# SAINTE GENEVIEVE, MISSOURI
# GENERAL REEVALUATION REPORT

# ENGINEERING DESIGN

## APPENDIX A

.

# MAIN REPORT

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# 1 INTRODUCTION

## 1.1 REPORT PURPOSE

### 1.1.1 Introduction

The USACE St. Louis District has completed the preliminary design and analysis for the Sainte Genevieve (Ste. Gen), Missouri, flood control project parts 2 and 3 as part of the General Reevaluation Report (GRR). Presented in the following sections are site investigations, analyses, and considerations for the project.

This GRR re-examines the remaining items, North and South Gabouri Creek flood protection and recreation, of the authorized project for flood risk reduction for the historically-significant city of Sainte Genevieve, Missouri. The authorized project is documented in the 1984 Feasibility Report (Ste. Genevieve, Missouri, Feasibility Report, Flood Control Study for Historic Ste. Gen - June 1984). The primary purpose of the GRR is to re-examine various alternatives (including the authorized plan) for providing flood damage reduction, identify the tentatively selected plan, and provide recommendations, giving consideration to each plan's economic, environmental, and social impacts. The GRR re-examines previously developed alternatives to evaluate the effects of features developed in response to the 1993 flooding events in the area which resulted in buyouts of a significant number of structures along both creeks. The GRR will serve as the decision document required to execute a Project Partnership Agreement for construction.

12 structural and 3 non-structural measures were developed and evaluated for both the North and South Gabouri Creeks as part of the GRR. See Appendix E of this report for a complete list and description of the developed measures. Based on initial evaluation and screening of the measures multiple alternatives were developed. See below for the developed alternatives for each creek.

North Gabouri Creek Alternatives

- Channelization, Bridge Replacement, and Floodproofing (CH-BR-FP), Authorized Plan
- Bridge Replacements (BR)
- Removal of Obstruction from the Floodplain (OF)
- LaHaye Street Levee (LH)
- LaHaye Street Levee and Bridge Replacements (LH-BR)
- Third Street Levee (3L)
- Third Street Levee and Channelization (L2-CH2)
- North Gabouri Levee Alternative (L2-CH2-FP)
- Upland Detention, five locations (N1, N2, N3, N4, N5)
- Floodproofing (FP-BO-RL)

South Gabouri Creek Alternatives

- Channelization, Bridge Replacement, and Floodproofing (CH-BR-FP), Authorized Plan
- Bridge Replacements (BR)

- Excavation of Lime Deposits (LE)
- Bridge Replacement and Excavation of Lime Deposits (BR-LE)
- Removal of Obstructions from the Floodplain (OF)
- Gabouri Street Levee (GL)
- Removal of Obstructions from the Floodplain and Channelization downstream of Main Street (OF-DW)
- Gabouri Street Levee, Removal of Obstructions from the Floodplain, and Channelization downstream of Main Street (GL-OF-DW)
- Upland Detention, seven location (S1 through S7)
- Floodproofing (FP-BO-RL)

### 1.1.2 Project and Site Description

The Sainte Genevieve (Ste. Gen), Missouri, flood control project parts 2 and 3 project is being implemented to safeguard and improve the quality of life of all citizens of the City of Ste. Genevieve. This project will prevent future flood damages to historic structures, such as the vertical stick framed homes shown in Figure 1-1, economic losses, and social disruption caused by flooding of North Gabouri Creek and South Gabouri Creek. Ultimately the new design will preserve and enhance the historic character of Ste. Gen.

The upper end of the North and South Gabouri Creeks' watersheds have intermittent flows during drought periods. Both creeks pass through a mixture of pasture, forest and cropland in their upper reaches and have beds of cobble and gravel with little in-stream cover. The lower portions of the creeks pass through urban Ste. Genevieve. The bottom of the creek beds typically are comprised of bedrock, cobbles, and gravel with some man-made debris. In the lower area, the creek banks are generally vegetated and the streams are shaded with narrow channels and low base flows.

The location of interest along the North Gabouri creek lies between stations 0+00 and 31+65. Elevations in the watershed range from 360 feet NGVD where the Gabouri Creek meets the Mississippi River to 900 feet NGVD in the western uplands of North Gabouri Creek. Large areas around the city exhibit karst features such as sink holes, joint cavities, caves, karst ponds, losing streams, swallow holes, and springs. The bedrock underlying the entire area is principally composed of limestones and occasional shales and sandstones.

The Gabouri Creek enters the Mississippi River at river mile 122.5 above the Ohio River. The creek divides into North Gabouri Creek and South Gabouri Creek at a point 0.9 miles from the Mississippi River. The North Gabouri project consists of a combination of structural and non-structural alternatives to protect against flooding. The North Gabouri Creek floodplain is used for pastures or crop production for the majority of its six mile length. Dense urban development occurs in the floodplain from river mile 1.2 to 2.0 from the Mississippi River. Above river mile 2.0, the watershed is primarily in farmland and low-density housing. The creek channel generally has a gravel and limestone bottom and is lined sparsely with trees.

The location of interest along the South Gabouri creek lies between station 15+00 and 90+00. Elevations in the watershed range from 360 feet NGVD where the Gabouri Creek meets the Mississippi River to 850 feet NGVD in the western uplands of South Gabouri Creek. Most areas around the city exhibit karst features such as sink holes, joint cavities, caves, karst ponds, losing streams, swallow holes, and springs.  The bedrock underlying the study area is principally composed of limestones and occasional shales and sandstones.

The South Gabouri project consists of a combination of structural and non-structural alternatives to protect against flooding.  The South Gabouri Creek floodplain is highly developed from river mile 1.4 to 2.3 above its confluence with the Mississippi River. A few homes are located in the floodplain from river mile 2.3 to 2.9 at U.S. Highway 61. Above U.S.  Highway 61 the creek flows through the Mississippi Lime Company mining operation for nearly one mile. For the remainder of its six mile length, the South Gabouri Creek floodplain is generally used for agricultural production. The creek channel generally consists of a gravel or clay bottom. The creek is lined with trees except in parts of the Mississippi Lime Company area and some areas within the city of Ste. Genevieve.

Figure 1-1. Historic Vertical Stick Framed Home

# 2 CIVIL/STRUCTURAL/MECHANICAL

## 2.1 GENERAL

Preliminary civil, structural, and mechanical design analyses were performed on project features for each alternatives as defined in section 1.1 of this appendix.

### 2.1.1 Project Features

Project features included creek channelization, levee design, Flood walls, bridge replacement, detention dams, structure floodproofing, right of way, pump station, utility relocations, and miscellaneous items.

Utility relocations include but are not limited to sewer, electrical, water, and communication.

#### 2.1.1.1 Creek Channelization

Creek channelization includes improvements to the channel cross section to improve conveyance of water such that flooding beyond the limits of the channel are minimal or nonexistent for the project design event. Improvements to the channel include increasing the channel cross section area by widening the channel bottom to a minimum of 20 feet and providing channel banks with a minimum 1 vertical on 2 horizontal side slopes. Additional improvements include multiple grade control structures and riprap bank protection and stabilization to control erosion and flow velocity concerns.

Creek channelization also includes improvements to the channel cross section and profile to realign the creek such that other features can be constructed to provide the desired level of flood protection. These features included levees and detention dams.

Bank protection and stabilization to control erosion consists of articulated concrete mat, 140 pound riprap, and 400 pound riprap. The size, location, and type of bank protection and stabilization used were dependent on preliminary creek velocities.

#### 2.1.1.2 Levee Design

The levee design includes the construction of new levees and raising an existing levee. The North Gabouri Creek new levee design and levee raise includes a 10 feet wide levee crown with 1 vertical on 3 horizontal side slopes. The South Gabouri Creek new levee design includes a 5 feet wide levee crown, 1 vertical on 3 horizontal side slopes on the landside, and a vertical face (a mechanically-stabilized earth wall) on the river side. A mechanically stabilized earth wall was assumed for the river side of the levee due to space constraints and to minimize visual impacts.

Proposed earthen materials used to construct the new levees and levee raises would be provided by both nearby borrow sites and excavation of the ponding areas associated with each alternative.

Proposed ponding areas are required for interior drainage. The sizes of the ponding areas were determined from preliminary hydraulic analysis. The ponding areas included gravity drains, pump stations, and reinforced concrete piping. The location of the ponding areas was based on available land within the project limits. Interior flooding and interior storm water management systems were not evaluated in detail as part of this study. A preliminary study was conducted but a detailed study will be required of the interior flooding and storm water management system to verify and alleviate any induced flooding as a result of the proposed project to include but not limited to the ponding area, pump station capacity, ditches, culverts, and inlets.

#### 2.1.1.3 Pump Station

Based on preliminary analysis adequate ponding area to capture and store the anticipated interior drainage, for alternatives considering a levee, for the duration of the flooding event could not be located within the project area. A pump station is required to provide the extra capacity of the ponding areas.

Preliminary analysis was conducted on the design of the pump station based on preliminary hydraulic demand analysis. Pump station features include a pump station capacity of 20 cfs, 2 pumps each 10 cfs, pump size of 45 hp with 16-inch discharge, lift station pump station type with 8 feet diameter concrete manhole, 16 inch steel discharge pipes with gatewell and flap gate, and a 48 inch gatewell with sluice gate. It was assumed that two 6 hour operation periods each month for the months of March through November were required with average maintenance cost of$2,000 per year.

#### 2.1.1.4 Floodwall

In area where construction of a levee is limited or not feasible due to space constants a floodwall is proposed. The floodwall will be of I-wall type construction with a reinforced concrete cap. The height of the I-wall will be limited to a maximum height of 6 feet by the construction of a small levee with a 10 feet wide crown and 1 vertical on 3 horizontal side slopes.

Preliminary analysis was conducted on the design of the floodwall. Design parameters included; top of wall elevation 396.0 feet, bottom of sheet pile elevation 374.00 feet, density of soil 110 PCF, cohesion of 600 PSF, and PZC 13 steel sheet pile. A factor of safety of 3.15 was achieved for the preliminary analysis without gap effects analyzed. Preliminary analysis and evaluations concluded that a satisfactory safety factor could be achieved considering gap effects. The risk of not achieving an adequate safety factor and requiring an L-wall design in place of an I-wall was considered in developing the cost risk analysis.

#### 2.1.1.5 Bridge and Roadway Replacement

Bridge and roadway replacement includes the raising and/or lengthening of bridges. Bridge raising and/or lengthening is required to improve the conveyance of water and provide a clear distance from the top of the flood elevation to the bottom of the bridge girders to account for debris passage per AASHTO LRFD Bridge Design Specifications, 2012. The overall size of the bridge openings and elevation of the bridges were based on preliminary hydraulic modeling.

Roadway bridges were assumed to be steel multi-girder with reinforced concrete deck construction. Railroad bridges were assumed to be pass-through steel girder type construction.

Roadway replacement included elevation of existing roadways. The new roadways were assumed to be asphalt with concrete sidewalks and gutters with mechanically stabilized walls.

#### 2.1.1.6 Right of Way

Permanent and temporary right of way will need to be acquired along the proposed alignments. The acquired permanent and temporary right of way should include adequate right of way for construction and maintenance of all floodwall features, levee features, structures, interior drainage features, etc.

#### 2.1.1.7 Upland Detention

The construction of an upland detention would include a large dry detention dam and basin outside the city limits to temporarily store runoff from large events and slowly release them into the creek over the course of a few days. The dam would be constructed with a combination of earth and roller-compacted concrete. The location of the dry detention dam and basin was chosen based on available holding volume and to minimize the length of the dam section.

#### 2.1.1.8 Floodproofing

Floodproofing is considered any combination of structural and non-structural additions, changes, or adjustments to structures which reduce or eliminate flood damage to real estate. It is recommend by FEMA that floodproofing measures be implemented up to one foot above the base flood elevation. For evaluation of the North and South Gabouri Creeks six floodproofing measures were considered: (1) relocation/buyout of the structure, (2) elevation of the structure, (3) wet floodproofing of the structure, (4) dry floodproofing of the structure, (5) walls around the structure, and (6) berms around the structure.

### 2.1.2 North Gabouri Creek Alternatives

Based on initial evaluations and screening, measures (see Appendix E of this report for a complete list of measures) that were found to be effective in reducing flood damage were carried forward alone or in combination with other measures into the alterative analysis. Ten alternatives were developed and evaluated for the North Gabouri Creek.

#### 2.1.2.1 Channelization, Bridge Replacement, and Floodproofing (CH-BR-FP), Authorized Plan

The Channelization, Bridge Replacement, and Floodprooging Alternatives (CH-BR-FP) combines channelization, bridge replacement, and floodproofing measures. The plan includes channel improvements from just downstream of the two railroad bridges to just upstream of 4th street bridge, 4th street and main street bridge and roadway replacement, removal of 3rd street creek crossing, two railroad bridge replacements, (Burlington-Northern and Missouri-Illinois Railroads), floodproofing two structures (structures 452 and 454), and removal of two structures (408 and 838). The channel improvements will include widening the channel bottom to a minimum of 30 feet wide with 1 vertical on 2.5 horizontal bank slopes and construction of a vertical solder pile wall just upstream of the Main Street Bridge. See Appendix V for floodproofing measures.

See Appendix I sheet NG-300 and NG-301 for overall plan features and sections.

#### 2.1.2.2 Bridge Replacements (BR)

The Bridge Replacement Alternative (BR) replaces the bridges at Burlington-Northern and Missouri-Illinois Railroads, Main Street, and 4th Street, and the culvert at 3rd Street. Minor excavation and riprap added to channel sections at and around the new bridges are required.

This alternative did not produce significant results during hydraulic modeling and was not further evaluated. See Appendix F for additional information.

#### 2.1.2.3 Removal of Obstructions from the Floodplain (OF)

The Removal of Obstructions for the Floodplain Alternative (OF) removes all bridges and structures impeding flow near the channel. This would allow a wide floodway width to pass high events, with no constrictions.

This alternative did not produce significant results during hydraulic modeling and would eliminate all creek crossing from 4th street to the railroad bridges. This alternative was not further evaluated.

#### 2.1.2.4 A levee located on top of LaHaye Street (LH),

The LaHaye Levee alternative (LH) would essentially raise LaHaye Street (and a portion of Sixth Street) to an elevation above the 1% event flood height. This would be a wide levee to accommodate two lanes of traffic with shoulders. The levee would be approximately 6 feet high from just upstream of 3rd street tying into high ground 0.25 miles upstream of 4th street along LaHaya Street.

It was determined that after the LaHaye Levee Alternative (LH) was further developed roadway and bridge replacements and project realignment would be required to account for utility relocations and ponding areas. To account for these items the LaHaye Levee (LH) alternative would require the same general features and layout as the North Gabouri Levee Alternative (L2-CH2-FP). This alternative was not further evaluated.

#### 2.1.2.5 The LaHaye Levee and Bridge Replacements (LH-BR),

The LaHaye Levee and Bridge Replacements Alternative (LH-BR) would essentially raise LaHaye Street (and a portion of Sixth Street) to an elevation above the 1% event flood height. This would be a wide levee to accommodate two lanes of traffic with shoulders. 4th street and 3rd street bridge and roadway replacements are required. The levee would be approximately 6 feet high from just upstream of 3rd street tying into high ground 0.25 miles upstream of 4th street following LaHaya Street.

It was determined that after the LaHaye Levee and Bridge Replacements Alternative (LH-BR) was further developed floodproofing of two structures and project realignment would be required to account for utility relocations and ponding areas. To account for these items the LaHaye Levee with Bridge Replacements (LH-BR) alternative would require the same general features and layout as the North Gabouri Levee Alternative (L2-CH2-FP). This alternative was not further evaluated.

#### 2.1.2.6 Third Street Levee (3L),

The Third Street levee alternative would connect high ground between 3rd and 4th Streets to high ground immediately downstream of 3rd Street. This would prevent floodwaters from flowing over the intersection of 3rd and LaHaye Streets.

This alternative did not produce significant results during hydraulic modeling and was not further evaluated. See Appendix F for additional information.

#### 2.1.2.7 Third Street Levee and Channelization (L2-CH2)

The Third Street Levee and Channelization Alternative (L2-CH2) would connect high ground between 3rd and 4th Streets to high ground immediately downstream of 3rd Street. Limited channelization would be included. The combination of Third Street levee and channelization was in an attempt to get further flooding reductions.

This alternative did not produce significant results during hydraulic modeling and was not further evaluated. See Appendix F for additional information.

#### 2.1.2.8 North Gabouri Levee Alternative (L2-CH2-FP)

The North Gabouri Levee Alternative (L2-CH2-FP) would connect high ground staring upstream behind the homes on the west side of Sixth Street, run southeast and curve through the City park, and then run adjacent to the north bank of the creek until it reaches high ground near Main Street. The levee would be approximately 8 feet high. During high water events, interior drainage would be temporarily ponded in the park (ponding area 1), along 3rd Street (ponding area 2), and between 3rd Street and Main Street (ponding area 2A). A floodwall is required just upstream of 4th Street Bridge. Bridge and roadway replacement is required at 4th street. The 3rd Street creek crossing would be removed. Channelization would be required to realign the creek for the construction of the levee 0.2 miles upstream of 4th street. Relocation of structure 408 will be required to facilitate the construction of the levee and roadway.. Floodproofing of two structures is required (Structures 452 and 454). See Appendix V for floodproofing measures.

Site improvements, utility relocation, structure relocations, roadway relocations, and miscellaneous items would be required to relocate utilities and structures outside of the levee and ponding area right of ways.

Utility relocations include but are not limited to sewer, electrical, water, and communication.

See Appendix I sheet NG-200 and NG-201 for overall plan features and sections.

#### 2.1.2.9 Upland Detention, 5 locations (N1, N2, N3, N4, N5).

The Upland Detention Alternative included the evaluation of 5 different dam locations with various levels of protection. Each location and variation was evaluated and the one that best met the project goals was further evaluated. Upland Detention location N5 evaluated for the 1% probability event (N5(100)) best met the project goals. This alternative would place a large dry detention dam and basin immediately outside the city limits (approximately 2 miles upstream of the existing Mississippi River pump station).

The preliminary design is a 150 feet wide concrete weir with a 4’ by 4’ square outlet. Minor channel improvements would be required at the base of the dam. Extensive site improvements, utility relocation, structure relocations, roadway relocations, and miscellaneous items would be required. The location and design is based on the 1% probability event.

Utility relocations include but are not limited to sewer, electrical, water, and communication.

Based on geotechnical concerns (section 3.1.3 of this appendix) and hydraulic modeling concerns (Appendix B) this alternative was not further evaluated.

#### 2.1.2.10 Floodproofing (FP-BO-RL)

The floodproofing Alternative (FP-BO-RL) includes floodproofing measures to be taken on all structures calculated to be damaged by the 1% event, as well as all structures within 1 foot of being damaged. This includes a total of 5 structures on the North Gabouri Creek. Further evaluation and floodproofing techniques for each structure are included in Appendix I.

See Appendix I sheet NG-400 for overall plan features.

### 2.1.3 South Gabouri Creek Alternatives

Based on initial evaluations and screening, measures (see Appendix E of this report for a complete list of measures) that were found to be effective in reducing flood damage were carried forward alone or in combination with other measures into the alternative analysis. Ten alternatives were evaluated for the South Gabouri Creek.

#### 2.1.3.1 Channelization, Bridge Replacement, and Floodproofing (CH-BR-FP), Authorized Plan

The Channelization, Bridge Replacement, and Floodproofing Alternative (CH-BR-FP) combines channelization, bridge replacement, and floodproofing measures. The plan includes channel improvement from just upstream of the railroad bridge to State Highway 61, two railroad bridge replacements, five bridge and roadway replacements, three roadway relocations, and floodproofing of two structures (236 and 255). The channel improvements will include widening the channel bottom to a minimum of 20 feet wide with 1 vertical on 2 horizontal bank slopes. See Appendix V for floodproofing measures.

See Appendix I sheet SG-300 for overall plan features.

#### 2.1.3.2 Bridge Replacements (BR)

The Bridge Replacement Alternative (BR) included the replacement of multiple bridges. Minor excavation and riprap added to channel sections at and around the new bridges are required.

This alternative did not produce significant results during hydraulic modeling and was not further evaluated. See Appendix F for additional information.

#### 2.1.3.3 Excavation of Lime Deposits (LE)

The Excavation of Lime Deposits Alternative (LE) includes only minor excavation of lime deposits along the length of the cannel.

This alternative did not produce significant results during hydraulic modeling and was not further evaluated. See Appendix F for additional information.

#### 2.1.3.4 Bridge Replacement and Excavate Lime Deposits (BR-LE)

The Bridge Replacement and Excavation of Lime Deposits Alternative (BR-LE) included only minor excavation of lime deposits and replacement of multiple bridges. Minor excavation and riprap added to channel section at and around the new bridges is required. The combination of bridge replacement and excavation of lime deposits was in an attempt to get further flooding reductions.

This alternative did not produce significant results during hydraulic modeling and was not further evaluated. See Appendix F for additional information.

#### 2.1.3.5 Removal of Obstructions from the Floodplain (OF)

The Removal of Obstructions from the Floodplain Alternative (OF) removes all bridges and structures impeding flow near the channel. This would allow a wide floodway width to pass high events, with no constrictions.

This alternative did not produce significant results during hydraulic modeling and would eliminate all creek crossing from the railroad bridge to Highway 61. This alternative was not further evaluated.

#### 2.1.3.6 Gabouri Street Levee (GL-FP)

The Gabouri Street Levee alternative (GL-FP) would connect high ground starting east of Fifth Street and running along the creek's north bank until it ties into high ground near the railroad bridge. Due to space constraints and to minimize visual impacts, the preliminary design assumes that the levee would have a vertical face (a mechanically-stabilized earth wall) on the creek side and an earth embankment on the land side. During high water events, interior drainage would be temporarily ponded in two ponding areas (ponding area 1 and 2). The ponding areas will be drained by gravity drains, one placed at each ponding area. The levee protects all but six structures (#76, #244, #246, #250, #255, #257), and causes some induced flooding upstream. These six structures would be floodproofed and induced damages would be addressed by floodproofing measures or acquiring proper right of way. See Appendix V for floodproofing measures.

Hydraulic modeling shows that there is no induced flooding for structure number 238. Due to the structure location and significant safety concerns it is recommend that this structure be removed or relocated.

Site improvements, utility relocation, structure relocations, roadway relocations, and miscellaneous items would be required to relocate utilities and structures outside of the levee and ponding area right of ways.

Utility relocations include but are not limited to sewer, electrical, water, and communication.

See Appendix I sheet SG-200 for overall plan features.

#### 2.1.3.7 Removal of Obstruction from the Floodplain and Channelization Downstream of Main Street (OF-DW)

The Removal of Obstruction from the Floodplain and Channelization Downstream of main Street Alternative (OF-DW) include the combination of obstruction removal and channelization in an attempt to reduce induced flooding impacts.

This alternative did not produce significant results during hydraulic modeling and was not further evaluated. See Appendix F for additional information.

### 2.1.3.8 Gabouri Street Levee, Removal of Obstruction from the Floodplain, and Channelization Downstream of Main Street (GL-OF-DW)

The Gabouri Street Levee, Removal of Obstructions from the Floodplain, and Channelization Downstream of Main Street Alternative (GL-OF-DW) includes the combination of the Gabouri Street Levee, obstruction Removal, and channelization in an attempt to reduce induced flooding impacts.

This alternative did not produce significant results during hydraulic modeling and was not further evaluated. See Appendix F for additional information.

### 2.1.3.9 Upland Detention, seven locations (S1 through S7)

The Upland Detention Alternative included the evaluation of 7 different dam locations with various levels of protection. Each location and variation was evaluated and the one that best met the project goals was further evaluated. Upland Detention location S7 evaluated for the 1% probability event (S7(100)) best met the project goals. This alternative would place a large dry detention dam and basin outside the city limits (approximately 4 miles upstream of the pump station).

The preliminary design is a 150 feet wide concrete weir with a 4’ by 4’ square outlet. Minor channel improvements would be required at the base of the dam. Extensive site improvements, utility relocation, structure relocations, roadway relocations, etc would be required. The location and design is based on the 1% probability event.

Utility relocations include but are not limited to sewer, electrical, water, and communication.

Based on geotechnical concerns (section 3.1.5 of this appendix) and hydraulic modeling concerns (Appendix B) this alternative was not further evaluated.

### 2.1.3.10 Floodproofing (FP-BO-RL)

The Floodproofing alternative (FP-BO-RL) includes floodproofing measures to be taken on all structures calculated to be damaged by the 1% event, as well as all structures within 1 foot of being damaged. This includes a total of 11 structures on the South Gabouri Creek. Further evaluation and floodproofing techniques for each structure are included in Appendix V.

See Appendix I sheet SG-400 for overall plan features.

# 3 GEOTECHNICAL

## 3.1 SUBSURFACE EXPLORATION AND LABORATORY TESTING

The subsurface exploration was completed by Brotcke Well and Pump, Inc., in 2009 in which twelve borings were drilled for the entire Ste. Gen project. All borings were drilled along the proposed levee location adjacent to the North Gabouri creek. Figure 3-1below shows the boring location layout. Figure 3-2 shows the boring logs of the 2009 subsurface exportation. The project borings were drilled to develop the in-situ soil stratagraphy, evaluate the potential for settlement, and evaluate the potential slope stability risks.

In order to determine selected engineering properties, the following laboratory tests were performed on selected samples recovered from the borings:

- Visual descriptions by color and texture of each sample
- Natural moisture content of each cohesive sample
- Atterberg Limits test on all cohesive samples
- Grain size analyses of all coarse grained samples

The pertinent laboratory testing results for borings SG-01 through SG-12 are shown in Table 3-1. After testing, the samples were classified according to the Unified Soil Classification System (USCS). The general stratigraphy of the area contains thick clays layers, Gravel and Sand lenses, and variable bedrock elevation.

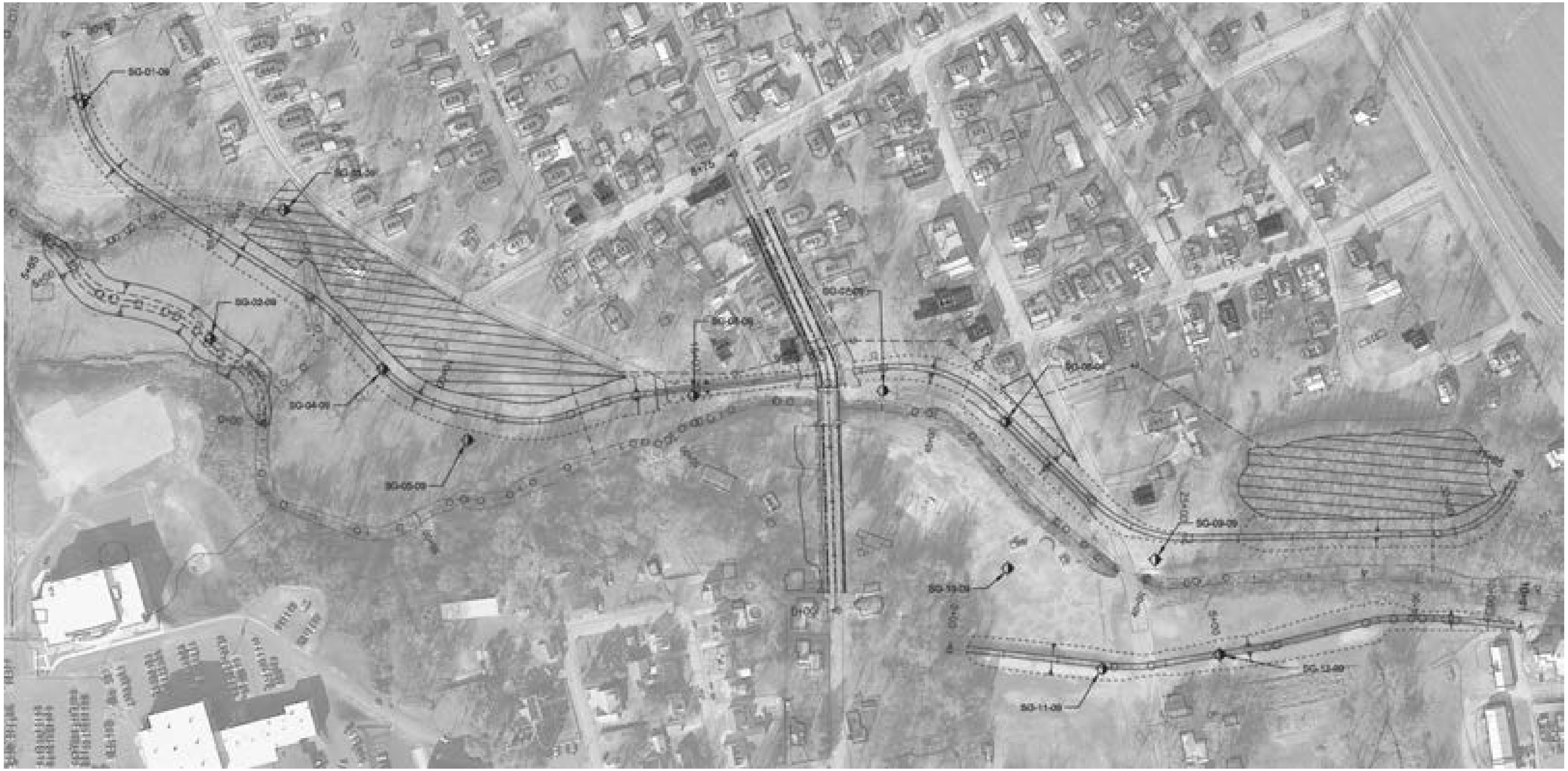

Figure 3-1. Boring Location

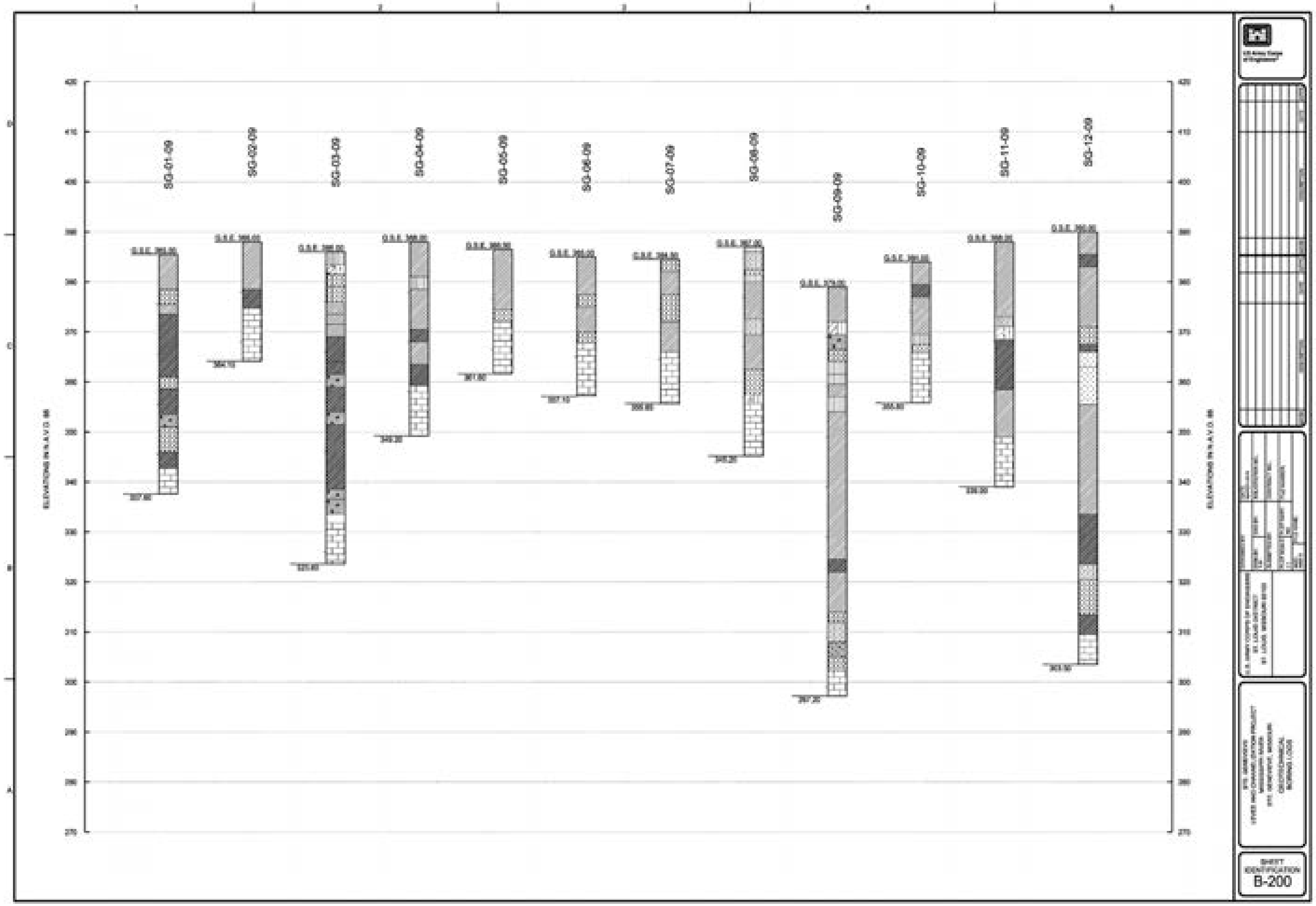

Figure 3-2. 2009 Boring Logs (Note the varying bedrock elevations)

### 3.1.1 Site Geology

The study area lies within the Salem Plateau section of the Ozark Plateau Province, on the east flank of the Ozark Uplift and east of the St. Francois Mountains. The eastern portion of the study area lies within the Mississippi River floodplain.

The topography of the area varies from flat-lying floodplain near the Mississippi River to gently rolling to rugged hills in the western uplands. Elevations range from 360 feet NGVD where Gabouri Creek meets the Mississippi River to 900 feet NGVD on the North Gabouri Creek watershed divide in the northwest part of the study area.

Areas to the north, south, and west of Ste. Genevieve exhibit karst features such as sinkholes, joint cavities, caves, karst ponds, loosing streams, swallow-holes and springs as shown in Figure 3-1 and Figure 3-9. These solution features have formed in the Salem, St. Louis, and Ste. Genevieve formations which underlie these areas. The bedrock underlying the study area is composed of Ordovician and Mississippian sedimentary rocks, principally limestone and occasional shales and sandstones.

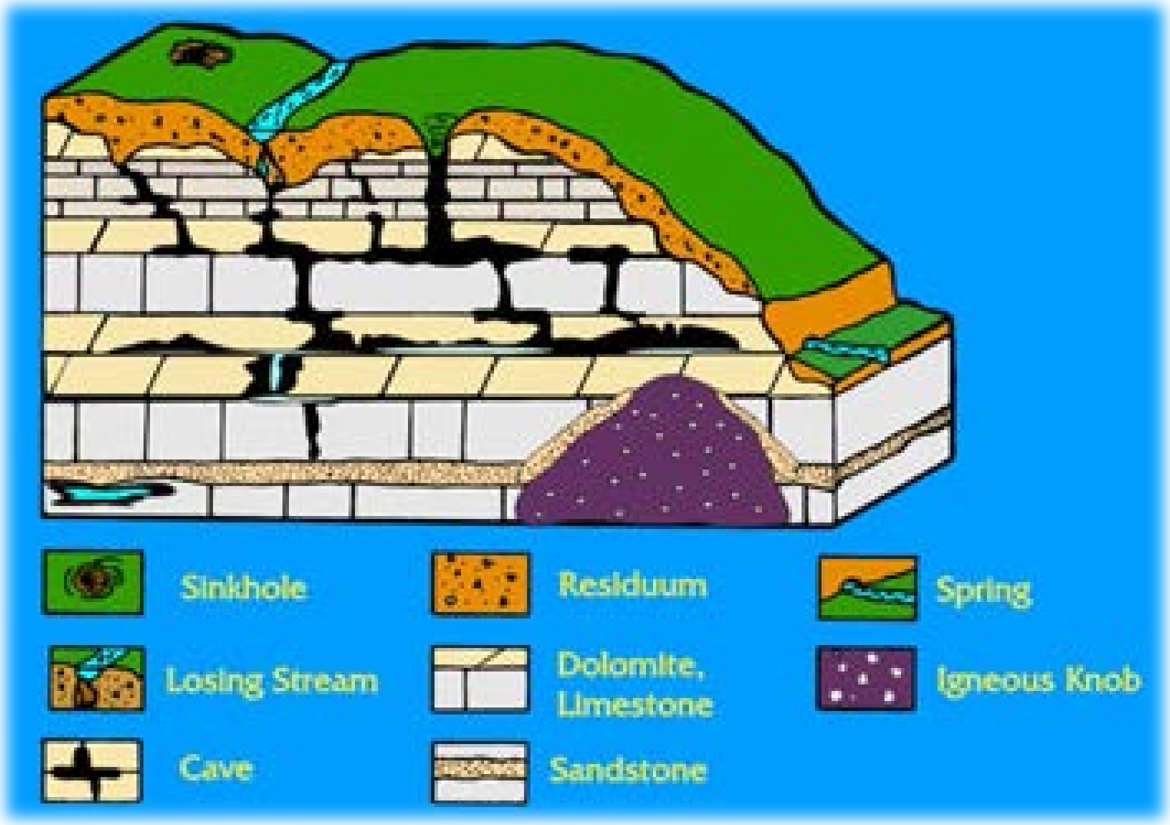

Figure 3-3. Geologic Features

### 3.1.2 Geotechnical Design Parameters

The St. Louis District assigned design parameters to the in-situ soils based on the results of the soil exploration and testing program. The development of the geotechnical design parameters was based upon soil descriptions, standard penetration (N) values, sieve analyses, moisture contents, and Atterberg limits. Since strength testing was not performed, data interpretation heavily relied on correlations published in the shear strength correlations for geotechnical engineering by Duncan et. al. 1989. Both drained and undrained parameters were estimated using averaged Atterberg limits and SPT blow counts across the 12 borings. The undrained shear strength above El. 370 was estimated very conservatively with Atterberg limit correlations. Since SPT correlations to cohesion are known to be highly variable, the correlated cohesion values are approximate and will need to be verified during design with Unconsolidated-Undrained (UU) triaxial testing.

The proposed borrow areas are composed of clays of varying plasticity, and it is anticipated that sufficient cohesive material are present for construction of the proposed embankment. Since no testing was performed on existing embankments constructed of borrow material from within Ste. Gen a minimum conservative cohesion value of 600 psf was chosen.

For cases where the levee fill materials are located above the phreatic surface, theories regarding partially saturated soil mechanics (Fredlund and Rahardjo, 1993) were used to account for a small contribution of the negative pore pressures to the drained shear strength. Slope stability analyses were conducted on hypothetical levee cross sections for levee heights ranging from 5 ft to 8 ft. Based on the analyses, it was determined that using an equivalent c’ of 75 psf would conservatively allow for an increased strength to reflect the presence of negative pore water pressures.

Results from the borings were plotted to develop a graph portraying undrained shear strength and friction angle verse depth. Using these results and the geologic profile, a typical section was developed for this site with soil layers and parameters. Soil strength parameters for the subsurface layers were typically based on a 1/3 percentile of the calculated strength value. Above elevation 370 ft correlations grossly underestimate the shear strength of the soil. Thus SPT shear strength correlations were utilized. This soil was classified as a medium stiff soil based on blow counts. Terzaghi and Peck (1967) stated medium stiff clays can vary in an undrained shear strength from 500 to 1000 psf. 500 was chosen to be conservative and then dropped to 490 psf to match the shear line characteristic of the correlations below. Soil unit weight values were approximated for this study. Saturated clay is typically in the range of 110-120 pcf. 120 pcf was chosen for all analyses because the heavier soil creates higher driving forces and larger soil loads.

Table 3-1– Soil Parameters

| Soil Type | Unit Weight - pcf | Shear Strength- psf | Friction Angle Degree |
|---|---|---|---|
| Clay – Levee Core | 120 | 600 | 0 |
| Clay – Above EL. 370 ft | 120 | 490 | 0 |
| S – Clay Above EL. 370 ft | 120 | 75 | 28 |
| S – Clay Below EL. 370 ft | 120 | 75 | 24 |
| S - Clay Levee | 120 | 75 | 28 |
| Clay - Below EL. 370 ft | 120 | 490-1100 | 0 |
| Gravel/Sand | 125 | 0 | 29 |

## 3.2 GEOTECHNICAL ANALYSES

### 3.2.1 Settlement

A settlement analysis was completed to determine the ultimate settlement for the levee and to account for levee overbuild. Analyses showed a maximum of 11.0 inches of settlement under the embankment. Settlement correlations, shown in Table 3-2, were used to estimate the consolidation parameters such as $C_c$, $C_r$, and $e_o$. Preconsolidation pressures were not available; but by assuming the soil was normally consolidated and incorporating the in-situ stresses of the soil, preconsolidation pressure estimates were developed. Time rate of consolidation was not evaluated for this analysis since ultimate settlement was the value of interest. As presented in Table 3-3, all analyses showed total settlement was less than 12 inches; but based on the approximated and conservative settlement data utilized, the final settlement is anticipated to be no more than 6 inches. When actual design information is obtained and implemented the overbuild for the levee will be adjusted accordingly to more indicative settlement measurements.

Table 3-2 – Settlement Correlations

| Location | Station |
|---|---|
| $C_c = 0.009(LL-10)$ | $C_r = 0.2 \text{ x } (Cc)$ |
| LL = Liquid Limit | $e_o = (w*G_s)/S$ |
| W = moisture content | S = Saturation |
| $G_s$ = Specific Gravity | |

Table 3-3 – Settlement Analysis

| Location | Station | Levee | Settlement (in) |
|---|---|---|---|
| North Gabouri | ~ 40 | North | ~11 |
| North Gabouri | ~ 40 | South | ~2 |

### 3.2.2 Slope Stability

The new levee embankment along the North and South side of the North Gabouri creek was analyzed under drained and undrained conditions. The representative cross section utilized in this area took into account the minimum offset distance from the centerline of the levee to the centerline of the creek as well as the lowest point in the creek and the highest levee elevation. By designing to these conditions the most critical scenario was accounted for in the slope stability analysis. Four different cases were analyzed to try and capture the changing subsurface conditions. The 12 borings taken in 2009 specifically borings SG-10, SG-11, and SG-12 showed that bedrock was highly variable in elevation, gravel and sand layers were intermittent and the majority of the subsurface was comprised of clay. To account for the non-uniform subsurface stability analyses were ran with bedrock at a high elevation, a thick gravel/sand layer at an intermediate depth, a solid clay layer throughout the model, and a drained s-case comprised of all clay that represented the most critical case in long term design. Based on the 2009 borings and visual observations that the creek is normally dry, a water elevation of 370 ft was utilized throughout the model. The calculated factors of safety are shown in Table 3-4 and are acceptable for both short term and long term conditions. The variation in factors of safety suggests that the levee could potentially move closer to the creek in some areas if needed. However for critical areas compromised mostly of clay, the minimum offset distances must be maintained to satisfy slope stability requirements.

Table 3-4– Slope Stability Factors of Safety for the levee design

| Levee Project | Factor of Safety |
|---|---|
| S- Water EL. 370 - (L to R) | 2.16 |
| S- Water EL. 370 - (L to R) | 1.71 |
| Q- Water EL. 370 - Bedrock - (L to R) | 1.96 |
| Q- Water EL. 370 - Bedrock - (L to R) | 1.80 |
| Q- Water EL. 370 - Gravel - (L to R) | 1.86 |
| Q- Water EL. 370 - Gravel - (L to R) | 1.71 |
| Q- Water EL. 370 - (L to R) | 1.44 |
| Q- Water EL. 370 - (R to L) | 1.30 |
| Q- Water EL. 391.5 - (L to R) | 6.31 |
| Q- Water EL. 391.5 - (R to L) | 2.57 |

The new channelization project along the North and South side of the North Gabouri creek was analyzed under drained and undrained conditions. The representative cross section utilized in this area took into account a variety of changing subsurface conditions. By designing to these conditions the most critical scenario was accounted for in the slope stability analysis. Four different cases were analyzed to try and capture the changing subsurface conditions. To account for the non-uniform subsurface, stability analyses were ran with bedrock at a high elevation, a thick gravel/sand layer at an intermediate depth, a solid clay layer throughout the model, and a drained s-case comprised of all clay that represented the most critical case in long term design. The calculated factors of safety are shown in Table 3-5 and are acceptable for both short term and long term conditions.

Table 3-5– Slope Stability Factors of Safety for the Channelization Design

| Channelization Project | Factor of Safety |
|---|---|
| S- Water EL. 370 - (L to R) | 2.06 |
| S- Water EL. 370 - (L to R) | 1.85 |
| Q- Water EL. 370 - Bedrock - (L to R) | 3.02 |
| Q- Water EL. 370 - Bedrock - (L to R) | 1.97 |
| Q- Water EL. 370 - Gravel - (L to R) | 2.13 |
| Q- Water EL. 370 - Gravel - (L to R) | 1.72 |
| Q- Water EL. 370 - (L to R) | 2.10 |
| Q- Water EL. 370 - (R to L) | 1.43 |

Figure 3-4. Existing Levee along the North Side of the North Gabouri Creek

Figure 3-5. Existing Levee along the South Side of the North Gabouri Creek

Figure 3-6. Creek bed along North Gabouri Creek around Sta. 37+00

Figure 3-7. Creek bed along North Gabouri Creek around Sta. 50+00

### 3.2.3 Geotechnical Considerations

There are a few Geotechnical considerations and assumptions that will need to be verified as the design is refined.

A rapid drawdown condition when the creek rises and falls quickly should be analyzed. Due to the possibility of a flash flood, a rapid drawdown case with a target Factor of Safety of 1 should be met. This type of analysis was not performed for this feasibility study. Sophisticated triaxial testing analyzing both drained and undrained conditions in the levee footprint and borrow areas will need to be conducted during design to properly account for this failure mode.

#### 3.2.3.1 Detention Basin Considerations

There are documented karst features in the vicinity of the two proposed detention basins (Figure 3-8 and Figure 3-9) along North and South Gabouri creeks as shown in Figure 3-10. The presence of existing karst features within the footprint of the proposed basins provides a potential for substandard performance of the proposed basins. Examples of substandard performance may be; uncontrolled seepage of detained waters through karst features within the impoundment area, and/or scour of embankment material into and/or through karst features. Both of these examples may lead to an uncontrolled release of potentially all impounded water with potentially damaging and life threatening impacts downstream of the proposed detention basins.

Water impounded by the proposed basins has the potential to accelerate the formation/growth of karst features. Existing karst features with infilling may experience scour of infilling soils from karst features resulting in increased water flow through features at these locations. The inundation created by the proposed basins would increase the flow of water to the bedrock for durations longer than under natural conditions. Karst features, as described above, are a result of acidic water dissolving soluble bedrock and creating voids typically along preexisting planar features such as bedding planes, joints, and faults.

There are both historic and active mining operations within the study area. The active mining is mainly for production of various lime products derived from the nearly pure $CaCO_3$ of the Salem Limestone formation. This mining may impact the project alternatives, specifically the proposed detention basins. Mississippi Lime Company currently operates a limestone mine in the immediate vicinity of the proposed south detention basin. This mine cavity is below the surface and the physical boundaries of the mine are not known by MVS EC-G. The presence of the mine may impact the ability to construct the south detention basin and/or the basin's ability to hold water. The mine may be affected by the construction of the proposed basin and/or any water that would potentially leak into or flood the mine.

A site specific study would be required to evaluate the constructability and feasibility of these basins and their ability to perform as designed. However, based on the above mentioned consideration it is not anticipated that a large upland detention basin would perform satisfactory and is not recommended for further consideration.

Figure 3-8. South Detention Basin

Figure 3-9. North Detention Basin

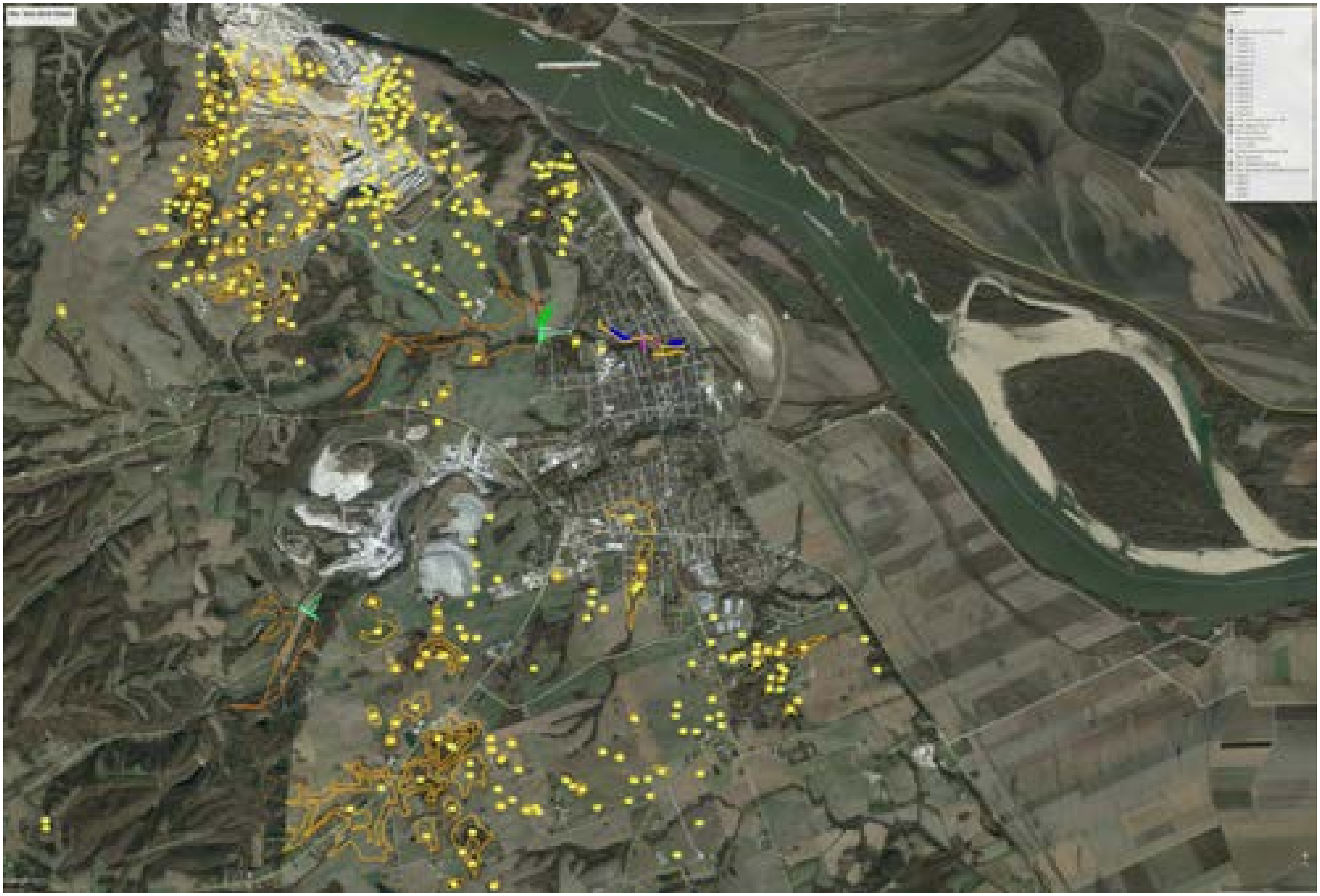

Figure 3-10. Location of known Sink holes

Appendix I

# Feasibility Drawings

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# STE GENEVIEVE, MISSOURI

## FLOOD CONTROL PROJECT

## PARTS 2 AND 3

## NORTH AND SOUTH GABOURI

INDEX OF DRAWINGS

| ALTERNATIVE | SHT | TITLE |
|---|---|---|
| | | GENERAL |
| | G-001 | COVER AND INDEX |
| | G-002 | OVERALL PLAN |
| | | |
| | | NORTH GABOURI |
| | NG-100 | EXISTING CONDITIONS |
| L2-CH2-FP | NG-200 | PLAN |
| | NG-201 | TYPICAL SECTIONS |
| CH-BR-FP | NG-300 | PLAN |
| | NG-301 | TYPICAL SECTIONS |
| FP | NG-400 | PLAN |
| | | |
| | | SOUTH GABOURI |
| | SG-100 | EXISTING CONDITIONS |
| GL-FP | SG-200 | PLAN |
| CH-BR-FP | SG-300 | PLAN |
| FP-BO | SG-400 | PLAN |
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GENERAL
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G-001

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GENERAL
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G-002

## PLAN

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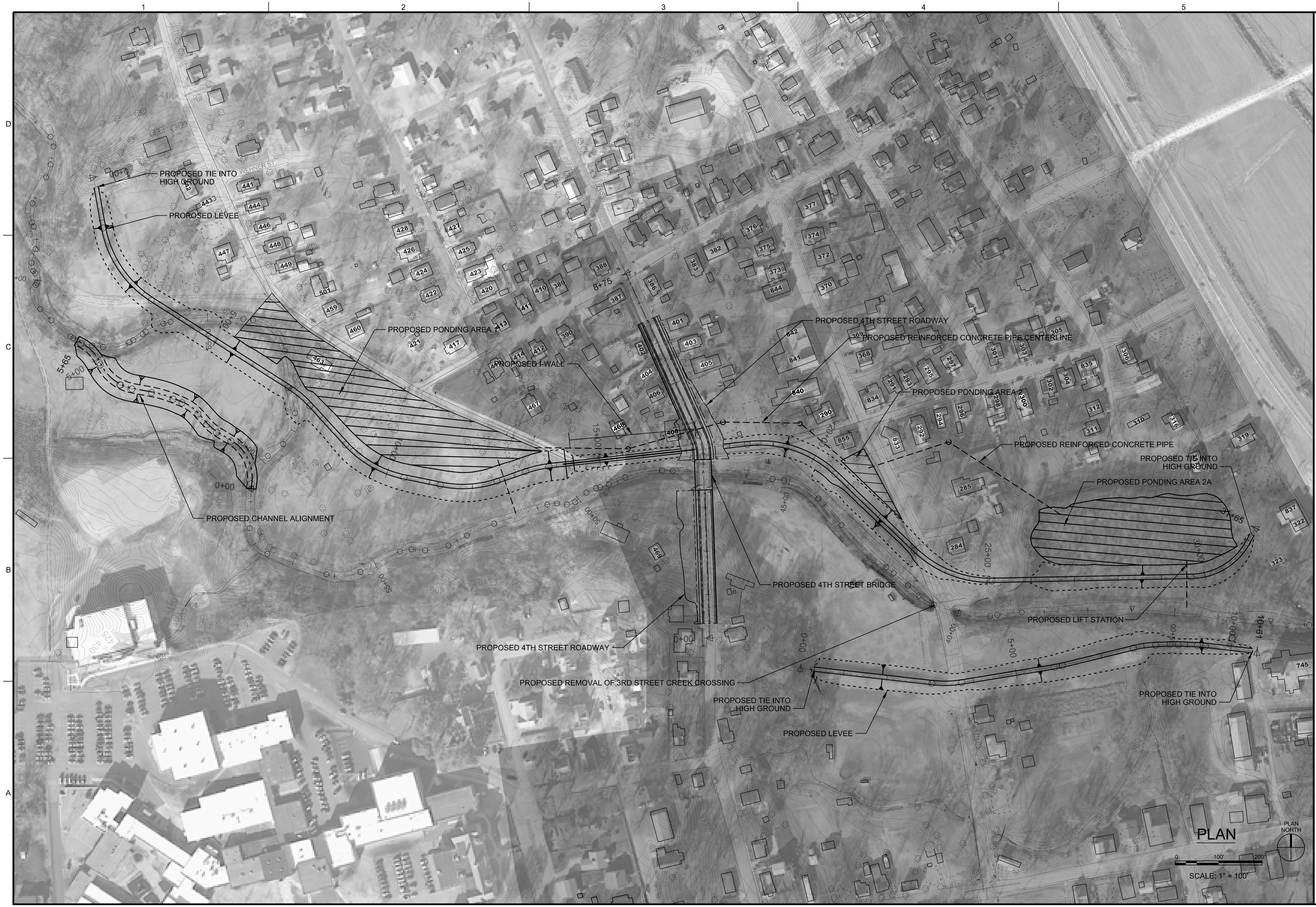

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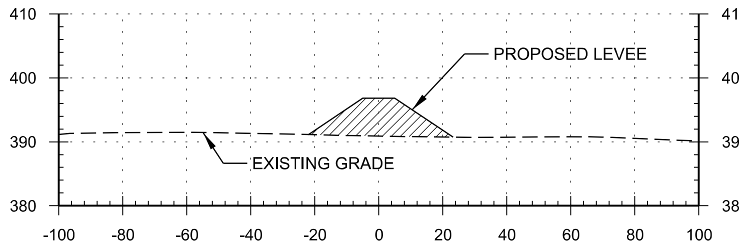

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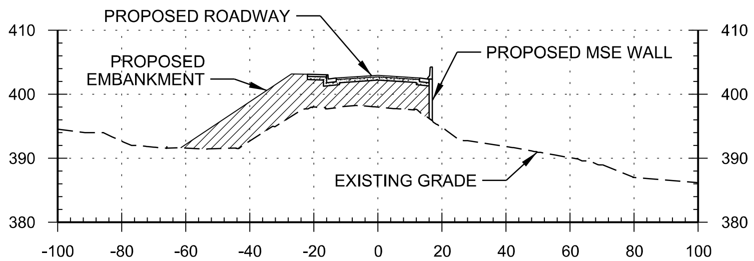

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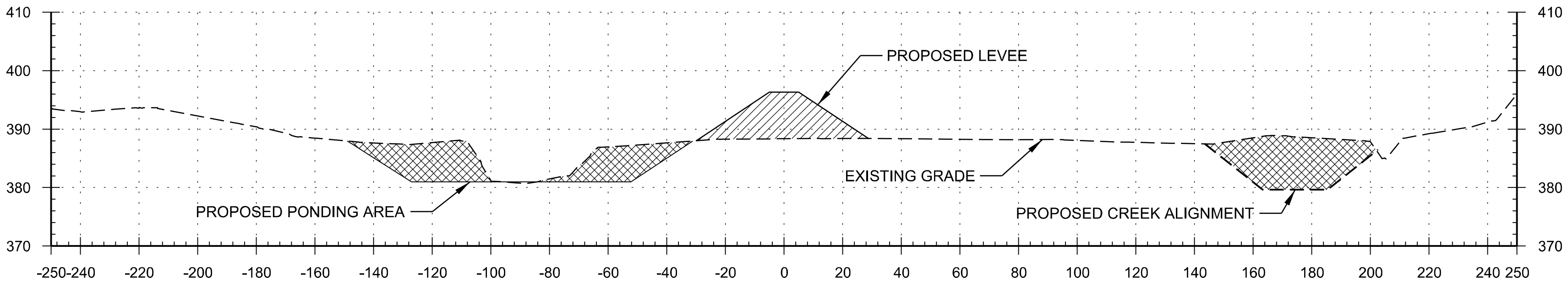

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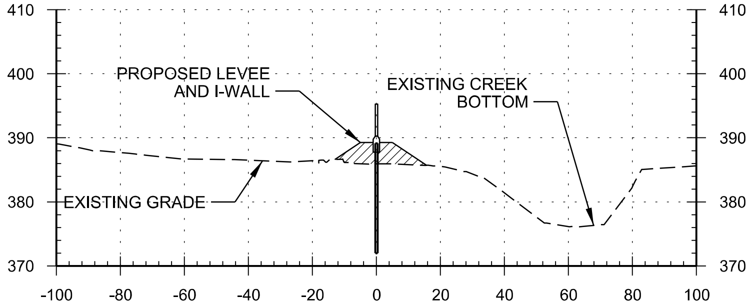

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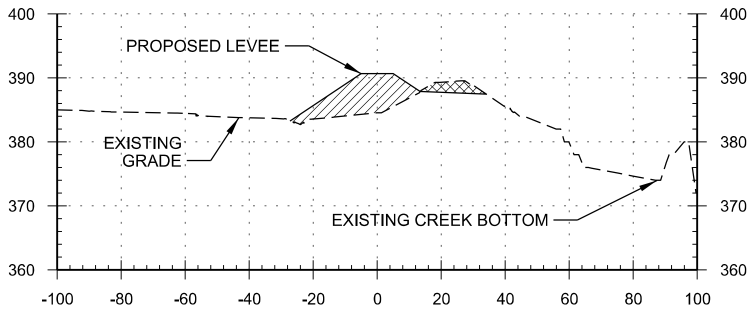

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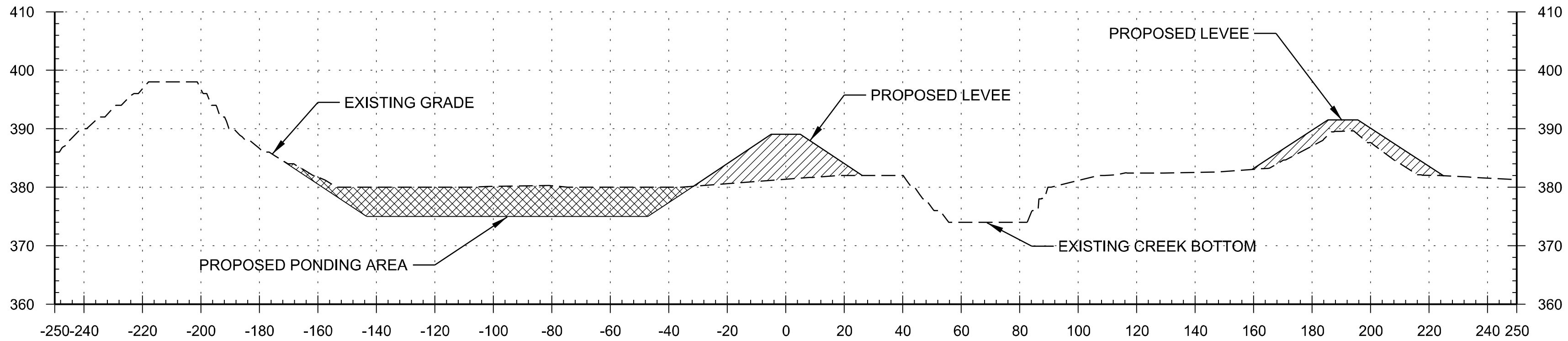

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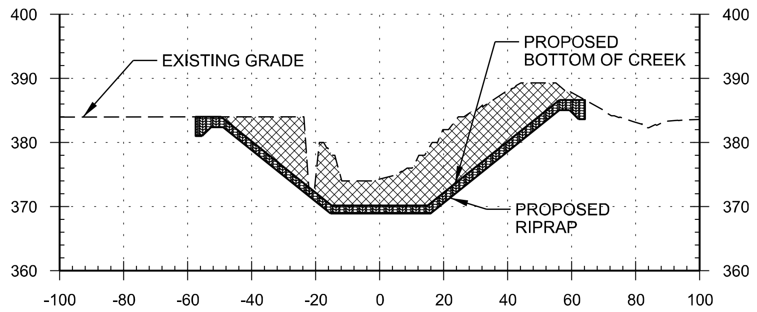

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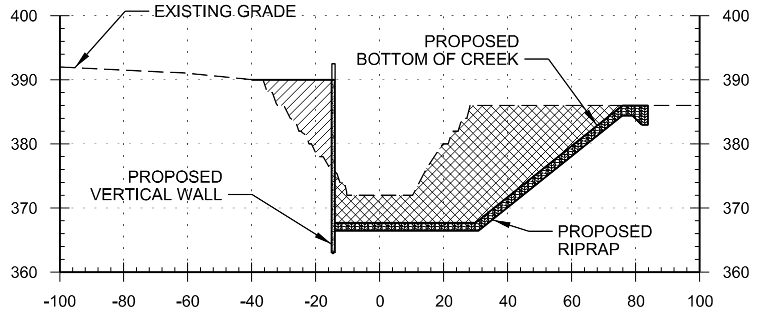

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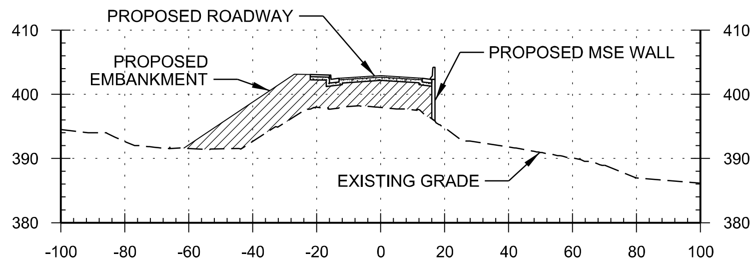

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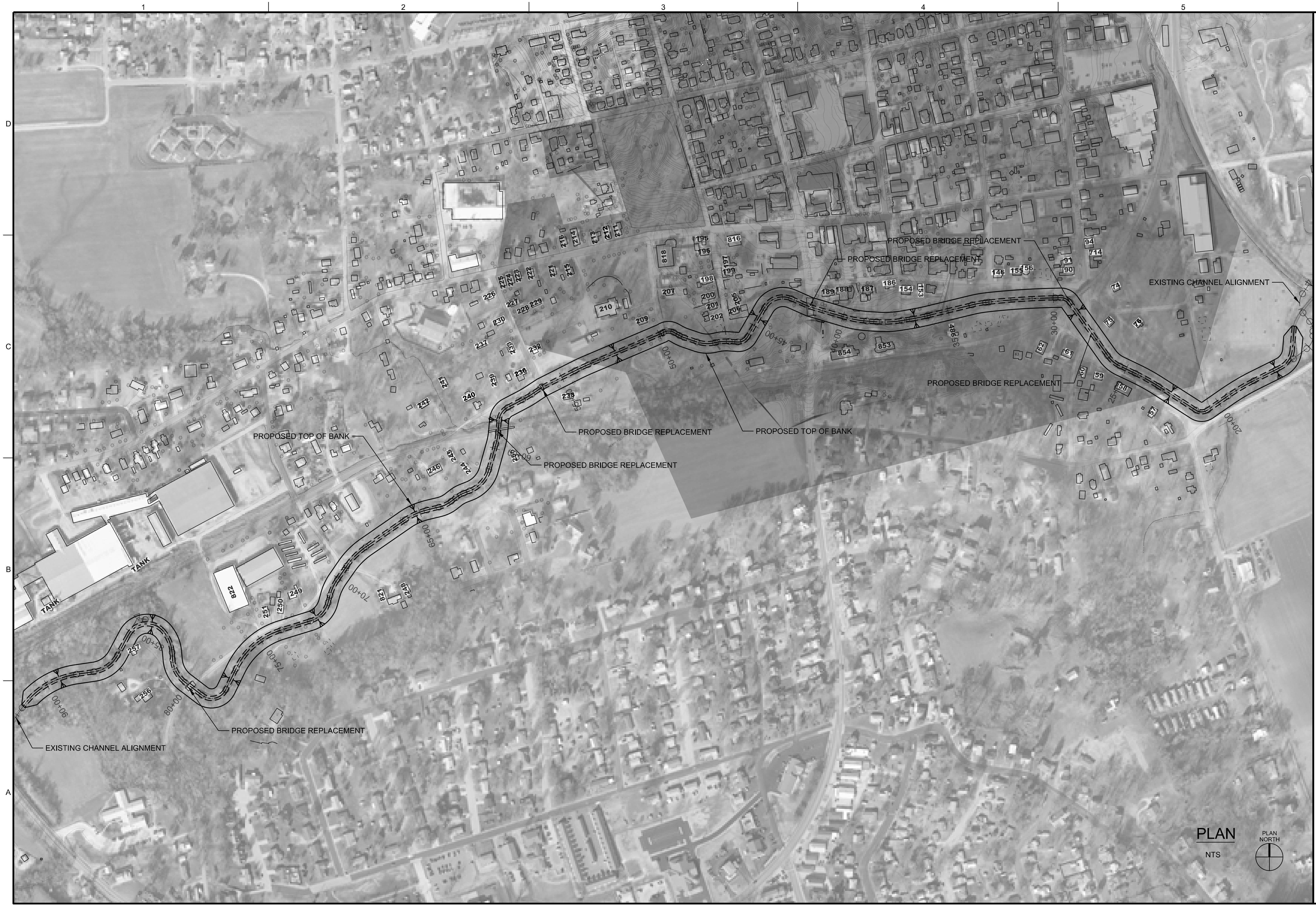

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Appendix II

# Geotechnical Analyses

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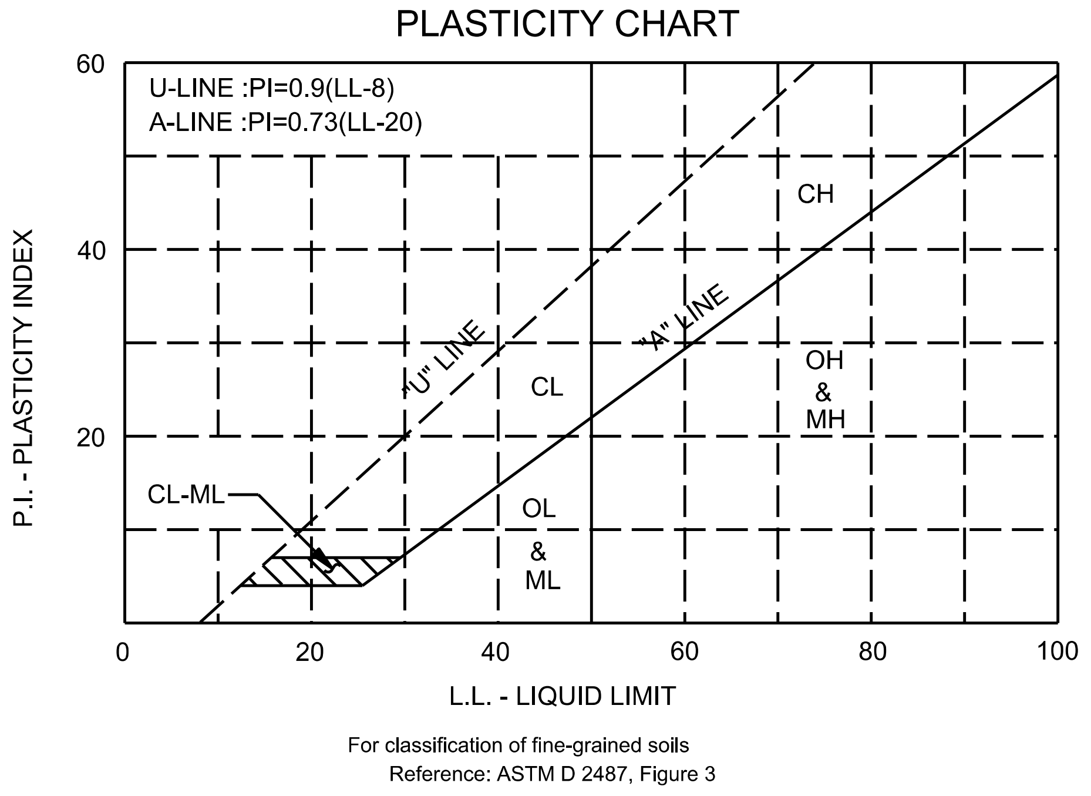
# UNIFIED SOIL CLASSIFICATION ASTM D 2487

| MAJOR DIVISION | | TYPE | LETTER SYMBOL | SYM BOL | TYPICAL NAMES |
|---|---|---|---|---|---|
| COARSE-GRAINED SOILS More than half of material is larger than No. 200 sieve size | GRAVELS More than half of coarse fraction is larger than No. 4 sieve size | CLEAN GRAVEL (Little or No fines) | GW | ▨ | GRAVEL, Well Graded, gravel-sand mixtures, little or no fines |
| | | | GP | ▨ | GRAVEL, Poorly Graded, gravel-sand mixtures, little or no fines |
| | | GRAVEL WITH FINES (Appreciable Amount of Fines) | GM | ▨ | SILTY GRAVEL, gravel-sand-silt mixtures |
| | | | GC | ▨ | CLAYEY GRAVEL, gravel-sand-clay mixtures |
| | SANDS More than half of coarse fraction is smaller than No. 4 sieve size | CLEAN SAND (Little or No fines) | SW | ▨ | SAND, Well-Graded, gravelly sands |
| | | | SP | ▨ | SAND, Poorly-graded, gravelly sands |
| | | SAND WITH FINES (Appreciable Amount of Fines) | SM | ▨ | SILTY SAND, sand-silt mixtures |
| | | | SC | ▨ | CLAYEY SAND, sand-clay mixtures |
| FINE-GRAINED SOILS More than half the material is smaller than No. 200 sieve size | | SILT AND CLAYS (Liquid Limit < 50) | ML | ▨ | SILT & very fine sand, silty or clayey fine sand or clayey silt with slight plasticity |
| | | | CL | ▨ | LEAN CLAY; Sandy Clay; Silty Clay; of low to medium plasticity |
| | | | OL | ▨ | ORGANIC SILTS and organic silty clays of low plasticity |
| | | SILT AND CLAYS (Liquid Limit > 50) | MH | ▨ | SILT, fine sandy or silty soil with high plasticity |
| | | | CH | ▨ | FAT CLAY, inorganic clay of high plasticity |
| | | | OH | ▨ | ORGANIC CLAYS of medium to high plasticity, organic silts |
| HIGHLY ORGANIC SOILS | | | Pt | ▨ | PEAT, and other highly organic soil |
| WOOD | | | Wd | ▨ | WOOD |
| SHELLS | | | Sl | ▨ | SHELLS |

NOTE: Soil possessing characteristics of two groups are designated by combinations of group symbols

## CLASSIFICATION AND DESCRIPTION OF ROCK AND GLACIAL TILL

| GROUP | LETTER SYMBOL | SYM BOL | ROCK CLASSIFICATION |
|---|---|---|---|
| SEDIMENTARY ROCKS | CON | ▨ | CONGLOMERATE |
| | SAN | ▨ | SANDSTONE |
| | GRA | ▨ | GRAYWACKE |
| | CLA | ▨ | CLAYSTONE OR SILTSTONE |
| | SHA | ▨ | COMPACTION SHALE |
| | CEM | ▨ | CEMENTED SHALE |
| | COA | ■ | COAL |
| | LIM | ▨ | LIMESTONE |
| | DOL | ▨ | DOLOMITE |
| | CHA | ▨ | CHALK (OR MARL) |
| | CT | ▨ | CHERT |
| | CA | | CAVITY |
| | GRN | ▨ | GRANITE |
| GLACIAL TILL | : MAY INCLUDE CH, CL, CL-ML, ML, SC, SM, SM-SP, AND SP. | | |


PLASTICITY CHART

For classification of fine-grained soils
Reference: ASTM D 2487, Figure 3

## BORING SUFFIX

| LETTER SYMBOL | DESCRIPTION |
|---|---|
| A | Angle Core Boring |
| B | Bag Samples-Soil-Borings |
| C | Core Boring |
| O | Observation Boring |
| P | Piezometer |
| U | Undistrubed Sample-Soil-Boring |
| | |

## FIGURES TO LEFT OF BORING UNDER COLUMN "W OR $D_{10}$"

Are natural water content in percent dry weight (FW denotes Free Water) ASTM D 2216

When underlined denotes $D_{10}$ size in mm - ASTM C 136 *

## FIGURES TO RIGHT OF BORING UNDER COLUMNS "LL" AND "PL"

Are liquid and plastic limits, respectively - ASTM D 4318

## SYMBOLS TO LEFT OF BORING

▽ Groundwater surface and date observed

Ⓒ Denotes location of consolidation test **

Ⓢ Denotes location of consolidation-drained direct shear test **

Ⓡ Denotes location of consolidation-undrained triaxial compression test **

Ⓠ Denotes location of unconsolidation-undrained triaxial compression test **

Ⓣ Denotes location of sample subjected to consolidation test and each of the above three types of shear tests **

↕ 5-50 Pressure Test Results
Shown as 5 gals/min at 50 psi

○— Denotes proposed channel grade

* The $D_{10}$ size of a soil is the grain diameter in millimeters of which 10% of the soil is finer, and 90% coarser than size $D_{10}$ - ASTM C 136.

** Results of these tests are available for inspection in the U.S. Army Engineer District Office, if these symbols appear beside the boring logs on the drawings.

## FIGURES TO RIGHT OF BORING

Are values of cohesion in lbs./sq. ft. from unconfined compression tests

In parenthesis and not underlined are driving resistance in blows per foot determined with a standard split spoon sampler (1⅜" I.D., 2 " O.D.) and a 140 lb. driving hammer with a 30 " drop - ASTM D 1586. In parenthesis and underlined are for a 2 ½" I.D., 3 " O.D. split spoon sampler and 350 lb. driving hammer with an 18 " drop.

Where underlined with a solid line denotes laboratory permeability in centimeters per second of undisturbed sample.

Where underlined with a dashed line denotes laboratory permeability in centimeters per second of sample remolded to the estimated natural void ratio.

## SYMBOLS TO RIGHT OF BORING

Ⓐ Denotes classification determined by process of drilling, no representative sample obtained.

# DESCRIPTIVE SYMBOLS

## MODIFICATIONS

| MODIFICATION | SYMBOL |
|---|---|
| Traces | Tr- |
| Fine | F |
| Very Fine | vF |
| Medium | M |
| Coarse | C |
| Calc. Concretions | cc |
| Rootlets | rt |
| Lignite fragments | lg |
| Shale fragments | shs |
| Sandstone fragments | sds |
| Shell fragments | slf |
| Organic matter | O |
| Clay strata or lenses | CS |
| Silt strata or lenses | SIS |
| Sand strata or lenses | SS |
| Sandy | S |
| Gravelly | G |
| Boulders | B |
| Slickensides | SL |
| Wood | Wd |
| Oxidized | Ox |
| Decomposed Limonite Concretions | DLC |
| Began use of drilling mud | B.D.M. |
| Began use of casing | B.Ca. |
| Beginning of Specified Core Size | NX Core |
| Ground Surface Elev. | G.S.E. |
| Water Surface Elev. | W.S.E. |

## COLORS

| COLOR | SYMBOL |
|---|---|
| TAN | T |
| YELLOW | Y |
| RED | R |
| BLACK | BK |
| GRAY | Gr |
| LIGHT GRAY | lGr |
| DARK GRAY | dGr |
| BROWN | Br |
| LIGHT BROWN | lBr |
| DARK BROWN | dBr |
| BROWNISH-GRAY | BRG |
| GRAYISH-BROWN | GYB |
| GREENISH-GRAY | GNG |
| GRAYISH-GREEN | Gyg |
| GREEN | Gn |
| BLUE | Bl |
| BLUE-GREEN | BLG |
| WHITE | Wh |
| MOTTLED | Mot |
| REDDISH | RD |

## CONSISTENCY FOR COHESIVE SOILS

| CONSISTENCY | COHESION IN LBS./SQ.FT. FROM UNCONFINED COMPRESSION TEST | SYMBOL |
|---|---|---|
| VERY SOFT | < 250 | vSo |
| SOFT | 250-500 | So |
| MEDIUM | 500-1000 | M |
| STIFF | 1000-2000 | St |
| VERY STIFF | 2000-4000 | vSt |
| HARD | > 4000 | H |

## GENERAL NOTES :

WHILE THE BORINGS ARE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT THEIR RESPECTIVE LOCATIONS AND FOR THEIR RESPECTIVE VERTICAL REACHES, LOCAL VARIATIONS CHARACTERISTIC OF THE SUBSURFACE MATERIALS OF THE REGION ARE ANTICIPATED AND, IF ENCOUNTERED, SUCH VARIATIONS WILL NOT BE CONSIDERED AS DIFFERING MATERIALLY WITHIN THE PURVIEW OF THE CONTRACT CLAUSE ENTITLED "DIFFERING SITE CONDITIONS."

GROUNDWATER ELEVATIONS SHOWN ON THE BORING LOGS REPRESENT GROUNDWATER SURFACE ENCOUNTERED IN SUCH BORINGS ON THE DATE SHOWN. ABSENCE OF WATER SURFACE DATA ON CERTAIN BORINGS INDICATES THAT NO GROUNDWATER DATA ARE AVAILABLE FROM THE BORING BUT DOES NOT NECESSARILY MEAN THAT GROUNDWATER WILL NOT BE ENCOUNTERED AT THE LOCATIONS OR WITHIN THE VERTICAL REACHES OF SUCH BORINGS. GROUNDWATER ELEVATION CAN VARY FROM THAT SHOWN ON THE LOGS WITH SEASONAL WEATHER CHANGES AND DEPENDING ON THE LENGTH OF TIME THE BORE HOLE IS LEFT OPEN.

CONSISTENCY OF COHESIVE SOIL SHOWN ON THE BORING LOGS IS BASED ON DRILLER'S LOG AND VISUAL EXAMINATION AND IS APPROXIMATE, EXCEPT WITHIN THOSE VERTICAL REACHES OF THE BORING WHERE SHEAR STRENGTHS FROM UNCONFINED COMPRESSION TESTS ARE SHOWN.

### APPLICABLE PUBLICATIONS

American Society for Testing and Materials (ASTM) Standards
ASTM C 136 Method for Sieve Analysis of Fine and Coarse Aggregates.
ASTM D 1586 Method for Penetration Test and Split-Barrel Sampling of Soils.
ASTM D 2166 Test Methods for Unconfined Compressive Strength of Cohesive Soil.
ASTM D 2216 Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures.
ASTM D 2487 Classification of Soils for Engineering Purposes.
ASTM D 2488 Description and Indentification of Soils (Visual-Manual Procedure).
ASTM D 4318 Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.

### U.S. Army Engineer Manual (EM)

EM 1110-2-1906
Engineering and Design, Laboratory
Soils Testing, 30 November 1970
Revised 20 August 1986

### DRILLING AND SAMPLING EQUIPMENT

AUG-AUGER
BKH-BACKHOE
CPT-CONE PENETROMETER
HDA-HAND AUGER
HSA-HOLLOW STEM AUGER
HSP-HAND SAMPLE PROBE
RB- ROLLER BIT
SSS-STANDARD SPLIT SPOON
VST-VACCUM SHELBY TUBE (5")
WB- WING BIT

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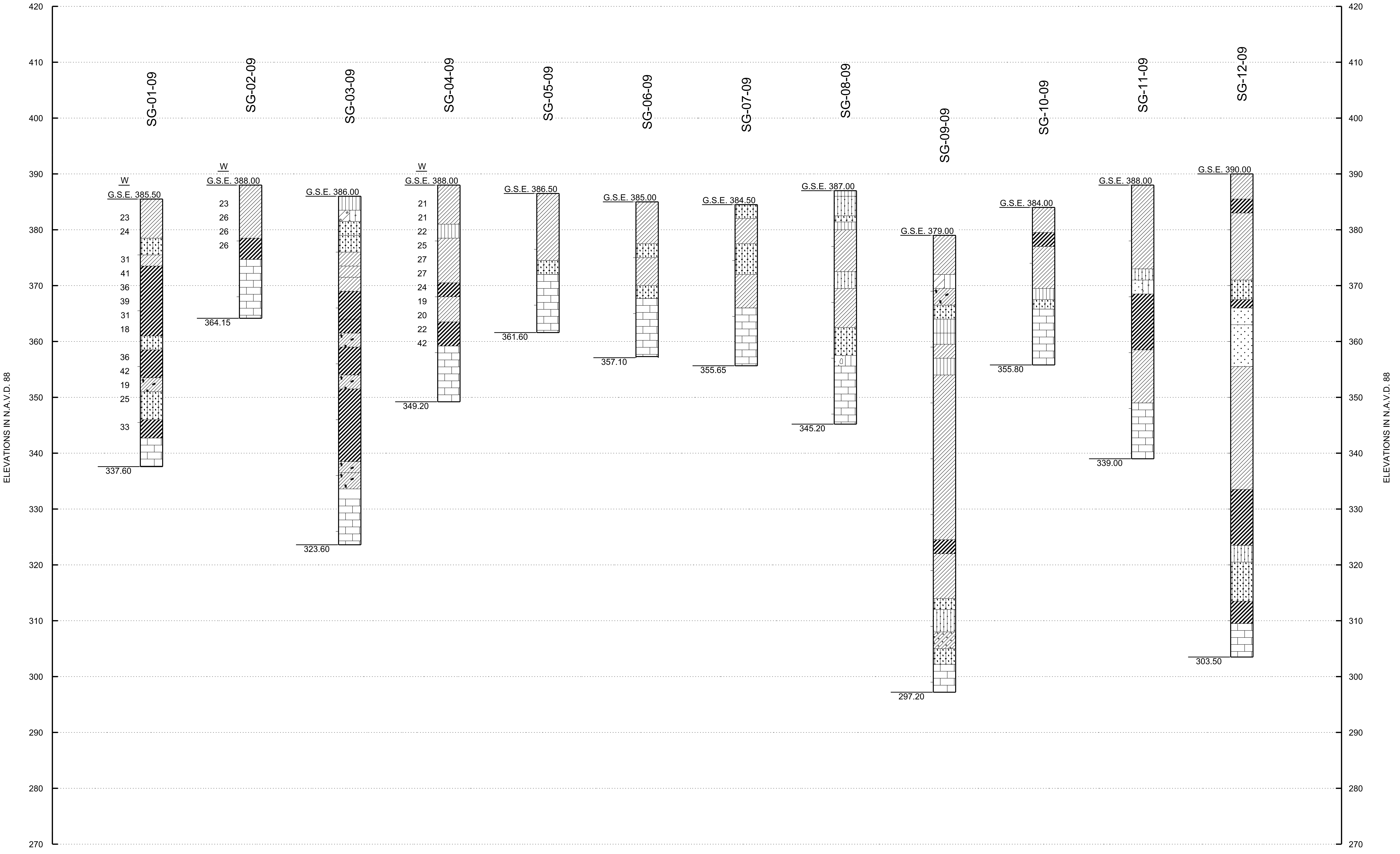
GEOTECHNICAL
SOIL AND ROCK LEGEND

SHEET IDENTIFICATION
B-001



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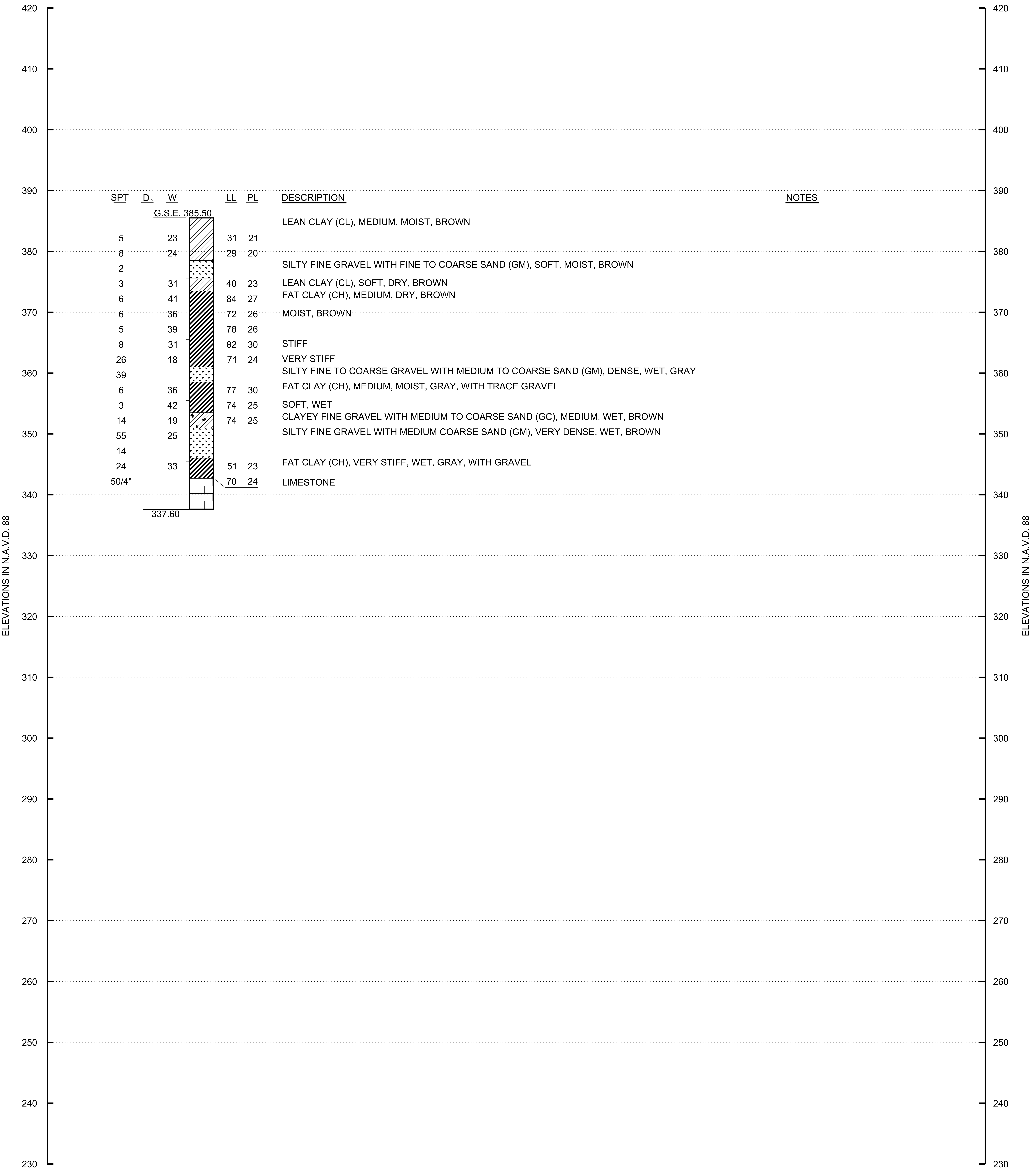
GEOTECHNICAL
BORING LOGS

SHEET
IDENTIFICATION
B-200

## SG-01-09

N 784039.3 E 948863.57
14 MAY 09
37°59'9.708" 90°3'12.924"



| SPT | $D_{10}$ | W | LL | PL | DESCRIPTION | NOTES |
|---|---|---|---|---|---|---|
|  | G.S.E. 385.50 |  |  |  | LEAN CLAY (CL), MEDIUM, MOIST, BROWN |  |
| 5 |  | 23 | 31 | 21 |  |  |
| 8 |  | 24 | 29 | 20 |  |  |
| 2 |  |  |  |  | SILTY FINE GRAVEL WITH FINE TO COARSE SAND (GM), SOFT, MOIST, BROWN |  |
| 3 |  | 31 | 40 | 23 | LEAN CLAY (CL), SOFT, DRY, BROWN |  |
| 6 |  | 41 | 84 | 27 | FAT CLAY (CH), MEDIUM, DRY, BROWN |  |
| 6 |  | 36 | 72 | 26 | MOIST, BROWN |  |
| 5 |  | 39 | 78 | 26 |  |  |
| 8 |  | 31 | 82 | 30 | STIFF |  |
| 26 |  | 18 | 71 | 24 | VERY STIFF |  |
| 39 |  |  |  |  | SILTY FINE TO COARSE GRAVEL WITH MEDIUM TO COARSE SAND (GM), DENSE, WET, GRAY |  |
| 6 |  | 36 | 77 | 30 | FAT CLAY (CH), MEDIUM, MOIST, GRAY, WITH TRACE GRAVEL |  |
| 3 |  | 42 | 74 | 25 | SOFT, WET |  |
| 14 |  | 19 | 74 | 25 | CLAYEY FINE GRAVEL WITH MEDIUM TO COARSE SAND (GC), MEDIUM, WET, BROWN |  |
| 55 |  | 25 |  |  | SILTY FINE GRAVEL WITH MEDIUM COARSE SAND (GM), VERY DENSE, WET, BROWN |  |
| 14 |  |  |  |  |  |  |
| 24 |  | 33 | 51 | 23 | FAT CLAY (CH), VERY STIFF, WET, GRAY, WITH GRAVEL |  |
| 50/4" |  |  | 70 | 24 | LIMESTONE |  |
|  | 337.60 |  |  |  |  |  |

SHEET IDENTIFICATION
B-201

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SG-01-09

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## SG-02-09

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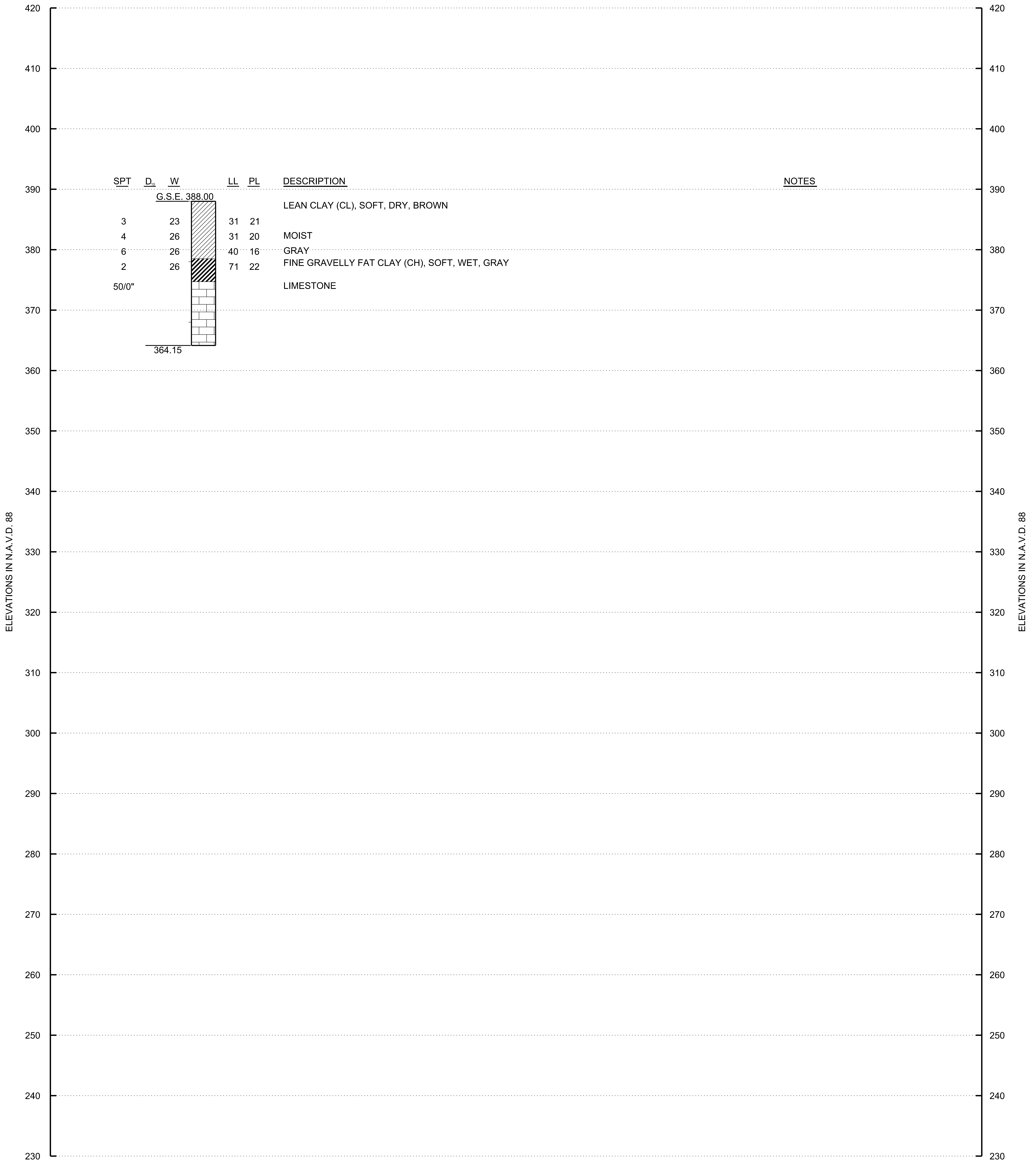

| SPT | D. | W | LL | PL | DESCRIPTION | NOTES |
|---|---|---|---|---|---|---|
| | | | | | LEAN CLAY (CL), SOFT, DRY, BROWN | |
| 3 | | 23 | 31 | 21 | | |
| 4 | | 26 | 31 | 20 | MOIST | |
| 6 | | 26 | 40 | 16 | GRAY | |
| 2 | | 26 | 71 | 22 | FINE GRAVELLY FAT CLAY (CH), SOFT, WET, GRAY | |
| 50/0" | | | | | LIMESTONE | |

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B-202

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## SG-03-09

N 783844.44 E 949233.42
4 JUNE 09
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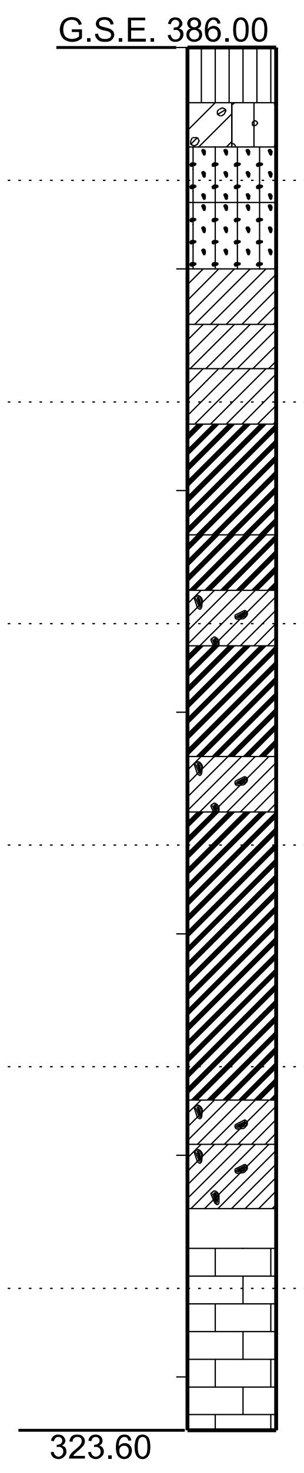
ELEVATIONS IN N.A.V.D. 88



| SPT | D$_{10}$ | W | LL | PL | DESCRIPTION | NOTES |
|---|---|---|---|---|---|---|
| | | | | | CLAYEY SILT (ML), DRY, BROWN WITH TRACE ORGANICS AND FILL | |
| 60 | | | 28 | 22 | SILTY CLAYEY FINE TO COARSE SAND WITH FINE GRAVEL (SC-SM), VERY DENSE, DRY, BROWN | |
| 13 | | | | | SILTY FINE TO COARSE GRAVEL WITH FINE TO COARSE SAND (GM), MEDIUM DENSE, DRY, BROWN | |
| 11 | | | | | SILTY FINE TO COARSE GRAVEL WITH MEDIUM TO COARSE SAND (GM), MEDIUM DENSE, DRY, BROWN | |
| | | | 39 | 23 | FINE SANDY LEAN CLAY (CL), VERY SOFT, WET, GRAY | WEIGHT OF HAMMER |
| 2 | | | 38 | 22 | LEAN CLAY (CL), SOFT, WET, GRAY, TRACE SAND | |
| 3 | | | 42 | 24 | FINE TO MEDIUM SANDY LEAN CLAY W/ FINE GRAVEL (CL), SOFT, WET, GRAY | WEIGHT OF HAMMER |
| 7 | | | 70 | 26 | FAT CLAY (CH), MEDIUM, WET, GRAY | |
| 5 | | | 80 | 27 | | |
| 9 | | | 77 | 24 | FINE GRAVELLY FAT CLAY (CH), STIFF, WET, GRAY | |
| 20 | | | 73 | 21 | CLAYEY FINE GRAVEL (GC), VERY STILL, WET, GRAY | |
| 5 | | | 67 | 25 | FAT CLAY (CH), MEDIUM, WET, GRAY | |
| 8 | | | 63 | 24 | | |
| 14 | | | 63 | 21 | CLAYEY FINE TO MEDIUM GRAVEL (GC), STIFF, WET, GRAY | |
| 8 | | | 59 | 24 | FAT CLAY (CH), MEDIUM, WET, GRAY | |
| 13 | | | 55 | 20 | | |
| 16 | | | 55 | 20 | | |
| 12 | | | 55 | 21 | | |
| 10 | | | 54 | 20 | | |
| 14 | | | 61 | 21 | CLAYEY FINE GRAVEL (GC), STIFF, WET, GRAY | |
| 26 | | | 68 | 20 | CLAYEY FINE GRAVEL W/ FINE TO COARSE SAND (GC), VERY STIFF, WET, GRAY | |
| | | | | | LIMESTONE | |

SHEET IDENTIFICATION
B-203

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## SG-04-09

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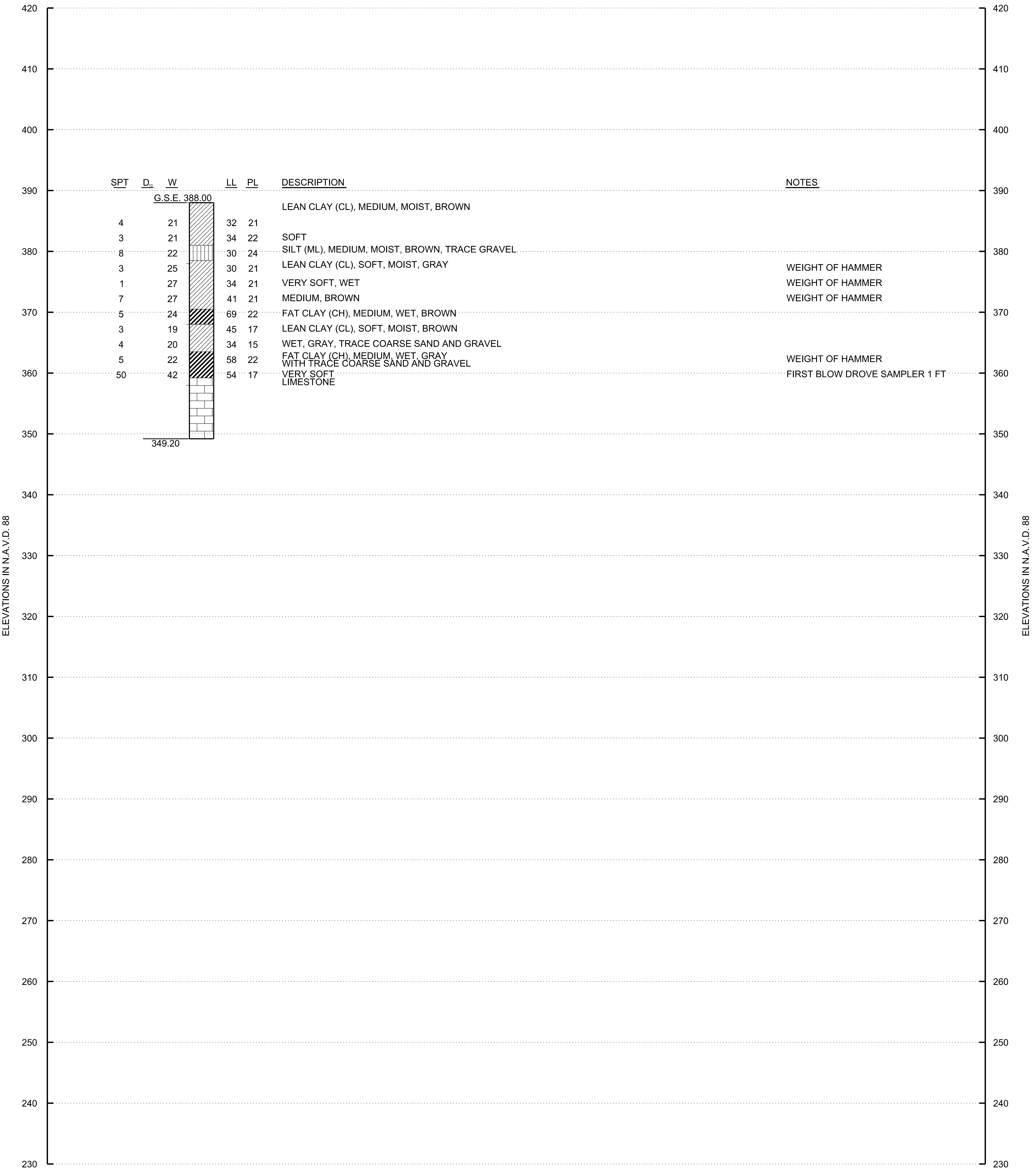
15 MAY 09
37°59'4.848" 90°3'6.048"



| SPT | $D_{10}$ | W | LL | PL | DESCRIPTION | NOTES |
|---|---|---|---|---|---|---|
| | | | | | LEAN CLAY (CL), MEDIUM, MOIST, BROWN | |
| 4 | | 21 | 32 | 21 | | |
| 3 | | 21 | 34 | 22 | SOFT | |
| 8 | | 22 | 30 | 24 | SILT (ML), MEDIUM, MOIST, BROWN, TRACE GRAVEL | |
| 3 | | 25 | 30 | 21 | LEAN CLAY (CL), SOFT, MOIST, GRAY | WEIGHT OF HAMMER |
| 1 | | 27 | 34 | 21 | VERY SOFT, WET | WEIGHT OF HAMMER |
| 7 | | 27 | 41 | 21 | MEDIUM, BROWN | WEIGHT OF HAMMER |
| 5 | | 24 | 69 | 22 | FAT CLAY (CH), MEDIUM, WET, BROWN | |
| 3 | | 19 | 45 | 17 | LEAN CLAY (CL), SOFT, MOIST, BROWN | |
| 4 | | 20 | 34 | 15 | WET, GRAY, TRACE COARSE SAND AND GRAVEL | |
| 5 | | 22 | 58 | 22 | FAT CLAY (CH), MEDIUM, WET, GRAY<br>WITH TRACE COARSE SAND AND GRAVEL | WEIGHT OF HAMMER |
| 50 | | 42 | 54 | 17 | VERY SOFT<br>LIMESTONE | FIRST BLOW DROVE SAMPLER 1 FT |

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N 783420.02 E 949572.67
18 MAY 09
37°59'3.552" 90°3'4.104"

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| SPT | $D_{10}$ | W | LL | PL | DESCRIPTION | NOTES |
|---|---|---|---|---|---|---|
|  |  |  |  |  | LEAN CLAY (CL), SOFT, DRY, BROWN |  |
| 4 |  |  | 31 | 21 | MOIST, TRACE ORGANICS |  |
| 5 |  |  | 31 | 18 | MEDIUM, MOIST, TRACE ORGANICS, TRACE COARSE SAND AND GRAVEL | WEIGHT OF HAMMER |
| 5 |  |  | 35 | 20 | WET, TRACE COARSE SAND AND GRAVEL |  |
| 4 |  |  | 31 | 19 | SOFT, WET, GRAY |  |
| 18 |  |  |  |  | SILTY FINE TO COARSE GRAVEL WITH MEDIUM TO COARSE SAND (GM), VERY STIFF, WET, BROWN |  |
|  |  |  |  |  | LIMESTONE |  |

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SG-05-09

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B-205

## SG-06-09

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19 MAY 09
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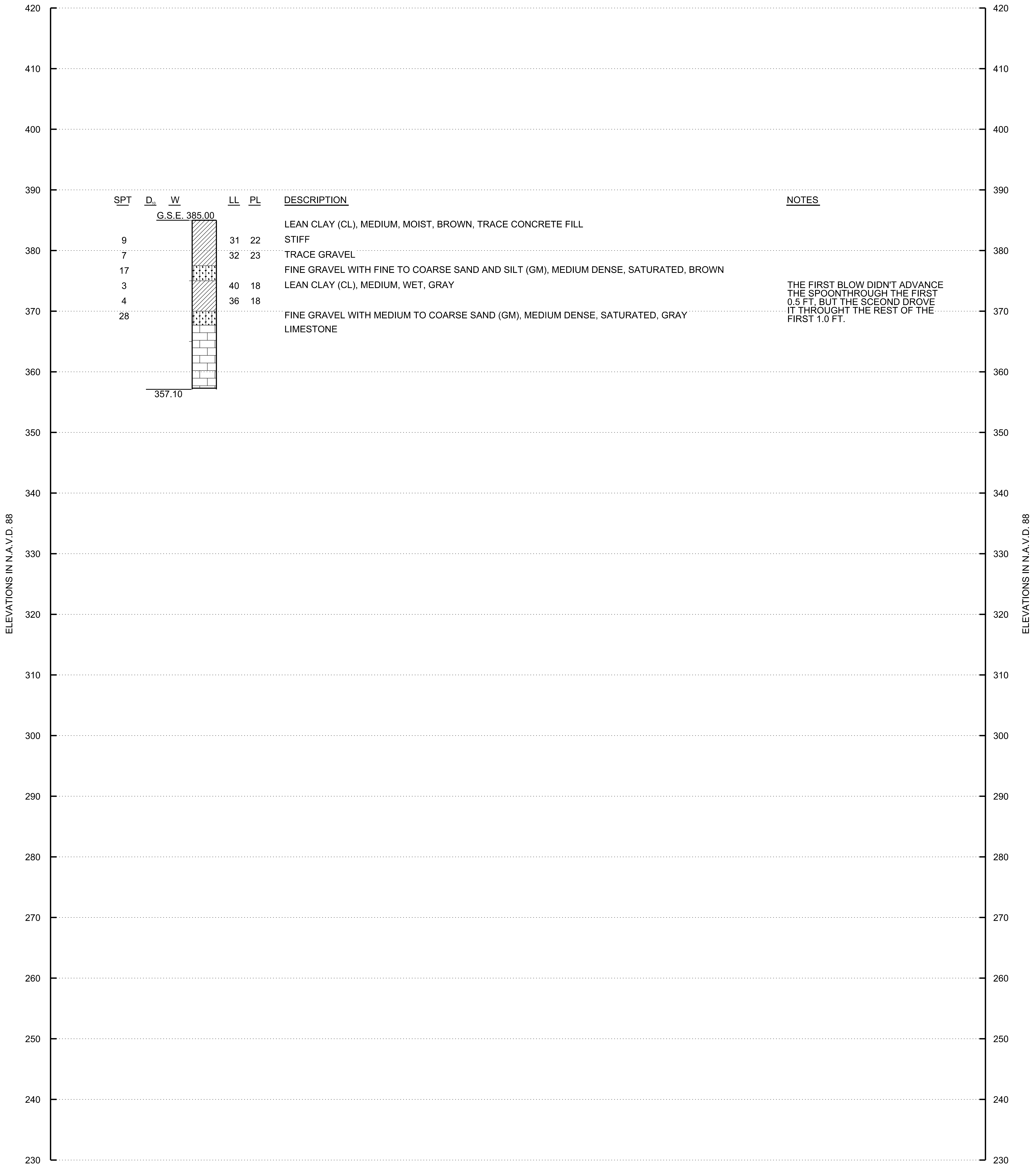

| SPT | $D_{10}$ | W | LL | PL | DESCRIPTION | NOTES |
|---|---|---|---|---|---|---|
| | | | | | LEAN CLAY (CL), MEDIUM, MOIST, BROWN, TRACE CONCRETE FILL | |
| 9 | | | 31 | 22 | STIFF | |
| 7 | | | 32 | 23 | TRACE GRAVEL | |
| 17 | | | | | FINE GRAVEL WITH FINE TO COARSE SAND AND SILT (GM), MEDIUM DENSE, SATURATED, BROWN | |
| 3 | | | 40 | 18 | LEAN CLAY (CL), MEDIUM, WET, GRAY | THE FIRST BLOW DIDN'T ADVANCE THE SPOONTHROUGH THE FIRST 0.5 FT, BUT THE SCEOND DROVE IT THROUGHT THE REST OF THE FIRST 1.0 FT. |
| 4 | | | 36 | 18 | | |
| 28 | | | | | FINE GRAVEL WITH MEDIUM TO COARSE SAND (GM), MEDIUM DENSE, SATURATED, GRAY | |
| | | | | | LIMESTONE | |

SHEET IDENTIFICATION
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SG-06-09

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## SG-07-09

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4 JUNE 09
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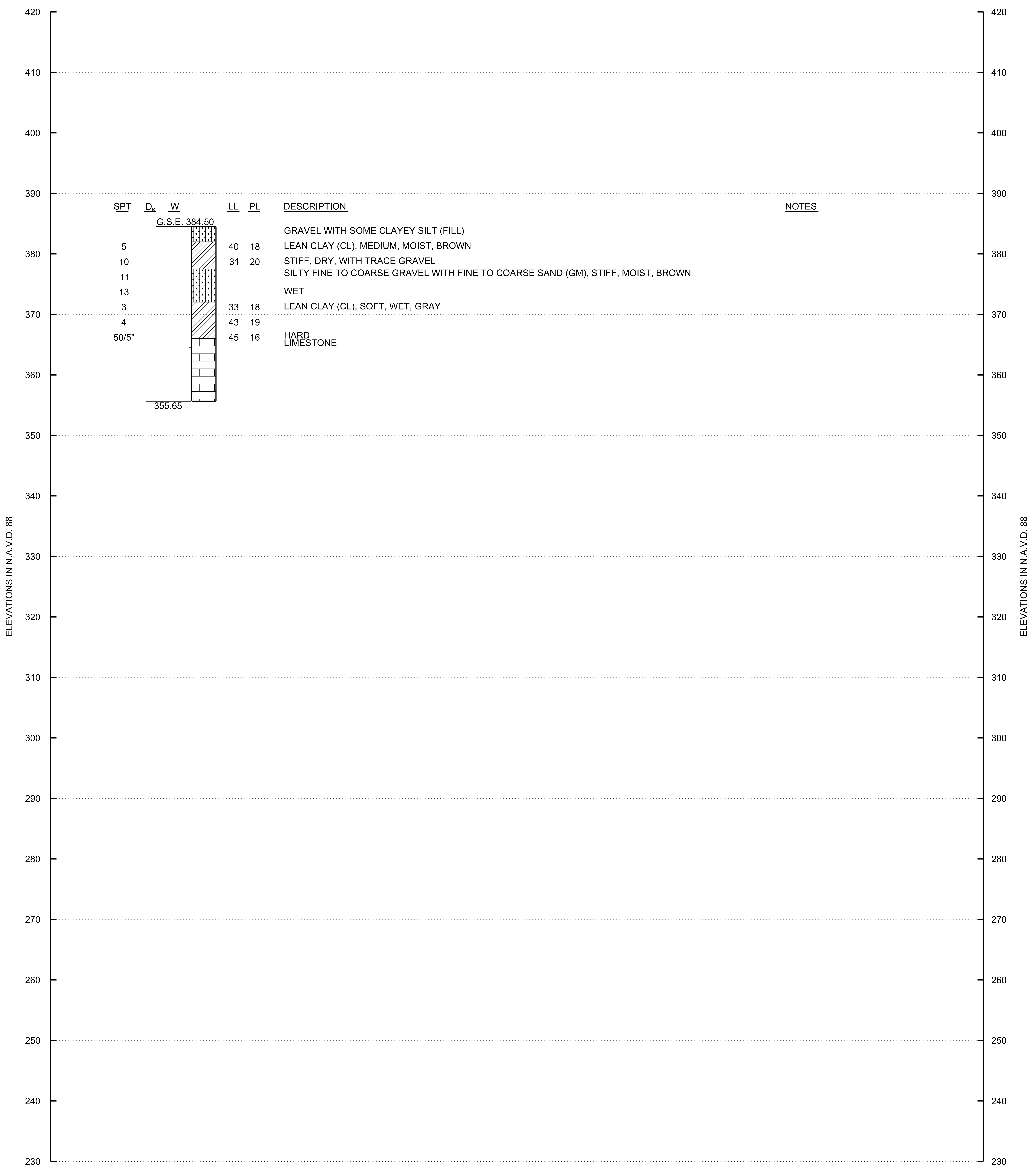

| SPT | $D_{10}$ | W | LL | PL | DESCRIPTION | NOTES |
|---|---|---|---|---|---|---|
| | | | | | GRAVEL WITH SOME CLAYEY SILT (FILL) | |
| 5 | | | 40 | 18 | LEAN CLAY (CL), MEDIUM, MOIST, BROWN | |
| 10 | | | 31 | 20 | STIFF, DRY, WITH TRACE GRAVEL | |
| 11 | | | | | SILTY FINE TO COARSE GRAVEL WITH FINE TO COARSE SAND (GM), STIFF, MOIST, BROWN | |
| 13 | | | | | WET | |
| 3 | | | 33 | 18 | LEAN CLAY (CL), SOFT, WET, GRAY | |
| 4 | | | 43 | 19 | | |
| 50/5" | | | 45 | 16 | HARD<br>LIMESTONE | |

SHEET IDENTIFICATION
B-207

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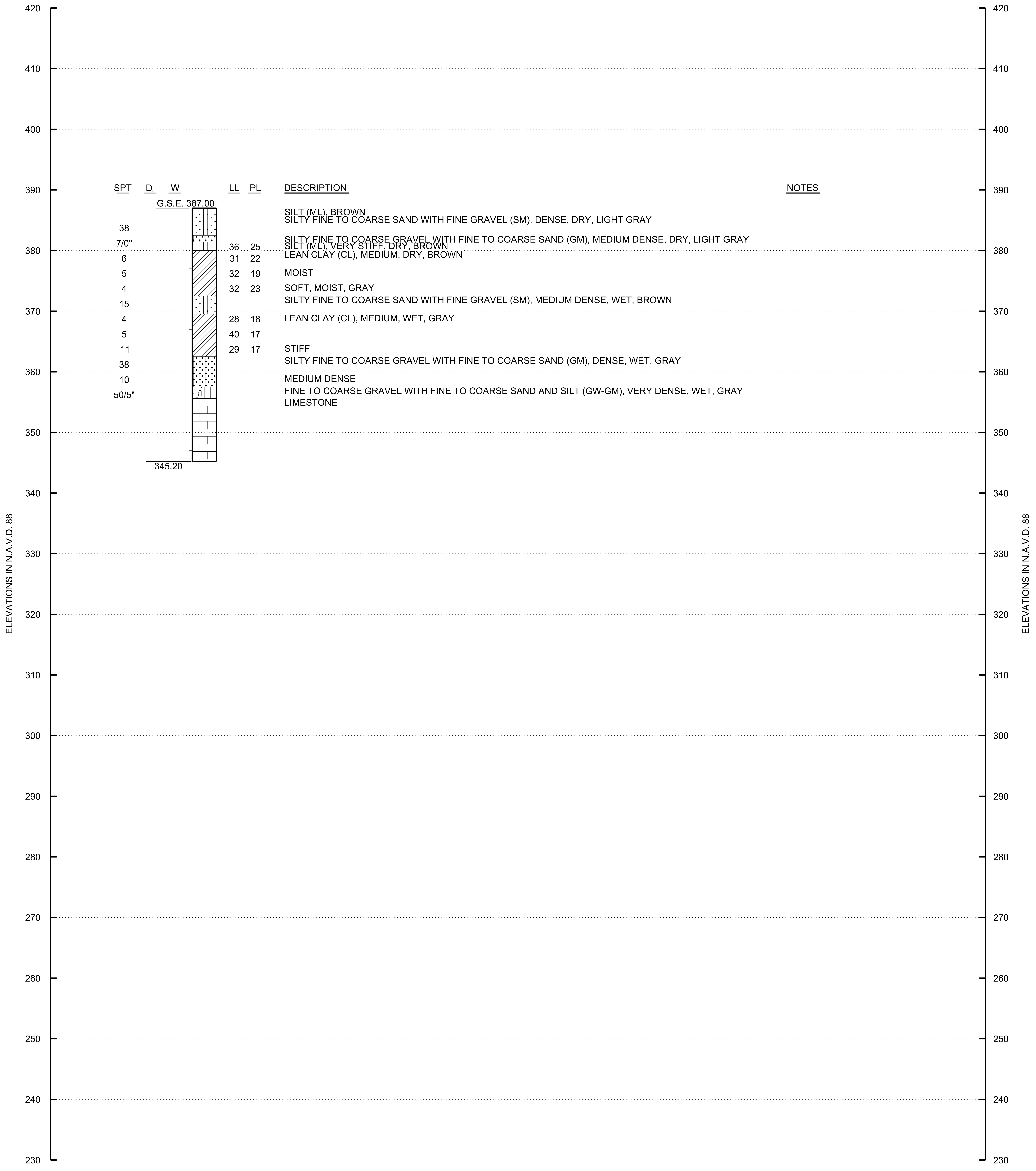
|---|---|---|
| DESIGNED BY: | | DATE: MARCH 2015 |
| DWN BY: TJD | CKD BY: | SOLICITATION NO.: |
| SUBMITTED BY: | | CONTRACT NO.: |
| PLOT SCALE: 1:1 | PLOT DATE: NO | FILE NUMBER: |
| SIZE: ANSI D | FILE NAME: | |

| MARK | DESCRIPTION | DATE | APPR. | MARK | DESCRIPTION | DATE | APPR. |
|---|---|---|---|---|---|---|---|

US Army Corps of Engineers®

## SG-08-09

N 783453.93 E 950561.08
20 MAY 09
37°59'3.84" 90°2'51.756"



| SPT | $D_{10}$ | W | LL | PL | DESCRIPTION | NOTES |
|---|---|---|---|---|---|---|
| | | G.S.E. 387.00 | | | SILT (ML), BROWN | |
| 38 | | | | | SILTY FINE TO COARSE SAND WITH FINE GRAVEL (SM), DENSE, DRY, LIGHT GRAY | |
| 7/0" | | | | | SILTY FINE TO COARSE GRAVEL WITH FINE TO COARSE SAND (GM), MEDIUM DENSE, DRY, LIGHT GRAY | |
| | | | 36 | 25 | SILT (ML), VERY STIFF, DRY, BROWN | |
| 6 | | | 31 | 22 | LEAN CLAY (CL), MEDIUM, DRY, BROWN | |
| 5 | | | 32 | 19 | MOIST | |
| 4 | | | 32 | 23 | SOFT, MOIST, GRAY | |
| 15 | | | | | SILTY FINE TO COARSE SAND WITH FINE GRAVEL (SM), MEDIUM DENSE, WET, BROWN | |
| 4 | | | 28 | 18 | LEAN CLAY (CL), MEDIUM, WET, GRAY | |
| 5 | | | 40 | 17 | | |
| 11 | | | 29 | 17 | STIFF | |
| 38 | | | | | SILTY FINE TO COARSE GRAVEL WITH FINE TO COARSE SAND (GM), DENSE, WET, GRAY | |
| 10 | | | | | MEDIUM DENSE | |
| 50/5" | | | | | FINE TO COARSE GRAVEL WITH FINE TO COARSE SAND AND SILT (GW-GM), VERY DENSE, WET, GRAY | |
| | | | | | LIMESTONE | |
| | 345.20 | | | | | |

SHEET IDENTIFICATION
B-208

STE. GENEVIEVE
LEVEE AND CHANNELIZATION PROJECT
MISSISSIPPI RIVER
STE. GENEVIEVE, MISSOURI
GEOTECHNICAL
BORING LOG
SG-08-09

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS DISTRICT
ST. LOUIS, MISSOURI 63103

| | | |
|---|---|---|
| DESIGNED BY: | | DATE: MARCH 2015 |
| DWN BY: TJD | CKD BY: | SOLICITATION NO.: |
| SUBMITTED BY: | | CONTRACT NO.: |
| PLOT SCALE: 1:1 | PLOT DATE: NO | FILE NUMBER: |
| SIZE: ANSI D | FILE NAME: | |

| MARK | DESCRIPTION | DATE | APPR. | MARK | DESCRIPTION | DATE | APPR. |
|---|---|---|---|---|---|---|---|

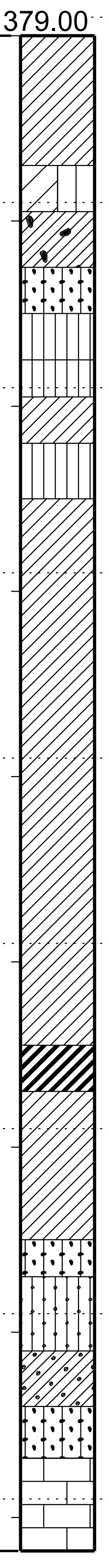
US Army Corps of Engineers®

## SG-09-09

N 783208.84  E 952565.38
18 APR 14
37°59'1.32" 90°2'26.736"

ELEVATIONS IN N.A.V.D. 88

G.S.E. 379.00



| SPT | D. | W | LL | PL | DESCRIPTION | NOTES |
|---|---|---|---|---|---|---|
| | | | | | LEAN CLAY (CL), STIFF, MOIST, BROWN, TRACE ORGANICS | |
| 11 | | | 32 | 20 | | |
| 7 | | | 33 | 20 | MEDIUM | |
| 7 | | | 29 | 22 | SILTY CLAY (CL-ML), MEDIUM, MOIST, BROWN | |
| 11 | | | 32 | 18 | CLAYEY FINE TO COARSE GRAVEL WITH FINE TO COARSE SAND (GC), MEDIUM DENSE, MOIST, BROWN | |
| 4 | | | | | SILTY FINE TO COARSE GRAVEL WITH MEDIUM TO COARSE SAND (GM), LOOSE, SATURATED, BROWN | |
| 2 | | | | | SILT WITH FINE SAND (ML), SOFT, WET, GRAY | |
| 4 | | | | | SILT (ML), SOFT, WET, GRAY | |
| 3 | | | 37 | 23 | LEAN CLAY (CL), SOFT, WET, GRAY | |
| 11 | | | 34 | 25 | SILT (ML), STIFF, WET, GRAY | |
| 5 | | | 47 | 20 | LEAN CLAY (CL), MEDIUM, WET, BROWN | |
| 12 | | | 46 | 24 | STIFF | |
| 15 | | | 46 | 23 | | |
| 8 | | | 39 | 20 | | |
| 20 | | | 43 | 21 | VERY STIFF | |
| 14 | | | 45 | 21 | STIFF, GRAY | |
| 12 | | | 48 | 18 | | |
| 14 | | | 47 | 19 | | |
| 7 | | | 41 | 19 | MEDIUM | |
| 14 | | | 43 | 21 | STIFF | |
| 15 | | | 39 | 19 | | |
| 16 | | | 44 | 20 | | |
| 8 | | | 55 | 21 | FAT CLAY (CH), STIFF, WET, GRAY | |
| 14 | | | 46 | 20 | LEAN CLAY (CL), STIFF, WET, GRAY | |
| 14 | | | 43 | 19 | | |
| 25 | | | 46 | 19 | | |
| 61 | | | | | SILTY FINE TO COARSE GRAVEL WITH FINE TO COARSE SAND (GM), VERY DENSE, WET, GRAY | |
| 50/4" | | | | | SILTY MEDIUM TO COARSE SAND WITH FINE GRAVEL (SM), VERY DENSE, WET, GRAY | |
| 50/2" | | | | | | |
| 25 | | | 82 | 21 | CLAYEL MEDIUM TO COARSE SAND WITH FINE GRAVEL (SC), MEDIUM DENSE, WET, GRAY | |
| 2 | | | | | SILTY FINE GRAVEL WITH FINE TO COARSE SAND (GM), VERY LOOSE, WET, GRAY | |
| | | | | | LIMESTONE | |

297.20

| MARK | DESCRIPTION | DATE | APPR. | MARK | DESCRIPTION | DATE | APPR. |
|---|---|---|---|---|---|---|---|

US Army Corps of Engineers®

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS DISTRICT
ST. LOUIS, MISSOURI 63103

| | | |
|---|---|---|
| DESIGNED BY: | | DATE: MARCH 2015 |
| DWN BY: TJD | CKD BY: | SOLICITATION NO.: |
| SUBMITTED BY: | | CONTRACT NO.: |
| PLOT SCALE: 1:1 | PLOT DATE: NO | FILE NUMBER: |
| SIZE: ANSI D | FILE NAME: | |

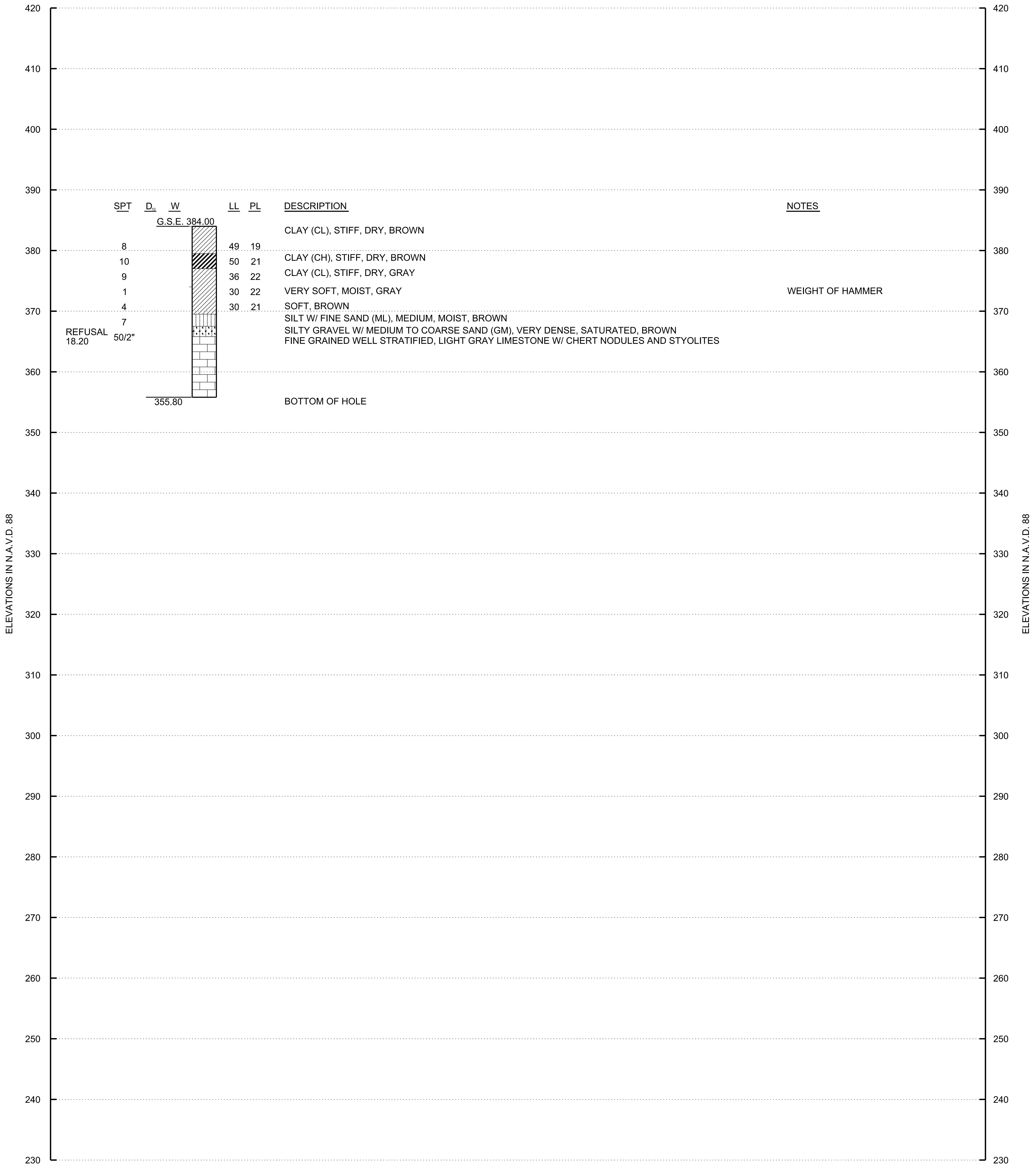
STE. GENEVIEVE
LEVEE AND CHANNELIZATION PROJECT
MISSISSIPPI RIVER
STE. GENEVIEVE, MISSOURI

GEOTECHNICAL
BORING LOG
SG-09-09

SHEET
IDENTIFICATION
B-209

# SG-10-09

N 783184.49 E 950565.27
26 MAY 09
37°59'1.176" 90°2'51.72"



| SPT | $D_{10}$ | W | LL | PL | DESCRIPTION | NOTES |
|---|---|---|---|---|---|---|
| | | | | | G.S.E. 384.00 | |
| 8 | | | 49 | 19 | CLAY (CL), STIFF, DRY, BROWN | |
| 10 | | | 50 | 21 | CLAY (CH), STIFF, DRY, BROWN | |
| 9 | | | 36 | 22 | CLAY (CL), STIFF, DRY, GRAY | |
| 1 | | | 30 | 22 | VERY SOFT, MOIST, GRAY | WEIGHT OF HAMMER |
| 4 | | | 30 | 21 | SOFT, BROWN | |
| 7 | | | | | SILT W/ FINE SAND (ML), MEDIUM, MOIST, BROWN | |
| REFUSAL 18.20 50/2" | | | | | SILTY GRAVEL W/ MEDIUM TO COARSE SAND (GM), VERY DENSE, SATURATED, BROWN | |
| | | | | | FINE GRAINED WELL STRATIFIED, LIGHT GRAY LIMESTONE W/ CHERT NODULES AND STYOLITES | |
| 355.80 | | | | | BOTTOM OF HOLE | |

SHEET IDENTIFICATION
B-210

STE. GENEVIEVE
LEVEE AND CHANNELIZATION PROJECT
MISSISSIPPI RIVER
STE. GENEVIEVE, MISSOURI

GEOTECHNICAL
BORING LOG
SG-10-09

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS DISTRICT
ST. LOUIS, MISSOURI 63103

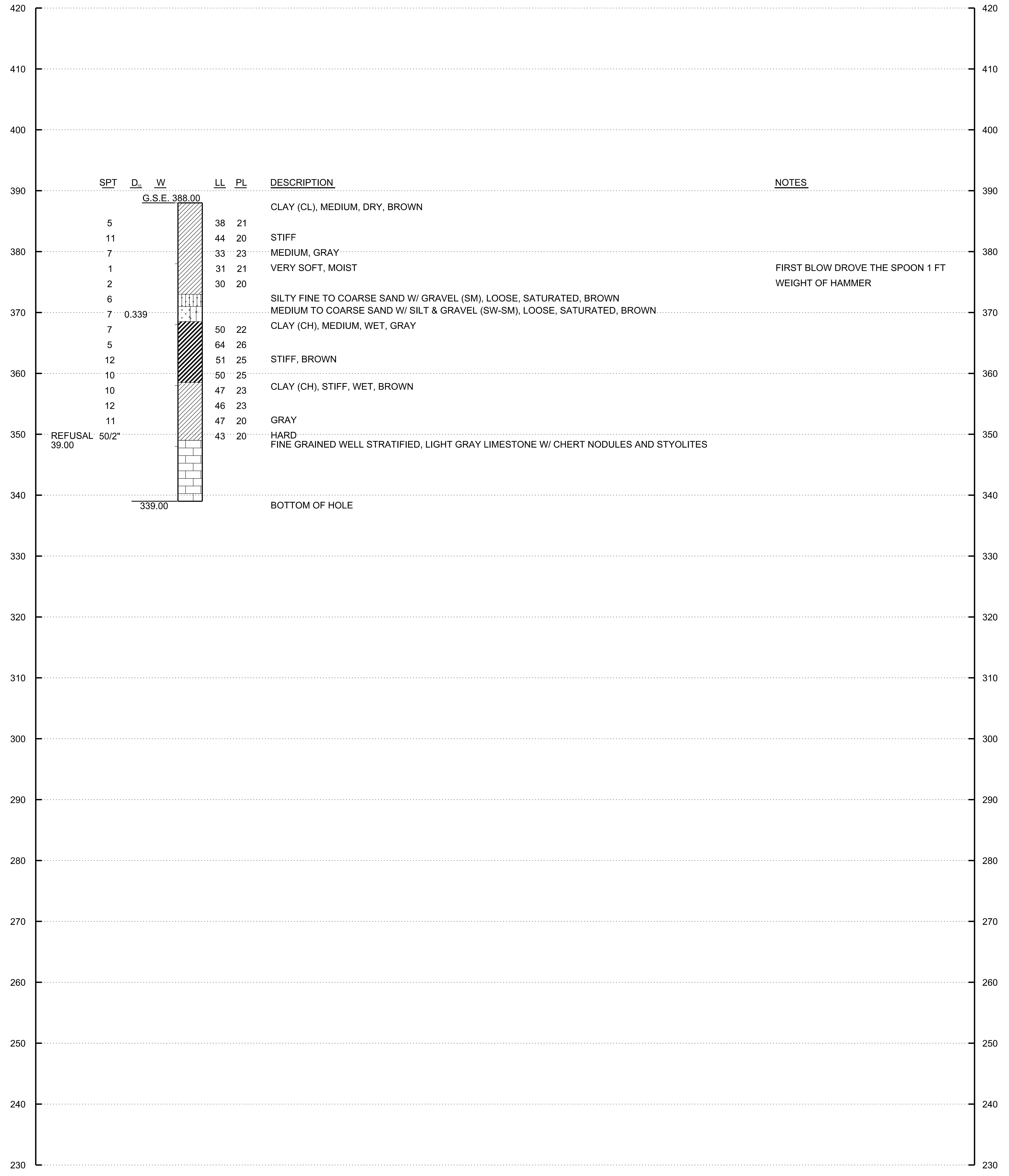
| | | |
|---|---|---|
| DESIGNED BY: | | DATE:<br>MARCH 2015 |
| DWN BY:<br>TJD | CKD BY: | SOLICITATION NO.: |
| SUBMITTED BY: | | CONTRACT NO.: |
| PLOT SCALE:<br>1:1 | PLOT DATE:<br>NO | FILE NUMBER: |
| SIZE:<br>ANSI D | FILE NAME: | |

| MARK | DESCRIPTION | DATE | APPR. | MARK | DESCRIPTION | DATE | APPR. |
|---|---|---|---|---|---|---|---|

US Army Corps of Engineers®

## SG-11-09

N 782999.62  E 950739.1
27 MAY 09
37°58'59.34" 90°2'49.56"



| SPT | D. | W | LL | PL | DESCRIPTION | NOTES |
|---|---|---|---|---|---|---|
| | | | | | CLAY (CL), MEDIUM, DRY, BROWN | |
| 5 | | | 38 | 21 | | |
| 11 | | | 44 | 20 | STIFF | |
| 7 | | | 33 | 23 | MEDIUM, GRAY | |
| 1 | | | 31 | 21 | VERY SOFT, MOIST | FIRST BLOW DROVE THE SPOON 1 FT |
| 2 | | | 30 | 20 | | WEIGHT OF HAMMER |
| 6 | | | | | SILTY FINE TO COARSE SAND W/ GRAVEL (SM), LOOSE, SATURATED, BROWN | |
| 7 | 0.339 | | | | MEDIUM TO COARSE SAND W/ SILT & GRAVEL (SW-SM), LOOSE, SATURATED, BROWN | |
| 7 | | | 50 | 22 | CLAY (CH), MEDIUM, WET, GRAY | |
| 5 | | | 64 | 26 | | |
| 12 | | | 51 | 25 | STIFF, BROWN | |
| 10 | | | 50 | 25 | | |
| 10 | | | 47 | 23 | CLAY (CH), STIFF, WET, BROWN | |
| 12 | | | 46 | 23 | | |
| 11 | | | 47 | 20 | GRAY | |
| REFUSAL 50/2"<br>39.00 | | | 43 | 20 | HARD<br>FINE GRAINED WELL STRATIFIED, LIGHT GRAY LIMESTONE W/ CHERT NODULES AND STYOLITES | |
| | | | | | BOTTOM OF HOLE | |

SHEET IDENTIFICATION
B-211

STE. GENEVIEVE
LEVEE AND CHANNELIZATION PROJECT
MISSISSIPPI RIVER
STE. GENEVIEVE, MISSOURI

GEOTECHNICAL
BORING LOG
SG-11-09

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS DISTRICT
ST. LOUIS, MISSOURI 63103

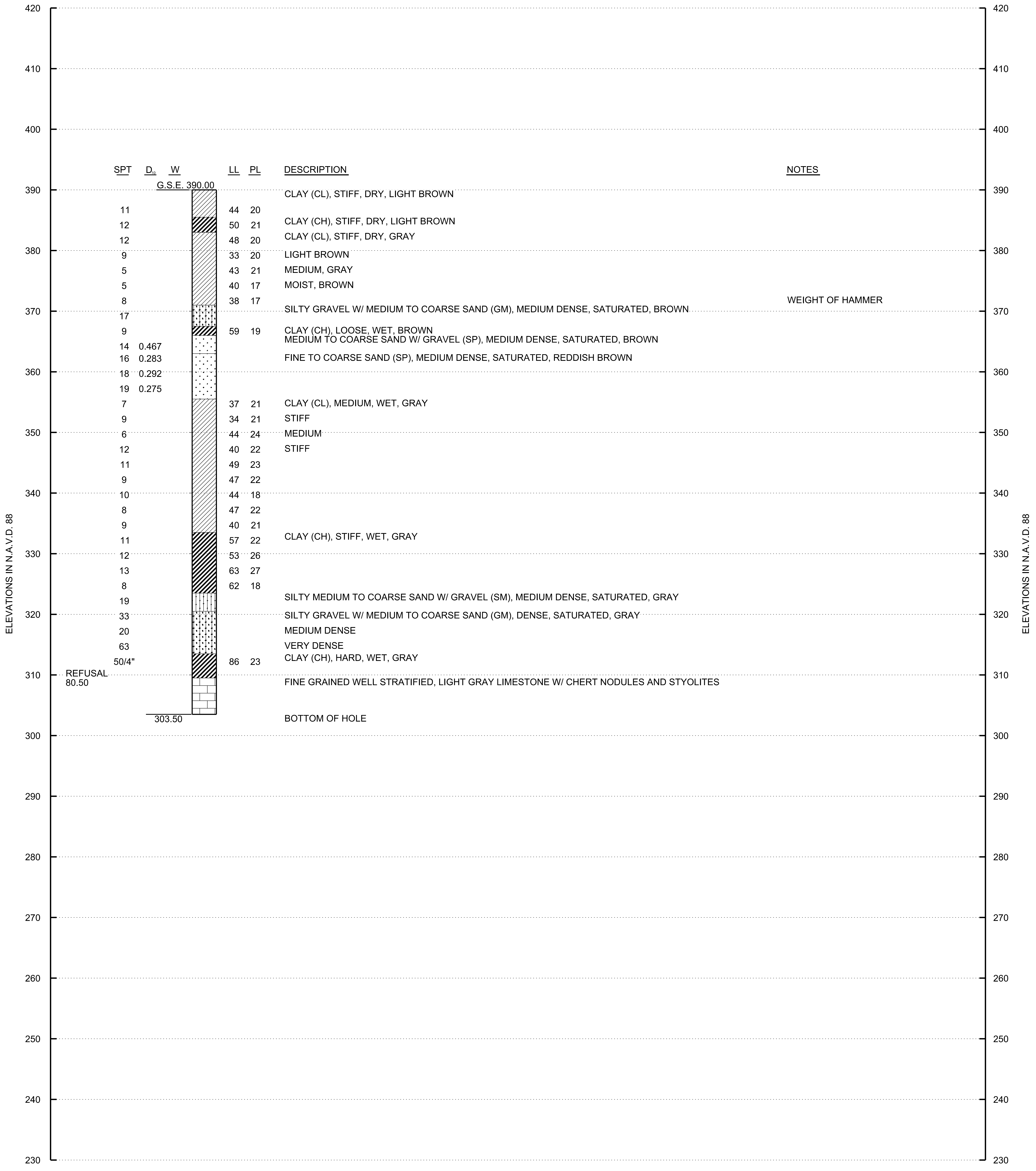
| | | |
|---|---|---|
| DESIGNED BY: | | DATE: MARCH 2015 |
| DWN BY: TJD | CKD BY: | SOLICITATION NO.: |
| SUBMITTED BY: | | CONTRACT NO.: |
| PLOT SCALE: 1:1 | PLOT DATE: NO | FILE NUMBER: |
| SIZE: ANSI D | FILE NAME: | |

| MARK | DESCRIPTION | DATE | APPR. | MARK | DESCRIPTION | DATE | APPR. |
|---|---|---|---|---|---|---|---|

US Army Corps of Engineers®

## SG-12-09

N 783026.16 E 950955.14
22 MAY 09
37°58'59.592" 90°2'46.86"



| SPT | $D_{10}$ | W | LL | PL | DESCRIPTION | NOTES |
|---|---|---|---|---|---|---|
| | | G.S.E. 390.00 | | | CLAY (CL), STIFF, DRY, LIGHT BROWN | |
| 11 | | | 44 | 20 | | |
| 12 | | | 50 | 21 | CLAY (CH), STIFF, DRY, LIGHT BROWN | |
| 12 | | | 48 | 20 | CLAY (CL), STIFF, DRY, GRAY | |
| 9 | | | 33 | 20 | LIGHT BROWN | |
| 5 | | | 43 | 21 | MEDIUM, GRAY | |
| 5 | | | 40 | 17 | MOIST, BROWN | |
| 8 | | | 38 | 17 | | WEIGHT OF HAMMER |
| 17 | | | | | SILTY GRAVEL W/ MEDIUM TO COARSE SAND (GM), MEDIUM DENSE, SATURATED, BROWN | |
| 9 | | | 59 | 19 | CLAY (CH), LOOSE, WET, BROWN | |
| 14 | 0.467 | | | | MEDIUM TO COARSE SAND W/ GRAVEL (SP), MEDIUM DENSE, SATURATED, BROWN | |
| 16 | 0.283 | | | | FINE TO COARSE SAND (SP), MEDIUM DENSE, SATURATED, REDDISH BROWN | |
| 18 | 0.292 | | | | | |
| 19 | 0.275 | | | | | |
| 7 | | | 37 | 21 | CLAY (CL), MEDIUM, WET, GRAY | |
| 9 | | | 34 | 21 | STIFF | |
| 6 | | | 44 | 24 | MEDIUM | |
| 12 | | | 40 | 22 | STIFF | |
| 11 | | | 49 | 23 | | |
| 9 | | | 47 | 22 | | |
| 10 | | | 44 | 18 | | |
| 8 | | | 47 | 22 | | |
| 9 | | | 40 | 21 | | |
| 11 | | | 57 | 22 | CLAY (CH), STIFF, WET, GRAY | |
| 12 | | | 53 | 26 | | |
| 13 | | | 63 | 27 | | |
| 8 | | | 62 | 18 | | |
| 19 | | | | | SILTY MEDIUM TO COARSE SAND W/ GRAVEL (SM), MEDIUM DENSE, SATURATED, GRAY | |
| 33 | | | | | SILTY GRAVEL W/ MEDIUM TO COARSE SAND (GM), DENSE, SATURATED, GRAY | |
| 20 | | | | | MEDIUM DENSE | |
| 63 | | | | | VERY DENSE | |
| 50/4" | | | 86 | 23 | CLAY (CH), HARD, WET, GRAY | |
| REFUSAL<br>80.50 | | | | | FINE GRAINED WELL STRATIFIED, LIGHT GRAY LIMESTONE W/ CHERT NODULES AND STYOLITES | |
| | | 303.50 | | | BOTTOM OF HOLE | |

SHEET
IDENTIFICATION
B-212

STE. GENEVIEVE
LEVEE AND CHANNELIZATION PROJECT
MISSISSIPPI RIVER
STE. GENEVIEVE, MISSOURI

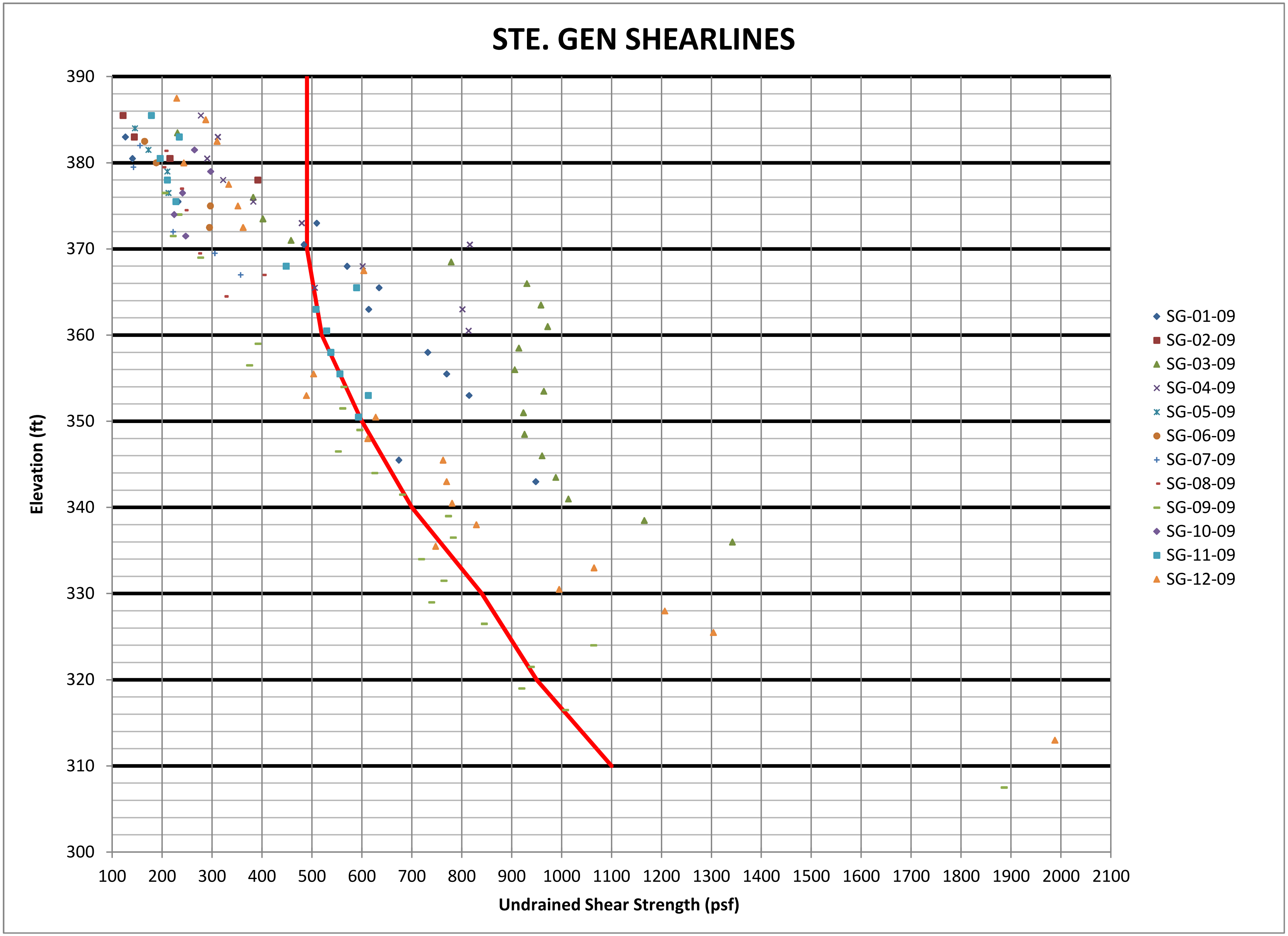
GEOTECHNICAL
BORING LOG
SG-12-09

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS DISTRICT
ST. LOUIS, MISSOURI 63103

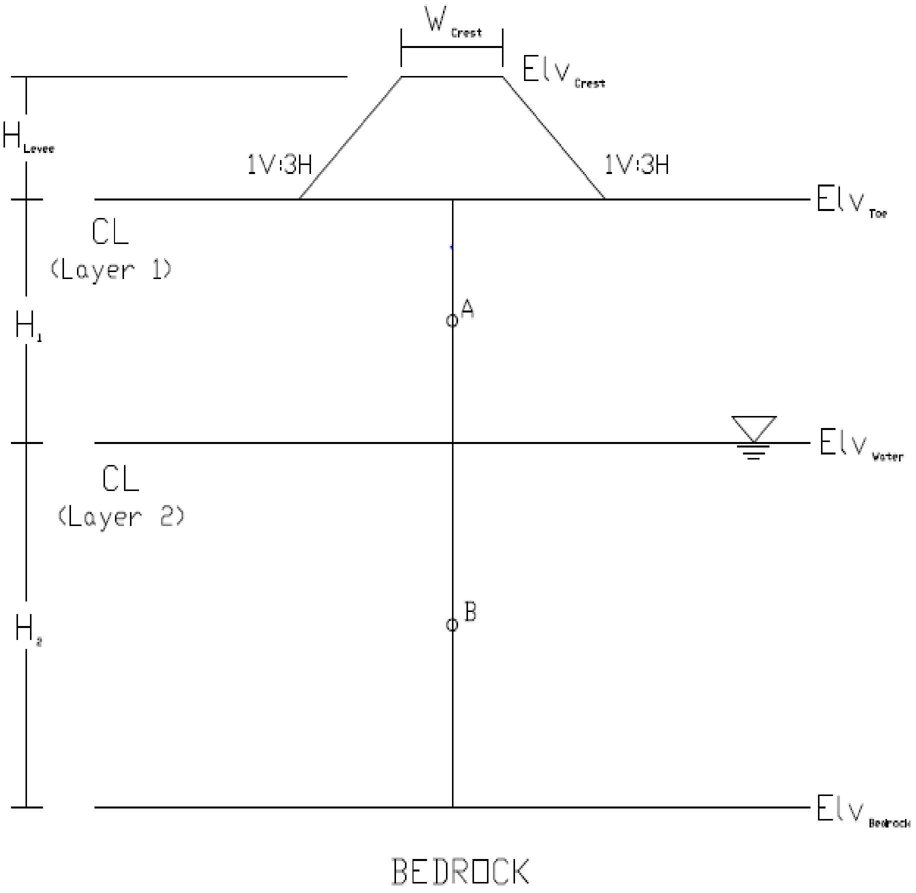
| | | |
|---|---|---|
| DESIGNED BY: | | DATE:<br>MARCH 2015 |
| DWN BY:<br>TJD | CKD BY: | SOLICITATION NO.: |
| SUBMITTED BY: | | CONTRACT NO.: |
| PLOT SCALE:<br>1:1 | PLOT DATE:<br>NO | FILE NUMBER: |
| SIZE:<br>ANSI D | FILE NAME: | |

| MARK | DESCRIPTION | DATE | APPR. | MARK | DESCRIPTION | DATE | APPR. |
|---|---|---|---|---|---|---|---|

US Army Corps
of Engineers®


STE. GEN SHEARLINES
Elevation (ft)
390
380
370
360
350
340
330
320
310
300
Undrained Shear Strength (psf)
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
SG-01-09
SG-02-09
SG-03-09
SG-04-09
SG-05-09
SG-06-09
SG-07-09
SG-08-09
SG-09-09
SG-10-09
SG-11-09
SG-12-09

# SETTLEMENT ANALYSES



$S_{alt} := 11in$

$\gamma := 120 \frac{lb}{ft^3}$

$\gamma_w := 62.4 \frac{lb}{ft^3}$

$Elv_{Crest} := 390ft$

$Elv_{Toe} := 382ft$

$Elv_{Water} := 370ft$

$Elv_{Bedrock} := 300ft$

$W_{Crest} := 10ft$

$H_{Levee} := Elv_{Crest} - Elv_{Toe} = 8 \cdot ft$

$H_1 := Elv_{Toe} - Elv_{Water} = 12 \cdot ft$

$H_2 := Elv_{Water} - Elv_{Bedrock} = 70 \cdot ft$

## CL Layer 1

$LL_1 := 37.6$  $OCR := 1$  $NC := OCR = 1$  $G_{s\_1} := 2.70$ Assumed

$w_1 := 27\%$

$$C_{C\_1} := .009 \cdot \left(LL_1 - 10\right) = 0.248 \qquad \sigma_A := \left(\frac{H_1}{2}\right)\gamma = 720 \cdot \frac{lb}{ft^2} \qquad \gamma_{d\_1} := \frac{\gamma}{1 + w_1} = 94.488 \cdot \frac{lb}{ft^3}$$

$$C_{R\_1} := .2C_{C\_1} = 0.05$$

$$P_{c\_A} := OCR \cdot \sigma_A = 720 \cdot \frac{lb}{ft^2}$$

$$S_1 := \frac{w_1}{\dfrac{\gamma_w}{\gamma_{d\_1}} - \dfrac{1}{G_{s\_1}}} = 93.094 \cdot \% \qquad e_{o\_1} := \frac{w_1 \cdot G_{s\_1}}{S_1} = 0.783$$

## CL Layer 2

$LL_2 := 50.7$  $OCR = 1$  $NC = 1$  $G_{s\_2} := 2.6$ Assumed

$w_2 := 28\%$

$$C_{C\_2} := .009 \cdot \left(LL_2 - 10\right) = 0.366 \qquad \sigma_B := \left(H_1 + \frac{H_2}{2}\right)\gamma = 5.64 \times 10^3 \cdot \frac{lb}{ft^2} \qquad \gamma_{d\_2} := \frac{\gamma}{1 + w_2} = 93.75 \cdot \frac{lb}{ft^3}$$

$$C_{R\_2} := .2C_{C\_2} = 0.073$$

$$P_{c\_B} := OCR \cdot \sigma_B = 5.64 \times 10^3 \cdot \frac{lb}{ft^2}$$ - (35 ft x 62.4 pcf) = 3456 psf

$$S_2 := \frac{w_2}{\dfrac{\gamma_w}{\gamma_{d\_2}} - \dfrac{1}{G_{s\_2}}} = 99.65 \cdot \% \qquad e_{o\_2} := \frac{w_2 \cdot G_{s\_2}}{S_2} = 0.731$$

```
PROGRAM CSETT - VERTICAL STRESS INDUCTION AND SETTLEMENT PROGRAM
DATE: 16-MAR-2015                                 TIME: 10.29.10



I.  INPUT DATA



1. TITLE - Ste. Gen North Levee



2. BOUSSINESQ SOLUTION WILL BE USED TO COMPUTE INDUCED STRESSES.
   THE MAXIMUM DEPTH TO WHICH THE ANALYSIS WILL BE EXTENDED
   IS   82.00 FEET.



3. 2-DIMENSIONAL PRESSURE LOAD DATA
   NONE



4. 2-DIMENSIONAL SOIL LOAD DATA

  PROFILE NUMBER  1 :NUMBER OF POINTS=  6
                     BEGINNING TIME OF APPLICATION = 0.0000 YRS.
                     ENDING TIME OF APPLICATION = 0.1000 YRS.
                     EFFECTIVE UNIT WEIGHT OF SOIL LOAD=  120.00 PCF


                     POINT NO.    X         Y
                               (FT.)     (FT.)


                         1   -9999.00    382.00
                         2    -114.00    382.00
                         3     -90.00    390.00
                         4     -80.00    390.00
                         5     -60.00    382.00
                         6    9999.00    382.00



5. 3-DIMENSIONAL RECTANGULAR LOAD DATA
   NONE



6. 3-DIMENSIONAL IRREGULAR LOAD DATA
```

```
   NONE



7. EXCAVATION DATA
   NONE



8. SOIL DATA


STRATA EL. OF TOP  DRAINAGE  EFF UNIT  RECOMPR. COEF.OF  POISSON'S
  NO.  OF STRATUM  CONDITION  WEIGHT   INDEX    CONSOL.   RATIO
       (FEET NGVD)            (PCF)            (SQFT/YR)


    1     382.00       S     120.00   0.04968   1.00000   0.32000
    2     370.00       S      57.60   0.07360   1.00000   0.32000



9. STRESS-STRAIN DATA


            STRATUM NO.  1
            --------------
       COMPRESSION INDEX= 0.24840
     RECOMPRESSION INDEX= 0.04968
       INSITU VOID RATIO= 0.78300
       INSITU OVERBURDEN=  720.00 PSF


            STRATUM NO.  2
            --------------
       COMPRESSION INDEX= 0.36630
     RECOMPRESSION INDEX= 0.07360
       INSITU VOID RATIO= 0.72800
       INSITU OVERBURDEN= 3456.00 PSF



10. TIME SEQUENCE FOR CONSOLIDATION CALCULATIONS


     TIME RATE OF CONSOLIDATION CALCULATIONS WILL BE MADE
     AT TIMES (YRS):
                     100.00



11. OUTPUT CONTROL DATA


      XXL=  -90.0000 FT.
      XUL=  -80.0000 FT.
     DELX=    5.0000 FT.
```

```
1
 PROGRAM CSETT - VERTICAL STRESS INDUCTION AND SETTLEMENT PROGRAM
 DATE: 16-MAR-2015                                 TIME: 10.29.10




 II.  OUTPUT SUMMARY.



 1. TITLE- Ste. Gen North Levee



                         POSITION:  X=   -90.0
                         *********************


 2. SUMMARY OF ULTIMATE SETTLEMENTS.

     STRATA   MID-DEPTH    IN-SITU    DELTA     ULTIMATE
       NO.    OF STRATA  OVERBURDEN   SIGMA    SETTLEMENT
               (FEET)    (LB/SQ FT) (LB/SQ FT)   (FEET)
     ------   ---------  ---------- ---------- ----------


        1          6.00      720.00    874.35     0.480
        2         47.00     3456.00    415.40     0.380



 3. TIME-SETTLEMENT SUMMARY.

            (SETTLEMENT IN FEET AT SPECIFIED TIMES)
 STRATA    ULT   100.00
    NO           (YRS.)
 ------    ---   ------


    1     0.480  0.410
    2     0.380  0.061

 TOTALS:  0.860  0.471



                         POSITION:  X=   -85.0
                         *********************


 2. SUMMARY OF ULTIMATE SETTLEMENTS.

     STRATA   MID-DEPTH    IN-SITU    DELTA     ULTIMATE
       NO.    OF STRATA  OVERBURDEN   SIGMA    SETTLEMENT
               (FEET)    (LB/SQ FT) (LB/SQ FT)   (FEET)
```

```
    ------   ---------  ---------- ---------- ----------


       1          6.00      720.00    906.77     0.494
       2         47.00     3456.00    422.14     0.386



3. TIME-SETTLEMENT SUMMARY.

           (SETTLEMENT IN FEET AT SPECIFIED TIMES)
STRATA    ULT   100.00
   NO           (YRS.)
------    ---   ------


   1     0.494  0.494
   2     0.386  0.062

TOTALS:  0.880  0.556



                         POSITION:  X=   -80.0
                         *********************



2. SUMMARY OF ULTIMATE SETTLEMENTS.

    STRATA   MID-DEPTH    IN-SITU    DELTA     ULTIMATE
      NO.    OF STRATA  OVERBURDEN   SIGMA    SETTLEMENT
              (FEET)    (LB/SQ FT) (LB/SQ FT)   (FEET)
    ------   ---------  ---------- ---------- ----------


       1          6.00      720.00    862.55     0.474
       2         47.00     3456.00    408.03     0.375



3. TIME-SETTLEMENT SUMMARY.

           (SETTLEMENT IN FEET AT SPECIFIED TIMES)
STRATA    ULT   100.00
   NO           (YRS.)
------    ---   ------


   1     0.474  0.474
   2     0.375  0.060

TOTALS:  0.849  0.534
```

```
PROGRAM CSETT - VERTICAL STRESS INDUCTION AND SETTLEMENT PROGRAM
DATE: 16-MAR-2015                                 TIME: 10.33.57



I.  INPUT DATA



1. TITLE - Ste. Gen South Levee



2. BOUSSINESQ SOLUTION WILL BE USED TO COMPUTE INDUCED STRESSES.
   THE MAXIMUM DEPTH TO WHICH THE ANALYSIS WILL BE EXTENDED
   IS   82.00 FEET.



3. 2-DIMENSIONAL PRESSURE LOAD DATA
   NONE



4. 2-DIMENSIONAL SOIL LOAD DATA

  PROFILE NUMBER  1 :NUMBER OF POINTS=  6
                     BEGINNING TIME OF APPLICATION = 0.0000 YRS.
                     ENDING TIME OF APPLICATION = 0.1000 YRS.
                     EFFECTIVE UNIT WEIGHT OF SOIL LOAD=  120.00 PCF

                     POINT NO.    X         Y
                                (FT.)     (FT.)


                         1   -9999.00    382.00
                         2    -114.00    382.00
                         3     -90.00    384.00
                         4     -80.00    384.00
                         5     -60.00    382.00
                         6    9999.00    382.00



5. 3-DIMENSIONAL RECTANGULAR LOAD DATA
   NONE



6. 3-DIMENSIONAL IRREGULAR LOAD DATA
```

```
   NONE



7. EXCAVATION DATA
   NONE



8. SOIL DATA


STRATA EL. OF TOP  DRAINAGE  EFF UNIT  RECOMPR. COEF.OF  POISSON'S
  NO.  OF STRATUM  CONDITION  WEIGHT   INDEX    CONSOL.   RATIO
       (FEET NGVD)            (PCF)            (SQFT/YR)


    1     382.00       S     120.00   0.04968   1.00000   0.32000
    2     370.00       S      57.60   0.07360   1.00000   0.32000



9. STRESS-STRAIN DATA


            STRATUM NO.  1
            --------------
       COMPRESSION INDEX= 0.24840
     RECOMPRESSION INDEX= 0.04968
       INSITU VOID RATIO= 0.78300
       INSITU OVERBURDEN=  720.00 PSF


            STRATUM NO.  2
            --------------
       COMPRESSION INDEX= 0.36630
     RECOMPRESSION INDEX= 0.07360
       INSITU VOID RATIO= 0.72800
       INSITU OVERBURDEN= 3456.00 PSF



10. TIME SEQUENCE FOR CONSOLIDATION CALCULATIONS


     TIME RATE OF CONSOLIDATION CALCULATIONS WILL BE MADE
     AT TIMES (YRS):
                     100.00



11. OUTPUT CONTROL DATA


      XXL=  -90.0000 FT.
      XUL=  -80.0000 FT.
     DELX=    5.0000 FT.
```

```
1
 PROGRAM CSETT - VERTICAL STRESS INDUCTION AND SETTLEMENT PROGRAM
 DATE: 16-MAR-2015                                 TIME: 10.33.57




 II.  OUTPUT SUMMARY.




 1. TITLE- Ste. Gen South Levee




                         POSITION:  X=   -90.0
                         *********************



 2. SUMMARY OF ULTIMATE SETTLEMENTS.

     STRATA   MID-DEPTH    IN-SITU    DELTA     ULTIMATE
       NO.    OF STRATA  OVERBURDEN   SIGMA    SETTLEMENT
               (FEET)    (LB/SQ FT) (LB/SQ FT)   (FEET)
     ------   ---------  ---------- ---------- ----------


        1         6.00      720.00    218.57     0.118
        2        47.00     3456.00    103.86     0.094



 3. TIME-SETTLEMENT SUMMARY.

            (SETTLEMENT IN FEET AT SPECIFIED TIMES)
 STRATA    ULT   100.00
    NO           (YRS.)
 ------    ---   ------


    1     0.118  0.100
    2     0.094  0.016

 TOTALS:  0.212  0.116



                         POSITION:  X=   -85.0
                         *********************



 2. SUMMARY OF ULTIMATE SETTLEMENTS.

     STRATA   MID-DEPTH    IN-SITU    DELTA     ULTIMATE
       NO.    OF STRATA  OVERBURDEN   SIGMA    SETTLEMENT
               (FEET)    (LB/SQ FT) (LB/SQ FT)   (FEET)
```

```
    ------   ---------  ---------- ---------- ----------


       1         6.00      720.00    226.67     0.124
       2        47.00     3456.00    105.55     0.094



3. TIME-SETTLEMENT SUMMARY.

           (SETTLEMENT IN FEET AT SPECIFIED TIMES)
STRATA    ULT   100.00
   NO           (YRS.)
------    ---   ------


   1     0.124  0.124
   2     0.094  0.016

TOTALS:  0.218  0.140



                         POSITION:  X=   -80.0
                         *********************



2. SUMMARY OF ULTIMATE SETTLEMENTS.

    STRATA   MID-DEPTH    IN-SITU     DELTA     ULTIMATE
      NO.    OF STRATA  OVERBURDEN   SIGMA    SETTLEMENT
              (FEET)    (LB/SQ FT) (LB/SQ FT)   (FEET)
    ------   ---------  ---------- ---------- ----------


       1         6.00      720.00    215.62     0.117
       2        47.00     3456.00    102.00     0.092



3. TIME-SETTLEMENT SUMMARY.

           (SETTLEMENT IN FEET AT SPECIFIED TIMES)
STRATA    ULT   100.00
   NO           (YRS.)
------    ---   ------


   1     0.117  0.117
   2     0.092  0.016

TOTALS:  0.209  0.133
```

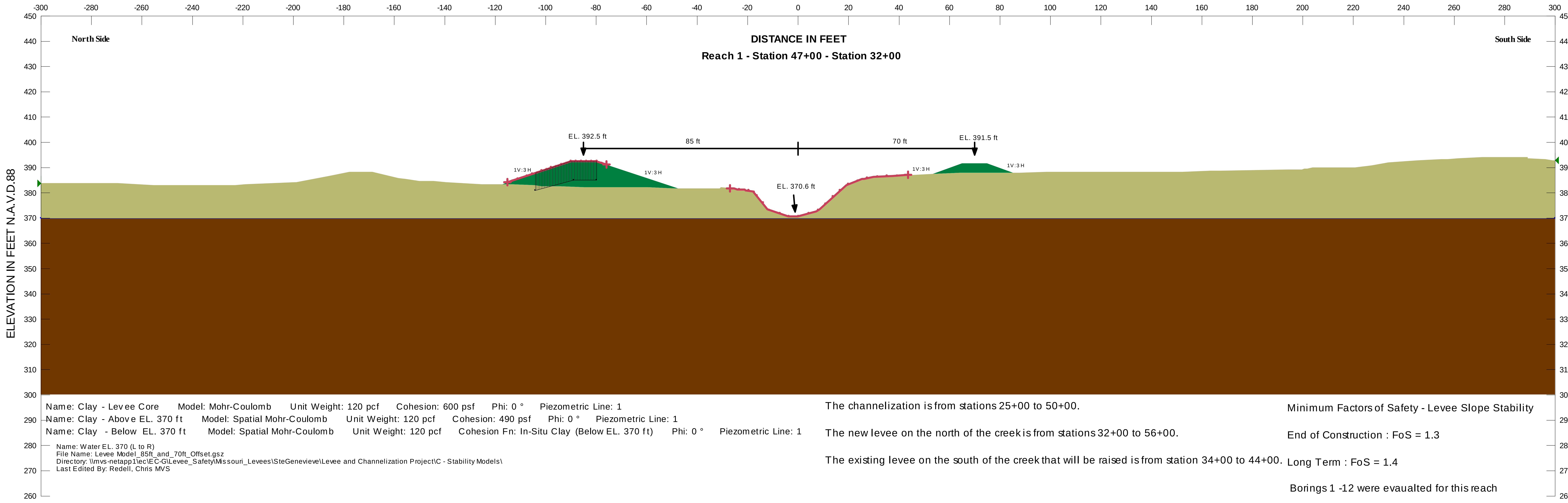
Appendix III

# Geotechnical Modeling

Ste. Genevieve GRR

# Levee Alternative - Reach 1 - Station 47+00 - Station 32+00

Report generated using GeoStudio 2007, version 7.23.



Name: Clay - Levee Core Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 600 psf Phi: 0 ° Piezometric Line: 1
Name: Clay - Above EL. 370 ft Model: Spatial Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 490 psf Phi: 0 ° Piezometric Line: 1
Name: Clay - Below EL. 370 ft Model: Spatial Mohr-Coulomb Unit Weight: 120 pcf Cohesion Fn: In-Situ Clay (Below EL. 370 ft) Phi: 0 ° Piezometric Line: 1

Name: Water EL. 370 (L to R)
File Name: Levee Model_85ft_and_70ft_Offset.gsz
Directory: \\mvs-netapp1\ec\EC-G\Levee_Safety\Missouri_Levees\SteGenevieve\Levee and Channelization Project\C - Stability Models\
Last Edited By: Redell, Chris MVS

The channelization is from stations 25+00 to 50+00.

The new levee on the north of the creek is from stations 32+00 to 56+00.

The existing levee on the south of the creek that will be raised is from station 34+00 to 44+00.

Minimum Factors of Safety - Levee Slope Stability

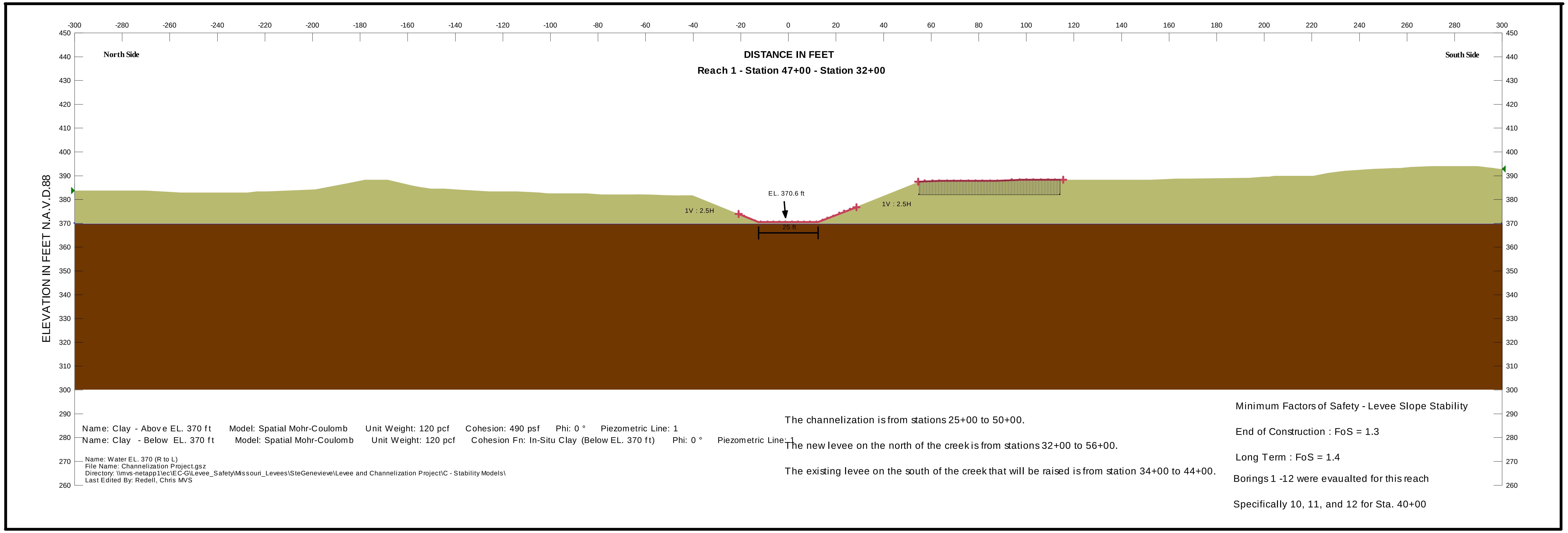
End of Construction : FoS = 1.3

Long Term : FoS = 1.4

Borings 1 -12 were evaualted for this reach

Specifically 10, 11, and 12 for Sta. 40+00

# Channelization Alternative - Reach 1 - Station 47+00 - Station 32+00



Name: Clay - Above EL. 370 ft Model: Spatial Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 490 psf Phi: 0 ° Piezometric Line: 1

Name: Clay - Below EL. 370 ft Model: Spatial Mohr-Coulomb Unit Weight: 120 pcf Cohesion Fn: In-Situ Clay (Below EL. 370 ft) Phi: 0 ° Piezometric Line: 1

Name: Water EL. 370 (R to L)
File Name: Channelization Project.gsz
Directory: \\mvs-netapp1\ec\EC-G\Levee_Safety\Missouri_Levees\SteGenevieve\Levee and Channelization Project\C - Stability Models\
Last Edited By: Redell, Chris MVS

The channelization is from stations 25+00 to 50+00.

The new levee on the north of the creek is from stations 32+00 to 56+00.

The existing levee on the south of the creek that will be raised is from station 34+00 to 44+00.

Minimum Factors of Safety - Levee Slope Stability

End of Construction : FoS = 1.3

Long Term : FoS = 1.4

Borings 1 -12 were evaualted for this reach

Specifically 10, 11, and 12 for Sta. 40+00

Appendix IV

# References

Ste. Genevieve GRR

# 1. DESIGN STANDARDS AND REFERENCES

## 1.1. Design guidance

The following design guidance documents were used to complete the tasks presented in this report:

EM 1110-1-1904, Settlement Analysis, September 1990

EM 1110-2-1913, Design and Construction of levees, April 2000

## 1.2. Journal & Book references

Duncan, J., Horz, R., and Yagi, T., 2007. "Shear Strength Correlations For Geotechnical Engineering." Virginia Tech Department of Civil Engineering – Geotechnical Engineering, August 1989.

Brandon, T. L. (2011), "S-Case Analysis Parameters for Outfall Canals," *G-CAT March 15, 2011*.

Brandon, Thomas et al. Strenght and Compressibility Correlations for New Orleans Area Soils. Report submitted to the New Orleans District U.S. Army Corps of Engineers. Virginia Tech, Blacksburg, Virginia. January 6, 2011.

Fredlund, D. G., and H. Rahardjo (1993), *Soil Mechanics for Unsaturated Soils*, Wiley Interscience, 544 pages.

## 1.3. Computer programs

The following computer programs were used to complete the tasks presented in this report:

Geostudio 2007 program, Version 7.23 (Seep/W and Slope/W), Geo-Slope International, Ltd. Calgary, Alberta, Canada.

CSETT, Induced Stresses and Consolidation Settlements program, Version date 2002/02/28, US Army Corps of Engineers Waterways Experiment Station Information Technology Laboratory, Vicksburg, MS; Computer Aided Structural Engineering Project.

http://dnr.mo.gov/geology/geostrat.htm

## 1.4. Project documents

The following documents were referenced to complete the tasks presented in this report:
US Army Corps of Engineers, St. Louis District, St. Louis, MO: "Ste. GEN GRR," October, 2010

Appendix V

# Floodproofing

Ste. Genevieve GRR

# Floodproofing Alternative

Floodproofing is considered any combination of structural and non-structural additions, changes, or adjustments to structures which reduce or eliminate flood damage to real estate. It is recommend by FEMA that floodproofing measures be implemented up to one foot above the base flood elevation.

## 1. Flood Characteristics

The flood source for the 12 structures located along South Gabouri Creek is South Gabouri Creek. The flood source for 7 structures located along North Gabouri Creek is North Gabouri Creek. Both streams are prone to flash flooding providing very little flood warning time and very short flood duration. Based on resident feedback within the project area the time from out of channel flooding to flood peak occurs in 30-60 minutes. The overall flood duration defined as out of channel flow is generally 1-2 hours. Flood velocity along the streams can be hazardous (greater than 3 feet per second) but velocity information from St Louis District hydraulic analysis shows that velocities at all structures considered for floodproofing is less than 3 feet per second.

## 2. Floodproofing Techniques

For evaluation of the North and South Gabouri Creeks six floodproofing measures were considered: (1) relocation/buyout of the structure, (2) elevation of the structure, (3) wet floodproofing of the structure, (4) dry floodproofing of the structure, (5) walls at openings, and (6) berms around the structure.

Additional floodproofing data and techniques can be found in FEMA P-312, Homeowner's Guide to Retrofitting.

### 2.1. Structure Re-location/Buyout of Structures

This measure includes physically relocating the structure to a flood free location or purchasing and demolishing the structure. Any and all such purchases would have permanent deed restrictions that would not allow damageable structures to ever be built again in these areas. These lands would be owned by the non Federal sponsor. The newly vacant land will allow conversion of the developed property to a "new use" such as recreation and/or ecosystem restoration. .

### 2.2. Elevation of the Structure

Elevation of structures is possible on many structures including structures with features such as brick chimneys, brick veneer, slab on grade, etc. This measure includes physically raising the structures using a method called "extended foundation walls." This would be a closed foundation system extending the existing foundation walls upward to the base of the elevated structures with new concrete or concrete masonry unit walls. A structural evaluation will be required to determine if the existing foundation is suitable or a new foundation is required for all structures that this measure is chosen.

When elevating a structure it is also required to fill areas that are below the flood elevation such as basement and crawl spaces. These areas will be filled with coarse sand or pea gravel to an elevation 30" below the joist of the elevated structure. Filling the areas below the flood elevation to an elevation 30” below the joists prevents these areas from being used or “finished off” and subsequently flood damage still accurse.

### 2.3. Wet Floodproofing of Structures

This measure would be applicable to any structures to reduce any damage to the parts of the structure that are below the flood elevation. These areas include basements and crawl spaces. These areas will be filled with coarse sand or pea gravel to an elevation 30” below the joist of the elevated structure. Filling the areas below the flood elevation to an elevation 30” below the joists prevents these areas from being used or “finished off” and subsequently flood damage still accurse. Any utilities would be relocated to areas above the design flood elevation or waterproofed. Items such as electrical connection boxes can be waterproofed. Vents that meet the FEMA requirements for ingress and egress of water are also required.

### 2.4. Dry Floodproofing of Structures

This measure is considered making a structure watertight below the level that needs flood protection to prevent floodwaters from entering. Making the structure watertight requires sealing the walls with a waterproof coating and construction of a brick veneer to protect the waterproof coating. The waterproof coating and brick veneer would be applied to the walls of the existing structure. Typical structures, residential and commercial, can usually withstand the pressure exerted by water up to about 3 feet deep without cracking or collapse. Structures at Ste Genevieve will only be considered for dry floodproofing when the design flood elevation is no more than 3 feet above the existing first floor elevation. Structures with basements and crawl spaces will be considered for this measure. Low permeable clay soil will need to be in direct contact with the basement walls to prevent flood waters from getting under the waterproof coating or exerting a large hydrostatic force on the basement walls.

If dry flood proofing with basements were to be used additional requirements would be required such as the following:

- A one way valve will be placed in the sewer line to prevent sewer back flows into the basement.
- A waterproof coating will be applied to the existing walls from one foot below grade to the design flood elevation.
- A veneer wall will be constructed to protect the waterproof coating. The veneer wall will extend from below the frost line to no more than 3 feet above the first floor.
- All openings to the structure that are not necessary that are below the design flood elevation will be filled in. This includes windows, doors, and vents.
- All openings to the structure that are necessary, waterproof doors or windows will be installed that do not require human intervention to make them watertight.
- A French drain will be installed around the base of the veneer wall. The French drain will required a sump pump in the basement that has a backup power source. The sump pump would evacuate any water in the French drain as well as any water seeping through the veneer wall, watertight door, etc.
- All outside utilities like heat pumps would be elevated to above the design flood elevation.

### 2.5. Walls at Openings

This measure includes the construction of walls at openings that are below the design flood elevation and below the first floor elevation, such as exterior basement door openings. The top of these walls would be at or above the design flood elevation and the bottom would be below the frost line. These walls would require either steps to cross over the wall or a self placing closure structure that would install itself as the flood water rose. A sump pump with a backup power source would also be required.

### 2.6. Berms around the Structure

This measure includes placing a berm around a structure to hold back flood water. Driveways and access ways would cross over the berm to avoid the need for a closure structure. An interior drainage system with a backup power supply would be required.

## 3. Other Floodproofing Considerations

### 3.1. Design Flood Elevation

The design flood elevation is 1% chance event.

### 3.2. Flood Insurance

Based on FEMA P-312, Homeowner's Guide to Retrofitting only elevation, relocation, and allowable wet floodproofing, and demolition can be used to meet the minimum requirements of the National Flood Insurance Program (NFIP).

Allowable wet floodproofing that can lead to NFIP compliance is (1) the area is limited to parking, access, or storage, (2) the area is designed to allow for automatic entry and exit of flood waters through the use of flood openings, and (3) the area uses only flood damage-resistant materials below the design flood event.

### 3.3. Substantial Improvements

Substaintal improvements is defined as an improvement to an existing structure in the 100 year flood plain as determined by the National Flood Insurance Program (NFIP) where the improvement cost is more than 50% of the pre improved value of the structure. If the substantial improvement criteria is triggered by a dry floodproofing project on a particular structure, that structure must come into compliance with the minimum flood plain management standards of the NFPI which means the structure must be elevated to at or above the 100 year flood or relocated/bought out.

## 4. Site Visit

A site visit was conducted 25-26 August, 2010 to evaluate floodproogfing techniques on 12 structures. 11 Structures were evaluated on the South Gabouri Creek and 1 structure was evaluated on the North Gabouri Creek.

Day 1 – Wednesday, 25 August 2010 attendees: Michelle Kniep (project manager), Larry Buss (non-structural advisor), Joie Lyerla (real estate), John Boeckmann (hydraulics), Kory Hannah (civil engineering), Terry Norris (cultural resources), Brenda Schloss (City planning)

Day 2 - Thursday, 26 August 2010 attendees: Michelle Kniep (project manager), Larry Buss (non-structural advisor), Joie Lyerla (real estate), John Boeckmann (hydraulics), Nancy Tokraks (civil), Clint Dougherty (structural), Paige Scott (cost estimates), Terry Norris (cultural resources), Rebecca Prater (SHPO), Angelo Logan (SHPO), Brenda Schloss (City planning).

## 5. Damaged Structures

Based on hydraulic modeling, 1st floor elevation surveys, and economic analysis 7 structures were determined to be damaged on the North Gabouri Creek and 10 structures were determined to be damaged on the South Gabouri Creek. See Table 1 and 2. The damage elevation was determined for each structure based on the surveyed 1st floor elevation and the structure type. The damage elevation is 0 feet below the first floor elevation for slab on grade structures, 2 feet below the first floor elevation for structures with crawl spaces and basements without exterior entrances, and 7 feet below the first floor elevation of structures with basements with exterior entrances. All structures that were within 1 foot of their damage elevation were also considered for flood protection measures to account for variations in models and to provide a 1 foot freeboard.

| Structure # | HEC-RAS Model Cross Section # | Bank | 1st Floor Elevation | Damage Elevation | 1% Flooding Event Elevation | Height of Water above Damage Elevation (FT) | Height of First Floor Flooding (FT) | Velocity at location of Structure (fps) |
|---|---|---|---|---|---|---|---|---|
| 300 | 4,118 | Left | 388.72 | 385.72 | 386.07 | 0.35 | -2.65 | 1.4 |
| 310 | 4,118 | Left | 386.81 | 385.81 | 386.07 | 0.26 | -0.74 | 1.4 |
| 311 | 4,118 | Left | 388.1 | 385.1 | 386.07 | 0.97 | -2.04 | 1.4 |
| 316 | 4,118 | Left | 388.89 | 385.89 | 386.07 | 0.18 | -2.82 | 1.4 |
| 408 | 4,751 | Left | 389.43 | 386.43 | 388.85 | 2.42 | -0.58 | 0.2 |
| 452 | 8,289 | Right | 394.73 | 391.73 | 395.39 | 3.66 | 0.66 | 1.7 |
| 454 | 8,711 | Left | 398.1 | 395.1 | 396.52 | 1.42 | -1.58 | 2.1 |

***Note: HEC-RAS cross section names represent the distance upstream of the Ste. Genevieve Pump Station***

Table 1. North Gabouri Creek Damaged Structures

| Structure # | HEC-RAS Model Cross Section # | Bank | 1st Floor Elevation | Damage Elevation | 1% Flooding Event Elevation | Height of Water above Damage Elevation (FT) | Height of First Floor Flooding (FT) | Velocity at location of Structure (fps) |
|---|---|---|---|---|---|---|---|---|
| 257 | 8,266 | Right | 403.82 | 400.82 | 406.04 | 5.22 | 2.22 | 2.7 |
| 246 | 6,392 | Left | 403.91 | 395.91 | 397.77 | 1.86 | -6.14 | 1.5 |
| 244 | 6,187 | Left | 397.8 | 394.8 | 397.26 | 2.46 | -0.54 | 2.1 |
| 255 | 6,187 | Right | 398.73 | 395.73 | 397.26 | 1.53 | -1.47 | 1.5 |
| 240 | 5,867 | Left | 397.96 | 394.96 | 395.20 | 0.24 | -2.76 | 1.3 |
| 233 | 5,714 | Left | 396.89 | 393.89 | 394.82 | 0.93 | -2.07 | 1.6 |
| 236 | 5,714 | Left | 396.48 | 393.48 | 394.82 | 1.34 | -1.66 | 1.6 |
| 232 | 5,568 | Left | 394.98 | 393.98 | 394.34 | 0.36 | -0.64 | 1.5 |
| 209 | 5,063 | Left | 394.91 | 391.91 | 393.37 | 1.46 | -1.54 | 1.0 |
| 207 | 4,948 | Left | 395.48 | 382.48 | 393.18 | 0.7 | -2.3 | 1.3 |
| 202 | 4,807 | Left | 392.5 | 391.5 | 392.91 | 1.41 | 0.41 | 1.8 |
| 76 | 2,624 | Left | 387.59 | 384.59 | 384.91 | 0.32 | -2.68 | 2.4 |

***Note: HEC-RAS cross section names represent the distance upstream of the Ste. Genevieve Pump Station***

Table 2. South Gabouri Creek Damaged Structures

Basic data and alternatives for each structure were developed based on the site visits conducted, structure surveys performed, hydraulic model data, and economic model data.

### 5.1. Structure #300

- Basic data:
    - Listed or eligible to be listed on the National Register of Historic Places
    - Basement flooding approximately 2.5 feet below first floor elevation
    - Crawl Space flooding approximately 2.5 feet below first floor elevation
    - Velocity is 1.4 feet per second
- Wood frame construction
- Alternatives:
    - Structure Re-location
        - Relocation of the structure is feasible. Due to the complexity and difficulty of moving a structure other floodproofing technique are preferred.
    - Buyout
        - No data
    - Elevate
        - No data on Foundation
        - Design Flood Elevation plus 1 foot is 2.65 feet below first floor elevation.
        - Elevation of the structure is not necessary. The design flood elevation plus 1 foot is below the first floor elevation and wet floodproofing is a more suitable alternative.

- Wet Floodproofing
    - Design Flood Elevation plus 1 foot is 2.65 feet below first floor elevation.
    - Move utilities above the design flood elevation or waterproof
    - Fill basement and crawl space to within 30” of first floor joists
    - Fragment basement floor
    - Compensate for loss of basement and crawl space.
- Dry Floodproofing
    - Soils are clay
    - Design Flood Elevation plus 1 foot is 2.65 feet below first floor elevation.
    - Watertight doors and windows for openings below design flood elevation
    - Elevate exterior utilities above design flood elevation

Photo 5.1a

### 5.2. Structure #310

- Structure has been removed.

### 5.3. Structure #311

- Basic data:
    - Basement flooding approximately 2 foot below first floor elevation
    - Velocity is 1.4 feet per second
- Wood frame construction
- Alternatives:
    - Structure Re-location
        - Relocation of the structure is feasible. Due to the complexity and difficulty of moving a structure other floodproofing technique are preferred.
    - Buyout
        - No data
    - Elevate
        - No data on Foundation
        - Design Flood Elevation plus 1 foot is 2 foot below first floor elevation.

    - Elevation of the structure is not necessary. The design flood elevation plus 1 foot is below the first floor elevation and wet floodproofing is a more suitable alternative.
  - Wet Floodproofing
    - Design Flood Elevation plus 1 foot is 2 foot below first floor elevation.
    - Move utilities above the design flood elevation or waterproof
    - Fill basement and crawl space to within 30” of first floor joists
    - Fragment basement floor
    - Compensate for loss of basement and crawl space.
  - Dry Floodproofing
    - Soils are clay
    - Design Flood Elevation plus 1 foot is 2 foot below first floor elevation.
    - Watertight doors and windows for openings below design flood elevation
    - Elevate exterior utilities above design flood elevation


Photo 5.3a

## 5.4. Structure #316

- Basic data:
  - Crawl Space flooding approximately 3 feet below first floor elevation
  - Velocity is 1.4 feet per second
- Wood frame construction
- No action is recommended. Design flood elevation plus 1 foot is 0.2 feet above anticipated crawl space floor.

Photo 5.4a

### 5.5. Structure #408

- Basic data:
    - Has as SHPO preservation covenant.
    - Basement flooding approximately 1 foot below first floor elevation
    - Velocity is 0.2 feet per second
- Unreinforced masonry construction
- Alternatives:
    - Structure Re-location
        - Relocation of the structure is feasible. Due to the complexity and difficulty of moving a structure other floodproofing technique are preferred.
    - Buyout
        - No data
    - Elevate
        - No data on Foundation
        - Design Flood Elevation plus 1 foot is 0.58 feet below first floor elevation.
        - Elevation of the structure is not necessary. The design flood elevation plus 1 foot is below the first floor elevation and wet floodproofing is a more suitable alternative.
    - Wet Floodproofing
        - Design Flood Elevation plus 1 foot is 0.58 feet below first floor elevation.
        - Move utilities above the design flood elevation or waterproof
        - Fill basement and crawl space to within 30” of first floor joists
        - Fragment basement floor
        - Compensate for loss of basement and crawl space.
    - Dry Floodproofing
        - Soils are clay
        - Design Flood Elevation plus 1 foot is 0.58 feet below first floor elevation.
        - Watertight doors and windows for openings below design flood elevation
        - Elevate exterior utilities above design flood elevation


Photo 5.5a

### 5.6. Structure #452 – [redacted]

- Basic data:
    - National Landmark contributing structure
    - First floor flooding to 0.66 feet above first floor elevation
    - Velocity is 1.7 feet per second
- Vertical log foundation is under the lower section of the house - across the front porch and on the right side.
- Full basement, access is from inside or at ground level from outside cellar door. Furnace, water heater.
- A/C on ground.
- Alternatives:
    - Structure Re-location
        - Parts of the structure are of a vertical log construction. Relocation is not a feasible option.
    - Buyout
        - Owner will consider buyout.
    - Elevate
        - Foundation is not suitable for elevation.
        - Parts of the structure are of a vertical log construction
    - Wet Floodproofing
        - Design flood elevation plus 1 foot is 0.66 feet above first floor elevation. Wet floodproofing is not a feasible option due to design flood elevation plus 1 foot being above first floor elevation.
    - Dry Floodproof with veneer wall against house
        - Soils are clay
        - Design flood elevation plus 1 foot is 0.66 feet above first floor elevation. A waterproof coating and a brick veneer would be required. Brick veneer would extend below the frost depth.
        - Watertight door for front door opening
        - Seal off external basement access and basement windows
        - Elevate exterior utilities above design flood elevation
    - Berm around Structure
        - Berm would be 8 to 10 feet tall
        - Access would need to be provided over the berm
        - A pump with backup power supply would be required


Photo 5.6a


Photo 5.6b


Photo 5.6c


Photo 5.6d


Photo 5.6e

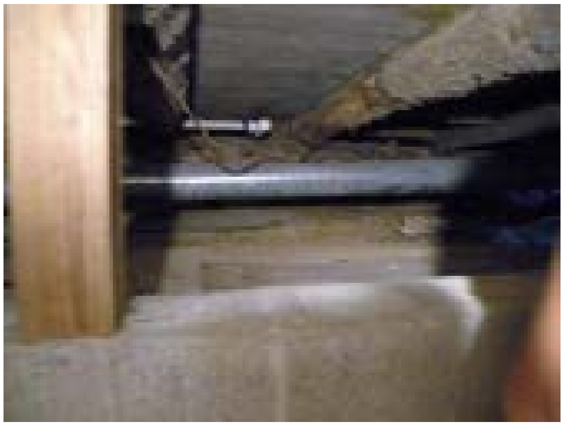


Photo 5.6f

Photo 5.6g

Photo 5.6h

### 5.7. Structure #454

- Basic data:
    - Basement flooding approximately 1.5 foot below first floor elevation
    - Velocity is 2.1 feet per second
- Wood frame construction
- Alternatives:
    - Structure Re-location
        - Relocation of the structure is feasible. Due to the complexity and difficulty of moving a structure other floodproofing technique are preferred.
    - Buyout
        - No data
    - Elevate
        - No data on Foundation
        - Design Flood Elevation plus 1 foot is 1.58 feet below first floor elevation.
        - Elevation of the structure is not necessary. The design flood elevation plus 1 foot is below the first floor elevation and wet floodproofing is a more suitable alternative.
    - Wet Floodproofing
        - Design Flood Elevation plus 1 foot is 1.58 feet below first floor elevation.
        - Move utilities above the design flood elevation or waterproof
        - Fill basement and crawl space to within 30” of first floor joists
        - Fragment basement floor
        - Compensate for loss of basement and crawl space.
    - Dry Floodproofing
        - Soils are clay
        - Design Flood Elevation plus 1 foot is 1.58 feet below first floor elevation.
        - Watertight doors and windows for openings below design flood elevation
        - Elevate exterior utilities above design flood elevation

Photo 5.7a

### 5.8. Structure #257 – [redacted]

- Basic data:
    - Listed or eligible to be listed on the National Register of Historic Places
    - Crawlspace flooding approximately 3 feet above first floor elevation
    - Velocity is 2.7 feet per second
- Currently Unoccupied. Being used for storage
- Alternatives:
    - Structure Re-location
        - Relocation of the structure is feasible. Due to the complexity and difficulty of moving a structure other floodproofing technique are preferred.
    - Buyout
        - No data.
    - Elevate
        - Foundation is in poor condition. Likely need to raise structure on new foundation
        - Move utilities above the design flood elevation or waterproof
        - Fill basement to within 30” of first floor joists
        - Fragment basement floor
        - Compensate for loss of basement space.
        - Design flood elevation plus 1 foot is 2.7 feet above first floor elevation
    - Wet Floodproofing
        - Design flood elevation plus 1 foot is 2.7 feet above first floor elevation. Wet floodproofing is not a feasible option due to design flood elevation plus 1 foot being above first floor elevation.
    - Dry Floodproof with veneer wall against house
        - Soils are clay
        - Design flood elevation plus 1 foot is 2.7 feet above first floor elevation. A waterproof coating and a brick veneer would be required. Brick veneer would extend below the frost depth.
        - Watertight door for front and back door opening
        - Elevate exterior utilities above design flood elevation

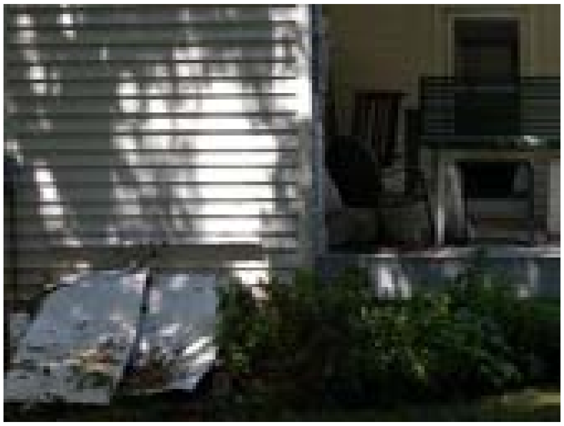


Photo 5.8a

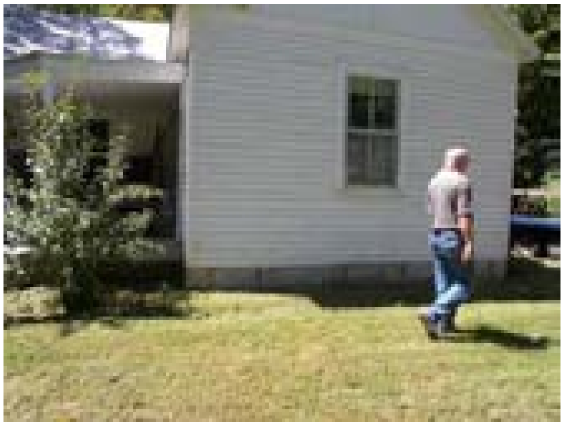


Photo 5.8b

Photo 5.8c

Photo 5.8d

Photo 5.8e

Photo 5.8f

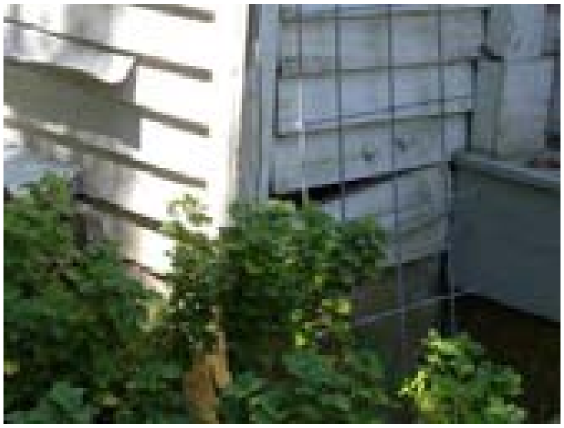


Photo 5.8g


Photo 5.8h


Photo 5.8i

### 5.9. Structure #246 – [redacted]

- Basic data:
  - Basement flooding approximately 6 feet below first floor
  - Velocity is 1.5 feet per second
- Exterior access to the basement has a concrete wall constructed to prevent flooding. Wall appears to be of adequate height.
- No action needed.

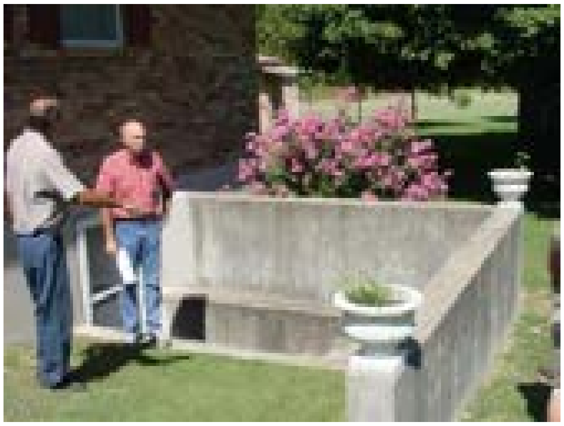


Photo 5.9a


Photo 5.9b

## 5.10. Structure #244 – [redacted]

- Basic data:
    - Listed or eligible to be listed on the National Register of Historic Places
    - Basement flooding approximately 0.5 feet below first floor elevation
    - Velocity is 2.1 feet per second
- Exterior access to full basement
- After 1993 water heater and utilities were removed from basement.
- Structure is currently unoccupied.
- Brick foundation in poor condition.
- Alternatives:
    - Structure Re-location
        - Relocation of the structure is feasible. Due to the complexity and difficulty of moving a structure other floodproofing technique are preferred.
    - Buyout
        - Owner is willing to consider buyout
    - Elevate
        - Foundation is in poor condition
        - Design Flood Elevation plus 1 foot is 0.5 feet below first floor elevation.
        - Elevation of the structure is not necessary. The design flood elevation plus 1 foot is below the first floor elevation and wet floodproofing is a more suitable alternative.
    - Wet Floodproofing
        - Move utilities above the design flood elevation or waterproof
        - Fill basement and crawl space to within 30” of first floor joists
        - Fragment basement floor
        - Compensate for loss of basement and crawl space.
    - Dry Floodproof with veneer wall against house
        - Soils are clay
        - Design flood elevation plus 1 foot is 0.5 feet below first floor elevation
        - Watertight door for front door opening
        - Seal off external basement access and provide access from inside
        - Elevate exterior utilities above design flood elevation

Photo 5.10a

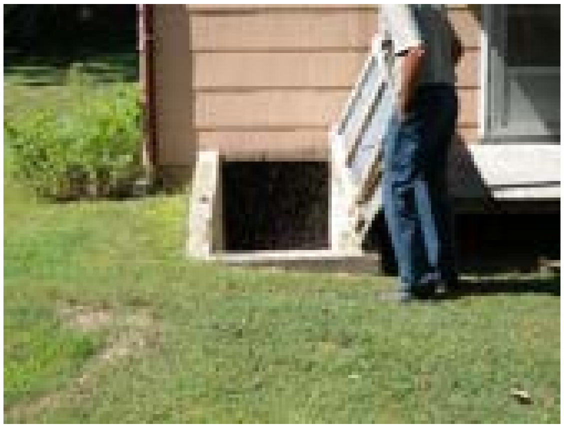


Photo 5.10b

Photo 5.10c

Photo 5.10d

Photo 5.10e

Photo 5.10f

### 5.11. Structure #255 – [redacted]

- Basic data:
    - Listed or eligible to be listed on the National Register of Historic Places
    - Basement flooding approximately 2 foot below first floor elevation
    - Velocity is 1.5 feet per second
- Full basement, access is at ground level from outside (cellar door), furnace

- A/C on the ground
- May have been 3” on the first floor in the May 2009 flood (owners were not clear about the timeframe)
- Alternatives:
    - Structure Re-location
        - Parts of the structure are of a vertical log construction. Relocation is not a feasible option.
    - Buyout
        - Owner stated not interested in buyout.
    - Elevate
        - Not sure about foundation (didn’t spend much time in basement due to poor environmental conditions)
        - Design flood elevation plus 1 foot is 1.5 feet below first floor elevation
        - Elevation of the structure is not necessary. The design flood elevation plus 1 foot is below the first floor elevation and wet floodproofing is a more suitable alternative.
    - Wet Floodproofing
        - Move utilities above the design flood elevation or waterproof
        - Design flood elevation plus 1 foot is 1.5 feet below first floor elevation
        - Fill basement and crawl space to within 30” of first floor joists
        - Fragment basement floor
        - Compensate for loss of basement and crawl space.
    - Dry Floodproof with veneer wall against house
        - Soils are clay
        - Design flood elevation plus 1 foot is 1.5 feet below first floor elevation
        - Watertight door for front door opening
        - Seal off external basement access and provide access from inside
        - Elevate exterior utilities above design flood elevation

Photo 5.11a

Photo 5.11b

Photo 5.11c

### 5.12. Structure #240 – [redacted]

- Basic data:
  - Listed or eligible to be listed on the National Register of Historic Places
  - Basement flooding approximately 3 feet below first floor
  - Velocity is 1.3 feet per second
- Structure has a stone foundation except walled-in back porch foundation (NE corner) is concrete.
- Full basement, access is from inside or at ground level from outside. Furnace and water heater is located in the basement.3 window wells.
- A/C on ground
- Utility room in back is lower than first floor, contains washer, dryer, water heater
- Rental property
- Alternatives:
  - Structure Re-location
    - Relocation of the structure is feasible. Due to the complexity and difficulty of moving a structure other floodproofing technique are preferred.
  - Buyout
    - Owner is silent on topic
  - Elevate
    - Foundation is in poor condition
    - Design flood elevation plus 1 foot is 2.7 feet below first floor elevation
    - Elevation of the structure is not necessary. The design flood elevation plus 1 foot is below the first floor elevation and wet floodproofing is a more suitable alternative.
  - Wet Floodproofing
    - Design flood elevation plus 1 foot is 2.7 feet below first floor elevation
    - Move utilities above the design flood elevation or waterproof
    - Fill basement and crawl space to within 30” of first floor joists
    - Fragment basement floor
    - Compensate for loss of basement and crawl space.
  - Dry Floodproof with veneer wall against house
    - Soils are clay
    - Design flood elevation plus 1 foot is 2.7 feet below first floor elevation
    - Watertight door for front door opening

        - Seal off external basement access and basement windows
        - Elevate exterior utilities above design flood elevation


Photo 5.12a


Photo 5.12b


Photo 5.12c


Photo 5.12d


Photo 5.12e

### 5.13. Structure #233 – [redacted]

- Basic data:
    - Listed or eligible to be listed on the National Register of Historic Places
    - Basement flooding approximately 2 feet below fist floor elevation

    - Velocity is 1.6 feet per second
- Foundation is in poor condition. It has concrete basement walls with evidence of concrete disintegration observed on multiple wall surfaces. A similar condition was noted in some other homes, but not to the extent of #233. Recommend further investigation of the foundation, i.e. concrete core samples or nondestructive testing to determine the in situ concrete strength. New foundation walls may be necessary.
- Full basement, interior and exterior. No utilities located in the basement.
- The windows on the North and South wall are bricked-up to within a few inches of the top of foundation
- Alternatives:
    - Structure Re-location
        - Relocation of the structure is feasible. Due to the complexity and difficulty of moving a structure other floodproofing technique are preferred.
    - Buyout
        - Owner is silent on topic
    - Elevate
        - Foundation is in poor condition
        - Design flood elevation plus 1 foot is 2.0 feet below first floor elevation
        - Elevation of the structure is not necessary. The design flood elevation plus 1 foot is below the first floor elevation and wet floodproofing is a more suitable alternative.
    - Wet Floodproofing
        - Design flood elevation plus 1 foot is 2.0 feet below first floor elevation
        - Move utilities above the design flood elevation or waterproof
        - Fill basement and crawl space to within 30” of first floor joists
        - Fragment basement floor
        - Compensate for loss of basement and crawl space.
    - Dry Floodproof with veneer wall against house
        - Soils are clay
        - Design flood elevation plus 1 foot is 2.0 feet below first floor elevation
        - Watertight door for front door opening
        - Seal off external basement access and basement windows
        - Elevate exterior utilities above design flood elevation

Photo 5.13a

Photo 5.13b

Photo 5.13c

Photo 5.13d

Photo 5.13e

Photo 5.13f

Photo 5.13g

Photo 5.13h

Photo 5.13i

Photo 5.13j

## 5.14. Structure #236

- Basic data:
    - Listed or eligible to be listed on the National Register of Historic Places
    - Basement flooding approximately 2 foot below first floor elevation
    - Velocity is 1.6 feet per second
- Wood frame construction
- Alternatives:
    - Structure Re-location
        - Relocation of the structure is feasible. Due to the complexity and difficulty of moving a structure other floodproofing technique are preferred.
    - Buyout
        - No data
    - Elevate
        - No data on Foundation
        - Design Flood Elevation plus 1 foot is 1.7 feet below first floor elevation.
        - Design flood elevation plus 1 foot is 1.6 feet below first floor elevation
        - Elevation of the structure is not necessary. The design flood elevation plus 1 foot is below the first floor elevation and wet floodproofing is a more suitable alternative.
    - Wet Floodproofing
        - Design Flood Elevation plus 1 foot is 1.7 feet below first floor elevation.
        - Move utilities above the design flood elevation or waterproof
        - Fill basement and crawl space to within 30” of first floor joists
        - Fragment basement floor
        - Compensate for loss of basement and crawl space.
    - Dry Floodproofing
        - Soils are clay
        - Design Flood Elevation plus 1 foot is 1.7 feet below first floor elevation
        - Watertight doors and windows for openings below design flood elevation
        - Elevate exterior utilities above design flood elevation

Photo 5.14a

## 5.15. Structure #232

- Basic data:
    - Basement flooding approximately 0.7 feet below first floor elevation
    - Velocity is 1.5 feet per second
- Wood frame construction
- Alternatives:
    - Structure Re-location
        - Relocation of the structure is feasible. Due to the complexity and difficulty of moving a structure other floodproofing technique are preferred.
    - Buyout
        - No data
    - Elevate
        - No data on Foundation
        - Design Flood Elevation plus 1 foot is 0.7 feet below first floor elevation.
        - Elevation of the structure is not necessary. The design flood elevation plus 1 foot is below the first floor elevation and wet floodproofing is a more suitable alternative.
    - Wet Floodproofing
        - Design Flood Elevation plus 1 foot is 0.7 feet below first floor elevation.
        - Move utilities above the design flood elevation or waterproof
        - Fill basement and crawl space to within 30” of first floor joists
        - Fragment basement floor
        - Compensate for loss of basement and crawl space.
    - Dry Floodproofing
        - Soils are clay
        - Design Flood Elevation plus 1 foot is 0.7 feet below first floor elevation.
        - Watertight doors and windows for openings below design flood elevation
        - Elevate exterior utilities above design flood elevation

Photo 5.15a

## 5.16. Structure #209 – [redacted]

- Basic data:
  - Basement flooding approximately 1 foot below first floor elevation
  - Crawl space flooding approximately 2 foot below fist floor elevation
  - Velocity is 1.0 feet per second
- Basement only on porch side, crawl space on creek side
- Water heater, washer, dryer, functional wood stove, furnace (suspended from floor), electrical panel
- Window on north side of basement, sealed vents on crawl space.
- Alternatives:
  - Structure Re-location
    - Relocation of the structure is feasible. Due to the complexity and difficulty of moving a structure other floodproofing technique are preferred.
  - Buyout
    - Owner is willing to consider buyout
  - Elevate
    - Foundation is in good condition
    - Design Flood Elevation plus 1 foot is 1.5 feet below first floor elevation.
    - Elevation of the structure is not necessary. The design flood elevation plus 1 foot is below the first floor elevation and wet floodproofing is a more suitable alternative.
  - Wet Floodproofing
    - Design Flood Elevation plus 1 foot is 1.5 feet below first floor elevation.
    - Move utilities above the design flood elevation or waterproof
    - Fill basement and crawl space to within 30” of first floor joists
    - Fragment basement floor
    - Compensate for loss of basement and crawl space.
  - Dry Floodproofing
    - Soils are clay
    - Design Flood Elevation plus 1 foot is 1.5 feet below first floor elevation.
    - Watertight door for front door opening
    - Elevate exterior utilites above design flood elevation


Photo 5.15a


Photo 5.15b

### 5.17. Structure #207 – [redacted]

- Basic data:
    - Basement flooding approximately 2 feet below first floor elevation
    - Slab on grade flooding approximately 1 foot below top of slab
    - Velocity is 1.3 feet per second
- Full basement, access is at ground level from outside
- Utility room in back is lower than first floor, contains washer, dryer, water heater
- Rental property
- Alternatives:
    - Structure Re-location
        - Relocation of the structure is feasible. Due to the complexity and difficulty of moving a structure other floodproofing technique are preferred.
    - Buyout
        - Owner is willing to consider buyout.
    - Elevate
        - Foundation is in good condition
        - Design flood elevation plus 1 foot is 2.3 feet below first floor elevation
        - Design flood elevation plus 1 foot is 1 foot below top of slab on grade.
        - Elevation of the structure is not necessary. The design flood elevation plus 1 foot is below the first floor elevation and wet floodproofing is a more suitable alternative.
    - Wet Floodproofing
        - Design flood elevation plus 1 foot is 2.3 feet below first floor elevation
        - Design flood elevation plus 1 foot is 1 foot below top of slab on grade.
        - Move utilities above the design flood elevation or waterproof
        - Fill basement and crawl space to within 30” of first floor joists
        - Fragment basement floor
        - Compensate for loss of basement and crawl space.
    - Dry Floodproof with veneer wall against house
        - Soils are clay
        - Design flood elevation plus 1 foot is 2.3 feet below first floor elevation
        - Design flood elevation plus 1 foot is 1 foot below top of slab on grade.
        - Watertight door for front door opening

        - Seal off external basement access and provide access from inside
        - Elevate exterior utilites above design flood elevation

Photo 5.17a

Photo 5.17b

Photo 5.17a

Photo 5.17b

### 5.18. Structure #202

- Structure has been removed.

### 5.19. Structure #76

- Basic data:
    - Listed or eligible to be listed on the National Register of Historic Places
    - Crawl Space flooding approximately 3 feet below first floor elevation
    - Velocity is 2.4 feet per second
- Wood frame construction
- Alternatives:
    - Structure Re-location
        - Parts of the structure are of a vertical log construction. Relocation is not a feasible option.
    - Buyout
        - No data

- Elevate
  - No data on Foundation
  - Design Flood Elevation plus 1 foot is 2.68 feet below first floor elevation.
  - Design flood elevation plus 1 foot is 1.6 feet below first floor elevation
  - Elevation of the structure is not necessary. The design flood elevation plus 1 foot is below the first floor elevation and wet floodproofing is a more suitable alternative.
- Wet Floodproofing
  - Design Flood Elevation plus 1 foot is 2.68 feet below first floor elevation.
  - Move utilities above the design flood elevation or waterproof
  - Fill basement and crawl space to within 30” of first floor joists
  - Fragment basement floor
  - Compensate for loss of basement and crawl space.
- Dry Floodproofing
  - Soils are clay
  - Design Flood Elevation plus 1 foot is 2.68 feet below first floor elevation.
  - Watertight doors and windows for openings below design flood elevation
  - Elevate exterior utilities above design flood elevation

Photo 5.19a

## 6. Summary of Floodproofing Alternatives

| Structure # | Historic | Structure Re-location | Buyout | Elevation | Wet Flood-proofing | Dry Flood-proofing | Walls | Berms |
|---|---|---|---|---|---|---|---|---|
| 300 | X | X | X | | X | X | | |
| 311 | | X | X | | X | X | | |
| 408 | X | X | X | | X | X | | |
| 452 | X | | X | | | X | | X |
| 454 | | X | X | | X | X | | |

Table 3. North Gabouri Creek Floodproofing Alternatives

| Structure # | Historic | Structure Re-location | Buyout | Elevation | Wet Flood-proofing | Dry Flood-proofing | Walls | Berms |
|---|---|---|---|---|---|---|---|---|
| 257 | X | X | X | X | | X | | |
| 244 | X | X | X | | X | X | | |
| 255 | X | | X | | X | X | | |
| 240 | X | X | X | | X | X | | |
| 233 | X | X | X | | X | X | | |
| 236 | X | X | X | | X | X | | |
| 232 | | X | X | | X | X | | |
| 209 | | X | X | | X | X | | |
| 207 | | X | X | | X | X | | |
| 76 | X | | X | | X | X | | |

Table 4. South Gabouri Creek Floodproofing Alternatives

## 7. Recommend Floodproofing Alternatives

### 7.1. Wet Floodproofing

Where wet floodproofing is a feasible alternative per table 3 and 4 it is the preferred alternative. Due to the depth of flooding, condition of each structure, technical challenges, and required human intervention dry flood was not the preferred floodproofing method. Additionally, the wet floodproofing methods as defined in the previous sections of this report meet the minimum requirements of the National Flood Insurance Program.

### 7.2. Structure 452

Due to its historic significance and unique location of structure 452, it was determined that any action taken to provide flood protect would result in unacceptable physical impacts to the structure and/or to the visual integrity of the setting. Therefore no action is recommended for structure 452.

### 7.3. Structure 257

Due to the depth of flooding, foundation conditions, and technical challenges elevation of structure 257 is the preferred alternative. Dry flood proofing was determined to be not an acceptable alternative because of the required human intervention and foundation condition.

| Structure # | Historic | Elevation | Wet Flood-proofing | No action Taken |
|---|---|---|---|---|
| 300 | X | | X | |
| 311 | | | X | |
| 408 | X | | X | |
| 452 | X | | | X |
| 454 | | | X | |

Table 5. North Gabouri Creek Recommend Floodproofing Alternative

| Structure # | Historic | Elevation | Wet Flood-proofing |
|---|---|---|---|
| 257 | X | X | |
| 244 | X | | X |
| 255 | X | | X |
| 240 | X | | X |
| 233 | X | | X |
| 236 | X | | X |
| 232 | | | X |
| 209 | | | X |
| 207 | | | X |
| 76 | X | | X |

Table 6. South Gabouri Creek Recommended Floodproofing Alternatives