GEOTECHNICAL EVALUATIONS/FIELD SUVEYING SERVICES/ DISTRESS SINKHOLE & CRACKING EVALUATIONS

Frog Hollow Dam (UT00418)
Washington County, Utah

Prepared for:

McMillen, LLC
1401 Shoreline Drive, Suite 100
Boise, Idaho 83702

ROSENBERG ASSOCIATES
CIVIL ENGINEERS LAND SURVEYORS

RA Project No. 8384-14-008
June 27, 2016

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June 27, 2016

McMillen, LLC
1401 Shoreline Drive, Suite 100
Boise, Idaho 83702

Attn: Mr. Greg Allington
Project Manager

Subject: **Geotechnical Evaluations / Field Surveying Services / Distress Sinkhole & Cracking Evaluations**
Frog Hollow Dam (UT00418), Washington County, Utah
RA Project No. 8384-14-008

Gentlemen:

Enclosed please find a report of the geotechnical evaluations, field surveying services, and distress sinkhole and cracking evaluations performed by Rosenberg Associates (RA) for the Frog Hollow Dam Rehabilitation Project in Washington County, Utah. Frog Hollow embankment has experienced reoccurring sinkhole/cracking conditions since construction of the raised portion of the embankment in 1978. At the time of our evaluations, a number of relatively deep sinkholes with apparent internal erosional features were observed along the embankment. Our services were conducted in general accordance with our Service Agreement dated March 17, 2015, our Amendment 1 dated April 22, 2015, and our Amendment 2 dated February 3, 2016.

As a sub-consultant to McMillen, LLC, the objectives of our services were to, in general:

1. Perform geotechnical field and laboratory investigations to:
   a. Evaluate the nature and engineering properties of the existing embankment and underlying subgrade soils.
   b. Assess the general stability of the existing embankment.
   c. Provide specific field surveying services to aid in the evaluation.
   d. Provide geotechnical recommendations for rehabilitation, if required.

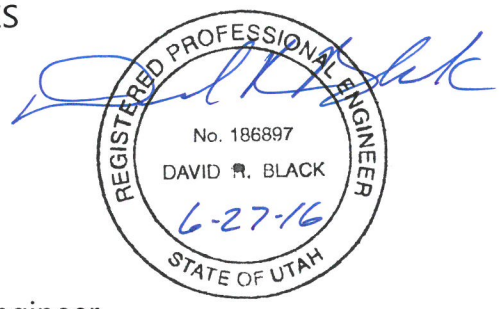
2. Perform a preliminary distress investigation of the vertical voids ("sinkholes") and cracking conditions observed within the embankment to:
   a. Evaluate the nature and extent of the holes and cracking conditions.

b. Further evaluate the engineering properties of the embankment materials.
c. Evaluate possible cause of the sinkholes and cracking conditions.
d. Provide our findings, conclusions and recommendations for potential remediation measures.

3. Perform additional field and laboratory evaluations to:
   a. Further evaluate the extensive cracking conditions along the embankment (ie, the continuance of desiccation cracking downstream of chimney drain).
   b. Further evaluate the dispersity of the embankment fill material.
   c. Evaluate whether or not cracking is extending down into the underlying basalt foundation material.
   d. Evaluate the filtering capabilities of the chimney drain materials.

The accompanying report presents the results of our services and geotechnical recommendations with respect to rehabilitation of the Frog Hollow Dam. We appreciate the opportunity to be of service on this project. If you have any questions or desire additional information, please call the undersigned at (435) 673-8586.

ROSENBERG ASSOCIATES



David R. Black, P.E.
Principal Geotechnical Engineer

DRB/WGT/DBS/16R-016.G

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EXECUTIVE SUMMARY

The executive summary is not intended to replace the information presented in the accompanying report. The executive summary should not be used separately from the report and is only provided as an overview to summarize conclusions and recommendations. The executive summary may omit a number of details, any one of which could be crucial to the proper interpretation and application of the report and implementation of the recommendations.

Rosenberg Associates (RA) performed and field surveying services (March and September, 2015) geotechnical investigations (September 2015), preliminary sinkhole and cracking distress evaluations (September, 2015), and additional field and laboratory investigations (March, 2016) at the Frog Hollow Dam (UT00418) in Washington County, Utah. Our services were conducted general accordance with our Service Agreement dated March 17, 2015, our Amendment 1 dated April 22, 2015 and our Amendment 2 dated February 3, 2016. Conclusions and recommendations by RA follow:

Geotechnical Stability Evaluation - Conclusions

1. Factors of safety for the embankment exceed the minimum values required by the State Division of Water Rights/Dam Safety under steady state (static and seismic) conditions, and under rapid drawdown conditions.

2. The two chimney drain outlet pipes were plugged with sediment. Plugged outlet pipes will not function as designed and may ultimately result in uncontrolled seepage through the dam, seepage around the drains, and possible localized piping and/or slump failures within the embankment. The plugged outlet pipes require timely remediation.

3. The principal spillway appeared to be in satisfactory condition with the exception that some sediment had been deposited along the base of the outlet conduit near the outlet.

4. The documented sinkhole and cracking conditions do not have a significant impact on global stability of the embankment. However, the sinkhole and cracking conditions impact the internal stability of the dam, and increase the potential for piping. The sinkhole and cracking conditions require timely remediation (see Sinkhole and Cracking Condition Evaluation – Conclusions and Recommendations below).

5. Our laboratory testing and evaluations indicate that the chimney drain materials are generally self-healing; but, their gradations do not quite fit within the filter criteria. Additional NRCS laboratory test results of the chimney drain materials had not been received at the time of this report.

6. The maximum surface elevation differential along the top of the embankment was surveyed at 0.83 feet.

7. The elevation of the auxiliary spillway was surveyed 3.6 feet lower than the lowest portion of the embankment crest, providing a freeboard of 3.6 feet.

8. Measured crest widths ranged from 12 to 16.5 feet.

9. Upstream embankment slopes were surveyed at 3.3H to 4H:1V.

10. Downstream embankment slopes were surveyed at 2.5H to 3.2H:1V.

11. As much as 8 to 9 feet of sediment had accumulated above the lowest opening of the intake riser structure. Localized erosion of sediment had occurred at the intake structure, resulting in deposition of sediment in the outlet conduit.

12. The embankment surface was covered with sparse to moderate desert vegetation, some of which was over "knee high". Vegetation was present inside of the protective cage of the intake structure.

13. The crest and the upstream face of the embankment (near the center portion of the dam) have been subjected to vehicular and ATV activities, resulting in some rutting and surface erosion.

14. The auxiliary spillway channel was un-lined (no structure present) and appeared to have been cut mostly into weathered, highly fractured, basalt bedrock.

Geotechnical Stability Evaluation - Recommendations

1. The chimney drain outlet pipes should be unplugged, cleared of all sediment, and inspected by video camera for additional sedimentation and structural integrity.

2. Either remove the sediment from around the intake structure, or seal off the lowest intake structure ports.

3. The principal outlet conduit should be cleaned of sediment as necessary.

4. Areas exhibiting rutting from vehicular/ATV activities, and/or erosion from surface runoff, should be repaired and stabilized.

5. ATV activities on the embankment and dike should be prohibited (i.e. signs, fencing, barriers, etc.).

6. The crest of the dam should be graded to a uniform elevation, and where less than the 14-foot minimum design width, widened to meet the minimum width requirements.

7. Where the upstream slope is steeper than 3.5H:1V, the slope should be modified to meet the minimum design requirements.

8. Vegetation over knee height on the embankment, and all vegetation within and around the intake riser cage, should be removed.

9. The unlined auxiliary spillway channel should be improved to meet the NRCS requirements for a Class "C" (high) hazard dam.

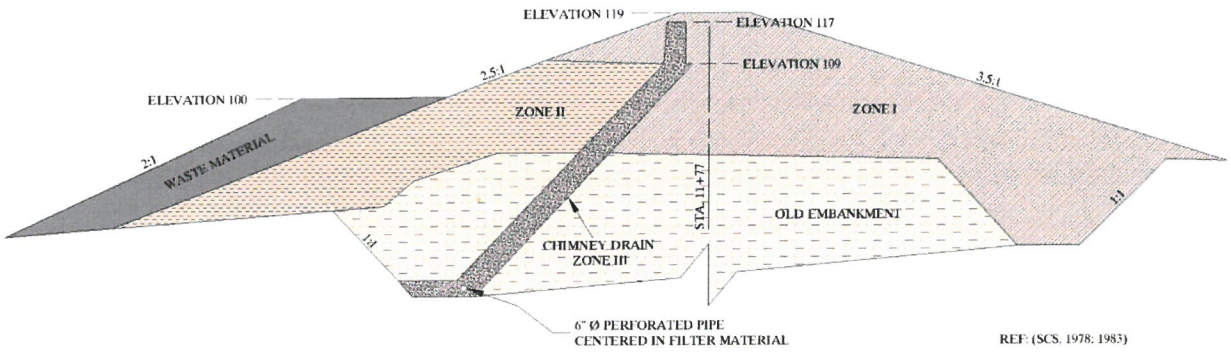
Sinkhole and Cracking Condition Evaluation - Conclusions

1. Sinkholes documented at Frog Hollow Dam:
   a. Are directly associated with extensive longitudinal and transverse cracking of the underlying Zone I embankment materials [i.e., primarily silty to sandy clay (CL) and clayey silt (CL-ML)].
   b. Formed by soil piping into subsurface desiccation cracks, primarily during periods of heavy rain.
   c. Will continue to occur without mitigation.

2. Cracks at Frog Hollow Dam:
   a. Were documented in the Zone I materials below the crest of the dam, and in both the upstream and downstream embankment slopes.
   b. Were oriented both longitudinal and transverse to the embankment.
   c. Ranged from hairline fractures up to 5 inches wide.
   d. Were either partially infilled with the Zone I embankment materials or were open with no in-filing.
   e. Are interconnected within the embankment.
   f. Are confined within the Zone I materials, and do not extend into the Zone II or the underlying foundation materials.

3. The primary cause of the cracks is desiccation of the Zone I embankment materials used during construction of the dam in 1978. The general zones of embankment materials are illustrated in Figure 8.2.

Figure 8.2: General Embankment Zones



4. The majority of the existing desiccation cracks occurred prior to the 1983 repair work. Previous investigations by SCS and ESA between 1981 and 1983 identified as many as 587 cracks; many of the transverse cracks extended through the entire embankment.

5. The 1983 repair work plan addressed internal drainage concerns by extending the chimney drain sand to within 2 feet of the crest, but did not specifically address (fill-in/rework) the desiccation cracks within the embankment, with the exception of a 1-foot granular blanket reportedly installed on the upstream slope.

6. Many of the transverse cracks documented by RA also appeared to extend through the embankment from the upstream to downstream slopes; however, the continuity of the cracks was generally interrupted by the extension of the chimney drain in 1983.

7. Transverse cracks, ranging from hairline fractures to about 1/8-inch wide, were documented in the chimney drain sand. The cracks in the chimney drain are due to either:
   a. Crack widening due to further desiccation of the Zone I embankment materials;
   b. Reflective cracking across the chimney drain, and/or;
   c. Differential consolidation of the drain materials, due to differential saturation from localized sinkholes and desiccation cracks.

8. Previous grouting and past maintenance (infilling) procedures of exposed sinkholes and cracks have not been successful in mitigating the sinkhole and cracking conditions at the dam.

9. The extensive sinkholes and cracks observed along the embankment are a concern and require timely remediation.

10. Long-term remediation measures should address adequate internal drainage, potential migration of fines through the chimney drain, and the presence of sinkholes/cracks upstream of the chimney drain.

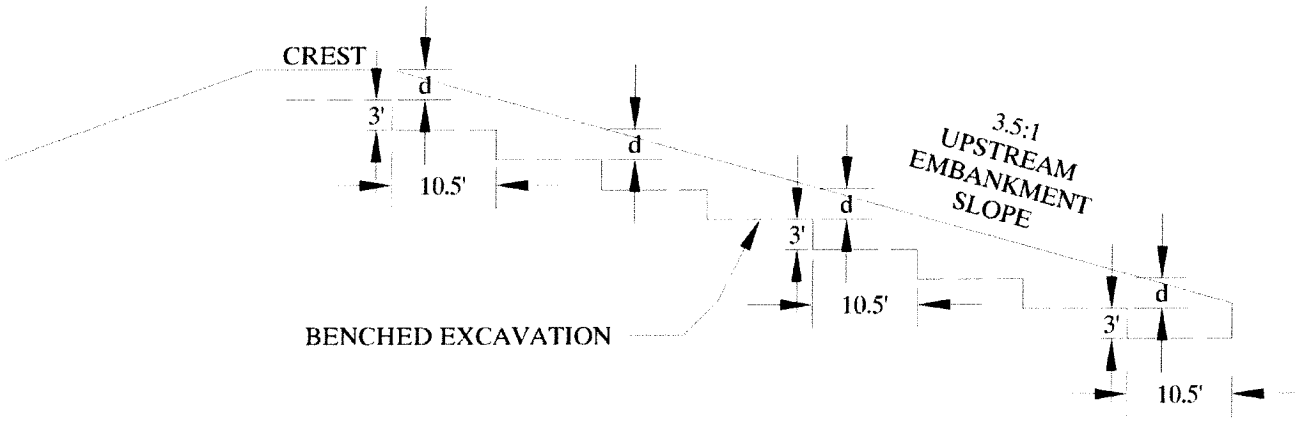
Sinkhole and Cracking Evaluation - Recommendations

1. Implementation of either:
   a. Short-term remediation measures to address the open sinkholes and near surface cracks along the crest and upstream embankment slope to reduce the risk of internal erosion through the dam, until funding is available for long-term mitigation.
   b. Long-term mitigation measures to address adequate internal drainage, potential migration of fines through the chimney drain, and the presence of sinkholes/cracks upstream of the chimney drain

2. Short-term remediation measures include:
   a. Reworking of the Upstream Embankment:
   This short-term option would include excavation of the crest and upstream embankment slope to a specified minimum depth to be determined by the engineer of record, and replace the excavated material in accordance with current NRCS earthwork standards (USDA-NRCS-UT, 2015). Excavations on the upstream slope should be cut to form benches with horizontal and vertical faces to allow the embankment fill to be replaced and compacted in

horizontal lifts. RA recommends minimum bench dimensions of at least 3 feet vertical by 10.5 feet horizontal as shown in Figure 9.2. The compaction requirements for the replacement fill should extend out to the slope face. An effective method for compacting the slope face is to overfill and then cut back to the properly compacted material.

Figure 9.2: Recommended Minimum Bench Dimensions



b. *Scarification and Recompaction of the Upstream Slope Embankment Surface:*
This short-term option would include stripping of the upstream embankment surface and crest of the dam to a depth of at least 4 inches to remove vegetation and organic matter, followed by scarification, moisture conditioning, and re-compaction to a depth of at least 12 inches in accordance with current NRCS earthwork standards (USDA-NRCS-UT, 2015).

3. Long-term remediation measures include:
   a. *New Filter System/Reworking Upstream slope/Protective Cover*:
   This option would include:
      i. Installation of a new filter system, consisting of granular filter material and a geotextile fabric, in order to retain soil particles and provide improved internal drainage, and provide two-levels of protection against internal erosion. At a minimum, the new filter system should extend down to the top elevation of the Zone II material, which appeared to be at the base of the 1983 vertical chimney drain extension. Recommended min/max gradations for a replacement filter are provided in Appendix C as Figure C-19.

ii. Excavation of the crest and upstream embankment slope to a specified minimum depth, and replace the excavated material in accordance with current NRCS earthwork standards (see short-term remediation Option "a" above).

ii. Construction of a protective cover for the upstream embankment slope, consisting of a 1-foot minimum cover of gravel fill to control rilling, and to reduce future cracking by providing some insulation affect. A suggested gradation of the protective cover is provided in Table 9.2.

Table 9.2: Protective Cover Gradation

Sieve Size	Percent Passing
6 Inch	100
3 Inch	70 - 100
No. 4	20 – 60
No. 200	5 - 10

b. *Impermeable Membrane:*

This option would include installation of an impermeable membrane (impermeable fill, geomembrane, etc.) on the upstream slope to restrict seepage into the embankment. Geomembrane materials should be installed in accordance with manufacturer's recommendations with at least 1-foot of protective cover.

c. *Demolition and Reconstruction:*

This option would include demolition of the existing embankment, at least in part, and reconstruction of a new embankment. Design requirements for the new embankment should address the suitability of existing embankment fill materials for reuse, and reducing the potential for desiccation (such as supplementing the fill materials, and/or providing a protective granular shell).

1.0 INTRODUCTION

1.1 General

This report presents the results of geotechnical evaluations, field surveying services, and distress cracking evaluations completed by Rosenberg Associates (RA) for the Frog Hollow Dam Rehabilitation Project in Washington County, Utah. Frog Hollow Dam, UT00418, was initially constructed by the Soil Conservation Service (SCS) in 1956 to retain infrequent flows of water resulting from storm events. Consequently, the reservoir behind the dam is dry, except after heavy rainfalls. In 1978, the embankment was enlarged under the USDA Small Watershed Program by increasing the height approximately 16 feet and increasing the crest length approximately 1300 feet. Frog Hollow Dam is classified by the Natural Resources Conservation Services (NRCS) as a Class "C" (high) hazard dam[1], and by the State Division of Water Rights/Dam Safety as a "Moderate" hazard dam[2]. The dam is located about 5 miles south and east of Hurricane, Utah in Section 24, T42S, R13W, at geographic coordinates 37.1°N, 113.26°W. A Vicinity Map, Drawing 1, is provided following the text of this report.

1.2 Background Information

Frog Hollow Dam was constructed in two stages. The smaller, original dam embankment was constructed in 1956 (NRCS, 2006) and had a maximum height of approximately 33 feet and a crest length of about 600 feet. Major portions of the old embankment were reportedly removed and used as reconstruction materials in the 1978 reconstruction of the dam under the USDA Small Watershed Program (ESA, 1982). The reconstruction resulted in a new dam with a maximum height of approximately 48 feet and a crest length of about 1,900 feet.

Since the 1978 reconstruction, the embankment of Frog Hollow Dam has experienced the on-going formation of sinkholes and cracks. Cracking conditions were first observed in 1980. In early 1981, the cracks were investigated by the Soil Conservation Service (SCS); subsequent investigations were performed by Earth Sciences Associates (ESA) and SCS in 1982 and 1983. Repair work in 1983 to mitigate the cracking conditions within the embankment generally consisted of extending the sand chimney drain to within 2 feet of the crest (NRCS, 2006b).

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1 High Hazard Class C—dams located where failure may cause loss of life, serious damage to homes, industrial and commercial buildings, important public utilities, main highways, or railroads.

2 Moderate Hazard—those dams which, if they fail, have a low probability of causing loss of human life, but would cause appreciable property damage, including damage to public utilities

Based on conversations with Mr. Mac Hall, Board member of the Hurricane Canal Company, RA understands that the embankment materials placed during the 1978 reconstruction of Frog Hollow Dam appeared to be very wet to the point that is was difficult for the construction equipment to operate without assistance (Hall, 2015).

1.3 Purpose of Investigation

As a sub-consultant to McMillen, LLC, the objectives of RA's services were to, in general:

1. Perform geotechnical field and laboratory investigations to:
   a. Evaluate the nature and engineering properties of the existing embankment and underlying subgrade soils.
   b. Assess the general stability of the existing embankment.
   c. Provide specific field surveying services to aid in the evaluation.
   d. Provide geotechnical recommendations for rehabilitation, if required.

2. Perform a preliminary distress investigation of the vertical voids ("sinkholes") and cracking conditions observed within the embankment to:
   a. Evaluate the nature and extent of the holes and cracking conditions.
   b. Further evaluate the engineering properties of the embankment materials.
   c. Evaluate possible cause of the sinkholes and cracking conditions.
   d. Provide our findings, conclusions and recommendations for potential remediation measures.

3. Perform additional field and laboratory evaluations to:
   a. Further evaluate the extensive cracking conditions along the embankment (ie, the continuance of desiccation cracking downstream of chimney drain).
   b. Further evaluate the dispersity of the embankment fill material.
   c. Evaluate whether or not cracking is extending down into the underlying basalt foundation material.
   d. Evaluate the filtering capabilities of the chimney drain materials.

The conclusions and recommendations contained herein are subject to the limitations presented in Section 11.1 of this report. Our services were conducted general accordance with: 1) our Service Agreement dated March 17, 2015; 2) Amendment 1 dated April 22, 2015; and 3) Amendment 2 dated February 3, 2016.

1.4 Scope-of-Work

In order to accomplish the objectives presented in Section 1.3, the following tasks were included in our scope of work:

1.4.1 Geotechnical Evaluations and Field Surveying Services

1. Available geological maps and reports, as-built drawings, previous dam studies, and inspection reports were reviewed.

2. A site reconnaissance was conducted to evaluate the surface conditions and general geologic conditions at the dam site.

3. The geotechnical field investigation program completed in September of 2015 consisted of drilling 4 exploratory borings to depths ranging from 28½ to 70 feet, and excavating 13 exploratory test pits to depths ranging from of about 2 to 16 feet, below the existing ground surface. In-place moisture and density tests were conducted within the test pits that were located within the embankment at select intervals by using a nuclear density gauge. Test results are provided on the test pit logs in Appendix A. The explorations were located by field survey. The locations of the explorations are shown on the enclosed Site Plan/Geotechnical Exploration Locations (Drawing 2).

4. Continuous logs of the subsurface conditions encountered in the explorations were recorded by our field engineer who was supervised by a professional geologist (Mr. David Simon, P.G. of Simon Associates, LLC, a sub-consultant to Rosenberg Associates). The subgrade soils were visually classified in accordance with the Unified Soil Classification System. A description of the equipment and procedures used during drilling and trenching is presented in Appendix A. Logs of the subsurface conditions encountered in the explorations are presented on the enclosed summary sheets in Appendix A.

5. Representative soil samples were obtained from the borings at select intervals and depths using a Modified California ring sampler. The sampler was driven with the aid of a 140 pound hammer free-falling through a distance of 30 inches. The blows required to drive the sampler through the six-inch intervals are recorded on the enclosed logs at the respective sample depths. The number of blows per foot was corrected for sampler type. Representative bulk samples were collected from the test pits. Soil samples were packaged, labeled, and returned to the laboratory for further testing and evaluation.

6. The laboratory testing program consisted of unit weight and moisture content determinations, gradation tests with and without hydrometer analyses, Atterberg limits, direct shear, solubility, modified consolidation, Proctor, and pin-hole dispersion tests. Descriptions of the procedures used for testing along with the test results are included in Appendix B.

7. Results of the field explorations and laboratory testing were evaluated and engineering analyses were performed to assess the stability of the existing embankment using the computer program SLIDE. The analyses also included an evaluation of the filtering capability of the chimney drain materials based on Chapter 26, Gradation Design of Sand and Gravel Filters from the National Engineering Handbook (via the NRCS). The analyses were performed by Mr. Bill Turner, P.E. of GHS Geotechnical, Inc. (a sub-consultant to Rosenberg Associates). Stability and chimney drain analysis results are presented in Appendix C.

8. Photos of the project site are provided in Appendix D.

9. Field surveying was completed in March and September of 2015 to locate pertinent project site features including outlet structures, boring locations, dam cross sections, profiles and easements. The field survey points, and boundary and easement information, were down loaded into AutoCAD. The line work is presented in Appendix E.

10. Topographic mapping was completed of the entire Frog Hollow basin area. The project base mapping in presented in Appendix E.

11. A draft report dated December 11, 2015 was prepared to present our geotechnical evaluation results, opinions, and recommendations.

1.4.2 Preliminary Distress Cracking Investigations

1. A site reconnaissance was conducted to observe, locate, and photograph sinkholes and cracks observed within the embankment. Each sinkhole/crack observed was numbered and located by a RA surveyor to within ±0.1 foot. Sinkhole/crack locations are presented on Drawing 3, Sinkhole Location Map. Photographic documentation and field measurements of the observed sinkhole dimensions are included in Appendix D, Section 2 through 4.

2. Sinkholes and cracks within the Frog Hollow Dam were initially investigated in September of 2015 at four (4) representative areas along the embankment. Exploration areas are shown on Drawing 4. Eleven (11) exploratory trenches were initially excavated to document the physical parameters of selected sinkholes and cracks. The exploratory trenches were advanced to depths of about 5 to 8 feet below existing ground surface. Trench locations within the specific areas are provided in Appendix F.

3. Subsurface conditions observed in the trenches were carefully documented at the time of excavation by RA field personnel and by Mr. David Simon of Simon Associates, LLC (a Utah professional geologist and sub-consultant to RA). Materials and cracks exposed in the initial 11 trenches are described on the trench logs presented as Figures F-6 through F-13 in Appendix F.

4. To evaluate the vertical and lateral dimensions of the sinkholes, selected sinkholes holes were saturated with about 375 gallons of water followed by the introduction of about 375 gallons of water with fluorescein, a diagnostic dye tracer that turns florescent green in water. After introduction of the fluorescein, the sinkholes were carefully excavated with the backhoe to follow the subsurface path of fluorescein dye and document the vertical and lateral dimensions of the sinkholes. A description of the equipment and procedures used during trenching and backfilling is presented in Appendix F.

5. Photos during the preliminary crack investigations are provided in Appendix D.

6. RA's analyses included a preliminary evaluation of the following potential causes for the observed sinkhole and cracking conditions: a) differential settlement; b) collapse of foundation materials; c) regional subsidence; d) expansive foundation soils, e) seismic ground shaking f) animal burrows; g) piping; and h) desiccation.

7. A draft report dated December 4, 2015 was prepared to present preliminary findings and recommendations developed during the initial crack evaluations.

1.4.3 Additional Field and Laboratory Evaluations

1. During the week of March 21, 2016, four (4) additional exploratory trenches were excavated to specifically evaluate the following conditions:
   a. Two (2) exploratory trenches (T-12 and T-15) were excavated in Area 2 on the downstream side of previous trench T-5 to evaluate the presence and continuance of desiccation cracking downstream of chimney drain.

b. One (1) exploratory trench (T-13) was excavated in Area 3 near previous trench T-8 to evaluate whether or not cracking was extending down into the underlying basalt foundation material.
c. One (1) exploratory trench (T-14) was excavated in new Area 5 at sinkhole No. 34 to expose the chimney drain materials and evaluate the presence of cracking on the downstream side of the embankment. Sinkholes holes No. 34 and No. 35 were both saturated with about 375 gallons of water with fluorescein diagnostic dye tracer prior to the excavation.

2. Subsurface conditions observed in the additional exploratory trenches (T-12 through T-15) were carefully documented at the time of excavation by RA field personnel and by Mr. David Simon of Simon Associates, LLC. Materials exposed in the trenches are described on the trench logs presented as Figures F-14 through F-17 in Appendix F.

3. Representative samples of the chimney drain and embankment materials were obtained from the additional exploratory trenches for laboratory testing to evaluate: a) the filter compatibility between the chimney drain and adjacent contact zones; and b) its self-healing properties. Laboratory testing consisted of Atterberg limits, sieve and hydrometer analyses, solubility, Proctor and pin-hole dispersion tests. Laboratory test results are included in Appendix B.

4. Samples of the chimney drain materials were also provided to the NRCS soils laboratory to further evaluate its self-healing properties. NRCS test results had not been received at the time of this report.

5. The explorations were backfilled to restore the dam to its original condition by moisture conditioning, replacement, and compaction the excavated soil utilizing heavy compaction equipment. A description of the equipment and procedures used during trenching and backfilling is presented in Appendix F.

6. The ends of the two (2) chimney drain outlet pipes were located in the field, with the aid of a metal detector, uncovered, and left exposed.

7. Photos during the additional field investigations are provided in Appendix D.

8. This final report was prepared to present RA's findings, evaluation results, conclusions, and recommendations for rehabilitation.

2.0 REFERENCED DOCUMENTS

2.1 SCS Geologic Report

In 1976, prior to reconstruction of Frog Hollow Dam, a geologic report was performed by the SCS for the Frog Hollow Debris Basin (SCS, 1976a). The report indicated:

a. Geologically, the site is a poor location for a flood control structure, owing to the high piping potential of available construction materials and the presence of fractured and vesicular basalt foundation materials.
b. The site is underlain by Quaternary basalt flows and gypsiferous, unconsolidated alluvium.
c. The site at the existing dam, built in 1956, was preferred over an alternative work plan location (located 350 feet downstream, investigated in 1972) because of the natural blanket and the past performance of the existing debris basin.
d. Sufficient fine-textured soils for embankment construction were present within 1-mile of the site.

SCS recommended:

a. Construction of a cut-off keyway at the base of the downstream embankment, excavated into bedrock (basalt), along the entire length of the dam foundation to reduce seepage and prevent piping within the embankment (possible dental grout was noted for fractured and vesicular zones which cannot be penetrated).
b. The foundation of the dam should be excavated to bedrock to remove gypsiferous alluvial soils.
c. The existing blanket upstream of the left abutment may have to be removed and recompacted to a depth of 3 feet.
d. Drains and filters may be necessary.
e. Protective measures may be needed throughout the emergency spillway to prevent erosion.

2.2 SCS Design Report

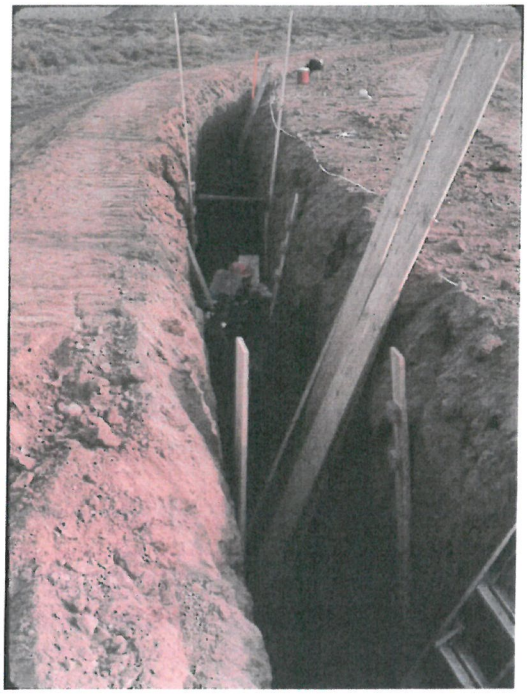
The SCS Design Report (SCS, 1976b) noted the cutoff trench was not excavated down to bedrock between the left abutment and about station 13+60, and that the as-built plans did not address dental grouting at the base of the cutoff as previously suggested by the SCS (SCS, 1976a).

2.3 SCS Construction Plans

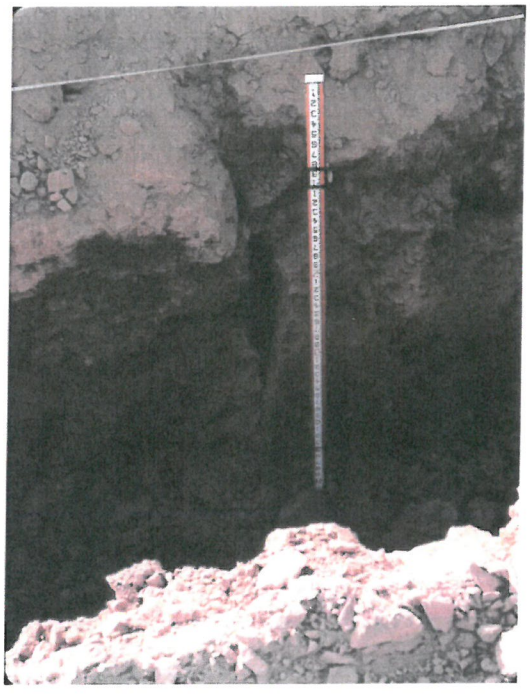
The As-Built Construction Plans prepared by Soil Conservation Service (SCS) (SCS, 1978; 1983), indicate:

a. The embankment is a zoned compacted earth dam with a designed crest width of 14 feet.
b. The upstream and downstream slopes were designed to be 3.5H:1V and 2.5H:1V, respectively.
c. Waste materials, disposed in the natural channel and adjacent to the downstream slope of the embankment, were to be placed with 2H:1V slopes.
d. Repair work was completed in 1983 to address a dam safety/function issue regarding cracking in the embankment.
e. Repair work on the structure consisted of:
    i. Removal of the upper 2 feet of the embankment.
    ii. Excavation of a vertical trench along the top of the dam and backfill with drain material to extend the existing embankment chimney drain.
    iii. Replacement of the upper 2 feet of embankment materials with compacted fill.
    iv. Construction of a gravel blanket on the upstream slope.

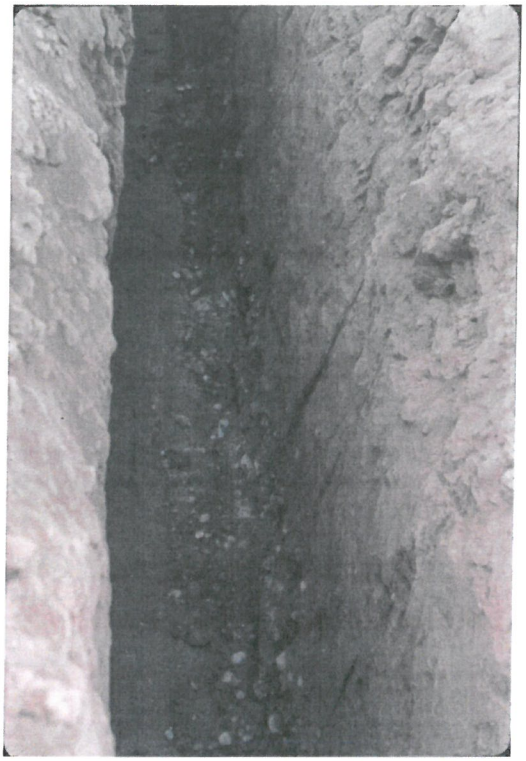
Select photographs taken by SCS during the repair work are provided below.



Photograph 1: Chimney drain excavation.



Photograph 2: Exposed transverse crack.



Photograph 3: Exposed transverse cracks.

Photograph 4: Chimney drain excavation.

2.4 SCS Abstract of Data

An SCS Abstract of Data (SCS, 1982a) indicated the presence of "new longitudinal cracks on the upstream face extending from left abutment to station 17+00. Ports on riser closed with plywood. Drains [presumably chimney drains] half filled with sediment."

2.5 ESA Seismic Safety Investigation – Phase I

In 1982 and 1983 Earth Sciences Associates (ESA) prepared Seismic Safety Investigations Reports for eight SCS dams in Southern Utah, which included the Frog Hollow dam (ESA, 1982 and 1983).

The Phase I report (ESA, 1982) indicated that Frog Hollow Dam had experience cracking problems since construction of the raised portion of the embankment in 1978. In early 1981, the cracks were investigated by ESA, which included drilling of borings and the excavation of trenches. Several trenches were excavated along the centerline of the embankment. According to ESA:

a. The cracks were mostly transverse to the centerline of the embankment and ranged from 3 to 9 feet in depth.
b. Many cracks were found to extend through the entire embankment fill.

c. The width of the cracks ranged from hairline fractures to 1½ (inches) and averaged about ½ inch.
d. The cracks were open at the surface and gradually narrowed at depth.
e. Many of the cracks were filled with grass and roots.
f. Transverse cracking was attributed to desiccation of the fill materials.
g. One longitudinal crack, about 100-feet long, was documented on the upstream face of the dam, about 35 feet upstream of centerline. The longitudinal crack was attributed to consolidation of old debris basin deposits and/or alluvial and colluvial deposits near the cut-off trench.

ESA documented anomalous water loss between about 50.5 and 55 feet in a drill hole on the crest of Frog Hollow Dam, which was interpreted to be a zone of low density soils. Two additional boreholes were drilled about either side of the first borehole; zones of water loss and low density soils were not documented in the two boreholes. ESA postulated the loose materials encountered in the initial borehole were associated with poorly placed and compacted backfill of the trench containing a pipe removed from the original dam (ESA, 1982).

ESA provided a representative cross section of the Frog Hollow Dam embankment which is presented below as Figure 2.5.

Figure 2.5: Representative Cross-Section of Embankment (ESA, 1982)

ESA reported that materials used in the construction of Zone I consisted of sandy and silty clays (CL), sandy silts (ML) and silty sands (SM) with varying amounts of gravel and scattered cobbles. Zone II materials consisted of coarse gravel and cobbles in a silty clay matrix. A 4-foot chimney drain of select fill (Zone III) was constructed below the downstream embankment, at a 1H:1V slope, with 6-inch diameter perforated concrete drain pipes at the base. The drain pipes were designed to connect to 6-inch diameter concrete outlet pipes. Old embankment fill materials left in place consisted of gravelly silty sand with some cobbles. Waste materials on the downstream slope, consisted of basalt rubble. Embankment foundation materials consisted of a southerly-dipping contact of weathered basalt and unconsolidated basin deposits. The basalt materials were reported to be fractured and jointed with relatively pervious zones at the upper and lower margins of the basalt flows. The basin deposits consisted of unconsolidated, gypsiferous alluvial and colluvial sediments; however according to ESA, this material was removed prior to construction of the embankment (ESA, 1982).

The left abutment of the dam is formed by two basalt flows separated by a 3- to 5-foot thick deposit of highly compacted sandy silt. Approximately 10 to 20 feet of alluvium originally covered the basalt flows at the left abutment; however, this material was reportedly removed in the cut-off/drain trench excavations. At the right abutment, the younger basalt flow was absent; however, the upper cooling zone of the basalt flow was found to be highly permeable. The right abutment was overlain by approximately 5 to 10 feet of calcareous, gypsiferous sand and clayey alluvium; however, this material was removed prior to the construction of the embankment (ESA, 1982).

2.6 ESA Seismic Safety Investigation – Phase II

In the Seismic Safety Investigations Report, Phase II (ESA, 1983), ESA recommended:

a. Cracks present in the embankment should be repaired by filling the cracks with properly compacted fill similar to the fill to raise embankment in 1978.
b. Cracks should not be repaired using a soil-slurry mixture.
c. Measures to prevent desiccation of the embankment soils may be desirable.

ESA concluded:

a. There was no evidence of active (Holocene-age) faulting at the Frog Hollow site.
b. The potential for surface-fault rupture is low.
c. The dam site may be subjected to strong ground shaking during a postulated magnitude 6.0 earthquake.
d. The dam should perform satisfactorily during the postulated earthquake, provided that the cracks in the embankment are adequately repaired.
e. The potential for liquefaction at the site is low (ESA, 1982; 1983).

2.7 SCS Speed Memo

On December 1, 1982, a Speed Memo was prepared by an SCS Geologist (SCS, 1982b). The memo indicated that 587 cracks had been plotted on a surface map. The greatest density of cracks appeared to be between Stations 21+60 to 27+00, and about 50 percent of all cracks occurred on the upstream face. SCS's indicated the dam cracks exhibited a preferential orientation to the dam. Therefore, SCS concluded that:

a. The cracking at Frog Hollow was not related to the subsurface or foundation.
b. The cracking mechanism is related to the structure and the crack-prone construction materials from which it was built

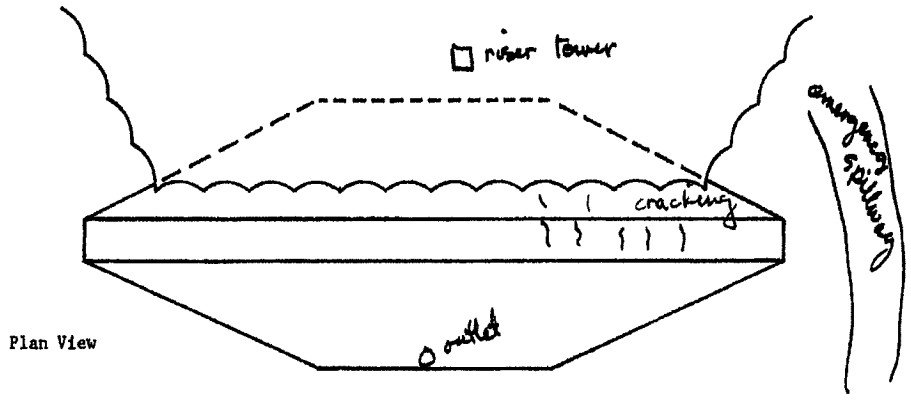
2.8 SCS Frog Hollow Repair Design

A letter sent to the SCS State Conservation Engineer (SCS, 1983a) indicated that the design for repair of the Frog Hollow Dam had been completed and that the design was based on the concept of crack control by providing internal embankment drainage which had been a common practice in SCS designs. Design considerations for the filter drain (SCS 1983b), indicated that the filter must be self-healing (% fines <5%, Cu<10) and must serve as a filter for adjacent embankment materials (d_{15} of filter $\leq$ 5 d_{85} of embankment). Specific repair work on the structure is discussed above in Section 2.3.

2.9 Dam Safety Inspection Reports and Correspondence

1. On June 22, 1982, A Dam Safety Inspection Report was completed by the State Division of Water Rights (DWR) for Frog Hollow Dam (DWR, 1982a). The DWR (1982a) report indicated the presence of surface cracking on the southern crest and on the upstream face of the embankment as shown on Figure 2.9a.

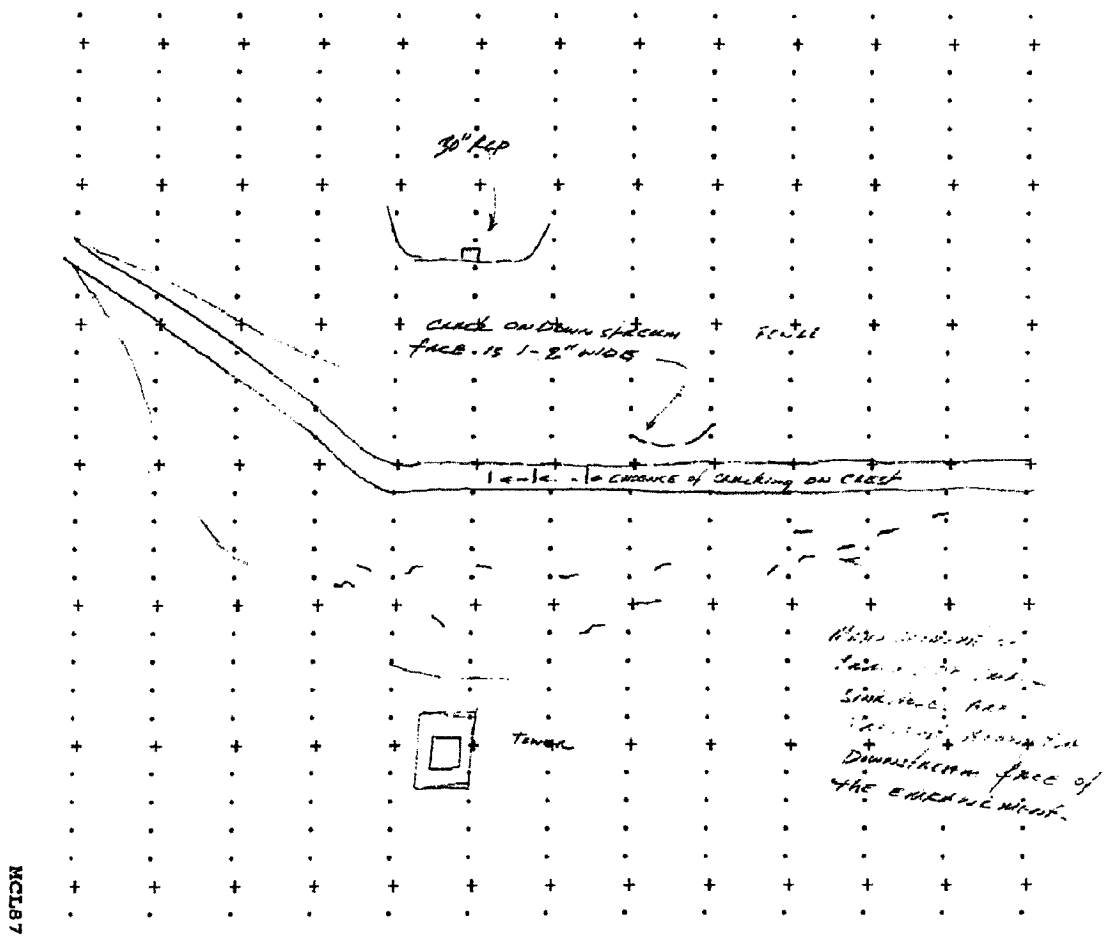
Figure 2.9a: Surface Cracking on the Upstream Face of the Embankment, (DWR, 1982a)



2. A DWR Dam Safety (DWR, 1982b) letter to Bench Lake Irrigation Company suggested an engineering analysis be performed to determine the cause and extent of the cracking, and its effect on the integrity of the structure.

3. A DWR Dam Safety Inspection Report (DWR, 1987) indicated the presence of several small "sink holes" along the mid to lower upstream face of the embankment as shown in Figure 2.9b. Most of the sink holes were north of the previously noted (DWR, 1982b) cracking locations.

Figure 2.9.b: Sink Holes on the Upstream Face of the Embankment, (DWR, 1982c)



4. DWR Dam Safety Inspection Report (DWR, 1989a) indicated that the filter (chimney drain) had been extended up to near the top of the crest, and that the cracks and holes were filled in with graded sandy gravel material.

5. A DWR letter (DWR, 1989b) to Bench Lake Irrigation Company noted the following items requiring attention to ensure the satisfactory long-term operation of the dam and related structures:
   a. "There were several cracks and holes on the upstream face of the structure. Dam Safety would like to hear the irrigation company's theory about what is causing these holes (i.e., evaporites, gypsum, dispersive soils, etc.).
   b. The holes should be marked with surveyor's lath and filled with impervious, non-dispersive clay with low-salt content."
   c. "If closing the lower ports in the outlet tower is a standard solution to sedimentation, Dam Safety would like to see how the blocked ports effect the routing of the 100 year and probable maximum floods."

6. Following the 1992 magnitude 5.8 St. George Earthquake, DWR Dam Safety performed a post-earthquake inspection of Frog Hollow Dam. A DWR Dam Safety inspection letter (DWR, 1992) noted:
   a. No cracks were observed in the principal spillway riser or outlet structures.
   b. Significant rutting from two and four wheeled vehicles on the embankment.
   c. A 2-foot diameter hole with caving sidewalls was present about 10 feet downstream of the wire cage on the principal spillway riser.
   d. Many 6-inch to 1-foot diameter holes were present on the upstream and downstream embankment slopes. The holes were partially animal burrow related and partially related to the cracking and piping problems that this structure has experienced. "These holes were anticipated to occur and were accounted for in the repair work of the mid-1980's."

7. A DWR letter (DWR, 1994) to Hurricane Canal Company noting the following items requiring attention to ensure the satisfactory long-term operation of the facilities:
   a. "Continue to monitor, investigate and repair as needed sinkholes in the reservoir basin and the embankment. Those near the outlet tower and in the dam crest should be given special attention."
   b. "Remove and control deep-rooted woody vegetation in and around the outlet tower and on the dam embankment."
   c. "Monitor, and repair as needed, erosion on the upstream face of the embankment."
   d. "Monitor and eradicate burrowing rodents on the embankment."

e. "Take whatever opportunities become available to observe the area below the dam when water is impounded in the basin to discover any evidence of seepage or piping which may be related to the sinkholes. It is understood that there is no record of observations to suggest such a relationship."

8. A DWR letter (DWR, 1999) to Hurricane Canal Company did not mention the presence of any cracking or sinkholes within the embankment.

9. A DWR letter (DWR, 2004) to Hurricane Canal Company indicated that Frog Hollow Dam has had historical problems with dispersive or collapsible soils (Hall, 2004), and that the dam should be monitored for pothole symptoms, settlement cracking, slumping or sloughing.

10. A March 20, 2007, a DWR Dam Safety Inspection Report (DWR, 2007), indicated:
    a. According to State standards and policies, the current moderate hazard rating assigned to this dam appears to be appropriate.
    b. Dam crest should be re-graded to remove ruts and allow for proper drainage.
    c. Additional effort to control woody vegetation is needed.
    d. ATV vehicles are causing embankment erosion and that fence or rock barriers should be placed along the upstream toe of the dam to divert traffic.
    e. Evidence of burrowing rodents was noted.
    f. Livestock should not be allowed on the dam.

11. A May 10, 2010, a DWR Dam Safety Inspection Report (DWR, 2010), indicated:
    a. Ruts present on upstream slope of dam, traffic on dam should be discouraged.
    b. Rodents should be eradicated from the crest.
    c. Salt cedar should be removed from around the intake.
    d. The wire cage at the intake needs repair.

12. An October 9, 2013, a DWR Dam Safety Inspection Report (DWR, 2013), indicated:
    a. Efforts should be expanded to remove woody vegetation from the dam.
    b. The upstream slope has significant erosion rills that should be filled and compacted with soil equal in quality to shell materials.
    c. The upstream slope of the dam has many large and deep rodent burrows that should be filled and compacted with soil equal in quality to that found on the shell of the dam. It did not appear to the inspector that the burrows were recent; however, it was recommended that efforts be made to eradicate any rodents burrowing on the dam.

13. An April 20, 2015, a DWR Dam Safety Inspection Report indicated:
    a. Numerous holes exist on-site. According to Rosenberg Associates, 51 holes have been documented. Each hole was survey and photographed. It appears that the Owner has historically used coarse gap-graded gravel to fill in similar holes. The mechanism causing these holes to form is considered a threat to the safety of the dam.
    b. An engineer's evaluation will need to be performed to determine the probable cause(s) of the holes and to make rehabilitation recommendations. It also needs to provide short term recommendations until rehabilitation can be completed. All plans must be reviewed by Dam Safety.
    c. Remove all woody vegetation from off the dam embankment and within 25 feet of the embankment's groins and toe. Excavations from the removal of the root-ball mass should be backfilled with in-kind material.
    d. The two chimney drain discharge pipes should be located, cleaned (if applicable) and marked with a T-post.

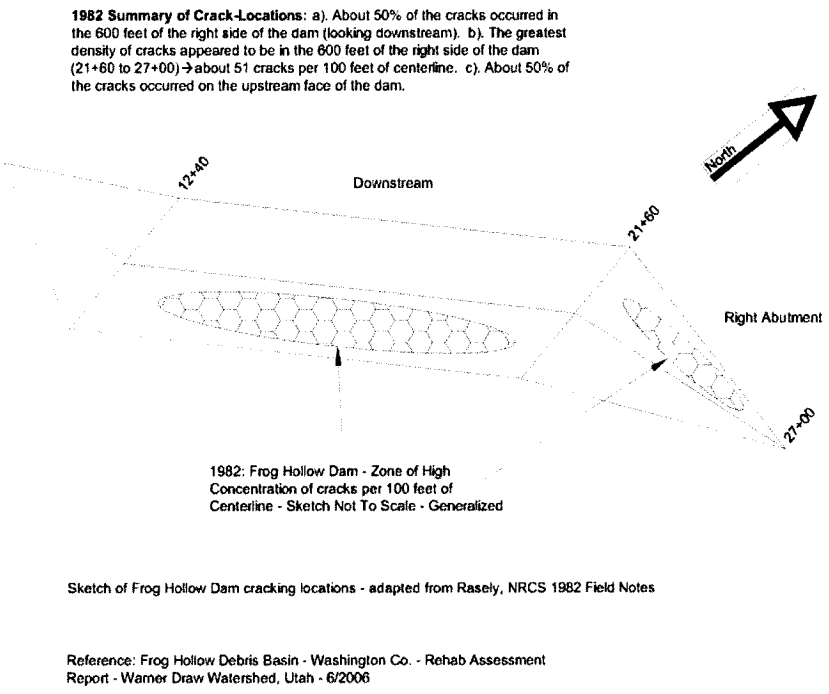
2.10 2006 NRCS Correspondence

A March 14, 2006, NRCS letter (NRCS, 2006a) to the DWR indicated:
    a. The NRCS had reviewed and updated the hazard classification for all PL566 Watershed Project dams in Utah having prior NRCS involvement.
    b. Frog Hollow Dam, among other dams, had been listed as a moderate or low hazard on the state's web page and the NRCS felt Frog Hollow Dam should be classified as a high hazard dam.

2.11 NRCS Rehab Assessment Report

In June of 2006, a NRCS Rehab Assessment Report was prepared for Frog Hollow Debris Basin; the summary history indicated:
    a. Between 1956 and 1976, about 25 feet of sediment had accumulated in the reservoir.
    b. Cracks were observed in the embankment in 1980, and in 1981, a crack investigation was completed (E. Stearns Trip Report), which concluded desiccation to be the primary cause of cracking and the dam was considered safe except if water rose to within 10 feet of the top of the embankment.
    c. In 1982, new longitudinal cracks appeared on the upstream face of the embankment extending from left abutment to station 17+00; a summary of the crack-locations was provided in the referenced report (see Figure 3.10 on the following page).

Figure 3.10: Frog Hollow Dam Cracking Locations, (NRCS, 2006)



d. In 1983, repairs were completed to the dam structure which consisted of removing the upper 2 feet of the embankment, excavation of a vertical trench along the top of the dam and backfill with drain material to extend the existing embankment chimney drain, replacing the upper 2 feet of dam with compacted fill, and placing a gravel blanket on the upstream slope.

2.12 USDA-NRCS Power Point Presentation

RA was provided a copy of a USDA-NRCS Power Point Presentation entitled "Rehabilitation of Cracked Earth Dams" (Doerge, 2015). The main points of the presentation follow:

a. Soils prone to cracking include low to moderate plasticity (PI<15) CL, CL-ML, ML, ML, SC SM and SC-SM soils.
   i. "High" cracking potential soils include CL, CL-ML, and ML (PI<15).

ii "Medium" cracking potential soils include GM, GC, and SC.
iii "Low" cracking potential soils include CH, CL and ML (PI>15).

b. Soils highly susceptible to cracking have a range of gradations between 40% to 73% fines passing a No. 200 sieve.
c. Low to moderate plasticity soils compacted wet of optimum are more prone to shrinkage and cracking.
d. Dispersive clays are not more susceptible to cracking than non-dispersive soils, are highly erodible, hazardous if cracked, and require defensive filters.
e. Transverse cracks are usually more serious, but longitudinal cracks are not necessarily benign. Longitudinal cracks may connect partial transverse cracks and cause slope stability problems.
f. Potential causes of cracking include:
    i. Differential settlement
    ii. Desiccation
    iii. Collapse of foundation materials
    iv. Regional subsidence
    v. Expansive soils, and
    vi. Seismic shaking.
g. Desiccation cracks are generally regularly spaced transverse cracks, often get narrower with depth, and are confined to the embankment materials.
h. Stages of internal erosion failure include:
i. Initiation – seepage forces
j. Continuation – unfiltered exit
k. Progression – maintain roof, particle detachment and transport during crack flow, sloughing of side walls, develops open cracks from upstream to downstream, erodibility is a key factor, and
l. Breach - gross enlargement, collapse, etc.
m. Extremely erodible soils include all dispersive soils (Pinhole classes D1 and D2). Highly erodible soils include ML, CL-ML, SC and SM soils with > 30% fines. Moderately erodible soils include CL, CL-CH soils (LL<65).
n. Cracks are a serious concern.
o. The presence of cracks does not guarantee failure.
p. Cracks should be repaired in timely manner.
q. Two repair/remedial measures include:
    i. Installation of a membrane (soil cement, grout, impermeable fill, geomembrane, etc.) to restrict seepage.
    ii. Installation of a filter (granular filter or geotextile) to retain soil particles.

2.13 2006 NRCS Correspondence

A March 14, 2006, NRCS letter (NRCS, 2006a) to the DWR indicated:

c. The NRCS had reviewed and updated the hazard classification for all PL566 Watershed Project dams in Utah having prior NRCS involvement.
d. Frog Hollow Dam, among other dams, had been listed as a moderate or low hazard on the state's web page and the NRCS felt Frog Hollow Dam should be classified as a high hazard dam.

2.14 NRCS Rehab Assessment Report

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b. Cracks were observed in the embankment in 1980, and in 1981, a crack investigation was completed (E. Stearns Trip Report), which concluded desiccation to be the primary cause of cracking and the dam was considered safe except if water rose to within 10 feet of the top of the embankment.
c. In 1982, new longitudinal cracks appeared on the upstream face of the embankment extending from left abutment to station 17+00; a summary of the crack-locations was provided in the referenced report as shown Figure 4.
d. In 1983, repairs were completed to the dam structure which consisted of removing the upper 2 feet of the embankment, excavation of a vertical trench along the top of the dam and backfill with drain material to extend the existing embankment chimney drain, replacing the upper 2 feet of dam with compacted fill, and placing a gravel blanket on the upstream slope.

3.0 GEOLOGIC CONDITIONS

3.1 General Geologic Setting

Frog Hollow dam site is located on the northwestern edge of the Uinkaret Plateau, in the transition zone between the Colorado Plateau and the Basin and Range physiographic provinces, about 2 miles east of the Hurricane Cliffs. The Hurricane fault is at the base of the Hurricane Cliffs. West of the Hurricane Cliffs lies the St. George Basin, and to the north are the High Plateaus and the Virgin River.

The general geology of the area is shown on Drawing 5, General Geologic Map. Bedrock in the area consists of Upper Permian to Triassic age sandstone, shale, siltstone, limestone, gypsum, and conglomerate, Quaternary-age basalt flows, and Pleistocene and Holocene-age alluvium (Hayden, 2004).

3.2 Local Geologic Conditions

Frog Hollow Dam is underlain by varying thicknesses of gypsiferous alluvium which is in turn underlain by Quaternary-age volcanic basalt flows. The basalt flows are underlain by sandy limestones of the Timpoweap member of the Triassic Moenkopi formation (Hayden, 2004).

Basalt at the site consists of two separate flows. Both flows are present on the left abutment, whereas the right abutment displays only the older flow. Workman Wash (Frog Hollow), in which the embankment is constructed, generally cuts along the edge of the younger flow dividing it from the older flow on the right side of the channel (SCS, 1976a).

At the left abutment, the two basalt flows are divided by a relatively thin (3 to 5 feet thick) layer of alluvium (SCS, 1976a). Approximately 10 to 20 feet of alluvium originally covered the basalt flows at the left abutment; however, most of this material was reportedly removed during construction of the cut-off and drain trenches (ESA, 1982). The upper basalt flow is highly permeable and seepage through the flow could be very high and possible piping of fine-grained embankment material could occur because of the highly permeable basalt (SCS, 1976a).

At the right abutment, the younger basalt flow is absent. The upper cooling zone of the older basalt flow was found to be highly permeable, and piping between the highly permeable zone and fine-grained embankment material could occur (SCS, 1976a). The alluvial cover overlying the basalt along the right abutment consisted of approximately 5 to 10 feet of gypsiferous, sand and clayey sediments; however, this material was reportedly removed prior to the construction of the embankment (ESA, 1982)

Circa 1976, the foundation materials below the embankment varied in composition from dense basalt, covered by existing embankment materials constructed in 1956, and by up to about 30 feet of silty sand sediments. The principal spillway was constructed on basalt bedrock. The emergency spillway was excavated through alluvium and weathered basalt bedrock (SCS, 1976a).

3.3 Faulting

There are no known faults passing through, or projecting towards, the Frog Hollow Dam site (USGS, 2015). The nearest documented Quaternary-age fault is the 155 mile long Hurricane fault, about 2 miles west of Frog Hollow Dam (Drawing 6, Fault Map).

The Hurricane fault exhibits abundant geologic evidence for down-to-the-west, Quaternary surface faulting (Lund and others, 2008). The Hurricane fault has been divided into individual seismogenic segments, each capable of generating their own earthquakes (e.g., Black and others, 2003). The Anderson Junction segment trends through the Hurricane metropolitan area. There has been no historical surface faulting on this segment, but based on available paleoseismic information, the most recent surface faulting likely occurred during the Holocene (Lund and others, 2008).

Review of aerial photographs and surface observations did not identify any fault-related geomorphic features indicative of past surface faulting at or near the property (e.g., fault scarps, vegetation lineaments, gullies, vegetation/soil contrasts, aligned springs and seeps, sag ponds, aligned or disrupted drainages, faceted spurs, grabens, and/or displaced landforms such as terraces, shorelines, geologic units, etc.). Based on these data, we judge the surface-fault-rupture hazard at the site to be low. A detailed site-specific fault study was beyond the scope of this investigation.

3.4 Seismicity

Frog Hollow Dam is situated at approximately 37.119 degrees north latitude, -113.263 degrees west longitude, near the west-end of the Intermountain Seismic Belt (ISB). The ISB, an approximately 100-mile-wide, north-south trending zone of earthquake activity that extends from northern Montana to northwestern Arizona, represents one of the most seismically active areas in the continental United States (Smith and Sbar, 1974).

In Utah, most earthquakes are associated with the ISB (Smith and Arabasz, 1991). Since 1850, there have been at least 16 earthquakes of magnitude 6.0 or greater within the ISB; moderate magnitude (5.5-6.5) earthquakes happen every several years on average, the most recent being the magnitude 5.8 St. George earthquake on September 2, 1992 (Lund and others, 2008). Seismological and isoseismal data suggest that the probable source of the 1992 magnitude 5.8 St. George earthquake was the Hurricane fault (Christenson, 1995).

Moderate to strong ground shaking should be anticipated within the life time of the dam. The nearest known active fault is the Hurricane fault zone, located approximately 2-miles to the west (Hayden, 2004), and is the most likely fault to initiate a seismic event at the site. Halling and others, 2002 report a maximum considered earthquake (Mw) of 7.5 for the Hurricane fault.

The 2008 USGS Interactive Deaggregation website (USGS, 2008) indicates that the peak horizontal ground acceleration at the site is 0.23g with a 2% exceedance in 50 years.

4.0 GENERAL SITE CONDITIONS

Frog Hollow Dam is located in a moderately remote area about 5 miles south and east of Hurricane, Utah in Section 24, T42S, R13W, Salt Lake Base and Meridian. Access is via State Route 59 about 2 miles out of Hurricane, then turning south on a diagonal gravel road for about 4 miles to the site. The main section of the dam is located on property owned by the Utah Water and Power Board (UTPB), with the auxiliary spillway and northern end of embankment on BLM property (See Drawing E-1 in Appendix E).

4.1 Embankment Description

Frog Hollow Dam embankment consists of a zoned compacted earth embankment with an average height of about 25 feet; the maximum reported height is 58 feet. Surveyed crest widths ranged from 12 to 16.5 feet. The crest length of the embankment is about 1982 feet. The maximum surface elevation differential along the top of the embankment was surveyed to be 0.83 feet, with the lowest portion located within the area where the embankment height is the greatest. The upstream slopes were surveyed at 3.3H to 4H:1V and the downstream slopes were surveyed at 2.5H to 3.2H:1V. An approximate 40-foot high berm of waste material was placed along the downstream toe of the deepest portion of the embankment.

The dam was initially constructed with a 4-foot wide chimney drain, inclined below the downstream embankment slope, with a 6-inch diameter perforated concrete drain pipe at the base of the drain fill (SCS, 1978; 1983). Dam repairs in 1983 included a vertical extension of the chimney up to within about 2 feet of the top of the dam. Drain outlets pipes could not be located during our initial investigations. However, the outlet pipes were found on April 22, 2016 and were plugged with sediment (see Section 8.1).

Sparse to moderate vegetation was present on the embankment surface, some of which was over knee high. Vehicular and ATV use on the dam has created a trail and some

rutting on the upstream face of the embankment. The trail and other localized areas, had been covered with coarse gravel to control surface erosion. A boundary fence located between the UTPB and the BLM properties extended across the northern portion of the embankment. Photos of the dam site are presented in Appendix D.

4.2 Spillway Description

The auxiliary (emergency) spillway, located at the southern end of the embankment, was un-lined (no structure present) and appeared to have been cut mostly into weathered, highly fractured, basalt bedrock as observed at test pits TP-1 and TP-2. The base of the spillway was 100 to 200 feet wide with 2H:1V side slopes. The elevation of the emergency spillway was surveyed at 3.6 feet and 4.4 feet lower than the lowest and highest portions of the embankment crest, respectively. Emergency spillway flows are directed north-westward back into a natural Workman Wash drainage channel, which consists mostly of exposed dense basalt. The auxiliary spillway was free of obstructions and operational.

The principal spillway in-take consisted of a reinforced concrete riser with an opening near the top and 5 openings in the front wall, 3 of which were exposed above the adjacent ground surface elevation. The elevation at the top of the riser was approximately 4 feet lower than the elevation of the auxiliary spillway.

Considerable sediment has been deposited in the reservoir pool over the years. Adjacent to the in-take riser, approximately 8 to 9 feet of sediment had accumulated above the lowest riser opening. Erosion of sediment at the intake structure and deposition in the outlet conduit was taking place. Some vegetation was present inside of the protective cage.

The principal spillway outlet consisted of a 24-inch diameter concrete pipe conduit supported by a concrete block. The principal spillway appeared to be in satisfactory condition with the exception that some sediment had been deposited along the base of the outlet conduit near the outlet (see photos in Appendix D.

Two 6-inch diameter chimney drain pipes reportedly outlet adjacent to each side of the principal spillway conduit; however the drain outlets could not be located during our initial investigations. As part of the additional investigation tasks, the ends of the outlet pipes were located with the aid of a metal detector. The ends of the pipes were covered with embankment fill and boulder, and completely filled with sediment.

4.3 Embankment Sinkholes

At the time of our initial site visit, a number of relatively deep sinkholes, with apparent internal erosional features, were observed along the embankment (see Photographs 5 through 8). During a site reconnaissance on March 12, 2015, a total of 51 sinkholes were observed within the embankment. The sinkholes were located by survey to within ±0.1 ft. and photographically documented, see Drawing 3. The majority of the sinkholes were located along the upstream slope and crest of the embankment. Several sinkholes were aligned longitudinally and perpendicular to the embankment. Representative sinkholes are shown in Photographs 5 through 8. Photographic documentation and measurements of all sinkholes are included in Appendix D.

Photograph 5: Sinkhole H-2 about 18 inches in diameter along crest of embankment.

Photograph 6: Crack about 5 inches wide along upstream embankment; view to north.

Photograph 7: Sinkholes H-6 & H-5 up to 18 inches wide along crest of embankment; view to north.

Photograph 8: Several sinkholes 13 to 22 inches in diameter along upstream slope (such as H-43 –H-45).

5.0 SUBSURFACE CONDITIONS

The embankment fill, foundation, and basin sedimentation conditions were explored during the geotechnical field investigations by drilling 4 exploratory borings to depths ranging from 28½ to 70 feet, and excavating 13 exploratory test pits to depths ranging from about 2 to 16 feet, below the existing ground surface. The encountered subsurface conditions are summarized in the following paragraphs and described in more detail on the exploration logs enclosed in Appendix A. In addition, fifteen exploratory trenches, in five (5) representative areas, were excavated within the Frog Hollow Dam embankment to document the physical parameters of select sinkholes and cracks. Subsurface conditions observed in the exploratory trenches are described in Appendix F.

5.1 Embankment Fill Materials

Embankment Fill (Zone I) materials documented by RA consisted of silty to sandy clay (CL), clayey silt (CL-ML), sandy silt (ML); and clayey sand (SC) with varying concentrations of gravel and gypsum. Corrected standard penetration (SPT) values within the embankment ranged from 22 blows per foot to refusal. Based on field and laboratory test results (see Appendix B), the Zone I embankment soils exhibited the following properties.

a. In-place dry density and moisture content values of 75 pcf to 130 pcf and 1.2% to 16.8%, respectively.
b. Percent fines (silt and clay) ranging from 39% to 99.7%.
c. D_{85} ranging from 0.196 mm to 23.1 mm.
d. Liquid limit and plasticity index values ranging from 19 to 31 and 4 to 12, respectively.
e. Friction and cohesion values of 28° to 32° and 200 pcf to 640 pcf, respectively.
f. Maximum laboratory compaction values of 114.4 pcf, 121.5 pcf and 130.9 pcf, at 15.3%, 10.9% and 6.5% moisture, respectively
g. Low to moderate degrees of solubility (0.1% to 2.1%).
h. Non-dispersive (ND1, ND2) and slight to moderately dispersive (ND3), highly erodible, and moderate to high cracking potential classifications.
i. Nuclear gauge in-place moisture content and density values within the upper 6 feet ranged from 3.7% to 12.4% and 98.9 pcf to 117.2 pcf, respectively. The average in-place moisture content and in-place density were 7.8% and 108.8 pcf. Using a Proctor value of 114.4 pcf at 15.3% moisture (from a bulk sample obtained from test pit TP-1), the relative compaction of the encountered fill soils ranged from 86.5% to 100%, with an average relative compaction of 95.1%.

Zone II embankment materials were encountered at depth in exploratory trenches T-14 and T-5 on the downstream side of the embankment and consisted of sandy clay (CL) with basalt gravel and cobbles and interlayered clayey silt (CL-ML) with sand. Based on laboratory test results (see Appendix B), the Zone II embankment soils exhibited the following properties:

a. Percent fines (silt and clay) ranging from 36% to 84%.
b. Liquid limit (LL) and plasticity index (PI) values ranging from 23 to 37 and 5 to 14, respectively.
c. Moderate degrees of solubility (1.9% to 3.1%).

Chimney drain (Zone III) materials were exposed in exploratory trenches T-5, T-12 and T-14. At trench location T-14 in Area 5, both the original and 1983 chimney drain materials were encountered. The vertical portion of the 1983 chimney drain was approximately 3-feet wide. The original chimney drain materials were sloping downward below the downstream portion embankment as illustrated in Figure 2.5. The drain materials were similar in color and texture and appeared to have been derived from the same source. Based on laboratory test results (see Appendix B), the original and 1983 chimney drain materials exhibited the following properties:

a. Percent sand ranging from 90 to 93.
b. Percent fines ranging from 3.8% to 7.4%.
c. Coefficients of uniformity (Cu) ranging from 6 to 8.
d. D_{15} ranging from 0.103 mm to 0.107 mm.
e. Non-plastic.

5.3 Foundation Conditions

Foundation materials documented by RA generally consisted of highly fractured, highly vesicular, very weathered to slightly weathered, basalt with clayey silt infilling materials. At Exploration location B-1, an approximate 6½-foot layer of very stiff clayey silt was found between the basalt. Basalt encountered at exploration location TP-3 was more massive, less weathered and less vesicular. Percent recovery from the coring operations and rock quality designation (RQD) values are presented on the boring logs in Appendix A. Rock core photos are included in Appendix D.

5.4 Groundwater

Groundwater was not encountered within the explorations performed for this study. Seasonal and long term variations in groundwater may occur. Numerous factors influence the occurrence of, and fluctuations in, groundwater levels. The evaluation of these factors was beyond the scope of this study.

6.0 GEOTECHNICAL EVALUATIONS

6.1 Embankment Slope Stability

Embankment stability was assessed using the computer program 'SLIDE'. This program uses a limit equilibrium method for calculating factors of safety (using Simplified Bishop's Method) against sliding and evaluates numerous potential failure surfaces, with the most critical failure surface identified as the one yielding the lowest factor of safety of those evaluated. It also allows finite element modeling of steady state groundwater conditions and flow, and uses the results of that modeling as part of the stability analysis. The conditions analyzed include: a) steady state seepage with full reservoir under static and seismic conditions for both the upstream and downstream slopes; b) seismic conditions with a psuedostatic coefficient of 0.115 (half of the peak ground acceleration) used to model sustained accelerations during ground shaking; and c) rapid draw down stability of the upstream slope assuming the same phreatic surface through the dam as we did for steady state seepage but with an empty reservoir.

6.1.1 Configurations for Analyses

The most critical cross section analyzed was at the principal spillway location (Section C-C'), which consisted of an 58 foot high embankment with sides sloped at 2½H:1V (downstream) and 3½H:1V (upstream), with a 15-foot crest width, a 3½-foot freeboard (worst case), and foundation material consisting of basalt. An approximate 40-foot high berm of waste material was present on the downstream toe of the embankment. A second cross section was analyzed at the location of B-3 (Section E-E') with an embankment height of 26. The actual configurations of the dams vary throughout the site (see Appendix E), but are shorter than the most critical configuration analyzed.

As-built plans (SCS, 1978; 1983) indicate three (3) zones within the embankment:

a. Zone I comprising the central and upstream portions of the consisting of sandy and silty clays (CL), sandy silts (ML) and silty sands (SM).
b. Zone II placed downstream of the chimney drain consisting of coarse gravel and cobbles in a silty clay matrix.
c. Zone III consisting of select chimney drain fill constructed below the downstream embankment at a 1H:1V slope, .(ESA, 1982).

6.1.2 Stability Analysis Parameters

The strength parameters for the embankment and underlying foundation materials were based on the results of our field exploration and laboratory testing, and our

experience with similar materials. Table 6.1.2 presents the values used for both static and seismic conditions:

Table 6.1.2: Stability Analysis Parameters

Embankment Material	Internal Friction Angle (static)	Internal Friction Angle (seismic)	Static Apparent Cohesion (psf)	Seismic Apparent Cohesion (psf)	Saturated Unit weight (psf)
Zone I	28	25	100	90	125
Zone II	32	29	100	90	130
Zone II (Drain)	35	35	0	0	130
Foundation (Basalt)	40	40	500	500	140
Berm (Waste)	40	40	0	0	135

6.1.3 Stability Analyses Results

The results of our analyses using the parameters outlined above, and most critical configuration at the principal spillway (Section C-C'), are provided below in Table 6.1.3a. The results indicate that under steady state conditions, both the static and seismic factors of safety for the downstream and upstream slopes are greater than the minimum values required. Under rapid drawdown conditions, the factor of safety is adequate for the upstream slope.

Table 6.1.3a: Stability Analysis Results (Most Critical Configuration)

Condition	Downstream Slope	Upstream Slope	Minimum FS Value
Steady State Seepage	2.56 (Static) 1.62 (Seismic)	2.63 (Static) 1.26 (Seismic)	1.5 1.0
Rapid Drawdown	---	1.3	1.3

The results of our analyses for the configuration at Section E-E' (provided in Table 6.1.3b on the following page), indicate adequate factors of safety against failure for this shorter configuration. Stability analyses results are included in Appendix C as Figures C-1 through C-10.

Table 6.1.3b: Stability Analysis Results (Configuration at Section E-E')

Condition	Downstream Slope	Upstream Slope	Minimum FS Value
Steady State Seepage	2.11 (Static) 1.43 (Seismic)	3.07 (Static) 1.46 (Seismic)	1.5 1.0
Rapid Drawdown	---	1.57	1.3

6.2 Chimney Drain Evaluation

1983 SCS design requirements for the chimney drain material (SCS 1983b) were that it be self-healing (% fines <5%, and a Cu<10), and serve as a filter for adjacent embankment materials (d_{15} of filter $\leq$ 5 d_{85} of embankment). Our laboratory test results indicated 3.8%, 4.4% and 7.4% fines, coefficients of uniformity (Cu) ranging from 6 to 8, and a d_{15} ranging from 0.103 mm to 0.107 mm. The d_{85} of the embankment soils ranged from 0.225 mm to 23.1 mm. NRCS laboratory test results had not been received at the time of this report

Our independent analysis of the Chimney drain filter criteria are presented in Appendix C as Figures C-11 through C-19. Based on the gradations of the chimney drain sand and the adjacent embankment soils, Figures C-11, C-13 and C-14 indicate that the chimney drain gradations are close but do not quite fit within the filter criteria. The chimney drain gradation shown in Figure C-12 does fit within the filter criteria. Recommended min/max gradations for a replacement filter are shown in Figure C-19.

6.3 Settlement

The basalt foundation materials documented in our explorations are not compressible. Apparent settlement observed along the crest of the embankment likely occurred within the embankment materials, as evidenced by the 0.83-foot elevation differential shown on the profiles provided in Appendix E. The lowest portion of the embankment is generally located within the area where the embankment height is the greatest.

6.4 Freeboard

The State of Utah requires a minimum 3 feet of freeboard. The elevation of the auxiliary spillway was surveyed 3.6 feet lower than the lowest portion of the embankment crest. For a fetch of approximately 1982 feet, and a wind velocity of 100 mph, a calculated wave height of approximately 2.5 feet could be generated (Sherard and others, 1963). Therefore, it is our opinion that the current freeboard at the site is adequate.

7.0 SINKHOLE AND CRACKING EVALUATIONS

7.1 Exploration Areas

Sinkholes and cracks were investigated in five (5) representative areas along the embankment. Exploration areas are shown on Drawing 4.

7.1.1 Exploration Area 1

In Exploration Area 1, at the southern end of the embankment, four (4) exploratory trenches (T-1 through T-4), were excavated to evaluate the physical characteristics of sinkholes H-48 through H-51 as shown on Drawing 4, and Figure F-1 in Appendix F. These sinkholes were aligned parallel to the crest of the embankment, and were at about the same elevation within the upstream embankment about 9 feet below the crest of the embankment. Trench T-3 was excavated initially in which a longitudinal crack, up to 3 inches wide, extended through sinkhole locations H-48 through H-51.

7.1.2 Exploration Area 2

In Exploration Area 2, near the central part of the embankment, two (2) exploratory trenches (T-5 and T-6), were excavated to evaluate the physical characteristics of sinkholes H-2, H-3, and H-4 as shown on Drawing 3 and Figure F-2 in Appendix F.

Sinkhole H-2, about 18 inches in diameter, was on the crest of the embankment. Fluorescein tracer was placed in the sinkhole and exploratory trench T-5 was subsequently excavated to follow the subsurface path of the fluorescein tracer. Chimney drain material, consisting of fine to medium grained sand, was observed along the northwest wall of T-5. The fluorescein tracer was observed to flow vertically down the sinkhole to a depth of about 3 feet where fluorescein tracer intersected a transverse crack and flowed directly into the chimney drain material. Exploratory Trench T-6 was excavated to evaluate whether or not the transverse crack documented in T-5 (sinkhole H-2) extended southeasterly through sinkholes H-3 and H-4. A transverse fissure up to 5 inches wide, free of any infilling material was documented at a depth of 1.75 feet below ground surface and continued vertically below the trench floor. This crack went through sinkholes H-3 and H-4, as shown on Figure F-2 in Appendix F.

Two additional trenches (T-12 and T-15) were excavated in Area 2 during the week of March 21, 2016 to specifically evaluate the presence and continuance of desiccation cracking downstream of chimney drain. Trench T-12 was excavated along the crest of the dam, on the downstream side of Trench T-5. Two transverse cracks (ranging from hairline to 1/8-inch) were observed in the exposed chimney drain materials. Downstream of the chimney drain two transverse cracks approximately 0.5-inch and

1-inch wide were observe in the floor of trench excavation, which appeared to join downstream into one zone of fracture about 4 to 7 inches wide with infilling.

Trench T-15 was excavated with two benches on the downstream embankment slope, below T-12. Zone II embankment materials were encountered in the lower portion of the lower bench. The Zone II embankment materials were interlayered with sandy clay (CL) with basalt gravel and cobbles, and clayey silt (CL-ML) with sand.

Two transverse cracks approximately 0.5-inch and 1-inch wide were observed in the trench excavation. The cracks were confined within the upper Zone I portion of the embankment and did not extend down into the lower Zone II materials.

7.1.3 Exploration Area 3

In Exploration Area 3, north of the center of the dam, two (2) exploratory trenches (T-7 and T-8) were excavated to evaluate the physical characteristics of sinkholes H-11 (about 12 inches in diameter) and H-12 (about 5 inches in diameter). As shown on Drawing 3 and Figure F-3 in Appendix F, sinkholes H-11 and H-12 were in the upstream embankment and aligned perpendicular to the crest of the dam.

Fluorescein tracer was placed in sinkhole H-11; and Trench T-8 was subsequently excavated. Our observations indicate sinkhole H-11 had previously been filled with grout to a depth of about 4.5 feet below ground surface. The grout was up to 1.5 feet wide measured perpendicular to the slope face and about 3 inches wide measured parallel to the slope face.

A transverse crack, up to 2.5-inches wide, predominately free of infilling material, extended from the surface to below the trench floor (at a depth of about 6 feet below ground surface). At a depth of 4.5 feet, the fluorescein tracer abruptly changed direction and followed the transverse crack northwest toward the crest.

Exploratory Trench T-7 was excavated to a depth of 5.5 feet below ground surface to evaluate whether or not the transverse crack documented in T-8 (sinkhole H-11) extended northwest through the crest of the dam, to the chimney drain.

Three (3) transverse cracks, up to 4.8-inches wide, were documented in the southeast wall of T-7, one of which was aligned with the transverse crack observed in T-8 (see Figure F-3 in Appendix F). The cracks extended into the chimney drain which was documented in the northwest wall of excavation T-7. Two of the cracks were predominantly open without any infilling material and one of the cracks was partially in-filled with embankment materials.

One additional trench (T-13) was excavated in Area 3 during the week of March 21, 2016 to specifically evaluate whether or not cracking previously observed in Trench T-8 extended down into the underlying basalt foundation material. The lower of Trench T-8 was re-excavated and extended further down slope in a series of benches. The lower bench excavation exposed native foundation soils generally consisting of clayey silt (ML) with basalt gravel and cobbles. The trench was terminated with refusal on fractured basalt. Two transverse cracks ranging in width from approximately 1 to 3½-inches were observed in the trench excavation. The cracks were confined within the embankment materials and did not extend down into native foundation materials.

7.1.4 Exploration Area 4

In Exploration Area 4 at the northern end of the embankment, three (3) exploratory trenches (T-9, T-10 and T-11), were excavated to evaluate the physical parameters of sinkholes H-20, H-26 and H-27 as shown on Drawing 3 and Figure F-4 in Appendix F.

Tracer dye was placed in sinkhole H-20; and Trench T-11 was subsequently excavated. A transverse crack up to 2½-inches wide was documented from the ground surface down to a depth of 5 feet (maximum depth of trench). The crack was partially infilled with sandy to clayey silt. A longitudinal round hole, which appeared to be an animal burrow (Krotovina), intersected the transverse crack at a depth of about 2.3 feet below ground surface in the northwest wall of the trench.

Exploratory trench T-10 was excavated to a depth of 6 feet to evaluate whether or not the crack in T-11 extended through the crest of the dam into the chimney drain. Two (2) transverse cracks, up to 2¾-inches wide, were observed along the southeast wall of T-10, one of which was contained tracer dye from sinkhole H-20 and was aligned with the transverse crack documented in T-11. The cracks were partially infilled with sandy to clayey silt. Both cracks were encountered at a depth of about 3 feet below ground surface and extended to and beyond the bottom of the excavation. The cracks extended into the chimney drain which was documented on the northwest wall of the excavation.

Exploratory Trench T-9 was excavated to a depth of 5 feet below ground surface to evaluate whether or not the cracks documented in T-11 and T-10 extended into the downstream embankment. One (1) transverse crack up to 1.8-inches wide was observed along the northwest wall of trench T-7. The crack was infilled with sandy to clayey silt material and was generally aligned with the transverse cracks observed in T-9 and T-10.

7.1.5 Exploration Area 5

In Exploration Area 5, near the northern end of the embankment, one exploratory trench (T-14) was excavated at sinkhole location No.34 during the week of March 21, 2016. The purpose of the excavation was specifically to expose the chimney drain material and evaluate the presence of cracking on the downstream side of the embankment. Prior to excavation, tracer dye was placed in both sinkhole No. 34 and sinkhole No. 35.

Both the vertical 1983 and inclined original chimney sand drain materials were exposed in the excavation. The sand materials were similar in color and texture and appeared to have been from the same source. Representative bulk samples of the sand materials were obtained for laboratory testing. The 1983 vertical section of the chimney drain was approximately 3 feet wide and extended up to within about 2 feet of the top of the dam.

Zone II embankment materials were encountered in the lower portion of the excavation, below a depth of approximately 10 feet. The Zone II embankment materials generally consisted of sandy clay (CL) with basalt gravel and cobbles.

With the aid of the tracer dye, both longitudinal and transverse cracks were observed within the exploratory trench on the downstream side of the embankment. The cracks were confined within the upper Zone I portion of the embankment and did not extend down into the lower Zone II embankment materials. Tracer dye was also observed in the chimney drain sand indicating a direct connection between the downstream sinkholes, cracks and chimney drain.

7.2 Discussion of Sinkhole and Cracking Conditions

RA's analyses included an evaluation of the following potential causes for the observed sinkholes and cracking conditions within the Frog Hollow Dam: a) differential settlement; b) collapse of foundation materials; c) regional subsidence; d) expansive soils, e) seismic ground shaking f) animal burrows; g) piping; and h) desiccation.

7.2.1 Differential Settlement

Cracking due to differential settlement is generally associated with non-uniform settlement of subsurface soils or fill, generally over short distances. With earthen dams, conditions susceptible to differential settlement include: a) abutments with gradients greater than 2H:1V); b) changes in elevation of underlying foundation materials, c) abrupt changes in compressibility of foundation materials; d) and non-uniform compaction of embankment fills.

At Frog Hollow Dam, conditions conducive to differential settlement exist at the southern end of the dam where the depth of embankment fill is the greatest, and the underlying natural channel below the embankment has relatively steep side slopes (i.e., <2:1). ESA (1982) attributed the 100-ft long longitudinal crack observed in 1981 to consolidation of old debris basin deposits and/or alluvial-colluvial deposits near the cut-off trench underlying the upstream slope of the embankment (ESA, 1982).

Based on our analyses, the sinkhole and cracking conditions are distributed along the entire length of the embankment where the depth of fill varies gradually. Sinkhole and cracking conditions were also documented where the embankment height was less than 5 feet. Therefore, it RA's opinion that differential is not a primary factor contributing to the formation of the sinkholes and cracks documented at Frog Hollow Dam.

7.2.2 Collapse of Foundation Materials

Based on our subsurface investigations, foundation materials beneath the majority of the dam embankment consist of basalt bedrock. Although the basalt bedrock is jointed and fractured, the basalt bedrock is, in our opinion, not collapsible.

Parts of the dam embankment may be founded on alluvial/colluvial sediments. However; according to ESA, this material was removed prior to construction of the embankment (ESA, 1982). It is RA's opinion the primary cause of the sinkholes and cracks observed at the dam is not collapse of foundation materials since: a) the geotechnical investigation for Frog Hollow Dam did not document collapsible foundation materials and; b) sinkholes and cracks were observed at the northern end of the embankment where the foundation soils have likely never been saturated by impounded watering.

7.2.3 Regional Subsidence

Cracks and fissures resulting from regional subsidence are well documented (Borchers, 1995). Regional subsidence is generally associated with alluvial basins where the groundwater aquifer is depleted to a level that triggers consolidation (i.e., subsidence) of the basin sediments (Penrod, 2015). Based on the absence of groundwater wells near Frog Hollow Dam, it is RA's opinion that regional subsidence is not contributing to the formation of the sinkholes and cracks documented at Frog Hollow Dam.

7.2.4 Expansive Soils

The presence of expansive soils below a dam embankment may cause cracking upon changes in soils moisture content of the soils below the embankment. Because expansive soils were not encountered in the geotechnical investigations performed by RA, it is our opinion that expansive foundation soils are not contributing to the formation of the sinkholes and cracks documented at Frog Hollow Dam.

7.2.5 Seismic Ground Shaking

It is possible that the Frog Hollow embankment may have experienced some cracking as a result of the 1992 magnitude 5.8 St. George Earthquake. However, the formation of sinkholes and cracks at Frog Hollow was well documented prior to 1992 (see Section 3.0). Therefore, it is RA's opinion that seismic ground shaking is not a primary factor contributing to the formation of the sinkholes and cracks documented at Frog Hollow Dam.

7.2.6 Animal Burrows

Animal burrows are documented at the Frog Hollow Dam. During our field program, animal burrows were distinguished from sinkholes by the presence of excavated soils ("soil mounds") around the animal burrow. Sinkholes shown on Drawing 3 did not contain soil mounds. It is RA's opinion that animal burrows are not a primary factor contributing to the formation of the sinkholes and cracks documented. However; animals may be utilizing pre-existing sinkholes, contributing to enlargement of sinkholes at surface.

7.2.7 Piping

Based on laboratory soil classifications, the embankment soils at Frog Hollow Dam are highly erodible. In addition, laboratory testing indicates that the embankment soils are non-dispersive (ND1, ND2) and slight to moderately dispersive (ND3).

Based on observations along the surface of the embankment and within the exploratory trenches, some piping (primarily from precipitation) is occurring along existing cracks into the coarse-grained chimney drain material (See Section 5.0). It is RA's opinion that piping in the major contributor to the formation of the sinkholes, but is not the cause of the observed cracking conditions. It is RA's opinion that the cracking occurred prior to the formation of the sinkholes.

Potential piping of embankment materials into the underlying fractured/vesicular basalt foundation materials was identified by the SCS as a potential concern at the Frog Hollow Dam site prior to its reconstruction in 1978 (SCS, 1976). However, exploratory trenching performed by RA revealed that the embankment cracking

conditions did not extend down into the underlying foundation materials. Therefore, it is RA's opinion that piping into foundation materials is not a primary factor contributing to the formation of the sinkholes and cracks documented.

7.2.8 Desiccation

In earth dams, desiccation cracks are generally regularly spaced transverse cracks, often becoming narrower with depth, and are confined to embankment materials. Compacted low-plasticity clayey soils are more prone to drying, shrinkage, and cracking if the clayey soils are placed too wet (at moisture contents above the optimum moisture content of the material).

Embankment materials documented by RA consisted of silty to sandy clay (CL), clayey silt (CL-ML), and clayey sand (SC). Based on laboratory soil classifications, these soils have moderate to high cracking potentials.

Based on the following factors, it is RA's opinion the primary cause of the cracking conditions observed at the dam is desiccation:

a. The upstream embankment slope, where the majority of the sinkholes and cracks were observed, faces southeast and is exposed to the sun most of the day.
b. Embankment soils placed during the 1978 reconstruction were reported to be "very wet" (Hall, 2015).
c. Site conditions are not representative of the causes discussed above for the formation of cracks in earth dams.
d. Previous crack investigations referenced in the NRCS Rehab Assessment Report (NRCS, 2006b) also concluded desiccation to be the primary cause of cracking at the Frog Hollow Dam.

7.2.8 Summary

The following summarized RA's opinion regarding the sinkhole and cracking conditions observed within the Frog Hollow Dam.

1. Sinkhole and cracking conditions were not a reported problem at Frog Hollow Dam until after its reconstruction in 1978.

2. Investigations by SCS and ESA between 1981 and 1983 identified and plotted as many as 587 cracks and concluded:
   a. Cracking at Frog Hollow was not related to the subsurface or foundation materials.

b. Cracking was related to the crack-prone construction materials from which the structure was reconstructed.

3. RA concurs with the above SCS and ESA conclusions. Of the potential causes of cracking considered in Section 7.0, it is RA's opinion the cause of the cracking conditions was desiccation of the crack-prone, Zone I embankment soils used during the 1978 dam reconstruction project.

4. Zone I Embankment materials documented by RA generally consisted of silty to sandy clay (CL), clayey silt (CL-ML), sandy silt (ML); and clayey sand (SC). Based on laboratory testing, these soils are non-dispersive (ND1, ND2) to slight to moderately dispersive (ND3), are highly erodible, and have moderate to high cracking potentials (particularly if placed in a "wet" condition).

5. Repair work in 1983 generally consisted of extending the sand chimney drain to within 2 feet of the crest, and reportedly constructing a gravel blanket on the upstream slope. Providing internal embankment drainage was a common practice by SCS to control cracking. The repair work did not specifically address the cracks themselves, and the cracks that had been documented prior to the repair work remained undisturbed on both the upstream and downstream sides of the embankment.

6. Exploratory trenching in Areas 2, 3 and 4 encountered transverse cracks within the Zone I embankment materials on both the upstream and downstream sides of the chimney drain; many of which appeared to have been connected prior to the 1983 extension of the chimney drain.

7. Small cracks ranging from hairline fractures to 1/8-inch wide cracks were observed within the chimney drain sand at trench location T-12.

8. On-going and reoccurring formation of sinkholes along the embankment is, in RA's opinion, a result of piping (internal erosion) of soil above the existing desiccation cracks, washing soil into the cracks and chimney drain, primarily during periods of precipitation. All of the sinkholes investigated by RA intersected a crack and did not extend below the corresponding crack. As this process continues, the sinkholes enlarge at the surface. Rodent activity may have enlarged some of the sinkholes and cracks along the embankment.

8.0 CONCLUSIONS

Conclusions presented by RA are based on: 1) our review of the referenced documents; 2) findings of field and laboratory investigation programs; 3) field surveys; 3) engineering evaluations; 4) our understanding of the construction conditions at the site; and 5) our geotechnical experience in the area. Section 8.1 presents conclusions from the geotechnical evaluations of the embankment. Section 8.2 presents conclusions from the distress evaluations of the documented sinkhole and cracking conditions.

8.1 Geotechnical Evaluation -Conclusions

1. Factors of safety for the embankment exceed the minimum values required by the State Division of Water Rights/Dam Safety under steady state (static and seismic) conditions, and under rapid drawdown conditions.

2. The two chimney drain outlet pipes were plugged with sediment. Plugged outlet pipes will not function as designed and may ultimately result in uncontrolled seepage through the dam, seepage around the drains, and possible localized piping and/or slump failures within the embankment. The plugged outlet pipes require timely remediation.

3. The principal spillway appeared to be in satisfactory condition with the exception that some sediment had been deposited along the base of the outlet conduit near the outlet.

4. The documented sinkhole and cracking conditions do not have a significant impact on global stability of the embankment. However, the sinkhole and cracking conditions impact the internal stability of the dam, and increase the potential for piping. The sinkhole and cracking conditions require timely remediation (see Section 8.2.

5. Our laboratory testing and evaluations indicate that the chimney drain materials are generally self-healing; but, their gradations do not quite fit within the filter criteria. Additional NRCS laboratory test results of the chimney drain materials had not been received at the time of this report.

6. The maximum surface elevation differential along the top of the embankment was surveyed at 0.83 feet.

7. The elevation of the auxiliary spillway was surveyed 3.6 feet lower than the lowest portion of the embankment crest, providing a freeboard of 3.6 feet.

8. Measured crest widths ranged from 12 to 16.5 feet.

9. Upstream embankment slopes were surveyed at 3.3H to 4H:1V.

10. Downstream embankment slopes were surveyed at 2.5H to 3.2H:1V.

11. As much as 8 to 9 feet of sediment had accumulated above the lowest opening of the intake riser structure. Localized erosion of sediment had occurred at the intake structure, resulting in deposition of sediment in the outlet conduit.

12. The embankment surface was covered with sparse to moderate desert vegetation, some of which was over "knee high". Vegetation was present inside of the protective cage of the intake structure.

13. The crest and the upstream face of the embankment (near the center portion of the dam) have been subjected to vehicular and ATV activities, resulting in some rutting and surface erosion.

14. The auxiliary spillway channel was un-lined (no structure present) and appeared to have been cut mostly into weathered, highly fractured, basalt bedrock.

8.2 Sinkhole and Cracking Evaluation - Conclusions

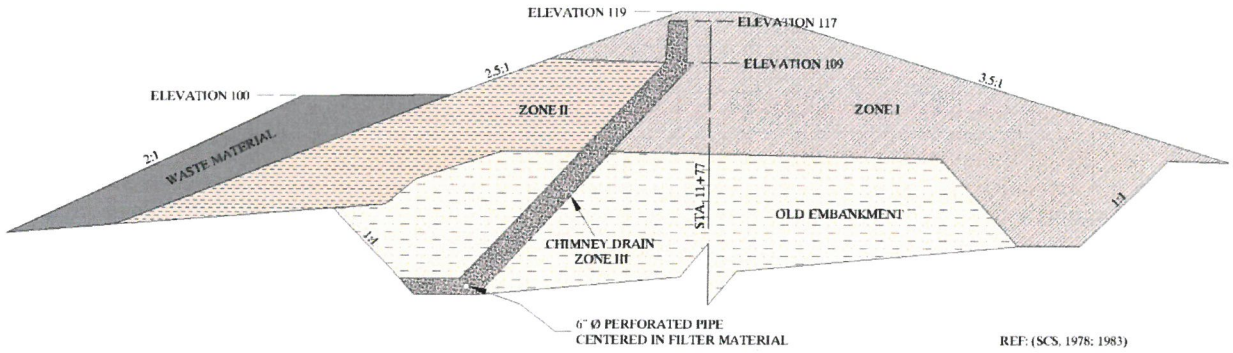
1. Sinkholes documented at Frog Hollow Dam:
   a. Are directly associated with extensive longitudinal and transverse cracking of the underlying Zone I embankment materials [i.e., primarily silty to sandy clay (CL) and clayey silt (CL-ML)].
   b. Formed by soil piping into subsurface desiccation cracks, primarily during periods of heavy rain.
   c. Will continue to occur without mitigation.

2. Cracks at Frog Hollow Dam:
   a. Were documented in the Zone I materials below the crest of the dam, and in both the upstream and downstream embankment slopes.
   b. Were oriented both longitudinal and transverse to the embankment.
   c. Ranged from hairline fractures up to 5 inches wide.

d. Were either partially infilled with the Zone I embankment materials or were open with no in-filing.
e. Are interconnected within the embankment.
f. Are confined within the Zone I materials, and do not extend into the Zone II or the underlying foundation materials.

3. The primary cause of the cracks is desiccation of the Zone I embankment materials used during construction of the dam in 1978. The general zones of embankment materials are illustrated in Figure 8.2.

Figure 8.2: General Embankment Zones



4. The majority of the existing desiccation cracks occurred prior to the 1983 repair work. Previous investigations by SCS and ESA between 1981 and 1983 identified as many as 587 cracks; many of the transverse cracks extended through the entire embankment.

5. The 1983 repair work plan addressed internal drainage concerns by extending the chimney drain sand to within 2 feet of the crest, but did not specifically address (fill-in/rework) the desiccation cracks within the embankment, with the exception of a 1-foot granular blanket reportedly installed on the upstream slope.

6. Many of the transverse cracks documented by RA also appeared to extend through the embankment from the upstream to downstream slopes; however, the continuity of the cracks was generally interrupted by the extension of the chimney drain in 1983.

7. Transverse cracks, ranging from hairline fractures to about 1/8-inch wide, were documented in the chimney drain sand. The cracks in the chimney drain are due to either:

a. Crack widening due to further desiccation of the Zone I embankment materials;
b. Reflective cracking across the chimney drain, and/or;
c. Differential consolidation of the drain materials, due to differential saturation from localized sinkholes and desiccation cracks.

8. Previous grouting and past maintenance (infilling) procedures of exposed sinkholes and cracks have not been successful in mitigating the sinkhole and cracking conditions at the dam.

9. The extensive sinkholes and cracks observed along the embankment are a concern and require timely remediation.

10. Long-term remediation measures should address adequate internal drainage, potential migration of fines through the chimney drain, and the presence of sinkholes/cracks upstream of the chimney drain.

9.0 RECOMMENDATIONS

Recommendations associated with RA's geotechnical evaluations are provided in Sections 9.1. RA's recommendations associated with the sinkhole and cracking conditions are provided in Section 9.2.

9.1 Geotechnical Evaluation - Recommendations

1. The ends of the two chimney drain outlet pipes should be unplugged, inspected (by video camera) for additional sedimentation, then cleaned of sediment as necessary.

2. Either the sediment should be removed from around the intake structure, or the lowest ports of the intake structures should be sealed off. The outlet conduit should be cleaned of sediment as necessary.

3. Areas exhibiting rutting from vehicular/ATV activities, and/or erosion from surface runoff, should be repaired and stabilized.

4. The crest of the dam should be graded to a uniform elevation. Where the crest width is less than 14 feet, the crest should be widened to meet the minimum width requirements.

5. ATV activities on the embankment and dike should be discouraged (i.e. fencing, barriers, etc.).

6. Where the upstream slope is steeper than 3.5H:1V, the slope should be graded to meet the minimum design requirements.

7. Vegetation over knee height on the embankment, and all vegetation within and around the intake riser cage, should be removed.

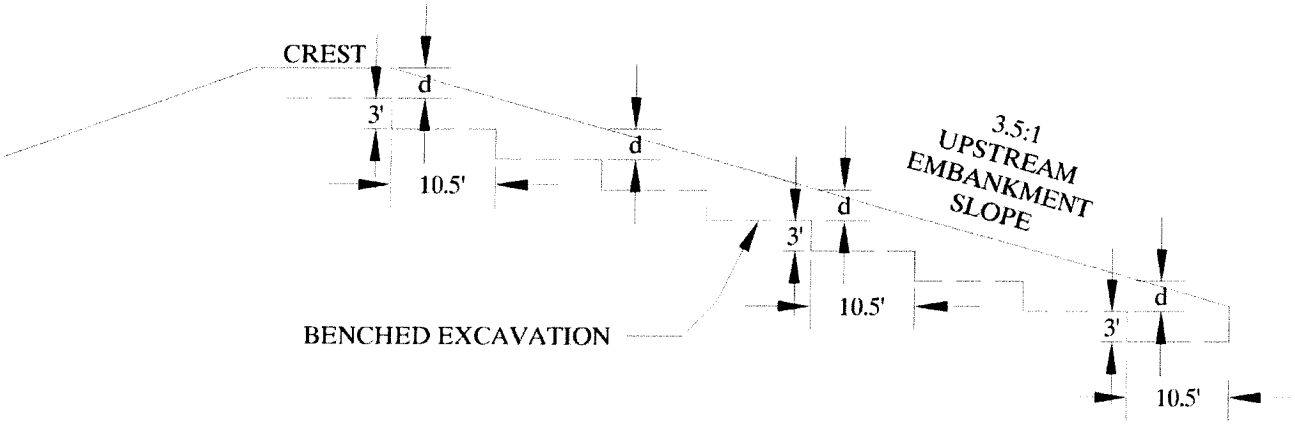
8. The unlined auxiliary spillway channel should be improved to meet the NRCS requirements for a Class "C" (high) hazard dam.

9.2 Sinkhole and Cracking Evaluation - Recommendations

1. Implementation of either:
   a. Short-term remediation measures to address the open sinkholes and near surface cracks along the crest and upstream embankment slope to reduce the risk of internal erosion through the dam, until funding is available for long-term mitigation.
   b. Long-term mitigation measures to address adequate internal drainage, potential migration of fines through the chimney drain, and the presence of sinkholes/cracks upstream of the chimney drain

2. Short-term remediation measures include:
   a. *Reworking of the Upstream Embankment:*
   This short-term option would include excavation of the crest and upstream embankment slope to a specified minimum depth to be determined by the engineer of record, and replace the excavated material in accordance with current NRCS earthwork standards (USDA-NRCS-UT, 2015). Excavations on the upstream slope should be cut to form benches with horizontal and vertical faces to allow the embankment fill to be replaced and compacted in horizontal lifts. RA recommends minimum bench dimensions of at least 3 feet vertical by 10.5 feet horizontal as shown on the following page in Figure 9.2. The compaction requirements for the replacement fill should extend out to the slope face. An effective method for compacting the slope face is to overfill and then cut back to the properly compacted material.

Figure 9.2: Recommended Minimum Bench Dimensions



b. *Scarification and Recompaction of the Upstream Slope Embankment Surface:*
This short-term option would include stripping of the upstream embankment surface and crest of the dam to a depth of at least 4 inches to remove vegetation and organic matter, followed by scarification, moisture conditioning, and re-compaction to a depth of at least 12 inches in accordance with current NRCS earthwork standards (USDA-NRCS-UT, 2015).

3. Long-term remediation measures include:
   a. *New Filter System/Reworking Upstream slope/Protective Cover*:
   This option would include:
      i. Installation of a new filter system, consisting of granular filter material and a geotextile fabric, in order to retain soil particles and provide improved internal drainage, and provide two-levels of protection against internal erosion. At a minimum, the new filter system should extend down to the top elevation of the Zone II material, which appeared to be at the base of the 1983 vertical chimney drain extension. Recommended min/max gradations for a replacement filter are provided in Appendix C as Figure C-19.
      ii. Excavation of the crest and upstream embankment slope to a specified minimum depth, and replace the excavated material in accordance with current NRCS earthwork standards (see short-term remediation Option "a" above).
      iii. Construction of a protective cover for the upstream embankment slope, consisting of a 1-foot minimum cover of gravel fill to control rilling, and to reduce future cracking by providing some insulation affect. A suggested gradation of the protective cover is provided on the following page in Table 9.2.

Table 9.2: Protective Cover Gradation

Sieve Size	Percent Passing
6 Inch	100
3 Inch	70 - 100
No. 4	20 – 60
No. 200	5 - 10

b. *Impermeable Membrane:*
This option would include installation of an impermeable membrane (impermeable fill, geomembrane, etc.) on the upstream slope to restrict seepage into the embankment. Geomembrane materials should be installed in accordance with manufacturer's recommendations with at least 1-foot of protective cover.

c. *Demolition and Reconstruction:*
This option would include demolition of the existing embankment, at least in part, and reconstruction of a new embankment. Design requirements for the new embankment should address the suitability of existing embankment fill materials for reuse, and reducing the potential for desiccation (such as supplementing the fill materials, and/or providing a protective granular shell).

10.0 DESIGN REVIEW

The recommendations presented in this report have been prepared to assist in design of the rehabilitation project. Prior to bid submittal, the Geotechnical Consultant should be provided the opportunity to review the rehabilitation plans, drawings, and specifications in order to determine whether the assumptions and recommendations presented in this report are valid and have been implemented.

11.0 CLOSURE

11.1 Limitations

Our conclusions, recommendations, and opinions contained in this report are: 1) based on our review of the referenced documents; 2) based on findings of the field and laboratory investigation programs; 3) based on findings of the field survey; 4) based on the results of our engineering evaluations; 5) based on our geotechnical experience in the area and with similar soil conditions; 6) based on our understanding of the construction conditions at the site; and 7) subject to confirmation of the conditions encountered during further studies and/or rehabilitation.

Possible variations in the subsurface conditions could exist beyond the points explored with the nature and extent of the variations not evident until rehabilitation occurs. If any conditions are encountered at this site which are different from those described in this report, RA should be notified. This report was prepared in accordance with the generally accepted standard of practice existing at the time the report was written. No warranty, express or implied, is made.

Rehabilitation recommendations made in this report are not final engineering plans or specifications for the recommended remediation and are not issued for construction. Any rehabilitation recommended in this report requires final engineering plans and specifications be issued before any repair or rehabilitation is performed.

11.2 Closing

We appreciate the opportunity to be of service on this project. Should you have any questions regarding the report, please contact us at your convenience at (435) 673-8586.

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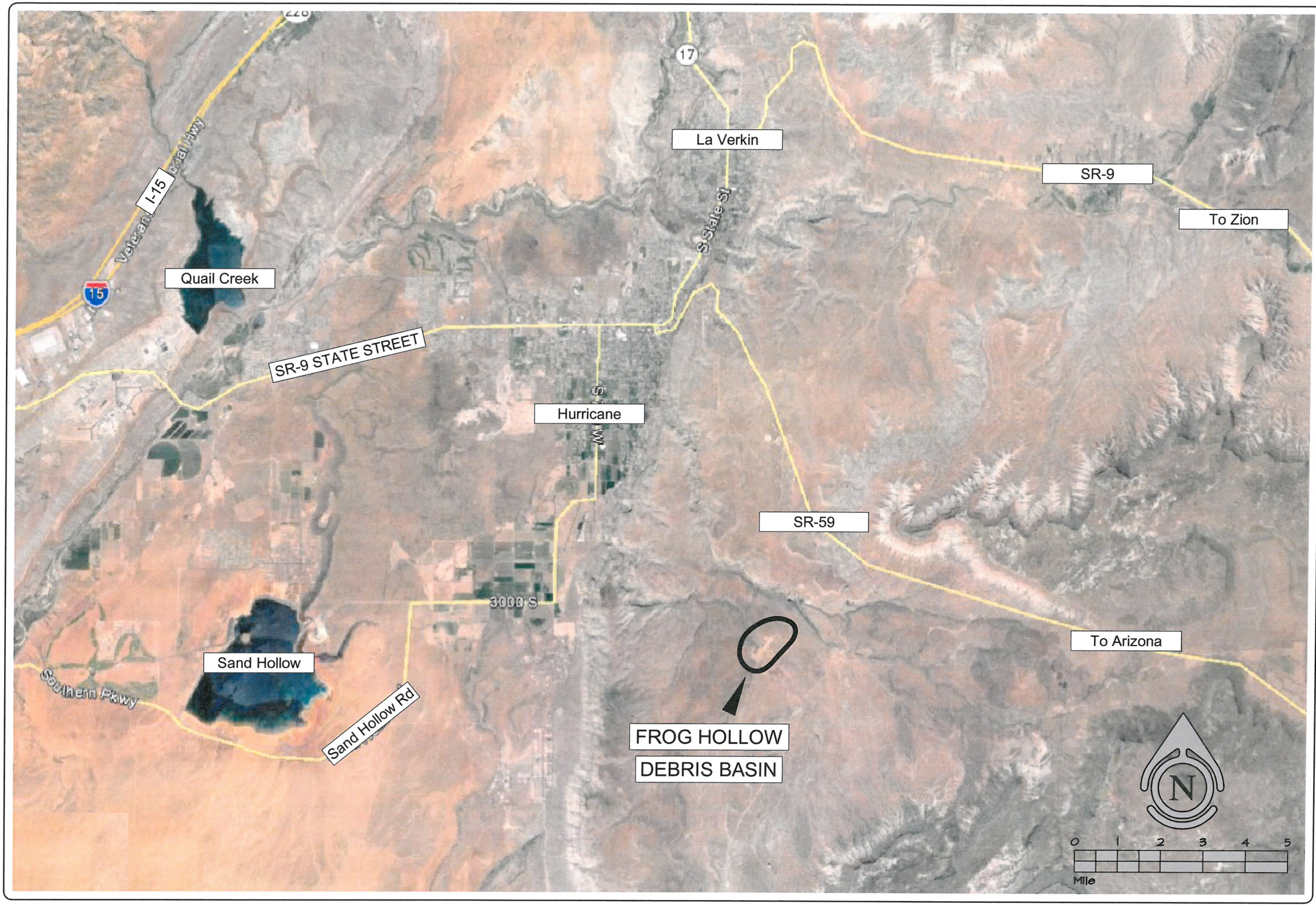
AERIAL PHOTOGRAPHS

SOURCE	DATE	FLIGHT	PHOTOGRAPHS	SCALE
Washington County, Utah*	1967	WT-67	125	1:24,000
UGS Aerial Imagery Collection**	10-22-1981	810941_AM	12-7, 12-8	1:24,000
	07-19-2000	BLM-24 UT-00-AC	1-19-08	1:24,000

*http://www.washco.utah.gov/assessor/archiveMaps.php
**https://geodata.geology.utah.gov/imagery



DATE: 12/10/2015
JOB NO.: 8364-14-008
DESIGNED BY: GLM
CHECKED BY: DRB
DWG: Vicinity Map

REVISIONS
DATE

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Ph (435) 673-8586 Fx (435) 673-8397 www.racivil.com

VICINITY MAP
FOR
FROG HOLLOW DAM REHABILITATION EVALUATION
WASHINGTON, UTAH

DRAWING
1

DATE: 12/10/2015
JOB NO: 8384-14-008
DESIGNED BY: GLM
CHECKED BY: DRB
DWG: HoleLocations

REVISIONS
DATE

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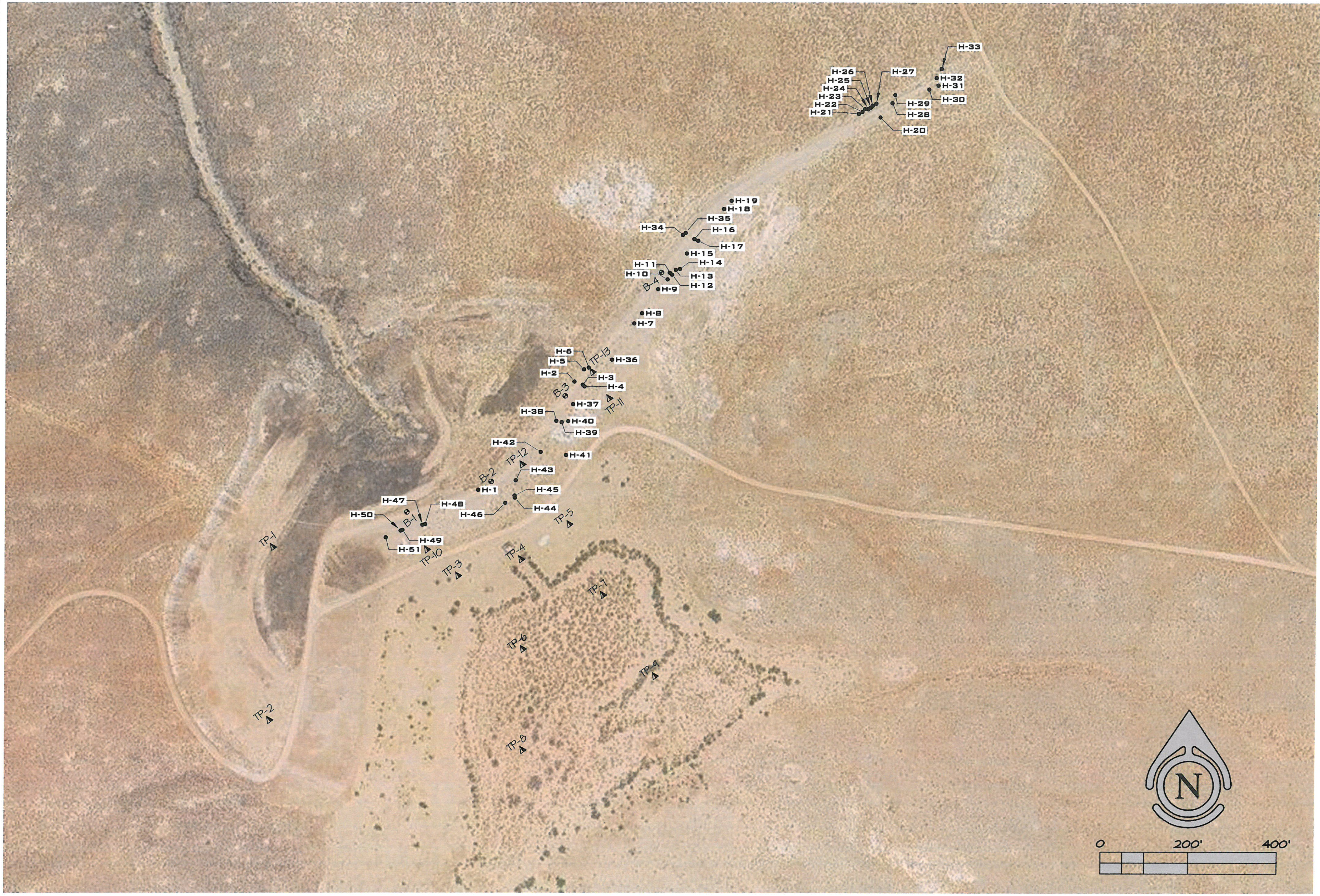
SITE PLAN / GEOTECHNICAL
FOR
FROG HOLLOW DAM REHABILITATION EVALUATION
WASHINGTON, UTAH

DRAWING
2



DATE: 12/10/2015
JOB NO.: 8384-14-008
DESIGNED BY: GLM
CHECKED BY: DRB
DWG: HoleLocations

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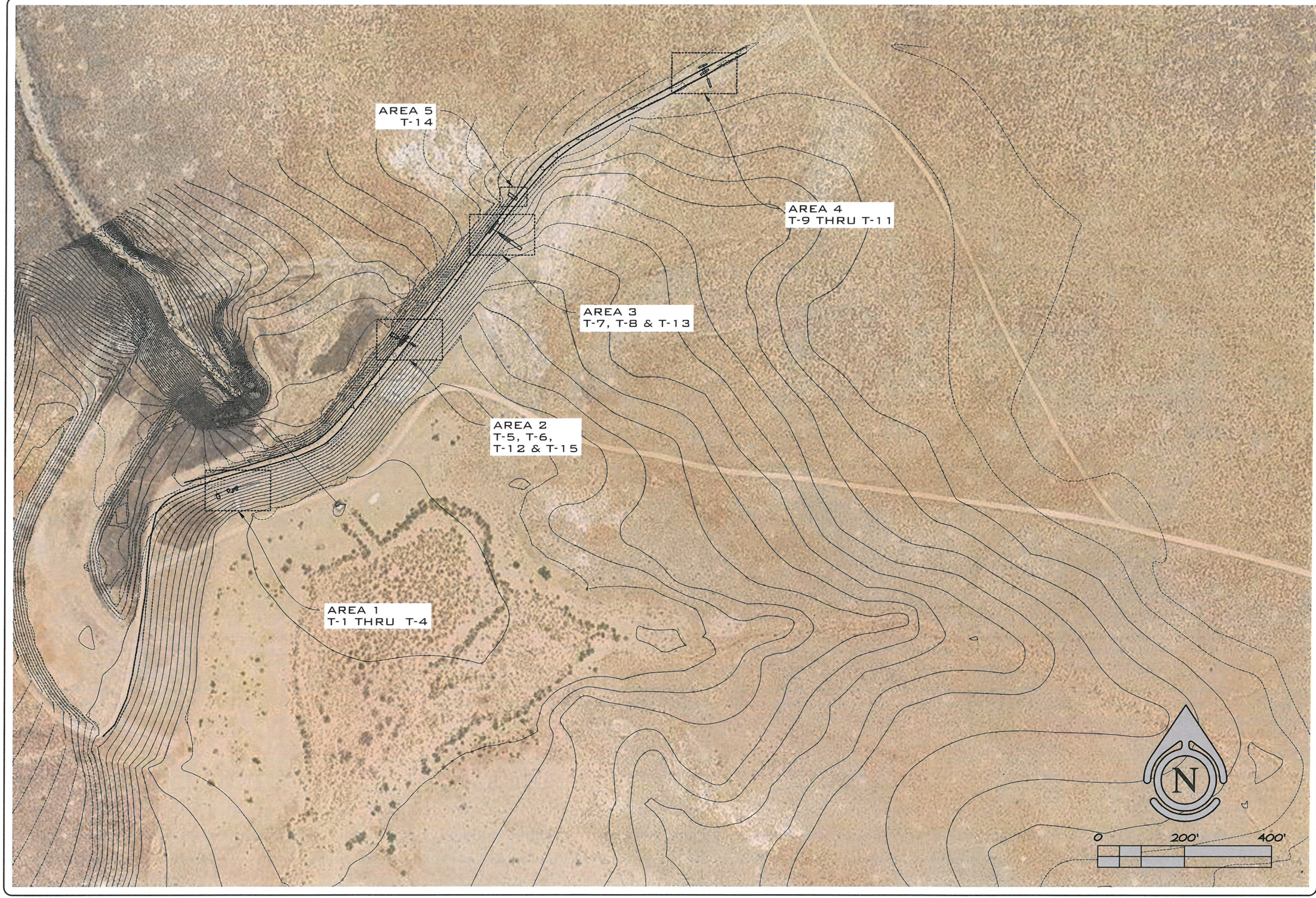
SINKHOLE LOCATION MAP
FOR
FROG HOLLOW DAM REHABILITATION EVALUATION
WASHINGTON, UTAH

DRAWING
3



DATE: 12/10/2015
JOB NO.: 8364-14-008
DESIGNED BY: GLM
CHECKED BY: DRB
DWG: TrenchandArea

REVISIONS
DATE

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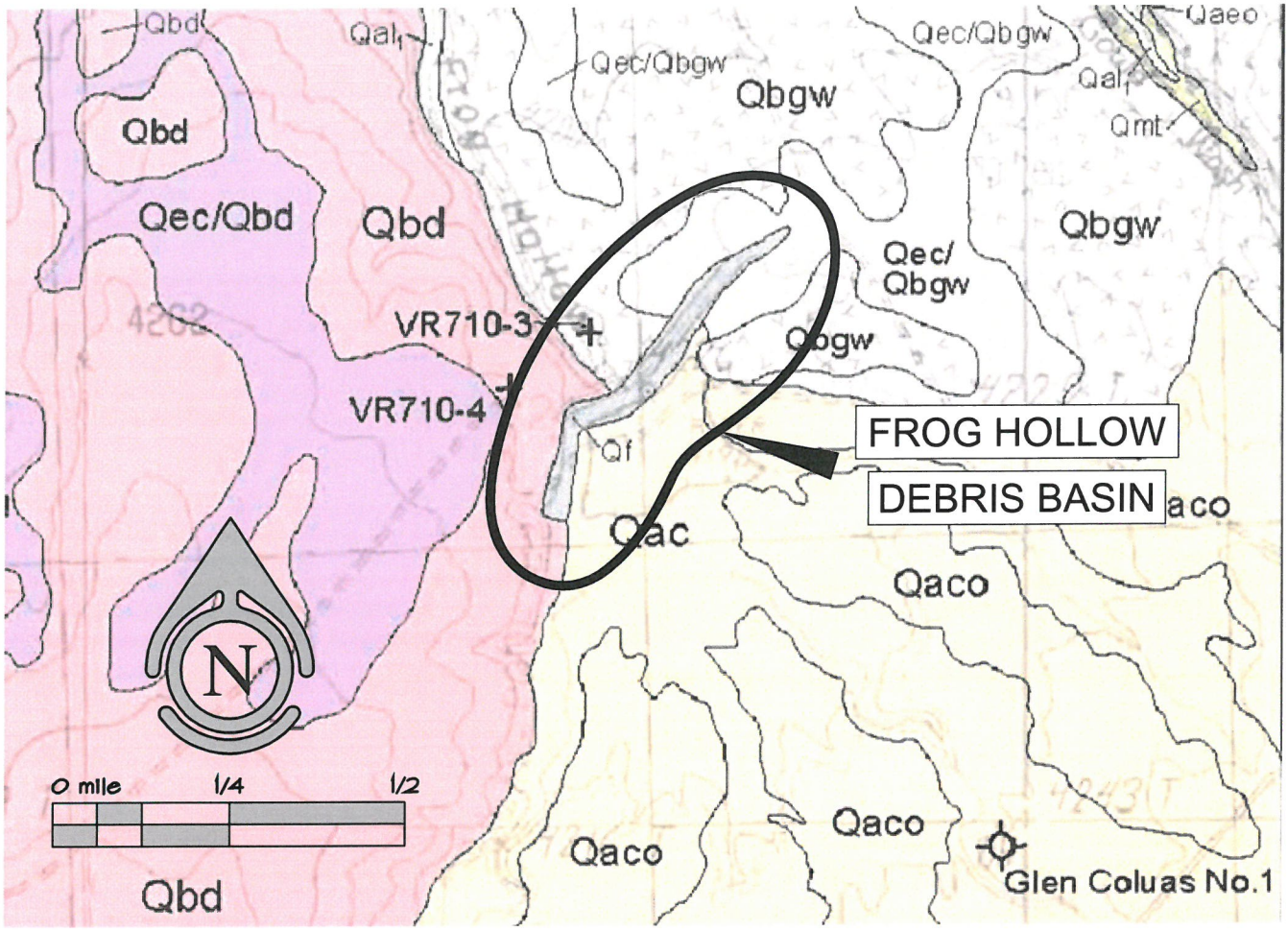
TRENCH AND AREA LOCATIONS
FOR
FROG HOLLOW DAM REHABILITATION EVALUATION
WASHINGTON, UTAH

DRAWING
4



Qf: Artificial-fill deposits (historical), engineered fill and general borrow material used to create small dams; thickness variable.

Qal1: Stream deposits, moderately to well-sorted clay to fine gravel deposits in large active drainages; includes terraces up to 10 feet (3 m) above active channels; 0 to 10 feet (0-3m) thick.

Qmt: Talus deposits (Holocene to upper Pleistocene), very poorly sorted, angular boulders with minor fine-grained interstitial materials; deposited on and at the base of steep slopes; 0 to 20 feet (0-6m) thick.

Qae/Qaeo: Mixed alluvial and eolian deposits (Holocene to upper Pleistocene), moderately to well-sorted, clay- to sand-sized alluvial sediment that locally includes abundant eolian sand and minor alluvial gravel; minor pedogenic carbonate development; Qae mapped in small valleys east of the Hurricane Cliffs and in Grass Valley; Qaeo forms deeply dissected deposit in Gould Wash; 0 to 30 feet (0-9m) thick.

Qac: Mixed alluvial and colluvial deposits (Holocene to upper Pleistocene), poorly to moderately sorted clay- to boulder-size sediment in minor drainages; gradational with colluvial deposits; Qac deposits are in active drainages and Qaco deposits are older and are dissected by active drainages; includes minor terraces too small to map separately; 0 to 10 feet (0-3m) thick.

Qbgw: Gould Wash basalt flow (middle Pleistocene), dark-gray, very fine-grained olivine basalt; abundant olivine phenocrysts; generally 20 to 30 feet (6-9 m) thick; yielded an 40Ar/ 39Ar age of 0.278 0.018 Ma (Downing, 2000); originated at cinder cone to the east in the Little Creek Mountain quadrangle; Qec/Qbgw indicates a veneer of eolian sand and pedogenic carbonate generally less than 3 feet (1m) thick that partly conceals underlying flow.

Qbd: The Divide basalt flow and cinder cones (middle Pleistocene), dark-gray, very fined-grained olivine basalt to borderline basanite; Qec/Qbd indicates a veneer of eolian sand and pedogenic carbonate generally less than 3 feet (1m) thick that partly conceals underlying flow.

Oil exploration test hole, plugged and abandoned, with name.

Geologic contact.

Sample location and number.

Ref: (Hayden, 2004)

DATE:	12/1/15
JOB NO.:	3384-14-008
DESIGNED BY:	GLM
CHECKED BY:	DRB
DWG:	Geologic

GENERAL GEOLOGIC MAP
FOR
FROG HOLLOW DAM EVALUATION
Washington County, Utah

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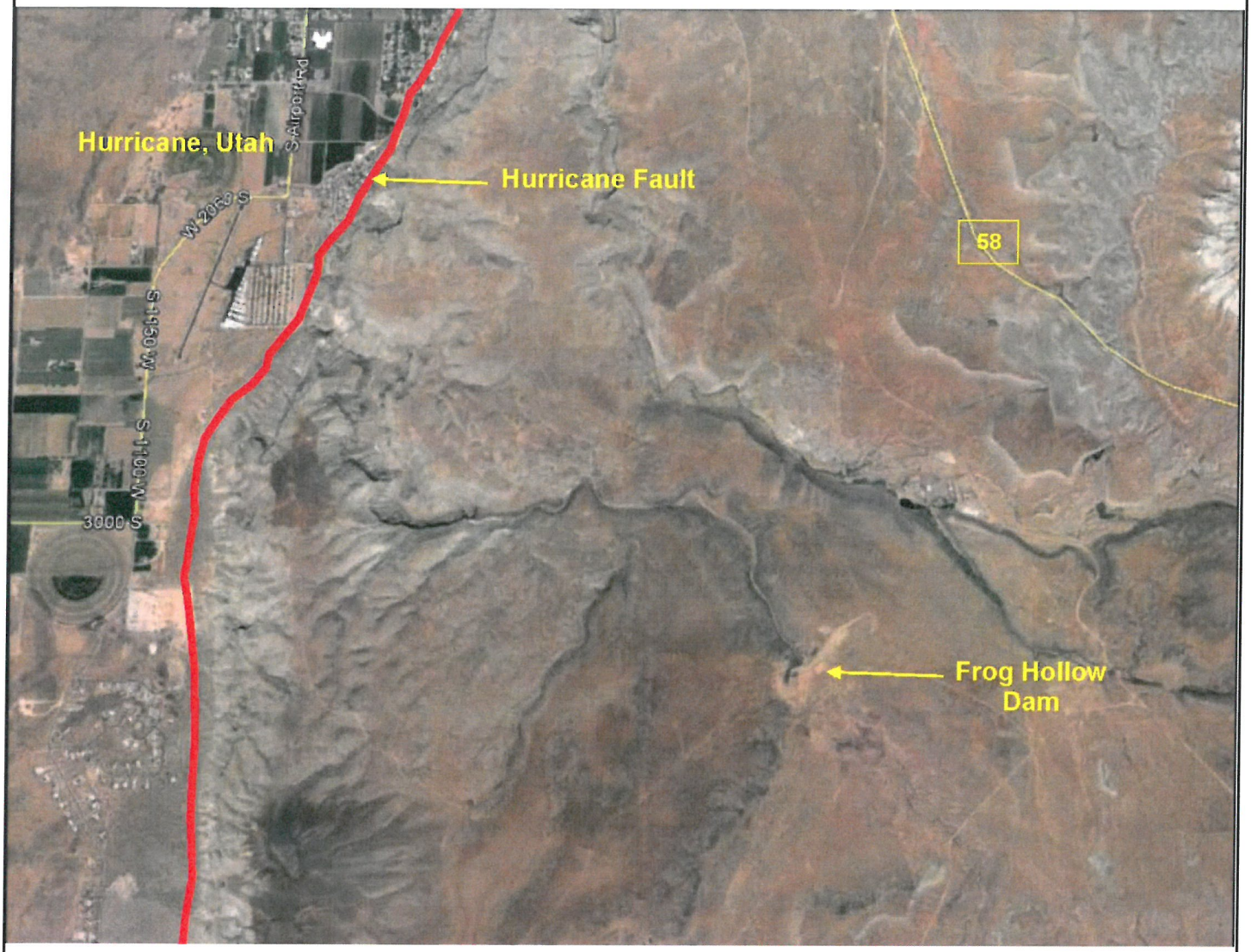
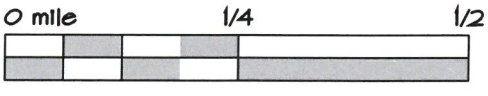
DRAWING
5





DATE:	12/1/15
JOB NO:	B384-14-008
DESIGNED BY:	GLM
CHECKED BY:	DRB
DWG:	Geologic

FAULT MAP
FOR
FROG HOLLOW DAM EVALUATION
Washington County, Utah

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DRAWING
6

APPENDIX A

GEOTECHNICAL FIELD INVESTIGATIONS

APPENDIX A

GEOTECHNICAL FIELD INVESTIGATIONS

The field investigation program consisted of drilling 4 exploratory borings to depths ranging from 28½ to 70 feet, and excavating 13 exploratory test pits to depths ranging from of about 2 to 16 feet, below the existing ground surface. The locations of the explorations are shown on the enclosed Exploration Locations/Site Plan (Drawing 2).

A Modified California ring sampler was used to collect soil samples from the borings at select intervals and depths. The Modified California sampler has a length of 18 inches, an O.D. of 3 inches, an I.D. of 2⅜ inches and is driven with 1-inch tall inner rings. Resistance to sampler penetration was recorded in the field as hammer blows required to drive the sampler through six-inch intervals. The blows required to drive the sampler through the six-inch intervals are recorded on the enclosed logs at the respective sample depths. The corrected number of blows per foot (for sampler type), are recorded on the logs in parenthesis below each sample.

Exploratory test pits were excavated with the aid of a rubber-tired backhoe. In-place moisture and density tests were conducted within the test pits that were located within the embankment at select intervals by using a nuclear density gauge method. The tests were performed by Geotechnical Testing Services (a sub-consultant to Rosenberg Associates). Representative bulk samples were collected from the test pits at select intervals. The excavated materials were replaced, moisture conditioned, and compacted with a wheel compactor in approximate 1-foot lifts.

Samples obtained from the explorations were packaged, labeled, and transported to the laboratory for further evaluation and testing. Continuous logs of the subsurface conditions encountered in the explorations were recorded by our field engineer who was supervised by a professional geologist (Mr. David Simon, P.G. of Simon Associates, LLC, a sub-consultant to Rosenberg Associates). The subgrade soils were visually classified in accordance with the Unified Soil Classification System (ASTM Method D 2488). Color designations follow standard Munsell Soil Color notations. Summaries of subsurface conditions are presented in this appendix on Drawings No. A-1 through A-25. A key to the soil symbols and terms is found on Drawing No. A-26.

Log of Boring No. B – 1

Date Drilled: 9/17/15 Logged By: JTT Ground Surface Elevation: _____

DEPTH (m)	DEPTH (ft.)	GRAPHIC LOG	SUMMARY OF SUBSURFACE CONDITIONS	TIME	SAMPLE	BLOWS	MOISTURE	DRIVEN (in)	RECOVERY (in)	MOISTURE (%)	DRY UNIT WT. (pcf)
			The following is a summary of subsurface conditions encountered at the time of exploration. Subsurface conditions may differ at other locations and may vary at this location with the passage of time. The data contained in this log is a simplification of actual conditions.								
			ZONE I EMBANKMENT FILL: CLAYEY SILT (CL-ML/A-4) Red Brown 5YR 4/4, With Sand, Trace Gypsum			10 18 20 (29)	Dry	18	14	5.3	116
	2		--Yellow Red 5YR 5/6			11 19 27 (35)		18	16	5.2	120
	4		--SILTY CLAY (CL/A-4) Red Brown 5YR 4/4, Trace Gravel, Some Sand, Occasional Cobbles			15 27 50 (59)	Slightly Moist	17	15	10.2	124
2	6		--CLAYEY SILT (CL-ML/A-4) Brown 7.5YR 4/4, Some Sand, Trace Organics, Trace Gypsum			28 30 50 (62)		17		6.3	122
	8					18 39 40 (61)		18	16	7.4	127
	10										
	12		--Yellow Red 5YR 4/6			15 20 28 (37)		18	14	8.3	123
4	14		--SILTY CLAY (CL/A-4) Trace Organics, Trace Sand, Trace Gypsum			5 20 50 (54)		17	15	16.8	110
	16										
	18		--CLAYEY SILT (CL-ML/A-4) Red Brown 5YR 5/4, Some Sand, Trace Gypsum			8 16 48 (49)		18	16	9.5	130
6											

APPROVED BY _____ ON _____

Groundwater: NE Driving Weight & Drop: 140 lbs / 30 inch End of Boring at 70 Feet

Project Title: Frog Hollow Detention Basin

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Project No. 8384-14-008

Drawing No. A-1

Log of Boring No. B – 1 cont.

Date Drilled: 9/17/15 Logged By: JTT Ground Surface Elevation: _____

DEPTH (m)	DEPTH (ft.)	GRAPHIC LOG	SUMMARY OF SUBSURFACE CONDITIONS	TIME	SAMPLE	BLOWS	MOISTURE	DRIVEN (in)	RECOVERY (in)	MOISTURE (%)	DRY UNIT WT. (pcf)
			The following is a summary of subsurface conditions encountered at the time of exploration. Subsurface conditions may differ at other locations and may vary at this location with the passage of time. The data contained in this log is a simplification of actual conditions.								
			ZONE I EMBANKMENT FILL: CLAYEY SILT (CL-ML/A-4) Red Brown 5YR 5/4, Trace Sand, Trace Gypsum			10 28 28 (43)	Slightly Moist	18	14	6.4	125
	22		OLD EMBANKMENT FILL: SILTY CLAY (CL/A-4) Brown 7YR 4/3, Some Sand, Trace Gypsum			7 17 42 (45)		18	16	8.1	122
	24										
	26					11 35 49 (65)		18	16	16.8	107
8			--Trace Gravel								
	28					12 21 38 (45)		18		9.9	119
	30					8 21 50 (55)		15	14	9.4	117
	32		--With Gravel, Occasional Cobbles								
10						22 32 26 (45)		18	17	8.7	107
	34		--Water Added During Drilling								
	36					8 9 19 (22)		18		11.5	116
	38					18 32 36 (52)		18	14	6.5	114
12											

APPROVED BY _____ ON _____

Groundwater: NE Driving Weight & Drop: 140 lbs / 30 inch End of Boring at 70 Feet

Project Title: Frog Hollow Detention Basin

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Project No. 8384-14-008

Drawing No. A-2

Log of Boring No. B – 1 cont.

Date Drilled: 9/17/15 Logged By: JTT Ground Surface Elevation: _____

DEPTH (m)	DEPTH (ft.)	GRAPHIC LOG	SUMMARY OF SUBSURFACE CONDITIONS	TIME	SAMPLE	BLOWS	MOISTURE	DRIVEN (in)	RECOVERY (in)	MOISTURE (%)	DRY UNIT WT. (pcf)
			The following is a summary of subsurface conditions encountered at the time of exploration. Subsurface conditions may differ at other locations and may vary at this location with the passage of time. The data contained in this log is a simplification of actual conditions.								
	42		OLD EMBANKMENT FILL: SILTY CLAY (CL/A-4) Brown 7YR 4/3, Some Sand, Trace Gypsum, With Gravel, Occasional Cobbles			22 29 22 (39)	Slightly Moist	18	NR		
	44					10 15 22 (28)		18	16		
14	46		FOUNDATION MATERIAL: BASALT - Light Gray, Lightly Fractured, Highly Weathered, With CLAYEY SILT (CL-ML) Infilling				Dry				
	48					Refusal					
	50		--Switch to Coring, Less Weathered			Refusal					
	52			0'			RQD (%) 11.7	60	18		
16	54		--Highly Vesicular, Gray, Harder Drilling	13'							
			--Change to Odex Drilling	0'							
	56						RQD (%) 45.0	60	38		
	58		CLAYEY SILT (CL-ML) Light Brown 7.5YR 6/4, Very Stiff	23'							
18											

APPROVED BY ON

Groundwater: NE Driving Weight & Drop: 140 lbs / 30 inch End of Boring at 70 Feet

Project Title: Frog Hollow Detention Basin

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Project No. 8384-14-008

Drawing No. A-3

Log of Boring No. B – 1 cont.

Date Drilled: 9/17/15 Logged By: JTT Ground Surface Elevation: _____

DEPTH (m)	DEPTH (ft.)	GRAPHIC LOG	SUMMARY OF SUBSURFACE CONDITIONS	TIME	SAMPLE/CORE	BLOWS	MOISTURE	DRIVEN (in)	RECOVERY (in)	MOISTURE (%)	DRY UNIT WT. (pcf)
	62		CLAYEY SILT (CL-ML) Light Brown 7.5YR 6/4, Very Stiff			29 50 for5"	Slightly Moist			14.3	119
	64		BASALT - Gray, Fractured With CLAYEY SILT (CL-ML) Infilling				Dry				
20	66										
	68					50 for2"					
			CLAYEY SILT (CL-ML) With Basalt Cobbles			50 for5"					
	70		BASALT - Gray, Fractured								
			End of Boring at 70'								
	72										
22	74										
	76										
	78										
24											

APPROVED BY ON

Groundwater: NE Driving Weight & Drop: 140 lbs / 30 inch End of Boring at 70 Feet

Project Title: Frog Hollow Detention Basin

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Project No. 8384-14-008

Drawing No. A-4

Log of Boring No. B – 2

Date Drilled: 9/16/15 Logged By: JTT Ground Surface Elevation: _____

DEPTH (m)	DEPTH (ft.)	GRAPHIC LOG	SUMMARY OF SUBSURFACE CONDITIONS	TIME	SAMPLE	BLOWS	MOISTURE	DRIVEN (in)	RECOVERY (in)	MOISTURE (%)	DRY UNIT WT. (pcf)
			The following is a summary of subsurface conditions encountered at the time of exploration. Subsurface conditions may differ at other locations and may vary at this location with the passage of time. The data contained in this log is a simplification of actual conditions.								
			ZONE I EMBANKMENT FILL: CLAYEY SILT (CL-ML/A-4) Yellow Red 7.5YR 6/6, Some Sand, Trace Gypsum			25 35 60 (73)	Dry	18	16	4.4	121
	2										
	4		--SANDY SILT (ML/A-4) Trace Gravel, Trace Gypsum			23 48 50 for3"		16	12	4.0	116
2	6		--CLAYEY SILT (CL-ML/A-4) Red Brown 5YR 6/4, Trace Gravel, Some Sand, Trace Gypsum			50 50 for5"		11	9	3.5	121
	8										
	10					23 50 for6"	Slightly Moist	9	9	4.8	
	12		--SILTY CLAY (CL/A-6) Red Brown 5YR 5/4, Trace Gravel, With Sand, Trace Gypsum			20 36 48 (65)		18	14	9.0	120
4	14					25 40 50 (69)		17	13	5.2	123
	16										
	18		OLD EMBANKMENT FILL: CLAYEY SAND (SC/A-4) Red Brown 2.5YR 4/4, With Gravel, Trace Gypsum			35 50		11	8	2.7	121
6			--SANDY CLAY (CL/A-4) Red Brown 2.5YR 4/4, Trace Gravel, Trace Gypsum			13 39		18	14	6.4	127

APPROVED BY ON

Groundwater: NE Driving Weight & Drop: 140 lbs / 30 inch End of Boring at 55.5 Feet

Project Title: Frog Hollow Detention Basin

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Project No. 8384-14-008

Drawing No. A-5

Log of Boring No. B – 2 cont.

Date Drilled: 9/16/15 Logged By: JTT Ground Surface Elevation: _____

DEPTH (m)	DEPTH (ft.)	GRAPHIC LOG	SUMMARY OF SUBSURFACE CONDITIONS	TIME	SAMPLE	BLOWS	MOISTURE	DRIVEN (in)	RECOVERY (in)	MOISTURE (%)	DRY UNIT WT. (pcf)
			The following is a summary of subsurface conditions encountered at the time of exploration. Subsurface conditions may differ at other locations and may vary at this location with the passage of time. The data contained in this log is a simplification of actual conditions.								
			OLD EMBANKMENT FILL: SANDY CLAY (CL/A-4) Red Brown 2.5YR 4/4, Trace Gravel, Trace Gypsum			48 (67)	Slightly Moist				
	22					25 50		11	10	10.6	110
	24					37 50		10	9	5.4	128
	26										
8			--SILTY CLAY (CL/A-4), Brown 7.5YR 4/3, Trace Sand, Trace Gypsum, Trace Organics			21 42 50		16	14	6.6	123
	28										
	30					16 30 50		18	16	13.4	117
	32					8 23 27 (39)		18	16	10.6	116
10											
	34					13 21 38 (45)		18	14	8.8	124
	36										
			--Some Sand, With Gravel			13 27 43 (54)		18	12	8.5	125
	38										
12						10 30		18		8.2	118

APPROVED BY ON

Groundwater: NE , Driving Weight & Drop: 140 lbs / 30 inch End of Boring at 55.5 Feet

Project Title: Frog Hollow Detention Basin

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Project No. 8384-14-008

Drawing No. A-6

Log of Boring No. B – 2 cont.

Date Drilled: 9/16/15 Logged By: JTT Ground Surface Elevation: _____

DEPTH (m)	DEPTH (ft.)	GRAPHIC LOG	SUMMARY OF SUBSURFACE CONDITIONS	TIME	SAMPLE	BLOWS	MOISTURE	DRIVEN (in)	RECOVERY (in)	MOISTURE (%)	DRY UNIT WT. (pcf)
			The following is a summary of subsurface conditions encountered at the time of exploration. Subsurface conditions may differ at other locations and may vary at this location with the passage of time. The data contained in this log is a simplification of actual conditions.								
	42		FOUNDATION MATERIAL: BASALT - Light Gray, Highly Fractured, Highly Weathered, With CLAYEY SILT (CL-ML) Infilling			42 (55) 11 32 50	Dry	16	12	9.9	100
	44					44 50		9	9	7.0	109
			--Switch to Core								
14	46		--Highly Vesicular, More Massive, Less Weathered, Fractured With CLAYEY SILT (CL-ML) Infilling	0' 30'			RQD (%) 30	60	60		
	48										
	50										
	52			0' 36'			RQD (%) 0	60	48		
16	54										
	56										
	58										
18											

APPROVED BY _____ ON _____

Groundwater: NE Driving Weight & Drop: 140 lbs / 30 inch End of Boring at 55.5 Feet

Project Title: Frog Hollow Detention Basin

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Project No. 8384-14-008

Drawing No. A-7

Log of Boring No. B – 3

Date Drilled: 9/14/15 Logged By: JTT Ground Surface Elevation: _____

DEPTH (m)	DEPTH (ft.)	GRAPHIC LOG	SUMMARY OF SUBSURFACE CONDITIONS	TIME	SAMPLE	BLOWS	MOISTURE	DRIVEN (in)	RECOVERY (in)	MOISTURE (%)	DRY UNIT WT. (pcf)
			The following is a summary of subsurface conditions encountered at the time of exploration. Subsurface conditions may differ at other locations and may vary at this location with the passage of time. The data contained in this log is a simplification of actual conditions.								
			ZONE I EMBANKMENT FILL: CLAYEY SILT (CL-ML/A-4) Dull Orange 7.5YR 7/4, Some Sand, Trace Gravel, Trace Gypsum			50 for 4"	Dry	4	4	3.1	90
	2					50		0	NR		
	4		--Yellow Red 5YR 4/6			50		6	5	5.4	87
2	6		--SILTY CLAY (CL/A-4) Dark Red Brown 5YR 3/4, With Sand, Trace Gravel, Trace Gypsum			50	Slightly Moist	5	5	10.9	108
	8										
	10					40 50		11	10	5.3	117
	12										
4			--Water Added During Drilling			47 50		11	11	5.2	115
	14										
			--Increasing Gravel			50		2	2	8.5	88
	16										
	18		--OLD EMBANKMENT: SILTY CLAY (CL/A-4) Yellow Red 5YR 4/6, With Sand, With Gravel, Trace Cobbles, Trace Gypsum			50		5		9.8	109
6											

APPROVED BY ON

Groundwater: NE Driving Weight & Drop: 140 lbs / 30 inch End of Boring at 49.5 Feet

Project Title: Frog Hollow Detention Basin

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Project No. 8384-14-008

Drawing No. A-8

Log of Boring No. B – 3 cont.

Date Drilled: 9/14/15 Logged By: JTT Ground Surface Elevation: _____

DEPTH (m)	DEPTH (ft.)	GRAPHIC LOG	SUMMARY OF SUBSURFACE CONDITIONS	TIME	SAMPLE	BLOWS	MOISTURE	DRIVEN (in)	RECOVERY (in)	MOISTURE (%)	DRY UNIT WT. (pcf)
			The following is a summary of subsurface conditions encountered at the time of exploration. Subsurface conditions may differ at other locations and may vary at this location with the passage of time. The data contained in this log is a simplification of actual conditions.								
	22		OLD EMBANKMENT: SILTY CLAY (CL/A-4) Yellow Red 5YR 4/6, With Gravel, With Sand, Trace Cobbles, Trace Gypsum			50	Slightly Moist	5	4	8.6	93
	24					50		5	5	7.3	105
			FOUNDATION MATERIAL: BASALT - Light Gray, Highly Fractured, Highly Weathered, With CLAYEY SILT (ML) Infilling			50	Dry	1	NR		
8	26										
	28										
	30		--Soil Infilling (6" Thick)								
	32		--Soil Infilling								
10											
	34		--Soil Infilling								
	36		--Soil Infilling								
	38		--Soil Infilling BASALT - Gray, with Visible Black Crystals (Presumably Pyroxene), Massive, Slightly Vesicular, Slightly Weathered, Fractured								
12											

Groundwater: NE Driving Weight & Drop: 140 lbs / 30 inch End of Boring at 49.5 Feet

APPROVED BY ON

Project Title: Frog Hollow Detention Basin

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Project No. 8384-14-008

Drawing No. A-9

Log of Boring No. B – 3 cont.

Date Drilled: 9/14/15 Logged By: JTT Ground Surface Elevation: _____

DEPTH (m)	DEPTH (Ft.)	GRAPHIC LOG	SUMMARY OF SUBSURFACE CONDITIONS	TIME	SAMPLE	BLOWS	MOISTURE	DRIVEN (in)	RECOVERY (in)	MOISTURE (%)	DRY UNIT WT. (pcf)
			The following is a summary of subsurface conditions encountered at the time of exploration. Subsurface conditions may differ at other locations and may vary at this location with the passage of time. The data contained in this log is a simplification of actual conditions.								
	42		BASALT - Gray, with Visible Black Crystals (Presumably Pyroxene), Massive, Slightly Vesicular, Less Weathered, Fractured	0'			RQD (%) 68	60	59		
	44			75'							
14	46			0'			RQD (%) 74	54	49		
	48			56'							
	50										
	52										
16	54										
	56										
	58										
18											

APPROVED BY ON

Groundwater: NE Driving Weight & Drop: 140 lbs / 30 inch End of Boring at 49.5 Feet

Project Title: Frog Hollow Detention Basin

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Project No. 8384-14-008

Drawing No. A-10

Log of Boring No. B – 4

Date Drilled: 9/17/15 Logged By: JTT Ground Surface Elevation: _____

DEPTH (m)	DEPTH (ft.)	GRAPHIC LOG	SUMMARY OF SUBSURFACE CONDITIONS	TIME	SAMPLE	BLOWS	MOISTURE	DRIVEN (in)	RECOVERY (in)	MOISTURE (%)	DRY UNIT WT. (pcf)
			The following is a summary of subsurface conditions encountered at the time of exploration. Subsurface conditions may differ at other locations and may vary at this location with the passage of time. The data contained in this log is a simplification of actual conditions.								
			ZONE I EMBANKMENT FILL: SILTY CLAY (CL/A-4) Light Red Brown 5YR 6/4, Trace Sand, Trace Gypsum			11 19 32 (39)	Dry	18	16	1.2	113
	2					39 50		10	9	3.0	114
	4										
			--(CL/A-6), Trace Gravel			20 38 50 (68)		17	15	5.1	118
2	6										
	8					15 38 41 (61)	Slightly Moist	18		6.6	121
	10					7 30 48 (60)		18	16	6.1	120
	12		--SANDY CLAY (CL/A-4) Brown 7.5YR 4/4, Trace Gravel, Trace Gypsum			8 32 50		17	16	7.6	126
4	14		--With Gravel			18 46 50		16	12	8.2	123
	16		--Red Brown 5YR 4/4, With Cobbles			15 33 50		17	14	8.3	126
	18										
6											

APPROVED BY _____ ON _____

Groundwater: NE Driving Weight & Drop: 140 lbs / 30 inch End of Boring at 28.5 Feet

Project Title: Frog Hollow Detention Basin

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Project No. 8384-14-008

Drawing No. A-11

Log of Boring No. B – 4 cont.

Date Drilled: 9/17/15 Logged By: JTT Ground Surface Elevation: _____

DEPTH (m)	DEPTH (Ft.)	GRAPHIC LOG	SUMMARY OF SUBSURFACE CONDITIONS	TIME	SAMPLE	BLOWS	MOISTURE	DRIVEN (in)	RECOVERY (in)	MOISTURE (%)	DRY UNIT WT. (pcf)
			The following is a summary of subsurface conditions encountered at the time of exploration. Subsurface conditions may differ at other locations and may vary at this location with the passage of time. The data contained in this log is a simplification of actual conditions.								
			ZONE I EMBANKMENT FILL: SANDY CLAY (CL/A-4) Brown 7.5YR 4/4			23 50	Slightly Moist	9	6	7.1	106
	22		--Sand and Gravel With Fractured Basalt, Trace Clay, Light Red Brown 5YR 6/4			50		4	NR	0.5	
				0'							
	24		BASALT - Gray, Highly Vesicular, Weathered, Highly Fractured, With CLAYEY SILT (CL-ML) Infilling				RQD (%)				
8	26						0	60	36		
	28		--Soil Infilling	17'							
						15		9	6		
						Refusal					
	30										
	32										
10											
	34										
	36										
	38										
12											

APPROVED BY _____ ON _____

Groundwater: NE Driving Weight & Drop: 140 lbs / 30 inch End of Boring at 28.5 Feet

Project Title: Frog Hollow Detention Basin

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Project No. 8384-14-008

Drawing No. A-12

Log of Trench No. T-P-1

Date Trenched: 9/23/15

Logged By: GLM

Ground Surface Elevation: _____

DEPTH (m)	DEPTH (ft.)	GRAPHIC LOG	SUMMARY OF SUBSURFACE CONDITIONS The following is a summary of subsurface conditions encountered at the time of exploration. Subsurface conditions may differ at other locations and may vary at this location with the passage of time. The data contained in this log is a simplification of actual conditions.	DRIVE	BULK	MOISTURE	CONSISTENCY	FIELD MOISTURE (%)	FIELD DENSITY (pcf)
			FILL: CLAYEY SILT (CL-ML/A-4) Brown, With Basalt Gravel and Cobbles			Slightly Moist			
	2		Refusal with Backhoe at 2' on Basalt						
1	4								
	6								
2									
	8								
3	10								
	12								
4									
	14								

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Groundwater: NE

End of Trench at 2 Feet

Project Title: Frog Hollow Detention Basin

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Project No. 8384-14-008

Drawing No. A-13

Log of Trench No. T-P-2

Date Trenched: 9/23/15

Logged By: GLM

Ground Surface Elevation: _____

DEPTH (m)	DEPTH (ft.)	GRAPHIC LOG	SUMMARY OF SUBSURFACE CONDITIONS The following is a summary of subsurface conditions encountered at the time of exploration. Subsurface conditions may differ at other locations and may vary at this location with the passage of time. The data contained in this log is a simplification of actual conditions.	DRIVE	BULK	MOISTURE	CONSISTENCY	FIELD MOISTURE (%)	FIELD DENSITY (pcf)
0	0		EMBANKMENT FILL: CLAYEY SILT (CL-ML/A-4) Brown, Some Sand, With Basalt Gravel and Cobbles (Disturbed)			Dry to Slightly Moist			
0.5	2		--More Basalt Cobbles with Depth						
1	4								
2	6		Refusal at 5' on Basalt						
2.5	8								
3	10								
3.5	12								
4	14								

APPROVED BY ON

Groundwater: NE

End of Trench at 5 Feet

Project Title: Frog Hollow Detention Basin

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Project No. 8384-14-008

Drawing No. A-14

Log of Trench No. T-P-3

Date Trenched: 9/23/15

Logged By: GLM

Ground Surface Elevation: _____

DEPTH (m)	DEPTH (ft.)	GRAPHIC LOG	SUMMARY OF SUBSURFACE CONDITIONS The following is a summary of subsurface conditions encountered at the time of exploration. Subsurface conditions may differ at other locations and may vary at this location with the passage of time. The data contained in this log is a simplification of actual conditions.	DRIVE	BULK	MOISTURE	CONSISTENCY	FIELD MOISTURE (%)	FIELD DENSITY (pcf)
	2		SILTY CLAY (CL/A-4) Brown, Porous Trace Sand, With Roots to 2', Trace Gypsum			Slightly Moist	Soft	2.9	75
1	4							2.5	80
	6								
2	8								
3	10								
	12								
4	14								
	15								
	16								

APPROVED BY ON

Groundwater: NE

End of Trench at 16 Feet

Project Title: Frog Hollow Detention Basin

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Project No. 8384-14-008

Drawing No. A-15

Log of Trench No. T-P-4

Date Trenched: 9/23/15

Logged By: GLM

Ground Surface Elevation: _____

DEPTH (m)	DEPTH (ft.)	GRAPHIC LOG	SUMMARY OF SUBSURFACE CONDITIONS The following is a summary of subsurface conditions encountered at the time of exploration. Subsurface conditions may differ at other locations and may vary at this location with the passage of time. The data contained in this log is a simplification of actual conditions.	DRIVE	BULK	MOISTURE	CONSISTENCY	FIELD MOISTURE (%)	FIELD DENSITY (pcf)
1	2		CLAYEY SILT (CL-ML/A-4) Brown, Trace Sand, Porous, Trace Gypsum, With Roots to 5'			Slightly Moist	Soft	2.9	79
	4							1.5	77
2	6								
	8		--With Gypsum						
3	10								
	12								
4	14								

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Groundwater: NE

End of Trench at 9 Feet

Project Title: Frog Hollow Detention Basin

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Project No. 8384-14-008

Drawing No. A-16

Log of Trench No. T-P-5

Date Trenched: 9/23/15

Logged By: GLM

Ground Surface Elevation: _____

DEPTH (m)	DEPTH (ft.)	GRAPHIC LOG	SUMMARY OF SUBSURFACE CONDITIONS The following is a summary of subsurface conditions encountered at the time of exploration. Subsurface conditions may differ at other locations and may vary at this location with the passage of time. The data contained in this log is a simplification of actual conditions.	DRIVE	BULK	MOISTURE	CONSISTENCY	FIELD MOISTURE (%)	FIELD DENSITY (pcf)
			SILTY CLAY (CL-ML/A-4) Brown, Trace Sand, Trace Gypsum			Slightly Moist	Soft		
1	2								
	4								
			--With Gypsum						
2	6								
	8								
3	10								
	12								
4									
	14								

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Groundwater: NE

End of Trench at 8 Feet

Project Title: Frog Hollow Detention Basin

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Project No. 8384-14-008

Drawing No. A-17

Log of Trench No. T-P-6

Date Trenched: 9/23/15

Logged By: GLM

Ground Surface Elevation: _____

DEPTH (m)	DEPTH (ft.)	GRAPHIC LOG	SUMMARY OF SUBSURFACE CONDITIONS The following is a summary of subsurface conditions encountered at the time of exploration. Subsurface conditions may differ at other locations and may vary at this location with the passage of time. The data contained in this log is a simplification of actual conditions.	DRIVE	BULK	MOISTURE	CONSISTENCY	FIELD MOISTURE (%)	FIELD DENSITY (pcf)
1	2		CLAYEY SILT (CL-ML/A-4) Brown, Porous, Trace Sand, Trace Gypsum, With Roots to 3'			Slightly Moist	Soft	2.9	77
2	4								
	6								
	8								
3	10								
4	12								
	14								

APPROVED BY _____ ON _____

Groundwater: NE

End of Trench at 11 Feet

Project Title: Frog Hollow Detention Basin

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Project No. 8384-14-008

Drawing No. A-18

Log of Trench No. T-P-7

Date Trenched: 9/23/15

Logged By: GLM

Ground Surface Elevation: _____

DEPTH (m)	DEPTH (ft.)	GRAPHIC LOG	SUMMARY OF SUBSURFACE CONDITIONS The following is a summary of subsurface conditions encountered at the time of exploration. Subsurface conditions may differ at other locations and may vary at this location with the passage of time. The data contained in this log is a simplification of actual conditions.	DRIVE	BULK	MOISTURE	CONSISTENCY	FIELD MOISTURE (%)	FIELD DENSITY (pcf)
1	2		CLAYEY SILT (CL-ML/A-4) Brown, Slightly Porous, Trace Sand, Trace Gypsum, With Roots to 3'			Slightly Moist	Soft	3.3	80
	4								
2	6								
	8								
3	10								
	12								
4	14								

APPROVED BY _____ ON _____

Groundwater: NE

End of Trench at 11 Feet

Project Title: Frog Hollow Detention Basin

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Project No. 8384-14-008

Drawing No. A-19

Log of Trench No. T-P-8

Date Trenched: 9/23/15

Logged By: GLM

Ground Surface Elevation: _____

DEPTH (m)	DEPTH (ft.)	GRAPHIC LOG	SUMMARY OF SUBSURFACE CONDITIONS The following is a summary of subsurface conditions encountered at the time of exploration. Subsurface conditions may differ at other locations and may vary at this location with the passage of time. The data contained in this log is a simplification of actual conditions.	DRIVE	BULK	MOISTURE	CONSISTENCY	FIELD MOISTURE (%)	FIELD DENSITY (pcf)
0	0		SILTY CLAY (CL/A-4) Brown, Slightly Porous, Trace Sand, Trace Gypsum, With Roots to 4'			Slightly Moist	Soft		
1	2								
	4								
2	6								
	8								
3	10								
	12								
4	14								

APPROVED BY _____ ON _____

Groundwater: NE

End of Trench at 10 Feet

Project Title: Frog Hollow Detention Basin

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Project No. 8384-14-008

Drawing No. A-20

Log of Trench No. T-P-9

Date Trenched: 9/23/15

Logged By: GLM

Ground Surface Elevation: _____

DEPTH (m)	DEPTH (ft.)	GRAPHIC LOG	SUMMARY OF SUBSURFACE CONDITIONS	DRIVE	BULK	MOISTURE	CONSISTENCY	FIELD MOISTURE (%)	FIELD DENSITY (pcf)
			The following is a summary of subsurface conditions encountered at the time of exploration. Subsurface conditions may differ at other locations and may vary at this location with the passage of time. The data contained in this log is a simplification of actual conditions.						
			SILTY CLAY (CL/A-4) Brown, Slightly Porous, Trace Sand, Trace Gypsum, With Roots to 3'			Slightly Moist	Soft		
	2					Moist		11.0	76
1	4								
	6								
2			--With Gypsum						
	8								
3	10								
	12								
4									
	14								

APPROVED BY ON

Groundwater: NE

End of Trench at 10 Feet

Project Title: Frog Hollow Detention Basin

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Project No. 8384-14-008

Drawing No. A-21

Log of Trench No. T-P-10

Date Trenched: 9/23/15

Logged By: GLM

Ground Surface Elevation: _____

DEPTH (m)	DEPTH (ft.)	GRAPHIC LOG	SUMMARY OF SUBSURFACE CONDITIONS	DRIVE	BULK	MOISTURE	CONSISTENCY	FIELD MOISTURE (%)	FIELD DENSITY (pcf)
			The following is a summary of subsurface conditions encountered at the time of exploration. Subsurface conditions may differ at other locations and may vary at this location with the passage of time. The data contained in this log is a simplification of actual conditions.						
			EMBANKMENT FILL: CLAYEY SAND (SC/A-4) Brown, With Roots to 1'			Slightly Moist		*7.7	100
	2		--CLAYEY SILT (CL-ML/A-4) Brown, Slightly Porous, Some Sand, Trace Gravel, Trace Cobbles, Trace Gypsum					*7.9	115
1								*12.4	104
	4							*9.3	115
								*7.1	117
	6								
2									
	8								
3	10								
	12								
4									
	14		*Nuclear Gauge Readings						

APPROVED BY ON

Groundwater: NE

End of Trench at 5 Feet

Project Title: Frog Hollow Detention Basin

ROSENBERG ASSOCIATES
CIVIL ENGINEERS • LAND SURVEYORS
352 East Riverside Drive Suite A2 St. George, Utah 84790 – (435) 673-8586

Project No. 8384-14-008

Drawing No. A-22

Log of Trench No. T-P-11

Date Trenched: 9/23/15

Logged By: GLM

Ground Surface Elevation: _____

DEPTH (m)	DEPTH (ft.)	GRAPHIC LOG	SUMMARY OF SUBSURFACE CONDITIONS	DRIVE	BULK	MOISTURE	CONSISTENCY	FIELD MOISTURE (%)	FIELD DENSITY (pcf)
			The following is a summary of subsurface conditions encountered at the time of exploration. Subsurface conditions may differ at other locations and may vary at this location with the passage of time. The data contained in this log is a simplification of actual conditions.						
			EMBANKMENT FILL: SILTY CLAY (CL/A-4) Brown, Some Sand, With Roots to 2', With Gravel, Trace Gypsum			Dry		*7.3	101
	2		--Trace Gravel, Trace Cobbles					*6.4	109
								*7.0	109
1						Slightly Moist		4.0	115
	4							*7.2	110
								*7.3	108
	6								
2									
	8								
3	10								
	12								
4									
	14		*Nuclear Gauge Readings						

APPROVED BY ON

Groundwater: NE

End of Trench at 5 Feet

Project Title: Frog Hollow Detention Basin

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Project No. 8384-14-008

Drawing No. A-23

Log of Trench No. T-P-12

Date Trenched: 9/23/15

Logged By: GLM

Ground Surface Elevation: _____

DEPTH (m)	DEPTH (ft.)	GRAPHIC LOG	SUMMARY OF SUBSURFACE CONDITIONS	DRIVE	BULK	MOISTURE	CONSISTENCY	FIELD MOISTURE (%)	FIELD DENSITY (pcf)
			The following is a summary of subsurface conditions encountered at the time of exploration. Subsurface conditions may differ at other locations and may vary at this location with the passage of time. The data contained in this log is a simplification of actual conditions.						
1	2		EMBANKMENT FILL: CLAYEY SILT (CL-ML/A-4) Brown, Some Sand, Trace Gravel, Porous, With Roots to 3', Trace Gypsum			Slightly Moist		*3.7	98.9
								*5.7	110
								*7.4	110
			--Trace Cobbles					*7.5	110
	4							*9.1	116
								*12.0	109
2	6								
	8								
3	10								
	12								
4									
	14		*Nuclear Gauge Readings						

APPROVED BY _____ ON _____

Groundwater: NE

End of Trench at 5 Feet

Project Title: Frog Hollow Detention Basin

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Project No. 8384-14-008

Drawing No. A-24

Log of Trench No. T-P-13

Date Trenched: 9/23/15

Logged By: GLM

Ground Surface Elevation: _____

DEPTH (m)	DEPTH (ft.)	GRAPHIC LOG	SUMMARY OF SUBSURFACE CONDITIONS The following is a summary of subsurface conditions encountered at the time of exploration. Subsurface conditions may differ at other locations and may vary at this location with the passage of time. The data contained in this log is a simplification of actual conditions.	DRIVE	BULK	MOISTURE	CONSISTENCY	FIELD MOISTURE (%)	FIELD DENSITY (pcf)
			EMBANKMENT FILL: CLAYEY SILT (CL-ML/A-4) Brown, Some Sand, With Gravel, Trace Gypsum			Slightly Moist		*3.8	107
	2							*7.8	108
1			--Gravelly Lense					*9.2	108
	4							*11.7	107
	6								
2									
	8								
3	10								
	12								
4									
	14		*Nuclear Gauge Readings						

APPROVED BY ON

Groundwater: NE

End of Trench at 5.5 Feet

Project Title: Frog Hollow Detention Basin

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Project No. 8384-14-008

Drawing No. A-25

KEY TO SOIL SYMBOLS AND TERMS

Terms used in this report for describing soils according to their texture or grain size distributions are generally in accordance with the Unified Soils Classification System.

TERMS DESCRIBING CONDITION, CONSISTENCY AND HARDNESS

COARSE GRAINED SOILS:

Major portion retained on No. 200 sieve. Includes: (1) clean gravels, (2) silty or clayey gravels and (3) silty, clayey or gravelly sands. Consistency is rated according to relative density, as determined by laboratory test.

DESCRIPTIVE TERM	BLOW COUNTS (N1)60
Very Loose	0 to 4
Loose	5 to 10
Medium Dense	11 to 30
Dense	31 to 50
Very Dense	> 50

FINE GRAINED SOILS:

Major portion passing No. 200 sieve. Includes: (1) inorganic and organic silts and clays (2) gravelly, sandy or silty clays, and (3) clayey silts. Consistency is rated according to shearing strength as indicated by penetrometer readings or by direct shear tests.

DESCRIPTIVE TERM	SHEAR STRENGTH (ksf)
Very Soft	Less than 0.25
Soft	0.25 to 0.50
Firm	0.50 to 1.00
Stiff	1.00 to 2.00
Very Stiff	2.00 to 4.00
Hard	4.00 and higher

ROCK:

Includes gravels, cobbles, rock, caliche and bedrock materials. Hardness is related to field identification procedures described below.

DESCRIPTIVE TERM	FIELD IDENTIFICATION TEST
Soft	Can be dug by hand and crushed by fingers.
Moderate Hard	Friable, can be gouged deeply with knife and will crumble readily under light hammer blows.
Hard	Knife scratch leaves dust trace, will withstand a few hammer blows before breaking.
Very Hard	Scratched with knife with difficulty, difficult to break with hammer blows.

SOIL MOISTURE

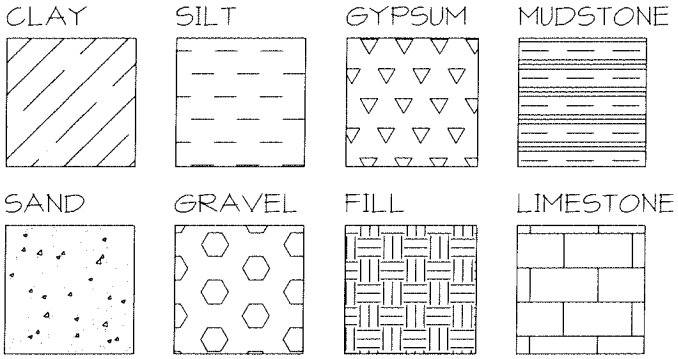
From low to high the soil moisture is indicated by:

Dry
Slightly Moist
Moist
Very Moist
Wet

SIZE PROPORTIONS

DESCRIPTIVE TERM	PERCENT BY WEIGHT
Trace	0 to 10
With	10 to 20
Some	20 to 35
And	35 to 50

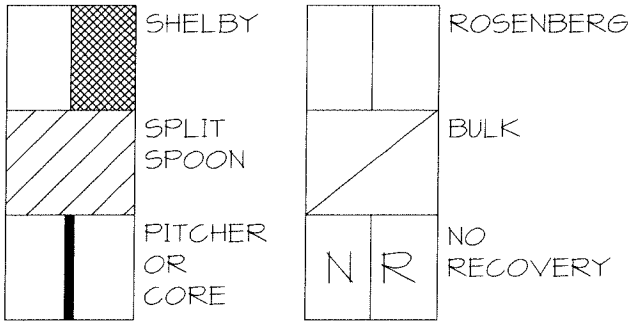
SOIL TYPE KEY



LEGEND OF LABORATORY TEST

G - Grain
S - Swell
DS - Direct Shear
A - Liquid & Plastic Limits
PP - Pocket Penetrometer
U - Unconfined
CH - Chemical
N - Chemical Heave
C - Consolidation
T - Triaxial
Sol - Solubility
P - Compaction

SAMPLER TYPES



Project Title: Frog Hollow Detention Basin

ROSENBERG ASSOCIATES
CIVIL ENGINEERS • LAND SURVEYORS
352 East Riverside Drive Suite A2 St. George, Utah 84790 - (435) 673-8586

Project No. 8384-14-008

Drawing No. A-26

APPENDIX B

LABORORATORY TESTING

APPENDIX B

LABORATORY TESTING

Laboratory testing was conducted on the representative soil samples collected from the site by Rosenberg Associates and GSH Geotechnical. Unit weight and moisture content determinations were performed to evaluate the in-place moisture and density conditions of the on-site soils. Atterberg Limits, sieve analyses and hydrometer tests were performed for soil classification purposes. A standard Proctor tests was performed to aid in evaluating the relative compaction of the embankment fill soils. Solubility tests were conducted to evaluate the potential for dissolution of gypsum and/or other soluble minerals from the site soils. Direct shear tests were conducted on select samples to evaluate soil strength. Pinhole dispersion tests were conducted to evaluate dispersivity of the embankment soils. Test results are summarized in the following Tables of Laboratory Test Results, on Figures B-1 through B-6, and on the boring and test pit logs in Appendix A..

Representative samples of chimney drain materials were also provided to the NRCS soils laboratory to further evaluate its self-healing properties. NRCS test results had not been received at the time of this report

FROG HOLLOW DAM REHABILITATION PROJECT
Laboratory Test Summary Sheets

Sample Location		Gradation (% Passing)						Hydrometer			Soil Classification	Field Dry Density	Field Moisture Content	Direct Shear Strength		Standard ASTM D698 Proctor		Pinhole Dispersion	Solubility	Sulfate
No.	Ft.	#4	#10	#40	#200	LL	PI	%Sand	%Silt	%Clay	USCS/AASHTO	(pcf)	(%)	ϕ(deg)	c (psf)	(pcf)	(%)		(%)	(mg/kg)
B-1	1	99	97	92	71	21	7				CL-ML / A-4	116	5.3							
	2.5	82	80	76	63	22	7				CL-ML / A-4	120	5.2							
	5	96	94	90	78			18	33.6	44.6	CL / A-4	124	10.2							
	7.5	97	95	87	64	20	4				CL-ML / A-4	122	6.3						1.3	
	10										CL-ML / A-4	127	7.4							
	12.5	100	100	98	73	21	5				CL-ML / A-4	123	8.3							
	15										CL / A-4	110	16.8	32	260					
	17.5										CL-ML / A-4	130	9.5						1.5	
	20	91	85	73	54	20	5				CL-ML / A-4	125	6.4						0.6	
	22.5										CL / A-4	122	8.1							
	25					30	9				CL / A-4	107	16.8							
	27.5										CL / A-4	119	9.9						1.1	
	30		100	99	91	25	8				CL / A-4	117	9.4							
	32.5										CL / A-4	107	8.7							
	35					26	10				CL / A-4	116	11.5	28	640					
	37.5										CL / A-4	114	6.5						0.1	
	60										CL / A-4	119	14.3							
	70												6.3							
B-2	1.5										CL-ML / A-4	121	4.4						0.8	
	4						NP				ML / A-4	116	4.0							
	6.5					20	5				CL-ML / A-4	121	3.5							
	9					20	5				CL-ML / A-4		4.8							
	11.5	100	100	99	89	27	11				CL / A-6	120	9.0							
	14										CL / A-6	123	5.2						1.2	

FROG HOLLOW DAM REHABILITATION PROJECT
Laboratory Test Summary Sheets

Sample Location		Gradation (% Passing)						Hydrometer			Soil Classification	Field Dry Density	Field Moisture Content	Direct Shear Strength		Standard ASTM D698 Proctor		Pinhole Dispersion	Solubility	Sulfate
No.	Ft.	#4	#10	#40	#200	LL	PI	%Sand	%Silt	%Clay	USCS/AASHTO	(pcf)	(%)	ϕ(deg)	c (psf)	(pcf)	(%)		(%)	(mg/kg)
B-2	16.5	77	72	63	39	19	NP				SC / A-4	121	2.7							
	19										CL / A-4	127	6.4							
	21.5	89	86	73	56			33	56		CL / A-4	110	10.6	30	200					
	24	92	87	75	47						CL / A-4	128	5.4						1.0	
	26.5										CL / A-4	123	6.6							
	29	99	98	97	93			7	43.4	49.9	CL / A-4	117	13.4							
	31.5										CL / A-4	116	10.6							
	34	97	97	95	74						CL / A-4	124	8.8							
	36.5										CL / A-4	125	8.5						1.0	
	39										CL / A-4	118	8.2							
	41.5											100	9.9							
	44											109	7.0							
B-3	1										CL-ML / A-4	90	3.1							
	5	100	100	97	72	19	4				CL-ML / A-4	87	5.4						1.3	
	7.5										CL / A-4	108	10.9							
	10										CL / A-4	117	5.3							
	12.5	90	86	75	53						CL / A-4	115	5.2						2.1	
	15										CL / A-4	88	8.5							
	17.5	99	98	97	87			12	35.0	51.6	CL / A-4	109	9.8							
	20										CL / A-4	93	8.6						1.1	
	22.5										CL / A-4	105	7.3							
B-4	1										CL / A-4	113	1.2						0.9	
	2.5										CL / A-4	114	3.0							

FROG HOLLOW DAM REHABILITATION PROJECT
Laboratory Test Summary Sheets

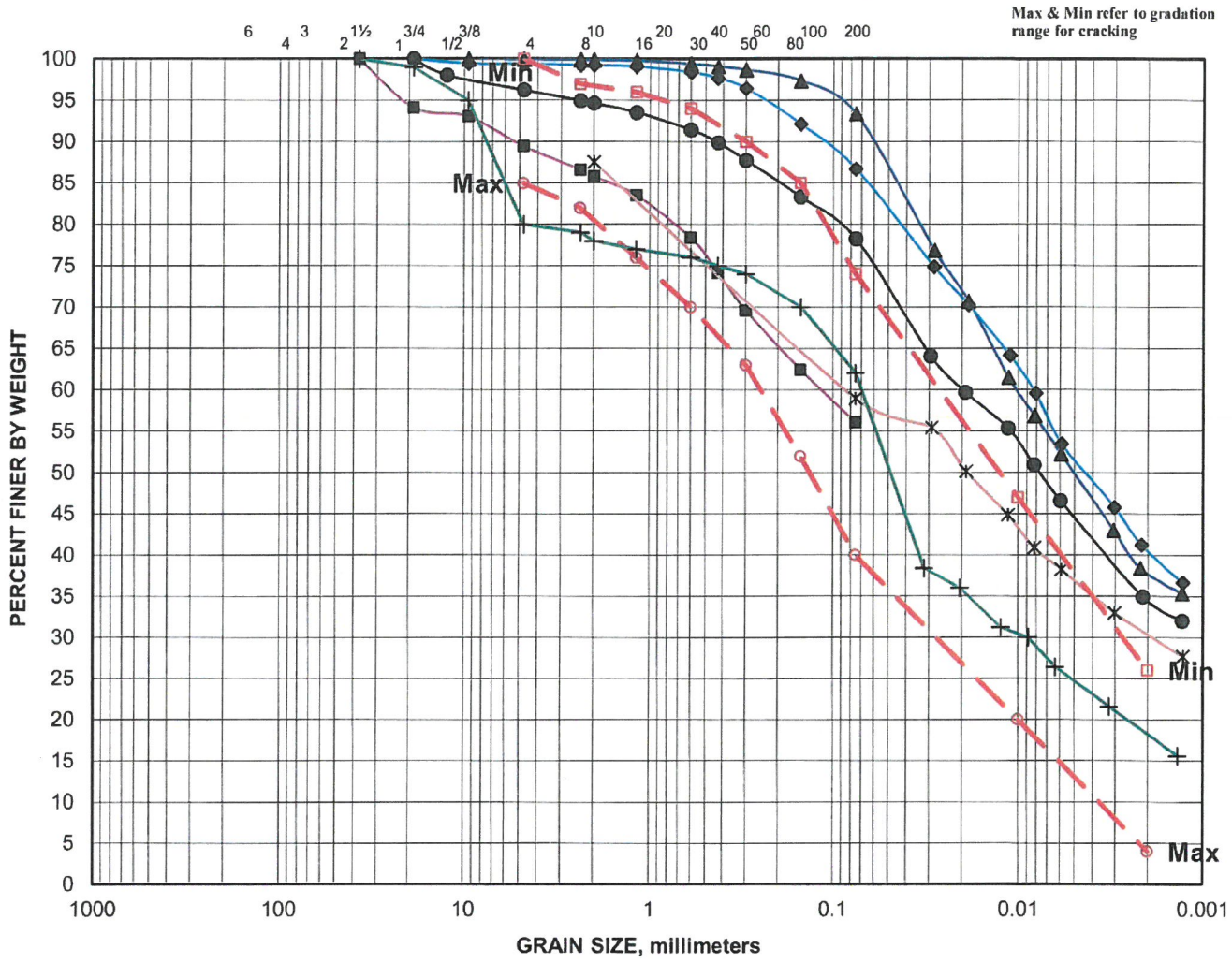
Sample Location		Gradation (% Passing)						Hydrometer			Soil Classification	Field Dry Density	Field Moisture Content	Direct Shear Strength		Standard ASTM D698 Proctor		Pinhole Dispersion	Solubility	Sulfate
No.	Ft.	#4	#10	#40	#200	LL	PI	%Sand	%Silt	%Clay	USCS/AASHTO	(pcf)	(%)	ϕ(deg)	c (psf)	(pcf)	(%)		(%)	(mg/kg)
B-4	5	100	100	100	100	31	12				CL / A-6	118	5.1							
	7.5										CL / A-6	121	6.6						0.5	
	10										CL / A-6	120	6.1						0.3	
	12.5	100	87	75	59			41	21.9	37.0	CL / A-4	126	7.6							2,530
	15	97	95	91	74						CL / A-4	123	8.2							
	17.5										CL / A-4	126	8.3							
	20										CL / A-4	106	7.1							
	22.5												0.5							
TP-3	1.5										CL / A-4	75	2.9							
	3.5										CL / A-4	80	2.5							
	3 to 4	100	100	100	90	26	9				CL / A-4								1.4	
TP-4	1										CL-ML / A-4	79	2.9							
	3										CL-ML / A-4	77	1.5							
TP-5	6 to 7	99	99	98	90	24	7				CL-ML / A-4								1.5	
TP-6	1										CL-ML / A-4	77	2.9						1.6	
TP-7	3										CL-ML / A-4	80	3.3							
TP-9	2										CL / A-4	76	11.0							

FROG HOLLOW DAM REHABILITATION PROJECT
Laboratory Test Summary Sheets

Sample Location		Gradation (% Passing)						Hydrometer			Soil Classification	Field Dry Density	Field Moisture Content	Direct Shear Strength		Standard ASTM D698 Proctor		Pinhole Dispersion	Solubility	Sulfate
No.	Ft.	#4	#10	#40	#200	LL	PI	%Sand	%Silt	%Clay	USCS/AASHTO	(pcf)	(%)	ϕ(deg)	c (psf)	(pcf)	(%)		(%)	(mg/kg)
TP-10	0.5 to 1.5	97	95	90	62	19	4				CL-ML / A-4									
	3.5 to 4.5										CL-ML / A-4							ND1		
TP-11	0 to 1.5										CL / A-4					114.4	15.3		2.1	
	3 to 4	80	78	75	62	26	8	18	37.3	24.7	CL / A-4		4.0	34	115			ND1		
TP-12	1 to 2	90	86	75	56	22	6				CL-ML / A-4								1.8	
	3 to 4										CL-ML / A-4							ND1		
TP-13	1 to 2	89	87	80	61	21	6				CL-ML / A-4								1.8	
	4 to 5										CL-ML / A-4							ND1		
T-12	1-2	99	98	93	74	22	7	31	29.7	24.7	CL-ML / A-4		4.5			127.9	8.5	ND3	1.4	
	3-4	97	93	56	4.4		NP				SP / A-3		1.9							
T-13	2-3	100	100	100	93	26	7	8	56.8	35.1	CL / A-4		4.0			121.5	10.9	ND2	1.9	
T-14	4-5	97	93	49	7.4		NP				SP-SM / A-1-b		0.7							
	13-14	96	92	53	3.8		NP				SP / A-3		0.7							
	12-13	82	79	73	58	37	14	27		42	CL / A-6		7.5					ND1	2.2	
T-15	7-8	64	60	51	36	30	9				SC / A-4		7.7						3.1	
	8-9	98	98	97	84	23	5	25		74	CL-ML / A-4		4.4						1.9	

GRAIN SIZE DISTRIBUTION

U.S. SIEVE OPENING, inches | U.S. SIEVE NUMBERS | HYDROMETER



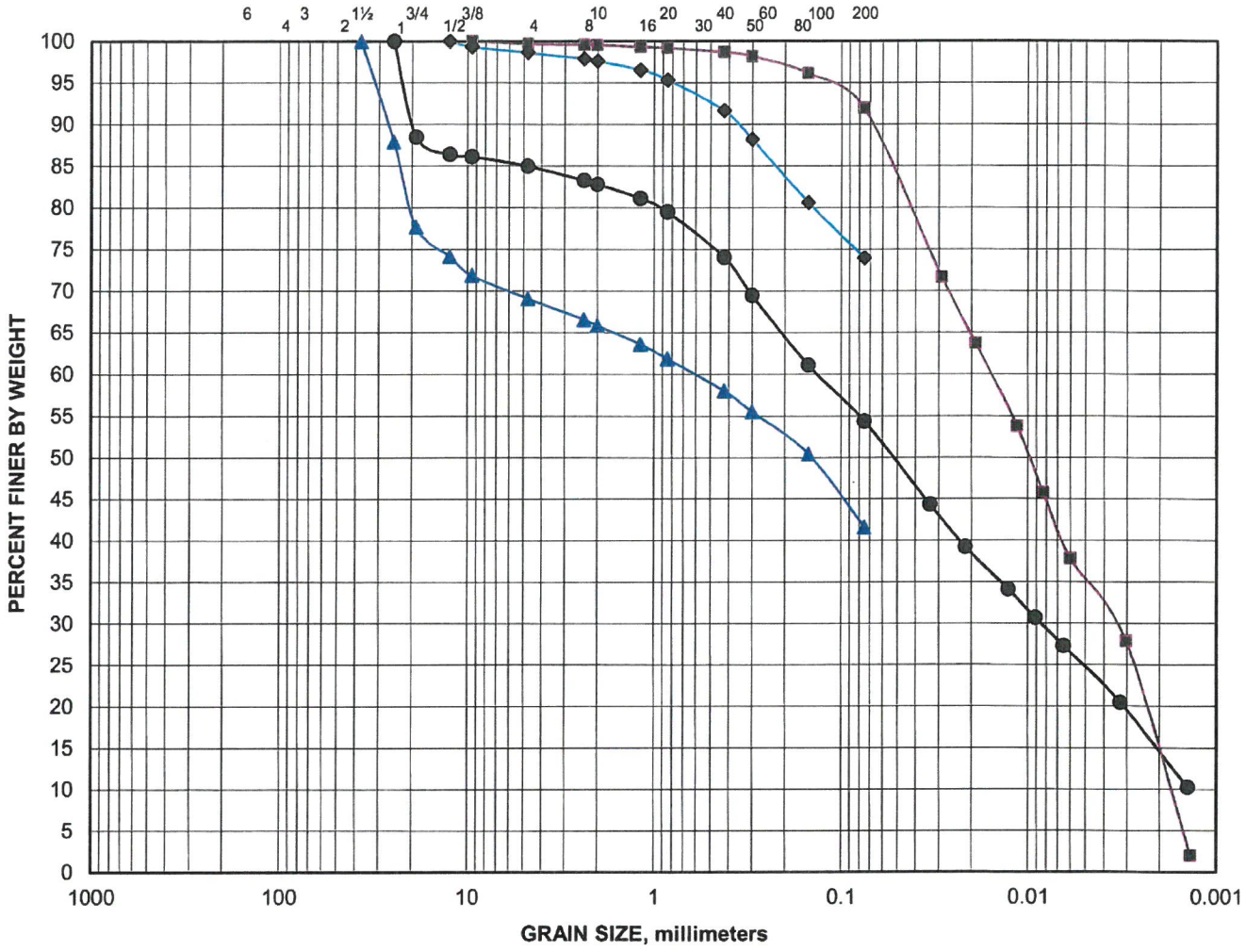
COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen Identification	Classification	MC%	LL	PL	PI	Cc	Cu
● B-1 @ 5 ft	Silty Clay with sand (CL)	7					
■ B-2 @ 21.5 ft	Sandy Silty Clay (CL)	8					
▲ B-2 @ 29 ft	Silty Clay (CL)	8					
◆ B-3 @ 17.5 ft	Silty Clay (CL)	7					
x B-4 @ 12.5 ft	Sandy Silty Clay (CL)	7					
+ TP-11 @ 3 ft	Gravelly Silty Clay with sand (CL)	4	26	18	8		

Specimen Identification	D100	D85	D60	D30	D15	D10	%Gravel	%Sand	%Silt	%Clay
● B-1 @ 5 ft	19.0	0.196					4	18	33.6	44.6
■ B-2 @ 21.5 ft	37.5	1.66	0.119				11	33	56	
▲ B-2 @ 29 ft	9.50						0	7	43.4	49.9
◆ B-3 @ 17.5 ft	19.0						1	12	35.0	51.6
x B-4 @ 12.5 ft		1.50	0.085				0	41	21.9	37.0
+ TP-11 @ 3 ft	37.5	5.98					20	18	37.3	24.7

PROJECT NO.: 1310-014-15 | GSH | FIGURE NO.: B-1

GRAIN SIZE DISTRIBUTION



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	T-12	Sandy CLAY with gravel (CL)	6					
■	T-13	Clayey SILT (ML)	8					
▲	T-14	Clayey GRAVEL with sand (GC)	7					
◆	T-15	SILT with sand (ML)	5					
x								

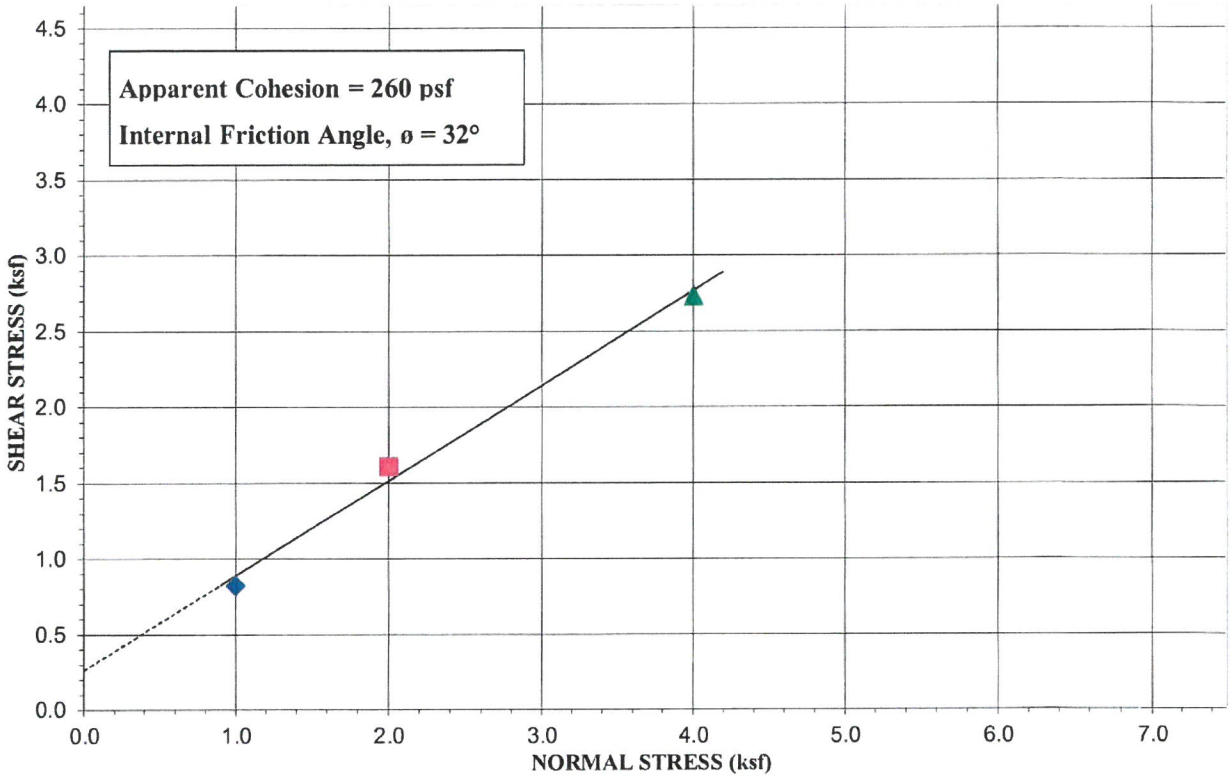
Specimen Identification		D100	D85	D60	D30	D15	D10	%Gravel	%Sand	%Silt	%Clay
●	T-12	25.0	4.84	0.137				15	31	29.7	24.7
■	T-13	9.50						0	8	56.8	35.1
▲	T-14	37.5	23.1	0.611				31	27	42	
◆	T-15	12.5	0.225					1	25	74	
x											

PROJECT NO.: 1310-014-15

GSH

FIGURE NO.: B–2

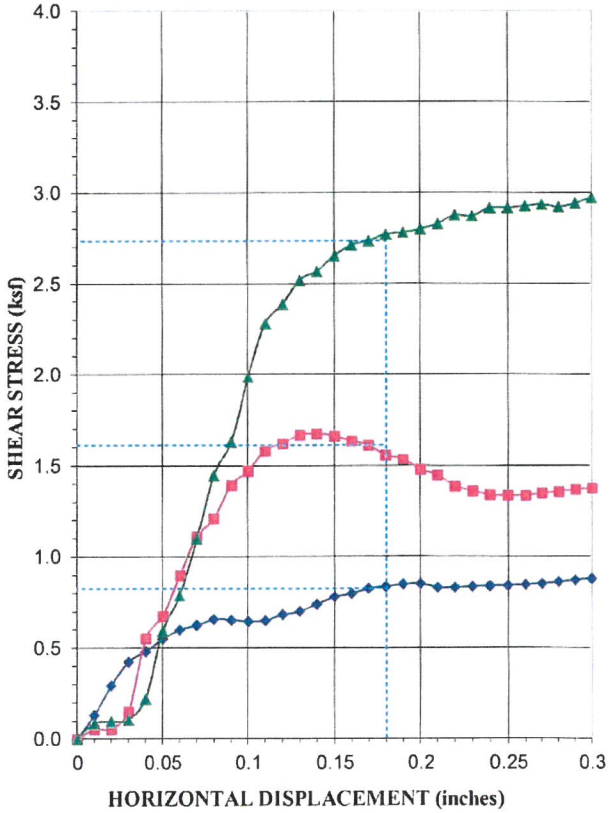
DIRECT SHEAR TEST



Source: B-1	Depth: 15 ft		
Type of Test:	Consolidated - Undrained		
Test No. (Symbol)	1 (◆)	2 (■)	3 (▲)
Sample Type	Relatively Undisturbed		
Initial Height, in.	1.06	1.16	1.10
Diameter, in.	2.45	2.45	2.45
Dry Density Before, pcf	107.1	110.2	112.4
Dry Density After, pcf	111.8	120.5	124.0
Moisture % Before	17.8	16.3	16.3
Moisture % After	24.0	24.3	21.0
Saturation % Before	59.9	57.9	60.4
Saturation % After	88.2	104.9	96.4
Normal Load, ksf	1.0	2.0	4.0
Shear Stress, ksf	0.82	1.61	2.73
Strain Rate	0.005 in/min		

Sample Properties	
Cohesion, psf	260
Friction Angle, ϕ	32
Liquid Limit, %	---
Plasticity Index, %	---
Percent Gravel	---
Percent Sand	---
Percent Passing No. 200 sieve	78
Classification	Silty Clay with sand (CL)

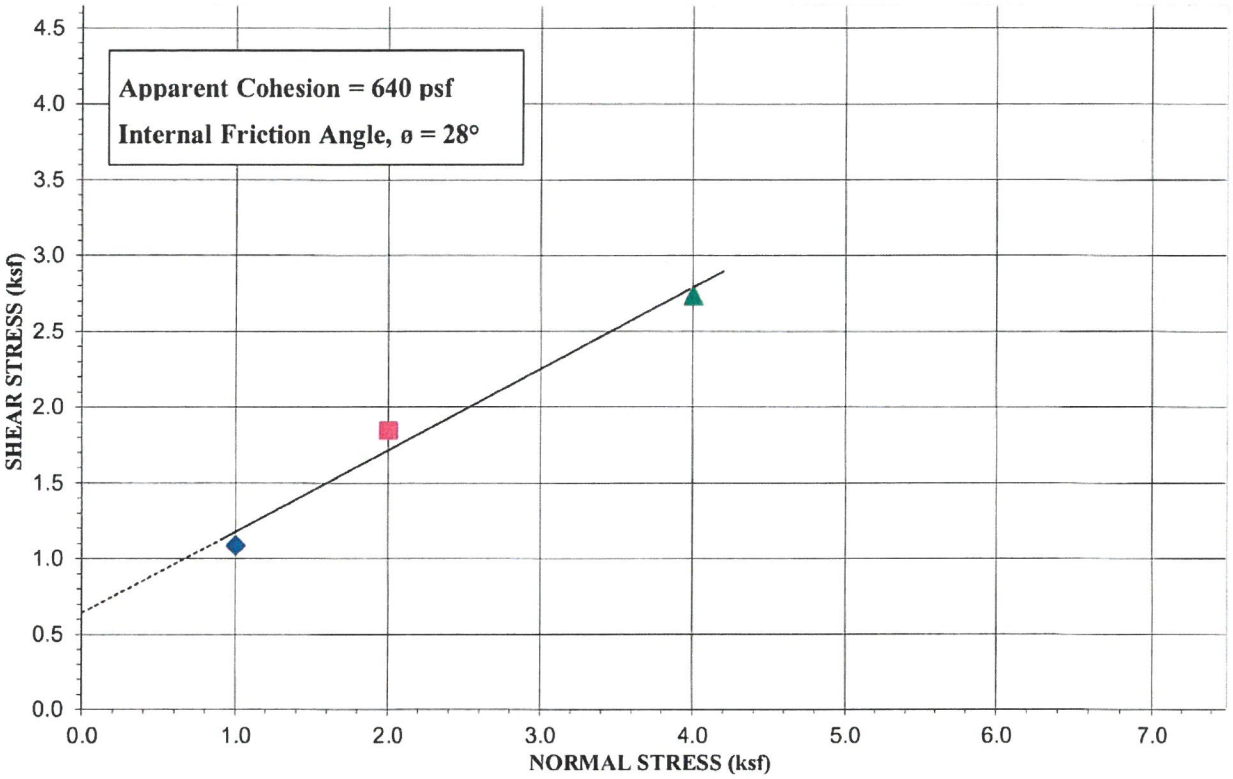
Testing Laboratory: GSH



PROJECT: Frog Hollow Dam

PROJECT NO.: 1310-014-15	GSH	FIGURE NO.: B-3

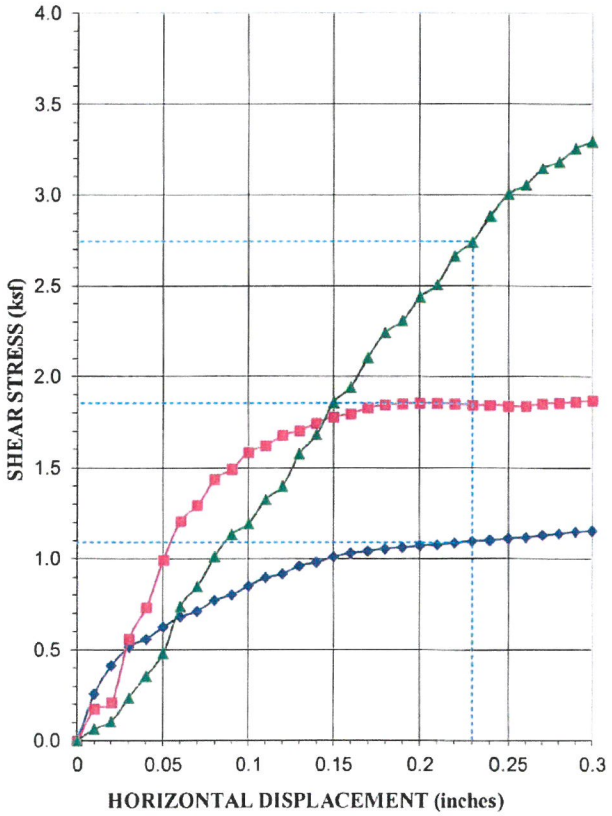
DIRECT SHEAR TEST



Source: B-1	Depth: 35 ft		
Type of Test:	Consolidated - Undrained		
Test No. (Symbol)	1 (◆)	2 (■)	3 (▲)
Sample Type	Relatively Undisturbed		
Initial Height, in.	1.06	1.16	1.10
Diameter, in.	2.45	2.45	2.45
Dry Density Before, pcf	109.7	112.8	116.1
Dry Density After, pcf	116.0	125.7	127.7
Moisture % Before	12.2	19.1	11.7
Moisture % After	17.9	18.8	17.4
Saturation % Before	46.6	78.0	50.8
Saturation % After	77.8	99.8	96.0
Normal Load, ksf	1.0	2.0	4.0
Shear Stress, ksf	1.09	1.85	2.74
Strain Rate	0.005 in/min		

Sample Properties	
Cohesion, psf	640
Friction Angle, ϕ	28
Liquid Limit, %	---
Plasticity Index, %	---
Percent Gravel	---
Percent Sand	---
Percent Passing No. 200 sieve	63
Classification	Sandy Silty Clay (CL)

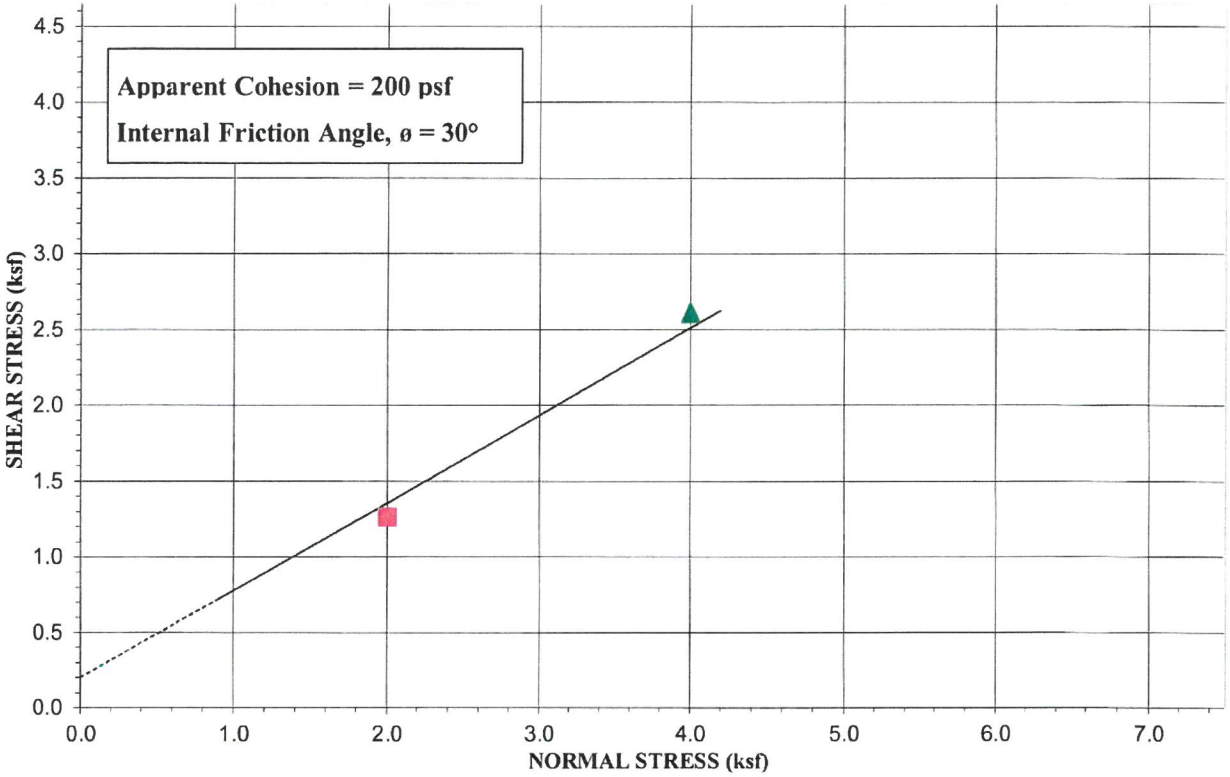
Testing Laboratory: GSH



PROJECT: Frog Hollow Dam

PROJECT NO.: 1310-014-15	GSH	FIGURE NO.: B-4

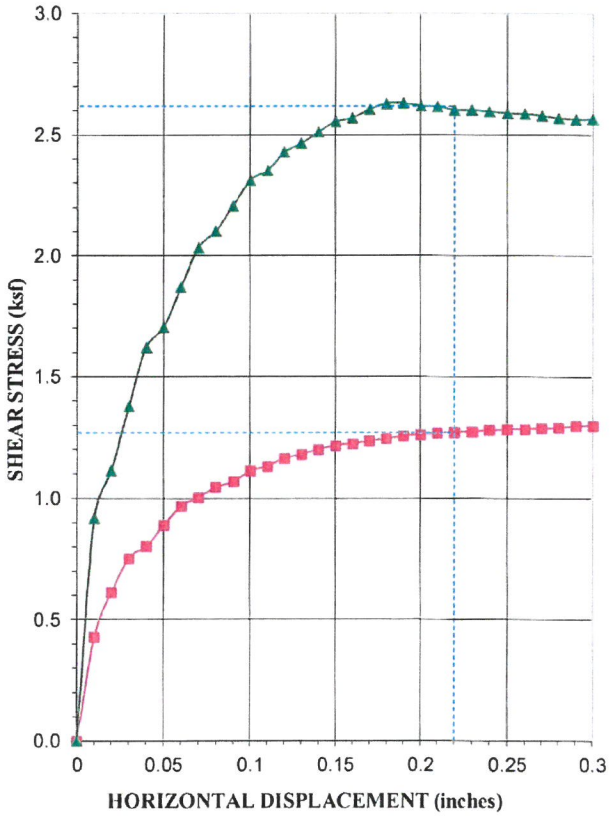
DIRECT SHEAR TEST



Source: B-2	Depth: 21.5 ft		
Type of Test:	Consolidated - Undrained		
Test No. (Symbol)	1 (◆)	2 (■)	3 (▲)
Sample Type	Relatively Undisturbed		
Initial Height, in.	1.06	1.16	1.10
Diameter, in.	2.45	2.45	2.45
Dry Density Before, pcf	108.4	111.0	110.8
Dry Density After, pcf	108.4	115.3	115.2
Moisture % Before	13.0	9.6	9.3
Moisture % After	27.9	21.2	17.1
Saturation % Before	48.6	37.7	36.4
Saturation % After	104.1	90.7	73.3
Normal Load, ksf	1.0	2.0	4.0
Shear Stress, ksf	#N/A	1.27	2.62
Strain Rate	0.005 in/min		

Sample Properties	
Cohesion, psf	200
Friction Angle, ϕ	30
Liquid Limit, %	---
Plasticity Index, %	---
Percent Gravel	11
Percent Sand	33
Percent Passing No. 200 sieve	56
Classification	Sandy Silty Clay (CL)

Testing Laboratory: GSH



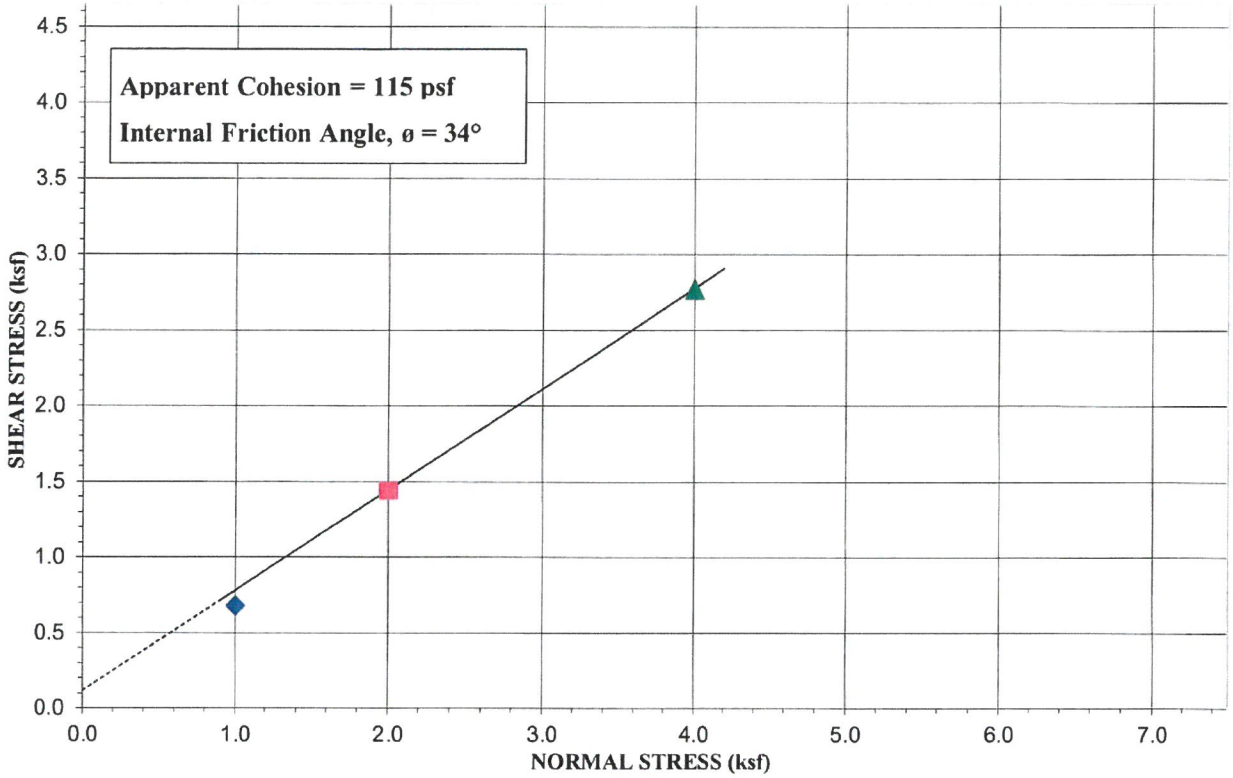
PROJECT: Frog Hollow Dam

PROJECT NO.: 1310-014-15

GSH

FIGURE NO.: B-5

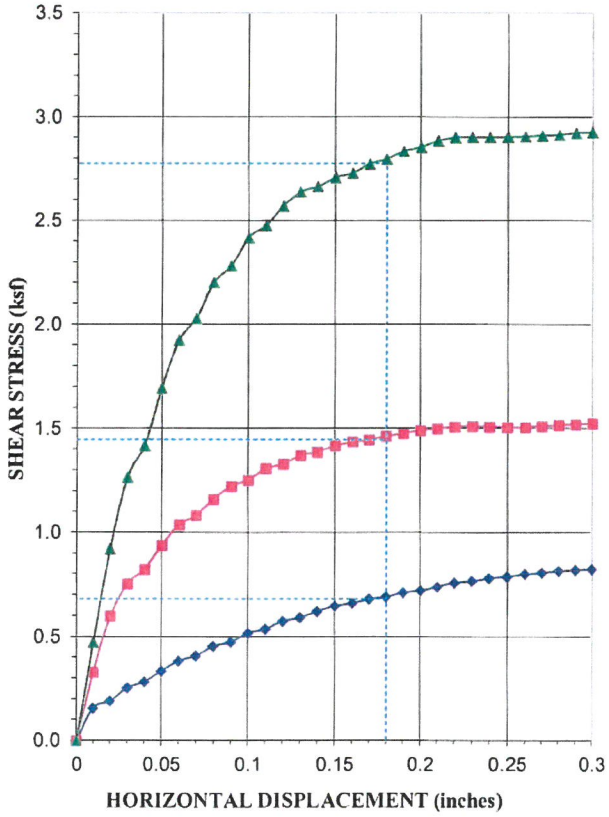
DIRECT SHEAR TEST



Source: TP-11	Depth: 3-4 ft		
Type of Test:	Consolidated - Undrained		
Test No. (Symbol)	1 (◆)	2 (■)	3 (▲)
Sample Type	Lab Compacted to 100%		
Initial Height, in.	1.06	1.16	1.10
Diameter, in.	2.45	2.45	2.45
Dry Density Before, pcf	100.9	98.9	95.1
Dry Density After, pcf	106.9	102.5	100.0
Moisture % Before	20.8	21.6	22.1
Moisture % After	26.1	22.9	22.4
Saturation % Before	73.1	72.6	68.5
Saturation % After	104.3	83.2	76.9
Normal Load, ksf	1.0	2.0	4.0
Shear Stress, ksf	0.68	1.45	2.77
Strain Rate	0.005 in/min		

Sample Properties	
Cohesion, psf	115
Friction Angle, ϕ	34
Liquid Limit, %	26
Plasticity Index, %	8
Percent Gravel	20
Percent Sand	18
Percent Passing No. 200 sieve	62
Classification	Gravelly Silty Clay with sand (CL)

Testing Laboratory: GSH



PROJECT: Frog Hollow Dam

PROJECT NO.: 1310-014-15 | GSH | **FIGURE NO.:** B-6

APPENDIX C

EMBANKMENT STABILITY AND CHIMNEY DRAIN ANALYSES

APPENDIX C

EMBANKMENT STABILITY ANALYSIS

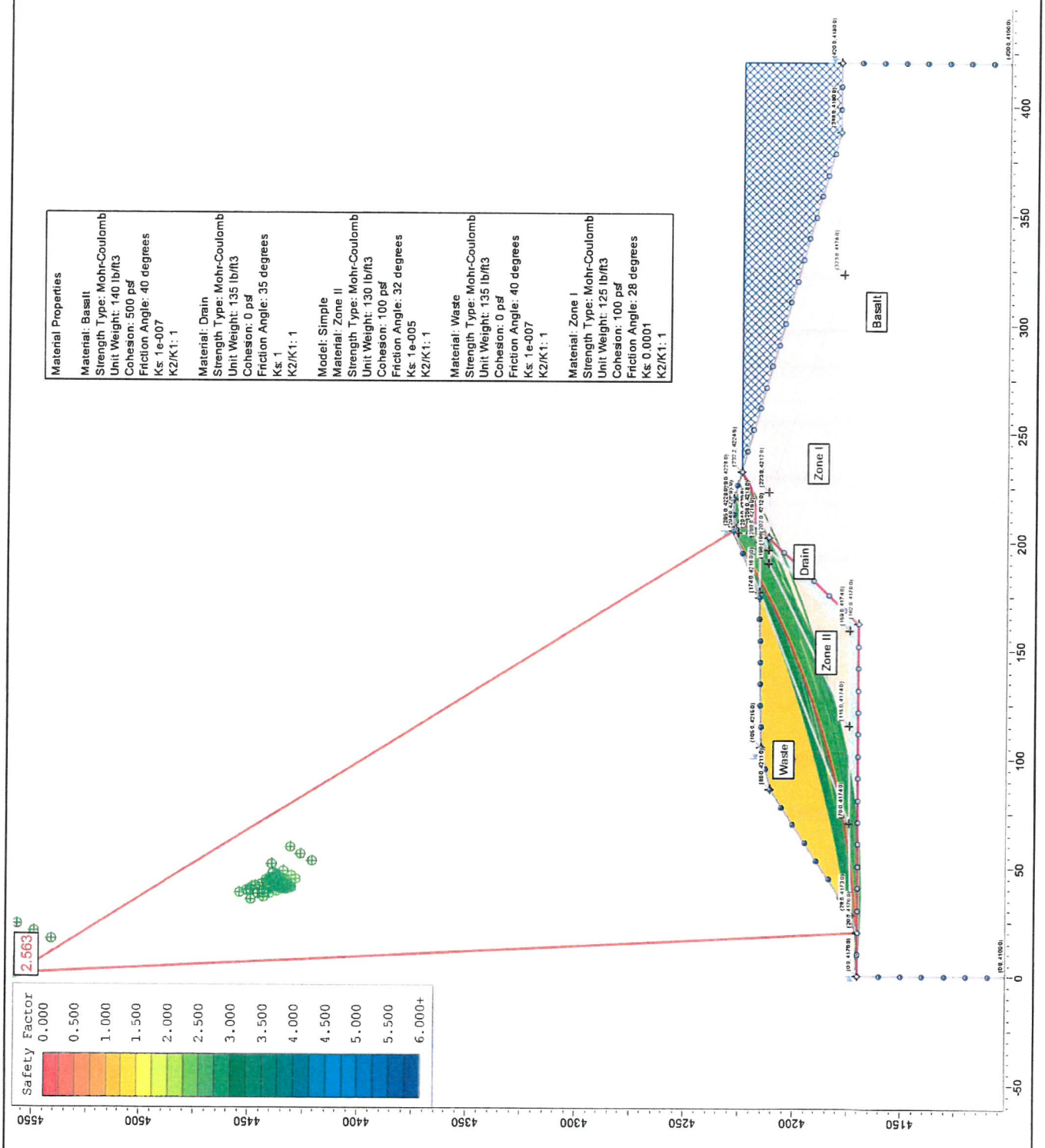
Results of the field explorations and laboratory testing were evaluated and engineering analyses were performed to assess the stability of the existing embankments using the computer program SLIDE. The analyses were performed by Mr. Bill Turner, P.E. of GHS Geotechnical, Inc. (a sub-consultant to Rosenberg Associates). Stability analyses results are included in this appendix as Figures C-1 through C-10.

CHIMNEY DRAIN ANALYSIS

Based on laboratory gradations of the chimney drain sand and the adjacent embankment materials, engineering analyses were performed to assess the filtering capability of the existing chimney drain materials. The analyses were based on Chapter 26, Gradation Design of Sand and Gravel Filters, from the National Engineering Handbook (via the NRCS). The analyses were performed by Mr. Bill Turner, P.E. of GHS Geotechnical, Inc. The results of the analyses are included in this appendix as Figures C-11 through C-18.

STABILITY RESULTS

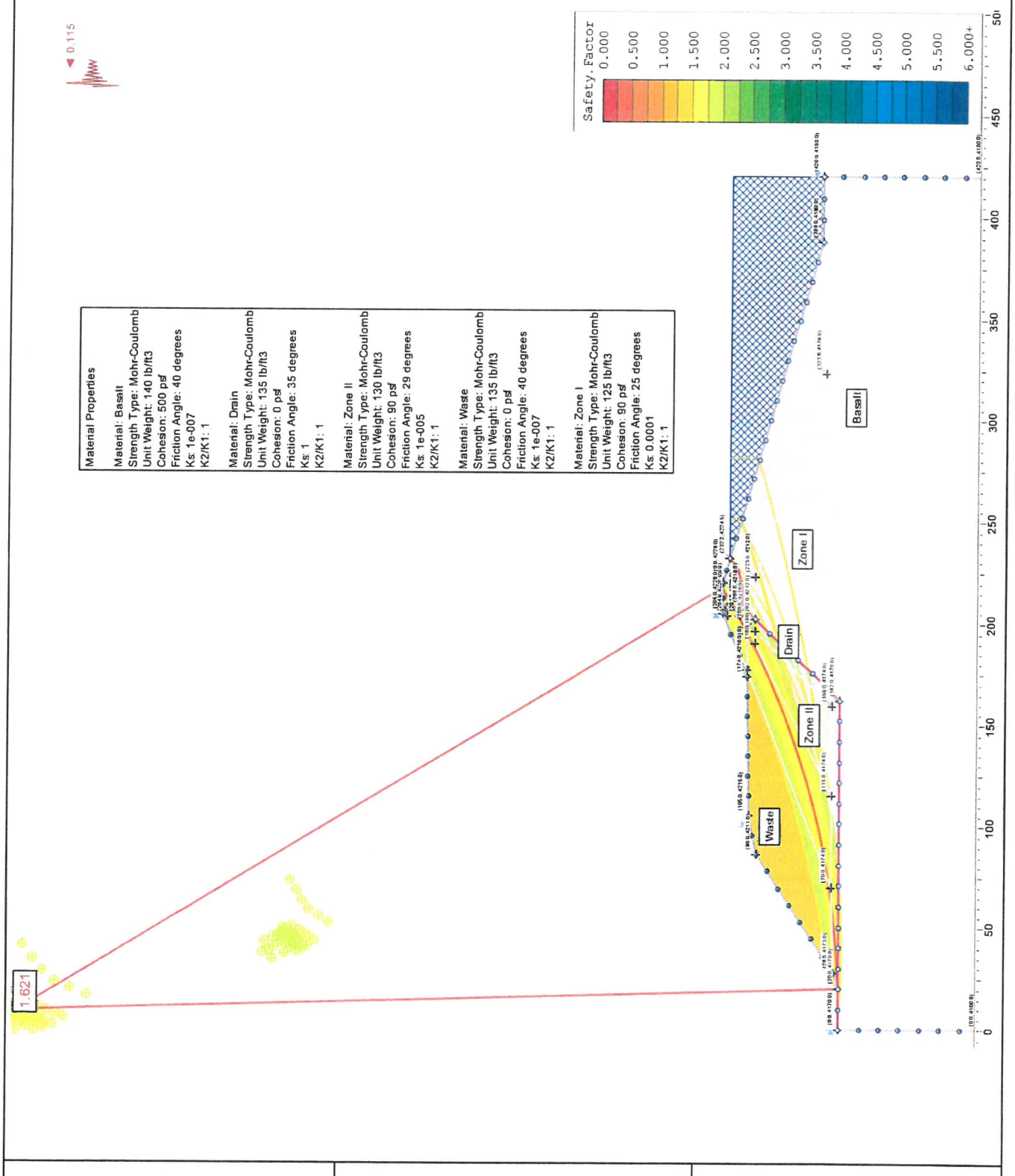
FROG HOLLOW DAM, WASHINGTON COUNTY – DOWNSTREAM STEADY STATE SECTION C-C'



PROJECT NO.: 1310-014-15	GSH	**FIGURE NO.:** C-1

STABILITY RESULTS

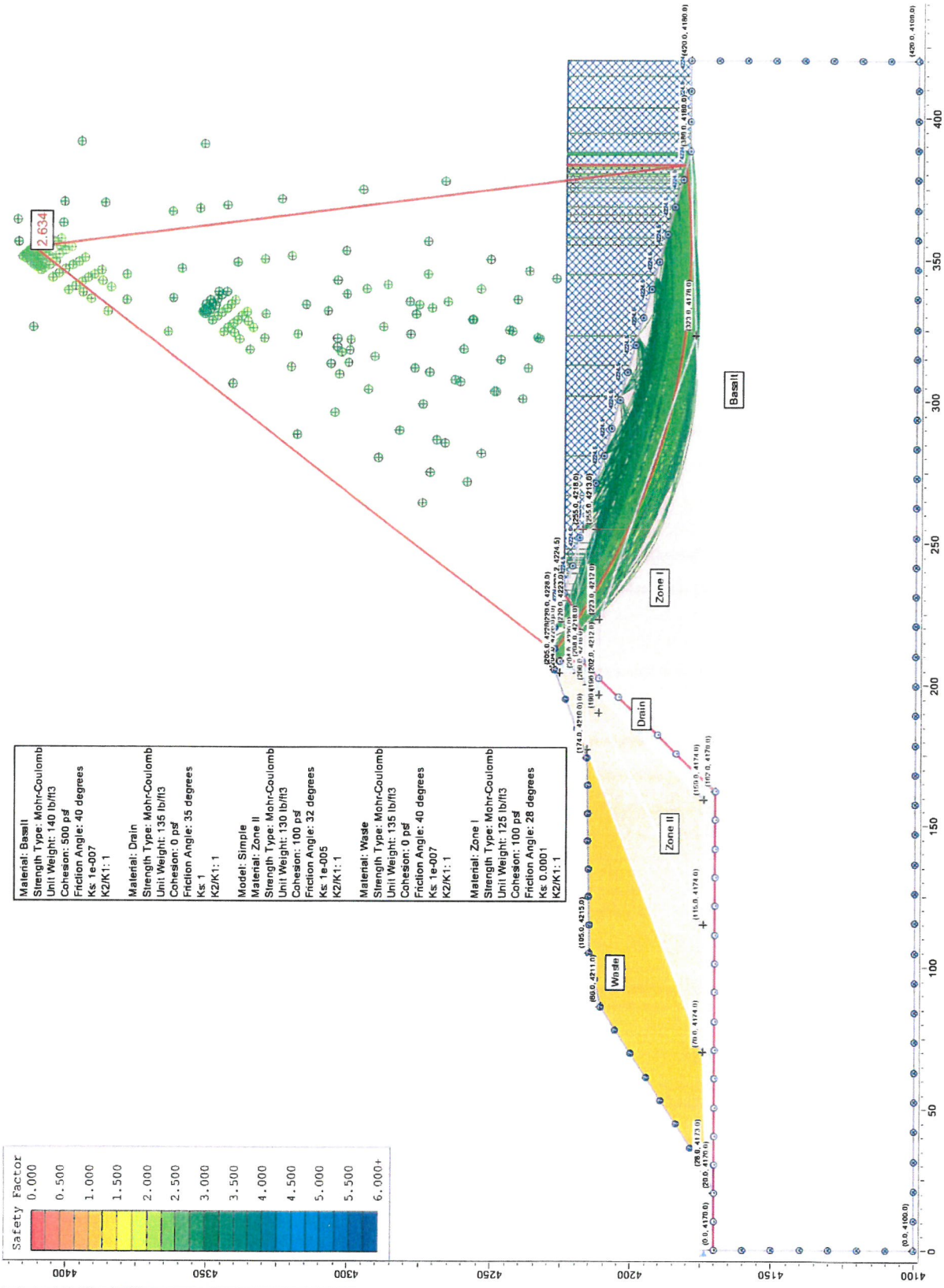
FROG HOLLOW DAM, WASHINGTON COUNTY – DOWNSTREAM STEADY STATE SECTION C-C'



PROJECT NO.: 1310-014-15	GSH	**FIGURE NO.:** C-2

STABILITY RESULTS

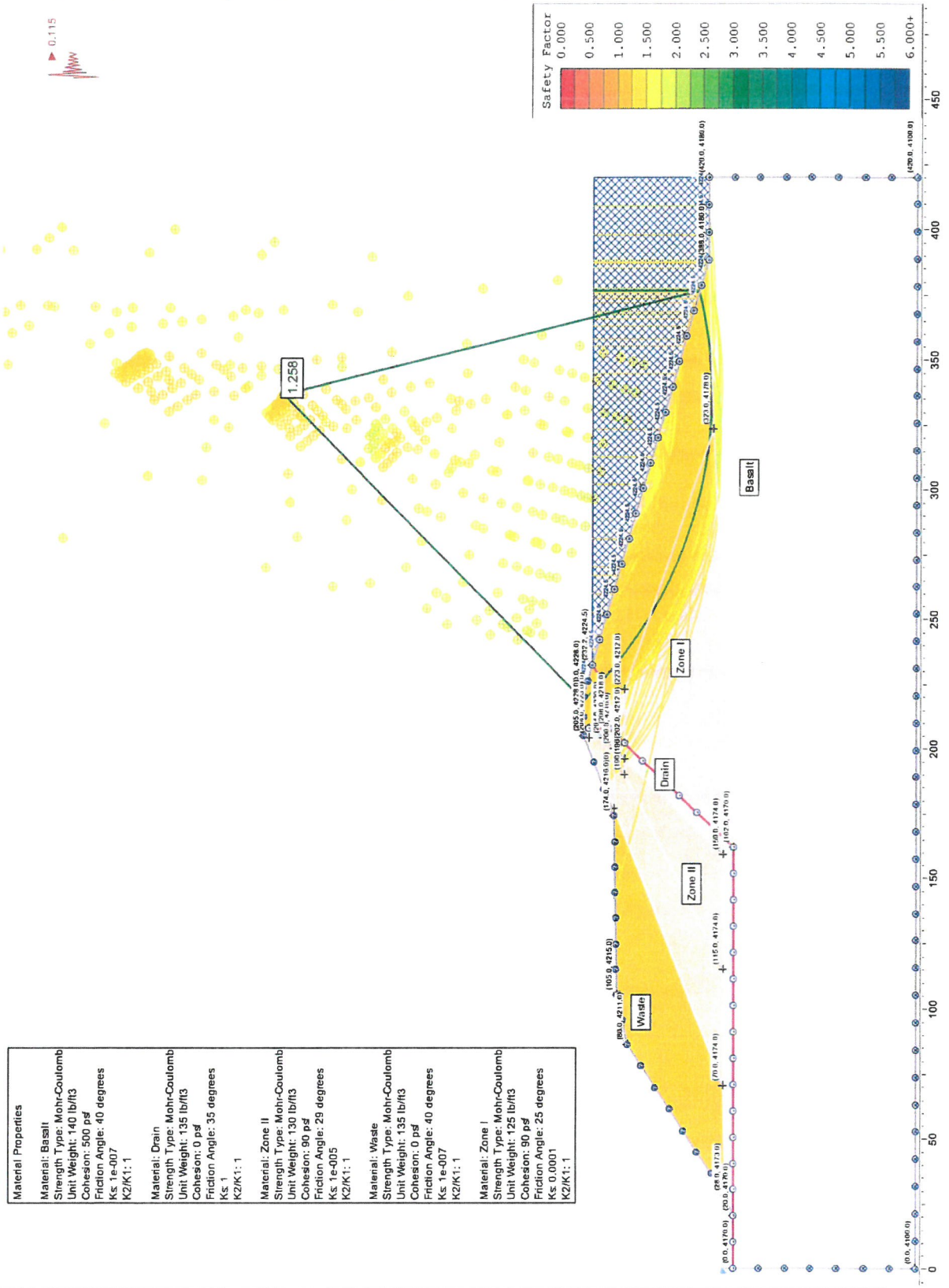
FROG HOLLOW DAM, WASHINGTON COUNTY – UPSTREAM STEADY STATE SECTION C-C'



PROJECT NO.: 1310-014-15	GSH	**FIGURE NO.:** C-3

STABILITY RESULTS

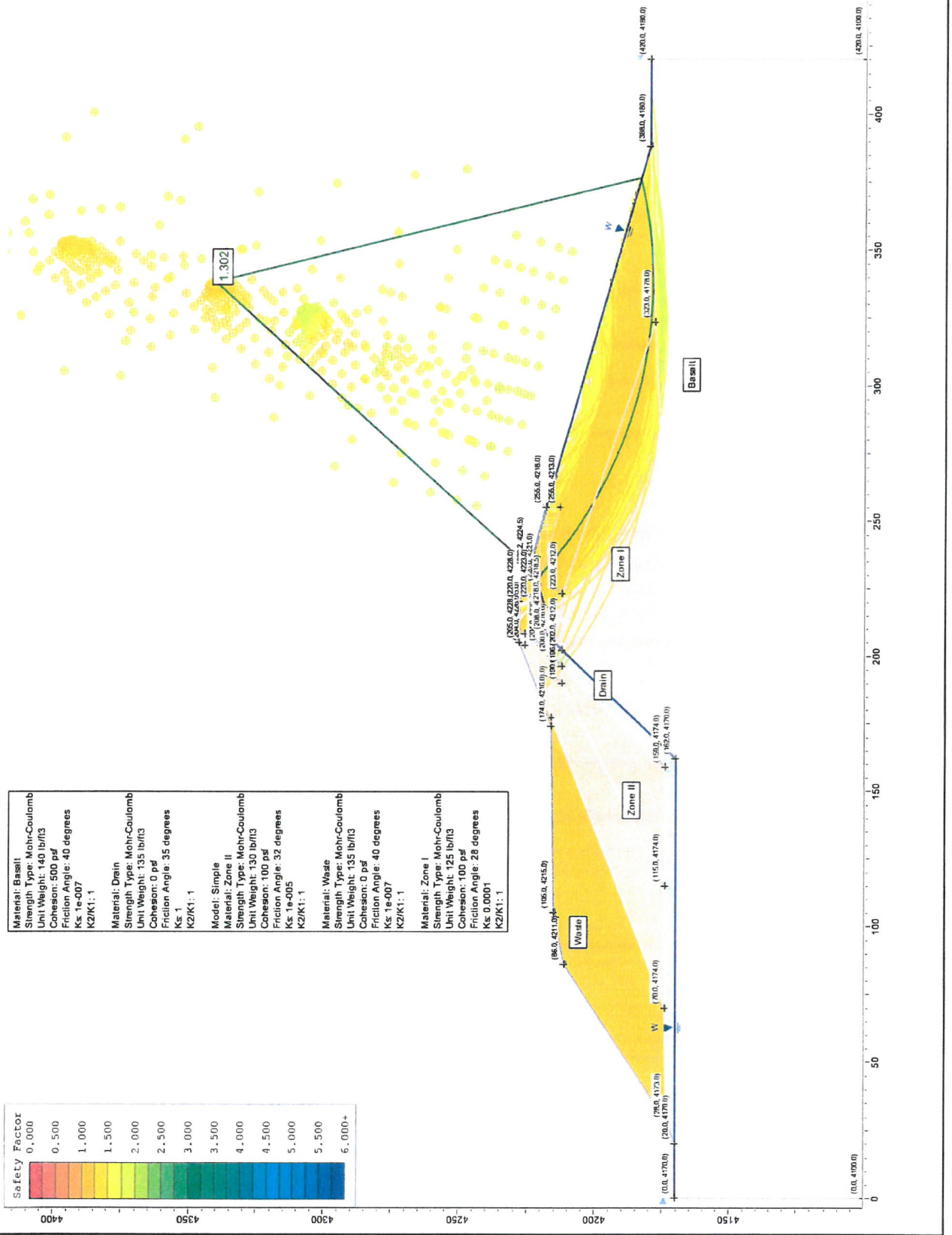
FROG HOLLOW DAM, WASHINGTON COUNTY – UPSTREAM STEADY STATE SECTION C-C'



PROJECT NO.: 1310-014-15	GSH	FIGURE NO.: C-4

STABILITY RESULTS

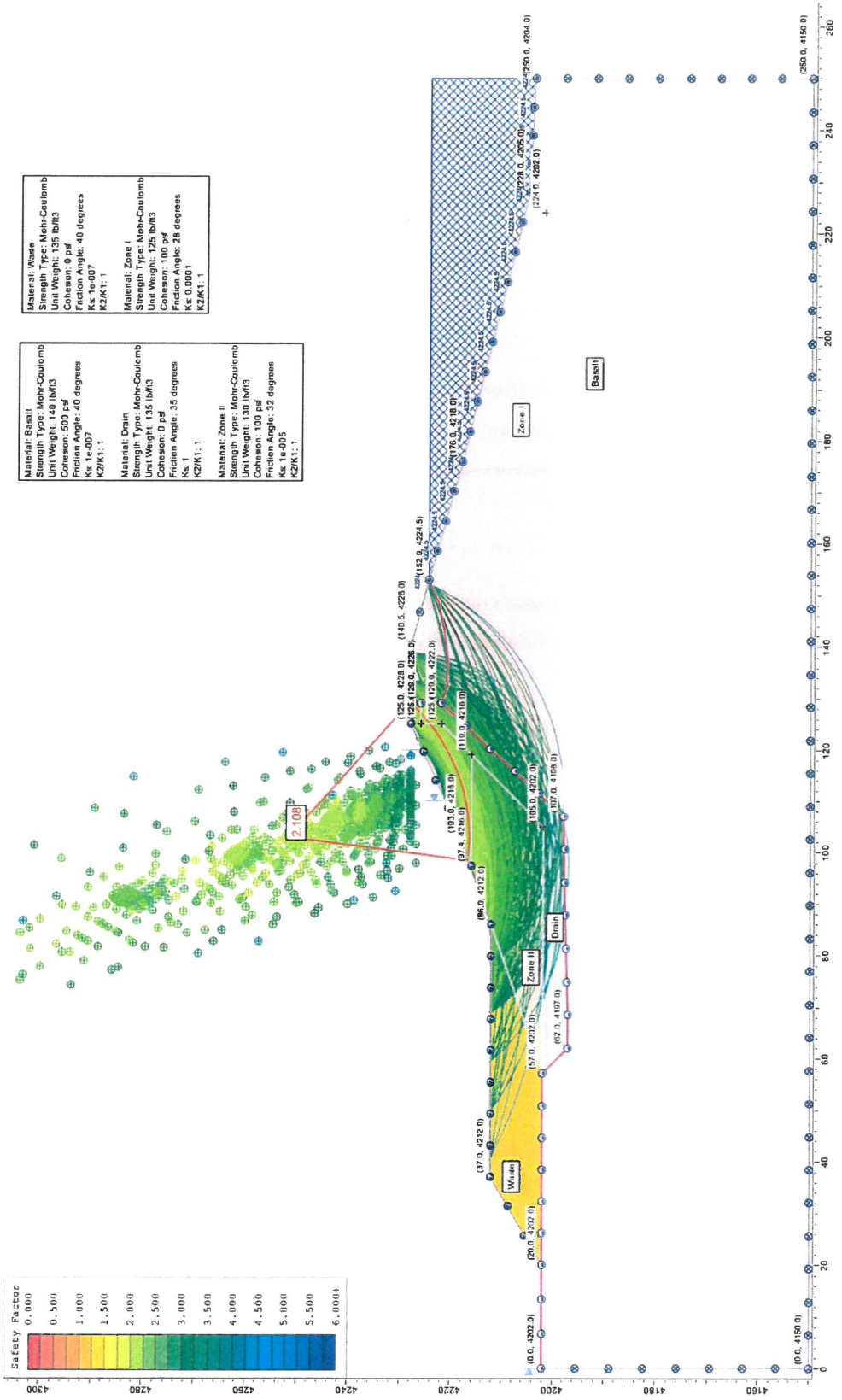
FROG HOLLOW DAM, WASHINGTON COUNTY – UPSTREAM RAPID DRAWDOWN SECTION C-C'



PROJECT NO.: 1310-014-15	GSH	FIGURE NO.: C-5

STABILITY RESULTS

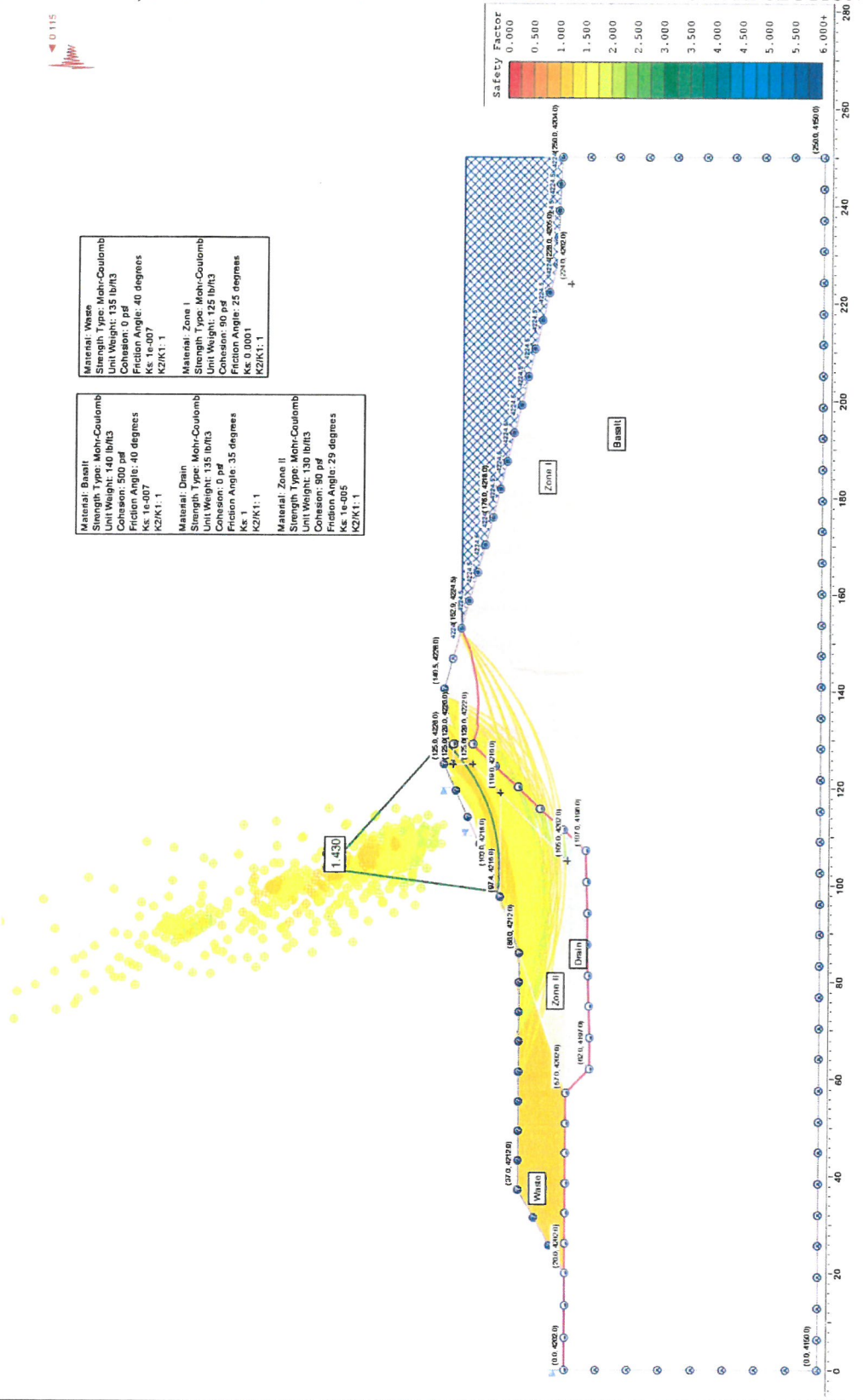
FROG HOLLOW DAM, WASHINGTON COUNTY – DOWNSTREAM STEADY STATE SECTION E-E'



PROJECT NO.: 1310-014-15	GSH	FIGURE NO.: C-6

STABILITY RESULTS

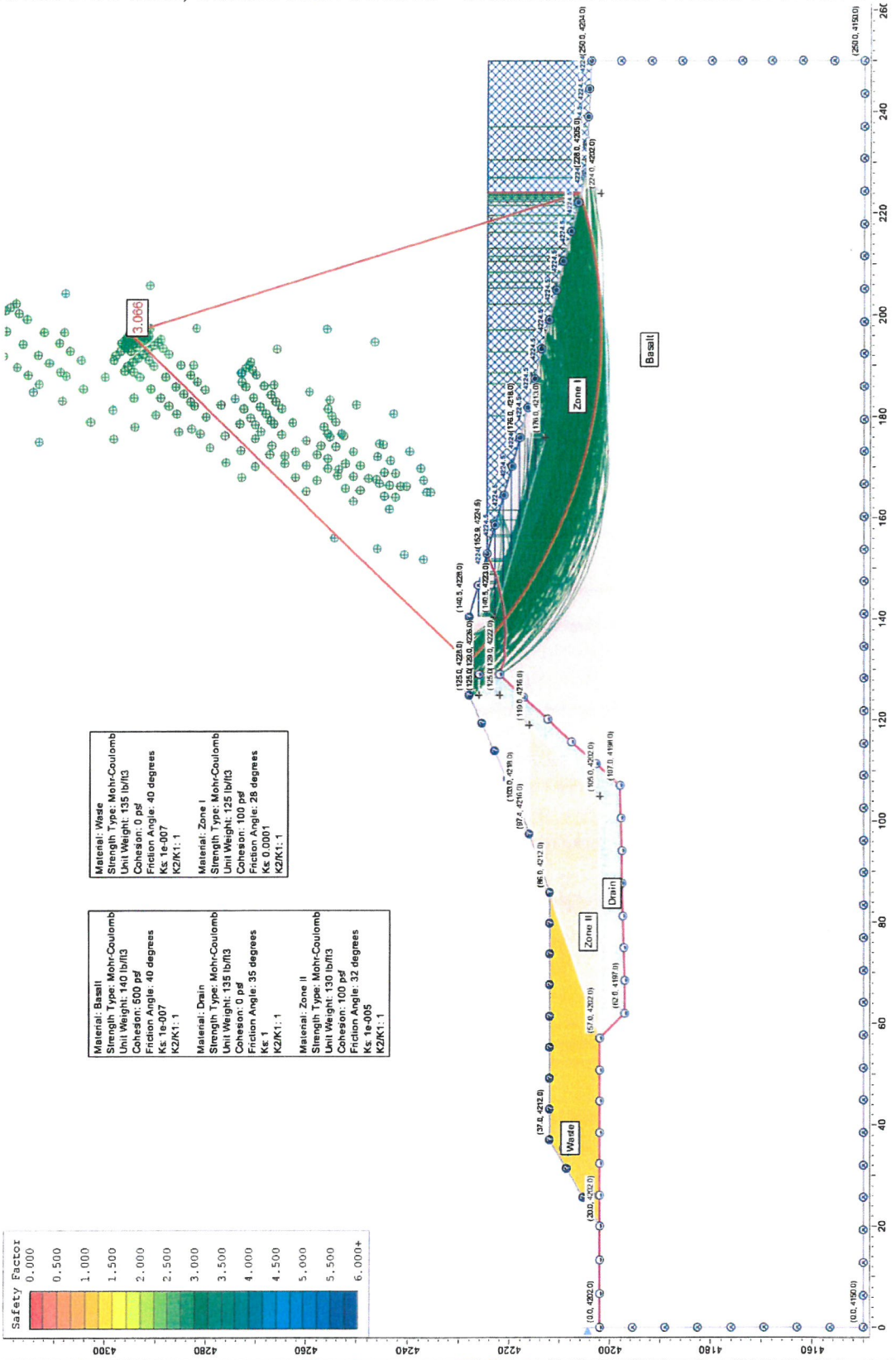
FROG HOLLOW DAM, WASHINGTON COUNTY – DOWNSTREAM STEADY STATE SECTION E-E'



PROJECT NO.: 1310-014-15	GSH	FIGURE NO.: C-7

STABILITY RESULTS

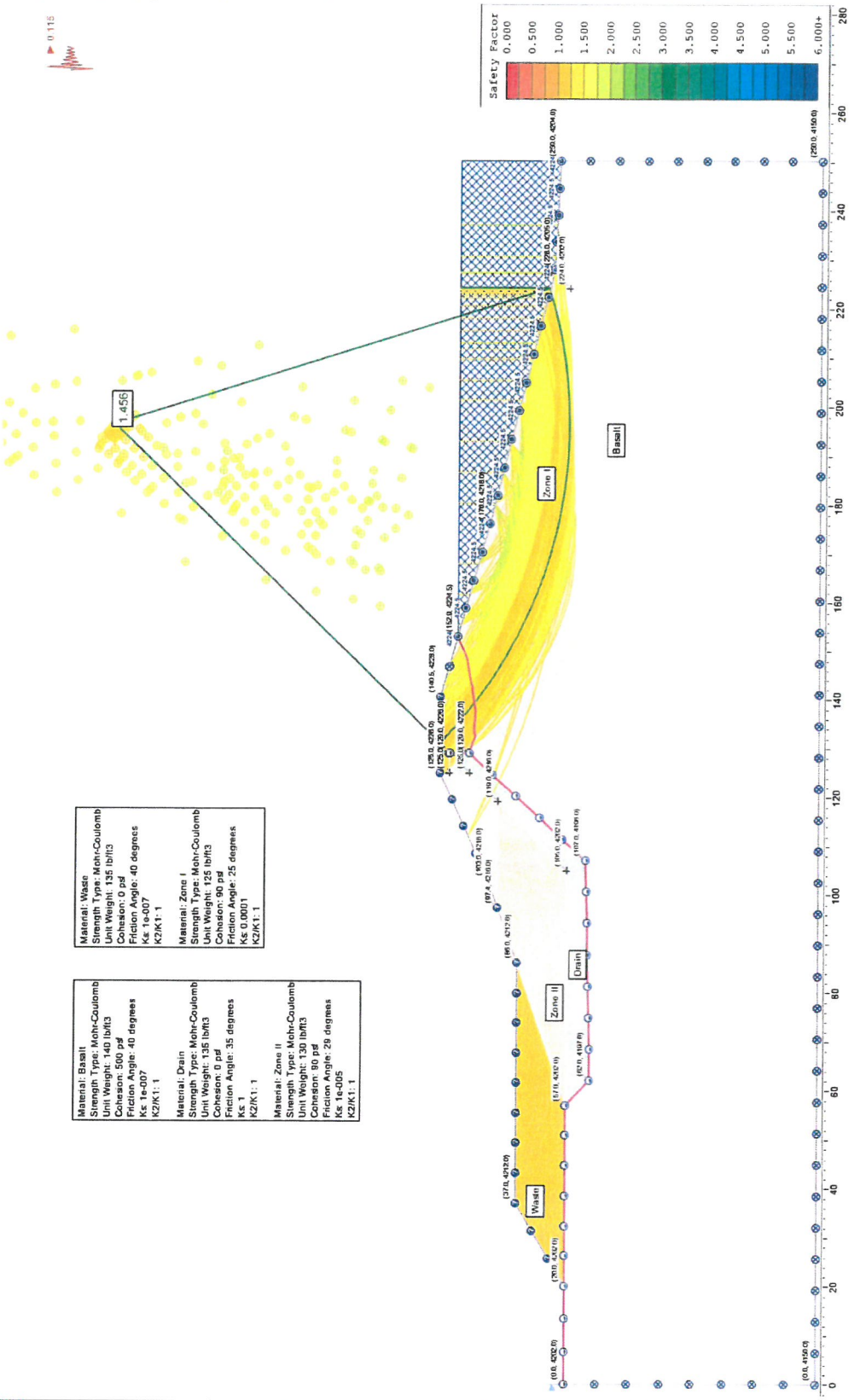
FROG HOLLOW DAM, WASHINGTON COUNTY – UPSTREAM STEADY STATE SECTION E-E'



PROJECT NO.: 1310-014-15	GSH	**FIGURE NO.:** C-8

STABILITY RESULTS

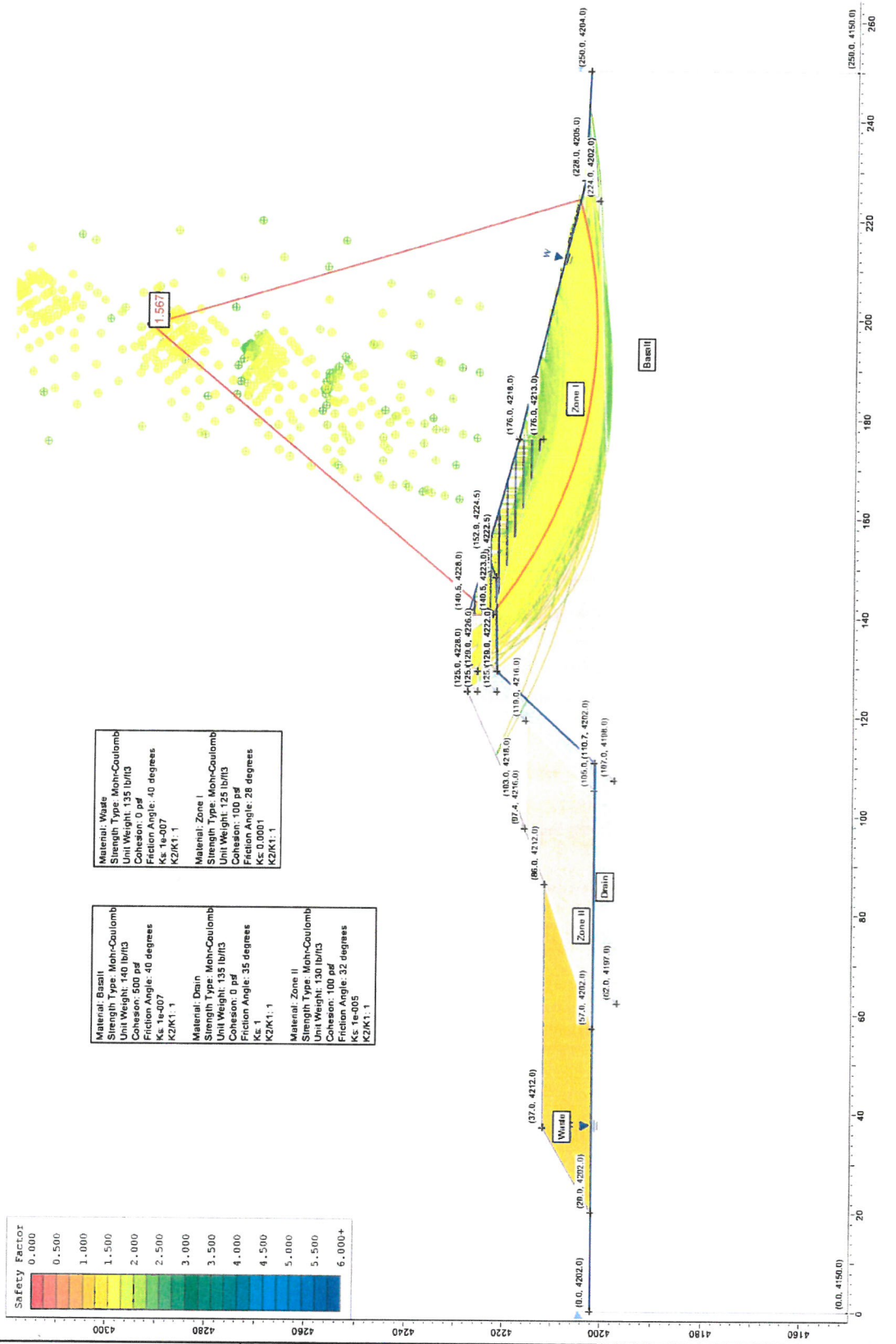
FROG HOLLOW DAM, WASHINGTON COUNTY – UPSTREAM STEADY STATE SECTION E-E'



PROJECT NO.: 1310-014-15	GSH	FIGURE NO.: C-9

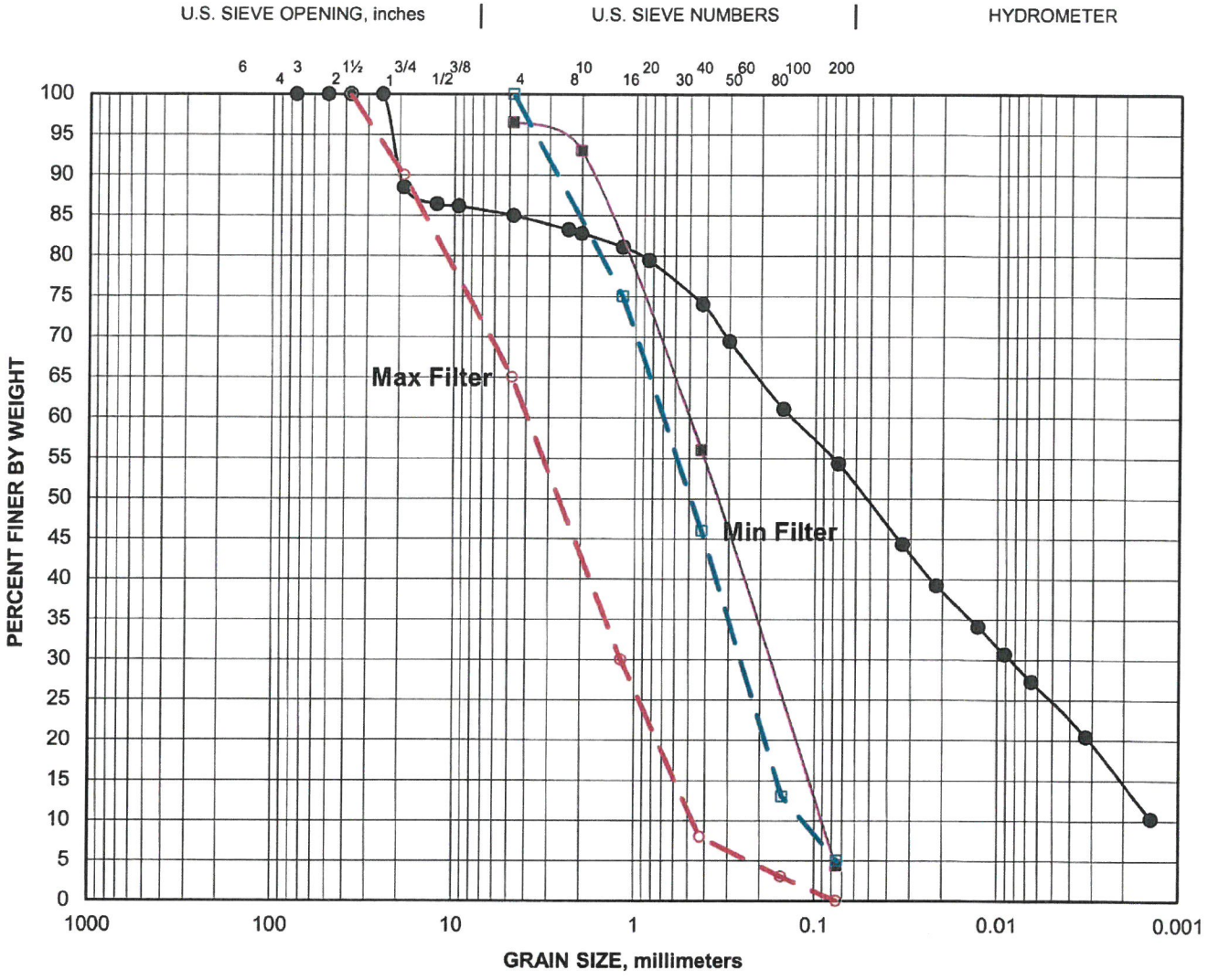
STABILITY RESULTS

FROG HOLLOW DAM, WASHINGTON COUNTY – UPSTREAM RAPID DRAWDOWN SECTION E-E'



PROJECT NO.: 1310-014-15	GSH	FIGURE NO.: C-10

GRAIN SIZE DISTRIBUTION



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen Identification	Classification	MC%	LL	PL	PI	Cc	Cu
● T-12 Embankmnt	Sandy CLAY with gravel (CL)	6					
■ T-12 Sand Drain	Poorly Graded SAND (SP)					0.7	6
▲							
◆							
X							

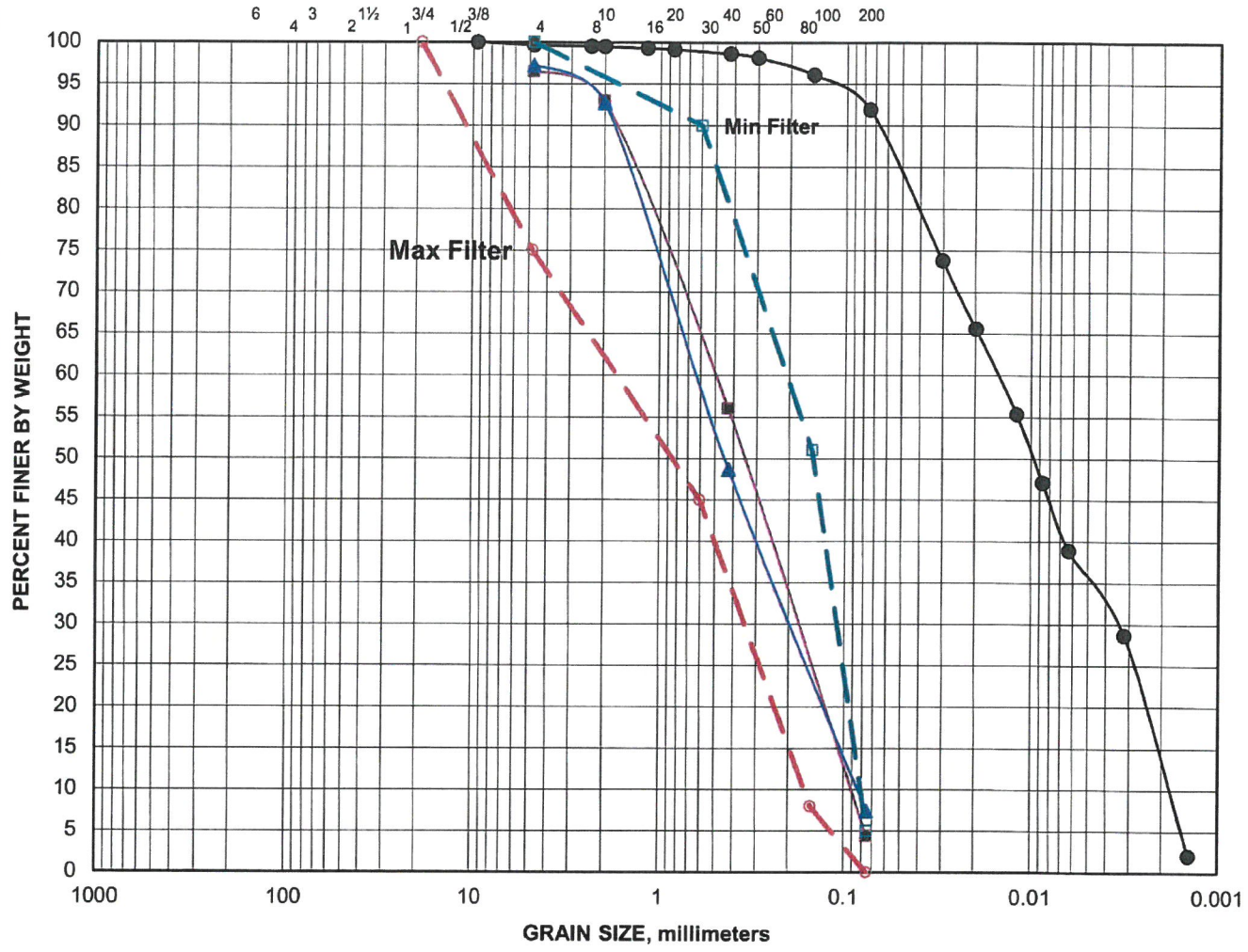
Specimen Identification	D100	D85	D60	D30	D15	D10	%Gravel	%Sand	%Silt	%Clay
● T-12 Embankmnt	75.0	4.84	0.137				15	31	29.7	24.7
■ T-12 Sand Drain		1.43	0.502	0.177	0.107	0.091	4	92	4	
▲										
◆										
X										

PROJECT NO.: 1310-014-16

GSH

FIGURE NO.: C-11

GRAIN SIZE DISTRIBUTION



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen Identification	Classification	MC%	LL	PL	PI	Cc	Cu
● T-13 Embankmnt	Clayey SILT (ML)	8					
■ T-12 Sand Drain	Poorly Graded SAND (SP)					0.7	6
▲ T-14 Sand Drain	Poorly Graded SAND with silt (SP-SM)					0.7	8
◆							
x							

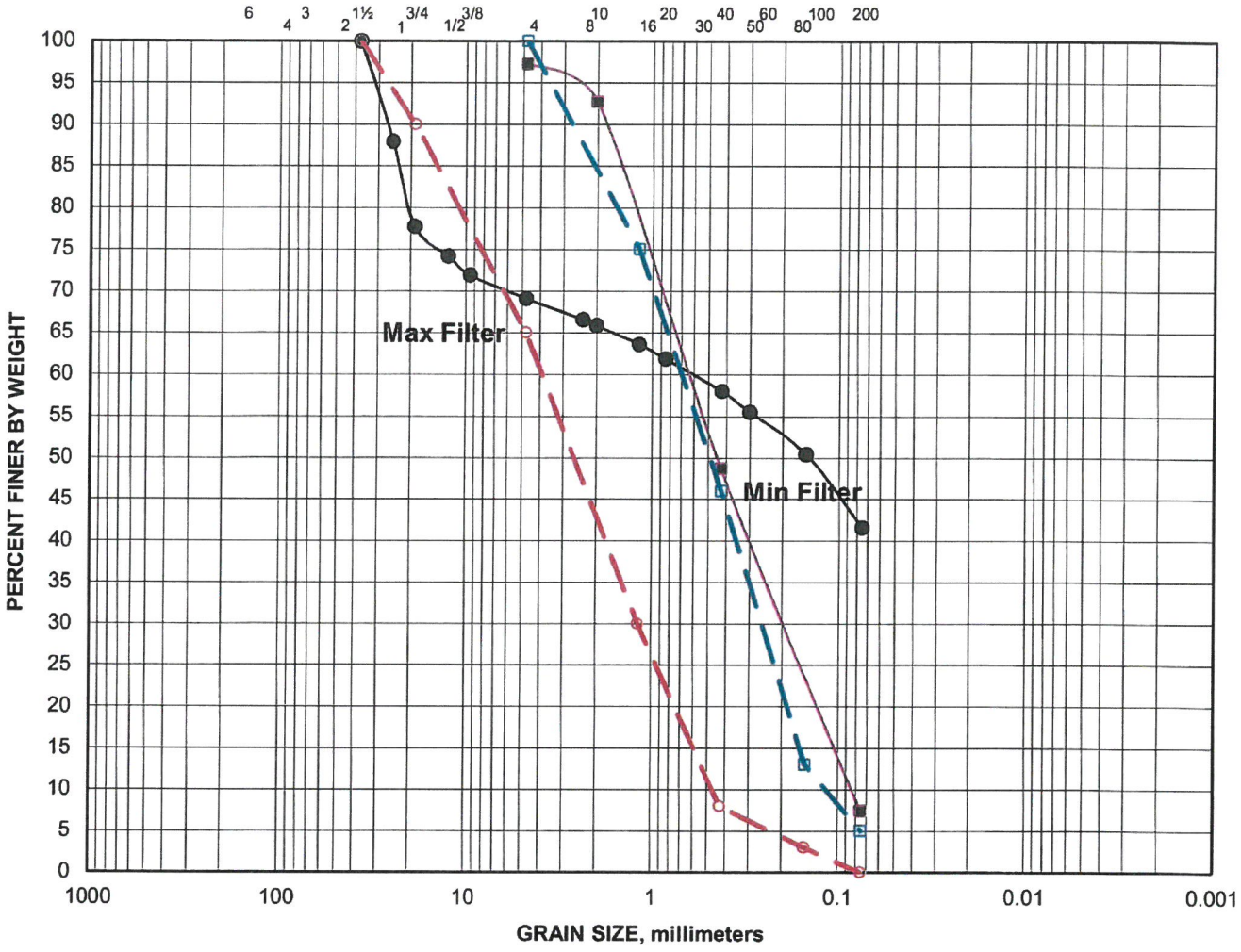
Specimen Identification	D100	D85	D60	D30	D15	D10	%Gravel	%Sand	%Silt	%Clay
● T-13 Embankmnt	9.50						0	8	56.4	35.4
■ T-12 Sand Drain		1.43	0.502	0.177	0.107	0.091	4	92	4	
▲ T-14 Sand Drain		1.53	0.633	0.194	0.103	0.084	3	90	7	
◆										
x										

PROJECT NO.: 1310-014-15

GSH

FIGURE NO.: C-12

GRAIN SIZE DISTRIBUTION



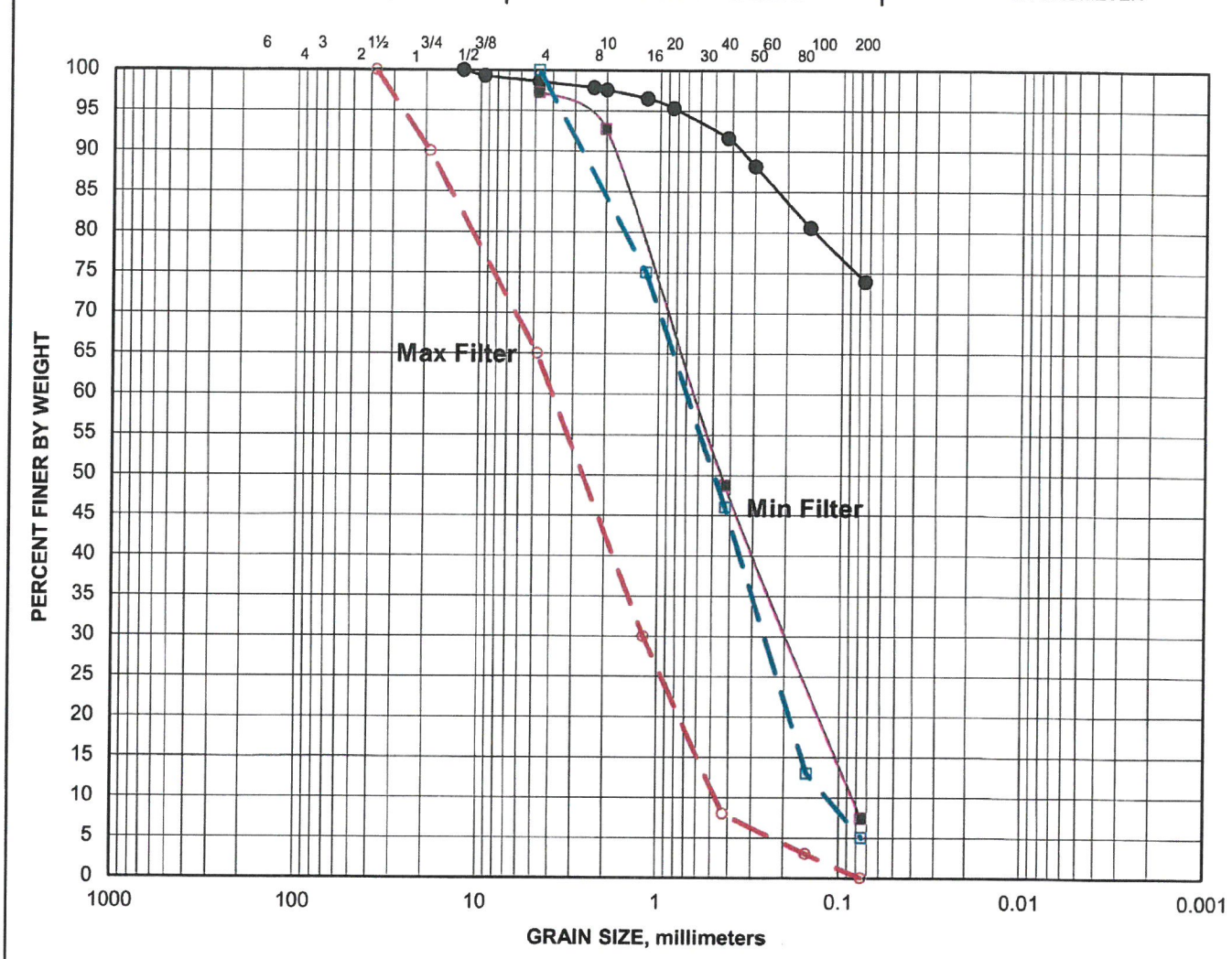
COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	T-14 Embankmnt	Clayey GRAVEL with sand (GC)	7					
■	T-14 Sand Drain	Poorly Graded SAND with silt (SP-SM)					0.7	8
▲								
◆								
x								

Specimen Identification		D100	D85	D60	D30	D15	D10	%Gravel	%Sand	%Silt	%Clay
●	T-14 Embankmnt	37.5	23.1	0.611				31	27	42	
■	T-14 Sand Drain		1.53	0.633	0.194	0.103	0.084	3	90	7	
▲											
◆											
x											

PROJECT NO.: 1310-014-15 | GSH | **FIGURE NO.:** C-13

GRAIN SIZE DISTRIBUTION



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

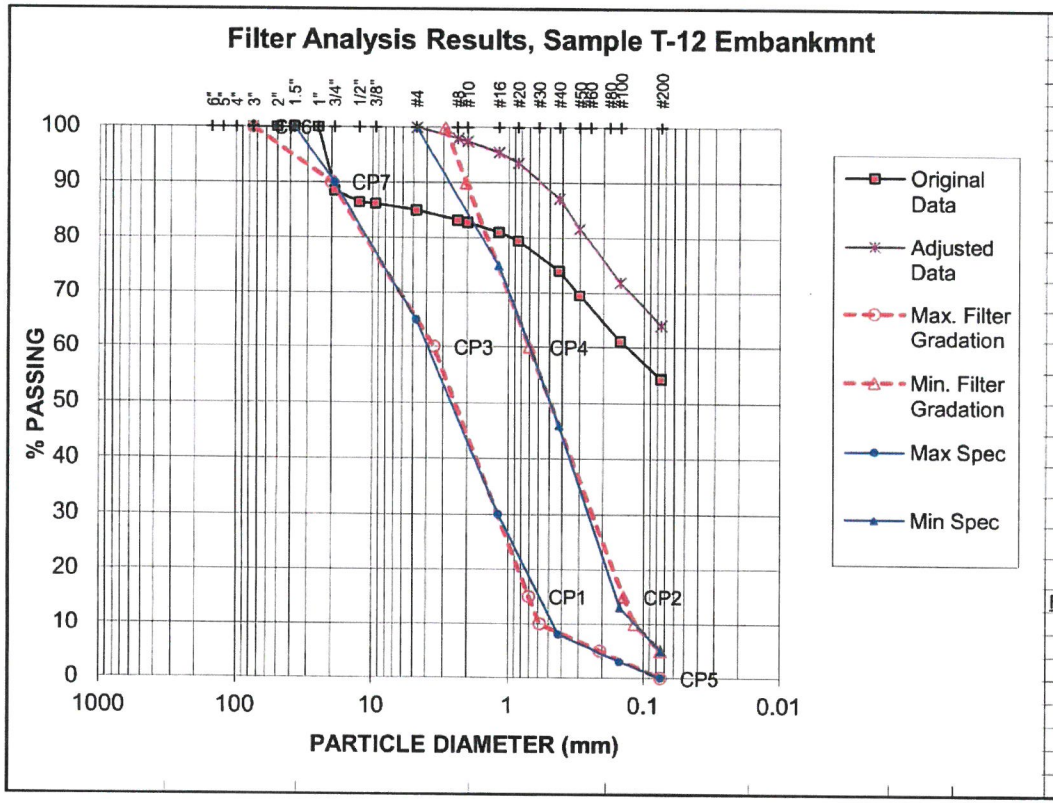
Specimen Identification	Classification	MC%	LL	PL	PI	Cc	Cu
● T-15 Embankmnt	SILT with sand (ML)	5					
■ T-14 Sand Drain	Poorly Graded SAND with silt (SP-SM)					0.7	8
▲							
◆							
X							

Specimen Identification	D100	D85	D60	D30	D15	D10	%Gravel	%Sand	%Silt	%Clay
● T-15 Embankmnt	12.5	0.225					1	25	74	
■ T-14 Sand Drain	#N/A	1.53	0.633	0.194	0.103	0.084	3	90	7	
▲										
◆										
X										

PROJECT NO.: 1310-014-15

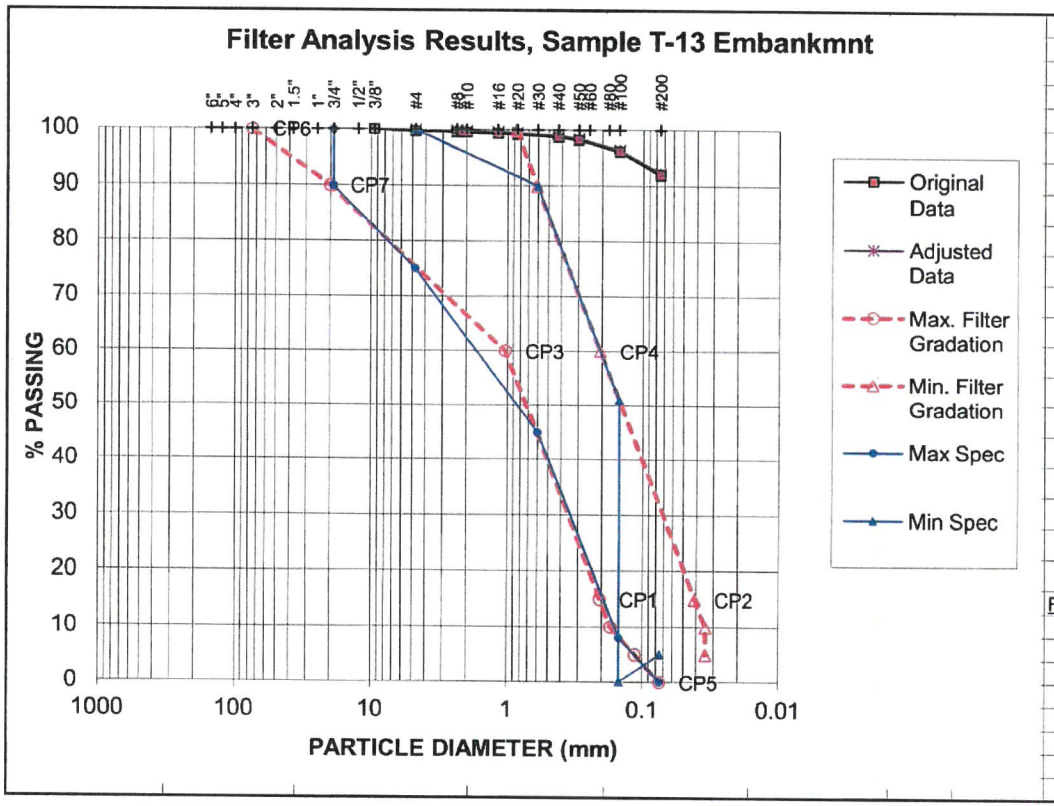
GSH

FIGURE NO.: C-14



Filter Gradation Calcs						
% Passing No. 4:		84.97				
Correction Factor:		1.177				
Corrected Minus 200:		63.98				
Base Soil Category:		2				
(corrected) D_{85B} size, mm:		0.370594874				
(Uncorrtd.) D_{15B} size, mm:		0.001287	(Estimated)			
prelim. max. D_{15F}, mm:		0.7				
prelim. min. D_{15F}, mm:		0.005148001				
maximum D_{15F} size, mm:		D15F <= 0.7 (Control Point 1)				
minimum D_{15F} size, mm:		D15F >= 0.1 (Control Point 2)				
max/min (D_{15F} size):		135.9751078	Greater than 5 !			
adjusted min.D_{15F}, mm:		0.14				
maximum D_{10F}, mm:		0.583333333				
maximum D_{60F}, mm:		3.5	(Control Pt 3)			
minimum D_{60F}, mm:		0.7	(Control Pt 4)			
minimum D_{10F}, mm:		0.116666667				
minimum D_{5F}, mm:		0.075	(Control Pt 5)			
maximum D_{100F}, mm:		75	(Control Pt 6)			
maximum D_{90F}, mm:		20	(Control Pt 7)			
FOR PLOTTING			For specifications		max.	min.
% passing	max size,mm	min size,mm	part.size,mm	sieve #	% pass.	% pass.
100	75	2.926878608	37.5	1.5"	100	#N/A
90	20	2.046812417	19	3/4"	90	#N/A
60	3.5	0.7	4.75	#4	65	100
15	0.7	0.14	1.18	#16	30	75
10	0.583333333	0.116666667	0.425	#40	8	46
5	0.209165007	0.075	0.15	#100	3	13
0	0.075	#N/A	0.075	#200	0	5

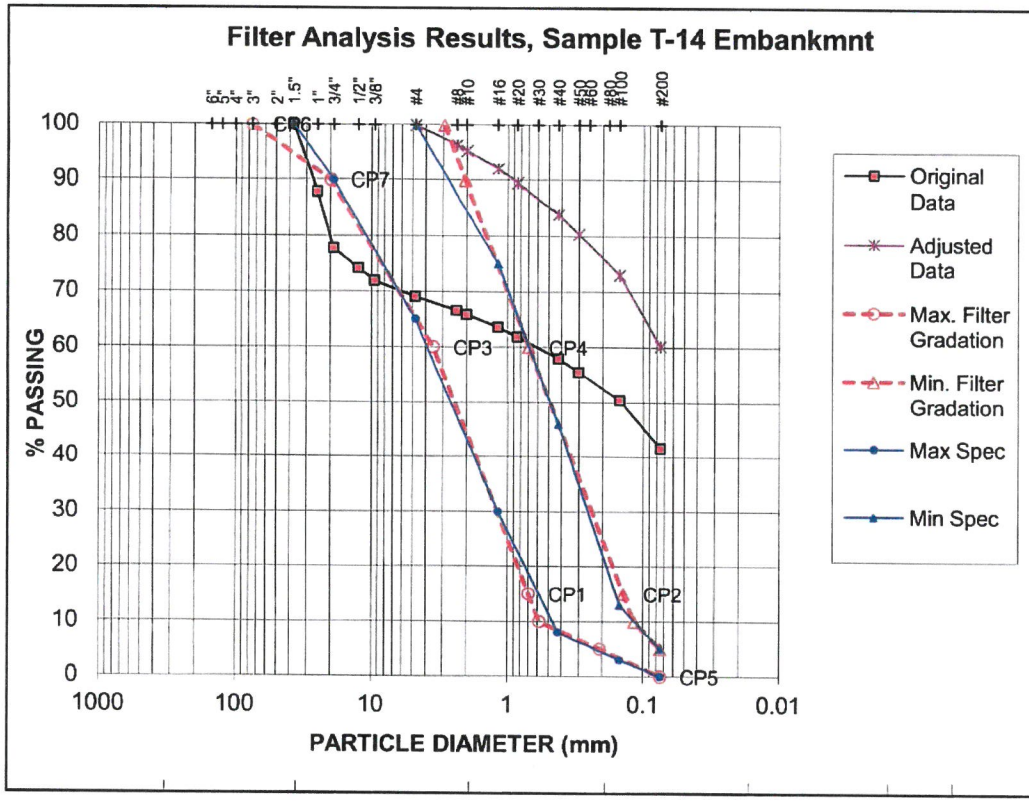
Figure No. C-15



Filter Gradation Calcs						
% Passing No. 4:	99.66					
Correction Factor:	1.003					
Corrected Minus 200:	92.20					
Base Soil Category:	1					
(corrected) D_{85B} size, mm:	0.022972973					
(Uncorrtd.) D_{15B} size, mm:	2.35383E-07	(Estimated)				
prelim. max. D_{15F}, mm:	0.206756756					
prelim. min. D_{15F}, mm:	9.41532E-07					
maximum D_{15F} size, mm:	D15F <= 0.207 (Control Point 1)					
minimum D_{15F} size, mm:	D15F >= 0.1 (Control Point 2)					
max/min (D_{15F} size):	219596.0181	Greater than 5 !				
adjusted min.D_{15F}, mm:	0.041351351					
maximum D_{10F}, mm:	0.172297297					
maximum D_{60F}, mm:	1.033783781	(Control Pt 3)				
minimum D_{60F}, mm:	0.206756756	(Control Pt 4)				
minimum D_{10F}, mm:	0.034459459					
minimum D_{5F}, mm:	0.075	(Control Pt 5)				
maximum D_{100F}, mm:	75	(Control Pt 6)				
maximum D_{90F}, mm:	20	(Control Pt 7)				

FOR PLOTTING			For specifications		max.	min.
% passing	max size,mm	min size,mm	part.size,mm	sieve #	% pass.	% pass.
100	75	0.864502753	19	3/4"	100	#N/A
90	20	0.604560423	19	3/4"	90	#N/A
60	1.033783781	0.206756756	4.75	#4	75	100
15	0.206756756	0.041351351	0.6	#30	45	90
10	0.172297297	0.034459459	0.15	#100	8	51
5	0.113676283	0.034459459	0.15	#100	8	#####
0	0.075	#N/A	0.075	#200	0	5

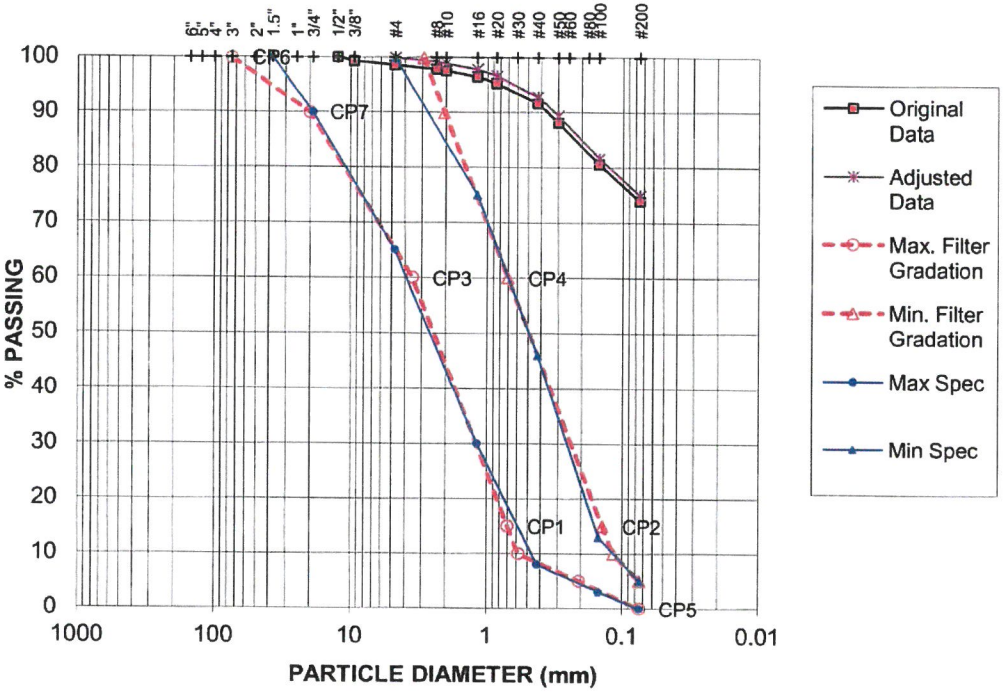
Figure No. C-16



Filter Gradation Calcs						
% Passing No. 4:	69.09					
Correction Factor:	1.447					
Corrected Minus 200:	60.20					
Base Soil Category:	2					
(corrected) D_{85B} size, mm:	0.485827885					
(Uncorrtd.) D_{15B} size, mm:	0.009347688	(Estimated)				
prelim. max. D_{15F}, mm:	0.7					
prelim. min. D_{15F}, mm:	0.03739075					
maximum D_{15F} size, mm:	D15F <= 0.7 (Control Point 1)					
minimum D_{15F} size, mm:	D15F >= 0.1 (Control Point 2)					
max/min (D_{15F} size):	18.72120776	Greater than 5 !				
adjusted min.D_{15F}, mm:	0.14					
maximum D_{10F}, mm:	0.583333333					
maximum D_{60F}, mm:	3.5	(Control Pt 3)				
minimum D_{60F}, mm:	0.7	(Control Pt 4)				
minimum D_{10F}, mm:	0.116666667					
minimum D_{5F}, mm:	0.075	(Control Pt 5)				
maximum D_{100F}, mm:	75	(Control Pt 6)				
maximum D_{90F}, mm:	20	(Control Pt 7)				

FOR PLOTTING			For specifications		max.	min.
% passing	max size,mm	min size,mm	part.size,mm	sieve #	% pass.	% pass.
100	75	2.926878608	37.5	1.5"	100	#N/A
90	20	2.046812417	19	3/4"	90	#N/A
60	3.5	0.7	4.75	#4	65	100
15	0.7	0.14	1.18	#16	30	75
10	0.583333333	0.116666667	0.425	#40	8	46
5	0.209165007	0.075	0.15	#100	3	13
0	0.075	#N/A	0.075	#200	0	5

Figure No. C–17

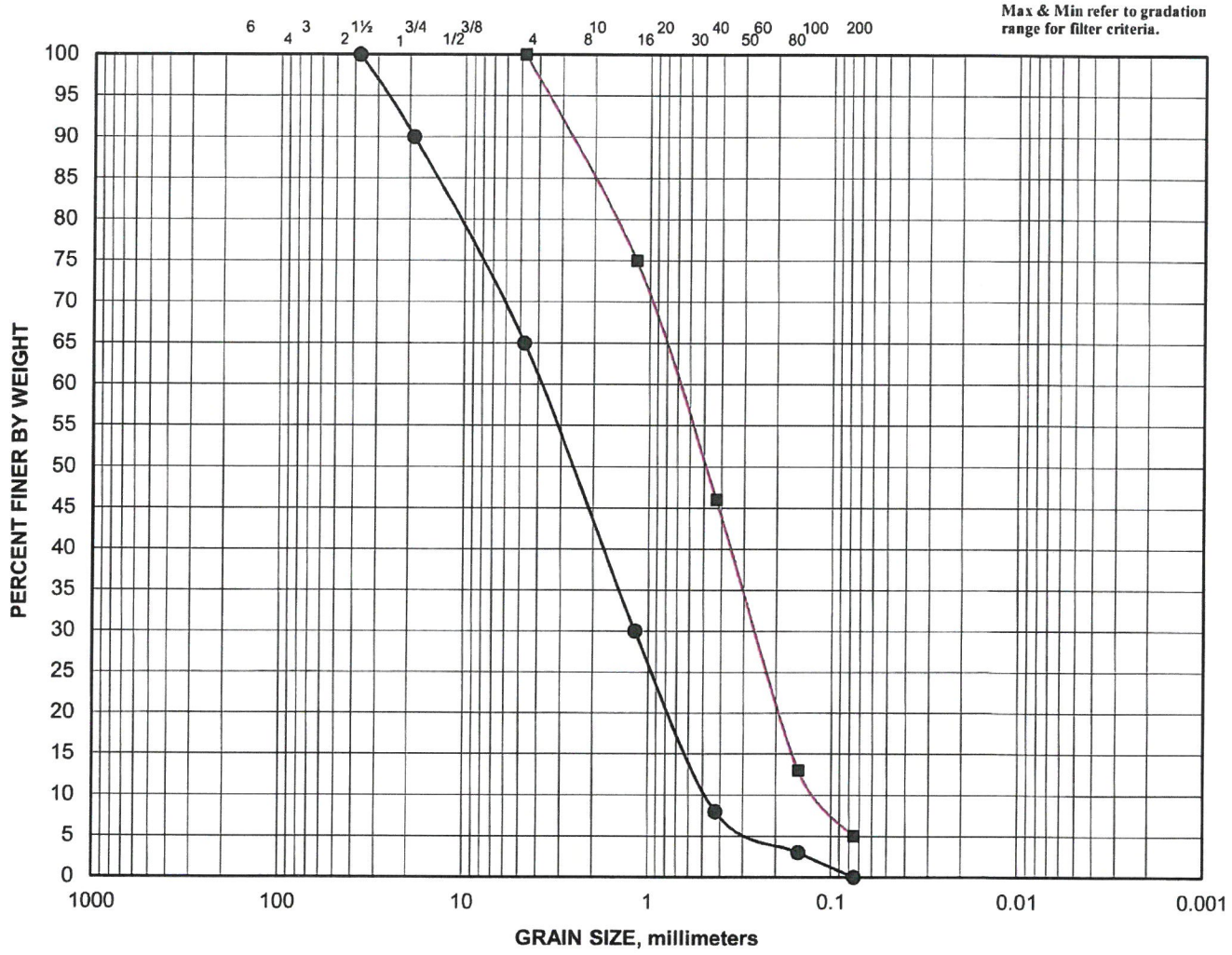


Filter Gradation Calcs						
% Passing No. 4:	98.58					
Correction Factor:	1.014					
Corrected Minus 200:	74.97					
Base Soil Category:	2					
(corrected) D_{85B} size, mm:	0.201811905					
(Uncorrtd.) D_{15B} size, mm:	0.000160736	(Estimated)				
prelim. max. D_{15F}, mm:	0.7					
prelim. min. D_{15F}, mm:	0.000642946					
maximum D_{15F} size, mm:	D15F <= 0.7 (Control Point 1)					
minimum D_{15F} size, mm:	D15F >= 0.1 (Control Point 2)					
max/min (D_{15F} size):	1088.73853	Greater than 5 !				
adjusted min.D_{15F}, mm:	0.14					
maximum D_{10F}, mm:	0.583333333					
maximum D_{60F}, mm:	3.5	(Control Pt 3)				
minimum D_{60F}, mm:	0.7	(Control Pt 4)				
minimum D_{10F}, mm:	0.116666667					
minimum D_{5F}, mm:	0.075	(Control Pt 5)				
maximum D_{100F}, mm:	75	(Control Pt 6)				
maximum D_{90F}, mm:	20	(Control Pt 7)				

FOR PLOTTING			For specifications		max.	min.
% passing	max size,mm	min size,mm	part.size,mm	sieve #	% pass.	% pass.
100	75	2.926878608	37.5	1.5"	100	#N/A
90	20	2.046812417	19	3/4"	90	#N/A
60	3.5	0.7	4.75	#4	65	100
15	0.7	0.14	1.18	#16	30	75
10	0.583333333	0.116666667	0.425	#40	8	46
5	0.209165007	0.075	0.15	#100	3	13
0	0.075	#N/A	0.075	#200	0	5

Figure No. C-18

GRAIN SIZE DISTRIBUTION



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification	Classification	MC%	LL	PL	PI	Cc	Cu
●	**Max Filter**	**Poorly Graded Sand with gravel (SP)**					**0.76**	**7.95**
■	**Min Filter**	**Poorly Graded Sand (SP)**					**0.8**	**6**
▲								
◆								
X								
+								

	Specimen Identification	D100	D85	D60	D30	D15	D10	%Gravel	%Sand	%Silt	%Clay
●	**Max Filter**	**37.5**	**14.4**	**3.89**	**1.18**	**0.588**	**0.466**	**35**	**65**	**0**	
■	**Min Filter**	**4.75**	**2.06**	**0.696**	**0.257**	**0.160**	**0.136**	**0**	**95**	**5**	
▲											
◆											
X											
+											

PROJECT NO.: 1310-014-15 | GSH | **FIGURE NO.:** C-19

APPENDIX D

PHOTOGRAPHS / FIELD MEASURMENTS

APPENDIX D

SECTION 1 – GENERAL CONDITION PHOTOGRAPHS

GENERAL CONDITIONS PHOTOGRAPHS

Photo D.1-1 - Looking west at dam and basin.

Photo D.1-2 - Looking west at dam and basin.

Photo D.1-3 - Looking northwest down discharge channel.

Photo D.1-4 - Looking east at discharge structure and basin.

Photo D.1-5 - Looking south across basin.

Photo D.1-6 - Looking east at discharge structure and basin.

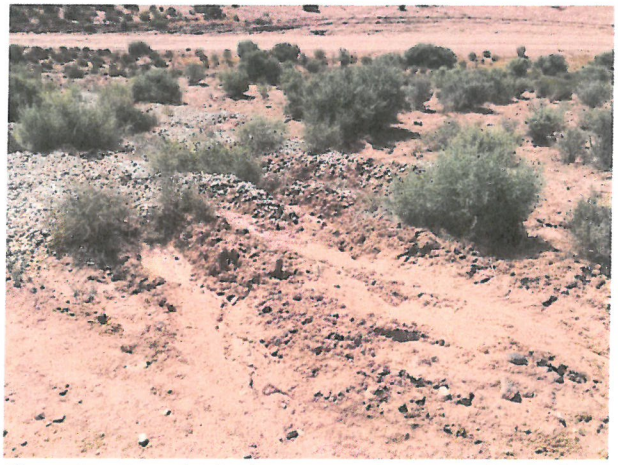


Photo D.1-7 - Vehicle damage on upstream slope of dam.

Photo D.1-8- Looking north, at emergency spillway.

Photo D.1-9- Looking east at emergency spillway.

Photo D.1-10 - Looking northeast along the upstream slope of the dam.

Photo D.1-11 - Looking northeast along crest of dam.

Photo D.1-12 - Looking northeast along the downstream slope of the dam.

Photo D.1-13 - Looking northeast along the upstream slope of the dam.

Photo D.1-14 - Looking northeast along crest of dam.

Photo D.1-15 - Looking northeast along the downstream slope of the dam.

Photo D.1-16 Looking northeast along the upstream slope of the dam.

Photo D.1-17 Looking northeast along crest of dam

Photo D.1-18 Looking northeast along the downstream slope of the dam, knee-high vegetation.

Photo D.1-19 Looking southwest along the upstream slope of dam.

Photo D.1-20 Looking southwest along crest of dam.

Photo D.1-21 Looking southwest along the downstream slope of dam.

Photo D.1-22 Looking northeast along the downstream slope of the dam, knee-high vegetation.

Photo D.1-23 Looking northeast along the center of the dam.

Photo D.1-24 Looking northeast along the upstream slope of the dam.

Photo D.1-25 Looking northeast along the downstream slope of the dam, knee-high vegetation.

Photo D.1-26 Looking northeast along the center of the dam, knee-high vegetation.

Photo D.1-27 Looking northeast along the upstream slope of the dam.

Photo D.1-28 Looking northeast along the downstream slope of the dam, fence crossing dam.

Photo D.1-29 Looking northeast along the crest of the dam, fence crossing dam.

Photo D.1-30 Looking northeast along the upstream slope of the dam, fence crossing dam.

Photo D.1-31 Vehicle tracks climbing up dam on upstream slope.

Photo D.1-32 Southeast face of drainage structure, two openings below ground-surface elevation.

Photo D.1-33 Northwest face of drainage structure, vegetation in cage.

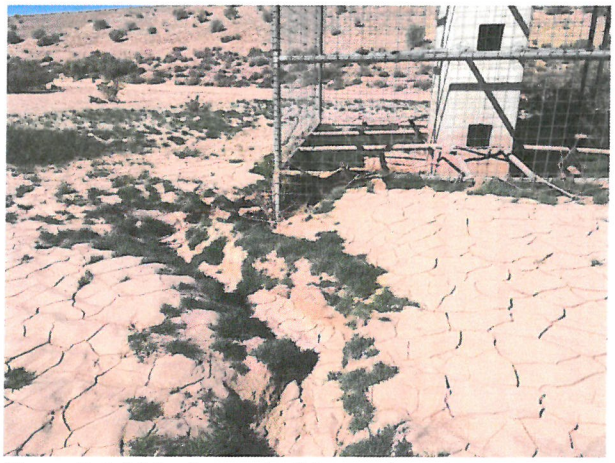


Photo D.1-34 Sediment buildup and erosion at southeast face of drainage structure.

Photo D.1-35 Sediment buildup and erosion at southeast face of drainage structure.

Photo D.1-36 Erosion at north corner of drainage structure, vegetation in cage.

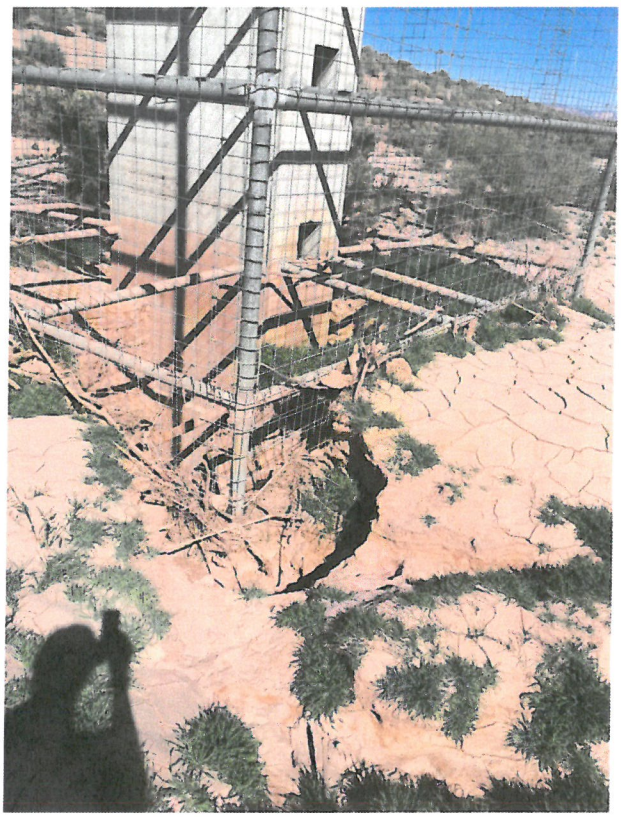


Photo D.1-37 Sediment buildup and erosion at south corner of drainage structure.

Photo D.1-38 Sediment buildup and erosion at southeast face of drainage structure.

Photo D.1-39 – Principal Outlet location: Looking towards dam along principal outlet prior to any excavation.

Photo D.1-40 – Principal Outlet location: Looking towards dam along outlet. Sedimentation is apparent in the principal outlet pipe.

Photo D.1-41 – Principal Outlet location: Looking towards dam into principal outlet. Sedimentation extends back into outlet pipe.

Photo D.1-42 – Principal Outlet location: Looking towards dam down at outlet after exposing chimney drain outlet pipes. One chimney drain outlet pipe is located on each side of the principal outlet pipe; Found at 24" below slope grade.

Photo D.1-43 – Southern Chimney Drain Outlet location: Looking towards dam. Outlet was found to be full of sediment.

Photo D.1-44 – Southern Chimney Drain Outlet location: Sediment within outlet extends more than 6" into pipe.

Photo D.1-45 – Northern Chimney Drain Outlet location: Looking northeast. Outlet was found to be full of sediment.

APPENDIX D

SECTION 2 – SINKHOLE/CRACKING EXPLORATION PHOTOGRAPHS

SINKHOLE / CRACKING EXPLORATION PHOTOGRAPHS

EXPLORATION AREA 1

Photo D.2-A1-1 – T-1 location: Overlooking H-51 before exploration. H-51 consists of a large primary opening (low and center) and clusters of smaller secondary openings (high center).

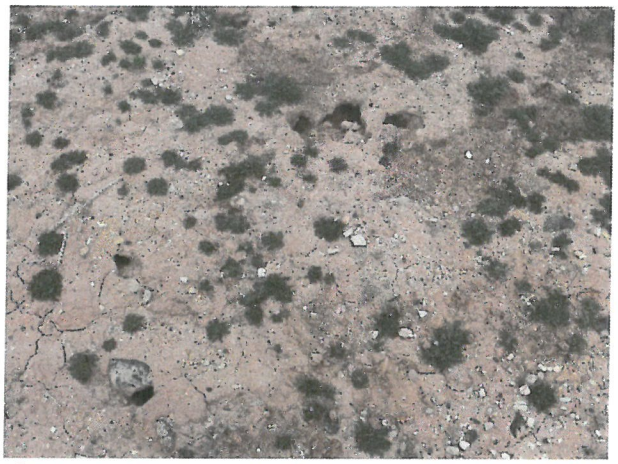


Photo D.2-A1-2 – T-1 location: Overlooking H-51 secondary openings before exploration.

Photo D.2-A1-3 – Overlooking Area 1. Looking northeast along the upstream slope of dam showing T-1 (foreground) in relation to T-2, T-3 and T-4 (background).

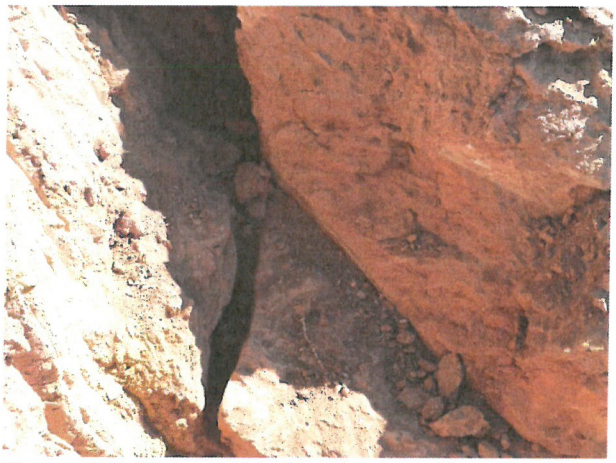


Photo D.2-A1-4 – T-1 location: Looking northeast toward T-2, T-3, and T-4 along longitudinal crack in floor and northeast wall.

Photo D.2-A1-5 – T-1 location: Looking north at intersection between longitudinal crack (left to right) and transverse crack in northwest wall (center left).

Photo D.2-A1-6 – T-2 location: Longitudinal crack is located in northeast wall of T-2 directly below wood stake (center left).

EXPLORATION AREA 1

Photo D.2-A1-7 - T-2 location: Looking northeast along general northeasterly direction of the longitudinal crack. Longitudinal crack is located in northeast wall of T-2 directly below wood stake (center left).

Photo D.2-A1-8 – T-3 location: Overlooking H-50 (left) and H-49 (right) before exploration. H-49 and H-50 consisted of two separate openings in same crack. Large rocks had been placed over the opening and dirt had been deposited over top.

Photo D.2-A1-9 – T-3 location: Overlooking H-50 (foreground) and H-49 (background) during exploration. Rocks have been removed to show general openness of the crack at the surface. A shallow dirt bridge still spans the crack between H-49 and H-50.

Photo D.2-A1-10 – T-3 location: Looking northeast toward T-4 along longitudinal crack in floor and northeast wall.

Photo D.2-A1-11 – T-4 location: Looking northeast along the upstream side of the dam showing longitudinal crack in northeast wall.

Photo D.2-A1-12 – T-4 location: Looking northeast along the upstream side of the dam showing longitudinal crack in northeast wall.

EXPLORATION AREA 2

Photo D.2-A2-1 – T-5 location: Looking northeast over H-2 after presoaking and staining prior to exploration.

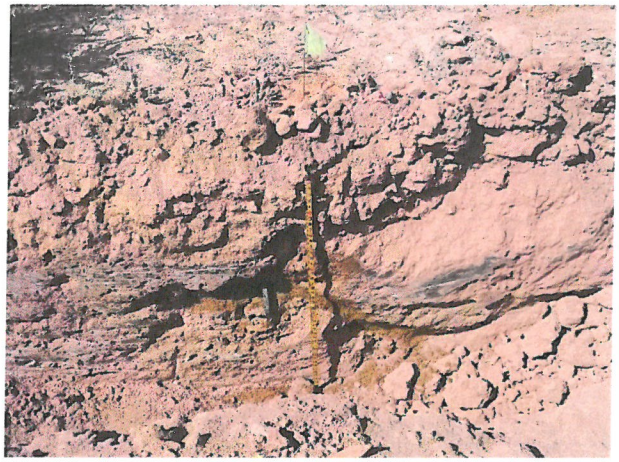


Photo D.2-A2-2 – T-5 location: Looking northwest into trench at staining on northwest wall. An approximate 10-inch diameter hole into chimney drain material is located center photo.

Photo D.2-A2-3 – T-5 location: Looking northwest into trench at staining around 10-inch hole in chimney drain material located on the northwest wall.

Photo D.2-A2-4 – T-6 location: Looking northwest over H-4 (background) and H-3 (foreground) prior to exploration.

Photo D.2-A2-5 – T-6 location: Looking northwest. A transverse crack can be observed in the floor and northwest wall of T-6.

Photo D.2-A2-6 – T-6 location: Looking northwest at the transverse crack can be observed in the northwest wall of T-6.

EXPLORATION AREA 2

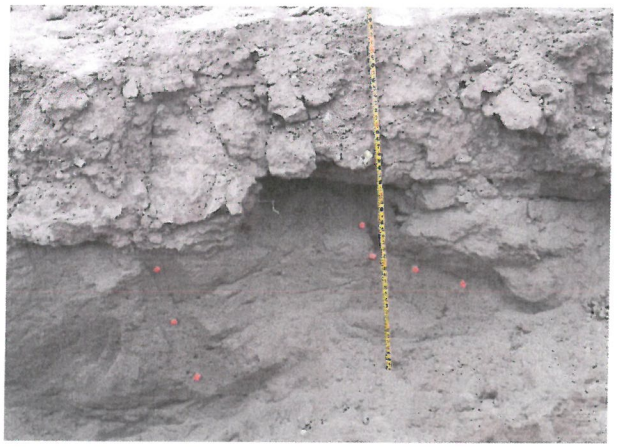


Photo D.2-A2-7 – T-12 location: Looking southeast toward H-2. Two cracks are located in the southeast wall/chimney drain. Staining from previous presoaking is located within the crack to the right.

Photo D.2-A2-8 – T-12 location: Looking northwest into trench at continuation of crack through northwest wall.

Photo D.2-A2-9 – T-12 location: Looking southwest into trench at continuation of crack in floor through the chimney drain to the left to the downstream embankment to the right. Two separate crack are located in the floor of the trench and appear to converge in the northwest wall.

Photo D.2-A2-10 – T-15 location: Looking southeast towards T-12. One transverse crack can be observed in the upper wall and two in the lower wall of T-15. Flagged lath in the background shows the alignment with the same crack observed in T-12.

Photo D.2-A2-11 – T-15 location: Looking southeast at the primary transverse crack in the lower wall of T-15. Roots can be observed within the primary crack.

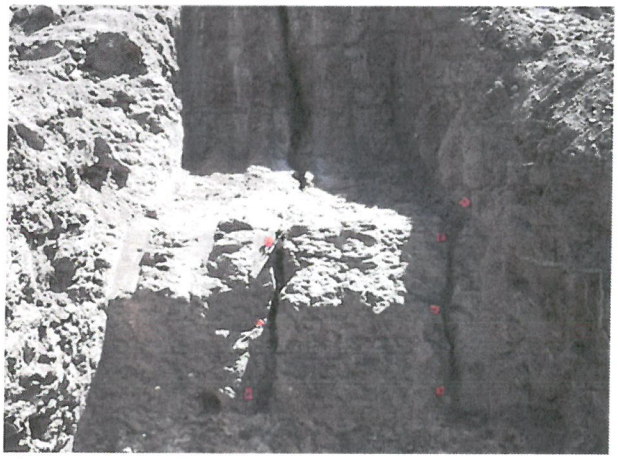


Photo D.2-A2-12 – T-15 location: Looking southeast along the primary transverse crack in the floor between the upper and lower walls of T-15. The secondary crack can be observed in the lower right corner of the photo. Both cracks end at the old embankment material.

EXPLORATION AREA 3

Photo D.2-A3-1 – T-7 location: Looking southwest along dam crest.

Photo D.2-A3-2 – T-7 location: Looking southeast into trench. An open crack can be observed in southeast wall.

Photo D.2-A3-3 – T-7 location: Looking southeast into trench. Multiple secondary crack can be observed in southeast wall.

Photo D.2-A3-4 – T-8 location: Looking overlooking H-11 prior to exploration. Remnants of grout from previous maintenance attempts can be observed at the surface.

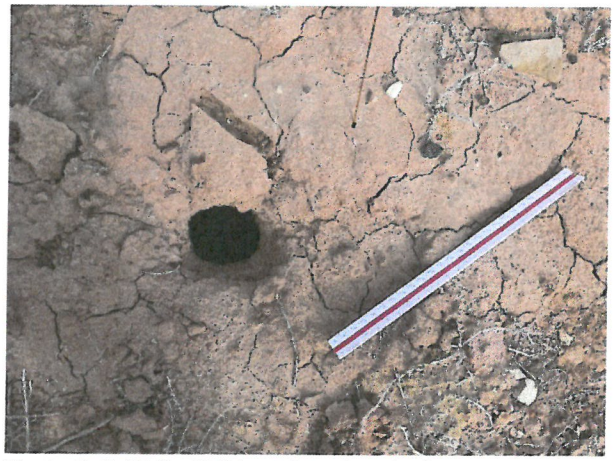


Photo D.2-A3-5 – T-8 location: Overlooking H-12 prior to exploration.

Photo D.2-A3-6 – Area 3 location: Looking southwest over exploration T-7 and T-8. T-8 is located (left) on upstream slope and T-7 is located on dam crest (right)

EXPLORATION AREA 3

Photo D.2-A3-7 – T-8 location: Looking northwest after 36 inches of excavation at H-11. A grout cap from previous maintenance attempts can be observed to end directly below the surface.

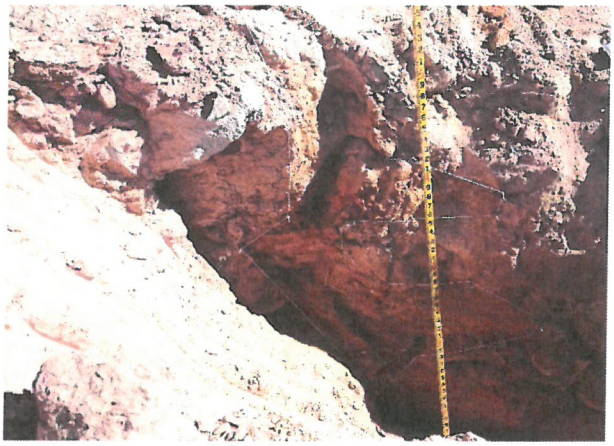


Photo D.2-A3-8 – T-8 location: Looking north after excavation was completed. Staining, outlined by string, can be observed on the northeast wall at H-11. A grout cap from previous maintenance attempts can be observed (top left).

Photo D.2-A3-9 – T-8 location: Looking northwest after excavation was completed. An open crack can be observed in the northwest wall below grout cap, and in the floor of trench.

EXPLORATION AREA 3

Photo D.2-A3-10 – T-13 location: Looking southeast into the trench from the upstream side of the embankment. Transverse cracking is visible in the floor of the trench.

Photo D.2-A3-11 – T-13 location: Looking northwest into trench at the crack located in the upper northwest wall.

Photo D.2-A3-11 – T-13 location: Looking northeast into trench at the crack located in the floor of the upper bench.

Photo D.2-A3-12 – T-13 location: Looking northeast into trench at the two cracks located in the wall of the middle bench and their continuation further downstream in the floor of the middle bench.

Photo D.2-A3-13 – T-13 location: Looking northwest along T-13 showing the continuation of two cracks into the lower wall. and finally terminating at the underlying basalt formation

EXPLORATION AREA 3

Photo D.2-A3-14 – T-13 location: Looking northwest along T-13 showing the continuation of two cracks into the lower walls. and finally terminating at the underlying basalt formation

EXPLORATION AREA 4

Photo D.2-A4-1 – T-9 location: Overlooking H-26 prior to exploration.

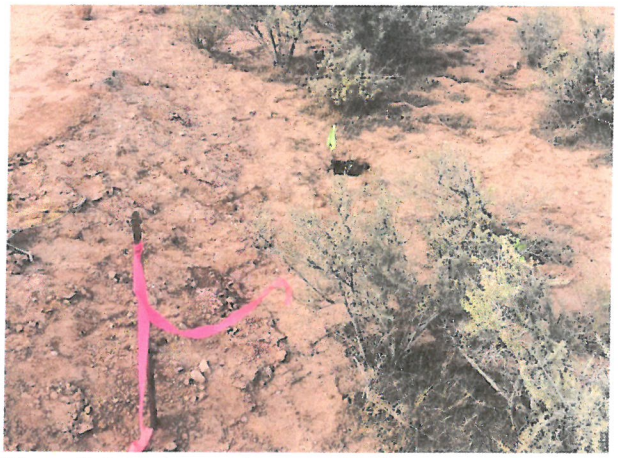


Photo D.2-A4-2 – T-9 location: Looking southwest over H-26 prior to exploration.

Photo D.2-A4-3 – T-9 location: Looking south after exploration.

Photo D.2-A4-4 – T-10 location: Looking southwest along dam crest.

Photo D.2-A4-5 – T-10 location: Looking southeast into trench. A transverse crack can be observed in the southeast wall.

Photo D.2-A4-6 – T-11 location: Overlooking H-20 prior to exploration.

EXPLORATION AREA 4

Photo D.2-A4-7 – T-11 location: Looking north after 36 inches of excavation at H-20. Transverse crack can be observed in northwest wall.

Photo D.2-A4-8 – T-11 location: Looking northwest. A transverse crack can be observed in the northwest wall and a 3 inch hole intersecting the crack and running longitudinally in a northeasterly direction along the dam.

Photo D.2-A4-9 – T-11 location: Looking northeast. 3 inch hole located in the northeast wall can be observed.

EXPLORATION AREA 5

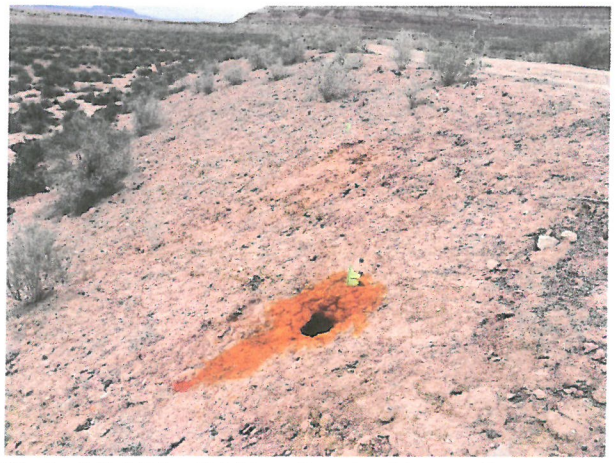


Photo D.2-A5-1 – T-14 location: Looking northwest over H-34(foreground) and H-35(background), located on the downstream embankment, after holes have been presoaked with tracer die.

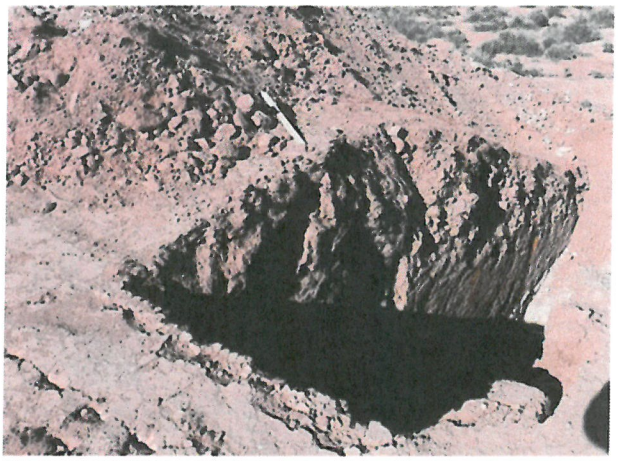


Photo D.2-A5-2 – T-14 location: Looking southwest over T-14.

Photo D.2-A5-3 – T-14 location: Looking northeast down into trench at the northeast wall. The chimney drain can be seen in the middle of the photo.

Photo D.2-A5-4 – T-14 location: Looking southeast into embankment. A crack can be observed at the top middle of the photo at the interaction between the embankment material and the chimney drain.

Photo D.2-A5-5 – T-14 close up of crack in southeast wall.

Photo D.2-A5-6 – T-14 location: Looking southwest down into trench at the southwest wall. The chimney drain can be seen in the middle of the photo.

EXPLORATION AREA 5

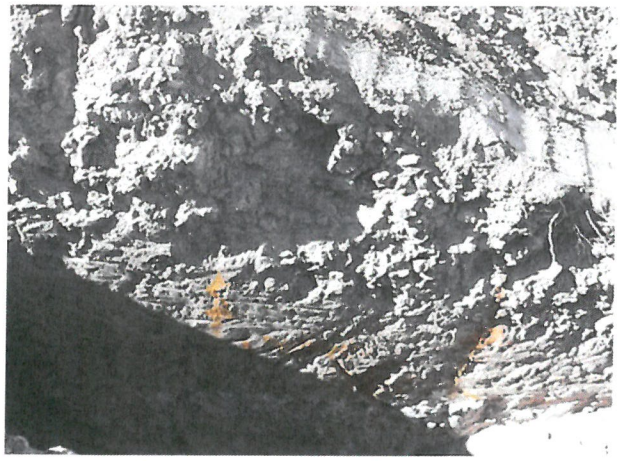


Photo D.2-A5-7 – T-14 location: Looking southwest down into trench at the southwest wall. Staining carried by longitudinal and transverse cracks can be seen on the wall.

Photo D.2-A5-8 – T-14 location: Looking southwest at the southwest wall. Died cracks can be observed in the new embankment terminating at the old embankment interaction

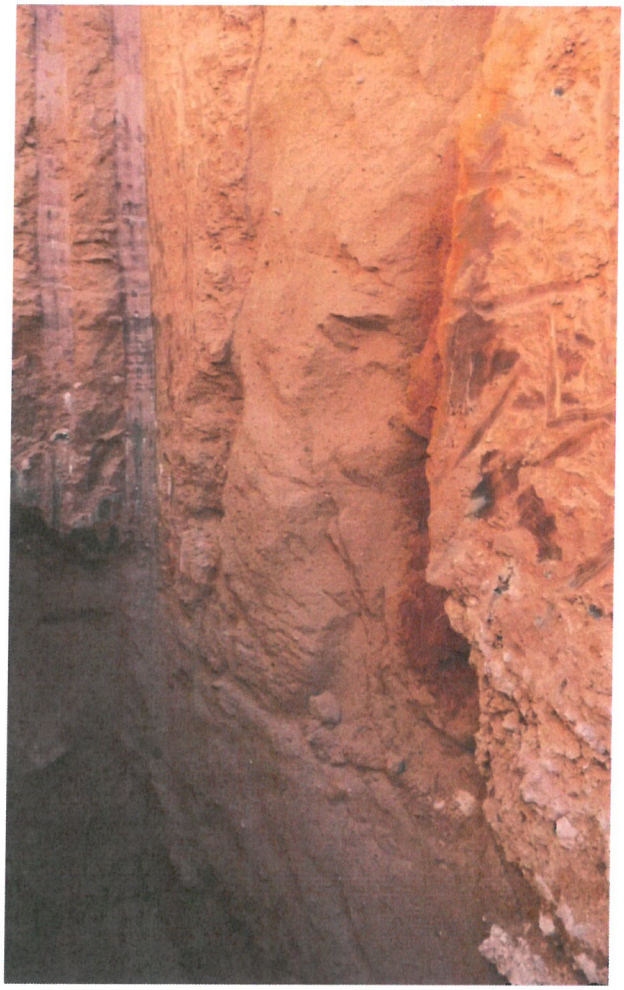


Photo D.2-A5-9 – T-8 location: Looking at the staining in the southwest wall along the chimney drain embankment interaction from the presoaking of holes H-34 & H-35.

APPENDIX D

SECTION 3 – INDIVIDUAL SINKHOLE PHOTOGRAPHS

INDIVIDUAL SINK HOLES PHOTOGRAPHS

Photo D.3-1 - Hole H-1 (0.45'Wide x 0.7'Long x 1.0' Depth)

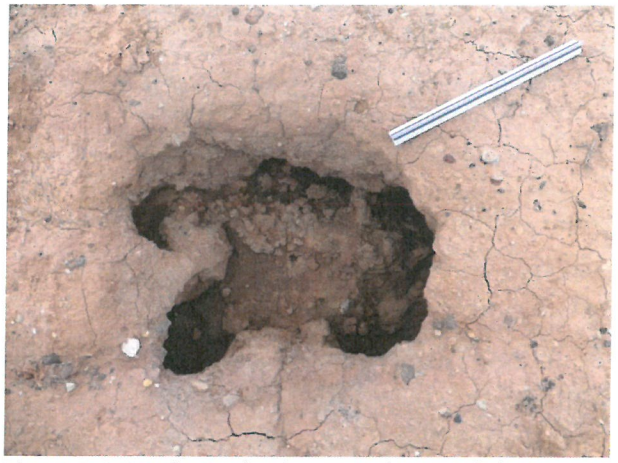


Photo D.3-2 Hole H-2 (1.6'W x 1.63'L x 1.45'D)

Photo D.3-3 Hole H-3 (0.4'W x 1.1'L x 2.8'D)

Photo D.3-4 Hole H-3 (0.4'W x 1.1'L x 2.8'D)

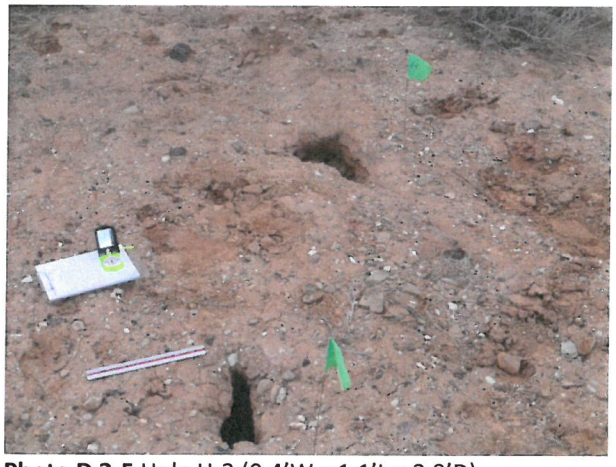


Photo D.3-5 Hole H-3 (0.4'W x 1.1'L x 2.8'D)

Photo D.3-6 Hole H-4 (0.8'W x 1.6'L x 2.6'D)

Photo D.3-7 Hole H-4 (0.8'W x 1.6'L x 2.6'D)

Photo D.3-8 Hole H-5 (1.25'W x 1.6'L x 1.5'D)

Photo D.3-9 Hole H-5 (1.25'W x 1.6'L x 1.5'D)

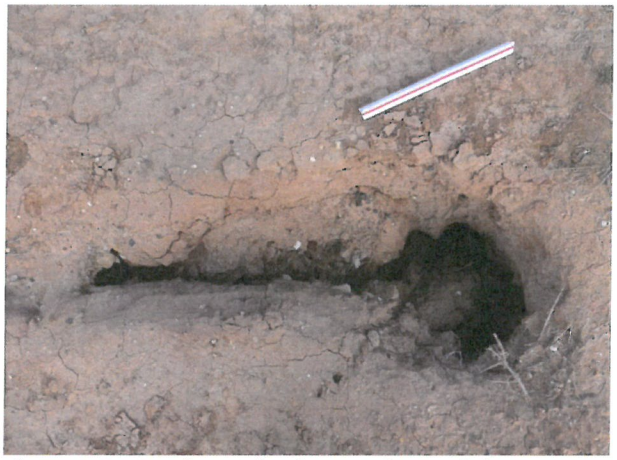


Photo D.3-10 Hole H-6 (3.1'W x 1.6'L x 1.8'D)

Photo D.3-11 Hole H-7 (0.7'W x 0.5'L x 1.0'D)

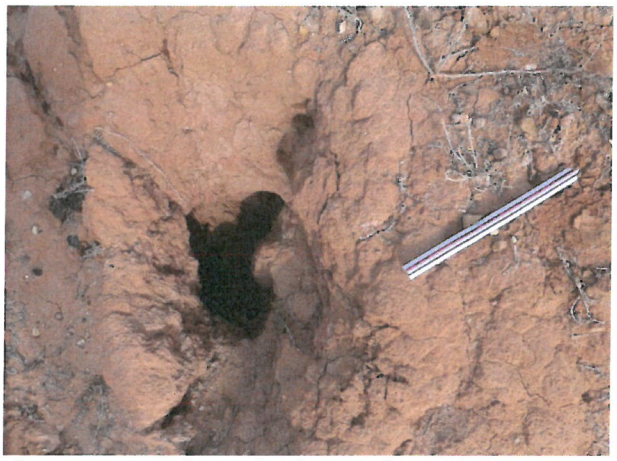


Photo D.3-12 Hole H-9 (2.9'W x 2.7'L x 3.4'D)

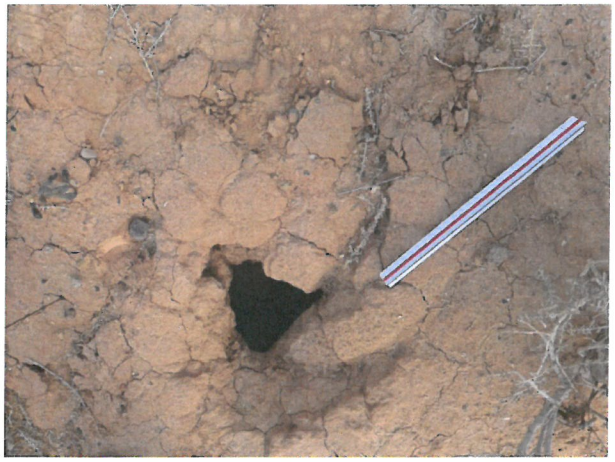


Photo D.3-13 Hole H-10 (0.6'W x 0.65'L x 1.8'D)

Photo D.3-14 Hole H-11 (1.1'W x 0.9'L x 1.4'D)

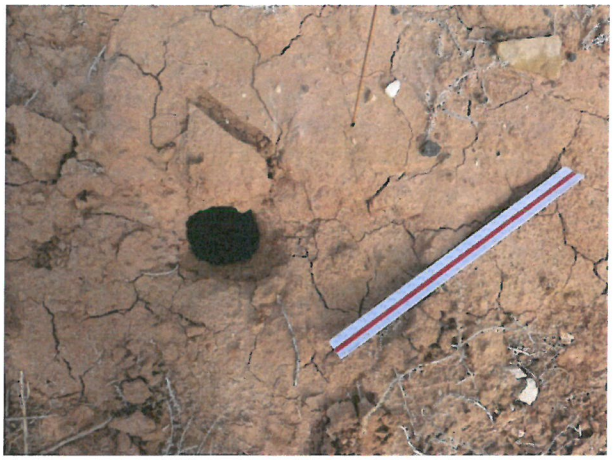


Photo D.3-15 Hole H-12 (0.4'W x 0.35'L x 1.3'D)

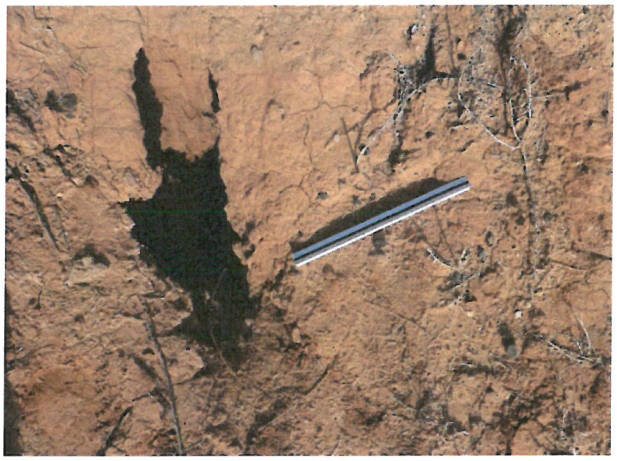


Photo D.3-16 Hole H-13 (0.8'W x 1.8'L x 3.4'D)

Photo D.3-17 Hole H-13 (0.8'W x 1.8'L x 3.4'D)

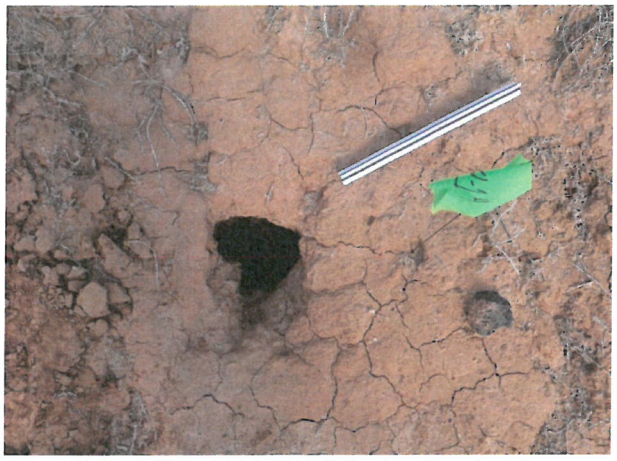


Photo D.3-18 Hole H-14 (0.55'W x 0.75'L x 2.3'D)

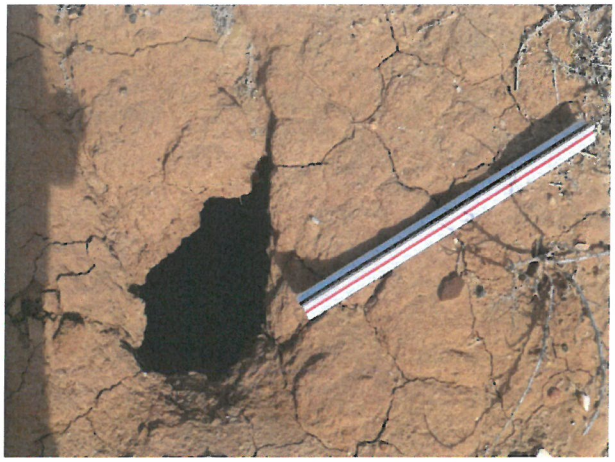


Photo D.3-19 Hole H-15 (0.5'W x 0.65'L x 2.9'D)

Photo D.3-20 Hole H-16 (2.6'W x 4.4'L x 1.0'D)

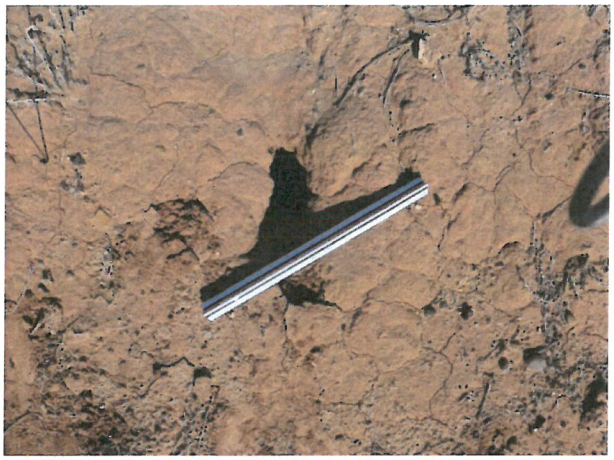


Photo D.3-21 Hole H-17 (0.2'W x 0.5'L x 2.8'D)

Photo D.3-22 Hole H-18 (2.5'W x 3.3'L x 1.4'D)

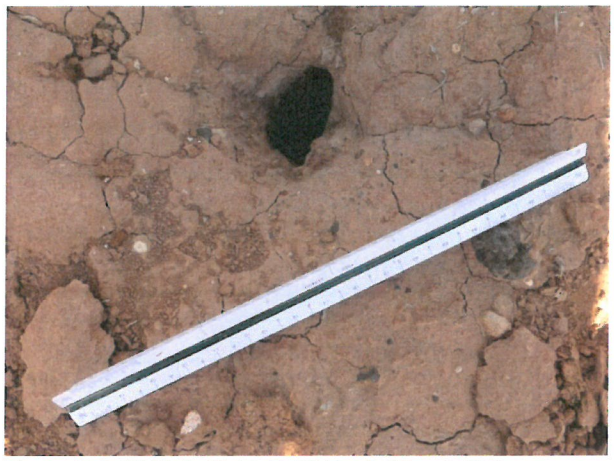


Photo D.3-23 Hole H-19 (0.2'W x 0.3'L x 1.4'D)

Photo D.3-24 Hole H-20 (3.3''W x 4.2'L x 1.95'D)

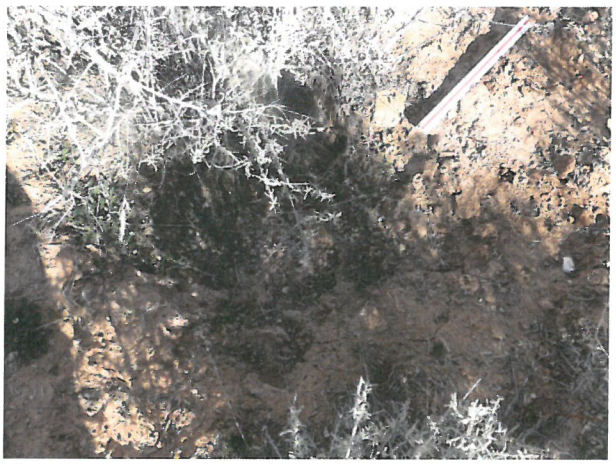


Photo D.3-25 Hole H-21 (1.9'W x 2.2'L x 0.6'D)

Photo D.3-26 Hole H-23 (1.5'W x 1.55'L x 0.65'D)

Photo D.3-27 Hole H-24 (1.7'W x 2.0'L x 1.25'D)

Photo D.3-28 Hole H-25 (0.9'W x 1.0'L x 0.9'D)

Photo D.3-29 Hole H-26(0.45'W x 0.4'L x 1.35'D)

Photo D.3-30 Hole H-27 (1.2'W x 1.6'L x 0.75'D)

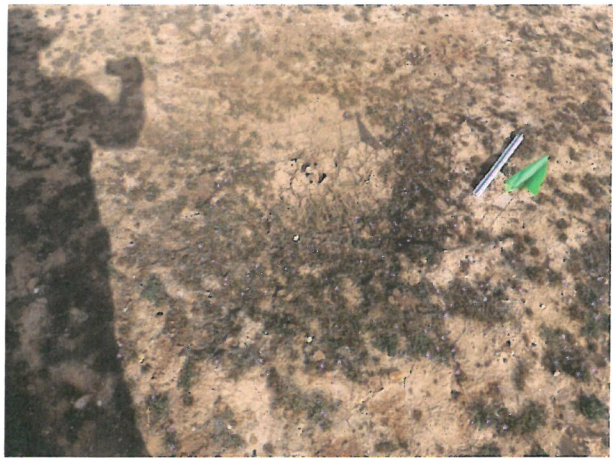


Photo D.3-31 Hole H-28 (4.6'W x 4.0'L x 0.65'D)

Photo D.3-32 Hole H-29 (3.7'W x 3.7'L x 0.65'D)

Photo D.3-33 Hole H-30 (4.5'W x 4.5'L x 2.6'D)

Photo D.3-34 Hole H-31 (3.8'W x 4.2'L x 0.85'D)

Photo D.3-35 Hole H-32 (3.1'W x 2.5'L x 1.0'D)

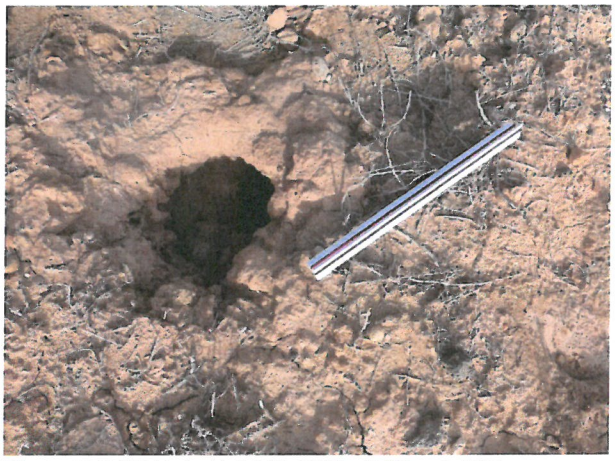


Photo D.3-36 Hole H-34 (0.6'W x 0.7'L x 1.9'D)

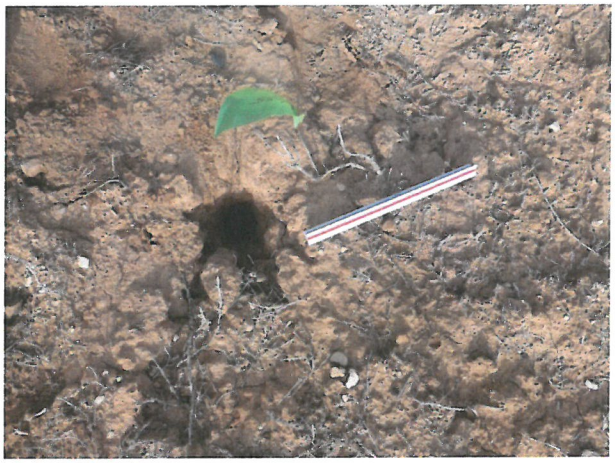


Photo D.3-37 Hole H-35 (.45'W x 0.5'L x 2.3'D)

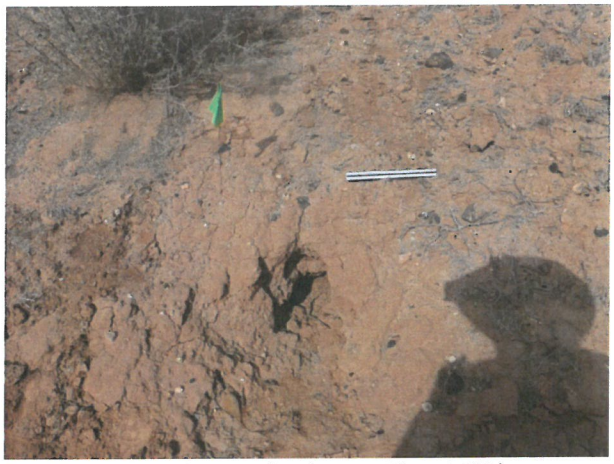


Photo D.3-38 Hole H-36 (1.5'W x 1.9'L x 1.3'D)

Photo D.3-39 Hole H-37 (0.85'W x 1.6'L x 4.6'D)

Photo D.3-40 Hole H-38 (1.3'W x 2.2'L x 2.4'D)

Photo D.3-41 Hole H-39 (8.5'W x 3.3'L x 0.6'D)

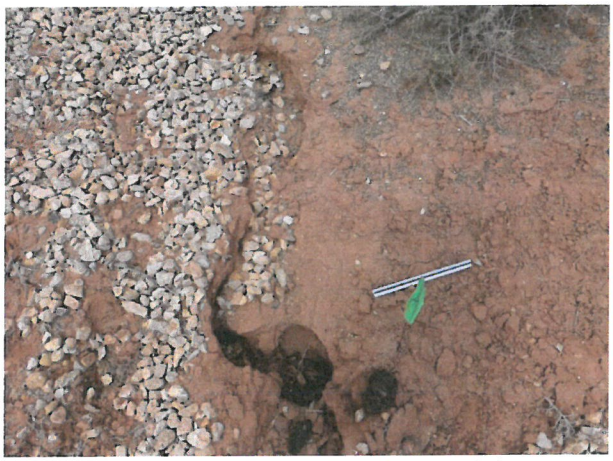


Photo D.3-42 Hole H-40 (1.4'W x 5.0'L x 1.1'D)

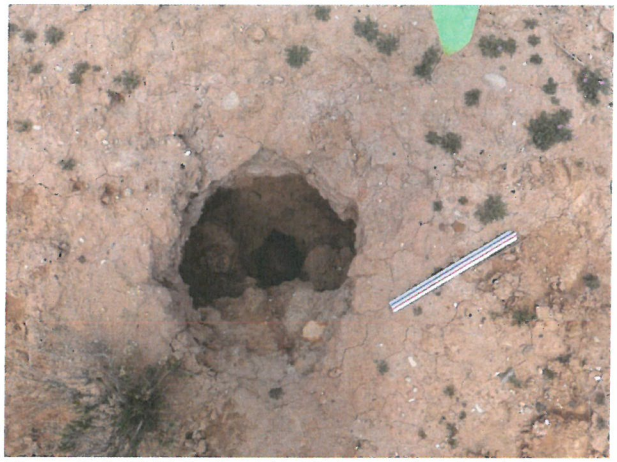


Photo D.3-43 Hole H-41 (1.6'W x 1.95'L x 2.65'D)

Photo D.3-44 Hole H-42 (1.9'W x 3.7'L x 2.7'D)

Photo D.3-45 Hole H-43 (1.9'W x 2.4'L x 3.0D)

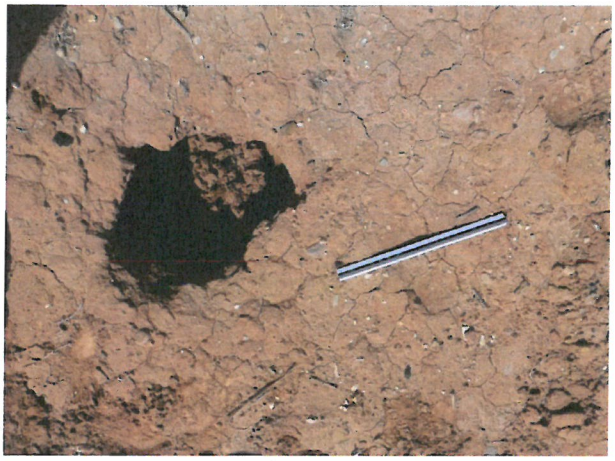


Photo D.3-46 Hole H-44 (1.25'W x 1.1'L x 2.0'D)

Photo D.3-47 Hole H-45 (1.8'W x 1.4'L x 1.6'D)

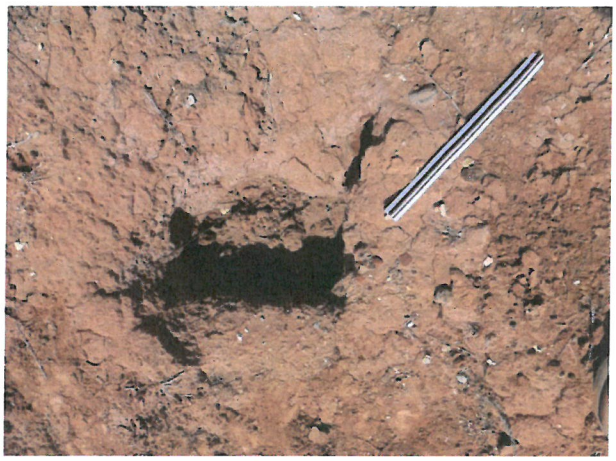


Photo D.3-48 Hole H-46 (1.55'W x 1.25'L x 1.15'D)

Photo D.3-49 Hole H-47 (1.1'W x 0.8'L x 2.55'D)

Photo D.3-50 Hole H-48 (1.45'W x 1.5'L x 1.0'D)

Photo D.3-51 Hole H-49 (0.75'W x 0.65'L x 3.2'D)

Photo D.3-52 Hole H-50 (3.2'W x 1.9'L x 3.1'D)

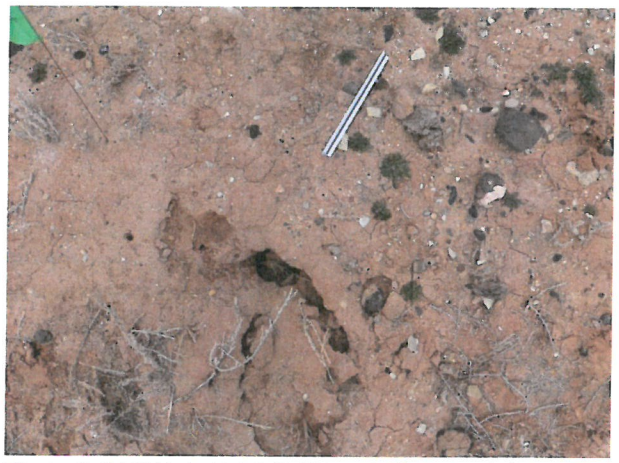
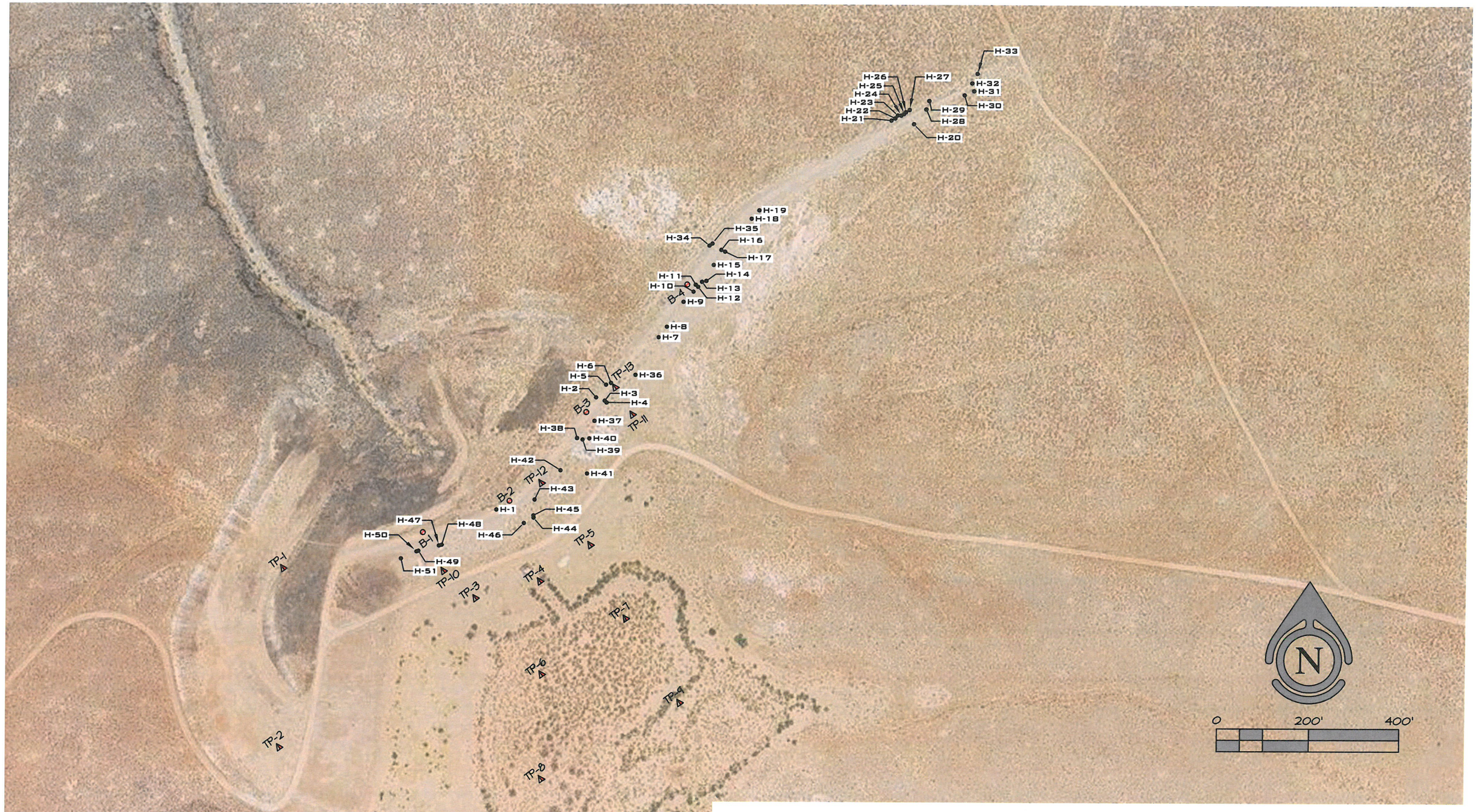


Photo D.3-53 Hole H-51 (3.0'W x 6.0'L x 0.85'D)

Photo D.3-54 Hole previously filled with grout.

APPENDIX D

SECTION 4 – INDIVIDUAL SINKHOLE MEASUREMENTS
(Drawing 3, Sinkhole Location Map, Included)



Scale: 1:200	Drawn By: GLM	ROSENBERG ASSOCIATES CIVIL ENGINEERS • LAND SURVEYORS 282 East Riverside Drive Suite A8 St. George, Utah 84790 – (435) 673-8586	Frog Hollow Debris Basin Sinkhole Location Map Washington County, Utah
Drawing 3	Checked By: DRB		
	Date: 12/11/15	Job Number: 8384-14-008	

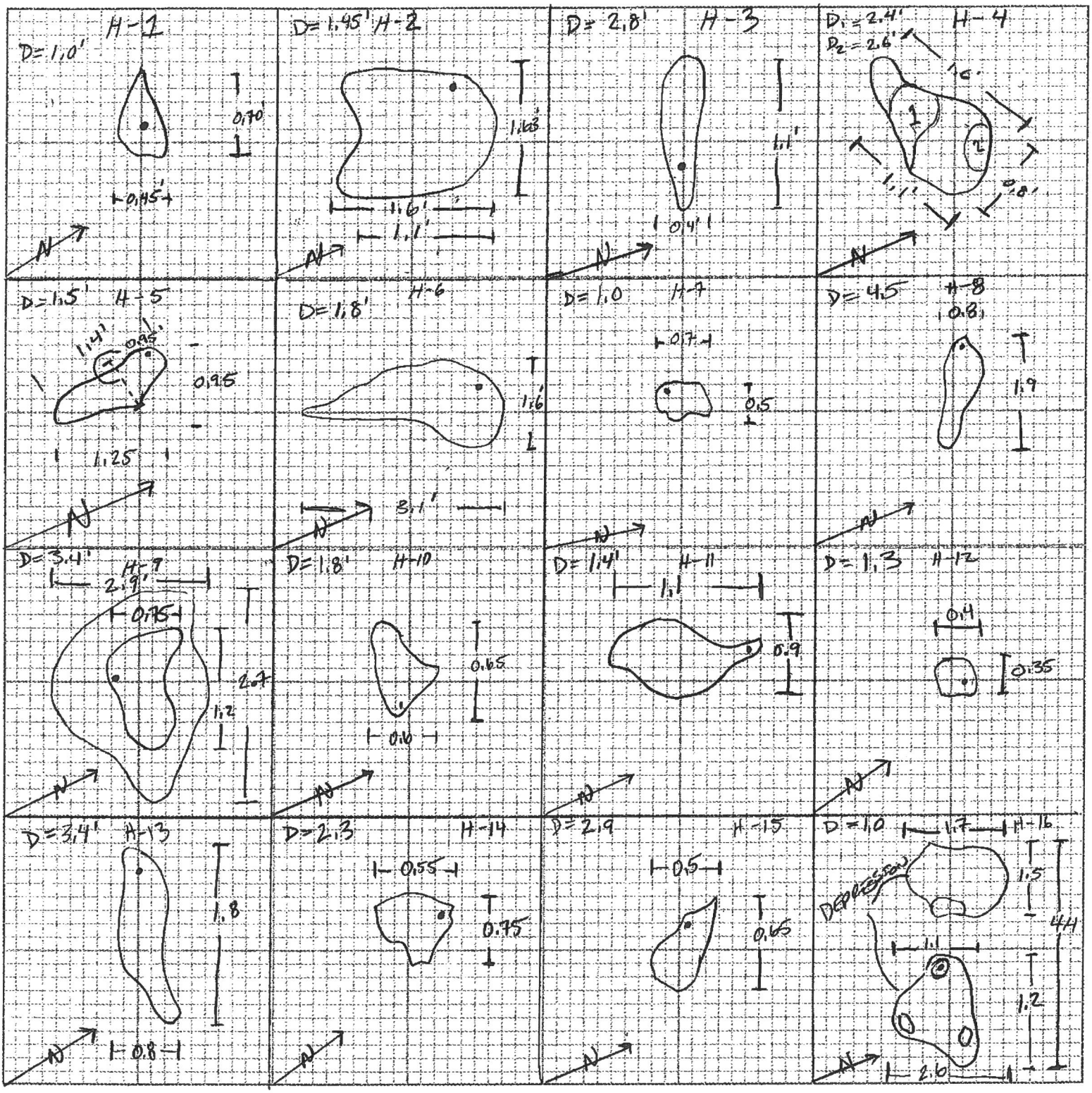
ROSENBERG (r) ASSOCIATES™
CIVIL ENGINEERS LAND SURVEYORS

SHEET 1 OF 5

PROJECT NO. 8384-14-008

PROJECT: Frog Hollow BY: Terron DATE: 03/12/2015

SUBJECT: Individual Sinkhole Measurements CHECKED BY: DRB DATE: 03/12/0215



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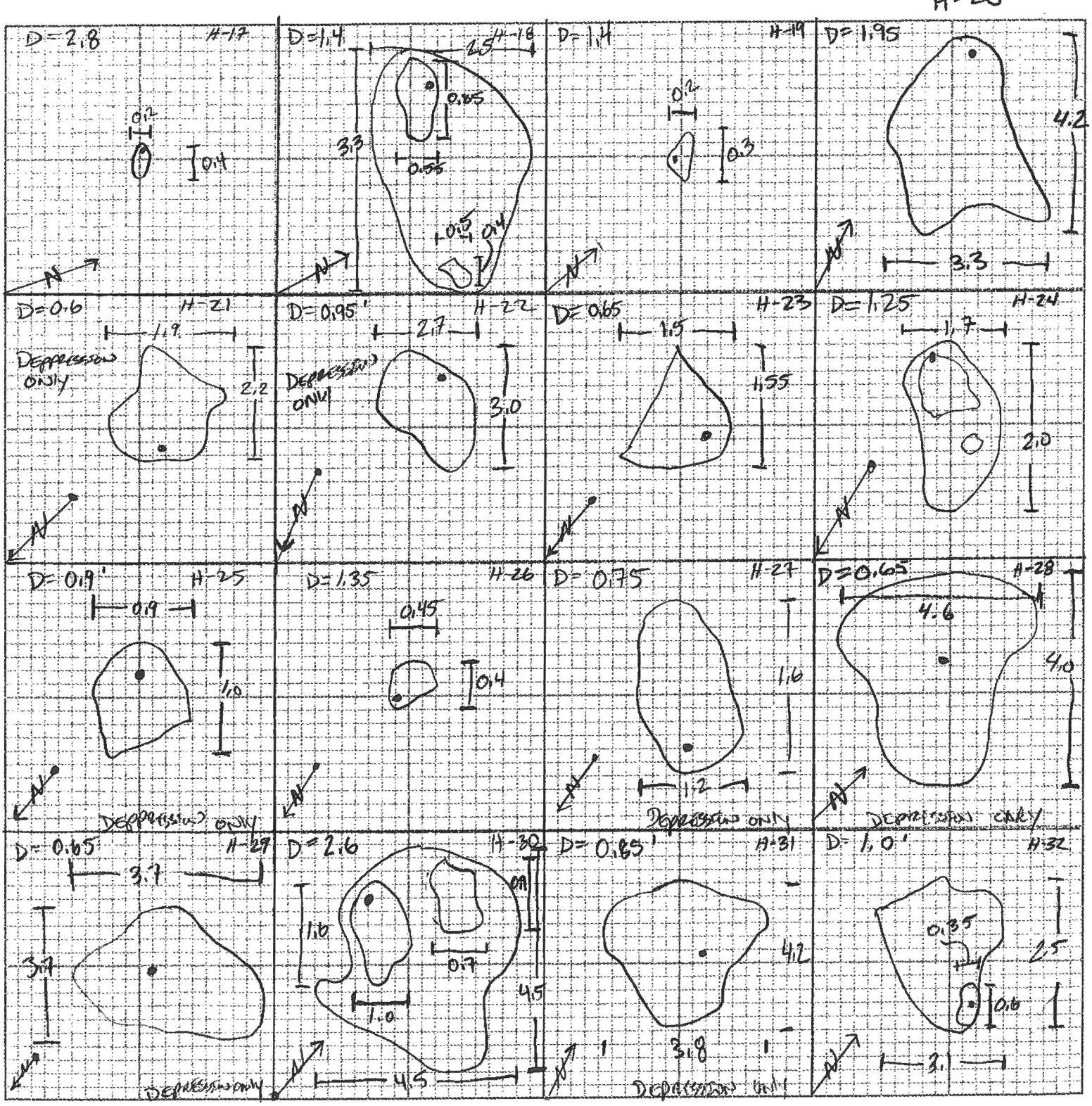
CIVIL ENGINEERS LAND SURVEYORS

SHEET 2 OF 5

PROJECT NO. 8384-14-008

PROJECT: Frog Hollow BY: Terron DATE: 03/12/2015

SUBJECT: Individual Sinkhole Measurements CHECKED BY: DRB DATE: 03/12/0215



ROSENBERG ASSOCIATES™
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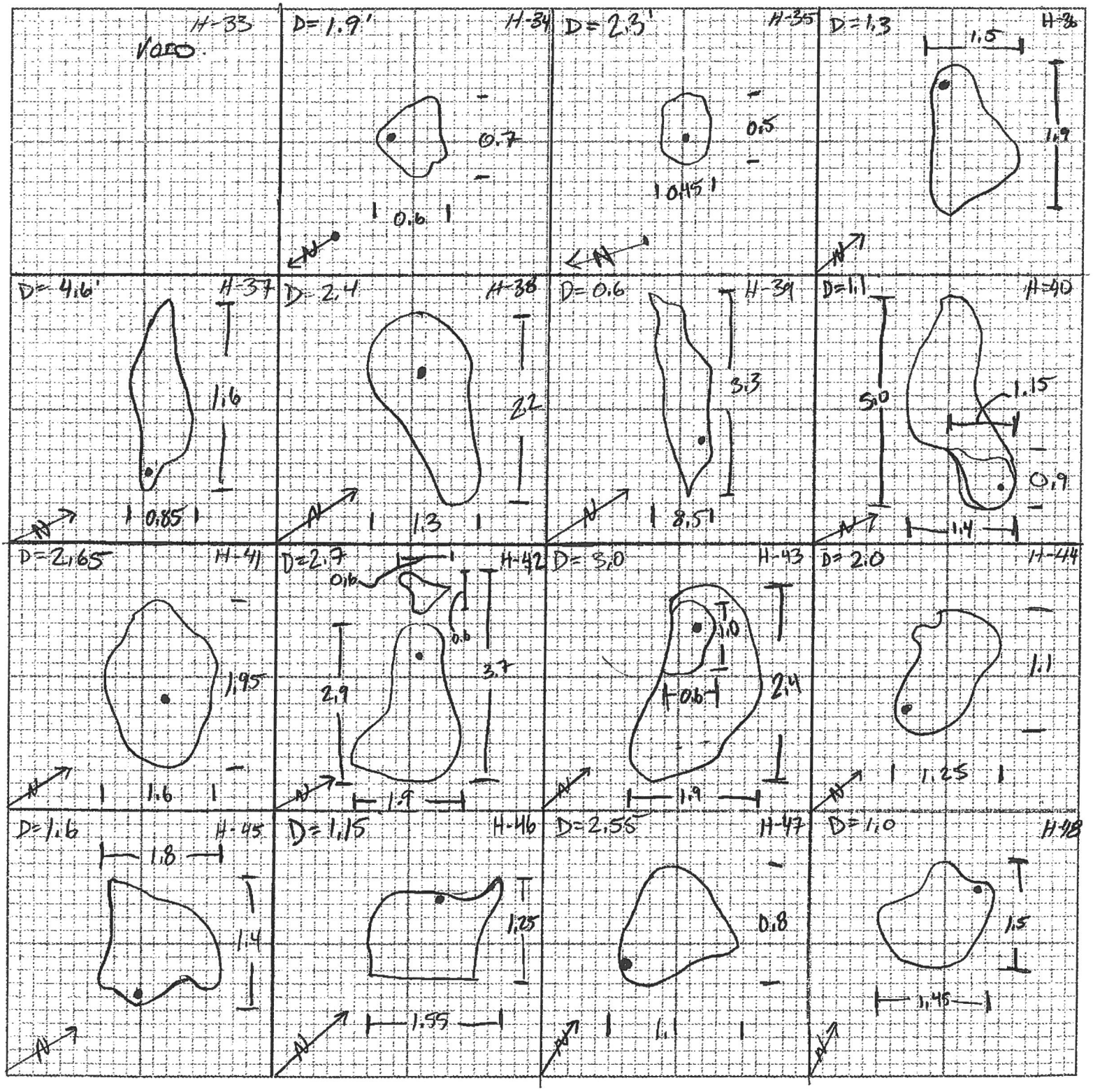
SHEET 3 OF 5

PROJECT NO. 8384-14-008

PROJECT: Frog Hollow BY: Terron DATE: 03/12/2015

SUBJECT: Individual Sinkhole Measurements CHECKED BY: DRB DATE: 03/12/0215



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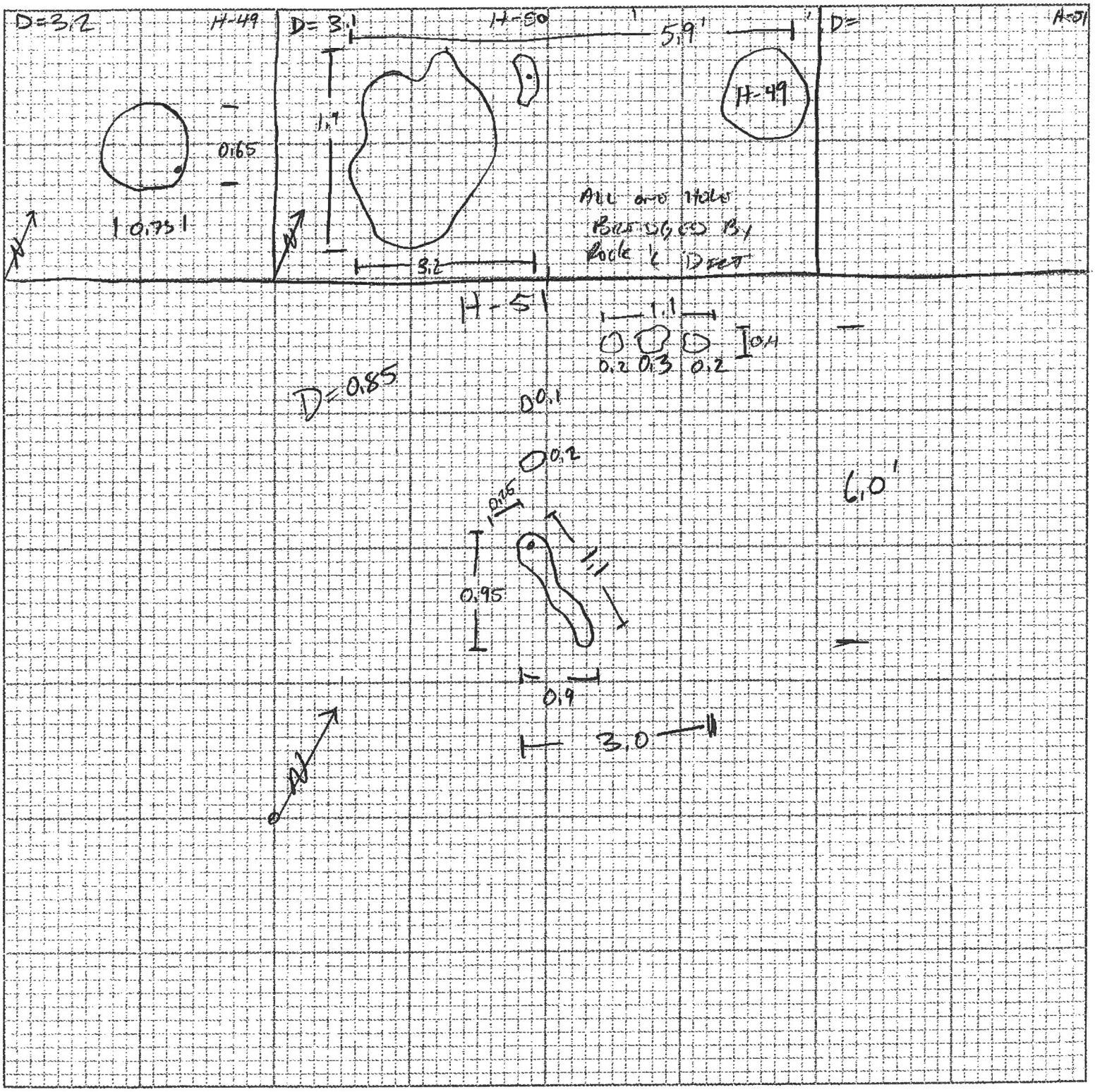
CIVIL ENGINEERS LAND SURVEYORS

SHEET 4 OF 5

PROJECT NO. 8384-14-008

PROJECT: Frog Hollow BY: Terron DATE: 03/12/2015

SUBJECT: Individual Sinkhole Measurements CHECKED BY: DRB DATE: 03/12/0215



ROSENBERG ASSOCIATES™ CIVIL ENGINEERS LAND SURVEYORS

SHEET 5 OF 5
PROJECT NO. 8384-14-008
PROJECT Frog Hollow BY Terron DATE 3/12/2015

SUBJECT Individual Sinkholes CHECKED BY DRB DATE 3/12/2015

Hole (#)	Width (ft)	Length (ft)	Depth (ft)	Photo (#)	Hole (#)	Width (ft)	Length (ft)	Depth (ft)	Photo (#)
H-1	0.45	0.70	1.00	D.3-1	H-26	0.45	0.40	1.35	D.3-29
H-2	1.60	1.63	1.45	D.3-2	H-27	1.20	1.60	0.75	D.3-30
H-3	0.40	1.10	2.80	D.3-3 / D.3-4 / D.3-5	H-28	4.60	4.00	0.65	D.3-31
H-4	0.80	1.60	2.60	D.3-6 / D.3-7	H-29	3.70	3.70	0.65	D.3-32
H-5	1.25	0.95	1.50	D.3-8/D.3-9	H-30	4.50	4.50	2.6	D.3-33
H-6	3.10	1.60	1.80	D.3-10	H-31	3.80	4.20	0.85	D.3-34
H-7	0.70	0.50	1.00	D.3-11	H-32	3.10	2.50	1	D.3-35
H-8	0.80	1.90	4.50		H-34	0.60	0.70	1.9	D.3-36
H-9	2.90	2.70	3.40	D.3-12	H-35	0.45	0.50	2.3	D.3-37
H-10	0.60	0.65	1.80	D.3-13	H-36	1.50	1.90	1.3	D.3-38
H-11	1.10	0.90	1.40	D.3-14	H-37	0.85	1.60	4.6	D.3-39
H-12	0.40	0.35	1.30	D.3-15	H-38	1.30	2.20	2.4	D.3-40
H-13	0.80	1.80	3.40	D.3-16 / D.3-17	H-39	8.50	3.30	0.6	D.3-41
H-14	0.55	0.75	2.30	D.3-18	H-40	1.40	5.00	1.1	D.3-42
H-15	0.50	0.65	2.90	D.3-19	H-41	1.60	1.95	2.65	D.3-43
H-16	2.60	4.40	1.00	D.3-20	H-42	1.90	3.70	2.7	D.3-44
H-17	0.20	0.40	2.80	D.3-21	H-43	1.90	2.40	3	D.3-45
H-18	2.50	3.30	1.40	D.3-22	H-44	1.25	1.10	2	D.3-46
H-19	0.20	0.30	1.40	D.3-23	H-45	1.80	1.40	1.6	D.3-47
H-20	3.30	4.20	1.95	D.3-24	H-46	1.55	1.25	1.15	D.3-48
H-21	1.90	2.20	0.60	D.3-25	H-47	1.10	0.80	2.55	D.3-49
H-22	2.70	3.00	0.95		H-48	1.45	1.50	1	D.3-50
H-23	1.50	1.55	0.65	D.3-26	H-49	0.75	0.65	3.2	D.3-51
H-24	1.70	2.00	1.25	D.3-27	H-50	3.20	1.90	3.1	D.3-52
H-25	0.90	1.00	0.90	D.3-28	H-51	3.00	6.00	0.85	D.3-53

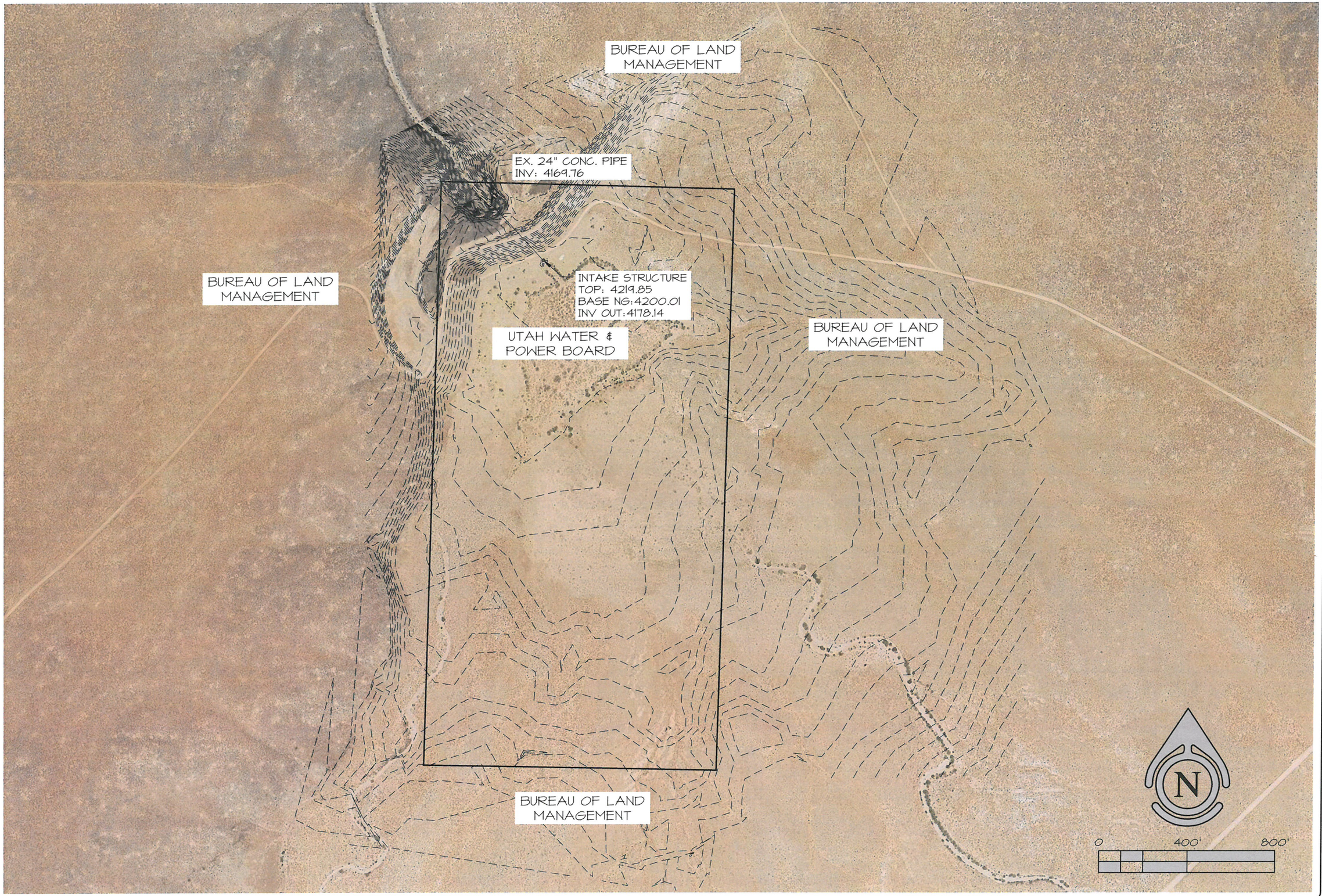
APPENDIX E

FIELD SURVEY

APPENDIX E

FIELD SURVEY

A field survey was completed by RA to locate pertinent project site features including outlet structures, boring locations, dam cross sections, profiles and easements. The field survey points, and boundary and easement information, were down loaded into AutoCAD. The line work is presented on Drawings E-1 through E-10.



DATE: 12/10/2015
JOB NO.: 8384-14-008
DESIGNED BY: SMR
CHECKED BY: DRB
DWG: PROJECT LAYOUT

REVISIONS
DATE

ROSENBERG ASSOCIATES
CIVIL ENGINEERS • LAND SURVEYORS
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BOUNDARY INFORMATION
FOR
FROG HOLLOW DAM REHABILITATION EVALUATION
WASHINGTON, UTAH

DRAWING
E-1

LEGEND

- LOCATION OF TEST PIT
- LOCATION OF BORING
- LOCATION OF CROSS-SECTION

24" DISCHARGE PIPE

A

SPILLWAY

A'

TP-1

B

B-1

B'

TP-10

C

CENTRAL OUTLET STATION

C'

TP-3

D

B-2

D'

TP-4

TP-12

TP-2

INTAKE RISER

TP-5

TP-6

TP-7

EMERGENCY OVERFLOW

TP-8

TP-9

E

B-3

TP-13

TP-11

E'

F

B-4

F'

N

0 200' 400'

DATE: 12/10/2015
JOB NO: 8364-14-008
DESIGNED BY: SMR
CHECKED BY: DRB
DWG: PROJECT LAYOUT
REVISIONS DATE

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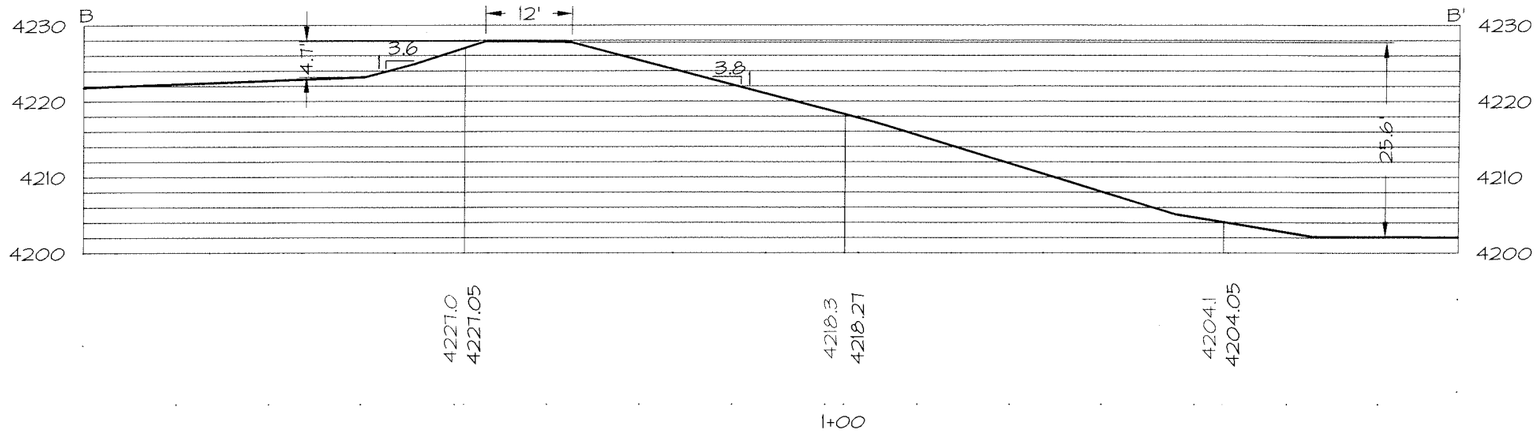
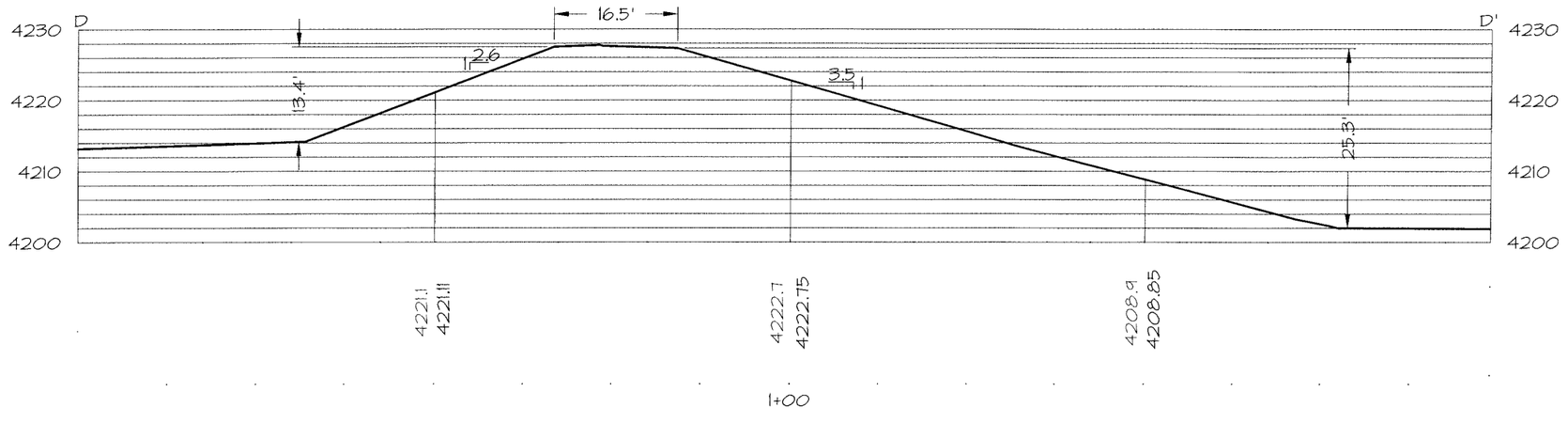
EXPLORATION AND CROSS-SECTION LOCATIONS
FOR
FROG HOLLOW DAM REHABILITATION EVALUATION
WASHINGTON, UTAH

DRAWING
E-2



BORING 1 - STA: 8+59.23



BORING 2 - STA: 10+62.97

0 20' 40'

DATE: 12/10/2015
JOB NO.: 8384-14-008
DESIGNED BY: SNR
CHECKED BY: DRB
DWG: PROJECT LAYOUT

DATE
REVISIONS

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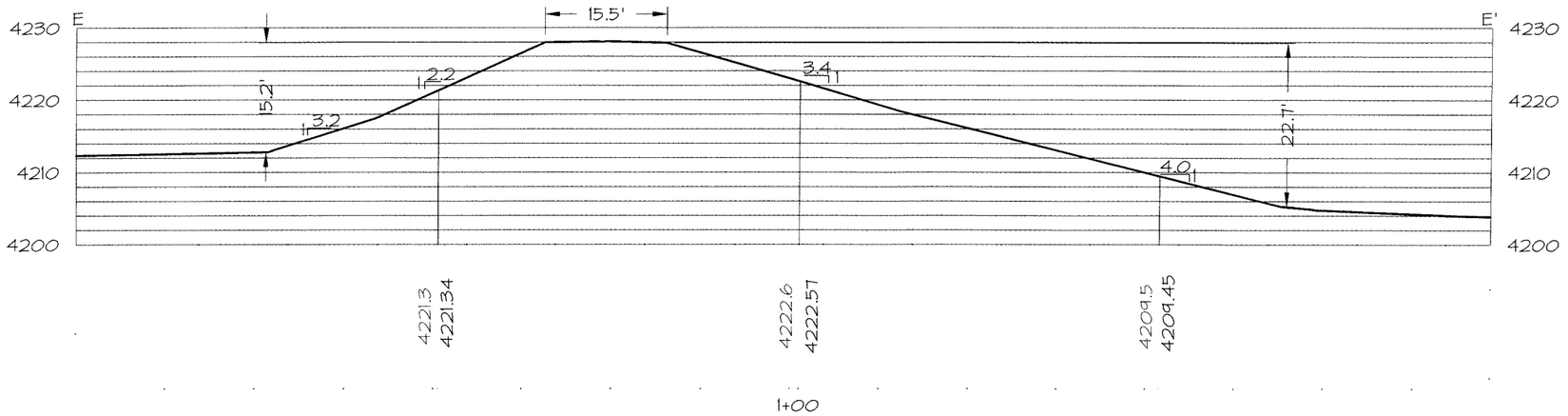
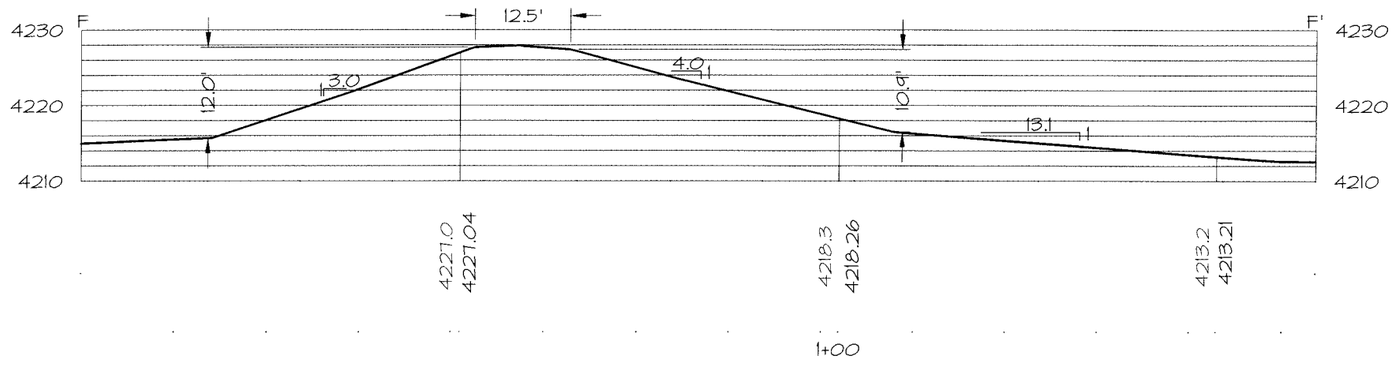
EMBANKMENT CROSS-SECTIONS
FOR
FROG HOLLOW DAM REHABILITATION EVALUATION
WASHINGTON, UTAH

DRAWING
E-3



BORING 3 - STA: 13+20.89



BORING 4 - STA: 16+75.16

0 20' 40'

DATE: 12/01/2015
JOB NO.: 8384-14-008
DESIGNED BY: SNR
CHECKED BY: DRB
DWG: PROJECT LAYOUT
REVISIONS DATE

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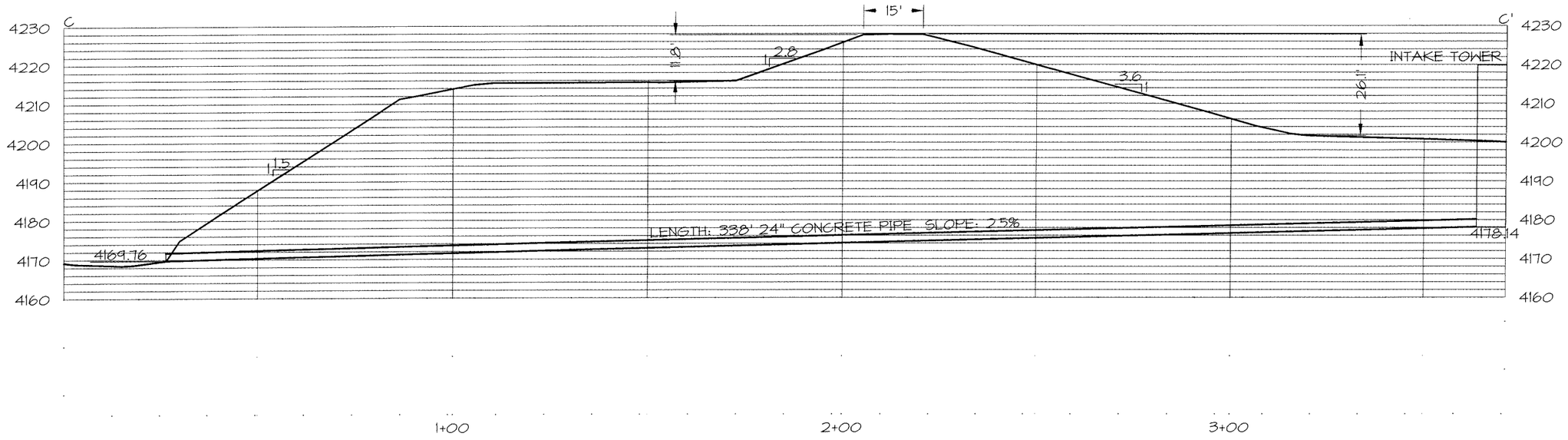
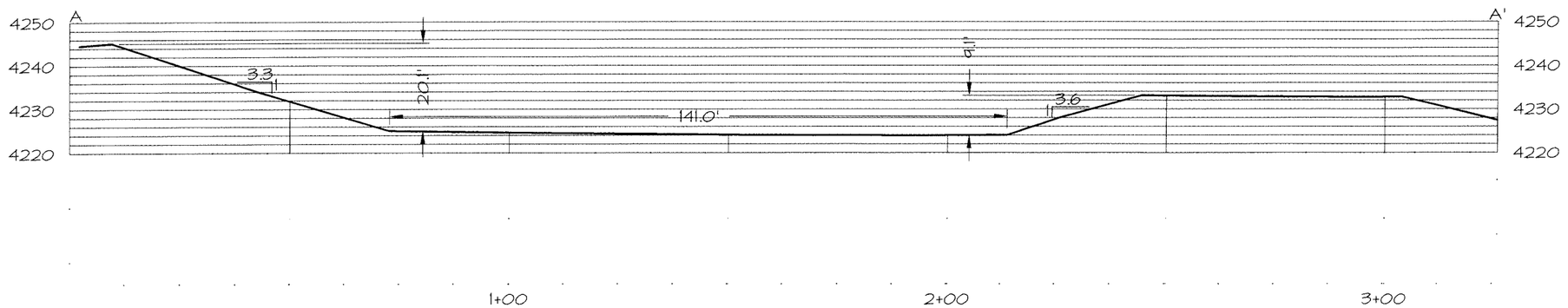
EMBANKMENT CROSS-SECTIONS
FOR
FROG HOLLOW DAM REHABILITATION EVALUATION
WASHINGTON, UTAH

DRAWING
E-4



Principal Outlet Pipe - STA: 9+89



Spillway

0 30' 60'

DATE: 12/10/2015
JOB NO: 8384-14-008
DESIGNED BY: SNR
CHECKED BY: DRB
DWG: PROJECT LAYOUT

DATE
REVISIONS

ROSENBERG ASSOCIATES
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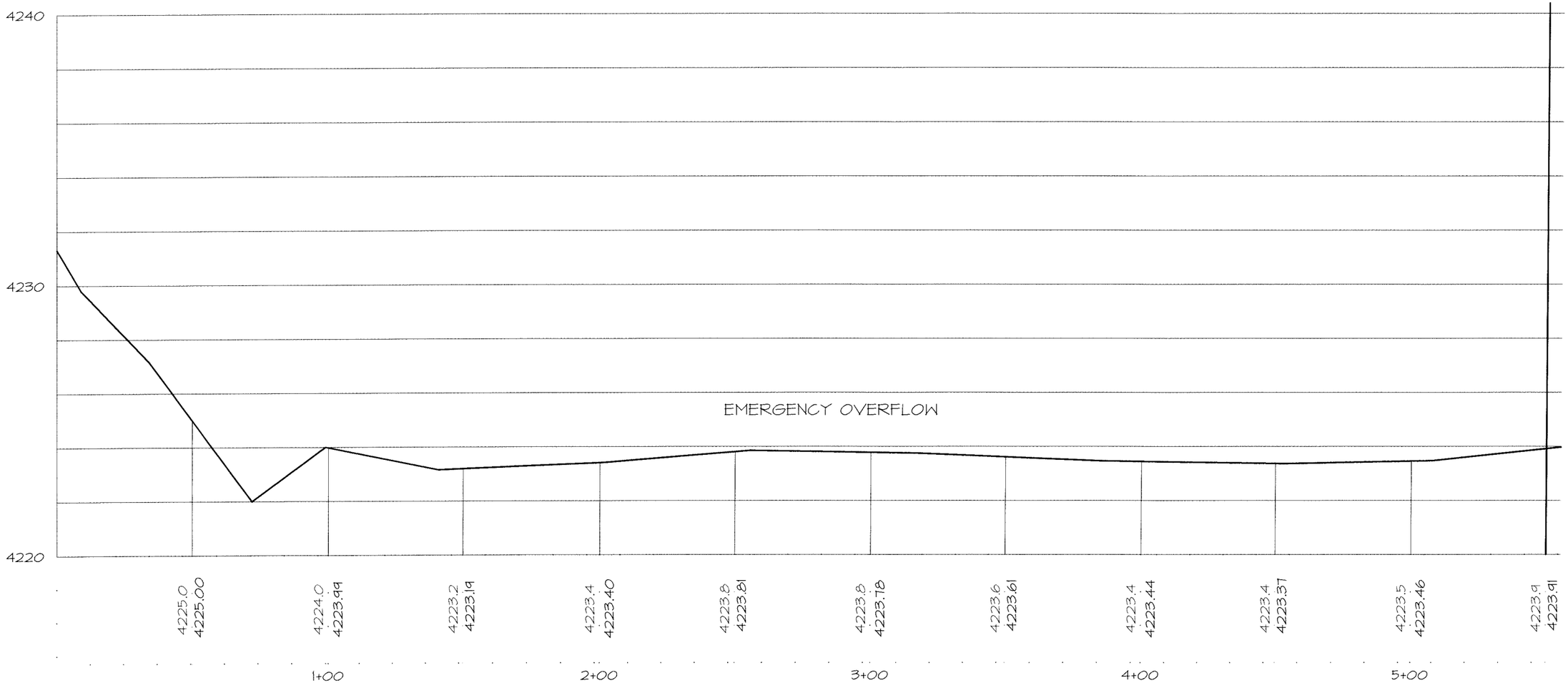
EMBANKMENT CROSS-SECTIONS
FOR
FROG HOLLOW DAM REHABILITATION EVALUATION
WASHINGTON, UTAH

DRAWING
E-5



STA: 0+00 - STA: 5+50

0 40' 80'

DATE: 12/10/2015
JOB NO.: 8384-14-008
DESIGNED BY: SHR
CHECKED BY: DRB
DWG: PROJECT LAYOUT

REVISIONS
DATE:

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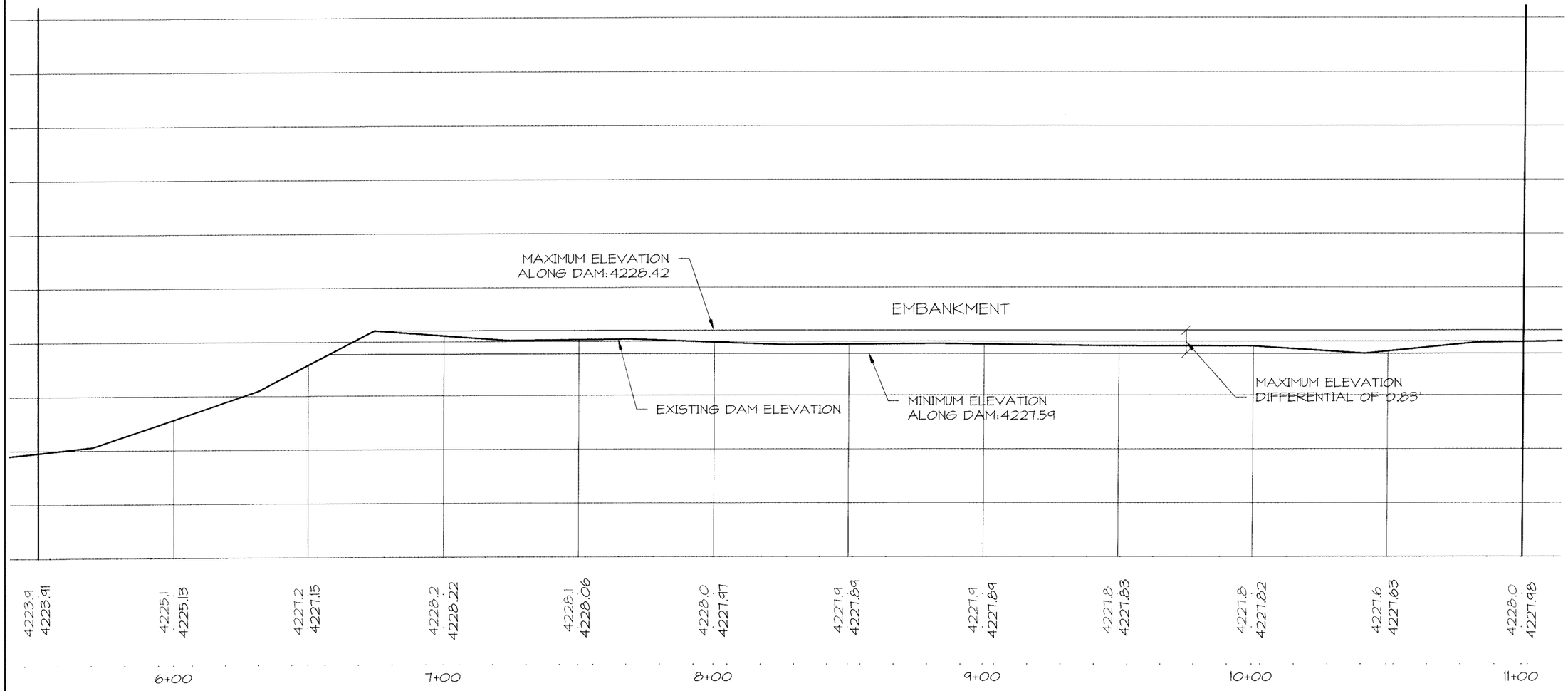
FROG HOLLOW DAM - PROFILE
FOR
FROG HOLLOW DAM REHABILITATION EVALUATION
WASHINGTON, UTAH

DRAWING
E-6



STA: 5+50 - STA: 11+00

0 40' 80'

DATE: 12/10/2015
JOB NO: 8384-14-008
DESIGNED BY: SNR
CHECKED BY: DRB
DWG: PROJECT LAYOUT

REVISIONS
DATE

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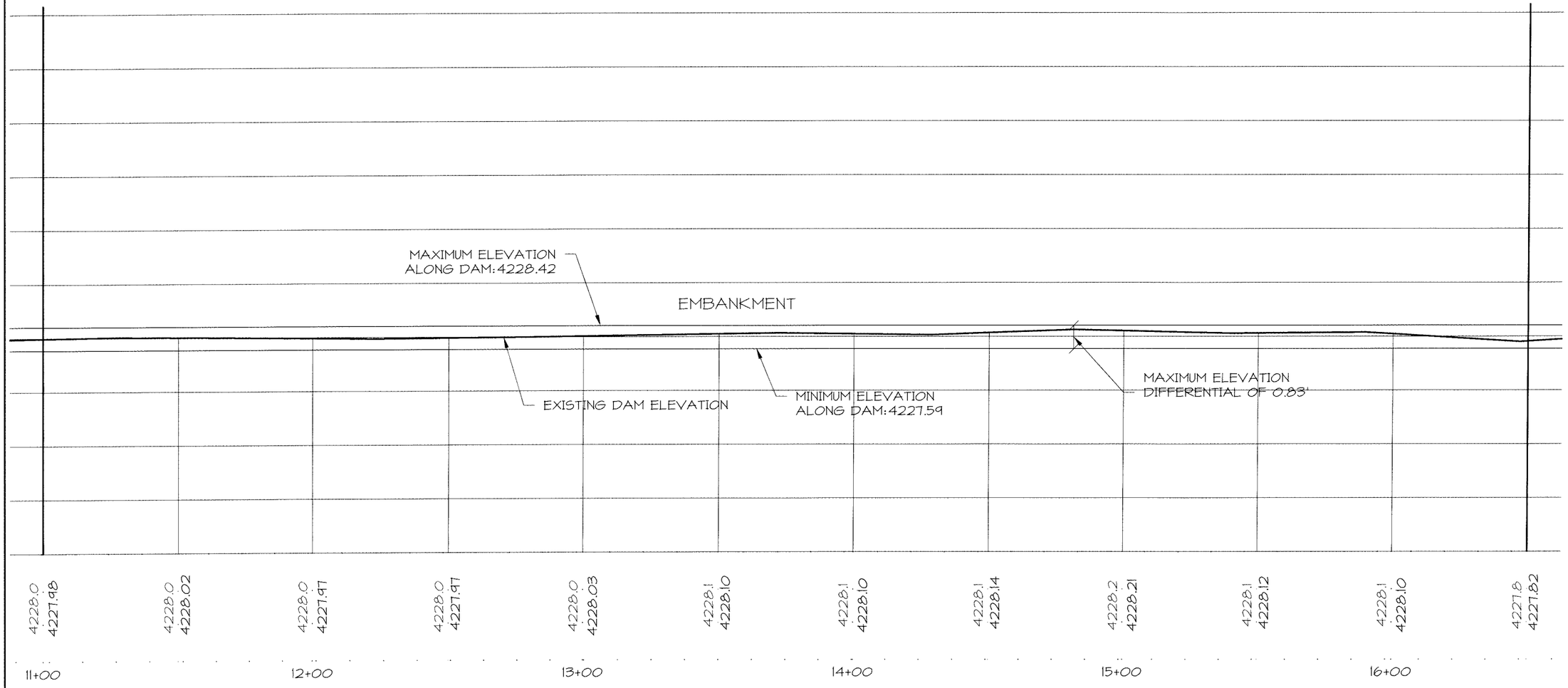
FROG HOLLOW DAM - PROFILE
FOR
FROG HOLLOW DAM REHABILITATION EVALUATION
WASHINGTON, UTAH

DRAWING
E-7



STA: 11+00 - STA: 16+50

0 40' 80'

DATE: 12/10/2015
JOB NO.: 8384-14-008
DESIGNED BY: SNR
CHECKED BY: DRB
DWG: PROJECT LAYOUT

REVISIONS
DATE

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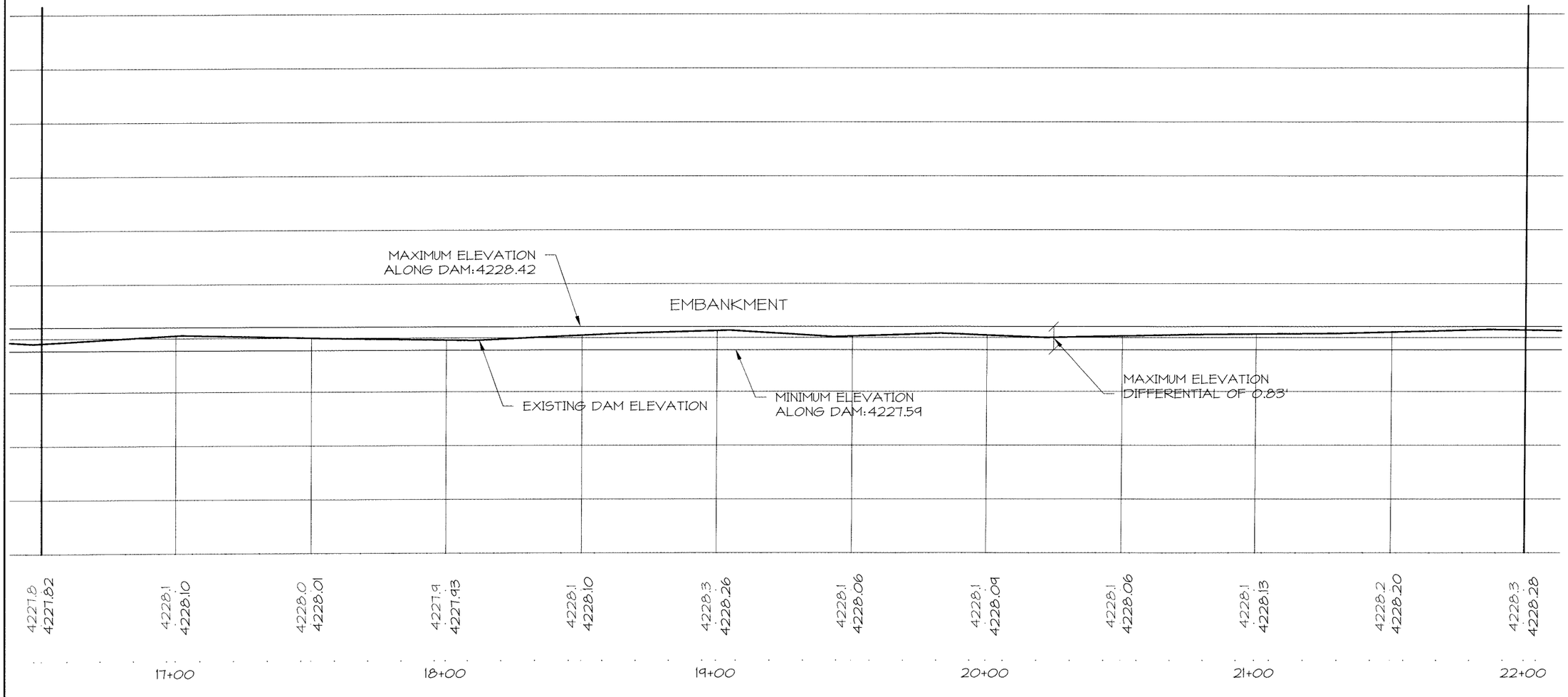
FROG HOLLOW DAM - PROFILE
FOR
FROG HOLLOW DAM REHABILITATION EVALUATION
WASHINGTON, UTAH

DRAWING
E-8



STA: 16+50 - STA: 22+00

0 40' 80'

DATE: 12/10/2015
JOB NO.: 8384-14-008
DESIGNED BY: SNR
CHECKED BY: DRB
DWG: PROJECT LAYOUT

REVISIONS
DATE

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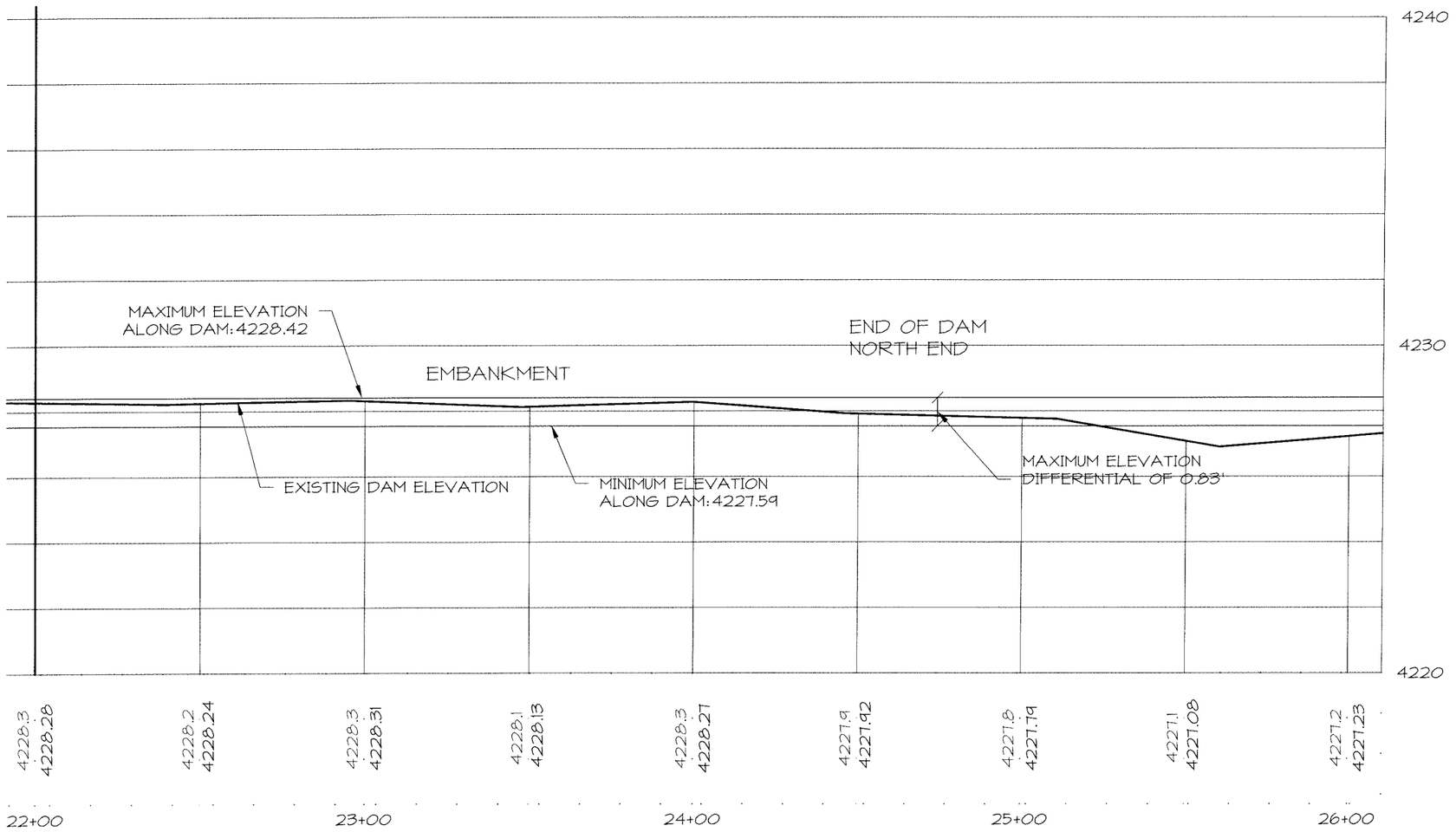
Ph (435) 673-8586 Fx (435) 673-8397 www.rasvil.com

FROG HOLLOW DAM - PROFILE
FOR
FROG HOLLOW DAM REHABILITATION EVALUATION
WASHINGTON, UTAH

DRAWING
E-9



STA: 22+00 - STA: 26+10.44

0 40' 80'

DATE: 12/10/2015
JOB NO.: 8384-14-008
DESIGNED BY: SNR
CHECKED BY: DRB
DWG: PROJECT LAYOUT

REVISIONS
DATE

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FROG HOLLOW DAM - PROFILE
FOR
FROG HOLLOW DAM REHABILITATION EVALUATION
WASHINGTON, UTAH

DRAWING
E-10

APPENDIX F

SINKHOLE/CRACKING EXPLORATIONS

APPENDIX F

SINKHOLE/CRACKING EXPLORATORY TRENCHING

Sinkholes and cracks within the Frog Hollow Dam were investigated in five (5) representative areas along the embankment. Exploration areas are shown on Drawing 4. A total of Fifteen (15) exploratory trenches were excavated to document the physical parameters of selected sinkholes and cracks. The exploratory trenches, excavated with rubber-tired and track-mounted backhoes, were advanced to depths of about 5 to 15 feet below existing ground surface. Trench locations within the specific areas are shown on Figures F-1 through F-5.

Subsurface conditions observed in the trenches were carefully documented at the time of excavation by RA field personnel and by Mr. David Simon of Simon Associates, LLC (a Utah professional geologist and sub-consultant to RA). Materials exposed in the trenches are described on Figures F-6 through F-17, and were classified, when applicable, in accordance with the Unified Soil Classification System (ASTM Method D 2488). Color designations follow standard Munsell Soil Color notations.

To evaluate the vertical and lateral dimensions of the sinkholes, selected sinkholes holes were saturated with about 375 gallons of water followed by the introduction of about 375 gallons water with fluorescein, a diagnostic dye tracer that turns florescent green in water. After introduction of the fluorescein, the sinkholes were carefully excavated with the backhoe to follow the subsurface path of fluorescein dye and document the vertical and lateral dimensions of the sinkholes.

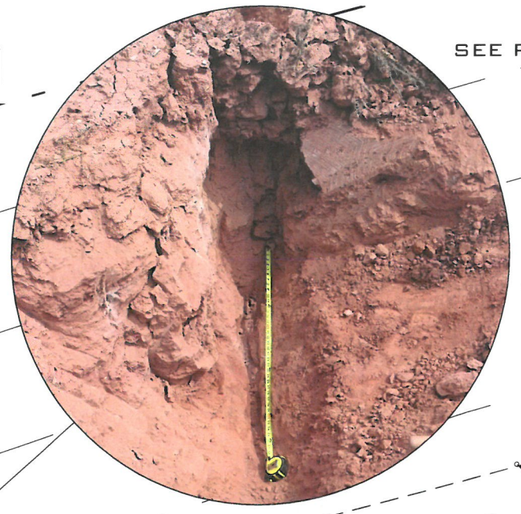
The trenches were backfilled to restore the dam to its original condition by moisture conditioning, replacing, and compacting the excavated soil utilizing heavy compaction equipment, placed in approximate 1-foot loose lifts. Trenches were backfilled following excavation. Backfilling of excavations deeper than 4 feet followed the "multiple-bench" method outlined in the current NRCS earthwork standards prior to backfilling and recompaction (USDA-NRCS-UT, 2015).

AREA 1

DOWNSTREAM SLOPE

CREST

SEE PHOTO A.1-10



4220

H-48

H-47

H-49

H-50

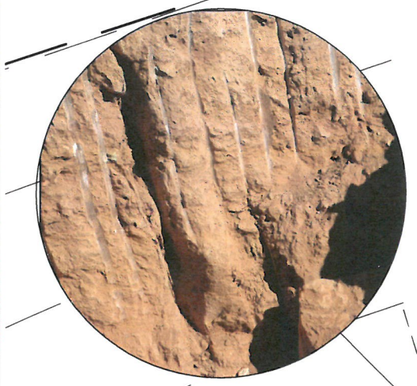
T-4

T-2

T-3

TRANSVERSE CRACK

LONGITUDINAL CRACK



SEE PHOTO A.1-5

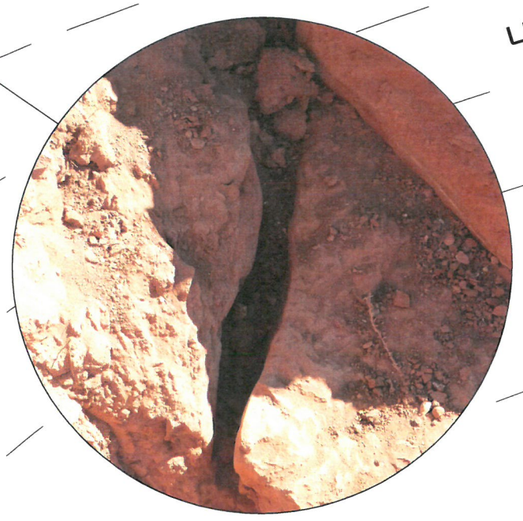
LONGITUDINAL CRACK

H-51

T-1

UPSTREAM SLOPE

4210



SEE PHOTO A.1-4

EXPLORATORY TRENCH

CRACK LOCATION

APPROXIMATE LOCATION OF CRACK

4210 MAJOR CONTOUR 10'

MINOR CONTOUR 2'

N

0 10' 20'

DATE: 11/19/2015
JOB NO.: 8364-14-004
DESIGNED BY: JTT
CHECKED BY: DRB
DWG: FISSURE STUDY
DATE
REVISIONS

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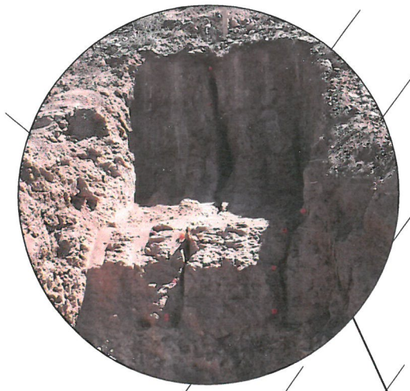
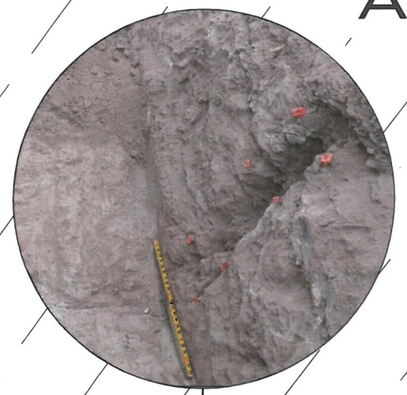
AREA 1: EXPLORATION TRENCH LOCATIONS
FOR
FROG HOLLOW DAM EVALUATION
WASHINGTON COUNTY, UTAH

FIGURE
F-1

AREA 2



SEE PHOTO A.2-10



SEE PHOTO A.2-9

DOWNSTREAM SLOPE

CREST

UPSTREAM SLOPE

T-15

T-12

T-5

T-6

4220

4210

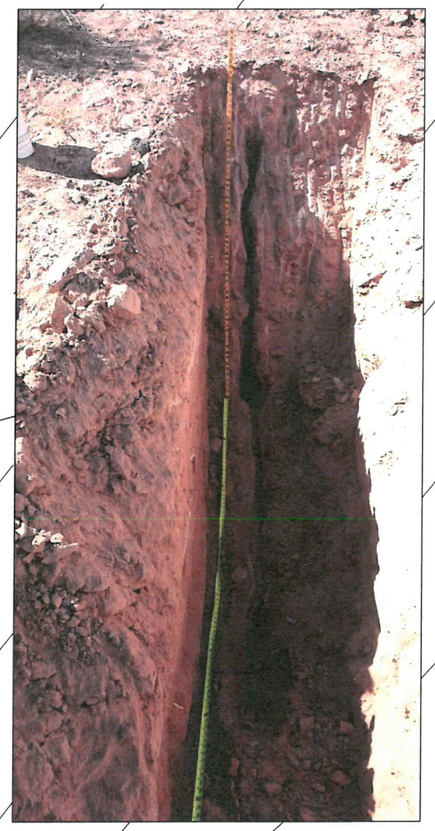
TRANSVERSE CRACK

CHIMNEY DRAIN

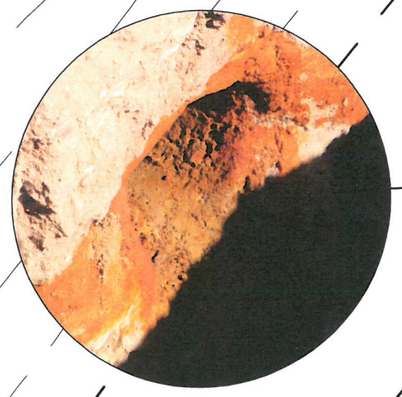
H-2

H-3

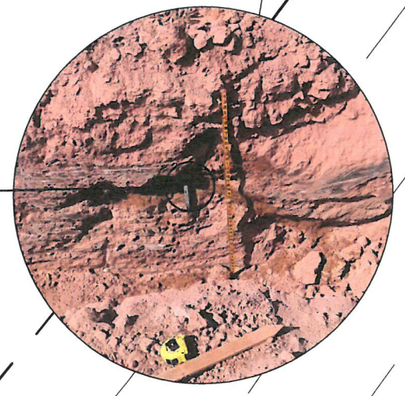
H-4



SEE PHOTO A.2-6



SEE PHOTO A.2-3



SEE PHOTO A.2-2

EXPLORATORY TRENCH

CRACK LOCATION

APPROXIMATE LOCATION OF CRACK

4210 MAJOR CONTOUR 10'

MINOR CONTOUR 2'

N

0 10' 20'

DATE: 11/19/2015
JOB NO.: 8364-14-004
DESIGNED BY: JTT
CHECKED BY: DRB
DWG: FISSURE STUDY

REVISIONS DATE

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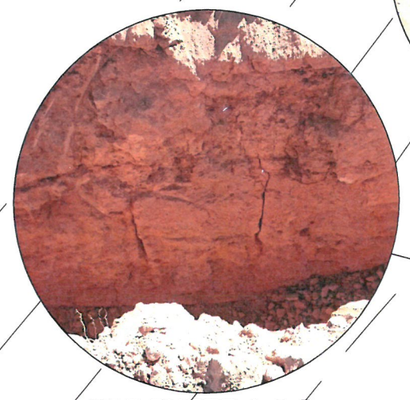
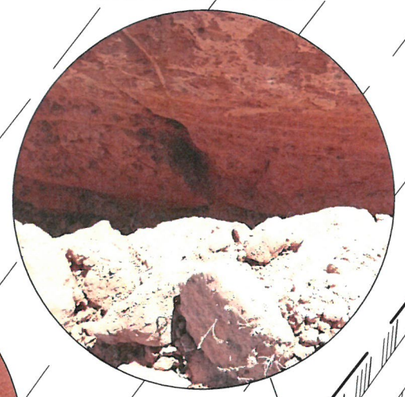
AREA 2: EXPLORATION TRENCH LOCATIONS
FOR
FROG HOLLOW DAM EVALUATION
WASHINGTON COUNTY, UTAH

FIGURE
F-2

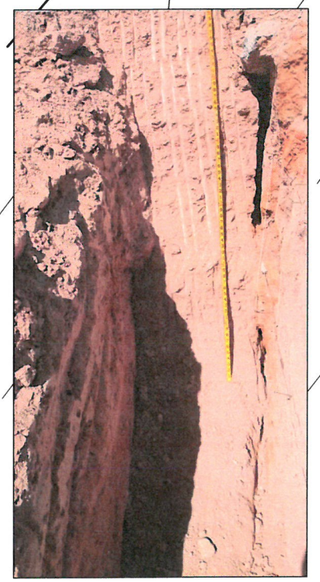
AREA 3



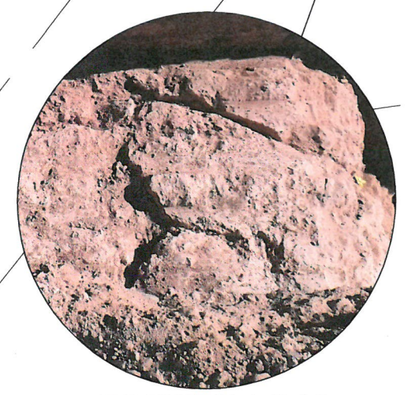
SEE PHOTO A.3-3



SEE PHOTO A.3-2

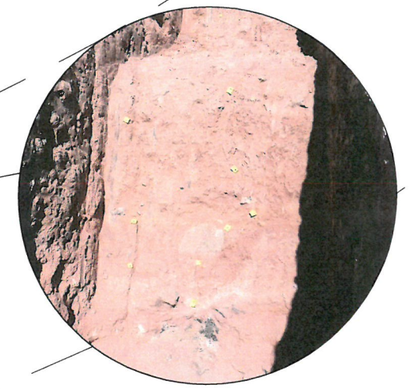


SEE PHOTO A.3-9



SEE PHOTO A.3-12

SEE PHOTO A.3-11



SEE PHOTO A.3-13

T-7

T-8

T-13

TRANSVERSE CRACK

H-11

H-12

H-13

H-14

4210

DOWNSTREAM SLOPE

CREST

UPSTREAM SLOPE

EXPLORATORY TRENCH

CRACK LOCATION

APPROXIMATE LOCATION OF CRACK

MAJOR CONTOUR 10'

MINOR CONTOUR 2'

N

0 10' 20'

DATE: 1/14/2015
JOB NO.: 8384-14-004
DESIGNED BY: JTT
CHECKED BY: DRB
DWG: FISSURE STUDY

REVISIONS DATE

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AREA 3: EXPLORATION TRENCH LOCATIONS
FOR
FROG HOLLOW DAM EVALUATION
WASHINGTON COUNTY, UTAH

FIGURE
F-3

AREA 4

DOWNSTREAM SLOPE

CREST

UPSTREAM SLOPE

H-29

H-28

H-27

H-26

H-25

H-24

H-23

H-22

H-21

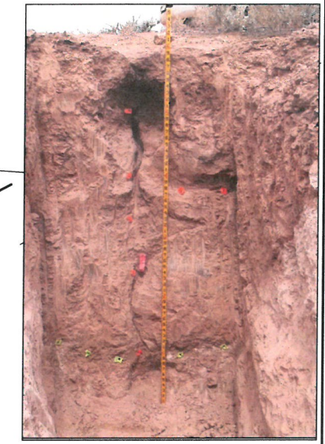
H-20

T-9

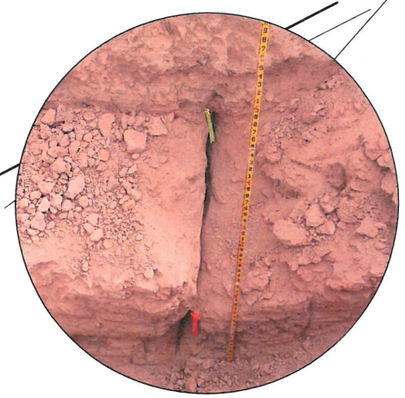
T-10

T-11

TRANSVERSE CRACK



SEE PHOTO A.4-8



SEE PHOTO A.4-5

EXPLORATORY TRENCH

CRACK LOCATION

APPROXIMATE LOCATION OF CRACK

MAJOR CONTOUR 10'

MINOR CONTOUR 2'

N

0 10' 20'

DATE: 11/9/2015
JOB NO.: 8384-14-004
DESIGNED BY: JTT
CHECKED BY: DRB
DWG: FISSURE STUDY

REVISIONS
DATE

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AREA 4: EXPLOTATION TRENCH LOCATIONS
FOR
FROG HOLLOW DAM EVALUATION
WASHINGTON COUNTY, UTAH

FIGURE
F-4

AREA 5

EXPLORATORY TRENCH

CRACK LOCATION

APPROXIMATE LOCATION OF CRACK

MAJOR CONTOUR 10'

MINOR CONTOUR 2'

DOWNSTREAM SLOPE

CREST

UPSTREAM SLOPE

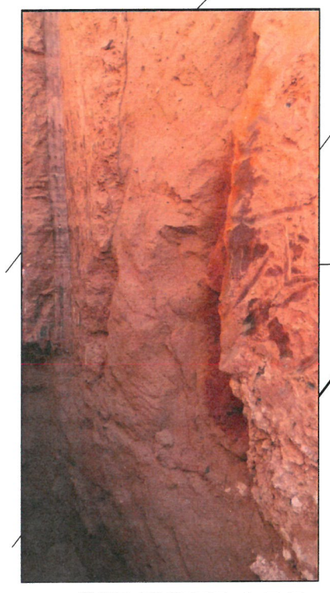
H-35

T-14

CHIMNEY DRAIN

H-34

4220



SEE PHOTO A.5-9

N

0 10' 20'

DATE:	11/9/2015
JOB NO.:	8364-14-004
DESIGNED BY:	JTT
CHECKED BY:	DRB
DWG:	FISSURE STUDY

REVISIONS DATE

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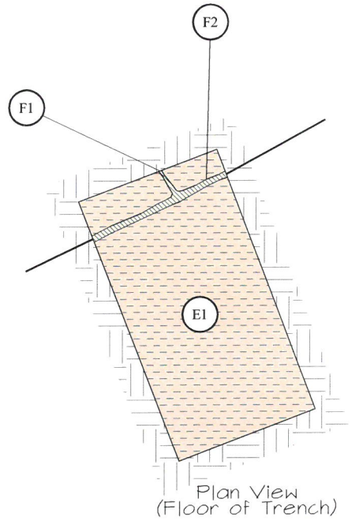
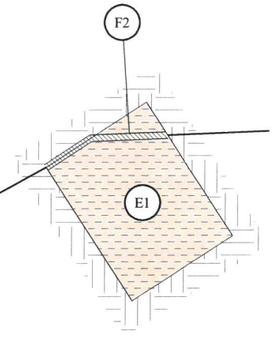
AREA 5: EXPLOTATION TRENCH LOCATIONS
FOR
FROG HOLLOW DAM EVALUATION
WASHINGTON COUNTY, UTAH

FIGURE
F-5



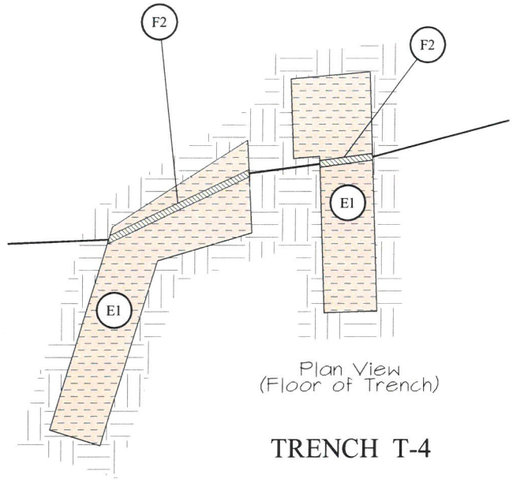
Plan View
(Floor of Trench)

TRENCH T-1



Plan View
(Floor of Trench)

TRENCH T-2



Plan View
(Floor of Trench)

TRENCH T-3

Plan View
(Floor of Trench)

TRENCH T-4

Legend:

E1 — 1978 Zone I Embankment: Silty Clay (CL) slightly moist, very stiff, brown (7.5YR4/4).

F1 — Transverse crack up to 2" wide, with Sandy to Clayey Silt infilling.

F2 — Longitudinal crack up to 3" wide, with Sandy to Clayey Silt infilling.

Crack partially infilled.

Approximate crack location.

DATE: 12/10/2015
JOB NO.: 8384-14-008
DESIGNED BY: GLM
CHECKED BY: DRB
DWG: HoleLocations

DATE
REVISIONS

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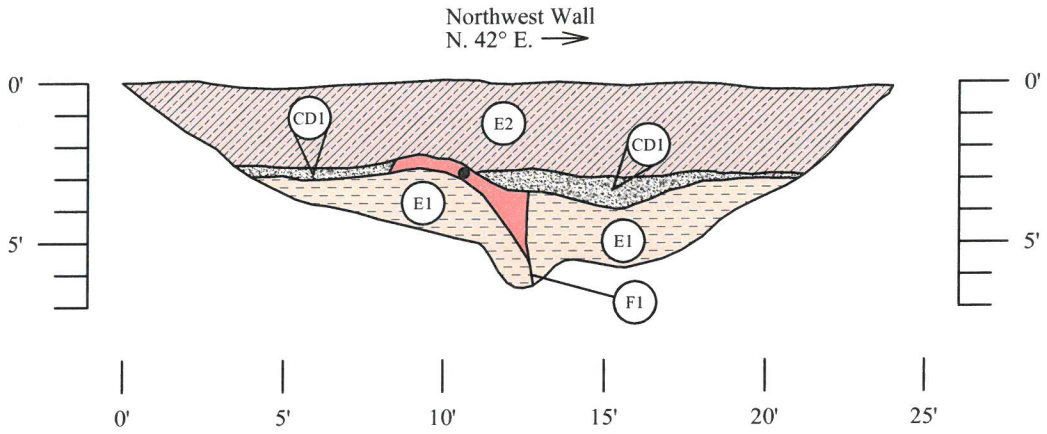
TRENCH LOGS
FOR
FROG HOLLOW DAM REHABILITATION EVALUATION
WASHINGTON, UTAH

DRAWING
F-6

TRENCH T-5



Legend:

E1 — 1978 Zone I Embankment: Silty Clay (CL) with some fine sand, with ≤ 2% Gypsum, brown (7.5YR5/4).

E2 — 1983 Embankment: Silty Clay (CL-ML) with some fine sand and ±1% angular clasts of limestone and basalt ≤ 1 inch long, strong brown (7.5YR5/6).

CD1 — 1983 Chimney Drain Edge: Sand (SP) medium grained, slight to moderate consolidated, light brown (7.5YR6/4).

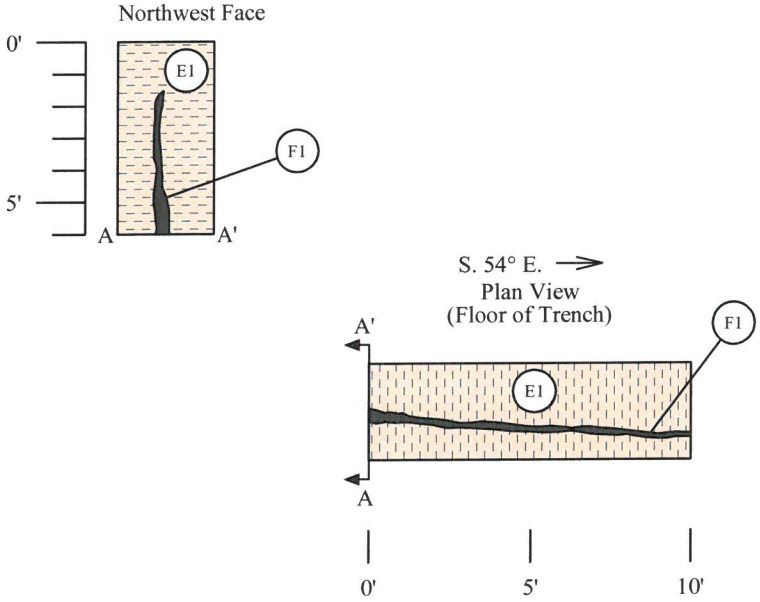
F1 — Transverse crack.

1978 Chimney Drain: Sand (SP-SM) Stained with dye.

Open void 18" deep, sand around void stained with dye.

Scale: See Sheet	Drawn By: GLM	ROSENBERG ASSOCIATES CIVIL ENGINEERS • LAND SURVEYORS 968 East Riverside Drive Suite A8 St. George, Utah 84790 – (435) 673-3535	Frog Hollow Trench Logs Washington County, Utah
Figure: F-7	Checked By: DRB		
	Date: 12/3/15	Job Number: 8384-14-008	

TRENCH T-6



Legend:

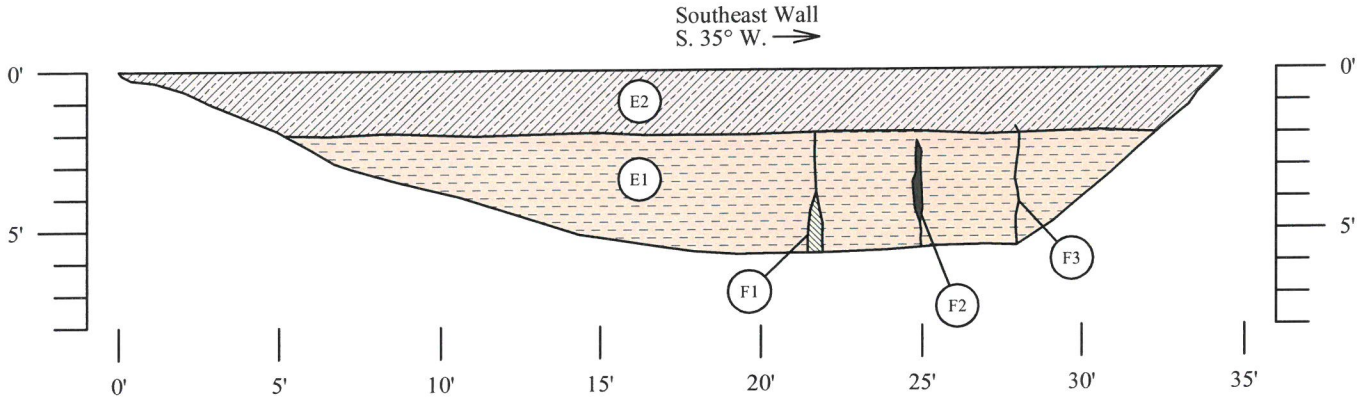
E1 — 1978 Zone I Embankment: Silty Clay (CL) With some fine sand, very stiff, dry, ≤ 1% angular clasts of Limestone and Basalt ≤ 0.25 inches long, reddish yellow (7.5YR6/6).

F1 — Transverse crack up to 5.0" wide at northwest end and floor of trench, crack was open with no infilling, no dye observed.

Open crack with no infilling.

Scale: See Sheet	Drawn By: GLM	ROSENBERG ASSOCIATES CIVIL ENGINEERS • LAND SURVEYORS 862 East Riverside Drive Suite A5 St. George, Utah 84790 – (435) 673-8586	Frog Hollow Trench Logs Washington County, Utah
Figure: F-8	Checked By: DRB		
	Date: 12/3/15	Job Number: 8384-14-008	

TRENCH T-7



Legend:

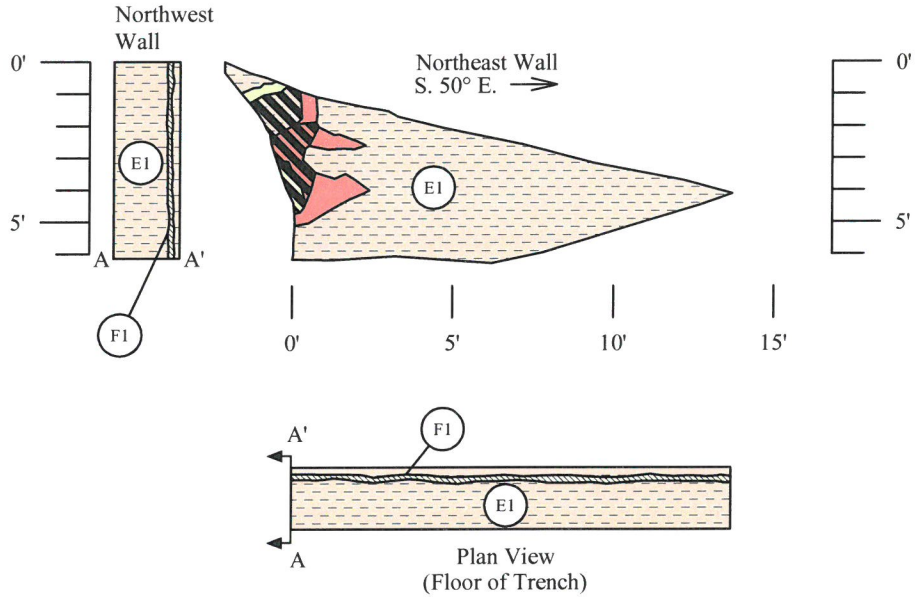
- E1 — 1978 Zone I Embankment: Silty Clay (CL) with some fine grained sand, very Stiff, dry, ≤ 1% angular clasts of Limestone and Basalt, ≤ 0.25" long, reddish yellow (7.5YR6/6).
- E2 — 1983 Embankment: Silty Clay (CL-ML) with some fine sand and ± 1% angular clasts of limestone and basalt ≤ 1 inch long, strong brown (7.5YR5/6)
- F1 — Transverse Crack: about 4.8"wide, infilled with Sandy to Clayey Silt, upper portion of crack 1/8" wide open.
- F2 — Transverse Crack: open crack up to 1.2" wide.
- F3 — Transverse Crack: 1/32" wide, with some Sandy to Clayey Silt infilling.

Crack partially infilled.

Open crack with no infilling.

Scale: See Sheet	Drawn By: GLM	ROSENBERG ASSOCIATES CIVIL ENGINEERS • LAND SURVEYORS 862 East Riverside Drive Suite A2 St. George, Utah 84790 – (435) 673-8586	Frog Hollow Trench Logs Washington County, Utah
Figure: F-9	Checked By: DRB		
	Date: 12/3/15	Job Number: 8384-14-008	

TRENCH T-8



Legend:

E1 — 1978 Zone I Embankment: Silty Clay (CL) with some fine grained sand, very stiff, dry, ≤ 1% angular clasts of Limestone and Basalt, ≤ 0.25" long, reddish yellow (7.5YR6/6).

F1 — Transverse crack up to 2.5" wide predominately open, with some Sandy to Clayey Silt infilling, dye predominately entered northwest wall and the floor.

Crack partially infilled

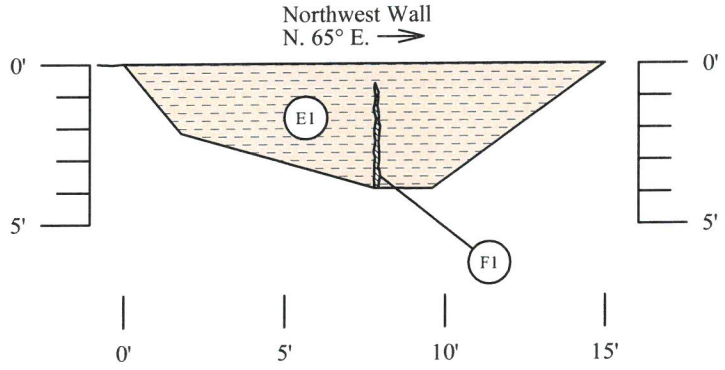
Block of grout

Grout removed from trenchwall

Area stained with dye

Scale: See Sheet	Drawn By: GLM	ROSENBERG ASSOCIATES CIVIL ENGINEERS • LAND SURVEYORS 302 East Riverside Drive Suite A8 St. George, Utah 84790 – (435) 673-3503	Frog Hollow Trench Logs Washington County, Utah
Figure: F-10	Checked By: DRB		
	Date: 12/3/15	Job Number: 8384-14-008	

TRENCH T-9



Legend:

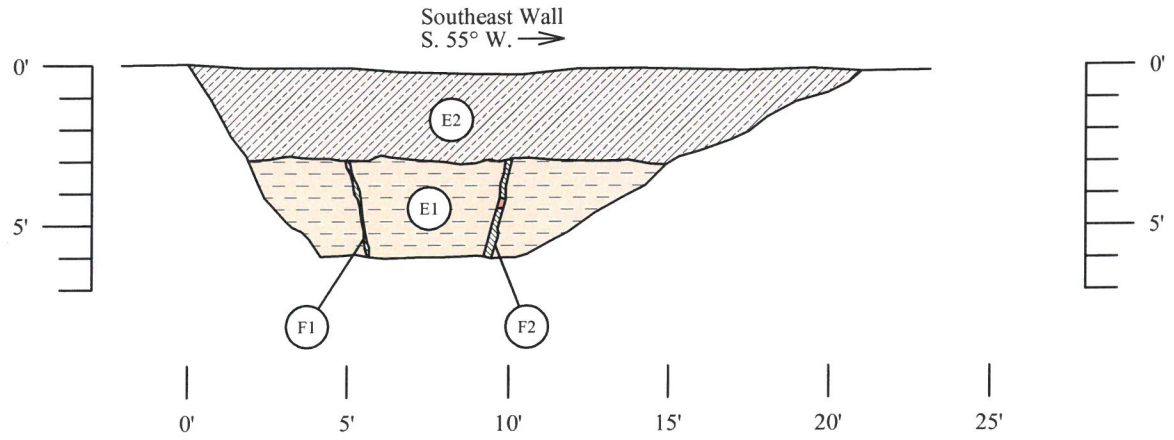
E1 — 1978 Zone I Embankment: Silty Clay (CL) slightly moist to dry, very stiff, pin hole voids in upper 2 feet, with some surface organics, 0'-1' loose, some horizontal bedding, brown (7.5YR5/4).

F1 — Transverse crack up to 1.8" wide with Sandy to Clayey Silt infilling.

Crack partially Infilled.

Scale: See Sheet	Drawn By: GLM	ROSENBERG ASSOCIATES CIVIL ENGINEERS • LAND SURVEYORS 868 East Riverside Drive Suite A8 St. George, Utah 84790 – (435) 673-8586	Frog Hollow Trench Logs Washington County, Utah
Figure: F-11	Checked By: DRB		
	Date: 12/3/15	Job Number: 8384-14-008	

TRENCH T-10

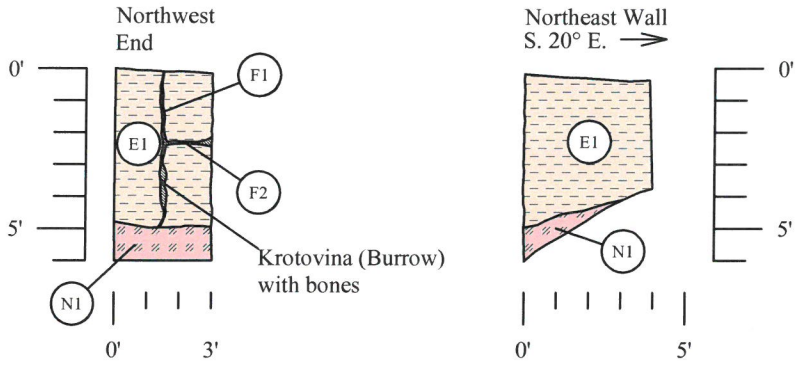


Legend:

- E1 — 1978 Zone I Embankment: Silty Clay (CL) slightly moist, very stiff, brown (7.5YR4/4).
- E2 — 1983 Embankment: Clayey Silt (CL-ML) with ±3% Basalt clasts ≤ 2" long (subangular), with ≤ 2% gypsum nodules ≤ ¼"Ø, brown (7.5YR5/3).
- F1 — Transverse crack up to 2" wide, with Sandy to Clayey Silt infilling.
- F2 — Transverse crack up to 3.5" wide.
- Cracks partially infilled.
- Stained with dye.

Scale: See Sheet	Drawn By: GLM	ROSENBERG ASSOCIATES CIVIL ENGINEERS • LAND SURVEYORS 968 East Riverside Drive Suite A8 St. George, Utah 84790 – (435) 673-8586	Frog Hollow Trench Logs Washington County, Utah
Figure: F-12	Checked By: DRB		
	Date: 12/3/15	Job Number: 8384-14-008	

TRENCH T-11



Legend:

E1 — 1978 Zone I Embankment: Silty Clay (CL) slightly moist, very stiff, brown (7.5YR4/4).

N1 — Native Qac: Sandy Silt (ML) pink (5YR7/4) with 15% subangular clasts of Basalt and Limestone up to 3" long, gypsiferous, $CaCo_3$ staining.

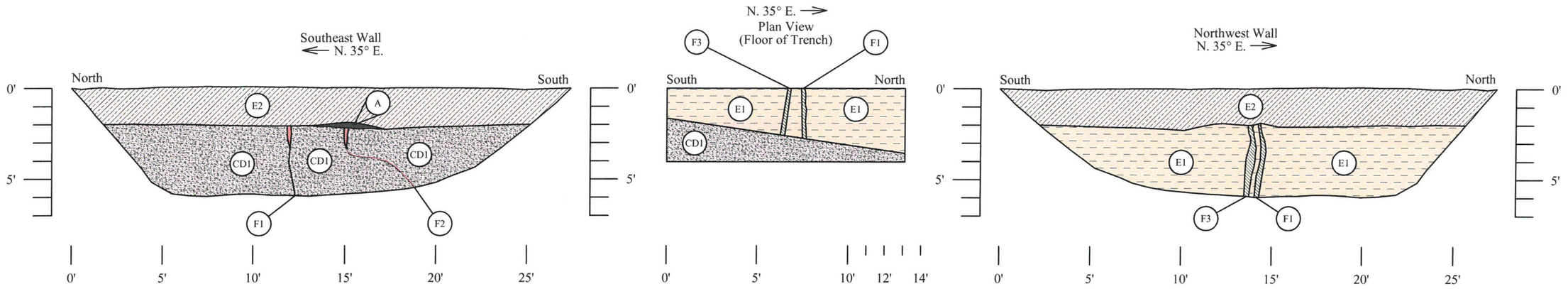
F1 — Transverse crack up to 2.5" wide, with Sandy to Clayey Silt infilling.

F2 — Longitudinal crack up to 3" wide, with Sandy to Clayey Silt infilling.

Crack partially infilled.

Scale: See Sheet	Drawn By: GLM	ROSENBERG ASSOCIATES CIVIL ENGINEERS • LAND SURVEYORS 862 East Riverside Drive Suite A8 St. George, Utah 84790 – (435) 673-3535	Frog Hollow Trench Logs Washington County, Utah
Figure: F-13	Checked By: DRB		
	Date: 12/3/15	Job Number: 8384-14-008	

TRENCH T-12



Legend:

E1 1978 Zone I Embankment: Silty Clay (CL) Slightly Moist, Very Stiff, Brown (7.5YR4/4)

E2 1983 Embankment: Sandy Clay (CL) with 20% clasts ≤ 0.2", some gypsum nodules, some roots, stiff, slightly Moist to dry, Light Brown (7.5YR6/4), blocky structure.

CD1 1983 Chimney Drain: Sand (SP), Fine to Medium Grained with ≤ 5% Sub round to round gravels ≤ 0.5", Average size ≤ 0.3", Dense, Slightly Moist, Light Yellow Brown (10YR6/4)

F1 Transverse Crack: within Chimney drain sand, primarily defined by roots following fracture, upper 1' is ~ ⅛" wide, becoming hairline width with depth. Fracture same as fracture documented in T-5 and T-6.

In floor of Trench Crack: Width ~ 0.5' wide, completely infilled with ~ 50% CL and 50% subangular gravels ≤ 1", average size ≤ 0.5".

F2 Transverse Crack within Chimney drain sand: defined by fluorescein dye from 2/4/15 upper 1' of crack 1.5" wide, becoming hair-line with depth.

F3 Transverse crack up to 1" wide, infilled with 90% CL and 10% subangular gravels ≤ 0.5".

F1 / F3 Combined transverse crack: North side of crack is a continuation of F1 from NE wall. South side is a crack that can be documented in floor of trench F3 but not in NE wall. Area between F1 and F3 appears to also be fractured with some infilling. Combined crack terminates 2" below ground surface.

A Open void along contact, from ~ 13.5' - 16', ~ 1" wide.

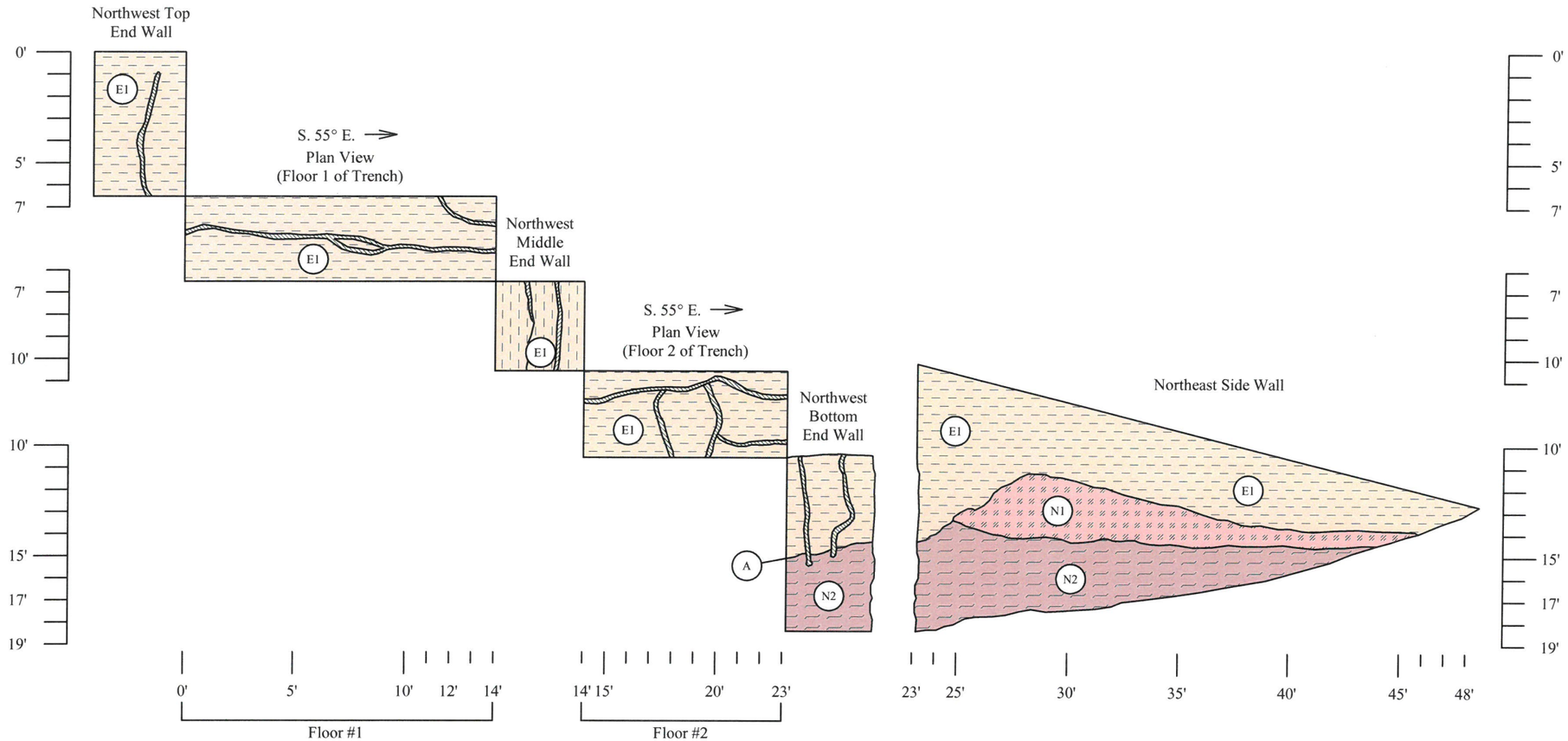
Cracks partially infilled.

Stained with dye.

Open crack with no infilling.

Scale: See Sheet	Drawn By: GLM	ROSENBERG ASSOCIATES CIVIL ENGINEERS • LAND SURVEYORS 352 East Riverside Drive Suite A5 St. George, Utah 84790 – (435) 673-3535	Frog Hollow Trench Logs Washington Count, Utah
Drawing Number: F-14	Checked By: DRB		
	Date: 5/4/16	Job Number: 8384-14-008	

TRENCH T-13



Legend:

E1 — 1978 Zone I Embankment: Silty Clay (CL) slightly moist, very stiff, brown (7.5YR4/4).

N1 — Native Qac: Sandy Silt (ML) with Clay and ~ 5% angular basalt gravels ≤ 0.5", pervasive $Caco_3$ Coating/Staining (Caliche), Dense, Slightly Moist, Pink (7.5YR8/3).

N2 — Native Qac: Clayey Silt (ML) with ~ 5% angular gravel to cobble size (0.5-1.2") Basalt and ≤ 0.5" caliche nodules gypsiferous, Dense, Slightly moist Reddish Yellow (7.5YR6/6).

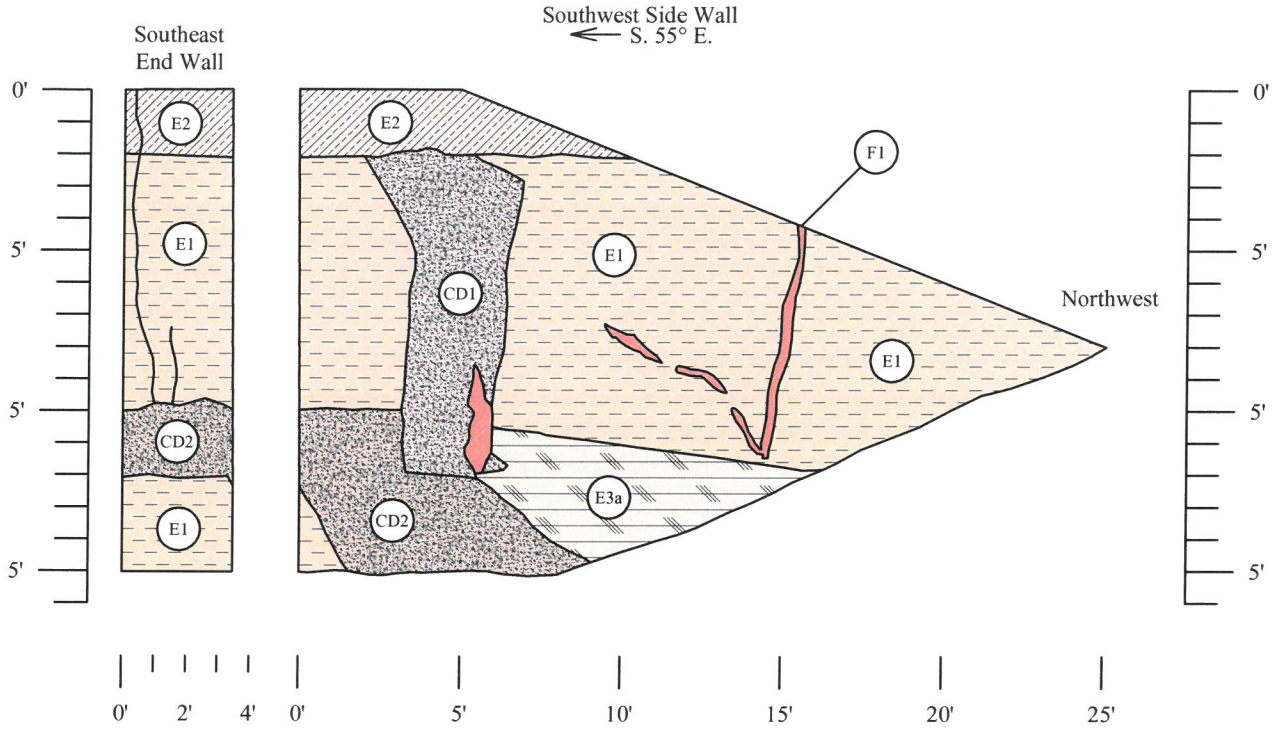
F1 — Transverse and Longitudinal cracks vary from 1" to 3.5" wide infilled with Sandy Clay (CL).

A — Transverse cracks do not extend below 4 to 12 inches.

Crack partially infilled.

Scale: See Sheet	Drawn By: GLM	ROSENBERG ASSOCIATES CIVIL ENGINEERS • LAND SURVEYORS 868 East Riverside Drive Suite A8 St. George, Utah 84790 – (435) 673-8586	Frog Hollow Trench Logs Washington Count, Utah
Drawing Number: F-15	Checked By: DRB	Job Number: 8384-14-008	
	Date: 5/4/16		

TRENCH T-14



Legend:

E1 — 1978 Zone I Embankment: Clayey Silt (ML), with ~ 20% angular gravels ≤ 12 inches, basalt ~ 6-12"; ≤ 2" sub round caliche nodules, Light Brown (7.5YR6/4) Very Stiff, Slightly Moist.

E2 — 1983 Embankment: Sandy Clay (CL) with 20% clasts ≤ 0.2", Some Gypsum Nodules, Some Roots, Stiff Slightly Moist to Dry, Light Brown (7.5YR6/4), Blocky Structure.

E3a — Zone II Embankment: Clayey Silt (ML) with 20% angular gravels ≤ 12", Basalt 6"-12" ≤ 2" sub-round caliche nodules, Light Brown (7.5YR6/4), Very Stiff, Slightly Moist.

CD1 — 1983 Chimney Drain: Sand (SP), Fine to Medium Grained with ≤ 5% Sub round to round gravel ≤ 0.5", Average size ≤ 0.3", Dense, Slightly Moist, Light Yellow Brown (10YR6/4)

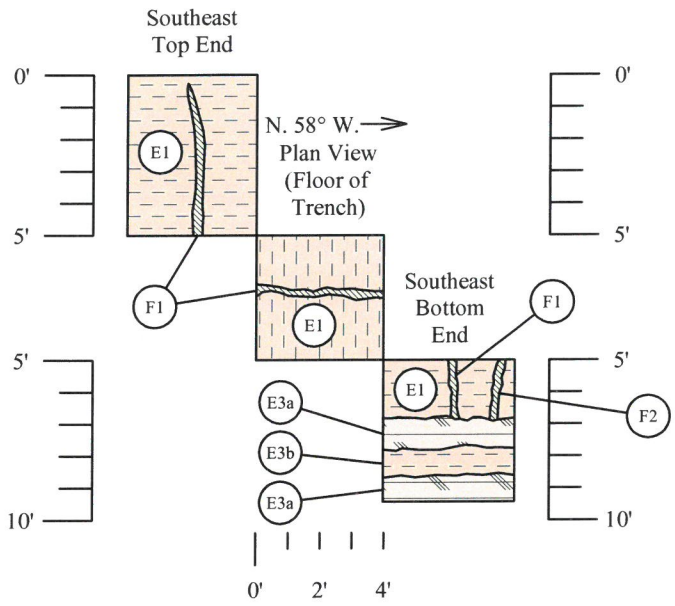
CD2 — Original Chimney Drain: Sand (SP-SM) Medium Grained, ≤ 10% round gravel ≤ 1", Average size 0.25", Medium Dense, Slightly Moist.

F1 — Longitudinal Crack:

Stained with dye.

Scale: See Sheet	Drawn By: GLM	ROSENBERG ASSOCIATES CIVIL ENGINEERS • LAND SURVEYORS 302 East Riverside Drive Suite A8 St. George, Utah 84790 – (435) 673-3200	Frog Hollow Trench Logs Washington County, Utah
Figure: F-16	Checked By: DRB		
	Date: 5/4/16	Job Number: 8384-14-008	

TRENCH T-15



Legend:

E1 — 1978 Zone I Embankment: Sandy Clay (CL) with 20% clasts ≤ 0.2", some gypsum nodules, some roots, stiff, slightly Moist to dry, Light Brown (7.5YR6/4), blocky structure.

E3a — Zone II Embankment: Clayey Silt (ML) with 20% angular gravels ≤ 12", Basalt 6"-12" ≤ 2" sub-round caliche nodules, Light Brown (7.5YR6/4), Very Stiff, Slightly Moist.

E3b — Zone II Embankment: Sandy Clay (CL) with 20% clasts ≤ 0.2", some gypsum nodules, some roots, stiff, slightly Moist to dry, Light Brown (7.5YR6/4)

F1 — Transverse crack: 2.4" to 4.8" wide in top Southeast end, 1.2" wide in floor of trench and bottom Southeast end.

F2 — Transverse crack: .5" wide in bottom Southeast end.

Crack partially infilled.

Scale: See Sheet	Drawn By: GLM	ROSENBERG ASSOCIATES CIVIL ENGINEERS • LAND SURVEYORS 860 East Riverside Drive Suite A5 St. George, Utah 84790 – (435) 673-8586	Frog Hollow Trench Logs Washington County, Utah
Figure: F-17	Checked By: DRB		
	Date: 5/4/16	Job Number: 8384-14-008	