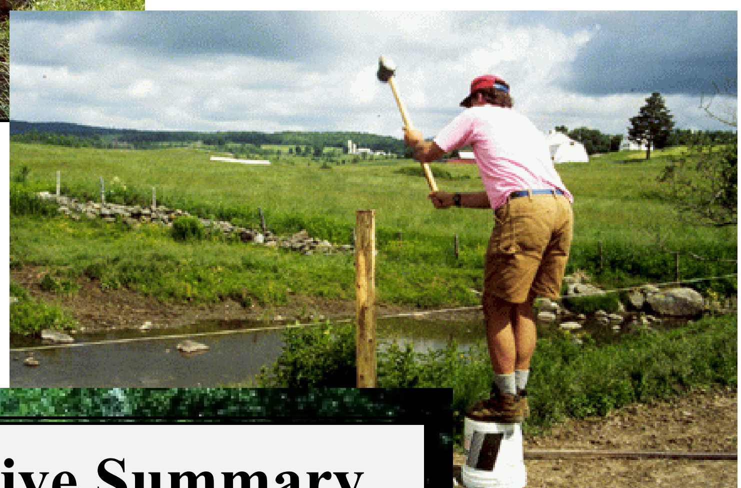
LAKE CHAMPLAIN BASIN AGRICULTURAL WATERSHEDS SECTION 319 NATIONAL MONITORING PROGRAM PROJECT



Executive Summary

FINAL PROJECT REPORT
May, 1994 - November, 2000

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PREFACE AND ACKNOWLEDGMENTS

This summary report covers the Project Year 7 period October 1, 1999 through September 30, 2000, the third project year of treatment, and presents the final analysis of project data, May, 1994 - November, 2000. It should again be cautioned that disturbances continued in one of the watersheds, with water quality effects that seriously compromised detection of treatment effectiveness in the final project year.

The vital contributions of numerous individuals during Project Year 7 and throughout the project should be acknowledged. **Dorothy Morley** at the University of Vermont served as project field technician and performed data management and organizational tasks. Her predecessors, including **Angela Shambaugh**, **Andrea Donlon**, and especially **Sally Ober**, deserve special mention for field operations support in previous project years. **Rick Hopkins** at the Vermont Department of Environmental Conservation administered the project and its budgets through the state Section 319 program, and got his hands dirty in the field pounding fence posts and moving rocks. **Rich Langdon** and **Steve Fiske** of the Vermont DEC collected and analyzed the fish and the bugs from the project streams and wrote the biomonitoring sections of this and previous reports. **Sarah Flack** carried out the annual farmer interviews with characteristic persistence and tact. **Judy Bond** did the GIS update of project land use coverage, produced new maps, and facilitated additional spatial analysis. **Neil Kamman** and **Brenda Clarkson** managed water quality data transfer to STORET.

Present and former staff of the USDA NRCS and FSA Franklin/Grand Isle District Office in St.Albans rendered considerable technical assistance and moral support throughout the project, especially **Tim Beaman, Kathy Hakey, Mike LaPointe, Jim Ryan, and Brandon Dennis. Eric Derleth** and **Chris Smith** of the U.S. Fish & Wildlife Service provided crucial technical assistance, guidance, and funding through the *Partners for Wildlife and Wetlands* program. **Cynthia Scott**, coordinator of the **Missisquoi River Basin Association**, organized and participated in volunteer work for the project. Individuals too numerous to mention from **Ben & Jerry's Homemade, Inc.**, **Cold Hollow Career Center**, and the **Vermont Youth Conservation Corps** helped with streambank bioengineering in the summer of 1997. **Tim Mayotte** and his skilled crew provided excavation and heavy equipment services, and practical advice throughout the project

Members of the Project Advisory Committee deserve special recognition for taking time to attend quarterly meetings and help resolve important issues: **Craig Altemose** (Extension), **Jon Anderson** (VT Natural Resources Conservation Council), **Phil Benedict** (VT Dept. of Agriculture, Food, and Markets), **Barry Rosen** (USDA-NRCS), **Eric Derleth** (USF&WS), **Steve Fiske** (VTDEC), **Daton Fleury** (dairy farmer, Berkshire, VT), **Rick Hopkins** (VTDEC) **Bill Jokela** (UVM Dept. of Plant and Soil Science), **Rich Langdon** (VTDEC), **Doug Lantagne** (UVM Extension), and **Eric Perkins** (USEPA, Region I). **Steve Dressing**, formerly of the US EPA Office of Wetlands, Oceans, & Watersheds in Washington, D.C. and **Tom Davenport,** Region V, leading the National Monitoring Program, provided critical support and assistance at the national level. **Jean Spooner**, **Garry Grabow**, and others at the **North Carolina State University Water Quality Group** have also contributed valuable technical support and encouragement.

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1.0 INTRODUCTION

Lake Champlain, the nation's sixth largest freshwater lake, is undergoing cultural eutrophication due to excessive phosphorus (P) loads from its 20,800 km^2 drainage basin, found in portions of Vermont, New York, and Quebec. The Lake currently fails to meet Vermont water quality standards for phosphorus, primarily due to excessive nonpoint source (nps) loads. About 71% of the average annual P load of 647 mt/yr comes from nonpoint sources)and 66% of the nps P load to Lake Champlain has been attributed to agricultural land in the basin.

The current management strategy for Lake Champlain calls for reductions of P loading from both point and nonpoint sources; much of this reduction will need to come from agricultural land. A major component of Vermont's water quality management strategy for Lake Champlain and its tributaries will rely on implementation of effective nps controls, particularly for agriculture, to reduce tributary P loads to meet state water quality standards established for the Lake.

Efforts to reduce agricultural nps pollution in Vermont over the past several decades have worked toward improving animal waste management in the state's predominantly dairy agriculture. Construction of manure storage structures, barnyard runoff management, and adoption of waste utilization plans to avoid winter spreading of manure have been widely encouraged under a variety of federal and state cost-share and technical assistance programs. However, dairy cows traditionally spend half of the year away from the barn on pasture, and livestock grazing impacts on water quality have been largely ignored in previous nonpoint source reduction studies in the region. Impacts of livestock grazing on stream and riparian ecosystems - including elevated stream nutrient and bacteria levels, accelerated streambank erosion, and changes in stream channel morphology - have been widely documented. Livestock exclusion and riparian zone restoration have often been recommended to protect water bodies from such influences.

Free access to streams and streambanks by livestock is commonplace in Vermont. Direct deposition of waste into streams, destruction of riparian vegetation, and trampling of streambanks and streambeds are all problems associated with livestock grazing. Such activities may represent important sources of sediment, nutrients, and bacteria to surface waters in Vermont. It is essential to test simple, practical, and cost-effective methods to address these issues and to provide quantitative evaluations of their effectiveness on water quality.

The *Lake Champlain Basin Agricultural Watersheds Section 319 NMP Project* was designed to evaluate the effectiveness of livestock exclusion, streambank protection, and riparian restoration practices in reducing runoff of sediment, nutrients, and bacteria from agricultural land to surface waters . The purpose of the project was to quantify treatment effectiveness at the watershed level to provide managers with tools of known effectiveness for phosphorus reduction programs. Treatment effectiveness was evaluated through intensive water quality monitoring at watershed outlets using a paired watershed design and through detailed land use and agricultural activity tracking over a seven-year period. The project was one of twenty-three special nonpoint source pollution control monitoring studies across the nation, funded in part by the U.S. Environmental Protection Agency under Section 319 of the Clean Water Act in the National Monitoring Program.

SUMMARY

Project Objectives

- The *Lake Champlain Basin Watersheds Section 319 NMP Project* was designed to evaluate the effectiveness of livestock exclusion, streambank protection, and riparian restoration practices in reducing concentrations and loads of nutrients, sediment, and bacteria from grazing land in the Lake Champlain Basin at the small watershed level through intensive water quality monitoring using a paired watershed design.

- Project objectives included:
  - ♦ Implement practical, low-technology practices to protect streams, streambanks, and riparian zones from livestock grazing, including exclusion of livestock from selected stream areas, creation of protected riparian zones, improvement or elimination of heavily used livestock stream crossings, and revegetation of degraded streambanks;
  - ♦ Assess operation, maintenance, and cost issues associated with treatments;
  - ♦ Track land use and agricultural management activities;
  - ♦ Document changes in concentrations and loads of nonpoint source pollutants (total Phosphorus (TP), total Kjeldahl Nitrogen (TKN), total suspended solids (TSS), and bacteria at the watershed outlet in response to treatment; and
  - ♦ Evaluate response of stream biota to land treatment.

Project Design

- The project was conducted by a paired watershed design using one control and two treatment watersheds and divided into three distinct periods:

PERIOD	ACTIVITY	DATES
CALIBRATION	PRE-TREATMENT	May 26, 1994 - May 29, 1997
TRANSITION	IMPLEMENTATION	June 5, 1997 - Nov. 6, 1997
TREATMENT	TREATMENTS ACTIVE	Nov. 12, 1997 - Nov. 27, 2000

- The effects of treatment were evaluated on the basis of statistically significant changes in the relationships among the study watersheds for pollutant concentration and mass export. Treatment effects on biological integrity were evaluated by quantifying changes in macroinvertebrate and fish communities
- The project was conducted in three small agricultural (predominantly dairy) watersheds,

tributaries of the Missisquoi River in northwestern VT: two **treatment watersheds** - WS 1, Samsonville Brook (690 ha), and WS 2, Godin Brook (1422 ha); and one **control watershed** - WS 3, Berry Brook (954 ha.).

- Monitoring included continuous precipitation and streamflow recording, weekly flow-proportional composite sampling for TP, TKN, and TSS concentration, twice-weekly grab sampling for *E. coli*, fecal coliform, and fecal streptococcus bacteria, dissolved oxygen, specific conductance, and water temperature at permanent monitoring stations at each watershed outlet. The biological communities of each study stream and of a fourth background reference site were assessed by annual sampling of fish and macroinvertebrate populations at locations near the monitoring stations.

- Land use and agricultural management was monitored through voluntary farmer record-keeping and annual interviews with each owner and/or operator of agricultural land in the three watersheds. Year-to-year changes in land use were also tracked through USDA-FSA crop compliance aerial photography. Spatial data were analyzed and maintained in a Geographic Information System.

- During the calibration monitoring period, critical areas needing treatment in the two treatment watersheds were identified through baseline farm inventories, direct inspection of streams and riparian areas, and interpretation of aerial video imagery. Specific implementation plans were developed for individual farms based on voluntary cooperation and negotiations with landowners. Technical assistance was provided by USDA-NRCS and the U.S. Fish and Wildlife Service. Additional funding and labor for treatment implementation was contributed by other conservation programs, landowners, and local volunteer groups.

Year 7 Water Quality

- Precipitation during Year 7 was greater than that of the previous drought year, but still ~15% below long-term regional average. Rainfall was above normal in spring, 2000 and summer rainfall was frequent, although with few large storm events. Streamflows were moderate through most of the year, with peak flows in late February/early March. Moderately high flows were sustained over the rainy spring, responding to storm events and summer streamflows were higher than those recorded in the previous drought summer. Nutrient and suspended solids concentrations generally varied in the low to moderate range in WS 1 and WS 3 during Year 7. Nutrient and sediment levels in the control WS 3 were noticeably lower than in the previous two years. TP, TKN, and TSS levels in WS 2 were notably higher than in previous years and higher than those observed at the other two stations, due to large-scale land disturbance and farm management problems upstream of Station 2. Numerous cases of severe water quality impacts in WS 2 during Year 7 were attributed to highly enriched concentrated overland flow from this land disturbance and to severe sedimentation caused by soil masses pushed into Godin Brook from the fields. Indicator bacteria counts continued to exhibit pronounced seasonal cycles - low during cold weather and very high during the growing season, coincident with the beginning of livestock pasturing in late May. Bacteria counts in WS 1 were substantially lower in Year 7 than previously, with median *E. coli* counts meeting Vermont Class B water quality criteria.

- Median values for water quality variables in Year 7 were:

	TP	TKN	TSS	E. Coli	F Col	F Strep	Q
	----------	mg/L	----------	----------	#/100 ml	----------	ft^3/sec
WS 1 - Samsonville Br.	0.072	0.54	13.0	43	34	158	2.8
WS 2 - Godin Br.	0.167	0.69	20.6	760	1175	1000	4.1
WS 3 - Berry Br.	0.055	0.42	5.5	258	335	355	7.4

- Additional experiments conducted during Year 7 confirmed that indicator bacteria survive in stream sediments during the warmer months and can be resuspended by streambed disturbance. Stocks of bacteria in streambeds appeared to be depleted by fall and remained so in early spring, consistent with the notion of depletion of bacteria stocks in the absence of input from land in winter and spring and rebuilding of stocks from renewed summer inputs from the land. The patterns observed in Year 7 appeared to be influenced by differences in precipitation/flow regime compared to previous years and, in WS 2, by the influence of the field runoff problems.

- Patterns of TP, TKN, and TSS export in Year 7 were typical of Vermont's seasonal cycle, where most annual export is usually associated with a few periods of high flow. In Year 7, the dominant export season was the snowmelt/spring season from late February to mid-May, 2000. Of particular note is the high flux of TP, TKN, and TSS from WS 2, another reflection of the field runoff problem in that watershed.

  Total export of TP, TKN, and TSS measured during Project Year 7 was:

	TP		TKN		TSS	
	mt/yr	kg/ha/yr	mt/yr	kg/ha/yr	mt/yr	kg/ha/yr
WS 1	0.98	1.43	3.8	5.6	234	339
WS 2	3.60	2.53	9.2	6.5	619	435
WS 3	1.74	1.83	8.2	8.6	479	502

  Year 7 nutrient and sediment export from WS 2 and WS 3 was generally higher than in Year 6, but export from WS 1 in Year 7 was lower than in the previous year. Export from WS 2 was highest among the watersheds, particularly for TP. Areal export rates for TP continued to exceed those generally reported for agricultural watersheds across the U.S., but were comparable to values reported in other small agricultural watersheds in the Champlain Valley of Vermont.

- Water quality patterns in Year 7 clearly showed the effects of higher precipitation and streamflow compared to the previous drought year. Whereas overall, most water quality variables continued in typical ranges observed in previous years, there was a marked increase in nutrient, suspended solids, and bacteria levels in WS 2 compared to the other monitored watersheds. There was also a slight tendency for lower pollutant levels in the control watershed, WS 3.

- Year 7 saw a shift in water quality patterns among the three monitored watersheds. Whereas the treated WS 1 continued to exhibit significantly lower pollutant concentrations and loads compared to the other two watersheds, WS 2 tended to show significantly higher nutrient, suspended solids concentrations and export than either WS 1 or the control WS 3. WS 2 mean bacteria levels were no longer significantly lower than those in the control watershed. These changes were likely due to the field runoff problems in WS 2 and perhaps to slightly improved water quality in the control watershed in Year 7.

- The macroinvertebrate assemblages in the study streams in 2000 continued to reflect some nutrient enrichment, generally yielding only a "fair" rating and failing to meet Vermont WQ biocriteria for small mountain streams. The macroinvertebrate community integrity in Samsonville Brook (WS 1), however, rated as good overall for the second straight year. Macroinvertebrate assemblages were dominated by the orders *Diptera* and *Trichoptera*, whereas *Ephemeroptera* and *Plecoptera* were under-represented. Generalist feeding groups collector/gatherers and collector/filterers dominated the communities, with predators, scrapers, and leaf-shredders under-represented. Improvements in biological integrity in Samsonville Brook (i.e., the Bio Index, EPT taxa, and species richness) compared to historical data may suggest a positive response to treatment.

- Fish assemblages in the study streams continued to show degradation in 2000, with MWIBI values ranging from 25 to 33, in a possible range of 9 - 45. Study streams generally failed to comply with the Class B biological water quality standards. The majority of fish species captured were considered tolerant of degradation. Blacknose dace and Creek chub were the dominant species in all of the study streams. In Godin Brook, downstream of the field runoff influence, the total one-run density for the 2000 sampling was the highest of the study sites (839 fish/100 m^2), and among the highest of any Vermont stream sampled by VT DEC. No intolerant species were recorded at this site.

Land Use

- 2000 generalized land use in the study watersheds was:

Land Use	WS 1 Samsonville Br.	WS 2 Godin Br.	WS 3 Berry Br.
Agriculture	168 ha (24%)	548 ha (38%)	272 ha (29%)
Forest	467 ha (68%)	772 ha (54%)	584 ha (61%)
Other	57 ha (8%)	101 ha (7%)	98 ha (10%)

Forest remained the dominant land use in each of the study watersheds, but agricultural land continued to represent a significant proportion of watershed area. The largest changes from 1999 were associated with the large farm expansion in WS 2 and the completion of conversion of some previously "Other" land to agriculture in both WS 1 and WS 2. Hay continued to be the dominant agricultural land use (13 to 19% of total watershed area), with pasture the next most prevalent use (8 to 15%). Land in corn continued to represent a very small percentage of land in WS 1 and was completely absent from WS 3 again in 2000. Management changes on the large farm in WS 2 drove a 20% decrease in corn land, mostly converted from highly eroding corn land in 1999. Only 2-3% of watershed land was in residential or farmstead use.

- Total livestock population in the study watersheds remained essentially stable in Year 7, increasing by about 3% (~98 AU). Animal population in WS 2 increased by ~16% (319 AU), offsetting small decreases in the other two watersheds. All of the increase in WS 2 reflected the continued expansion of the large farm, whose permitted animal population was increased by the VT Department of Agriculture, Food, and Markets late in the year. Overall, estimated animal populations in the project area in the final project year were ~22% above baseline values recorded in 1994.

- The most dramatic impact of land use change and agricultural management in Year 7 continued to be erosion and runoff from major land clearing and poor riparian management associated with the expansion of a large farm facility in the center of WS 2. Excessive erosion, extremely high manure application rates, concentrated overland flow, inadequate buffers along Godin Brook, and bulldozing of trees, soil, and debris into the stream caused serious impacts to water quality monitored in WS 2. Unlike Year 6, when such impacts were limited to a few isolated "anomalies," this problem was continuous in Year 7 and overwhelmed the effects of land treatment elsewhere in the watershed.

- With several exceptions, land use and agricultural activity was remarkably stable over the 1994 - 2000 project period. In general, the watershed land tracked county-wide trends of slow population growth and consolidation of dairy agriculture into fewer, but larger, farms. For the most part, farms were stable in ownership and size over the life of the project, although there were a few exceptions. Over the project period, two dairy farmers, one each in WS 1 and WS 2, retired from farming; their herds were sold, but their land continued in production as it was absorbed into neighboring operations. Several dairy farms expanded (notably in WS 2). Overall, total livestock population of the three watersheds increased by 20% over the project. Clearly, most of this increase was driven by a 42% increase in animal units in WS 2, mostly associated with the large farm expansion. This expansion offset retirement of one WS 2 farmer late in Year 6. Livestock populations in WS 1 showed a net decline of ~12%, all of which occurred between Year 6 and Year 7, when one watershed farmer retired. Livestock numbers in the control watershed showed a 14% increase over the entire project period, but were nearly level from Year 4 through Year 7.

Land Treatment

- Land treatments installed in 1997 continued to function as expected. Livestock exclusion fences worked well, as did the bridge and culvert crossings. Bioengineering protected formerly eroding streambanks and noticeable quantities of sediment accumulated in brushrolls. No major damage occurred during winter/spring 2000 that required significant maintenance to installed practices.

- Analysis of the extent of land treatment achieved in the project using GIS showed that WS 1 received a higher level of treatment, relative to need, than WS 2:

Variable	WS 1	WS 2	WS 3
Total stream length (m)	10,382	24,776	18,051
Pasture stream length (m)	1,481	8,150	2,085
Treated stream length (m)	726	2,283	0
Stream length treated (%)	7%	9%	--
Pasture stream length treated (%)	49%	28%	--
Livestock grazing on treated pasture (%)	96 - 97%	15 - 23%	--
Pasture area draining to treated stream (%)	42%	32%	--

Changes in Water Quality

- Direct comparisons of water quality data among watersheds over the Calibration and Treatment periods suggest some important changes. Total P, TKN, and TSS concentrations, *E. coli* and Fecal coliform counts, conductance, and TP, TKN, and TSS export appear to have decreased in WS 1 following treatment. Although water quality in WS 2 was seriously compromised by field runoff problems especially in Year 7, there were still indications of significant declines in *E. coli* and Fecal coliform counts and in nutrient and suspended solids export in the Treatment period:

		Calibration Period Mean Annual Export (mt/yr)	**Treatment Period** Mean Annual Export (mt/yr)
WS 1	TP	1.33	0.87
	TKN	6.7	3.6
	TSS	579	302
WS 2	TP	2.13	2.75
	TKN	11.9	7.9
	TSS	698	799
WS 3	TP	1.85	3.36
	TKN	8.3	7.7
	TSS	547	695

- Paired-regression ANCOVA between control and treated watersheds confirmed significant response to treatment in both watersheds with respect to physical/chemical water quality variables:

    - WS 1 TP, TKN, and TSS concentrations decreased significantly in the Treatment period. Post-treatment nutrient and suspended solids levels were less than pre-treatment levels over the upper ~70 - 90% of observed conditions.

    - Post-treatment *E. coli*, Fecal coliform, and Fecal streptococcus bacteria counts in WS 1 were markedly lower than during Calibration. These decreases occurred over nearly all seasonal conditions, including summer when highest bacteria counts are typically observed.

    - Specific conductance in WS 1 was slightly, but significantly lower in the Treatment period, suggesting a decrease in dissolved material carried by Samsonville Brook, compared to Calibration.

- Post-treatment water temperatures in Samsonville Brook were slightly higher in cold weather and slightly cooler in hot weather, compared to the pre-treatment period. This pattern may have been a response to narrowing and deepening of treated stream reaches resulting from riparian restoration.

- Export of TP, TKN, and TSS from WS 1 all decreased significantly over the mid- to high-range following treatment, representing the upper ~20-30% of conditions, when the bulk of annual export typically occurs.

- WS 2 TP, TKN, and TSS concentrations decreased significantly in the Treatment period over the mid to high range of concentrations, representing the upper ~20 - 50% of the concentration range.

- Significant drops in post-treatment *E. coli* and Fecal coliform bacteria counts were observed in WS 2 over the entire range/season of bacteria counts; a similar, but nonsignificant trend was seen for Fecal strep. bacteria.

- Conductance and temperature in Godin Brook both increased slightly, but significantly, in the Treatment period, probably due to the effects of the field runoff problem in Years 6 and 7.

- No change in TP export from WS 2 were seen, a reversal of reductions noted in the first two post-treatment years. Export of TKN and TSS from WS 2 decreased significantly in the Treatment period in the upper -most range, but the decreases were moderated by the runoff problem compared to the pattern seen in the first two post-treatment years.

- Water quality changes in the treated watersheds took place in the context of essentially no significant change in water quality in the control watershed over the Treatment Period.

- The **average** treatment response was estimated by comparing predicted values for each treatment watershed for the Calibration and Treatment periods at the average value for the Control watershed for the entire study period. Results suggest that the effect of treatment on water quality in WS 1 was substantial and that, in some cases, average water quality did not improve in WS 2 when the entire Treatment period is considered:

	WS 1 % change in mean	WS 2 % change in mean
[TP]	-15%	+18%
[TKN]	-12%	0
[TSS]	-34%	+40%
E. coli	-29%	-44%
Fecal coliform	-38%	-46%
Fecal strep.	-40%	-20% (n.s.)
Conductance	-11%	+1%
Water temperature	-6%	+3%
TP export	+47%	---
TKN export	+125%	+16%
TSS export	+40%	+32%

- The magnitude of treatment response was assessed with respect to export over the full range of conditions by inserting all weekly values for the Treatment period from the control watershed into the Calibration regressions to yield estimates of predicted WS 1 and WS 2 export *under pre-treatment management conditions but post-treatment hydrologic conditions*. These estimates were then compared to observed values from WS 1 and WS 2 during the Treatment period. Differences between these two data sets - predicted without treatment vs. observed with treatment - indicate the total change in mass export in response to treatment over the entire range of the Treatment period. This assessment suggested:

	WS 1		WS 2	
	% Change	Mass Change	% Change	Mass Change
TP export	-49%	-827 kg/yr	+80%	+1,181 kg/yr
TKN export	-38%	-2,171 kg/yr	+44%	+235,126 kg/yr
TSS export	-28%	-114,893 kg/yr	+104%	+392,202 kg/yr

For WS 1, the estimated change over the entire Treatment period shows substantial reductions in nutrient and suspended solids export, a result that differs markedly from the increases in average treatment response. This underlines the importance of considering extreme events which provide the majority of watershed export in a year. Post-treatment export increased from WS 2, a probable reflection of the field runoff problems.

- Analysis of the timing of differences between observed and predicted export showed that for WS 1, cases of large excess of observed over predicted export during the post-treatment period occurred during extreme hydrologic events, such as hurricane Floyd. In WS 2, this pattern was accentuated by elevated export from the disturbed fields during similar extreme events.

- In both Samsonville Brook (WS 1) and Godin Brook (WS 2), the macroinvertebrate communities responded significantly to treatment, while community metrics remained unchanged in local control streams. Improvements in biological integrity were indicated by significant changes in Bio Index and EPT/EPT&chiro ratio values. Shifts in community composition suggested that the changes occurred in response to reductions in nutrient loading. In the second and third years after treatment, Bio Index values met or approached Vermont Class B Water Quality Biocriteria, although community composition continued to indicate impacts of moderate organic enrichment.

- Improvements noted in the macroinvertebrate community in Godin Brook after two years of treatment were reversed in the final year due to catastrophic sedimentation events from upstream sources.

- No significant changes in fish assemblages between the Calibration and Treatment Periods were observed for either of the two treatment watersheds. Lack of observed response to treatment may have been due to high variability in MWIBI values, insufficient time to measure biological responses, or to inadequate level of treatment. In addition, ability to detect changes was impaired by water quality problems at control sites that prevented a true measure of normal background variation.

- Although no observable changes in fish assemblage structure were recorded after land treatments some physical habitat improvements were noted in treated sections of both Samsonville and Godin Brooks. These improvements included reduction of silt and increase in gravel in substrates, and an increase in overhanging vegetation and narrowing of channels.

Information and Education

- At the close of the project, information and education in support of the project focused on getting the message on project results to watershed landowners, the general public, state and regional managers, and the scientific community. A project communication plan was developed and implemented that addressed local, regional, and national audiences. Project papers have been or will be presented at the International Water Association 5th International Conference on Diffuse/Nonpoint Pollution and Watershed Management, Milwaukee, WI and at the 9th National Nonpoint Source Monitoring Workshop: "Monitoring and Modeling Nonpoint Source Pollution in Agricultural Landscapes," August, 2001, Indianapolis, IN

- The project is documented on the world wide web at: http://www.vtwaterquality.org/VT319Watershed.htm

Project Modifications

- There were no significant modifications to project monitoring or land treatments in the final project year. Following the completion of active monitoring in November, 2000, monitoring facilities were removed and sites restored.

Project Conclusions

The project was successful in meeting its objectives:

- **Implement practical, low-technology practices to protect streams, streambanks, and riparian zones from livestock grazing**.

  Land treatments were implemented that addressed a significant portion of grazing-related water quality problems in each treatment watershed. This success was due in large measure to technical assistance from USDA-NRCS and USFWS personnel, to local volunteer labor, and, of course, to the voluntary participation of landowners.

- **Assess operation, maintenance, and cost issues associated with treatments**.

  Fencing livestock away from streams and protection of riparian zones did not appear to impair normal farm operation or grazing management on the participating farms. Even including the few sites where heavy equipment was required, the price tag for implementation was low. The ~$40,000 expended in the two treated watersheds can easily be spent in implementing structural practices on a single farm in traditional land treatment programs. Maintenance needs for the treatments fell within the range of typical farm management.

- **Track land use and agricultural management activities.**

  Land use monitoring effectively documented a number of important factors in the project, including the relative stability of overall agricultural land use over the seven years of the project, the modest growth in livestock populations, and the expansion of a new large farm operation in one watershed, along with its observed water quality impacts. Direct observation and inspection in the field was of critical importance. Improvements in both collection and use of detailed agricultural management information are desirable in future projects.

- **Document changes in concentrations and loads of nonpoint pollutants at the watershed outlet in response to treatment.**

  The project successfully documented significant reductions in phosphorus, nitrogen, suspended solids, and indicator bacteria in response to livestock exclusion and riparian zone protection, with pollutant reductions tending to be greatest under high concentration/high flow conditions characteristic of significant nonpoint source/runoff activity. Treatment effectiveness, however, appeared to be reduced under extreme conditions associated with unusual hydrologic events. The project also demonstrated the extent to which water quality impacts arising from a single, acute problem can overwhelm the ability to detect response to land treatment.

- **Evaluate response of stream biota to land treatment.**

  Riparian zone treatments had a positive effect on stream biota, through reduction in nutrient loading, resulting in a food web response by the macroinvertebrate community. A reduction in sediment loading may have also had some effect on riffle habitat. In the second and third years after treatment, Bio Index values met or approached Vermont Class B Water Quality Biocriteria, although community composition continued to indicate impacts of moderate organic enrichment. Improvements in the macroinvertebrate community in Godin Brook after two years of treatment were reversed in the final year due to catastrophic sedimentation events from upstream sources. No significant changes in fish assemblages between the Calibration and Treatment Periods were observed for either of the two treatment watersheds, although physical habitat improvements were noted in treated sections of both Samsonville and Godin Brooks.

Riparian zone protection/restoration is a cost-effective tool for reducing nonpoint source pollutant concentrations and loads from livestock grazing lands in the Lake Champlain Basin.

CONCLUSIONS

At the conclusion of the project, it is important to re-visit project objectives and to place project results in context. This section will review project success and failure in achieving its objectives and highlight important project results and observations.

Objective I.: Implement practical, low-technology practices to protect streams, streambanks, and riparian zones from livestock grazing.

The project was successful in implementing land treatments that addressed a significant portion of grazing-related water quality problems in two small, typical Vermont agricultural watersheds. This success was due in large measure to technical assistance from USDA-NRCS and USFWS personnel, to local volunteer labor, and, of course, to the voluntary participation of landowners. While several landowners participated purely out of sincere conservation motives, incentives were critical. Incentives were not only financial but also based on improved farm management. The livestock bridge constructed across Godin Brook in WS 2, for example, solved a long-standing problem of herd crossing during high water, even as it facilitated protecting of the riparian zone. Provision of clean, reliable water supply and improved herd travel lanes were also important incentives for several farmers.

Clearly, not all farmers participated. One reason for this was a strong local aesthetic tradition that favors "clean" pastures and resists the idea of streambanks growing up into "brush." A second reason was, unfortunately, an apparent disregard for conservation or water quality considerations. In some cases, such an attitude may have been rooted in economic pressures, but a few cases appeared to be based on more fundamental attitudes. Both of these reasons suggest areas for future information and education action.

The practices implemented were simple and inexpensive. Fencing and streambank bioengineering are not complex, but do require labor. Volunteers were key in the implementation process and such work continues to be a common focus of river basin associations in the region

Objective II.: Assess operation, maintenance, and cost issues associated with treatments.

Even including the few sites where heavy equipment was required, the price tag for implementation was low. By way of comparison, the ~$40,000 expended in the two watersheds might easily be spent in structural practices on a single farm. The cost of the treatments must, of course, be weighed against the water quality (and farm management) benefits, but the costs did not seem to exceed the magnitude that is typical of normal farm financial operation. It is worth noting that removal of land from grazing, often cited as an obstacle to livestock exclusion, was not a significant issue in this project. No participating landowner complained of losing excessive grazing land to protected riparian zones, and several expressed surprise at how little land was converted into protected riparian area.

Water supply was an obvious concern following livestock exclusion from stream reaches. The project was fortunate in that alternative supplies could be exploited relatively simply at all sites. This may not always be the case. In a limited way, the project demonstrated some success in using pasture pumps to provide water for beef cattle, but water for dairy cows is a serious operational issue to be considered in future applications.

Maintenance was not a major problem for the treatments. Only normal fence maintenance was required. Erosion damage that was repaired by the project was, with one exception, the result of extreme weather and would have occurred without the project. The exception was erosion to the reconstructed livestock travel lane in WS 2 which was the result of a design deficiency. The principal design/maintenance issue that occurred was associated with the livestock bridge in WS 2. As mentioned earlier, poor drainage at the bridge approaches interfered with livestock use. Future bridge construction would benefit from better engineering design.

Visually, bioengineering installations appeared to work quite well. Growth of planted willows and native riparian zone vegetation was rapid and strong throughout the Treatment period. Brushrolls survived high flows very well and appeared to perform their function of trapping sediment, supporting new vegetation growth, and protecting streambanks. In a few cases, brushrolls began to disintegrate in their third season and a few required replacement. These cases seemed to be in areas where sediment load from incoming overland flow was low and the brushrolls did not fill in quickly.

Objective III. : Track land use and agricultural management activities.

For the most part, the project was successful in tracking land use and management activities through a variety of means, including farmer reporting, aerial photography, and direct observation. Management and analysis of this data, mostly through GIS, improved throughout the project and was extremely useful in assessing the level of treatment achieved in the watersheds. Land use monitoring effectively documented a number of important factors in the project, including the relative stability of overall agricultural land use over the seven years of the project, the modest growth in livestock populations, and the expansion of a new large farm operation in one watershed, along with its observed water quality impacts.

There were, however, some obvious deficiencies in this monitoring activity. There was an enormous range in the content and precision of management data reported by landowners, ranging from refusal to provide any information to volunteering of detailed weekly management records. This variation made comparison among farms and correlation to water quality data difficult and uncertain. Furthermore, while the project set out to collect data on a full range of farm management activities, from manure and fertilizer applications to hay cuts, some information was of limited utility, regardless of precision. On the other hand, specific pasture management data were sparse, limited to documenting general beginning and ending dates of the grazing season and a few direct observations of herds present on pasture. Although it would be difficult and labor-intensive to collect, much more detailed data on stocking rates, animal distribution, and even daily/weekly grazing schedules would be desirable in future studies.

Finally, a major lesson learned was the critical importance of direct observation and inspection in the field. The importance of this was clearly demonstrated by the problems in WS 2 associated with the land clearing and field runoff. Without direct surveillance, the water quality anomalies recorded at Station 2 would have been unexplained. Moreover, such incidents clearly demonstrate the potential for a single acute problem to overwhelm the benefits of land treatment elsewhere in the watershed.

Objective IV. : Document changes in concentrations and loads of nonpoint pollutants at the watershed outlet in response to treatment.

The principal goal of this project was to test the effectiveness of livestock exclusion and riparian restoration in reducing nonpoint pollutant delivery from pasture land to streams in Vermont. The project has successfully documented significant reductions in phosphorus, nitrogen, suspended solids, and indicator bacteria in response to treatment. Average pollutant reductions documented over all three post-treatment years in WS 1, which received the highest degree of treatment, included:

[TP]	-15%	*E. coli*	-29%
[TKN]	-12%	Fecal coliform	-38%
[TSS]	-34%	Fecal strep.	-40%
TP export	-49%	Conductance	-11%
TKN export	-38%	Temperature	-6%
TSS export	-28%		

Pollutant reductions tended to be even greater at high concentration/high flow conditions. Significant water quality improvements had been noted in WS 2 before the confounding influence of the field runoff in Year 7. Despite that problem, significant bacteria reductions (~45%) were shown in WS 2 over the entire post-treatment period. It should be noted, however, that even with the statistically significant reductions in bacteria counts, summer bacteria counts were still quite high in both treatment streams and frequently exceeded Vermont water quality criteria for Class B waters. The water quality effects observed in this study are generally consistent with those reported in the literature.

It is interesting to note that, while not a specific water quality objective or expected outcome, changes in water temperature were noted in Samsonville Brook. These changes involved a slight increase in cold-season water temperatures and a slight decrease in warm-season temperatures. Whereas the three-year treatment period was probably not long enough to promote growth of vegetation sufficient to provide shade, these changes in temperature regime could be a response to observed changes in stream morphology. Narrowing and deepening of the stream, for example, would tend to hold higher cold-season temperatures and lower summer temperatures.

The specific mechanisms responsible for the observed pollutant removal are uncertain and beyond the scope of this study. In general, three general principles were probably in operation: (1) reduction of direct deposit of nutrients, bacteria, and organic matter from livestock ; (2) filtration of overland flow by the restored riparian zone (i.e., as a vegetated filter strip); and (3) reduction of streambank erosion. It was impossible to sort out the importance of these forces within the study design. It should be cautioned that direct comparison of this project's results on a watershed scale with other studies on the plot or field scale are not entirely fair. The performance of the riparian zones as "vegetated filter strips," for example, was probably less effective than that shown in plot or field studies because no attempts were made to promote sheet flow or prevent concentrated overland flow through the protected riparian zones.

Objective V. : Evaluate response of stream biota to land treatment.

According to certain metrics (BioIndex, EPT, and EPT/EPT&chiro ratio), the macroinvertebrate communities improved within both treatment watersheds WS 1 (Samsonville Brook) and WS 2 (Godin Brook), particularly during the second year of treatment (Year 6, 1999), while both the control streams within the WS 3 watershed N.Br Berry Brook, and Berry Brook 1.2 (reference reach) did not show significant change. These biometrics appear to indicate significant shifts in the percent composition of several major orders of aquatic insects, and the percent composition of the functional groups within the treatment watersheds. All of these changes suggest that a shift in the food base is most responsible for improved biological integrity within the treatment streams.

The macroinvertebrate community from Samsonville Brook responded most positively to the treatment. The community compositional shifts appear to be due to a shift in the macro- algae food base, due to a reduction in nutrient loading. The macroinvertebrate community integrity was within Class B threshold criteria for the last two years of the study. In 2000, the macroinvertebrate community structure below a section of untreated pasture downstream of the study area was similar to that of the study site before treatment. This reinforces the notion that the treatment in Samsonville Brook was able to positively influence the biological integrity of the macroinvertebrate community.

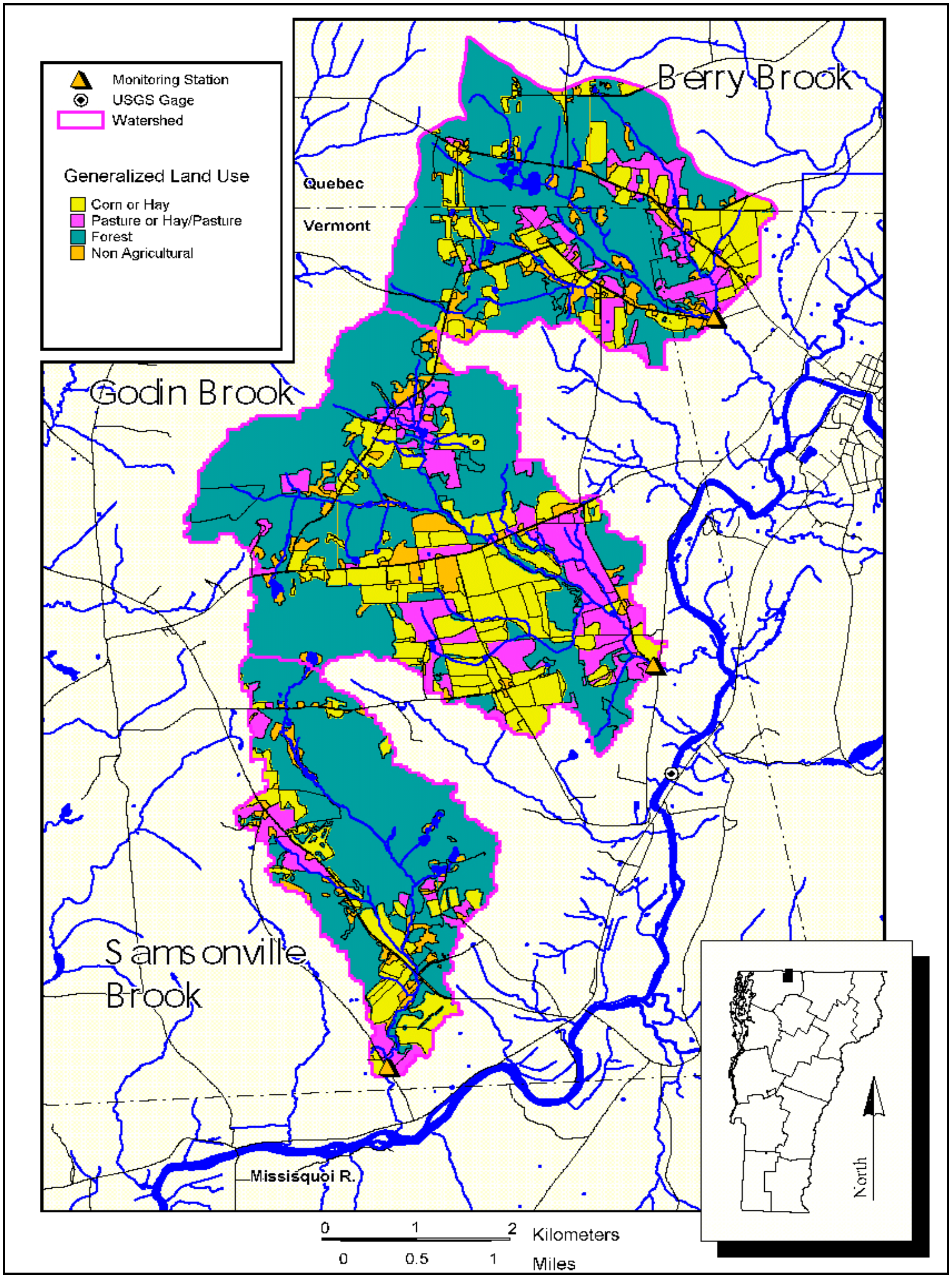
Godin Brook also showed a positive response after the second year of treatment (Year 6, 1999). However during the third year (Year 7, 2000), the community structure returned to pretreatment condition. During this third year of treatment, a catastrophic sedimentation insult occurred from a large farm expansion in the watershed. This sedimentation elevated nutrient and TSS levels of the stream, masking improvements seen in the first two years of the Treatment Period. Consequently, after meeting the VTDEC Class B threshold criteria in 1999 for the first time, Godin Brook failed to support these threshold values in 2000.

Overall, the treatments of riparian zone protection with the study watersheds had a positive effect on the macroinvertebrate community. The most likely cause for the improvements was an abatement in nutrient loading, resulting in a food web response by the macroinvertebrate community. A reduction in sediment loading may have also had some effect on the riffle habitat quality, by reducing embeddedness. The study period was probably too short to allow for increased shading of the stream and increased allochthonous matter from larger shrubs and trees. Future monitoring may show further improvements to the biological integrity of the macroinvertebrate community if the riparian treatments remain intact.

The results of the fish assemblage monitoring showed no significant changes in structure of the assemblages between the Calibration and Treatment Periods for either of the two treatment watersheds. Calibration MWIBI values for Samsonville and Godin Brook sections varied widely. This may have obscured any minor changes which may have taken place as a result of land treatments. Data from the VTDEC database indicates that background variation in the MWIBI is 4 points or less (9 % of the MWIBI index). MWIBI values form Godin 0.9 varied 4 points from 1994-1996. The remaining three treatment sites on WS1 and WS2 each varied 8 points (18 %) during that period. A true measure of normal background variation from a regional reference site, with no impacts over the study period, was to have been provided by sampling the Berry 1.2 site. Unfortunately a major bank-slump and possibly the placement of a mobile home adjacent to the upper portion of the section most probably depressed MWIBI values after 1997.

Three years of post-treatment data may not have been sufficient to measure biological responses to the treatments in the fish communities. Within the Samsonville and Godin Brook watersheds, improvements upstream from the sampled sections may not have been extensive enough to have caused population changes. Additionally, the impact from uncontrolled agricultural activities (up stream from the sampled sections) that evolved over the study period in Godin Brook may have offset any improvements arising from on-section riparian treatments. Fish community productivity in watersheds WS 1 and WS 2, as measured by standing stock (for this study, two-run total abundance), was not significantly different between Calibration and Treatment Periods using the Mann-Whitney rank sum test at $P<0.05$. Although significant decreases were observed in comparison to the control watershed, in absolute terms, mean annual TP and TKN concentrations did not decline between Calibration and Treatment Periods in Samsonville and Godin Brooks. Thus, nutrient-dependent fish abundance would not have changed either. Two-run density at the two Samsonville sites was slightly lower during 1998-2000. This was accompanied by a significant Treatment Period decline in total suspended solids.

Although no observable changes in fish assemblage structure were recorded after land treatments in both watersheds, some physical habitat improvements were noted at Samsonville 0.7 and Godin 0.9. The reduction of silt in the substrate, an increase in overhanging vegetation and the establishment of revetments were noted as improvements at the Samsonville site. The narrowing of the channel in the upstream pool and the increase in gravel and related deceases in sand and silt were regarded as favorable changes at the Godin site. Also at the Godin site, extensive growth of overhanging grasses and the appearance of cattails should also be viewed as positive. The continuing development of vegetation in the riparian zones of the Samsonville 0.7 and Godin 0.9 sites may yet produce changes in the fish assemblages. Subsequent sampling will focus on these two sites, provided the land treatments there are maintained past the conclusion of the study period.


Monitoring Station
USGS Gage
Watershed
Generalized Land Use
Corn or Hay
Pasture or Hay/Pasture
Forest
Non Agricultural
Berry Brook
Quebec
Vermont
Godin Brook
Samsonville Brook
Missisquoi R.
0 1 2 Kilometers
0 0.5 1 Miles
North