

**Missisquoi Bay Watershed Phosphorus Load
Monitoring Program**

Workplan

**Prepared by the Missisquoi Bay Phosphorus
Reduction Task Force**

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Vermont Agency of Natural Resources

**Ministère du Développement durable, de l'Environnement et des
Parcs, Québec**

Purpose of the Monitoring Program

The *Agreement between the Gouvernement du Québec and the Government of the State of Vermont Concerning Phosphorus Reduction in Missisquoi Bay* (signed August 26, 2002) adopted a total target phosphorus load of 97.2 metric tons per year (mt/yr) for the Missisquoi Bay watershed. The agreement assigned 58.3 mt/yr of this total target load to sources in the Vermont portion of the watershed, and 38.9 mt/yr to Québec sources. The parties committed in the agreement to achieving their respective target loads for the Missisquoi Bay watershed in a manner consistent with implementation plans developed by the Lake Champlain Basin Program and with the Québec, New York, and Vermont Memorandum of Understanding on Environmental Cooperation on the Management of Lake Champlain.

The Report of the Missisquoi Bay Phosphorus Reduction Task Force (June 17, 2000) recommended that progress toward achieving these target phosphorus loads be monitored by enhancing the stream flow gage and water quality sampling network in the Missisquoi Bay watershed in order to permit the direct measurement of phosphorus loads from Vermont and Québec, including the establishment of monitoring sites where the Missisquoi, Pike, and Rock Rivers cross the international border. Accordingly, the 2002 phosphorus reduction agreement stated that “the Parties will enhance phosphorus monitoring of Missisquoi Bay tributaries and wastewater effluent from treatment facilities in the watershed.”

The Québec Ministère du Développement durable, de l’Environnement et des Parcs (MDDEP), the Vermont Department of Environmental Conservation (VT DEC), and cooperating agencies such as the U.S. Geological Survey (USGS) have recently established new sampling and flow gage stations for this purpose in the Missisquoi Bay watershed. These new sites, along with a number of previously existing stations, provide a monitoring network that can be used to estimate annual phosphorus loads to Missisquoi Bay from Vermont and Québec. The purpose of this workplan is to document the network of monitoring stations in the Missisquoi Bay watershed, define the sampling methods employed, and describe how the data will be used to estimate the separate contributions from Vermont and Québec to the annual phosphorus load delivered to Missisquoi Bay.

Monitoring Network

Direct measurement of annual phosphorus loads in rivers requires data on flow rates and total phosphorus concentrations. Previous phosphorus load estimation studies in the Lake Champlain Basin have used continuously recorded flow measurements made at gage stations, combined with analysis of phosphorus samples obtained at discrete times throughout the year, with an emphasis on high flow conditions (e.g., Vermont DEC and New York State DEC, 1997). This general approach to load estimation will be used for the Missisquoi Bay Watershed Phosphorus Load Monitoring Program, and the network of flow gages and sampling stations described below will support this program.

River Flow Gages

There are nine continuous flow gages on rivers in the Missisquoi Bay watershed that are relevant to the purposes of this program. These gages are shown in Figure 1 and listed in Table 1. These gages include long-term stations operated by the USGS on the Missisquoi River at Swanton, East Berkshire, and North Troy, Vermont, and on the Rivière aux Brochets (Pike R.) by the MDDEP

at Bedford, Québec. Three new flow gage stations have been added recently to support the phosphorus load monitoring programs, including sites on the Rivière aux Brochets at Notre-Dame-de-Stanbridge, Québec, the Pike River at East Franklin, Vermont, and the Rivière de la Roche (Rock R.) in St. Armand, Québec. In addition to these stations, the MDDEP and the ministère de l'Agriculture, des Pêcheries et de l'Alimentation (MAPAQ) also installed four continuous flow gage stations on the main tributaries of the Rivière aux Brochets, namely the Castor, Ewing, Morpions, and Wallbridge Brooks. However, of these last four only the Castor and Ewing gages are of direct value for the present program because they flow into the R. aux Brochets downstream of the other gages on the main stem of this river. The flow and phosphorus load contributions of the Morpions and Walbridge Brooks are captured by the other gages and sampling stations on the R. aux Brochets.

River Sampling Stations

There are eleven water quality monitoring stations in the Missisquoi Bay watershed that are relevant to the purposes of this program. These sampling stations are shown in Figure 1 and listed in Table 2. These stations include two long-term tributary monitoring sites (Missisquoi R. at Swanton, Vermont and R. aux Brochets at Pike River, Québec) sampled by the VT DEC as part of the Lake Champlain Basin Program Long-Term Water Quality and Biological Monitoring Program (Vermont DEC and New York State DEC, 2005). The R. aux Brochets sampling site at Pike River, Québec has also been sampled by the MDDEP since 1979 (station 03040015).

Ten additional monitoring stations have been established more recently by the MDDEP. Six of them are located on the R. Missisquoi, R. aux Brochets, R. Sutton, and R. de la Roche near the border crossings to support the phosphorus load monitoring program. Four others have been installed on the main tributaries of R. aux Brochets (the Ewing, Castor, Morpions and Wallbridge Brooks). The Ewing and Castor Brooks are of direct value to this program, since they flow into R. aux Brochets downstream of the stations located on the main stem of the Pike River (PIKE01/03040015). Phosphorus measurements taken at the sampling site located at Pike River do not take into account the load of these two brooks.

Wastewater Treatment Facilities

There are eight wastewater treatment facilities in the Vermont portion of the Missisquoi Bay watershed that discharge significant amounts of phosphorus. The permitted flow rate, permitted phosphorus concentration limit, TMDL phosphorus wasteload allocation, and the actual phosphorus load discharged during 2003 are listed for each facility in Table 3.

Similar information is provided for the Québec facilities in Table 3. In 2001, 30 municipalities were totally or partially found within the boundaries of the Missisquoi Bay watershed in the Province of Québec. Among the 20 municipalities most likely to discharge wastewaters in the rivers and streams of the Missisquoi Bay watershed, 11 are served by sewers. However, only 9 of them have their wastewaters treated by a total of 6 wastewater treatment plants. Even though Venise-en-Québec and Saint-Georges-de-Clarenceville are located within the watershed, their wastewaters are treated by a single facility and discharged in the Rivière du Sud, outside the limits of the Missisquoi Bay watershed. In addition, wastewaters treatment projects are currently under study for the municipalities of Abercorn and Notre-Dame-de-Stanbridge. Two of Québec's treatment facilities are small scale private projects serving a camping ground and trailer park (Stukely-Sud), and a ski resort area (Owl's Head).

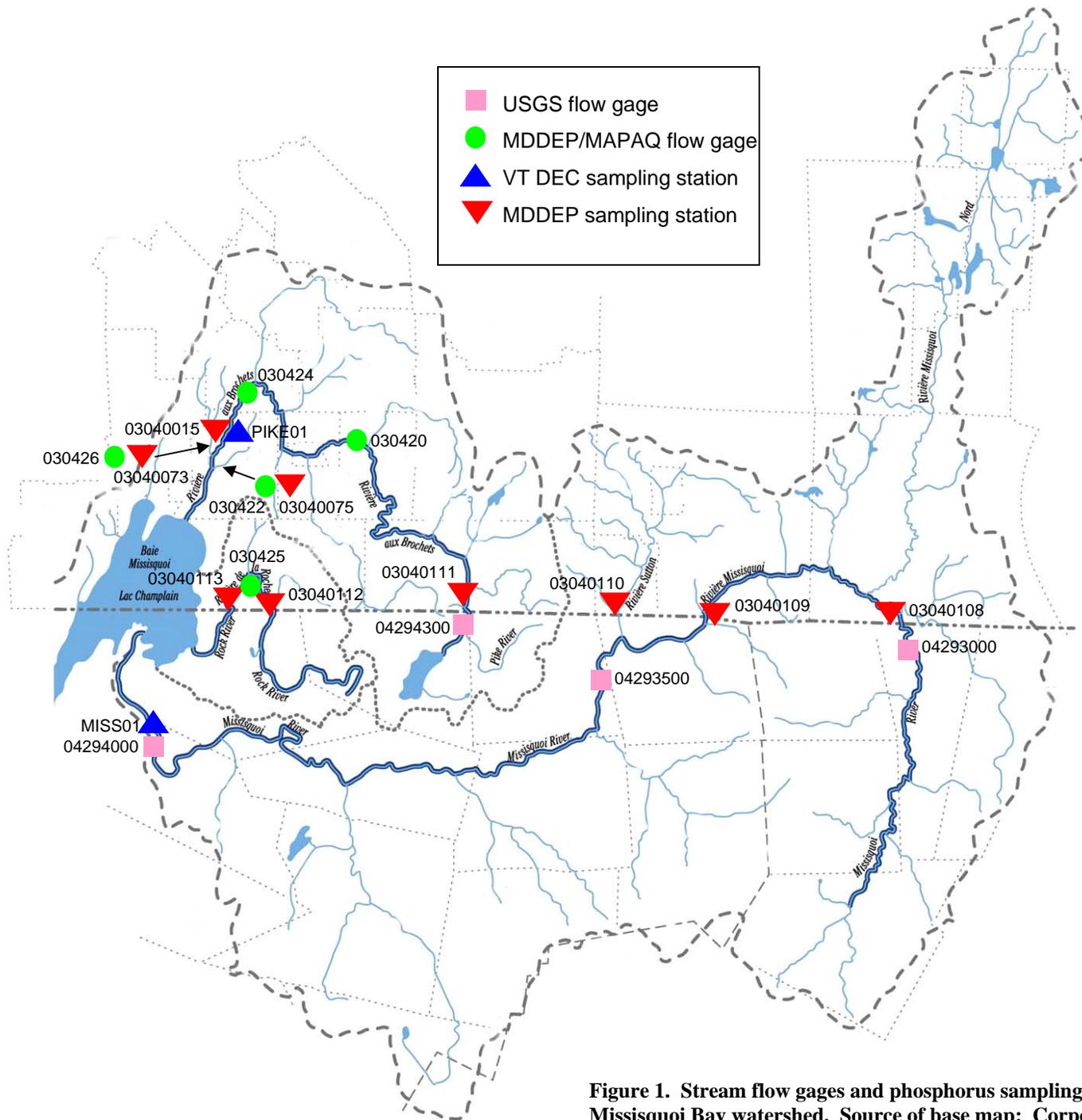


Figure 1. Stream flow gages and phosphorus sampling stations in the Missisquoi Bay watershed. Source of base map: Corporation Bassin Versant Baie Missisquoi.

Table 1. List of river flow gages in the Missisquoi Bay watershed.

Agency	Reference	Location	Latitude °N	Longitude °W	Start Year	Drainage Area (km ²)
USGS	04294000	Missisquoi River at Swanton	44.9167	73.1289	1990	2,201
USGS	04293500	Missisquoi River at East Berkshire	44.9600	72.6969	1915	1,240
USGS	04293000	Missisquoi River at North Troy	44.9728	72.3858	1931	339
USGS	04294300	Pike River at East Franklin	45.0028	72.8356	2001	89.3
MDDEP	030420	Rivière aux Brochets à Bedford	45.1219	72.9942	1979	404
MDDEP	030424	Rivière aux Brochets à Notre-Dame-de-Stanbridge	45.1586	73.0506	2002	586
MDDEP	030425	Rivière de la Roche à Saint Armand	45.0217	73.0161	2002	70.9
MAPAQ	030422	Ruisseau Castor	45.1103	73.0736	1997	11
MDDEP	030426	Ruisseau Ewing à Saint-Pierre-de-Véronne-à-Pike-River	45.1253	73.0772	2002	29.1

Table 2. List of river phosphorus sampling stations in the Missisquoi Bay watershed.

Agency	Reference	Location	Latitude °N	Longitude °W	Start Year
VT DEC	MISS01	Missisquoi River at Swanton	44.9205	73.1272	1990
VT DEC ¹	PIKE 01	Pike River at Pike River, Rt. 133	45.1230	73.0697	1990
MDDEP ¹	03040015	Rivière aux Brochets at Pike River, Rt. 133	45.1230	73.0697	1979
MDDEP	03040108	Rivière Missisquoi upstream of Mud Brook	45.0132	72.3974	1998
MDDEP	03040109	Rivière Missisquoi near East Richford	45.0121	72.5879	1998
MDDEP	03040110	Rivière Sutton, bridge on Road 139 near Abercorn	45.0325	72.6625	1998
MDDEP	03040111	Rivière aux Brochets, north of border near 188, Highway 237	45.0177	72.8255	1998
MDDEP	03040075	Ruisseau au Castor, bridge near its mouth	45.1095	73.0750	2001
MDDEP	03040073	Ruisseau Ewing, bridge near its mouth	45.1195	73.0791	2001
MDDEP	03040112	Rivière de la Roche, north of border	45.0243	73.0168	1998
MDDEP	03040113	Rivière de la Roche, north of border (111, Bradley Rd.)	45.0177	73.0519	1998

¹ same location

Table 3. List of wastewater treatment facilities in the Missisquoi Bay watershed.

Facility	Permit Flow Limit (mgd)	Permit Flow Limit (m³/d)	Permit Conc. Limit (mg/l)	Wasteload Allocation⁷ (mt/yr)	2003 Actual Load (mt/yr)
Vermont					
Enosburg Falls	0.450	1,703	0.8	0.373	0.150
Newport Center	0.042	159		0.006	0.003
North Troy	0.110	416		0.760	0.183
Richford	0.380	1,438	0.8 ¹	0.420	0.814
Rock Tenn Co.	3.500	13,248	0.8	1.260	0.180
Sheldon Springs	0.054	204		0.373	0.056
Swanton	0.900	3,407	0.8 ¹	0.746	0.287
Troy/Jay	0.200	757	0.8 ¹	0.221	0.250
Vermont Total				4.159	1.878
Québec					
Abercorn (no facility) ²					0.196 ²
Bedford ³	1.156	4,375	1.0	1.597	0.672
Eastman	0.064	243	1.0	0.089	0.040
Notre-Dame-de-Stanbridge (no facility)					0.309 ²
Potton	0.064	244	1.0	0.089	0.029
Potton (Owl's Head area) ⁴	0.099	375	1.0	0.137	0.040
Stukely-Sud ⁵	0.016	60	1.0	0.022	
Sutton	0.388	1,468	1.0	0.536	0.416
Saint Armand	0.030	115	0.5	0.021	0.004
Québec Total ⁶				2.490	1.706

¹ Effective on next permit renewal.

² The 2003 actual load was estimated using 2.0 g/person/d and the total sewer population of the municipality.

³ The Bedford wastewater treatment facility (WWTF) is also serving Stanbridge Station.

⁴ This is a private facility serving a ski resort area.

⁵ This is a private facility serving a camp and trailer park. Stukely-Sud has 91% of its territory located in the Yamaska River watershed.

⁶ The Venise-en-Québec facility (not listed in table) also treats the wastewater of Saint-Georges-de-Clarenceville and discharges the treated wastewater to the Rivière du Sud, outside of the Missisquoi Bay watershed.

⁷ Vermont wasteload allocations are as defined in the Lake Champlain Phosphorus TMDL (Vermont DEC and New York State DEC, 2002).

Québec wasteload allocations = Permit Flow Limit (m³/d) x 1000 l/m³ x Permit Concentration Limit (mg/l x 1kg/1000000 mg x 1mt/1000 kg x 365 d/yr.

Sampling Methods

Vermont River Samples

The Vermont tributary sampling stations in the Missisquoi Bay Watershed are sampled as part of the Lake Champlain Long-Term Water Quality and Biological Monitoring Program, supported by the Lake Champlain Basin Program. This monitoring project includes many other stations on Lake Champlain and its tributaries, and many other sampling parameters in addition to total phosphorus (Vermont DEC and New York State DEC, 2005).

Tributary samples are obtained from bridges using depth and velocity-integrating sampling devices (USGS DH-48 or DH-59 suspended sediment samplers). An effort is made to obtain up to 20 total phosphorus samples per year at each tributary site, including as high a proportion of samples as possible during high flow conditions in order to improve the precision of annual mass loading estimates.

Québec River Samples

The Québec tributary sampling stations in the Missisquoi Bay Watershed are sampled as part of the Québec River Monitoring Network (Réseau-rivières) supported by the MDDEP. As it is the case for Vermont, this monitoring project also includes many other stations located in more than 40 different watersheds, and many other sampling parameters in addition to total phosphorus.

For most of the stations, tributary samples are obtained from bridges using a depth-integrating sampling device (open bottle mounted on a sampling iron; Hébert and Légaré, 2000). For a few small tributaries, grab samples are obtained by using an open bottle mounted at the end of an aluminum pole. Since 2001, Québec has been duplicating Vermont's approach and making an effort to obtain up to 20 total phosphorus samples per year at each tributary site, including as high a proportion of samples as possible during high flow conditions in order to improve the precision of annual mass loading estimates.

Vermont Wastewater Samples

Vermont wastewater treatment facilities are sampled for total phosphorus in the final effluent by the plant operators under the terms of their state discharge permits. The phosphorus samples are generally obtained monthly as 8-hr composites. Wastewater flows are monitored continuously. The monthly average flow and total phosphorus results are reported by the plant operators to the VT DEC.

Québec Wastewater Samples

As part of an agreement with the MDDEP, the ministère des Affaires municipales et Régions (MAMR) is operating a municipal wastewater treatment facility monitoring program to assess the plants' performance and determine whether or not environmental requirements are met. Depending upon the facility type and equipment, environmental requirements are determined for one or many of the following parameters: total phosphorus, BOD, suspended solids and fecal coliforms. For most of the facilities, monthly average wastewater flows and total phosphorus results are reported by the plant operators to the MAMR.

Analytical Methods

Vermont Samples

Samples obtained at Vermont monitoring stations for total phosphorus analysis are immediately placed without filtration or preservation into 75 ml borosilicate glass test tubes. The samples are analyzed at the VT DEC Laboratory using acid-persulfate digestion in their original containers followed by colorimetric analysis (American Public Health Association, 1998, Method 4500-P).

Québec Samples

Samples obtained at Québec monitoring stations for total phosphorus analysis are immediately placed without filtration or preservation into 500-ml high density polyethylene bottles. Samples are kept refrigerated at 4 degrees Celsius before analysis which takes place within 48 hours. Filtration through a 1.2- μ m pore diameter GF/C membrane filter separates dissolved from suspended forms of phosphorus in the Québec River Monitoring Network. This analytical technique was adopted many years ago, instead of the standard 0.45- μ m pore diameter membrane filtration, to make a gross separation between dissolved and suspended forms of phosphorus. The choice was made to reduce filtration time and hence the cost of the analyses. The dissolved and suspended forms are added to produce the total phosphorus concentration.

The samples are analyzed at the MDDEP Laboratory, known as the Centre d'expertise en analyses environnementales du Québec (CEAEQ), using acid-persulfate digestion in their original containers followed by colorimetric analysis (American Public Health Association, 1998, Method 4500-P; Stannous chloride method).

Sample Exchange

Sample processing procedures for total phosphorus differ somewhat between Vermont and Québec, and it will be important to ensure that the analytical results are comparable between the two laboratories. Sampling personnel will periodically produce and exchange split samples for duplicate analysis at the Vermont and Québec laboratories. The results from the split samples will be compared statistically to determine whether any significant differences exist in the total phosphorus measurements produced by the two laboratories. If any differences are found, adjustments will be made in the data analysis and load estimation procedures as appropriate.

Data Management and Availability

Vermont Phosphorus Concentration Data

The database for the Lake Champlain Long-Term Water Quality and Biological Monitoring Program is maintained by VT DEC on a personal computer network using Microsoft® Access 2000 software. Daily tape backup is provided, and copies of backup files are archived in separate locations. The data are available on request in either electronic or paper copy form to other government agencies, researchers, consultants, students, and the general public. The data can be obtained directly from the project website:

http://www.anr.state.vt.us/dec/waterq/lakes/htm/lp_longterm.htm

Québec Phosphorus Concentration Data

The database for the Missisquoi Bay Water Quality Monitoring Program is maintained by the Direction du suivi de l'état de l'environnement (DSEE, State of the Environment Monitoring Directorate) on the main computer where the Québec River Monitoring Network database is stored. The data are available on request in either electronic or paper copy form to other government agencies, researchers, consultants, students, and the general public. For the time being, data cannot be obtained directly from the MDDEP website. Data requests may be sent to the database manager at the following e-mail address: mario.berube@mddep.gouv.qc.ca

USGS Stream Flow Data

Flow data recorded at the gage stations in Vermont are maintained by the USGS. Average daily flow values for the period of record for each station are available at the following website:

<http://nwis.waterdata.usgs.gov/vt/nwis/discharge>

Québec Stream Flow Data

Flow data recorded at the gage stations in Québec are maintained by the MDDEP. The average daily flow values for the most recent seven days only are available at the website given below. Longer term historical average daily flow data will be available on-line at a future date. In the meantime, requests for historical average daily flow data may be sent to:

<http://www.cehq.gouv.qc.ca/suivihydro/ListeStation.asp?regionhydro=03&Tri=Non>

Load Estimation Methods

Calculating Annual Tributary Loads

There are a variety of methods and computer programs available for calculating mass loading from continuous stream flow and discrete sample concentration data. All data from this monitoring program will be freely available to any investigator, so the data may be used to calculate loadings using a variety of methods in the future.

One tributary phosphorus load estimation method which has been applied successfully in the Lake Champlain Basin makes use of the U.S. Army Corps of Engineers FLUX program (Walker, 1987, 1996; Vermont DEC and New York State DEC, 1997) A recent application of the FLUX program by Medalie and Smeltzer (2004) to estimate phosphorus loads from monitored Lake Champlain tributaries provides an example of how data from the Missisquoi Bay Phosphorus Load Monitoring Program will be used to calculate loads at each sampling point in the bay's watershed.

Medalie and Smeltzer (2004) calculated tributary phosphorus loads based on water years (ending on September 30 of the indicated year), using two-year intervals in order to improve precision by increasing the sample size. For tributaries and time intervals with significant ($p < 0.10$) concentration versus stream flow regression relationships, loading estimates were based on log-log regressions between the phosphorus concentration and the average daily flow on the day of sampling (Walker, 1996, Method 6). When regression residuals were found to be dependent on flow, separate regression relationships were established for different flow strata in order to eliminate the residual dependence. Where significant concentration versus flow relations did not exist, phosphorus load was calculated based on the flow-weighted mean concentration times the

mean flow for the averaging period (Walker, 1996, Method 2). An error-analysis procedure in the FLUX program was used to estimate 95-percent confidence intervals for the loading estimates.

Medalie and Smeltzer (2004) adjusted the loading estimates produced by the FLUX program proportionally for the additional drainage area downstream from each stream flow gage station so that the estimates would apply at the mouths of each tributary. Similar drainage area adjustments will be necessary for the Missisquoi Bay watershed data in order to calculate phosphorus loads from individual sub-basins in Vermont and Québec, as discussed below.

In an attempt to assess the effects of the Québec Municipal Wastewater Abatement Program in the R. aux Brochets watershed, MDDEP has also applied the FLUX load estimation method (Simoneau, 2002; unpublished data) to compare phosphorus loads before and after the opening of the Bedford wastewater treatment facility. Using Vermont's method (Vermont DEC and New York State DEC, 1997; Medalie and Smeltzer, 2004), Québec also adjusted the loading estimates produced by the FLUX program proportionally for the additional drainage area downstream from the stream flow gage station so that the phosphorus estimate would apply at the mouth of R. aux Brochets.

Delineating Québec and Vermont Sub-Basins

A proposed scheme for dividing the Missisquoi Bay watershed into individual Québec and Vermont sub-basins for the purpose of phosphorus load estimation is shown in Figure 2. Each of the sub-basins shown in Figure 2 has a phosphorus sampling station located near its outlet. The phosphorus concentration measurements at the outlet of each sub-basin can be used with average daily flow data from the appropriate gage station to calculate annual phosphorus loading rates from each sub-basin. The phosphorus sampling stations and flow gages that apply to each sub-basin for this purpose are listed in Table 4.

Prior to conducting the loading analysis, the boundaries of each sub-basin will need to be delineated and their drainage areas will need to be determined precisely. Adjustments to the flow data will need to be made to account for drainage area differences between the gage stations and the sub-basin areas. Loads from upstream sub-basins will need to be subtracted from the loads measured at downstream stations (which include the cumulative loads) in order to estimate loads separately for each sub-basin.

Table 4. Sampling stations and flow gages corresponding to Missisquoi Bay watershed sub-basins (Figure 2).

Sub-Basin	Government	Sampling Station	Flow Gage Station
Upper Missisquoi	VT	03040108	04293000
Missisquoi Nord	QC	03040109	04293500
Sutton	QC	03040110	04293500
Lower Missisquoi	VT	MISS01	04294000
Pike	VT	03040111	04294300
aux Brochets	QC	03040015, PIKE01	030420, 030424
		03040073, 03040075	030426, 030422
Rock	VT	03040112	030425
de la Roche	QC	03040113	030425

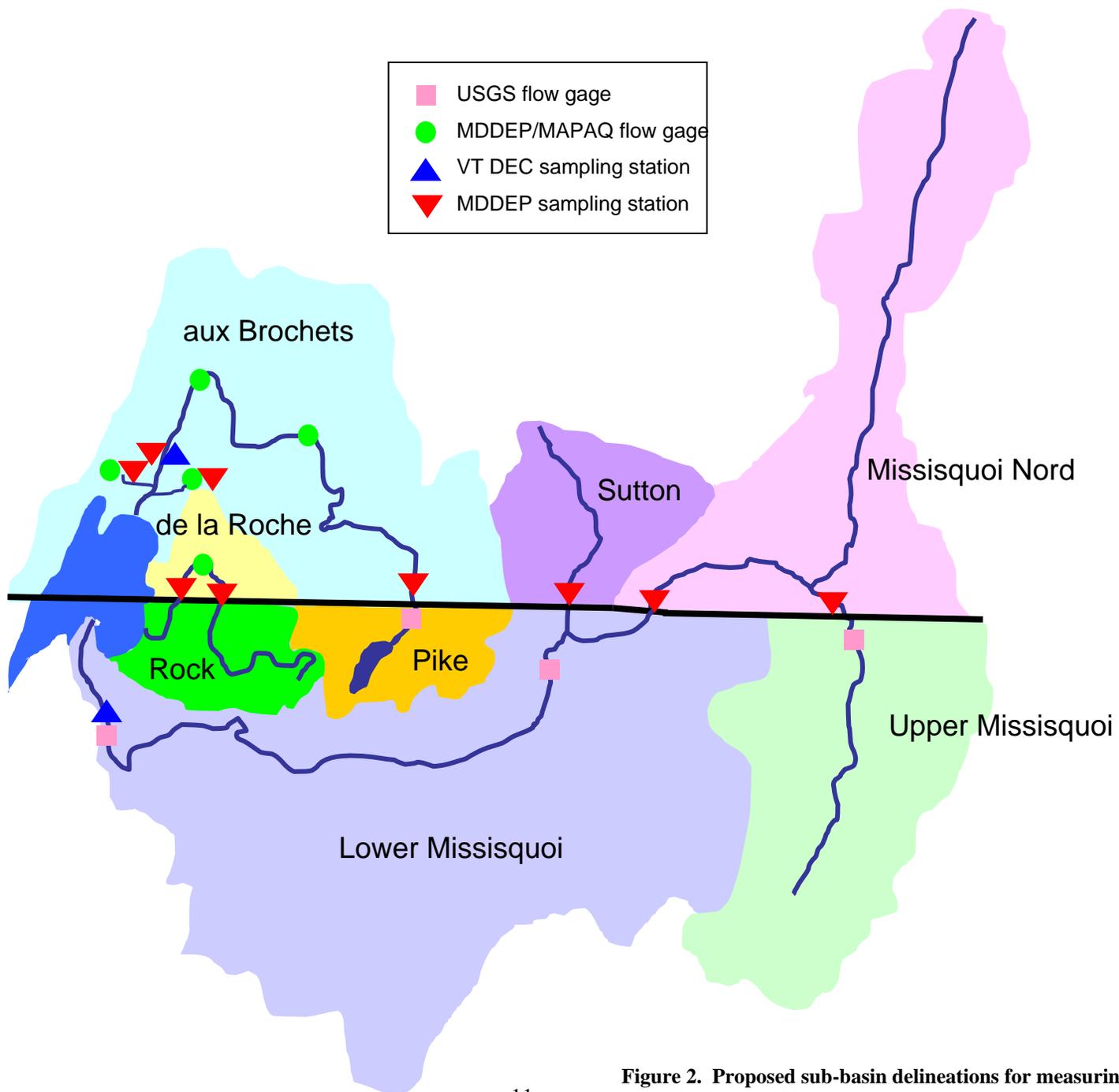


Figure 2. Proposed sub-basin delineations for measuring phosphorus loads from Québec and Vermont.

Calculating Wastewater Loads

Phosphorus discharged from the wastewater treatment facilities in the Missisquoi Bay watershed is captured in the samples obtained at the sampling stations shown in Figure 1. The exception is the Swanton, VT facility which discharges downstream of the monitoring sites. Even though most of the wastewater phosphorus loading will be accounted for in the tributary samples, there is still value in documenting this point source component of the phosphorus load to Missisquoi Bay separately. Vermont and Québec are committing significant public funds to upgrade wastewater treatment facilities in the watershed for phosphorus removal. The wastewater phosphorus discharge data are readily available, and it will be useful to track progress in reducing this component of the total load to Missisquoi Bay.

In Vermont, the wastewater flows and phosphorus concentrations are reported monthly by the facility operators to the VT DEC. This information will be compiled annually (by calendar year) by VT DEC. Annual phosphorus loads from each facility will be calculated as the product of the annual average flow and the annual average total phosphorus concentration.

In Québec, wastewater flows, BOD₅, suspended solids, total phosphorus concentrations and loads are reported monthly by the facility operators to the MAMR for both the raw wastewaters and the treated effluent. This information is compiled annually (by calendar year) by the MAMR. Annual phosphorus loads from each facility are calculated as the product of the annual average flow and the annual average total phosphorus concentration. Annual suspended solids and BOD₅ loads are also calculated the same way.

Reporting

MDDEP and VT DEC staff will work in collaboration to estimate phosphorus loads from the Missisquoi Bay watershed using the monitoring data. Reports evaluating phosphorus loads from Vermont and Québec will be prepared, reviewed, approved, and issued jointly by the MDDEP and VT DEC at approximately two-year intervals, beginning in 2006. These reports will be presented to the Lake Champlain Basin Program Technical Advisory Committee and to the Lake Champlain Steering Committee.

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