Site Design for Utilities and Stormwater Management in Belmont, Massachusetts

A Major Qualifying Project Submitted to the Faculty of
Worcester Polytechnic Institute
In Partial Fulfillment of the requirements for the Bachelor of Science Degree

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Abstract

In collaboration with Stantec Consulting Inc. in their North Boston office, the project team completed a Major Qualifying Project (MQP) for the development and stormwater management of a site in Belmont, Massachusetts. The goal of this MQP was to design the utility and stormwater infrastructure for a proposed senior living community in an established zone on the McLean Hospital property. This team produced schematic level plans for the site to provide a basis for future pursuance of the project.

Executive Summary

Project Overview

Stantec Consulting Inc., an international professional services company, has an anticipated site redevelopment project in Belmont, Massachusetts. The project site is located in the McLean District, in a subdistrict rezoned for senior living. Currently, the site is mostly forested and contains two buildings, Elliot Memorial Chapel, which is to remain due to its historical significance, and the old superintendent's residence, which is to be demolished (Figure 0-1).

Figure 0-1. Existing Conditions

Figure 0-2. Proposed Site Layout

The proposed site plan (Figure 0-2) includes 299 total new senior housing units split among one large building, four medium-sized buildings, and eleven town-house style homes. Parking will be provided underneath the large and medium-sized buildings and in surface lots and garages.

Project Objectives

The goal of this project was to assist Stantec in site development for the property in Belmont by producing a preliminary site design for utilities and stormwater management. The main objectives for the completion of this project include reviewing the existing site conditions, designing a layout for providing utilities to the site, designing stormwater Best Management Practices (BMPs) for the site, and producing a set of schematic level design plans for the site.

Existing Conditions

An evaluation of existing conditions included zoning and GIS analyses. In the zoning analysis, town and state regulations were compared to the proposed site design to ensure that the project complied with zoning bylaws. ArcMap GIS was used to determine environmental and absolute constraints limiting site development, including wetlands, priority habitats, flood zones, and hazardous waste disposal sites. It was determined that no constraints limit site development.

Utility Design

Utilities that need to be provided to the site include water, sewer, gas, and electric. Utility design was based on the location of existing utilities in the area, site aesthetics for overhead utilities, pressure in water and gas lines, and minimum separation requirements. A drawing for the utility plan was developed in AutoCAD and included as part of the schematic design plan set.

Stormwater BMP Design

To analyze stormwater onsite, subcatchments were established for pre- and post-development conditions. Using the site's existing and proposed grading as well as potential BMP locations, two subcatchments were established for pre-development conditions (Figure 0-3) and six subcatchments were established for post-development conditions (Figure 0-4).

Stormwater infrastructure was designed to meet MassDEP Stormwater Standards. To ensure compliance, the pre-development peak discharge rates were calculated and used to design BMPs for the developed site. BMPs are installed to collect and store runoff and recharge the groundwater through infiltration.

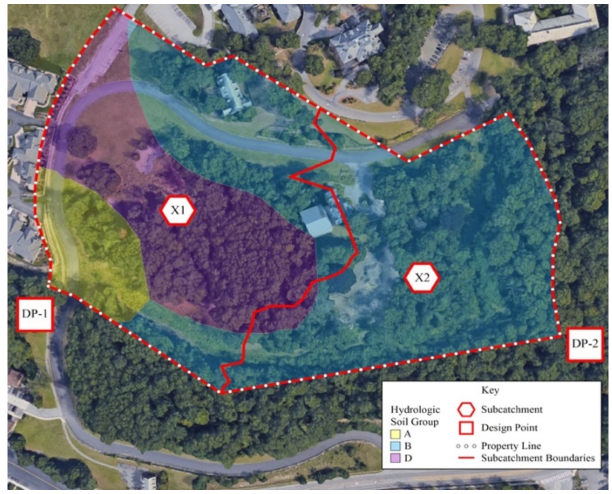

Figure 0-3. Existing Conditions Subcatchments

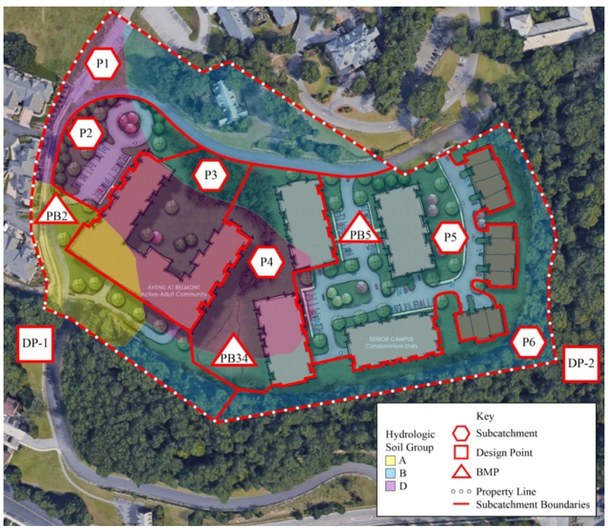

Figure 0-4. Proposed Site Subcatchments

Subcatchments P1 and P6 had little to no additional impervious surface with development, showing BMPs weren't needed. Subsurface chambers were selected to collect runoff from subarea P2. P2 is composed of soils with poor infiltration, so the chambers were proposed south of the parking lot in soils that would allow the BMP to provide both storage and recharge. The proposed grading for this subcatchment involved mostly cutting, so retaining walls were proposed along the roads to raise the ground elevation and provide more depth underground for chambers. Chambers were sized based on required storage and recharge volumes and the available space onsite. A detention pond was designed in subarea P4 to collect runoff from P3 and P4. A drainage pipe will carry water from a low point in P3 to the pond. The pond was designed in soils with poor infiltration, so it would only provide detention. A subsurface chamber system was designed to the south of the pond in soils with good infiltration to store the pond's overflow and provide recharge. A porous pavement system was designed for subcatchment P5 due to the amount of cutting in the proposed grading and the short depth to the groundwater table. The pavement would provide storage and recharge. It was recommended to implement a maintenance plan for the porous pavement to ensure it gets cleaned regularly in order for it to work as intended.

Once BMPs were designed, it was determined that the designs complied with MassDEP Stormwater Standard 3, which states that the loss in groundwater recharge from site development shall be eliminated. All of the stormwater management Best Management Practices were designed as measures of low impact development, which aims to maintain a site's natural and pre-developed ability to manage stormwater. These designs intend to meet all of the needs of future residents and be the least environmentally impactful to the site.

Acknowledgements

Our team would like to formally thank everyone who aided in the completion of this Major Qualifying Project. We would like to particularly thank Professor Suzanne LePage and Professor Leonard Albano for their support and assistance throughout the entirety of the project. We would also like to thank the Stantec employees from the Boston office for welcoming our team, providing us with information needed to complete the project, and enhancing our engineering knowledge through technical and professional learning experiences. A special thank you to Frank Holmes, Jordan Loffredo, and Theo Kindermans for their guidance and time throughout our project.

Capstone Design Statement

The Accreditation Board for Engineering and Technology (ABET) requires that all accredited engineering programs include a capstone design experience. At Worcester Polytechnic Institute (WPI), this requirement is met through the Major Qualifying Project. The capstone design must address many of the following realistic constraints of a project: economic, environmental, sustainability, constructability, ethical, health and safety, social, and political. This Major Qualifying Project (MQP) focuses on preliminary site design for utilities and stormwater management for a property in Belmont, Massachusetts. The following is a description of how the project addressed seven of the realistic constraints.

Economic: This project considered efficiency and effectiveness of utility and stormwater infrastructure designs in order to produce a set of preliminary plans that would be economically feasible, such as eliminating the need for utility pumps by working with the proposed grading and reducing the number of subsurface chambers needed by selecting larger model sizes.

Environmental: This project considered a variety of methods to reduce environmental impacts, such as best management practices for stormwater and low impact development techniques.

Sustainability: This project recommended developing maintenance plans for the proposed best management practices and performing field testing for further site evaluation to develop a sustainable site design.

Constructability: This project addressed constructability in a two-fold manner. First, a proactive approach was taken in which the site constraints impacted the initial design ideas. Then a reactive approach was taken by evaluating options for site design, and using an analysis of constructability and limitations of each option as a key factor in the decision-making process.

Ethical: The designs for this project complied with the American Society of Civil Engineers (ASCE) code of ethics, meeting the requirements of the ASCE fundamental principles. The following ASCE canons were most applicable to this project.

> Canon 1: Engineers shall hold paramount the safety, health and welfare of the public and shall strive to comply with the principles of sustainable development in the performance of their professional duties.
>
> Canon 4: Engineers shall act in professional matters for each employer or client as faithful agents or trustees, and shall avoid conflicts of interest.
>
> Canon 5: Engineers shall build their professional reputation on the merit of their services and shall not compete unfairly with others.
>
> Canon 6: Engineers shall act in such a manner as to uphold and enhance the honor, integrity, and dignity of the engineering profession and shall act with zero tolerance for bribery, fraud, and corruption.

Social: This project considered the social constraints of site development by pursuing solutions with limited impact on the surrounding McLean property and residents. The schematic level plans produced in this project will aid Stantec in progressing it forward to design development.

Health and Safety: Stormwater management Best Management Practices were designed for the project site to meet pollutant and TSS removal requirements in order to ensure the health and safety of the surrounding community. Maintaining pre-development runoff rates through the redevelopment also maintains safety during extreme storm events.

Professional Licensure

In the United States, engineers are licensed by the state in which they practice. Every state has a licensure board with its own requirements and exam to obtain a professional license. There are several requirements to become a Professional Engineer: a degree from an ABET-accredited college, passing two proficiency exams, and several years of professional experience. The National Council of Examiners for Engineering and Surveying (NCEES) administers the two exams and proposes model laws for obtaining licensure while states regulate their own licensing boards. Once an engineer obtains their professional license, they are authorized to practice engineering, provide their engineering services to the public, and take legal responsibility for their work. Possessing this license means that the engineer has accepted the technical and ethical obligations of the profession they practice. The majority of projects completed by civil engineers revolve around the public, and therefore state laws require that project designs be approved by professional engineers because their professional license shows their understanding of the fundamentals of engineering, experience in the profession, and knowledge of the ethical duties it entails.

This MQP involved aspects of professional practice through the close communication and work with Stantec professional engineers and project managers, as well as through the completion of the project goal and its objectives. Team members matured professionally and technically throughout the MQP experience with Stantec, both of which are directly connected to the path to obtain professional licensure.

Authorship

This project was completed collaboratively by all project group members. Each member was given specific tasks and respective sections of the paper to write so that individual skill sets and educational backgrounds were highlighted. All group members reviewed and edited one another's work and educated each other on all aspects of their personal work. Below is an overview of the primary responsibilities of each team member:

Marissa Bernard was responsible for performing stormwater calculations, selecting and designing BMPs, drawing subcatchments in AutoCAD, and writing the following sections of this report: Background section 2.2, Methodology sections 3.1 and 3.3, Results section 4.5, and the Conclusion.

Cierra Ford was responsible for performing stormwater calculations, performing the zoning and GIS analyses, selecting and designing BMPs, drawing the utility layout in AutoCAD, and writing the following sections of this report: Executive Summary, Background section 2.3, Methodology sections 3.1, 3.2, 3.3, and 3.4, Results sections 4.1, 4.2, 4.4, and 4.5.

Kayla Salmon was responsible for drawing the grading plan, existing conditions, and site details; compiling all drawings into a plan set, and writing the Abstract and Background section 2.1 and 2.4, Methodology section 3.1.3, and Results section 4.3.

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1.0 Introduction

The site design process considers a range of constraints and parameters in order to produce a graphical representation of a proposed site layout. Stantec Consulting Inc, an international professional services company, has an anticipated site redevelopment project in Belmont, Massachusetts. The associated site design components include the analyses of earthwork to develop a construction phasing plan, stormwater to implement low impact development techniques and control site runoff, and utilities to ensure the site's service needs are met. In this Major Qualifying Project, the focus was specifically on the stormwater management and utility design aspects of the site redevelopment project.

The goal of this project was to assist Stantec in site development for the location in Belmont by producing a preliminary site design for utilities and stormwater in the form of plan sets and calculations. To accomplish this goal, the existing site conditions in terms of stormwater management and utilities were reviewed. A preliminary design for providing these elements of the site's infrastructure was produced and analyzed based on several design constraints and Stantec's objectives for the project. Based on the analyses, the project team prepared a schematic level set of plans for the stormwater and utilities aspects of the site development.

2.0 Background

This chapter provides details on the proposed redevelopment of the site in Belmont and an overview of common methods to approach site development with regards to stormwater management and utilities design.

2.1 Overview of Project Site

The project site is located on Olmsted Drive in Belmont, Massachusetts on a property owned by McLean Hospital (Figure 1). Current structures onsite include a building that once served as a superintendent's residence and later as an office building (Figure 2) and the Samuel Eliot Memorial Chapel (Figure 3).

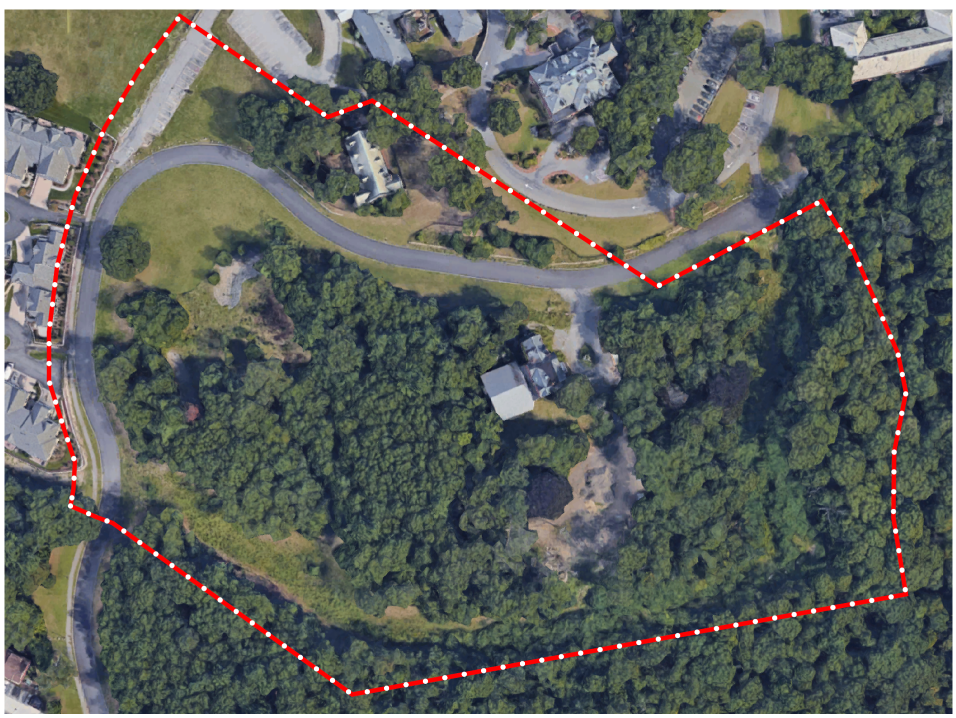

Figure 1. Existing conditions of project site

Figure 2. McLean Campus Superintendent Building [1]

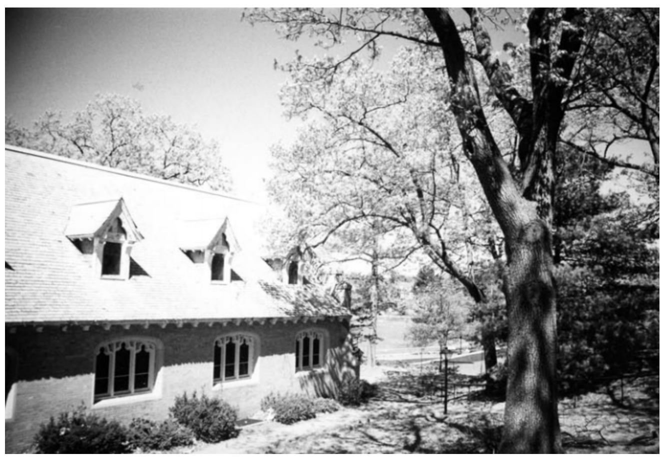

Figure 3. Eliot Memorial Chapel [1]

The Superintendent's Residence, constructed in 1895, occupies an isolated site at the end of Olmsted Drive. The seclusion of the building is enhanced by the terrain which begins with a steep decline to the south edge of the grounds where there is a large amount of vegetation and uneven grading. This building has deteriorated since its construction, and was zoned for demolition along with ten other buildings on the McLean property that had historical significance. No buildings of primary historic value were ordered to be demolished, but because of the condition of the Superintendent's Residence building, it was decided that the land the building was on would be better suited for redevelopment. The Eliot Memorial Chapel will stay undisturbed on the site due to its documented historical value to the property. This call for redevelopment was initiated due to “financial realities” [1] that had forced the owners to create three new development zones in accordance with the Town of Belmont. This plan included 120 acres of dedicated public and private open space and a 20-acre cemetery.

The Town of Belmont adopted a zoning amendment in 1999 to rezone approximately 238 acres of property owned by the McLean Hospital Corporation into six different subdistricts. The project site is located in the McLean District of Belmont, specifically in Zone 3 (Figure 4), the McLean Senior Living Subdistrict.

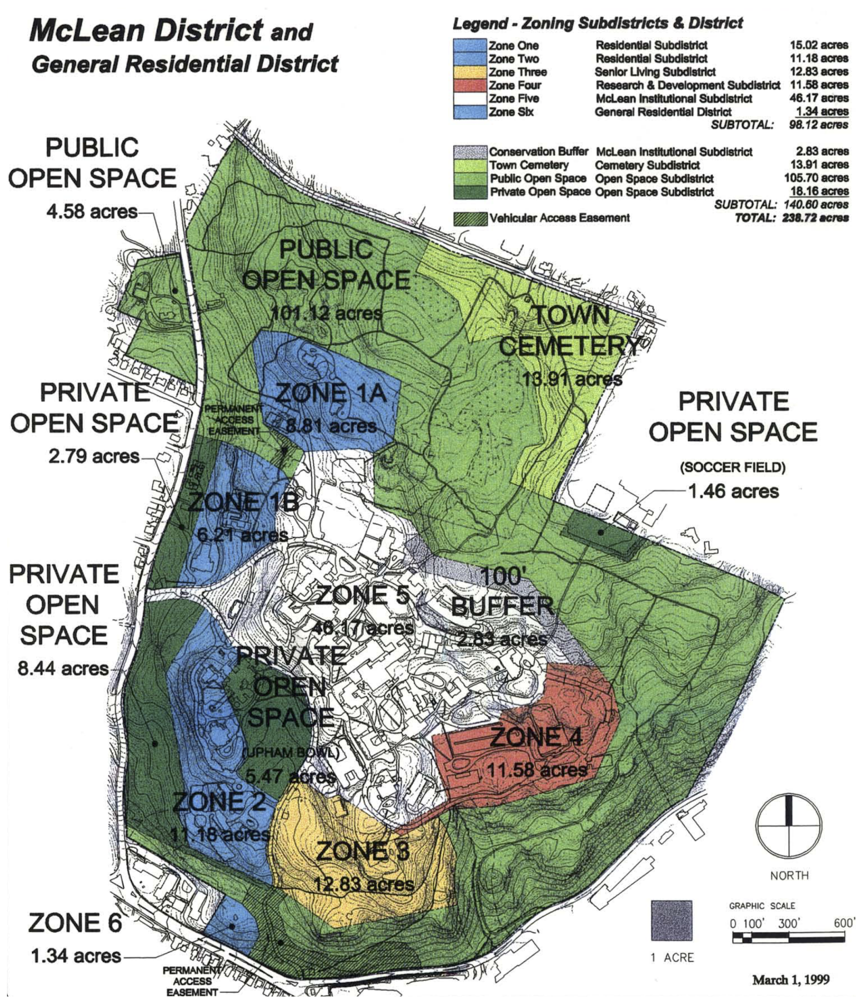

Figure 4. McLean District Zoning Map [2]

This subdistrict borders the McLean Open Space, Institutional, and Residential Subdistricts. The permitted use of this subdistrict is a continuing care retirement community, defined as a development made up of housing and other services designed for the purpose of providing housing, care, and assistance to elderly persons (*§* 6A.1.2 of the Belmont McLean District Bylaws). One of the limitations for development of this subdistrict presented in the McLean District Bylaws is that no more than 350 parking spaces within the Senior Living Subdistrict may be outdoor surface spaces, and the remainder must be located within a parking garage or other building (*§* 6A.3.2 of the Belmont McLean District Bylaws).

Stantec's client plans to develop 299 new housing units on the site. The construction will consist of one large building of 144 units, four medium buildings with 36 units each, and three small buildings of 11 units total. Parking will be provided underneath the large and medium sized buildings, in surface lots adjacent to the larger buildings, and in private garages for the smaller townhouse-style homes. The proposed site layout is provided in Figure 5.

Figure 5. Proposed Site Layout (designed by Stantec landscape architects)

2.2 Stormwater Management

In site development, stormwater analysis and management is necessary to mitigate environmental impacts to the site, abutting properties, and vulnerable watersheds. This section provides background on stormwater regulations in Belmont as well as an overview of how to perform a stormwater analysis and design infrastructure for stormwater management purposes.

2.2.1 Stormwater Regulations

Regulations and standards on the state and federal levels require stormwater management practices to be implemented when a site is developed or redeveloped. In 1996, The Stormwater Policy was issued by the Massachusetts Department of Environmental Protection (MassDEP) to establish Stormwater Management Standards [3]. These standards address increasing stormwater recharge, preventing pollution to surface or groundwater from stormwater discharge, treating stormwater runoff, using low impact development techniques, removing illicit stormwater discharges, and improving the operation and maintenance of stormwater best management practices (BMPs) [3]. On the Federal level, the US Environmental Protection Agency (EPA) has implemented the National Pollutant Discharge Elimination System [4] to regulate stormwater discharges. One potential source of discharge is municipal separate storm sewer systems (MS4s), and any work affecting them requires a permit to prevent stormwater runoff from polluting surface waters.

Belmont's response to federal legislation and upholding MS4 permits was the passing of the Town of Belmont Stormwater Management and Erosion Control Bylaw, finalized and approved in July 2013. The bylaw states that any increase in stormwater runoff volumes and its effects, such as erosion and flooding, must not change the existing conditions of abutting properties [5]. Stormwater management techniques must be implemented onsite to mitigate these impacts. The success of these efforts can be evaluated by completing the Town of Belmont Checklist for Stormwater Management and Erosion Control Report. This checklist references computations and information provided in the Documenting Compliance document (Volume 3 Chapter 1) of the MassDEP Stormwater Handbook, which is an essential reference for designing stormwater management systems [6].

2.2.2 Stormwater Analysis

A general understanding of hydrology, or how water moves on a site, before and after development is required to perform site design for stormwater infrastructure. Development of land inherently poses the risk of erosion and increases the discharge of storm runoff. A site's existing conditions must be analyzed to understand the current behavior of water resources on the site in order to maintain pre-development conditions with a proposed site design. Stormwater aspects essential in this analysis are the inflows to the site including precipitation, streamflow, groundwater, and runoff; the outflows such as evaporation and transpiration, streamflow, and groundwater recharge; and the capacity of the site to store water. Massachusetts Geographic Information Systems (MassGIS) data, US Geological Survey (USGS) maps, Federal Emergency Management Agency (FEMA) flood maps, Natural Resources Conservation Service soil maps, and the Town of Belmont are the main sources for information regarding existing conditions. Proposed topography maps for the developed site can be used to map the direction of stormwater runoff and determine optimal locations for BMPs.

2.2.3 Stormwater Design

Designs for stormwater management are developed once the existing conditions regarding stormwater are determined. The MassDEP Stormwater Handbook establishes the three components of stormwater management: site planning; implementing non-structural source and pollution prevention controls; and designing, building, and maintaining structural BMPs [3]. Guidance on approaches to stormwater infrastructure design is also provided in the MassDEP Stormwater Handbook, including variations of filters, basins, and channels for stormwater BMPs [3]. Because this project includes redevelopment, consideration of the standards for redevelopment projects established in the MassDEP Stormwater Handbook Checklist for Redevelopment Projects is also critical to the design of a stormwater management system at the project site.

The Natural Resources Conservation Service Technical Release 55 (NRCS TR-55) provides guidance on calculating storm runoff volume, peak rate of discharge, hydrographs, and storage volume requirements for floodwater reservoirs. The NRCS TR-55 presents a flowchart (Figure 6) outlining the process of determining the existing hydrologic conditions, and it is used to select which procedures to apply to a project [7].

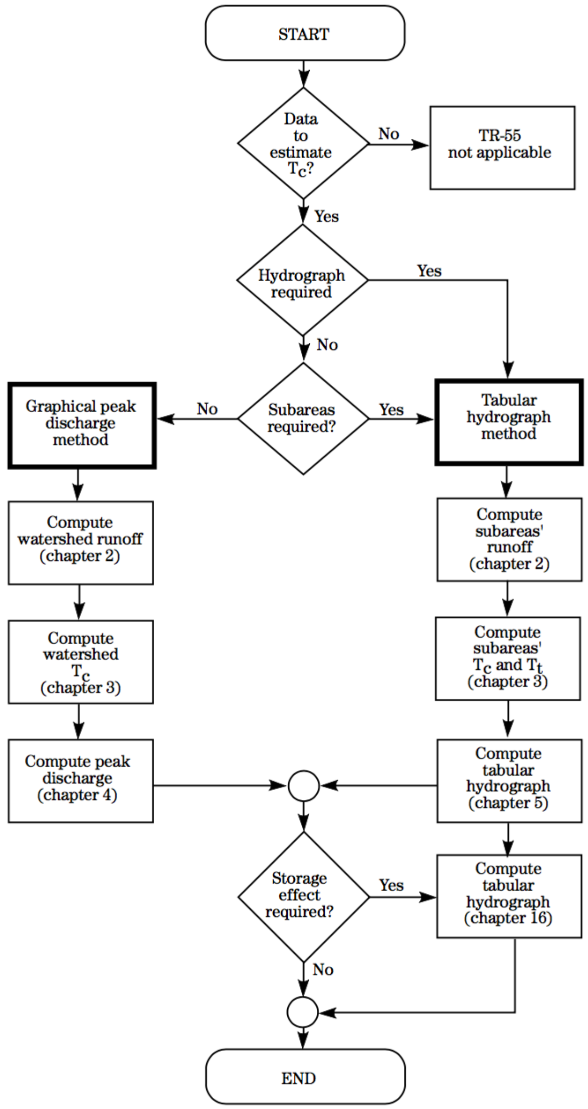

Figure 6. Flowchart for selecting appropriate procedures in TR-55 [7]

The NRCS TR-55 considers several key hydrologic principles in its calculations for designing a stormwater management system, which are outlined below:

- Precipitation and storm events: 1- and 2-year storm event data is often applied to sedimentation and erosion in receiving channels, 5- and 10-year storm event data is used for flow conveyance and minor flooding, and 100-year storm event data helps delineate limits of floodplains and major flooding considerations.

- Rainfall abstractions: Vegetation, evaporation, infiltration, and storage are key considerations for modeling hydrology during and after construction, because site development increases impervious surfaces, decreases abstraction, and increases runoff.
- Surface runoff: In undeveloped conditions, surface runoff ranges from 10-30% of precipitation; development can increase surface runoff to over 50% of precipitation.
- Groundwater recharge: Rainfall infiltrates into the soil and contributes to groundwater that is critical for the health of biological systems and habitats in streams [8].

The specific computations and considerations for stormwater management system design include peak discharge rate, time of concentration, runoff, recharge volume, and 72-hour drawdown analysis [3]. In addition, a mounding analysis is required when a proposed system is within four feet of the seasonal high groundwater table. These calculations provide information about input flows, storage capacity, and output flows on a site. They also help in sizing BMPs for the site that will decrease runoff and discharge rates by storing stormwater and improving a site's infiltration. Calculations are performed for both existing conditions and the proposed development so a stormwater management system can be designed that minimizes changes from pre-development conditions.

In order to minimize the environmental impact of site development, Low Impact Development (LID) techniques are utilized in designing stormwater management systems. The Massachusetts Stormwater Handbook outlines three Low Impact Development Site Design Credits that can be obtained by minimizing impervious surfaces and preserving natural hydrologic conditions. These credits allow site developers to meet Standards 3 and 4 for recharge and treatment by directing stormwater to approved pervious surfaces which reduces or eliminates the need for structural BMPs. In cases where achieving these credits is not feasible, other LID techniques may be utilized for environmentally sensitive site design as listed on the Town of Belmont Checklist for Stormwater Management and Erosion Control Report. Some LID techniques include minimizing disturbance to existing vegetation, not working within Wetland Resource Areas, and incorporating BMPs for infiltration and treatment.

2.3 Site Design for Utilities

Utilities refer to a publicly owned or investor-owned set of services provided to people, including electric power, landline telephone networks, cable, gas, sewer, and water. In the town of Belmont, Verizon and Comcast provide telephone and cable services, the Belmont Municipal Light Department provides electric services, National Grid provides natural gas, and the Department of Public Works Water Division maintains Belmont's water system [9]. This section provides an overview of considerations and requirements for designing utilities for a site.

2.3.1 General Utility Design

Utility design is an important step in site development to determine the most efficient and feasible way to provide services to a site. Aesthetics also play a large role in utility layout and design. If utilities are located above ground, they are placed in locations that have the least impact on a site's appearance. Utilities are commonly run underground, and therefore color coding and flags are used to mark their locations to protect them from damage during landscaping or excavation. The American Public Works Association publishes a list of Uniform Color Codes for each utility.

There are several clearance requirements for underground utility installation, including minimum separation from other utility lines, distance from other objects, and depth below grade. Separation requirements protect a utility from damage while an adjacent utility is being repaired. Depth requirements protect utility lines from weather and surface conditions. Such requirements can be obtained from a town's Department of Public Works.

2.3.2 Water Infrastructure Design

Water infrastructure is essential for supplying water to and treating wastewater on a site. Knowledge of existing water and sewer lines is required to design a framework that will connect to the town's sewer network. This information can be obtained from a town's planning office. Analyzing the proposed water demand is necessary to design infrastructure that meets the site's water needs. Water and sewer demand can be calculated from the number of units in a building and expected water use. Pipe size and invert elevations are important factors to consider because they help determine a pipe's carrying capacity and the pressure needed to maintain flow in the system.

Local resources and site topography are examined to determine potential supply routes that will deliver sufficient pressure for the water supply and reduce pumping costs. Pumping stations are employed to provide the right amount of pressure for a water system to function properly.

2.4 Relevant Software

Several computer-based programs are required to create a set of plans for site development projects. Some relevant software packages applicable to this project include

AutoCAD, AutoCAD Civil 3D, and ArcMap, a Geographic Information System (GIS) program. AutoCAD is a drafting application that aids computer-based design. It is frequently used for utility plans and site specific conditions for projects encompassing land development, water, and transportation. AutoCAD Civil 3D specifically allows for the creation of 3D models of land, water, and transportation characteristics while also maintaining dynamic relationships such as grading objects, break lines, contours, and corridors. It is frequently used for planning, designing, and maintaining civil engineering projects.

ArcGIS is a standard mapping tool that is used to analyze any geographic location. For the state of Massachusetts, the MassGIS website can be used to download data layers that represent different existing conditions, such as soil types, water bodies, impervious surfaces, and aquifers. The data layers are uploaded to the ArcGIS software, where they are displayed graphically on a map. ArcGIS is frequently used to model aspects of the real world, store and manage geographic data in files, and analyzing geographic data.

3.0 Methodology

The goal of this project was to assist Stantec in site development for the property in Belmont by producing a preliminary site design for utilities and stormwater management. The main objectives for the completion of this project were as follows.

- Review the existing site conditions
- Design a layout for providing utilities to the site
- Design stormwater Best Management Practices (BMPs) for the project site
- Produce a set of schematic level design plans for the site

3.1 Review the existing site conditions

The existing site conditions of the property were researched to gain an understanding of the current state of the project site with regard to stormwater management and utilities. The information needed to determine the locations of existing utilities surrounding the site was obtained from existing conditions plan view utility and topography drawings provided by Stantec. Knowing the locations of local utilities is necessary for designing water, sewer, electric, and gas lines that effectively connect to existing networks in the town.

3.1.1 Zoning Analysis

As part of reviewing the existing conditions for the project site, a zoning analysis was performed. The purpose of a zoning analysis was to determine if the proposed design is in compliance with the town's zoning bylaws.

A Zoning Checklist (Appendix B), provided by Stantec, was used to compile the information necessary to assess the proposed site design's compliance with zoning regulations for the town of Belmont and the McLean Senior Living Subdistrict. The checklist included information on abutting zoning districts, dimensional requirements, parking, curbing, lighting, landscaping requirements, and municipal contacts. The information required to complete the checklist was found by researching the Town of Belmont Zoning Bylaw and the Town of Belmont Planning Board Design Review Guidelines.

Once the checklist was completed, fact finding was used to perform a comparative analysis between the regulations and the project design to determine if the project met regulations. The checklist was also referenced for site design of utilities and stormwater.

3.1.2 GIS Analysis

ArcMap GIS was used to develop a map to show geographic information on flood zones, water resources, roadways, wetlands, watersheds, historic areas, priority habitats, and other features that may present building constraints for the project. The geographic information obtained from the MassGIS data layers was recorded in a Site Constraints Checklist (Appendix C) provided by Stantec. This checklist looks for environmental and absolute constraints for site development, such as flood zones, vernal pools, resource areas, coastal areas, rivers, wetlands, historic places, and hazardous waste sites. The constraints were analyzed to determine permitting requirements, design standards, and impacts of the proposed development on surroundings.

3.1.3 Soil Survey

Analyzing the soil types was pertinent to site design because the movement of water on and the properties of each soil are used to determine appropriate stormwater infrastructure for a site. The Natural Resources Conservation Service online website was used to conduct the soil survey and find the hydrologic soil groups in the project area.

3.2 Design a layout for providing utilities to the site

Based on research into common approaches to provide utilities and the available resources in Belmont, site design for gas, sewer, electric, and water was performed. Factors that were considered in the utility design included aesthetics for overhead utilities, building sizes and their respective needs, existing utilities in the area, minimum separation requirements for utility lines, and site grading. Water supply routes were chosen based on an analysis of the site's proposed grading so as to minimize the required pump stations while maintaining proper water pressure in the system for the end user. An AutoCAD drawing was developed to present the layout for providing utilities to each building on site.

3.3 Design Stormwater Best Management Practices (BMPs) for the project site

Stormwater design was based on guidance from the MassDEP Stormwater Handbook, Natural Resources Conservation Service Technical Review 55, and the Town of Belmont Stormwater Management and Erosion Control Bylaw. Several stormwater calculations were performed to ensure compliance with town and state standards and to determine the sizes, locations, and types of stormwater BMPs for the site. LID techniques were considered in the design of stormwater management infrastructure to reduce impact on the environment.

In order to ensure the project's compliance with town and state stormwater standards as well as properly design BMPs for the site, the following steps were taken:

- Divide the existing and proposed site layouts into subcatchments

- Estimate stormwater runoff for pre- and post-development conditions
- Calculate peak discharge rates
- Design appropriate BMPs

3.3.1 Divide the existing and proposed site layouts into subcatchments

The maps provided by Stantec were used to divide the pre-development and post-development site plans into subcatchments. Subcatchments are used to model the runoff on a site, and can be defined as an area of land where water collects and flows to a single discharge point. Discharge points, also known as design points, were identified based on contour lines and the assumed paths of water flow off of the site. The plan view topography drawings for the existing and proposed conditions, provided by Stantec, were used to establish subcatchments so that all of the water within one subcatchment would flow to the same discharge point. For the proposed site layout, it was assumed that the medium and small buildings had flat roofs with singular drainage systems and the large building had two roof drainage systems. Potential BMP locations for the proposed site plan, based on low points, proposed grading, and hydrologic soil groups were also considered in establishing subcatchments. Discharge points, however, were the same for pre- and post-development conditions in order to consider a “do nothing” approach where BMPs would not be installed in these potential locations and runoff from their respective subcatchments would instead drain to the discharge point. Once subcatchments were established, they were drawn in AutoCAD, which was used to calculate the areas and the percentages of impervious coverage for each.

3.3.2 Estimate stormwater runoff for pre- and post-development conditions

In order to evaluate the impact of development on a site, the runoff for pre- and post-development conditions must be calculated. The major parameters in determining runoff are the curve number for the type of land coverage and rainfall based on the storm frequency in question. The curve number for an area is based on hydrologic soil group, impervious cover, plant cover, treatment, and hydrologic condition. The NRCS hydrologic soil groups are classified by transmission of water, texture, and depth to the water table. The soil groups for the project site were obtained from the NRCS Web Soil Survey. TR-55 provides tables and figures to obtain the pervious and composite curve number for an area depending on impervious coverage and hydrologic conditions.

The impervious areas were used to compute the weighted curve number (CN) for each subcatchment. The total impervious coverage for each subcatchment in the pre-developed site was less than 30%, so in accordance with the TR-55 Figure 2-2 procedure, the pervious curve number was found and used to determine the composite curve number. TR-55 Table 2-2 was used to determine the pervious curve number based on cover type, “good” hydrologic condition, and the NRCS hydrologic soil groups that comprise the area. A curve number was determined for each hydrologic soil type, and then a weighted curve number was calculated for each subcatchment based on the areas of different hydrologic soil groups in each. For impervious coverage of less than 30%, the weighted pervious curve number and the percentage of impervious coverage were plotted in TR-55 Figure 2-3 to determine the composite curve number for each subcatchment.

For the proposed site conditions, there was an increase in impervious surfaces, and therefore the composite curve number was calculated differently for each subcatchment. When the impervious coverage in a subcatchment was greater than 30%, TR-55 Table 2-2 was used to determine the curve numbers for each soil type based on land coverage, with an assumed CN of 98 for all impervious surfaces. These values and their corresponding areas were then used to calculate the weighted curve number for the entire subcatchment.

Runoff was calculated from the composite curve number and precipitation for each subcatchment using TR-55 Equations 2-3 and 2-4, provided below. Stantec's stormwater reports include an analysis of the 2-, 10-, 25-, and 100-year storms. The town of Belmont requires an evaluation of discharges and volumes for the 2-, 10-, and 100-year storms, and Stantec typically includes an evaluation for the 25-year storm frequency. The precipitation in inches for each of these storm frequencies was found from Extreme Precipitation Tables provided by Cornell University [10], typically used by Stantec for stormwater calculations. TR-55 provides 24-hour rainfall for each storm frequency by region, however, due to recent weather changes possibly linked to climate change, Stantec uses the more current precipitation data from Cornell University. Runoff was calculated for each storm frequency and for both pre- and post-development conditions.

$$S = \frac{1000}{CN} - 10 \qquad \text{(TR-55 Equation 2-3)}$$

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} \qquad \text{(TR-55 Equation 2-4)}$$

Q = runoff (in)
P = rainfall (in), obtained from Extreme Precipitation Tables provided by Cornell University
S = potential maximum retention after runoff begins (in)

3.3.3 Calculate the peak discharge rate for pre- and post-development conditions

In order to calculate the peak discharge rate, the time of concentration needed to be determined for each storm frequency and subcatchment. Several potential flow paths for each pre-development subcatchment were drawn using the contours on the topography drawing. The longest flow path in each subcatchment was divided into segments for sheet flow and shallow concentrated flow. The first 50 feet of a flow path is considered sheet flow by Massachusetts standards. The slopes and lengths of these segments were then calculated.

The travel time (T_t) is the time it takes for water to travel from one location to another in a watershed, while time of concentration (T_c) is the sum of all travel times, or the time it takes for water to travel from the most distant point in the watershed to the point of interest. The following equations were used to calculate these times (in hours).

$$T_t = \frac{L}{3600V}$$ (TR-55 Equation 3-1, for shallow concentrated flow)

$$T_t = \frac{0.007(nL)^{0.8}}{(P_2)^{0.5}s^{0.4}}$$ (TR-55 Equation 3-3, for sheet flow <300 ft)

$$T_c = T_{t1} + T_{t2} + \ldots T_{tm}$$ (TR-55 Equation 3-2)

L = flow length (ft)
V= average velocity (ft/sec) (obtained from TR-55 Figure 3-1)
n = Manning's roughness coefficient (obtained from TR-55 Table 3-1)
m = number of flow segments

For post-development conditions, Stantec uses a standard time of concentration of 6 minutes to account for the initial storm fluctuation and depression storage, so T_c was only calculated using the above equations for the pre-development conditions. Travel time and time of concentration were used to distribute runoff into a hydrograph, a model that compares the discharge versus time elapsed during a storm event. The tabular method for hydrographs was used because it is not limited to a single watershed subarea and can be divided into a number of homogeneous subwatersheds. Tabular hydrographs, provided in TR-55 Exhibit 5 for each rainfall type, are used to determine unit discharges by time for different times of concentration, initial abstractions (I_a), precipitations (P), and travel times. A Type III rainfall distribution was used for the hydrograph based on the location of the project site which is within the Atlantic coastal region. The initial abstraction, based on the composite curve number for each subcatchment, was obtained from TR-55 Table 5-1.

The highest value of unit discharge was determined for the selected hydrograph times and used to calculate the peak discharge with the equation below.

$$q = q_t A_m Q \qquad \text{(TR-55 Equation 5-1)}$$

q = hydrograph coordinate (cfs) at hydrograph time t
q_t = tabular hydrograph unit discharge from Exhibit 5 in TR-55 (csm/in)
A_m = drainage area (square miles)
Q = runoff

It is critical to calculate the peak discharge rate for both the pre- and post-development site conditions to ensure compliance with MassDEP Standard 2, which states that the peak discharge rate for post-development conditions may not exceed that of pre-development conditions. The peak discharge rate for post-development conditions was a calculation for the "do nothing" approach for the site design, or the site without BMPs. The purpose of performing calculations for the "do nothing" approach is to determine if stormwater BMPs are needed on the site to satisfy Standard 2. When the standard was not met for the "do nothing" approach, BMPs were designed and proposed that would ensure compliance. Because subcatchments were not consistent from pre- to post-development conditions, the peak discharge rates for all subcatchments running off to the same discharge point were added together to get a total peak discharge for each discharge point.

3.3.4 Determine the types, sizes, and locations of BMPs for the site

The first step to designing BMPs for the project site was to determine their required size, or storage volume needed to ensure compliance with MassDEP standards to maintain pre-development discharge rates. The 100-year storm frequency was used for all sizing calculations to obtain conservative values as encouraged by Stantec.

The recharge requirement for the project site was calculated to ensure compliance with Standard 3 of the Massachusetts Stormwater Management Standards. This standard states that infiltration measures should be used to eliminate or minimize the loss of annual recharge to groundwater, so that at a minimum, annual recharge from the post-development site shall be similar to the annual recharge from pre-development conditions.

The recharge volume is the product of the depth of runoff by hydrologic soil type and the area of impervious coverage for each soil type within the project's limit of work. The target depth factor for each soil type on the project site was obtained from Table 2.3.2 "*Recharge Target Depth by Hydrologic Soil Group"* in the MassDEP Stormwater Handbook Ch. 3, Vol. 1.

$$Rv = F \times impervious\ area \qquad \text{(Vol. 3, Ch. 1 Equation 1)}$$

Rv = required recharge volume (cf, cy, or acre feet)
F = target depth factor associated with each Hydrologic Soil Group
Impervious area = pavement and rooftop area on site

The required water quality volume was calculated to ensure compliance with Standard 4 of the Massachusetts Stormwater Management Standards. This standard states that stormwater management systems shall be designed to remove 80% of the average annual post-construction load of Total Suspended Solids (TSS). The Massachusetts Stormwater Handbook provides TSS removal efficiencies for each type of BMP. Required water quality volume was calculated using the MassDEP Stormwater Handbook Volume 3 Chapter 1 Equation 3.

$$V_{WQ} = \frac{D_{WQ}}{12\ inches/foot} \times (A_{IMP}) \qquad \text{(Vol. 3, Ch. 1 Equation 3)}$$

V_{WQ} = required water quality volume (cf)
D_{WQ} = water quality depth*
A_{IMP} = impervious area (sf)
*One-inch for discharges within a Zone II or Interim Wellhead Protection Area, to or near another critical area, runoff from a LUHPPL, or exfiltration to soils with infiltration rate greater than 2.4 inches/hour or greater; ½ - inch for discharges near or to other areas.

The storage capacity required to maintain the pre-development peak discharge rates was also calculated for each subcatchment to size the BMPs. Storage volume was calculated using TR-55 Figure 6-1. The ratio of peak outflow to inflow discharge (q_o/q_i) for the subcatchment was plotted against the Type III rainfall type distribution to determine the ratio of storage volume to runoff volume. Runoff volume was found by multiplying the drainage area by the runoff (Q). The inflow rate (q_i) was the subcatchment's peak discharge rate, and the outflow rate (q_o) was the reduced discharge from the subcatchment that would maintain the total peak discharge rate to each discharge point from pre- to post-development conditions. The q_o/q_iratio and the runoff volume were used to calculate the storage volume for each subcatchment. The total required storage volume for each BMP was equal to the sum of the storage volume and water quality volume.

Once the required volumes were calculated, the appropriate type of BMP was selected for each subcatchment. The selection was based on hydrologic soil type, depth to groundwater table and bedrock, adequate space, and required volume.

CULTEC stormwater subsurface chambers for onsite detention and infiltration have been used by Stantec in previous projects, and therefore this type of BMP was proposed for the project site where there was enough open space and depth to the groundwater table. Porous pavement was proposed for the parking lots and driveways in the center of the project site because of the large area of pavement there as well as the amount of cut required for regrading resulting in insufficient depth to the groundwater table to install subsurface chambers. A detention pond was proposed for the open space in the southern portion of the project site because of the ability to access it for maintenance, the amount of space available, and the potential cost and time savings to install a pond over subsurface chambers.

Calculations for the dimensions of the proposed CULTEC subsurface chambers were performed using the CULTEC Stormwater Management Design Guide [11] for reference. The required number of chambers was calculated by dividing the total storage volume by the chamber and stone base storage per unit for the chamber model (Table 2 of the design guide). The required bed area was calculated by multiplying this number of chambers by the surface area required per unit for the chamber model (Table 3 of the design guide). The stone required for the system was determined by multiplying the number of chambers by the amount of stone required per chamber (Table 4 of the design guide). Next, the maximum area available on site to install the chambers was determined using the proposed site layout drawing in AutoCAD, and accounting for spacing adjustments between chambers, the total number of chambers in length and width for the assembly was determined. Catch basins are required to pipe the water from an impervious surface to the chamber system. Stantec typically uses a maximum flow rate per catch basin of 3 cfs because a rate much higher than this would cause ponding on the basin. The pipe size required to carry runoff to the chambers was calculated using Manning's equation:

$$Q = \frac{1.49}{n} A R^{2/3} \sqrt{S}$$

Q = flow rate (cfs)
n = Manning's roughness coefficient
A = flow area (sf)
R = hydraulic radius (ft)
S = channel slope (ft/ft)

For the porous pavement, the depth of storage was determined by using a crushed stone depth of 2 feet under the pavement and 30% of void space according to the MassDEP Stormwater BMP Design Manual. The depth to seasonal high groundwater, determined from the hydrologic soil type in the area, was used to determine if the proposed grading would be feasible for the required depth of the pavement.

Detention ponds require an embankment with a 1:3 slope [3], an eight foot long flat surface for the top of the embankment, and another 1:3 slope grading down to the existing ground. The proposed detention pond on this project site is located between two buildings, which presents an option to design a pond that runs the entire span between the buildings. Embankments would still be required for the pond edges that are not contained by a foundation wall. This design is only feasible if the pond's highest potential water level is against a concrete wall (not wood). To calculate the size of the detention pond, the area of the pond was calculated by drawing it into the proposed layout in AutoCAD, and then the required storage volume divided by this area would determine the required depth for the pond. This depth must comply with Belmont's stormwater bylaws. The reduced volume from the embankments was considered in this calculation. Depending on the hydrologic soil type at the location of the detention pond, it could only provide detention and an outlet control structure would be needed to account for the required recharge volume.

In the occurrence where the detention pond serves more than one subcatchment, drainage pipes are typically required to carry the water from an adjacent subcatchment to the pond. Pipes for this purpose were sized using Manning's equation.

A mounding analysis is required when the vertical distance between the bottom of an infiltration basin to the groundwater level is less than four feet and the recharge system is designed to reduce the peak discharge from a 10-year or higher 24-hour storm. The Hantush Method, available in free online calculators (Groundwater Software was used for this project [12]), was used to predict the maximum height of the groundwater mound beneath a recharge area. This method uses percolation rate, hydraulic conductivity, specific yield, initial saturated thickness, and the length and width of the recharge area to calculate the maximum hydraulic head. A value of 0.01 was used for specific yield to calculate the largest potential mounding for the groundwater table. Hydraulic conductivity was determined using the Rawls Rates, and percolation rate was calculated from the storage volume and area of the BMP. Initial saturated thickness was assumed to be five feet because Stantec typically uses this value for mounding analysis calculations. If the mounding analysis showed the BMP would not work in the area, either changes were recommended to the proposed grading or other BMP types were considered for their workability with the site. The BMPs were also evaluated to confirm that they would provide a TSS removal of at least 80% to comply with MassDEP Stormwater Standard 4.

Once the BMP types and sizes were selected for each subcatchment, the bottom area, storage volume, and the infiltration rate of the soils were used to determine if the BMPs would successfully recharge the groundwater. In the "Static" Method from the MA DEP Stormwater Management (Vol. 3, Ch. 1 of the MassDEP Stormwater Handbook), the infiltration rate is based on Rawls Rates (Table 2.3.3 in Vol. 3, Ch. 1 of Handbook), which use the hydrologic soil type at the project location to determine whether the soil is classified as having a rapid infiltration rate, or a rate greater than 2.4 inches/hour. The weighted Rawls infiltration rates were calculated for each soil type in each subcatchment and substituted into the equation below to confirm that the infiltration BMP will drain completely within 72 hours and recharge the groundwater. The infiltration rates used in these calculations were specific to the hydrologic soil groups present within the footprint of the proposed BMP.

$$Time_{drawdown} = \frac{Rv}{(K)(Bottom\ Area)}$$

Rv = Storage Volume
K = Saturated Hydraulic Conductivity (Rawls Rate for "Static" Method)
Bottom Area = Bottom Area of Recharge Structure

3.4 Produce a set of schematic level design plans for the site

Once the utility layout and the BMPs were designed, a set of schematic level design plans were developed in AutoCAD. The plans included drawings to document the existing site conditions, topographic survey, soils map, grading plan, site plan, utility plan, subcatchments, and site details. The plan set was the final deliverable to Stantec and will be used for future progress of the project.

4.0 Results and Analysis

In this chapter, the results obtained from completing the project's four objectives are discussed and analyzed. The existing conditions were reviewed and analyzed through GIS and zoning analyses, a site plan for the proposed utilities was developed, a complete stormwater analysis was performed, and the BMPs were designed for the necessary subcatchments.

4.1 Zoning Analysis

The McLean District Bylaws present the regulations for uses, dimensions, and stormwater for each subdistrict. The McLean Senior Living Subdistrict allows for the following facilities to be constructed: independent living, assisted living, nursing care, multipurpose senior, and daycare facilities (*§* 6A.1.2 of the Belmont McLean District Bylaws). The proposed site development of senior housing and facilities is compliant with these allowed uses.

Many zoning regulations for the subdistrict match those for the town of Belmont, such as parking lot and space dimensions, lighting, and landscape treatment, but there are also some bylaws specific to each McLean subdistrict. For instance, no more than 350 parking spaces in the subdistrict may be outdoor surface spaces, and the remainder must be located in a parking garage or other building. In order to meet this bylaw, the proposed site layout includes parking underneath the larger buildings to account for the number of residents, nurses, and visitors expected to bring a car to the subdistrict. Dimensional requirements specific to the Senior Living Subdistrict are shown in Table 1, all of which are met by the proposed site design.

Table 1. Dimensional Requirements for McLean Senior Living Subdistrict (§ 6A.2.2 of the Belmont McLean District Bylaws)

Dimension	**Subdistrict Requirement**
Maximum building height	5 stories (58 feet)
Maximum number units	480 units
Maximum total gross floor area	600,000 square feet
Minimum open space	30% of lot area
Maximum lot coverage	40% of lot area
Maximum impervious surface coverage	70% of lot area
Minimum setback to boundary lines	10 feet
Maximum fence our outdoor wall height	4 feet

The subdistrict also provides zoning bylaws regarding stormwater management facilities. The bylaws state that pre- and post-development runoff calculations for the 100-year 24-hour storm need to be submitted, and the discharges and volumes for the 2- and 10-year storms need to be evaluated. Roof drainage should be piped directly into the ground wherever possible via infiltration trenches and/or dry wells, and paved areas must be absorbent or direct runoff toward pervious areas. The bylaws require the use of an underground system similar or equivalent to the CULTEC Contractor Chamber Systems for least 50% of the subdistrict's required detention. The bylaws also recommend the use of open detention basins for retaining stormwater runoff, and require that the water storage depth shall be no more than three feet at peak in the event of the 100-year storm. Finally, the bylaws propose that all stormwater management facilities shall be the least visually obtrusive as possible. The site design for BMPs considered these bylaws in order to ensure compliance. (*§* 6A.5 of the Belmont McLean District Bylaws)

A summary of the information obtained from research of the Belmont and Senior Living McLean Subdistrict zoning bylaws and regulations was compiled in Stantec's standardized Zoning Checklist (Appendix B).

4.2 GIS Analysis

A GIS Analysis was performed to evaluate the existing conditions of the project site. The resulting map includes locations of watersheds, soils, local water bodies, priority habitat areas, aquifers, hazardous waste landfills, vernal pools, areas of critical environmental concern, and other layers that help identify constraints for site development (see Appendix C for a complete list of the MassGIS layers used). A map of the site displaying these constraints is shown in Figure 7.

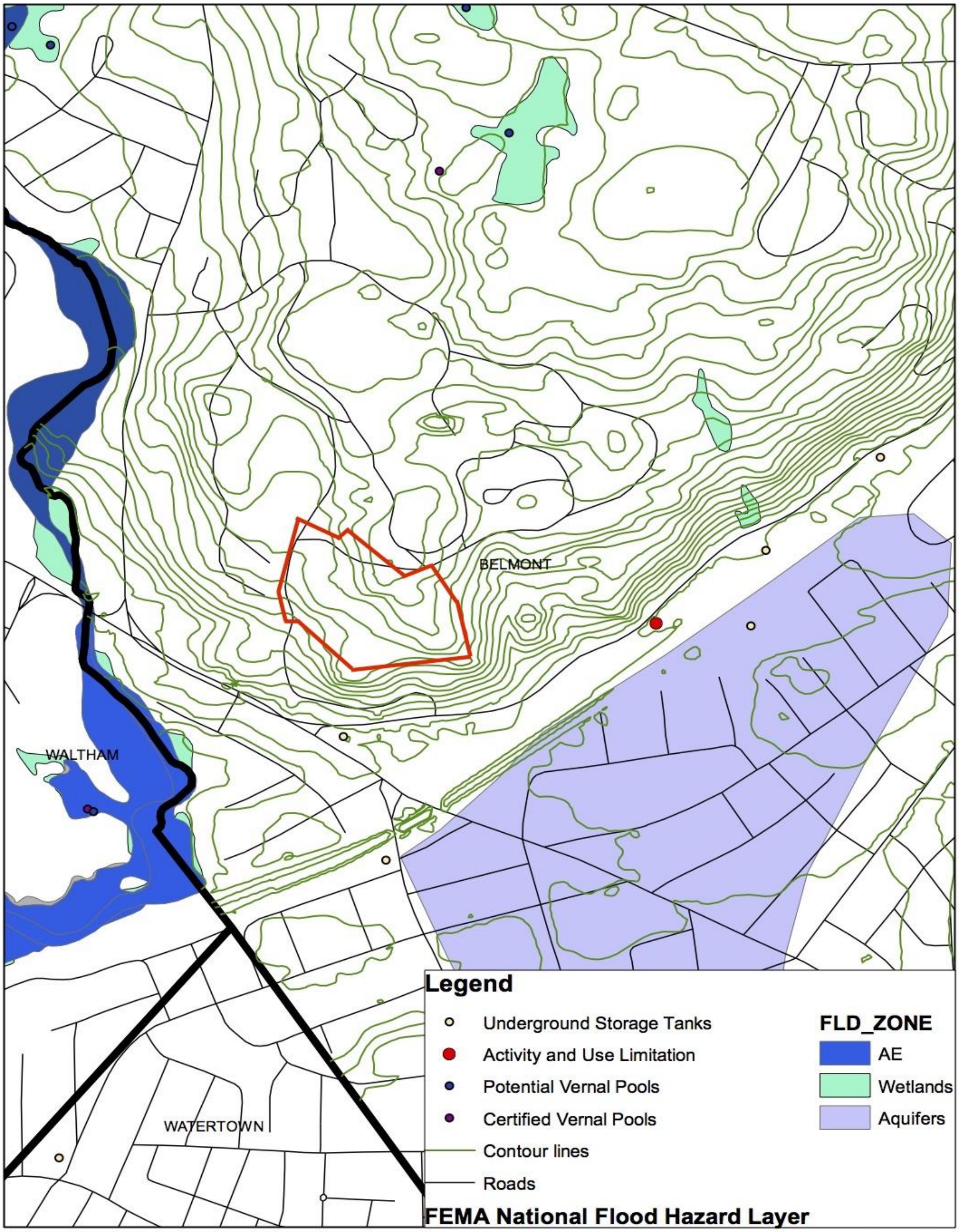

Figure 7. GIS Analysis

Once the layers were added, Stantec's Site Constraints Checklist was completed (Appendix C), and it was determined that there were no absolute constraints affecting this site development. Other information obtained from the GIS analysis that the client should be made aware of include the following: there is an aquifer to the south of the project site; there is no flood zone designation on the project site, but a short distance to the west there is an AE Flood Zone, or an area that has 1% chance of flooding every year; there are no wetlands on the project site, but several surrounding the site; and there is a hazardous material disposal site just to the south of the site where an Activity and Use Limitation, a document identifying the use of the property, has been filed at the County Registry of Deeds office for the respective town [13].

4.3 Soil Survey

The NRCS web soil survey showed that the site contained three main soil types: Narragansett-Hollis-Rock, Pittstown, and Charlton. Narragansett-Hollis-Rock is split into 45% Narragansett, 20% Hollis, 10% Rock, and 25% minor components. Narragansett is an A hydrologic soil type and Hollis is a D soil type. Without the time and resources to conduct geotechnical soil testing on site, it was assumed that the Narragansett-Hollis-Rock soil was a B type soil for calculation purposes. This assumption posed limitations on the calculations, thus soil testing will need to be performed to determine the exact soil types onsite for further development of the project. Pittstown is a D hydrologic soil type with silty clay loam properties and Charlton is an A type soil with fine sandy loam properties. Narragansett-Hollis-Rock comprises roughly 62.5% of the site, followed by Pittstown with 28.5%, and Charlton with 9%. The A and B type soils, making up most of the site, have low runoff potential and high infiltration rates, which is helpful for natural stormwater and runoff drainage, while the D type soils are more difficult to grade and have the highest runoff and swelling potential with very low infiltration rates. Depths to the seasonal high groundwater table and limiting features are provided in Table 2 for each hydrologic soil type.

Table 2. Depths to restricting features by soil type

Soil Type	Depth to Water Table	Depth to restricting feature
A	>80 inches	>80 inches
B	>80 inches	Narragansett, 45% of soil composition: 18-35 inches to strongly contrasting textural stratification
D	18-36 inches	15-30 inches to densic material

4.4 Utility Site Design

Utilities that need to be provided to and from the site include water, sewer, gas, and electric. The proposed layout for water, gas, and electric utilities was based on existing utilities in the area, which were located along the main road on the plan view drawing. At the other end of the service lines, the utilities were designed to connect to the central part of each building.

Overhead electric lines were designed to span the southernmost edge of the property to avoid creating a visual obstruction. Underground electric lines connected the overhead lines to each building. Based on Stantec's standard approach to electric utilities, the design included one transformer for the largest building, one transformer for the two medium-sized buildings, and one transformer to all four small buildings. Transformers were placed close to the edge of roadways to provide appropriate access for maintenance purposes.

The water service included a loop design, or a line that connects to a valve on the roadway, runs through the site, and then reconnects to a different valve along the roadway. This design will ensure that there is less friction loss and thus more sufficient water pressure throughout the entire service line. For preliminary design work, it was assumed that pumps would not be necessary. In order to determine the need for pumps, hydrant flow tests would need to be performed to measure static pressure in the system. Since none of the proposed buildings are high-rise buildings, a pump is likely not required. Gas was also provided in a loop service for similar reasons, and gas lines were designed to run concurrent with the water lines.

Sewer was designed based on the existing sewer line along the southern border of the project site. Sewer lines were designed to connect this line to each proposed building. "Y" fittings were used for connecting the sewer lines for the smaller buildings to the main line and manholes were placed at 90-degree bends to provide sufficient and uninterrupted flow. The biggest building required a grease trap in the outgoing sewer line due to an assumed cafeteria inside. The proposed utility layout can be found in the plan set in Appendix D.

4.5 Stormwater Infrastructure Analysis and Design

Stormwater infrastructure design for a project site requires the calculation of runoff and peak discharge rates to ensure the proposed BMPs meet standards and are sized appropriately. This section provides a summary of the subcatchment delineation, results from runoff and peak discharge rate calculations, and results from BMP design and sizing calculations.

4.5.1 Subcatchment Delineation

The existing site was divided into two subcatchments, each with its own discharge point offsite (Figure 8).

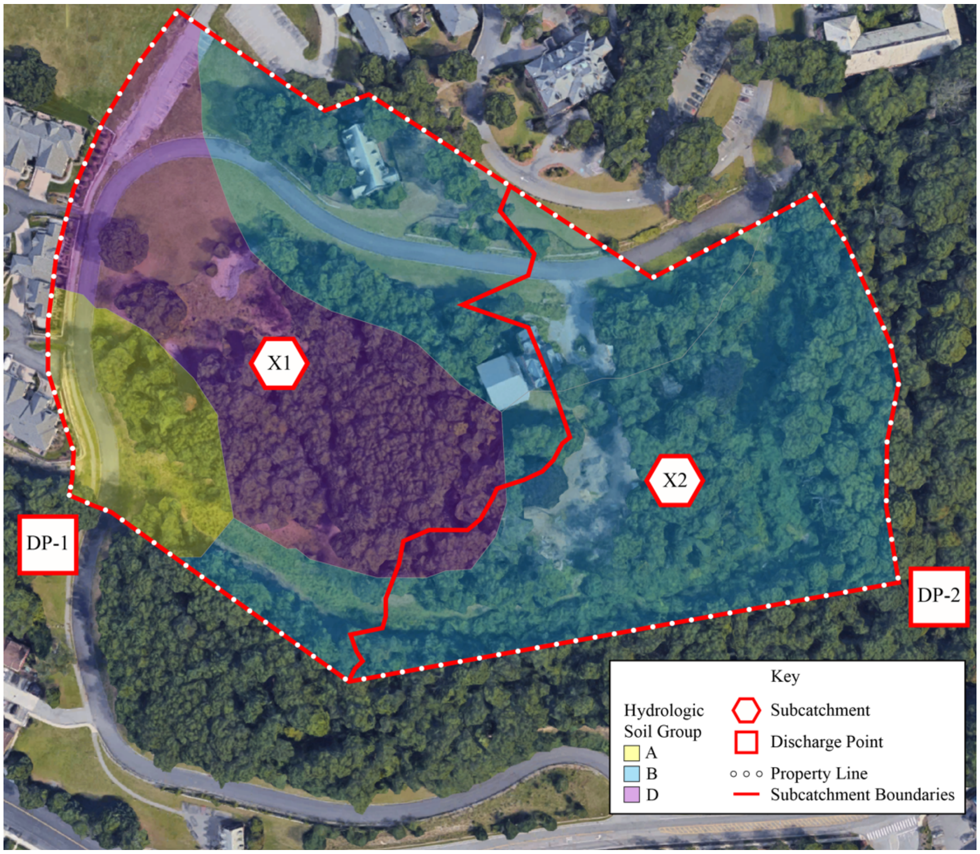

Figure 8. Subcatchments for project site's existing conditions

Subcatchment X1: Offsite to Southwest: Subcatchment area X1 contains the chapel, the majority of the superintendent's residence, Olmsted Drive, and the forested land on the western side of the property. Based on the topography of the subcatchment, stormwater runoff flows on top of Olmsted Drive or over land to the offsite discharge point DP-1 in the southwest corner of the lot.

Subcatchment X2: Offsite to Southeast: Subcatchment area X2 includes the remaining portion of the superintendent's residence, Olmsted Drive, and forested areas of the property as well as the driveway and parking area adjacent to the building. Based on the topography of the subcatchment, stormwater runoff flows on top of the impervious surfaces or over land to the offsite discharge point DP-2 in the southeast corner of the property.

The total areas of the two pre-development subcatchments and the amount of impervious coverage in each are provided in Table 3.

Table 3. Pre-Development Conditions Drainage Area Summary

Drainage Area	Impervious Area (sf)	Total Area (sf)	Percent Impervious
X1	38,205.95	332,808.40	11.48%
X2	12,182.16	229,265.04	5.31%

The proposed site was divided into six subcatchments, two of which have discharge points off of the site and four of which contain their own stormwater BMPs to capture the runoff. Subcatchments for proposed conditions are shown in Figure 9, followed by summaries of each.

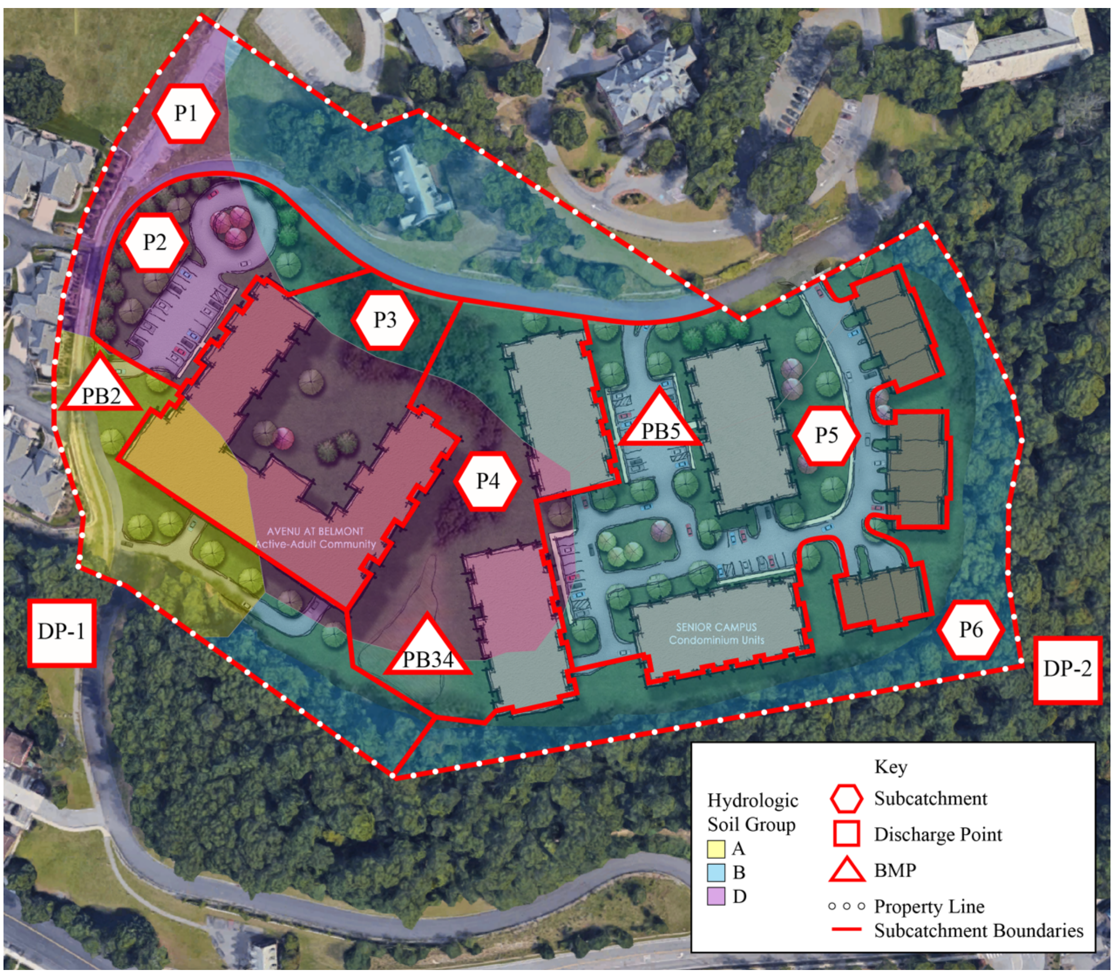

Figure 9. Subcatchments for project site's proposed conditions

Subcatchment P1: Subcatchment P1 contains the chapel, Olmsted Drive, the driveway into the westernmost parking lot, and the garage entrances to the large building. The subcatchment also includes the landscaped and partially forested areas surrounding the chapel and other impervious areas along the southwestern border of the property. Stormwater runoff area from this area flows on top of Olmsted Drive, similar to existing conditions. The proposed impervious surfaces in P1 covered less than 1% of the subcatchment's area, and therefore had negligible impact on stormwater runoff for the subcatchment.

Subcatchment P2: Subcatchment P2 contains the westernmost parking lot and landscaped areas surrounding it along Olmsted drive to the north and west and the large building to the east. Stormwater runoff from the increased impervious area will be collected in catch basins and directed to a subsurface chamber system south of the parking lot in hydrologic soil group A soils.

Subcatchment P3: Subcatchment P3 includes the large building, and the landscaped and partially forested area from the northern edges of the building to Olmsted Drive. Stormwater runoff will be collected from the area north of the largest building and transferred via drainage pipes to a detention basin in adjacent subcatchment P4.

Subcatchment P4: Subcatchment P4 contains the two westernmost medium-sized buildings, the landscaped area, and the partially forested area. It is bounded by the existing sewer line to the south, the edge of the largest building to the west, and Olmsted Drive to the north. Stormwater runoff will be collected in one roof drain on the medium building and in two roof drains on the large building and directed to a detention basin in the southern portion of the subcatchment.

Water from the detention basin will be directed to a chamber system followed by a manhole and outlet at the south of the end of the detention pond and north of the sewer line to account for groundwater recharge.

Subcatchment P5: Subcatchment P5 contains the two remaining medium-sized buildings, all three of the small buildings, all of the driveways and parking areas for these buildings, and the landscaped areas in between. Each building will have roof drains to collect stormwater runoff. This runoff will be directed to rain gardens that were recommended for installation in the landscaped areas surrounding the buildings. Porous pavement will be used on all driveways and parking areas which will collect, store, and infiltrate stormwater from the paved areas. The rain gardens will store some of the flow from the roof runoff to minimize ponding on the porous pavement. The driveways and parking lots will have catch basins at low points to collect overflow.

Subcatchment P6: Subcatchment P6 contains the remaining landscaped and partially forested areas between the three small buildings and two southernmost medium-sized buildings and the southern and eastern boundaries of the property. Stormwater runoff from this area will flow offsite in the southeasterly direction, similar to existing conditions.

The total areas of the six post-development subcatchments and the amount of impervious coverage in each are provided in Table 4.

Table 4. Post-Development Conditions Drainage Area Summary

Drainage Area (sf)	Impervious Area (sf)	Total Area (sf)	Percent Impervious
P1	4,214.76	89,013.38	4.73%
P2	11,784.41	35,837.44	32.88%
P3	44,953.40	86,840.85	51.76%
P4	30,124.92	76,062.31	39.61%
P5	90,522.45	143,405.95	63.12%
P6	592.81	70,829.23	0.84%

4.5.2 Stormwater Runoff and Peak Discharge Rates

The NRCS Web Soil Survey identified three hydrologic soil groups on the project site: A, B, and D. The composite curve numbers that were obtained for each subcatchment based on hydrologic soil groups and the amount of impervious area provided were used to calculate the runoff volumes for each subcatchment (Tables 5 and 6). These curve numbers as well as runoff calculations checked by Stantec are provided in Appendix E for both pre- and post-development conditions.

Table 5. Runoff volumes for pre-development conditions

Storm Frequency	Runoff Volumes (cf)	
	X1	X2
2	17400	7500
10	44300	22700
25	69700	37900
100	128800	74800
Runoff to DP1 for 100-yr storm		128800
Runoff to DP2 for 100-yr storm		74800

Table 6. Runoff volumes for post-development conditions

Storm Frequency	Runoff Volumes (cf)					
	P1	P2	P3	P4	P5	P6
2	10400	5000	13400	10400	20700	2200
10	24000	9300	24300	19500	38200	6800
25	36400	12900	33200	27100	52600	11500
100	64500	20500	51900	43200	83300	22800
Total runoff to DP1 (P1, P2, P3, P4), 100-yr storm				180100		
Total runoff to DP2 (P5, P6), 100-yr storm				106000		

The calculated peak discharges to each discharge point for the pre- and post-development conditions are summarized in Table 7. Calculations for the time of concentration and peak discharge rates are provided in Appendix F and G, respectively.

Table 7. Pre-development peak discharge rates for 100-year storm

Discharge point	Pre-development peak discharge rate (cfs) for 100-yr storm	Post-development peak discharge rate (cfs) for 100-yr storm
DP-1	28	43
DP-2	18	25

Table 7 compares runoff and peak discharges between the existing site conditions and a “do nothing” approach for the site development, or a site with no BMPs installed to provide stormwater management. Standards 2 and 3 of the MassDEP Stormwater Standards would not be met with a “do nothing” approach due to the increase in runoff volume and peak discharge rate from pre- to post-development conditions. Therefore, BMPs were designed and proposed for the project site.

4.5.3 BMP Designs

Subcatchment delineation and peak discharge analysis showed that runoff from subcatchments P1 and P6 was similar to pre-development conditions, meaning that BMPs were not necessary in these subcatchments. For the other four subcatchments on the proposed project site, recharge volumes, water quality volumes, and storage volumes were used to determine the appropriate size and type of BMP required (see Appendix H for recharge and water quality volume calculations, and Appendix I for storage volume calculations).

CULTEC stormwater subsurface chambers are proposed for stormwater management in subcatchment P2 (the location of this BMP is provided in the Utility Plan of the plan set in Appendix D). These chambers provide 80% TSS removal. This BMP is designed to be located to the south of the parking lot, in subcatchment P1, to avoid D hydrologic type soils; this way, the chambers could provide infiltration as well as detention. The proposed grading for this area will involve a great amount of cutting, and thus an insufficient amount of space to install the chambers between the proposed surface and the groundwater table. A retaining wall is proposed along the edge of the parking lot and roadway to bring the ground elevation where the BMP will be installed to the first floor elevation of the largest building, 177 feet. This new proposed grading will provide sufficient depth for the subsurface chambers above the groundwater table. Subsurface chambers are typically located under pavement, and these are proposed under landscaping, meaning there is potential for infiltration into the system from rainfall above. The amount of water potentially infiltrating into the system is negligible, however, because Stantec landscapes at approximately a 2% slope to ensure water will generally run off.

Two catch basins are proposed to carry runoff from the low points of the parking lot to the subsurface chambers. Each is designed to carry half of the peak discharge rate from the subcatchment to the chambers. The pipes required to handle this flow rate are 6-inch HDPE (see Appendix J for calculations).

The Recharger 330XLHD is the CULTEC chamber model chosen to optimize available space and use the least amount of chambers as possible to provide the required storage volume. Chamber dimensions are summarized in Table 8 (see Appendix J for calculations).

Table 8. CULTEC Subsurface Chamber Dimensions for P2

Total number of chambers	79
Bed area (sf)	2,659
Bed width (ft)	44
Bed length (ft)	67
Stone required (cy)	197
Number of chambers wide	9
Number of chambers long	9
Total Storage Capacity (cf)	6,420

A detention pond will capture runoff from subcatchments P3 and P4 (a plan view of this BMP is provided in the Utility Plan of the plan set in Appendix D). There will be drain lines running from the space of land in the "U" shape of the largest building to the detention pond. A 14" HDPE pipe size will be sufficient to carry the runoff from P3 in the 100-year design storm (see Appendix K for calculations). The surface area of the detention pond running between, and up against, the largest building and the adjacent medium-sized building in subcatchment P4 as calculated in AutoCAD is 13,233 square feet. The northern and southern edges of the pond that are not against a building require embankments with 1:3 slopes. The volume of the detention pond accounting for the embankments and a depth of three feet is approximately 36,454 cubic feet, which allows for plenty of storage space to make up for a required 31,667 cubic feet for storage and water quality volume. Including one foot of freeboard space to account for potential overflow, the pond depth will be four feet. The bottom of the pond is designed at an elevation of 170 feet, allowing for an elevation at the top of the basin to be 174 feet, giving 3 feet of room between the top of the basin and the first floor elevation for the largest building.

The distance between the southern edge of the detention pond and the existing sewer line is about 43 feet, giving enough space for the embankment, a width of 8 feet at the top of the basin, and grading down at a 1:3 slope to the existing grade before the utility line (Figure 10). For ease of access to the sewer line, it is important to maintain this distance so that proposed excess fill will not obstruct maintenance operations. This also provides adequate space for an outlet control structure and subsurface chambers to account for the recharge volume, since the detention pond will not provide recharge in a D hydrologic soil type. An outlet control structure is necessary to ensure that the pond stores water and to control the rate of outflow to the chambers. To reduce the rate of water draining out of the control structure, a baffle wall with an orifice and/or weir will be required. The outlet control structure will be designed by Stantec as this project moves past the preliminary design phase. Typical designs include an entrance orifice and a grate at the top in case the water level in the pond rises above the structure and needs an alternate route to flow in. The dimensions for the subsurface chambers, to be located under the filled embankment at an elevation of 165 feet, are summarized in Table 9. This elevation is above the location's existing grade (for chamber location, see the Utility Layout in Appendix D) to account for the chamber height and sufficient space above the groundwater table.

Table 9. CULTEC Subsurface Chamber Dimensions for P4

Number of Chambers	20
Bed area (sf)	813.23
Bed width (ft)	15.49
Bed length (ft)	52.5
Stone required (cy)	49.5
Number of chambers wide	3
Number of chambers long	7

These subsurface chambers will drain to a manhole, and this manhole will discharge to DP-1. The manhole provides storage for overflow from the chamber system. The outlet pipe from the manhole is designed so that an ample amount of water would be held, allowing time for the water to infiltrate into the ground below, before discharging to DP-1. This design ensures that the recharge volume will be achieved to comply with Standard 3. An elevation view drawing for the outlet control structure, subsurface chambers, and manhole is provided in Figure 10.

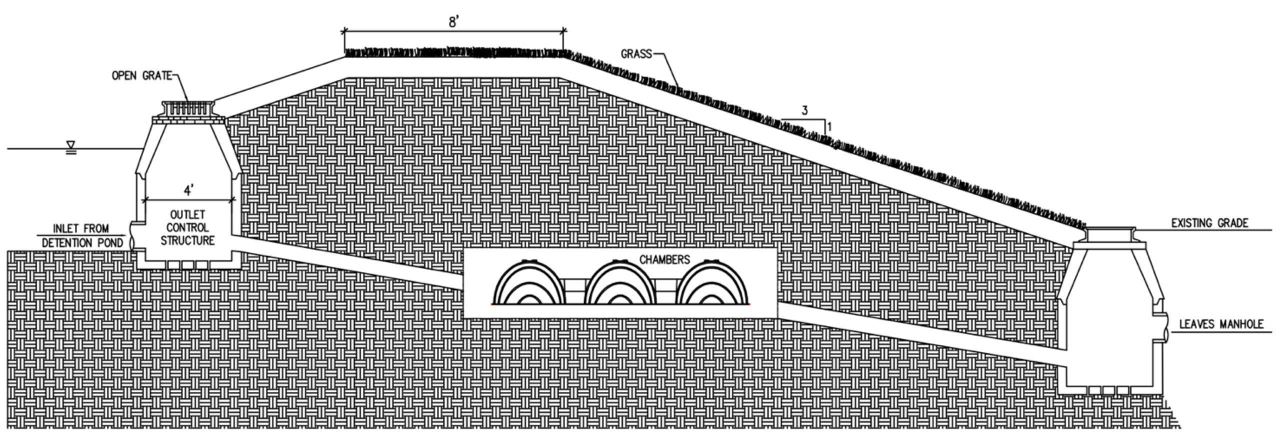

Figure 10. Elevation view of outlet structure, subsurface chambers, and manhole

Porous pavement is proposed in subcatchment P5, providing 80% TSS removal credit. The storage depth for the pavement is 7.2 inches, and the storage volume for the pavement is 23,472 cubic feet, plenty of space to meet the requirement of 22,926 cubic feet of storage (see Appendix L for calculations). Runoff from the roofs of the buildings within subcatchment P5 will be directed to the ground by gutters and downspouts. Installing the downspouts to discharge onto the porous pavement could cause the pavement to deteriorate and ponding to occur because of a concentrated flow to one area, therefore the downspouts are recommended to be designed to discharge onto the landscaped area. Rain gardens are proposed for these discharge locations to help improve infiltration for this concentrated volume of runoff and to protect the porous pavement.

The groundwater table is greater than 80 inches below the surface for the hydrologic soil type in subcatchment P5. In some areas in the subcatchment, the proposed grading requires up to 10 feet of cut. Geotechnical investigation, such as test pits and monitoring wells, is required to better estimate the depth to the groundwater table. Therefore, there is not enough information currently to determine if there is enough space for the pavement, two feet of crushed stone, and four feet below the stone to the groundwater table. If the geotechnical investigation concludes that there is not sufficient space for the porous pavement, the team recommends to change the proposed grading for the area to achieve the required separation.

The drawdown times for each BMP are all less than 72 hours (Appendix M), meaning that the groundwater will be recharged.

A mounding analysis is required when the bottom of a BMP is within four feet of the seasonal high groundwater table. The Town of Belmont Checklist for Stormwater Management and Erosion Control states that any potential impacts to groundwater levels have to be identified in the stormwater report, which include mounding calculations for the 10-year 24-hour design storm. Due to the varying depths from the surface to the groundwater table (Table 2), a mounding analysis was performed for all BMPs. Calculations for the mounding analyses are provided in Appendix N. The results of the mounding analysis for each BMP are summarized in Table 10. For the porous pavement in P5, if the field tests show that the top of the mound will rise above the groundwater table, the team recommends a change to the proposed grading.

Table 10. Mounding Analysis

BMP	Max increase in groundwater elevation due to infiltration (ft)	Comments on interpretation
P2 Subsurface Chambers	0.79	Depth to groundwater table > 80 in. With proposed retaining wall and fill for landscaping, mounding will not reach bottom of BMP
P4 Subsurface Chambers	6.27	Depth to groundwater table > 80 in. Proposed grading requires fill, so top of mound will not rise above bottom of BMP
P5 Porous Pavement	6.46	Depth to groundwater table > 80 in. Proposed grading requires cut. Field tests are needed to estimate exact depth to groundwater table to determine if top of mound will reach bottom of BMP

4.5.4 Low Impact Development

The incorporation of BMPs into the site design was a strategy to achieve Low Impact Development (LID). This project does not qualify for any of the Low Impact Development Design Credits that are outlined in the MassDEP Stormwater Management Handbook due to the lack of abundant pervious, natural areas for flow to be directed to in lieu of BMPs. Therefore, BMPs were used to mimic natural water drainage processes by storing runoff and allowing it to infiltrate and recharge into the groundwater. According to the MassDEP Checklist for Stormwater Report and the Town of Belmont Checklist for Stormwater Management and Erosion Control Report, LID Techniques that apply to this project include no disturbance to any Wetland Resource Areas and the implementation of BMPs: subsurface detention/infiltration basins, porous pavement, and a detention pond (completed checklist in Appendix O). Using Low Impact Development techniques helped this project design comply with stormwater management standards and meet the needs of the future residents to ensure longevity of the facility and its sustainable, environmentally friendly nature.

5.0 Conclusions and Recommendations

In this project, the team developed a plan set for the McLean Senior Living Subdistrict project in Belmont, MA including a proposed utility layout for the site and the types and sizes of stormwater management BMPs. The BMPs were selected and designed based on an analysis of environmental constraints and compliance with state and town regulations, as well as the results from calculations performed using guidance from the NCRS TR-55, MassDEP Stormwater Handbook, and online calculators when necessary. Specifically, the MassDEP Stormwater Management Standards and the Town of Belmont Stormwater Management and Erosion Control By-Law governed the stormwater management designs. Zoning and GIS analyses were performed to ensure that the project was in compliance with zoning regulations and that all potential constraints to project development were identified and addressed in the proposed designs. AutoCAD software was used to create the schematic level plan set and determine the dimensions required for stormwater calculations and BMP sizing. As a means to fully achieve this project's goal of assisting Stantec in site development for the property in Belmont by producing a preliminary site design for utilities and stormwater management, the team recommends the following further steps to supplement the designs created as part of this MQP.

5.1 Utility Design Recommendations

The utilities were designed and proposed at a preliminary level of analysis, and therefore the team developed several recommendations to provide to Stantec for moving forward with this project. For the scope of this project in its conceptual phase, it was assumed that pumps would not be necessary in the water lines because no high rise buildings were proposed. The next steps needed for the continuation of this project include conducting hydrant flow tests to measure the static pressure in the system. Once the pressure is known, the design can progress through this preliminary design to a more in-depth determination of the components and requirements that this utility system would need.

5.2 Stormwater Management Design Recommendations

Due to the resources and expertise of the team, many of the determinations made regarding soils in the project site were based solely on GIS data and the NRCS soil surveys. In order for the project to progress, geotechnical tests of the site including monitoring wells and soil borings would need to be conducted to obtain the most accurate information on the soils. These tests would provide specific values for the depth to groundwater, bedrock, and other restrictive features to consider when developing a site. A more accurate determination of the composition of different soil types and hydrologic soil groups would also be obtained from these tests. The results from such studies would provide the knowledge needed to evaluate the proposed BMPs to ensure that they infiltrate properly and are built at the required depth above bedrock and the water table.

The next steps for completing the designs for the BMPs are to model the outlets and fully design the outlet structures. Since the storage volumes calculated to size the BMPs were based on TR-55 Figure 6-1 in this project, more accurate volumes could be calculated using HydroCAD software. HydroCAD is a program that models stormwater runoff and performs calculations for BMP designs. At the end of the project, HydroCAD was used to model the pre-development subcatchment X1 and post-development subcatchment P2 to compare the TR-55 stormwater calculations with HydroCAD's. There was a slight difference in results between methods because HydroCAD implements the TR-20 process, which is capable of using more conservative and accurate calculations because it is a computer software and does not involve charts and rounding. The differences in results were not enough to change the BMP design for subcatchment P2, but the use of HydroCAD is recommended for checking the design of the other BMPs onsite.

The modeling done in HydroCAD would also help determine the elevations of the inlet to the outflow structure from the BMP and the best components to incorporate such as a weir or orifice. The diameter of the orifice, length of the weir, or other dimensions of the components deemed most suitable for the BMP can also be determined using HydroCAD modeling. Testing different elevations and dimensions of these structures shows the storage capacity of the BMP, the amount of storage being utilized for each storm, and the discharge rate offsite to ensure it is in compliance with stormwater management standards. HydroCAD modeling of the BMP outflow structures ultimately verifies that the BMP is effectively sized so that it can handle a more extreme storm event, but is not mainly comprised of empty space during the more frequent storm events which would render the BMP not cost effective.

The team also recommends the development of operation and maintenance plans for all BMPs. These plans are essential for the upkeep of BMPs to ensure that they work properly and continue to meet stormwater management standards. Maintenance is particularly essential to the porous pavement BMP. Porous pavement must be cleaned regularly so that the pavement does not clog which would prevent it from storing and infiltrating stormwater. Development of operation and maintenance plans are also required by MassDEP Stormwater Management Standard 9.

As per stormwater management standards, the creation of a long-term pollution prevention plan is crucial to the success of the proposed BMPs as well as to the regulatory authorities approving of these development plans. Plans to control construction-related impacts are also required by Standard 8. These plans will ensure that the impact of development on stormwater is appropriately addressed in the construction of the site and for its lifetime thereafter. Low impact development techniques paired with the implementation of these plans provides the means for development to take place in the least environmentally impactful way.

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Appendix A: Project Proposal

Site Development for Stormwater and Utilities in Belmont, MA

A Major Qualifying Project Proposal Submitted to the Faculty of
Worcester Polytechnic Institute
In Partial Fulfillment of the requirements for the Bachelor of Science Degree
By

Marissa Bernard
Cierra Ford
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December 12, 2017

Advisors:
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Capstone Design Statement

The Accreditation Board for Engineering and Technology (ABET) requires that all accredited engineering programs include a capstone design experience. At Worcester Polytechnic Institute (WPI), this requirement is met through the Major Qualifying Project. The capstone design addresses eight realistic constraints of a project including economic, environmental, sustainability, constructability, ethical, health and safety, social, and political. This Major Qualifying Project focuses on preliminary site design for utilities and stormwater management for a site in Belmont, Massachusetts. The following is a description of how the project intends to address seven of these constraints.

Economic: The site design and development process involves a cost analysis, using preliminary estimates from the designs, material costs, and projected benefits of the alternatives, to determine the best alternatives for each part of the project in order to produce a design that is economically feasible.

Environmental: This project will consider a variety of methods to reduce environmental impacts, such as best management practices for stormwater and low impact development techniques.

Sustainability: Along with reducing environmental impacts through site design, this project will include a feasibility analysis of renewable energy sources, aiming to provide a platform for sustainable development on the McLean campus.

Constructability: This project will evaluate several options for site design, and a key factor in the decision-making process is analyzing the constructability of the alternatives with the provided site and site plans and the limitations they produce.

Ethical: The designs for this project will comply with the American Society of Civil Engineers (ASCE) code of ethics, meeting the requirements of the ASCE fundamental principles. The following ASCE canons are most applicable to this project.

> Canon 1: Engineers shall hold paramount the safety, health and welfare of the public and shall strive to comply with the principles of sustainable development in the performance of their professional duties.
>
> Canon 4: Engineers shall act in professional matters for each employer or client as faithful agents or trustees, and shall avoid conflicts of interest.
>
> Canon 5: Engineers shall build their professional reputation on the merit of their services and shall not compete unfairly with others.
>
> Canon 6: Engineers shall act in such a manner as to uphold and enhance the honor, integrity, and dignity of the engineering profession and shall act with zero tolerance for bribery, fraud, and corruption.

Health and Safety: This project will consider the wellbeing of the Belmont community by understanding and mitigating the environmental effects of the site development project.

Social: This project will consider the social constraints of site development by pursuing solutions with limited impact on the surrounding McLean property and residents.

1.0 Introduction

The site development process involves the consideration of a range of constraints and parameters in order to produce a graphical representation of the site layout prior to the start of construction. Stantec, an international professional services company in the design and consulting industry, has an upcoming site redevelopment project in Belmont, Massachusetts. Site design components include an analysis of earthwork to develop a construction phasing plan that aids in the balance of cuts and fills, a stormwater management aspect to determine low impact development techniques and reduction of site runoff, and an evaluation of utilities, e.g. how to best provide them, and the opportunity for renewable energy sources on site. In this proposed Major Qualifying Project, the focus will be on the stormwater management and utilities aspects of the site redevelopment project.

The goal of this project is to assist Stantec in site development for the location in Belmont by producing preliminary site design options for utilities and stormwater. In order to accomplish this goal, the existing site conditions in terms of stormwater management and utilities will be documented and evaluated, and then several options for how to satisfy and provide for the site's basic needs will be produced. Next, the options will be analyzed based on economic, environmental, sustainability, constructability, ethical, health and safety, and social constraints as well as weightings predetermined by the student group, that align with Stantec's goals for the project. Finally, students will prepare several possible schematic level designs for the stormwater and utilities aspects of the site development.

2.0 Background

This chapter provides details on the proposed redevelopment of the site in Belmont and an overview of common methods to approach site development with regards to stormwater management and providing appropriate utilities to the site.

2.1 Overview of Project Site

The project site is located on Olmsted Drive in Belmont, Massachusetts on property owned by McLean Hospital. Stantec's developer client involved in this project plans to develop 299 new housing units on the site. The housing units will consist of one large building of 144 units, four medium buildings with 36 units each, and three small buildings of 11 units total. Parking will be provided at grade under the large and medium sized buildings, in side lots adjacent to the larger buildings, and in private garages for the smaller town house style homes. Current conditions of the site include a building that once served as a superintendent's residence and an office building (Figure 1). There is also a large amount of foliage and uneven grading that must be excavated.

Figure 1. McLean Campus Superintendent Building [1]

Because most of this site is currently undeveloped, the zoning laws in the area and how they would affect construction of the proposed site were researched. Zoning subdistricts on the McLean campus were established with plans to further develop back in 1999 (Figure 2). The zone relevant to this project is Zone 3, which was approved to be a senior living subdistrict prior to this project, easing the process to add additional housing to the campus.

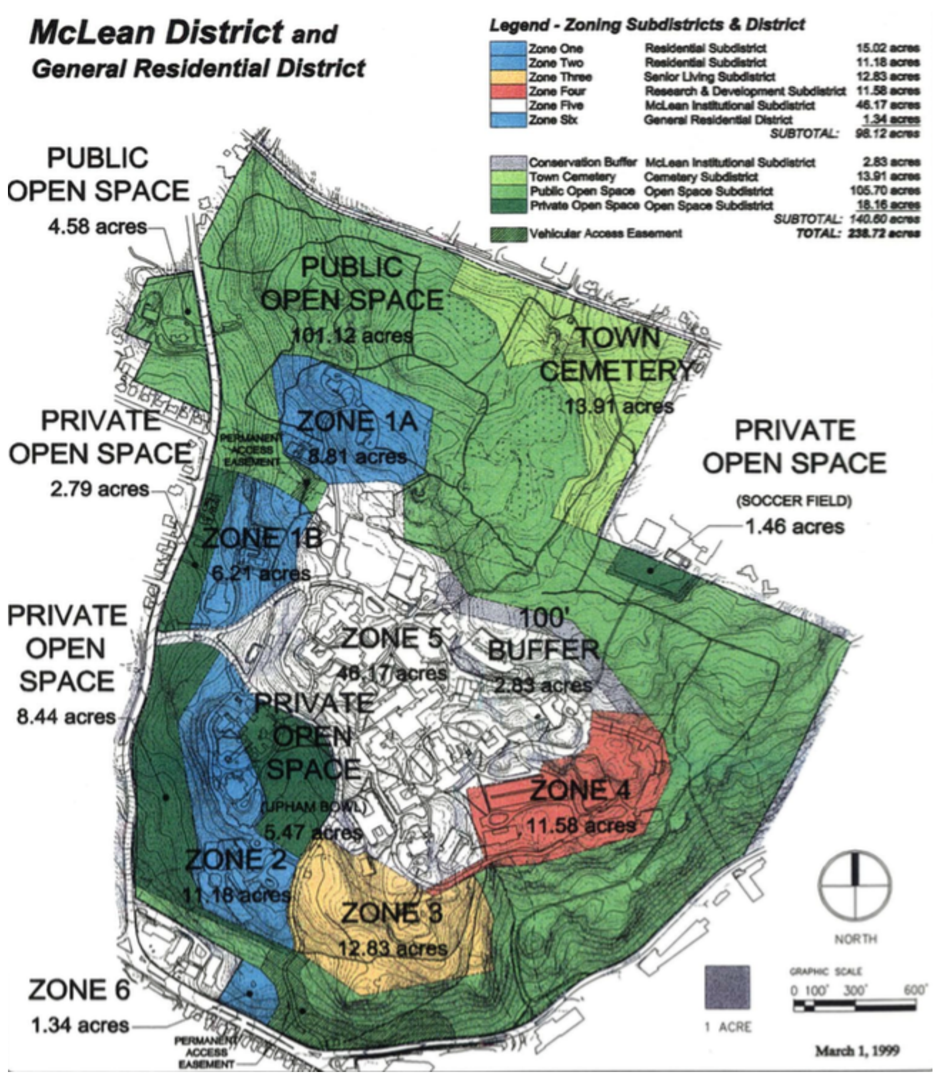


Figure 2. McLean District Zoning Map [2]

2.2 Stormwater Management

In site development, stormwater analysis and management is necessary to mitigate environmental impacts to the site, abutting properties, and vulnerable watersheds. Regulations and standards on the state and federal levels require stormwater management practices to be implemented when a site is developed or redeveloped. In 1996, The Stormwater Policy was issued by the Massachusetts Department of Environmental Protection (MassDEP) to establish Stormwater Management Standards [3]. These standards address increasing stormwater recharge, preventing pollution to surface or groundwater from stormwater discharge, treating stormwater runoff, using low impact development techniques, removing illicit stormwater discharges, and improving operation and maintenance of stormwater best management practices (BMPs) [3]. On the federal level, the US Environmental Protection Agency has implemented the National Pollutant Discharge Elimination System to regulate stormwater discharges. One potential source of discharge is municipal separate storm sewer systems (MS4s) which require the attainment of permits in an effort to prevent stormwater runoff from polluting surface waters.

Belmont's response to federal legislation and upholding MS4 permits was the passing of the Town of Belmont Stormwater Management and Erosion Control By-Law, finalized and approved in July 2013. The by-law states that any increased stormwater runoff volume, erosion, silting, flooding, sedimentation, or wetland or groundwater level or well impacts must not change the existing conditions of abutting properties [4]. The stormwater management designs for the project must ensure that any increases in stormwater runoff and their subsequent effects be mitigated on site [4]. The success of these efforts can be evaluated by completing the Town of Belmont Checklist for Stormwater Management and Erosion Control Report. This checklist references computations and information provided in the Documenting Compliance document

(Volume 3 Chapter 1) of the MassDEP Stormwater Handbook which will be essential as a reference when designing the stormwater management system at this project site [5].

In order to perform site design for stormwater infrastructure, a general understanding of hydrology, or how water moves on the site pre- and post-development, is required. Development of land inherently poses the risk of erosion and increases the discharge of storm runoff. The existing conditions of the site with respect to water must first be established to understand the water resources and their current behavior on the site so that changes that might ensue from development of the site can be mitigated. Stormwater aspects essential in this analysis are the inflows to the site including precipitation, streamflow, groundwater, and runoff; the outflows such as evaporation and transpiration, streamflow, and groundwater recharge; and the capacity of the site to store water. These existing conditions can be obtained from Massachusetts Geographic Information Systems (MassGIS) data, US Geological Survey (USGS) maps, Federal Emergency Management Agency (FEMA) flood maps, and information provided by the Town of Belmont regarding precipitation, streamflow, and groundwater. Proposed topography maps for the developed site, as provided by Stantec, will help understand the direction of flow based on contours and, from this information, will help determine the best location for stormwater BMPs, the volume of flow, and the susceptibility to erosion on the site.

After the existing conditions regarding stormwater have been established, designs for stormwater management can be developed. There are many methods to approach site development with regard to stormwater management. The MassDEP Stormwater Handbook establishes the three components of stormwater management: site planning, implementing non-structural source and pollution prevention controls, and designing, building, and maintaining structural BMPs [3]. Guidance on approaches to stormwater infrastructure design is also provided in the MassDEP Stormwater Handbook, including variations of filters, basins, and channels for stormwater BMPs [3]. Because this project includes redevelopment, consideration of the standards for redevelopment projects established in the MassDEP Stormwater Handbook Checklist for Redevelopment Projects is also critical to the design of a stormwater management system at the project site.

The Natural Resources Conservation Service Technical Release 55 (NRCS TR-55) provides guidance on calculating storm runoff volume, peak rate of discharge, hydrographs, and storage volume requirements for floodwater reservoirs. The NRCS TR-55 presents the flowchart, provided in Figure 3, outlining the process of determining the existing hydrologic conditions which will be utilized to help decide which procedures to apply to this project [6].

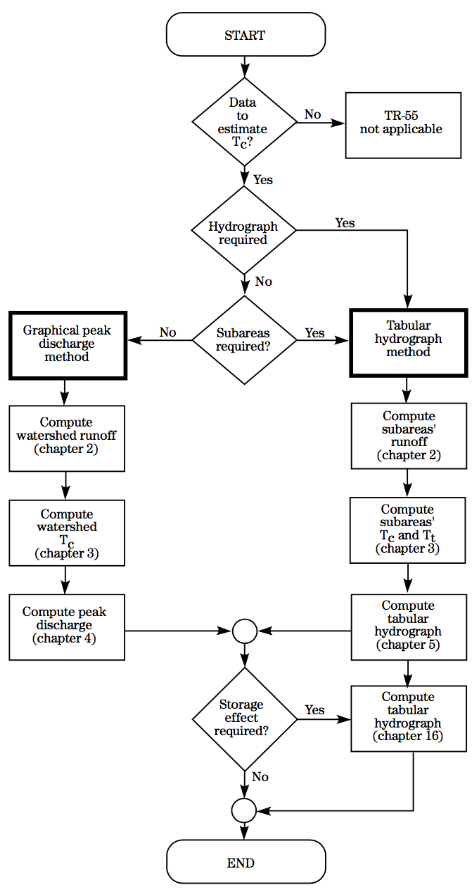


Figure 3. Flowchart for selecting appropriate procedures in TR-55 [6]

The Low-Impact Development Hydrologic Analysis prepared by the Department of Environmental Resources in Prince George's County, Maryland in January 2001, based on the NRCS TR-55 and archived by the Environmental Protection Agency, provides additional insight on approaching stormwater analysis. The details of key hydrologic principles to consider are outlined below:

- Precipitation and storm events: 1 and 2-year storm event data is often applied to sedimentation and erosion in receiving channels, 5 and 10-year storm event data is used for flow conveyance and minor flooding, 100-year storm event data helps provide limits of floodplains and major flooding considerations.
- Rainfall abstractions: Vegetation, evaporation, transpiration, infiltration, and storage on the site are key considerations for modeling hydrology on site during development which increases impervious surfaces, decreases abstraction, and increases runoff.
- Surface runoff: In undeveloped conditions, surface runoff ranges from 10-30% of precipitation; development can increase surface runoff to over 50% of precipitation.
- Groundwater recharge: Rainfall infiltrates into the soil and contributes to groundwater that is critical for the health of biological systems and habitats in streams [7].

The specific computations and considerations from the handbook include peak rate attenuation, recharge volume, soil evaluation, sizing storage volume, 72-hour drawdown analysis, capture area adjustment, and mounding analysis [3]. These calculations will provide the needed information about the input flows, storage capacity, and output flows on the site with regard to the existing conditions such as type of soil or hydrologic connections on site as well as proposed development, which would include increased impervious surfaces. Another important consideration for stormwater is runoff, which is commonly calculated using the SCS runoff curve number method, the rational method, and the IDF curve. HydroCAD, a computer software for modeling stormwater runoff and designing stormwater management systems may also be utilized in this project.

2.3 Site Development for Utilities

In order to perform site development for utilities, an understanding of common methods for providing utilities to a site is required. Utilities refer to a publicly owned or investor-owned set of services provided to people, including electric power, landline telephone networks, cable, gas, and water. In the town of Belmont, Verizon and Comcast provide telephone and cable services, the Belmont Municipal Light Department provides electric services, National Grid provides natural gas, and the Department of Public Works Water Division maintains Belmont's water system [8].

It is important to know the basic needs of a site in order to design utility infrastructure. There are common methods to determine the needs for each type of utility service.

Electric power requirements for a site can be determined through the completion of several steps. First, an understanding of the technical specifications for the private and public electric services must be gained, for instance the magnitude of current they can provide to the site. The estimation of power required of a site also needs to be determined to prepare a site design for electrical utilities. This can be done by determining average power demands based on the number of buildings, number of units, size, lighting requirements, and amount of power-using instruments needed on site [9]. It can also be estimated by knowing the principal building activity, such as office, warehouse, healthcare, retail, lodging, religious worship, and other purposes, as well as the year constructed, region of location, and building floorspace [10].

Sites can also be classified as needing single-phase or three-phase services or both. Single-phase power is a two-wire Alternating Current circuit, used in households to power lights and televisions. Three-phase power is an Alternating Current circuit with three wires and is commonly used in commercial buildings because it has better power density and flexibility [11]. Finally, the best location on site for an electricity meter, which tracks electrical energy consumption of a building for billing purposes, must be determined.

Water infrastructure is essential to supplying water to and draining wastewater from a site. Analyzing existing and proposed water demand is necessary to design infrastructure that will meet these needs. Local resources and site topography are examined to determine alternative supply routes that will deliver sufficient pressure for the supply water and reduce pumping costs. Pumping stations are employed to provide the right amount of pressure for a water system to function properly. Water flows downhill, and therefore pumps are required when water in a pipe must oppose the force of gravity to get where it needs as well as to provide end users with better water pressure. There are two types of pumps that can improve pump efficiency and lower operation costs. Unique Speed Pumps turn on and off at a defined level at which the system can operate properly without over pressurizing it. Variable Speed Pumps can modify their velocities to operate most efficiently and reduce costs [12]. For these pumps, velocities at which the system would function must be calculated.

For wastewater, there are several treatment and disposal options that depend on several constraints determined from evaluating available resources and the site. Wastewater management opportunities on a site depend on whether tie-ins to the town's sanitary sewer system are available or feasible. Site evaluation consists of client contact, field testing, and researching US Geological Surveys. The constraints include soil permeability, depth to bedrock, depth to water table, slope, and size of lot, and some potential disposal methods include trenches, beds, pits, mounds, fill systems, and evaporation infiltration lagoons. These constraints, a cost analysis, and an analysis of public health and environmental criteria, are used to determine the best method for a site's wastewater disposal. For the design of a treatment system, the characteristics of the produced wastewater must be examined, such as average, maximum and minimum daily flows, peak flows, and quality. Common flows from specific activities can be found from several online sources. Onsite treatment methods include septic tanks, sand filters, disinfection units, and nutrient removal systems, each with different performance criteria with separate advantages based on type, amount, and quality of wastewater, operation and maintenance, and site characteristics [13].

For all utilities, it is important to examine alternative ways to provide for the site's basic needs that are more sustainable, such as opportunities to implement renewable energy and reduce water movement and power usage. Leadership in Energy and Environmental Design (LEED) is a rating system developed by the US Green Building Council to set standards for assessing environmental performance of buildings and promoting sustainable design. Projects can earn points toward their rating by taking action toward sustainable design, construction, and use. Credits can include devices that produce less wastewater, optimize energy performance, and reduce light pollution.

3.0 Methodology

The goal of this project is to assist Stantec in site development for the location in Belmont by producing preliminary site design options for utilities and stormwater management. The main objectives for the completion of this project are as follows.

- Document the existing site conditions
- Develop alternatives for providing utilities and stormwater management to the site
- Analyze and evaluate alternatives based on design constraints and predetermined weightings
- Produce schematic level designs for the site

3.1 Document the existing site conditions

The existing site conditions of the property will be researched and gathered to gain an understanding of the current state of the project site with regard to stormwater management and utilities.

In order to understand the existing condition on the site regarding stormwater, information on the hydrological and geological features impacting stormwater will be obtained from MassGIS data, USGS maps, FEMA flood maps, and information provided by the Town of Belmont regarding precipitation, streamflow, and groundwater. This information will be acquired electronically from the Town of Belmont's website or from paper records obtained from Belmont Town Hall. Any other pertinent information in Stantec's possession regarding stormwater on the site will also be reviewed.

The Town of Belmont Stormwater Management and Erosion Control By-Law will be researched to understand the regulatory framework that stormwater management designs must adhere to at the project site. Low Impact Development (LID) techniques used in Belmont and in similar projects in the surrounding area will also be researched to learn about current practices in similar contexts that may help develop site designs.

The information needed to determine the availability and accessibility of utilities to the site will be obtained from MassGIS data, the Belmont Town Hall, site visits, and site data from Stantec. This data and information will consist of the location of existing utilities, electricity usage, energy efficiency and renewable energy initiatives in Belmont, pressure and flow in the town water distribution system including the hydraulic grade line, and the town's pressure and flow requirements for buildings.

3.2 Analyze the alternatives for providing basic needs to the site

Based on available resources in Belmont and research into common approaches to provide utilities and develop stormwater infrastructure, methods for redesigning the site to move forward with the site development process will be determined.

Stormwater design will be based on guidance from the MassDEP Stormwater Handbook, Natural Resources Conservation Service Technical Review 55, and the Town of Belmont Stormwater Management and Erosion Control By-Law. Calculations will be performed including stormwater runoff volumes, mounding analysis, soil evaluations, and storage volumes. The results from these computations along with the site conditions will help determine which BMPs to implement on the site and the appropriate sizes and locations for the stormwater management designs.

To produce a design for electrical utilities, the site's power demand will be estimated. There are eight proposed buildings on the site, each with its own power demand that will add to the sites' total electrical utility needs. To calculate the power demand, each buildings' main activities, size, and location will be used. This same method will be used to determine the natural gas demand for the site. To determine the potential routes for energy supply, the closest electricity and natural gas utility lines will be located.

For the design of water infrastructure on site, local resources and site topography will be researched to understand the local water resources and their available pressure, and to determine potential routes for water supply. Water supply routes will be chosen based on minimizing pump stations while maintaining proper water pressure in the system for the end user.

To determine potential options for wastewater disposal and treatment, the team will use predicted wastewater characteristics, common flows from the activities that will occur on site, as well as collected data from site evaluations on soil permeability, bedrock and water table depths.

Next, potential renewable energy sources, methods to reduce energy consumption, water movement, and wastewater production will be examined to promote sustainable site development and allow the project to meet LEED standards.

Once an evaluation of the individual aspects of site design is completed, the interplay of these options will be analyzed. This is a crucial step in site planning and development because the use of one feature may eliminate the need for or make another more favorable to use. Design criteria and weightings will be developed in order to compare different combinations, or packages, of the different options for each aspect of site design. The criteria will be determined based on economic, ethical, social, constructability, sustainability, health and safety, and environmental considerations. To assign a weight to each category, there will be communication with Stantec to align the weights with their goals for the project.

3.3 Produce schematic level designs for the site

Once the criteria and weightings are developed, a variety of preliminary designs will be produced, containing different combinations of utilities and stormwater management alternatives. The first will be a “traditional” design, with ease of constructability and lowest cost as the main objectives. The second will be a “green” design, where LEED standards are taken into high consideration. In this green design, elements that meet LEED standards will either replace or add to elements of the traditional site design, such as devices that reduce wastewater generation, solar panels on the roof and/or other renewable energy sources, a water collection system on the roof, and other energy-saving waste-reducing alternatives. Other designs will be created to incorporate aspects of both the “traditional” and “green” designs to explore opportunities between these two extremes. These designs will be compared with one another, and the evaluation criteria and weightings will be used again to determine the best and most feasible design.

3.4 Deliverables and Schedule

The deliverables for this project include AutoCAD drawings of preliminary site design options for stormwater and utilities, a report to fulfill the Major Qualifying Project requirement, and a poster summarizing our project and its results.

The project’s duration is an important consideration to address with sponsors at Stantec. Seven weeks will be spent at Stantec, therefore presenting many limitations to the project. All of the stated objectives will be completed during this time frame, and the proposed schedule for the time at Stantec is shown in Figure 4.

Task	**Dates**								
	Prep	Jan. 10-12	Jan. 15-19	Jan. 22-26	Jan. 29 - Feb. 2	Feb. 5-9	Feb. 12-16	Feb. 19-23	Feb. 26 - Mar. 2
Gain knowledge about project from sponsor and refine information	■								
Document existing site conditions	■	■	■						
Expand Background section of report		■	■						
Develop alternatives for providing utilities and stormwater management			■	■	■				
Expand Methods section of report			■	■	■				
Write Results section of report				■	■	■			
Analyze and evaluate alternatives based on design constraints and weightings				■	■	■			
Evaluate findings				■	■	■	■		
Produce schematic level designs for utilities and stormwater						■	■	■	
Submit to sponsor and advisors for final commentary								■	
Finalize project report								■	■
Present to Stantec and advisors									■

Figure 4. Proposed Schedule

4.0 References

1. National Register of Historic Places Registration Form. (2002, November 29). Retrieved December 1, 2017, from http://www.belmont-ma.gov/sites/belmontma/files/uploads/mclean_hospital_national_historic_register_nomination.pdf

2. McLean Zoning Map. (1999, March 1). Retrieved December 1, 2017, from http://www.belmont-ma.gov/sites/belmontma/files/file/file/mclean_zoning_map.pdf

3. Massachusetts Department of Environmental Protection. *Massachusetts Stormwater Handbook.* Massachusetts, 1997.

4. Belmont, MA. *Town of Belmont Stormwater Management and Erosion Control By-Law.* (Article 34). [by July 2, 2013]

5. Belmont, MA. *Town of Belmont Checklist for Stormwater Management and Erosion Control Report*. 2013, October 21.

6. United States Department of Agriculture. Natural Resources Conservation Service. Conservation Engineering Division. *Urban Hydrology for Small Watersheds Technical Release*. Second Edition. Washington: USDA, 1986.

7. Prince George's County, Maryland Department of Environmental Resources Programs and Planning Division. *Low Impact Development Hydrologic Analysis: Site Planning, Hydrology, Distributed IMP Technologies, Erosion and Sediment Control, Public Outreach*. 2000, January.

8. Utility Services. (n.d.). Retrieved December 6, 2017, from http://www.belmont-ma.gov/department-of-public-works-dpw/pages/utility-services

9. Planning of Electric Power Distribution. (2016). *Totally Integrated Power*. Retrieved December 6, 2017, from http://w3.siemens.com/powerdistribution/global/en/consultant-support/pages/power-distribution.aspx

10. U.S. Energy Information Administration - EIA - Independent Statistics and Analysis. (n.d.). Retrieved December 12, 2017, from https://www.eia.gov/electricity/annual/

11. 3 Phase Power vs Single Phase Power. (2017, March 14). Retrieved December 6, 2017, from http://www.oempanels.com/what-does-single-and-three-phase-power-mean

12. Bohórquez, J., Saldarriaga, J., & Vallejo, D. (2015). Pumping pattern optimization in order to reduce WDS operation costs. *Procedia Engineering, 119*, 1069-1077.

13. *Design Manual: Onsite Wastewater Treatment and Disposal Systems* (Vol. 625, 1-80-012). (1980). Cincinnati, OH: United States Environmental Protection Agency.

Appendix B: Zoning Checklist

ZONING CHECKLIST

Stantec

Prepared by	*WPI Belmont MQP Group*	Project Name	*McLean Senior Living Subdistrict*
Checked by		Project #	
Project Manager	*Frank Holmes*	Date	*2018.01.22*
Partner In Charge		Revised Date	

1. PROJECT INFORMATION

Project Address	*Olmsted Drive*
City/Town	*Belmont, MA*
County	*Middlesex County*
Acreage	*12.83 ±*
Is it a corner lot?	*No*
Attach 8 1/2 x 11 plan of site	
GIS Plans Compiled? (attach copies)	*Yes*
Has there been a site visit? (date, attendees)	2017.11.29, Kayla Salmon, Cierra Ford, Marissa Bernard

2. ZONING

2.a. ZONING - GENERAL INFORMATION

Zoning Bylaw Date	*Town of Belmont Zoning By-law - September 20, 2017*
Zoning Bylaw Date Amended	*1-May-17*
Attach 8 1/2 x 11 of Zoning Map at Site	http://www.belmont-ma.gov/sites/belmontma/files/u646/zoning_map.pdf
Zoning Map Date	*2016*
Zoning Map Amended	*N/A*
Zoning Districts	*McLean District, McLean Senior Living Subdistrict*
Abutting Zoning Districts	*McLean Open Space Subdistrict, McLean Residential Subdistrict, and McLean Institutional Subdistrict*
Overlay Districts	*N/A*
Permitted Uses	
As-of-right uses or with Special Permit?	*Yes, Senior Living*
If Special Permit, what is trigger?	*N/A*
Abutting Uses	
Any Residential Abutting Use?	*Yes*
Restrictions to Multiple Buildings on One Lot?	*No*

2.b. ZONING - DIMENSIONAL REQUIREMENTS

(read and note Bylaw definitions for terms below)
(check dimensional chart, applicable footnotes)

	Section/Page	Required
Setbacks (feet)		
Front Yard	*6A.2.2*	*10'*
Side Yard	*6A.2.2*	*10'*
Rear Yard	*6A.2.2*	*10'*
Corner Lot setbacks	*6A.2.2*	*N/A*
Setback Dimension from what part of Building?	*General, 1.4, setback*	*refer to definition ->*
Max. Bldg. Height (feet)	*6A.2.2*	*58'*
How is height measured?	*Zoning By-Law, General, 1.4 Definitions: The vertical distance from the grade to:*	
	the highest point of the roof or parapet for flat or shed roofs;	
	the midpoint between the lowest and highest points of the roof for gable, hip and gambrel roofs (upper roof pitch 4" per foot or greater); or	
	the point of change in roof slope for mansard roofs (upper roof pitch under 4" per foot).	
Max. Height	*6A.2.2*	*58'*
Residential Density	*6A.2.2*	*max: 480 units, senior*
District Height Limitations - Exemptions	*6A.2.2*	*one building may be as high as 67' as approved by the Planning Board*
Max. Coverage (percent)		
Max. Bldg. Coverage	*6A.2.2*	*max 40%*
Max. Impervious Coverage	*6A.2.2*	*max 70%*
Special Density/ Intensity Measures for this Distri	*N/A*	

2.c. ZONING - PARKING/DRIVEWAY REQUIREMENTS

Rules and Regulations - Chapter 3.00 Site Plan (3.08) Figures for Parking lot requirements

	Section/Page	Required
Location		
Parking in Front of building	*5.1.3.A*	*paved area covers max. of 25% of front yard*
Dimensional Requirements		
Regular Space	*Design Review Guidelines, 3.E*	*9' W x 18' L*
Aisles	*Design Review Guidelines, 3.E*	*100' of maneuvering area required for a parking lot*
Handicap Spaces	*5.1.3.C*	*Planning Board adopts dimensional standards reflecting current vehicle sizes*
Number of Spaces	*6A.3.1*	
Transportation Demand management (TDM)		
Ridesharing services	*Design Review Guidelines, 3.E*	*strongly encouraged*
Parking Lot		
Less than 180' W or 180' L		
Less than 10,000 sf	*5.1.3.A*	*encouraged to utilize onsite drainage system*
Landscaped Areas		
Pervious Landscaped Island	5.3.3	*min 2% of interior area of parking lots*
Parking Setbacks (feet)	*Design Review Guidelines, 3.E*	*10' W min.*
Construction (Parking Lot, loading dock, driveways)		
bit conc	*5.1.3*	*2" bit conc top course*
Striping		
Curbing	*5.1.3*	*no striping needed*
Driveways/Curb Cut Locations		
Entrance/Exit/Driveway	*5.1.3*	*12' max. width, min 20' to intersecting street*
Distances between driveways	*5.1.3*	*250' on arterial streets, 150' on other streets*

2.e. ZONING - LIGHTING REQUIREMENTS

	Section/Page	
Access Road/Parking	*5.4.3*	*See bylaw section for maximum luminaire mounting height for each type of light fixture*
Walkway	*5.4.3*	
Type	*5.4.3*	
Bollards	*5.4.3*	

2.g. ZONING - LANDSCAPE TREATMENT

	Section/Page	
Minimums		
Deciduous shade trees	*5.3.2*	*2.5" caliper*
Deciduous ornamental trees	*5.3.2*	*2.5" caliper*
Evergreen	*5.3.2*	*5' height*
Shrubs	*5.3.2*	*5' height, 1 shrub per 3 feet planting area*
Setback		
6" minimum caliper within 25' of street	*5.3.5*	*shall be preserved*
building structures, roadways, paved areas	*5.3.3*	*min. of one tree and four shrubs must be planted for every 3,500 SF of parking lot*
Tree replacement	*5.3.2*	
min deciduous	*5.3.2*	*2.5" caliper*
min evergreen	*5.3.2*	*5' height*

2.h. ZONING - PLAN SUBMISSION REQUIREMENTS

	Section/Page	Rules and Regulations - 974 CMR 3.00 Site Plan
Refer to rules and regulations for list fo requirements		

2.i. ZONING - MISC. REQUIREMENTS	
	Section/Page
Signs (setbacks, size, free-standing, etc.)	***Belmont Zoning By-laws, section 5.2***
Earth Removal	***Belmont Zoning By-laws, section 6.2***
Aquifer/Groundwater Protection/Floodplain/Overlay/etc. Districts	***Floodplain district: Belmont Zoning By-laws, sections 2.4 and 6.6***
Other	

Appendix C: GIS Analysis

MassGIS Data Layers

Layer Name	Layer Description	Purpose in Project
EOTROADS_ARC	Public and private roads in Massachusetts including Interstate, U.S. and State highways.	These layers show all roadways and provide a more accurate location of the project site.
PRIHAB_POLY	Includes Priority Habitats of state-listed rare species documented within the last 25 years in the Natural Heritage & Endangered Species Program (NHESP) database	This layer shows areas that may be subject to review by NHESP for compliance with the MA Endangered Species Act before development may proceed.
MAJPOND_POLY	Includes large water bodies and rivers according to the United States Geological Survey	This layer shows major wetlands that limit where development may occur
watshdp1	Includes the extents of the major watersheds of Massachusetts by name	This layer shows the relevant watersheds to the project and shows water bodies stormwater runoff may travel to
WETLANDSDEP_POLY	Includes wetlands such as open water, marshes, swamps, tidal flats identified by the Massachusetts DEP	This layer shows wetland areas that may be vulnerable to stormwater runoff and need mitigation efforts to protect them
SOILS_POLY	Includes geographic soil data such as soil slopes and soil type	This layer helps determine susceptibility to erosion
AQUIFERS_POLY	Includes underground water sources of high and medium yield	This layer maps aquifers that may be impacted by stormwater runoff from the project site
TOMNSURVEY_POLY	Includes Massachusetts town boundaries	This layer provides an outline of town boundaries to easily locate Belmont and the project site
hp26	Includes contour lines for a specific selection of Belmont (data layer created with MassGIS Oliver)	This layer provides elevation information to help determine the flow of stormwater runoff
FEMA_NFHL_POLY	The National Flood Hazard Layer provides current flood risk data	This layer locates FEMA flood zone designations for an area

	geographically from the Federal Emergency Management Agency	(1% annual chance of flooding and regulatory floodways)
PVP_PT	Identifies locations of potential, unverified, vernal pool habitats	This layer shows potential vernal pools to avoid interference
GISDATA_CVP_PT	Includes locations of certified vernal pool habitats	This layer shows certified vernal pools to avoid interference
acecs_poly	Identifies areas of critical environmental concern (ACEC)	This layer shows ACEC to avoid interference with them
ORW_POLY	Identifies waters that have outstanding resource waters protection	This layer shows waters that are given ORW protection by MA surface water quality standards
CSTZONE_POLY	Identifies Massachusetts coastal zones	This layer shows the coastal zone to avoid interference
AUL_PT	Identifies locations of oil or hazardous material release or disposal sites where an Activity and Use Limitation (AUL) has been filed	This layer show where oil contamination is present. AUL is a document that explains what uses are and are not allowed on these properties
BWP_PT_UST	Identifies locations of underground storage tanks	Underground storage tanks contain regulated substances (sometimes hazardous) and need to be avoided in construction
SW_LD_POLY	Identifies locations of solid waste landfills, dumping grounds, and other facilities	This layer shows areas to avoid constructing on due to the presence of solid waste facilities
ZONE2_POLY	Identifies Approved Wellhead Protection Areas (Zone 2)	Wellhead protection areas are important for protecting recharge areas around public water supply groundwater sources.

GIS Site Constraints Checklist

Stantec

Stantec Consulting Inc
226 Causeway Street
Boston, MA 02114

Project:
Date:

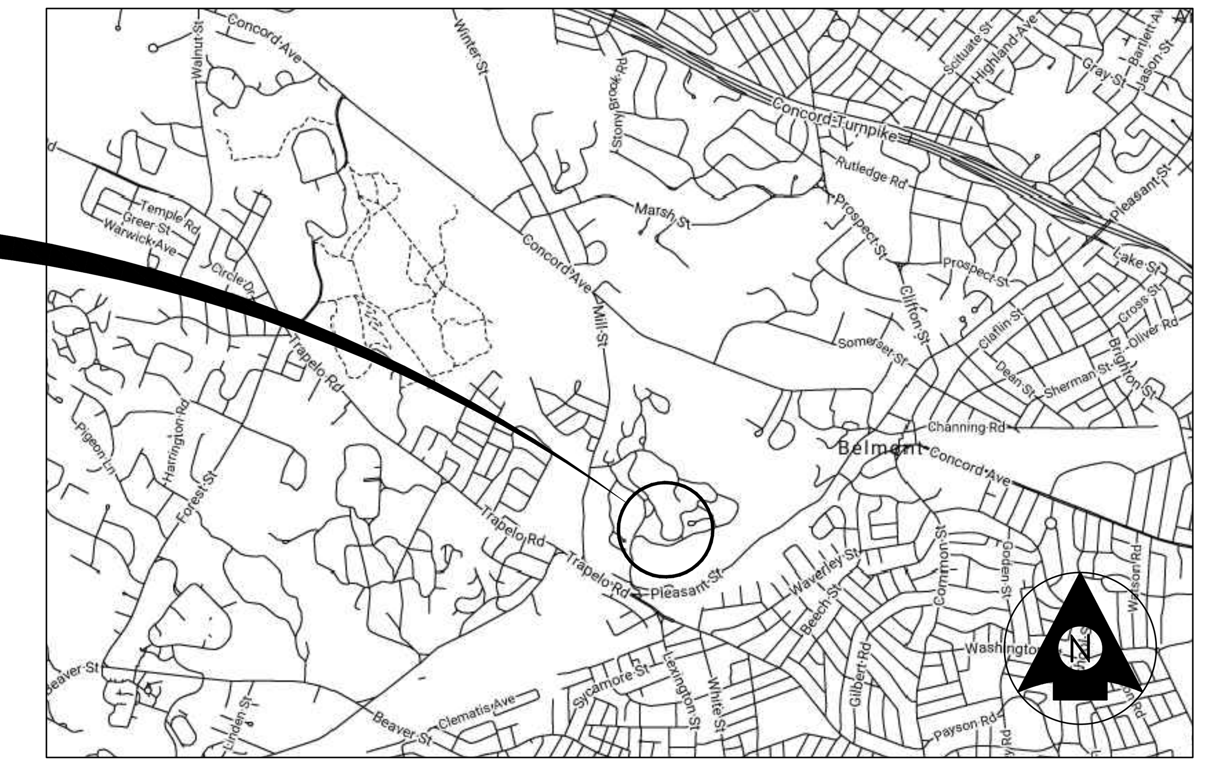
Site Constraints Checklist (Massachusetts)

			Y/N	Comments
1. Flood Zone				
	a)	100 Year Flood Zone	N	
	b)	100 Year Velocity Zone	N	
	c)	Floodway Zone	N	
2. NHESP Map				
	a)	NHESP Potential Vernal Pool	N	
	b)	NHESP Certified Vernal Pool	N	
	c)	NHESP Estimated Habitat of Rare Wildlife	N	
	d)	NHESP Priority Habitat of Rare Species	N	
3. Resource Area				
	a)	The Areas of Critical Environmental Concern (ACEC)	N	
	b)	Outstanding Water Resource	N	
4. Hydrology				
	a)	River, Stream, Brook etc.	N	
	b)	Intermittent Stream	N	
	c)	Wetlands	N	
5. Coastal Area				
	a)	Coastal Zone	N	
	b)	Barrier Beaches	N	
	c)	Chapter 91 - Tidelands Jurisdiction (Historic High Water and Historic Low Water)	N	
	d)	Anadromous Fish Runs	N	
	e)	Shellfish Growing Area	N	
6. Water Resource Area				
	a)	Zone II Wellhead Protection Area	N	
	b)	Surface Water Protection Zone A, B, C	N	
	c)	Interim Wellhead Protection Area	N	
	d)	Sole Source Aquifer	N	
	c)	Aquifer	N	
7. Historic Places				
	a)	State Register of Historic Places	N	
	b)	State Register of Historic Places Regions	N	
8. Solid Waste/Hazardous Materials				
	a)	Underground Storage Tanks	N	
	b)	Limits of Solid Waste Facility	N	
	c)	Landfills	N	
	d)	DEP Oil or Hazardous Material Sites	N	
	e)	Integrated List of Impaired Waters	N	
	f)	DEP Oil and/or Hazardous Material Sites with Activity and Use Limitations	N*	* directly south of project there is an AUL s
9. Check the other resources				
	a)	Town GIS Info		
	b)	FEMA web site		

Appendix D: Project Plan Set

Stantec

PROJECT LOCATION



LOCUS PLAN

NOT TO SCALE

SPECIAL PERMIT PLAN SET

MCLEAN HOSPITAL
PROPOSED SENIOR RESIDENCES

BELMONT, MASSACHUSETTS

SPONSOR

STANTEC
226 CAUSEWAY STREET
BOSTON, MA 02114
617.523.8103

PRODUCED BY

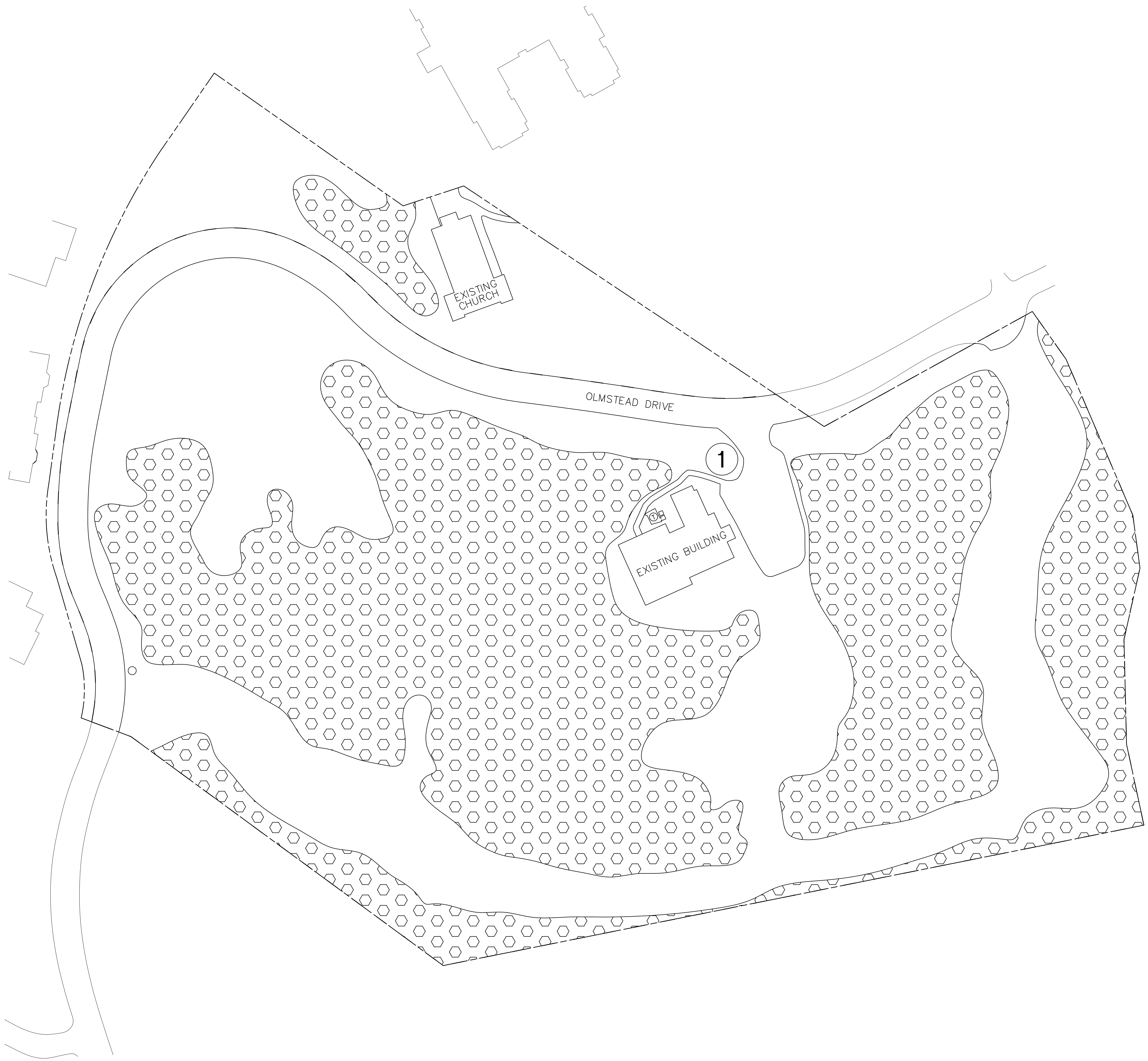
WORCESTER POLYTECHNIC INSTITUTE
MAJOR QUALIFYING PROJECT MEMBERS
MARISSA BERNARD
CIERRA FORD
KAYLA SALMON

DRAWING INDEX

ZONING DATA - SRB

REQUIREMENTS	ALLOWED/ REQUIRED BY ZONING	PROPOSED
SENIOR LIVING FACILITY		
MAXIMUM RESIDENTIAL DENSITY	480 UNITS	299 UNITS
LOT SIZE (ACRES)	12.83	
MINIMUM PARKING REQUIREMENT	25% FRONT MAX.	
SETBACKS FROM PROPERTY LINES (FEET)		
FRONT	10'	
REAR	10'	
SIDE	10'	
PARKING DIMENSIONAL REQUIREMENTS		
REGULAR SPACE	9' W x 18' L	
AISLES	100'	
MINIMUM IMPERVIOUS COVERAGE	70%	
MAXIMUM BUILDING COVERAGE	40%	
MAXIMUM HEIGHT	58'	
STORIES	5	
EXCEMPTIONS	67' AS APPROVED	

*(ALL BUILDINGS, STRUCTURES AND PAVED AREAS BUT EXCLUDING
DRIVEWAYS, PARKING, SIDEWALKS AND LANDSCAPED PARKING LOT ISLANDS)

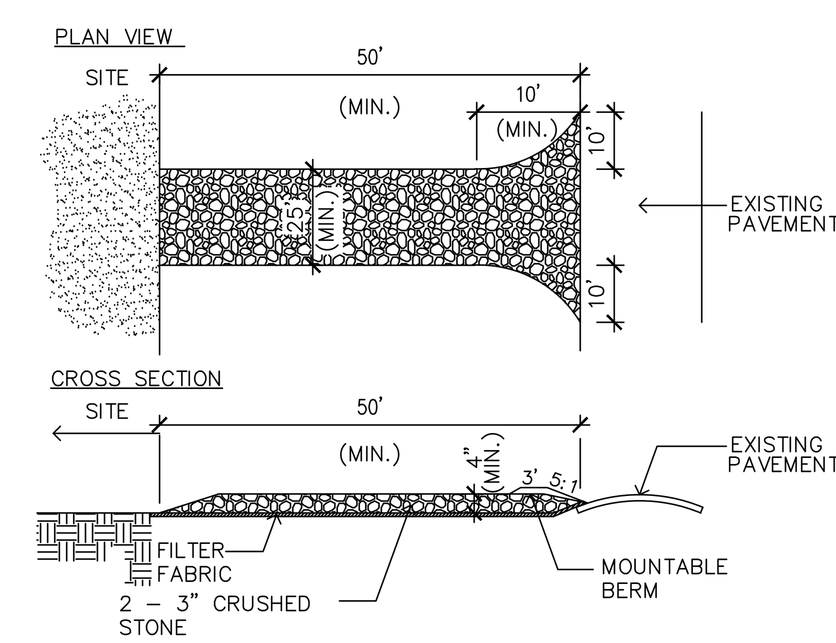


SITE PREPARATION NOTES

1. EXISTING TOPOGRAPHIC INFORMATION IS REPRODUCED FROM AN SURVEY PROVIDED BY THE CITY OF BELMONT.
2. WITHIN THE LIMIT OF THE WORK LINE AS NOTED, REMOVE AND DISCARD ALL CONCRETE PAVEMENT, TOP SOIL, TRASH, TREES AND STUMPS, SHRUBBERY, CONCRETE TRANSFORMERS, GRAVEL, EXISTING BUILDINGS, WALLS AND CURBS UNLESS OTHERWISE NOTED.
3. THE OWNER'S REPRESENTATIVE SHALL BE CONSULTED AND WILL REVIEW THE LIMIT OF WORK LINE ON SITE WITH THE CONTRACTOR BEFORE ANY WORK SHALL COMMENCE.
4. THE CONTRACTOR SHALL VERIFY ALL EXISTING CONDITIONS IN THE FIELD AND REPORT ANY DISCREPANCIES BETWEEN PLANS AND ACTUAL CONDITIONS TO THE OWNER'S REPRESENTATIVE PRIOR TO STARTING WORK.
5. THE CONTRACTOR IS RESPONSIBLE FOR ANY DAMAGE TO EXISTING CONDITIONS TO REMAIN THAT ARE DUE TO CONTRACTOR OPERATIONS.
6. ALL ITEMS TO BE REMOVED THAT ARE NOT STOCKPILED FOR LATER REUSE ON THE PROJECT OR DELIVERED TO THE OWNER SHALL BE LEGALLY DISPOSED OF OFF SITE BY THE CONTRACTOR.
7. THE LOCATIONS OF UNDERGROUND UTILITIES SHOWN ON THIS PLAN ARE BASED ON THE SURVEY REFERENCED ABOVE. THE CONTRACTOR SHALL CONTACT DIGSAFE AND THE PROPER LOCAL AUTHORITIES OR RESPECTIVE UTILITY COMPANIES TO CONFIRM THE LOCATION OF ALL EXISTING UTILITIES BEFORE COMMENCING WORK. ANY DAMAGE DUE TO FAILURE OF THE CONTRACTOR TO CONTACT THE PROPER AUTHORITIES SHALL BE BORNE BY THE CONTRACTOR.
8. THE CONTRACTOR SHALL BE RESPONSIBLE FOR COORDINATING HIS EFFORTS OF THE DEMOLITION WITH ALL TRADES.
9. THE CONTRACTOR SHALL COORDINATE ALL ADJUSTMENT OR ABANDONMENT OF UTILITIES WITH THE RESPECTIVE UTILITY COMPANY.
10. THE CONTRACTOR SHALL MAINTAIN OR ADJUST TO NEW FINISH GRADE AS NECESSARY ALL UTILITY AND SITE STRUCTURES SUCH AS LIGHT POLES, SIGN POLES, MAN HOLES, CATCH BASINS. HAND HOLES, WATER AND GAS GATES, HYDRANTS, ETC., FROM MAINTAINED UTILITY AND SITE SYSTEMS UNLESS OTHERWISE NOTED OR DIRECTED BY THE OWNER'S REPRESENTATIVE.
11. TRAILER, STOCKPILES, AND STAGING AREAS ARE RECOMMENDED AREAS. FINAL LOCATIONS WILL BE DETERMINED BY THE MEANS AND METHODS SELECTED BY THE CONSTRACTOR. VARIATIONS FROM THIS PLAN SHALL BE REVIEWED WITH THE OWNER'S REPRESENTATIVE PRIOR TO IMPLEMENTATION.
12. CONTRACTOR SHALL COORDINATE WITH THE BELMONT BOARD OF HEALTH FOR THE REMOVAL OF THE EXISTING SEPTIC SYSTEM AND ALL CONNECTIONS.

GENERAL CONSTRUCTION SEQUENCE

1. CONSTRUCT TEMPORARY AND PERMANENT EROSION CONTROL FACILITIES. EROSION CONTROL FACILITIES SHALL BE INSTALLED PRIOR TO ANY EARTHMOVING.
2. ALL PERMANENT DITCHES AND SWALES ARE TO BE STABILIZED WITH VEGETATION OR RIP-RAP PRIOR TO DIRECTING RUNOFF TO THEM.
3. CLEAR CUT, DEMOLISH, AND DISPOSE OF EXISTING SITE ELEMENTS NOT TO REMAIN.
4. GRADE AND GRAVEL ALL PAVED AREAS. ALL PROPOSED PAVED AREAS SHALL BE STABILIZED IMMEDIATELY AFTER GRADING.
5. BEGIN ALL PERMANENT AND TEMPORARY SEEDING AND MULCHING. ALL CUT AND FILL SLOPES SHALL BE SEEDED AND MULCHED IMMEDIATELY AFTER THEIR CONSTRUCTION.
6. DAILY, OR AS REQUIRED, CONSTRUCT TEMPORARY BERMS, DRAINS, DITCHES, SILT FENCES; MULCH AND SEED AS REQUIRED.
7. FINISH PAVING ALL HARD SURFACE AREAS.
8. INSPECT AND MAINTAIN ALL EROSION AND SEDIMENT CONTROL MEASURES.
9. COMPLETE SODDING, PERMANENT SEEDING AND LANDSCAPING.
10. REMOVE TEMPORARY EROSION CONTROL MEASURES UPON PERMANENT STABILIZATION OF THE SITE.
11. THE CONSTRUCTION SEQUENCE SHALL BE CONFINED TO THE LIMIT OF GRADING AS SHOWN ON THE DRAWINGS.
12. UPON COMPLETION OF CONSTRUCTION THE OWNER SHALL AGREE TO MAINTAIN AND CLEAN ALL DRAINAGE STRUCTURES PER THE OPERATION AND MAINTENANCE PLAN.



NOTES:

1. ENTRANCE WIDTH SHALL BE A TWENTY-FIVE (25) FOOT MINIMUM, BUT NOT LESS THAN THE FULL WIDTH AT POINTS WHERE INGRESS OR EGRESS OCCURS.
2. THE ENTRANCE SHALL BE MAINTAINED IN A CONDITION WHICH SHALL PREVENT TRACKING OR FLOWING OF SEDIMENT ONTO PUBLIC RIGHTS-OF-WAY. THIS MAY REQUIRE PERIODIC TOP DRESSING WITH ADDITIONAL STONE AS CONDITIONS DEMAND AND REPAIR OR CLEANOUT OF ANY MEASURES USED TO TRAP SEDIMENT. ALL SEDIMENT SPILLED, DROPPED, WASHED OR TRACKED ONTO PUBLIC RIGHTS-OF-WAY MUST BE REMOVED IMMEDIATELY. BERM SHALL BE PERMITTED. PERIODIC INSPECTION AND MAINTENANCE SHALL BE PROVIDED AS NEEDED.

1 **STABILIZED CONSTRUCTION ENTRANCE**

SCALE: NTS

NORTH

0 20' 40' 80'

Stantec

226 Causeway Street
Boston, MA 02114
Tel. 617.523.8103
www.stantec.com

WORCESTER POLYTECHNIC INSTITUTE 1865 WPI

LEGEND

(hatch)	EXISTING BUILDING TO BE REMOVED
(circles)	EXISTING FOREST TO BE REMOVED
(stipple)	EXISTING CONCRETE TO BE REMOVED
— — — —	PROPERTY LINE
—— ——	LIMIT OF WORK

Notes

Issued | By | Appd. | MM.DD.YY

File Name: | Dwn. | Chkd. | Dsgn. | MM.DD.YY

Permit-Seal

Client/Project

MCLEAN

BELMONT, MA

Title

SITE CONDITIONS

Project No. | Scale AS NOTED

SP-101

Drawing No.

02/12/2018

Stantec
226 Causeway Street
Boston, MA 02114
Tel. 617.523.8103
www.stantec.com

WPI

Notes

Issued | By | Appd. | MM.DD.YY

File Name: | Dwn. | Chkd. | Dsgn. | MM.DD.YY

Permit-Seal

Client/Project

MCLEAN

BELMONT, MA

Title

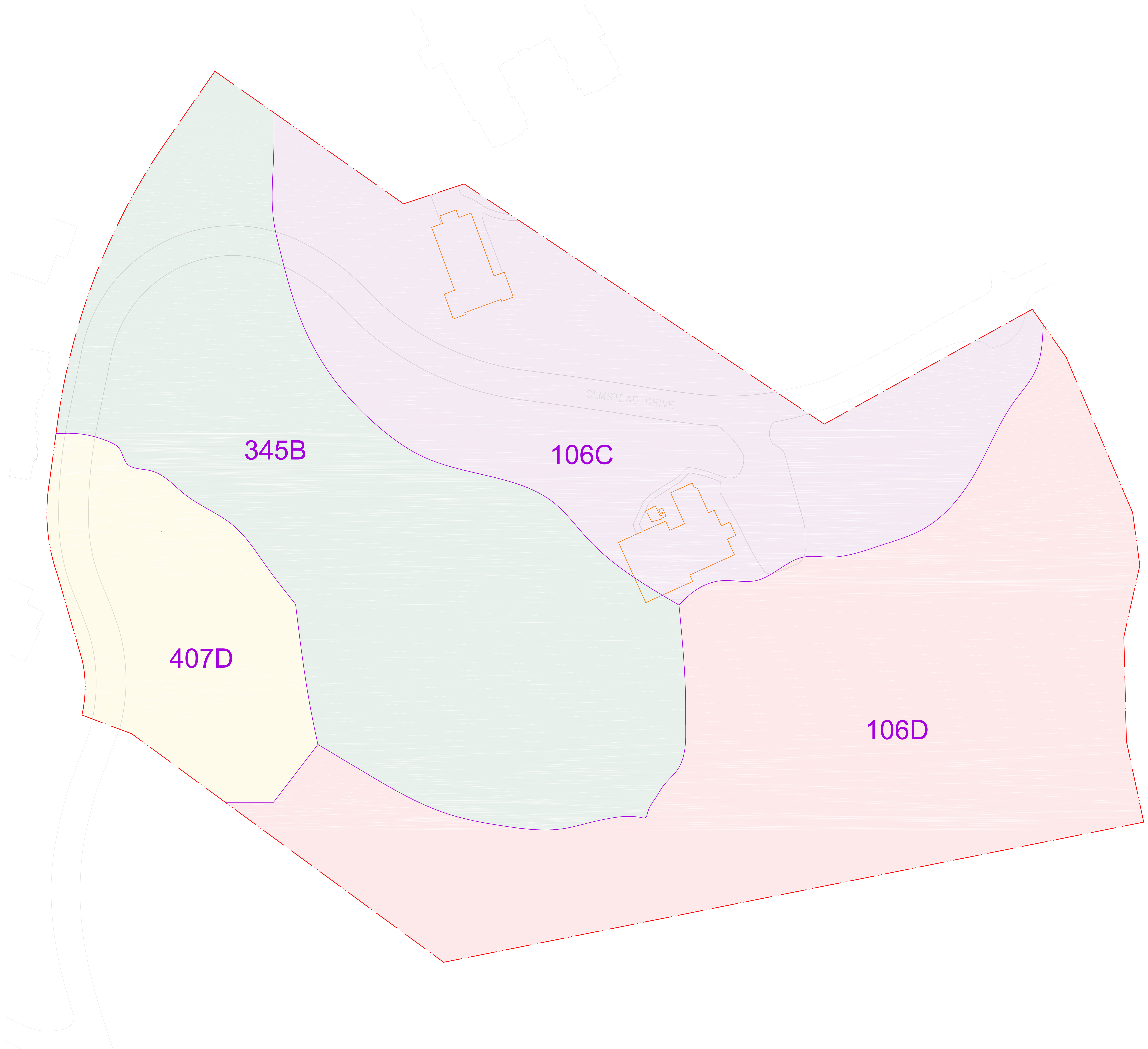
TOPOGRAPHIC SURVEY

Project No.

Scale
AS NOTED

SP-201
Drawing No.

02/08/2018



LEGEND:

345B Pittstown silt loam (makes up 28.5 percent of site)

- 3 to 8 percent slope
- Pittstown and similar soils: 85 percent
- Minor components: 15 percent
- Typical profile:
  - H1 – 0 to 2 inches: silt loam
  - H2 – 2 to 17 inches: silt loam
  - H3 – 17 to 65 inches: channery silt loam
- 15 to 30 inches to densic material
- Moderately well drained
- About 18 to 36 inches to water table
- Hydrologic Soil Group D

407D Charlton fine sandy loam (makes up 9 percent of site)

- 15 to 25 percent slope
- Charlton and similar soils: 85 percent
- Minor components: 15 percent
- Typical profile
  - H1 – 0 to 5 inches: fine sandy loam
  - H2 – 5 to 22 inches: sandy loam
  - H3 – 22 to 65 inches: gravelly sandy loam
- More than 80 inches to restrictive material
- Well drained
- More than 80 inches to water table
- Hydrologic Soil Group A

106C Narragansett–Hollis–Rock outcrop complex

- 3 to 15 percent slope
- Narragansett and similar soils: 45 percent
- Hollis and similar soils: 20 percent
- Rock outcrop: 10 percent
- Minor components: 25 percent

106D Narragansett–Hollis–Rock outcrop complex

- 15 to 25 percent slope
- Narragansett and similar soils: 45 percent
- Hollis and similar soils: 20 percent
- Rock outcrop: 10 percent
- Minor components: 25 percent
- Made up of both Narragansett and Hollis soils and therefore regarded as a B Hydrologic soil for calculation purposes

Narragansett Properties:

- H1 – 0 to 2 inches: slightly decomposed plant material
- H2 – 2 to 7 inches: silt loam
- H3 – 7 to 35 inches: silt loam
- H4 – 35 to 60 inches: very gravelly loamy sand
- H5 – 60 to 65 inches: very gravelly loamy sand
- 18 to 35 inches to strongly contrasting textural stratification
- Well drained
- More than 80 inches to water table
- Hydrologic Soil Group A

Hollis Properties:

- H1 – 0 to 2 inches: fine sandy loam
- H2 – 2 to 14 inches: fine sandy loam
- H3 – 14 to 18 inches: unweathered bedrock
- 8 to 20 inches to lithic bedrock
- Well drained
- More than 80 inches to water table
- Hydrologic Soil Group D

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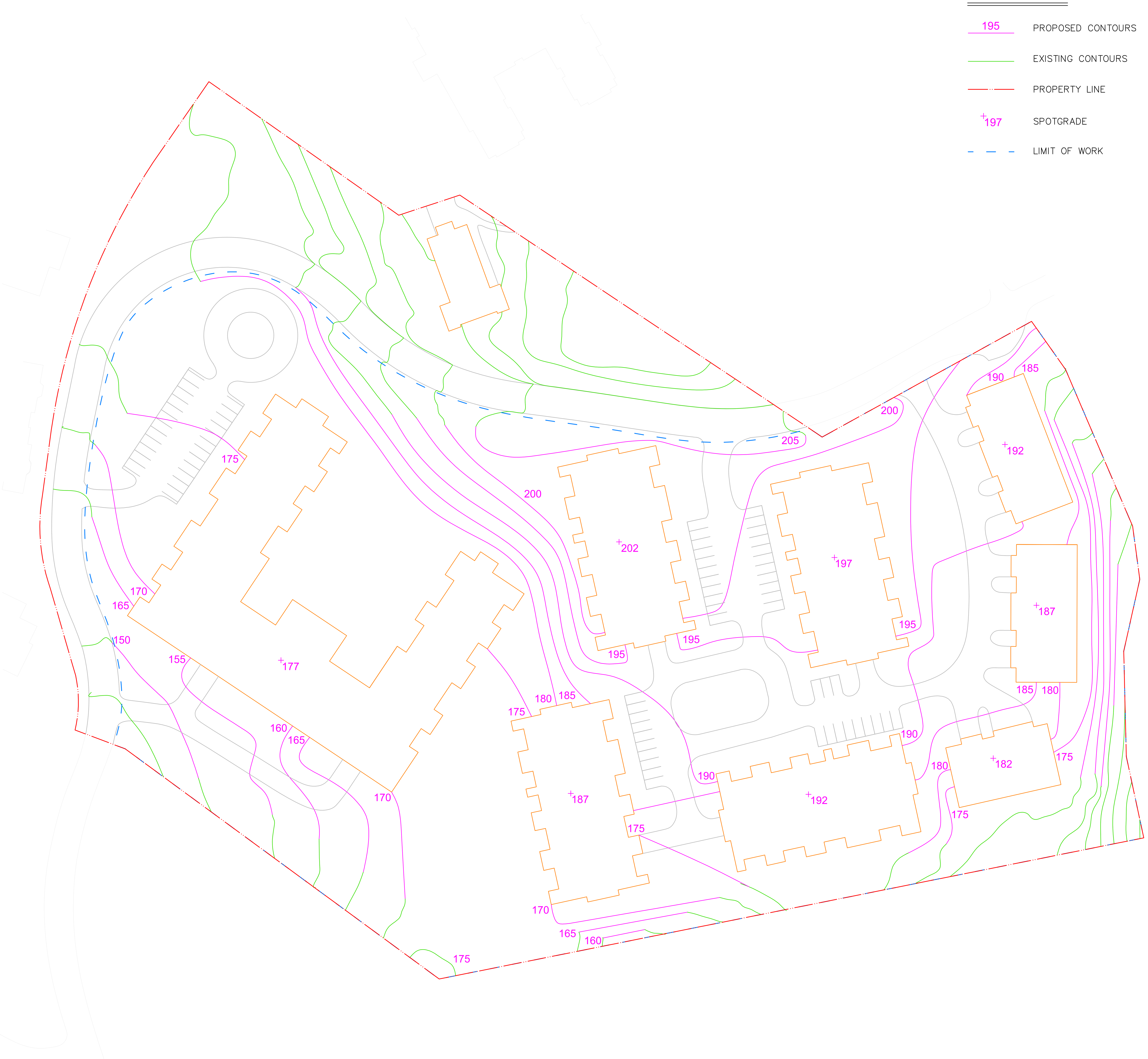
SOILS MAP

Project No. | Scale: AS NOTED

Drawing No. SP-301

02/08/2018

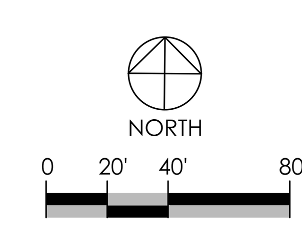


GRADING LEGEND

195	PROPOSED CONTOURS
	EXISTING CONTOURS
	PROPERTY LINE
+197	SPOTGRADE
	LIMIT OF WORK

GRADING NOTES

1. EXISTING TOPOGRAPHIC INFORMATION IS REPRODUCED FROM AN ELECTRONIC SURVEY PROVIDED BY THE CITY OF BELMONT
2. PRIOR TO THE START OF ANY EXCAVATION FOR THE PROJECT, BOTH ON AND OFF THE SITE, THE CONTRACTOR SHALL NOTIFY DIGSAFE AND BE PROVIDED WITH A DIGSAFE NUMBER INDICATING THAT ALL EXISTING UTILITIES HAVE BEEN LOCATED AND MARKED.
3. WHERE PROPOSED GRADES MEET EXISTING GRADES, CONTRACTOR SHALL BLEND GRADES TO PROVIDE A SMOOTH TRANSITION BETWEEN EXISTING AND NEW WORK. PONDING AT TRANSITION AREAS WILL NOT BE ALLOWED.
4. CONTRACTOR SHALL MAINTAIN POSITIVE DRAINAGE AWAY FROM ALL BUILDING FOUNDATIONS, STRUCTURES AND PLANTING BEDS.
5. MAXIMUM SLOPE IN DISTURBED AREAS SHALL NOT EXCEED 3:1, UNLESS OTHERWISE NOTED.
6. ENSURE ALL EXISTING (TO REMAIN), AND PROPOSED MANHOLE COVERS PROPERLY IDENTIFY UTILITY SERVICED.
7. CONTRACTOR SHALL VERIFY EXISTING GRADES AND NOTIFY OWNER'S REPRESENTATIVE OF ANY DISCREPANCIES.
8. CONTRACTOR SHALL ADJUST UTILITY ELEMENT MEANT TO BE FLUSH WITH GRADE (CLEAN-OUTS, UTILITY MANHOLES, CATCH BASINS, INLETS, ETC) THAT IS AFFECTED BY SITE WORK OR GRADE CHANGES, WHETHER SPECIFICALLY NOTED ON PLANS OR NOT.
9. SCREENED IMAGES SHOW EXISTING CONDITIONS. WHERE EXISTING CONDITIONS LIE UNDER OR ARE IMPINGED UPON BY PROPOSED BUILDINGS AND/OR SITE ELEMENTS, THE EXISTING CONDITION WILL BE REMOVED, ABANDONED AND/OR CAPPED OR DEMOLISHED AS REQUIRED.
10. ALL DISTURBED SOILS TO REMAIN ON SITE, REFER TO GEOTECHNICAL DRAWINGS AND EARTHWORK SPECIFICATION FOR ADDITIONAL INFORMATION.



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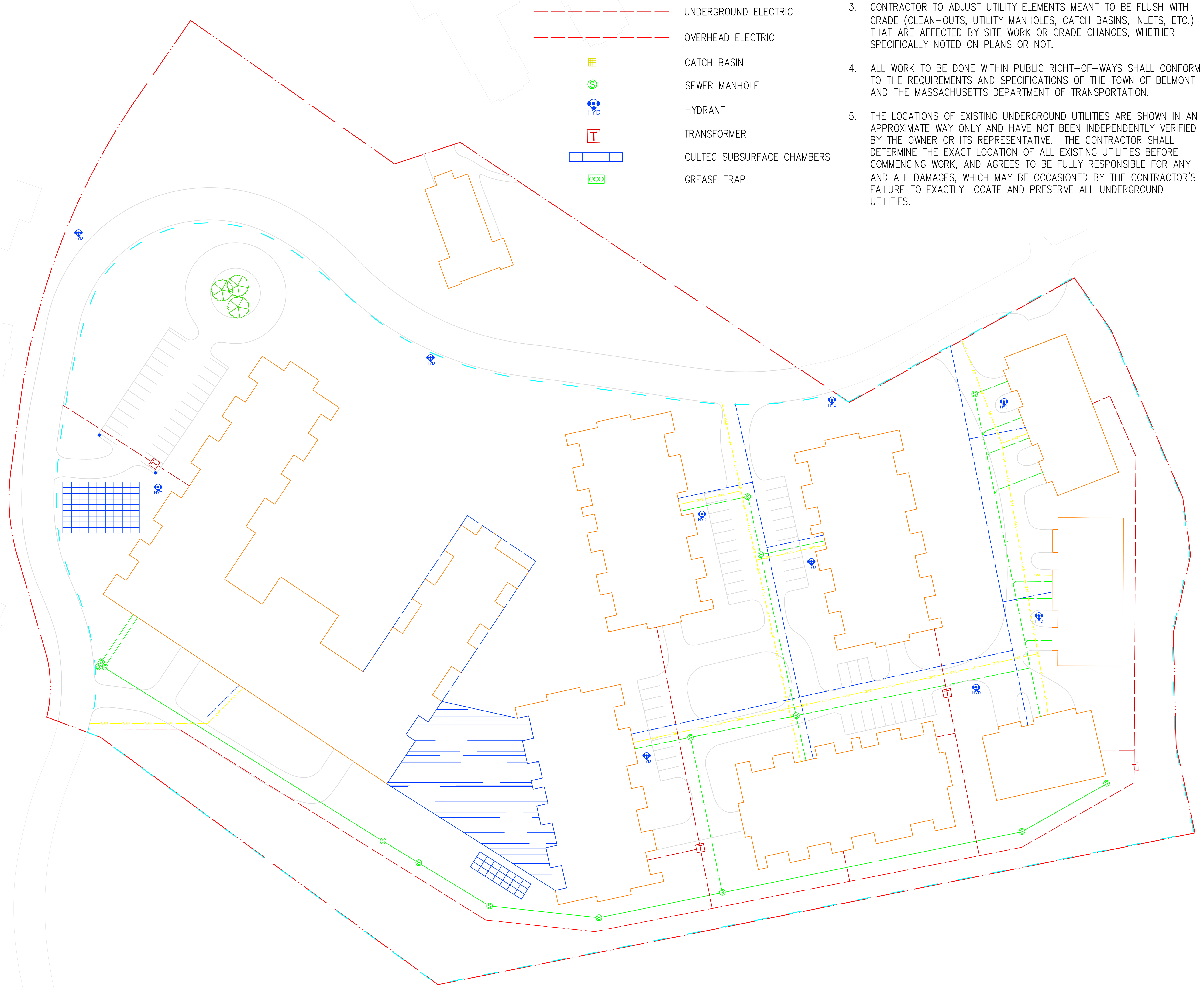
GRADING PLAN

Project No. Scale AS NOTED

L-101

Drawing No.

02/19/2018

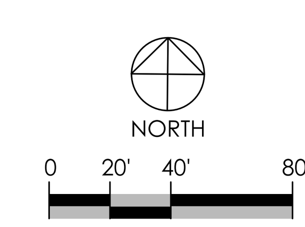


UTILITY LEGEND

- PROPERTY LINE
- LIMIT OF WORK
- SEWER LINE
- WATER LINE
- GAS LINE
- UNDERGROUND ELECTRIC
- OVERHEAD ELECTRIC
- CATCH BASIN
- SEWER MANHOLE
- HYDRANT
- TRANSFORMER
- CULTEC SUBSURFACE CHAMBERS
- GREASE TRAP

UTILITY NOTES

1. EXISTING TOPOGRAPHIC INFORMATION WAS PROVIDED FROM THE TOWN OF BELMONT.
2. PRIOR TO THE START OF ANY EXCAVATION FOR THE PROJECT, BOTH ON AND OFF THE SITE, THE CONTRACTOR SHALL NOTIFY DIGSAFE AND BE PROVIDED WITH A DIGSAFE NUMBER INDICATING THAT ALL EXISTING UTILITIES HAVE BEEN LOCATED AND MARKED.
3. CONTRACTOR TO ADJUST UTILITY ELEMENTS MEANT TO BE FLUSH WITH GRADE (CLEAN-OUTS, UTILITY MANHOLES, CATCH BASINS, INLETS, ETC.) THAT ARE AFFECTED BY SITE WORK OR GRADE CHANGES, WHETHER SPECIFICALLY NOTED ON PLANS OR NOT.
4. ALL WORK TO BE DONE WITHIN PUBLIC RIGHT-OF-WAYS SHALL CONFORM TO THE REQUIREMENTS AND SPECIFICATIONS OF THE TOWN OF BELMONT AND THE MASSACHUSETTS DEPARTMENT OF TRANSPORTATION.
5. THE LOCATIONS OF EXISTING UNDERGROUND UTILITIES ARE SHOWN IN AN APPROXIMATE WAY ONLY AND HAVE NOT BEEN INDEPENDENTLY VERIFIED BY THE OWNER OR ITS REPRESENTATIVE. THE CONTRACTOR SHALL DETERMINE THE EXACT LOCATION OF ALL EXISTING UTILITIES BEFORE COMMENCING WORK, AND AGREES TO BE FULLY RESPONSIBLE FOR ANY AND ALL DAMAGES, WHICH MAY BE OCCASIONED BY THE CONTRACTOR'S FAILURE TO EXACTLY LOCATE AND PRESERVE ALL UNDERGROUND UTILITIES.
6. WHERE AN EXISTING UTILITY IS FOUND TO CONFLICT WITH THE PROPOSED WORK, THE LOCATION, ELEVATION, AND SIZE OF THE UTILITY SHALL BE ACCURATELY DETERMINED WITHOUT DELAY BY THE CONTRACTOR, AND THE INFORMATION FURNISHED TO THE ENGINEER FOR RESOLUTION OF THE CONFLICT.
7. THE CONTRACTOR SHALL ALTER THE MASONRY OF THE TOP SECTION OF ALL EXISTING DRAINAGE STRUCTURES AS NECESSARY FOR CHANGES IN GRADE, AND RESET ALL WATER AND DRAINAGE FRAMES, GRATES, AND BOXES TO THE PROPOSED FINISH SURFACE GRADE.
8. THE CONTRACTOR SHALL MAKE ALL ARRANGEMENTS FOR THE ALTERATION AND ADJUSTMENT OF ALL GAS, ELECTRIC, TELEPHONE, AND ANY OTHER PRIVATE UTILITIES BY THE RESPECTIVE UTILITY COMPANIES.
9. CONTRACTOR SHALL MAINTAIN, OR ADJUST TO NEW FINISH GRADE, AS NECESSARY ALL UTILITY AND SITE STRUCTURES SUCH AS: LIGHT POLES, SIGN POLES, MANHOLES, CATCH BASINS, HAND HOLES, WATER AND GAS GATES, HYDRANTS, ETC., FROM MAINTAINED UTILITY AND SITE SYSTEMS, UNLESS OTHERWISE NOTED OR DIRECTED BY OWNER'S REPRESENTATIVE.
10. ALL SEWER PIPES SHALL BE PVC PER ASTM D3034, SDR-35 AND ASTM D1784 WITH RUBBER GASKET JOINTS.
11. REFER TO ELECTRICAL PLANS FOR SECTIONS AND DETAILS OF THE UTILITY DUCT BANK.
12. AREAS OUTSIDE THE LIMITS OF PROPOSED WORK DISTURBED BY THE CONTRACTOR'S OPERATIONS SHALL BE RESTORED BY THE CONTRACTOR TO THEIR ORIGINAL CONDITION, AT THE CONTRACTOR'S EXPENSE.
13. REFER TO ARCHITECTURAL PLANS FOR PROPOSED LOCATION OF UTILITY SERVICE STUBS AT BUILDING. THE LOCATION, SIZE, DEPTH, AND SPECIFICATIONS FOR CONSTRUCTION OF PRIVATE UTILITY SERVICES SHALL BE INSTALLED ACCORDING TO THE REQUIREMENTS PROVIDED BY, AND APPROVED BY, THE RESPECTIVE UTILITY COMPANY (GAS, TELEPHONE, ELECTRICAL).
14. FINAL DESIGN AND LOCATIONS AT THE BUILDING WILL BE PROVIDED BY THE ARCHITECT. THE CONTRACTOR SHALL COORDINATE THE INSTALLATION OF THE UTILITY CONNECTIONS WITH THE RESPECTIVE COMPANIES PRIOR TO ANY UTILITY CONSTRUCTION.
15. ALL CEMENT LINED DUCTILE IRON JOINTS AT FITTINGS (CLASS 52,) VALVES, AND HYDRANT LATERALS SHALL BE MECHANICAL JOINT WITH NEOPRENE GASKETS. JOINTS AT OTHER LOCATIONS SHALL BE PUSH-ON TYPE WITH NEOPRENE OR SYNTHETIC RUBBER GASKETS.
16. ALL WATER GATES SHALL OPEN AS PER TOWN WATER DEPARTMENT REQUIREMENTS.
17. ALL WATER LINES SHALL HAVE A MINIMUM OF 5.0 FEET OF GROUND COVER AND A MINIMUM OF 10 FOOT SEPARATION FROM THE SEWER SYSTEM. AT WATER AND SEWER CROSSINGS, THE WATER LINE SHALL BE ENCASED IN SIX INCHES OF CONCRETE FOR A DISTANCE OF 10 FEET ON EITHER SIDE OF THE CROSSING PROTECT AND MAINTAIN EXISTING ON-SITE UTILITY STRUCTURES AND PIPES UNLESS OTHERWISE NOTED.
18. CONTRACTOR SHALL PROTECT ALL STORMWATER INFRASTRUCTURE FROM EROSION AND SEDIMENT UNTIL THE PROJECT SITE HAS REACHED PERMANENT STABILIZATION BY THE OWNERS REPRESENTATIVE. IN THE EVENT SEDIMENT DOES ENTER THE STORMWATER SYSTEM THE CONTRACTOR SHALL CLEAN AND REMOVE ALL SEDIMENT.
19. ALL DRAINAGE PIPE SHALL BE 12" HDPE UNLESS OTHERWISE NOTED.
20. ALL SEWER MANHOLES WITH AN INTERIOR DROP SHALL HAVE A 5-FOOT INSIDE DIAMETER.
21. ALL STRUCTURES SHALL BE DESIGNED TO ACCOUNT FOR BUOYANCY. CONTRACTOR SHALL PROVIDE STAMPED ANTI-BUYOUANCY CALCULATIONS FOR ALL STRUCTURES TO THE OWNERS REPRESENTATIVE FOR REVIEW PRIOR TO ORDERING.
22. ALL PIPING WITHIN 10 FEET OF THE BUILDING FOUNDATION SHALL BE INSTALLED PER PLUMBING CODE.



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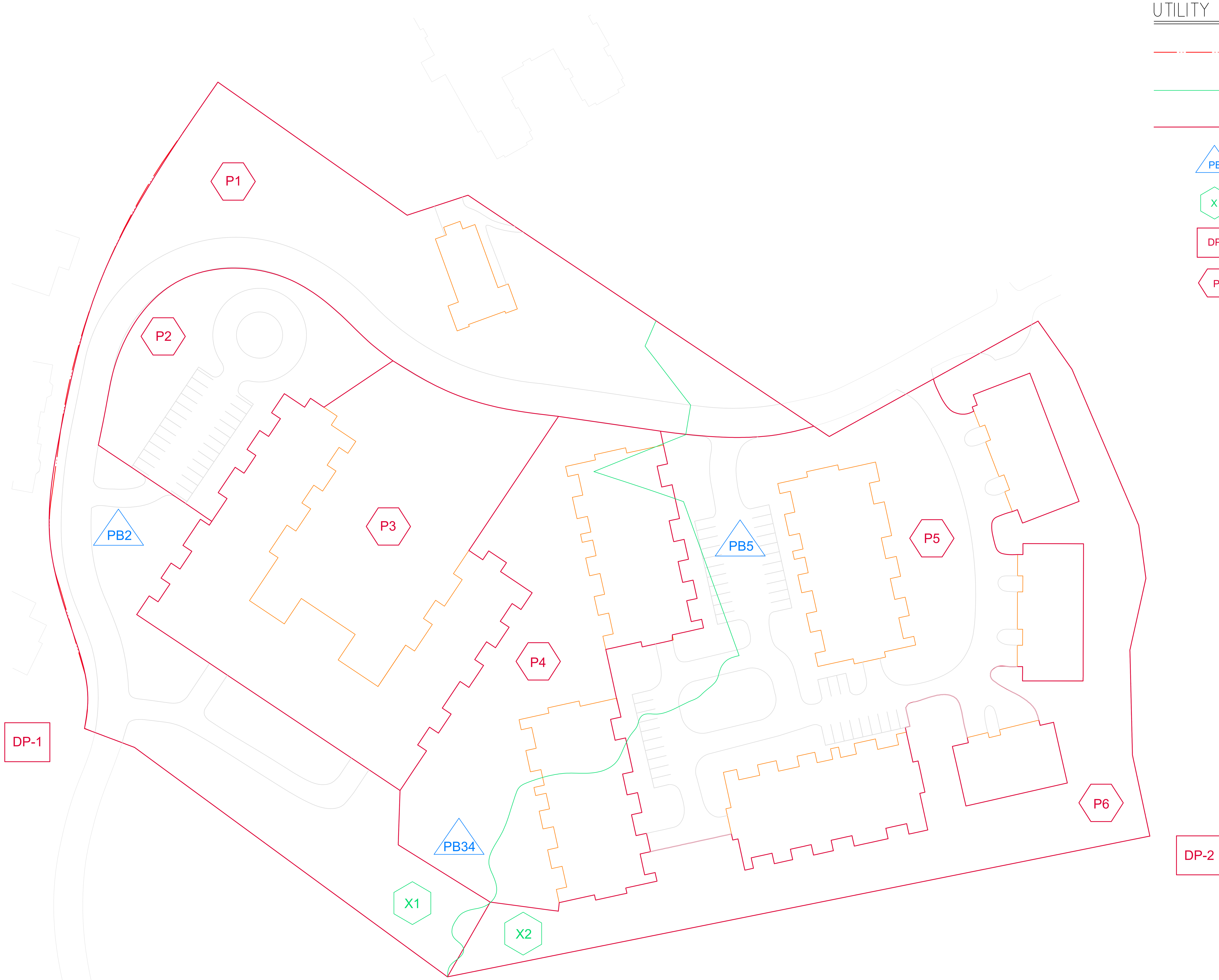
UTILITY PLAN

Project No. | Scale AS NOTED

L-201

Drawing No.

02/08/2018



UTILITY LEGEND

(red dash-dot line)	PROPERTY LINE
(green line)	PRE-DEVELOPMENT SUBCATCHMENT LINE
(red line)	POST-DEVELOPMENT SUBCATCHMENT LINE
PB	BMP
X	PRE-DEVELOPMENT SUBCATCHMENT
DP	DESIGN POINT
P	POST-DEVELOPMENT SUBCATCHMENT

NORTH

0 20' 40' 80'

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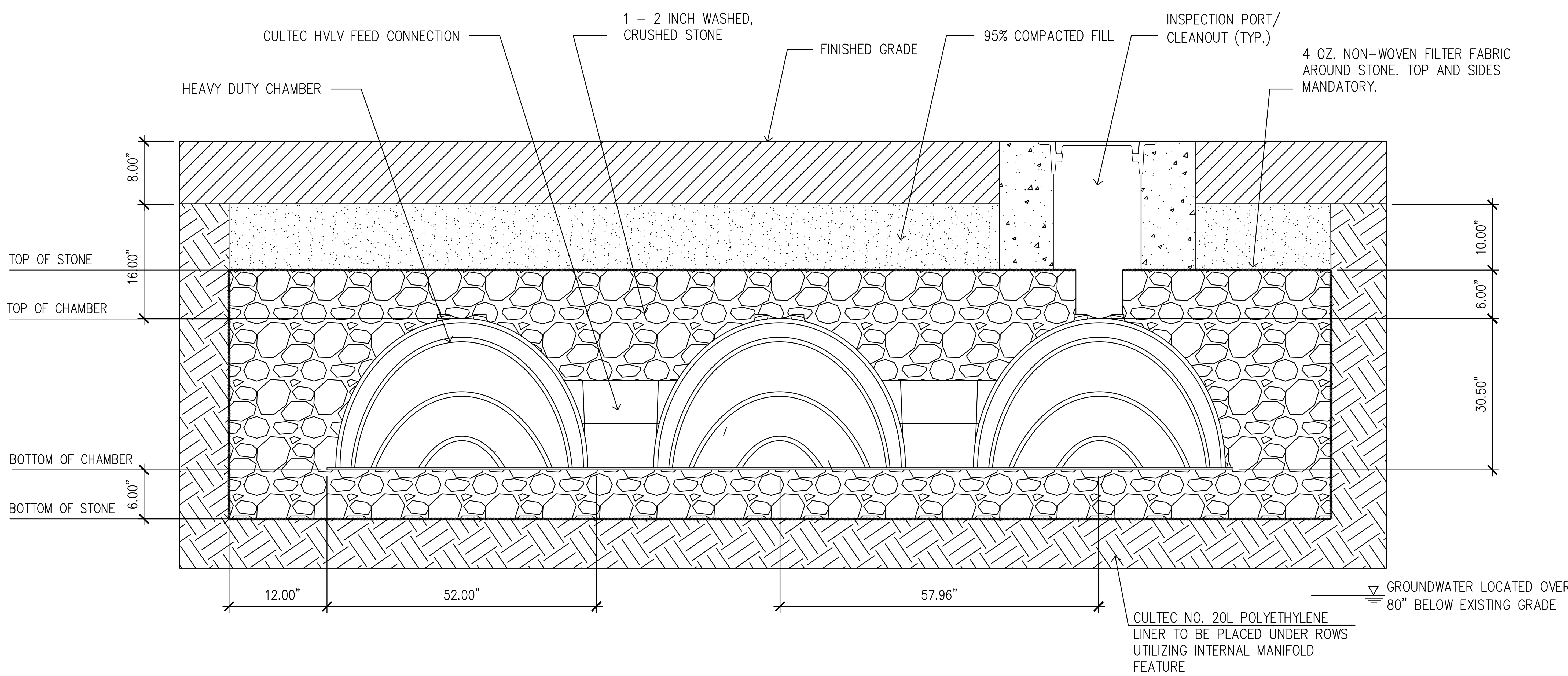
SUBCATCHMENTS

Project No.

Scale: AS NOTED

Drawing No.: L-301

02/25/2018



1 **SUBSURFACE CHAMBER**

SCALE: N.T.S.

1) THE CONTRACTOR SHALL NOTIFY AND COORDINATE WITH THE OWNER'S REPRESENTATIVE FOR AN INSPECTION OF THE SUBGRADE OF THE SUBSURFACE CHAMBERS ON SITE AFTER ALL REQUIRED EXISTING SOIL MATERIAL HAS BEEN REMOVED AS INDICATED ON THE PLANS. THE CONTRACTOR SHALL PROVIDE A MINIMUM OF 72 HOURS NOTICE OF THE EXPECTED TIME THAT THE SUBGRADE WILL BE READY FOR INSPECTION TO THE OWNER'S REPRESENTATIVE. AT THE TIME OF THE OWNER'S REPRESENTATIVE INSPECTION, THE CONTRACTOR SHALL HAVE AVAILABLE FOR REVIEW ALL SOIL MATERIALS REQUIRED TO COMPLETE THE CONSTRUCTION OF THE INFILTRATION BASINS.

2) THE CONTRACTOR SHALL TAKE CARE TO AVOID COMPACTION OF SUBGRADE SOILS BELOW THE LIMITS OF THE PROPOSED SUBSURFACE SYSTEM. TRACK–MOUNTED EQUIPMENT ONLY SHALL BE USED WITHIN THE LIMITS OF THE PROPOSED SUBSURFACE SYSTEM. AT THE COMPLETION OF THE SUBGRADE PREPARATION, AND PRIOR TO PLACEMENT OF BOTTOM LAYER OF FILTER FABRIC AND DRAINAGE STONE, THE OWNER'S REPRESENTATIVE SHALL INSPECT THE BASIN AND WILL REQUIRE THAT THE TOP 12" OF SOIL MATERIAL BE LOOSENED BY HARROWING IF THE SOILS HAVE BEEN COMPACTED IN THE OPINION OF THE OWNER'S REPRESENTATIVE.

3) IN AREAS OF PROPOSED FILL MATERIAL PLACED WITHIN 4FEET OF THE BOTTOM OF THE SYSTEM. THE FILL SHALL MEET THE FOLLOW GRADATION: CONTRACTOR SHALL PROVIDE A SIEVE ANALYSIS TO THE OWNERS REPRESENTATIVE PRIOR TO PLACEMENT OF FILL MATERIAL.

4) ALL RECHARGER 330XLHD HEAVY DUTY UNITS ARE MARKED WITH A COLORED STRIPE FORMED INTO THE PART ALONG THE LENGTH OF THE CHAMBER.

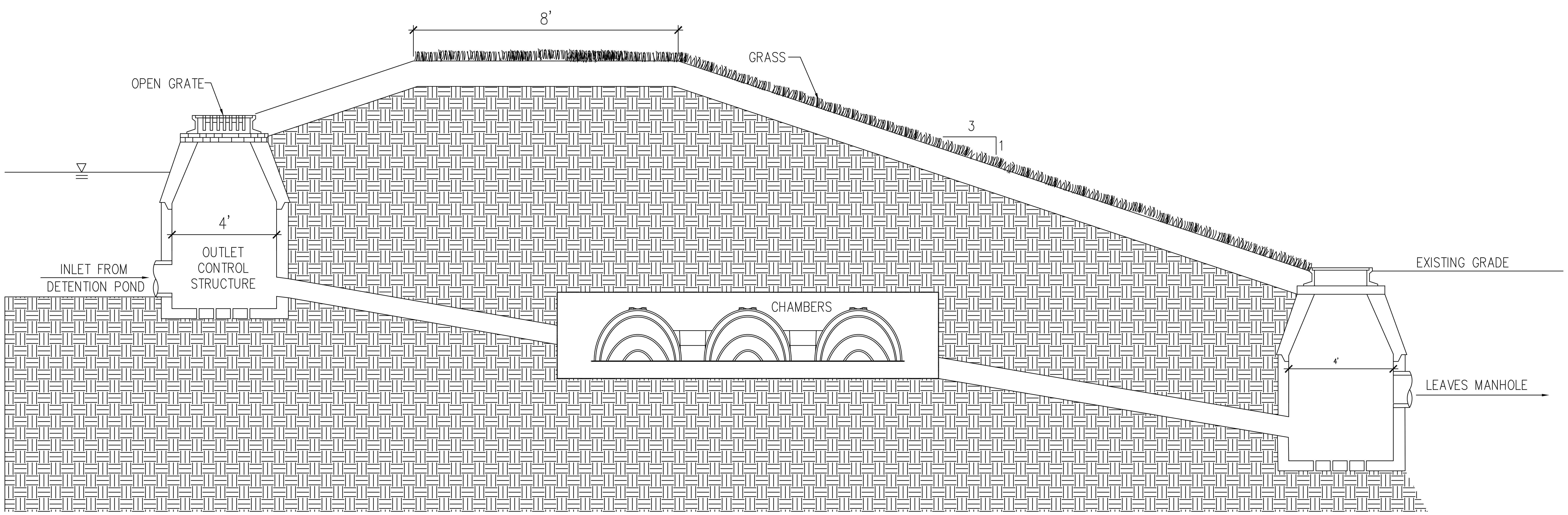
5) ALL RECHARGER 330XLHD CHAMBERS MUST BE INSTALLED IN ACCORDANCE WITH ALL APPLICABLE LOCAL, STATE AND FEDERAL REGULATIONS.

6) RECHARGER 330XLHD BY CULTEC, INC. OF BROOKFIELD, CT. STORAGE PROVIDED = 7.46 CF/FT PER DESIGN UNIT.

7) REFER TO CULTEC, INC.'S CURRENT RECOMMENDED INSTALLATION GUIDELINES.

8) MAXIMUM ALLOWED COVER OVER TOP OF UNIT SHALL BE 8'

9) THE CHAMBER WILL BE DESIGNED TO WITHSTAND TRAFFIC LOADS WHEN INSTALLED ACCORDING TO CULTEC'S RECOMMENDED INSTALLATION INSTRUCTIONS.



2 **FLOW FROM DETENTION POND**

SCALE: N.T.S.

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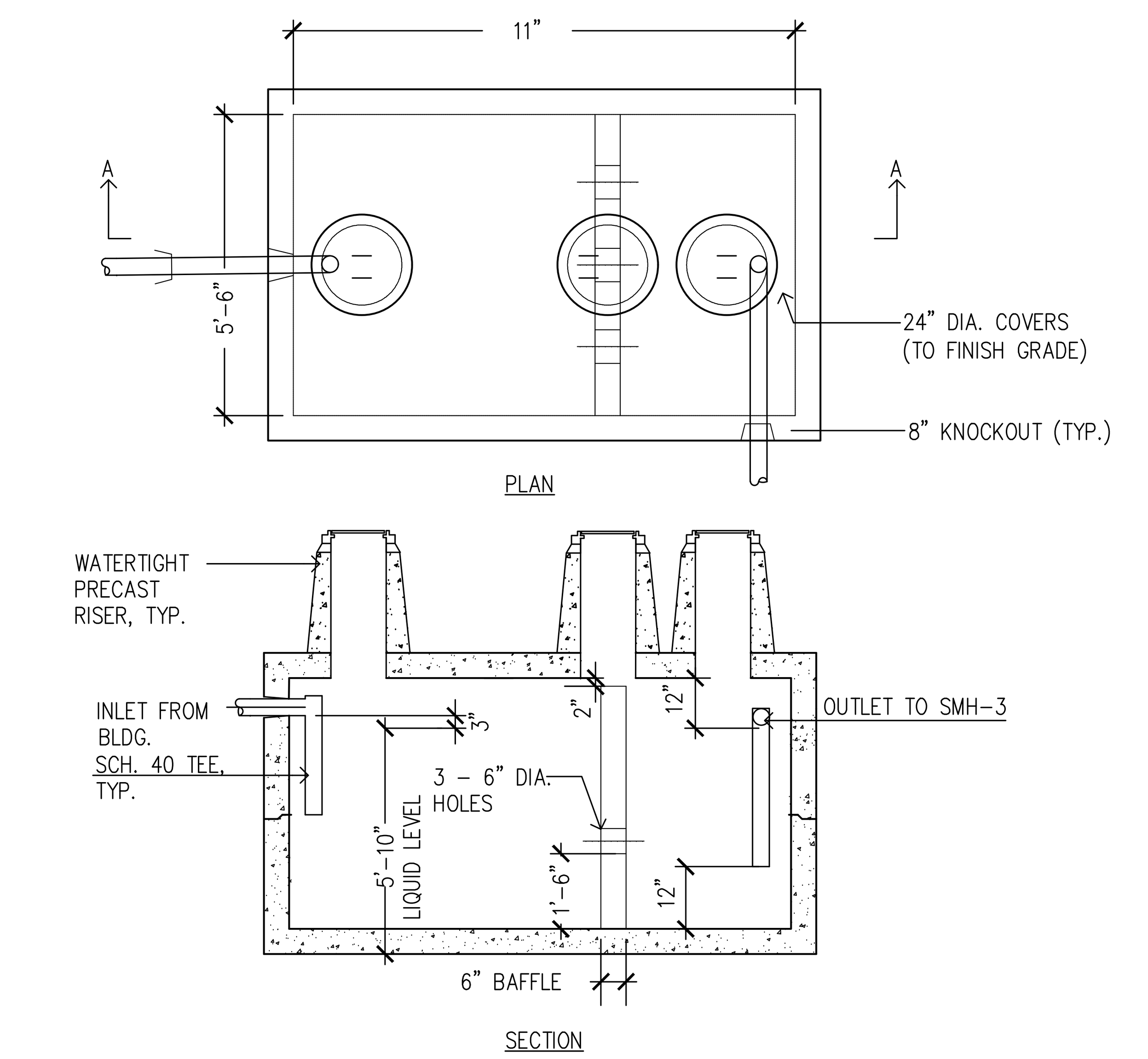
SITE DETAILS 1

Project No. — Scale: AS NOTED

L-401

Drawing No.

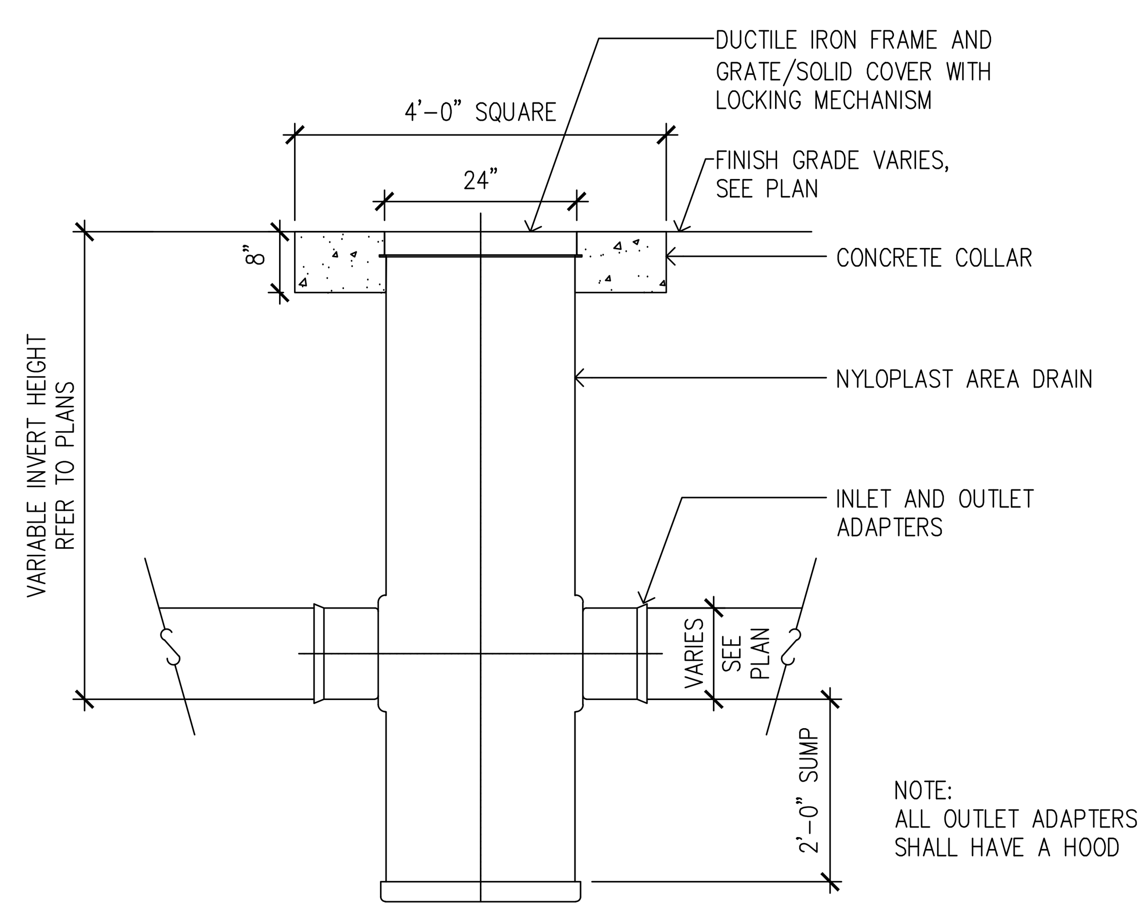


NOTES:

PROVIDED FOR REFERENCE ONLY. EXTERIOR GREASE TRAP TO BE INCLUDED IN PLUMBING ENGINEER'S DRAWINGS.

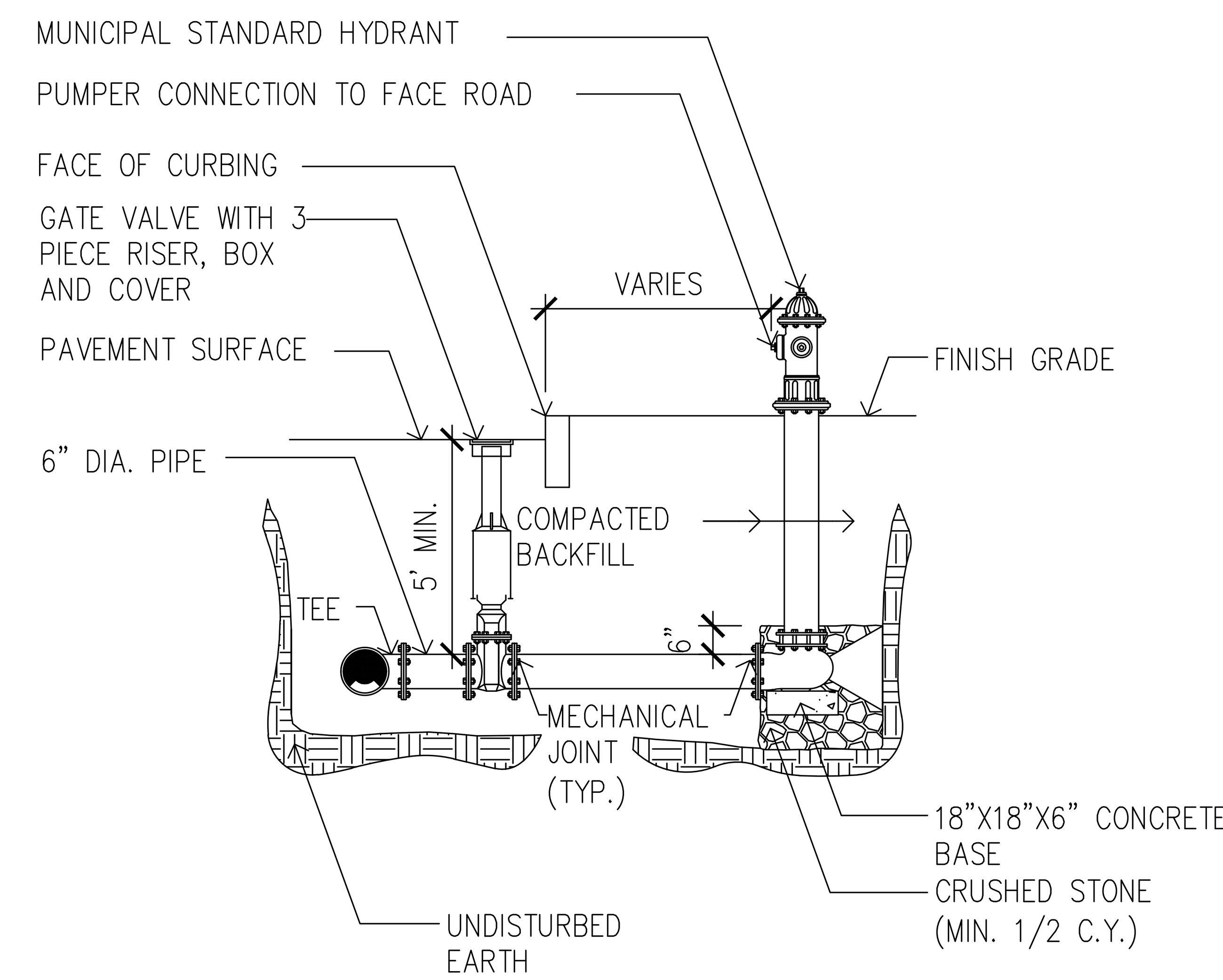
1 GREASE TRAP

SCALE: N.T.S.



2 CATCH BASIN

SCALE: N.T.S.

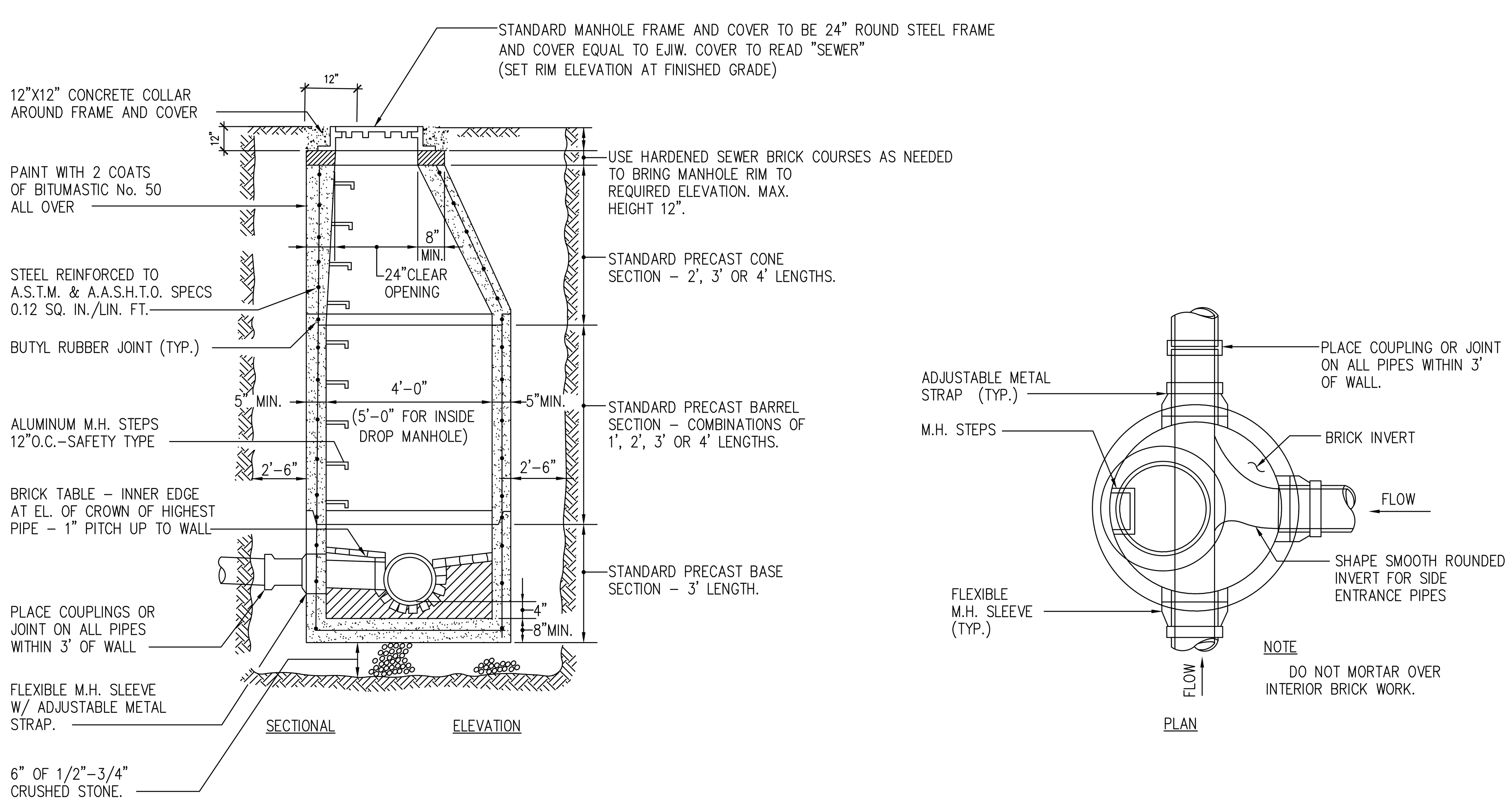


NOTE:

1. AN APPROVED TOWN OF ANDOVER JOINT RESTRAINT METHOD SHALL BE USED AT ALL ELBOW LOCATIONS.
2. GATES AND HYDRANTS OPEN PER THE TOWN OF ANDOVER STANDARD.
3. ALL HYDRANTS OPEN LEFT AND VALVES OPEN RIGHT.

3 HYDRANT

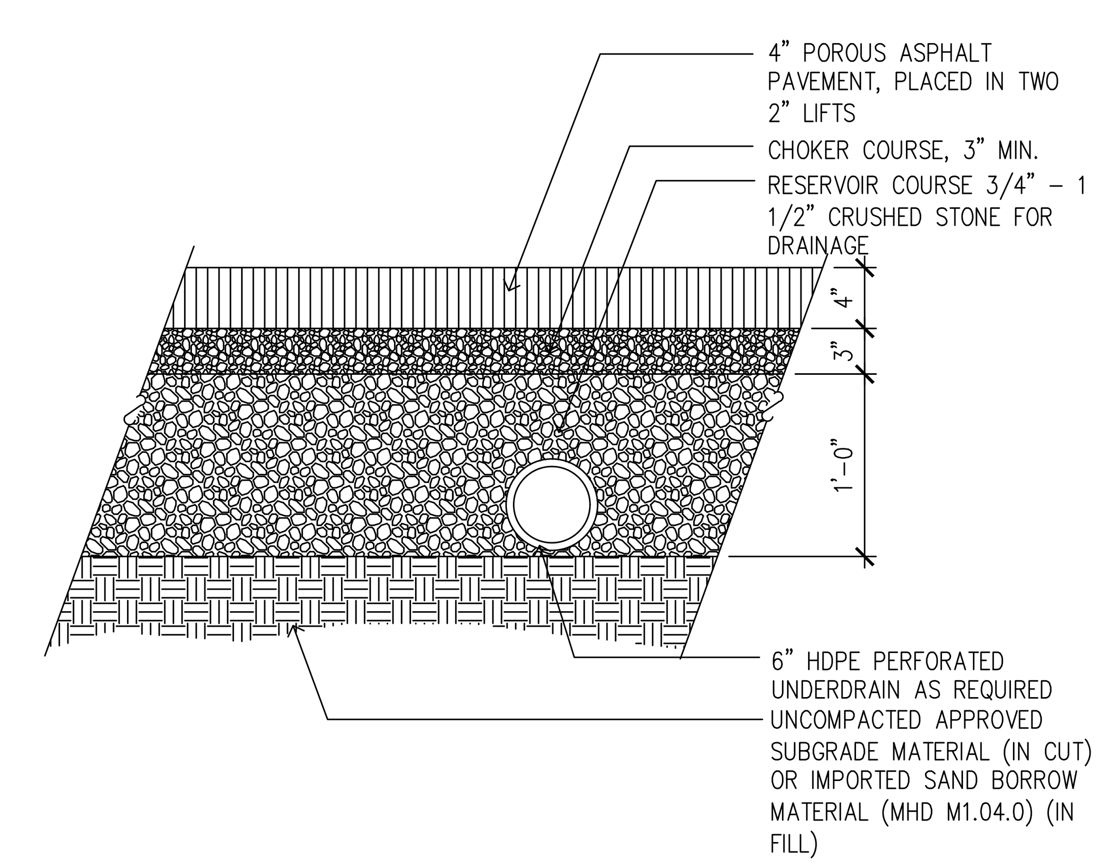
SCALE: N.T.S.



TYPICAL PRECAST CONCRETE SEWER MANHOLE DETAILS

4 SEWER MANHOLE

SCALE: N.T.S.



5 POROUS PAVEMENT

SCALE: N.T.S.

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SITE DETAILS 2

Project No.

Scale: AS NOTED

L-402

Drawing No.

02/08/2018

Appendix E: Runoff Calculations

X1 Curve Number Calculations

Soil type	Area	CN
B	113,929.56	55
A	56421.68	30
D	162457.12	77
Total	332808.36	
Pervious CN (weighted average)		61.50
Composite CN (TR-55 Figure 2-3)		65.50

X2 Curve Number Calculations

Soil Type	Area	CN
B	217,174.16	55
D	12088.83	77
Total	229262.99	
Pervious CN (weighted average)		56.16
Composite CN (TR-55 Figure 2-3)		59.50

P1 Curve Number Calculations

Soil Type	Total area	Pervious CN	Impervious area
D	27831.66	80	8758.88
B	80215.35	59.5 (weighted)	21388.29
A	40982.44	39	13200.74
Total	149029.45		43347.91
Weighted pervious CN		58.12	
Impervious coverage percent			29%
Composite CN (TR-55 Figure 2-3)			70

P2 Curve Number Calculations

Soil Type	Total area	Pervious area	Impervious area	Pervious CN
D	31501.62	19839.67	11661.95	80
B	4302.48	4219	83.48	61
A	33.34	9.52	23.82	39
Total area	35837.44	24068.19	11769.25	
Weighted pervious CN			77.68	
Impervious coverage percent			32.84%	
Weighted composite CN (TR-55 Table 2-2)			83.66	

P3 Curve Number Calculations

Soil Type	Total area	Pervious area	Impervious area	Pervious CN
A	15577.7	865.63	14712.07	39
D	58761.86	28520.53	30241.33	80
B	12501.29	12483.62	17.67	61
Total	86840.85	41869.78	44971.07	
Weighted pervious CN			69.91	
Impervious coverage percent			51.77%	
Weighted composite CN (TR-55 Table 2-2)			86.18	

P4 Curve Number Calculations

Soil Type	Total area	Pervious area	Impervious area	Pervious CN
D	46202.46	31988.97	14213.49	80
B	29859.85	60450.48	15909.37	59.5 (weighted)
Total	76062.31	45939.45	30122.86	
Weighted pervious CN			72.04	
Impervious coverage percent			39.60%	
Weighted composite CN (TR-55 Table 2-2)			83.33	

P5 Curve Number Calculations

Soil Type	Total area	Pervious area	Impervious area	Pervious CN
D	10030.4	5420.94	4609.46	80
B	133375.55	47457.52	85918.03	59.5 (weighted
Total	143405.95	52878.46	90527.49	
Weighted pervious CN			60.41	
Impervious coverage percent			63.13%	
Weighted composite CN (TR-55 Table 2-2)			84.53	

P6 Curve Number Calculations

Soil Type	Total area	Impervious area	Pervious CN
B	70829.23	592.81	59.5 (weighted)
Total	70829.23	592.81	
Impervious coverage percent			0.84%
Weighted pervious CN			57.67
Weighted composite CN (TR-55 Figure 2-3)			59

Pre-development Conditions Runoff Calculation using TR-55 Equations 2-3 and 2-4

Storm Frequency	Rainfall (in)	X1			X2		
		CN	S	Q (in)	CN	S	Q (in)
2	3.21	65.5	5.27	0.63	59.5	6.81	0.39
10	4.86	65.5	5.27	1.60	59.5	6.81	1.19
25	6.16	65.5	5.27	2.51	59.5	6.81	1.98
100	8.84	65.5	5.27	4.64	59.5	6.81	3.92

Post-development Conditions Runoff Calculation using TR-55 Equations 2-3 and 2-4

Storm Frequency	Rainfall (in)	P1			P2		
		CN	S	Q (in)	CN	S	Q (in)
2	3.21	70	4.29	0.83	83.66	1.95	1.67
10	4.86	70	4.29	1.93	83.66	1.95	3.11
25	6.16	70	4.29	2.93	83.66	1.95	4.31
100	8.84	70	4.29	5.19	83.66	1.95	6.86

P3			P4			P5			P6		
CN	S	Q (in)	CN	S	Q (in)	CN	S	Q (in)	CN	S	Q (in)
86.18	1.60	1.86	83.33	2.00	1.64	84.53	1.83	1.73	59	6.95	0.38
86.18	1.60	3.35	83.33	2.00	3.08	84.53	1.83	3.19	59	6.95	1.16
86.18	1.60	4.58	83.33	2.00	4.28	84.53	1.83	4.40	59	6.95	1.94
86.18	1.60	7.17	83.33	2.00	6.82	84.53	1.83	6.97	59	6.95	3.85

Appendix F: Time of Concentration Calculations for Existing Conditions

Subcatchment X1

Flow Paths (drawn in AutoCAD)

X1 Flow Paths	Length (ft)	Start Elev. (ft)	Finish Elev. (ft)	Elev. difference (ft)	Slope
1*	777.38	218	141	77	0.099
2	654.1	218	143.5	74.5	0.114
3	604.87	218	145.5	72.5	0.120
1**	First 50 feet	218	213		0.1

X2 Flow Paths	Length (ft)	Start Elev. (ft)	Finish Elev. (ft)	Elev. difference (ft)	Slope
1	589.65	218	160	58	0.0984
2	638.42	218	152	66	0.1034
3*	661.98	218	150	68	0.1027
3**	First 50 feet	218	215		0.06

*Yellow highlighted row indicates longest flow path, used for the calculating T_c and T_t
**AutoCAD was used to calculate the slope of first 50' (sheet flow) of the longest flow path

X1 Sheet Flow Travel Time

Sheet Flow	2-yr storm	10-yr storm	25-yr storm	100-yr storm
Surface description	light underbrush			
Manning's roughness coefficient	0.4			
Flow Length (L)	50			
24-hour rainfall (in)	3.21	4.86	6.16	8.84
Land slope	0.1			
Travel time (Tt)	0.108	0.088	0.078	0.065

X1 Shallow Concentrated Flow Travel Time

Shallow Concentrated Flow	all storm frequencies
Surface description	unpaved
Flow Length (L)	727.38
Watercourse slope	0.099
Average Velocity (ft/s)	1.6
Tt (hours)	0.126

X1 Total Time of Concentration

	2-year storm	10-year storm	25-year storm	100-year storm
Time of concentration (hr)	0.234	0.214	0.204	0.191
Tc (min)	14.05	12.83	12.25	11.47

Subcatchment X2

X2 Sheet Flow Travel Time Calculations

Sheet Flow	2-year storm	10-year storm	25-year storm	100-year storm
Surface description	woods, light underbrush			
Manning's roughness coefficient	0.4			
Flow Length (L)	50			
24-hour rainfall (in)	3.21	4.86	6.16	8.84
Land slope	0.06			
Tt (hr)	0.132	0.107	0.095	0.080

X2 Shallow Concentrated Flow Travel Time Calculations

Shallow Concentrated Flow	All storm frequencies
Surface description	unpaved
Flow Length (L)	611.98
Watercourse slope	0.106
Average Velocity (ft/s)	5.4
Tt (hr)	0.031

X2 Total Time of Concentration Calculations

	2-year	10-year	25-year	100-year
Time of concentration (hr)	0.164	0.139	0.127	0.111
Tc (min)	9.82	8.34	7.62	6.67

Appendix G: Peak Discharge Rate Calculations

Pre-Development Conditions Calculations

2-year storm							
Subarea	Area, Am (sq mi)	Tc (hr)	24-hour rainfall	Runoff Q (in)	Am*Q (sq.mi-in)	Initial Abstraction	Ia/P
X1	0.012	0.234	3.210	0.626	0.007	1.054	0.328
X2	0.008	0.164	3.210	0.395	0.003	1.362	0.424

10-year storm							
Subarea	Area, Am (sq mi)	Tc (hr)	24-hour rainfall	Runoff Q (in)	Am*Q (sq.mi-in)	Initial Abstraction	Ia/P
X1	0.012	0.214	4.860	1.597	0.019	1.054	0.217
X2	0.008	0.139	4.860	1.188	0.010	1.362	0.280

25-year storm							
Subarea	Area, Am (sq mi)	Tc (hr)	24-hour rainfall	Runoff Q (in)	Am*Q (sq.mi-in)	Initial Abstraction	Ia/P
X1	0.012	0.204	6.160	2.514	0.030	1.054	0.171
X2	0.008	0.127	6.160	1.984	0.016	1.362	0.221

100-year storm							
Subarea	Area, Am (sq mi)	Tc (hr)	24-hour rainfall	Runoff Q (in)	Am*Q (sq.mi-in)	Initial Abstraction	Ia/P
X1	0.012	0.191	8.840	4.645	0.055	1.054	0.119
X2	0.008	0.111	8.840	3.915	0.032	1.362	0.154

Pre-Development Conditions Tabular Hydrographs

2-year storm				Selected hydrograph times in hours from exhibit 5-III in TR-55										
				12	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	13	13.2
Subarea	Tc	Ia/P	AmQ (mi^2 in)	Discharges at selected hydrograph times (csm/in)										
X1	0.2	0.3	0.007	8	27	69	175	326	403	401	359	297	182	126
X2*	0.2	0.4	0.003	4	13.5	37	113.5	226	295	310	288.5	245	163.5	122.5

10-year storm				Selected hydrograph times in hours from exhibit 5-III in TR-55											
				12	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	13	13.2	13.4
Sub area	Tc	Ia/P	AmQ (mi^2 in)	Discharges at selected hydrograph times (csm/in)											
X1*	0.2	0.2	0.193	90	131	192	312	438	472	425	351	273	153	101	78
				8	27	69	175	326	403	401	359	297	182	126	100
X2	0.1	0.3	0.010	82	225	473	488	408	336	260	190	147	113	94	67

25-year storm				Selected hydrograph times in hours from exhibit 5-III in TR-55											
				12	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	13	13.2	13.4
Sub area	Tc	Ia/P	AmQ (mi^2 in)	Discharges at selected hydrograph times (csm/in)											
X1*	0.2	0.17	.030	90	131	192	312	438	472	425	351	273	153	101	78
				8	27	69	175	326	403	401	359	297	182	126	100
X2	0.1	0.1	0.029	147	210	353	559	540	410	313	231	164	101	80	67

100-year storm				Selected hydrograph times in hours from exhibit 5-III in TR-55											
				12	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	13	13.2	13.4
Sub area	Tc	Ia/P	AmQ (mi^2 in)	Discharges at selected hydrograph times (csm/in)											
X1	0.2	0.1	0.055	103	151	222	372	501	489	402	314	234	128	91	73
X2	0.1	0.1	0.032	147	210	353	559	540	410	313	231	164	101	80	67

*Used interpolation to get a more accurate Ia/P value to obtain discharge values from the table Pre-Development Peak Discharge Rates (TR-55 Equation 5-1)

Subcatchment	Storm frequency	Peak discharge rate (cfs)
X1	2	3.014
X1	10	8.340
X1	25	12.818
X1	100	27.779
X2	2	0.958
X2	10	4.767
X2	25	8.542
X2	100	17.998

Post-Development Conditions Calculations

2-year storm							
Subarea Name	Drainage Area Am (mi^2)	Tc (hr)	24-hour rainfall	Runoff Q (in)	AmQ	Initial Abstraction	Ia/P
P1	0.005	0.100	3.210	0.834	.004	0.857	0.267
P2	0.001	0.100	3.210	1.666	0.002	0.400	0.125
P3	0.003	0.100	3.210	1.858	0.006	0.304	0.095
P4	0.003	0.100	3.210	1.641	0.004	0.391	0.122
P5	0.005	0.100	3.210	1.730	0.009	0.368	0.115
P6	0.003	0.100	3.210	0.378	0.001	1.390	0.433

10-year storm							
Subarea Name	Drainage Area Am (mi^2)	Tc (hr)	24-hour rainfall	Runoff Q (in)	AmQ	Initial Abstraction	Ia/P
P1	0.005	0.100	4.860	1.933	0.010	0.857	0.176
P2	0.001	0.100	4.860	3.110	0.004	0.4	0.082
P3	0.003	0.100	4.860	3.354	0.010	0.304	0.063
P4	0.003	0.100	4.860	3.079	0.008	0.391	0.080
P5	0.005	0.100	4.860	3.193	0.016	0.368	0.076
P6	0.003	0.100	4.860	1.156	0.003	1.39	0.286

25-year storm							
Subarea Name	Drainage Area Am (mi^2)	Tc (hr)	24-hour rainfall	Runoff Q (in)	AmQ	Initial Abstraction	Ia/P
P1	0.005	0.100	6.160	2.8330	0.016	0.857	0.139
P2	0.001	0.100	6.160	4.310	0.006	0.400	0.065
P3	0.003	0.100	6.160	4.581	0.014	0.304	0.049
P4	0.003	0.100	6.160	4.275	0.012	0.391	0.063
P5	0.005	0.100	6.160	4.403	0.023	0.368	0.060
P6	0.003	0.100	6.160	1.942	0.005	1.390	0.226

100-year storm							
Subarea Name	Drainage Area Am (mi^2)	Tc (hr)	24-hour rainfall	Runoff Q (in)	AmQ	Initial Abstraction	Ia/P
P1	0.005	0.100	8.840	5.194	0.028	0.857	0.097
P2	0.001	0.100	8.840	6.863	0.009	0.400	0.045
P3	0.003	0.100	8.840	7.170	0.022	0.304	0.034
P4	0.003	0.100	8.840	6.823	0.019	0.391	0.044
P5	0.005	0.100	8.840	6.969	0.036	0.368	0.042
P6	0.003	0.100	8.840	3.855	0.010	1.390	0.157

Post-Development Conditions Tabular Hydrographs

*Note: many Ia/P values were not in the TR-55 Tabular Hydrographs, so the discharges were interpolated based on the Ia/P value.

2-year storm					Selected hydrograph times in hours from exhibit 5-III in TR-55										
					12	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	13	13.2
Sub area	Tc	Ia/P	AmQ		Discharges at selected hydrograph times (csm/in)										
P1	0.1	0.267	0.0045	Ia/P = 0.1	147	210	353	559	540	410	313	231	164	101	80
				Ia/P = 0.3	82	225	473	488	408	336	260	190	147	113	94
		Weighted Ia/P (0.267)			92.73	222.5	453.2	499.7	429	348	269	197	150	111	92
P2	0.1	0.1	0.0021		147	210	353	559	540	410	313	231	164	101	80
P3	0.1	0.1	0.0058		147	210	353	559	540	410	313	231	164	101	80
P4	0.1	0.1	0.0045		147	210	353	559	540	410	313	231	164	101	80
P5	0.1	0.1	0.0089		82	225	473	488	408	336	260	190	147	113	94
P6	0.1	0.15	0.001		130.75	214	383	541.25	507	392	300	221	160	104	83.5

10-year storm					Selected hydrograph times in hours from exhibit 5-III in TR-55										
					12	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	13	13.2
Sub area	Tc	Ia/P	AmQ		Discharges at selected hydrograph times (csm/in)										
P1	0.1	0.176	0.0103	IaP=0.1	147	210	353	559	540	410	313	231	164	101	80
				Ia/P=0.3	82	225	473	488	408	336	260	190	147	113	94
		Weighted Ia/P (0.176)			122	216	399	532	490	382	293	215	157.5	106	85.3
P2	0.1	0.1	0.004		147	210	353	559	540	410	313	231	164	101	80
P3	0.1	0.1	0.0104		147	210	353	559	540	410	313	231	164	101	80
P4	0.1	0.1	0.0084		147	210	353	559	540	410	313	231	164	101	80
P5	0.1	0.1	0.0164		147	210	353	559	540	410	313	231	164	101	80
P6	0.1	0..286	0.003	IaP=0.1	147	210	353	559	540	410	313	231	164	101	80
				Ia/P=0.3	82	225	473	488	408	336	260	190	147	113	94
		Weighted Ia/P (0.286)			87	224	465	493	417	341	263	193	148	112	93

25-year storm				Selected hydrograph times in hours from exhibit 5-III in TR-55										
				12	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	13	13.2
Sub area	Tc	Ia/P	AmQ	Discharges at selected hydrograph times (csm/in)										
P1	0.1	0.1	0.016	147	210	353	559	540	410	313	231	164	101	80
P2	0.1	0.1	0.006	147	210	353	559	540	410	313	231	164	101	80
P3	0.1	0.1	0.014	147	210	353	559	540	410	313	231	164	101	80
P4	0.1	0.1	0.012	147	210	353	559	540	410	313	231	164	101	80
P5	0.1	0.1	0.023	147	210	353	559	540	410	313	231	164	101	80
P6	0.1	0.2	0.005	115	218	413	523.5	474	373	287	211	156	107	87

100-year storm					Selected hydrograph times in hours from exhibit 5-III in TR-55										
					12	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	13	13.2
Sub area	Tc	Ia/P	AmQ		Discharges at selected hydrograph times (csm/in)										
P1	0.1	0.1	0.0.278		147	210	353	559	540	410	313	231	164	101	80
P2	0.1	0.1	0.0088		147	210	353	559	540	410	313	231	164	101	80
P3	0.1	0.1	0.0223		147	210	353	559	540	410	313	231	164	101	80
P4	0.1	0.1	0.0186		147	210	353	559	540	410	313	231	164	101	80
P5	0.1	0.1	0.0358		147	210	353	559	540	410	313	231	164	101	80
P6	0.1	0.157	0.0098	IaP=0.1	147	210	353	559	540	410	313	231	164	101	80
				Ia/P=0.3	82	225	473	488	408	336	260	190	147	113	94
		Weighted Ia/P (0.157)			128	214	387	539	502	389	298	219	159	104	84

Post-Development Peak Discharge Rates (TR-55 Equation 5-1)

Subcatchment	Storm frequency	Peak discharge rate (cfs)
P1	2	2.23
P1	10	5.50
P1	25	8.76
P1	100	15.52
P2	2	1.20
P2	10	2.23
P2	25	3.10
P2	100	4.93
P3	2	3.24
P3	10	5.84
P3	25	7.98
P3	100	12.48
P4	2	2.50
P4	10	4.70
P4	25	6.52
P4	100	10.41
P5	2	4.98
P5	10	9.18
P5	25	12.66
P5	100	20.04
P6	2	0.52
P6	10	1.48
P6	25	2.58
P6	100	5.28

Post-Development Peak Discharge Rates by Storm Frequency

2 year storm	
Subcatchment	Peak discharge rate (cfs)
P1	2.228
P2	1.197
P3	3.235
P4	2.503
P5	4.976
P6	0.520
Total	14.658

10 year storm	
Subcatchment	Peak discharge rate (cfs)
P1	5.5
P2	2.23
P3	5.84
P4	47.0
P5	9.18
P6	1.48
Total	28.93

25 year storm	
Subcatchment	Peak discharge rate (cfs)
P1	8.764
P2	3.10
P3	7.98
P4	6.52
P5	12.66
P6	2.58
Total	41.60

100 year storm	
Subcatchment	Peak discharge rate (cfs)
P1	15.52
P2	4.93
P3	12.48
P4	10.41
P5	20.04
P6	5.28
Total	68.66

Appendix H: Post-Development Recharge and Water Quality Volumes

Recharge Volume Calculations

Recharge Target Depth by Hydrologic Soil Group (MA DEP Stormwater Handbook Ch. 3, Vol. 1)

NRCS Hydrologic Soil Type	Approximate Soil Texture	Target Depth Factor (F)
A	sand	0.6-inch
B	loam	0.35-inch
C	silty loam	0.25-inch
D	clay	0.1 inch

Subcatchment P1			
Soil type	Impervious area (sf)	Target depth factor (ft)	Recharge volume (cf)
D	8758.88	0.008	72.991
B	21388.29	.029	623.825
A	13200.74	.050	660.037
		Total recharge volume:	1356.853

Subcatchment P2			
Soil type	Impervious area (sf)	Target depth factor (ft)	Recharge volume (cf)
D	11661.95	.008	97.183
B	83.48	.029	2.435
A	23.82	.050	1.191
		Total recharge volume:	100.809

Subcatchment P3			
Soil type	Impervious area (sf)	Target depth factor (ft)	Recharge volume (cf)
D	30241.33	.008	252.011
B	17.67	.029	.515
A	14712.07	.050	735.604
		Total recharge volume:	988.13

Subcatchment P4			
Soil type	Impervious area (sf)	Target depth factor (ft)	Recharge volume (cf)
D	14215.44	.008	118.462
B	15909.37	.029	464.023
		Total recharge volume:	582.485

Subcatchment P5			
Soil type	Impervious area (sf)	Target depth factor (ft)	Recharge volume (cf)
D	4609.46	.008	36.876
B	85918.03	.029	2505.943
		Total recharge volume:	2542.818

Subcatchment P6			
Soil type	Impervious area (sf)	Target depth factor (ft)	Recharge volume (cf)
B	592.81	.029	17.29
		Total recharge volume:	17.29

Water Quality Volume Calculations

Subcatchment P1		
Depth (ft)	Impervious area (sf)	Water quality volume (cf)
0.0417	42141.76	1755.91

Subcatchment P2		
Depth (ft)	Impervious area (sf)	Water quality volume (cf)
0.0417	11784.41	491.01

Subcatchment P3		
Depth (ft)	Impervious area (sf)	Water quality volume (cf)
0.0417	44953.4	1873.06

Subcatchment P4		
Depth (ft)	Impervious area (sf)	Water quality volume (cf)
0.0417	30124.92	1255.21

Subcatchment P5		
Depth (ft)	Impervious area (sf)	Water quality volume (cf)
0.0417	90522.45	3771.77

Subcatchment P6		
Depth (ft)	Impervious area (sf)	Water quality volume (cf)
0.0417	592.81	24.70

Appendix I: BMP Required Storage Volume Calculations

First, the required volume for each BMP was determined using the table below. The table below shows which discharge points water in each subcatchments runs off to, and the flow rate, area, runoff volume, and pre-development peak discharge rates for each subcatchment. Then it uses these values to convert the flow rate for each into cfs and determine a desired value for Qo for each subcatchment that will maintain the pre-development peak discharge rate for each discharge point. The ratio Qo/Qi is plugged into TR-55 Figure 6-1 to obtain the ratio of storage volume over runoff volume. Then the value of runoff volume was used to calculate the storage volume. This volume was added to the water quality volume to get the total required volume for the BMP in that subcatchment. The boxes in the table for subcatchments P1 and P6 are filled with gray because there are no additional impervious surfaces in these subcatchments, and therefore no BMP and no volume for a BMP that needs to be calculated.

<table>
<tr><th></th><th>Sub area</th><th>Q (ft)</th><th>Area (sf)</th><th>Runoff Volume (Vr)</th><th>Flow rate, Qi (cfs)</th><th>Flow Rate to BMP</th><th>Pre-Dev. Peak Discharge Rate</th><th>Flow rate to DP cfs (Qo)</th><th>Qo/ Qi</th><th>Vs/ Vr</th><th>Vs</th><th>Water Quality Volume</th><th>Required volume of BMP (cf)</th></tr>
<tr><td rowspan="4">DP-1</td><td>P1</td><td></td><td></td><td></td><td>15.52</td><td>-</td><td rowspan="4">27.78</td><td>15.52</td><td></td><td></td><td></td><td>1755.9</td><td>-</td></tr>
<tr><td>P2</td><td>0.57</td><td>35837.4</td><td>20495.86</td><td>4.93</td><td>4.93</td><td>2</td><td>0.5</td><td>0.28</td><td>5739</td><td>491.0</td><td>6229.9</td></tr>
<tr><td>P3</td><td>0.60</td><td>86840.9</td><td>51885.19</td><td>12.48</td><td rowspan="2">22.89</td><td rowspan="2">10</td><td rowspan="2">0.44</td><td rowspan="2">0.3</td><td rowspan="2">28539</td><td rowspan="2">3128.3</td><td rowspan="2">31667.7</td></tr>
<tr><td>P4</td><td>0.57</td><td>76062.3</td><td>43246.09</td><td>10.41</td></tr>
<tr><td rowspan="2">DP-2</td><td>P5</td><td>0.58</td><td>143406</td><td>83281.88</td><td>20.04</td><td>20.04</td><td rowspan="2">18.00</td><td>12.72</td><td>0.63</td><td>0.23</td><td>19155</td><td>3771.8</td><td>22926.6</td></tr>
<tr><td>P6</td><td></td><td></td><td></td><td>5.28</td><td>-</td><td>5.28</td><td></td><td></td><td></td><td></td><td>-</td></tr>
</table>

Appendix J: CULTEC Stormwater Subsurface Chambers Calculations

Subsurface Chamber calculations for subcatchment P2

Chambers for P2	Vol.	Chamber per unit	# Chamber	Bed Area	Stone Required	Avail. Length	Avail. width	Chambers Wide	Chambers Long	Bed length	Bed Width	Actual Bed Area	Actual Vol
Recharger 330XL	62299	79.26	78.60	2659	196.5	82	48	9	9	66.5	44.47	2957	6420

Appendix K: Detention Pond Calculations

Calculations for drainage pipe from P3 to detention pond in P4

Table of input and output values for Manning's Equation

Elevation of inlet	Elevation of pond bottom	Horizontal distance (in AutoCAD)	Slope (S)	Q (cfs, 100-year storm)	Pipe material	Manning's roughness coefficient	Calculated value of R (ft)	D in inches	Rounded pipe size
177	170	381.25	0.018	12.48	HDPE	0.009	0.52	12.54	14" HDPE

Detention pond volume calculations

Volume required (cf)	Area (sf)	Length southern edge of pond (ft)	Length northern edge of pond (ft)	Required water depth (ft)	Volumes of embankments (1:3 slope, 3' depth)	Storage volume (cf)	Total depth with 1' freeboard (ft)	Bottom elev. of pond	Highest elev. of pond	1st floor elev. of left building
31667.7	13233.8	173.26	67.29	3	3247.43	36453.92	4	170	174	177

Calculations for subsurface chambers in P4

- Recharge volume required (since pond only provided detention) = sum of recharge volumes for P3 and P4 = 1570.62
- Bottom elevation of pond (the outlet control structure will be at this elevation) = 170'
- Bottom elevation of subsurface chambers (with enough space to groundwater table and with a downward sloping pipe from the outlet control structure to the chambers) = 165'
- Elevation of detention basin embankment tie-in to existing grade = 170'
- Width available for chambers underground (this was calculated as the sum of half of the distance of the top of the embankment (8'/2=4') and the horizontal distance from the top of the basin at a 1:3 slope to meet the existing surface (12') = 16'
- Depth to groundwater table: >80 inches
- Type of chamber proposed: Recharger 330XLHD with crushed stone
- Chambers per unit = 79.26
- Number of chambers = required volume / chambers per unit = 19.82 = 20 (all chamber calculations performed using the equations and standard values in the CULTEC Design Manual [11])
- Bed area = number of chambers * 33.83 (value obtained from Design Manual) = 670.37
- Bed width = the available width under the embankment, calculated above = 16'
- Stone required = number of chambers * 2.5 (see Design Manual) = 49.54 cy
- Chambers wide = 3
- Chambers long = 6.61 = 7
- Bed length = 52.5 ft
- Actual volume for storage = 1585.2 cf

Appendix L: Porous Pavement Calculations

The table below summarizes the calculations performed to find the storage volume of the porous pavement in P5. The gray columns represent values that were used to calculate the total area of parking and driveways in the subcatchment. The depth of storage space was calculated by multiplying the percentage of voids (30%) by the depth of crushed stone (2 feet). The parking surface area was then multiplied by the depth of storage space to get the available storage volume.

Depth of Materials (ft)	Total Impervious Area (sf)	Area of Medium Buildings (sf)	Area of Small Buildings (sf)	Area of Parking/ Driveways (sf)	Depth of Storage Space (ft)	Volume of Porous Pavement (cf)	Required Storage Volume (cf)
2ft deep of stone	90527.49	30124.92	21282.22	39120.35	0.6	23472.21	22926.60

Appendix M: Drawdown Times

PB2: CULTEC Subsurface Chambers Drawdown Time

Storage volume (cf)	K (ft/hr)	Bottom area of BMP (sf)	Drawdown time (hr)
100.81	0.201	2957.26	0.17

PB5: Porous Pavement Drawdown Time

Storage volume (cf)	K (ft/hr)	Bottom area of BMP (sf)	Drawdown time (hr)
2542.82	0.041	39120.35	1.59

PB34: Detention Pond Drawdown Time

Storage volume (cf)	K (ft/hr)	Bottom area of BMP (sf)	Drawdown time (hr)
1570.62	0.034	13233.78	3.52

PB34: Subsurface Chambers Drawdown Time

Storage volume (cf)	K (ft/hr)	Bottom area of BMP (sf)	Drawdown time (hr)
1585.2	0.043	670.37	54.57

Appendix N: Mounding Analysis Calculations

Infiltration BMP	Recharge Volume (cf)	Area of bottom BMP (sf)	Time (hr)	Percolation Rate (ft/hr)	Hydraulic Conductivity (ft/hr)	Specific Yield	Initial Saturated Thickness (ft)	Recharge Area Dimensions		Max Hydraulic Head (ft)	Increase in Hydraulic Head (ft)
								Length (ft)	Width (ft)		
PB2: Subsurface Chambers	100.8	2957.255	24	0.0014	0.201	0.01	5	66.5	44.47	**5.79**	**0.79**
PB34: Subsurface Chambers	1570.615	4121.475	24	0.016	0.043	0.01	5	52.5	15.49	**11.27**	**6.27**
PB5: Porous Pavement	2542.818	39120.35	24	0.0027	0.041	0.01	5	197.8	197.8	**11.46**	**6.46**

Appendix O: Belmont Stormwater Management Checklist and Erosion Control Report

TOWN OF BELMONT
Checklist for Stormwater Management and Erosion Control Report

A. Introduction

Important: When filling out forms on the computer, use only the tab key to move your cursor - do not use the return key.

A Stormwater Management and Erosion Control Report must be submitted with the building permit application for a project that is covered by the Town of Belmont Stormwater Management and Erosion Control By-Law. The following checklist is NOT a substitute for the Report (which should provide more substantive and detailed information) but is offered here as a tool to help the applicant organize their Stormwater Management and Erosion Control documentation for their Report and for the reviewer to assess this information in a consistent format. As noted in the Checklist, the Report must contain the engineering computations and supporting information set forth in Volume 3 of the Massachusetts Stormwater Handbook. The Stormwater Report must be prepared and certified by a Registered Professional Engineer (RPE) licensed in the Commonwealth.

The Report must include:

- The Checklist completed and stamped by a Registered Professional Engineer (see page 2) that certifies that the Report contains all required submittals.[1] This Checklist is to be used as the cover for the completed Report.
- Applicant/Project Name
- Project Address
- Name of Firm and Registered Professional Engineer that prepared the Report
- Long-Term Pollution Prevention Plan required by Standards 4-6
- Construction Period Pollution Prevention and Erosion and Sedimentation Control Plan required by Standard 8[2]
- Operation and Maintenance Plan required by Standard 9

In addition to all plans and supporting information, the Report must include a brief narrative describing stormwater management practices, including environmentally sensitive site design and LID techniques, along with a diagram depicting runoff through the proposed BMP treatment train. Plans are required to show existing and proposed conditions, identify all wetland resource areas, NRCS soil types, critical areas, Land Uses with Higher Potential Pollutant Loads (LUHPPL), and any areas on the site where infiltration rate is greater than 2.4 inches per hour. The Plans shall identify the drainage areas for both existing and proposed conditions at a scale that enables verification of supporting calculations.

As noted in the Checklist, the Report shall document compliance with each of the Stormwater Management Standards as provided in the Massachusetts Stormwater Handbook. The soils evaluation and calculations shall be done using the methodologies set forth in Volume 3 of the Massachusetts Stormwater Handbook.

To ensure that the Report is complete, applicants are required to fill in the Report Checklist by checking the box to indicate that the specified information has been included in the Report. If any of the information specified in the checklist has not been submitted, the applicant must provide an explanation. The completed Stormwater Management and Erosion Control Checklist and Certification must be submitted with the Report.

[1] The Stormwater Report may also include the Illicit Discharge Compliance Statement required by Standard 10. If not included in the Stormwater Report, the Illicit Discharge Compliance Statement must be submitted prior to the discharge of stormwater runoff to the post-construction best management practices.

[2] For some complex projects, it may not be possible to include the Construction Period Erosion and Sedimentation Control Plan in the Stormwater Report. In that event, the issuing authority has the discretion to issue an Order of Conditions that approves the project and includes a condition requiring the proponent to submit the Construction Period Erosion and Sedimentation Control Plan before commencing any land disturbance activity on the site.

TOWN OF BELMONT
Checklist for Stormwater Management and Erosion Control Report

B. Report Checklist and Certification

The following checklist is intended to serve as a guide for applicants as to the elements that ordinarily need to be addressed in a complete Report. The checklist is also intended to provide the reviewing authority with a summary of the components necessary for a comprehensive Report that addresses the ten Stormwater Standards.

Note: Because stormwater requirements vary from project to project, it is possible that a complete Report may not include information on some of the subjects specified in the Checklist. If it is determined that a specific item does not apply to the project under review, please note that the item is not applicable (N.A.) and provide the reasons for that determination.

A complete checklist must include the Certification set forth below signed by the Registered Professional Engineer who prepared the Report.

Registered Professional Engineer's Certification

I have reviewed the Stormwater Management and Erosion Control Report, including the soil evaluation, computations, Long-term Pollution Prevention Plan, the Construction Period Erosion and Sedimentation Control Plan, the Long-term Post-Construction Operation and Maintenance Plan, the Illicit Discharge Compliance Statement (if included) and the plans showing the stormwater management system, and have determined that they have been prepared in accordance with the requirements of the Stormwater Management Standards as further elaborated by the Massachusetts Stormwater Handbook. I have also determined that the information presented in the Stormwater Checklist is accurate and that the information presented in the Stormwater Report accurately reflects conditions at the site as of the date of this permit application.

Registered Professional Engineer Block and Signature

Signature and Date

TOWN OF BELMONT
Checklist for Stormwater Management and Erosion Control Report

Article 34 - Stormwater Management and Erosion Control By-Law (excerpt)

34.6 Stormwater Management and Erosion Control

34.6.1 Regulated Activities

A Stormwater Management and Erosion Control Permit shall be required prior to undertaking any land disturbance that involves:

(a) An alteration that will result in land disturbances of 2,500 square feet of total area or more, or that is part of a common plan for development that will disturb 2,500 square feet or more;
(b) An alteration that will increase the amount of a lot's impervious surface area to more than 25% of the lot's total area; or
(c) Storage or permanent placement of more than 100 cubic yards of excavated material, fill, snow or ice.

34.6.3 General Requirements

34.6.3.1 An Operation and Maintenance Plan shall be submitted to the OCD for approval prior to the issuance of a Stormwater Management and Erosion Control Permit. The Operation and Maintenance Plan shall be designed to ensure compliance with the Stormwater Management and Erosion Control Permit, this By-Law, and the Massachusetts Surface Water Quality Standards, 314 CMR 4.00, in all seasons and throughout the life of the system.

34.6.3.2 As-built drawings showing all stormwater management systems shall be submitted to the OCD at the completion of a project.

34.6.3.3 The OCD may require the applicant to contribute to the cost of design, construction, and maintenance of a public or shared stormwater facility in lieu of an onsite stormwater facility where the OCD determines that there are not sufficient site conditions for onsite Best Management Practices that will satisfy the design criteria set forth in Section 34.6.4.1 of this By-Law and the performance standards set forth in the regulations promulgated under this By-Law. Funds so contributed may be used to design, construct, and maintain stormwater projects that will improve the quality and quantity of surface waters in Belmont by treating and recharging stormwater from existing impervious surfaces that is now discharged to said waters with inadequate treatment or recharge. The amount of any required contribution to the fund shall be determined by the OCD pursuant to standards established in the Regulations adopted pursuant to this By-Law.

34.6.4 Design Criteria (The Report shall consider all of the design criteria below)

34.6.4.1 All Development shall satisfy the following design criteria:

(a) Compliance with all applicable provisions of the Stormwater Management Standards, regardless of the proximity of the development to resource areas or their buffer zones, as defined by the *Wetlands Protection Act, M.G.L*. c. 131, § 40 and its implementing regulations.
(b) Erosion and sediment controls must be implemented to prevent adverse impacts during disturbance and construction activities.
(c) There shall be no change to the existing conditions of abutting properties from any increase in volume of stormwater runoff or from erosion, silting, flooding, sedimentation or impacts to wetlands, ground water levels or wells.
(d) When any proposed discharge may have an impact upon streams, wetlands and/or storm sewers, the OCD may require minimization or elimination of this impact based on site conditions and existing stormwater system capacity.

TOWN OF BELMONT
Checklist for Stormwater Management and Erosion Control Report

Checklist

Project Type: Is the application for new development, redevelopment, or a mix of new and redevelopment?

- ☐ New development
- ☐ Redevelopment
- ☑ Mix of New Development and Redevelopment

LID Measures: Stormwater Standards require LID measures to be considered. Document what environmentally sensitive design and LID Techniques were considered during the planning and design of the project:

- ☑ No disturbance to any Wetland Resource Areas
- ☐ Site Design Practices
- ☐ Reduced Impervious Area (Redevelopment Only)
- ☐ Minimizing disturbance to existing trees and shrubs
- ☐ LID Site Design Credit Requested:
  - ☐ Credit 1
  - ☐ Credit 2
  - ☐ Credit 3
- ☐ Use of "country drainage" versus curb and gutter conveyance and pipe
- ☐ Bioretention Cells (includes Rain Gardens)
- ☐ Constructed Stormwater Wetlands (includes Gravel Wetlands designs)
- ☐ Treebox Filter
- ☐ Water Quality Swale
- ☐ Grass Channel
- ☐ Green Roof
- ☑ Other (describe): Subsurface detention / infiltration basins, porous pavement, detention basin

TOWN OF BELMONT
Checklist for Stormwater Management and Erosion Control Report

Standard 1: No New Untreated Discharges

- [x] No new untreated discharges
- [ ] Outlets have been designed so there is no erosion or scour to wetlands and waters of the Commonwealth
- [x] Supporting calculations specified in Volume 3 of the Massachusetts Stormwater Handbook included.

Standard 2: Peak Rate Attenuation

- [ ] Standard 2 waiver requested because the project is located in land subject to coastal storm flowage and stormwater discharge is to a wetland subject to coastal flooding.
- [ ] Evaluation provided to determine whether off-site flooding increases during the 100-year 24-hour storm.
- [x] Calculations provided to show that post-development peak discharge rates do not exceed pre-development rates for the 2-year and 10-year 24-hour storms. If evaluation shows that off-site flooding increases during the 100-year 24-hour storm, calculations are also provided to show that post-development peak discharge rates do not exceed pre-development rates for the 100-year 24-hour storm.

Standard 3: Recharge

- [ ] Soil Analysis provided.
- [x] Required Recharge Volume calculation provided.
- [ ] Required Recharge volume reduced through use of the LID site Design Credits.
- [x] Sizing the infiltration, BMPs is based on the following method: Check the method used.
  - [x] Static
  - [ ] Simple Dynamic
  - [ ] Dynamic Field[1]
- [x] Runoff from all impervious areas at the site discharging to the infiltration BMP.
- [ ] Runoff from all impervious areas at the site is *not* discharging to the infiltration BMP and calculations are provided showing that the drainage area contributing runoff to the infiltration BMPs is sufficient to generate the required recharge volume.
- [x] Recharge BMPs have been sized to infiltrate the Required Recharge Volume.
- [ ] Recharge BMPs have been sized to infiltrate the Required Recharge Volume *only* to the maximum extent practicable for the following reason:
  - [ ] Site is comprised solely of C and D soils and/or bedrock at the land surface
  - [ ] M.G.L. c. 21E sites pursuant to 310 CMR 40.0000
  - [ ] Solid Waste Landfill pursuant to 310 CMR 19.000
  - [ ] Project is otherwise subject to Stormwater Management Standards only to the maximum extent practicable.
- [x] Calculations showing that the infiltration BMPs will drain in 72 hours are provided.
- [ ] Property includes a M.G.L. c. 21E site or a solid waste landfill and a mounding analysis is included.

[1] 80% TSS removal is required prior to discharge to infiltration BMP if Dynamic Field method is used.

Checklist (continued)

Standard 3: Recharge (continued)

☑ The infiltration BMP is used to attenuate peak flows during storms greater than or equal to the 10-year 24-hour storm and separation to seasonal high groundwater is less than 4 feet and a mounding analysis is provided.

☐ Documentation is provided showing that infiltration BMPs do not adversely impact nearby wetland resource areas.

Standard 4: Water Quality

The Long-Term Pollution Prevention Plan typically includes the following:

- Good housekeeping practices;
- Provisions for storing materials and waste products inside or under cover;
- Vehicle washing controls;
- Requirements for routine inspections and maintenance of stormwater BMPs;
- Spill prevention and response plans;
- Provisions for maintenance of lawns, gardens, and other landscaped areas;
- Requirements for storage and use of fertilizers, herbicides, and pesticides;
- Pet waste management provisions;
- Provisions for operation and management of septic systems;
- Provisions for solid waste management;
- Snow disposal and plowing plans relative to Wetland Resource Areas;
- Winter Road Salt and/or Sand Use and Storage restrictions;
- Street sweeping schedules;
- Provisions for prevention of illicit discharges to the stormwater management system;
- Documentation that Stormwater BMPs are designed to provide for shutdown and containment in the event of a spill or discharges to or near critical areas or from LUHPPL;
- Training for staff or personnel involved with implementing Long-Term Pollution Prevention Plan;
- List of Emergency contacts for implementing Long-Term Pollution Prevention Plan.

☐ A Long-Term Pollution Prevention Plan is attached to Stormwater Report and is included as an attachment to the Wetlands Notice of Intent.

☐ Treatment BMPs subject to the 44% TSS removal pretreatment requirement and the one inch rule for calculating the water quality volume are included, and discharge:

  ☐ is within the Zone II or Interim Wellhead Protection Area

  ☐ is near or to other critical areas

  ☐ is within soils with a rapid infiltration rate (greater than 2.4 inches per hour)

  ☐ involves runoff from land uses with higher potential pollutant loads.

☐ The Required Water Quality Volume is reduced through use of the LID site Design Credits.

☐ Calculations documenting that the treatment train meets the 80% TSS removal requirement and, if applicable, the 44% TSS removal pretreatment requirement, are provided.

Checklist (continued)

Standard 4: Water Quality (continued)

☑ The BMP is sized (and calculations provided) based on:

- ☑ The ½" or 1" Water Quality Volume or
- ☐ The equivalent flow rate associated with the Water Quality Volume and documentation is provided showing that the BMP treats the required water quality volume.

☐ The applicant proposes to use proprietary BMPs, and documentation supporting use of proprietary BMP and proposed TSS removal rate is provided. This documentation may be in the form of the propriety BMP checklist found in Volume 2, Chapter 4 of the Massachusetts Stormwater Handbook and submitting copies of the TARP Report, STEP Report, and/or other third party studies verifying performance of the proprietary BMPs.

☐ A TMDL exists that indicates a need to reduce pollutants other than TSS and documentation showing that the BMPs selected are consistent with the TMDL is provided.

Standard 5: Land Uses With Higher Potential Pollutant Loads (LUHPPLs)

☐ The NPDES Multi-Sector General Permit covers the land use and the Stormwater Pollution Prevention Plan (SWPPP) has been included with the Stormwater Report.

☐ The NPDES Multi-Sector General Permit covers the land use and the SWPPP will be submitted ***prior to*** the discharge of stormwater to the post-construction stormwater BMPs.

☐ The NPDES Multi-Sector General Permit does ***not*** cover the land use.

☐ LUHPPLs are located at the site and industry specific source control and pollution prevention measures have been proposed to reduce or eliminate the exposure of LUHPPLs to rain, snow, snow melt and runoff, and been included in the long term Pollution Prevention Plan.

☐ All exposure has been eliminated.

☐ All exposure has ***not*** been eliminated and all BMPs selected are on MassDEP LUHPPL list.

☐ The LUHPPL has the potential to generate runoff with moderate to higher concentrations of oil and grease (e.g. all parking lots with >1000 vehicle trips per day) and the treatment train includes an oil grit separator, a filtering bioretention area, a sand filter or equivalent.

Standard 6: Critical Areas

☐ The discharge is near or to a critical area and the treatment train includes only BMPs that MassDEP has approved for stormwater discharges to or near that particular class of critical area.

☐ Critical areas and BMPs are identified in the Stormwater Report.

Standard 7: Redevelopments and Other Projects Subject to the Standards only to the maximum extent practicable

☐ The project is subject to the Stormwater Management Standards only to the maximum Extent Practicable as a:

- ☐ Limited Project
- ☐ Small Residential Projects: 5-9 single family houses or 5-9 units in a multi-family development provided there is no discharge that may potentially affect a critical area.

Checklist (continued)

- ☐ Small Residential Projects: 2-4 single family houses or 2-4 units in a multi-family development with a discharge to a critical area
- ☐ Marina and/or boatyard provided the hull painting, service and maintenance areas are protected from exposure to rain, snow, snow melt and runoff
- ☐ Bike Path and/or Foot Path
- ☐ Redevelopment Project
- ☐ Redevelopment portion of mix of new and redevelopment.

☐ Certain standards are not fully met (Standard No. 1, 8, 9, and 10 must always be fully met) and an explanation of why these standards are not met is contained in the Stormwater Report.

☐ The project involves redevelopment and a description of all measures that have been taken to improve existing conditions is provided in the Stormwater Report. The redevelopment checklist found in Volume 2 Chapter 3 of the Massachusetts Stormwater Handbook may be used to document that the proposed stormwater management system (a) complies with Standards 2, 3 and the pretreatment and structural BMP requirements of Standards 4-6 to the maximum extent practicable and (b) improves existing conditions.

Standard 8: Construction Period Pollution Prevention and Erosion and Sedimentation Control

A Construction Period Pollution Prevention and Erosion and Sedimentation Control Plan must include the following information:

- Narrative;
- Construction Period Operation and Maintenance Plan;
- Names of Persons or Entity Responsible for Plan Compliance;
- Construction Period Pollution Prevention Measures;
- Erosion and Sedimentation Control Plan Drawings;
- Detail drawings and specifications for erosion control BMPs, including sizing calculations;
- Vegetation Planning;
- Site Development Plan;
- Construction Sequencing Plan;
- Sequencing of Erosion and Sedimentation Controls;
- Operation and Maintenance of Erosion and Sedimentation Controls;
- Inspection Schedule;
- Maintenance Schedule;
- Inspection and Maintenance Log Form.

☐ A Construction Period Pollution Prevention and Erosion and Sedimentation Control Plan containing the information set forth above has been included in the Stormwater Report.

☐ The project is highly complex and information is included in the Stormwater Report that explains why it is not possible to submit the Construction Period Pollution Prevention and Erosion and Sedimentation Control Plan with the application. A Construction Period Pollution Prevention and Erosion and Sedimentation Control has ***not*** been included in the Stormwater Report but will be submitted ***before*** land disturbance begins.

☐ The project is ***not*** covered by a NPDES Construction General Permit.

Checklist (continued)

- ☐ The project is covered by a NPDES Construction General Permit and a copy of the SWPPP is in the Stormwater Report.
- ☐ The project is covered by a NPDES Construction General Permit but no SWPPP been submitted. The SWPPP will be submitted BEFORE land disturbance begins.

Standard 9: Operation and Maintenance Plan

- ☐ The Post Construction Operation and Maintenance Plan is included in the Stormwater Report and includes the following information:
  - ☐ Name of the stormwater management system owners;
  - ☐ Party responsible for operation and maintenance;
  - ☐ Schedule for implementation of routine and non-routine maintenance tasks;
  - ☐ Plan showing the location of all stormwater BMPs maintenance access areas;
  - ☐ Description and delineation of public safety features;
  - ☐ Estimated operation and maintenance budget; and
  - ☐ Operation and Maintenance Log Form.
- ☐ The responsible party is ***not*** the owner of the parcel where the BMP is located and the Stormwater Report includes the following submissions:
  - ☐ A copy of the legal instrument (deed, homeowner's association, utility trust or other legal entity) that establishes the terms of and legal responsibility for the operation and maintenance of the project site stormwater BMPs;
  - ☐ A plan and easement deed that allows site access for the legal entity to operate and maintain BMP functions.

Standard 10: Prohibition of Illicit Discharges

- ☐ The Long-Term Pollution Prevention Plan includes measures to prevent illicit discharges;
- ☐ An Illicit Discharge Compliance Statement is attached;
- ☐ NO Illicit Discharge Compliance Statement is attached but will be submitted ***prior to*** the discharge of any stormwater to post-construction BMPs.