# Standard Operating Procedures for Tracking & Accounting of Developed Lands Regulatory Projects & Non-Regulatory Clean Water Projects

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| Infiltration Trench | Provides storage of runoff using the void spaces within the soil, sand, gravel mixture within the trench for infiltration into the surrounding soils. | Latitude & longitude<br>Developed impervious acres draining to practice<br>Developed pervious acres draining to practice<br>Storage volume<br>Infiltration rate | Acres draining to practice | Average 90% (depends on storage volume and infiltration rate) | Regulatory project: 20 years<br>Non-regulatory project: 10 years |
| Subsurface Infiltration | Provides storage of runoff using the combination of storage structures and void spaces within the washed stone within the system for infiltration into the surrounding soils. | Latitude & longitude<br>Developed impervious acres draining to practice<br>Developed pervious acres draining to practice<br>Storage volume<br>Infiltration rate | Acres draining to practice | Average 90% (depends on storage volume and infiltration rate) | Regulatory project: 20 years<br>Non-regulatory project: 10 years |
| Surface Infiltration | Provides storage of runoff through surface ponding (e.g., basin or swale) for subsequent infiltration into the underlying soils. | Latitude & longitude<br>Developed impervious acres draining to practice<br>Developed pervious acres draining to practice<br>Storage volume<br>Infiltration rate | Acres draining to practice | Average 93% (depends on storage volume and infiltration rate) | Regulatory project: 20 years<br>Non-regulatory project: 10 years |

| Project Type | Definition and Practice Standards | Data Requirements | Area Treated Definition | Total Phosphorus Load Reduction Efficiency | Design Life |
|---|---|---|---|---|---|
| Rain Garden, Bioretention (no underdrains) | Provides storage of runoff through surface ponding and possibly void spaces within the soil, sand, washed stone mixture that is used to filter runoff prior to infiltration into underlying soils. | Latitude & longitude<br>Developed impervious acres draining to practice<br>Developed pervious acres draining to practice<br>Storage volume<br>Infiltration rate | Acres draining to practice | Average 93% (depends on storage volume and infiltration rate) | Regulatory project: 20 years<br>Non-regulatory project: 10 years |
| Rain Garden, Bioretention (with underdrain) | Provides storage of runoff by filtering through an engineered soil media. The storage capacity includes void spaces in the filter media and temporary ponding at the surface. After runoff passes through the filter media it discharges through an underdrain pipe. | Latitude & longitude<br>Developed impervious acres draining to practice<br>Developed pervious acres draining to practice<br>Storage volume | Acres draining to practice | Average 47% (depends on storage volume) | Regulatory project: 20 years<br>Non-regulatory project: 10 years |
| Gravel Wetland | Provides surface storage of runoff in a wetland cell that is routed to an underlying saturated gravel internal storage reservoir (ISR). Outflow is controlled by an orifice that has its invert elevation equal to the top of the ISR layer and provides retention of at least 24 hours. | Latitude & longitude<br>Developed impervious acres draining to practice<br>Developed pervious acres draining to practice<br>Storage volume | Acres draining to practice | Average 61% (depends on storage volume) | Regulatory project: 20 years<br>Non-regulatory project: 10 years |
| Porous Pavement (with infiltration) | Provides filtering of runoff through a filter course and temporary storage of runoff within the void spaces of a subsurface gravel reservoir prior to infiltration into subsoils. | Latitude & longitude<br>Developed impervious acres draining to practice<br>Developed pervious acres draining to practice<br>Storage volume<br>Infiltration rate | Acres draining to practice | Average 90% (depends on storage volume and infiltration rate) | Regulatory project: 20 years<br>Non-regulatory project: 10 years |

| Project Type | Definition and Practice Standards | Data Requirements | Area Treated Definition | Total Phosphorus Load Reduction Efficiency | Design Life |
| --- | --- | --- | --- | --- | --- |
| Porous Pavement (with impermeable underlining or underdrain) | Provides filtering of runoff through a filter course and temporary storage of runoff within the void spaces prior to discharge by way of an underdrain. | Latitude & longitude<br>Developed impervious acres draining to practice<br>Developed pervious acres draining to practice<br>Storage volume<br>Filter course depth | Acres draining to practice | Average 70% (depends on storage volume and filter course depth) | Regulatory project: 20 years<br>Non-regulatory project: 10 years |
| Sand Filter (with underdrain) | Provides filtering of runoff through a sand filter course and temporary storage of runoff through surface ponding and within void spaces of the sand and washed stone layers prior to discharge by way of an underdrain. | Lat Latitude & longitude<br>Developed impervious acres draining to practice<br>Developed pervious acres draining to practice<br>Storage volume | Acres draining to practice | Average 47% (depends on storage volume) | Regulatory project: 20 years<br>Non-regulatory project: 10 years |
| Wet Pond | Provides treatment of runoff by routing through permanent pool. | Latitude & longitude<br>Developed impervious acres draining to practice<br>Developed pervious acres draining to practice<br>Storage volume | Acres draining to practice | Average 53% (depends on storage volume) | Regulatory project: 20 years<br>Non-regulatory project: 10 years |
| Extended Dry Detention Basin | Provides temporary detention storage for the design storage volume to drain in 24 hours through multiple outlet controls. | Latitude & longitude<br>Developed impervious acres draining to practice<br>Developed pervious acres draining to practice<br>Storage volume | Acres draining to practice | Average 12% (depends on storage volume) | Regulatory project: 20 years<br>Non-regulatory project: 10 years |

| Project Type | Definition and Practice Standards | Data Requirements | Area Treated Definition | Total Phosphorus Load Reduction Efficiency | Design Life |
|---|---|---|---|---|---|
| Grass Conveyance Swale | Conveys runoff through an open channel vegetated with grass. Primary removal mechanism is infiltration. | Latitude & longitude<br>Developed impervious acres draining to practice<br>Developed pervious acres draining to practice<br>Storage volume | Acres draining to practice | Average 19% (depends on storage volume) | Regulatory project: 20 years<br>Non-regulatory project: 10 years |
| Hydrodynamic (Swirl) Separator | Devices designed to improve quality of stormwater runoff by physically removing sediment and nutrients. Must be a stand-alone practice to receive P reduction credit, if included as pretreatment for another practice, no additional credit is given. | Latitude & longitude<br>Developed impervious acres draining to practice<br>Developed pervious acres draining to practice | Acres draining to practice | 10% | Regulatory project: 20 years<br>Non-regulatory project: 10 years |
| Mechanical Broom Sweeper | A vehicle with a rotating broom the brushes street sediment and debris into a hopper. | TMDL drainage area<br>Developed impervious acres swept<br>Developed pervious acres swept<br>Sweeping frequency | Acres swept | 1-5%<br>(depends on frequency) | 1 year |
| Vacuum-assisted Sweeper | A vehicle with a vacuum for removing street sediment and debris. | TMDL drainage area<br>Developed impervious acres swept<br>Developed pervious acres swept<br>Sweeping frequency | Acres swept | 2-8%<br>(depends on frequency) | 1 year |

| Project Type | Definition and Practice Standards | Data Requirements | Area Treated Definition | Total Phosphorus Load Reduction Efficiency | Design Life |
|---|---|---|---|---|---|
| High Efficiency Regenerative Air Vacuum Sweeper | A vehicle that uses a blast of air to dislodge with a vacuum for removing street sediment and debris from the road surface, which is then vacuumed into a hopper. | TMDL drainage area<br>Developed impervious acres swept<br>Developed pervious acres swept<br>Sweeping frequency | Acres swept | 2-10%<br>(depends on frequency) | 1 year |
| Enhanced leaf collection on Streets with ≥ 17% Tree Cover | Use of any sweeper technology on streets with ≥ 17% tree cover at least four times in the fall to remove the majority of leaf fall. | TMDL drainage area<br>Developed impervious acres swept<br>Developed pervious acres swept<br>Sweeping frequency | Acres swept | 17% | 1 year |
| Catch Basin Cleaning | Removal of sediment and debris from catch basins. | TMDL drainage area<br>Developed impervious acres treated<br>Developed pervious acres treated | Acres draining to catch basin | 2% | 1 year |
| Road Erosion Remediation on Paved and Unpaved Municipal Roads with Ditches | Installation of a suite of practices to correct road related erosion problems for gravel and paved roads and road drainage culverts. Practices are intended to improve Municipal Roads General Permit compliance status and may include drainage ditch installation and upgrades, turnouts, removal of high road shoulders, and stabilization of drainage culverts. | Road segment ID and length<br>Road type (paved, unpaved)<br>Hydrologic connectivity<br>Road slope<br>Municipal Roads General Permit compliance status before & after implementation | Road segment length (100 m) | Not compliant → partially compliant: 40%<br>Partially compliant → fully compliant: 40%<br>Not compliant → fully compliant 80% | 8 years |

| Project Type | Definition and Practice Standards | Data Requirements | Area Treated Definition | Total Phosphorus Load Reduction Efficiency | Design Life |
|---|---|---|---|---|---|
| Road Erosion Remediation on Class 4 Municipal Roads | Correction of gully erosion on Class 4 road surface and shoulder resulting in full Municipal Roads General Permit compliance. Gully erosion is defined as erosion equal to or greater than 1 foot in depth. | Road segment ID and length<br>Hydrologic connectivity<br>Road slope<br>Volume of gully erosion<br>Municipal Roads General Permit compliance status before & after implementation | Road segment length (100 m) | 20% if pre-construction erosion volume is < 3 cubic yards<br>40% if pre-construction erosion volume is > 3 cubic yards | 8 years |
| Road Erosion Remediation on Paved and Unpaved Private Roads with Ditches | Installation of a suite of practices to correct road related erosion problems for private gravel and paved roads and road drainage culverts. | Road segment ID and length<br>Road type (paved, unpaved)<br>Hydrologic connectivity<br>Road slope<br>Compliance status before & after implementation | Road segment length (100 m) | Not compliant → partially compliant: 40%<br>Partially compliant → fully compliant: 40%<br>Not compliant → fully compliant 80% | 8 years |
| Road Erosion Remediation on Paved State Roads | Installation of a suite of practices to correct road related erosion problems for state-owned paved roads and road drainage culverts. | Road segment ID and length<br>Road type (paved, unpaved)<br>Hydrologic connectivity<br>Road slope<br>Compliance status before & after implementation | Road segment length (80.5 m) | Not compliant → partially compliant: 40%<br>Partially compliant → fully compliant: 40%<br>Not compliant → fully compliant 80% | 8 years |

| Project Type | Definition and Practice Standards | Data Requirements | Area Treated Definition | Total Phosphorus Load Reduction Efficiency | Design Life |
|---|---|---|---|---|---|
| Outlet and Gully Stabilization | Correction of erosion at catch basin outlet by stabilizing flow path from outlet to surface waters. | Catch basin outlet ID or Latitude and Longitude<br>Volume of erosion<br>Age of erosion<br>Municipal Roads General Permit compliance status before & after implementation | Volume of erosion restored | Calculated based on volume of erosion prior to stabilization | 8 years |
| Tree Canopy Expansion | Tree plantings on developed land (pervious or impervious) that result in an increase in tree canopy but are not intended to result in forest-like conditions. Trees do not need to be planted contiguously and there is no minimum density requirement. The trees cannot be part of a forested riparian buffer or structural stormwater BMP, and the replacement of existing trees is not eligible for credit. | Number of trees planted<br>TMDL drainage area | 94 $ft^2$ | 24% for canopy over Developed Pervious<br>11% for canopy over Developed Impervious | 20 years |
| Native Revegetation | Conversion of developed pervious (e.g., lawns) land uses to native vegetation by the implementation of "no mow" zones or native shrub plantings. Over time, natural succession will allow the area to return to vegetative cover consisting of a mix of trees, shrubs, saplings, and groundcover. | Acres of native revegetation<br>TMDL drainage area | Acres of native revegetation | Land use conversion from Developed Pervious to Range Brush (or Forest) | 10 years |

# Introduction

While many of Vermont's surface waters are high quality, several surface waters suffer from non-point source pollution coming from the landscape. The State of Vermont is covered by several large-scale Total Maximum Daily Load (TMDL) plans that identify pollutant reductions required for an impaired waterbody to meet the State of Vermont's water quality standards. The Lake Champlain and Lake Memphremagog TMDLs target phosphorus pollution to address cyanobacteria blooms, while the five-state Long Island Sound TMDL targets nitrogen pollution causing hypoxia in the Sound.

The US Environmental Protection Agency (EPA) approved the Phosphorus TMDLs for the Vermont Segments of Lake Champlain in 2016 (US EPA 2016). The TMDL Accountability Framework requires the State of Vermont to track investments and progress towards achieving TMDL targets. The Vermont Clean Water Act (Act 64 of 2015) and Clean Water Service Delivery Act (Act 76 of 2019) both establish funding to support clean water efforts and require the state track and report on regulatory and non-regulatory clean water projects across land use sectors. Act 76 of 2019 requires the state to publish methods for estimating phosphorus reductions for all clean water project types in the Lake Champlain and Lake Memphremagog basins.

The Vermont Agency of Natural Resources Department of Environmental Conservation (DEC) is leading the effort to develop and implement methods for tracking nutrient load reductions from both non-regulatory clean water projects as well as regulatory water quality improvement projects across all land use sectors. Developed lands projects decrease nutrient (e.g., phosphorus and nitrogen) and sediment pollution through the installation of practices that prevent future erosion and sedimentation, or that treat stormwater runoff from developed lands, such as roads, parking lots, sidewalks, and rooftops. The purpose of this document is to outline the current methods used to track and account for total phosphorus load reductions from developed lands projects in the Lake Champlain and Lake Memphremagog watersheds.[1] This document is intended to be updated as new information becomes available or if new research is conducted. DEC plans to review methods in this document for accuracy at least every five years but it could be updated more frequently. All methods are subject to change.

# Practice Tracking

Developed lands projects, including structural stormwater practices, non-structural stormwater practices, road erosion remediation, outlet and gully stabilization, and developed lands tree plantings, are implemented through multiple regulatory and funding programs administered by the following agencies and organizations:

- Vermont Department of Environmental Conservation
- Vermont Agency of Transportation
- Lake Champlain Basin Program

[1] Total phosphorus load reductions cannot be estimated for practices implemented outside of the Lake Champlain and Lake Memphremagog basins due to a lack of baseline phosphorus loading rates. This document also does not include methods for estimating total nitrogen load reductions in the Connecticut River watershed draining to the Long Island Sound due to a lack of baseline nitrogen loading rates and BMP efficiencies.

## Developed Lands Regulatory Programs

Regulatory programs drive the implementation of many developed lands clean water projects. Operational Stormwater Permits, including **General Permit (3-9050)**, are intended to minimize the adverse impacts of stormwater runoff to surface waters throughout Vermont. Projects subject to stormwater discharge permitting must meet the treatment standards within the 2017 Vermont Stormwater Management Manual (VSMM). DEC regulates the following three types of impervious surfaces under the operational permitting program.

- New impervious surface of one or more acres, or expansions resulting in an acre or more of impervious surface.
- Re-developed impervious surface of an acre or more.
- Existing impervious surface designated as requiring treatment in order to meet water quality goals, such as the requirement to regulate impervious surfaces of three acres or more that are not permitted under the 2002 or the 2017 VSMM.

Stormwater practice designs and specifications required to comply with operational stormwater regulations are submitted to the DEC Stormwater Program in order to obtain permit coverage.

The **Municipal Separate Storm Sewer System (MS4) Permit** authorizes stormwater discharges within the urbanized areas of the following small MS4s: Burlington, Colchester, Essex, Essex Junction, Milton, Rutland, Shelburne, South Burlington, St. Albans City, St. Albans Town, Williston, and Winooski, the University of Vermont, and the Burlington International Airport. In April 2021, MS4 communities submitted Phosphorus Control Plans (PCPs) and Flow Restoration Plans (FRPs) for reducing stormwater runoff to address the Lake Champlain TMDL's developed lands waste load allocation to the DEC Stormwater Program.[2] Each MS4 community submits an MS4 Annual Report to the DEC Stormwater Program with information on the stormwater BMPs designed and implemented through PCPs and FRPs.[3,4]

The **Municipal Roads General Permit (MRGP)** is intended to achieve significant reductions in stormwater-related erosion from paved and unpaved municipal roads. Under the MRGP, municipalities are required to complete baseline road erosion inventories to determine if the required MRGP standards are being met. To achieve progress towards meeting TMDLs and other water quality restoration goals, road drainage systems are brought up to maintenance standards and additional corrective measures to reduce erosion may be performed. Municipalities submit MRGP road erosion inventories and update DEC annually in progress made in upgrading non-compliant roads to MRGP standards.

The **Transportation Separate Storm Sewer System (TS4) General Permit** covers stormwater discharges from all Vermont Agency of Transportation (VTrans) owned or controlled impervious

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[2] Practices constructed in 2002 or later are credited towards the PCP targets, which is earlier than the end of the TMDL modeling period (2010) but is consistent with the FRP crediting period.
[3] Prior to 2018, MS4s were not required to report on the details of stormwater practices installed outside of state funding programs.
[4] Some operational permits may be incorporated into MS4 authorizations under the control of the municipality. Phosphorus load reductions will be awarded for expired or issued operational permits being incorporated into MS4 authorizations if the impervious existed prior to 2002 and the treatment improved after 2002. Once controlled by the MS4, the site must be operated and maintained in compliance with the operational permit issued most recently for the impervious surface.

surfaces. The TS4 combines VTrans stormwater compliance obligations from several permit programs, including the MS4 General Permit and its associated Flow Restoration Plan (FRP) and Phosphorus Control Plan (PCP) requirements, industrial activities commonly regulated under the Multi-Sector General Permit (MSGP), and previously permitted, new, redeveloped, and expanded impervious surface, commonly regulated under State Operational Stormwater permits. The permit requires VTrans to develop a PCP for its stormwater discharges in the Lake Champlain Basin and requires VTrans to reduce the discharge of pollutants from the TS4 to the maximum extent practicable through compliance with the six minimum control measure requirements throughout the entire state. VTrans reports to the DEC Stormwater Program annually on stormwater BMPs designed and implemented through the TS4 permit.[5]

Regulatory stormwater practice data are managed by the DEC Stormwater Program in the Stormwater Management Database. Road erosion inventory and compliance data are managed by the DEC Stormwater Program in the MRGP Database. The DEC Stormwater Program submits regulatory compliance data to DEC CWIP annually for clean water reporting.

## Developed Lands Funding Programs

Numerous stormwater practices and road erosion remediation projects are also funded and tracked by clean water funding programs, including:

- DEC Clean Water Initiative Program (CWIP)
- VTrans Municipal Roads Grants-in-Aid Program
- VTrans Better Roads Program
- VTrans Municipal Highway Stormwater Mitigation Program
- VTrans Transportation Alternatives Program
- Lake Champlain Basin Program (LCBP)

Funding programs support implementation of a mixture of regulatory and non-regulatory projects. The Municipal Roads Grants-in-Aid Program, for instance, only funds practices that are in compliance with the Municipal Roads General Permit.

Grant recipients are required to submit a final report to their funding program containing project funding, performance measures, and data needed to estimate phosphorus reductions. Non-regulatory stormwater project information funded by DEC CWIP is tracked in the Watershed Projects Database (WPD). VTrans and LCBP track data within their own respective databases before reporting the data annually to DEC for annual clean water reporting.

## Annual Clean Water Reporting

DEC's Clean Water Initiative Program obtains developed lands project data from partners annually for legislative and EPA reporting. DEC compiles and manages all clean water project data tracked through state and federal funding and regulatory programs using the Clean Water Reporting Framework

[5] Note as of 2021, TS4 data are not yet included in CWIP's annual reporting. DEC plans to include TS4 data in the 2022 Annual Performance Report.

(CWRF). CWRF also contains the BMP Accounting and Tracking Tool (BATT), which is a model used to estimate total phosphorus load reductions associated with the implementation of various clean water projects. Vermont's clean water project funding and results are summarized annually in the *Vermont Clean Water Initiative Annual Performance Report*.[6]

# TMDL Phosphorus Accounting

Developed lands clean water projects target nutrient and sediment pollution to waterbodies and improve water quality over the long term. While measured water quality parameters are the ultimate indicator of progress, it will take time for Vermont's waters to realize the benefits of clean water projects. To provide incremental measures of accountability and estimate progress towards achieving TMDLs, DEC estimates the phosphorus load reductions associated with clean water projects completed across state and federal funding programs and regulatory programs in the Lake Champlain and Lake Memphremagog basins.

Total phosphorus load reduction estimates are modeled based on the clean water project type. Most clean water project phosphorus load reduction estimates are based on the following:

1. Estimated **baseline total phosphorus load from land being treated**, prior to treatment by a practice. This is based on the area of land draining to the practice or the practice area and the average phosphorus loading rate from the land use. Baseline phosphorus loading rates for each land use are obtained or adapted from the TMDL SWAT model (Tetra Tech, 2015a).

2. **Average annual pollutant reduction performance** – referred to as an "efficiency" – of the practice type. This is often expressed as a percent of total load reduced and is based on research of project performance relevant to conditions in Vermont.

Phosphorus load reductions are the product of the baseline phosphorus load for the area treated by the practice and the practice phosphorus reduction efficiency (Figure 1). The phosphorus load reduction efficiency is applied starting on the practice implementation date and continues for the expected design life of the practice. In all cases, results of accounting methodologies should only be referred to as "total phosphorus load reduction estimates" because phosphorus load reductions were not directly measured.

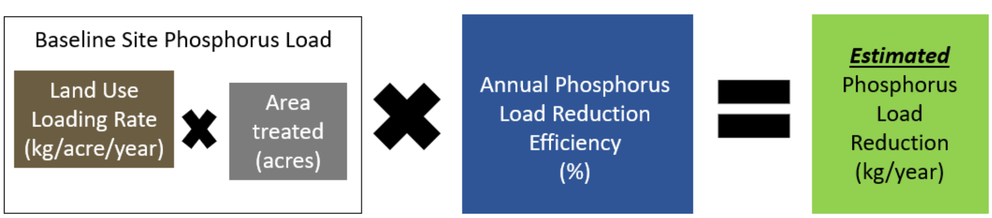


Figure 1. General methodology used to estimate phosphorus reductions from regulatory and non-regulatory clean water projects.

[6] The Vermont Clean Water Initiative Annual Performance Reports can be accessed here: https://dec.vermont.gov/water-investment/cwi/reports

Limitations of total phosphorus load reduction estimates and accounting methods include:

- Baseline phosphorus loading rates were the result of watershed modeling and not direct loading measurements at study sites. The model's generalized assumptions may not be accurate to all localized areas.
- Some phosphorus load reduction efficiencies were not derived from experimental studies conducted in Vermont due to limited localized research in this area. Some phosphorus reduction efficiencies were derived from SWAT modeling or studies outside Vermont with different climate and/or agricultural settings. In cases where data were insufficient or conflicting, DEC consulted with experts and used the best available information at the time to establish reduction efficiencies.
- Realized phosphorus load reductions may differ from estimated phosphorus load reductions due to climate variability and actual practice performance.

## Delivered Load Versus Source Load

Total phosphorus loading rates and targets may be estimated as source load or delivered load. Delivered load is the mass of a pollutant after accounting for estimated pollutant storage or loss enroute to the receiving waterbody. Source load is the pollutant load from the landscape source that does not account for potential storage or loss in the watershed. As water carrying pollutants flows from its landscape source to a receiving water, some pollutants may be attenuated by nutrient uptake in plants, infiltration into soils, or settle out as it flows through inland lakes or ponds before reaching Lake Champlain or Lake Memphremagog. Therefore, the delivered pollutant load is less than at its source (i.e., source load). Delivered load is estimated based on a percent delivery rate that is applied to the source load (summarized in the tables below) and varies and depending on the distance to receiving water and obstacles in its path (e.g., inland lakes). Lake Champlain and Lake Memphremagog phosphorus TMDLs' base load and target load allocations are expressed in delivered load, reflecting total phosphorus load capacity delivered to the lakes. Estimated total phosphorus load reductions are presented as delivered load when reported/presented in the context of TMDLs' base load and target load allocations (e.g., delivered loads are typically reported in the Vermont Clean Water Initiative Annual Performance Report and the Clean Water Interactive Dashboard). However, source loading rates may be used in other applications such as Tactical Basin Planning targets and Water Quality Restoration Formula Grant targets to Clean Water Service Providers (CWSP). Loading rate tables in this document represent source load unless otherwise indicated.

Table 1. The Lake Champlain Phosphorus TMDLs' estimated total phosphorus load delivery percentages by TMDL drainage area.

| Drainage Area ID | Drainage Area | Champlain Segment | Delivery Percentage |
|---|---|---|---|
| 1 | Mettawee River | South Lake B | 80.4% |
| 2 | Poultney River | South Lake B | 80.4% |
| 3 | South Lake B Direct Drainage | South Lake B | 80.4% |
| 4 | South Lake A Direct Drainage | South Lake A | 98.8% |

| | | | |
|---|---|---|---|
| 5 | Port Henry Direct Drainage | Port Henry | 99.5% |
| 6 | Lewis Creek | Otter Creek | 63.1% |
| 7 | Little Otter Creek | Otter Creek | 63.1% |
| 8 | Otter Creek | Otter Creek | 63.1% |
| 9 | Otter Creek Direct Drainage | Otter Creek | 63.1% |
| 10 | Main Lake Direct Drainage | Main Lake | 87.0% |
| 11 | Winooski River | Main Lake | 87.0% |
| 12 | LaPlatte River | Shelburne Bay | 79.9% |
| 13 | Burlington Bay - CSO | Burlington Bay | 96.8% |
| 14 | Burlington Bay Direct Drainage | Burlington Bay | 96.8% |
| 17 | Lamoille River | Malletts Bay | 77.6% |
| 18 | Malletts Bay Direct Drainage | Malletts Bay | 77.6% |
| 19 | Northeast Arm Direct Drainage | Northeast Arm | 97.4% |
| 20 | St. Albans Bay Direct Drainage | St. Albans Bay | 90.5% |
| 21 | Missisquoi Bay Direct Drainage | Missisquoi Bay | 89.9% |
| 22 | Missisquoi River | Missisquoi Bay | 89.9% |
| 23 | Isle La Motte Direct Drainage | Isle La Motte | 98.8% |

Table 2. The Lake Memphremagog TMDLs' estimated total phosphorus load delivery percentages by HUC 12 watersheds.

| HUC 12 | Memphremagog Basin HUC 12 name | Delivery Percentage |
|---|---|---|
| 011100000101 | Black River-headwaters to Seaver Branch | 91% |
| 011100000102 | Black River-Seaver Branch to Lords Creek | 100% |
| 011100000103 | Lords Creek | 98% |
| 011100000104 | Black River-Lords Creek to mouth | 99% |
| 011100000201 | Barton River-headwaters to Roaring Brook | 83% |
| 011100000202 | Barton River-Roaring Branch to Willoughby River | 64% |
| 011100000203 | Willoughby River | 75% |
| 011100000204 | Barton River-Willoughby River to mouth | 94% |
| 011100000301 | Clyde River-headwaters to Echo Lake stream | 34% |
| 011100000302 | Seymour and Echo Lakes | 11% |

| | | |
|---|---|---|
| 011100000303 | Clyde River-Echo Lake stream to mouth | 60% |
| 011100000501 | Direct drainage-south end of Lake Memphremagog | 96% |

## Anticipated Future Improvements

DEC reviews phosphorus accounting methods at least once every five years to confirm the adequacy and accuracy of phosphorus load reduction efficiencies and design lives. The methods presented below will be updated as new research or information are made available.

DEC plans to develop linear loading rates for roadway impervious cover in the Memphremagog basin as was done for the Champlain Basin.

For stormwater projects implemented on lake shoreland properties through the Lake Wise program, DEC is developing simplified reporting forms for determining the area treated for small-scale structural stormwater treatment practices to reduce the reporting burden on homeowners who implement practices without a stormwater designer.

Practices implemented near streams or rivers that impact the connectivity of that river such as gully remediation may also be eligible for stream stability credit for restoring temporal connectivity of the watershed by diverting and infiltrating stormwater that would otherwise enter a drainage ditch, form a gully, and enter a perennial stream. However, this overlap in accounting methods has not yet been fully vetted. DEC plans to update this method for how this interaction may occur in the future.

Refer to the "Standard Operating Procedures for Tracking & Accounting of Natural Resources Restoration Projects" for information on lake shoreline practices and river and floodplain restoration practices.

## Developed Lands Tracking & Accounting Methods

The following section describes the current tracking and accounting methods for each applicable project type using the following format:

1. Project type definition
2. Project type tracking mechanisms
3. Determination of area treated
4. Baseline loading rate
5. Total phosphorus load reduction efficiency
6. Design life

**Design life** is defined in Act 76 as the period of time that a clean water project is designed to operate according to its intended purpose. Phosphorus reductions are initially assigned to a project based on the project's expected design life. The **lifespan** and associated pollution reduction credit of any single project may be extended beyond the initial design life if the BMP Verification Program finds the project is still functioning according to its intended purpose. A project's lifespan and associated credit ends when it is no longer functioning, and it cannot or will not be repaired to its original intended purpose.

## Structural Stormwater Treatment Practices

Structural stormwater practices collect, store, infiltrate, and filter runoff that contains nutrient and sediment pollution from hard surfaces associated with developed, urban, and suburban areas. The following list defines the structural stormwater practices eligible for phosphorus credit in Vermont.

- Infiltration trench: Provides storage of runoff using the void spaces within the soil, sand, gravel mixture within the trench for infiltration into the surrounding soils.
- Subsurface infiltration: Provides storage of runoff using the combination of storage structures and void spaces within the washed stone within the system for infiltration into the surrounding soils.
- Surface infiltration: Provides storage of runoff through surface ponding (e.g., basin or swale) for subsequent infiltration into the underlying soils.
- Bioretention/ rain garden (no underdrain): Provides storage of runoff through surface ponding and possibly void spaces within the soil, sand, washed stone mixture that is used to filter runoff prior to infiltration into underlying soils.
- Bioretention/ rain garden (with underdrain): Provides storage of runoff by filtering through an engineered soil media. The storage capacity includes void spaces in the filter media and temporary ponding at the surface. After runoff passes through the filter media it discharges through an under-drainpipe.
- Gravel wetland: Provides surface storage of runoff in a wetland cell that is routed to an underlying saturated gravel internal storage reservoir (ISR). Outflow is controlled by an orifice that has its invert elevation equal to the top of the ISR layer and provides retention of at least 24 hours.
- Porous pavement (with infiltration): Provides filtering of runoff through a filter course and temporary storage of runoff within the void spaces of a subsurface gravel reservoir prior to infiltration into subsoils.
- Porous pavement (with impermeable underlining or underdrain): Provides filtering of runoff through a filter course and temporary storage of runoff within the void spaces prior to discharge by way of an underdrain.
- Sand filter (with underdrain): Provides filtering of runoff through a sand filter course and temporary storage of runoff through surface ponding and within void spaces of the sand and washed stone layers prior to discharge by way of an underdrain.
- Wet pond: Provides treatment of runoff by routing through permanent pool.
- Extended dry detention basin: Provides temporary detention storage for the design storage volume to drain in 24 hours through multiple outlet controls.

- Grass conveyance swale: Conveys runoff through an open channel vegetated with grass. Primary removal mechanism is infiltration.
- Hydrodynamic (swirl) separator: Devices designed to improve quality of stormwater runoff by physically removing sediment and nutrients. Must be a stand-alone practice to receive P reduction credit, if included as pretreatment for another practice, no additional credit is given.
- Disconnection (regulatory practice only): Stormwater disconnection spreads runoff generated from parking lots, driveways, rooftops, sidewalks, and other impervious surfaces onto adjacent pervious areas where it can be infiltrated.
- Alternative practices or enhancements may be accepted on a case-by-case basis following review by the Stormwater Program.

## Project Type Tracking Mechanisms

Structural stormwater practices are funded, implemented, and tracked through the following regulatory programs and non-regulatory funding programs. These programs report stormwater funding, performance measures, and phosphorus accounting data annually to DEC CWIP for clean water reporting.

- General Permit 3-9050 for Operational Stormwater Discharges
- MS4 General Permit
- TS4 General Permit
- DEC Clean Water Initiative Program
- Lake Champlain Basin Program

## Area Treated

The area treated by structural stormwater practices is defined as the acres of pervious land use (i.e., vegetation, trees, grass, or landscaped areas, etc.) and impervious land use (i.e., rooftop, road, gravel, parking lot, driveway, etc.) draining to the practice. The treatment area and land uses draining to the stormwater practice are determined using site reconnaissance, site elevation data, land use maps, and/or tools for delineating watersheds.[7]

## Baseline Phosphorus Loading Rates

The original Lake Champlain TMDL Soil Water Assessment Tool (SWAT) model contained the following developed lands loading rate categories with individual loading rates for combinations of drainage area, hydrologic soil group, and slope (Tetra Tech, 2015a):

- Residential – Low Density (Pervious)
- Residential – Medium Density (Pervious)
- Residential – High Density (Pervious)

[7] Note that the DEC Stormwater Management Database has not always tracked the drainage area for regulatory stormwater practices. The database has historically tracked drainage area by discharge point, which may contain multiple treatment practices.

- Residential – Low Density (Impervious)
- Residential – Medium Density (Impervious)
- Residential – High Density (Impervious)
- Industrial Commercial (Pervious)
- Industrial Commercial (Impervious)
- Roads – Paved (Impervious)
- Roads – Unpaved (Impervious)

To simplify phosphorus accounting for structural stormwater practices, DEC developed three aggregated loading rate categories for developed land uses in the Lake Champlain basin. Area-weighted loading rates (kilograms per acre per year) for each category below were calculated by dividing the total phosphorus load for each land use type by the total area of that land use for each drainage area (major river basins within each lake segment basin) within the Lake Champlain basin. Loading rates were then averaged across slope classes, and weighted averages were calculated across hydrological soil groups to further simplify loading rate data requirements.

- <u>Developed Impervious</u>: Area-weighted for Industrial Commercial (Impervious), Residential – High Density (Impervious), Residential – Medium Density (Impervious), and Residential – Low Density (Impervious)
- <u>Developed Impervious with Paved Roads</u>: Area-weighted for Roads – Paved (Impervious), Industrial Commercial (Impervious), Residential – High Density (Impervious), Residential – Medium Density (Impervious), and Residential – Low Density (Impervious)
- <u>Developed Pervious</u>: Area-weighted for Industrial Commercial (Pervious), Residential – High Density (Pervious), Residential – Medium Density (Pervious), and Residential – Low Density (Pervious)

The Lake Memphremagog TMDL model included the following developed lands loading rate categories with individual loading rates for each drainage area (VT DEC, 2017). Loading rates in the Lake Memphremagog TMDL were not broken out by hydrological soil group or slope as they were in the Lake Champlain TMDL; therefore, developed lands loading rates in the Lake Memphremagog watershed were not post-processed for phosphorus accounting as they were for the Lake Champlain loading rates.

- Developed Impervious
- Developed Pervious
- Roads – Paved
- Roads – Unpaved

Baseline developed lands phosphorus loading rates currently used in the phosphorus accounting for structural stormwater practices in the Lake Champlain and Lake Memphremagog basins are listed in Appendix A: Baseline Phosphorus Loading Rates for Stormwater Practices.

## Total Phosphorus Load Reduction Efficiencies

The creation of new impervious surfaces often results in an increase in total phosphorus (TP) loading. Treating runoff from new impervious surfaces with stormwater treatment practices, however, can reduce or eliminate an increase in phosphorus loading. The net change in phosphorus loading from new development is calculated as:

$$\begin{aligned}\Delta\, TP\ Load\ from\ New\ Development \\ &= (Post\ Development\ Load - Pre\ Development\ Load) \\ &- (Post\ Development\ Load\ \times TP\ Reduction\ Efficiency\ (\%)\ of\ Practice)\end{aligned}$$

For the purpose of accounting for TP from new impervious surfaces, the predevelopment condition is conservatively assumed to be forest.

Treatment of re-developed and existing impervious surfaces does not result in a change in land use, so stormwater treatment practices result in a net reduction in phosphorus, calculated as:

$$\begin{aligned}\Delta\, TP\ Load\ from\ Redevelopment\ or\ Existing\ Impervious\ Surfaces \\ &= -(Post\ Development\ Load\ \times TP\ Reduction\ Efficiency\ (\%)\ of\ Practice)\end{aligned}$$

If a stormwater project upgrades, or retrofits, a previously built practice, then the resulting load reduction is the difference between the upgraded practice's load reduction and the original practice's load reduction.

Phosphorus reduction efficiencies for infiltration trenches, subsurface infiltration, surface infiltration, rain gardens, gravel wetlands, porous pavement, sand filters, wet ponds, extended dry detention basins, and grass swales are determined using performance curves that reflect the phosphorus removal efficiencies for each stormwater practice type according to the size (i.e., storage volume) of the practice (US EPA, 2010). The storage volume of a practice is the amount of water that the practice can hold during storms up to the 1-year, 24-hour return storm. Some practices are designed to provide attenuation and safe passage of larger storms, such as the 10-year or 100-year return storm, but this additional volume is not considered in phosphorus accounting because it does not remain in the practice long enough to receive significant treatment. Stormwater treatment practice performance curves and storage volume equations for each stormwater practice type are outlined in Appendix B. Stormwater Performance Curves & Storage Volume Calculations.

To use the performance curves, the storage volume must be expressed as the depth of runoff (inches) from impervious surfaces treated ($R_I$). The goal of Equations 1-8 (modified from LC BATT) is to solve for $R_I$ using the storage volume of the practice and the acreage of impervious and pervious areas draining to that practice.

Runoff depths are defined using Equations 1-5:

Impervious: $R_I = P$ (1)

Pervious HSG A: $R_A = 0.0413 \times P^2 - 0.0118 \times P$ (2)

Pervious HSG B: $R_B = 0.0652 \times P^2 - 0.0231 \times P$ (3)

Pervious HSG C: $R_C = 0.2 \times P^2 - 0.0597 \times P$ (4)

Pervious HSG D: $R_D = 0.2746 \times P^2 + 0.0057 \times P$ (5)

Where:
P = Precipitation (inches)
$R_I$ = Runoff depth from impervious areas in drainage area (inches)
$R_A$ = Runoff depth from pervious areas with hydrologic soil group A in drainage area (inches)
$R_B$ = Runoff depth from pervious areas with hydrologic soil group B in drainage area (inches)
$R_C$ = Runoff depth from pervious areas with hydrologic soil group C in drainage area (inches)
$R_D$ = Runoff depth from pervious areas with hydrologic soil group D in drainage area (inches)

The storage volume of the practice (calculated using equations in Appendix Table B-2) is equal to the sum of the runoff depth for each land use type (Equations 1-5) multiplied by the area of each land type draining to the practice, as defined in Equation 6.

$$V = (A_I \times R_I + A_A \times R_A + A_B \times R_B + A_C \times R_C + A_D \times R_D) \times 43560/12 \quad (6)$$

Where:
V = Storage volume of the treatment practice ($\text{feet}^3$)
$A_I$ = Impervious surface in drainage area (acres)
$A_A$ = Pervious area over hydrologic soil group A in drainage area (acres)
$A_B$ = Pervious area over hydrologic soil group B in drainage area (acres)
$A_C$ = Pervious area over hydrologic soil group C in drainage area (acres)
$A_D$ = Pervious area over hydrologic soil group D in drainage area (acres)

Equations 1-5 are then substituted into the storage volume equation (Equation 6) to reduce the equation to $R_I$ as the main variable, as shown in Equation 7:

$$V = A_I \times R_I + A_A \times (0.0413 \times R_I^2 - 0.0118 \times R_I) + A_B \times (0.0652 \times R_I^2 - 0.0231 \times R_I) + A_C \times (0.2 \times R_I^2 - 0.0597 \times R_I) + A_D \times (0.2746 \times R_I^2 + 0.0057 \times R_I) \times 3630 \quad (7)$$

The Watershed Projects Database (WPD) and STP Calculator[8] solve for $R_I$ using an iterative approach. $R_I$ can also be solved by rearranging and solving by the quadratic equation. The following solution is used to calculate storage depth in a spreadsheet, such as the BMP Tracking table used by MS4 permittees:

$$R_I = -(3630 \times A_I - 42.834 \times A_A - 83.853 \times A_B - 216.711 \times A_C + 42.834 \times A_D) - \left(\left((3630 \times A_I - 42.834 \times A_A - 83.853 \times A_B - 216.711 \times A_C + 42.834 \times A_D)\right)^2 + 4 \times (149.919 \times A_A + 236.676 \times A_B + 726 \times A_C + 996.798 \times A_D) \times V\right)^{1/2} / \left(2 \times (149.919 \times A_A + 236.676 \times A_B + 726 \times A_C + 996.798 \times A_D)\right) \quad (8)$$

In some instances, practice sizing data are inadequate for estimating phosphorus reduction efficiencies from structural stormwater practices. As a result, DEC developed generalized phosphorus reduction efficiencies based on typical practice sizes designed to meet the water quality standard per the Vermont

[8] STP Calculator can be accessed here: https://anrweb.vt.gov/DEC/CleanWaterDashboard/STPCalculator.aspx

Stormwater Management Manual. Generalized phosphorus reductions are mainly used for planning purposes or if practice sizing data are inadequate and will likely be phased out of use in the coming years. These generalized phosphorus reduction efficiencies for stormwater treatment practices and a timeline of operational permit phosphorus accounting methodologies are presented in Appendix C. Generalized Phosphorus Accounting for Operational Stormwater Permits.

The 10% TP reduction efficiency for hydrodynamic separators was determined by reviewing studies of hydrodynamic separators in climates similar to Vermont and considering the TP reduction efficiency adopted by the Chesapeake Bay Program (CBP). The mean TP reduction efficiency for seven studies conducted in similar climates to Vermont was 11.1%, while the median TP reduction efficiency was 11% (Table 3). CBP adopted a 10% TP reduction efficiency for hydrodynamic separators. Considering the literature review finding of a 11% mean TP reduction based on studies conducted in climates similar to Vermont and the 10% TP reduction efficiency adopted by CBP, DEC adopted a conservative 10% TP reduction efficiency for Vermont. In the future, as additional research is available, reduction efficiencies may be revised to differentiate between online and offline hydrodynamic separator systems.

Table 3. Hydrodynamic separator studies conducted in climates similar to Vermont.

| Source | Location | Technology | TSS Removal (%) | TP Removal (%) |
|---|---|---|---|---|
| USGS (1999) | Madison, WI | Stormcepter | 21 | 19 |
| WI DOT (2008) | Milwaukee, WI | Vortechs | 42 | 16 |
| UNH (2012) | Durham, NH | Unknown | 21 | 0 |
| Rinker Materials (2002) | Cono Park, MN | Stormcepter | 76 | 32 |
| UNH (2012) | Durham, NH | Unknown | 75 | 0 |
| New York State (2001) | Lake George, NY | Vortechs | 65 | 0 |
| Associated Earth Sciences (2001) | Seatac, WA | Stormcepter | 87 | 11 |
| | | | Median | 11 |
| | | | Mean | 11.1 |

## Design Life

The performance of structural stormwater treatment practices declines over time. Regulatory stormwater treatment practices are assigned a 20-year design life due to the stringent operation and maintenance requirements of stormwater permits. Non-regulatory stormwater treatment practices are assigned a more conservative 10-year design life because the operation and maintenance agreements for non-regulatory projects are not legally binding. The lifespan and associated credit of any single project may be extended beyond the initial design life if the BMP Verification Program finds the project is still functioning according to its intended purpose.

### Structural Stormwater Practice Tracking & Accounting Summary

Table 4. Summary of data used for estimating phosphorus reductions from structural stormwater treatment practices.

| Data Required | Value & Source |
|---|---|
| Baseline phosphorus loading rate<br>• Latitude & longitude<br>• Acres of pervious and impervious draining to practice | Appendix A (pg. 45) |
| Practice specifications (e.g., storage volume, infiltration rate) | Measured |
| Practice efficiency | Varies by practice type and sizing (US EPA 2010) |
| Design life | Non-regulatory practice – 10 years<br>Regulatory practice – 20 years |

## Non-Structural Stormwater Practices

Non-structural stormwater practices focus on management of sediment and nutrients at their source by minimizing exposure to runoff rather than treating runoff in structural stormwater practices. Non-structural practices include:

- Mechanical Broom Sweeper: A vehicle with a rotating broom the brushes street sediment and debris into a hopper.
- Vacuum-assisted Sweeper: A vehicle with a vacuum for removing street sediment and debris.
- High Efficiency Regenerative Air Vacuum Sweeper: A vehicle that uses a blast of air to dislodge with a vacuum for removing street sediment and debris from the road surface, which is then vacuumed into a hopper.
- Enhanced leaf collection: Use of any sweeper technology on streets with ≥ 17% tree cover at least four times in the fall to remove the majority of leaf fall.
- Catch Basin Cleaning: Removal of sediment and debris from catch basins.

### Project Type Tracking Mechanisms

Non-structural stormwater practices are currently only tracked through the MS4 General Permit and TS4 Permit for PCP compliance. There are no MS4 communities in the Lake Memphremagog basin; therefore, MS4 non-structural practice data are only reported for the Lake Champlain basin. MS4 communities submit an MS4 Annual Report summarizing non-structural stormwater practice information annually to the DEC Stormwater Program. DEC Stormwater Program began reporting MS4 data to CWIP for annual clean water reporting in 2021. While the TS4 is a statewide permit, a PCP is only required for VTrans areas in the Lake Champlain Basin. VTrans submits data annually to the DEC Stormwater Program but these data are not yet reported to CWIP for annual clean water reporting.

## Area Treated

The area treated for non-structural road sweeping practices is defined as the acres of streets swept. The area treated for catch basin cleaning is defined as the road area draining to the catch basins.

## Baseline Phosphorus Loading Rates

Paved road loading rates were derived from the Lake Champlain TMDL Soil and Water Assessment Tool (SWAT) model (Tetra Tech, 2015). The SWAT model's paved road loading rates were derived from published literature values for the northeastern United States (Artuso et al., 1996; Budd and Meals 1994; Stone Environmental 2011).

In 2017, however, DEC discovered that that the TMDL SWAT model road areas greatly exceeded the road areas in the 2011 Lake Champlain Basin Impervious Surface GIS Layer.[9] As the 2011 impervious surface data layer is more detailed than the SWAT impervious surface layer, DEC adjusted road areas to match 2011 data layer. Impervious areas were divided based on road surface type and road class groupings. These analyses resulted in new adjusted phosphorus loading rates for paved and unpaved roads in the Lake Champlain basin. Paved road loading rates for Lake Champlain and Lake Memphremagog basins can be found in Appendix A.

## Total Phosphorus Load Reduction Efficiency

Phosphorus reduction efficiencies for non-structural stormwater practices (Table 5) were derived from Appendix F of the Massachusetts MS4 General Permit (2016) and Wisconsin Department of Environmental Protection (2017). Phosphorus credits are only given for an increase or enhancement in street sweeping during or after the TMDL modeling period. Full credit is awarded for practices that started after the TMDL modeling period (2000-2010). For practices commenced or increased prior to 2010, credit is reduced by 10% for each year prior to 2010.

Phosphorus credits from monthly and weekly practices are assumed to be performed year-round. If sweeping is only performed during part of the year, the credit is prorated based on the percent of the year during which sweeping occurs. For example, if a town typically sweeps monthly with a vacuum assisted sweeper for 9 months of the year, then they can take (9/12) * 4% = 3%.

Table 5. Phosphorus reduction efficiencies credited for non-structural practices.

| Non-Structural Stormwater Practice | Frequency | Phosphorus Reduction Efficiency |
|---|---|---|
| Mechanical Broom | 2/year (spring and fall) | 1% |
| Mechanical Broom | Monthly | 3% |
| Mechanical Broom | Weekly | 5% |
| Vacuum Assisted | 2/year (spring and fall) | 2% |
| Vacuum Assisted | Monthly | 4% |

[9] To access the 2011 Lake Champlain Impervious Surface GIS Layer, please visit: https://geodata.vermont.gov/datasets/738766d2549b49ab80c573408e300215_7.

| | | |
|---|---|---|
| Vacuum Assisted | Weekly | 8% |
| High Efficiency Regenerative Air-Vacuum | 2/year (spring and fall) | 2% |
| High Efficiency Regenerative Air-Vacuum | Monthly | 8% |
| High Efficiency Regenerative Air-Vacuum | Weekly | 10% |
| Any technology on streets with ≥17% tree cover | 4X in the fall | 17% |
| Catch Basin Cleaning | Semi-Annually | 2% |

USGS (2021) conducted a study of non-structural stormwater practices in Vermont in 2017 and 2018. This study measured total organic carbon, total Kjeldahl nitrogen, and total phosphorus concentrations in materials collected from catch basins (CB) and street cleaning (SC) operations in nine Vermont communities. This study also evaluated the potential total phosphorus load reductions associated with CB and SC in the Lake Champlain basin by (1) applying of the Wisconsin Department of Natural Resources (WDNR) load reduction crediting approach (WDNR, 201942) to conditions in central and northwestern Vermont using 2018 municipal BMPs and tree-cover density information, and (2) conducting simulations of a small urban catchment in northwestern Vermont using the Source Loading and Management Model.

The results of the WDNR exercise are useful for municipal planning purposes, and the results of the loading simulation can be used to assess the effectiveness of non-structural practices. Three model scenarios were compared: (1) no CB or SC control practices; (2) current (2018) CB and SC operations where CBs are cleaned every 5 years and SC frequencies vary by municipal route (weekly, twice per year, and one time per year, figure 9, table 2); and (3) high-frequency control practices, including semiannual CB cleaning and weekly SC to manage leaf loading in the fall. The results illustrated that 2018 CB and SC operations produced a 0.08% TP reduction in the Englesby Brook watershed compared to no CB and SC practices, while higher frequency practices produced a 0.10% TP reduction. Street-solid loads before and after street-cleaning events were also estimated by integrating nutrient concentration results with the model simulations. This analysis illustrated that percent reduction attributed to the simulations of weekly street cleaning control practices ranges from 0% to 22%. Considering the range of results from different modeling exercises, DEC will continue to use the phosphorus reduction efficiencies for non-structural stormwater practices in Table 5.

## Design Life

The design life for street sweeping and catch basin cleaning is one year since the practice must be performed annually to receive credit. The lifespan and associated credit of this project type will not extend beyond its design life.

## Non-Structural Stormwater Practice Tracking & Accounting Summary

Table 6. Summary of data used for estimating phosphorus reductions from non-structural stormwater treatment practices.

| Data Required | Value & Source |
|---|---|
| Baseline phosphorus loading rate | Appendix A |

| | |
|---|---|
| • TMDL drainage area<br>• Acres swept or acres of roads draining to catch basins | |
| Practice efficiency | 1-17% depending on practice (Massachusetts MS4 General Permit 2016 and Wisconsin Department of Environmental Protection 2017) |
| Design life | 1 year |

## Road Erosion Remediation

There are four categories of road erosion remediation projects classified according to road type that have different accounting methodologies. [10]

1. *Road Erosion Remediation on Paved & Unpaved Municipal Roads with Ditches (Class 1-3):* Installation of a suite of practices to correct road-related erosion problems for paved and unpaved municipal roads and road drainage culverts. Practices may include drainage ditch installation and upgrades, turnouts, removal of high road shoulders, and stabilization of drainage culverts.
2. *Road Erosion Remediation on Class 4 Municipal Roads:* Correction of gully erosion on Class 4 municipal road surface and shoulder.
3. *Road Erosion Remediation for Paved and Unpaved Roads with Catch Basins.* Outlet and gully stabilization accounting is addressed in the following gully section.
4. *Road Erosion Remediation on Paved & Unpaved Private Roads with Ditches:* Installation of a suite of practices to correct road-related erosion problems for paved and unpaved private roads and road drainage culverts.
5. *Road Erosion Remediation on State Roads:* Installation of a suite of practices to correct road-related erosion problems for paved state roads, ditches, and road drainage culverts.

### Project Type Tracking Mechanisms

The Municipal Roads General Permit (MRGP) drives municipal road erosion remediation projects.[11] The MRGP is intended to achieve significant reductions in stormwater-related erosion from paved and unpaved municipal roads. Municipalities are required to assess hydrologically connected road segments to determine if segments meet MRGP standards. Road segments are prioritized for water quality purposes in order to achieve progress towards meeting TMDLs and other water quality restoration goals. Actions include bringing road drainage systems up to maintenance standards and performing additional corrective measures to reduce erosion.

Municipal roads are classified into three general categories under the MRGP:

1. Paved and unpaved roads with ditches (Class 1-3)

[10] For more information on road erosion remediation practices, see the VTrans Better Roads Manual: https://vtrans.vermont.gov/sites/aot/files/highway/documents/ltf/Better%20Roads%20Manual%20Final%202019.pdf
[11] For more information on the MRGP, please visit: https://dec.vermont.gov/watershed/stormwater/permit-information-applications-fees/municipal-roads-program

2. Paved roads with curbs and catch basins
3. Class 4 roads

Municipal road segments are classified as either "hydrologically connected" or "not hydrologically connected" based on field surveys and GIS analyses.[12,13] All hydrologically connected road segments are required to be assessed for compliance with road standards. A hydrologically connected road segment meets one of the following criteria:

- Municipal road segment within 100' of a perennial or intermittent stream, lake, pond, wetland, or defined channel
- Municipal road segment that bisects water or a defined channel
- Municipal road segment is uphill from, and drains to, a municipal road that bisects water or a defined channel.

Each road category has specific standards under the MRGP, as summarized in Appendix D. For Class 4 roads and paved/unpaved roads with ditches, MRGP standards are based on the conditions on the road segment. The standards for paved roads with curbs and catch basin are based on the condition of the catch basin outlet rather than the road segment. The degree to which each road segment adheres to the MRGP standards determines its compliance score. Compliance scores fall in to three categories: *Does Not Meet* (DNM), *Partially Meets* (PM), or *Fully Meets* (FM) standard. The specific definition of DNM, PM, and FM varies based on the road type scoring. Compliance scores are the basis for the municipal road accounting methodologies outlined below.

Municipal road erosion remediation projects are funded, implemented, and tracked through the following mechanisms.

- Municipal Road Erosion Inventories (REIs) assess the compliance scores of all hydrologically connected road segments within a municipality. REI data is collected in the field using two mobile applications: ArcGIS Collector is used to locate the segment or outlet for inventory, then Survey123 is used to complete the assessment of the road segment.[14] Initial REIs were completed and submitted to DEC in December 2020, and municipalities will be required to submit new REIs during each five-year MRGP permit cycle. REI data are submitted to the DEC Stormwater Program in spreadsheet format or via Survey123. Municipal road data are stored in the MRGP Implementation Table Portal.[15] Road erosion scoring can also be displayed spatially

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[12] When assessments occur in the field, a road segment's classification may be updated based on the conditions observed. For more information on the methods used to classify municipal roads, please visit: https://dec.vermont.gov/sites/dec/files/wsm/stormwater/docs/Permitinformation/MunicipalRoads/sw_MethodologyForDeterminingMunicipalRoadsHydrologicConnectivity_GIS-DerivedProximityAnalysis.pdf
[13] A map layer titled "Hydrologically Connected Road Segments (MRGP)" can be displayed on the Natural Resource Atlas under the "Stormwater" layer. All roads-related data can also be displayed on the Atlas under the Municipal Roads Theme from the drop-down menu. The Atlas can be accessed at: http://anrmaps.vermont.gov/websites/anra5/.
[14] For more information on REI data collection, please visit: https://vtanr.maps.arcgis.com/home/item.html?id=fe11c5ffd0d04eeca968115d84dacf90
[15] To access the MRGP Implementation Table Portal, please visit: https://anrweb.vt.gov/DEC/IWIS/MRGPReportViewer.aspx?ViewParms=True&Report=Portal

on the Natural Resources Atlas[16] and the new MRGP Reporter web-based tool[17]. The DEC Stormwater Program submits REI data to DEC CWIP annually for clean water reporting.

- Municipal Roads Grants-in-Aid (MRGIA) Program, administered by Vermont Agency of Transportation, provides funding for municipalities to comply with the MRGP. Funding is directed to road improvement project construction on hydrologically connected municipal road segments that do not meet or partially meet MRGP standards. All work must result in bringing those segments into full compliance with the MRGP. Grantees are required to submit data collected on the pre-construction condition and the post-construction condition of the road for each segment improved under the program annually to VTrans. VTrans submits data to DEC CWIP annually for clean water annual reporting.
- VTrans Better Roads Program, Transportation Alternatives Program, and Municipal Highway and Stormwater Mitigation Program provide funding to towns to inventory, maintain and improve roads. VTrans submits the results of their funding programs to DEC CWIP annually.

Private road erosion remediation projects are funded, implemented, and tracked through the following programs.

- DEC Clean Water Initiative Program
- Lake Champlain Basin Program

State road erosion remediation projects are funded, implemented, and tracked by VTrans through the TS4 Permit.

## Area Treated

The area treated for each municipal road erosion remediation project is defined as the 100-meter (328 feet) road segment of the project. In order to track MRGP projects, municipal roads were divided into 100-meter road segments with unique identification numbers using a geographic information system (GIS) analysis.

The area treated for private road erosion remediation projects is defined as the 100-meter road segment of the project. Private roads will be divided into 100-meter segments using GIS analysis.

The area treated for each state road erosion remediation project is defined as the 0.05-mile (80.5 meters, 264 feet) road segment of the project. To track VTrans phosphorus control plan (PCP) projects, state roads were divided into segments with unique identification numbers, similar to the approach used for MRGP projects.

## Baseline Phosphorus Loading Rates

Since DEC began tracking road projects for phosphorus reductions, different loading rates were used at different times. When tracking first began, Adjusted Generalized Road phosphorus loading rates were

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[16] A map layer of "Road Erosion Scoring (MRGP)" can be displayed on the Natural Resource Atlas under the "Stormwater" layer or Municipal Roads Theme. If a road erosion inventory has been completed for a municipality, the road condition of each segment will be displayed on the map. The Atlas can be accessed at: http://anrmaps.vermont.gov/websites/anra5/

[17] The MRGP Reporter can be accessed here: https://vtanr.maps.arcgis.com/home/webmap/viewer.html?webmap=1f9ba3d3ebf8465f992d2ca20ed123af

used for all road types for the existing funding programs. Once the MRGP and TS4 regulatory programs were further developed, more detailed loading rates were developed for those programs to work better with the data collected via those programs and to better reflect the relative impact of roads under different conditions.

*Adjusted Generalized Road Phosphorus Loading Rates*[18]

Paved and unpaved road loading rates were derived from the Lake Champlain TMDL Soil and Water Assessment Tool (SWAT) model (Tetra Tech, 2015). The SWAT model's paved road loading rates were derived from published literature values for the northeastern United States (Artuso et al., 1996; Budd and Meals 1994; Stone Environmental 2011).. Using GIS estimates of hydrologic connectivity, Wemple (2013) estimated that only approximately 50% of the sediment and phosphorus eroded from roads is discharged directly to receiving waters. The TMDL SWAT model calibrated unpaved loading rates to the Wemple (2013) monitoring data and factored in the 50% hydrologic connectivity. The load averaged across hydrologically connected and unconnected segments in the Lake Champlain basin was approximately 5 kg/km/year, factoring about 10 kg/km/year for connected segments, which is consistent with Wemple (2013).

In 2017, DEC discovered that that the TMDL SWAT model road areas greatly exceeded the road areas in the 2011 Lake Champlain Basin Impervious Surface GIS Layer.[19] As the 2011 impervious surface data layer is more detailed than the SWAT impervious surface layer, DEC adjusted road areas to match 2011 data layer. Impervious areas were divided based on road surface type and road class groupings. It was determined that the "Class 4 Impervious" grouping significantly undercounted road surface, so impervious area for these segments was estimated by buffering the road centerlines to 12 feet wide, as was consistent with previous observations and measurements made by DEC. These analyses resulted in adjusted phosphorus loading rates for paved and unpaved roads in the Lake Champlain basin.

Adjusted linear phosphorus loading rates (kg/km/year) for the Lake Champlain basin were estimated using road phosphorus loads from the Lake Champlain TMDL SWAT model (Tetra Tech, 2015) and road length from VTrans centerline GIS data.[20]

$$Adjusted\ P\ loading\ rate = \frac{total\ (paved\ or\ unpaved)\ road\ P\ load\ in\ drainage\ area\ (\frac{kg}{yr})}{length\ of\ (paved\ or\ unpaved)\ road\ in\ drainage\ area\ (km)}.$$

This analysis produced adjusted phosphorus loading rates for paved and unpaved roads within each unique lake segment-drainage area combination. Adjusted generalized loading rates are presented Appendix E.

Adjusted linear phosphorus loading rates (kg/km/year) for the Lake Memphremagog basin were calculated using the total phosphorus loading rate per Lake Memphremagog TMDL drainage area

[18] Adjusted phosphorus loading rates were used for road improvement projects implemented under the VTrans Better Roads Grants during SFY 2016-2019 because they did not collect REIs or pre-construction assessments to serve as the baseline for phosphorus accounting. Adjusted phosphorus loading rates were also applied to Municipal Roads Grants-in-Aid projects during SFY 2017-2019 before MRGP-specific loading rates were developed.
[19] To access the 2011 Lake Champlain Impervious Surface GIS Layer, please visit: https://geodata.vermont.gov/datasets/738766d2549b49ab80c573408e300215_7
[20] To access the Vermont road centerline GIS dataset, please visit: https://geodata.vermont.gov/datasets/1dee5cb935894f9abe1b8e7ccec1253e_39.

divided by average road width of ten meters per road type (paved, unpaved) per TMDL drainage area. The loading rates are unchanged from the Lake Memphremagog TMDL model, but each drainage area is adjusted using a delivery factor.

*MRGP Phosphorus Loading Rates*

Municipal roads were classified based on a combination of surface type, hydrologic connectivity, road class, slope class, and compliance score, as shown in Table 7. The adjusted paved and unpaved road loading rates did not differentiate loading rates for the various road classifications associated with the MRGP. To develop more specific loading rates for MRGP phosphorus accounting, DEC performed additional analyses to estimate baseline phosphorus loading rates for MRGP road classifications in the Lake Champlain basin. This analysis has not yet been performed for the Lake Memphremagog basin (see Appendix F for more information).

The goal of the new loading rate development was to set loading rates that reflect the relative phosphorus load from different combinations of loading factors without changing the total phosphorus load from municipal roads as estimated by the Lake Champlain SWAT model. All factors in Table 7 except compliance score were based on existing GIS layers. Available REI compliance score data were used to assign road lengths to each compliance class.

DEC used the *Solver* add-in for Microsoft Excel to develop loading rates for each combination of loading factors. *Solver* adjusted the adjusted baseline phosphorus loading rate using a set of multipliers for hydrologic connectivity, road slope, and MRGP compliance status. The multiplier for hydrologic connectivity was set so that road length multiplied by the new loading rates matched the initial SWAT load. Multipliers for compliance score were based on the phosphorus accounting methodologies summarized below. In the unpaved loading rate model, multipliers for slope were derived from Figure 8 of Wemple (2013), which illustrates that higher road slopes are associated with greater erosion. In the paved loading rate model, multipliers for slope were discounted from the unpaved model, as slope has less of an effect on paved phosphorus loading rates according to Figure 3.12 in Stone Environmental (2011). The unpaved loading rate models were also constrained using the 10 kg/km/year average measured loading rate from Wemple (2013). Final MRGP linear loading rates are available in Appendix F.

Table 7. Loading factors used to differentiate MRGP phosphorus loading rates.

| Loading Factor | Variables |
|---|---|
| Road Type | Paved, Unpaved |
| Hydrologic Connectivity | Connected, Unconnected |
| Road Class | Class 1-3, Class 4 (unpaved only) |
| Road Slope | <5%, 5-10%, >10% |
| Compliance Status | *Does Not Meet, Partially Meets, Fully Meets* |

*Private Road Loading Rates*

DEC has not yet established baseline phosphorus loading rates for private roads in the Lake Champlain or Lake Memphremagog basins. These are anticipated to be similar to the municipal road loading rates.

*State Road Loading Rates*

VTrans developed loading rates for state highways based on connectivity and slope. DEC and VTrans determined the total phosphorus load for each drainage area in the Champlain basin based on area loading rates in Appendix A and impervious surfaces from the 2011 impervious surface data with state within state right-of-way in GIS. Roads were divided first into 0.05 mile (~80.5-meter) segments; each segment was further divided based on hydrologic connectivity (classified as low, medium, or highly connected) and roadway slope (0%-10% or >10% slope). The load was reallocated amongst the segments using a series of loading factors, similar to the process undertaken for municipal roads. Loading rates for paved state highways are presented in Appendix G. Additional information on the development of the VTrans loading rates for state highways is available in the VTrans Phosphorus Control Plan Story Map.[21] Nearly all state highways are paved, so refined loading rates were not developed for unpaved state highways.

## Total Phosphorus Load Reduction Efficiencies

Phosphorus accounting methodologies for municipal roads vary based on the type of road improvement project.[22]

*Road Erosion Remediation on Paved and Unpaved Roads with Ditches (excluding Class 4)*

MRGP standards for paved and unpaved roads with ditches are based on the implementation of a suite of practices both on the road surface, drainage ditch, road shoulder, and non-perennial stream, road and drive culverts. Rather than accounting for phosphorus load reductions for each individual road BMP installed, DEC accounts for road phosphorus load reductions at the road segment-level based on compliance with MRGP standards.

REIs or pre-construction assessments determine if a road segment *Fully Meets*, *Partially Meets* or *Does Not Meet* MRGP standards. This assessment serves as the baseline condition from which phosphorus reductions are estimated. Road improvement projects that improve the compliance score for a segment (e.g., *Does Not Meet* to *Fully Meets*) will receive phosphorus load reductions.[23]

Phosphorus reduction efficiencies for changes in MRGP compliance were developed based on Wemple and Ross (2015). Wemple and Ross (2015) measured sediment reductions associated with individual road BMPs rather than reductions resulting from a suite of practices based on MRGP compliance. To estimate phosphorus reductions for changes in MRGP compliance, DEC formed a workgroup to develop adjusted reduction efficiencies, which are presented in Table 8. For projects that result in the compliance status changing from *Does Not Meet* to *Fully Meets*, an 80% phosphorus load reduction is

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[21] https://www.arcgis.com/apps/MapJournal/index.html?appid=af0d93d2e55f42f1803ca79e0c492f3f

[22] Municipal road improvement projects constructed between 2010 and 2015 are not able to receive credit toward the Lake Champlain TMDL unless all data required to calculate reductions are provided to DEC. It is not likely that any road projects implemented would have met MRGP standards prior to 2015, as the MRGP standards were not yet developed. DEC considers requests for phosphorus reduction credit of projects completed during this time on a case-by-case basis.

[23] Generally, a pre- and post-construction assessment is required to receive credit for a road improvement project. Some road improvement projects that have been implemented without a pre-construction MRGP compliance assessment (i.e., non-Grants-in-Aid projects), however, may receive phosphorus loading reductions. For example, the VTrans Better Roads grant agreements may not require pre-and post-construction assessments to be completed. In the absence of these assessments, a 40% phosphorus reduction credit may be applied based on the assumption that the road project improved the compliance score but may not have fully brought the segment into compliance.

credited. For projects that result in the compliance status changing from *Does Not Meet* to *Partially Meets* or from *Partially Meets* to *Fully Meets*, a 40% phosphorus load reduction (half credit) is credited. These percent reductions are incorporated into the municipal linear loading rates in Appendix F.

Table 8. Total phosphorus load reduction efficiencies based on change in MRGP compliance status.

| To \ From | | Pre-Construction Compliance Status | |
|---|---|---|---|
| | | *Partially Meets* | *Does Not Meet* |
| Post Construction Compliance Status | *Partially Meets* | 0% | 40% |
| | *Fully Meets* | 40% | 80% |

* Percent reductions are calculated relative to the loading rate for segments not meeting standards

*Road Erosion Remediation on Class 4 Roads*

As Class 4 roads in Vermont are not designed for heavy travel and are only minimally maintained by towns, the MRGP standards for Class 4 roads are less onerous than standards for paved and unpaved roads with ditches. The MRGP standard for Class 4 roads requires only the stabilization of gully erosion, which is defined as erosion equal to or greater than 1 foot in depth.

Phosphorus crediting for Class 4 road remediation is based on the initial measured volume of erosion recorded in the REI. Sites with Does Not Meet REI scores on slopes greater than 10% are considered "Very High Priority" for remediation. Bringing a "Very High Priority" Class 4 road segment into MRGP compliance (>10% road slope) is assigned a phosphorus reduction efficiency equivalent to bringing a Class 1-3 segment from *Not Meeting* to *Partially Meeting*, or a 40% phosphorus load reduction (Table 9). Phosphorus reduction efficiencies for lower erosion volumes were then prorated due to lower quantities of erosion. These phosphorus reduction efficiencies are incorporated into the MRGP linear loading rates in Appendix F.

Table 9. Phosphorus reduction credits for improvements on Class 4 roads resulting in full MRGP compliance.

| Pre-construction Erosion Volume | Compliant Phosphorus Credit |
|---|---|
| < 3 cubic yards | 20% |
| ≥ 3 cubic yards | 40% |

*Road Erosion Remediation on Paved & Unpaved Private Roads with Ditches*

Private road remediation phosphorus crediting will use the same phosphorus reduction efficiencies as municipal roads. Private road REIs and compliance scores will use the same road standards as outlined in the MRGP.

*Road Erosion Remediation on VTrans (State) Roads*

Crediting of state road remediation will use the same phosphorus reduction efficiencies as municipal roads (Table 8). The compliance status of state road segments is based on the VTrans Small Culvert Inventory[24] and the TS4 Drainage Inventory.[25] Note the location of this inventory may change as VTrans tracking and accounting system is updated.

## Design Life

Both municipal and state road erosion remediation regulatory projects are credited with an initial 8-year design life based on Garton (2015). Municipal road projects under the MRGP are required to be assessed approximately once per MRGP permit cycle. If the segment is in compliance when it is reassessed, the credit will be extended until the next required REI. If the project is not in compliance, the credit may be ceased until the municipality remediates the segment.

Private road erosion remediation projects and other non-regulatory projects are also assumed to have an 8-year design life The lifespan and associated credit of a project may be extended beyond the initial design life if the BMP Verification Program finds the project is still functioning according to its intended purpose.

## Road Erosion Remediation Tracking & Accounting Summary

Table 10. Data tracked to calculate phosphorus reductions from road erosion remediation projects.

| Data Required | Value & Source |
|---|---|
| Baseline phosphorus loading rate<br>• Road segment ID<br>• Hydrologic connectivity<br>• Slope<br>• Road type (Paved and unpaved roads with ditches, paved roads with curbs and catch basins, or Class 4 Roads)<br>• Compliance score pre-construction | Loading rates provided in Appendix E and Appendix F |
| Practice efficiency | 20-80% depending on increase in compliance score and road type |
| Design life | 8 years (Garton 2015) |

24 The VTrans Small Culvert inventory can be accessed online here: https://geodata.vermont.gov/datasets/VTrans::vtrans-small-culvert-inventory-culverts/explore?location=43.870575%2C-72.459721%2C8.26&showTable=true.

25 The VTrans Road Drainage inventory can be viewed online here: https://stone-env.maps.arcgis.com/apps/webappviewer/index.html?id=f762ae432a69427eb2d05d65b26b26d8.

## Outlet and Gully Stabilization

Outlet erosion represents a major source of sediment in urban watersheds due to high energy conditions and steep channel slopes. An "outlet" is the point at which stormwater discharges from a pipe or other collection system. In contrast, "outfall" means the point where a stormwater discharge meets waters of the state. Outlet and gully stabilization projects restore eroding channels to a state where sediment loss is minimized or eliminated. Restoration techniques include but are not limited to rock aprons, plunge pools, riprap, step pools, check dams, armored turnouts, outlet headwalls, seeding/mulching, and vegetated or structural bank and slope stabilization techniques.[26]

Please note that the following accounting method only applies to outlet and gully stabilization in intermittent or ephemeral streams adjacent to developed lands. Gully stabilization in perennial streams is accounted for using Functioning Floodplain Initiative methods, as described in the *Natural Resources Tracking & Accounting SOP*.

### Project Type Tracking Mechanisms

Outlet and gully stabilization projects are tracked through regulatory programs and state funding programs (i.e., non-regulatory). The Municipal Roads General Permit (MRGP) established standards for paved roads with hydrologically connected catch basin outlets, requiring all gully or rill erosion associated with catch basin outlets must be remediated. Gully erosion is severe erosion defined as equal or greater than 12" in depth, whereas rill erosion is moderate erosion defined as rivulets greater than 1" but less than 12" in depth. If the total volume of erosion is equal to or greater than three cubic yards, projects are considered "Very High Priority" for remediation by Dec 31, 2025.

Municipal outlet and gully stabilization projects are funded, implemented, and tracked through the following mechanisms, as described in detail under Road Erosion Remediation.

- Municipal Road Erosion Inventories (REIs) and updates to the MRGP Implementation Table Portal
- Municipal Roads Grants-in-Aid (MRGIA) Program
- VTrans Better Roads Program
- Municipal Highway and Stormwater Mitigation Program
- MS4 Permit

State-owned road outlet and gully stabilization projects are funded, implemented, and tracked by VTrans to comply with the TS4 Permit.

Non-regulatory outlet and gully stabilization projects are not under the purview of the MRGP or TS4 Permit and generally occur on private property (i.e., outside of state-owned or municipally owned roadways). Non-regulatory projects are funded by the following programs:

- Clean Water Initiative Program
- Lake Champlain Basin Program

[26] For more information on gully stabilization practices, see the VTrans Better Roads Manual: https://vtrans.vermont.gov/sites/aot/files/highway/documents/ltf/Better%20Roads%20Manual%20Final%202019.pdf

## Area Treated

The area treated for outlet and gully stabilization projects is defined as the area of gully erosion remediated. Please note the difference between the total gully area and the area of gully erosion remediated. For example, some gullies may extend beyond the right-of-way and towns may only be able to remediate some of the gully erosion. For this reason, the area treated is only defined as the area of erosion remediated and not the total gully area.

## Baseline Phosphorus Loading Rates

TMDL phosphorus loading rates are not used to determine the baseline loading rate for gully restoration projects. Instead, the baseline loading rate is determined by estimating an average gully erosion rate prior to restoration and converting the erosion rate to phosphorus loading rate through the equations and variables in Table 11 and Table 12.

Table 11: Equations used to calculate phosphorus loading from gully erosion.

| Equation | Formula |
|---|---|
| Equation 1: Rate of Erosion | E = (VS) / T |
| Equation 2: Phosphorus Loading Rate | P = E (Sc) |

Table 12: Variables used in gully erosion phosphorus loading rate calculations.

| Variable | Description | Directions | Units | Notes |
|---|---|---|---|---|
| E | Sediment erosion rate | Calculate with Eq. 1 | kg sediment (TSS) / year | ------ |
| V | Total volume of erosion treated | Length x Avg. Width x Avg. Depth | $ft^3$ | Must only represent area remediated[27] |
| S | Sediment bulk density | 35.08 | kg / $ft^3$ | Wemple et al. (2021) |
| T | Age of erosion observed | Rill erosion: 5<br>Gully erosion: 15 | Years | See below for further explanation |
| P | Phosphorus erosion rate | Calculate with Eq. 2 | kg TP / year | ------ |
| Sc | Sediment to total phosphorus (TP) weight conversion | 0.000694 | kg (P)/ kg sediment (TSS) | Wemple et al. (2021)[28] |

Partners should provide known dates or ages of the start of erosion or outlet structure with supporting evidence, if known. Supporting evidence (i.e., aerial imagery, past communication, time stamped

[27] MRGP and certain VTrans regulatory projects are only obligated to repair gully erosion within the road right of way.
[28] If a soil sample is taken from the site and tested for P content, that alternative value may be used instead of the average value presented here.

photos, past design plans that were constructed, known system implementation dates, known system repairs and erosion mitigation in the past 30 years) must be submitted during reporting before values other than the default are used for phosphorus accounting. In the absence of this information, five years is used as the default age of erosion for rill erosion (< 12 inches), while 15 years was selected as the default age of erosion for gully erosion (> 12 inches). [29]

Average volume shall be measured as follows:

- Width: measure at top of bank across the gully
- Depth: measure from deepest point vertically to top of bank, at the same point width is measured
- Length: measure from outlet to end of gully erosion. If gully extends outside the right of way, measure length of gully within right-of-way or other jurisdictional boundary. If the full gully length cannot be measured during REI or other field inventory, desktop approximation using GIS, Google Earth, or other mapping tools is acceptable.

For a small gully (e.g., less than 15 feet in length of erosion) one length-width-depth measurement shall be collected at minimum[30]. For larger gullies, collecting representative width and depth measurements at two or more locations along the gully length is encouraged as it will result in a more accurate determination of gully erosion volume. A more precise measurement of gully volume (e.g., estimated by an engineering survey) will also be accepted but is not required.

## Total Phosphorus Load Reduction Efficiency

Total phosphorus load reduction efficiencies for gully restoration were informed by Wemple et al. (2021). This VTrans-funded study examined the occurrence of gully formation and change at road drainage outlets in northern Vermont to address three study objectives:

1. Quantify rates of sediment and phosphorus production associated with erosion at concentrated road drainage points on unpaved and paved roads;
2. Assess the effectiveness of intervention measures in reducing sediment and P mobility from roads, and
3. Develop a framework for providing credits for erosion mitigation measures that can be implemented under the Lake Champlain TMDL.

Gully erosion rates were measured before and after restoration at five sets of control and experimental sites, which provides insights into the effectiveness of gully restoration projects. The rates of effectiveness of the improvements made to the first four gullies were 50%, 60%, 80%, and 100%. The fifth gully was partially stabilized, and the area below the remedy continued to erode following construction.

[29] DEC recognizes that erosive forces change over time and become stronger as the system becomes more incised or progresses from a rill to a gully. However, for the purposes of this calculation an average rate of erosion over a long period of time is used.

[30] Note, it is not required to collect measurements outside of the right of way on a municipal road or state road. One measurement is acceptable if less than 15 feet are within the right of way.

DEC adopted two total phosphorus load reduction efficiencies as described below.

1. Outlet and gully stabilization projects that address the full extent of gully erosion receive an 80% reduction efficiency.
2. Outlet and gully stabilization projects that partially mitigate erosion, for instance by stabilizing the area immediately around an outlet and limiting corrections to the area within the right-of-way, receive a 40% total phosphorus load reduction efficiency. The efficiency is consistent with the "partially meets" road erosion post-construction compliance status.

## Design Life

Wemple et. al (2021) included a retrospective analysis of previously completed road erosion projects that expanded upon Garton (2015) and included 2012-2020 data from VTrans detailed damage inspection reports (DDIRs), Better Roads, and Municipal Grants-In-Aid. In that assessment, of 271 outlet structures and slope stabilization measures, 71% were assessed as intact and functioning, 20% were 'compromised' and in need of maintenance, and 9% were assessed as 'failed' (evidence of washout or slope failure).

Outlet and gully stabilization projects are assigned an 8-year design life to be consistent with this study and other road erosion remediation projects. Municipal road projects under the MRGP are required to be assessed approximately once per MRGP permit cycle. If the segment is in compliance when it is reassessed, the credit will be extended until the next required REI. If the project is not in compliance, the credit may be ceased until the municipality remediates the outlet or gully.

For non-regulatory practices, the design life is assumed to be 8 years. The lifespan and associated credit of a project may be extended beyond the initial design life if the BMP Verification Program finds the project is still functioning according to its intended purpose.

## Outlet and Gully Stabilization Tracking & Accounting Summary

Table 13. Data tracked to calculate phosphorus reductions from outlet and gully stabilization projects.

| Data Required | Value & Source |
|---|---|
| Project Latitude and Longitude or Catch Basin Outlet ID<br>Baseline phosphorus loading rate<br>• Volume of erosion treated (length x average width x average depth)<br>• Age of erosion: Based on known history or 5 years for rill erosion, 15 years for gully erosion<br>• Site sediment bulk density, if known | <br><br>Measured<br>Estimated<br>Measured |
| Practice efficiency | Full-length projects – 80%<br>Partial-length projects – 40% |
| Design life | REI inspection cycle or 8 years |

## Tree Canopy Expansion

Tree plantings on developed pervious or impervious land use that result in an increase in tree canopy but are not intended to result in forest-like conditions. Tree canopies intercept rainfall before it becomes stormwater runoff, and the uncompacted soil into which trees are ideally planted can be used to capture and treat runoff.

Trees do not need to be planted contiguously or along a waterbody and there is no minimum density requirement. Trees cannot be part of a forested riparian buffer or structural stormwater BMP, and the replacement of existing trees is not eligible for credit.

In order to receive stormwater permitting credits for tree canopy expansion, projects must meet the required elements for single tree plantings under the "Reforestation and Tree Planting" BMP in the 2017 Vermont Stormwater Management Manual.

### Project Type Tracking Mechanisms

Individual tree plantings are funded and tracked through the following technical assistance and regulatory programs.

- DEC Lake Wise Program
- Shoreland Protection Act
- Operational Stormwater Permits
- MS4 Permit

### Area Treated

The area treated is the average annual projected canopy area for a single tree planted. The Chesapeake Bay Program determined a 144 $ft^2$ standard canopy area at 10 years using i-Tree forecast simulations with input parameters for growing season length, size of tree at planting, baseline mortality rate, crown light exposure, condition of tree at planting, and tree species (CBP, 2016). Since the length of the growing season in Vermont is shorter than the growing season in the Chesapeake Bay watershed, DEC used model outputs from Table 10(a) of CBP (2016) to determine the relationship between frost free days (FFD) and projected average canopy spread (canopy spread = 0.67(FFD) + 3.21). The average number of FFD in Vermont (135.8) was input to the equation to determine each newly planted tree would be treat an area of 94 $ft^2$ in Vermont.

### Baseline Phosphorus Loading Rates

DEC developed aggregated Developed Pervious and Developed Impervious loading rate categories for the Lake Champlain basin using various loading rates from the Lake Champlain TMDL Soil Water Assessment Tool (SWAT) model. Area-weighted loading rates (kilograms per acre per year) for each category below were calculated by dividing the total phosphorus load for each land use type by the total area of that land use for each drainage area (major river basins within each lake segment basin) within the Lake Champlain basin. Loading rates were then averaged across slope classes, and weighted averages were calculated across hydrological soil groups to further simplify loading rate data requirements.

- Developed Impervious: Area-weighted for Industrial Commercial (Impervious), Residential – High Density (Impervious), Residential – Medium Density (Impervious), and Residential – Low Density (Impervious)
- Developed Pervious: Area-weighted for Industrial Commercial (Pervious), Residential – High Density (Pervious), Residential – Medium Density (Pervious), and Residential – Low Density (Pervious)

The Lake Memphremagog TMDL model included developed pervious and developed impervious loading rates for each drainage area (VT DEC, 2017). Loading rates in the Lake Memphremagog TMDL were not broken out by hydrological soil group or slope as they were in the Lake Champlain TMDL; therefore, developed lands loading rates in the Lake Memphremagog watershed were not post-processed for phosphorus accounting as they were for the Lake Champlain loading rates.

## Total Phosphorus Load Reduction Efficiency

CBP (2016) used a general water balance approach where input (I) equals output (O) plus any change in storage (ΔS) is used to derive the relative effectiveness of tree canopy over turfgrass and impervious cover. This method provides an estimate of the proportion of precipitation that becomes surface flow (edge of field), or water yield. The water balance approach incorporates key hydrologic processes that affect the movement and fate of nutrients and sediment: precipitation (P), runoff (R), evapotranspiration (ET), soil leachate (L) and a change in storage term (ΔS). This analysis determined a 23.8% TP load reduction for tree canopy over turfgrass (Developed Pervious) and an 11% reduction for canopy over impervious. For more detailed information on how the efficiencies were developed, see CBP (2016).

## Design Life

The design life for tree canopy expansion is 20 years. The design life of any single project may be extended beyond the initial design life if the BMP Verification Program finds the project is still functioning according to its intended purpose.

## Tree Canopy Expansion Tracking & Accounting Summary

Table 14. Data tracked to calculate phosphorus reductions from tree canopy expansion projects.

| Data Required | Value & Source |
|---|---|
| Baseline phosphorus loading rate<br>• TMDL drainage area<br>• Planting area (number of trees planted x 94 $ft^2$)<br>• Land use of planting area (developed pervious or impervious) | Loading rates provided in Appendix A |
| Practice efficiency | Developed pervious – 23.8%<br>Developed impervious – 11% |
| Design life | 20 years |

## Native Revegetation

Conversion of developed pervious (e.g., lawns) land uses to native vegetation by the implementation of "no mow" zones or native shrub plantings. Over time, natural succession will allow the area to return to vegetative cover consisting of a mix of trees, shrubs, saplings, and groundcover.

In order to receive stormwater permitting credits for native revegetation, projects must meet the required elements for passive reforestation under the "Reforestation and Tree Planting" BMP in the 2017 Vermont Stormwater Management Manual.

The Native Revegetation phosphorus credit can only be applied to a standalone practice. The phosphorus credit cannot be combined with the Bioengineered Shoreline Stabilization BMP, Forested Riparian Buffer Restoration BMP, or the Developed Lands Tree Planting BMP if it covers the same project area.

### Project Type Tracking Mechanisms

Native revegetation projects are funded, tracked, and/or implemented through the following funding, technical assistance, and regulatory programs.

- DEC Clean Water Initiative Program
- DEC Lake Wise Program
- Shoreland Protection Act
- Operational Stormwater Permits
- MS4 Permit

### Area Treated

The area treated for lake shoreland revegetation projects is defined as the area converted from developed pervious land use (i.e., lawn) to native vegetation.

### Baseline Loading Rates

The Lake Memphremagog TMDL model includes a Developed Pervious loading rate for each drainage area (VT DEC, 2017). The original Lake Champlain TMDL Soil Water Assessment Tool (SWAT) model contained the following developed pervious loading rate categories with individual loading rates for each combination of drainage area, hydrological soil group, and slope (Tetra Tech, 2015a):

- Residential – Low Density (Pervious)
- Residential – Medium Density (Pervious)
- Residential – High Density (Pervious)
- Industrial Commercial (Pervious)

To simplify phosphorus accounting and reporting, DEC developed an aggregated loading rate categories for developed pervious land uses in the Lake Champlain basin. Area-weighted loading rates (kilograms per acre per year) were calculated by dividing the total phosphorus load for each land use type by the total area of that land use for each drainage area (major river basins within each lake segment basin) within the Lake Champlain basin. Loading rates were then averaged across slope classes, and weighted averages were calculated across hydrological soil groups to further simplify loading rate data requirements.

### Total Phosphorus Load Reduction Efficiency

Native revegetation is credited with a land use conversion from Developed Pervious land use to Range Brush (i.e., Shrub/Scrub) land use in the absence of direct measurements of the phosphorus reduction efficiency of revegetation. In the 2006 National Land Cover Dataset used in the Lake Champlain TMDL SWAT model, the Shrub/Scrub (i.e., Range Brush) land use was defined as "*areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.*"

All Lake Memphremagog drainage areas have a Range Brush land use, but not all Lake Champlain drainage areas have Range Brush loading rate. Some land uses with less than 5% in a HUC-12 were merged with other land use classes for modeling purposes. In cases where Range Brush data are lacking, the project will be credited with a land use conversion from Developed Pervious to Forest because native revegetation areas follow natural succession towards forest and the average Forest loading rate (0.05 kg/year) is only slightly lower than the Range Brush loading rate (0.07 kg/year).

### Design Life

The design life for native revegetation is 10 years. The lifespan and associated credit of any single project may be extended beyond the initial design life if the BMP Verification Program finds the project is still functioning according to its intended purpose.

### Native Revegetation Tracking & Accounting Summary

Table 15. Data tracked to calculate phosphorus reductions from native revegetation projects.

| Data Required | Value & Source |
|---|---|
| Baseline phosphorus loading rate<br>• TMDL drainage area<br>• Area converted from developed pervious land use to native revegetation | Loading rates provided in Appendix A |
| Practice efficiency | Conversion from developed pervious to range brush land use |
| Design life | 10 years |

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# Appendix A: Baseline Phosphorus Loading Rates for Stormwater Practices

Table A-1. Lake Champlain basin phosphorus loading rates for developed lands (kg/acre/year). Data adapted from Tetra Tech (2015) using the updated roads layer.

| Lake Segment | Drainage Area | Unpaved Roads | Paved Roads | Non-Road Impervious | Developed Impervious | Developed Pervious | | | | | Forest |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | HSG A | HSG B | HSG C | HSG D | Weighted Average | |
| South Lake B | Mettawee River | 2.299 | 0.823 | 1.197 | 1.040 | 0.062 | 0.273 | 0.420 | 0.787 | 0.289 | 0.259 |
| South Lake B | Poultney River | 2.259 | 0.839 | 1.169 | 1.012 | 0.142 | 0.137 | 0.164 | 0.643 | 0.289 | 0.261 |
| South Lake B | South Lake B DD | 2.381 | 1.097 | 1.464 | 1.298 | 0.036* | 0.238* | 0.947 | 0.412* | 0.947 | 0.131 |
| South Lake A | South Lake A DD | 2.321 | 0.927 | 1.309 | 1.127 | 0.036* | 0.238* | 0.250 | 0.374 | 0.373 | 0.132 |
| Port Henry | Port Henry DD | 2.224 | 0.894 | 1.241 | 1.081 | 0.001 | 0.556 | 0.288* | 0.506 | 0.503 | 0.073 |
| Otter Creek | Lewis Creek | 2.208 | 0.854 | 0.989 | 0.928 | 0.010 | 0.342 | 0.283 | 0.332 | 0.290 | 0.071 |
| Otter Creek | Little Otter Creek | 2.360 | 0.957 | 1.233 | 1.097 | 0.024 | n/a | 0.144 | 0.400 | 0.366 | 0.037 |
| Otter Creek | Otter Creek | 2.115 | 0.818 | 1.150 | 0.998 | 0.100 | 0.276 | 0.271 | 0.398 | 0.292 | 0.248 |
| Otter Creek | Otter Creek DD | 2.272 | 0.881 | 1.095 | 1.005 | 0.036* | 0.238* | 0.273 | 0.351 | 0.348 | 0.399 |
| Main Lake | Main Lake DD | 2.081 | 0.877 | 0.933 | 0.914 | 0.001 | 0.043 | 0.288* | 0.301 | 0.095 | 0.268 |
| Main Lake | Winooski River | 2.207 | 0.802 | 1.117 | 0.980 | 0.020 | 0.254 | 0.284 | 0.467 | 0.231 | 0.181 |
| Shelburne Bay | Laplatte River | 2.075 | 0.735 | 0.952 | 0.878 | 0.010 | 0.059 | 0.123 | 0.243 | 0.172 | 0.061 |
| Burlington Bay | Burlington Bay - CSO | n/a | 0.921 | 1.651 | 1.449 | 0.015 | 0.158 | 0.288* | 0.354 | 0.082 | 0.096 |
| Burlington Bay | Burlington Bay DD | 1.939 | 0.750 | 1.369 | 1.215 | 0.001 | 0.058 | 0.288* | 0.340 | 0.064 | 0.170 |
| Malletts Bay | Lamoille River | 2.034 | 0.810 | 1.138 | 0.986 | 0.037 | 0.213 | 0.438 | 0.547 | 0.228 | 0.069 |
| Malletts Bay | Malletts Bay DD | 2.010 | 0.677 | 0.825 | 0.758 | 0.011 | 0.099 | 0.288* | 0.392 | 0.012 | 0.028 |
| Northeast Arm | Northeast Arm DD | 2.067 | 0.819 | 1.144 | 1.002 | 0.036* | 0.238* | 0.104 | 0.298 | 0.298 | 0.342 |
| St. Albans Bay | St. Albans Bay DD | 1.992 | 0.791 | 1.240 | 1.059 | 0.036* | 0.049 | 0.194 | 0.412* | 0.178 | 0.069 |
| Missisquoi Bay | Missisquoi Bay DD | 2.000 | 0.817 | 0.714 | 0.760 | 0.023 | 0.285 | 0.508 | 0.316 | 0.415 | 0.088 |
| Missisquoi Bay | Missisquoi River | 2.056 | 0.806 | 1.149 | 0.981 | 0.009 | 0.266 | 0.286 | 0.433 | 0.261 | 0.204 |

| Lake Segment | Drainage Area | Unpaved Roads | Paved Roads | Non-Road Impervious | Developed Impervious | Developed Pervious | | | | | Forest |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | HSG A | HSG B | HSG C | HSG D | Weighted Average | |
| Isle La Motte | Isle La Motte DD | 1.967 | 0.729 | 0.759 | 0.746 | 0.036* | 0.024 | 0.084 | 0.076 | 0.077 | 0.069 |
| Basin-wide | | 2.138 | 0.810 | 1.115 | 0.980 | 0.036 | 0.238 | 0.288 | 0.412 | 0.243 | 0.064 |
| *The basin wide average of the HSG soil type was used here, as these loads were not included in the TMDL modeling. | | | | | | | | | | | |

Table A-2. Lake Memphremagog basin phosphorus delivered loading rates for developed lands (kg/acre/year). Data from VT DEC (2017). WA = weighted average

| Drainage Area | Developed Pervious (WA) | Developed Impervious (WA) | Paved Roads | Unpaved Roads | Forest (WA) |
|---|---|---|---|---|---|
| Black River-headwaters to Seaver Branch | 0.2426 | 0.8511 | 0.4622 | 2.0335 | 0.0297 |
| Black River-Seaver Branch to Lords Creek | 0.2674 | 0.9382 | 0.5094 | 2.2414 | 0.0327 |
| Lords Creek | 0.2613 | 0.9166 | 0.4977 | 2.1899 | 0.0319 |
| Black River-Lords Creek to mouth | 0.2651 | 0.9301 | 0.505 | 2.2221 | 0.0324 |
| Barton River-headwaters to Roaring Brook | 0.2035 | 0.7139 | 0.3876 | 1.7056 | 0.0249 |
| Barton River-Roaring Branch to Willoughby River | 0.1567 | 0.5498 | 0.2986 | 1.3136 | 0.0192 |
| Willoughby River | 0.1834 | 0.6432 | 0.3493 | 1.5368 | 0.0224 |
| Barton River-Willoughby River to mouth | 0.2305 | 0.8085 | 0.439 | 1.9317 | 0.0282 |
| Clyde River-headwaters to Echo Lake stream | 0.0852 | 0.2989 | 0.1623 | 0.7141 | 0.0104 |
| Seymour and Echo Lakes | 0.0266 | 0.0933 | 0.0507 | 0.2229 | 0.0033 |
| Clyde River-Echo Lake stream to mouth | 0.1507 | 0.5288 | 0.2871 | 1.2633 | 0.0184 |
| Direct drainage-south end of Lake Memphremagog | 0.2458 | 0.8622 | 0.4681 | 2.0598 | 0.03 |

# Appendix B. Stormwater Performance Curves & Storage Volume Calculations

Table B-1. Phosphorus removal rates from BMP performance curves. Data from US EPA (2010).

| Depth of Runoff from Impervious Surfaces (inches) | 0.1 | 0.2 | 0.4 | 0.6 | 0.8 | 1 | 1.5 | 2 |
|---|---|---|---|---|---|---|---|---|
| Infiltration Basin 8.27 in/hr | 59% | 81% | 96% | 99% | 100% | 100% | 100% | 100% |
| Infiltration Basin 2.41 in/hr | 46% | 67% | 87% | 94% | 97% | 98% | 100% | 100% |
| Infiltration Basin 1.02 in/hr | 41% | 60% | 81% | 90% | 94% | 97% | 99% | 100% |
| Infiltration Basin 0.52 in/hr | 38% | 56% | 77% | 87% | 92% | 95% | 98% | 99% |
| Infiltration Basin 0.27 in/hr | 37% | 54% | 74% | 85% | 90% | 93% | 98% | 99% |
| Infiltration Basin 0.17 in/hr | 35% | 52% | 72% | 82% | 88% | 92% | 97% | 99% |
| Infiltration Trench 8.27 in/hr | 50% | 75% | 94% | 98% | 99% | 100% | 100% | 100% |
| Infiltration Trench 2.41 in/hr | 33% | 55% | 81% | 91% | 96% | 98% | 100% | 100% |
| Infiltration Trench 1.02 in/hr | 27% | 47% | 73% | 86% | 92% | 96% | 99% | 100% |
| Infiltration Trench 0.52 in/hr | 23% | 42% | 68% | 82% | 89% | 94% | 98% | 99% |
| Infiltration Trench 0.27 in/hr | 20% | 37% | 63% | 78% | 86% | 92% | 97% | 99% |
| Infiltration Trench 0.17 in/hr | 18% | 33% | 57% | 73% | 83% | 90% | 97% | 99% |
| Gravel Wetland | 19% | 26% | 41% | 51% | 57% | 61% | 65% | 66% |
| Wet Pond/ Constructed Wetland/ Bioretention/ Sand Filter | 14% | 25% | 37% | 44% | 48% | 53% | 58% | 63% |
| Dry Pond | 3% | 6% | 8% | 9% | 11% | 12% | 13% | 14% |
| Grass Swale | 2% | 5% | 9% | 13% | 17% | 21% | 29% | 36% |

Table B-2. Stormwater treatment practice type storage volume equations. Table adapted from Tetra Tech (2016).

| STP Type | Description | STP Calculator Curve | Method for Calculating Design Storage Volume (DSV) |
|---|---|---|---|
| Infiltration Trench | Provides storage of runoff using the void spaces within the soil/sand/gravel mixture within the trench for infiltration into the surrounding soils. | Infiltration Trench | DSV = void space volumes of stone and sand layers<br>DSV = $(A_{trench} \times D_{stone} \times n_{stone}) + (A_{trench} \times D_{sand} \times n_{sand})$<br>n = 0.33 |
| Subsurface Infiltration | Provides storage of runoff using the combination of storage structures and void spaces within the washed stone within the system for infiltration into the surrounding soils. | Infiltration Trench | DSV = storage volume of storage units and void space of backfill materials. Example for subsurface galleys backfilled with washed stone: DSV = $(L \times W \times D)_{galley} + (A_{backfill} \times D_{stone} \times n_{gravel})$<br>$n_{gravel}$ = 0.33 |
| Surface Infiltration | Provides storage of runoff through surface ponding (e.g., basin or swale) for subsequent infiltration into the underlying soils. | Surface Infiltration | DSV = volume of storage structure before bypass. Example for linear trapezoidal vegetated swale.<br>DSV = $(L \times ((W_{bottom}+W_{top@Dmax})/2) \times D)$ |
| Bioretention/ Rain Garden (no underdrains) | Provides storage of runoff through surface ponding and possibly void spaces within the soil/sand/washed stone mixture that is used to filter runoff prior to infiltration into underlying soils. | Surface Infiltration | DSV = Ponding water storage volume and void space volumes of soil filter media. Example for raingarden:<br>DSV = $(A_{pond} \times D_{pond}) + (A_{soil} \times D_{soil} \times n_{soil\ mix})$<br>$n_{soil\ mix}$ = 0.33 |
| Bioretention/ Rain Garden (w/underdrain) | Provides storage of runoff by filtering through an engineered soil media. The storage capacity includes void spaces in the filter media and temporary ponding at the surface. After runoff passes through the filter media it discharges through an under-drain pipe. | Bioretention | DSV = Ponding water storage volume and void space volume of soil filter media.<br>DSV = $(A_{bed} \times D_{ponding}) + (A_{bed} \times D_{soil} \times n_{soil})$<br>$n_{soil}$ = 0.33 |
| Gravel Wetland | Provides surface storage of runoff in a wetland cell that is routed to an underlying saturated gravel internal storage reservoir (ISR). Outflow is controlled by an orifice that has its invert elevation equal to the top of the ISR layer and provides retention of at least 24 hrs. | Gravel Wetland | DSV = pretreatment volume + ponding volume + void space volume of gravel ISR.<br>DSV = $(A_{pretreatment} \times D_{Pretreatment}) + (A_{wetland} \times D_{ponding}) + (A_{ISR} \times D_{gravel} \times n_{gravel})$<br>$n_{gravel}$ = 0.33 See (0) below. |

| STP Type | Description | STP Calculator Curve | Method for Calculating Design Storage Volume (DSV) |
|---|---|---|---|
| Porous Pavement with infiltration | Provides filtering of runoff through a filter course and temporary storage of runoff within the void spaces of a subsurface gravel reservoir prior to infiltration into subsoils. | Infiltration Trench | DSV = void space volumes of gravel layer<br>DSV = ($A_{pavement}$ x $D_{stone}$ x $n_{gravel}$)<br>$n_{gravel}$ = 0.33 |
| Porous pavement w/ impermeable underlining or underdrain | Provides filtering of runoff through a filter course and temporary storage of runoff within the void spaces prior to discharge by way of an underdrain. | Porous Pavement | Depth of Filter Course = $D_{FC}$ |
| Sand Filter w/underdrain | Provides filtering of runoff through a sand filter course and temporary storage of runoff through surface ponding and within void spaces of the sand and washed stone layers prior to discharge by way of an underdrain. | Sand Filter | DSV = pretreatment volume + ponding volume + void space volume of sand and washed stone layers.<br>DSV = ($A_{pretreatment}$ x $D_{preTreatment}$) + ($A_{bed}$ x $D_{ponding}$) + ($A_{bed}$ x $D_{sand}$ x $n_{sand}$) + ($A_{bed}$ x $D_{stone}$ x $n_{stone}$)<br>n = 0.33 |
| Wet Pond | Provides treatment of runoff through routing through permanent pool. | Wet Pond | DSV= Permanent pool volume prior to high flow bypass. See (0) below. |
| Extended Dry Detention Basin | Provides temporary detention storage for the design storage volume to drain in 24 hours through multiple outlet controls. | Dry Pond | DSV= Ponding volume prior to high flow bypass<br>DSV=$A_{pond}$ x $D_{pond}$ (does not include pretreatment volume) |
| Grass Conveyance Swale | Conveys runoff through an open channel vegetated with grass. Primary removal mechanism is infiltration. | Grass Swale | DSV = Volume of swale at full design flow<br>See (0) below. |
| DSV= Design Storage Volume = physical storage capacity | | | |
| L= length, W= width, D= depth at design capacity before bypass, n=porosity fill material, A= average surface area for calculating volume | | | |
| Infiltration rate = saturated soil hydraulic conductivity | | | |

## (a) Storage Volume for Ponds and Wetlands

For wet ponds and gravel wetlands, there is typically a large outlet at or near the top of the outlet riser that allows larger storms to exit the practice quickly. Storage above that level is considered flood storage and should be excluded from credit calculations.

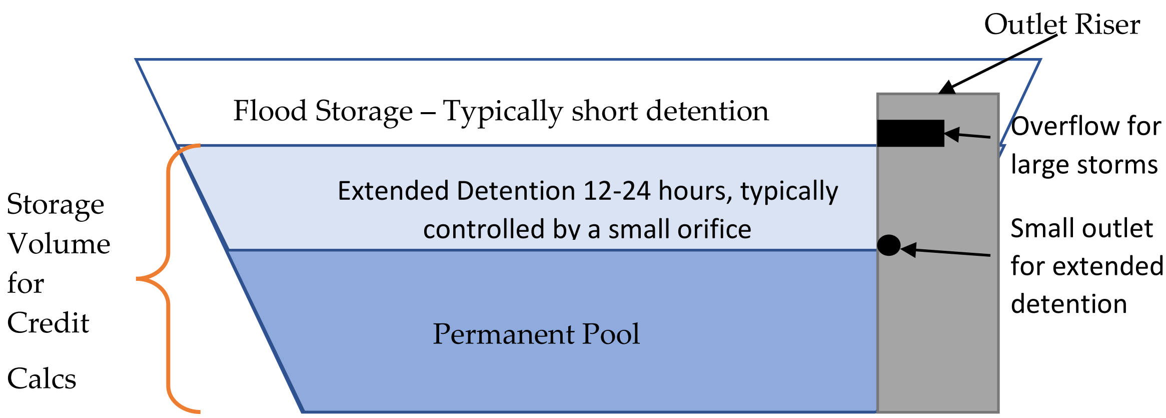


Figure B-1. Generalized schematic of a Wet Pond.

Modeling documentation for the practice should include a stage vs. storage table that can be used to determine the appropriate volume for crediting.

| Elevation (feet) | Surf.Area (sq-ft) | Inc.Store (cubic-feet) | Cum.Store (cubic-feet) |
|---|---|---|---|
| 364.00 | 27 | 0 | 0 |
| 365.00 | 2,208 | 1,118 | 1,118 |
| 366.00 | 3,123 | 2,666 | 3,783 |
| 368.00 | 5,591 | 8,714 | 12,497 |
| 370.00 | 8,301 | 13,892 | 26,389 |
| 372.00 | 11,418 | 19,719 | 46,108 |

Storage volume @ 370′ = 26,389 $ft^3$

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 365.00' | **15.0" Round Culvert**<br>L= 50.0' CPP, projecting, no headwall, Ke= 0.900<br>Inlet / Outlet Invert= 365.00' / 360.50' S= 0.0900 '/' Cc= 0.900<br>n= 0.013 Corrugated PE, smooth interior, Flow Area= 1.23 sf |
| #2 | Device 1 | 368.00' | **2.2" Vert. Orifice/Grate** C= 0.600 |
| #3 | Device 1 | 370.00' | **24.0" Horiz. Orifice/Grate** C= 0.600<br>Limited to weir flow at low heads |
| #4 | Secondary | 371.00' | **4.0' long x 8.0' breadth Broad-Crested Rectangular Weir**<br>Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 |

Overflow Orifice

Figure B-2. Storage volume determination from a HydroCAD summary.

Many ponds built prior to the adoption of the 2002 Vermont Stormwater Management Manual were designed for peak flow attenuation and have neither a permanent pool nor extended detention. Ponds lacking these features are not assigned a phosphorus credit as they do not provide significant treatment.

## (b) Storage Volume for Grass Channels

Grass channels were a popular treatment practice under the 2002 Vermont Stormwater Management Manual (VSMM). Grass channels were typically sized to provide treatment for the water quality storm, which was the 0.9” storm under the 2002 VSMM. Grass channel typically have volume to convey large storms but credit calculations should be based on the peak volume of water in the swale during the water quality storm.

**Summary for Reach 16R: Grass Channel 1**

Inflow Area = 0.653 ac,100.00% Impervious, Inflow Depth > 0.65" for Wqv event
Inflow = 0.65 cfs @ 12.01 hrs, Volume= 0.035 af
Outflow = 0.47 cfs @ 12.28 hrs, Volume= 0.035 af, Atten= 28%, Lag= 16.2 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-20.00 hrs, dt= 0.05 hrs
Max. Velocity= 0.27 fps, Min. Travel Time= 11.2 min
Avg. Velocity = 0.07 fps, Avg. Travel Time= 40.3 min

Peak Storage= 320 cf @ 12.09 hrs, Average Depth at Peak Storage= 0.26'
Bank-Full Depth= 1.50', Capacity at Bank-Full= 11.16 cfs

6.00' x 1.50' deep channel, n= 0.150 Sheet flow over Short Grass
Side Slope Z-value= 3.0 '/' Top Width= 15.00'
Length= 178.0' Slope= 0.0050 '/'
Inlet Invert= 698.50', Outlet Invert= 697.61'


Figure B-1. HydroCAD summary of a grass channel during the water quality storm event.

# Appendix C. Generalized Phosphorus Accounting for Operational Stormwater Permits

Phosphorus accounting methodologies for operational permit tracking have changed over time as data availability and tracking capabilities have increased. In the *Vermont Clean Water Initiative 2018 Investment Report* & *2019 Performance Report*, the following assumptions were made when accounting for phosphorus reductions from operational stormwater permits:

1. As STP storage volumes were not readily available for all practices, generalized phosphorus reductions (Table D-1) were estimated based on the typical treatment depth of each practice type required to meet the water quality standard. Practices designed to meet the water quality standard of the 2002 Vermont Stormwater Management Manual (VSMM) were sized to treat 0.9" of precipitation and those designed to meet the 2017 VSMM standard were sized to treat 1.0" of precipitation.
2. Permit applications received by DEC on or before 6/30/2017 were issued under the 2002 VSMM, whereas applications received on or after 7/1/2017 had to comply with the standards in the 2017 VSMM. Phosphorus reductions from the 2002 or 2017 VSMM sizing requirements were assigned based on the application received date.
3. If the area draining to one discharge point contained more than one practice, the total drainage area and phosphorus load were divided equally amongst the practices.
4. Redevelopment received 20% of the generalized reduction under the 2002 VSMM and 50% of the generalized reduction under the 2017 VSMM. This is because the 2002 VSMM and the 2017 VSMM manuals specify that for redeveloped area 20% or 50%, respectively of the water quality volume must be treated.
5. Where the most recently issued permit superseded a previous permit, the net change in phosphorus load was calculated by subtracting the previous phosphorus load from that of the most recent permit.

Table C-1. Generalized phosphorus reduction efficiencies applied to structural stormwater treatment practices in the *Vermont Clean Water Initiative 2018 Performance Report* and the *Vermont Clean Water Initiative 2019 Performance Report*. Generalized phosphorus reduction efficiencies, which are used when there is inadequate practice sizing data, are based on typical practice sizes designed to meet the water quality standard per the Vermont Stormwater Management Manual.

| Practice Type | Tier | Performance Curve | Generalized Phosphorus Reduction Efficiency | |
|---|---|---|---|---|
| | | | 0.9" (2002) | 1" (2017) |
| Infiltration Basin | Tier 1 | Surface Infiltration | 94% | 95% |
| Infiltration Other | Tier 1 | Infiltration Trench | 87% | 90% |
| Infiltration Trench | Tier 1 | Infiltration Trench | 87% | 90% |
| Dry Swale Infiltrating | Tier 1 | Surface Infiltration | 91% | 93% |
| Bioretention Infiltrating | Tier 1 | Surface Infiltration | 91% | 93% |
| Surface Sand Filter Infiltrating | Tier 1 | Infiltration Trench | 87% | 89% |
| Disconnection to Filter Strips or Vegetated Buffers/ Non-Rooftop Disconnection | Tier 1 | Disconnection | 55% | 57% |
| Simple/ Rooftop Disconnection | Tier 1 | Disconnection | 55% | 57% |
| Gravel Wetland | Tier 2 | Gravel Wetland | 59% | 61% |
| Bioretention Under-drained | Tier 3 | Biofiltration | 45% | 46% |
| Sand Filter Underdrain | Tier 3 | Biofiltration | 67% | 68% |
| Surface Wetland | Tier 3 | Wet Pond | 51% | 53% |
| Wet Pond | Tier 3 | Wet Pond | 51% | 53% |
| Dry Detention Pond | N/A | Dry Pond | 12% | 12% |
| Environmentally Sensitive Rural Development | Not 2017 VSMM | Disconnection/ Grass Channel | 34% | 38% |
| Grass Channels | Not 2017 VSMM | Grass Channel | 19% | 19% |

# Appendix D: MRGP Standards and Definitions

Table D-1. Road features, standards, and compliance scores under the MRGP. Compliance scores: Does Not Meet (DNM), Partially Meets (PM), or Fully Meets (FM). Gully erosion is severe erosion defined as equal or greater than 12" in depth, whereas rill erosion is moderate erosion defined as rivulets greater than 1" but less than 12" in depth.

| Class 1-3 Paved and Unpaved Roads with Ditches | | |
|---|---|---|
| Road Feature | Standards Required | Compliance Scores |
| Roadway Crown | Gravel roads shall be crowned, in-sloped or out-sloped, by a minimum of 2%. | DNM: 0-49% in place<br>PM: 50-89% in place<br>FM: ≥90% in place |
| Shoulder Berms | Shoulder berms shall be removed to allow precipitation to shed from the travel lane into the road drainage system. | DNM: 0-49% in place<br>PM: 50-89% in place<br>FM: ≥90% in place |
| Road Drainage | If distributed flow is possible, road shoulder shall be lower than the travel lane within the right-of-way.<br>If distributed flow is not possible, ditches shall meet following standards according to road slope:<br>• < 5%: grass-lined<br>• ≥ 5-8%: stone-lined or grass-lined with check dams or two or more cross culverts or turn outs<br>• ≥ 8%: stone-lined | DNM: 0-49% in place<br>PM: 50-89% in place<br>FM: ≥90% in place |
| Drainage Outlets and Turnouts | If distributed flow is possible, road drainage shall flow to a grass or forested filter area (road shoulder lower than travel lane).<br>If distributed flow is not possible, turnouts shall meet the following standards according to embankment slopes:<br>• < 5%: stabilize with grass<br>• ≥ 5%: stabilize with stone | DNM: gully erosion<br>FM: no erosion (or less than 1" in depth) |

| | | |
|---|---|---|
| Drainage and Driveway Culverts | Rill or gully erosion must be stabilized by replacing or retrofitting culvert. Does not apply to perennial stream crossings. | DNM: gully erosion<br><br>PM: rill erosion<br><br>FM: no erosion (or less than 1" in depth) |
| Overall Segment Compliance Scoring | Compliance scoring for the entire segment is based upon the scoring of the above individual parameters. | DNM: ≥ 3 parameters Partially Meet, or ≥ 1 Does Not Meet<br><br>PM: 1 or 2 Partially Meet, remaining Fully Meet<br><br>FM: All parameters Fully Meet |

| Class 4 Roads | | |
|---|---|---|
| Road Feature | Standards Required | Compliance Scores |
| Erosion | Any gully erosion that is one foot or deeper must be remediated. | DNM: gully erosion<br><br>FM: rill/no erosion |

| Paved Roads with Curbs and Catch Basins | | |
|---|---|---|
| Road Feature | Standards Required | Compliance Scores |
| Catch Basin Outlet Erosion | Stabilize rill and gully erosion. | DNM: gully erosion<br><br>PM: rill erosion<br><br>FM: no erosion (or less than 1" depth) |

# Appendix E. Adjusted Generalized Road Phosphorus Loading Rates

Table E-1. Adjusted road phosphorus loading rates for the Lake Champlain basin. Loading rates were modified from Tetra Tech (2015) because the TMDL SWAT model road areas greatly exceeded the road areas in the 2011 Lake Champlain Basin Impervious Surface GIS layer.

| Lake Segment | Drainage Area | Loading Rate (kg/km/year) | |
|---|---|---|---|
| | | Paved Roads | Unpaved Roads |
| BURLINGTON BAY | Burlington Bay - CSO | 2.296 | 0.000 |
| BURLINGTON BAY | Burlington Bay - DD | 1.872 | 5.744 |
| ISLE LA MOTTE | Isle La Motte - DD | 2.140 | 5.370 |
| MALLETTS BAY | Lamoille River | 2.679 | 6.784 |
| SHELBURNE BAY | LaPlatte River | 2.084 | 6.399 |
| OTTER CREEK | Lewis Creek | 3.248 | 6.264 |
| OTTER CREEK | Little Otter Creek | 2.996 | 6.512 |
| MAIN LAKE | Main Lake - DD | 2.705 | 6.909 |
| MALLETTS BAY | Malletts Bay - DD | 2.092 | 4.366 |
| SOUTH LAKE B | Mettawee River | 3.064 | 6.338 |
| MISSISQUOI BAY | Missisquoi Bay - DD | 4.077 | 1.504 |
| MISSISQUOI BAY | Missisquoi River | 3.280 | 6.175 |
| NORTHEAST ARM | Northeast Arm - DD | 2.522 | 5.589 |
| OTTER CREEK | Otter Creek | 2.483 | 6.839 |
| OTTER CREEK | Otter Creek - DD | 2.682 | 7.872 |
| PORT HENRY | Port Henry - DD | 2.623 | 6.606 |
| SOUTH LAKE B | Poultney River | 2.627 | 7.530 |
| SOUTH LAKE A | South Lake A - DD | 3.256 | 7.426 |
| SOUTH LAKE B | South Lake B - DD | 3.758 | 8.524 |
| ST ALBANS BAY | St. Albans Bay - DD | 2.396 | 4.706 |
| MAIN LAKE | Winooski River | 2.580 | 7.067 |
| | Basin-Wide Average | 2.655 | 6.679 |

Table E-2. Adjusted road phosphorus delivered loading rates for the Lake Memphremagog basin. The loading rates are unchanged from the Lake Memphremagog TMDL model, but each drainage area is adjusted using a delivery factor.

| Drainage Area | Loading Rate (kg/km/year) | |
|---|---|---|
| | Paved Roads | Unpaved Roads |
| Headwaters Black River | 1.253 | 5.141 |
| Lamphean Brook-Black River | 1.381 | 5.667 |
| Lords Creek | 1.350 | 5.537 |
| Black River | 1.369 | 5.618 |
| Headwaters Barton River | 1.051 | 4.312 |
| Willoughby Brook-Barton River | 0.810 | 3.321 |
| Willoughby River | 0.947 | 3.885 |
| Barton River | 1.190 | 4.884 |
| Headwaters Clyde River | 0.440 | 1.805 |
| Seymour Lake-Clyde River | 0.137 | 0.564 |
| Clyde River | 0.778 | 3.194 |
| Lake Memphremagog | 1.269 | 5.208 |
| Basin-Wide Average | 1.312 | 5.361 |

# Appendix F: Municipal Road Phosphorus Loading Rates

Table F-1. **MRGP unpaved Class 1-3 phosphorus loading rates** (kg/km/yr) for the Lake Champlain basin.[31] Data modified from Tetra Tech (2015). CSO = combined sewer overflow. DD = direct drainage to lake segment. % = road slopes. Data may be updated following completion of all REIs.

| Drainage Areas | Hydrologically Connected Segments | | | | | | | | | Un-connected Segments |
|---|---|---|---|---|---|---|---|---|---|---|
| | Fully Meets MRGP Standards | | | Partially Meets MRGP Standards | | | Does Not Meet MRGP Standards | | | |
| | <5% | 5-10% | >10% | <5% | 5-10% | >10% | <5% | 5-10% | >10% | |
| Burlington Bay - CSO | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Burlington Bay - DD | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Isle La Motte - DD | 1.054 | 3.506 | 6.130 | 3.162 | 10.518 | 18.391 | 5.271 | 17.530 | 30.652 | 1.005 |
| Lamoille River | 0.937 | 3.118 | 5.452 | 2.812 | 9.354 | 16.355 | 4.687 | 15.589 | 27.259 | 0.894 |
| LaPlatte River | 0.998 | 3.318 | 5.802 | 2.993 | 9.954 | 17.406 | 4.988 | 16.590 | 29.009 | 0.951 |
| Lewis Creek | 0.900 | 2.995 | 5.237 | 2.701 | 8.984 | 15.710 | 4.502 | 14.974 | 26.183 | 0.858 |
| Little Otter Creek | 1.246 | 4.145 | 7.248 | 3.739 | 12.436 | 21.745 | 6.232 | 20.727 | 36.242 | 1.188 |
| Main Lake - DD | 0.956 | 3.180 | 5.560 | 2.868 | 9.539 | 16.680 | 4.780 | 15.898 | 27.799 | 0.911 |
| Malletts Bay - DD | 0.957 | 3.184 | 5.568 | 2.872 | 9.553 | 16.703 | 4.787 | 15.921 | 27.839 | 0.913 |
| Mettawee River | 0.986 | 3.280 | 5.734 | 2.958 | 9.839 | 17.203 | 4.930 | 16.398 | 28.672 | 0.940 |
| Missisquoi Bay - DD | 1.046 | 3.481 | 6.086 | 3.139 | 10.442 | 18.258 | 5.232 | 17.403 | 30.430 | 0.997 |
| Missisquoi River | 1.026 | 3.412 | 5.966 | 3.077 | 10.235 | 17.897 | 5.129 | 17.059 | 29.829 | 0.978 |
| Northeast Arm - DD | 1.213 | 4.035 | 7.056 | 3.640 | 12.105 | 21.167 | 6.066 | 20.175 | 35.278 | 1.156 |
| Otter Creek | 0.851 | 2.831 | 4.950 | 2.553 | 8.492 | 14.850 | 4.256 | 14.154 | 24.749 | 0.811 |

[31] Note this road loading rate analysis has not been done for the Lake Memphremagog Basin. DEC plans to conduct this analysis in the near future.

| Drainage Areas | Hydrologically Connected Segments | | | | | | | | | Un-connected Segments |
|---|---|---|---|---|---|---|---|---|---|---|
| | Fully Meets MRGP Standards | | | Partially Meets MRGP Standards | | | Does Not Meet MRGP Standards | | | |
| | <5% | 5-10% | >10% | <5% | 5-10% | >10% | <5% | 5-10% | >10% | |
| Otter Creek - DD | 0.884 | 2.939 | 5.139 | 2.651 | 8.818 | 15.418 | 4.419 | 14.696 | 25.697 | 0.842 |
| Port Henry - DD | 1.355 | 4.507 | 7.881 | 4.065 | 13.521 | 23.642 | 6.775 | 22.535 | 39.404 | 1.292 |
| Poultney River | 0.968 | 3.221 | 5.632 | 2.905 | 9.662 | 16.895 | 4.842 | 16.104 | 28.158 | 0.923 |
| South Lake A - DD | 0.915 | 3.044 | 5.322 | 2.745 | 9.131 | 15.966 | 4.576 | 15.218 | 26.610 | 0.872 |
| South Lake B - DD | 0.875 | 2.911 | 5.090 | 2.626 | 8.733 | 15.270 | 4.376 | 14.555 | 25.450 | 0.834 |
| St. Albans Bay - DD | 1.002 | 3.333 | 5.828 | 3.006 | 9.999 | 17.484 | 5.011 | 16.665 | 29.140 | 0.955 |
| Winooski River | 0.989 | 3.289 | 5.751 | 2.967 | 9.867 | 17.253 | 4.944 | 16.445 | 28.755 | 0.943 |

Table F-2. **MRGP unpaved Class 4 phosphorus loading rates** (kg/km/yr) for the Lake Champlain basin. Data modified from Tetra Tech (2015). CSO = combined sewer overflow. DD = direct drainage to lake segment. % = road slopes. Data may be updated following completion of all REIs.

| Drainage Areas | Hydrologically Connected Segments | | | | | | Unconnected Segments |
|---|---|---|---|---|---|---|---|
| | Fully Meets MRGP Standards | | < 3 cubic yards Erosion | | > 3 cubic yards Erosion | | |
| | <10% | >10% | < 10% | > 10% | <10% | >10% | |
| **Burlington Bay - CSO** | 8.212 | 22.368 | 10.949 | 29.824 | 13.686 | 37.280 | 1.222 |
| **Burlington Bay - DD** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| **Isle La Motte - DD** | 3.566 | 9.713 | 4.754 | 12.950 | 5.943 | 16.188 | 0.531 |
| **Lamoille River** | 3.711 | 10.108 | 4.948 | 13.477 | 6.185 | 16.847 | 0.552 |
| **LaPlatte River** | 3.762 | 10.247 | 5.016 | 13.663 | 6.270 | 17.079 | 0.560 |
| **Lewis Creek** | 4.003 | 10.904 | 5.338 | 14.539 | 6.672 | 18.174 | 0.596 |
| **Little Otter Creek** | 4.304 | 11.723 | 5.738 | 15.631 | 7.173 | 19.539 | 0.640 |
| **Main Lake - DD** | 3.796 | 10.339 | 5.061 | 13.786 | 6.326 | 17.232 | 0.565 |
| **Malletts Bay - DD** | 3.672 | 10.001 | 4.896 | 13.335 | 6.119 | 16.669 | 0.546 |
| **Mettawee River** | 4.204 | 11.451 | 5.605 | 15.268 | 7.006 | 19.084 | 0.626 |
| **Missisquoi Bay - DD** | 3.625 | 9.875 | 4.834 | 13.167 | 6.042 | 16.458 | 0.539 |
| **Missisquoi River** | 3.748 | 10.208 | 4.997 | 13.611 | 6.246 | 17.014 | 0.558 |
| **Northeast Arm - DD** | 3.708 | 10.101 | 4.944 | 13.468 | 6.180 | 16.834 | 0.552 |
| **Otter Creek** | 3.856 | 10.505 | 5.142 | 14.007 | 6.427 | 17.508 | 0.574 |
| **Otter Creek - DD** | 4.246 | 11.567 | 5.662 | 15.423 | 7.077 | 19.279 | 0.632 |
| **Port Henry - DD** | 4.058 | 11.053 | 5.410 | 14.737 | 6.763 | 18.422 | 0.604 |
| **Poultney River** | 4.121 | 11.224 | 5.494 | 14.966 | 6.868 | 18.707 | 0.613 |
| **South Lake A - DD** | 4.188 | 11.408 | 5.584 | 15.211 | 6.980 | 19.013 | 0.623 |
| **South Lake B - DD** | 4.382 | 11.936 | 5.842 | 15.914 | 7.303 | 19.893 | 0.652 |
| **St. Albans Bay - DD** | 3.670 | 9.996 | 4.893 | 13.328 | 6.116 | 16.661 | 0.546 |
| **Winooski River** | 4.024 | 10.963 | 5.366 | 14.617 | 6.707 | 18.271 | 0.599 |

Table F-3. **MRGP paved municipal road phosphorus loading rates** (kg/km/yr) for the Lake Champlain basin. Data modified from Tetra Tech (2015). CSO = combined sewer overflow. DD = direct drainage to lake segment. % = road slopes. Data may be updated following completion of all REIs.

| Drainage Areas | Hydrologically Connected Segments | | | | | | | | | Un-connected Segments |
|---|---|---|---|---|---|---|---|---|---|---|
| | Fully Meets MRGP Standards | | | Partially Meets MRGP Standards | | | Does Not Meet MRGP Standards | | | |
| | <5% | 5-10% | >10% | <5% | 5-10% | >10% | <5% | 5-10% | >10% | |
| **Burlington Bay - CSO** | 1.555 | 2.073 | 2.592 | 4.665 | 6.220 | 7.775 | 7.775 | 10.367 | 12.959 | 1.230 |
| **Burlington Bay - DD** | 1.122 | 1.496 | 1.870 | 3.365 | 4.487 | 5.609 | 5.609 | 7.478 | 9.348 | 0.887 |
| **Isle La Motte - DD** | 0.786 | 1.048 | 1.310 | 2.357 | 3.143 | 3.929 | 3.929 | 5.238 | 6.548 | 0.621 |
| **Lamoille River** | 0.963 | 1.284 | 1.605 | 2.888 | 3.851 | 4.814 | 4.814 | 6.418 | 8.023 | 0.761 |
| **LaPlatte River** | 1.037 | 1.382 | 1.728 | 3.110 | 4.146 | 5.183 | 5.183 | 6.911 | 8.638 | 0.820 |
| **Lewis Creek** | 0.923 | 1.231 | 1.539 | 2.770 | 3.693 | 4.616 | 4.616 | 6.155 | 7.694 | 0.730 |
| **Little Otter Creek** | 1.126 | 1.501 | 1.877 | 3.378 | 4.504 | 5.630 | 5.630 | 7.507 | 9.384 | 0.890 |
| **Main Lake - DD** | 1.000 | 1.333 | 1.667 | 3.000 | 4.000 | 5.000 | 5.000 | 6.667 | 8.333 | 0.791 |
| **Malletts Bay - DD** | 0.899 | 1.199 | 1.499 | 2.698 | 3.597 | 4.496 | 4.496 | 5.995 | 7.493 | 0.711 |
| **Mettawee River** | 0.949 | 1.266 | 1.582 | 2.848 | 3.797 | 4.746 | 4.746 | 6.328 | 7.910 | 0.751 |
| **Missisquoi Bay - DD** | 1.041 | 1.387 | 1.734 | 3.122 | 4.162 | 5.203 | 5.203 | 6.937 | 8.672 | 0.823 |
| **Missisquoi River** | 1.013 | 1.350 | 1.688 | 3.038 | 4.051 | 5.064 | 5.064 | 6.752 | 8.440 | 0.801 |
| **Northeast Arm - DD** | 0.954 | 1.272 | 1.590 | 2.862 | 3.815 | 4.769 | 4.769 | 6.359 | 7.949 | 0.754 |
| **Otter Creek** | 0.946 | 1.262 | 1.577 | 2.839 | 3.786 | 4.732 | 4.732 | 6.310 | 7.887 | 0.748 |
| **Otter Creek - DD** | 0.869 | 1.159 | 1.449 | 2.608 | 3.477 | 4.347 | 4.347 | 5.795 | 7.244 | 0.687 |
| **Port Henry - DD** | 1.022 | 1.362 | 1.703 | 3.065 | 4.087 | 5.108 | 5.108 | 6.811 | 8.514 | 0.808 |
| **Poultney River** | 1.053 | 1.404 | 1.754 | 3.158 | 4.211 | 5.263 | 5.263 | 7.018 | 8.772 | 0.832 |
| **South Lake A - DD** | 0.967 | 1.289 | 1.611 | 2.900 | 3.867 | 4.833 | 4.833 | 6.444 | 8.055 | 0.764 |

| Drainage Areas | Hydrologically Connected Segments | | | | | | | | | Un-connected Segments |
|---|---|---|---|---|---|---|---|---|---|---|
| | Fully Meets MRGP Standards | | | Partially Meets MRGP Standards | | | Does Not Meet MRGP Standards | | | |
| | <5% | 5-10% | >10% | <5% | 5-10% | >10% | <5% | 5-10% | >10% | |
| **South Lake B - DD** | 1.306 | 1.742 | 2.177 | 3.919 | 5.225 | 6.532 | 6.532 | 8.709 | 10.886 | 1.033 |
| **St. Albans Bay** | 0.992 | 1.323 | 1.654 | 2.977 | 3.969 | 4.961 | 4.961 | 6.615 | 8.269 | 0.784 |
| **Winooski River** | 1.145 | 1.527 | 1.908 | 3.435 | 4.580 | 5.725 | 5.725 | 7.634 | 9.542 | 0.905 |

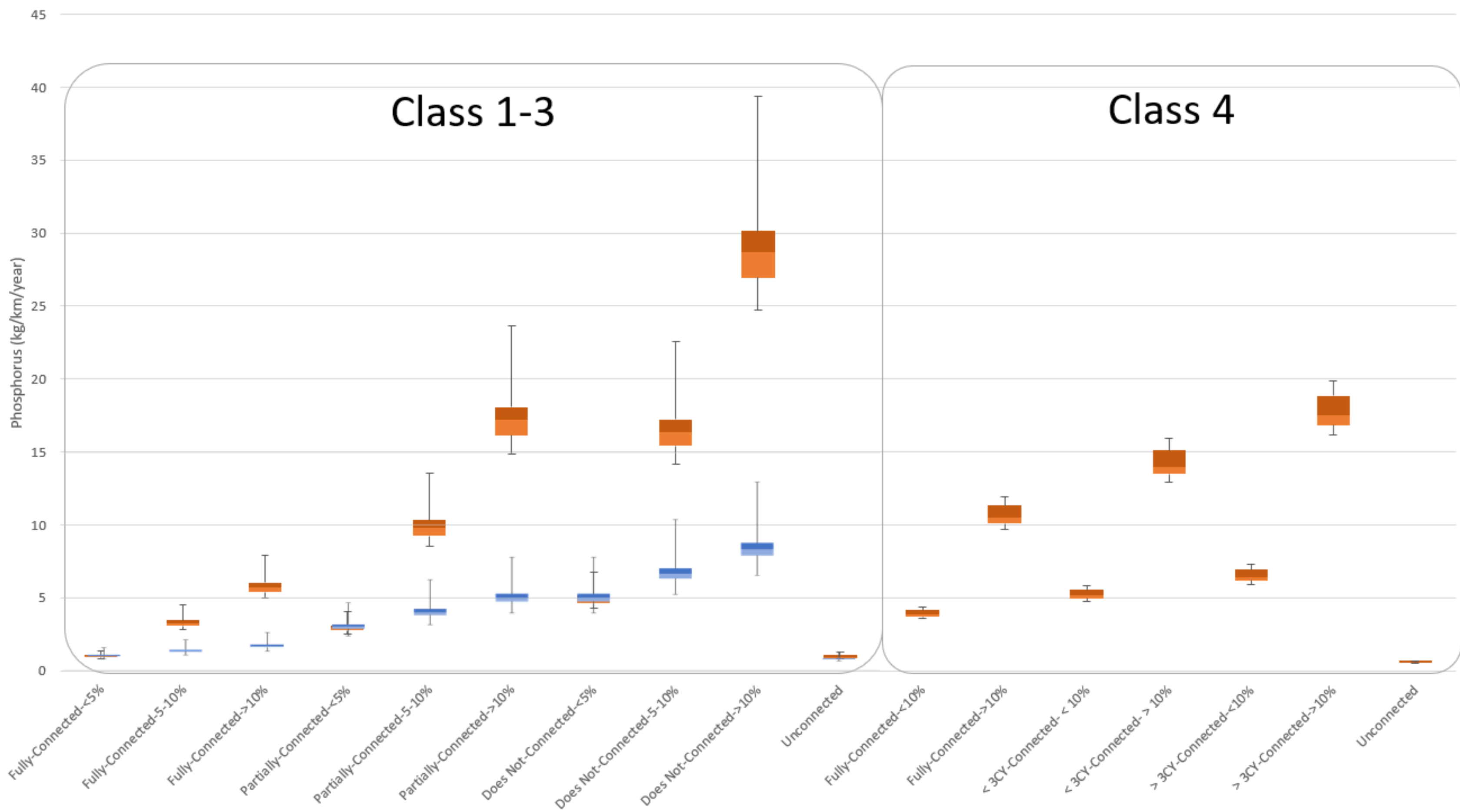


Figure F-1. Post-MRGP remediation loading rates for the Lake Champlain watershed for unpaved (orange) and paved (blue) roads. Data may be updated following completion of all REIs. X-axis labels represent different combinations of road segment classifications under the MRGP. For example, "Fully-Connected-<5%" represents road segments that Fully Meet standards, are hydrologically connected, and are sloped less than 5%.

# Appendix G. VTrans State Highway Loading Rates

Table G-1. **VTrans State Highway Loading Rates** (kg/mi/yr) for the Lake Champlain basin. Data modified from Tetra Tech (2015). CSO = combined sewer overflow. DD = direct drainage to lake segment.

| Drainage Area | High Hydrologic Connectivity | | Moderate Hydrologic Connectivity | | Low Hydrologic Connectivity | |
|---|---|---|---|---|---|---|
| | 0-10% Slope | >10% Slope | 0-10% Slope | >10% Slope | 0-10% Slope | >10% Slope |
| Burlington Bay - CSO | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Burlington Bay - DD | 6.00 | 9.12 | 4.36 | 6.63 | 2.81 | 4.27 |
| Isle La Motte - DD | 3.41 | 4.61 | 2.20 | 2.98 | 1.61 | 2.18 |
| Lamoille River | 4.29 | 4.74 | 2.77 | 3.06 | 2.01 | 2.23 |
| Laplatte River | 4.78 | 7.75 | 3.31 | 5.35 | 2.30 | 3.73 |
| Lewis Creek | 4.45 | 5.59 | 2.86 | 3.59 | 2.09 | 2.63 |
| Little Otter Creek | 5.90 | 5.80 | 3.97 | 3.90 | 2.77 | 2.72 |
| Main Lake - DD | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Malletts Bay - DD | 4.51 | 6.16 | 3.34 | 4.57 | 2.33 | 3.18 |
| Mettawee River | 3.73 | 3.61 | 2.43 | 2.35 | 1.77 | 1.71 |
| Mississquoi Bay - DD | 3.61 | 5.70 | 2.33 | 3.68 | 1.69 | 2.68 |
| Mississquoi River | 4.24 | 4.86 | 2.73 | 3.14 | 1.99 | 2.29 |
| Northeast Arm - DD | 4.57 | 6.73 | 3.00 | 4.42 | 2.19 | 3.22 |
| Otter Creek | 4.59 | 4.24 | 2.98 | 2.75 | 2.15 | 1.99 |
| Otter Creek - DD | 3.92 | 0.00 | 2.62 | 0.00 | 1.89 | 0.00 |
| Port Henry - DD | 4.58 | 2.77 | 3.07 | 1.86 | 2.33 | 1.41 |
| Poultney River | 4.60 | 4.89 | 2.96 | 3.15 | 2.17 | 2.30 |
| South Lake A - DD | 3.95 | 6.55 | 2.59 | 4.28 | 1.89 | 3.13 |
| South Lake B - DD | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| St. Albans Bay - DD | 4.78 | 9.53 | 3.29 | 6.56 | 2.29 | 4.56 |
| Winooski River | 4.56 | 6.07 | 2.94 | 3.92 | 2.14 | 2.85 |