Total Maximum Daily Load
To Address Biological Impairment in
Potash Brook (VT05-11)
Chittenden County, Vermont

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Introduction

Section 303(d) of the Federal Clean Water Act requires each state to identify waters not attaining water quality standards, and to establish total maximum daily loads (TMDLs) for such waters for the pollutant of concern. The TMDL establishes the allowable pollutant loading from all contributing sources at a level necessary to attain the applicable water quality standards. TMDLs must account for seasonal variability and include a margin of safety that accounts for uncertainty of how pollutant loadings may impact the receiving water's quality. Once the public has had an opportunity to review and comment on the TMDL, it is submitted to the U.S. Environmental Protection Agency (USEPA) for approval. Upon approval, the TMDL is incorporated into the state's water quality management plan.

This TMDL establishes a scientifically based water quality target for Potash Brook that, when attained, will allow the stream to meet or exceed the established Vermont Water Quality Standards (VTWQS) for which it is impaired. This TMDL has been established in accordance with Section 303(d) of the Federal Clean Water Act, implementing regulations (40 CFR §130) regarding TMDL development, and other relevant USEPA guidance documents.

The basis for this TMDL was initially explained in the final report produced by the Vermont Water Resources Board Investigative Docket (Vermont Water Resources Board, 2004). More specifically, Appendix A of that document ("*A Scientifically Based Assessment and Adaptive Management Approach to Stormwater Management (Stormwater Cleanup Plan Framework)*") outlined the necessary steps to develop a scientifically sound approach in creating TMDLs for stormwater-impaired waters. Henceforth, this approach is referred to as the "Framework". The Vermont Department of Environmental Conservation (VTDEC) adhered to the Framework's approach for developing cleanup targets in this TMDL.

Several investigations have been conducted by multiple parties to derive the necessary information called for in the Framework. Significant results and findings of those investigations are summarized in this TMDL. Additionally, frequent interaction between VTDEC and the VTDEC-convened Stormwater Advisory Group (SWAG) yielded useful guidance for the development of this TMDL.

Description of Waterbody

Potash Brook and its watershed are located in Chittenden County, principally in the municipality of South Burlington, and encompass an area of approximately 7.13 square miles (Figure 1). The main stem of Potash Brook originates in the southeast portion of South Burlington, south of Interstate 89 and east of Route 116, and flows to its mouth at Shelburne Bay in Lake Champlain. Several major tributaries flow to the main stem and drain significant portions of the watershed north and south. The entire stream and its tributaries are Class B waters designated as cold water fish habitat pursuant to the VTWQS.

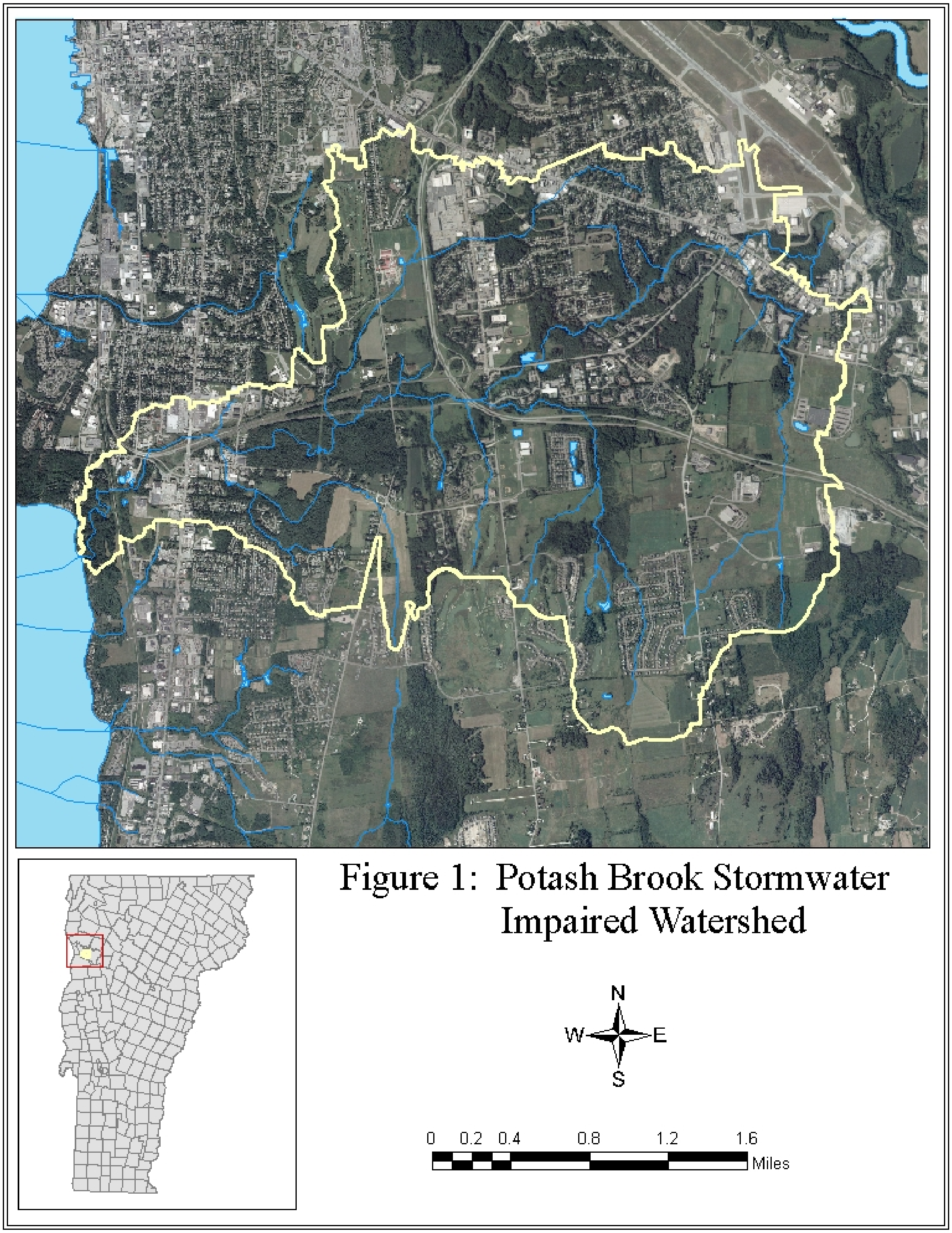

Figure 1: Potash Brook Stormwater Impaired Watershed

The land uses within the watershed are comprised of 53% developed land (residential, commercial, industrial, etc.), 30% agricultural or open land, and 17% forest, wetland or open water. Recent surveys indicate a watershed that is approximately 22% impervious.

Priority Ranking/303d List of Impaired Waters

Potash Brook is designated as impaired on the 2004 Vermont 303(d) List from its mouth at Lake Champlain to a point upstream 5.2 miles due to non-support of aquatic life designated uses. Since all tributaries and the upstream main stem drain to the impaired lower portion of the stream, the entire Potash Brook watershed is considered to contribute to its impairment. The source of the impairment is multiple impacts associated with excess stormwater runoff.

According to the 2004 Vermont 303(d) List, TMDL development for Potash Brook is scheduled for completion in 2009. In the 2004-2005 Legislative session, the Vermont Legislature amended the Vermont stormwater statute, 10 VSA §§1264 and 1264(a), to require the development of TMDLs or water quality remediation plans for each stormwater-impaired water by September 2007. VTDEC agrees with the Legislature that TMDL development for these streams is a high priority and is an integral component of the remediation process.

Description of Impairment

Biological Monitoring

In all the stormwater-impaired streams in Vermont, aquatic life impairments are detected through the use of biological monitoring of the fish and macroinvertebrate communities. The biological monitoring program relies on data from reference sites to help define biological community goals for a given stream type. This approach is provided for in the VTWQS and specific numeric biological criteria have been established for several stream types, including Potash Brook, to indicate compliance with the VTWQS.

The monitoring is extremely useful in that it directly measures the health of the aquatic life community. Also, the monitoring is reflective of environmental conditions that occur in the stream over an extended period of time (i.e., months) including the effects of intermittent discharges such as stormwater. However, biological monitoring is limited when trying to identify the various causes and the extent to which they contribute to the impairment.

Biological data was collected on Potash Brook by the VTDEC from 1987 to 2004, and at several sites by the City of South Burlington in 2001 and 2004. The biological data collected by South Burlington has been approved for use by the VTDEC through the development of a Quality Assurance/Quality Control plan, and through replicate sampling. Table 1 gives the extent of the biological sampling from 1987 to 2004.

Table 1. Biomonitoring frequency at multiple sampling sites in Potash Brook.

Stream Reach (RM=river mile)	# of macroinvertebrate samples	# of fish samples
Main stem RM 0.7	4	2
Main stem RM 1.0	9	5
Main stem RM 1.3	-	3
Main stem RM 1.8	3	4
Main stem RM 1.9	2	-
Main stem RM 2.1	-	1
Main stem RM 3.0	2	-
Main stem RM 4.3	3	-
Trib 3, RM 0.3	3	1
Trib 7, RM 0.1	2	-

Macroinvertebrates were assessed in the *poor* range for a majority of the samples. All sampling results from RM 0.7 and RM 1.0 scored *poor,* with the exception of RM 1.0 during 1989 (*fair*). At site RM 1.8, samples taken during 1989, 1994 and 1997 scored *good*, *good-fair* and *fair* respectively. The remaining upstream RM 1.9, 3.0, and 4.3 all scored a *poor* for all sampling events. The tributary samples have also been consistently assessed as poor, except for Trib 7, RM 0.1 in 1997 was rated as fair-good.

Fish community evaluations were consistently in the *good* range with the exception of RM 1.3 during 1989 when the site scored in the *very good* range, and the Trib 3 site, which scored *poor*. In most cases, biological condition ratings of *fair or poor* will indicate impaired status for Class B waters when collected for a minimum of two years.

Pollutants of Concern and Other Stressors

In streams draining developed watersheds, biological communities are subjected to many stressors associated with stormwater runoff. These stressors are related either directly or indirectly to stormwater runoff volumes and include increased watershed pollutant load (e.g. sediment), increased pollutant load from in-stream sources (e.g., bank erosion), habitat degradation (e.g. siltation, scour, over-widening of stream channel), washout of biota, and loss of habitat due to reductions in stream base flow. The stressors associated with stormwater runoff may act individually or cumulatively to degrade the overall biological community in a stream to a point, as in Potash Brook, where aquatic life uses are not fully supported and the stream does not attain the VTWQS.

Surrogate Measure for Multiple Stressors

This TMDL utilizes the surrogate of stormwater runoff volume in place of the traditional "pollutant of concern" approach. The combination of stressors is represented by the surrogate of stormwater runoff volume. First, the use of this surrogate has the primary benefit of addressing the physical impacts to the stream channel caused by stormwater runoff such as sediment release from channel erosion and scour from increased flows. These physical alterations to the stream are substantial contributors to the aquatic life impairment. Also, reductions in stormwater runoff volume will help restore diminished base flow (increased groundwater recharge), another aquatic life stressor. This surrogate is also appropriate because the amount of sediment load discharged from out of channel sources is a function of the amount of stormwater runoff generated from a watershed.

Fluvial Geomorphic Considerations

Where biological impairment of a stream is principally the result of physical stressors, such as in Potash Brook, the natural and anthropogenic factors controlling physical form and process may be quantified, and the strategies for restoring modified fluvial processes may be devised.

Channel morphology and fluvial processes are primarily controlled by a) watershed inputs from the production zone of the watershed; b) the valley morphology of the stream reach; and c) the boundary material characteristics of the channel (McCrae, 1991, Figure 2).

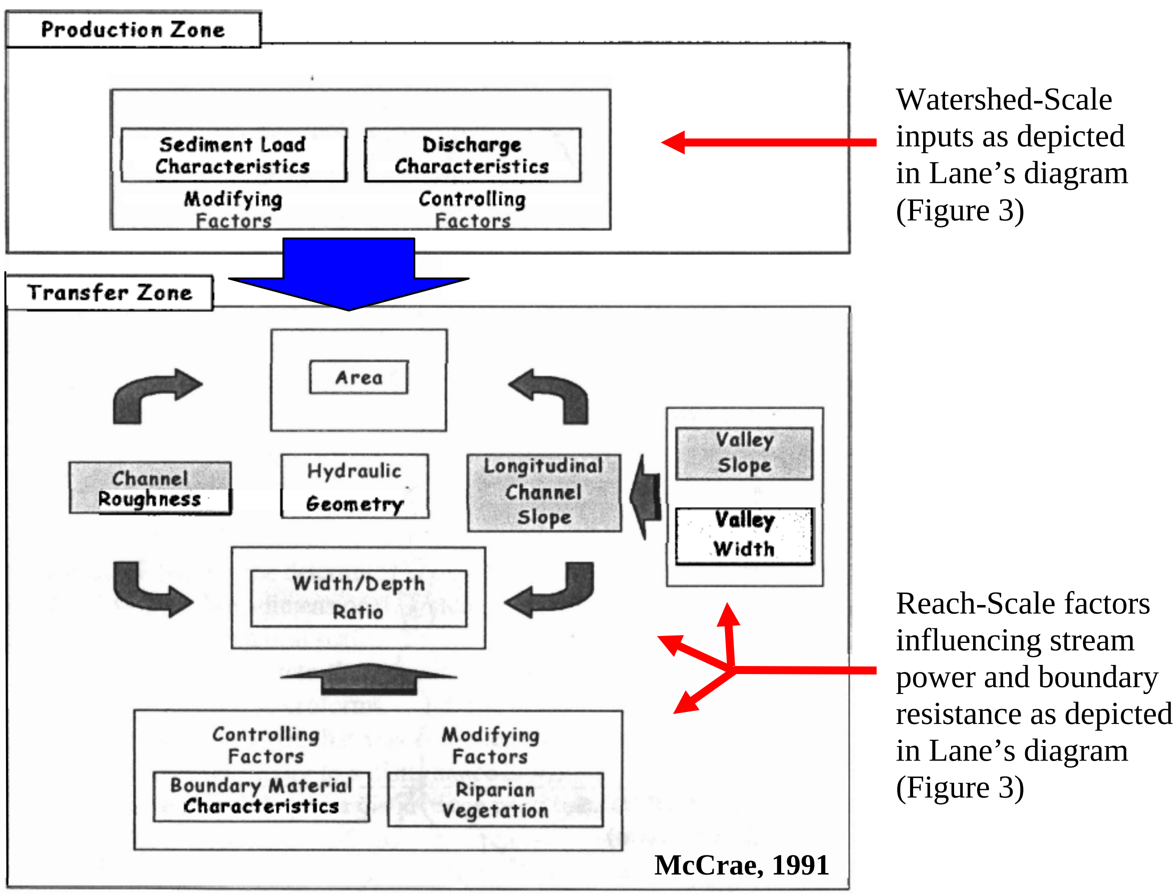

Figure 2. Diagram explaining the watershed and reach-scale controlling and modifying factors affecting the hydraulic geometry and fluvial processes of a stream.

In turn, channel and floodplain modifications and changes to the controlling factors of discharge and boundary materials brought about by watershed and riparian land use modifications place stress on biological communities by altering key physical habitat features of the stream network, including: hydrology; longitudinal and lateral connectivity; temperature; and the transport and retention of sediment, large wood, and organics.

Where the overall goal in the stormwater-impaired watersheds is to reduce physical stressors on key habitat features, the primary objective is to cost effectively manage toward the "reference" hydraulic geometry conditions of the stream channel where the energy grade or stream power, ***as influenced by stream flow (discharge characteristics)***, is in balance with the resistance of the natural boundary materials (see Figure 3).

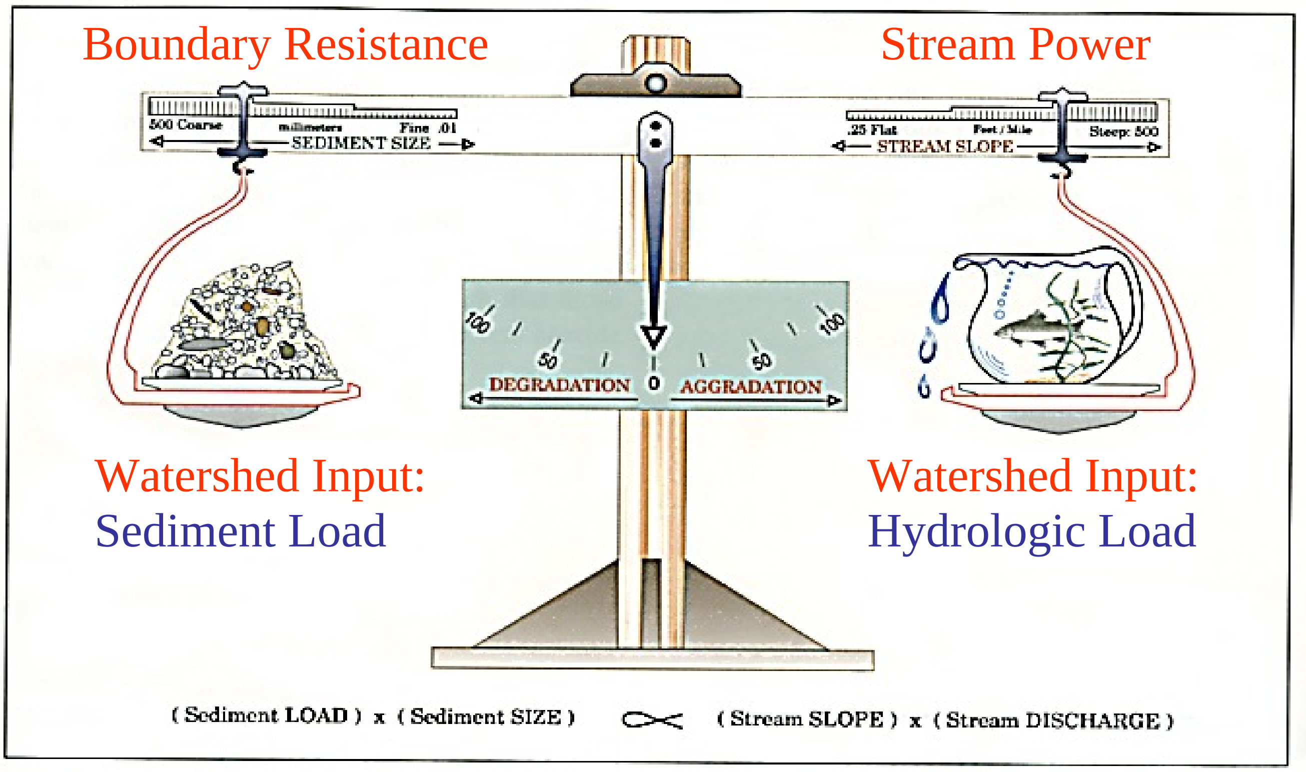

Figure 3: Lane's Diagram (1955) from Rosgen 1996 explaining the balance of stream energy grade with boundary resistance as controlled by hydrologic and sediment load.

The first priority in managing energy grade is to look at stream flow characteristics (Figure 2. production zone input) as the primary controlling factor influencing hydraulic geometry and stream power. To meet the stated goal, alterations to watershed inputs (i.e., stormwater) must be addressed before attempts to remediate other reach-scale (transfer zone) factors affecting hydraulic geometry are undertaken (e.g., dealing with river corridor encroachments to change artificial valley constraints affecting channel plan form and slope and/or restoring floodplain connection to reduce flood depths).

Additionally, sediment load from the production zone may also be a controlling factor to channel hydraulic geometry (Figure 2). In the case of stormwater-impaired streams in Vermont, production zone contributions (colluvial and runoff generated) are far outweighed by the sediment contributions at the transfer zone or reach scale (channel bed and banks), due to channel degradation and widening initiated by stormwater increases.

Stream geomorphic assessment data specific to Potash Brook confirms the significance of the instream sediment generation, as opposed to production zone sediment inputs, and its resultant negative impact on aquatic biota habitat. Results from a 2005 geomorphic assessment in Potash Brook indicate that the stream channel is in a less than stable condition and that the potential for more degradation is high. Of 15 reaches assessed in the Potash Brook mainstem, 14 were rated as being in "fair" geomorphic condition with the remaining reach in "poor" condition. In the same 15 reaches, sensitivity to further channel instability was rated as "very high" in 11 reaches and "high" in the remaining 4. These conditions in turn reflect a generally degraded aquatic habitat whereby 3 reaches were rated as having "poor" habitat conditions, 8 reaches rated as "fair" and 4 reaches rated as "good".

This TMDL aims to address this controlling factor of instream sediment production by determining the departure of existing discharge characteristics in Potash Brook from attainment stream discharge characteristics and setting flow reduction targets to allow for the reestablishment of good habitat conditions throughout the stream in order to meet VTWQS.

Reduced Base Flow

Increased impervious cover and the resulting increase in surface runoff reduces the amount of rainfall that falls on pervious (e.g., vegetated) watershed areas and that is recharged to groundwater. For many streams, groundwater recharge is the predominant source of stream base flow. Diminished base flow can further stress aquatic life and cause or contribute to aquatic life impairments through loss of aquatic habitat (shrinking wetted perimeter) and increased susceptibility to pollutants.

The loss in base flow is directly proportional to the increase in stormwater runoff volume. It is possible to reasonably estimate stormwater runoff and the amount being recharged. It can be far more complicated to estimate the relationship between groundwater recharge and stream base flow. However, simpler methods involving hydrologic models have been used to successfully predict stream base flow as a function of groundwater recharge. More difficult, however, is understanding and quantifying the net effect of diminished base flow on aquatic life for a given stream.

Water Quality Standards

Potash Brook is listed as impaired based on narrative criteria relating to aquatic biota. The impact of excessive stormwater flows into Potash Brook has resulted in a violation of the VTWQS §3-04(B)(4) which states that there shall be:

"No change from the reference condition that would prevent the full support of aquatic biota, wildlife, or aquatic habitat uses. Biological integrity is maintained and all expected functional groups are present in a high quality habitat. All life-cycle functions, including overwintering and reproductive requirements are maintained and protected."

In Vermont, numeric biological indices are used to determine the condition of fish and aquatic life uses. Vermont's Water Quality Standards at 3-01(D)(1) and (2) provide the following regulatory basis for these numeric biological indices:

"(1) In addition to other applicable provisions of these rules and other appropriate methods of evaluation, the Secretary may establish and apply numeric biological indices to determine whether there is full support of aquatic biota and aquatic habitat uses. These numeric biological indices shall be derived from measures of the biological integrity of the reference condition for different water body types. In establishing numeric biological indices, the Secretary shall establish procedures that employ standard sampling and analytical methods to characterize the biological integrity of the appropriate reference condition. Characteristic measures of biological integrity include but are not limited to community level measurements such as: species richness, diversity, relative abundance of tolerant and intolerant species, density, and functional composition.

(2) In addition, the Secretary may determine whether there is full support of aquatic biota and aquatic habitat uses through other appropriate methods of evaluation, including habitat assessments."

Designated Uses

Potash Brook is a Class B waterbody. Section 3-04(A) of the VTWQS states:

Class B waters shall be managed to achieve and maintain a high level of quality that is compatible with the following beneficial values and uses: . . .

§3-04(A)(1):

aquatic biota and wildlife sustained by a high quality aquatic habitat with additional protection in those waters where these uses are sustainable at a higher level based on Water Management Type designation.

Since biomonitoring data does not meet the criteria for Class B standards, Potash Brook does not support the designated uses for Class B waters.

Antidegradation Policy

In addition to the above standards, the VTWQS contain the following General Antidegradation Policy in §1-03(B):

All waters shall be managed in accordance with these rules to protect, maintain, and improve water quality.

Numeric Water Quality Target

In a pollutant-specific TMDL, a stream's water quality target, or loading capacity, is the greatest amount of pollutant loading the water can receive without violating water quality standards. In this TMDL, because the "pollutant of concern" is represented by the surrogate measure of stormwater runoff volume, the loading capacity is the greatest volume of stormwater runoff Potash Brook can receive without violating the stream's aquatic life criteria. The challenge is to determine the maximum stormwater runoff volume for each stormwater-impaired stream.

Target Setting Approach

The Framework identifies a reference watershed approach whereby hydrologic targets are developed by using similar "attainment" watersheds as a guide. The term "attainment" is used here rather than "reference" because reference tends to imply that the ultimate goal for the impaired stream approaches pristine. Instead, the attainment watershed(s), while meeting or exceeding the Vermont water quality standards criteria for aquatic life, should contain some level of development in order to better approximate the true ecological potential of the impaired stream. This TMDL uses the attainment watershed approach for target setting and identifies hydrologic targets for Potash Brook based on the hydrologic characteristics of similar watersheds where the VTWQS aquatic life criteria are currently met.

The first step in using the attainment watershed approach is to select appropriate attainment streams, which, ideally, are as similar to the impaired watershed as possible in physical makeup, such as slope, soils, climatic patterns, channel type, and land use/cover, etc. Since all of the lowland stormwater-impaired streams are located in the Lake Champlain Valley, a collection of similarly located streams was identified as a pool from which the most representative attainment watersheds could be selected for each stormwater-impaired watershed.

The Framework identifies flow duration curves (FDCs) as the best surrogate for defining hydrologic targets. FDCs are very useful at describing the hydrologic condition of a stream/watershed because the curves incorporate the full spectrum of flow conditions (very low to very high) that occur in the stream system over a long period of time. The FDCs also incorporate any flow variability due to seasonal variations. A comparison of FDC between an impaired and appropriate attainment stream/watershed can reveal obvious patterns. For example, a FDC for a stormwater-impaired stream/watershed will typically show significantly higher flow rates per unit area for high flow events and significantly lower flow rates per unit area for low-base flow conditions than the FDC for the attainment watersheds. The increased predominance of high flow events in the impaired watershed creates the potential for increased watershed stormwater pollutant loadings, increased scouring and stream bank erosion events, and the possible displacement of biota from within the system. Also the reduction in stream base flow revealed by the FDC can create a potential loss of habitat for low flow conditions.

A high flow value (0.3%) and a low flow value (95%) were selected as points along the continuum of the FDCs useful for setting specific hydrologic targets. The 0.3% exceedance flow closely matches the one year return flow and the 95% exceedance flow represents a low flow condition comparable to the 7Q10.

Since there is limited hydrologic data for either impaired or attainment streams, the Framework recommends developing synthetic FDCs by employing a calibrated rainfall-runoff model based on land use and cover. FDCs can then be developed for both impaired and attainment streams and the relative difference between the two is used to establish the flows needed to restore the stream's hydrology. In this TMDL, the hydrologic targets are expressed as percentage reductions or increases relative to the attainment watersheds' FDCs at the representative high and low flow values.

Flow Duration Curves

Based on available data and the model outputs necessary to develop the FDCs, the P8-Urban Catchment Model (P8-UCM) was selected (Walker, 1990). Inputs to P8-UCM for hydrologic simulation include climatological data, percent watershed imperviousness, pervious curve number, and times of concentration for ground water base flow and surface runoff.

After initial calibration and review, additional changes were made to improve the low flow prediction capability of the model and refine the estimated surface runoff time of concentration. Upon final review and model verification, the calibrated model was used to develop FDCs for all impaired and attainment streams in the lowland areas. A complete discussion of the model setup, calibration, adjustments and results can be found in the report entitled *"Stormwater Modeling for Flow Duration Curve Development in Vermont"* (Tetra Tech, 2005). The complete FDC for Potash Brook along with expanded views of the high and low flow portions of the curve are given below in Figures 4-6.

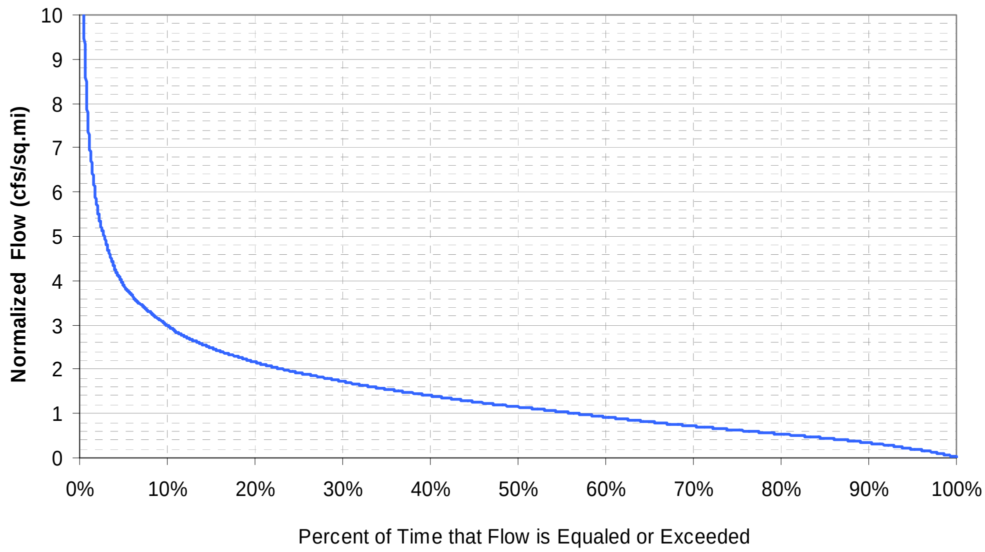

Figure 4: Potash Brook flow duration curve.

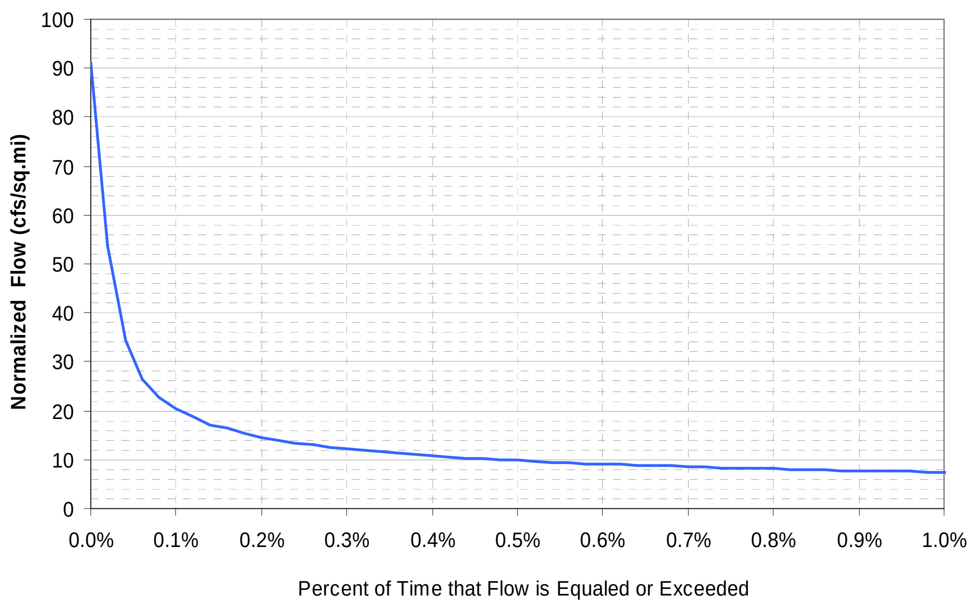

Figure 5: High flow portion of the Potash Brook flow duration curve.

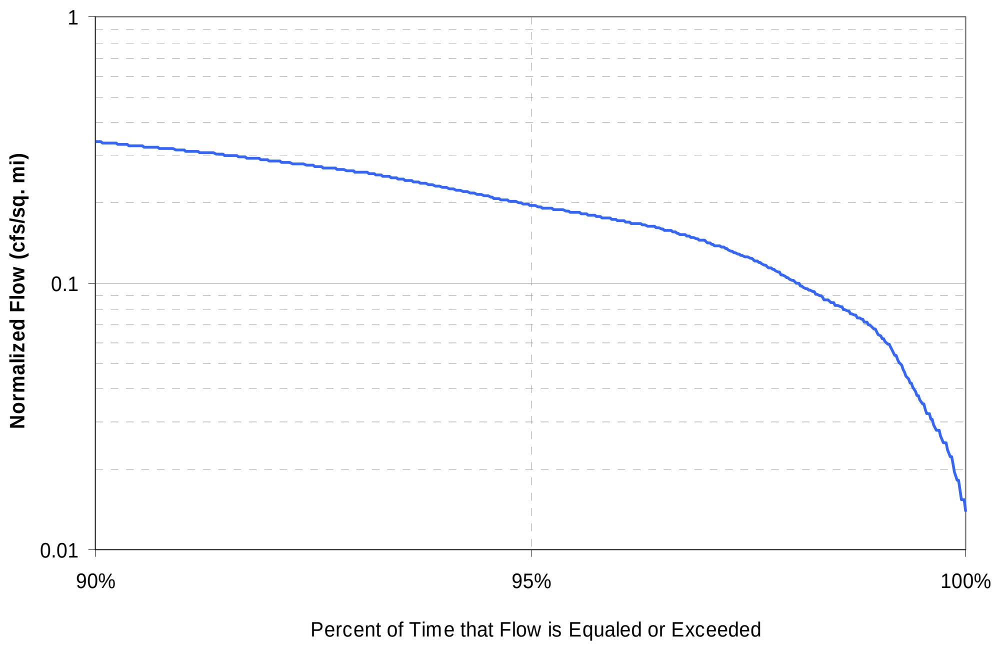

Figure 6: Low flow portion of the Potash Brook flow duration curve

Target Setting

With the FDCs for all attainment and impaired streams in hand, a process was developed to determine which attainment streams to use for setting appropriate hydrologic targets. A statistical approach was developed cooperatively by researchers at the University of Vermont and the VTDEC that allowed for the selection of the most appropriate attainment streams for each stormwater-impaired stream. A summary of this methodology is given below; however, the complete methodology and results can be found in a report under separate cover (Foley, 2005).

The first step in this target setting approach was a statistical analysis of the P8 input variables for each watershed to establish what are the most influential factors determining impairment/attainment in the sample of Lake Champlain Valley streams. The second step grouped impaired streams with the most similar attainment streams based on watershed features that were least likely to determine impairment based on step one. By doing this, watersheds were grouped based on intrinsic similarities that effect flow, resulting in attainment streams being grouped with the most similar stormwater-impaired streams. Within each group, the attainment stream FDCs represent a hydrologic regime that will most likely support healthy aquatic life and thus the attainment of the VTWQS for each stormwater-impaired stream.

Due to the relatively small sample size of attainment streams (15) relative to the number of lowland stormwater-impaired streams (12), the concept of a range of appropriate FDC values is useful to alleviate some uncertainty associated with selecting the single best matching watershed. While the entire range of flows within each attainment group represents flow regimes associated with attainment conditions (i.e. supporting VTWQS criteria for aquatic life), the selection of the mean value provides an intrinsic margin of safety that the selected target represents an attainment condition. The group of attainment streams best matched with Potash Brook is given in Table 2 with FDC flows at the high and low flow intervals.

Table 2. Attainment streams matched with Potash Brook and corresponding flows.

	Status	Q 0.3% (cfs/mi^2)	Q 95% (cfs/mi^2)
Potash Brook	Impaired	12.2374	0.1964
LaPlatte River	Attainment	11.5221	0.2132
Little Otter Creek	Attainment	9.0217	0.2249
Attainment streams mean flow		10.2719	0.2190
Difference between Potash and mean attainment flows		1.9655	0.0226

The actual TMDL target flow rates for Potash Brook are the percentage differences between the Potash Brook flows and the mean of the attainments at both Q0.3% and Q95% (Table 3). This accounts for any lack of accuracy in the FDCs developed with the P8-UCM. Considering the relative simplicity of the model, it is likely that there may be some inaccuracy with the final modeled flow values compared to actual flows. However, since similar data sources and calibrated model were used across all watersheds, both impaired and attained, inaccuracies are expected to be relative across all watersheds. Therefore, the relative difference between impaired and target flows are best described as a percentage rather than actual flow rates.

Table 3. Watershed flow targets given as percentage increase/decrease from current conditions.

Target decrease in flow at Q 0.3%	Target increase in flow at Q 95%
-16 %	12 %

Margin of Safety

The Clean Water Act and implementing regulations require that a TMDL include a margin of safety (MOS) to account for any lack of knowledge concerning the relationship between the TMDL allocations and water quality. EPA guidance explains that the MOS may be either implicit (i.e. incorporated into the TMDL through conservative assumptions in the analysis) or explicit (i.e. expressed as a separate allocation). The MOS in this TMDL is implicit and is incorporated through conservative assumptions in the target setting approach.

As described above, the mean flow of the attainment streams was selected as the target flow condition in the Potash Brook TMDL to provide an intrinsic margin of safety that the selected targets would provide for the attainment of the VTWQS. Due to the rigorous application of the attainment stream approach in the Potash Brook TMDL, the targets are believed to be particularly accurate thus reducing the need for an overly conservative or arbitrary margin of safety.

The use of the attainment stream approach is a particularly good approach to identify flow targets because it relates appropriate flow conditions in streams that comply with the VTWQS (attainment streams) back to Potash Brook. However, haphazard matching of attainment streams, and thus flow targets, to Potash Brook could lead to targets with a high degree of uncertainty as to whether standards would be met. To provide a more rigorous target setting approach, attainment streams for Potash Brook were selected using an analysis described in "Statistical Analysis of Watershed Variables" (Foley, J. and Bowden, 2005). VTDEC believes that by utilizing this approach, Potash Brook was paired with the "most similar" attainment streams available in the Lake Champlain Basin. By identifying the "most similar" attainment streams through standard statistical approaches, a significant amount of uncertainty is eliminated regarding what are the best target values.

According to the attainment stream approach, by definition, the flows for the attainment streams (LaPlatte River and Little Otter Creek) represent flows under which the biologic criteria are currently being met. This can be thought of as a range of flows in streams most similar to Potash Brook that are capable of sustaining appropriate aquatic life standards as defined by the VTWQS. At the high flow target interval, this represents a range of flows from 9.02 to 11.52 cfs/sq mi. It is reasonable to assume that attainment of flows at the high end of this range (11.52 cfs/sq mi) would allow Potash Brook to comply with the VTWQS, however, by lowering the target by 10% to the attainment stream mean, an appropriate margin of safety is added.

Additionally, it is likely that the flows represented by the attainment stream are not at the "threshold" of attainment. That is, the modeled flows in the streams currently meeting standards likely represent flows somewhat below that which impairment would occur, thus adding an additional level of safety.

VTDEC affirms the attainment stream approach outlined in the Docket report and has taken steps to reduce a significant level of target setting uncertainty by incorporating a solid statistical approach. The fact that the stormwater runoff volume target approach has not routinely been utilized in the development of TMDLs should not detract from its firm basis in sound science and logical experimental design.

Further, the Docket strongly urges the concept of adaptive management when implementing controls in the stormwater-impaired streams and VTDEC is firmly committed to this idea. Various types of watershed monitoring, many of which have already been initiated, will provide the necessary data to either adjust the targets or implementation measures to ensure ultimate compliance with VTWQS in Potash Brook. While VTDEC believes there is an adequately conservative margin of safety associated with these targets, post-implementation adaptive management provides yet another layer of "safety" that the VTWQS will be met.

Seasonal Variation

The Clean Water Act and implementing regulations require that a TMDL be established with consideration of seasonable variations. The Framework identifies flow duration curves (FDCs) as the best surrogate for defining hydrologic targets. The FDCs developed for this TMDL are very useful at describing the hydrologic condition of a stream/watershed because the curves incorporate the full spectrum of flow conditions (very low to very high) that occur in the stream system over a long period of time. The FDCs also incorporate any flow variability due to seasonal variations.

Allocations

In addition to the overall watershed target, this TMDL also must provide for an allocation of that target between point sources and nonpoint sources, or, the Wasteload Allocation (WLA) and the Load Allocation (LA) respectively. USEPA guidance allows for a gross allocation between these two stormwater source types rather than accounting for every discrete stormwater conveyance and the areas draining to them (USEPA 2002). Data is currently unavailable for a finer allocation among sources in Potash Brook or any of the other stormwater-impaired streams in Vermont. The USEPA guidance also allows for dividing the allocation by using a land use analysis to simplify the process. By making the assumption that more developed areas typically convey stormwater via discrete means such as pipes or swales and lesser developed areas mostly convey stormwater via surface sheetflow, the allocation process can be developed with land use analysis whereby developed areas fall into the WLA and the lesser developed areas into the LA.

This TMDL uses the land use based allocation approach to distribute the overall percent targets for the watershed. To do this, the Potash Brook watershed was divided into three broad categories including Urban/Developed, Agriculture/Open, and Forest/Wetland. Table 4 below illustrates how the land use categories were divided into these three broader categories and the associated land areas within the Potash Brook watershed.

Table 4. Categorization of Land Uses into broader classes.

Major Land Use Categories	Land Use Name
Urban/Developed	Residential
	Commercial
	Industrial
	Transportation
	Other Urban
Agriculture/Open	Agriculture/Mixed Open
	Row Crops
	Hay/Pasture
	Barren Land
Forest/Wetland	Deciduous Forest
	Coniferous Forest
	Mixed Forest
	Brush/Transitional
	Wetland
	Water

The overall percent reduction/increase in flows was then distributed among these three categories to meet watershed targets. It was determined that there would be a zero allocation, or no expected change in flow levels emanating from the Forest/Wetland category since the runoff characteristics from these areas are likely optimal with regard to overall watershed hydrology. This left the allocation to be distributed between the Urban/Developed (WLA) and Agriculture/Open (LA) categories. The next step was to determine the relative amount of influence each category had on runoff characteristics, and thus the FDC, and divide the allocation accordingly. To accomplish this, the concept of a runoff coefficient was utilized.

A runoff coefficient (R_v) is an expression of the percentage of precipitation that appears as runoff. The value of the coefficient is determined on the basis of climatic conditions and physiographic characteristics of the drainage area and is expressed as a constant between zero and one. By determining the relative contribution to stormwater runoff from each land use category using the R_v, the allocation between WLA and LA can be made accordingly.

The primary influence on R_v is the degree of watershed imperviousness. This is shown through data collected from numerous watersheds during the National Urban Runoff Program Study from which an equation was developed to define the R_v. as shown below (Schueler 1987):

$$R_v = 0.05 + 0.9(I_a)$$

Where: I_a = Impervious fraction

Percent imperviousness was estimated using a previously developed relationship (CWP et al., 1999) for the Vermont Center for Geographic Information (VCGI) land use data layer. Table 5 presents the estimated vales for various land use categories.

Table 5. Relationship between VCGI Land Use and percent imperviousness.

VCGI Land Use Code	Land Use Name	Percent Impervious Cover
3	Brush/Transitional	0%
5	Water	0%
7	Barren Land	0%
11	Residential	14%
12	Commercial	80%
13	Industrial	60%
14	Transportation	41%
17	Other Urban	60%
24	Agriculture/Mixed Open	2%
41	Deciduous Forest	0%
42	Coniferous Forest	0%
43	Mixed Forest	0%
61,62	Wetland	0%
211	Row Crops	2%
212	Hay/Pasture	2%

By calculating the R_v for each broad land use group, and then weighting that coefficient's influence on runoff based on the amount of land area within each group, the relative influence of each group on runoff (and conversely groundwater recharge) can be used to allocate the watershed targets across the entire watershed. The results for Potash Brook are given below in Table 6.

Table 6. The relative influence of each land use category on stormwater runoff in Potash Brook based on the calculation of the R_v.

	R_v	Area (acres)	Weighted influence on runoff
Urban/Developed	0.40	2,434	91%
Agriculture/Open	0.07	1,340	9%

USEPA interprets 40 CFR 130.2 to require that allocations for NPDES-regulated discharges of stormwater runoff be included within the wasteload allocation component of the TMDL (USEPA, 2002). USEPA also states that in instances where there is insufficient data to calculate loads on an outfall by outfall basis, the stormwater wasteload may be expressed as an aggregate or categorical allocation. USEPA acknowledges that in cases where it is difficult to separate NPDES-regulated from non NPDES-regulated stormwater discharges, it is acceptable to include both NPDES-regulated stormwater discharges and non NPDES-regulated discharges (which would typically be included in the load allocation portion of the TMDL) in this aggregated wasteload category.

Because of data limitations and the wide variability of stormwater discharges, it is not possible to separate the stormwater discharges subject to the NPDES program (e.g. stormwater discharges from construction activity and multi-sector industries) from stormwater discharges that are not subject to NPDES permitting (e.g. stormwater discharges from impervious surfaces regulated under Vermont's stormwater program). Therefore, all stormwater discharges from the urban/developed land category are included in the wasteload allocation portion of this TMDL. This category includes the

NPDES-regulated stormwater discharges as well as other sources of stormwater runoff not regulated as NPDES discharges.

In other words, the weighted proportion of runoff from the more developed areas, where the vast majority of the "regulated" stormwater was generated, established the limit of the WLA. Therefore, the "regulated" areas, including all the NPDES permitted sources required to be in the WLA, are responsible for reducing and maintaining a 91% decrease in the high flow target. The same is true for the LA whereby the "nonregulated" areas are responsible for reducing and maintaining a 9% decrease in the high flow target.

By aggregating NPDES-regulated and non NPDES-regulated stormwater discharges in the wasteload allocation, the public is provided with a clearer understanding of how Vermont proposes to achieve water quality standards and meet the cleanup target established in the TMDL. However, the inclusion of stormwater discharges outside the scope of the NPDES permit program in the wasteload allocation does not mean that these discharges will require a NPDES stormwater permit.

Future Growth

The Agency has applied a two step analysis in allocating for future growth in this TMDL. First, as to "jurisdictional" new growth that is subject to the VTDEC's permit program for impervious surfaces under 10 V.S.A. Section 1264 (i.e. new impervious surfaces greater than one acre), the Agency assumes that the channel protection requirements in the Vermont Stormwater Management Manual requiring 12-hour detention of the 1-year storm, or 24-hour detention if discharging to a warm-water fishery, are sufficient to protect against future stream degradation. The manual requires sites to meet channel protection (CPv) as well as groundwater recharge treatment standards. The premise of the channel protection standard is that runoff would be stored and released in such a gradual manner that critical erosive velocities would seldom be exceeded in downstream channels. MacRae (1991) found that the traditionally used 2-year control approach failed to protect channels worn into more sensitive boundary materials and actually aggravated erosion hazard in very sensitive channels. Therefore, MacRae (1991) developed the DRC (Distributed Runoff Control) as a method to vary the degree of control from the 2-year control to the 80% over control based on the strength of boundary material. A study done in Maryland (Cappuccitti, 2000) showed that "the CPv and DRC methods provide a comparable level of management." Additionally, the Center for Watershed Protection (CWP) recommends the use of the channel protection criteria stating that "the criterion balances the need to use a scientifically valid approach with a methodology that is relatively easy to implement in the context of a statewide program." (CWP, 2000) VTDEC believes that if future growth complies with the channel protection standard as well as the groundwater treatment standard, Potash Brook will still be able to meet both the high and low flow targets of the TMDL.

For "jurisdictional"new growth relative to the low flow targets, the Vermont Stormwater Management Manual groundwater recharge treatment standard requires that predevelopment recharge volumes be maintained, thus providing adequate protection.

As to “non-jurisdiction” new growth (i.e. new impervious surfaces less than one acre), runoff from which could contribute to stream degradation, the Agency has allocated additional stream flow reductions from current conditions to account for these potential impacts. This allocation is based on future growth predictions of “non-jurisdiction” impervious surfaces provided by the City of South Burlington. South Burlington estimates that thirty (30) acres of “non-jurisdictional” impervious surfaces will be created, at a maximum, over the next ten years. By requiring reductions from currently developed areas that are equal to the future impacts of the additional 30 acres this type of future development should have no effect on the overall watershed stream flow targets. The same approach has been applied to the low flow targets.

Based on a subsequent P8-UCM model run, the projected 30 acres of impervious surfaces increased the flow at the 0.3% high flow point on the FDC from 12.2374 to 12.4670 cfs/mi^2. The flow at the 95% low flow point on the FDC decreased from 0.1964 to 0.1950 cfs/mi^2.

Overall Allocation

In the broadest sense, the primary function of a TMDL is to determine and allocate among sources the maximum pollutant loading a waterbody can receive to maintain compliance with the appropriate water quality standard. For the Potash Brook TMDL, it’s the stormwater runoff volume that is being limited overall and allocated among sources. This approach works well within the TMDL framework for the high flow target whereby an overall reduction of stormwater runoff is required. However, this approach does not fit particularly well for the low flow target where an increase in non-stormwater instream flow is necessary and loading of stormwater runoff volume is not directly being allocated. The restoration of low flows in Potash Brook is actually a secondary result of controlling stormwater runoff (high flows) and increasing groundwater recharge. As stormwater runoff volumes are controlled (high flow reductions), the water that eventually reaches the stream (low flow increases) is no longer considered stormwater runoff because it is generally routed through the groundwater and does not reach the stream for a significant amount of time following the precipitation event.

Also, the benefit of decreased pollutant loading (sediment, nutrients, etc.) due to reduced stormwater runoff at high flows provides a good fit, although indirectly, within the TMDL framework. The same cannot be said of the low flow targets. The low flow targets represent conditions where pollutants are already substantially removed from water the stream receives from groundwater and thus there are no problematic “pollutants” to allocate.

For these reasons, EPA does not consider the low flow targets applicable to an allocation scenario and thus they will not be presented as such in this TMDL. Therefore, Table 7 gives the overall Potash Brook TMDL allocation for the high flows and Table 8 presents the overall Potash Brook targets for the low flow condition.

It should be emphasized here that even though the low flow targets are not part of the formal TMDL allocation, VTDEC remains committed to retaining these low flow targets within the remediation plan for the watershed.

Table 7. Potash Brook TMDL high flow allocation at Q0.3%.

Wasteload Allocation	Stormwater reduction from current Urban/Developed areas	-14.6 %	-16.5 %
	Additional stormwater flow reduction from Urban/Developed areas to account for future growth	-1.9 %	
Load Allocation	Stormwater reduction from Agriculture/Open areas		-1.4 %
Total Potash Brook watershed stormwater flow reduction allocation at Q0.3%			-17.9 %

Table 8. Potash Brook low flow targets at Q95%.

Wasteload Allocation	Base flow increase from current Urban/Developed areas	10.5 %	11.2 %
	Additional base flow increase from Urban/Developed areas to account for future growth	0.7 %	
Load Allocation	Base flow increase from Agriculture/Open areas		1.0 %
Total Potash Brook watershed base flow increase target at Q95%			12.2 %

Reasonable Assurances

When a TMDL is developed for waters impaired by both point and nonpoint sources, and the waste load allocation is based on an assumption that nonpoint source load reductions will occur. EPA's TMDL guidance provides that a TMDL must provide reasonable assurances that nonpoint source control measures will achieve expected load reductions in order for the TMDL to be approvable. In order to allocate loads among both nonpoint and point sources, there must be reasonable assurances that nonpoint source reduction will in fact be achieved. Where there are not reasonable assurances, under the Clean Water Act, the entire load reduction must be assigned to point sources.

As discussed earlier, this TMDL has been structured with an aggregate waste load allocation category that includes both NPDES-regulated stormwater discharges and non NPDES-regulated stormwater discharges. This category includes all stormwater discharges from the urban/developed land category. Under the Clean Water Act, the only federally enforceable controls are those for point sources through the NPDES permitting process. However, VTDEC implements both a federally-authorized NPDES permit program for stormwater discharges from construction activities, industrial activities and municipal discharges under the MS4 program and a state-authorized permitting program for stormwater discharges from impervious surfaces equal to or greater than one acre.

VTDEC is, therefore, well positioned to require implementation of stormwater treatment and control measures through NPDES permit conditions and state stormwater permit conditions for discharges in the urban/developed land category. This wasteload allocation category constitutes a 91% weighted influence on stormwater runoff.

The load allocation is comprised of the agriculture/open land use category that constitutes a 9% weighted influence on stormwater runoff. VTDEC believes that nonpoint source control measures that will be implemented through Vermont's Clean and Clear Action Plan will achieve the required load reductions set forth in this TMDL. Although the Clean and Clear Action Plan is primarily a phosphorus reduction plan, action items in that Plan will also benefit the stormwater-impaired streams in the Champlain Basin. These action items include:

- Expand the Conservation Reserve Enhancement Program statewide to create conservation easements on farms along streams for buffer implementation.
- Provide technical assistance by Agricultural Resource Specialists to help farmers statewide with best management practices, riparian buffer conservation, nutrient management, compliance with Accepted Agricultural Practices, basin planning, and other technical needs.
- Support agricultural participation in the basin planning process.
- Hire Watershed Coordinators for Lake Champlain Basin watersheds to help develop and implement river basin plans.
- Expand the Department's River Management Program to promote stream stability and reduce phosphorus loading from stream bank and stream channel erosion in the Lake Champlain Basin through a comprehensive program of assessment, protection, management, restoration, and education, with additional federal funding being sought from the U.S. Environmental Protection Agency, the U.S. Fish and Wildlife Service, the U.S. Army Corps of Engineers, and other agencies.
- Enhance the Vermont Better Backroads Program throughout the Lake Champlain Basin with staffing for technical assistance and increased funding for erosion control grants to towns.
- Offer technical assistance to towns in the Lake Champlain Basin seeking to provide better water quality protection through local ordinances and other municipal actions.
- Protect and/or restore riparian wetlands.

The nonpoint source phosphorus reduction activities listed in the Lake Champlain Phosphorus TMDL implementation plan will be actively pursued, contingent on the availability of state and federal funding and the provision of other necessary authority to the Department to carry out these implementation activities. Vermont Governor Douglas announced his "Clean and Clear Action Plan" on September 30, 2003. A major focus of this plan is implementation of the Lake Champlain Phosphorus TMDL.

A total of $8.4 million in state funds was appropriated by the Vermont General Assembly at the request of the Governor for state fiscal year 2006 for the Clean and Clear Action Plan. This follows the $7.5 million state appropriation in 2005. These funds are being used to support the above mentioned activities by the Agency of Natural Resources, the Agency of Agriculture Food and Markets, and many partners.

Implementation Plan

EPA is not required to and does not approve TMDL implementation plans. Moreover, TMDLs are not legally required to include implementation plans. Despite this, the Agency has provided below a brief description of the general framework that it anticipates using to implement this TMDL. The Agency is providing this general description to aid the public in understanding the myriad of tools that the Agency possesses to effectively implement this TMDL. This framework may change over time based on new information gathered by VTDEC and as necessary to meet the requirements of this TMDL.

As a starting point, the Agency has been undertaking various projects to collect information to aid in the development of the implementation plan and in monitoring to assess the success of the plan as it is implemented and make necessary adjustments to the implementation plan. These projects include stream geomorphic assessment, subwatershed mapping, flow gaging and precipitation monitoring, impervious surface mapping and engineering feasibility assessment

Stream Geomorphic Assessment

In order to support the monitoring phase of stream remediation efforts, ANR has contracted with UVM and various consultants to develop a consistent baseline of stream geomorphic assessments (SGAs) for the stormwater-impaired streams, including Potash Brook. These SGAs can be used as a point of comparison for future assessments to document improvements or degradation of these streams on a set of reaches from stormwater-impaired streams.

Subwatershed Mapping

The objective of this project is to identify discharge points within the stormwater-impaired watersheds and delineate the associated watersheds for those discharge points. The previously available subwatershed data is of varying quality. In some cases, there was data on stormwater collection systems and discharge points. However, all of the watersheds took a substantial amount of work to get an accurate subwatershed delineation. The delineation of these sub-watersheds will help to focus stormwater treatment and control measures on higher risk areas within each stormwater-impaired watershed.

Flow Gaging and Precipitation Monitoring

Altered hydrology within the stormwater-impaired watersheds is the dominant factor in causing the impairments. To support the monitoring phase of stream remediation, ANR hired a consultant to establish and operate stream flow and precipitation recording stations within each of the stormwater-impaired waters. This data will form an essential part of the adaptive management approach (discussed below) as stream flow is anticipated to reflect the initial response of Potash Brook to stormwater treatment and control measures that are implemented in accordance with this TMDL.

Impervious Surface Mapping

ANR is mapping the impervious surface area of each stormwater-impaired watershed using QuickBird satellite data. The QuickBird satellite acquires high-quality satellite imagery for map creation, detection of change over time, and image analysis. This project is being undertaken in conjunction with School of Natural Resources at the University of Vermont.

ANR has performed the digital analysis of the data for the Potash Brook watershed. UVM will apply advanced object oriented eCognition classification techniques to potentially improve the mapping accuracy for the previously analyzed data using the QuickBird satellite data. This data will be used in developing the implementation plan for this TMDL.

Engineering Feasibility Assessment

To help develop the implementation plan for this TMDL, ANR is currently collecting technical data for all significant stormwater treatment practices (including ponds, infiltration basins, constructed wetlands, etc.) in the Potash Brook watershed. Technical information including pond volume, drainage area and detention time is being collected through permit review and site modeling using HydroCAD software. Once information is collected, site visits are conducted to ensure the accuracy of data. In addition to data collection, ANR is also conducting a limited engineering feasibility analysis at each site to determine what can reasonably be achieved at each site with regard to stormwater detention and infiltration.

Spatial Analysis of Watershed Sensitivity (SAWS)

Spatial Analysis of Watershed Sensitivity (SAWS) is a Geographic Information System (GIS) analysis which will be used to help develop the implementation plan for this TMDL. SAWS ranks the sensitivity of subwatersheds within the stormwater-impaired watershed by analyzing watershed characteristics such as impervious surface, slope, stream stability, and soils. This analysis will help focus where to begin implementing stormwater treatment and control practices, beginning with the subwatersheds with highest risk and continuing down the list until the VTWQS are attained. The SAWS method will help to evaluate where the implementation of stormwater treatment and control will result in the greatest improvements on the flow regime, and ultimately the water quality in the watershed.

Watershed-Wide General Permits and NPDES Permits

As discussed above, Vermont is authorized to implement both a federally-authorized NPDES permit program for stormwater discharges from construction activities, industrial activities and municipal discharges under the MS4 program and a state-authorized permitting program for stormwater discharges from impervious surfaces equal to or greater than one acre. This duel permitting authority provides Vermont with powerful tools for requiring the implementation of stormwater treatment and control practices necessary to meet the cleanup targets in this TMDL.

The Agency anticipates that it will utilize an iterative, adaptive management approach to implementing this TMDL. The first prong of implementation will involve the issuance of a watershed-wide general permit pursuant to Vermont's state stormwater law. Stormwater treatment and control measures will be required in the first-round watershed-wide general permit, including the construction and/or upgrade of stormwater treatment and control systems by specifically identified dischargers of stormwater runoff. The first-round general permit will include a coordinated and cost-effective monitoring program to gather necessary information to determine the extent to which the general permit provides for the attainment of the VTWQS and to determine the appropriate conditions or limitations for subsequent permits. Such a monitoring program may include ambient monitoring, receiving water assessment, discharge monitoring (as needed), or a combination of monitoring procedures designed to gather the necessary information. Based on this information, the permit will be amended, as needed, through the implementation of more widespread and/or more stringent treatment and controls or other best management practices as necessary to meet the water quality targets in the TMDL. This adaptive management approach is a cyclical process in which a TMDL implementation plan is periodically assessed for its achievement of water quality standards and adjustments to the plan are made as necessary.

The second prong of the implementation plan includes NPDES permits issued by the Agency for construction activities, industrial activities and municipal discharges under the MS4 permitting program. These permits contain conditions for implementation of appropriate best management practices to provide for attainment of the VTWQS.

Monitoring Plan

USEPA recommends a monitoring plan to track the effectiveness of a TMDL. The Framework supports the concept of adaptive management which necessitates a substantial monitoring plan at several levels. The Framework identifies three levels of monitoring that are necessary for an adaptive management process to proceed most effectively. These include monitoring: 1) stormwater treatment and control practices, 2) the primary stressors in the watershed, and 3) the instream habitat and biological condition. VTDEC intends to institute a comprehensive monitoring plan that addresses all the aspects identified in Framework. At this point, certain parts of the monitoring plan have already been initiated while it is premature for others to begin. Several of the initiated monitoring programs have been summarized in the previous "Implementation Plan" section.

Since the watershed general permit that will require the implementation of stormwater treatment and control measures necessary to meet the TMDL target for Potash Brook has yet to be developed, there is currently no specific monitoring plan for Potash Brook.

However, VTDEC will include requirements for the monitoring components listed in the Framework, namely tracking BMPs implemented, percentage of stormwater treated, percent of land area treated, etc. in the general permit. This should be accomplished relatively easily through database tracking of permits.

Monitoring of the primary stressors in Potash Brook is necessary to reveal if the implementation measures are having the desired impact. To date, some background monitoring has occurred to provide baseline information against which to measure future change. Continuous streamflow monitoring has been initiated in Potash Brook. Also, VTDEC has developed the in-house capability to accurately measure imperviousness within the watershed based on satellite imagery.

Monitoring of habitat condition and biological condition in Potash Brook has also been initiated. Stream geomorphic assessments have been completed which include an assessment of aquatic life habitat. This data will provide a baseline against which to compare future assessments. Recent biological monitoring has also been conducted to verify the stormwater impairment listing of Potash Brook. Similarly, this will be used as background data to track future improvements and ultimate meeting of the VTWQS.

Public Participation

A public comment period was established upon the release of the draft Potash Brook TMDL from November 18, 2005 through December 19, 2005. However, at the request of the public, the comment period was extended until January 9, 2006. In conjunction with the release of the draft TMDL, an informational public meeting was conducted in South Burlington on December 14, 2005 to present the TMDL and to answer any questions.

Notices of the Potash Brook TMDL availability, the public comment period and the public meeting were given in several different venues. Table 9 identifies how the various stages of the TMDL were noticed to the public.

Table 9. Public notices pertaining to the release of the Potash Brook TMDL.

Event	Venue	Date
Notice of Potash Brook TMDL public meeting	Burlington Free Press (daily newspaper)	November 9, 2005
	VTDEC Water Quality Division public website	November 3, 2005
	VT Department of Libraries website	November 10, 2005
Notice of Potash Brook TMDL availability and public comment period	Burlington Free Press (daily newspaper)	November 18, 2005
	VTDEC Water Quality Division public website	November 17, 2005

At the close of the public comment period, VTDEC had received comments from seven (7) parties. A responsiveness summary has been developed and is included under separate cover. Multiple changes were made to the final version of the TMDL and these changes are noted in the responsiveness summary.

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