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Preliminary
STORMWATER MANAGEMENT REPORT
WITH OPERATION & MAINTENANCE PLAN

Brem Property - 40B

AN AFFORDABLE SINGLE FAMILY HOUSING DEVELOPMENT

100 LONG RIDGE ROAD
CARLISLE, MASSACHUSETTS

PREPARED BY:

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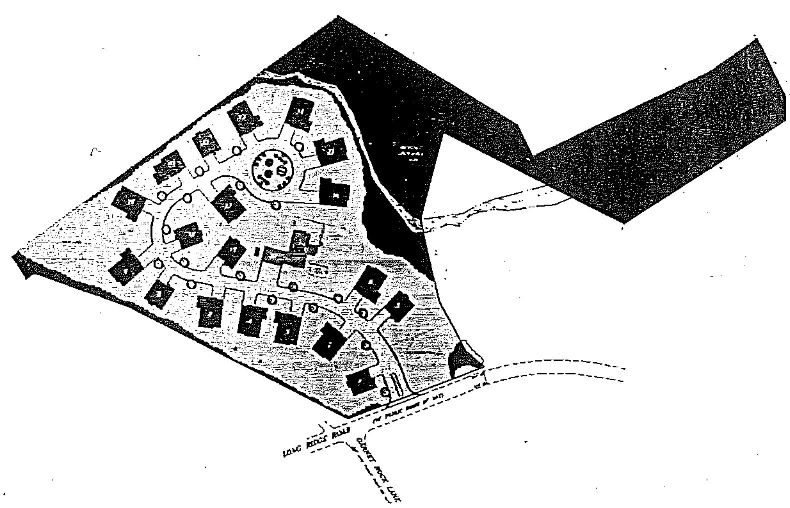
MBC JOB # 2066

JUNE 20, 2014, Rev: 7-3-2014



Site Plan

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OFF LONG RIDGE ROAD
CARLISLE, MASSACHUSETTS

PRELIMINARY

STORMWATER MANAGEMENT REPORT

VOLUME 1 OF 2

STORMWATER MANAGEMENT DESIGN

July 1, 2014

PREPARED FOR:

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THE FOLLOWING REPORT HAS BEEN PREPARED UNDER THE SUPERVISION OF A REGISTERED PROFESSIONAL ENGINEER LICENSED IN THE COMMONWEALTH OF MASSACHUSETTS.

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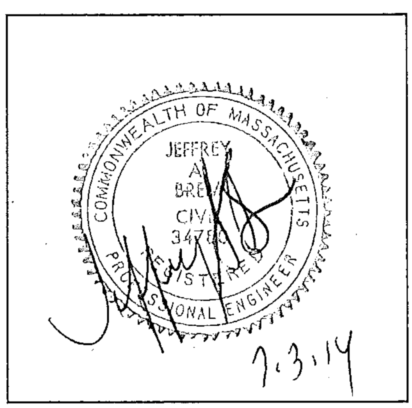
Volume 1

STORMWATER MANAGEMENT DESIGN



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VOLUME 1

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VOLUME 1 (CONTINUED)

VOLUME 2 - STORMWATER CHECKLIST & HYDROCAD PRINTOUTS

SECTION 1.0 INTRODUCTION

The following Preliminary Stormwater Management Report outlines the proposed drainage design intended to mitigate the impacts from the stormwater runoff due to the site development. It is intended to satisfy the requirements to protect the surrounding neighborhoods, the natural resources, the existing drainage utilities and the waters of the Commonwealth from adverse impacts resulting from the stormwater runoff.

Pursuant to the definitions and requirements of a project proposed under MGL Chapter 40B, the proponent is required to provide preliminary drawings and computations only as changes are typical for these types of projects. Accordingly, this is a Preliminary Stormwater Management Report. However, in order to properly document the parameters necessary to comply with the regulations and requirements of the Board of Appeals, and to answer the questions already suggested in various forums and documents by the neighbors, this report is much more than a preliminary report and contains the complete design intent.

This program defines a program for controlling, conveying, treating and discharging the stormwater runoff from the site in accordance with the adopted *Stormwater Management Policy of the Commonwealth of Massachusetts, the Federal and State Clean Water Acts, the Wetlands Protection Act, the Coastal Zone Act, the National Pollutant Discharge Elimination System Program and the Town of Carlisle Subdivision of Land Regulations.*

The report identifies by means of narratives, calculations, plans and specifications that suitable and appropriate quantity and quality control measures have been provided to gather, control, treat, and discharge stormwater runoff. The storm frequencies analyzed are the 2 yr, 10 yr, 25 yr, and 100 yr pursuant to MassDEP. A summary tabulation of the pre development and post development peak flow rates is provided.

Low Impact Development (LID) and Best Management Practices (BMP) concepts and designs are utilized in accordance with MassDEP guidelines.

This stormwater analysis includes a quantity comparison of the pre-developed flows to the post-developed flows to assure that no increase in the rate of runoff at the property boundaries. The design includes the totality of LID practices, BMP's, and Stormwater Management Facilities (SMF's) to control the discharge flow rate from the site at a rate no greater than the existing pre-developed flow rate. This Report also discusses the design for the water quality treatment methods and evaluates the compliance to the various codes, regulations, and policies.

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This report includes:

- i) a full analysis of the Pre vs. Post Development conditions,
- ii) a division of the land into SubCatchment Areas,
- iii) a computation of the weighted average "CN" for each SubCatchment area,
- iv) a computation of the time of concentrations for each SubCatchment area,
- v) a preliminary grading of the bio-retention area to determine storage volumes,
- vi) a schedule of pipe sizes, slopes, and preliminary invert elevations,
- vii) a preliminary sizing of the infiltration system,
- viii) a layout of the entire drainage system,
- ix) a sample bio retention system design, and
- x) a manufacturers cut sheet for the infiltration chambers

SECTION 2.0 GENERAL PROJECT INFORMATION -

SECTION 2.1 GENERAL

The proposed residential project is a 20 unit, single family housing project proposed under Massachusetts General Law (MGL) Chapter 40B off Long Ridge Road in Carlisle, Massachusetts. The parcel area is 9.84 acres. The property is currently used as a home and horse stables and riding arena - with outside boarders - as an exempted farm over 5 acres. The existing home will be remodeled as one of the homes in the project. A new private roadway will provide access to the homes.

SECTION 2.2 EXISTING CONDITIONS

2.2.1 Site

The project is located at 100 Long Ridge Road in Carlisle, Massachusetts and consists of 9.84 acres of land. It is currently used as one existing residential dwelling constructed about 1974 by Deck House, Inc. and horse farm.

About 4 ½ acres of the property is cleared with the balance as woodland. The timber is primarily a mix of large eastern white pines and pin oaks with lesser quantities of other high canopy species such as hemlock, maple, and birch.

The topography throughout the property ranges a total of approximately 30 feet (from minimum to maximum) but a large portion near the house and barn is fairly level . Most of the other areas have a modest slope and a few select areas are quite steep.

Soil testing throughout the property indicate a well drained soil with percolation rates of 2-5 minutes per inch with depths to the seasonal high water table ranging from 24" to 84". In summary, the soils are very good and will certainly support septic system(s).

The property abuts the Blood Farm Trail which connects to Estabrook Woods and other conservation open space areas and trails totaling over 900 acres of land used frequently by many members of the community.

The property has been improved by the addition of a 6 stall, 2 story barn with tack room, feed room, and hay storage. In addition, the property includes several dirt paddocks, grass paddocks, and grass turn-out areas (fields) as outdoor spaces on the farm for the horses. A manure pile conforming to the regulations of the Carlisle Board of Health is maintained regularly.

Currently, all the stormwater runoff from this site flows easterly or southerly on the property and then easterly to the intermittent stream which then flows easterly until it crosses Nowell Farme Road and eventually River Road to the Concord River to the east.

2.2.2 Geology

The topography ranges from a relative low of about elevation 80 at the far east of the site to a high point at about elevation 126 at the northwestern corner and adjacent to the Blood Trail. More than half of the area of development is fairly flat with a sloping area to the easterly sections.

The soils are generally fairly well draining glacial till but veins of sand have been observed. In addition rock outcroppings are noticeable along the intermittent stream in areas that are not proposed for development.

For more information on soil types, especially NCRS soil mapping see Section 2.3.

2.2.4 Wetlands

An intermittent stream and narrow wetland system traverses the rear portion of the property flowing southerly and turning easterly in the narrower section of the property. The bordering vegetated wetland associated with this stream is quite narrow and follows within several feet of the streambed to a point about 500 feet to the east where the wetland widens significantly prior to crossing Nowell Farme Road. There is also a potential vernal pool in this most easterly area.

At this time the proposed project does not expect to alter any wetland resource areas. Building and disturbance is proposed directly adjacent to the wetland in the buffer zone.

SECTION 2.3 EXISTING SOILS

2.3.1 NRCS Soil Types

The Soil Conservation Service with the United States Department of Agriculture has mapped the project area for soil types. The SCS soils types are now available online at the USDA Natural Resources Conservation Service (NRCS) website. A print-out of the Off Site Soils and On Site Soils is included herein in Section 3.4.

The USDA classifies soils into four (4) hydrologic soil groups as follows:

TABLE 2.3: NRCS - SCS SOIL GROUPS

SCS Soils Group	General Description
A	Sands & Gravels - highly permeable
B	Glacial Till – more permeable
C	Glacial Till – less permeable
D	Impermeable, silts, clays, muck

Group A—Soils in this group have low runoff potential when thoroughly wet. Water is transmitted freely through the soil. Group A soils typically have less than 10 percent clay and more than 90 percent sand or gravel and have gravel or sand textures. Some soils having loamy sand, sandy loam, loam or silt loam textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments.

Group B—Soils in this group have moderately low runoff potential when thoroughly wet. Water transmission through the soil is unimpeded. Group B soils typically have between 10 percent and 20 percent clay and 50 percent to 90 percent sand and have loamy sand or sandy loam textures. Some soils having loam, silt loam, silt, or sandy clay loam textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments.

Group C—Soils in this group have moderately high runoff potential when thoroughly wet. Water transmission through the soil is somewhat restricted. Group C soils typically have between 20 percent and 40 percent clay and less than 50 percent sand and have loam, silt loam, sandy clay loam, clay loam, and silty clay loam textures. Some soils having clay, silty clay, or sandy clay textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments.

Group D—Soils in this group have high runoff potential when thoroughly wet. Water movement through the soil is restricted or very restricted. Group D soils typically have greater than 40 percent clay, less than 50 percent sand, and have clayey textures. In some areas, they also have high shrink-swell potential. All soils with a depth to a water impermeable layer less than 50 centimeters [20 inches] and all soils with a water table within 60 centimeters [24 inches] of the surface are in this group, although some may have a dual classification, as described in the next section, if they can be adequately drained.[1]

The soils on the site consist of soils within Hydrologic Soil Groups B, C, and D. However, the NCRS map is obviously incorrect in some locations as clearly noted by the wetland survey.

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[1] Part 630, Hydrology, National Engineering Handbook, Chapter 7, Hydrology by United States Department of Agriculture, Natural Resources Conservation Service, 2007 (210-V1-NEH, May, 2007)

Therefore, the Woodbridge soil is extrapolated to most all of the developed area. Woodbridge is within the Soil Hydological Group C.

For more information, See Section

SECTION 2.4 PROPOSED DEVELOPMENT

The project proposes 20 units, including the existing home, at a density of 2.03 units per acre. The homes will be single family with two car garages and three bedrooms totaling an average of about 2500 square feet of living space. Approximately seven of the nineteen new homes will have walk out basements as the site grades allow. Each house will be designed with a usable front porch sited 20' to 35' from the edge of the road to encourage lot owners to socialize with their neighbors regularly. The land between the porch and roadway will be landscaped with formal garden areas; not just green lawn. These garden areas will be maintained by each homeowner to offer personalization and will enhance the view as one drives through the project. The outdoor spaces in the rear will be the typical patio, deck, and screened porch for more private entertaining.

The layout of the proposed roadway begins opposite, and over 100 feet east of, the existing intersection of Garnet Rock Lane and Long Ridge Road. The design includes a small boulevard entrance to allow for signage and landscaping features. The roadway is curvilinear and traverses a gentle grade for 500 feet to a sharp right curve downhill to a cul-de-sac turnaround feature. The proposed roadway width includes a traveled way to match the existing roadways with a paved 20 foot travelled way. The roadway width and cul-de-sac will be designed for the maneuvering of fire apparatus and will be landscaped in the middle with a stormwater feature underground.

Stormwater controls will utilize the principles of Low Impact Development (LID) design wherever feasible. LID strives to mimic nature in reducing runoff by limiting disturbed areas where possible, infiltrating runoff as close to the original point of contact as possible, developing rain gardens to aid in infiltrating the lower storm intensities, and designing sustainable best management practices to address concentrated runoff to mitigate the impact to the groundwater, wetland, and receiving waters.

Electricity service is currently by NStar via underground wires and surface mounted transformers. This project will extend the electrical service, in kind. The site is also serviced for cable television by Comcast, also underground. Domestic water service will be provided by shared, private wells with the required legal restrictions, easements, and use agreements. Sewerage will be by three separate shared systems and will utilize Alternative Technologies (MassDEP approved state of the art components). Water supply for fire suppression will be provided by the proposed fire cistern. Homeownership documents will allow for the assessment of fees to maintain the sewerage, drainage, and water systems as well as the roadways, utilities, and open space areas, etc. The primary heat source is still being investigated to provide the most efficient design and includes propane, oil, and heat pumps as alternatives being considered. Natural gas is not available in the street system. Solid waste will be as all other residences in Carlisle – to the Transfer Station.

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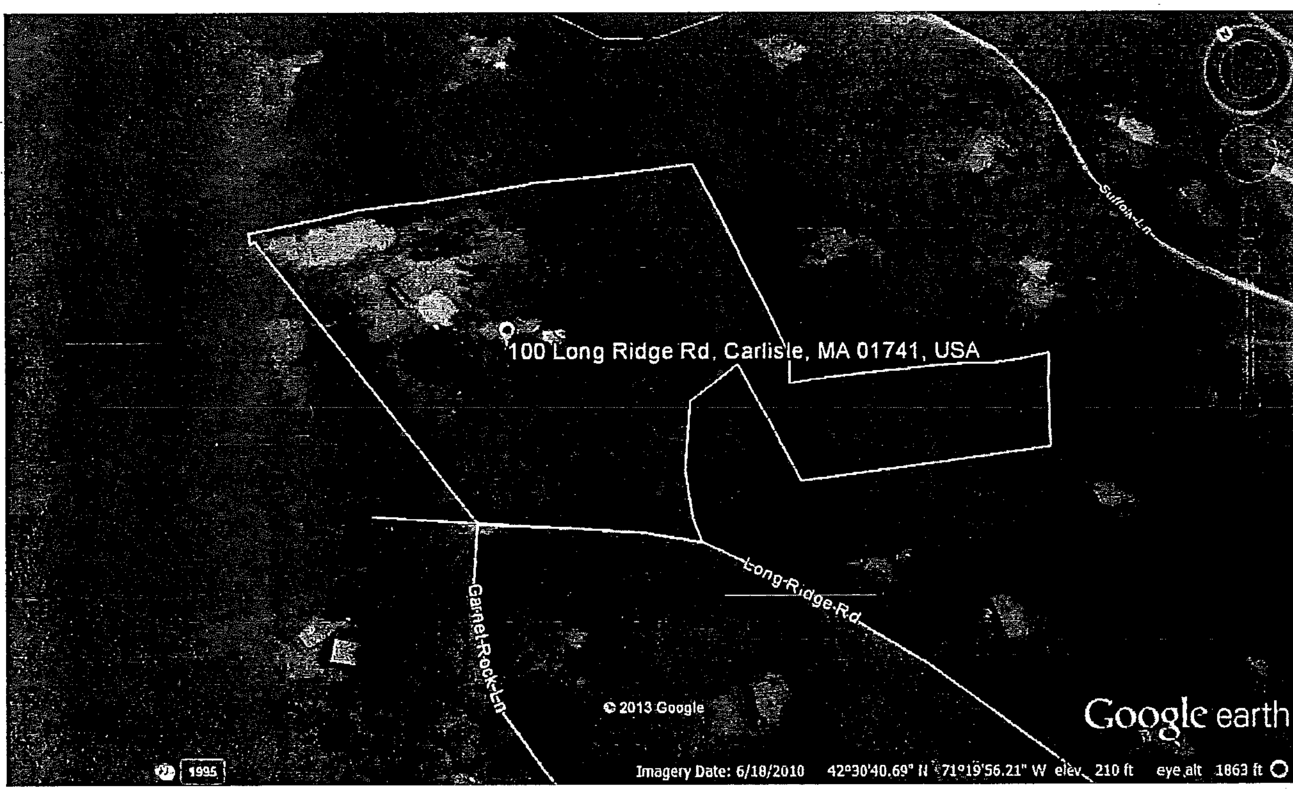
Section 3.0 Maps

SECTION 3.1 SITE LOCUS / GOOGLE EARTH MAP

FIGURE 3.1 NOT TO SCALE



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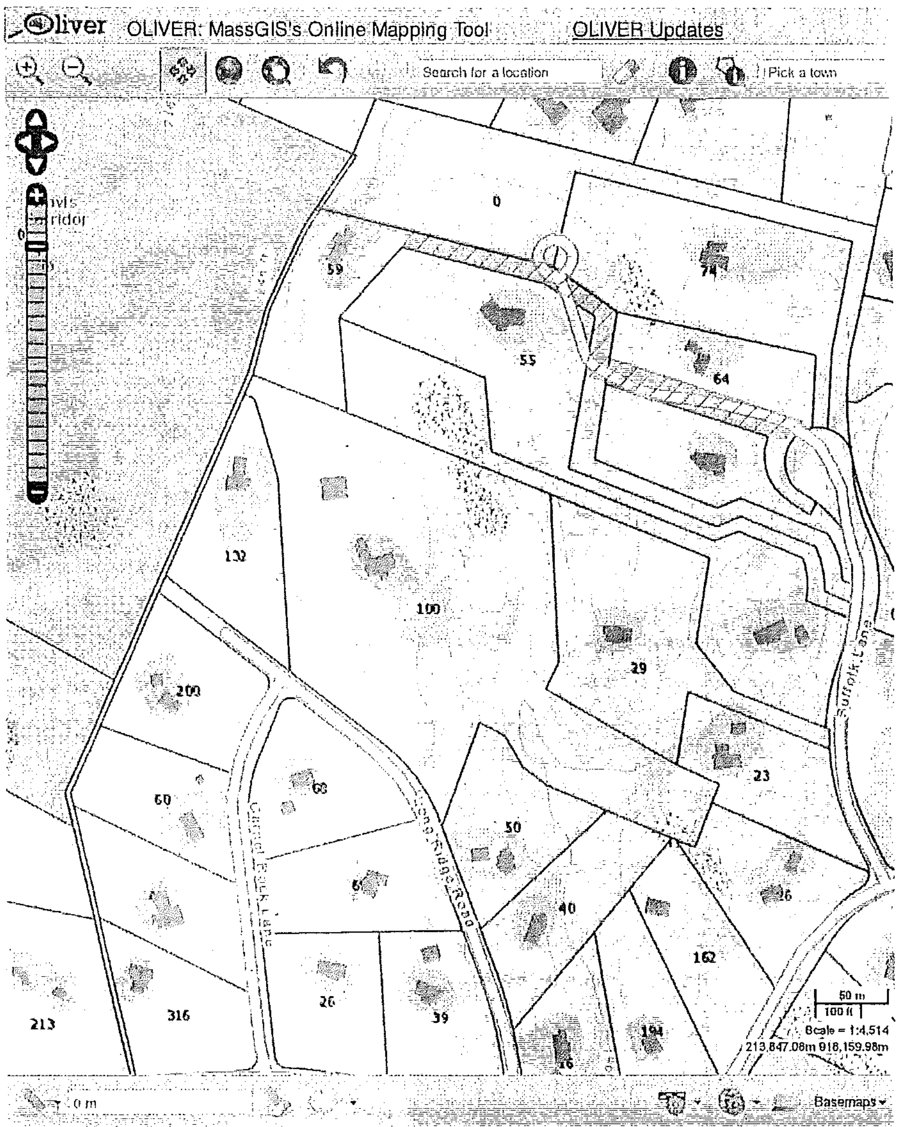
SECTION 3.2 MASS GIS MAP

FIGURE 3.2 NOT TO SCALE



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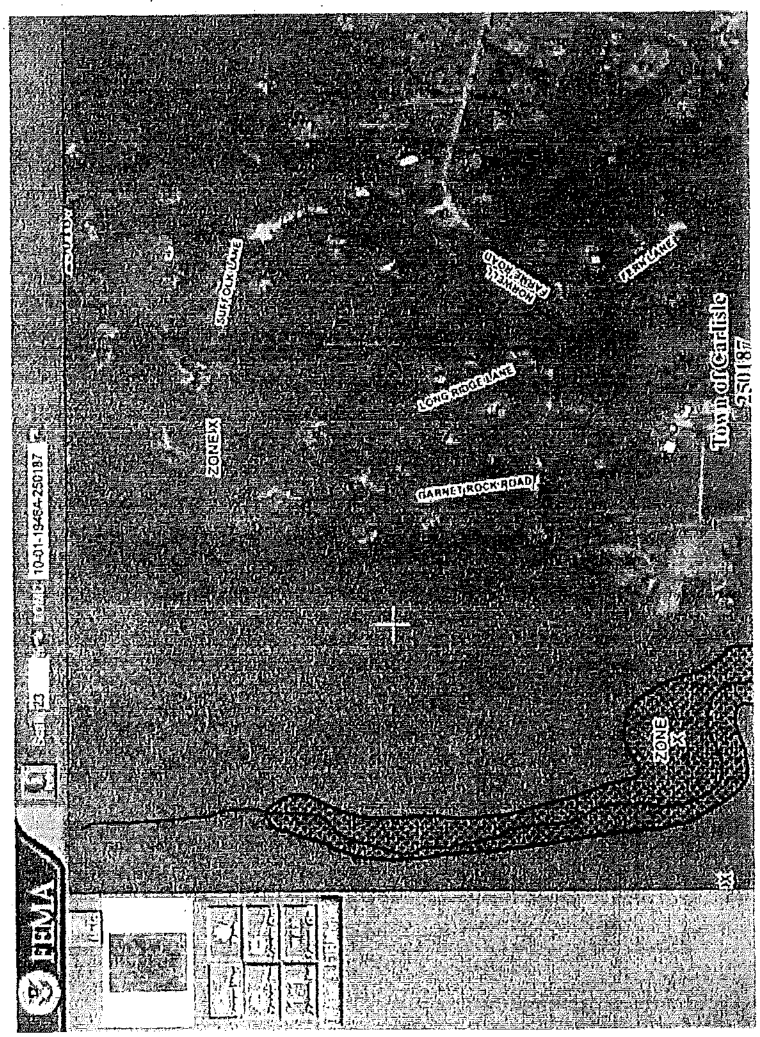
3.3 FLOOD INSURANCE RATE MAP (FIRM)

FIGURE 3.3 COMMUNITY PANEL: 250176 0264 E
MAP DATE: JUNE 4, 2010



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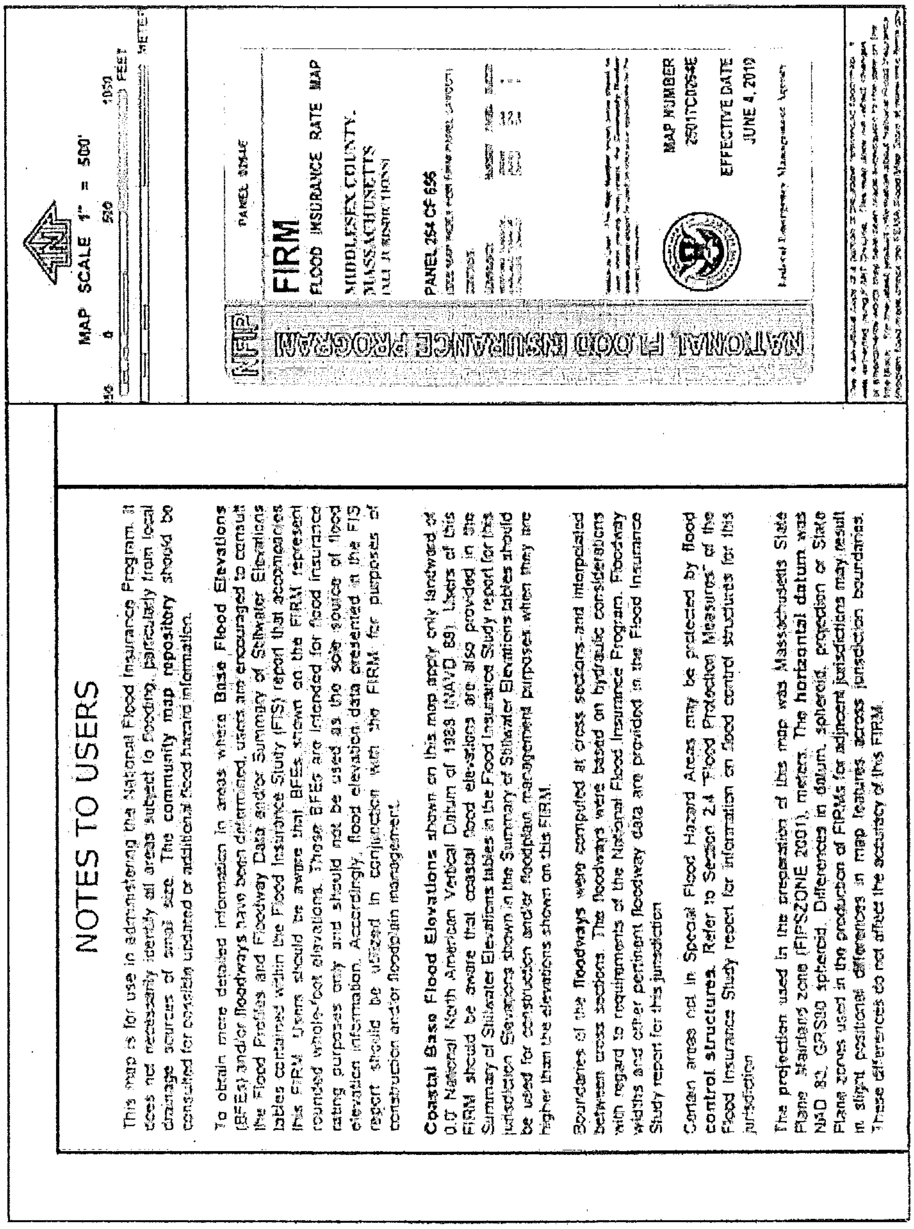

NOTES TO USERS

This map is for use in administering the National Flood Insurance Program. It does not necessarily identify all areas subject to flooding, particularly from local drainage sources of small size. The **community map repository** should be consulted for possible updated or additional flood hazard information.

To obtain more detailed information in areas where **Base Flood Elevations** (BFEs) and/or **floodways** have been determined, users are encouraged to consult the Flood Profiles and Floodway Data and/or Summary of Stillwater Elevations tables contained within the Flood Insurance Study (FIS) report that accompanies this FIRM. Users should be aware that BFEs shown on the FIRM represent rounded whole-foot elevations. These BFEs are intended for flood insurance rating purposes only and should not be used as the sole source of flood elevation information. Accordingly, flood elevation data presented in the FIS report should be utilized in conjunction with the FIRM for purposes of construction and/or floodplain management.

Coastal Base Flood Elevations shown on this map apply only landward of 0.0' North American Vertical Datum of 1988 (NAVD 88). Users of this FIRM should be aware that coastal flood elevations are also provided in the Summary of Stillwater Elevations tables in the Flood Insurance Study report for this jurisdiction. Elevations shown in the Summary of Stillwater Elevations tables should be used for construction and/or floodplain management purposes when they are higher than the elevations shown on this FIRM.

Boundaries of the **floodways** were computed at cross sections and interpolated between cross sections. The floodways were based on hydraulic considerations with regard to requirements of the National Flood Insurance Program. Floodway widths and other pertinent floodway data are provided in the Flood Insurance Study report for this jurisdiction.

Certain areas not in Special Flood Hazard Areas may be protected by **flood control structures**. Refer to Section 2.4 "Flood Protection Measures" of the Flood Insurance Study report for information on flood control structures for this jurisdiction.

The **projection** used in the preparation of this map was Massachusetts State Plane Mainland zone (FIPSZONE 2001), meters. The **horizontal datum** was NAD 83, GRS80 spheroid. Differences in datum, spheroid, projection or State Plane zones used in the production of FIRMs for adjacent jurisdictions may result in slight positional differences in map features across jurisdiction boundaries. These differences do not affect the accuracy of this FIRM.

MAP SCALE 1" = 500'

0 500 1000 FEET

METERS

NFIP NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0254E

FIRM
FLOOD INSURANCE RATE MAP

MIDDLESEX COUNTY, MASSACHUSETTS
(ALL JURISDICTIONS)

PANEL 254 OF 656

MAP NUMBER
25017C0254E

EFFECTIVE DATE
JUNE 4, 2010

Federal Emergency Management Agency

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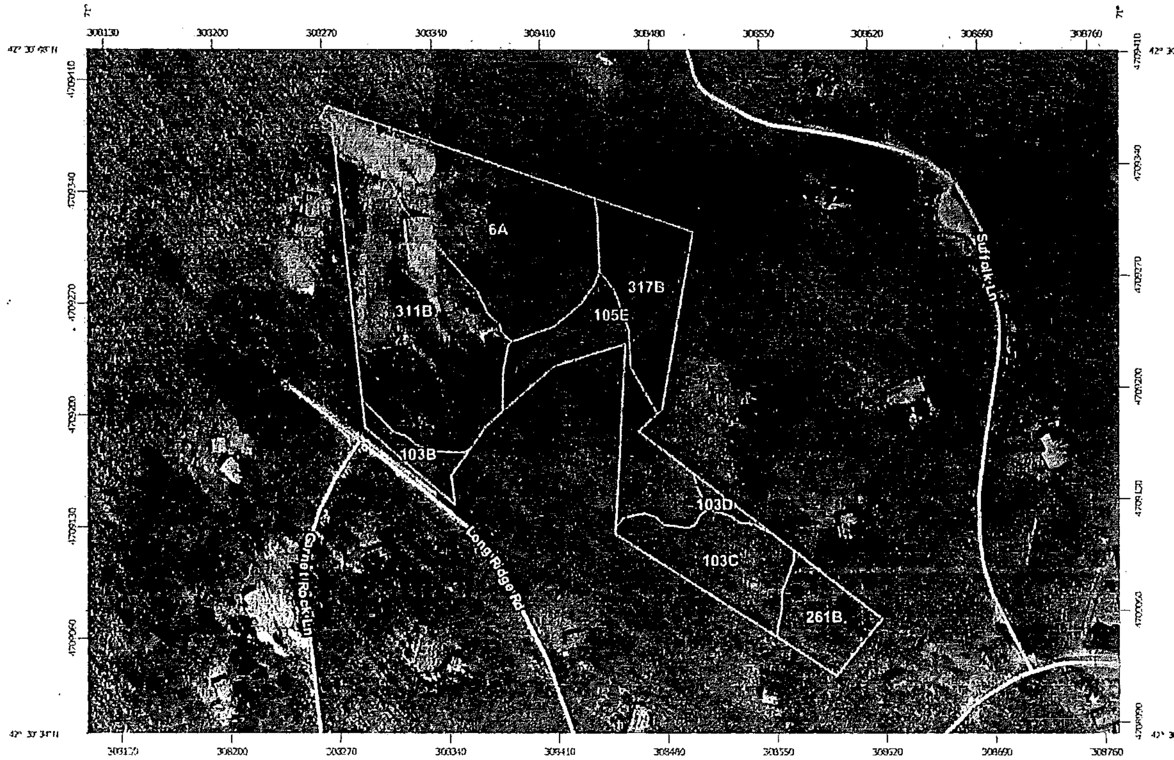
SECTION 3.4 SOILS MAP

FIGURE 3.4 ON SITE SOILS: SCALE: AS SHOWN

Soil Map—Middlesex County, Massachusetts
(Brem Property - 100 Long Ridge, Carlisle, MA)



Map Scale: 1:3,020 if printed on A landscape (11" x 8.5") sheet.

Meters: 0 40 80 160 240

Feet: 0 100 200 400 600

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 19N WGS84

USDA Natural Resources Conservation Service

Web Soil Survey
National Cooperative Soil Survey

6/25/2014
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FIGURE 3.5 SOILS MAP LEGEND

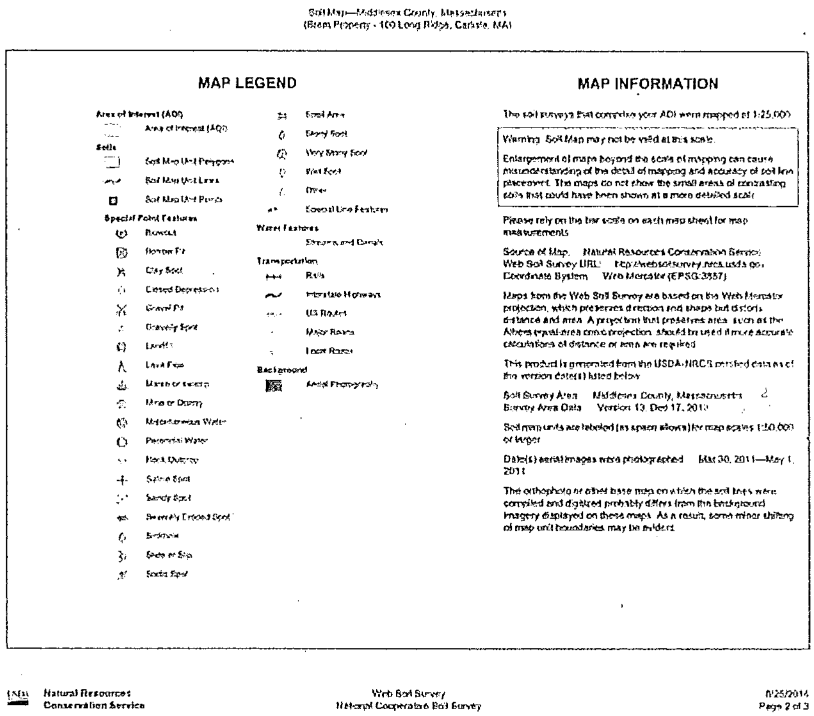


FIGURE 3.6: SOILS HYDROLOGIC SOIL GROUP AND SITE COVERAGE (% OF AOI)

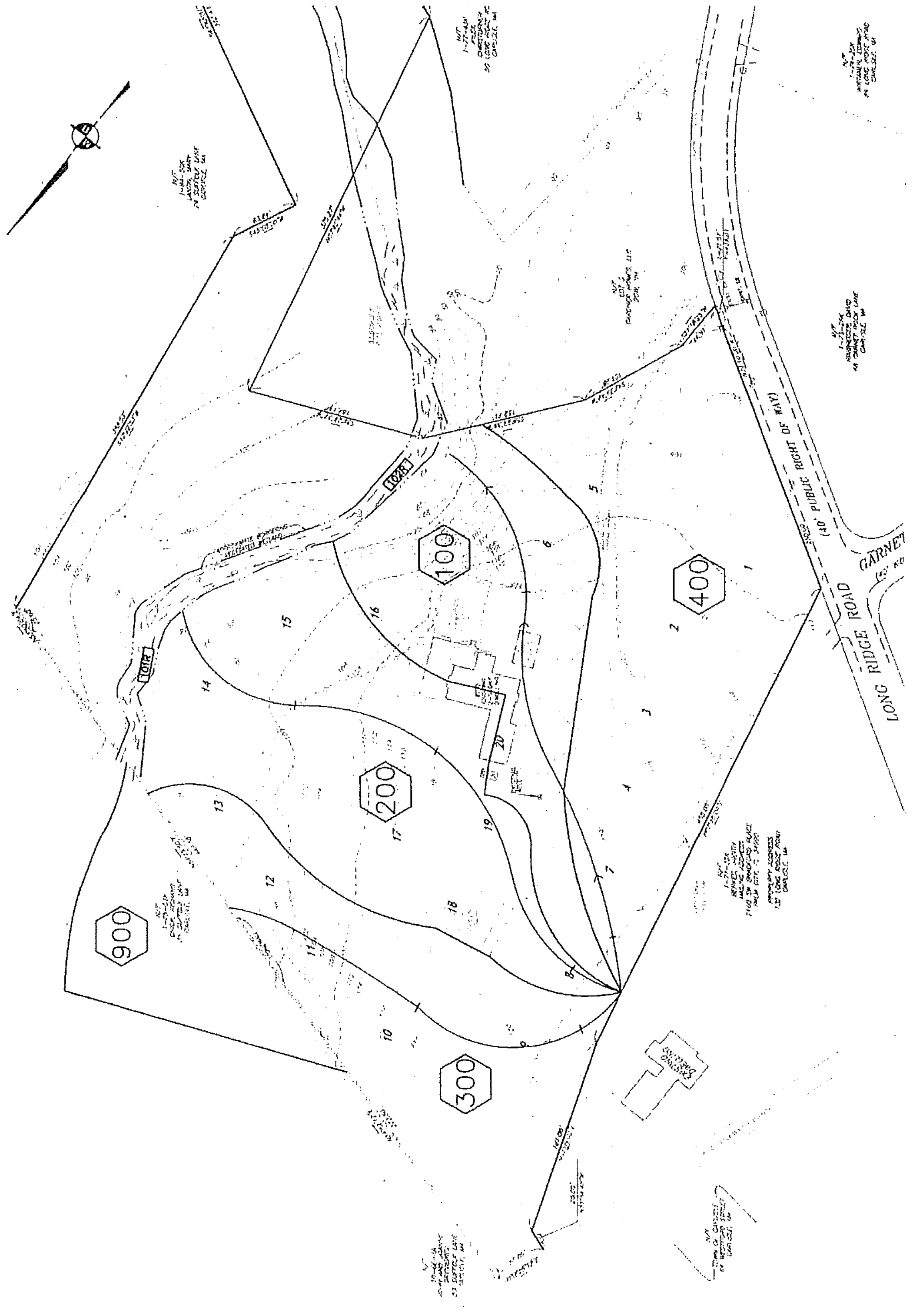
Soil Map—Middlesex County, Massachusetts

Brem Property - 100 Long Ridge, Carlisle, MA

Map Unit Legend

Middlesex County, Massachusetts (MA017)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
6A	Scarboro mucky fine sandy loam, 0 to 3 percent slopes	2.6	24.7%
103B	Charlton-Hollis-Rock outcrop complex, 3 to 8 percent slopes	0.3	2.6%
103C	Charlton-Hollis-Rock outcrop complex, 8 to 15 percent slopes	1.1	10.5%
103D	Charlton-Hollis-Rock outcrop complex, 15 to 25 percent slopes	0.1	0.9%
105E	Rock outcrop-Hollis complex, 3 to 35 percent slopes	1.4	13.2%
261B	Tisbury silt loam, 3 to 8 percent slopes	0.7	6.6%
311B	Woodbridge fine sandy loam, 3 to 8 percent slopes, very stony	3.3	30.7%
317B	Scituate fine sandy loam, 3 to 8 percent slopes, extremely stony	1.1	10.7%
Totals for Area of Interest		**10.6**	**100.0%**

SECTION 3.5 DRAINAGE AREA MAPS – PRE DEVELOPMENT



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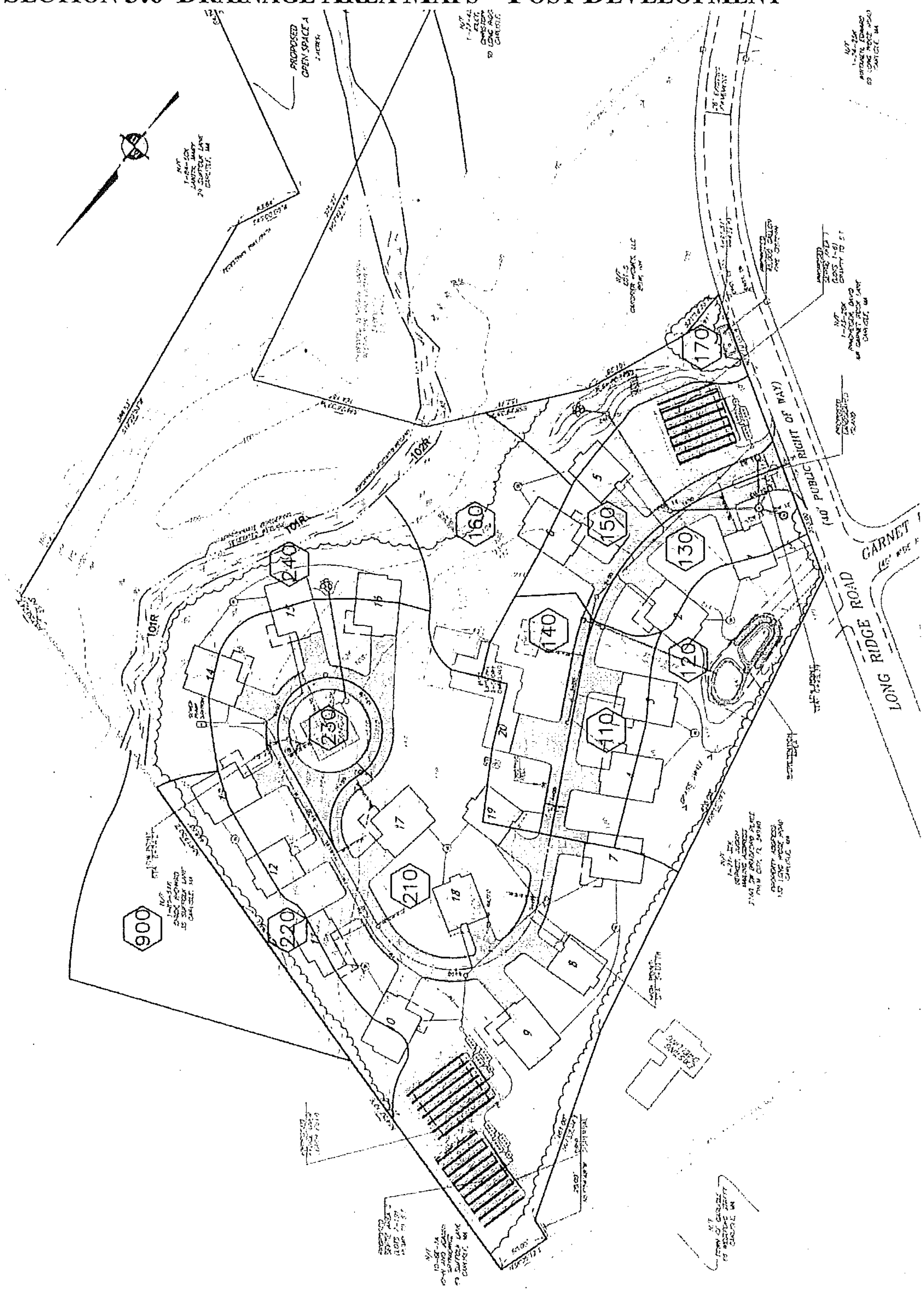
SECTION 3.6 DRAINAGE AREA MAPS – POST DEVELOPMENT



Section 4.0 Stormwater Management Overview

SECTION 4.1 STORMWATER MANAGEMENT PLAN – DEFINITION AND GOALS

4.1.1 Definition

A *Stormwater Management Plan* is a program for controlling, conveying, treating and discharging stormwater runoff. It is a system intended to protect the surrounding neighborhoods, the existing drainage facilities, and the waters of the Commonwealth of Massachusetts from adverse impacts caused by stormwater runoff. The plan consists of engineering designs including drawings, details and specifications of construction, narratives, and supporting calculations to justify the feasibility to construct and comply with the requirements of the adopted Stormwater Management Policy and Regulations within the Commonwealth of Massachusetts, the Federal and State Clean Water Acts, the Wetlands Protection Act, the Coastal Zone Act, and the National Pollutant Discharge Elimination System Program.

4.1.2 Goal

The goal of a *Stormwater Management Plan* is to provide suitable quantity and quality control measures for stormwater runoff from a developed property compliant with the standards of the Stormwater Management Policy. It should be simplistic in design, cost effective to construct, and reasonable to maintain. The design should blend into the natural features and site resources and take full advantage of existing environmental mechanisms to accomplish any necessary mitigation. The primary intention of the stormwater management plan is to provide the guidance for the selection, implementation and management of such systems.

SECTION 4.2 UNDERSTANDING RUNOFF AND STORMWATER MANAGEMENT

4.2.1 Hydrologic Cycle

The basis of stormwater management begins with the understanding of the natural mechanisms of the earth's ecosystems. This requires the knowledge of the hydrologic cycle that generates the runoff that in turn creates the rivers, ponds and wetlands we are so familiar with. These surface features are the primary source for the recharge of the subsurface aquifers. Development or the construction of man-made features alters these natural cycles and their performances. The key to good management of the altered circumstances is to know and understand, then imitate the natural mechanisms, controlling the stormwater runoff in much the same way that nature does. This is also a key component of Low Impact Development, mirroring nature by limiting the changed environment, recharging as close as possible to the location of each raindrop, and using natural, sustainable structures where necessary with as little impact as possible.

The hydrologic cycle describes the simplistic logical mechanisms of water within the earth's ecosystems. It is a representation of the equilibrium that is constantly balancing the status of water affected by the variations in the seasons, temperatures, weather and rainfall. It also is affected by both natural and man-made impacts to the ecosystem. The cycle is presented as three basic steps:

PRECIPITATION: consisting of rain, snow, hail, sleet, fog or mist.

COLLECTION and INFILTRATION: representative of the precipitation converting to runoff, concentrating into surface drainage features such as rivers, creeks, lakes, ponds, and wetlands. A portion of this will infiltrate into the soils, percolating downward to recharge the groundwater and contribute to the subsurface aquifers.

EVAPORATION and TRANSPIRATION: is the process of vaporizing the water fluid to return it to the atmosphere, by means of thermally evaporating the surface waters, or via the vegetation uptake and natural release through the leaves.[2]

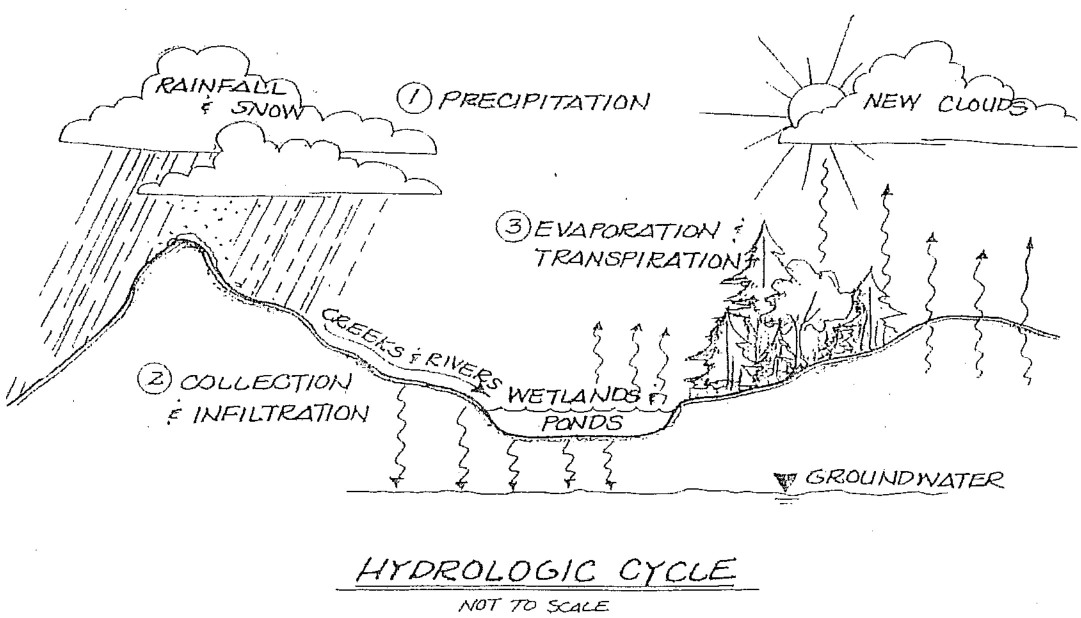


Figure 4.1

2 Excerpted from: "*Managing Stormwater in Massachusetts*", Volume Two: Best Management Practices (BMP) Manual, dated March 1997

After understanding the role water plays in the earth's ecosystem, the next focus is on the localized features that effect the generation of the runoff. This will aid in predicting the quantities, the quality and the character of the flows.

4.2.2 Stormwater Runoff

Runoff, or surface water movement, is a result of the COLLECTION and INFILTRATION stage of the hydrologic cycle. The volume, speed and character of the runoff flow is dependent on the size of the precipitation event (i.e. the amount of water in a given time period) and the conditions of the land. As the precipitation contacts the surface, the runoff generated is dependent on the contributing area size, shape, topography, soils, antecedent moisture content, vegetative coverage, and drainage features. These items, in conjunction with man-made features, directly affect the water's movements.

4.2.2.1 Contributing Area

The contributing area establishes the boundary limits for the waters movement. It is the relationship between the topographic features and the physics of gravitational forces. Simply put, as the precipitation falls to the surface, it runs downhill from the highest point. The boundary limits represent the highest established elevations within the "lay of the land", i.e.; the break lines between the basin areas, much like the peak of a roofline, directing the flow in a direction of the lower elevations. The contributing area size is a factor directly correlating the total runoff volume to the available collection surface. The area shape is a function of its consistency or homogeneous nature established by the topography and land features (e.g. a sharp valley with a wide flat floodplain, vs. a long rolling meadows with multiple intermittent drainage channels which will potentially generate two completely different runoff flow regimes).

4.2.2.2 Topography

The topography not only defines the contributing area, but also has a major effect on the rate of runoff, the peak discharge, velocity and the resulting soil erosion potential, and other flow characteristics. The slope differential, or total change in elevation, quantifies the physical vertical drop through the flow travel path length (drop per length, rise/run), used in calculating the runoff velocity (length traveled per time period, feet per second) and thus the travel time (Tc).

The velocity is a result of the concentration of flows that in turn define the creation of the drainage features. The flow velocities are a factor in the energy force behind surface weathering and wear related to erosional factors that develop streambeds and channels. The lack of significant velocity is evident in the ponded areas such as lakes and wetlands. When the velocities increase, the flow regime has the ability to move materials of heavier weight (suspended solids). As it slows the heavier particles separate out and drop to the bottom. The end result is erosion or sedimentation. The velocity changes not only with the slope, but is directly related to the size of the precipitation event, the smoothness of the channel surface (roughness coefficient, n), the cross-sectional geometry, and the depth of flow in the channel bed which is a function of the flow rate (Q).

4.2.2.3 Soils

Soil properties influence the process of the generation of the runoff from rainfall. The major effect of soils to runoff is on the volume of runoff generated as the remnant flow of the soils' ability to percolate, or infiltrate the precipitation contacting it. The type of soil regulates the overall capacity and ability over time to absorb runoff. For example, a clay matrix of soil may percolate a large portion of the beginning precipitation, but as the material quickly reaches a saturation point, it swells, stopping the ability of the runoff to infiltrate into the soil, thus generating a higher level of runoff. On the other hand, a clean sand or gravel matrix could potentially infiltrate all the runoff indefinitely, minimizing surface runoff. The effect of the soils on the runoff estimation calculations is represented as one component of the *"runoff curve number" (CN)*. Soils are categorized in one of four generalized groupings, "A","B","C", and "D", ranging from a high infiltration – low runoff "A" type (sand), to a low infiltration – high runoff "D" type (clay or muck).

Infiltration into the different soil horizons (layers) offers water quality treatment by filtration, adsorption, absorption and biochemical breakdown of pollutants. Some soils offer better removal capacities for specific pollutants than others do. The organic topsoil has a tremendous ability to collect and breakdown organic and hydrocarbon compounds. This is due to the composition of the materials similar to compost (breaking down of the foliage, litter and debris), in an environment rich in aerobic (presence of oxygen) bacteria cultures and free-ion receptor points. As the water infiltrates downward into the anaerobic (lack of oxygen) conditions other chemical reactions that can only occur under those environmental conditions will occur along with the physical act of filtering remove and breakdown additional pollutants. The type of soil including its chemical composition affects the removal rate based on its ionization capacity. Lastly, soil acts as a physical filter trapping particulates, suspended solids, and pathogens.

In summary, infiltration of rain water through the ground helps to cleanse the water by physical (filtration), chemical (ionic exchange), and biological (bacteria) processes.

4.2.2.4 Vegetation

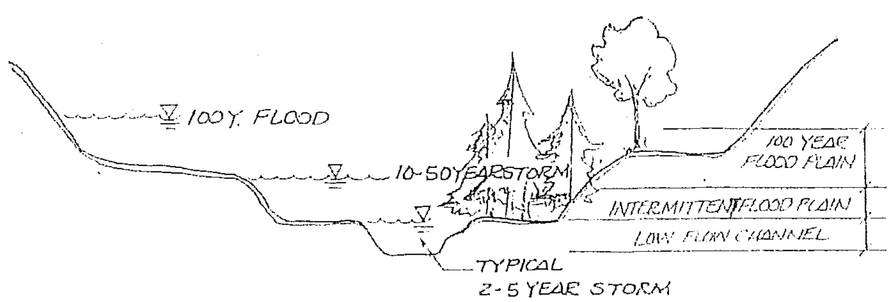
Vegetation affects runoff in several ways. The foliage and its litter maintain the surfaces' ability to infiltrate by protecting it from compacting and sealing under the impacts of precipitation. Some of the rainfall is retained on the surfaces of the leaves and evaporates directly back into the atmosphere. Other trapped water is lagged or stored so long prior to contacting the surface and joining the flow regime, that it is insignificant to affecting the peak runoff. Transpiration from the plants takes a portion of the soil moisture and releases it through the leaves as a natural byproduct of their nutrient uptake. The ground cover vegetation, in combination with the ground litter create numerous micro barriers damming the water flow, slowing and detaining it, resulting in an elongated time of concentration. This flow through the vegetation acts as nature's water quality treatment method, "biofiltering", removing pollutants from the flow regime by plant uptake and biological breakdown. The effects of the vegetation or ground surface characteristics on the runoff estimation is represented as the other component of the *"runoff curve number"(CN)*, incorporated with the soil type.

4.2.2.5 Drainage Features

The drainage features affect the runoff characteristics by collecting, conveying, storing and distributing the flows according to specific site features and their attributes. These include the intermittent rills, creek beds, channels, streams, lakes, ponds, wetlands, swamps, low points, dams, and any other element, structural, man-made or not, that the runoff must pass through to complete the hydrologic cycle. All stormwater modeling assigns a mathematical input to each element in order to represent the resultant water or runoff flows.

Some elements function to reduce, detain, store or slow the runoff flows, such as ponds, wetlands and swamps. The runoff cycle's flow increases and decreases and are often stored and slowed by the ponding of the larger, flatter areas, buffering the downstream features from damaging excessive flow. Part of the micro-ecosystem characteristic of ponding is their ability to survive the water surface fluctuation caused by the periodic flooding and receding. During low flow periods the stored water is a critical source to support the local fauna and flora, contributing to recharging the subsurface aquifers. These areas also act as natural water quality treatment facilities by allowing for sedimentation, biofilter pollutant uptake within the vegetation, and filtering both through the vegetation and the soils.

Other elements increase the flows and the related velocities, such as creeks, rivers and drainage channels. These features are the conduits for which to transport the runoff and, by virtue of what they are, tend to collect and concentrate the flows, increasing the speed as they go. Since the velocity is a result of the slope, the channel section and roughness coefficient, then natural site characteristics such as the topography, soils, vegetation and ground cover which control those factors thus controlling the velocities. Most drainage channels geometry and capacities are a result of the channel adapting to the natural flow conditions contributing to them. A typical stream cross-section consists of a low flow drainage channel with a capacity to convey the small storm events occurring up to the two year storm frequency (i.e. the typical day to day rainfall). Above the low flow channel is a flatter zone contained



TYPICAL DRAINAGE CHANNEL SECTION
NOT TO SCALE

Figure 4.2

between higher banking, referred to as the intermittent flood plain, with a capacity to flow and store the runoff from the five year to up to fifty year storm events, i.e.; the larger, less occurring, but more damaging events. This zone tends to be vegetated, sometimes heavily, due to the infrequency of flooding, and the availability of water from the low flow channel saturation during the drought periods. The vegetation is beneficial in that it slows the flows with root systems that protect the stream channel from erosion. An additional elevated bench to the section is common, and is configured the same, above the intermittent flood plain, and may be commonly referred to as the 100 year floodplain. This is an area that becomes inundated with flooded runoff during extreme rainfalls. It is compounded by the fact that all components of the drainage system are operating beyond capacity, backing the water up into any available storage volume. These events tend to be of uncommon frequency, short lived, but they cause considerable damages.

Finally, total watershed areas and time of concentration are significant factors in the impacts of various storm frequencies. Typically, rivers and large streams will engage in maximum flow many days after the initial or the most intense part of the rainfall event. This is because it takes many hours for the runoff from large watersheds to join with other flows from hundreds of rills and channels, dozens of creeks, tributaries, and streams prior to joining sections of the upstream river, then time for the river to flow downstream for many miles. Therefore, on shorter, intense storms the small drainage area sites near rivers may have little impact on the river's flooding impacts that will be occurring many hours in the future and well after the peak discharges from a specific small site, downstream and near the river. Detaining these small site flows could actually be detrimental by delaying the peak discharge rate to join with the larger watershed peak flows. The topic point being discussed is simply that an individual site's drainage system should be analyzed as part of a whole and not myopically, by each small developed site.

SECTION 4.3 STORMWATER MANAGEMENT DESIGN

Stormwater Management Facilities need to be developed with consideration of a wide range of variables within the clearly defined objective to provide runoff control. Selection of the proper treatment mechanisms for the specific site use and characteristics are the key to successful management.

Generally, stormwater management systems are considered an element of the framework of an overall water resource system for a particular watershed. The designer first evaluates the impacts from a regional perspective, and then narrows the focus to the specific site. As the designer determines the components of the specific site drainage system, various related factors, both regionally and locally are considered, evaluated, incorporated, and detailed into the engineering design.

Stormwater management combines a distinct range of interrelated variables to compose a unified program of action. These are divided into five categories:

1) Design Issues: storm frequencies and intensities, soils, vegetation, groundwater, peak flows, quality treatment, life/safety
2) Regional Issues: climate, watershed/ sub-basin relationship, environmental sensitivity to receiving waters
3) Local Issues: adjacent land use, material specifications and availability, access and construction feasibility
4) Costs: project costs, stormwater management costs, cost/benefit analysis, land availability and value
5) Maintenance: owner/manager of system, responsible entity, expertise, equipment handler, inspection, protection, monitoring

Using these parameters as a guide, the designer evaluates the site conditions, develops a drainage concept, and performs hydrologic and stormwater design and hydraulic calculations to prepare the basis for the plan. The design concept is supported by the engineering hydraulic and routing calculations, the plan details and the material specifications of the drainage system components. After a submittal and approval process with the appropriate authority, the design engineer or municipal engineer should monitor the construction for compliance with the intended design concept of the plans. Site inspections are performed to verify the assumed site conditions and allow for modifications if the conditions vary. Upon completing the construction, the system implementation, performance monitoring, and maintenance phase begins. At this point the day to day operation would be the responsibility of the operating entity. The design engineer should be available to the owner to monitor the system for operational troubleshooting and in-situ modifications as required.

Selection of suitable stormwater management systems is site-specific; all sites are different, this is inherent in stormwater management design. There is no single process or detail that can be used in every instance. All of the previously mentioned design parameters should be reviewed to help in developing the "best design" for a particular site, but note that ultimately each design is customized to the specifics of the runoff and site characteristics. As mentioned previously, the final design is based on Low Impact Development (LID) techniques or the selection of Best Management Practices (BMP) that have been developed considering all site parameters. All BMP's must have detailed specifications designed for each site and for each usage within a project.

Above all, throughout the system design and BMP selection process, the final choices should adhere to the following primary goals:

1) Imitate Natural Control Mechanisms
2) Preserve and Utilize the Existing Natural Resources
3) Quantity and Quality control
4) Simple, Long Lasting Design
5) Cost Effective Construction

6) Easy Maintenance

With these concepts in mind, the design engineer determines the best choice for a quality design.

SECTION 4.4 BEST MANAGEMENT PRACTICES (BMP)

Best Management Practices (BMP), for the purposes of stormwater management, are structural, non-structural and managerial techniques that are recognized to be the most effective and practical means to prevent, control and reduce non-point source pollutants from entering receiving waters. They consist of proven engineering designs, source controls, managed facility operations and maintenance, and public education and awareness programs.

Best Management Practices are utilized to prevent and reduce the adverse impacts due to runoff by:

1) Preserving the hydrologic conditions to resemble the pre-developed conditions,
2) Reducing and preventing flooding by managing the peak runoff rates,
3) Treating the discharges prior to entering the receiving water bodies; removing sediments, oils, and other pollutants; "polishing" the runoff,
4) Minimizing erosion and sedimentation,
5) Reducing the total suspended solids and other pollutants; improving the water quality,
6) Protecting the sensitive environments related to the natural resources.

BMP's vary in their intended usage and ability to be adapted to the site conditions. They also offer differing types and degrees of mitigation, sometimes requiring combinations of systems in order to comply with performance standards. It is imperative that the BMP selection process includes the review of the benefits and drawbacks to identify the limitations of the choice.

The most cost efficient, productive and yet simple BMP's are those that are constructed and operate similar to natural systems. The mechanisms of the earth's ecosystems offer examples of the best practices. Surface vegetation acts to control erosion, slow runoff, filter out and biologically uptake pollutants. Creeks and rivers convey flows through channels with a natural capacity to handle runoff. Ponds, lakes and wetland swamps store excessive flows, slowing the runoff allowing for sedimentation and biological pollutant breakdown. All these items contribute to the recharge of the subsurface aquifers. Because of their natural origins, they continually adapt to changes modifying their configurations, balancing the system as a whole.

The best manmade systems are those similar to the existing natural site features, incorporated into the terrain and operated under the same mechanisms. The end product is an aesthetic blend of synthetic facilities melded into the natural landscape, requiring less maintenance, and resulting in better performance.

SECTION 4.5 LOW IMPACT DEVELOPMENT (LID)

Low impact development (LID) is an innovative land development strategy that utilizes man-made stormwater management features in an effort to re-create naturally occurring drainage characteristics.

It is often easiest to visualize LID practices by imagining a drop of water within the rainstorm. In nature, as explained previously, the raindrop can infiltrate into the ground, absorbed within plants and transpired, evaporated, or joins other raindrops as runoff. As runoff, the drop eventually travels over the ground surface, possibly joins up with much larger flows in some sort of conveyance system (pipes, culverts, etc.), flows through wetland systems, brooks, streams, rivers, and ultimately to the ocean. During this travel the raindrop, as runoff, can add to negative features such as soil erosion or flooding. The concept of LID is to start at the beginning of the cycle instead of the end and attempt to eliminate the raindrop as runoff by various techniques, or if it is runoff, to try to control it early on its travel by creating infiltration mechanisms, reducing slopes, extending the travel time, or other design methods to minimize the impact of the runoff.

LID includes primarily three main design principles that will be discussed below.

1. **Maximize the existing vegetative features**. This design principle is generally inherent in most conventional developments as well as LID projects, particularly in residential subdivision proposals. Open space developments which serve to permanently protect larger swaths of open areas such as forested areas, meadows, and wetlands are preferred. The "do nothing" maxim is the first and foremost part of LID. Otherwise, setting aside land as open space, creating no cut zones, minimizing land alteration are all techniques in the planning process which can have a major impact on minimizing runoff.

2. **Minimize pavement**. The separation from typical land development strategy and LID techniques really begins with principle #2. In an effort to provide a more environmentally friendly LID project, typical roadway widths and pavement areas should be minimized. This could involve proposing narrower paved roadway widths than a typical subdivision roadway or even what is required in a municipality's regulations and standards. Often reduced pavement widths require waivers.

   Asphalt or concrete sidewalks should be considered for reduction or elimination altogether. Of course public safety must be maintained in all instances, but on dead-end streets and other minor roadways, in areas that don't connect to existing sidewalk networks, there are opportunities to reduce the proposed impervious surfaces by eliminating sidewalks and/or reducing the required pavement widths.

   Porous pavement should also be considered but with the evaluation of a cost / benefit analysis, aesthetics, maintenance, ownership, and use. For example, porous asphalt pavement on standard roadways in New England are not practical in that regular sanding and salting for winter conditions will shortly seal the pores and render the pavement impervious in a relatively short time period.

3. **Disconnect large drainage area Sub Catchments into smaller, localized runoff areas.** This principle is the largest separation between conventional development projects and LID projects. The goal of this principle is to more closely mirror the naturally occurring runoff characteristics and infiltration processes. Under natural conditions, a portion of the precipitation that falls infiltrates almost immediately, recharging the groundwater at the point of contact with the ground. Once impervious surfaces and other manmade structures are introduced to an area, this precipitation is more likely to runoff to another ground area, and may not recharge the groundwater at all.

   Conventional stormwater mitigation systems collect this increased stormwater runoff from large land areas and conveys it to a concentrated mitigation facility or directly discharges the runoff to a receiving water. While this strategy is effective in minimizing negative impacts due to potential stormwater runoff increases (reduction of flooding), the naturally occurring stormwater runoff characteristics are altered and large, stormwater collection areas are often constructed, usually in areas near wetland resource areas and within wetland buffer zones. These large stormwater management facilities require removal of the existing vegetated areas usually in close proximity to important resource areas (wetlands).

   An LID stormwater management system will more closely match the undeveloped condition by providing stormwater recharge and infiltration areas in close proximity to the precipitation contact point. LID Stormwater Management Facilities will include numerous vegetated collection and infiltration areas that will provide opportunities for the stormwater runoff to seep into the ground throughout the site. Vegetated drainage channels are utilized to convey stormwater to constructed 'rain gardens' designed to disrupt the overland flow and provide areas for groundwater recharge. Proposed buildings are connected to roof drain dry wells or chamber infiltration systems, designed to provide stormwater recharge, especially the smaller, normal storm frequencies. This allows for annual recharge, an important feature that often gets overlooked when stormwater conveyances and mitigation is typically designed.

   By providing isolated areas for stormwater recharge and removing roof runoff from the overall stormwater flow, the magnitude of the increased stormwater runoff will be substantially reduced. This in turn, will reduce the required size of the final stormwater management facility (SMF). A smaller SMF within the resource area buffer zone will minimize the impact to the naturally occurring vegetation in the sensitive buffer zone as well as result in larger areas of naturally occurring vegetation (LID principle #1).

The concepts of LID cannot be used 100%, all the time. In steeper areas, areas with higher erosion potential, areas of poor soils, areas requiring intensive development, certain "hotspots", and other site specific or project specific instances, LID concepts are not always directly applicable. This necessary variance is also part of the LID concept: that each site is unique and requires a specific set of goals to be developed with their ensuing design intent following, and not the reverse. LID is more guideline oriented than requirement or code oriented. This is necessary to deal with the many variables of each particular site.

Generally speaking, LID is a reasonable approach to stormwater management using eco-friendly and sustainable solutions to stormwater mitigation. The site design utilizes 'naturally occurring' stormwater design, treatment, and mitigation. Though manmade, the proposed drainage features will generally imitate the natural drainage characteristics found in undeveloped areas. The well designed LID project will attempt to mirror the site's pre-development drainage characteristics to treat, infiltrate and mitigate increased stormwater runoff generally associated with land development projects.

SECTION 4.6 STORMWATER MANAGEMENT OVERVIEW - SUMMARY AND CONCLUSION

Precipitation, whether it occurs as rain or snow, is the primary contributing source of water that **runs off** the surface of a watershed. The kind of soil and type of vegetation have a major controlling effect on the portion of the precipitation that "runs off" or generally known as runoff. The combined effect of the soil and the vegetative cover on the amount of runoff is represented by the runoff Curve Numbers (CN).

The hydrologic cycle is an explanation of how rainfall either infiltrates, transpires, evaporates, or runs off. The runoff component is the primary feature of stormwater management. The concepts of LID and BMP are to mirror nature as much as possible to have the least impact as possible. Properly designed stormwater management systems serve to minimize the impact of development through designed processes and controls.

Development and drainage improvements, along with the site's topography and shape characteristics are a factor in the rate of runoff. Drainage systems are modeled, both hydrologic and hydraulic, to determine the peak runoff flow rates which are used to predict the impacts due to development and to design a stormwater management system for mitigation.

The stormwater management plan identifies the site parameters and conditions for a designer to take advantage of the mechanisms of the naturally occurring features. With careful planning, many of the natural resources can be left undisturbed benefiting and enhancing the project and yet providing mitigation for the impacts of the development. A quality plan will not only control the flow and provide treatment, but it will also protect the sensitive natural resources.

Lastly, any specific BMP's utilized should be constructed and maintained properly to be fully effective. Often, the maintenance falls onto municipal public works staff, a homeowner's association, or a single homeowner. Also too often, simple maintenance is neglected and eventually affects the systems capacity to properly treat the runoff as designed.

Yet, in the last 30 years, stormwater management has made a huge and positive impact on our environment in developed areas, which should continue with the advent of newer technologies and increased use.

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SECTION 5.0 STORMWATER MANAGEMENT SYSTEM

SECTION 5.1 MASSDEP STORMWATER MANAGEMENT STANDARDS

The proposed Storm Water Management Plan addresses the Storm Water Management Standards that have been developed by MassDEP to protect the waters of the Commonwealth from adverse impacts resulting from storm water runoff. The design is based on concepts and recommendations obtained from various sources and criteria primarily the Massachusetts Stormwater Handbook, http://www.mass.gov/eea/agencies/massdep/water/regulations/massachusetts-stormwater-handbook.html

The following is a re-printing of the Massachusetts Stormwater Standards

THE STORMWATER MANAGEMENT STANDARDS

1. No new stormwater conveyances (e.g. outfalls) may discharge untreated stormwater directly to or cause erosion in wetlands or waters of the Commonwealth.
2. Stormwater management systems shall be designed so that post-development peak discharge rates do not exceed pre-development peak discharge rates. This Standard may be waived for discharges to land subject to coastal storm flowage as defined in 310 CMR 10.04.
3. Loss of annual recharge to groundwater shall be eliminated or minimized through the use of infiltration measures including environmentally sensitive site design, low impact development techniques, stormwater best management practices, and good operation and maintenance. At a minimum, the annual recharge from the post-development site shall approximate the annual recharge from pre-development conditions based on soil type. This Standard is met when the stormwater management system is designed to infiltrate the required recharge volume as determined in accordance with the Massachusetts Stormwater Handbook.
4. Stormwater management systems shall be designed to remove 80% of the average annual post-construction load of Total Suspended Solids (TSS). This Standard is met when:

   a. Suitable practices for source control and pollution prevention are identified in a long-term pollution prevention plan, and thereafter are implemented and maintained;

   b. Structural stormwater best management practices are sized to capture the required water quality volume determined in accordance with the Massachusetts Stormwater Handbook; and

   c. Pretreatment is provided in accordance with the Massachusetts Stormwater Handbook.

5. For land uses with higher potential pollutant loads, source control and pollution prevention shall be implemented in accordance with the Massachusetts Stormwater Handbook to eliminate or reduce the discharge of stormwater runoff from such land uses to the maximum extent practicable. If through source control and/or pollution prevention all land uses with higher potential pollutant loads cannot be completely protected from exposure to rain, snow, snow melt, and stormwater runoff, the proponent shall use the specific structural stormwater BMPs determined by the Department to be suitable for such uses as provided in the Massachusetts Stormwater Handbook. Stormwater discharges from land uses with higher potential pollutant loads shall also comply with the requirements of the Massachusetts Clean Waters Act, M.G.L. c. 21, §§ 26-53 and the regulations promulgated thereunder at 314 CMR 3.00, 314 CMR 4.00 and 314 CMR 5.00.

6. Stormwater discharges within the Zone II or Interim Wellhead Protection Area of a public water supply, and stormwater discharges near or to any other critical area, require the use of the specific source control and pollution prevention measures and the specific structural stormwater best management practices determined by the Department to be suitable for managing discharges to such areas, as provided in the Massachusetts Stormwater Handbook. A discharge is near a critical area if there is a strong likelihood of a significant impact occurring to said area, taking into account site-specific factors. Stormwater discharges to Outstanding Resource Waters and Special Resource Waters shall be removed and set back from the receiving water or wetland and receive the highest and best practical method of treatment. A "storm water discharge" as defined in 314 CMR 3.04(2)(a)1 or (b) to an Outstanding Resource Water or Special Resource Water shall comply with 314 CMR 3.00 and 314 CMR 4.00. Stormwater discharges to a Zone I or Zone A are prohibited unless essential to the operation of a public water supply.

7. A redevelopment project is required to meet the following Stormwater Management Standards only to the maximum extent practicable: Standard 2, Standard 3, and the pretreatment and structural best management practice requirements of Standards 4, 5, and 6. Existing stormwater discharges shall comply with Standard 1 only to the maximum extent practicable. A redevelopment project shall also comply with all other requirements of the Stormwater Management Standards and improve existing conditions.

8. A plan to control construction-related impacts including erosion, sedimentation and other pollutant sources during construction and land disturbance activities (construction period erosion, sedimentation, and pollution prevention plan) shall be developed and implemented.

9. A long-term operation and maintenance plan shall be developed and implemented to ensure that stormwater management systems function as designed.

10. All illicit discharges to the stormwater management system are prohibited.[3]

[3] Massachusetts Stormwater Handbook, Volume 1:
http://www.mass.gov/eea/agencies/massdep/water/regulations/massachusetts-stormwater-handbook.html

SECTION 5.2 HYDROLOGIC MODEL

5.2.1 Flow Rate Models

Flow rate estimates were predicted utilizing *Guidelines for Soil and Water Conservation in Urbanized Areas of Massachusetts*, dated October 1997, prepared by U.S. National Resources Conservation Service (NRCS) and "Urban Hydrology for Small Watersheds, Technical Release Number 55", dated 1986, prepared by NRCS. The chosen storm type for this area is the TR 55, Type III storm.

Flow estimate calculations were performed using the "HydroCAD v 8.00" (HydroCAD) stormwater computer modeling software. In addition, the facilities are designed in accordance with generally accepted engineering principles and practices, in conformance with all jurisdictional requirements.

5.2.2 Standard 2: No Increase in Post Development Peak Discharge Rates

The purpose of a majority of the Stormwater Management Calculations is an attempt to model the Pre Development vs. Post Development flow rates. This is a critical component of stormwater management outline as Standard 2 and is encapsulated best by again quoting from the MassDEP Stormwater Handbook:

> **Standard 2:** Stormwater management systems shall be designed so that the post-development peak discharge rates do not exceed pre-development peak discharge rates. This Standard may be waived for discharges to land subject to coastal storm flowage as defined in 310 CMR 10.04.
>
> To prevent storm damage and downstream and off-site flooding, Standard 2 requires that the post-development peak discharge rate is equal to or less than the pre-development rate from the 2-year and the 10-year 24-hour storms. BMPs that slow runoff rates through storage and gradual release, such as LID techniques, extended dry detention basins, and wet basins, must be provided to meet Standard 2. Where an area is within the 100-year coastal flood plain or land subject to coastal storm flowage, the control of peak discharge rates is usually unnecessary and may be waived.
>
> For projects subject to jurisdiction under the Wetlands Protection Act, the issuing authority relies on TR 20 and 55[4], which are guides for estimating the effects of land use changes on runoff volume and peak rates of discharge published by Natural Resource Conservation Service (NRCS). Applicants must calculate runoff rates from pre-existing and post-development conditions. **Measurement of peak discharge rates is calculated at a design point, typically the lowest point of discharge at the downgradient property boundary.** (emphasis added) The topography of the site may require evaluation at more than

[4] NRCS TR 20&55 - http://www.wsi.nrcs.usda.gov/products/W2Q/H&H/Tools_Models/tool_mod.html. See the Hydrology Handbook for Conservation Commissioners, http://www.mass.gov/dep/water/laws/hydrol.pdf.

one design point, if flow leaves the property in more than one direction. An applicant may demonstrate that a feature beyond the property boundary (e.g. culvert) is more appropriate as a design point.[5]

Proponents must also evaluate the impact of peak discharges from the 100-year 24-hour storm. If this evaluation shows that increased off-site flooding will result from peak discharges from the 100-year 24-hour storms, BMPs must also be provided to attenuate these discharges. [6]

5.2.3 Point of Analysis

5.2.3.1 Description of Subject Site – Point of Analysis Determination

Note the underlined portion above (emphasis added) to highlight a critical component in Stormwater Management and Hydrologic Analysis: The Point of Analysis at the downgradient property boundary.

In order to meet Standard 2 to determine the impact from runoff quantity as a result of development it is necessary to hydrologically model the runoff in an undeveloped site condition, pre-development, and then again in a proposed developed condition, post-development. The representative models are run under the critical design storm frequency events to determine the estimated flow rates for the given scenarios. In all instances, the models are run at a determined Point of Analysis, or possibly at multiple Points of Analysis dependent on property lines, grades, and if the site is within more than one primary watershed. This is a critical concept in stormwater management.

The Points of Analysis for this subject property are at one location since the property flows into the intermittent stream at all sub catchment areas.

Point of Analysis A: Wetland easterly at intermittent stream

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[5] The evaluation may show that retaining the 100-year 24-hour storm event is not needed. In some cases, retaining stormwater from the 100-year 24-hour storm event onsite may aggravate downstream impacts, because of the project's location within the watershed and the timing of the release of stormwater.
[6]Massachusetts Stormwater Handbook, Volume 1:
http://www.mass.gov/eea/agencies/massdep/water/regulations/massachusetts-stormwater-handbook.html

5.2.4 Strategies for Mitigation of Stormwater Runoff

The undeveloped rates are compared to the developed rates, resulting in a differential volume representative of the "*increase in peak runoff due to the development*". At such time a set of Best Management Practice (BMP) designs are incorporated to mitigate the increase. In this case the structural components for the majority of the changed runoff is the Bio-Retention area in the front portion and the infiltration area in the rear.

The proposed stormwater management design is incorporated into the proposed post-development HydroCAD model and run under the critical design storm scenarios to determine the operational performance of the system. Discharge volumes, velocities, depth of flows and dissipation spreads are then calculated to verify the impacts to the receiving areas.

The proposed storm water management plan for this project has been developed using Structural and Non-Structural Best Management Practices (BMP's). Specific BMP's for this project are identified in Section 5.4.

SECTION 5.3 LOW IMPACT DEVELOPMENT (LID)

What is LID?

Low Impact Development (LID) are techniques. They essentially try to mimic nature. In nature, a typical raindrop becomes part of the hydrologic cycle explained in Section 2.2.1. LID attempts to get that raindrop to evapotranspire or infiltrate as recharge and to minimize the amount of runoff.

The first technique is to limit the areas of the site to be developed. In particular, critical areas should to be left undisturbed, if at all possible. On this site an Open Space project is proposed protecting more than 33% of the site area as open space. This is a key and important component of LID – no disturbance. Further, the extensive slope on the westerly portion of the property will remain undisturbed as well as the fairly large wetland area at the base of this slope on the westerly property line. These are clearly the most sensitive areas of the site.

LID encourages minimizing pavement. As such, the applicant is proposing to maintain the reasonable roadway standard in the Town of Carlisle of 20 feet.

SECTION 5.4 BEST MANAGEMENT PRACTICES (BMP) AND LOW IMPACT DEVELOPMENT (LID)

5.4.1 Discussion

Best Management Practices are structural mitigation components of a stormwater management system designed to treat or detain stormwater runoff.

For the subject site, the following Low Impact Development programs and Best Management Practices are proposed (underlined items have samples provided for information purposes only):

- Large area of undevelopment – Open Space B – 3.5 acres (35% of total site) - LID
- Flat roof drain onto lawn prior to entering closed system – LID *(although no special credit is applied)*
- Infiltration Chambers – LID and BMP – See Product Information in Section 5.4.1
- Bio – Retention Facility – LID and BMP – See Sample Detail in Section 5.4.2
- Vegetated Buffer Strip – BMP
- Grassed Swales – BMP
- Discharge over 100 feet from wetland, if possible - LID

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5.4.2 Infiltration Chambers – Product Information

The following is part of a manufacturing cut sheet for the Cultec Infiltration Product for information purposes only. The final design plans will have details of construction particularly for this site.

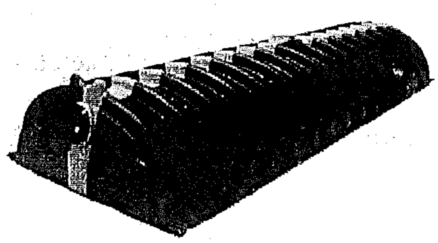
Product Information

Stormwater Chambers

Contactor® Series

The Contactor® Chamber series consists of lower profile chambers and are typically used for installations with depth restrictions or when a larger infiltrative area is required. The 12-inch high Contactor® 100HD is the most popular model within this series for stormwater design.

Other models available within the Contactor® series are: Contactor® EZ-24, Contactor® Field Drain C-4, and Contactor® 125. Design information for these models is available upon request

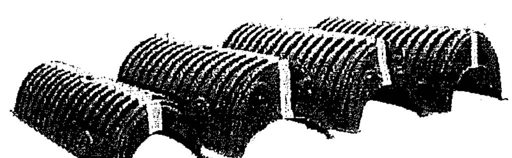


Recharger® Series

CULTEC's Recharger® series includes higher profile, larger capacity chambers. Sizes range from 18.5" - 32" (470 - 813 mm) high. Chamber capacities vary from 2.65 - 8.679 cu. ft./ft. (0.246 - 0.806 cu. m/m).

The most popular models within this series are the Recharger® 150HD, 280HD, 330XLHD and V8HD.

Alternate model available within the Recharger® series is, Recharger 180HD. Design information for this model is available upon request



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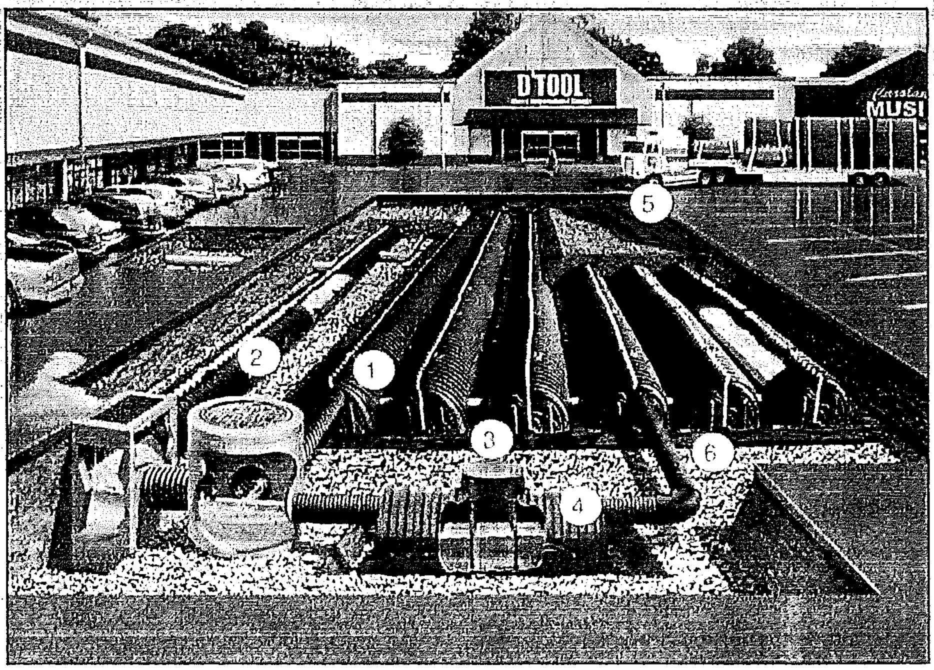
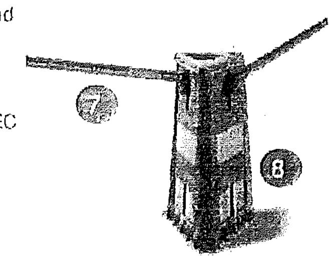
Product Information

CULTEC



Typical CULTEC Stormwater System Components

1. CULTEC Stormwater Chamber - used for retention, detention, reclamation
2. CULTEC PAC™ 150 - chamber with bottom used for water conveyance
3. CULTEC HVLV™ Feed Connector - internal manifold component
4. CULTEC StormFilter™ 330 - Water Quality Unit
5. CULTEC No. 410™ Filter Fabric - prevents soil intrusion into system
6. CULTEC No. 201 ™ Polyethylene Liner - placed under CULTEC manifold components, prevents scouring
7. CULTEC Warning Tape - Marks off location of underground CULTEC Stormwater System during construction to prevent vehicular traffic
8. Multicade™ Pylon - Marks location of underground CULTEC Stormwater System during construction phase



MEISNER BREM CORPORATION

142 LITTLETON ROAD, STE. 16, WESTFORD, MA 01886

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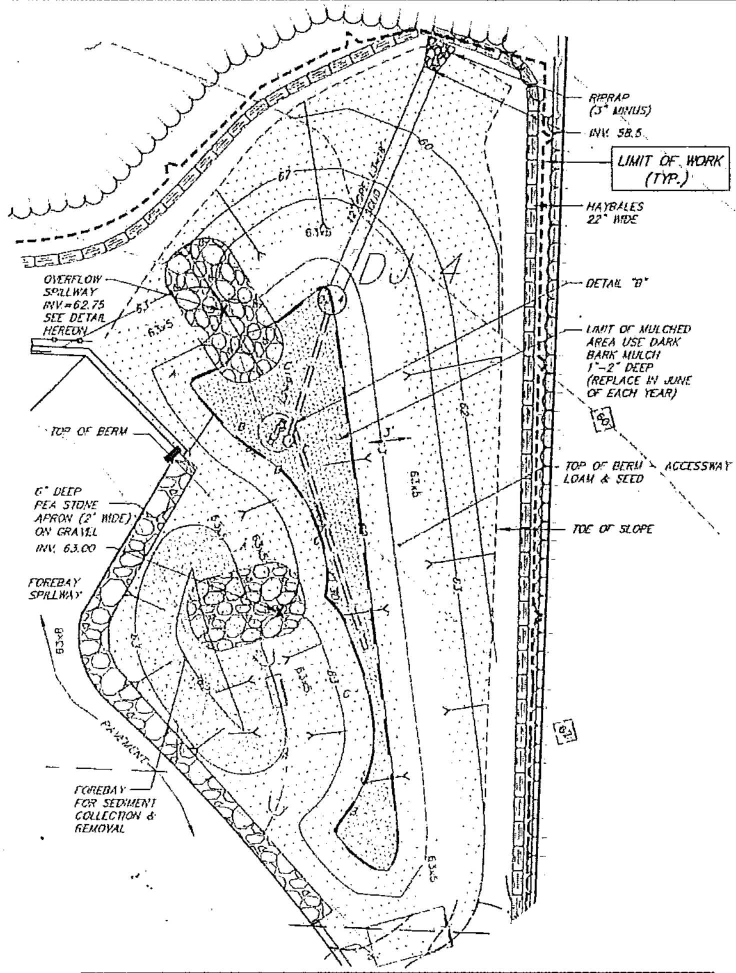
5.4.3 Bio – Retention Facility– See Sample Detail Below

The following is part of a cut sheet of a similar Bio Retention facility for another project presented here for information purposes only. The final design plans will have details of construction particularly for this site.



PLANTING		SCHEDULE			
	SYMBOL	COMMON NAME	SCIENTIFIC NAME	DELIVERED AS	NUMBER OF PLANTS
A		AMERICAN MOUNTAIN ASH	SORBUS AMERICANA	2" CALIPER	3
B		ARROWWOOD VIBURNUM	VIBURNUM RECOGNITUM	18" CONTAINER	3
C		NORTHERN HIGHBUSH BLUEBERRY	VACCINIUM CORYMBOSUM	12" CONTAINER	4
		COMPOSTED BLACK MULCH		2 CUBIC YARDS	

BIORETENTION FACILITY – SAMPLE

SECTION 6.0 DESIGN CONCLUSIONS AND SUMMARY

6.1 SUMMARY - DISCUSSION

The following informational charts are a synopsis of the comparative scenario models to determine the stormwater runoff conditions. The data is a result of mathematical models representing the pre and post developed conditions. The pre-developed results were compared to the post-developed results to determine the approximate sizing requirements of the BMP's to be used to mitigate the impacts due to development.

The following tables represent the site condition data and the results of the HydroCAD computer software models to verify that the proposed stormwater management system will comply with the guidelines for *Soil and Water Conservation in Urbanized Areas of Massachusetts,* and the Commonwealth of Massachusetts adopted and referenced *Stormwater Management Handbook.*

The following summary tabulations are developed separately for each design storm event for the Point of Analysis described in Section 5.2.3. The design storm events include the 2-year, 10-year, 25-year, and 100-year design storm frequencies. The tabulations show the results of the entire stormwater management system to the points of analysis.

The Points of Analysis outlined in Section 5.2.3 above is reprinted here for reference:

Point of Analysis A: Wetland easterly at intermittent stream

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6.2 SUMMARY TABLES: PRE-DEVELOPED PEAK FLOW RATES VS. POST-DEVELOPED PEAK FLOW RATES

Storm Frequency	Rainfall (in)	Pre-Development (cfs)	Post-Development (cfs)	Difference (cfs)
2 Year Storm	3.00	**6.29**	**3.53**	**-2.76**
10 Year Storm	4.50	**13.43**	**12.07**	**-1.36**
25 Year Storm	5.30	**17.50**	**14.73**	**-2.77**
100 Year Storm	6.50	**23.76**	**16.78**	**-6.98**

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6.3 CONCLUSION

Standard 2 of The Stormwater Handbook and associated regulations issued by MassDEP states:

> **Standard 2:** Stormwater management systems shall be designed so that the post-development peak discharge rates do not exceed pre-development peak discharge rates. This Standard may be waived for discharges to land subject to coastal storm flowage as defined in 310 CMR 10.04.
>
> To prevent storm damage and downstream and off-site flooding, Standard 2 requires that the post-development peak discharge rate is equal to or less than the pre-development rate from the 2-year and the 10-year 24-hour storms. [7]

Then also,

> Proponents must also evaluate the impact of peak discharges from the 100-year 24-hour storm. If this evaluation shows that increased off-site flooding will result from peak discharges from the 100-year 24-hour storms, BMPs must also be provided to attenuate these discharges.

The location of the design point is a critical criteria, also defined in the Stormwater Handbook as:

> Measurement of peak discharge rates is calculated at a design point, typically the lowest point of discharge at the downgradient property boundary. The topography of the site may require evaluation at more than one design point, if flow leaves the property in more than one direction. (emphasis added).

The quantitative analysis of the peak flow rates tabulated above show no increase in the rate of runoff at the property lines at all Points of Analysis for the 2 year, 10 year, 25 year and 100 year storm events.

---

[7] Massachusetts Stormwater Handbook, Volume 1: Standard 2,
http://www.mass.gov/eea/agencies/massdep/water/regulations/massachusetts-stormwater-handbook.html

Section 7.0 Documenting Compliance with STANDARD 3: RECHARGE

7.1 RECHARGE – RV

7.1.1 Annual Recharge – Rv – Brief Description of Requirement

Mass DEP states the intent of this standard succinctly and directly.

> The intent of this standard is to ensure that the infiltration volume of precipitation into the ground under post-development conditions is at least as much as the infiltration volume under pre-development conditions.[8]

Reference is made to the regulations and Volume 3 of the Stormwater Handbook as to the basis of the required calculations.

The stormwater runoff volume to be recharged to groundwater is determined using the existing site (predevelopment) soil conditions. The total impervious area introduced through site development is multiplied by one of the following recharge factors.

TABLE 7.1 RECHARGE RATES

Hydrologic Group	Volume to Recharge (x Total Impervious Area)
A	0.60 inches of runoff
B	0.35 inches of runoff
C	0.25 inches of runoff
D	0.10 inches of runoff

[8] Massachusetts Stormwater Handbook, Volume 1: Page 5
http://www.mass.gov/eea/agencies/massdep/water/regulations/massachusetts-stormwater-handbook.html

The Required Recharge is based on the following formula:

$Rv = F \times A_{IMP}$

Where:

Rv	= *Required Recharge Volume*, expressed in Ft^3, cubic yards, or acre-feet
F	= Target Depth Factor associated with each Hydrologic Soil Group
A_{IMP}	= Impervious Area pavement and rooftop area on site

7.1.2 Time to Drain Recharge Volume

The regulations stipulate that the required time to drain the recharge area must be less than 72 hours. Use the following formula and infiltration rates to verify this time.

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

Where:

Rv = Storage Volume
K = Saturated Hydraulic Conductivity For "Static" and "Simple Dynamic" Methods, use Rawls Rate (see Table 8). For "Dynamic Field" Method, use 50% of the in-situ saturated hydraulic conductivity.
Bottom Area = Bottom Area of Recharge Structure

in = inches
SF = square feet
ft^3 or CF = cubic feet
hr = hour

<The remainder of this page is blank>

TABLE 7.2: 1982 RAWLS RATES[9]

Texture Class	NRCS Hydrologic Soil Group (HSG)	Infiltration Rate Inches/Hour
Sand	A	8.27
Loamy Sand	A	2.41
Sandy Loam	B	1.02
Loam	B	0.52
Silt Loam	C	0.27
Sandy Clay Loam	C	0.17
Clay Loam	D	0.09
Silty Clay Loam	D	0.06
Sandy Clay	D	0.05
Silty Clay	D	0.04
Clay	D	0.02

7.1.3 Determine Required Recharge (Rv)

The following is a computation of the required Recharge Volume (Rv), and the provided Recharge Volume. All areas provided are somewhat approximate.

7.1.3.1 Recharge Volume at:

Point of Analysis A: Wetland easterly at intermittent stream

Given:

	HSG C =	0.25 in.
	$A_{IMP\ ROOF} =$	43,400 ft^2
	$A_{IMP\ PAVEMENT} =$	39,200 ft^2

Calculations:

$Rv = (43400\ ft^2 + 39200\ ft^2)(0.25\ in) / (12\ in/ft) =$ 1720 CF Required

$Rv_{(Provided,\ 2\ Yr)} =$ Volume of Rain Garden Cell 1 + Cell 2 + Infiltration System

[9] Rawls, Brakensiek and Saxton, 1982, Estimation of Soil Water Properties, Transactions American Society of Agricultural Engineers 25(5): 1316 - 1320, 1328

$Rv_{(Provided, 2\ Yr)} = 961\ CF + 411\ CF + 4421\ CF = 5793\ CF$

$Rv_{(Provided)} = 5793\ CF > Rv = 1720\ CF$ OK

Check Time to Drain < 72 hours

Bottom Area of Rain Garden Cell 1 + Cell 2 + Infiltration System

Bottom Area = $701\ ft^2 + 425\ ft^2 + 2200\ ft^2 = 3326\ ft^2$

Time = $1720\ ft^3 / [(0.27\ in/hr)*(1\ ft/12\ in)*(3326\ ft^2) = 23.0$ hours < 72 hours OK

SECTION 8.0 DOCUMENTING COMPLIANCE WITH STANDARD 4: WATER QUALITY VOLUME

8.1 WATER QUALITY VOLUME – V_{WQ}

8.1.1 Water Quality Volume V_{WQ} – Brief Description of Requirement

Mass DEP outlines Standard 4 to address Total Suspended Solids as follows:

Standard 4

Stormwater management systems shall be designed to remove 80% of the average annual post-construction load of Total Suspended Solids (TSS). This standard is met when:

Suitable practices for source control and pollution prevention are identified in a long-term pollution prevention plan, and thereafter are implemented and maintained;

Structural stormwater best management practices are sized to capture the required water quality volume as determined in accordance with the Massachusetts Stormwater Handbook; and

Pretreatment is provided in accordance with the Massachusetts Stormwater Handbook.

The formula for determining the Water Quality Volume is:

V_{WQ} = **(DWQ/12 inches/foot) * (A_{IMP})**

Where:

V_{WQ} = *Required Water Quality Volume (in cubic feet)*

D_{WQ} = *Water Quality Depth: 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.*

A_{IMP} = *Impervious Area (in square feet)*

For the subject project, it is not within a Zone II of a public water supply or any other required area for enhanced recharge nor as a hotspot so:

Use: D_{WQ} = 0.5 inch

8.1.2 Water Quality Volume VWQ at:
Point of Analysis A: Wetland at east portion of site at property boundary (from SMF 1) - 300 Series

Therefore:

V_{WQ} = (D_{WQ} / 12 inches/foot) * (A_{IMP} square feet)

V_{WQ} = (*0.5 inch*/12 inches/foot) * (43,400 ft^2 + 39,200 ft^2)

V_{WQ} = 3442 cubic feet

Volume of Water Quality Provided in Chamber System = 4421 cubic feet.

(No need to include effect of Rain Garden as Chamber System is sufficient for site)

V_{WQ} = 4421 cubic feet Provided is greater than V_{WQ} Required of 3442 cubic feet ------ OK

8.1.5 Total Suspended Solids (TSS)

The street runoff will enter standard catch basins designed with deep sumps ($\geq$ 4 feet) to settle large suspended and non suspended solids or be directed to a grassed swale for filtration prior to entering the bio-filtration system.

The Total Suspended Solids from the infiltration system in the cul-de-sac will be treated by a proprietary underground system. There are several on the market and a full determination of the exact model will be chosen at the time of final design. It will be sufficient pre-treatment.

The system then includes an infiltration system constructed of 48 Cultec Chambers to recharge the runoff into the ground. This location is more than 100 feet from the wetland resource area. However, an overflow piped discharge for larger storm events will discharge some runoff into a vegetated filter strip and eventually into the wetland system by overland flow. Peak discharges will be fully mitigated as previously described in the hydrologic models.

The system from the southerly portion of the site is not required to meet TSS removal as the discharge is over 100 feet from the wetland resource area. Although TSS removal processes are still designed for this system as well, a computation is not required.

See the following page for the Mass DEP stormwater worksheet for the infiltration system within the cul-de-sac island.

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TABLE 8.1: TOTAL SUSPENDED SOLIDS: STORMWATER MANAGEMENT FACILITY 1

INSTRUCTIONS:
1. In BMP Column, click on Blue Cell to Activate Drop Down Menu
2. Select BMP from Drop Down Menu
3. After BMP is selected, TSS Removal and other Columns are automatically completed.

Version 1, Automated: Mar. 4, 2008

Location: Long Ridge 40B - Cul-de-sac

TSS Removal Calculation Worksheet

B BMP[1]	C TSS Removal Rate[1]	D Starting TSS Load*	E Amount Removed (C*D)	F Remaining Load (D-E)
Deep Sump and Hooded Catch Basin	0.25	1.00	0.25	0.75
Proprietary Treatment Practice	0.00	0.75	0.00	0.75
Infiltration Basin	0.60	0.75	0.60	0.15
	0.00	0.15	0.00	0.15
	0.00	0.15	0.00	0.15

Total TSS Removal = 85%

Separate Form Needs to be Completed for Each Outlet or BMP Train

Project: 2060
Prepared By: JA Brem
Date: 6/25/2014

*Equals remaining load from previous BMP (E) which enters the BMP

Non-automated TSS Calculation Sheet must be used if Proprietary BMP Proposed
1. From MassDEP Stormwater Handbook Vol. 1

Mass. Dept. of Environmental Protection

TSS = 85% which is greater than 80% required ------------ OK

SECTION 9.0 OPERATION AND MAINTENANCE

9.1 INTRODUCTION

This section addresses the issue of operation and maintenance for the proposed Stormwater Management System. If this section, Section 10 is separated from the remainder of this Stormwater Management Report (SMR), the SMR is hereby incorporated by reference, a copy of which will be in the records of the Carlisle Planning Board as well as other locations. The title of the final SMR is:

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PROJECT NOT YET NAMED, OFF LONG RIDGE ROAD
CARLISLE, MASSACHUSETTS
STORMWATER MANAGEMENT REPORT
July 1, 2014
Prepared For:
Lifetime Green Homes, LLC
142 Littleton Road, Westford, MA 01886
Prepared By:
Meisner Brem Corporation
142 Littleton Road, Ste. 16
Westford, MA 01886
MBC Job Number: 2066

The maintenance standards presented herein are based on Mass DEP "The Stormwater Handbook", as previously referenced, the superseded *Managing Stormwater in Massachusetts, Volume One: Stormwater Handbook, March 1997, Prepared by: MA Department of Environmental Protection and the MA Office of Coastal Zone Management,* and *the United States Environmental Protection Agency (US EPA), National Pollution Discharge Elimination System (NPDES)* with various reports and guidance associated therewith.

These maintenance and operations procedures are intended as general guidelines, however additional procedures shall be developed if necessary, as the systems are completed and operated over a period of time. As with all stormwater facilities, the conditions change or the management of them can be simplified as the operation personnel become more familiar with them. The most effective maintenance and operations can be customized to the specific facility as the system develops and situations merit.

9.2 DESIGN PARAMETERS OF EROSION CONTROL AND MANAGEMENT

The US EPA has mandated that all land disturbance of greater than 1 acre at any one time seek a NPDES permit through the preparation of a Storm Water Pollution Protection Plan (SWPPP) to control the erosion potential and transfer of erodible soils off properties. The goal of a SWPPP is to provide suitable quantity and quality control measures for runoff, during and after construction, from a developed property, meeting the standards of the EPA and the Massachusetts Stormwater Management Policy. Ideally, the plan should be simplistic in design, cost effective to construct, and reasonable to maintain. The design should blend into the natural features and site resources and take full advantage of existing environmental mechanisms to accomplish mitigation.

Generally, storm water management systems are considered an element of the framework of an overall water resource system for a particular watershed. The designer first evaluates the impacts from a regional perspective, then narrows the focus to the specific site. As the designer determines the components of the specific site drainage system, various related factors, both regionally and locally are considered, evaluated, incorporated, and detailed into the engineering design.

Stormwater management combines a distinct range of interrelated variables to compose a unified program of action. These are divided into five categories:

- Design Issues: storm frequencies and intensities, soils, vegetation, groundwater, peak flows, quality treatment, life/safety
- Regional Issues: climate, watershed/ sub-basin relationship, environmental sensitivity to receiving waters
- Local Issues: adjacent land use, material specifications and availability, access and construction feasibility
- Costs: project costs, storm water management costs, cost/benefit analysis, land availability and value
- Maintenance: owner/manager of system, responsible entity, expertise, equipment handler, inspection, protection, monitoring

Using these parameters as a guide, the designer evaluates the site conditions, developing a drainage concept and performs hydrologic and design calculations to prepare the basis for the plan. The design concept is supported by the engineering hydraulic and routing calculations, the plan details and the material specifications of the drainage system components. A key component of a good design is an understanding of the requirements of maintenance, especially since many of these systems will be maintained by Homeowner's Association.

9.3 OPERATION AND MAINTENANCE OF STORMWATER MANAGEMENT FACILITIES

Proper maintenance is essential to ensure that the performance of the system meets the design expectation. A system that is not maintained may fail and could lead to financial loss, damage to surrounding infrastructure or environmentally sensitive areas and increasing the liability of the property owners.

9.3.1 Personnel and Education

Personnel make the difference between a Stormwater Management System that performs as designed throughout its lifetime or one that fails due to lack of attention. *Education* provides the personnel with the skills needed to effectively maintain a Stormwater Management System. *Record Keeping* allows the personnel to track the maintenance and the System's performance so as to determine when major maintenance tasks are required.

Maintenance of the structural components of the stormwater management facility will be the responsibility of the master Homeowner's Association (HO). Maintenance should be performed as outlined below in items 1-10. In addition to the town, each of the homeowners – through their association - should have a copy of this report with a copy of the grading design plan. Full comprehension of these documents will educate the homeowners and allow them to properly maintain the stormwater management system.

The HO should be aware of the Stormwater Management Facilities' intended purpose of removing contaminants from the stormwater runoff flow from the site. The result is the collection, removal and storage of the contaminants within the facility components. These potentially consist of trash/debris, oils, sediment and soluble/insoluble materials. In most situations, these can be handled, stored and disposed of with minimal safety requirements, in that the health hazards are non-existent or minimal with the concentrations involved. However, the HO shall be aware of the risk and/or the possibility of potential dangers. An example would be in the system was inundated with an excessive concentration due to an accidental spill.

9.3.2 Record Keeping

Record Keeping – It is recommended that a record log be kept of measured sediment levels at regular (annual) maintenance and after each major storm event. Sediment accumulation should be measured at each of the drop inlets and detention basin and logged in the record. Sediment should be removed annually, or when the sediment buildup has met the threshold outlined below. These activities should be logged as well.

Forms for recording the inspections and maintenance are included at the end of this section. The SWPPP will identify the party(ies) responsible for operations and maintenance, both temporarily and permanently.

9.3.3 Construction Erosion Control Process

Note: The "Operator" is the responsible party as defined by the US EPA in the NPDES regulations and is responsible for all site construction. The Operator may be the contractor or another party assigned during as part of the SWPPP.

9.3.3.1 Construction / Implementation

Stormwater management during construction should be considered as part of the construction operation of the whole site. A successful stormwater management system uses the various erosion control processes and components to work in tandem and in parallel to achieve the results of minimizing soil transport and protecting off-site areas from sediment conveyance. The Operator shall recognize and develop erosion control strategies to minimize soil erosion in the first instance, then to control its transport, and finally to capture any silt or sediment prior to discharge off site.
The Operator shall consider all of the following as part of the site excavation and erosion control strategy.

9.3.3.2 Minimize Disturbed Soil:

The contractor shall limit the disturbed areas to only those portions necessary for construction to proceed. The disturbance shall be limited to those times of year that will allow successful stabilization. Creation of work zones and phases are encouraged.

9.3.3.3 Source Controls: Stabilize Exposed Soil:

The contractor shall develop a construction plan for all areas that are exposed to soil erosion. These strategies could include maintaining tight soil compaction especially in proposed paved or impervious areas. Keeping all slightly sloped exposed gravel or subgrade areas compacted, especially prior to anticipated rain events, will serve to minimize the rilling and scouring of the soil and thus minimize soil transport. Other areas can be temporary loamed and seeded, especially areas intended to be grassed in the final plan. Common sense solutions to source control often yields the best erosion controls.

9.3.3.4 Prevent Runoff from Offsite Areas from Flowing Across Disturbed Areas

The contractor shall divert flow from offsite drainage areas away from disturbed areas by utilizing earth dikes, interceptor swales or other acceptable methods to ensure erosion of disturbed areas is minimized.

9.3.3.5 Slow Down Runoff Travelling Across the Site

The contractor shall utilize check dams, gradient terraces, sod, geotextiles or other acceptable methods where necessary in areas of steep slopes to ensure that erosion of unstable areas are minimized and to maximize soil infiltration.

9.3.3.6 Remove Sediment from Onsite Runoff Before it Leaves the Site

The contractor shall utilize temporary sediment basins for large (greater than ten acres) areas of disturbed soil to allow settling time for suspended solids. The location of temporary basins are shown on the construction plan set where necessary. All forms of erosion control are shown on the design plans and are to be located by survey to ensure appropriate placement of controls.

9.3.3.7 Meet or Exceed Local / State Requirements for Erosion Control.

The Contractor shall meet or exceed all additional Local and State requirements for erosion control and will ensure that all performance standards are met. Any changes required by the permitting authority shall be made within 7 days of the notification or an individual application should be submitted. The permittee shall update the plan as necessary to reflect any changes onsite, which may affect the potential for discharges of pollutants from the site.

9.3.3.8 Inspection and Maintenance Plan

1. Contractor shall use the blank inspection forms found within this Report or use alternative equivalent written inspection reports.
2. Inspections shall be logged on forms and reports and shall be completed by the Operator every 14 days and within 24 hours after a rainfall event over 0.25".
3. Proper record keeping for inspection and maintenance should be kept within the Storm Water Pollution Plan box installed on site. Blank inspection forms are included herein.
4. The inspector of pollution prevention measures should fully understand these Operation and Maintenance Requirements, the Storm-Water Pollution Prevention Plan, and NPDES permit with emphasis on erosion controls, spill prevention and cleanup, and inspection and maintenance.

5. The Operator shall instruct the Contractor to remove all sediment or debris whenever the volume is equal to 50% of the design capacity. This is imperative. All maintenance activity including silt removal, cutting of vegetation (mechanically or manually), and all other maintenance activities during the construction period shall be included in the Maintenance Logs / Reports.
6. The Operator is responsible to ensure the reliability of all measures of maintenance and erosion control measures including silt fence, mitigation swales, sedimentation pond, stabilized construction entrance and loam and seeding.
7. Maintenance of construction activities shall be performed in accordance with this Operation and Maintenance Plan and the Storm Water Pollution Prevention Plan. In general, maintenance should be performed on the specified intervals, or whenever the controls require maintenance for proper operation. If any conflicts exist, the Storm Water Pollution Prevention Plan shall be used.

9.3.4 Construction Operation and Maintenance schedule

The Operation and Maintenance (O&M) schedule during the construction phase is the responsibility of the **developer and/or site contractor**. The outline below shall be adhered to as closely as possible to ensure the proper construction and function of the drainage system.

1. Prior to construction, haybales and/or silt fence shall be installed per the approved plans. The erosion control barrier shall be inspected prior to a large storm event to ensure that it will function as required and following a storm to inspect for damage to the erosion control. Any damage or improper installation that is noticed prior to or following a storm event shall be promptly replaced or repaired in a satisfactory manner so as to prevent sediment from bypassing the silt fence barrier.

2. A stone construction entrance shall be installed at the entrance to the development and shall be 50' long and 24' wide. The entrance shall be cleared and once cleared, filter fabric shall be placed over the area which is to be overtopped by crushed stone to a depth of 6". The stone size shall be 1 ½" with smaller stones only used to fill the leftover voids. Should the stone become clogged with sediment, it shall be replaced. The construction entrance shall be constructed with a temporary berm at the entrance to prevent flow of runoff onto the existing roadway.

3. The limit of clearing shown on the approved plan shall be adhered to as closely as possible. It shall be the contractor's responsibility to determine the level of safety of standing trees.

4. In this construction operation and maintenance schedule, an area is considered stable if base course gravels have been installed in areas to be paved, a minimum of 85% vegetated growth

has been established, a minimum of three inches if non-erosive material such as stone or rip-rap has been installed, or erosion control blankets have been properly installed.

5. All areas shall be stabilized within 45 days of initial disturbance.

6. Temporary and permanent seeding specifications shall be obtained by the contractor by a qualified person/company and shall consult with the town's wetland expert prior to planting to ensure no adverse effects to the site.

7. In conjunction with construction, all drainage structures, including swales and detention basins, shall be constructed and stabilized as soon as possible and prior to directing runoff to them. Methods of stabilization include, but are not limited to, hydro seed, loam and seed, straw mulch, erosion control blanket, etc.

8. Silt sacks shall be installed in each catch basin and shall be inspected once per week and after every storm event of 0.5" or greater. Devices with sediment buildup shall have the sediment disposed of in accordance with all local, state, and federal regulations and have the silt sack cleaned or replaced.

9. All roadways shall be stabilized within 72 hours of achieving finished grade.

10. All areas of cuts and fills shall be seeded/loamed within 72 hours of achieving finished grade.

11. The smallest practical area shall be disturbed during construction, but in no case shall exceed 3 acres at any one time before disturbed areas are stabilized.

12. The swales, roadway culverts, and detention basins shall be inspected weekly or after a storm event of 0.5" or greater over a 24-hour period during construction. Any sediment buildup in the structures shall be promptly removed using a vacuum removal process and all debris removed in accordance with all local, state, and federal regulations.

13. The detention basins and swale shall be inspected weekly and after all rainfall events greater than 0.5" over a 24-hour period. Any erosion within the basin or swales shall be filled and re-stabilized in a manner to prevent future erosion. In addition, the outer portions of the basin shall be inspected in a similar manner.

14. **Standard Winter Notes:**

    a) All proposed vegetated areas that do not exhibit a minimum of 85% vegetative growth by October 15, or which are disturbed after October 15, shall be stabilized by seeding and installing erosion control blankets on slopes greater than 3:1, and seeding and placing 3 to 4 tons of mulch per acre, secured with anchored netting, elsewhere. The installation of erosion control blankets or mulch and netting shall not occur over accumulated snow or on frozen ground and shall be completed in advance of thaw or spring melt events.

b) All ditches or swales which do not exhibit a minimum of 85% vegetative growth by October 15, or which are disturbed after October 15, shall be stabilized temporarily with stone or erosion control blankets appropriate for the design flow conditions.

c) After November 15, incomplete road or parking surfaces, where work has stopped for the winter season, shall be protected with a minimum of three inches of crushed gravel per NHDOT item 304.3.

15. This schedule must be adhered to by the owner and/or contractor until the site is conveyed to a homeowner's association.

16. Lot disturbance, other than that shown on the approved plans, shall not commence until after the roadway has the base course to design elevation and the associated drainage in complete and stable.

9.3.5 Post-Development Operation and Maintenance schedule

Upon completion of construction, this Operation and Maintenance schedule shall be adhered to by the Homeowner's Association and their agents, advisors, consultants, and contractors, or any future agent with associated responsibility. The outline below shall be adhered to as closely as possible to ensure the proper function of the drainage system.

1. The roadway shall be swept four times annually, at a minimum. Sweeping shall be done after the final snow melt when sand or de-icer can be easily swept. Any collected debris shall be removed in accordance with all local, state, and federal regulations.

2. The swales shall be cleaned four times per year and inspected monthly. In addition, the bottom and/or side slopes shall be mowed and all grass clippings and debris disposed of in accordance with all local, state, and federal regulations. No clippings shall be dumped within 100 feet of any wetland resource area.

3. The Bio-Retention Basin shall be inspected four times per year and any repairs made as necessary. The back side slopes of the Bio-Retention Basin shall be mowed at least once per year and the outlets inspected for signs of clogging and/or debris. Debris shall be disposed of in accordance with all local, state, and federal regulations. At least twice per year, inspection shall include erosion and/or cracking of the side slopes. If this condition is noticed, repairs shall be made to immediately stabilize the affected area(s) and measures taken to prevent a reoccurrence.

4. The roadway culverts shall be inspected twice per year, including one time after the final snowmelt of the season, and any obstructions shall be removed and disposed of in accordance with all local, state, and federal regulations.

5. No erosion control measures shall be removed until all contributing upslope areas are stabilized.

9.3.6 Temporary Erosion Controls

The following erosion controls, as locations shown on the plans or otherwise installed, shall be used to limit soil erosion and transport during all construction phases:

1. Source Control: The best and most effective method of retaining soil and prohibiting transport is to use methods and techniques to prohibit the lifting, suspending, or transport of soil. These techniques include compaction, mixing, adding soil amendments including stabilizers, and surface treatment such as mulch, straw, jute matting, mesh, geotextiles fabrics, covers, and others
2. Silt Fence Barrier: A silt fence is a temporary barrier of geotextile fabric (filter cloth) attached to supporting posts and entrenched into the soil that is used to intercept sediment laden runoff from small areas of disturbed soil. The expected life of a silt fence is generally limited to 6 months.
3. Hay Bale Barrier: A Hay Bale barrier is a temporary barrier constructed of carefully stacked hay bales secured into the ground by embedding by digging a shallow 4" trough for the hay bale and securing them into the ground with wooden or steel stakes. Behind the hay bales, a silt fence is installed as described in 1 above. The expected life of a hay bale / silt fence is generally limited to 6 months.
4. Hay Bale/Silt Fence Barrier: Combination of 2 and 3 above. The hay bale is positioned on the high side.
5. Temporary Swale: Temporary swales are constructed channels with temporary vegetation for stabilization that intercept sediment-laden runoff and direct the flow to a secondary erosion control or into a natural drainage system. Swales can improve water quality by filtering and infiltrating the runoff. Installing stone check dams are quite easy to install and allows for sedimentation of the solids and easier cleaning.
6. Conveyance Swale: Conveyance swales are constructed open channels, some with dense vegetation, that are constructed to convey runoff and direct the flow to a BMP or to the discharge point into a natural drainage system. Conveyance swales direct the water to other BMP's and/or improve water quality by physically filtering and infiltrating the runoff and allowing for ionic exchange and chemical actions to aid in polishing the runoff.

7. Temporary Sediment Basins: Sediment basins are effective at ponding and detaining runoff enough to allow sedimentation. Temporary outlets allow for a discharge. In this project portions of the forebay and the detention basin will be utilized as temporary sediment basins. Sediment removal should be regular during construction. This should be done whenever the sediment is 12" deep or deeper.
8. Loam and Seed: Loam and seed establishes grasses on highly erodible soils or critically eroding areas. Loam and seed stabilizes the underlying soil, reduces damages from sediment, maintains or improves water quality and reduces stormwater runoff. On steeper slopes, jute matting, organic mesh, or other devices are used to retain the soil until a full lawn or slope is fully stabilized with mature grow in. Fertilizer and seed type and application rates are on the final drawings.

9.3.7 Permanent Best Management Practices

Operation and maintenance of the catch basins, inlets, drainage swales, rain gardens, Bio-Retention systems, infiltration systems, and associated drainage structures should occur as follows:

1. Catch Basins – Deep Sump – Inspect or clean deep sump basins at least four times per year and at the end of the foliage and snow- removal seasons. Sediments must also be removed four times per year or whenever the depth of deposits is greater than or equal to one half the depth from the bottom of the invert of the lowest pipe in the basin. If handling runoff from land uses with higher potential pollutant loads or discharging runoff near or to a critical area, more frequent cleaning may be necessary.
2. Inlets – Pipe inlets and spillway structures should be inspected annually and after every major storm. Accumulated debris and sediment should be removed. If pipes are coated, the coating should be checked and repaired as necessary.
3. Outlets – Pipe outlets should be inspected annually and after every major storm. The condition of the pipes should then be noted and repairs made as necessary. If erosion is taking place, then measures should be taken to stabilize and protect the affected area of the outlet.
4. Earth Berm (embankment) –Vegetation – All vegetated areas should be inspected annually and after every major storm The vegetated areas within and around the stormwater management facilities should be protected from damage by fire, grazing, traffic, and dense weed growth. Lime and fertilizer should be applied as necessary as determined by soil tests. Trees and shrubs should be kept off of the detention basin embankment and emergency spillway areas. Trimming, mowing, cutting of weeds and invasive vegetation is one of the primary components of maintenance and is usually quite easy if done regularly, at least once per year. Neglect though may create a much greater chore.

5. Bio Retention System – The Bio Retention System should be inspected four times per year and any repairs made as necessary. The basins shall be mowed at least once per year and the outlets inspected for signs of clogging and/or debris. Debris shall be disposed of in accordance with all local, state, and federal regulations. At least twice per year, inspection shall include erosion and/or cracking of the side slopes. If this condition is noticed, repairs shall be made to immediately stabilize the affected area(s) and measures taken to prevent a reoccurrence.

   Should sediment accumulations reach an average depth of greater than 12 inches, the sediment should be removed and properly disposed of. Earth berms should be inspected annually and after every major storm. The earth berm of the forebay and extended detention system should be inspected annually to determine if rodent burrows, wet areas, or erosion of the fill is taking place.

   All permanent impoundments should be inspected annually by a qualified professional engineer on a periodic basis to assure that no erosion has impacted the structural integrity of the embankments.

   The spillway shall be inspected annually and reconstructed if evidence of overtopping occurred with appropriate base course and rip rap constructed as necessary under the direction of a professional engineer.

   The plantings shall be healthy and restored to health or replaced, in kind or type, if found not so. The plantings shall be trimmed and pruned at least once yearly to assure that they do not outgrow their intended use or that of others.

6. Infiltration System – The Cultec Chamber Infiltration system should be inspected four times per year and any repairs made as necessary. The surface of the basin should be maintained as lawn and shall be mowed at twice per year. The overflow outlets inspected for signs of clogging and/or debris at least once per year. Any debris shall be disposed of in accordance with all local, state, and federal regulations. At least twice per year, inspection shall include checking the inspection port for water retention and other signs of partial or full failure. If this condition is noticed, an analysis with a written report and photographs should immediately be performed and any repairs shall be made as soon as possible.

   Should sediment accumulations reach an average depth of greater than 12 inches, the sediment should be removed by flushing and vacuuming and properly disposed of.

7. Outlet Protection (riprap apron) – The outlet protection should be inspected at least annually and after every major storm. If the riprap has been displaced, undermined or damaged, it should be repaired immediately. The channel immediately below the outlet should be checked to see that erosion is not occurring. The downstream channel should be kept clear of obstructions such as fallen trees, debris, and sediment that could change flow patterns and/or tailwater depths on the pipes. Repairs must be carried out immediately to avoid additional damage to the outlet protection apron.

8. Drainage swale – The drainage swales should be inspected quarterly and during/after every major storm over 1" of rainfall. All cross culverts at driveway crossings should be kept clear and free of debris regularly. Should sediment buildup at the inlet or outlet of the driveway culverts (or other location) impede the free flow of stormwater through the culvert, the sediment should be immediately removed and properly disposed of.
9. Loam and Seed: Loam and seed establishes grasses on highly erodible soils or critically eroding areas. Loam and seed stabilizes the underlying soil, reduces damages from sediment, maintains or improves water quality and reduces stormwater runoff. On steeper slopes, jute matting, organic mesh, or other devices are used to retain the soil until a full lawn or slope is fully stabilized with mature grow in. Fertilizer and seed type and application rates are on the final drawings.
10. Construction Site Entrance – Stone pads are used to limit the transport of sediment from the times on construction and other vehicles. These pads should be maintained regularly.

9.3.8 Other Site Controls

1. Good house keeping - The contractor is necessary for maintaining accurate and complete records of the construction activities on site. The contractor must also ensure that chemicals, pesticides, and fertilizers are properly stored. Regular disposal of garbage, rubbish or sanitary waste disposal, and prompt cleanup of spills is necessary to minimize the potential for pollution.

2. Waste disposal, sanitary septic disposal, and materials management - The proper management should include storage of hazardous materials such as paints, oils, etc. These materials should be stored in the contractor's vehicle or placed on an impervious floor or surface, i.e. (Basement floor or concrete slab.)

3. Spills - All personnel involved with the construction activities have knowledge of whom to contact in the event of a spill that is a source of storm water contamination. The contractor shall ensure that appropriate measures are taken to prevent spills and respond in the event of a spill. In the event of a spill the contractor should take measures to reduce storm water contact stopping the source of the spill, contain the spill, and absorb the material as quickly as possible.
4. Sanitary portable toilets –
5. Vehicle wash down – in appropriate locations over 100 feet from wetlands draining to a sediment basin

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9.3.5 Operation and Maintenance Generic Forms

See the following pages for the following forms:

- Best Management Practices – Summary of Inspections
- Grading and Stabilization Activities Log

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MEISNER BREM CORPORATION

142 LITTLETON ROAD, STE. 16, WESTFORD, MA 01886

BREM 40B

PROJECT NOT YET NAMED, OFF LONG RIDGE ROAD, CARLISLE, MA

Best Management Practices

Summary of Inspections

Project Site: ____________________

Location: ____________________

Phase or Limits: ____________________

Inspection Number	Date	Inspector	Item Inspected (see list @ right)	Condition/Remarks	Action to be Taken	Follow up Comments

List of Inspections

A. Hay Bale/Silt Fence
B. Sediment Ponds
C. Site Clearing, Grub
D. Storm Drain Pipe & Conveyance
E. BMP - Indicate type (mandatory)
F. Stone Condition
G. Velocity Dissipaters
H. Structural Components
I. Permanent Stabilization

Submittal Log

Date	Agency

Grading and Stabilization Activities Log

Date Grading Activity Initiated	Description of Grading Activity	Description of Stabilization Measure and Location	Date Grading Activity Ceased (Indicate Temporary or Permanent)	Date When Stabilization Measures Initiated

Use Additional Sheets if Necessary

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