

**Atmospheric Deposition in the Lake Champlain Basin:  
Research Plan and Workshop Proceedings**

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## Executive Summary

The Lake Champlain Basin is located within the Great Lakes-St. Lawrence drainage system and extends over 8,234 mi<sup>2</sup> of largely forested (72.1%) and agricultural lands (16.9%). It is home to over 608,000 people. Overall, the economic worth of the Basin was estimated at \$9.1 billion in 1992, of which \$2.2 billion was tourism related and, of that, 40% (\$880 million) was Lake-related. Over 34% of the population in the basin depends directly on Lake Champlain for drinking water and an estimated 16,400 people in New York and Vermont alone depend directly on Lake-related tourism jobs.

Declines in forest health and water quality due to the long-term impacts and interactions of acid deposition and climate change and increasing concerns about mercury contamination of sport fish, threaten to negatively affect both quality of life and economic prospects for the region. Atmospheric pollutants from local, regional and global sources, such as coal-fired power plants, smelters, and urban centers, pose a threat both directly and through bioaccumulation. There is thus clear need to quantify the fate and transport of these pollutants into the basin, determine their various sources, characterize their fate and movement through the terrestrial and aquatic environments and assess their potential impact on human, ecosystem and economic health.

A framework for a five-year strategic research plan (2004 – 2009) is presented that addresses atmospheric deposition issues in the Lake Champlain basin in the context of known and anticipated funding opportunities. The prioritized goals and recommendations outlined were reached by a consensus of scientists, program managers and policy representatives at a workshop sponsored by the National Sea Grant Office and conducted by the NOAA Air Resources Laboratory and Lake Champlain Sea Grant, June 5-6, 2003 in Burlington, VT. The recommendations of this report were developed from the workshop which produced a snapshot of the status of research and monitoring in the basin.

The overall goal of this research plan is to quantify the annual atmospheric deposition of mercury, major inorganic ions (sulfate, oxidized and reduced nitrogen), and selected toxins within the Lake Champlain watershed. This program will support the subsequent development of a pollutant budget for Lake Champlain. The plan outlines specific research objectives and a suggested framework to coordinate sampling, quality control, and data management and distribution activities to foster integration and collaboration among interested parties. Specific objectives that will contribute to these goals include:

- Development of a framework for coordination of activities among participants in atmospheric research and monitoring, with links to the user community in the basin and region,
- Continuation of current long-term atmospheric and meteorological monitoring activities,
- Upgrading and amendment of existing monitoring activities to improve spatial, temporal and species characterizations to support fate and transport model development and application,
- Coupling of monitoring and modeling activities to project annual deposition rates of measured pollutants for the watershed as a whole,
- Modeling of fate and transport of measured pollutants and linkage of products to comprehensive basin wide research programs, and
- Development of outreach efforts to improve understanding by decision makers, the scientific community and the public of the value of atmospheric deposition research and monitoring activities, and their contribution to the protection of human and environmental health in the basin.

Given the complex and logistical challenges inherent in these goals and objectives, success in meeting them will depend upon a multi-program, multi-disciplinary approach that integrates measurement and modeling efforts. The focus provided by this plan will improve coordination of ongoing federal, state and local atmospheric research programs operating within the basin to better utilize funding opportunities, available data and other limited resources and foster better interactions between atmospheric research and monitoring activities and related research. An indicator of collaboration will be future programmatic requests for proposals that reflect the focus and research agenda outlined by this plan.

### **Acknowledgements**

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Holmes and Associates and A. Artuso. 1996. Economic analysis of the draft final plan for the Lake Champlain Management Conference. Lake Champlain Basin Program, Grand Isle, VT. 72 pages.

## Research Plan

### *A. Introduction*

Declines in forest health and water quality threaten both quality of life and economic prospects within the Lake Champlain Basin and surrounding region (Figure 1). Concerns over the long-term impacts and interactions of acid and nutrient deposition, climate change, and mercury contamination in the environment are major issues requiring improved understanding and clear policy directives. These issues have initiated debate among governments and the public bringing focus to the numerous implications of the trans-political boundary transport and deposition of pollutants by atmospheric processes.

To address these issues, various environmental monitoring programs have been initiated over the past two decades by federal, state and local organizations. Each of these programs was designed to determine and ultimately predict the response of terrestrial and aquatic ecosystems to environmental perturbations posed by atmospheric deposition. Such efforts were directed toward the identification of pollutant source areas, assessments of the need for or effectiveness of emissions controls, and assessment of the ecological and economic impact of such controls. As has been the case in many locations, decision making and development of effects-based environmental policy has been dependent upon such programs [Finnish Environmental Institute, 2004; Johnson and Lindberg, 1992, Moldan and Cerny, 1994]. However, as with many mature programs, changes in programmatic focus, paucity of funding, uneven data quality and limited coordination between programs has compromised the success of these efforts. Intermittent or short-term monitoring efforts will not provide the required information at appropriate spatial or temporal scales required to distinguish natural from anthropogenic induced effects.

The prioritized goals and recommendations outlined below were developed through consensus by scientists, program managers and policy representatives at a workshop sponsored by the NOAA National Sea Grant Program and facilitated by the NOAA Air Resources Laboratory and the Lake Champlain Sea Grant program, June 5-6, 2003 in Burlington, VT. The recommendations of this report were developed from a snapshot of the status of research and monitoring in the basin as presented during the workshop. A framework of a five-year strategic research plan (2004 – 2009) that addresses atmospheric deposition issues in the Lake Champlain Basin in the context of known and anticipated funding opportunities is presented.

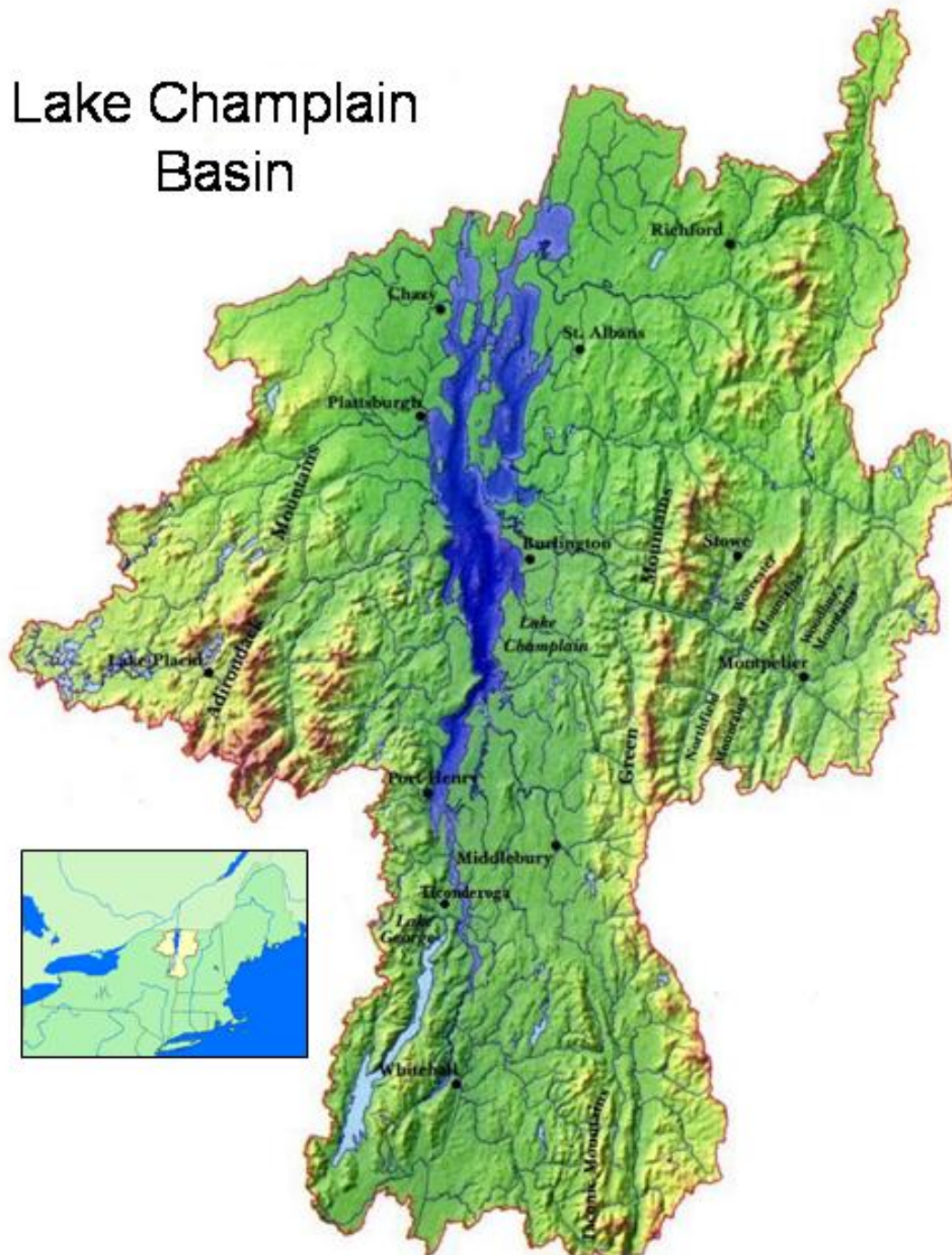
To support development of regional policy to regulate emissions of anthropogenic pollutants, the primary recommendation of the workshop participants was to develop an integrated research and outreach program to address perceived impacts on human, ecosystem, and economic health in the Lake Champlain Basin. To be effective, the program must quantify the input of atmospheric pollutants into the basin, determine their various sources, and characterize their fate and movement through the terrestrial and aquatic environments. The main intent of this strategic plan is to provide focus, illicit commitment, and foster integration of efforts between federal, state and local programs to achieve this goal.

The scope of the resultant effort is clearly resource dependent. The specific objectives recommended in the research plan are prioritized based on their scientific merit and probability of success in view of known and anticipated funding sources and commitments as of June 2003. Although the scope of the proposed plan is beyond currently available resources, many of the objectives outlined already benefit from funding or other direct support from one or more of the various organizations committed to the plan. Preliminary commitment of resources by the participating organizations made at the June 2003 Workshop must still be formalized. Remaining resource gaps will be addressed by seeking funding through programmatic and competitive

sources as opportunities present. A formal Steering Committee composed of representatives of the various participating organizations will assume the responsibilities of periodically re-examining priorities, coordinating resource needs, recommending potential sources of funding, and formalizing an implementation plan.

A successful program will require the development of reliable, long-term datasets measuring the deposition, transport and fate of pollutants within the Lake Champlain watershed. Additionally, the development, validation and application of models are required to extend these data over temporal and spatial scales and environmental scenarios beyond that observed. The research plan outlined addresses each of these components, although the primary focus is on monitoring and modeling atmospheric deposition of selected pollutants across the basin. Pending success in meeting the project goals, this program should be well positioned to address regional and policy decision assessments, thus better meeting the needs of regional and international policy makers.

Figure 1. The Lake Champlain Basin.



## ***B. Goals and Objectives***

The goal of this research plan is to quantify the annual atmospheric deposition of mercury, major inorganic ions (sulfate, oxidized and reduced nitrogen), and selected toxins within the Lake Champlain watershed to support the subsequent development of a pollutant budget for Lake Champlain. The plan outlines prioritized research objectives and a suggested framework to coordinate sampling, quality control, and data management and distribution activities to foster integration and synergy amongst the participating projects and communication with the public. Specific objectives that will contribute to these goals are as follows:

- Develop a framework for coordination of activities among participants in atmospheric research and monitoring, with links to the user community in the basin and region,
- Continue current long-term atmospheric monitoring activities,
- Upgrade and amend existing monitoring activities to improve spatial, temporal and species characterizations to support fate and transport model development and application,
- Couple monitoring and modeling activities to project annual deposition rates of measured pollutants for the watershed as a whole,
- Model fate and transport of measured pollutants and link products to comprehensive basin wide research programs, and
- Develop outreach efforts to improve understanding by decision makers, the scientific community and the public of the value of atmospheric deposition research and monitoring activities, and their contribution to the protection of human and environmental health in the basin.

These goals, in turn, support state, federal and regional programmatic efforts to identify cost effective means to reduce pollution impacts on human and environmental health in the basin. For example, to accelerate reductions in mercury and acid deposition ahead of U.S. and Canadian federal policies, New England Governors and Eastern Canadian Premiers agreed upon reduction targets and set a framework for cooperation to support reduction efforts.

The primary focus and commitment of this program is to ensure and extend current long-term time series observations at a single or limited number of sites to support model development and validation. Secondary emphasis will address estimation of spatial variability across different landscape features to aid regional scale prediction efforts.

Implementation of this plan will significantly improve characterization of atmospheric deposition within the Lake Champlain Basin and surrounding region, contribute to development of improved models applicable to the region, and support dialog and decisions regarding current and proposed emission regulations. The focus provided by this plan also will improve coordination of ongoing federal, state and local atmospheric deposition research programs in the basin to better use staff, funds, data and other limited resources.

## ***Study Area***

Located within the Great Lakes-St. Lawrence drainage system, the Lake Champlain Basin (Figure 1) extends over 8,234 mi<sup>2</sup> of largely forested (72.1%) and agricultural lands (16.9%) and is home to over 608,000 people. Overall, the economic worth of the Basin was estimated at \$9.1 billion in 1992, of which \$2.2 billion was tourism related and, of that, 40% (\$880 million) was Lake-related. Over 34% of the population in the basin depends directly on Lake Champlain for drinking



water and an estimated 16,400 people in New York and Vermont alone depend directly on Lake-related tourism jobs [Holmes et al., 1996].

The Basin is a well defined watershed ecosystem, yet is large enough to encompass a diversity of land use/land cover and landscape features representative of northeastern environments. Results of this effort will provide a source of information for comparison over a broad range of temporal scales, as well as across elevation gradients, ecosystem and political boundaries.

### ***Mercury***

*Background:* Mercury is found in its elemental form and in various compounds and complexes throughout the environment. Its use in many products and its emission from combustion processes has resulted in worldwide, elevated concentrations above that of pre-industrial levels. Methylmercury, in particular, is a human and environmental health concern because of its toxicity and ability to accumulate in fish and wildlife. Human consumption of predatory fish containing high concentrations of methylmercury can result in an increased risk of health problems, particularly in children and women of child-bearing age [National Academy of Sciences, 2002; EPA, 2004]. Waterfowl and other wildlife populations that consume mercury-laden fish similarly are at risk [Environment Canada, 2004]. The concern for human health is evidenced by the number of fish consumption advisories in effect throughout the northeastern U.S. and Canada and in the legislative actions by Vermont and Canadian Provinces to reduce local sources of mercury. Mercury based fish consumption advisories constrain sports fishing and fish consumption throughout the Lake Champlain Basin. It is, therefore, important to understand mercury deposition pathways, transport and accumulation in the Basin to protect human and environmental health.

Research on the atmospheric deposition of mercury in the Lake Champlain basin began in 1992 at the Proctor Maple Research Center (PMRC) near Underhill, VT. Sponsored by NOAA, through the Lake Champlain Research Consortium, and EPA in collaboration with the Universities of Vermont and Michigan, and the Vermont Monitoring Cooperative, the station has maintained a near-continuous event-based record of mercury in precipitation and a long standing weekly record of mercury vapor and mercury in aerosol particulates [Scherbatskoy and Keeler, 1996; Scherbatskoy et al., 1997]. These data have confirmed that a) atmospheric deposition is the primary mechanism of mercury input into the Lake Champlain drainage system and b) that improved characterization of wet and dry deposition processes is essential to understand total atmospheric mercury input. These data have supported a variety of investigations on the fate and transport of mercury in terrestrial and aquatic environments throughout the basin [Gao et al., *in press*; Shanley et al., 1999]. In addition, event-based sampling has allowed investigators to relate the mercury concentration patterns in individual storms to specific air mass trajectories, leading to more accurate identification of the geographic source areas of atmospheric emissions [Poirot et al., 1999]. In turn, these results have supported positions taken by the Vermont Agency of Natural Resources, the state legislature, and the Governor's Task Force on Mercury to initiate actions on mercury to safeguard natural resources and human health.

*Issues:* Survival of the Underhill site and its long-term, continuous data record have been threatened by gaps in funding, funding distribution, and programmatic issues related to funding of long-term monitoring efforts. Funding gaps also affect data analyses, data distribution and communications, and pose a serious threat to the integrity of the data record.

Following re-direction of funds by the LCRC in 2000, the Vermont Monitoring Cooperative and the University of Michigan continued comprehensive mercury sampling at the PMRC site. The collected wet and mercury vapor samples were stored and await analysis pending availability of

funds to complete this task. Loss of funding in 2000 also resulted in the termination of the particulate measurement part of the program.

*Objectives:* Comprehensive information on mercury loading from all sources is essential to understand mercury transport and fate into and within the basin. The following prioritized objectives address the atmospheric component of this effort in the context of data issues and funding opportunities at this time as identified through consensus by workshop participants. However, it is recognized that mercury science and related measurement technologies are rapidly evolving. As such, present research objectives and priorities must be periodically re-evaluated and adjusted as new findings or funding opportunities present themselves.

1. Complete analysis of all stored samples from the PMRC site and publish the data as soon as possible.
2. Maintain the long-term, event-based record of mercury concentration in precipitation and routine measurement of total gas-phase mercury (TGM) in air at the PMRC site near Underhill, VT.
3. Continue current source-receptor and basin-wide mercury mass balance modeling efforts to further understanding of potential source areas and to develop an initial characterization of mercury movement from the watershed into Lake Champlain.
4. Characterize the temporal and spatial deposition of mercury in its various forms within the basin.
5. Estimate net speciated atmospheric mercury deposition for the entire basin using the PMRC observations linked to appropriate fate and transport models.

### ***Major Ions***

While the Clean Air Act of 1970 and subsequent Amendments of 1990 have measurably reduced sulfur emissions, ecosystem recovery in sensitive areas throughout the northeast has been much slower than expected and the evidence is building that full recovery is unlikely under current mandated emissions reductions. Atmospheric deposition of sulfur and nitrogen over the past 20 years has measurably altered soils, reduced the ability of sensitive ecosystems to recover the effects of acidification, and has contributed to a cascading series of adverse environmental effects not recognized in the early phases of research [Driscoll et al., 2001; Environment Canada, 2004]. Sensitive upper watershed ecosystems in the Lake Champlain Basin are under continued threat of acidification and deposition of airborne nutrients contributes to problems with alga blooms and eutrophication. In addition, mercury dynamics should be understood in conjunction with major ion cycling to help distinguish between regional sources and global background.

*Background:* The Vermont Monitoring Cooperative (VMC) has monitored wet deposition at the Proctor Maple Research Center site near Underhill, VT since 1980 under state and federal (National Atmospheric Deposition Program (NADP) and Atmospheric Integrated Research Monitoring Network (AIRMoN)) guidelines. Dry deposition under the NOAA AIRMoN program was also monitored from 1992 until April 2000 when funding was redirected by the LCRC. These efforts contributed to understanding of regional nutrient cycling, stream acidification, and source-receptor linkages in the basin [Scherbatskoy et al., 1999]. Numerous parallel ecosystem studies on cloud, stream and soil chemistries and forest ecosystem health make use of these data.

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Dr. Keeler of U. Michigan has agreed to complete analysis of all stored PMRC mercury samples and forward the complete data base (1992-present), along with supporting QA/QC information, to the VMC to be archived and made publicly accessible via the VMC web page.

*Issues:* Many studies demonstrate that deposition of atmospheric nitrogen oxides may lead to a wide range of deleterious environmental impacts to both terrestrial and aquatic ecosystems. Reliable estimates of total regional nutrient deposition are required to determine if the measures called for in the CAAA effectively protect ecosystem health. Comprehensive major ion sampling (wet, dry and cloud/fog deposition) must be maintained to meet these objectives. Activities associated with major ion monitoring programs within the basin should be linked, as appropriate, with national monitoring and assessment programs.

*Objectives:* Improved understanding and subsequent policy decisions regarding nutrient deposition in the basin support development of an improved estimate of total major ion deposition and establishment of a long term trends measurement program for the Lake Champlain watershed, Vermont and the northeast. Steps required to meet these objectives include:

1. Maintain existing precipitation chemistry sampling programs at the PMRC.
2. Establish a routine dry-deposition measurements program in coordination with the EPA CASTNET program
3. Continue current source-receptor modeling efforts.
4. Examine improved species characterizations for both wet and dry deposition programs.
5. Improve spatial and temporal characterizations of both wet and dry deposition. Present measurement programs at PMRC are insufficient to resolve many temporal and spatial resolution questions in the basin.
  - a. Characterization of temporal variability at the PMRC site using appropriate measurement technology and historical data.
  - b. Development of a regional data set with observations from PMRC and nearby sites in Québec, New York and Ontario.
  - c. Characterization of spatial variability in deposition within and between selected landscapes across the basin.
  - d. Consideration of development of a trace metal concentration measurement activity to better understand source receptor relationships within the basin.
6. Develop a plan to add the PMRC monitoring site to the existing EPA IMPROVE program.
7. Integrate atmospheric, hydrological and aquatic models to address deposition, fate and transport of major ions across the entire basin.
8. Consider extending the analysis suite to include trace metals and VOC's to support a full range of air quality and ecosystem loading programs.

### ***Toxins***

There are hundreds of new synthetic compounds introduced into the environment annually. Some of these compounds have important atmospheric transport pathways and bear on human health. Many of these substances appear in drinking water because they are not removed in standard treatment. Other materials may be taken up either by consumption of milk products or through ingestion of contaminated feed stock. In response to the need for improved monitoring of toxics in ambient air, the Vermont legislature established the Hazardous Air Contaminant Monitoring Program in 1993 with the goals to monitor the presence of air-borne hazardous contaminants,

identify their sources and assess the human health and ecological risks posed [Vermont ANR, 1998]. Continued vigilance of these potentially hazardous materials is needed to ensure their risk to human health is identified and their emissions regulated.

*Background:* Some expertise exists in the Lake Champlain basin to measure these compounds.

*Issues:* Present efforts to measure toxin deposition in the basin are haphazard and poorly coordinated, as is the case nationally.

*Objectives:*

1. Identify responsible agencies to examine existing PBT (persistent and bioaccumulative toxic) chemical measurement strategies and adapt appropriate measures for regional use. The strategies adopted must be consistent within the existing Great Lakes toxics program.
2. Develop a plan to add a Lake Champlain Basin site to the existing Great Lakes IADN (Integrated Atmospheric Deposition Network).

### ***Supporting data***

Various data are common and essential to each of the three research themes addressed in this plan, including site and basin characterizations (e.g., topography, land use / land cover, etc.), meteorological observations and other atmospheric data. Identification of data needs and subsequent acquisition, quality control, management and distribution of these data is a high priority need. The Vermont Monitoring Cooperative (VMC) will be a strong partner in coordinating this effort. The VMC currently collects and archives meteorological observations along a transect extending from Lake Champlain eastward over the summit of Mt. Mansfield. It also operates the PMRC monitoring site and is actively engaged in database development and data distribution.

## ***C. Data Management***

### ***Quality Assurance and Quality Control Guidelines***

Established standard operating procedures (SOP's) and strict quality control of all data acquisition and management activities is essential to the integrity of this program. The consensus among workshop participants was that program managers require peer-approved QA/QC plans for all data acquisition and database management activities as a condition of funding, and the implementation of procedures to ensure that proposed quality control measures are actually met.

To these ends, the VMC – which is already actively reviewing and updating its QA/QC plans for VMC-supported meteorological data -- may be a strong partner in aiding with final assessment of the adequacy of QA/QC plans for this project. QA/QC plans are critically important for both implementation as well as for the integrity of observational data associated with this research program from acquisition to distribution. The research plan will benefit from a standing QA/QC committee whose charter will be to review, prioritize and coordinate the implementation of all QA/QC plans in this project, assist in data quality assessments and recommend remedial action where needed. The committee will also serve as a forum for QA/QC discussion. In turn, the QA/QC committee will answer to an Atmospheric Steering Committee (described in the Project Coordination section below).

Suggested QA/QC guidelines should be based on well accepted protocols, such as EPA's protocols for atmospheric chemistry observations, and National Weather Service practices for meteorological observations. Metadata describing the source, history, calibration histories and quality of all data must be maintained, updated daily as necessary, made readily available to

potential users via a user-friendly web site, such as the new web pages being developed by the VMC, and must accompany all data distributions. In addition, measurement programs should participate in relevant inter-laboratory measurement comparisons and model evaluations within and outside the basin.

### ***Data and Database Management Guidelines***

Workshop participants broadly support establishment of a high-quality, peer-reviewed, distributed database that is user accessible via the web. If resources are available, the VMC will help coordinate data management and distribution activities related to this research plan and to integrate such actions with local, regional, and federal ongoing activities. Data stored at VMC and elsewhere will need to meet at least minimal QA/QC guidelines and are to be accessed via links transparent to the user to appropriate sites.

A partner, such as VMC, will lead the development of a data management and distribution plan for this project – a plan that incorporates existing data management guidelines of the participating agencies. Data integration, database management, and data distribution should be guided by NARSTO or similar protocols, e.g. federal Spatial Data Transfer Standards (SDTS). Key components of the data management plan must address how to archive near-real-time observations and associated metadata, data and metadata quality control, data integration, program investigator and public access, data archival and distribution formats, data products, schedule of activities, system maintenance, projected costs, etc. The plan will establish that only data that meet QA/QC requirements will be accepted or distributed. QA/QC and data management and distribution requirements, therefore, must be explicitly outlined to aid investigators and managers in allied or future research programs in the basin best manage their data to ensure integration or web access.

By consensus of the workshop participants and in view of ongoing activities, it is currently recommended that, if resources are available for the effort, the VMC should be the lead in proposing and establishing a database/data distribution management committee and initiate planning activities for this effort. Resources directed to VMC would allow the involvement of investigators, database and QA/QC managers in the development of this plan and coordinate efforts as appropriate with complementary regional and Canadian database activities. The resultant plan is to be submitted to the Atmospheric Steering Committee for approval.

We recognize that there will be costs associated with the planning and data management activities described above. The Atmospheric Steering Committee –including representatives from NOAA, the LCRC, EPA, the University of Vermont, the State of Vermont, and the VMC -- will continue to develop a budget for the cost of the proposed research activities and identify resources and means to access them.

### ***D. Program Coordination***

Coordination of federal, state, and local programs and of the various participating organizations is essential to the success of this research plan. To facilitate this coordination, an Atmospheric Steering Committee will be established whose charter will be to integrate resources and individual research efforts, facilitate communication between the various program managers and investigators, oversee activities of technical committees, and evaluate progress towards the proposed goals. The Steering Committee will have overall oversight and responsibility for the implementation of the research plan and for the integrity of the overall research program. Committee membership will include the participating program managers and outside experts in the atmospheric sciences. Programs that have demonstrated past commitment to atmospheric

deposition research or interest in collaborative research shall also be invited to participate in the Steering Committee. The Committee shall meet at least annually, concurrently with investigators.

The VT DEC and VMC are expected to play critical operational roles in program coordination, through their respective site operations, database management, outreach and ongoing facilitation activities. Because of their parallel but independent responsibilities, the VT DEC, VMC and the Atmospheric Steering Committee should closely coordinate their respective activities.

## ***E. Resources***

### ***Funding***

The funding demands of this research program will require close coordination of programmatic and operational base funding from various sources augmented by competitive funds. The coordination of available resources will be a major responsibility of the Steering Committee.

Programs seeking to participate in this research effort will demonstrate their commitment by prioritizing their respective activities and amending subsequent requests for proposals to explicitly reflect the prioritized goals set forth in this research plan (Section B). Participating organizations similarly will directly support or facilitate their investigators efforts to seek support for these goals.

Considerable progress towards coordination of resources has already begun. At the close of the June 2003 Workshop, formal commitments from several of the participating programs were being discussed or had been made.

### ***Participating organizations and points of contact***

The following programs have demonstrated their commitments in the past to atmospheric deposition research or to associated research addressing the environmental, economic or public health interests in the Lake Champlain Basin. Representatives of these organizations are invited to participate in the Steering Committee. Additional contact information is listed in Appendix A.

#### ***Local organizations and field based offices of national agencies***

- [Lake Champlain Basin Program, William Howland](#)
- [Lake Champlain Research Consortium, Tom Manley](#)
- [NOAA / Lake Champlain Sea Grant, Jurij Homziak](#)
- [Northeastern States Research Cooperative, Melody Burkins](#)
- [National Weather Service, Paul Sisson](#)
- Local universities
  - Dartmouth College, [Eric Miller](#)
  - St. Lawrence University, [Ning Gao](#)
  - University of Vermont, [Deane Wang](#)
- [USGS, Jamie Shanley](#)
- [Vermont Monitoring Cooperative, Melody Burkins](#)
- [VT DEC, Richard Valentinetti, Harold Garrabedian](#)

#### *National/International*

- [Environment Canada](#) / Atmospheric Environment Services, [Jeff Brook](#)
- [EPA / Office of Research & Development](#), [Alan Van Arsdale](#)
- [NOAA ARL](#), [Rick Artz](#)
- [NOAA Sea Grant](#), [Ron Baird](#)
- [University of Michigan Air Quality Laboratory](#), [Jerry Keeler](#)

#### ***Facilities and staff***

Access to and use of existing field sites, facilities, data, models and supporting infrastructures is essential. The VMC would again be a key partner as it currently operates the Underhill PMRC site in ongoing studies of major ion and mercury deposition and a meteorological network that extends from Lake Champlain to the eastern slopes of Mt. Mansfield. Co-located at the PMRC site, the VT DEC also conducts a variety of monitoring programs for ozone, aerosols and other hazardous airborne contaminants. The PMRC site is currently the central data collection point for atmospheric research and monitoring in the basin. Currently, site operations, field operations, and instrumentation and associated infrastructure and utilities are supported collaboratively by the VMC and the VT DEC. If resources are available for this project, continued commitment and coordination of staff and facilities between the VMC and the VT DEC will greatly facilitate the Atmospheric Steering Committee to meet research goals outlined in this plan. A final research and funding plan that recognizes that these organizations and the Steering Committee will benefit from working together is ideal.

#### ***F. Public Awareness, Outreach and Education***

Conveying the significance of atmospheric deposition research and its relationship to environmental, economic and public health issues is an essential component of this research plan. The general public, policy makers, terrestrial and aquatic managers, the basin research community and public health officials must be made aware of the importance and consequences of atmospheric deposition in the northeast and how this coordinated research program proposes to address this issue. In particular, it is essential the public be made aware that air-borne pollutants within the basin can have very serious local impacts and that the origins of these pollutants are both local and far distant from the basin.

Outreach efforts, must inform basin residents about origin, transport and fate of atmospheric pollutants in the Lake Champlain ecosystem, and the economic and environmental and human health consequences. Public outreach efforts should explain the goals of this research, emphasize the importance of monitoring and modeling to understanding pollutant origins and movement, and explain how this research contributes to reducing pollutant loading. Outreach will link atmospheric deposition research efforts to the many ongoing land use, hydrodynamic, toxicity, remote sensing and management activities that take place within the Lake Champlain basin.

Audiences and potential outreach products as resources allow are:

- Scientific and research community: data, peer reviewed publications, gray literature, technical presentations,
- Decision and policy makers: white papers, synoptic articles, testimony,

- Public health community: Tailored technical symposia and presentations, white papers,
- K-12 and university youth: educational products, site visits, and
- General public: print and electronic media, exhibits.

The VMC is already engaged in public outreach at various levels on forest health, meteorological and selected atmospheric issues within the basin. The VMC would be an obvious partnership to use to extend these efforts to include the research and findings of this research program. If resources were available, a coordinated outreach program would be developed among VMC, Lake Champlain Sea Grant and other organizations engaged in outreach in the basin. Participating investigators will be required to provide project abstracts, summary reports, data, and copies of resultant publications to the outreach program. This information will be used to develop materials for public awareness and outreach.

Developing graduate and undergraduate student interest in environmental studies, including atmospheric deposition, is an outreach objective. Investigators will be encouraged to incorporate students into their research projects where possible. Regional educational institutions will be encouraged to foster and facilitate such efforts.

### ***G. Outcome-based Evaluation***

Achieving the outcomes defined below will provide important measures of success for the proposed Lake Champlain atmospheric deposition research program.

#### *Science*

- Characterization of relevant sources of nutrients and toxic pollutants affecting the basin.
- Adequate measures of deposition of nutrients, toxic pollutants and acidifying compounds in the basin.
- Development of sufficient meteorological databases for the region.
- Development of fate and transport models for the basin for all pollutants of interest.
- Integration of atmospheric fate and transport model approaches with comprehensive environmental and human health studies in the basin.

#### *Program coordination and integration*

- Establishment of a working Steering Committee, technical committees addressing QA/QC and database management, and a framework for collaboration for participating institutions.
- Sufficient funding and other resources within participating institutions to accomplish the science objectives.
- A peer-reviewed VMC database and web site from which participating institutions and the public can readily access quality controlled data and associated metadata.
- Established benchmarks and milestones to measure progress and manage contributions of individuals and institutions to the overall goals.
- Joint US-Canada collaborative research.



## Outreach

Outreach activities will focus principally on pollutants with significant air transport pathways.

Outcomes will include:

- Definition of the target audiences (who, numbers, etc.) in the basin and how they receive information.
- Development of targeted materials for each audience.
- Feedback from audiences on outreach efforts to determine a change in knowledge, perception or change in behavior.
- Engagement of decision makers, public health or research community in research or policy initiatives addressing air transported pollutants.
- Participating institutions, as a unit, will participate in the national and regional policy debates on the reduction of mercury, major ion, and toxin depositions to the northeast.
- Contribution to improved legislation regulating emissions of the identified atmospheric pollutants.

## H. References

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## Appendices

### *Appendix A: Workshop Participants*

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***Appendix B: Workshop Announcement***

**WORKSHOP**

***Atmospheric Deposition  
in the Lake Champlain Basin***

***June 5-6, 2003***

The Lake Champlain Sea Grant Program and the National Oceanic and Atmospheric Administration are co-sponsoring a 1.5 day workshop with the intent to coordinate and leverage modest research programs addressing atmospheric deposition in the Lake Champlain watershed and surrounding areas. The workshop objectives are:

- Identify existing and proposed research programs
- Define and prioritize common research themes
- Identify resources (funding, facilities, personnel)
- Attempt to establish consensus on funding priorities
- Develop a concise five year strategic plan that addresses the atmospheric research needs of the Basin. The plan should outline:
  - Research goals and priorities
  - Quality assurance guidelines
  - Database management goals
  - Outreach goals

Schedule: June 5: 8:30 AM – June 6: ~ 2:30 PM

Location: University of Vermont, Burlington, VT

Details: The goal of this workshop is to develop a five year strategic research plan that addresses the transport and fate of atmospheric acids, mercury, and toxics into and within the Lake Champlain watershed and surrounding areas. The challenge is to leverage modest programmatic funding to best meet the research goals identified.

The format of the workshop will be largely technical and centered about short summary presentations followed by open discussions to identify gaps in current understanding, prioritize research goals, identify potential partnerships, and outline approaches. Specific topics of interest will include measurement technologies, quality control, database management and modeling. Discussions also will address the design of a public awareness component of the plan to facilitate the exchange of information between investigators, the public and policy makers.

A summary of workshop discussions and the resultant strategic research and public awareness plans will be published in a proceeding by Lake Champlain Sea Grant/NOAA to aid coordination of follow-on interagency funding and inter-institutional research efforts.

Travel arrangements: To facilitate arrangement of local accommodations, we request that you please RSVP your intentions to participate and your accommodation needs as soon as is possible.

For those interested, a tour of the Vermont Monitoring Cooperative's air quality site on Mt. Mansfield (Underhill Center, VT) will be scheduled the evening of the 5<sup>th</sup> and afternoon of the 6<sup>th</sup> (~30 min. driving time). Please let us know of your interest.

The workshop agenda, up-dated list of participants and other materials pertaining to on-going research and monitoring activities in the area will be forwarded shortly. General information on Burlington and the local environment can be found at: <http://www.ci.burlington.vt.us/> , <http://www.uvm.edu/~empact/>.

Contact Information: Please address questions, comments and RSVP's via email to Gerry Livingston ([gerald.livingston@uvm.edu](mailto:gerald.livingston@uvm.edu)), Tel: 970 490-8240 (Ft. Collins, CO).

We look forward to your participation.

Workshop  
 Coordination of Atmospheric Deposition Research in the Lake Champlain Basin  
 June 5-6, 2003  
 Bishop Booth Conference Center\*  
 Burlington, Vermont

***Appendix C: Workshop Agenda***

***Day 1 – Thursday, June 5, 2003***

8:00	Continental breakfast	Bishop Booth Conference Center
8:30	<i>Introduction</i>	Deane Wang, UVM Sch. of Natural Resources
	Welcome	Bob Paquin, Sen. Leahy's Office
	Introductions & logistics	Rick Artz, NOAA ARL
		Jurij Homziak, Lake Champlain Sea Grant
	Review of workshop objectives	
	Overview of meeting agenda	
9:10	<i>Overview of existing and potential programs</i>	
	Lake Champlain Sea Grant	J. Homziak
	National Weather Service	Paul Sisson
	USGS	Jamie Shanley
	Northeastern States Research Consortium	Melody Burkins
	Break	
	Vermont DEC	Harold Garabedian
	Vermont Monitoring Cooperative	Eric Miller
	Lake Champlain Research Consortium	Bob Genter
	Lake Champlain Basin Program	Bill Howland
	EPA	Alan Van Arsdale
	NOAA Air Resources Lab	R. Artz
12:00	Lunch Break	
1:00	<i>Status, issues &amp; gaps in current understanding</i>	
	Mercury	
	<i>Measurements &amp; Data synthesis</i>	R. Artz, A. Van Arsdale, Jerry Keeler, E. Miller
	Wet deposition	
	Dry deposition	
	<i>Modeling</i>	Ning Gao, Mark Cohen, E. Miller
	Break	
	Major ions	
	<i>Measurements &amp; Data synthesis</i>	R. Artz, Jeff Brook
	Wet deposition	
	Dry deposition	
	<i>Modeling</i>	Paul Wishinski, R. Artz, E. Miller
	Hazardous air pollutants	J. Brook, Bart Sponseller
	Meteorological observations	P. Sisson, Carl Waite
	Quality Control	A. VanArsdale, J. Keeler
5:00	Break	

Dinner. Program managers will meet for dinner at 6:30. Details to be determined later.

Workshop  
Coordination of Atmospheric Deposition Research in the Lake Champlain Basin  
June 5-6, 2003  
Bishop Booth Conference Center\*  
Burlington, Vermont

***Day 2 – Friday, June, 2003***

8:00 Continental breakfast

8:30 *Open discussion: How can we pool resources to integrate, focus and communicate research efforts to the public? (Facilitators: R. Artz, R. Poirot, J. Homziak)*

- Identify and prioritize common research themes, goals, spatial and temporal scales of interest
- Develop agreement between programs regarding pooled resources
- Determine funding priorities and research schedules
- Define outreach needs/requirements
- Outline schedule of activities

*Outline a strawman five year strategic plan\* (Facilitators: R. Artz, J. Homziak)*

- Define overall goal
- Outline:
  - Working agreement between programs
  - Research themes, goals
  - Outreach goals
  - Quality control guidelines
  - Database management guidelines
  - Identify measures of success
  - Schedule of activities

1:00 *Summarize, Review action items, Close meeting*

\*About five pages; to be completed and reviewed after the meeting.

***Directions to the Bishop Booth Conference Center***

Address: 20 Rock Point Circle  
Burlington, VT 05401-2735  
Tel: 802 658-6233  
Fax: 802 658-8836

From the Airport or I-89 (Exit 14W)

Proceed West on Main St. (US Rte 2) towards Lake Champlain for approximately 2 miles, past Burlington's city center to the foot of the hill. At the stop light, turn north (right) onto Battery St. At the top of the hill, follow the street as it curves to the west and then back again north onto North Ave. (Rte. 127). Proceed on North Ave. approximately 2 miles. Turn west (left) at the traffic light onto Institute Road (Note Burlington High School will be immediately to the northwest of the intersection.). Proceed past the High School and take the first right onto Rock Point Rd. through the brick gate. Continue along Rock Point Rd, bearing right at the intersection. The Bishop Booth Conference Center is at the end of the road.

Bring your walking shoes and take advantage of the footpaths along the lake.



Workshop  
Coordination of Atmospheric Deposition Research in the Lake Champlain Basin  
June 5-6, 2003  
Bishop Booth Conference Center\*  
Burlington, Vermont

**Appendix D: Workshop Proceedings**

**Table of Contents**

Note: The presentations identified below are accessible in the *Proceedings* directory that accompanies this report (click on the proceedings.htm file).

**Overview of Current Programs**

Burkins, M. UVM

[Northern States Research Consortium](#)

Garrabedian, H., VT DEC

Overview of Vermont APCD's Existing & Future Air Monitoring Programs

Sisson, P.A., NWS

Overview of National Weather Service Products, Services and Data for Lake Champlain

Waite, C., VMC

Atmospheric Deposition Research in the Lake Champlain Basin

Waite, C., VMC

Collection of Meteorological Data

Wilmot, S., VMC

Vermont Monitoring Cooperative

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Stockwell, W.R., R.S. Artz, J.F. Meagher, R.A. Petersen, K.L. Schere, G.A. Grell, S.E. Peckham, A.F. Stein, R.V. Pierce, J.M. O'Sullivan, and Pai-Yei Whung, The scientific basis of NOAA's air quality forecasting program, *Environ. Monitoring*, 20-27, 2002.

Wayland, R.A., J.E. White, P.G. Dickerson, and J.S. Dye, Communicating real-time and forecasted air quality to the public, *Environ. Monitoring*, 28-36, 2002.

Wayland, R.A. and Pai-Yei Whung, Air quality forecasting: past, present, future, *Environ. Monitoring*, 18, 2002.

**Mercury Deposition**

Artz, R. NOAA ARL

Mercury: A Short Introduction to Mercury Monitoring in the Lake Champlain Basin

Cohen, M., NOAA ARL

Modeling the Atmospheric Deposition of Mercury to Lake Champlain from Anthropogenic Sources in the U.S. and Canada

Gao, N., N.G. Armatas, S. Drake, B. Olsen, C.Cady, J.B. Shanley, N.C. Kamman, G.J. Keeler, T.

Scherbatskoy, T.M. Holsen and T. Young, and L. McIlroy,

St. Lawrence Univ., USGS, VT DEC, U. Michigan, Univ. Vermont, Clarkson Univ., Plattsburgh State Univ.,

A Mass Balance Assessment for Mercury in Lake Champlain

Shanley, J., USGS  
Mercury and Methylmercury Dynamics in Surface Waters

***Major Ion Deposition***

Artz, R. NOAA ARL  
National Atmospheric Deposition Program

Artz, R. NOAA ARL  
Acid Deposition Monitoring

Brook, J., Meteorological Service of Canada  
Canadian Acid and Toxic Deposition

Brook, J., Meteorological Service of Canada  
Some Recent Results Under the Canadian Acid Deposition and SMOG Programs

Lear, G. and D. Schmelz, U.S. EPA  
Total Nitrogen Deposition in the Eastern U.S.

Artz, R. NOAA ARL  
Monitoring for Dry Deposition: Current Strategy Used in NOAA/AIRMoN

***HAC Deposition***

Sponseller, B, VT DEC  
Hazardous Air Contaminant Deposition in Vermont

***Atmospheric Modeling***

Artz, R. NOAA ARL  
READY: Realtime Environmental and Application Display System

Poirot, R. VT DEC  
Source / Receptor Modeling

Wishinski, P. VT DEC  
Lake Champlain Basin Atmospheric Modeling  
Area Impact Modeling: Calpuff  
Area Impact Modeling: HYSPLIT

## **Appendix E: Publications to Date**

### **Refereed Articles & Reports**

- Burke, J., M. Hoyer, G. Keeler, and T. Scherbatskoy, Wet deposition of mercury and ambient mercury contamination at a site in the Lake Champlain Basin. *Water, Air and Soil Pollution*, 80, 353-362, 1995.
- Cleckner, L.B., E. Esseks, P.G. Meier, and G.J. Keeler, Mercury concentrations in two Great Waters, *Water, Air and Soil Pollution*, 80, 581-584, 1995.
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- Driscoll, C.T., C. Yan, C.L. Schofield, R. Munson, and J. Holsapple, The mercury cycle and fish in the Adirondack lakes, *Environ. Sci. Technol.*, 28, 136A-143A, 1994.
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- Kamman, N. and D.R. Engstrom, Historical and present fluxes of mercury to Vermont and New Hampshire lakes inferred from 210Pb dated sediment cores, *Atmos. Environ.*, 36, 1599-1609, 2002.
- Keeler, G., G. Glinsorn, and N. Pirrone, Particulate mercury in the atmosphere: its significance, transport, transformation and sources, *Water, Air, and Soil Pollution*, 80, 159-168, 1995.
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### **Conference Abstracts & Proceedings**

- Leger, W., J.E. Hurley and P. Arp, Mapping Forest Sensitivity to Acid Deposition: A Regional Perspective. International Conference on Ecosystem Health, Brisbane, Australia, 2000.
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- Poirot, R.L. and P.R. Wishinski, Long-term ozone trajectory climatology for the Eastern U.S., Part 2: Results, 98-A615, Proceedings 91<sup>st</sup> Annual A&WMA Meeting, San Diego, CA, 1998.
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### **Graduate Theses and Dissertations**

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- Duchovnay, A., Uptake of mercury from contaminated sediments by the freshwater oligochaete *Limnodrilus hoffmeisteri* and determination of sites of mercury accumulation using autometallography, M.S. Thesis, Univ. of Vermont, 1994.
- Lawson, S.T., Cloud water chemistry and mercury deposition in a high elevation spruce-fir forest, M.S. Thesis, Univ. of Vermont, 1999
- Reinhart, Krista. Mercury in streamwater from watersheds with contrasting land use in northern Vermont. M.S. Thesis, University of Vermont, 2003.
- Scherbatskoy, T., Response of spruce and birch foliage to leaching by acidic precipitation, M.S. Thesis, Univ. of Vermont, 1980.

**Appendix F: Acronyms**

AIRMoN	<a href="#">Atmospheric Integrated Research Monitoring Network</a>
APCD	<a href="#">Air Pollution Control Division</a>
ARL	<a href="#">Air Resources Laboratory</a>
CAAA	<a href="#">Clean Air Act Amendments</a>
CASTNET	<a href="#">Clean Air Status and Trends Network</a>
DEC	<a href="#">VT Department of Environmental Conservation</a>
EPA	<a href="#">U.S. Environmental Protection Agency</a>
IADN	<a href="#">The Integrated Atmospheric Deposition Network</a>
IMPROVE	<a href="#">Interagency Monitoring of Protected Visual Environments</a>
LCBP	<a href="#">Lake Champlain Basin Program</a>
LCRC	<a href="#">Lake Champlain Research Consortium</a>
NADP	<a href="#">National Atmospheric Deposition Program</a>
NARSTO	<a href="#">NARSTO</a>
NOAA	<a href="#">National Oceanographic and Atmospheric Administration</a>
NSRC	<a href="#">Northeastern States Research Cooperative</a>
NWS	<a href="#">NOAA - National Weather Service</a>
PBT	<a href="#">Persistent Bioaccumulative and Toxic Chemical Program</a>
QA/QC	Quality Assurance / Quality Control
	<ul style="list-style-type: none"><li>• <a href="#">NARSTO</a></li><li>• NWS</li><li>• <a href="#">SDTS</a></li></ul>
SDTS	<a href="#">Spatial Data Transfer Standard</a>
SOP	Standard Operating Procedure
TGM	Total gaseous mercury
USGS	<a href="#">U.S. Geologic Survey</a>
UVM	<a href="#">University of Vermont</a>
VMC	<a href="#">Vermont Monitoring Cooperative</a>
VOC	Volatile Organic Carbon

