STATE OF MICHIGAN
DEPARTMENT OF ENVIRONMENTAL QUALITY
LANSING

RICK SNYDER
GOVERNOR

DAN WYANT
DIRECTOR

Brown Bridge Dam – Temporary Dewatering Structure

Root Cause Analysis of the October 6, 2012, Failure Incident

Photo courtesy of John Russell, Great Lakes Images

June 2014

Preface

The purpose of this report is to present the findings of the State of Michigan, Department of Environmental Quality (MDEQ), Water Resources Division's (WRD) investigation into the cause of the failure of a temporary dewatering structure (TDS) and an earthen embankment of the Brown Bridge Dam in Grand Traverse County, Michigan on October 6, 2012. Members of the Hydrologic Studies and Dam Safety Unit (Dam Safety) have gathered, compiled, and reviewed all available information on the design and construction of the Brown Bridge Dam removal project, including the design and construction of the TDS; the events leading up to the failure of the TDS and earthen embankment; and the subsequent release of floodwaters and sediment to the downstream Boardman River channel and floodplain.

Additionally, MDEQ Dam Safety staff members performed post-failure investigations and interviews, collaborated in a geotechnical investigation, reviewed laboratory analyses of soil samples and data collected, and collaborated on an engineering analysis of the data to aid in determining the most probable failure mode of the TDS structure and adjacent earthen embankment.

Respectfully submitted,

Lucas A. Trumble, P.E.
Environmental Engineer, MDEQ-WRD-HSDSU

Mario Fusco, Jr. P.E.
Environmental Engineer, MDEQ-WRD-HSDSU

Executive Summary

The Brown Bridge Dam, formerly located on the Boardman River in Grand Traverse County, Michigan, was owned by the City of Traverse City and originally constructed in 1921 for the purpose of generating hydroelectricity. The dam was operated by Traverse City Light & Power (TCL&P) under lease from the City. It generated electricity continuously until its decommissioning in November 2006. Until the time of its removal, the Brown Bridge Dam consisted of an approximately 1600-foot long earthen embankment and a combined powerhouse/spillway structure. The dam had a structural height of approximately 46 feet. At normal pool elevation, the surface area of the Brown Bridge Pond was approximately 190 acres, and the storage volume was approximately 1,900 acre-feet.

In 2012, the City of Traverse City was granted a permit from the MDEQ, WRD to remove the Brown Bridge Dam and restore a natural river channel through the former Brown Bridge Pond impoundment. The project included a steel sheetpile walled diversion channel and drawdown structure, referred to as the TDS, to be constructed adjacent to the existing spillway structure.

On the morning of October 6, 2012, at first loading of the TDS water control structure, a boil was noticed downstream of the concrete slab lining the bottom of the channel. Flow from the boil increased quickly, ultimately resulting in failure of the TDS and collapse of the earthen embankment section located between the TDS and the Brown Bridge Dam spillway structure. The ensuing uncontrolled release of impounded water resulted in significant flooding along the Boardman River.

A series of post-failure investigations and subsequent geotechnical analyses found that the most likely failure mode of the TDS was internal erosion of the foundation material from underneath the water control structure within the TDS. The hydraulic loading that the control section was subjected to on October 6, 2012, resulted in an unstable subsurface soil condition, which led to erosion of the foundation soils, release of water underneath of the control structure, collapse of the earthen embankment adjacent to the south TDS wall, and ultimately the uncontrolled release of water from the Brown Bridge Pond.

Table of Contents

List of Figures

Authority

This investigation into the root cause of the October 6, 2012, failure of the Brown Bridge Dam Removal Project, TDS, was conducted by the State of Michigan, MDEQ. Staff from Dam Safety, WRD are responsible for the majority of the report content and analyses.

From November 2006 until the time of its removal, the Brown Bridge Dam was regulated by the MDEQ under Part 315, Dam Safety, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended (Part 315 of the NREPA). Additionally, WRD staff issued a Joint Permit, MDEQ Permit No. 12-28-0011-P, for the removal of the dam and restoration of the natural river channel in the area of the former Brown Bridge impoundment.

Methodology

The following methodologies were implemented in order to determine the potential failure mode of the TDS:

1. Observations made by MDEQ staff onsite immediately following the initiation of the failure.
2. Review of historic plans, inspection reports, geotechnical explorations, and other available documents.
3. Collection of verbal accounts of personnel onsite during the failure event.
4. Field investigations, exploratory excavation, and geotechnical exploration in the weeks following the failure event.
5. Observations made by MDEQ staff onsite during the deconstruction of the TDS.
6. Laboratory analysis of soil samples collected during the geotechnical exploration.
7. Seepage and stability analyses of the structure using results of the laboratory analysis.

MDEQ Dam Safety staff arrived onsite approximately two (2) hours after being alerted of the uncontrolled release of water through the TDS, which ultimately resulted in the structure's failure and a rapid release of impounded water and sediment to the downstream Boardman River on Saturday, October 6, 2012. The role of Dam Safety staff during dam failure incidents is to offer technical guidance to the dam owner, personnel onsite, and emergency management, with the overall goal of protecting public safety and preventing the dam's failure. Dam Safety staff remained onsite for the remainder of the day to observe and document the developing failure.

Two days later, on Monday, October 8, 2012, Dam Safety staff returned to the project site to perform a site investigation and conduct interviews with the dam owner, personnel onsite, and other parties present during the failure. Notes from these interviews are provided in Appendix A. On that date, the MDEQ coordinated with stakeholders to develop a plan for continuing the removal project and to allow for forensic investigation of the TDS failure.

Soon after the failure, the dam owner and their representatives requested MDEQ approval of a plan for continuing the removal project in a manner that would allow for forensic investigation of the TDS failure at a later date. After discussions, it was agreed to stabilize the failed TDS and divert all flow of the Boardman River through the TDS during deconstruction of the former combination powerhouse/spillway structure (spillway) and restoration of the river channel through that area. Stabilization and flow diversion was achieved through the placement of bulk sand bags and earthen fill. Flow was passed through the TDS until late November, at which time the river channel had been restored in the vicinity of the former spillway and flow could be diverted to the newly-formed channel.

On December 3, 2012, Dam Safety staff returned to the project site to meet with the dam owner, removal project personnel, other involved parties, and their respective legal representation for the purposes of proceeding with the forensic investigation of the TDS failure. A consensus was reached that a geotechnical exploration of the TDS foundation and the adjacent embankments and exploratory excavation of the failure area should be completed prior to the deconstruction of the TDS.

Starting December 3, 2012, those parties involved in the failure investigation met onsite to finalize the geotechnical investigation plans and perform visual inspections of the TDS. From December 4 through 6, 2012, a total of eleven (11) soil boring samples were taken from the TDS channel and adjacent embankment areas. The samples were collected using a split-spoon sampler in accordance with ASTM D-1586. Photo and video documentation and surveying services were provided throughout all phases of the field investigation.

In addition, probing of the area beneath the TDS control section was performed using a depth of refusal (DOR) rod in an attempt to determine the depth of scour under the structure. Following the completion of soil borings under the concrete control section, the concrete slab was demolished and removed from the area. The slab and area underneath were visually inspected and photo documented. Finally, upon completion of all soil borings in the area, exploratory excavation was conducted in the TDS channel and inlet in order to determine the subsurface soil conditions and locate any foreign or unusual materials.

The final step in the physical investigation of the TDS was the removal and investigation of the TDS sheetpiles. Dam Safety staff was onsite the weeks of December 10 and 17, 2012, to observe and document the condition of each sheetpile section as it was removed. The elevations and lengths of each section were also documented. A summary of the TDS sheetpile data is located in Appendix H.

Soil samples collected during the investigation were sent to AECOM's soils laboratory in Vernon Hills, Illinois for analysis. A variety of tests designed to determine the physical characteristics and makeup of the soil materials were completed. Results of these laboratory analyses were provided to the MDEQ on June 18, 2013. The laboratory results, along with survey data and information gathered during the investigation, were used to perform a seepage analyses on the TDS foundation soils under the loading conditions they were subjected to on October 6, 2012. The detailed results of these analyses, along with the investigation, survey, and laboratory data are in the Appendices of this report.

I. Project Description

The following descriptions and history of the Brown Bridge Dam were adapted from a “Safety Inspection of Brown Bridge Dam” prepared by STS/AECOM on September 18, 2008. Additional information has been added for events occurring after the 2008 report was completed. All references to “right” and “left” in this report are based on the observer facing downstream.

The Brown Bridge Dam, formerly located on the Boardman River in Grand Traverse County, Michigan, was originally constructed in 1921 for TCL&P. It generated electricity continuously up to its decommissioning in November 2006. One of the turbines was replaced in 1941, the other was original. Both generators were original equipment, but were taken off-line and rendered incapable of generating electricity in 2006. In 1984, TCL&P installed new control equipment in the powerhouse. All generating and control equipment was removed from the dam during its deconstruction in late 2012.

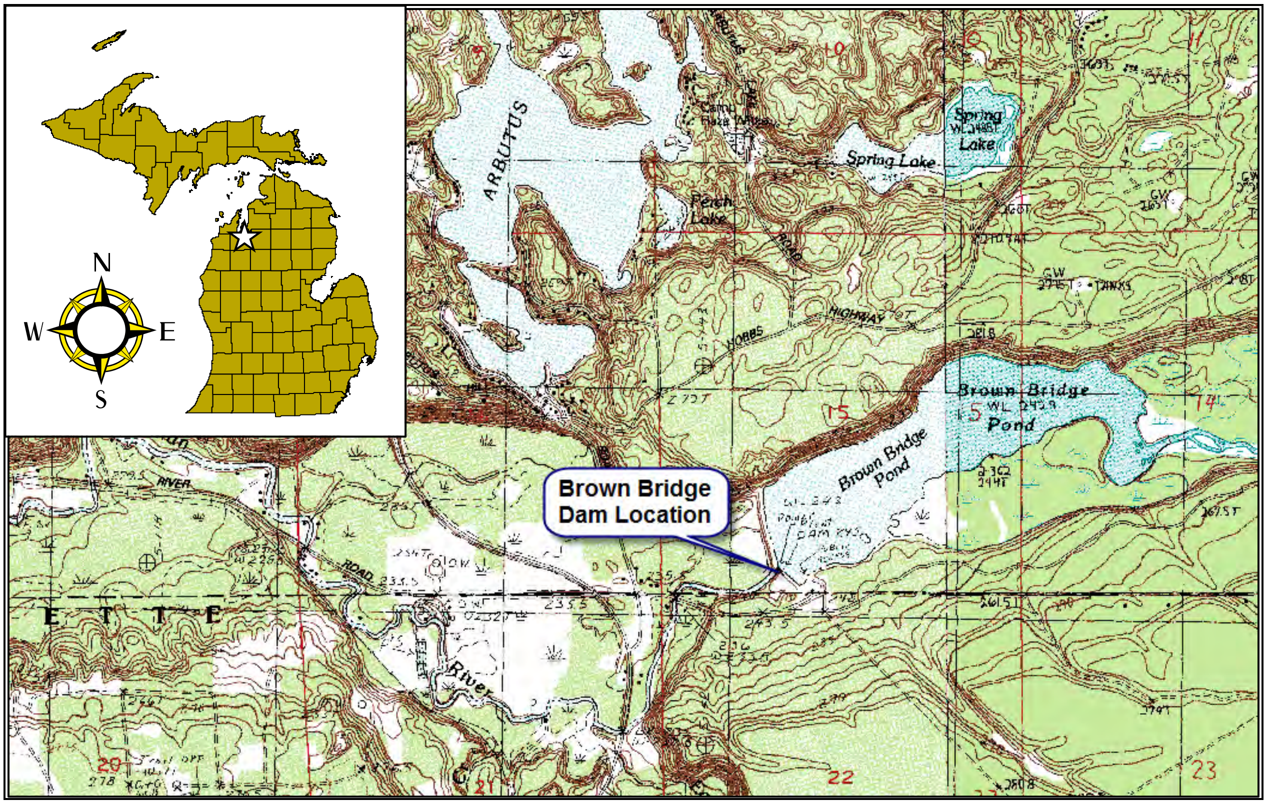


Figure I-1. Project Location Map

Prior to surrendering its license to produce hydroelectricity in 2006, the Brown Bridge Dam fell under the regulatory authority of the Federal Energy Regulatory Commission (FERC). After surrendering its license, regulatory authority for the dam was transferred to the MDEQ under Part 315 of the NREPA.

Until the time of its removal, the Brown Bridge Dam consisted of an approximately 400-foot long left embankment, a combined powerhouse/spillway structure (spillway), and an approximately 1,150-foot long right embankment. A log chute with slide gate was located adjacent to the right wall of the powerhouse. An abandoned fish ladder was located on the right embankment just right of the log chute. In late 2012, the powerhouse, spillway, and adjacent embankment material were removed as part of a regional Boardman River restoration project.

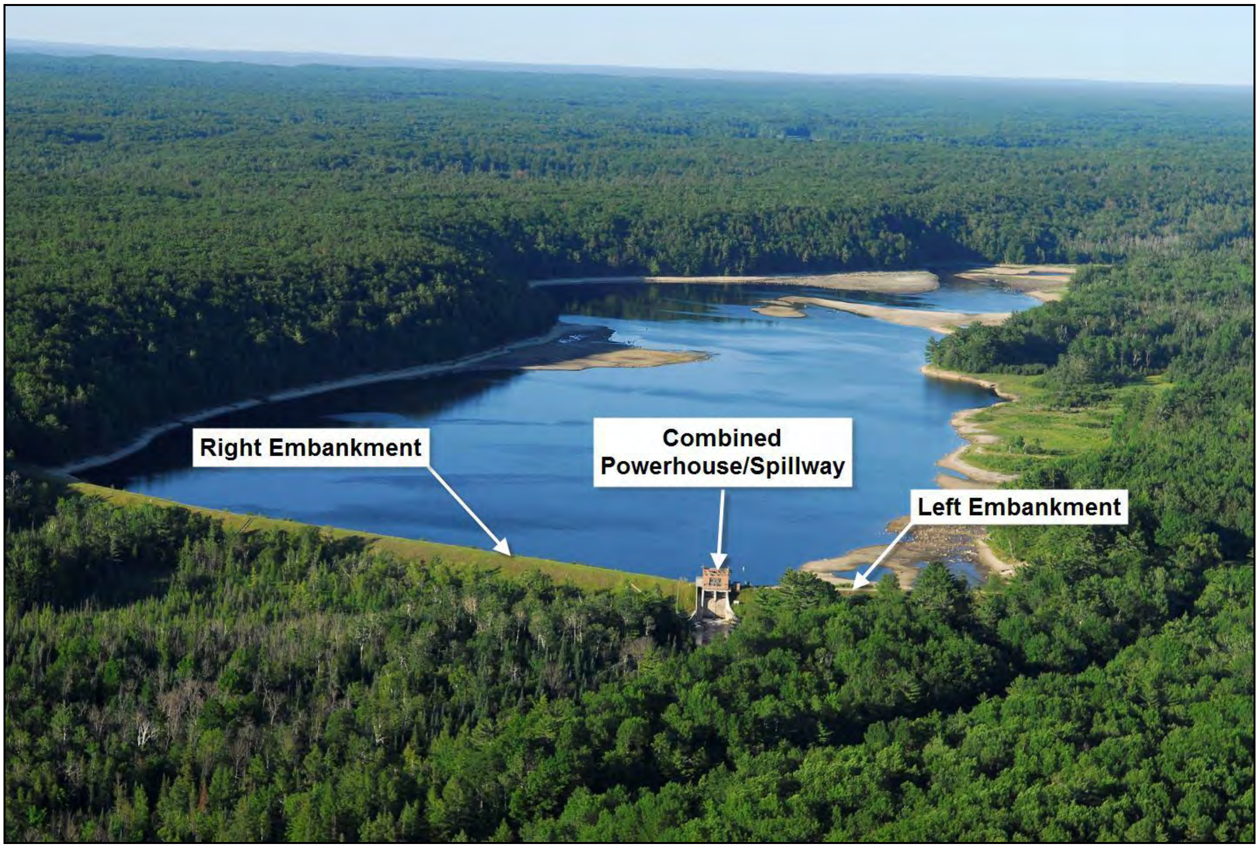


Figure I-2. Diagram of the dam and pond prior to removal
Photo courtesy of John Russell, Great Lakes Images

The lower portion of the embankments consists of hydraulic fill, and the upper portion of the embankments consists of compacted fill. There is a concrete core wall along the entire upstream length of both earth embankments, with a nominal top elevation of 798.4 feet NGVD29 +/-. The project drawings show the core wall extended vertically to a depth of eight feet, except at the powerhouse/spillway structure where it functioned as a cutoff wall and extended vertically below the upstream wall of the powerhouse / spillway and was keyed two feet into the clayey till. The wall extended laterally at this depth left and right of the upstream approach walls for a distance of 20 feet beyond the wall footings. The minimum crest elevation of the embankments identified during a 2008 centerline survey was 802.0 feet NGVD29. Based on the original design drawings, the design embankment crest elevation was 802.4 feet NGVD29. The embankment crest width varies from 12 to 15 feet. The downstream slopes are reported to vary from 2H:1V to 2.5H:1V; however, the 1994 stability analysis assumed downstream slopes as steep as 1.8:1V. Cross sections surveyed during a 2008 inspection showed downstream slopes on the right embankment as steep as 1.5H:1V. The left embankment adjacent to the left powerhouse/spillway wall appeared to be steeper than 1.5H:1V.

As part of the spillway structure, the Brown Bridge spillway contained two upper 12-foot wide by 5.5-foot high tainter gates. The upper spillway sill was at elevation 792.5 feet NGVD29. The two lower 12-foot wide by 5.5-foot high tainter gates functioned as a turbine bypass and could not be opened if the water level was above elevation 791.0 feet NGVD29. The lower spillway sill was at elevation 786.7 feet NGVD29. In addition, there was a log chute with a slide gate measuring 6-foot wide by 6-foot high adjacent to the powerhouse. The log chute sill was at elevation 792.5 feet NGVD29. The log chute was intended for additional discharge capacity but had been used to pass base river flows since November 2006.

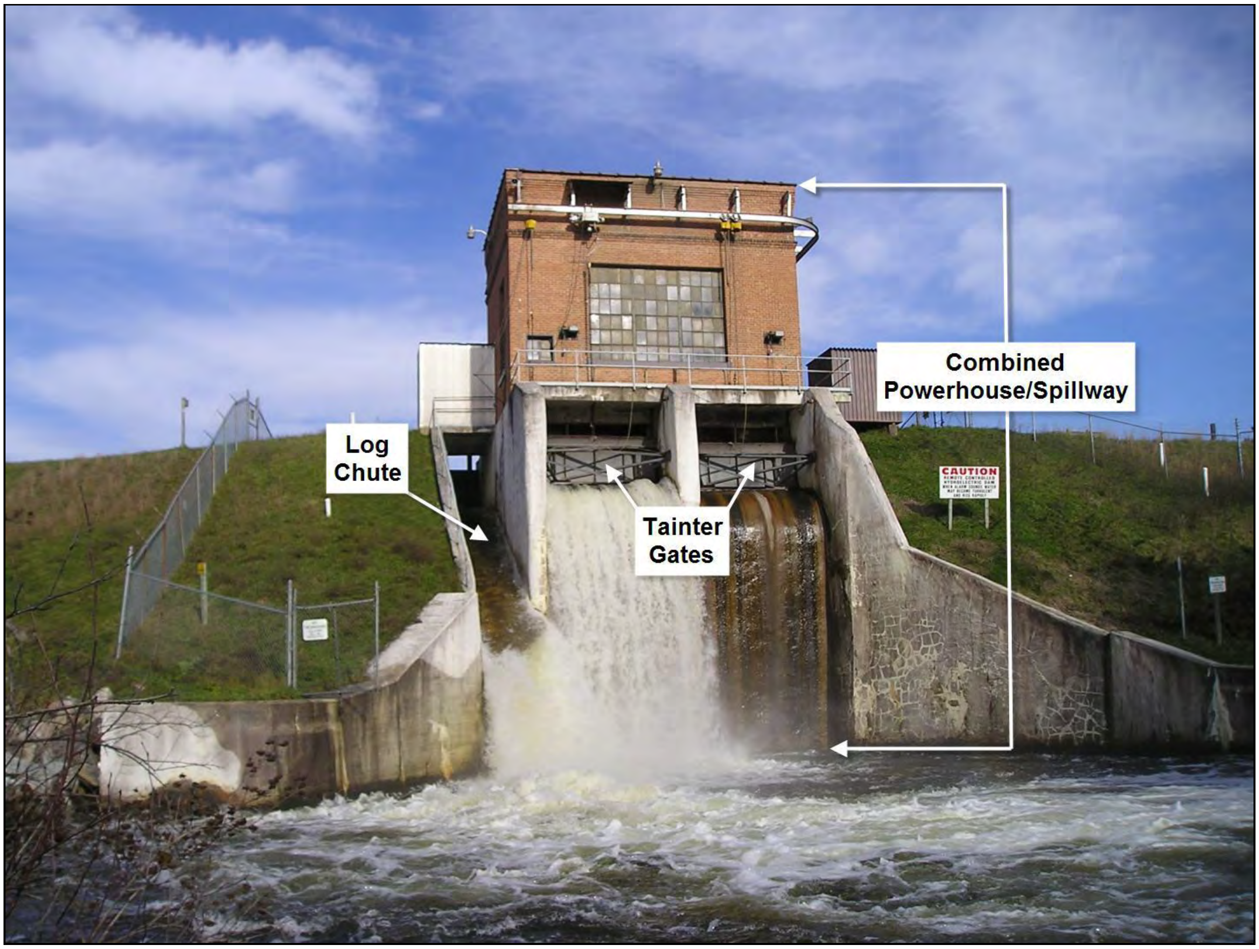


Figure I-3. Diagram of the spillway viewed from downstream
Photo courtesy of Jim Pawloski, MDEQ

The powerhouse was a brick structure supported on a reinforced concrete substructure. The powerhouse contained two vertical shaft Francis turbines with an installed capacity of 830 kW. The turbines consisted of one Leffel Type Z, rated at 690 HP, and one Leffel Type F, rated at 375 HP. The powerhouse was constructed in 1921, was an integral part of the original dam project, and was in continuous operation until November 2006, when TCL&P surrendered its operating license and decommissioned the plant. All of the turbine-generating and control equipment remained in the powerhouse until the dam was removed in 2012.

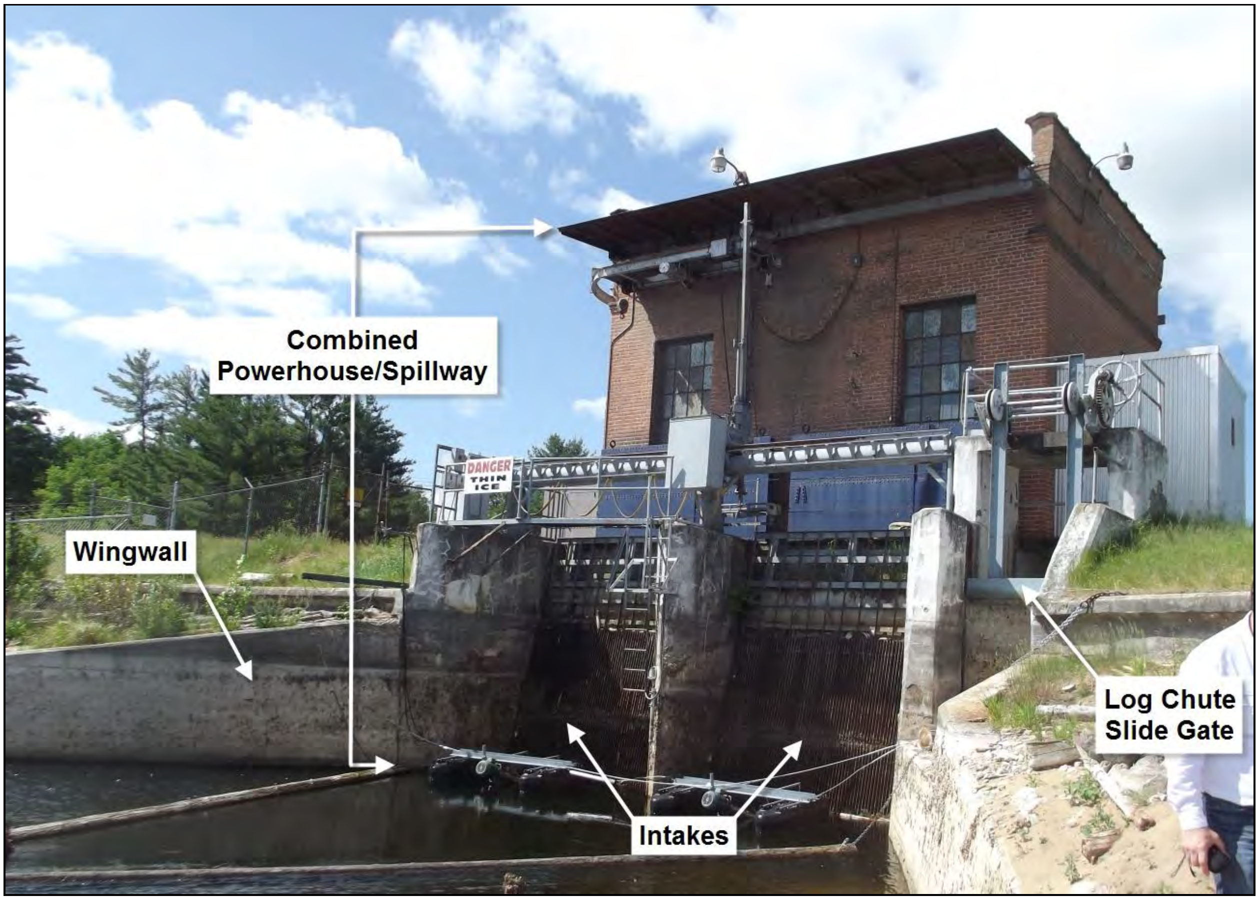


Figure I-4. Diagram of the spillway viewed from upstream
Photo courtesy of Luke Trumble, MDEQ

The intake structure was integral to the powerhouse. Left and right concrete approach (wing) walls flanked either side of the intake bays. Inclined trash racks were located on the upstream side of the intake. After the plant was decommissioned in 2006, the upper tainter gates were opened and wicket gates closed. Water passed through the inclined trash racks and flowed over the upper tainter gate concrete sill at elevation 792.5 feet NGVD29. With the wicket gates open, water passed through a set of horizontal trash racks inside the structure at elevation 792.5 feet NGVD29, through the turbines, and dropped into a short tailrace under the powerhouse. The tailrace discharged to the spillway apron at invert elevation 756.5 feet NGVD29.

The Brown Bridge Dam was operated as a run-of-river facility, meaning that the dam gates were operated such that the dam passed only what flow was received into the impoundment. In other words, the dam was not operated in such a manner that water was stored in the impoundment for the purposes of flood control and/or “peaking” type hydroelectric production. The normal headwater elevation of the Brown Bridge Reservoir was 796.7 feet NGVD29. At normal pool elevation, the surface area of the pond was 191 acres, and the storage volume was approximately 1,900 acre-feet. The drainage area of the Boardman River at the dam is 151 square miles (STS/AECOM pp. 7-8).

II. About the Failure Event

Prior to removal of the spillway structure, the Brown Bridge impoundment was drawn down to the maximum extent possible using the dam's existing equipment. This drawdown, to elevation 786.7 feet NGVD29, left a difference in elevation upstream and downstream of the dam (head) of approximately 18 feet under normal flow conditions. In order to fully remove the spillway, complete drawdown of the impoundment was needed.

To complete the drawdown of the impoundment, a TDS was constructed immediately right of the powerhouse/spillway structure. The TDS consisted of steel sheetpile side walls, a concrete control section, two timber stoplog bays, and a riprap-lined channel downstream of the control section, as shown in Figure II-1 below.

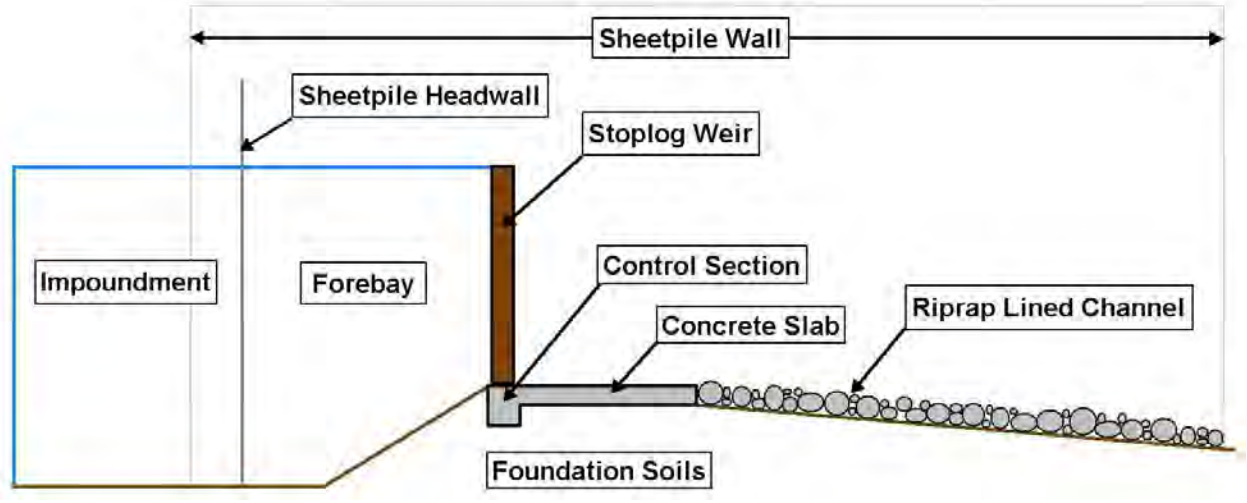


Figure II-1. Profile view of TDS construction

Figure II-2. Photo of the dam during TDS construction
Photo courtesy of AMEC

During construction of the TDS, a steel sheetpile headwall was installed at the inlet to prevent flow into the structure. Embankment material was then excavated from between the TDS walls, and construction of the control structure and downstream channel was completed in early October. Testing of the structure and continuation of the drawdown was scheduled to begin on Saturday, October 6, 2012. A photographic diagram of the completed TDS structure is shown in Figure II-3 below.

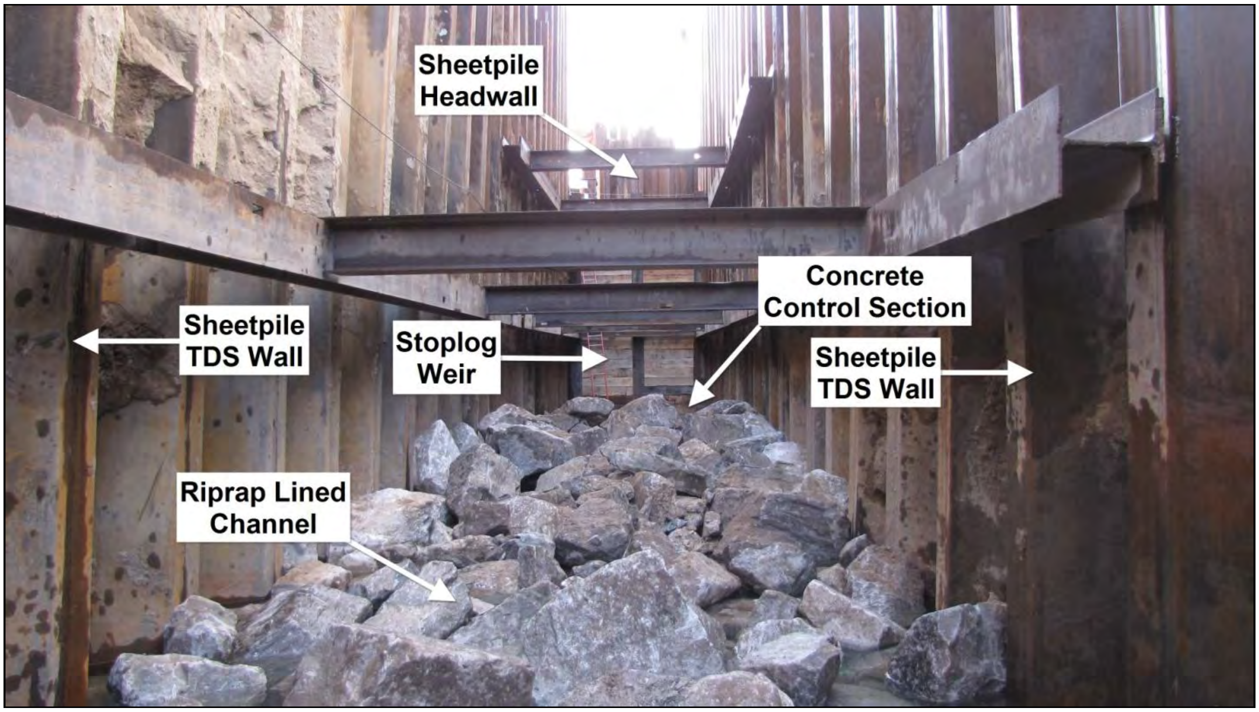


Figure II-3. Diagram of TDS structure viewed from downstream
Photo courtesy of AMEC

At approximately 10:00 AM on October 6, 2012, a single steel sheet was removed from the TDS headwall to allow water to flood the forebay for testing of the stoplog weir and concrete control section. As the water level in the forebay equalized with the impoundment level minimal flow over the stoplog weir, leakage between the timber stoplogs was observed, as shown in Figure II-4 below.

Figure II-4. Photo of TDS stoplog weir at first testing
Photo courtesy of AMEC

Approximately 10 minutes after the first headwall sheet was removed, water was observed to be boiling up from the TDS channel immediately downstream of the concrete control section slab, adjacent to the southern TDS wall, as shown in Figure II-5 below.

Figure II-5. Photo of TDS channel at initial boil formation (arrow indicates boil location) *Courtesy of AMEC*

Flow from the boil increased rapidly, causing scouring of foundation soils from underneath the TDS control section, turbulent flow through the downstream TDS channel, and a rapid rise in the tailwater elevation below the TDS outlet, as shown in Figure II-6 below.

Figure II-6. Photo of TDS channel with turbulent flow from boil
Photo courtesy of AMEC

The uncontrolled release of water from the TDS caused significant scouring and erosion of the upstream earthen embankments adjacent to the TDS structure. The rapid loss of embankment soils in these areas resulted in complete failure of the embankment section located between the TDS and Brown Bridge Dam spillway structures. The rapid release of impoundment waters through the TDS and failed embankment section ultimately resulted in draining of the Brown Bridge Pond in approximately 6 hours, causing a flood wave to travel downstream.

Figure II-7. Photo of the dam and TDS after complete failure
Photo courtesy of John Russell, Great Lakes Imaging

Additional information on the failure event and MDEQ notes from the interviews with personnel onsite during the incident is located in Appendix A.

Figure II-8. Photo of downstream flooding
Photo courtesy of John Russell, Great Lakes Imaging

III. Failure Modes Considered

Upon considering the verbal accounts of project personnel onsite at the time of the TDS failure, reviewing photographs of the incident, and conducting onsite investigations and exploratory excavations; it became apparent that the failure of the TDS was caused by internal erosion (piping) of earthen embankment material in the vicinity of the TDS, causing undermining of the structure and breaching of the embankment section between the TDS and former spillway structure. Piping occurs when seepage waters begin to transport soil particles from the dam embankment, in this case the TDS foundation.

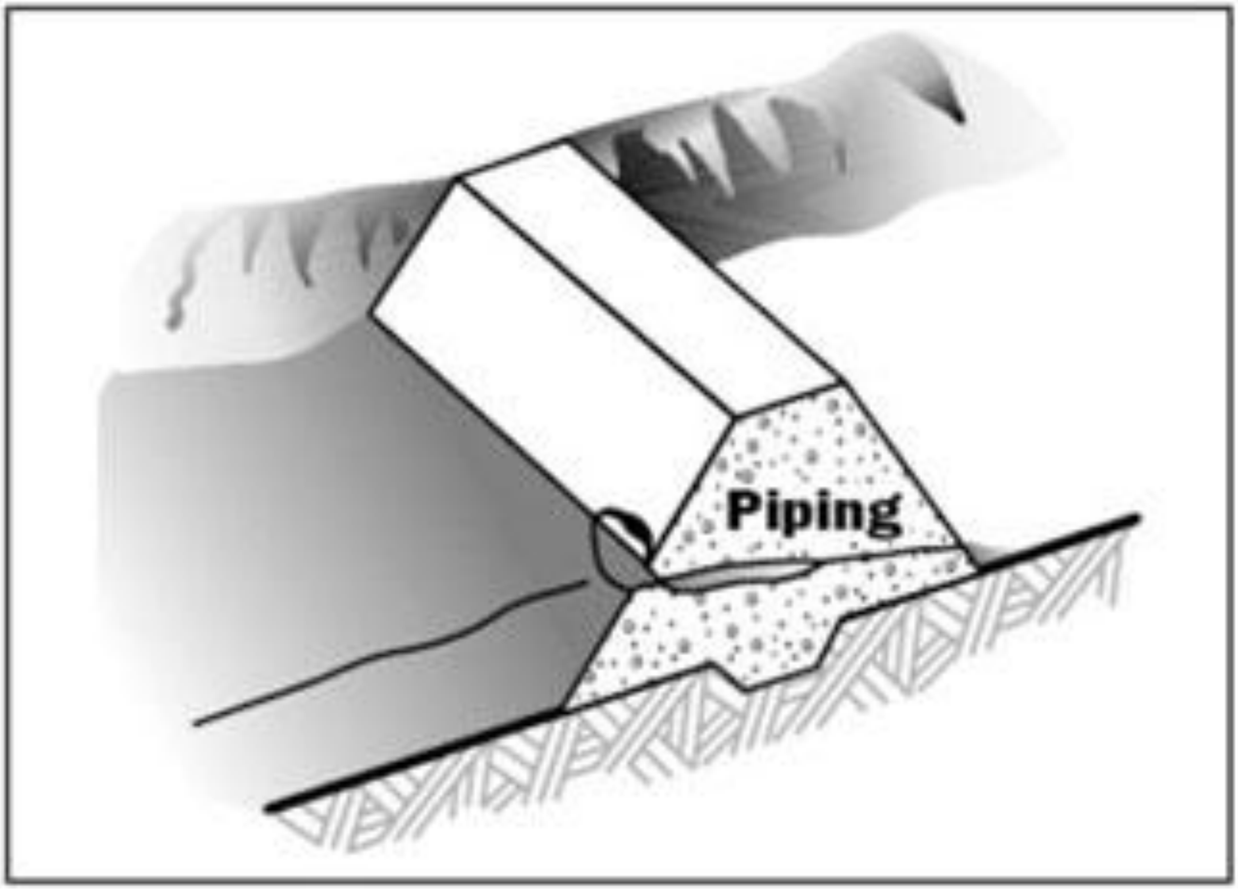


Figure III-1. Diagram of a pipe forming in an embankment dam
Source: Dam Safety: An Owner's Guidance Manual

If uncorrected, piping of embankment materials can progress to the point where an open conduit forms through the embankment soils. At this time, flow is unrestricted through the embankment, causing severe erosion and eventual collapse of the embankment. The analyses contained in this report were designed to determine the root cause of this piping and predict the development of the failure as it progressed.

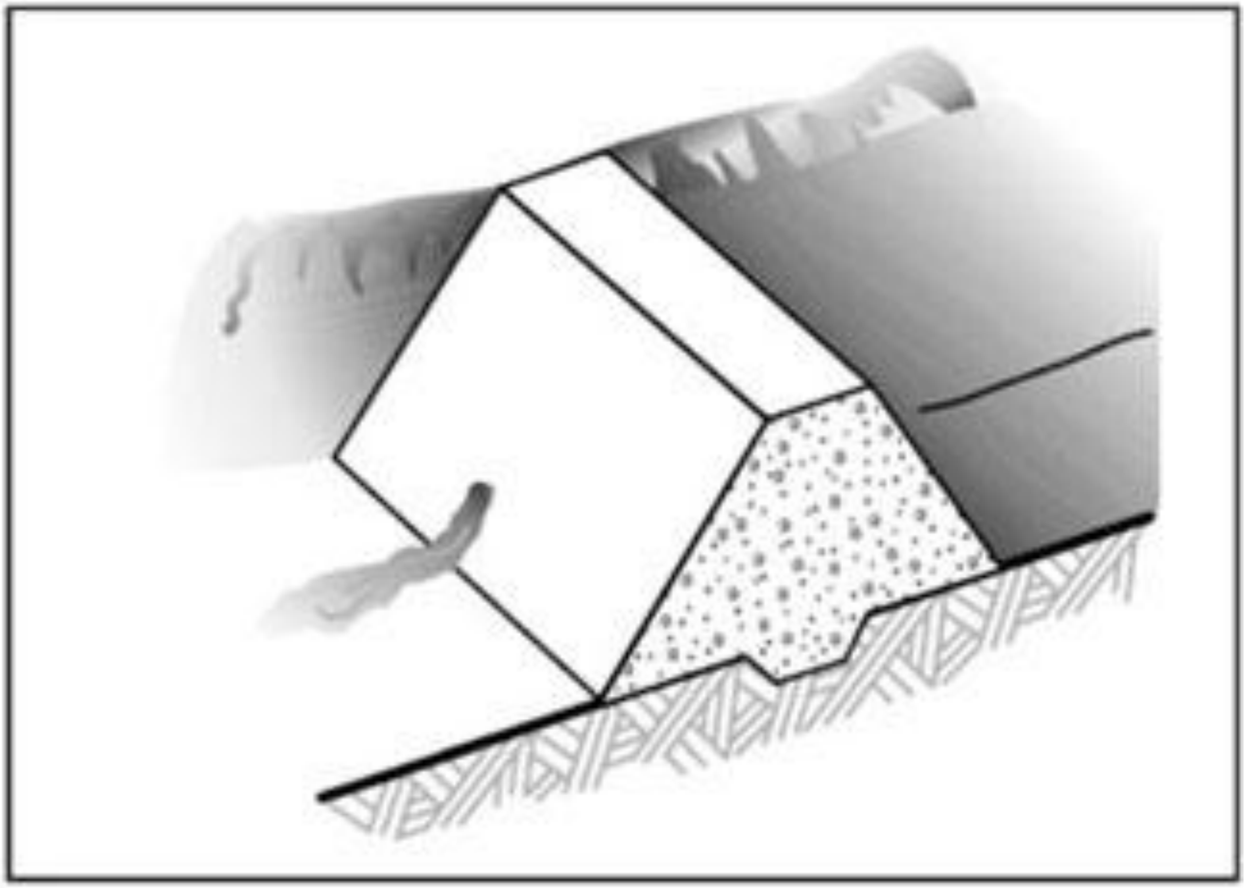


Figure III-2. Diagram of a pipe after formation, unrestricted flow
Source: Dam Safety: An Owner's Guidance Manual

Three possible primary failure modes were considered as part of this analysis. The first failure mode considered was that a pipe formed in the embankment/foundation material directly underneath the TDS control section, eventually leading to the uncontrolled release of water and sediments through the TDS, breaching of the left adjacent embankment section, and total failure of the dam. A diagram of piping through the foundation of a dam is shown in Figure IV.3 below.

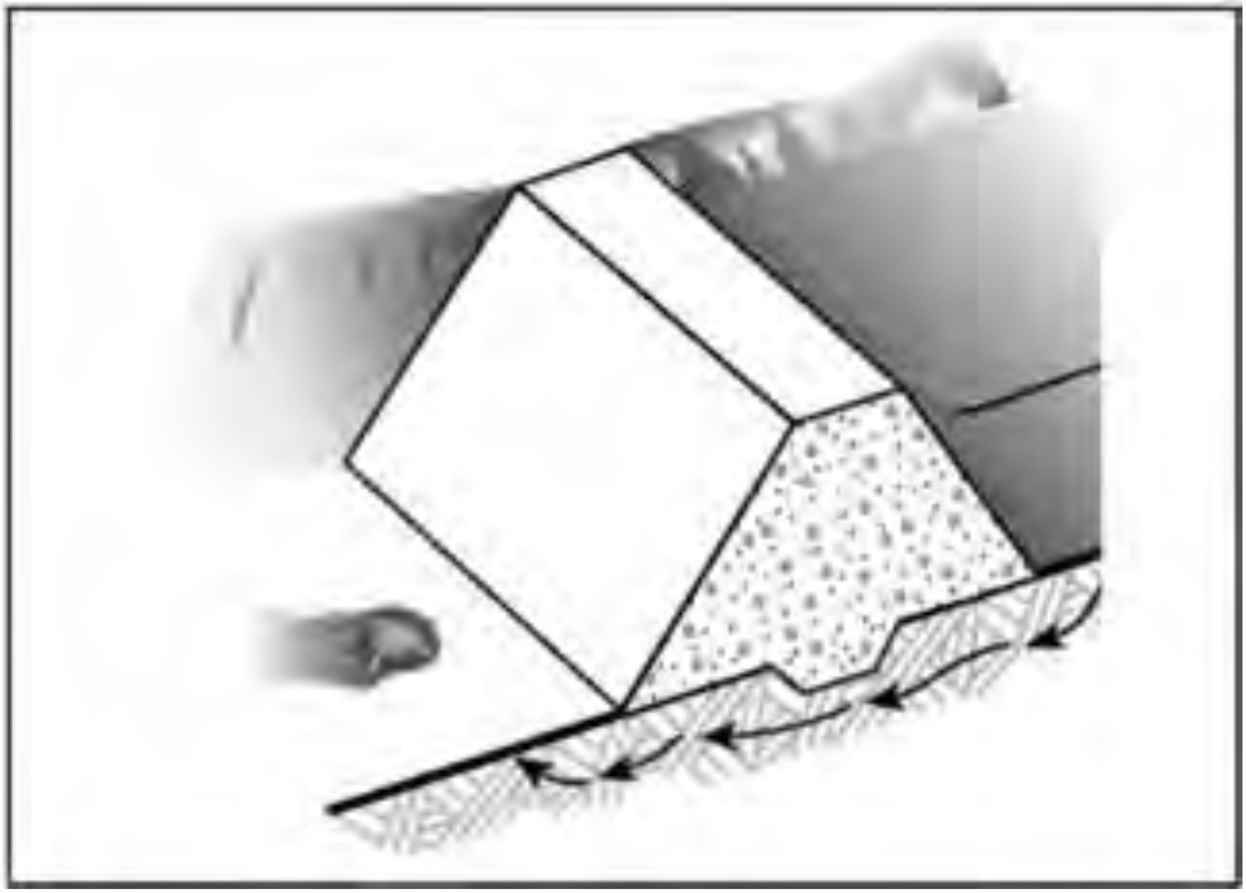


Figure III-3. Diagram of a foundation piping and sand boil formation
Source: Dam Safety: An Owner's Guidance Manual

The second failure mode considered was that a pipe formed along the left wall of the TDS, outside of the structure, which eventually undermined the left TDS wall and resulted in the uncontrolled release of water and sediments through the TDS, breaching of the left adjacent embankment, and total failure of the dam.

The third possible failure mode considered was that a pipe formed along a historical sheetpile wall that possibly remained in the embankment/foundation since the dam's construction in 1921, causing the uncontrolled release of water and sediments through the TDS, breaching of the left adjacent embankment, and total failure of the dam. Remnant sheetpiling was discovered during the construction of the downstream TDS channel adjacent to the left wall. Another section of remnant sheetpiling was discovered adjacent to the left TDS wall, near the inlet, following the failure incident. Given the locations and alignment of these remnant sheetpile sections; it was conceivable that a continuous sheetpile wall was present throughout the TDS channel foundation and had provided a pathway for a piping failure. However, exploratory excavation conducted the week of December 3, 2012, revealed that the sheetpile wall was not continuous and was only present in the two (2) locations mentioned above. For this reason, a piping failure that propagated along a sheetpile wall in the TDS foundation was eliminated from further consideration.

IV. Summary of Field Data

During the post-failure investigations, a total of 11 soil borings were completed. These samples were retained in their entirety and sent to the AECOM soils laboratory in Vernon Hills, Illinois for analysis. Samples were analyzed using the following parameters:

- Visual Classification (ASTM D2488)
- Moisture Content (ASTM D2216)
- Sieve Analysis (ASTM D422 and ASTM D6913)
- Combined Sieve-Hydrometer Analysis (ASTM D422)
- Double Hydrometer Analysis (ASTM D4221)
- Atterberg Limits Test (ASTM D4318)
- Pinhole Dispersion Test (ASTM D4647)
- Pocket Erodometer Test (No ASTM standard)

The intent of these analyses was to characterize the soils located underneath the TDS structure and in the adjacent, undisturbed embankment areas. The TDS foundation soils had been scoured out to depths of approximately 9 to 12 feet. The soil characterization obtained from the lab analysis was used to estimate and reconstruct the underlying soil conditions prior to the TDS's failure.

The locations of previous and the most recent subsurface geotechnical investigations performed in the vicinity of the TDS are shown in a Figure B-1 of Appendix B. These investigations include borings performed in the 1920s by the Fargo Engineering Company, in 1985 and 1992 by Gosling Czubak Associates, and in December 2012 (after the failure of TDS) by AECOM. Additionally, the Soil Testing Results Report dated June 20, 2013, prepared by AECOM (Appendix C), was used to obtain the soil properties used in the seepage analysis. A summary of the results of the sieve analyses performed on soil samples obtained from the 2012 borings is located in Appendix E. Additionally, the entire investigation process was photo-, video-, hand-, and survey-documented, including the removal of the TDS sheetpile walls. Details of the soils laboratory analysis and survey documentation are located in Appendices C and F through I, respectively.

In general, the subsurface soil condition under the TDS water control structure was determined to consist of approximately 9 to 12 feet of fine to coarse sands with trace silts and gravels. Stiff clay lenses were observed in the vicinity of the TDS structure ranging from less than one (1) foot to approximately two (2) feet in thickness. It is to be noted that one clay lens was observed and documented directly under the TDS control structure concrete slab during construction of the TDS. This lens was not observed in soil borings upstream or downstream of the slab and is therefore assumed to have been localized to the area under the slab. Based on its absence in all of the adjacent soil boring locations; it is also believed that this clay lens did not extend to the deeper foundational clay layer located 9 to 12 feet below the slab.

V. Analyses

A seepage analysis was performed for the TDS using the Geo-Slope International Ltd., SEEP/W – Groundwater Seepage Analysis software package. The purpose of the analysis was to evaluate the stability and resistance to piping failure of the soil foundation located under the concrete slab of the structure's water control section.

The first step in setting up the seepage analysis was to characterize the soils that had been underneath the TDS control section prior to the structure's failure. Interpolation of the boring results was used to characterize the soil make-up and properties in this area. An estimate of hydraulic conductivity, or the ability of the soil to pass the flow of liquid through its pore spaces, was needed to perform the analysis. To estimate coefficients of permeability (k), or maximum unit volume of flow per unit area, for these foundational soils, a relationship between the soil grain sizes and permeability needed to be established. A plot of k versus grain size, obtained from the Naval Facilities Engineering Command (NAVFAC) Design Manual 7.1 – Soil Mechanics, is provided in Appendix E. This table, in particular Hazen Formula (1911), was used to relate k values for the granular foundation soils to the grain size distributions contained in the AECOM lab report. The estimated k values for the foundation soils ranged from approximately 0.003 ft/sec to 0.03 ft/sec. A summary spreadsheet of the estimated k values for each of the granular soil samples is also located in Appendix E.

Based on the borings performed in the vicinity of the TDS, the general subsurface condition consisted of fine to coarse sand with trace silt and gravel, followed by a layer of very stiff, silty clay. It should be noted that AMEC informed the MDEQ that a stiff clay lens was encountered in the area directly below the concrete slab of the TDS control section during construction. However, this lens was not present in any of the adjacent soil borings and its thickness could not be determined. Therefore, it is believed that the lens was localized to the area under the control section and deemed not significant for the purposes of this seepage analysis. For the analysis, the sandy fill under the TDS control section was considered to be homogeneous, saturated, and isotropic. Coefficient of permeability values of k = 0.003 ft/sec (0.015 cm/sec) and k = 0.03 feet/sec (0.15 cm/sec) were analyzed. The underlying clay layer was assumed to be impervious.

The configuration and dimensions of the TDS used in the analysis were obtained from a survey drawing titled, "Soil Borings and Sheet Pile Elevations," prepared by GFA on August 16, 2013 (Appendix G), and project design plans submitted with MDEQ Permit Application No. 11-28-0011-P.

The SEEP/W model was used to determine the hydraulic exit gradient (i_{exit}) at the end of the concrete slab, or the head differential upstream to downstream over the length of the seepage path. Hydraulic exit gradient (i_{exit}) is defined in the following equation:

$$i_{exit} = \frac{dh}{dl} = \frac{head\ in\ the\ pond - head\ downstream\ of\ the\ slab}{seepage\ path\ length\ under\ the\ slab}$$

Where:

$$i_{exit} = \ hydraulic\ exit\ gradient\ (dimensionless)$$
$$dh\ = \ head\ differential\ (ft)$$
$$dl\ = \ seepage\ path\ length\ (ft)$$

Based on the analysis, i_{exit} was estimated to be approximately 1.50 at the end of the concrete slab, as shown in Figure VI-1 below. It should be noted that hydraulic exit gradient is independent of hydraulic conductivity when the soil is homogenous and isotropic.

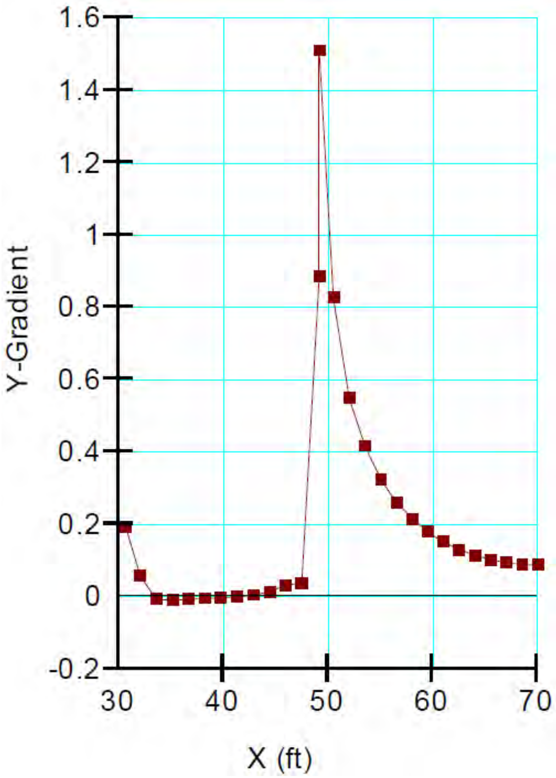


Figure VI-1. Plot of i_{exit} versus downstream distance

Also shown below in Figure VI-2, is a flow net developed by the SEEP/W model showing the potential flow paths for seepage under the structure. The k = 0.03 ft/sec condition is shown in Figure VI-2. It should be noted that the model predicts high seepage velocities at the terminal end of the concrete slab in both cases. This is consistent with the location of the initial boil that developed during the TDS failure.

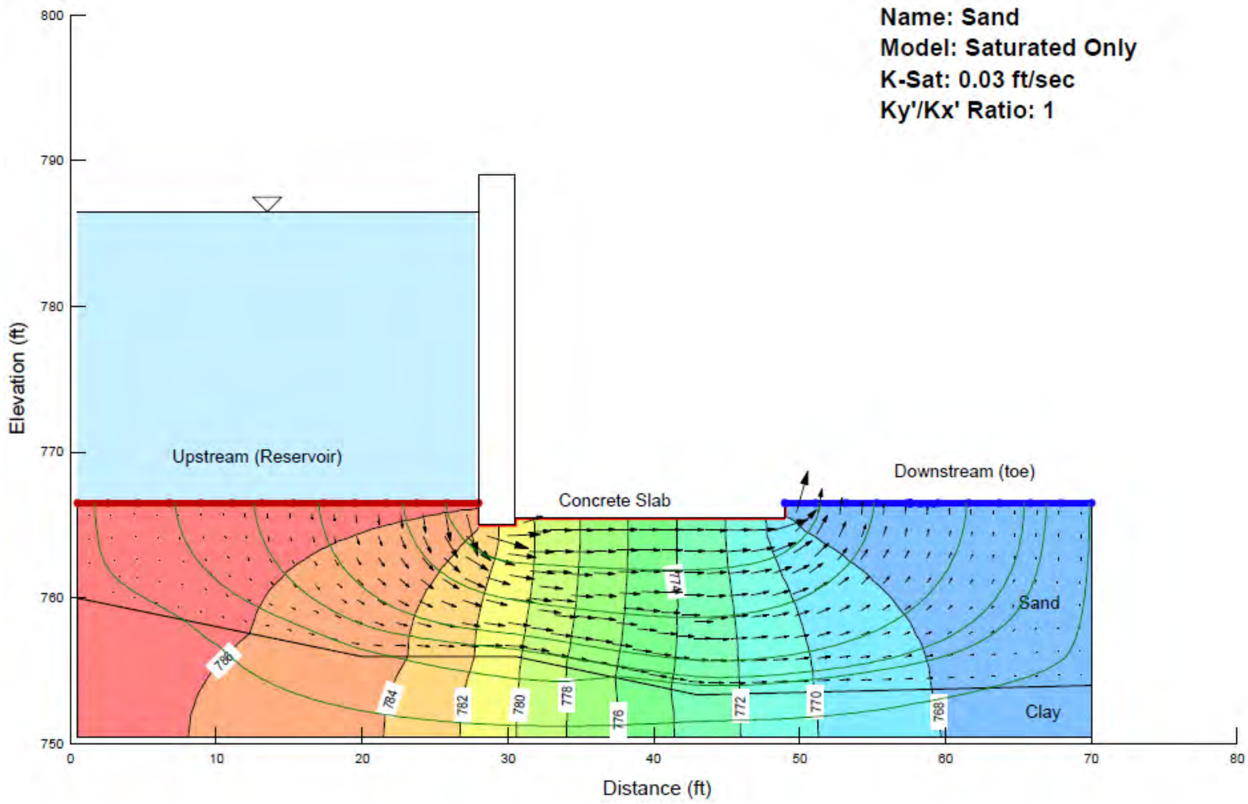


Figure VI-2. SEEP/W flow net for k = 0.03 ft/sec

When a cohesionless soil is subjected to a water condition that results in zero effective stress, the strength of the soil becomes zero, and a "quick" condition forms. At this point, the soil can bear no weight. The hydraulic gradient at which a "quick" condition forms is referred to as the critical hydraulic gradient (i_{cr}). Critical hydraulic gradient (i_{cr}) is defined in the following equation:

$$i_{cr} = \frac{G_S - 1}{1 + e} = \frac{\gamma_b}{\gamma_w} \cong 1$$

Where:

$i_{cr} = the\ critical\ hydraulic\ gradient$
$G_S = specific\ gravity\ of\ the\ soil$
$e = void\ ratio\ of\ the\ soil$
$\gamma_b = buoyant\ density\ of\ the\ soil$
$\gamma_w = density\ of\ water$

It should also be noted that as hydraulic gradient approaches the critical value, soils become much looser and the coefficient of permeability (K) increases; thus increasing seepage velocities and the susceptibility of the soil to piping.

Critical hydraulic gradient occurs when the hydraulic exit gradient approaches a value of 1.0, much less than the value of 1.5 predicted by the model. This indicates that the hydraulic loading of the TDS foundation soils very likely resulted in a “quick” condition as described above. Additionally, a factor of safety (FS) against piping for the TDS soil foundation can be computed using the following equation:

$$FS = \frac{i_{cr}}{i_{exit}}$$

The FS calculated from the above estimated critical and exit gradients for the TDS foundation is 0.67. Generally, an FS of 3 to 4 is required for the safe performance of a structure; thus indicating an inadequate FS for the TDS structure to perform safely.

The formation of a sand boil downstream of the TDS control structure was reported by personnel during the development of the TDS failure. A sand boil is a phenomenon that occurs when the upward flow of seepage water is strong enough to carry soil particles. A diagram of a typical sand boil in an earthen dam is shown in Figure III-3 above. Seepage under the TDS control structure and formation of a sand boil downstream of the concrete slab would have developed much like what is shown in the diagram.

VI. Probable Failure Mode

The most likely cause of failure was internal erosion (piping) of the TDS foundation soils causing an open conduit (pipe) to form directly underneath of the TDS control section. This pipe allowed the uncontrolled release of water and sediments through the TDS, which eventually led to breaching of the left adjacent embankment section and total dam failure.

As scouring of the material under the TDS control section progressed, it is likely that adjacent soil material was lost through an opening that formed underneath one of the steel sheets in the south wall of the TDS structure (See Figure B-3 in Appendix B). Water and sediments flowing underneath the TDS structure could have then scoured the adjacent embankment materials, accounting for the formation of a sinkhole in the area between the TDS and the spillway structure. Loss of embankment material through the sinkhole, combined with the erosion that was occurring along the upstream face of the embankment, eventually led to breaching of the embankment in this area and total failure of the dam.

The second failure mode considered: piping along the left wall of the TDS, outside of the structure, eventually undermining the left TDS wall and resulting in the uncontrolled release of water and sediments through the TDS, breaching of the left adjacent embankment, and total failure of the dam, was determined to be unlikely given the timing and the reported progression of the failure. The embankment between the TDS and spillway structure had been subject to hydraulic loading greater than or equal to that experienced on October 6th throughout construction without an issue. When the first sheet of the TDS headwall was removed, a boil formed downstream of the concrete slab within minutes. The sinkhole in the embankment between the TDS and spillway structure was not detected for some time following this initial boil. Additionally, the toe of the highest TDS sheet was approximately 9 feet below the base of the concrete slab, making the likelihood of piping from outside the TDS underneath this sheet very low. Therefore, it is much more likely that the piping failure developed in the foundation material directly underneath the TDS water control structure and spread to the adjacent embankment as material was scoured from beneath the concrete control section.

VII. Conclusions

On the morning of October 6, 2012, at the first loading of the TDS water control structure, a boil was noticed downstream of the concrete slab lining the bottom of the channel. Flow from the boil increased quickly, scouring foundation soils from the area below the slab. When enough foundation soils had been scoured away, unrestricted flow water from the impoundment passed underneath the TDS control section. As the failure progressed, upstream erosion and scouring of soils through an opening under one of the TDS sheetpiles ultimately caused the collapse and failure of the earthen embankment section located between the TDS and the Brown Bridge Dam spillway structure.

Despite efforts of workers onsite to stem the outflow through the TDS and failed embankment section, the dam completely failed, releasing the entire contents of the impoundment.

A series of post-failure investigations and subsequent geotechnical analyses indicate the most likely failure mode of the TDS structure was piping of the foundation material from underneath the water control structure within the TDS. The hydraulic loading the control section was subjected to on October 6, 2012, resulted in an unstable subsurface soil condition, which led to the formation of a sand boil downstream of the concrete slab, piping of foundation soils, uncontrolled release of water underneath the control structure, collapse of the earthen embankment adjacent to the south TDS wall, and ultimately the uncontrolled release of water from the Brown Bridge Pond.

References

1. STS/AECOM, “Safety Inspection of Brown Bridge Dam”, September 18, 2008.

2. Gannett Flemming, “Supporting Technical Information Document, Brown Bridge Hydroelectric Project, FERC Project No. 2978”, December 2005.

3. The Boardman River Dams Implementation Team, “Brown Bridge Dam Removal October 6 Incident, Project Team Summary”, November 2012.

4. The Boardman River Dams Implementation Team, “Brown Bridge Dam Status Update”, November 7, 2012.

5. Association of State Dam Safety Officials – Dam Failure Investigation Committee, “Dam Failure Investigation Guideline”, December 8, 2011.

6. The City of Traverse City, “Response to Violation Notice, Brown Bridge Dam Removal and Restoration Project, Order to Restore”, December 20, 2012.

7. Geo-Slope International Ltd., “SEEP/W – Groundwater Seepage Analysis”, 2012.

8. Fargo Engineering Company, “Plans for Browns Bridge Hydro-Electric Plant on the Boardman River for the City of Traverse City Michigan”, September 21, 1922.

9. Mead and Hunt Inc., “Plan for Evaluating the Liquefaction Potential of the Brown Bridge Hydro Dam Embankment and Foundation”, April 19, 1985.

10. Gosling Czubak Associates, “Soil Investigation – Brown Bridge Pond”, May 7, 1985.

11. Gosling Czubak Associates, “Soil Borings – Brown Bridge Dam”, November 11, 1992.

12. Gannett Fleming Engineers and Planners, “TCLP – Brown Bridge Spillway; Grand Traverse County, MI – Test Pit Logs”, February 6, 2003.

13. Kaniraj, Shenbaga R., “Design Aids in Soil Mechanics and Foundation Engineering”, Tata McGraw-Hill Publishing Company Limited, 1988.

14. FEMA, “Dam Safety: An Owner’s Guidance Manual”, December 1986.

Acknowledgements

The MDEQ would like to acknowledge the following people/agencies for their contributions in the preparation of this report:

- James T. Pawloski, P.E., MDEQ – for technical assistance during the failure incident, for his assistance and documentation of the post-failure investigations, and for compiling many of the resources and data used in the report.

- M. Golam Kabir, Ph.D., P.E., Federal Energy Regulatory Commission – for his assistance during the post-failure investigations and assistance with the seepage analysis for the TDS structure.

- Spicer Group, Incorporated – for providing AutoCAD services for the preparation of details and figures related to the geotechnical exploration and seepage analysis.

- John Russell, Great Lakes Images – for providing ground and aerial photos during and after the failure event.

List of Appendices

Appendix A – Post-Failure Field Interviews

The following are summaries of verbal interviews conducted by MDEQ staff of project personnel who were onsite during the October 6, 2012, failure of the TDS constructed as part of the Brown Bridge Dam removal project in Grand Traverse County, Michigan. Most interviews took place on Monday, October 8, 2012, at the project site.

Interview with Clayton Buntion, Project Superintendent, AMEC
October 8, 2012, 10:30am
Interviewer: Lucas Trumble, MDEQ

(Times are approximate)
6:30am – Clayton arrives on site.

7:00am – Clayton attends Health and Safety meeting.

8:00am – Clayton take water levels readings upstream and downstream of the dam.

8:30am – Clayton inspect interior of TDS with Joe Caryl. Both ask Molon to add riprap to fill voids.

9:45am – (Molon excavated material from upstream of the headwall on Thursday, October 4, 2012.) Molon begins slowly pulling one of the center sheets of the headwall. Water equalizes against the logs. Everything holding steady. Process takes 15 to 20 minutes.

10:00am – Molon removes center sheet completely. Ten to 15 minutes pass without incident. Hears a loud “pop” sound inside the structure. Stoplogs remain in place, but flow increases through the TDS. Heard someone yell that the water was coming up on the downstream side of the stoplogs. Water appears to be boiling from southwest corner, just downstream of the concrete slab. Flow increases quickly starts to get out of hand.

10:15am – Joe Caryl and Ken Gregory activate the EAP by calling Emergency Response. Molon starts placing sand from the north side of the TDS, upstream of the stoplog structure, in an attempt to plug the “hole”. Cannot determine the exact location of void. Placing material is not stopping the flow. The removed sheet cannot be reinstalled. Molon begins moving tools away from the TDS and bringing more material in to place into the hole upstream of the stoplogs. Molon brings in a “long reach” excavator to place material from the south side of the TDS.

10:45am – Emergency responders arrive on site. At this point, it is believed that they can get the situation under control. Decision is made to start voluntary evacuations downstream.

11:00am – Joe Caryl places a call to AMEC engineers for advice. Decision is made to bring in “mass” materials in an attempt to plug the breach. Materials are to include concrete, rocks, trees, etc.

11:45am – Clayton is advised that Jim Pawloski, MDEQ, would like a phone call from him to bring him up to speed. Clayton briefs Jim on the situation.

12:00pm – Trucks begin to arrive, bringing “mass” materials. Local contractors also begin sending operators to help out. Off-road dump trucks are supplying both excavators with material brought in by local haulers. Consensus is that Molon will not be able to get the situation under control. Word is sent to Emergency Management to begin mandatory evacuations per the EAP. Molon continues to place material to slow the breach until 4:00pm or 5:00pm. After the breach of the embankment between the dam and TDS, the focus shifts to constructing a control device upstream of the TDS to slow embankment erosion.

5:00pm – Impoundment is completely drained. Flows downstream return to normal.

5:20pm – Clayton takes a tailwater reading. Flows close to normal just downstream of the dam. Everyone takes a step back and slows down. Crowd has gathered to see what’s going on. It has been a struggle to keep people back and the site safe. This was Clayton’s main concern.

Interview with Ben Bifoss, City Manager, City of Traverse City
October 8, 2012, 11:50am
Interviewer: Lucas Trumble, MDEQ

(Times are approximate)
11:15 to 11:30am – Ben arrives onsite. Lots of spectators have gathered. Instructs Pat Parker to close roads and to get people out of the dangerous areas. Molon is placing onsite materials upstream of the TDS and has called for more material to be delivered. Ben stands away from the TDS near the canoe launch. As offsite materials begin to arrive, it appears that the south side of the TDS is under control, but there is major erosion occurring at the north side of the TDS.

2:00pm – Ben and Emergency Managers determine that the north side will likely fail and make the call to begin mandatory evacuations.

2:30pm – Ben needs to be at a press conference to give an update of the situation developing. Has to travel around the east side of Brown Bridge Pond due to bridge closures. Arrives at the Nature Center to speak at the press conference.

3:30pm – Ben arrives onsite for a second time. “Mass” material from offsite is being placed upstream of the TDS from both the north and south sides. Molon appears to be making progress against the erosion that is occurring.

4:00pm – Mandatory evacuations are cancelled. Only 6 feet to 8 feet of head remain at the dam. Tailwater elevations have receded by 3 feet.

5:30pm – Ben attends another press conference onsite.

6:00pm – Ben leaves site.

Interview with Joe Caryl, Senior Construction Manager, AMEC
October 8, 2012, 12:05pm
Interviewer: Lucas Trumble, MDEQ

(Times are approximate)
6:30am – Joe arrives onsite. Attends a Health and Safety meeting until 7:45am. Makes some adjustments to the stoplog puller.

8:00am – Workers begin warming up the equipment. The plan is to remove the headwall of the TDS to test the stoplog structure. Then logs are to be removed to continue the drawdown.

9:00am to 9:30am – Molon starts pulling sheets. Tries a few sheets, but some are stuck. Tries pulling for 5 to 10 minutes and then switches to another sheet. Settle on one of the center sheets.

9:45am – Molon starts to remove one of the center sheets. Sheets are approximately 25 inches wide. Sheet breaks free, allowing water to enter the forebay. Sheet is not removed completely. Molon stopped pulling the sheet as soon as the seal was broken and water entered the forebay. Water level is allowed to equalize. Water level in the forebay rises to the level of the stoplogs, starts to lower, and then stabilizes at the top of the stoplogs.

10:00am – After 5 to 10 minutes of water stabilizing, the center sheet is completely removed. No flow is observed through the TDS, minus what is spilling over and leaking through the stoplogs.

10:10am to 10:15am – Joe hears some sort of “popping” noise. Runs to end of TDS. Water is boiling up at the southwest corner, just downstream of the concrete slab. Estimates 400 to 500 cfs of sandy/dirty flow coming up from under slab. Flow is lifting and tumbling 32-inch diameter riprap. A scour hole begins to form downstream of the slab. Flow is increasing.

10:15am to 10:20am – Ken Gregory calls 911. Alerts emergency responders that there is an issue with the TDS and an uncontrolled release to the Boardman River. Indicates a potential for flooding.

10:30am – Molon places sand upstream of TDS from the north side. North wall of the TDS near the inlet begins to move as result of scour. North embankment begins to erode. Molon begins moving equipment and tools back as embankment erodes.

10:45am to 11:00am – Joe calls Lyle Tracy, AMEC. Decision is made to place “mass” material upstream of TDS in an attempt to stop the breach.

11:00am – Emergency responders arrive onsite. Joe asks them to close roads so trucks can access the site.

11:15am – Sirens sound, voluntary evacuations begin.

11:45am – Molon continues to place embankment materials along the northeast corner of the TDS.

12:00pm – Mandatory evacuations begin due to a fear of a complete breach at the north embankment. Material is eroding from downstream of the cutoff wall between the TDS and dam structure (south of TDS).

12:30pm – All material is eroded from downstream of the cutoff wall and the wall fails. Releases impoundment waters between the TDS and dam structure. Water levels down 4 to 5 feet at this point. Tailwater levels rise 1 to 2 feet following failure of the cutoff wall.

12:30pm to 12:45pm – Molon brings a “long reach” excavator to the south side of the TDS to begin placing “mass” material, mostly concrete. Material is placed downstream of the failed cutoff wall and along the north side of the TDS to mitigate erosion. Erosion slows at north of the TDS and material placement catches up with erosion.

2:00pm to 3:00pm – Water level at Brown Bridge Road 4 inches from the top of the culvert.

3:30pm – Pond level is down approximately 12 feet. Outflows begin to recede.

4:00pm – Pond is completely drained and mandatory evacuations are lifted. Water levels at the Garfield Road bridge reach the bottom chord of the structure.

4:00pm to 4:30pm – Erosion at the north side of the TDS is mitigated, so Molon begins placing in structure.

5:00pm – Water levels are approximately equal upstream and downstream of the TDS. Molon constructs check dam upstream of TDS from concrete to control flows and erosion. Tailwater has receded approximately 2 feet. Work continues on check dam until dark. At this time, it is believed that approximately 15 to 20 structures downstream have been flooded.

Interview with Chris Kelly, Equipment Operator, Molon
October 8, 2012, 12:55pm
Interviewer: Lucas Trumble, MDEQ

(Times are approximate)
7:00am – Chris arrives onsite. Attends a Health and Safety and work plan meeting.

8:00am – Chris begins moving equipment and makes some adjustments the stoplog puller.

9:00am – Molon hooks vibratory hammer up to headwall sheets and begins to try to pull the sheets. They try 3 sheets that do not move. They try a center sheet, and after about 10 to 15 minutes of pulling, it starts to move. They pull that sheet until water and soil enter the forebay, then stop. Water equalizes and starts flowing over the stoplogs.

9:30am – Molon removes the center sheet completely. Water is flowing over the TDS stoplogs and through the dam structure. Water in the forebay rises above pond level and then equalizes, with just a trickle flowing over the stoplogs. Chris brings the loader over to accept the sheet that was pulled. While in the machine, everyone starts running toward the TDS. Chris places the pulled sheet out of the way and exits the machine to see what's going on. Process takes 10 to 15 minutes.

9:45am – Chris walks to the catwalk over the TDS and stands at the edge. No water is flowing over the stoplogs. Water is coming up approximately 20 to 30 feet downstream of the stoplogs near the end of the concrete slab in the riprap channel. Water is brown and boiling.

10:00am – Chris gets in the excavator to move equipment and tools back from the TDS. Northern embankment is eroding. Chris starts to place sand material from the embankment along the north wall of the TDS, near the stoplog structure, in an attempt to plug the hole. He doesn't appear to be making any progress. Mike Walton brings another excavator to help place material. Both place sand along the northern TDS wall downstream of the stoplog structure for approximately ½ hour.

11:00am – Chris moves equipment and tools back again as the embankment continues to erode. Concrete and "mass" material begins to arrive onsite. Chris Holton moves the crane back out of the way. Mike Walton continues to place material along the TDS. At this point, it appears that Mike is maintaining the erosion, but not making forward progress.

11:30am – Chris gets into an off-road dump truck to bring rock and concrete material to Mike Walton in the excavator. Chris exits the dump truck and gets into the loader to load off-road trucks at Brown Bridge Road. Chris continues to load off-road trucks with "mass" material until 5:00pm.

5:00pm – Chris returns to the project site to load sandbags until dark.

Interview with Chris Holton, Crane Operator, Molon
October 8, 2012, 1:20pm
Interviewer: Lucas Trumble, MDEQ

(Times are approximate)
6:45am – Chris arrives onsite. Attends a Health and Safety meeting.

8:00am – Chris begins moving equipment. The plan for the day is to remove the sheetpile headwall and start the drawdown of the impoundment through the TDS. Chris helps make adjustments to the log puller and gets ready to start pulling sheets.

10:00am – Chris starts pulling sheets one at a time very slowly. They settle on one of the center sheets after trying others that don't move. They pull the center sheet until water starts to enter the forebay and stop. They let the water equalize with the sheet partially removed. Ten to 15 minutes pass and they remove the sheet completely. Chris cannot see inside the TDS. Five to 10 minutes pass and Chris runs over to the TDS. Chris sees water boiling up approximately 30 feet downstream of the stoplogs. Chris observes a brown sand boil along the south wall of the TDS.

11:00am – Chris starts moving crane and equipment farther north on the embankment as the embankment erodes. Chris gets into the "long reach" excavator and begins placing sand material from the south side of the TDS between the TDS and dam structure. Chris continues to place sand embankment materials until "mass" materials arrive onsite. Chris then places concrete pieces downstream of the cutoff wall. At first it looks like Chris is maintaining the erosion, but then starts to lose ground. After approximately 2 hours of placing material, the cutoff wall fails.

2:00pm – Chris begins to construct a rock and concrete weir between the TDS and dam, downstream of the cutoff wall. Chris doesn't appear to be making any headway. Chris continues to place concrete and rock between the TDS and dam structure until 5:00pm.

5:00pm – Chris starts to construct a concrete check dam upstream of the TDS. By this time, the pond is completely drained and the water levels downstream of the dam have receded.

7:00pm – Chris stops working for the day. Returns home around 7:45pm.

Interview with Greg Needham, Welder/Equipment Operator, Molon
October 8, 2012, 1:40pm
Interviewer: Lucas Trumble, MDEQ

(Times are approximate)
7:00am – Greg arrives onsite. Attends a Health and Safety meeting.

8:00am – Greg begins to move equipment and make adjustments to the stoplog puller. Chris also begins to clean out the TDS structure.

9:30am – Molon hooks up to the first sheet of the headwall and starts to pull. Corner sheets will not move. Molon relocates the crane and hooks onto the center sheet. They pull for 10 to 15 minutes until the tip of the sheet is about 1 foot off the bottom of the impoundment. Water equalizes in the forebay, rises slightly above the stoplogs, and then equalizes again.

10:30am – Molon removes the center sheet completely and lays it down on the northern embankment. There is talk of removing the top course of stoplogs to begin the drawdown. Greg walks to the catwalk over the TDS with Al McDonald. They see water start to boil up in the structure. Water is coming up approximately 30 to 40 feet downstream of the stoplogs. The water level upstream of the stoplogs drops. Greg can't see where water is coming from. For 10 to 20 minutes after pulling the first sheet, everything seemed fine. Erosion is occurring near the head wall and the upstream sheets of the TDS start to move.

11:00am – Molon places a crane mat upstream of the headwall in an attempt to block flow. The pulled sheet could not be replaced, as the headwall sheets had moved. Erosion is occurring along the north embankment. Greg begins to move equipment and tools out of the path of erosion. Chris Holton moves the crane to the north. Greg gives Chris Holton a ride around to the north side of the dam to get the "long reach" excavator. Chris Holton attempts to fill where erosion is occurring along the south side of the TDS. Greg gets into the bulldozer to push sand embankment material to Chris Holton in the excavator.

12:00pm – Trucks begin to arrive hauling "mass" material to the site. Greg pushes "mass" material, mostly concrete, to Chris Holton in the excavator until 4:00pm or 5:00pm.

5:00pm – Greg begins working on construction of a check dam upstream of the TDS. Flows recede and become manageable upstream of the TDS.

7:00pm – Molon shuts down for the day.

Interview with Steve Largent, Grand Traverse Conservation District
October 9, 2012, 12:30pm
Interviewer: Lucas Trumble, MDEQ (via telephone)

(Times are approximate)
9:00am – Steve arrives onsite. Molon is preparing to pull sheetpiles from the headwall and completing final placement of riprap in the TDS channel.

10:00am – Molon starts pulling headwall sheets. The outer sheets won't move, so they try a center sheet. Molon runs the vibratory hammer on the center sheet for 10 to 15 minutes, and then it starts to move. When the sheet clears the bottom of the impoundment, water flows into the forebay and equalizes. Steve waits another 10 to 15 minutes and walks to the downstream end of the TDS.

11:00am – Steve notices more water than he would expect coming from the TDS so he takes a picture. Water appears to be bubbling up along the south side of the TDS downstream of the concrete slab. Mike Walton runs down to check the situation. In a matter of moments, the flow begins to increase and starts to move the boulders in the channel. John Russell and Bob Hoxey are with Steve. Steve brings John and Bob around to his vehicle for safety. The flow through the TDS appears to be boiling up in line with the pulled headwall sheet. Steve takes John and Bob from the north side of the TDS to inform the downstream homeowners of the situation. Steve drops John and Bob off and heads out to continue informing homeowners. Steve meets with Frank Dituri and Ken Gregory. Ken Gregory calls the Emergency Manager, Dan Scott, from Steve's phone. Frank stays at Garfield Road to monitor the crossing. Emergency Management advises to begin closing roads downstream of the dam.

12:00 – Steve returns to Brown Bridge Road to move people who had gathered out of harm's way. Steve stays at Brown Bridge Road crossing to monitor for debris. They removed 1 tree from the culvert using a loader. Steve runs home to grab his rain gear as it has started raining. When he returns, Steve notices that the water level at Brown Bridge Road had risen from 3 feet to approximately 5 to 6 feet on the gage. About the time the cutoff wall broke between the TDS and the dam structure, a surge of water travels downstream and almost overtops Brown Bridge Road. Steve goes to meet with the Grand Traverse County Road Commission at the River Road crossing to monitor for debris there. Steve advises the Road Commission to have equipment available to remove debris at River Road and the railroad crossing as needed. Steve finishes the day out monitoring road crossings downstream of the dam.

4:30pm – Evacuation order and road closings are cancelled.

5:00pm to 6:00pm – Water levels downstream of the dam have receded. Steve returns to job trailer onsite. For the rest of the evening, Steve monitors "cresting" of the flood wave as it travels downstream.

9:00pm – Steve returns home. Last communication with the Road Commission and downstream home owners until 11:00am the next morning. At this time, Steve estimates approximately 30 structures have been impacted. With docks, debris, etc., he estimates this number could increase to 50 or so.

Interview with Nate Winkler, Project Manager, Implementation Team (IT)
October 8, 2012
Interviewer: Mario Fusco, MDEQ

Question: Before telling me about of the failure of the TDS, can you tell me something about the construction activities earlier in the week?

Answer: Early in the week the sheet piling was installed, the sheet pile length was 60 feet, at the depth of 30 to 40 feet they found refusal. It got harder to go deeper than they wanted to, so they changed to larger drives to do the job. They changed drives four times. After that, they staged material (Chris Kelly on the Dozer and Mike Walton on the Backhoe), they started pushing material from upstream to downstream direction up to 2 feet of finish grade, total length of about 767 feet. After that the concrete slab was poured in place and the riprap (energy dissipaters) was installed. The work was completed on Friday afternoon, but the decision was made to wait until Saturday to remove the sheet pile to allow the water to go through the TDS.

Question: What time did you arrive at the site on Saturday?

Answer: I arrived at the site at 8:30 a.m.

Question: Can you tell me what you did when you arrived at the site and what activity was going on at the site?

Answer: When I arrived I “gator” to the embankment at the north side of the TDS. They then pulled out the middle sheet pile and the forebay was filled with water, it overtopped the stop logs, then it went down for about 2 to 3 minutes. I then went to the embankment on the downstream end with the other guys. There was some wave action and there was a fluctuation of the water level behind the spillway in the tale race (inside the TDS). I heard boulders rolling inside the structure and the temporary structure was filled with 6 feet of water with waves. I ran to the top (north end) with Steve Largent and saw that Molon’s people were concerned about where the water was coming from. The area on the north side of the TDS started eroding away and become filled with water. They tried to contain the failure by dumping material, first with bulk bags and then with other material available at the site. Mike Walton tried to break the core wall to fill the gap. I talked to Joe Caryl, AMEC Project Manager, and around 9:30 and 9:45 am, I called Jim Pawloski. I then went on taking care of mitigation matters, started making calls. The EAP was put to action and at 9:45 am, Ken Gregory, the onsite city representative, called 911. Soon after other people started showing up, the Sheriff Department, Red Cross, etc. Red Cross also brought food. Meanwhile Molon and Elmers (another excavation company in the area) continue to dump truck after truck of riprap material from their yards. Mike Walton (Molon’s owner) operating the excavator put himself at risk trying to avoid a total failure. About one hour later the excavator started dumping material on the south end (to create a rock weir) to control flow. For about 2 to 3 hours, dump trucks were in and out and 4 people were working on it. AMEC and Molon’s people started contacting flood restoration contractors and a Steve

Largent went knocking door-to-door, warning people of the failure and to put together a list of home owners that had their houses/properties impacted by the failure. Work at the site continued to just before dark, construction of temporary sediment traps and placing rocks (temporary rock weir) upstream to try to control flow. After dark, just monitoring activity took place.

Interview with Frank Dituri, Co-Chair, Implementation Team (IT)
October 8, 2012
Interviewer: Mario Fusco, MDEQ

Question: Before telling me about of the failure of the TDS, can you tell me something about the construction activities earlier in the week?

Answer: They constructed the TDS, they had to use several hammers (vibrating bangers) to be able to drive the sheet piles. The work was completed on Friday midafternoon. At around 6:30 pm, Clayton made the decision to wait until Saturday morning to remove the sheet pile to allow the water to go through the TDS.

Question: What time did you arrive at the site on Saturday?

Answer: I arrived at the site sometime between 7:50 and 8:15 a.m. Mike's crew was at the site and so was Ken Gregory from the City and Nate Wrinkler.

Question: Can you tell me what you did when you arrived at the site and what activity was going on at the site?

Answer: I went to the north side of the structure and they tried to start pulling the piles 2 and 3, just remember one coming loose, the sheet pile number 3. It was down about 15 to 20 feet. Soon water started filling the chamber in front of the stop log and overtopping it, then I heard a big sound of rocks rolling and hitting the sheet pile. Water was filling from the bottom on the south side of the wall (Frank showed me a picture he took with his cell phone), a vortex could be seen on the south side in front of the concrete wall, and there was also erosion going on the north side. I thought something was not right and talked to Ken Gregory from Traverse City to call 911. At that time Molon's people were moving equipment to the north end and I saw a lot of people walking up and down on the north side. I then went downstream to Brown Bridge Road crossing with Steve Largent, then to the Garfield Road crossing to monitor the water flow level. Flow at Garfield Road Bridge seemed to be normal so we returned to the Brow Bridge Road crossing. Met the Sheriff and other people, and I asked them to go to the other crossings downstream and measure/monitor the height of flow. While at the Brown Bridge Road, I heard a cracking noise. It was a piece of dock with a canoe tied to it floating downstream. Water flow level was about 8 inches from the top on the twin culvert at the Brown Bridge Road. After a while I jumped back in the vehicle with Steve Largent and went to monitor the two bridges downstream but nothing had changed, so we returned to the site. I got in a gator with Joe Caryl from AMEC and we drove upstream. I spend about 1 to 1.5 hours monitoring upstream, everything looked normal over there. When I returned, trucks were still dumping broken concrete pieces and rocks between the dam and the south of the pile structure, and also dumping material on the eroded area on the north side and working on the rock weir upstream the dam to try to control the water flow. This work went on until before dark.

Interview with Brett Fessell, Fish Biologist/Coordinator, Grand Traverse Band of Ottawa and Chippewa Indians/Implementation Team (IT)
October 8, 2012
Interviewer: Mario Fusco, MDEQ

Question: Before telling me about of the failure of the TDS, can you tell me something about the construction activities earlier in the week?

Answer: I am a Fish Biologist for the tribe and most of the time I am working upstream where the relic channel is being excavated. About the activities related to the construction of the TDS, I know they were having problems driving down the piles the last ten feet. They have to use different hammers and that they broke some rubber bumpers.

Question: What time did you arrive at the site on Saturday?

Answer: I got a call from Frank Dituri between 11:30 and 11:45 am, and I got here around noon.

Question: Can you tell me what you did when you arrived at the site and what activity was going on at the site?

Answer: When I got here around noon, I saw some workers coming up from the TDS and when I looked down there, the sheet pile that failed in the upstream side of the TDS was folded as it is right now. They were bailing material and trying to slow down the water flow. I just stayed in the south side but from there I saw them dumping material in the channel as well as outside of the channel on both sides of the TDS. After that, I started going down the river doing an assessment of the potential environmental impact of the partial failure with Frank Dituri and others. One thing I noticed was an increase in turbidity in the water to about 12 miles downstream of the Brown Bridge Dam.

Interview with Al MacDonald, Marine Division Estimation, Molon
October 8, 2012, 9:35am
Interviewer: Jim Pawloski, MDEQ

Installation –

- Difficult driving conditions
- Vibratory/hard impact hammers

- Excavated inside cell
- Struts/whalers on way down
- No sheet movement during excavating
- Constructed interior – good process
- Pulled first sheets – tried 3 or 4 different
- No extraordinary vibes
- Little water coming
- See bottom of sheet – some soil
- Sheet up 3 feet above existing grade
- Water came in fast contact
- Removed entire sheet
- Water settled down
- Some stoplog leakage
- Attempted 2
- Noticed turbulence on outside of structure – thought something happened
- Turned around and saw bubbling up violently 30 to 40 feet d/s from stop logs
- Then panic time – major, major problem – contacted Mike W.
- Rode gator to other side lot powerhouse/TDS
- Saw bubbling – 20 feet soil between structures
- Massively bubbling both side at the walls all the way down
- Got underneath concrete slab somehow
- Some failure of sheeting where bubbling first occurred.
- Lots of debris in excavation
- Ran into steel sheeting

Interview with Mike Walton, Superintendent Overall/Earthmoving, Molon
On October 8, 2012, 12:45pm
Inteviewer: Jim Pawloski, MDEQ

- TDS – Al’s driving sheeting
- Mike started w/ excavating of TDS
- Chris Kelley, Foreman, sheeting crew took about double time anticipated because of:
  - Difficult driving conditions
  - One impact hammer anvil broken
  - Rented progressively larger equipment
- Two soil borings in area
- Design slab raised 2:0 – hitting cribbing/old sheeting from 765 to 767
- TW@767.0
- Could isolate powerhouse w/ gabions or other methods
- Powerhouse ultimate bottom 760 with 5.0 foot granular – fill up to 765.0
- Last 10 feet at cell – not sand – pit run gravel – cobble gravel, stones, entire length of cell

- Set a mini excavator and dozer in cell – so difficult - broke cutting edges off excavator and dozer
- Put down 2 layers of filter fabric under concrete slab, heavy non-woven and under riprap sheeting in cell
- Providing concrete GPA – tested in spec on concrete – 3300 psi on 10/05/2012
- Placard on 10/02/2012
- Sheeting cutoff – dry sump to dewater
- Wood timber cribbing @ U/S end of sheeting
- All sorts of construction debris in cell excavation
- Left D/S and sheeting TDS not constructed
- Total of 45 feet maybe not completed
- 50 feet dimensions maybe not completed
- Stone done 10/5/2012 Friday afternoon
- 10/6 AM team inspect final details (Frank D/Joe C, cosmetic rock placement = 5 cu yds)
- Tweaking hydraulic extractor – prior to extraction
- Thursday – acquired larger hammer for extraction
- Vibrator still on site
- 1st/2nd/3rd sheet wouldn't move
- 10 minutes in a single sheet, finally single sheet broke, pulled up, could see bottom of sheet but no water yet
- Excavating upstream channel couldn't reach all
- Friday PM – water up against sheets – 2 ft. – sat all Friday night until Saturday AM
- 1st sheet extracted still on site
- Slow at first, rushed in quicker, two stop logs above water
- Preparing to extract additional sheets
- Al MacDonald says we have blowout
- Saw water/mud boil up downstream from stop logs, didn't recall swirl upstream
- Somehow water was coming downstream, soil came around upstream, end of sheeting eroding curb material
- Bailed as much as possible
- Hauling broken concrete from yard to off-road truck onsite and to Elmer's
- Taking chunks of core wall, pieces of sheeting
- Suspicious of the core wall depths
- Stop log/gate on us face at powerhouse
- Feeling like water went under core wall

Interview with Ken Gregory, City of Traverse City
October 8, 2012, 3:00pm
Inteviewer: Jim Pawloski, MDEQ

8:00am Saturday –

- Water dropped 2 – 2 ½ ft. while sheet was still in place, but elevated

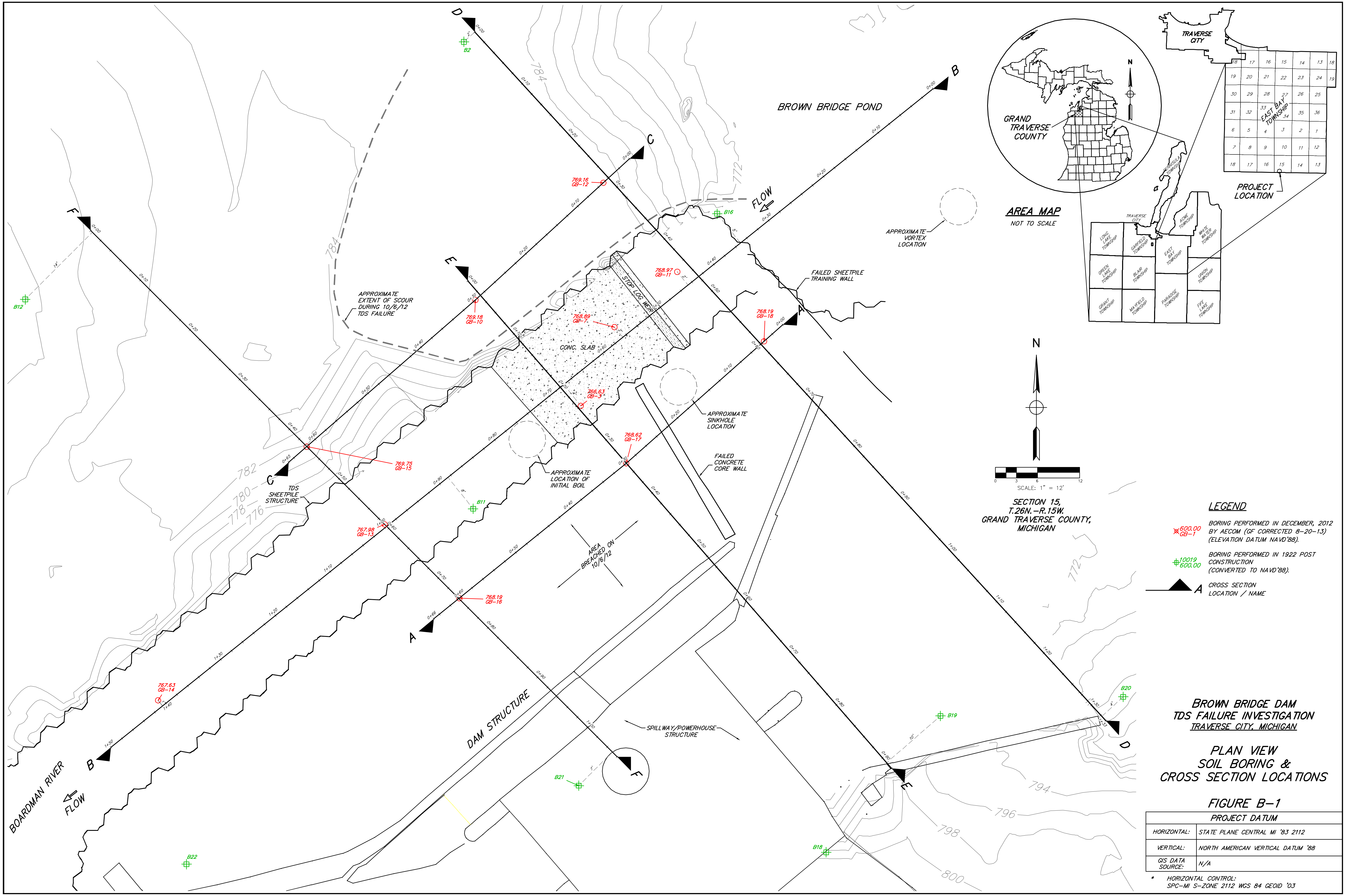
- Getting set to extract 2nd sheet - water is upstream and TDS – boiling/roiling/frothing
- Ken thought they had dropped vibrator and broke stop logs could hear water rushing thru structure
- Ken called 911 using Frank’s phone
- 2 to 3 minutes after +/- race photos
- Water was on downstream side of core wall at intersection w/ TDS area of 10-150’, frothy but static
- Bailing sand w/ long reach into area downstream & core wall
- Chris (tall guy) crane operator photos

AMEC E&I Inc.
BB Dam Removal
33101200011
Chronology of Events (Clayton Buntion)
Saturday 10/06/2012

- 7:00AM Plan of day and safety meeting.
- 8:00AM water readings head pond, tail water and new staff gauge in pond. Tail water elevation 765.4, Head pond elevation 786.4 staff gauge 8.5 = 786.4 off of powerhouse gauge.
- 8:30 Joe Caryl and I did and inspection of the rip rap and ask Molon to add additional rip rap in some voids at the tail end of the dewatering structure.
- 9:00AM Molon added the rip rap and set up to pull sheet piling serving as a temporary headwall for construction of inside work in dewatering structure.
- 9:45AM Started pulling one piece of sheet piling very slow to allow water to start applying pressure against stop logs. After allowing pressure against stop logs for about 15 minutes and things seemed fine. Molon continued to pull that sheet the rest of the way out.
- 10:00AM a loud popping noise inside of the dewatering structure and water started to come up from the bottom of structure. Everyone on site was looking to see how the water was entering the structure. The water started coming faster. The water appeared to be coming in the structure on the south side sheet piling just after the concrete pad.
- 10:15Am Joe Caryl and Ken Gregory started calling Emergency Response team. After watching Molon try to stop the water with no luck. The water became uncontrollable. Mike Walton (Molon) was in the 450 excavator bailing material as fast as he could against dewatering structure trying to stop the water. North side of dewatering structure.
- 10:30AM Molons crews started getting tools and equipment out of the area on the north side of the structure. To keep equipment and tools from falling into water and make room for more additional material. At the same time Long reach excavator on the south side started bailing material between Powerhouse and dewatering structure with a dozer pushing material to the long reach.
- 10:45 Emergency Response started showing up. Started asking people downstream for voluntary evacuation.
- 11:00AM Plan implemented to stop/reduce the flow with material with mass such as concrete. At this time people started calling for rock and concrete material.
- 11:45 Nate Winkler (CRA) told me Jim Pawloski (DEQ) wanted me to call him. So I immediately called Jim and gave him a brief description as to what was taking place and had taken place.
- 12:00PM Joe Caryl (AMEC) contacted Emergency Response team and made it a mandatory evacuation downstream because conditions were getting worse.
- 12:00PM Trucks started showing up with concrete and rock from Molon, Elemers and operators from Elpers.
- 12:00-4:30PM basically just keeping the site safe and keeping the trucks coming to dump concrete and bailing concrete into the channel trying to get the flow under control.
- 5:00PM had the water under control started building grade and sediment control in front of powerhouse.

- 5:30PM tail water elevation 764.9 lost about 12.5’ of water in pond.
- For the next 24 hours (AMEC) had personal onsite to make sure the site was in a safe and secure condition.

Appendix B – Drawings and Figures



LEGEND

☒ 600.00 GB–1	BORING PERFORMED IN DECEMBER, 2012 BY AECOM (GF CORRECTED 8–20–13) (ELEVATION DATUM NAVD'88).
⌖ 10019 600.00	BORING PERFORMED IN 1922 POST CONSTRUCTION (CONVERTED TO NAVD'88).
▲ A	CROSS SECTION LOCATION / NAME

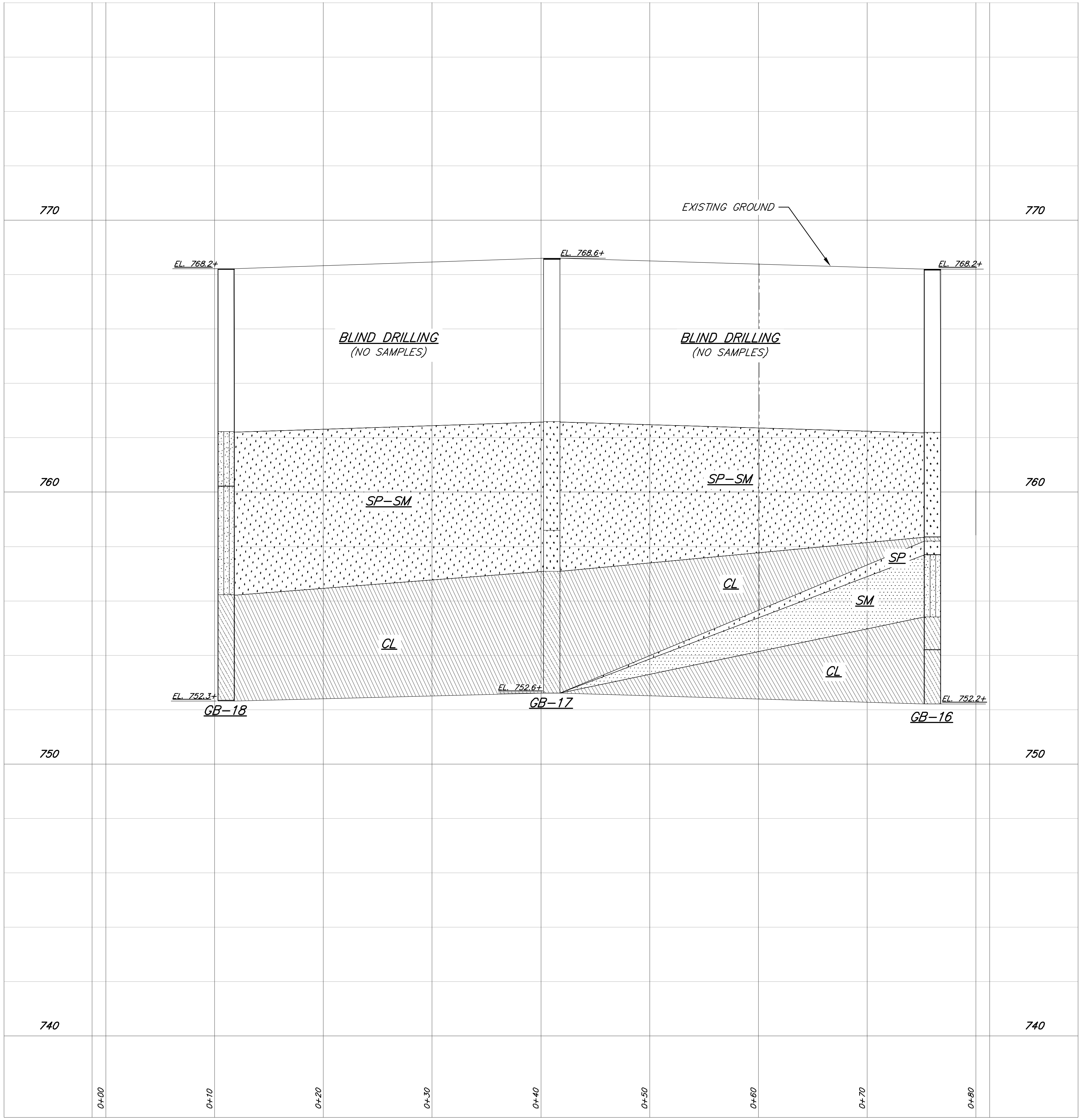
BROWN BRIDGE DAM
TDS FAILURE INVESTIGATION
TRAVERSE CITY, MICHIGAN

PLAN VIEW SOIL BORING & CROSS SECTION LOCATIONS

FIGURE B–1

PROJECT DATUM	
HORIZONTAL:	STATE PLANE CENTRAL MI '83 2112
VERTICAL:	NORTH AMERICAN VERTICAL DATUM '88
GIS DATA SOURCE:	N/A

* HORIZONTAL CONTROL:
SPC–MI S–ZONE 2112 WGS 84 GEOID '03



SECTION A-A
SCALE: H: 1" = 10' V: 1" = 4'

MATERIAL LEGEND

⁙	POORLY GRADED TO SILTY SAND (SP-SM)
┄	SILTY SAND (SM)
⁙	POORLY GRADED SAND (SP)
▨	LOW PLASTICITY CLAY (CL)

BROWN BRIDGE DAM
TDS FAILURE INVESTIGATION
TRAVERSE CITY, MICHIGAN

GEOLOGIC PROFILE
SECTION A-A

FIGURE B-2

PROJECT DATUM	
HORIZONTAL:	STATE PLANE CENTRAL MI '83 2112
VERTICAL:	NORTH AMERICAN VERTICAL DATUM '88
GIS DATA SOURCE:	N/A

* HORIZONTAL CONTROL:
SPC-MI S-ZONE 2112 WGS 84 GEOID '03

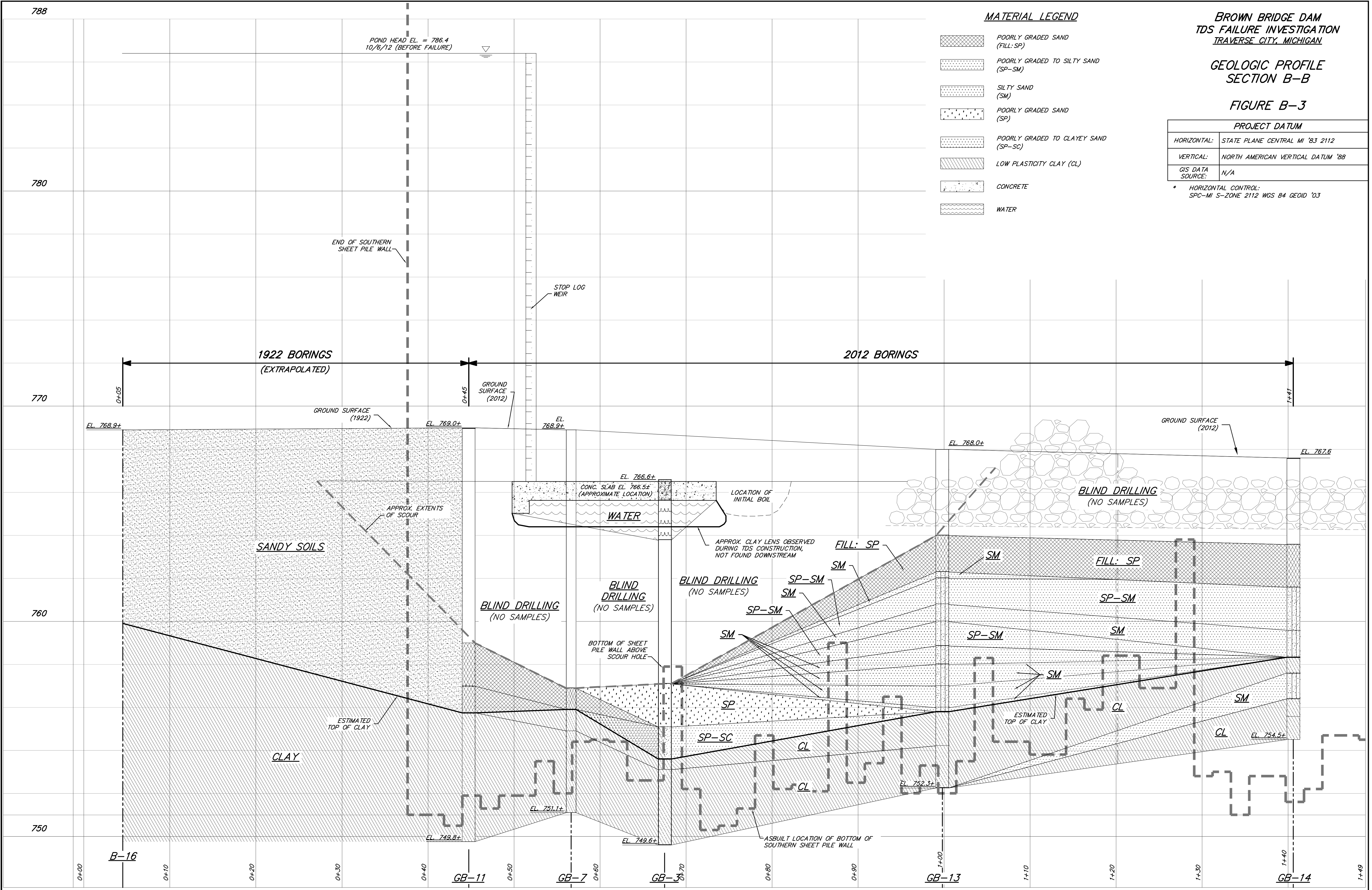
BROWN BRIDGE DAM
TDS FAILURE INVESTIGATION
TRAVERSE CITY, MICHIGAN

GEOLOGIC PROFILE
SECTION B–B

FIGURE B–3

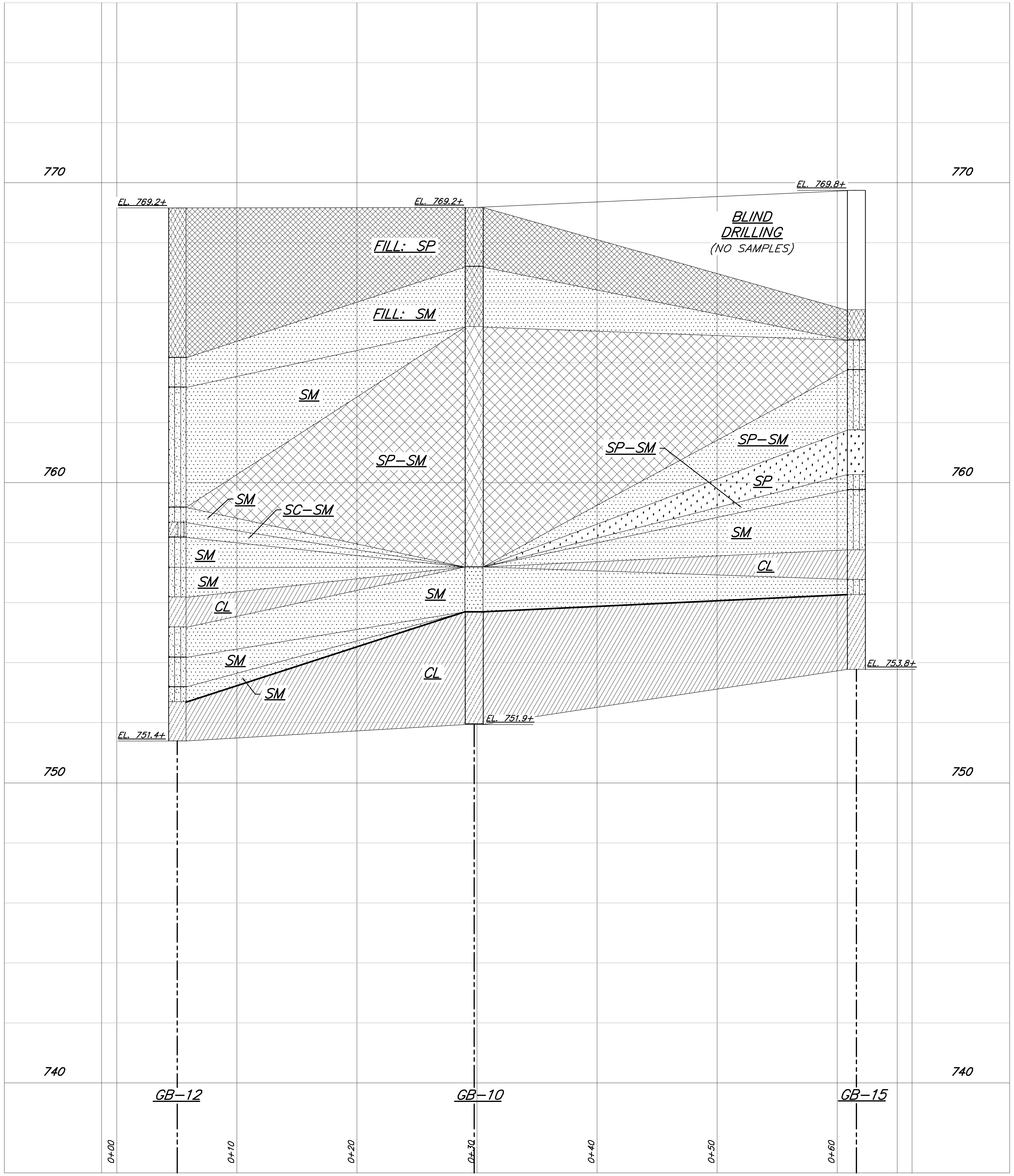
PROJECT DATUM	
HORIZONTAL:	STATE PLANE CENTRAL MI '83 2112
VERTICAL:	NORTH AMERICAN VERTICAL DATUM '88
GIS DATA SOURCE:	N/A

* HORIZONTAL CONTROL:
SPC–MI S–ZONE 2112 WGS 84 GEOID '03



SECTION B–B
SCALE: H: 1" = 10' V: 1" = 4'

P:\proj2013\121015SG2013_BrownBridgeDamFailureCAD\dwg\JDR-2449-01.dwg, (B-3) B 11x17, 2/12/2014 12:06:31 PM, PDF-XChange for AcroPlot Pro, Landscape Tabloid/ANSI B, 1:2



SECTION C–C
SCALE: H: 1" = 10' V: 1" = 4'

MATERIAL LEGEND

▩	POORLY GRADED SAND (FILL: SP)
▦	POORLY GRADED TO SILTY SAND (SP–SM)
░	SILTY SAND (SM)
▚	POORLY GRADED SAND (SP)
░	CLAYEY TO SILTY SAND (SC–SM)
▨	LOW PLASTICITY CLAY (CL)

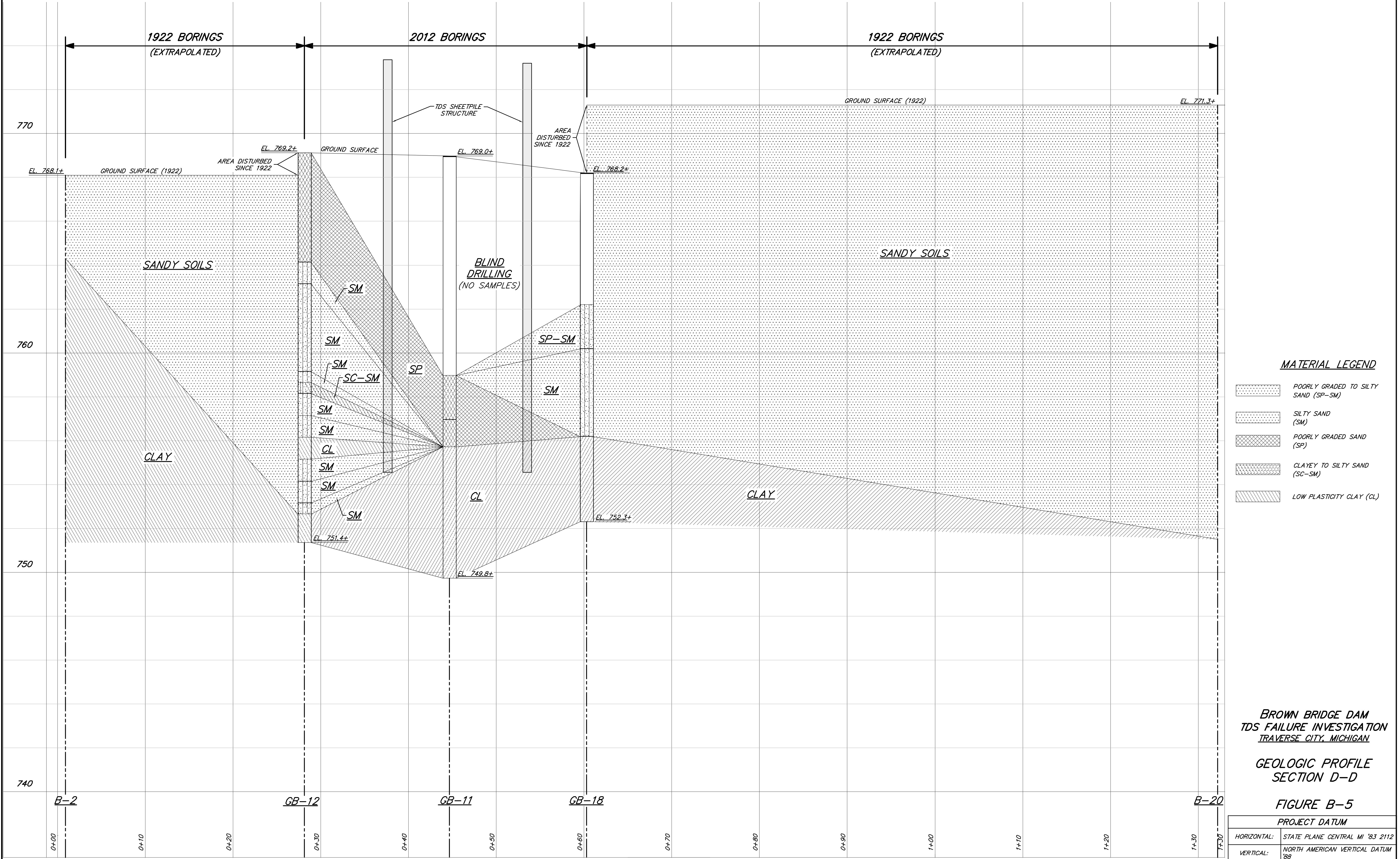
BROWN BRIDGE DAM
TDS FAILURE INVESTIGATION
TRAVERSE CITY, MICHIGAN

GEOLOGIC PROFILE
SECTION C–C

FIGURE B–4

PROJECT DATUM	
HORIZONTAL:	STATE PLANE CENTRAL MI '83 2112
VERTICAL:	NORTH AMERICAN VERTICAL DATUM '88
GIS DATA SOURCE:	N/A

* HORIZONTAL CONTROL:
SPC–MI S–ZONE 2112 WGS 84 GEOID '03



SECTION D-D

SCALE: H: 1" = 10' V: 1" = 4'

BROWN BRIDGE DAM
TDS FAILURE INVESTIGATION
TRAVERSE CITY, MICHIGAN

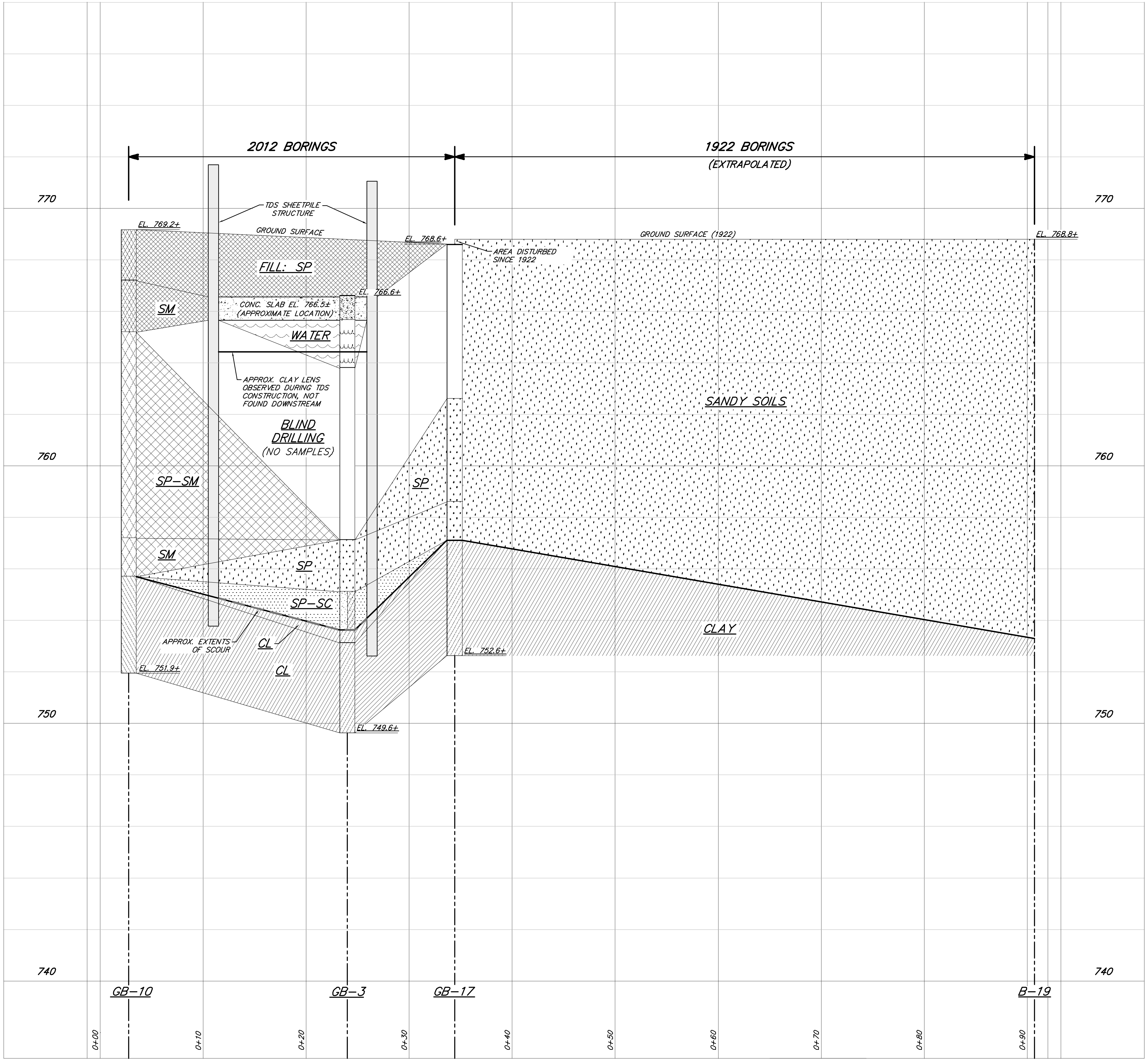
GEOLOGIC PROFILE
SECTION D-D

FIGURE B-5

PROJECT DATUM	
HORIZONTAL:	STATE PLANE CENTRAL MI '83 2112
VERTICAL:	NORTH AMERICAN VERTICAL DATUM '88
GIS DATA SOURCE:	N/A

* HORIZONTAL CONTROL:
SPC-MI S-ZONE 2112 WGS 84 GEOID '03

:\proj2013\121015SG2013_BrownBridgeDamFailureCAD\dwg\JDR-2449-01.dwg, (B-5) D 11x17, 2/12/2014 11:54:05 AM, PDF-XChange for AcroPlot Pro, Landscape Tabloid/ANSI B, 1:2



SECTION E–E

SCALE: H: 1" = 10' V: 1" = 4'

MATERIAL LEGEND

- ▦ POORLY GRADED SAND (FILL: SP)
- ▩ POORLY GRADED TO SILTY SAND (SP–SM)
- ▩ SILTY SAND (SM)
- ⁘ POORLY GRADED SAND (SP)
- ⁘ POORLY GRADED TO CLAYEY SAND (SP–SC)
- ▨ LOW PLASTICITY CLAY (CL)
- ▒ CONCRETE
- ≈ WATER

BROWN BRIDGE DAM
TDS FAILURE INVESTIGATION
TRAVERSE CITY, MICHIGAN

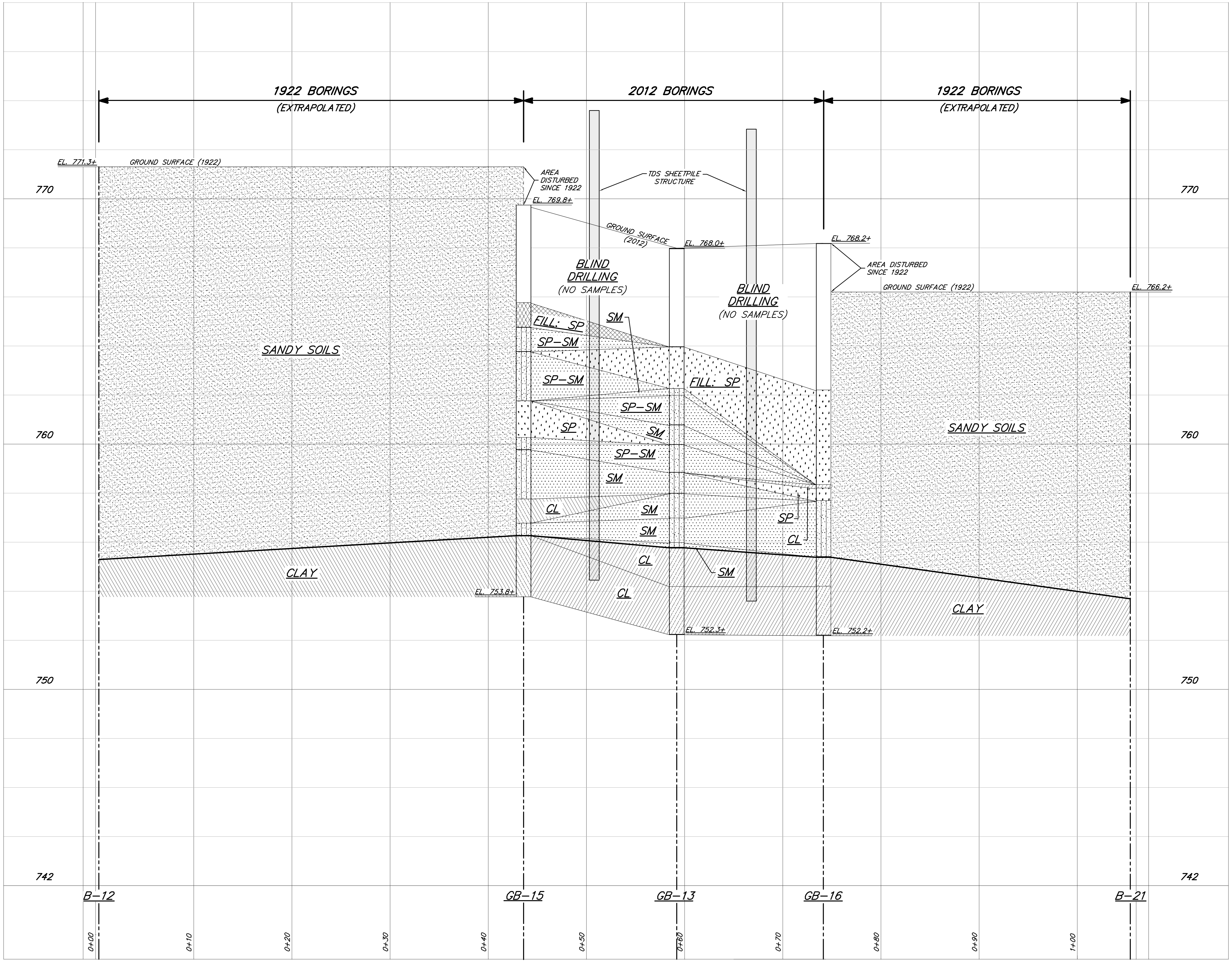
GEOLOGIC PROFILE
SECTION E–E

FIGURE B–6

PROJECT DATUM	
HORIZONTAL:	STATE PLANE CENTRAL MI '83 2112
VERTICAL:	NORTH AMERICAN VERTICAL DATUM '88
GIS DATA SOURCE:	N/A

* HORIZONTAL CONTROL:
SPC–MI S–ZONE 2112 WGS 84 GEOID '03

P:\proj2013\121015SG2013_BrownBridgeDamFailureCAD\dwg\JDR-2449-01.dwg, (B-6) E 11x17, 2/12/2014 11:53:27 AM, PDF-XChange for AcroPlot Pro, Landscape Tabloid/ANSI B, 1:2



SECTION F-F

SCALE: H: 1" = 10' V: 1" = 4'

MATERIAL LEGEND

- ▨ POORLY GRADED SAND (FILL: SP)
- ▨ POORLY GRADED TO SILTY SAND (SP-SM)
- ▨ SILTY SAND (SM)
- ▨ POORLY GRADED SAND (SP)
- ▨ LOW PLASTICITY CLAY (CL)

BROWN BRIDGE DAM
TDS FAILURE INVESTIGATION
TRAVERSE CITY, MICHIGAN

GEOLOGIC PROFILE
SECTION F-F

FIGURE B-7

PROJECT DATUM	
HORIZONTAL:	STATE PLANE CENTRAL MI '83 2112
VERTICAL:	NORTH AMERICAN VERTICAL DATUM '88
GIS DATA SOURCE:	N/A

* HORIZONTAL CONTROL:
SPC-MI S-ZONE 2112 WGS 84 GEOID '03

:\proj2013\121015SG2013_BrownBridgeDamFailureCAD\dwg\JDR-2449-01.dwg, (B-7) F 11x17, 2/12/2014 11:55:49 AM, PDF-XChange for AcroPlot Pro, Landscape Tabloid/ANSI B, 1:2

Appendix C – 2012 Soil Boring Data

AECOM
750 Corporate Woods Parkway
Vernon Hills, IL 60061
www.aecom.com

847.279.2500 tel
847.279.2510 fax

June 20, 2012

Sent via email: pworden@garanlucow.com

Mr. Peter B. Worden, Jr.
Garan Lucow Miller P.C.
1131 East Eighth Street
Traverse City, MI 49686-2936

RE: Brown Bridge Dam Failure – Boardman River
Traverse City, Michigan
Soil Testing Results
AECOM Project No. 60279499

Dear Peter:

AECOM has completed soil testing for samples collected from the Brown Bridge Dam site through week ending December 14, 2012. The soil samples were transported from the site to our Grand Rapids office at the end of testing. We then transported the samples to our lab located in Vernon Hills, Illinois on December 17, 2012.

The soil samples were stored in our office until all parties agreed to the soil sample test protocol. This protocol was finalized on May 13, 2013 with the addition of Pocket Erdometer testing that was requested by AMEC. The final test protocol was submitted by Peter Worden at Garan Lukow Miller P.C. to AMEC, MDEQ, the City of Traverse City, The Schiffer Group and the Conservation Resource Alliance on May 14, 2013. When concurrence of all parties was obtained, AECOM was directed by Peter Worden to proceed and testing was mobilized on May 20, 2013.

The soil tests were completed at the AECOM soil testing laboratory in Vernon Hills, Illinois. The AECOM soil testing laboratory is accredited by: United States Army Corps of Engineers (USACE), the American Association of State Highway and Transportation Officials (AASHTO), National Voluntary Laboratory Accreditation Program (NVLAP), Illinois Department of Transportation, and the Wisconsin Department of Transportation.

The following summarizes the tests that were completed and the test protocols:

- Visual Classification (ASTM D2488): This test consists of visual-manual description and identification of soils in the laboratory and results in the assignment of a USCS classification. This test is used to evaluate the accuracy of the descriptions and classifications that were assigned in the field. This test was performed on all soil samples. A total of eighty-five (85) of these tests were completed. The visual classification results are provided in Appendix A.

- Moisture Content Tests (ASTM D2216): This test was performed to determine the mass based water content of selected soil samples. Cohesive (e.g., clayey) soils and soils with considerable clay content (e.g., clayey sand) were selected for this testing. A total of thirty-six (36) of these tests were completed.

- Sieve Analysis (ASTM D422 or ASTM D6913): This test was performed to determine the gradation of selected granular (e.g., sandy) soil samples. This test results in a determination of the percentage of various sized soil particles larger than the No. 200 sieve size (e.g., silt and clay size). A total of thirteen (13) of these tests were completed.

- Combined Sieve-Hydrometer Analysis (ASTM D422): This test is similar to the sieve analysis with the addition of the hydrometer portion of the test which allows for the determination of the percentage of silt size particles and clay sized particles. This test was performed on selected cohesive and cohesionless soil samples. A total of thirty-three (33) of these tests were completed and are provided in Appendix B.

- Double Hydrometer Analysis (ASTM D4221): This test is similar to and is run in conjunction with the combined sieve-hydrometer test. This test allows for measure of the dispersivity and erosion potential of granular soils with considerable clay content. The test protocol estimated that the number of these tests was likely to be fourteen (14). As stated in the test protocol, lab testing can reveal that this testing is not pertinent for certain soil samples. The actual number of tests performed based on lab testing analysis was thirteen (13). The Double Hydrometer analysis test results are provided in Appendix C.

- Atterberg Limits Tests (ASTM D4318): This testing was performed on selected cohesive soil samples to characterize the plasticity of clayey soils. This data is used as an input in various published empirical correlations to other soil properties. A total of sixteen (16) of these tests were completed. Results are provided in Appendix D.

- Pinhole Dispersion Test (ASTM D4647): This testing is used to estimate the erosion potential of cohesive soils. This testing is generally to be performed on the upper (e.g., highest elevation) clayey soil samples that were identified in the borings which potentially may have eroded during the discharge through the TDS. A total of three (3) of these tests were completed. Results are provided in Appendix E.

- Pocket Erdometer Test (No Known ASTM Standard): This testing is used to estimate the erosion resistance of soils. This testing consists of using a regulated/calibrated mini-jet of water (e.g., commercially purchased squirt gun) aimed horizontally at a vertical face of a soil sample. The depth of the hole created by the jet following twenty (20) water impulses is recorded. The depth of the hole is then compared to an erosion chart to determine the erodibility category of the soil. This testing is largely experimental and no known standard procedures are available. The guidance for this testing was obtained from a technical paper titled “Bridge Foundation Scour” written by Jean-Louis Briaud and Seung Jae Oh and published in the “Geotechnical Engineering Journal of the SEAGS & AGSSEA”, Vol 41 No. 2 June 2010”. A total of eight (8) of these tests were performed. The selection of the samples was focused on the first (highest elevation) cohesive samples obtained in borings, with a focus on borings from within the TDS. AECOM has not performed this testing prior to this effort; our lab has made effort within reason to produce repeatable results. As we indicated in the testing protocol agreement, if more rigorous testing is required using the Briaud Erosion Function apparatus, an independent laboratory will need to be identified and contracted to perform the testing at higher cost. The results of the Pocket Erdometer Testing are provided in Appendix F.

The final soil boring logs that consider the above test results are provided in Appendix G.

If you have any questions regarding the test results provided in this report, please feel free to call me at (847) 323-2171.

Sincerely,

AECOM Technical Services, Inc.

William J. Weaver

William J. Weaver, P.E., D.WRE
Senior Principal Engineer – Vice President

AECOM
750 Corporate Woods Parkway
Vernon Hills, IL 60061
www.aecom.com

847.279.2500 tel
847.279.2510 fax

Appendix A – Visual Classification Test Results

AECOM
750 Corporate Woods Parkway
Vernon Hills, IL 60061
www.aecom.com

847.279.2500 tel
847.279.2510 fax

Appendix B – Combined Sieve Analysis Results

AECOM
750 Corporate Woods Parkway
Vernon Hills, IL 60061
www.aecom.com

847.279.2500 tel
847.279.2510 fax

Appendix C – Double Hydrometer Test Results

AECOM
750 Corporate Woods Parkway
Vernon Hills, IL 60061
www.aecom.com

847.279.2500 tel
847.279.2510 fax

Appendix D – Atterberg Limits Test Results

AECOM
750 Corporate Woods Parkway
Vernon Hills, IL 60061
www.aecom.com

847.279.2500 tel
847.279.2510 fax

Appendix E – Pinhole Dispersion Test Results

AECOM

CLIENT	**GLW**
LOG OF BORING NUMBER	**GB-13**
PROJECT NAME	**Brown Bridge Dam**
ARCHITECT-ENGINEER	**AECOM**
SITE LOCATION	**Traverse City, MI**

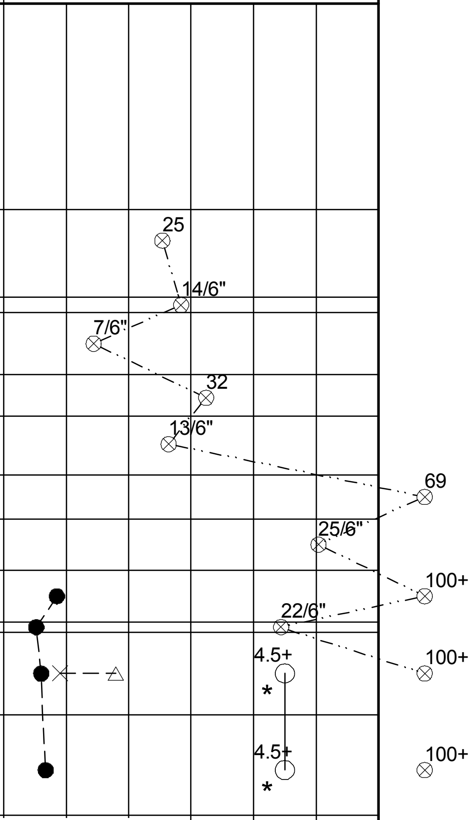
SURFACE ELEVATION +768.0

UNCONFINED COMPRESSIVE STRENGTH TONS/FT.^{2} ○ 1 2 3 4 5

PLASTIC LIMIT % ✕ — WATER CONTENT % ● — LIQUID LIMIT % △ 10 20 30 40 50

⊗ STANDARD PENETRATION BLOWS/(FT) 10 20 30 40 50

DEPTH(FT)	SAMPLE NO.	SAMPLE TYPE	STRATUM DEPTH	DESCRIPTION OF MATERIAL	UNIT DRY WT. LBS./FT.^{3}
2.5		HS	4.0	Blind drilling (No soil samples obtained)	
5.0	1	SS	5.7	FILL: Fine to coarse sand, trace silt - brown - medium dense - wet (FILL: SP)	
	1A	SS	6.0		
	2	SS	7.2	Silty fine to coarse sand, little fine to coarse gravel with piece of gravel stuck in spoon tip - brown - medium dense - wet (SM)	
7.5	2A	SS	8.0	Fine to coarse sand, trace fine gravel, trace silt - brown - medium dense - wet (SP-SM)	
	3	SS	9.2	Silty fine to coarse sand, trace fine gravel with occasional silt seams - brown - dense -wet (SM)	
10.0	3A	SS	10.0	Fine to coarse sand, some silt, trace fine gravel - brown - medium dense - wet (SP-SM)	
	4	SS	11.0	Fine to coarse sand, little fine to coarse gravel, little silt, trace clay with occasional silt lenses - brownish gray with orangish oxidized banding - very dense - wet (SM)	
	4A	SS	12.0	Fine to coarse sand, little silt, little clay, trace fine gravel - brown - very dense - wet (SM)	
12.5	5	SS	12.2	Fine to coarse sand, some silt, little clay, trace fine gravel - brown - dense - wet (SM)	
	5A	SS	13.8	Silty fine to coarse sand, trace fine gravel - brown - dense - wet (SM)	
		HSA		Silty clay and fine to medium sand - brown - hard (CL)	
15.0 15.8	6	SS	15.8	Silty clay, little fine to coarse sand, trace fine gravel - brown - hard (CL)	134



End of borehole at 15.75 feet. Borehole backfilled with cuttings. Borehole elevation is approximate. SPT-N values obtained with use of automatic hammer. Borehole advanced with 4-1/4" I.D. HSA.

NOTE: All laboratory testing performed in May-June 2013. Partial drying of samples has likely occurred.

* Calibrated Penetrometer

The stratification lines represent the approximate boundary lines between soil types: in situ, the transition may be gradual.

NORTHING **485806.651**	BORING STARTED **12/6/12**	AECOM OFFICE **Grand Rapids**	
EASTING **19387531.58**	BORING COMPLETED **12/6/12**	ENTERED BY **AMH**	SHEET NO. **1** OF **1**
WL **W.L. @ 1.7' W.D.**	RIG/FOREMAN **CME 750 ATV/Al Guzdzial (Rau)**	APP'D BY **TDB**	AECOM JOB NO. **60279499**

AECOM

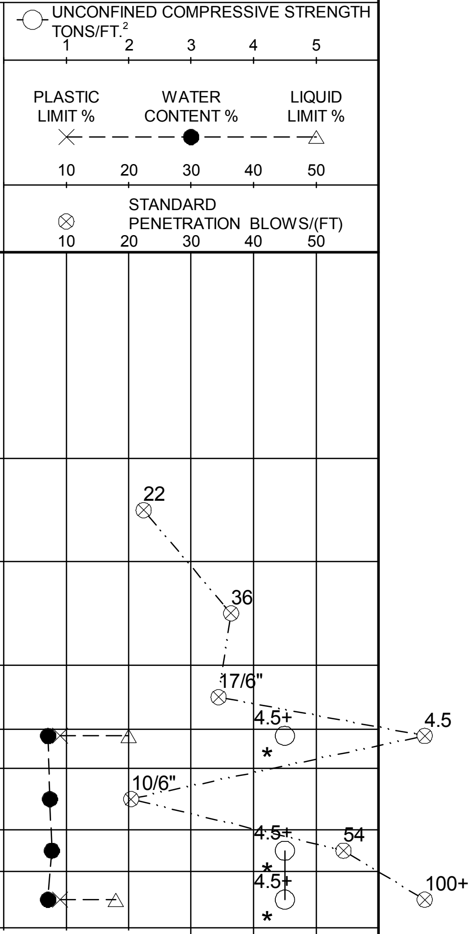
CLIENT	**GLW**
LOG OF BORING NUMBER	**GB-14**
PROJECT NAME	**Brown Bridge Dam**
ARCHITECT-ENGINEER	**AECOM**
SITE LOCATION	**Traverse City, MI**

SURFACE ELEVATION +767.6

DEPTH(FT)	ELEVATION(FT)	SAMPLE NO.	SAMPLE TYPE	SAMPLE DISTANCE	RECOVERY		DESCRIPTION OF MATERIAL	UNIT DRY WT. LBS./FT.³
2.5			HS			4.0	Blind drilling (No soil samples obtained)	
5.0		1	SS			6.0	FILL: Fine to coarse sand, trace silt - brown - medium dense - wet (FILL: SP)	
7.5		2	SS			8.0	Fine to coarse sand, trace silt, trace fine gravel - brown with slight oxidation - dense - wet (SP-SM)	
		3	SS			9.3	Fine to coarse sand, little silt, trace clay, trace fine gravel with occasional silt seams - brownish gray with orange - medium dense -wet (SM)	
10.0		3A	SS			10.0	Silty clay, little fine to coarse sand, trace fine gravel- brown - hard (CL)	
		4	SS			11.2	Fine to coarse sand, some silt, little clay, trace fine gravel - brown - medium dense - wet (SM)	
		4A	SS			12.0	Silty clay, little fine to coarse sand, trace fine gravel - brown - hard (CL)	126
12.5 13.1		5	SS			13.1	Silty clay and fine to medium sand, trace fine gravel - brown - hard (CL)	

End of borehole at 13.1 feet. Borehole backfilled with cuttings. Borehole elevation is approximate. SPT-N values obtained with use of automatic hammer. Borehole advanced with 4-1/4" I.D. HSA.

NOTE: All laboratory testing performed in May-June 2013. Partial drying of samples has likely occurred.



* Calibrated Penetrometer

The stratification lines represent the approximate boundary lines between soil types: in situ, the transition may be gradual.

NORTHING	485781.605	BORING STARTED	12/6/12	AECOM OFFICE	Grand Rapids
EASTING	19387499.31	BORING COMPLETED	12/6/12	ENTERED BY AMH	SHEET NO. 1 OF 1
WL		RIG/FOREMAN	CME 750 ATV/Al Guzdzial (Rau)	APP'D BY TDB	AECOM JOB NO. 60279499

AECOM

CLIENT
GLW

LOG OF BORING NUMBER **GB-15**

PROJECT NAME
Brown Bridge Dam

ARCHITECT-ENGINEER
AECOM

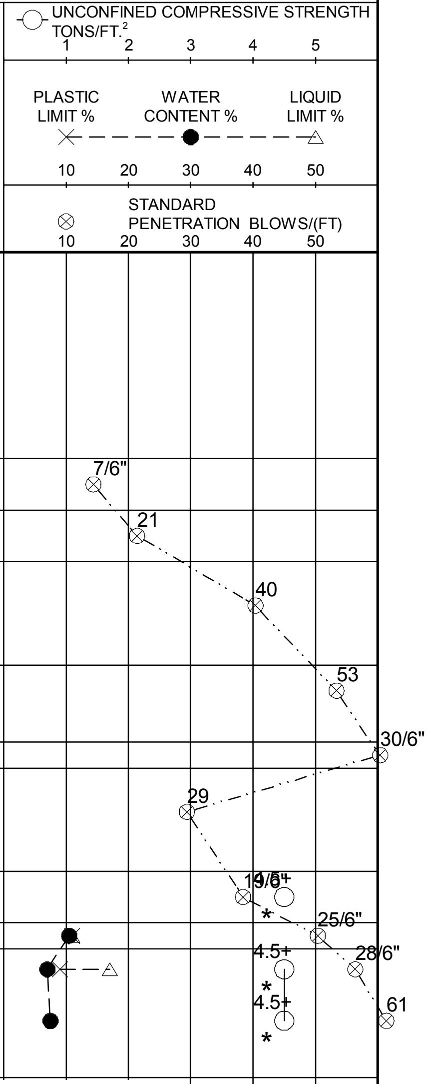
SITE LOCATION
Traverse City, MI

SURFACE ELEVATION +769.8

DEPTH(FT)	ELEVATION(FT)	SAMPLE NO.	SAMPLE TYPE	SAMPLE DISTANCE	RECOVERY		DESCRIPTION OF MATERIAL	UNIT DRY WT. LBS./FT.³
2.5			HS			4.0	Blind drilling (No soil samples obtained)	
5.0		1	SS			5.0	FILL: Fine to coarse sand, trace silt, trace fine gravel - brown - medium dense - wet (FILL: SP)	
		1A	SS			6.0	Fine to coarse sand, trace silt, little fine gravel - brown - medium dense - wet (SP-SM)	
7.5		2	SS			8.0	Fine to coarse sand, trace silt, trace fine gravel with 2" sandy clay seam @ 7' depth - brown - dense - wet (SP-SM)	
		3	SS			9.5	Fine to coarse sand, trace silt - brown - very dense - wet (SP)	
10.0		3A	SS			10.0	Fine to coarse sand, trace silt - brown - very dense - wet (SP-SM)	
		4	SS			12.0	Fine to medium sand, little silt, trace clay - brown - medium dense - wet (SM)	
12.5		5	SS			13.0	Silty clay, little fine to coarse sand, trace fine gravel - brown - hard (CL)	
		5A	SS			13.5	Fine to coarse sand, little silt, trace clay, trace fine gravel - brown - dense - wet (SM)	
		5B	SS					
15.0 16.0		6	SS			16.0	Silty clay and fine to coarse sand, trace fine gravel - brown - hard (CL)	126

End of borehole at 16.0 feet. Borehole backfilled with cuttings. Borehole elevation is approximate. SPT-N values obtained with use of automatic hammer. Borehole advanced with 4-1/4" I.D. HSA.

NOTE: All laboratory testing performed in May-June 2013. Partial drying of samples has likely occurred.



* Calibrated Penetrometer

The stratification lines represent the approximate boundary lines between soil types: in situ, the transition may be gradual.

NORTHING 485817.721	BORING STARTED 12/6/12	AECOM OFFICE Grand Rapids
EASTING 19387520.5	BORING COMPLETED 12/6/12	ENTERED BY AMH SHEET NO. 1 OF 1
WL	RIG/FOREMAN CME 750 ATV/Al Guzdzial (Rau)	APP'D BY TDB AECOM JOB NO. 60279499

AECOM

CLIENT
GLW

LOG OF BORING NUMBER **GB-16**

PROJECT NAME
Brown Bridge Dam

ARCHITECT-ENGINEER
AECOM

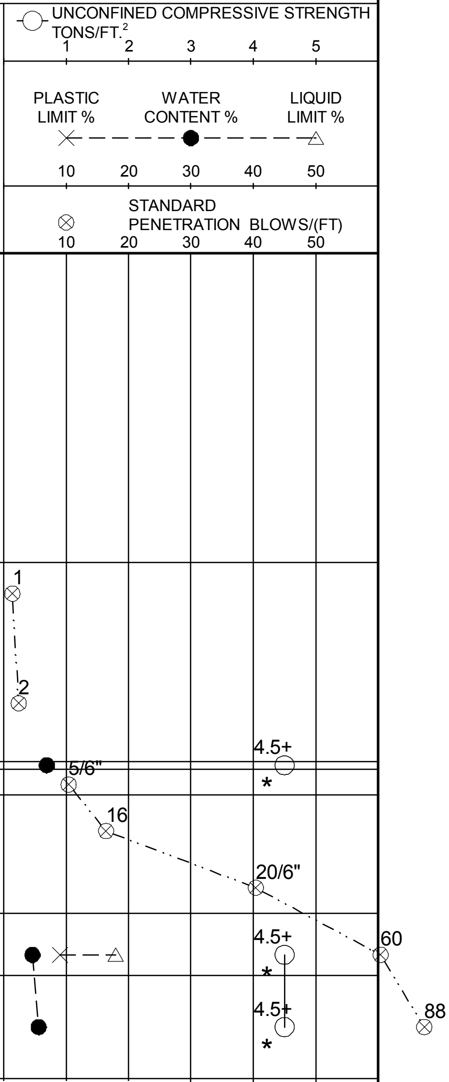
SITE LOCATION
Traverse City, MI

SURFACE ELEVATION +768.2

DEPTH(FT)	ELEVATION(FT)	SAMPLE NO.	SAMPLE TYPE	SAMPLE DISTANCE	RECOVERY	STRATUM DEPTH	DESCRIPTION OF MATERIAL	UNIT DRY WT. LBS./FT.^{3}
2.5 5.0			HS			6.0	Blind drilling (No soil samples obtained)	
7.5		1 2	SS SS			9.9	Fine to coarse sand, trace fine gravel, trace silt, trace organics - gray - very loose - wet (SP) (Possible outwash from TDS during event)	
10.0		2A	SS			10.0	Silty clay, little fine to coarse sand, trace fine gravel - brown - hard (CL)	
		3	SS			10.5	Fine to coarse sand, trace fine gravel, trace silt - brownish gray - medium dense - wet (SP)	
12.5		3A 4	SS SS			12.8	Fine to coarse sand, little silt, trace clay, trace fine gravel - brown with slight oxidation - medium dense to dense - wet (SM)	
		4A	SS			14.0	Silty clay and fine to coarse sand, little fine gravel - brown - hard (CL)	125
15.0 16.0		5	SS			16.0	Silty clay, little fine to coarse sand, trace fine gravel - brown - hard (CL)	

End of borehole at 16.0 feet. Borehole backfilled with cuttings. Borehole elevation is approximate. SPT-N values obtained with use of automatic hammer. Borehole advanced with 4-1/4" I.D. HSA.

NOTE: All laboratory testing performed in May-June 2013. Partial drying of samples has likely occurred.



* Calibrated Penetrometer

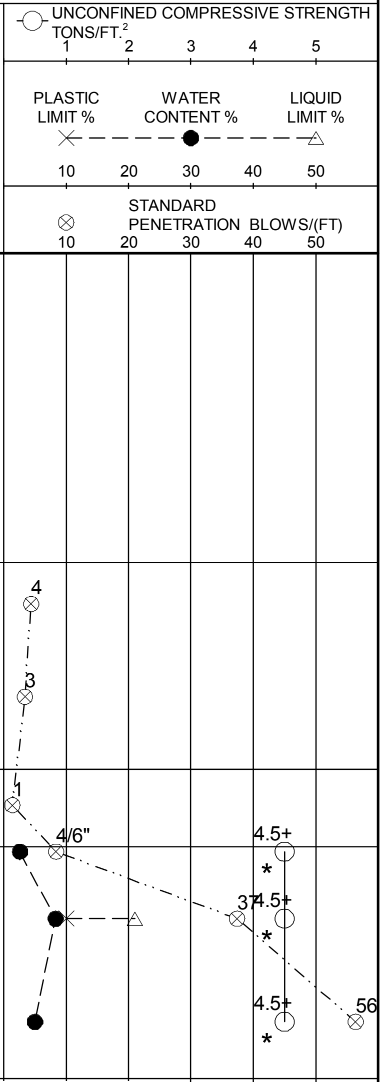
The stratification lines represent the approximate boundary lines between soil types: in situ, the transition may be gradual.

NORTHING 485796.141	BORING STARTED 12/6/12	AECOM OFFICE Grand Rapids	
EASTING 19387542.23	BORING COMPLETED 12/6/12	ENTERED BY AMH	SHEET NO. 1 OF 1
WL	RIG/FOREMAN CME 750 ATV/Al Guzdzial (Rau)	APP'D BY TDB	AECOM JOB NO. 60279499

AECOM	CLIENT **GLW**	LOG OF BORING NUMBER **GB-17**
	PROJECT NAME **Brown Bridge Dam**	ARCHITECT-ENGINEER **AECOM**
SITE LOCATION **Traverse City, MI**		

SURFACE ELEVATION +768.6

DEPTH(FT)	ELEVATION(FT)	SAMPLE NO.	SAMPLE TYPE	SAMPLE DISTANCE	RECOVERY	DESCRIPTION OF MATERIAL	UNIT DRY WT. LBS./FT.^{3}
2.5 5.0			HS			Blind drilling (No soil samples obtained) 6.0	
7.5		1	SS			Fine to coarse sand, trace silt, trace fine gravel - brown - loose to very loose - wet (SP)	
10.0		2	SS			10.0	
		3	SS			Fine to medium sand, trace silt, trace clay - brown - very loose - wet (SP) 11.5	
		3A	SS			Silty clay, little fine to coarse sand, trace fine gravel, with occasional sand partings - reddish brown - hard (CL)	
12.5		4	SS				
15.0 16.0		5	SS			16.0	132



* Calibrated Penetrometer

End of borehole at 16.0 feet. Borehole backfilled with cuttings. Borehole elevation is approximate. SPT-N values obtained with use of automatic hammer. Borehole advanced with 4-1/4" I.D. HSA.

NOTE: All laboratory testing performed in May-June 2013. Partial drying of samples has likely occurred.

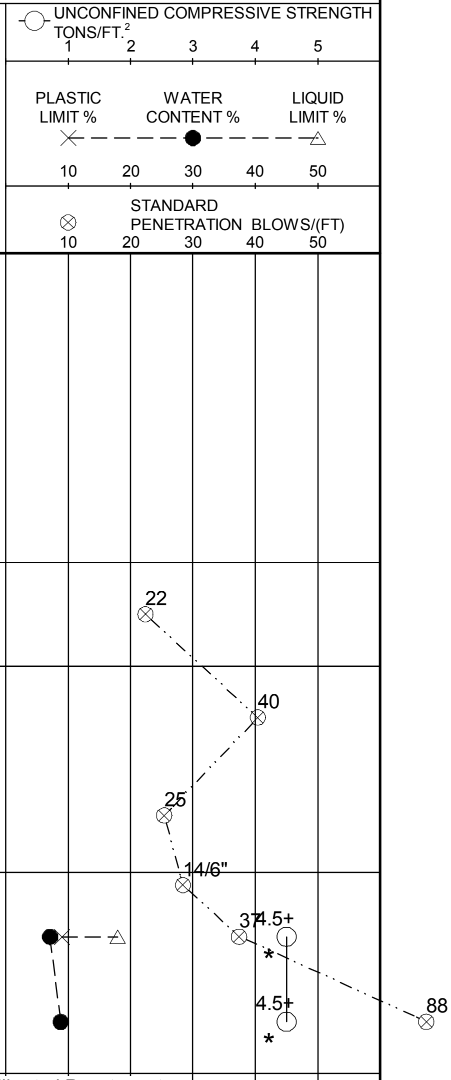
The stratification lines represent the approximate boundary lines between soil types: in situ, the transition may be gradual.

NORTHING 485815.36	BORING STARTED 12/6/12	AECOM OFFICE **Grand Rapids**	
EASTING 19387566.01	BORING COMPLETED 12/6/12	ENTERED BY **AMH**	SHEET NO. 1 OF 1
WL	RIG/FOREMAN **CME 750 ATV/Al Guzdzial (Rau)**	APP'D BY **TDB**	AECOM JOB NO. **60279499**

AECOM	CLIENT **GLW**	LOG OF BORING NUMBER **GB-18**
	PROJECT NAME **Brown Bridge Dam**	ARCHITECT-ENGINEER **AECOM**

SITE LOCATION
Traverse City, MI

DEPTH(FT)	ELEVATION(FT)	SAMPLE NO.	SAMPLE TYPE	SAMPLE DISTANCE	RECOVERY	DESCRIPTION OF MATERIAL SURFACE ELEVATION +768.2	UNIT DRY WT. LBS./FT.³
2.5 5.0		HS				Blind drilling (No soil samples obtained) 6.0	
7.5		1	SS			Fine to medium sand, trace silt - brown - medium dense - wet (SP-SM) 8.0	
10.0		2	SS			Fine to medium sand, little silt, trace clay and occasional clay seams ranging from 1/2"-2" thick - brown - dense to medium dense - wet (SM)	
		3	SS			12.0	
12.5		4	SS			Silty clay, little fine to coarse sand, trace fine gravel - brown - hard (CL)	
		4A	SS				
15.0 15.9		5	SS			15.9	127



End of borehole at 15.9 feet. Borehole backfilled with cuttings. Borehole elevation is approximate. SPT-N values obtained with use of automatic hammer. Borehole advanced with 4-1/4" I.D. HSA.

NOTE: All laboratory testing performed in May-June 2013. Partial drying of samples has likely occurred.
NOTE: Approximate elevation of borehole is based on estimated elevation reported by AMEC during performance of the boring.

* Calibrated Penetrometer

The stratification lines represent the approximate boundary lines between soil types: in situ, the transition may be gradual.

NORTHING **485832.7197**	BORING STARTED **12/6/12**	AECOM OFFICE **Grand Rapids**	
EASTING **19387585.63**	BORING COMPLETED **12/6/12**	ENTERED BY **AMH**	SHEET NO. **1** OF **1**
WL	RIG/FOREMAN **CME 750 ATV/Al Guzdzial (Rau)**	APP'D BY **TDB**	AECOM JOB NO. **60279499**

SUMMARY OF RESULTS

Boring No.	Sample No.	Depth (ft.)	Classification	USCS	WC %	Density (pcf)	Sample Arrival Condition*
B-GB-3							
	S-1	9.5'-11.5'	F-C SAND AND F-C GRAVEL TRACE SILT - BROWN	SP			MOIST
	S-2	11.5'-13.0'	F-C SAND LITTLE F GRAVEL TRACE CLAY TRACE SILT - BROWN	SP-SC			MOIST
	S-2 DOUBLE	11.5'-13.0'	F-C SAND LITTLE F GRAVEL TRACE CLAY TRACE SILT - BROWN	SP-SC			MOIST
	S-2A	13.0'-13.5'	SILTY CLAY AND F-M SAND - BROWN	CL	8.0		DESSICATED
	S-3	13.5'-15.5'	SILTY CLAY LITTLE F-C SAND TRACE F GRAVEL - BROWN	CL	6.9	133.3	DESSICATED
	S-4	15.5'-17.0'	SILTY CLAY LITTLE F-C SAND TRACE F GRAVEL - BROWN	CL	8.0		DESSICATED
B-GB-7							
	S-1	12.0'-13.0'	F-C SAND LITTLE F GRAVEL TRACE CLAY - BROWN	SP			MOIST
	S-1A	13.0'-14.0'	SILTY CLAY AND F-C SAND TRACE F GRAVEL - BROWN	CL	7.2		DESSICATED
	S-2	14.0'-16.0'	SILTY CLAY LITTLE F-C SAND TRACE F GRAVEL - BROWN	CL	6.1	139.2	DESSICATED
	S-3	16.0'-17.6'	SILTY CLAY LITTLE F-C SAND TRACE F GRAVEL - BROWN	CL	6.3		DESSICATED
B-GB-10							
	S-1	0.0'-2.0'	F-M SAND LITTLE SILT TRACE CLAY - BROWN	SM			MOIST
	S-2	2.0'-4.0'	F-C SAND SOME F-C GRAVEL TRACE SILT - BROWN	SP			MOIST
	S-3	4.0'-6.0'	F-C SAND TRACE SILT TRACE F GRAVEL - BROWN	SP			MOIST
	S-4	6.0'-8.0'	F-C SAND TRACE SILT TRACE F GRAVEL - BROWN	SP			MOIST
	S-5	8.0'-10.0'	F-C SAND SOME SILT TRACE F GRAVEL - BROWN	SP-SM			MOIST
	S-6	10.0'-12.0'	F-C SAND TRACE SILT TRACE F GRAVEL - BROWN	SP			MOIST
	S-7	12.0'-14.0'	F-C SAND TRACE F GRAVEL - BROWN	SM			MOIST
	S-7A	13.5'-14.0'	SILTY CLAY AND F-M SAND TRACE F GRAVEL - BROWN	CL	6.4		DESSICATED
	S-8	14.0'-16.0'	SILTY CLAY LITTLE F-C SAND TRACE F GRAVEL - BROWN	CL	7.6	132.1	DESSICATED
	S-9	16.0'-17.25'	SILTY CLAY LITTLE F-C SAND TRACE F GRAVEL - BROWN	CL	7.0		DESSICATED

SUMMARY OF RESULTS

Boring No.	Sample No.	Depth (ft.)	Classification	USCS	WC %	Density (pcf)	Sample Arrival Condition*
B-GB-11							
	S-1	10.0'-12.0'	F-C SAND TRACE SILT TRACE F GRAVEL - BROWN	SP			
	S-2	12.0'-13.5'	F-C SAND LITTLE F GRAVEL TRACE CLAY TRACE SILT - BROWN	SP			MOIST
	S-2 DOUBLE	12.0-13.5	F-C SAND LITTLE F GRAVEL TRACE CLAY TRACE SILT - BROWN	SP			MOIST
	S-2A	13.5'-14.0'	SILTY CLAY AND F-M SAND TRACE F GRAVEL - BROWN	CL	7.5		DESSICATED
	S-3	14.0'-16.0'	SILTY CLAY LITTLE F-C SAND TRACE F GRAVEL - BROWN	CL	6.7	120.5	SEMI-DESSICATED
	S-5	17.5-19.25'	SILTY CLAY LITTLE F-C SAND TRACE F GRAVEL - BROWN	CL	4.0		DESSICATED
B-GB-12							
	S-1	4.0'-5.0'	F-C SAND LITTLE F-C GRAVEL TRACE SILT - BROWN	SP			MOIST
	S-1A	5.0'-6.0'	F-M SAND SOME SILT TRACE CLAY TRACE F GRAVEL - BROWN	SM			MOIST
	S-1A DOUBLE	5.0'-6.0'	F-M SAND SOME SILT TRACE CLAY TRACE F GRAVEL - BROWN	SM			MOIST
	S-2	6.0'-8.0'	SILTY F-C SAND TRACE F GRAVEL - BROWN	SM			MOIST
	S-3	8.0'-10.0'	SILTY F-C SAND - BROWN	SM			MOIST
	S-4	10.0'-10.5'	F-C SAND LITTLE SILT TRACE CLAY - BROWN	SM			MOIST
	S-4 DOUBLE	10.0'-10.5'	F-C SAND LITTLE SILT TRACE CLAY - BROWN	SM			MOIST
	S-4A	10.5'-11.0'	F-C SAND SOME SILT LITTLE CLAY TRACE F GRAVEL - BROWN	SC-SM	1.9		MOIST
	S-4B	11.0'-12.0'	SILTY F-M SAND - BROWN	SM			MOIST
	S-5	12.0'-13.0'	SILTY F-C SAND - BROWN	SM			MOIST
	S-5A	13.0'-14.0'	SILTY CLAY AND F-C SAND - BROWN	CL	5.7		MOIST
	S-6	14.0'-15.0'	F-C SAND LITTLE SILT TRACE CLAY TRACE F GRAVEL - BROWN	SM	7.7		MOIST
	S-6 DOUBLE	14.0'-15.0'	F-C SAND LITTLE SILT TRACE CLAY TRACE F GRAVEL - BROWN	SM	1.6		MOIST
	S-6A	15.0'-16.0'	F-C SAND SOME F GRAVEL LITTLE SILT LITTLE CLAY - BROWN	SM			MOIST
	S-7	16.0'-16.5'	F-M SAND LITTLE SILT TRACE CLAY - BROWN	SM			MOIST
	S-7 DOUBLE	16.0'-16.5'	F-M SAND LITTLE SILT TRACE CLAY - BROWN	SM			MOIST
	S-7A	16.5'-17.5'	SILTY CLAY AND F-M SAND TRACE F GRAVEL - BROWN	CL	6.0	125.3	DESSICATED

SUMMARY OF RESULTS

Boring No.	Sample No.	Depth (ft.)	Classification	USCS	WC %	Density (pcf)	Sample Arrival Condition*
B-GB-13							
	S-1	4.0'-5.7'	F-C SAND TRACE SILT - BROWN	SP			MOIST
	S-1A	5.7'-6.0'	SILTY F-C SAND LITTLE F-C GRAVEL - BROWN	SM			MOIST
	S-2	6.0'-7.2'	F-C SAND TRACE SILT TRACE F GRAVEL - BROWN	SP-SM			MOIST
	S-2A	7.2'-8.0'	SILTY F-C SAND TRACE F GRAVEL - BROWN	SM			MOIST
	S-3	8.0'-9.15'	F-C SAND SOME SILT TRACE F GRAVEL - BROWN	SP-SM			MOIST
	S-3A	9.5'-10.0'	F-C SAND LITTLE F-C GRAVEL LITTLE SILT TRACE CLAY - BROWN	SM			MOIST
	S-4	10.0'-11.0'	F-C SAND LITTLE SILT TRACE CLAY TRACE F GRAVEL - BROWN	SM			MOIST
	S-4 DOUBLE	10.0'-11.0'	F-C SAND LITTLE SILT TRACE CLAY TRACE F GRAVEL - BROWN	SM			MOIST
	S-4A	11.0'-12.0'	F-C SAND SOME SILT LITTLE CLAY TRACE F GRAVEL - BROWN	SM	8.5		MOIST
	S-4A DOUBLE	11.0'-12.0'	F-C SAND SOME SILT LITTLE CLAY TRACE F GRAVEL - BROWN	SM			MOIST
	S-5	12.0'-12.2'	SILTY F-C SAND TRACE F GRAVEL - BROWN	SM	5.2		MOIST
	S-5A	12.2'-12.8'	SILTY CLAY AND F-M SAND - BROWN	CL	6.0		DESSICATED
	S-6	14.0'-15.75'	SILTY CLAY LITTLE F-C SAND TRACE F GRAVEL - BROWN	CL	6.7	133.6	DESSICATED
B-GB-14							
	S-1	4.0'-6.0'	F-C SAND TRACE SILT - BROWN	SP			MOIST
	S-2	6.0'-8.0'	F-C SAND TRACE SILT TRACE F GRAVEL - BROWN	SP-SM			MOIST
	S-3	8.0'-9.25'	F-C SAND LITTLE SILT TRACE CLAY TRACE F GRAVEL - BROWN	SM			MOIST
	S-3 DOUBLE	8.0'-9.25'	F-C SAND LITTLE SILT TRACE CLAY TRACE F GRAVEL - BROWN	SM			MOIST
	S-3A	9.25'-10.0'	SILTY CLAY AND F-C SAND TRACE F GRAVEL - BROWN	CL	7.1		DESSICATED
	S-4	10.0'-11.2'	F-C SAND SOME SILT LITTLE CLAY TRACE F GRAVEL - BROWN	SM	7.4		MOIST
	S-4 DOUBLE	10.0'-11.2'	F-C SAND SOME SILT LITTLE CLAY TRACE F GRAVEL - BROWN	SM			MOIST
	S-4A	11.2'-12.0'	SILTY CLAY LITTLE F-C SAND TRACE F GRAVEL - BROWN	CL	7.7	125.8	DESSICATED
	S-5	12.0'-13.1'	SILTY CLAY AND F-M SAND TRACE F GRAVEL - BROWN	CL	7.1		DESSICATED

SUMMARY OF RESULTS

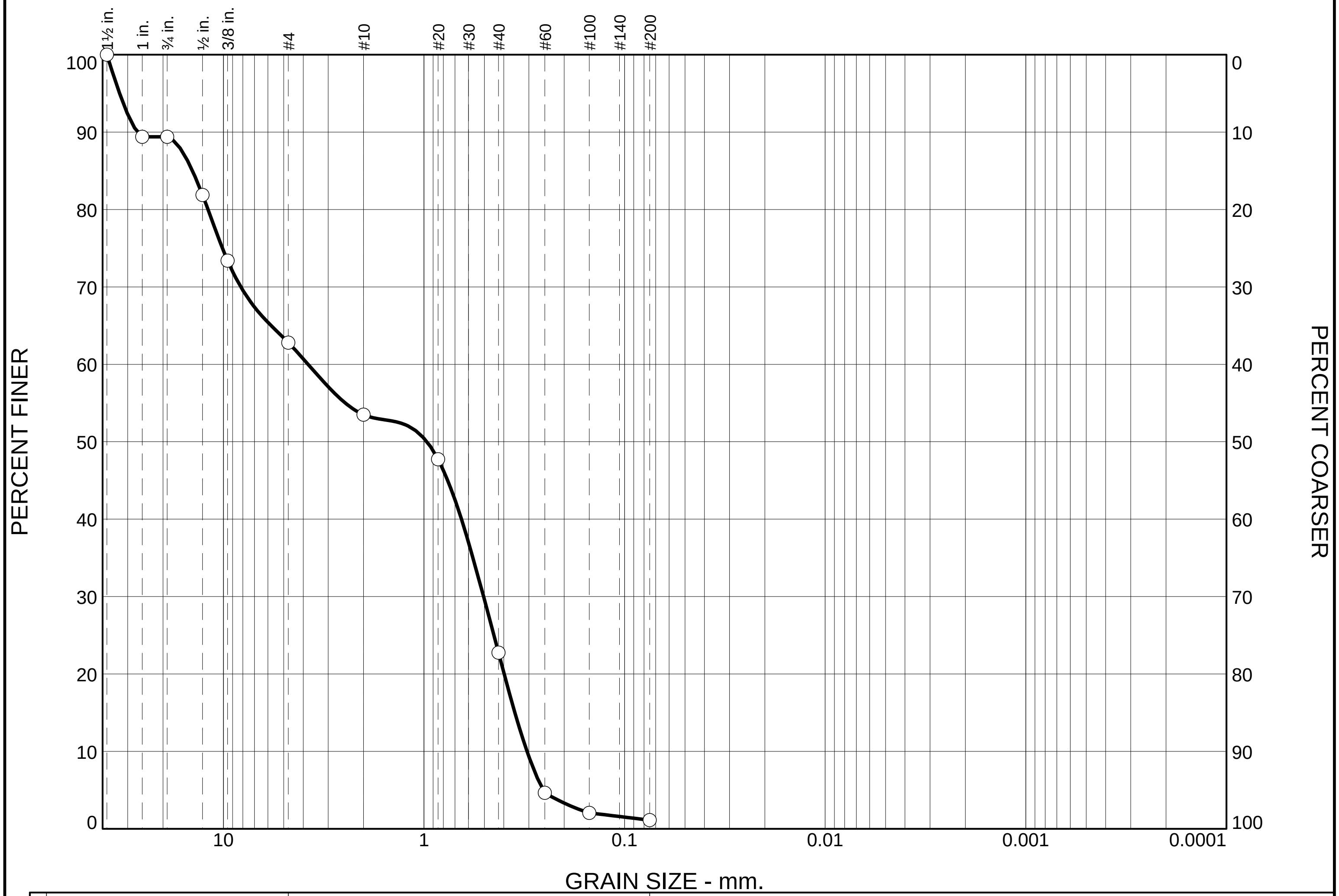
Boring No.	Sample No.	Depth (ft.)	Classification	USCS	WC %	Density (pcf)	Sample Arrival Condition*
B-GB-15							
	S-1	4.0'-5.0'	F-C SAND TRACE SILT TRACE F GRAVEL - BROWN	SP			MOIST
	S-1A	5.0'-6.0'	F-C SAND TRACE SILT LITTLE F GRAVEL - BROWN	SP-SM			MOIST
	S-2	6.0'-8.0'	F-C SAND TRACE SILT TRACE F GRAVEL - BROWN	SP-SM			MOIST
	S-3	8.0'-9.5'	F-C SAND TRACE SILT - BROWN	SP			MOIST
	S-3A	9.5'-10.0'	F-C SAND TRACE SILT - BROWN	SP-SM			MOIST
	S-4	10.0'-12.0'	F-M SAND LITTLE SILT TRACE CLAY - BROWN	SM			MOIST
	S-4 DOUBLE	10.0'-12.0'	F-M SAND LITTLE SILT TRACE CLAY - BROWN	SM			MOIST
	S-5	12.0'-13.0'	F-M SAND TRACE SILT TRACE CLAY - BROWN	SP-SM			MOIST
	S-5 DOUBLE	12.0'-13.0'	F-M SAND TRACE SILT TRACE CLAY - BROWN	SP-SM			MOIST
	S-6	12.0'-14.0'	SILTY CLAY LITTLE F-C SAND TRACE F GRAVEL - BROWN	CL	7.5	126.4	DESSICATED
	S-5A	13.0'-13.5'	F-C SAND LITTLE SILT TRACE CLAY TRACE F GRAVEL - BROWN	SM	10.5		MOIST
	S-5B	13.5'-14.0'	SILTY CLAY AND F-C SAND TRACE F GRAVEL - BROWN	CL	7.0		DESSICATED
B-GB-16							
	S-1	6.0'-8.0'	F-C SAND TRACE SILT TRACE F GRAVEL - BROWN	SP			MOIST
	S-2	8.0'-9.85'	F-C SAND TRACE SILT TRACE F GRAVEL - BROWN	SP			MOIST
	S-2A	9.85'-10.0'	SILTY CLAY LITTLE F-C SAND TRACE F GRAVEL - BROWN	CL	6.9		DESSICATED
	S-3	10.0'-10.5'	F-C SAND TRACE SILT TRACE F GRAVEL - BROWN	SP			MOIST
	S-3A	10.5'-12.0'	F-C SAND LITTLE SILT TRACE CLAY TRACE F GRAVEL - BROWN	SM			MOIST
	S-3A DOUBLE	10.5'-12.0'	F-C SAND LITTLE SILT TRACE CLAY TRACE F GRAVEL - BROWN	SM			MOIST
	S-4	12.0'-13.0'	F-C SAND TRACE SILT TRACE F GRAVEL - BROWN	SP-SM			MOIST
	S-4A	13.0'-14.0'	SILTY CLAY AND F-C SAND LITTLE F GRAVEL - BROWN	CL	4.6	125	DESSICATED
	S-5	14.0'-16.0'	SILTY CLAY LITTLE F-C SAND TRACE F GRAVEL - BROWN	CL	5.6		DESSICATED

SUMMARY OF RESULTS

Boring No.	Sample No.	Depth (ft.)	Classification	USCS	WC %	Density (pcf)	Sample Arrival Condition*
B-GB-17							
	S-1	6.0'-8.0'	F-C SAND TRACE SILT TRACE F GRAVEL - BROWN	SP			MOIST
	S-2	8.0'-10.0'	F-C SAND TRACE SILT TRACE F GRAVEL - BROWN	SP			MOIST
	S-3	10.0'-11.5'	F-M SAND TRACE SILT TRACE CLAY - BROWN	SP			MOIST
	S-3A	11.8'-12.0'	SILTY CLAY LITTLE F-C SAND TRACE F GRAVEL - BROWN	CL	2.6		DESSICATED
	S-4	12.0'-14.0'	SILTY CLAY AND F-C SAND - BROWN	CL	8.3		DESSICATED
	S-5	14.0'-16.0'	SILTY CLAY LITTLE F-C SAND TRACE F GRAVEL - BROWN	CL	5.0	131.7	DESSICATED
B-GB-18							
	S-1	6.0'-8.0'	F-M SAND TRACE SILT - BROWN	SP-SM			MOIST
	S-3	10.0'-12.0'	F-M SAND LITTLE SILT TRACE CLAY - BROWN	SM			MOIST
	S-3 DOUBLE	10.0'-12.0'	F-M SAND LITTLE SILT TRACE CLAY - BROWN	SM			MOIST
	S-4	12.0'-12.5'	SILTY CLAY LITTLE F-C SAND TRACE F GRAVEL - BROWN	CL			DESSICATED
	S-4A	12.5'-14.0'	SILTY CLAY AND F-C SAND TRACE F GRAVEL - BROWN	CL	7.1		DESSICATED
	S-5	14.0'-15.9'	SILTY CLAY LITTLE F-C SAND TRACE F GRAVEL - BROWN	CL	8.7	127.3	MOIST

* **ALL SAMPLES WERE ABSENT OF MOLD OR ORGANICS**

Particle Size Analysis of Soils ASTM D422



	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○ 0.0	10.6	26.6	9.3	30.7	21.7	1.1	

☒	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			14.2567	3.7848	0.9664	0.5043	0.3519	0.3064	0.22	12.35

Material Description	USCS	AASHTO
○ F-C SAND AND F-C GRAVEL TRACE SILT - BROWN	SP	

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

○ **Source of Sample:** B-GB-3 **Depth:** 9.5'-11.5' **Sample Number:** S-1

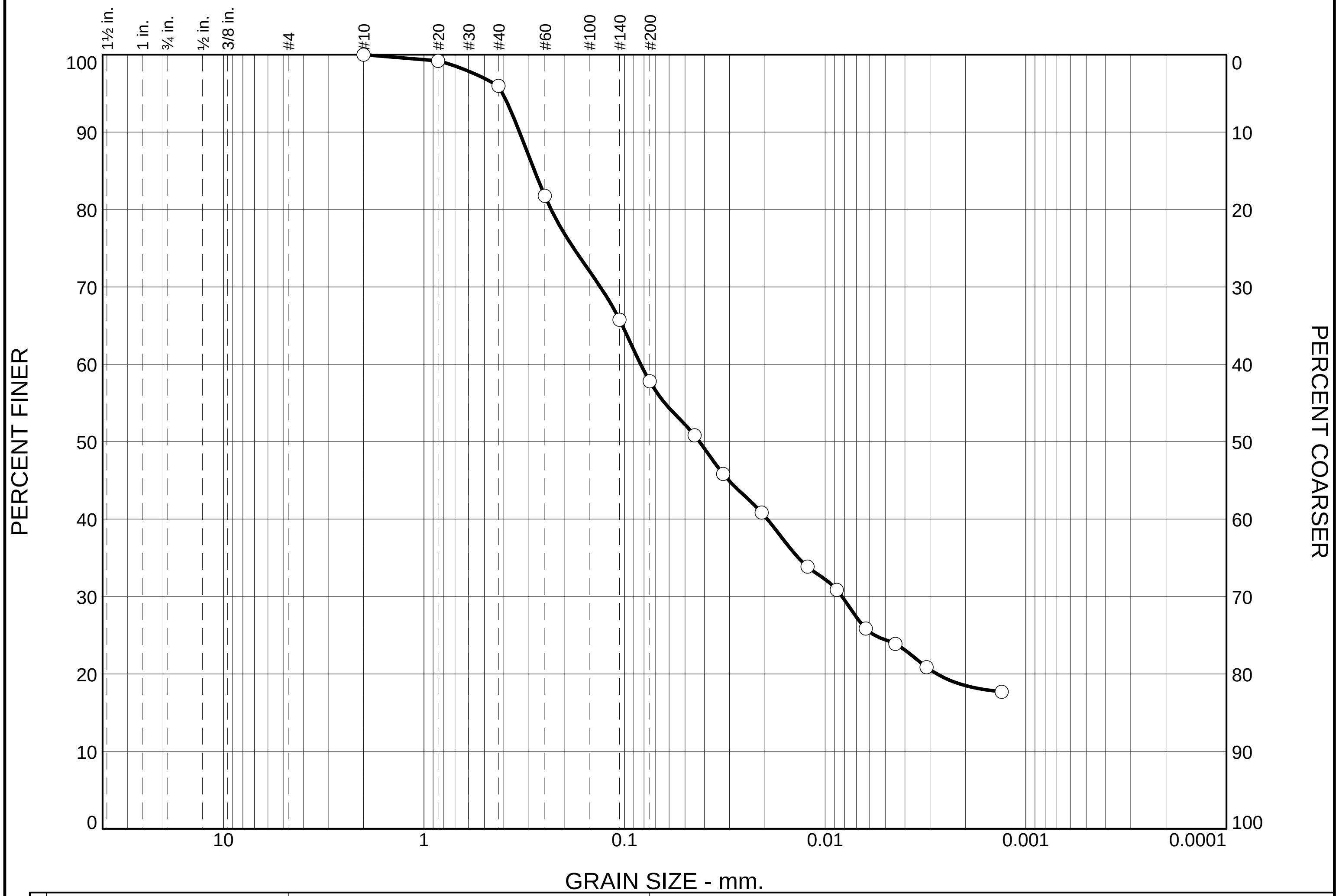
AECOM

Remarks:

○F.M.=4.20

Tested By: EMR **Checked By:** WPQ

Particle Size Analysis of Soils ASTM D422



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	0.0	0.0	4.0	38.2	33.4	24.4

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	19	9	0.2813		0.0423	0.0082				

Material Description	USCS	AASHTO
○ SILTY CLAY AND F-M SAND - BROWN	CL	A-4(2)

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

○ **Source of Sample:** B-GB-3 **Depth:** 13.0'-13.5' **Sample Number:** S-2A

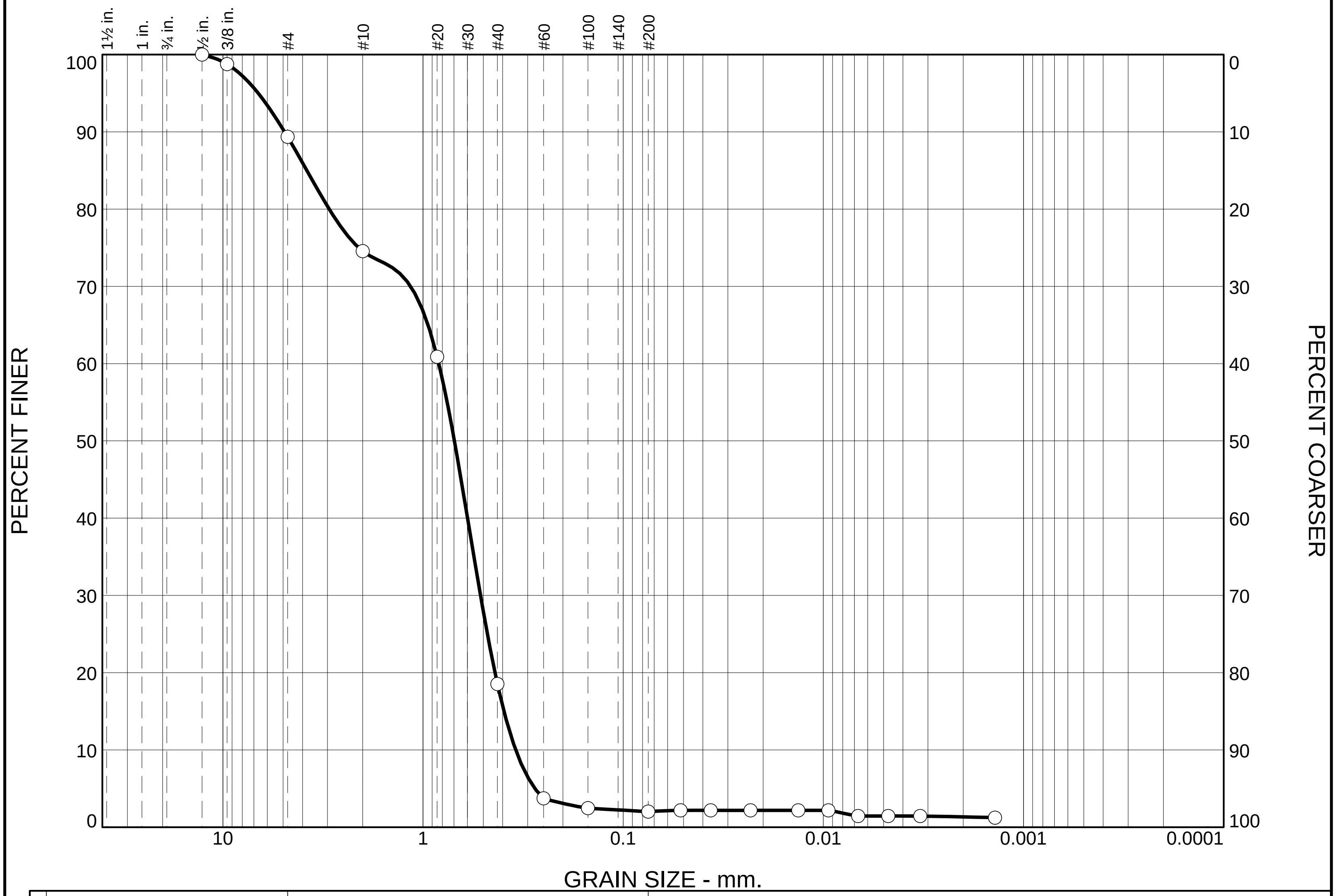
Remarks:

○F.M.=0.44

AECOM

Tested By: EMR **Checked By:** WPQ

Particle Size Analysis of Soils ASTM D422



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	10.6	14.8	56.1	16.5	0.6	1.4

╳	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			3.8078	0.8338	0.6977	0.5162	0.3941	0.3441	0.93	2.42

Material Description	USCS	AASHTO
○ F-C SAND LITTLE F GRAVEL TRACE CLAY - BROWN	SP	

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

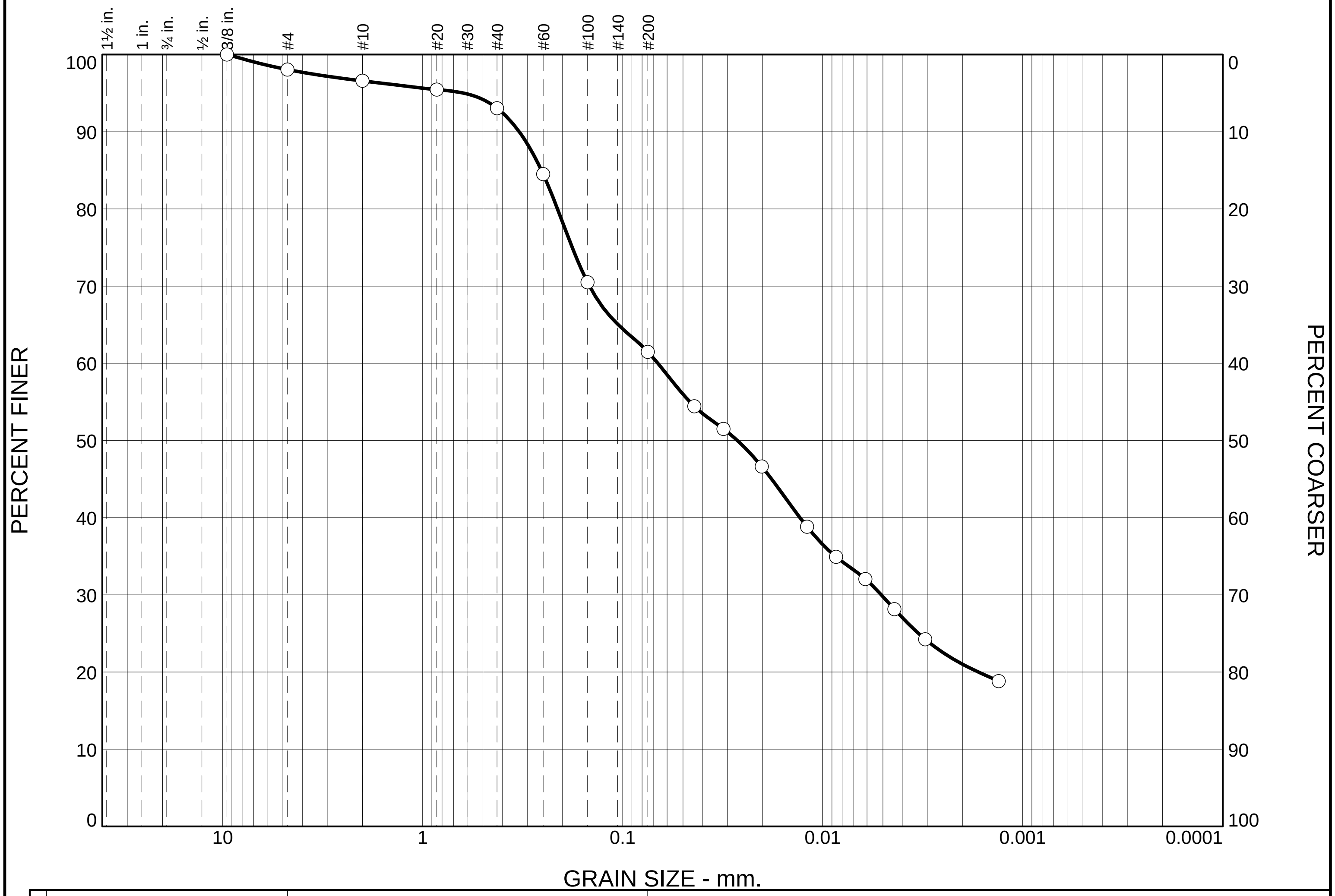
○ **Source of Sample:** B-GB-7 **Depth:** 12.0'-13.0' **Sample Number:** S-1

Remarks:

○F.M.=3.16

Tested By: SJH **Checked By:** WPQ

Particle Size Analysis of Soils ASTM D422



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	2.0	1.4	3.6	31.5	31.7	29.8

☒	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			0.2551		0.0267	0.0051				

Material Description	USCS	AASHTO
○ SILTY CLAY AND F-C SAND TRACE F GRAVEL - BROWN	CL	

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

○ **Source of Sample:** B-GB-7 **Depth:** 13.0'-14.0' **Sample Number:** S-1A

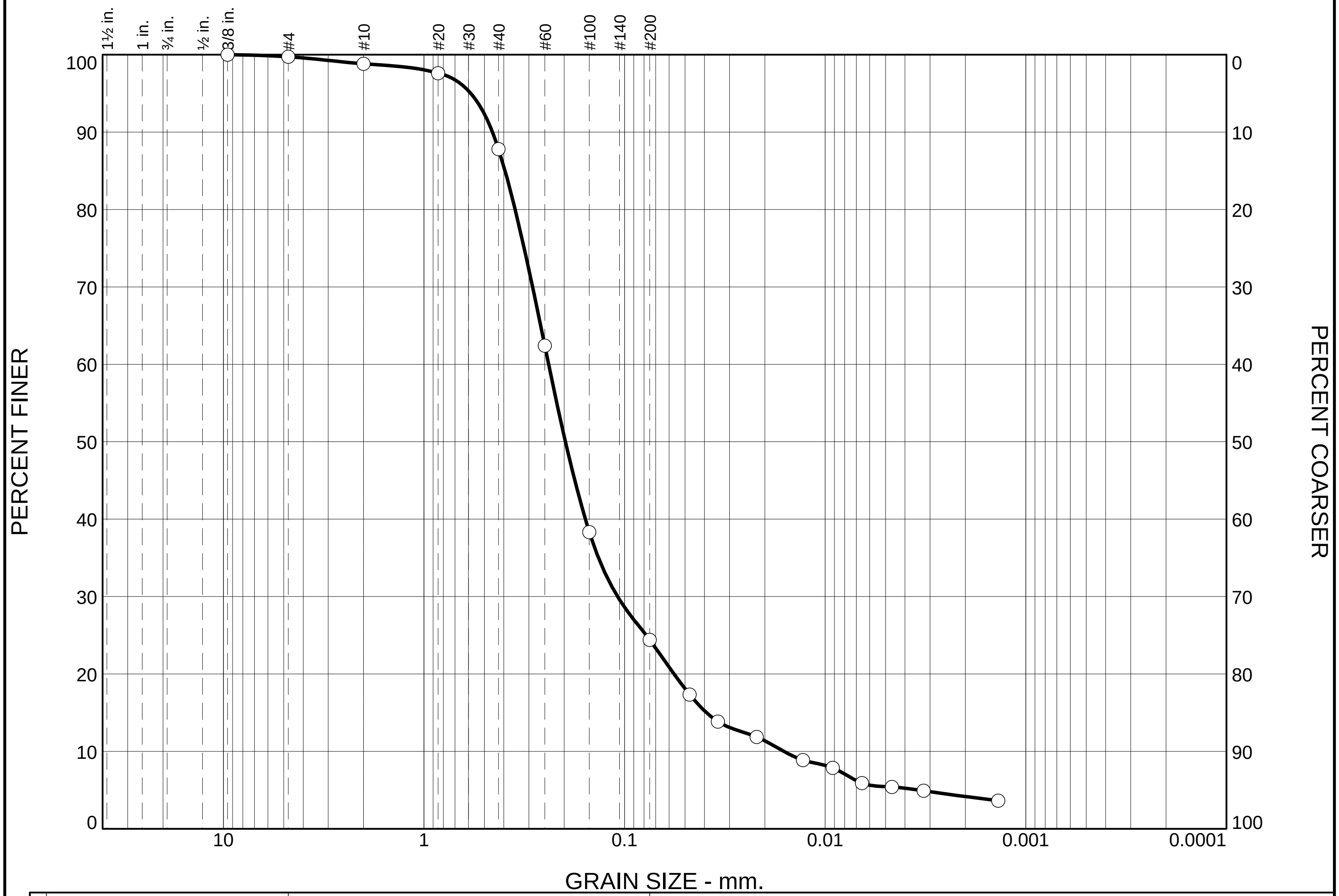
Remarks:

○F.M.=0.55

AECOM

Tested By: SJH **Checked By:** WPQ

Particle Size Analysis of Soils ASTM D422



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	0.3	0.9	11.0	63.4	19.0	5.4

☒	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			0.3940	0.2391	0.1971	0.1083	0.0391	0.0161	3.06	14.89

Material Description	USCS	AASHTO
○ F-M SAND LITTLE SILT TRACE CLAY - BROWN - MOIST	SM	

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

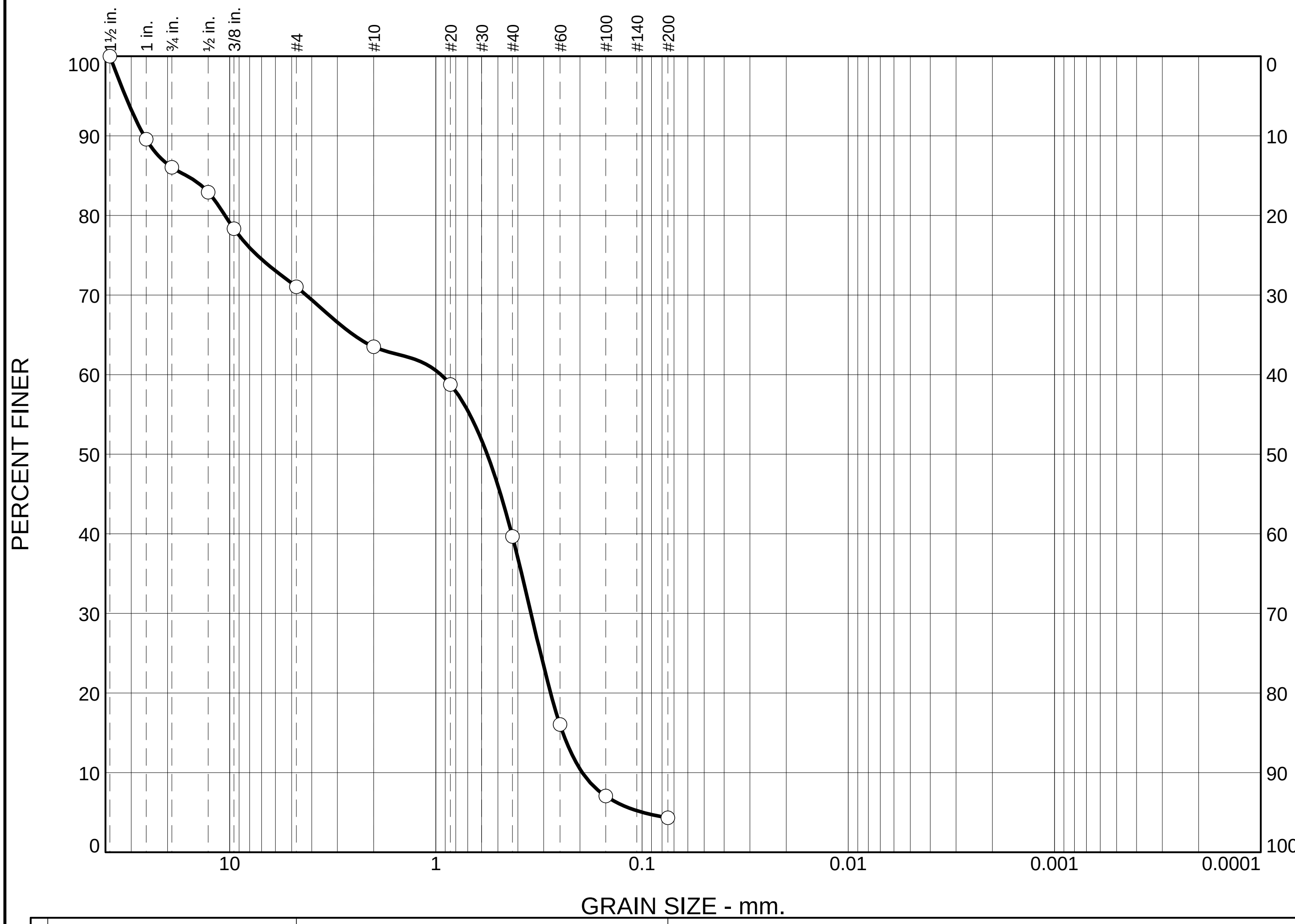
○ **Source of Sample:** B-GB-10 **Depth:** 0.0'-2.0' **Sample Number:** S-1

Remarks:

○F.M.=0.97

Tested By: SJH **Checked By:** WPQ

Particle Size Analysis of Soils ASTM D422



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	13.9	15.1	7.5	23.8	35.4	4.3	

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			16.2026	0.9449	0.5642	0.3454	0.2420	0.1950	0.65	4.85

Material Description	USCS	AASHTO
○ F-C SAND SOME F-C GRAVEL TRACE SILT - BROWN	SP	

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

○ **Source of Sample:** B-GB-10 **Depth:** 2.0'-4.0' **Sample Number:** S-2

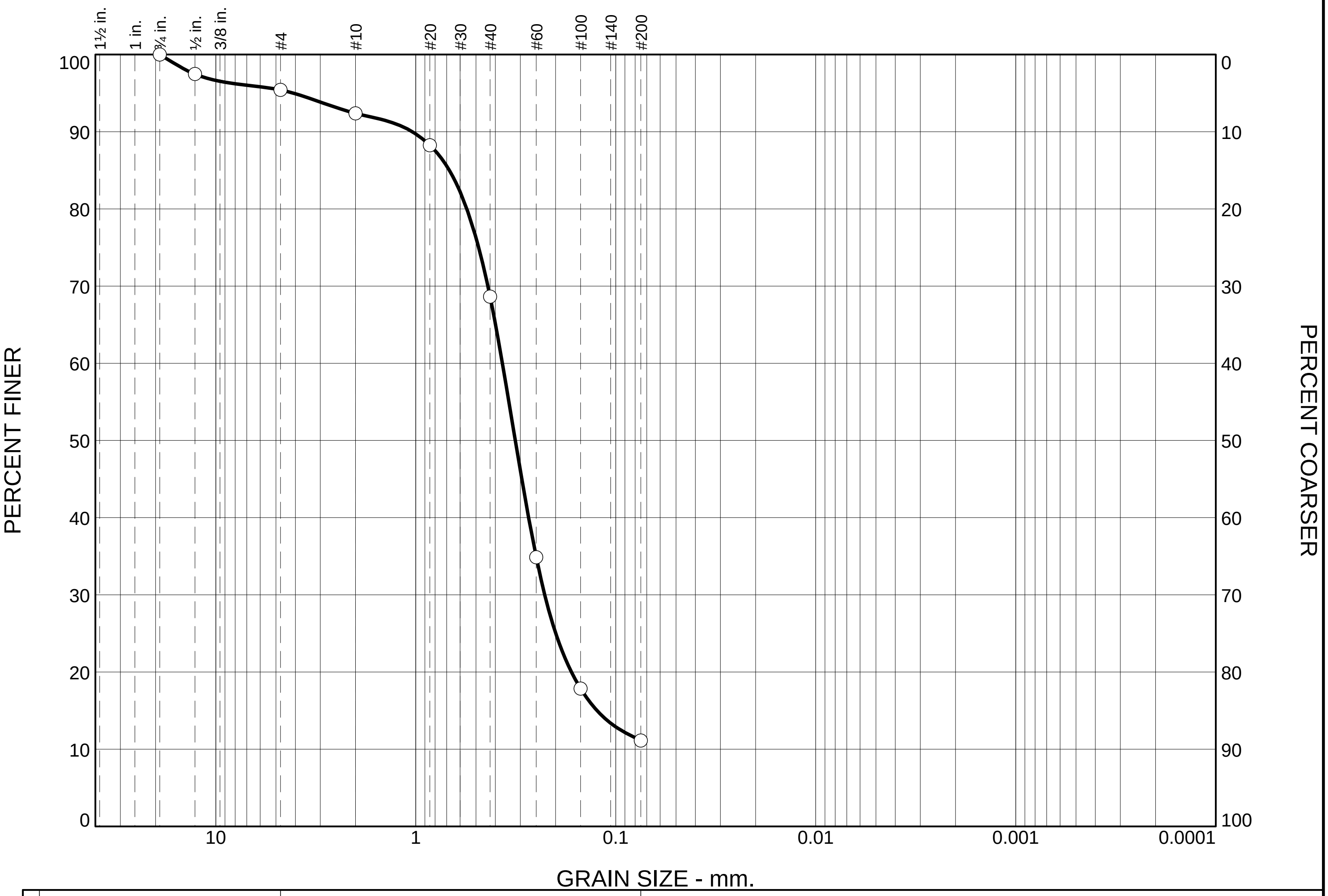
Remarks:

○F.M.=3.56

AECOM

Tested By: EMR **Checked By:** WPQ

Particle Size Analysis of Soils ASTM D422



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	4.6	3.0	23.8	57.5	11.1	

☒	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			0.6800	0.3687	0.3179	0.2265	0.1240			

Material Description	USCS	AASHTO
○ F-C SAND SOME SILT TRACE F GRAVEL - BROWN	SP-SM	

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

○ **Source of Sample:** B-GB-10 **Depth:** 8.0'-10.0' **Sample Number:** S-5

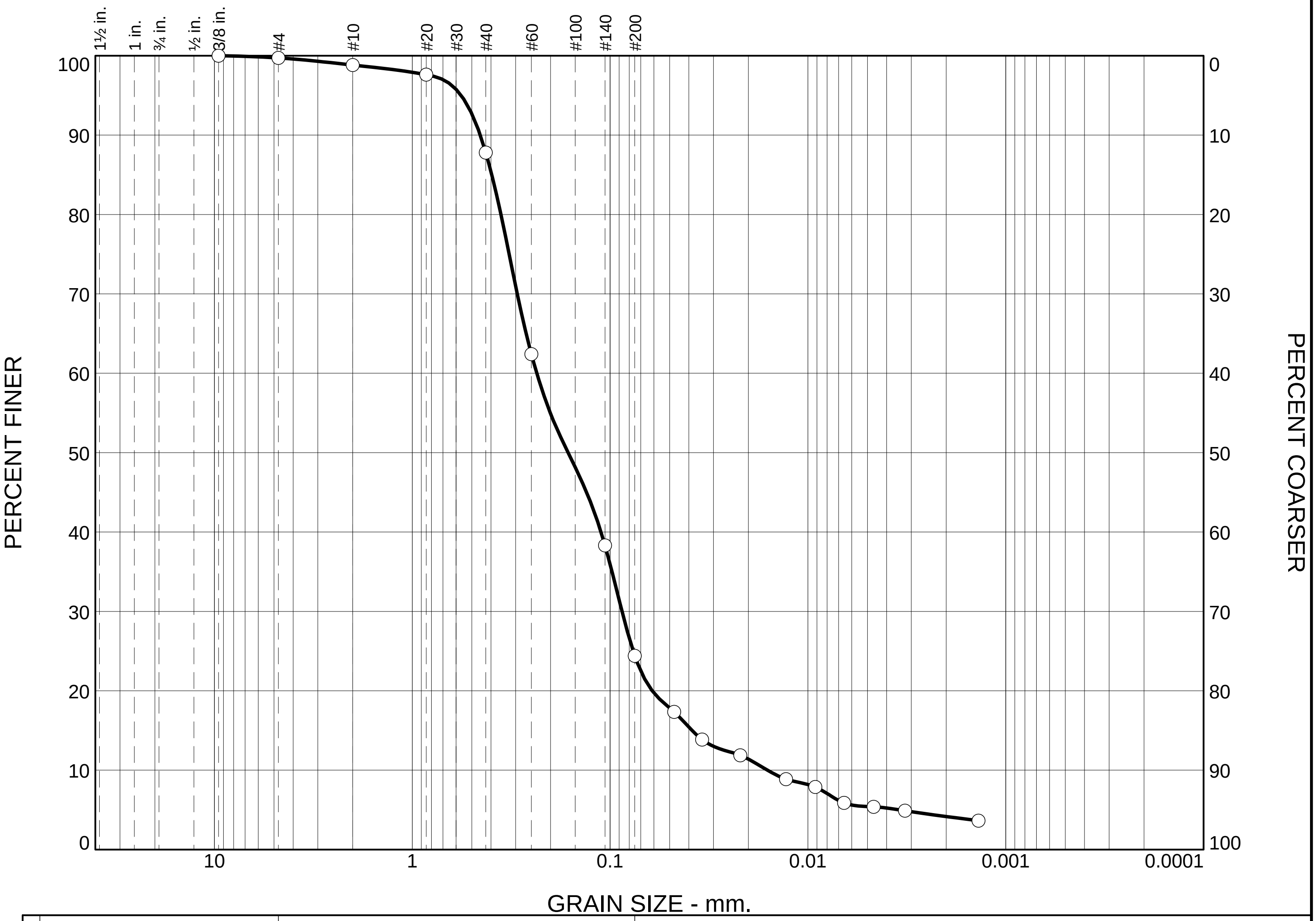
Remarks:

○F.M.=1.78

AECOM

Tested By: EMR **Checked By:** WPQ

Particle Size Analysis of Soils ASTM D422



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	0.3	0.9	11.0	63.4	19.0	5.4

☒	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			0.3969	0.2350	0.1629	0.0870	0.0385	0.0160	2.01	14.69

Material Description	USCS	AASHTO
○ F-M SAND LITTLE SILT TRACE CLAY - BROWN - MOIST	SM	

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

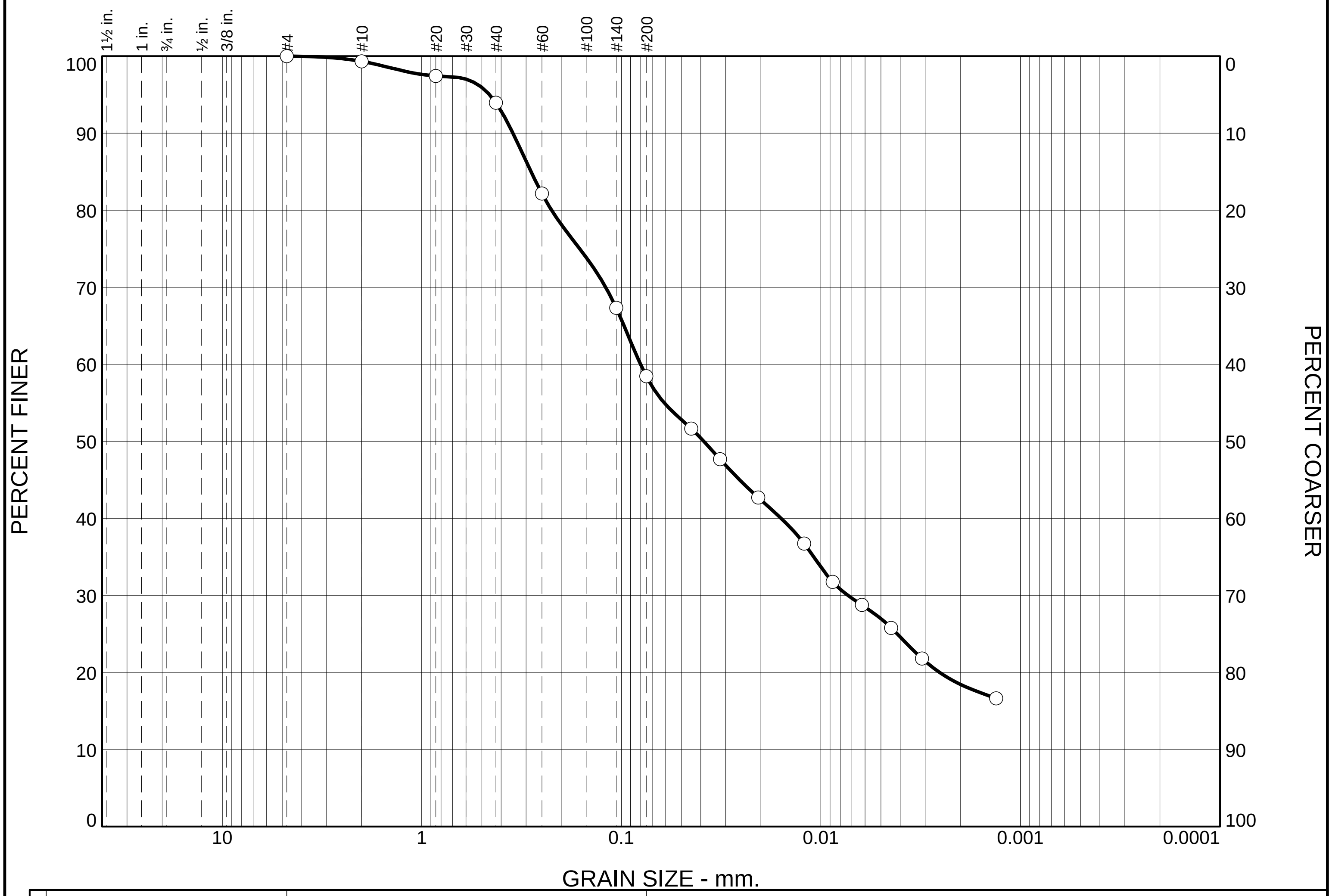
○ **Source of Sample:** B-GB-10 **Depth:** 12.0'-14.0' **Sample Number:** S-7

Remarks:

○F.M.=0.88

AECOM

Particle Size Analysis of Soils ASTM D422



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	0.0	0.7	5.3	35.5	31.5	27.0

☒	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	18	10	0.2835		0.0386	0.0073				

Material Description	USCS	AASHTO
○ SILTY CLAY AND F-M SAND - BROWN	CL	A-4(1)

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

○ **Source of Sample:** B-GB-10 **Depth:** 13.5'-14.0' **Sample Number:** S-7A

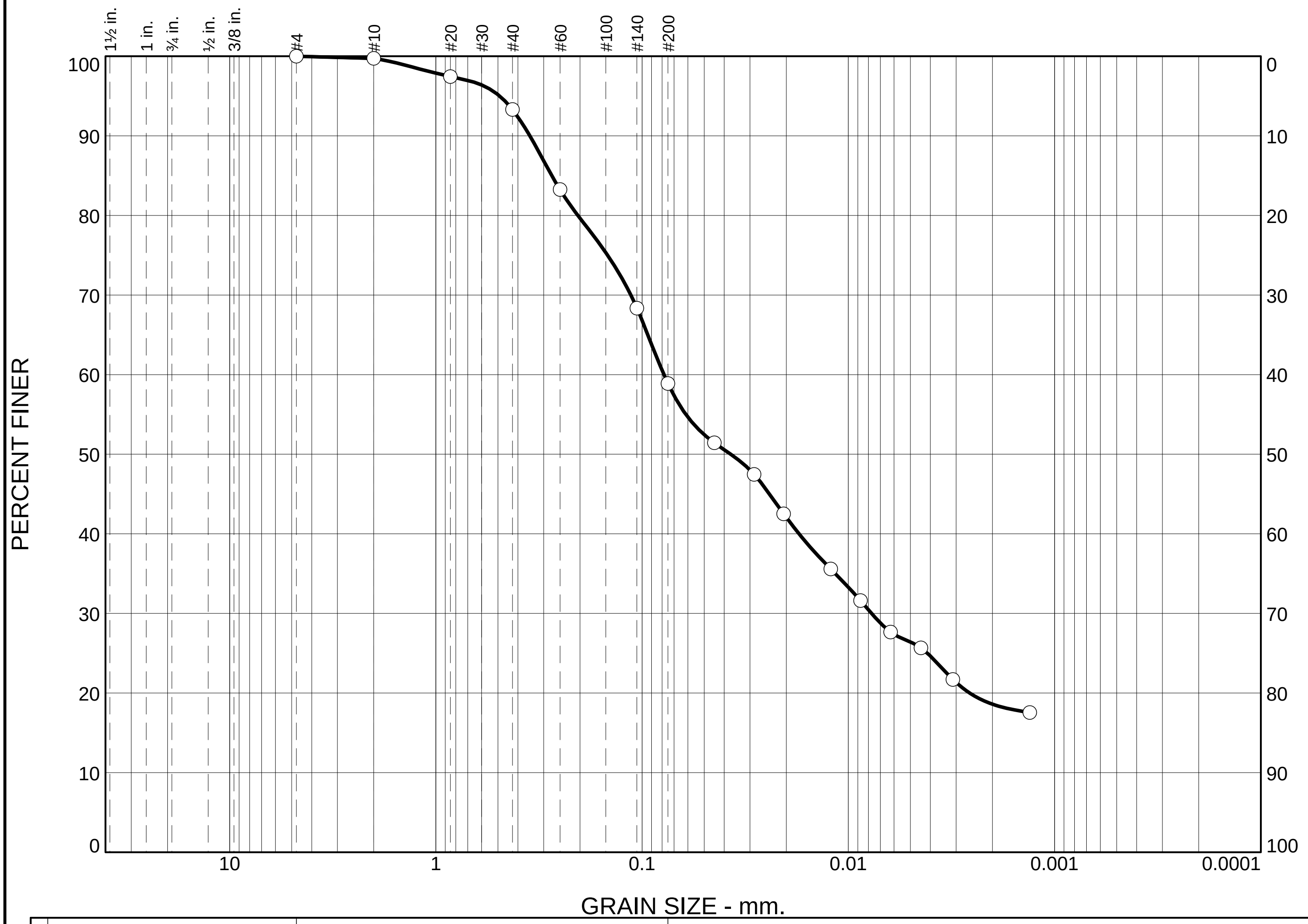
Remarks:

○SEAMS OF SAND NOTED
F.M.=0.45

AECOM

Tested By: BCM **Checked By:** WPQ

Particle Size Analysis of Soils ASTM D422



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	0.0	0.3	6.4	34.4	32.5	26.4

☒	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	18	10	0.2739		0.0372	0.0077				

Material Description	USCS	AASHTO
○ SILTY CLAY AND F-M SAND - BROWN	CL	A-4(1)

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

○ **Source of Sample:** B-GB-11 **Depth:** 13.5'-14.0' **Sample Number:** S-2A

Remarks:

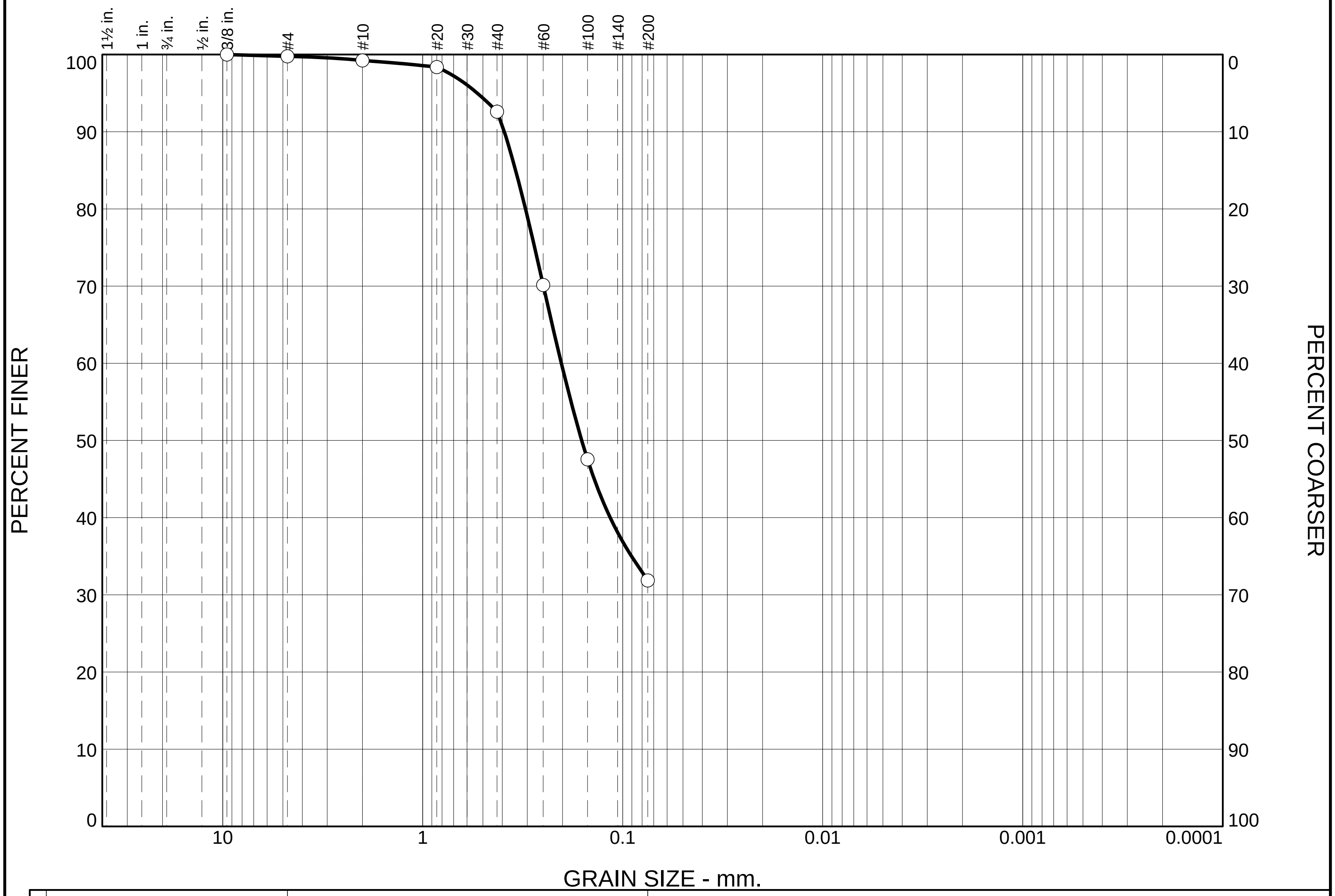
○SEAM OF SILT AND SAND NOTED

F.M.=0.43

AECOM

Tested By: BCM **Checked By:** WPQ

Particle Size Analysis of Soils ASTM D422



	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○ 0.0	0.0	0.2	0.6	6.6	60.7	31.9	

☒	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			0.3429	0.2026	0.1604					

Material Description	USCS	AASHTO
○ SILTY F-M SAND - BROWN	SM	

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

○ **Source of Sample:** B-GB-12 **Depth:** 8.0'-10.0' **Sample Number:** S-3

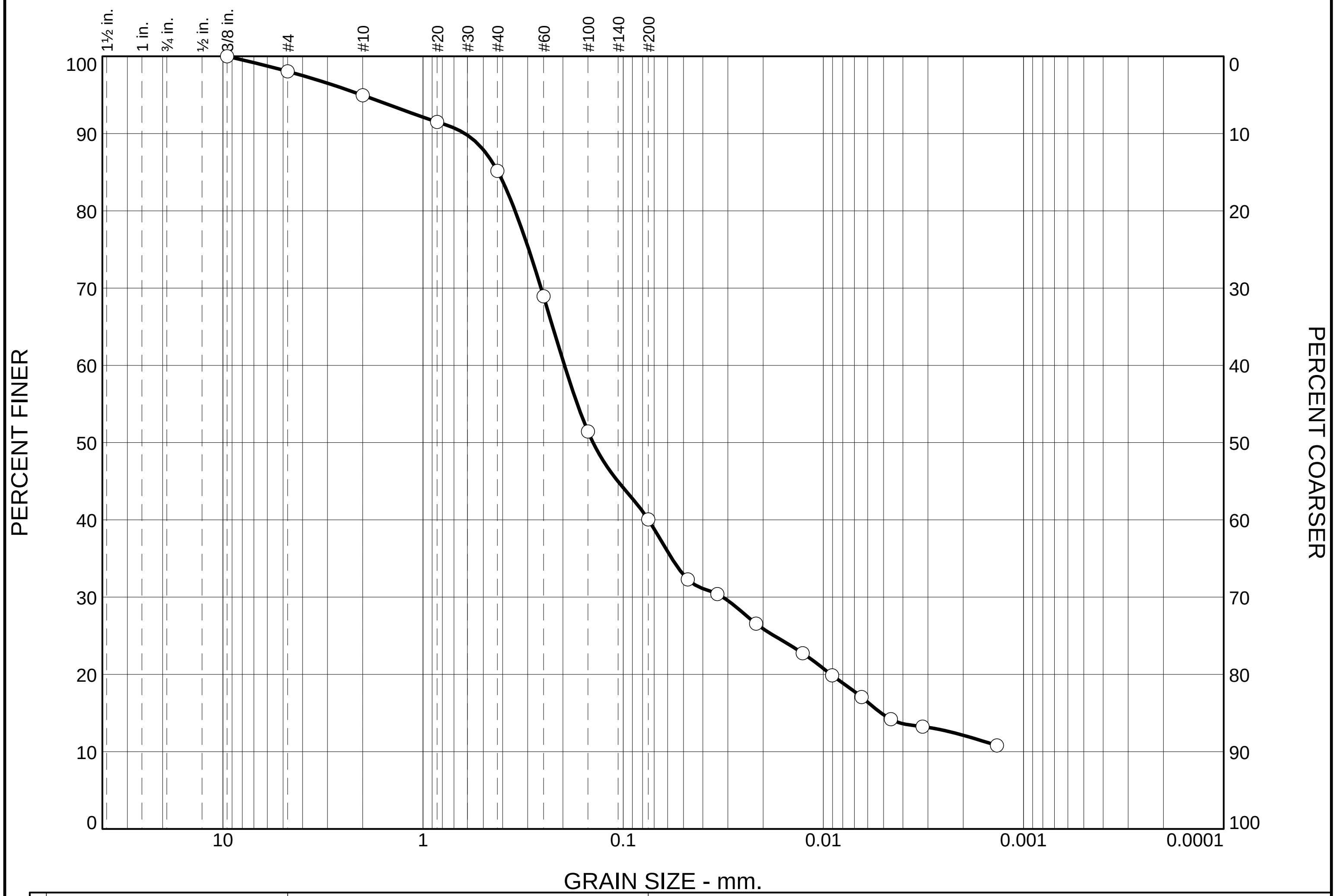
Remarks:

○F.M.=0.79

AECOM

Tested By: EMR **Checked By:** WPQ

Particle Size Analysis of Soils ASTM D422



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	1.9	3.1	9.8	45.1	25.3	14.8

☒	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	15	10	0.4217	0.1966	0.1413	0.0318	0.0051			

Material Description	USCS	AASHTO
○ F-C SAND SOME SILT LITTLE CLAY TRACE F GRAVEL - BROWN	SC-SM	A-4(0)

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

○ **Source of Sample:** B-GB-12 **Depth:** 10.5'-11.0' **Sample Number:** S-4A

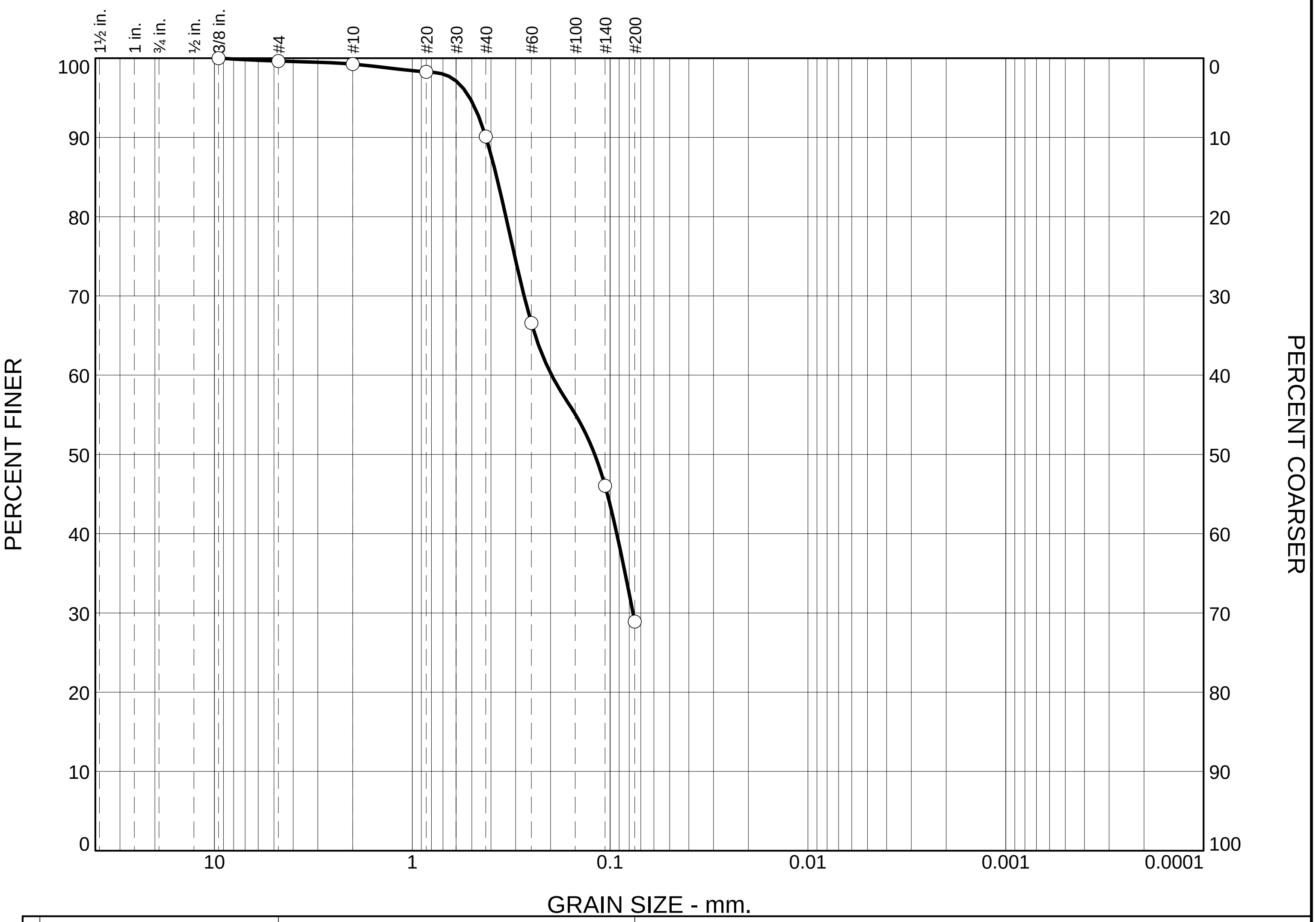
Remarks:

○F.M.=0.97

AECOM

Tested By: SJH **Checked By:** WPQ

Particle Size Analysis of Soils ASTM D422



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	0.4	0.3	9.2	61.2	28.9	

☒	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			0.3743	0.1972	0.1195	0.0765				

Material Description	USCS	AASHTO
○ SILTY F-M SAND - BROWN - MOIST	SM	

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

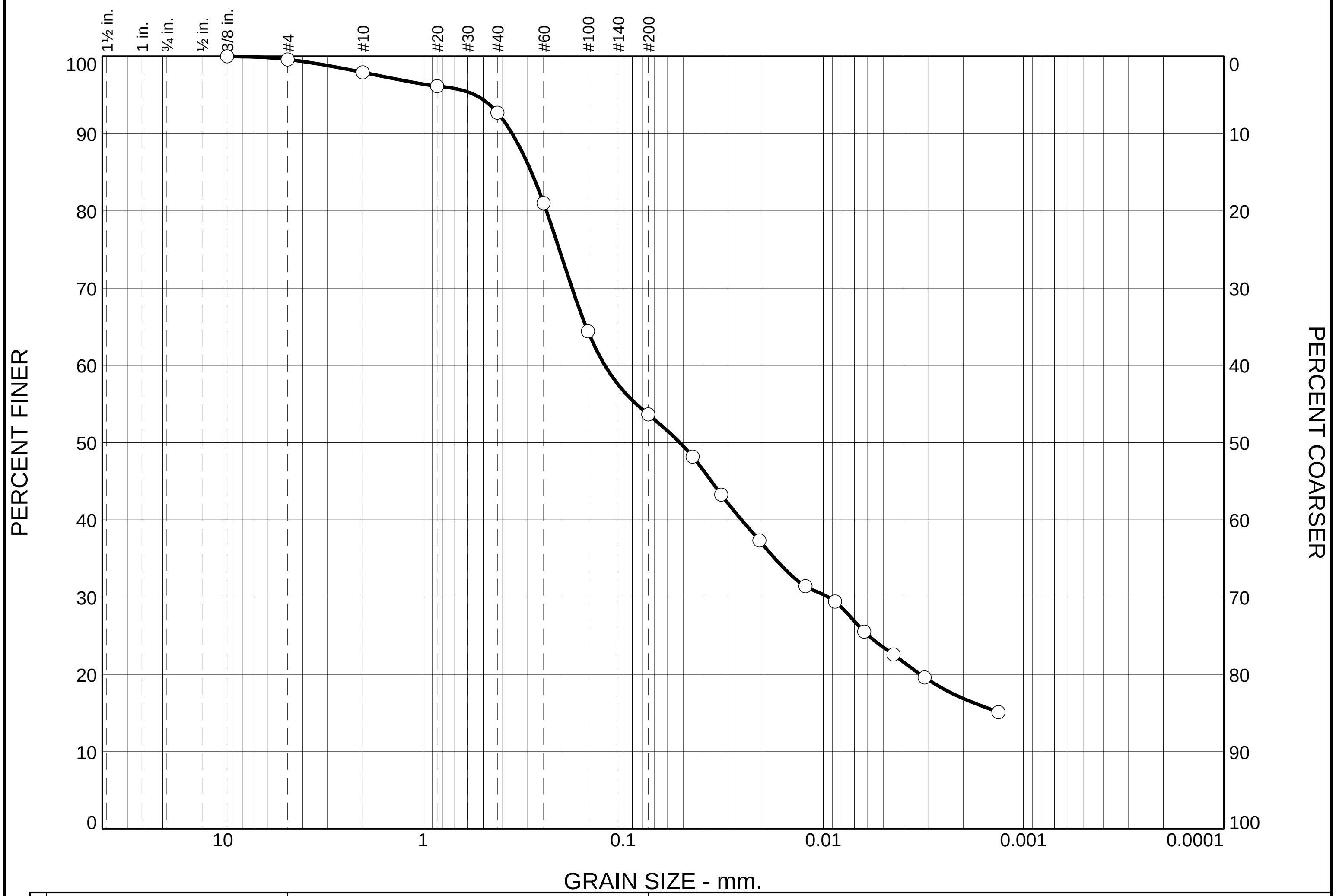
○ **Source of Sample:** B-GB-12 **Depth:** 12.0'-13.0' **Sample Number:** S-5

AECOM

Remarks:

○F.M.=0.76

Particle Size Analysis of Soils ASTM D422



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	0.4	1.7	5.2	39.0	30.2	23.5

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	18	10	0.2873	0.1235	0.0520	0.0094				

Material Description	USCS	AASHTO
○ SILTY CLAY AND F-C SAND - BROWN	CL	A-4(1)

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

○ **Source of Sample:** B-GB-12 **Depth:** 13.0'-14.0' **Sample Number:** S-5A

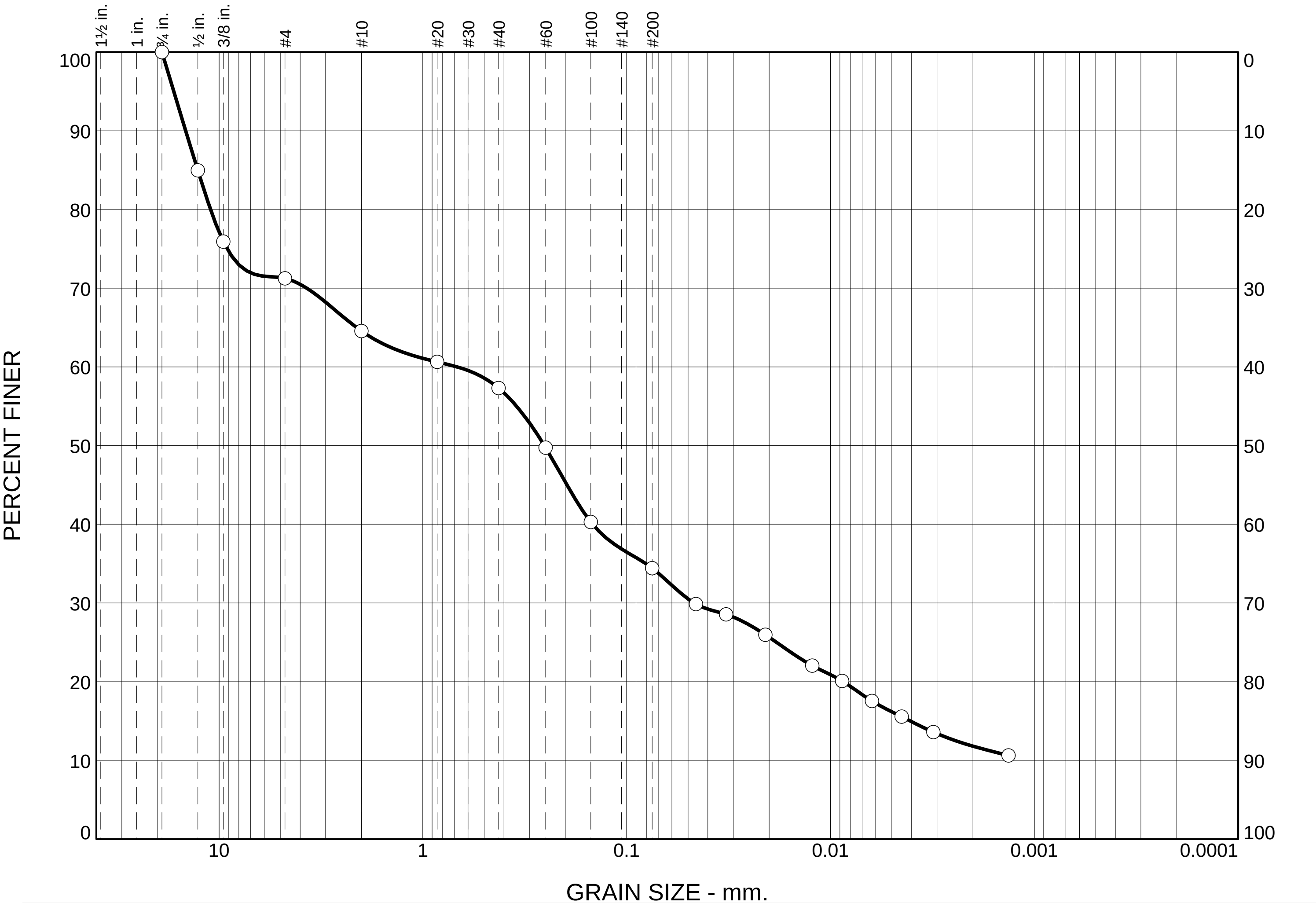
Remarks:

○F.M.=0.59

AECOM

Tested By: SJH **Checked By:** WPQ

Particle Size Analysis of Soils ASTM D422



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	28.8	6.7	7.2	22.9	18.2	16.2

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	18	9	12.7137	0.6810	0.2535	0.0467	0.0041			

Material Description	USCS	AASHTO
○ F-C SAND SOME F GRAVEL LITTLE SILT LITTLE CLAY - BROWN	SC	A-2-4(0)

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

○ **Source of Sample:** B-GB-12 **Depth:** 15.0'-16.0' **Sample Number:** S-6A

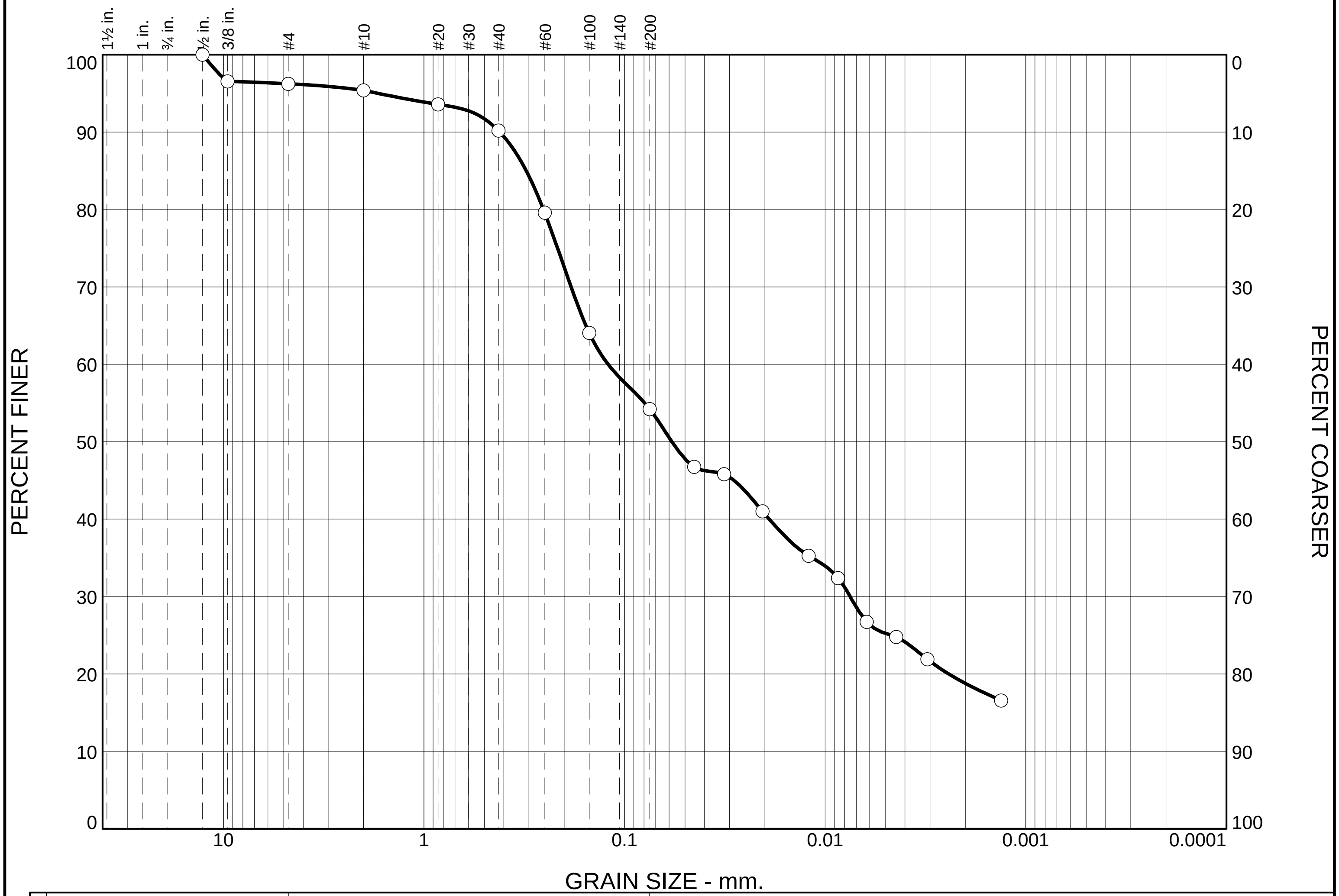
Remarks:

○F.M.=2.73

AECOM

Tested By: SJH **Checked By:** WPQ

Particle Size Analysis of Soils ASTM D422



	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○ 0.0	0.0	3.8	0.8	5.2	36.0	28.9	25.3

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	18	9	0.3099	0.1208	0.0581	0.0075				

Material Description	USCS	AASHTO
○ SILTY CLAY AND F-M SAND TRACE F GRAVEL - BROWN	CL	A-4(1)

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

○ **Source of Sample:** B-GB-12 **Depth:** 16.5'-17.5' **Sample Number:** S-7A

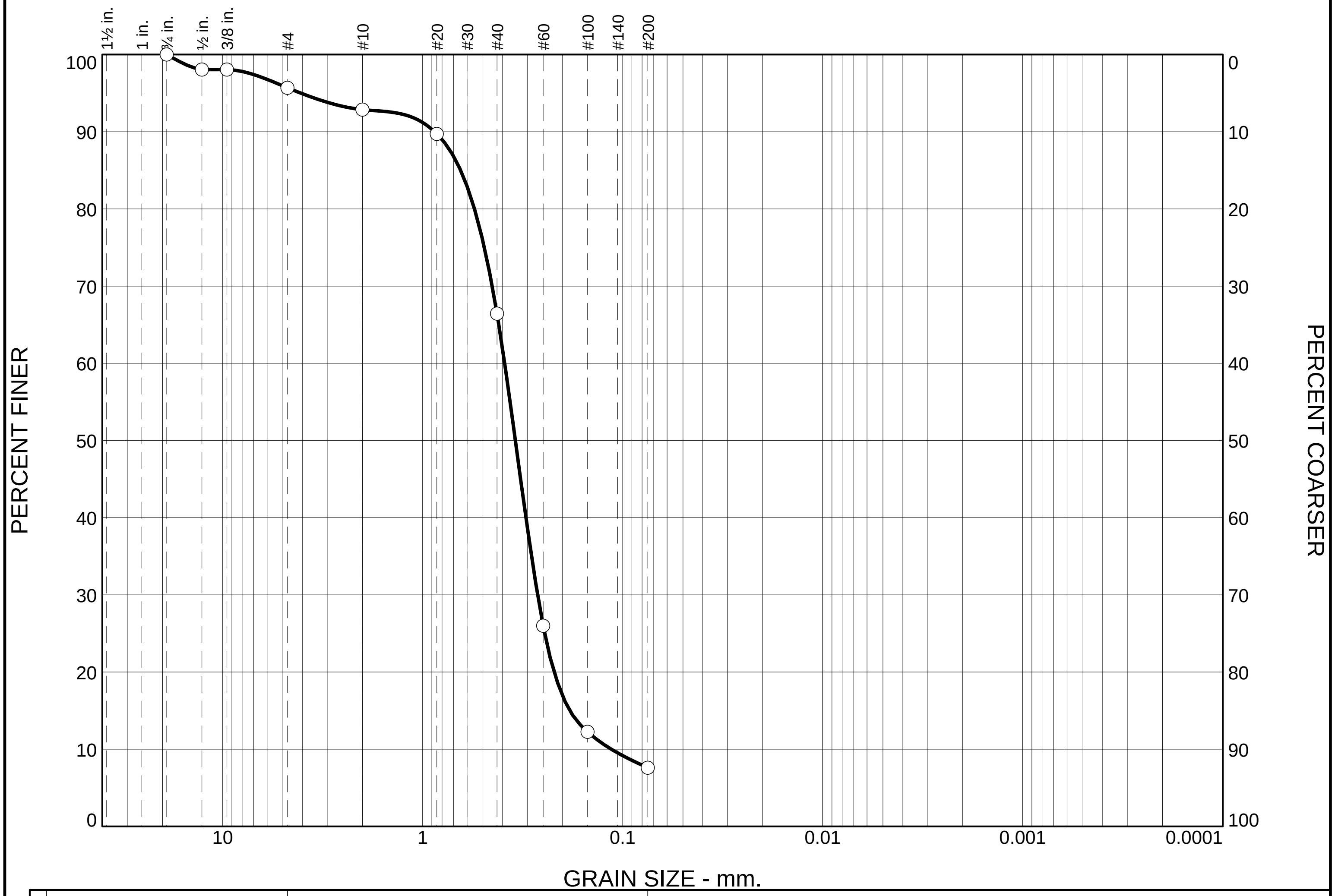
Remarks:

○F.M.=0.76

AECOM

Tested By: SJH **Checked By:** WPQ

Particle Size Analysis of Soils ASTM D422



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	4.3	2.8	26.5	58.8	7.6	

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			0.6466	0.3892	0.3440	0.2665	0.1839	0.1140	1.60	3.41

Material Description	USCS	AASHTO
○ F-C SAND TRACE SILT TRACE F GRAVEL - BROWN	SP-SM	

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

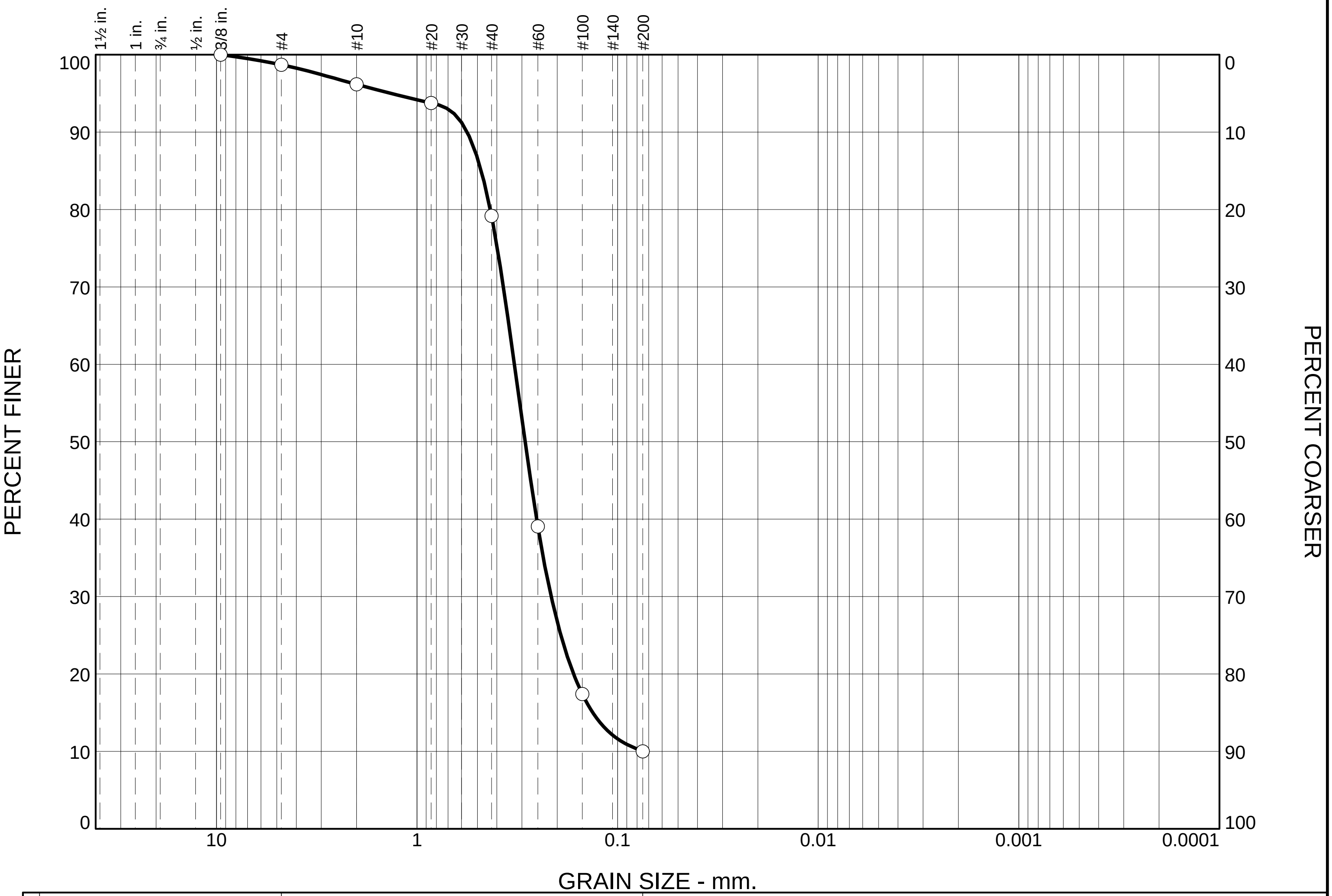
○ **Source of Sample:** B-GB-13 **Depth:** 6.0'-7.2' **Sample Number:** S-2

Remarks:

○F.M.=1.87

Tested By: EMR **Checked By:** WPQ

Particle Size Analysis of Soils ASTM D422



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	1.3	2.5	17.0	69.2	10.0	

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			0.4786	0.3269	0.2893	0.2144	0.1328			

Material Description	USCS	AASHTO
○ F-C SAND LITTLE SILT TRACE F GRAVEL - BROWN	SP-SM	

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C
Project: BROWN BRIDGE DAM

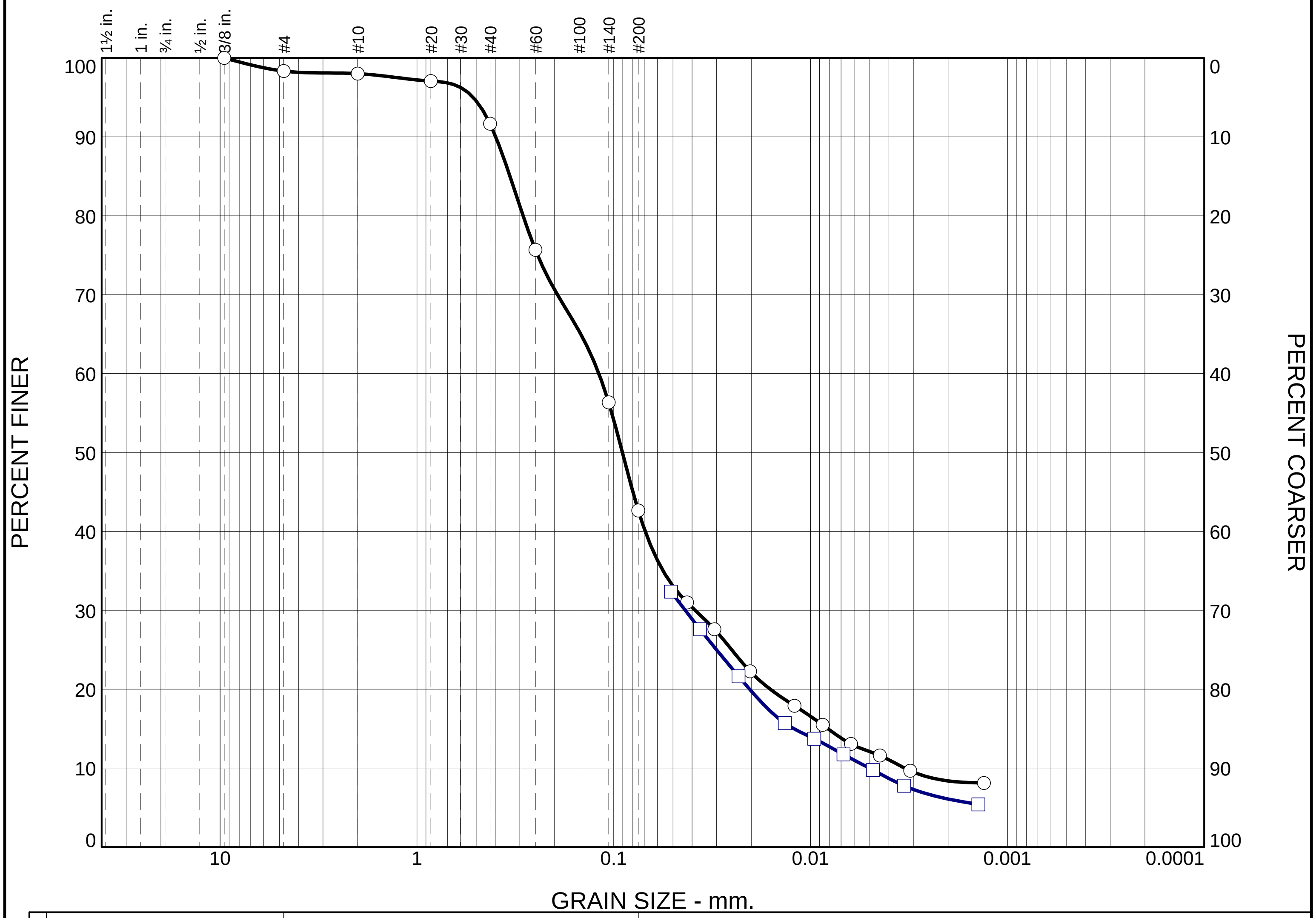
○ **Source of Sample:** B-GB-13 **Depth:** 8.0'-9.15' **Sample Number:** S-3

AECOM

Remarks:
○F.M.=1.48

Tested By: EMR **Checked By:** WPQ

Dispersive Analysis by Double Hydrometer ASTM D 4221



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	1.7	0.3	6.3	49.1	30.5	12.1
□								10.0

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			0.3367	0.1189	0.0903	0.0386	0.0082	0.0033	3.77	35.78
□						0.0433	0.0122	0.0050		

Material Description	USCS	AASHTO
○ F-C SAND SOME SILT LITTLE CLAY TRACE F GRAVEL - BROWN	SM	
□		

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

○ **Source of Sample:** B-GB-13 **Depth:** 11.0'-12.0' **Sample Number:** S-4A

□ **Sample Source:** B-GB-13 **Depth:** 11.0'-12.0' **Sample No.:** S-4A DOUBLE

AECOM

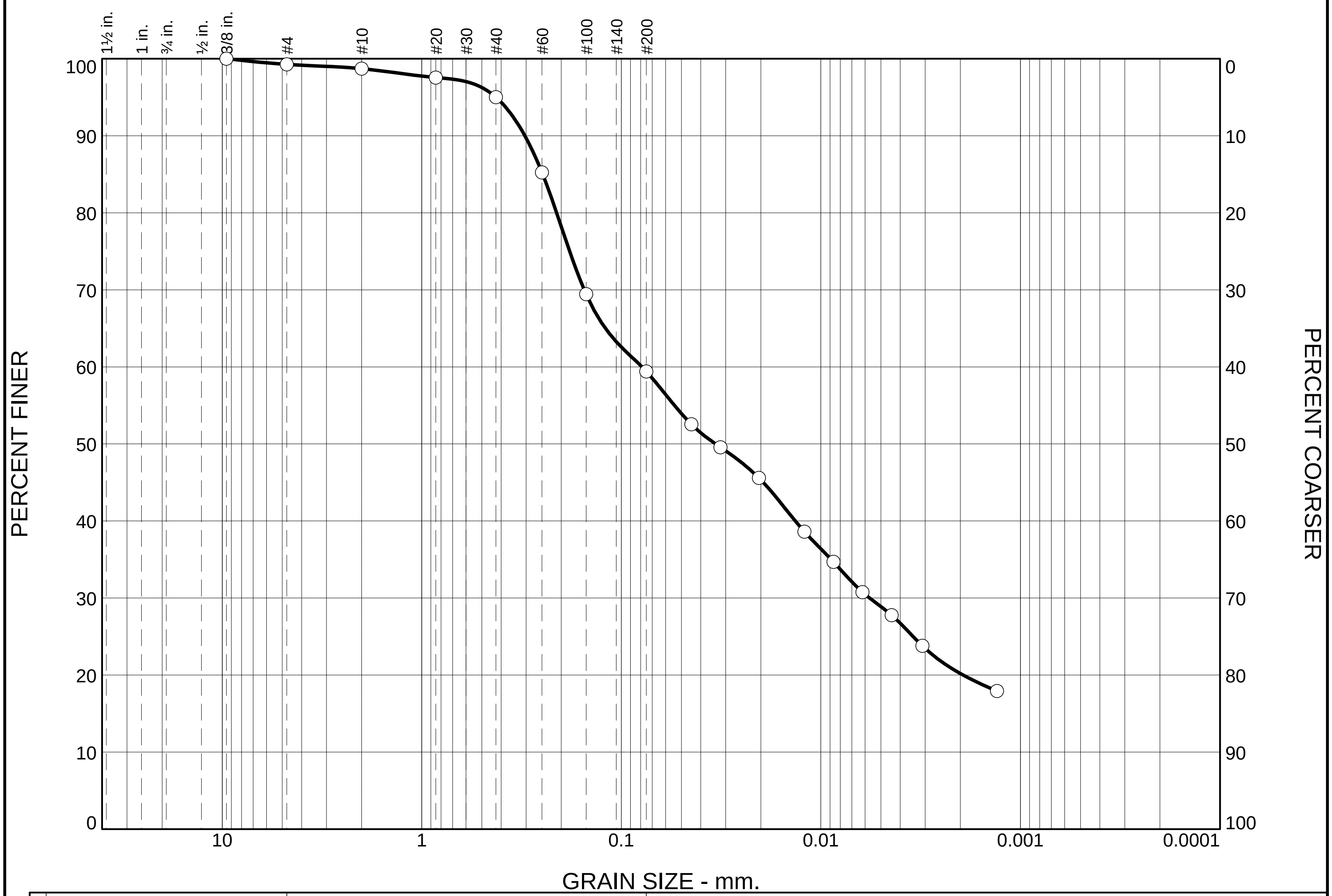
Remarks:

○SEAMS AND LAYERS OF SAND NOTED

F.M.=0.63

□82.6% DISPERSION FOR THE CLAY PORTION OF THIS SAMPLE.

Particle Size Analysis of Soils ASTM D422



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	0.7	0.6	3.7	35.6	30.5	28.9

☒	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	18	9	0.2480		0.0337	0.0057				

Material Description	USCS	AASHTO
○ SILTY CLAY AND F-M SAND - BROWN	CL	A-4(2)

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

○ **Source of Sample:** B-GB-13 **Depth:** 12.2'-12.8' **Sample Number:** S-5A

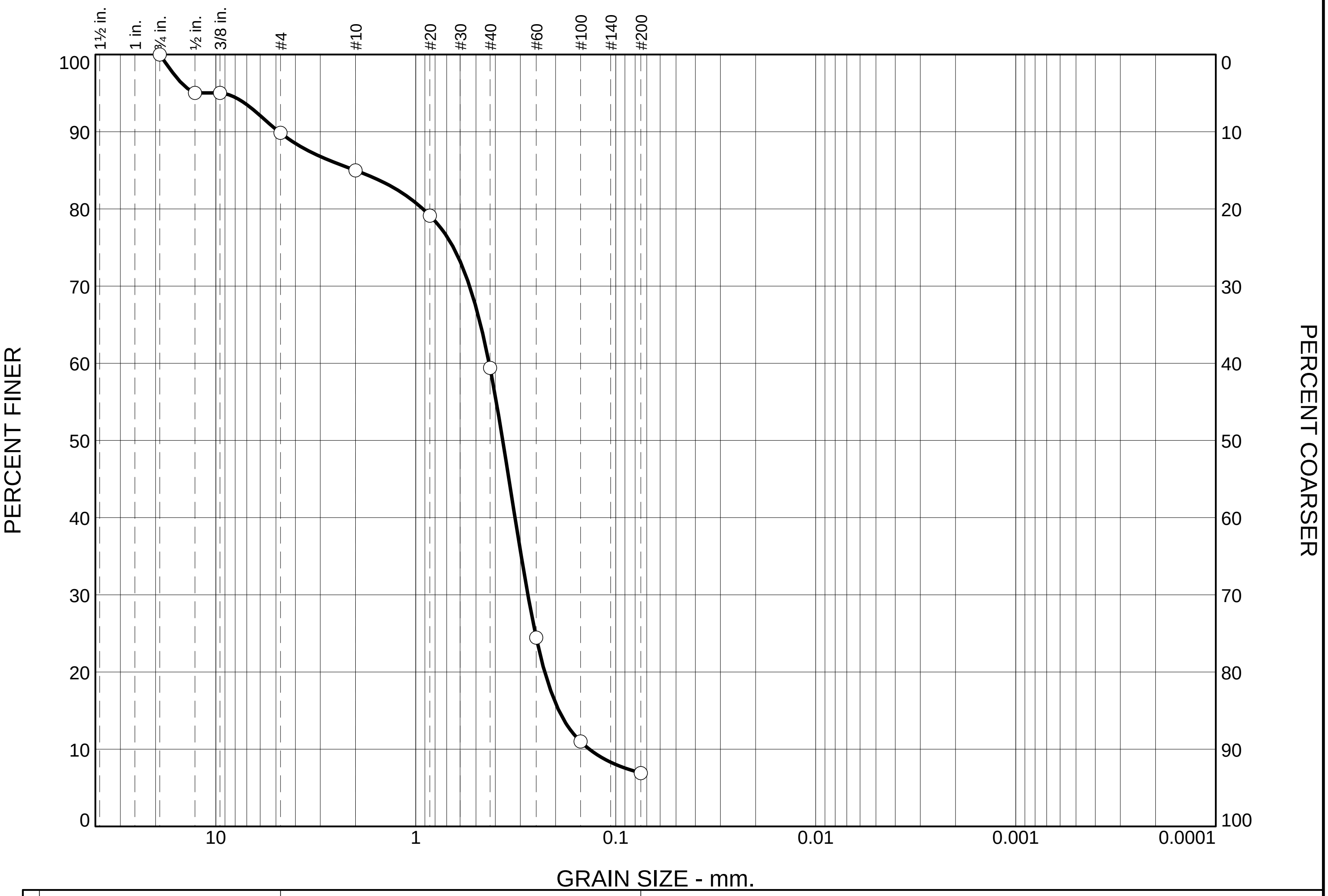
Remarks:

○F.M.=0.48

AECOM

Tested By: SJH **Checked By:** WPQ

Particle Size Analysis of Soils ASTM D422



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	10.2	4.8	25.6	52.5	6.9	

☒	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			2.0082	0.4296	0.3671	0.2752	0.1926	0.1353	1.30	3.17

Material Description	USCS	AASHTO
○ F-C SAND LITTLE F GRAVEL TRACE SILT - BROWN	SP-SM	

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

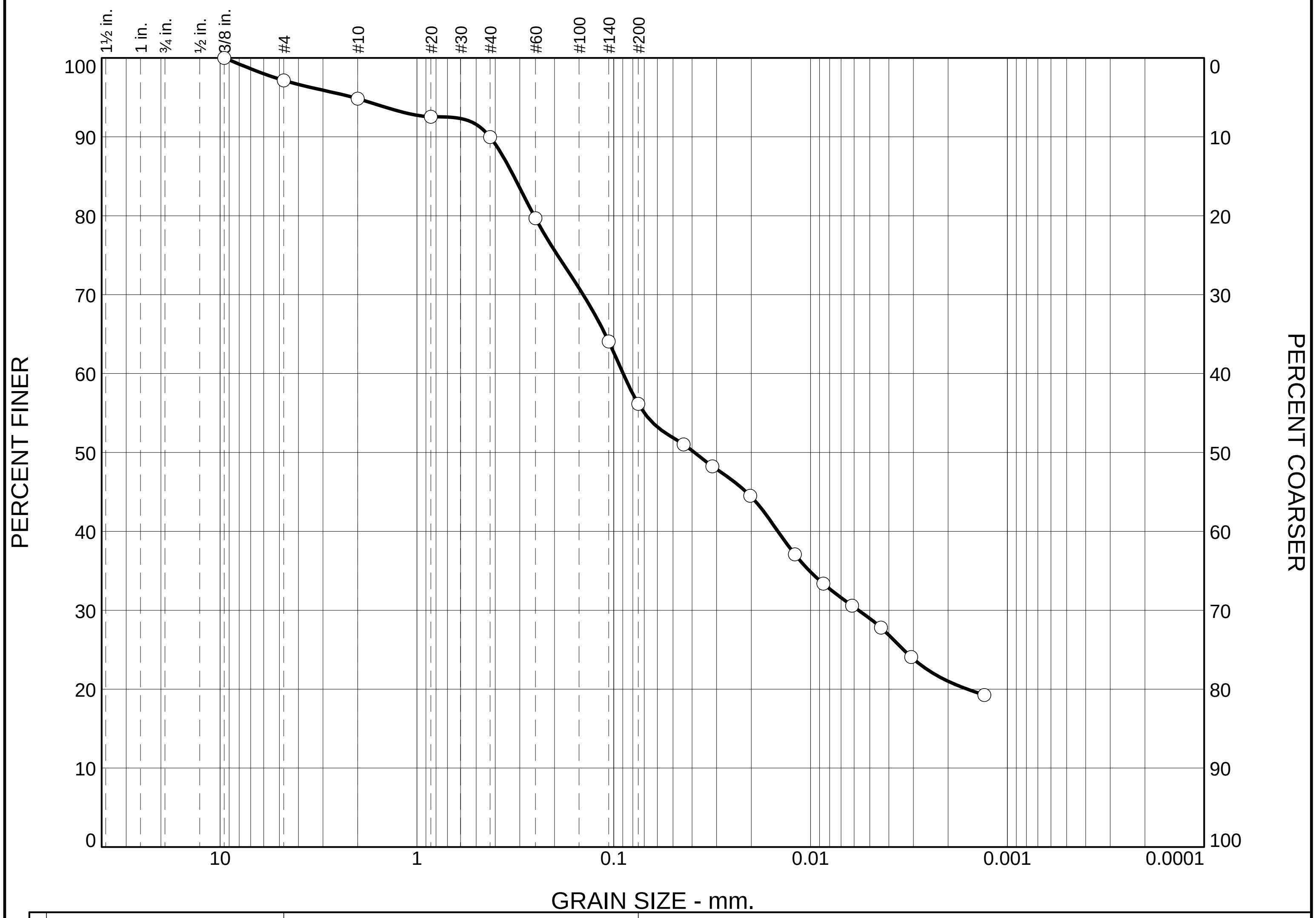
○ **Source of Sample:** B-GB-14 **Depth:** 6.0'-8.0' **Sample Number:** S-2

Remarks:

○F.M.=2.27

Tested By: EMR **Checked By:** WPQ

Particle Size Analysis of Soils ASTM D422



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	2.8	2.4	4.8	33.8	27.2	29.0

☒	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	20	9	0.3216		0.0389	0.0057				

Material Description	USCS	AASHTO
○ SILTY CLAY AND F-C SAND TRACE F GRAVEL - BROWN	CL	A-6(3)

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

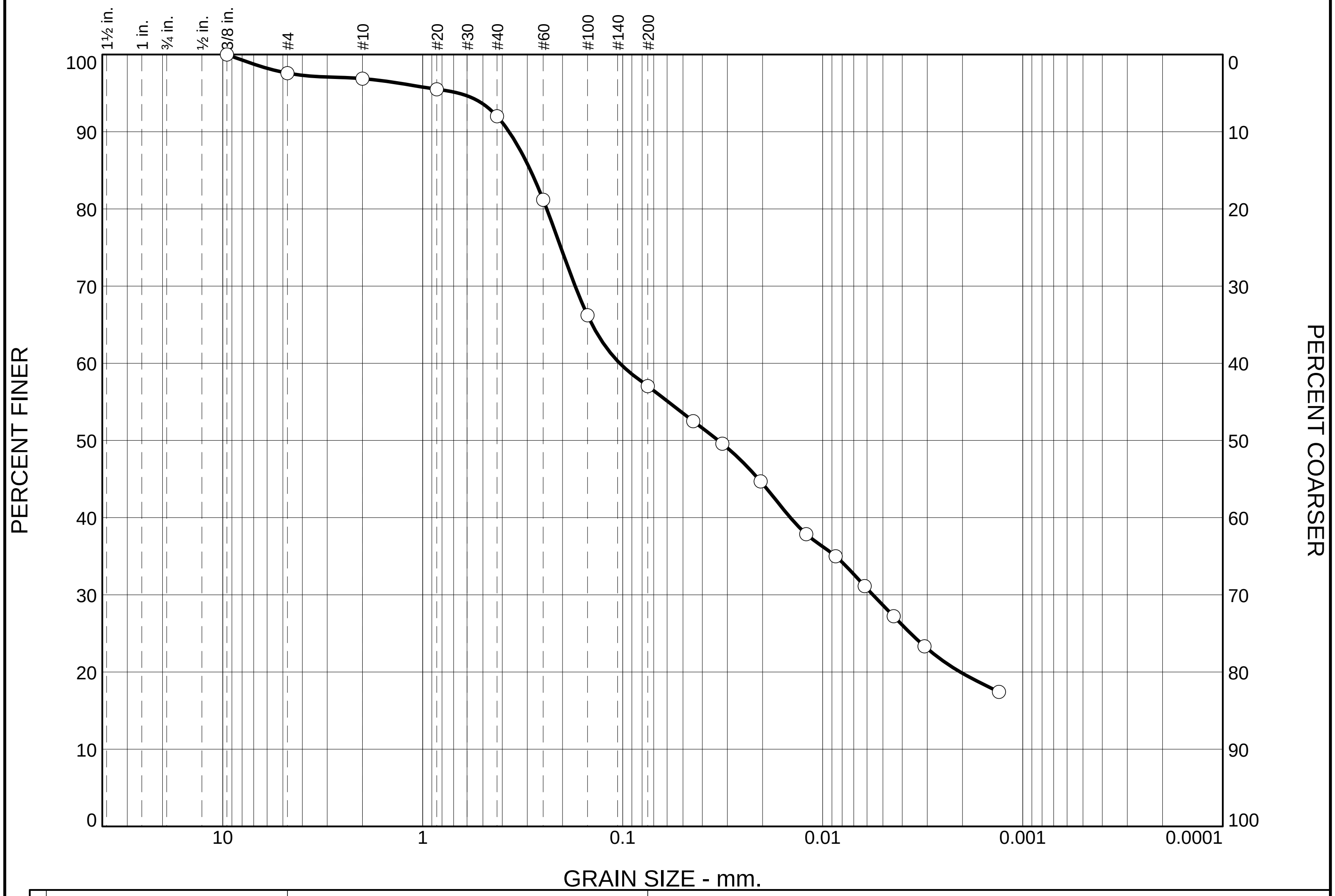
○ **Source of Sample:** B-GB-14 **Depth:** 9.25'-10.0' **Sample Number:** S-3A

Remarks:

○SEAMS OF SILT AND SAND NOTED

F.M.=0.68

Particle Size Analysis of Soils ASTM D422



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	2.4	0.7	4.9	35.0	28.3	28.7

☒	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	18	9	0.2893	0.1034	0.0333	0.0056				

Material Description	USCS	AASHTO
○ SILTY CLAY AND F-M SAND TRACE F GRAVEL - BROWN	CL	A-4(2)

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

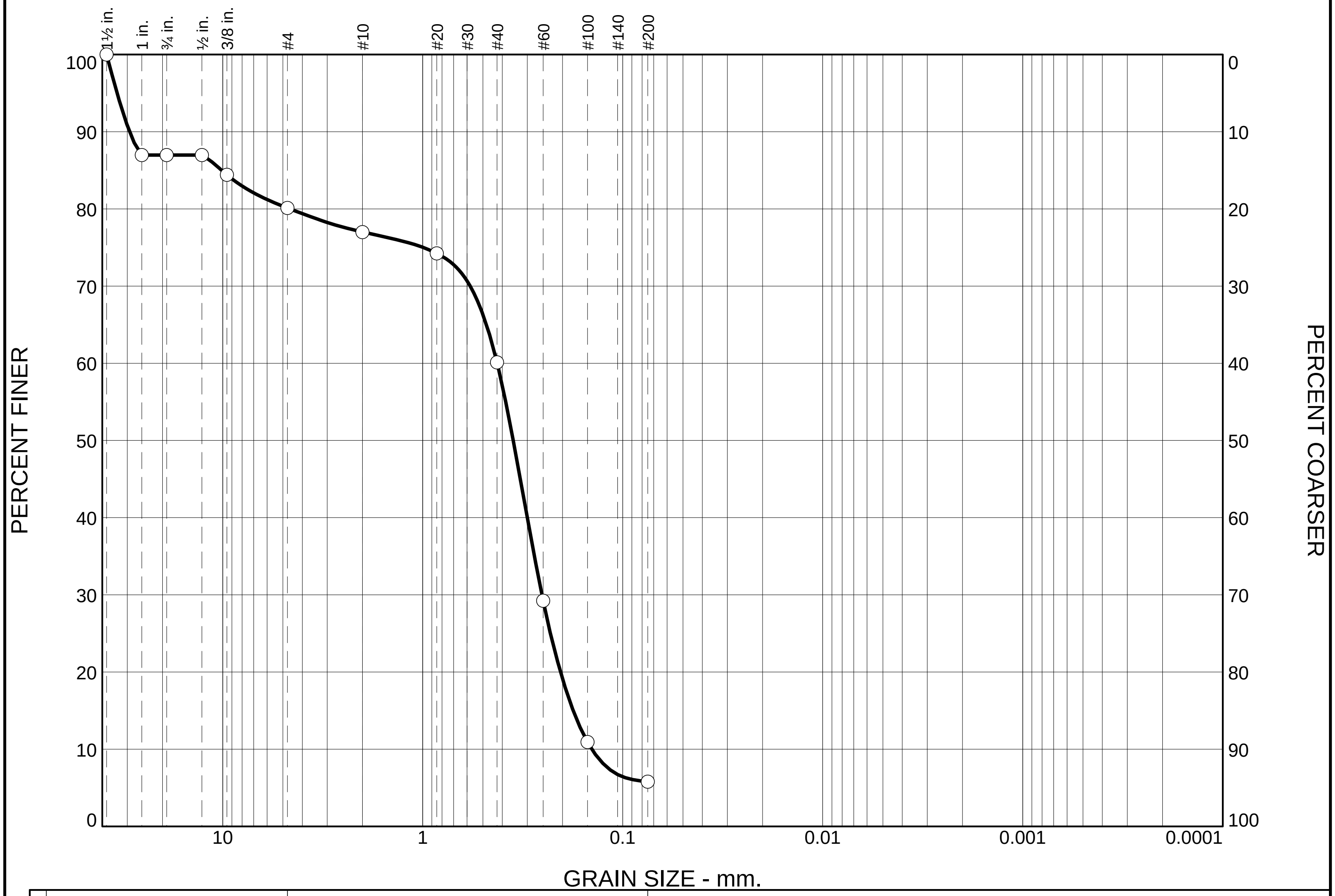
○ **Source of Sample:** B-GB-14 **Depth:** 12.0'-13.1' **Sample Number:** S-5

Remarks:

○F.M.=0.63

Tested By: SJH **Checked By:** WPQ

Particle Size Analysis of Soils ASTM D422



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	13.0	6.9	3.1	16.9	54.3	5.8	

☒	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			10.1190	0.4239	0.3526	0.2535	0.1770	0.1427	1.06	2.97

Material Description	USCS	AASHTO
○ F-C SAND LITTLE F GRAVEL TRACE SILT - BROWN	SP-SM	

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

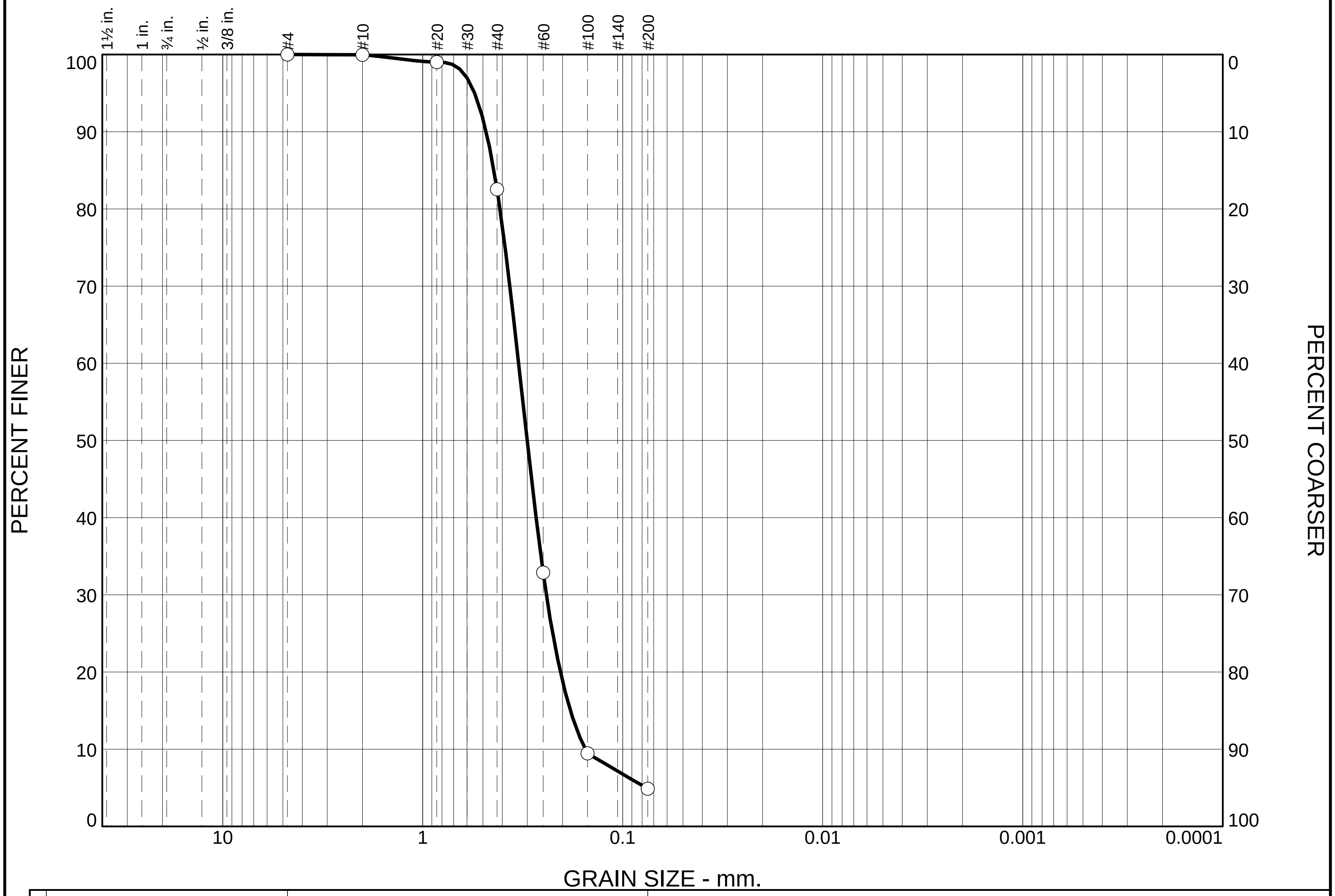
○ **Source of Sample:** B-GB-15 **Depth:** 5.0'-6.0' **Sample Number:** S-1A

Remarks:

○F.M.=2.74

Tested By: EMR **Checked By:** WPQ

Particle Size Analysis of Soils ASTM D422



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	0.0	0.0	17.5	77.6	4.9	

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			0.4406	0.3314	0.3004	0.2409	0.1828	0.1538	1.14	2.15

Material Description	USCS	AASHTO
○ F-C SAND TRACE SILT - BROWN	SP	

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

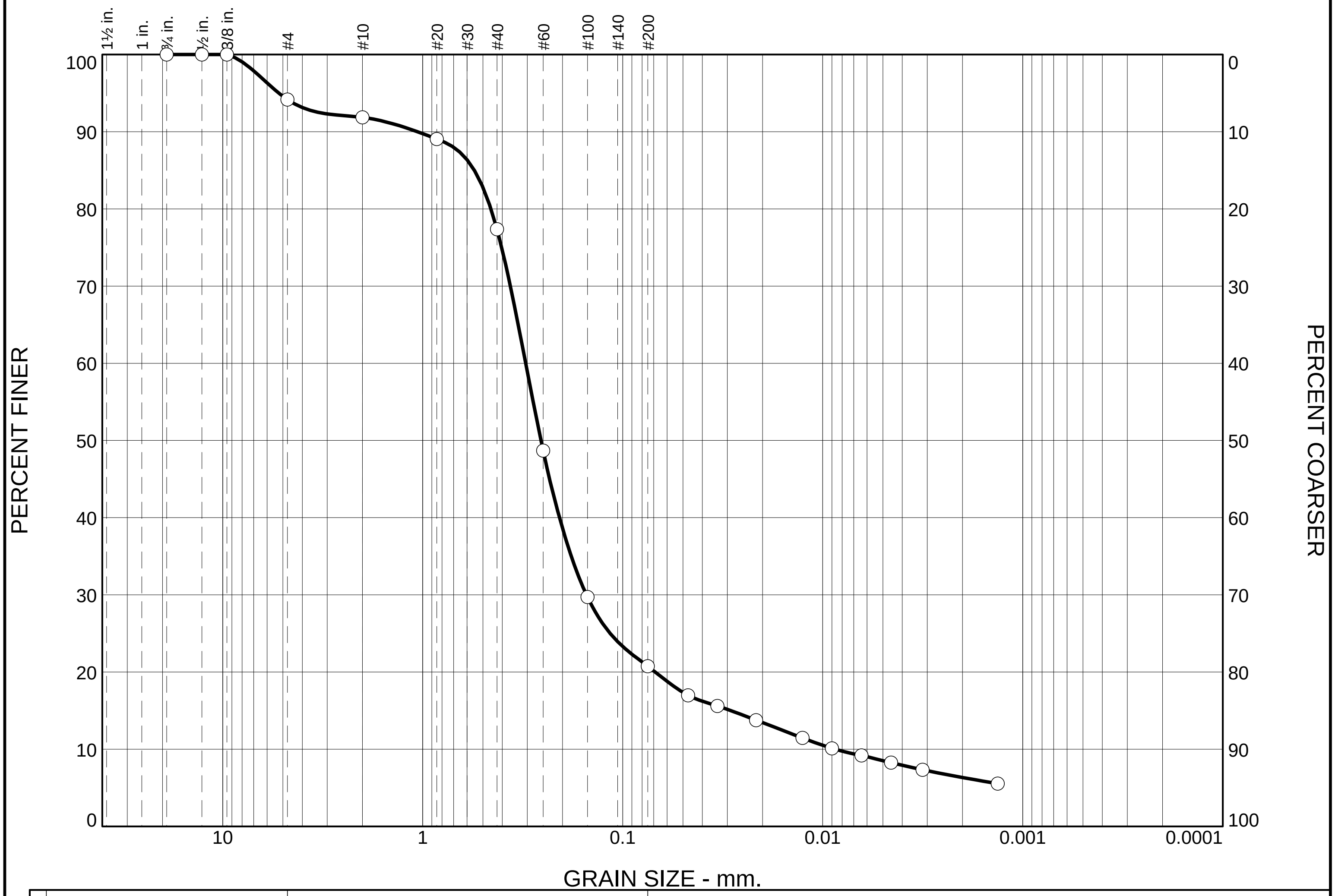
○ **Source of Sample:** B-GB-15 **Depth:** 8.0'-9.5' **Sample Number:** S-3

Remarks:

○F.M.=1.44

Tested By: EMR **Checked By:** WPQ

Particle Size Analysis of Soils ASTM D422



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	5.8	2.4	14.4	56.6	12.3	8.5

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	11	11	0.5520	0.3056	0.2563	0.1518	0.0288	0.0087	8.68	35.19

Material Description	USCS	AASHTO
○ F-C SAND LITTLE SILT TRACE CLAY TRACE F GRAVEL - BROWN	SM	A-2-4(0)

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

○ **Source of Sample:** B-GB-15 **Depth:** 13.0'-13.5' **Sample Number:** S-5A

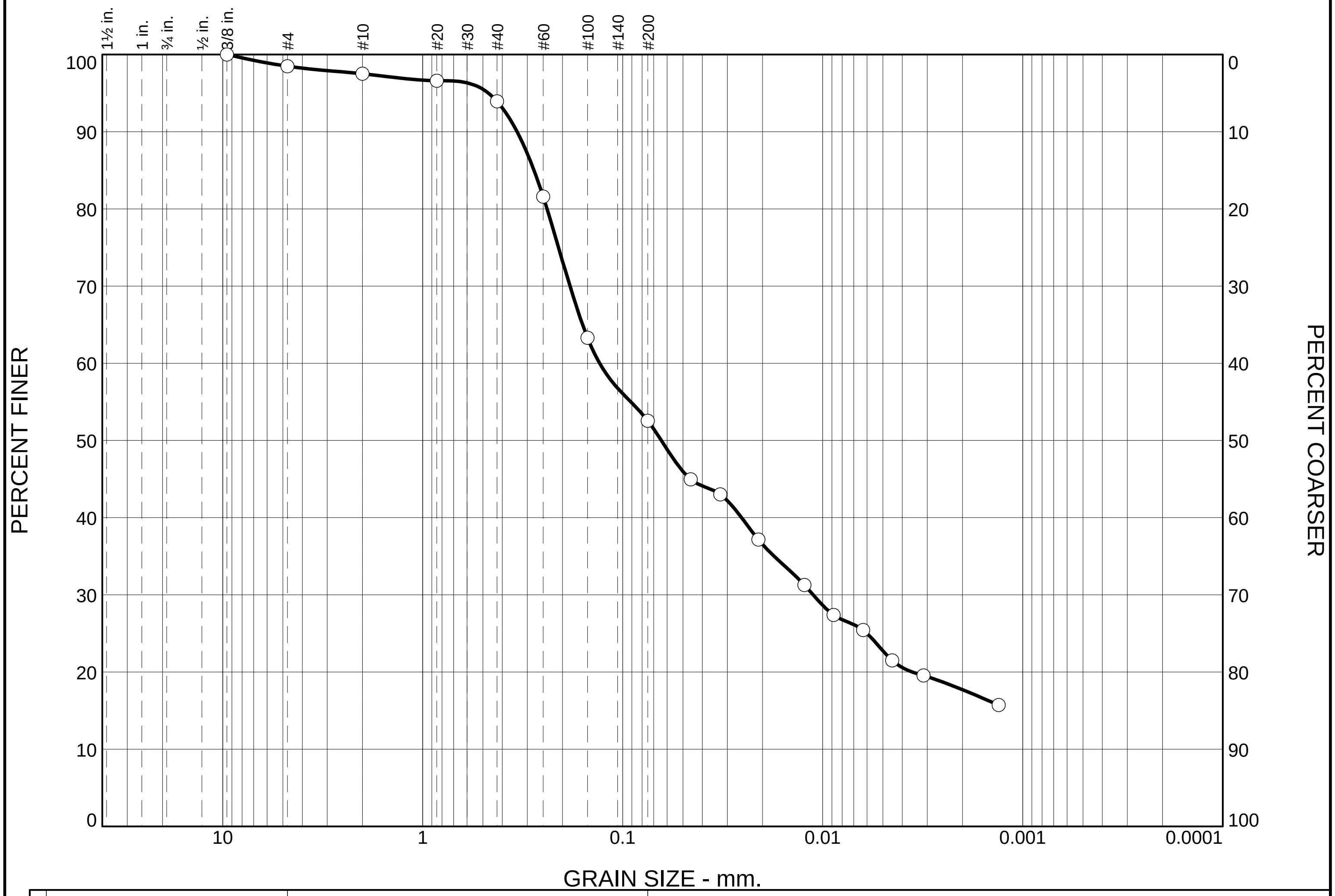
Remarks:

○F.M.=1.48

AECOM

Tested By: SJH **Checked By:** WLPQ

Particle Size Analysis of Soils ASTM D422



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	1.5	1.0	3.6	41.3	29.9	22.7

☒	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	17	9	0.2780	0.1303	0.0641	0.0112				

Material Description	USCS	AASHTO
○ SILTY CLAY AND F-C SAND TRACE F GRAVEL - BROWN	CL	A-4(1)

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

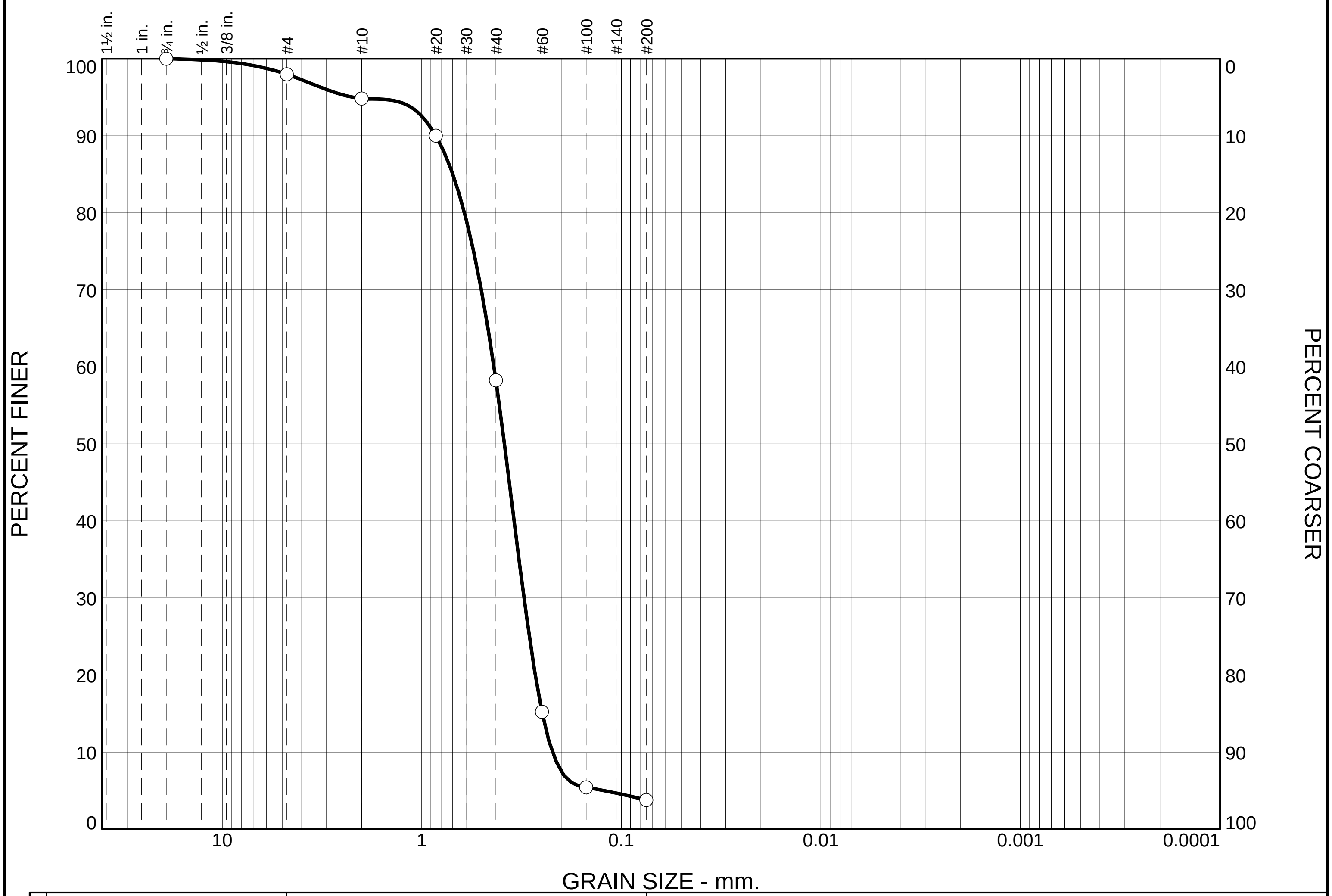
○ **Source of Sample:** B-GB-15 **Depth:** 13.5'-14.0' **Sample Number:** S-5B

Remarks:

○F.M.=0.60

Tested By: SJH **Checked By:** WPQ

Particle Size Analysis of Soils ASTM D422



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	2.0	3.2	36.5	54.5	3.8	

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			0.6991	0.4347	0.3851	0.3073	0.2490	0.2213	0.98	1.96

Material Description	USCS	AASHTO
○ F-C SAND TRACE SILT TRACE F GRAVEL - BROWN	SP	

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

○ **Source of Sample:** B-GB-16 **Depth:** 10.0'-10.5' **Sample Number:** S-3

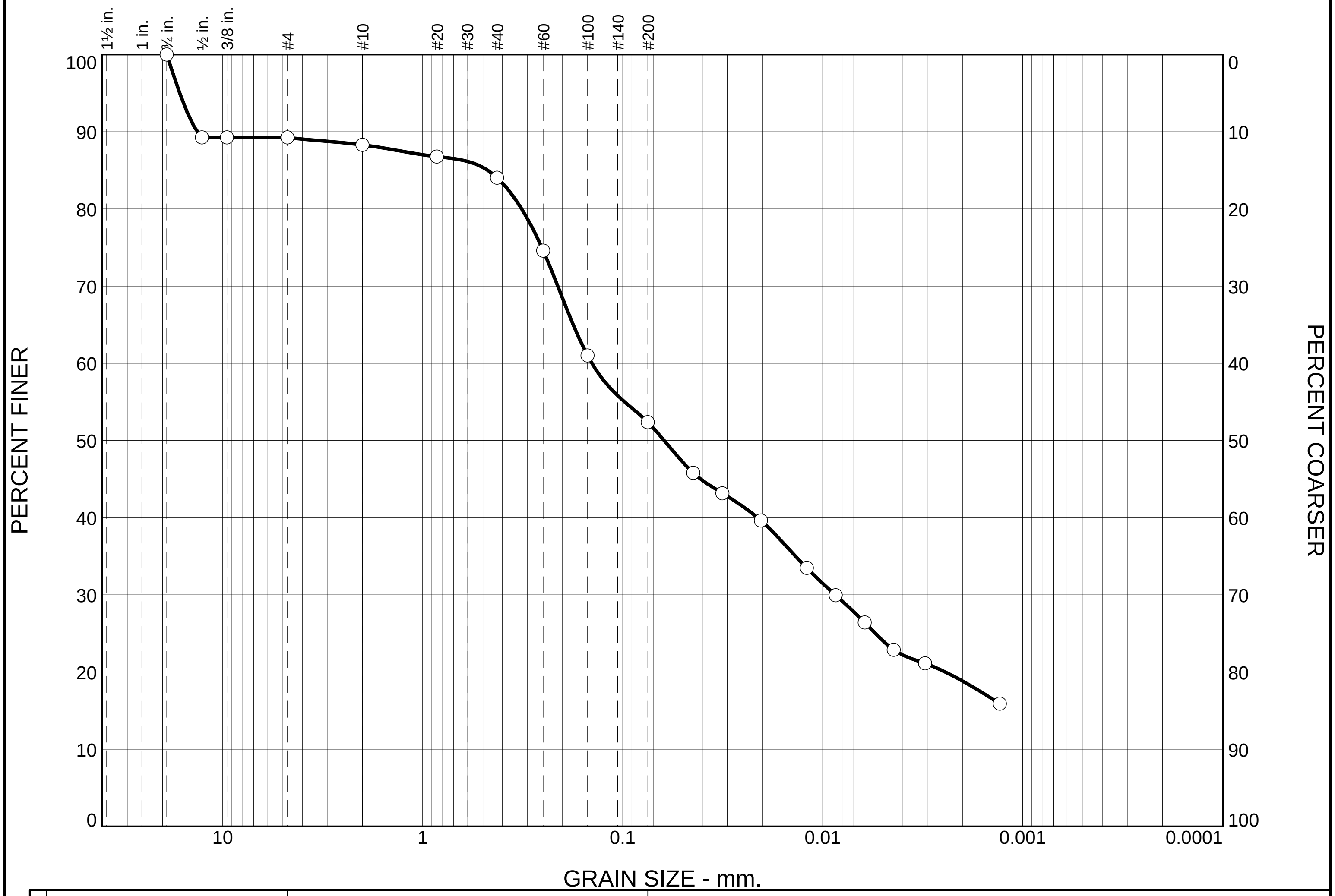
AECOM

Remarks:

○F.M.=2.01

Tested By: EMR **Checked By:** WPQ

Particle Size Analysis of Soils ASTM D422



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	10.7	1.0	4.3	31.6	28.4	24.0

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	18	9	0.4743	0.1426	0.0621	0.0087				

Material Description	USCS	AASHTO
○ SILTY CLAY AND F-C SAND LITTLE F GRAVEL - BROWN	CL	A-4(1)

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

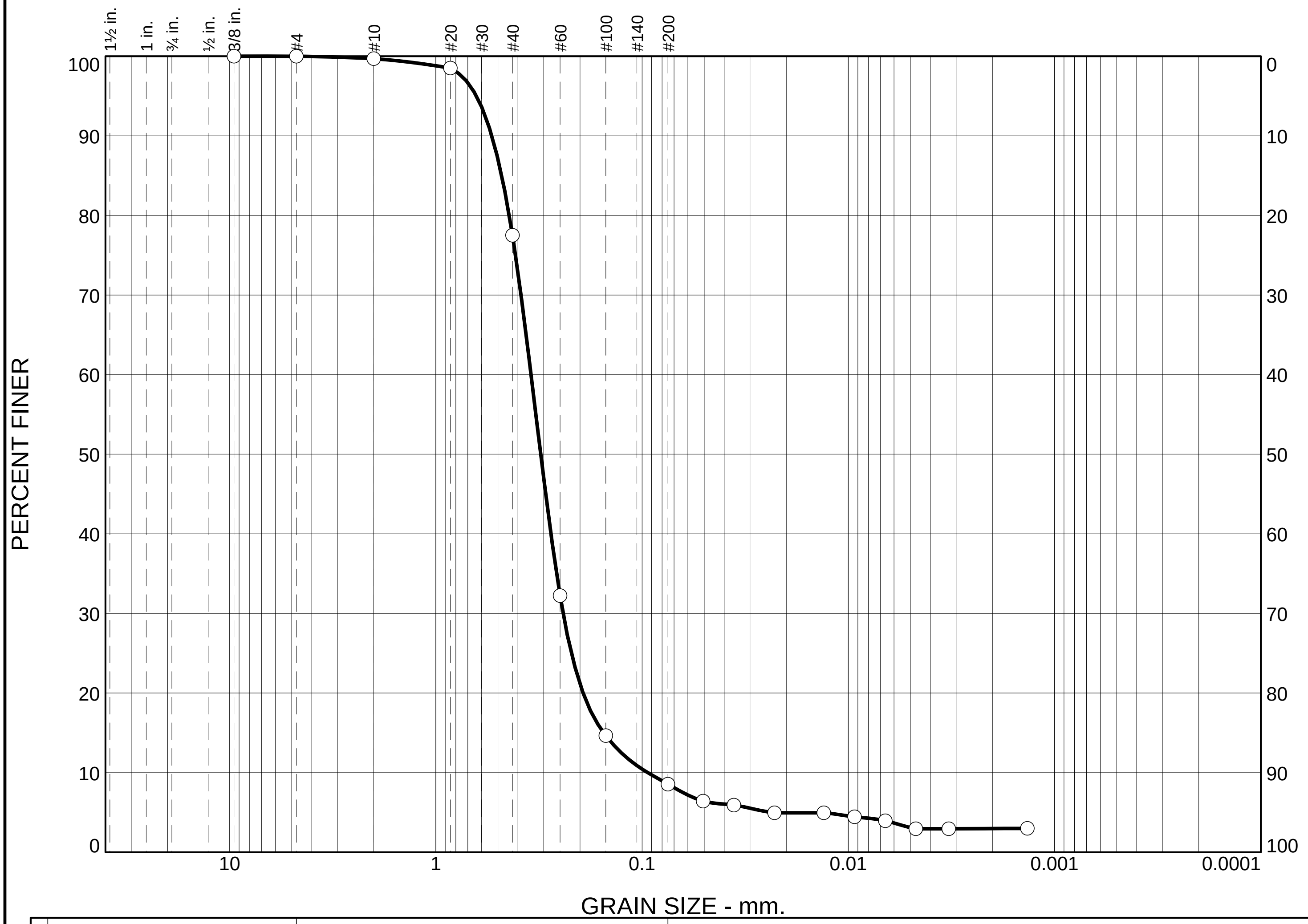
○ **Source of Sample:** B-GB-16 **Depth:** 13.0'-14.0' **Sample Number:** S-4A

Remarks:

○F.M.=1.20

Tested By: SJH **Checked By:** WPQ

Particle Size Analysis of Soils ASTM D422



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	0.0	0.3	22.2	68.9	5.5	3.1

☒	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			0.4797	0.3454	0.3101	0.2415	0.1536	0.0938	1.80	3.68

Material Description	USCS	AASHTO
○ F-M SAND TRACE SILT TRACE CLAY - BROWN	SP-SM	

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

○ **Source of Sample:** B-GB-17 **Depth:** 10.0'-11.5' **Sample Number:** S-3

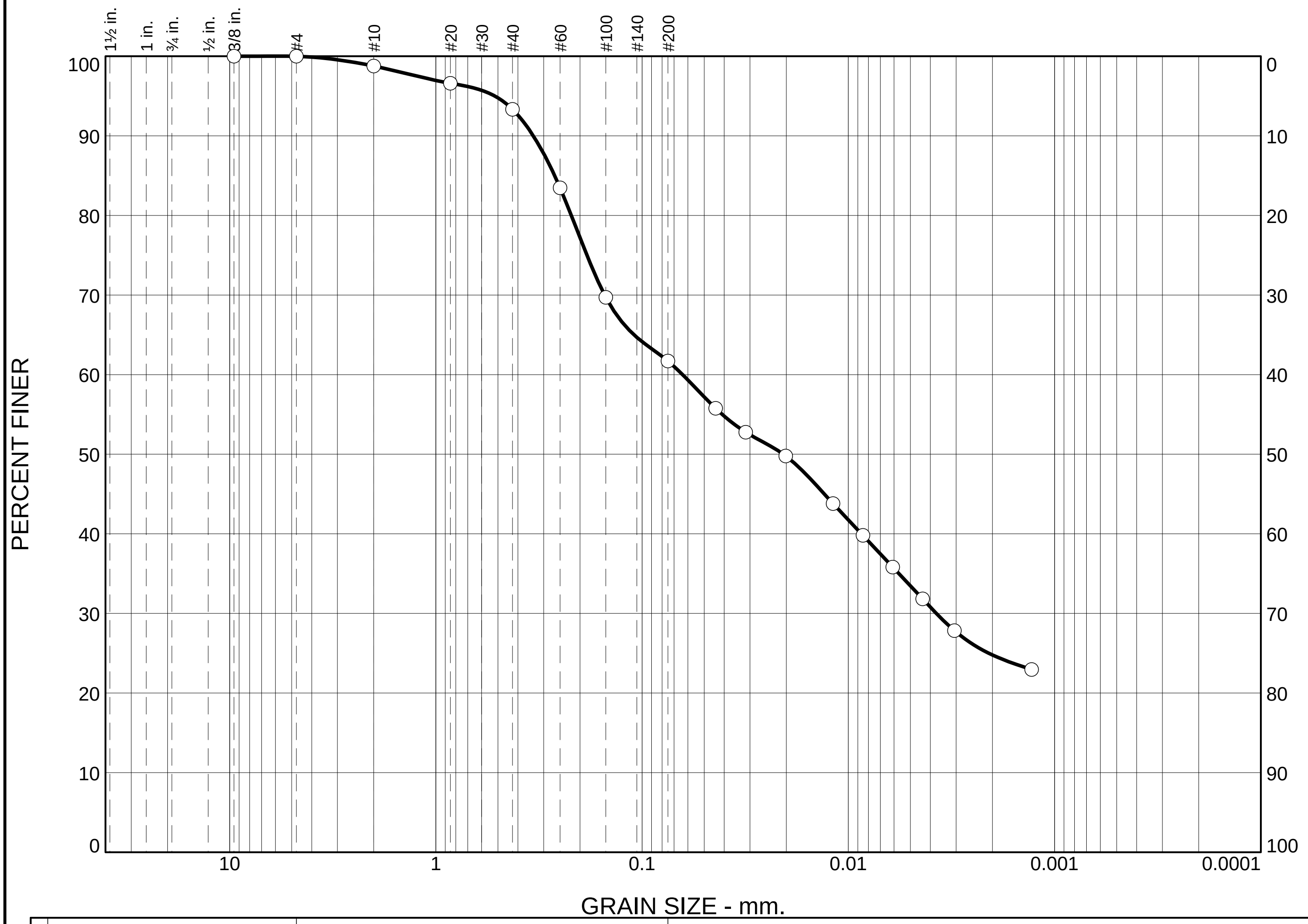
Remarks:

○F.M.=1.46

AECOM

Tested By: SJH **Checked By:** WPQ

Particle Size Analysis of Soils ASTM D422



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	0.0	1.2	5.5	31.6	28.2	33.5

☒	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	21	10	0.2656		0.0206	0.0037				

Material Description	USCS	AASHTO
○ SILTY CLAY AND F-C SAND - BROWN	CL	A-6(3)

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

○ **Source of Sample:** B-GB-17 **Depth:** 12.0'-14.0' **Sample Number:** S-4

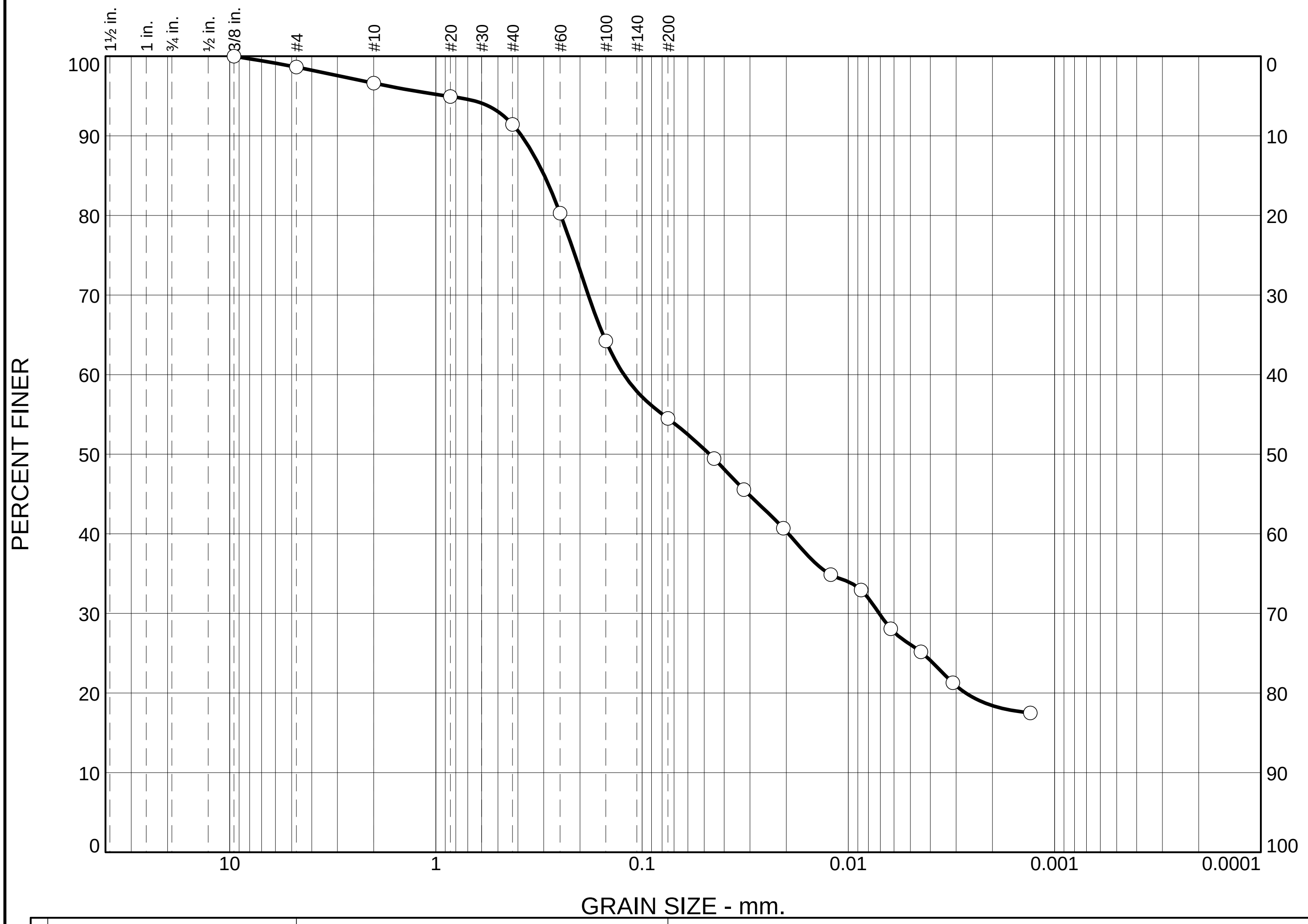
Remarks:

○F.M.=0.50

AECOM

Tested By: SJH **Checked By:** WPQ

Particle Size Analysis of Soils ASTM D422



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	1.4	2.0	5.2	36.9	28.4	26.1

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	18	9	0.2979	0.1226	0.0471	0.0071				

Material Description	USCS	AASHTO
○ SILTY CLAY AND F-C SAND TRACE F GRAVEL - BROWN	CL	A-4(1)

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

○ **Source of Sample:** B-GB-18 **Depth:** 12.5'-14.0' **Sample Number:** S-4A

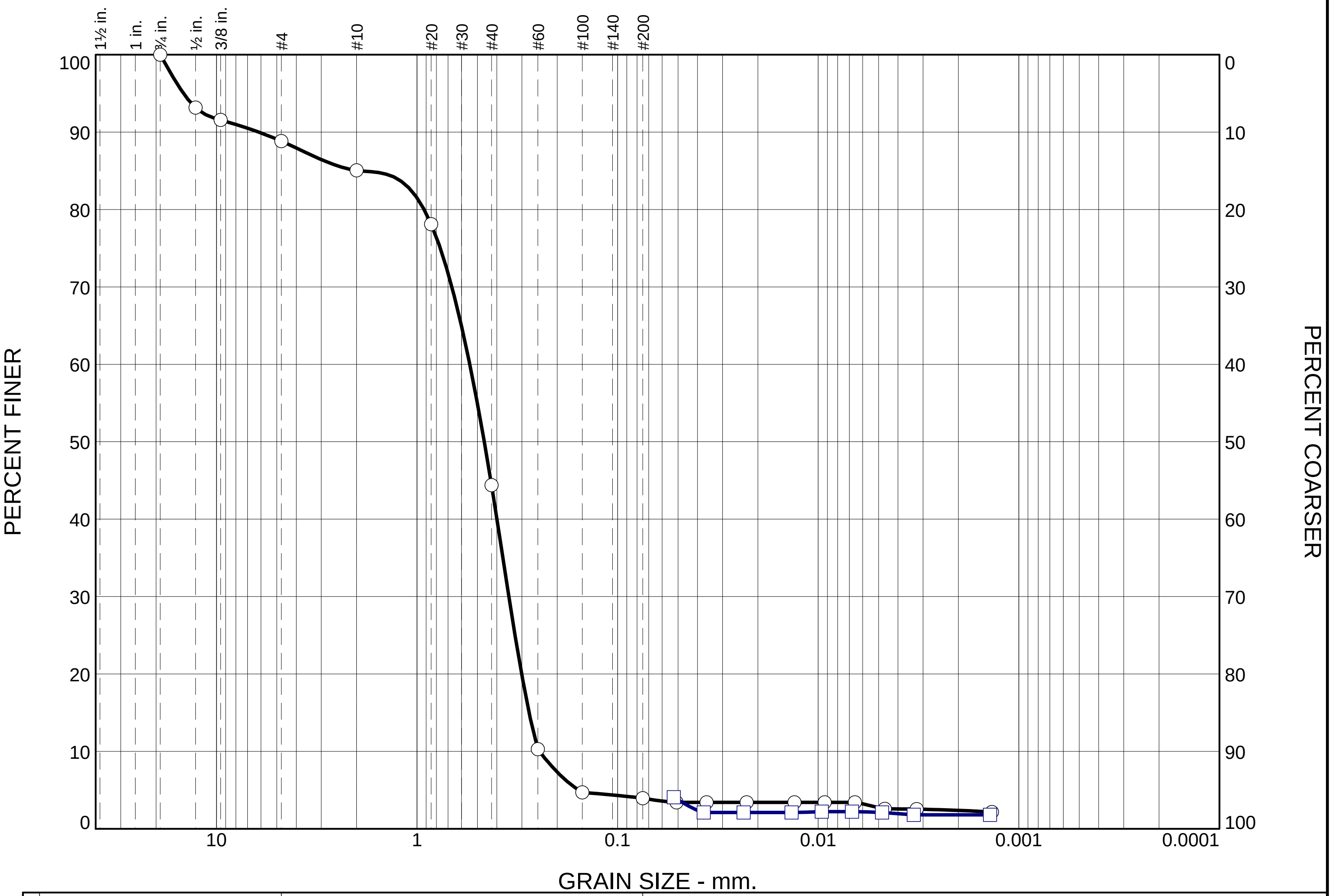
Remarks:

○F.M.=0.65

AECOM

Tested By: SJH **Checked By:** WPQ

Dispersive Analysis by Double Hydrometer ASTM D 4221



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	11.2	3.8	40.6	40.4	1.3	2.7
□								2.1

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			1.9297	0.5460	0.4620	0.3482	0.2765	0.2453	0.91	2.23
□										

Material Description	USCS	AASHTO
○ F-C SAND LITTLE F GRAVEL TRACE CLAY TRACE SILT - BROWN	SP	
□		

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

○ **Source of Sample:** B-GB-11 **Depth:** 12.0'-13.5' **Sample Number:** S-2

□ **Sample Source:** B-GB-11 **Depth:** 12.0-13.5 **Sample No.:** S-2 DOUBLE

AECOM

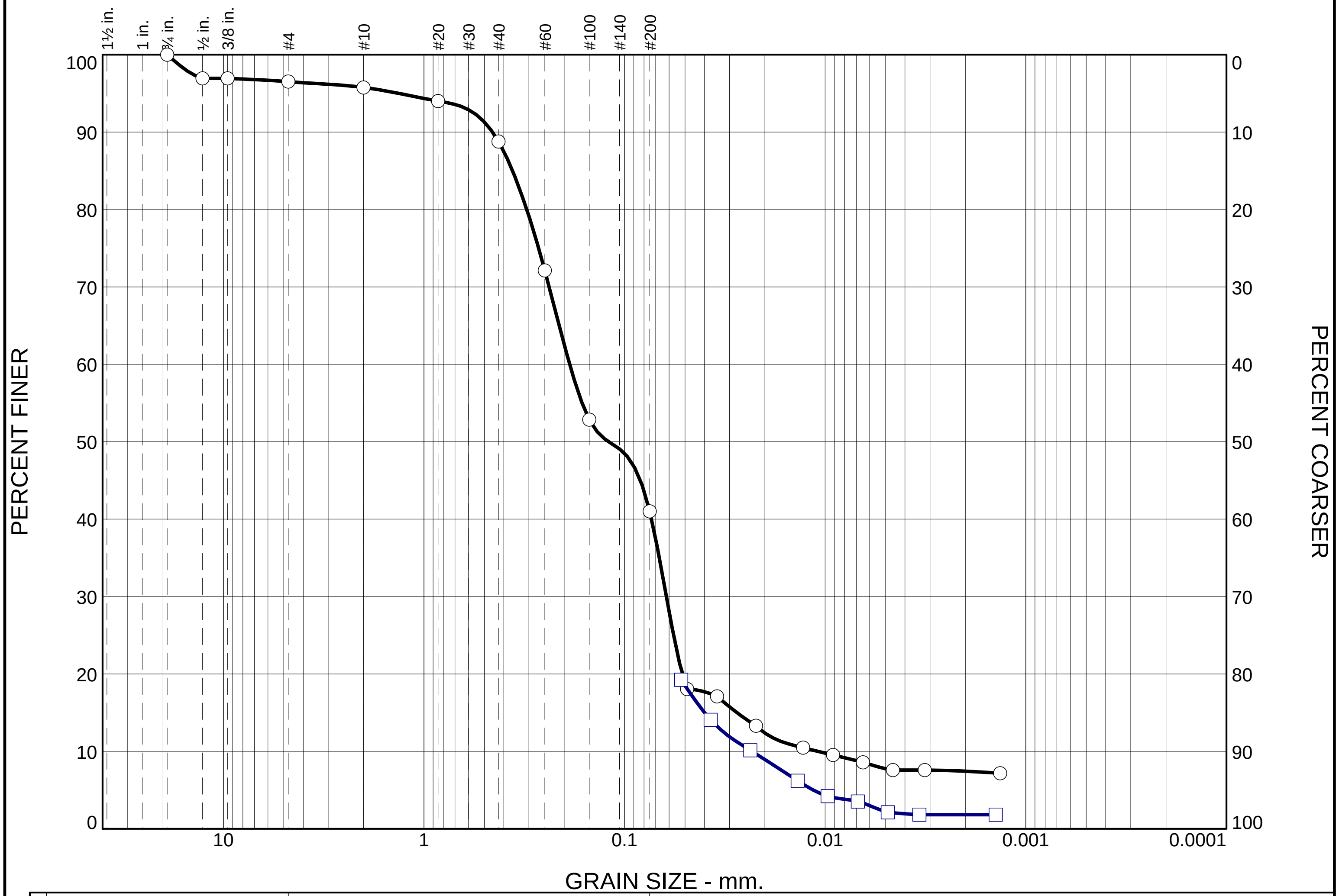
Remarks:

○F.M.=2.61

□77.7% DISPERSION FOR THE CLAY PORTION OF THIS SAMPLE.

Tested By: SH **Checked By:** WPQ

Dispersive Analysis by Double Hydrometer ASTM D 4221



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	3.5	0.7	7.0	47.8	33.2	7.8
□								2.2

☒	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			0.3616	0.1879	0.1200	0.0619	0.0275	0.0109	1.88	17.31
□							0.0399	0.0232		

Material Description	USCS	AASHTO
○ F-M SAND SOME SILT TRACE CLAY TRACE F GRAVEL - BROWN - MOIST	SM	
□		

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

○ **Source of Sample:** B-GB-12 **Depth:** 5.0'-6.0' **Sample Number:** S-1A

□ **Sample Source:** B-GB-12 **Depth:** 5.0'-6.0' **Sample No.:** S-1A DOUBLE

Remarks:

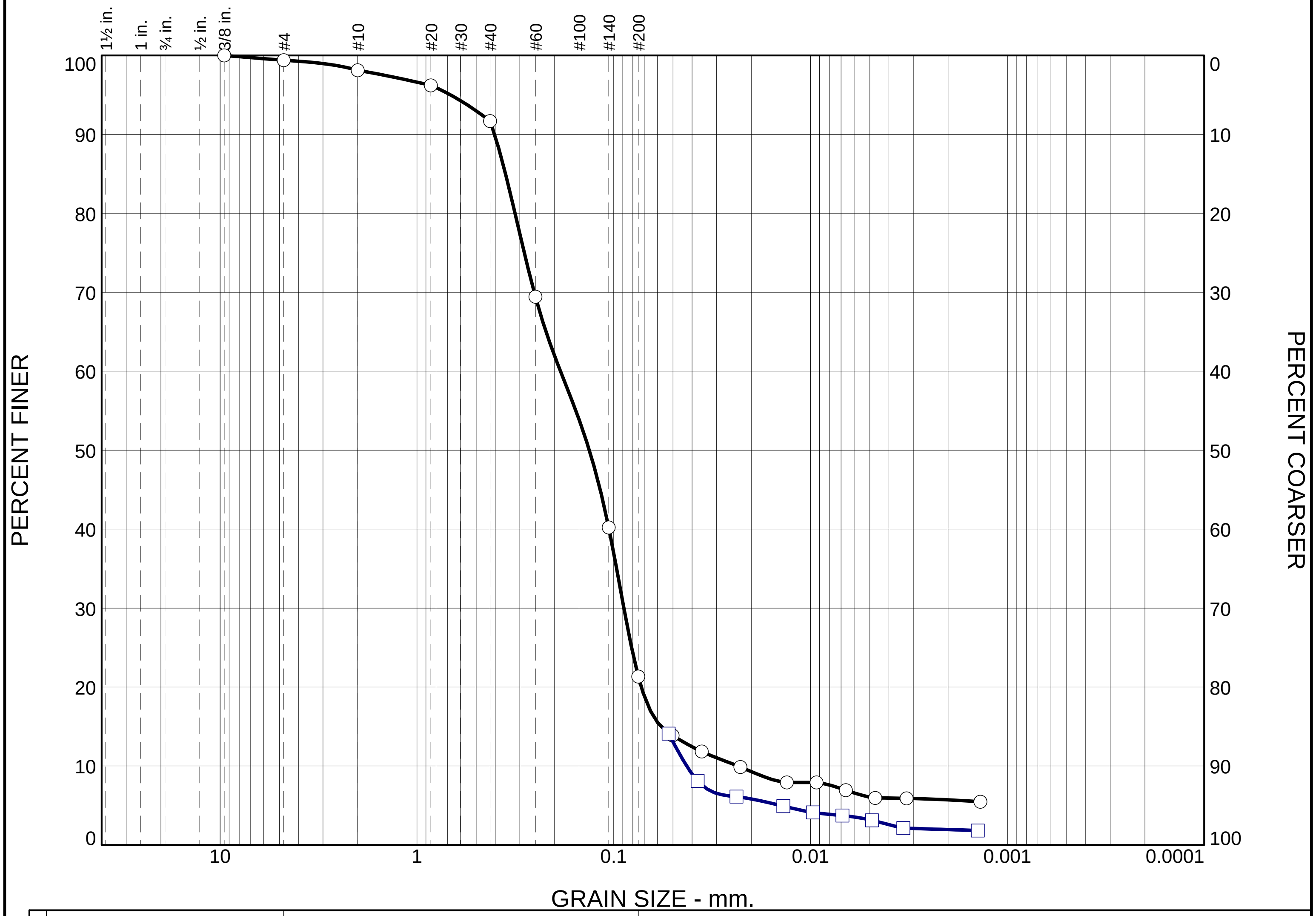
○F.M.=0.91

□28.2% DISPERSION FOR THE CLAY PORTION OF THIS SAMPLE.

AECOM

Tested By: SH **Checked By:** WPQ

Dispersive Analysis by Double Hydrometer ASTM D 4221



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	0.6	1.3	6.4	70.4	15.2	6.1
□								3.2

☒	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			0.3548	0.1864	0.1330	0.0887	0.0574	0.0234	1.81	7.97
□								0.0426		

Material Description	USCS	AASHTO
○ F-C SAND LITTLE SILT TRACE CLAY - BROWN - MOIST	SM	
□		

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

○ **Source of Sample:** B-GB-12 **Depth:** 10.0'-10.5' **Sample Number:** S-4

□ **Sample Source:** B-GB-12 **Depth:** 10.0'-10.5' **Sample No.:** S-4 DOUBLE

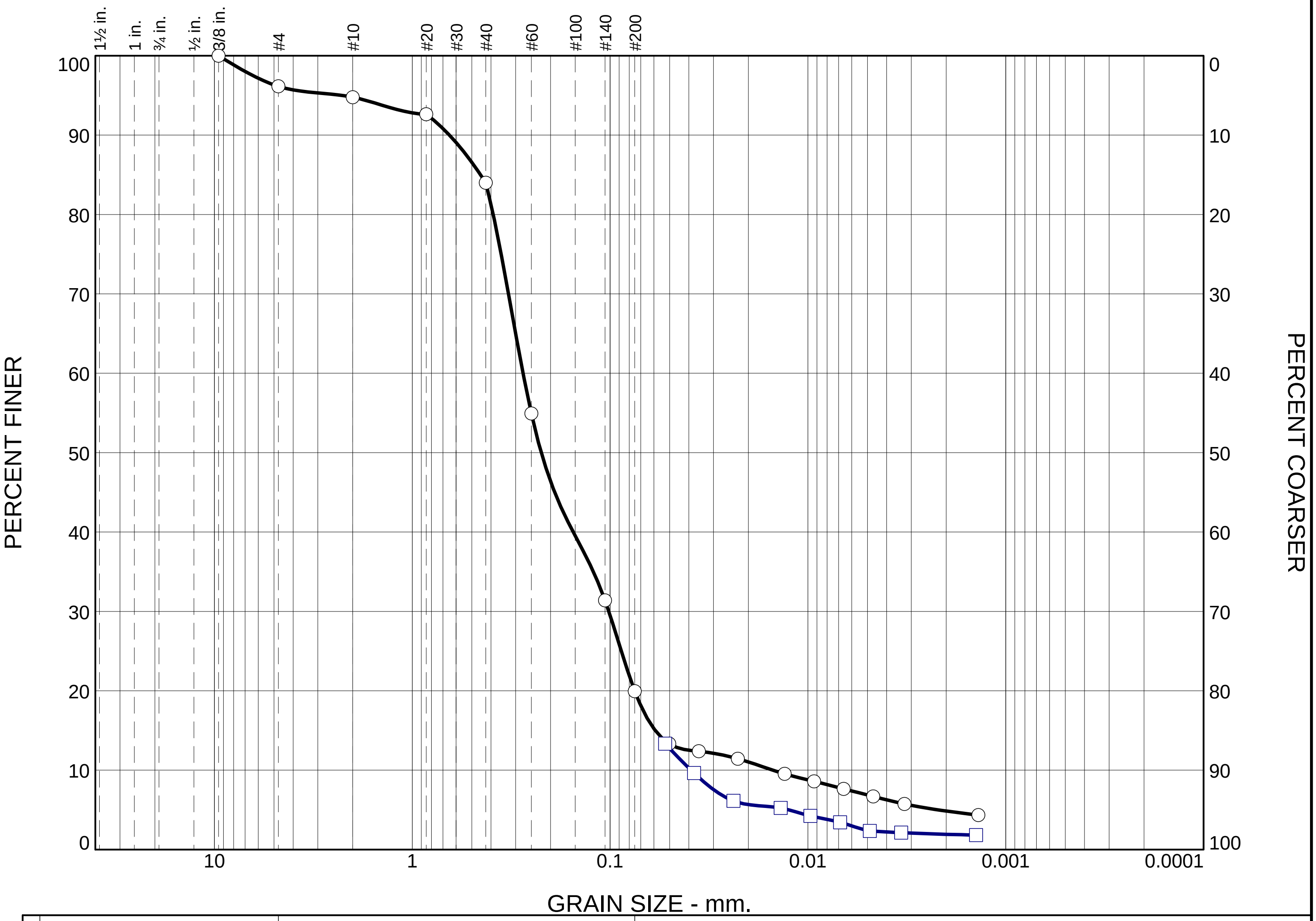
AECOM

Remarks:

○F.M.=0.79

□52.4% DISPERSION FOR THE CLAY PORTION OF THIS SAMPLE.

Dispersive Analysis by Double Hydrometer ASTM D 4221



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	3.9	1.3	10.8	64.1	13.0	6.9
□								2.4

╳	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			0.4517	0.2754	0.2226	0.1014	0.0591	0.0150	2.48	18.31
□								0.0390		

Material Description	USCS	AASHTO
○ F-C SAND LITTLE SILT TRACE CLAY TRACE F GRAVEL - BROWN	SM	
□		

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

○ **Source of Sample:** B-GB-12 **Depth:** 14.0'-15.0' **Sample Number:** S-6

□ **Sample Source:** B-GB-12 **Depth:** 14.0'-15.0' **Sample No.:** S-6 DOUBLE

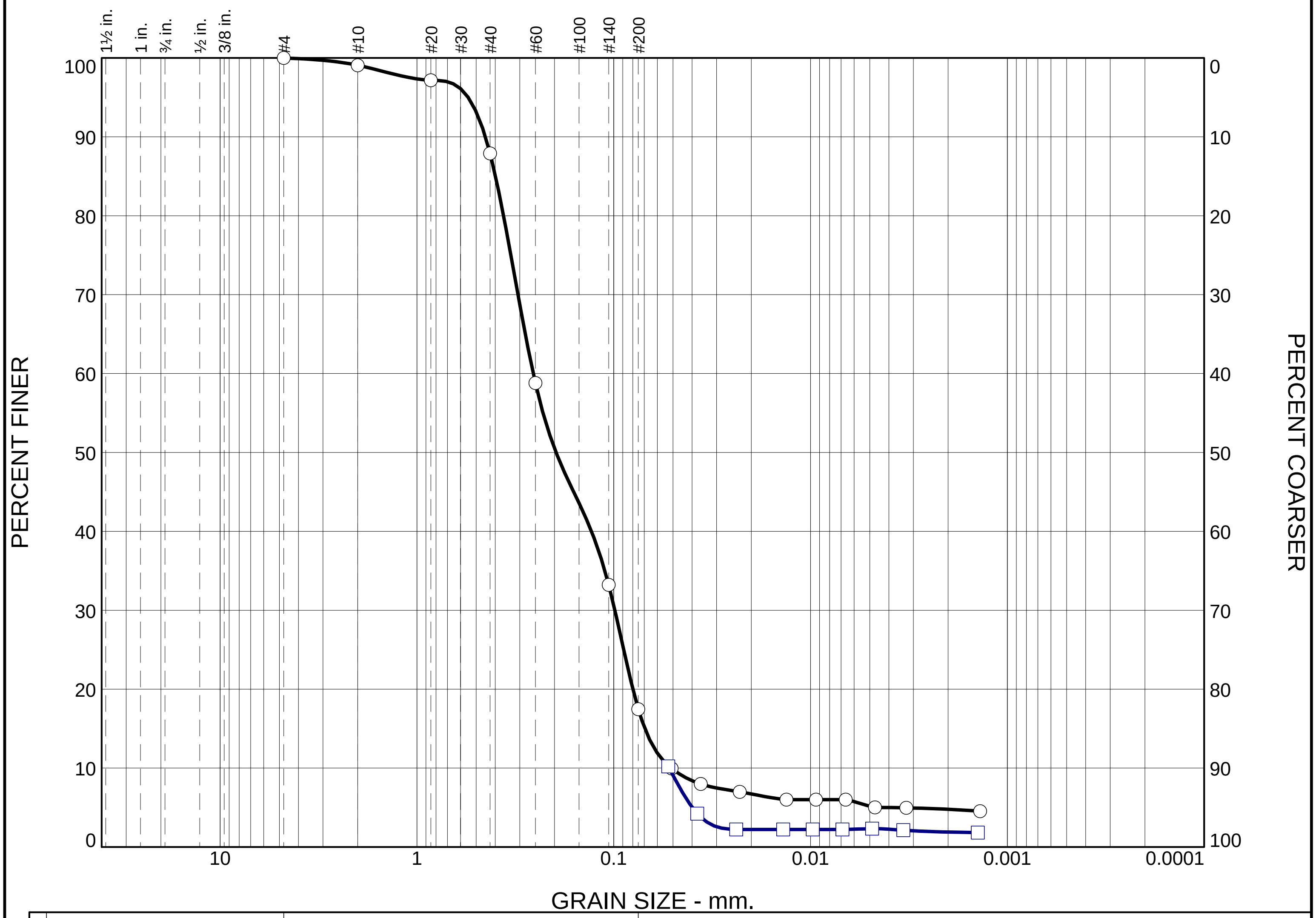
AECOM

Remarks:

○F.M.=1.22

□34.8% DISPERSION FOR THE CLAY PORTION OF THIS SAMPLE.

Dispersive Analysis by Double Hydrometer ASTM D 4221



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	0.0	0.9	11.2	70.4	12.3	5.2
□								2.3

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			0.3988	0.2563	0.1962	0.0986	0.0695	0.0510	0.74	5.02
□								0.0523		

Material Description	USCS	AASHTO
○ F-M SAND LITTLE SILT TRACE CLAY - BROWN - MOIST		
□		

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

○ **Source of Sample:** B-GB-12 **Depth:** 16.0'-16.5' **Sample Number:** S-7

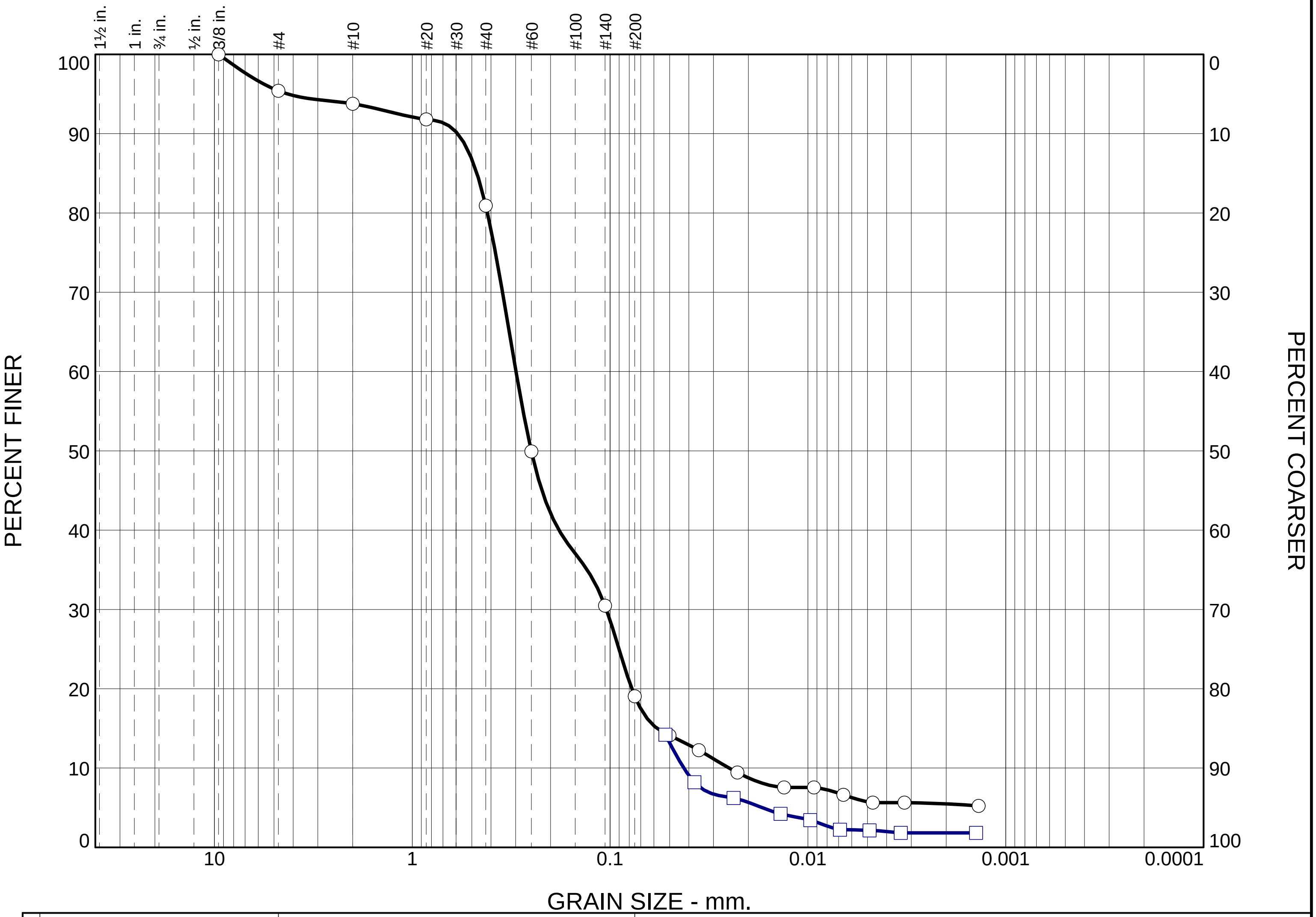
□ **Sample Source:** B-GB-12 **Depth:** 16.0'-16.5' **Sample No.:** S-7 DOUBLE

Remarks:

○F.M.=0.95

□44.2% DISPERSION FOR THE CLAY PORTION OF THIS SAMPLE.

Dispersive Analysis by Double Hydrometer ASTM D 4221



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	4.6	1.6	12.9	61.8	13.4	5.7
□								2.1

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			0.4711	0.2989	0.2503	0.1043	0.0578	0.0250	1.46	11.95
□								0.0424		

Material Description	USCS	AASHTO
○ F-C SAND LITTLE SILT TRACE CLAY TRACE F GRAVEL - BROWN - MOIST	SM	
□		

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

○ **Source of Sample:** B-GB-13 **Depth:** 10.0'-11.0' **Sample Number:** S-4

□ **Sample Source:** B-GB-13 **Depth:** 10.0'-11.0' **Sample No.:** S-4 DOUBLE

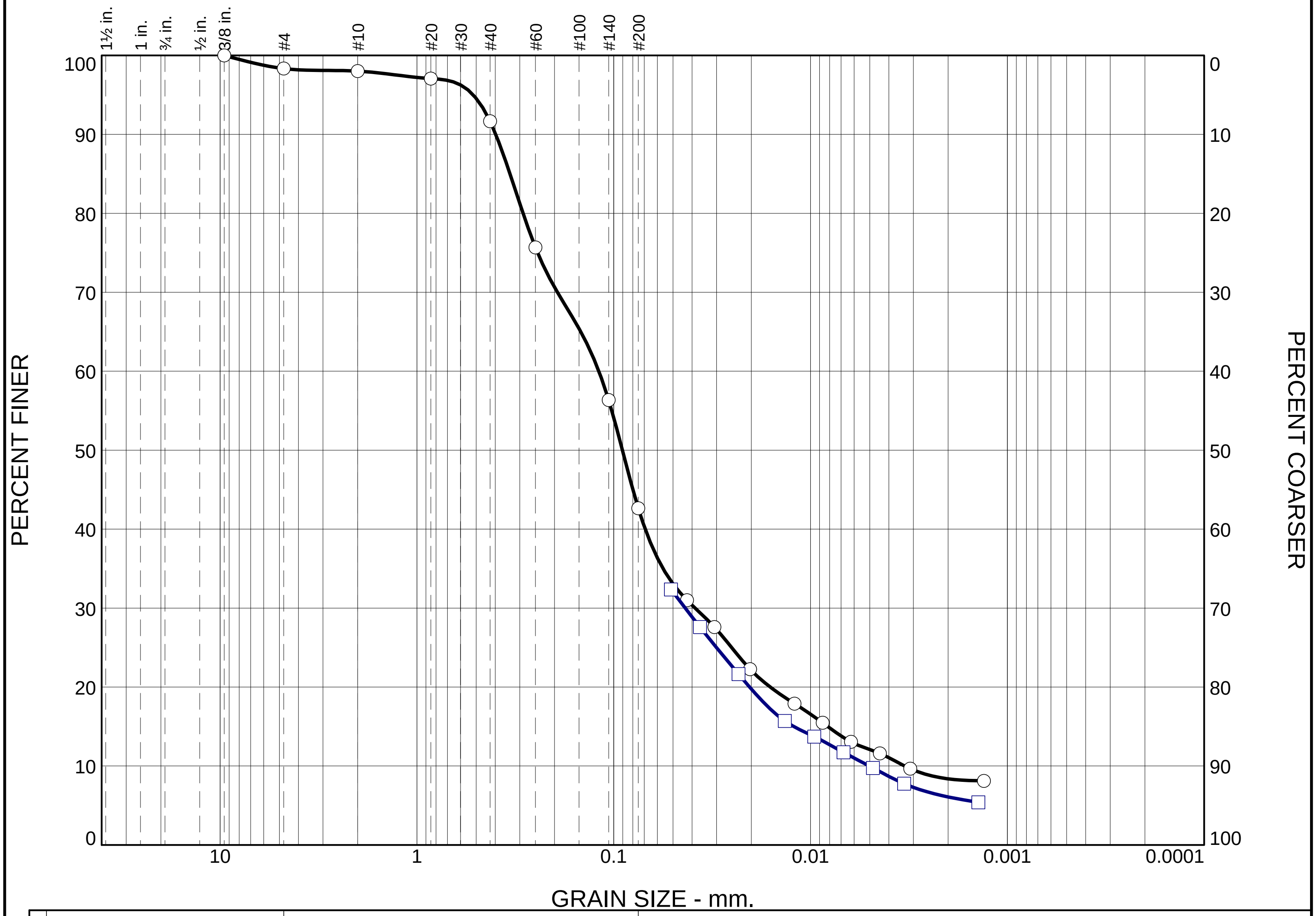
AECOM

Remarks:

○F.M.=1.31

□36.8% DISPERSION FOR THE CLAY PORTION OF THIS SAMPLE.

Dispersive Analysis by Double Hydrometer ASTM D 4221



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	1.7	0.3	6.3	49.1	30.5	12.1
□								10.0

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			0.3367	0.1189	0.0903	0.0386	0.0082	0.0033	3.77	35.78
□						0.0433	0.0122	0.0050		

Material Description	USCS	AASHTO
○ F-C SAND SOME SILT LITTLE CLAY TRACE F GRAVEL - BROWN	CL	
□		

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

○ **Source of Sample:** B-GB-13 **Depth:** 11.0'-12.0' **Sample Number:** S-4A

□ **Sample Source:** B-GB-13 **Depth:** 11.0'-12.0' **Sample No.:** S-4A DOUBLE

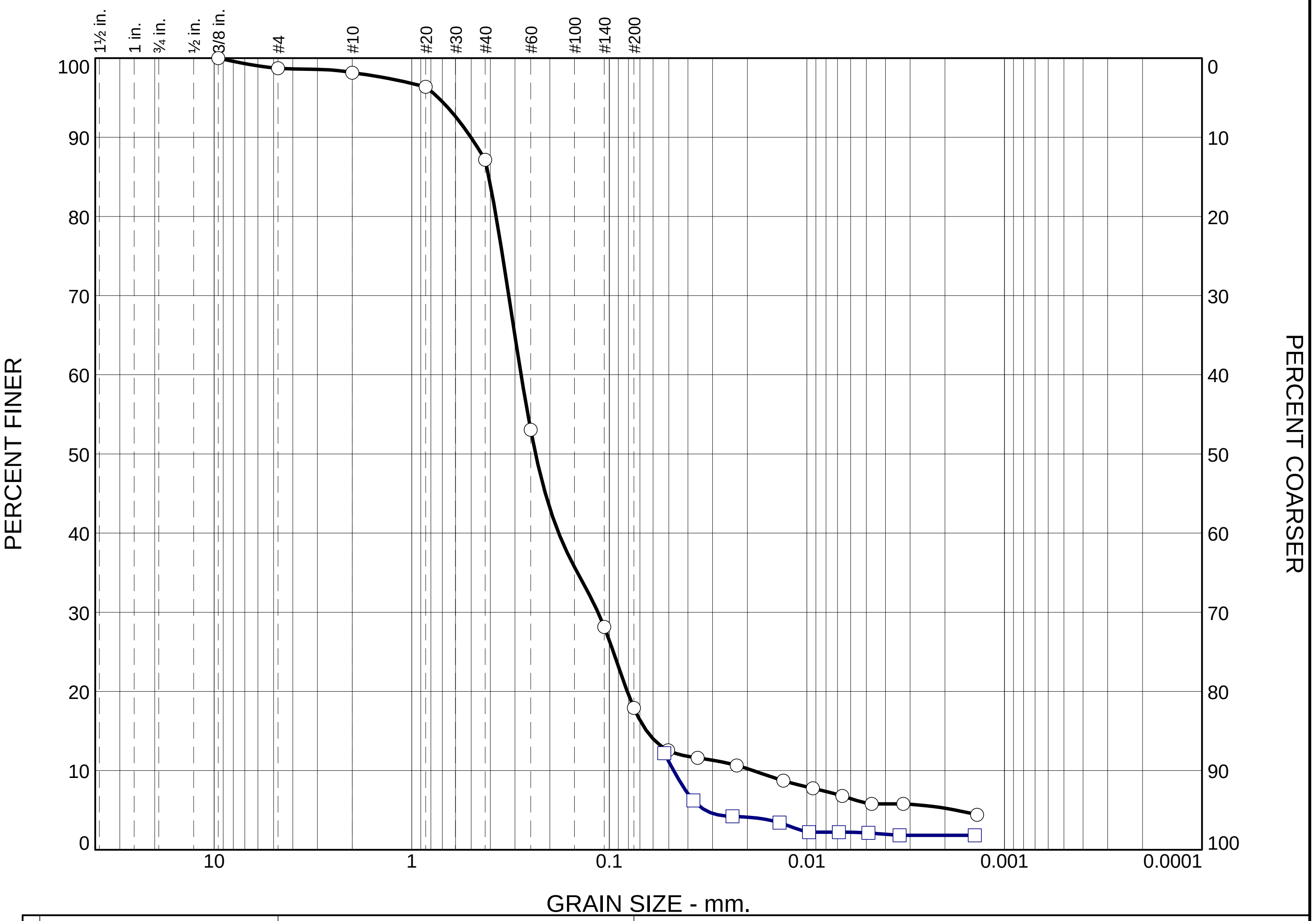
Remarks:

○SEAMS AND LAYERS OF SAND NOTED

F.M.=0.63

□82.6% DISPERSION FOR THE CLAY PORTION OF THIS SAMPLE.

Dispersive Analysis by Double Hydrometer ASTM D 4221



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	1.3	0.5	11.0	69.3	12.0	5.9
□								2.1

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			0.4073	0.2796	0.2360	0.1140	0.0647	0.0187	2.49	14.94
□								0.0472		

Material Description	USCS	AASHTO
○ F-C SAND LITTLE SILT TRACE CLAY TRACE F GRAVEL - BROWN - MOIST	SM	
□		

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

○ **Source of Sample:** B-GB-14 **Depth:** 8.0'-9.25' **Sample Number:** S-3

□ **Sample Source:** B-GB-14 **Depth:** 8.0'-9.25' **Sample No.:** S-3 DOUBLE

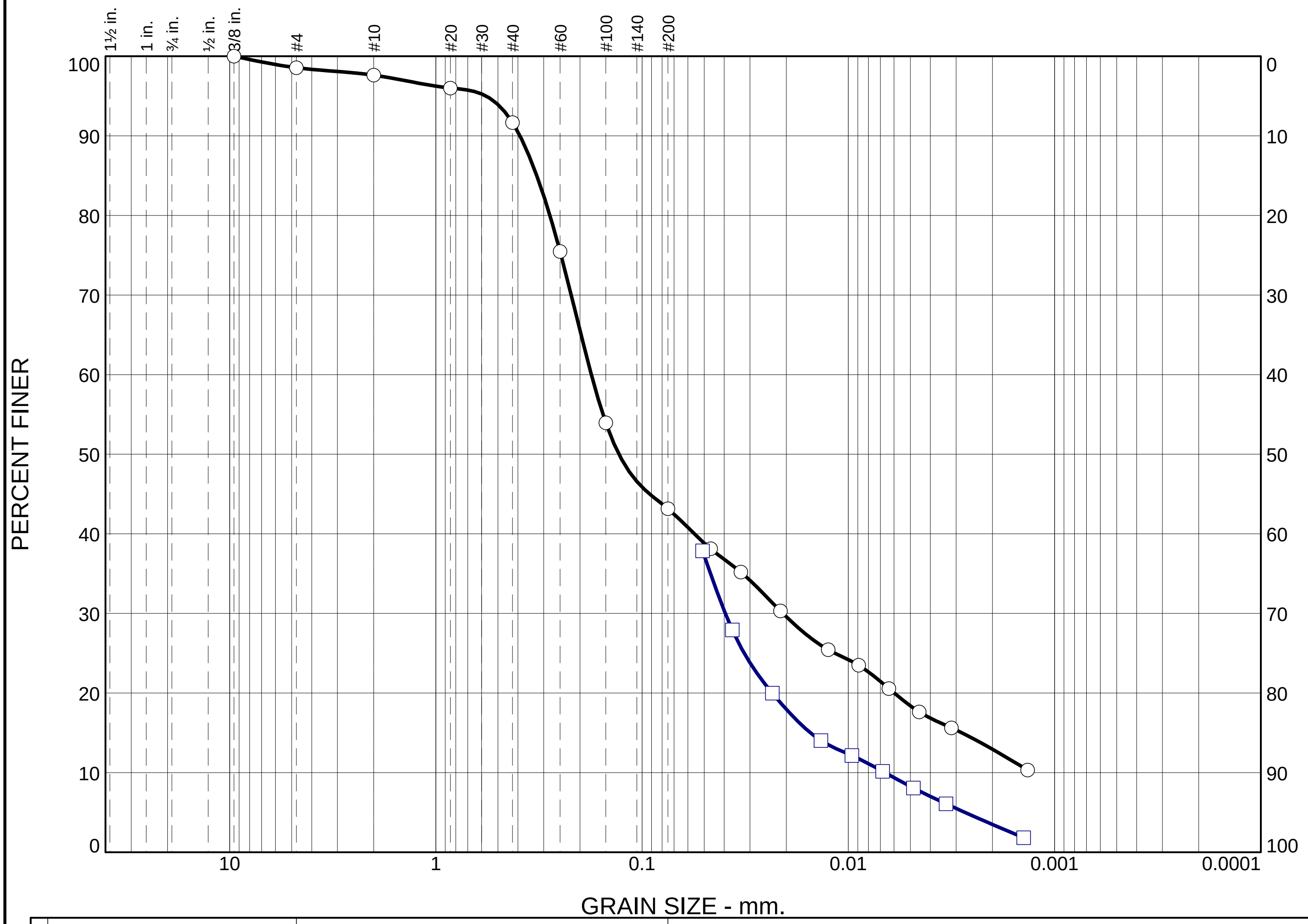
AECOM

Remarks:

○F.M.=1.12

□35.5% DISPERSION FOR THE CLAY PORTION OF THIS SAMPLE.

Dispersive Analysis by Double Hydrometer ASTM D 4221



	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○ 0.0	0.0	1.4	1.0	5.9	48.6	24.7	18.4
□							8.3

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	12	11	0.3241	0.1763	0.1295	0.0208	0.0028			
□						0.0395	0.0153	0.0066		

Material Description	USCS	AASHTO
○ F-C SAND SOME SILT LITTLE CLAY TRACE F GRAVEL - BROWN	SM	A-4(0)
□		

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

○ **Source of Sample:** B-GB-14 **Depth:** 10.0'-11.2' **Sample Number:** S-4

□ **Sample Source:** B-GB-14 **Depth:** 10.0'-11.2' **Sample No.:** S-4 DOUBLE

AECOM

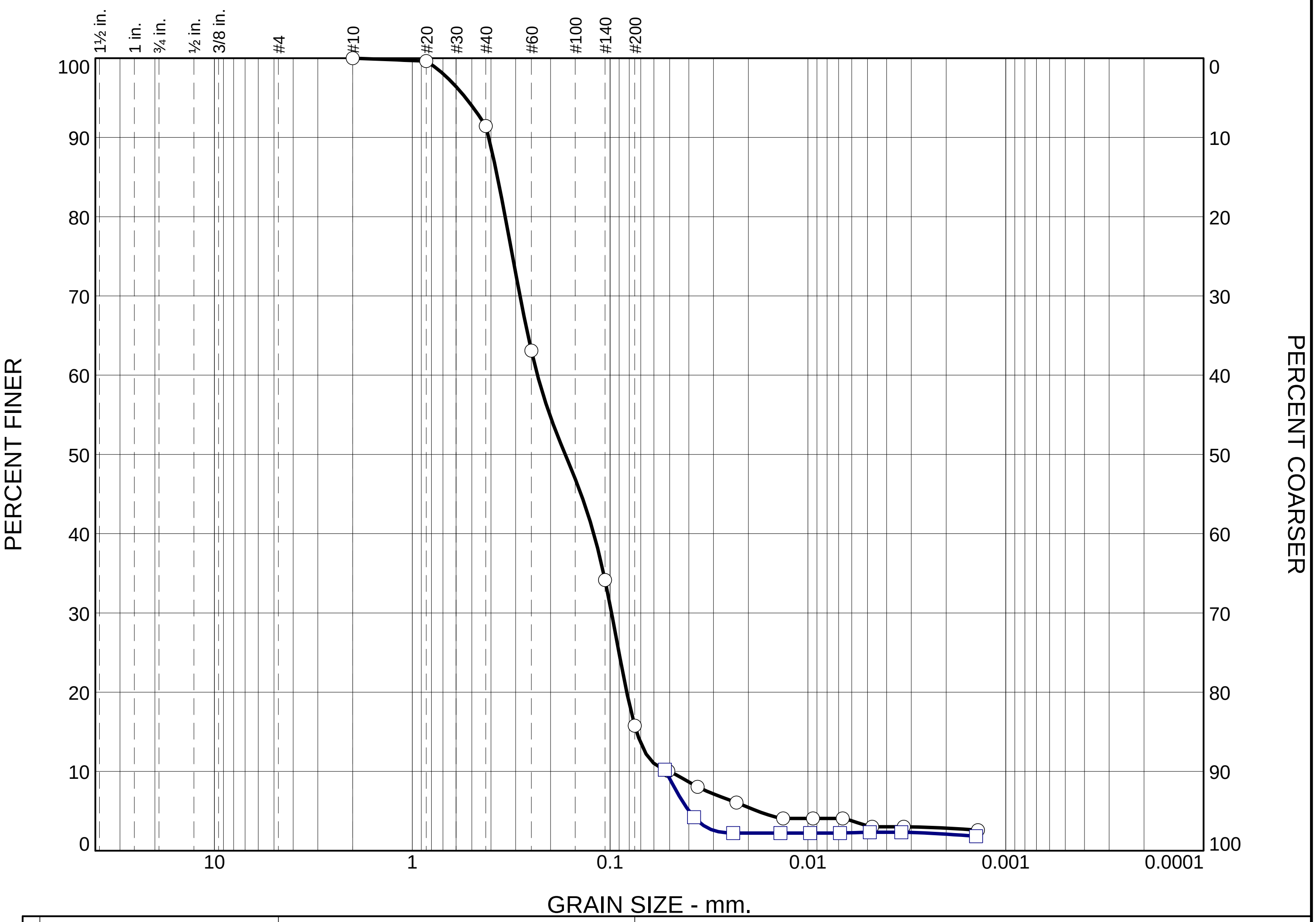
Remarks:

○F.M.=0.75

□45.1% DISPERSION FOR THE CLAY PORTION OF THIS SAMPLE.

Tested By: BCM/SJH **Checked By:** WPQ

Dispersive Analysis by Double Hydrometer ASTM D 4221



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	0.0	0.0	8.6	75.6	12.7	3.1
□								2.3

☒	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			0.3709	0.2327	0.1684	0.0982	0.0734	0.0502	0.83	4.64
□								0.0523		

Material Description	USCS	AASHTO
○ F-M SAND LITTLE SILT TRACE CLAY - BROWN - MOIST	SM	
□		

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

○ **Source of Sample:** B-GB-15 **Depth:** 10.0'-12.0' **Sample Number:** S-4

□ **Sample Source:** B-GB-15 **Depth:** 10.0'-12.0' **Sample No.:** S-4 DOUBLE

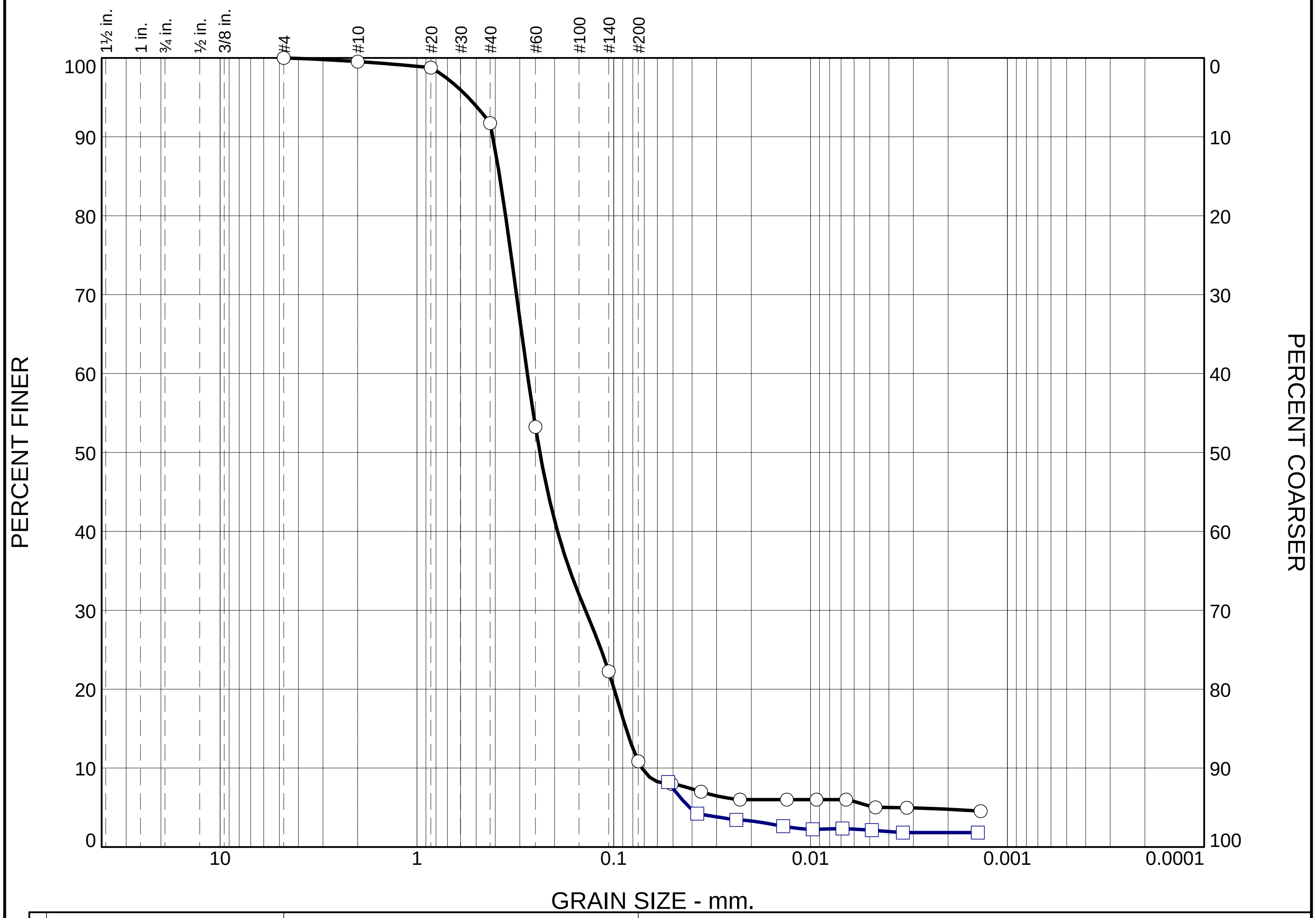
AECOM

Remarks:

○F.M.=0.84

□74.2% DISPERSION FOR THE CLAY PORTION OF THIS SAMPLE.

Dispersive Analysis by Double Hydrometer ASTM D 4221



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	0.0	0.5	7.8	80.9	5.6	5.2
□								2.1

╳	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			0.3800	0.2749	0.2373	0.1392	0.0865	0.0718	0.98	3.83
□										

Material Description	USCS	AASHTO
○ F-M SAND TRACE SILT TRACE CLAY - BROWN - MOIST	SP-SM	
□		

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

○ **Source of Sample:** B-GB-15 **Depth:** 12.0'-13.0' **Sample Number:** S-5

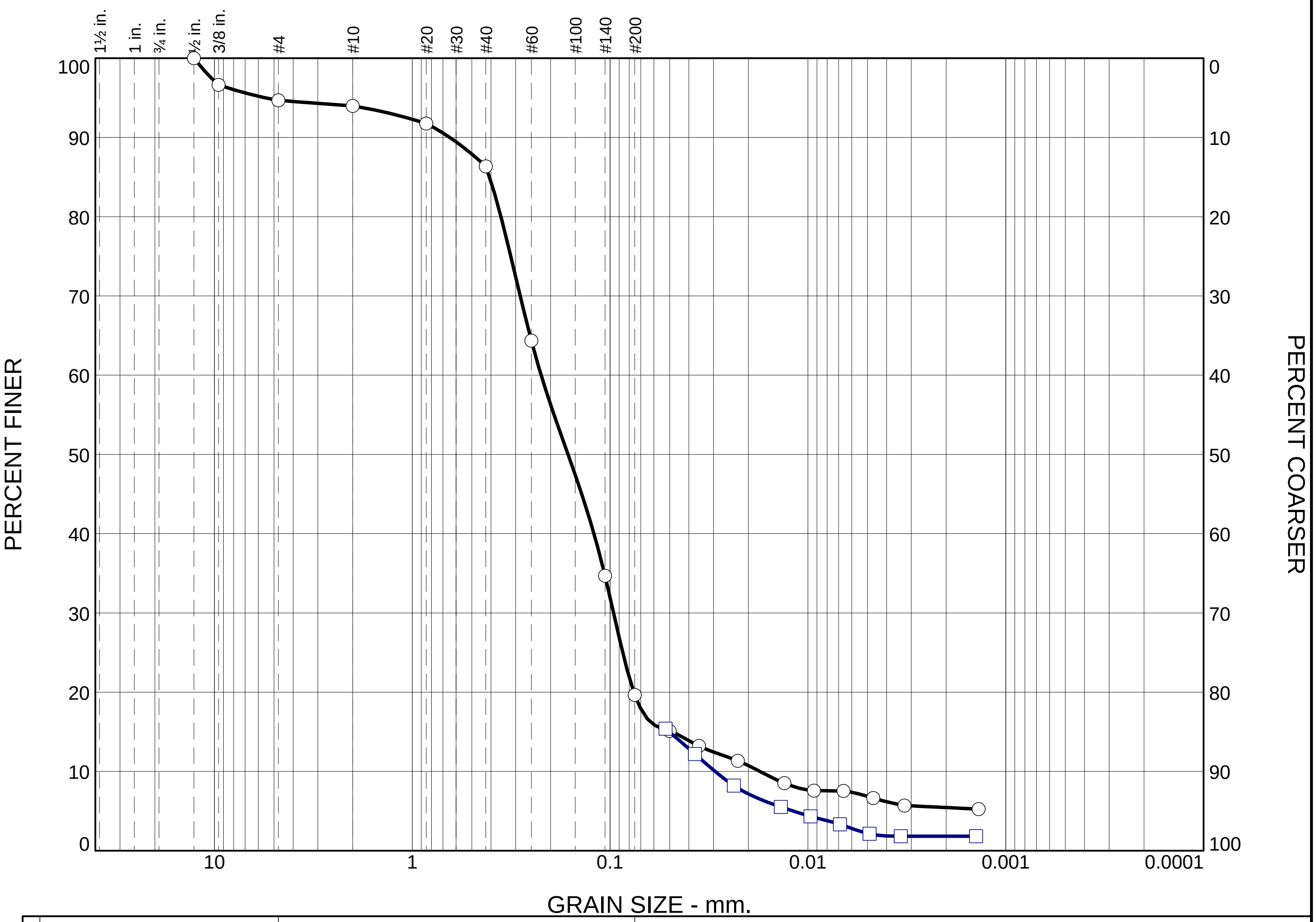
□ **Sample Source:** B-GB-15 **Depth:** 12.0'-13.0' **Sample No.:** S-5 DOUBLE

Remarks:

○F.M.=1.06

□40.4% DISPERSION FOR THE CLAY PORTION OF THIS SAMPLE.

Dispersive Analysis by Double Hydrometer ASTM D 4221



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	5.3	0.7	7.7	66.6	12.8	6.9
□								2.2

☒	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			0.4069	0.2229	0.1630	0.0959	0.0488	0.0175	2.36	12.75
□							0.0503	0.0295		

Material Description	USCS	AASHTO
○ F-C SAND LITTLE SILT TRACE CLAY TRACE F GRAVEL - BROWN - MOIST	SM	
□		

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

○ **Source of Sample:** B-GB-16 **Depth:** 10.5'-12.0' **Sample Number:** S-3A

□ **Sample Source:** B-GB-16 **Depth:** 10.5'-12.0' **Sample No.:** S-3A DOUBLE

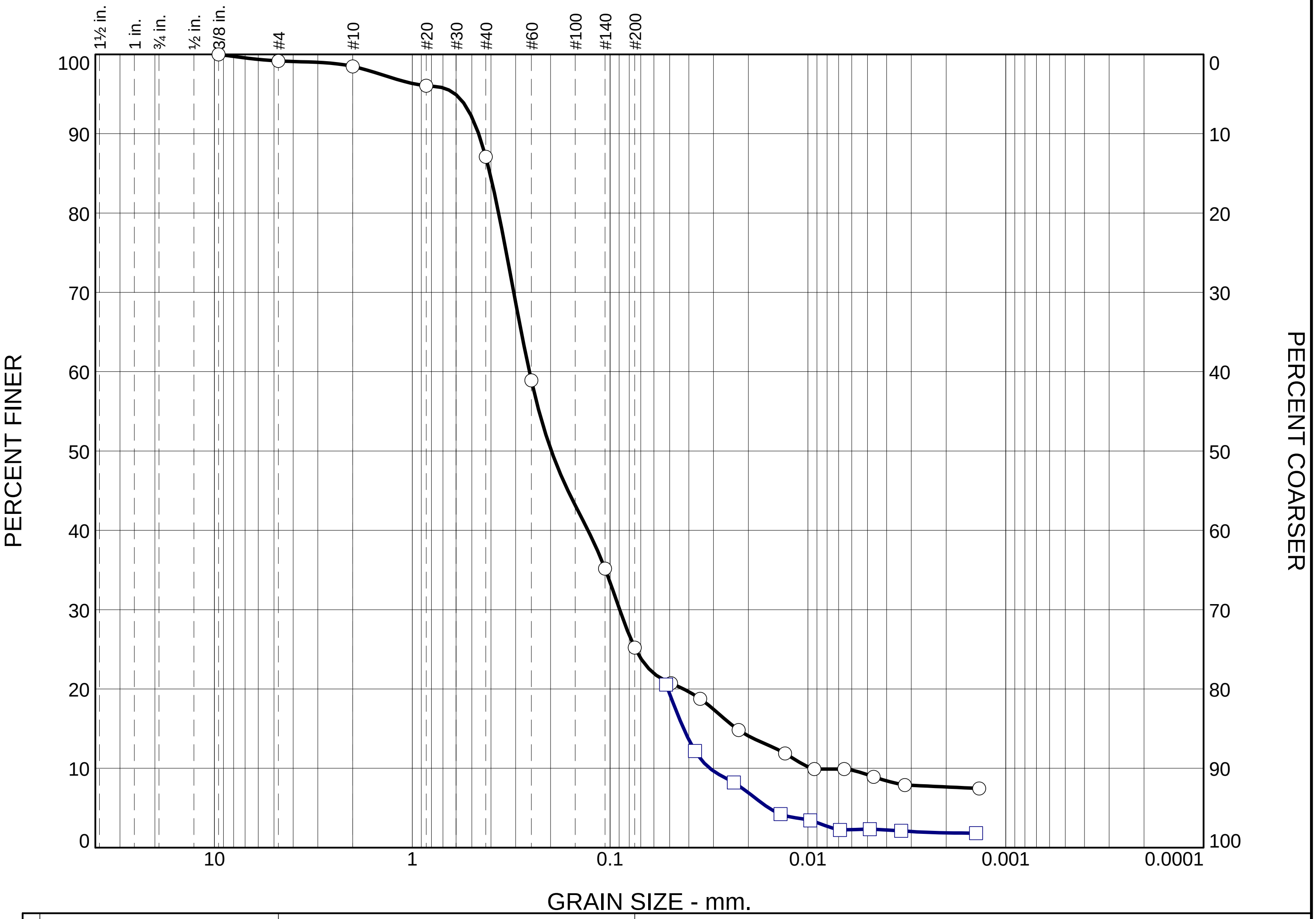
Remarks:

○F.M.=1.13

□32.4% DISPERSION FOR THE CLAY PORTION OF THIS SAMPLE.

AECOM

Dispersive Analysis by Double Hydrometer ASTM D 4221



		% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	0.8	0.7	11.4	61.9	16.0	9.2
□								2.3

☒	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			0.4047	0.2557	0.1979	0.0894	0.0229	0.0096	3.27	26.75
□							0.0425	0.0314		

Material Description	USCS	AASHTO
○ F-M SAND LITTLE SILT TRACE CLAY - BROWN - MOIST	SM	
□		

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

○ **Source of Sample:** B-GB-18 **Depth:** 10.0'-12.0' **Sample Number:** S-3

□ **Sample Source:** B-GB-18 **Depth:** 10.0'-12.0' **Sample No.:** S-3 DOUBLE

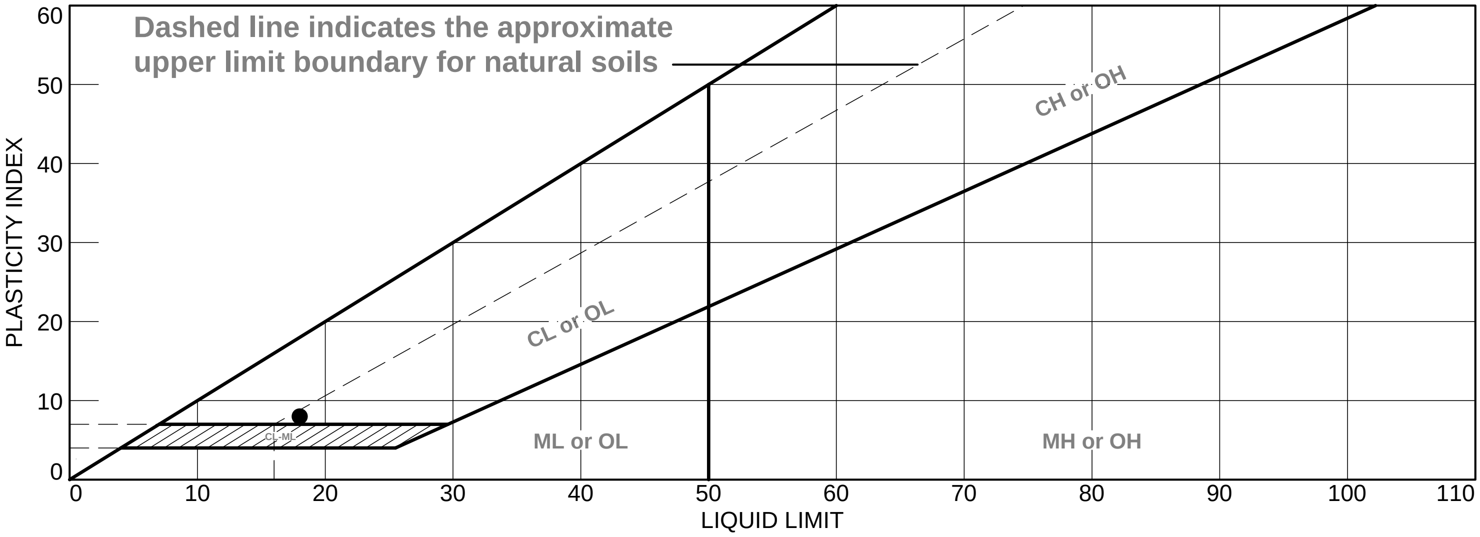
AECOM

Remarks:

○F.M.=0.98

□25.0% DISPERSION FOR THE CLAY PORTION OF THIS SAMPLE.

LIQUID AND PLASTIC LIMITS ASTM D 4318



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	SILTY CLAY AND F-C SAND - BROWN	18	10	8	92.7	53.7	CL

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

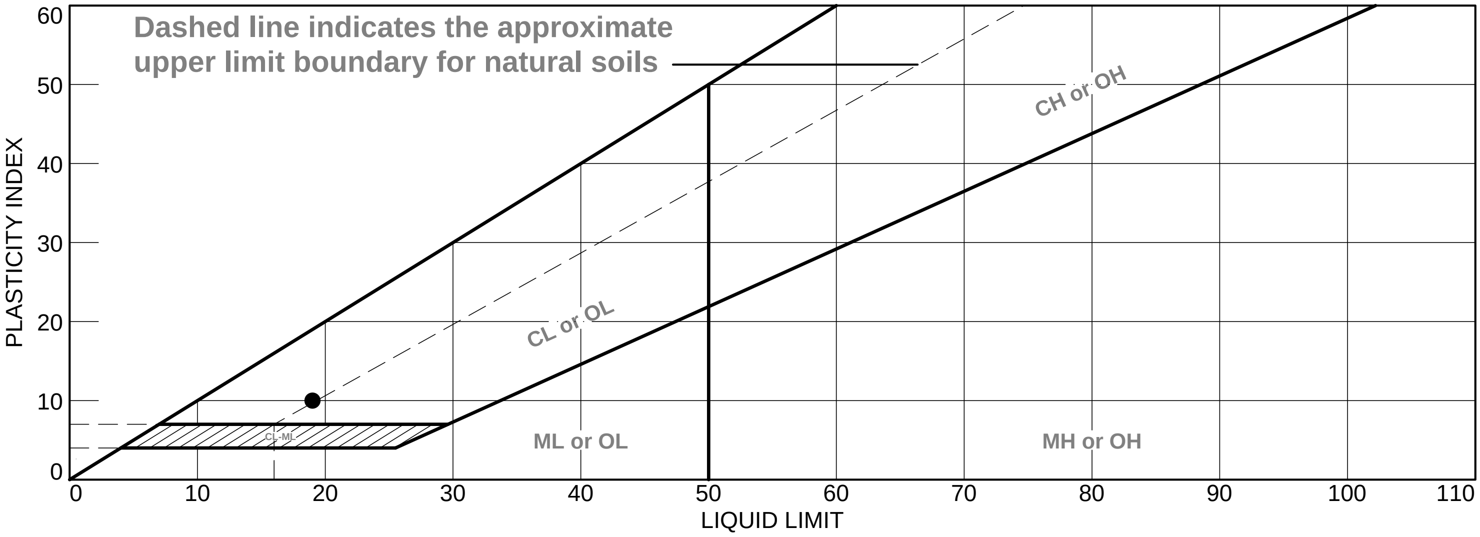
● **Source of Sample:** B-GB-12 **Depth:** 13.0'-14.0' **Sample Number:** S-5A

Remarks:

AECOM

Tested By: EMR **Checked By:** WPQ

LIQUID AND PLASTIC LIMITS ASTM D 4318



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	SILTY CLAY AND F-M SAND - BROWN	19	9	10	96.0	57.8	CL

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

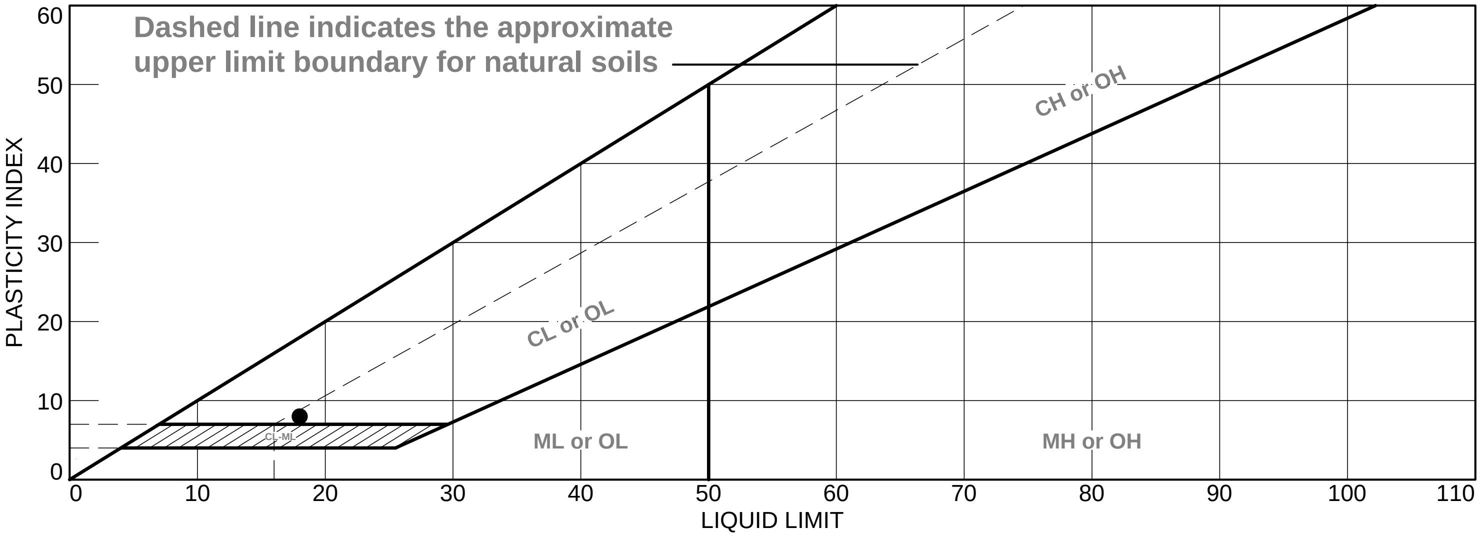
Project: BROWN BRIDGE DAM

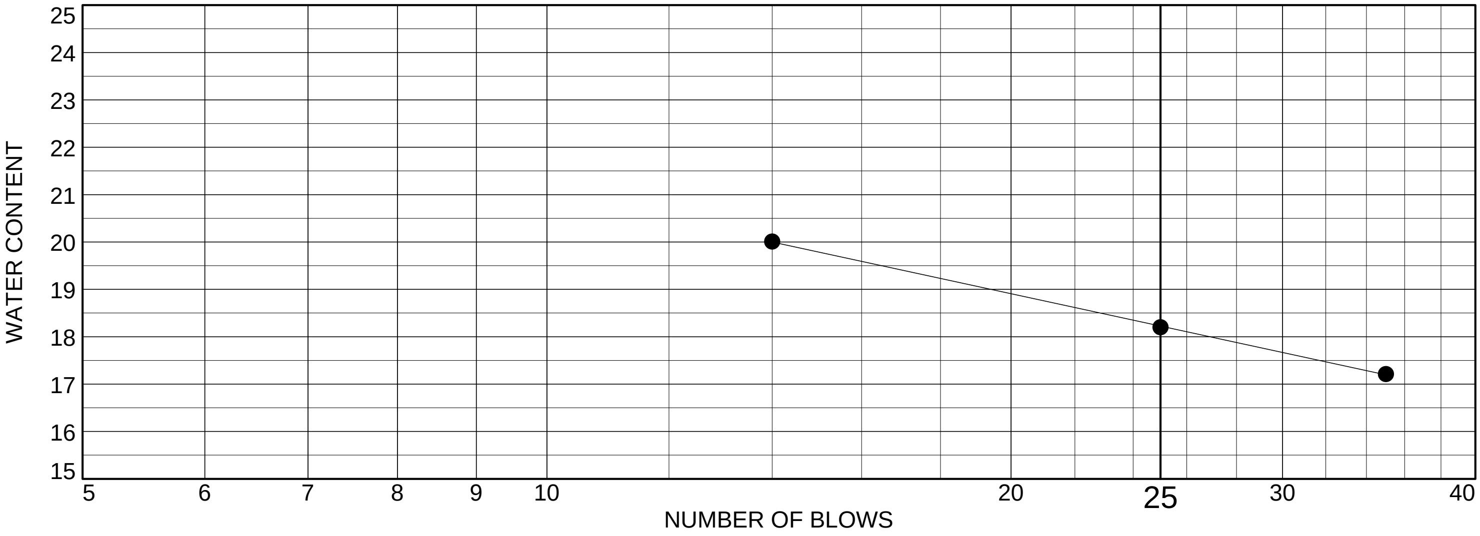
● **Source of Sample:** B-GB-3 **Depth:** 13.0'-13.5' **Sample Number:** S-2A

Remarks:

Tested By: EMR **Checked By:** WPQ

LIQUID AND PLASTIC LIMITS ASTM D 4318





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	SILTY CLAY LITTLE F-C SAND TRACE F GRAVEL - BROWN	18	10	8			CL

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

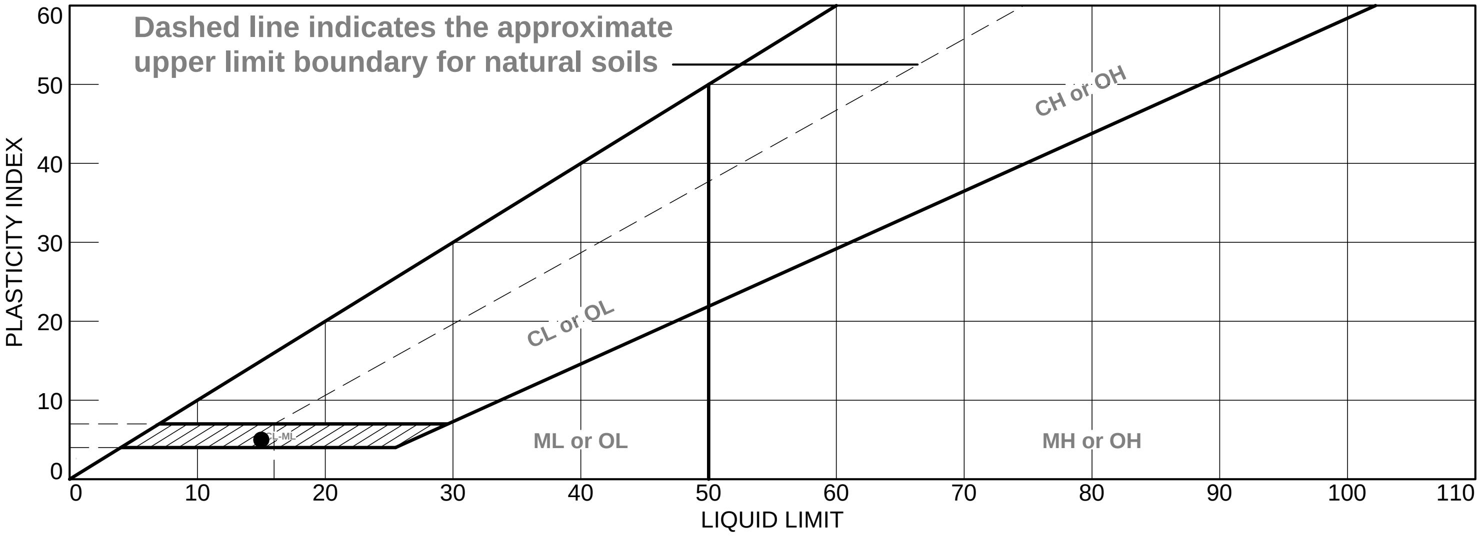
● **Source of Sample:** B-GB-7 **Depth:** 14.0'-16.0' **Sample Number:** S-2

Remarks:

AECOM

Tested By: EMR **Checked By:** WPQ

LIQUID AND PLASTIC LIMITS ASTM D 4318



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	F-C SAND SOME SILT LITTLE CLAY TRACE F GRAVEL - BROWN	15	10	5	85.2	40.1	SC-SM

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

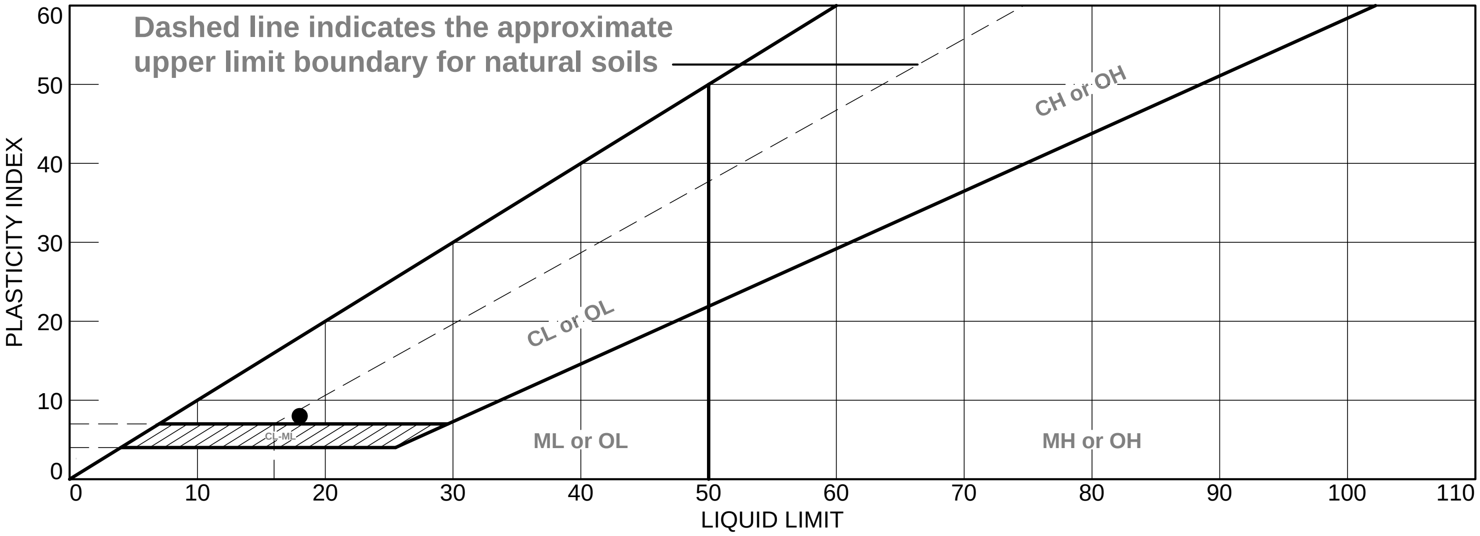
● **Source of Sample:** B-GB-12 **Depth:** 10.5'-11.0' **Sample Number:** S-4A

Remarks:

AECOM

Tested By: EMR **Checked By:** WPQ

LIQUID AND PLASTIC LIMITS ASTM D 4318



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	SILTY CLAY AND F-M SAND - BROWN	18	10	8	93.3	58.9	CL

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

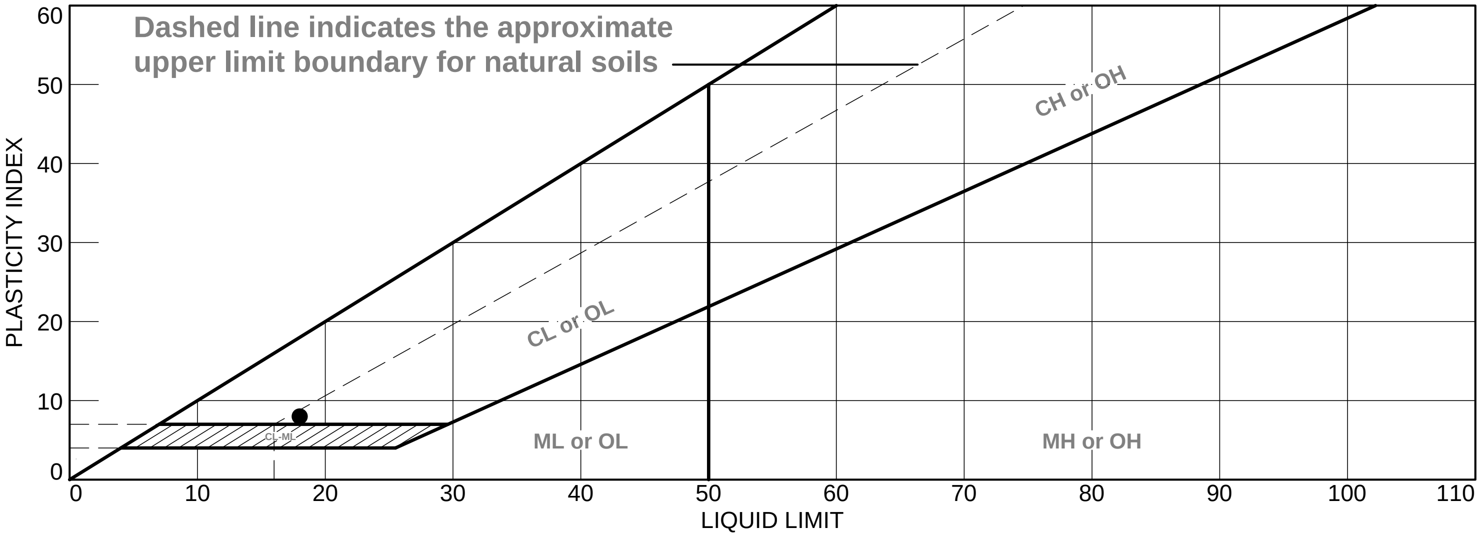
● **Source of Sample:** B-GB-11 **Depth:** 13.5'-14.0' **Sample Number:** S-2A

Remarks:

AECOM

Tested By: EMR **Checked By:** WPQ

LIQUID AND PLASTIC LIMITS ASTM D 4318



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	SILTY CLAY AND F-M SAND - BROWN	18	10	8	94.0	58.5	CL

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

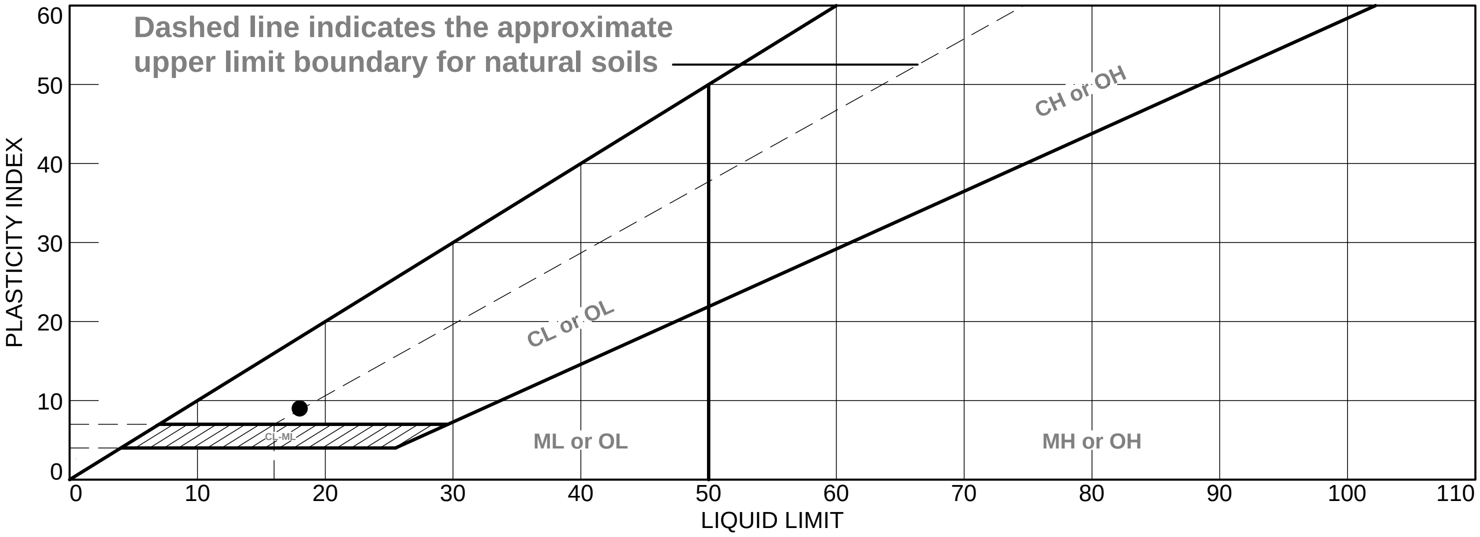
Project: BROWN BRIDGE DAM

● **Source of Sample:** B-GB-10 **Depth:** 13.5'-14.0' **Sample Number:** S-7A

Remarks:

Tested By: EMR **Checked By:** WPQ

LIQUID AND PLASTIC LIMITS ASTM D 4318



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	F-C SAND SOME F GRAVEL LITTLE SILT LITTLE CLAY - BROWN	18	9	9	57.3	34.4	SC

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

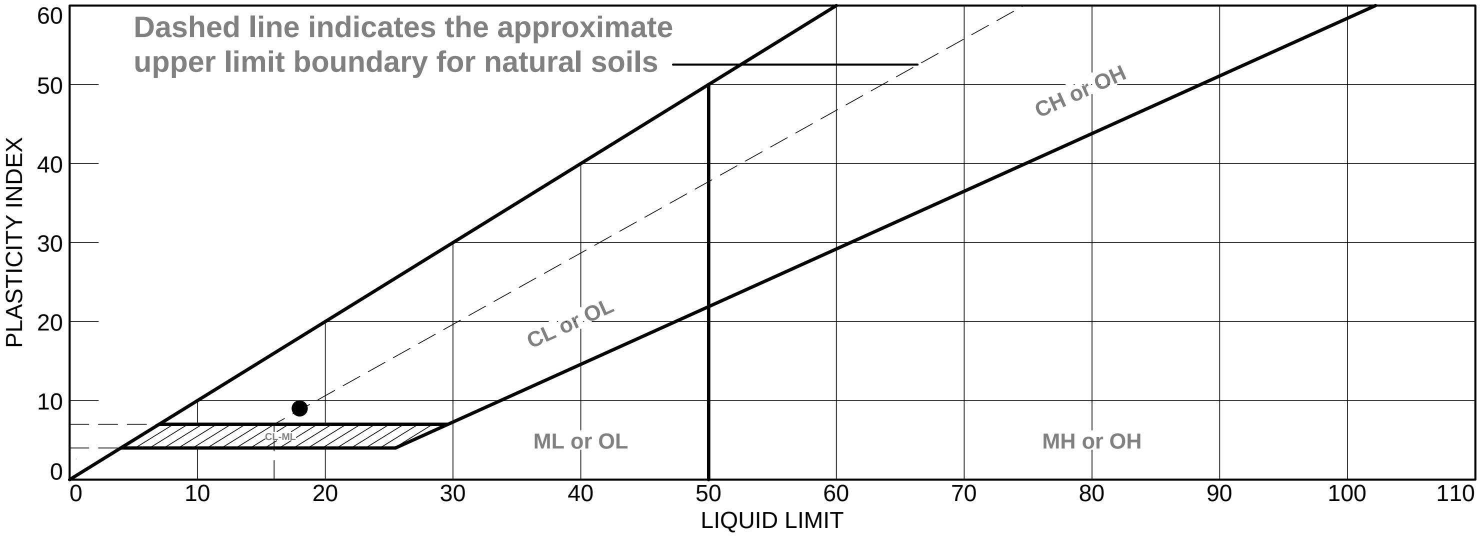
Project: BROWN BRIDGE DAM

● **Source of Sample:** B-GB-12 **Depth:** 15.0'-16.0' **Sample Number:** S-6A

Remarks:

Tested By: EMR **Checked By:** WPQ

LIQUID AND PLASTIC LIMITS ASTM D 4318



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	SILTY CLAY AND F-M SAND TRACE F GRAVEL - BROWN	18	9	9	90.2	54.2	CL

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

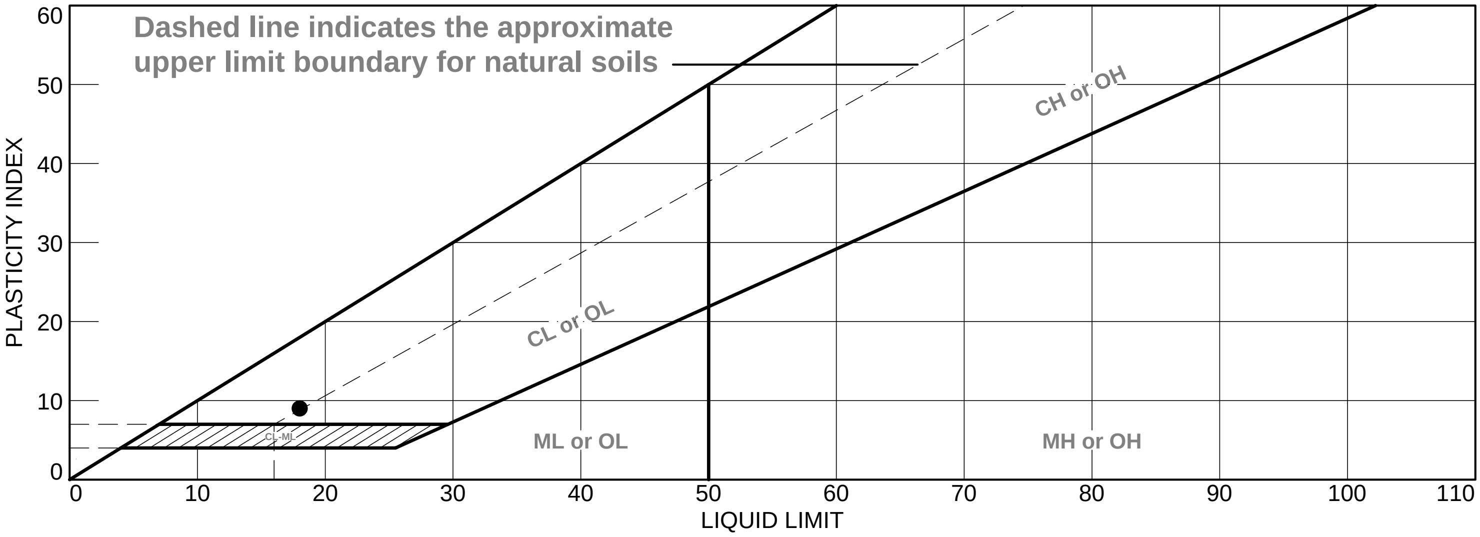
Project: BROWN BRIDGE DAM

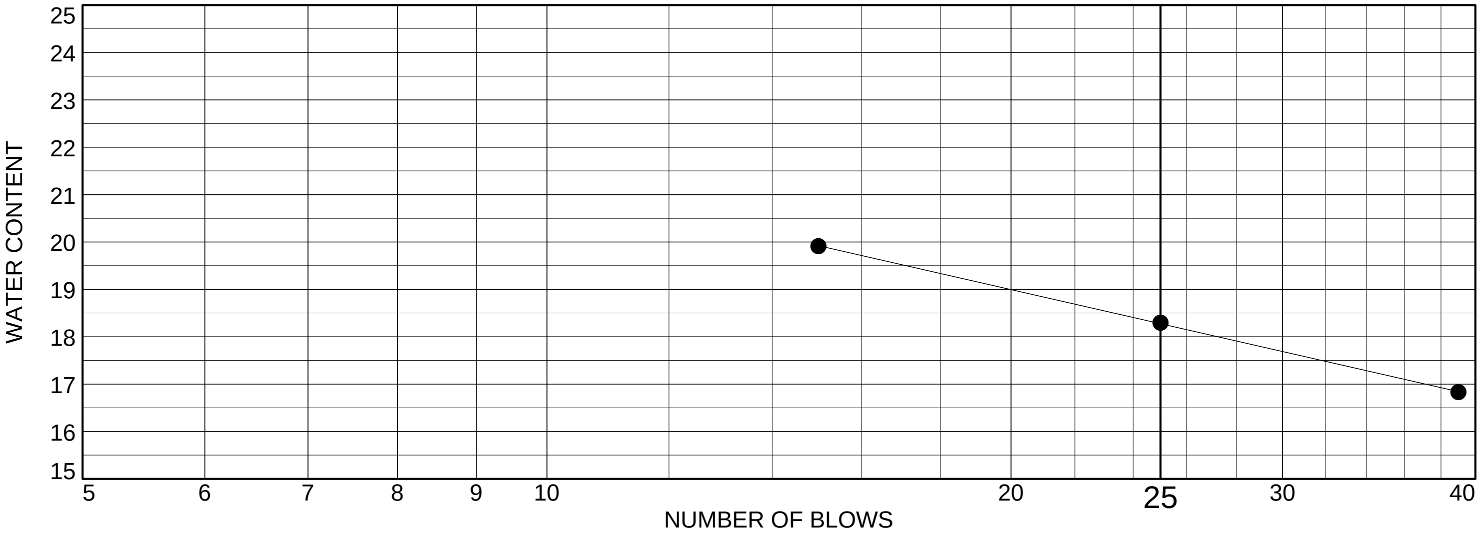
● **Source of Sample:** B-GB-12 **Depth:** 16.5'-17.5' **Sample Number:** S-7A

Remarks:

Tested By: EMR **Checked By:** WPQ

LIQUID AND PLASTIC LIMITS ASTM D 4318





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	SILTY CLAY AND F-M SAND - BROWN	18	9	9	95.0	59.4	CL

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

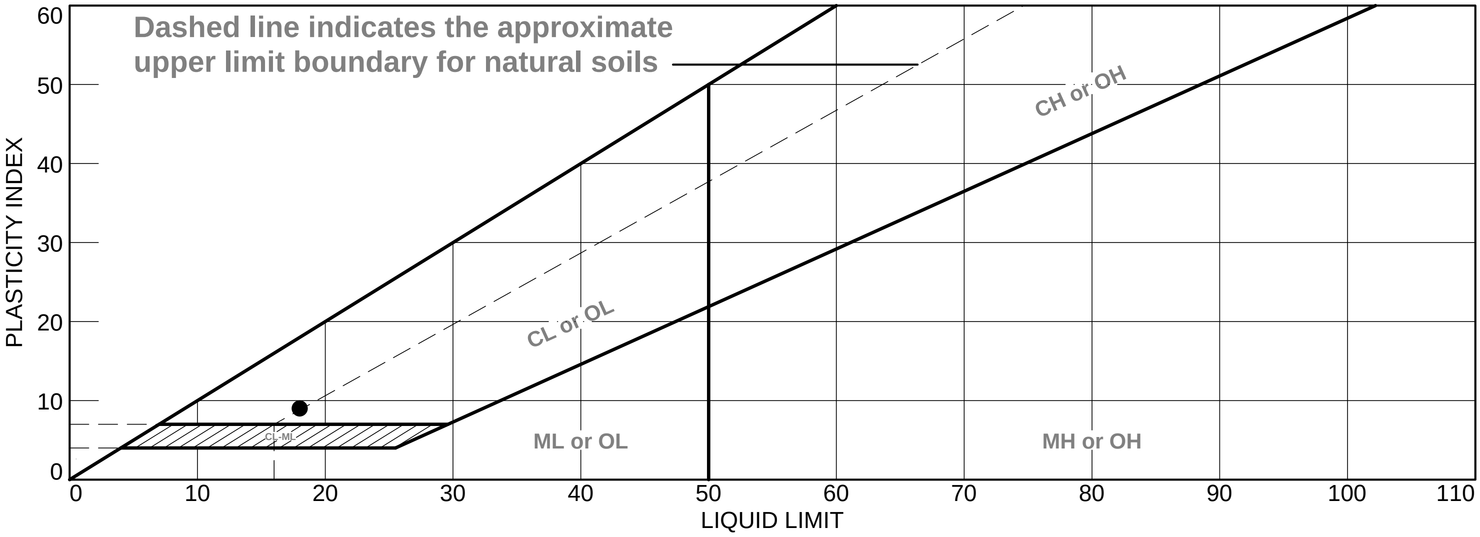
● **Source of Sample:** B-GB-13 **Depth:** 12.2'-12.8' **Sample Number:** S-5A

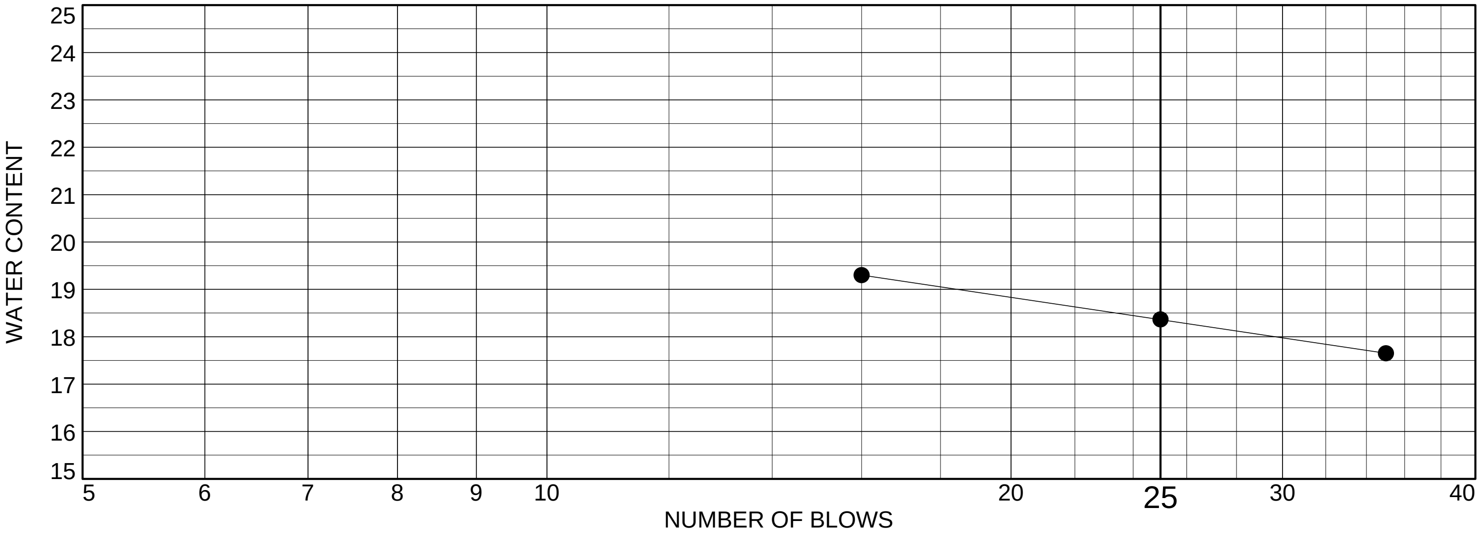
Remarks:

AECOM

Tested By: EMR **Checked By:** WPQ

LIQUID AND PLASTIC LIMITS ASTM D 4318





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	SILTY CLAY AND F-M SAND TRACE F GRAVEL - BROWN	18	9	9	92.0	57.0	CL

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

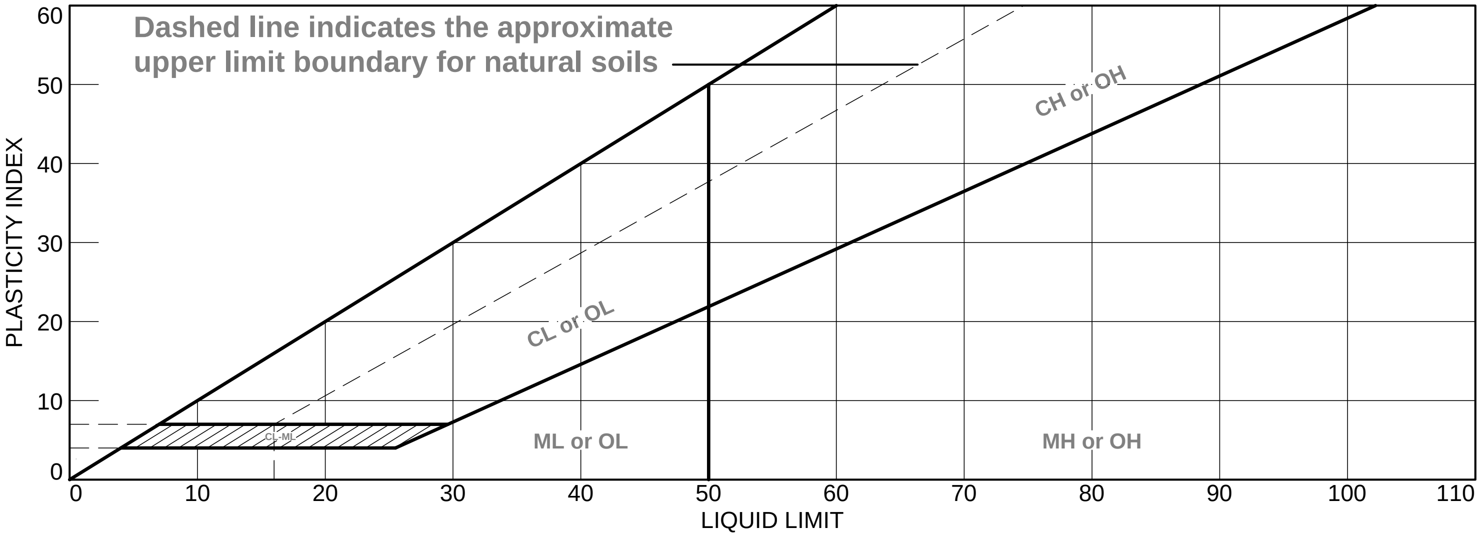
● **Source of Sample:** B-GB-14 **Depth:** 12.0'-13.1' **Sample Number:** S-5

Remarks:

AECOM

Tested By: EMR **Checked By:** WPQ

LIQUID AND PLASTIC LIMITS ASTM D 4318



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	F-C SAND LITTLE SILT TRACE CLAY TRACE F GRAVEL - BROWN	11	11	NP	77.4	20.8	SM

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

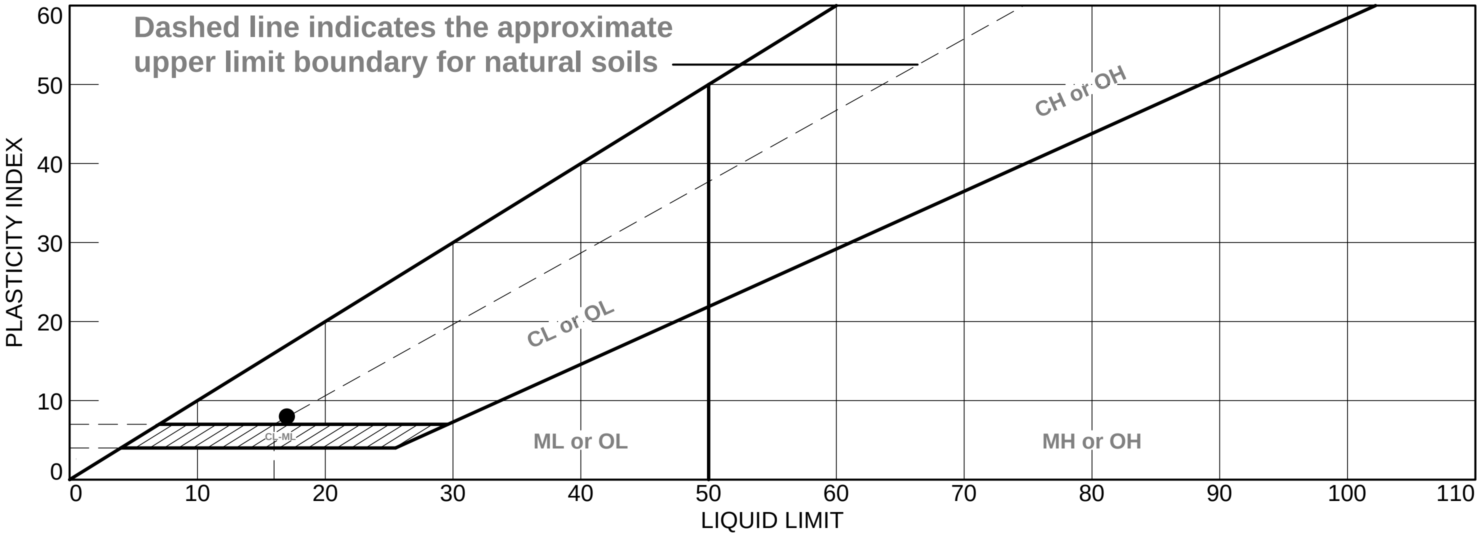
● **Source of Sample:** B-GB-15 **Depth:** 13.0'-13.5' **Sample Number:** S-5A

Remarks:

AECOM

Tested By: EMR **Checked By:** WPQ

LIQUID AND PLASTIC LIMITS ASTM D 4318



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	SILTY CLAY AND F-C SAND TRACE F GRAVEL - BROWN	17	9	8	93.9	52.6	CL

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

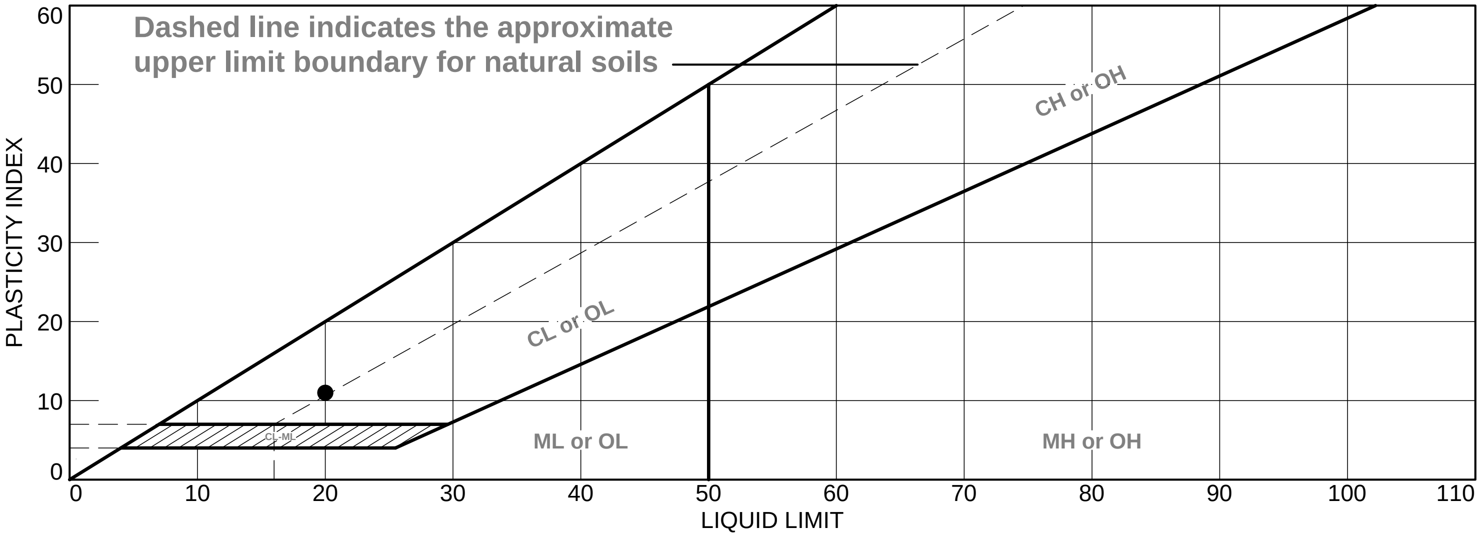
Project: BROWN BRIDGE DAM

● **Source of Sample:** B-GB-15 **Depth:** 13.5'-14.0' **Sample Number:** S-5B

Remarks:

Tested By: EMR **Checked By:** WPQ

LIQUID AND PLASTIC LIMITS ASTM D 4318



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	SILTY CLAY AND F-C SAND TRACE F GRAVEL - BROWN	20	9	11	90.0	56.2	CL

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

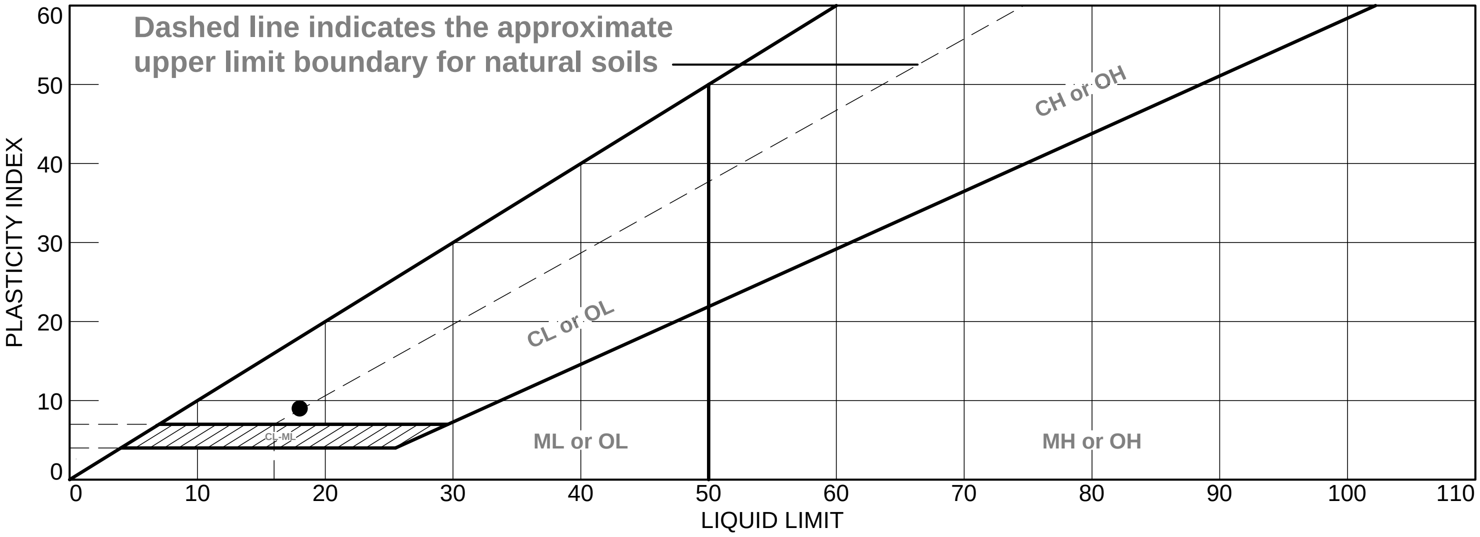
Project: BROWN BRIDGE DAM

● **Source of Sample:** B-GB-14 **Depth:** 9.25'-10.0' **Sample Number:** S-3A

Remarks:

Tested By: EMR **Checked By:** WPQ

LIQUID AND PLASTIC LIMITS ASTM D 4318



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	SILTY CLAY AND F-C SAND LITTLE F GRAVEL - BROWN	18	9	9	84.0	52.4	CL

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

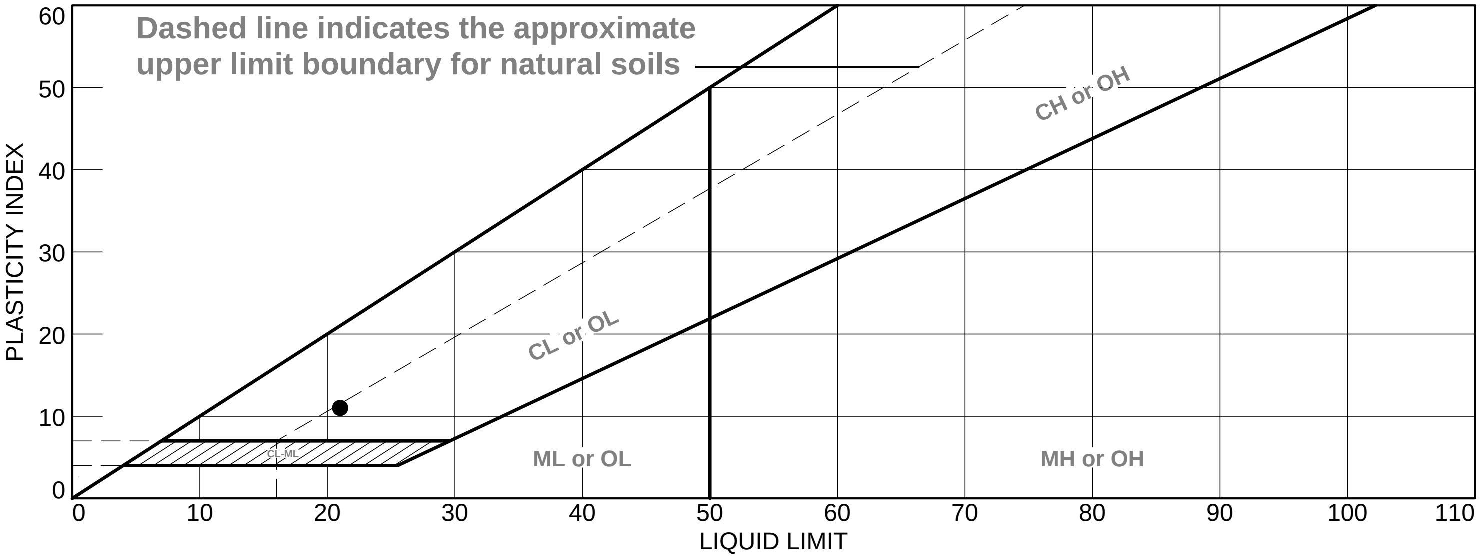
Project: BROWN BRIDGE DAM

● **Source of Sample:** B-GB-16 **Depth:** 13.0'-14.0' **Sample Number:** S-4A

Remarks:

Tested By: EMR **Checked By:** WPQ

LIQUID AND PLASTIC LIMITS ASTM D 4318



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	SILTY CLAY AND F-C SAND - BROWN	21	10	11	93.3	61.7	CL

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

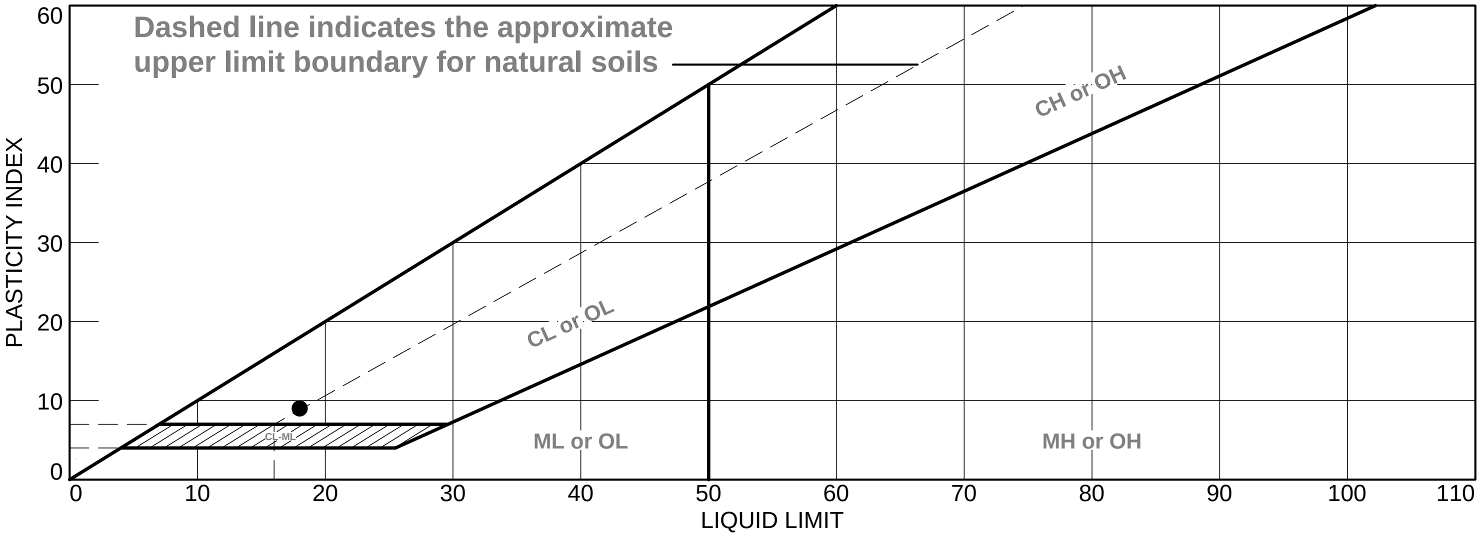
Project: BROWN BRIDGE DAM

● **Source of Sample:** B-GB-17 **Depth:** 12.0'-14.0' **Sample Number:** S-4

Remarks:

AECOM

LIQUID AND PLASTIC LIMITS ASTM D 4318



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	SILTY CLAY AND F-C SAND TRACE F GRAVEL - BROWN	18	9	9	91.4	54.5	CL

Project No. 60279499 **Client:** GARAN LUCOW MILLER, P.C

Project: BROWN BRIDGE DAM

● **Source of Sample:** B-GB-18 **Depth:** 12.5'-14.0' **Sample Number:** S-4A

Remarks:

Tested By: EMR **Checked By:** WPQ

AECOM

Dispersive Clay Soils by Pinhole Test
ASTM D 4647

Laboratory Services Group *750 Corporate Woods Parkway Vernon Hills, Il 60031* *Phone: (847) 279-2500 Fax: (847) 279-255*

Project No.: 60279499
Project: Brown Bridge Dam
Date: 6/6/2013

Boring number: GB-3
Sample Number: 3
Depth (ft) 13.5'-15.5'

Dry Unit Weight (pcf): 131.7
Moisture Content (%): 6.5

Soil Description: Silty Clay Little F-C Sand Trace F Gravel - Brown CL

Final Hole Diameter (mm):

1.28

Dispersion Classification:

ND2
Non- Dispersive

Specimen After Test

TEST RESULTS

Clock Time	Head (in)	Flow		Flow Rate (ml/sec)	Turbidity From Side						Completely Clear From Top	Remarks
		ml	sec		Very Dark	Dark	Moderately Dark	Slightly Dark	Barely Visable	Completely Clear		
12:14	0	0	0	0								Start of Test
12:15	2	25	60	0.4167						X	X	
12:16	2	56	120	0.4667						X	X	
12:17	2	81	180	0.45						X	X	
12:18	2	103	240	0.4292						X	X	
12:19	2	133	300	0.4433						X	X	
12:24	2	269	600	0.4483						X	X	
12:25	7	75	60	1.25						X	X	Raised Head to 7.0"
12:26	7	156	120	1.3						X	X	
12:27	7	226	180	1.2556						X	X	
12:28	7	297	240	1.2375						X	X	
12:29	7	364	300	1.2133						X	X	
12:30	15	101	60	1.6833						X	X	Raised Head to 15.0"
12:31	15	203	120	1.6917						X	X	
12:32	15	300	180	1.6667						X	X	
12:33	15	405	240	1.6875						X	X	
12:34	15	505	300	1.6833						X	X	
12:34	40	203	60	3.3833						X	X	Raised Head to 40.0"
12:34	40	355	120	2.9583						X	X	
12:34	40	576	180	3.2						X	X	
12:34	40	801	240	3.3375					X		X	Barely Visible Solution
12:34	40	1020	300	3.4					X		X	Stop Test

Technician: BCM Date: 6/6/2013
Checked By; WPQ Date: 6/6/2013

AECOM

Dispersive Clay Soils by Pinhole Test
ASTM D 4647

Laboratory Services Group *750 Corporate Woods Parkway Vernon Hills, Il 60031* *Phone: (847) 279-2500* *Fax: (847) 279-255*

Project No.: 60279499
Project: Brown Bridge Dam
Date: 6/6/2013

Boring number: GB-7
Sample Number: 2
Depth (ft) 14.0'-16.0'

Dry Unit Weight (pcf): 132.8
Moisture Content (%): 6.2

Soil Description: Silty Clay Little F-C Sand Trace F Gravel - Brown CL

Final Hole Diameter (mm):

1.18

Dispersion Classification:

ND1
Non- Dispersive

Specimen After Test

TEST RESULTS

Clock Time	Head (in)	Flow		Flow Rate (ml/sec)	Turbidity From Side						Completely Clear From Top	Remarks
		ml	sec		Very Dark	Dark	Moderately Dark	Slightly Dark	Barely Visable	Completely Clear		
1:29	0	0	0	0								Start of Test
1:30	2	22	60	0.3667					X		X	Start of Test Produced Limited
1:31	2	49	120	0.4083					X		X	Material
1:32	2	72	180	0.4						X	X	Transition to clear
1:33	2	99	240	0.4125						X	X	
1:34	2	130	300	0.4333						X	X	
1:39	2	254	600	0.4233						X	X	
1:41	7	50	60	0.8333						X	X	Raised Head to 7.0"
1:42	7	103	120	0.8583						X	X	
1:43	7	152	180	0.8444						X	X	
1:44	7	202	240	0.8417						X	X	
1:45	7	249	300	0.83						X	X	
1:46	15	62	60	1.0333						X	X	Raised Head to 15.0"
1:47	15	144	120	1.2						X	X	
1:48	15	300	180	1.6667						X	X	
1:49	15	420	240	1.75						X	X	
1:50	15	520	300	1.7333						X	X	
1:51	40	136	60	2.2667						X	X	Raised Head to 40.0"
1:52	40	321	120	2.675						X	X	
1:53	40	450	180	2.5						X	X	
1:54	40	578	240	2.4083						X	X	Fluid Clear
1:55	40	756	300	2.52						X	X	Stop Test

Technician: BCM
Checked By; WPQ

Date: 6/6/2013
Date: 6/6/2013

Dispersive Clay Soils by Pinhole Test
ASTM D 4647

Laboratory Services Group *750 Corporate Woods Parkway Vernon Hills, Il 60031* *Phone: (847) 279-2500 Fax: (847) 279-255*

Project No.: 60279499
Project: Brown Bridge Dam
Date: 6/6/2013

Boring number: GB-13
Sample Number: 4A
Depth (ft) 11.0'-12.0'

Dry Unit Weight (pcf): 109.0
Moisture Content (%): 7.7

Soil Description: F-C Sand Some Silt Little Clay Trace F Gravel - Brown SM

Final Hole Diameter (mm):

1.73

Dispersion Classification:

ND3
Slightly-Dispersive

Specimen After Test

TEST RESULTS

Clock Time	Head (in)	Flow		Flow Rate (ml/sec)	Turbidity From Side						Completely Clear From Top	Remarks
		ml	sec		Very Dark	Dark	Moderately Dark	Slightly Dark	Barely Visable	Completely Clear		
3:06	0	0	0	0								Start of Test
3:07	2	33	60	0.55					X		X	
3:08	2	68	120	0.5667					X		X	
3:09	2	92	180	0.5111					X		X	
3:10	2	128	240	0.5333					X		X	
3:11	2	161	300	0.5367					X		X	
3:16	2	342	600	0.57					X		X	
3:17	7	58	60	0.9667					X		X	Raised Head to 7.0"
3:18	7	132	120	1.1					X		X	
3:19	7	225	180	1.25					X		X	
3:20	7	335	240	1.3958					X		X	
3:21	7	412	300	1.3733					X		X	
3:22	15	119	60	1.9833					X			Raised Head to 15.0"
3:23	15	246	120	2.05					X			
3:24	15	413	180	2.2944				X	X			Fluid Transitions to Slightly Dark
3:25	15	598	240	2.4917				X				
3:26	15	745	300	2.4833				X				Stop Test

Technician: BCM Date: 6/6/2013
Checked By; WPQ Date: 6/6/2013

Pocket Erodometer
Test
(PET)

Laboratory Services Group *750 Corporate Woods Parkway, Vernon Hills, Illinois 60061* *Phone: (847) 279-2500 Fax:(847) 279-2510*

AECOM Project No.: 60279499
Project Name: Brown Bridge Dam
Date: 6/11/2013

Nozzle Diameter: 0.5 mm
Nozzle Velosity: Approx. 8 m/s
Distance From Nozzle to Specimen: 50 mm

Sample Information

Boring No.	Sample No.	Depth (ft)	PET Depth (mm)	PET Category	PET Category Range
GB-3	2A	13.0-13.5	0.38	4	3.5-4.5
GB-7	1A	13.0-14.0	0.1	4	3.5-4.5
GB-10	7A	13.5-14.0	0.15	4	3.5-4.5
GB-11	2A	13.5-14.0	0.37	4	3.5-4.5
GB-13	4A	11.0-12.0	3.52	3	2.5-3.5
GB-13	5A	12.2-13.8	0.26	4	3.5-4.5
Gb-14	3A	9.0-10.0	0.21	4	3.5-4.5
GB-18	4A	12.5-14.0	1.41	3	2.5-3.5

Note: All samples appeared to be desicated prior to testing.