Shelburne Stormwater Mitigation Best Management Practice (BMP) Design and Implementation Project
Shelburne, VT

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1.0 Introduction

1.1 Project Background

The Town of Shelburne has been installing stormwater pipes in place of grass-lined channels (commonly referred to as drainage swales) at the request of property owners. The request to install a pipe is typically made for safety (eliminate a steep eroding ditch) or aesthetics (remove the channel depression in the lawn). Swale replacement may be a good alternative in some cases, yet in others it would be preferable to retain the swale and the associated water quality benefits. Swales are a stormwater best management practice due to their ability to: (1) slow the movement of stormwater; (2) allow for the settling of fine sediment; and (3) take up nutrients for growing grass. In summary, swales are an effective measure for the protection of water quality. The many water quality benefits of grass swales have been well-demonstrated through a variety of studies such as the Jordan Cove National Monitoring Study (Dietz and Clausen 2007).

Piped stormwater collection and transport systems do not have the same water quality benefits as swales. Although the water is moved out of sight, the runoff in pipes moves quickly leading to more extreme high and low flows in receiving waters. Pipes eliminate infiltration and do not provide treatment of the water as it travels to a discharge point leading to sediment and nutrient release to downstream waters.

Shelburne is one of nine municipal separate storm sewer system (MS4) towns in Vermont. The MS4 rule requires towns to reduce the discharge of pollutants to the maximum extent practicable, to protect water quality, and to satisfy appropriate water quality requirements of the Clean Water Act. Munroe Brook in Shelburne is designated as impaired on the Vermont 303(d) list (VTDEC 2012) from its confluence with Shelburne Bay to 2.8 miles upstream due to failure to support aquatic life. The TMDL for Munroe Brook was approved on August 21, 2008. The underlying cause of this impairment detailed in the TMDL has been attributed to impacts of stormwater runoff. The goal of the TMDL is to address the controlling factors of watershed sediment production by setting high flow reduction targets, and to enhance habitat by setting base flow targets. These include:

- Decreasing flow at Q 0.3% by 6% (roughly estimated as 8 acre-feet)
- Increasing flow at Q 95% by 9% (roughly estimated as 0.2 acre-feet)

In 2006, the Town of Shelburne constructed a stormwater treatment system at Hullcrest Park. Its purpose was to reduce the impacts of stormwater runoff from the Oak Hill-Martindale, Juniper Ridge-Woodbine Road, and Birch Road neighborhoods on the North Branch of Munroe Brook. The system was designed to treat the runoff from the water quality volume (i.e., runoff from a 0.9-inch storm) and reduce the peak discharge for a 1-year, 24-hour storm event. Excess flow from larger storm events would bypass the treatment system and enter the stream. The system was designed to remove up to 80 % of the total suspended solids (TCE 2005). The groundwater recharge treatment standard was to be met using the existing grass lined channels and through the use of rooftop disconnection credits and rooftop infiltration (TCE 2005). The volume calculated for recharge to be met in this way was calculated to be 0.33 acre-feet.

1.2 Project Goals and Objectives

The goals of the project are to:

1. Assist the Town with the development and implementation of improved designs of piped stormwater systems to reduce erosion, equalize stormwater runoff flows, enhance ground water recharge, remove sediment, and reduce nutrient loading and
2. Document/analyze the effectiveness of existing swales over a range of soils and slopes in mitigating the effects of stormwater runoff that can be used both in Shelburne and other Towns.

1.3 Project Approach

This project explored the use of swales versus pipes to convey residential roadside stormwater flows. The overall outcome of the project was to create a process and associated tools for screening a site for suitability for a swale, a pipe, or an alternative stormwater BMP. This project has helped illustrate when swales are most appropriate and provides options for maintaining the stormwater benefits of a swale system in the case that a pipe system is installed. Specific tasks, tools, and deliverables completed include:

- A hydrologic modeling exercise to quantify differences in infiltration and water quality when a swales are converted to pipes;
- A screening matrix to guide decision-making on the appropriateness of a swale versus a pipe at a particular location based on characteristics of the site;
- Field observations of existing swales in the Town of Shelburne and creation of a GIS map of existing swales that includes other stormwater components that were previously mapped;
- Initial screen result for all existing swales illustrating their suitability for retention as a swale or conversion to a pipe;
- A list of BMPs spanning the spectrum between swales and pipes with information on appropriate site conditions for each technology to serve as a guide during Town/landowner decision-making;

- Conceptual designs, material lists, and unit pricing for four BMPs that preserve the water quality benefits of swales to provide alternatives for future implementation; and
- A preliminary design for a high-priority swale conversion site that included a perforated pipe conveyance system and other features that increase infiltration and stormwater treatment.

2.0 Hydrology Modeling and Infiltration Calculations (originally published 4/10/2012)

The existing conditions hydrology model used for design of the stormwater treatment system in the Hullcrest and Hedgerow Neighborhoods of Shelburne, Vermont was obtained and recreated to explore the influence of grass-lined swales relative to stormwater pipes. The model was reviewed to identify where swales were entered in the subbasins in the model and preliminary swale mapping was provided by Bill Hoadley. Swales were converted to pipes for the entire model to see how the peak flow rate and volume entering and discharging from the existing stormwater treatment system in Hullcrest Park changed for the storm generated by a 0.9-inch rainfall (i.e., the water quality storm) and the 1-year flood (i.e., the channel protection storm). The swale to pipe conversion affected the hydrology modeling by changing the timing (i.e., time of concentration and reach routing) of how stormwater moves through the subbasins. The modeling results show minimal influence of swale to pipe conversion (Table 1). For example, the peak flow for the water quality storm increase by 0.1 cubic feet per second (cfs) during swale conversion and the runoff volume does not change or slightly decreases. A small increase in flow and volume is observed for the channel protection storm.

Table 1: Summary of Modeling Results

	DESIGN ^		**ALL PIPES ^^**		**CHANGE^^^**		
Pipes (ft)	10,298		12,723		2,425		
Swales (ft)*	3,425		1,000		-2,425		
	Inflow^^^^		Inflow		Inflow		
	Q (cfs)	V (ac-ft)	Q (cfs)	V (ac-ft)	Q (cfs)	V (ac-ft)	V (cf)
Water Quality	0.72	2.40	0.82	2.40	0.10	0.00	-43.56
Channel Protection	8.72	3.91	8.89	3.93	0.17	0.01	653.40

*Tc calculations changed in upper basin to represent swale conversion in upper basin. Does not include 1,000 linear feet of swale conversion due modeling limitation (Tc < 1 min).

^Values taken from TCE design report appendix.

^^Values taken from TCE hydrologic model (HydroCad) recreated by MMI (HydroGraphs).

^^^Change is determined by subtracting all pipe scenario from design scenario.

^^^^Inflow and outflow to treatment system at watershed outlet.

Note: Design Water Quality Volume is 1.40 ac-ft, taken as the storm from 0.9 inches of rain. Design Channel Protection Volume is 1.56 ac-ft, taken as the 1-year storm event.

This exercise illustrates that standard modeling practice does not account for the potential infiltration in the grass-lined swales at this basin size and for the existing swale lengths. The change in timing alone is not enough to illustrate the differences between swales and pipes. In rainfall-runoff hydrology models curve numbers that are a function of land use and soil types are primarily used to determine the amount of runoff versus infiltration. Since there is no change in land use associated with swale to pipe conversions, the amount of runoff versus infiltration remains largely unchanged.

Although full conversion of swales to pipes was anticipated during the modeling exercise, 1,000 feet of swales remained unchanged due to modeling limitations. The time of concentration utilized in the original hydrologic model was less than 1 minute in two subbasins. This is lower than what the hydrologic model would allow (~5 minutes); therefore the time of concentration could not be decreased to reflect the quicker travel time due to converting a swale to a pipe. This indicates that water is moving very fast through these subbasins during storms.

To further explore how swale to pipe conversions could influence runoff and infiltration, calculations were performed to estimate the amount of infiltration that could potentially take place in the existing grass-lined swales during the water quality and channel protection storms. Infiltration rates (inches per hour) in the swales were assumed based on soil types in the NRCS web soil survey and published values in the Vermont Drainage Guide Appendix 14G published through the local NRCS regional office in Colchester, VT. Hydraulic calculations were performed on each swale to be converted to determine the surface area of the swale in contact with water during the two storms. Assuming a 24-hour duration storm, the potential infiltration rate and volume is determined and can be compared to the predicted runoff rate and volume from the Design hydrology model.

The infiltration calculations illustrate the importance of grass-lined swales for local infiltration and runoff reduction. For example, the swales are estimated to be able to absorb nearly four times (12,278 cubic feet (cf) vs. 2,526 cf) the runoff volume during the water quality storm (Table 2).

Table 2: Infiltration Calculation Results for Water Quality Storm

		Runoff (from model)*		Potential Infiltration**		
Sub-Basin	**Swale Length**	**Rate**	**Volume**	**Rate**	**Volume**	**Change*** **
ID	**(FT)**	**(cfs)**	**(cf)**	**(cfs)**	**(cf)**	**(cf)**
Reach 15R - BL1 ditch	400	0.02	392	0.00	78	314
Reach 17R - Pinehurst Ditch, SNOO	100	0.14	1,002	0.00	234	768
Subcatchment BL1 - Brook Lane	400	0.14	610	0.00	91	519
Subcatchment JR1 - Juniper Ridge	600	0.00	87	0.01	1,248	-1,161
Subcatchment MD6 - Back Yards Oak Hill/Summit	700	0.00	44	0.10	9,024	-8,980
Subcatchment WB1 - Woodbine	1,225	0.01	392	0.02	1,602	-1,210
Total:	**3,425**	**n/a**	**2,526**	**n/a**	**12,278**	-9,751

*0.00 indicates value is < 0.01 and > 0.

**Infiltration estimated based on infiltration rate by soil type and the wetted perimetter of the swale during the 24-hour duration storm.

*** Change = runoff - infiltation. > 0 indicates excess runoff and <0 indicates excess infiltration capacity.

During the channel protection storm nearly 25% (16,057cf / 66,865cf) of the stormwater runoff generated is infiltrated by the swales (Table 3) and the remaining portion of the flow travels in the small channels downstream until combining in collector pipes to head to the treatment system in Hullcrest Park. The infiltration calculations illustrate the expected influence of soil type on the partitioning between runoff and infiltration.

Table 3: Infiltration Calculation Results for Channel Protection Storm

		Runoff (from model)		Potential Infiltration**		
Sub-Basin	**Swale Length**	**Rate**	**Volume**	**Rate***	**Volume**	**Change**
ID	**(FT)**	**(cfs)**	**(cf)**	**(cfs)**	**(cf)**	**(cf)**
Reach 15R - BL1 ditch	400	2.80	14,985	0.00	177	14,808
Reach 17R - Pinehurst Ditch, SNOO	100	3.22	20,560	0.01	460	20,101
Subcatchment BL1 - Brook Lane	400	2.78	6,403	0.00	177	6,226
Subcatchment JR1 - Juniper Ridge	600	1.58	4,225	0.02	2,112	2,113
Subcatchment MD6 - Back Yards Oak Hill/Summit	700	1.28	5,663	0.11	9,162	-3,499
Subcatchment WB1 - Woodbine	1,225	2.88	15,028	0.05	3,969	11,059
Total:	**3,425**	**n/a**	**66,865**	**n/a**	**16,057**	**50,808**

*0.00 indicates value is < 0.01 and > 0.

**Infiltration estimated based on infiltration rate by soil type and the wetted perimetter of the swale during the 24-hour duration storm.

*** Change = runoff - infiltation. > 0 indicates excess runoff and <0 indicates excess infiltration capacity.

3.0 Stormwater Grass-Lined Channel versus Pipe Screening Matrix

The *Stormwater Grass-Lined Swale versus Pipe Screening Matrix* (Appendix A) was created to help screen sites for retention of grass-lined channels or conversion to stormwater drainage pipes. The matrix is a screening tool to help guide selection of preferred alternatives rather than a design tool. Field verification and additional data collection will typically be needed for design. The matrix is set up to score a range of variables between 1 (grass-lined channel most likely preferred) to 10 (pipe most likely preferred). Scores less than or equal to three indicate grass-lined channels are likely applicable, while scores of greater than or equal to 8 indicate that pipes are likely preferred. Grass-lined channels, pipes or a spectrum of other stormwater treatment BMPs (see Section 5.0 and Appendix C) can be used in the middle range (i.e., score between four and seven).

The decision tree is used by checking off boxes for the selected value under the categories of topography, soils, site characteristics, and hydraulics as these data are available. It is necessary to use available data and then collect field data to complete the assessment. Nevertheless, the user can view where the available data fall on the matrix and use visual interpretation to see where most of the scores land and make a decision to use a grass-lined channel, a pipe, or another BMP.

Select stormwater design manuals and guidelines documents from around the United States were reviewed to develop the Swale BMP Decision Tree (GCRMD 1999; VADCR 1999; VTANR 2002; VTANR 2002; NJDEP 2004; AMEC 2008; LWA 2008; CharMeck 2010; VADCR 2011).

Design experience and typical levels of data availability during site screening were also considered to create a practical tool with realistic expectations and results at each step of the BMP design.

4.0 Swale Mapping and Initial Screening Results

4.1 Swale Mapping

A field survey of swales was conducted in May 2012. Swales were hand drawn onto field maps to show location and direction of flow. General observations on vegetation were recorded. Swale dimensions were recorded at a variety of locations to describe typical conditions. Field observations were digitized to create a GIS shapefile. Swale maps were verified by the project team to increase accuracy. A swale map was produced for the entire town, also showing other known stormwater and drainage infrastructure (Appendix B-1). The Hullcrest neighborhood swale mapping is included as an example (Figure 1).

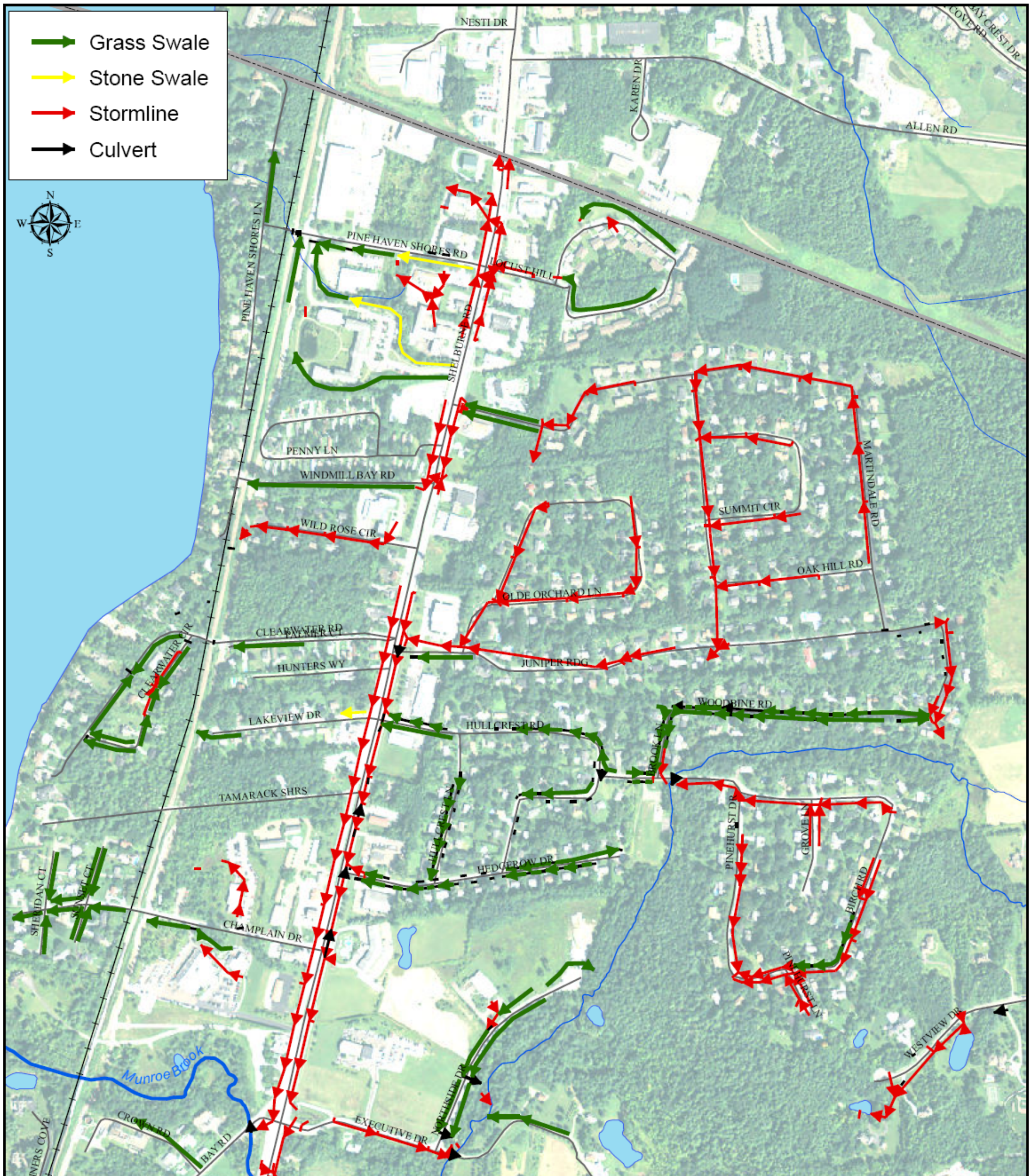
4.2 Swale Initial Screening

The *Stormwater Grass-Lined Swale versus Pipe Screening Matrix* was used to assign a rank to each swale across the spectrum of channel to pipe.

Categories include:

- Swale Should Remain – Site characteristics are appropriate at the location for a swale and existing swale should remain;
- Mid-Range Condition – Some characteristics are good for swale and others are good for pipes; and
- Could Change to Pipe – Many characteristics are not suitable for a swale. Consider changing to pipe or use of alternative to retain stormwater treatment.

The initial screening was a broad-brush approach that used data that was readily available at the town-wide scale. Not all data included in the screening matrix were available for use during this GIS exercise (Table 4). A determination for each data category was made based on values in the screening matrix if the swale would fall into the Swale, Mid-Range, or Pipe Category.



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1 South Main Street, 2nd Floor Waterbury, Vermont 05676 (802) 882-8335 Fax: (802) 882-8346 www.miloneandmacbroom.com	**Shelburne Stormwater Mitigation BMP** **Design and Implementation Project**	DATE: Jan 2013 SCALE: see scale bar	SHEET: **Figure 1**

Table 4: Data Included in the Initial Screening

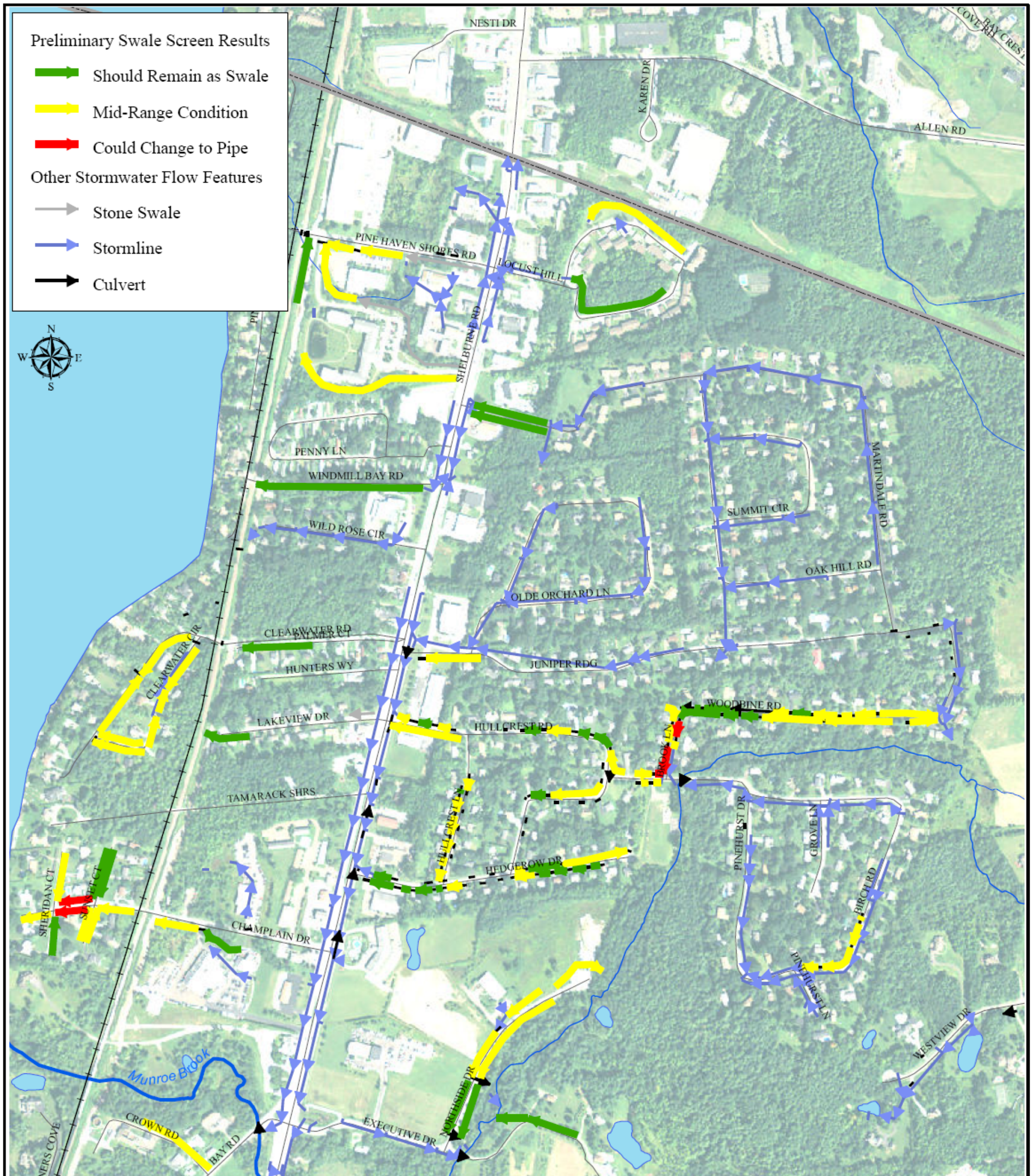
	Swale	Mid-Range	Pipe	Data Source	Data Notes
Ground Slope (percent)	< 2%		>= 5%	MMI GIS analysis using LiDAR	The LIDAR did not always pick up the elevation of the bottom of the swale.
Drainage Area (acres)	<= 3 acres		>= 10 acres	MMI GIS analysis using LiDAR	Delineation of individual Drainage Areas is more accurate than the automated method used here.
HSG	A or B	C	D	NRCS Soil Data viewer	
Permeability Class	excessively drained, somewhat excessively drained, well drained	moderately well drained, somewhat poorly drained	poorly drained, very poorly drained	NRCS Soil Data viewer	NRCS "Drainage Class"
Depth to Water Table (feet)	>= 2 feet		<= 1 feet	NRCS Soil Data viewer	Used "shallower" value from range.
Landuse	Forest, Brush, Agriculture, Urban-Open	all other catagories		2001 Data Corrected by the UVM Spatial Analysis Lab	Urban landuse category includes many areas of rural neighborhoods where swales function well.
Vegetation/Root Mass	dense	moderate	sparse	MMI field observations May 2012	

4.3 Swale Initial Screening Results

The initial screening results may be used as a stormwater drainage planning tool by Towns. Maps of screen results were created to guide decision making (Figure 2, Appendix B-2). The initial screen results can be used as an initial evaluation of site criteria when considering whether to leave a swale or change to a pipe or another BMP at a particular location. A field visit is recommended to collect information to make a final determination and begin design.

5.0 Stormwater Treatment Swale/Pipe BMPs

There are many BMPs that have been developed for stormwater management that cover a large range of approaches and technologies. These BMPs can be implemented at different scales and in different locations in the stormwater conveyance and treatment system. A list of a subset of some common and novel BMPs has been provided along with when each would typically be applied (Appendix C). This list may be referenced following an initial screening to look at some of the options available for channel flow, channel improvement, channel pre-treatment, pipe flow, pipe inlet, pipe pre-treatment, and pipe improvement.



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A description of the BMP classes and some examples follow.

- Channel Flow – This BMP category includes all forms of open-channel conveyance such as grass-lined channels and stone lined channels. These options include little hard infrastructure and are thus typically lower cost than a piped stormwater collection system.
- Channel Improvement – These BMPs are used in conjunction with a channel flow BMP. These options typically will add stability to a channel or add treatment capacity by storing or slowing water. Options include treatments such as check dams or planting trees in the channel to slow water.
- Channel Pre-Treatment – These BMPs are typically used prior to flow into a channel. Water is spread out to slow down, filter sediment, or allow for some infiltration prior to concentrating the flow in the channel. Options include a grass filter strip or a pea gravel diaphragm.
- Pipe Flow – This BMP category includes various closed-conduit conveyance options that are located underground. These options carry stormwater from one location to another and can be designed to allow for some infiltration or treatment if the pipe perforated.
- Pipe Inlet – These BMPs are used to allow stormwater to enter a pipe flow system. An inlet can be designed to include some level of stormwater treatment, as well as an entrance to the collection system. Treatment options include a catch basin or a hydrodynamic separator that can remove sediment or other pollutants.
- Pipe Pretreatment – These BMPs are used before stormwater enters the collection system. They are designed to remove sediment or other pollutants. Options include a catch basin insert or an oil and grit separator.
- Pipe Improvement – These BMPs are used to increase the treatment capability of a pipe flow system. Options include disconnection of non-rooftop runoff or a raingarden.

6.0 Engineering BMP Concept Designs

Four BMPs were selected from the Stormwater Treatment Swale/Pipe BMPs List and a concept design drawing, materials list, and unit costs were developed. These design typicals were developed to provide examples of swale replacement options that would enhance stormwater infiltration, retention, and treatment. Additional site specific design is required for implementation. Concept design drawings, material list, and unit costs are provided for each (Appendix D).

6.1 Pipe Flow – Perforated Pipe

This BMP was selected for conceptual level design because it is a relatively simple adjustment to a traditional stormwater pipe that can be implemented within a roadway right-of-way. This design allows for stormwater conveyance underground while also allowing infiltration and ground water recharge to occur. This system is configured and installed similarly to a traditional stormwater pipe. The differences from a traditional pipe system include using a perforated pipe, digging a deeper trench, possibly lining it with geotextile depending on site conditions, and importing crushed stone to fill the trench below and around the pipe. This BMP is not recommended for areas with clay soils or very high groundwater.

6.2 Pipe Inlet – Improved Catch Basin

Catch basin type inlets are very common in pipe flow stormwater systems. This BMP was included to demonstrate design features that will not just collect water into the conveyance system, but also provide some treatment. Catch basins can include features such as a sediment sump to allow sediment to settle out at the bottom, a bell and spigot elbow at the outlet to prevent floatables such as oil from leaving the structure, and an open or perforated bottom to allow for infiltration. A catch basin with a sediment sump requires routine maintenance to remove sediment and accumulated floatable debris.

6.3 Pipe Improvement – Raingarden

A raingarden, also called a bio-retention area or infiltration planter, is a vegetated depression that allows water to temporarily pond and either infiltrate, filter through medium to an underdrain, or overflow and leave the system. This BMP was chosen because it can be easily incorporated into a swale conversion project in many different formats. The design typical presented includes a depression formed around the inlet to a new underground stormwater pipe system. In this case the raingarden collects local runoff that would have otherwise directly entered the swale. The collected water is allowed to pond to promote infiltration through the amended soil medium, while during a larger storm event water would enter a yard drain inlet to the stormwater pipe system. A variety of plants can be chosen and either maintained as a typical ornamental flower garden or as a more natural meadow that could be mowed once a year. This system could be used even where infiltration is poor by installing an underdrain under the soil filter medium. The raingarden design was guided by the Vermont Raingarden Manual (WNRCD 2009).

6.4 Pipe Inlet – Hydrodynamic Separator

A hydrodynamic separator is a manufactured stormwater treatment system that is used in line with stormwater pipes or as a catchbasin and uses swirling motion to remove sediment from the runoff. Separators often include oil and floatables traps. These units are sized according to a specific water quality flow rate and specific designs will range in price according to the required size. A few examples of these systems have been included to guide decision making.

7.0 Preliminary Design of a Demonstration Project

A high priority swale replacement site was identified in conjunction with the Town of Shelburne. An eroding grass swale on Brook Lane, adjacent to the corner of Pinehurst Drive, was selected for a preliminary design (Photo 1 and 2). The existing swale is 136 feet long, with the lower 100 feet on one property and encompassing the majority of the erosion. The swale initial screening results classified this swale as red implying a change to pipe or alternative treatment system is recommended (Figure 2). This classification is based on high groundwater, poorly drained soils that are hydrologic soil group D, and moderate vegetative cover. The soils are Covington Silty Clay.

Upstream of this section of grass swale is a series of other swales on Brook Lane and Woodbine Road with culverts under driveways. The upstream drainage area is 12.7 acres and flows to the swale are 3.5 cfs for the 2-year storm and 6.1 cfs for the 10-year storm (TCE 2005). The preliminary design at Brook Lane has been sized to carry the 10-year storm with extra capacity.

The design includes the existing eroding grass swale being replaced with a perforated pipe and infiltration trench and a raingarden (Appendix E). The perforated pipe will be 100 feet long and will begin at the upstream property line and connect to the existing 18" HDPE stormwater pipe located at the end of the swale. The perforated pipe will be embedded in a trench of gravel to allow for some infiltration. A very shallow grass swale will be formed in the ground surface above the perforated pipe to direct local runoff to the downstream inlet. Above the last 30 feet of the perforated pipe the swale will be graded to create a depression that can be planted with vegetation and maintained as a raingarden. An inlet to the storm drainage system will be located in the raingarden and raised above the surface to allow for ponding. This raingarden area will be maintained like a garden and will require cooperation from the adjacent landowner to maintain this landscape feature. An itemized materials list and cost opinion for the project has been included assuming that the labor would be provided by the Town. Material cost for this project is estimated at $5,100.

In order to extend the perforated pipe design upstream, the upstream driveway culvert would need to be lowered and likely replaced. The existing driveway culvert is too high and does not allow enough vertical space between the pipe invert and the elevation of Brook Lane road surface to install a pipe. If the driveway culvert and upstream swale were modified, another section of perforated pipe could be installed between the current design and the driveway culvert.

Photo 1: Looking up the Brook Lane Swale.

Photo 2: Looking down the Brook Lane swale toward Hullcrest Park.

8.0 References

AMEC (2008). Knox County, Tennessee Stormwater Management Manual, Volume 2 Technical Guidance. Knoxville, TN, Prepared for Knox County Department of Engineering and Public Works by AMEC Earth & Environmental, Inc. **2**.

CharMeck (2010). Charlotte-Mecklenburg BMP Design Manual, Section 4.5 Grassed Channel BMP Summary Fact Sheets. Charlotte, NC, Charlotte - Mecklenburg Stormwater Services.

Dietz, M. E. and J. C. Clausen (2007). "Stormwater Runoff and Export Changes with Development in a Traditional and Low Impact Subdivision." Journal of Environmental Management.

GCRMD (1999). Greene County Design Standards, Section 111 Open Channels. Springfield, MO, Greene County Resource Management Department.

LWA (2008). City of Davis Manual of Stormwater Quality Control Standards for New Development and Redevelopment. Davis, CA, Prepared by Larry Walker Associates for the City of Davis.

NJDEP (2004). NJ Stormwater Best Management Practices Manual, Chapter 6.5 Grass Swale (Draft). Trenton, NJ, New Jersey Department of Environmental Protection, Division of Watershed Management.

TCE (2005). Munroe Brook Stormwater Improvement Project._. Williston, VT, Prepared by Trudell Consulting Engineers for the Town of Shelburne. .

VADCR (1999). Virginia Stormwater Management Handbook, Minimum Standard 3.13 Grassed Swale. Richmond, VA, Virginia Department of Conservation and Recreation.

VADCR (2011). VA DCR Stormwater Design Specification No. 3, Grass Channels. Richmond, VA, Virginia Department of Conservation and Recreation.

VTANR (2002). The Vermont Stormwater Management Manual, Volume I - Stormwater Treatment Standards. Waterbury, VT, Vermont Agency of Natural Resources, Department of Environmental Conservation. **1**.

VTANR (2002). The Vermont Stormwater Management Manual, Volume II - Technical Guidance. Waterbury, VT, Vermont Agency of Natural Resources, Department of Environmental Conservation. **2**.

VTDEC (2012). STATE OF VERMONT 303(d) LIST OF WATERS: PART A - IMPAIRED SURFACE WATERS IN NEED OF TMDL. Montpelier, VT, Vermont Agency of Natural Resources, Department of Environmental Conservation, Watershed Management Division.

WNRCD. (2009). "The Vermont Rain Garden Manual "Gardening to Absorb the Storm"." Retrieved March 30, 2010, 2010, from http://vacd.org/winooski/VtRainGardenManual.pdf.

Appendix A

Stormwater Grass-Lined Channel versus Pipe Screening Matrix
Developed as part of the Shelburne Stormwater Mitigation BMP Design and Implementation Project
11/2/2012

← Best Management Practice (BMP) Spectrum →

Grass-Lined Channel **Pipe**

	1	2	3	4	5	6	7	8	9	10
TOPOGRAPHY										
Ground slope (%)*	0.5-1			2		3	4	5		
DA (Acres)	0-2		3		4		5	10	15	
SOILS†										
HSG	A,B					C			D	
Texture	Gravel	Sand	Silty Gravel		Silty Sand		Clayey Sand or Gravel			Silt or Clay
Permeability	High				Moderate					Low
Depth to water table (ft)	>2		2			1.5		1		<1
Infiltration (in/hr)	3		2		1					<1
SITE CHARACTERISTICS										
Space for Side slopes (H:1)	≥ 5	4	3		2				< 2	
Space for Bottom Width (ft)	4-8	2-4				1.5		≤ 1		
Vegetation / Root Mass±	Dense				Moderate					Sparse or Eroded
HYDRAULICS¥										
Flow Capacity	CPv		WQv							
Flow Depth (feet)	1		1.5			2				>3
Flow velocity (fps)	0-1		2-3	4-5						>5
Retention time (min)€	>10	10			8					<8
	1	2	3	4	5	6	7	8	9	10

Grass-Lined Channel **Pipe**

Notes

*Evaluate effective slope that considers presence of check dams. Check dams recommended in grass-lined channels for slopes larger than 2%.

†Soil amendments can be used to improve permeability of slow-draining soils.

±Evaluate existing and potential vegetative cover and root mass density in grass-lined channel.

¥Assess by field observations or hydraulic calculations (i.e., Manning's equation, nomographs, or modeling) needed to design grass-lined channel.

€Time of localized ponding prior to infiltration or downstream flow.

(See back of page for references.)

References

AMEC. 2008. Knox County, Tennessee Stormwater Management Manual, Volume 2 Technical Guidance. Prepared for Knox County Department of Engineering and Public Works by AMEC Earth & Environmental, Inc., Knoxville, TN.

CharMeck. 2010. Charlotte-Mecklenburg BMP Design Manual, Section 4.5 Grassed Channel BMP Summary Fact Sheets. Charlotte - Mecklenburg Stormwater Services, Charlotte, NC.

GCRMD. 1999. Greene County Design Standards, Section 111 Open Channels. Greene County Resource Management Department, Springfield, MO.

LWA. 2008. City of Davis Manual of Stormwater Quality Control Standards for New Development and Redevelopment. Prepared by Larry Walker Associates for the City of Davis, Davis, CA.

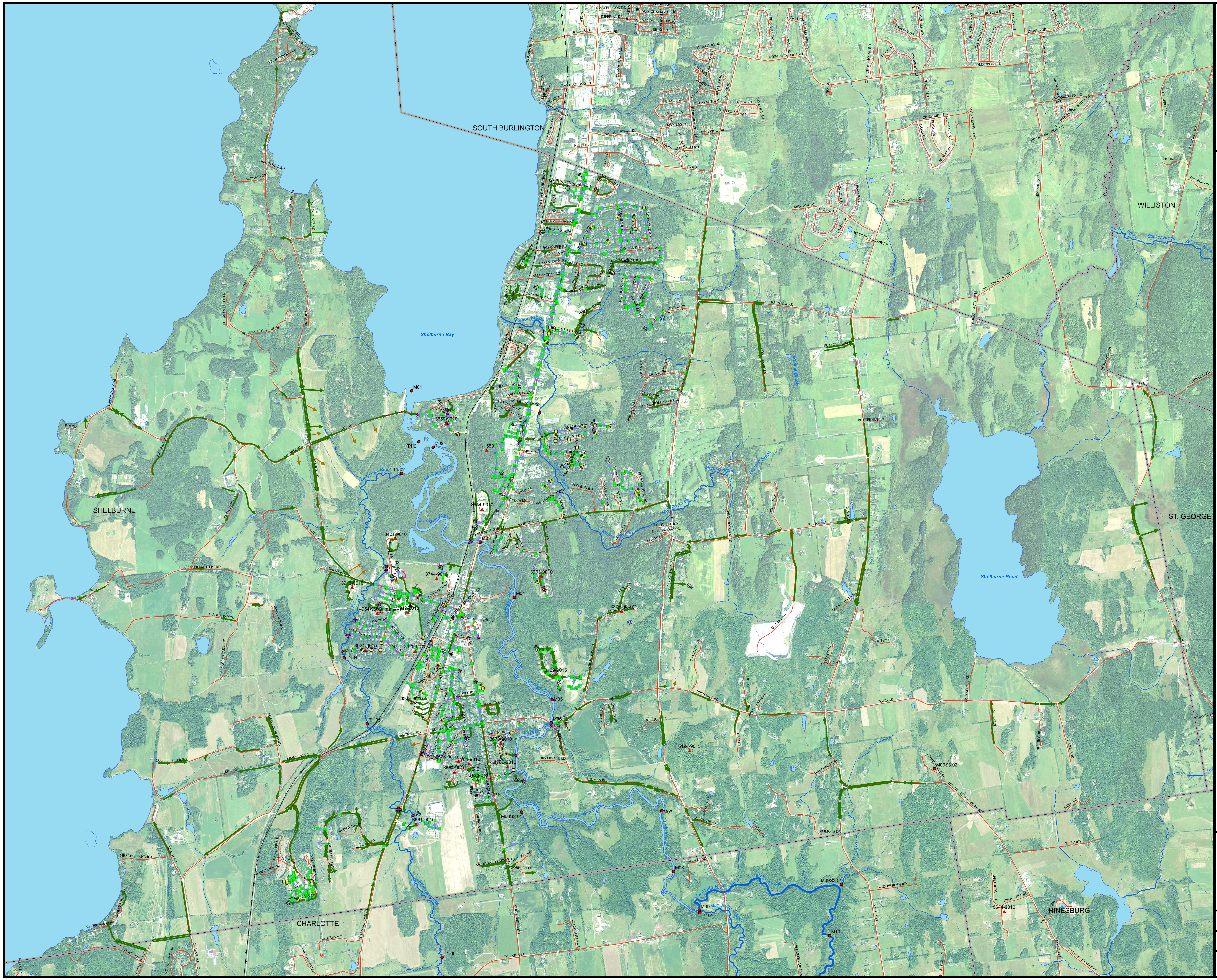
NJDEP. 2004. NJ Stormwater Best Management Practices Manual, Chapter 6.5 Grass Swale (Draft). New Jersey Department of Environmental Protection, Division of Watershed Management, Trenton, NJ.

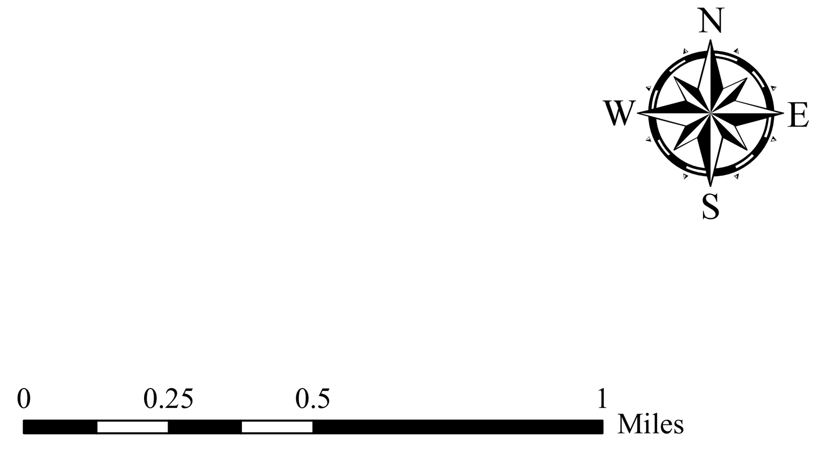
VADCR. 1999. Virginia Stormwater Management Handbook, Minimum Standard 3.13 Grassed Swale. Virginia Department of Conservation and Recreation, Richmond, VA.

VADCR. 2011. VA DCR Stormwater Design Specification No. 3, Grass Channels. Virginia Department of Conservation and Recreation, Richmond, VA.

VTANR. 2002a. The Vermont Stormwater Management Manual, Volume I - Stormwater Treatment Standards. Vermont Agency of Natural Resources, Department of Environmental Conservation, Waterbury, VT.

VTANR. 2002b. The Vermont Stormwater Management Manual, Volume II - Technical Guidance. Vermont Agency of Natural Resources, Department of Environmental Conservation, Waterbury, VT.





Legend

- ANR Issued Stormwater Permits

Stormwater Point Features

- Catchbasin
- Concrete Pad
- Detention Pond
- Drop Inlet
- Dry Well
- Grease Trap
- Manhole
- Outfall
- Outlet Structure
- Spillway
- Stone Filter
- Other

Stormwater Line Features

- Culvert
- Overland
- Stone Swale
- Stormline
- Grass Swale
- ANR SGA Identified Stormwater Inputs
- Towns
- Lakes and Ponds
- Roads
- Railroad

River (By Stream Order)

1 2 3 4 5

Aerial Photography is 2008 1:40,000 (1 meter) Color NAIP

SHELBURNE STORMWATER INFRASTRUCTURE

SHELBURNE STORMWATER MITIGATION BMP DESIGN AND IMPLEMENTATION PROJECT

SHELBURNE, VERMONT

DESIGNED	DRAWN	CHECKED
JCL	JCL	RKS

SCALE: 1" = 1300'

PROJECT NO.: 3452-14

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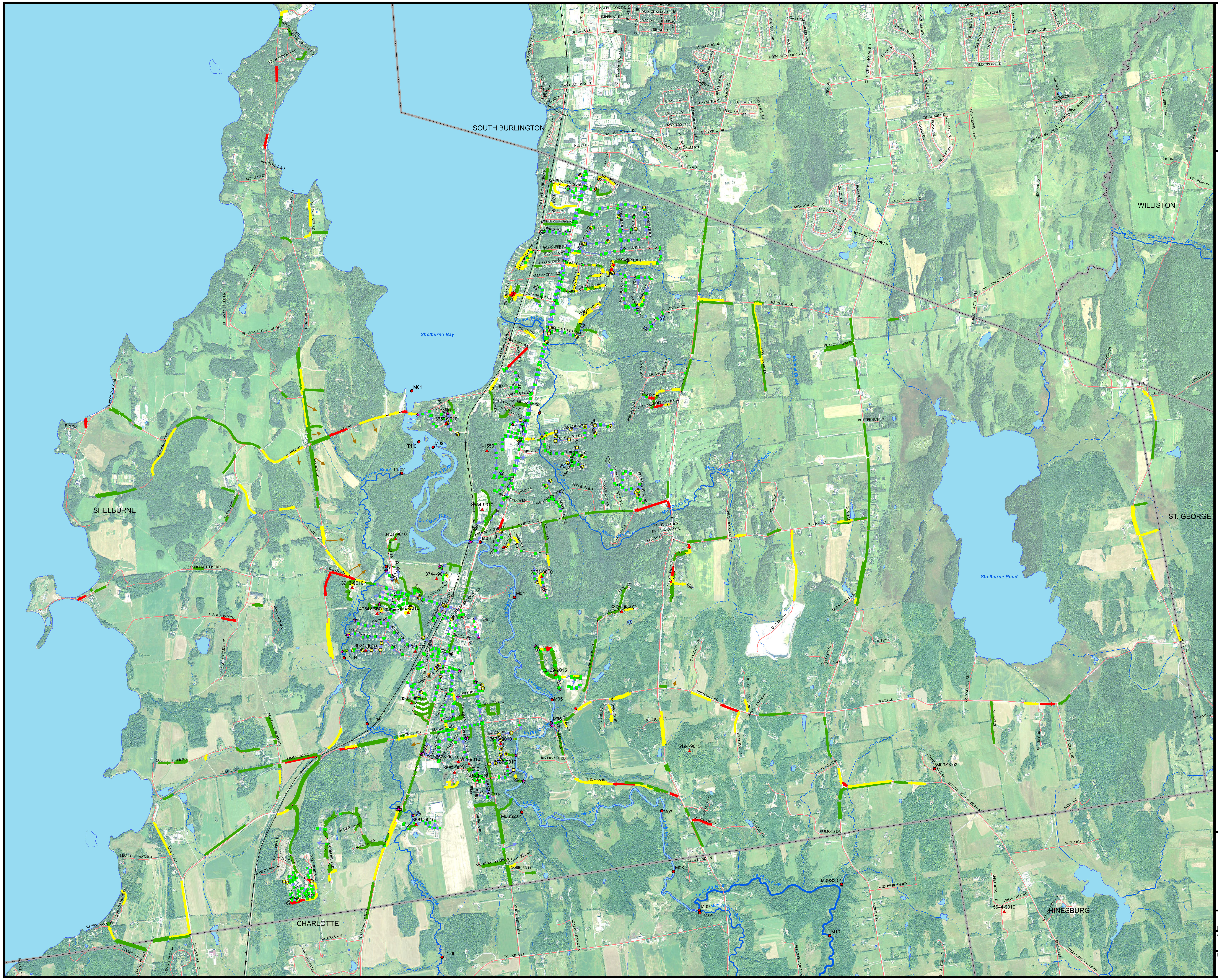
SHEET: APPENDIX B-1



N
W E
S

0 0.25 0.5 1 Miles

Legend

- ANR Issued Stormwater Permits

Stormwater Point Features

- Catchbasin
- Concrete Pad
- Detention Pond
- Drop Inlet
- Dry Well
- Grease Trap
- Manhole
- Outfall
- Outlet Structure
- Spillway
- Stone Filter

Preliminary Swale Screen Results

- Channel, Should Remain
- Channel, Mid-Range Condition
- Channel, Could Change to Pipe

Stormwater Line Features

- Culvert
- Overland
- Stone Swale
- Stormline
- ANR SGA Identified Stormwater Inputs
- Towns
- Lakes and Ponds
- Roads
- Railroad

River (By Stream Order)

1 2 3 4 5

Aerial Photography is 2008 1:40,000 (1 meter) Color NAIP

INITIAL SWALE SCREEN RESULTS

SHELBURNE STORMWATER MITIGATION BMP DESIGN AND IMPLEMENTATION PROJECT

SHELBURNE, VERMONT

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Stormwater Treatment Swale/Pipe BMPs
Developed as part of the Shelburne Stormwater Mitigation BMP Design and Implementation Project
11/2/2012

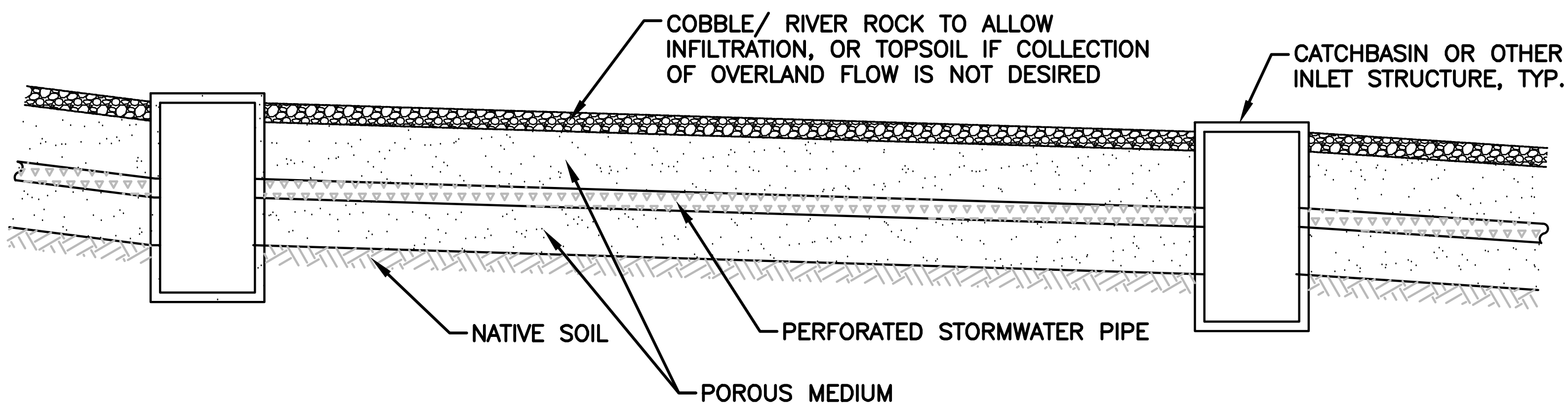
BMP Class	BMP Practice	Typical Application
Channel Flow	Grass Channel - Open vegetated channel or depression designed to carry minimal flow.	Shallow Slopes (<2%); Low velocity (< 1 ft/s); Design can detain water quality volume minimum residence time (> 10 min).
Channel Flow	Wet Swale - Open vegetated channel or depression designed to retain water or intercept groundwater for water quality treatment.	Shallow slopes (< 2%); Standing water tolerable.
Channel Flow	Dry Swale - Open vegetated channel or depression designed to detain and promote filtration to underlying media, includes permeable medium and underdrain.	Deep groundwater (>2ft); Best when infiltration of natural soil possible.
Channel Flow	Stone Lined Channel- Open channel lined with stone.	Steeper slope channels (> 2%); prone to erosion (5 ft/s < V < 10 ft/s).
Channel Flow	Rigid Lined Channel - Open channel lined with concrete, asphalt or other rigid lining.	High flow capacity; High velocities are expected (10 ft/s < V < 15 ft/s); steep slope (>10%) that would be erosion prone; or low slope (<0.5%) that requires draining.
Channel Improvement	Check Dams - Typically 6-12" vertical drops installed in an open channel system to reduce effective slope and promote micro-pools.	Recommended in open channel systems for moderate or steep slopes (>2%).
Channel Improvement	Log and Brush Check Dam - Small drops constructed from logs and brush to slow water in an open channel system.	Recommended in open channel systems for moderate or steep slopes (>2%).
Channel Improvement	Tree Check Dams - A street tree planted in the bottom of the conveyance, with the mound 9-12" taller than open channel bottom. Root ball acts as partial check dam.	Tree planting is appropriate; An alterative to a traditional check dam to reduce effective slope in an open channel system that is too steep (>2%).
Channel Pre-Treatment	Pea Gravel Diaphragm - A trench filled with pea gravel located at the top of the channel's bank slope. Provides some pretreatment and reduces surface erosion by encouraging infiltration of lateral sheet flow entering swale.	Sheet flow enters conveyance laterally, such as along a roadway; Space available.
Channel Pre-Treatment	Concentrated Flow Curb cut Pretreatment - Gravel Flow Spreader - Stone inlet channel and level spreader located where concentrated flow enters an open channel to dissipate energy and reduce erosive forces.	Concentrated flow enters conveyance laterally, such as at a curb cut.

Stormwater Treatment Swale/Pipe BMPs
Developed as part of the Shelburne Stormwater Mitigation BMP Design and Implementation Project
11/2/2012

BMP Class	BMP Practice	Typical Application
Channel Pre-Treatment	Grass Filter Strip - A grass lined, shallow lateral depression between an impervious surface and the open channel.	Open channel is a distance from impervious surface; space allows for shallow slope (<5:1) between impervious surface and channel.
Pipe Flow	Stormwater pipe/ Storm drain - Pipe designed to carry water to an outfall location.	Steeper Slopes (>5%); when open channel conveyance is not possible due to design setting.
Pipe Flow	Perforated Pipe - Pipe with hole patterns in porous medium to allow infiltration to groundwater during low flows and conveyance during higher flows (see Figure 1).	Soils allow for infiltration; Deep groundwater; Space is limited.
Pipe Flow	Linear Recharge Gallery - Manufactured stormwater treatment system that allows for storage, infiltration, and flow (e.g. one row of underground recharge gallery cells installed in place of pipe length).	Soils allow for infiltration; Deep groundwater; Space is limited.
Pipe Inlet	Hydrodynamic Separators - Manufactured product used in line with stormwater pipes or as a catchbasin, uses swirling motion to settle sediments. Often includes oil and floatables trapping (see Figure 4).	Retrofit design or pretreatment; Space is limited.
Pipe Inlet	Catch Basin - A grate or curb inlet set in an impervious surface that serves as an entrance to stormwater collection system. Can capture sediment if includes a sediment sump (see Figure 2).	Curbed streets or parking areas; When minimal sediment removal is required for pretreatment; Frequent maintenance is available to remove sediments.
Pipe Pre-Treatment	Catch Basin Insert - Filtering mechanism placed inside catchbasin to remove sediments and debris, prevents resuspension (e.g., simple cloth filter, geotextile, filter medium, upflow devices).	Retrofit design for existing catchbasins where additional sediment removal is desired.
Pipe Pre-Treatment	Catch Basin with Infiltration - The bottom of the catchbasin is left open to allow for infiltration.	Curbed streets or parking areas; Where runoff is not expected to negatively impact groundwater quality; Soil properties allow for infiltration.
Pipe Pre-Treatment	Oil and Grit Separators - A wet vault may be fitted with a sponge material or other mechanical filter that binds oil and grease.	Limited treatment capacity; use when contaminated runoff is likely.

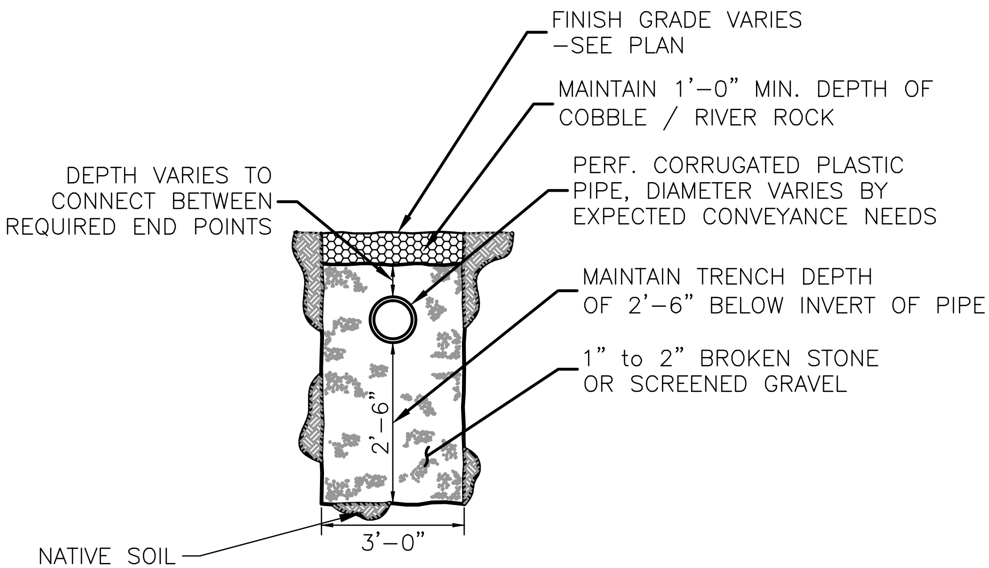
Stormwater Treatment Swale/Pipe BMPs
Developed as part of the Shelburne Stormwater Mitigation BMP Design and Implementation Project
11/2/2012

BMP Class	BMP Practice	Typical Application
Pipe Improvement	In-Line Storage - Stormwater conveyance systems that are fitted with flow reducing devices to store water in the system during a storm.	Stormwater systems are oversized and volume for storage exists; Infrastructure adjacent to the system is not vulnerable to flooding; Steeper systems are better suited.
Pipe Improvement	Disconnection of Non-Rooftop Runoff (Curb Cut) - A break in the curb or other disconnection of flow on impervious surface to enter a treatment area. Pair with stormwater tree box filter, infiltration planters, pea gravel filter, overland flow, or others.	Curbed streets or parking areas; An appropriate receiving area exists that will treat stormwater.
Pipe Improvement	Infiltration Planters (Bi-retention, raingarden)- Small planting areas that capture stormwater, typically directed from a curb cut in a curb and gutter system (see Figure 3).	Curbed streets or parking lots; Populated areas where street trees or other structured landscaping is appropriate; At entrance to pipe conveyance system.
Pipe Improvement	Stormwater Tree Box Filter (Tree Box, Street Tree Well) - A street tree planted in a porous medium along a roadway system that collects water from impervious surface and allows detention, filtering and either infiltration or underdrain to stormwater system.	Street trees are appropriate; Limited space is available; Entrance to pipe conveyance system.



PERFORATED PIPE – PROFILE VIEW

1"=10'



PERFORATED PIPE – SECTION VIEW

NOT TO SCALE

DESIGN NOTES:

THIS CONVEYANCE SYSTEM USES A PERFORATED PIPE EMBEDDED IN POUROUS MEDIUM TO ALLOW FOR CONVEYANCE OF STORMWATER BETWEEN POINTS UNDERGROUND, WHILE ALSO ALLOWING FOR INFILTRATION OF STORMWATER INTO THE GROUND.

SUITABILITY:

GROUNDWATER LEVELS SHOULD BE DEEP ENOUGH TO PREVENT COLLECTION OF GROUNDWATER IN CONVEYANCE PIPE.

SOILS SHOULD ALLOW FOR INFILTRATION.

REQUIRES MINIMAL SPACE

VARIATION:

REPLACE COBBLE/ RIVER ROCK SURFACE LAYER WITH 6" OF TOPSOIL AND PLANT WITH GRASS OR LANDSCAPE PLANTS IF COLLECTION OF OVERLAND FLOW IS NOT DESIRED. THIS VARIATION WILL REQUIRE INSTALLATION OF A YARD DRAIN OR OTHER INLET DEVICE.

FILTER FABRIC MAY BE WARRANTED BASED ON SEDIMENT SIZE AND FILTER RATIO.

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DESIGNED	JCL
DRAWN	JCL
CHECKED	RKS

PIPE FLOW - PERFORATED PIPE

STORMWATER BEST MANAGEMENT PRACTICE CONCEPTUAL DESIGN TYPICAL

DEVELOPED AS PART OF THE SHELBURNE STORMWATER MITIGATION BMP DESIGN AND IMPLEMENTATION PROJECT

DRAWING NAME:

FIGURE 1

Drawing: P:\3452-14 SHELBURNE SWALES\DESIGN\CAD\SS-DETAILS.DWG Layout Tab:PERFORATED PIPE
Plotted by: JESSICAC On this date: Thu, 2012 December 6 - 9:26am

Pipe Flow - Perforated Pipe
Conceptual Design Typical - Material List and Unit Cost
Shelburne Swales Project
12/5/2012

	Unit Price	Units	Quantity Per Linear Foot	Minimum Quantity	Price Per Linear Foot	Quantity for 100 foot long project	Price for 100 foot long project	Notes	Price Quote Source	Quote Source Phone Number
Perforated Pipe										
1" crushed stone + delivery	$ 23.60	yard	0.32	up to 11 yards	$ 7.55	**32**	$ 755	price controlled by delivery price, listed for 32 yards split into 3 loads	Hinesburg Sand and Gravel	482-2342
Geotextile Fabric - non-woven, 15' wide, 4.5 oz	$ 0.64	square yard	1.7	**600**	$ 1.09	170	$ 384	1 600 sq ft roll = 360 linear feet of trench	E.J. Prescott	865-3958
18" HDPE Perforated Pipe	$ 17.49	linear feet	1	20	$ 17.49	**100**	$ 1,749	need to round up in 20 foot increments due to pipe length	E.J. Prescott	
Lawn Grass Seed	$ 15.00	pound	0.005	0.5	$ 0.08	**0.5**	$ 8			
Erosion Fabric - optional	$ 3.00	square yard	1.1	20	$ 3.30	**75**	$ 225			
Total					**$ 29.51**		**$ 3,121**			
Drainage Inlet - Would not be required at all projects if other inlet to drainage system exists										
Nyoplast 24" Yard Drain, 12" Vertical Riser	$ 875.00	each	per project	1	N/A	**1**	$ 875	Would not require at all projects	E.J. Prescott	
Yard Drain T connection	$ 216.24	each	per project	1	N/A	**1**	$ 216	Would not require at all projects	E.J. Prescott	
Coupling for Yard Drain	$ 29.31	total	per project	2	N/A	**1**	$ 59	Would not require at all projects	E.J. Prescott	
Total							**$ 1,150**			

Drawing: P:\3452-14 SHELBURNE SWALES\DESIGN\CAD\SS-DETAILS.DWG Layout Tab:CATCH BASIN
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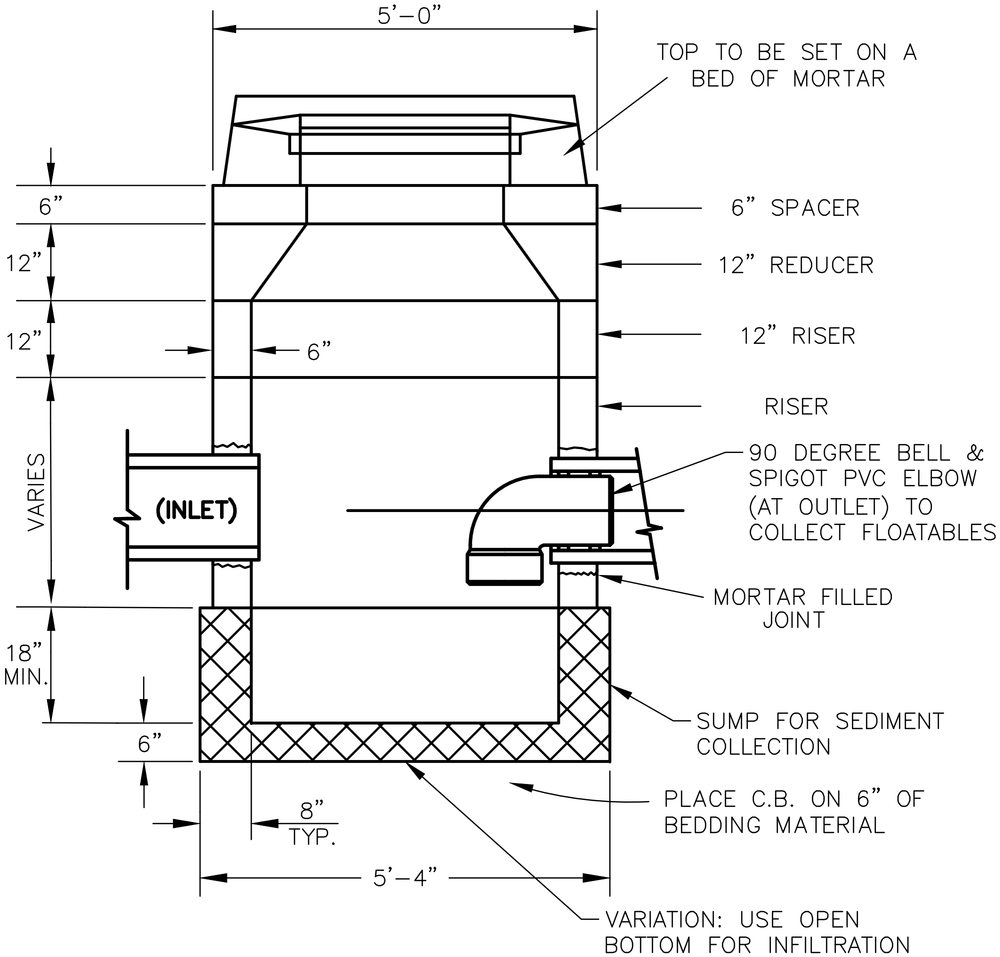

NOTE:
ALL CATCH BASIN COMPONENTS TO BE PRE-CAST REINFORCED CONCRETE, ABLE TO WITHSTAND THE APPLIED EARTH LOADS WITH AN HS-20 TRUCK LOAD. ALL JOINTS TO BE MORTARED. CATCH BASIN SHALL CONFORM TO ASTM C478.

IMPROVED CATCH BASIN
NOT TO SCALE

DESIGN NOTES:

A CATCH BASIN ALLOWS COLLECTED STORMATER TO ENTER THE CONVEYANCE SYSTEM. A MINIMUM 18 INCH DEEP SEDIMENT SUMP IS REQUIRED BELOW THE INVERT OF INLET AND OUTLET PIPES TO ALLOW FOR SETTLING OF SEDIMENTS AND A HOOD ON THE OUTLET TO PREVENT FLOATABLES FROM LEAVING THE CATCH BASIN.

SUITABILITY:

REQUIRES REGULAR MAINTENANCE TO REMOVE SEDIMENT AND ACCUMULATED FLOATABLE DEBRIS.

VARIATION:

REPLACE SOLID CONCRETE BOTTOM WITH OPEN BOTTOM OR CONCRETE WITH PRECAST HOLES TO ALLOW FOR INFILTRATION INTO SURROUNDING NATIVE SOILS. THIS VARIATION IS RECOMMENDED WHERE GROUNDWATER IS DEEP AND SOILS ALLOW FOR INFILTRATION.

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PIPE INLET - IMPROVED CATCH BASIN

STORMWATER BEST MANAGEMENT PRACTICE CONCEPTUAL DESIGN TYPICAL

DEVELOPED AS PART OF THE SHELBURNE STORMWATER MITIGATION BMP DESIGN AND IMPLEMENTATION PROJECT

DRAWING NAME:

FIGURE 2

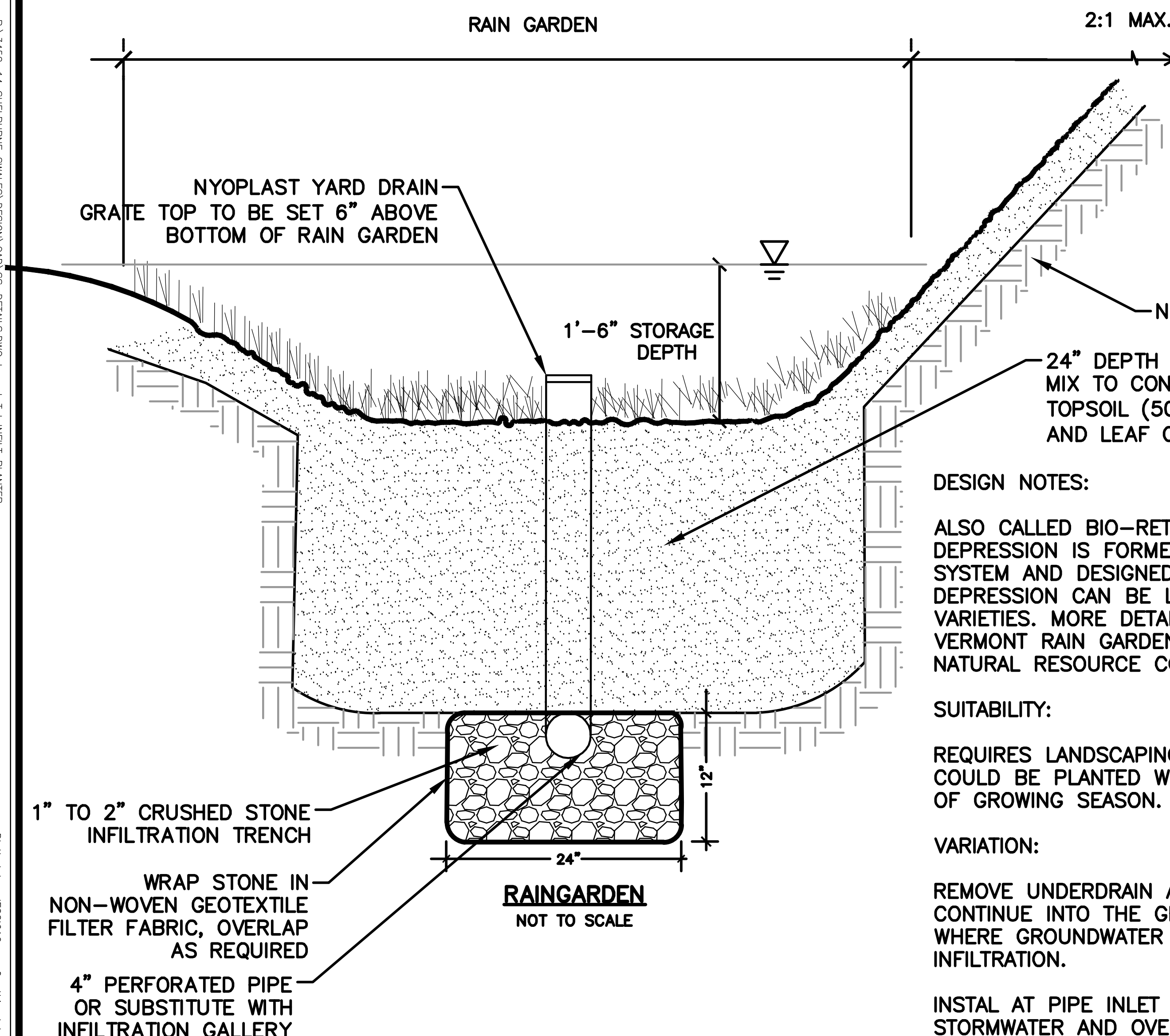
Pipe Inlet - Improved Catch Basin
Conceptual Design Typical - Material List and Unit Cost
Shelburne Swales Project
12/5/2012

	Unit Price	Units	Quantity	Price	Notes	Price Quote Source	Quote Source Phone Number
Materials							
Catch Basin Structure	$ 2,100.00	each	1	$ 2,100	Includes frame, cover, ladder, boots	Camp Precast	893-2401
Brick or Grade Rings, Morter	$ 350.00	each	1	$ 350	Average price	Gravel Construction	472-3776
Pipe Length for connections (assumes 24 inch)	$ 39.00	linear foot	14	$ 546		E.J. Prescott	865-3958
Flex Coupling	$ 329.00	each	2	$ 658		E.J. Prescott	865-3958
90 degree Bell Hood Entrance	$ 420.00	each	1	$ 420		E.J. Prescott	865-3958
Aggregate	$ 23.60	yard	10	$ 300	price controlled by delivery price		
Asphalt Patching	$ 5.45	sf	220	$ 1,200			
Materials Total				**$ 5,574**			
Labor*							
Exavator Machine Time	$ 125.00	hour	8	$ 1,000	assumes 1 day labor	Gravel Construction	472-3776
Labor	$ 40.00	hour	32	$ 1,280	assumes 4 men, 1 day labor	Gravel Construction	472-3776
Compaction Equiptment Rent	$ 200.00	day	1	$ 200			
Labor Total				**$ 2,480**			
Materials and Labor Total				**$ 8,054**			

* Cost Estimates based on project completed by Gravel Construction and MMI in November 2012

Pipe Improvement - Raingarden
Conceptual Design Typical - Material List and Unit Cost
Shelburne Swales Project
12/5/2012

	Unit Price	Units	Quantity Per Square Foot	Minimum Quantity	Price Per Square Foot	Quantity for 150 square foot project	Price for 150 square foot project	Notes	Price Quote Source	Quote Source Phone Number
Raingarden										
Planting Medium - Fine Washed Sand + delivery	$ -	cubic yard	0	1	$ -	2	$ -	price controlled by delivery price, included with topsoil	Hinesburg Sand and Gravel	482-2342
Planting Medium - Topsoil + delivery	$ 44.91	cubic yard	0.2	*see notes	$ 8.98	4	$ 269	price controlled by delivery price	Hinesburg Sand and Gravel	482-2342
Planting Medium - Compost Material Price	$ 37.50	cubic yard	0.067	1	$ 2.51	2	$ 75		Green Mountain Compost	660-4949
Planting Medium - Compost Delivery	$ 60.00	each	0.033	1	$ 1.98	1	$ 60	aggragated by quantity delivered	Green Mountain Compost	660-4949
Raingarden Plants	$ 14.00	each	0.2	1	$ 2.80	**30**	$ 420	Need to round to the next whole number	Horsford Nursery	425-2811
Grass Seed and Mulch	$ 30.00	pound	0.000625	**1**	$ 0.02	0.25	$ 30		Vermont Wetland Plant Supply	948-2553
Erosion Fabric - optional	$ 3.00	square yard	1	60	$ 3.00	**35**	$ 105	Includes side slopes		
Total					**$ 16.29**					
Drainage Inlet - Would not be required at all projects if other inlet or other water control device already exists										
Nyoplast 24" Yard Drain, 12" Vertical Riser	$ 875.00	each	per project	1	N/A	**1**	$ 875	Would not require at all projects	E.J. Prescott	
Yard Drain T connection	$ 216.24	each	per project	1	N/A	**1**	$ 216	Would not require at all projects		E.J. Prescott
Coupling for Yard Drain	$ 29.31	total	per project	2	N/A	**1**	$ 59	Would not require at all projects	E.J. Prescott	
Total							**$ 1,150**			



RAINGARDEN
NOT TO SCALE

DESIGN NOTES:

ALSO CALLED BIO-RETENTION AREA OR INFILTRATION PLANTER. A DEPRESSION IS FORMED AROUND THE INLET TO THE STORMWATER SYSTEM AND DESIGNED TO POND AND INFILTRATE STORMWATER. THE DEPRESSION CAN BE LANDSCAPED WITH A VARIETY OF PLANT VARIETIES. MORE DETAILED DESIGN INFORMATION IS IN THE VERMONT RAIN GARDEN MANUAL, PUBLISHED BY THE WINOOSKI NATURAL RESOURCE CONSERVATION DISTRICT.

SUITABILITY:

REQUIRES LANDSCAPING CARE, SUCH AS ANY OTHER GARDEN BED. COULD BE PLANTED WITH SPECIES THAT CAN BE MOWED AT END OF GROWING SEASON.

VARIATION:

REMOVE UNDERDRAIN AND ALLOW ALL INFILTRATED STORMWATER TO CONTINUE INTO THE GROUND. THIS VARIATION IS RECOMMENDED WHERE GROUNDWATER IS DEEP AND SOILS ALLOW FOR INFILTRATION.

INSTAL AT PIPE INLET TO ALLOW INFILTRATION OF SOME STORMWATER AND OVERFLOW OF HIGH FLOWS INTO THE INLET.

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PIPE IMPROVEMENT - RAINGARDEN

STORMWATER BEST MANAGEMENT PRACTICE CONCEPTUAL DESIGN TYPICAL

DEVELOPED AS PART OF THE SHELBURNE STORMWATER MITIGATION BMP DESIGN AND IMPLEMENTATION PROJECT

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FIGURE 3

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Plotted by: JESSICAC On this date: Thu, 2012 December 6 - 9:26am

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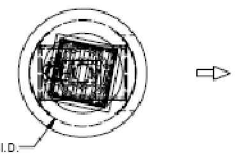
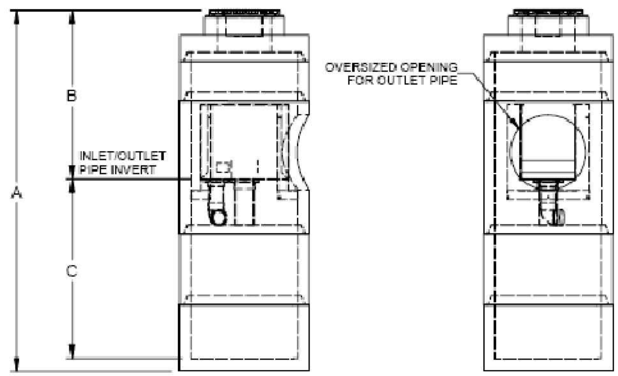
THE VORTSENTRY HS CONTROL SECTION SHALL BE STENCILED WITH THE CONTECH STORMWATER SOLUTIONS NAME AND LOGO. PIPE OPENINGS SHALL BE STENCILED "INLET" OR "OUTLET" AS APPROPRIATE



PLAN

THE GRATED INLET VORTSENTRY HS SYSTEM MAY ALSO INCORPORATE AN INLET PIPE (NOT SHOWN)



ELEVATION

RIGHT SIDE

NOTES:

1. STORMWATER TREATMENT SYSTEM (SWTS) SHALL REMOVE 80% OF A SEDIMENT GRADATION WITH AN AVERAGE PARTICLE SIZE OF 240 MICRONS AT THE DESIGNATED TREATMENT FLOW RATE LISTED IN THE TABLE FOR EACH CORRESPONDING MODEL.

2. SWTS REMOVAL EFFICIENCY CLAIM SHALL BE CORROBORATED BY FULL SCALE LABORATORY TEST PERFORMANCE DATA.

3. SWTS MAINTENANCE RECOMMENDATION SHALL BE SUPPORTED BY FULL SCALE WASH-OUT TESTING.

4. SWTS SHALL PROVIDE INTERNAL BYPASS OF FLOWS THAT EXCEED THE TREATMENT FLOW RATE.

5. SWTS MAXIMUM HYDRAULIC CAPACITY MAY VARY DEPENDING UPON THE DEPTH OF FLOW OVER THE GRATE.

6. IF THE SWTS INCORPORATES THE OPTIONAL INLET PIPE, INVERTS IN AND OUT SHALL BE AT THE SAME ELEVATION AND 180° FROM EACH OTHER.

7. MINIMUM RIM TO INVERT DISTANCE MAY BE REDUCED DEPENDING UPON ACTUAL PIPE DIAMETER. CONTACT CONTECH STORMWATER SOLUTIONS FOR SITE SPECIFIC INFORMATION.

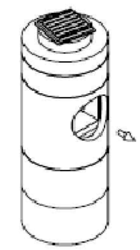
8. PIPE SIZE MAY BE SMALLER THAN THE MAXIMUM PIPE SHOWN ON THE TABLE; SEE SITE PLAN FOR PIPE SIZE.

9. PURCHASER SHALL NOT BE RESPONSIBLE FOR ASSEMBLY OF INTERNAL COMPONENTS.

10. ACCESS FRAME AND GRATED COVER SUPPLIED WITH SYSTEM, NOT INSTALLED. SWTS MAY ALSO HAVE A SOLID COVER AND INLET PIPE (NOT SHOWN).

11. PURCHASER TO PREPARE EXCAVATION AND PROVIDE LIFTING EQUIPMENT.

12. VORTSENTRY HS BY CONTECH STORMWATER SOLUTIONS; PORTLAND, OR (800) 548-4667; SCARBOROUGH, ME (877) 907-8676; LINTHICUM, MD (866) 740-3318.



ASSEMBLED VIEW

VortSentry Model	Manhole Diameter (ID)		Total Treatment Flow Rate		Typical Total Distance Rim to Outside Bottom A		Typical Distance Rim to Invert B		Typical Depth Below Invert (Inside) C		Approximate Minimum Distance Rim to Invert (See Note 7)		Maximum Pipe Diameter (ID)	
	ft	mm	cfs	l/s	ft	m	ft	m	ft	mm	ft	m	in	mm
HS36	3	900	0.55	15.6	10.16	3.10	4.08	1.24	5.5833	1702	3.00	0.91	18	450
HS48	4	1200	1.20	34.0	13.25	4.04	6.00	1.83	6.75	2057	4.00	1.22	24	600
HS60	5	1500	2.20	62.3	16.38	4.99	6.50	1.98	9.21	2807	4.82	1.47	30	750
HS72	6	1800	3.70	104.8	16.56	5.05	6.75	2.06	9.15	2788	5.59	1.70	36	900
HS84	7	2100	5.60	158.6	18.85	5.75	7.75	2.36	10.35	3156	4.77	1.45	42	1050
HS96	8	2400	8.10	229.4	20.87	6.36	8.50	2.59	11.54	3518	6.91	2.11	48	1200

FOR INFORMATIONAL PURPOSES ONLY - NOT INTENDED FOR CONSTRUCTION

TYPICAL DETAIL WITH SIZING TABLE
STORMWATER TREATMENT SYSTEM
VORTSENTRY® HS GRATE INLET US PATENT PENDING

CONTECH® STORMWATER SOLUTIONS
contechstormwater.com

SCALE:
DRAWN: NDG
CHECKED: GWB
FILE NAME: VSHS-G TYPTBL
DATE: 8/17/07

DESIGN NOTES:
MANUFACTURED PRODUCT. ONE EXAMPLE FROM CONTECH SHOWN.
DESIGN TO CONSIDER INFLOW, SEDIMENTATION, AND MAINTENANCE.

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DATE	11/2/2012
SCALE	NOT TO SCALE
PROJ. NO.	3452-14
DESIGNED	JCL
DRAWN	JCL
CHECKED	RKS

PIPE INLET - HYDRODYNAMIC SEPARATOR

STORMWATER BEST MANAGEMENT PRACTICE CONCEPTUAL DESIGN TYPICAL

DEVELOPED AS PART OF THE SHELBURNE STORMWATER MITIGATION BMP DESIGN AND IMPLEMENTATION PROJECT

DRAWING NAME:

FIGURE 4

Pipe Inlet - Hydrodynamic Separator
Conceptual Design Typical - Material List and Unit Cost
Shelburne Swales Project
12/5/2012

	Particle Size of 80% Removal Efficiency (micron)	**Design Flow (cfs)**	**Price**	**Price Quote Source**	**Quote Source Phone Number**
Vortsentry HS60	240	2.2	$ 12,420.00	Contech	207-885-6112
VortSentry 60	110	1.77	$ 17,100.00	Contech	207-885-6112
CDS 3020	125	2	$ 19,500.00	Contech	207-885-6112
Vortechs model 4000	110	2.2	$ 20,500.00	Contech	207-885-6112

Notes:
Prices include delivery to the site and technical assistance with installation
This unit may require additional materials for connection depending on existing infrastructure at the project site.
Installation is similar to a manhole

Appendix E

BROOK LANE DEMONSTRATION
SHELBURNE STORMWATER MITIGATION BMP DESIGN AND IMPLEMENTATION PROJECT

SHELBURNE, VERMONT
PRELIMINARY DESIGN
JAN. 2013

- **LIST OF DRAWINGS:**

01 - TITLE SHEET AND LOCATION MAP
02 - PROPOSED LAYOUT
03 - RAINGARDEN LAYOUT AND DETAIL
04 - PROFILE
05 - CROSS SECTIONS
06 - CROSS SECTIONS

- **PROJECT PARTNERS**

Town of Shelburne
5420 Shelburne Road
Shelburne, VT 05482

Ecosystem Restoration Program
Vermont Department of Environmental Conservation
1 National Life Drive
Montpelier, Vermont 05620

Lewis Creek Association &
LaPlatte Watershed Partnership
442 Lewis Creek Road
Charlotte, VT 05445

- **PREPARED BY:**

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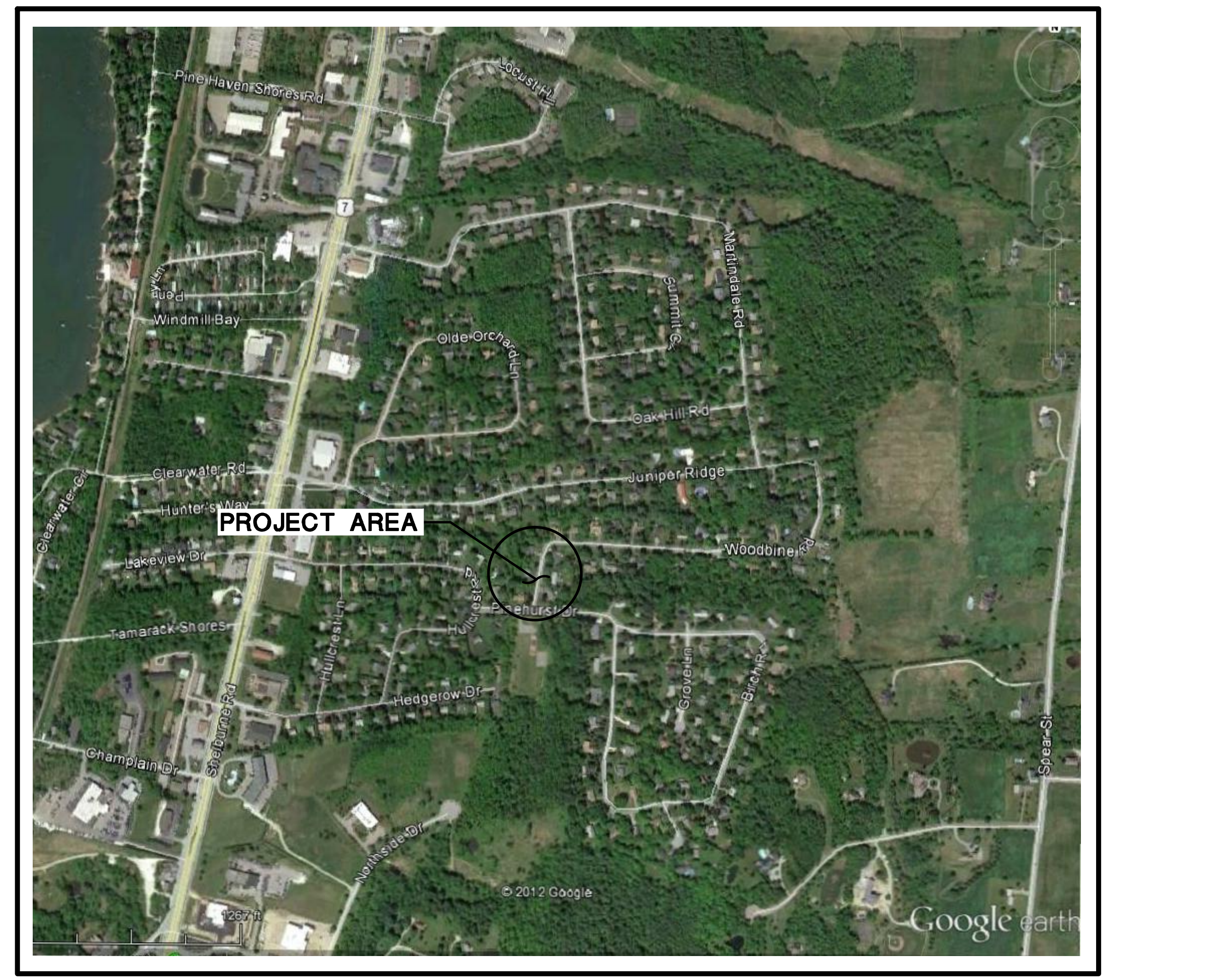

PROJECT SITE VICINITY MAP:
1"=1,000'

Drawing: P:\3452-14 SHELBURNE SWALES\DESIGN\CAD\SS-TITLE.DWG Layout Tab:11X17-TITLE

Plotted by: JESSICAC On this date: Mon, 2013 January 7 - 1:30pm

REFERENCES

1. BACKGROUND AERIAL PHOTOGRAPH IS FROM GOOGLE EARTH, OBTAINED NOVEMBER 2012.
2. PROPERTY BOUNDARIES ARE APPROXIMATE AND RECEIVED FROM THE CHITTENDEN COUNTY REGIONAL PLANNING COMMISSION. NO BOUNDARY SURVEY WAS PERFORMED AS PART OF THIS PROJECT.
3. SITE CONDITIONS AND FEATURES, INCLUDING CROSS SECTIONS, WERE MEASURED IN THE FIELD.
4. ADDITIONAL SITE FEATURES WERE DIGITIZED FROM THE AERIAL PHOTOGRAPH, REFERENCE 1.
5. TOPOGRAPHIC CONTOUR LINES ARE FROM LIDAR DATA FLOWN IN 2009 AND AVAILABLE THROUGH VCGI.

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REVISIONS

PRELIMINARY DESIGN

PROPOSED LAYOUT

SHELBURNE STORMWATER MITIGATION BMP DESIGN AND IMPLEMENTATION PROJECT

BROOK LANE
SHELBURNE, VERMONT

DESIGNED	DRAWN	CHECKED
JCL	JCL	RKS

SCALE 1"=20'

DATE JAN. 2013

PROJECT NO. 3452-14

SHEET NO. 02

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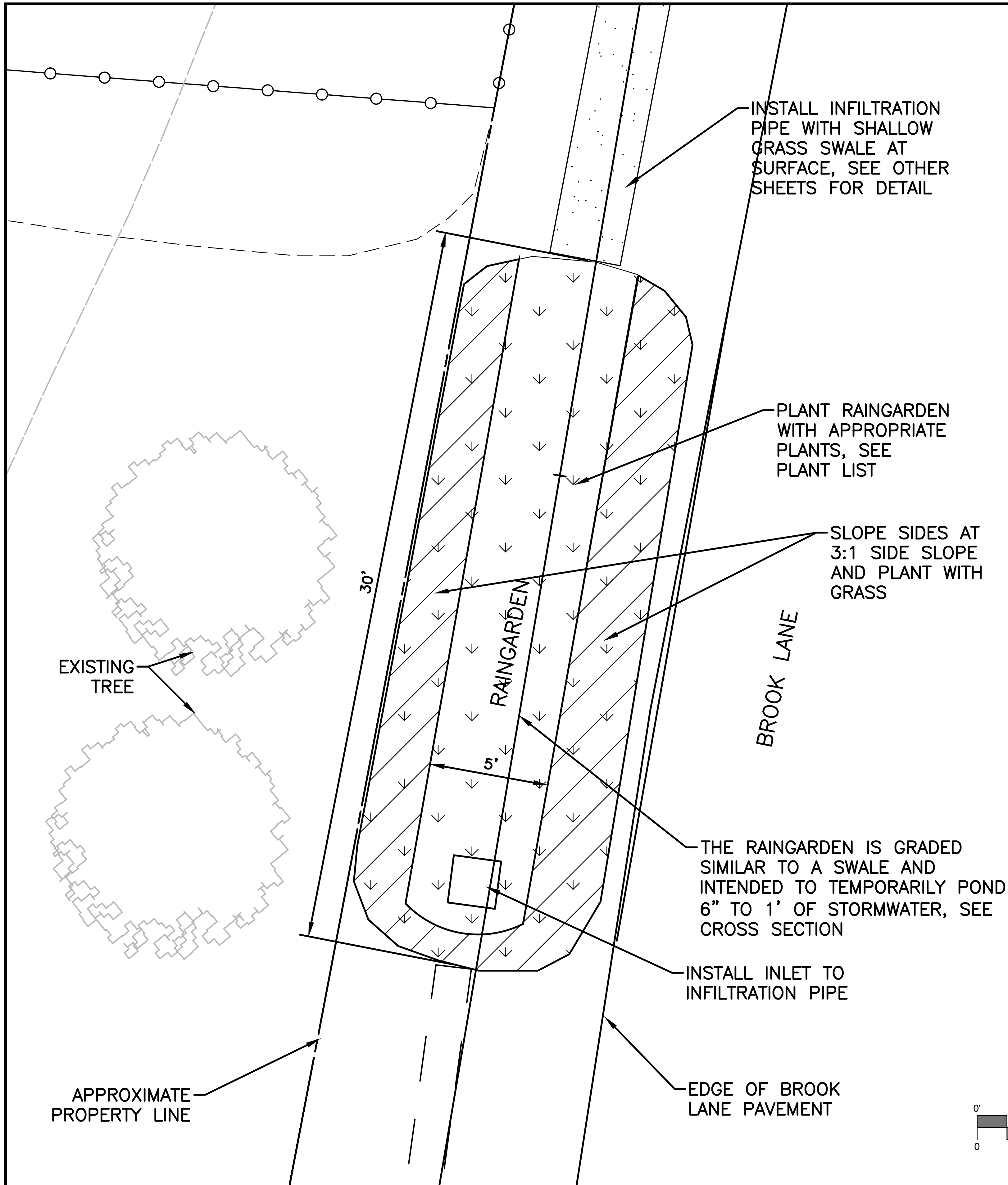
Drawing: P:\3452-14 SHELBURNE SWALES\DESIGN\CAD\SS-LAYOUT.DWG Layout Tab:LAYOUT
Plotted by: JESSICAC On this date: Mon, 2013 January 7 - 1:30pm

Drawing: P:\3452-14 SHELBURNE SWALES\DESIGN\CAD\SS-LAYOUT.DWG Layout Tab:RAINGARDEN
Plotted by: JESSICAC On this date: Mon, 2013 January 7 - 1:30pm



0' 2.5' 5'
0 1/2" 1"

RAINGARDEN PLANT INFORMATION

1. THE RAINGARDEN AREA SHOULD BE VEGETATED. THE RECOMMENDED VEGETATION IS A VARIETY OF PERENNIAL PLANTS THAT IS MAINTAINED SIMILAR TO A PERENNIAL FLOWER BED. IF THE LEVEL OF CARE IS NOT AVAILABLE, IT IS POSSIBLE TO MAINTAIN THIS AREA AS A GRASS SWALE AND CARE FOR THE AREA SIMILAR TO A LAWN.
2. A LIST OF POSSIBLE PERENNIAL PLANTS HAS BEEN PROVIDED. FINAL SELECTION OF THE PLANTS SHOULD BE COORDINATED BETWEEN THE ADJACENT LANDOWNER AND THE TOWN.
3. PLANTS LISTED WERE CHOSEN BECAUSE THEY ARE NATIVE TO VERMONT AND MOST ARE ALSO SALT RESISTANT.
4. ADDITIONAL PLANT INFORMATION CAN BE FOUND IN THE VERMONT RAIN GARDEN MANUAL, PUBLISHED BY THE WINOOSKI NATURAL RESOURCE CONSERVATION DISTRICT.

Perrenials	
Anemone canadensis	Windflower
Aquilegia cacadensis	Colombine
Aster novae-angliae	New England Aster
Aster umbellatus	Flat-topped Aster
Baptisia australis	Blue False Indigo
Iris versicolor	Blue Flag Iris
Lobelia cardinalis	Cardinal Flower
Lobelia spicata	Spiked Lobelia
Rudbeckia hirta	Black-Eyed Susan
Caltha palustris	Marsh Marigold
Echinacea purpurea spp.	Coneflower
Hemerocallis	Daylilies

Fern:	
Athyrium filix-femina	Lady Fern
Osmunda cinnamomea	Cinnamon Fern

Grasses:	
Carex Grayi	Gray Sedge
Panicum virgatum	Switch Grass
Schizachyrium scoparium	Little Bluestem

RAINGARDEN MAINTENANCE

1. RAINGARDEN REQUIRES LANSCAPING CARE SIMILAR TO OTHER PLANTED FLOWER BEDS INCLUDING REGULAR WEEDING TO SELECT WHICH PLANTS CONTINUE TO GROW SUCCESSFULLY.
2. SELECTED SPECIES CAN BE MOWED OR BRUSH–HOGGED AT THE END OF THE GROWING SEASON IF DESIRED.
3. PERIODICALLY, INCLUDING AFTER LARGE STORMS AND REGULARLY DURING THE FALL, REMOVE LEAVES AND DEBRIS ACCUMULATED AT THE STORMWATER INLET.
4. OPTIONALLY ADD MULCH TO ASSIST IN WEED CONTROL.

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PRELIMINARY DESIGN

RAINGARDEN LAYOUT AND DETAIL

SHELBURNE STORMWATER MITIGATION BMP
DESIGN AND IMPLEMENTATION PROJECT

BROOK LANE
SHELBURNE, VERMONT

DESIGNED	DRAWN	CHECKED
JCL	JCL	RKS

SCALE: 1"=5'
DATE: JAN. 2013
PROJECT NO. 3452-14
SHEET NO. 03

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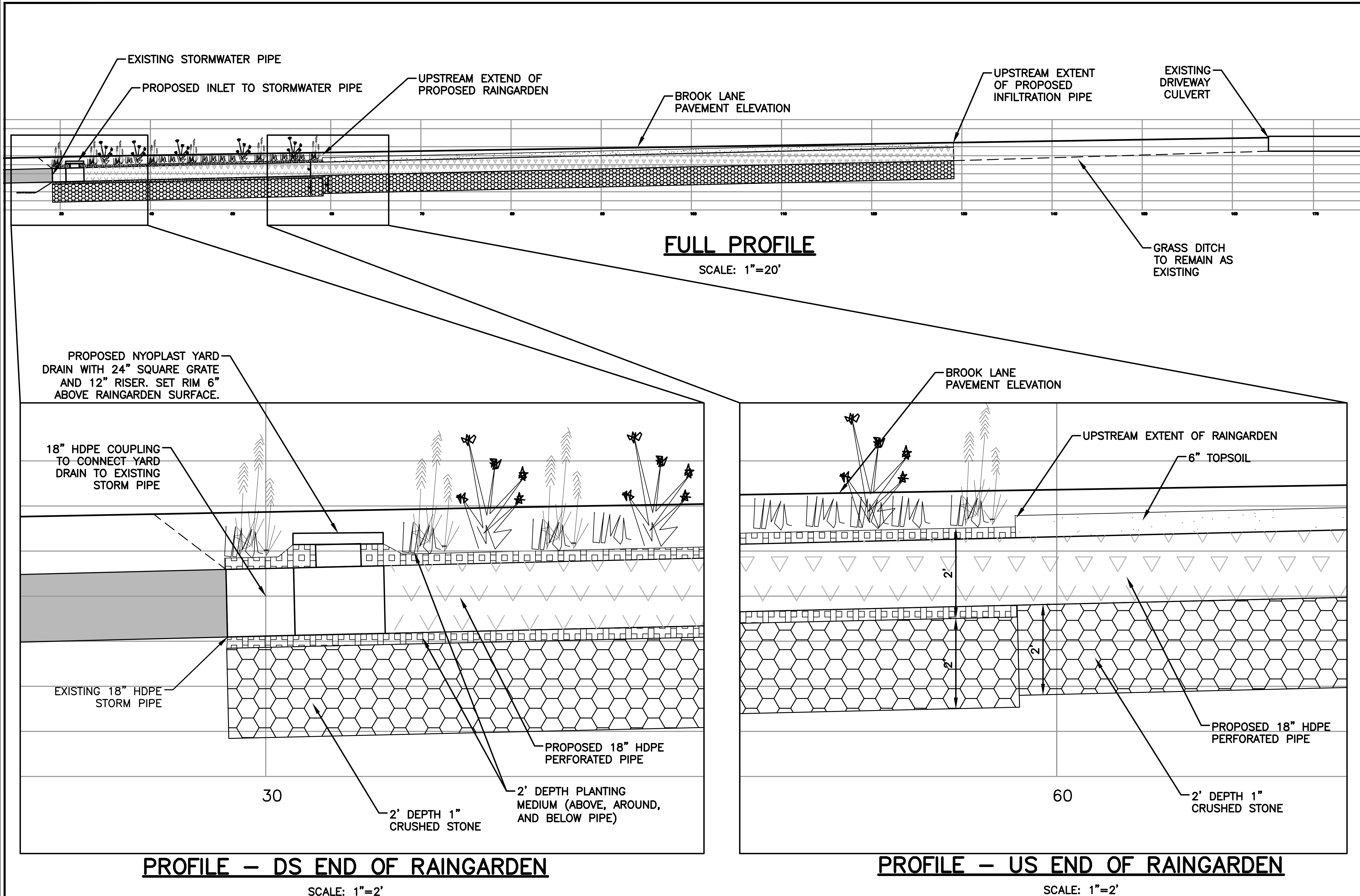

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PRELIMINARY DESIGN

PROFILE

SHELBURNE STORMWATER MITIGATION BMP DESIGN AND IMPLEMENTATION PROJECT

BROOK LANE
SHELBURNE, VERMONT

DESIGNED	DRAWN	CHECKED
JCL	JCL	RKS

SCALE: VARIES

DATE: JAN. 2013

PROJECT NO. 3452-14

SHEET NO. 04

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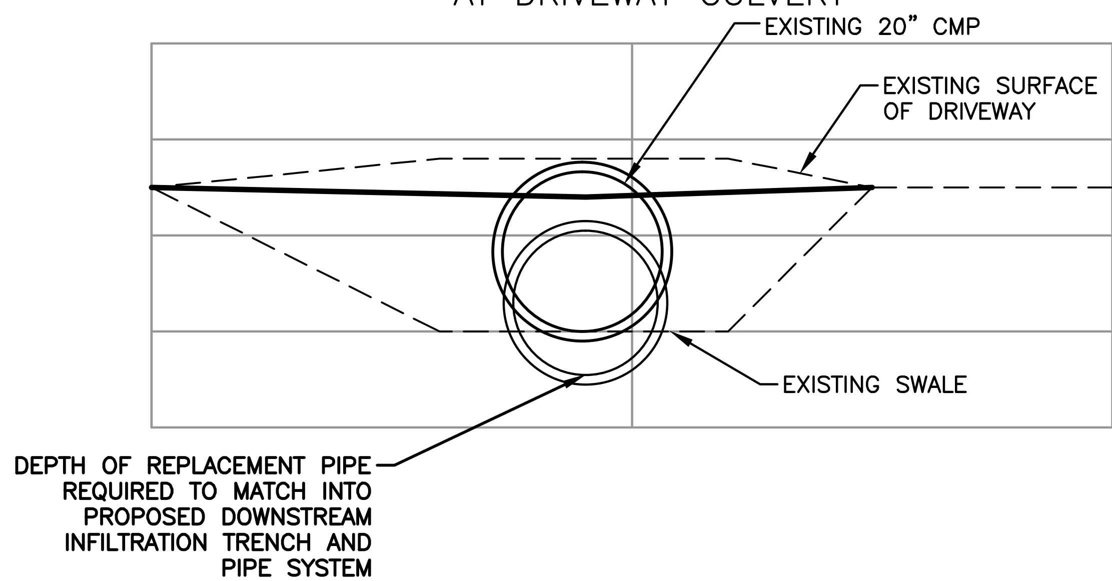
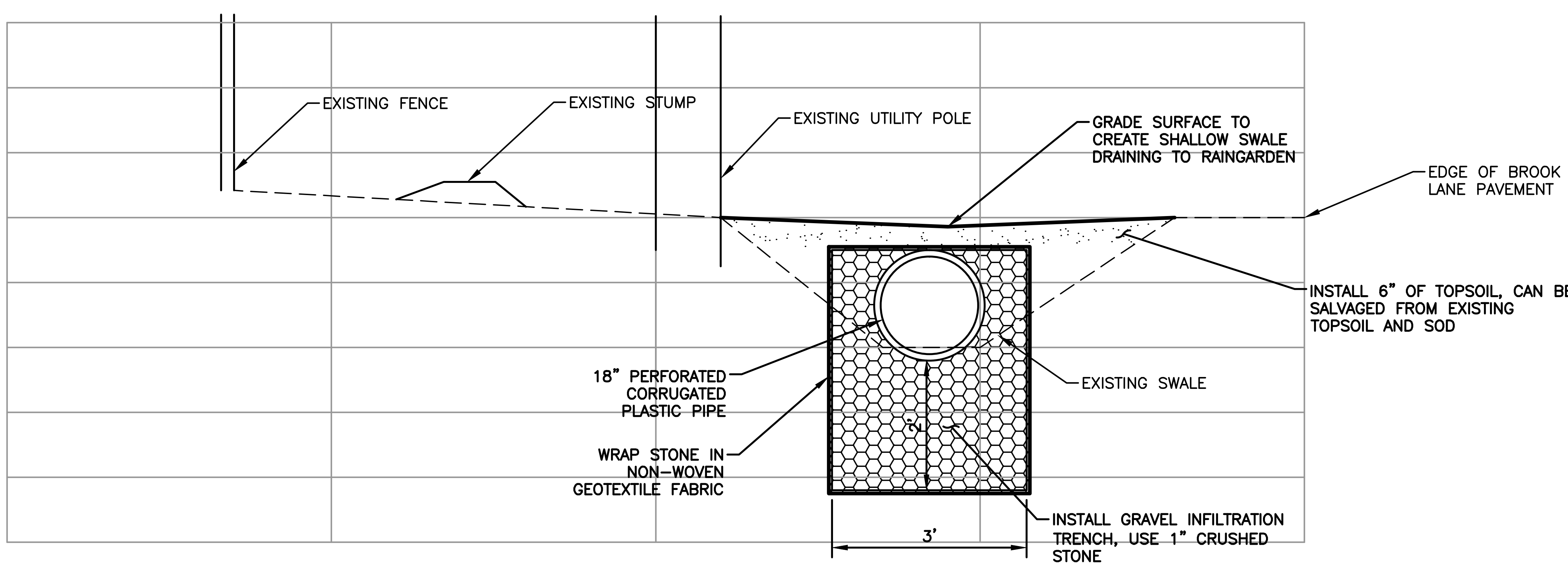
1+64
AT DRIVEWAY CULVERT



WOULD REQUIRE REPLACEMENT AND LOWERING OF DRIVEWAY CULVERT TO EXTEND TREATMENT TO THIS LOCATION

1+22
AT UTILITY POLE



0' 1' 2'
0 1/2" 1"

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REVISIONS

PRELIMINARY DESIGN

CROSS SECTIONS

SHELBURNE STORMWATER MITIGATION BMP DESIGN AND IMPLEMENTATION PROJECT

BROOK LANE
SHELBURNE, VERMONT

DESIGNED	DRAWN	CHECKED
JCL	JCL	RKS

SCALE: 1"=2'

DATE: JAN. 2013

PROJECT NO. 3452-14

SHEET NO. 05

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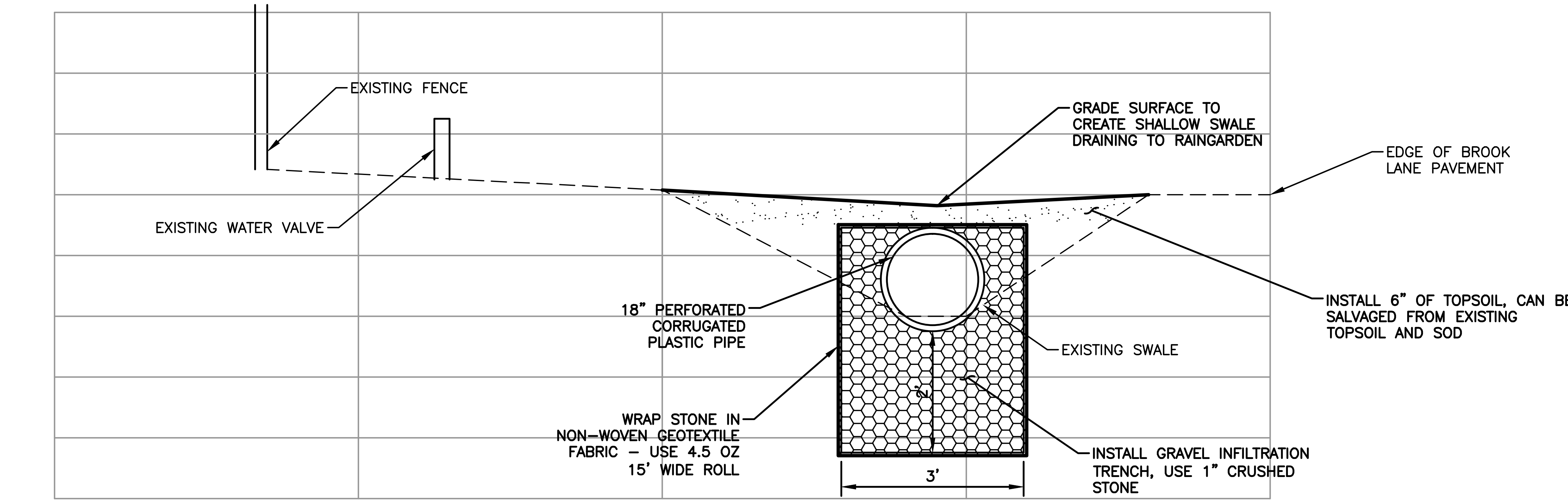
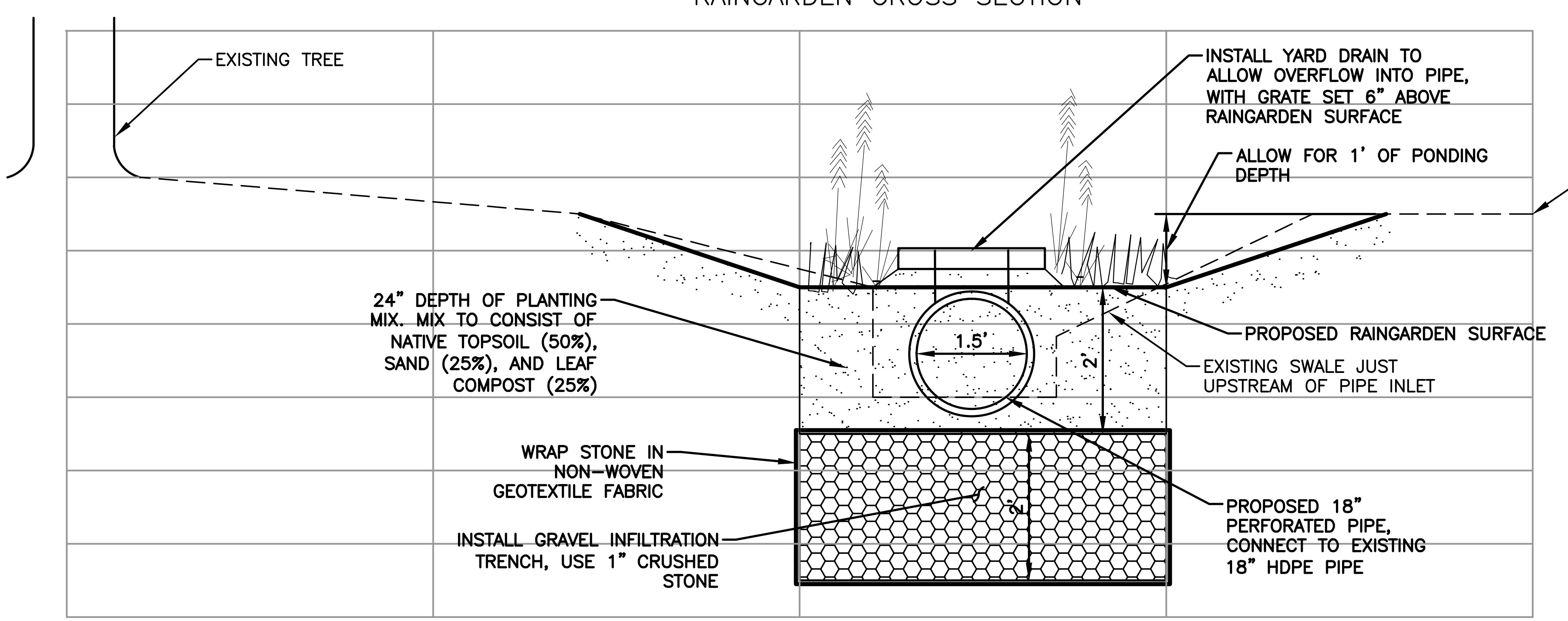
1+00
AT FLOWER BED



0+32
RAINGARDEN CROSS SECTION



0' 1' 2'
0 1/2" 1"

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REVISIONS

PRELIMINARY DESIGN

CROSS SECTIONS

SHELBURNE STORMWATER MITIGATION BMP DESIGN AND IMPLEMENTATION PROJECT

BROOK LANE
SHELBURNE, VERMONT

DESIGNED	DRAWN	CHECKED
JCL	JCL	RKS

SCALE 1"=2'
DATE JAN. 2013
PROJECT NO. 3452-14
SHEET NO. 06

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Brook Lane Demonstration
Shelburne Stormwater Mitigation BMP Design and Implementation Project
11/30/2012

	Unit Price		Units	Quantity	Price		Price Quote Source	Phone Number
Infiltration Pipe and Trench								
1" crushed stone + delivery		varies with delivery	cubic yard	32	$	755	Hinesburg Sand and Gravel	482-2342
Geotextile Fabric	$	384.00	roll	1	$	384	E.J. Prescott	865-3958
18" HDPE Perforated Pipe	$	17.49	linear feet	100	$	1,749	E.J. Prescott	
Nyoplast 24" Yard Drain, 12" Vertical Riser	$	875.00	each	1	$	875	E.J. Prescott	
Yard Drain T connection	$	216.24	each	1	$	216	E.J. Prescott	
Coupling for Yard Drain	$	29.31	total	2	$	59	E.J. Prescott	
Lawn Grass Seed	$	15.00	pound	0.5	$	8		
Erosion Fabric - optional	$	3.00	square yard	75	$	225		
Raingarden Treatment Area								
Planting Medium - Fine Washed Sand + delivery		varies with delivery	cubic yard	2	$	-	* Priced with Topsoil because same delivery	
Planting Medium - Topsoil + delivery		varies with delivery	cubic yard	4	$	270	Hinesburg Sand and Gravel	
Planting Medium - Compost + delivery		varies with delivery	cubic yard	2	$	136	Green Mountain Compost	660-4949
Raingarden Plants	$	14.00	each	30	$	420	Horsford Nursery	425-2811
Grass Seed and Mulch	$	30.00	pound	1	$	30	Vermont Wetland Plant Supply	948-2553
Erosion Fabric - optional	$	3.00	square yard	35	$	105		
Total					**$**	**5,096**		

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