QUARRY HILL AND STERLING HILL STORMWATER MASTER PLAN

BARRE TOWN AND BARRE CITY, VERMONT

FINAL REPORT

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Stormwater Management | Erosion Control

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I. Disclaimer

The intent of this report is to present the data collected, evaluations, analysis, designs, and cost estimates for the Quarry Hill and Sterling Hill drainage areas under a contract between the Friends of the Winooski and Watershed Consulting Associates, LLC. Funding for the project was provided by a grant from the Vermont Ecosystem Restoration Program (ERP). The plan presented is intended to provide the watershed's stakeholders a means by which to identify and prioritize future stormwater management efforts. This planning study presents a recommended potential collection of Best Management Practices (BMPs) that would address specific concerns that have been raised for the drainage areas including excessive stormwater runoff and resultant erosion and nutrient pollution. There are certainly other BMP strategies that could be implemented in the watershed. However, the sites identified and described in this report are those sites and practices that project stakeholders felt would have the greatest impact and the greatest probability of implementation. **These practices do not represent a regulatory obligation of any type at this time, nor is any property owner within the watershed obligated to implement them.**

1 Project Overview

In May 2013, the State of Vermont Department of Environmental Conservation (VT DEC) issued a document entitled "Vermont Stormwater Master Planning Guidelines". This document is designed to provide communities in Vermont with a standardized guideline and series of templates to assist them in planning for future stormwater management practices and programs. Vermont has had stormwater regulations in place since 1978, with updates concerning unified sizing criteria in 2002. The State has recently rewritten the stormwater manual to reflect new priorities. The State recognizes that managing stormwater can be a costly endeavor, and the guidelines were written to help identify the appropriate practices for each watershed, community, and site in order to maximize the use of funds.

The guidelines encourage each stormwater master plan (SWMP) to follow the same procedures. They are:

- Problem definition
- Collection of existing data
- Development of new data
- Existing and proposed program, procedure, or practice evaluation
- Summary and recommendations

In keeping with these guidelines, the following report has been prepared.

2 Background

2.1 Problem Definition

The Quarry Hill and Sterling Hill drainage areas comprise a combined 891 acres located in Washington County, primarily in Barre Town with a small area in Barre City, VT. The Quarry Hill watershed drains to a highly eroded outfall at the end of Pouliot Avenue, which has resulted in significant erosion that threatens to undermine the road (Figure 1). A previous project served to develop a solution for the erosion occurring at this outfall, but this design does not address the stormwater generated from the greater drainage area contributing to this issue (see the Story Map at the following URL for more information about this project: https://goo.gl/y8Xm99).

Figure 1. Significant erosion at the Pouliot Ave stormwater outfall and resultant large gully.

The drainage area contributing to the Pouliot Ave outfall, hereafter referred to as the "Quarry Hill drainage area", has been specifically targeted by the VT DEC as a high priority retrofit area in the Upper Winooski Basin Stormwater Infrastructure Mapping Project Report (2013). Given the large size of the contributing watershed and the reported flooding and erosion issues, a watershed-wide investigation was warranted to identify and prioritize stormwater retrofit projects in order to reduce runoff before it reaches the outfall area.

The adjacent drainage area located to the west that encompasses Sterling Hill Road and the Barre View St/ Cherry View Dr neighborhood, hereafter referred to as the "Sterling Hill drainage area", has also been identified by Barre Town as problematic for stormwater runoff and erosion. This adjacent watershed shares similar characteristics with the Quarry Hill drainage area; it is steep, underlain with erosive soils, and has been moderately developed. The Barre Town Garage and Maintenance Garage sites were added to the scope of this project despite falling just outside (to the east) of the drainage areas. These areas were added because there are no stormwater management practices installed at these sites, and stormwater runoff from these locations is contributing pollutant-laden stormwater runoff to receiving waters. Barre Town, who owns these properties, is committed to implementing stormwater BMPs at these locations. This landowner buy-in is critical in moving projects to implementation. As such, this SWMP was developed to address the known issues in these two drainage areas and the Town Garage sites.

2.2 Existing Conditions

The Quarry Hill and Sterling Hill drainage areas cover approximately 891 acres within the Town and City of Barre (Figure 2). The Quarry Hill drainage area is the eastern half of the study area, encompassing 296 acres, while the Sterling Hill drainage area, which is 595 acres in area, comprises the western half of the study area. The study area is located in the headwaters of the Stevens Branch watershed, which drains the southeastern 10% of the Winooski River watershed. The Winooski River drains approximately 1,080 mi^2 before discharging into Lake Champlain. The area is fairly steep with mean slopes in the Quarry Hill drainage area of 14.9% (±15.3%), and average slopes in the Sterling Hill drainage of 18.5% (±17.9%).

Soils analyses indicate that of the 891 total acres in the watershed, 793 acres or 89% are classified as either potentially highly erodible or highly erodible by the latest Natural Resources Conservation Service (NRCS) soil mapping data. Additionally, the majority of the soils in the watershed have very low infiltration potential as indicated by NRCS Hydrologic Soil Group classifications where soils are classified from group A (highest infiltration potential) to group D (lowest infiltration potential). In the drainage areas, the majority of areas belong to either Hydrologic Soil Group C (56%) or D (17%), while only 80 acres (9%) are in group A and 142 acres (16%) are in group B. The remainder is not classified or comprised of water. This combination of steep slopes with limited infiltration capacity and a highly erodible surface make the area particularly susceptible to erosion, as evidenced by the large gully that has formed at the Pouliot Ave stormwater outfall and resultant high turbidity levels.

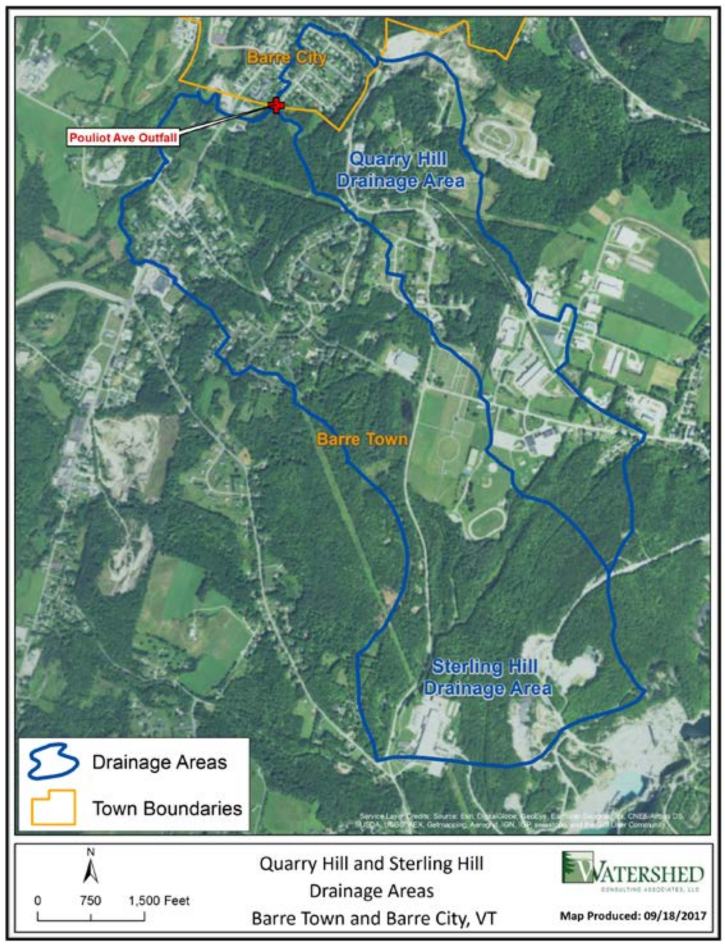

Figure 2. The Sterling Hill (west) and Quarry Hill (east) drainage areas are located primarily in Barre Town. The eroded Pouliot Ave outfall is shown in red.

There is moderate development throughout the study area with 129 acres of impervious cover or 14.5% of the watershed area. Of this impervious cover, 63 acres are within the Quarry Hill drainage area (21%) and 66 acres are within the Sterling Hill drainage area (11%). Maps depicting existing watershed conditions can be found in Appendix A-1 – Map Atlas. Maps include:

- river corridors and wetlands,
- parcel boundaries,
- soil erodibility,
- soil infiltration potential,
- stormwater infrastructure,
- stormwater permits,
- contours,
- slope,
- land cover,
- and impervious cover.

The human-influenced stressors in the watershed include the development of roads, residential development, construction of commercial buildings and associated parking areas, and clearing of previously forested areas. Additionally, in part due to historic straightening of rivers in the area, associated incision of stream channels, and limited floodplain access, both nuisance flooding and extreme flood events can and do occur. Unmanaged stormwater runoff, particularly from impervious surfaces and landscaped pervious areas, exacerbate flooding. The Winooski River watershed and its tributaries have experienced extreme flooding in the past, and these flood events are only expected to occur more frequently due to the predicted increased frequency and intensity of extreme weather events associated with climate change. These heavy rains and easily erodible soils have contributed to erosion issues throughout the area.

While development of the area is moderate, the underlying watershed characteristics make development very impactful. These developments, even if under Vermont state stormwater permit requirements, must approach stormwater management with sensitivity as the soils within the watershed are highly susceptible to development-induced erosion.

3 Methodology

3.1 Initial Data Collection and Review

All relevant prior watershed studies and any studies that may inform planning in the project area were assembled and reviewed in the context of this SWMP study. These reports include the Water Quality Management Plan, geomorphic studies including the River Corridor Management Plan, aquatic life studies, and stormwater infrastructure mapping and prioritization.

Relevant Geographic Information System (GIS) data was drawn from a variety of public resources including the Agency of Natural Resource's Atlas, Vermont Center for Geographic Information, and data created by the University of Vermont's Spatial Analysis Lab. A file geodatabase was created to ensure organization and for ease of use. These data represent the "best available" data at the time of data collection (2016). Download or access dates were noted for all data to indicate currency. A list of information collected and reviewed for the creation of this SWMP is included as Appendix A-2.

3.2 Desktop Assessment and Map Preparation

A desktop assessment was completed in order to identify potential sites for stormwater BMP implementation. This process involved a thorough review of existing GIS resources and associated attribute data. Data included, but was not limited to, storm sewer infrastructure, soils classifications, parcel data, wetlands, and river corridors. This data was used to identify and map stormwater subwatersheds with particularly high impervious cover, stormwater subwatersheds that are more directly connected to water bodies (direct pipes to streams or via overland flow), areas where infill development may occur, worsening stormwater impacts in the future, and parcels with ≥3 acres of impervious cover without a current stormwater permit as these areas will be subject to a permit in the future. These areas were noted, and a point location was created for assessment in the field.

A 'green streets' assessment was also conducted to identify any road segments throughout the drainage area appropriate for green stormwater infrastructure (GSI) retrofit opportunities. Streets were evaluated and scored according to width, slope, and soil permeability utilizing a methodology adapted from the "Promoting Green Streets" report published by the River Network (July 2016; included as Appendix A-3). Preference was given to those highest-scoring road segments in more urban areas.

The methodology was modified to better fit specific conditions found in the study area. The analysis utilized two prerequisites and one secondary consideration.

Prerequisites:

1. Road Slope
   - 1-5% Slope = Ideal (Score: 2 points)
   - 5-7.5% Slope = Potential (Score: 1 point)
   - >7.5% Slope = Unsuitable (Score: 0 points; discarded from further analysis)
2. Road Right-of-Way Width
   - ≥ 50 ft = Ideal (Score: 2 points)
   - 46-50 ft = Potential (Score: 1 point)
   - < 46 ft = Unsuitable (Score: 0 points; discarded from further analysis)

Secondary Consideration:

1. Hydrologic Soil Group (indication of infiltration potential)
   - A/B (highest infiltration potential) =

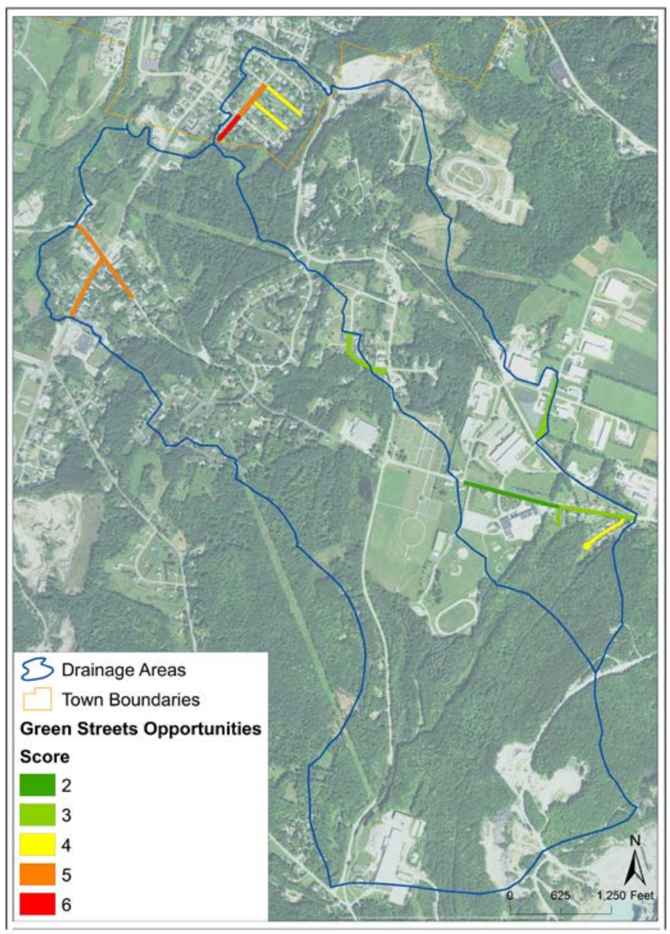

Figure 3. Identified green streets opportunities.

Ideal (Score: 2 points)
- B/C (moderate infiltration potential) = Potential (Score: 1 point)
- C/D (lowest infiltration potential) = Unsuitable (Score: 0 points; **not** discarded from further analysis)

The scores from each of the three criteria were added, and a score was assigned for each road segment with higher scores indicating a greater potential for GSI suitability. Those sites with greater potential were noted for assessment in the field (Figure 3; see Appendix A-4 for a larger version of this map).

Using this data, digital maps for field investigations were developed for 56 potential BMP sites, both general watershed-wide sites and green streets locations. Base layers included parcel boundaries, public parcels, stormwater infrastructure, hydrologic soils groups, river corridors, and wetlands. A watershed-specific mobile app for the drainage area was customized, and the app was pre-loaded with the potential BMP sites for ease of location and data collection in the field.

3.3 Field Data Collection

Each of the 56 previously identified potential BMP locations were evaluated in the field during the Summer and Fall of 2016 (Figure 4; also provided as Appendix A-5). 9 of these points are located at the Barre Town Garage sites (to the east of the drainage area boundaries), and the remainder are within the Quarry Hill and Sterling Hill drainage areas. 15 sites were identified during the Green Streets assessment (Figure 3), and 17 sites are located at the Barre Town Elementary and Middle School.

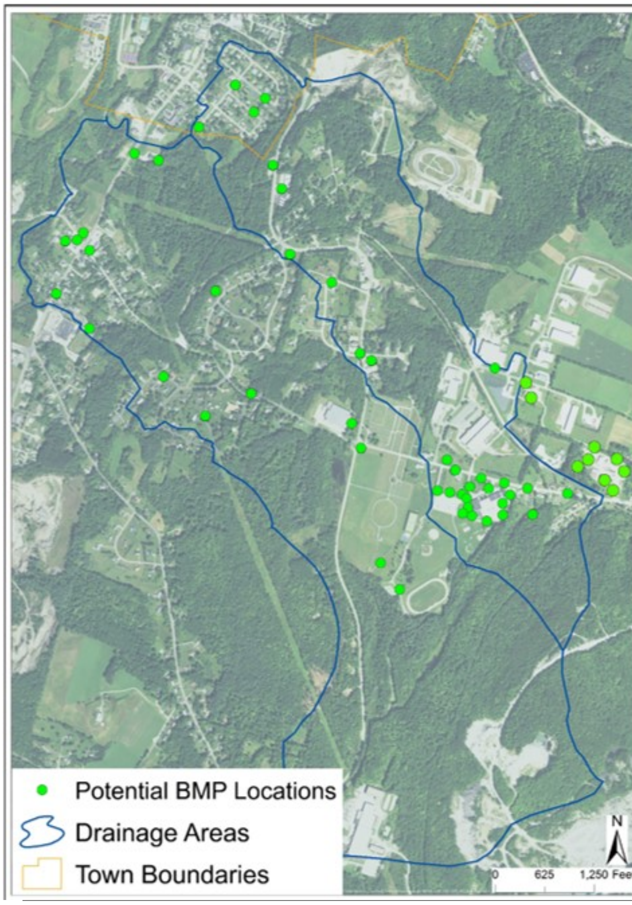

Figure 4. Initial sites for field investigation.

The customized mobile app was used to collect information at each site including site suitability, potential practice description, site description, photographic documentation, follow-up notes or questions, and other pertinent data.

During initial field assessment, some sites were discarded as infeasible for stormwater retrofit implementation due to site-specific conditions (i.e., utilities conflicts, wetlands conflicts, landowner conflicts, steepness, etc.). Following this assessment, the list of potential BMPs was reduced to 49 sites: 23 watershed-wide sites, 17 sites at the Barre Town Elementary and Middle School, and 9 sites identified at the Barre Town Garage sites. An ArcGIS Online Story Map was created to communicate the 23 watershed-wide BMP opportunities to stakeholders. The Story Map can be accessed at the following URL: https://goo.gl/gnPGhP.

3.4 Preliminary BMP Ranking

After the initial field assessments were completed, a preliminary ranking system was devised to narrow down the list of possible projects to those that could potentially do the most to improve water quality. This prioritization was accomplished by completing an assessment of project feasibility and associated benefits. Site-specific information identified in the field and metrics developed during GIS analyses were used to perform a preliminary ranking of each of the potential BMP locations within the watershed. The ranking criteria are provided in Table 1. The three groups of projects (watershed-wide, Barre Town School, and Barre Town Garage Sites) were ranked independently. An abbreviated version of this ranking (excluding impervious % and proximity to water) was used to rank the school and Town Garage sites. The scores for each category were totaled and used to rank each project from highest to lowest with those sites with the highest scores assigned the highest rank. Impervious cover managed was used as a tiebreaker where necessary.

Table 1 Scoring matrix for preliminary BMP ranking

Criteria	Description	Score
Drainage Area Size	L - Large M - Medium S - Small	25 10 5
Pollutant Load Reduction Potential	H - High M - Medium L - Low	25 10 5
Cost Projection	H - High (>$50K) M - Medium ($10-50K) L - Low (<$10K)	5 10 25
Additional Design Required	Min - Minimal Med - Medium Complex	25 10 5
Impervious Area %	H - High M - Medium L - Low	25 10 5
Proximity to Water	H - High M - Medium L - Low	25 10 5

This ranking was used to identify the highest value sites for further analysis. Ranking tables are provided in Appendix A-6 and shown below for the overall watershed (Table 2), the Barre Town

School (Table 3), and Barre Town Garage (Table 4). Note that the ranking for the Town Garage sites differ slightly from rankings previously presented as two potential BMP locations at the Maintenance Garage were added to the initial assessment that only covered the Town Garage. Site location maps (Appendix A-7) and one-page project summary sheets were developed that summarize each of the proposed BMPs (Appendix A-8).

Table 2. Preliminary ranking scores for all watershed-wide BMP drainage areas

Site ID	Address	Drainage Area Size (S, M, L)	Pollutant Load Reduction (H, M, L)	Cost Projection (H, M, L)	Additional Design Required (Min, Med, Complex)	Impervious Area % (L, M, H)	Proximity to Water (L, M, H)	Total Impervious Area (Acres)	Total Score	Rank
Post Office	S Barre Rd, south of Bridge St	M	H	L	Min	H	H	0.82	135	1
Websterville & Graniteville	Websterville Rd and Graniteville Rd	L	H	L	Min	L	H	0.99	130	2
Conti Cir Swale	Conti Circle	L	M	L	Min	M	H	1.18	120	3
Bridge St GSI	Bridge St, west of Sterling Hill Rd	L	H	M	Complex	H	H	1.17	115	4
Gulf Station	Beede Cir and Quarry Hill Rd	S	M	L	Min	H	H	0.33	115	5
S Barre Rd South	S Barre Rd	S	M	L	Med	H	H	0.37	100	6
Sterling Hill Rd	Sterling Hill Rd, east of S Barre Rd	L	H	M	Complex	L	H	3.69	95	7
Quarry Hill Rd N	Quarry Hill Rd, east of White St	L	M	H	Complex	H	H	1.24	95	8
Conti Cir GSI	Conti Circle	L	L	L	Min	L	M	0.63	95	9
Teamster Building	Quarry Hill Rd, north of Fisher Rd	S	M	L	Min	H	L	0.57	95	10
Quarry Hill & Cherrywood	Quarry Hill and Cherrywood	L	M	L	Med	L	L	2.88	80	11
Downes Ave	Downes Ave	M	L	L	Min	M	L	0.45	80	12
Touch of Class	S Barre Rd	S	L	M	Min	M	H	0.28	80	13
Crescent St GSI	Crescent St	M	L	L	Min	L	L	0.54	75	14
Hebert Swale	Between Herbert Dr and Websterville Rd	L	M	M	Med	L	M	1.55	70	15
Websterville GSI 1	Websterville Rd, east of Quarry Hill Rd	M	M	H	Med	H	M	0.76	70	16

Wilson St Park	Wilson St	M	M	M	Med	L	H	0.30	70	17
Pouliot GSI	Pouliot St	S	M	M	Med	H	M	0.27	70	18
Websterville GSI 3	Websterville Rd, east of Quarry Hill Rd	S	M	M	Med	H	L	0.11	65	19
N Parkside Terr	N Parkside Terr, northeast of Pouliot Ave	S	M	M	Med	M	M	0.35	55	20
Gold Spur	Gold Spur	M	L	M	Med	L	M	0.28	50	21
Websterville GSI 2	Websterville Rd, east of Quarry Hill Rd	S	M	H	Med	M	L	0.32	45	22
Store It All	Quarry Hill Rd, north of Fisher Rd	M	L	H	Complex	M	L	0.80	40	23

Table 3. Preliminary ranking for Barre Town Elementary and Middle School sites.

Site	Drainage Area Size (L - M -S)	Pollutant Load Reduction Potential (H - M - L)	Cost Projection (H - M - L)	Additional Design Required (Min - Med - Complex)	Score	Rank
Access road greenspace	S	M	L	Min	65	1
Dumpster hot spot	S	M	L	Min	65	1
Track area drainage outfall	M	L	L	Min	65	1
BTS Infiltration Swale and Basin	L	M-H	M	Med - Complex	60.5	2
Maintenance building roof	S	L	L	Min	60	3
Wilson Industrial Park Riser	L	H	H	Complex	60	3
Back of school playground area 1	M	L	M-L	Min	58	4
Roadside swale	S	M	M-L	Min - Med	51	5
Entrance drive swales	S	M	M	Min	50	6
Maintenance shed swale	S	M	L	Med	50	6
Playground rain garden	S	L	L	Med	45	7
Back playground access road swale	S	L	L	Med	45	7
BTS Parking Lot Bioretention	M	M	M	Med	40	8
CB and roof drain runoff swale	M	M	M	Med	40	8
School garden	S	L	L	Complex	40	8
Parking lot entrance road	S	M	M	Med	35	9
Back of school playground area 2	M	L	M	Med - Complex	33	10

Table 4. Preliminary ranking for Town Garage sites.

Site Name	Drainage Area Size (L - M -S)	Pollutant Load Reduction Potential (H - M - L)	Cost Projection (H - M - L)	Additional Design Required (Min - Med - Complex)	Score	Rank
Town Garage Bioretention	L	H	M	Min	85	1
Eroded swale	L	H	M	Min	85	1
Maintenance Garage Swale	M	M	L	Min	70	2
Back Access Road	M	L	L	Min	65	3
Salt Shed Yard	S	L	L	Min	60	4
Front Entrance Parking Area	M	M	M	Med	40	5
Town Garage Cistern	M	L	M	Med	35	6
Maintenance Garage Cistern	M	L	M	Med	35	6
Salt Shed Roof	S	L	M	Med	30	7

The initial ranking, though preliminary in nature, was helpful in gaining a better understanding of each site's feasibility and benefit. Following this ranking, discussion with the Friends of the Winooski, and an assessment of potential landowner interest, the project list was narrowed down from 49 to 19 projects. These projects are listed below in Table 5; the location can be found in Appendix A-9, Top 19 Project Location Map. It was determined that each of these 19 projects would positively impact water quality and should thus be assessed further.

Table 5. Top 19 projects.

Project Name	BMP Type
BTS Infiltration Swale and Basin	Infiltration Swale to Basin
Wilson Industrial Park Riser	Riser Retrofit
BTS Parking Lot Bioretention	Bioretention
Sterling Hill Rd	Infiltration Chambers
Town Garage Bioretention	Bioretention
Maintenance Garage Cistern	Cistern
Town Garage Cistern	Cistern
Conti Cir GSI	Sand Filter
Quarry Hill & Cherrywood	Gravel Wetland
Conti Cir Swale	Sand Filter
Crescent St GSI	Sand Filter
Downes Ave	Sand Filter
Websterville & Graniteville	Gravel Wetland
Post Office	Infiltration Trench
Touch of Class	Bioretention
S Barre Rd South	Bioretention
Bridge St GSI	Bioretention
Gulf Station	Filter Strip

3.5 Modeling

Modeling was completed for each of the top 19 sites. This modeling allowed for accurate sizing of the proposed practices as well as an understanding of the water quality and quantity benefits. The contributing drainage area of each of the BMPs was defined and landuse/ landcover was digitized using the best available topographic data and aerial imagery. Drainage areas were refined based on field observations (see Appendix A-10 for drainage area delineations). Then, each of the sites was modeled in HydroCAD to determine the appropriate BMP size and resultant stormwater volume reductions.

Each of these sites was also modeled using the Source Loading and Management Model for Windows (WinSLAMM) to determine the annual total suspended solids (TSS) and total phosphorus (TP) loading from the drainage area of each site. Pollutant load reductions from each of the BMPs were then calculated using one of two sources, depending on the practice type. WinSLAMM was used when possible, and, for those practices that WinSLAMM does not model well (based on experience and literature), pollutant removal rates published by the University of New Hampshire Stormwater Center were applied to the initial pollutant loading modeled with WinSLAMM for the site's current conditions. This yielded expected pollutant removal loads (lbs) and rates (%). The modeled volume and pollutant loading reductions are shown in Table 6. Note that in the table below, "BTS" stands for "Barre Town School". Modeling results are provided in Appendix A-11.

Table 6. Top 19 projects and modeled pollutant and volume reductions.

Project Name	BMP Type	Volume Managed (ac-ft)	Volume Infiltrated (ac-ft)	TSS Removal (lbs)	TSS Removal (%)	TP Removal (lbs)	TP Removal (%)
BTS Infiltration Swale and Basin	Infiltration Swale to Basin	1.133	0.17	22,620	76%	86.3	74%
Wilson Industrial Park Riser	Riser Retrofit	6.300	0.10	4,980	20%	14.0	17%
BTS Parking Lot Bioretention	Bioretention	0.394	0.394	6,992	82%	49.1	81%
Sterling Hill Rd	Infiltration Chambers	0.581	0.581	7,775	92.2%	31.0	90.8%
Town Garage Bioretention	Bioretention	0.463	TBD with soil test	6,364	87%	2.9	34%
Maintenance Garage Cistern	Cistern	0.022	N/A	479	100%	0.160	100%
Town Garage Cistern	Cistern	0.025	N/A	376	100%	0.130	100%
Conti Cir GSI	Sand Filter	0.040	0	534	51%	1.5	33.0%
Quarry Hill & Cherrywood	Gravel Wetland	0.676	0	7,486	96%	20.3	58%
Conti Cir Swale	Sand Filter	0.062	0	1,047	51%	3.1	33%
Crescent St GSI	Sand Filter	0.033	0	880	51%	2.8	33%
Downes Ave	Sand Filter	0.018	0	325	51%	0.9	33%
Websterville & Graniteville	Gravel Wetland	0.300	0	6,449	96%	20.0	58%
Post Office	Infiltration Trench	0.074	0.074	718	97.6%	0.7	97.4%
Touch of Class	Bioretention	0.041	0.041	471	88.9%	2.2	84.4%
S Barre Rd South	Bioretention	0.057	0.057	402	86.1%	1.4	85.6%
Bridge St GSI	Bioretention	0.084	0.084	1,462	53.1%	2.7	45.3%
Gulf Station	Filter Strip	0.047	0	290	69.5%	0.6	22.6%

3.6 *Final Ranking Methodology*

A prioritization matrix was utilized in order to quantitatively rank each of the "Top 19" projects. Considerations that factored into the ranking of BMP projects included:

- Impervious area managed
- Ease of operation and maintenance
- Volume managed
- Volume infiltrated
- Permitting restrictions
- Land availability
- Flood mitigation
- TSS removed
- TP removed
- Other project benefits

- Project cost

Each of these criteria are listed and explained in Appendix A-12. The scores associated with each of the categories are also provided in this table. Project cost, listed as one of the criteria considered, was calculated for each project using a spreadsheet-based method. The methodology for determining these planning level costs was first developed for the City of South Burlington by the Horsley Witten (HW) Group as part of the Centennial Brook Flow Restoration Plan development. The HW Memorandum describing this methodology is provided in Appendix A-13. Note that a variation of this method was used for this plan. The criteria used in this cost estimation can be found in Appendix A-14. This methodology provides consistent budgetary cost estimates across BMPs.

Cost estimates are based on average costs for conceptual level projects and deviation from these estimates are expected as projects move forward with engineering design. There are differences between project cost estimates presented in the plan and actual project bid costs. The BMP cost estimates presented in the plan are based on limited site investigation. This methodology, while providing consistency in budget cost estimating, may fail to accurately reflect project cost impacts associated with actual site conditions and constraints. Therefore, the BMP cost estimates presented are suitable for planning purposes only, and not detailed program budgeting. The BMP cost estimates were developed based on the following assumptions:

Design Control Volumes: Design control volumes were based on the estimated runoff volume associated with the 1-year storm event for off-line, underground, or GSI-type practices. Off-line stormwater management systems are designed to manage storm events by diverting a percentage of stormwater from a stream or storm drainage system. Control volumes for large, in-line infiltration or detention basins were based on the estimated runoff associated with the 100-year storm event, plus approximately 2 feet of freeboard volume. Underground systems and GSI-type practices were conceptually designed as offline practices that only accept runoff from the 1-year event. Runoff volumes for all storm events were determined based on HydroCAD model results that rely on the Soil Conservation Service (SCS) TR-55 and TR-20 hydrologic methods.

Unit Costs and Site Adjustment Factors: Unit cost for each BMP and site adjustment factors were derived from research by the Charles River Watershed Association and Center for Watershed Protection, as well as from experience with actual construction[1] and modified for this project to reflect the newest cost estimates available. Underground detention and infiltration chamber systems were typically designed using Stormtech SC-740™ chamber systems. Cost adjustment factors were used to account for site-specific differences typically related to project size, location, and complexity. The values used to estimate BMP costs are summarized in Table 7 below.

[1] Horsley Witten Group, Inc. 2014. Centennial Brook Watershed: Flow Restoration VTBMPDSS Modeling Analysis and BMP Supporting Information. Memorandum dated January 9th, 2014.

Table 7. BMP unit costs and adjustment factors modified to reflect newer information.

BMP Type	Base Cost ($/ft³)
Porous Asphalt	$5.32
Infiltration Basin	$6.24
Underground Chamber (infiltration or detention)	$6.25
Detention Basin / Dry Pond	$6.80
Gravel Wetland	$8.78
Infiltration Trench	$12.49
Bioretention	$15.46
Sand Filter	$17.94
Porous Concrete	$18.07
Site Type	**Cost Multiplier**
Existing BMP retrofit	0.25
Large aboveground basin projects	0.5
New BMP in undeveloped area	1
New BMP in partially developed area	1.5
New BMP in developed area	2
Difficult installation in highly urban settings	3

Site-Specific Costs: Cost of significant utility or other work related to the construction of the BMP itself. Site-specific costs are variable based on past experience.

Base Construction Cost: Calculated as the product of the design control volume, the unit cost, and the site adjustment factor.

Permits and Engineering Costs: Used either 20% for large above-ground projects or 35% for smaller or complex projects.

Land Acquisition Costs *(Modified)*: A variation from the HW method was applied. Based on prior studies completed by WCA, the land acquisition cost was calculated as $120,000 per acre required for the BMP when located on private land. It should be noted that this value is based on a limited estimate and not necessarily an expected cost per acre.

Total Project Cost: Calculated as the sum of the base construction cost, permitting and engineering costs, and land acquisition costs.

Cost per Impervious Acre: Calculated as the construction costs plus the permitting and engineering costs, divided by the impervious acres managed by the BMP.

Operation and Maintenance: The annual O&M was calculated as 3% of the base construction costs, with a maximum of $10,000.

Minimum Cost Adjustment: After total project costs were determined for each proposed BMP based on the HW methodology, costs were reviewed and adjusted so that projects involving an outlet retrofit, such as a new outlet structure, were assigned a minimum cost of $10,000 and more complex projects were assigned a minimum cost of $25,000.

Each of the factors noted in Appendix A-12 were scored, and scores were totaled for each of the criteria. These scores were totaled, and projects were assigned a rank from 1 to 19 with those projects receiving the highest scores assigned the highest rank. In the case of a tie between two projects, the P removed (lbs) by the practice was used as a tiebreaker.

3.7 Final Ranking Results

A summary of the practices with scores and ranks are shown below in Table 8. The comprehensive ranking matrix used to rank the proposed BMP projects is provided in Appendix A-15. If future funding becomes available for further implementation, this prioritization matrix can be utilized in selecting additional projects for implementation.

As noted previously, a map of each project showing the drainage areas and BMP locations can be found in Appendix A-10, and project locations within the watershed can be found in Appendix A-9.

Table 8. Projects were ranked, and are shown in the table below in order of priority.

Project Name	BMP Type	BMP Description	Total Score	BMP Rank
BTS Infiltration Swale and Basin	Infiltration Swale to Basin	Retrofit existing vegetated swale to include check dams. Create large infiltration basin at end of swale to detain up to CPv, mitigate larger storms.	29	1
Wilson Industrial Park Riser	Riser Retrofit	Retrofit existing culvert in roadside area across from BTS with riser to control CPv, QP10	29	2
BTS Parking Lot Bioretention	Bioretention	Install a linear bioretention feature along the edge of the main school parking lot. Ensure that BMP is underdrained - possibility of high seasonal groundwater.	27	3
Sterling Hill Rd	Infiltration Chambers	Construct infiltration chambers under road ROW. Alternate: replace existing stormwater pipes with perforated pipes. There are currently a lot of drainage issues in this area. This would be a good opportunity to incorporate stormwater upgrades into repairs.	27	4

Town Garage Bioretention	Bioretention	Use a small portion of the Town garage's parking lot to install a bioretention. Depending on groundwater, bioretention may need to be lined.	23	5
Maintenance Garage Cistern	Cistern	Install a 7,500-gallon cistern at the Maintenance garage to capture rooftop runoff for reuse in road watering or other non-potable applications.	22	6
Town Garage Cistern	Cistern	Install a 7,500-gallon cistern at the Town garage to capture rooftop runoff for reuse in road watering or other non-potable applications.	22	7
Conti Cir GSI	Sand Filter	Construct linear sand filter in depressed area where stormwater currently drains.	20	8
Quarry Hill & Cherrywood	Gravel Wetland	Construct gravel wetland in open space near the intersection of Quarry Hill and Cherrywood Dr. Reroute catchbasin along Cherrywood Dr to this area.	19	9
Conti Cir Swale	Sand Filter	Improve swale and amend with sand to create a sand filter to improve water quality. Large swale outlets to stream. Could be an easy low cost opportunity.	19	10
Crescent St GSI	Sand Filter	Create linear sand filter in ROW. Road is wide and flat.	19	11
Downes Ave	Sand Filter	Create linear sand filter in ROW. Road is wide and flat.	19	12
Websterville & Graniteville	Gravel Wetland	Implement gravel wetland in open space near ROW to improve water quality and slow runoff. Can be kept partially in road ROW, but some private land would be necessary.	18	13
Post Office	Infiltration Trench	Shave down berm and allow for infiltration along perimeter of parking lot. Resident stated that water tends to infiltrate well in this area, but said there were a few areas by residences where ponding occurs when conditions are very wet.	18	14
Touch of Class	Bioretention	Potential for a bioretention along back of parking lot.	17	15
S Barre Rd South	Bioretention	Create bioretention along ROW before stream.	16	16
Bridge St GSI	Bioretention	Remove unused impervious area to construct linear bioretention.	15	17
Gulf Station	Filter Strip	Construct filter strip along the parking lot of the Gulf Station to slow and filter runoff. Currently drains to tributary with very little buffer.	14	18
Teamster Building	Filter Strip	Construct filter strip along the parking lot of the Teamster building to slow and filter runoff.	14	19

3.8 Recommendations

Following this ranking, it was recommended that 6 of the 19 projects included in the ranking move forward with additional investigation and design. These projects were:

1. BTS Infiltration Swale and Basin
2. Wilson Industrial Park Riser
3. BTS Parking Lot Bioretention
4. Town Garage Bioretention
5. Town Garage Cistern
6. Maintenance Garage Cistern

Although the Sterling Hill Rd project also ranked highly (#4), this is a complex project and the project stakeholders were motivated to pursue those projects listed above. However, it is recommended that this concept be developed further in the future.

The Wilson Industrial Park Riser and the BTS Parking Lot Bioretention are related projects. The Town Garage Bioretention and the Town Garage Cistern are also related. Although these projects were ranked separately, they are described together below. It was recommended that these practices be constructed in concert if possible. These projects all ranked within the top 6 BMPs (Table 8). Drainage areas for each of these projects can be seen in Appendix A-10. Project locations within the watershed can be found in Appendix A-9.

1. *BTS Infiltration Swale and Basin*

This project, located at the Barre Town School, involves the retrofit of an existing vegetated swale (shown in the photo to the right) to include check dams. The proposed plan is to create a large infiltration basin at the end of the swale to detain up to the channel protection volume (CPv) and mitigate larger storms.

There is considerable head cutting at the end of the swale where the grade changes, despite the fact that the swale leading to the head cut is well-vegetated and not eroded. This head cut erosion enters a tributary directly and is a source of significant sediment and phosphorus pollution. This project is could be relatively inexpensive, uses existing treatment, and will prevent further erosion.

Annually, this project would prevent more than 22,000 lbs of TSS (potentially even more as the model does not take into account sediment transport associated with erosion) and 86 lbs of TP from entering surface waters. This project was estimated to cost approximately $125,000 following this initial concept design.

2. *Wilson Industrial Park Riser*
   and
3. *BTS Parking Lot Bioretention*

The BTS Bioretention project, located at the Barre Town School, involves installing a linear bioretention feature along the edge of the main school parking lot (shown in photo to the right). This bioretention would likely need to be underdrained and potentially lined as there is a possibility of high seasonal groundwater. As such, it would function similarly to a large sand filter.

The second component of this project would be to retrofit the existing culvert in the roadside area across from school in the Wilson Industrial Park with a riser outlet structure that would control at least the CPv, but potentially the QP10 as well. This project may also reduce downstream flooding. This land is currently privately owned by Malone Properties of Barre. There are no recorded drainage easements that the Town was able to find. A State Wetlands Ecologist was consulted regarding the Wilson Industrial Park Riser portion of this project to ensure that this BMP would not adversely impact any wetlands in this area. This project would not fundamentally change the hydrology of this area.

These projects would prevent nearly 12,000 lbs of TSS and approximately 63 lbs of TP from entering surface waters from these drainage areas annually. These projects combined are estimated to cost approximately $115,000.

4. *Town Garage Bioretention*
   and
5. *Town Garage Cistern*

These two projects involve the Town Garage site. The first part of this retrofit would be to install a 7,500-gallon cistern to capture the roof runoff from the Town Garage building (roof shown in photo to the right). The water collected in the cistern would be used for road watering or other non-potable applications. Modeling conducted using the runoff generated by the roofs, along with recorded usage by the Town shows that a 7,500-gallon cistern is the optimal size vis-à-vis generation and usage. The second part of this retrofit would be to install a bioretention in a portion of the parking area and re-establish a 50' riparian buffer along the edge of a small stream that abuts the parking lot. This bioretention would treat the parking area and also capture the overflow from the cistern.

These projects combined would prevent approximately 6,700 lbs of TSS and 3 lbs of TP from entering surface waters annually. They will also reduce the Town's usage of potable water for non-potable uses, saving money and serving as a valuable resource. Together, these projects are expected to cost approximately $164,000.

6. *Maintenance Garage Cistern*

The final recommended project, located at the Town's Maintenance Garage, involves installing a 7,500-gallon cistern to capture the runoff from the garage roof (shown in photo to the right). This captured water would be used for road watering or other non-potable applications. The overflow from the cistern would be directed to a stable vegetated area to prevent erosion.

This project has a fairly low cost ($8,000), minimal footprint, and would reduce dependence on potable water.

3.9 Selection of Top Projects

Project stakeholders considered each of the recommended projects, and selected five of the six recommended projects to move forward with 30% design with the goal of 100% design and implementation in the future. Following assessment of the Wilson Industrial Park Riser project by a state wetlands ecologist, it was determined that further wetland delineations and study of the suitability of the industrial park access road's suitability to function as a dam would be required to move forward with this project. The landowner, Malone Properties, has not been contacted at this time to determine if they would be amenable to a stormwater retrofit project at this location. It is recommended that this outreach occur at a later date.

Drainage areas for these top projects are shown in Appendix A-16. When implemented, these five BMPs would treat approximately 35.5 acres, 11.1 acres (31%) of which is impervious. Each site is owned by the Town of Barre, and, as such, landowner cooperation will not be a barrier for implementation. There are no concerns with obtaining necessary permits for implementation. Modeled pollutant reductions for each of the projects, shown below in Table 9, indicate that these BMPs will prevent more than 37,800 lbs of TSS and nearly 35 lbs of TP from reaching receiving waters. These reported numbers differ slightly from those presented above (Table 6) as further concept design was completed and modeling was updated at this stage.

Table 9. Modeled pollutant reductions for recommended BMPs.

Project Name	BMP Type	TSS Removal (lbs)	TP Removal (lbs)
BTS Infiltration Swale and Basin	Infiltration Swale to Basin	22,644	23.8
BTS Parking Lot Bioretention	Bioretention	7,740	8.15
Town Garage Bioretention	Bioretention	6,584	2.52
Maintenance Garage Cistern	Cistern	479	0.16
Town Garage Cistern	Cistern	376	0.13

4 30% Designs

4.1 BTS Infiltration Swale and Basin

4.1.1 30% Concept Design Description

A large portion of the Barre Town Elementary School playing fields area drains via a grass swale on to property owned by the St. Sylvester's Church Cemetery. The outlet of this swale falls over a steep bank. Considerable erosion has taken place on this bank in recent years. At the toe of the bank is a small tributary that receives runoff flows and eroded material directly.

The proposed retrofit for this site is an improved conveyance and pre-treatment swale leading to a large infiltration basin. Soil mapping for the sites indicates that soils in this area are likely suitable, though detailed geotechnical assessment has not yet been performed. Modeling thus far has used only a limited amount of infiltration in order to conservatively estimate the amount of runoff that will infiltrate (1.0" / hour). Further testing may reveal a smaller basin is needed due to higher infiltration rates.

Additionally, the area below the proposed basin will need to be armored using stone or some other bank retention practice. This specific practice and the amount of material needed for this is not known at this time as this area must be surveyed and studied more critically before this design can be completed.

The design standard used for this retrofit was retention and slow release of the Channel Protection volume (CPv, or 1.91" of rain in a 24-hour period), equal to 26,876 ft^3 of runoff. This standard will have the greatest potential of reducing erosion in the receiving tributary as well as on the steep bank below the existing swale.

A 30% design plan is provided in Appendix A-17 - BTS Infiltration Swale and Basin.

4.1.2 Pollutant Removal and Other Water Quality Benefits

This practice has the potential to prevent nearly 25,000 lbs of TSS and 24 lbs of TP from entering receiving waters (Table 10). Note that the TSS and TP removed does not reflect the potential amount of each of these pollutants that may be removed by reducing the amount of erosion occurring on the steep bank below the existing swale. The amount of each of these constituents that may be prevented from reaching the stream may be significant.

Table 10. BTS Infiltration Swale and Basin benefit summary table.

TSS Removed	24,644 lbs
TP Removed	23.80 lbs
Impervious Treated	2.88 acres
Total Drainage Area	22.28 acres

4.1.3 Cost Estimates

Note that these costs and benefits are very preliminary and do not reflect armoring of the bank (neither the cost nor the benefits potentially associated with that work). Initial cost projections can be found in Table 11. This amount differs from the amount initially projected for this site as design-specific amounts and costs were used.

- The cost per pound of phosphorus treated is $1,344.00.
- The cost per impervious acre treated is $11,111.00.
- The cost per cubic foot of runoff treated is $1.19.

Table 11. BTS Infiltration Swale and Basin project initial construction cost projection.

VTrans Code	Description	Unit	Quantity	Unit Price	Amount
Site Preparation					
	Mobilization	LS	1	$ 1,000.00	$ 1,000.00
652.10	EPSC Plan*	LS	1	$ 500.00	$ 500.00
652.20	Monitoring EPSC Plan	HR	5	$ 40.21	$ 201.05
	Construction Site Stakeout	HR	4	$ 100.00	$ 400.00
				Subtotal:	$ 2,101.05
BTS Infiltration Swale					
203.15	Common Excavation	CY	1800	$9.50	$ 17,100.00
613.11	Stone, Type II	CY	14	$41.39	$ 579.46
601.0915	15" CPEP	LF	40	$34.05	$ 1,362.00
604.20	Precast Reinforced Concrete Catch Basin with Cast Iron Grate (Manifold Structure and New CB as junction)	EACH	1	$3,478.51	$ 3,478.51
651.25	Hay Mulch	TON	0.5	$596.75	$ 298.38
651.15	Seed	LBS	25	$7.79	$ 194.75
				Subtotal:	$ 23,013.10
Subtotal:					$ 25,114.15
	Construction Oversight	HR	20	$ 100.00	$ 2,000.00
	Construction Contingency - 10%				$ 2,511.41
	Incidentals to Construction - 5%				$ 1,255.71
	Minor Additional Design Items - 5%				$ 1,255.71
Total (Rounded)					**$ 32,000.00**

*Note this amount is not the standard VTrans amount for EPSC plan development. Given the simplicity of this project, $500 should be adequate.

4.1.4 Next Steps

Preliminary outreach has been conducted with St. Sylvester's Church Cemetery Board of Directors. They have indicated their willingness to proceed with further design of this retrofit. Further design will involve additional survey to characterize the topography of the erosion below the existing swale on the steep bank. Geotechnical assessment of the soils on-site will also need to be performed to support additional modeling and design. Once these tasks have been accomplished, the retrofit will be refined with respect to size and outlet design to ensure that CPv can be properly retained and slowly released and that the full WQv infiltrates completely.

4.1.5 Permit Needs

Stormwater Permit
This site will likely need a stormwater permit under the proposed 3-acre impervious cover rule. Though this particular drainage area does not exceed 3 acres impervious cover, the school and Town parcel as a whole does, therefore necessitating a permit.
The site should qualify for an Erosion Prevention and Sediment Control permit (3-9020) under the Low Risk categorization if the following guidelines are followed:

- Less than 2 acres of disturbance at any one time
- All soils must be stabilized (temporary or final) within 7 days.
- Runoff from the site must pass through a 50' vegetated buffer prior to entering any Water of the State.

Act 250
There is an existing Act 250 permit on the Barre Town School property (#5W0308). As work for this project will only minimally be on the BTS property, there would likely be little to no Act 250 review. This information was communicated to WCA by Act 250 District Coordinator Susan Baird during a phone conversation. If review is found to be necessary, based on the detailed description WCA furnished to Ms. Baird, an administrative amendment might be required. Administrative amendments are generally simple to obtain and do not require full Act 250 process. No Act 250 permit was found on the St. Sylvester's Cemetery property on the Agency of Natural Resource's Atlas or within the Act 250 database.

Local Permitting
No local permits are anticipated.

Other Permits
No Wetlands, or River Corridor permitting is anticipated for this project.

4.2 BTS Parking Lot Bioretention

4.2.1 30% Concept Design Description

Following geotechnical assessment of the site using published NRCS soils data, it was determined that a lined bioretention practice would be the best solution for the BTS parking lot area as there is typically high ground water in this location. To capture the maximum amount of runoff possible from the school's campus and rooftops, a 2' wide and 2' deep grass swale will need to be installed from the eastern edge of the parking lot paralleling the parking. It will then pick up the outlet of the school's other main drainage system on the western edge of the parking lot. This swale will serve as pre-treatment as well as conveyance. The lined bioretention will be located near the western entrance to the school's parking lot. A 10' X 10' bottomed forebay with 3:1 sides at 3' deep will be installed adjacent to the access drive. Runoff will be pre-treated here before being transferred to the main lined bioretention area, a 24' X 44' bottomed main bay with 3:1 sides at 4.5'. This main bay will be lined with an impermeable liner and make use of a 6" underdrain under 18-24" of filter media (TBD with final design). Discharge will be via a controlled outlet system to an existing catch basin along Websterville Road that then outlets across the street in the Wilson Industrial Park wetland area.

The design standard used was treatment of the Water Quality volume (WQv). This standard is met by fully filtering all storms up to 1.0" of rain in a 24-hour period. The Water Quality volume filtered is 41,120 ft^3 of runoff.

A 30% design plan is provided in Appendix A-17 - BTS Parking Lot Bioretention.

4.2.2 Pollutant Removal and Other Water Quality Benefits

This practice has the potential to prevent nearly 8,000 lbs of TSS and more than 8 lbs of TP from entering receiving waters (Table 12).

Table 12. BTS Parking Lot Bioretention benefit summary table.

TSS Removed	7,740 lbs
TP Removed	8.15 lbs
Impervious Acres Treated	4.39 acres
Total Drainage Area Acres	8.51 acres

1.1.1 Cost Estimates

The initial preliminary construction cost for this project is $53,000. Details of this cost estimate can be found in Table 13. This amount differs from the amount initially projected for this site as design-specific amounts and costs were used.

- The cost per pound of phosphorus treated is $6,503.00
- The cost per impervious acre treated is $12,072.00.
- The cost per cubic foot of runoff treated is $1.28.

Table 13. BTS Parking Lot Bioretention initial construction cost projection.

VTrans Code	Description	Unit	Quantity	Unit Price	Amount
Site Preparation					
	Mobilization	LS	1	$ 1,000.00	$ 1,000.00
652.10	EPSC Plan*	LS	1	$ 500.00	$ 500.00
652.20	Monitoring EPSC Plan	HR	5	$ 40.21	$ 201.05
	Construction Site Stakeout	HR	4	$ 100.00	$ 400.00
				Subtotal:	$ 2,101.05
BTS Parking Lot - Lined Bioretention					
203.15	Common Excavation	CY	1120	$9.50	$ 10,640.00
651.35	Topsoil (Bioretention Soil Mix)	CY	60	$31.48	$ 1,888.80
613.11	Stone, Type II	CY	14	$41.39	$ 579.46
629.54	3/4" to 1 1/2" Crushed Stone (Crushed Stone Bedding)	TON	15	$35.93	$ 538.95
649.31	Geotextile Under Stone Fill	SY	27	$2.52	$ 68.04
656.41	Plants** (Perennials)	EACH	1000	$8.77	$ 8,770.00
605.10	6 Inch Underdrain Pipe	LF	190	$20.86	$ 3,963.40
601.0915	15" CPEP	LF	100	$34.05	$ 3,405.00
604.20	Precast Reinforced Concrete Catch Basin with Cast Iron Grate (Manifold Structure and New CB as junction)	EACH	2	$3,478.51	$ 6,957.02
605.95	Underdrain Flushing Basin (Cleanout)	EACH	4	$331.59	$ 1,326.36
N/A	30 Mil PVC Liner	SY	275	$5.68	$ 1,562.00
651.25	Hay Mulch	TON	0.25	$596.75	$ 149.19
651.15	Seed	LBS	25	$7.79	$ 194.75
				Subtotal:	$ 40,042.97
Subtotal:					$ 42,144.02
	Construction Oversight	HR	20	$ 100.00	$ 2,000.00
	Construction Contingency- 10%				$ 4,214.40
	Incidentals to Construction- 5%				$ 2,107.20
	Minor Additional Design Items- 5%				$ 2,107.20
Total (Rounded)					**$ 53,000.00**

*Note this amount is not the standard VTrans amount for EPSC plan development. Given the simplicity of this project, $500 should be adequate.

** Costs can be substantially reduced through the use of perennial flower seeds versus plugs.

4.2.3 Next Steps

During development of the plans for the proposed retrofit at the Barre Town Elementary School, Town and School officials communicated that a concept for a shared use path was in development. The shared use path will potentially make use of the same open space adjacent the School's access road and parking lot that the proposed lined bioretention would use. This development was only discovered after the 30% plans for the bioretention retrofit had been significantly matured. The project team chose to leave the plans as developed, with the understanding that the 30% plans would have to be updated to reflect the presence of the shared use path during 60% and 100% plan development under a future grant. This project is still feasible along with the installation of the shared use path, but greater collaboration between Town and School project stakeholders will need to take place during subsequent design development.

4.2.4 Permit Needs

Stormwater Permit
This site will likely need a stormwater permit under the proposed 3-acre impervious cover rule. Though this particular drainage area does not exceed 3 acres impervious cover, the school and Town parcel as a whole does, therefore necessitating a permit.
The site should qualify for an Erosion Prevention and Sediment Control permit (3-9020) under the Low Risk categorization if the following guidelines are followed:

- Less than 2 acres of disturbance at any one time
- All soils must be stabilized (temporary or final) within 7 days.
- Runoff from the site must pass through a 50' vegetated buffer prior to entering any Water of the State.

Act 250
There is an existing Act 250 permit on the Barre Town School property (#5W0308). This change may require review by Act 250. Act 250 District Coordinator Susan Baird communicated to WCA that this change, while it may require Act 250 review, would be likely to be granted a simple administrative amendment, or may require a minor amendment. Neither of these amendments require full Act 250 process (public hearings, etc.,) and should be regarded as fairly simple processes.

Local Permitting
No local permits are anticipated.

Other Permits
No Act 250, Wetlands, or River Corridor permitting is anticipated for this project.

4.3 Town Garage Bioretention

4.3.1 30% Concept Design Description

Runoff from the Barre Town Garage currently either sheet flows directly to a small tributary via a gravel parking area or is directly piped to the tributary via two catch basins and associated piping. The proposed retrofit would make use of a lightly-used area of the parking lot to install a lined bioretention practice with two pre-treatment forebays (one for each area of channel flow). The practice would be entirely surrounded by a grass filter strip to provided pre-treatment for sheet flow. The reason for lining the practice is the likelihood of season high ground water at this site given the presence of the stream directly adjacent to the project site. In consultation with Town of Barre staff, it was discovered that there are underground utilities in the proposed project area. There are potentially two sanitary sewer lines that would affect the position of this practice, as well as the presence of underground electric lines. It may be possible to design the practice around these features, however the data regarding these utilities was received later in the design process and could not be fully incorporated in the design. Subsequent design work will need to take these features in to account.
The design standard used for this retrofit was filtration of the full WQv along with retention and slow release of the CPv in order to protect the adjacent tributary from in-stream erosion in accordance with Vermont Stormwater Manual Design Standards. The CPv is 20,168 ft^3.

A 30% design plan is provided in Appendix A-17 - Town Garage Bioretention.

4.3.2 Pollutant Removal and Other Water Quality Benefits

This practice has the potential to prevent more than 6,500 lbs of TSS and more than 2.5 lbs of TP from entering receiving waters (Table 14).

Table 14. Town Garage benefit summary table.

TSS Removed	6,584 lbs
TP Removed	2.52 lbs
Impervious Acres Treated	3.20 acres
Total Drainage Area Acres	3.66 acres

1.1.1 Cost Estimates

Note that these costs and benefits are very preliminary and do not reflect potential costs for redesigning system with respect to underground utilities and/or relocation of utilities. Initial construction cost projections, which total $70,000, can be found in Table 15. This amount differs from the amount initially projected for this site as design-specific amounts and costs were used.

- The cost per pound of phosphorus treated is $27,777.00
- The cost per impervious acre treated is $21,875.00.

- The cost per cubic foot of runoff treated is $3.47.

Table 15. Town Garage project initial construction cost projection.

VTrans Code	Description	Unit	Quantity	Unit Price	Amount
Site Preparation					
	Mobilization	LS	1	$ 1,000.00	$ 1,000.00
652.10	EPSC Plan*	LS	1	$ 500.00	$ 500.00
652.20	Monitoring EPSC Plan	HR	5	$ 40.21	$ 201.05
	Construction Site Stakeout	HR	4	$ 100.00	$ 400.00
				Subtotal:	$ 2,101.05
BTS Infiltration Swale					
203.15	Common Excavation	CY	1850	$9.50	$ 17,575.00
613.11	Stone, Type II	CY	15	$41.39	$ 620.85
651.35	Topsoil (Bioretention Soil Mix)	CY	450	$31.48	$ 14,166.00
601.0915	18" CPEP	LF	40	$62.94	$ 2,517.60
604.20	Precast Reinforced Concrete Catch Basin with Cast Iron Grate (Manifold Structure and New CB as junction)	EACH	1	$3,478.51	$ 3,478.51
629.54	3/4" to 1 1/2" Crushed Stone (Crushed Stone Bedding)	TON	25	$35.93	$ 898.25
649.31	Geotextile Under Stone Fill	SY	10	$2.52	$ 25.20
605.10	6 Inch Underdrain Pipe	LF	375	$20.86	$ 7,822.50
605.95	Underdrain Flushing Basin (Cleanout)	EACH	4	$331.59	$ 1,326.36
N/A	30 Mil PVC Liner	SY	1000	$5.68	$ 5,680.00
651.25	Hay Mulch	TON	0.25	$596.75	$ 149.19
651.15	Seed	LBS	25	$7.79	$ 194.75
				Subtotal:	$ 54,454.21
Subtotal:					$ 56,555.26
	Construction Oversight	HR	20	$ 100.00	$ 2,000.00
	Construction Contingency - 10%				$ 5,655.53
	Incidentals to Construction - 5%				$ 2,827.76
	Minor Additional Design Items - 5%				$ 2,827.76
Total (Rounded)					**$ 70,000.00**

*Note this amount is not the standard VTrans amount for EPSC plan development. Given the simplicity of this project, $500 should be adequate.

4.3.3 Next Steps

Considerable additional design is needed for this site, especially with regard to the underground utilities. Utility locations will need to be more accurately determined prior to finalizing sizing and siting of the retrofit. Additionally, the site should be reviewed with Wetlands and River Corridor staff to discuss placement. Geotechnical assessment should be conducted to ascertain the level of seasonal high ground water, which will heavily influence design.

4.3.4 Permit Needs

Stormwater Permit
This site will likely need a stormwater permit under the proposed 3-acre impervious cover rule. The site should qualify for an Erosion Prevention and Sediment Control permit (3-9020) under the Low Risk categorization if the following guidelines are followed:

- Less than 2 acres of disturbance at any one time
- All soils must be stabilized (temporary or final) within 7 days.
- Runoff from the site must pass through a 50' vegetated buffer prior to entering any Water of the State.

Act 250
Development of the Town Garage site pre-dated the development of the Wilson Industrial Park and an associated subdivision (as well as Act 250). There is subsequently no Act 250 permit associated with this site.

Local Permitting
No local permits are anticipated.

Other Permits
River Corridor and / or Wetland permitting may be needed for this site as it is adjacent to a small tributary. However, every effort to keep the retrofit outside of the 50' generally required for streams of this size has been made.

4.4 Town Garage and Maintenance Garage Cisterns

4.4.1 30% Concept Design Description

In discussion with the Town of Barre, it was determined that the installation of rooftop runoff capture cisterns was a desired stormwater retrofit, particularly given that the Town of Barre uses potable water to water local unpaved roads to suppress dust. By utilizing captured rainwater instead of using potable water, they can both decrease the cost of using potable water supplies and decrease the stormwater volume discharged to the stream. The following road watering statistics were provided by the Town of Barre (Table 16).

Table 16. Road watering use statistics provided by Barre Town.

Month	*East Barre* Usage (gal.)	*South Barre* Usage (gal.)	Total Usage (gal.)	Daily Use (gal.)
May	0	6,657	*6,657*	*222*
June	11,500	1,047	*12,547*	*418*
July	12,000	0	*12,000*	*400*
August	9,000	0	*9,000*	*300*
September	24,700	972	*25,672*	*856*
October	28,500	4,264	*32,764*	*1,092*
November	3,000	3,216	*6,216*	*207*

These usage amounts were entered in to a cistern model developed by the Center for Watershed Protection. This model was originally developed for use in Virginia for crediting the installation of cisterns and makes use of rainfall data for that area. However, since rainfall amounts between VA and VT are similar, credible modeling for cisterns could be completed using this tool. The cistern model is effective in that custom water-usage data can be entered in to the model. The output will then take in to account the runoff collected compared with water used during specific time periods to optimize cistern size.

4.4.2 Cistern Modeling:

When roof size, precipitation, and water usage was taken in to account, the model determined that a 7,500-gallon cistern would likely be the best size to install at both garages. Two 7,500-gallon cistern will effectively supply greater than 90% of the anticipated use by the Town of Barre for road watering. While larger cisterns would supply more of the anticipated use by the Town, the increase in cistern size represents a significant increase in cistern cost and a decreased return on investment. A cost-benefit analysis of the sizing indicated that the 7,500-gallon cistern had the greatest benefit given the cost of cistern acquisition, installation, and maintenance. The Town's water need met by the various cistern sizes assessed is shown in Table 17 below. This table reflects the modeling for the Town Maintenance Garage. Modeling results for the Town Garage site is nearly identical as roof sizes are similar and precipitation and water use data was identical. Modeling results for both sites can be found in Appendix A-18.

Table 17. Cistern modeling results for the Town Maintenance Garage site.

RESULTS: USING PRECIP DATA FROM ALL STORMS WITH YEAR-ROUND AND SEASONAL USES						
Cistern Storage Associated with Design Volume (gallons)	Average Annual Overflow days for all storms (days/year)	Average Annual Overflow Volume for all storms (1000's gal/year)	Average Annual "Dry" days (days/year)	Average Cistern Volume	% of Demand Met by Captured Rainwater	Annual Volume Supplied, Demand Met (1000's gal/year)
2,500	71	256	41	1,918	72%	39
5,000	69	249	20	4,162	85%	46
7,500	69	246	12	6,502	91%	49
12,500	68	243	5	11,301	96%	52
17,500	67	241	3	16,163	98%	53
25,000	67	241	1	23,595	99%	53
32,500	67	241	1	31,060	99%	53
45,000	67	240	1	43,490	99%	53

In a typical year, the cisterns will supply most road watering needs, but there are times when the cistern is anticipated to be empty. This is illustrated by Figure 5, which shows precipitation (blue) and water level (predicted, red). When water use is anticipated to be highest (late summer and early autumn months), there may be times when the cistern runs dry. At these times, staff may need to make use of other water sources. With two cisterns in use, the likelihood of both cisterns running dry at a critical time is lessened.

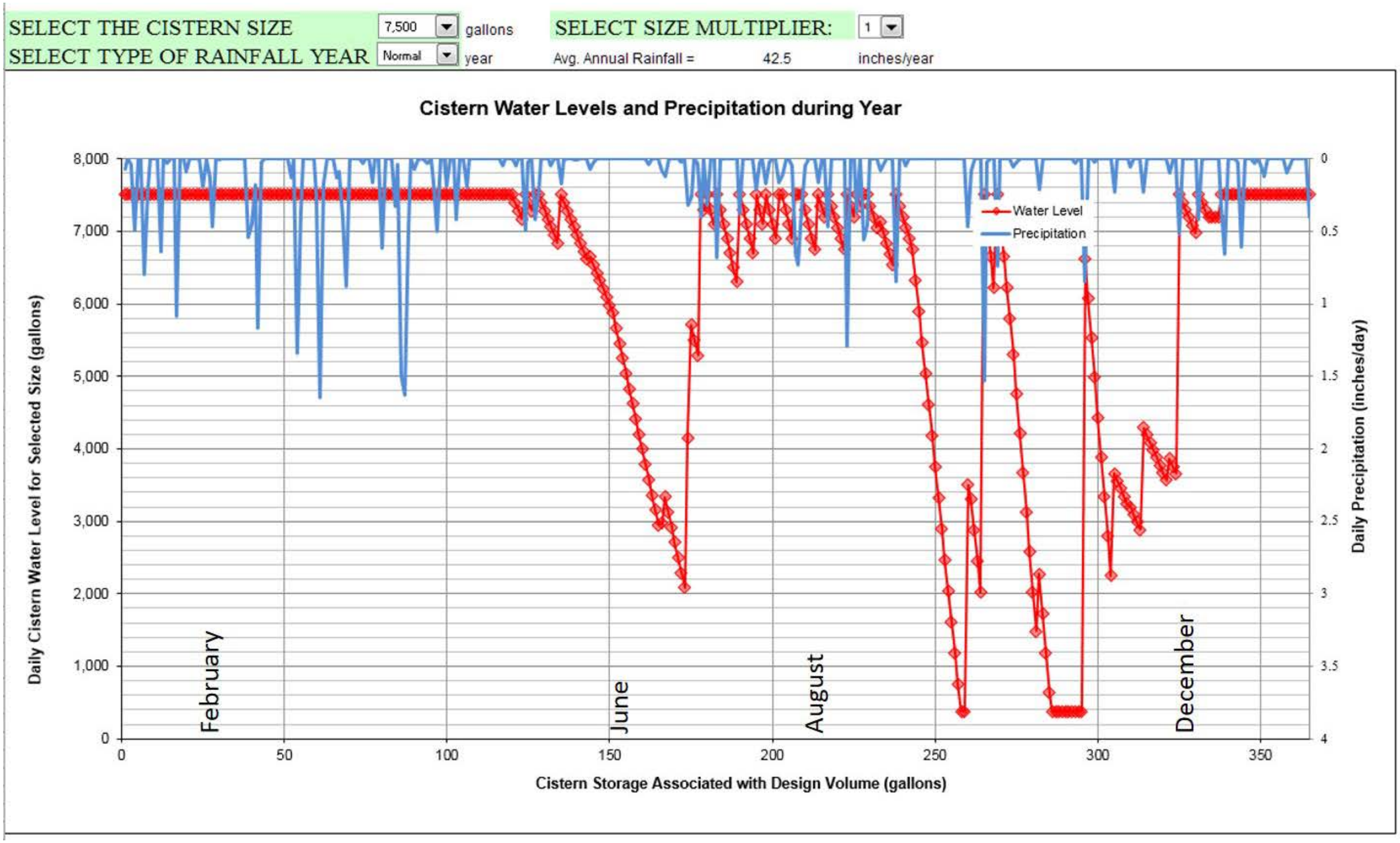

Figure 5. Modeled annual cistern water levels and precipitation for the Town Maintenance Garage site**.**

4.4.3 Cost Estimates

Each of these cisterns will cost approximately $8,000 for materials and shipping. Installation and guttering of the roof to ensure delivery of rooftop runoff to each cistern will incur additional costs.

4.4.4 Permit Needs

Stormwater Permit
The Town Garage site will likely need a stormwater permit under the proposed 3-acre impervious cover rule. The site should qualify for an Erosion Prevention and Sediment Control permit (3-9020) under the Low Risk categorization if the following guidelines are followed:

- Less than 2 acres of disturbance at any one time
- All soils must be stabilized (temporary or final) within 7 days.
- Runoff from the site must pass through a 50' vegetated buffer prior to entering any Water of the State.

The Maintenance Garage site will not need a new stormwater permit as it is covered under the Wilson Industrial Park stormwater permit.

Act 250
There is no Act 250 permit for the Town Garage site (see section 4.3.4).

The Maintenance Garage is in the Wilson Industrial Park, which does have an Act 250 Permit (#5W0308), but a retrofit like the cistern proposed is unlikely to require a significant change of the permit beyond potentially an administrative amendment. This decision information was communicated to WCA by Act 250 District Coordinator Susan Baird during a phone conversation where the project was described in detail. Administrative amendments are relatively simple to obtain and don't require a full Act 250 process.

Local Permitting
No local permits are anticipated.

Other Permits
No River Corridor or Wetlands permits are anticipated as a result of these retrofits.

5 Summary and Recommendations:

The results of this Stormwater Master Plan have identified a number of potential BMP concepts and locations that would have a positive impact on water quality in the Quarry Hill and Sterling Hill Drainage Areas and receiving waters. Although designs were only advanced for the top 5 projects, this plan also serves to highlight these other opportunities throughout the drainage areas.

5.1 Projects Recommended for Additional Study and/or Design

There are many other sites and potential practices within the watershed that deserve additional attention and should be further developed with a goal of final design and construction. It is our recommendation that eight sites be more thoroughly investigated and designs pursued for each of them, pending landowner approval and cooperation. As these practice concepts are the result of a stormwater master planning effort, they are well-suited as candidates for an implementation grant from the State. These sites are:

- *Sterling Hill Rd* – Construct infiltration chambers under road ROW. Alternatively, replace existing stormwater pipes with perforated pipes. There are currently a lot of drainage issues in this area. This would be a good opportunity to incorporate stormwater upgrades into repairs.
- *Conti Cir GSI* – Construct linear sand filter in depressed area where stormwater currently drains.
- *Conti Cir Swale* – Improve swale and amend with sand to create a sand filter to improve water quality. Large swale outlets to stream. Could be an easy low-cost opportunity.
-
- *Crescent St GSI* – Create linear sand filter in ROW. Road is wide and flat.
- *Downes Ave* – Create linear sand filter in ROW. Road is wide and flat.
- Websterville & Graniteville - Implement gravel wetland in open space near ROW to improve water quality and slow runoff. Can be kept partially in road ROW, but some private land would be necessary.
- *Post Office* - Shave down berm and allow for infiltration along perimeter of parking lot. Resident stated that water tends to infiltrate well in this area, but said there were a few areas by residences where ponding occurs when conditions are very wet.
- *Gulf Station* - Construct filter strip along the parking lot of the Gulf Station to slow and filter runoff. Currently drains to tributary with very little buffer.

More information on these sites can be found in Appendix A-15 – Top 19 Ranking Spreadsheet.

The momentum developed during this study, as well as the partnerships created between the Friends of the Winooski and local stakeholders should be strengthened and promoted in the next phase of work for the area.