Preliminary Geotechnical and Materials Report

Missoula County and Montana Department of Transportation

Bitterroot River – W of Missoula
BR 9032(65)

Prepared for:

HDR
Mr. Dustin Hirose, P.E.
700 SW Higgins Avenue, Suite 200
Missoula, Montana 59803-1489

Prepared by:

Tetra Tech
2525 Palmer Street, Suite 2
Missoula MT 59808
(406) 543-3045
Tetra Tech Project No. 114-570937

July 22, 2016

TABLE OF CONTENTS

LIST OF APPENDICES

1.0 PROJECT DESCRIPTION

A new multi-span bridge will replace the structurally obsolete through-truss, Maclay Bridge which crosses the Bitterroot River at North Avenue in Missoula, Montana. The South Avenue Bridge project will be located at the west end of South Avenue, several blocks upstream of the current bridge crossing. The new bridge will span the Bitterroot River and its associated floodplain, connecting South Avenue with River Pines Road. The new structure and approach lanes will be inside the 100-year floodplain limits.

The preliminary project evaluation process by HDR determined the preliminary bridge design to consist of a 900-foot long, two-lane, 7 to 9 span structure with a dedicated pedestrian walkway. The deck width will be on the order of 50 feet to accommodate a 28- foot wide roadway, 10-foot wide walkway, pedestrian rail and safety barrier. Span lengths could be greater than 200 feet between bridge bents, with the superstructure consisting of steel plate girder or possibly precast concrete beams. Bents are skewed approximately 29 degrees to the roadway alignment to optimize orientation with the Bitterroot River channel. New Right-of-Way will need to be acquired and utilities relocated to accommodate the new structure.

The geotechnical engineering Scope of Work for the project includes; preliminary recommendations for foundation design at bridge abutments and piers, liquefaction evaluation, and a probabilistic site seismic analysis. To date, private landowner access restrictions have not been mutually cleared to the satisfaction of all involved stakeholders, thus planned investigations at the intermediate bents are still pending negotiation of those agreements. Preliminary recommendations contained herein, have been developed solely on two initial borings drilled, one per each probable abutment location. Since project funding is through the Federal Highway Administration (FHWA) off-system bridge program administered by MDT, geotechnical design for this report will follow general organization and topical discussion consistent with MDT standards and will provide sufficient information to carry the design through the TS&L phase. The report addresses typical MDT geotechnical and materials task 130 requirements, with the exception of the geotechnical borings to be drilled for the intermediate bents and approach fills. A supplement to this report will be required to address; 1) drilling and foundation design for the final intermediate bridge bent locations, 2) final approach fill types, elevations and locations, 3) and any other geotechnical items not covered in this investigation.

2.0 GEOTECHNICAL EVALUATION AND INVESTIGATION

Prior to the geotechnical investigation being performed, a geotechnical field and office evaluation was completed. The following sections discuss the geotechnical evaluation and field investigation.

2.1 Geotechnical Evaluation

2.1.1 Project Location, Land Use, and Site Geology

Tetra Tech performed a reconnaissance of the site geology, topography, utility conflicts, drill rig access, and current land use as they relate to geotechnical issues along the project length. This information was supplemented with published geologic references and data from the field investigation. The objectives of the geologic reconnaissance were to 1) provide a general geologic framework for the project corridor, and 2) provide additional data in consideration of the proposed structure's design and foundation alternatives. Work under this item generally followed guidelines outlined in MDT's *Geotechnical Manual* (June 2008).

The project is located on the southwest side of the Missoula Valley, approximately ½-mile south of the confluence of the Bitterroot and Clark Fork Rivers. The new bridge site is located on relatively level floodplain terrain, with the mouth of O'Brien Creek entering the river channel just south of the structure alignment on the west side of the Bitterroot River. Under routine seasonal flows, the river is generally confined to its current channel location at the bridge crossing but does exhibit some braided channel characteristics downstream where streamflow diverges around a rather large island just upstream of Maclay Bridge. An irrigation ditch parallels the east side of River Pines Road at the proposed west abutment location. Adjacent property primarily consists of residential homes on larger rural tracts of privately-owned land and open fields used for agricultural purposes or for grazing livestock. Both banks of the river have substantial growth of small brush and numerous large cottonwood trees.

The Missoula Valley is part of the Northern Rocky Mountains physiographic province, where north- to northwest-trending mountain ranges separate intermontane valleys drained by the Clark Fork River and its tributaries. The Missoula Valley is a northwest trending intermontane basin bounded by the Rattlesnake Mountains and Reservation Divide to the north, the Grave Creek Range to the south, Hellgate Canyon and the Sapphire Mountains to the east, and the Clark Fork and Ninemile Valleys to the west. The Missoula Valley is a relatively wide valley characterized by large areas of low-relief grassy and wooded terrain into which modern streams have cut relatively narrow channels 50 to 100 feet below the valley floor.

The valley basin is filled with unconsolidated to weakly lithified materials ranging in thickness from less than 100 feet to as much as several thousand feet thick in areas that have been down-dropped by faults relative to the surrounding mountains. Near-surface alluvial sediments consist of coarse-grained sand and gravel with minor interbeds of silt and clay along the modern stream floodplains and low terraces. Since Pleistocene time, the Bitterroot and Clark Fork Rivers have down cut and removed nearly 800 feet of sediment from the valley floor as they meander across their floodplains. Two terrace levels to the Bitterroot River are visible when approaching the site on South Avenue illustrative of active erosion by the river during periods of higher stream flows.

The Missoula Valley was inundated by Glacial Lake Missoula during the last ice age, about 13,000 to 15,000 years ago. Studies by David Alt documented through investigation of the varved lakebed sediments exposed in the Ninemile area indicate that a total of 36 fillings of the glacial lake occurred, followed by rapid draining of the lake basin down the Clark Fork River Valley with each breach of the ice dam in north Idaho. The intervals between each flood event range from approximately 56 years to as short as nine years over a time span of about 1,000 years (Alt, 2001). During Glacial Lake Missoula flood events, the water flowing north out of the Bitterroot Valley fluvial system emptied into Glacial Lake Missoula and deposited sand and gravel alluvium around the confluence of the two drainage systems. The current river system is actively down cutting through these same alluvial deposits.

Review of the Geologic Map of Montana part of the Missoula West 30' by 60' Quadrangle, Western Montana (MBMG, 1998), indicates that the project site is predominately underlain by older alluvium deposited on benches above the modern Bitterroot River channel and floodplain. The natural subsurface alluvial profile along the Bitterroot River is best characterized as a dense alluvial deposit of sand, gravel, cobbles, and boulders extending to depths on the order of 200 feet or greater. In the Missoula Valley, built construction projects document boulders from about 1.5 to more than 5 feet in size as a common occurrence in the alluvium, due to the sequential filling and draining of the glacial lake.

2.1.2 Review of Published Data

Tetra Tech met with Dustin Hirose of HDR to obtain available aerial photos of the project alignment, and proposed structure locations for the project. Tetra Tech also performed a review of past geotechnical projects that have been completed in the area including recently constructed bridges at Orange Street, California Street, Madison Street and Russell Street. The information gathered was used to determine what drilling methods and sampling procedures would be used during the geotechnical investigation.

2.2 Geotechnical Investigation

A preliminary geotechnical investigation was performed for the bridge foundation and includes laboratory testing of subsurface soil strata from the boreholes. The fieldwork was performed to obtain subsurface information, and to identify suitable foundation types and provide foundation recommendations for the design alternatives proposed by HDR.

Boring locations and depths were determined by Tetra Tech and HDR based on the proposed roadway alignment, the approximate location of the proposed structure, and typical sampling frequencies specified in the MDT Geotechnical Manual. As noted previously, this investigation was limited solely to the bridge abutment locations because of landowner access restrictions.

2.2.1 Subsurface Field Investigation

The geotechnical investigation was conducted in August 20 and 21, 2015. Drilling dates of the individual exploratory borings are indicated on the boring logs (Appendix 2A). Based on Tetra Tech's field visit, one boring was drilled at the South Avenue cul-de-sac for the east bridge abutment and one boring in the Right-Of-Way near the east shoulder of River Pines Road near the west abutment, Photos 1 and 2. The locations of both borings are shown on Figure 1 in Appendix 1A.

Photo 1. Drill Rig Positioned at Boring BH-1.

Photo 2. Drilling Rig Positioned at Boring DH-2a.

Locations of the borings were initially marked in the field by Tetra Tech using aerial site maps. Both borings were located using hand held GPS equipment to facilitate incorporation into the site survey prepared by DJ&A. Following completion of the geotechnical drilling, the boring locations were surveyed by DJ&A to obtain the elevation and horizontal and vertical coordinates of each boring. The horizontal and vertical coordinates and elevations are listed on the log of each boring and in Table 1. Note that at the time of this report submittal, the project stationing has not been determined; therefore no stationing has been listed on the logs of the borings in Appendix 2A.

Table 1. Geotechnical Boreholes: Collar Locations and Depths.

Borehole No.	Northing (NAD 83)	Easting (NAD 83)	Collar Elevation, Ft.	Total Length, Ft.
BH-1	N 981553.177	E 817490.835	3114.61	109.4
BH-2a	N 981174.148	E 818558.318	3114.61	101.0

The first boring (BH-2) was advanced utilizing truck-mounted, air-rotary drilling equipment. However, complications with heaving sands encountered during the drilling process caused the drill rod to bind within the steel casing, impeding borehole advancement. Therefore, to counteract the heaving sand flow conditions, boring BH-2 was abandoned and the remaining borings BH-1 and BH-2a and were drilled using a truck-mounted drill rig equipped with 8-inch O.D. hollow-stem augers and mud rotary equipment. The boreholes were logged by Tetra Tech's geotechnical field engineer.

Samples of the subsurface soils were obtained with a 2-inch outside-diameter (1-3/8 inch inside-diameter) split-spoon sampler or a 2.5-inch outside-diameter (2-inch inside-diameter) modified California sampler driven into the various strata using a 140-pound hammer falling 30 inches. Per discussions with the MDT Geotechnical Section prior to commencing drilling, Tetra Tech intermixed the California sampler with the standard 2-inch O.D. SPT sampler at 5-foot intervals, primarily to improve sample recovery because a larger volume, more representative sample of the sand and gravel alluvium can be obtained with the California sampler. The number of blows required to advance the samplers each successive 6-inch increment was recorded; the total number of blows required to advance the sampler the second and third 6-inch increments is the penetration resistance value (N value). The 2-inch O.D. sampler conforms to the standard penetration test described by American Society for Testing and Materials (ASTM) Method D1586 and the larger diameter California sampler is a modified version of this test. Penetration resistance values indicate the relative density or consistency of the soils. The N-values for the larger California split-spoon sampler shown on the logs of the borings are uncorrected. Discussions with the MDT Geotechnical Section indicate a preference to predict engineering properties of soils and design parameters based on correlations obtained from the SPT sampler, and not the California sampler, thus the California values were not corrected. Bulk samples of soil were obtained from the hollow-stem augers at select locations. Shelby Tube samples were not obtained given the elevated pressure conditions encountered while drilling and since subsoils consisted predominately of saturated, medium to very dense granular soils. Depths at which the samples were obtained and the penetration resistance values are shown on the logs of exploration borings in Appendix 2A.

2.2.2 Laboratory Testing

Soil samples obtained during the field exploration were taken to Tetra Tech's laboratory, where they were observed and visually classified in accordance with ASTM Method D2487, which is based on the Unified Soil Classification System. Representative soil samples were selected for testing to determine their engineering and physical properties in general accordance with the Montana Materials Manual of Test Procedures, American Association of State Highway and Transportation Officials (AASHTO), ASTM, or other approved procedures. Laboratory testing was specified to include, grain size distribution, Atterburg limits, and natural water content tests, performed to aid in determining the general site stratigraphy.

Tests Conducted:	**To Determine**:
Atterberg Limits	The effect of varying water content on the consistency of fine-grained soils.
Grain-size Distribution	Size and distribution of soil particles (i.e., clay, silt, sand, and gravel).
Moisture-Density Relationship	The optimum moisture content for compacting soil and the maximum dry unit weight (density) for a given compaction effort.
Natural Moisture Content	Moisture content representative of field conditions at the time samples were taken.
Resistivity and pH	The combination of these characteristics determines the potential of soil to corrode metal.
Sulfate Content	Potential of soils to deteriorate normal strength concrete.

Field and laboratory tests results are presented in Appendices 2B through 2D. These data, along with the field information, were used to prepare the exploration boring logs on Figures 2A-1 and 2A-2 in Appendix 2A.

2.2.3 Subsurface Conditions

Subsurface soils were classified in accordance with the AASHTO soil classification system. Descriptive terms were obtained using the ASTM Soil Classification System. Both classifications are included on the logs and laboratory data presented in Appendices 2A through 2C for each soil sample tested.

<u>West Abutment</u>: The subsurface soil profile encountered in boring BH-1 located at the southern edge of the pavement on River Pines Road near the proposed west abutment consisted of a thin layer of asphalt pavement overlying silty sand with gravel to a depth of 14.3 feet. A thin 3.7-foot thick interbedded seam of medium dense, subangular to subrounded, poorly graded gravel with sand extended below the sand to a depth of 18 feet followed by a second sand layer which classified as poorly graded sand with gravel to a depth of 29 feet.

Below the sand, a thicker deposit of medium dense to dense gravel was encountered, which extended to a depth of 54 feet, overlying a deeper layer of medium dense to dense, silty sand to a depth of 90 feet. Heaving sand conditions occurred frequently while drilling in the sand layers below depths of about 25 feet and again between depths of 65 to 90 feet. Dense to very dense gravel with smaller percentages of silt and sand was encountered in the boring below the silty sand to the final depth of the boring, 109.4 feet. The gravel is considered a suitable bearing stratum for support of deep foundations.

East Abutment: The subsurface soil profile encountered in boring BH-2a, located at the cul-de-sac on the west end of South Avenue near the proposed east abutment consisted of asphalt pavement overlying poorly graded gravel with sand to a depth of 13 feet. Fine to coarse-grained silty sand was encountered below the gravel to a depth of 35 feet, grading to a seam of less silty, medium dense poorly graded sand with scattered gravel.

The sand is underlain by a second layer of loose to medium dense, intermixed sands to depths of about 81 feet where seams of silty sand with gravel and poorly graded sand with gravel extend to a depth of 93 feet. Relative density in the sands increased from 81 to 93 feet in depth, consistent with an increased percentage of gravel. Medium dense to very dense gravel with minor percentages of silt and sand was encountered in the boring below the sand to the final depth of the boring, 101.0 feet. The gravel is considered a suitable bearing stratum for support of deep foundations.

A characterization of the subsurface profile includes grouping soils having similar physical and engineering properties into a number of distinct layers. The soils encountered within the exploratory borings are discussed in detail below, beginning at the ground surface. The boring logs in Appendix 2A should be referenced for complete descriptions of the soil types and their estimated depths.

Asphalt

Asphalt concrete pavement thickness ranged from 0.2 feet (Boring BH-2a) to 0.3 feet (Boring BH-1). The asphalt surface condition varied between locations appearing significantly older and more distressed at boring BH-2a in comparison to that at Boring BH-1.

Gravel Base-Subbase

Base course was encountered beneath the pavement asphalt surface layer in both of the borings. The layer did not appear to be a crushed-manufactured product, but more similar to a native pit-run granular material. The thickness averaged approximately 0.3 feet (Borings BH-1, BH-2a). The natural moisture content in the base course ranged from 4 to 6 percent.

Alluvial Sand

Layers of tan to medium brown, natural sand were encountered in the borings at varying depths interbedded with differing layers of gravel. The sands range from fine- to coarse-grained and contain varying amounts of silt and small subangular to subrounded gravel. Samples of the sand classify as silty sand, silty sand with gravel, and poorly graded sand with gravel according to the ASTM classification system (Figures 2B-1, 2B-3, 2B-5, and 2B-6 in Appendix 2B). Penetration resistance values in the sand layers above depths of about 55 feet generally ranged from 11 to 31 blows per foot, averaging about 24. In the deeper sand deposits, percentages of small gravel increased, resulting in increased blow counts from a low of 20 to 52 blows per foot. Liquid and plastic limit testing determined the fine-grained portion of the sand is non-plastic. A natural moisture content of 3 percent was measured for a sand sample above the water table, and due to the shallower groundwater table, most of the sand is saturated. Results of a moisture-density test determined an optimum moisture content of 11.2 percent and a maximum dry density of 115.8 pounds per cubic foot (pcf) for a sample of the sand (Figure 2C-1).

Hydraulic pressure gradients encountered throughout the stratum created flowing/heaving sand conditions while drilling. Little or no apparent drilling resistance was encountered during advancement of hollowstem augers in the sand, and upon disturbance this layer often appeared to lose strength. During initial shaft construction the apparent strength of the layer could be compromised and conditions are favorable to lose support as the shaft is advanced.

Sulfate, resistivity, and pH testing were performed on samples obtained from the upper sand layers, with the following results;

Table 2. Chemical Analysis Test Results, Resistivity and pH.

Boring	Depth (feet)	pH	Minimum Resistivity (ohm-cm)	Sulfate (%)
BH-1	9-10.5	8.0	2,900	Not Detected
BH-2a	9.5-11	8.2	Insufficient Sample to Test	Not Detected
BH-2a	9-10.5	8.0	Insufficient Sample to Test	Not Detected

The combination of pH and resistivity indicates the potential of corrosion of buried metal is low. Sulfate content tests determine the potential of soil to deteriorate normal strength concrete. The concentration of water soluble sulfates measured in the samples tested was not detectable at the reporting limit. This concentration of water soluble sulfates is indicative of a negligible exposure to sulfate attack in normal strength concrete exposed to these materials.

Alluvial Gravel

Two distinct gravel layers were encountered in the borings, the upper layer was relatively close to the surface extending to total depths of 13 and 18 feet, respectively. The second or deeper layer was encountered at 90 to 93 feet in depth and extended to the maximum explored depths of 101.0 and 109.4 feet. An intermediate gravel seam was penetrated in boring BH-1 from 29 to 54 feet but appears discontinuous since it did not extend laterally across the subsurface profile into boring BH-2a. The upper gravel layer contains varying amounts of silt, fine- to coarse-grained sand, occasional sand seams, occasional cobbles, and is subangular to subrounded. Samples of the gravel classify as poorly graded gravel with silt and sand according to the ASTM classification system (Figures 2B-2, 2B-4, and 2B-7) in Appendix 2B. Random pockets of cobbles were interspersed within the gravel layer. Penetration resistance values (SPT) of 16 to 44 blows per foot were determined in the gravel, which is indicative of a medium dense to dense relative density.

In the deeper gravel layers, penetration resistance values ranged from 29 blows per foot to more than 50 blows per foot indicative of a medium dense to very dense strata. Gravel having this range of SPT values should exhibit moderate shear strength characteristics and be relatively incompressible. The gravel also contains varying amounts of silt, fine- to coarse-grained sand, occasional cobbles and boulders, and is subangular to subrounded.

Groundwater

Subsurface water was encountered in both borings at the time of the field exploration (August 2015). Subsurface water was encountered at a depth of 14.3 feet in boring BH-1 and 9.0 feet in BH-2a, as measured from ground surface. All borings were backfilled immediately after drilling using bentonite grout pumped into the annular borehole space.

Groundwater levels will rise with seasonal precipitation and seasonal fluctuations in the Bitterroot River flows during spring runoff. Numerous factors contribute to fluctuations in groundwater levels and evaluation of such factors is beyond the scope of this report.

3.0 GEOTECHNICAL ENGINEERING – STRUCTURES

The following sections discuss the proposed bridge foundation design. As discussed in the Project Description section of this report, this report will provide sufficient information to carry the design through the TS&L phase, and includes some of the MDT Activity 130 requirements as listed in the Consultant Design Manual, with the exception of the geotechnical borings to be drilled for the intermediate piers in the river floodplain and channel. At this point of design, the structure location, height, and configuration are preliminary. The design data presented below is based on the conditions encountered in the geotechnical borings drilled to date. A supplement to this report will be required to address, 1) drilling and design for the final bridge bent locations, 2) final retaining wall types and locations, if needed, and 3) any other geotechnical items not covered in this investigation.

3.1 Conceptual Bridge Design

The South Avenue Bridge project will be located several blocks upstream of the Maclay Bridge crossing, on the west end of South Avenue, west of Reserve Street. The bridge will span the Bitterroot River and its associated floodplain connecting South Avenue with River Pines Road at the Maclay Flats. The preliminary bridge conceptual design could be up to a 900-foot long, two-lane, 7 to 9 span structure with a dedicated pedestrian walkway. Deck width will be on the order of 50 feet to accommodate a 28- foot wide roadway, 10- foot wide walkway, pedestrian rail, and safety barrier. Span lengths are anticipated to be up to 200 feet or greater between bridge bents with the superstructure consisting of steel plate girders or possibly precast concrete beams. Bents are skewed approximately 29 degrees to the roadway alignment to optimize orientation with the Bitterroot River channel. The new bridge structure will be designed to meet current standards in accordance with Montana Department of Transportation (MDT) Bridge design and AASHTO LRFD criteria. The specific design codes utilized for the bridge and foundation design are in the AASHTO LRFD Bridge Design Specifications (2012) and the 2011 AASHTO Guide Specifications for LRFD Seismic Bridge Design, 2nd Edition.

3.2 Preliminary Bridge Foundation Analysis

Options for both drilled shafts and driven pile foundations are being considered as viable foundations to support the abutment and bent structural loads including; pile groups, rows of single piles, and full-height drilled shafts. In discussions with HDR bridge design engineers, there is a preference to support any piers constructed in the river using drilled shafts versus driven piling. In Tetra Tech's opinion, for bent locations over open water, drilled shafts allow the contractor to better manage environmental issues related to the endangered bull trout population and shafts present some advantages in constructability, mainly that a cofferdam would be required to construct pile caps below scour depth for driven piles but is not required for drilled shafts.

Because the bridge layout and configuration have not been finalized, no structural axial or lateral loadings have been determined at this time. Since either or both deep foundation types could eventually be recommended based on cost, constructability, time constraints or aesthetics, preliminary recommendations for each foundation type will be provided in this report.

The soil properties listed below in Table 3 were used for the preliminary pile and shaft axial and lateral analyses.

Table 3. Soil Parameter for Preliminary Axial and Lateral Load Analyses.

Location	Soil Type	Bottom Depth of Layer, (ft.)	Soil Friction Angle	Subgrade Modulus – k
East Abutment and Intermediate Piers – Boring BH-2a	Poorly Graded Gravel with Sand	15	30	80
East Abutment – Boring BH-2a	Silty and Poorly Graded Sand	95	20	40
East Abutment – Boring BH-2a	Poorly graded Gravel with Silt and Sand	110	34	125
West Abutment – Boring BH-1	Silty Sand with Gravel	15	30	80
West Abutment – Boring BH-1	Poorly Graded to Silty Sand and Gravel	95	24	50
West Abutment – Boring BH-1	Poorly Graded Gravel with Silt and Sand	110`	34	125

3.2.1 Driven Pipe Pile

Closed-ended, steel pipe piles with driving shoes, having a ½-inch wall thickness are recommended for the site conditions encountered in the exploration borings. Pipe pile will most likely encounter refusal and terminate in the dense gravel layers encountered in the two abutment borings at depths of about 90 feet below existing grade. Depending on structural loads at the west abutment, pipe pile could achieve capacity in the upper medium dense to dense gravel layer encountered in boring BH-1, between the depths of 29 to 54 feet, provided adequate capacity is achieved to satisfy both the axial and lateral structural load demands. Open-ended pile are expected to plug in the sand soils during driving.

Estimations of axial pile capacity were calculated for pipe pile diameters of 16, 20, and 24 inches using the software program APILE for Windows, Version 2014.6.4. Graphs of factored axial pile capacity versus depth for the various pile diameters are shown for each boring location on Figures 3A-1 and 3A-2, Appendix 3A. Figure 3A-1 should be used for preliminary design of the west abutment, and Figure 3A-2 should be used for preliminary design purposes at the east abutment and the intermediate bents until additional borings are drilled.

A lateral pile loading analysis was performed for the worst-case soils in Boring BH-2a using the software program LPILE Plus for Windows, Version 2013-07.007. Estimations of bending moment versus depth, and shear force versus depth were calculated for pipe pile diameters of 16, 20, and 24 inches, Figures 3B-1 through 3B- 6 in Appendix 3B.

The MDT geotechnical section or their representative are recommended to perform a wave equation analysis to determine whether the contractor has selected a suitable pile hammer for production driving. In addition, one test pile should be driven at each abutment location using a pile driving analyzer (PDA) and re-struck after a period of 72 hours. The software program CAPWAP should be used to evaluate the PDA results. The Geotechnical Section or their representative will use the PDA results to establish the driving criteria for installation of the production piles.

The following design and construction details should be observed for a driven pile foundation system, and should be considered when preparing the construction documents.

1. From the attached nominal axial capacity graphs in Appendix 3A, select the appropriate pipe pile diameter to support structural loads. A resistance factor of 0.65 was applied to the nominal resistance to obtain the factored pile resistance shown in the graphs.

2. ½-inch wall thickness, closed-ended steel pipe-piles with driving shoes are recommended for the site conditions. The pipe pile sections are assumed to be 45 ksi steel per MDT Standard Specifications.

3. Uplift due to structural loadings on the piles can be resisted by using the factored skin resistance value for the selected pile size, plus an allowance for the pile weight and concrete cap weight. Once the structural engineer and Tetra Tech determine the necessary design depth to provide axial and lateral capacity, the factored skin friction can be determined. An LRFD resistance factor of 0.50 will be utilized to determine the factored skin resistance value to use for design.

4. The contractor should select a driving hammer and cushion combination capable of installing the selected piling without overstressing the pile material. The contractor should submit the pile-driving plan and the pile hammer-cushion combination to the MDT Geotechnical Section well in advance of pile installation for evaluation of the driving stresses using a wave equation analysis. After a pile hammer is selected, the MDT Geotechnical Section should establish the initial driving criteria using wave equation analysis.

5. Dynamic analysis should be performed during pile installation at each bent location using a PDA to evaluate the driving resistance required to obtain the predicted design load and establish the final driving criteria. The software program CAPWAP should be used to evaluate the PDA results.

6. An MDT Geotechnical Section representative should observe pile driving operations on a full-time basis. Each pile should be observed and checked for buckling and crimping, in addition to recording penetration resistance, depth of penetration, and general pile driving operations.

3.2.2 Drilled Shafts

The factored axial capacities for drilled shafts were calculated based on the parameters listed in Table 3 above for Boring BH-2a. References include; methodologies presented in the *FHWA Drilled Shaft Construction Procedures and Methods Work Book* (1999) and computer program SHAFT for Windows, Version 2012.7.9, *A Program for the Study of Drilled Shafts Under Axial Loads* (2012), and the current '*AASHTO LRFD Bridge Design Specifications.*

Drilled shaft axial capacities were calculated for shaft diameters of 4, 5, and 6 feet. A factored axial capacity chart is presented in Appendix 3C. For the factored drilled shaft capacities, LRFD resistance factors were used as follows based on the LRFD code; 0.55 for side resistance in sand, 0.50 for tip resistance in sand.

Lateral load analyses were not performed at this time for the drilled shafts. Once lateral loads become available, Tetra Tech will perform a lateral load analysis, and at that point determine the depth of shaft embedment necessary to support both the axial and lateral loads. As discussed for piles, once a shaft size is determined, factored uplift capacities can be determined and will be included in the final report.

3.2.3 Drilled Shaft Construction

Construction of drilled shafts through the sand and gravel will require installation of temporary casing to maintain an open hole.

Temporary casing lengths are required for the full depth of the shaft excavations. Special drilling equipment, including a vibratory hammer, will be necessary to install and remove the temporary casing to the size and depth required. Due to the presence of shallow groundwater in the borings, placement of concrete by tremie or pumping methods will be required during shaft construction.

The design and construction criteria presented below should be observed for a drilled shaft foundation system. The construction details should be considered when preparing the project documents. Drilled shaft construction should be in accordance with the current MDT Drilled Shaft Standard Provision, except as noted herein.

1. Select the appropriate drilled shaft diameter to support the structural loads, ensuring embedment into the gravel layer at depth. For preliminary planning purposes, shafts should extend into the gravel layer at depth a minimum of two shaft diameters.

2. Uplift due to structural loadings on the piles can be resisted by using the factored skin resistance value for the selected shaft size, plus an allowance for the pile weight and concrete cap weight. Once the structural engineer and Tetra Tech determine the necessary design depth to provide axial and lateral capacity, the factored skin friction can be determined. An LRFD resistance factor of 0.45 will be utilized to determine the factored skin resistance value to use for design.

3. The use of temporary casing is recommended the entire depth of the shaft excavations. Removal of temporary casing could be problematic. Drilling contractors should anticipate the need for special drilling and support equipment, including but not limited to a vibratory hammer to advance and extract the temporary casing.

4. Concrete placed below the water table will require placement by tremie or pumping methods. All pumping lines should have a minimum diameter of 4 inches and should be constructed with watertight joints. A plug or similar device should be used to separate the concrete from the fluid in the hole until concreting begins. Concrete placement must not begin until the discharge orifice is at the shaft base.

5. Before the temporary casing is withdrawn, the level of fresh concrete in the casing must be a minimum of 5 feet above the hydrostatic water level or the level of the drilling fluid, whichever is greater. As the casing is withdrawn, care must be exercised to maintain an adequate level of concrete within the casing so that the fluid trapped behind the casing is displaced upward and discharged at the ground surface without contaminating or displacing the shaft concrete. The casing should be pulled up in a manner that minimizes concrete “hang-up” in the casing.

6. Concrete used in the drilled shafts should have a slump on the order of 8 inches +/- one inch.

7. A minimum drilled shaft spacing of three diameters from center to center is recommended.

8. At all abutment and bent locations, install four access tubes evenly spaced around the reinforcing cage edge to permit nondestructive cross-hole sonic log testing. Access tubes should be 2 inch nominal diameter with water-tight joints and should be placed the full length of the reinforcement cage. Nondestructive testing will be performed at a minimum of one shaft per bent once the concrete has cured sufficiently to give consistent test readings.

9. The contractor performing the drilled shaft construction should have experience installing drilled shafts of similar diameter and length and in similar subsurface conditions and should have a minimum of five years’ experience prior to the bid date for this project. The drilled shaft contractor must submit a drilled shaft construction plan to the project engineer listing previous project experience and references and outlining the proposed construction methods, installation sequence, and equipment types.

10. To ensure proper drilled-shaft construction methods and penetration into the desired layers, it is imperative that a Tetra Tech geotechnical engineer be present to observe the materials penetrated and document the drilled shaft installation.

3.2.4 Additional Borings at Intermediate Piers

Tetra Tech has not yet drilled borings for the intermediate piers; the borings will be drilled once the final bridge layout has been determined by HDR and access to site is acquired. Drilling for the remaining intermediate bridge bents is recommended to obtain location specific subsurface information at each bent. Tetra Tech has currently budgeted to drill three additional borings. Of these borings, one boring should be located as close as practical to the east bank of the river for extrapolation of subsurface information below the current river channel and for comparison with that at the west abutment boring. Depending on the final bridge configuration, one or two additional borings should be spaced between the east rivers edge and the easternmost abutment.

A final decision regarding the necessity to drill in the active river channel can be made once the final bridge layout is complete and following generation of the additional subsurface information from the floodplain investigation, which should provide better insight on the relative degree of variability within the subsoil layers. Should access to drilling on the river's edge be possible, then drilling in the river channel will likely not be necessary.

3.3 Seismic and Liquefaction Analysis

3.3.1 Seismic Analysis for Structures

Tetra Tech performed a 'General Procedure' seismic hazard analysis per LRFD 3.10.2.1 (AASHTO Guide Specifications for LRFD Seismic Bridge Design, 2011). The bridge site seismic design parameters were developed utilizing the AASHTO LRFD code and the site latitude and longitude, assuming earthquake ground motions that have a 7 percent probability of exceedance in 75 years. The LRFD code requires obtaining the PGA, SD_S, and SD_1 values for soil (Site Class B) for the project site, then using the soil parameters to develop the seismic coefficients for the site specific soils. Based on the USGS National Seismic Hazard Mapping on-line mapping tool, the peak ground acceleration at the South Avenue Bridge site having a 7 percent probability of exceedance in any 75 year period is 0.131g.

The methods of AASHTO LRFD code require the properties of the rock or soil at the proposed site be classified as one of several site classes. The seismic design parameters for this site include a seismic zone soil profile type of (D), in accordance with the above referenced standard. Site Class D corresponds to a stiff soil profile having standard penetration resistance values between 15 and 50 blows per foot. This classification is based on the laboratory test data and exploration boring information.

The USGS database presents spectral response acceleration data in bedrock for short (0.2 sec) periods (S_S) and for long (1 sec) periods (S_1) for similar probability and 75-year return periods. According to USGS design procedures, these acceleration data are then adjusted upward or amplified depending on soil classification to reflect magnification effects as the earthquake wave energies pass from bedrock into soil. The values are then reduced by a factor that accounts for partial damping of the wave energy by the structure. The final values obtained (known as S_{DS} and S_{D1}) become the basis for the structural design and in this case at South Avenue Bridge are estimated as 0.487g (S_{DS}) and 0.236g (S_{D1}). The data is summarized in the table below.

Table 4. Earthquake and Seismic Design Parameters.

Site	Latitude (North)	Longitude (West)	PGA	S_s	S_1	Site Class	F_a	F_v
South Ave. Site	46.84903	-114.10302	0.131g	0.315	0.098	D	1.55	2.4

Notes: **PGA** = Peak Ground Acceleration
S_s = 0.2 sec. Spectral Response Acceleration
S_1 = 1.0 sec. Spectral Response Acceleration
F_a = Short Period Seismic Design Factor
F_v = Long Period Seismic Design Factor
Return period = 7%
Time period = 75 years
As = 0.202

3.3.2 Liquefaction

The South Avenue Bridge location as discussed previously is underlain by floodplain deposits of interbedded loose to medium dense sands and medium dense to very dense gravel to considerable depth. Groundwater levels measured in the two borings ranged from 9.0 (BH-2a) to 14.3 ft. (BH-1), respectively.

Generally, four criteria are evaluated to determine if liquefaction of the soil can occur: 1) the soils must be saturated (relatively shallow ground water); 2) the soils must be relatively loosely packed (low to medium relative density; 3) the soils must be relatively cohesionless, fine to medium-grained sands with a low clay or silt content; and 4) ground shaking of sufficient intensity and cyclical duration must occur to function as a trigger mechanism. Laboratory testing and field evidence has shown that the possible zone of liquefaction at most sites usually extends from the ground surface to a maximum depth of about 50 feet. Deeper soils generally do not liquefy because of high confining pressures (Day, 2002).

In review of the subsurface information to determine the potential for liquefaction to occur, analysis using the simplified procedure by Seed and Idriss (1971) and Idriss and Boulanger (2008) was performed using the standard penetration test (SPT) values for each abutment boring. The first step of the procedure is to calculate the cyclic stress ratio (CSR) that is induced by the earthquake based on the peak horizontal ground acceleration. Then the cyclic resistance ratio (CRR) is calculated using the $(N_1)_{60}$ corrected SPT values over the depth intervals evaluated. If the CSR induced by the earthquake is greater than the CRR determined from the standard penetration test, then it is likely that liquefaction is possible during the earthquake event. Lastly, a factor of safety (FS) is determined by depth against liquefaction which is defined as FS = CRR/CSR. A factor of safety of 1 or slightly less than 1 suggests the soils may liquefy during an earthquake of sufficient magnitude. The data outcome is summarized in Tables 5 and 6 below:

Table 5. Liquefaction Analysis; BH-1

Depth, ft.	CSR	CRR	FS =CRR/CSR
15	0.116	0.44*	3.8
20	0.128	0.45*	3.5
25	0.136	0.31	2.3
30	0.141	0.40*	2.8
35	0.144	0.40*	2.7
40	0.146	0.23	1.6
45	0.148	0.34	2.3
50	0.148	0.44*	3.0

Note: * Denotes data extrapolated using Figure 6.6 (Seed et al., 1985).

Table 6 Liquefaction Analysis; BH- 2a

Depth, ft.	CSR	CRR	FS =CRR/CSR
10	0.94	0.34	3.6
15	0.109	0.20	1.8
20	0.119	0.24	2.0
25	0.126	0.17	1.3
30	0.131	0.40	3.0
35	0.134	0.21	1.6
40	0.136	0.17	1.3
45	0.139	0.30	2.2
50	0.139	0.34	2.4

Based on the above findings, the potential for earthquake-induced liquefaction at the South Avenue Bridge abutments is considered low for the two borings drilled to date. Given the fact that significant sand lenses are likely throughout the floodplain deposits at varying depths coupled with shallow groundwater levels, a similar investigation and analysis is recommended to be performed for all additional borings drilled at the intermediate bents once completed.

4.0 REFERENCES

Alt, D., (2001), "Glacial Lake Missoula and Its Humongous Floods", Mountain Press Publishing Company, Missoula, Montana.

A-Pile for Windows, Version 2014.6.4, "A Program for Analyzing the Axial Capacity and Short-Term Settlement of Driven Piles under Axial Loading", Ensoft, Inc., 1987-2014.

Day, R., (2002), "Geotechnical Earthquake Engineering Handbook", McGraw Hill Publishing Company, New York, New York.

Federal Highway Administration, (2012), "AASHTO LRFD Bridge Design Specifications, 6th Edition, with June 2012 errata", U.S. Department of Transportation, U.S. Govt. Print. Off.

Federal Highway Administration, (1999) "Drilled Shaft Construction Procedures and Methods Work Book", Publication No. FHWA – IF – 99 – 025, U.S. Department of Transportation, U.S. Govt. Print. Off.

Federal Highway Administration, (2011), "AASHTO Guide Specifications for LRFD Seismic Bridge Design ", 2nd Edition with 2012 interim revisions, Publication No. LRFDSEIS-2, U.S. Department of Transportation, U.S. Govt. Print. Off.

Federal Highway Administration, (2014), "Standard Specifications for the Construction of Roads and Bridges on Federal Highway Projects" FP-14, U.S. Department of Transportation, Federal Lands Highways, U.S. Govt. Print. Off.

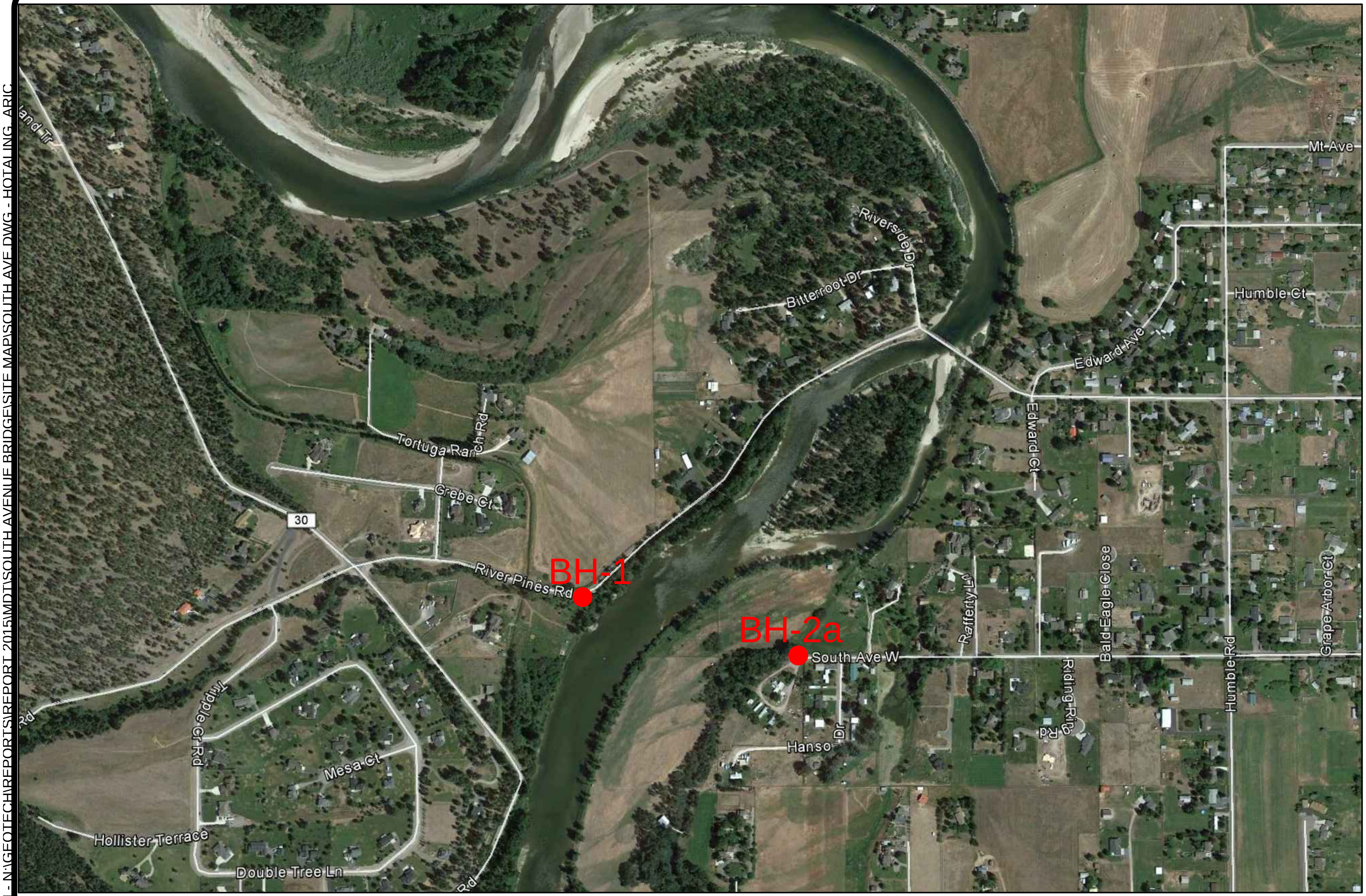
Idris, I.M. and Boulanger, R.W., (2008). "Soil Liquefaction during Earthquakes", Earthquake Engineering Research Institute, Publication No. MNO-12., Oakland, CA.

Lewis, R.S. (1998). "Preliminary Geologic Map of the Montana Part of the Missoula West 30' x 60' Quadrangle, (MBMG-373), Montana Bureau of Mines and Geology Open File Report, U.S. Department of the Interior, United States Geological Survey.

L-Pile Plus for Windows, Version 2013-07.007, "Analysis of Individual Piles and Drilled Shafts Subjected to Lateral Loading Using the p-y Method", Ensoft, Inc., 1985-2013.

SHAFT for Windows, Version 2012.7.9, "A Program for Vertically Loaded Drilled Shaft Analysis", Ensoft, Inc., 1987-2012.

APPENDIX 1



1/25/2016 3:41:31 PM - N:\GEOTECH\REPORTS\REPORT 2015\MD\SOUTH AVENUE BRIDGE\SITE MAP\SOUTH AVE.DWG - HOTALING, ARIC

TETRA TECH

www.tetratech.com

2525 Palmer St. Suite 2
Missoula, MT 59808
Phone: (406) 543-3045

Client: HDR

South Avenue Bridge
Missoula, Montana
LOCATION OF EXPLORATORY BORINGS

Project No.:	114-570937
Date:	January 2016
Drawn By:	A. Hotaling

Drawing Number

Figure 1A-1

NORTH

0 200 400 800

APPENDIX 2

Tetra Tech Boring Log Descriptive Terminology
Key to Soil Symbols and Terms

12/06/12

TETRA TECH

SOIL CLASSIFICATION CHART

MAJOR DIVISIONS			SYMBOLS GRAPH	SYMBOLS LETTER	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS MORE THAN 50% OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE	GRAVEL AND GRAVELLY SOILS MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	Well-graded gravels, gravel sand mixtures, little or no fines.
				GP	Poorly graded gravels, gravel-sand mixtures, little or no fines.
		GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	Silty gravels, gravel-sand-silt mixtures.
				GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS MORE THAN 50% OF COARSE FRACTION PASSING ON NO. 4 SIEVE	CLEAN SANDS (LITTLE OR NO FINES)		SW	Well-graded sands, gravelly sands, little or no fines.
				SP	Poorly graded sands, gravelly sands, little or no fines.
		SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	Silty sands, sand-silt mixtures.
				SC	Clayey sands, sand-clay mixures.
FINE GRAINED SOILS MORE THAN 50% OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
				CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
				OL	Organic silts and organic silty clays of low plasticity.
	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
				CH	Inorganic clays of high plasticity, fat clays.
				OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS				PT	Peat and other highly organic soils.

NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS

Notes

See Soil Boring Information Special Provision.

SPT (Standard Penetration Test-ASTM D1586):
The number of blows of a 140 lb (63.6 kg) hammer falling 2.5 ft (750 mm) used to drive a 2 in (50 mm) O.D. Split Spoon sampler for a total of 1.5 ft (0.45 m) of penetration.
Written as follows:
first 0.5 ft (0.15 m) - second 0.5 ft (0.15 m) - third 0.5 ft (0.15 m) (ex: 1-3-9)
Note: if the number of blows exceeds 50 before 0.5 ft (0.15 m) of penetration is achieved, the actual penetration rounded to the nearest 0.1 ft (0.03 m) follows the number of blows in parentheses (ex: 12-24-50 (0.09 m), 34-50 (0.4 ft), or 100 (0.3 ft)).WR denotes a zero blow count with the weight of the rods only.
WH denotes a zero blow count with the weight of the rods plus the weight of the hammer.

MC=Moisture Content, LL=Liquid limit, PL=Plastic Limit
-200%=percent soil passing 200 sieve, DD=Dry Density

Soil Classifications are Based on the Unified Soil Classification System, ASTM D2487 and D2488. Also included are the AASHTO group classifications (M145). Descriptions are based on visual observation, except where they have been modified to reflect results of laboratory tests as deemed appropriate.

Order of Descriptors

- Group Name
- Consistency or Relative Density
- Moisture Condition
- Color
- Particle size descriptor(s) (coarse grained soils only)
- Angularity of coarse grained soils
- Other relevant notes

Criteria For Descriptors

Consistency of Fine Grained Soils

Consistency	N-Value (uncorrected)
Very Soft	< 2
Soft	2 - 4
Medium Stiff	5 - 8
Stiff	9 - 15
Very Stiff	16 - 30
Hard	> 30

Apparent Density of Coarse Grained Soils

Relative Density	N-Value (uncorrected)
Very Loose	< 4
Loose	4 - 10
Medium Dense	11 - 30
Dense	31 - 50
Very Dense	> 50

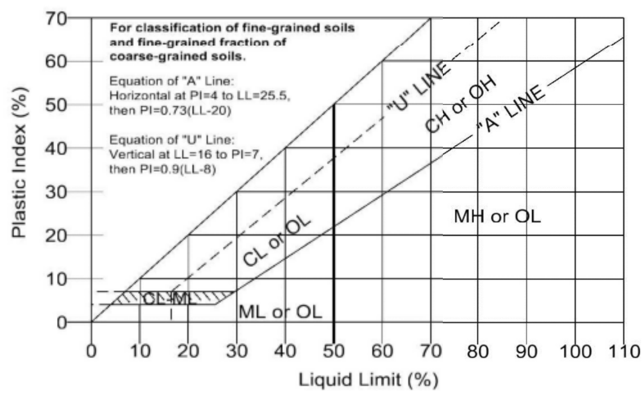
Moisture Condition

Dry	-Absence of moisture, dusty, dry to the touch.
Moist	-Damp, but no visible water.
Wet	-Visible free water.

Definition of Particle Size Ranges

Soil Component	Size Range
Boulder	> 12 in (300 mm)
Cobble	3 in (75 mm) - 12 in (300 mm)
Gravel	No. 4 Sieve (4.75 mm) to 3 in (75 mm)
Sand	No. 200 (0.075 mm) to No. 4 Sieves (4.75 mm)
Silt	< No. 200 Sieve (0.075 mm)*
Clay	< No. 200 Sieve (0.075 mm)*

*Atterberg limits and chart below to differentiate between silt and clay.



Angularity of Coarse-Grained Particles

Angular	-Particles have sharp edges and relative plane sides with unpolished surfaces.
Subangular	-Particles are similar to angular description, but have rounded edges.
Subrounded	-Particles have nearly plane sides, but have no edges.
Rounded	-Particles have smoothly curved sides and well-rounded corners and edges.

Example soil description: Sandy FAT CLAY (CH), soft, wet, brown. (A-7)

TETRA TECH

Tetra Tech Boring Log Descriptive Terminology
Key to Rock Symbols and Terms

Rock Type	Symbol	Rock Type	Symbol	Rock Type	Symbol
Argillite		Dolomite		Quartzite	
Basalt		Gneiss		Rhyolite	
Bedrock (other)		Granitic		Sandstone	
Breccia		Limestone		Schist	
Claystone		Siltstone		Shale	
		Conglomerate			

Order of Descriptors

- Rock Type
- Color
- Grain size (if applicable)
- Stratification/Foliation (as applicable)
- Field Hardness
- Other relevant notes

Criteria For Descriptors

Grain Size

Description	Characteristic
Coarse Grained	-Individual grains can be easily distinguished by eye
Fine Grained	-Individual grains can be distinguished with difficulty

Stratum Thickness

Thickly Bedded	3-10 ft (1-3 m)
Medium Bedded	1-3 ft (300 mm - 1 m)
Thinly Bedded	2-12 in (50-300 mm)
Very Thinly Bedded	< 2 in (50 mm)

Rock Field Hardness

Very Soft	-Can be carved with knife. Can be excavated readily with point of rock hammer. Can be scratched readily by fingernail.
Soft	-Can be grooved or gouged readily by knife or point of rock hammer. Can be excavated in fragments from chips to several inches in size by moderate blows of the point of a rock hammer.
Medium	-Can be grooved or gouged 0.05 in (2 mm) deep by firm pressure of knife or rock hammer point. Can be excavated in small chips to pieces about 1 in (25 mm) maximum size by hard blows of the point of a rock hammer.
Moderately hard	-Can be scratched with knife or pick. Gouges or grooves to 0.25 in (6 mm) can be excavated by hard blow of rock hammer. Hand specimen can be detached by moderate blows.
Hard	-Can be scratched with knife or pick only with difficulty. Hard hammer blows required to detach hand specimen.
Very Hard	-Cannot be scratched with knife or sharp rock hammer point. Breaking of hand specimens requires several hard blows of a rock hammer.

Notes:

UCS = Unconfined Compressive Strength obtained from laboratory testing at the given depth.

See Soil Boring Information Special Provision.

Miscellaneous Soil/Rock Symbols and Terms

- Concrete
- Asphalt
- Water
- Boulders and Cobbles
- Coal
- Fill
- Millings
- Topsoil

Explanation of Text Fields in Boring Logs:

Material Description: Lithologic Description of soil or rock encountered.

Remarks: Comments on drilling, including method, bit type, and problems encountered.

Unless stated on logs as being surveyed by district survey, all locations are considered approximate.

General Notes

- Descriptions on these boring logs apply only at the specific boring, and at the time the time the borings were made. These logs are not warranted to be representative of subsurface conditions at other locations or times.
- Water level observations apply only at the specific boring, and at the time the borings were made. Due to the variability of groundwater measurements given the type of drilling used, and the stratification of the soil in the boring, these logs are not warranted to be representative of groundwater conditions at other locations or times.
- Other terms may be used as descriptors, as defined by the profession.

Operation Types: Auger; Casing Advancer; Core Barrel; Drive Casing

Sample Types: Split Spoon; Shelby; Bulk Sample; Grab Sample; Cone Penetrometer; Vane Shear; Special Samplers; Testpit

-Soil and Rock descriptions are based on visual observation, except where they have been modified to reflect results of laboratory tests as deemed appropriate.

Example Rock Log

SANDSTONE, gray, fine grained, thickly bedded, hard field hardness.

2525 Palmer Street, Suite 2
Missoula, MT 59808
Phone: (406) 543-3045
Fax: (406) 543-3045

LOG OF BORING

Boring BH-1

TETRA TECH

Project: South Avenue Bridge	**Rig:** Dedrich D-50 **Hammer:** Auto	**Boring Location Coordinates** N: 981553.177 ft E: 817490.835 ft	**Station:** **Offset:**
Project Number: 114-570937 **UPN:**	**Boring Diameter:** 8"	**System:** Decimal Degrees **Datum:** NAD83	**Top of Boring Elevation:** 3114.6 ft
Date Started: 8/21/15 **Date Finished:** 8/21/15	**Drilling Fluid:** Bentonite/Polymer	**Location Source:** Surveyed	**Elevation Source:** GPS
Driller: Interstate Drilling **Logger:** Cole Duncan	**Abandonment Method:** Bentonite	**Township, Range, and Section:** 13N 20W S27	

Depth (ft) Elev. (ft)	Operation	Sample Type	Recovery (%)	RQD (%)	Blow Count	Lithology	Material Description	Depth (ft) Elev. (ft)	MC (%)	LL	PL	-200 (%)	DD	Remarks and Other Tests
							Asphalt, very loose, slightly moist.	0.3 3114.3	6					
			80		12 - 9 - 20		BASE COURSE, Poorly-Graded SAND with gravel (SP), [A-1]. medium dense, slightly moist, medium to coarse grained.	0.6 3114.0						
							Silty SAND with gravel (SM), [A-2]. medium dense to dense, moist to wet.							
5 3109.6			7		10 - 14 - 17									
10 3104.6			73		9 - 10 - 10				3	NV	NP	25		pH: 8.0 Resistivity 2,900 ohm-cm
15 3099.6			67		13 - 14 - 14		Poorly-Graded GRAVEL with sand (GP), [A-1]. medium dense, wet, multi-colored, medium to coarse grained, subangular to subrounded, Occasional cobbles.	14.3 3100.3						
20 3094.6			87		3 - 9 - 14		Poorly-Graded SAND with gravel (SP), [A-2]. medium dense, wet, tan/brown, medium to coarse grained, subangular.	18.0 3096.6						
25 3089.6			100		6 - 10 - 9		Heaving Sand.							
30 3084.6			100		8 - 10 - 18		Poorly-Graded GRAVEL with silt and sand (GP-GM),	29.0 3085.6						

Water Level Observations		Remarks:
	During Drilling: 14.0 ft *(3100.6 ft)*	
After Drilling: Not Recorded	After Drilling: Not Recorded	

2525 Palmer Street, Suite 2
Missoula, MT 59808
Phone: (406) 543-3045
Fax: (406) 543-3045

LOG OF BORING

Boring BH-1

TETRA TECH

Project: South Avenue Bridge		**Rig:** Dedrich D-50 **Hammer:** Auto	**Boring Location Coordinates** N: 981553.177 ft E: 817490.835 ft		**Station:** **Offset:**
Project Number: 114-570937	**UPN:**	**Boring Diameter:** 8"	**System:** Decimal Degrees **Datum:** NAD83		**Top of Boring Elevation:** 3114.6 ft
Date Started: 8/21/15	**Date Finished:** 8/21/15	**Drilling Fluid:** Bentonite/Polymer	**Location Source:** Surveyed		**Elevation Source:** GPS
Driller: Interstate Drilling **Logger:** Cole Duncan		**Abandonment Method:** Bentonite		**Township, Range, and Section:** 13N 20W S27	

Depth (ft) / *Elev. (ft)*	Operation	Sample Type	Recovery (%)	RQD (%)	Blow Count	Lithology	Material Description	Depth (ft) / *Elev. (ft)*	MC (%)	LL	PL	-200 (%)	DD	Remarks and Other Tests
							[A-1]. medium dense to dense, wet, multi-colored, medium to coarse grained, subrounded to angular, Occasional cobbles.							
35 / *3079.6*			73		8 - 13 - 12									
										NV	NP	8		
40 / *3074.6*			80		5 - 5 - 11									
45 / *3069.6*			100		10 - 9 - 14									
50 / *3064.6*			67		10 - 16 - 18									
							Silty SAND (SM), [A-2]. medium dense to dense, wet, tan/brown, medium to coarse grained, angular to subrounded.	54.0 / *3060.6*						
55 / *3059.6*			100		18 - 17 - 17									
60 / *3054.6*			100		7 - 12 - 20									

Water Level Observations		Remarks:
	During Drilling: 14.0 ft *(3100.6 ft)*	
After Drilling: Not Recorded	After Drilling: Not Recorded	

2525 Palmer Street, Suite 2
Missoula, MT 59808
Phone: (406) 543-3045
Fax: (406) 543-3045

LOG OF BORING

Boring BH-1

TETRA TECH

Project: South Avenue Bridge		**Rig:** Dedrich D-50 **Hammer:** Auto	**Boring Location Coordinates** N: 981553.177 ft E: 817490.835 ft	**Station:** **Offset:**
Project Number: 114-570937	**UPN:**	**Boring Diameter:** 8"	**System:** Decimal Degrees **Datum:** NAD83	**Top of Boring Elevation:** 3114.6 ft
Date Started: 8/21/15	**Date Finished:** 8/21/15	**Drilling Fluid:** Bentonite/Polymer	**Location Source:** Surveyed	**Elevation Source:** GPS
Driller: Interstate Drilling **Logger:** Cole Duncan		**Abandonment Method:** Bentonite	**Township, Range, and Section:** 13N 20W S27	

Depth (ft) / Elev. (ft)	Operation	Sample Type	Recovery (%)	RQD (%)	Blow Count	Lithology	Material Description	Depth (ft) / Elev. (ft)	MC (%)	LL	PL	-200 (%)	DD	Remarks and Other Tests
65 / 3049.6			67		5 - 10 - 20		Heaving Sand.							
										NV	NP	15		
70 / 3044.6			80		5 - 8 - 12									
75 / 3039.6			87		8 - 9 - 22		Heaving Sand with red clay nodules intermixed and very thin (1mm) lenses of red clay, scattered gravels.							
80 / 3034.6			53		8 - 13 - 25									Switched from auger to mud rotary due to heaving sands binding up auger
85 / 3029.6			80		15 - 20 - 21		Heaving Sand.							
90 / 3024.6			93		11 - 24 - 20									

Water Level Observations		Remarks:
After Drilling: Not Recorded	During Drilling: 14.0 ft *(3100.6 ft)*	
	After Drilling: Not Recorded	

2525 Palmer Street, Suite 2
Missoula, MT 59808
Phone: (406) 543-3045
Fax: (406) 543-3045

LOG OF BORING

Boring BH-1

TETRA TECH

Project: South Avenue Bridge		**Rig:** Dedrich D-50 **Hammer:** Auto	**Boring Location Coordinates** N: 981553.177 ft E: 817490.835 ft	**Station:** **Offset:**
Project Number: 114-570937	**UPN:**	**Boring Diameter:** 8"	**System:** Decimal Degrees **Datum:** NAD83	**Top of Boring Elevation:** 3114.6 ft
Date Started: 8/21/15	**Date Finished:** 8/21/15	**Drilling Fluid:** Bentonite/Polymer	**Location Source:** Surveyed	**Elevation Source:** GPS
Driller: Interstate Drilling **Logger:** Cole Duncan		**Abandonment Method:** Bentonite	**Township, Range, and Section:** 13N 20W S27	

Depth (ft) / *Elev. (ft)*	Operation	Sample Type	Recovery (%)	RQD (%)	Blow Count	Lithology	Material Description	Depth (ft) / *Elev. (ft)*	MC (%)	LL	PL	-200 (%)	DD	Remarks and Other Tests
							Poorly-Graded GRAVEL with silt and sand (GP-GM), [A-1]. dense to very dense, wet, multi-colored, medium to coarse grained, subangular to subrounded, Occasional cobbles and boulders.	90.0 / *3024.6*						
95 / *3019.6*			73		21 - 17 - 14									
										NV	NP	11		
100 / *3014.6*			87		46 - 35 - 38									
			75		50/0.4ft									
105 / *3009.6*														
			50		50/0.4ft									
							Boring Depth: 109.4 ft, *Elevation: 3005.2 ft*	109.4 / *3005.2*						

Water Level Observations	During Drilling: 14.0 ft *(3100.6 ft)*	Remarks:
After Drilling: Not Recorded	After Drilling: Not Recorded	

2525 Palmer Street, Suite 2
Missoula, MT 59808
Phone: (406) 543-3045
Fax: (406) 543-3045

LOG OF BORING

Boring BH-2a

TETRA TECH

Project: South Avenue Bridge		**Rig:** Dedrich D-50 **Hammer:** Auto	**Boring Location Coordinates** N: 981174.148 ft E: 818558.318 ft	**Station:** **Offset:**
Project Number: 114-570937	**UPN:**	**Boring Diameter:** 8 in	**System:** Decimal Degrees **Datum:** NAD83	**Top of Boring Elevation:** 3114.0 ft
Date Started: 8/20/15	**Date Finished:** 8/20/15	**Drilling Fluid:** Bentonite/Polymer	**Location Source:** Surveyed	**Elevation Source:** GPS
Driller: Interstate Drilling **Logger:** Aric Hotaling		**Abandonment Method:** Bentonite	**Township, Range, and Section:** 13N 20W S26	

Depth (ft) *Elev. (ft)*	Sample Type	Recovery (%)	RQD (%)	Blow Count	Material Description	Depth (ft) *Elev. (ft)*	MC (%)	LL	PL	-200 (%)	DD	Remarks and Other Tests
		53		13 - 20 - 24	Asphalt.	0.2 *3113.8*	4					
					BASE COURSE, Poorly-Graded SAND with gravel (SP), [A-1]. dense, moist, brown to black, fine to medium grained, subangular.	0.5 *3113.5*						
					Poorly-Graded GRAVEL with sand (GP), [A-1]. medium dense, moist to wet, multi-colored, medium to coarse grained, subrounded, Occasional cobbles.		2					
5 *3109.0*		60		8 - 9 - 7								
10 *3104.0*		27		15 - 10 - 11								
					Silty SAND (SM), [A-2]. medium dense, wet, tan/brown, fine to coarse grained, subangular to subrounded.	13.0 *3101.0*						
15 *3099.0*		67		5 - 6 - 9								
20 *3094.0*		80		9 - 9 - 10								
								NV	NP	23		
25 *3089.0*		67		3 - 4 - 7	Heaving Sand.							
30 *3084.0*												

Water Level Observations	During Drilling: 9.0 ft *(3105.0 ft)*	Remarks:
After Drilling: Not Recorded	After Drilling: Not Recorded	

2525 Palmer Street, Suite 2
Missoula, MT 59808
Phone: (406) 543-3045
Fax: (406) 543-3045

LOG OF BORING

Boring BH-2a

TETRA TECH

Project: South Avenue Bridge		**Rig:** Dedrich D-50 **Hammer:** Auto	**Boring Location Coordinates** N: 981174.148 ft E: 818558.318 ft	**Station:** **Offset:**
Project Number: 114-570937	**UPN:**	**Boring Diameter:** 8 in	**System:** Decimal Degrees **Datum:** NAD83	**Top of Boring Elevation:** 3114.0 ft
Date Started: 8/20/15	**Date Finished:** 8/20/15	**Drilling Fluid:** Bentonite/Polymer	**Location Source:** Surveyed	**Elevation Source:** GPS
Driller: Interstate Drilling **Logger:** Aric Hotaling		**Abandonment Method:** Bentonite	**Township, Range, and Section:** 13N 20W S26	

Depth (ft) / Elev. (ft)	Operation	Sample Type	Recovery (%)	RQD (%)	Blow Count	Lithology	Material Description	Depth (ft) / Elev. (ft)	MC (%)	LL	PL	-200 (%)	DD	Remarks and Other Tests
			80		10 - 12 - 16									
35 / 3079.0			67		8 - 7 - 9		Poorly-Graded SAND (SP), [A-2]. medium dense, wet, tan/brown, fine to coarse grained, subangular, scattered gravels and heaving sands.	35.0 / 3079.0						
40 / 3074.0			13		5 - 9 - 13									
45 / 3069.0			47		12 - 12 - 12		Heaving Sand.							
50 / 3064.0			73		7 - 15 - 12									
55 / 3059.0			80		3 - 4 - 4		Silty SAND (SM), [A-2]. loose to medium dense, wet, tan/brown to red, fine to coarse grained, subangular, red clay nodules intermixed with the poorly graded sand and very thin (1mm) lenses of red clay, scattered gravels.	54.5 / 3059.5						
60 / 3054.0														

Water Level Observations		Remarks:
	During Drilling: 9.0 ft *(3105.0 ft)*	
After Drilling: Not Recorded	After Drilling: Not Recorded	

2525 Palmer Street, Suite 2
Missoula, MT 59808
Phone: (406) 543-3045
Fax: (406) 543-3045

LOG OF BORING

Boring BH-2a

TETRA TECH

Project: South Avenue Bridge		**Rig:** Dedrich D-50 **Hammer:** Auto	**Boring Location Coordinates** N: 981174.148 ft E: 818558.318 ft	**Station:** **Offset:**
Project Number: 114-570937	**UPN:**	**Boring Diameter:** 8 in	**System:** Decimal Degrees **Datum:** NAD83	**Top of Boring Elevation:** 3114.0 ft
Date Started: 8/20/15	**Date Finished:** 8/20/15	**Drilling Fluid:** Bentonite/Polymer	**Location Source:** Surveyed	**Elevation Source:** GPS
Driller: Interstate Drilling **Logger:** Aric Hotaling		**Abandonment Method:** Bentonite	**Township, Range, and Section:** 13N 20W S26	

Depth (ft) *Elev. (ft)*	Operation	Sample Type	Recovery (%)	RQD (%)	Blow Count	Lithology	Material Description	Depth (ft) *Elev. (ft)*	MC (%)	LL	PL	-200 (%)	DD	Remarks and Other Tests
			100		3 - 5 - 6									SS @ 59.5 and 64.5 approx. 6" sand heave
										NV	NP	18		
65 *3049.0*			100		5 - 7 - 7		Heaving Sand.							
70 *3044.0*			100		5 - 6 - 10									
75 *3039.0*			53		17 - 10 - 8									
80 *3034.0*			100		14 - 12 - 9									
							Sandy SILT (ML), [A-4]. very stiff, wet, gray, low plasticity, silt lense.	80.6 *3033.4*						
							Silty SAND with gravel (SM), [A-2]. very dense, wet, brown to gray, fine to coarse grained, subrounded.	81.5 *3032.5*						
85 *3029.0*			73		20 - 30 - 22									
								89.5						
90 *3024.0*														

Water Level Observations		Remarks:
After Drilling: Not Recorded	During Drilling: 9.0 ft *(3105.0 ft)* After Drilling: Not Recorded	

2525 Palmer Street, Suite 2
Missoula, MT 59808
Phone: (406) 543-3045
Fax: (406) 543-3045

LOG OF BORING

Boring BH-2a

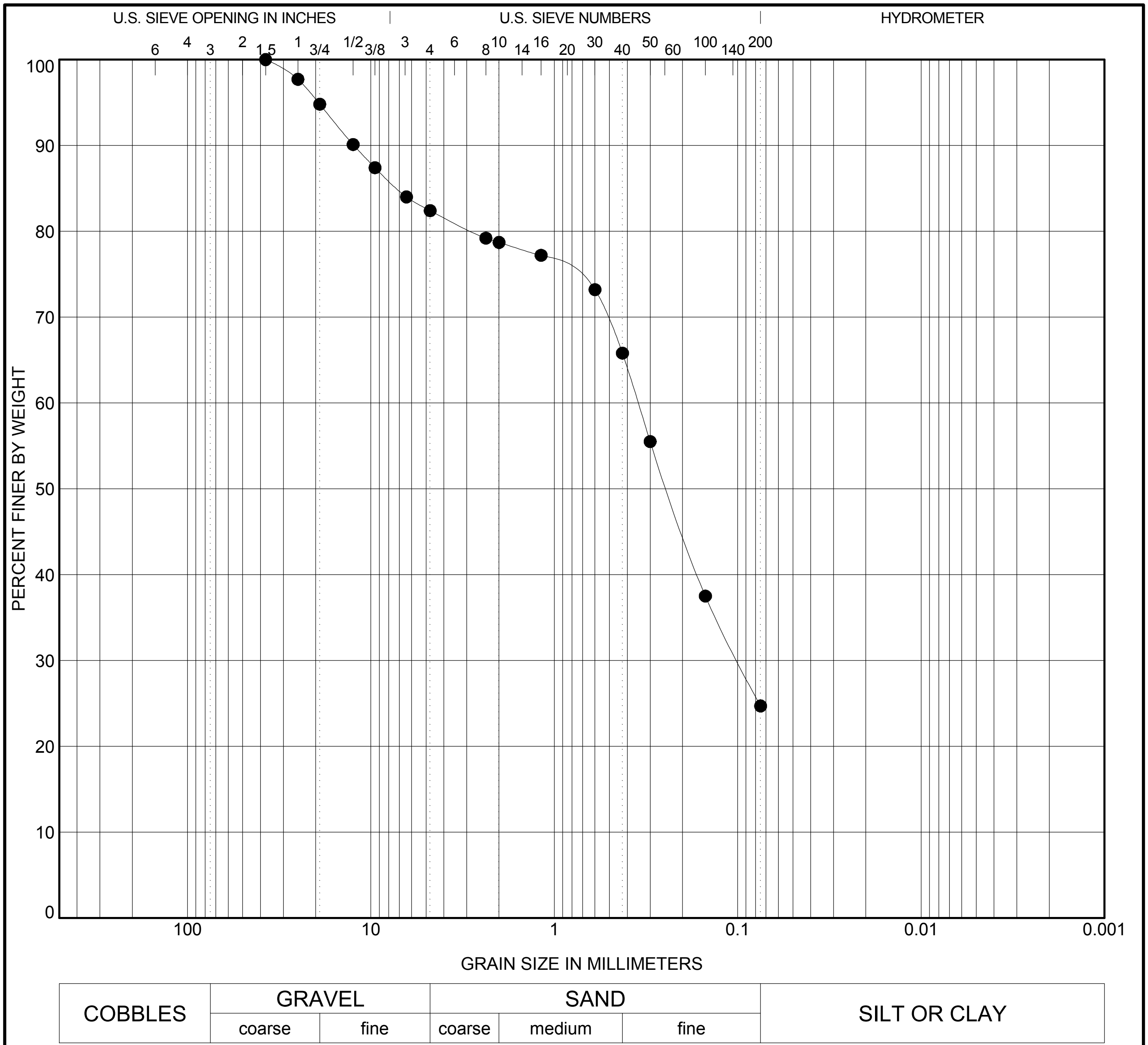
TETRA TECH

Project: South Avenue Bridge		**Rig:** Dedrich D-50 **Hammer:** Auto	**Boring Location Coordinates** N: 981174.148 ft E: 818558.318 ft	**Station:** **Offset:**
Project Number: 114-570937	**UPN:**	**Boring Diameter:** 8 in	**System:** Decimal Degrees **Datum:** NAD83	**Top of Boring Elevation:** 3114.0 ft
Date Started: 8/20/15	**Date Finished:** 8/20/15	**Drilling Fluid:** Bentonite/Polymer	**Location Source:** Surveyed	**Elevation Source:** GPS
Driller: Interstate Drilling **Logger:** Aric Hotaling		**Abandonment Method:** Bentonite	**Township, Range, and Section:** 13N 20W S26	

Depth (ft) / Elev. (ft)	Operation	Sample Type	Recovery (%)	RQD (%)	Blow Count	Lithology	Material Description	Depth (ft) / Elev. (ft)	MC (%)	LL	PL	-200 (%)	DD	Remarks and Other Tests
			100		5 - 9 - 19		Poorly-Graded SAND with gravel (SP), [A-1]. medium dense, wet, tan/brown to multi-colored, medium to coarse grained, subangular to subrounded.	3024.5						
							Poorly-Graded GRAVEL with silt and sand (GP-GM), [A-1]. medium dense to very dense, wet, multi-colored, fine to medium grained, subangular to subrounded, occasional cobbles and boulders.	93.0 3021.0		NV	NP	8		
95 3019.0			47		14 - 36 - 48									
100 3014.0			40		16 - 17 - 12			101.0 3013.0						

Boring Depth: 101.0 ft, *Elevation: 3013.0 ft*

Water Level Observations	During Drilling: 9.0 ft *(3105.0 ft)*	Remarks:
After Drilling: Not Recorded	After Drilling: Not Recorded	



Specimen Identification	Classification	LL	PL	PI	Cc	Cu
BH-1 - (9.2 - 14 ft)	**SILTY SAND with GRAVEL(SM)**	**NV**	**NV**	**NP**		

Specimen Identification	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
BH-1 - (9.2 - 14 ft)	**37.5**	**0.349**	**0.1**		**18**	**58**	**25**	

TETRA TECH

GRAIN SIZE DISTRIBUTION

Project: South Avenue Bridge

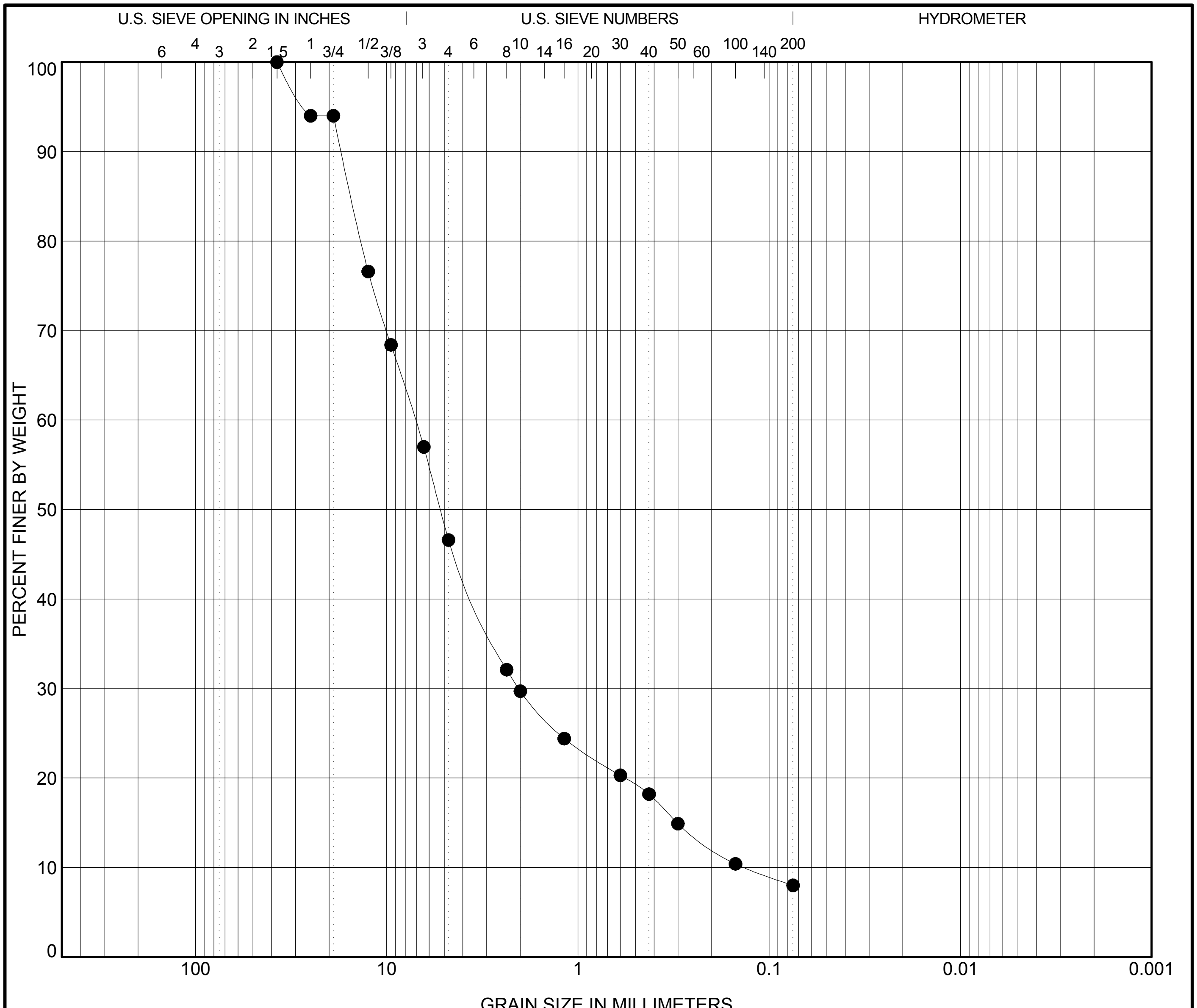
Location: Southern edge of pavement at bend in River Pines Rd

Number: 114-570937

Figure No. 2B-1

SOUTH AVE LOGS.GPJ ' 1-29-16 ' ' TT_US GRAIN SIZE

Revised 1-23-08 (MAT)



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen Identification	Classification	LL	PL	PI	Cc	Cu
BH-1 - (35 - 44 ft)	**POORLY GRADED GRAVEL with SILT and SAND(GP-GM)**	**NV**	**NV**	**NP**	**4.39**	**53.14**

Specimen Identification	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
BH-1 - (35 - 44 ft)	**37.5**	**7.101**	**2.042**	**0.134**	**53**	**39**	**8**	

TETRA TECH

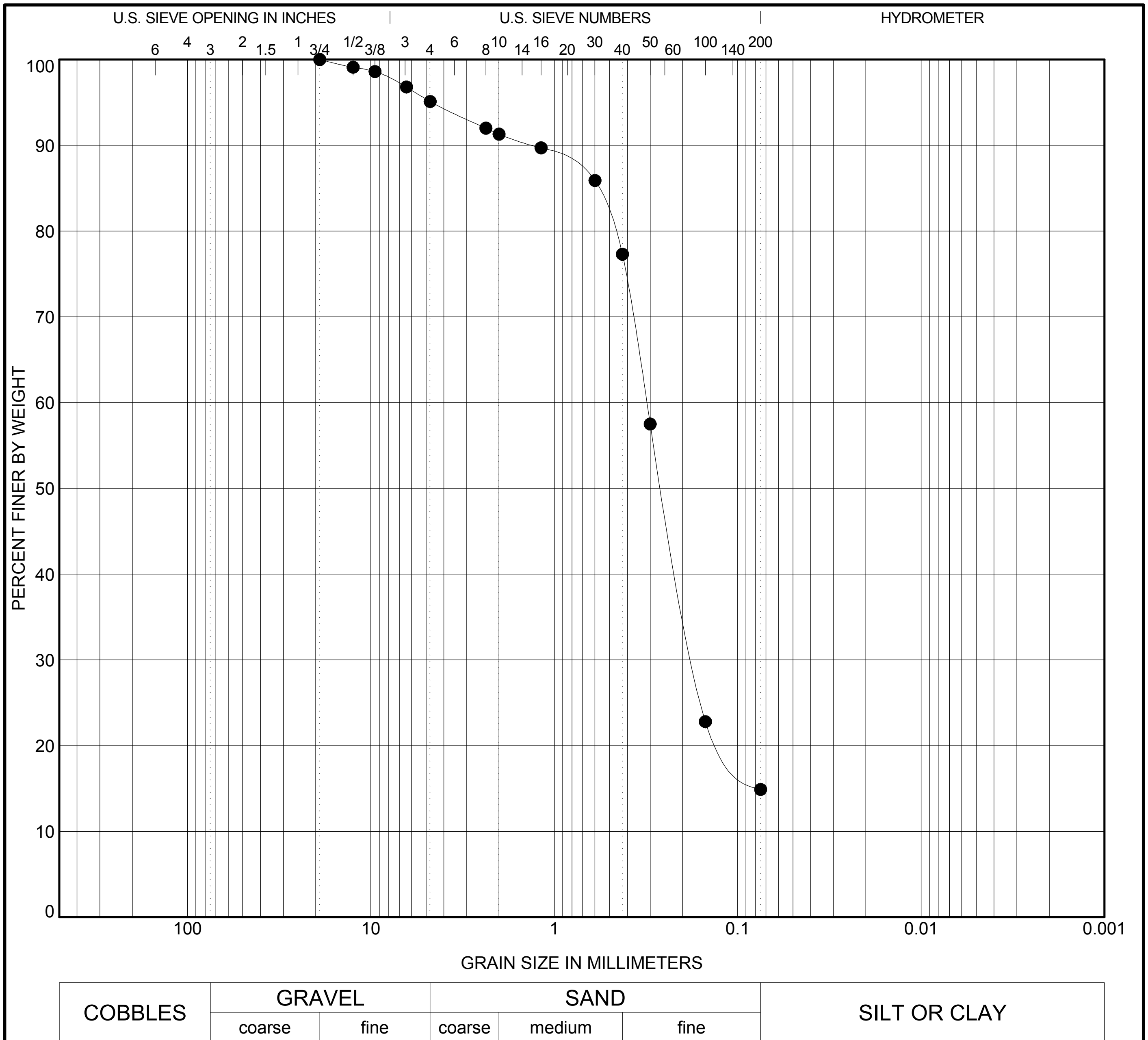
GRAIN SIZE DISTRIBUTION

Project: South Avenue Bridge

Location: Southern edge of pavement at bend in River Pines Rd

Number: 114-570937

Figure No. 2B-2



Specimen Identification	Classification	LL	PL	PI	Cc	Cu
BH-1 - (64 - 74 ft)	**SILTY SAND(SM)**	**NV**	**NV**	**NP**		

Specimen Identification	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
BH-1 - (64 - 74 ft)	**19**	**0.313**	**0.173**		**5**	**80**	**15**	

TETRA TECH

GRAIN SIZE DISTRIBUTION

Project: South Avenue Bridge

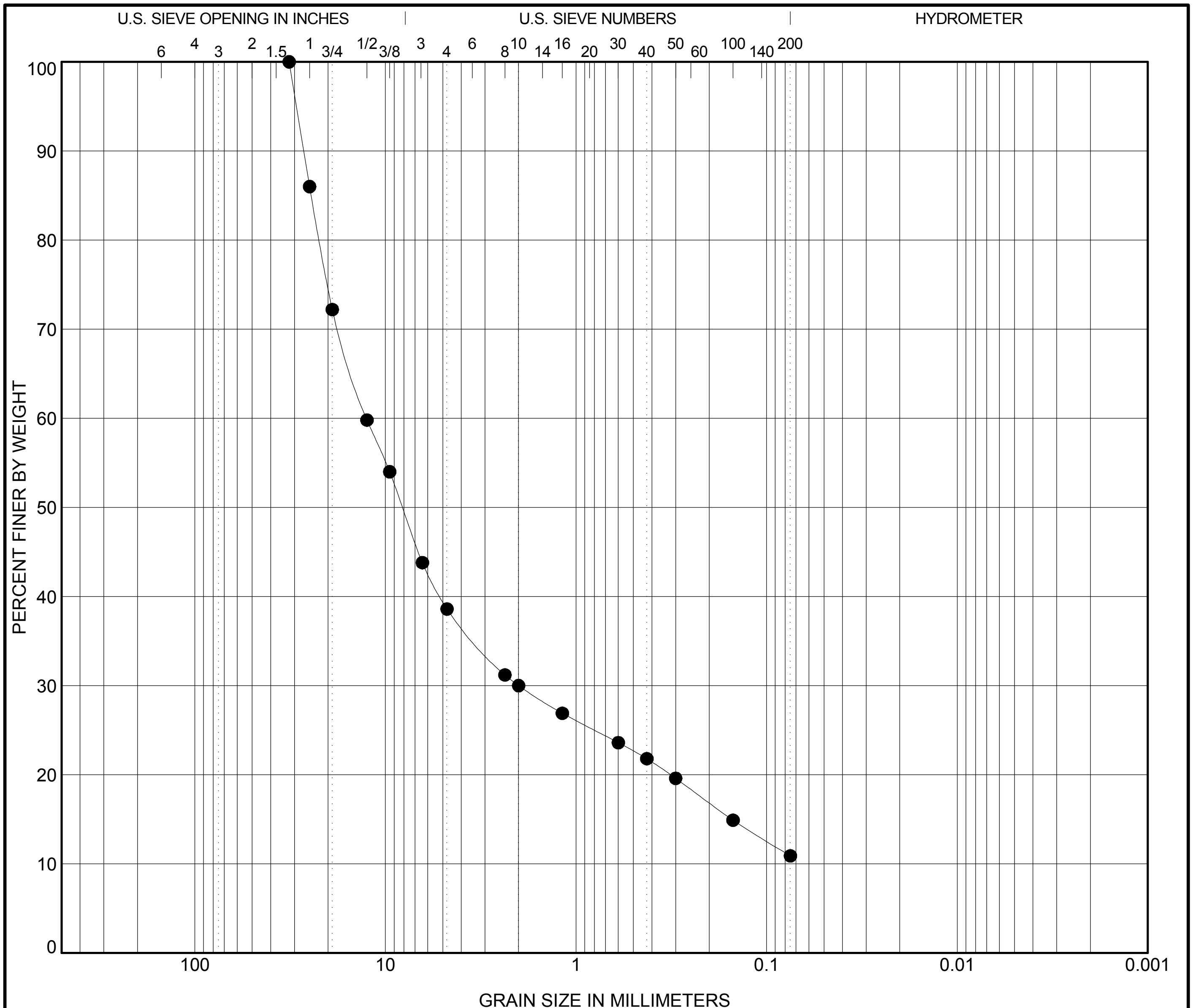
Location: Southern edge of pavement at bend in River Pines Rd

Number: 114-570937

Figure No. 2B-3

SOUTH AVE LOGS.GPJ 1-29-16 TT_US GRAIN SIZE

Revised 1-23-08 (MAT)



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen Identification	Classification	LL	PL	PI	Cc	Cu
BH-1 - (94 - 104 ft)	**POORLY GRADED GRAVEL with SILT and SAND(GP-GM)**	**NV**	**NV**	**NP**	**4.95**	**196.12**

Specimen Identification	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
BH-1 - (94 - 104 ft)	**32**	**12.585**	**2**		**61**	**28**	**11**	

TETRA TECH

GRAIN SIZE DISTRIBUTION

Project: South Avenue Bridge

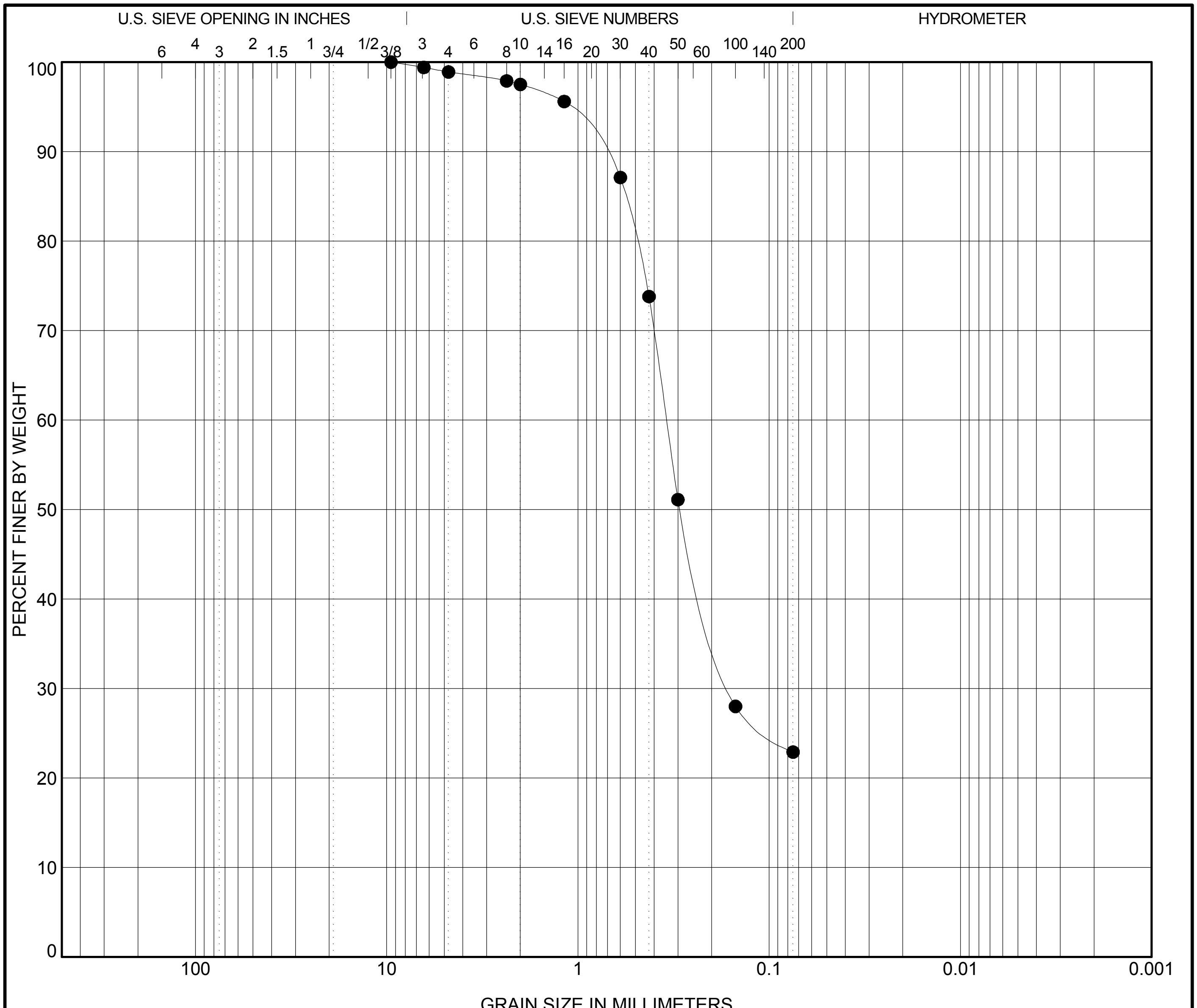
Location: Southern edge of pavement at bend in River Pines Rd

Number: 114-570937

Figure No. 2B-4

SOUTH AVE LOGS.GPJ ` 1-29-16 ` ` TT_US GRAIN SIZE

Revised 1-23-08 (MAT)



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen Identification	Classification	LL	PL	PI	Cc	Cu
BH-2a - (19.5 - 29.5 ft)	**SILTY SAND(SM)**	**NV**	**NV**	**NP**		

Specimen Identification	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
BH-2a - (19.5 - 29.5 ft)	**9.5**	**0.344**	**0.159**		**1**	**76**	**23**	

TETRA TECH

GRAIN SIZE DISTRIBUTION

Project: South Avenue Bridge

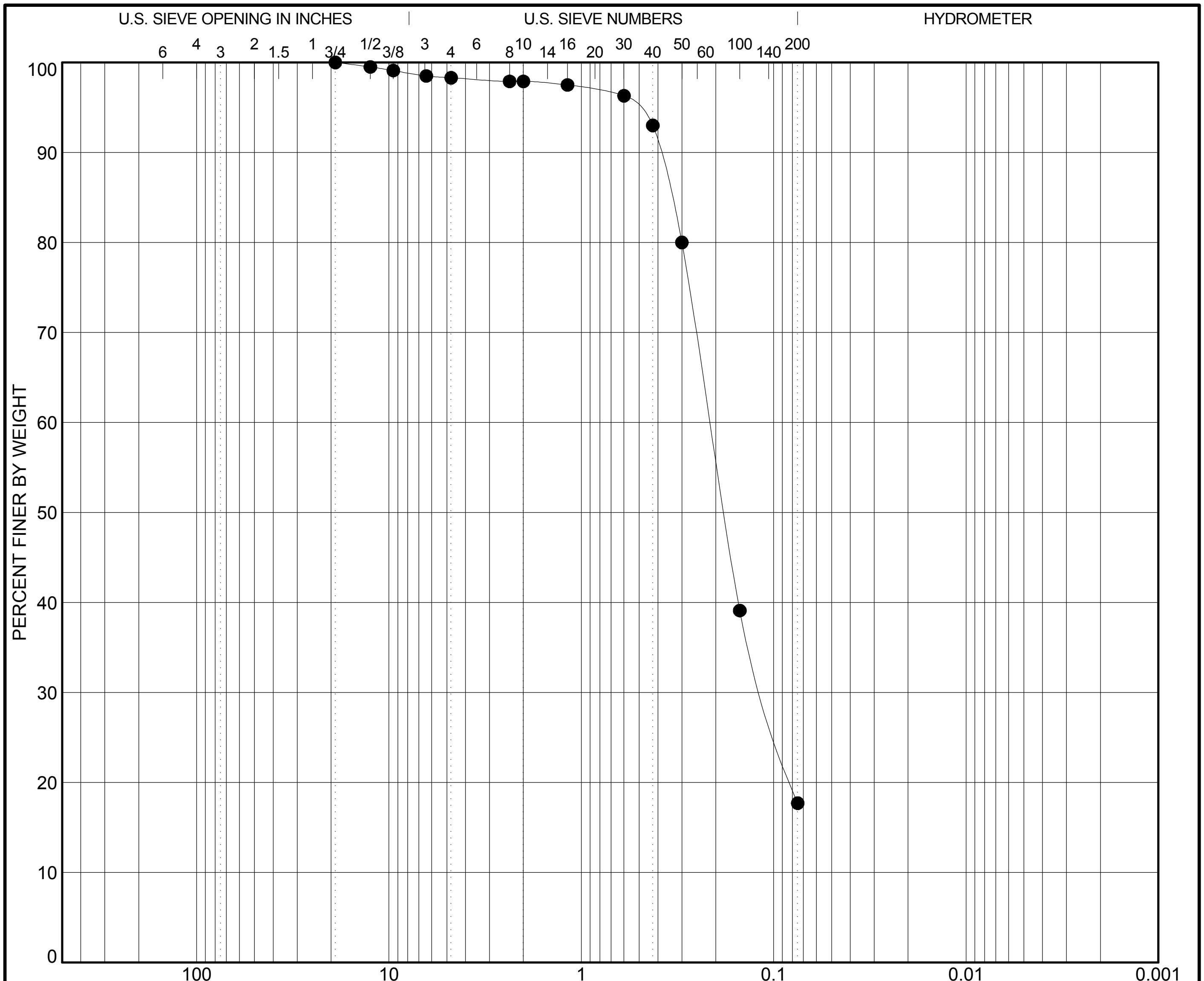
Location: End of cul de sac on South Ave.

Number: 114-570937

Figure No. 2B-5

SOUTH AVE LOGS.GPJ ` 1-29-16 ` ` TT_US GRAIN SIZE

Revised 1-23-08 (MAT)



<table>
<tr><td rowspan="2">COBBLES</td><td colspan="2">GRAVEL</td><td colspan="3">SAND</td><td rowspan="2">SILT OR CLAY</td></tr>
<tr><td>coarse</td><td>fine</td><td>coarse</td><td>medium</td><td>fine</td></tr>
</table>

Specimen Identification	Classification	LL	PL	PI	Cc	Cu
BH-2a - (59.5 - 69.5 ft)	**SILTY SAND(SM)**	**NV**	**NV**	**NP**		

Specimen Identification	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
BH-2a - (59.5 - 69.5 ft)	**19**	**0.214**	**0.112**		**2**	**81**	**18**	

SOUTH AVE LOGS.GPJ 1-29-16 TT_US GRAIN SIZE

TETRA TECH

GRAIN SIZE DISTRIBUTION

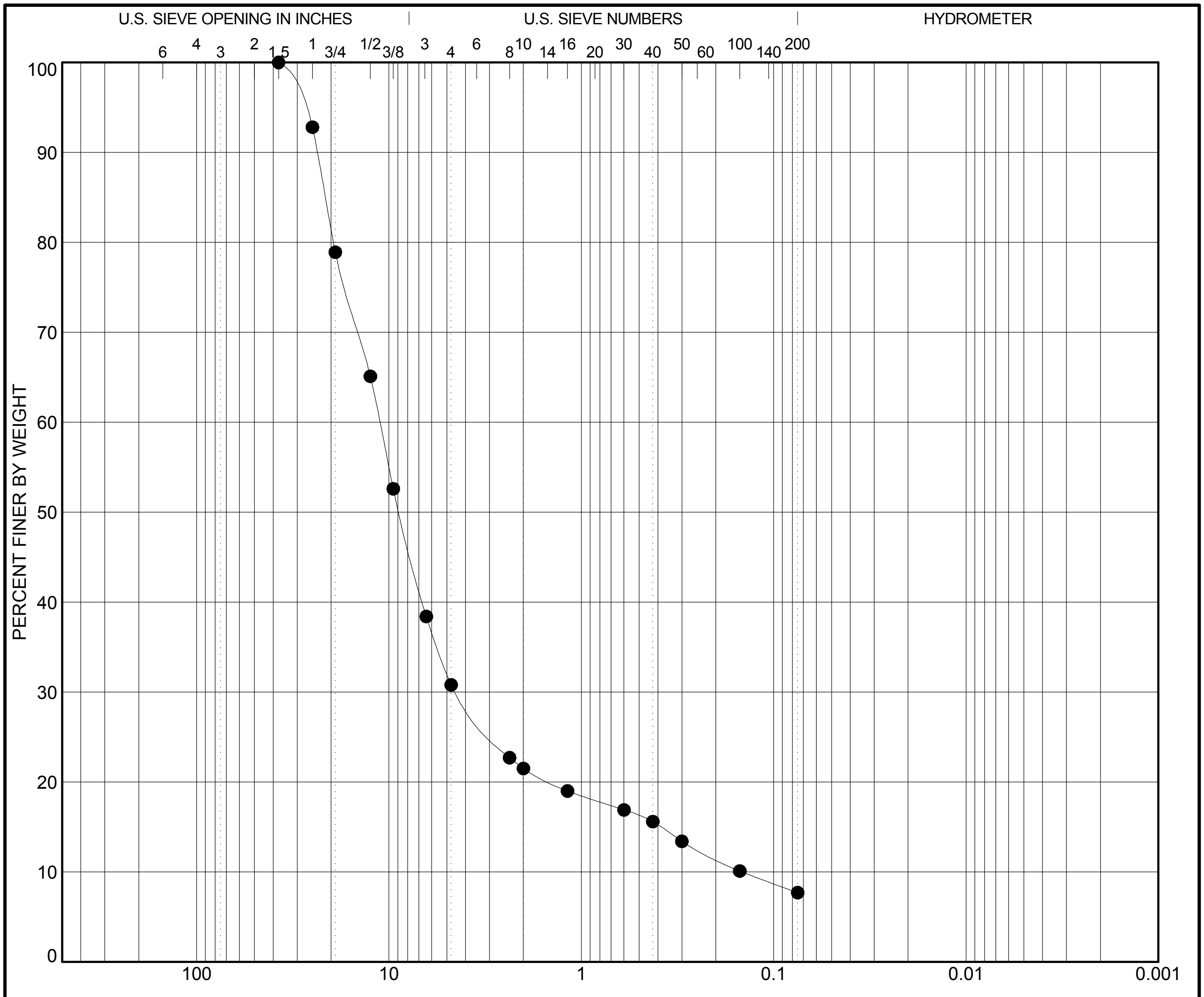
Project: South Avenue Bridge

Location: End of cul de sac on South Ave.

Number: 114-570937

Figure No. 2B-6

Revised 1-23-08 (MAT)



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen Identification	Classification	LL	PL	PI	Cc	Cu
BH-2a - (94.5 - 99.5 ft)	**POORLY GRADED GRAVEL with SILT and SAND(GP-GM)**	**NV**	**NV**	**NP**	**12.07**	**76.69**

Specimen Identification	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
BH-2a - (94.5 - 99.5 ft)	**37.5**	**11.176**	**4.433**	**0.146**	**69**	**23**	**8**	

SOUTH AVE LOGS.GPJ 1-29-16 TT_US GRAIN SIZE

TETRA TECH

GRAIN SIZE DISTRIBUTION

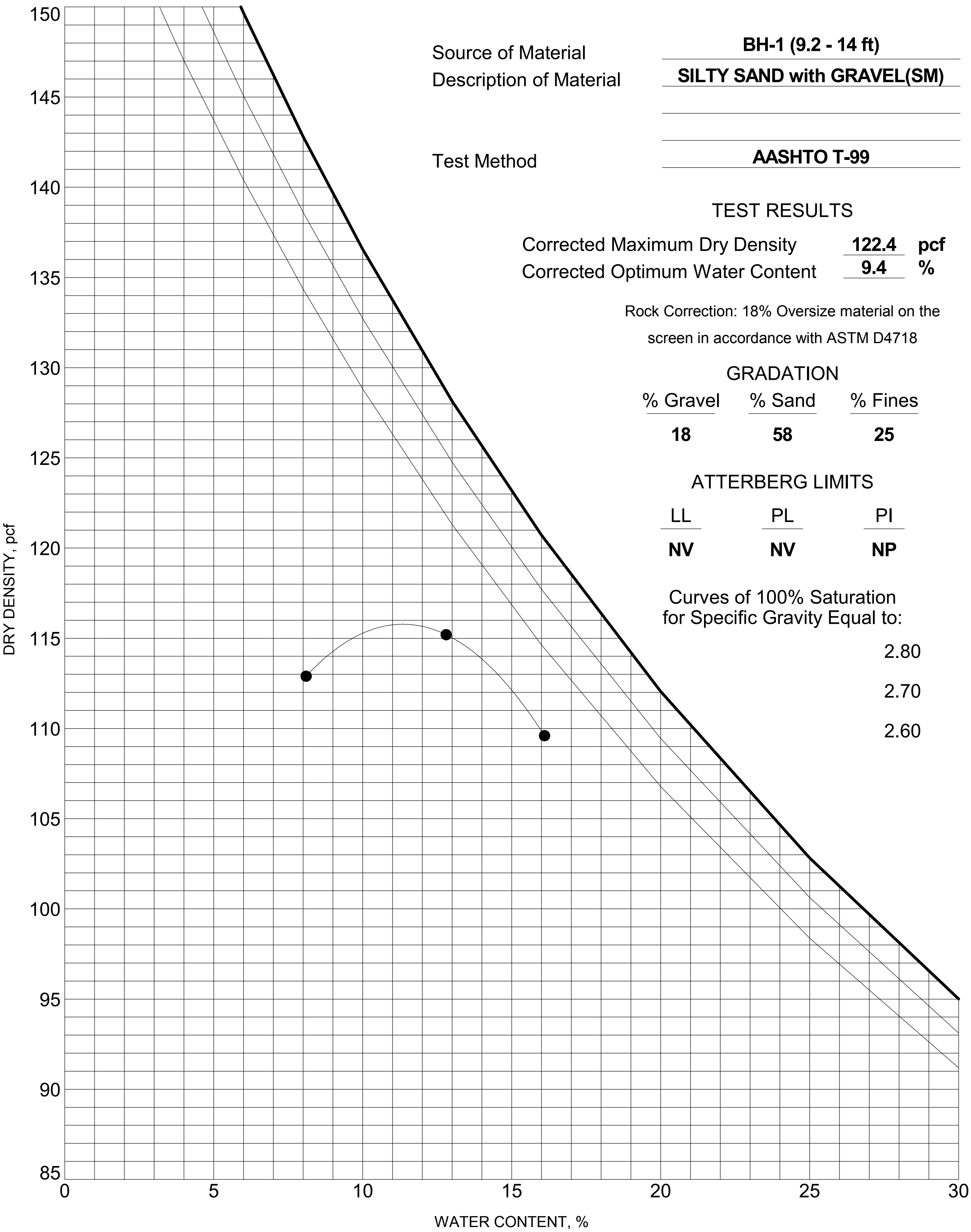
Project: South Avenue Bridge

Location: End of cul de sac on South Ave.

Number: 114-570937

Figure No. 2B-7

Revised 1-23-08 (MAT)



Source of Material: **BH-1 (9.2 - 14 ft)**

Description of Material: **SILTY SAND with GRAVEL(SM)**

Test Method: **AASHTO T-99**

TEST RESULTS

Corrected Maximum Dry Density **122.4** pcf

Corrected Optimum Water Content **9.4** %

Rock Correction: 18% Oversize material on the screen in accordance with ASTM D4718

GRADATION

% Gravel	% Sand	% Fines
18	**58**	**25**

ATTERBERG LIMITS

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

MOISTURE-DENSITY RELATIONSHIP

TETRA TECH

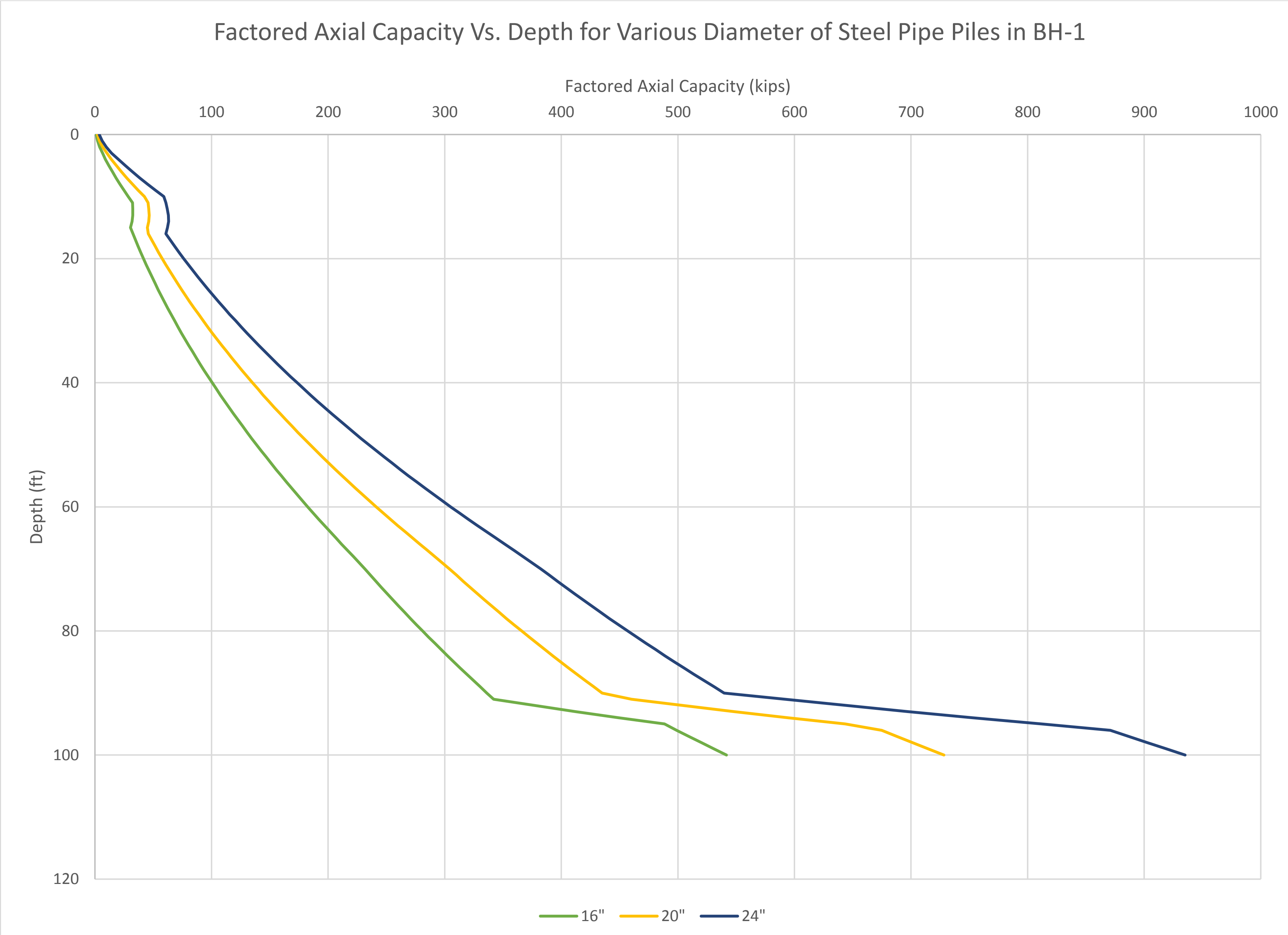
Project: South Avenue Bridge

Location: Southern edge of pavement at bend in River Pines Rd

Number: 114-570937

Figure No. 2C-1

APPENDIX 3



Factored Axial Capacity Vs. Depth for Various Diameter of Steel Pipe Piles in BH-1
Factored Axial Capacity (kips)
0
100
200
300
400
500
600
700
800
900
1000
Depth (ft)
0
20
40
60
80
100
120
16"
20"
24"

Figure 3A-1

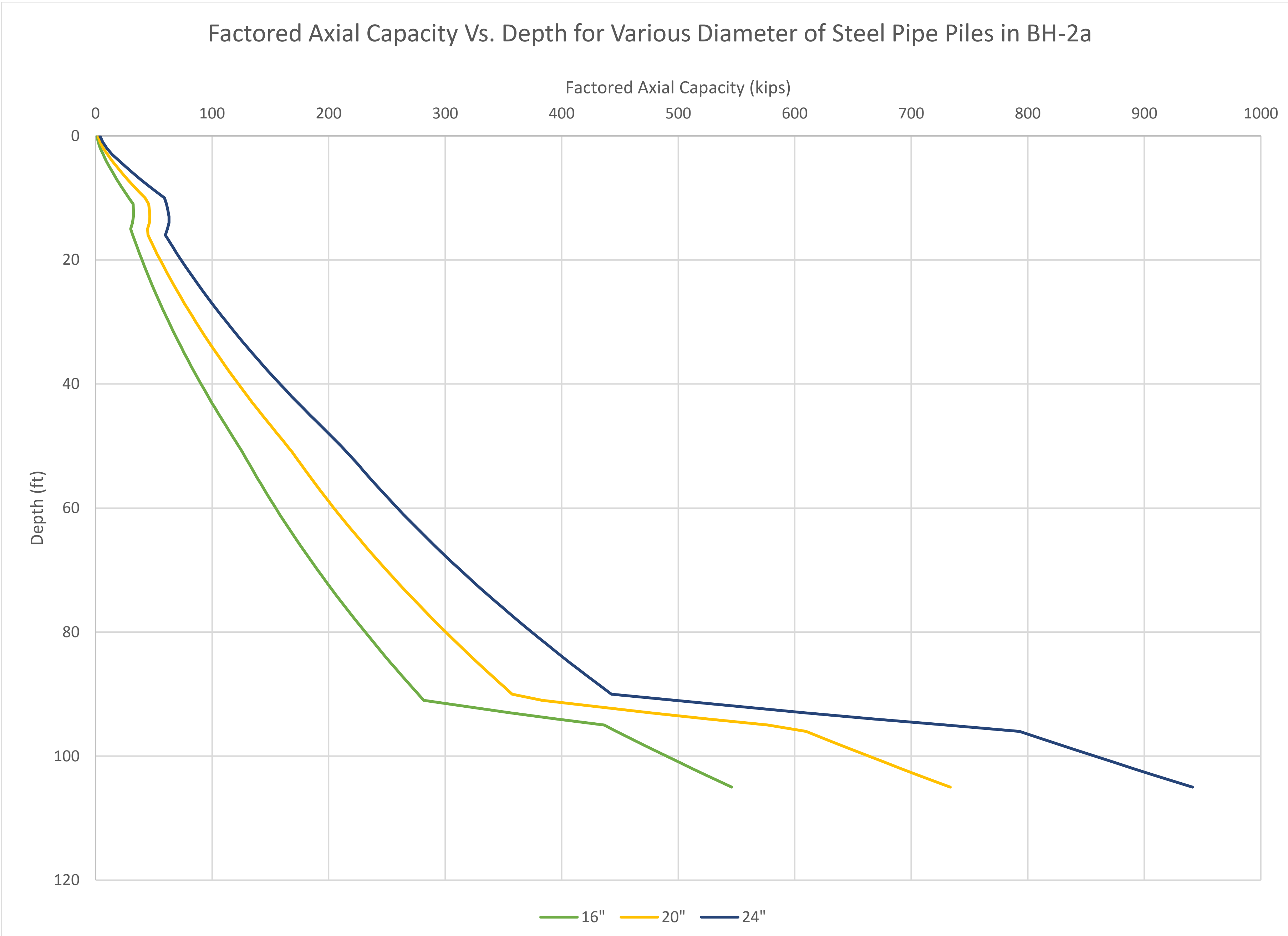

Factored Axial Capacity Vs. Depth for Various Diameter of Steel Pipe Piles in BH-2a
Factored Axial Capacity (kips)
0
100
200
300
400
500
600
700
800
900
1000
Depth (ft)
0
20
40
60
80
100
120
16"
20"
24"

Figure 3A-2

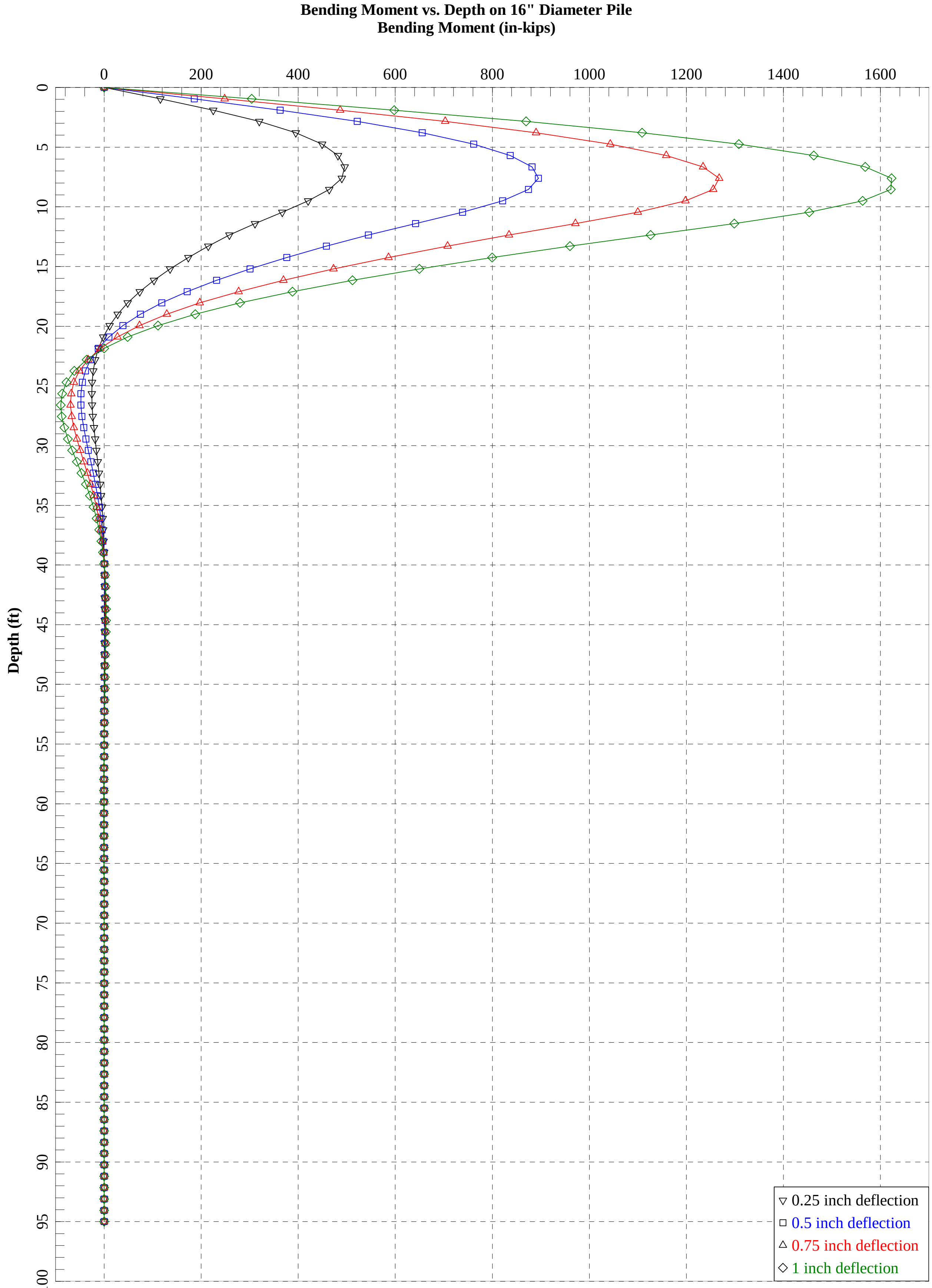

Bending Moment vs. Depth on 16" Diameter Pile
Bending Moment (in-kips)
0
200
400
600
800
1000
1200
1400
1600
Depth (ft)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
0.25 inch deflection
0.5 inch deflection
0.75 inch deflection
1 inch deflection

Figure 3B-1

Shear Force vs. Depth on 16" Diameter Pile
Shear Force (kips)

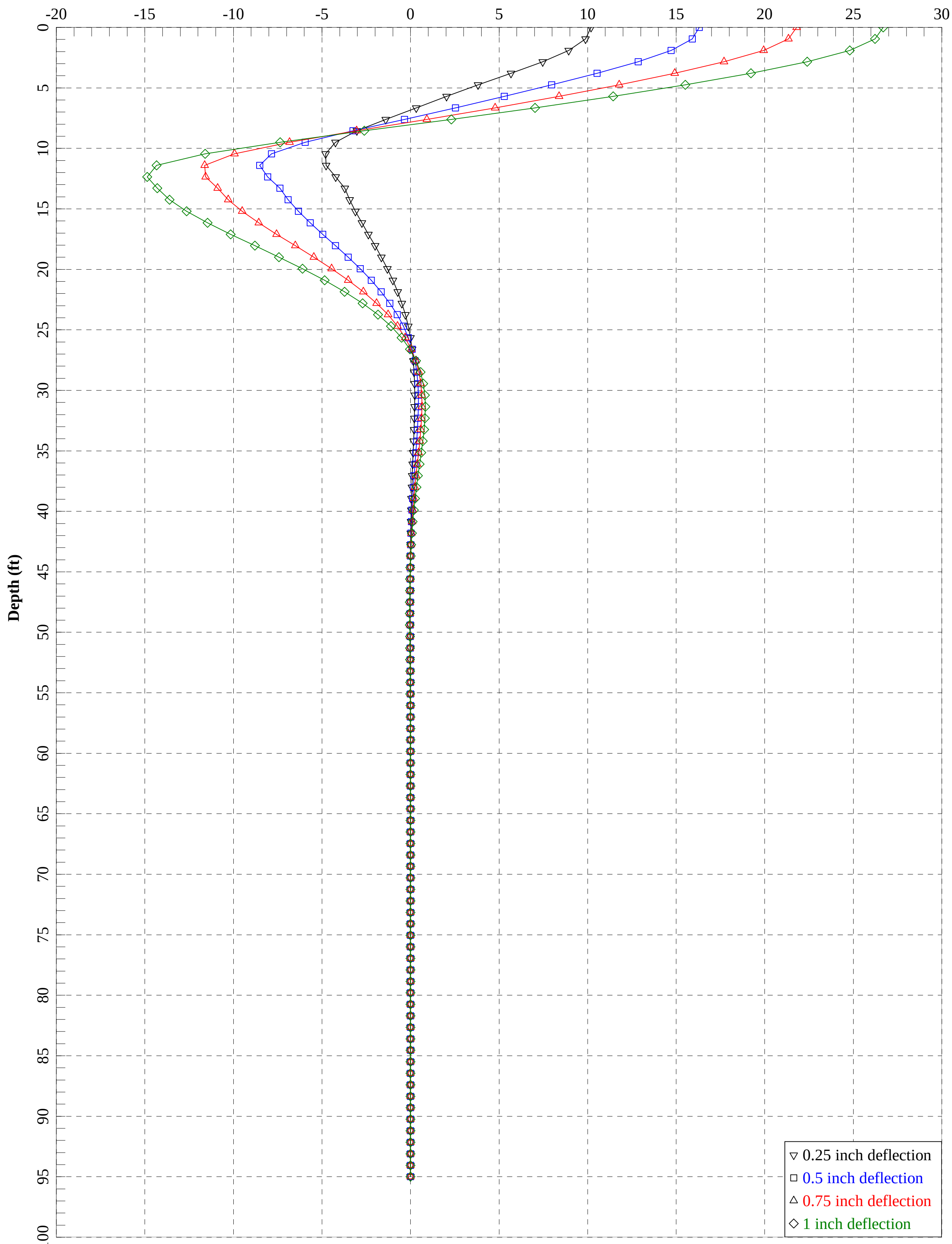


Figure 3B-2

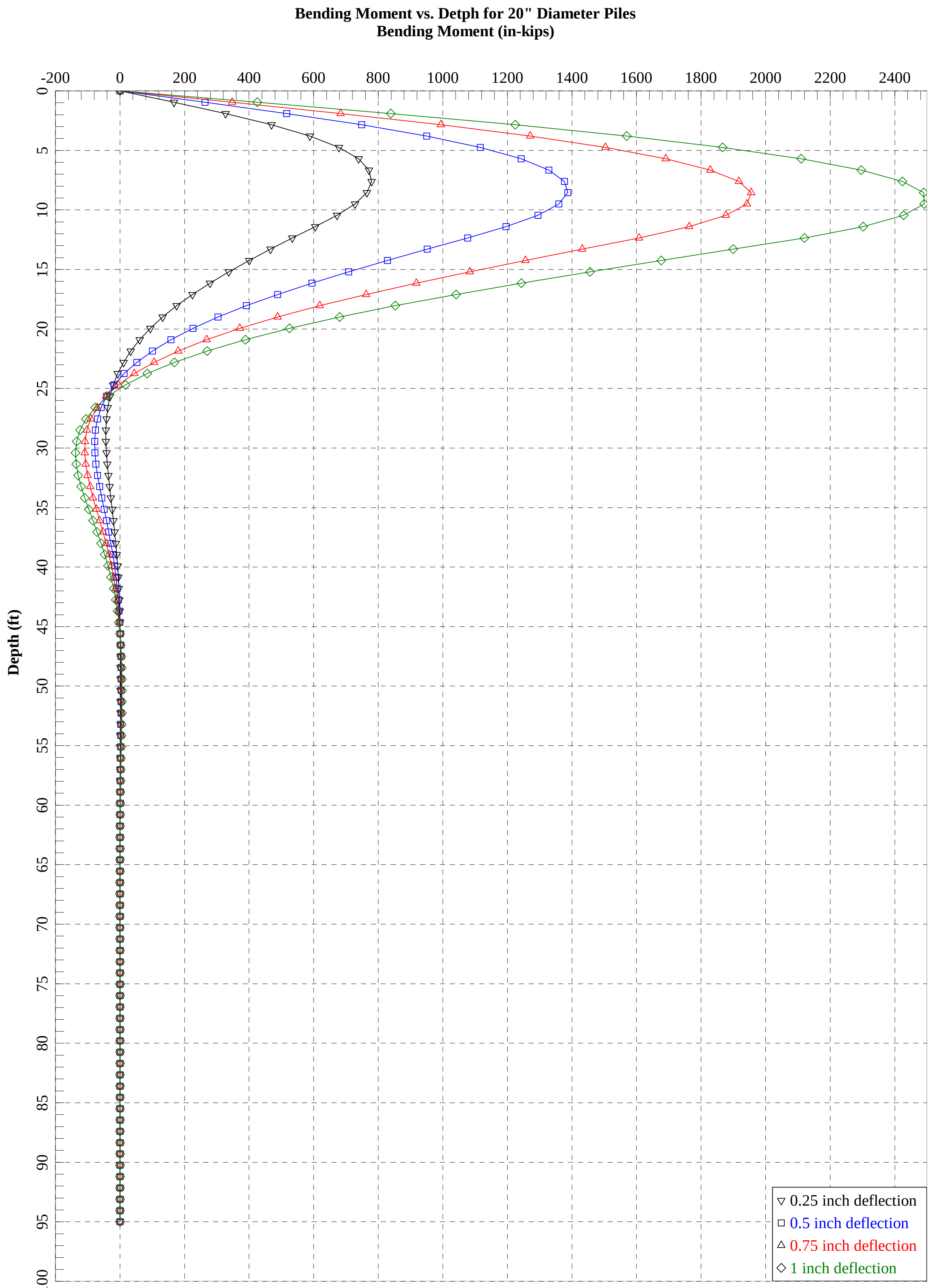

Bending Moment vs. Detph for 20" Diameter Piles
Bending Moment (in-kips)
-200
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
Depth (ft)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
0.25 inch deflection
0.5 inch deflection
0.75 inch deflection
1 inch deflection

Figure 3B-3

Shear Force vs. Depth for 20" Diameter Pile

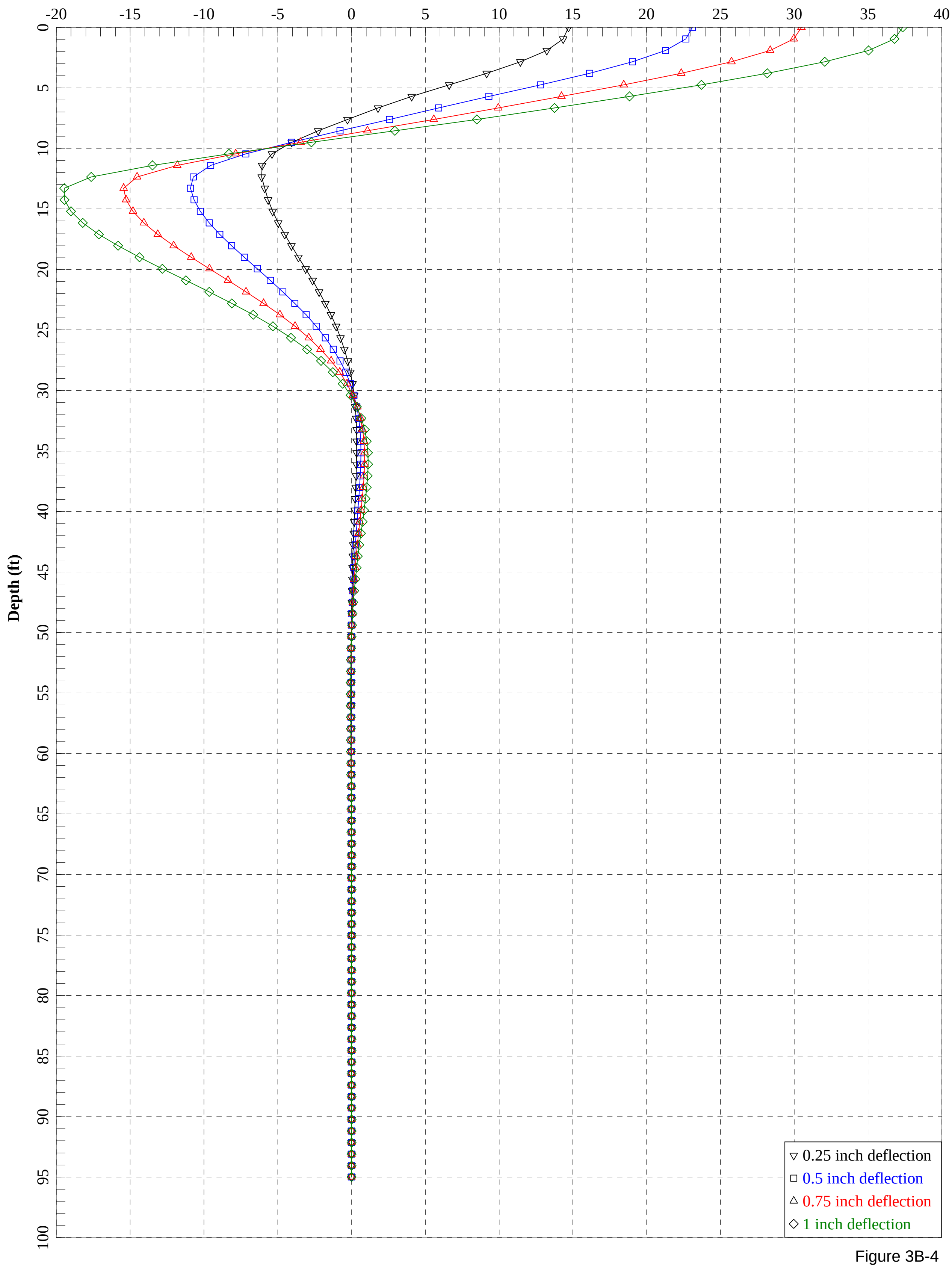


Figure 3B-4

Bending Moment vs. Detph for 24" Diameter Piles
Bending Moment (in-kips)

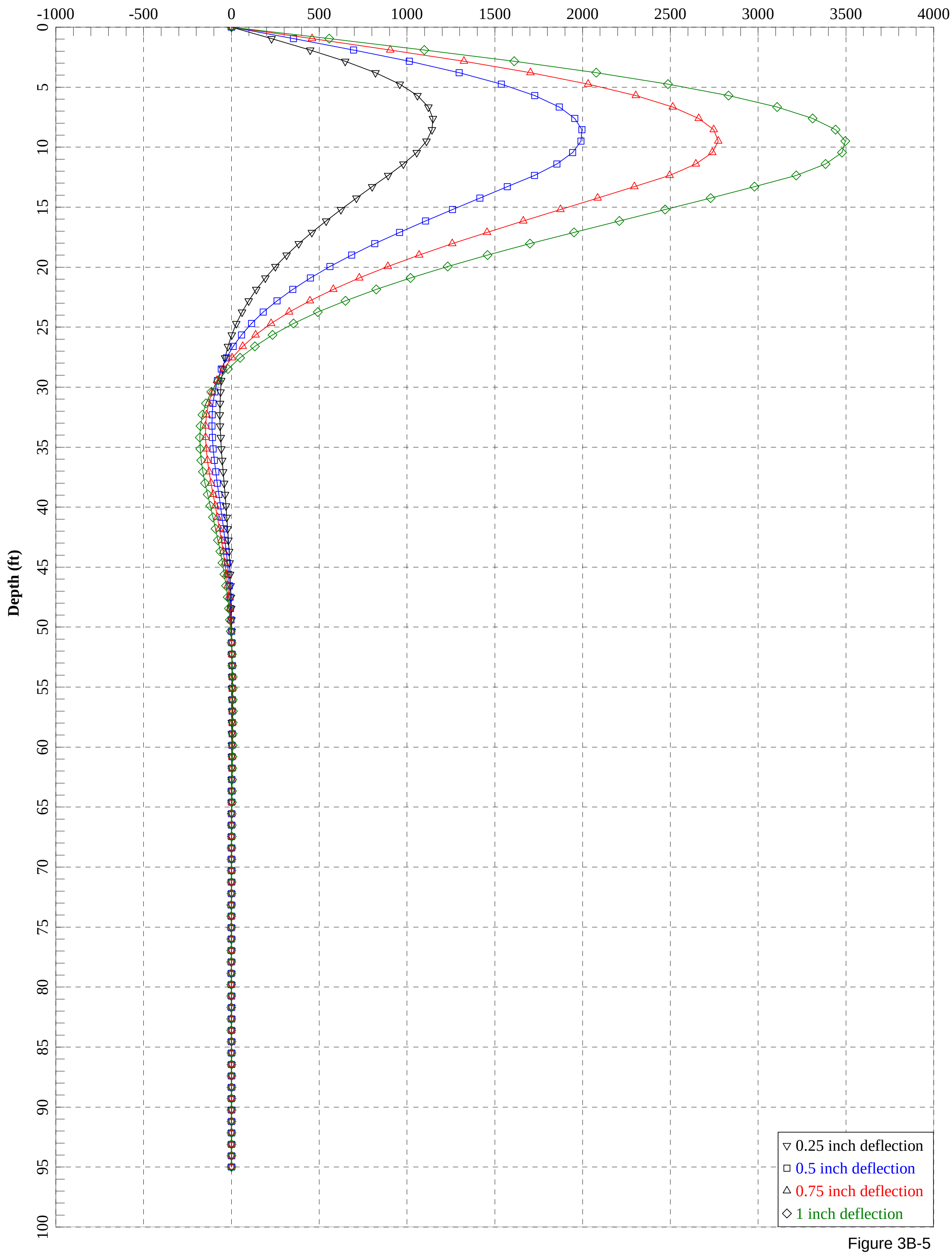


Figure 3B-5

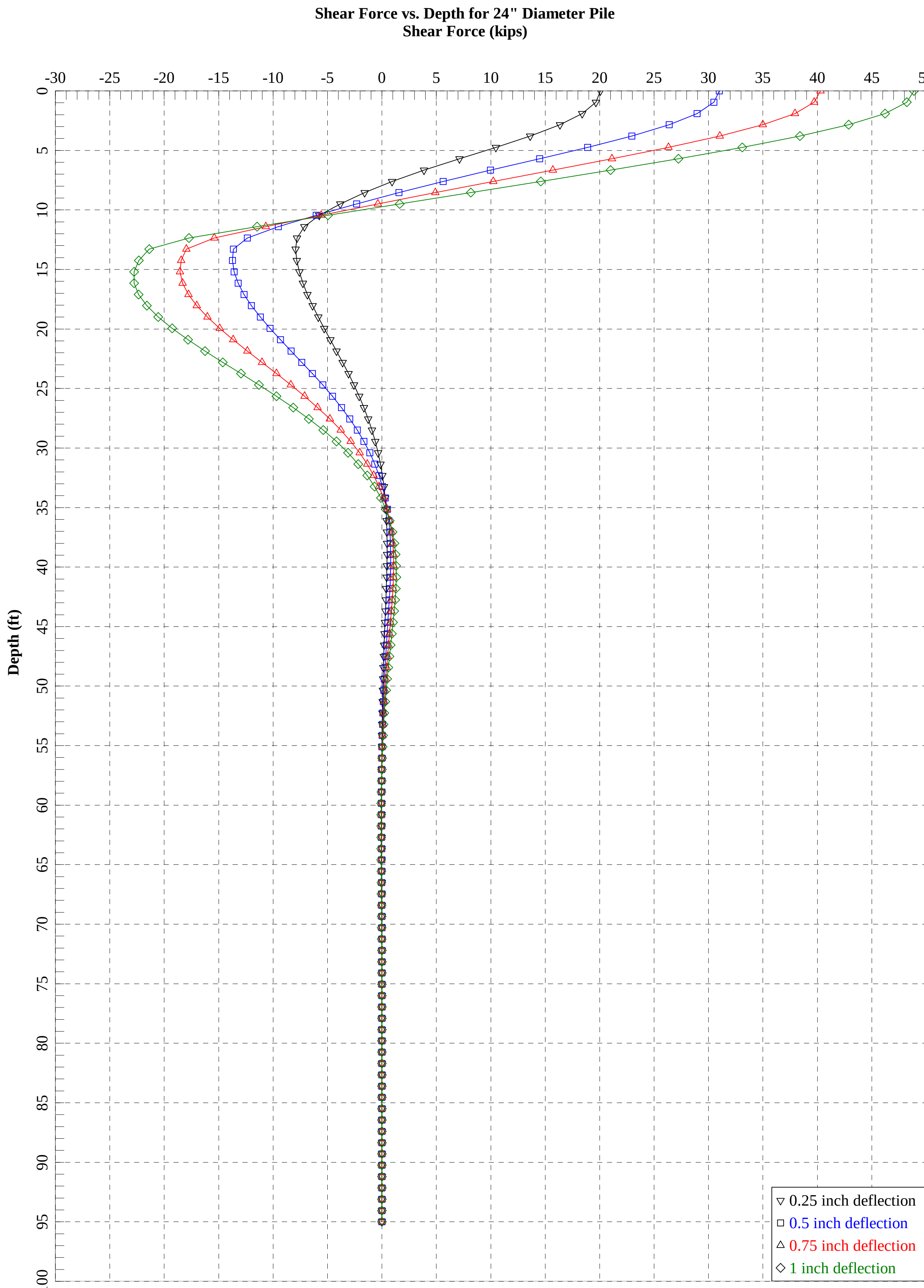

Shear Force vs. Depth for 24" Diameter Pile
Shear Force (kips)
-30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30 35 40 45 50
Depth (ft)
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
0.25 inch deflection
0.5 inch deflection
0.75 inch deflection
1 inch deflection

Figure 3B-6

Shaft Axial Capacity vs Depth

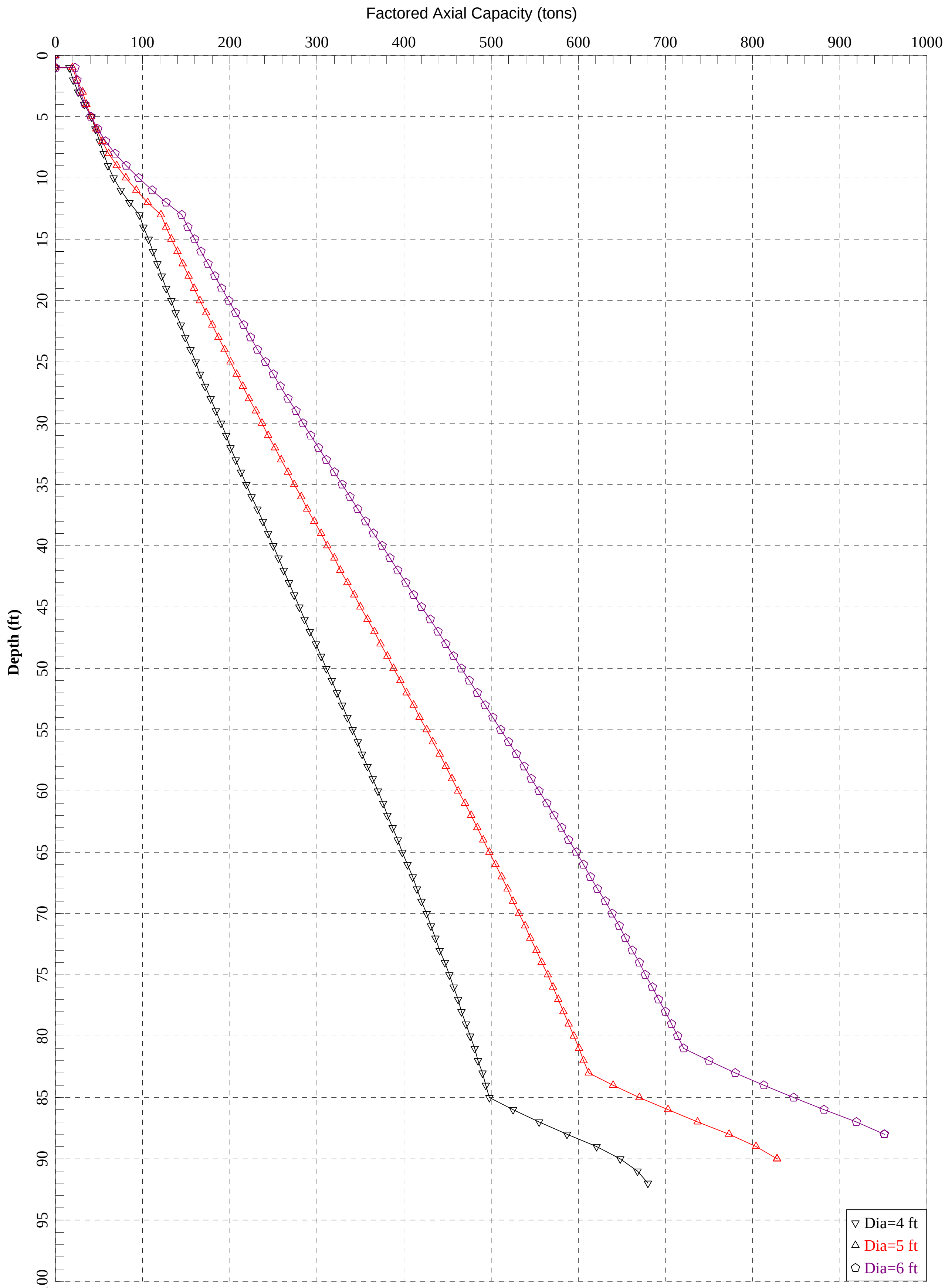


Figure 3C-1

Assume 0 feet is top of boring elevation