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MEMORANDUM

DATE: February 4, 2013

TO: Dan Albrecht; Megan Moir; Tom DiPietro; Jennifer Callahan and Craig DiGiammarino; Bill Nedde, Derick Read, Linda Seavey and Lani Ravin; and Jeff Padgett and Andrew Mills

FROM: Horsley Witten Group, Inc

RE: Centennial Brook Watershed Flow Restoration Plan Development: Phase I Findings

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This memorandum summarizes findings from: 1) a review of the 2007 Centennial Brook Flow-based Total Maximum Daily Load (TMDL); 2) an evaluation of the VTBMPDSS model used by the Department of Environmental Conservation (DEC) to establish the flow restoration targets for Centennial Brook; and 3) an allocation of remaining flow targets across the four contributing MS4 jurisdictions—Burlington, South Burlington, University of Vermont (UVM), and VT Transportation Department (VTrans)—using impervious cover as the basis for cost sharing for initial planning activities. This effort represents Phase I of a larger project to ultimately develop a Flow Restoration Plan (FRP) for Centennial Brook that meets the 63.4% high flow and 23.2% low flow restoration targets of the TMDL.

A more detailed documentation of our conclusion is presented herein, but in general, the following are our key findings:

1. The TMDL is scientifically-based on reference watershed methodology and the application of flow duration curves generated using the P8-UCM model. This approach, in our opinion, is valid, as is the use of the VTBMPDSS to evaluate progress towards meeting TMDL targets. The VTBMPDSS watershed outflows were calibrated to the P8-UCM, however this data was not available for review. Centennial Brook has a higher percentage of C and D soils than the reference watersheds, which may result in higher high flows and lower low flows under natural condition. ***We recommend running the VTBMPDSS model under natural conditions to ensure that TMDL targets are attainable in this watershed.*** See Section 1 for more detail.

2. The input variables used in the "Base" and "Credit" model runs by DEC were cross-checked with GIS data and BMP design information. These inputs were also compared with updated impervious cover values and BMP drainage areas. In general, ***no significant issues were identified that make us question the results of either the "Base" or "Credit" model runs***.

Most discrepancies (i.e., slight changes in impervious cover, drainage areas, or addition of small infiltration swales) did not have a meaningful effect on overall model results; therefore, comprehensive revisions to the state's "Credit" model were not made at this time. See section 2 for more detail.

3. High flow restoration targets were allocated based on impervious cover across the four MS4s (Table 1). Based on this analysis, it appears that: A) South Burlington has the furthest to go in meeting flow restoration goals; B) ***managing to the minimum standards of the 2002 Stormwater Manual does not appear to result in attainment of the high flow reduction targets, which suggests the need for over-control***; and C) the ease of implementation will be based on the number of existing facilities you already have. Table 2 summarizes the low flow restoration targets, though low flow augmentation is not currently required. Larger infiltration basins, or many small facilities, will likely be required in the residential areas if low flow targets are to be met. Of course, the input parameters used to derive these allocations have some inherent variability, and we are actively investigating the nuances of model. See Section 3 for more detail.

4. Updated land cover, existing BMP input adjustments, new BMPs, and potential retrofits will be incorporated into Phase II modeling to determine if TMDL target flows can be met. Additionally, Phase II may include additional efforts to generate information needed for MS4s to equitably allocate implementation responsibilities (i.e., accounting for existing BMP investments, adjusting "managed" impervious acres where UVM facilities manage non-UVM impervious cover, and reflecting a realistic distribution of 40 acres of future impervious cover). See Section 4 for more details.

Table 1. Percent High Flow Reduction Targets for each MS4

MS4	Allocation[1]	"Credit" Scenario		Using Recently Updated Impervious Cover[3]	
		Treated[2]	Remaining	Treated[2]	Remaining
UVM	20.5	10.6	9.9	11.1	9.4
VTrans	4.2	0.0	4.2	0.0	4.2
Burlington	10.0	3.9	6.1	3.6	6.4
S.Burlington	28.8	1.7	27.1	1.4	27.4
Total	**63.4**	**16.1**	**47.3**	**16.1**	**47.3**

[1] Allocation targets are based on results from the VTBMPDSS "Base" model.

[2] Treated refers to flow restoration improvements over base conditions using results from the "Credit" model runs. The "Credit" model was revised slightly to include a revision of the retrofitted Quarry Ridge pond modeled inputs. Neither the Main St. or Queensbury ponds show flow improvement between the "Base" and "Credit" model runs; therefore, their contributing impervious area does not count towards %Treated at this time.

[3] Updated impervious cover includes recent GIS mapping provided by Burlington and South Burlington, as well as estimates provided by UVM.

Table 2. Percent Low Flow Augmentation Targets for each MS4

MS4	Allocation[1]	"Credit" Scenario		Using Recently Updated Impervious Cover[3]	
		Treated[2]	Remaining	Treated[2]	Remaining
UVM	7.5	0.0	7.5	0.0	7.5
VTrans	1.5	0.0	1.5	0.0	1.5
Burlington	3.6	0.0	3.6	0.0	3.6
S.Burlington	10.5	0.0	10.5	0.0	10.5
Total	**23.2**	**0.0**	**23.2**	**0.0**	**23.2**

[1] Allocation targets are based on results from the VTBMPDSS "Base" model.
[2]Treated refers to flow restoration improvements over base conditions using results from the "Credit" model runs. The "Credit" model was revised slightly to include a revision of the retrofitted Quarry Ridge pond modeled inputs. Neither the Main St. or Queensbury ponds show flow improvement between the "Base" and "Credit" model runs; therefore, their contributing impervious area does not count towards %Treated at this time.
[3] Updated impervious cover includes recent GIS mapping provided by Burlington and South Burlington, as well as estimates provided by UVM.

1.0 Review of the 2007 Centennial Brook TMDL

Under Phase I, HW was asked to conduct a cursory review of the 2007 TMDL to determine if there were issues with the TMDL development process or the application of reference conditions to the Centennial Brook that might call into question the established flow restoration targets. Centennial Brook is an 887-acre highly-developed tributary to the Winooski River that flows northward from the intersection of Route 2 and I-89. The brook is designated as a Class B water supporting a cold water fishery. Prior assessments for fish were fair to good and the macro invertebrate assessments were poor. Most watershed reaches rated as poor for sediment content. The TMDL uses high flow as a surrogate for "pollutant of concern" with the assumption that restoration of the high and low flow is assumed to restore the physical, biological, and chemical regime.

In our opinion, the Centennial Brook flow TMDL was developed using rigorous methodologies and appears valid. Findings from our review include:

- The flow TMDL uses a reference watershed approach using 15 attainment streams meeting their designated uses and 12 stormwater impaired streams to develop flow duration curves (FDCs) for each. The FDC is used as measure of flow changes, both for the high and low flow components. The FDCs were developed by TetraTech (2005) using a calibrated P8-UCM model that is parameterized for these 27 watersheds. The TMDL uses the natural flow at the 0.3% percentile as the high flow target and the 95% percentile as the low flow target. The TMDL says that the Q0.3 is equivalent to the one-year storm and the Q95 is approximately the same as the 7Q10 but these relationships are not documented.

- The P8-UCM model was initially calibrated to two nearby New York watersheds with long-term flow records where there were some issues with groundwater predictions, and later to six UVM-monitored watersheds with shorter flow records. The model prediction of storm flow was tested on the UVM watersheds and produced satisfactory results, but it should be noted that none of the UVM watersheds had more than 16% impervious cover. For application of the P8-UCM model in ungaged watersheds, such as Centennial Brook, several input parameters have to be estimated or set as a constant, which can introduce potential error.

- Impaired and natural watersheds were grouped using a rigorous statistical analysis of parameters like drainage area, land use, soils, slope, and impervious cover (Foley and Bowden, 2005). However, average precipitation and surficial geology were omitted from this grouping analysis; these two parameters were found to be important for estimating natural FDCs in Massachusetts (Archfield et al., 2009). As a check, the generated FDCs could be validated against other FDC methods.

- Centennial Brook was found to be similar to the attainment watersheds Sand Hill Brook and Youngman Brook. An average of the values 0.3% and 95% percentile flows from the two attainment watersheds were used to set the high and low flow targets, respectively. The TMDL mentions that this is a conservative approach. Flow allocations used a land use allocation approach based on runoff coefficient with 99% going to developed areas and 1% being assigned to agricultural areas. Future growth with no stormwater controls (40 acres in Centennial Brook) increased high flow but made no change to low flow. The final TMDL flow reduction/augmentation targets are -63.4% for high flow and + 23.2% for low flow.

- UVM and DEC have reportedly discussed the exclusion of flows derived from agricultural/open space lands, which would reduce the 63.4% TMDL reduction target to 63.0%. Once verified, this change will be incorporated into the revised VTBMPDSS model and proposed cost share allocations for restoration implementation.

- While the TMDL does not use an explicit margin of safety, it does assume that an additional 40 acres of unregulated impervious cover (i.e., small sites that fall below the required size threshold triggering stormwater management) will be created in the future. A valid question remains as to whether an additional 40 acres of unregulated imperviousness is realistic or not, given Burlington's stringent stormwater ordinance (with a threshold of 400 sq ft of disturbance) and the fact that all of UVM is jurisdictional. The spatial distribution of the future 40 acres is not presumed in the TMDL and is difficult to model in the VTBMPDSS; however, the implications could influence the allocation of implementation costs.

- A potential issue was raised with DEC related to the calculation of the TMDL high flow reduction target and future growth. After further discussions with DEC, we no longer

believe that the calculation is in error, and agree that 63.4% reduction (rather than the 56.1% reduction target proposed) is accurate based on the current, future, and attainment flow assumptions of the TMDL. See supplementary memos dated December 21, 2012 and January 16, 2013 for further discussion.

- Seasonal variation in the TMDL was adequately accounted for by using the FDC approach and running the P8-UCM model for a 10-year simulation (1990-1999). These years include some very dry years and wet years so that period should be adequate for covering seasonal variation.

- Implementation of the TMDL uses the VTBMPDSS model to test the effectiveness of various stormwater BMPs on reaching the flow reduction/augmentation targets. The model uses pre-generated time series of flow for each hydrologic response units (HRUs) which are a function of soil, land use, impervious area, and slope. The model then routes the HRU flow through BMPs and watersheds. The overall flow from VTBMPDSS was calibrated to the P8-UCM flow for Centennial Brook (per. com., Emily Shelley), but the calibration results were not reported. Cumulative flow is also generated at sub-watershed outlets and watershed outlets to quantify flow performance of upstream BMPs. The natural condition using this model was not cross-checked against the natural flow conditions of the selected attainment watersheds. ***To build confidence in the TMDL flow restoration requirements, the P8-UCM calibration results should be reported and natural conditions should be modeled for Centennial Brook using the VTBMPDSS and compared to reference conditions.***

2.0 Assessment of the VTBMPDSS Model Runs for Centennial Brook

Assessment of the VTBMPDSS model involved a thorough verification of model input variables, assumptions, and results of the "Base" and "Credit" models. The "Base" model establishes baseline flows against which the TMDL flow restoration targets are applied, and include six existing stormwater BMPs designed prior to the 2002 VT Stormwater Standards (management of flows from the 1-yr, 24-hr storm were first introduced into the regulations in 2002). The "Credit" model reflects post-2002 upgrades to four of the "Base" BMPs that were retrofitted to meet the newer stormwater standards, as well as the addition of a new facility. Emily Schelley at VT Department of Environmental Conservation (DEC) provided HW with all the files used to run the Centennial VTBMPDSS model (e.g., program files, GIS, HydroCAD simulations), as well as troubleshooting assistance.

HW cross-checked model input variables (e.g., drainage areas, impervious cover, soils, stormwater facility design information) against GIS data and evaluated design calculations and site plans for each of the stormwater practices. Emily Schelley, Tom Dipietro, Megan Moir, and Derick Read (Krebs and Lansing) provided most of the information needed to complete this

assessment; however, a few pieces of additional information remain outstanding (such as UVM impervious cover data, additional BMP design information). Key findings include:

- We confirmed that the soils, watershed boundary, and 2002 land use data were consistently applied to both the "Base" and "Credit" model runs. The "Credit" model used slightly different impervious area and BMP drainage areas to reflect post-2002 conditions.

- We confirmed that the Hydrologic Response Unit (HRU) parameters of soils, land use, slope, and impervious cover were in line with the GIS data. Many of the small discrepancies found between GIS area calculations and model inputs were attributed to the HRU grid system used by the model (where individual grids cannot be split and are assigned either inside or outside of a boundary).

- Impervious cover estimates differ slightly between the "Base" and "Credit" model, with the latter being more accurate. Recently updated impervious cover mapping provided by South Burlington shows a net increase in 1.3 acres over the "Credit" version and a net decrease in 4.5 acres of VTrans impervious cover, which appears to reflect more accurate mapping rather than an actual change in land cover. Updated impervious cover from Burlington was received on 11/30/12, which included revised UVM coverage, and separate calculations from UVM were received on 12/17/12. Review of the data shows an increase in 0.75 acres for the City and a decrease of 11.8 UVM acres from the "Credit" conditions. Minor changes in drainage boundaries are also reflected in the UVM numbers. In UVM's case, this change will be confirmed in Phase II. Table 3 summarizes changes in total acres and impervious area for each MS4 for the "Base" and "Credit" models compared to the more recently updated data.

Table 3. Cross-check of MS4 Area and Impervious Acres by Model Runs*

MS4	Total Acres			Impervious Acres		
	Base Model	Credit Model	Recently Updated	Base Model	Credit Model	Recently Updated
UVM	301.3	301.3	300.0	90.0	89.1	77.3
VTrans	59.6	59.6	59.6	18.3	18.3	13.8
Burlington	101.8	101.8	101.9	43.8	45.1	45.9
South Burlington	423.3	423.3	423.4	126.5	126.5	127.8
Total Watershed	**886.0**	**886.0**	**884.9**	**278.6**	**279.1**	**264.8**

*Areas are derived from GIS data; recently updated impervious cover based on data provided by S. Burlington and Burlington (not confirmed with UVM)

- We were able to generate MS4 boundaries using a parcel-based delineation for VTrans (provided by Emily Schelley), a property boundary provided by UVM, and an assumed boundary for Burlington and South Burlington based on the Vermont Center for Geographic Information (VCGI) municipal boundary shapefile.

- BMP drainage area information was cross-checked between the HRU and BMP model input tables, GIS information, and BMP design information. Table 4 shows discrepancies between GIS and HRU inputs in the VTMPDSS and updated impervious estimates. The biggest discrepancy found is a ≥6.5 acre difference between the model inputs and updated estimates for the North Campus pond, for example, and the DEC's HydroCAD run and UVM's sizing calculations show approximately 10 acres less impervious cover than input used in the VTBMPDSS. The differences seen for the North Campus pond may be due to outdated mapping and/or the exclusion of non-UVM impervious cover from the sizing calculations (per. com., Bill Nedde on 12/1/12). Updated drainage boundaries were provided by UVM, which when combined with an updated impervious cover shapefile (data received 1/10/13), will be used to try to reconcile some of these issues. Table 5 shows impervious cover for each MS4 within each BMP's contributing drainage area.

- DEC modeled stormwater facilities using HydroCAD to generate the BMP information needed to input into the VTBMPDSS. We reviewed both the HydroCAD and the VTBMPDSS input for each BMP, as well as the design plans and any calculations we could obtain. Specifically, we checked pond storage volumes, confirmed drainage areas, and verified outlet elevations and orifice sizes. Three discrepancies were found that require some further investigation: storage volumes for M9 Quarry Ridge (post-2002); drainage areas for M4 Sheraton (pre-2002); and volume and outlet assumptions for M5 Main St Pond (pre-2002). We revised the BMP input for M9 Quarry Ridge and re-ran the "Credit" model to assess the magnitude of the change to the overall results—the high flow reduction at the watershed outlet changed by 0.1%. This resulted in an overall increase from 16.0% to 16.1% in the Q0.3% reduction for the watershed. Additional analysis is required to fully vet M4 and M5 conditions. As mentioned previously, other minor inconsistencies in drainage areas and volume calculations were deemed insignificant. Discrepancies detected in the size or elevation of upper orifices and spillways were ignored where they did not have a direct affect on detention of the 1-yr storms. Table 6 summarizes our findings from the BMP evaluation and recommendations for correction where necessary.

- Information was collected and evaluated on two recently installed facilities that have not yet been included in the "Credit" model. The insignificant storage provided by these practices and the opinion that this would not significantly impact our initial conclusions prompted us to continue to hold on comprehensive revisions to the credit model at this time. Our plan is to include these facilities under Phase II.

Table 4. Cross-check of Impervious Acres Draining to each BMP

BMP	IMPERVIOUS ACRES IN BMP DRAINAGE AREA				
	Base Model		Credit Model		Recently Updated
	HRU model input	*GIS*	*HRU model input*	*GIS*	
M1 East Campus Pond (and retrofit)	53.2	52.7	52.5	52.4	47.7
M2/9 Quarry Ridge Pond	5.1	4.6	5.1	4.6	4.2
M3 Queensbury Pond	1.8	1.7	1.8	1.7	1.5
M4 Sheraton (and retrofit)	5.8	6.2	6.7	7.1	6.8
M5 Main St. Pond	11.6	11.8	11.6	11.8	9.0
M6/7 North Campus Pond	50.9	48.1	50.0	47.6	43.5
M8 Burlington Co Housing Pond/Infil.	-	0.0	1.6	1.3	1.6
TOTAL	**128.3**	**125.0**	**129.2**	**126.4**	**114.3**

Table 5. Updated Impervious Acres by MS4 Contributing to each BMP

BMP	UVM	Vtrans	Burlington	South Burlington	Total
M1 East Campus Pond (and retrofit)	43.74		3.79	0.14	47.67
M2/9 Quarry Ridge Pond				4.19	4.19
M3 Queensbury Pond				1.45	1.45
M4 Sheraton (and retrofit)	1.16			5.63	6.79
M5 Main St. Pond	3.84		4.94	0.22	9.00
M6/7 North Campus Pond	22.55		20.98		43.53
M8 Burlington Co Housing Pond/Infil.			1.63		1.63
Total acres (all BMPs)	71.29	0.00	31.34	11.63	**114.26**
Acres to post-2002 BMPs only	67.45	0	26.40	10.18	104.04
Acres to post-2002 + Main St. pond	71.29	0.00	31.34	10.18	112.81

* Data generated using updated impervious cover and drainage boundary information available. Only UVM impervious cover is based on calculations provided by UVM on 12/17/12; therefore, non-UVM contributions and/or total impervious cover draining to each BMP may not match UVM's estimates.

Table 6. Summary of BMP Information Review

BMP ID*	Name	Comments
M1 (Pre)	UVM - East Campus BASE	**Acceptable**. Small discrepancy in volume between DSS and HydroCAD model, but it appears to correspond to permanent pool storage. HydroCAD matches existing conditions plan. Consider revising dual outlet pipe routing.
M1 (Post)	UVM - East Campus--CREDIT	**Acceptable**. Volumes match between models, but no plan set was available to confirm. Inconsistencies in number of outlets; seems ok based on calculations provided by engineer.
M2 (Pre)	Quarry Ridge Pond--BASE	**Acceptable**. All volumes match with plans. As-built plans have an outlet adjustment from 240.0' to 240.3' which is not reflected in the model, but not likely significant.
M9 (Post)	Quarry Ridge Pond CREDIT	**Model to be revised.** Impervious area in HydroCAD is slightly lower than in model input. Storage volumes and outflows incorrectly modeled in relation to M2.
M3 (Pre)	Queensbury Road BASE AND CREDIT	**Acceptable**. Plans are difficult to read. Pond volumes all appear to check. Cannot verify hole size/count on perforated standpipe outlet structure. The modeled overflow diameter may be slightly understated according the plans. Plans appear to show a 15” dia. orifice, model says 12” diameter. This may not matter as it does not affect the 1-yr storm.
M4 (Pre)	Sheraton Hotel BASE	**Additional review**. All volumes and outlets check, however, the total drainage area (DA) and impervious acres (IA) are twice as large in the HydroCAD model as in the model input (i.e., 11.3 IA /16 DA acres in HydroCAD compared to ~6 IA/8.2 DA acres in VTBMPDSS and GIS.
M4 (Post)	Sheraton Hotel CREDIT	**Acceptable**. All volumes and outlets check. Should model 24" PVC outlet culvert from outlet structure.
M5 (Pre)	Main Street Pond BASE AND CREDIT	**Review**. Volumes cannot be verified because page scaling is not included on plan set. Primary outlet elevations inconsistent, may be assuming more flow being released.
M6 (Pre)	UVM - North Campus BASE	**Acceptable**. Volumes checked, but inconsistency in model for upper orifices; probably doesn’t matter since these do not affect 1-yr storm release. Impervious cover in the DA is off ~10 acres.
M7 (Post)	UVM - North Campus--CREDIT	**Acceptable**. May want to adjust the HydroCAD routing input parameters if this BMP is to be remodeled under retrofit scenario.
M8 (Post)	Burlington Co-Housing--CREDIT	**Acceptable**. May want to make minor adjustments to outlets to more accurately reflect design.
NEW	Rt. 2 Expansion	We have the information needed to plug into VTBMPDSS model as an existing or proposed facility, as appropriate.
NEW	Patchen Woods	We have the information needed to plug into VTBMPDSS model.

* Pre- and Post-2002 stormwater design standards

Results of the Centennial VTVTBMPDSS are summarized in Table 7; these match the results generated by DEC. From the flows modeled under the "Credit" scenario (with minor adjustment to the M9 Quarry Ridge BMP input) at the watershed outlet, there has been a 16.1% reduction in high flows and a 0.03% increase in low flows over base conditions. This result leaves an additional 47.3% reduction and 23.2% increase to meet the overall high and low flow restoration targets, respectively.

Table 7. Summary of Centennial Brook Flows Modeled at the Watershed Outlet *

Model Run	High Flow (Q 0.3%)	Low Flow (Q 95%)
TMDL Target	63.4% reduction	23.2% increase
Base Model (cfs/mi2)	20.1	0.17
Credit Model (cfs/mi2)	16.9	0.17
% Change	16.1%	-0.03%
% Remaining	47.3	23.2%

Based on DEC Credit Model run, with revisions to BMP M9 model input.

To gain additional understanding of model results, we also looked at the percent change in flow at the individual subwatersheds, which range from 0% to 50% reduction in high flow (Table 8) with the UVM dominated subwatersheds (#2 and #4) showing the highest current reductions of 50% and 45%, respectively. For reference, the subwatersheds and the BMP drainage areas within each subwatershed are shown in Figure 1. The subwatershed flows do not add up to the total flow at the watershed outlet for two reasons. First, the flow distributions of multiple subwatersheds are mixed in the VTBMPDSS, so flow distributions are flatter on the extremes (i.e., lower in the high end and higher on the low end). If the VTBMPDSS averaged the flows instead, then the subwatershed flows would add up to the total watershed flow. Second, there is probably some attenuation in the stream network. The VTBMPDSS does have the ability to incorporate complex routing, but Centennial Brook mostly uses simple connections that sum flows except for the river network, which have more realistic channel routing.

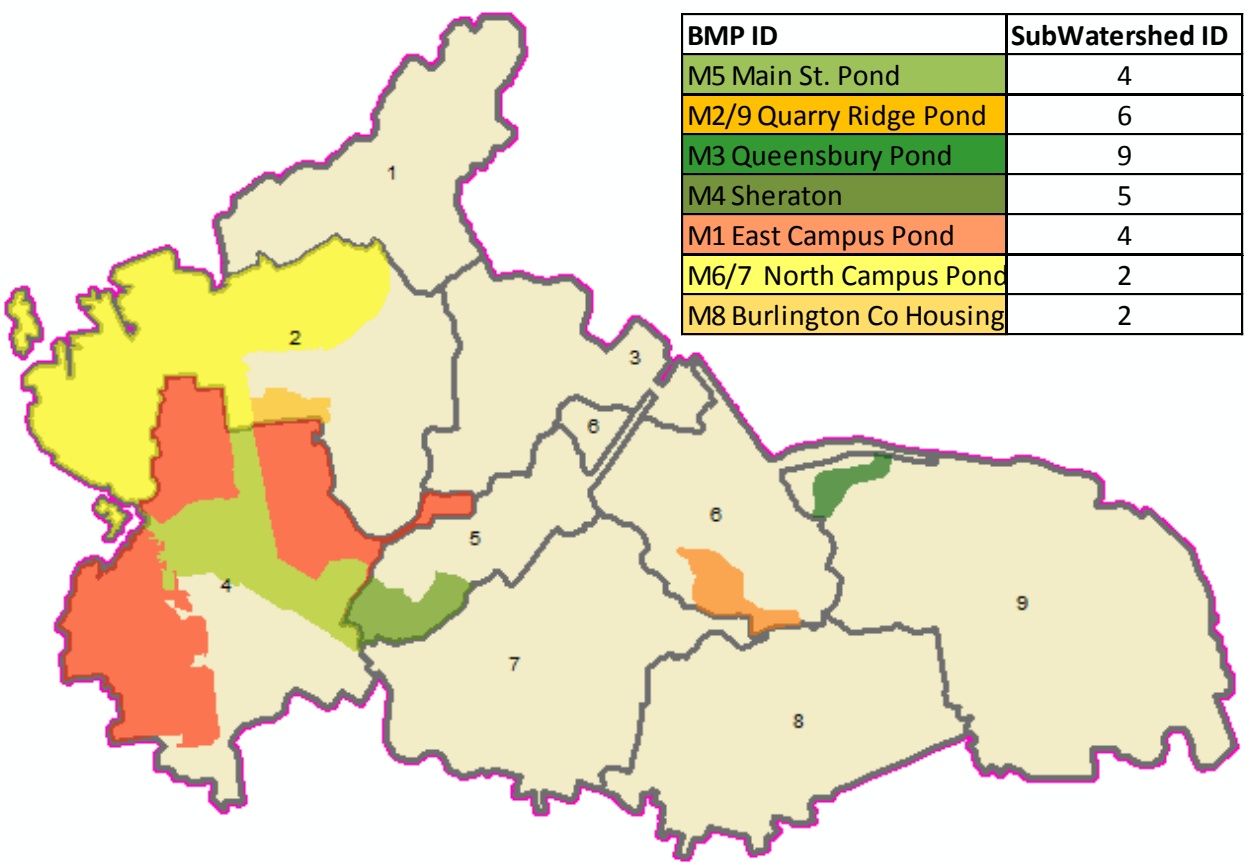
Some additional effort will be needed to understand the nuances of this subwatershed-scale analysis; however, it does seem reasonable to assume that in order to meet the flow targets for the entire watershed, each subwatershed ideally should attain close to the target amount of 63.4%. In reality, some watersheds are likely to reach higher attainment values, reducing the burden of control for other subwatersheds. It will be the location of retrofit opportunities and the cost/benefit of implementation that will drive which subwatersheds are targeted.

Table 8. Summary of Centennial Brook Flows Modeled for Each Subwatershed

Subwatershed	High Flow (Q 0.3%)			Low Flow (Q 95%)		
	Base (cfs/mi^2)	Credit (cfs/mi^2)	% Reduction	Base (cfs/mi^2)	Credit (cfs/mi^2)	% Augmentation
1	18.9	18.9	0	0.09	0.09	0.0
2	34.5	17.4	49.5	0.10	0.10	-0.2
3	7.4	7.4	0	0.11	0.11	0.0
4	41.9	23.9	43	0.05	0.05	0.0
5	27.7	18.5	33.1	0.00	0.00	0.0
6	18.4	14.8	19.7	0.09	0.09	0.0
7	31.6	31.6	-0.2	0.13	0.13	-0.2
8	32.9	32.9	0	0.07	0.07	0.0
9	19.5	19.5	0	0.15	0.15	0.0
Watershed Outlet*	20.1	16.9	16.1	0.17	0.17	-0.03

Based on DEC Credit Model run, with revisions to BMP M9 model input.
*Does not constitute a summation of subwatershed flows.

Figure 1. Centennial Lake Subwatersheds and BMP Drainage Areas.



BMP ID	SubWatershed ID
M5 Main St. Pond	4
M2/9 Quarry Ridge Pond	6
M3 Queensbury Pond	9
M4 Sheraton	5
M1 East Campus Pond	4
M6/7 North Campus Pond	2
M8 Burlington Co Housing	2

3.0 Phase II Fee Allocations for each MS4

One of the primary objectives of the Phase I effort was to allocate the fee for planning in Phase II fairly across each of the four MS4 jurisdictions based on impervious cover. Table 9 compares the percent cost share per MS4 for meeting 100% of remaining high flow reductions and low flow augmentation targets. The derivation of the flow target allocations is described below in more detail.

Table 9. Proposed Fee Allocation across MS4s for Phase II

MS4	High Flow		Low Flow	
	Remaining Flow Target	Cost Share for Meeting Target	Remaining Flow Target	Cost Share for Meeting Target
UVM	9.4%	19.8%	7.5%	32.2%
VTrans	4.2%	8.8%	1.5%	6.6%
Burlington	6.4%	13.5%	3.6%	15.7%
South Burlington	27.4%	57.9%	10.5%	45.5%
Total	**47.3%**	**100%**	**23.2%**	**100%**

Tables 10 and 11 summarize preliminary allocations for high and low flow restoration targets, respectively. With the exception of the using the revised M9 BMP model input and updated impervious cover information, this analysis was performed on the "Credit" model scenario without significant updates or revisions to the model input. Tables 10 and 11 reflect updated total and managed impervious cover using GIS for Burlington and South Burlington and UVM's estimates (12/17/12). UVM's estimates included a breakdown of UVM, non-UVM and total impervious cover draining to each BMP; however, UVM's estimates for non-UVM contributions and/or total impervious cover are not used at this time (these will be confirmed based on impervious data from UVM received 1/10/13). We believe the relative allocations summarized in Tables 10 and 11 are not likely to change significantly until additional retrofits are incorporated under Phase II.

Watershed impervious acres (IA) were derived for each MS4 using "Base" and recently updated mapping information. IA was then classified as "managed" if it drained to a post-2002 BMP that contributed to an improvement in flow conditions between the "Base" and "Credit" models. Figure 2 shows a breakdown in the impervious cover by MS4 jurisdiction, as well as the BMP drainage boundaries that help delineate managed vs. unmanaged impervious acres. BMPs that were installed or retrofitted after 2002 are assumed to meet stormwater standards for controlling the 1-yr storm, which is accurately reflected in the VTBMPDSS with improvement in flow reductions between the "Base" and "Credit" models. The Main St. and Queensbury ponds are the two facilities with the same input/output for both "Base" and "Credit" models and do not currently contribute to flow reduction credits in the VTBMPDSS. Therefore, in accordance with DEC protocol, the IA draining to these two facilities as well as IA not captured by any existing BMP is considered "unmanaged" for the purposes of fee allocation.

Table 10. Revised High Flow Load Reduction Allocation Across MS4s (with updated Impervious Cover)

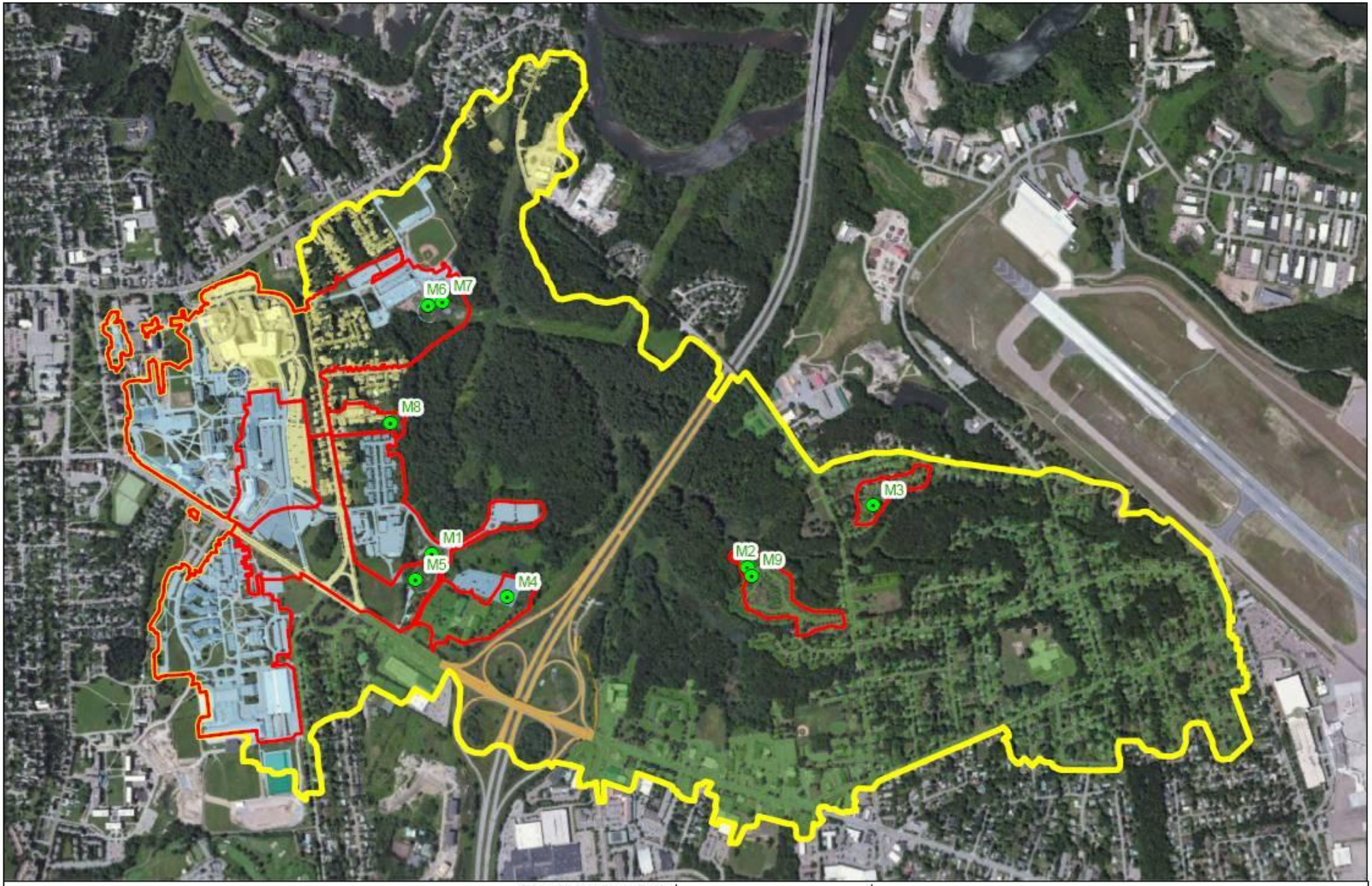
MS4	Watershed Impervious Acres (IA)		Managed IA[1]	Unmanaged IA	High Flow Load Allocation[2]	High Flow Treatment Credit Towards TMDL		High Flow TMDL Target Allocation Remaining Untreated[5]
	Base	Recently Updated				% Treated[3]	Discounted Performance[4]	
UVM	89.96	77.27	67.45	9.82	20.5%	17.9%	11.1%	9.4%
VTrans	18.32	13.77	0.00	13.77	4.2%	0.0%	0.0%	4.2%
Burlington	43.80	45.92	26.40	19.52	10.0%	5.7%	3.6%	6.4%
S. Burlington	126.55	127.83	10.18	117.65	28.8%	2.3%	1.4%	27.4%
Total	**278.63**	**264.79**	**104.04**	**160.75**	**63.4%**	**25.9%**	**16.1%**	**47.3%**

[1] IA draining to post-2002 BMPs only
[2] High Flow Load Allocation = (Base MS4 IA/Base Total watershed IA)* 63.4% TMDL Target
[3] High Flow Treatment Credit:% Treated = (Managed MS4 IA/Recently Updated MS4 IA)* MS4 High Flow Allocation
[4] Discounted Performance = (Model Output Reduction of 16.1%/Total % Treated of 25.9%)*MS4 % Treated
[5] High Flow TMDL Target Allocation Remaining Untreated = MS4 High Flow Load Allocation - MS4 Discounted Performance

Table 11. Revised Low Flow Load Reduction Allocation Across MS4s (with updated Impervious Cover)

MS4	Watershed Impervious Acres (IA)		Managed IA[1]	Unmanaged IA	Low Flow Load Allocation[2]	Low Flow Treatment Credit Towards TMDL		Low Flow TMDL Target Allocation Remaining Untreated[5]
	Base	Recently Updated				% Treated[3]	Discounted Performance[4]	
UVM	89.96	77.27	67.45	9.82	7.5%	6.5%	0.02%	7.5%
VTrans	18.32	13.77	0.00	13.77	1.5%	0.0%	0.00%	1.5%
Burlington	43.80	45.92	26.40	19.52	3.6%	2.1%	0.01%	3.6%
S. Burlington	126.55	127.83	10.18	117.65	10.5%	0.8%	0.00%	10.5%
Total	**278.63**	**264.79**	**104.04**	**160.75**	**23.2%**	**9.5%**	**0.03%**	**23.2%**

[1] IA draining to Post-2002 BMPs only
[2] Low Flow Load Allocation = (Base MS4 IA/Base Total watershed IA)* 23.2% TMDL Target
[3] Low Flow Treatment Credit:% Treated = (Managed MS4 IA/Recently Updated MS4 IA)* MS4 Low Flow Allocation
[4] Discounted Performance = (Model Output Reduction of 0.03%/Total % Treated of 9.48%)*MS4 % Treated
[5] Low Flow TMDL Target Allocation Remaining Untreated = MS4 Low Flow Load Allocation - MS4 Discounted Performance



Bing Maps Aerial, ESRI

Legend

- Base and/or Credit BMP
- Watershed (updated UVM)
- BMP DA (UVM updated)

Impervious Cover
(updated S. Burlington/Burlington)

- VTrans
- SouthBurlington
- UVM
- Burlington

N

Feet
1,200

Horsley Witten Group
Sustainable Environmental Solutions

Figure 2. MS4 Impervious Area and BMP Drainages (Updated)

Path: H:\Projects\2012\12106 Chittenden County-Centennial Brook WS\GIS\Maps\ack_workingmap_revised_credit.mxd

This is not to say that issues of equitability, “un-permitted” versus “basis-of-design” IA, and future IA draining to the Main St. Pond are insignificant. We assume that the several “variables” discovered in this Phase I assessment will be refined when determining allocation of responsibility for future implementation of measures recommended in the Flow Restoration Plan.

The High Flow Load Allocation is the percentage of the TMDL target (63.4% or 23.2%) multiplied by the proportion of IA (Base MS4 IA/Base Total Watershed IA) in each MS4 under the baseline conditions. This result is, effectively, the percent reduction to be met by each MS4. South Burlington and UVM have the most impervious cover in the watershed and, therefore, have the largest flow restoration allocations at 28.8% and 20.5% of the total 63.4%, respectively.

Treatment credits are given to each MS4 based on their proportion of managed IA over their MS4 IA recently updated for the “Credit” scenario multiplied by the respective High Flow Load Allocation. This represents how much has already been done towards meeting allocated flow restoration targets. The total % Treated is estimated at 25.9% and 9.5%, which is more than the 16.1% and 0.03% calculated by the VTBMPDSS high and low flow outputs, respectively. Our assessment is that this difference can be accounted for by lower BMP performance than what is required by the TMDL (i.e., BMPs are not managing IA to meet the necessary flow targets). Therefore, a Discounted Performance is scaled by multiplying the respective % Treated by the proportion of the model output reduction to total % Treated (e.g., 16.1%/25.9% for high flows).

The Remaining Untreated Allocation, therefore, is equivalent to the Load Allocation minus the Discounted Treatment Credit. This remaining allocation represents how much more each MS4 has to do under this allocation scenario. As shown in Tables 10 and 11, South Burlington has made little progress towards meeting these allocation targets to date, which makes sense given the lack of treatment provided for IA in this jurisdiction. UVM and Burlington have gone the furthest; however, much of Burlington’s IA is managed by UVM-owned facilities and may need to be accounted for differently when allocating implementation responsibility in the future.

Given the amount of IA managed by UVM, it may be surprising that they are only approximately half way (~11% out of 20.5%) towards meeting their assigned allocation. At the subwatershed-scale (refer to Table 8 and Figure 1), subwatershed 2, is highly impervious, yet mostly managed by the North Campus Pond and Burlington Co. Housing facility. The VTBMPDSS model indicates a 49.5% reduction in high flow has already been achieved—further reductions in this subwatershed are unlikely without boosting management performance or over-controlling the existing facilities. Review of the North Campus Pond indicates that it is achieving approximately 10 hours detention time for the 1-yr storm, which is below the 12-hour goal in the 2002 VT Manual, and may provide an opportunity for increasing detention (e.g., reducing the 8” outlet orifice diameter to something smaller and raising the embankment). This example shows that merely designing BMPs to meet the 2002 standards may not result in meeting TMDL high flow targets.

In addition, there appears to be no progress on meeting low flow restoration targets, which is expected given that only one infiltration practice is included in the "Credit" model. Inclusion of the Rt. 2 expansion and Patchen Woods infiltration swales may slightly improve conditions; however, the installation of large infiltration practices in South Burlington's portion of the watershed where soils are conducive to infiltration seem to be necessary to meet this target.

4.0 Next Steps

In order to move forward to Phase II, which includes the identification and modeling of feasible retrofit opportunities to meet TMDL high flow requirements, the MS4's will need to reach agreement on the final fee allocation to fund Phase II (note: this is not the likely to be the same allocation to be used for future implementation activities). Once notification to proceed on Phase II, we anticipate the following next steps:

1. Confirm with DEC a reduction in the high flow target from 63.4% to 63.0% due to exclusion of agricultural-derived flows.

2. Discuss with DEC the potential to adjust future impervious acreage to better reflect watershed buildout conditions and distribution within each of the MS4s, and if there is a mechanism to take credit for reductions in future unregulated impervious cover via more stringent stormwater regulations.

3. Confirm with DEC the impervious cover to be used for running a revised credit model. Assuming the most up-to-date information can be used, updated impervious and drainage boundary mapping will need to be input into the VTBMPDSS to generate new HRU's. In addition, we will need to confirm with DEC on M9, M4, and M5 BMP model input adjustments; and add new infiltration practices in South Burlington (Rt. 2 improvements and Patchen Woods dry swales) to the model.

4. Continued testing of VTBMPDSS model to better understand the influence of individual existing BMPs on current flow reductions; define the extent of retrofitting required by modeling flow reductions using hypothetical retrofits; and identify critical locations for Phase II field work.

5. Discuss with UVM the potential for retrofitting of existing facilities and confirm with DEC that new projects can be permitted in "over-controlled" facilities. UVM has a good understanding of future campus expansion plans that can be helpful in sizing storage retrofits that can accommodate future stormwater.

6. Prepare for Phase II retrofit inventory by reviewing of South Burlington's Williston Rd. Report, which identifies a number of retrofit opportunities; further evaluate restoration potential of existing facilities; review with project partners the potential sites for field investigation; and arrange for site access as soon as field work is scheduled.

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