FLOOD MITIGATION STRATEGY FEASIBILITY ANALYSIS AND CONCEPTUAL DESIGN

CITY OF MEDFORD, MASSACHUSETTS
JUNE 2020

KLEINFELDER PROJECT #20202050.001A

A Report Prepared for:

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June 2020
Kleinfelder Project No: 20202050.001A

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1 INTRODUCTION

1.1 BACKGROUND

The City of Medford (“City”) is interested in employing structural control measures and exploring green infrastructure opportunities to mitigate surface flooding of critical streets and neighborhoods within specific areas of South Medford.

This project is a continuation of the City’s prior stormwater flood modeling efforts, which were funded, in part, through a Massachusetts Municipal Vulnerability Preparedness (MVP) program Action Grant in 2019. In the prior study, the City’s hydrologic and hydraulic (H+H) model was refined and updated for South Medford. In the final report submitted to the City (June 2019), Tufts Park and Barry Playground were identified as high priority sites for the implementation of grey and green stormwater infrastructure strategies, as both sites were demonstrated to have significant potential for flood reduction in their respective neighborhoods.

This project is partly funded by an MVP Action Grant. This program has been a significant partner to the City to help understand flooding and develop this conceptual design.

Under Task 1A of this project, it was determined that the flood reduction benefit of stormwater infrastructure in Tufts Park would be more significant than in Barry Playground. Also, both locations were found to have a high groundwater table, making an infiltration-based approach infeasible. Based on Task 1A, the project focused on a stormwater retention/detention solution and evaluation of other green infrastructure opportunities at Tufts Park.

The Task 1A technical memorandum is included in Appendix A.

1.1.1 Site Location and Description

Tufts Park is an 8.4-acre public open space along Medford Street in a multi-family residential neighborhood. Tufts Park is used by the City for organized sports and recreation. The park is bounded to the west by Winchester Street and Granville Avenue, to the south by Morton Avenue, to the east by Medford Street, and to the north by the Marion Street. See below for a map of the project area with Tufts Park outlined in red.

Figure 1-1: Locus Map of Tufts Park

1.1.2 Flood Characteristics

Stormwater flows in South Medford concentrate quickly from small hills in Somerville. The concentrated stormwater flows pond in low-lying areas in various locations within South Medford, causing access problems to major streets. The mix of commercial and mostly high to medium density residential with limited open space available creates a highly urbanized environment in which accommodating new infrastructure to enhance the drainage system is a challenge.

This project focuses infrastructure improvements at Tufts Park, which is one of a few locations in South Medford with the available space for a significant stormwater retrofit system. Approximately 55 acres of drainage converge at Tufts Park, which is a large, flat, low lying area that frequently floods. Once flooded, the field takes time to drain and dry out due to a high groundwater table. As a large, low-lying park, Tufts Park benefits the City since the ponding that occurs on site reduces the volume of stormwater ponding and accumulation on the adjacent streets. However, ponding will still often occur on roads such as Morton Avenue, Medford Street, Main Street, and Marion Street. Photos of recent flooding at Tufts Park are provided on the following pages.

During significant storm events, the drainage system flowing into Tufts Park will back up into Granville Avenue and Winchester Street. The drainage system will overflow onto Harvard Street at an underpass beneath the railway. This flooding can disrupt travel on this important through street. Figure 4-7 illustrates the projected future condition of this type of flooding in the year 2070.

Refer to Appendix B for additional flooding photos.

Figure 1-2: Representative Flooding Photos (Source: Mike Nestor, City of Medford)

Figure 1-3: Representative Flooding Photos (Source: Kleinfelder)

1.2 SCOPE OF PROJECT

The project establishes the conceptual design basis of a new stormwater retention/detention tank in Tufts Park to help alleviate flooding at the Harvard Street underpass and to reduce the peak flow rate to the downstream storm drain system.

The following tasks were completed as part of this project, as amended, during the course of the project.

Task 1A – Preliminary Site Suitability – This task included conducting two borings at each of Barry Playground and Tufts Park. One of the borings at each park was completed as a groundwater observation well. The team collected soil jar samples for characterization and laboratory analysis and performed visual inspection and x-ray fluorescence testing of soil samples to develop an initial opinion of possible contaminants in the soil samples. Based primarily on groundwater depth, the conclusion derived from Task 1A activities was that infiltrating stormwater into the ground is infeasible.

The original project scope was adjusted based on the findings of Task 1A. Tasks 1B, 1C and 3 were eliminated from the project as these tasks were envisioned to support development of a conceptual design of an infiltration tank solution. The amended scope included an expansion of Task 4 – Conceptual Design and the associated project write up described in Task 6.

Task 2 – Tank Sizing – This task utilized the City's PCSWMM 2D storm drain model for South Medford to test three different tank concepts and a variety of tank sizes in order to recommend a preferred tank arrangement, operation mode, and storage volume. The design storm for the project is the 10-year, 24-hour storm in the year 2070. Chapter 4 of this report summarizes the modeling effort completed to test tank configuration alternatives and tank sizes.

Task 4 – Conceptual Design – This task developed the conceptual design of the infiltration tank addressing major design criteria for the project alternative selected in Task 2. In addition, an initial conceptual design drawing package was developed in AutoCAD illustrating the proposed tank system layout and construction details. Finally, this Task included the development of a construction cost estimate.

Task 5 – Evaluate Green Infrastructure Opportunities - This task included an evaluation and conceptual design of surface green infrastructure to capture and treat stormwater runoff at the selected site. In addition, this task included the conceptual design of an underdrain system to facilitate park drainage.

Task 6 – Draft and Final Report – The conceptual design of the stormwater tank and green infrastructure elements are described in this report.

Task 7 – Project Management and Meetings - Kleinfelder provided project management including quality assurance/quality control review, team coordination, schedule and budget monitoring and project progress meetings with the City of Medford.

2 EXISTING CONDITIONS AND FIELD PROGRAM

2.1 BASE MAPPING

Kleinfelder developed an existing conditions base plan utilizing the City's GIS augmented with additional drawing information provided by the City and the Massachusetts Water Resources Authority (MWRA). City records provided approximate locations of existing utilities at Tufts Park. Further, the MWRA records provided additional water main information for the two water mains crossing through Tufts Park.

Topographical and utility survey would be warranted during a subsequent design phase to verify the base mapping developed during this project.

2.2 RECORDS RESEARCH

2.2.1 Historic Uses

According to City records, Tufts Park was historically used as a clay pit. Clay was mined from the surface of the park. When the clay pit operations ceased, it was backfilled with urban fill.

In addition, the grassed lawn area in the northwest portion of Tufts Park was formerly the City of Medford swimming pool. According to City personnel, the pool was buried in place and its walls are still below ground today.

2.2.2 Utilities

A number of utilities exist in Tufts Park that have been identified through the base mapping effort. These utilities are displayed in Appendix D, Sheet EC-1 and listed below.

- Storm Drain – A 42" diameter stormwater conveyance crosses the park from west to east. This storm drain will be the point of diversion into the proposed tank.

- Water Mains – The MWRA owns two water mains within the park. The first water main is 20" diameter and runs parallel and to the north of the storm drain. The second water main is 24" diameter and runs from northwest to southeast.
- Sewer – A 12" sanitary sewer exists in the southwest portion of the park. The sewer will generally be outside of the project area.
- Buried Electric and Mast Lighting – buried electrical conduit for park lighting exists at the park. The conduits generally run along the outside perimeter of the park. The conduit size and bury depth is unknown.

2.3 FIELD INVESTIGATIONS

The following sections summarize the geotechnical and environmental existing conditions at Tufts Park. For a detailed assessment, refer to the Task 1A Technical Memorandum provided in Appendix A.

2.3.1 Geotechnical Conditions

Two borings (TP-B-101 and TP-B-102) were drilled at Tufts Park on November 13 and 14, 2019. TP-B-102 was finished as a groundwater observation well. Both borings were advanced just over 40-feet deep each.

The following layers of soil strata were observed in the borings.

Topsoil: Both borings encountered an approximately 6-inch-thick layer of topsoil at the ground surface. The topsoil was described as moist, dark brown fine to medium-grained sand with trace grass, roots, and organic silt.

Fill: Artificial Fill was encountered underlying the topsoil in both borings and extended to a depth of 13 feet below ground surface at TP-B-101 and 8 feet at TP-B-102 (OW). The Fill was generally described as brown, dark gray, black, medium to coarse-grained sand with gravel and silt and intermittent lenses of clay. Ash, coal, brick and glass fragments were observed within the Fill at various depths. The relative density of this deposit ranged from very loose to loose, as N-Values in this deposit ranged from 2 to 10 blows per foot. One sample of this layer was submitted for geotechnical lab testing and was classified as Silty Sand with Gravel (SM).

Clay: Below the Fill, a layer of clay deposit was encountered and extended to 22 to 25.5 feet in thickness in both borings. Two samples from this layer were submitted for geotechnical lab testing, one from 14 feet below ground surface and the other from 24 feet below ground surface. The sample tested from 14 feet below ground surface classified as a high plasticity clay (CH) whereas the sample tested from 24 feet below ground surface classified as a lean clay (CL). The samples were generally described as bluish gray to gray, medium to high plasticity clay. The consistency of clay deposit generally increased with depth. One (1) undisturbed sample of this material was collected during advancement of TP-B-102 (OW).

Glacial Till: Below the Clay, Glacial Till was encountered. The materials within the Glacial Till were generally described as light gray sand with silt and gravel. One sample from this deposit was submitted for lab testing to substantiate field classifications and it was classified as Silty Sand with Gravel (SM). The relative density of this deposit based on SPT N-Values (generally over 50) is very dense.

Probable Weathered Rock/Bedrock: No rock cores were taken during the exploration, so the top of bedrock was not confirmed. However, rock fragments indicative of probable top of weathered rock/bedrock were observed at a depth of 41.4 feet below ground surface during advancement of boring TP-B-101.

Groundwater was measured three times over the course of the study. It was found to range from 2.6 to 3.1 feet below surface, as documented in Table 1.

Table 1: Tufts Park Observation Well Readings

Well ID	**Date**	**Depth to Water (ft.)**
TP-B-102 (OW)	11/22/2019	2.6
	12/26/2019	3.1
	3/16/2020	3.1

2.3.2 Environmental Conditions

Kleinfelder reviewed the Massachusetts Department of Environmental Protection (MassDEP) Massachusetts Contingency Plan (MCP) Searchable Sites Database, plans provided by the City

of Medford, as well as resources available from the Environmental Protection Agency (EPA) to determine whether any known open or closed reportable releases of oil or hazardous material (OHM) were documented at, or in proximity to, Tufts Park. This review also served to evaluate the potential for encountering OHM-contaminated soil or groundwater during project work.
MassDEP's MCP Searchable Sites Database cited several release sites in the vicinity of Tufts Park. Two releases were identified as RTN 3-27363 and RTN3-29737. Based upon extent and nature of the releases and regulatory closure of the two sites, it is unlikely the project area would be impacted by either release.

During subsurface investigations at Tufts Park, soils within borings TP-B-101 and TP-B-102(OW) were observed to contain visible ash and coal, indicating the potential for contamination with OHM such as metals, polycyclic aromatic hydrocarbons, petroleum constituents and/or other contaminants associated with historic fill material.

Soils were screened with a portable x-ray fluorescence (XRF) analyzer to screen for the presence of metals. XRF screening provides approximate metals concentrations in the field without submitting samples for laboratory analysis. Results of XRF screening identified concentrations of the metals lead, arsenic and chromium in the soils, at levels which would exceed the corresponding MassDEP MCP Reportable Concentrations for soil laboratory analytical results. Since XRF screening does not provide laboratory-quality definitive analytical results, there is currently no Reportable Condition. If lab samples are analyzed at a later time, however, we expect based on this screening data that a Reportable Condition would likely be identified.

Depending on the results of potential future soil laboratory analytical samples, there is a potential that certain regulatory exemptions relating to wood ash, coal, and coal ash could apply to the conditions at the site. We recommend that analytical samples be collected as part of the final design process, to determine soil management options, regulatory requirements and/or exposure considerations, if plans for the project move forward.

Should a reportable condition to MassDEP be identified, the timeframe to comply with MassDEP MCP requirements to advance site conditions to Permanent Solution status with a condition of "No Significant Risk" (closure) consists of a series of milestones, including:

- Perform initial assessment by Year 1;
- Comprehensively assess site conditions by Year 3;

- Site closure (complete remediation if necessary) by Year 6.

If soil contamination levels at depths less than 12 inches are discovered during design, the site will immediately require restricted access (typically by installing a temporary fence). The chance that such concentrations would be identified in shallow soils is not very likely.

The timeframe to advance site conditions to Permanent Solution status outlined above can be significantly accelerated by making the assessment and potential remediation activities a part of the construction contract that ensues after completion of design.

3 GREEN LINE EXTENSION (GLX) DRAINAGE CHANGES

As part of the Green Line Extension (GLX) project, there are two changes to local drainage within the contribution area of the proposed project at Tufts Park. These changes have been incorporated into our H&H model to represent conditions that will exist in the near future. The two changes include (i) newly installed drainage upgrades at Granville Avenue and (ii) a proposed roadway grade adjustment at the Harvard Street underpass.

3.1 WINTER BROOK DRAINAGE CHANGES

In the Winter Brook drainage area, the GLX project replaced two 15” drainage pipes that parallel the railway and then turn onto Granville Avenue, terminating at the intersection of Winchester Street. The newly installed pipe is a 36” fiberglass pipe. The drainage changes that resulted from the GLX project has altered the flow condition into the City of Medford’s drainage system at Granville Avenue. The City’s hydraulic model was updated to account for this change in flow. City personnel provided proposed peak discharge from Somerville that was developed for the GLX project. The data provided covered storm frequencies ranging from the 2-year 24-hour storm through the 100-year 24-hour storm under the current year conditions. Kleinfelder used the data provided to estimate the future peak flow discharge condition for the design storm used for this project.

3.2 HARVARD STREET UNDERPASS

As part of the GLX project, the roadway grade elevation at the Harvard Street underpass is designed to increase from approximately elevation 19.1’ NAVD88 to elevation 20.5’ NAVD88. Kleinfelder updated the model to reflect this proposed change. This planned increase will reduce the degree of flooding experienced today.

4 HYDRAULICS

4.1 DESCRIPTION OF MODEL

The City of Medford has an existing Citywide EPA Stormwater Management Model (EPA SWMM) for flood inundation mapping. The Citywide model was developed in PCSWMM, a software developed by Computational Hydraulics International (CHI, Inc.) that is based on the same computation engine as the EPA SWMM, with an improved user interface.

As part of this study, Kleinfelder extracted the South Medford project area from the Citywide model to develop a dedicated two-dimensional (2D) PCSWMM sub-model that includes additional drainage details. The refined sub-model can better simulate the hydraulics in the South Medford area and hence is better suited for the tank design purpose of this project.

The extracted sub-model (the model) has been improved, adjusted and calibrated based on the most updated data available. Updated data input and parameters include:

- LiDAR Digital elevation model
- Improved delineation of sub-catchments
- Improved representation of hydrological conditions at the Somerville city boundary
- Finer 2D mesh for the project area
- GLX drainage changes, summarized in Section 3

4.2 DESCRIPTION OF DESIGN STORM

The selected design storm is a 10-year 24-hour event with future climate conditions in 2070. This storm event has an annual return frequency of 10% with a precipitation distribution pattern SCS Type III, totaling 6.38 inches of precipitation over 24 hours.

Climate conditions in 2070 have been the City's focus to better understand potential vulnerabilities for the City due to climate change. The City's recent efforts on collaborative Mystic River watershed regional planning and other MVP grants have also studied potential flood hazards caused by sea-level-rise and increased precipitation.

Figure 4-1: South Medford 2D PCSWMM Model Overview

4.2.1 Source of 2070 Projections

The total rainfall volume of the 2070 10-year 24-hour storm, at 6.38 inches, is comparable to a present-day 25-year 24-hour storm, as shown in the Climate Change Vulnerability Analysis (CCVA) conducted by the City of Cambridge[1].

The projections for climate conditions in 2070 are based on a statistical analysis using raw data provided by the Climate Model Intercomparison Project (CMIP5). The CMIP5 is a global project with contributions from various government entities to study the global coupled ocean-atmosphere general circulation models.

Kleinfelder used the CMIP5 data to statistically estimate precipitation projections in future climate conditions for the City of Cambridge's CCVA.

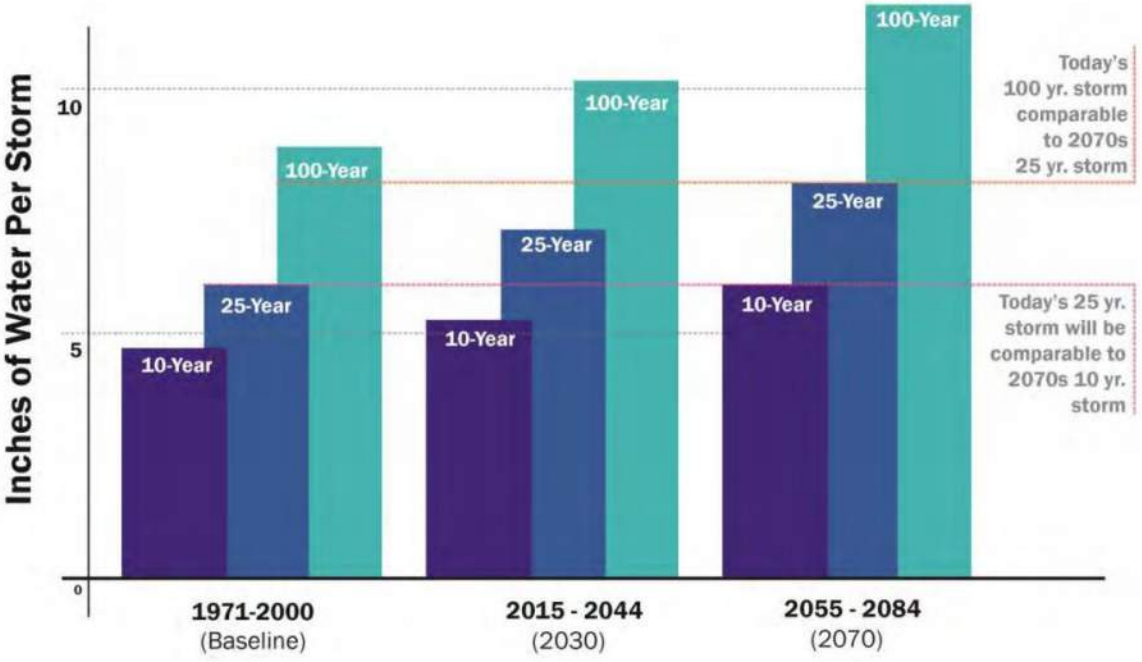

Figure 4-2: Precipitation Projections

(Source: Kleinfelder based on ATMOS projections November 2015)[1]

4.3 EXISTING CONDITIONS HYDRAULICS

The City currently experiences flood impacts at various locations in South Medford. This project focuses on the drainage areas that are near the Tufts Park, carrying flows from the western City boundary with neighboring Somerville to the Mystic River eastward of South Medford.

Upstream of Tufts Park, tributary areas from Somerville carry surface runoff onto Harvard Street and Winchester Street, which then merge with the flows coming from Ball Square converging at a 42-inch drain pipe under Tufts Park. The Harvard Street underpass, due to the roadway depression, is a local low spot of the upstream drainage system and is known as a chronic flooding hotspot. Harvard Street is a main artery connecting I-93, and State Route 16 to Somerville and Cambridge. Current flood problems at the underpass significantly disrupt traffic flow in South Medford and often cause severe congestion during rain events. After the GLX Project, the peak

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[1] Kleinfelder. "CCVA Appendix B: Temperature and Precipitation Projections." City of Cambridge, MA, Nov. 2015.

hydraulic grade line (HGL) at the Harvard Street Underpass is at 20.25' NAVD88, which is 0.25' below the proposed roadway surface. By virtue of elevating the Harvard Street underpass roadway grades, the severity of flooding will be reduced.

Downstream of Tufts Park, two large catchments from opposite directions along Main Street merge with flows coming off the 42-inch pipe from the Tufts Park. This configuration creates a hydraulic conveyance capacity restriction at the confluence where flows merge, near the intersection of Willis Avenue and Ellis Avenue.

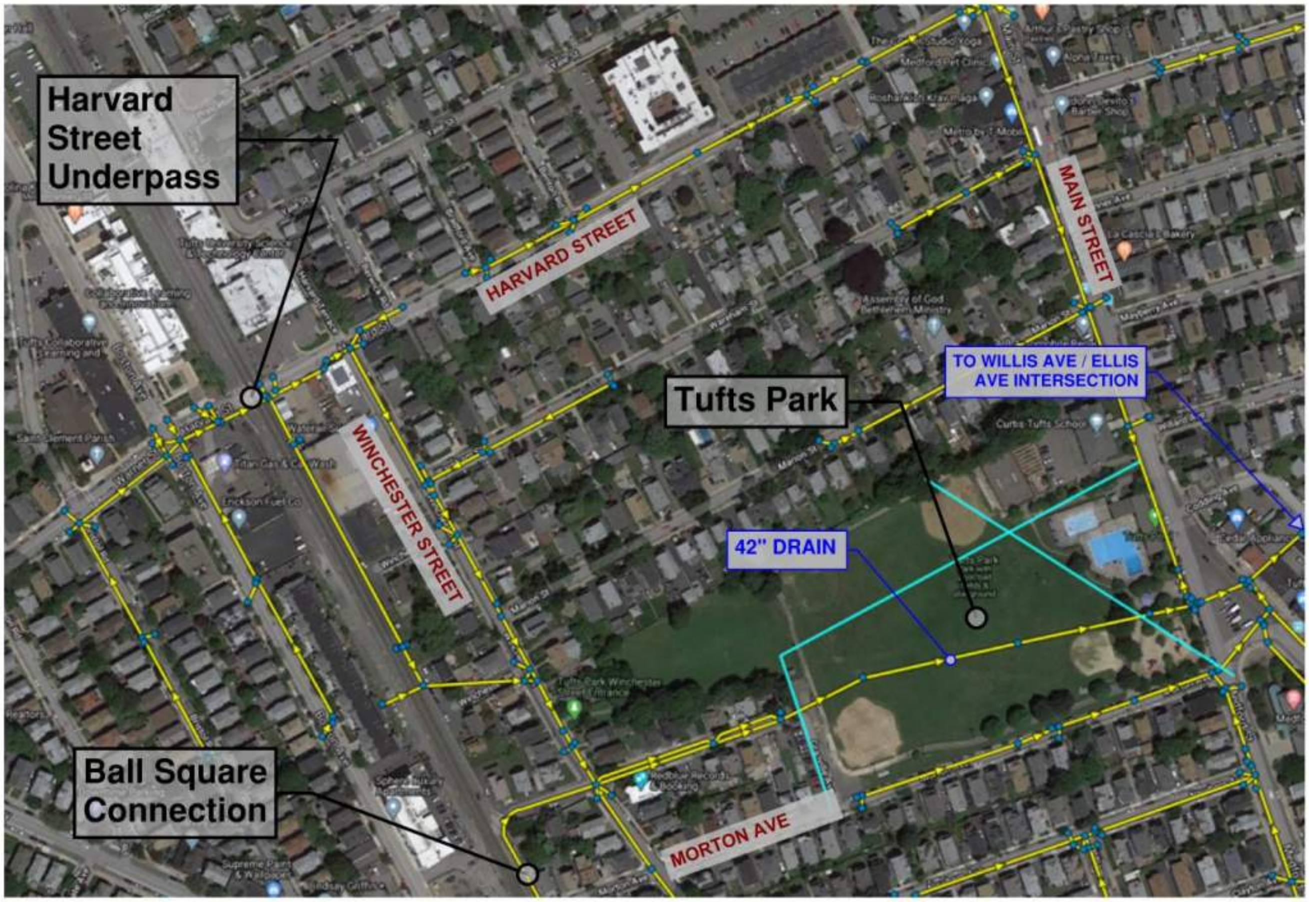


Figure 4-3: Locus Map of Tufts Park

4.3.1 Short-Duration Storm

Short-duration storms are typical to the coastal northeast region. These storm events typically last shorter than two hours and can sometimes produce precipitation at an intense rate of over 3-inches per hour. In most urban areas, these storms create flash flood problems where surface runoff does not drain into the stormwater collection system quickly enough, hence resulting in surface ponding. This is due to inlet capacity limits at the catch basins, responsible for capturing surface runoff and directing the flows to the main drainage system.

As short-duration storms cause surface flooding due primarily to inlet capacity issues, the tank design of this project does not target these types of storm events. Nevertheless, the City would like to utilize the improved 2D model for South Medford to identify any conveyance capacity limitations in the drainage system under short-duration high intensity storm conditions. For this purpose, the team selected the 2070 10-year 2-hr storm for the short duration storm analysis.

4.4 TANK SIZING ALTERNATIVES ANALYSIS

Discussions with the City resulted in a consensus that it is the City's priority to mitigate flood problems at and downstream of the Harvard Street underpass. Based on the team's understanding of the existing hydraulic conditions, Kleinfelder proposed three tank configuration alternatives with various levels of flood mitigation benefits, costs, and constructability.

All three configurations utilize a backflow preventer at the outlet of the tank. A backflow preventer at the outlet prevents the backflow from entering the storage tank prematurely when the 42-inch pipe is at capacity. The team made this decision so that the tank will prioritize capturing flows from upstream catchments from Ball Square and Harvard Street, where steep terrain causing upstream runoffs flow into Tufts Park rapidly during rain events.

4.4.1 Tank Configuration Alternative 1

Alternative 1 would implement a single 1.5 million-gallon (MG) storage tank along the southern edge of Tufts Park. This design allows the tank to maintain a larger buffer between the tank and the diagonally running MWRA water mains existing in Tufts Park. The single tank design also allows a simpler inlet and outlet control structure. Overall, this constitutes a more straightforward design with better ease of construction.

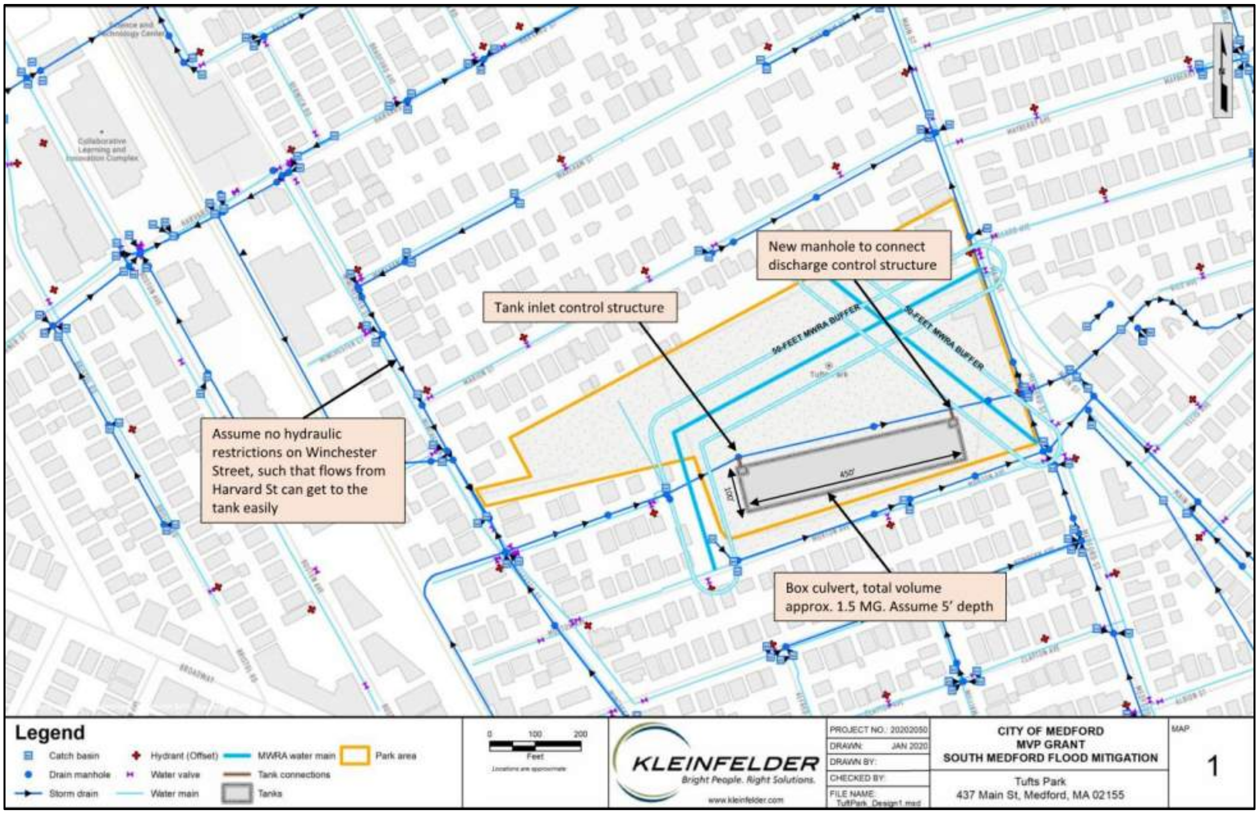


Figure 4-4: Alternative 1 Overview

4.4.2 Tank Configuration Alternative 2

Alternative 2 implements two parallel 1 MG storage tanks totaling 2 MG of storage volume. This design serves as an intermediate design with high flexibility to adapt to future investment projects. The northern tank is feasible to interconnect with stormwater management infrastructure installed at the unused space at the northwest corner of Tufts Park, further described in Alternative 3. The southern tank allows for interconnections with potential green infrastructure or drainage improvements on Morton Avenue.

This design is more challenging because of the known proximities to the existing MWRA water mains, running within 20-feet at the closest separation.

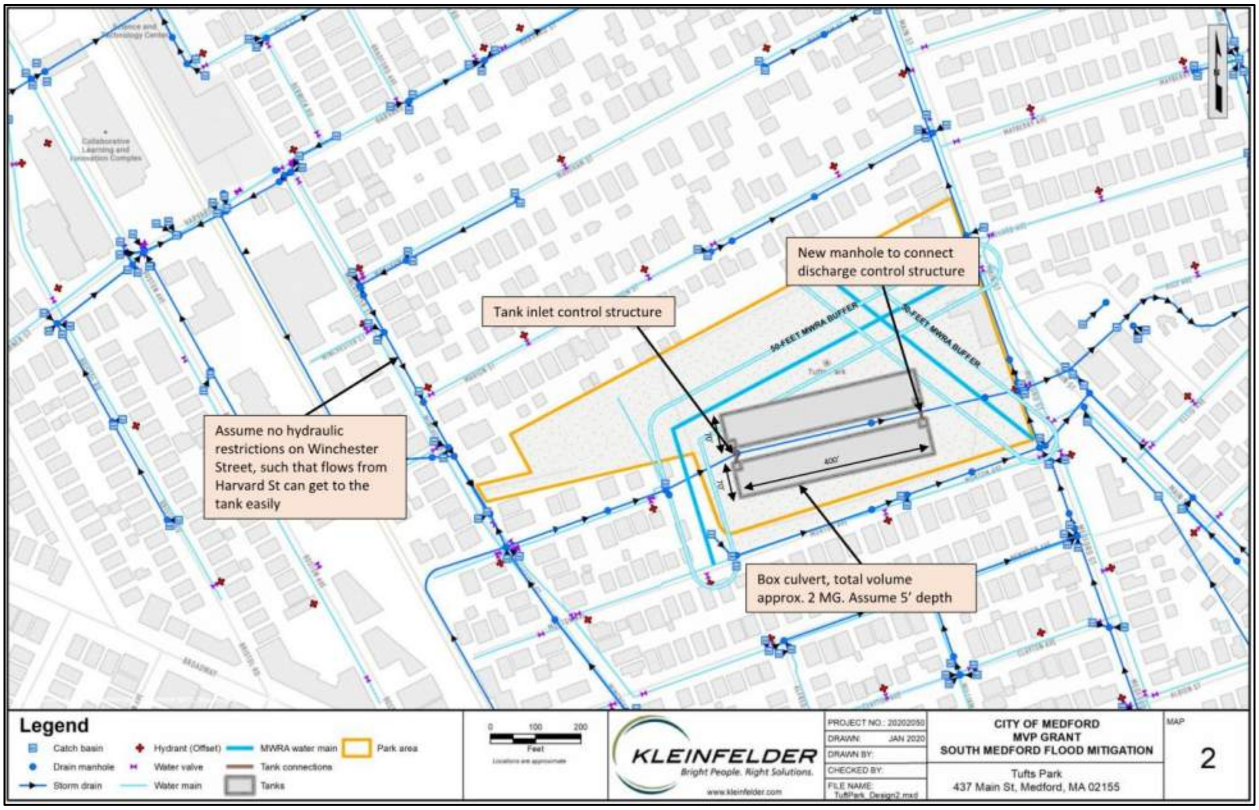


Figure 4-5: Alternative 2 Overview

4.4.3 Tank Configuration Alternative 3

Alternative 3 is an expansion of Alternative 2. This configuration kept the same parallel tank design, but added a green infrastructure installation at the unused depression in the northwest portion of the park, as seen in Figure 4-6. The green infrastructure is connected to Winchester Street via an existing easement owned by the City. The green infrastructure serves two main purposes:

1) Targeting flows from Winchester Street to provide additional hydraulic relief to the Harvard Street underpass; and
2) Provide sediment screening for the northern storage tank connected downstream to the green infrastructure.

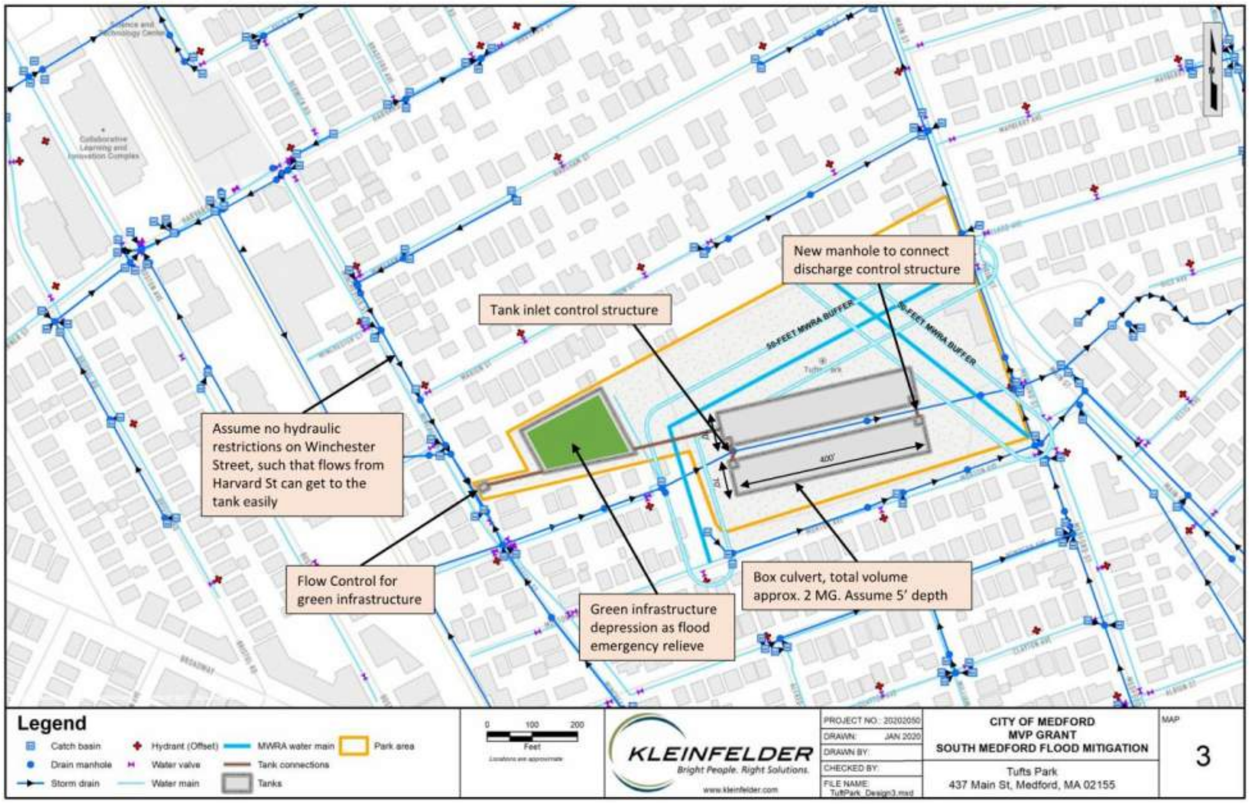


Figure 4-6: Alternative 3 Overview

4.5 MODELED PERFORMANCE

4.5.1 Baseline Conditions Comparisons

The maps in Figure 4-7 compare the 2070 10-year short duration 2-hour storm against the 2070 10-year 24-hour design storm under baseline conditions with the raised roadway surface at Harvard Street underpass and added discharge from the new 36-inch drain as part of Winter Brook drainage changes. Model results show that the 24-hour storm creates more flood problems than that of the 2-hour short duration storm, and the conveyance capacity restriction at Willis Avenue can be seen for both events.

Figure 4-7: Comparison of Baseline Model Results

It is important to note here that the 2D PCSWMM model used in this project does not simulate the inlet capacity limitations. In other words, all flows generated by the rain event are injected directly into the drainage system, without restriction, at various manhole locations in the model. Based on this assumption, the model results show that short-duration storm patterns do not result in any additional conveyance capacity restricted bottlenecks when compared to long-duration storm events.

In another perspective, these model results suggest that the surface flooding currently experienced by the City during short-duration high-intensity storms are mainly due to inlet capacity issues, where flows are ponding over inlets and could not be captured into the drainage system efficiently.

4.5.2 2070 10-Year 24-Hour Design Storm for Each Design Alternative

The figures below visualize the flood extents and depths for each of the design alternatives under the 2070 10-year 24-hour storm.

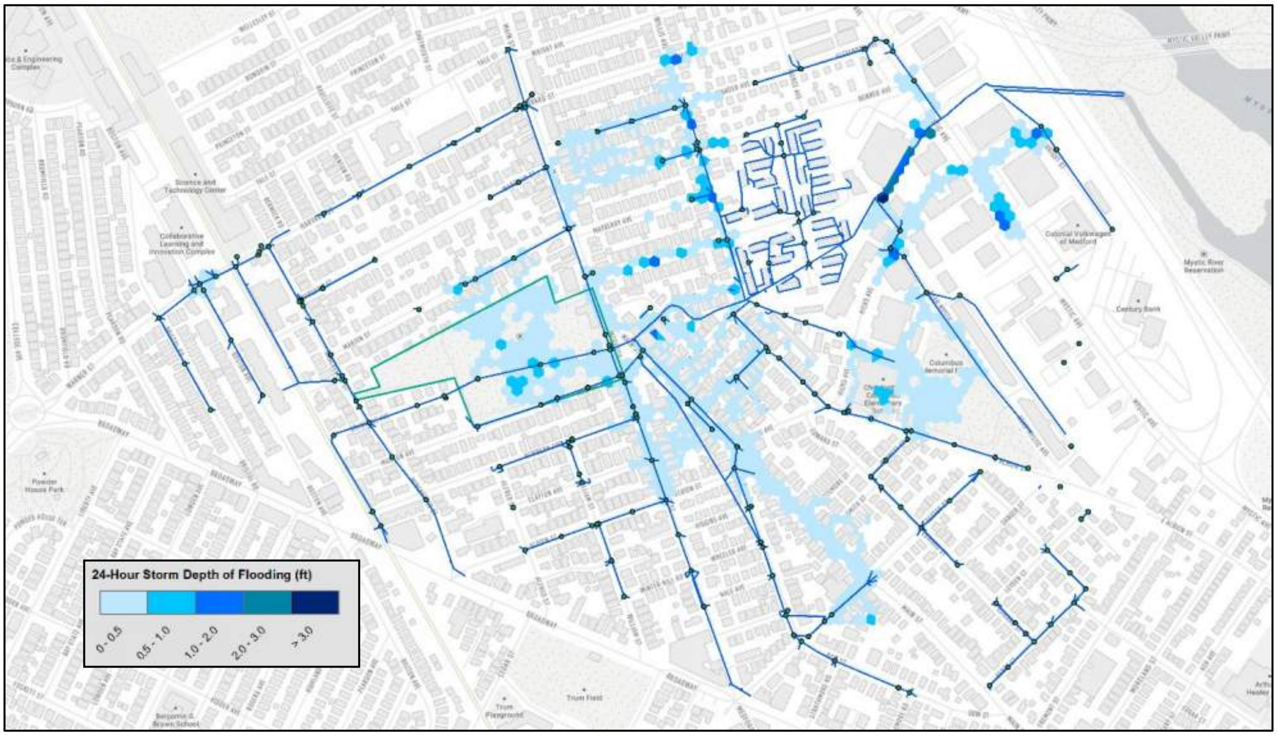


Figure 4-8: Model Results for Alternative 1 Under 2070 10-Year 24-Hour Storm

Figure 4-9: Model Results for Alternative 2 Under 2070 10-Year 24-Hour Storm

Figure 4-10: Model Results for Alternative 3 Under 2070 10-Year 24-Hour Storm

The table below summarizes the hydraulic performance at two key locations on which this project focuses.

Table 2: Comparison of Hydraulic Performance of Alternatives

	HGL (NAVD88-ft) @Tufts Park	**HGL (NAVD88-ft) @Harvard Street underpass**
Baseline condition	12.8’	20.25’
Alternative 1	11.7’	19.3’
Alternative 2	11.2’	19.1’
Alternative 3	10.4’	18.4’

At Tufts Park, the existing baseline flood elevation is at 12.8’, about 6 to 12 inches of flood depth over the park area. This aligns with what the City has observed at the Park, where it is usually ponding during wet weather events. Alternatives 1 and 2 have comparable benefits, which is expected with the small increment of 0.5MG storage volume. Alternative 3 is most effective and can lower the flood elevation at the park by over 2 feet, largely credited to the green infrastructure depression targeting flows from Winchester Street.

At the Harvard Street underpass, the proposed roadway surface is being raised to 20.5’, resulting in a baseline condition with a peak HGL right at the surface of the roadway. The peak HGL represents the water surface elevation in the drainage system, and hence proximates the risk of flooding associated with each alternative. Alternatives 1 and 2 bring comparable HGL reduction, due to a similar tank configuration. Again, Alternative 3, which targets the Harvard Street flows routed to Winchester Street is proven to be the most effective, bringing the HGL down to 18.4’, and significantly lowers the flood risks for the Harvard Street underpass to provide a two feet buffer from the roadway surface under a 2070 10-year 24-hour storm event.

4.6 RECOMMENDED TANK SIZE

Consolidating the results from the three alternatives, the City has elected to optimize the tank size to maximize the utilization of the park space. The idea is to locate the storage tank north of the existing 42-inch pipe and south and west of the two MWRA water mains. The areas south of the 42-inch pipe will be reserved for green infrastructure implementation (Chapter 6).

The high groundwater conditions at the park combined with the shallow inverts of the existing 42-inch pipe also limits the depth of the tank to an effectively storage depth of approximately 26-inches.

Combining all the available information, it became apparent that a 1.5MG tank may not be feasible given the site conditions. Additional model scenarios were run to determine the sensitivity of implementing a smaller storage tank in the range of 0.5MG to 1MG. Model results show that with a smaller tank, the tank's flow attenuation ability diminishes, and functions more as a large culvert that adds conveyance capacity to the drainage system.

The team looked at the peak flow reduction exiting the 42-inch drain pipe at the east end of Tufts Park. As shown in Figure 4-11 below, the baseline scenario reports a peak flow rate excess of 80 cubic feet per second (cfs), while the alternatives are all reporting comparable peak flow rate at approximately 60 cfs. The 20 cfs reduction in peak flow rate shows the flow attenuation benefits provided in each alternative tank configuration.

The difference in the shape of the curves are mainly due to the variation in tank size, where a larger tank (1.5MG in alternative 1, and 2MG in alternative 2) can hold a higher volume thus having a flatter curve. The recommended 0.73MG tank provides the same 20 cfs peak flow reduction but does not provide the same benefits to flatten the flow rates in the early part of the storm.

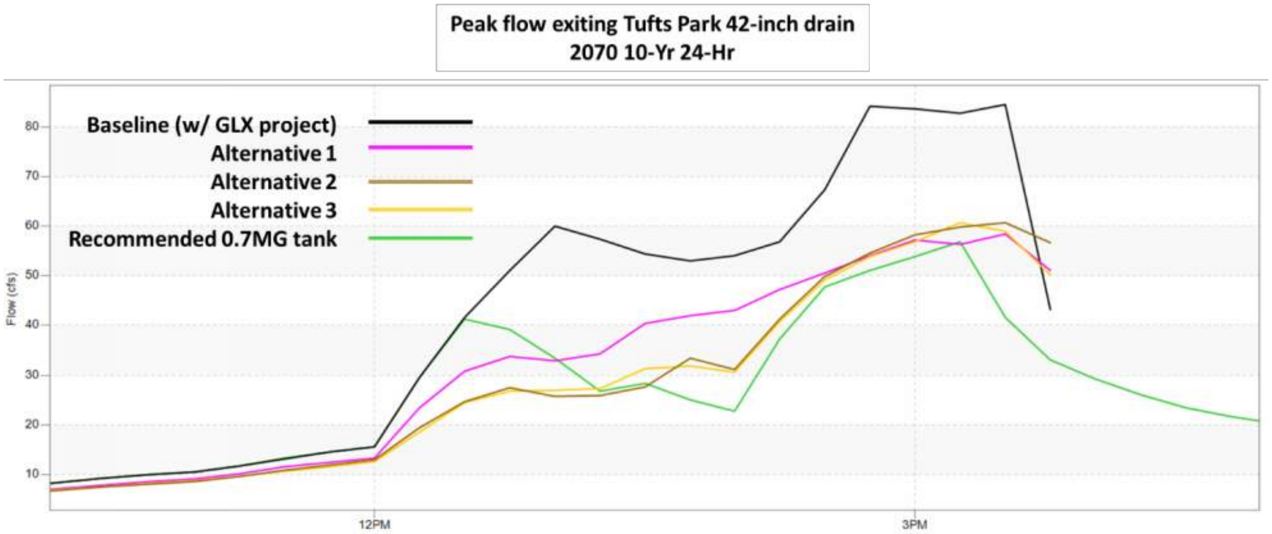


Figure 4-11: Comparison of peak flow at Tufts park for tank size optimization

The recommended tank size is to use up the available space bounded by the MWRA water mains and the existing 42-inch storm drain pipe, providing a total storage volume of approximately 0.73 MG with a tank depth of about 26-inches.

The schematic below depicts the recommended configuration of the tank as described above.

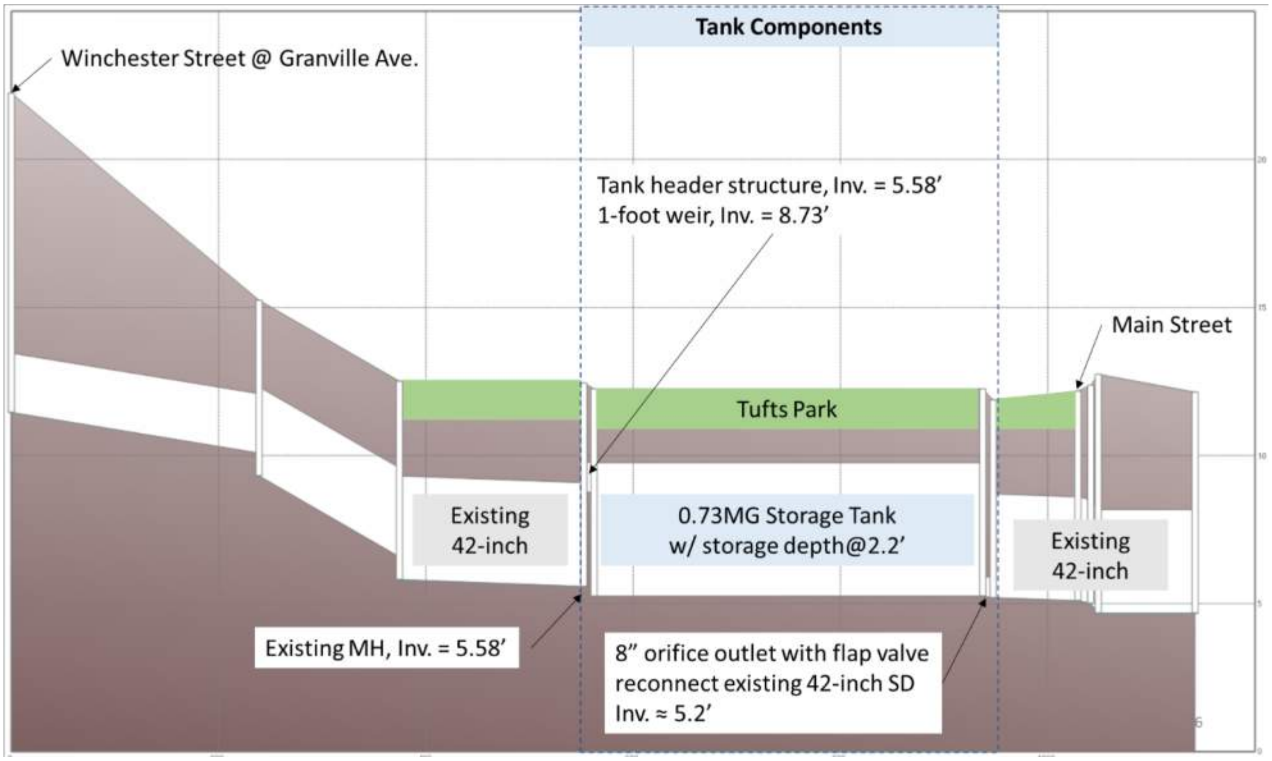


Figure 4-12: Tank Configuration Schematic

4.7 HYDRAULICS RECOMMENDATIONS

4.7.1 Tank Inlet Structures, Weirs

The tank will begin to capture flows after the 42-inch pipe is at capacity. The inlet structure will have a weir with an activation elevation close to the crown of the 42-inch pipe. At peak intensity during rain events, the steep terrain upstream of Tufts Park will produce high flow rates at the inlet structure, such that the weir should be wide enough to receive the high flow rate to divert flows into the tank.

4.7.2 Inlet Restrictions at Harvard Street

The City indicated that the catch basins at the Harvard Street underpass are traditional single-grated catch basins. The project team speculates this configuration to be inadequate to capture surface runoffs from the steep gradient on Harvard Street from Somerville. The team suggests the City review the overall configuration of inlet structures within the area tributary to the depression at the Harvard Street underpass through a field investigation program. This would offer the information necessary to perform hydraulic calculations for inlet capacity and determine if any further modifications are necessary.

4.7.3 Backflow Preventer and Outlet Control Structure

The conveyance restriction downstream of the park on Willis Avenue can cause flows in the system to backflow into the 42-inch pipe, and hence potentially into the storage tank. While that may provide flood mitigation benefits to the downstream areas, the backflow is competing for the same storage volume dedicated to capturing flows from Ball Square and the Harvard Street underpass.

A backflow preventer at the outlet prevents the backflow from entering the storage tank prematurely when the 42-inch pipe is at capacity. The size of the outlet should also be small enough such that the storage tank is not drained too quickly. The design team chose an 8-inch orifice for this purpose. An outlet larger than 8-inches will reduce the flow attenuation ability of the tank, and any outlet smaller than 8-inches will be very challenging to maintain, especially when coupled with a backflow preventer.

5 CIVIL DESIGN

This Chapter discusses the various design elements of the proposed tank including pretreatment, inlet and outlet flow control, and the tank design itself. In addition, considerations relative to geotechnical design, environmental materials handling, and operations and maintenance considerations are described.

5.1 TANK DESIGN ELEMENTS

5.1.1 Inlet Flow Control Structure

The inlet flow control structure is proposed to run parallel to the existing 42” concrete drain that runs through Tufts Park. The 42” pipe would be cut above the spring line for the installation of the inlet flow control weir. The flow control weir is proposed to be a straight weir that is 50-feet long and is placed at Elevation 9.84 NAVD88. On the back side of the weir, there would be a sumped section of the structure that will have a cast-in-place bottom and a precast top. During a storm event, the hydraulic grade would build up within the flow control structure. During peak rainfall, the hydraulic grade line would rise above the weir and flow into the pretreatment screening chamber.

5.1.2 Pretreatment Screening Chamber

The intent of the pretreatment screening chamber would be to control influent sediment and floatables to the maximum extent practicable. It is envisioned that the pretreatment would be integral with the inlet flow control structure. The design for the pretreatment screening chamber will be suitable for the tank type designed. The detailed pretreatment design will be determined in the next phase of this project.

5.1.3 Tank Design

5.1.3.1 Size and Depth

The tank volume is proposed to be approximately 0.73 MG. This volume is modeled to provide the desired hydraulic performance while being small enough to be located at the desired location. The tank effective height for storage would be approximately 26-inches. The tank is proposed to be approximately 45,000 square feet in footprint.

5.1.3.2 Location

The pretreatment chamber and tank would be placed north of the existing 42” concrete drain and south of the 20” CI MWRA water main. This location is suitable to place a pretreatment structure, inlet connection to the tank, and a 45,000 square foot tank without crossing over or under the MWRA water main. See Appendix D, Sheet C-2 for this layout.

The proposed location allows for inspection and access to the inlet control and pretreatment structure. This access would take place off of the field near the tank in the parking lot on Granville Avenue.

5.1.3.3 Tank System Options

Kleinfelder compared four different tank system alternatives for this project. Every tank system considered has extensive use for the purposes of stormwater detention, but each system has differing characteristics as described in this Section.

Precast Concrete Segmental System

StormTrap® designs components for installation of a precast concrete segmental system. These units are installed in a linear configuration and are stackable. A rendering of the StormTrap® system, created by the vendor, is illustrated below.

Figure 5-1: StormTrap SingleTrap system depiction
(Source:Stormtrap.com)

The vendor expressed concern about the clay found on the site as its bearing pressure could potentially make the installation of the system more difficult. The concrete material of the StormTrap® system creates less concern for buoyancy than other materials. Given the shallow tank depth required due to groundwater levels in the Park, the StormTrap® system did not offer the flexibility that the design team was seeking. The cost of this system was approximately $22 per cubic foot of tank storage, which was considered higher than other tank systems available.

Precast Concrete Gasketed System

The design team discussed the implementation of a concrete box culvert system with Scituate Concrete Products. A series of four-foot high by seven-foot wide culvert systems would have the potential to work in Tufts Park. The individual culverts would be tied together with a precast closed-end section, which would be cored to allow the connection of inflow and outflow conveyance piping.

With the box culvert alternative, the manufacturer indicated that with the box culverts placed in close proximity with each other, it would be a challenge to incorporate cross-connection between rows of box culvert sections and still maintain a water-tight connection. Therefore, an external piping system would be needed for the distribution of water storage across several rows of box culverts. The price of this system is estimated to be similar to that of the StormTrap® alternative at about $27 per cubic foot of tank storage.

Corrugated Metal Pipe System

A corrugated metal pipe (CMP) system from Contech Engineered Solutions LLC was considered. Its cost was found to be higher than the R-Tank but less than the concrete alternative. There were two CMP systems evaluated. The first was a CMP system with storage volume included in the surrounding stone, and the second option had storage in the pipe only. The first option would provide a much smaller footprint. However, the life expectancy of this material was considered less than the other systems.

Modular Plastic Storage System

The design team evaluated the use of a modular plastic storage system through coordination with ACF Environmental (ACF). ACF's product, the R-Tank, is the recommended solution for Tufts Park. The remainder of the report assumes the R-Tank is used as the tank system. This product has numerous advantages over other tank systems reviewed including:

- ***Cost Savings –*** The R-Tank system is anticipated to provide cost savings in the range of 10% to 30% when compared to other systems.
- ***Ease of Installation –*** The R-Tank modular units arrive at the site fully assembled and can be installed without the need for a crane or special heavy equipment.
- ***System Configuration & Flexibility –*** The R-Tank is a modular system that provides the flexibility to install it in irregular shapes at varying heights (if needed). This characteristic of this system suits the Tufts Park well since the available space at the desired location is irregular in shape.

The conceptual design proposes to utilize the Single+Mini HD R-Tank units. The R-Tank units arrive at the site pre-assembled, which would help to eliminate contractor error during installation. The timing of the delivery of the units to the site can be adjusted based on the contractor's preference and installation speed.

A typical installation photograph of the R-tank is shown in Figure 5-2.

Figure 5-2: Typical R-Tank Installation (Source: ACF Environmental)

5.1.3.4 Groundwater Control

The R-Tank system will require an impermeable 40-mil geomembrane liner surrounding it on all sides. The geomembrane liner seams will be welded to ensure a water-tight seal. All points of penetration, including inspection ports and pipe connections, will utilize a booted geomembrane and seal. The 40-mil geomembrane will be “sandwiched” by 8-oz nonwoven geotextile fabric as protective layer to reduce the risk of puncture of the liner.

5.1.4 Effluent Flow Control

There will be a 12-inch ductile iron outlet pipe from the R-Tank connecting to a five-foot manhole outlet control structure with a Tideflex backflow preventer. An 8-inch orifice control will be located downstream of the backflow preventer at the proposed new doghouse manhole that will be installed over the existing 42-inch drain.

5.2 OPERATION AND MAINTENANCE

5.2.1 Tank Cleaning

The pretreatment screening chamber is anticipated to capture and prevent the majority of the sediment and floatables of concern from entering the tank. By keeping these materials out of the tank, the frequency of tank cleaning will be reduced. This will also concentrate the regular cleaning efforts to the pretreatment screening chamber itself.

Tank cleaning is performed through an array of 12” diameter maintenance ports. The tank manufacturer (ACF) recommends, as a rule of thumb, that about one maintenance port is installed in the tank for every 1,000 square feet of tank area. However, with a robust pretreatment screening chamber, the number of maintenance ports can be substantially reduced.

System maintenance and tank cleaning will require a jet-vactor truck for cleaning via the 12” maintenance ports. These will be used for City personnel to monitor and remove sediment buildup on the tank bottom. Water will be flushed through the system from one maintenance port towards the next. The sediment that accumulates downstream of the pretreatment measures can then be removed. Due to large amounts of water required to re-suspend sediments at the bottom of the system, later stages of design will consider different pre-treatment alternatives, as well as different configurations of the tank to facilitate future solids removal.

ACF recommends the tank is inspected quarterly during its first year of operation, and then annually thereafter. The tank should be cleaned if sediment depth is measured to be greater than 15% of the depth of the tank, or approximately 4-inches.

Inspection and maintenance frequencies for the pretreatment screening chamber should be determined during future design phases.

5.3 GEOTECHNICAL CONSIDERATIONS

5.3.1 Foundation

The site was historically used as a clay pit which was subsequently backfilled with urban fill. We anticipate that the proposed tank and inlet control structures can be supported on the existing soils; however, due to the variable nature of fills, over excavation may be required to remove the fill below the structures to mitigate total and differential settlement.

Additional explorations consisting of a combination of borings and geoprobes are recommended to further assess the variable thickness and density of the existing fill within the proposed development area of the field. This information will be used to assess the potential for differential settlement of the system and corresponding subgrade preparation recommendations.

5.3.2 Anti-Floatation

The anti-floatation strategy detailed in the conceptual design utilizes crushed stone above and below the R-Tank and wrapped within the 40-mil geomembrane. Additional crushed stone and pea stone is proposed outside of the geomembrane.

Preliminary buoyancy calculations have been prepared on the R-Tank system, as part of this project. Assuming the groundwater table was equal to the ground surface, a factor of safety of 1.33 was achieved under the conceptual design approach.

Anti-floatation calculations will be performed as part of the final design of the pretreatment screening chamber and outlet control structures.

5.4 ENVIRONMENTAL CONSIDERATIONS

5.4.1 Soil Sampling and Testing

As described in Section 2.3.2, based on observations made during subsurface investigations and subsequent screening of soil samples with an XRF analyzer, it is possible that a reportable condition under the MCP could exist at the site. This initial finding should be confirmed with site soil laboratory analysis.

Kleinfelder recommends that soil samples be collected and submitted for laboratory analysis, in conjunction with the additional geotechnical subsurface explorations described above in Section 5.3, to determine soil management options, regulatory requirements and/or exposure considerations for future use of the park. We recommend soil samples be collected from the areas of observed fill, as well as areas of clay which are anticipated to be excavated during construction, to gain additional information on chemical quality of the soil. An initial sampling program targeted to areas of anticipated excavation for the project is recommended. This will allow the team to determine options and requirements for soil management and implications for cost of soil disposal.

Based upon XRF screening data and visual observation of ash and coal particles in fill soil, the soil has the potential to be impacted with elevated levels of OHM such as metals, polycyclic aromatic hydrocarbons, petroleum constituents and/or other contaminants associated with historic fill material. Laboratory analysis for contaminants of concern is necessary to quantify the levels of contamination in soil. Additionally, Kleinfelder recommends laboratory analysis in accordance with MassDEP LSP Association guidance document “Methods for Evaluating Application of the Coal Ash and Wood Ash Exemption under the Massachusetts Contingency Plan” to determine whether a regulatory exemption could apply to the site. Based upon the results of the proposed sampling, additional subsurface exploration could be recommended. Kleinfelder also notes that additional sampling for waste characterization of actual soils to be generated as excess is anticipated to be performed by the contractor during construction prior to offsite disposal.

5.4.2 Groundwater Sampling

Based upon the identified need for significant groundwater dewatering to be performed during installation of stormwater infrastructure, we recommend that sampling of groundwater also be performed to determine requirements for treatment during discharge, as well as to determine appropriate permitting requirements under the National Pollutant Discharge Elimination System (NPDES).

5.4.3 Soil Management

Management of soil during construction will depend upon the results of analytical sampling recommended above as well as waste characterization sampling performed by the contractor. A soil management plan should be developed by the contractor to detail plans for excavation, onsite management of soil and soil stockpiling, and offsite transportation and disposal. Level and type of personal protective equipment necessary during soil management activities will also be determined within the soil management plan as well as the site-specific health and safety plan.

If it is determined that excavated soil would be considered characteristic hazardous waste, onsite treatment of soil prior to shipment for offsite disposal could reduce the cost of transportation and disposal. Characteristic hazardous waste is sometimes identified based upon “failure” of the toxicity characteristic leaching procedure (TCLP) for lead or another metal, indicating that these metals are leachable in soil. Laboratory analytical analysis will determine whether metals present in the soil, if existing, are at levels which would require such treatment.

5.5 SUMMARY OF CIVIL RECOMMENDATIONS

After evaluating three types of stormwater detention systems, the recommended detention tank is the R-Tank by ACF. The R-Tank provides a 10 to 30-percent savings compared to the other systems evaluated. The 730,000-gallon tank would be installed north of the existing 42” drain line and south of the 20” MWRA water main. The tank would have a geomembrane surrounding it to prevent groundwater entry. There would be an inlet control and pretreatment unit upstream of the tank, and an outlet control structure with a backflow preventer prior to the connection back to the 42” drain. The tank would require maintenance ports for inspections, cleaning, and maintenance.

Table 3: Tank Basis of Design Criteria

Criterion	**Design Value**
Design Storm	10-year, 24-hour in the Year 2070
Tank Catchment Area	55 acres
Peak Inlet Flow	75.03 cfs
Inlet Control Device - Type	 50-foot straight weir

Elevation	9.84’ NAVD88
Pretreatment Chamber - Dimensions - Treatment Features	*To be determined during design*
Tank System Type	R-Tank
Tank Unit Type	Single+Mini HD units
Tank Manufacturer	ACF Environmental
Tank Footprint	45,000 square feet
Tank Effective Storage Depth	~ 26-inches
Tank Storage Volume	730,000 gallons
Effluent Control	8” orifice with backflow preventer
Groundwater Control	40-mil geomembrane
Anti-Floatation Type	Passive via crushed stone
Anti-Floatation Safety Factor	1.33

6 GREEN INFRASTRUCTURE OPPORTUNITIES

6.1 PARK DRAINAGE

Based on feedback from the City about known flooding issues in Tufts Park, Kleinfelder developed a conceptual design for a subdrain system that would help alleviate flooding issues in the central-northern portion of the field. An independent drainage system, utilizing an open vegetated swale concept, is proposed to address field flooding in the southern portion of Tufts Park. See Section 6.2 for the vegetated swale drainage description.

The contributing watershed area to the conceptual subdrain in the north-central portion of Tufts Park is approximately 6.75 acres. This area was estimated using one-foot contours. This does not include the area of the proposed tank. It is assumed that the crushed stone layer on top of the tank will act as a subdrain and that drains will be placed around the tank to collect precipitation falling on this area of the field.

6.1.1 Design Storm

The subdrain system was designed to accommodate a Type III 2-year 24-hour present-day storm for Middlesex County which has an approximate flow of 278 gallons per minute (gpm) to the contributing area.

6.1.2 Materials

The recommended material for the subdrain is the AdvanEdge Flat Pipe and N-12 Smooth Interior Pipe, both manufactured by Advanced Drainage Systems, Inc. (ADS, Inc.). The AdvanEdge Flat Pipe would be used for the subdrain branches and the N-12 Pipe would be used for the header pipe and connection to the proposed stormwater detention tank. All piping would be 12-inch to accommodate the flow expected in the design storm.

6.1.3 Layout and Capacity

The subdrain piping would be installed north of the 20-inch MWRA water main that crosses Tufts Park. Each of the 14 branches of the AdvanEdge Flat Pipe would be 125 feet long and placed 29 feet apart, for a total area of 51,000 square feet. All branches would connect to the 500-foot long header pipe that would connect to the proposed stormwater detention tank. To connect to the stormwater detention tank, the piping would have to cross through the MWRA easement for the 20” water main. All piping would be installed at a 0.5% slope. The subdrain layout is depicted in Appendix D, Sheet C-3.

The system would have a carrying capacity of approximately 300 gpm, which is greater than the estimated flow to the area for the design storm. The subdrain would be able to accommodate a storm event intensity of up to 3.14 inches per hour. The installation of the subdrain would significantly improve drainage in the field and surrounding areas.

6.2 GREEN STORMWATER INFRASTRUCTURE (GSI) OPPORTUNITIES

6.2.1 Locations

In addition to the field subdrain, the conceptual design includes multiple green stormwater infrastructure (GSI) elements to manage roadway runoff from Morton Avenue and the southern portion of Tufts Park. The recommended GSI strategies include a combination of structural stormwater best management practices (BMPs), including an open vegetated swale concept (to mitigate roadway flooding and improve playing field drainage), and a water quality bioretention BMP near the southwest softball field.

The primary recommended location for GSI at Tufts Park is the long, linear lawn space along Morton Ave (between the roadway and the existing pedestrian walking path), which includes portions of the public right-of-way and the Tufts Park open space parcel. This area is a prime location for linear green infrastructure, as there are multiple catch basins/manhole structures which can be easily retrofitted to reroute large amounts of stormwater runoff from upstream roadway and private parcel impervious surfaces. Existing utilities information (provided by City) also indicates that there are minimal overland or subsurface utility conflicts in this location. As it is observed that roadway flooding occurs along Morton Avenue during high-intensity short duration storm events, the implementation of GSI in this location would provide important benefits that could be realized immediately.

Figure 6-1: Recommended location for GSI along Morton Avenue

Several additional locations were considered as alternate or supplemental GSI locations, including the southwest ballfield parking lot, the parking lot at the adjacent Curtis-Tufts public school (northeast of the Park) and the east park entrance, and in the underutilized open space portion of the Park between Winchester Avenue and the proposed subsurface tank location (northwest portion of the Park). The location of these areas is outlined in the figure below.

Figure 6-2: Locations considered for GSI

The suitability and proposed next steps for each of these areas is summarized below:

- ***Ballfield Parking Lot (Southwest)* –** This parking lot was considered in early stages of concept design as an alternative area for a flood mitigation and/or water quality treatment BMP. Potential BMPs considered for this location include porous pavement, subsurface infiltration or detention, and drywells. While there is limited tree cover (and presence of organic debris) in this location, the presence of large amounts of fine materials (wind-blown sediments from playing fields) make this area a challenge for siting porous pavement due to risk of surface clogging. It was further noted by Parks Department maintenance staff that an existing dry well in this location is at capacity during even small rainfall events (i.e., rainfall events with 0.1” of precipitation or less). Groundwater monitoring data from the field investigation task of this project identified that high seasonal high groundwater table in nearby park areas indicate that infiltration is not likely feasible in this location. While a subsurface detention BMP could be suitable in this location, the installation of this BMP would require excavation of the parking lot (making portions inaccessible for duration of construction activities). Further, the runoff from the immediate drainage area to this BMP is already conveyed to the Morton Avenue storm network. As it would be more cost-effective and less intrusive to collect this runoff downstream and manage it with BMPs sited in the linear strip along Morton Ave., this location is not recommended as an alternate location for GSI.

- ***Curtis-Tufts School Parking Lot & East Entrance*** – This parking lot (northeast of the Park) is a large impervious area that generates a large amount of uncontrolled overland runoff towards Tufts Park. While the school building’s roof leaders are directly connected (via subsurface piping) to the storm network, there are several leaking roof gutters that add additional overland flow. This overland runoff currently generates a significant amount of sheet flow erosion along the east entrance (pedestrian pathway between the school and the pool fieldhouse). Excess runoff from this area combines with sheet flow from the outdoor basketball and tennis court facilities, resulting in significant washout of turf grass areas near the Park’s northeast ballfield.

  The landscaped areas along the east entrance pathway provide suitable locations for GSI intended to reduce erosion stormwater volume, including enhanced tree pits/trenches (such as Contech Filterra units, or similar products), or shallow bioretention facilities. The school building and retaining wall on the north side of the parking lot shield this area well from trees and other organic debris sources, making this area a potential candidate for a pilot porous pavement BMP and/or subsurface infiltration/detention, contingent upon seasonal high groundwater conditions. Detention-based facilities could also be proposed in this area. Assuming there is no private stormwater BMP present on-site, the buried roof leader connections from the school building’s northwest and southwest corners (which appear directly connected to the City’s MS4) could be easily disconnected to a subsurface stone storage reservoir, maximizing runoff capture and management. Figure 6-3 shows the roof leaders at the Curtis School. Modular pre-cast systems (such as Stormcrete modular pavers) could be strategic in this location in terms of low-risk porous technology that can reduce future maintenance burden of any porous surfaces.

Figure 6-3 Roof Leaders at the Curtis School

Additional “pocket bioretention” areas in the interior of the Park near this location could further improve playing field drainage and address spot erosion.

As each of the above design concepts are separate from the priority flood mitigation and water quality BMPs along Morton Avenue, it is recommended that these concepts be further investigated and designed in the next stages of the project.

- ***Northwest Portion of Park -*** The large lawn area between Winchester Avenue and the proposed subsurface storage tank (i.e., west of the MWRA potable water line and northeast ballfield), is an underutilized portion of the park. This area is the former location of a municipal pool that was abandoned-in-place and capped with fill. While this area is largely free of subsurface conflicts aside from the buried pool, its legacy use and ground surface elevation (relative to the rest of the Park and the subsurface 42-inch storm sewer) introduce challenges for this area to be used in a cost-effective manner for flood storage. Large amounts of excavation would be required to achieve significant storage via gravity flow from the existing storm sewer. However, the large amount of non-programmed open space may introduce opportunities for water quality-based BMPs.

  We recommend that this area also be further investigated in the next stages of the project.

6.2.2 System Types

Based on the initial site investigations and suitability assessment, the following types of GSI are recommended:

- ***Bioretention -*** A bioretention BMP near the southwest softball field (south of the walkway and seating area) will manage runoff from upstream Morton Avenue roadway and paved surfaces (driveways/rooftop downspout flow disconnected to driveways). This BMP serves as a dual-purpose water quantity and quality improvement, mitigating flooding along Morton Avenue during high-intensity short-duration storm events, as well as water quality treatment for the majority of storm events (i.e., first inch of runoff). This BMP would manage runoff from upstream Morton Avenue roadway and paved surfaces (e.g., the Park's pedestrian pathway, private driveways, and rooftop downspout flow disconnected to driveways).

Figure 6-4: Schematic of Bioretention Managing Roadway Runoff

(Source: Philadelphia Stormwater Guidance Manual v3.1, 2018)

An open vegetated swale is recommended for the public right-of-way segment along Morton Avenue. This BMP would serve primarily as a flood mitigation improvement that manages runoff from Morton Avenue, as well as poorly drained portions of the park playing fields.

The primary design intent for this BMP is to mitigate street flooding that occurs at a low-elevation point along Morton Avenue, which floods under both high-intensity short-duration ("flash flood") events, as well as longer duration storms of greater magnitude (i.e., a 10-year, 24-hour recurrence event). The former of these two types of flooding has been observed by the City to be occurring more and more frequently, with impacts to residents and park users in the present-day condition.

In addition to the street flooding, the Tufts Park pedestrian path also becomes impassable due to large amounts of pooled water during these events. A secondary benefit of the linear bioswale is to improve the playing field drainage, particularly for the southern two ballfields. The BMP would be comprised of a 425-foot long surface swale, supplemented with a subsurface detention stone storage reservoir encapsulated in an impermeable liner.

6.2.3 Operations & Maintenance Description

A primary goal of this design is to limit the future maintenance requirements of GSI interventions. For example, the proposed open vegetated swale concept would best limit intensive vegetation maintenance for a large surface stormwater facility. The final design of these BMPs would aim to limit surface maintenance activities (i.e., vegetation maintenance) to a quarterly basis and subsurface maintenance (i.e., pipe and structure cleaning) to an annual or bi-annual basis. With respect to design of these BMPs, the following strategies are recommended:

- All structures (domed risers or small overflow structures) should be sited in the public right-of-way (within the reach of a jet-vactor truck mechanical arm) and include a sump for debris (extending the time between maintenance mobilizations).
- All piped features (runoff distribution pipes and underdrains) should be sized appropriately and include cleanout sweeps (surface maintenance access points) spaced appropriately to ensure compatibility with jet-rodding, vacuum, and CCTV inspection equipment hose length.
- To limit the conveyance of sediment fines and trash into the BMPs, pretreatment strategies should be installed upstream of the proposed bioretention and linear swale BMPs, including catch basin filter bag inserts, TrashGuards, and/or energy dissipators or small sediment forebays. The design of proposed bioretention BMPs will consider proprietary systems (e.g. ACF’s FocalPoint, Contech’s Filterra, or similar modular bioretention) that utilize high-performance soil media and have standardized maintenance procedures and vendor maintenance services (as desired).

In terms of planting palette, a limited list of native plantings should be selected based on survivability (drought- and inundation-tolerable species), cost, and ease of maintenance (species requiring limited landscaping skills, or minimal pre-knowledge to differentiate these species from invasives).

Recommended Subdrain and GSI Improvements

Table 4 summarizes the basis of design criteria for the recommended subdrain system for the north-central portion of the field, which experiences the most flooding.

The field subdrain system was sized to convey storm runoff generated by a present day 2-year, 24-hour storm event. Given antecedent dry conditions, the subdrain system will have sufficient shallow subsurface capacity to store water that would otherwise pond on the playing field and will facilitate surface draining to return to dry condition following larger storm events.

Table 4: Basis of Design Criteria - Park Drainage

Criterion	**Design Value**
Design Storm	Present day 2-year 24-hour
Subdrain Catchment Area	6.75 acres
Subdrain Flow Volume	300 gpm
Subdrain Footprint	51,000 square feet
Subdrain Pipe Length	Approx. 3,000 LF
Subdrain Type	AdvanEdge Flat Pipe/N12 Smooth Interior Pipe
Subdrain Manufacturer	Advanced Drainage Systems, Inc.
Subdrain Pipe Size	12”

Table 5 summarizes the basis of design criteria for the water quality-based bioretention BMP. As this is a water-quality BMP, the system is designed to filter the “first flush” of pollutants (assumed to be the initial inch of runoff from any particular storm event). This bioretention BMP may be designed using traditional design practices (using standard bioretention media and surface loading ratios to size the BMP) or using proprietary bioretention products. Existing proprietary products, such as the ACF FocalPoint, maximize surface permeability and leverage subsurface modular storage (i.e. R-Tank Mini plastic storage modules) to decrease surface footprint. Key design parameters are presented for both sizing methods to meet the water quality volume. Given the high seasonal groundwater conditions at the proposed location of this BMP, an impermeable liner would be required for either design approach so that there is no storage loss.

Table 5: Basis of Design Criteria - Green Infrastructure Bioretention BMP

Criterion	**Design Value**
Design Storm/Parameter	Initial 1” of runoff over impervious surfaces (i.e., “first flush”)

Criterion	**Design Value**
Contributing drainage area	1.15 acres
Contributing drainage area imperviousness (%)	90%
BMP footprint	3,350 ft^2 (traditional bioretention surface area) ~190 ft^2 (proprietary bioretention; based on ACF FocalPoint sizing guidance)
Design Surface Loading Ratio	16:1 (traditional bioretention) 263:1 (high-performance Focal Point media)
Surface Ponding depth	6”
Surface mulch layer depth	3”
Bioretention media depth	6”
Subsurface high-performance bioretention media depth (FocalPoint system only)	*18” (FocalPoint system)*
Stone storage depth	21”
Subsurface storage chamber depth (FocalPoint system only)	*4” (FocalPoint system)*
Underdrain diameter	6” to 8” (connected to GI swale underdrain)
Est. static surface storage volume	1,240 cf (traditional bioretention)
Est. static subsurface storage volume	2,525 cf (traditional bioretention; assuming subsurface footprint is equal to surface footprint)
Est. water quality volume (impervious area * 1.0” runoff)	3,755 cf
Impermeable liner?	Yes

Table 6 summarizes the basis of design criteria for the open vegetated swale BMP. This BMP would be hydraulically connected to the bioretention BMP (receiving overflow from the bioretention BMP via underdrain connection) and sized appropriately to mitigate roadway flooding and improve park drainage for southern portions of the park's playing fields. We recommend that the shared overflow connection be made via an underdrain connection from the storage stone reservoir (below the swale) to a new doghouse manhole at the 42" storm sewer that runs through the middle of the Park. See Figure 6-5 for a schematic of the flows within the GSI.

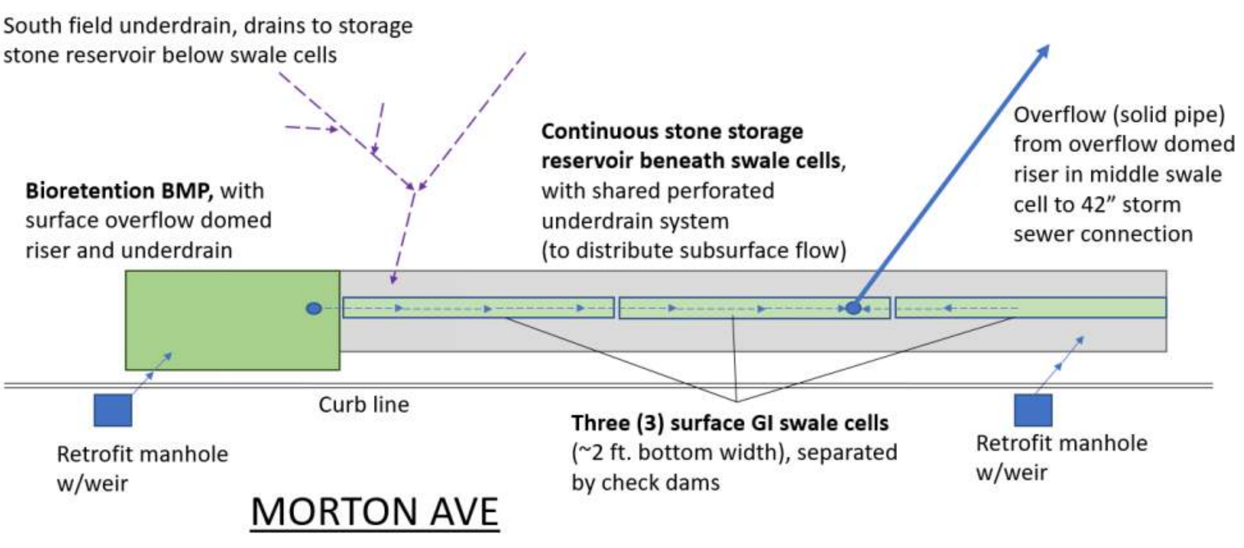
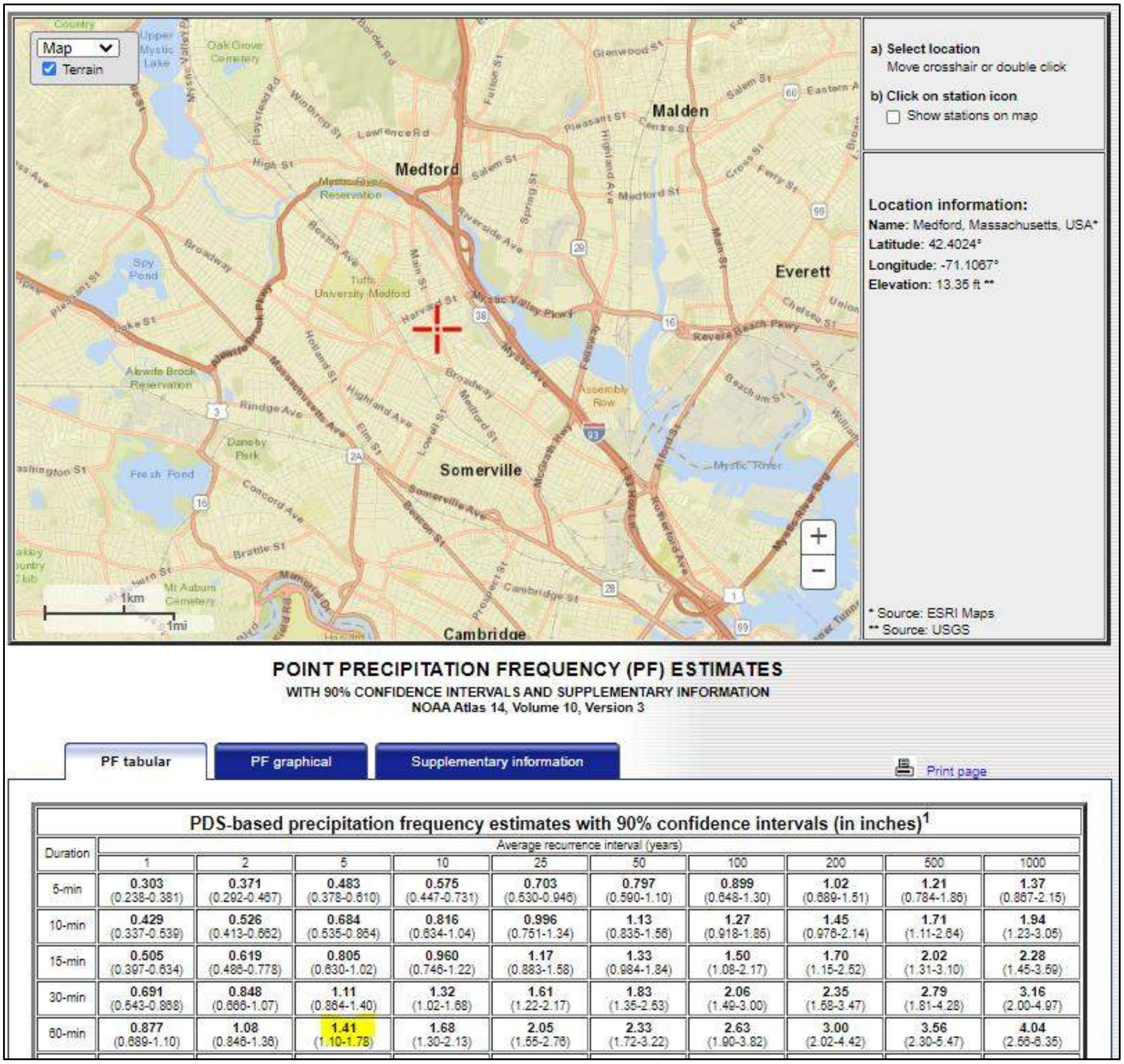


Figure 6-5: GI Drainage Schematic

Since this is a flood mitigation (water quantity-based) BMP, we assumed that the design storm of interest is a high-intensity short-duration rainfall event (i.e., a "flash flood" event). This design assumes a 2-year, 1-hour event using NOAA point precipitation frequency estimates obtained from NOAA Atlas 14, Volume 10. To factor future impacts of climate change on precipitation volume, we assumed that the 2-year recurrence event in 2070 will be similar to the 5-year recurrence event of present day.



a) Select location
Move crosshair or double click

b) Click on station icon
☐ Show stations on map

Location information:
Name: Medford, Massachusetts, USA*
Latitude: 42.4024°
Longitude: -71.1067°
Elevation: 13.35 ft **

* Source: ESRI Maps
** Source: USGS

POINT PRECIPITATION FREQUENCY (PF) ESTIMATES
WITH 90% CONFIDENCE INTERVALS AND SUPPLEMENTARY INFORMATION
NOAA Atlas 14, Volume 10, Version 3

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**0.303** (0.238-0.381)	**0.371** (0.292-0.467)	**0.483** (0.378-0.610)	**0.575** (0.447-0.731)	**0.703** (0.530-0.946)	**0.797** (0.590-1.10)	**0.899** (0.648-1.30)	**1.02** (0.689-1.51)	**1.21** (0.784-1.86)	**1.37** (0.867-2.15)
10-min	**0.429** (0.337-0.539)	**0.526** (0.413-0.662)	**0.684** (0.535-0.864)	**0.816** (0.634-1.04)	**0.996** (0.751-1.34)	**1.13** (0.835-1.56)	**1.27** (0.918-1.85)	**1.45** (0.976-2.14)	**1.71** (1.11-2.64)	**1.94** (1.23-3.05)
15-min	**0.505** (0.397-0.634)	**0.619** (0.486-0.778)	**0.805** (0.630-1.02)	**0.960** (0.746-1.22)	**1.17** (0.883-1.58)	**1.33** (0.984-1.84)	**1.50** (1.08-2.17)	**1.70** (1.15-2.52)	**2.02** (1.31-3.10)	**2.28** (1.45-3.59)
30-min	**0.691** (0.543-0.868)	**0.848** (0.666-1.07)	**1.11** (0.864-1.40)	**1.32** (1.02-1.68)	**1.61** (1.22-2.17)	**1.83** (1.35-2.53)	**2.06** (1.49-3.00)	**2.35** (1.58-3.47)	**2.79** (1.81-4.28)	**3.16** (2.00-4.97)
60-min	**0.877** (0.689-1.10)	**1.08** (0.846-1.36)	**1.41** (1.10-1.78)	**1.68** (1.30-2.13)	**2.05** (1.55-2.76)	**2.33** (1.72-3.22)	**2.63** (1.90-3.82)	**3.00** (2.02-4.42)	**3.56** (2.30-5.47)	**4.04** (2.56-6.35)

Figure 6-6: NOAA Point Precipitation-Frequency Estimates for Medford, MA

(obtained June 2020)

Table 6: Basis of Design Criteria - Green Infrastructure Swale

Criterion	**Design Value**
Design Storm/Parameter	1.41” rainfall event (2-year, 1-hour event; adjusted to 2070 conditions based on climate change projections)[1]
Contributing drainage area from Morton Ave.	0.75 acres (excluding upstream roadway area routed through Bioretention BMP)
Roadway imperviousness (%)	100%
Contributing drainage area from Tufts Park ballfields (via south-central field subdrain)	2.70 acres
Ballfield/park pathway imperviousness (%)	10%
Step-out zone width (offset from parked vehicles)	5 feet (minimum)
System length	425 feet (total)
# of swale segments (separated by surface check dams)	3
Typ. section width	8‘ (surface swale w/side slopes) 13-20 feet (subsurface stone trench)
Surface Ponding depth	6”
Choker stone layer depth	4”
Subsurface stone storage reservoir depth	30”
Underdrain diameter	8” to 10” (varies per segment; the middle segment of the swale is at lowest elevation requiring largest underdrain connection back to existing storm drain)
Est. static surface storage volume	1,025 cf
Est. static subsurface storage volume	4,485 cf
Est. water quality volume (impervious area * 1.41” runoff)	4,865 cf
Impermeable liner?	Yes

The catchment areas for each of the GSI improvements are shown in Figure 6-7.

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[1] Kleinfelder. “CCVA Appendix B: Temperature and Precipitation Projections.” City of Cambridge, MA, Nov. 2015.

Figure 6-7: Catchment Areas for GSI

7 PERMITTING CONSIDERATIONS

The proposed project will disturb the existing environment to excavate and temporarily dewater the site for construction of the tank and appurtenant piping and structures. We reviewed MassGIS's online mapping system (OLIVER) to rate the potential for environmental protection and construction permits for this project. This Chapter does not consider management of oil or hazardous materials (OHM) that might be covered by the Massachusetts Contingency Plan (MCP). Environmental management of OHM is discussed elsewhere is this report.

Based on mapping available on OLIVER, there are no environmental resources that are in the vicinity of the project that would trigger permitting. The data layers reviewed, but not found in the project area, include the following:

- DEP Wetlands
- FEMA Flood Zones
- Natural Heritage and Endangered Species Program
    - Estimated or Priority Habitats of Rare Wildlife
    - Certified Vernal Pools
- Areas of Critical Environmental Concern (ACEC)
- Drinking water buffers Zone I, Zone II, and Interim Wellhead Protection Areas
- Title 5 Buffers
    - Note that MassGIS shows the area around the abandoned pool with a Title 5 buffer. This is assumed to be a mapping error based on our knowledge of the site history.

The following permits are anticipated, as described in the following sections:

- MWRA 8(m) Permit
- NPDES General Construction Permit
- City of Medford Local Permits

7.1 MWRA 8(M)

The MWRA 8(m) permit enables the MWRA to issue permits to other entities to build, construct, excavate, or cross within an easement or other property interest held by the Authority.

The proposed project area encroaches within the vicinity of both MWRA water mains. Efforts were made during the conceptual design development to remain outside of the MWRA easements for these water mains; however, at a minimum, the park drainage concept will cross the MWRA water main. Further, we anticipate that construction activities will impinge within the MWRA water main easements. This should be confirmed during final design.

7.2 NPDES STORMWATER PERMIT FOR CONSTRUCTION DEWATERING

Construction activities that involve stormwater management and discharge of groundwater require NPDES stormwater permits. Depending on the results of the soil and groundwater environmental sampling recommended, the stormwater management permit may require a permit for groundwater remediation.

In general, the recommended approach will be to require the contractor to obtain the necessary NPDES stormwater management permit for this project.

7.3 NPDES CONSTRUCTION GENERAL PERMIT

Construction activities requiring a total land disturbance of greater than one acre require a Construction General Permit. The permit requires the preparation of a Stormwater Pollution Prevention Plan (SWPPP) and the submission of a Notice of Intent (NOI). The contractor will be required to install and maintain erosion and sediment controls and implement pollution prevention controls throughout the project. Site inspections will need to be conducted once every seven calendar days or once every fourteen calendar days and within 24 hours of a 0.25-inch storm event.

In general, the recommended approach will be to require the contractor to obtain the necessary NPDES construction general permit for this project.

7.4 CITY PERMITS

This project will primarily be contained to Tufts Park itself. However, interconnections from catch basins on Morton Avenue to the proposed swale will require work in the road. City permits may include a Street Opening Permit and an occupancy permit for construction in Tufts Park.

8 CONSTRUCTION CONSIDERATIONS

8.1 GROUNDWATER CONTROL

As presented in Section 2.3.1 of this report, the groundwater table is located approximately 3 feet below grade. The excavation depth for the R-Tank System would be approximately 6 feet below ground surface. Therefore, the contractor would need to install a dewatering system as part of the construction effort. The contractor's excavation means and methods would dictate what type of dewatering system will be incorporated. Should the contractor choose to perform all excavation in advance of installing the R-Tank, it is likely a well point system would be installed around the perimeter of the tank. Should the contractor choose to sub-divide the construction of the tank and excavate smaller portions of the site, a deep well dewatering system may be necessary. Each method presents advantages and disadvantages. The opinion of probable cost provided in this report assumes a well point system would be utilized during construction.

8.2 SOIL MANAGEMENT

The anticipated volume of soil excavation for the tank construction is approximately 11,000 cubic yards. Given the field is located within a residential area, we anticipate the frequency of truck traffic will be reduced in an effort to limit the traffic impact to abutting residents. Therefore, the contractor will be required to have a soil management plan prepared as part of this project. Based on laboratory analysis, the contractor should potentially prepare to conduct onsite treatment of soil to reduce transportation and disposal costs, as discussed in Section 5.4.35.4.2. We suggest that the northwestern portion of Tufts Park be reserved for an on-site soil stockpile area. This location will allow easy access to trucks to access and soil load-out from the Granville Avenue parking lot.

8.3 ENVIRONMENTAL MANAGEMENT

The contractor would be expected to perform waste characterization of the actual soils generated in excess prior to offsite disposal. Further environmental management practices for the construction phase will depend upon the findings from the environmental sampling recommendations outlined in Section 5.4.

8.4 IMPACT TO ABUTTERS

The construction process is expected to impact abutters. In general, construction noise and visual presence of construction activity will impact abutters. In particular, the subdrain installation would occur closely to the northern abutters to the park along Marion Street. The installation of the bioretention features, in the southern portion of the park, may require temporary restrictions of parking spaces along Morton Avenue, as well as in the southwest ballfield parking lot for equipment staging and construction. These restrictions are anticipated to last several weeks.

Impact to abutters can be mitigated through controls in the construction contract. For example, the contractor would complete their installation during the standard working hours of 7 AM – 3 PM to avoid disruptions to the surrounding neighborhood.

8.5 TEMPORARY LOSS OF PUBLIC USE

The recreational activities used at the field would not be able to be used throughout the construction process for public safety reasons. We anticipate that the pool, playground, and basketball court on site will be able to maintain regular schedules.

8.6 CONSTRUCTION SCHEDULE

The anticipated range in schedule duration is 4 to 7 months for the construction of the tank and green infrastructure components. This range in construction duration is contingent upon the lead time associated with manufacturing of the R-Tank storage units. If the Contractor's approved tank submittal are received by the manufacturer early in the construction season (prior to July) the anticipated manufacturing period for R-Tank is 3 to 4 weeks. In the event that the manufacturer receives submittals later in the construction season, the turn-around time to manufacturer R-Tank units is 8 to 10 weeks.

8.6.1 Construction Phasing

The opinion of probable cost presented in this report is based on a linear construction approach which incorporates the following phases:

1. Mobilization
2. Submittals Review/Approval
3. Site Preparation (i.e. erosion controls, dewatering, sampling, etc.)

4. Construction of Inlet and Outlet Control Structures
5. Tank Excavation
6. Installation of 40-mil Geomembrane Base/Bottom
7. Install R-Tank Storage Units
8. Installation of 40-mil Geomembrane Side Walls, Top & Backfill
9. Construct Green Infrastructure & Drainage Swale
10. Construct Subdrain Systems
11. Restore Tufts Field with Loam & Seed

9 OPINION OF PROBABLE CONSTRUCTION COSTS

This project has provided a conceptual basis of design for a new stormwater detention tank, drainage improvements to Tufts Park, and incorporation of green infrastructure elements. Based on the conceptual design described herein, we have produced an opinion of probable construction cost that meets a Class 4 estimate in accordance with the Association for the Advancement of Cost Engineering (AACE).

Given the stage of conceptual design and the degree of unknown design details, the cost estimate includes a construction contingency of 30%. This contingency would be expected to be decreased throughout the subsequent progress of the design, as more details of the design become defined.

Table 7 provides a summary of the opinion of probable construction costs. These costs do not include final design, permitting, bidding, construction administration or oversight. Appendix E includes a more detailed breakdown for the derivation of these costs.

Table 7: Summary of Conceptual Design Opinion of Probable Construction Cost

Cost Item	**Cost**
Mobilization and Demobilization	$151,700
Site Preparation and Erosion Controls	$62,495
Inlet Control & Pretreatment Structure	$120,660
Stormwater Detention Tank	$1,556,390
Park Drainage – Northern System	$113,350
Green Infrastructure Improvements	$340,000
Soil and Waste Management	$159,375
Transport and Disposal of Soil – Clean Fill	$273,460
Transport and Disposal of Soil – Daily Cover at Lined Landfill	$394,990
One Year of Vegetative Maintenance	$12,750
Construction Subtotal	$3,185,170
Contingency (30%)	$955,551
Total Construction Cost	**$4,140,721**

Appendix A: Task 1A Technical Memorandum

TECHNICAL MEMORANDUM

TO:	Timothy McGivern, Penny Antonoglou | City of Medford
FROM:	David Peterson | Kleinfelder
DATE:	March 26, 2020
SUBJECT:	Task 1A Field Investigation Technical Memorandum
CC:	Betsy Frederick, Kyle Johnson, Kenneth Yu, Jennifer MacGregor, Madeline Soule | Kleinfelder

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1.0 INTRODUCTION

The City of Medford ("City") is interested in employing structural control measures to mitigate surface flooding of critical streets and neighborhoods within specific areas of South Medford. This project is a continuation of the City's prior stormwater flood modeling efforts, which were funded, in part, through a Massachusetts Municipal Vulnerability Preparedness (MVP) program Action Grant in 2019. In the prior study, the City's hydrologic and hydraulic (H+H) model was refined and updated for South Medford. In the final report submitted to the City (June 2019), Tufts Park and Barry Playground were identified as high priority sites for the implementation of grey and green stormwater infrastructure strategies, as both sites were demonstrated to have significant potential for flood reduction in their respective neighborhoods.

While the June 2019 report considered only storm drain upsizing or storm drain re-routing as grey infrastructure interventions, the site-specific feasibility of green infrastructure interventions (such as subsurface infiltration, surface detention, or distributed green infrastructure) had not yet been explored. Understanding that the modeled flood mitigation benefits of projects at either of these public open space locations might be achievable either via green or grey infrastructure (i.e., subsurface detention/storage tanks), the basis of this field investigation was to determine site-specific feasibility of these strategies at each location and to recommend a preferred location to focus the remainder of this study.

A separate field investigation was performed at each of the two sites, consisting of field reconnaissance and site mark-out, soil borings and sampling, as well as installation and monitoring of groundwater observation wells. The soil samples were used to perform geotechnical lab testing (Grain Size Distribution and Atterberg Limits tests), as well as screening for environmental indicators utilizing x-ray fluorescence (XRF). No test pitting or environmental laboratory tests were conducted as part of the field investigation at either site.

This Technical Memorandum summarizes the results of the field investigations. It is divided into three major sections: Site Explorations & Methods (Section 2), Subsurface Observations & Test Results at each location (Section 3), and Environmental Review (Section 4). The Technical Memorandum concludes with site-specific recommendations (Section 5).

2.0 SITE EXPLORATIONS & METHODS

2.1 SITE RECONNAISSANCE

Before performing site reconnaissance, Kleinfelder received City drawings of existing conditions and buried utilities at the sites. In addition, Kleinfelder obtained additional water main records from the Massachusetts Water Resources Authority (MWRA) because MWRA owns two water mains crossing through Tufts Park.

Kleinfelder used the record drawings to identify potential locations for subsurface explorations. We then performed site reconnaissance at Barry Playground and Tufts Park to verify site conditions and stake out the locations for the explorations.

The driller contacted DigSafe to clear the proposed exploration locations. During drilling options, boring locations were slightly adjusted based on utility mark outs and other noted site features. The final locations of the borings were measured n the field by Kleinfelder personnel.

2.2 SUBSURFACE EXPLORATION METHODS

A subsurface exploration program consisting of four (4) borings was performed between November 11 and 13, 2019 under the technical direction of a Kleinfelder geo-professional. Two (2) borings were performed at Tufts Park and two (2) borings were performed at Barry Playground. An overview of the field exploration program is shown in Table 1.

Table 1: Exploration Overview

Location	Exploration ID	Date Performed	Depth (ft.)
Tufts Park	TP-B-101	11/13/19	41.4
	TP-B-102(OW)(1)	11/14/19	41.5
Barry Playground	BP-B-101 (OW)(1)	11/12/19	25.3
	BP-B-102	11/12/19	27

(1) Boring completed as a groundwater observation well.

The as-drilled locations at each park were located by taping from existing site features and are shown on the site plans included in Appendix A.1. Boring locations should be considered accurate only to the degree implied by the method used.

Carr-Dee Test Boring & Construction of Medford, Massachusetts advanced the borings using an ATV drill rig at Barry Playground and a truck-mounted drill rig at Tufts Park. Hollow stem auger and drive-and-wash drilling techniques were utilized to advance the borings as indicated on the boring logs included in Appendix A.2.

Soil sampling within the borings was performed using the Standard Penetration Test (SPT) in general accordance with ASTM D1586. The SPT involves advancing a 2-inch outer diameter, 1-3/8-inch inner diameter, split-barrel sampler with a 140-pound weight (known as the hammer) falling 30 inches. The sampler is advanced up to 24 inches and the number of blows to advance the sampler each 6-inch interval is recorded. If the sampler is advanced less than 6 inches in 100 blows, the test is stopped and the distance the spoon was driven with 100 blows is recorded. The number of blows to advance the split spoon from 6 to 18 inches (the 2nd and 3rd intervals) is commonly referred to as the N-value. The hammer used for SPT testing was an automatic hammer and split spoon samples were obtained continuously or at five-foot intervals.

Upon completion of the drilling, the boreholes were backfilled with the soil cuttings except TP-B102(OW) and BP-B-101(OW), which were converted to groundwater observation wells. Excess cuttings produced at each observation well were treated based on our knowledge of the local soil conditions and through judgment by our geo-professional on site. At Barry Playground, excess cuttings were spread on site and at Tufts Park, excess cuttings were collected in a drum and temporarily stored at the park. Soil within the drum was sampled and submitted for environmental lab testing for classification/disposal purposes.

Kleinfelder’s geo-professional provided technical oversight during the explorations, maintained boring logs, and described the soils in general accordance with the visual manual procedure described in ASTM D2488. Descriptions of the soil encountered in the explorations are included in the boring logs provided in Appendix A.2. A key to the symbols used on the logs and a soil description key are also provided in Appendix A.2.

The subsurface descriptions in this report are based on a limited number of explorations. Variations may occur and should be expected between exploration locations. The strata boundaries shown in our boring logs are based on our interpretations and the actual transition may be gradual.

2.3 LABORATORY TESTING

Laboratory testing was performed on representative samples to substantiate field classifications and provide engineering parameters for geotechnical design. The laboratory testing included the following tests performed in general accordance with the referenced standards:

- Grain Size Distribution (ASTM D6913)
- Atterberg Limits (ASTM D4318)

The tests were performed by GeoTesting Express, Inc. of Acton, Massachusetts. For select soil samples which were sent to the laboratory for grain-size analysis, the soil classifications were updated per ASTM D6913. Results of the laboratory tests are included in Appendix A.3 and shown on the boring logs in Appendix A.2.

3.0 SUBSURFACE OBSERVATIONS & TEST RESULTS

3.1 BARRY PLAYGROUND

3.1.1 Regional Geology

The surficial geology of the site was evaluated by reviewing publicly available geologic maps (Stone, B.D., and DiGiacomo-Cohen, M.L., comps., 2018). The surficial soil within the general area of the site is thin till, a glacial deposit which consists of non-sorted, non-stratified matrix of sand, some silt, and little clay containing scattered pebble. Thin till is generally less than 10 to 15 feet thick.

According to the USGS Bedrock Geological Maps (Kaye, C.A., 1980), the underlying bedrock is Argillite/ Argillite and Sandstone or Quartzite.

3.1.2 Summary of Site Conditions

Subsurface conditions encountered at Barry Playground during Kleinfelder's field exploration program are summarized in Table 2 and described below, in general order of occurrence and are in general agreement with the mapped geology.

Table 2: Barry Playground Subsurface Exploration - Detailed Summary

Site	Boring	Depth to Water (ft.)	Total Exploration Depth (ft.)	Fill/ Topsoil	Clay/ Sandy Clay	Glacial Till		Probable Weathered Rock/Bedrock
				Thickness (ft.)	Thickness (ft.)	Depth to Top (ft.)	Thickness (ft.)	Depth to Top (ft.)
Barry Playground	BP-B-101 (OW)	~5	25.3	2.9	16	19	6.3	25.3
	BP-B-102	~6	27	2	5.5	7.5	(2)	(1)

(1) Material not encountered in boring
(2) Thickness of Strata Not Determined

Topsoil: Both borings at Barry Playground encountered topsoil at the ground surface. The topsoil ranged in thickness from approximately 2 to 3 feet. Topsoil was sampled as moist, dark brown fine to medium-grained sand with trace grass, roots, and organic silt.

Clay/Sandy Clay: Underlying the topsoil, a layer of clay/sandy clay was encountered; this stratum extended to about 19 feet in BP-B-101 (OW) and about 7.5 feet in BP-B-102. This layer was generally described as a brownish gray sandy clay or clay with trace sand. The consistency of this material varied from medium stiff to very stiff. The average SPT N-value in this layer was approximately 18 blows per foot across both borings. In general, the SPT N-values within this layer decreased with depth. A sample from this layer was submitted for geotechnical lab testing and was classified as a lean clay (CL).

Glacial Till: Below the clay/sandy clay deposits, Glacial Till was encountered. The Glacial Till was generally described as brownish gray, medium to coarse grained sand, with gravel and silt. Two samples were submitted to the lab for characterization and both samples were classified as Silty Sand with Gravel (SM). The relative density of this deposit based on SPT N-values ranged from very dense to medium dense.

Probable Weathered Rock/Bedrock: No rock cores were taken during the exploration, so the top of bedrock was not confirmed. However, rock fragments indicative of probable top of weathered rock/bedrock were observed at the end of each boring at depths of 25.3 ft. and 27 ft. below ground surface during borings BP-B-101 (OW) and BP-B-102, respectively.

3.1.3 Groundwater

3.1.3.1 Observations During Drilling

In general, groundwater was encountered within our borings during drilling at a depth of about 6 feet below ground surface. Groundwater levels at the end of drilling may be influenced by the introduction of drilling fluids during boring advancement and are therefore not reported.

The groundwater information reported herein is based on observations made during drilling and may not represent the actual groundwater level. The groundwater level presented in this section only represents the conditions encountered at the time and location of the explorations. Seasonal fluctuation should be anticipated.

3.1.3.1 Monitoring Well Data

An open standpipe groundwater observation well was installed upon completion of boring BP-B-101(OW) with a 20-ft screened interval between 3 and 23 feet below ground surface (bgs). Three readings were taken in this well and are listed in Table 3.

Table 3: Barry Playground Observation Well readings

Well ID	Date	Depth to Water (ft.)
BP- B-101OW	11/22/2019	2.25
	12/26/2019	3.1
	3/16/2020	3.3

3.2 TUFTS PARK

3.2.1 Regional Geology

The surficial geology of the site was evaluated by reviewing publicly available geologic maps (Stone, B.D., and DiGiacomo-Cohen, M.L., comps., 2018). The surficial soil within the general area of the site is coarse deposit and artificial fill. Coarse deposits generally consist of gravel deposits, sand and gravel deposits, and sand deposits. Artificial fill indicates earth/manmade materials that have been artificially emplaced, whose property highly depends on the type of fill material and method used to backfill.

According to the USGS Bedrock Geological Maps (Kaye, C.A., 1980), the underlying bedrock consists of Sandstone and quartzite, and argillite and sandstone or quartzite.

3.2.2 Summary of Site Conditions

Subsurface conditions encountered during Kleinfelder's field exploration program at Tufts Park are summarized in Table 4 and described below, in general order of occurrence and are in general agreement with the mapped geology.

Table 4: Tufts Park Subsurface Exploration - Detailed Summary

Site	Boring	Depth to Water (ft.)	Total Exploration Depth (ft.)	Topsoil/ Fill	Clay	Glacial Till		Probable Weathered Rock/Bedrock
				Thickness (ft.)	Thickness (ft.)	Depth to Top (ft.)	Thickness (ft.)	Depth to Top (ft.)
Tufts Park	TP-B-101	~6	41.4	13	22	35	6.4	41.4
	TP-B-102 (OW)	~6.5	41.5	8	25.5	33.5	--(2)	--(1)

(1) Material not encountered in boring
(2) Thickness of Strata Not Determined

Topsoil: Both borings encountered an approximately 6-inch-thick layer of topsoil at the ground surface. The topsoil was described as moist, dark brown fine to medium-grained sand with trace grass, roots, and organic silt.

Fill: Artificial Fill was encountered underlying the topsoil in both borings and extended to a depth of 13 feet below ground surface at TP-B-101 and 8 feet at TP-B-102 (OW). The Fill was generally described as brown, dark gray, black, medium to coarse-grained sand with gravel and silt and intermittent lenses of clay. Ash, coal, brick and glass fragments were observed within the Fill at various depths. The relative density of this deposit ranged from very loose to loose, as N-Value in this deposit ranged from 2 to 10 blows per foot. One sample of this layer was submitted for geotechnical lab testing and was classified as Silty Sand with Gravel (SM).

Clay: Below the Fill, a layer of clay deposit was encountered and extended to 22 to 25.5 feet in thickness in both borings. Two samples from this layer were submitted for geotechnical lab testing, one from 14 feet below ground surface and the other from 24 feet below ground surface. The sample tested from 14 feet below ground surface classified as a high plasticity clay (CH) whereas the sample tested from 24 ft. below ground surface classified as a lean clay (CL). The samples were generally described as bluish gray to gray, medium to high plasticity clay. The consistency of clay deposit generally increased with depth. One (1) undisturbed sample of this material was collected during TP-B-102 (OW).

Glacial Till: Below the Clay, Glacial Till was encountered. The materials within the Glacial Till were generally described as light gray sand with silt and gravel. One sample from this deposit was submitted for lab testing to substantiate field classifications and it was classified as Silty Sand with Gravel (SM). The relative density of this deposit based on SPT N-values (generally over 50) is very dense.

Probable Weathered Rock/Bedrock: No rock cores were taken during the exploration, so the top of bedrock was not confirmed. However, rock fragments indicative of probable top of weathered rock/bedrock were observed at a depth of 41.4 ft. below ground surface during boring TP-B-101.

3.2.3 Groundwater

3.2.3.1 Observations During Drilling

In general, groundwater was encountered within our test borings during drilling at a depth of about 6 feet below ground surface during augering (prior to the introduction of water into the borehole). Groundwater levels at the end of drilling may be influenced by the introduction of drilling fluids during boring advancement and are therefore not reported.

The groundwater information reported herein is based on observations made during drilling and may not represent the actual groundwater level. The groundwater level presented in this section only represents the conditions encountered at the time and location of the explorations. Seasonal fluctuation should be anticipated.

3.2.3.2 Monitoring Well Data

An open standpipe groundwater observation well was installed upon completion of boring TP-B-102(OW) with a 10-ft screened interval between 4 and 14 feet below ground surface. Three readings were taken in this well and are listed in Table 5.

Table 5: Tufts Park Observation Well readings

Well ID	Date	Depth to Water (ft.)
TP-B-102 (OW)	11/22/2019	2.6
	12/26/2019	3.1
	3/16/2020	3.1

4.0 ENVIRONMENTAL REVIEW

Kleinfelder reviewed the Massachusetts Department of Environmental Protection (MassDEP) Massachusetts Contingency Plan (MCP) Searchable Sites Database, plans provided by the City of Medford, as well as resources available from the Environmental Protection Agency (EPA) to determine whether any known open or closed release of oil or hazardous material (OHM) was reported at or in proximity to Barry Playground and Tufts Park, and to evaluate the potential for encountering OHM-contaminated soil or groundwater during project work.

According to the EPA's Superfund Sites Search there are no National Priority List and Superfund Alternative Approach Sites or Superfund National Priority Sites in the vicinity of either Project area.

4.1 BARRY PLAYGROUND

4.1.1 Site Overview

MassDEP Searchable Sites Database was reviewed for sites which may pose an environmental concern in the vicinity of Barry Playground. One site was identified in the vicinity of Barry Playground, located at 46 Summer Street, approximately 20 feet east of the playground. This site was assigned Release Tracking Number (RTN) 3-28722 in September 2009 due to a spill of #2 Fuel Oil within the basement of a residential property. The release was limited to approximately 20-50 gallons of oil. Cleanup of the release included use of sorbents, as well as the excavation of soil from beneath the basement slab. The site was closed with a Class A-1 Response Action Outcome in December 2009.

4.1.2 Site Soils – Field Investigation

No visual or olfactory evidence of contamination was identified during subsurface investigations performed at Barry Playground.

4.2 TUFTS PARK

4.2.1 Site Overview

Based upon available documents reviewed from MassDEP's MCP Searchable Sites Database, several release sites were identified in the vicinity of Tufts Park. Based upon the nature and extent of release, location in relation to the project area, and regulatory status of the sites, most of the sites are not expected to represent an environmental concern to the project area.

One site of concern was identified at 448 Main Street located due east of Tufts Park, which was assigned RTN 3-27363 in December 2007. Several petroleum-related constituents were identified in site soil (above reportable concentrations) and groundwater (below reportable concentrations), which were attributed to the historic use of the site as a gasoline filling station. Additionally, lead was identified in soils at the site, and was attributed to historic fill. The site underwent a remedial soil excavation and extent sampling indicated that soil contained concentrations of OHM below standards. This site was closed with a Class A-2 Response Action Outcome Statement in March 2008. Based upon extent and nature of the release and regulatory closure of this site, it is considered to be unlikely the project area would be impacted by this offsite release.

Another site of concern was identified at 55-57 Marion Street, located north of Tufts Park, which was assigned RTN 3-29737 in January 2011 due to a sudden release of #2 fuel oil into the basement of a residence. Sorbents were used to contain the release, and excavation of soils was performed. Groundwater samples collected did not identify petroleum constituents at levels above reportable concentrations. The site was closed with a Class A-2 Response Action Outcome Statement in September 2011. Based upon extent and nature of the release and regulatory closure of this site, it is considered to be unlikely the project area would be impacted by this offsite release.

4.2.2 Historic Use of Tufts Park

A plan provided by the City of Medford entitled "City of Medford Engineering Department, Preliminary plan showing proposed Drain in Tufts Park" dated July 11, 1906 was also reviewed. This plan shows areas of the park identified as "Old Clay Pits" and "Old Pits nearly all filled now," indicating that the park was previously used to source clay, likely for the brick-making industry, but had since been backfilled with material. The backfilling of these former clay pits and the time period in which the filling occurred are indications of the potential that historic fill impacted by OHM may have been utilized at the site.

4.2.3 Site Soils – Field Investigation

During subsurface investigations at Tufts Park, soils within borings TP-B-101 and TP-B-102(OW) were observed to contain visible ash and coal, indicating the potential for contamination with OHM such as metals, polycyclic aromatic hydrocarbons, petroleum constituents and/or other contaminants associated with historic fill material.

Soils were screened with a portable x-ray fluorescence (XRF) analyzer to screen for the presence of metals. XRF screening provides approximate metals concentrations in the field without submitting samples for laboratory analysis. Results of XRF screening identified concentrations of the metals lead, arsenic and chromium in the soils, at levels which would exceed the corresponding MassDEP MCP Reportable Concentrations for soil laboratory analytical results. Since XRF screening does not provide laboratory-quality definitive analytical results, there is currently no Reportable Condition. If lab samples are analyzed at a later time, however, we expect based on this screening data that a Reportable Condition would likely be identified. Depending on the results of potential future soil laboratory analytical samples, there is a potential that certain regulatory exemptions could apply to the conditions at the site. We recommend that analytical samples be collected as part of the final design process, to determine soil management options, regulatory requirements and/or exposure considerations, if plans for the project move forward.

Should a reportable condition to MassDEP be identified, the timeframe to comply with MassDEP MCP requirements to advance site conditions to Permanent Solution with a condition of “No Significant Risk” (closure) consists of a series of milestones including:

- Perform initial assessment by Year 1;
- Comprehensively assess site conditions by Year 3;
- Site closure (complete remediation if necessary) by Year 6.

There is a lesser risk that, if soil contamination levels at depths less than 12 inches are discovered during design, then the site will immediately require restricted access (typically by installing a temporary fence).

The timeframe to advance site conditions to Permanent Solution outlined above, can be significantly accelerated by making the assessment and potential remediation activities a part of the construction contract that ensues after completion of design.

5.0 RECOMMENDATIONS

At Barry Playground, groundwater depths measured between 11/22/2019 and 3/16/2020 ranged from 2.25 to 3.30 feet below ground surface. Similarly, at Tufts Park, groundwater depths measured between 11/22/2019 and 3/16/2020 ranged from 2.60 to 3.10 feet below ground surface.

The soils at Barry Playground were less conducive to the concept of an infiltration-based BMP than were observed at Tufts Park. The top layer at Barry Playground (which consisted of topsoil and urban fill) was only 2-3 feet thick (as opposed to 8-13 feet at Tufts Park borings). Below this surface layer, the soil strata between 3.0 and 7.5 feet for boring BP-B-102 (or between 3.0 and 19.0 feet for boring BP-B-101) was described visually as a moist, grayish brown clay. Laboratory tests performed for a soil sample taken at boring BP-B-102 (at 5-7 foot depth) classified the soil as a lean clay. Given the hydraulic conductivity of this type of soil, a structural stormwater BMP implemented within this soil horizon would likely require amendment or replacement of soils below the bottom footprint in order to be suitable for infiltration.

Due primarily to high groundwater table elevation, we have determined that a large-scale infiltration-based BMP system is infeasible at either the Barry Playground of Tufts Park site. We reviewed this conclusion with the City, and the City was in agreement that the flood reduction approach should employ a stormwater detention and release system rather than an infiltration system. Further, the City indicated that the near- and long-term flood hazards in the vicinity of Tufts Park are of a greater magnitude and near-term priority to address.

Recent flood events and 2070 flood modeling together amplify the need to address flooding that occurs at the Harvard Street railroad underpass, which is a significant transportation thoroughfare between Medford and Somerville. Modeling analysis has shown that the Harvard Street underpass location has the highest magnitude of flooding of any of the four primary roadways connecting into Somerville at the southern edge of South Medford.

In summary, we recommend the City consider a subsurface strategy at Tufts Park to target storage and detention, rather than infiltration. We also recommend that subsurface conditions, related to environmental contaminant indicators, are revisited as part of a later stage of design, and/or as part of any testing activities pursuant to pre-construction activities.

APPENDIX A

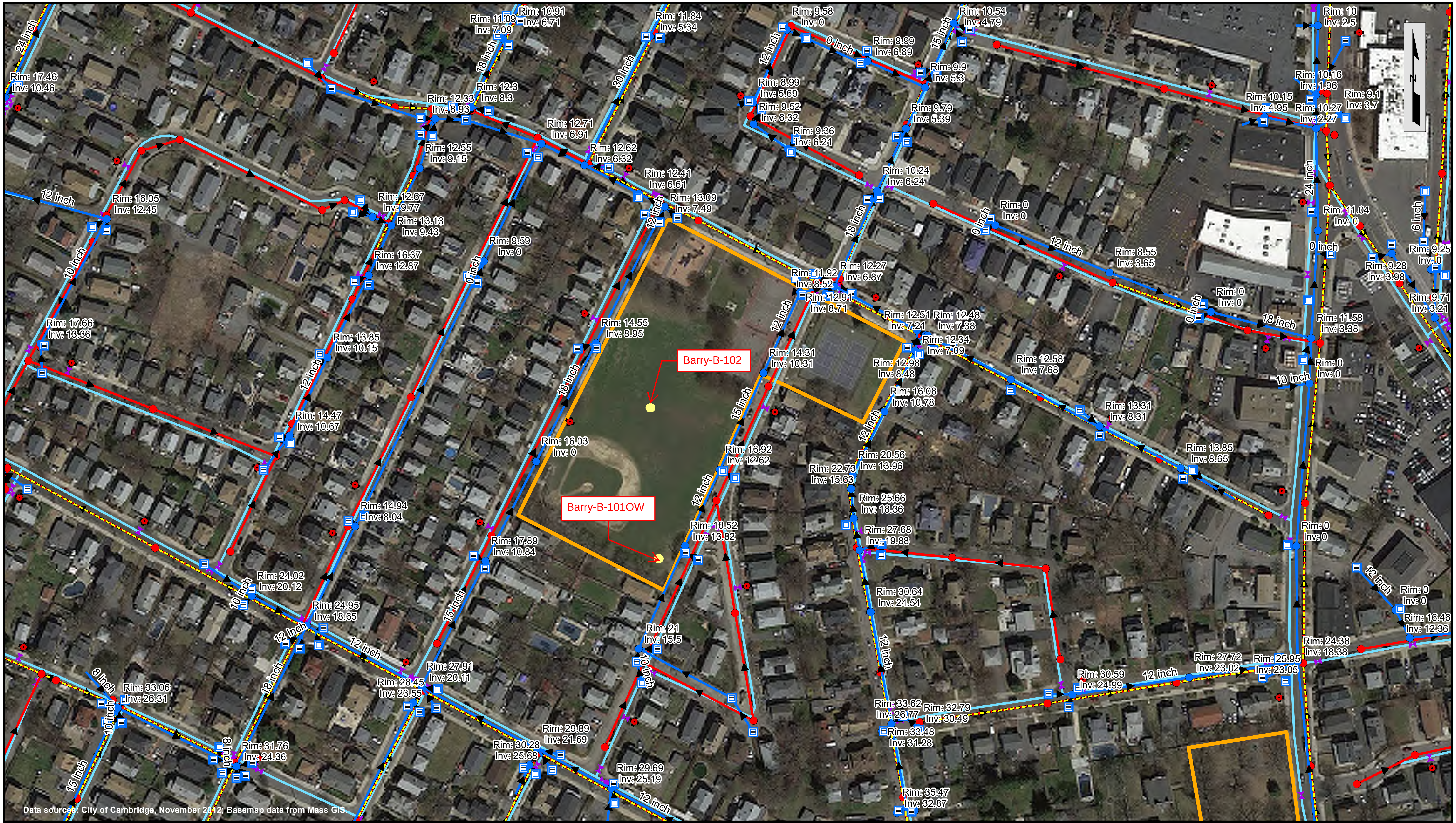
Site Boring Plan Locations

Soil Borings

Soil Laboratory Test Results

Appendix A.1-1

Barry Playground Boring Location Plan



Legend

▣	Catch basin	●	Sewer manhole	✚	Hydrant (Offset)
●	Drain manhole	------	Sewer underdrain	⋈	Water valve
─▶─	Storm drain	─▶─	Sewer main	──	Water main

☐ Park Area

0 100 200
Feet

Locations are approximate

This information was developed specifically and for the exclusive use for the City of Cambridge's Climate Change Vulnerability Assessment.The materials are not intended to be suitable for re-use on extensions of the project or any other project. Any re-use, without the prior written verification or adaptation by Kleinfelder for the specific purpose intended will be at the user's sole risk without liability or legal exposure to Kleinfelder, ATMOS or the City of Cambridge.

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CITY OF MEDFORD
MVP GRANT
SOUTH MEDFORD FLOOD MITIGATION

Barry Playground
74 Summer St, Medford, MA 02155

MAP

Appendix A.1-2

Tufts Park Boring Location Plan

Data sources: City of Cambridge, November 2012; Basemap data from Mass GIS.

Legend

- ▣ Catch basin
- ● Drain manhole
- ─▶─ Storm drain
- ● Sewer manhole
- ‐‐‐‐ Sewer underdrain
- ─▶─ Sewer main
- ✚ Hydrant (Offset)
- ⋈ Water valve
- ── Water main
- ▭ Park Area

0 100 200
Feet

Locations are approximate

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CITY OF MEDFORD
MVP GRANT
SOUTH MEDFORD FLOOD MITIGATION

Tufts Park
437 Main St, Medford, MA 02155

MAP

Appendix A.2

Boring Logs

SAMPLE/SAMPLER TYPE GRAPHICS

SHELBY TUBE SAMPLER

STANDARD PENETRATION SPLIT SPOON SAMPLER
(2 in. (50.8 mm.) outer diameter and 1-3/8 in. (34.9 mm.) inner diameter)

GROUND WATER GRAPHICS

- ▽ WATER LEVEL (level where first observed)
- ▼ WATER LEVEL (level after exploration completion)
- ▼ WATER LEVEL (additional levels after exploration)
- ≈ OBSERVED SEEPAGE

NOTES

- The report and graphics key are an integral part of these logs. All data and interpretations in this log are subject to the explanations and limitations stated in the report.
- Lines separating strata on the logs represent approximate boundaries only. Actual transitions may be gradual or differ from those shown.
- No warranty is provided as to the continuity of soil or rock conditions between individual sample locations.
- Logs represent general soil or rock conditions observed at the point of exploration on the date indicated.
- In general, Unified Soil Classification System designations presented on the logs were based on visual classification in the field and were modified where appropriate based on gradation and index property testing.
- Fine grained soils that plot within the hatched area on the Plasticity Chart, and coarse grained soils with between 5% and 12% passing the No. 200 sieve require dual USCS symbols, ie., GW-GM, GP-GM, GW-GC, GP-GC, GC-GM, SW-SM, SP-SM, SW-SC, SP-SC, SC-SM.
- If sampler is not able to be driven at least 6 inches then 50/X indicates number of blows required to drive the identified sampler X inches with a 140 pound hammer falling 30 inches.

ABBREVIATIONS

WOH - Weight of Hammer
WOR - Weight of Rod

UNIFIED SOIL CLASSIFICATION SYSTEM (ASTM D 2487)

COARSE GRAINED SOILS (More than half of material is larger than the #200 sieve)	**GRAVELS** (More than half of coarse fraction is larger than the #4 sieve)	CLEAN GRAVEL WITH <5% FINES	Cu≥4 and 1≤Cc≤3		**GW**	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES WITH LITTLE OR NO FINES
			Cu<4 and/ or 1>Cc>3		**GP**	POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES WITH LITTLE OR NO FINES
		GRAVELS WITH 5% TO 12% FINES	Cu≥4 and 1≤Cc≤3		**GW-GM**	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES WITH LITTLE FINES
					GW-GC	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES WITH LITTLE CLAY FINES
			Cu<4 and/ or 1>Cc>3		**GP-GM**	POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES WITH LITTLE FINES
					GP-GC	POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES WITH LITTLE CLAY FINES
		GRAVELS WITH > 12% FINES			**GM**	SILTY GRAVELS, GRAVEL-SILT-SAND MIXTURES
					GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES
					GC-GM	CLAYEY GRAVELS, GRAVEL-SAND-CLAY-SILT MIXTURES
	SANDS (Half or more of coarse fraction is smaller than the #4 sieve)	CLEAN SANDS WITH <5% FINES	Cu≥6 and 1≤Cc≤3		**SW**	WELL-GRADED SANDS, SAND-GRAVEL MIXTURES WITH LITTLE OR NO FINES
			Cu<6 and/ or 1>Cc>3		**SP**	POORLY GRADED SANDS, SAND-GRAVEL MIXTURES WITH LITTLE OR NO FINES
		SANDS WITH 5% TO 12% FINES	Cu≥6 and 1≤Cc≤3		**SW-SM**	WELL-GRADED SANDS, SAND-GRAVEL MIXTURES WITH LITTLE FINES
					SW-SC	WELL-GRADED SANDS, SAND-GRAVEL MIXTURES WITH LITTLE CLAY FINES
			Cu<6 and/ or 1>Cc>3		**SP-SM**	POORLY GRADED SANDS, SAND-GRAVEL MIXTURES WITH LITTLE FINES
					SP-SC	POORLY GRADED SANDS, SAND-GRAVEL MIXTURES WITH LITTLE CLAY FINES
		SANDS WITH > 12% FINES			**SM**	SILTY SANDS, SAND-GRAVEL-SILT MIXTURES
					SC	CLAYEY SANDS, SAND-GRAVEL-CLAY MIXTURES
					SC-SM	CLAYEY SANDS, SAND-SILT-CLAY MIXTURES

FINE GRAINED SOILS (Half or more of material is smaller than the #200 sieve)	SILTS AND CLAYS (Liquid Limit less than 50)		**ML**	INORGANIC SILTS AND VERY FINE SANDS, SILTY OR CLAYEY FINE SANDS, SILTS WITH SLIGHT PLASTICITY
			CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
			CL-ML	INORGANIC CLAYS-SILTS OF LOW PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
			OL	ORGANIC SILTS & ORGANIC SILTY CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS (Liquid Limit 50 or greater)		**MH**	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILT
			CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
			OH	ORGANIC CLAYS & ORGANIC SILTS OF MEDIUM-TO-HIGH PLASTICITY

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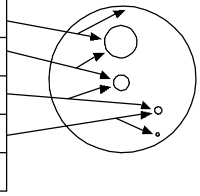
GRAPHICS KEY

South Medford Flood Study
Medford, Massachusetts

FIGURE
A-1

GRAIN SIZE

DESCRIPTION		SIEVE SIZE	GRAIN SIZE	APPROXIMATE SIZE
Boulders		>12 in. (304.8 mm.)	>12 in. (304.8 mm.)	Larger than basketball-sized
Cobbles		3 - 12 in. (76.2 - 304.8 mm.)	3 - 12 in. (76.2 - 304.8 mm.)	Fist-sized to basketball-sized
Gravel	coarse	3/4 -3 in. (19 - 76.2 mm.)	3/4 -3 in. (19 - 76.2 mm.)	Thumb-sized to fist-sized
	fine	#4 - 3/4 in. (#4 - 19 mm.)	0.19 - 0.75 in. (4.8 - 19 mm.)	Pea-sized to thumb-sized
Sand	coarse	#10 - #4	0.079 - 0.19 in. (2 - 4.9 mm.)	Rock salt-sized to pea-sized
	medium	#40 - #10	0.017 - 0.079 in. (0.43 - 2 mm.)	Sugar-sized to rock salt-sized
	fine	#200 - #40	0.0029 - 0.017 in. (0.07 - 0.43 mm.)	Flour-sized to sugar-sized
Fines		Passing #200	<0.0029 in. (<0.07 mm.)	Flour-sized and smaller



SECONDARY CONSTITUENT

	AMOUNT	
Term of Use	Secondary Constituent is Fine Grained	Secondary Constituent is Coarse Grained
Trace	<5%	<15%
With	≥5 to <15%	≥15 to <30%
Modifier	≥15%	≥30%

MOISTURE CONTENT

DESCRIPTION	FIELD TEST
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, usually soil is below water table

CEMENTATION

DESCRIPTION	FIELD TEST
Weakly	Crumbles or breaks with handling or slight finger pressure
Moderately	Crumbles or breaks with considerable finger pressure
Strongly	Will not crumble or break with finger pressure

CONSISTENCY - FINE-GRAINED SOIL

CONSISTENCY	SPT - N_{60} (# blows / ft)	Pocket Pen (tsf)	UNCONFINED COMPRESSIVE STRENGTH (Q_u)(psf)	VISUAL / MANUAL CRITERIA
Very Soft	<2	PP < 0.25	<500	Thumb will penetrate more than 1 inch (25 mm). Extrudes between fingers when squeezed.
Soft	2 - 4	0.25 ≤ PP <0.5	500 - 1000	Thumb will penetrate soil about 1 inch (25 mm). Remolded by light finger pressure.
Medium Stiff	4 - 8	0.5 ≤ PP <1	1000 - 2000	Thumb will penetrate soil about 1/4 inch (6 mm). Remolded by strong finger pressure.
Stiff	8 - 15	1 ≤ PP <2	2000 - 4000	Can be imprinted with considerable pressure from thumb.
Very Stiff	15 - 30	2 ≤ PP <4	4000 - 8000	Thumb will not indent soil but readily indented with thumbnail.
Hard	>30	4 ≤ PP	>8000	Thumbnail will not indent soil.

FROM TERZAGHI AND PECK, 1948; LAMBE AND WHITMAN, 1969; FHWA, 2002; AND ASTM D2488

REACTION WITH HYDROCHLORIC ACID

DESCRIPTION	FIELD TEST
None	No visible reaction
Weak	Some reaction, with bubbles forming slowly
Strong	Violent reaction, with bubbles forming immediately

APPARENT / RELATIVE DENSITY - COARSE-GRAINED SOIL

APPARENT DENSITY	SPT-N_{60} (# blows/ft)	MODIFIED CA SAMPLER (# blows/ft)	CALIFORNIA SAMPLER (# blows/ft)	RELATIVE DENSITY (%)
Very Loose	<4	<4	<5	0 - 15
Loose	4 - 10	5 - 12	5 - 15	15 - 35
Medium Dense	10 - 30	12 - 35	15 - 40	35 - 65
Dense	30 - 50	35 - 60	40 - 70	65 - 85
Very Dense	>50	>60	>70	85 - 100

FROM TERZAGHI AND PECK, 1948

PLASTICITY

DESCRIPTION	LL	FIELD TEST
Non-plastic	NP	A 1/8-in. (3 mm.) thread cannot be rolled at any water content.
Low (L)	< 30	The thread can barely be rolled and the lump or thread cannot be formed when drier than the plastic limit.
Medium (M)	30 - 50	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. The lump or thread crumbles when drier than the plastic limit.
High (H)	> 50	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rerolled several times after reaching the plastic limit. The lump or thread can be formed without crumbling when drier than the plastic limit.

STRUCTURE

DESCRIPTION	CRITERIA
Stratified	Alternating layers of varying material or color with layers at least 1/4-in. thick, note thickness.
Laminated	Alternating layers of varying material or color with the layer less than 1/4-in. thick, note thickness.
Fissured	Breaks along definite planes of fracture with little resistance to fracturing.
Slickensided	Fracture planes appear polished or glossy, sometimes striated.
Blocky	Cohesive soil that can be broken down into small angular lumps which resist further breakdown.
Lensed	Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay; note thickness.

ANGULARITY

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

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SOIL DESCRIPTION KEY

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Medford, Massachusetts

FIGURE

A-2

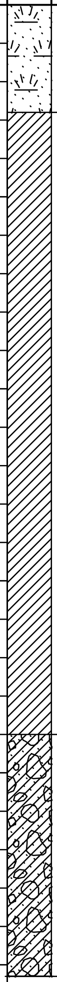
BORING LOG BP-B-101(OW)

Date Begin - End: 11/12/2019
Drilling Company: CarrDee
Logged By: L. Wang
Drill Crew: Steve & Frank
Hor.-Vert. Datum: Not Available
Drilling Equipment: ATV
Hammer Type - Drop: 140 lb. Auto - 30 in.
Plunge: -90 degrees
Drilling Method: Drive and Wash
Weather: Rain and Snow
Exploration Diameter: 3 in. O.D.

FIELD EXPLORATION — Surface Condition: Grass

LABORATORY RESULTS

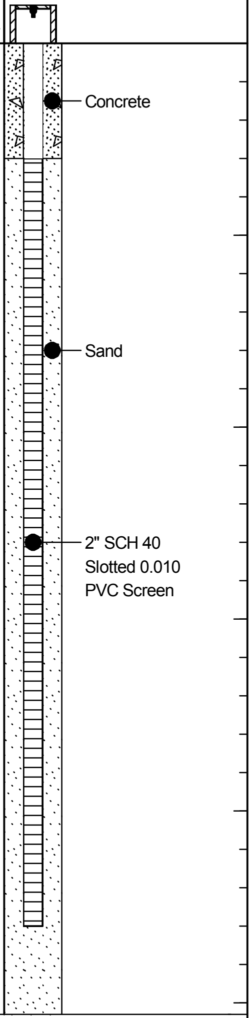
Depth (feet)	Graphical Log	Lithologic Description	Sample Number	Sample Type	Blow Counts(BC)= Uncorr. Blows/6 in. Pocket Pen(PP)= tsf	Recovery (NR=No Recovery)	USCS Symbol	Water Content (%)	Dry Unit Wt. (pcf)	Passing #4 (%)	Passing #200 (%)	Liquid Limit	Plasticity Index (NP=NonPlastic)
		S-1: TOPSOIL: Silty SAND (SM): reddish brown, moist, loose, trace grass roots, PID=0.1	S-1		BC=2 3 2 2	6"							
		S-2: top 10": similar to S-1, PID=0.0	S-2		BC=2 3 7 8	24"							
		S-2: bottom 14": **Lean CLAY (CL)**: low plasticity, brownish gray, moist, stiff, with iron oxide staining											
5		**S-3:** similar to bottom 14" of S-2 except very stiff, PID=0.0	S-3		BC=12 14 21 14	16"						41	19
10		**S-4: Sandy CLAY (CL)**: medium plasticity, light brownish gray, wet, medium stiff, PID=0.0	S-4		BC=2 3 4 4	9"							
15		**S-5:** No recovery, possible clay based on outwash	S-5		BC=2 2 2 5	NR							
		Assumed lithology change based on drilling action, drill rig shaking at 19 feet											
20		**S-6: GLACIAL TILL: Silty SAND with Gravel (SM)**: medium-grained sand, gravel observed as rock fragments, gray, wet, PID=0.0	S-6		BC=24 26 16 21	17"				73	23		
25		**S-7:** sampled as rock fragments	S-7		BC=100/4"	1"							
30													



▽ (groundwater at approximately 6 ft.)

MONITORING WELL CONSTRUCTION*

Completion Method: Roadbox



The boring was terminated at approximately 25.3 ft. below ground surface. A monitoring well was installed after the completion of drilling.

GROUNDWATER LEVEL INFORMATION:

▽ Groundwater was observed at approximately 6 ft. below ground surface during drilling.

GENERAL NOTES:

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BORING LOG BP-B-101(OW)

South Medford Flood Study
Medford, Massachusetts

BORING

BP-B-101(OW)

Date Begin - End: 11/12/2019
Logged By: L. Wang
Hor.-Vert. Datum: Not Available
Plunge: -90 degrees
Weather: Rainy

Drilling Company: CarrDee
Drill Crew: Steve & Frank
Drilling Equipment: ATV
Drilling Method: Drive and Wash
Exploration Diameter: 3 in. O.D.

BORING LOG BP-B-102

Hammer Type - Drop: 140 lb. Auto - 30 in.

FIELD EXPLORATION						LABORATORY RESULTS							
Depth (feet)	Surface Condition: Grass Lithologic Description	Sample Number	Sample Type	Blow Counts(BC)= Uncorr. Blows/6 in. Pocket Pen(PP)= tsf	Recovery (NR=No Recovery)	USCS Symbol	Water Content (%)	Dry Unit Wt. (pcf)	Passing #4 (%)	Passing #200 (%)	Liquid Limit	Plasticity Index (NP=NonPlastic)	Additional Tests/ Remarks
	S-1: TOPSOIL: Poorly Graded SAND with Silt (SP-SM): medium to coarse-grained, dark brown, moist, loose, trace grass roots, PID=0.3	S-1	◣	BC=2 2 5 6	6"								
	S-2: CLAY (CL): trace sand, light brown and gray, moist, very stiff, PID=0.2	S-2	◣	BC=7 13 11 16	17"								
⊻ 5	**S-3:** top 18": similar to S-2, PID=0.2 **S-3:** bottom 6": **Silty SAND (SM)**: fine-grained sand, light brownish gray, wet	S-3	◣	BC=18 17 17 17	24"								
	S-4: top 14": **Sandy CLAY (CL)**: low plasticity, light brown, wet, medium stiff, PID=0.1 **S-4:** bottom 7": **GLACIAL TILL: Silty SAND with Gravel (SM)**: 15% gravel, brownish gray, wet	S-4	◣	BC=3 4 15 13	21"				74	45			Switch to drive and wash at 6 feet
10	**S-5:** similar to bottom 7" of S-4 except olive yellow and dark brown, medium dense, angular, PID=0.1	S-5	◣	BC=16 15 9 11	7"								
													Drill rig shaking at 13 feet
15	**S-6: GLACIAL TILL: Poorly Graded SAND with Silt and Gravel (SP-SM)**: coarse-grained sand, 30% gravel, olive yellow, wet, very dense, PID=0.1	S-6	◣	BC=19 23 56 99	12"								High SPT N-Value due to presence of boulder which was encountered at an approximate depth of 16.5 ft.
20	**S-7:** similar to S-8 except brownish gray, medium to coarse-grained sand, 15% gravel, sub-angular to angular, dark gray rock fragments, dense	S-7	◣	BC=14 22 27 21	7"								
25	**S-8:** similar to S-7 except very dense - fine to medium-grained sand, 10% fine-grained gravel at bottom of sample - rock fragments at tip of sampler spoon	S-8	◣	BC=13 33 44 56	7"								
30	The boring was terminated at approximately 27 ft. below ground surface. The boring was backfilled with auger cuttings on November 12, 2019.												

GROUNDWATER LEVEL INFORMATION:
⊻ Groundwater was observed at approximately 5 ft. below ground surface during drilling.
GENERAL NOTES:

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DATE: 12/12/2019

BORING LOG BP-B-102

South Medford Flood Study
Medford, Massachusetts

BORING
BP-B-102
PAGE: 1 of 1

Date Begin - End:	11/13/2019	**Drilling Company:**	CarrDee		**BORING LOG TP-B-101**
Logged By:	L. Wang	**Drill Crew:**	Steve & Frank		
Hor.-Vert. Datum:	Not Available	**Drilling Equipment:**	ATV	**Hammer Type - Drop:**	140 lb. Auto - 30 in.
Plunge:	-90 degrees	**Drilling Method:**	HSA & Drive and Wash		
Weather:	Sunny	**Exploration Diameter:**	4 in. O.D.		

Latitude: 42.40149°
Longitude: -71.10805°
Surface Condition: Grass

FIELD EXPLORATION							LABORATORY RESULTS							
Depth (feet)	Graphical Log	Lithologic Description	Sample Number	Sample Type	Blow Counts(BC)= Uncorr. Blows/6 in. Pocket Pen(PP)= tsf	Recovery (NR=No Recovery)	USCS Symbol	Water Content (%)	Dry Unit Wt. (pcf)	Passing #4 (%)	Passing #200 (%)	Liquid Limit	Plasticity Index (NP=NonPlastic)	Additional Tests/ Remarks
		S-1: top 6": **TOPSOIL: Poorly Graded SAND with Silt (SP-SM)**: medium-grained sand, brown, wet, trace grass	S-1		BC=3 2 2 3	10"								Ground was frozen
		S-1: bottom 4": **FILL: Silty SAND with Gravel (SM)**: light brown, trace ash and coal **S-2:** similar to bottom 4" of S-1 except brown	S-2		BC=3 4 3 3	7"								
5		**S-3:** similar to bottom 4" of S-1 except grayish brown, fine to medium-grained sand, 10% gravel, very loose	S-3		BC=2 1 1 1	8"				84	35			Auger from 4 to 10 feet
▽		**S-4:** top 7": similar to S-3 **S-4:** bottom 8": **FILL: Poorly Graded SAND (SP)**: medium to coarse-grained sand, black, wet, trace ash, brick, and glass	S-4		BC=1 1 1 1	15"								
		S-5: No recovery	S-5		BC=1 1 1 1	NR								
10		**S-6:** similar to bottom 8" of S-4 except black and dark gray, medium-grained sand, trace gravel and coal	S-6		BC=1 1 1 1	7"								
		S-7: top 4": similar to S-6 except trace glass, coal, and wood debris **S-7:** bottom 15": **Fat CLAY (CH)**: bluish gray, wet, very soft	S-7		BC=1 WOH WOH WOH	19"								
15		**S-8:** similar to bottom 15" of S-7	S-8		BC=WOH WOH 1 1	19"						59	29	
		S-9: similar to bottom 15" of S-7	S-9		BC=WOH WOH 1 1	24"								
		S-10: similar to bottom 15" of S-7 except medium stiff	S-10		BC=2 3 2 2	24"								
20		**S-11: GLACIAL OUTWASH: Poorly Graded SAND with Silt and Gravel (SP-SM)**: fine to medium-grained sand, 30% gravel, olive yellow, wet, loose	S-11		BC=6 4 3 4	5"								Switched from HSA to 4" casing at 20 ft. bgs. and drilling fluid introduced into borehole.
		S-12: CLAY (CL): trace medium-grained sand, light gray, moist, stiff	S-12		BC=5 4 5 4	24"								
25		**S-13:** similar to S-12 except gray, medium stiff, gravel in tip of spoon	S-13		BC=3 3 4 6	24"						39	17	
		S-14: similar to S-13 except stiff	S-14		BC=5 6 6 6	24"								
30		**S-15: CLAY with Sand (CL)**: moist, medium stiff	S-15		BC=3 3 4 5	24"								
		ST-1: No Recovery	ST-1											Drill rig shaking at 34.5 feet

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PROJECT NO.: 20202050.001A
DRAWN BY: MAP
CHECKED BY: DD
DATE: 12/12/2019

BORING LOG TP-B-101

South Medford Flood Study
Medford, Massachusetts

BORING
TP-B-101

Date Begin - End: 11/13/2019
Drilling Company: CarrDee
BORING LOG TP-B-101
Logged By: L. Wang
Drill Crew: Steve & Frank
Hor.-Vert. Datum: Not Available
Drilling Equipment: ATV
Hammer Type - Drop: 140 lb. Auto - 30 in.
Plunge: -90 degrees
Drilling Method: HSA & Drive and Wash
Weather: Sunny
Exploration Diameter: 4 in. O.D.

		FIELD EXPLORATION					LABORATORY RESULTS							
Depth (feet)	Graphical Log	Latitude: 42.40149° Longitude: -71.10805° Surface Condition: Grass Lithologic Description	Sample Number	Sample Type	Blow Counts(BC)= Uncorr. Blows/6 in. Pocket Pen(PP)= tsf	Recovery (NR=No Recovery)	USCS Symbol	Water Content (%)	Dry Unit Wt. (pcf)	Passing #4 (%)	Passing #200 (%)	Liquid Limit	Plasticity Index (NP=NonPlastic)	Additional Tests/ Remarks
		S-16: GLACIAL TILL: Silty SAND with Gravel (SM): medium-grained sand, 25% gravel, angular to sub-angular, light gray, wet, very dense	S-16		BC=30 34 29 23									
40		**S-17:** similar to S-16 except with 30% gravel	S-17		BC=30 50 100/5"	12"				64	22			
		S-17: tip of sample spoon: **CAMBRIDGE ARGILLITE: Highly Weathered BEDROCK**: dark gray												
45		The boring was terminated at approximately 41.4 ft. below ground surface. The boring was backfilled with auger cuttings and well sand on surface on November 13, 2019.												
50														
55														
60														
65														

GROUNDWATER LEVEL INFORMATION:

⊻ Groundwater was observed at approximately 6 ft. below ground surface during drilling.

GENERAL NOTES:

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PROJECT NO.: 20202050.001A
DRAWN BY: MAP
CHECKED BY: DD
DATE: 12/12/2019

BORING LOG TP-B-101

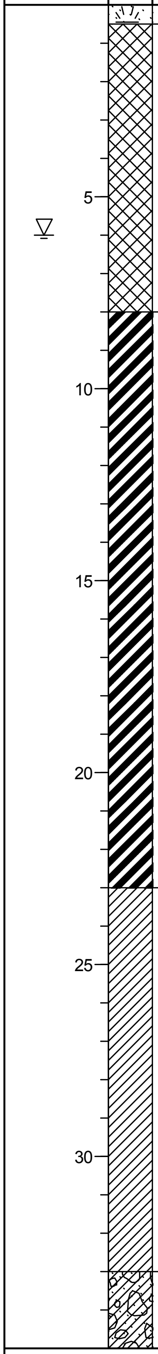
South Medford Flood Study
Medford, Massachusetts

BORING
TP-B-101

Date Begin - End: 11/14/2019
Drilling Company: CarrDee
BORING LOG TP-B-102(OW)
Logged By: M. Chea
Drill Crew: Steve & Frank
Hor.-Vert. Datum: Not Available
Drilling Equipment: ATV
Hammer Type - Drop: 140 lb. Auto - 30 in.
Plunge: -90 degrees
Drilling Method: HSA & Drive and Wash
Weather: Clear
Exploration Diameter: 4 in. O.D.

FIELD EXPLORATION

Latitude: 42.40180°
Longitude: -71.10824°
Surface Condition: Bare Earth



Lithologic Description

S-1: top 6": **TOPSOIL: Silty SAND (SM)**: fine-grained sand, dark brown, moist, loose, trace organic fines and roots, PID=0.309

S-1: bottom 10": **FILL: Poorly Graded SAND with Silt (SP-SM)**: fine to medium-grained sand, brown, moist, loose, trace ash and slag, PID=0.09

S-2: similar to bottom 10" of S-1 except 10% fine-grained angular gravel, very loose, PID=0.126

S-3: top 4": **FILL: Silty SAND (SM)**: fine-grained sand, dark brown, moist, loose, trace organic fines and roots (buried topsoil), PID=0.268

S-3: bottom 3": trace medium-grained sand, trace fine-grained angular gravel, trace clay, brown, PID=0.083

S-4: top 4": **FILL: Poorly Graded SAND with Silt (SP-SM)**: fine-grained sand, trace fine-grained gravel, light gray, wet, loose, PID=0.113

S-4: bottom 6": **FILL: Lean CLAY (CL)**: trace fine-grained sand, low plasticity, light gray, wet, medium stiff, PID=0.113

S-5: Fat CLAY (CH): trace fine-grained sand, medium plasticity, light gray, wet, soft, PID=0.101

S-6: similar to S-5 except medium stiff, PID=0.101

S-7: similar to S-5 except medium to high plasticity, very soft, PID=0.193

ST-1: Obtained undisturbed sample from 17 to 19 feet

S-8: similar to S-7 except soft, PID=0.099

Assumed lithology

S-9: Lean CLAY (CL): light gray, wet, stiff, PID=0.097

S-10: similar to S-9 except trace fine-grained sand, medium stiff, PID=0.096

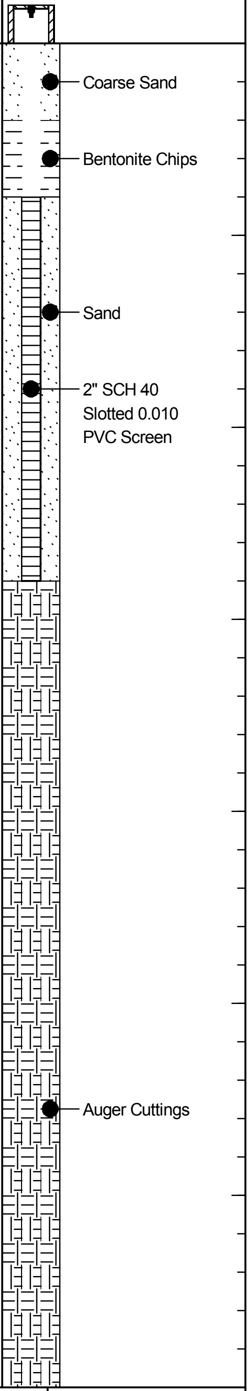
S-11: GLACIAL TILL

Sample Number	Blow Counts(BC)= Uncorr. Blows/6 in. Pocket Pen(PP)= tsf	Recovery (NR=No Recovery)	USCS Symbol	Water Content (%)	Dry Unit Wt. (pcf)	Passing #4 (%)	Passing #200 (%)	Liquid Limit	Plasticity Index (NP=NonPlastic)
S-1	BC=1 3 2 3	16"							
S-2	BC=1 1 1 3	7"							
S-3	BC=2 3 7 10	7"							
S-4	BC=7 3 2 3	10"							
S-5	BC=3 1 3 3 PP=0.25	17"							
S-6	BC=4 4 4 4 PP=0.5	19"							
S-7	BC=1 1 1 2 PP=<0.25	24"							
ST-1		21"							
S-8	BC=1 1 2 2 PP=0.5	24"							
S-9	BC=3 5 5 6 PP=1.75	24"							
S-10	BC=2 3 4 3 PP=1.5	24"							
S-11	BC=100/0"								

LABORATORY RESULTS

MONITORING WELL CONSTRUCTION*

Completion Method: Roadbox



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PROJECT NO.: 20202050.001A
DRAWN BY: MAP
CHECKED BY: DD
DATE: 12/12/2019

BORING LOG TP-B-102(OW)

South Medford Flood Study
Medford, Massachusetts

BORING
TP-B-102(OW)

PLOTTED: 12/12/2019 12:54 PM BY: MPalmer
OFFICE FILTER: BOSTON
PROJECT NUMBER: 20202050.001A
gINT FILE: Klf_gint_master_2020
gINT TEMPLATE: E:KLF_STANDARD_GINT_LIBRARY_2020.GLB [_KLF_BORING/TEST PIT SOIL LOG]

Date Begin - End:	11/14/2019	**Drilling Company:**	CarrDee	**BORING LOG TP-B-102(OW)**
Logged By:	M. Chea	**Drill Crew:**	Steve & Frank	
Hor.-Vert. Datum:	Not Available	**Drilling Equipment:**	ATV	**Hammer Type - Drop:** 140 lb. Auto - 30 in.
Plunge:	-90 degrees	**Drilling Method:**	HSA & Drive and Wash	
Weather:	Clear	**Exploration Diameter:**	4 in. O.D.	

Latitude: 42.40180°
Longitude: -71.10824°
Surface Condition: Bare Earth

MONITORING WELL CONSTRUCTION*
Completion Method: Roadbox

Depth (feet)	Graphical Log	FIELD EXPLORATION Lithologic Description	Sample Number	Sample Type	Blow Counts(BC)= Uncorr. Blows/6 in. Pocket Pen(PP)= tsf	Recovery (NR=No Recovery)	LABORATORY RESULTS USCS Symbol	Water Content (%)	Dry Unit Wt. (pcf)	Passing #4 (%)	Passing #200 (%)	Liquid Limit	Plasticity Index (NP=NonPlastic)	MONITORING WELL CONSTRUCTION*
		Note: Boulder encountered at 33.5 feet bgs. Cored through 3.5 foot boulder and 1 foot through the till.												
		S-12: GLACIAL TILL: Silty SAND with Gravel (SM): fine to medium-grained sand, fine-grained sub-angular to angular gravel, gray, wet, very dense, PID=0.155	S-12		BC=26 29 30 35	15"								
40		**S-13:** similar to S-12, PID=0.102	S-13		BC=47 33 29 30									

45

50

55

60

65

The boring was terminated at approximately 41.5 ft. below ground surface. A monitoring well was installed after the completion of drilling.

GROUNDWATER LEVEL INFORMATION:
⊻ Groundwater was observed at approximately 6 ft. below ground surface during drilling.

GENERAL NOTES:
Switched from hollow stem augers to 4" casing and drive and wash at a depth of 10 feet.

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PROJECT NO.: 20202050.001A		BORING LOG TP-B-102(OW)	BORING
DRAWN BY:	MAP	South Medford Flood Study Medford, Massachusetts	TP-B-102(OW)
CHECKED BY:	DD		
DATE:	12/12/2019		PAGE: 2 of 2

Appendix A.3

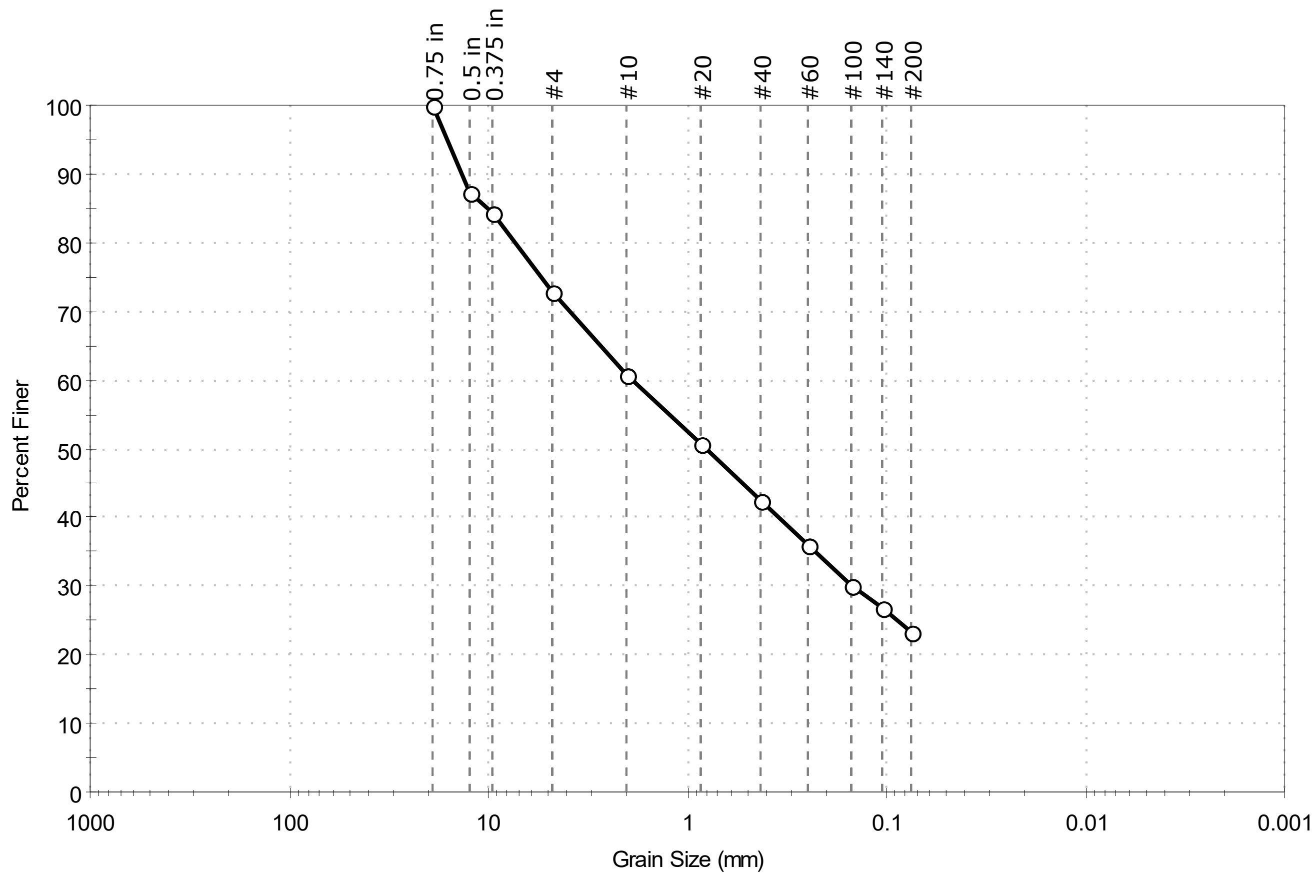
Geotechnical Lab Analysis Result

GeoTesting
EXPRESS

Client:	Kleinfelder, Inc.				
Project:	S-Medford Flood Study				
Location:	Medford, MA			Project No:	GTX-310955
Boring ID:	Barry B101	Sample Type:	jar	Tested By:	ckg
Sample ID:	S6	Test Date:	12/04/19	Checked By:	bfs
Depth :	20-22	Test Id:	531188		

Test Comment: ---
Visual Description: Moist, light yellowish brown silty sand with gravel
Sample Comment: ---

Particle Size Analysis - ASTM D6913



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	27.1	49.7	23.2

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.75 in	19.00	100		
0.5 in	12.50	87		
0.375 in	9.50	84		
#4	4.75	73		
#10	2.00	61		
#20	0.85	51		
#40	0.42	42		
#60	0.25	36		
#100	0.15	30		
#140	0.11	27		
#200	0.075	23		

Coefficients

D_{85} =10.0455 mm	D_{30} =0.1501 mm
D_{60} =1.8796 mm	D_{15} =N/A
D_{50} =0.8060 mm	D_{10} =N/A
C_u =N/A	C_c =N/A

Classification

ASTM N/A

AASHTO Stone Fragments, Gravel and Sand (A-1-b (0))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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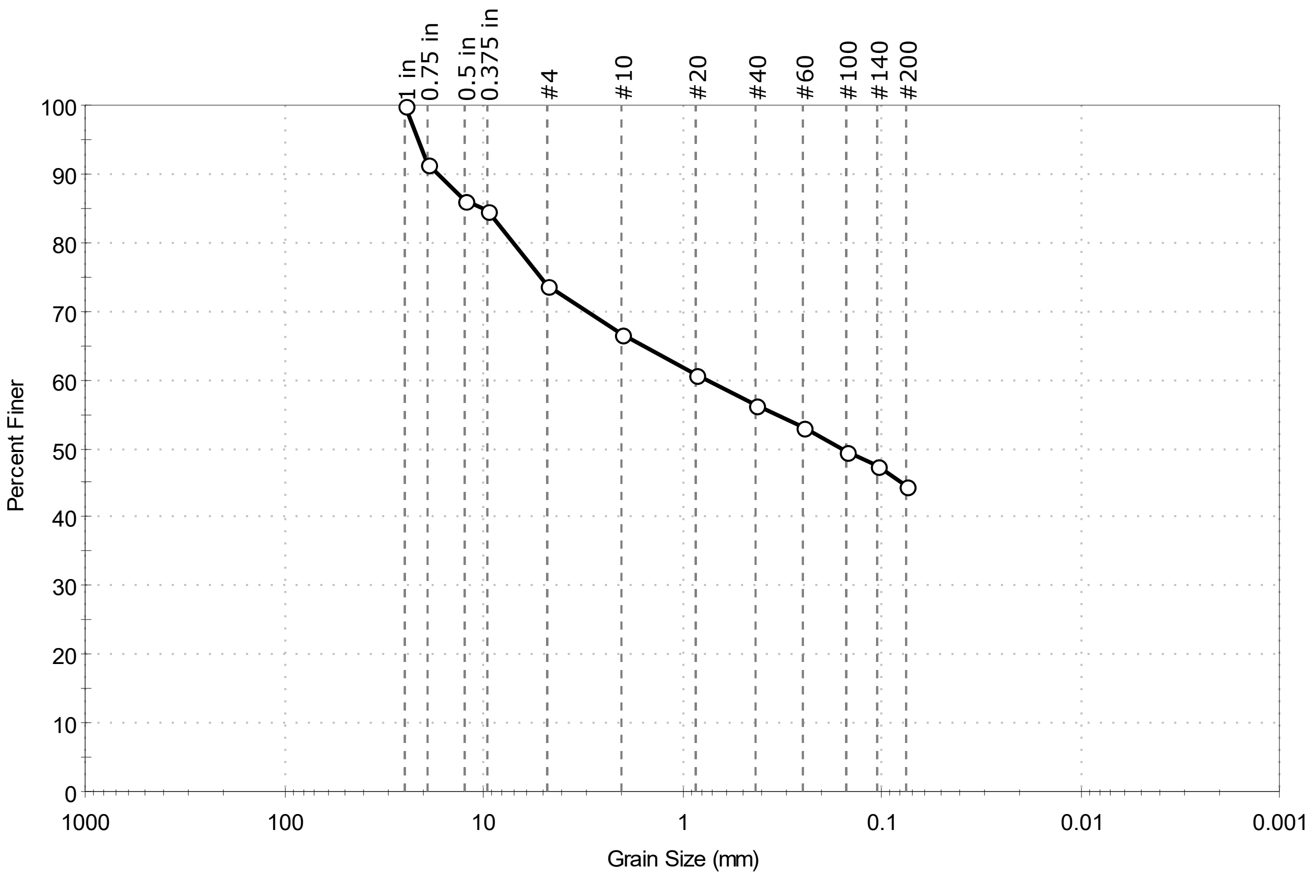
GeoTesting
EXPRESS

Client: Kleinfelder, Inc.
Project: S-Medford Flood Study
Location: Medford, MA
Project No: GTX-310955

Boring ID: Barry B102
Sample Type: jar
Tested By: ckg
Sample ID: S4-2
Test Date: 12/04/19
Checked By: bfs
Depth : 6-8
Test Id: 531189

Test Comment: ---
Visual Description: Moist, pale olive silty sand with gravel
Sample Comment: ---

Particle Size Analysis - ASTM D6913



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	26.4	29.1	44.5

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
1 in	25.00	100		
0.75 in	19.00	91		
0.5 in	12.50	86		
0.375 in	9.50	85		
#4	4.75	74		
#10	2.00	67		
#20	0.85	61		
#40	0.42	56		
#60	0.25	53		
#100	0.15	50		
#140	0.11	47		
#200	0.075	45		

Coefficients

D_{85} =10.2655 mm
D_{30} =N/A
D_{60} =0.7650 mm
D_{15} =N/A
D_{50} =0.1579 mm
D_{10} =N/A
C_u =N/A
C_c =N/A

Classification

ASTM N/A

AASHTO Silty Soils (A-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

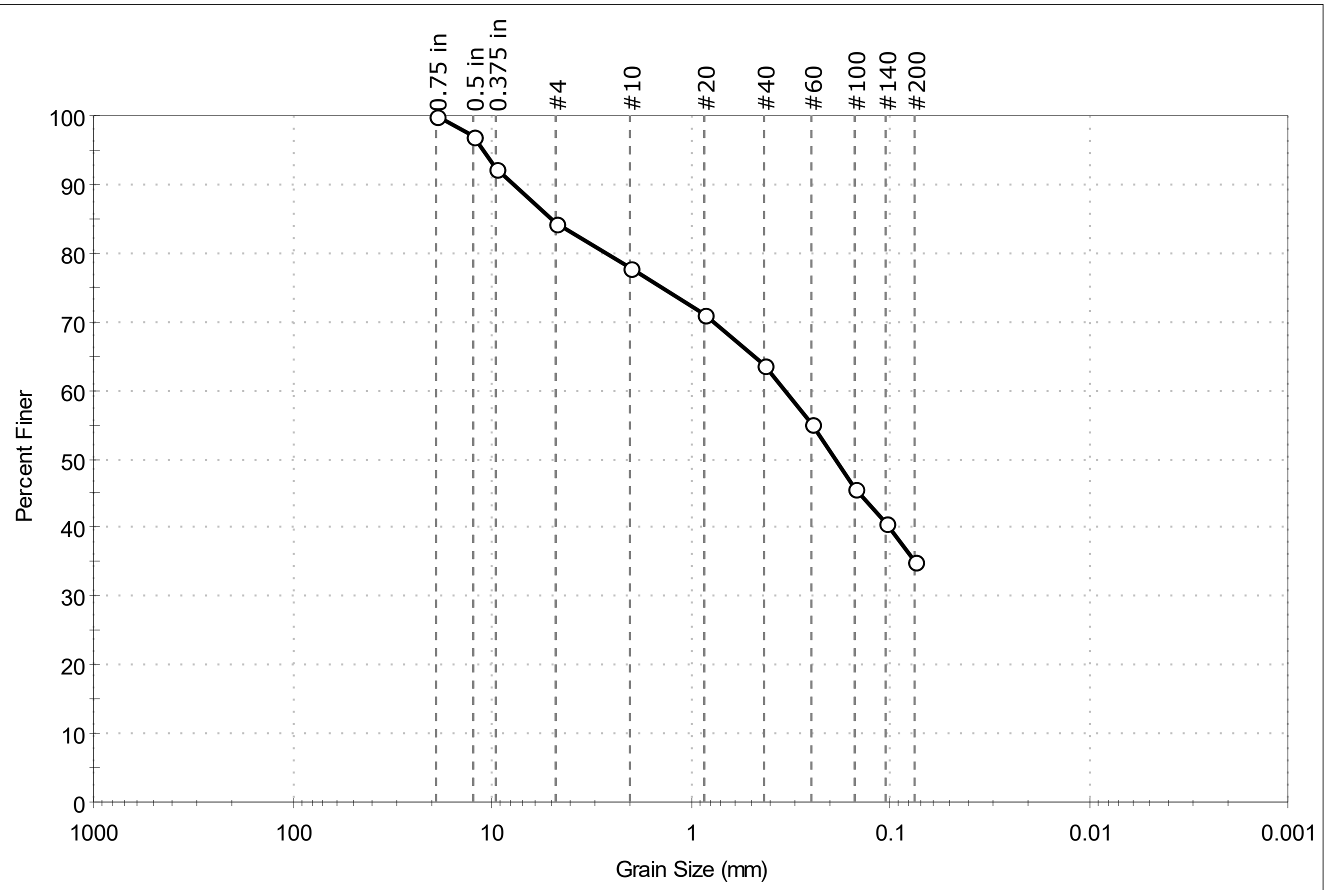
Sand/Gravel Hardness : HARD

printed 12/5/2019 10:20:01 AM

GeoTesting
EXPRESS

Client: Kleinfelder, Inc.
Project: S-Medford Flood Study
Location: Medford, MA
Project No: GTX-310955
Boring ID: Tufts B101
Sample Type: jar
Tested By: ckg
Sample ID: S3
Test Date: 12/04/19
Checked By: bfs
Depth : 4-6
Test Id: 531186
Test Comment: ---
Visual Description: Moist, mottled yellowish brown and greenish gray silty sand with gravel
Sample Comment: ---

Particle Size Analysis - ASTM D6913



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	15.8	49.0	35.2

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.75 in	19.00	100		
0.5 in	12.50	97		
0.375 in	9.50	92		
#4	4.75	84		
#10	2.00	78		
#20	0.85	71		
#40	0.42	64		
#60	0.25	55		
#100	0.15	46		
#140	0.11	41		
#200	0.075	35		

Coefficients

D_{85} =5.0797 mm
D_{30} =N/A
D_{60} =0.3383 mm
D_{15} =N/A
D_{50} =0.1883 mm
D_{10} =N/A
C_u =N/A
C_c =N/A

Classification

ASTM N/A

AASHTO Silty Soils (A-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

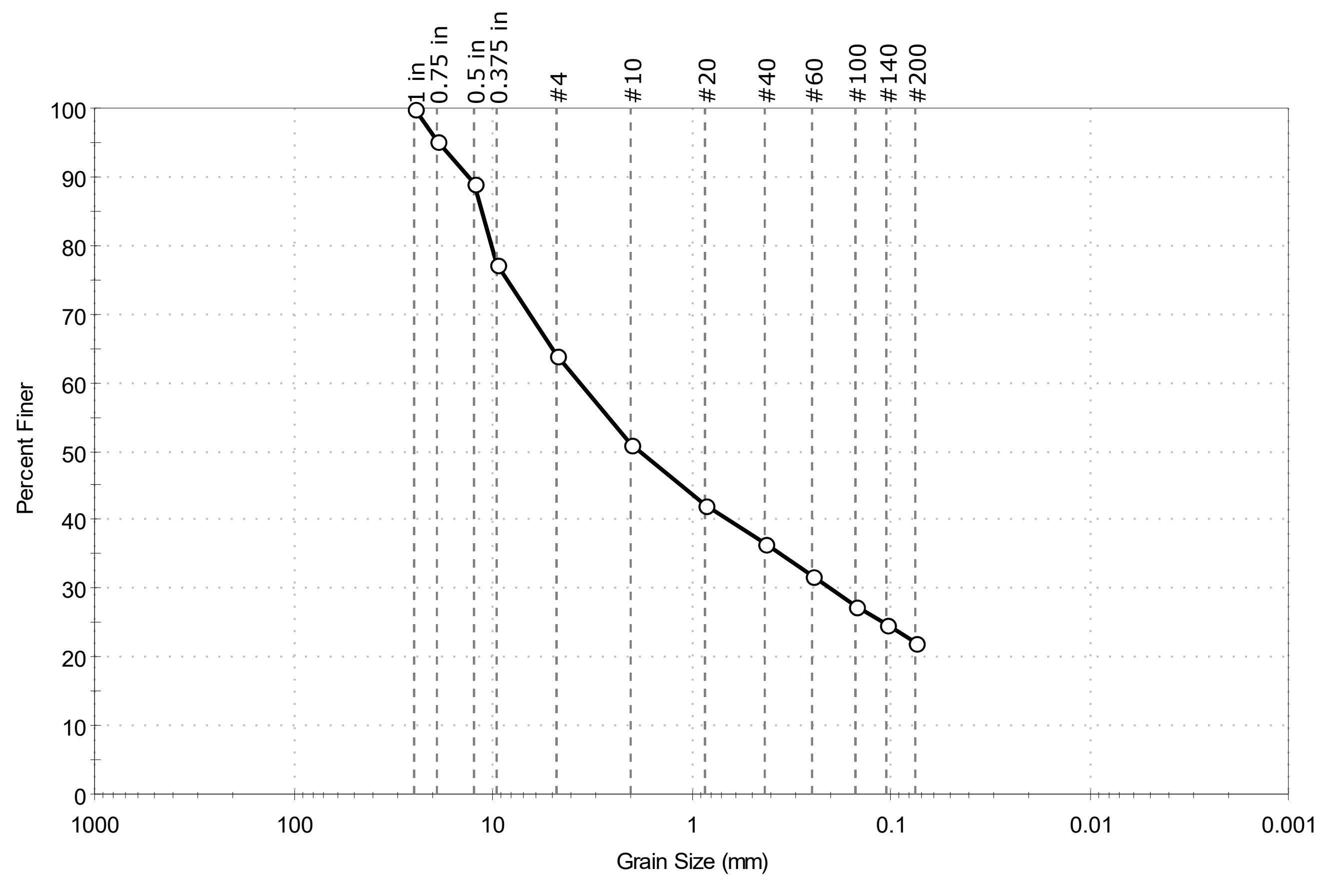
Sand/Gravel Hardness : HARD

printed 12/5/2019 10:20:02 AM

Client:	Kleinfelder, Inc.				
Project:	S-Medford Flood Study				
Location:	Medford, MA			Project No:	GTX-310955
Boring ID:	Tufts B101	Sample Type:	jar	Tested By:	ckg
Sample ID:	S17	Test Date:	12/04/19	Checked By:	bfs
Depth :	40-42	Test Id:	531187		

Test Comment: ---
Visual Description: Moist, olive gray silty sand with gravel
Sample Comment: ---

Particle Size Analysis - ASTM D6913



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	35.8	42.0	22.2

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
1 in	25.00	100		
0.75 in	19.00	95		
0.5 in	12.50	89		
0.375 in	9.50	77		
#4	4.75	64		
#10	2.00	51		
#20	0.85	42		
#40	0.42	37		
#60	0.25	32		
#100	0.15	27		
#140	0.11	25		
#200	0.075	22		

Coefficients

D_{85} =11.3717 mm
D_{30} =0.2001 mm
D_{60} =3.6067 mm
D_{15} =N/A
D_{50} =1.7982 mm
D_{10} =N/A
C_u =N/A
C_c =N/A

Classification

ASTM N/A

AASHTO Stone Fragments, Gravel and Sand (A-1-b (0))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

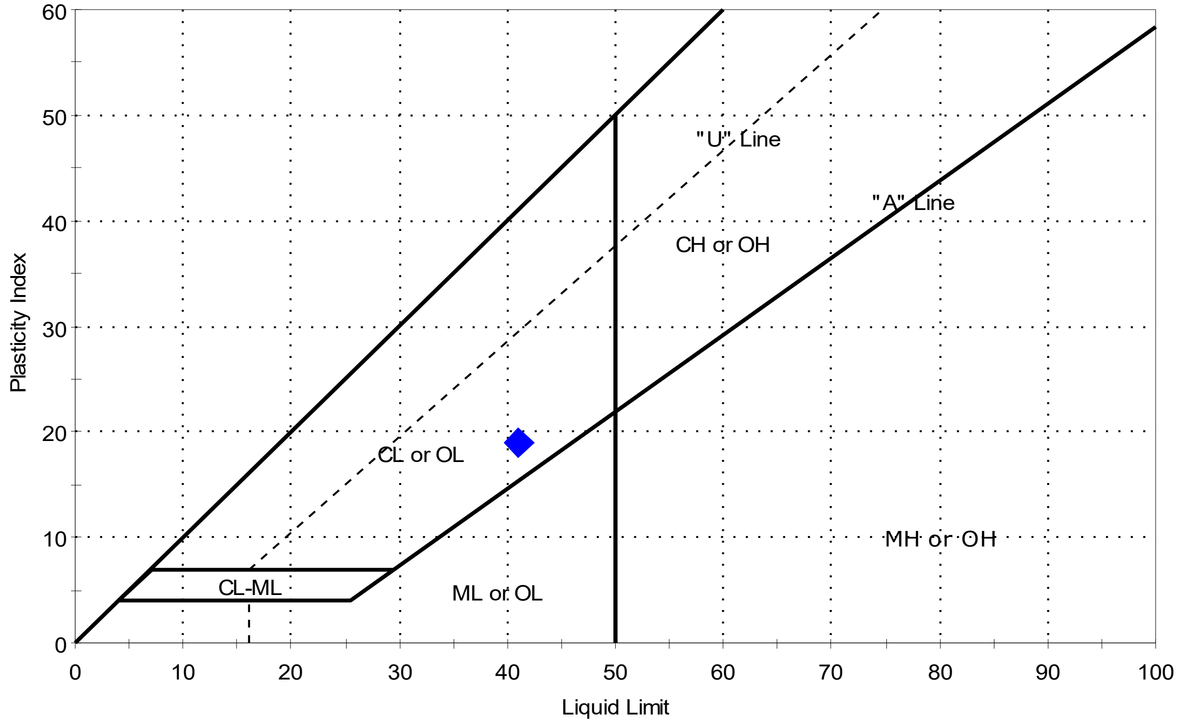
printed 12/5/2019 10:20:03 AM

Client:	Kleinfelder, Inc.				
Project:	S-Medford Flood Study				
Location:	Medford, MA			Project No:	GTX-310955
Boring ID:	Barry B101	Sample Type:	jar	Tested By:	cam
Sample ID:	S3	Test Date:	12/02/19	Checked By:	bfs
Depth :	5-7	Test Id:	531185		

Test Comment: ---
Visual Description: Moist, grayish brown clay
Sample Comment: ---

Atterberg Limits - ASTM D4318

Plasticity Chart



Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	S3	Barry B101	5-7	15	41	22	19	-0.4	

Sample Prepared using the WET method

Dry Strength: VERY HIGH
Dilatancy: SLOW
Toughness: LOW

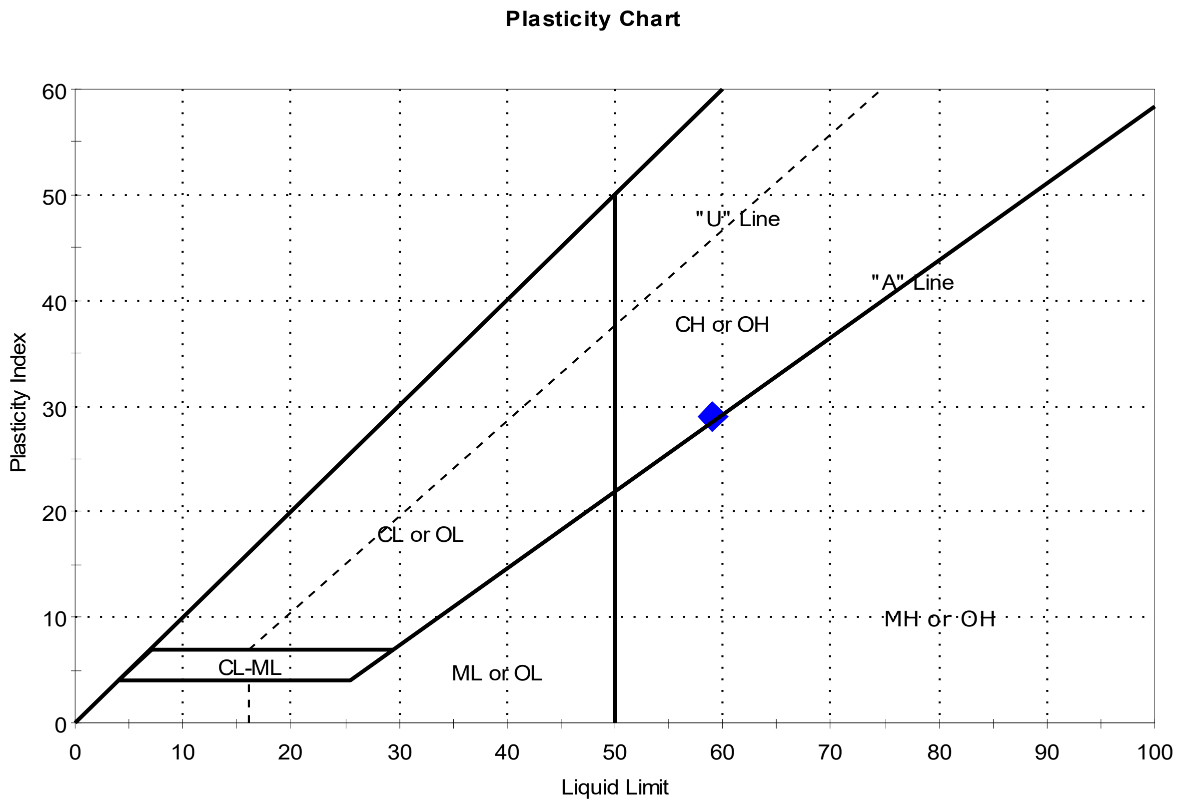
printed 12/5/2019 10:17:19 AM

Client: Kleinfelder, Inc.
Project: S-Medford Flood Study
Location: Medford, MA
Project No: GTX-310955

Boring ID: Tufts B101
Sample ID: S8
Depth : 14-16
Sample Type: jar
Test Date: 12/02/19
Test Id: 531183
Tested By: cam
Checked By: bfs

Test Comment: ---
Visual Description: Moist, dark gray clay
Sample Comment: ---

Atterberg Limits - ASTM D4318



Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	S8	Tufts B101	14-16	60	59	30	29	1	

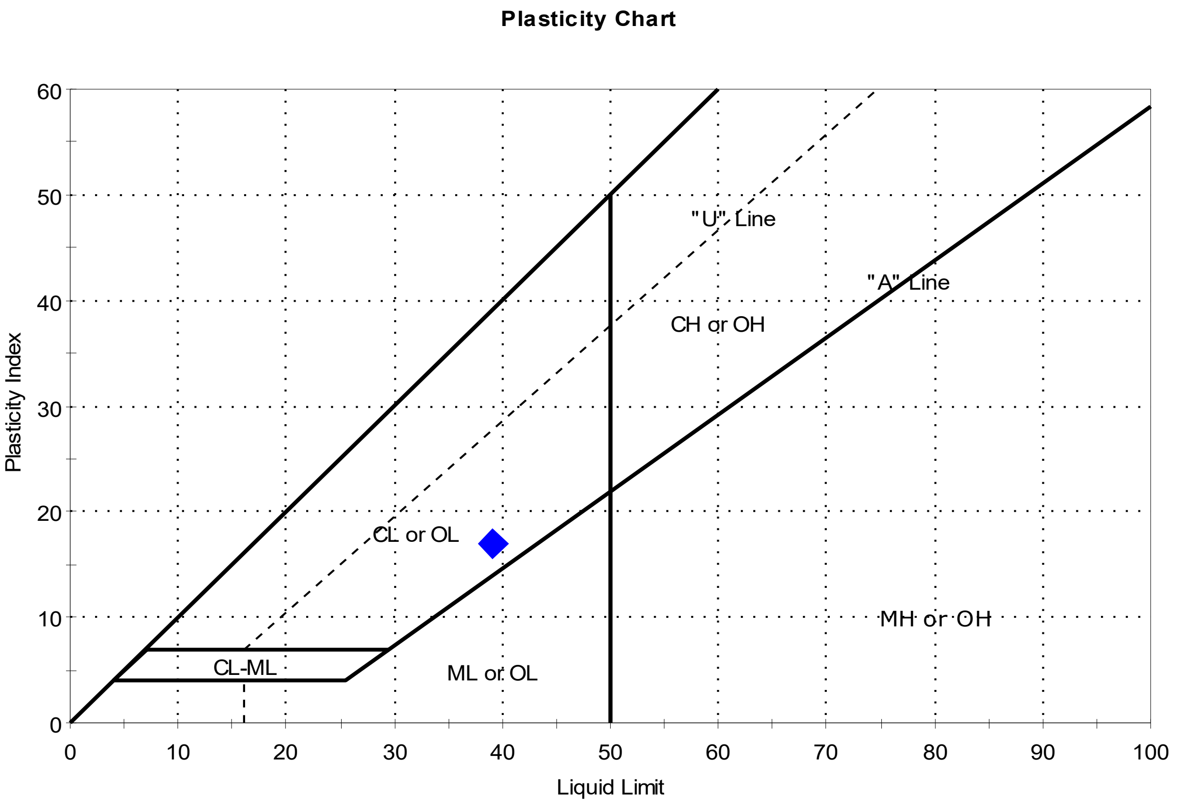
Sample Prepared using the WET method

Dry Strength: VERY HIGH
Dilatancy: SLOW
Toughness: LOW

Client:	Kleinfelder, Inc.				
Project:	S-Medford Flood Study				
Location:	Medford, MA			Project No:	GTX-310955
Boring ID:	Tufts B101	Sample Type:	jar	Tested By:	cam
Sample ID:	S13	Test Date:	12/02/19	Checked By:	bfs
Depth :	24-26	Test Id:	531184		

Test Comment: ---
Visual Description: Moist, greenish gray clay
Sample Comment: ---

Atterberg Limits - ASTM D4318



Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	S13	Tufts B101	24-26	24	39	22	17	0.1	

Sample Prepared using the WET method

Dry Strength: VERY HIGH
Dilatancy: SLOW
Toughness: LOW

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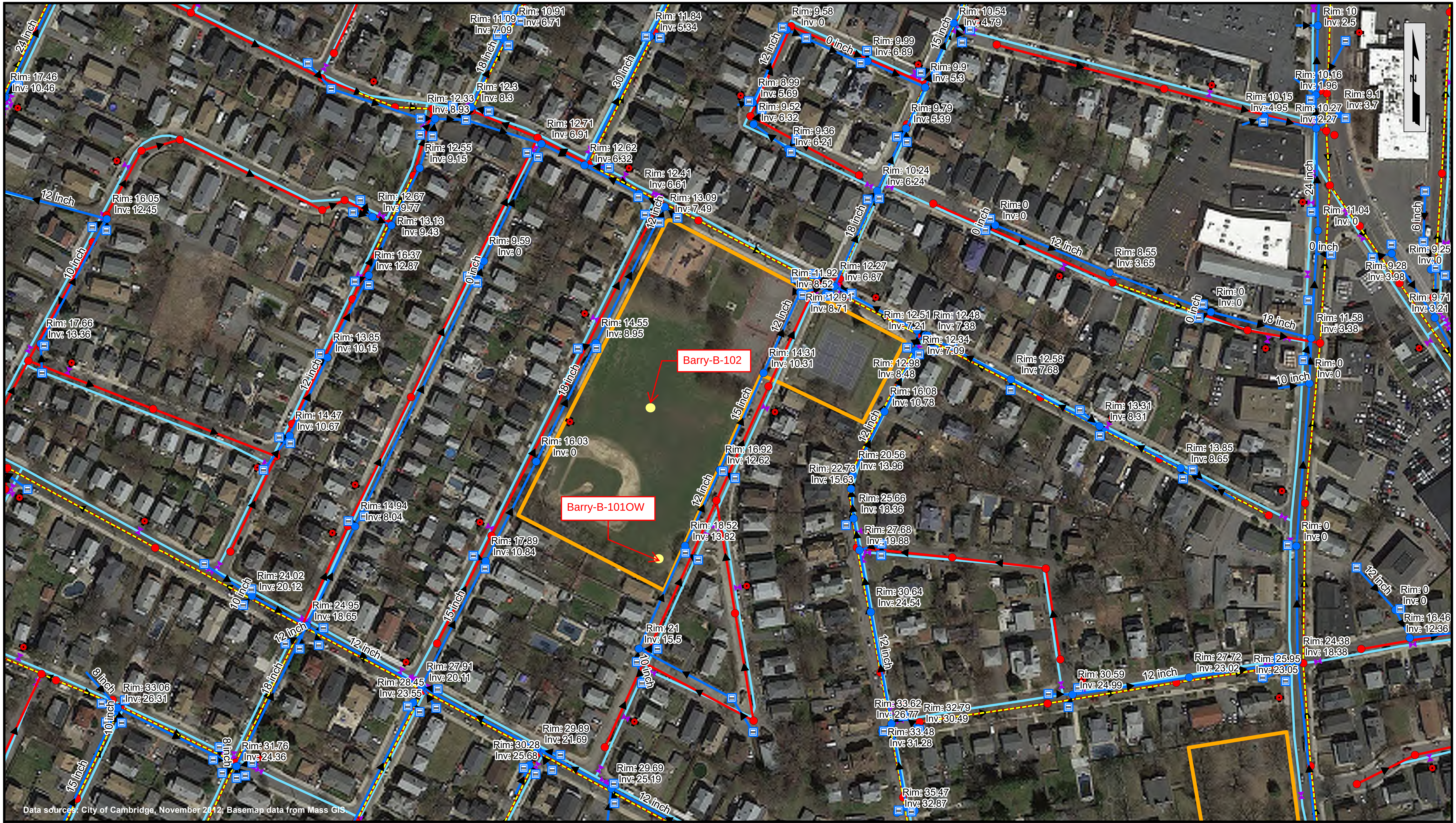
Appendix A

Appendix A.1-1

Barry Playground Boring Location Plan



Data sources: City of Cambridge, November 2012; Basemap data from Mass GIS.

Legend

▣	Catch basin	●	Sewer manhole	✚	Hydrant (Offset)	▭	Park Area
●	Drain manhole	----	Sewer underdrain	⋈	Water valve		
➝	Storm drain	➝	Sewer main	—	Water main		

0 100 200
Feet

Locations are approximate

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PROJECT NO.: 20202050
DRAWN: OCT 2019
DRAWN BY:
CHECKED BY:
FILE NAME:
S.Medford_MVP.mxd

CITY OF MEDFORD
MVP GRANT
SOUTH MEDFORD FLOOD MITIGATION

Barry Playground
74 Summer St, Medford, MA 02155

MAP

Appendix A.1-2

Tufts Park Boring Location Plan

Data sources: City of Cambridge, November 2012; Basemap data from Mass GIS.

Legend

▣	Catch basin	●	Sewer manhole	✚	Hydrant (Offset)	▭	Park Area
●	Drain manhole	- - -	Sewer underdrain	⋈	Water valve		
─►	Storm drain	─►	Sewer main	──	Water main		

0 100 200
Feet

Locations are approximate

This information was developed specifically and for the exclusive use for the City of Cambridge's Climate Change Vulnerability Assessment.The materials are not intended to be suitable for re-use on extensions of the project or any other project. Any re-use, without the prior written verification or adaptation by Kleinfelder for the specific purpose intended will be at the user's sole risk without liability or legal exposure to Kleinfelder, ATMOS or the City of Cambridge.

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PROJECT NO.: 20202050
DRAWN: OCT 2019
DRAWN BY:
CHECKED BY:
FILE NAME: S.Medford_MVP.mxd

CITY OF MEDFORD
MVP GRANT
SOUTH MEDFORD FLOOD MITIGATION

Tufts Park
437 Main St, Medford, MA 02155

MAP

Appendix A.2

Boring Logs

SAMPLE/SAMPLER TYPE GRAPHICS

- ▯ SHELBY TUBE SAMPLER
- ◪ STANDARD PENETRATION SPLIT SPOON SAMPLER (2 in. (50.8 mm.) outer diameter and 1-3/8 in. (34.9 mm.) inner diameter)

GROUND WATER GRAPHICS

- ▽ WATER LEVEL (level where first observed)
- ▼ WATER LEVEL (level after exploration completion)
- ▼ WATER LEVEL (additional levels after exploration)
- ≋ OBSERVED SEEPAGE

NOTES

- The report and graphics key are an integral part of these logs. All data and interpretations in this log are subject to the explanations and limitations stated in the report.
- Lines separating strata on the logs represent approximate boundaries only. Actual transitions may be gradual or differ from those shown.
- No warranty is provided as to the continuity of soil or rock conditions between individual sample locations.
- Logs represent general soil or rock conditions observed at the point of exploration on the date indicated.
- In general, Unified Soil Classification System designations presented on the logs were based on visual classification in the field and were modified where appropriate based on gradation and index property testing.
- Fine grained soils that plot within the hatched area on the Plasticity Chart, and coarse grained soils with between 5% and 12% passing the No. 200 sieve require dual USCS symbols, ie., GW-GM, GP-GM, GW-GC, GP-GC, GC-GM, SW-SM, SP-SM, SW-SC, SP-SC, SC-SM.
- If sampler is not able to be driven at least 6 inches then 50/X indicates number of blows required to drive the identified sampler X inches with a 140 pound hammer falling 30 inches.

ABBREVIATIONS

WOH - Weight of Hammer
WOR - Weight of Rod

UNIFIED SOIL CLASSIFICATION SYSTEM (ASTM D 2487)

COARSE GRAINED SOILS (More than half of material is larger than the #200 sieve)	**GRAVELS** (More than half of coarse fraction is larger than the #4 sieve)	CLEAN GRAVEL WITH <5% FINES	Cu≥4 and 1≤Cc≤3	**GW**	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES WITH LITTLE OR NO FINES
			Cu<4 and/ or 1>Cc>3	**GP**	POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES WITH LITTLE OR NO FINES
		GRAVELS WITH 5% TO 12% FINES	Cu≥4 and 1≤Cc≤3	**GW-GM**	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES WITH LITTLE FINES
				GW-GC	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES WITH LITTLE CLAY FINES
			Cu<4 and/ or 1>Cc>3	**GP-GM**	POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES WITH LITTLE FINES
				GP-GC	POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES WITH LITTLE CLAY FINES
		GRAVELS WITH > 12% FINES		**GM**	SILTY GRAVELS, GRAVEL-SILT-SAND MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES
				GC-GM	CLAYEY GRAVELS, GRAVEL-SAND-CLAY-SILT MIXTURES
	SANDS (Half or more of coarse fraction is smaller than the #4 sieve)	CLEAN SANDS WITH <5% FINES	Cu≥6 and 1≤Cc≤3	**SW**	WELL-GRADED SANDS, SAND-GRAVEL MIXTURES WITH LITTLE OR NO FINES
			Cu<6 and/ or 1>Cc>3	**SP**	POORLY GRADED SANDS, SAND-GRAVEL MIXTURES WITH LITTLE OR NO FINES
		SANDS WITH 5% TO 12% FINES	Cu≥6 and 1≤Cc≤3	**SW-SM**	WELL-GRADED SANDS, SAND-GRAVEL MIXTURES WITH LITTLE FINES
				SW-SC	WELL-GRADED SANDS, SAND-GRAVEL MIXTURES WITH LITTLE CLAY FINES
			Cu<6 and/ or 1>Cc>3	**SP-SM**	POORLY GRADED SANDS, SAND-GRAVEL MIXTURES WITH LITTLE FINES
				SP-SC	POORLY GRADED SANDS, SAND-GRAVEL MIXTURES WITH LITTLE CLAY FINES
		SANDS WITH > 12% FINES		**SM**	SILTY SANDS, SAND-GRAVEL-SILT MIXTURES
				SC	CLAYEY SANDS, SAND-GRAVEL-CLAY MIXTURES
				SC-SM	CLAYEY SANDS, SAND-SILT-CLAY MIXTURES

FINE GRAINED SOILS (Half or more of material is smaller than the #200 sieve)	SILTS AND CLAYS (Liquid Limit less than 50)	**ML**	INORGANIC SILTS AND VERY FINE SANDS, SILTY OR CLAYEY FINE SANDS, SILTS WITH SLIGHT PLASTICITY
		CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
		CL-ML	INORGANIC CLAYS-SILTS OF LOW PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
		OL	ORGANIC SILTS & ORGANIC SILTY CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS (Liquid Limit 50 or greater)	**MH**	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILT
		CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
		OH	ORGANIC CLAYS & ORGANIC SILTS OF MEDIUM-TO-HIGH PLASTICITY

KLEINFELDER
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PROJECT NO.: 20202050.001A	GRAPHICS KEY	FIGURE
DRAWN BY: MAP	South Medford Flood Study Medford, Massachusetts	A-1
CHECKED BY: DD		
DATE: 12/10/2019		

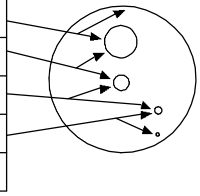
PLOTTED: 12/10/2019 04:50 PM BY: MPalmer

gINT FILE: Klf_gint_master_2020 PROJECT NUMBER: 20202050.001A OFFICE FILTER: BOSTON

gINT TEMPLATE: E:KLF_STANDARD_GINT_LIBRARY_2020.GLB [_KLF_GEO-LEG1 (GRAPHICS KEY) WITH USCS]

GRAIN SIZE

DESCRIPTION		SIEVE SIZE	GRAIN SIZE	APPROXIMATE SIZE
Boulders		>12 in. (304.8 mm.)	>12 in. (304.8 mm.)	Larger than basketball-sized
Cobbles		3 - 12 in. (76.2 - 304.8 mm.)	3 - 12 in. (76.2 - 304.8 mm.)	Fist-sized to basketball-sized
Gravel	coarse	3/4 -3 in. (19 - 76.2 mm.)	3/4 -3 in. (19 - 76.2 mm.)	Thumb-sized to fist-sized
	fine	#4 - 3/4 in. (#4 - 19 mm.)	0.19 - 0.75 in. (4.8 - 19 mm.)	Pea-sized to thumb-sized
Sand	coarse	#10 - #4	0.079 - 0.19 in. (2 - 4.9 mm.)	Rock salt-sized to pea-sized
	medium	#40 - #10	0.017 - 0.079 in. (0.43 - 2 mm.)	Sugar-sized to rock salt-sized
	fine	#200 - #40	0.0029 - 0.017 in. (0.07 - 0.43 mm.)	Flour-sized to sugar-sized
Fines		Passing #200	<0.0029 in. (<0.07 mm.)	Flour-sized and smaller



SECONDARY CONSTITUENT

	AMOUNT	
Term of Use	Secondary Constituent is Fine Grained	Secondary Constituent is Coarse Grained
Trace	<5%	<15%
With	≥5 to <15%	≥15 to <30%
Modifier	≥15%	≥30%

MOISTURE CONTENT

DESCRIPTION	FIELD TEST
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, usually soil is below water table

CEMENTATION

DESCRIPTION	FIELD TEST
Weakly	Crumbles or breaks with handling or slight finger pressure
Moderately	Crumbles or breaks with considerable finger pressure
Strongly	Will not crumble or break with finger pressure

CONSISTENCY - FINE-GRAINED SOIL

CONSISTENCY	SPT - N_{60} (# blows / ft)	Pocket Pen (tsf)	UNCONFINED COMPRESSIVE STRENGTH (Q_u)(psf)	VISUAL / MANUAL CRITERIA
Very Soft	<2	PP < 0.25	<500	Thumb will penetrate more than 1 inch (25 mm). Extrudes between fingers when squeezed.
Soft	2 - 4	0.25 ≤ PP <0.5	500 - 1000	Thumb will penetrate soil about 1 inch (25 mm). Remolded by light finger pressure.
Medium Stiff	4 - 8	0.5 ≤ PP <1	1000 - 2000	Thumb will penetrate soil about 1/4 inch (6 mm). Remolded by strong finger pressure.
Stiff	8 - 15	1 ≤ PP <2	2000 - 4000	Can be imprinted with considerable pressure from thumb.
Very Stiff	15 - 30	2 ≤ PP <4	4000 - 8000	Thumb will not indent soil but readily indented with thumbnail.
Hard	>30	4 ≤ PP	>8000	Thumbnail will not indent soil.

FROM TERZAGHI AND PECK, 1948; LAMBE AND WHITMAN, 1969; FHWA, 2002; AND ASTM D2488

REACTION WITH HYDROCHLORIC ACID

DESCRIPTION	FIELD TEST
None	No visible reaction
Weak	Some reaction, with bubbles forming slowly
Strong	Violent reaction, with bubbles forming immediately

APPARENT / RELATIVE DENSITY - COARSE-GRAINED SOIL

APPARENT DENSITY	SPT-N_{60} (# blows/ft)	MODIFIED CA SAMPLER (# blows/ft)	CALIFORNIA SAMPLER (# blows/ft)	RELATIVE DENSITY (%)
Very Loose	<4	<4	<5	0 - 15
Loose	4 - 10	5 - 12	5 - 15	15 - 35
Medium Dense	10 - 30	12 - 35	15 - 40	35 - 65
Dense	30 - 50	35 - 60	40 - 70	65 - 85
Very Dense	>50	>60	>70	85 - 100

FROM TERZAGHI AND PECK, 1948

PLASTICITY

DESCRIPTION	LL	FIELD TEST
Non-plastic	NP	A 1/8-in. (3 mm.) thread cannot be rolled at any water content.
Low (L)	< 30	The thread can barely be rolled and the lump or thread cannot be formed when drier than the plastic limit.
Medium (M)	30 - 50	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. The lump or thread crumbles when drier than the plastic limit.
High (H)	> 50	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rerolled several times after reaching the plastic limit. The lump or thread can be formed without crumbling when drier than the plastic limit.

STRUCTURE

DESCRIPTION	CRITERIA
Stratified	Alternating layers of varying material or color with layers at least 1/4-in. thick, note thickness.
Laminated	Alternating layers of varying material or color with the layer less than 1/4-in. thick, note thickness.
Fissured	Breaks along definite planes of fracture with little resistance to fracturing.
Slickensided	Fracture planes appear polished or glossy, sometimes striated.
Blocky	Cohesive soil that can be broken down into small angular lumps which resist further breakdown.
Lensed	Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay; note thickness.

ANGULARITY

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

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PROJECT NO.:
20202050.001A

DRAWN BY: MAP

CHECKED BY: DD

DATE: 12/10/2019

SOIL DESCRIPTION KEY

South Medford Flood Study
Medford, Massachusetts

FIGURE

A-2

PLOTTED: 12/10/2019 04:51 PM BY: MPalmer

OFFICE FILTER: BOSTON

PROJECT NUMBER: 20202050.001A

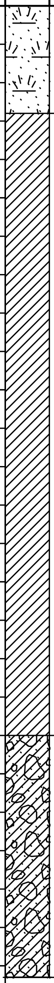
gINT FILE: Klf_gint_master_2020
gINT TEMPLATE: E:KLF_STANDARD_GINT_LIBRARY_2020.GLB [_KLF_GEO-LEG 2 (SOIL DESC KEY)]

BORING LOG BP-B-101(OW)

Date Begin - End: 11/12/2019
Logged By: L. Wang
Hor.-Vert. Datum: Not Available
Plunge: -90 degrees
Weather: Rain and Snow
Drilling Company: CarrDee
Drill Crew: Steve & Frank
Drilling Equipment: ATV
Drilling Method: Drive and Wash
Exploration Diameter: 3 in. O.D.
Hammer Type - Drop: 140 lb. Auto - 30 in.

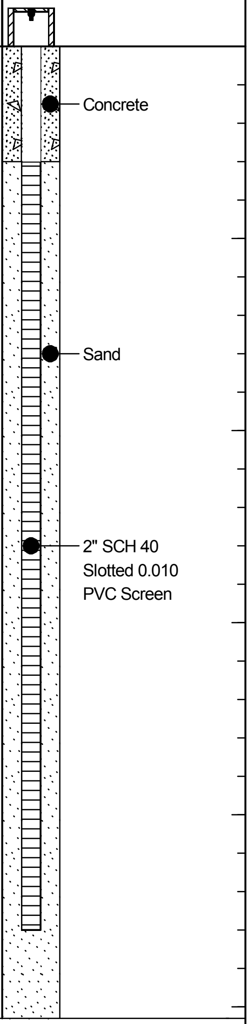
Depth (feet)	Surface Condition: Grass Lithologic Description	Sample Number	Sample Type	Blow Counts(BC)= Uncorr. Blows/6 in. Pocket Pen(PP)= tsf	Recovery (NR=No Recovery)	USCS Symbol	Water Content (%)	Dry Unit Wt. (pcf)	Passing #4 (%)	Passing #200 (%)	Liquid Limit	Plasticity Index (NP=NonPlastic)
	FIELD EXPLORATION					LABORATORY RESULTS						
	S-1: TOPSOIL: Silty SAND (SM): reddish brown, moist, loose, trace grass roots, PID=0.1	S-1		BC=2 3 2 2	6"							
	S-2: top 10": similar to S-1, PID=0.0	S-2		BC=2 3 7 8	24"							
	S-2: bottom 14": **Lean CLAY (CL)**: low plasticity, brownish gray, moist, stiff, with iron oxide staining											
5 ∇	**S-3:** similar to bottom 14" of S-2 except very stiff, PID=0.0	S-3		BC=12 14 21 14	16"						41	19
10	**S-4: Sandy CLAY (CL)**: medium plasticity, light brownish gray, wet, medium stiff, PID=0.0	S-4		BC=2 3 4 4	9"							
15	**S-5:** No recovery, possible clay based on outwash	S-5		BC=2 2 2 5	NR							
	Assumed lithology change based on drilling action, drill rig shaking at 19 feet											
20	**S-6: GLACIAL TILL: Silty SAND with Gravel (SM)**: medium-grained sand, gravel observed as rock fragments, gray, wet, PID=0.0	S-6		BC=24 26 16 21	17"				73	23		
25	**S-7:** sampled as rock fragments	S-7		BC=100/4"	1"							
30												

Graphical Log



MONITORING WELL CONSTRUCTION*

Completion Method: Roadbox



The boring was terminated at approximately 25.3 ft. below ground surface. A monitoring well was installed after the completion of drilling.

GROUNDWATER LEVEL INFORMATION:
∇ Groundwater was observed at approximately 6 ft. below ground surface during drilling.

GENERAL NOTES:

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PROJECT NO.:	20202050.001A
DRAWN BY:	MAP
CHECKED BY:	DD
DATE:	12/12/2019

BORING LOG BP-B-101(OW)

South Medford Flood Study
Medford, Massachusetts

BORING
BP-B-101(OW)

PLOTTED: 12/12/2019 12:54 PM BY: MPalmer
OFFICE FILTER: BOSTON
PROJECT NUMBER: 20202050.001A
gINT FILE: Klf_gint_master_2020
gINT TEMPLATE: E:KLF_STANDARD_GINT_LIBRARY_2020.GLB [_KLF_BORING/TEST PIT SOIL LOG]

BORING LOG BP-B-102

Date Begin - End: 11/12/2019
Logged By: L. Wang
Hor.-Vert. Datum: Not Available
Plunge: -90 degrees
Weather: Rainy
Drilling Company: CarrDee
Drill Crew: Steve & Frank
Drilling Equipment: ATV
Drilling Method: Drive and Wash
Exploration Diameter: 3 in. O.D.
Hammer Type - Drop: 140 lb. Auto - 30 in.

FIELD EXPLORATION						LABORATORY RESULTS							
Depth (feet)	Surface Condition: Grass Lithologic Description	Sample Number	Sample Type	Blow Counts(BC)=Uncorr. Blows/6 in. Pocket Pen(PP)= tsf	Recovery (NR=No Recovery)	USCS Symbol	Water Content (%)	Dry Unit Wt. (pcf)	Passing #4 (%)	Passing #200 (%)	Liquid Limit	Plasticity Index (NP=NonPlastic)	Additional Tests/ Remarks
	S-1: TOPSOIL: Poorly Graded SAND with Silt (SP-SM): medium to coarse-grained, dark brown, moist, loose, trace grass roots, PID=0.3	S-1	◣	BC=2 2 5 6	6"								
	S-2: CLAY (CL): trace sand, light brown and gray, moist, very stiff, PID=0.2	S-2	◣	BC=7 13 11 16	17"								
⊻ 5	**S-3:** top 18": similar to S-2, PID=0.2 **S-3:** bottom 6": **Silty SAND (SM)**: fine-grained sand, light brownish gray, wet	S-3	◣	BC=18 17 17 17	24"								
	S-4: top 14": **Sandy CLAY (CL)**: low plasticity, light brown, wet, medium stiff, PID=0.1 **S-4:** bottom 7": **GLACIAL TILL: Silty SAND with Gravel (SM)**: 15% gravel, brownish gray, wet	S-4	◣	BC=3 4 15 13	21"				74	45			Switch to drive and wash at 6 feet
10	**S-5:** similar to bottom 7" of S-4 except olive yellow and dark brown, medium dense, angular, PID=0.1	S-5	◣	BC=16 15 9 11	7"								Drill rig shaking at 13 feet
15	**S-6: GLACIAL TILL: Poorly Graded SAND with Silt and Gravel (SP-SM)**: coarse-grained sand, 30% gravel, olive yellow, wet, very dense, PID=0.1	S-6	◣	BC=19 23 56 99	12"								High SPT N-Value due to presence of boulder which was encountered at an approximate depth of 16.5 ft.
20	**S-7:** similar to S-8 except brownish gray, medium to coarse-grained sand, 15% gravel, sub-angular to angular, dark gray rock fragments, dense	S-7	◣	BC=14 22 27 21	7"								
25	**S-8:** similar to S-7 except very dense - fine to medium-grained sand, 10% fine-grained gravel at bottom of sample - rock fragments at tip of sampler spoon	S-8	◣	BC=13 33 44 56	7"								
30													

The boring was terminated at approximately 27 ft. below ground surface. The boring was backfilled with auger cuttings on November 12, 2019.

GROUNDWATER LEVEL INFORMATION:
⊻ Groundwater was observed at approximately 5 ft. below ground surface during drilling.
GENERAL NOTES:

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PROJECT NO.: 20202050.001A
DRAWN BY: MAP
CHECKED BY: DD
DATE: 12/12/2019

BORING LOG BP-B-102

South Medford Flood Study
Medford, Massachusetts

BORING
BP-B-102

PLOTTED: 12/12/2019 12:54 PM BY: MPalmer

OFFICE FILTER: BOSTON

PROJECT NUMBER: 20202050.001A

gINT FILE: Klf_gint_master_2020

gINT TEMPLATE: E:KLF_STANDARD_GINT_LIBRARY_2020.GLB [__KLF_BORING/TEST PIT SOIL LOG]

BORING LOG TP-B-101

Date Begin - End: 11/13/2019
Logged By: L. Wang
Hor.-Vert. Datum: Not Available
Plunge: -90 degrees
Weather: Sunny
Drilling Company: CarrDee
Drill Crew: Steve & Frank
Drilling Equipment: ATV
Drilling Method: HSA & Drive and Wash
Exploration Diameter: 4 in. O.D.
Hammer Type - Drop: 140 lb. Auto - 30 in.

		FIELD EXPLORATION					LABORATORY RESULTS							
Depth (feet)	Graphical Log	Latitude: 42.40149° Longitude: -71.10805° Surface Condition: Grass Lithologic Description	Sample Number	Sample Type	Blow Counts(BC)= Uncorr. Blows/6 in. Pocket Pen(PP)= tsf	Recovery (NR=No Recovery)	USCS Symbol	Water Content (%)	Dry Unit Wt. (pcf)	Passing #4 (%)	Passing #200 (%)	Liquid Limit	Plasticity Index (NP=NonPlastic)	Additional Tests/ Remarks
		S-1: top 6": **TOPSOIL: Poorly Graded SAND with Silt (SP-SM)**: medium-grained sand, brown, wet, trace grass	S-1		BC=3 2 2 3	10"								Ground was frozen
		S-1: bottom 4": **FILL: Silty SAND with Gravel (SM)**: light brown, trace ash and coal **S-2:** similar to bottom 4" of S-1 except brown	S-2		BC=3 4 3 3	7"								
5		**S-3:** similar to bottom 4" of S-1 except grayish brown, fine to medium-grained sand, 10% gravel, very loose	S-3		BC=2 1 1 1	8"				84	35			Auger from 4 to 10 feet
▽		**S-4:** top 7": similar to S-3 **S-4:** bottom 8": **FILL: Poorly Graded SAND (SP)**: medium to coarse-grained sand, black, wet, trace ash, brick, and glass	S-4		BC=1 1 1 1	15"								
		S-5: No recovery	S-5		BC=1 1 1 1	NR								
10		**S-6:** similar to bottom 8" of S-4 except black and dark gray, medium-grained sand, trace gravel and coal	S-6		BC=1 1 1 1	7"								
		S-7: top 4": similar to S-6 except trace glass, coal, and wood debris **S-7:** bottom 15": **Fat CLAY (CH)**: bluish gray, wet, very soft	S-7		BC=1 WOH WOH WOH	19"								
15		**S-8:** similar to bottom 15" of S-7	S-8		BC=WOH WOH 1 1	19"						59	29	
		S-9: similar to bottom 15" of S-7	S-9		BC=WOH WOH 1 1	24"								
		S-10: similar to bottom 15" of S-7 except medium stiff	S-10		BC=2 3 2 2	24"								
20		**S-11: GLACIAL OUTWASH: Poorly Graded SAND with Silt and Gravel (SP-SM)**: fine to medium-grained sand, 30% gravel, olive yellow, wet, loose	S-11		BC=6 4 3 4	5"								Switched from HSA to 4" casing at 20 ft. bgs. and drilling fluid introduced into borehole.
		S-12: CLAY (CL): trace medium-grained sand, light gray, moist, stiff	S-12		BC=5 4 5 4	24"								
25		**S-13:** similar to S-12 except gray, medium stiff, gravel in tip of spoon	S-13		BC=3 3 4 6	24"						39	17	
		S-14: similar to S-13 except stiff	S-14		BC=5 6 6 6	24"								
30		**S-15: CLAY with Sand (CL)**: moist, medium stiff	S-15		BC=3 3 4 5	24"								
		ST-1: No Recovery	ST-1											Drill rig shaking at 34.5 feet

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PROJECT NO.: 20202050.001A
DRAWN BY: MAP
CHECKED BY: DD
DATE: 12/12/2019

BORING LOG TP-B-101

South Medford Flood Study
Medford, Massachusetts

BORING
TP-B-101

Date Begin - End: 11/13/2019
Drilling Company: CarrDee
BORING LOG TP-B-101
Logged By: L. Wang
Drill Crew: Steve & Frank
Hor.-Vert. Datum: Not Available
Drilling Equipment: ATV
Hammer Type - Drop: 140 lb. Auto - 30 in.
Plunge: -90 degrees
Drilling Method: HSA & Drive and Wash
Weather: Sunny
Exploration Diameter: 4 in. O.D.

Latitude: 42.40149°
Longitude: -71.10805°
Surface Condition: Grass

FIELD EXPLORATION							LABORATORY RESULTS							
Depth (feet)	Graphical Log	Lithologic Description	Sample Number	Sample Type	Blow Counts(BC)= Uncorr. Blows/6 in. Pocket Pen(PP)= tsf	Recovery (NR=No Recovery)	USCS Symbol	Water Content (%)	Dry Unit Wt. (pcf)	Passing #4 (%)	Passing #200 (%)	Liquid Limit	Plasticity Index (NP=NonPlastic)	Additional Tests/ Remarks
		S-16: GLACIAL TILL: Silty SAND with Gravel (SM): medium-grained sand, 25% gravel, angular to sub-angular, light gray, wet, very dense	S-16		BC=30 34 29 23									
40		**S-17:** similar to S-16 except with 30% gravel	S-17		BC=30 50 100/5"	12"				64	22			

S-17: tip of sample spoon: **CAMBRIDGE ARGILLITE: Highly Weathered BEDROCK**: dark gray

The boring was terminated at approximately 41.4 ft. below ground surface. The boring was backfilled with auger cuttings and well sand on surface on November 13, 2019.

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GROUNDWATER LEVEL INFORMATION:
Groundwater was observed at approximately 6 ft. below ground surface during drilling.
GENERAL NOTES:

KLEINFELDER
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PROJECT NO.: 20202050.001A
DRAWN BY: MAP
CHECKED BY: DD
DATE: 12/12/2019

BORING LOG TP-B-101

South Medford Flood Study
Medford, Massachusetts

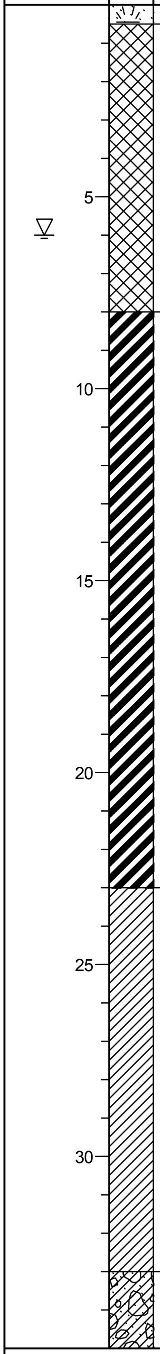
BORING
TP-B-101

BORING LOG TP-B-102(OW)

Date Begin - End: 11/14/2019
Logged By: M. Chea
Hor.-Vert. Datum: Not Available
Plunge: -90 degrees
Weather: Clear
Drilling Company: CarrDee
Drill Crew: Steve & Frank
Drilling Equipment: ATV
Drilling Method: HSA & Drive and Wash
Exploration Diameter: 4 in. O.D.
Hammer Type - Drop: 140 lb. Auto - 30 in.

FIELD EXPLORATION

Latitude: 42.40180°
Longitude: -71.10824°
Surface Condition: Bare Earth



Lithologic Description

S-1: top 6": **TOPSOIL: Silty SAND (SM)**: fine-grained sand, dark brown, moist, loose, trace organic fines and roots, PID=0.309

S-1: bottom 10": **FILL: Poorly Graded SAND with Silt (SP-SM)**: fine to medium-grained sand, brown, moist, loose, trace ash and slag, PID=0.09

S-2: similar to bottom 10" of S-1 except 10% fine-grained angular gravel, very loose, PID=0.126

S-3: top 4": **FILL: Silty SAND (SM)**: fine-grained sand, dark brown, moist, loose, trace organic fines and roots (buried topsoil), PID=0.268

S-3: bottom 3": trace medium-grained sand, trace fine-grained angular gravel, trace clay, brown, PID=0.083

S-4: top 4": **FILL: Poorly Graded SAND with Silt (SP-SM)**: fine-grained sand, trace fine-grained gravel, light gray, wet, loose, PID=0.113

S-4: bottom 6": **FILL: Lean CLAY (CL)**: trace fine-grained sand, low plasticity, light gray, wet, medium stiff, PID=0.113

S-5: Fat CLAY (CH): trace fine-grained sand, medium plasticity, light gray, wet, soft, PID=0.101

S-6: similar to S-5 except medium stiff, PID=0.101

S-7: similar to S-5 except medium to high plasticity, very soft, PID=0.193

ST-1: Obtained undisturbed sample from 17 to 19 feet

S-8: similar to S-7 except soft, PID=0.099

Assumed lithology

S-9: Lean CLAY (CL): light gray, wet, stiff, PID=0.097

S-10: similar to S-9 except trace fine-grained sand, medium stiff, PID=0.096

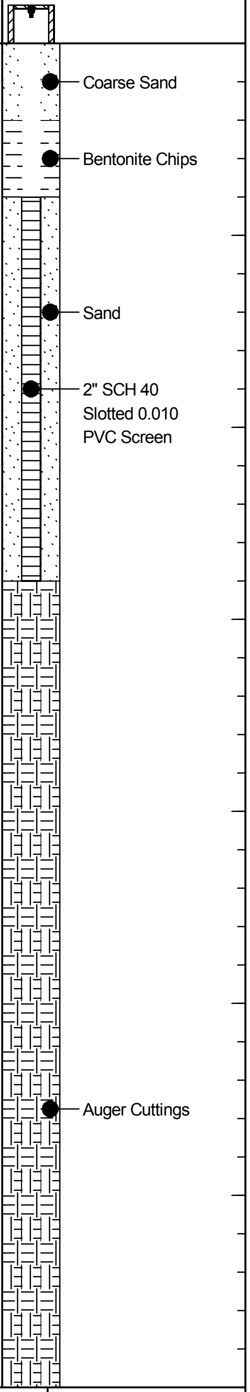
S-11: GLACIAL TILL

Sample Number	Sample Type	Blow Counts(BC)= Uncorr. Blows/6 in. Pocket Pen(PP)= tsf	Recovery (NR=No Recovery)	USCS Symbol	Water Content (%)	Dry Unit Wt. (pcf)	Passing #4 (%)	Passing #200 (%)	Liquid Limit	Plasticity Index (NP=NonPlastic)
S-1		BC=1 3 2 3	16"							
S-2		BC=1 1 1 3	7"							
S-3		BC=2 3 7 10	7"							
S-4		BC=7 3 2 3	10"							
S-5		BC=3 1 3 3 PP=0.25	17"							
S-6		BC=4 4 4 4 PP=0.5	19"							
S-7		BC=1 1 1 2 PP=<0.25	24"							
ST-1			21"							
S-8		BC=1 1 2 2 PP=0.5	24"							
S-9		BC=3 5 5 6 PP=1.75	24"							
S-10		BC=2 3 4 3 PP=1.5	24"							
S-11		BC=100/0"								

LABORATORY RESULTS

MONITORING WELL CONSTRUCTION*

Completion Method: Roadbox



KLEINFELDER
Bright People. Right Solutions.

PROJECT NO.: 20202050.001A
DRAWN BY: MAP
CHECKED BY: DD
DATE: 12/12/2019

BORING LOG TP-B-102(OW)

South Medford Flood Study
Medford, Massachusetts

BORING
TP-B-102(OW)

Date Begin - End: 11/14/2019
Logged By: M. Chea
Hor.-Vert. Datum: Not Available
Plunge: -90 degrees
Weather: Clear

Drilling Company: CarrDee
Drill Crew: Steve & Frank
Drilling Equipment: ATV
Drilling Method: HSA & Drive and Wash
Exploration Diameter: 4 in. O.D.

BORING LOG TP-B-102(OW)

Hammer Type - Drop: 140 lb. Auto - 30 in.

		FIELD EXPLORATION					LABORATORY RESULTS							MONITORING WELL CONSTRUCTION*
Depth (feet)	Graphical Log	Latitude: 42.40180° Longitude: -71.10824° Surface Condition: Bare Earth Lithologic Description	Sample Number	Sample Type	Blow Counts(BC)= Uncorr. Blows/6 in. Pocket Pen(PP)= tsf	Recovery (NR=No Recovery)	USCS Symbol	Water Content (%)	Dry Unit Wt. (pcf)	Passing #4 (%)	Passing #200 (%)	Liquid Limit	Plasticity Index (NP=NonPlastic)	Completion Method: Roadbox
		Note: Boulder encountered at 33.5 feet bgs. Cored through 3.5 foot boulder and 1 foot through the till.												
		S-12: GLACIAL TILL: Silty SAND with Gravel (SM): fine to medium-grained sand, fine-grained sub-angular to angular gravel, gray, wet, very dense, PID=0.155	S-12		BC=26 29 30 35	15"								
40		**S-13:** similar to S-12, PID=0.102	S-13		BC=47 33 29 30									

The boring was terminated at approximately 41.5 ft. below ground surface. A monitoring well was installed after the completion of drilling.

GROUNDWATER LEVEL INFORMATION:
⊻ Groundwater was observed at approximately 6 ft. below ground surface during drilling.

GENERAL NOTES:
Switched from hollow stem augers to 4" casing and drive and wash at a depth of 10 feet.

45

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PROJECT NO.:	20202050.001A
DRAWN BY:	MAP
CHECKED BY:	DD
DATE:	12/12/2019

BORING LOG TP-B-102(OW)

South Medford Flood Study
Medford, Massachusetts

BORING

TP-B-102(OW)

PLOTTED: 12/12/2019 12:55 PM BY: MPalmer

PROJECT NUMBER: 20202050.001A OFFICE FILTER: BOSTON

gINT FILE: Klf_gint_master_2020

gINT TEMPLATE: E:KLF_STANDARD_GINT_LIBRARY_2020.GLB [_KLF_BORING/TEST PIT SOIL LOG]

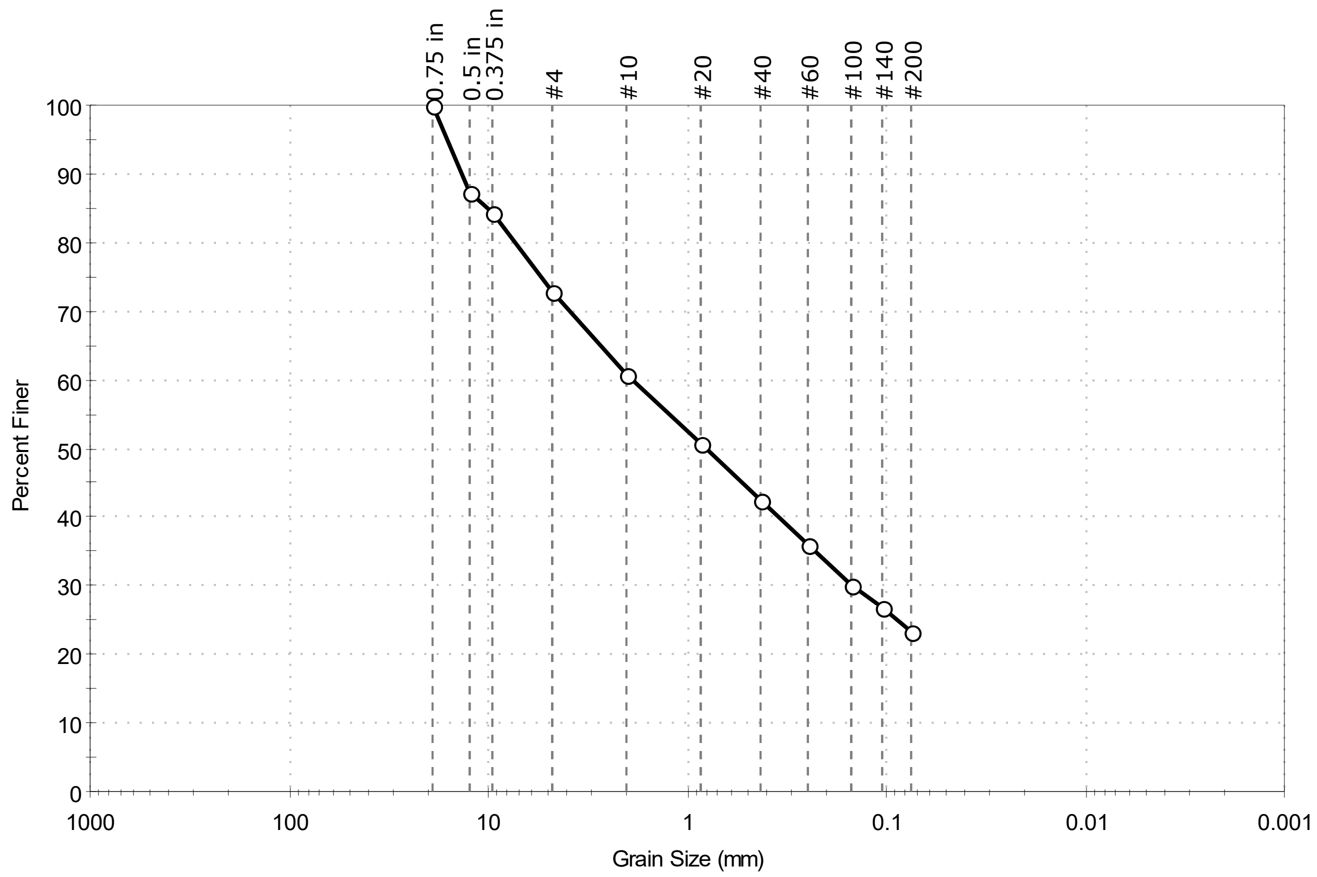
Appendix A.3

Geotechnical Lab Analysis Result

GeoTesting EXPRESS

Client: Kleinfelder, Inc.
Project: S-Medford Flood Study
Location: Medford, MA
Project No: GTX-310955
Boring ID: Barry B101
Sample Type: jar
Tested By: ckg
Sample ID: S6
Test Date: 12/04/19
Checked By: bfs
Depth : 20-22
Test Id: 531188
Test Comment: ---
Visual Description: Moist, light yellowish brown silty sand with gravel
Sample Comment: ---

Particle Size Analysis - ASTM D6913



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	27.1	49.7	23.2

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.75 in	19.00	100		
0.5 in	12.50	87		
0.375 in	9.50	84		
#4	4.75	73		
#10	2.00	61		
#20	0.85	51		
#40	0.42	42		
#60	0.25	36		
#100	0.15	30		
#140	0.11	27		
#200	0.075	23		

Coefficients

D_{85} =10.0455 mm
D_{30} =0.1501 mm
D_{60} =1.8796 mm
D_{15} =N/A
D_{50} =0.8060 mm
D_{10} =N/A
C_u =N/A
C_c =N/A

Classification

ASTM N/A

AASHTO Stone Fragments, Gravel and Sand (A-1-b (0))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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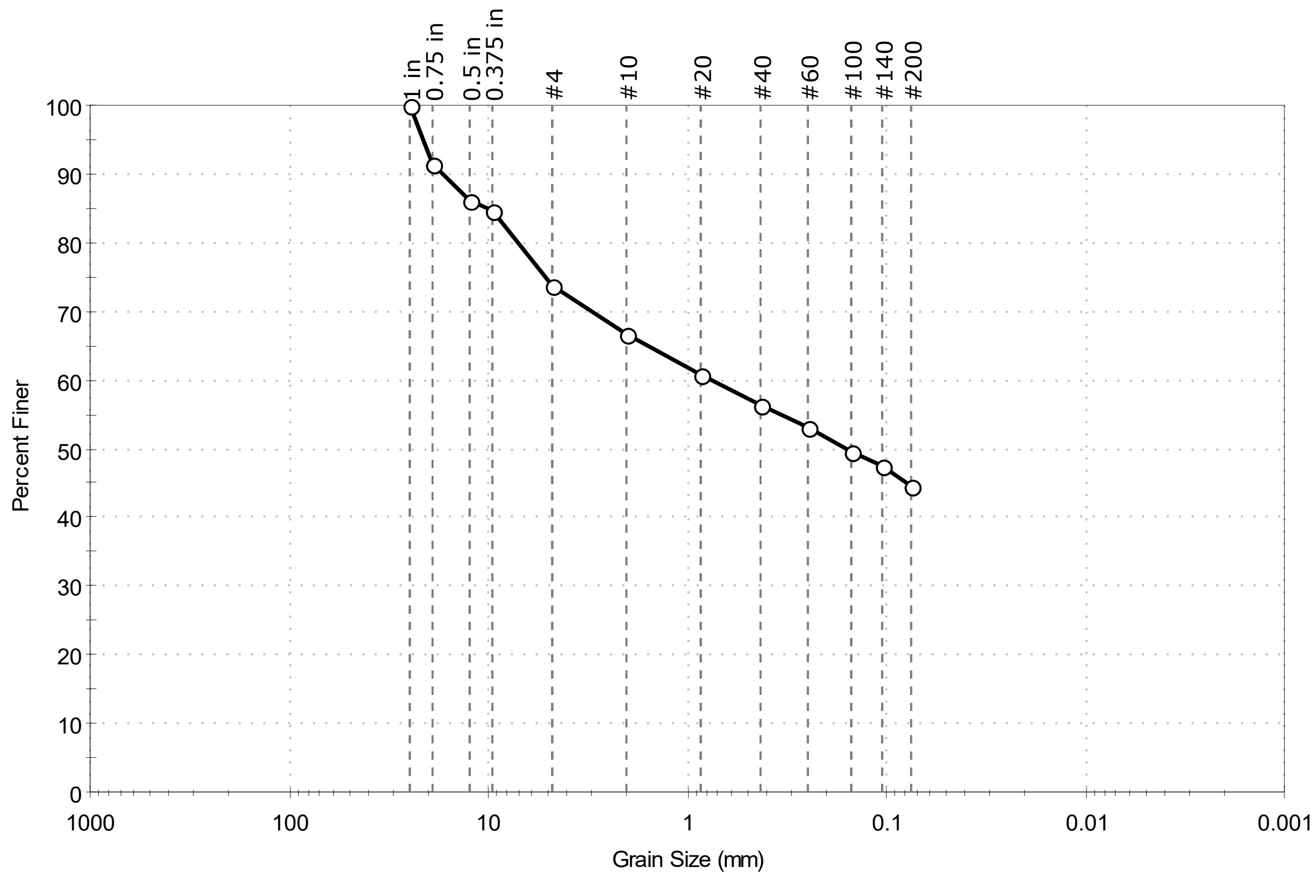
GeoTesting
EXPRESS

Client: Kleinfelder, Inc.
Project: S-Medford Flood Study
Location: Medford, MA
Project No: GTX-310955
Boring ID: Barry B102
Sample Type: jar
Tested By: ckg
Sample ID: S4-2
Test Date: 12/04/19
Checked By: bfs
Depth : 6-8
Test Id: 531189
Test Comment: ---
Visual Description: Moist, pale olive silty sand with gravel
Sample Comment: ---

Particle Size Analysis - ASTM D6913



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	26.4	29.1	44.5

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
1 in	25.00	100		
0.75 in	19.00	91		
0.5 in	12.50	86		
0.375 in	9.50	85		
#4	4.75	74		
#10	2.00	67		
#20	0.85	61		
#40	0.42	56		
#60	0.25	53		
#100	0.15	50		
#140	0.11	47		
#200	0.075	45		

Coefficients

D_{85} =10.2655 mm
D_{30} =N/A
D_{60} =0.7650 mm
D_{15} =N/A
D_{50} =0.1579 mm
D_{10} =N/A
C_u =N/A
C_c =N/A

Classification

ASTM N/A

AASHTO Silty Soils (A-4 (0))

Sample/Test Description

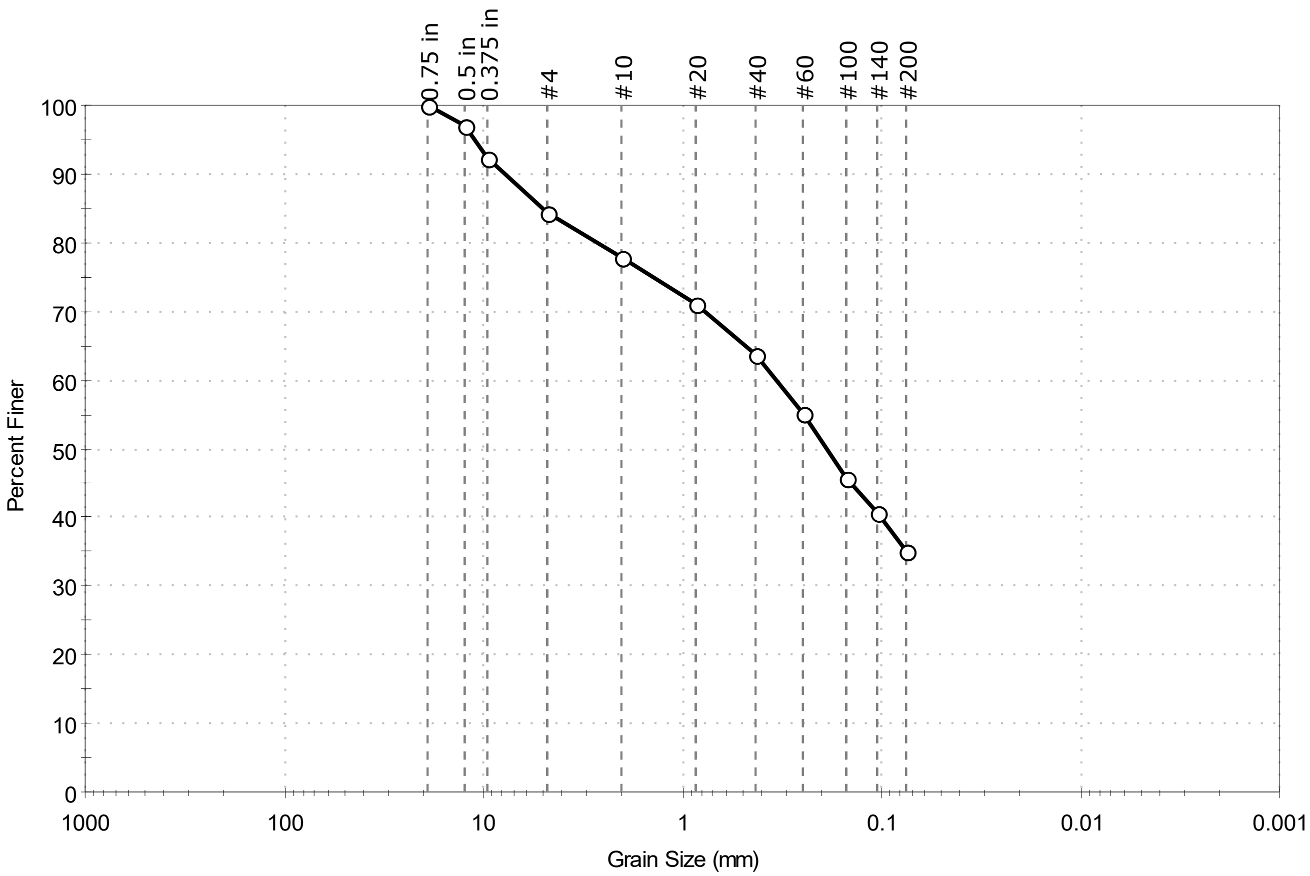
Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

printed 12/5/2019 10:20:01 AM

Client: Kleinfelder, Inc.
Project: S-Medford Flood Study
Location: Medford, MA
Project No: GTX-310955
Boring ID: Tufts B101
Sample Type: jar
Tested By: ckg
Sample ID: S3
Test Date: 12/04/19
Checked By: bfs
Depth : 4-6
Test Id: 531186
Test Comment: ---
Visual Description: Moist, mottled yellowish brown and greenish gray silty sand with gravel
Sample Comment: ---

Particle Size Analysis - ASTM D6913



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	15.8	49.0	35.2

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.75 in	19.00	100		
0.5 in	12.50	97		
0.375 in	9.50	92		
#4	4.75	84		
#10	2.00	78		
#20	0.85	71		
#40	0.42	64		
#60	0.25	55		
#100	0.15	46		
#140	0.11	41		
#200	0.075	35		

Coefficients

D_{85} =5.0797 mm
D_{30} =N/A
D_{60} =0.3383 mm
D_{15} =N/A
D_{50} =0.1883 mm
D_{10} =N/A
C_u =N/A
C_c =N/A

Classification

ASTM N/A

AASHTO Silty Soils (A-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

Client:	Kleinfelder, Inc.		
Project:	S-Medford Flood Study		
Location:	Medford, MA	Project No:	GTX-310955

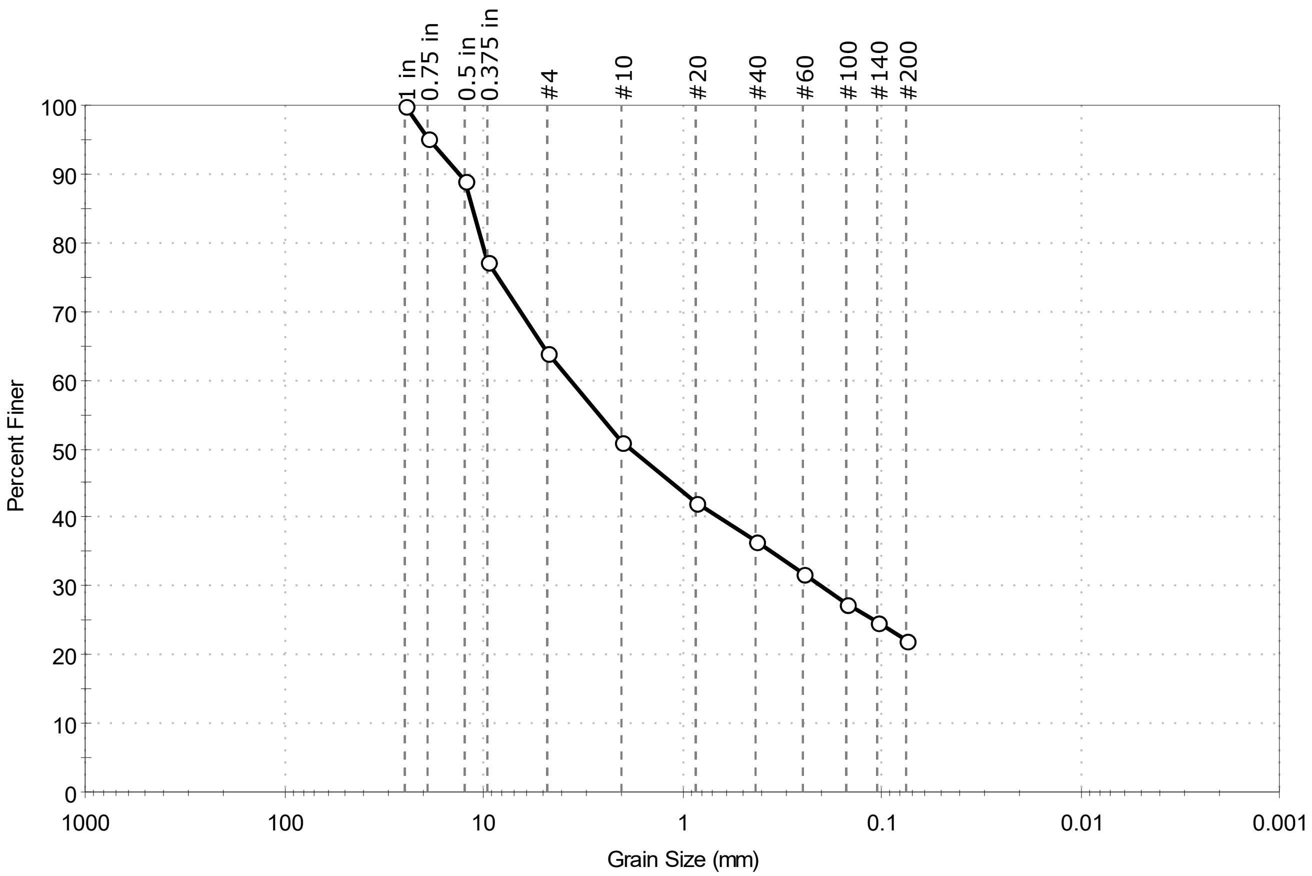
Boring ID:	Tufts B101	Sample Type:	jar	Tested By:	ckg
Sample ID:	S17	Test Date:	12/04/19	Checked By:	bfs
Depth :	40-42	Test Id:	531187		

Test Comment: ---

Visual Description: Moist, olive gray silty sand with gravel

Sample Comment: ---

Particle Size Analysis - ASTM D6913



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	35.8	42.0	22.2

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
1 in	25.00	100		
0.75 in	19.00	95		
0.5 in	12.50	89		
0.375 in	9.50	77		
#4	4.75	64		
#10	2.00	51		
#20	0.85	42		
#40	0.42	37		
#60	0.25	32		
#100	0.15	27		
#140	0.11	25		
#200	0.075	22		

Coefficients

D_{85} =11.3717 mm	D_{30} =0.2001 mm
D_{60} =3.6067 mm	D_{15} =N/A
D_{50} =1.7982 mm	D_{10} =N/A
C_u =N/A	C_c =N/A

Classification

ASTM	N/A
AASHTO	Stone Fragments, Gravel and Sand (A-1-b (0))

Sample/Test Description

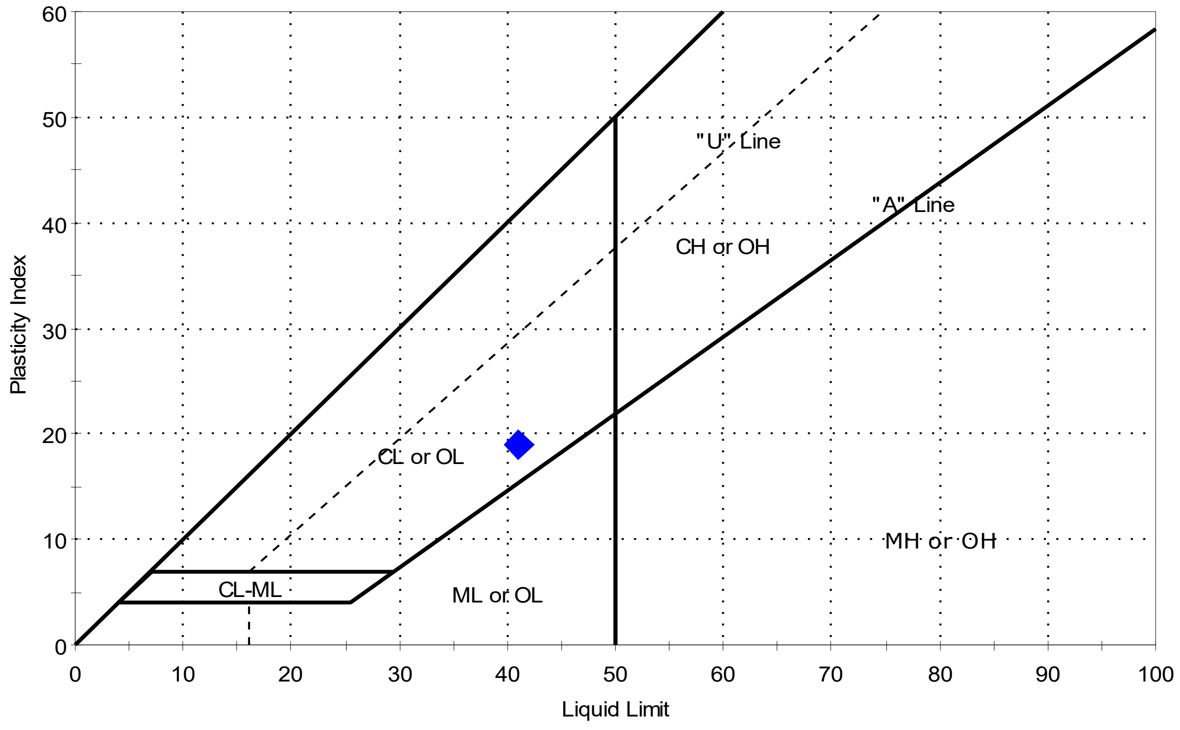
Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

Client: Kleinfelder, Inc.
Project: S-Medford Flood Study
Location: Medford, MA
Project No: GTX-310955
Boring ID: Barry B101
Sample Type: jar
Tested By: cam
Sample ID: S3
Test Date: 12/02/19
Checked By: bfs
Depth : 5-7
Test Id: 531185
Test Comment: ---
Visual Description: Moist, grayish brown clay
Sample Comment: ---

Atterberg Limits - ASTM D4318

Plasticity Chart



Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	S3	Barry B101	5-7	15	41	22	19	-0.4	

Sample Prepared using the WET method

Dry Strength: VERY HIGH
Dilatancy: SLOW
Toughness: LOW

printed 12/5/2019 10:17:19 AM

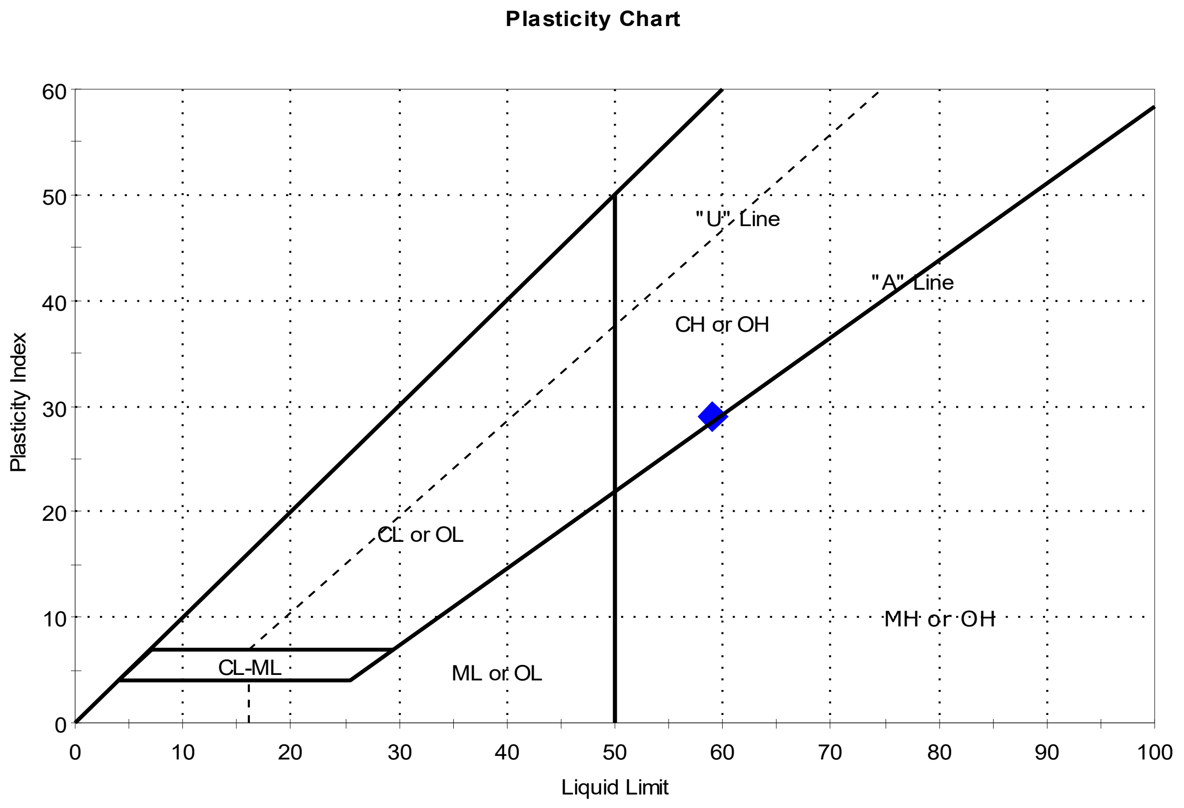
GeoTesting EXPRESS

Client: Kleinfelder, Inc.
Project: S-Medford Flood Study
Location: Medford, MA
Project No: GTX-310955

Boring ID: Tufts B101
Sample ID: S8
Depth : 14-16
Sample Type: jar
Test Date: 12/02/19
Test Id: 531183
Tested By: cam
Checked By: bfs

Test Comment: ---
Visual Description: Moist, dark gray clay
Sample Comment: ---

Atterberg Limits - ASTM D4318



Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	S8	Tufts B101	14-16	60	59	30	29	1	

Sample Prepared using the WET method

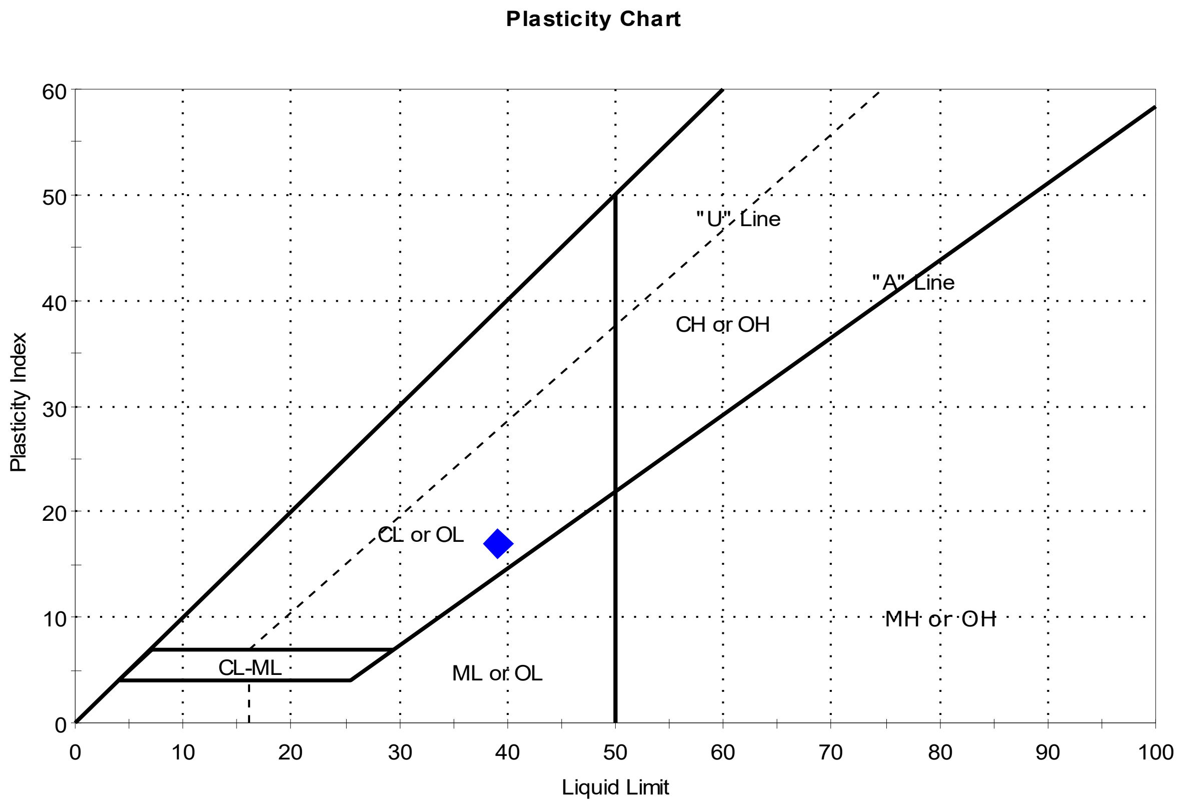
Dry Strength: VERY HIGH
Dilatancy: SLOW
Toughness: LOW

Client: Kleinfelder, Inc.
Project: S-Medford Flood Study
Location: Medford, MA
Project No: GTX-310955

Boring ID:	Tufts B101	Sample Type:	jar	Tested By:	cam
Sample ID:	S13	Test Date:	12/02/19	Checked By:	bfs
Depth :	24-26	Test Id:	531184		

Test Comment: ---
Visual Description: Moist, greenish gray clay
Sample Comment: ---

Atterberg Limits - ASTM D4318



Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	S13	Tufts B101	24-26	24	39	22	17	0.1	

Sample Prepared using the WET method

Dry Strength: VERY HIGH
Dilatancy: SLOW
Toughness: LOW

printed 12/5/2019 10:17:20 AM

Appendix B: Photos of Tufts Park Existing Flooding *

** (All Photos are credit to Kleinfelder unless otherwise noted)*

Turf area flooding between northeast and southeast ballfields; typical conditions after small-to-medium-sized storm event (credit: Mike Nestor, City of Medford)

Infield flooding at southwest ballfield; typical conditions after small-to-medium-sized storm event. (credit: Mike Nestor, City of Medford)

Sheet flow from impervious surfaces at tennis and basketball courts, pedestrian pathways, and school parking lot (to northeast) result in flooding and erosion of low-lying areas near northeast ballfield. (credit: Mike Nestor, City of Medford)

Sheet flow from impervious surfaces at school parking lot (to northeast) result in erosion of turf areas along parkway entrance from Main St.

Sheet flow from impervious surfaces at school parking lot (to northeast) result in erosion of turf areas along parkway entrance from Main St.

Low-lying areas near MWRA manholes pond with water during all rainfall events; vehicle tracks from Parks maintenance vehicle in outfield grass (alternate vehicle path is also flooded during these rain events)

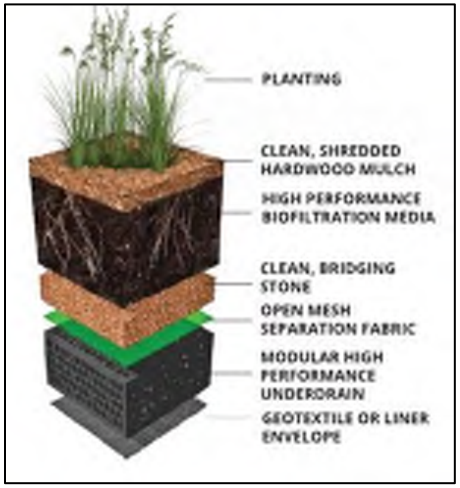
Low-lying areas near MWRA manholes pond with water during all rainfall events; vehicle tracks from Parks maintenance vehicle in outfield grass

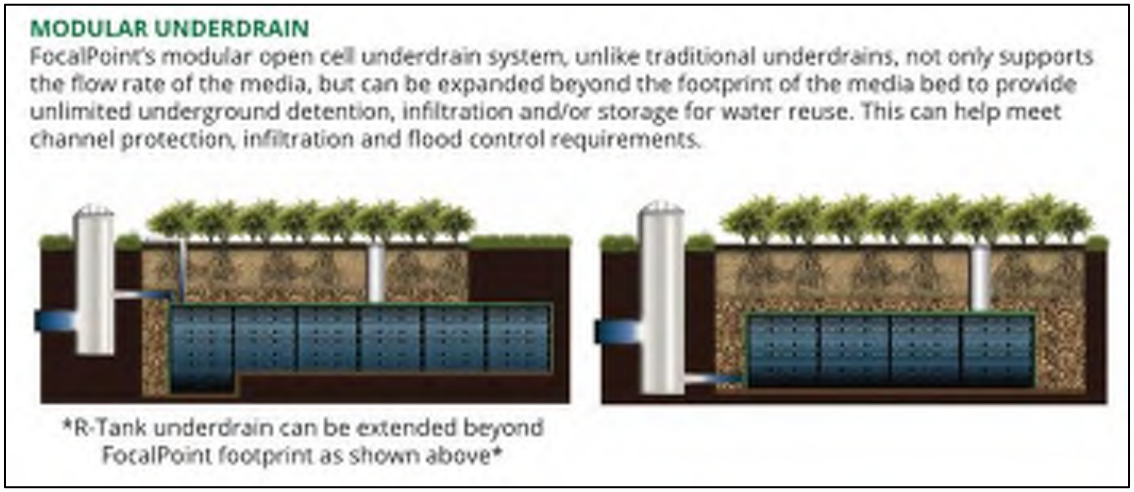
Alternate pedestrian/vehicle path is also flooded during these rain events (photo taken after a 0.1" rain event, May 2020)

Typical maintenance after small storm event, vacuuming excess water from flooded ballfield and pedestrian pathway (such flooding and washout can occur after as little as 0.1" of rainfall).
(credit: Mike Nestor, City of Medford)

Roadway flooding at Morton Ave (low-lying area between two Park ballfields) during a high-intensity short duration storm event on 5/15/2020. This flood event resulted from ~0.6" of rainfall in a 1-hour timeframe, which is less than the 1-year recurrence event for present day conditions. This type of flooding also occurs during other large storm events of longer duration (e.g., 24-hour events with 2+ inches of rainfall). It is likely that such events (short-duration "flash" flooding, and high-volume events) will occur more frequently with future climate change.

Appendix C: GSI Concepts





MODULAR UNDERDRAIN

FocalPoint's modular open cell underdrain system, unlike traditional underdrains, not only supports the flow rate of the media, but can be expanded beyond the footprint of the media bed to provide unlimited underground detention, infiltration and/or storage for water reuse. This can help meet channel protection, infiltration and flood control requirements.

R-Tank underdrain can be extended beyond FocalPoint footprint as shown above

Schematic concept for proposed bioretention BMP (image sources: Philadelphia Water Department, ACF)

Concept for proposed linear open vegetated swale BMP (refer to detail, Sheet GC-3) (left image source: Biocycle)

Concept for modular pre-cast porous pavement slabs and subsurface storage at public school parking lot (image source: Stormcrete)

Concept for Filterra modular stormwater tree pit to reduce spot erosion near Tufts Park east entrance (images source: Contech)

Appendix D: Conceptual Design Drawings

CITY OF MEDFORD, MASSACHUSETTS
SOUTH MEDFORD FLOOD MITIGATION
CONCEPTUAL DESIGN

JUNE 2020

MAYOR

BREANNA LUNGO-KOEHN

CITY ENGINEER

TIMOTHY MCGIVERN, P.E.

STAFF CIVIL ENGINEER

PENNY ANTONOGLOU

FOREMAN, PARK DIVISION

MICHAEL NESTOR

LOCUS PLAN

SCALE: 1" = 200'

INDEX

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CONCEPT DESIGN
NOT FOR
CONSTRUCTION

PLOTTED: 6/26/2020 1:49 PM BY: sally kramer

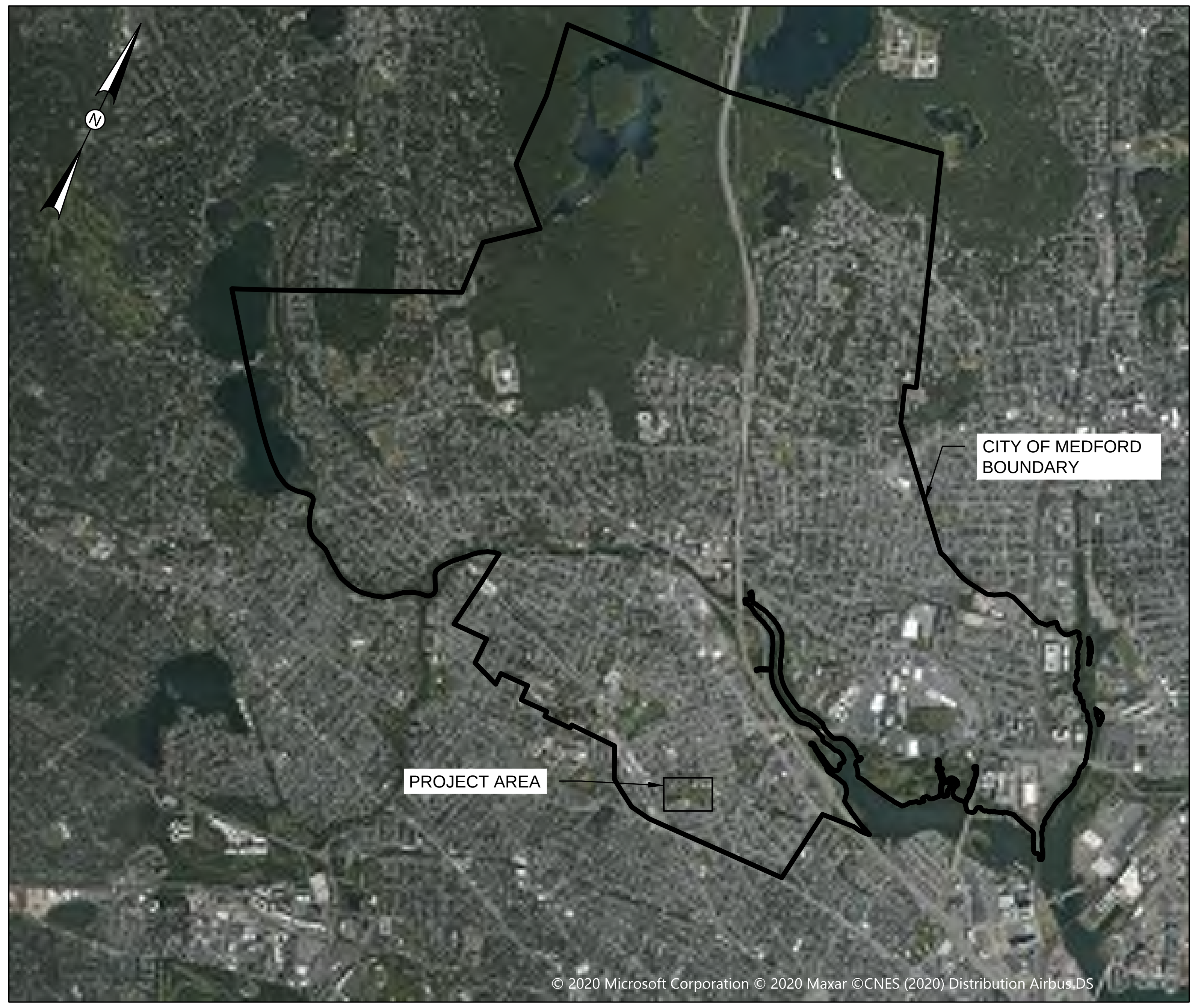
CAD FILE: G:_clients\Medford MA\20202050 - MVP Grant - S Medford Flood Mitigation Study\CAD\Cover.dwg LAYOUT: Cover

LEGEND

△	SURVEY CONTROL STATION
◉ DH	DRILL HOLE
MAG	MAGNETIC
FND	FOUND
(R)	RECORD
(M)	MARKED
︶︶︶︶︶︶	TREE LINE/HEDGE
✿	DECIDUOUS TREE
TW	TREE WELL
UNK	UNKNOWN
——o——	CHAIN LINK FENCE
CLF	CHAIN LINK FENCE
DWS	DUCTILE WARNING STRIP
═══	CURBING(TYPE)
CONC	CONCRETE
BIT CONC	BITUMINOUS CONCRETE
BCC	BITUMINOUS CONCRETE CURB
GRAN	GRANITE
GC	GRANITE CURB
CC	CONCRETE CURB
ϕ UP	UTILITY POLE
ϕ UP/LP	UTILITY POLE/LIGHT POLE
▣	TRAFFIC SIGNAL
ȯ	PEDESTRIAN SIGNAL
⊙	MANHOLE
FA	FIRE ALARM
WV ⋈	WATER GATE
☼	HYDRANT
⋈	GAS GATE
DMH	DRAIN MANHOLE
R	RIM
I	INVERT
TOB	TOP OF BELL
TOP	TOP OF PIPE
TOS	TOP OF SILT
TOW	TOP OF WATER
CU	CONNECTION UNKNOWN
VCP	VITREOUS CLAY PIPE
⊡	TYPE 1 CATCH BASIN
□	FLEX COUPLING
Ⓓ	DRAIN MANHOLE
Ⓢ	SEWER MANHOLE
RCP	REINFORCED CONCRETE PIPE
CPP	CORRUGATED PLASTIC PIPE
CIP	CAST IRON PIPE
NPV	NO PIPE VISIBLE
BCD	BITUMINOUS CONCRETE DRIVE
CCD	CONCRETE DRIVE
BCW	BITUMINOUS CONCRETE WALK
CW	CONCRETE WALK
BR	BRICK
LST	LANDSCAPE TIMBER
TRW	TIMBER RETAINING WALL
CRW	CONCRETE RETAINING WALL
SRW	STONE RETAINING WALL
PL	PLANTED
○ MP	MARKER POST
—o—	SIGN
□ HH	HANDHOLE
DPW	DEPARTMENT OF PUBLIC WORKS
TEL	TELEPHONE
WRIF	WROUGHT IRON FENCE
⊕	MONITORING WELL
□—☼	LIGHT POLE
BRW	BRICK RETAINING WALL
○ MTP	METAL POST
○ GP	GUARD POST
○ CP	CONCRETE POST
◎ TC	TRASH CAN
EMH	ELECTRIC MANHOLE
SMH	SEWER MANHOLE
TMH	TELEPHONE MANHOLE
TSCC	TRAFFIC SIGNAL CONTROL CABINET
——E——	ELECTRIC LINE
——D——	DRAIN LINE
——UD——	UNDERDRAIN LINE
——G——	GAS LINE
——W——	WATER LINE
——S——	SEWER LINE
——CS——	COMBINED SEWER LINE
——T——	TELEPHONE LINE
——CATV——	CABLE TELEVISION LINE
FF	FINISHED FLOOR
TH	THRESHOLD
PARKMTR	PARKING METER
MRW	MASONERY RETAINING WALL
————	ABANDONED GAS

GENERAL NOTES:

1. EXISTING CONDITIONS LINEWORK SHALL BE REPRESENTED IN GREY.
2. PROPOSED CONDITIONS LINEWORK SHALL BE REPRESENTED IN BLACK.
3. ALL ELEVATIONS IN THIS DRAWING SET ARE PRESENTED IN NAVD88.
4. THE FOLLOWING REFERENCES WERE USED IN THE CREATION OF THIS DRAWING SET:
   - 4.1. LIDAR FROM USGS CONED DATABASE FOR 1-FT CONTOURS
   - 4.2. CITY OF MEDFORD GIS FOR LOCATION OF CITY-OWNED DRAINAGE, WATER, AND SEWER UTILITIES; PARCELS; BUILDINGS
   - 4.3. CITY OF MEDFORD RECORD DRAWING FOR LOCATION OF ELECTRICAL UTILITIES; TREES (RECEIVED FROM CITY ON 10/22/2019)
   - 4.4. MASSACHUSETTS WATER RESOURCES AUTHORITY CONTRACT 6394 DRAWINGS DATED OCTOBER 31, 2008, SHEETS PP-11, PP-14 AND PP-15 BY PARSONS BRINCKERHOFF FOR LOCATION OF MWRA WATER MAINS



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LOCUS PLAN OF CITY OF MEDFORD

SCALE: 1" = 3000'

0 3000 6000 9000

SCALE: 1" = 3000' SCALE IN FEET

ABBREVIATIONS

AVE	AVENUE
BC	BOTTOM OF CURB
BIT	BITUMINOUS PAVEMENT
BIT CONC	BITUMINOUS CONCRETE
BCD	BITUMINOUS CONCRETE DRIVE
BCC	BITUMINOUS CONCRETE CURB
BCW	BITUMINOUS CONCRETE WALK
BIT	BITUMINOUS PAVEMENT
BR	BRICK
BRW	BRICK RETAINING WALL
CB	CATCH BASIN
CDF	CONTROLLED DENSITY FILL
CEM	CEMENT
CL	CENTERLINE
CONC	CONCRETE
CC	CONCRETE CURB
CCD	CONCRETE DRIVE
CI/CIP	CAST IRON PIPE
CLF	CHAIN LINK FENCE
CPP	CORRUGATED PLASTIC PIPE
CRW	CONCRETE RETAINING WALL
CS	COMBINED SEWER
CATV	CABLE TELEVISION
CU	CONNECTION UNKNOWN
CW	CONCRETE WALK
DI	DUCTILE IRON
DMH	DRAIN MANHOLE
DPW	DEPARTMENT OF PUBLIC WORKS
DWS	DUCTILE WARNING STRIP
EG	EXISTING GRADE
ELEV	ELEVATION
EMH	ELECTRIC MANHOLE
EXIST	EXISTING
FA	FIRE ALARM
FF	FINISHED FLOOR
FG	FINISHED GRADE
FND	FOUND
GC	GRANITE CURB
GM	GAS METER
GRAN	GRANITE
GV	GATE VALVE
HYD	HYDRANT
INV	INVERT
LP	LIGHT POST
LPH	LAMPHOLE
LST	LANDSCAPE TIMBER
MAG	MAGNETIC
MJ	MECHANICAL JOINT
NPV	NO PIPE VISIBLE
PARKMTR	PARKING METER
PL	PLANTED
PROP	PROPOSED
PT	POINT OF TANGENT
PVC	POLYVINYL CHLORIDE
R	RIM
RCP	REINFORCED CONCRETE PIPE
RD	ROAD
R&R	REMOVE AND REPLACE
SD	STORM DRAIN
SMH	SEWER MANHOLE
SRW	STONE RETAINING WALL
SS	SANITARY SEWER
ST	STREET
STA	STATION
TBM	TEMPORARY BENCH MARK
TC	TOP OF CURB
TEL	TELEPHONE
TH	THRESHOLD
TMH	TELEPHONE MANHOLE
TOB	TOP OF BELL
TOH	TOP OF HOOD
TOP	TOP OF PIPE
TOS	TOP OF SILT
TSCC	TRAFFIC SIGNAL CONTROL CABINET
TOW	TOP OF WATER
TRW	TIMBER RETAINING WALL
TYP	TYPICAL
UNK	UNKNOWN
UP	UTILITY POLE
VC	VITRIFIED CLAY
VCP	VITREOUS CLAY PIPE
VGC	VERTICAL GRANITE CURB
WG	WATER GATE
WRIF	WROUGHT IRON FENCE

CONCEPT DESIGN
NOT FOR
CONSTRUCTION

KLEINFELDER
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REVISIONS

DATE	JUNE 2020
PROJECT NO.	20202050
DRAWN BY	SMK
CHECKED BY	DL
FILE NAME	

GENERAL NOTES AND LEGEND

CITY OFMEDFORD, MASSACHUSETTS
SOUTH MEDFORD FLOOD MITIGATION STUDY

SHEET

G-1

PLAN

SCALE: 1" = 40'

0 40 80

SCALE: 1" = 40' SCALE IN FEET

CONCEPT DESIGN
NOT FOR
CONSTRUCTION

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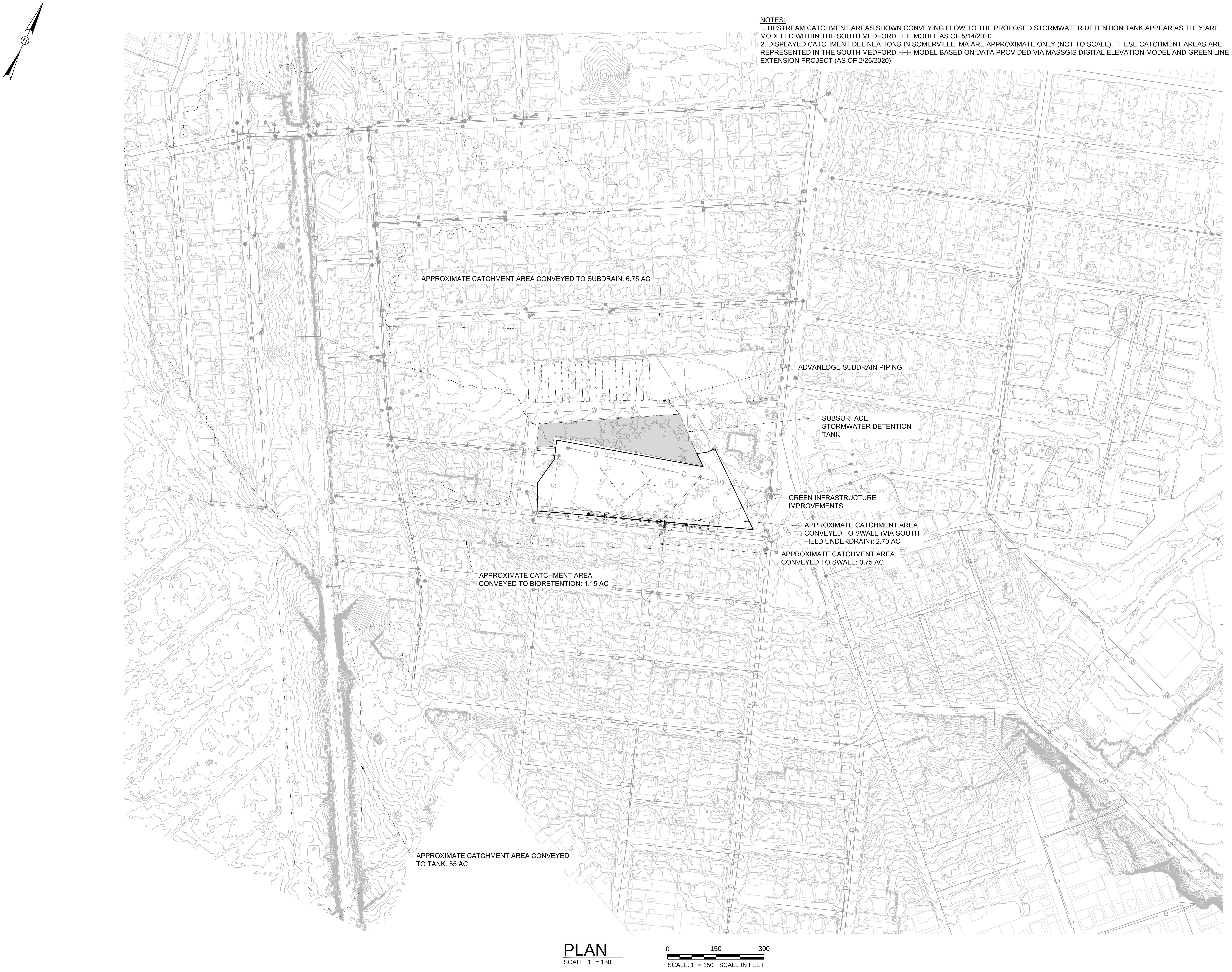
EXISTING SITE CONDITIONS PLAN
TUFTS PARK

CITY OFMEDFORD, MASSACHUSETTS
SOUTH MEDFORD FLOOD MITIGATION STUDY

SHEET
EC-1

NOTES:
1. UPSTREAM CATCHMENT AREAS SHOWN CONVEYING FLOW TO THE PROPOSED STORMWATER DETENTION TANK APPEAR AS THEY ARE MODELED WITHIN THE SOUTH MEDFORD H+H MODEL AS OF 5/14/2020.
2. DISPLAYED CATCHMENT DELINEATIONS IN SOMERVILLE, MA ARE APPROXIMATE ONLY (NOT TO SCALE). THESE CATCHMENT AREAS ARE REPRESENTED IN THE SOUTH MEDFORD H+H MODEL BASED ON DATA PROVIDED VIA MASSGIS DIGITAL ELEVATION MODEL AND GREEN LINE EXTENSION PROJECT (AS OF 2/26/2020).



PLAN
SCALE: 1" = 150'

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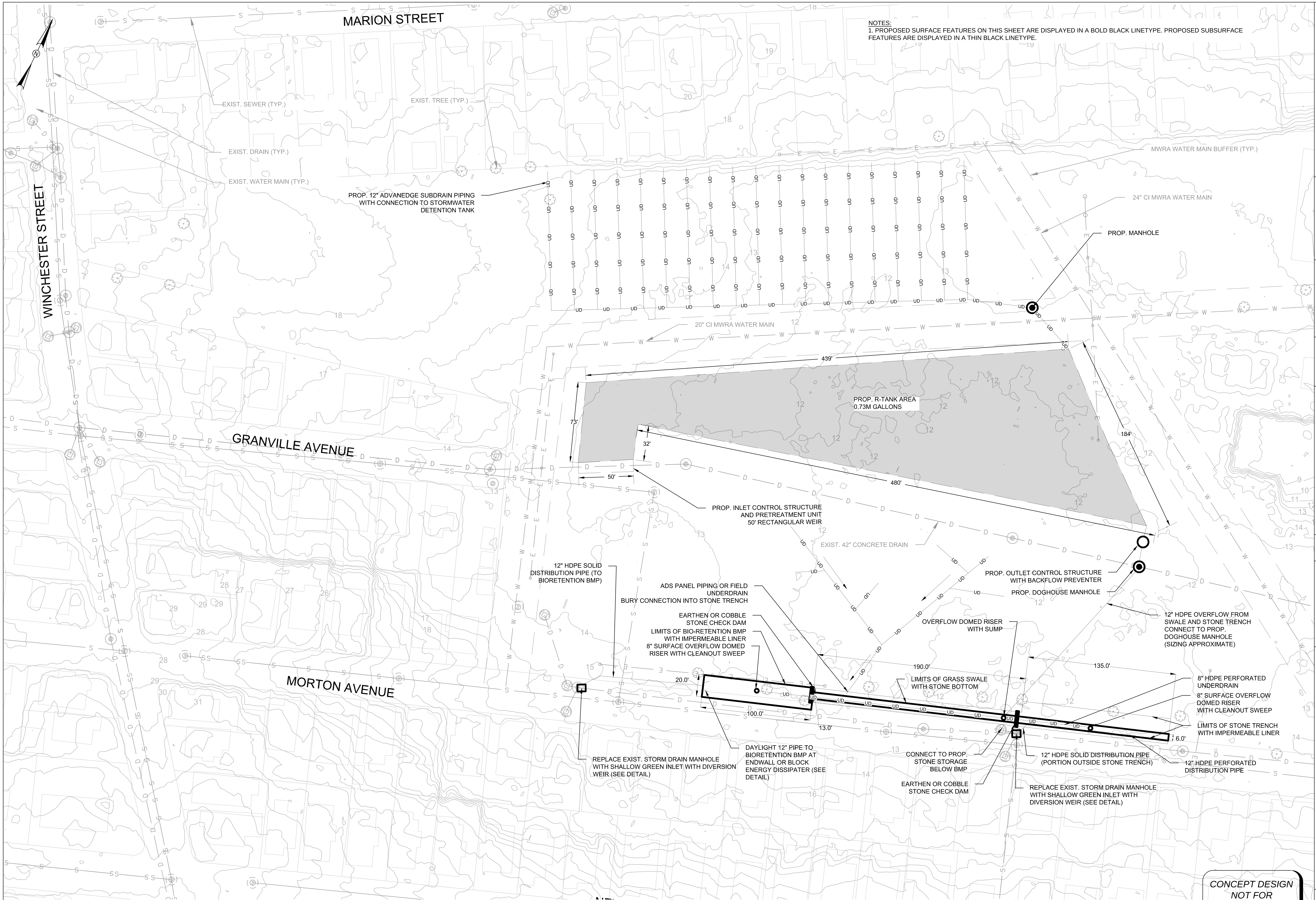
TOPOGRAPHY AND
CONTRIBUTING DRAINAGE AREA

CITY OFMEDFORD, MASSACHUSETTS
SOUTH MEDFORD FLOOD MITIGATION STUDY

SHEET
C-1

NOTES:
1. PROPOSED SURFACE FEATURES ON THIS SHEET ARE DISPLAYED IN A BOLD BLACK LINETYPE. PROPOSED SUBSURFACE FEATURES ARE DISPLAYED IN A THIN BLACK LINETYPE.



*CONCEPT DESIGN
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CONSTRUCTION*

PLAN
SCALE: 1" = 40'

0 40 80
SCALE: 1" = 40' SCALE IN FEET

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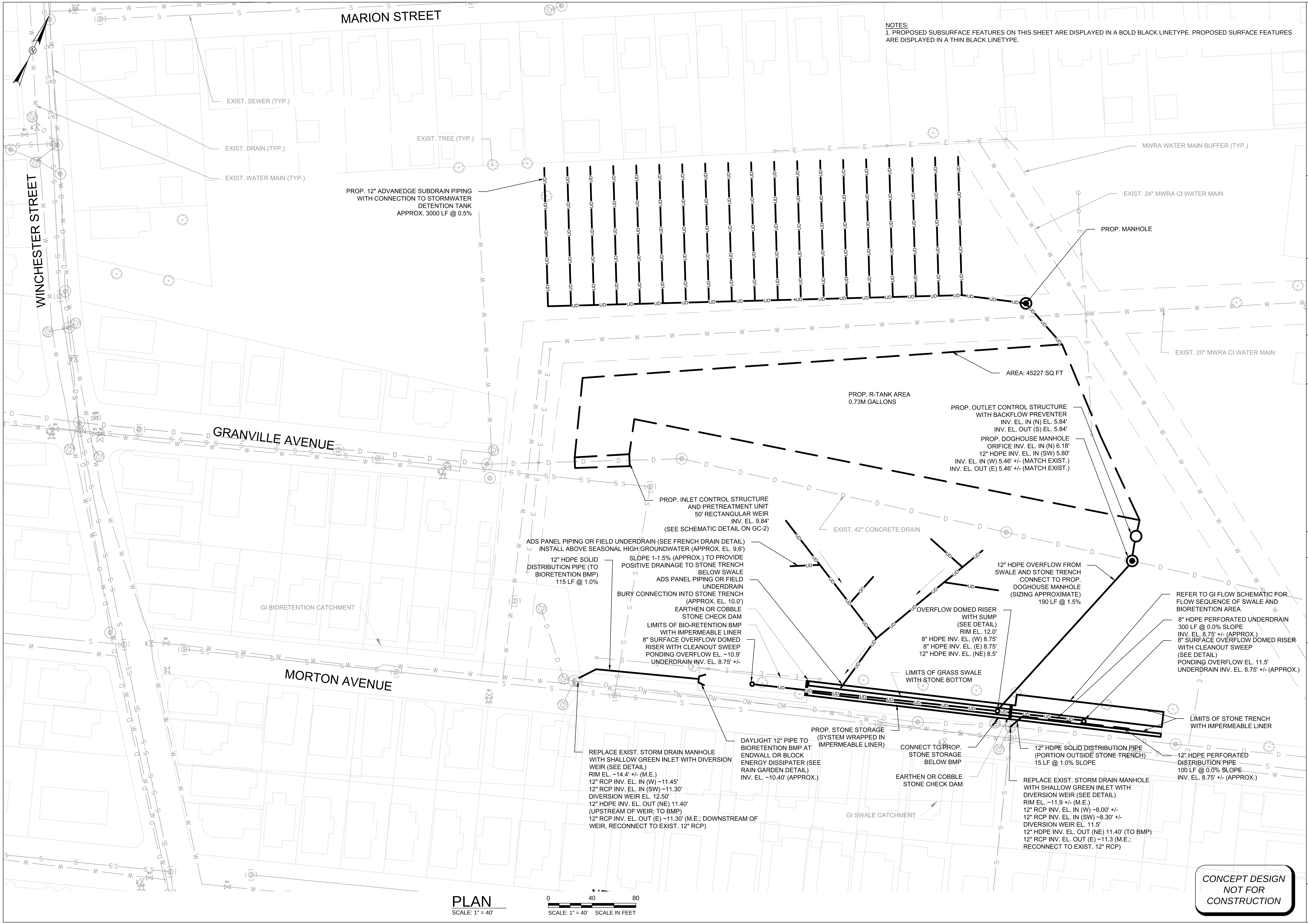
PROPOSED SITE LAYOUT AND DIMENSIONS

CITY OFMEDFORD, MASSACHUSETTS
SOUTH MEDFORD FLOOD MITIGATION STUDY

SHEET
C-2

NOTES:
1. PROPOSED SUBSURFACE FEATURES ON THIS SHEET ARE DISPLAYED IN A BOLD BLACK LINETYPE. PROPOSED SURFACE FEATURES ARE DISPLAYED IN A THIN BLACK LINETYPE.



PLAN

SCALE: 1" = 40'

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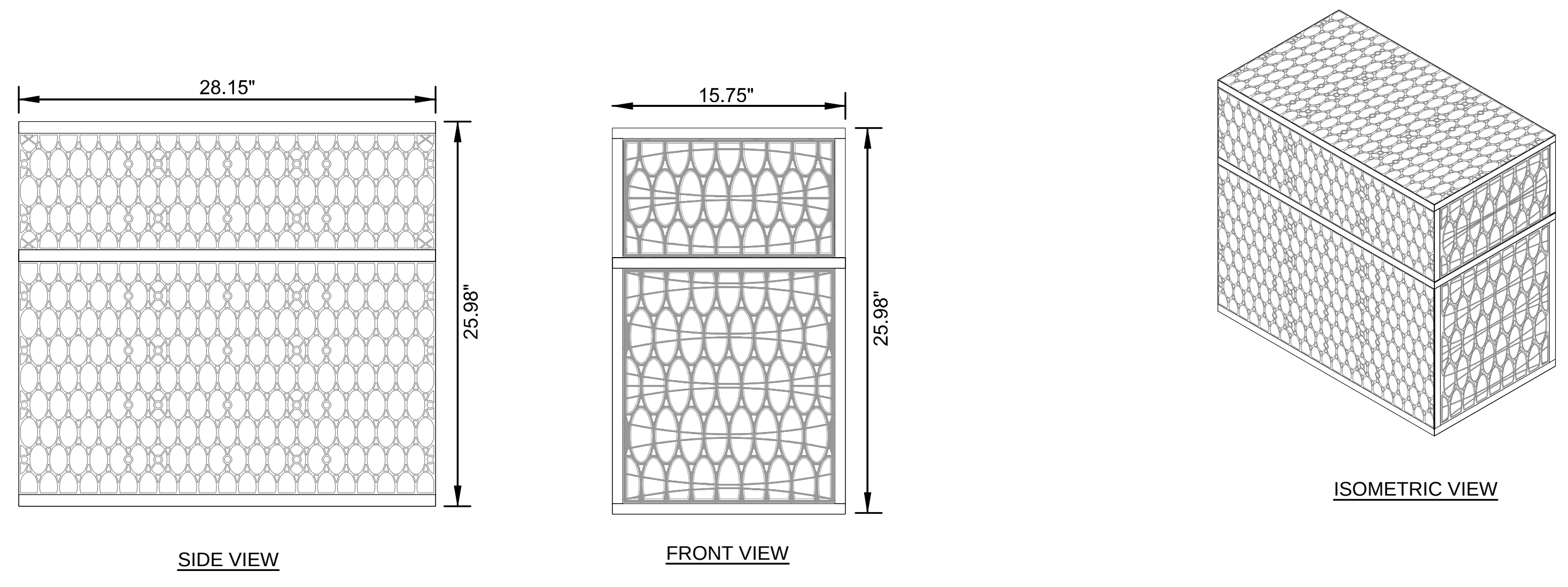
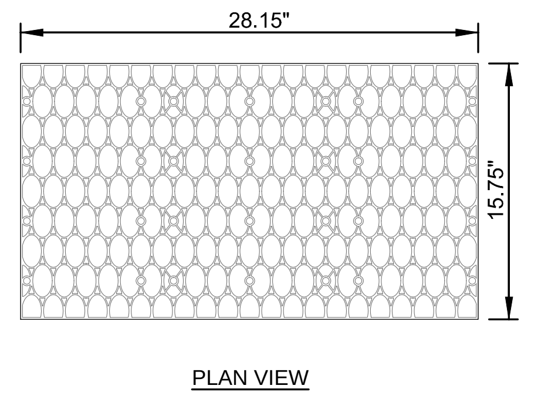
PROPOSED SUBSURFACE BMP
AND DRAINAGE PLAN

CITY OFMEDFORD, MASSACHUSETTS
SOUTH MEDFORD FLOOD MITIGATION STUDY

SHEET
C-3





MODULE DATA

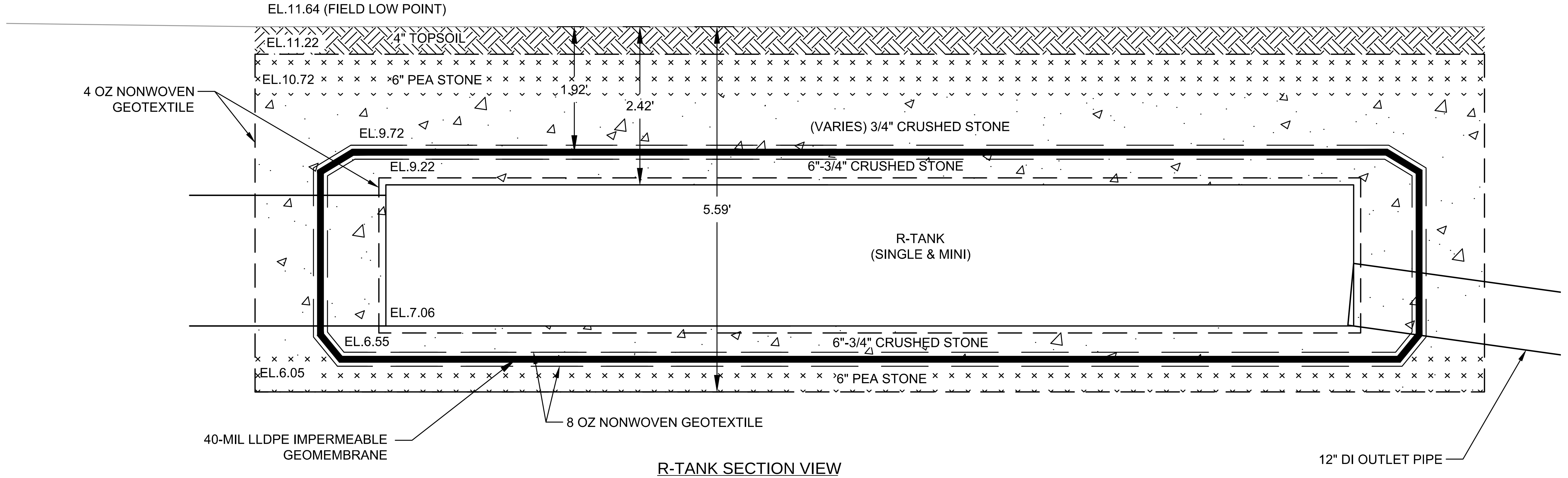
GEOMETRY: LENGTH = 28.15 IN. (715 MM)
WIDTH = 15.75 IN. (400 MM)
HEIGHT = 25.98 IN. (660 MM)
TANK VOLUME = 6.67 CF
STORAGE VOLUME = 6.33 CF
VOID INTERNAL VOLUME: 95%
VOID SURFACE AREA: 90%

LOAD RATING: 33.4 PSI, (MODULE ONLY)
HS25, (WITH ACF COVER SYSTEM)

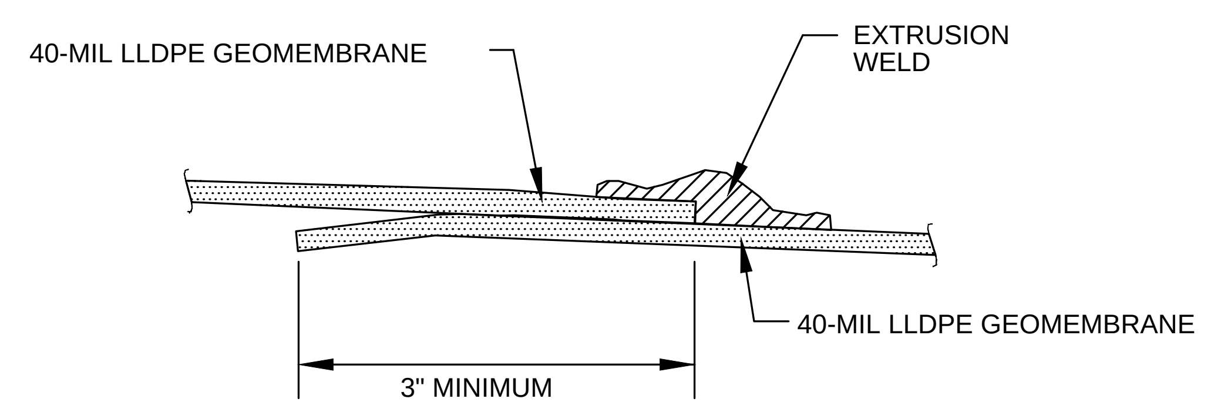
MATERIAL: 100% RECYCLED POLYPROPYLENE

SMALL PLATES PER SEGMENT/TOTAL: 5/10

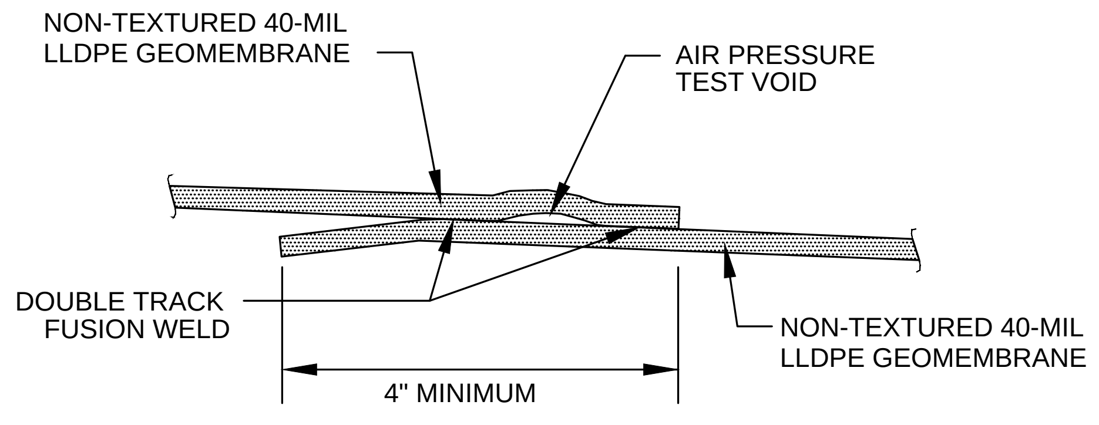
R-TANK SINGLE + MINI HD UNITS FROM ACF ENVIRONMENTAL
SCALE: AS NOTED



R-TANK SECTION VIEW
SCALE: AS NOTED

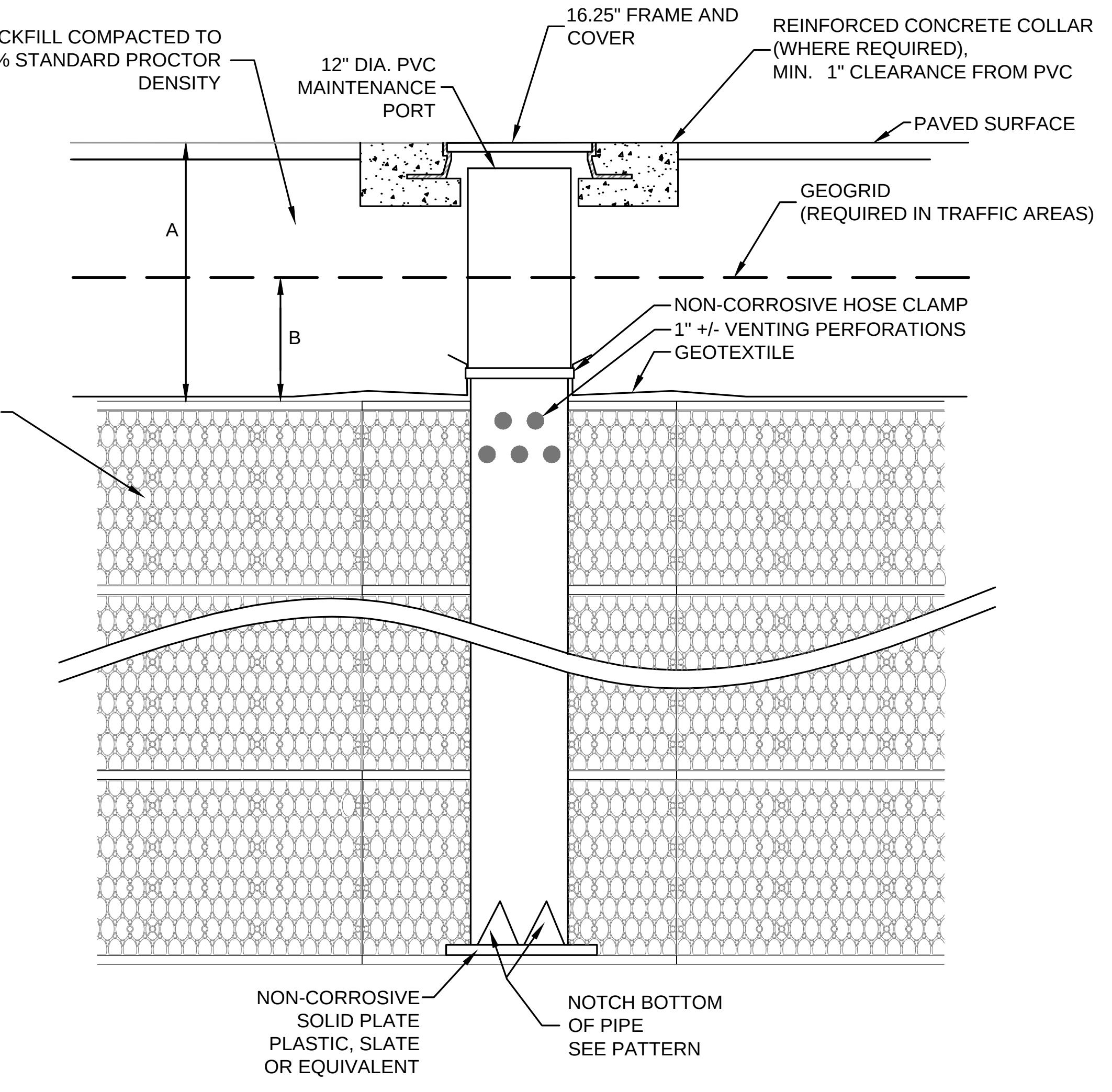


EXTRUSION WELD DETAIL
SCALE: NTS



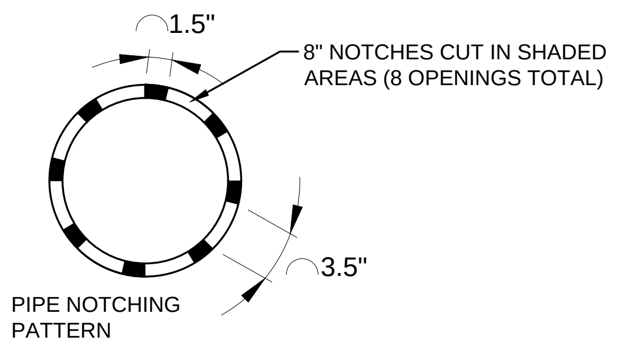
HOT SHOE WELD DETAIL
SCALE: NTS

NOTES
- THIS PORT IS USED TO PUMP WATER INTO THE SYSTEM AND RE-SUSPEND ACCUMULATED SEDIMENT SO THAT IT MAY BE PUMPED OUT.
- MINIMUM REQUIRED MAINTENANCE INCLUDES A QUARTERLY INSPECTION DURING THE FIRST YEAR OF OPERATION AND A YEARLY INSPECTION THEREAFTER. FLUSH AS NEEDED.
- ONLY R-TANK^{HD} AND R-TANK^{SD} MAY BE USED IN TRAFFIC APPLICATIONS.

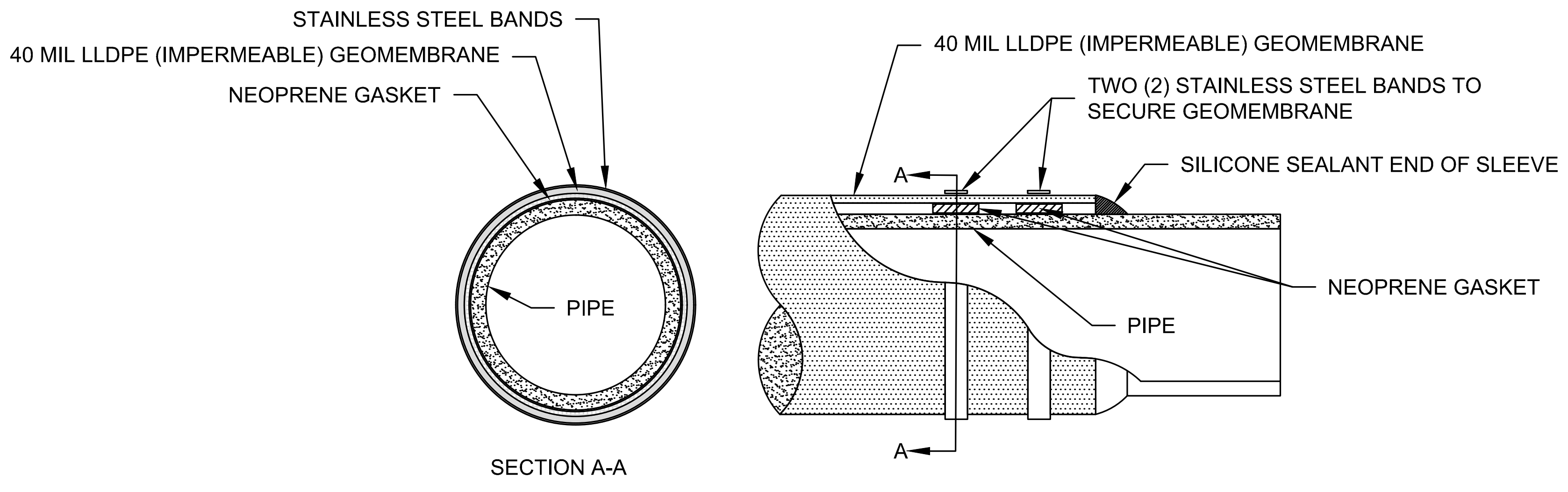


DEPTH SUMMARY

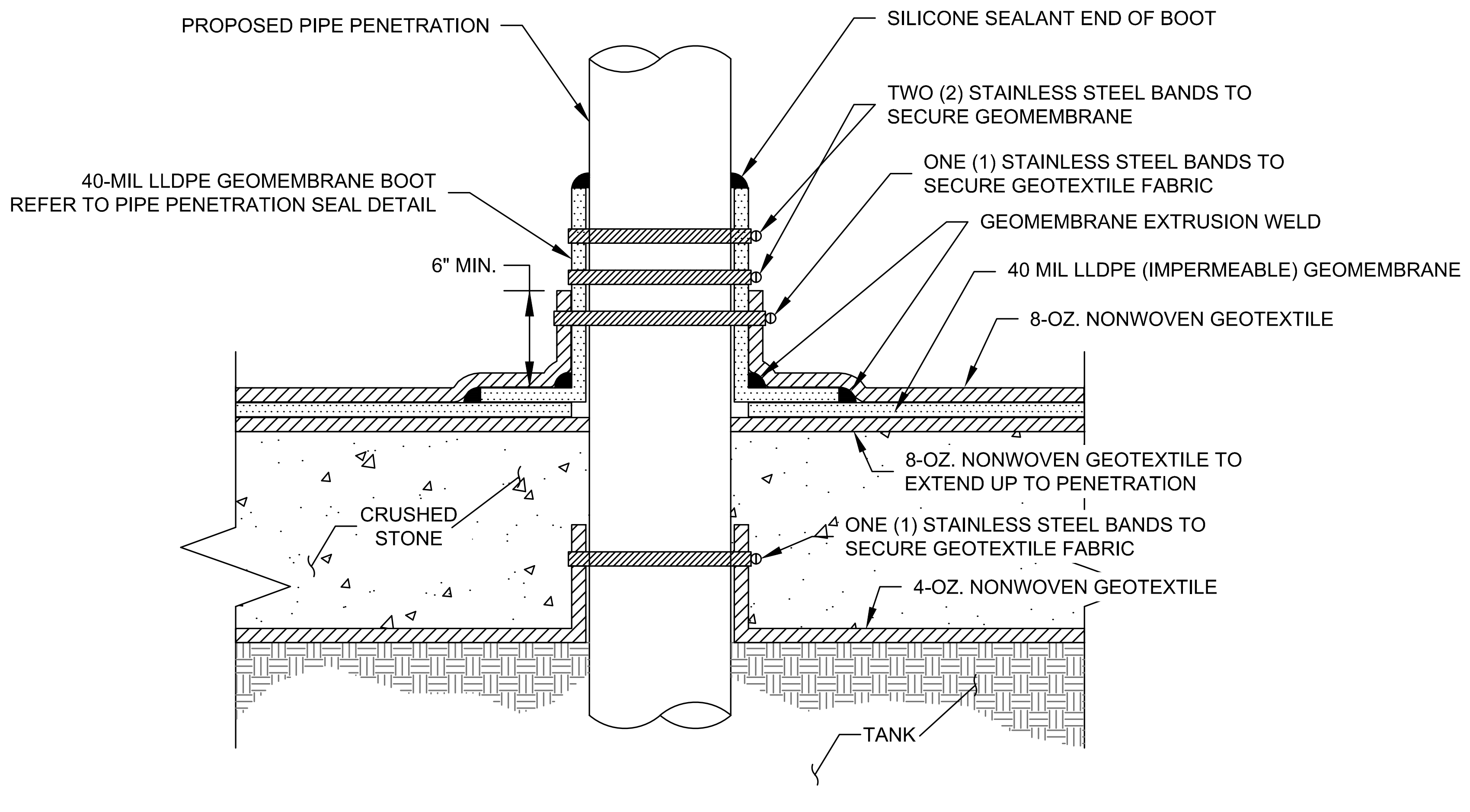
TYPE	A	B
R-TANK^{LD}	12" MIN - 36" MAX	AS SHOWN ON PLANS
R-TANK^{HD}	20" MIN - 6.99' MAX	12"
R-TANK^{SD}	18" MIN - 9.99' MAX	12"



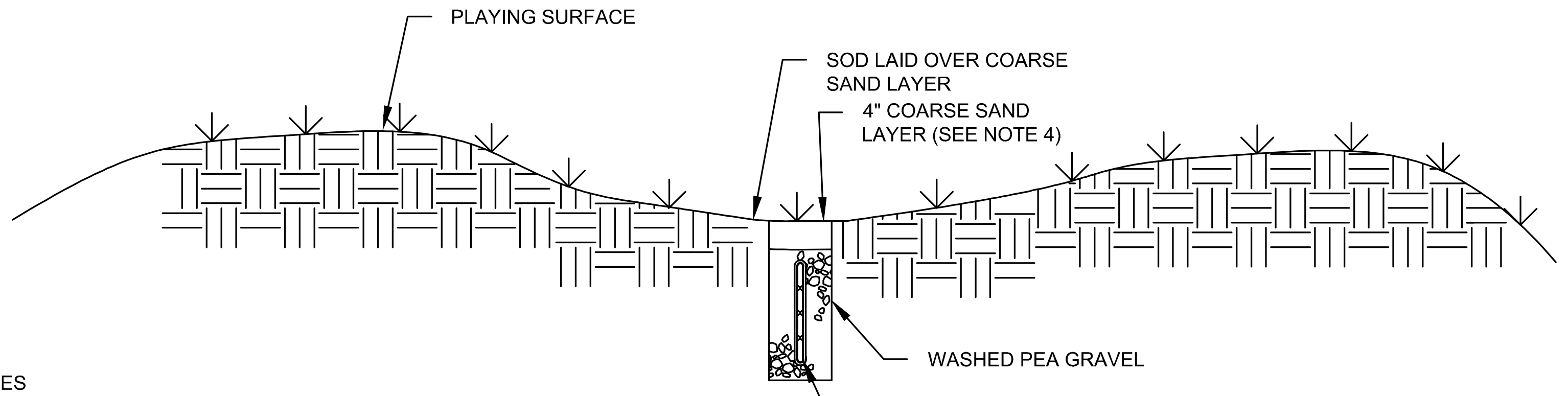
R-TANK TYPICAL MAINTENANCE PORT
SCALE: NTS



PIPE PENETRATION SEAL DETAIL
SCALE: NTS



TANK PIPE PENETRATION DETAIL
SCALE: NTS



NOTES
1. TRENCH MUST BE NO LESS THAN 4" WIDE
2. MINIMUM COVER SHALL BE NO LESS THAN 4"
3. MINIMUM SLOPE TO VARY AS REQUIRED TO PROVIDE POSITIVE DRAINAGE.
4. FINISH SURFACE AS SAND, OR SEED WITH SANDY SOIL TURF MIX.

FIELD UNDERDRAIN DETAIL (ADVANEDGE FROM ADS)
SCALE: NTS

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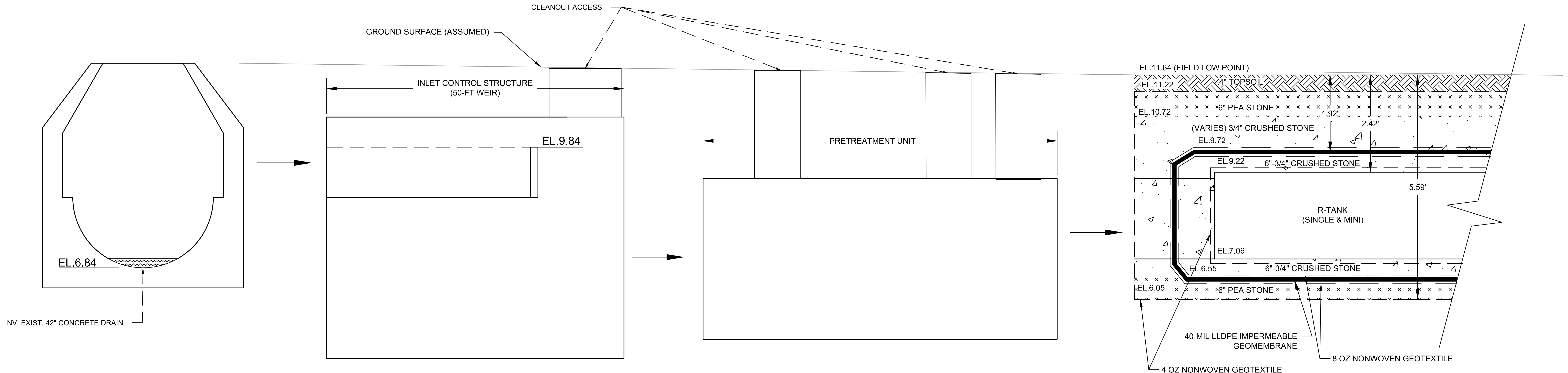
CONSTRUCTION DETAILS

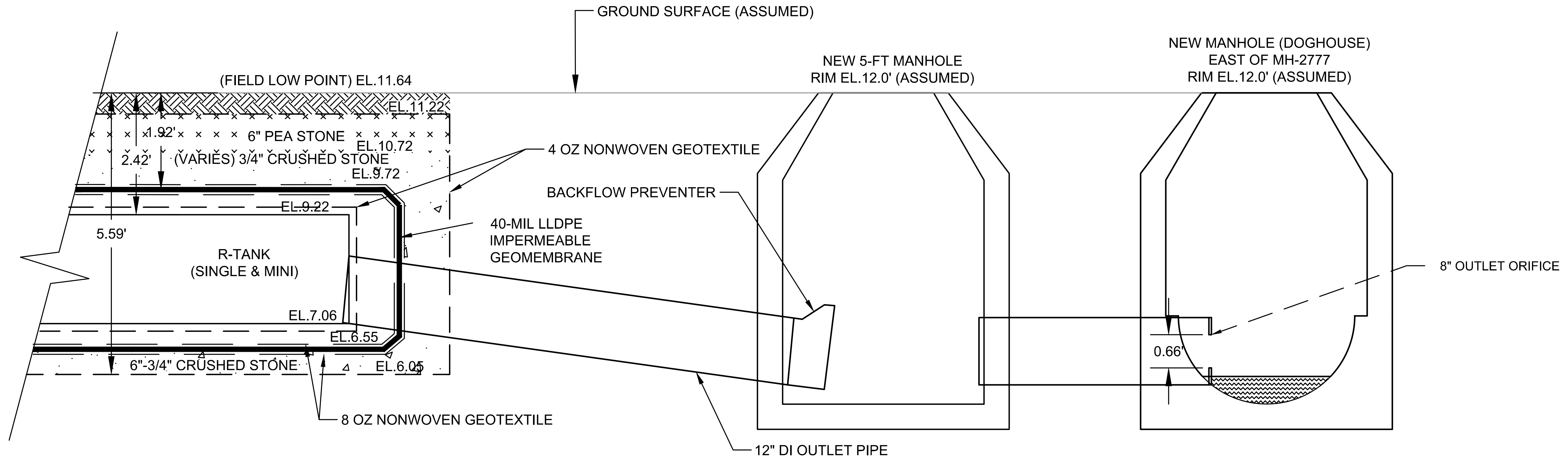
CITY OFMEDFORD, MASSACHUSETTS
SOUTH MEDFORD FLOOD MITIGATION STUDY

SHEET
GC-1

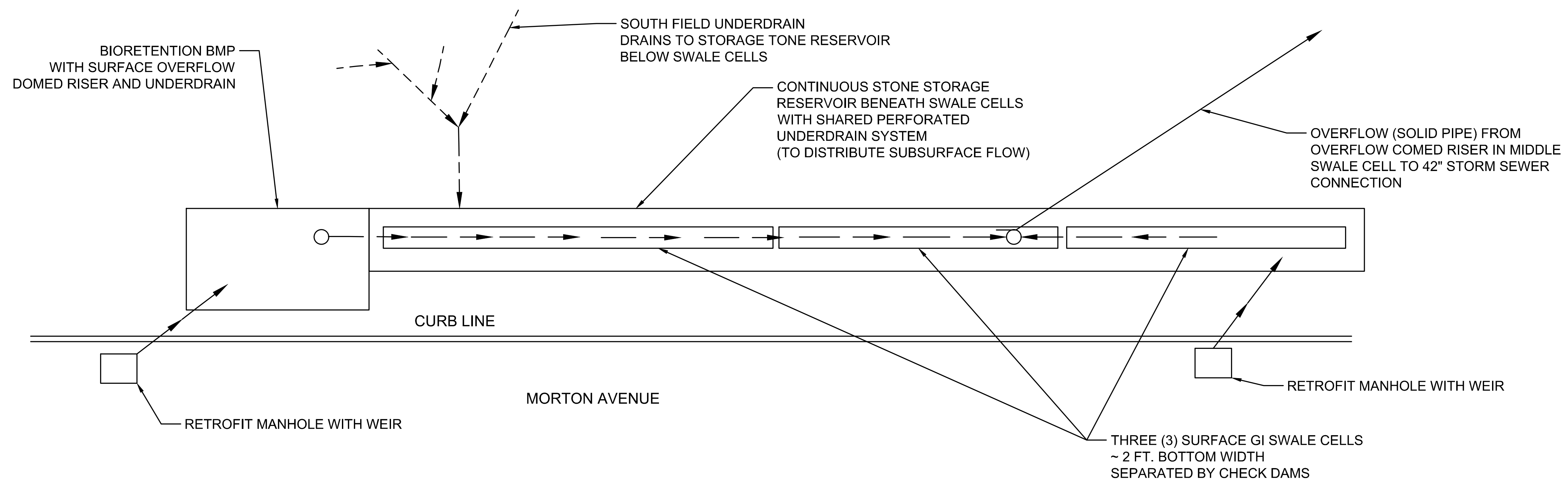


SCHEMATIC DETAIL OF INLET CONTROL STRUCTURE & PROPOSED TIE-IN MANHOLE
SCALE: NTS

NOTES:
1. DETAIL OF PRETREATMENT AND INLET CONTROL STRUCTURE TO BE DESIGNED IN A LATER PHASE.



SCHEMATIC DETAIL OF OUTLET CONTROL STRUCTURE & PROPOSED TIE-IN MANHOLE
SCALE: NTS



GI DRAINAGE SCHEMATIC
SCALE: NTS

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FLOW SCHEMATICS

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SOUTH MEDFORD FLOOD MITIGATION STUDY

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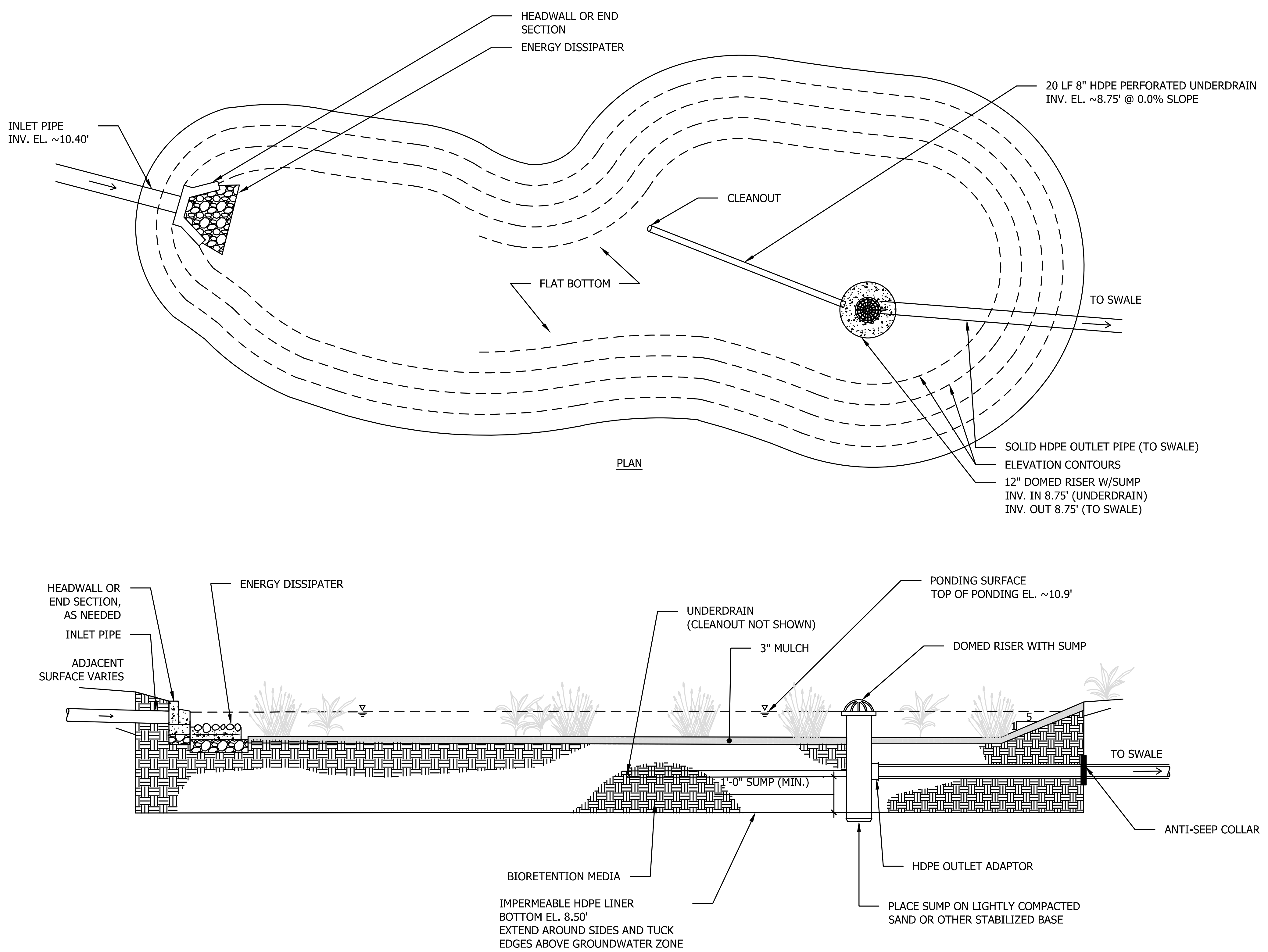
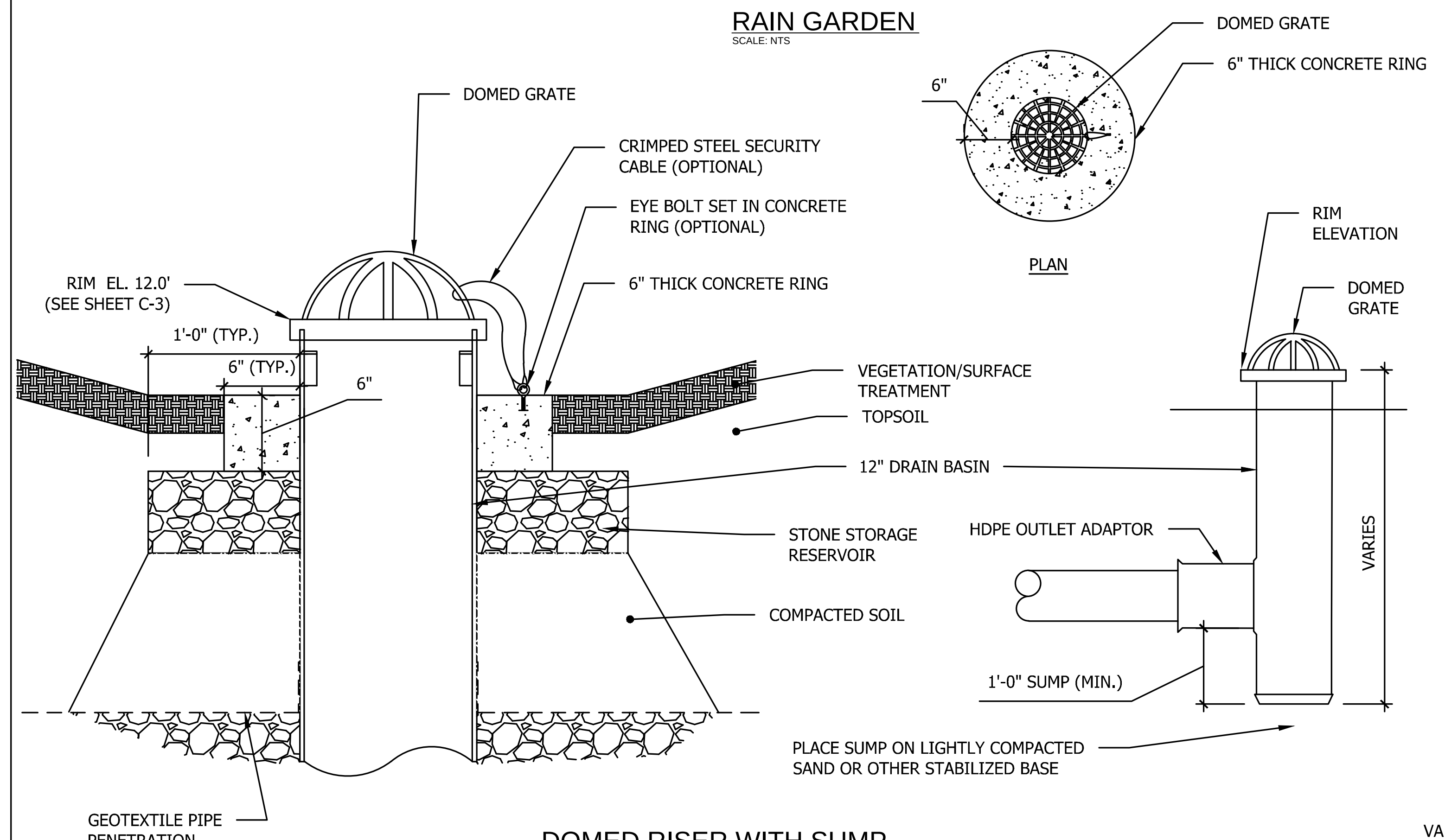
GC-2



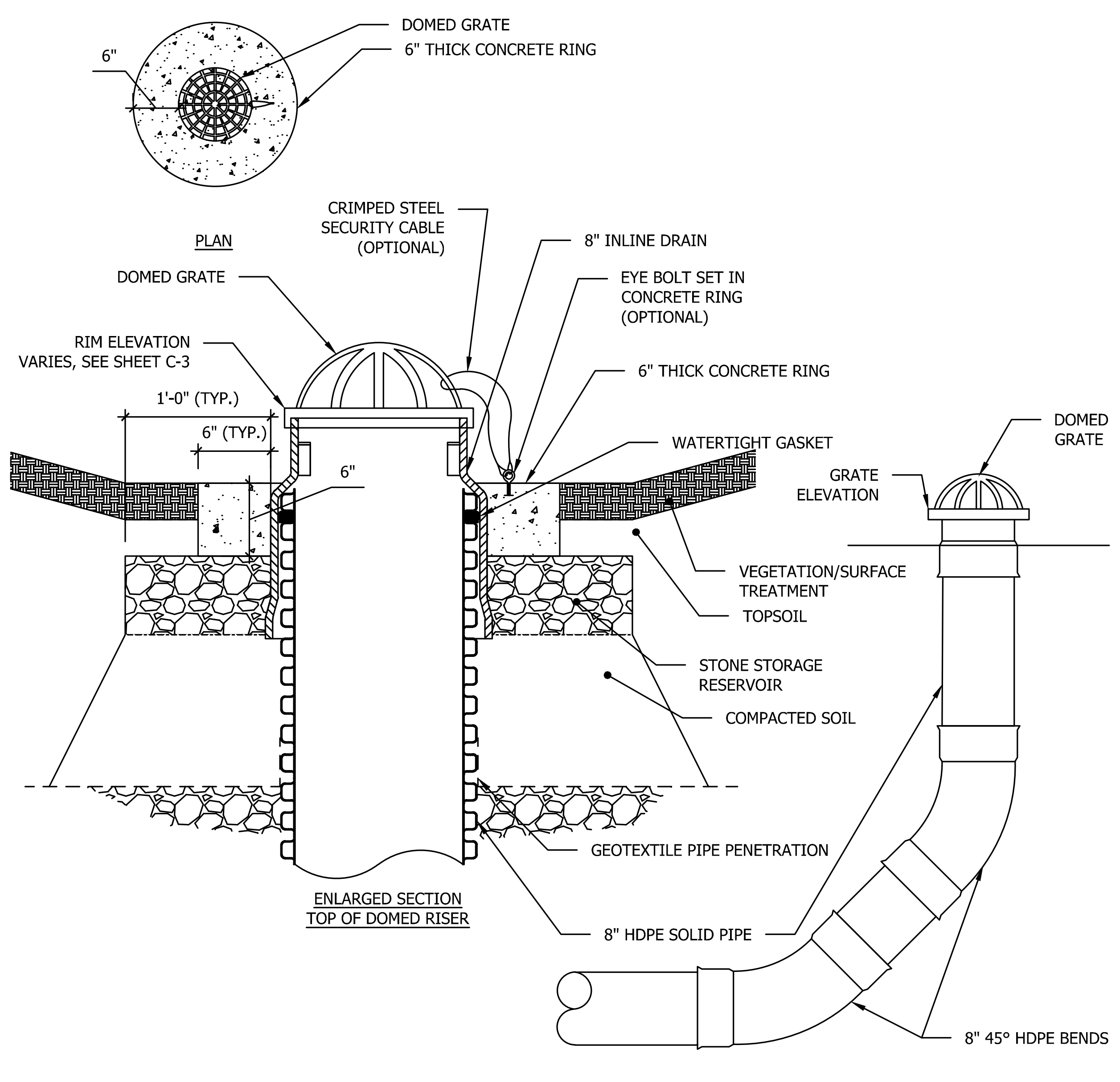
RAIN GARDEN

SCALE: NTS



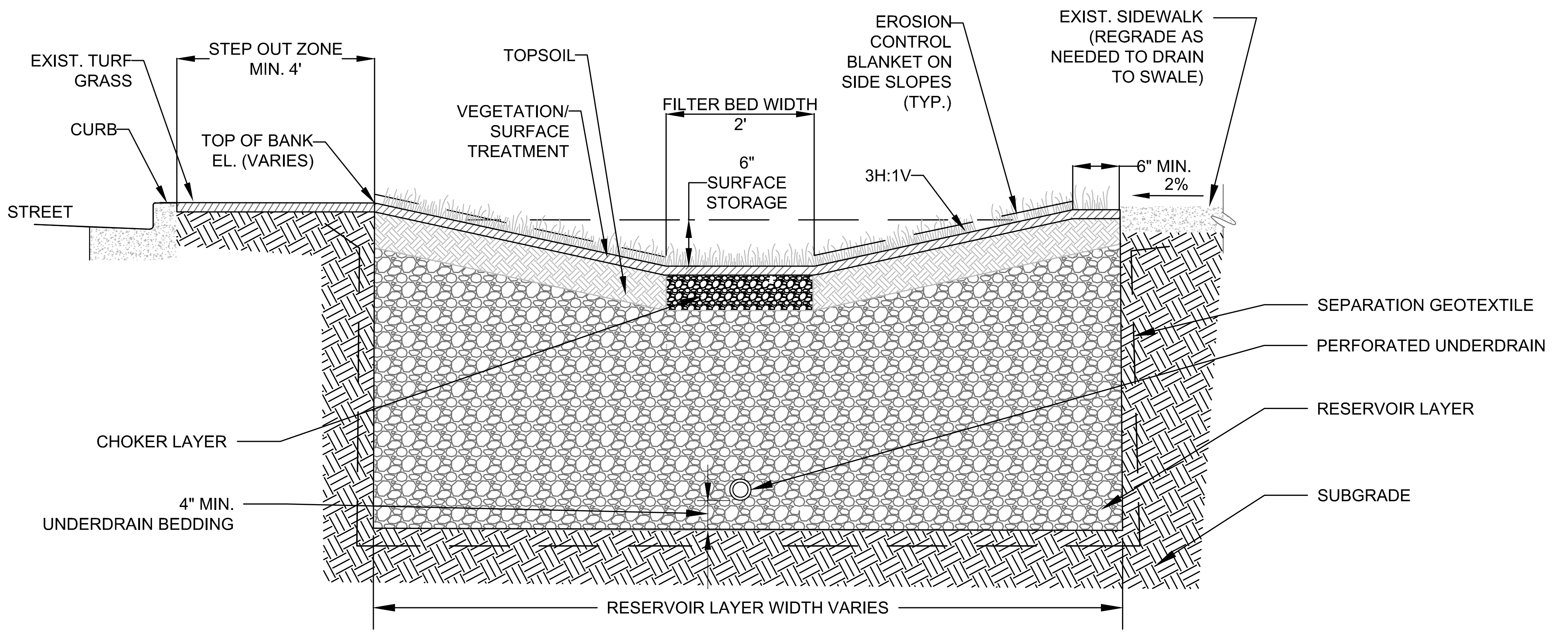
DOMED RISER WITH SUMP

SCALE: NTS



OVERFLOW DOMED RISER WITH CLEANOUT SWEEP

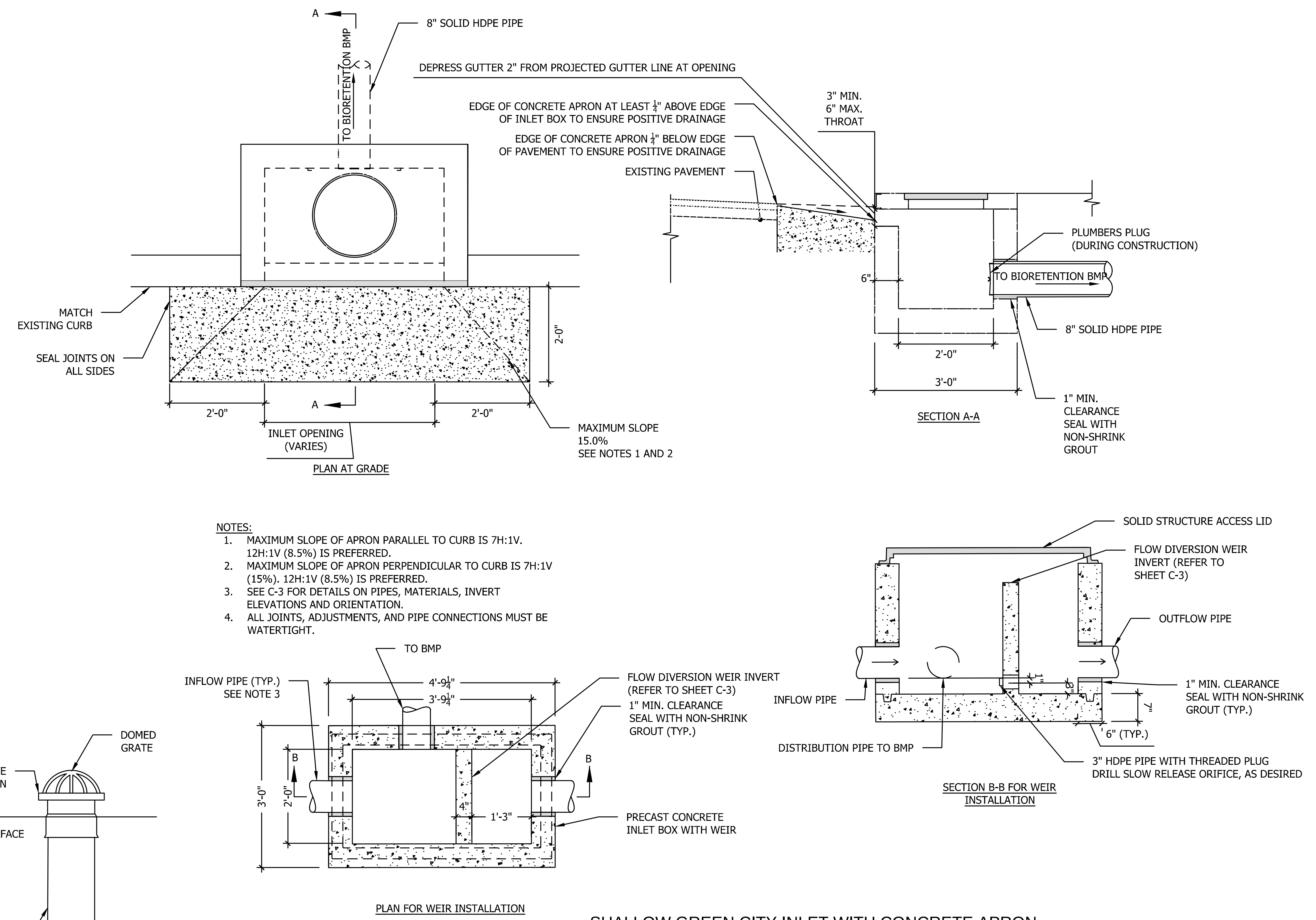
SCALE: NTS



NOTES:
1. STEP OUT ZONE REQUIRED WHEN PARALLEL PARKING IS PROVIDED. SEE DESIGN PLANS FOR SUFRACE TREATMENT.
2. SWALE DEPICTED WITHOUT AN OVERFLOW STRUCTURE AND SURFACE OUTLET (DOMED RISER). THIS SYSTEM REQUIRES AN OVERFLOW STRUCTURE TO CONVERY RUNOFF VIA UNDERDRAIN AND SURFACE OUTLET.

LINEAR SWALE AND STONE (DETENTION) TRENCH, ADJACENT TO ROADWAY WITH STEP OUT ZONE

SCALE: NTS



NOTES:
1. MAXIMUM SLOPE OF APRON PARALLEL TO CURB IS 7H:1V. 12H:1V (8.5%) IS PREFERRED.
2. MAXIMUM SLOPE OF APRON PERPENDICULAR TO CURB IS 7H:1V (15%). 12H:1V (8.5%) IS PREFERRED.
3. SEE C-3 FOR DETAILS ON PIPES, MATERIALS, INVERT ELEVATIONS AND ORIENTATION.
4. ALL JOINTS, ADJUSTMENTS, AND PIPE CONNECTIONS MUST BE WATERTIGHT.

SHALLOW GREEN CITY INLET WITH CONCRETE APRON

SCALE: NTS

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GREEN STORMWATER
INFRASTRUCTURE DETAILS

CITY OFMEDFORD, MASSACHUSETTS
SOUTH MEDFORD FLOOD MITIGATION STUDY

SHEET
GC-3

Appendix E: Conceptual Design Opinion of Probable Construction Cost

Stormwater Flood Protection Improvement
Tufts Field, Medford, MA
Conceptual Design Opinion of Probable Cost - Plastic R-Tank
June 30, 2020

BID ITEM	NOTE	DESCRIPTION	QNTY	UNITS	UNIT PRICE (NOTE 2)	COST	EXTENDED COST
1		**MOBILIZATION & DEMOBILIZATION**	**1**	**LS**	**$ 151,700.00**	**---**	**$ 151,700.00**
2		**STRAW WATTLE**	**2,720**	**FT**	**$ 7.97**	**---**	**$ 21,675.00**
3	**1**	**SILT FENCE**	**2,720**	**FT**	**$ 5.00**	**---**	**$ 13,600.00**
4		**SITE PREPARATION**	**1**	**LS**	**$ 27,220.00**	**---**	**$ 27,220.00**
	1	SILT SACKS	10	EA	$ 363.00	$ 3,630.00	
		CONSTRUCTION SIGNAGE	1	LS	$ 637.50	$ 640.00	
		TEMPORARY CONSTRUCTION GATE (6-FT X 20FT)	2	EA	$ 2,868.75	$ 5,740.00	
		TEMPORARY CONSTRUCTION FENCE PANEL W/ BASE (6 FT)	1,800	LF	$ 9.56	$ 17,210.00	
5		**INLET CONTROL & PRETREATMENT STRUCTURE**	**1**	**LS**	**$ 120,660.00**	**---**	**$ 120,660.00**
	1	EARTH EXCAVATION	744	CY	$ 35.00	$ 26,030.00	
	1	FINE GRADING AND COMPACTING - SUBGRADE AREA	144	SY	$ 6.00	$ 870.00	
	1	3/4-inch CRUSHED STONE	28	CY	$ 50.00	$ 1,400.00	
	1	8-oz NONWOVEN GEOTEXTILE FABRIC FOR SEPERATION	328	SY	$ 5.00	$ 1,640.00	
		SAW-CUT TOP OF EXISTING CONCRETE PIPE	111	LF	$ 51.00	$ 5,660.00	
		CONCRETE PIPE DISPOSAL	9	TON	$ 95.63	$ 880.00	
	1	GRAVEL BORROW BACKFILL	486	CY	$ 45.00	$ 21,850.00	
		CONCRETE PRETREATMENT STRUCTURE	1	LS	$ 57,846.75	$ 57,850.00	
	1	LOAM BORROW (4-INCH LAWN AREAS)	61	CY	$ 55.00	$ 3,370.00	
	1	SEEDING (LAWN MIX)	557	SY	$ 2.00	$ 1,110.00	
6		**STORMWATER DETENTION TANK CONSTRUCTION**	**1**	**LS**	**$ 1,556,390.00**	**---**	**$ 1,556,390.00**
	1	EARTH EXCAVATION	10,863	CY	$ 35.00	$ 380,200.00	
	1	FINE GRADING AND COMPACTING - SUBGRADE AREA	5,032	SY	$ 6.00	$ 30,190.00	
		PEA STONE	1,947	CY	$ 63.75	$ 124,110.00	
	1	3/4-inch CRUSHED STONE	3,055	CY	$ 50.00	$ 152,770.00	
		Plastic R-Tank Storage Units	93,989	CF	$ 1.30	$ 122,580.00	
		TANK WATERPROOFING - 40-MIL GEOMEMBRANE	10,790	SY	$ 8.12	$ 87,610.00	
	1	TANK - 8-oz NONWOVEN GEOTEXTILE FABRIC FOR SEPERATION	17,148	SY	$ 5.00	$ 85,740.00	
	1	TANK - 4-oz NONWOVEN GEOTEXTILE FABRIC FOR SEPERATION	17,844	SY	$ 5.00	$ 89,220.00	
		OUTLET CONTROL MANHOLE	1	EA	$ 5,737.50	$ 5,740.00	
		OUTLET CONTROL PIPE	44.5	LF	$ 184.98	$ 8,230.00	
		BACKFLOW PREVENTOR	1	LS	$ 3,825.00	$ 3,830.00	
		WELL POINT DEWATERING SYSTEM (8" HEADER)	1,350	LF	$ 305.36	$ 412,240.00	
	1	LOAM BORROW (4-INCH LAWN AREAS)	739	CY	$ 55.00	$ 40,630.00	
	1	SEEDING (LAWN MIX)	6,649	SY	$ 2.00	$ 13,300.00	
7		**NORTH FIELD DRAINAGE - SUBDRAIN IMPROVEMENTS**	**1**	**LS**	**$ 113,350.00**	**---**	**$ 113,350.00**
		HDPE Panel Pipe - Subdrain	2755	LF	$ -	---	
		12-inch AdvanEDGE Panel Pipe	2755	LF	$ 11.59	$ 31,930.00	
		Chain Trenching (22-inch deep)	2755	LF	$ 8.68	$ 23,920.00	
		Peastone - Trench Infill	61	CY	$ 63.75	$ 3,890.00	
		Advanedge 12" End Outlet	19	EA	$ 107.63	$ 2,040.00	
		Advanedge 12" End Cap	19	EA	$ 60.07	$ 1,140.00	
		Advanedge 12" Coupler	38	EA	$ 51.39	$ 1,950.00	
		Manhole	1	EA	$ 5,737.50	$ 5,740.00	
		Installation Labor (2 laborers)	6.39	DAYS	$ 1,377.00	$ 8,800.00	
		6" Clean Out Plug	2	EA	$ 95.68	$ 190.00	
		6" Corrugated Tee	2	EA	$ 24.80	$ 50.00	
		6" Clean Out Riser	4	LF	$ 9.08	$ 40.00	
		Installation Labor (2 laborers)	0.30	DAYS	$ 1,377.00	$ 410.00	
		12-inch HDPE Corrugated Pipe ST IB	500	LF	$ 29.11	$ 14,550.00	
		12" Dual Wall Fabricated Tee	19	EA	$ 407.00	$ 7,730.00	
		Installation Labor (2 laborers)	4.98	DAYS	$ 1,377.00	$ 6,860.00	
		Trench Excavation (30-inch deep)	500	LF	$ 2.01	$ 1,000.00	
	1	LOAM BORROW (4-INCH LAWN AREAS)	12	CY	$ 55.00	$ 660.00	
	1	SEEDING (LAWN MIX)	1,225	SY	$ 2.00	$ 2,450.00	
8		**GREEN INFRASTRUCTURE STORMWATER IMPROVEMENTS**	**1**	**LS**	**$ 340,000.00**	**---**	**$ 340,000.00**
		BIORETENTION BMP	800	SF	$ 200.00	$ 160,000.00	
		GREEN INFRASTRUCTURE DRAINAGE SWALE, UNDERDRAIN & STRUCTURES	1	LS	$ 180,000.00	$ 180,000.00	
9		**SOIL AND WASTE MANAGEMENT**	**1**	**LS**	**$ 159,375.00**	**---**	**$ 159,375.00**
10		**TRANSPORTATION AND DISPOSAL OF SOIL – CLEAN FILL**	**14,298**	**TON**	**$ 19.13**	**---**	**$ 273,460.00**
11		**TRANSPORTATION AND DISPOSAL OF SOIL – DAILY COVER LINED LANDFILL (**	**4,766**	**TON**	**$ 82.88**	**---**	**$ 394,990.00**
12		**ONE YEAR VEGETATIVE MAINTAINANCE**	**1**	**LS**	**$ 12,750.00**	**---**	**$ 12,750.00**
					Construction Sub-Total		$ 3,185,170.00
					Construction Contingency	30.0%	$ 955,551.00
					TOTAL CONSTRUCTION COST (SEE NOTE 3)		**$ 4,140,721.00**

Notes: 1. - Unit Price based on MassDOT Weighted Average Prices between April of 2019 and April 2020.
2 - Unit Costs Include General Contractor Costs, Profits, Bonds and Insurance
3 - Total Project Cost does not include final design, permitting, bidding, construction administration or engineering oversight.