Moon Brook Flow Restoration Plan (FRP)

Town of Rutland, VT

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Prepared for:
Town of Rutland

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I. Disclaimer

The intent of this plan is to present the data collected, evaluations, analysis, designs, and cost estimates for the Moon Brook Flow Restoration Plan (FRP) Project, completed under a contract between the Town of Rutland and the hired consultant team, Watershed Consulting Associates, LLC. The Moon Brook FRP was prepared to meet the compliance requirements for the National Pollutant Discharge Elimination System General Permit 3-9014 (Vermont Department of Environmental Conservation, 2012) for stormwater discharges to impaired waters for Moon Brook impervious surface owners. This plan is intended as a regulatory document for the Town of Rutland only, and is not meant to serve as a watershed-wide plan.

II. Executive Summary

This Flow Restoration Plan (FRP) for the section of the Moon Brook Watershed (MBW) that falls within the Town of Rutland was developed in accordance with requirements for Municipal Separate Storm Sewer System (MS4) entities. Once approved by the Vermont Department of Environmental Conservation (VT DEC) this FRP will become part of the Moon Brook Stormwater Management Plan (SWMP) prepared by the Town of Rutland. The MS4 permitees in this watershed are the Town of Rutland, the City of Rutland, and the Vermont Department of Transportation (VTrans). This FRP will serve as a long term planning tool for the Town of Rutland to implement stormwater best management practices (BMPs) throughout their section of the watershed in the effort to return Moon Brook to its attainment condition. Although three MS4 entities own impervious cover within the MBW, the Town of Rutland has elected to prepare its own FRP document.

The Vermont Best Management Practice Decision Support System (BMPDSS) model, a Geographic Information Systems (GIS)-based hydrologic model maintained by the VT DEC, was used to assess the impact of various stormwater BMP scenarios proposed as part of this FRP process. The VT DEC provided a Pre-2002 model run for the watershed, which included any BMPs that existed prior to 2002 in the watershed and provided an estimated stream flow during the 1-year storm event. The goal of the FRP is to reduce stream flow by 11.9% during this target storm event as outlined in the Total Maximum Daily Load (TMDL) document described below.

A second BMPDSS model was run by the VT DEC for the Post-2002 condition, including all BMPs that were constructed in the watershed after 2002 and thus designed to meet the Vermont 2002 Stormwater Management Manual (VT SWMM) design standards. This model reflected the existing conditions in the watershed and it was used to determine to what extent current stormwater controls have reduced high flows (flows occurring less than 0.3% of the time).

Revisions were made to both the Pre-2002 and Post-2002 models based on field investigations of BMPs with expired stormwater permits, discussions with the MS4s, and information from the VT DEC. These revisions were made watershed-wide, not just within the Town of Rutland, as the BMPDSS is an aggregate model and thus takes into account the condition of the entire watershed. Both of these models (Pre-2002 and Post-2002) were rerun following revisions, and these revised model runs were used for all subsequent modeling. Following revisions, the Post-2002 BMPDSS model run showed a 0.71% reduction in high flows from the revised Pre-2002 condition, which accounts for 6% of the required flow reduction of 11.9%. Once allocated by impervious area for each MS4, this reduction accounted for 6.6% of the Town of Rutland's high flow allocation. As such, additional BMPs were required to meet 100% of the required high flow reduction target for the Town.

An initial list of potential BMP sites was identified remotely using GIS with a focus on managing impervious area within the Town of Rutland. A preliminary field assessment was completed at

each site to document potential BMP practices, constructability issues, and review drainage areas. These new BMPs were then incorporated into the BMPDSS Credit model, which simulates the high flow reduction from the future construction of the identified BMPs. This was an iterative process where new BMPs were added and the model rerun as new BMPs were identified. The final run of the model was aimed at achieving target high flow reduction for the Town of Rutland. Watershed-wide, a high flow reduction of 2.72% was achieved with the proposed scenario, which, allocated by impervious cover managed, resulted in a 1.9% high flow reduction for the Town of Rutland. This equates to 67% of the Town's allocated target. While the target was not achieved by the Town, the proposed BMP scenario does manage 35% of the Town's impervious surfaces. The majority of the remaining impervious cover is low density and widely distributed throughout the watershed. This makes large stormwater BMPs infeasible for this area. Additional reductions could be achieved through distributed green stormwater infrastructure (GSI).

The final BMPDSS Credit model run included a total of eight retrofits, all of which are located in the Town of Rutland. One project, a gravel wetland site known as Randbury Road, is a joint project with VTrans. Of the eight projects, three are gravel wetlands, three are detention swales, and two are outlet retrofits of existing detention ponds. The total cost for implementation of these BMPs for the Town of Rutland is estimated at approximately $1,027,000. This total is reduced to $948,000 when a cost-share for the Randbury Road project was estimated. All cost estimates utilize 2014 construction cost estimates.

While not an actionable target, increasing the stream's low flow (baseflow) is still a water quality goal. However, due to limited soil infiltration potential within the Town of Rutland, the proposed BMPs do not improve modeled watershed-wide stream low flow (reduction of -0.45%).

III. Background

Moon Brook, located in central Vermont in Rutland County, extends into the Town of Rutland, the City of Rutland, and the Town of Mendon. This watershed covers approximately 7.8 mi^2 (5032 acres) and contains approximately 10% impervious cover (0.8 mi^2). The watershed is currently on the State of Vermont's impaired waters list, determined by the Environmental Protection Agency's (EPA) 303(d) list, as a result of stormwater runoff. Biological monitoring data has shown that Moon Brook fails to meet Vermont Water Quality Standards.

The final MS4 general permit, dated December 2012, requires that the Town of Rutland develop and submit a comprehensive FRP for their section of the MBW. The purpose of this Moon Brook FRP is to identify the necessary stormwater BMPs that will be used to achieve the flow restoration targets prescribed in the Moon Brook TMDL document.

III.1 TMDL Flow Targets

In the effort to restore Moon Brook to its attainment condition and lift its impaired designation, a flow-based TMDL was developed for Moon Brook using flow as a surrogate for pollutant loading. This document outlines required reductions in stream high flows and increase in stream low or base flows.

The basis for the TMDL required high flow reductions was the comparison of modeled Flow Duration Curves (FDCs) between the impaired Moon Brook and comparable attainment watersheds. An FDC graphs the percentage of time during a period that flow exceeds a certain value, with the low flow represented by the 95th percentile ($Q_{95\%}$) and the high flow represented by the 5th percentile ($Q_{0.3\%}$). The Program for Predicting Polluting Particles Passage through Pits, Puddles, and Ponds, Urban Catchment Model (P8) was used to model gauged and ungauged watersheds in Vermont to develop FDCs from which an area of normalized high flow and low flow were extracted by drainage area. The percent change between impaired and attainment FDCs was used as a basis for the TMDL requirements. The high flow ($Q_{0.3\%}$) was determined to be relatively equivalent to the 1-year design storm flow. Therefore, all proposed BMPs are designed to the Channel Protection volume (CP_v) storage standard to address the high flow reduction target.

Included in the 2012 MS4 permit issuance were requirements for municipalities to develop FRPs to comply with the stormwater TMDLs. The FRPs must be developed for each impaired watershed by October 1, 2016, and must include the following elements:

1) An identification of required controls,
2) A design and construction schedule,
3) A financial plan,
4) A regulatory analysis,
5) The identification of regulatory assistance, and
6) Identification of any third party implementation.

The schedule shall provide for implementation of the required BMPs no later than 20 years from the effective date of the permit, before December 5, 2032.

III.1.1 Future Growth

A future growth factor was included in the TMDL to account for future non-jurisdictional impervious growth within the watershed. Non-jurisdictional growth is, by definition, impervious area that does not require a stormwater permit and is not managed by a stormwater BMP. Therefore, the long term stormwater management plan must account for this type of growth and future unmanaged impervious area. The VT DEC estimated a future growth of 25 acres in the watershed based on local development and projected growth for Moon Brook. The approved TMDL flow targets for Moon Brook are shown in Table 1.

Table 1. Moon Brook TMDL flow restoration targets

Target High Flow $Q_{0.3}$ (± %) Reduction	Target Low Flow Q_{95} (± %) Increase
-11.9%	**23.9%**

While the low flow goal is important to ensure flow during the dry summer months, it is not an actionable requirement in the EPA approved TMDL, and therefore was not the primary focus of the BMP identification for this study.

III.2 MS4 Allocation of Flow Targets

Allocation of the flow targets by MS4 was approximated for Moon Brook based on relative impervious cover. However, there are limitations to this method as the BMPDSS model is an aggregate model in which upstream BMPs affect downstream flow and runoff does not necessarily follow political boundaries.

Approximately 76% of the impervious cover within the Moon Brook Watershed is within the City of Rutland, 24% within the Town of Rutland, and 0.5% is owned by VTrans (Table 2). Although a section of Moon Brook is located in the Town of Mendon, this town is not considered a small MS4 community and therefore was not included in the allocation. Based on impervious surface ownership, the Town of Rutland is responsible for a high flow reduction of 2.82% and a low flow increase of 5.66% of the overall TMDL targets.

Table 2. Moon Brook flow targets allocated by MS4

Owner	Total Watershed Area (acres)	Impervious Cover (acres)	% of Watershed Impervious Cover	Target High Flow $Q_{0.3}$ (± %) Reduction [1]	Target Low Flow Q_{95} (± %) Increase
Mendon	2041.8	42.1	----	----	----
Rutland City	1415.3	353.8	75.8%	-9.02%	18.12%
Rutland Town	1556.4	110.6	23.7%	-2.82%	5.66%
VTrans	18.7	2.3	0.5%	-0.06%	0.12%
Watershed Total [2]	**2990.4**	**466.7**		**-11.90%**	**23.90%**

[1] The high flow target is negative (-), indicating a reduction in high flow from the baseline condition is required. The low flow target is positive (+), indicating a need for an increase in low flow from the baseline condition.

[2] Watershed totals do not include watershed area or impervious area within the Town of Mendon as this community is not designated as a small MS4 community.

IV. Best Management Practice Decision Support System Model Assessment

The VT DEC worked with an external consultant (TetraTech) to develop a Vermont specific hydrologic model, the VT BMPDSS, to predict progress toward the TMDL flow targets based on proposed BMP implementation scenarios. This modeling was adapted for use in Vermont with funding from the Vermont Agency of Natural Resources. The BMPDSS model is used to predict peak flows at the watershed outlet for a Pre-2002 (baseline), Post-2002 (existing condition), and a Credit (BMP implementation) scenario. All models are compared to the Pre-2002 model on a percent change basis.

IV.1.1 Permit Review

In order to confirm the information included in the Pre-2002 and Post-2002 BMPDSS models, all expired stormwater permits in the Town of Rutland, in the Moon Brook Watershed were acquired and reviewed. Two expired permits were identified. The first was Permit #4375-INDS - Wynnmere Senior Housing, and the second was Permit #1-1031 - La Victoire Subdivision (Table 3). The permitted detention pond under #4375-INDS was assessed for compliance with Vermont 2002 Stormwater Standards and for a retrofit opportunity. Based upon this review, a change to the outlet structure would bring the pond into compliance with these standards and increase detention. The stormwater system permitted under #1-1031 consists of a system of vegetated swales and culverts. A portion of the permitted runoff area drains to another proposed BMP, the Hitzel Terrace detention pond (further details regarding this proposed BMP can be found in Appendix B). Only a portion of the site permitted under #1-1031 drains to the proposed Hitzel Terrace detention pond because it was determined to be most feasible. A portion of the permitted site will remain uncollected. The entire permitted site however is planned to be incorporated into the Town of Rutland MS4.

Table 3. Expired stormwater permits in Moon Brook

Site Name	Permit #	Permit Expiration Date	Stormwater System
Wynnmere Senior Housing Project	4375-INDS	1/22/2012	Swales and catchbasin collection to detention pond
LaVictoire residential subdivision	1-1031	6/30/1996	Vegetated swales to culverts
Table prepared by Emily Schelley (VT DEC, Jan. 2014). Revised by WCA (2015).			

IV.1.2 Review of Existing Models

Both the Pre-2002 and Post-2002 models were assessed and revised as needed. New BMPs, either developed since the models were last updated or BMPs that were unknown at the time of the last model updates, were added. Additionally, other revisions such as watershed boundary changes, subwatershed boundary changes, and combined sewershed boundary

changes were incorporated. Updated input files for the Pre-2002 and Post-2002 models were submitted to VT DEC so that updated model scenarios could be run. Input files included revised HydroCAD® models of each BMP as necessary, and GIS data for BMP drainage areas, subwatersheds, and BMP locations. A full list of the existing BMPs in the Pre-2002 and Post-2002 models is included in Appendix D and a map is included in Appendix E.

IV.1.2.1 Pre-2002 Condition Revisions

Several revisions were made to the Pre-2002 BMPDSS model based on information provided by the MS4 entities and the VT DEC, as well as field investigations. The model was revised as follows:

- Replaced previous combined sewershed delineation with revised version provided by Rutland City (currency: February 2013).
- Revised subwatershed delineations to reflect updated sewershed boundaries. These revisions reduced the watershed area from 5070 acres to 5032 acres.
- Revised subwatershed boundaries to account for updated utility infrastructure mapping and field verification of drainage paths in areas where there was either an existing BMP installed or a permitted discharge.
- Based on field observations and discussion with the City of Rutland staff, a section of the mapped MBW near the VTrans-owned rail yard was determined to be out of the watershed as it was concluded that the property drains to the combined sewer rather than to Moon Brook.
- Added four existing but previous unmodeled BMPs to the Pre-2002 model:
    1. Allen Pond Development - detention pond,
    2. Family Dental Associates - detention pond,
    3. Natural Detention area near Rutland Plywood, and
    4. Northeast School (Thrall Avenue) – detention pond (without new outlet structure, which was added after 2002 and included in the Post-2002 model revisions).

IV.1.2.2 Post-2002 Model Revisions

Upon field and remote review, and in light of information provided by the MS4 entities, several revisions were necessary for the Post-2002 BMPDSS model. The model was revised as follows:

- Mapped impervious cover was adjusted in areas where an existing BMP was located.
- Revised Pre-2002 model subwatershed boundaries to account for additional BMPs.
- Added five rain gardens (Rutland Natural Resources Conservation District projects).
- Added five existing BMPs implemented after 2002 to the model including:
    1. Vermont Eye Care Center - detention pond,
    2. Rutland Eye Physicians building - detention swale,
    3. Rutland Heart Center, Common Street – detention pond,

4. Gravel Wetland - Rutland Natural Resources Conservation District project, and
5. Northeast School (Thrall Avenue) - detention pond with new outlet structure added after 2002.

IV.1.2.3 Post-2002 Model Results

Following the revisions to the Pre-2002 and Post-2002 BMPDSS models described above, the model scenarios were rerun by the VT DEC. A watershed-wide high flow reduction of 0.71% was observed as a result of Post-2002 BMPs in place in the watershed. This accounts for 6% of the total required, watershed-wide, high flow reduction of 11.9%. The Post-2002 model results show that the Town of Rutland has addressed approximately 6.6% of their high flow target reduction. Model results are summarized in Table 4.

Based on the model results, additional CPv stormwater controls will be required to meet the Town of Rutland's allocated portion of the high flow reduction target. Biomonitoring of Moon Brook will ultimately determine when the stream has reached attainment conditions, but the minimal modeled high flow reduction with existing BMPs suggests that additional stormwater controls will be needed.

Table 4. Post-2002 BMPDSS model assessment results

Owner	Target High Flow $Q_{0.3}$ (± %) Reduction	High Flow $Q_{0.3}$ (± %) Reduction Achieved with Post-2002 Model	High Flow $Q_{0.3}$ (± %) Reduction Remaining with Post-2002 Model	High Flow ($Q_{0.3}$) Target addressed (%)
Rutland City	-9.02%	-0.52%	-8.5%	5.8%
Rutland Town	-2.82%	-0.19%	-2.63%	6.6%
VTrans	-0.06%	0.00%	-0.06%	0.0%
Watershed Total	**-11.90%**	**-0.71%**	**-11.19%**	**6.0%**

V. Required Controls Identification

Initial analyses utilizing GIS and remotely sensed data provided a basis for targeted field investigation. This process identified large, contiguous, unmanaged areas of impervious cover, existing stormwater infrastructure, town-owned parcels, and existing stormwater management features. Soils data provided by the Natural Resource Conservation Service and topographic data were also reviewed. A list of potential BMP locations was identified, and sites were investigated in the field to determine BMP feasibility.

Field investigations also involved documenting potential constructability issues, assessing site conditions, assessing natural resource concerns, determining utility conflicts, assessing ease of

operation and maintenance, and reviewing drainage areas. An in-depth engineering assessment will still be required at each site to confirm the presence or absence of utilities, natural resource constraints, and potential transportation impacts as part of the final design process. The BMPs were designed using the HydroCAD® model to meet the CPv storage criteria for cold waters (12-hour detention standard).

Ultimately, it was determined that eight of the assessed locations were appropriate for BMP implementation (Table 6). These BMPs included three gravel wetlands, three detention swales, and two outlet retrofits of existing detention systems. Though all projects are located in the Town of Rutland, the Randbury Road gravel wetland project is a joint project with VTrans. Project details, photos, and maps for all BMPs are included in Appendix A and Appendix B, and a brief summary of each BMP is located in Table 6. Concept level designs of the Randbury Road project can be found in Appendix G.

V.1 BMPDSS Model Assessment Results

Selection of the final proposed BMP list was an iterative process and a total of three BMPDSS Credit model runs were completed. The initial BMPDSS Credit model run (Credit 1) included one BMP, the Randbury Road project. The Credit 1 scenario did not achieve the Town of Rutland's allocated flow reductions required by the TMDL, only addressing 20.5% of the Town of Rutland's allocated high flow reduction target. As such, three additional BMPs were identified and added in a subsequent iteration of the model. These projects included the 4375-INDS Wynnmere pond retrofit, the VELCO / Carmel Place project, and the Hitzel Terrace project. Following this Credit 2 model run, a high flow reduction of 1.59% of the Town of Rutland's allocation target reduction of 2.82%, was modeled. This equates to 56% of the Town's target high flow reduction. As high flow reduction targets were still not met, a Credit 3 model run was completed. This model run included the remaining four projects: Cannon Drive, Industrial Park, North End Drive, and Nancy Lane. Following this model run, a high flow reduction of 2.72% was modeled, 1.89% of which was allocated to the Town of Rutland (Table 5). This reduction equates to 67% of the Town's high flow reduction target. All model runs are summarized in Appendix F.

As these BMPs were targeted within the Town of Rutland and excluded BMP placement in the City of Rutland, the total watershed-wide high flow reduction was only 2.72%, which is 22.9% of the watershed-wide high flow target.

Table 5. BMPDSS final BMPDSS Credit model summary for the proposed FRP scenario

Owner	Target High Flow $Q_{0.3}$ (± %) Reduction	High Flow $Q_{0.3}$ (± %) Reduction Achieved with Credit Model	High Flow $Q_{0.3}$ (± %) Reduction Remaining with Credit Model	High Flow ($Q_{0.3}$) Target addressed (%)
Rutland City	-9.02%	-0.72%	-8.3%	8.0%
Rutland Town	-2.82%	-1.89%	-0.93%	66.9%
VTrans	-0.06%	-0.11%	0.05%	189.5%
Watershed Total	**11.9%**	**-2.72%**	**-9.18%**	**22.9%**

V.2 Proposed FRP Model Scenario

The final recommended BMP list includes eight proposed BMPs (Table 6), and the proposed FRP scenario addresses 22.9**%** of the watershed-wide high flow target. As BMPs were not proposed for the City of Rutland at this time, it was not expected that this Credit scenario would achieve 100% of the Moon Brook TMDL high flow reduction targets. However, the BMPs proposed for the Town of Rutland managed 35% of the Town's impervious cover and address 67% of their allocated high flow reduction target. The remaining unmanaged impervious area in the Town of Rutland is low density and widely distributed. Any additional stormwater management would likely need to be addressed through distributed GSI. As such, the Credit 3 scenario described above was considered the most feasible for implementation by the Town. It is expected that 100% of the watershed-wide high flow target would be met if the City of Rutland chose to implement BMPs throughout their section of the watershed. The ultimate determination of when Moon Brook returns to its attainment condition will be made by the State, based on monitoring data or other relevant information (MS4 General Permit Sec. IV.J.3).

VI. Proposed Implementation Plan

The final list of proposed BMPs for the Town of Rutland are summarized in Table 6, including the impervious cover managed, drainage area, and CPv storage estimated by the HydroCAD® model. A map of the proposed BMP locations is included in Appendix A. Further details about each project can be found in Appendix B. The high flow target managed by BMP (%) based on managed impervious cover is also included in Table 6.

Table 6. Final proposed BMPs for the Moon Brook FRP

Site Name	MS4 Impervious Owner	Ownership of Land where BMP is Located	BMP Type	Permit #	Drainage Area (acres)	Impervious Cover Managed (acres)	% Impervious	% of Total Managed Impervious Cover in the Town of Rutland MS4	Runoff Channel Protection Volume (CPv) Storage (ac-ft)	Town of Rutland High Flow Target Managed by BMP (%)
4375-INDS - Wynnmere Pond Retrofit	Town of Rutland	Private	Outlet Retrofit	4375-INDS	17.3	3.7	21.1%	100%	0.55	9.8%
Cannon Dr	Town of Rutland	Town of Rutland	Gravel Wetland	No Permit	3.7	0.7	18.1%	100%	0.15	1.8%
Hitzel Terrace	Town of Rutland	Private	Outlet Retrofit	No Permit	67.2	9.4	14.0%	100%	1.03	25.2%
Industrial Park	Town of Rutland	Private	Gravel Wetland	No Permit	8.5	4.1	48.3%	100%	0.79	11.0%
N End Dr	Town of Rutland	VELCO	Detention Swale	No Permit	16.4	2.5	15.0%	100%	0.50	6.6%
Nancy Ln	Town of Rutland	VELCO	Detention Swale	No Permit	34.1	5.9	17.4%	100%	1.27	15.9%
Randbury Rd	VTrans/ Town of Rutland	VTrans/ Town of Rutland/ Private	Gravel Wetland	New Road Project (Construction Permit)	23.1	11.0	47.6%	80%	0.86	23.7%
VELCO / Carmel Place	Town of Rutland	VELCO	Detention Swale	No Permit	21.3	2.3	10.6%	100%	0.62	6.1%

VII. Design and Construction Schedule

A design and construction (D&C) schedule was developed to provide a long term plan for the implementation of the FRP. The eight projects were spaced out over the timeframe in eight separate, 2-year phases. The timeline provides for design, acquisition of necessary permits, regulatory approvals, acquisition of necessary land, and actual construction. The flow restoration targets are subject to adjustment by the Secretary, based on biological monitoring data or other confounding information concerning high flow reduction progress. Adjustments to the flow targets may impact the schedule and full implementation of the proposed projects. The D&C is a working document and will be revised based on new information regarding the projects and stream conditions.

The projects were scheduled based on the ease of construction as well as the benefit of the individual BMP based on the relative impervious cover managed by that BMP. The two retrofits of existing BMPs were scheduled first as it was assumed that these projects would provide a significant benefit to the watershed while costs and construction complexity remain low. This allows time for the Town of Rutland to plan for the construction of the remaining five BMPs where the Town is the sole impervious cover owner. These projects, which are more expensive to construct and will require more extensive engineering and design, were ranked based on relative impervious cover managed. The final project, Randbury Road, is not scheduled until 2032 as this is the timeframe that VTrans has agreed to for this project and cooperation from VTrans is required for the construction of this BMP. The proposed implementation schedule and cost per implementation phase can be found in Table 7.

Table 7. Implementation schedule for proposed BMPs

Site Name	MS4 Impervious Owner	Ownership of Land where BMP is Located	BMP Type	Permit #	Impervious Cover Managed (acres)	Runoff Channel Protection Volume (CPv) Storage (ac-ft)	Town of Rutland High Flow Target Managed (%)	Estimated Cost (Rounded to Nearest $1,000)	Estimated Cost for Town of Rutland with Cost Share	Implementation Year
Hitzel Terrace	Town of Rutland	Town of Rutland	Outlet Retrofit	No Permit	9.4	1.03	25.2%	$14,000	$14,000	2018
4375-INDS - Wynnmere Pond Retrofit	Town of Rutland	Private	Outlet Retrofit	4375-INDS	3.7	0.55	9.8%	$10,000	$10,000	2020
Nancy Ln	Town of Rutland	VELCO	Detention Swale	No Permit	5.9	1.27	15.9%	$133,000	$133,000	2022
Industrial Park	Town of Rutland	Private	Gravel Wetland	No Permit	4.1	0.79	11.0%	$307,000	$307,000	2024
N End Dr	Town of Rutland	VELCO	Detention Swale	No Permit	2.5	0.50	6.6%	$52,000	$52,000	2026
VELCO / Carmel Place	Town of Rutland	VELCO	Detention Swale	No Permit	2.3	0.62	6.1%	$65,000	$65,000	2028
Cannon Dr	Town of Rutland	Town of Rutland	Gravel Wetland	No Permit	0.7	0.15	1.8%	$130,000	$130,000	2030
Randbury Rd	VTrans/ Town of Rutland	Private	Gravel Wetland	New Road Project (Construction Permit)	11.0	0.86	23.7%	$316,000	$237,000	2032
Watershed Total					**39.5**			**$1,027,000**	**$948,000**	

VIII. Financial Plan

Planning level costs were estimated for each project using a consistent spreadsheet-based method. A cost-share allocation was calculated for the Randbury Road project due to joint MS4 contributions. As of now, the Town of Rutland does not have a separate funding source for stormwater related costs. The stormwater program is funded from the general tax, which is pooled for the Town's Public Works Department. The Town is in the process of developing their stormwater program and regulations in the upcoming year, which will determine how they will fund the FRP projects. Several additional funding sources that may be available for larger projects, which may need to be phased over several years, include the Clean Water State Revolving Fund program and municipal bond bank funds.

VIII.1 BMP Cost Estimates:

A spreadsheet-based method, originally developed by the Horsley-Witten (HW) Group, was used to develop planning level costs for all proposed BMPs. The methodology was used in the development of the Centennial Brook FRP and provides consistent cost estimates for each BMP within the watershed (see HW Memo in Appendix H). It is expected that these costs will change as further designs are completed and site conditions and constraints are better understood. Cost estimates are based on limited site investigation, but are useful for planning purposes. All estimates presented are based on 2014 dollars.

VIII.1.1 Cost-Share Allocation

A cost-share was calculated for the Randbury Road project, which manages impervious cover owned by both the Town of Rutland and VTrans. A concept plan was developed for this project (Appendix G). This cost-share was determined using a combination of the percent runoff contribution and percent impervious surface ownership managed within the BMP drainage area. The runoff managed was determined by site-specific HydroCAD models. The percent impervious was determined through GIS using 2011 impervious cover mapping published by the Lake Champlain Basin Program. An average of the percent runoff volume generated and the impervious cover managed by MS4 was taken. The average was rounded to the nearest quarter, and the cost was allocated based on this percent. The cost-share allocation applied provides one example for how these two MS4s can share the financial responsibility for this project. The cost breakdown is summarized in Table 8.

Table 8. A potential cost-share for the Randbury Rd project by MS4

Total Cost: $356,000		
	VTrans	**Town of Rutland**
Runoff Volume 1-Year (ac-ft)	0.4	0.5
Percent Runoff Volume	45%	55%
Impervious Acres	2.2	8.8
Percent Impervious	20%	80%
Percent Cost Allocation	32%	68%
Cost Allocation Rounded to Nearest 25%	**25%**	**75%**
Cost Share	**$ 89,000**	**$ 267,000**

VIII.1.2 Cost Estimate Calculations

The BMP cost estimation is based on the design control volume as determined by HydroCAD models developed for each site, unit costs that take into account the type of BMP, a site adjustment factor that takes into account the difficulty of construction based on present development at a location, a factor for the design and permitting of the BMP, and a land acquisition cost.

Base unit costs were dependent on the type of BMP proposed, as well as the area of the BMP. For example, a detention basin's base cost would be $2 per ft^3 (Table 9 upper). Depending on the type of site where the BMP will be constructed, a cost multiplier was used with more constricted and developed sites assumed to increase construction complexity and cost (Table 9 lower).

Table 9. Unit costs and adjustment factors for each BMP type

BMP Type	Base Cost ($/$ft^3$)
Detention Basin	$2
Infiltration Basin	$4
Underground Chamber (infiltration or detention)	$12
Bioretention	$10
Green Infrastructure/ Underground Chamber Combo	$22
Site Type	Cost Multiplier
Existing BMP retrofit	0.25
New BMP in undeveloped area	1
New BMP in partially developed area	1.5
New BMP in developed area	2
Adjustment factor for large aboveground basin projects	0.5

Final costs were also influenced by a number of other factors. These include:

- Base Construction Cost: Calculated as the product of the design control volume, the unit cost, and the site adjustment factor.
- Permits and Engineering Costs: A cost multiplier of either 20% for large storage volume projects, or 35% for small or complex projects was applied.
- Land Acquisition Costs (modified from the HW method): For projects that require the acquisition of private land, a variation from the HW method was applied. An approximate land acquisition cost of $120,000 was applied per acre required for the BMP. 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. This cost was then rounded to the nearest $1,000.
- 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 (O&M): The annual O&M was calculated as 3% of the base construction costs. A maximum of $10,000 was used.
- Minimum Cost Adjustment: This methodology tends to underestimate the cost of small retrofits, so a minimum project cost of $10,000 was applied for a simple, small project such as an outlet retrofit, and a minimum cost of $25,000 was applied for more complex projects.

VIII.1.3 BMP Cost Estimates

The total cost for implementation of the FRP projects for the Town of Rutland was determined to be $948,000. This total assumes a cost-share for the joint-MS4 project (Randbury Road, Table 8). This is an approximate estimate and is subject to change based on more refined design and cost-sharing agreements. Table 10, below, includes a summary of the project cost estimates. The worksheet used to develop cost estimates for each proposed BMP is included in Appendix C.

Table 10. Cost estimates for proposed BMPs

Project Name	Retrofit Type	Impervious Area (acres)	Design Control Volume (ac-ft)	Base Unit Cost ($/cft)	Site Adjustment Factor	Minimum Project Cost ($10k for simple retrofits; $25k otherwise)	Final Project Cost Rounded to Nearest $1,000	% of Impervious within the Town of Rutland MS4	Town of Rutland Cost Share	Cost/ Impervious Acre	O&M
4375-INDS - Wynnmere Pond Retrofit	Outlet Retrofit	17.3	0.11	$2	0.25	$10,000	$10,000	100%	$10,000	$166	$72
Hitzel Terrace	Outlet Retrofit	67.2	0.55	$2	0.25	$10,000	$14,000	100%	$14,000	$212	$356
VELCO / Carmel Place	Detention Swale	21.34	0.62	$2	1	$25,000	$65,000	100%	$65,000	$3,047	$1,626
N End Dr	Detention Swale	16.4	0.50	$2	1	$25,000	$52,000	100%	$52,000	$3,185	$1,309
Nancy Ln	Detention Swale	34.1	1.27	$2	1	$25,000	$133,000	100%	$133,000	$3,888	$3,314
Randbury Rd	Gravel Wetland	23.1	0.86	$10	0.5	$25,000	$316,000	75%	$237,000	$9,671	$5,587
Industrial Park	Gravel Wetland	8.5	0.79	$10	0.5	$25,000	$307,000	100%	$307,000	$27,389	$5,162
Cannon Dr	Gravel Wetland	3.7	0.15	$10	1.5	$25,000	$130,000	100%	$130,000	$34,931	$2,881
Total:							**$1,027,000**		**$948,000**		

IX. Regulatory Analysis

The Town of Rutland intends to incorporate the two expired permits in the MBW into the Town's MS4 permit. The Town has not yet worked out details of this transfer with homeowners covered under these two permits, so the possibility does exist that the Town may ask the State to issue a Residual Designation Authority permit in the future if this incorporation process fails. A description of both expired permits in the Town of Rutland with discharges to Moon Brook is included in Table 3.

X. Glossary of Terms

A glossary of relevant terms is provided below.

Best Management Practice (BMP)- Generally, BMPs are defined as, "schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the pollution of waters of the State and waters of the United States. BMPs also include treatment requirements, operating procedures, and practices to control runoff, spillage or leaks, sludge or waste disposal, or drainage from raw material storage" (MS4 Permit, 2012). In the context of the FRP, BMPs include prescribed stormwater flow control practices as defined in the computer-based BMPDSS model, in which various BMPs scenarios can be assessed.

Best Management Practice Decision Support System (BMPDSS)- A computer-based hydrologic model used to assess the impact of various stormwater BMP scenarios. This tool was developed by a private consultant for the VT DEC to use as the assessment tool for compliance with the Stormwater TMDLs.

Channel Protection Volume (CPv)- The stormwater volume generated from the 1-year, 24-hour rainfall event. The Vermont Stormwater CPv Design Standard requires 24 hours of extended detention storage of the CPv in warm water fish habitat and 12 hours for cold water fish habitat as a means to reduce channel erosion.

Detention BMP- A BMP (e.g. detention pond) which stores stormwater for a defined length of time before it eventually drains to the receiving water body. Stormwater is not retained in the practice long term. The objective with a detention BMP is to reduce the peak discharge (Q_p) from the basin in the effort to reduce channel erosion and settle out pollutants from the stormwater.

Flow Duration Curve (FDC)- An FDC is a curve displaying the percentage of time during a period that flow exceeds a certain value, with the low flow represented by the 95th percentile ($Q_{95\%}$) of the curve, and the high flow represented by the 5th percentile ($Q_{0.3\%}$).

Flow Restoration Plan (FRP)- The FRP is a required element of the MS4 General Permit #3-9014, under section IV. C. 1., for stormwater discharges to impaired waters. The FRP is a 20-year implementation plan of stormwater flow control BMPs to meet the TMDL high flow target and return the impaired water to its attainment condition. The FRP is required to include a list of stormwater BMP controls, as well as modeling results from the VT BMPDSS model demonstrating compliance of the approved TMDL flow target with the proposed BMP list.

Infiltration BMP- A BMP that allows for the infiltration of stormwater into the subsurface soil as groundwater, which returns to the stream as baseflow. Mapped soils of Hydrologic group A or B (sandy, well-drained soils) are an indicator of infiltration potential. Infiltration reduces the

amount of surface storage required. Typical BMP practices include infiltration basins, underground chamber systems, bioretention practices, and others.

Non-Jurisdictional Impervious- Non-jurisdictional impervious area is impervious cover that does not require a stormwater permit and is not managed by a stormwater BMP (impervious growth < 1 acre).

Residual Designation Authority (RDA)- The RDA permit is separate from the MS4 permit, held by the private landowner.

Stormwater Management Plan (SWMP)- A comprehensive program to manage stormwater discharges from the Municipal Separated Storm Sewer System as mandated by the MS4 General Permit #3-9014.

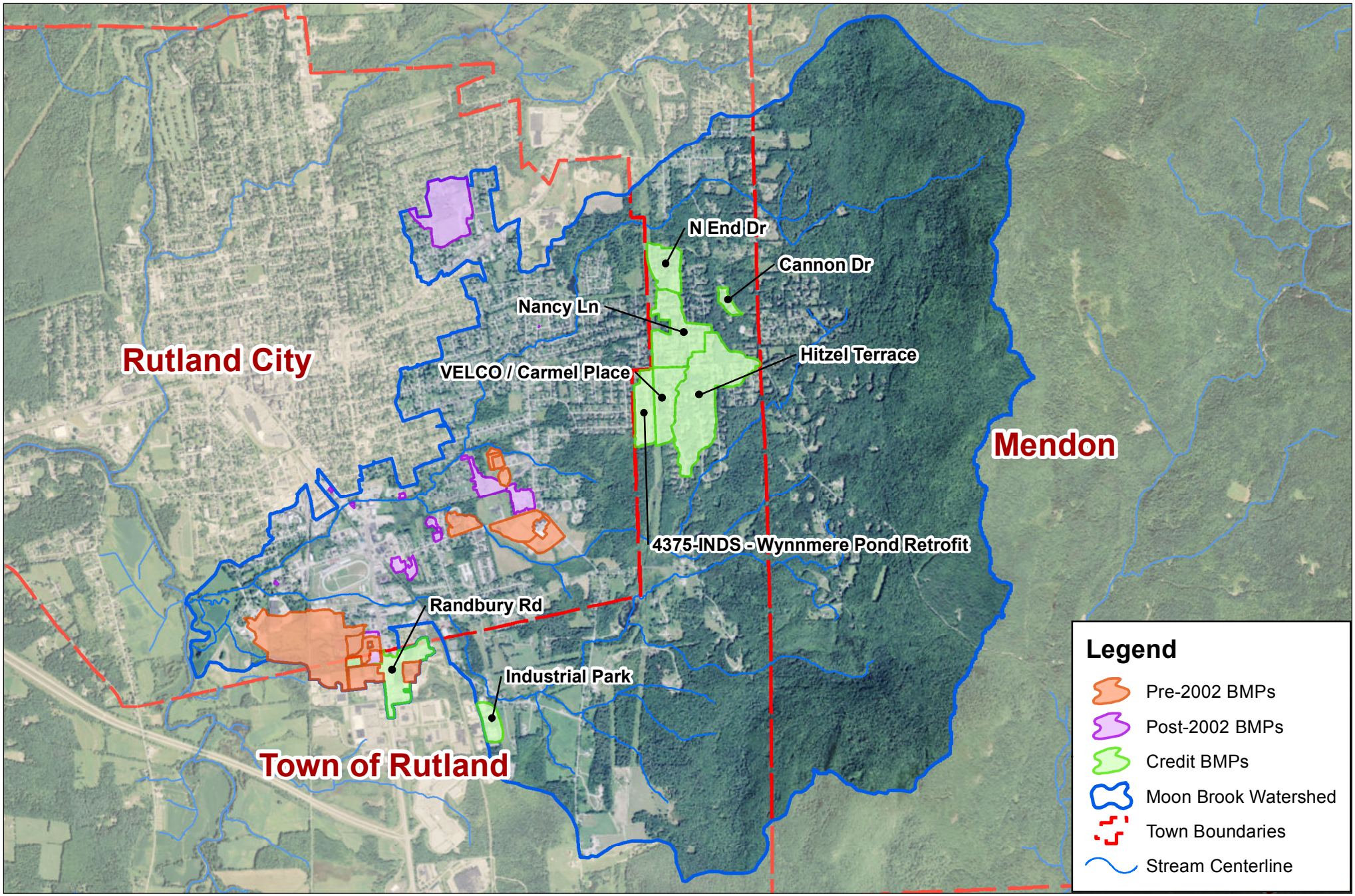
Stormwater TMDL- Vermont developed stormwater Total Maximum Daily Loads (TMDLs) for impaired watersheds using stormwater flow as a surrogate for pollutants. The basis for the flow-based TMDL is the understanding that stormwater is the source of pollutant loading. Therefore, minimizing stormwater flows will reduce pollutant loading to the streams and Lake Champlain. The approved TMDL requires a reduction in high flows, defined as greater than the 1-year storm event. The TMDL also includes a non-actionable (not enforced) low flow target, which is measured by an increase in stream baseflow (groundwater flow to streams).

Total Maximum Daily Load (TMDL)- A TMDL is a calculation of the maximum pollutant loading that a water body can accommodate and still meet Vermont Water Quality Standards. The term TMDL also refers to the regulated management plan, which defines how the water body will be regulated and returned to its acceptable condition, including the maximum loading, sources of pollution, and criteria for determining if the TMDL is met.

TMDL High Flow Target- The TMDL target defined as the percent change between the Pre-2002 (baseline) condition and the Post-2002 (existing) high flow. The high flow is the flow rate in the stream that is exceeded 0.3% of the time ($Q_{0.3\%}$) over a 10-year simulation period. The $Q_{0.3\%}$ has been equated to the 1-year design storm runoff.

TMDL Low Flow Target- The non-actionable TMDL target defined as the percent change between the Pre-2002 (baseline) condition and the Post-2002 (existing) low flow. The low flow is the flow rate in the stream that is exceeded 95% of the time ($Q_{95\%}$), over a 10-year simulation period. The $Q_{95\%}$ is considered baseflow, which is the flow in a stream fed by groundwater.

XI. Appendices



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0 0.25 0.5 Miles

Proposed and Existing Stormwater BMPs
Moon Brook Watershed

WATERSHED CONSULTING ASSOCIATES, LLC

Map Produced: 9/23/2016

Moon Brook FRP BMP Summary Sheet

Site name:	4375-INDS - Wynnmere Pond Retrofit		
MS4 Impervious Owner	Town of Rutland	**Ownership of Land where BMP is Located**	Private
Proposed BMP type:	Outlet Retrofit		

Proposed BMP description:

The Wynnmere Senior Housing Project on Killington Avenue (expired permit #4375-INDS) consists of a series of catchbasins and swales that drain to a detention pond. Though the pond meets the 2002 Vermont Stormwater Design Standards, it was determined that the pond has capacity for additional detention to maximize flow control. The retrofit would involve raising the outlet structure to increase Channel Protection storage by 0.11 acre-feet. Survey should be completed to verify outlet inverts and detention capacity prior to implementation.

Proposed BMP details

Permit #	4375-INDS
Drainage area (acres)	17.33
Impervious area managed (acres)	3.65
Impervious cover managed (% of drainage area)	21%
Town of Rutland Impervious Cover Managed (acres)	3.65
Town of Rutland Impervious Cover Managed (% of Managed Impervious Cover)	100%
Runoff Channel Protection Volume (CPv) Storage (ac-ft)	0.55
Town of Rutland High-Flow Target Managed (%)	9%
Estimated Cost (Rounded to Nearest $1,000)	$10,000
Implementation Year	2020

Site map

Site photo

View of existing detention pond.

Moon Brook FRP BMP Summary Sheet

Site name:	Cannon Dr		
MS4 Impervious Owner	Town of Rutland	**Ownership of Land where BMP is Located**	Town of Rutland
Proposed BMP type:	Gravel Wetland		

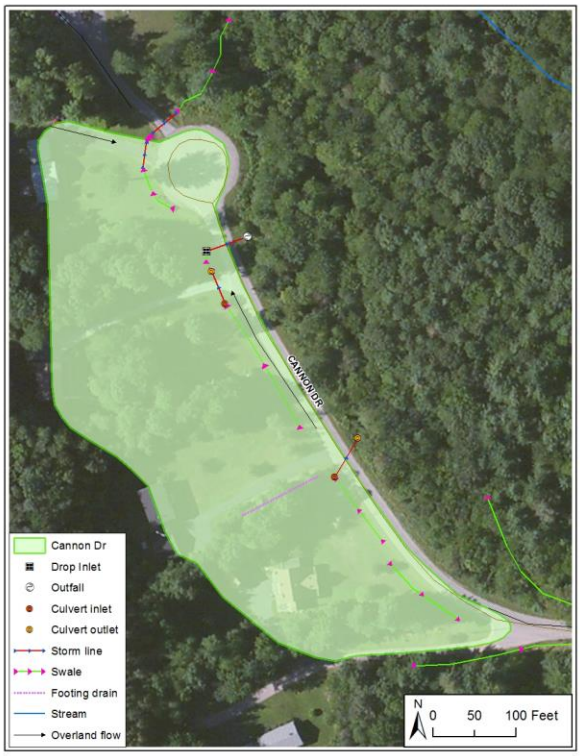
Proposed BMP description:

Currently, a large area of impervious cover exists in the cul-de-sac at the end of Cannon Dr. This much impervious cover is not necessary to accommodate traffic turning around at the end of this residential low traffic street. As such, it is proposed that with the exception of a strip of driveable pavement around the outer edge of the cul-de-sac, the impervious cover be removed and the stormline from the west side of the road rerouted to a gravel wetland in the center of this currently paved cul-de-sac.

Proposed BMP details

Permit #	No Permit
Drainage area (acres)	3.71
Impervious area managed (acres)	0.67
Impervious cover managed (% of drainage area)	18%
Town of Rutland Impervious Cover Managed (acres)	0.67
Town of Rutland Impervious Cover Managed (% of Managed Impervious Cover)	100%
Runoff Channel Protection Volume (CPv) Storage (ac-ft)	0.15
Town of Rutland High-Flow Target Managed (%)	2%
Estimated Cost (Rounded to Nearest $1,000)	$130,000
Implementation Year	2030

Site map



Site photo

View of proposed BMP location where impervious cover will be removed.

Moon Brook FRP BMP Summary Sheet

Site name:	Hitzel Terrace		
MS4 Impervious Owner	Town of Rutland	**Ownership of Land where BMP is Located**	Town of Rutland
Proposed BMP type:	Outlet Retrofit		

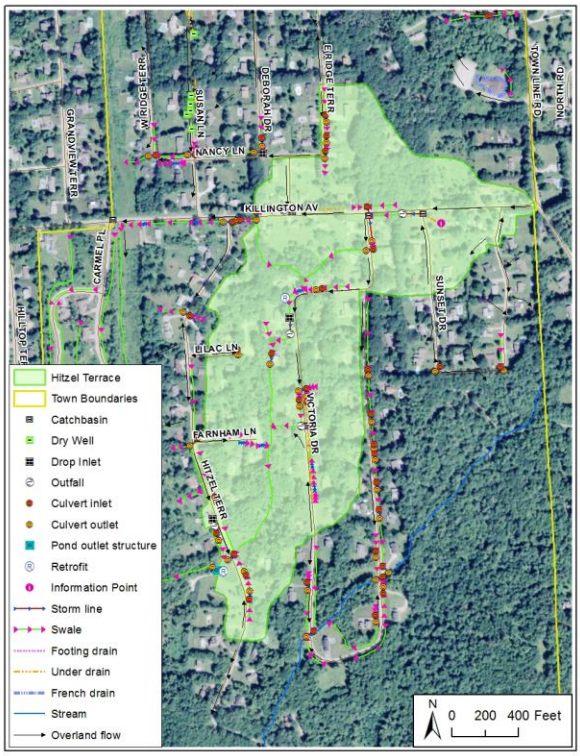
Proposed BMP description:

The town owned parcel along Hitzel Terrace is a natural wetland area which currently provides some level of stormwater detention and peak-flow attenuation. The proposed project would involve retrofitting the existing culvert under Hitzel Terrace with a low-flow outlet structure to allow for additional ponding and detention of stormwater in the town owned area. The proposed retrofit would not increase flow to the existing downstream privately owned pond. The State Wetlands Ecologist determined this area to be a Class III Wetland, so wetlands are not a limiting factor for construction. The U.S. Army Corps project manager determined this site may qualify as Category 1 of the VT General Streams Alteration Permit, so only a self-verification form would be required.

Proposed BMP details

Permit #	No Permit
Drainage area (acres)	67.24
Impervious area managed (acres)	9.39
Impervious cover managed (% of drainage area)	14%
Town of Rutland Impervious Cover Managed (acres)	9.39
Town of Rutland Impervious Cover Managed (% of Managed Impervious Cover)	100%
Runoff Channel Protection Volume (CPv) Storage (ac-ft)	1.03
Town of Rutland High-Flow Target Managed (%)	24%
Estimated Cost (Rounded to Nearest $1,000)	$14,000
Implementation Year	2018

Site map



Site photo

View of natural detention area from Hitzel Terrace Road, just south of site.

Moon Brook FRP BMP Summary Sheet

Site name:	Industrial Park		
MS4 Impervious Owner	Town of Rutland	**Ownership of Land where BMP is Located**	Private
Proposed BMP type:	Gravel Wetland		

Proposed BMP description:

Runoff from a large section of this industiral park currently flows north via a swale through the wooded area to the east of the buildings and enters the stream untreated. A gravel wetland is proposed to capture this runoff prior to the stream and outside of the river corridor.

Proposed BMP details	
Permit #	No Permit
Drainage area (acres)	8.48
Impervious area managed (acres)	4.10
Impervious cover managed (% of drainage area)	48%
Town of Rutland Impervious Cover Managed (acres)	4.10
Town of Rutland Impervious Cover Managed (% of Managed Impervious Cover)	100%
Runoff Channel Protection Volume (CPv) Storage (ac-ft)	0.79
Town of Rutland High-Flow Target Managed (%)	10%
Estimated Cost (Rounded to Nearest $1,000)	$307,000
Implementation Year	2024

Site map

Site photo

View of impervious area that will be managed with this proposed BMP, which is located just south of this location.

Moon Brook FRP BMP Summary Sheet

Site name:	N End Dr		
MS4 Impervious Owner	Town of Rutland	**Ownership of Land where BMP is Located**	VELCO
Proposed BMP type:	Detention Swale		

Proposed BMP description:

Adjacent to the power lines, just west of N End Drive, a BMP is proposed. BMP would require amending the existing soil in a long vegetated swale with periodic stone check dams to detain the 1-yr design storm. A concrete weir is proposed at the outlet of the channel to control overflow. The culvert can be rerouted at the north end of David Road to the west along N End Dr. This project would require approval by VELCO.

Proposed BMP details

Permit #	No Permit
Drainage area (acres)	16.44
Impervious area managed (acres)	2.47
Impervious cover managed (% of drainage area)	15%
Town of Rutland Impervious Cover Managed (acres)	2.47
Town of Rutland Impervious Cover Managed (% of Managed Impervious Cover)	100%
Runoff Channel Protection Volume (CPv) Storage (ac-ft)	0.50
Town of Rutland High-Flow Target Managed (%)	6%
Estimated Cost (Rounded to Nearest $1,000)	$52,000
Implementation Year	2026

Site map

Site photo

View from west of N End Dr of the proposed BMP area, which will run adjacent to the power lines.

Moon Brook FRP BMP Summary Sheet

Site name:	Nancy Ln		
MS4 Impervious Owner	Town of Rutland	**Ownership of Land where BMP is Located**	VELCO
Proposed BMP type:	Detention Swale		

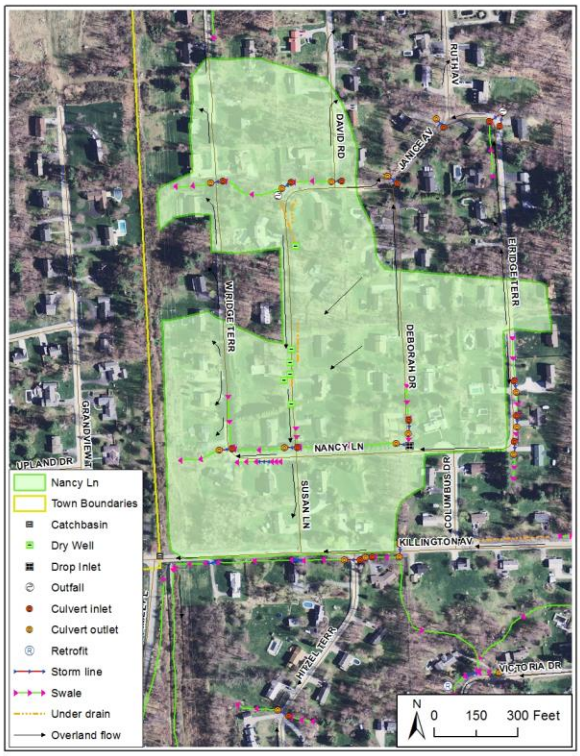
Proposed BMP description:

Adjacent to the power lines, just west of Nancy Lane, a BMP is proposed. BMP would require amending the existing soil in a long vegetated swale with periodic stone check dams to detain the 1-yr design storm. A concrete weir is proposed at the outlet of the channel to control overflow. Two swales would need to be rerouted to this BMP - one along Janice Ave currently draining to the north of the proposed BMP and another along Killington Ave. This project would require approval by VELCO.

Proposed BMP details

Permit #	No Permit
Drainage area (acres)	34.10
Impervious area managed (acres)	5.92
Impervious cover managed (% of drainage area)	17%
Town of Rutland Impervious Cover Managed (acres)	5.92
Town of Rutland Impervious Cover Managed (% of Managed Impervious Cover)	100%
Runoff Channel Protection Volume (CPv) Storage (ac-ft)	1.27
Town of Rutland High-Flow Target Managed (%)	15%
Estimated Cost (Rounded to Nearest $1,000)	$133,000
Implementation Year	2022

Site map



Site photo

View from Killington Ave of the proposed BMP area, which will run adjacent to the power lines.

Moon Brook FRP BMP Summary Sheet

Site name:	Randbury Rd		
MS4 Impervious Owner	VTrans/ Town of Rutland	**Ownership of Land where BMP is Located**	Private
Proposed BMP type:	Gravel Wetland		

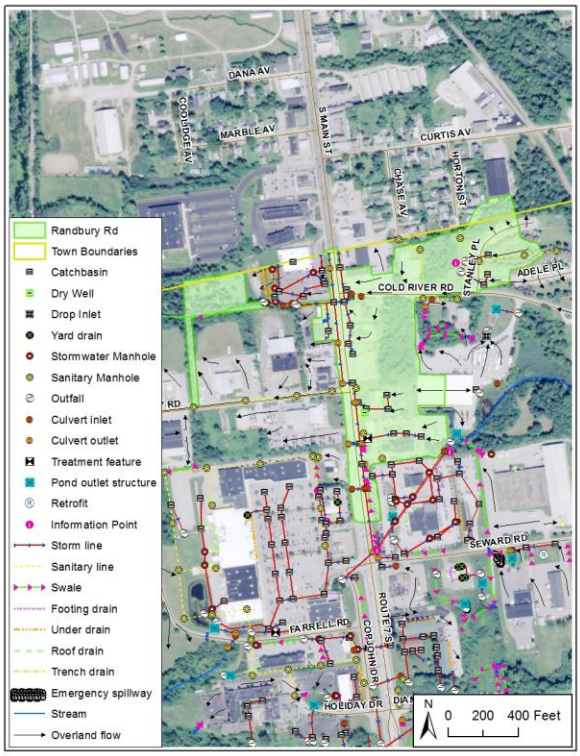
Proposed BMP description:

A gravel wetland is proposed behind the new Aldi Store along Route 7/ Cold River Rd. VTrans owns approximately 20% of the impervious cover managed by this BMP and thus should be engaged as a partner. This retrofit would also improve the highly eroded drainage ditch. The site is underlain by sandy soils, so infiltration of runoff may be possible. The State Fisheries Biologist determined this drainage ditch to be void of fisheries resources, so ditch alterations would be feasible. Design could align with the Town's re-development goals for the area including a new access road to ease traffic on Route 7, which would require a stormwater management regardless.

Proposed BMP details

Permit #	NP/ New Road Project (Construction Permit)
Drainage area (acres)	23.11
Impervious area managed (acres)	11.00
Impervious cover managed (% of drainage area)	48%
Town of Rutland Impervious Cover Managed (acres)	8.82
Town of Rutland Impervious Cover Managed (% of Managed Impervious Cover)	80%
Runoff Channel Protection Volume (CPv) Storage (ac-ft)	0.86
Town of Rutland High-Flow Target Managed (%)	28%
Estimated Cost (Rounded to Nearest $1,000)	$316,000
Implementation Year	2032

Site map



Site photo

Proposed BMP location, behind new Aldi Store along Cold River Road, Route 7

Moon Brook FRP BMP Summary Sheet

Site name:	VELCO / Carmel Place		
MS4 Impervious Owner	Town of Rutland	**Ownership of Land where BMP is Located**	VELCO
Proposed BMP type:	Detention Swale		

Proposed BMP description:

Adjacent to the power lines, just west of Carmel Place (Wynnmere Senior Housing Development) there is a naturally depressed area that collects runoff from homes along Victoria Drive and Killington Ave. The proposed BMP would consist of amending the existing soil in a 1,700 ft long vegetated swale with periodic stone check dams to detain the 1-yr design storm. A concrete weir is proposed at the outlet of the channel to control overflow. This project would require approval by VELCO.

Proposed BMP details

Permit #	No Permit
Drainage area (acres)	21.34
Impervious area managed (acres)	2.27
Impervious cover managed (% of drainage area)	11%
Town of Rutland Impervious Cover Managed (acres)	2.27
Town of Rutland Impervious Cover Managed (% of Managed Impervious Cover)	100%
Runoff Channel Protection Volume (CPv) Storage (ac-ft)	0.62
Town of Rutland High-Flow Target Managed (%)	6%
Estimated Cost (Rounded to Nearest $1,000)	$65,000
Implementation Year	2028

Site map

Site photo

View from Killington Ave of the proposed BMP area, which will run adjacent to the power lines.

Moon Brook FRP
9/23/2016
Appendix C. Proposed BMP cost estimate table

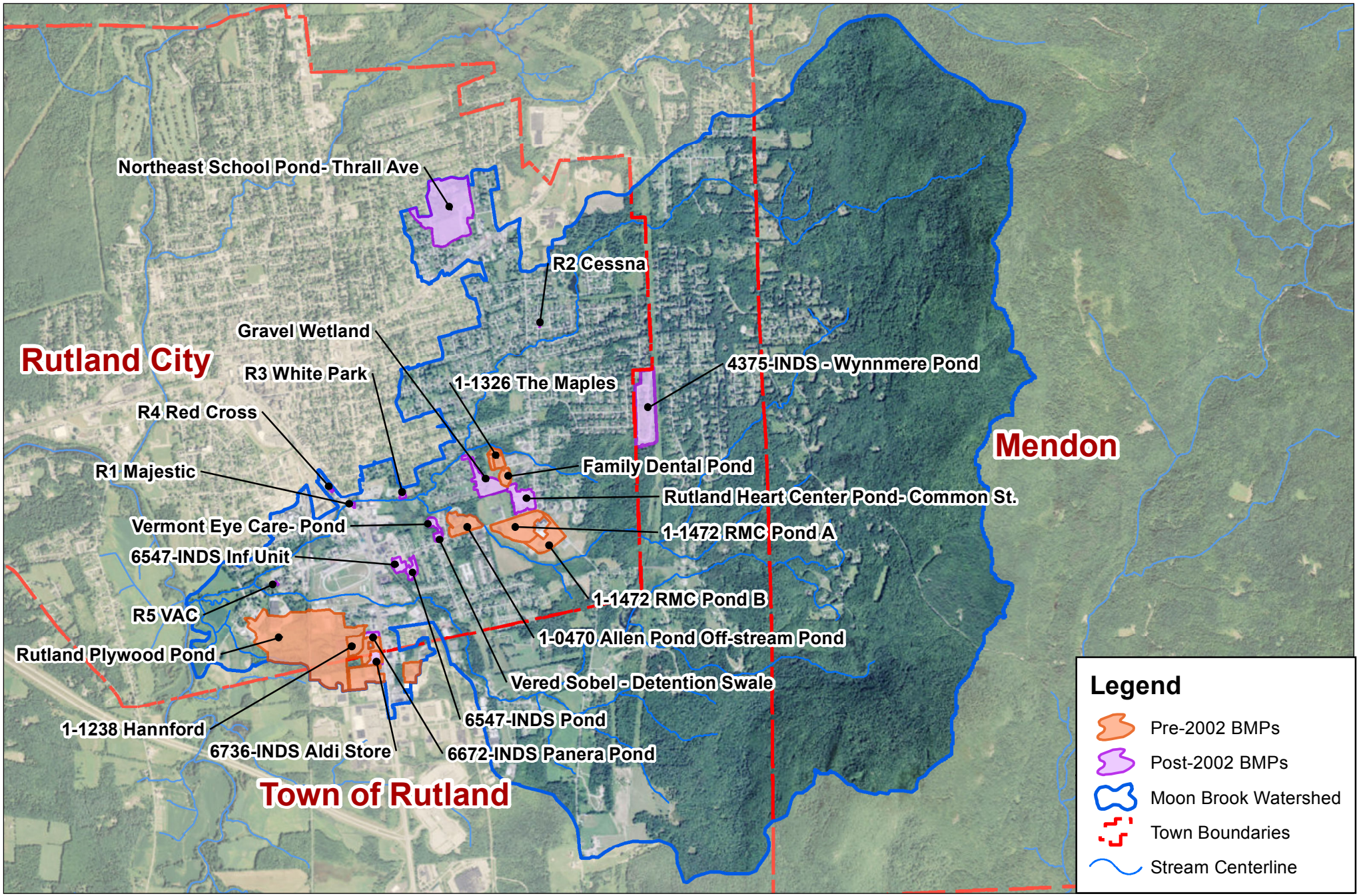
Project Name	Retrofit Description	Impervious Area (acres)	Design Control Volume (ac-ft)	Design Control Volume (cft)	Base Unit Cost ($/cft)	Site Adjustment Factor	Base Construction Cost	Permits & Engineering Contingency	BMP Footprint Area (Acres)[1]	Land Cost	Summed Project Cost	Minimum Project Cost ($10k for simple retrofits; $25k otherwise)	Final Project Cost	Final Project Cost Rounded to Nearest $1,000	% of Impervious within the Town of Rutland MS4	Town of Rutland Cost Share	Cost per Impervious Acre	O&M
4375-INDS - Wynnmere Pond Retrofit	Outlet Retrofit	17.3	0.11	4792	$2	0.25	$2,396	$479	--	$0	$2,875	$10,000	$10,000	$10,000	100%	$10,000	$166	$72
Hitzel Terrace	Outlet Retrofit	67.2	0.55	23740	$2	0.25	$11,870	$2,374	--	$0	$14,244	$10,000	$14,244	$14,000	100%	$14,000	$212	$356
VELCO / Carmel Place	Detention Swale	21.3	0.62	27094	$2	1	$54,189	$10,838	--	$0	$65,026	$25,000	$65,026	$65,000	100%	$65,000	$3,047	$1,626
N End Dr	Detention Swale	16.4	0.50	21824	$2	1	$43,647	$8,729	--	$0	$52,377	$25,000	$52,377	$52,000	100%	$52,000	$3,185	$1,309
Nancy Ln	Detention Swale	34.1	1.27	55234	$2	1	$110,468	$22,094	--	$0	$132,562	$25,000	$132,562	$133,000	100%	$133,000	$3,888	$3,314
Randbury Rd	Gravel Wetland	23.1	0.86	37244	$10	0.5	$186,219	$37,244	0.772	$92,640	$316,103	$25,000	$316,103	$316,000	75%	$237,000	$9,671	$5,587
Industrial Park	Gravel Wetland	8.5	0.79	34412	$10	0.5	$172,062	$60,222	0.624	$74,880	$307,164	$25,000	$307,164	$307,000	100%	$307,000	$27,389	$5,162
Cannon Dr	Gravel Wetland	3.7	0.15	6403	$10	1.5	$96,050	$33,617	--	$0	$129,667	$25,000	$129,667	$130,000	100%	$130,000	$34,931	$2,881
Total:													**$1,027,143**	**$1,027,000**		**$948,000**		

[1] This value is left as null if land acquisition will not be required for this project.

Moon Brook FRP
9/23/2016
Appendix D. Pre-2002 and Post-2002 BMPs

Site Name	MS4	Model Scenario	Drainage Area (Acres)	Impervious Area (Acres)	Impervious Area (%)
Rutland Plywood Pond	Rutland City	Pre-2002	83.03	24.44	29%
1-1472 RMC Pond A	Rutland City	Pre-2002	11.58	7.57	65%
1-1472 RMC Pond B	Rutland City	Pre-2002	7.41	5.22	70%
1-0470 Allen Pond Off-stream Pond	Rutland City	Pre-2002	6.64	3.05	46%
1-1238 Hannford	Rutland City	Pre-2002	3.57	2.80	79%
1-1326 The Maples	Rutland City	Pre-2002	3.29	2.40	73%
Family Dental Pond	Rutland City	Pre-2002	1.98	1.07	54%
Northeast School Pond- Thrall Ave	Rutland City	Post-2002	33.04	5.36	16%
Rutland Heart Center Pond- Common St.	Rutland City	Post-2002	6.47	3.93	61%
6736-INDS Aldi Store	Town of Rutland	Post-2002	1.97	1.88	95%
Gravel Wetland	Rutland City	Post-2002	7.28	1.19	16%
6672-INDS Panera Pond	Rutland City	Post-2002	1.06	0.93	88%
6547-INDS Inf Unit	Rutland City	Post-2002	2.02	0.82	40%
6547-INDS Pond	Rutland City	Post-2002	1.97	0.78	40%
Vered Sobel - Detention Swale	Rutland City	Post-2002	0.75	0.50	68%
R3 White Park	Rutland City	Post-2002	0.37	0.27	73%
Vermont Eye Care- Pond	Rutland City	Post-2002	1.32	0.22	17%
R1 Majestic	Rutland City	Post-2002	0.15	0.11	74%
R4 Red Cross	Rutland City	Post-2002	0.13	0.11	86%
4375-INDS - Wynnmere Pond[1]	Town of Rutland	Post-2002	17.33	3.65	21%
R5 VAC	Rutland City	Post-2002	0.09	0.06	75%
R2 Cessna	Rutland City	Post-2002	0.006	0.002	34%

[1] This project was proposed for a retrofit of the existing pond in the Credit model.



N

0 0.25 0.5 Miles

Pre-2002 and Post-2002 Stormwater BMPs

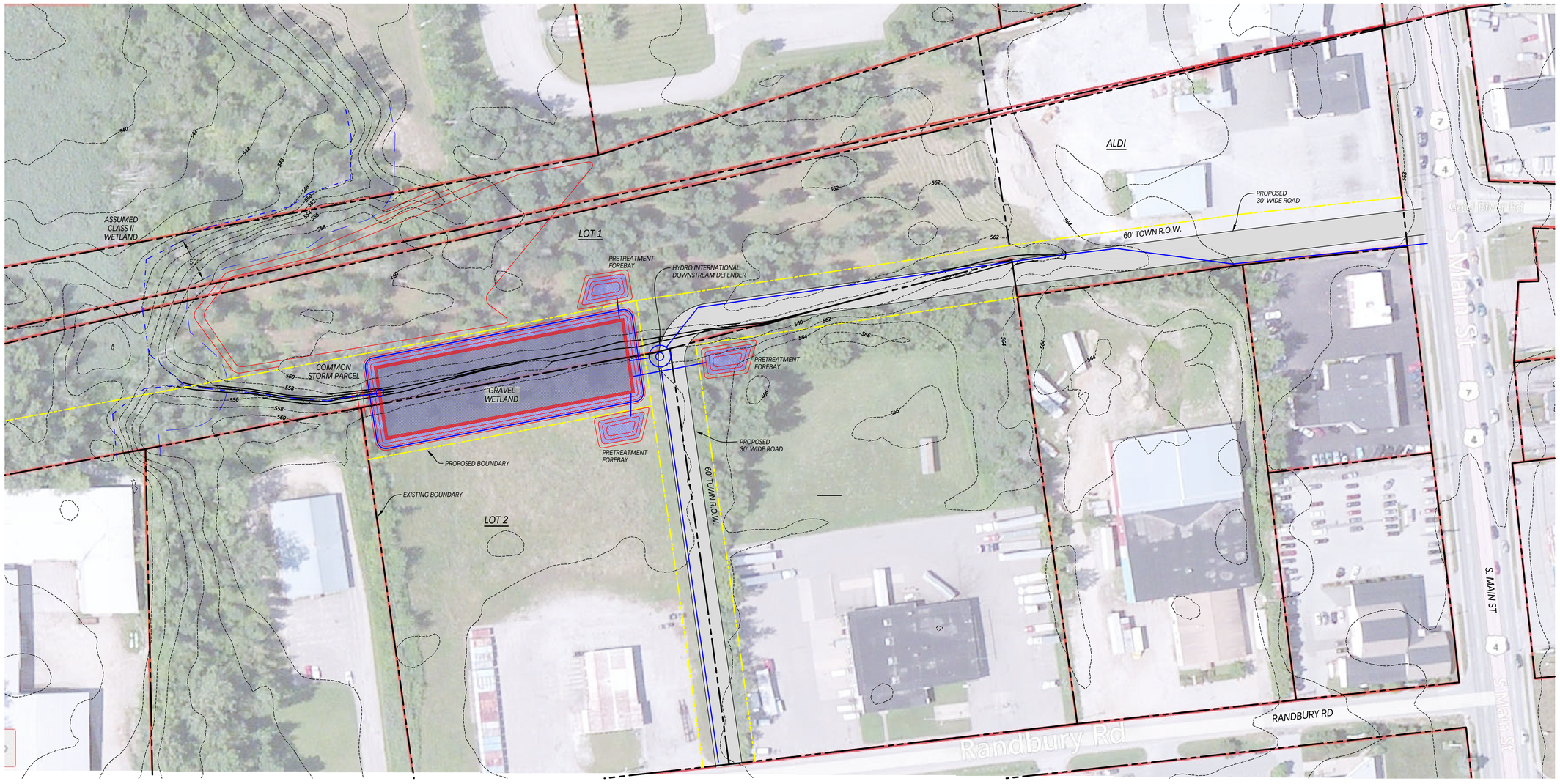
Moon Brook Watershed

WATERSHED CONSULTING ASSOCIATES, LLC

Map Produced: 9/23/2016

Moon Brook FRP
9/27/2016
Appendix F. BMPDSS Model Runs Summary Table

BMPDSS Model Run	BMPDSS Run Description	High Flow Target Q 0.3 Achieved (± %)	TMDL High Flow Target Managed (%)	Town of Rutland High Flow Target Managed (%)	Town of Rutland Percent of Target FRP Allocation Managed (%)	BMPDSS Run Date
--	*TMDL Target for Moon Brook*	*-11.90%*	----	*-2.82*	----	----
Post-2002	Existing Condition-Post2002 Revised	-0.71%	6.0%	-0.19%	6.6%	5/5/2014
Credit 1	Randbury Rd BMP	-1.37%	11.5%	-0.60%	20.5%	5/5/2014
Credit 2	Credit 1 + VELCO / Carmel Pl, and 4375-INDS Pond Retrofit, and Hitzel Terrace BMPs	-2.29%	19.2%	-1.59%	56.4%	5/5/2014
Credit 3	Credit 2 + Cannon Dr, Industrial Park, N End Dr, and Nancy Ln BMPs	-2.72%	22.9%	-1.89%	67.0%	9/27/2016



60 0 30 60 120 240

(IN FEET)
1 inch = 60 ft.

CONCEPT

VTRANS MOON BROOK FLOW RESTORATION PLAN

RUTLAND, VERMONT

RANDBURY ROAD BASIN

LAKESIDE ENVIRONMENTAL GROUP

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DRAWN BY:	ATS/SMS
CHECKED BY:	AT/ATS
APPROVED BY:	AT
DATE:	9-26-13
SCALE:	NOTED
SHEET:	1 OF 1

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tce TRUDELL CONSULTING ENGINEERS

MEMORANDUM

DATE: January 9, 2014

TO: Dan Albrecht; Megan Moir; Tom DiPietro; Jennifer Callahan; Bill Nedde, Linda Seavey, and Lani Ravin

FROM: Horsley Witten Group, Inc.

RE: Centennial Brook Watershed: Flow Restoration VTBMPDSS Modeling Analysis and BMP Supporting Information

This memorandum describes the basic approach used to model potential stormwater retrofits for the Centennial Brook Flow Restoration Plan (FRP) using the VT BMPDSS model. Modeling efforts have proven that is it difficult to meet the **63.0%** high flow reduction target required by the Centennial Brook TMDL. In fact, the percent flow reduction achieved under the proposed restoration scenario is **44.2%**. This reduction reflects management of 90% of the watershed impervious cover using all retrofits identified in the field and vetted with the MS4s. Under this scenario, UVM's existing Main St. and North Campus ponds would be modified from their current configuration to improve performance while maintaining 12-hr detention times and storage capacity for future development activities (only the proposed Colchester Ave. watershed expansion is incorporated into the model at this time).

Table 1 summarizes high flow reduction targets established by the TMDL, a revised target based on an analysis of future impervious cover, and the percent reduction achieved under the currently modeled VTBMPDSS restoration scenario. Figures 1-3 show impervious cover and drainage area maps for the proposed restoration scenario, including a zoom in of the proposed Colchester Avenue expansion.

Table 1. Summary of Percent Flow Reductions Achieved

Description		% High Flow Reduction	Managed IA (acres)	Planning Level Cost[5]
TMDL Reduction Targets	TMDL baseline with no agriculture.	49.9	--	--
	TMDL with no agriculture and 40 acres future, unmanaged impervious cover.	63.0	--	--
	TMDL with no agriculture and revised 5 acres of future, unmanaged impervious cover.[1]	51.5[2]	--	--
Current Conditions	All existing BMPs (revised ANR BMPDSS Credit Model)	14.8	106.1[3]	--
Proposed Flow Restoration Scenario	All primary and secondary retrofits; existing UVM facilities meeting 12-hr detention criteria and maintaining future use allocations; Colchester Ave watershed expansion included.[4]	44.2	243.7	$9,740,000

[1] Based on 2013 analysis conducted by CCRPC for Burlington and South Burlington.
[2] 51.5% = 49.9% baseline target + 5/40 acres future IA * 13.1% reduction target associated with future IA
[3] IA managed by post-2002 BMPs, which does not include Main Street and Queensbury ponds (based on most recently available GIS)
[4] One surface detention facility proposed in the VTrans right-of-way is designed to exceed 24-hr detention time.
[5] See cost section for more detail on planning level assumptions and costing analysis.

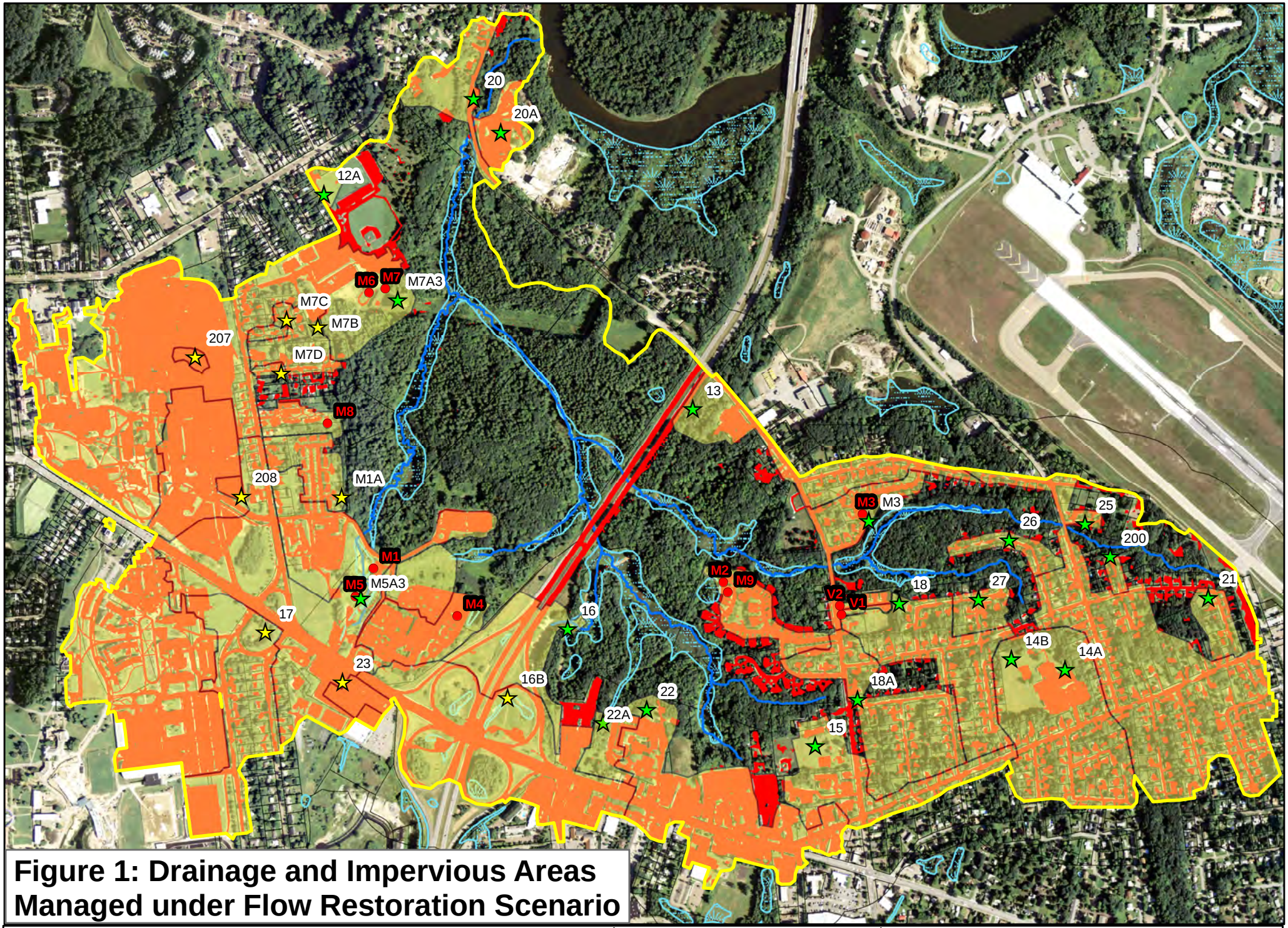

Figure 1: Drainage and Impervious Areas Managed under Flow Restoration Scenario

Legend

- Primary Retrofit
- Secondary Retrofit
- Retrofit DA
- Existing BMP
- stream
- Watershed
- Wetlands_SoBu
- Impervious Cover

N

Feet

1,000

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Horsley Witten Group
Sustainable Environmental Solutions

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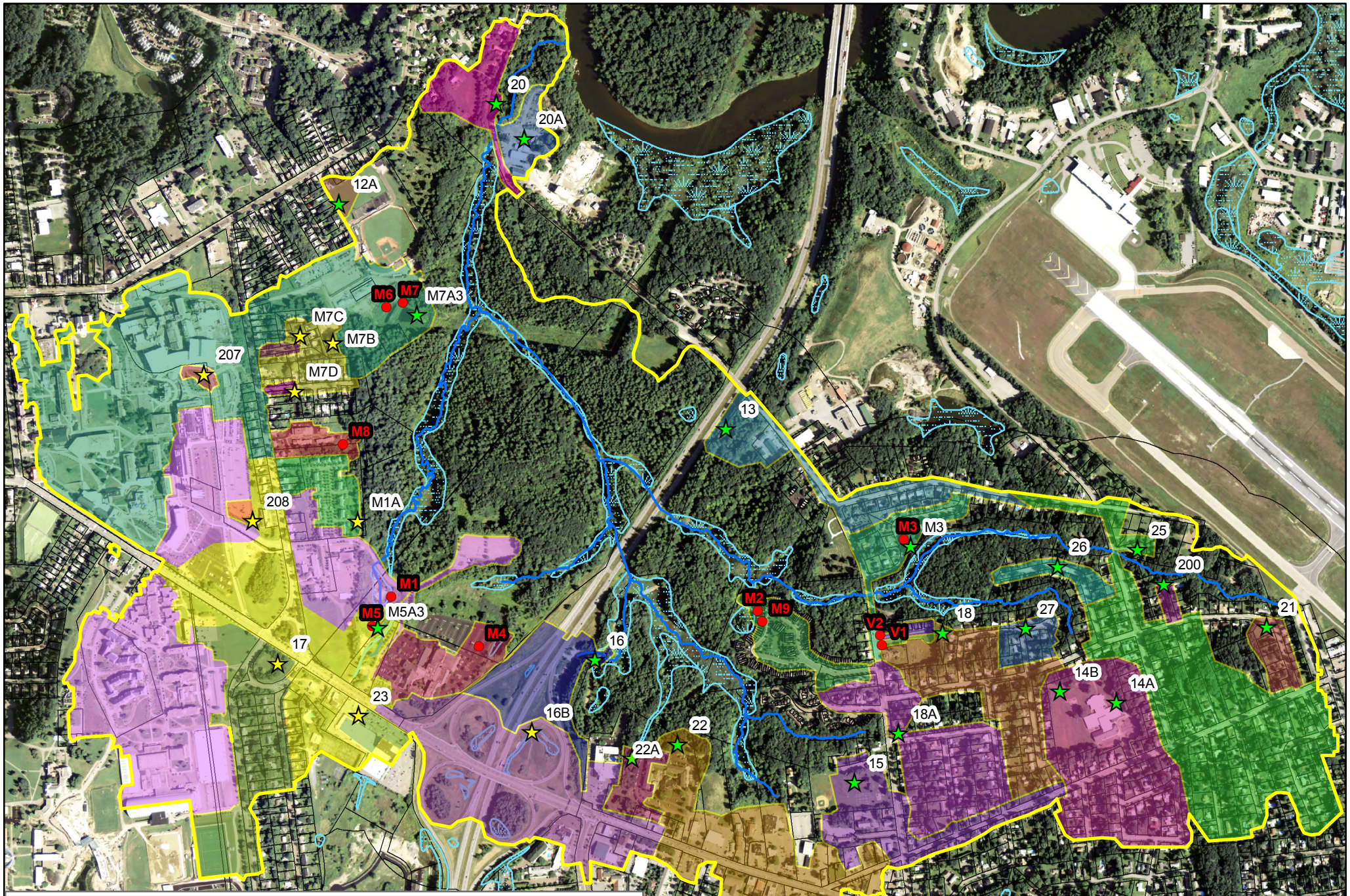

Figure 2: BMP Drainage Areas Managed under Flow Restoration Scenario

Legend

- Primary Retrofit
- Secondary Retrofit
- Retrofit DA
- Existing BMP
- stream
- Watershed
- Wetlands_SoBu
- Parcels

N

Feet

1,000

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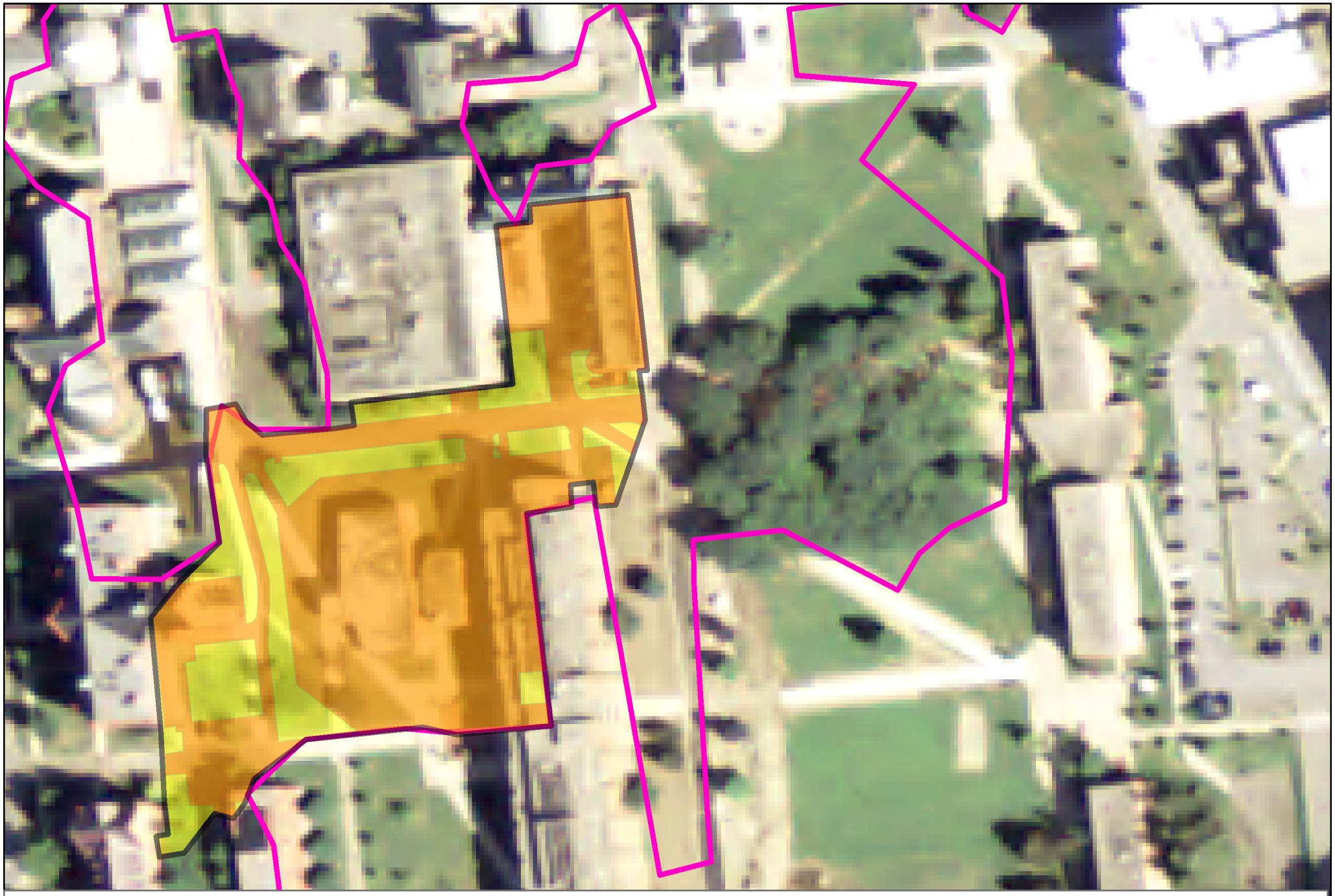

Figure 3. Colchester Ave. Proposed Watershed Expansion

Legend

- Colchester Ave Area
- Impervious Cover
- Existing Watershed Boundary

N

100 Feet

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General Conclusions

The restoration scenario presented here is not intended to represent the optimal implementation scenario proposed by the MS4s, rather it represents the maximum reduction all MS4s agree is achievable, regardless of cost considerations. Prior to moving forward with finalizing the flow restoration plan for Centennial Brook, the MS4s and the VT Agency of Natural Resources (ANR) may want to consider the following:

1. A detailed analysis was conducted by Chittenden County Regional Planning Commission in July, 2013 that refined the estimate of future, unregulated impervious cover to a more realistic estimate of 5 acres, rather than the 40 acres assumed in the TMDL. This change, if approved by ANR, would lower the high flow TMDL target from 63.0% to 51.5%.
2. Restoration activities other than the implementation of structural stormwater retrofits, such as tree planting, buffer enhancement, impervious cover reduction, or more stringent development requirements could potentially bridge the remaining gap for meeting the reduction target if a crediting mechanism was established.
3. Higher flow reductions are possible if surface detention time (center of mass) are relaxed in Centennial Brook; although modeling suggests that detention times >24 hrs for retrofits of existing and new ponds still cannot meet the 63% reduction target. If increased detentions times were allowed, future permitting of proposed development projects draining to those retrofitted facilities would also need to be considered.
4. The proposed retrofits with the most influence on flow reduction modeled at the watershed outlet include: Best Western (#22 at 13.6% relative reduction); North Campus Pond (M7A3 at 7.7%); Chamberlain School (#14 at 5.9%); and Picard Circle (#25 at 4.3%). The East Campus Pond (M1) contributes to 13.4% of the achieved flow reduction, though no retrofit of this facility is proposed. The Main St. pond retrofit's (M5A3) relative reduction was 3.4%. These "regional" storage facilities manage more impervious cover than the smaller on-site BMPs, which have less of an individual influence on reductions measured at the watershed outlet. Based on the results of the VTBMPDSS, the revised 51.5% flow reduction target can be met by extending detention times of the UVM ponds beyond 24 hours; however, since over-detention in these existing facilities was reported by Krebs and Lansing to significantly reduce UVM's future development opportunities, this retrofit option is not considered practical. Regardless, the 63% target was not reached under any modeling scenarios.
5. A number of secondary BMPs (practices within the drainage areas of primary sites) were identified as backup options in case primary sites become infeasible or are down-sized. None of the secondary practices are able to completely replace the relevant primary practice, however. The I-89 clover-leaf (16B) comes the closest, but is about ½ as effective as the primary BMP proposed at I-89 outfall (16). Currently, these secondary practices are included in the proposed restoration scenario in addition to the primary facilities to show the maximum amount of flow reduction deemed achievable, regardless of cost. Removing the secondary facilities from the restoration scenario will likely result in a very modest change the flow reduction at significant cost savings.
6. The VTBMPDSS model runs for Centennial Brook do not fully depict expected increases in low flow despite a substantial increase in annual infiltration volumes from the proposed infiltration BMPs. Under the proposed restoration scenario, 94 acres of impervious cover are directed to infiltration practices designed to infiltrate the 1-year storm. Using the Burlington rainfall record, a rough analysis of recharge from the impervious area runoff should yield approximately 22 inches/year.

This recharge should augment streamflow by approximately 0.24 cfs across the entire flow duration curve; however, the model predictions of increase in low flow from infiltration practices are only 0.02 cfs (an 8% increase over baseline conditions).

7. The planning level estimate of overall capital costs for the proposed flow restoration scenario modeled is $9,740,000.

The remainder of this memorandum provides more detailed information on the modeling analyses, BMP input information, and estimated construction costs. Additional supporting information submitted separately from, but in conjunction with, this memo includes:

- VTBMPDSS model runs for the revised baseline, the revised credit, and the proposed restoration scenario.
- GIS shapefiles used in each scenario, including updated impervious cover layer, BMP footprints, and other shapefiles created during this effort.
- HydroCAD models—created for all of the revised Credit BMPs and potential retrofits using HydroCAD version 10.00 for calibrating VTBMPDSS input;
- Spreadsheets—summarizing reductions, input variables, and cost estimates.

VTBMPDSS Modeling Analysis

The VTBMPDSS model is a continuous hydrological simulation model that estimates the effect of land use changes and stormwater BMPs on streamflow. This model was applied to the Centennial Brook watershed, which has a drainage area of about 1.4 square miles. The most important inputs to the model for this study are the GIS layers of land use, impervious cover, and soil, as well as the locations, configuration, and connections of the BMPs themselves.

Establishing Baseline Conditions

The ANR Baseline Scenario represents the watershed condition prior to the Centennial TMDL (2002), which in this case reflects six existing BMPs. In coordination with ANR, a Revised Baseline Scenario was created to address an issue discovered during subsequent modeling runs involving the application of BMPs with small drainage areas. Each time one of these on-site BMPs is added, the model creates a new routing connection that increases downstream flow and reduces times of concentration in the drainage area. This phenomenon can cause the VTBMPDSS model to underestimate the reduction potential of smaller green infrastructure (GI) practices and negates some of the potential benefits of BMP treatment trains. To accurately account for this effect, the Baseline Scenario was revised to incorporate virtual outlets (VOs) and drainage areas with “dummy” connections in the same manner as in the subsequently modeled flow restoration scenario. This adjustment did not alter flow paths in the Baseline Scenario, but did slightly increase Q03 base flows. Thus, slight increases in percent reductions over baseline conditions were achieved in the restoration scenarios.

FDC Statistics and Flow Reductions

The VTBMPDSS model outputs both summary files and complete records of hourly flows for any specified control points. The outlet is the primary control point (number 16 for this model). The outlet summary file (Init_Eval.out) provides a quick way to see the control point flows for Q95 and Q03 flows (cfsm) from the current scenario. These numbers were used as a quick guide on performance.

For the final FDC flow numbers, ANR recommends that a separate FDC analysis be performed using only the last 10 years of the 12 year output record for the desired control point (Init_VirtualOutlet_16.out). The FDC spreadsheet was used to provide these numbers for all current scenarios. Only these FDC numbers are reported in this memo.

Additionally, ANR requires computation of the flow reductions percentages based on flow in cubic feet per second (cfs) not cubic feet per second per square mile (cfsm). The logic is that additional watershed area would increase flow (in cfs) and require instream morphological changes that could be detrimental, like augmenting sediment load. The flow per square mile (cfsm) might be unchanged and not reflect this impact. Only flows in cfs were reported in this memo.

Current Condition (Credit) Models

The ANR Credit Scenario reflects upgrades to four of the six ponds included in the baseline model to meet 2002 VT Stormwater Manual criteria. Updated ponds include: the East Campus Pond (M1), Sheraton Pond (M4); the North Campus Pond (M6) with sediment forebay (M7); and the Quarry Ridge Pond (M9) with sediment forebay (M2). The Queensbury Rd. Pond (M3) and the Main St. Pond (M5) remained unchanged from the baseline model. The ANR Credit Scenario was reviewed and revised to account for: 1) an error discovered in the HydroCAD and VTBMPDSS setup for the East Campus pond (M1), and 2) recent construction at Patchen Woods that added two vegetated swales (V1 and V2), increased impervious cover, and required slight changes to sub-watershed boundaries.

HydroCAD modeling of BMPs

HydroCAD models were set up for most of the proposed retrofits identified during field investigations in May, 2013. The Field Findings Memorandum (dated June 13, 2013) that documented procedures and feasible retrofit concepts has been revised to reflect subsequent changes to some of the retrofit concepts (see Revised Field Summaries Memorandum, dated October, 2013). The HydroCAD runs were saved as PDF files, marked up to show the relevant VTBMPDSS parameters used, and then the selected parameters were saved in a model input spreadsheet, thus providing full documentation of each VTBMPDSS model run. All HydroCAD models and the input spreadsheet are available for review. The following two modeling adjustments should be noted:

- HydroCAD models were based on the most updated impervious cover and soils data, which may differ slightly from what is being used in the VTBMPDSS model. ANR requested consistency in the GIS layers used for running model scenarios to ensure that results are comparable to baseline conditions; however, they agreed that the BMPs should be adequately designed using the latest data.
- Because of the differing methods that HydroCAD and the VTBMPDSS models aggregate runoff from soils and impervious areas and deal with flow lag times (time of concentration), the size of the HydroCAD designs for some infiltration practices (e.g., Jaycee Park (15) and Patchen Rd. (18A)) had to be increased to achieve maximum infiltration in the VTBMPDSS.

Flow Restoration Scenario

A number of restoration scenarios were modeled to compare various implementation options using 39 stormwater BMPs. In these scenarios, primary BMPs are defined as having an outlet directly to a stream while secondary BMPs drain to a downstream BMP. More details of the BMP concept summaries, based on GIS and field data, can be found in the revised “Centennial Brook Watershed: Retrofit Field Findings Summary Memorandum” (dated October, 2013). A few key model parameters used during the restoration scenarios include:

- The revised impervious cover used in the Revised Credit Scenario was updated slightly to account for new parking lots and buildings recently constructed/removed based on a visual inspection of the latest satellite images. Even though more recent impervious cover GIS layers were available, this approach was recommended by ANR since it allows direct comparison with the baseline scenarios without introducing differences between remote sensing technology used to develop the old and new impervious cover layers.
- The watershed boundary was changed in a few locations based on MS4 input and field verification. For example, the area north of University Avenue and west of the baseball diamond was removed because it is now connected to the combined sewer system. The UVM proposed expansion on the corner of Colchester Avenue and University Place was modeled as part of the restoration scenario presented here.
- All the stormwater practices, except for vegetated swales, were modeled as multistage ponds. The multistage pond allows the volume-stage relationship to be well represented, has more options for outlet control structures, and has all the controls represented in other model BMPs like infiltration or biofiltration. The multi-stage pond also has the added advantage in that it can be turned on/off or scaled with a multiplier (normally set to 1.0). The parameter allows the same network to be preserved for all flow restoration scenarios and is extremely useful for evaluating different scenarios and individual BMP performance.

Table 2 summarizes the base, credit, and restoration scenarios discussed above. Table 3 provides an accounting of some of the key input parameters of each proposed BMP used in the proposed restoration scenario.

Table 2. Summary of Modeling Scenarios

Model Scenario			Purpose	Q03 High Flow		Conclusion
				(cfs)	% Red.	
Pre-TMDL	ANR Base	Six pre-2002 BMPs, 2002 land use and IA GIS layers	What were the flows at the time the TMDL was established? These flows are the baseline from which restoration/treatment is measured.	27.2	--	We were able to successfully replicate ANR's model.
	Revised Base	ANR Base + virtual outlets, DAs, and network	Add "dummy" BMP connections to allow for more accurate comparison with restoration scenarios.	27.9	--	This is the new baseline to measure achieved flow reductions.
Current	ANR Credit	ANR Base + upgrades to some existing BMPs	What is the change in baseline flow with the retrofit of 4 of 6 existing BMPs to 2002 standards?	23.1	15.2%	We were able to replicate ANR's model.
	Revised Credit	ANR Credit + BMP revisions/addition	Revise current conditions by correcting model inputs on East Campus Pond (M1) and adding the Patchen Woods development.	23.2	14.8%	Corrections result in a slight decrease from ANR's prediction of the current reductions.
Proposed Restoration Scenario		All primary and secondary retrofits (see Table 3)	What is the max. flow reduction achievable if all feasible retrofits are implemented with UVM-designed retrofits of the Main St. (M5A3) and North Campus (M7A3) ponds and the Colchester Ave. expansion.	15.6	44.2%	Does not meet the revised 51.5%% TMDL reduction target, and benefit of secondary practices probably not worth the additional cost.

Table 3. BMPs used in Flow Restoration Scenarios

Site ID	Site Name	BMP Type[1]	Class[2]	DA (ac)	IA (ac)[3]	% Difference in Q03[4]		Design Notes
						BMP Outlet	Watershed Outlet	
12A	University soccer field	IB	E	1.41	0.33	-100.0	0.0	--
13	Patchen Rd. depression	URC	P	14.06	5.07	-100.0	-1.2	Max. ponding depth=7'; Exfiltration = 2.41 in/hr
14A/B	Chamberlin School	URC	P	31.49	10.12	-100.0	-5.9	Field size: 97'(w) x 167'(l) x 3.5'(h); Exf. = 0.52 in/hr
15	Jaycee Park	DB	P	15.73	6.28	-100.0	-2.7	Field size: 87'(w) x 60'(l) x 3.5'(h); Exf. = 2.41 in/hr
16	I-89 outfall	DB	P	52.25	18.88	-26.4[4]	-2.1	Max det. time= 46.6 hr; max. ponding depth=12'
16B	I-89 cloverleaf (NE)	UDC	S	39.17	16.14	-83.0	-0.9	Max det. time=48.8 hrs; max. ponding depth=8'
17	Jug handle @ Spear & Main St. (east)	UDC	S	22.01	7.28	-74.9	-0.3	Field size: 144'(w) x 231'(l) x 3.5'(h)
18	Fielding Lane Condos	URC	P	18.74	5.48	-100.0	-2.3	Max. ponding depth=4'; Exf. = 2.41 in/hr
18A	Patchen Rd & Pine St	URC	P	20.41	6.00	-100.0	-1.8	Field size: 49'(w) x 81'(l) x 3.5'(h); Exf. = 2.41 in/hr
20	Grove St Parking Lot	URC	P	8.82	2.54	-100.0	-0.3	Field size: 30'(w) x 74'(l) x 3.5'(h); Exf. = 2.41 in/hr
20A	SD Ireland Property	URC	P	4.66	3.82	-100.0	-0.2	--
21	Dumont Ave (south)	URC	P	3.93	1.20	-100.0	-0.1	Field size: 21'(w) x 24'(l) x 3.5'(h); Exf. = 2.41 in/hr
22	Best Western Windjammer (N)	IB	P	29.25	21.68	-100.0	-13.6	Max. ponding depth=12'; Exf. = 2.41 in/hr
22A	Best Western Windjammer (W)	IB	P	4.09	1.24	-100.0	-0.5	Max. ponding depth=3'; Exf. = 2.41 in/hr
23A/B	Staples Plaza	UDC	S	2.50	2.43	-67.7	-0.2	Field size: 35'(w) x 259'(l) x 2.33'(h)
25	Picard Circle	URC	P	51.85	17.11	-86.7	-4.3	Field size: 49'(w) x 138'(l) x 3.5'(h); Exf. = 2.41 in/hr
26	Duval St	URC	P	3.57	1.18	-100.0	-0.1	Field size: 21'(w) x 24'(l) x 3.5'(h); Exf. = 2.41 in/hr
27	Clover St	URC	P	3.82	1.43	-100.0	0.0	Field size: 26'(w) x 31'(l) x 3.5'(h); Exf. = 2.41 in/hr
200	N Henry Court	URC	P	1.03	0.45	-100.0	0.0	Field size: 11'(w) x 24'(l) x 3.5'(h); Exf. = 2.41 in/hr
207	Fletcher Allen green space	Bio	S	0.89	0.85	-100.0	0.0	Bio surface area: 3,200 sf
208	Fletcher Allen parking lot	Bio	S	0.83	0.53	-100.0	-0.1	Bio surface area: 2,300 sf
M1A	Centennial Crt Apartments	IB	S	6.54	3.03	-100.0	-0.6	Max. ponding depth=4'; Exfiltration=0.52 in/hr

Site ID	Site Name	BMP Type[1]	Class[2]	DA (ac)	IA (ac)[3]	% Difference in Q03[4]		Design Notes
						BMP Outlet	Watershed Outlet	
M1	East Campus Pond	DB	E	80.30	49.34	-58.1	-13.4	Existing UVM design. Max. det. time= < 12 hrs. Stor. Vol. = 11.3 ac-ft
M2/ M9	Quarry Ridge	DB	E	7.44	4.2	-59.7	-1.1	Max det. time= 12.5 hrs
M3A	Queensbury Pond (modified)	IB	P	8.99	4.17	-86.5	-0.8	Max. ponding depth=10'; Exfiltration=2.41 in/hr
M4	Sheraton	DB	E	9.81	6.70	-52.4	-0.2	Max det. time= 9.9 hrs
M5A3	Main St (UVM modified)	DB	P	64.15	26.59	-39.0	-3.4	UVM design. Max. det. time= < 12 hrs. Stor. Vol. =8.5 ac-ft; with smaller low flow orifice of 5.8" than existing
M6 / M7A3	North Campus (UVM modified)	DB	P	86.36	48.22	-46.3	-7.7	UVM design. Max. det. time= < 12 hrs. Stor. Vol. =21.5 ac-ft.; perm pool elevation 236.0, with smaller low flow orifice of 7.3" than existing and raised to 9-ft embankment
M7B	Open area east of Case Pkwy	URC	S	7.04	3.19	-100.0	-0.1	Field size: 40'(w) x 74'(l) x 3.5'(h); Exf. = 2.41 in/hr
M7C	Case Pkwy center island	Bio	S	0.86	0.50	-100.0	0.1	Bio surface area: 700 sf
M7D	140 East Ave residence	Bio	S	0.63	0.36	0.0	0.0	Bio surface area: 1,550 sf
M8	Burlington COOP	DB	E	3.73	1.62	-100.0	-0.4	Max det. time= 2hrs
V1	Patchen Woods	VS	E	0.48	0.32	-50.0	-0.3	
V2	Patchen Woods	VS	E	0.91	0.81	-100.0	-0.11	

[1] Bio=bioretention; DB=detention basin, IB= infiltration basin; UDC= underground detention chamber; URC=underground recharge chambers; and VS=vegetated swale

[2] P=Primary BMP; S= Secondary BMP that drains to a primary BMP; E=Existing practice (no modification)

[3] Impervious area shown here is based on the most recent/ accurate information that was used to size potential retrofits and may not correspond exactly with GIS layers used in the VTBMPDSS model

[4] Percent difference in high flows is negative when showing a reduction. The model was run with all BMPs turned on and then with individual BMPs turned off, one at a time, to quantify differences in flow and relative performance at the outlet of individual BMPs. Differences at each BMP outlet were determined by comparing the inflows and outflows. 100% represents no surface discharge; BMPS with less than 50% at the BMP outlet could be opportunities to enhance performance. Differences in flow at the watershed outlet are intended as a relative comparison of BMP effectiveness, but are not absolute or additive. Individual BMP values do not add up to corresponding total watershed reductions due to other losses in the system.

[4] Relative performance for #16 appears low because #16B is already managing a large portion of the drainage area.

Estimated Project Costs

This section provides estimates of construction costs for the various stormwater retrofit facilities based on volume managed, the type of BMP, and the type of project site. The total cost for implementation of the restoration scenario presented here is $9,740,000.

The cost estimates were developed based on the following assumptions and design decisions:

1. **Design Control Volumes** are based on the estimated runoff volume associated with the one-year storm event for underground systems or green infrastructure-type practices. Control volumes for large, above-ground infiltration or detention basins are based on the estimated runoff associated with the one hundred year storm event plus approximately two feet of freeboard volume. Underground systems and green infrastructure-type practices were conceptually designed as off-line practices that only accept runoff from the one-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.
2. Table 4 summarizes **Unit Costs** for each BMP and **Site Adjustment Factors** that were derived from research by the Charles River Watershed Association and Center for Watershed Protection, as well as from our experience with actual construction. Underground detention chambers (UDC) and underground recharge chamber (URC) systems were typically designed using Stormtech SC-740™ chamber systems. A Stormtech SC-310™ system was used at Site 23A/B due to a shallow existing drainage system. Cost estimates for the retrofit sites described as "GI/URC" were calculated as bioretention treatment systems followed by Stormtech SC-740™ chambers for recharge benefits. The cost adjustment factors were used to account for site-specific differences typically related to project size, location, and complexity. Retrofits of existing BMPs, for example, generally cost less than new installations.

Table 4. Retrofit unit costs and adjustment factors

BMP	Base Cost ($/ft^3)
Detention Basin	$2
Infiltration Basin	$4
Underground Chamber (infiltration or detention)	$12
Bioretention	$10
Green Infrastructure/ Underground Chamber Combo	$22
Site Type	**Cost Multiplier**
Existing BMP retrofit	0.25
New BMP in undeveloped area	1.00
New BMP in partially developed area	1.50
New BMP in developed area	2.00
Adjustment factor for large aboveground basin projects	0.50

3. For certain retrofit locations, additional **Site-Specific Costs** were added to the construction costs. For example, Sites #13, #22, and M3A will require significant drainage or utility reconstruction. Site M5A3 will require ledge removal if constructed. Site M7A3 will require elevating the existing electric transmission lines to provide adequate clearance for the basin berm construction. Site-specific construction items are described in detail in the Retrofit

Summary Sheets provided as part of the Revised Field Findings Memo (dated October 14), except for the most recent retrofit concepts by UVM for M5A3 and M7A3, which were updated after submittal of the Revised Field Findings Memo. Table 3 provides information on the key design elements of M5A3 and M7A3.

4. **Base Construction Cost** is the product of the design control volume, the unit cost, and the site adjustment factor. Site-specific costs were added to this result for the applicable retrofit sites.
5. **Permits & Engineering Costs** were estimated at either 20% or 35% of the construction cost depending on the scale of the project. The largest projects (in terms of control volume) were estimated at 20% and the smaller projects at 35%. Certain large-scale projects that are likely to include high levels of engineering or permitting effort were assigned a 35% fee, despite their overall size.
6. **Land Acquisition Cost** was added to the total costs for facilities located on private, non-UVM properties. Retrofits that may require partial land acquisition fees were marked up by $150,000; retrofits possibly requiring total land acquisition were marked up by $300,000. These land acquisition estimates are considered to be place-holders at this time and may require adjustments based on current land values and the willingness of land owners to grant easements for the proposed drainage improvements. It was assumed that no land acquisition fees would be necessary for privately owned Sites 22, 22B, and 23A/B due to possible Residual Designation Authority (RDA) applicability. Site M1A was also not assigned a land acquisition fee due to possible existing agreements between UVM and the Centennial Court Apartments property management; however additional refinement of costs for UVM property may require inclusion of a land acquisition cost.
7. **Total Project Cost** is the sum of the base construction cost, permitting & engineering costs, and land acquisitions costs; it does not include operation & maintenance costs.
8. **Relative Cost** is described in terms of total project costs and represented by dollar signs. A project costing less than $100,000 is given $; a project between $100,000 and $250,000 is given $$; a project between $250,000 and $500,000 is given $$$; and a project greater than $500,000 is given $$$$.
9. **Costs per Impervious Acre** treated was calculated by dividing the sum of the construction costs and the permitting & engineering costs by the total impervious area directed to each BMP. Impervious areas used in this calculation are displayed in Table 3. Land acquisition costs and operation & maintenance costs are not included as part of this calculation.
10. **Operation & Maintenance** costs were estimated separately for each BMP, but are <u>not</u> included in the total construction costs. We assume that annual O&M is approximately 3% of project construction costs, with a cap at $10,000.

Each of the numbered descriptions above provides clarification to the corresponding columns in Table 5. The spreadsheet used to develop Table 5 is provided separately as supporting information.

Table 5. BMP Cost Summary Table

Site ID	Site Name	BMP Type	Class	Design Control Volume[1] (ft3)	Base Unit Cost[2] ($/cu.ft.)	Site Adjust. Factor[2]	Site Specific Cost[3]	Base Constr. Cost[4]	Permits & Eng.[5]	Land Cost[6]	Total Project Cost[7]	Relative Cost[8]	Cost/ Imp. Acre[9]	O&M[10]
12A	University soccer field	IB	E	2,700	-	-	-	-	-	-	-	-	-	-
13	Patchen Rd depression	URC	P	66,800	$4	0.25	$25,000	$91,800	$33,000	$150,000	$280,000	$$$	$25,000	$2,800
14A/B	Chamberlin School	URC	P	35,200	$12	1.50	$0	$633,600	$127,000	$0	$770,000	$$$$	$76,000	$10,000
15	Jaycee Park	DB	P	11,300	$12	1.50	$0	$203,400	$72,000	$0	$280,000	$$$	$48,000	$6,200
16	I-89 outfall	DB	P	566,000	$2	1.00	$0	$1,132,000	$227,000	$150,000	$1,510,000	$$$$	$72,000	$10,000
16B	I-89 cloverleaf (NE)	UDC	S	320,000	$2	0.50	$0	$320,000	$112,000	$0	$440,000	$$$	$27,000	$9,600
17	Jug handle @ Spear & Main St.	UDC	S	73,000	$12	1.50	$0	$1,314,000	$263,000	$0	$1,580,000	$$$$	$217,000	$10,000
18	Fielding Lane Condos	URC	P	21,700	$4	1.00	$0	$86,800	$31,000	$300,000	$420,000	$$$	$23,000	$2,700
18A	Patchen Rd & Pine St	URC	P	8,600	$12	1.50	$0	$154,800	$55,000	$150,000	$360,000	$$$	$35,000	$4,700
20	Grove St Parking Lot	URC	P	4,800	$12	2.00	$0	$115,200	$41,000	$0	$160,000	$$	$62,000	$3,500
20A	SD Ireland Property	URC	P	28,700	-	-	-	-	-	-	-	-	-	-
21	Dumont Ave (south)	URC	P	1,100	$12	1.50	$0	$19,800	$7,000	$0	$30,000	$	$23,000	$600
22	Best West.(N)	IB	P	181,000	$4	0.50	$50,000	$412,000	$145,000	$0	$560,000	$$$$	$26,000	$10,000
22A	Best West. (W)	IB	P	30,000	$4	0.50	$0	$60,000	$21,000	$0	$90,000	$	$75,000	$1,800
23A/B	Staples Plaza	UDC	S	11,600	$12	2.00	$0	$278,400	$56,000	$0	$340,000	$$$	$139,000	$8,400
25	Picard Circle	URC	P	14,700	$12	1.50	$0	$264,600	$53,000	$0	$320,000	$$$	$20,000	$8,000
26	Duval St	URC	P	1,100	$22	1.50	$0	$36,300	$13,000	$150,000	$200,000	$$	$42,000	$1,100
27	Clover St	URC	P	1,700	$12	1.50	$0	$30,600	$11,000	$150,000	$200,000	$$	$30,000	$1,000

Site ID	Site Name	BMP Type	Class	Design Control Volume[1] (ft3)	Base Unit Cost[2] ($/cu.ft.)	Site Adjust. Factor[2]	Site Specific Cost[3]	Base Constr. Cost[4]	Permits & Eng.[5]	Land Cost[6]	Total Project Cost[7]	Relative Cost[8]	Cost/ Imp. Acre[9]	O&M[10]
200	N Henry Court	URC	P	600	$22	1.50	$0	$19,800	$7,000	$0	$30,000	$	$60,000	$600
207	Fletcher Allen green space	Bio	S	3,700	$10	1.00	$0	$37,000	$13,000	$0	$50,000	$	$59,000	$1,200
208	Fletcher Allen parking lot	Bio	S	2,700	$10	1.00	$0	$27,000	$10,000	$0	$40,000	$	$70,000	$900
M1A	Centennial Court Apts.	IB	S	30,800	$4	1.00	$0	$123,200	$44,000	$0	$170,000	$$	$59,000	$3,700
M3A	Queensbury (modified)	IB	P	26,700	$4	0.25	$25,000	$51,700	$19,000	$150,000	$230,000	$$	$24,000	$1,600
M5A3	Main St (UVM modified)	DB	P	370,900	$2	0.50	$100,000	$470,900	$95,000	$0	$570,000	$$$$	$22,000	$10,000
M7A3	North Campus (with extra DA)	DB	P	1,008,000	$2	0.25	$100,000	$604,000	$121,000	$0	$730,000	$$$$	$16,000	$10,000
M7B	Open area east of Case Pkwy	URC	S	6,300	$12	1.50	$0	$113,400	$40,000	$0	$160,000	$$	$38,000	$3,500
M7C	Case Pkwy center island	Bio	S	1,000	$10	1.50	$0	$15,000	$6,000	$0	$30,000	$	$42,000	$500
M7D	140 East Ave residence	Bio	S	1,800	$10	1.50	$0	$27,000	$10,000	$150,000	$190,000	$$	$103,000	$900

See preceding text for footnotes.

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