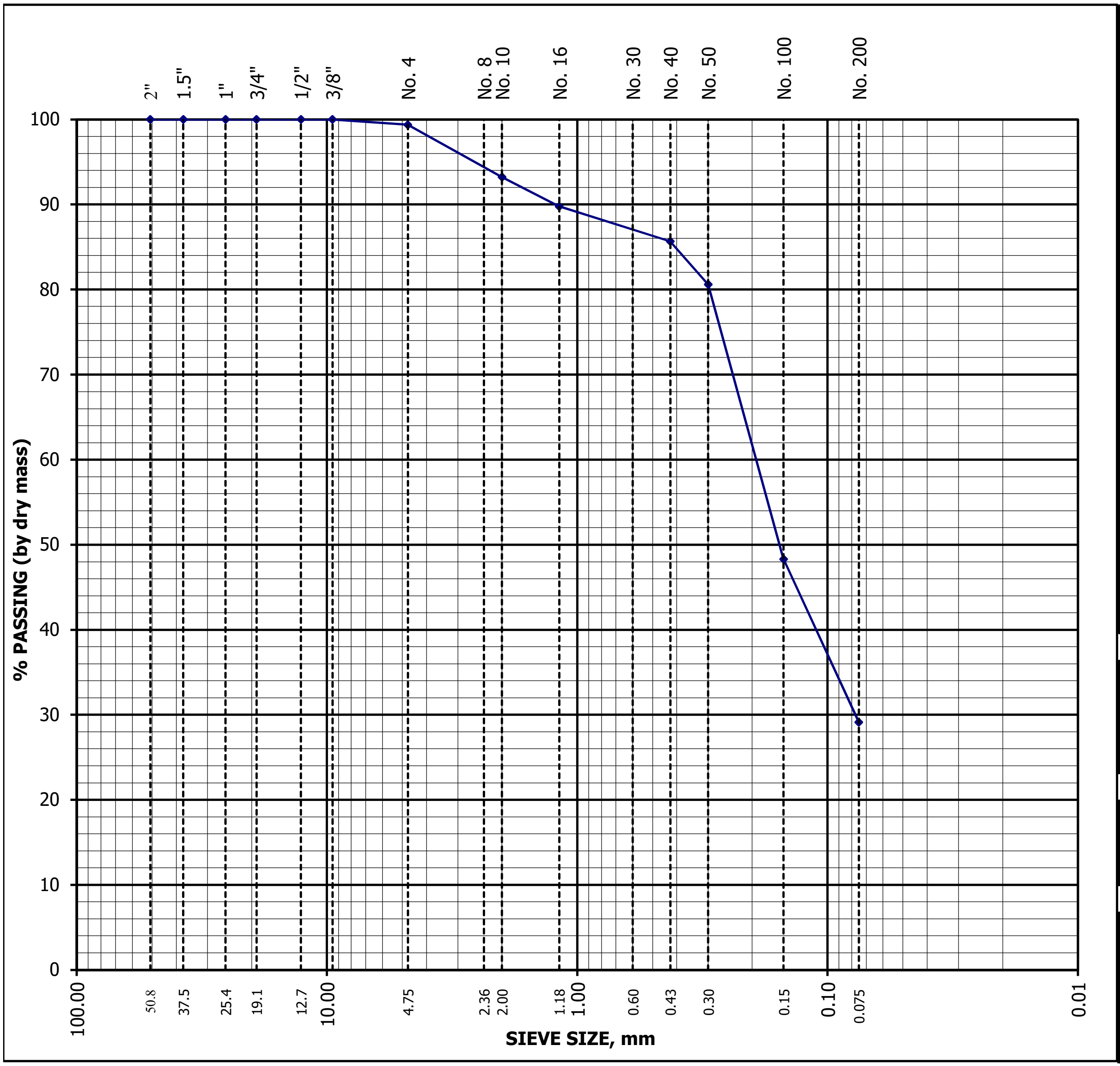
GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	5-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Weinerth
Lab ID Number:	1822875	Reviewer:	J. Crystal
Sample Location:	BC-3 at 5'		
Visual Description:	SAND, silty, clayey, brown		

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

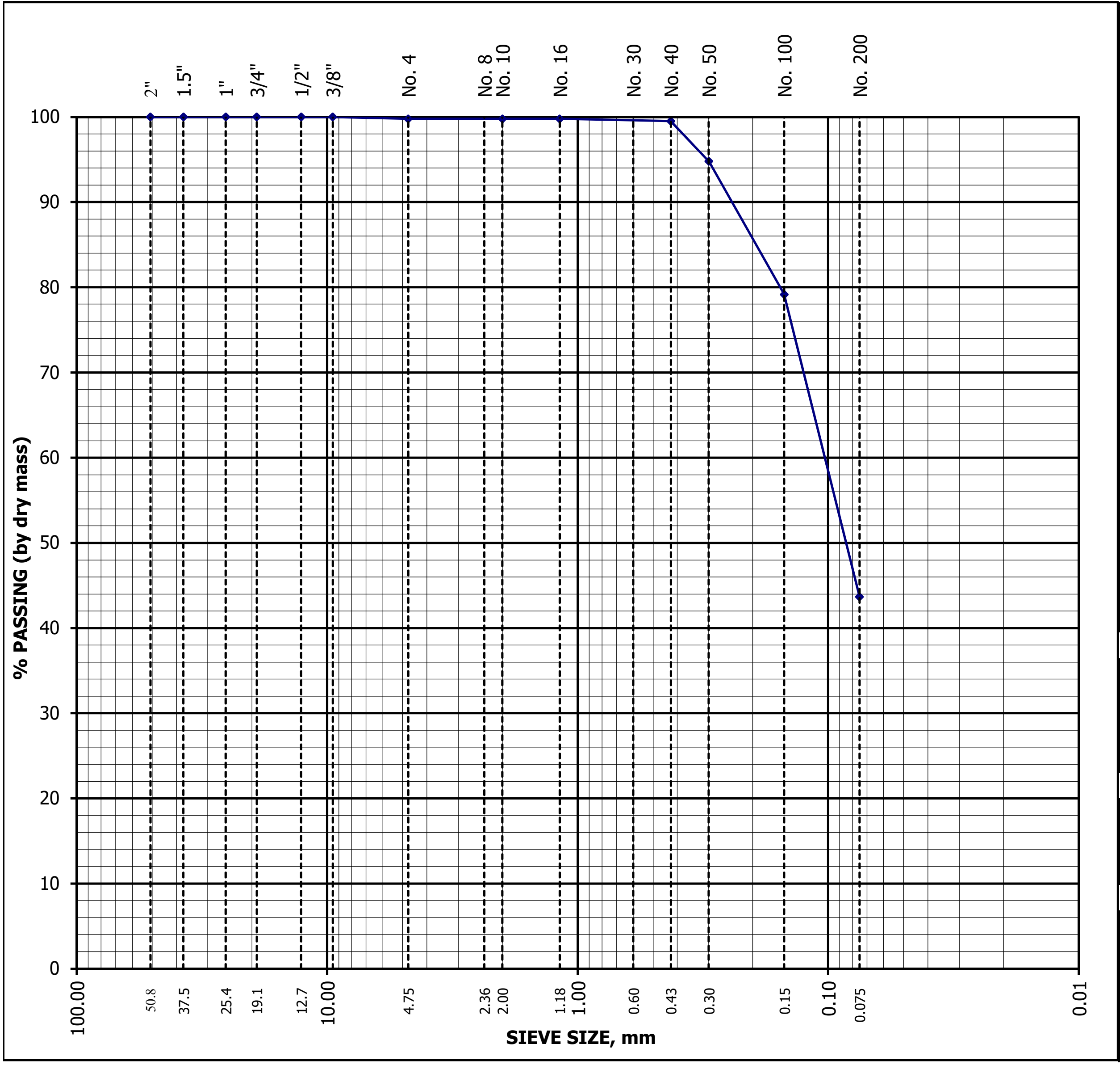
D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

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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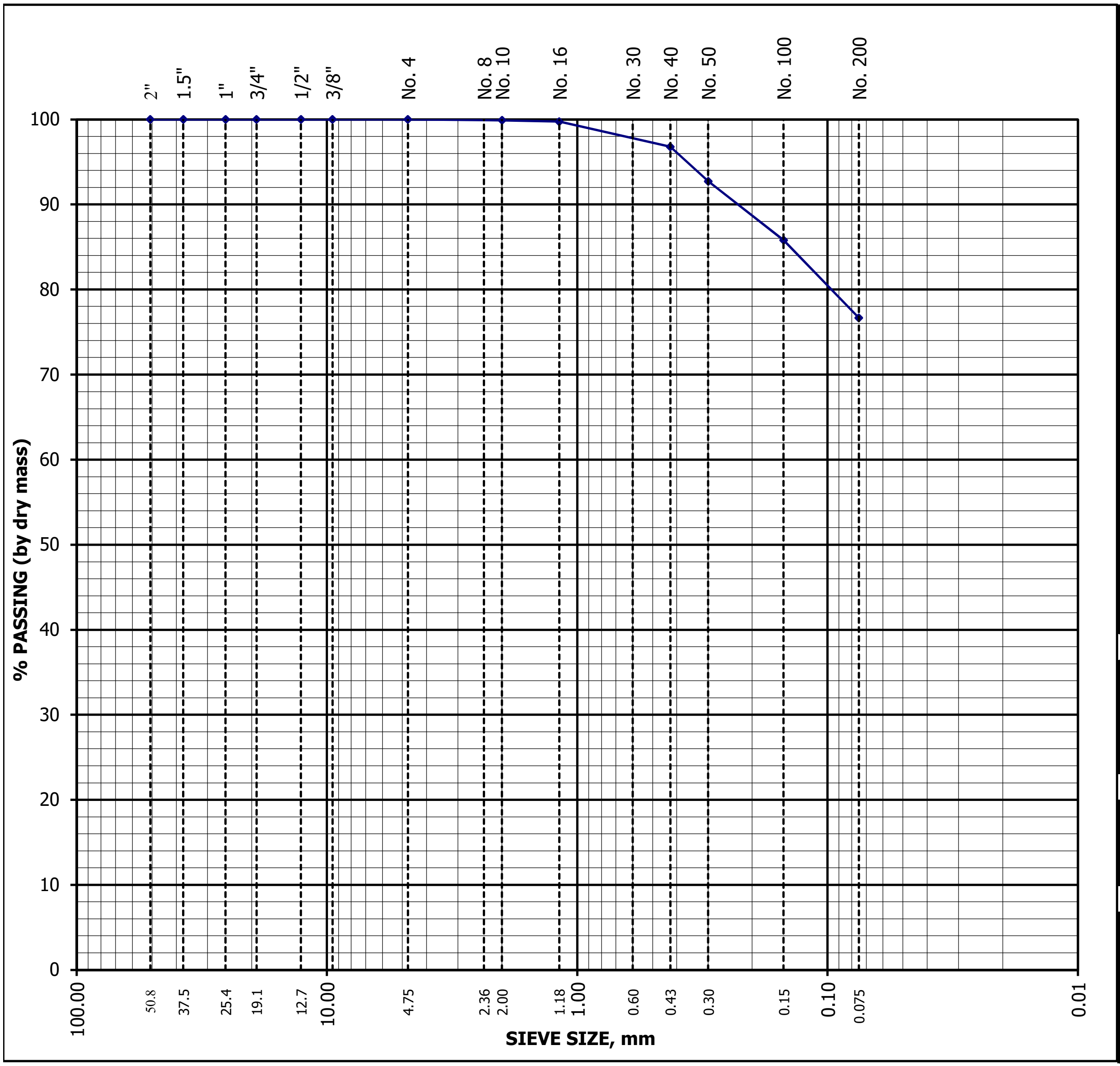
GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1921469
Sample Location: BC-4 at 10'
Visual Description: CLAY, with sand, brown

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

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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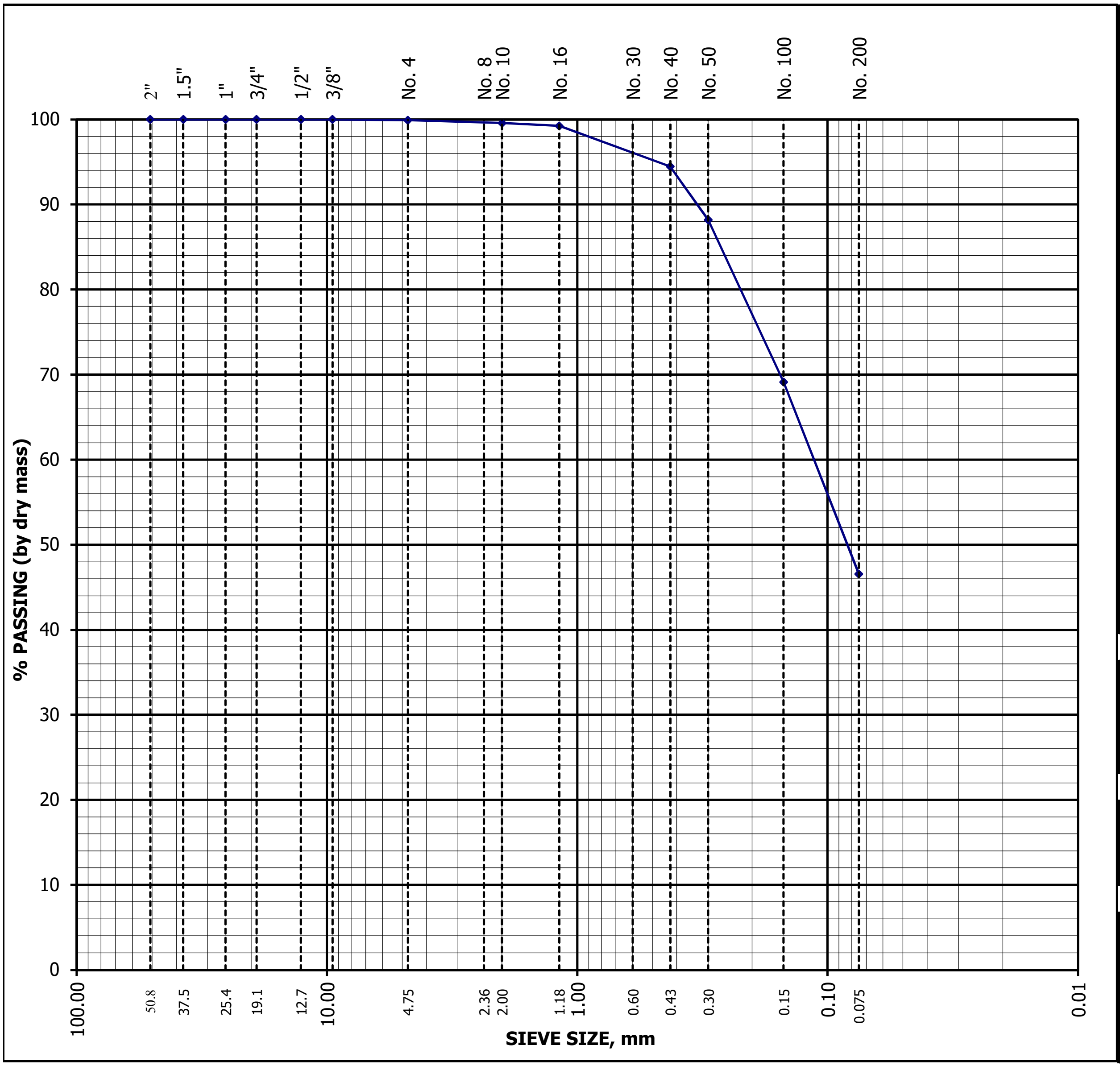
GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	25-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Holiman
Lab ID Number:	1822652	Reviewer:	J. Crystal
Sample Location:	BCP-1 at 1' to 8'		
Visual Description:	SAND, clayey, brown		

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

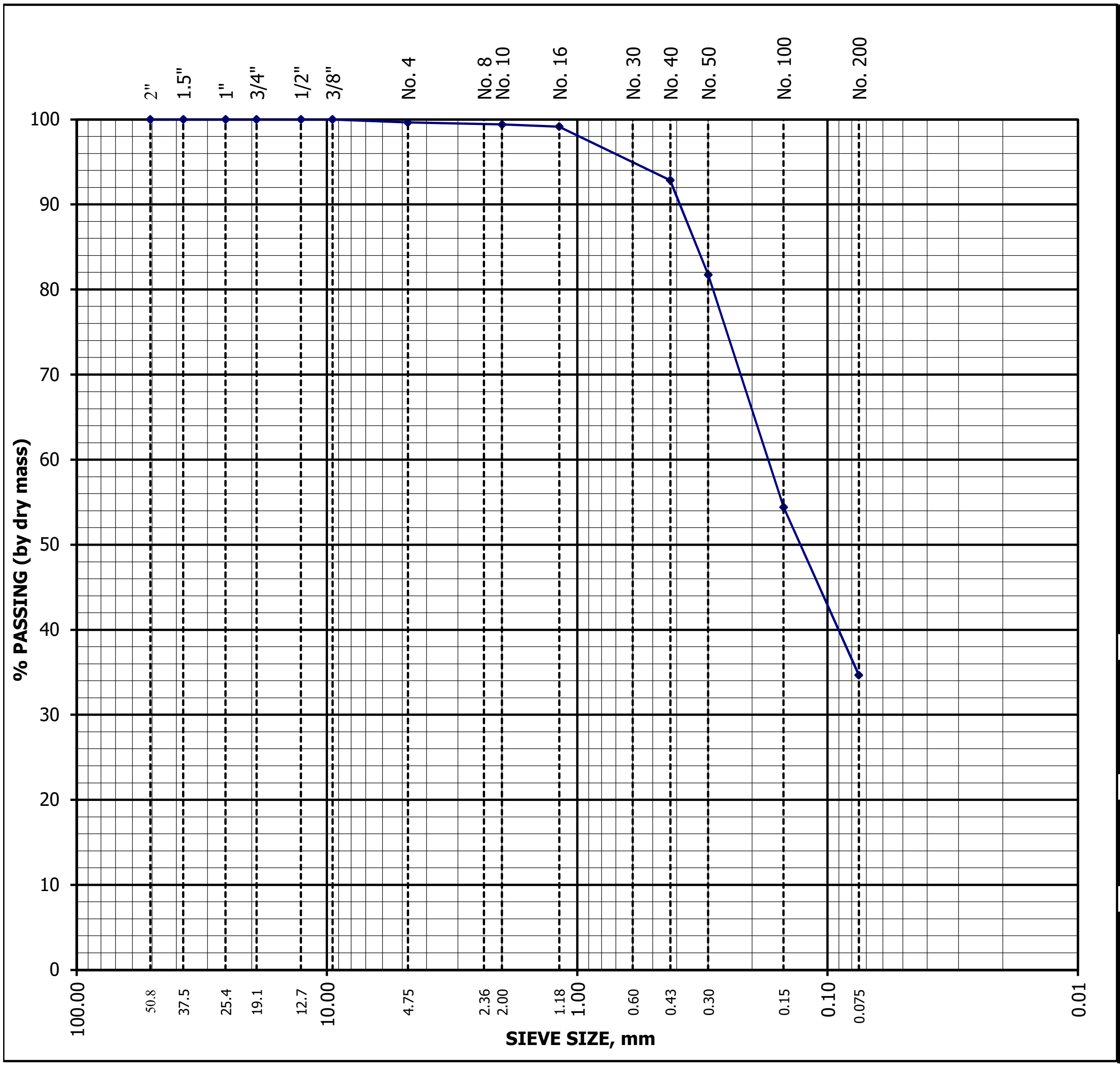
D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

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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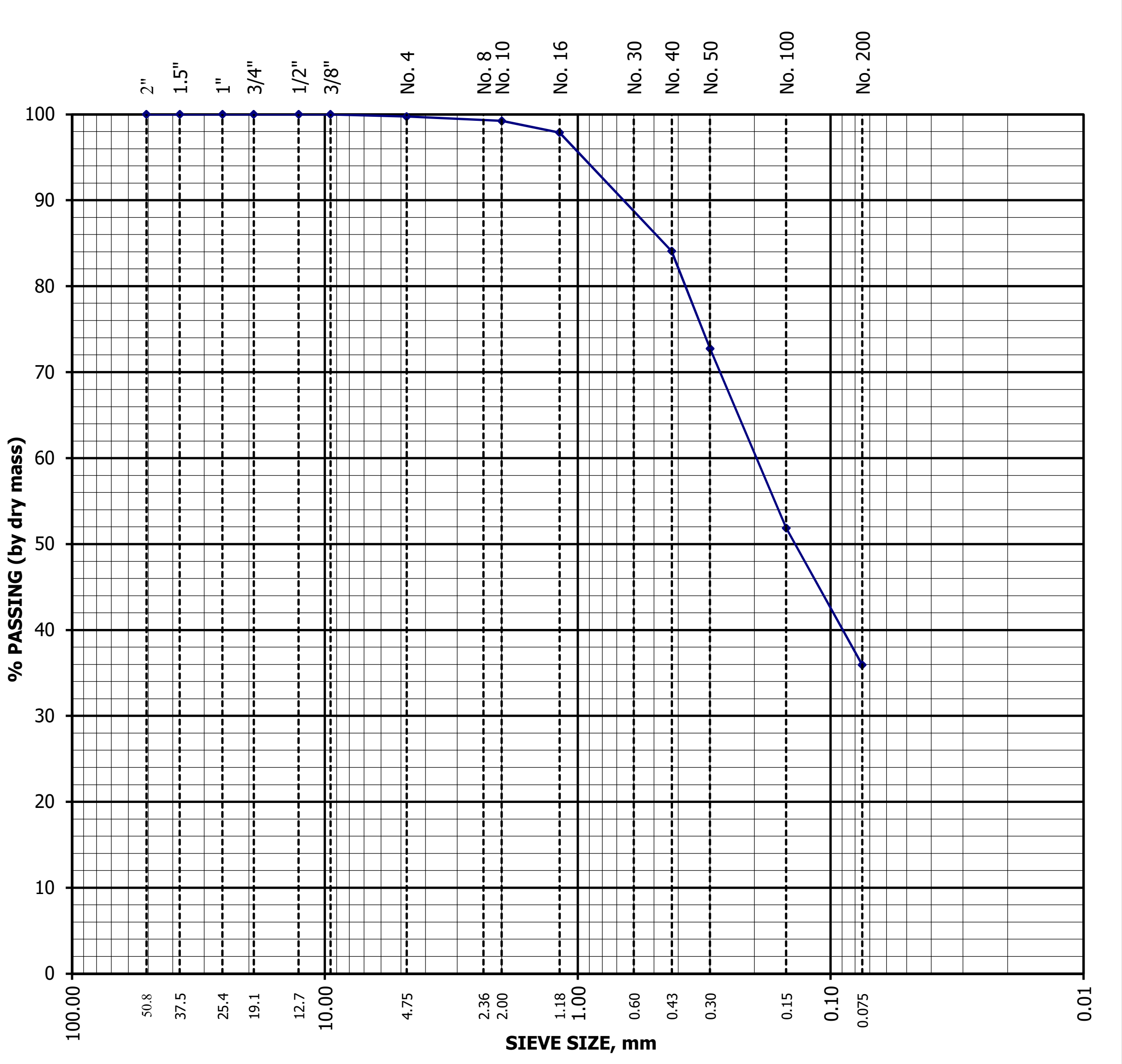
GRADATION PLOT - SOIL & AGGREGATE

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**



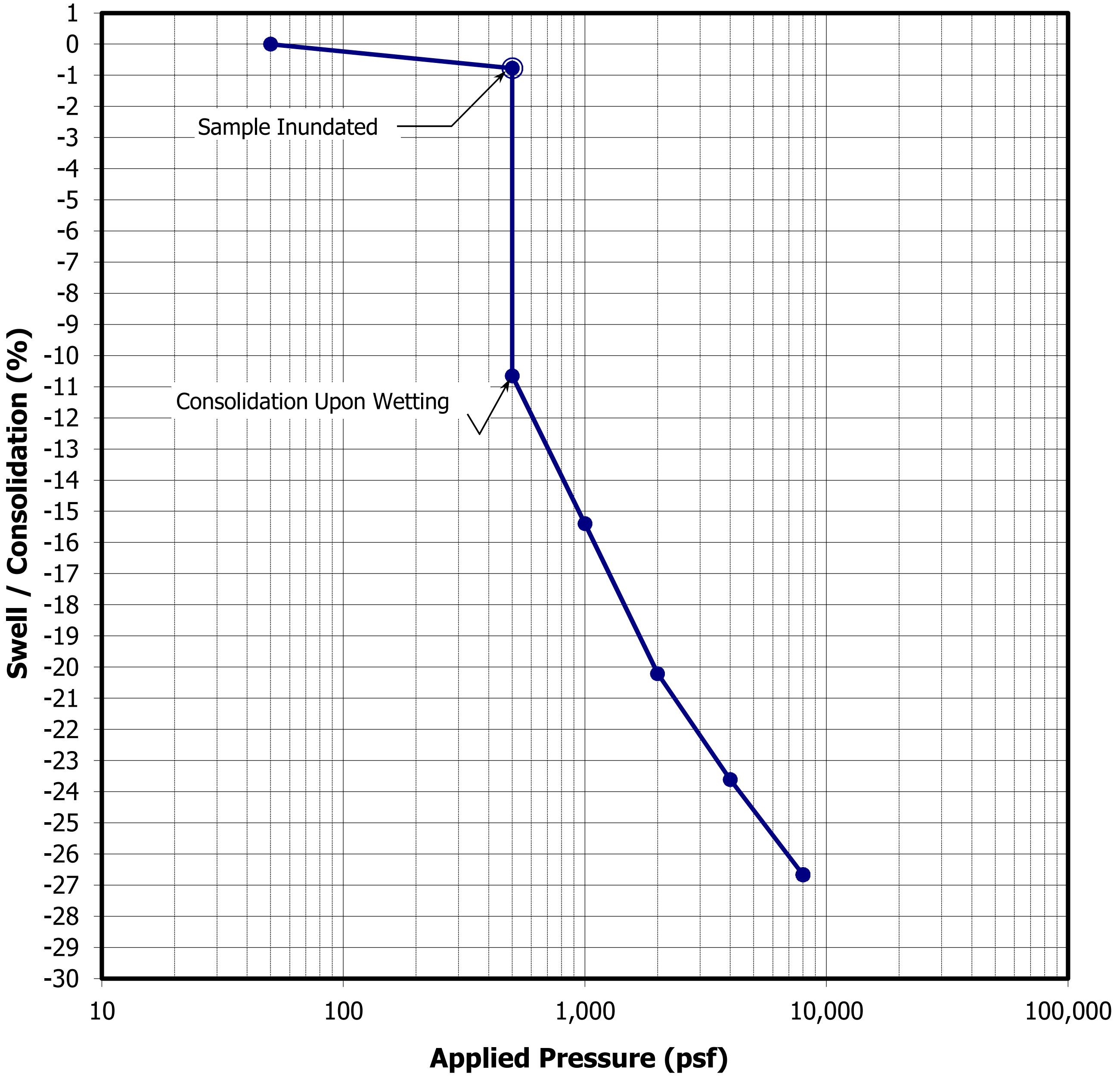
Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	
3/8"	100
#4	100
#8	
#10	99
#16	98
#30	
#40	84
#50	73
#100	52
#200	36.0

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

LL	25
PL	16
PI	9

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

SWELL/CONSOLIDATION PLOT



Sample Location	Sample Depth (feet)	Lab ID Number: 1822500 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

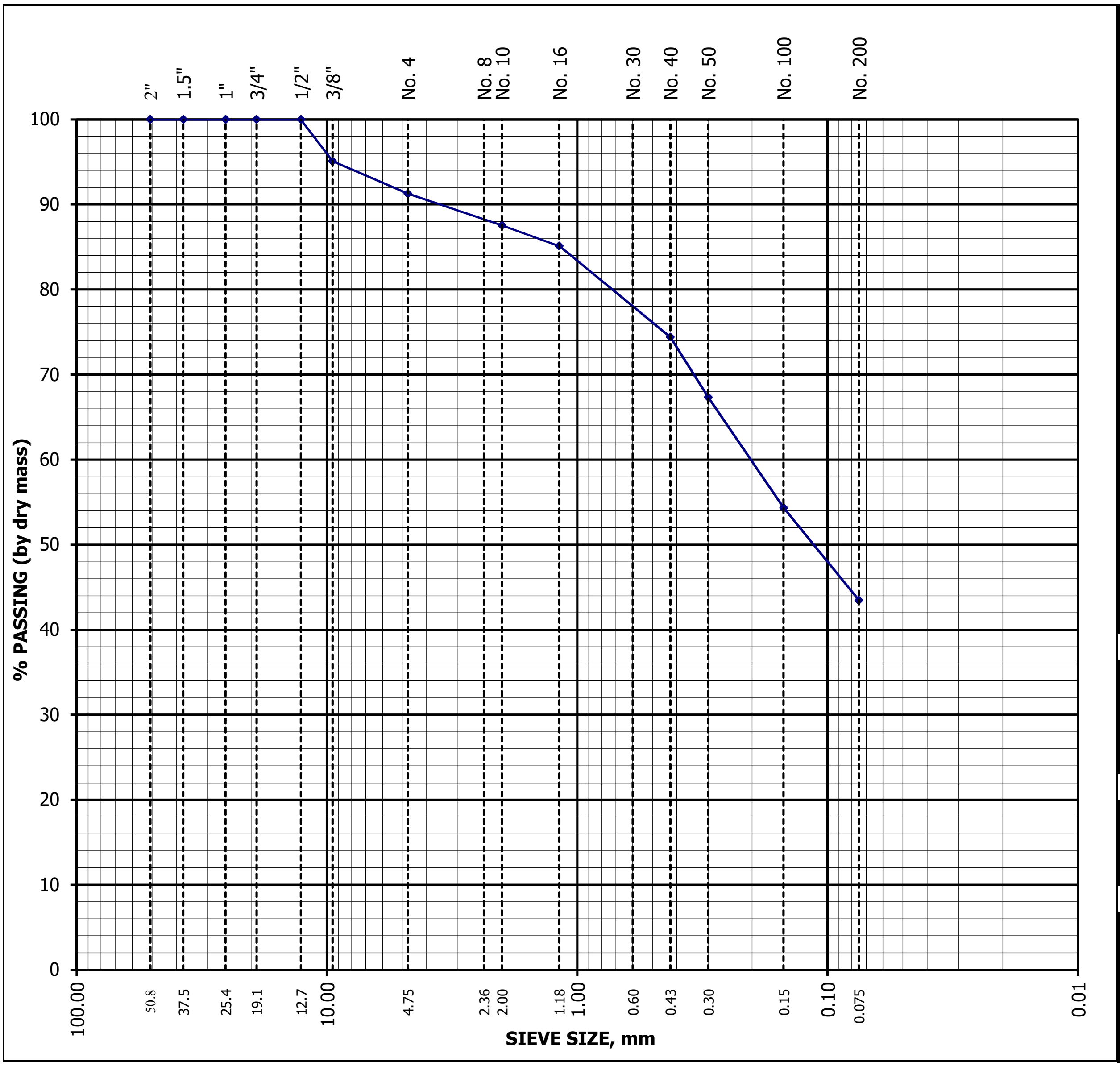
Client:	**Applegate Group**	**Project No.:**	**18.117**
Project:	**Cucharas Basin Collaborative Storage**	**Figure:**	**1822500**

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	

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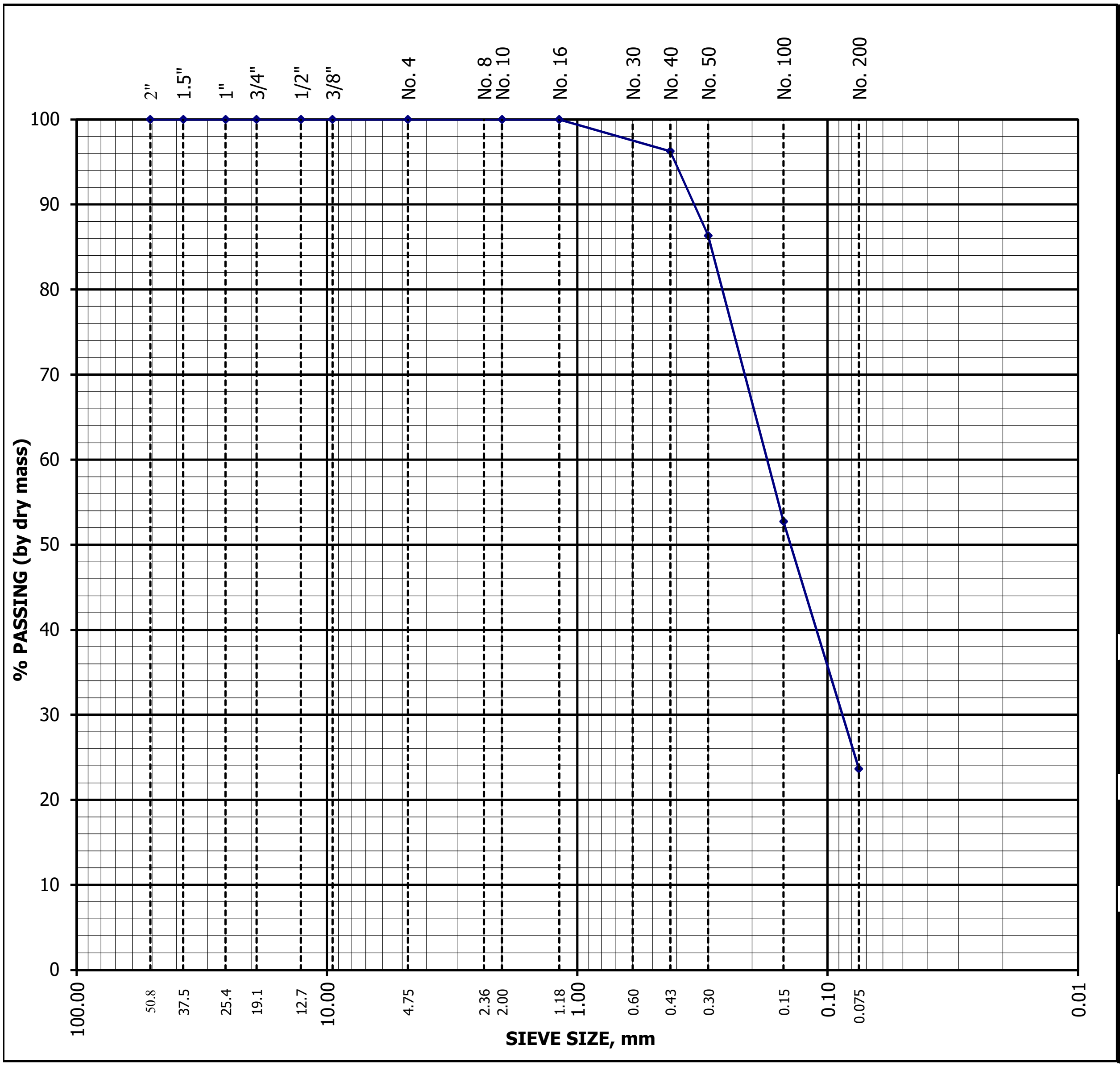
GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	6-Oct-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Holiman
Lab ID Number:	1822656	Reviewer:	J. Crystal
Sample Location:	BCP-6 at 7' to 9'		
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"	
#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	

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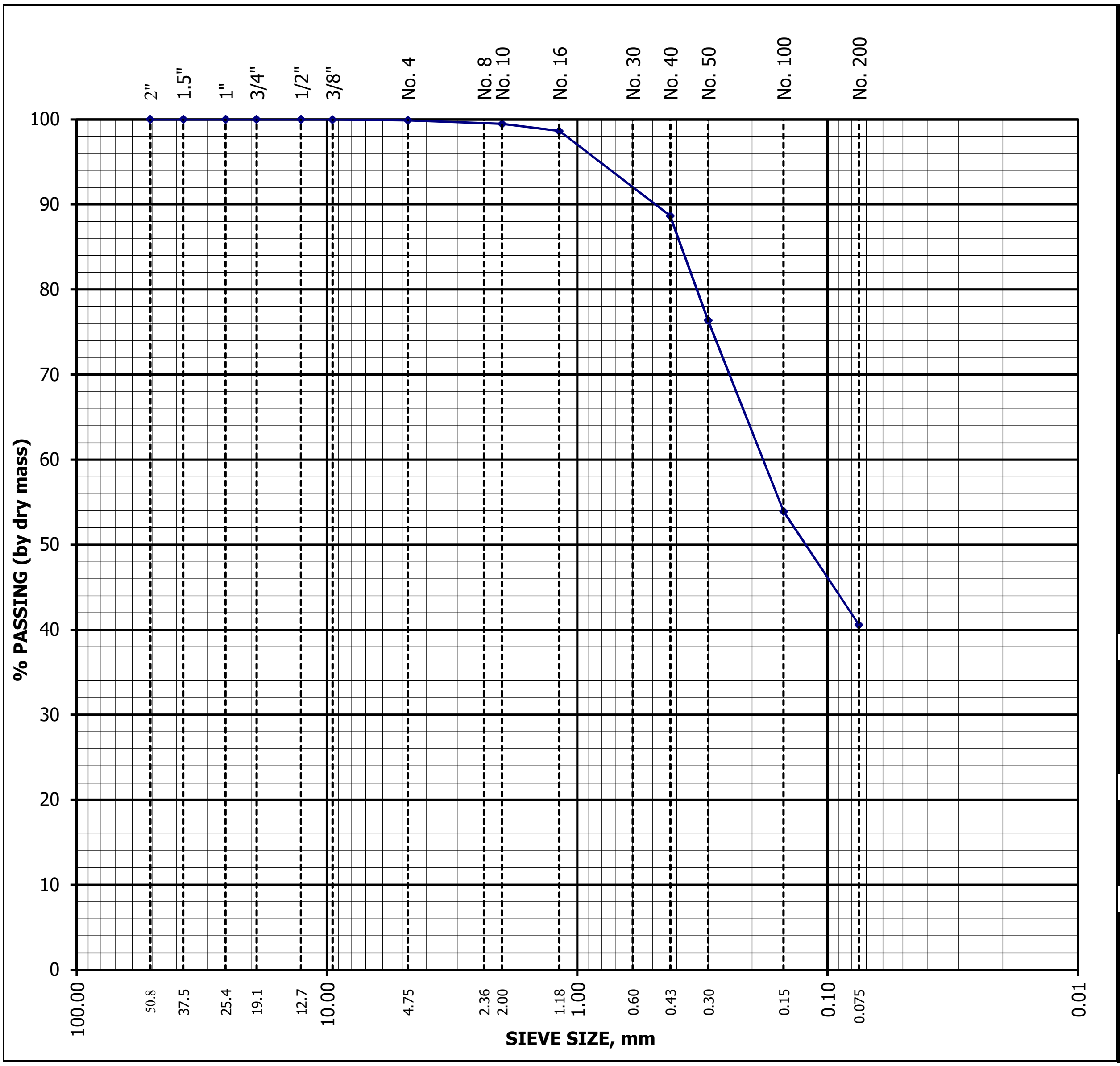
GRADATION PLOT - SOIL & AGGREGATE

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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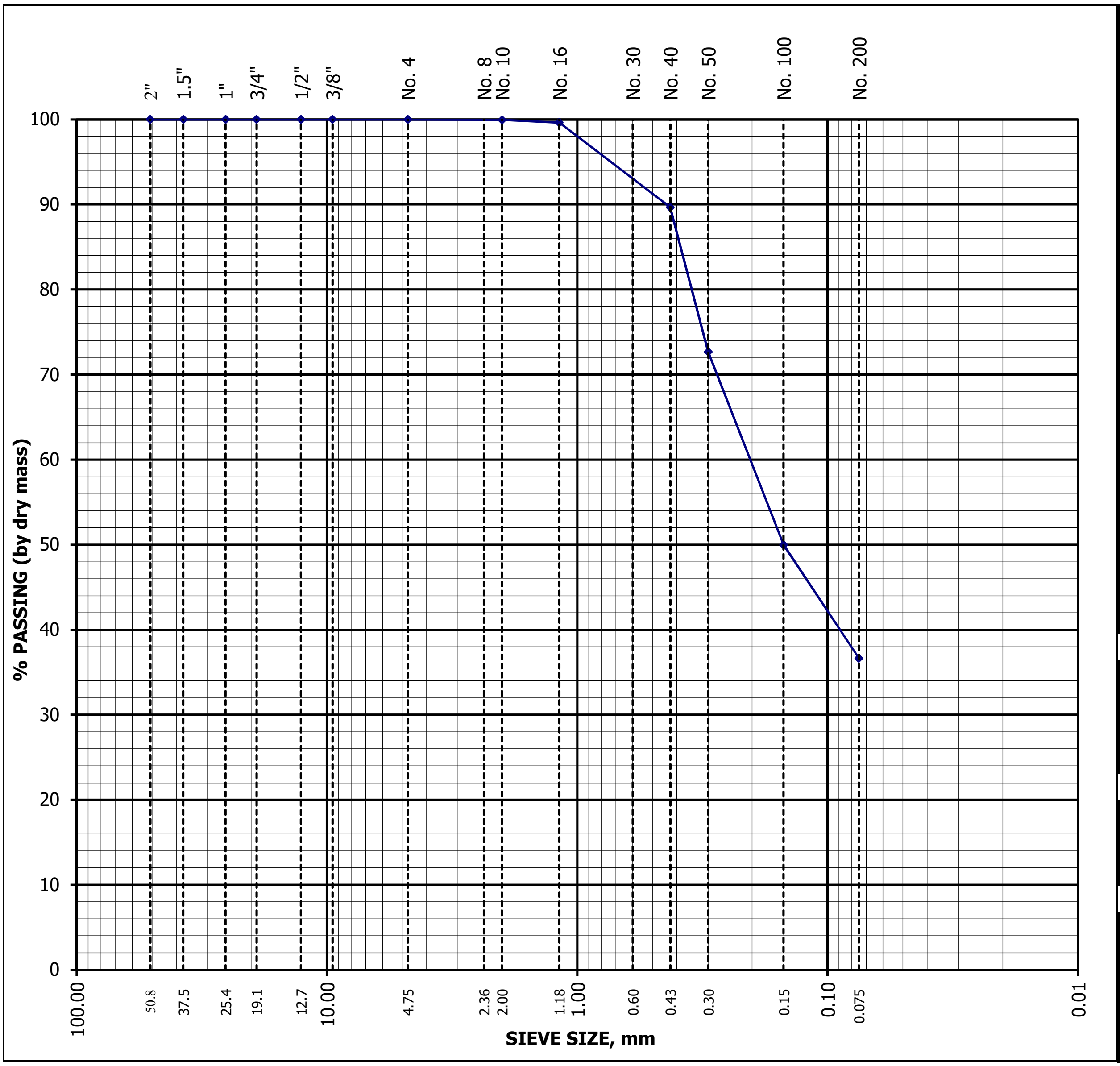
GRADATION PLOT - SOIL & AGGREGATE

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	

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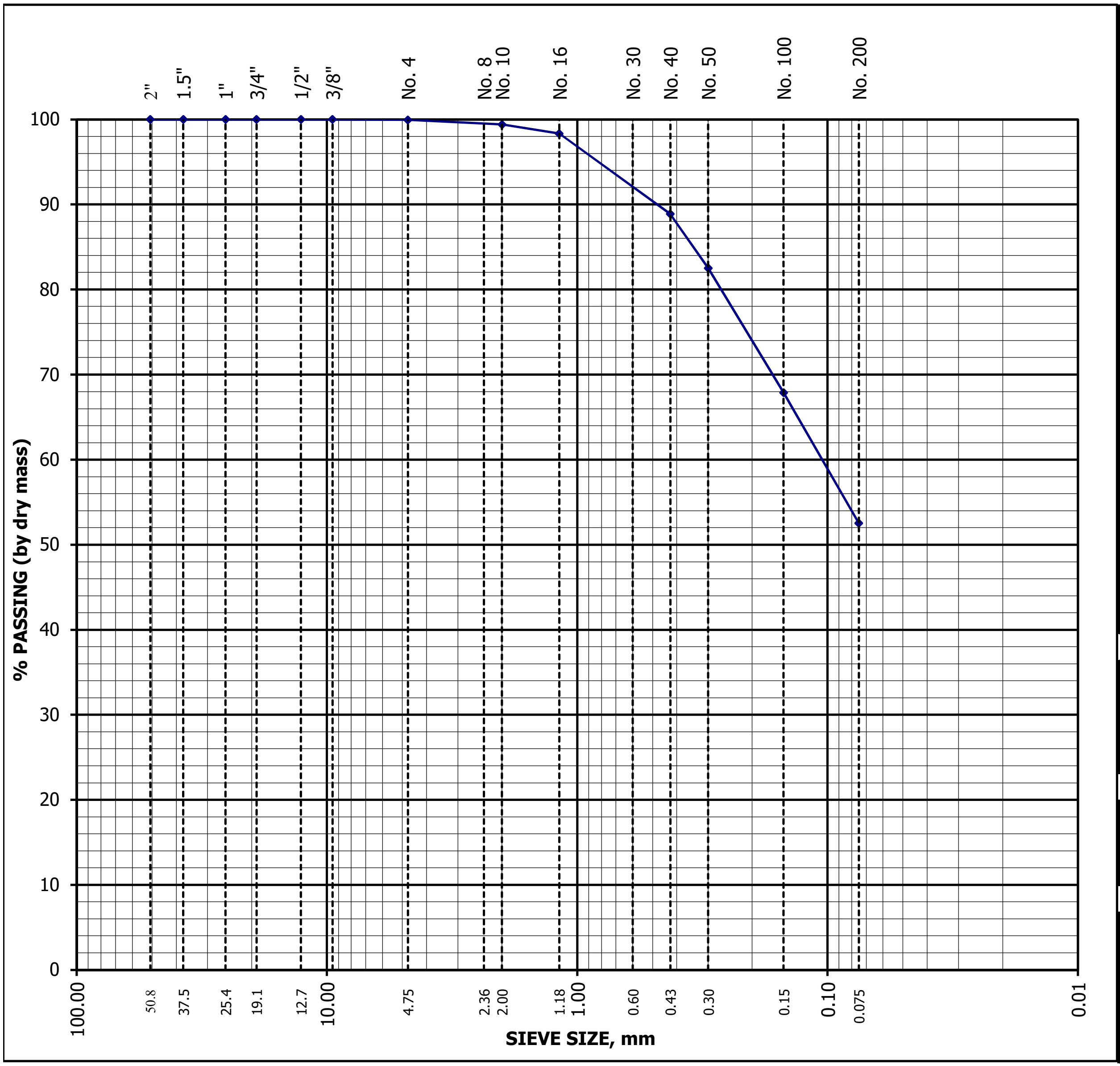
GRADATION PLOT - SOIL & AGGREGATE

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

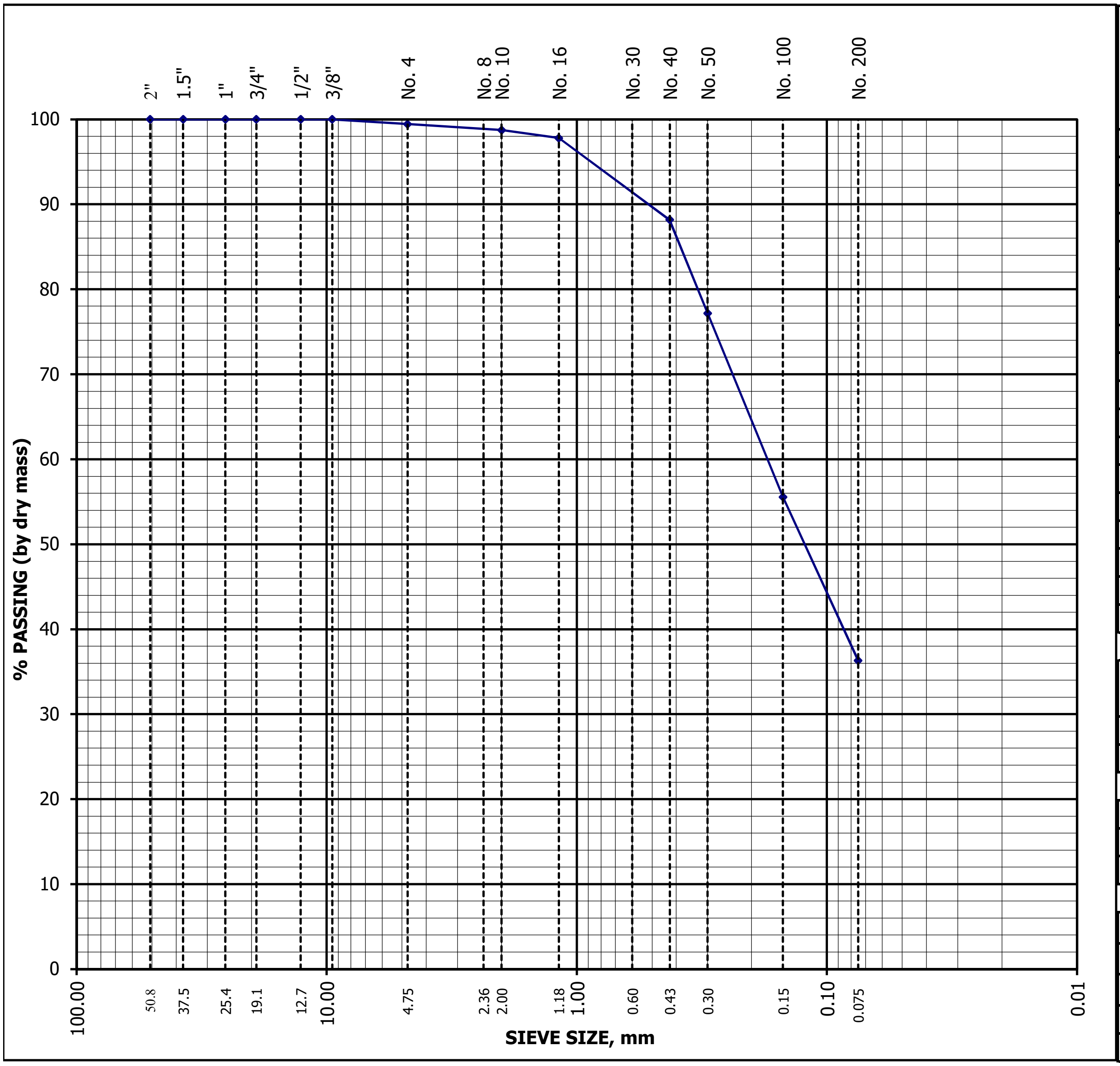
D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822898
Sample Location: LVL-7 at 4'
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	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	

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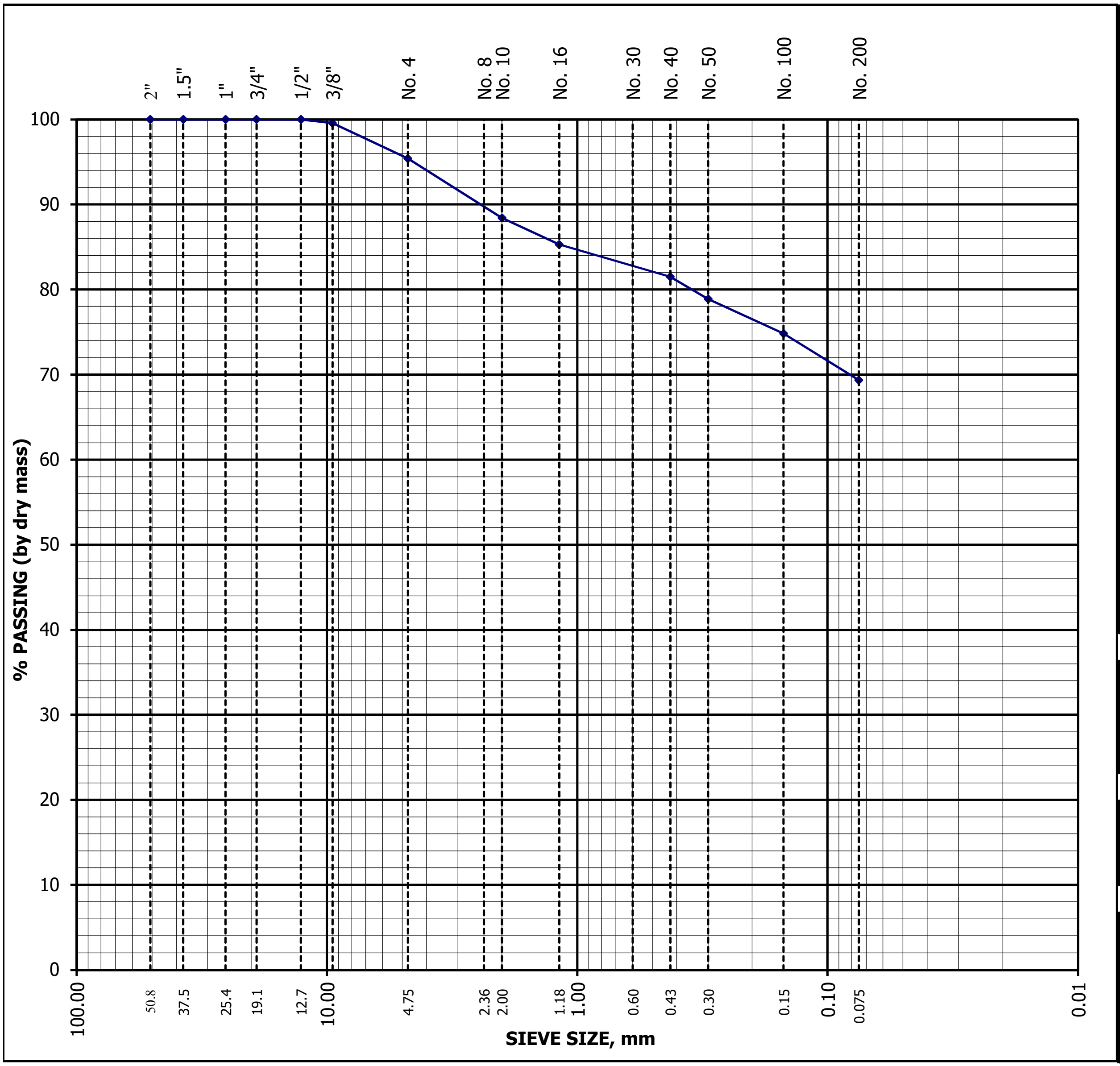
GRADATION PLOT - SOIL & AGGREGATE

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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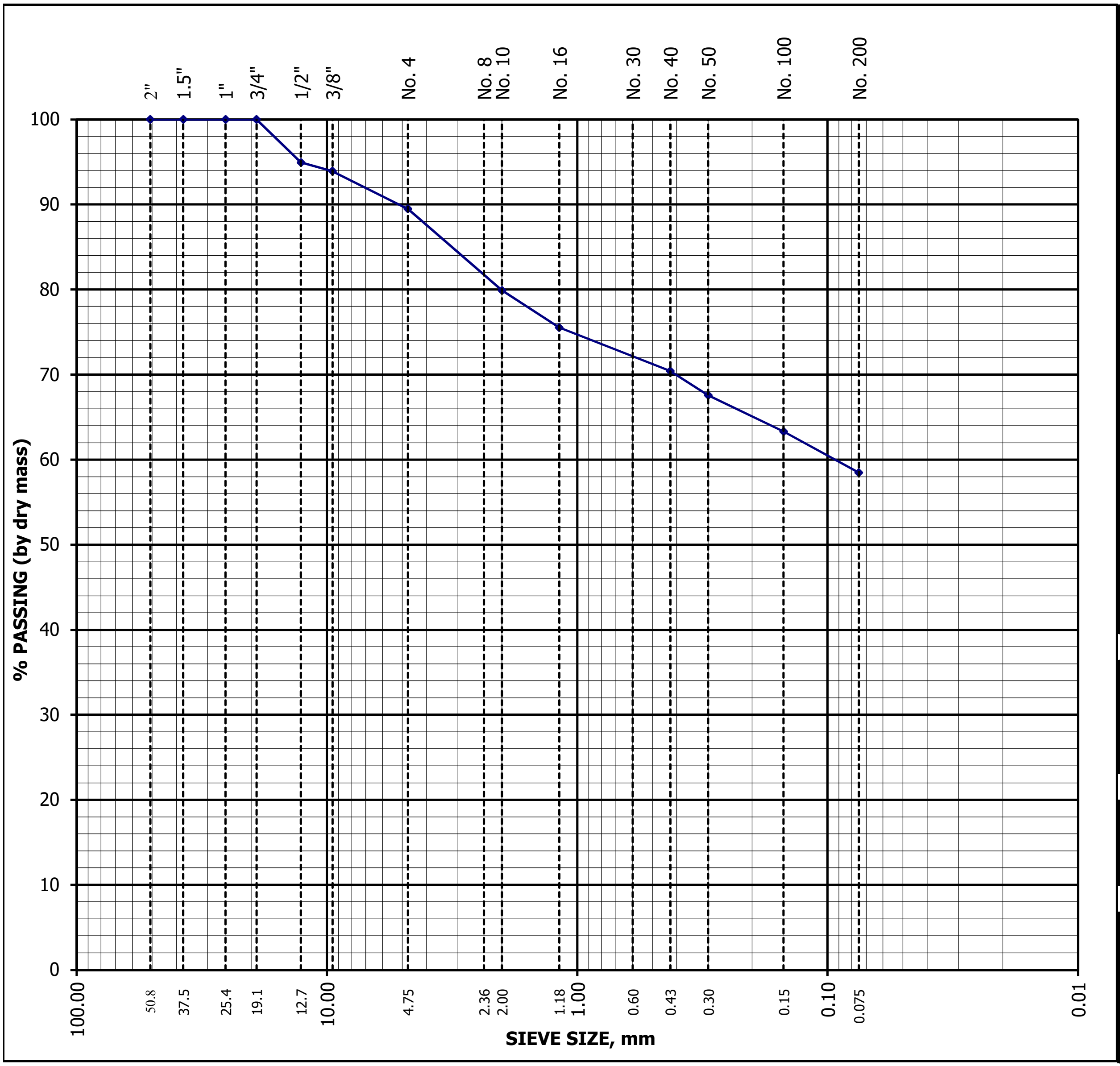
GRADATION PLOT - SOIL & AGGREGATE

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

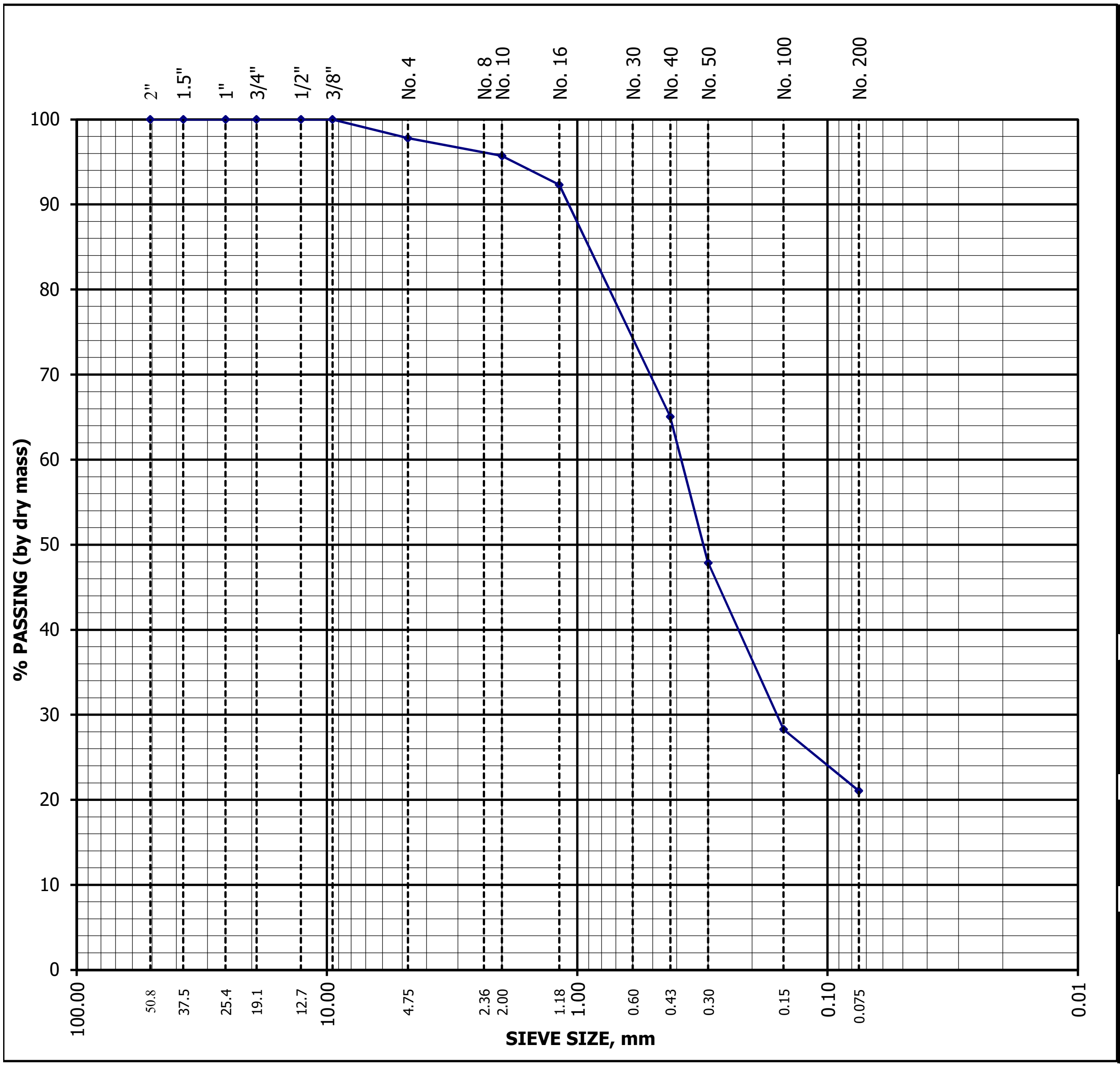
D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822879
Sample Location: MS-2 at 10'
Visual Description: SAND, silty, 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): **(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

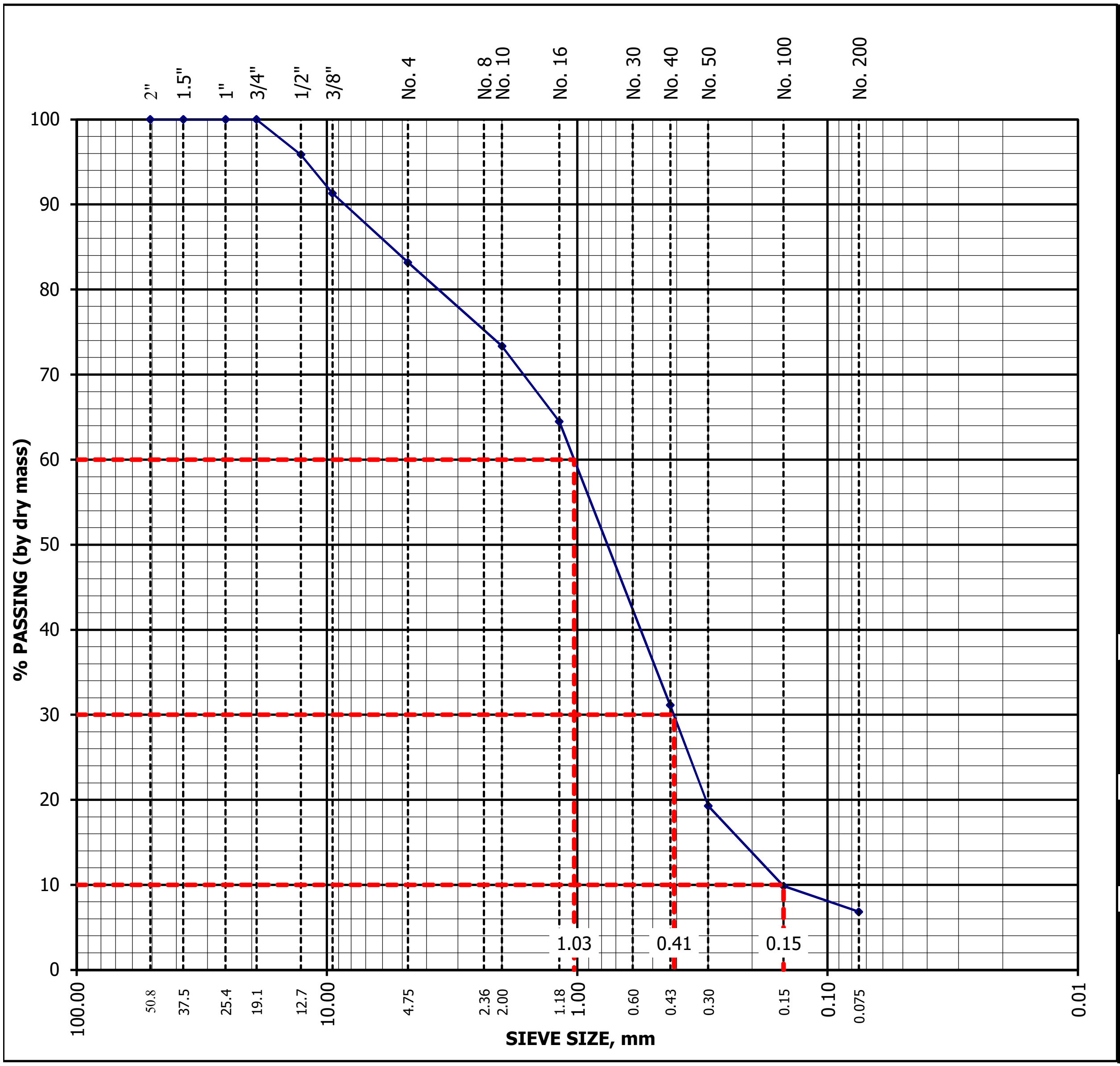
D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

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

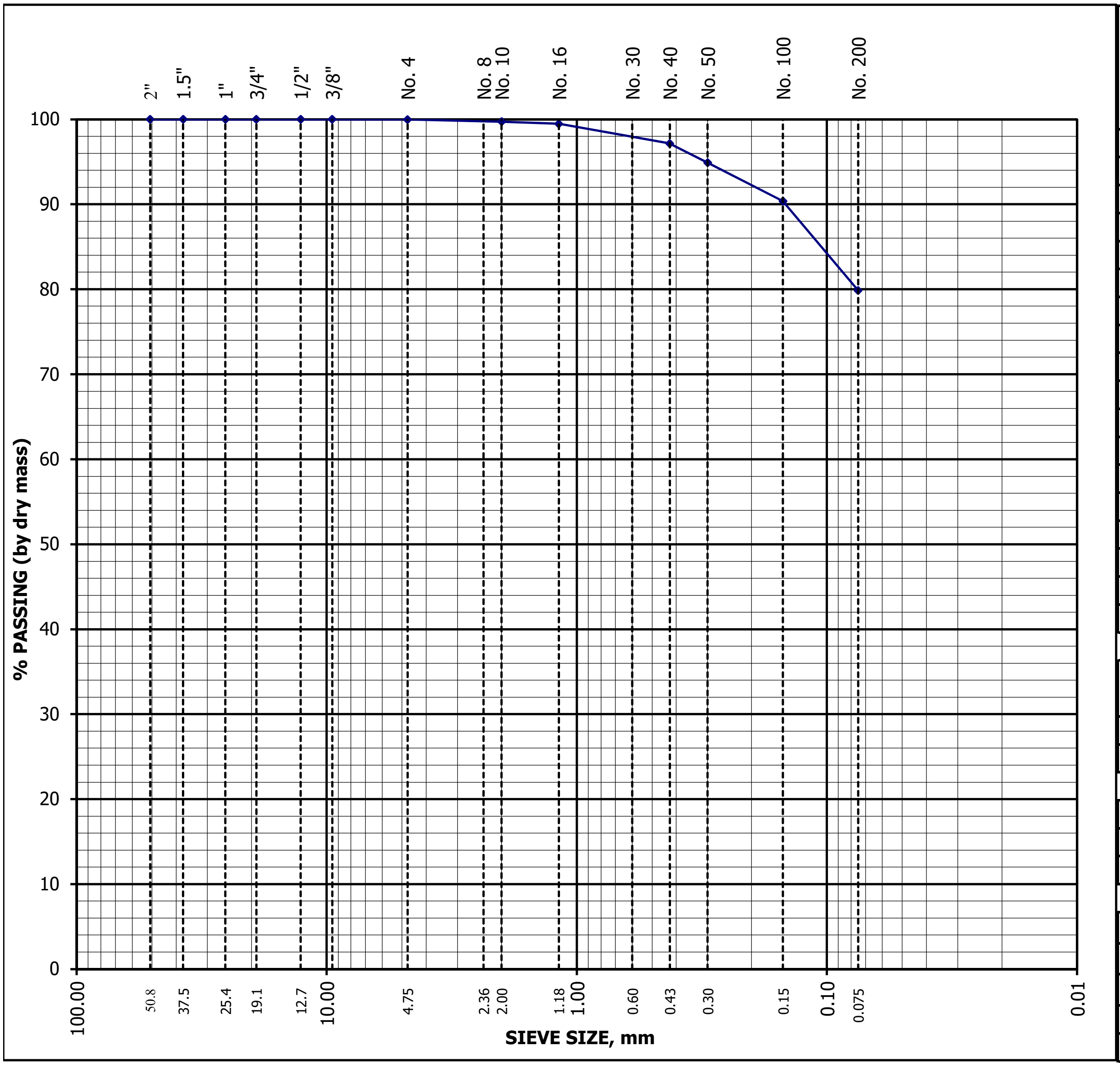
D_{60}	1.03
D_{30}	0.41
D_{10}	0.15
Cu	**6.87**
Cc	**1.09**

GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822881
Sample Location: MS-3 at 5'
Visual Description: CLAY, with sand, brown

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

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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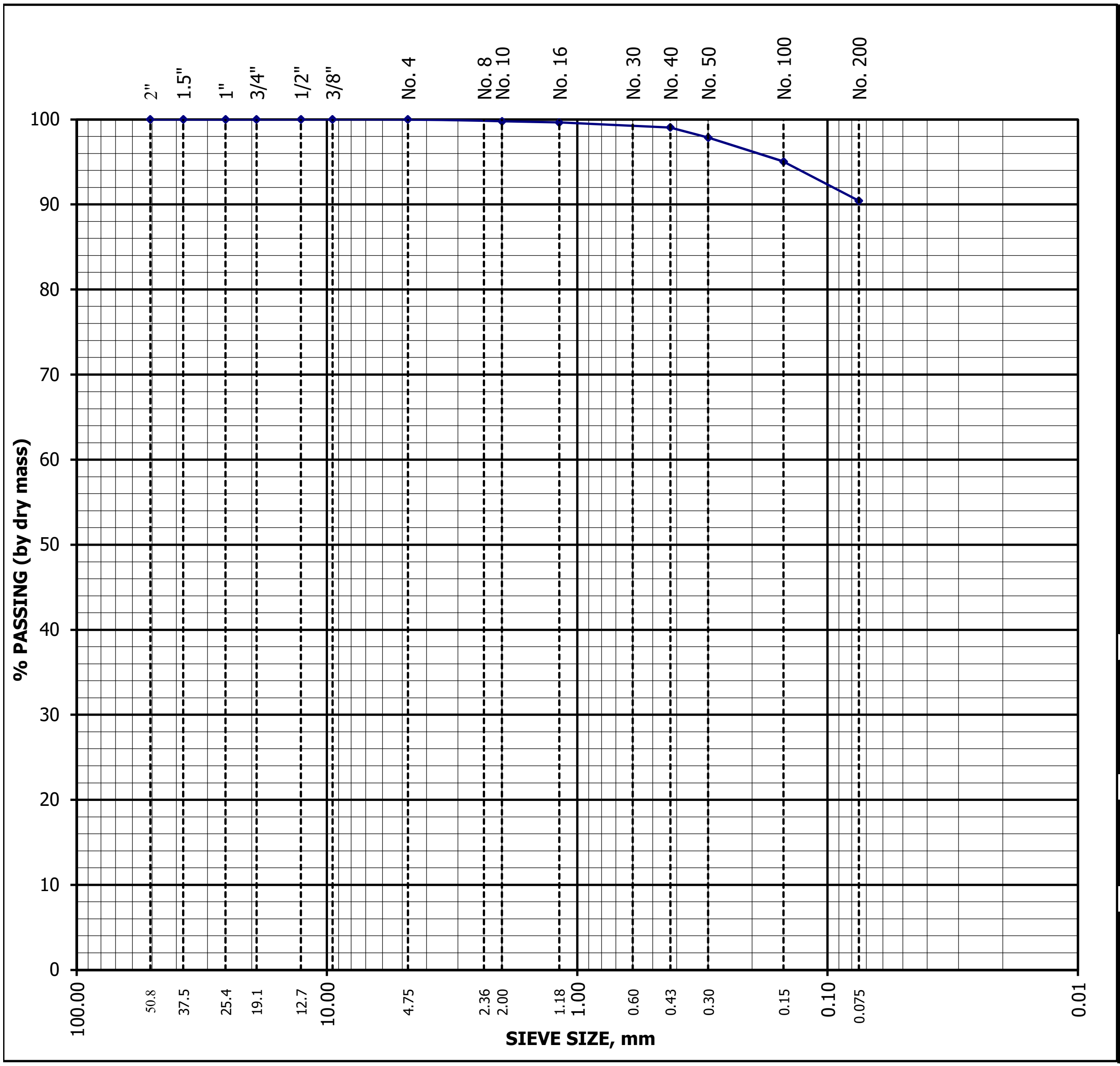
GRADATION PLOT - SOIL & AGGREGATE

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

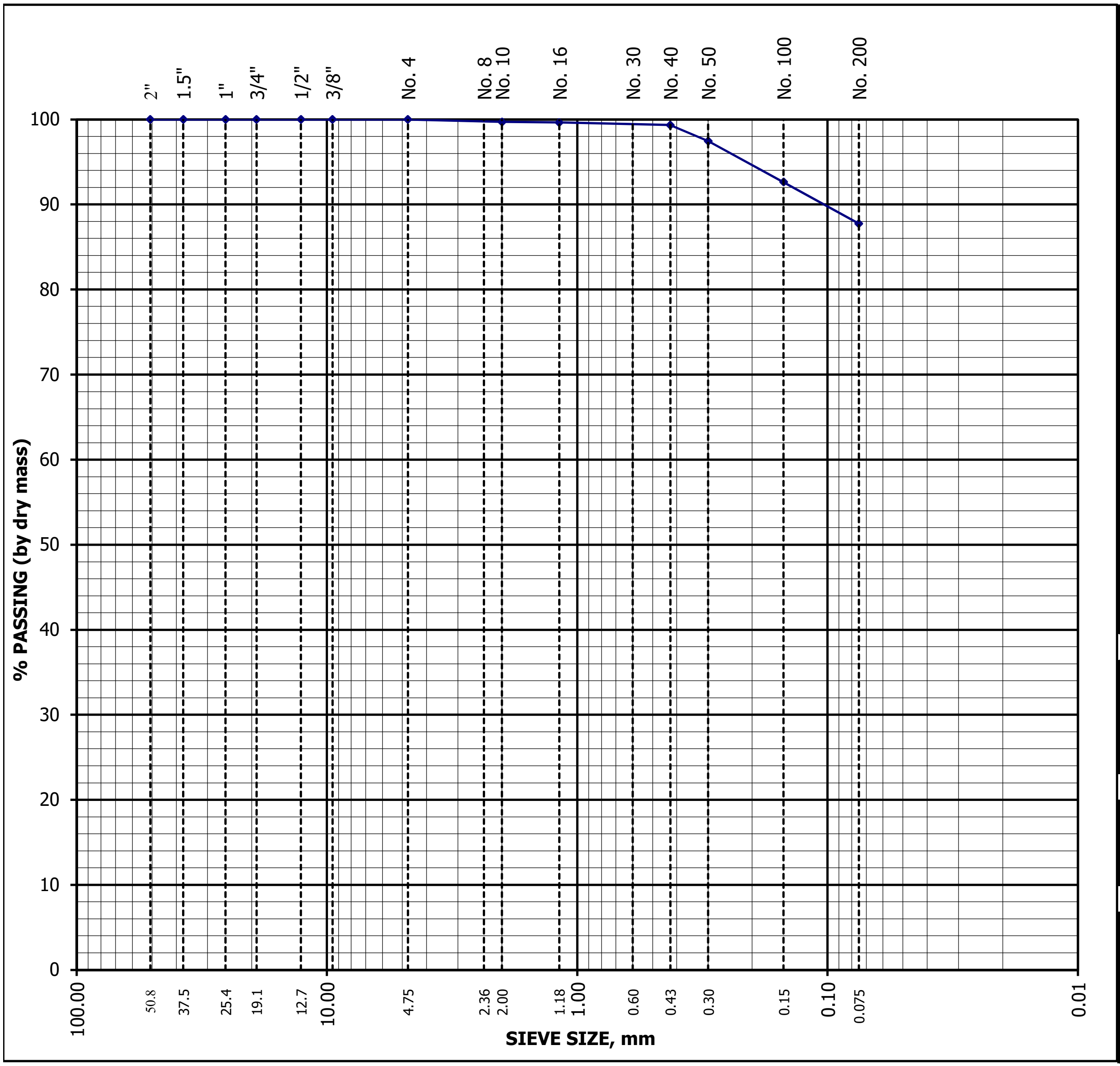
D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

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

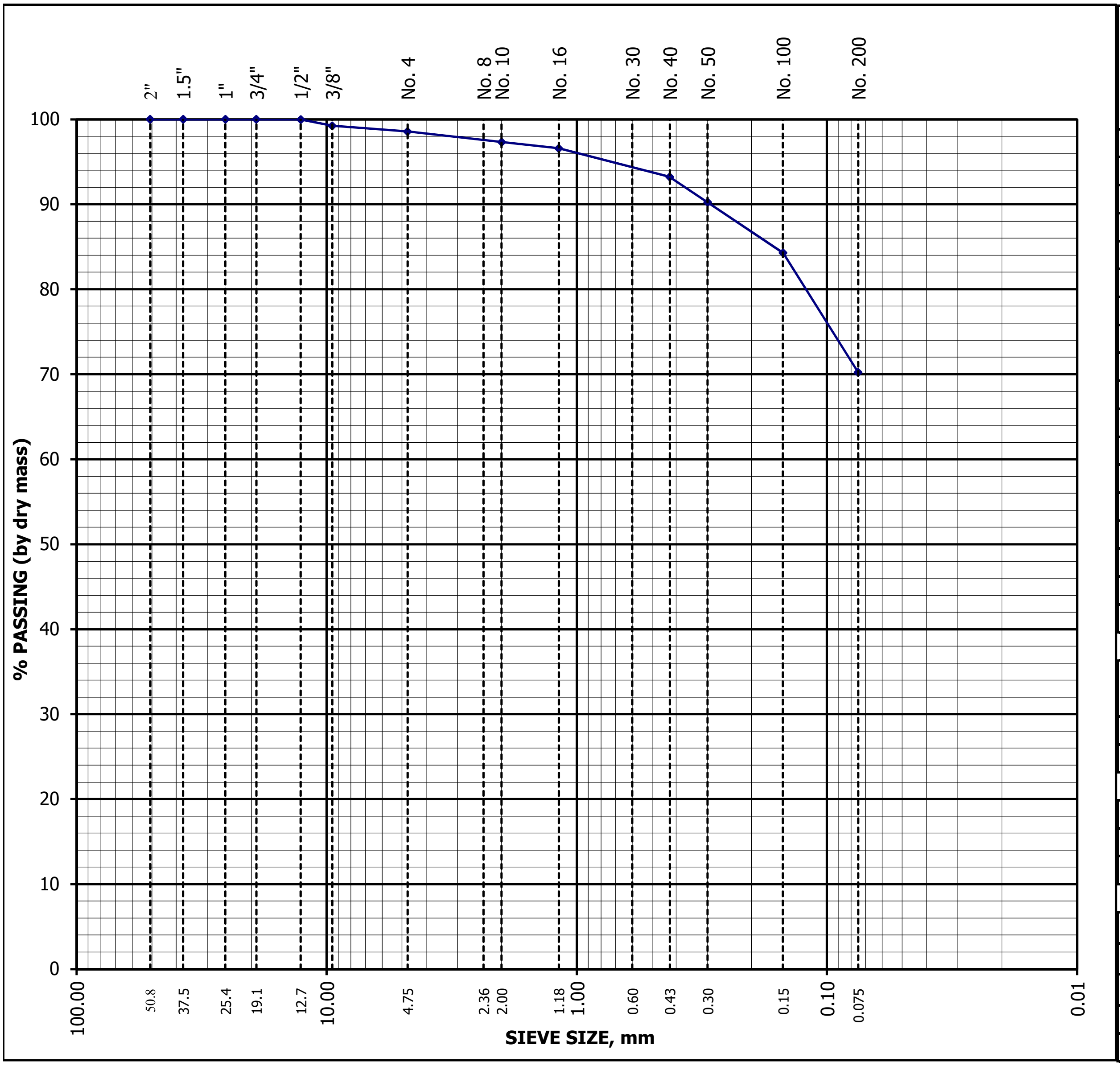
D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

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:	1822884	Reviewer:	J. Crystal
Sample Location:	MS-6 at 10'		
Visual Description:	CLAY, sandy, brown		

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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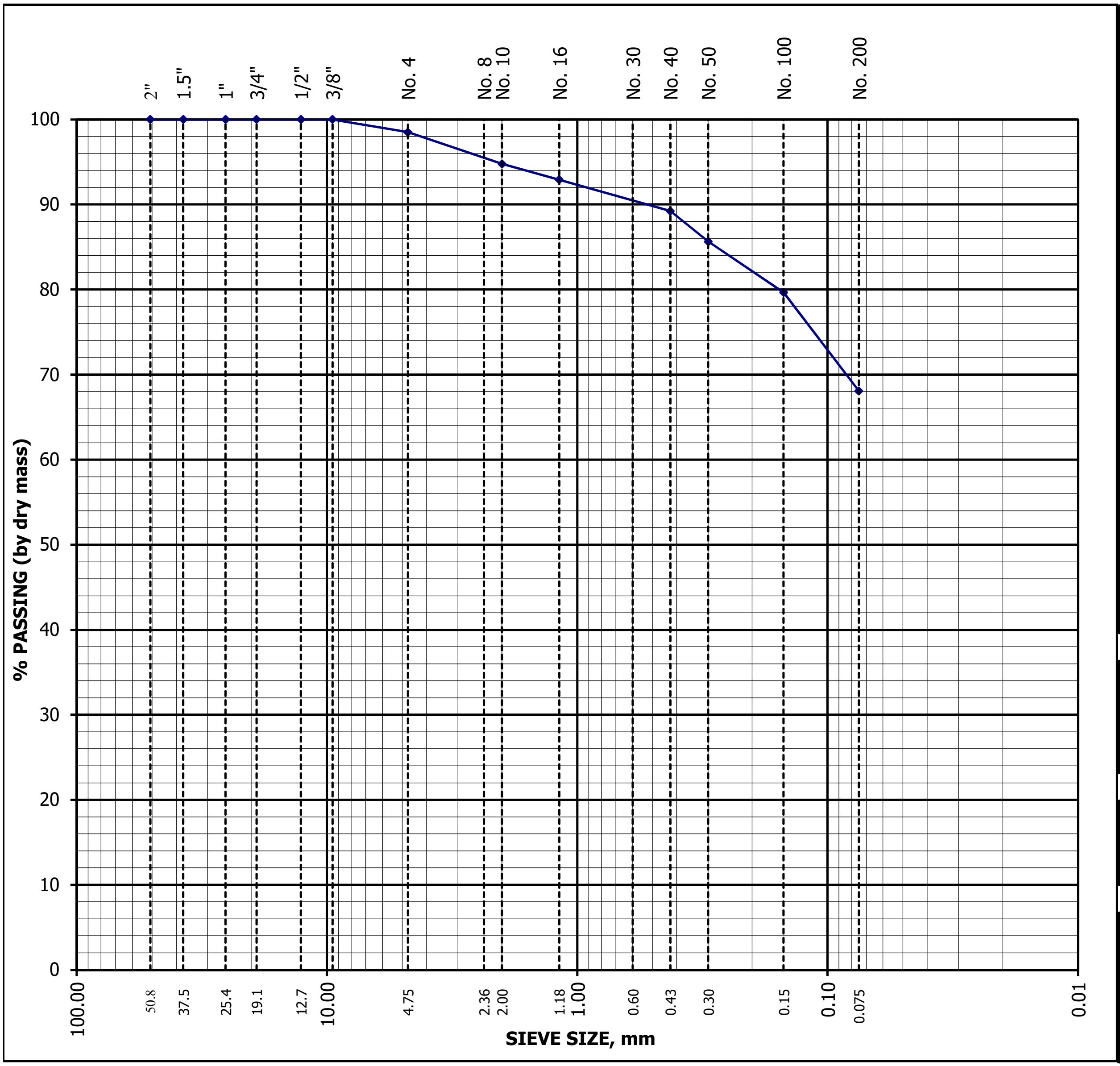
GRADATION PLOT - SOIL & AGGREGATE

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

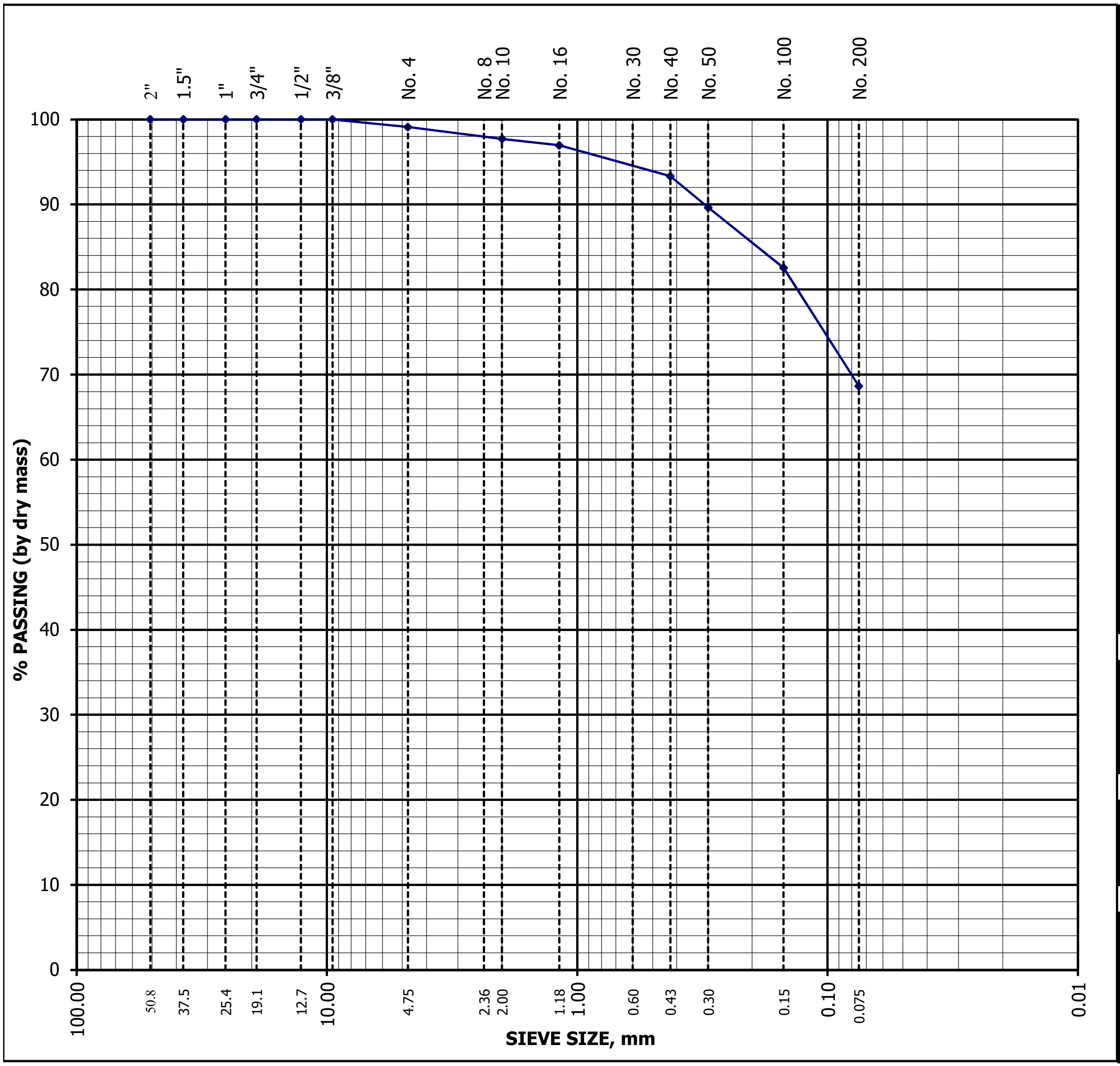
D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

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	

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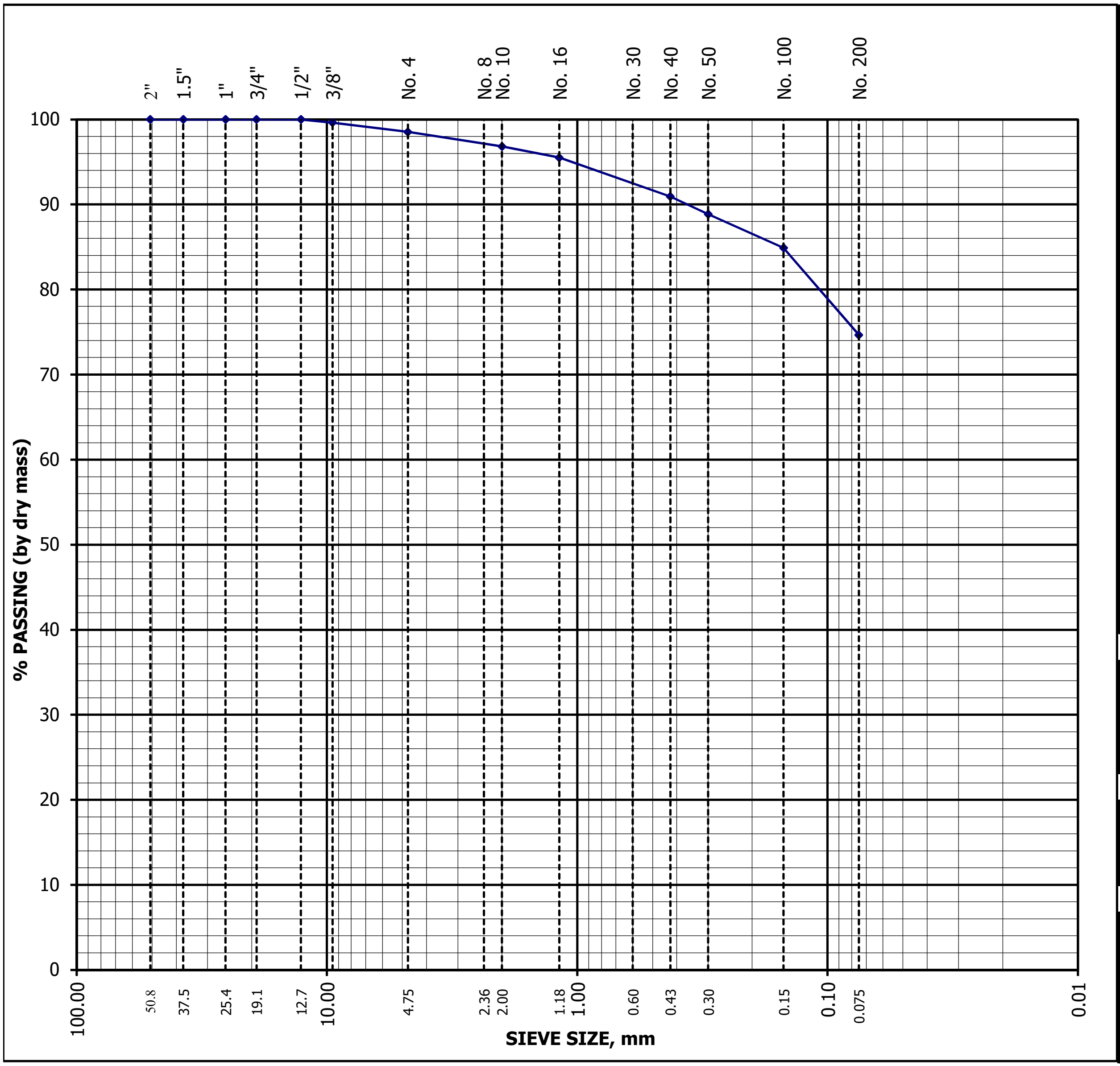
GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	7-Oct-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	G. Hoyos
Lab ID Number:	1822642	Reviewer:	J. Crystal
Sample Location:	MSP-4 at 1' to 4'		
Visual Description:	CLAY, with sand, brown		

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	

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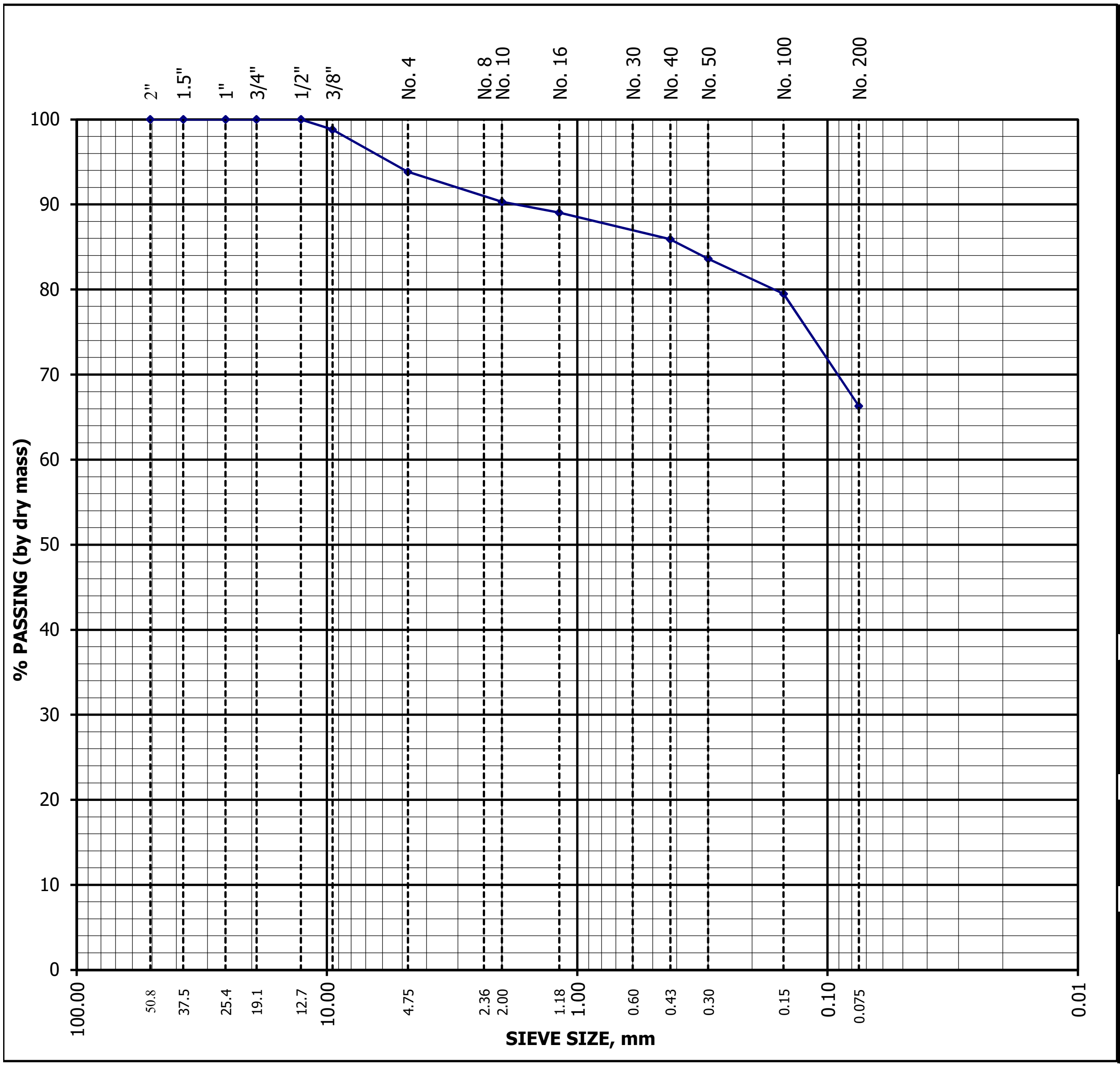
GRADATION PLOT - SOIL & AGGREGATE

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

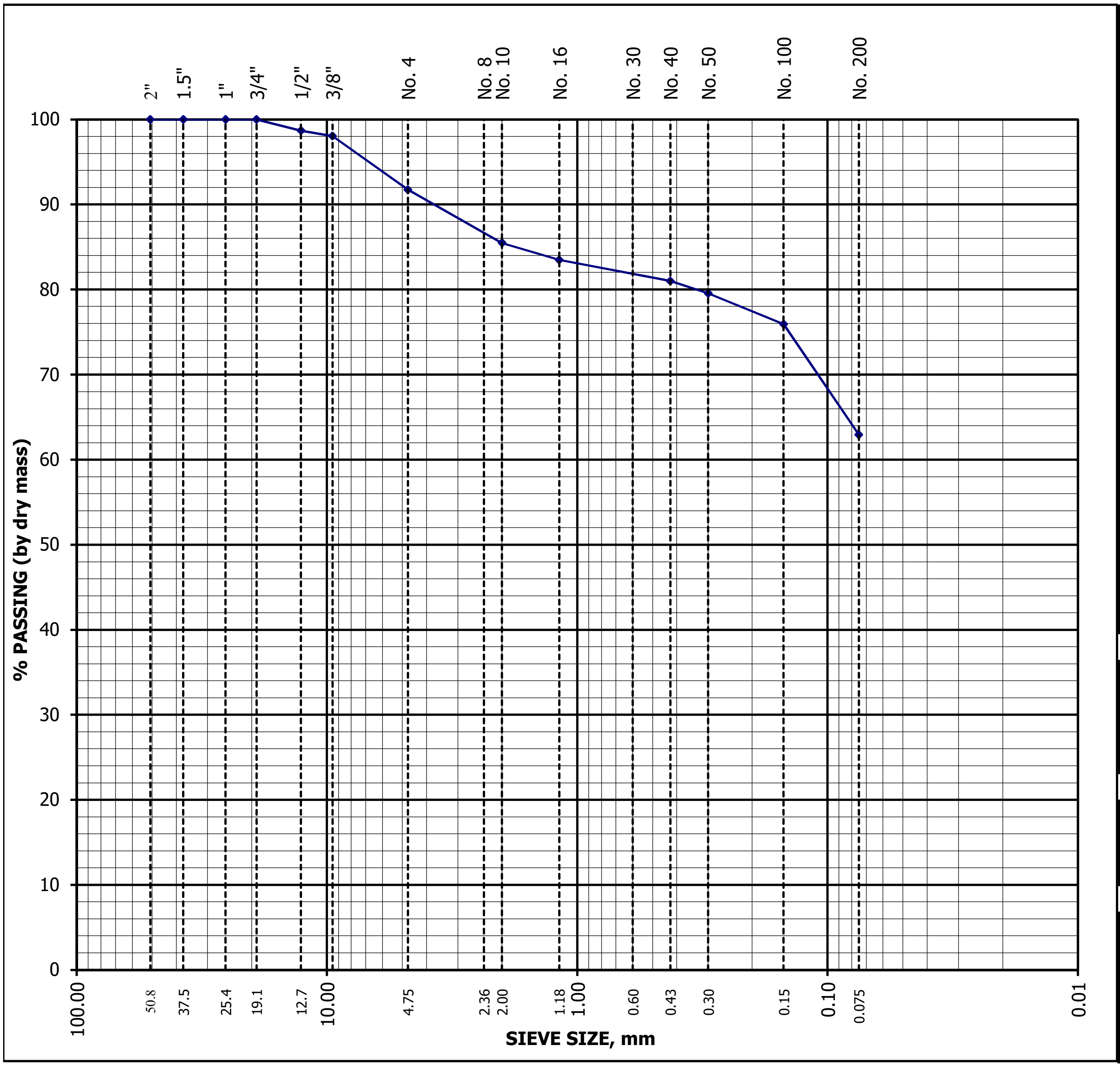
D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

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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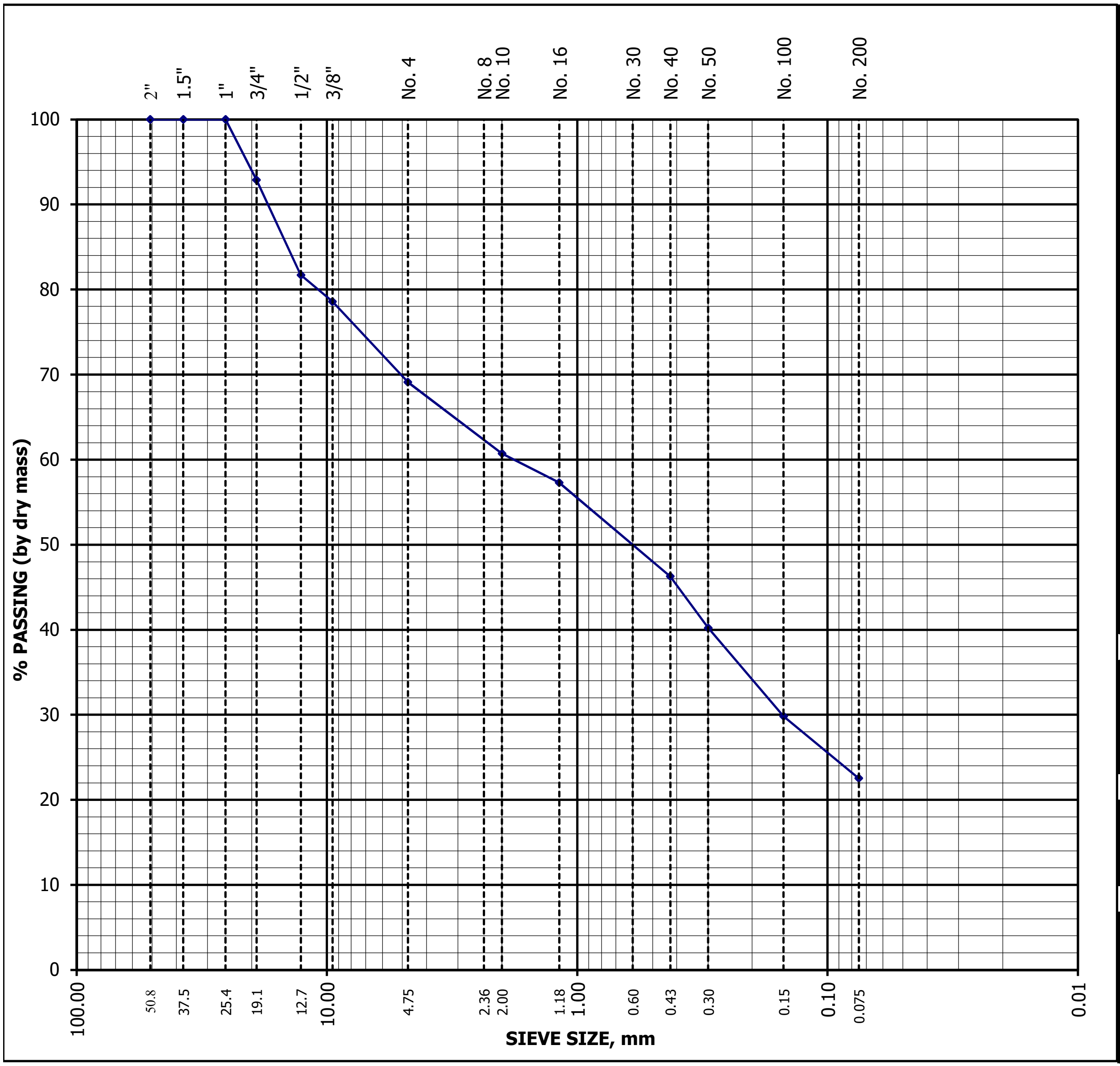
GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822886
Sample Location: SB-1 at 5'
Visual Description: SAND, silty, with 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): **(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

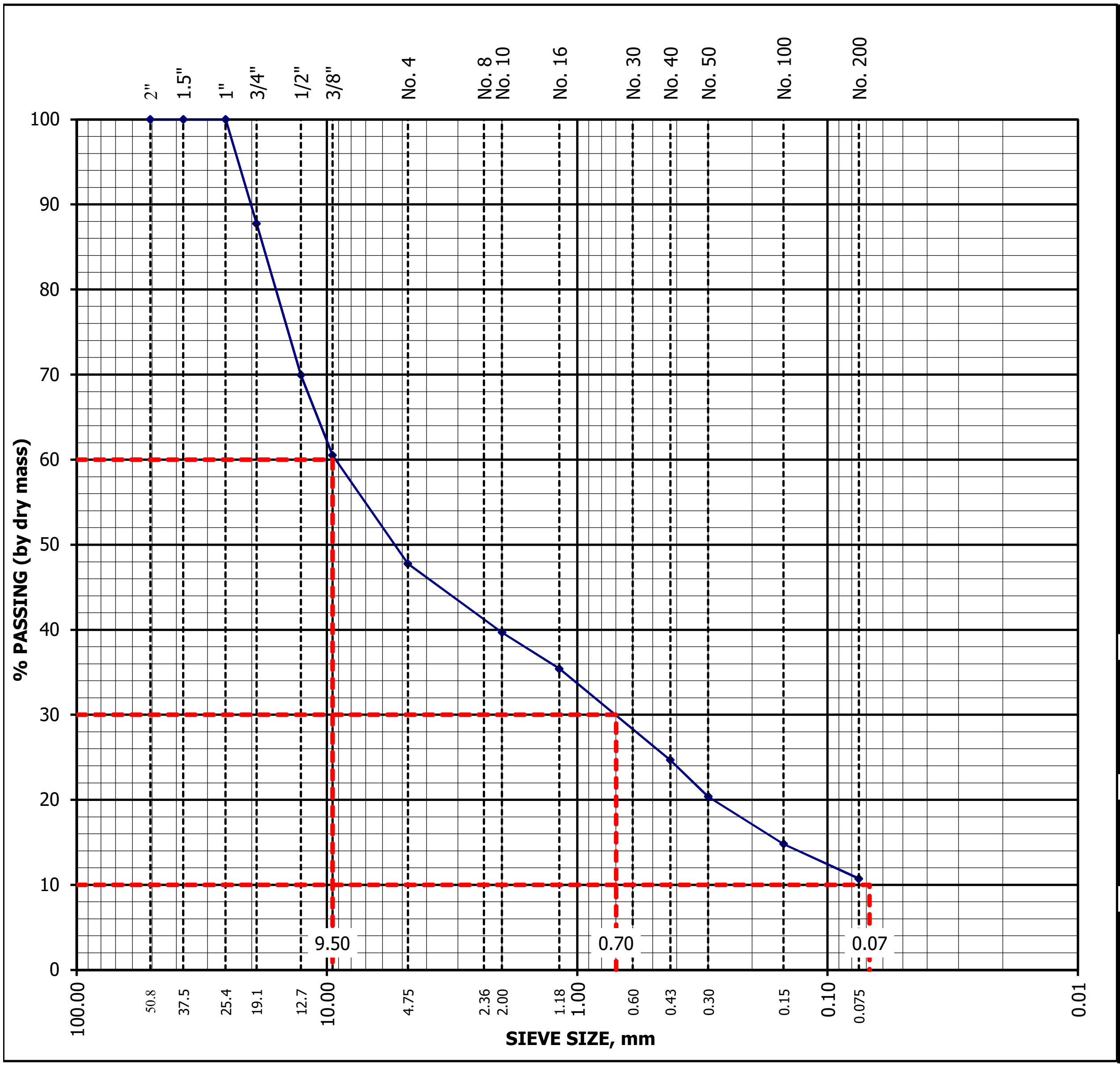
D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

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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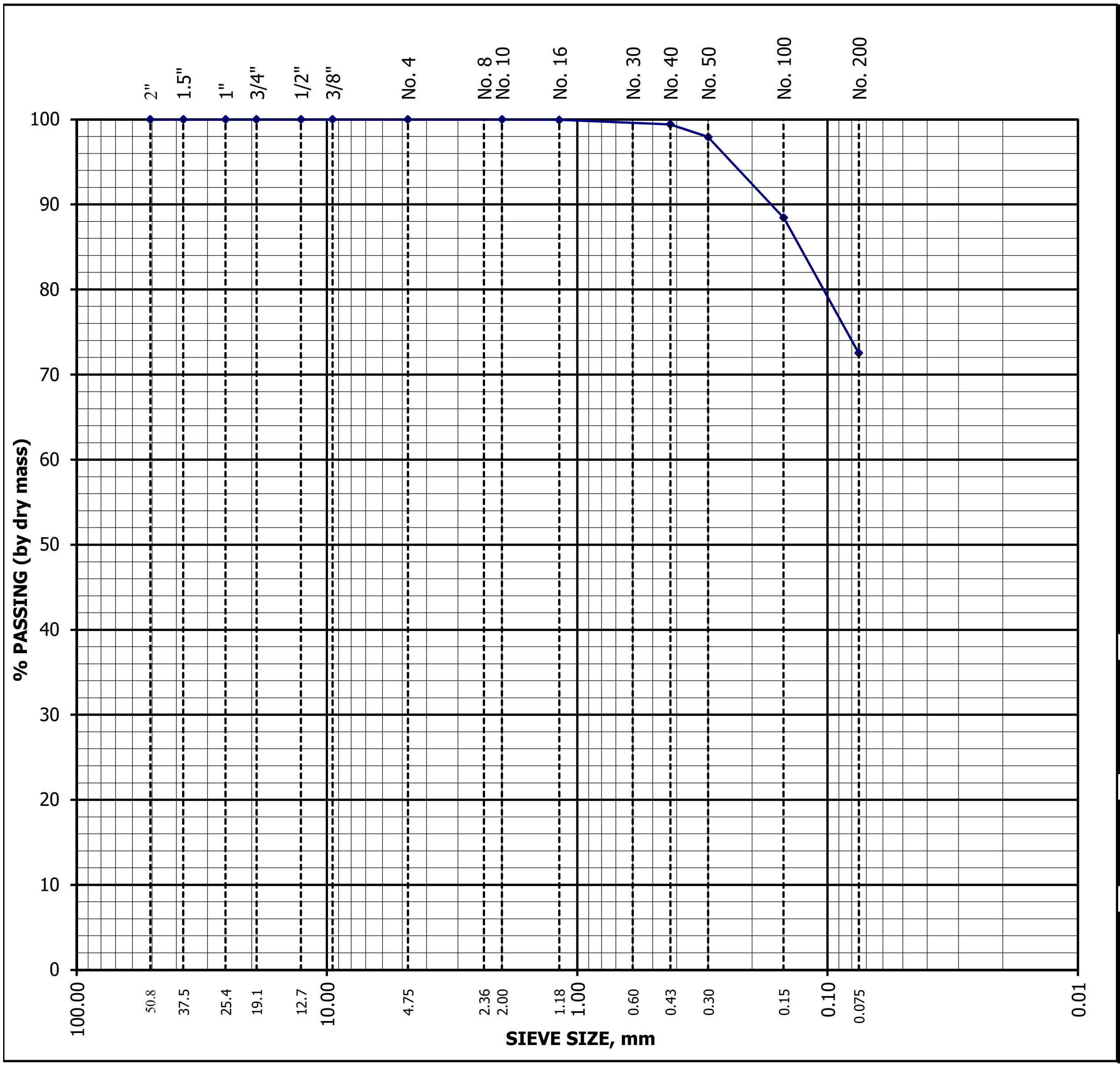
GRADATION PLOT - SOIL & AGGREGATE

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	

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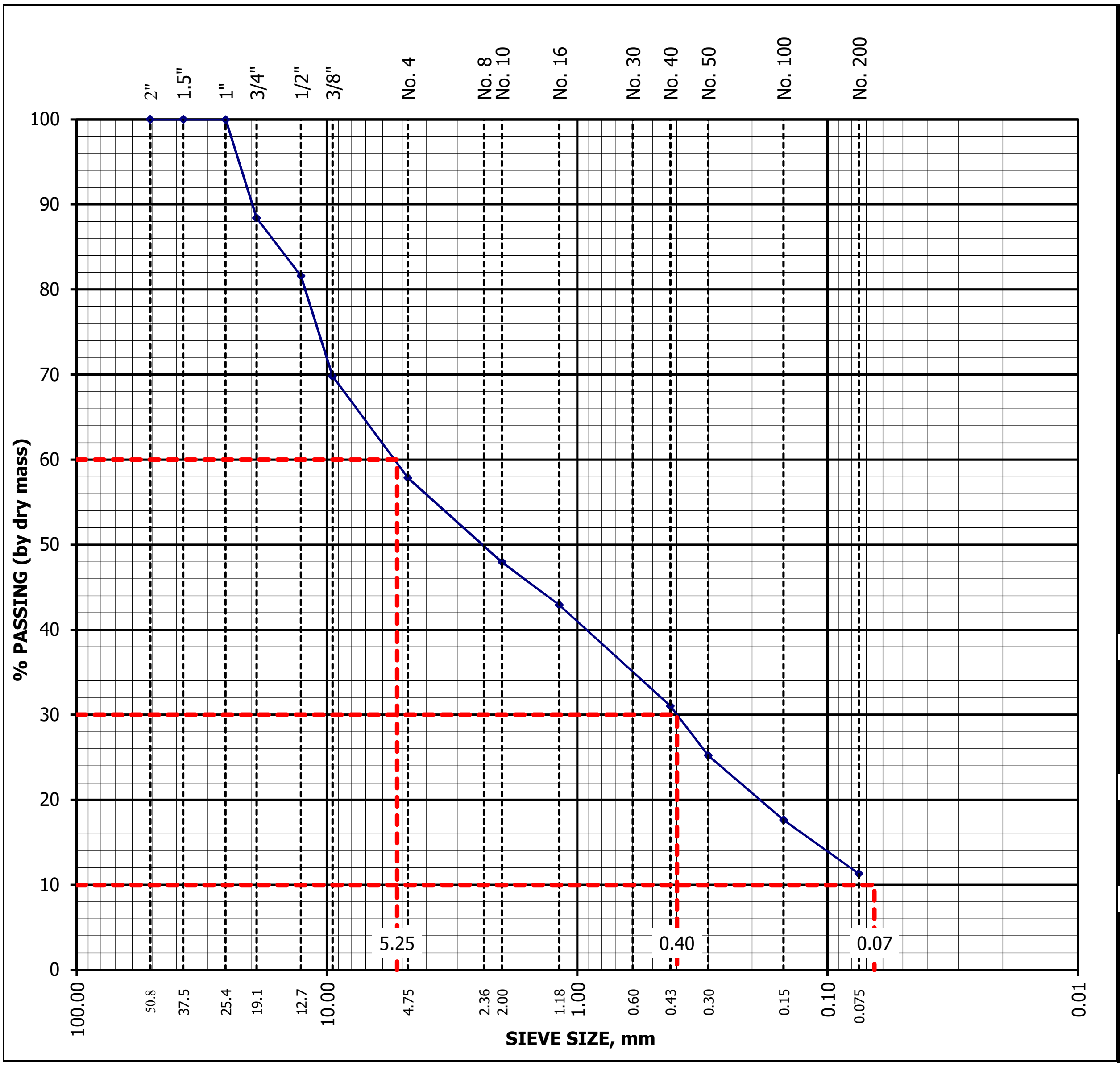
GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822889
Sample Location: SB-2 at 10'
Visual Description: SAND, with silt and gravel, red 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): (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

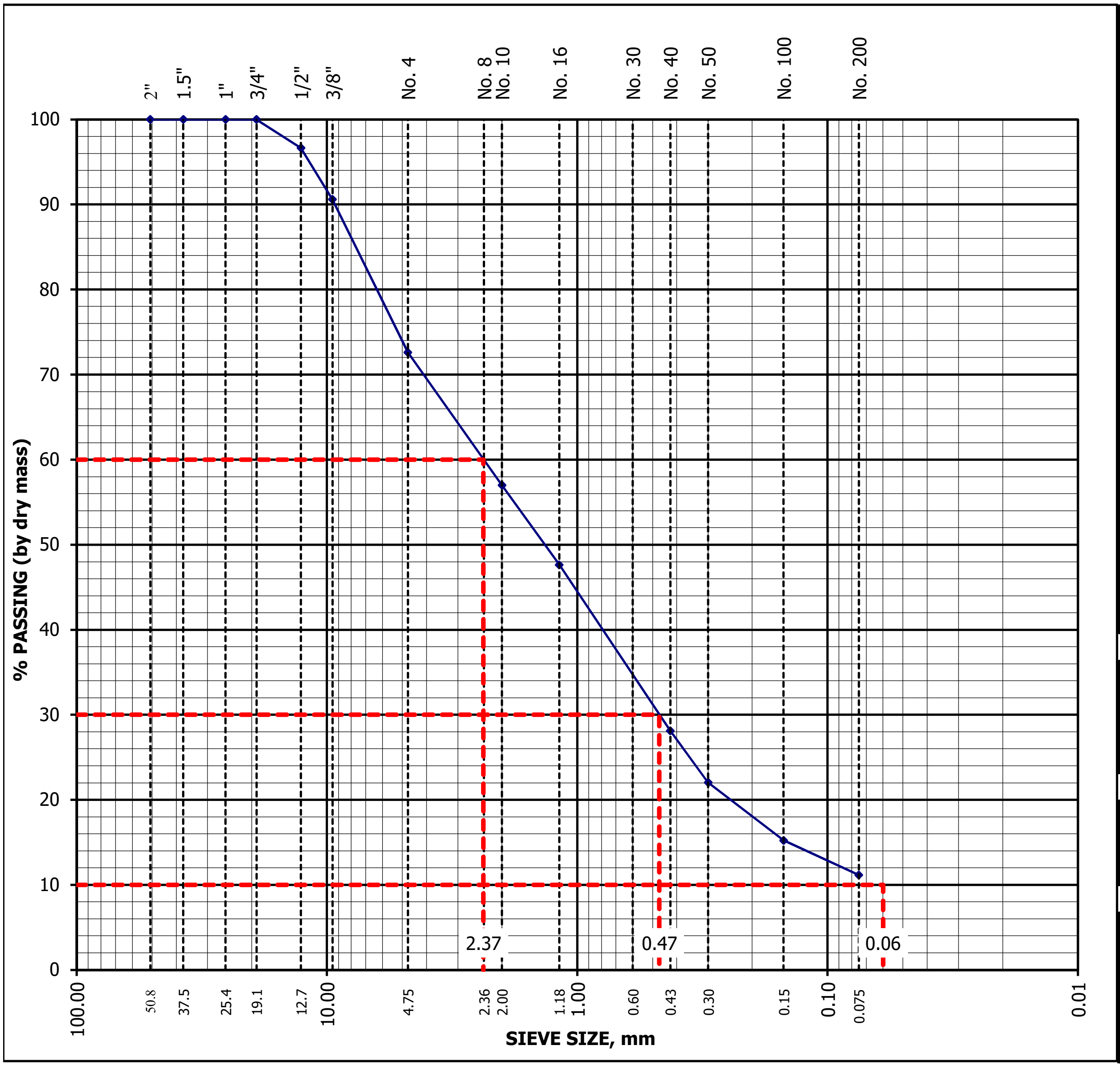
D_{60}	5.25
D_{30}	0.40
D_{10}	0.07
Cu	**80.77**
Cc	**0.47**

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:	1822890	Reviewer:	J. Crystal
Sample Location:	SB-3 at 5'		
Visual Description:	SAND, with silt and gravel, red		

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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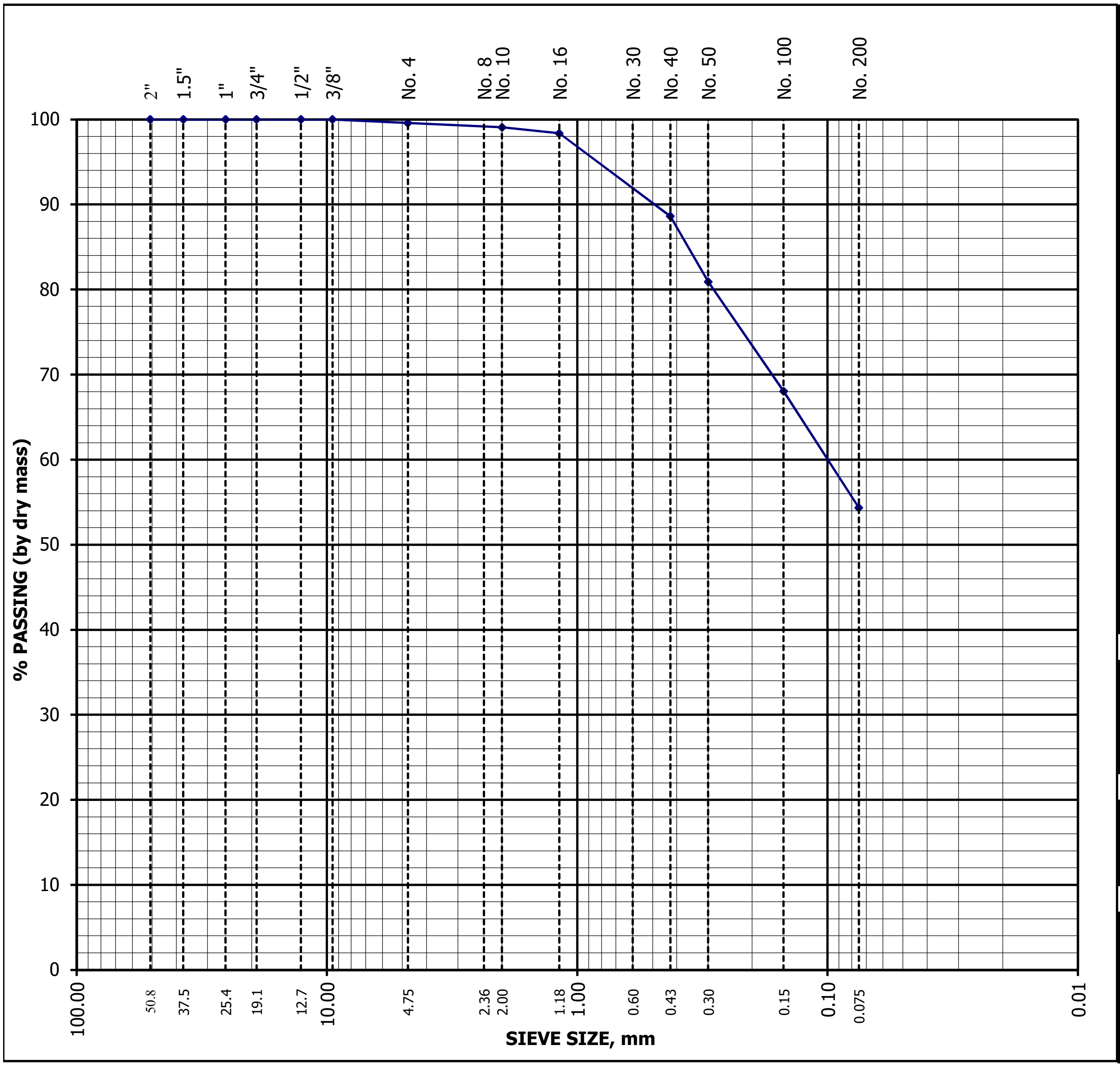
GRADATION PLOT - SOIL & AGGREGATE

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	

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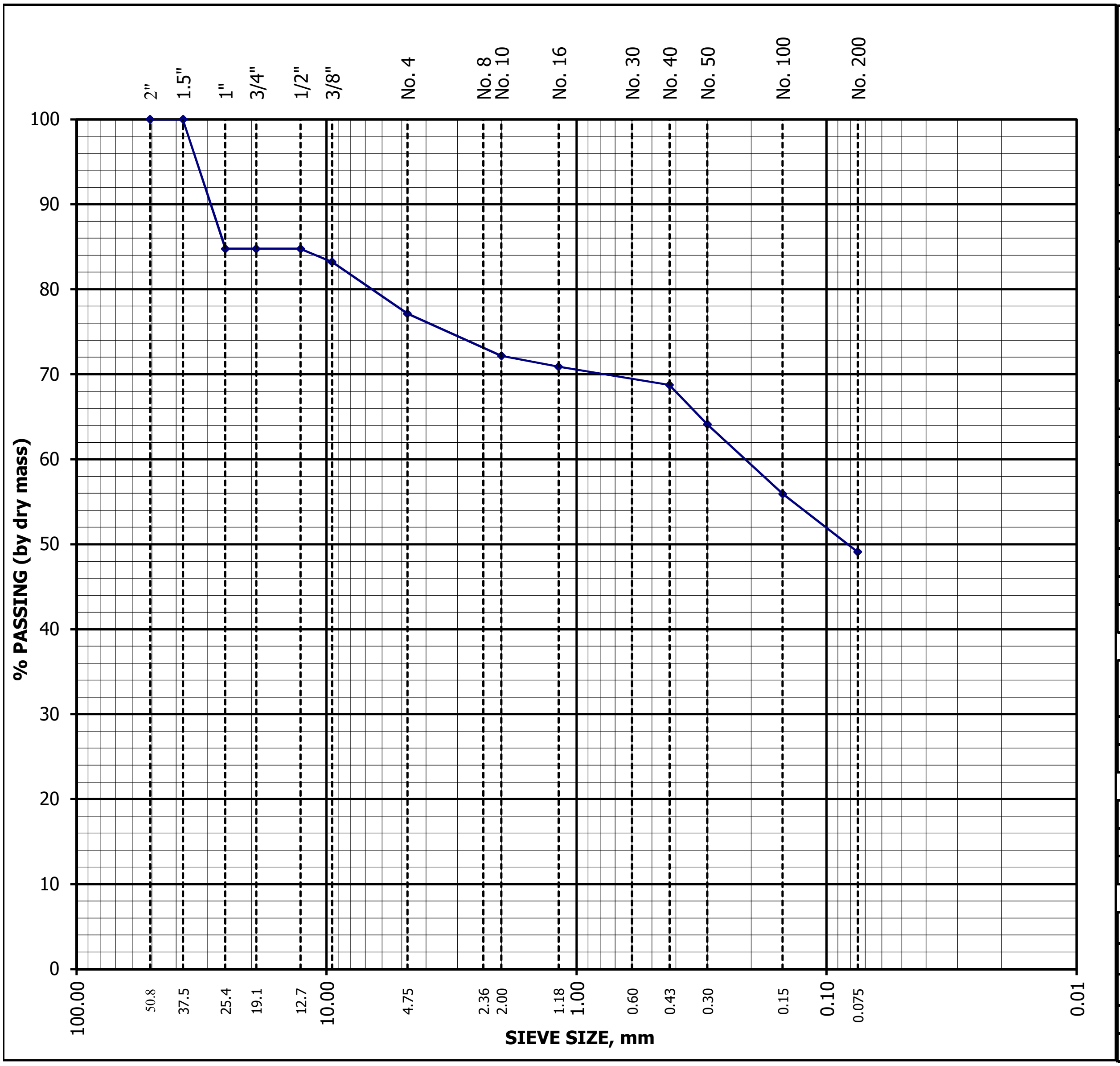
GRADATION PLOT - SOIL & AGGREGATE

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

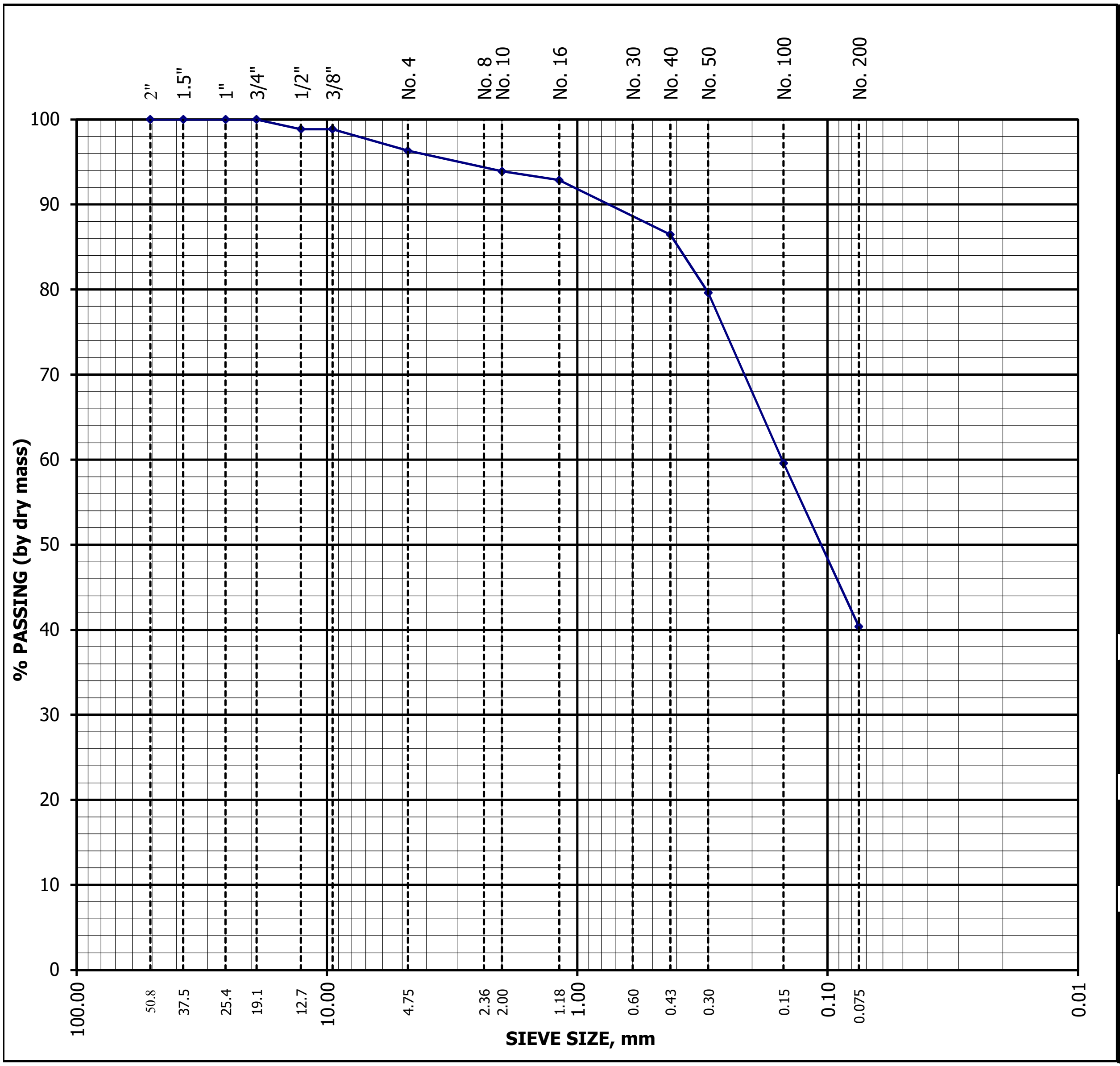
D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

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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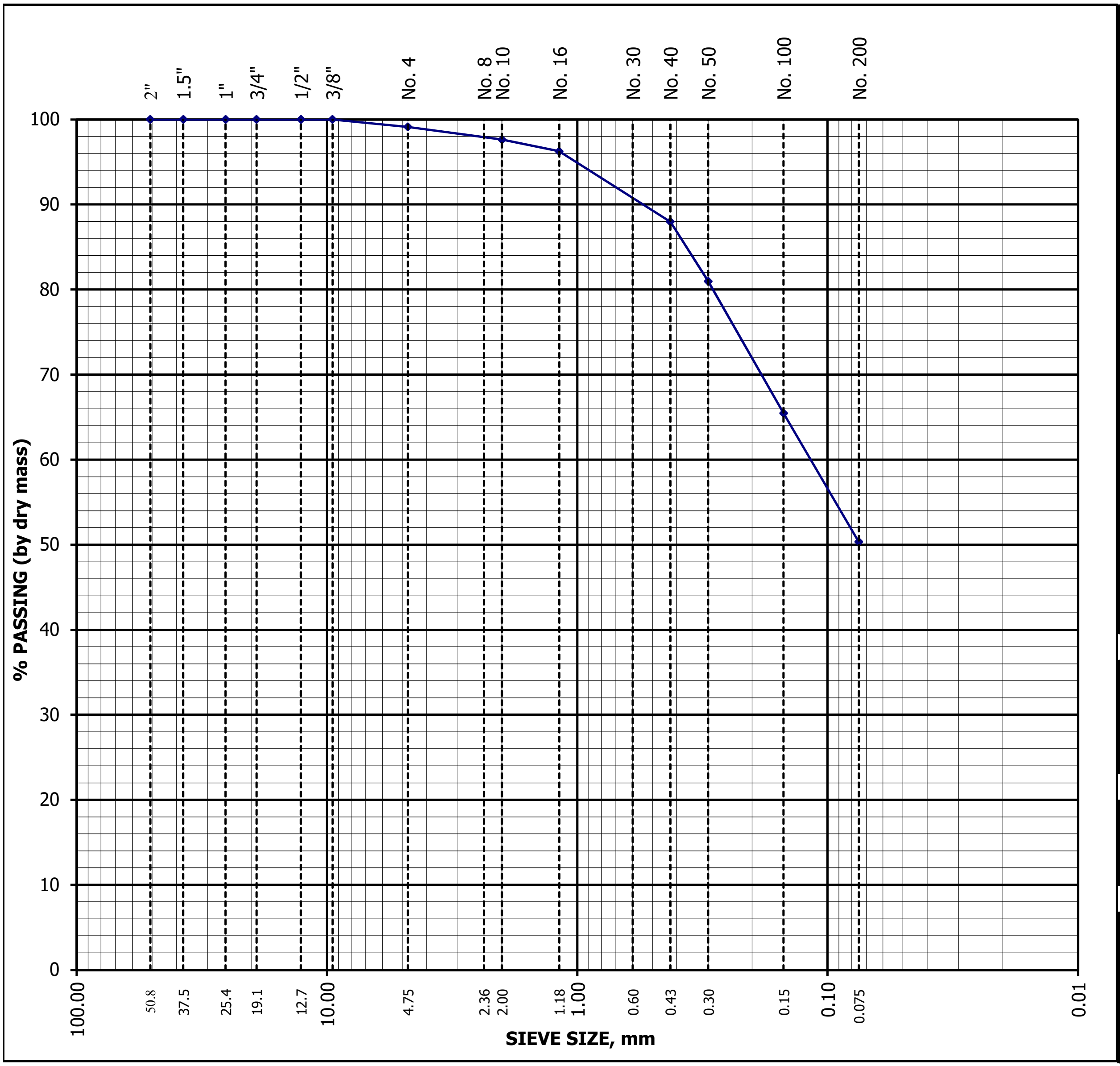
GRADATION PLOT - SOIL & AGGREGATE

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	

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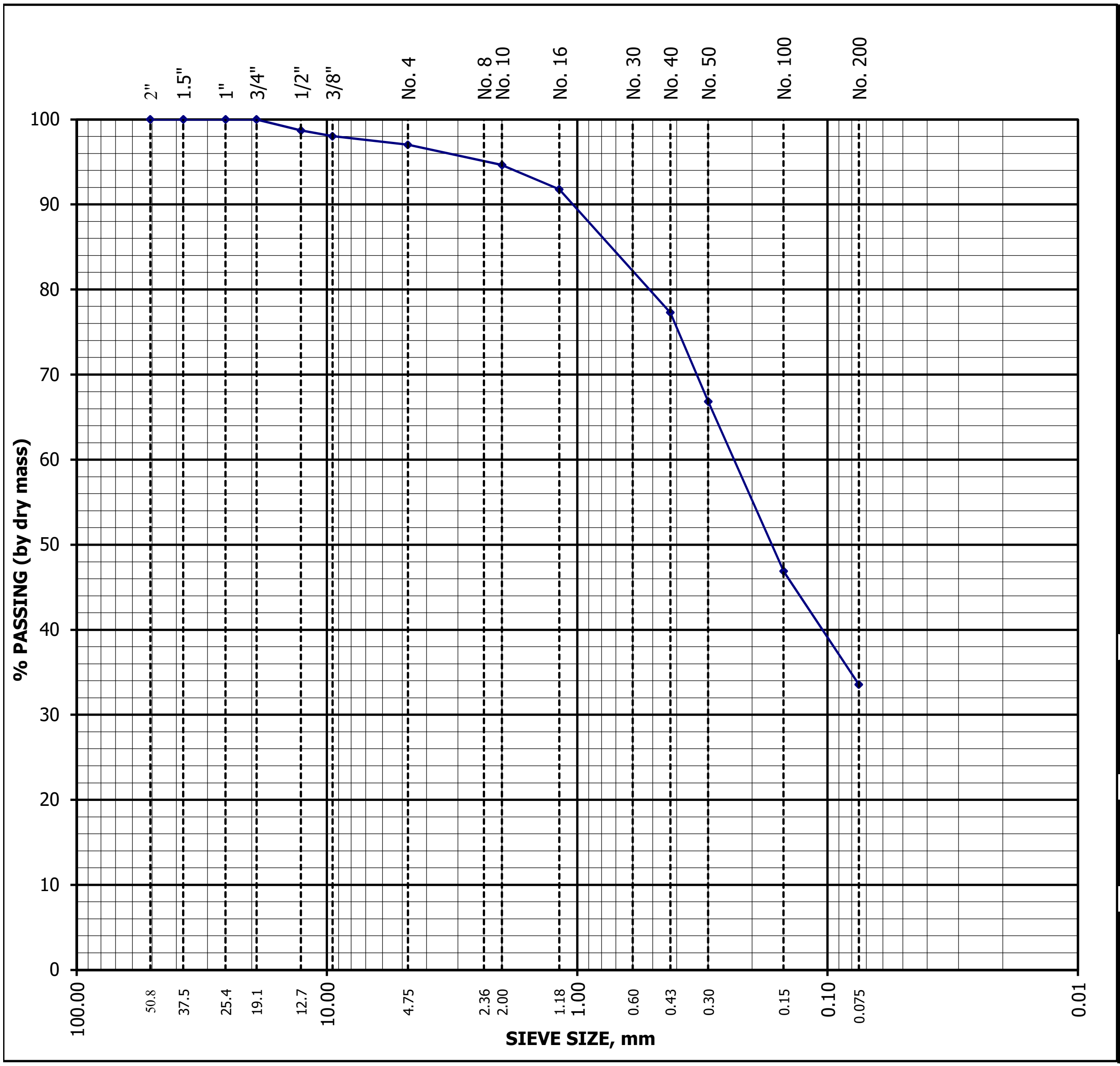
GRADATION PLOT - SOIL & AGGREGATE

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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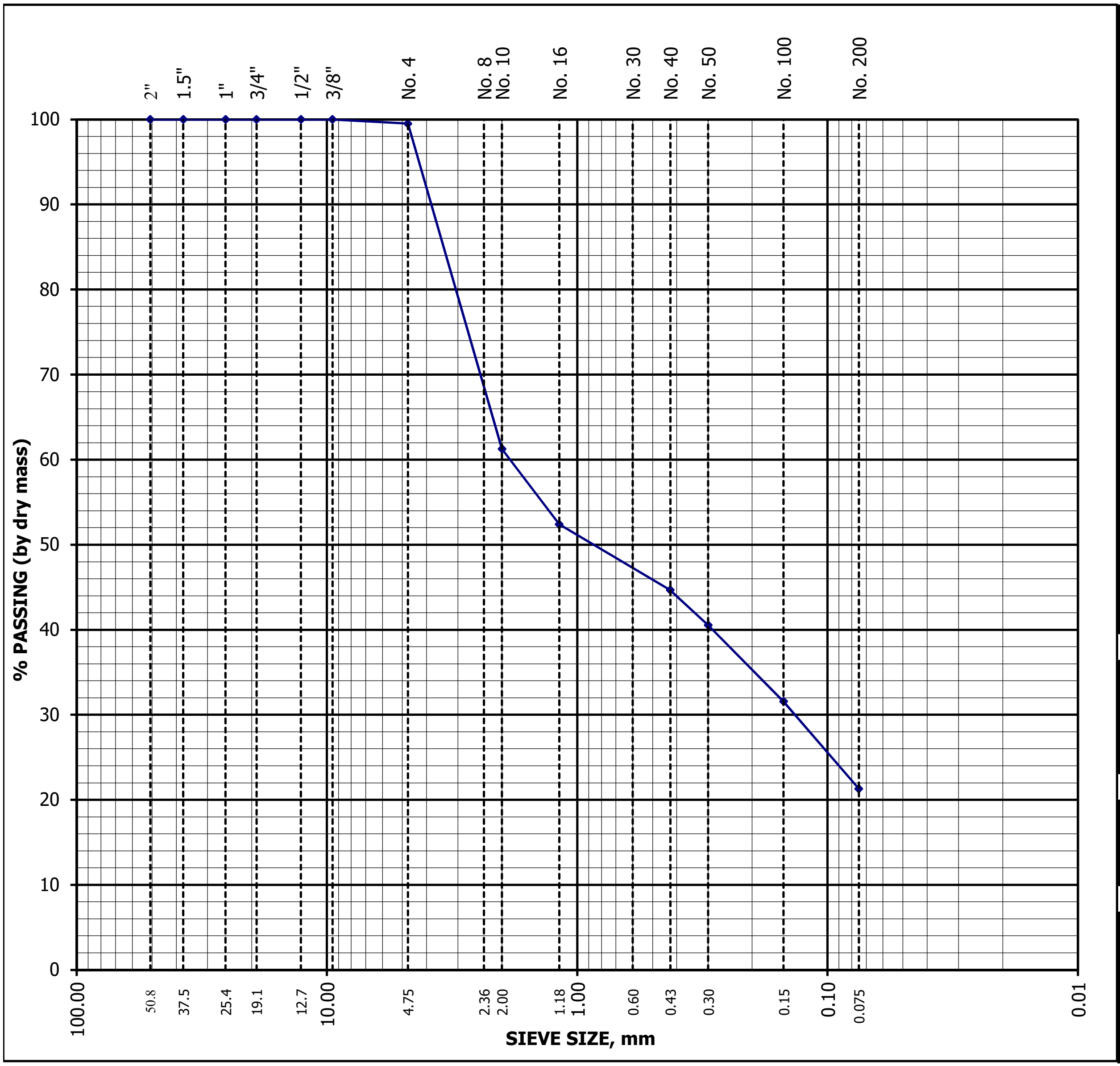
GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	6-Oct-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Holiman
Lab ID Number:	1822647	Reviewer:	J. Crystal
Sample Location:	SBP-3 at 6' to 8'		
Visual Description:	SAND, clayey, red brown		

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	

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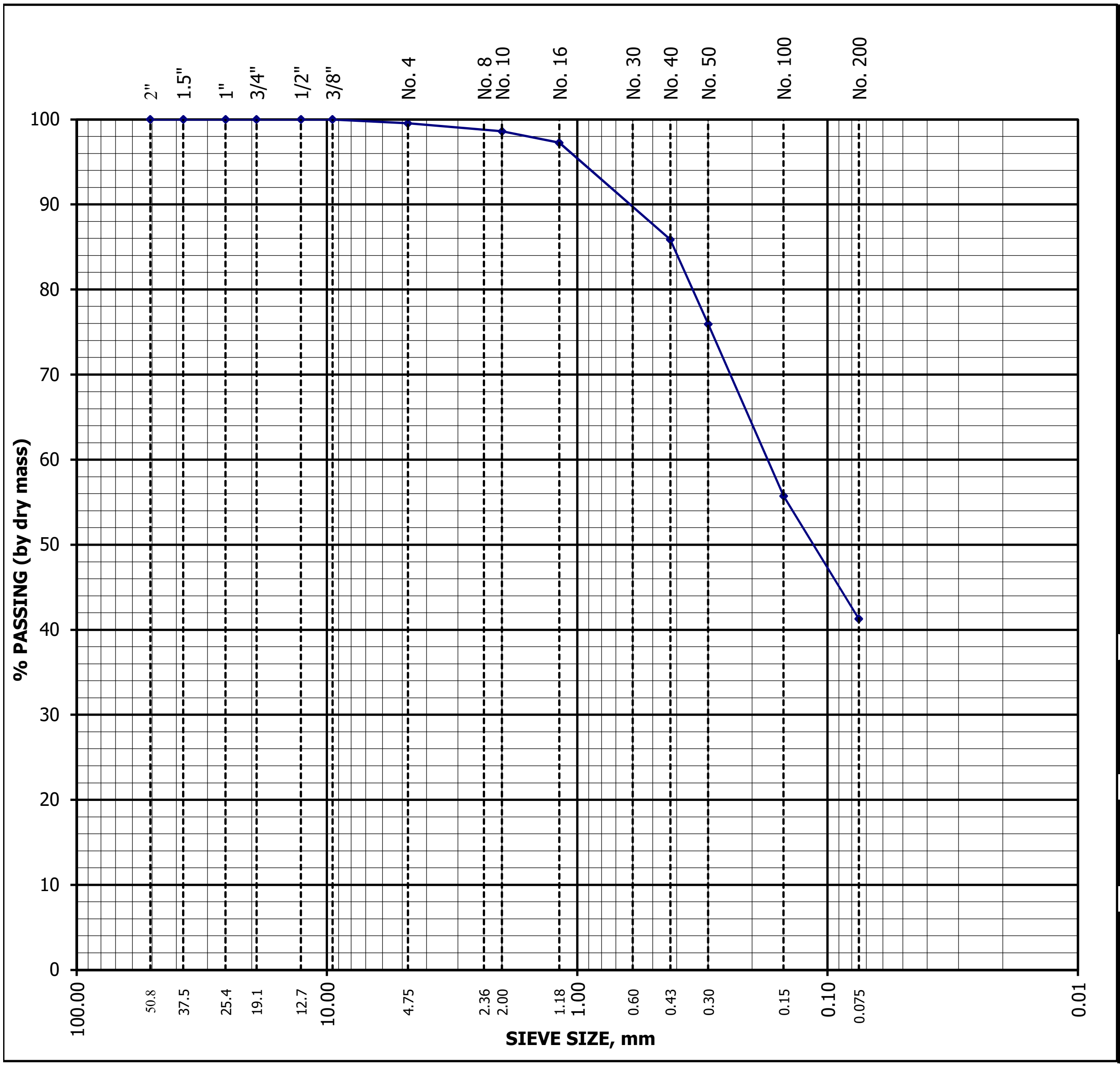
GRADATION PLOT - SOIL & AGGREGATE

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Lab ID Number: 1822648
Sample Location: SBP-5 at 1' to 3'
Visual Description: SAND, silty, clayey, 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-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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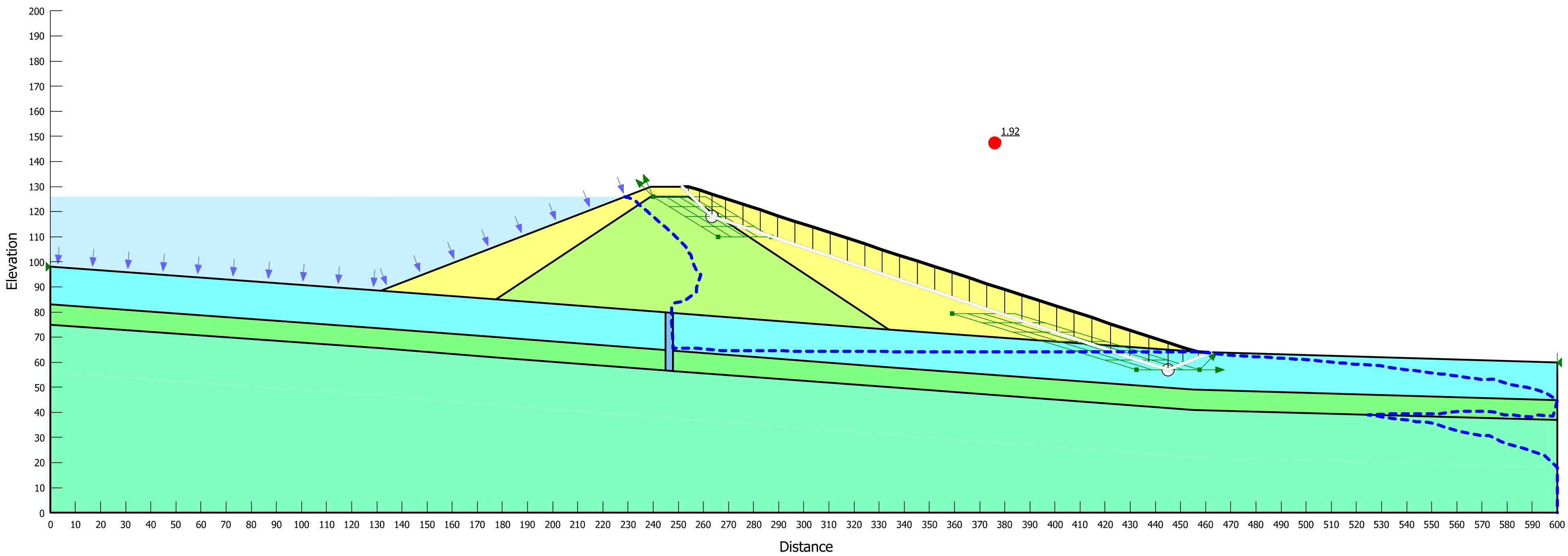
APPENDIX D

Stability Analysis Results

CUCHARAS BASIN COLLABORATIVE STORAGE
PROJECT NO. 18.117

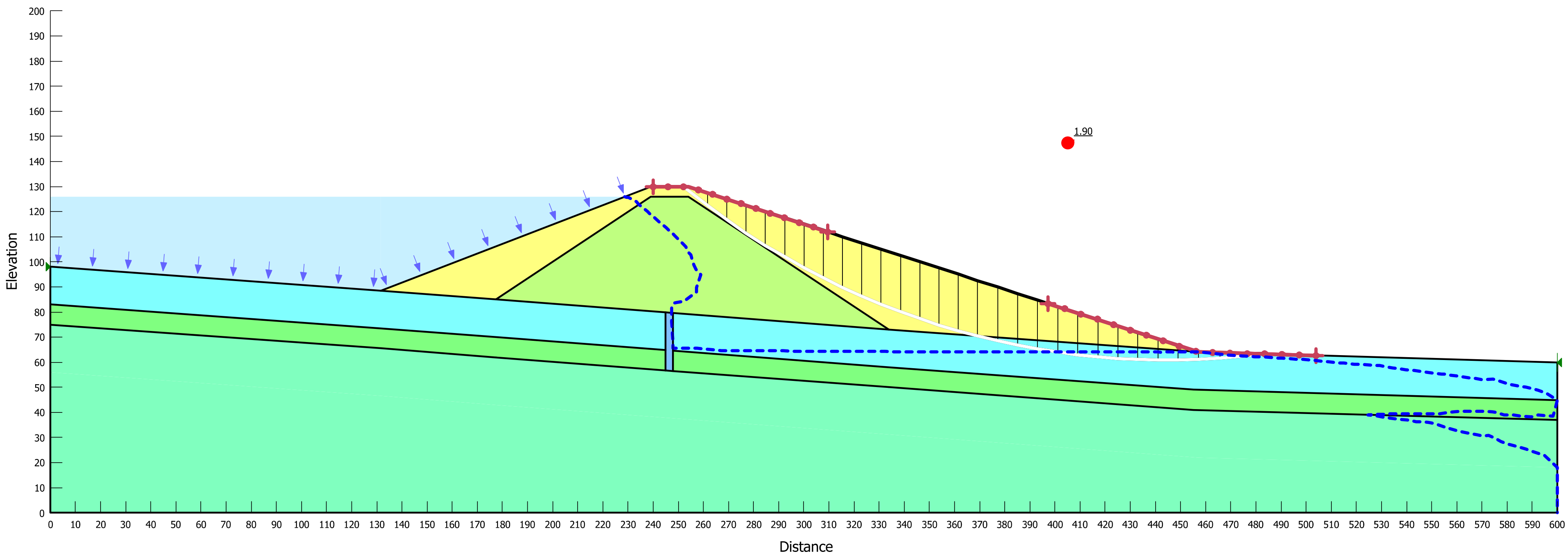


Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
🟩	**Claystone**	**Mohr-Coulomb**	**135**	**3,000**	**0**	**0**
🟩	**Core**	**Mohr-Coulomb**	**125**	**25**	**30**	**0**
🟦	**Cutoff**	**Mohr-Coulomb**	**125**	**10**	**11**	**0**
🟦	**Overburden**	**Mohr-Coulomb**	**130**	**10**	**30**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

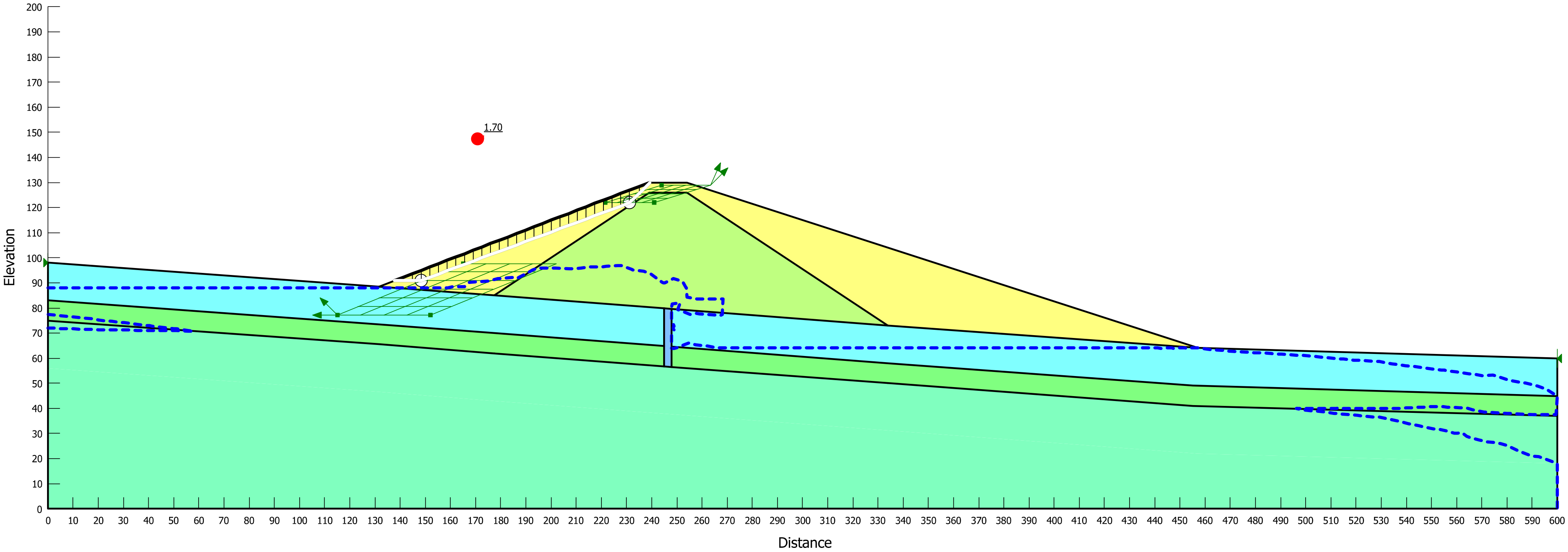


Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
🟩	**Claystone**	**Mohr-Coulomb**	**135**	**3,000**	**0**	**0**
🟩	**Core**	**Mohr-Coulomb**	**125**	**25**	**30**	**0**
🟦	**Cutoff**	**Mohr-Coulomb**	**125**	**10**	**11**	**0**
🟦	**Overburden**	**Mohr-Coulomb**	**130**	**10**	**30**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

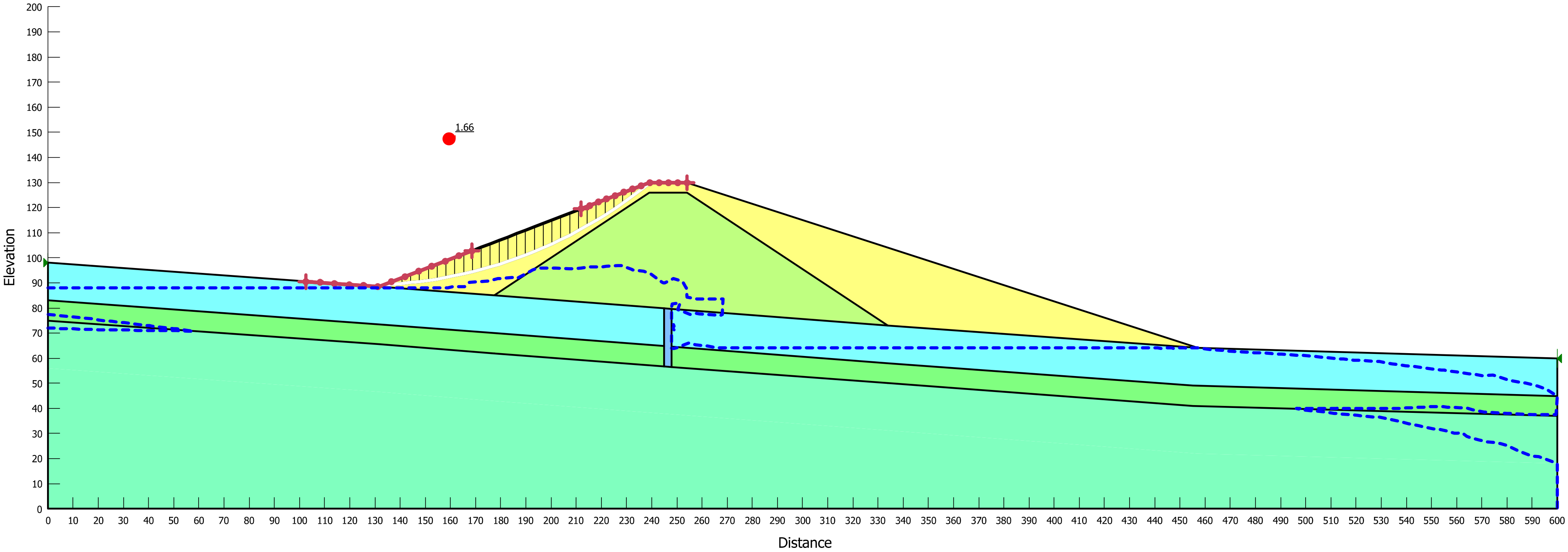


Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
🟩	**Claystone**	**Mohr-Coulomb**	**135**	**3,000**	**0**	**0**
🟩	**Core**	**Mohr-Coulomb**	**125**	**25**	**30**	**0**
🟦	**Cutoff**	**Mohr-Coulomb**	**125**	**10**	**11**	**0**
🟦	**Overburden**	**Mohr-Coulomb**	**130**	**10**	**30**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

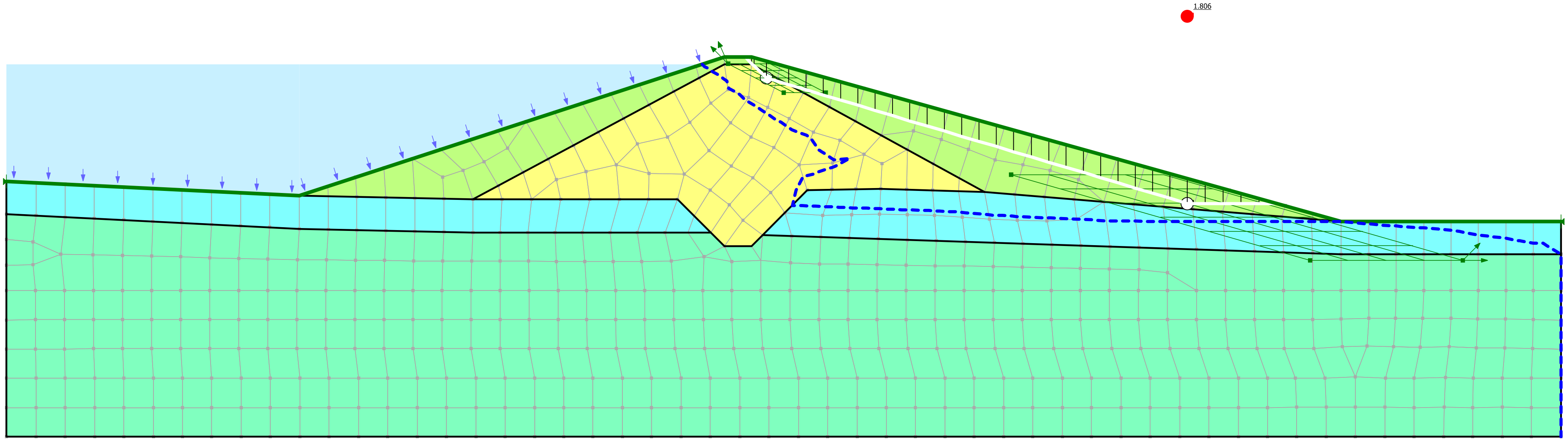


Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
🟩	**Claystone**	**Mohr-Coulomb**	**135**	**3,000**	**0**	**0**
🟩	**Core**	**Mohr-Coulomb**	**125**	**25**	**30**	**0**
🟦	**Cutoff**	**Mohr-Coulomb**	**125**	**10**	**11**	**0**
🟦	**Overburden**	**Mohr-Coulomb**	**130**	**10**	**30**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

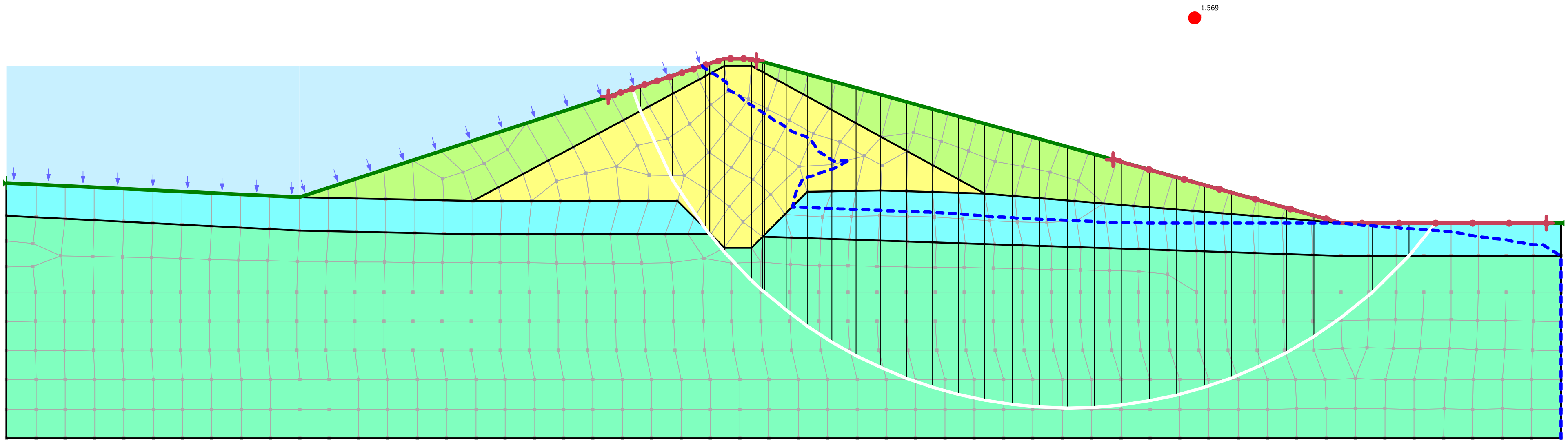


Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
🟨	Core	Mohr-Coulomb	125	25	25	0
🟦	Gravel	Mohr-Coulomb	132	10	35	0
🟩	Sandstone	Mohr-Coulomb	140	3,000	0	0
🟩	Shell	Mohr-Coulomb	125	25	25	0

Steady State Seepage Stability, Block Failure

Bruce Canyon

CUCHARAS BASIN COLLABORATIVE STORAGE
PROJECT NO. 18.117

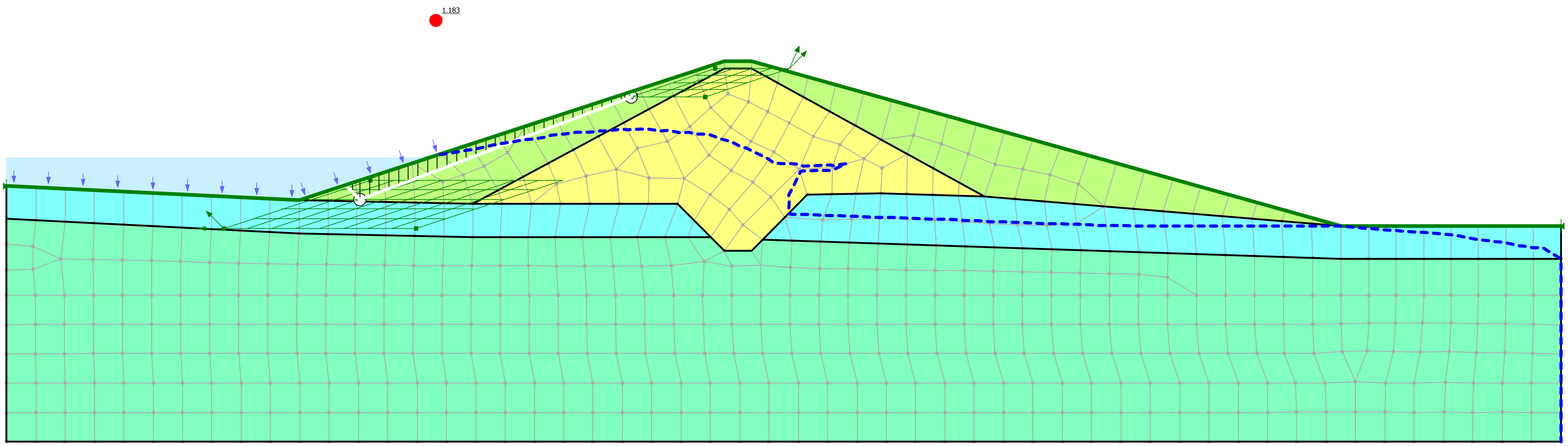


Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
🟨	Core	Mohr-Coulomb	125	25	25	0
🟦	Gravel	Mohr-Coulomb	132	10	35	0
🟩	Sandstone	Mohr-Coulomb	140	3,000	0	0
🟩	Shell	Mohr-Coulomb	125	25	25	0

Steady State Seepage Stability, Circular Failure

Bruce Canyon

CUCHARAS BASIN COLLABORATIVE STORAGE
PROJECT NO. 18.117

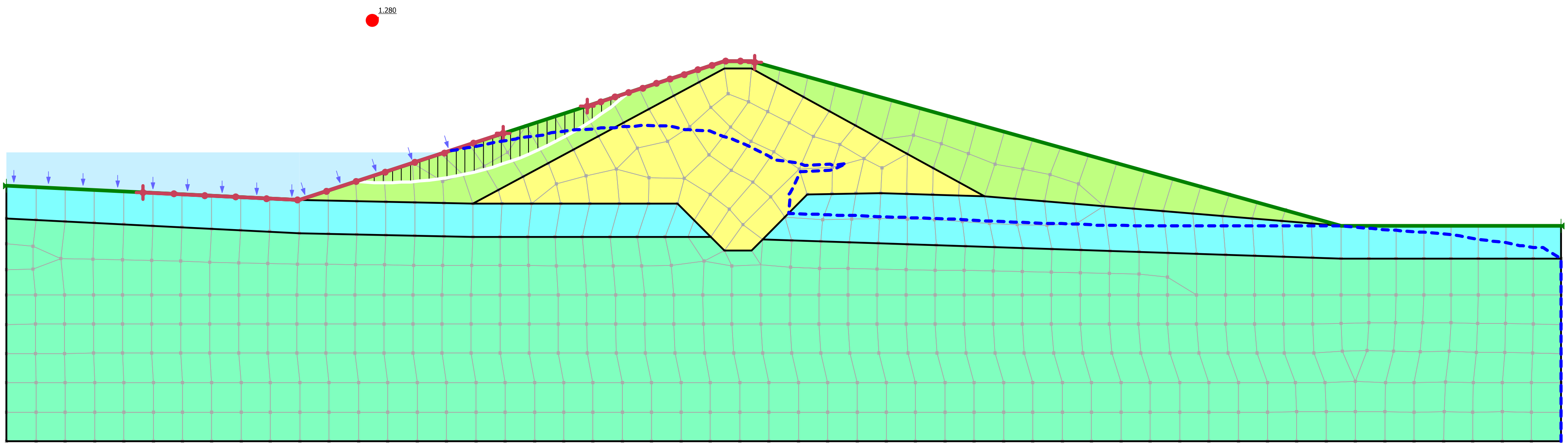


Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
🟨	Core	Mohr-Coulomb	125	25	25	0
🟦	Gravel	Mohr-Coulomb	132	10	35	0
🟩	Sandstone	Mohr-Coulomb	140	3,000	0	0
🟩	Shell	Mohr-Coulomb	125	25	25	0

Transient Seepage Stability, Block Failure, 52nd Day

Bruce Canyon

CUCHARAS BASIN COLLABORATIVE STORAGE
PROJECT NO. 18.117

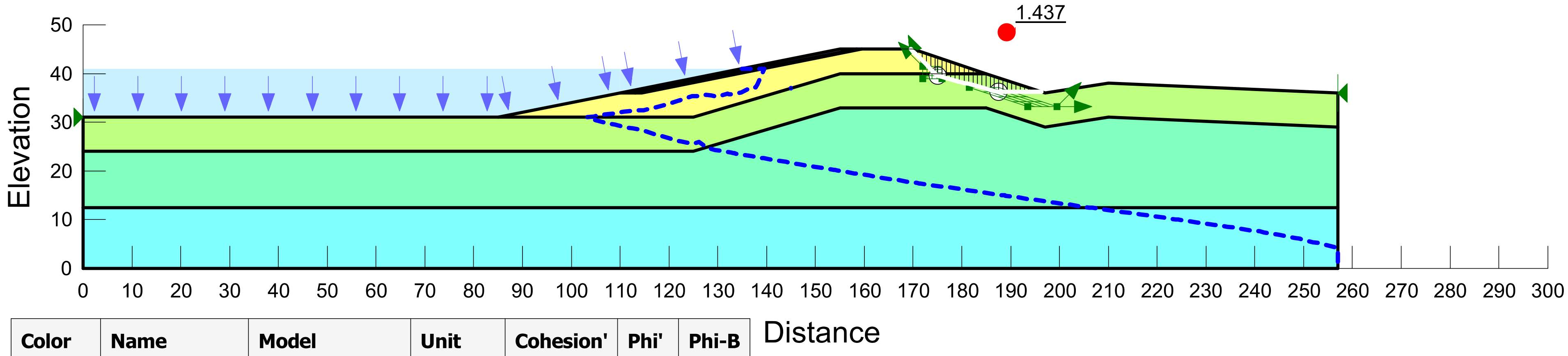


Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
🟨	Core	Mohr-Coulomb	125	25	25	0
🟦	Gravel	Mohr-Coulomb	132	10	35	0
🟩	Sandstone	Mohr-Coulomb	140	3,000	0	0
🟩	Shell	Mohr-Coulomb	125	25	25	0

Transient Seepage Stability, Circular Failure, 48th Day

Bruce Canyon

CUCHARAS BASIN COLLABORATIVE STORAGE
PROJECT NO. 18.117

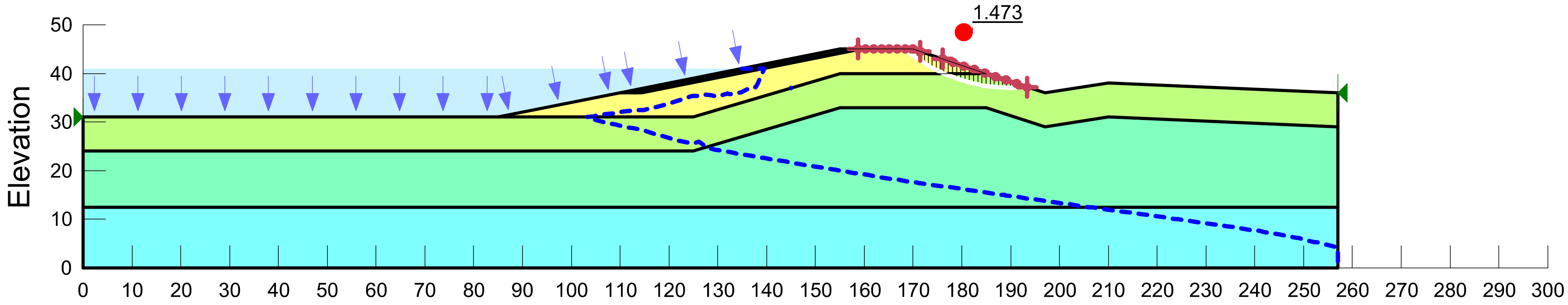


Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
🟨	**Clay Embankment**	**Mohr-Coulomb**	**125**	**25**	**25**	**0**
🟦	**Claystone**	**Mohr-Coulomb**	**135**	**3,000**	**0**	**0**
🟩	**Existing Fill**	**Mohr-Coulomb**	**115**	**10**	**20**	**0**
🟩	**Native Clay**	**Mohr-Coulomb**	**115**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

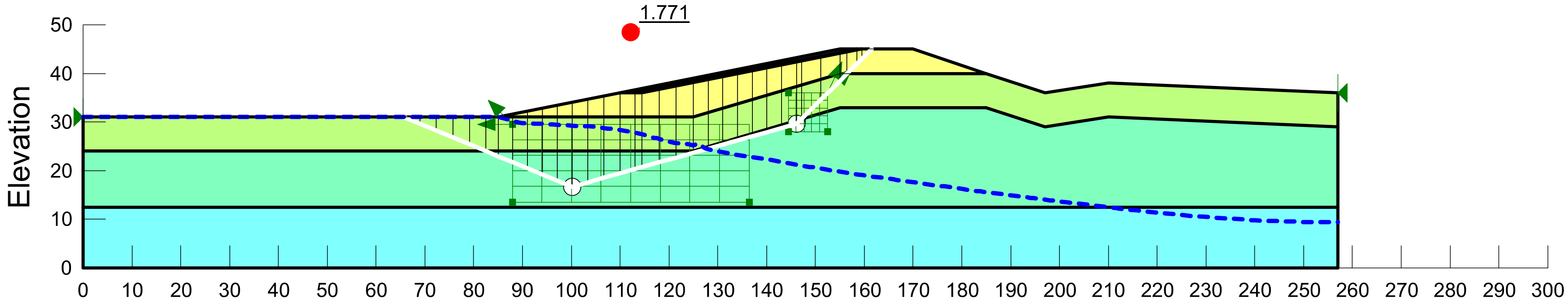


Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
🟨	Clay Embankment	Mohr-Coulomb	125	25	25	0
🟦	Claystone	Mohr-Coulomb	135	3,000	0	0
🟩	Existing Fill	Mohr-Coulomb	115	10	20	0
🟩	Native Clay	Mohr-Coulomb	115	10	15	0
🟦	Rip Rap	Mohr-Coulomb	135	10	40	0
🟩	Sand Bedding	Mohr-Coulomb	125	10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

Steady State Seepage Stability, Circular Failure

Maria Stevens South

CUCHARAS BASIN COLLABORATIVE STORAGE
PROJECT NO. 18.117

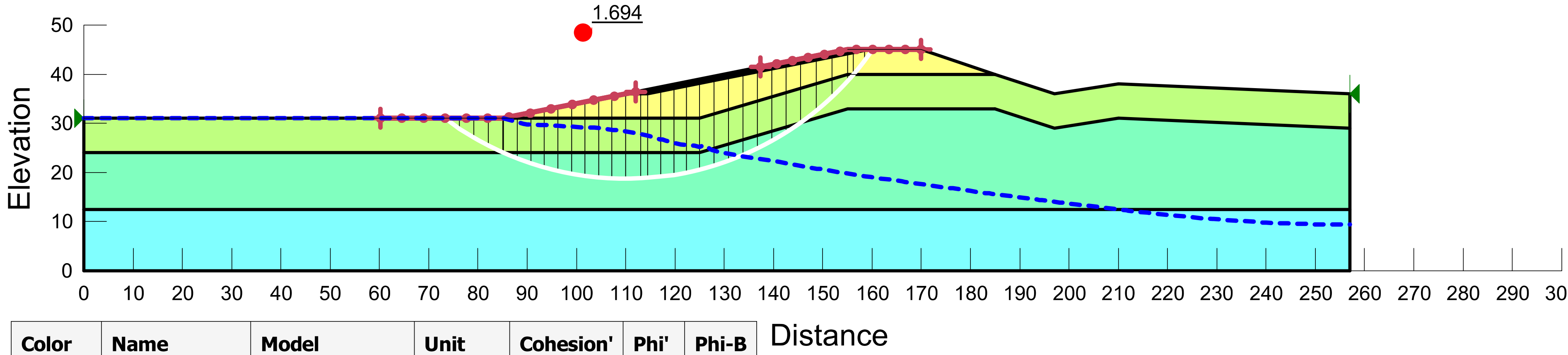


Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
🟨	**Clay Embankment**	**Mohr-Coulomb**	**125**	**25**	**25**	**0**
🟦	**Claystone**	**Mohr-Coulomb**	**135**	**3,000**	**0**	**0**
🟩	**Existing Fill**	**Mohr-Coulomb**	**115**	**10**	**20**	**0**
🟩	**Native Clay**	**Mohr-Coulomb**	**115**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

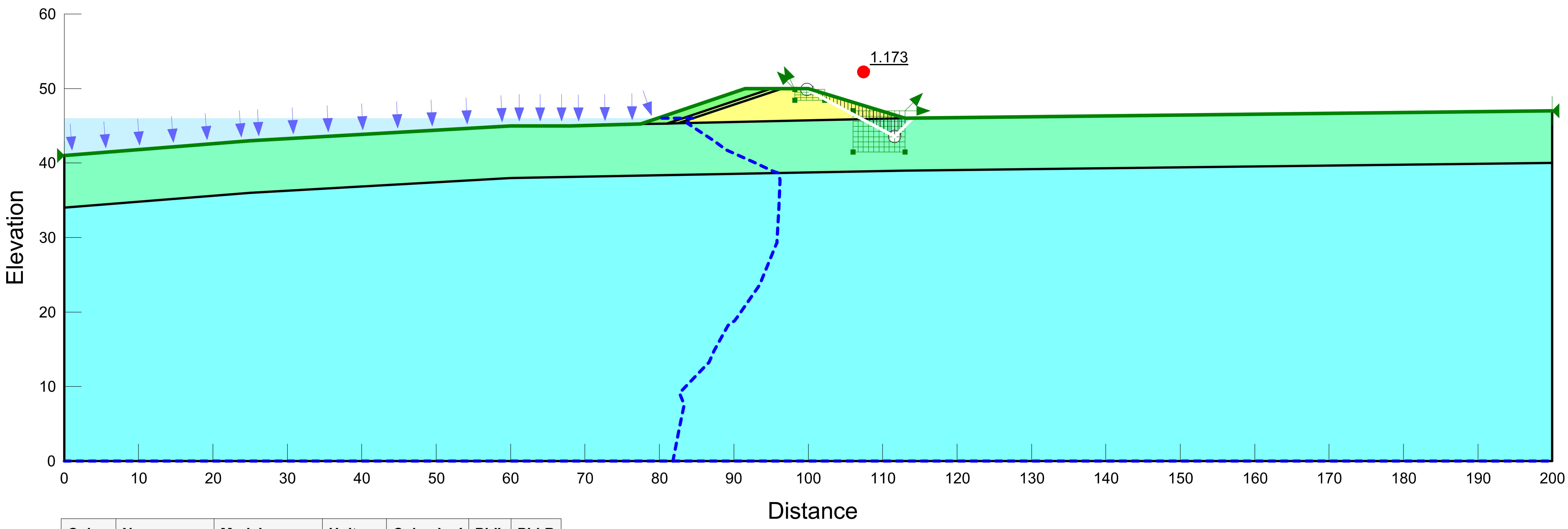


Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
🟨	Clay Embankment	Mohr-Coulomb	125	25	25	0
🟦	Claystone	Mohr-Coulomb	135	3,000	0	0
🟩	Existing Fill	Mohr-Coulomb	115	10	20	0
🟩	Native Clay	Mohr-Coulomb	115	10	15	0
🟦	Rip Rap	Mohr-Coulomb	135	10	40	0
🟩	Sand Bedding	Mohr-Coulomb	125	10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

Transient Seepage Stability, Circular Failure, Tenth Day

Maria Stevens South

CUCHARAS BASIN COLLABORATIVE STORAGE
PROJECT NO. 18.117



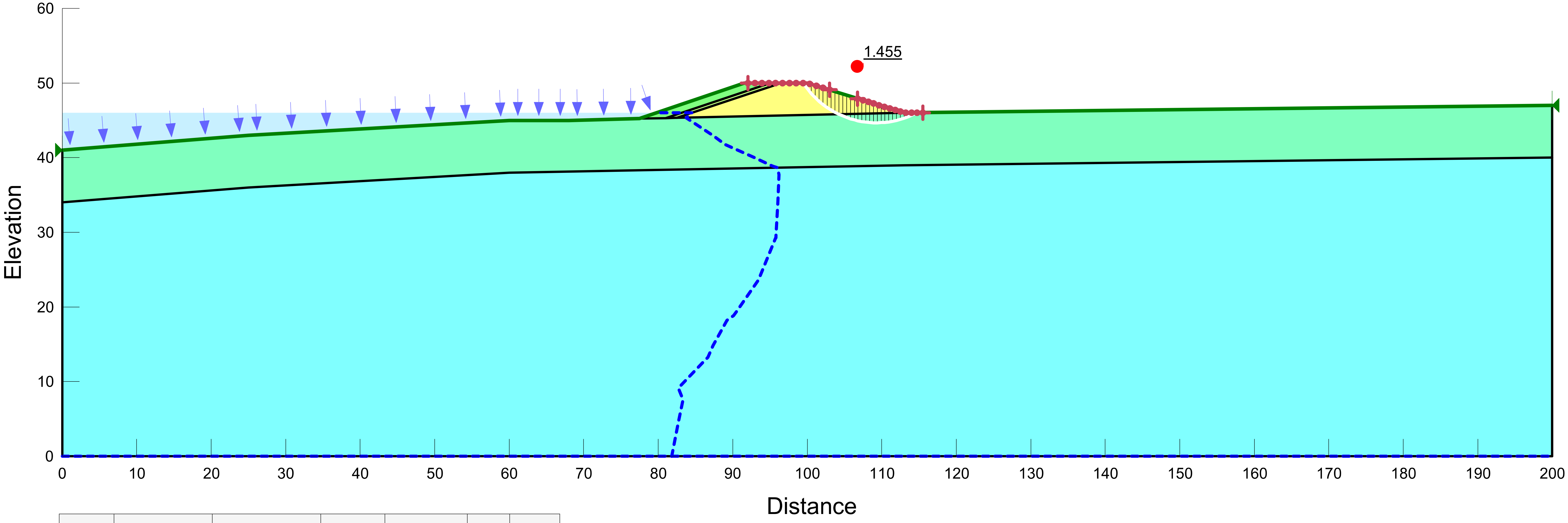
Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
🟨	Clay Embankment	Mohr-Coulomb	125	25	25	0
🟦	Claystone	Mohr-Coulomb	135	3,000	0	0
🟩	Native Clay	Mohr-Coulomb	115	0	15	0
🟩	Rip Rap	Mohr-Coulomb	135	10	40	0
🟩	Sand Bedding	Mohr-Coulomb	125	10	30	0

Steady State Seepage, Block Failure Stability Analysis

Maria Stevens West.gsz

10/24/2018 1:159

CUCHARAS BASIN COLLABORATIVE STORAGE
PROJECT NO. 18.117



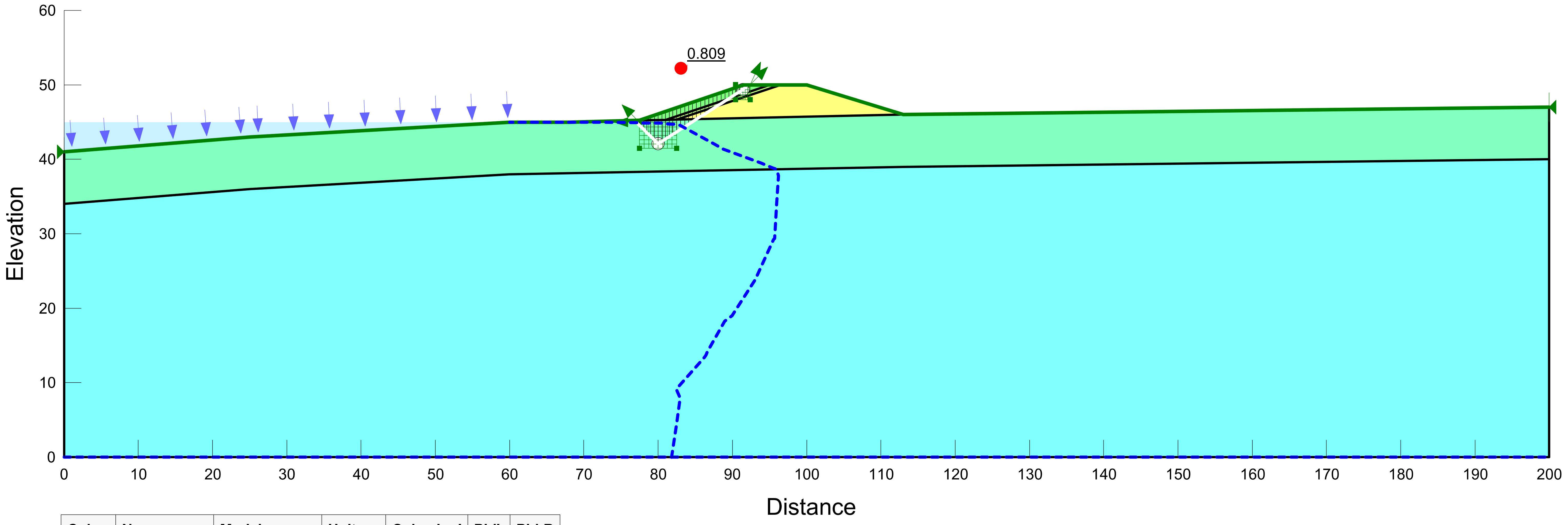
Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
🟨	Clay Embankment	Mohr-Coulomb	125	25	25	0
🟦	Claystone	Mohr-Coulomb	135	3,000	0	0
🟩	Native Clay	Mohr-Coulomb	115	0	15	0
🟩	Rip Rap	Mohr-Coulomb	135	10	40	0
🟩	Sand Bedding	Mohr-Coulomb	125	10	30	0

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



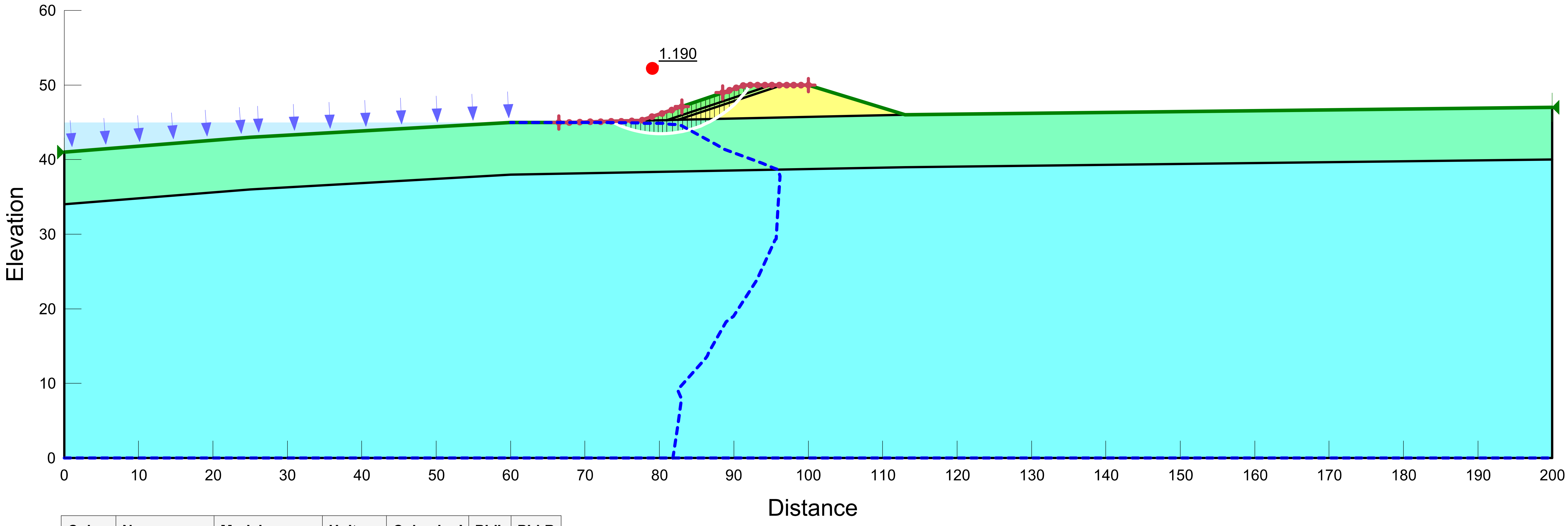
Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
🟨	Clay Embankment	Mohr-Coulomb	125	25	25	0
🟦	Claystone	Mohr-Coulomb	135	3,000	0	0
🟩	Native Clay	Mohr-Coulomb	115	0	15	0
🟩	Rip Rap	Mohr-Coulomb	135	10	40	0
🟩	Sand Bedding	Mohr-Coulomb	125	10	30	0

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

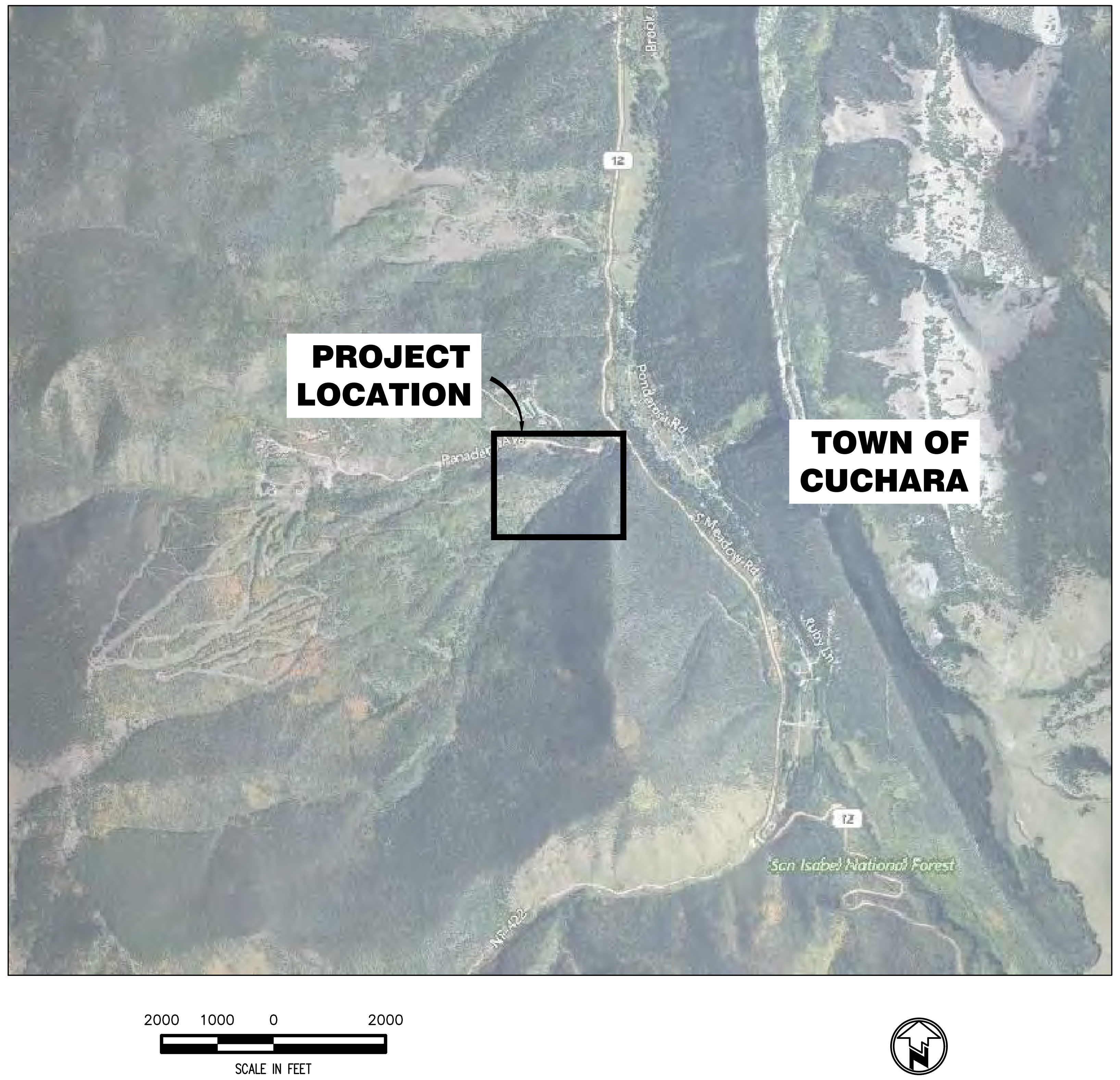
APPENDIX B

30% DESIGN DRAWINGS

CUCHARAS COLLABORATIVE
SOUTH BAKER CREEK RESERVOIR
30% DESIGN PLANS, NOT FOR CONSTRUCTION
HUERFANO COUNTY, COLORADO

DECEMBER, 2019

VICINITY MAP
SCALE 1" = 2000'



OWNER:
HUERFANO COUNTY WATER
CONSERVANCY DISTRICT
P.O. BOX 442
La Veta, CO 80155
(720) 989-7259

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

Sheet List Table

Sheet Number	Sheet Title
1	COVER SHEET
2	SITE PLAN
3	DAM AND SPILLWAY CROSS-SECTIONS
4	SPILLWAY PLAN AND PROFILE

I hereby certify that these plans for the South Baker Creek Reservoir were prepared by me or under my direct supervision for the Cucharas Collaborative.

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

COLORADO 811
KNOW WHAT'S BELOW. CALL BEFORE YOU DIG.

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

SOUTH BAKER CREEK RESERVOIR

COVER SHEET

CUCHARAS COLLABORATIVE

NO	DATE	BY	CHK'D	DESCRIPTION

REVISIONS

Date: 05/10/17
Job No: 16-106
Drawn: TRH
Design: SS
Checked: SS
Scale: AS SHOWN

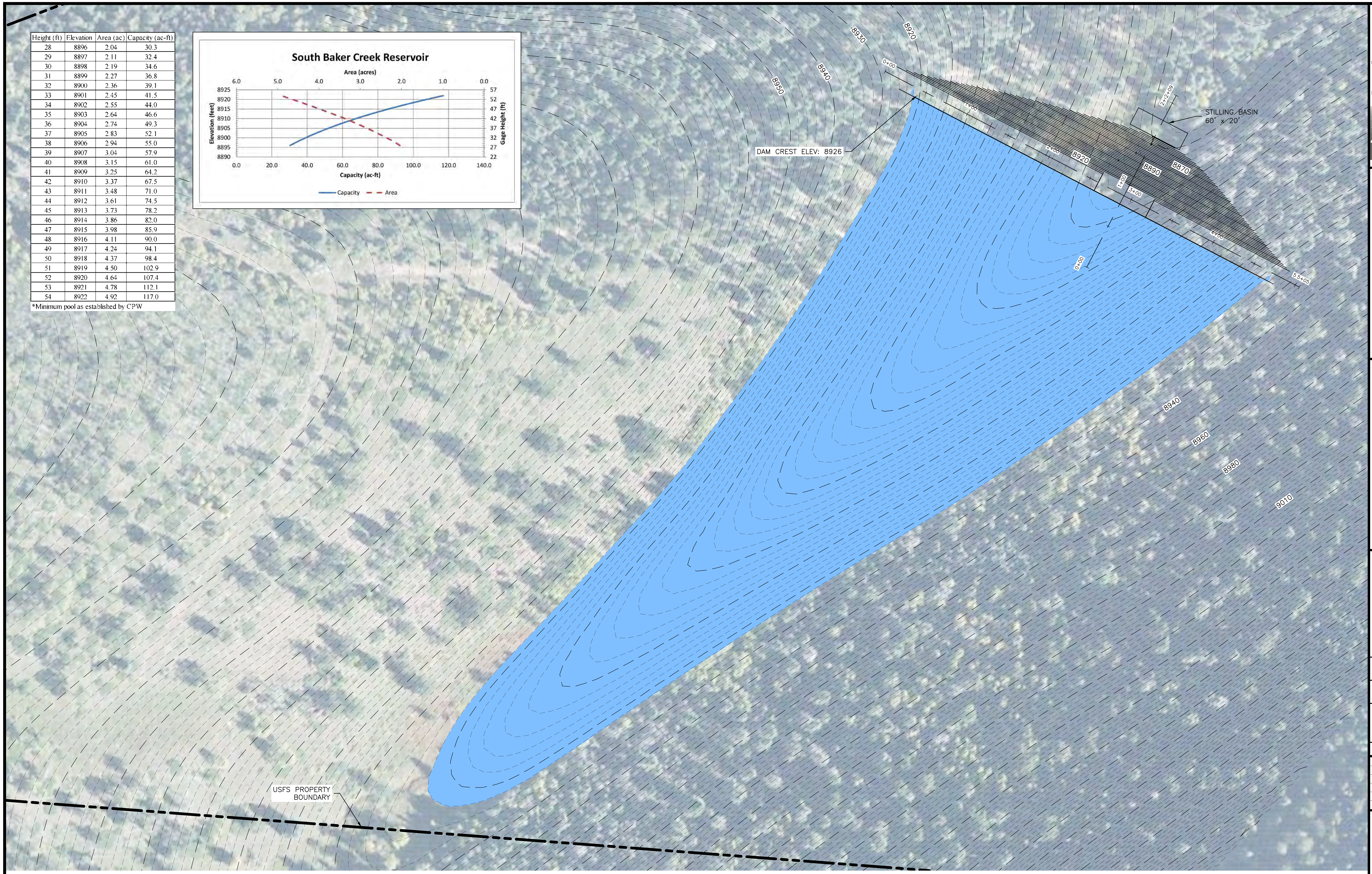
Sheet: **1**
Of: **4**

Filing No. **C-**

Plot Date: 01/27/20-2:37pm, Plotted by:THorn, Drawing Path: N:\16106 Cucharas Basin Collaborative Storage Study\Drawings\Plan Set\Baker Creek\Drawing Name:Baker Creek Cover.dwg

Height (ft)	Elevation	Area (ac)	Capacity (ac-ft)
28	8896	2.04	30.3
29	8897	2.11	32.4
30	8898	2.19	34.6
31	8899	2.27	36.8
32	8900	2.36	39.1
33	8901	2.45	41.5
34	8902	2.55	44.0
35	8903	2.64	46.6
36	8904	2.74	49.3
37	8905	2.83	52.1
38	8906	2.94	55.0
39	8907	3.04	57.9
40	8908	3.15	61.0
41	8909	3.25	64.2
42	8910	3.37	67.5
43	8911	3.48	71.0
44	8912	3.61	74.5
45	8913	3.73	78.2
46	8914	3.86	82.0
47	8915	3.98	85.9
48	8916	4.11	90.0
49	8917	4.24	94.1
50	8918	4.37	98.4
51	8919	4.50	102.9
52	8920	4.64	107.4
53	8921	4.78	112.1
54	8922	4.92	117.0

*Minimum pool as established by CPW



SCALE 1"=50'
2' CONTOUR INTERVAL

50 25 0 50 100 150
SCALE IN FEET

30% DESIGN DRAWINGS, NOT FOR CONSTRUCTION

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email: info@applegategroup.com Website: www.applegategroup.com

SOUTH BAKER CREEK RESERVOIR

SITE PLAN

CUCHARAS COLLABORATIVE

NO	DATE	BY	CHK'D	DESCRIPTION

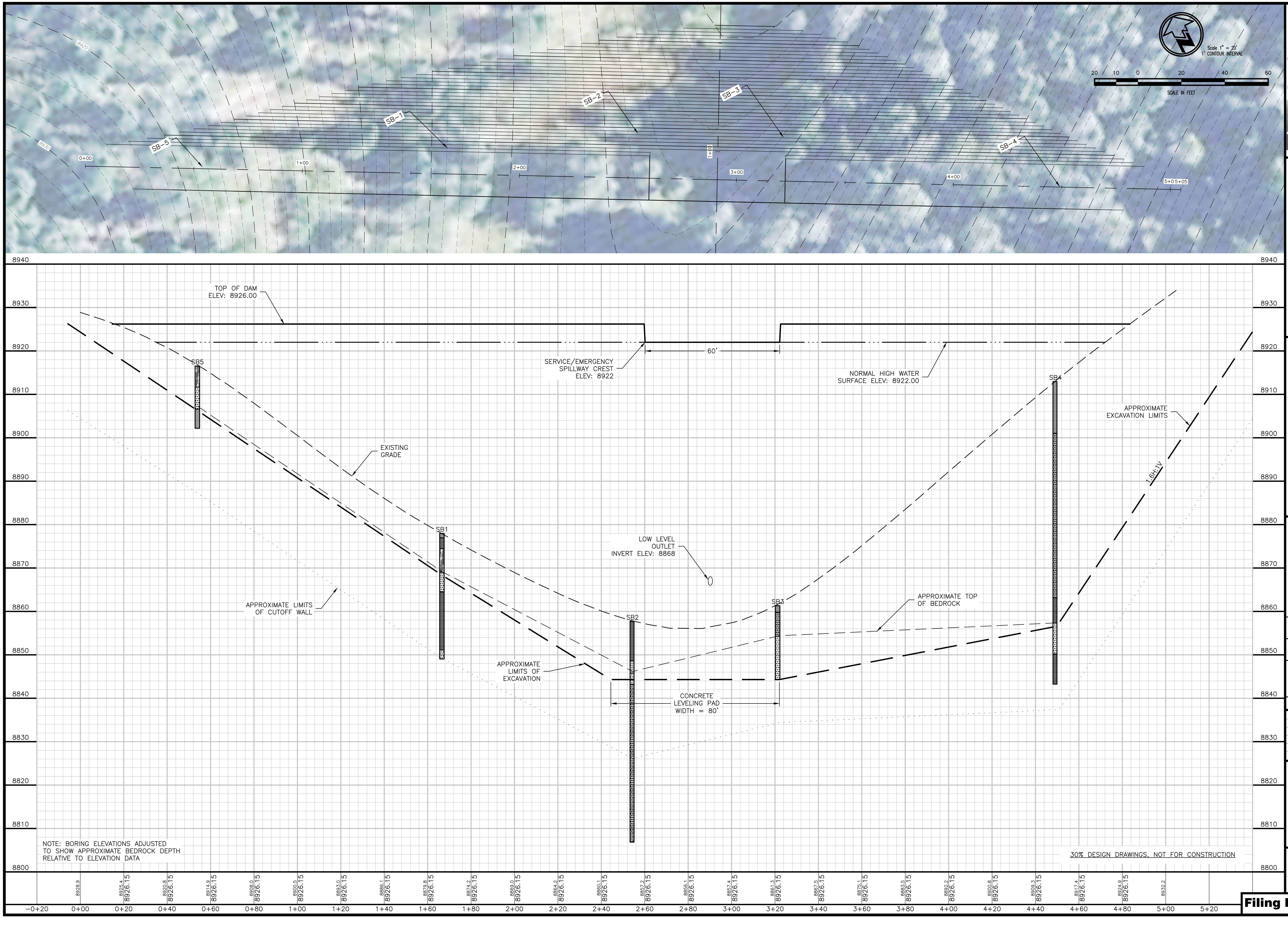
REVISIONS

Date:	05/10/17
Job No:	16–106
Drawn:	TRH
Design:	SS
Checked:	SS
Scale:	1" = 50'

Sheet: 2
Of: 4

Filing No. C-

Plot Date: 01/27/20–2:37pm, Plotted by:THorn, Drawing Path: N:\16106 Cucharas Basin Collaborative Storage Study\Drawings\Plan Set\Baker Creek\Drawing Name:BakerSitePlan.dwg



NOTE: BORING ELEVATIONS ADJUSTED
TO SHOW APPROXIMATE BEDROCK DEPTH
RELATIVE TO ELEVATION DATA

30% DESIGN DRAWINGS, NOT FOR CONSTRUCTION

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email: info@applegategroup.com Website: www.applegategroup.com

SOUTH BAKER CREEK RESERVOIR

DAM PLAN AND PROFILE

CUCHARAS COLLABORATIVE

NO	DATE	BY	CHK'D	DESCRIPTION

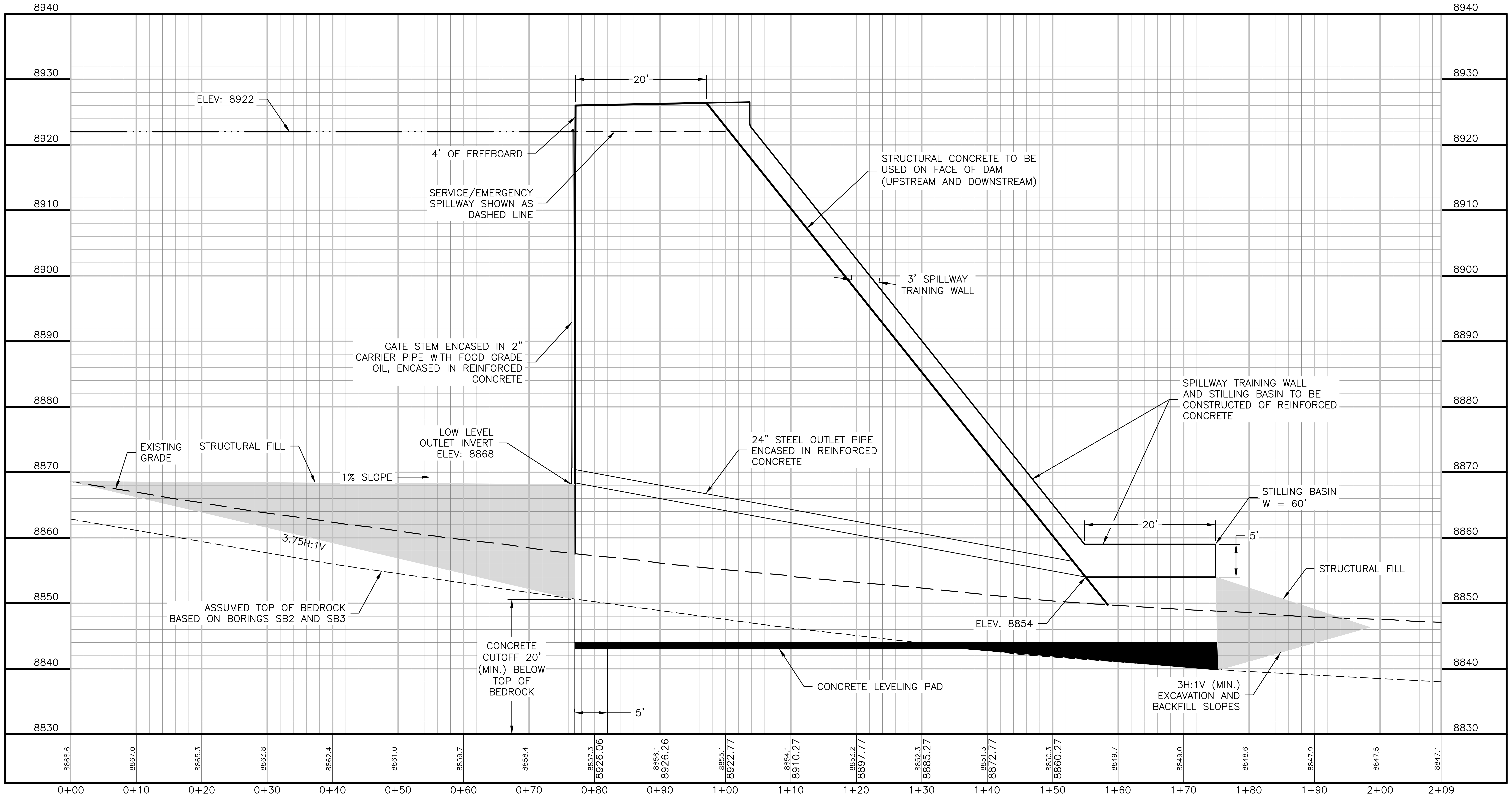
REVISIONS

Date:	05/10/17
Job No:	16–106
Drawn:	TRH
Design:	SS
Checked:	SS
Scale:	SCALE = 20'H/10V

Sheet: **3**
Of: **4**

Filing No. C-

Plot Date: 01/27/20–2:38pm, Plotted by:THorn, Drawing Path: N:\16106 Cucharas Basin Collaborative Storage Study\Drawings\Plan Set\Baker Creek\Drawing Name:BakerRCCDamPP.dwg



30% DESIGN DRAWINGS, NOT FOR CONSTRUCTION

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Water Resource Advisors for the West

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

SOUTH BAKER CREEK RESERVOIR

MAX DAM SECTION

CUCHARAS COLLABORATIVE

REVISIONS

NO	DATE	BY	CHK'D	DESCRIPTION

Date:	05/10/17
Job No:	16–106
Drawn:	TRH
Design:	SS
Checked:	SS
Scale:	1"=10'

Sheet: **4**
Of: **4**

Filing No. C-

Plot Date: 01/27/20–2:38pm, Plotted by:THorn, Drawing Path: N:\16106 Cucharas Basin Collaborative Storage Study\Drawings\Plan Set\Baker Creek\Drawing Name:BakerRCCDamCrossSection.dwg

APPENDIX C

ENGINEER'S 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

South Baker Creek Reservoir

(Excluding Deferred Maintenance Costs)

Job No. : 18-117
By: DAB/SAS
Date: 1/6/2020
Client: Cucharas Collaborative

Description of Work	Item	Item Description	Units	Quantity	Unit Cost	Total Cost
Construction of a Large, High Hazard Dam on South Baker Creek		**Administration**				
	1a	Mobilization	%		6%	$ 374,900
	1b	Bonds and Permits	%		2%	$ 125,000
		Site Preparation				
	2a	Dewatering and Water Control	LS	1	$ 90,000	$ 90,000
	2b	Clearing and Grubbing	AC	3.0	$ 15,000	$ 45,000
	2c	Erosion and Sediment Control	LS	1	$ 15,000	$ 15,000
	2d	Construction Surveying	LS	1	$ 20,000	$ 20,000
	2e	Geotechnical Investigation	LS	1	$ 20,000	$ 20,000
		Earthwork				
	3a	Stripping and Stockpiling Topsoil	CY	4,500	$ 8	$ 36,000
	3b	Excavation for Dam Foundation	CY	20,000	$ 12	$ 240,000
	3c	Excavation (Rock) for Dam Foundation	CY	2,100	$ 25	$ 52,500
	3d	Excavation (Cut) for Inlet Channel	CY	2,800	$ 12	$ 33,600
		Dam Structures and Outlet Works				
	4a	Concrete Cutoff Wall - 20' Deep	CY	2,100	$ 100	$ 210,000
	4b	Furnish and Place Leveling Concrete	CY	500	$ 310	$ 155,000
	4c	Import Coarse Aggregate for RCC Mix	CY	9,510	$ 20	$ 190,200
	4d	Furnish and Place Roller-Compacted Concrete	CY	30,500	$ 110	$ 3,355,000
	4e	Furnish and Place Concrete Facing (Conventional Concrete - 18in)	SF	54,000	$ 23	$ 1,242,000
	4f	Furnish and Place Structural Fill (Class I)	CY	3,000	$ 100	$ 300,000
	4g	Furnish and Place 24" Ductile Iron Concrete Encased Outlet Pipe (Low-Level)	LF	80	$ 500	$ 40,000
	4h	Furnish and Place 24" Sluice Gate for Low-Level Outlet	LS	1	$ 20,000	$ 20,000
	4i	Construct Reinforced Concrete Stilling Basin and Spillway Training Walls	CY	105	$ 1,200	$ 126,000
	4j	Furnish and Place Low Level Outlet Trashrack	LS	1	$ 3,000	$ 3,000
		Site Reclamation				
	5a	Seeding	AC	2.3	$ 7,500	$ 17,600
	5b	Place topsoil	CY	3,800	$ 10	$ 38,000
		Construction Subtotal				**$ 6,748,800**
		Contingency	%		20%	$ 1,350,000
		Construction Total				**$ 8,098,800**
		Permitting	%		2.5%	$ 202,500
		Land Acquisition	AC	4.2	$ 5,000	$ 21,000
		Engineering	LS	1	$ 135,000	$ 135,000
		Construction Observation	LS	1	$ 70,000	$ 70,000
		Annual O&M Costs	LS	1	$ 20,000	$ 20,000
		Total				**$ 8,547,300**