Appendix D

Vermont Department of Environmental Conservation

Ambient Water Quality Monitoring Program Strategy 2005-2015

September 2005

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Executive Summary

This ambient water quality monitoring program strategy provides a framework describing existing monitoring and assessment efforts in Vermont, and elaborates on elements of an ideal monitoring program to meet several objectives. The strategy presented herein has multiple uses and purposes, and is organized into USEPA's "Elements of a State Water Monitoring and Assessment Program" (March, 2003). This strategy presents a roster of specific monitoring goals and objectives, and a listing of existing and potential monitoring designs for Vermont waters. Recommendations for core and supplemental water quality indicators are provided. Detail is provided on quality control and assurance, data management approaches, a description of data analysis and assessment procedures, and the use of these procedures to support federally required reporting. The final sections of the strategy address suggestions for periodic review of the monitoring program, and provide estimates of necessary resources for full program implementation. Throughout the strategy, the term "waters" is intended to comprise rivers and streams, lakes, ponds and reservoirs, and wetlands. Groundwater is not yet addressed by this strategy.

Section one introduces the strategy, while Section two provides the goals and objectives to be met, which are as follows:

Goal 1: Predict and monitor the condition of Vermont's aquatic and wetland resources to:

- identify emerging problems before they become widespread or irreversible;
- provide information essential to protecting, maintaining and/or restoring the integrity and use of these resources;
- achieve comprehensive monitoring coverage of all Vermont waters;
- identify water quality conditions, impairments, causes, and sources; and,
- evaluate the success of current policies and programs.

Objectives for Goal 1:

A. Identify the status of Vermont's aquatic and wetland resources
B. Identify trends in the condition of Vermont's aquatic and wetland resources, including high-quality waters in need of protection
C. Identify existing and emerging threats to Vermont's aquatic and wetland resources
D. Identify where watershed level activities impact aquatic and wetland resources
E. Provide information to support and evaluate Agency and Department planning, management and regulatory programs, including the development of environmental indicators
F. Respond to citizen complaints and emergency situations regarding Vermont's aquatic and wetland resources (as appropriate)
G. Determine compliance with Vermont Water Quality Standards, and identify where standards may need to be modified to account for natural conditions
H. Provide technical data and information to public water supply operators
I. Obtain monitoring data coverage for all waters such that each significant public water will be monitored directly, or will have its condition estimated based on a statistically unbiased random probability determination

Goal 2: Communicate, collaborate and coordinate with organizations, agencies, and the general public to:

- increase public knowledge of and involvement in aquatic and wetland resource monitoring and assessment (and hence water resource management);
- promote efficient and effective monitoring and assessment programs; and
- collect useful data to supplement state monitoring and assessment programs.

Objectives for Goal 2:

A. Develop a mechanism for identifying and coordinating monitoring and assessment programs in Vermont
B. Identify aquatic and wetland resource data needs and develop mechanisms to enable volunteer monitoring and assessment programs to collect data that are of high quality and relevant to those needs
C. Communicate with other state and federal agencies to assure complementary monitoring programs
D. Encourage volunteer monitoring programs

Section three addresses monitoring designs. It provides detail on existing monitoring approaches in Vermont, including the rotational watershed assessment approach and existing core and supplemental projects, broken into physical, chemical, biological, and volunteer-based categories. A comprehensive listing of potential threats to Vermont waters is provided. Section four lists core and supplemental indicators of water quality that are measured by the individual monitoring projects. These indicators spring from the Vermont Water Quality Standards, but also include parameters that relate to ecological and habitat quality. Section five describes approaches to quality assurance, provides a listing of active quality assurance project plans, and discusses briefly how quality assurance planning relates to quality management planning.

Section six of the strategy provides a listing of existing databases that house water quality information generated by the monitoring program described in Section 3, discusses the current status of Vermont's water quality assessment databases, and relates information housed in those data archives to the Vermont Hydrographic Dataset. Section seven describes how VTDEC assesses water quality data to arrive at determinations of water quality standards attainment, and further elaborates on approaches to listing waters where uses are not met. Here the strategy references Vermont's Water Quality Assessment and Listing Methodology as a standalone document that guides the listing process. Section eight describes required Federal reporting that is supported in large part by the monitoring program and associated assessment and listing processes. Finally, Sections nine and ten describe monitoring program review and institutional needs.

Specific recommendations are provided within each of the above categories. The highest priority items requiring funding include securing long-term technician and summer staff support for the biomonitoring and lakes programs, and developing a coordinator position to support volunteer organizations participating in the highly successful LaRosa Laboratory Services Partnership Program. Other priority items regard increasing consistency in the archiving of water quality assessment findings, and expansion of the use of STORET (a national water quality data archive) to hold biomonitoring data.

This strategy includes more broadly applicable recommendations that address new monitoring designs: methods for assessment, listing, and reporting; and, to a small degree, water quality criteria development. The strategy recommends using a hybrid of fixed station and probability-based surveys to assess the conditions of waters statewide. Projects that are developing biological indices of aquatic life use support for large rivers, lakes and reservoirs, and wetlands have identified needs. The strategy also highlights approaches to developing nutrient criteria and modifying pathogen criteria. With respect to Federal assessment methods and reporting requirements, this strategy specifically recommends that assessment methods be fixed for a period of three assessment and listing cycles, and that reporting during those periods be consistent. This will enable VTDEC to track changes in use attainment with time. The specific recommendations and strategy items are wide-ranging, and are provided following each monitoring program element as listed above. From the roster of recommendations and strategies, several higher-priority, unmet needs are evident, and these are listed in the following table:

Projected unmet staffing/funding needs to accomplish all elements of the Water Quality Monitoring Program Strategy

Item	Program Area	Need	Start year	Completion target	Resource requirement
1	Monitoring Program	Maintain core monitoring program including State, USGS, and LaRosa components	2005	Ongoing	Consistent base monitoring funding under §106 and other mechanisms (PPA), which increase annually by inflationary costs plus COLA
2		Support/augment core monitoring program	2006	Ongoing	Add 1FTE permanent technician support to biomonitoring program $54.5K*
3			2006	Ongoing	Add ½ FTE permanent technician support to lakes monitoring program - $27.3K**
4			2006	Ongoing	Add 1FTE permanent technician support to wetlands monitoring program $54.5K
5			2006	Ongoing	Augment technician staff by two temporary staff supporting lakes and rivers volunteer programs (April-August) and biomonitoring (Sept-Jan) programs -
6			2006	One time	Purchase a large, laboratory-grade freezer for tissue sample storage $3.5K
7			2006	One time	Purchase a dissecting microscope for aquatic plant identification $3K
8		Initiate wetlands biomonitoring project	2007	2008	$60K operational/technician support in addition to item 4.
9		Incorporate bioassessments into lake assessment program	2007	Ongoing	$1K/lake/assessment
10		Support of the LaRosa Partnership volunteers	2006	Ongoing	Add 1 FTE staff support to coordinate volunteer groups, $27.2K*
10					
11	WQ Indicators and Criteria	Complete nutrient criteria development project	2005	2007	Complete analysis of nutrient criteria project dataset according to VT Plan for Nutrient Criteria Development - $40K****
12		Begin development of wetland biological criteria	See item 7 above		
13	Data management	Data manager	2007	Ongoing	Add ½ FTE technical staff to support data management activities associated with data archiving, and conversion of the Storet biomonitoring database, $27.3K,***

Item	Program Area	Need	Start year	Completion target	Resource requirement
14		Archive biomonitoring data to Storet	2007	Ongoing	Use technical staff associated with items 12 and 14, plus contractor services, to migrate existing biomonitoring data to Storet, and develop a routine data submission system for Storet. $20K of contractor services would assist in this regard.
15		Develop pocket computer-based tools to streamline data management	2006	Ongoing	Using in-house or contracted services, develop a pocket PC-based data collection platform that essentially eliminate paper data collection and entry. 20K
16	Assessment and reporting	Staff support - assessment	2008	Ongoing	Add ½ FTE staff to assist in waterbody assessments and basin report preparation, $27.2K,***

* Calculated as an environmental technician II (VT Pay Grade 18), per FTE basis, plus fringe and indirect costs.

, * these would logically be combined into single positions.

**** funding has been received for this project under §104(b)(3) for 2006.

1. Introduction

This ambient water quality monitoring program strategy provides a framework describing existing monitoring and assessment efforts in Vermont, and describes elements of an ideal monitoring program to meet several objectives. The Strategy presented herein has multiple uses and purposes. It simultaneously:

Provides specific monitoring goals and objectives;
Discusses several types of monitoring designs used in Vermont;
Recommends core and supplemental water quality indicators;
Provides detail on quality assurance procedures;
Provides detail on data management approaches;
Gives data analysis and detailed assessment procedures;
Describes required federal reporting;
Suggests methods for periodic review of this monitoring program; and,
Provides estimates of necessary resources for full program implementation.

Throughout this document, the terms "waters" and "water resources," where used generically, mean wetlands, lakes and ponds, streams and rivers, and even watersheds. The term "monitoring" is intended to address measurement or estimation of ambient water quality conditions. Groundwater is not presently addressed in this strategy, nor are monitoring activities related to permit compliance or in-facility monitoring. This strategy is intended to be evolving, reflecting the ever-improving methods available for ambient water quality monitoring. It provides a range of activities that could be implemented based on availability of resources in any given year. This strategy is intended to have a finite lifespan of ten years, and provides for annual and mid-stream changes to the monitoring program. Vermont's citizenry, Federal and academic collaborators, and regulated entities are encouraged to view this strategy with an eye towards where and how they can participate in understanding, protecting, and improving Vermont's waters.

There are numerous reasons to monitor the quality of Vermont's water resources. Principally, the Clean Water Act requires states to characterize the baseline quality or status of waters, understand the trends or directions in which this baseline is moving, and determine what factors or stressors may be influencing that movement. These are critical components to properly managing any waters. In Vermont and indeed nationwide, significant emphasis is currently being placed on determining whether waters are in compliance with applicable water quality standards and criteria. Such decisions carry significant regulatory repercussions, hence the need for a robust and scientifically defensible framework that describes every step of the assessment, remediation, and protection processes.

The process of assessment begins with the three components listed above: status, trend, and causality. Estimating the status and trends of waters, with known and quantifiable precision, is the first step in assessing standards attainment. Should a waterbody be determined to not be attaining standards, then determining the extent of the water quality impact caused by any number of stressors, again with known and quantifiable precision, is the first step toward remediating a problem.

While the current water quality management climate forces scientists and managers to think about monitoring in the framework of use support, impaired waters listings and de-listings, and TMDL preparation, there are other, equally important goals that must be met by monitoring activities. Chief among these are the understanding of what is unique about a waterbody, and the understanding of how these unique waterbodies respond to management actions. These two objectives provide for protection and efficient remediation of waters. An important corollary objective is to provide, via education and participation, avenues for Vermont's citizenry to contribute in a meaningful way to the protection and/or improvement of rivers, streams, lakes, ponds, and wetlands.

2. Monitoring Objectives

A. Regulatory Justification

The present Strategy has two basic goals: to directly gather information about Vermont's water resources; and to work with partners at all levels to gather additional information while explaining how sound, scientifically-based monitoring data is used to properly manage Vermont waters. Embodied within these goals are specific objectives intended to meet the goals and intent of the Federal and State Law. Specifically, these objectives address several sections of the Federal Clean Water Act, including Sections 106(e), 303(d), 304, 305(b), and others. These objectives also support sections of Vermont Statutes Annotated (e.g., 10 V.S.A. Chapters 37 through 49, 10A V.S.A. Chapter 2). Goal statements and associated objectives are described in the following.

B. Goals and Objectives:

Goal 1: Predict and monitor the condition of Vermont's aquatic and wetland resources to:

- identify emerging problems before they become widespread or irreversible;
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B. Identify aquatic and wetland resource data needs and develop mechanisms to enable volunteer monitoring and assessment programs to collect data that are of high quality and relevant to those needs

C. Communicate with other state and federal agencies to assure complementary monitoring programs
D. Encourage volunteer monitoring programs

C. Existing and Designated Uses

Vermont's Water Quality Standards are promulgated under the legal jurisdiction of the Vermont Water Resources Board (10 V.S.A. Chapter 37, §905), consistent with the intent of the Federal Clean Water Act (40 C.F.R. 131.3). In keeping with C.F.R. 131.10(f), "Existing Uses" are those uses actually attained in a waterbody on or after November 27, 1975. Vermont's standards establish narrative and numeric criteria to support the following designated and existing uses, as established in §1-03(B)(1) for those Standards:

a) Aquatic biota and wildlife that utilize or are present in the waters;
b) Habitat that supports existing aquatic biota, wildlife, or plant life;
c) The use of waters for recreation and fishing;
d) The use of water for water supply, or commercial activity that depends directly on an existing high level of water quality; and,
e) With regard to the factors considered under paragraphs (a) and (b) above, evidence of the use's ecological significance in the functioning of the ecosystem or evidence of the uses rarity.

Thus, water uses protected under Vermont law are more colloquially described as aquatic life, habitat, aesthetics, fishing and swimming, and water supply. Waters of particular ecological significance in regards to aquatic biota and habitat, otherwise known as "High Quality Waters," are afforded additional protections. The present Monitoring Program Strategy describes Vermont's approach to assessing the level of support of these uses, in light of the standards and criteria established within the VT Water Quality Standards. A more thorough discussion of Vermont's standards is available in Section 4A, below.

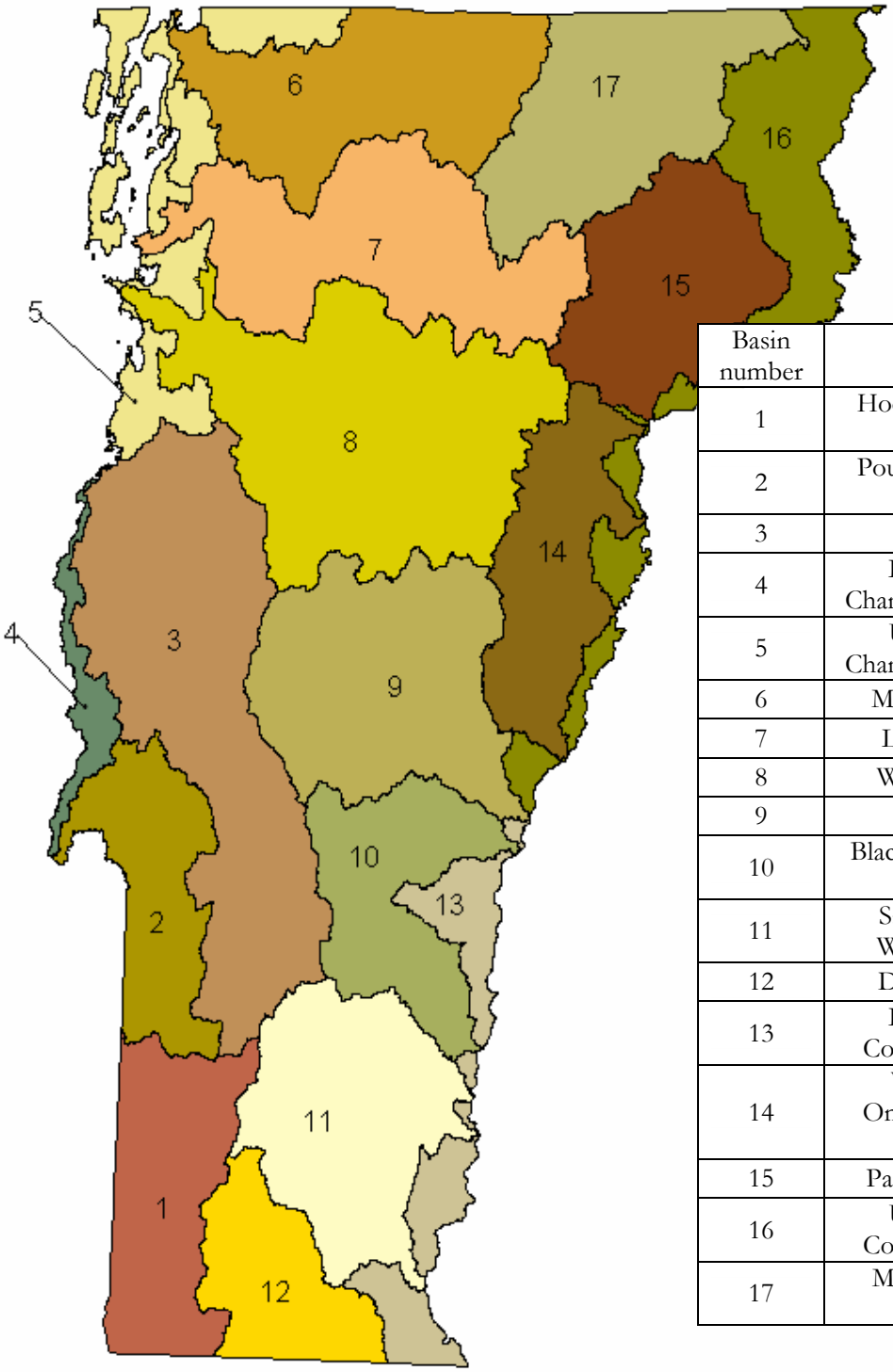
3. Monitoring Design

A. Monitoring Designs

i) Vermont's 17 basin rotational assessment approach

For the purposes of assessing and reporting water quality information, the state has been divided into seventeen major drainage basins that have from four to twenty-two river sub-basins or mainstem segments ("waterbodies") within them. The seventeen major basins drain to either Lake Champlain, the Connecticut River, Lake Memphremagog, or the Hudson River.

In order to more comprehensively and thoroughly assess the State's water and to take advantage of the untapped sources of information, the Vermont DEC Water Quality Division has designed a rotational watershed assessment process such that lakes and rivers of all seventeen major basins in the state are evaluated once every five years. To the extent possible, wetland assessment work also follows this rotation schedule. By focusing evaluations on selected watersheds each year, more systematic and intensive efforts can be made to evaluate status and trends. A focus on a limited number of watersheds also provides the opportunity to determine the best characteristics of the river system to: use as indicators of improving water quality and aquatic habitat; potentially reveal water quality trends; involve the general public; and, provide interagency coordination. Assessment reporting and basin planning are described in detail in Section 8 of this Strategy. The schedule for each basin assessment is shown in Figure 3.1.



Basin number	Basin Name	Schedule year
1	Hoosic, Wallomsac Rivers	2008-2009
2	Poultney-Mettawee Rivers	2007-2008
3	Otter Creek	2006-2007
4	Lower Direct Champlain Drainages	2006-2007
5	Upper Direct Champlain Drainages	2009-2010
6	Missisquoi River	2004-2005
7	Lamoille River	2007-2008
8	Winooski River	2005-2006
9	White River	2006-2007
10	Black, Ottaqueechee Rivers	2007-2008
11	Saxton's, West, Williams Rivers	2008-2009
12	Deerfield River	2008-2009
13	Lower Direct Connecticut River	2008-2009
14	Waits, Wells, Ompompanoosuc Rivers	2007-2008
15	Passumpsic River	2005-2006,
16	Upper Direct Connecticut River	2005-2006
17	Memphremagog Tributaries	2004-2005

Figure 3.1. Vermont's 17 major river basin groupings with rotation assessment schedule.

ii) Fixed station monitoring

The Vermont DEC coordinates a large number of fixed-station monitoring projects, incorporating river and stream, and lake water quality projects. Projects considered "fixed station" in Vermont are long-term, recurring projects which the Department has operated (or intends to operate) for several years. Some of these projects, such as the Ambient Biomonitoring Network and Lake Assessment Programs (both of which incorporate several individual monitoring projects and studies) achieve dense statewide spatial coverage. The total number of stream and lake stations established under these two programs alone exceed 1,500 and 650, respectively. These monitoring networks are designed to assess status, and detect trends, and therefore meet Objectives 1A through 1E, and 1G, of this strategy. As one of Vermont's major lake monitoring programs is a fixed-station, volunteer-based initiative, Objective 2B, of this Strategy is also met by fixed station monitoring. A listing of fixed station monitoring projects is provided in Section 3.B. Stations are added to the roster as needed to achieve more comprehensive and complete coverage. In addition, the existing fixed stations can serve as pre-established monitoring locations for random-probability based projects (such as has been done by two of the four probability-based projects listed below, allowing for hybridization of fixed and probability surveys, while maintaining consistency in monitoring location coverage. A map of existing monitoring stations is provided in Figure 3.2.

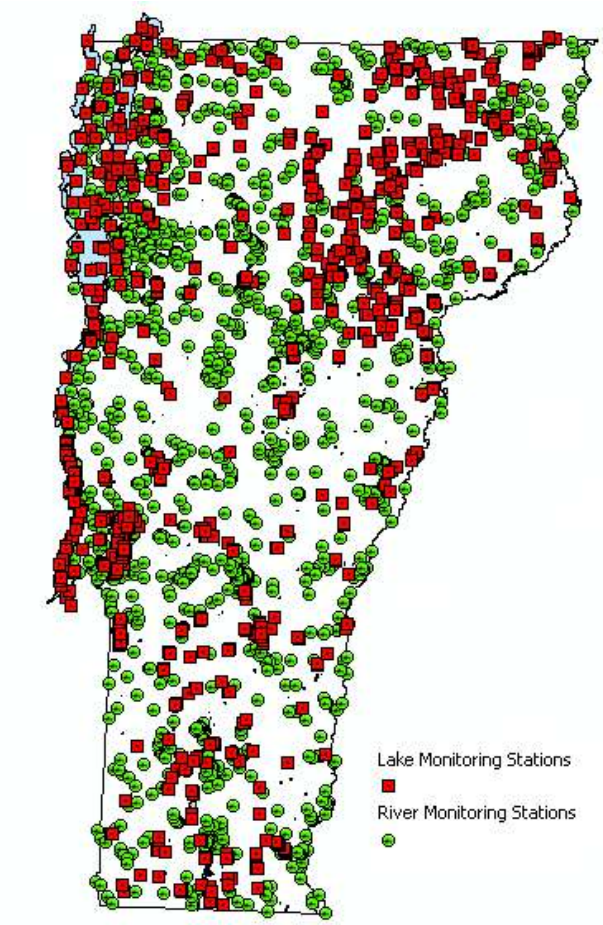


Figure 3.2 Fixed-location monitoring stations as of Dec., 2004

iii) Probability based monitoring

Probability surveys are useful for determining statewide water quality conditions in regards to some uses, and are appropriate for statistically estimating use attainment levels on a resource-wide (typically state or basin-wide) basis. VTDEC recognizes the value of probability-based monitoring initiatives, where prediction of use attainability is inherent in the project design. Such designs permit the use of statistically-derived models for inferring use attainment in appropriately selected waters where sampling was not performed. Given the density of fixed-station coverage in Vermont, probability-based surveys are considered of lesser utility where prediction outside the sample frame is not inherent in the project design. Accordingly, VTDEC strives to maximize the benefits of probability-based surveys, by actively supporting or designing projects in which a predictive system can be part of the outcome. VTDEC has undertaken four such probability-based projects in collaboration with USEPA Region 1 in recent years, and is planning to participate in a fifth. VTDEC also subscribes to the notion that properly designed probability surveys should provide estimates of the target attainment condition with a 90+ % confidence level. To achieve this, VTDEC monitoring staff have routinely worked with EPA-ORD in Corvallis, OR and in Narragansett, RI, to build sample draws that provide such coverage. These sample draws leverage EMAP algorithms for site selection, and are statistically robust.

The four probability surveys VTDEC has implemented or participated in are discussed in detail in Section 3.B, and include:

- A REMAP assessment of mercury concentration in sediments, waters, and biota of Vermont and New Hampshire Lakes using a spatially randomized design (1998-2003).
- Characterization of use attainment for aquatic life using a spatially randomized draw of existing Ambient Biomonitoring Network data at varying site intensities (2001).
- A REMAP assessment of aquatic life use attainment in New England Wadeable Streams (2002-2006).
- Participation in the National Study of Chemical Residues in Fishes (2002-2005).

Additional examples of probability-based surveys that would be appropriate for determining statewide or basinwide use attainment, where predictability is an anticipated outcome of the project are as follows:

- Assessment of aquatic life use support inferred by physical, chemical, habitat, and biological data for lakes across Vermont. Such an assessment should be stratified using the Human Disturbance Gradient to ensure adequate representation of reference-class lakes (note: this project is in development as a regional REMAP project as of this writing, to occur 2005-2009).
- Assessment of sediment-based toxics in large-order rivers and developed lakes.
- Development of a reproducible, indicator-based assessment of fish tissue contaminants (Hg and organic contaminants) across Vermont. With specific respect to mercury bioaccumulation, the sampling units selected for such an assessment should be stratified by trophic state, acidity, and degree of water level manipulation.

iv) Special and TMDL studies

VTDEC undertakes special and TMDL studies as needed, in response to compelling data and information supplied under fixed-station and probability-based projects. The number and nature of special studies is commonly dictated by the nature of issues and problems that are reported in Vermont's Priority Waters List, part C (see Section 8.B). Such waters are typically those where additional information is necessary to make an informed impairment decision. These types of studies include detailed sampling to assess use support or standards violations, diagnostic-feasibility studies, watershed-based surveys and evaluations, and enhanced monitoring of stormwater-impaired watersheds. TMDL studies are scheduled as needed consistent with the timeline established in Vermont's impaired waters-303(d) list, and depending on available resources.

v) LaRosa Environmental Laboratory

VTDEC maintains a full service environmental chemistry laboratory in Waterbury, Vermont. The LaRosa laboratory provides a range of services to Vermont state agencies, as well as federal agencies and other users. The LaRosa laboratory is subject to strict USEPA quality assurance planning, and participates in national-scale laboratory performance studies several times per year. The LaRosa facility is also accredited by the National Environmental Laboratory Accreditation Conference. The majority of environmental samples taken in conjunction with the monitoring projects discussed below are processed at the LaRosa laboratory. The existing analytical equipment at the LaRosa facility is modern and up-to-date, and includes a high-resolution ICP-MS, and dedicated centers for low-level mercury and air toxics.

Funding for the LaRosa Laboratory is shared across all VTDEC Divisions, with the vast majority of services associated with this Strategy being allocated to the Water Quality Division. Annually, the Water Quality Division contributes funds in the form of a laboratory "assessment" fee, which serves to fund LaRosa's base, consumable, and capitol needs. In exchange for this assessment, the Water Quality Division receives laboratory services up to the capacity of the laboratory to handle the sample submission load. This funding mechanism, which in 2000 replaced a fee-for-test model, has proven a tremendous asset in support of VTDEC's ambient water quality monitoring program. In order to ensure long-term viability of the monitoring program, it is vital that this funding mechanism remain in place. For FY2005, the Water Quality Division's assessment fee was $287K, which supported all of the core monitoring needs. Complete information regarding the analytical services provided by the LaRosa laboratory are available online at http://www.anr.state.vt.us/dec/lab/index.htm.

B. Existing Water Quality Division Monitoring Projects

The following description of the WQD's current ambient monitoring program, comprised of numerous discrete projects, is up-to-date as of January, 2004. The WQD's monitoring efforts are classified herein as physical/chemical, biomonitoring, volunteer, and other. Within each of these classes, monitoring projects are further described as core, or long-term projects; diagnostic studies, which identify the causes of particular water quality problems; and special studies, which provide information and data on specific water quality issues. Other projects coordinated by close partners of the WQD are also included in this listing.

i) Physical and chemical monitoring

Core Programs

The Spring Phosphorus Program collects spring overturn nutrient and physical and chemical data on Vermont lakes and ponds that are 20 acres in size or larger. Parameters include total phosphorus, total nitrogen, alkalinity, calcium, magnesium, hardness, Secchi disk transparency, and multi-probe profiles (temperature, dissolved oxygen, conductivity, and pH). Since 1977, 236 lakes have been monitored in conjunction with this program. Forty-eight lakes have 10 or more years of data, and 18 of these have 15 years or more. The Spring Phosphorus Database contains over 1,700 records.

The Lake Assessment Program is designed to rapidly assess the extent to which lakes meet designated uses and to gather information to focus lake management and protection efforts. The sampling intensity for assessment lakes varies with the degree to which impairment is evident or must be documented. In general, lakes are circumnavigated and detailed assessment observations are made regarding in-lake and shoreline conditions with respect to designated uses and threats to water quality. Detailed notes are made regarding the extent and species composition of the macrophyte community. Sampling is performed for total phosphorus, alkalinity, Secchi disk transparency, and multi-probe profiling. Additional sampling may be performed as necessary to determine compliance with VT Water Quality Standards. Since 1989, 281 comprehensive assessments and 59 cursory assessments have been performed.

The River Assessment Program is designed to assess the extent to which rivers and streams support designated uses to focus management and protection efforts. Rivers and streams in the basins of focus are visited to look for obvious sources of pollution from the land or indicators of problems or threats in the water such as sedimentation, heavy algae growth, or water with unnatural color or odor. The Ambient Biomonitoring Program (described below) provides most of the information used to determine a waterbody's aquatic life use support and compliance with VT Water Quality Standards. Temperature, nutrients, pH, conductivity, and alkalinity are parameters commonly measured concurrently with the biological sampling. Where such data are needed, loading estimates for nutrients or other pollutants can assist in determining pollution sources and impacts.

The Water Level Monitoring Program monitors lake surface elevations to establish mean water levels for a variety of purposes, most notably to determine the jurisdictional boundary of the State's lakes and ponds under the shoreland encroachment permit program and Vermont's Public Trust Doctrine.

The Lake Champlain Long-Term Monitoring Program surveys the quality of Lake Champlain waters on a biweekly basis, May to November, at 13 locations throughout the lake. Eighteen major tributaries are sampled on an event basis as well. The program's large physico-chemical parameter list includes: species of phosphorus, nitrogen and organic carbon; chlorophyll-a; base cations; alkalinity; total suspended solids; dissolved oxygen; conductivity; and pH. As of April, 2003, this program had assembled a database comprising 6,366 lake and 4,282 tributary sampling events.

The Vermont Long-Term Monitoring of Acid Lakes Program (LTM) collects chemical and biological data on lakes located in low alkalinity regions to determine the effects of acid deposition on Vermont's lakes. Initially, nearly 200 lakes statewide were surveyed during the winters of 1980 through 1982 to identify the acid sensitive areas of the state. Eleven lakes selected from these areas are now included in the LTM and are sampled at least eight times every year for 16 chemical parameters related to acidification. These data are used to classify lakes according to their acidification status, evaluate spatial and temporal variability in measured parameters, track changes in acidification status over time as related to reductions in atmospheric emissions of acid precursors (e.g., oxides of sulfur and nitrogen), and evaluate impacts of acidification on aquatic communities. As of April, 2003, the LTM data archive comprised 1,857 in-lake and 405 lake-outlet sampling records. This project contributed data to a seminal article describing long-term acidification trends across northeast North America, which was published in the journal Nature in 2000.

The Stream Geomorphic Assessment Program collects geomorphologic data on streams throughout the state to assess stream geomorphic condition and develop regime relations for Vermont's streams. Geomorphic assessments enable the prediction of expected rates of river adjustment and an evaluation of the effects of various land and river management practices on geomorphic condition and physical habitat quality. Regime relations guide stream protection, management, and restoration projects and assist in the establishment of Vermont-specific physical criteria for water quality classification and use attainment determinations. Parameters measured include channel dimension (cross section), pattern (meander geometry), longitudinal profile, channel substrate conditions, structure and composition of riparian vegetation, and floodplain and valley morphology.

Diagnostic Studies

Diagnostic studies are typically aimed at identifying the cause of eutrophication in Vermont lakes. Over the past 20 years, Vermont has performed numerous such monitoring studies, and the results of these studies have led to remediation steps. Lakes on which diagnostic studies have been performed include Harveys Lake (Barnet), Lake Morey (Fairlee), Lake Iroquois (Hinesburg), Fairfield Pond (Fairfield), Lake Parker (Glover), Lake Carmi (Franklin), and Lake Champlain. Presently, VTDEC is initiating a new diagnostic study for Ticklenaked Pond, a nutrient-impaired lake in Ryegate, beginning 2005.

A wide variety of parameters are sampled in conjunction with diagnostic studies, and the actual tests performed are specific to the project. Standard eutrophication parameters (total phosphorus, Secchi disk transparency, and dissolved oxygen) are always measured. Other parameters from sediments and the water column are measured as needed.

Special Studies and TMDL Studies

Special studies are those performed to gain more information about a particular environmental issue of importance to the VTDEC, or to perform load and wasteload allocations for the purpose of TMDL development.

Several TMDL studies are ongoing or recently completed as of this writing, including load and wasteload allocations for several impaired waters in Vermont. Specific waters that are subject to recent TMDL analyses include all of Lake Champlain, segments of the Winooski and Mettawee Rivers, the Otter Creek, Allen Brook, and 37 acid-impaired lakes subject to acidic precipitation.

The EPA-sponsored REMAP Assessment of Mercury in Sediments, Waters and Biota of VT and NH Lakes Project is a three-year effort to identify lake types occurring in VT and NH that have elevated levels of mercury in fish and upper trophic level biota. The parameter list for this integrated collaborative monitoring project is large, and includes standard limnological measurements and mercury in total and methyl phases in sediment, water, and biota. There is also a paleolimnological component that has determined the extent to which atmospherically deposited mercury has entered lakes in the study set. Two peer-reviewed journal articles have been produced from this study, which was completed in 2003.

The Lake Champlain Agricultural Best Management Practices Monitoring Project was a seven-year project (1994-2001). This comparative observational study used a three-way experimental design with one control and two treatment watersheds. The goal was to evaluate the efficacy of both low- and high-intensity reach-specific BMP implementation strategies. Parameters measured included total phosphorus, total and Kjeldahl nitrogen, total suspended solids, and *E. coli*. Biological assessments were also performed on each of the three watersheds.

The Best Management Practices Effectiveness Demonstration Project is a stream monitoring effort designed to assess the efficacy of best management practices in controlling pollutants in nonpoint source runoff. This cooperative VTDEC-USGS project differs from the project described above in that it uses an upstream-downstream approach to pinpoint reductions in pollutant runoff attributable to specific installed BMPs. The project is being carried out on one agricultural and one urban stream in the Lake Champlain basin. The agricultural site will likely be discontinued this year due to lack of commitments from the farmer to finish BMP implementation.

In conjunction with the Paleolimnology of Vermont Lakes Project, the VTDEC is collaborating with the University of Vermont to develop a set of indicators of present and historical trophic status based on the paleolimnology of carbon and nitrogen stable isotopes ($\delta^{13}C$ and $\delta^{15}N$). Using cores from the sediments of several lakes, VTDEC is working to identify the extent to which the present trophic condition in these lakes deviates from the historic background. Such information is instrumental in understanding the extent to which productivity (and thus phosphorus) has been elevated since the lake watersheds were first cleared in the early 1800's.

A new approach to stormwater-impaired watershed monitoring was instituted beginning in 2004. Vermont's 17 stormwater-impaired watersheds are being monitored using an integrated approach of precipitation and flow monitoring, suspended sediment sampling, and geomorphic assessment. This monitoring is in-place as of spring 2005, and is projected to continue through 2010. These monitoring data will be used to assess improvements in individual watersheds given implementation of stormwater control initiatives.

ii) Biological monitoring

Core Programs

The Ambient Biomonitoring Program was established in 1982 to: 1) monitor long-term trends in water quality as revealed by changes in ambient aquatic biological communities over time; 2) evaluate potential impacts on aquatic biological communities from permitted direct and indirect discharges, ACT 250 (10 V.S.A. 151) projects, nonpoint sources, and spills; and 3) establish a reference database to facilitate the generation of Vermont-specific biological criteria for water quality classification and use attainment determinations. Since 1985, the VTDEC has used standardized methods for sampling fish and macroinvertebrate communities, evaluating physical habitat, processing samples, and analyzing and evaluating data. The program has led to the development of two Vermont-specific fish community Indexes of Biotic Integrity (IBI) and several macroinvertebrate metrics. Guidelines have been developed to determine water quality standards attainment using both macroinvertebrate community biological integrity metrics and the IBI. Approximately 75 sites per year are assessed using fish and/or macroinvertebrate assemblages. Alkalinity, pH, conductivity, temperature and such measurements as substrate composition, embeddedness, canopy cover, percent and type of periphyton cover, and approximate velocity are routinely monitored. From 1985 to April, 2003, well over 1,700 stream assessments were completed using macroinvertebrate and/or fish from 1229 stream reaches.

The Aquatic Macrophyte Monitoring Program collects baseline information on aquatic plant communities in Vermont lakes by conducting descriptive surveys using a pre-established plant cover scale. This program has been active since the late 1970's, and information is available from 177 discrete surveys.

The WQD conducts numerous Aquatic Nuisance Species Searches and Surveys each year to search for new populations and monitor existing populations of nuisance aquatic species, primarily Eurasian watermilfoil (*Myriophyllum spicatum*), water chestnut (*Trapa natans),* zebra mussels (*Dreissena polymorpha*), and the wetland invasive purple loosestrife (*Lythrum salicaria*).

One interesting component of these aquatic nuisance species efforts is the Lake Champlain Zebra Mussel Monitoring Program. For this effort, 13 in-lake and 12 shoreline stations in Lake Champlain are monitored for larval and settler zebra mussel presence and density every two weeks from April through November. In addition, adult zebra mussel surveys are performed at selected shoreline locations during late summer. This is the only such zebra mussel monitoring project of it's kind in the United States. As of April, 2003, there were 2,220 veliger records and 1,013 settler records within this program's nine years of data records.

Special Studies and TMDL studies

The stormwater-impaired watershed monitoring discussed above also carries a biological monitoring component. In addition to the physical/chemical monitoring, each watershed has been scheduled for macroinvertebrate and/or fish bioassessment at a minimum of one site per watershed. In concert with the physical/chemical parameters, these monitoring data will be used to assess improvements in individual watersheds given implementation of stormwater control initiatives.

The Biodiversity Monitoring Program evaluates the status of selected biological species and communities in Vermont. Specific activities include: 1) distribution surveys of aquatic plant, fish and macroinvertebrate species listed by the Vermont Endangered Species Committee as rare, threatened, endangered, or of special concern; 2) distribution surveys of communities having species considered likely candidates for future listing (e.g., snails); and 3) monitoring of biological communities or community types, the diversity of which is threatened (e.g., Lake Champlain mussel and cobble/shale macroinvertebrate communities threatened by zebra mussels). Data are used to describe species distribution, identify species/communities at risk, and develop management plans for the protection of identified species/communities.

The Lake Bioassessment Project was initiated in 1995 to begin developing biological criteria for Vermont lakes. This monitoring effort was launched as a cooperative project with the State of New Hampshire. The goal of the project is to develop numeric measurements of the phytoplankton, macrophyte, and

macroinvertebrate communities in reference lakes for use in assessing aquatic life use attainment in lakes. Consistent protocols have been developed to measure these biological assemblages, and to date, 12 NH and 41 VT lakes have been included in the project. Statistically-validated multimetric indices have been developed for the phytoplankton and macroinvertebrate communities. To date, data describing macrophyte communities have proven insufficiently precise to develop macrophyte criteria.

The Vermont Wetlands Bioassessment Project is a coordinated effort between the VTDEC and the VT Department of Fish and Wildlife's Nongame and Natural Heritage Program to document and understand the biological and physical characteristics associated with seasonal pools (vernal pools) and northern white cedar swamps in Vermont. Since 1999, the project has collected biological, physical and chemical data from 28 seasonal pools throughout the state. Information collected on the invertebrates, amphibians, algae, and plants associated with seasonal pools has been used to assess and monitor the ecological health of seasonal pools in Vermont. This project was completed in 2002, and efforts at using these data to develop vernal pool biocriteria have seen limited success. VTDEC plans to modify this project for 2004 by adopting protocols and sampling strategies consistent with the Lake Bioassessment Project, to include more rigorous procedures for monitoring marginal wetland macrophytes.

The Lake Champlain Long-Term Monitoring Program described above also includes biological sampling, which is primarily aimed at assessing phytoplankton, zooplankton, and macroinvertebrate communities. Data from this element of the project resides in the New York State Natural History Museum, with copies available only in spreadsheet form in Vermont. These data have been underanalyzed and underutilized as of this writing, but should provide a baseline for evaluating changes in ecosystem structure given implementation of the Lake Champlain TMDL for phosphorus.

The Northern Leopard Frog Surveys in the Lake Champlain Basin Project was initiated in response to reports of malformed frogs in the Lake Champlain basin in Vermont in the summer of 1996. Malformed frogs were reported from 12 sites in five counties within the Lake Champlain basin. Systematic field surveys were initiated in 1997, targeting the northern leopard frog (*Rana pipiens*). These surveys recorded the frequency and morphological characteristics of gross abnormalities among newly metamorphosed northern leopard frog populations at 20 sites within the Lake Champlain basin. With subsequent support through the USEPA REMAP program, VTDEC has examined over 6,000 northern leopard frogs since 1996, and external malformations have been detected in 7.5% of the frogs examined. Data characterizing the gross abnormalities and describing the frequency and occurrence of abnormalities within northern leopard frog populations continues to be gathered at 10 established sites within the Lake Champlain basin. All findings are reported to the North American Reporting Center for Amphibian Malformations (http://www.npwrc.usgs.gov/narcam/). The VTDEC also continues to collaborate with the National Institute of Environmental Health and Sciences, the National Wildlife Health Center, and other researchers, providing environmental samples and specimens to help further malformed frog investigations.

Other Biological Monitoring Projects either ongoing or conducted on a periodic basis include:

- monitoring nontarget impacts to aquatic biota in lakes chemically treated with the aquatic herbicide Sonar® (fluoridone) to control Eurasian watermilfoil infestations;
- monitoring the effects on both target and nontarget organisms of copper sulfate treatments to small recreational lakes and water supply reservoirs; and
- monitoring impacts to nontarget fish and macroinvertebrates in rivers treated with lampricide (TFM) to control sea lamprey (*Petromyzon marinus*) in Lake Champlain..

The Fish Contaminant Monitoring Program is managed by the WQD and performed in cooperation with the VT Department of Fish and Wildlife and the Vermont Department of Health. Edible tissue from game fish

acquired throughout the state is analyzed for mercury and other contaminants. These data are then used to set and subsequently refine fish consumption advisories issued by the Vermont Department of Health.

iii) Volunteer monitoring

Citizen groups are becoming increasingly involved in monitoring, education, protection, and restoration projects in Vermont. The VTDEC provides assistance and training to volunteers whenever possible. Watershed and lake associations are presently active on numerous rivers and lakes in the state. In fact, there are over 100 such associations statewide. The VTDEC has developed a directory listing various watershed associations and their activities in "Current Programs of Vermont Watershed Associations – 2002," with a lake association addendum listing active lake groups.

Core programs

The Vermont Lay Monitoring Program equips and trains local lake users to measure the nutrient enrichment of lakes by collecting water quality data following a rigorously documented and quality assured methodology. This citizen monitoring program is based on trophic parameters and monitors approximately 40 lakes and 25 Lake Champlain stations per year. All Lake Champlain stations and many inland lakes in the program are sampled for chlorophyll-a, total phosphorus, and Secchi disk transparency. Other lakes are sampled only for Secchi disk transparency. All sampling occurs on a weekly basis during the summer. Since the development of the Lay Monitoring Program in 1979, data has been generated on 84 lakes and 36 Lake Champlain stations. Seventy-two inland lakes and 30 Lake Champlain stations have five or more years of full season data. In addition to their standard monitoring, Vermont's citizen lake monitors also assist in the ANS Watchers Program (see below), and in collecting data for the Lake Bioassessment Project.

The Citizen Lake and Watershed Survey Program provides survey sheets and technical training to volunteers, lake and watershed associations, and other interested groups to enable them to perform screening level assessments to identify potential nonpoint sources of pollution to lakes by conducting in-lake, lakeshore, and lake watershed surveys.

The Aquatic Nuisance Species (ANS) Watchers Program trains citizen volunteers to monitor for the presence of invasive nonnative aquatic species. The program is currently focusing on monitoring for Eurasian watermilfoil, water chestnut, hydrilla and zebra mussels. There are presently 110 ANS Watchers throughout Vermont.

The Volunteer Acid Precipitation Monitoring Program was initiated in 1980 to monitor changes in precipitation chemistry. Dedicated volunteers at five sites around Vermont (Morrisville, Mt. Mansfield, St. Albans, St. Johnsbury, and Underhill) collect precipitation samples on an event basis. The volume and pH of each storm event is recorded. Additional parameters such as conductivity and wind direction are recorded at individual stations. The data are used to assess spatial and temporal variability in the pH of bulk precipitation and assess changes in the pH of bulk precipitation over time and as related to reductions in atmospheric emissions of acid precursors (e.g., oxides of sulfur and nitrogen).

Other volunteer initiatives

The VTDEC Water Quality Division collaborates with the LaRosa Laboratory (described below) on a novel program to assist citizen monitoring groups statewide. Beginning in 2003, the Water Quality Division and LaRosa Laboratory initiated analytical services partnerships with volunteer organizations, based on a competitive proposal process. The project has been extremely successful since its inception, when eleven projects were supported. These projects ranged in scope from small, single-lake studies to large, multi-year and multi-parameter watershed assessment initiatives. In 2003, the program produced in excess of 1,800 viable, quality-assured data records across Vermont. In 2004, over 4,400 monitoring datapoints were collected by 12 projects. For 2005, 13 projects are being supported, with coverage across every major VT watershed save the Passumpsic and North CT River Direct.

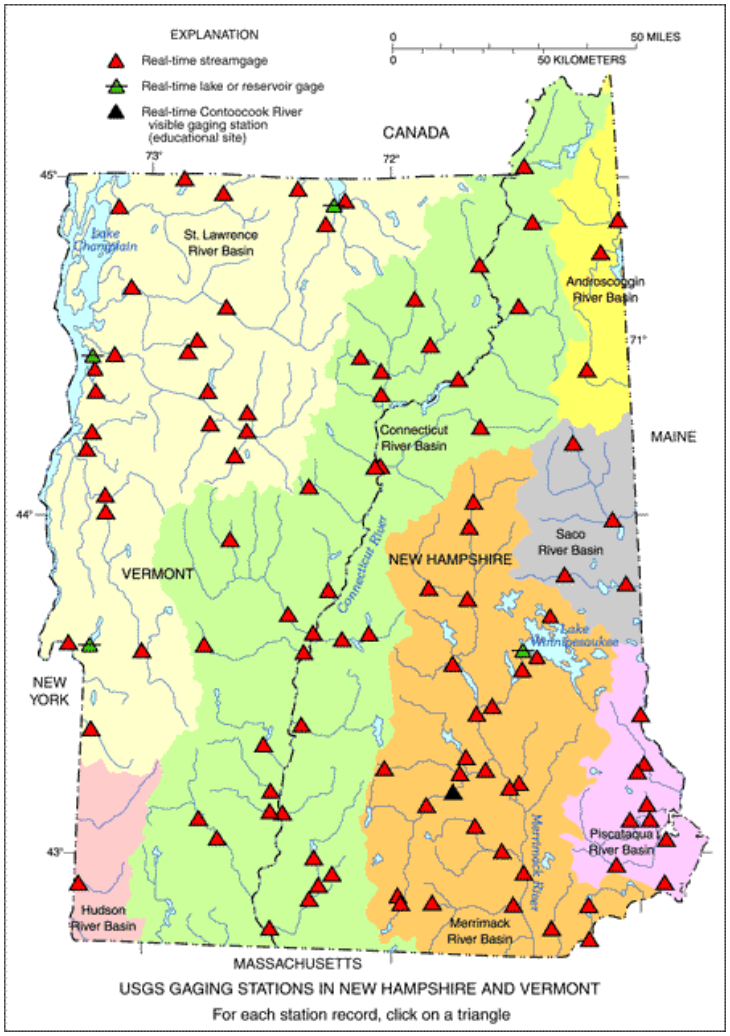
In early 2005, USEPA drafted a proposal to develop a "bank" on monitoring equipment that would be available for long-term loan to volunteer organizations. WQD supports this concept and enocourages EPA to pursue this novel idea. Administration of equipment loans for Vermont volunteer organizations could efficiently be handled through the LaRosa Laboratory Partnership Program.

Guidance for volunteer monitoring at the local level
VTDEC has now completed preparation of two guidance documents intended to support volunteer monitoring statewide. These are the 2003 *Citizens Guide to Monitoring E. coli in Vermont Waters*, and the 2005 *Volunteer Guide to Water Quality Monitoring.*

iv) Monitoring partnerships

Federal
The US Army Corps of Engineers (ACOE) manages several flood control reservoirs in Vermont Waters. These are monitored routinely for flow and stage, and periodically for a variety of physico-chemical constituents. ACOE reservoirs with designated swimming beaches are also monitored for *E. coli* regularly during the swimming season. ACOE reports on its monitoring activities annually, and shares these reports with WQD. ACOE sampling results are used in conjunction with Integrated Assessment reporting.

The USEPA coordinates regional water quality monitoring projects of a variety of types. In recent years, projects which WQD has collaborated on include the REMAP New England Wadeable Streams Project and the National Study of Chemical Residues in Fish. USEPA was also the principal sponsor of the REMAP Assessment of Mercury in Waters, Sediments and Biota of VT and NH Lakes project. WQD plans to participate in the upcoming REMAP New England Lakes Project. Results of these studies are used for a variety of purposes in addition to Integrated Assessment reporting.



The US Fish and Wildlife Service (USFWS) sponsors projects across New England dealing with toxic contamination of aquatic biota. WQD has collaborated with USFWS on several projects, and data are freely shared. In addition, USFWS co-sponsored the REMAP mercury project discussed above.

The United States Geological Survey (USGS) operates a network of gauging stations on Vermont waters, which are supported by a cooperative agreement with VTDEC (see map at right). This gauging network provides water flow data that are critical for numerous applications and programs, both within and outside of VTDEC. USGS also coordinates several water quality studies throughout Vermont and regionally in a variety of disciplines, and the results and data are commonly shared with VTDEC for numerous uses including permitting and

integrated Assessment reporting. It is imperative that the gauging network remain in place, and to the extent practical, that new gauges can be emplaced with minimal difficulty. A gage network analysis that analyzes the current and past network to determine holes/duplication in the network should be carried out. This was done in NH using FEMA funds.

The USGS also operates two watershed study sites, and has developed (or is developing) useful models to predict nutrient losses and mercury bioavailability given watershed characteristics. The Sleepers River Watershed study, which is a long term monitoring program studying natural variations in the biogeochemistry of a small catchment. A similar study is being conducted at paired watersheds on Mount Mansfield. The SPARROW model is a geographically-based system that predicts nutrient export given watershed attributes, which has proven useful in several applications in Vermont since it's publication in 2004.

The Lake Champlain Basin Program (LCBP) is a quasi-public agency, funded by Federal EPA. USGS, and NOAA appropriation, that is dedicated to implementation of the pollution prevention and cleanup plan for Lake Champlain known as *Opportunities for Action*. LCBP supports numerous monitoring and research projects, which are overseen by a Technical Advisory Committee comprised of Federal, State, Academic, Non-profit, and public members. LCBP funds the Long-term Lake Champlain Monitoring Program nearly in entirety, and is a very important partner to VTDEC (and New York State DEC).

State

The Vermont Department of Forests, Parks, and Recreation operates a comprehensive beach monitoring program for all of its public use beaches on State Park lands. Twenty-nine beaches are monitored on a weekly basis following established protocols. Swim advisories are posted based on results of the testing, when *E. coli* sample values exceed the Vermont standard for Class B waters of 77 *E. coli* /100ml. These data are openly shared with VTDEC. They are used for assessments as well as for identifying beaches subject to chronic, controllable bacterial contamination.

The Vermont Department of Health (VTDOH) operates a program whereby appointed Town Health Officers are trained to collect water quality samples at designated beaches. This program is suitable for small municipalities with informally-used swim beaches. Data reported back to Town Health Officers from the VTDOH laboratory take the form "safe for swimming," or "violates Vermont's standard: unsafe for swimming." These data are not reported or tracked as numeric results. Town Health Officers commonly use these data to post warnings at swim beaches. Owing to resource constraints, samples collected in conjunction with that program cannot follow the strict QA procedures required by VTDEC and the Department of Forests, Parks and Recreation in their *E. coli* monitoring projects. As such, this program provides useful and preliminary screening information to determine where swim beach water quality may need further assessment.

The Vermont Monitoring Cooperative (VMC) is a collaborative organization in which scientists collect and pool information and data for the purpose of improving our understanding, protection, and management of Vermont's forested ecosystems. Participating cooperators from government, academic and private sectors, conduct research projects on a variety of topics including forest health, air quality and meteorology, wildlife, aquatic systems and others. The VMC helps make the data and results from these projects available to other scientists, educators, resource managers and the general public. The Vermont Monitoring VMC was initiated in 1990 as a state, university, and federal partnership, with a one-hundred year envisioned lifespan. The centerpiece of the VMC is the data library and card catalogue system that allow data to be shared, archived, and accessed by scientists and other interested parties via the VMC website. The data archive contains data and ancillary textual material from over 100 projects, and is geographically referenced.

The data results and monitoring designs articulated above provide necessary information for use by other State permit and compliance programs. Examples of State programs that make use of monitoring data include the NPDES and Indirect Discharge Programs, the Source Water Protection Program, Stormwater Management Program.

Academic
VTDEC maintains ties with several academic institutions interested in water quality monitoring. A partial list of these include Dartmouth College, Middlebury College, the University of Vermont, and member schools of the Vermont State College System. Collectively, these institutions carry out numerous projects, and resultant data are commonly used by VTDEC for assessment purposes. The University of Vermont also carries out several larger-scale research and monitoring projects cooperatively with or of significant interest to VTDEC. A non-inclusive list of University of Vermont projects includes paired assessments of geomorphic and macroinvertebrate biometrics on streams, research into natural background levels and strategies to mitigate *E. coli* in Vermont waters, assessment of cyanotoxins in Lake Champlain and elsewhere, and impacts of non-native species on aquatic food webs.

Local
The Addison County Collaborative (ACC) is a volunteer-based consortium of local volunteer organizations that monitor waters in several watersheds in the vicinity of Addison County. Funding is typically allocated through the Addison County Regional Planning Commission and by member municipalities. ACC has monitored approximately 45 sites across four watersheds for *E. coli* and eutrophication-related parameters. ACC provides data and summary reports to VTDEC on an annual basis. These data are used to assist development and implementation of the Otter Creek and Lower Direct Champlain Basin Plans, and in Integrated Assessment reporting. The ACC received a LaRosa laboratory services grant in 2003. This organization plans to launch a new monitoring project, in partnership with VTDEC, during 2004, to assist in the development of nutrient criteria.

The West River Association (WRA) is a newly forming group dedicated to similar goals as the WRP and ACC, for waters in the West River watershed. The WRA also received a LaRosa laboratory services grant in 2003.

The White River Partnership (WRP) is a private, non-profit organization dedicated to helping local communities balance the long-term cultural, economic and environmental health of the watershed through active citizen participation. WRP, using federal United States Department of Agriculture funding leveraged by private donations, has established a monitoring program for the watershed, comprised of multiple elements and several volunteer "stream-teams." Activities include geomorphic assessment, priority site mapping, and water quality sampling for a variety of constituents including temperature, turbidity, conductivity, and *E. coli*. WRP's active base of volunteer monitors generate quality-assured data that is used to identify priority reaches for protection or remediation. VTDEC is periodically provided data summaries for use in implementation of the VTDEC-prepared White River Basin Plan, for assessment purposes, and in other joint special studies.

The City of Burlington and Town of Colchester collectively monitor several heavily-used swimming beaches, by measuring *E. coli* on a regular basis. These data are made publicly in near real-time via the "Burlington Eco-Info" website (www.burlingtonecoinfo.net).

C. Emerging Threats to Water Quality

There are numerous existing and potential threats to Vermont's waters. These threats range from the well understood and easily documented, such as infestations of Eurasian watermilfoil, to those that are newly emerging onto the environmental consciousness, such as estrogen mimicking compounds. A threat is defined herein as an environmental pollutant that has the potential to impact or impair water quality, resulting in a reduction or complete loss of one or more beneficial values or designated uses. A number of existing and potential threats to Vermont's aquatic and wetland resources are identified in Table 3.C. An ideal monitoring program would have a component to track each of these threats. Given fiscal realities, this roster of threats must instead be prioritized and monitoring efforts focused on the highest priority items. Table 3.C provides information and recommendations regarding identified threats to Vermont waters.

Table 3.C. Existing and emerging threats to the quality of Vermont waters

Toxic Substances and Persistent Organic Contaminants	
Trace metals	The extent of mercury contamination to Vermont lakes is well characterized. However other trace metals are also deposited to watersheds from the atmosphere, and the breadth and severity of associated impacts are less well understood. Waters that are sensitive to acidification are thought to be sensitive to contamination by trace metals as well. Trace metals accumulate in the sediments of lakes and of wetlands.
Toxics substances	Down gradient of many unlined landfills and hazardous waste sites, groundwater data often suggest that organic compounds and metals are reaching surface waters. Little is known about the levels and impacts of these toxics on aquatic life in downstream waters.
General urban and stormwater runoff	Urban catchments and stormwater systems have the potential to deliver significant loads of metals and organic contaminants to receiving waters. The WQD has documented chemical and biological impairments to several urban streams.
Algaecides	While cupric algaecides were commonly used in the past to control algae in lakes, their use has declined significantly in recent years. Their use is now mostly limited to very small ponds on private property. Recently, water supply operators have begun to limit their use of copper-based algaecides in drinking water reservoirs to control algae-induced taste and odor problems. The biological impact of copper-based algaecides is poorly understood for Vermont waters.
Herbicides and pesticides	Herbicides and pesticides are commonly used for numerous purposes statewide, ranging from lawn care for individual homes to large-scale agricultural use. The delivery of currently used pesticides and their derivatives to small suburban drainages could compromise biota in downstream waters. The impacts from golf course and agricultural applications have the potential to be large, but are in many cases unquantified. Some ambient monitoring for these compounds, at water quality criterion levels, may be warranted to identify where chronic toxicity might be anticipated. Sites thus identified would become candidates for biological assessments. The aquatic herbicide, Sonar® has recently been permitted for the control on Eurasian watermilfoil in Vermont lakes; monitoring of biota has been and may continue to be warranted in association with these treatments.
Organic contaminants	Known persistent organic contaminants such as PCBs, PAHs, dioxins and furans, and metabolites of DDT exist in certain locations within Vermont's aquatic environment. Good data are available on the distribution of these compounds in Lake Champlain. Data for other waterbodies are spotty at best, although there are occasional occurrences of one or more of these compounds found in the tissue of fish in certain lakes. For example, the occurrence of documented high levels of DDT metabolites in large lake trout of Lake Dunmore should be verified with additional testing, since this is a popular and important lake trout fishery. There are many other Vermont lakes for which fish tissue has not previously been tested, and any fish collected in conjunction with fish tissue contaminant monitoring efforts should be analyzed for a wide suite of organic contaminants. In addition, no data are available from Vermont regarding PBDE flame retardants (poly-brominated diphenyl-ethers) in fish tissues. PBDE's have been found in fishes of nearly all systems where such measurements have been made. The occurrence of PBDE in human breast milk is widespread in Europe, where certain PBDE formulations have been banned from use or manufacture. The toxicity of PBDE's is ill-understood, but is reported to be similar to that of dioxin-like compounds.
Emerging threats	
Endocrine disruptors, pharmaceuticals, and estrogen mimicking	A large number of synthetic chemicals that have been released by humans into the environment have the potential to disrupt the endocrine system of fish, humans, and wildlife, or cause unquantifiable impacts. These chemicals include persistent bio-accumulative organohalogen compounds found in some pesticides, pharmaceuticals, industrial chemicals, and other synthetic products. Known aquatic life impacts include thyroid dysfunction in fish,

compounds (i.e., nonylphenols)	decreased hatching in fish and turtles, gross birth abnormalities, metabolic and behavioral abnormalities including (de)masculinization and (de)feminization of fish, and compromised immune systems.
Cyanotoxins	As this is an issue of particular concern to the public, a plan should be developed to document when and where cyanobacteria blooms occur to better understand the potential distribution of these toxins and to provide a public health warning when toxins are present. Lake Champlain is presently the subject of active monitoring for cyanotoxins.
Sprawl	Suburban commercial development and rural residential development are two forms of sprawl having the potential to impact water quality in developing watersheds in a variety of ways. Many of the larger development projects are regulated through permits, with monitoring requirements. In watersheds where land is being converted from agriculture or forest to low density residential uses, the potential for downstream water quality impacts also exists. These impacts are far more difficult to diagnose due to the scattered nature of small residential building projects. Stream channel evolution studies and paleolimnological assessments of current and historical lake water quality provide approaches to understanding the potential impacts attributable to land use conversions.
Threats attributable to non-native species	
Eurasian watermilfoil, water chestnut, and zebra mussels	Eurasian watermilfoil has been found in 59 lakes and ponds, and 19 other waters in Vermont; water chestnut populations exist in Lake Champlain, Lake Bomoseen and several smaller waterbodies located in both the western and eastern Vermont; zebra mussel adult populations exist in Lake Champlain and Lake Bomoseen, and zebra mussel veligers (larvae) have been found in Lake Dunmore and Lake Hortonia. All three species have the potential to spread to other waterbodies in the state, primarily through human activities such as boating. Purple loosestrife is well established throughout the State. VTDEC currently conducts veliger monitoring and plant surveys on only a small percentage of uninfested waterbodies. Citizen volunteers provide some additional survey assistance, but the state's ability for early detection of new infestations, both of species already present and those at risk of being introduced, is limited. Early detection is critical to enable implementation of effective management techniques and to prevent the spread to other waterbodies. In addition, applications for permits to apply the aquatic herbicide Sonar® have increased dramatically in Vermont lakes following the treatments in 2001 of Lake Hortonia and Burr Pond. Pre- and post-treatment biological monitoring, along with appropriate non-chemical controls, should accompany Sonar ® treatments to identify what nontarget impacts, if any, may occur.
Other nonnative aquatic organisms	Nonnative fish species such as alewife are primarily monitored by the VT Department of Fish and Wildlife. Water quality changes attributable to alewife infestation are well documented in Lake St. Catherine, Wells, VT. The distribution and impact of other nonnative aquatic species are primarily known only through anecdotal observations from unrelated survey or research activities. Little is known about the distribution or impact of the vast majority of nonnative aquatic organisms within Vermont.
Threats Regarding Stream Hydrology and Sediment Regime	
Changes to stream geomorphic condition	The WQD is developing a stream geomorphic assessment program to determine the impacts of floodplain, channel management, and flood remediation practices on stream stability (the ability of the stream to transport the water and sediment produced in its watershed without aggrading or degrading). The removal of watershed and riparian corridor vegetation, floodplain encroachment, dredging, armoring, flow regulation, and channelization practices have initiated major channel adjustments and instability in stream and river systems in every basin in the state. The River Management Section is building the capacity to assess the spatial and temporal adjustment trends underway in streams to determine threats to physical habitat as well as threats to public property and safety.
Threats at the Watershed Level	

Nonpoint sources of nutrients and sediment	In Vermont, nonpoint sources of nutrients and sediment are commonly implicated in the eutrophication of lakes and the degradation of streams and wetlands. Regulations state that agricultural and forestry practices must conform with accepted management practices, and it is implicitly understood that no water quality standards violations ensue from activities that are in conformance with the accepted practices. However, there have been documented violations of standards in several logging and agricultural operations that were technically in conformance with the accepted practices. Monitoring should be undertaken to document the efficacy of the Accepted Agricultural Practices and the Acceptable Management Practices for agriculture and silviculture. Another noteworthy non-point source of nutrients and sediment is highway and gravel road erosion. Runoff from roads is diffused throughout watersheds, and can have long-term, low level impacts to water quality due to sediment and nutrient delivery to receiving waters. Moreover, improperly sized and installed bridges and culverts can result in flood damage, which results in additional sediment and nutrient inputs to waterways. Through the Better Backroads Program, the VTDEC is assisting towns in making considerable progress towards remediating these sources. An experimentally designed, paired watershed approach may be a useful way to document the efficacy of the Better Backroads practices.
Stream corridor development and floodplain encroachment	Stream and floodplain dimension (i.e., width/depth), meander pattern and slope are critical geomorphic components of stream systems in equilibrium condition. Stable, equilibrium streams are capable of transporting the flow and sediment produced in their watersheds without aggrading or degrading. Without knowledge of these fluvial processes and their consequences, people build roads, railroads, houses, farms, and communities near streams, cutting the streams off from their floodplains. Streams that do not have room to move in their historic floodplains may become very unstable following changes to watershed hydrology or sediment regime. The VTDEC has a large effort underway to document channel adjustments throughout the state and inform the public of the tremendous costs and risks associated with stream corridor and floodplain development.
Lack of riparian buffers	Riparian corridor and lakeshore vegetation serves important water quality, habitat, and stream and shoreline stability functions. The width and character of riparian buffers required to perform these functions needs to be assessed and monitoring is needed to determine the efficacy of buffer practices.
Threats at the Global Level	
Global climate change	Impacts of global climate change will be pervasive across aquatic systems nationwide Vermont. Documenting the effects of climate change on aquatic systems in Vermont will further justify action at the federal level to combat global warming.

D. Recommendations and Strategies

The following strategies and recommendations are organized in relation to the goals and objectives elaborated in Section 2.B.

Objective 1A and Objective 1B:

- Continue implementation of existing core monitoring programs. Consistent base monitoring funding under the C.W.A. §106 mechanism, and supplemental funding in conjunction with on-going Performance Partnership agreements is critical to achieving these objectives.
- Continue use of the LaRosa Laboratory annual assessment fee funding model to ensure availability of analytical capacity.

- Continue operation of the cooperative gauging network run by USGS, and work with USGS to streamline procedures for instrumenting new sites. Implement a gage network analysis.
- Evaluate available biomonitoring data from the Lake Champlain Agricultural BMP Monitoring Project to determine the biological response to BMP implementation.
- Perform biological monitoring associated with the new Best Management Practices Effectiveness Demonstration Project to relate changes in biological communities attributable to BMP implementation to changes in stream chemistry. Findings related to these efforts need to be publicized to generate confidence among the affected community that the practices they employ will make measurable improvements to the environment.
- Perform paleolimnological assessments of lakes that are identified as not meeting or potentially not meeting water quality standards for nutrients to assist in the development of post-remediation target nutrient concentrations, and to provide a 'reality-check' on the applicability of the nutrient criteria proposed for promulgation by USEPA Region 1. (Note, 2005 TMDL funding will enable this analysis for the nutrient-impaired Shelburne Pond during 2005/2006).
- Develop a program of sediment contaminant screening downstream of sites of concern (e.g., identified hazardous materials sties).
- In addition to professional staff, ensure funding for at least one FTE as a long-term technician in the lakes and biomonitoring programs. The cost for both technicians, in 2006 dollars, will be $109K.
- One additional wetlands staff would be necessary to develop an ambient wetlands monitoring program ($54.5K).

Objective 1C:

- New monitoring initiatives or special studies related to water quality threats should address one or more of the threats outlined in Section 3.C (above) to the extent practical.
- The current approach to fish tissue contaminant monitoring should be changed to a synoptic recurring assessment aimed at assessing trends over time. Such an approach could be randomized or fixed-station, and would provide landscape-level monitoring data to measure changes in tissue contaminant burdens related to forthcoming national regulations on mercury emissions. One iteration of a recurring five-year initiative is estimated to cost $200K in 2006 dollars.
- Fish tissue monitoring efforts must focus on emerging as well as known contaminants. Additional laboratory resources may be needed to provide analysis of low-level metals, and esoteric organic contaminants (e.g., PDBE's).
- There exists the need for a large, laboratory-grade freezer to store fish tissue samples, as the current capacity for tissue storage is too limited.
- There exists the need for a freeze drier to prepare fish tissue for organic contaminant analysis.
- There exists a need for a dissecting scope to aid in accurate aquatic plant identification.
- Monitoring for cyanotoxins and development of predictive systems to rapidly identify cyanotoxins-producing algal blooms should be supported to the extent practical. This is presently supported by the Lake Champlain Basin Program for waters within the Champlain Basin.

Objective 1D:

- Continue to employ Phase I, II, and III geomorphic assessments to assess stream geomorphic condition.
- Continue to foster monitoring of stream and river water chemistry by volunteer organizations to assess waters of specific interest.

Objective 1E:

- As needed and appropriate, continue to modify the monitoring-related indicators of program success published in the VTDEC Strategic Plan and the Performance Partnership Agreement with USEPA in accordance with the recommendations contained in Section 4.B.
- Continue implementation of monitoring initiatives in stormwater-impaired watersheds, including on-going physical/chemical, biological, and geomorphic assessments.
- Prepare guidance for volunteer organizations to perform measurements of lake morphometry and thermal mixing to assist lake associations who need this information to design aquatic nuisance species control projects using aquatic herbicides.

Objective 1G and H:

- Prioritize water quality standards and criteria that are not presently measured. Monitoring involving volunteer participation is also relevant to the action items of Objective 1D, and is amenable to standards such as temperature, DO, turbidity, and *E. coli*.
- Develop nutrient criteria for lakes that will satisfy Clean Water Act §304 criteria while being tailored specifically to Vermont (see section 4.C.i).
- Initiate process to revise the current water quality criterion for *E. coli* (see section 4.C.iii)
- Incorporate procedures presented at the 2003 National Symposium on Biological Assessment and Criteria for assessing the biological integrity of low gradient large rivers, and to the extent practical, wetlands.
- Complete lake biocriteria development. Funding is in place to complete investigations into trial biocriteria derivation for lakes. Long-term implementation of the lake program will require approximately $1000 per lake per assessment in addition to monitoring staff time.
- Initiate wetland biocriteria development for lake-margin and stream-laved wetlands (see 4.C.ii). A limited trial project costing $40K (2006 dollars) would permit initiation of this project, to provide technician support and taxonomic costs.

Objective 2A:

- Through the basin planning process, ensure that watershed coordinators and monitoring staff are communicating regarding existing monitoring programs and outstanding monitoring needs in basins of interest, such that the Coordinators can bring this information to potential and existing volunteer organizations and to others involved in monitoring in the basins.
- Open a dialogue with existing volunteer monitoring programs (such as those managed by RiverWatch Network, the University of Vermont, or St. Michaels College) to identify shared needs for volunteer-collected data and to determine where volunteer resources may exist to fill those needs.

Objective 2B and Objective 2D:

- VTDEC has made great strides in enhance its ability to support volunteer-based monitoring groups through the LaRosa Partnership Program. In order to maximize our ability to properly manage data and quality control of individual projects findings, additional support of approximately ½ FTE of full-time staff, plus 0.3 FTE temporary technician support, is necessary. These personnel resources would supplement the ¾ FTE and 0.3 FTE temporary staffing already dedicated to volunteer monitoring in conjunction with the Lay Monitoring Program.
- Encourage EPA's New England's monitoring equipment loan concept.
- To ensure wide distribution of the 2005 Volunteer Guide to Citizen Water Quality Monitoring in Vermont, approximately $20K would be helpful for four-color printing of this excellent 100 page manual. Presently, no funding is available for printing the guide, which will be made available online.

Professional printing would permit VTDEC to distribute to interested organizations this professionally-designed, content rich resource.

- Continue the LaRosa Laboratory Services Partnership Program

Objective 2C:

- Continue to support and foster long-term partnership monitoring programs. These include, but are not limited to the USGS, ACOE, White River Partnership, Addison County Riverwatch Collaborative, West River Watershed Alliance, Poultney-Mettawee Partnership, Upper Otter Creek Watershed Council.

4. Recommended Core and Supplemental Indicators

A. Vermont Water Quality Standards

i) Overview

The Vermont Water Quality Standards are the foundation for Vermont's surface water pollution control and surface water quality management efforts. The Water Quality Standards (Standards or WQS) are promulgated by the Vermont Water Resources Board and provide the specific criteria and policies for the management and protection of Vermont's surface waters. The classification of waters (rivers, streams, lakes and ponds) as Class A, Class B or Class B with Waste Management Zone are the management goals to be attained and maintained. Within Class B classes, the Standards provide for specific water management types {(B(1), B(2), and B(3)} to be attributed during the basin planning process. The classification also specifies the designated water uses for each class. The current Vermont WQS were adopted June 10, 1999 and became effective July 2, 2000.

The Vermont WQS establish narrative and numeric criteria to support existing and designated uses. Existing uses of waters and the level of water quality necessary to protect those uses is to be maintained and protected regardless of the water's classification. A determination of what may constitute an existing water use on a particular waterbody is made either on a case-by-case basis, during the basin planning process, or by the Secretary of VTANR during the consideration of an application.

ii) Designated uses, and surface water classification and typing

All surface waters in Vermont are presently classified either Class A or Class B. Waters designated as Class A(1) are Ecological Waters, managed to maintain an essentially natural condition. Waters designated as Class A(2) are Public Water Supplies. There may be a change from the reference condition due to the fluctuations in reservoir water level and in the reduction in streamflow that result from water withdrawals for water supply purposes. Designated uses, as established in Sections 3-02(A), 3-03(A) and 3-04(A) of the Standards, mean any value or use, whether presently occurring or not, that is specified in the management objectives for each class of water. Table 4.A.i indicates applicable designated uses.

Table 4.A.i. Designated uses for water classifications.

Designated uses	Class A waters		Class B waters
	Water management type A(1) – ecological waters	Water management type A(2) – public water supplies	Water management type B(1), B(2), B(3)
Aquatic biota, wildlife & aquatic habitat	√	√	√
Aesthetics	√	√	√
Swimming & other primary contact recreation	√	√	√
Boating, fishing & other recreation uses	√	√	√
Public water supplies		√	√
Irrigation of crops & other agricultural uses			√

Class B waters comprise approximately 97% of all waters in the State. Class B waters are managed to achieve and maintain a level of quality that is compatible with designated uses. The Standards contain a requirement that all Class B waters shall eventually be designated as Water Management Type B1, Type B2 or Type B3. In designating a Water Quality Management Type, the Vermont Water Resources Board must take into account attainable uses and the level of water quality already existing. Recommendations for Water Management

Typing are developed during VTDEC's basin planning process. Once a basin plan is adopted by the Secretary of VTANR, a petition for classification and Water Management Typing is prepared by VTDEC and submitted to the Water Resources Board for their consideration and adoption.

iii) Water quality standards and criteria

The following provides a summary overview of the Standards, including a listing of parameters for which standards or criteria are promulgated (Table 4.A.ii). Guidelines for assessment of waters in light of the Standards and of the indicators below are provided in section 7B of this document. Copies of the Standards may be obtained from the Water Resources Board or from the Water Quality Division. Persons may also access the Standards by visiting the web site of the Vermont Water Resources Board (refer to www.state.vt.us/wtrboard, click on "Rules").

Table 4.A.ii. Roster of existing water quality standards and criteria

Water quality standards-section and indicator	Type of standard (numeric criterion or narrative)	Varies by water management type?	Water quality standards-section and indicator	Type of standard (numeric criterion or narrative)	Varies by water management type?
3-01 - B-1 Temperature	Numeric criterion	No[1]	3-01 - B-10 Toxic Substances	Narrative[2]	No
3-01 - B-2 Phosphorus	Narrative[3]	No	3-01 - B-11 Radioactivity[4]	Numeric criterion	No
3-01 - B-3 Nitrates	Numeric criterion	No[5]	3-01 - C Hydrology	Narrative	Yes
3-01 - B-4 Sludge and Refuse	Narrative	No	3-01 - D Biocriteria	Numeric criterion[5]	Yes
3-01 - B-5 TSS, Oil, and Grease	Narrative	No	3-02 - 3-04 Turbidity	Numeric criterion	Yes
3-01 - B-6 Taste and Odor	Narrative	No	3-02 - 3-04 *Escherichia coli*	Numeric criterion	Yes
3-01 - B-7 Color	Narrative	No	3-02 - 3-04 Habitat	Narrative	Yes
3-01 - B-8 Alkalinity	Narrative	No	3-02 - 3-04 Dissolved Oxygen	Numeric criteria	No
3-01 - B-9 pH	Numeric	No	3-02 - 3-04 Aesthetics	Narrative	Yes

1. Criterion varies with fish habitat designation and waterbody type.
2. Appendix C of the Standards provides numeric criteria for priority pollutants and organics.
3. Numeric criteria have been promulgated for 12 segments of Lake Champlain and two segments of Lake Memphremagog. Also in effect is a criterion limit of 10 ppb for waters above 2,500 feet of elevation.
4. Criteria are by reference to C.F.R. and to Vermont Health regulations
5. Criteria vary by waterbody type, and numeric criteria are contained within implementation procedures promulgated under authority of the VT Agency of Natural Resources.

B. Other Core and Supplemental Indicators

Table 4B provides a listing of additional supplemental indicators that are not expressly stated in the Standards.

Table 4B. Supplemental indicators of water quality.

Water quality indicator endpoint	Metric or parameter
Water clarity	Secchi transparency Chlorophyll-a
Water chemistry	Total nitrogen Total silica Conductivity Oxidation-reduction potential Salinity Base cations and anions Iron, manganese, sulfides Organic carbon, dissolved Mercury, total and methyl Pesticides, current use
Sediment quality	Acid volatile sulfides Metals, priority Organics, priority volatile and semivolatile Pesticides, current use Loss on ignition
Biological integrity	Macrophyte cover Fish tissue contaminants: mercury; PCBs; TCDD/TCDFs; PBDEs Fish kills and/or gamefish abnormalities.
Watershed integrity	Stream geomorphic condition Land use type and land use conversion Shoreline development density

C. Recommendations and Strategies

i) Nutrient criteria

Under authority of §304 of the Clean Water Act, USEPA has prepared ecoregional nutrient criteria for lakes and rivers for several regions of the United States. These criteria were introduced via 66 C.F.R. 1673 in 2001. That notice established a timeline of approximately four years for States to either adopt the proposed §304(a) criteria, or develop and implement a plan to derive similarly suitable criteria that are relevant to individual State conditions.

Vermont cannot subscribe to the §304(a) criteria as proposed. Evidence from long-term, Vermont datasets indicates that a very significant proportion of Vermont lakes and rivers would exceed the proposed criterion, were the VT Water Resources Board to adopt the USEPA proposal. Vermont has thus prepared a nutrient criteria development plan, and committed to making significant progress towards the implementation of that plan, as indicated by 66 C.F.R. 1673.

Vermont's plan calls for the derivation of effects-based nutrient criteria for phosphorus that protect designated uses established by the Standards, stratified within waterbody classification and water management

type. The ensuing suite of criteria would be presented in the form of a matrix, with individual criteria values for each combination of designated use, and waterbody class/water management type. Vermont's plan presents evidence supporting limiting the evaluation of criteria to total phosphorus and total nitrogen. Implicit in Vermont's plan is the premise that aesthetics and aquatic biota and habitat represent the most sensitive of those designated uses amenable to assessment using nutrient criteria. Accordingly, the Vermont plan concentrates on evaluating the relationship between nutrient concentrations and these uses.

This will be accomplished by a two-step approach. For aesthetics, nutrient samples will paired with semi-quantitative observations of aesthetic conditions derived using a user survey, to be administered at the time of sample collection. This approach will be implemented at a minimum of 250 sites statewide. The sampling design will incorporate classification and temporal and flow-mediated variability. The cumulative frequency of nutrient concentrations will be related to derived aesthetic scores, to determine the nutrient concentration beyond which aesthetic scores are noted to decline significantly. For aquatic biota and habitat, nutrient sampling results at a minimum of 250 ambient biomonitoring sampling station will be related to biological indices calculated from those sites, to derive the relationship between nutrient concentration and biological integrity. The geometric mean nutrient concentration above which biotic integrity scores indicate impairment, as determined by VT Water Quality Standards (see sections 4.A.3 and 7.B), will form the basis for criteria to protect aquatic biota and habitat.

As of early 2004, Vermont has entered into a cooperative agreement with USEPA, with funding supplied under §104(b)(3) of the Clean Water Act, to implement the field program necessary to support nutrient criteria development. Vermont's ability to complete the process of analyzing the data and carrying forward the criteria proposal and adoption will be predicated on the availability of resources and competing Federal mandate promulgated under authority of the Clean Water Act. Vermont's Nutrient Criteria Development Plan is available online at http://www.vtwaterquality.org/LakesPonds/lp_vtnutrientcriteriaplan.pdf.

ii) Lake, wetland, and large river biological criteria

Vermont is recognized nationally as having made significant progress towards development and implementation of lake biological criteria. VTDEC first began the process of developing lake biological indices in 1995, via a cooperative agreement with USEPA. This and subsequent agreements have enabled VTDEC to develop a series of trial biometrics that are useful in assessing aquatic life use support for lakes. The current lake biological indices describe the reference condition for whole-lake phytoplankton, and for macroinvertebrates within four habitat types. These indices are specific to one of three lake classes that have statistically been verified to influence the reference expectation for both biological assemblages. The biocriteria system developed for Vermont lakes is unique in that it incorporates elements of traditional multimetric bioassessment with the rigor imposed by multivariate statistical approaches to classification and index development.

As of early 2004, Vermont has entered into a cooperative agreement with USEPA, with funding supplied under §104(b)(3) of the Clean Water Act, to finalize development of lake biological criteria for lakes. The first goal of this project is to make new assessments of a set of lakes that are either naturally eutrophic, or have known water level manipulations. Results of these new assessments will be incorporated into the existing database comprised of assessments of 45 lakes. The entire dataset will then be reanalyzed to either verify that the criteria system previously developed still stands up to statistical testing, or to build a new, more improved and rigorous system. Pending positive results of these analytical activities, a lake biological criteria implementation procedure will be developed, for consideration by the VT Water Resources Panel in light of existing standards for aquatic life use support in lakes. This project is anticipated to be complete by the end of 2006. Additional information regarding Vermont's lake biological criteria is available online at http://www.vtwaterquality.org/lakes/htm/lp_monitoring.htm. The development of biological indices of water quality for Lake Champlain is a long-term project area overseen by the Lake Champlain Basin Program.

VTDEC has also participated in the development of wetland biocriteria, in conjunction with the New England and National Wetlands Biological Assessment Workgroup. To date, Vermont's efforts have been centered on vernal pool and northern cedar swamp wetland types, and data results have not been suitable for development of biocriteria. In 2004, VTDEC did not receive competitive funds under §104(b)(3) of the Clean Water Act to support additional biological characterizations of wetlands in conjunction with the lake bioassessment studies discussed directly above. One new approach VTDEC is adopting is to assess wetlands that are associated with lake margins or those interlaced by small streams, using both the methods already established for stream and lake bioassessment, along with new methods for wetland vegetation characterization. If a proposal similar to that written in 2004 were ultimately funded, VTDEC would use data collected under that new project to develop trial biometrics assessing wetland functions and values. Additional information regarding VTDEC's existing efforts to biologically assess wetlands is available online at http://www.vtwaterquality.org/bass/htm/bs_vernal.htm#vernal.

As part of the long-term Ambient Biomonitoring Network, data are being collected from larger rivers in Vermont. These data should be evaluated in a reference-based index-development framework once a sufficient number of sites are available.

iii) Pathogen criteria

E. coli concentrations are known to vary considerably over space and time, in response to natural and human-related factors. Very few strains of *E. coli* are themselves pathogenic. Rather, they are indicators of the presence of fecal material of warm-blooded animal origin. This fecal material may contain harmful pathogens. On a national scale, *E. coli*-based criteria are expressed either as geometric mean values, or as one-time, instantaneous single-sample values. These values equate to a likelihood of developing gastrointestinal illness from exposure to waterborne pathogens associated with *E. coli*. EPA originally (1986) derived freshwater criterion recommendations using a set of statistical relationships relating geometric mean *E. coli* levels to observed gastrointestinal illness rates directly attributable to the *E. coli* exposure. Using these relationships, EPA recommended that the most conservative *E. coli*-based criterion be a geometric mean of 126 *E. coli* /100ml. At highly populated beaches (defined as greater than or equal to 2,427 swimmers/day on average), that are subject to direct sewage effluent contamination, exceedance of this criterion means that on a season-wide average basis, eight in 1,000 swimmers may develop gastrointestinal illness due to *E. coli* exposure. At *E. coli* concentrations below 126 *E. coli* /100ml, the illness rate attributable to exposure to the indicator bacteria (presumably less than eight in 1,000) could not be separated from the general rate of gastrointestinal illness present for any number of reasons. In 2002, EPA reaffirmed its 126 *E. coli* /100ml geometric mean recommendation considering all more recently available data and studies.

Vermont's current water quality criteria for bacteria reflect a long-term intent to maintain a high level of protection to swimmers and other forms of contact recreation use. The current criteria are also far more conservative than those recommended by EPA. Vermont's current criteria are not to exceed a three-sample geometric mean of 18 *E. coli* /100ml (or a single sample maximum of 33) for Class A(1) and A(2) waters, and not to exceed 77 *E. coli* /100ml for Class B waters in all management types. Interpreted using EPA's published statistical relationships, a single instantaneous concentration of 77 *E. coli* /100ml equates to a 75% likelihood that a beach closure will prevent swimmers from incurring a 3.4 in 1,000 risk of developing gastrointestinal illness. Such an interpretation must be treated very cautiously as any illness rate attributed to *E. coli* exposure less than 8 in 1,000 is below the level quantifiable using EPA's statistical relationships.

Recent Vermont research indicates that the present Vermont Class B criterion can be exceeded in low to moderate streamflows issuing from undisturbed forested watersheds due to natural background sources. Based on calculations using EPA's statistical relationships, 77 *E. coli* /100ml, expressed as a geometric mean of several samples, results in a projected illness rate of 6 in 1,000 swimmers. While this level of risk remains below the EPA minimum recommendation, it is consistent with the intent of current and prior Vermont water quality criteria for bacteria, beginning in 1985. In addition, new EPA guidance (USEPA, 2003b) on the application of water quality criteria for pathogens allows that impairment determinations can be based on

geometric seasonal means or some number of single sample exceedances. EPA expresses preference for use of a longer-term indicator (geometric mean) for reporting use attainment. Ultimately, however, Vermont's Water Quality Standards serve as the guidepost for assessment and listing determinations. Accordingly, modified assessment guidelines have been developed from Vermont's Water Quality Standards for the 2004 Integrated Reporting cycle (see 7B, below). Moreover, the Water Resources Board should be petitioned to modify the existing water quality criteria for *E. coli* in all waters to reflect a real-world approach that is consistent with current EPA guidance, although such an action would necessitate stakeholder input from multiple user and advocacy groups. Additional information regarding *E. coli* monitoring in Vermont is available online at http://www.vtwaterquality.org/lakes/docs/lp_citbactmonguide.pdf.

5. Quality Assurance

A. Quality Management Plan

VTDEC maintains a Quality Management Plan that establishes the flow of information used environmental decisionmaking. This plan is updated annually as required under VTDEC's partnership agreements with EPA, and reflect the goals and priorities elaborated in current VTDEC Strategic Plan.

B. LaRosa Laboratory Quality Assurance Plan

The LaRosa Laboratory is subject to Quality assurance planning per EPA requirements for laboratory certification. The LaRosa laboratory employs a full-time quality assurance officer, and the LaRosa Quality Assurance Plan is update annually to reflect modifications to data handling procedures, as well as new analytical methods. The entire LaRosa laboratory Quality Assurance Plan is available online, at http://www.anr.state.vt.us/dec/lab/htm/QualityControl.htm.

C. Quality assurance plan preparation

All monitoring projects carried out in whole or part using EPA funding are subject to quality assurance planning. VTDEC uses the most recent guidance for quality assurance project plan (QAPP) preparation whenever practical, and typically consults with appropriate EPA QA officers when beginning to develop a plan. Recently, VTDEC has began to prepare more comprehensive QAPPs that present collections of methodologies which are relevant to much of the routine field work described in this document. One good example of this is the new 2005 Lake Assessment Program QAPP, which provides field and analytical methods, and quality assurance procedures, for a wide variety of routine field tasks undertaken to assess lakes including chemical assessment, biological assessment, sediment analysis, and bacteriological monitoring. Where practical, these types of "umbrella" QAPPs can provide all of the necessary methodological detail needed by VTDEC to perform both routine sampling and also to perform sampling in response to emergency events, where there is no time to prepare a QAPP, or to have that QAPP approved by USEPA.

D. Archive of QAPPs

An archive of all QAPPs is maintained as part of the DEC Quality Management Plan. This list is updated annually. Table 5.D provides this list for 2005, the most recently-available roster as of this writing.

Table 5.D. 2005 roster of quality assurance project plans.

Program	Project #	Project Manager	Yr QAPP written / last updated	EPA Approval in Place?	Scheduled Update?
Core Programs					
Spring Phosphorus	1	Kamman	1996	Yes	2004
Lake Assessment Program	2	Kamman	2005	In review	2010
The Lake Champlain Long-Term Monitoring Program	**3**	Smeltzer	2003	Yes	2004
The Long-Term Monitoring (LTM)	4	Kellogg	2000	yes	2004

Program	Project #	Project Manager	Yr QAPP written / last updated	EPA Approval in Place?	Scheduled Update?
Acid Lakes Program					
The Stream Geomorphic Assessment Program	5	Kline	2001	yes	??
The Fish Contaminant Monitoring Program	6	Langdon	2002	Yes	??
REMAP Mercury Project	7	Kamman	2000	Yes	NA
Ag. Best Management Practice Effectiveness Monitoring	8	USGS		USGS project. EPA approval not required.	
Urban Best Management Practice Effectiveness Monitoring	9	USGS		USGS project. EPA approval not required.	
Ambient Biomonitoring Network (ABN) Program	10	Fiske/ Langdon	1994	Yes	??
Lake Bioassessment Project	11	Kamman	2004	Yes	2009
Aquatic Macrophyte Monitoring Program	12	Warren	1995	Yes	
Aquatic Nuisance Species Searches and Surveys	13	Bove	Procedures as in Project 17		
Lake Champlain Zebra Mussel Monitoring Program	14	Smeltzer	2003	Yes	
Vermont Vernal Pool Bioassessment Project	15	Burnham/ Popp	1999	Yes	
Northern Leopard Frog Surveys in the Lake Champlain Basin	16	Levey	2001	Yes	NA

Program	Project #	Project Manager	Yr QAPP written / last updated	EPA Approval in Place?	Scheduled Update?
The Vermont Lay Monitoring Program	17	Picotte	2002	Yes	
Volunteer Acid Precipitation Monitoring Program	18	Pembrook	None in place	no EPA funding	
LaRosa Laboratory Volunteer Monitoring Analytical Grants Project	19	Kamman	2005	Not subject to EPA Review per VT Program Liaison E. Beck	2006
Nutrient Criteria Development Project	20	Kamman	2004	Yes	

E. Recommendations and Strategies

Quality assurance project planning is an essential part of any properly executed study. VTDEC recognizes that QAPPs are a useful and sometimes critical tool for improving data collection and analysis. Accordingly, QAPPs are a means to an end, and not a final, free standing product of their own. Since QAPP preparation is time consuming, VTDEC recommends that QAPPs cover multiple projects (e.g., the Lake Assessment Program QAPP), to introduce the maximum possible efficiency into the preparation and approval process. The use of umbrella QAPPs, prepared for a fixed time span of five years can greatly enhance efficiency in project planning by reallocation the resources necessary for project planning to project design and execution. Currently, VTDEC has in place "umbrella" QAPPs for the Lake Assessment Program, Ambient Biomonitoring Network, and Volunteer Lab Services Grants Program.

6. Data Management

A. Water Quality Data

i) Chemical data

Data collected in conjunction with VTDEC monitoring programs, as well as some volunteer-based data, are archived to VTDEC's dedicated water quality data archive. As of January, 2005, this archive contains in excess of 360,000 individual data records, beginning prior to 1970. Data from all core chemical monitoring programs are archived on an annual basis, following quality assurance screening, in advance of the April STORET submission timeline (see below). In certain instances, project-specific data will be held outside of the data archive until a project is completed prior to submission. The Water Quality Data Archive is intended to be VTDEC's final repository for water chemistry and associated data. It is structured to hold data in a 'quasi STORET-compatible' form, for incorporation into the national STORET data archive.

The Water Quality Data Archive is presently maintained in a Microsoft Access© database, which is carried on VTDEC's central file server. This database is backed up on a daily or more frequent basis, with archive media also protected off-site. During the course of execution of this Strategy, the Water Quality Data Archive may be transferred to a more powerful database system, such as Microsoft SQL Server©.

ii) Biological data

Data collected in conjunction with all VTDEC biomonitoring programs are archived to a dedicated biomonitoring database, which is a component of the Water Quality Data Archive. As of January, 2004, this database contains in excess of 99,000 individual macroinvertebrate occurrence records from 2,873 discrete sampling events. The database also holds 5,606 individual fish occurrence records representing 851 discrete sampling events. Data from all core biomonitoring programs are archived as data become available from the laboratory, following quality assurance screening. In certain instances, project-specific data will be held outside of the data archive until a project is completed prior to submission. The Water Quality Data Archive is intended to be VTDEC's final repository for biomonitoring and associated data.

iii) STORET

VTDEC began implementing a local STORET archive in 2003. In response to USEPA requests, and with support from the National Environmental Information Exchange Network, VTDEC has been able to develop the largest STORET archive of all New England States, with nearly 260,000 records archived across numerous programs as of this writing. At present, the VTDEC STORET archive is limited to water chemistry information, although the addition data contained in the biomonitoring database is currently under consideration. Migrating long-term biomonitoring data to STORET is a major task, likely best accomplished by a suitable contractor. In order for biomonitoring data to be archived to STORET, taxonomic codes need to be translated, approximately 1,500 sampling stations need to be established (into the STORET system). VTDEC annually uploads of data contained in the local STORET archive to the national STORET data warehouse, typically in April.

iv) Standard Operating Procedures

VTDEC maintains a roster of standard operating procedures for field collections. These are updated regularly, and were last updated in March of 2005. Individual S.O.P.'s are available on request.

B. Assessment Data

i) Lake water quality inventory

VTDEC maintains a database containing physical and cultural characteristics, and water quality data summaries, for 918 inventoried Vermont lakes. The so-named Lake Inventory is used to track information such as waterbody classification, known existing uses, lake physical attributes, counts of shoreline dwellings, and characteristics relevant to lake protection prioritization. Much of the data contained in the lake inventory database is available online through the VTDEC-Water Quality Division website. These data are updated on an annual basis, or as warranted based on new information.

ii) Assessment database

VTDEC currently maintains two discrete databases that are used to track use support; one for lakes, and the other for streams. No such assessment dataset is available for wetlands. These databases are updated continually throughout the year, and each year, the database is archived prior to fulfilling EPA-required assessment data submissions, in April. In this way, static archive copies of assessment databases for lakes and streams are maintained, for each year.

These assessment databases are structured to be compliant with the current USEPA "ADB" database architecture. One significant departure from the "ADB" architecture is that Vermont waterbodies are not segmented into individual segments representing unique combinations of use support, and pollutant cause and source. Rather, each waterbody entry shows the proportion of waters meeting or not meeting individual uses, by cause-source combination. This is a particular concern within the river and stream assessment database. These databases are presently housed in Microsoft Access©.

iii) TMDL database

Details regarding how waters are assessed and allocated into lists of impaired and priority waters are available in Section 7 (below). VTDEC presently maintains a database of priority and impaired waters that is separate from the assessment databases. This database is presently maintained in Microsoft Access©, and is relationally linked to the assessment databases. Impaired and priority waters lists are provided to USEPA biennially in conjunction with integrated reporting, in April of even-numbered years.

iv) Vermont Hydrographic Dataset

Late in 2003, the Vermont Center for Geographic Information finalized the Vermont Hydrographic Dataset (VHD). VHD is a GIS-based waterbody coverage is based on the National Hydrographic Dataset (NHD) architecture. It is fully compliant with NHD, and includes all metadata requirements and reach coding. VHD differs from NHD in that it is a 1:5,000 scale water coverage. NHD is presently available in all New England states only at 1:100,000 scale resolution.

Vermont's existing 208 river/stream and 558 lake waterbodies are presently georeferenced to older Vermont 1:100,000 scale stream coverages. A present need is to attribute individual waterbody identification codes to the VHD, a project that is beginning within VTDEC at present.

C. Recommendations and Strategies

In general, database management is handled by project-level staff with assistance from the Agency of Natural Resources Information Technology staff. One additional FTE in database management and assessment data entry and reporting would provide consistency in data archiving, and permit program staff to focus on using monitoring data as opposed to simply archiving it. This additional staff time would enable the following.

i) Waterbody segmentation and database integration

In order to accurately and dynamically georeference individual use impairments and pollutant cause/source combinations, the existing waterbodies must be segmented. This task will be significantly facilitated by the attribution of existing waterbody identification codes to VHD, which can then be used to segment waters, using a new waterbody identification code. At present, VTDEC envisions that VHD reach codes will supplement and eventually replace existing waterbody identification codes, permitting a direct linkage between assessment databases and VHD. This will provide more sophisticated mapping capabilities that can be shared with the public and interested parties using online, web-based GIS mapping tools. Migration of assessment data to the ADB system is underway for lakes with assistance from Research Triangle Institute. Technical staff at RTI have indicated that the process of updating the Lake Assessment database to ADB will require more time than they had previously estimated.

ii) Conversion of the Water Quality Data Archive to a more powerful database handling system

Implementation of STORET by VTDEC necessitated converting the structure of the water quality data archive from a ~70,000 record "transposed" database to a ~350,000 record standard database. This database was completely redesigned to accommodate data requirements of STORET. The size of the archive is now considerably larger. The water quality data archive may be transferred to a more powerful system such as MS-SQL Server© or Oracle. There are advantages and drawbacks to SQL, and these will be evaluated prior to any major changes.

iii) STORET data submissions

The current VTDEC STORET archive is to be uploaded to the national STORET data warehouse on an annual basis. VTDEC's moved approximately 220,000 records to the national STORET archive for it's initial submission in December of 2003. As part of an on-going "network readiness grant," VTDEC has been investigating the feasibility of using the "network node" architecture to allow EPA to draw data as needed as opposed to performing submissions of STORET data to the national data warehouse. In order for this system to be implemented, an XML schema for STORET is needed, the development of which is incumbent on USEPA. VTDEC envisions this "node" as a means for facilitating future STORET data transfers. A major initiative will be required to migrate existing biomonitoring data to STORET, and build a routine data submission system. This will require resources of a biologist to consult on taxonomic code translations, a database technician to assist with data manipulations within VTDEC, and a qualified contractor to process the data into STORET.

iv) Development of pocket computer-based field data entry tools

Nearly all VTDEC-WQD monitoring projects rely on some form of field record-keeping on paper, including field sheets, calibrations, paper recording of GPS coordinates or custody forms, and similar activities. Considerable time is required to input these data into project-specific databases; a process that is both resource intensive and error-prone. Often, some of the data that are collected remain on paper field forms and never is input and used for analysis, even when it could yield useful insights into data trends. Recently, monitoring programs in VT and elsewhere have begun using pocket PC-based data entry forms to highly streamline the data acquisition, sample tracking, and information archiving. WQD staff have done this to a very low level of sophistication to date, owing to limited programming skills. WQD staff have, however, been provided examples of highly successful and sophisticated projects from Quebec waters adjacent to VT that took maximum advantage of small conputing technology. VTDEC should consider contracting the services of an IT firm who can develop data entry systems that interface with both the LIMS and WQData systems, as well as project-specific databases. Such a project should not exceed $20,000 in size, although it should in fact be significantly smaller.

7. Data Analysis and Assessment

A. Data Analysis

Specific procedures used to analyze project data are beyond the scope of this strategy. Project-specific data analysis approaches are commonly spelled out in QAPPs, although data analysis is often an adaptive task, where results of one analysis lead to subsequent analyses. For the purposes of use support assessment or enforcement, however, the following considerations regarding data quality and statistical analyses are relevant.

When used for assessment or enforcement, data employed must be of known quality and should be representative of the water's condition. All data generated in conjunction with any active and/or approved QAPP are considered readily available and reliable data, and are considered in determining use support. Data can be rejected from consideration in the event that it does not meet data quality objectives established by individual QAPPs. Guidance and assistance regarding quality assurance is also provided from the LaRosa Laboratory.

For data provided by organizations other than VTDEC and WQD, efforts are made to ascertain the quality of the data prior to considering it in the determination of use support. The number of samples, the length of the sampling period, the antecedent weather conditions, degree of compliance or violation, laboratory and field methods employed, quality assurance and control results are all considered when evaluating data from other organizations. Where data of unknown or unquantifiable quality are at odds with companion data of quantified quality, the higher quality data will be accorded greater weight in determining use support. Where data of unknown or suspect quality are the only information available, the waterbody is scheduled for additional monitoring prior to determining use support.

VTDEC has expertise in the use of non-parametric, parametric, and multivariate statistical methods. In most instances, it cannot be decided a-priori what type of statistical analysis may be used to assess use support, except for experimentally designed studies. For certain data types, long-term trend detection using linear, non-linear, or non-parametric regression approaches is appropriate. For designed studies aimed at determining the level of use support in an experimental framework (e.g., lakes that are likely to display elevated fish tissue mercury concentrations), parametric analyses of variance, covariance, and/or linear discriminant analysis are most appropriate. To classify waterbodies into meaningful biological groupings to compare biometrics to reference biological communities, linear discriminant analysis, principal components and factor analysis, canonical correspondence and non-metric multidimensional scaling analysis are appropriate. Simple T-tests and ANOVA tests are appropriate where data are being compared to a criterion value or to a set of reference waters. Consequently, these last two tests are more commonly or routinely performed during VTDEC assessment efforts. Where a statistically parametric method is used to evaluate hypotheses concerning standards attainment, consideration is accorded as to whether "attainment" is established as the null or alternative hypothesis.

VTDEC does not, on a unilateral basis, subscribe to the notion that a pre-determined proportion of samples exceeding a criterion value automatically equates to impairment, particularly where the total number of samples is low. The proportion of violations or frequency of exceedance in an array of data are treated and used by VTDEC on an individualized and case-specific basis to determine use support.

In general, VTDEC believes waters must be proven to be impaired, and thus statistical hypothesis tests, when necessary, are most often structured in that fashion. Nonetheless, in the interest of maintaining solidly defensible and repeatable use support decisions, where the cost of erroneous decisions is high, a decision call of impairment will be accorded to the null or alternate, depending on which test provides the greatest statistical power while maintaining the type-I error rate to a pre-established level (typically 5% to 10%).

B. Water Quality Assessment Methodology

i) Overall methodology

Overview and data sources

The assessment process involves identifying, compiling and evaluating all existing and readily available water quality data and information as well as evident point and nonpoint source pollution impacts on designated uses specific to the basins and waters being assessed in any given year. The data and other information are maintained in databases designed to be consistent with EPA's current Assessment Database package. Vermont relies on the following sources of data and information when assessing designated use support:

- VTDEC Water Quality Division (monitoring data)
- VTDEC Wastewater Management Division (National Point Source Discharge Elimination System permit compliance, indirect discharge permit compliance, residuals management)
- VTDEC Waste Management Division (solid and hazardous waste sites monitoring data)
- VTDEC Water Supply Division (compliance and sourcewater monitoring data and information)
- VTDEC Geology and Mineral Resources Division (fluvial and surficial mapping, hazard identification)
- VTDEC Laboratory Services at R.A. LaRosa Laboratory (quality assurance, analytical services, pollutant data)
- Vermont Agency of Natural Resources Enforcement Division (violations of water quality standards)
- Vermont Department of Fish & Wildlife (data on game fish and temperature, habitat studies)
- Vermont Department of Health (beach closure information, fish consumption risk assessments)
- Vermont Department of Forests, Parks, and Recreation (bacteriological testing, beach closure information)
- Vermont Agency of Agriculture, Food and Markets (agricultural water quality violations)
- Vermont Regional Planning Commissions (known locations of problems)
- US Department of Agriculture, Natural Resource Conservation Service (agricultural nonpoint sources, locations of pollution abatement projects)
- Citizens and citizen associations (citizen monitoring data, location of sources, complaints)
- US Geological Survey Water Resources Division (monitoring and research)
- US Forest Service (fish habitat and water quality data and information)
- US Environmental Protection Agency (monitoring and research)
- US Army Corps of Engineers (environmental assessments of project waters)
- University of Vermont, Vermont State Colleges System and other colleges (monitoring and research)

The VTDEC Biomonitoring and Aquatic Studies and River Management Sections provide much of the data used in the assessment of monitored river miles. The VTDEC Lakes and Ponds Management and Protection Section provides much of the data used in the assessment of monitored lake acres. The other sources noted immediately above provide fewer and less widespread, but nevertheless important, data points.

Biological monitoring and assessments

Assessment of biological integrity is conducted on the state's rivers and streams for the purpose of trend detection and site-specific impact evaluation. Macroinvertebrate and/or fish populations of rivers and streams considered to be "wadeable" are assessed by comparing a series of biometrics measuring community structure and function to a set of biocriteria that represent the biological potential for the ecoregion/habitat being evaluated. The biomonitoring activities carried out by VTDEC can be placed into three categories; 1)

long-term monitoring of reference level sites, 2) site-specific impact evaluations and 3) statewide probability-based surveys.

Individual site surveys and subsequent processing steps are detailed in *"Methods for Determining Aquatic Life Use Status in Selected Wadeable Streams Pursuant to Applicable Water Quality Management Objectives and Criteria for Aquatic Biota Found in Vermont Water Quality Standards (VWQS) Chapter 3 '3-01, as Well as Those Specified in 3-02(A1 and B3), 3-03(A1 and B3), and 3-04(A1 and B4:a-d."* (a.k.a. biocriteria procedure). Using the biocriteria procedure, the aquatic biota community inhabiting the sites in question is attributed a rank of excellent, good, fair, or poor.

The biological potential for various sites is established through long-term reference site monitoring. Information from this program element also serves to refine existing biocriteria and detect trends in baseline biological integrity. The long-term goal of reference site monitoring is gather information on a set of known reference sites on a 5-year rotating basis, so as to generate five years of continuous data for each site. Sites are stratified across stream ecotypes differing in drainage area size, elevation, and alkalinity. Human activity in reference site drainages is judged to be minimal relative to other streams in the ecoregion.

Where site-specific impact assessments are conducted (along with appropriate chemical and physical data), potential pollution sources that are not of natural origin are spatially bracketed (i.e. above and below) with sample sites to determine effects on the aquatic biota attributable to the pollution source. Either macroinvertebrate or fish populations or both may be sampled. Approximately 50 river sites are assessed each year in the late summer-early fall (September to October 15) on a five-year rotational watershed basis. VTDEC has evaluated over 1,200 sites since 1990.

Until recently, very little biological assessment data has been available for lakes, except for a rather comprehensive, long-term database describing the distribution of aquatic macrophytes in lakes. Past assessments often relied on qualitative observations of habitat conditions, in some cases using the aquatic macrophyte data. VTDEC, with cooperative funding from USEPA, is now finalizing a multi-metric biological index based on phytoplankton communities, and is also developing a multi-metric index to describe the condition of macroinvertebrate communities within lakes. It is anticipated that future aquatic life use assessments will be more directly based on biological data for phytoplankton, macrophyte, and macroinvertebrate assemblages. Where data are available, results of phytoplankton, macrophyte, and macroinvertebrate community assessments are being incorporated into the assessments of individual lakes. As part of the cooperative agreement with USEPA, a lake biological criteria implementation procedure should be finalized as early as 2005. Macroinvertebrate and amphibian community indices are also currently being evaluated for use as biomonitors of aquatic life use support for wetlands.

Stream geomorphic assessment

Data collected during stream geomorphic assessments according to recognized procedures: provide a better understanding of the physical processes and features shaping a watershed; help characterize erosion and flood hazards; help identify high quality habitat; and contribute to understanding the effects of watershed land use activities on stream condition.

The Vermont DEC stream geomorphic assessment program objectives are:

1) To create a data collection protocol for the physical assessment of streams and rivers that is scientifically sound and produces repeatable results, so that data can be compared not only within a watershed, but also between watersheds and regions.
2) To create a state Geographic Information System (GIS) and database system of fluvial geomorphic data that is accessible to users inside and outside the Agency of Natural Resources.

3) To create a method for predicting stream channel and flood plain evolution in Vermont that will technically support the resolution of river/land use conflicts and allow for sound land use practices and planning at the watershed scale.
4) To create a river assessment methodology that will help lay people understand how human activities over time within a watershed can be conducted in a manner that is both ecologically and economically sustainable.

The Vermont Stream Geomorphic Assessment protocols help river planners and managers take the first steps in applying channel form, adjustment process, and channel evolution data by providing a method for assigning a geomorphic and physical habitat condition to stream reaches. The term "departure from reference" is used synonymously with stream geomorphic condition throughout the protocols. The degree of departure is captured by the following three terms:

In Regime – a stream reach in *reference and good* condition that:

- Is in dynamic equilibrium which involves localized change to its shape or location while maintaining the fluvial processes and functions of its watershed over time and within the range of natural variability; and
- Provides high quality aquatic and riparian habitat with persistent bed features and channel forms that experience periodic disturbance as a result of erosion, deposition, and woody debris.

In Adjustment – a stream reach in *fair* condition that:

- Has experienced changes in channel form and fluvial processes outside the expected range of natural variability; may be poised for additional adjustment with future flooding or changes in watershed inputs that would change the stream type; and
- Provides aquatic and riparian habitat that may lack certain bed features and channel forms due to increases or decreases in the rate of erosion and deposition-related processes.

Active Adjustment and Stream Type Departure – a stream reach in *poor* condition that:

- Is experiencing adjustment outside the expected range of natural variability; is exhibiting a new stream type; is expected to continue to adjust, either evolving back to the historic reference stream type or to a new stream type consistent with watershed inputs; and
- Provides aquatic and riparian habitat that lacks certain bed features and channel forms due to substantial increases or decreases in the rate of erosion and deposition-related processes. Habitat features may be frequently disturbed beyond the range of many species' adaptability.

Phase 1 of the protocols is the remote sensing phase and involves the collection of data from topographic maps and aerial photographs, from existing studies, and from very limited field studies, called "windshield surveys." Geomorphic reaches and provisional reference stream types are established based on valley land forms and their geology. Predictions of channel condition (departure from reference), adjustment process, and reach sensitivity are based on evaluations of watershed and river corridor land use and channel and floodplain modifications.

Phase 2 is the rapid field assessment phase and involves the collection of field data from measurements and observations at the reach or sub-reach (segment) scale. Existing stream types are established based on channel and floodplain cross-section and stream substrate measurements. Stream geomorphic condition, physical habitat condition, adjustment processes, reach sensitivity, and stage of channel evolution are based on a qualitative field evaluation of erosion and depositional processes, changes in channel and floodplain geometry, and riparian land use/land cover.

Phase 3 is the survey-level field assessment phase and involves the collection of detailed field measurements at the sub-reach or site scale. Existing stream types and adjustment processes are further detailed and

confirmed based on quantitative measurements of channel dimension, pattern, profile, and sediments. Phase 3 assessments are completed with field survey and other accurate measuring devices.

Data solicitation
In conjunction with the 2004 assessment process, VTDEC conducted a solicitation for data to further enhance the quantity and spatial coverage of water quality data and other information that is used in assessing surface waters. The solicitation for water quality data, issued as a press release, has also been posted to the WQD website (refer to http://www.vtwaterquality.org/cfm/notices/notices.cfm). The solicitation notice has also been posted on the web pages of VTDEC and the Vermont Agency of Natural Resources. The solicitation seeks data and information to be submitted on or before October 31, 2003 in order to be considered for the 2004 reporting cycle. Data and other information submitted after that date will be considered for the 2006 reporting cycle. VTDEC intends to continue similar notices in advance of future reporting efforts.

ii) Vermont surface water assessment categories

Vermont's rivers, streams, lakes, and ponds have been designated into "waterbodies" which serve as the cataloging units for the overall statewide assessment. Waterbodies are typically entire lakes, subwatersheds of river drainages or segments of major rivers. Using data that is quality assured along with other contextual information that is reliable, the Water Quality Division determines whether each waterbody meets or does not meet Vermont Water Quality Standards, and then places waters into one of four assessment categories, taking into account the waterbody classification and water management type. The four categories used in Vermont's surface water assessment are **full support, stressed, altered** and **impaired**.[1] Waters that support designated uses and meet Water Quality Standards are attributed to the full support or stressed categories. Waters that do not meet standards are placed into the altered or impaired category. Waters can also be put into an **unassessed** category. These assessment categories are described below.

Full support waters
This assessment category includes waters of high quality that meet all designated use support standards for the water's classification and water management type.

In Vermont, there are many smaller waters that are a lower priority for sampling visits given resource constraints, lack of public access or interest, and competing needs within VTDEC's water quality monitoring program. VTDEC therefore makes preliminary assessments, where practical, by considering five factors that address the likelihood that significant stressors exist within the subject watershed. Waters that meet these factors are then considered to support their uses (e.g., the waters are "innocent until proven guilty"). The factors VTDEC uses to develop preliminary, screening-level assessments for these waters are:

- no discharges or contaminated sites in proximity to the waterbody;
- low probability of habitat degradation as evaluated by "Phase One" geomorphic assessments or other remote sensing evaluations;
- nearby sites have biological assessment findings compliant with Vermont Water Quality Standards, for like class and water management type;
- no problems are uncovered during outreach efforts associated with the rotational assessment process and basin planning; and
- no known water level manipulations beyond the natural range of fluctuation.

[1] The four assessment categories formerly used by VTDEC prior to 2004 were known as full support, full support/threatened, partial support, and non-support. The new categories are not directly equivalent to the four categories used in former assessments.

Stressed waters
These are waters that fully support the designated uses for the classification but the water quality and/or aquatic habitat have been disturbed to some degree by adjacent land uses or some human-induced stressor. For stressed waters EITHER there is insufficient data or documentation to determine water quality or aquatic habitat does not meet standards OR the data/information that is available indicates there are disturbances which are stressing the aquatic system but not to a point of altering or impairing it. Uses are not significantly limited or restricted but occasional water quality or quantity conditions and/or associated habitat disturbance periodically discourage or disrupt a use.

This assessment category includes some of the waters in the formerly used category known as "full support/threatened" with the most imminent threats. This category also captures many of those waters in the formerly used category "partial support – evaluated" that included waters where there were clearly problems and disturbances or uses discouraged, but reliable or recent data were not available. Waters that are labeled stressed because of documented disturbances or impacts but the degree of the problem or impact is not known would be characterized as needing further assessment.

Altered waters
These are waters where a lack of flow, water level or flow fluctuations, modified hydrology, physical channel alterations, documented channel degradation or stream type change occurs and arises from some human activity, or where exotic species growth has had negative impacts on the aquatic habitat. The aquatic communities are understood to be altered from the expected stable ecological state.

This assessment category includes those waters where there is a documentation of water quality standards violations for flow and aquatic habitat but EPA does not consider the problem(s) caused by a pollutant OR there are no specific criteria in the Water Quality Standards against which to judge the alterations that have been documented using accepted protocols.

Impaired waters
These are surface waters where there are chemical, physical and/or biological data collected from quality assured and reliable monitoring efforts that reveal 1) an ongoing violation of one or more of the criteria in the Water Quality Standards; 2) one or more pollutants cause of the violation; and 3) the pollutant is of human origin and cannot be attributed to a natural condition or event. These are waters that have been in the formerly used "partial or non-support - monitored" category.

Unassessed waters
Waters for which VTDEC has no monitoring data and only limited information and knowledge is available are considered unassessed.

iii) Guidelines for the assessment of use support

The complete Vermont Surface Water Assessment and Listing Methodology is provided at http://www.anr.state.vt.us/dec/waterq/planning/docs/pl_assessmethod.pdf. This document is updated biennially and undergoes separate USEPA review. As such, it is referenced herein but maintained separately.

C. TMDL Listing Methodology

The complete Vermont Surface Water Assessment and Listing Methodology is provided at http://www.anr.state.vt.us/dec/waterq/planning/docs/pl_assessmethod.pdf. This document is updated biennially and undergoes separate USEPA review and public comment. As such, it is referenced herein but maintained separately.

D. Recommendations and Strategies

To date, every 305(b) water quality assessment and subsequent 303(d) listing have been produced using subtly differing assessment and listing methods. These method changes in many cases have been the result of changes in guidance from USEPA, but also to a lesser degree are attributable to changes in Vermont's Water Quality Standards.

The 2004 data analysis and assessment and listing methodologies represent the newest thinking of VTDEC on these subjects. These methods are intended to be used for the 2004 and subsequent assessment and listing cycles. Reports and lists will be produced from these methods as described in Section 8. Owing to the ever changing nature of reporting guidance as well as continual improvements to Vermont's assessments, comparisons across prior years' statewide water quality assessments cannot be made with consistency. Accordingly, the recommended overall strategy for Vermont's new assessment and listing methods is that assessment methods be standardized for a period of at least three listing cycles. So doing will permit intercomparisons among subsequent biennial reports.

8. Reporting

A. The Basin Planning Process, Watershed Assessment Reports and Basin Plans

Vermont's WQS establish the requirement to develop basin plans that address water quality maintenance and improvement, for the 17 planning basins discussed in Section 3.A. The basin planning process empowers people with information and tools, and provides focus for activities to protect and restore water quality. A basin plan may, for example, give special attention to protecting particularly high quality waters or restoring habitat or other important impaired water resources.

This process begins with the preparation of assessment reports. As assessments are completed for waters within individual basins, reports are prepared summarizing findings of each assessment. These documents are prepared by assessment program staff in consultation with field professionals familiar with the basin in question. Watershed assessment reports contain sections addressing special water features, summaries of sampling locations and dams, and summaries of use support and pollutant or stressor cause/source combinations for rivers and lakes and wetlands. Assessment reports also identify waterbodies that are considered stressed or altered by non-pollutants, or that merit protection owing to some significant natural feature or attribute. These reports contain recommendations for additional monitoring, as well as initial recommendations for waterbody reclassification. Assessment reports are prepared approximately every five years, and are intended to provide initial information to develop basin plans through Vermont's basin planning process.

A committee, comprised of representatives from industries and organizations across Vermont, has created a framework for basin planning. Adhering to the framework assures that local interests drive the planning process, that the most important issues rise are addressed, that planning leads to action and that the process is inclusive of many interests and points of view.

The basin planning process focuses on the big picture. It concentrates on issues of basinwide importance where cooperation among municipalities, private organizations and branches of state government can be effective in protecting, restoring or enhancing water quality. The process takes maximum advantage of existing planning processes that relate to the management of our state's waters. It identifies existing local organizations (authorized by law to undertake planning) in each basin to establish advisory committees that will foster continuing basin planning, collaboration and communication among all basin stakeholders. The local organizations and their advisory committees advise the Agency of Natural Resources on all elements of a basin plan.

A basin plan is prepared approximately every five years. It summarizes current and past assessment, planning, and implementation activities. It integrates topics of local importance with topics of state importance, and makes management recommendations on these topics. It updates previous water quality plans. A basin plan is not encyclopedic. It calls out areas where attention is appropriate. It presents the key elements of the basin planning process and describes the ongoing actions of many individuals and organizations. It focuses on surface waters, recognizing that a complete and separate process exists for ground water protection. It takes into account the findings contained in the Vermont Water Quality Report (305 b) and other pertinent documents.

A basin plan must be considered in the issuance of permits by the Federal Energy Regulatory Commission, and National Pollutant Discharge Elimination System permits must be consistent with basin plans. The plans may give guidance to Act 250 permitting, regional planning, and municipal planning and zoning. A basin plan also identifies a "continuing planning process" within each basin, including individuals and organizations who can carry out the process. It recommends incentives to ensure a continuing basin planning process and the implementation of recommendations contained in the Plan.

All elements of the basin planning process include public involvement. Public opinion is consulted through meetings, mailings, newspaper and web notices, interviews and contact with community groups. Draft basin plans are made available to interested parties for comment during the year in which it is prepared. Examples of current basin plans and information regarding developing plans is available at www.vtwaterquality.org/planning.htm.

B. Integrated Assessment Reporting

i) Reporting for Clean Water Act section 305(b)

VTDEC-Water Quality Division prepares statewide water quality assessment reports biennially, in fulfillment of §305(b) of the Clean Water Act. These statewide assessment reports are statewide in scope. VTDEC always strives to produce reports that are concise, timely, and provide useful information for Vermont's citizenry. Biennial "305(b)" reports provide an opportunity to highlight Vermont's concerns to USEPA and other federal agencies interested in water quality management. VTDEC will continue to issue reports in this light. VTDEC also is continually modifying the outline and content of the "305(b)" report to reflect changing USEPA guidance. Vermont's "305(b)" reports are typically submitted to USEPA every April of even-numbered years. Vermont's "305(b)" reports from 1998 on are available online at www.vtwaterquality.org/resources.htm. Also, in compliance with new USEPA guidance, VTDEC will submit to USEPA annual updates of Vermont's assessment database and STORET data archive every April.

ii) Listing for state prioritization and for Clean Water Act section 303(d)

VTDEC also prepares lists of priority and impaired waters on a biennial basis. The Impaired Waters List, or "303(d)" list, will be submitted to USEPA every April of even-numbered years. VTDEC has customarily provided USEPA copies of the other components of the Vermont Priority Waters List. VTDEC publishes the Vermont Priority Waters Listing and "303(d)" list online at www.vtwaterquality.org/planning.htm. VTDEC favors reporting waters within Parts A through G of the Vermont priority waters over USEPA's newly suggested Categories one through five. The Vermont Priority Waters List contains a table that permits comparison of the two categorization schemes, and this is also shown in Section 7C above. For the 2006 Integrated Report, VT will strive to provide listings following both categorization schemes.

C. TMDLs

Part A of the Vermont Priority Waters List identifies those impaired waters in need of TMDL development, and provides a schedule for TMDL development. VTDEC strives to prepare all TMDLs within the scheduled time. TMDL pollution control plans are prepared according to USEPA guidance that is in effect at the time the TMDL is drafted.

D. Recommendations

For consistency and predictability in the integrated reporting process, the process of 305(b) reporting and 303(d) listing should become part of the same process, due April of even-numbered years. This is the direction of current USEPA guidance, and also the current approach VTDEC has taken since the 2004 listing cycle. VT will evaluate reporting assessments using both the EPA and VT listing categorization schemes.

9. Periodic Review of this Monitoring Program

A. Annual Review

VTDEC will annually review progress in monitoring waters in light of the recommendations contained in the present strategy. At that time, priorities for the coming year may be readjusted based on availability of resources and/or competing needs for monitoring information. As part of ongoing Quality Management Planning, the quality assurance project plan archive is updated annually, and individual QAPP's are scheduled for revision at that time. The LaRosa Laboratory undergoes annual quality assurance assessment, biennial performance audits, and routine quality assessments consistent with its *National Environmental Laboratory Accreditation Conference* status as an accredited laboratory. Individual S.O.P.'s for monitoring will be updated annually as needed. Additional funding needs will be identified at this time.

B. Mid-stream Gap Analysis

Since the present strategy has a ten-year lifespan, it will be beneficial to revisit recommendations at the midpoint of its implementation, approximately 2010. At this time, recommendations that have not yet been implemented can be reprioritized in relation to available resources. This is also a good time to evaluate the need for revisions to the larger programmatic QAPPs (e.g. Biomonitoring and Lake Assessment Programs), revise the Field Methods Manual of S.O.P.s, and review the assessment methodology. The gap analysis can be undertaken sooner in the event that organizational changes necessitate changes in the strategy.

10. General Support and Infrastructure Planning

A. Program Support

i) Field monitoring

The current field monitoring program elaborated in Section 3.B currently requires approximately 12 full time equivalents (FTE) of staff time. At this level of support, the monitoring program is functional, but inflexible. Unanticipated high-priority monitoring needs and/or underfunded participation in larger-scale monitoring projects can result in loss of core program functionality at this staffing level. Complete implementation of the standard monitoring activities along with high-profile and needs projects such as stormwater-impaired waterbody monitoring, and development of monitoring systems for wetlands is presently beyond the scope of monitoring staff resources.

ii) Laboratory services

VTDEC no longer assesses laboratory charges to individual programs on a fee-for-test basis. Beginning in 2003, VTDEC began levying an annual laboratory assessment on each division that uses the LaRosa laboratory. This mechanism allows divisions to access all of the laboratory services necessary to meet current needs. This is a major departure from prior practices, and provides tremendous flexibility to fulfill this monitoring program strategy. Annual assessments to individual divisions are approximately proportionate to each division's overall lab services usage. The Water Quality Division, the group largely responsible for implementing this monitoring program strategy, is assessed approximately $250,000 annually (2005 value), and this value will increase with inflation over time. Using this approach to compensation of the laboratory, the vast majority of analytical services required to fulfill the current monitoring program are presently met by the LaRosa facility. It is critical that funds remain available to individual divisions, and particularly within the Water Quality Division budget, to accommodate the annual laboratory services assessments.

iii) Assessment, listing, and reporting

The current assessment and listing functions outlined in Section 7 are supported within VTDEC at approximately three FTE. The current reporting functions are supported at approximately ¾ FTE. These levels are insufficient to fulfill all of the assessment and reporting requirements outlined in this strategy, and this shortfall is most notably observed in assessment functions. Assessment staff resources are insufficient to produce basinwide assessments at the rate envisioned by the 2000 Vermont Water Quality Standards and this strategy, while also meeting reporting requirements. However, basinwide assessments form the core of VTDEC's basin planning process, and they are critical to VTDEC for sound watershed management. The shortfall in assessment resources is partly attributable to increasing requirements within continually-updating federal guidance on minimally acceptable assessment practices, listing and reporting requirements. For example, during the 2004 reporting period alone, fulfillment of all guidance elements regarding Integrated Reporting and monitoring program strategy development imposed numerous unanticipated tasks. These have reduced the ability of assessment staff to produce basinwide assessments in a reasonable timeframe. There exists the need for one additional assessment staff to assist in assessment reporting and ADB conversions.

iv) Information management

There is currently approximately one FTE allocated to information technology needs associated with this strategy; a level which is likely to decrease significantly in response to changes in information technology management at the Agency of Natural Resources level. This will result in database maintenance and design activities being pushed down to the project-level within the Water Quality Division and other Divisions of VTDEC. In terms of proper data management and metadata qualification, this is dangerous, as database skills vary very widely among individuals at the project management level. While Vermont's information

management system for monitoring and assessment data is fully functional, this may change dramatically in the next few years as these changes are put into place. The need for rigorous data management approaches and tools will only increase as the level of scrutiny over data used to make environmental management decisions increases.

v) Monitoring and assessment program planning and other functions

Planning for future years monitoring and assessment priorities occupies no more than one and one half FTE, including in-house staffing for TMDL pollution planning. Quality assurance and water quality standards planning also requires significant staff-time, although an estimate of annual FTE's associated with these functions are not available.

B. Projected Infrastructure Needs

i) Staffing

In order to continue the core monitoring program, stable support is necessary. A particular need exists for temporary technical staff to fulfill field-season monitoring activities, and VTDEC funding for short-term field staff has been unpredictable and tight in recent years. Two additional long-term technician level staff or a commitment to support several short-term temporary staff members ("summer technicians") are necessary to ensure long-term implementation of the core monitoring program described by Section 3.B. One additional professional-level FTE is necessary to meet recommendations related to Objectives 2B-D in Section 3.D.

If assessment functions are to proceed at the pace envisioned by this strategy over the long-term, one additional FTE should be allocated towards the assessment process, specifically to maintain assessment databases and assist in the preparation of basinwide assessment reports.

ii) Laboratory resources

Laboratory services currently support the needs of the present monitoring program strategy well. A long-term commitment to implementation of this strategy will necessitate that laboratory equipment is upgraded as necessary, in keeping with advances in analytical chemistry. As stated above (section 3.B), the LaRosa facility is well equipped. Additional equipment purchases that would enhance the ability of VTDEC to implement this strategy include a second (parallel) nutrient autoanalyzer, a carbon autoanalyzer, a freeze-drier, and implementation of a trace-metals clean work area to permit low-level analyses for methylmercury. Additional analytical capabilities that would benefit this strategy include dioxins/furans and poly-brominated diphenyl-ethers.

iii) Information technology resources

Information technology resources are presently just adequate to meet the needs of this strategy. However, retirements and or other changes in information technology staffing will result in the need to enhance support to data archiving and assessment data maintenance, if data integrity and quality are to be maintained. Accordingly, one FTE of information technology support will be needed by 2007 to continue support of this strategy. Also, site licenses for functional GIS software should be available to each staff member working on assessment of water quality data.

iv) Combined roster of unmet staffing and project needs

Please refer to the executive summary for projected staffing/funding needs to accomplish all elements of this Water Quality Monitoring Program Strategy

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