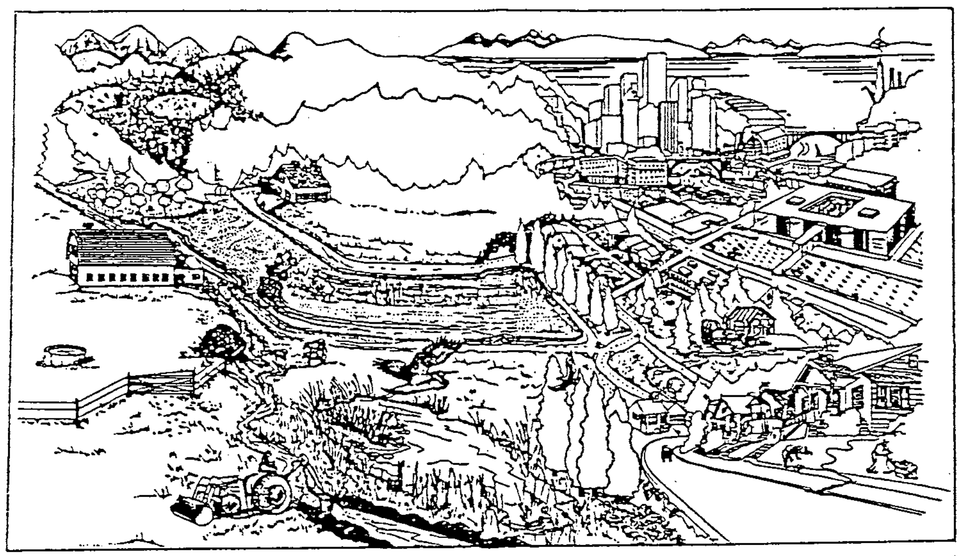
Lake Champlain
Basin Program

Technical Report No. 6A

Lake Champlain Nonpoint Source Pollution Assessment



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PUBLICATION SERIES

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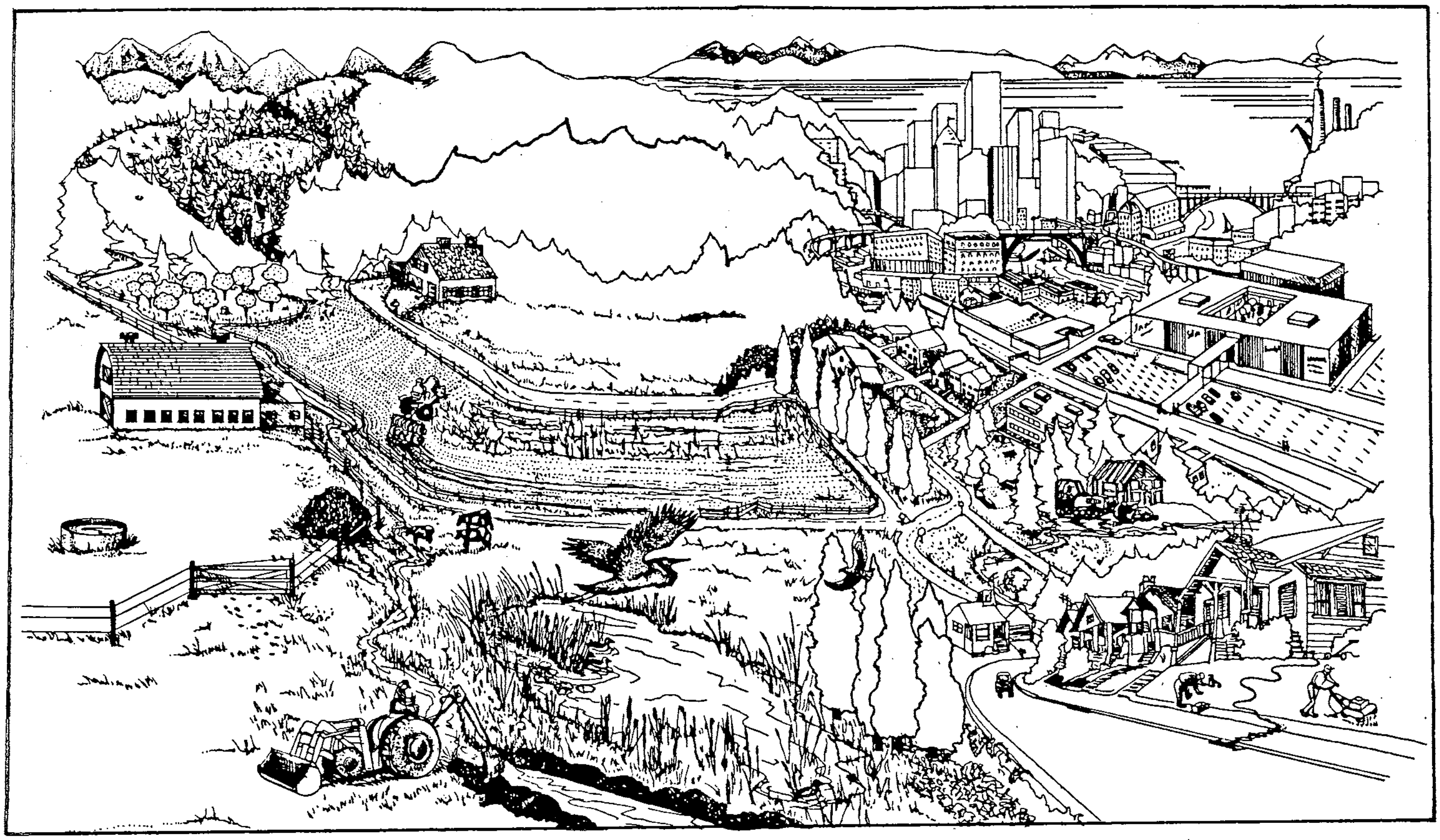
FINAL REPORT



Lake Champlain Nonpoint Source Pollution Assessment

April, 1994

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This technical report is the seventh in a series of reports prepared under the Lake Champlain Basin Program. Those in print are listed below.

Lake Champlain Basin Program Technical Reports

1. *A Research and Monitoring Agenda for Lake Champlain.* Proceedings of a Workshop, December 17-19, 1991, Burlington, VT. Lake Champlain Research Consortium. May, 1992.

2. *Design and Initial Implementation of a Comprehensive Agricultural Monitoring and Evaluation Network for the Lake Champlain Basin.* NY-VT Strategic Core Group. February, 1993.

3. (A) *GIS Management Plan for the Lake Champlain Basin Program.* Vermont Center for Geographic Information, Inc., and Associates in Rural Development. March, 1993.

   (B) *Handbook of GIS Standards and Procedures for the Lake Champlain Basin Program.* Vermont Center for Geographic Information, Inc. March, 1993.

   (C) *GIS Data Inventory for the Lake Champlain Basin Program.* Vermont Center for Geographic Information, Inc. March, 1993.

4. (A) *Lake Champlain Economic Database Project. Executive Summary.* Holmes & Associates. March 1993.

   (B) *Socio-Economic Profile, Database, and Description of the Tourism Economy for the Lake Champlain Basin.* Holmes & Associates. March 1993

   (C) *Potential Applications of Economic Instruments for Environmental Protection in the Lake Champlain Basin.* Anthony Artuso. March 1993.

   (D) *Conceptual Framework for Evaluation of Pollution Control Strategies and Water Quality Standards for Lake Champlain.* Anthony Artuso. March 1993.

5. *Lake Champlain Sediment Toxics Assessment Program. An Assessment of Sediment - Associated Contaminants in Lake Champlain - Phase 1.* Alan McIntosh, Editor, UVM School of Natural Resources. February 1994.

   Lake Champlain Sediment Toxics Assessment Program. An Assessment of Sediment - Associated Contaminants in Lake Champlain - Phase 1. Executive Summary. Alan McIntosh, Editor, UVM School of Natural Resources. February 1994.

6. (A) *Lake Champlain Nonpoint Source Pollution Assessment.* Lenore Budd, Associates in Rural Development Inc. and Donald Meals, UVM School of Natural Resources. February 1994.

   (B) *Lake Champlain Nonpoint Source Pollution Assessment.* Appendices A-J. Lenore Budd, Associates in Rural Development Inc. and Donald Meals, UVM School of Natural Resources. February 1994.

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LIST OF ACRONYMS and ABBREVIATIONS

ARD	Associates in Rural Development, Inc.
CI	Confidence interval
D/F	Lake Champlain Diagnostic/Feasibility Study
DLG	Digital line graph
EC	Export coefficient
EPA	United States Environmental Protection Agency
GIRAS	Geographic Information Retrieval & Analysis System
GIS	Geographic Information System
GWLF	Generalized Watershed Loading Function
HU	Hydrologic unit
ICNSS	It's Cows Not Septic Systems
LCB	Lake Champlain Basin
LCBP	Lake Champlain Basin Program
LCMC	Lake Champlain Management Conference
LF	Loading function
N	Nitrogen
NASA	National Aeronautics & Space Administration
NOAA	National Oceanic & Atmospheric Administration
NOAV	Notice of alleged violation
NPS	Nonpoint source
NURP	National Urban Runoff Program
NYSDEC	New York State Department of Environmental Conservation
P	Phosphorus
RCWP	Rural Clean Water Program
PAC	Project Advisory Committee
SCS	USDA Soil Conservation Service
SRP	Soluble reactive phosphorus
TKN	Total Kjeldahl nitrogen
TN	Total nitrogen
TP	Total phosphorus
TSS	Total suspended solids
USDA	United States Department of Agriculture
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
UVM	University of Vermont
VCGI	Vermont Center for Geographic Information
VTANR	Vermont Agency of Natural Resources
VTDEC	Vermont Department of Environmental Conservation
WS	Watershed
WY	Water year

1.0 EXECUTIVE SUMMARY

1.1 Introduction

Over the last several decades, eutrophication in Lake Champlain has been accelerated in response to excessive nutrient loads, primarily phosphorus (P). According to recent monitoring, about 71% of the lake's P load comes from nonpoint sources within the lake's 8,200 square mile drainage basin. However, there is little understanding or agreement concerning the relative magnitude of the nutrient loads contributed by major land use activities and regions of the basin.

1.2 Objectives and Approach

Because understanding and controlling nonpoint sources of P and other pollutants is essential to improving water quality in the lake, the Lake Champlain Basin Program sponsored a "Lake Champlain Nonpoint Source Pollution Assessment" to begin to answer the question, "Where is the phosphorus coming from?" Specific objectives of this study were:

- Estimate nonpoint source loads to Lake Champlain based on existing land use data.
- Verify the estimates using phosphorus loading data from the Lake Champlain Phosphorus Diagnostic Feasibility (D/F) Study and small subwatersheds within the LCB.
- Estimate the relative contributions from major land use categories and from major regions of the Lake Champlain Basin.
- Make recommendations concerning land use information and water quality data needed to improve this assessment.

Research has shown that within a region, land use tends to be more important in determining stream phosphorus and nitrogen concentrations and loads than watershed geology, soils, and slope. For this reason, this study focused on the relationship between land use and nutrient loads exported by tributaries, combining nonpoint source loading values derived from the literature with existing land use and hydrologic data, to estimate the relative contributions of nonpoint source pollutants by land use and by drainage area to Lake Champlain.

1.3 Methods

Two techniques were employed to estimate annual phosphorus and nitrogen loads from the basin to the lake under a variety of scenarios: <u>export coefficients</u> (i.e. unit area loads by land use) and <u>loading functions</u> (i.e. runoff concentrations x flow). The calculations for both methods require:

- defined drainage areas,
- land use composition of each of the drainage areas, and
- appropriate nonpoint source coefficient values (either export coefficients or runoff concentrations).

Because the loading function method requires estimates of streamflow, additional data on long term precipitation and runoff coefficients were acquired for the region. The overall process employed is shown schematically in Figure 1.1.

The drainage areas used for this study were the eighty-five 11-digit hydrologic units (HUs) that comprise the LCB as defined by the USDA Soil Conservation Service and USGS. Land use information for the basin (excluding Canada) came from the 1:250,000 scale 1973-76 USGS GIRAS data set. Appropriate nonpoint source coefficients for the basin were selected following an extensive literature search. A geographic information system (GIS) was used to manipulate and overlay the spatial data layers and to perform some of the calculations involved in determining pollutant loads.

Phosphorus loads measured at tributary mouths in the Lake Champlain Diagnostic/Feasibility study were used to validate the load estimation models. The model and scenario that gave the best fit was then used to estimate the contributions of forest, urban, and agricultural land in the basin as well as the contributions of the major watersheds. Estimates for SRP and TN could not be validated because the D/F study did not measure these pollutant loads.

In Phase II of the study, the load estimation procedures were tested on four small watersheds (two in Lake George Village, NY and one in each of the St. Albans Bay and LaPlatte River watersheds, VT) to use more detailed land use information contemporaneous with available water quality data. Again, pollutant loads were estimated using the two methods under a variety of scenarios. Results were compared to measured loads.

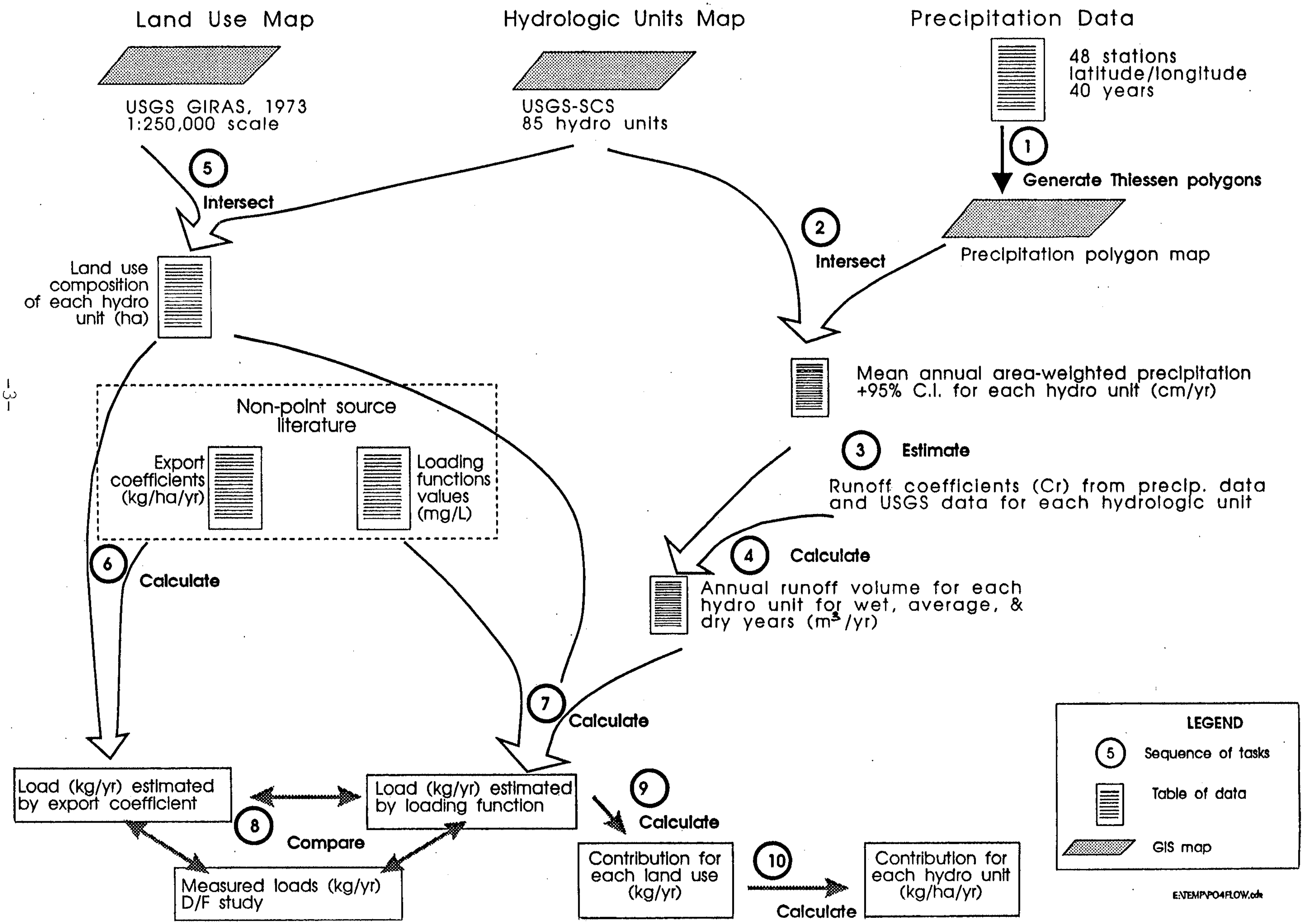
1.4 <u>Results</u>

A GIS was indispensable for this basin-wide assessment and will facilitate additional iterations of the model as better data, particularly land use, become available. As a result of this study, several GIS data layers will be contributed to the LCBP's GIS database including: 11-digit hydrologic units, 1973-76 land use, precipitation gage locations, precipitation polygons, and D/F tributary monitoring station locations.

In 1973-1976, the land use baseline for this assessment, the Lake Champlain Basin (excluding the Canadian portion) consisted of 62% forested land, 28% agricultural land, 3% urban land, and 7% water. By intersecting the land use and HU data layers in the GIS, the land use composition of each of the 85 HUs was also calculated.

An extensive review of the nonpoint source literature yielded runoff concentration values and export coefficients for total phosphorus (TP), soluble reactive phosphorus (SRP), and total nitrogen (TN) that are appropriate for the Lake Champlain Basin, but only very limited values for other nonpoint source pollutants.

Fig. .1 Lake Champlain Non-Point Pollution Assessment



For example, the average values for TP selected as appropriate for the Basin were:

	Export Coefficient	Runoff Concentration
Forest	0.1 kg/ha/yr	0.015 mg/l
Agriculture	0.5 kg/ha/yr	0.20 mg/l
Urban	1.5 kg/ha/yr	0.35 mg/l

Low- and high-end values bracketing these average values were also selected to account for a range of potential conditions. A variety of different scenarios of coefficient selection, hydrologic condition, and land use change were evaluated.

1.4.1 Model Verification. The loading function method using "low-end" runoff concentration values under average hydrologic conditions gave an estimated annual total P load to the lake of 457 t/year, a prediction that agreed very well with the 458 t/year measured for an average hydrologic year by the D/F study. This method and scenario not only predicted total load to the lake extremely well, but also predicted individual tributary loads accurately (paired t-test, $P \leq 0.05$).

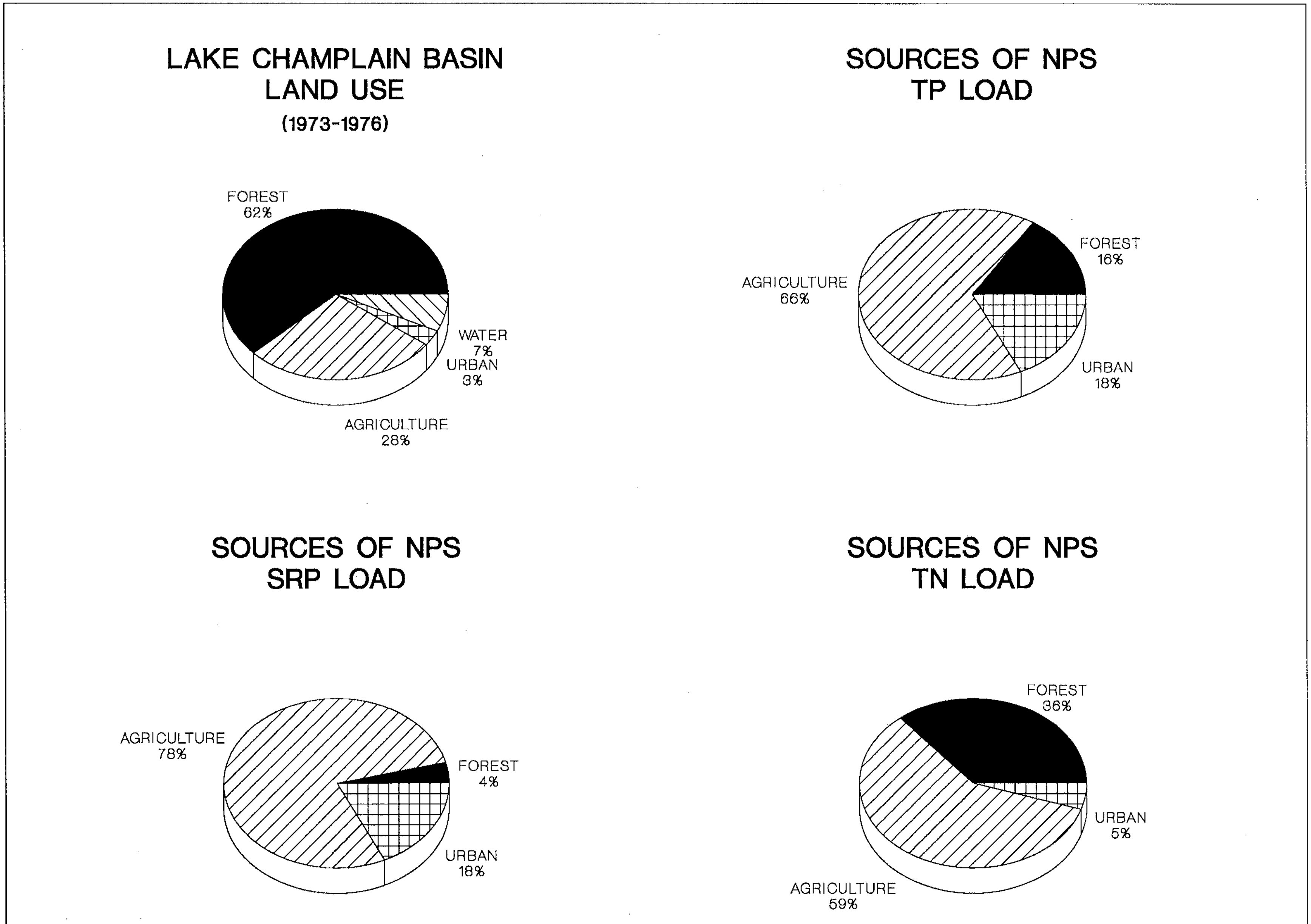
Results using average export coefficients were also reasonable but did not agree with measured loads as well as did the loading function estimates. The export coefficient method also has the disadvantage of not being sensitive to variations in annual precipitation and streamflow. For these two reasons, the loading function method of nonpoint source load estimation is preferred over the export coefficient method.

In Phase II, nonpoint source loads from the small Lake George watersheds were not estimated very well by either of the methods that seemed to work at the basin scale. Load estimates in the Vermont small watersheds were somewhat better and reasonably good agreement between estimated and measured SRP and TN loads in these watersheds does lend some confidence to the basin-scale SRP and TN estimates that could not otherwise be validated. The relatively good agreement between measured and estimated stream flow in the Phase II watersheds provides confidence in the overall flow estimation procedures used in the loading function model in both Phase I and Phase II.

1.4.2 Contributions to Lake Champlain Nutrient Loads. Based on the best-fit nonpoint source estimation model, agriculture contributes 66% of the average annual TP load to Lake Champlain, urban land contributes an estimated 18% of the annual TP load, and forest land contributes 16%. A generally similar pattern emerged for SRP and for TN loads (Fig. 1.2).

Approximately 73% of the nonpoint source TP load is estimated to come from the Vermont/Quebec side of the Lake Champlain Basin, and 27% from the New York portion. Large drainage basins which include much agricultural land, such as the Missisquoi River basin, tend to contribute the largest loads to the lake. Predominantly forested drainage basins such as the Boquet-Ausable, contributed the smallest estimated loads (Fig. 1.3).

FIGURE 1.2



(Load estimates from LF, low coeff. values, average flows)

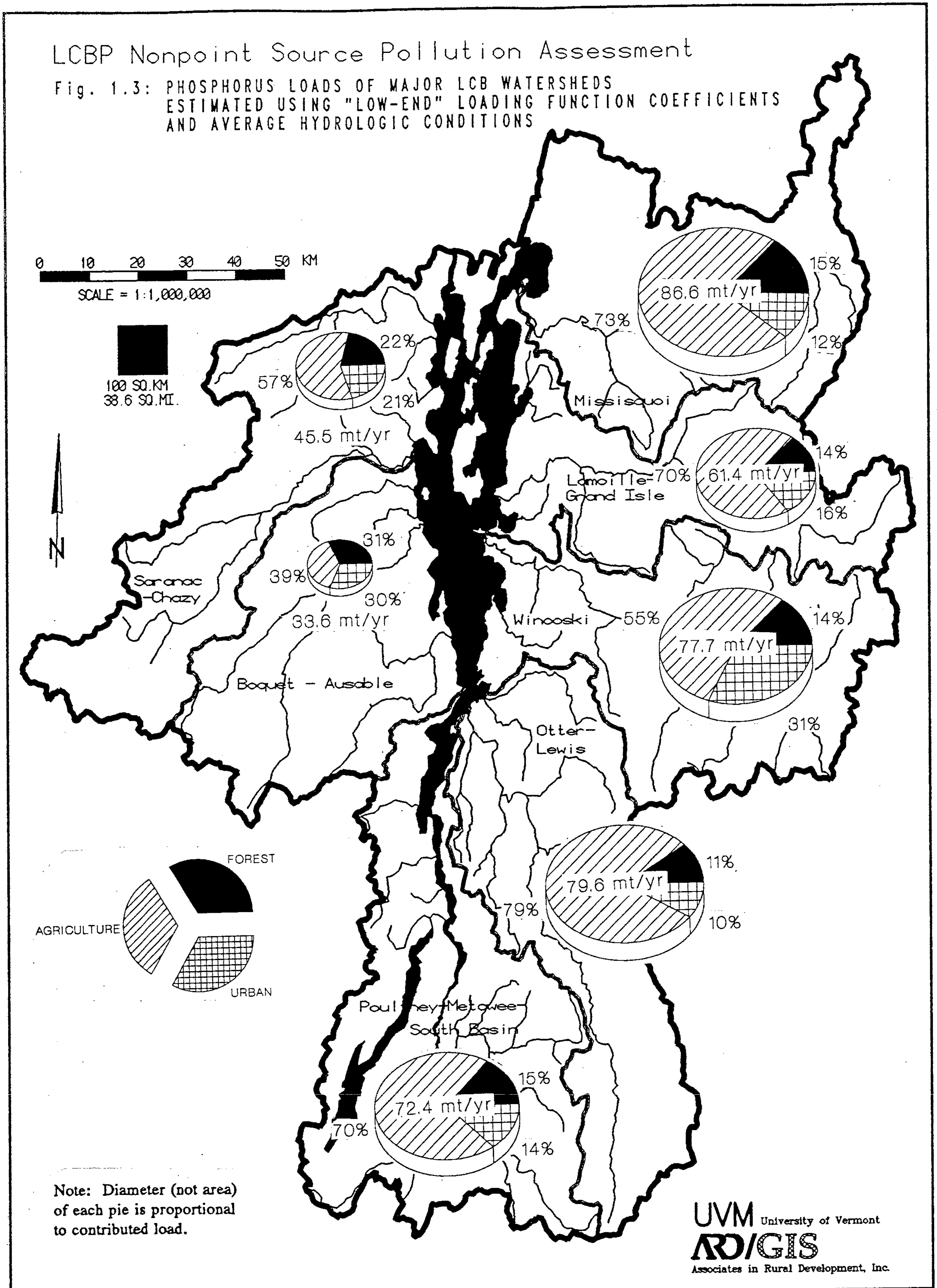


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Fig. 1.3: PHOSPHORUS LOADS OF MAJOR LCB WATERSHEDS ESTIMATED USING "LOW-END" LOADING FUNCTION COEFFICIENTS AND AVERAGE HYDROLOGIC CONDITIONS

The HU containing the most urbanized area in the Lake Champlain Basin - Burlington, Vermont - showed the highest estimated areal TP export rate (0.85 kg/ha/yr). In general, the highest-contributing 11-digit HUs included highly urban areas as well as predominantly agricultural land (Fig. 1.4).

Because agricultural land contributes the majority of nonpoint source P and N to Lake Champlain, any strategy to reduce nonpoint source loads must deal with agricultural sources. However, urban land, comprising just 3% of the basin, contributed 18% of the estimated load; this disproportionate contribution suggests that relatively high efficiencies in nonpoint source load reductions might be achieved by also addressing urban nonpoint source controls.

1.4.3 Impact of Septic Systems. The likely significance of P load from septic systems on Lake Champlain was estimated using existing data. Even under worst-case assumptions, failed septic systems are likely to be responsible for only up to about 5% of the total annual phosphorus load to Lake Champlain. While failed septic systems can be serious threats to public health and water quality on a local or county scale, at the scale of the Lake Champlain Basin, they appear to represent only a very small portion of the phosphorus load to the lake, comparable to that contributed by direct precipitation.

1.4.4 Limitations of Methodology and Interpretation of Results. The choice of coefficient values and natural hydrologic variability were the most important sources of uncertainty in the load estimations. Errors in estimation of discharge from the HUs and errors or shifts in land use distribution have relatively small influence on load estimates. However, at the basin scale, relative contributions of the three general land use categories were not radically affected by coefficient selection or hydrologic variability. The range of relative contributions to annual TP load was surprisingly consistent under different model scenarios: Forest 13-16%; Agriculture, 66-74%; and Urban 12-18%.

Because the simple loading function model does not account for important natural and cultural processes that influence nonpoint source activity and because the model was run using twenty year old land use data, little reliance should be placed on the absolute estimates of nonpoint source contributions to the lake by individual 11-digit HUs.

The use of 20 year old land use data was a major weakness of this study and limits the conclusions that can be drawn regarding specific land uses and areas of the basin to be targeted for nonpoint source management. Without contemporary land use data, it is impossible to evaluate, in an absolute sense, what the "correct" nonpoint source runoff coefficients are for the Lake Champlain Basin and, in turn, to calculate more precise estimates of actual loads for each land use and hydrologic unit.

The load estimation models used in Phase I of this assessment were based on average conditions: average export coefficients, average runoff concentrations,

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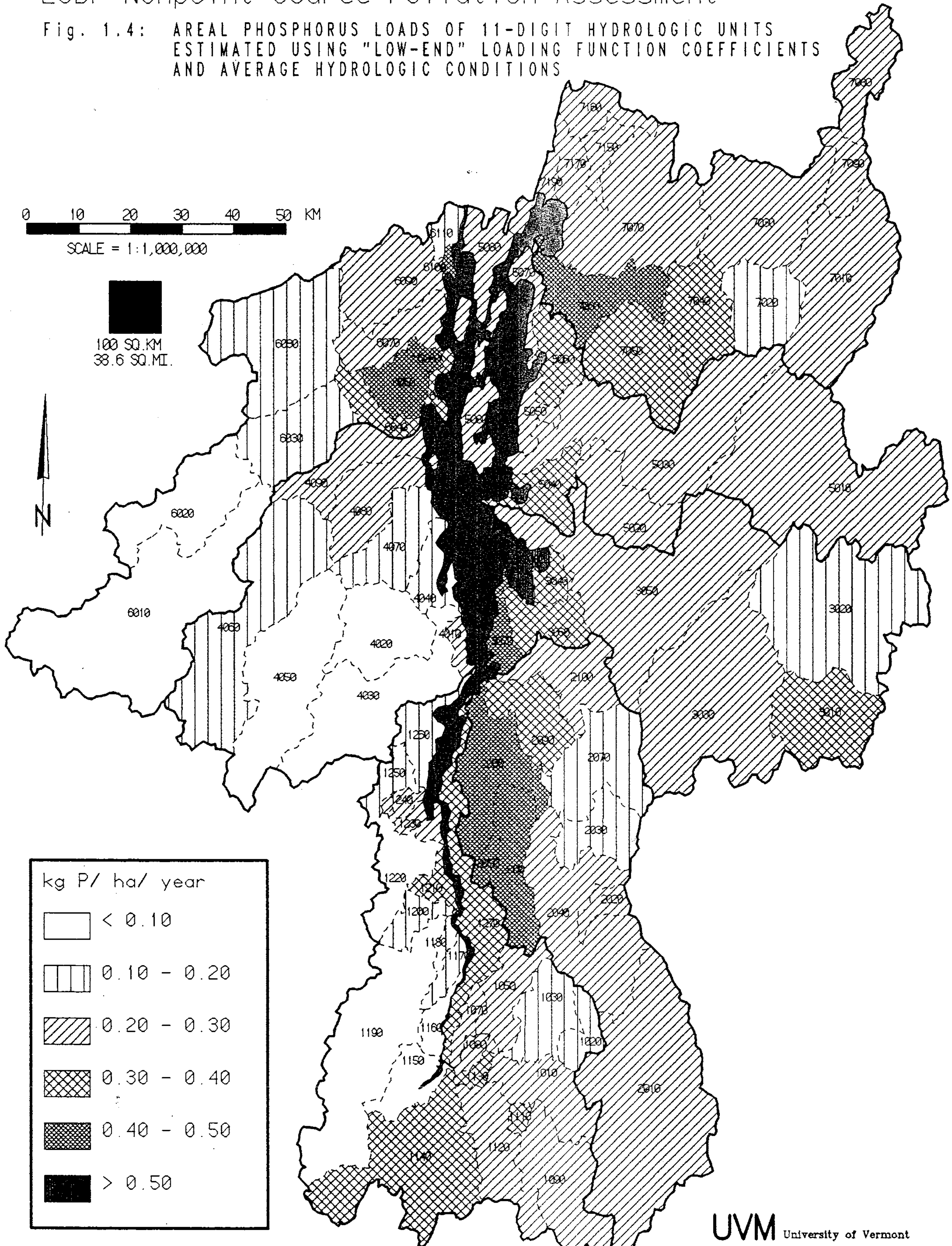
Fig. 1.4: AREAL PHOSPHORUS LOADS OF 11-DIGIT HYDROLOGIC UNITS ESTIMATED USING "LOW-END" LOADING FUNCTION COEFFICIENTS AND AVERAGE HYDROLOGIC CONDITIONS



Refer to Table 7.2 for total P load estimates for individual hydrologic units.

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average precipitation, average runoff coefficients, average stream flow, etc. While this approach works at the Lake Champlain Basin or major river basin scale, it does not seem to work well at a very local scale. Very small watersheds can behave very differently from average expectations in response to individual storm events, transient activities such as construction, or particular cultural practices. While such factors probably tend to average out in large watersheds, they are very likely to be more significant in small watersheds, confounding the accuracy of load estimates.

1.5 Recommendations

This load estimation procedure should be reiterated when the new land use mapping effort for the basin is completed to:

-confirm the validity of the approach, and
-confirm the appropriateness of loading coefficients selected for the three major land use classes in the basin.

However, because the selection of nonpoint source runoff coefficients is so critical, more accurate load estimates will require verifying or developing runoff coefficients that are specific to land uses, conditions, and practices in the Lake Champlain Basin instead of relying upon general values selected from the literature. Developing such coefficients will involve water quality monitoring in small watersheds with relatively homogeneous land use over several years.

Any more detailed land use mapping effort for the Lake Champlain Basin should select and define land use categories based on available runoff coefficients if it is expected to yield more refined indications of nonpoint sources. Unless there is a correspondence between mapped land use categories and runoff coefficients, load estimates based on detailed coefficients and detailed land use mapping will not result in a more refined estimate of nonpoint loads.

The SCS-USGS hydrologic unit mapping scheme was adequate for the purposes of this basin-wide assessment. However, a hierarchical coding of watersheds based on river branching would be much more useful and accurate for studying and managing water quality.

In view of the inherent limitations of simplified, empirical estimation models, it would be ultimately desirable to develop a linked watershed-lake, calibrated physical process simulation model of the type now in use for the Chesapeake Bay. Such a model could be used to reliably estimate nonpoint source loads to the lake and to evaluate the impacts of changes in land-based management practices on water quality in Lake Champlain.

2.0 ACKNOWLEDGEMENTS

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3.0 INTRODUCTION

3.1 Study Area.
Lake Champlain, with a surface area of about 1,124 km^2 (435 mi^2), is situated in the states of Vermont and New York and the Province of Quebec and drains a watershed of 21,326 km^2 (8,234 mi^2) (Lake Champlain Basin Study, 1979). Slightly over half of the watershed is in Vermont and over one third is in New York. About 65% of the lake's 944 km (587 mi) shoreline is in Vermont, 31% is in New York, and 4% is in Quebec (Figure 3.1).

Nearly half of the state of Vermont (48%, or 11,942 km^2), 6% of the state of New York (7,892 km^2), and just 0.1% of the province of Quebec (1,492 km^2) fall within the Lake Champlain basin (Lake Champlain Basin Study, 1979). The basin includes all or part of 11 counties and 146 municipalities in Vermont, 5 counties and 61 municipalities in New York, and 34 municipalities in 6 counties in Quebec. More than 607,000 people live in the basin (Holmes et al., 1993), and some 6 million people visit the basin each year. Forested land dominates the watershed; agricultural land use is extensive, while only a small amount of the basin is urban/developed.

3.2 The Lake Champlain Basin Program.
The 1990 Lake Champlain Special Designation Act established the Lake Champlain Basin Program (LCBP) and charged the Lake Champlain Management Conference (LCMC) with the preparation of a pollution prevention, control, and restoration plan for the lake. Because eutrophication resulting from excessive nutrient loading is one of the most critical lake water quality problems, understanding the nature and extent of nutrient loading to the lake is a high priority for the LCBP, as is the consideration of potential measures for reduction of the quantity of nutrients reaching the lake.

3.3 Nature and Extent of the Nonpoint Source Problem.
Nutrient loading to Lake Champlain is a critical problem because an excess nutrient supply contributes to accelerated eutrophication, a process of increasing biological productivity, e.g., accelerated growth of algae and other aquatic plants. Eutrophication often impairs popular human uses of lakes, such as swimming, fishing, boating, water consumption, and aesthetics; consequently, efforts to reduce or control eutrophication are usually a high priority for lake management. In Lake Champlain, phosphorus (P) is typically the limiting nutrient, controlling productivity because it is in shortest supply relative to need. Management of phosphorus levels in the lake and of quantities of phosphorus delivered to the lake is thus of critical importance.

Eutrophication has been recognized as a significant problem in Lake Champlain for several decades (VTAEC, 1977; Lake Champlain Basin Study, 1979). Most areas of Lake Champlain are currently classified as mesotrophic (moderately productive); some areas such as Missisquoi Bay, St. Albans Bay, and the South Lake, are considered to be eutrophic (Smeltzer, 1989). Phosphorus concentrations in some parts of Lake Champlain are similar to those observed in the most severely eutrophic areas of the Great Lakes in the 1970s, such as western Lake Erie and Saginaw Bay in Lake Huron (Smeltzer, 1989). Even in parts of the lake where the average phosphorus concentration is low, fluctuations in P concentration, particularly in near-shore areas, can cause periodic algae blooms.

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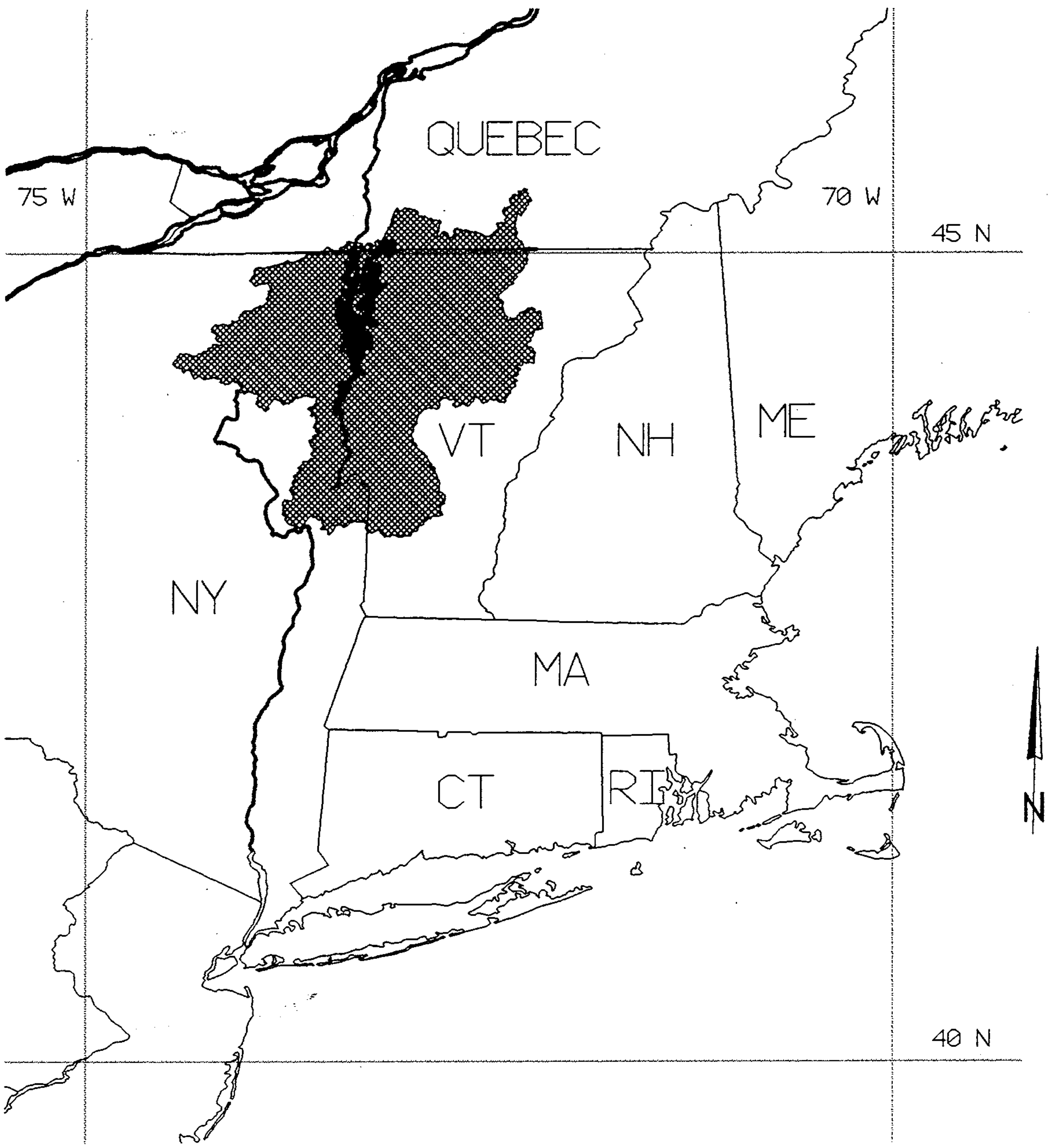
Fig. 3.1: LOCATION OF THE LAKE CHAMPLAIN BASIN



DATA SOURCES: The Lake Champlain shoreline and basin boundaries were derived from 1:24,000 scale USGS topographic maps. Other features appearing on this map were derived from Environmental Systems Research Institute's 1:3,000,000 ArcWorld database.

APPROXIMATE SCALE = 1:4,700,000

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Phosphorus, as well as other pollutants such as nitrogen, sediment, and toxic substances, may enter the lake from a variety of sourcess, including **atmospheric deposition**, **point sources** (discharges from specific pipes or outlets such as wastewater treatment plants or industrial discharges), and **nonpoint sources** (surface runoff or subsurface flow washing pollutants from wide land areas to the lake or its tributaries). Based on recent monitoring, approximately 71% of Lake Champlain's phosphorus load is attributable to nonpoint sources (VTDEC and NYSDEC, 1993). An estimated 2% of the lake's annual phosphorus load is delivered by atmospheric deposition.

Management efforts to reduce point source phosphorus loads to the lake over the last two decades have included bans on phosphorus in detergents and the construction of new and improved wastewater treatment plants. These efforts, as well as some implementation of agricultural nonpoint phosphorus management practices in priority watersheds, have essentially "held the line" on further increases in phosphorus concentrations in Lake Champlain during the 1980s (Smeltzer, 1989). However, it is clear that efforts to control eutrophication in the lake in the 1990s cannot succeed unless nonpoint sources are reduced (Smeltzer, 1991).

A Memorandum of Understanding on Environmental Cooperation on the Management of Lake Champlain, signed by the States of Vermont and New York and the Province of Quebec in 1988 (VTANR and NYSDEC, 1988) outlined a phosphorus management strategy for the lake consisting of three steps:

1. Establish numeric in-lake phosphorus concentration criteria for each segment of the lake.

2. Measure the phosphorus loadings to the lake and develop a whole-lake water quality model predicting the lake's response to changing phosphorus loadings.

3. Use the lake model to conduct a phosphorus load allocation at tributary mouths and other major sources and set phosphorus management policies to attain the in-lake water quality criteria.

The first step in this process for Lake Champlain was achieved in 1993 with the signing of a New York, Quebec, and Vermont Water Quality Agreement on in-lake phosphorus criteria. Substantial progress has been made on the second step with the completion of the Diagnostic/Feasibility Study (VTDEC and NYSDEC, 1993) and preliminary model development (Smeltzer, 1993). The third step will likely call for further reductions of phosphorus loads from tributaries to achieve the desired in-lake phosphorus levels. Such reductions will surely require decreases in nonpoint source phosphorus loads generated by human activity in some parts of the basin.

Unfortunately, there is little firm knowledge or agreement concerning the importance and relative contributions of even general nonpoint source categories, such as forest land, agricultural activities, and urban/residential land, to Lake Champlain. Before embarking on a nonpoint source management program for the Basin, a better understanding of what land use activities and which drainage areas contribute most nonpoint source pollutants to the lake is essential. This is especially important when allocation of tributary phosphorus loads begins. Without understanding of the contributions of nonpoint source types and land areas, it will be extremely difficult to focus cost-effective control measures, expend limited resources, and make the complex decisions required to protect and restore Lake Champlain.

4.0 STUDY OBJECTIVES AND APPROACH

4.1 Objectives.
The principal objective of this project is to provide preliminary estimates of the quantities of potentially available nonpoint source pollutants and the relative significance of major nonpoint source types in the LCB. In simple terms, we must begin to answer the question: WHERE IS THE NONPOINT SOURCE PHOSPHORUS COMING FROM? The results of the study will help serve as a basis for setting priorities and allocating resources for the control of nonpoint source pollution and will identify additional data required to improve future nonpoint source loading estimates.

Two specific objectives have been identified by the LCBP Technical Advisory Committee:

1. Assemble the available relevant land use and source category loading coefficients to estimate phosphorus and other pollutant loads to Lake Champlain. This includes:

   a. developing estimates of the relative nonpoint source pollutant contributions to Lake Champlain from major categories of land use within subwatersheds of the Lake Champlain Basin, and

   b. to the extent possible, verifying these estimates using basin-scale phosphorus loading data collected through the Lake Champlain Phosphorus Diagnostic-Feasibility Study as well as existing data from smaller case-study sub-watersheds within the Lake Champlain Basin.

2. Develop recommendations for land use information and water quality data needed to improve this assessment.

An advisory group comprised of individuals representing the interests of the various nonpoint source pollution source categories within the basin was assembled to help guide the progress of the study. This Project Advisory Committee (PAC) met five times during the course of the project and provided valuable criticisms and suggestions, as well as review of all project outputs. Members of the PAC are listed in Appendix A.

4.2 Study Approach.
It is well recognized that water quality in a stream or lake is an expression of the character of its watershed and the activities taking place within that watershed. Natural factors such as geology, account for some of this influence (Dillon and Kirchner, 1975), but land use is often the overriding influence. Omernik (1976, 1977) found that after regional differences were accounted for, land use was a more important determinant of stream phosphorus and nitrogen concentration than were watershed characteristics such as geology, soils, and slope. In Omernik's studies, nutrient levels tended to be higher in streams draining agricultural watersheds than in those draining forested land; nutrient levels were proportional to the percent of land in agriculture or combined agriculture+urban land (Omernik, 1976). This kind of relationship has been documented in a variety of areas (e.g. Clesceri et al., 1986) and has recently been suggested in the Lake Champlain basin (Smeltzer, 1993).

Since the 1970s, pollutant losses from many different land uses have been measured, ranging from pollutant concentrations in edge-of-field runoff to annual mass export per unit area from large watersheds (e.g. McElroy et al., 1976; Reckhow et al., 1980; Athayde et al., 1983; Mills et al., 1985). Numerous techniques have been advanced to estimate the total quantities of nonpoint source pollutants arising from unmonitored watersheds using such values. These techniques range from the very simple multiplication of unit area loads by land area to the application of complex physical process models.

Under the **export coefficient (EC)** approach, some representative value of pollutant export per unit area of land is applied to a land area to estimate potential pollutant contribution. Reckhow et al. (1980) proposed a procedure to quantify land use and lake water quality relationships using phosphorus export coefficients (kg/ha/yr) to calculate phosphorus load and compiled an extensive list of export coefficients. Similar land use-nutrient export relationships were further explored by Beaulac and Reckhow (1982). Rast and Lee (1983) found good agreement between phosphorus and nitrogen loads estimated by export coefficients and measured amounts of phosphorus and nitrogen transported to 38 U.S. water bodies. Clesceri et al. (1986) documented the use of export coefficients as a cost-effective means of estimating nonpoint source nutrient loads to Wisconsin lakes. A similar approach was used to characterize and assess the relative contributions of sediment, nutrients, and metals to surface waters by different land uses in North Carolina (Smolen et al., 1990). Using just three land use classes - urban, forest, and agriculture - Frink (1991) found good agreement between in-lake phosphorus and nitrogen concentrations predicted from watershed land use and concentrations measured in Connecticut lakes.

Another common approach - the **loading function (LF)** technique - estimates pollutant load as a function of estimated pollutant concentration and estimated runoff or streamflow volume. This approach has the advantage of incorporating climatic variation into nonpoint source load estimates and has been used successfully in the Chesapeake Bay watershed (Hartigan et al., 1982) and in the Galveston Bay estuary (Newell et al., 1992). This concept is incorporated in the EUTROMOD model relating land use to lake eutrophication (Reckhow and Coffey, 1990).

More sophisticated modifications of the loading function technique have been proposed. Dean (1983) refined the approach using potency factors, representing pollutant concentrations in soil, enrichment ratios, and particulate transport factors. Mills et al. (1985) employed a nonpoint source estimation procedure based on runoff estimated by the SCS curve number technique, the Universal Soil Loss Equation, and soil concentration of pollutants. The Generalized Watershed Loading Function (GWLF) model developed at Cornell University uses the loading function concept along with precipitation, transport, and chemical process parameters to estimate dissolved and total monthly nitrogen and phosphorus loads in streamflow from complex watersheds (Haith et al., 1992).

In recent years, geographic information system (GIS) technology has been applied effectively to the process of nonpoint source load estimation. ARC/INFO was used in the Galveston Bay National Estuary Program to calculate nonpoint source loads from various land uses based on geographic analysis combined with pollutant event mean concentrations, map the location of generated nonpoint source loads, and conduct a priority ranking of loadings by subwatershed (Newell et al., 1992). Sixty-five percent of phosphorus and nitrogen loads to four Texas reservoirs estimated using a GIS and published export coefficients agreed within one standard deviation of measured loads (Ernst et al., 1993). Agricultural land in Pennsylvania has been assessed by layering watershed boundaries, slope, soil, and land use information with animal density and precipitation factors to rank 104 watersheds for nonpoint source pollution potential (Mertz, 1993). GIS applications have combined land use analysis with complex hydrologic and water quality models to evaluate nonpoint source management options in Oregon (McMillen and Gorman, 1993) and in North Carolina (Quinlan and Simmons, 1993).

Clearly there are a wide variety of options available to estimate nonpoint source loads to Lake Champlain. Given the scale of the problem, the lack of detailed land use and water quality data at the basin scale, and the limited resources available, a relatively simple approach was required. In this project, a GIS was used to evaluate and manipulate existing land use data for the basin. Both the export coefficient and the loading function technique were applied, using published values selected as appropriate to the basin. Estimates of nonpoint source loadings were calculated for each of the 85 11-digit hydrologic units (HUs) that comprise the basin and compiled for each of the major drainages contributing to the Lake. The proportion of the estimated nonpoint source load arising from three major land uses - forest, agriculture, and urban/developed - was assessed. Estimates of nonpoint source phosphorus loads were compared to loads actually measured at tributary mouths during 1990-1992 in order to assess the accuracy of the load estimates.

In the second phase of the project, several small watersheds within the LCB, for which detailed land use and water quality data exist, were evaluated as a further test of the estimation approach.

Finally, recommendations for future land use and water quality data needed to improve this assessment were made based on the results of the project.

4.3 Use of Geographic Information Systems (GIS)

Throughout this project, geographic information system (GIS) technology was used to analyze and display spatial data. GIS is a computer technology that uses specialized software and hardware to record the identity, location, and attributes of spatial features such as water sampling stations (points), streams (lines), and watersheds (polygons). The attributes associated with these features - for example, the watershed ID number, area, and land use composition of a watershed - are stored in the GIS's relational database in the same way that tabular data are stored by more commonly used database management software. This allows any attribute associated with a spatial feature to be analyzed and mapped. For example, the spatial relationship between population density and total phosphorus loads per unit area could be analyzed provided the necessary data had been entered into the GIS. In order for computerized spatial analysis to be possible, the location of spatial features must be very accurately defined based on a known map projection and on latitude/longitude or some other coordinate system. Once entered into the GIS, the data can be thought of as "layers" representing various themes, e.g. a land use layer, a surface water layer, etc. (Figure 4.1). Because of the precise spatial registration of data layers, the computer can help us understand the relationships between layers far more easily than can be done by viewing stacked plastic overlays depicting the same layers.

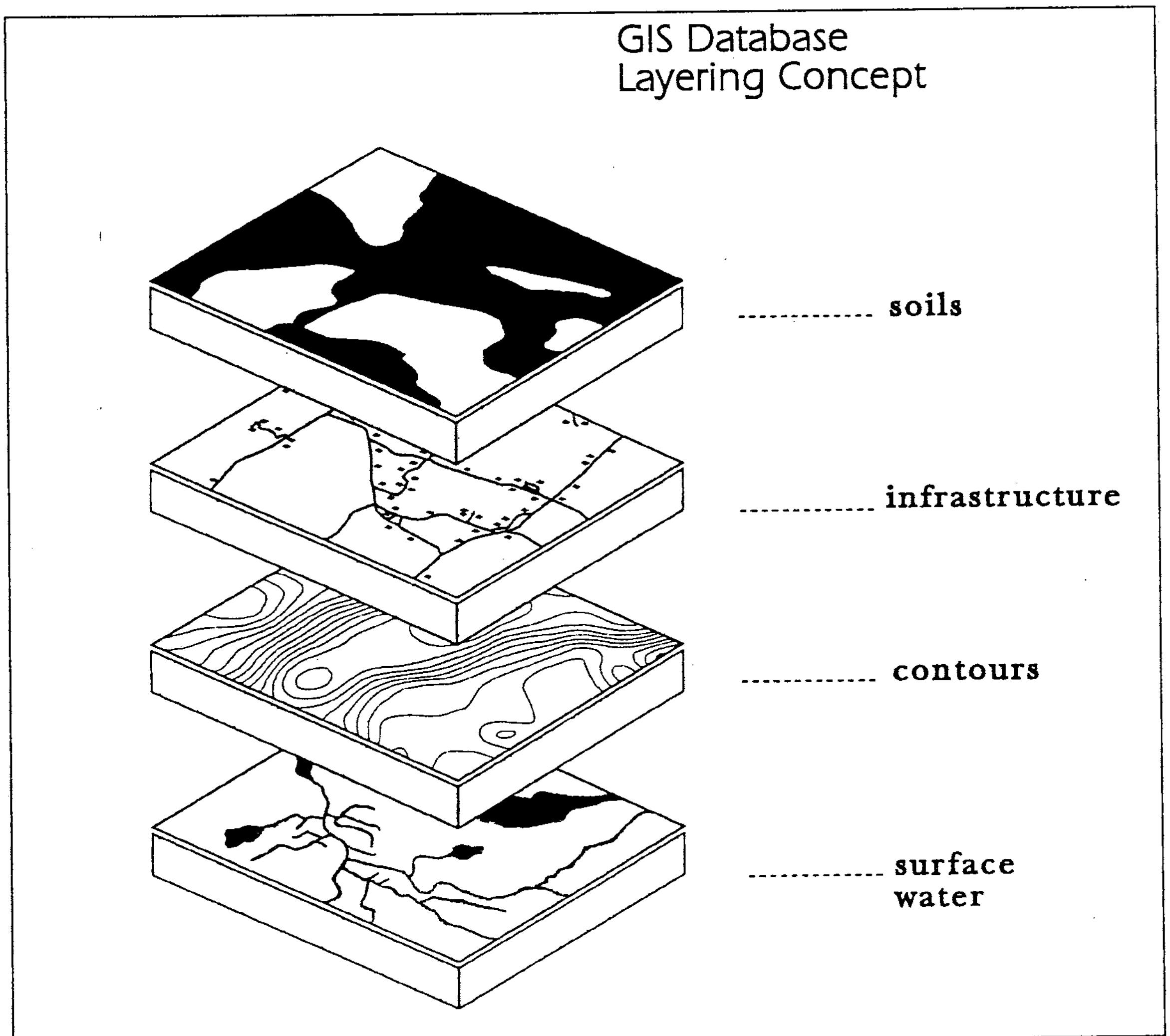


Fig. 4.1 Because of the precise registration of each feature to a position on the earth's surface, data layers can be "stacked" within a GIS.

5.0 METHODS

Nonpoint source pollutant loads were estimated by both the export coefficient (EC) and the loading function (LF) method. Both methods require defined drainage areas, in this case USDA designated hydrologic units (HUs), data concerning the land use composition within each of the HUs, and appropriate nonpoint source coefficient values (either export coefficient or runoff concentration). The overall process employed is shown schematically in Figure 5.1 and each step is described in detail below.

5.1 Literature Review for NPS Concentration and Export Coefficients.
An extensive review of the recent scientific literature was conducted in order to select appropriate nonpoint source loading function concentration values and export coefficients for the LCB. Sources consulted included leading scientific journals such as the Journal of Environmental Quality, Journal of Soil and Water Conservation, and Water Resources Bulletin; computerized reference systems such as Selected Water Resources Abstracts and AGRICOLA; government documents, primarily EPA and USDA; and personal reference collections. A computer-aided literature search was also conducted through the National Water Quality Evaluation Program at North Carolina State University. In addition, members of the Project Advisory Committee (PAC) contributed citations, particularly of state, regional, and county reports.

References collected in the review were screened for acceptance according to five principal criteria:

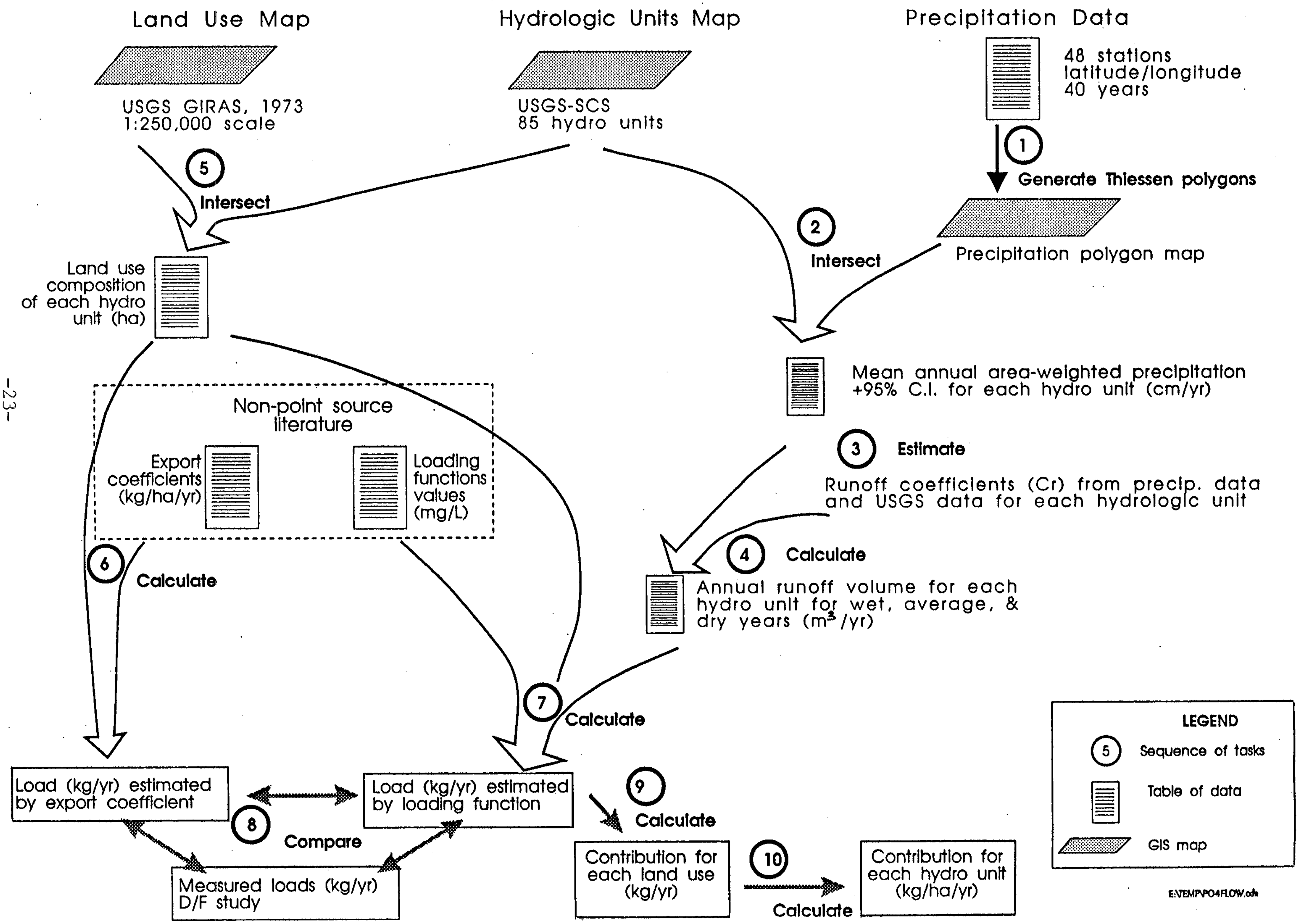
1. Contemporary value In general, only work conducted and published since 1970 was accepted, although there were a few exceptions. Differences in experimental design, analytical methods, and the understanding of nonpoint source processes cast some doubt on the applicability of the older reported values.

2. Real data In general, only work reported from actual monitoring studies was accepted; values derived from purely modeling studies were not considered. One exception was a set of coefficients used in the Chesapeake Bay watershed which were derived from a validated watershed model which was in turn developed from actual field studies.

3. Watershed studies Only data reported from monitoring at a watershed scale were included, although watershed size varied tremendously. Data reported from plot studies were rejected because small (e.g. 100 m^2) plots behave very differently compared to real drainage areas and are very difficult to apply to HUs of the size considered in this project.

4. Scientific validity Studies based on poor or inappropriate experimental design, such as very low sampling frequency or only base flow sampling, were not considered. Studies that did not encompass a complete annual seasonal cycle were rejected.

Fig. 5.1 Lake Champlain Non-Point Pollution Assessment



5.Regional relevance Studies from regions with climate, landscape, and land use characteristics strongly different from that of the LCB were not included. Data from Louisiana, the desert Southwest U.S, or downtown Houston, for example, were typically rejected. In general, only data from areas with cold winters and a significant spring runoff period were considered. Every effort was made to include data from studies conducted within the LCB.

Values from reported studies that met the above criteria were collected and tabulated in spreadsheet tables which included the location (e.g. state), the type of study (e.g. monitoring, literature review), the reported values for nonpoint source pollutants (either the mean/median value or the range in values reported), the citation, and relevant comments on the reported study. References concerning runoff concentrations were tabulated separately from referenced export coefficients. References were organized according to general land use category - forest, agriculture, and urban - and, within these categories, according to more detailed land use (e.g. cropland, residential) within each category.

Because of the critical importance of the choice of coefficient values, no single value was selected for a given land use. There is tremendous range reported in the literature and a wide range of actual nonpoint source pollutant levels would be expected in the LCB due to variations in land management and in hydrology. Thus, values were selected for use in loading estimates at three levels: the low and high ends of a most commonly reported range (approximately the interquartile range of reported values) and a single baseline value. The baseline value chosen **is not** simply the average of all reported values, but represents the best judgement of an appropriate value to be applied in the LCB, with emphasis given to data reported from work within the basin or in the region. Baseline values chosen for urban runoff, for example, reflect values reported from the Lake George, NY National Urban Runoff Program study more than data reported from the Washington, DC metropolitan area.

Nonpoint source loading estimates will, therefore, reflect some of this uncertainty and a **range** will generally be reported and discussed based on different coefficient scenarios.

5.2 GIS and Spatial Data Layers.

Environmental Systems Research Institute's PC-ARC/INFO 3.4D Plus was the GIS software used throughout this study. Clark University's (Worcester, MA) IDRISI 3.1 software was used to create Thiessen polygons for precipitation estimation.

The GIS data layers used for this nonpoint assessment were:

- hydrologic units
- land use
- precipitation*
- tributary sampling stations*
- surface water
- political boundaries

(*discussed in sections 5.3.1 and 5.5 respectively).

All data layers were projected to Universal Transverse Mercator (UTM) Zone 18 with a -4,000,000 meters Y shift.

5.2.1 Hydrologic Units. The eleven-digit hydrologic units (HUs) defined by the USDA Soil Conservation Service (SCS) comprising the Lake Champlain Basin (LCB) were chosen to be the level of spatial resolution of this assessment. The boundary locations and coding scheme for the 11-digit HUs were delineated on 1:24,000 scale (U.S.) and 1:50,000 scale (Canada) topographic maps by U.S. Geological Survey (USGS) and USDA-SCS staff. The mapped information was then digitized by USGS staff to create two ARC/INFO coverages: one for Vermont and Canada and one for New York. Provisional versions of these two coverages provided by USGS Water Resources Division in Albany, NY, were adapted for this study by removing the US-Canada border as a feature wherever it split one hydrologic unit into two.

Since the first seven digits of all the 11-digit SCS codes for LCB HUs are identical, only the last four digits are used throughout the text and figures for the sake of simplicity. For example, the HU that consists of the extreme upland portion of the Otter Creek drainage has the 11-digit code: 02010002010. In this text, it is referred to simply as -2010. For convenience, an attempt was made to give each 11-digit HU a name indicating the water body or location included; while the names given in this project were checked against names commonly used in the Vermont State Office of the SCS and in the Vermont DEC, they may not correspond to names used elsewhere in all cases.

5.2.2 Land Use. Because of time and resource constraints, it was necessary to use existing digital land use data in this study. After an extensive search, it was determined that the only existing data set that approached covering the entire basin is USGS's Geographic Information Retrieval and Analysis System (GIRAS) land use/land cover data collected over a period from 1973 to 1976. The GIRAS data provide approximately 40 land use/land cover classes with a minimum mapping unit of 4 hectares for urban land uses and 16 hectares for other land uses (Table 5.1). Land use/land cover was interpreted from NASA high-altitude aerial photographs and National High-Altitude Photography program photographs usually at scales smaller than 1:60,000 and compiled on a 1:250,000 scale base (USGS, 1990). No classification or positional accuracy information is provided with the data set nor is there any mention of field-checking of the mapping. This data set does not cover the Canadian portion of the Lake Champlain basin and, in fact, it also excludes a small strip of land about a mile wide between 45 degrees north latitude and the US-Canada border.

The GIRAS land use/land cover data for the basin were put together from three sources: from a 9-track tape ordered directly from USGS in Reston, VA, from an edited version of the same data provided by the US Fish & Wildlife Service's Gap Analysis Program at the University of Vermont, and from data downloaded by the Cornell Laboratory of the Environment and Remote Sensing.

No digital land use data were available for the Quebec portion of the basin; specific, spatially-referenced land use data were not available in any form. Therefore, a simple estimate of 72% forest, 23% agriculture, and 2% urban obtained from the

Table 5.1
U.S.G.S. LAND USE AND LAND COVER CLASSIFICATION SYSTEM
FOR USE WITH REMOTE SENSOR DATA

	Level I		Level II
1	Urban or built-up land	11	Residential
		12	Commercial and services
		13	Industrial
		14	Transportation, communication, and services
		15	Industrial and commercial complexes
		16	Mixed urban or built-up land
		17	Other urban or built-up land
2	Agricultural land	21	Cropland or pasture
		22	Orchards, groves, vineyards, nurseries, ornamental horticultural areas
		23	Confined feeding operations
		24	Other agricultural land
3	Rangeland	31	Herbaceous rangeland
		32	Shrub-brushland rangeland
		33	Mixed rangeland
4	Forest land	41	Deciduous forest land
		42	Evergreen forest land
		43	Mixed forest land
5	Water	51	Streams and canals
		52	Lakes
		53	Reservoirs
		54	Bays and estuaries
6	Wetland	61	Forested wetland
		62	Nonforested wetland
7	Barren land	71	Dry salt flats
		72	Beaches
		73	Sandy areas (other than beaches)
		74	Bare exposed rock
		75	Strip mines, quarries, and gravel pits
		76	Transitional areas
		77	Mixed barren land
8	Tundra	81	Shrub and brush tundra
		82	Herbaceous tundra
		83	Bare ground
		84	Wet tundra
		85	Mixed tundra
9	Perennial Snow or ice	91	Perennial snowfields
		92	Glaciers

Source: USGS. 1990. Land use and land cover digital data from 1:250,000 and 1:100,000 scale maps. Data Users Guide 4. 33 pp. Reston, VA.

Quebec Ministry of the Environment (Simoneau, 1993) was used as the basis for estimation of land use in each of the HUs or portions of HUs within the Canadian part of the basin. It should be noted that this crude estimate is not spatially referenced, since all land in the Canadian part of the LCB was assumed to have this same land use composition, and furthermore reflects current conditions, not those of the 1973-76 era. Thus, interpretations of results which involve HUs partially or wholly in Canada should be viewed with great caution.

5.2.3 Surface Water and Political Boundaries. The surface water and political boundaries data layers were used simply for visual references and were not involved in spatial analysis.

Surface water features (lakes, rivers, and streams) were used to help visualize the relationships among ll-digit HUs. The source of digital surface water data for the basin was the USGS 1:100,000 scale digital line graph (DLG) data. USGS Water Resources Division, Albany provided the data for the New York side of the basin and the US Fish & Wildlife Service's Gap Analysis Program at University of Vermont provided the data for the Vermont side of the basin. The New York and Vermont surface water data was extensively edited and simplified to remove unneeded detail because their only use in the study was as a visual reference. No Canadian surface water was included in this study.

Digital versions of the Vermont/New York and the United States/Canada boundaries were needed for display purposes. These were extracted from 1:24,000 ARC/INFO coverages provided by the Vermont Center for Geographic Information (VCGI) and the Adirondack Park Agency.

5.3 Hydrology.

In order to use the loading function approach to estimate nonpoint source loads to Lake Champlain, estimates of annual streamflow from each of the HUs were required so that estimated annual mass export could be calculated from runoff concentration values derived from the literature (mass = concentration x flow). None of the 11-digit HUs in the LCB have long-term discharge records that could be used for this purpose. It was also desireable to obtain some estimate of variability of runoff and streamflow from each of the HUs, since nonpoint source magnitude is strongly driven by weather. One of the principal benefits of the loading function approach is its ability to include natural variability expected due to weather.

The method used to derive streamflow estimates from each of the 85 HUs was a two-step process which used precipitation data and a runoff coefficient (the average percent of annual precipitation to a watershed which is expressed as streamflow). This is the procedure recommended by Reckhow, et al. (1990) for the land use/lake loading model EUTROMOD. This process resulted in an estimate the mean and range of streamflow from each of the HUs in the LCB.

5.3.1 Precipitation. In order to estimate streamflow, annual total precipitation data from 1951-1990 were obtained for 47 precipitation stations in the LCB (NOAA, various years; and Canadian Climate Normals, 1991). The name and location of each of these stations is presented in Table 5.2. Annual precipitation to each of the HUs was estimated using the Thiessen polygon technique (Chow, 1964). This technique weights each precipitation gage in direct proportion to the area it represents; the area represented by each station is assumed to be the area closer to it than to any other gage (Hjelmfelt and Cassidy, 1975).

IDRISI GIS software was used to calculate the "precipitation polygons" around the points representing the locations of the precipitation stations. These Thiessen polygons divided the study area such that every point in the study area was closer to the center of its polygon that to the center of any other polygon. These polygons were then vectorized, exported back to ARC/INFO, and intersected with the HU layer in order to determine the weighted average annual precipitation for each HU for each year of record.

For example, HU 7050 has 50% of its area within the polygon for precipitation gage #7032, 38% of its area within the gage #2769 polygon, and 11% of its area within the gage #5416 polygon. The weighted average precipitation this HU for each year of record was therefore calculated as:

Annual precip. = (0.5 x Gage #7032 precip.)+(0.38 x Gage #2769 precip)+(0.11 x Gage #5416 precip.)

This process was repeated for each HU for each year of complete record from 1951-1990 to obtain a data base of annual area-weighted precipitation for each HU.

Missing data represented a significant problem. For each gage, only annual totals based on complete data were used; annual totals were missing for at least a few years for each gage. For some HUs, precipitation was based on as many as seven different gages and true areal averages could only be calculated when data existed for each of those stations. Exclusion of years when any one of those stations had missing data often resulted in only a few years of effective record for a HU. One partial solution to this problem could have been to eliminate precipitation gages with considerable missing data from the polygon analysis; however, the laborious process could not be repeated within the time available when this problem was fully revealed.

Instead, the approach taken was to eliminate stations which contributed only a small percentage to a HU from the calculation and re-allocate its area to the next closest station. A maximum of 10% of area in any single HU was re-allocated in this manner; in most cases the area involved was less than 5%.

The end result of the process was a period of record of not less than 10 years of **area-weighted annual precipitation for each HU**; in most cases the period of record exceeded 20 years. This was judged to be sufficient for this project. If the process were to be repeated for the purpose of developing the best precipitation data base possible for the LCB, it is recommended that stations with large data gaps be eliminated before construction of Thiessen polygons.

TABLE 5.2
LAKE CHAMPLAIN BASIN PRECIPITATION STATIONS

Station Name	Index #	County	Latitude	Longitude
		--NEW YORK--		
Chazy	1401	Clinton	44 53	73 26 W
Dannemora	1966	Clinton	44 43	73 43 W
Elizabethtown	2554	Essex	44 13	73 36 W
Ellenburg Dep	2574	Clinton	44 54	73 48 W
Glens Falls AP	3294	Warren	43 21	73 37 W
Lake Placid	4555	Essex	44 15	73 59 W
Newcomb	5714	Essex	43 58	74 06 W
North Creek	5925	Warren	43 40	73 54 W
Peru	6538	Clinton	44 34	73 34 W
PlattsburghAFB	6659	Clinton	44 39	73 28 W
Ray Brook	6957	Essex	44 18	74 06 W
Smiths Basin	7818	Wash	43 21	73 30 W
Ticonderoga	8507	Essex	43 50	73 26 W
Tupper Lake	8631	Franklin	44 14	74 26 W
Whitehall	9389	Wash.	43 33	73 24 W
Warrensburg	8959	Warren		
		--VERMONT--		
Burlington	1081	Chitt.	44 28	73 09 W
Chittenden	1433	Rutland	43 42	72 57 W
Cornwall	1580	Addison	43 57	73 13 W
Dorset	1786	Benn.	43 14	73 05 W
Enosburg Falls	2769	Franklin	44 55	72 49 W
Essex Jct.	2843	Chitt.	44 31	73 07 W
Huntington Ctr	4052	Chitt.	44 19	73 00 W
Montpelier AP	5278	Wash.	44 12	72 34 W
Morrisville	5376	Lamoille	44 32	72 36 W
Mt. Mansfield	5416	Lamoille	44 32	72 49 W
Newport	5542	Orleans	44 56	72 12 W
Northfield	5740	Wash.	44 06	72 37 W
Peru	6335	Benn.	43 16	72 54 W
Rochester	6893	Windsor	43 51	72 48 W
Rutland	6995	Rutland	43 37	72 58 W
St Albans Rdio	7032	Franklin	44 50	73 05 W
St. Johnsbury	7054	Caledonia	44 25	72 01 W
Salisbury	7098	Addison	43 56	73 06 W
So. Hero	7607	Grand Isle	44 38	73 18 W
Waitsfield	8637	Wash.	44 11	72 53 W
Waterbury	8815	Wash..	44 19	72 45 W
		--QUEBEC--		
Abercorn	7020040		45 02	72 40 W
Brome	7020840		45 11	72 34 W
Farnham	7022320		45 18	72 54 W
Georgeville	7022720		45 08	72 14 W
Hemmingford	7023075		45 04	73 43 W
Iberville	7023270		45 20	73 15 W
Magog	7024440		45 16	72 07 W
Phillipsburg	7026040		45 02	73 05 W
Sutton Jct.	7028295		45 09	72 38 W
Warden	7028890		45 23	72 30 W

The final step of precipitation estimation was to assess the year-to-year variability in weather that is clearly characteristic of the LCB. To accomplish this, area-weighted HU precipitation was evaluated not only for long-term average but also for variability. Specifically, the standard deviation of annual area-weighted precipitation was used to calculate a 95% confidence interval around the mean (i.e. the mean $\pm$1.96 x std. dev.). The resulting range represents a low annual precipitation value such that lower precipitation would be expected only 5% of the time and a high annual value that could be expected to be exceeded only 5% of the time. This range, therefore, represents the most likely range for precipitation in each of the LCB HUs.

5.3.2 Runoff. A runoff coefficient (C_r) was estimated for each LCB HU to be applied to the estimated precipitation as described above. General values for C_r are available in the literature (Chow, 1964; Coote, et al., 1982; Van der Leeden, et al., 1990). Some information is available for small watersheds in Vermont (Meals, 1990) and in New York (Sutherland, et al., 1990). While such published values were used for range-finding and as a check on final estimated values, values of C_r for each LCB HU were mainly estimated from long-term precipitation data as described above and from long-term streamflow data from USGS gaging stations in the LCB.

The general procedure was as follows. For each HU, the nearest USGS gaging station was identified. (USGS gaging stations in the LCB are listed in Table 5.3) For each HU, the estimated C_r was defined as the average annual streamflow recorded at the nearest USGS gaging station divided by the average annual area-weighted precipitation:

$$C_r = \bar{Q}/\bar{P}$$

Note that Q is expressed as inches of runoff (total streamflow volume divided by watershed area). This not only accounts for variations in watershed size but also simplifies the calculation so that the resulting C_r can be viewed as a straightforward percentage of precipitation expressed as streamflow.

It should be noted that this calculation was essentially based only on the USGS stations with long-term record shown in Table 5.3. The 30 additional gaging stations started in 1990 as part of the Lake Champlain Diagnostic/Feasibility monitoring (Smeltzer, 1993) could not be used in the same way, since they included only two years of record and were therefore unsuitable for estimation of long-term averages. However, because the long-term stations were scattered thinly around the basin, it was judged important to somehow include the more recent stations where they coincided with HUs not adequately represented by older stations.

This was done by constructing a simple linear regression between long-term average discharge and water year 1991 discharge at the long-term USGS stations in the LCB, then applying this as an adjustment factor to the water year 1991 discharge from the D/F gaging stations. The resulting estimate of "average" discharge from the new D/F stations was considered informally in estimating runoff coefficients. It should be noted that this very crude estimate of average discharge was never used as the sole basis for estimating a runoff coefficient for a HU. Preference was always given to discharge based on measured long-term record.

TABLE 5.3
USGS GAGING STATIONS LAKE CHAMPLAIN BASIN[1]

STATION NAME	STATION #	AREA(mi^2)	Q(cfs)	Q(in)	Years
	--NEW YORK--				
Gt Chazy R @Perry Mls	04271500	247	262	14.40	41
Saranac R @Plattsburgh	04273500	608	841	18.78	75
E Br Ausable R @As.Frks	04275000	198	315	21.61	67
Ausable R AusableFrks	04275500	448	664	20.13	59
Boquet R nr Willsboro	04276500	275	291	14.38	46
NWBay Br nr Bolton Lnd	04278300	22	36.6	22.59	23
	--VERMONT--				
Poultny R b Fair Haven	04280000	187	257	18.66	63
Mettawee R nr Pawlet	04280350	70.2	117	22.63	7
Otter Ck @ Ctr Rutland	04282000	307	554	24.51	63
Otter Ck @ Middlebury	04282500	628	997	21.56	75
Jail Branch @ E Barre	04284000	38.9	55.1	19.24	61
NBr Winooski @ Wrghtvl	04285500	69.2	135	26.49	58
Winnoski R @ Montpelier	04286000	397	594	20.31	72
Dog R @ Northfield Falls	04287000	76.1	124	22.13	57
Mad R nr Moretown	04288000	139	260	25.40	63
Little R nr Waterbury	04289000	111	242	29.59	56
Winooski R nr Essex Jct	04290500	1044	1725	22.43	63
Lamoille R. @ Johnson	04292000	310	537	23.52	65
Lamoille R @ E Georgia	04292500	686	1535	24.63	62
StoneBrdge Br nr Georgia	04292700	8.45	8.2	13.18	12
Miss R nr No. Troy	04293000	131	270	27.99	60
Miss R nr E Berkshire	04293500	479	929	26.34	75

Sources: Water Resources Data New Hampshire and Vermont Water Year 1991 U.S. Geological Survey Water-Data Report NH-VT-91-1, K.W. Toppin, K.E. McKenna, J.E. Cotton, and J.C. Denner, U.S. Geological Survey, Water Resources Division, Bow, NH.

Water Resorces Data New York Water Year 1991. Vol. 1 Eastern New York. U.S. Geological Survey Water-Data Report NY-91-1 Firda, G.F., R. Lumia, and P.M. Murray, U.S. Geological Survey, Water Resources Division, Albany, NY.

[1]Does not include stations installed in 1990 for D/F

The resulting runoff coefficients were then applied to the mean and ±95% confidence range of annual area-weighted precipitation in each HU to obtain estimates of total HU discharge. The final result of the hydrology estimation was essentially a **mean and ±95% confidence range of annual discharge expected from each of the 85 HUs in the LCB.**

5.4 Load Estimation.

As described earlier, nonpoint source loads were estimated using two different approaches: the loading function technique and the export coefficient technique. Both techniques rely on coefficients selected from the literature review described earlier. While the work focused on total phosphorus (TP) loads, export of other nonpoint source pollutants such as soluble reactive phosphorus (SRP) and total Nitrogen (TN) were also estimated to the extent possible from the results of the literature review.

It should be noted that the resulting nonpoint source estimates must be viewed as **potentially available** pollutant loads. Transport loss and attenuation of pollutants with downstream travel - e.g. deposition, adsorption, biological uptake - was not considered. Delivery of loads from headwater HUs to the Lake was assumed to be 100% and loads from individual HUs were simply summed to arrive at tributary mouth loads to Lake Champlain. This is unlikely to be true at all times.

5.4.1 Export Coefficients. The first method of estimating nonpoint source loads is the widely used technique of **export coefficients**, which are average or representative values for the mass of a pollutant exported per unit area per year, e.g. kg/ha/yr (Reckhow, et al., 1980; Rast and Lee, 1983; Frink, 1991). This approach has been used successfully to estimate nonpoint source loads to waterbodies (Smolen, et al., 1990; Frink, 1991).

For each 11-digit HU in this assessment, an export coefficient for forested, agricultural, and urban land was multiplied by the area of the HU in that land use to yield an estimate of pollutant load from each land use from that HU:

$$LD_k = A_k \times EC_k$$

where LD_k = annual load from land use k
A_k = area in land use k
EC_k = areal export from land use k

e.g. TP load from 450 ha of urban land:
LD_u = 450 ha x 1.5 kg/ha/yr = 675 kg/yr

Within each HU, estimated loads from each general land use category were summed to give an estimate of the total average pollutant load from that HU. Estimated loads from each 11-digit HU were summed within each of the 8-digit HUs for a estimated total load from each of the major sub-basins in the LCB. As outlined in Section 5.1, three levels of coefficients were used: low, baseline, and high.

The primary advantage of the export coefficient method is its simplicity. The appropriate export coefficient for a particular land use is simply multiplied by the area in that land use to give the estimated annual load. The accuracy of the technique can be higher than more complex methods, since only one parameter - the export coefficient - must be chosen by the investigator (Reckhow, et al., 1990). However, the simplicity of the export coefficient technique is also its primary weakness -there is no provision for year to year hydrologic variation; nonpoint source export is estimated solely as a function of land use. Since nonpoint source pollutant loads are also highly dependent on rainfall frequency, intensity, and duration, the "average" export coefficients would be most applicable in years of "average" climatic conditions, and estimates will likely be inaccurate during "atypical" years (Rast and Lee, 1983). This approach also ignores spatial variability, assuming that residential land in one location, for example, behaves exactly as residential land in another part of a basin, i.e. contributes pollutants at an identical rate.

5.4.2 Loading Functions. The second method of estimating nonpoint source loads was the **loading function** technique. This technique is essentially a very simple model which estimates annual pollutant load as a function of pollutant runoff **concentration** and runoff **volume** (McElroy, et al., 1976; Haith and Shoemaker, 1987; Reckhow et al., 1990). This technique has been used effectively to estimate nutrient loads to lakes and estuaries (Hartigan, et al., 1982; Newell, et al., 1992) and is the conceptual basis of more comprehensive watershed loading models such as EUTROMOD (Reckhow et al., 1990) and GWLF (Haith et al., 1992).

The procedure followed for this technique was essentially that presented in the model EUTROMOD (Reckhow et al., 1990). For each 11-digit HU in this assessment, the estimated streamflow (derived as described in Section 5.3) was apportioned to each land use category in the HU according to its percentage of the total HU area. If forest land represented 63% of a particular HU, for example, 63% of the streamflow from that HU was assumed to be derived from forest land. This streamflow volume was then multiplied by the pollutant concentration selected from the literature to yield an estimated annual pollutant mass exported from that land use within that HU:

$$LD_k = (Q_{HU} \times A_k) \times C_k \times f$$

where:
LD_k = annual load from land use k
Q_H = annual streamflow from HU
A_k = percent of area of HU in land use k
C_k = concentration coefficient for land use k
f = units conversion factor

e.g. TP load from 1108 ha of agricultural land:

$$LD_a = (4.36 \times 10^7 \text{ m}^3/\text{yr} \times 0.13) \times 0.2 \text{ mg/l} \times f = 1134 \text{ kg/yr}$$

Export was estimated similarly from each of the three general land use categories, then summed to yield an estimate of total pollutant export from the HU:

$LD_T = LD_F + LD_A + LD_U$
where:
LD_T = total annual load from HU
LD_F = annual load from forested land
LD_A = annual load from agricultural land
LD_U = annual load from urban land

This procedure was applied not only to estimated "average" HU streamflow but also to the "low" and "high" HU streamflow values as described in Section 5.3, resulting in low, average, and high estimates of nonpoint source pollutant load from each 11-digit HU. Estimated loads from each 11-digit HU were summed within each of the 8-digit HUs for a estimated total load from each of the major sub-basins in the LCB. The range from the low estimate to the high estimate essentially represents the most likely range of nonpoint source pollutant export to be expected within the most likely range of annual weather conditions, while average estimate represents the export to be expected during a "typical" year. As with the export coefficient technique, three sets of concentration coefficients were used: low, baseline, and high.

The loading function is a compromise between the simplistic export coefficient approach and the much greater complexity of a detailed mechanistic watershed model. The primary advantage of the loading function technique is its incorporation of some natural hydrologic variability. Estimates of pollutant load will clearly be higher in wet years and lower in dry years, reflecting some of the uncertainty of the real world.

This technique also at least partially addresses the issue of spatial variability. While the same pollutant runoff concentrations are assumed throughout the basin (perhaps a questionable assumption), spatial variability in precipitation and runoff are incorporated to some degree in the streamflow estimates which are based on regional precipitation and stream flow measurements. As discussed later in Section 6.0, there is substantial variation in precipitation received in different parts of the Basin, and major differences in runoff and streamflow from different HUs.

There are also disadvantages to this approach. First, there is a greater opportunity for bias and error since the technique requires judgement in selecting not only the concentration from the literature but also in estimating runoff and streamflow.

Second, the approach of apportioning streamflow to each land use category based only on its proportion of total HU area is clearly oversimplified. Runoff coefficients vary with land use and cover; forested land typically shows very low values of C_r, while urban land, with considerable impervious area, usually shows much higher values. Thus, use of an average C_r for an entire HU could be expected to overestimate streamflow deriving from forested land and underestimate the quantity of urban runoff (and perhaps agricultural land runoff as well). Dealing with this problem effectively is beyond the scope of this broad basin-scale assessment. Adjustment of runoff coefficients for each land use area within each HU was judged to be too time-consuming and too arbitrary. It should also be noted that the method of estimating runoff coefficients described in Section 5.3 does, to some extent, integrate the behavior of different land use types, since the average values streamflow values used at the watershed outlet reflect whole-watershed behavior.

5.5 Validation.
The accuracy of the basin-scale nonpoint source load estimates generated through the procedures described above was evaluated by comparison with tributary total phosphorus (TP) loading data collected through the Lake Champlain Diagnostic/Feasibility Study (VTDEC and NYSDEC, 1992). This is the only basin-wide pollutant loading data base available at this time; thus only total phosphorus loading estimates could be evaluated.

The location of the 31 D/F tributary sampling stations were entered into the GIS and plotted in order to determine their relationship to the 11-digit and 8-digit HUs and their position relative to tributary mouths. There was not always an exact correspondence, since some 11-digit HUs that lie in separate drainages are combined into an 8-digit HU to which they do not really belong, (e.g. the Rock River and Pike River, Quebec drainages are lumped into the Missisquoi River basin) and some "direct to lake" HUs are not included in D/F monitored basins. It should also be noted that, while some D/F stations were actually located considerably upstream of tributary mouths, the reported loads used in this report for validation have been adjusted for the entire tributary area (VTDEC and NYSDEC, 1993).

The 11-digit HU TP load estimates derived from both the export coefficient and loading function approach under a variety of scenarios were re-tabulated to correspond with the D/F monitoring stations. The average annual TP loads for the period 1990-1992 and the water year 1991 TP loads, which were selected as the base hydrologic year, i.e. "average condition" (Smeltzer, 1993), serve as the basis of comparison with estimated TP loads.
Estimated TP loads were compared to measured loads by several methods. First, estimated and measured TP loads are compared using a paired t-test (Snedecor and Cochran, 1989) to test the hypothesis that estimated and measured loads are not significantly different. Second, linear regression was used to determine whether estimated values vary consistently with observed values or vary randomly. In addition, slopes and intercepts of the regression were tested against an ideal slope of one and intercept of zero (exact match of estimated to measured).

It should be noted that the basin-scale estimates are based on land use data more than a decade older than the measured tributary TP loading and the measured loads represent just two years of monitoring (1990-1992). Thus, a high level of agreement between estimated and measured loads is unlikely and at best, order of magnitude agreement should be expected.

5.6 Phase II.
To address the disparities between land use information and water quality data at the basin scale, several small subwatersheds within the LCB with recent, higher resolution land use data and concurrent water quality data were investigated to better assess and refine this nonpoint source load estimation approach. This also provided an opportunity to utilize more detailed land use classes than was possible in the basin-wide assessment.

5.6.1 Watershed Selection. On the Vermont side of the LCB, two small primarily agricultural watersheds were selected. The Mud Hollow Brook watershed in Charlotte (1676 ha) has seven years of detailed, ground-truthed land use data and monitored phosphorus and nitrogen loads from the LaPlatte River Watershed Monitoring and Evaluation Project (Meals, 1990). The Mill River watershed in Georgia and St. Albans (5733 ha) has eight years of similar land use and water quality data from the St. Albans Bay RCWP Monitoring and Evaluation Project (VT RCWP Coord. Comm., 1991). Both of these watersheds had detailed land use data in ARC/INFO for the same time periods as intensive water quality monitoring.

In New York, two small forested/urban watersheds in the Lake George basin - LG39 (Sheriff's Dock watershed, 188 ha) and LG40 (Marine Village watershed, 96 ha) - were selected. These watersheds had extensive water quality data as part of the Lake George Urban Runoff Program (NURP) (Sutherland et al., 1983).

In the Vermont agricultural watersheds, two different years were evaluated in each watershed. The choice of years - 1986 and 1987 for Mud Hollow Brook, 1985 and 1990 for Mill River watershed - was based on data quality and representativeness of precipitation and streamflow. In each watershed, one of the years selected received very nearly average precipitation and one year received below-average precipitation. In the New York watersheds, only two years of data were available. One water year, 1980/1981 received nearly average precipitation, while precipitation in water year 1981/1982 was slightly above normal.

5.6.2 Literature review. Export coefficients and loading function concentrations for the Phase II watersheds were drawn from the literature review described in Section 5.1. Where the literature base existed and aligned with land use categories in the small watersheds, values were chosen for the detailed land use categories documented in the small watersheds. Coefficients were selected, for example, for low and high density residential, commercial, industrial, open/recreation, and institutional classifications of urban land use and for row crop, hayland, pasture, and open/idle classes of agricultural land.

Ranges of export coefficients and loading function concentrations were evaluated and selected using the same protocols as outlined in Section 5.1; low, baseline, and high values for coefficients were selected. It should be noted that there were significantly fewer citations for some of the more detailed land use categories compared to those for the general categories. In some cases, this required more professional judgement than would be ideal.

5.6.3 Land Use. In the Vermont agricultural watersheds, land use was derived from aerial photo interpretation combined with extensive field survey. In both project areas, agricultural land use data were obtained through interviews with landowners and direct observation. Detailed agricultural land use categories included corn, hay, hay-pasture, pasture, open/idle, and farmstead; urban/developed land use was also tracked, including residential, commercial, open/recreation, and roads.
LG39 and LG40 were among several small watersheds that were land use mapped on a parcel-by parcel basis between 1991 and 1993 as part of the Lake George Park Commission's "Study of the Feasibility of Retrofitting Stormwater Management

Practices in Developed Areas of the Lake George Basin". Parcel boundaries were derived from county land records. Land use was determined during field surveys that also recorded the number, size, and type of structures on each lot and pervious and impervious area of each lot. The digital land use data for LG39 and LG40 were made available as ARC/INFO coverages by the New York State Parks Management and Research Institute in Saratoga Springs, NY. Because some of the land use classes used in the stormwater study were too general (e.g. "vacant" for any parcel without a building) and because the land use field survey had been conducted 10 years after the NURP water quality data were collected, an additional source of land use information was needed. A set of 1978 1:24,000 stereoscopic black and white airphotos of Lake George Village was made available by the Adirondack Park Agency. By examining these stereoscopically and making use of the 1991-93 information on structures, land use for LG39 and LG40 was interpreted into the following categories:

Low density residential - residential with less than 2 dwelling units/acre.
High density residential - more than 2 inhabited buildings/acre or a residential parcel of less than 0.5 acre
Commercial - businesses, offices, and parking areas
Transportation - roads
Institutional -diverse category including a cemetery, schools and their playing fields, institutional buildings with extensive lawns (library, e.g.), and empty lots that were predominantly grassy.
Urban/Open - empty lots and utility right of ways that are predominantly bushy.
Forest - large un-built upon "upland" area in each watershed as well as the empty lots and parks that have over 50% canopy cover.

5.6.4 Hydrology. For the loading function technique, streamflow was estimated as described in Section 5.3. For each year considered, the runoff coefficient used for the 11-digit HU containing the Phase II watershed was applied to **actual measured** precipitation to obtain an estimate of streamflow from that watershed for that year. Since actual measured streamflow data were also available, comparison of estimated to measured streamflow shed some light on the estimation process.

5.6.5 Load Estimation. As in the basin-scale assessment, nonpoint source loads were estimated by both the export coefficient and the loading function techniques, using a variety of scenarios based on different coefficient values. In addition to TP, nonpoint source loads of SRP and TN were estimated in a similar manner.

5.6.6 Validation. Estimated nonpoint source loads were compared to measured loads in all four Phase II watersheds for all years considered. Loads reported in the relevant project reports were the basis for comparison (Meals, 1990; VT RCWP Coord. Comm., 1991; Sutherland et al., 1983). New York State DEC provided additional loading data for SRP and nitrogen beyond the TP data reported in the original project report (Sutherland, 1993). It should be noted that for the Mud Hollow Brook watershed in Vermont, TN data are not available. Only total Kjeldahl nitrogen (TKN) was measured in that study; nitrite+nitrate data would be required to calculate TN export (TN = TKN + NO_2+NO_3). In comparing estimated TN loads to measured TKN loads, TKN loads would be expected to be less than TN loads. It is worth noting that occasional NO_2+NO_3 analyses in the LaPlatte River watershed project showed very low concentrations of that form of nitrogen.

Because there were only two points of comparison between estimated and measured loads for each watershed evaluated, statistical evaluation of the comparison is not possible. Comparisons were therefore qualitative in nature.

6.0 RESULTS

6.1 GIS database

As a result of this project, several GIS data layers will be contributed to the LCBP GIS database as documented ARC/INFO coverages: the hydrologic units, the 1973-76 land use, precipitation gage location, precipitation polygons, and D/F tributary monitoring station locations.

6.1.1 Hydrologic Units. The LCB consists of 84 11-digit hydrologic units. These can be grouped into eight 8-digit hydrologic units or major drainage basins. (see Table 6.6 and Figure 6.1). The outermost boundaries of the HUs represent the limits of the study area and define, in the most accurate rendition to date, the Lake Champlain Basin. Attributes for the HUs include area, perimeter, and the SCS codes.

Additional work is needed on the HU coverages to make them completely accurate. In the version received from USGS, several islands in the lake were omitted or mis-coded, the division of HUs along the US-Canada border does not make sense in terms of hydrology, and several HUs along the Poultney River have coding or boundary errors. These problems were minor for the purposes of this basin-wide assessment, but may be significant for others attempting to use the database. Detailed recommendations are provided in section 7.5.

6.1.2 Land use. Of the thirty seven land use/cover classes included in the USGS Level II classification, only twenty-four occurred in the basin in 1973-76 (Table 6.1). Because most of these classes occurred so infrequently (comprise less than 1% of the basin) or had no corresponding runoff concentration or export coefficient in the nonpoint literature, they were combined with other classes as appropriate (Table 6.2).

Even land use classes for which literature values were available had to be lumped to match the GIRAS data. For example, runoff concentrations for P are available in the literature for row crops, hayland and pasture, but because the GIRAS database does not distinguish among these types, they were combined under "cropland". On the other hand, the GIRAS database includes three other agricultural land use classes and several urban, forest, and wetland classes for which no suitable runoff coefficients could be found in the literature. As a result of using existing land use data, all agricultural classes were lumped into one class, urban classes were lumped into one class, forest into one, and wetlands and other land uses were assigned to classes as seemed most appropriate. This condensation of land use into forest, agricultural, urban, and water classes is detailed in Table 6.2 and illustrated in Figure 6.2. Of course, the original un-aggregated land use data remain within the GIS, so they can be used for other purposes or re-aggregated in other ways.

The lack of correspondence between literature values and existing land use data was anticipated given the restriction of using existing data. This also suggests a way in which the model could be refined, if desired. Recommendations for future land use mapping efforts are discussed in section 7.5.

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Fig. 6.1: THE LAKE CHAMPLAIN BASIN STUDY AREA:
MAJOR WATERSHEDS,
11-DIGIT HYDROLOGIC UNITS,
PHASE II WATERSHEDS

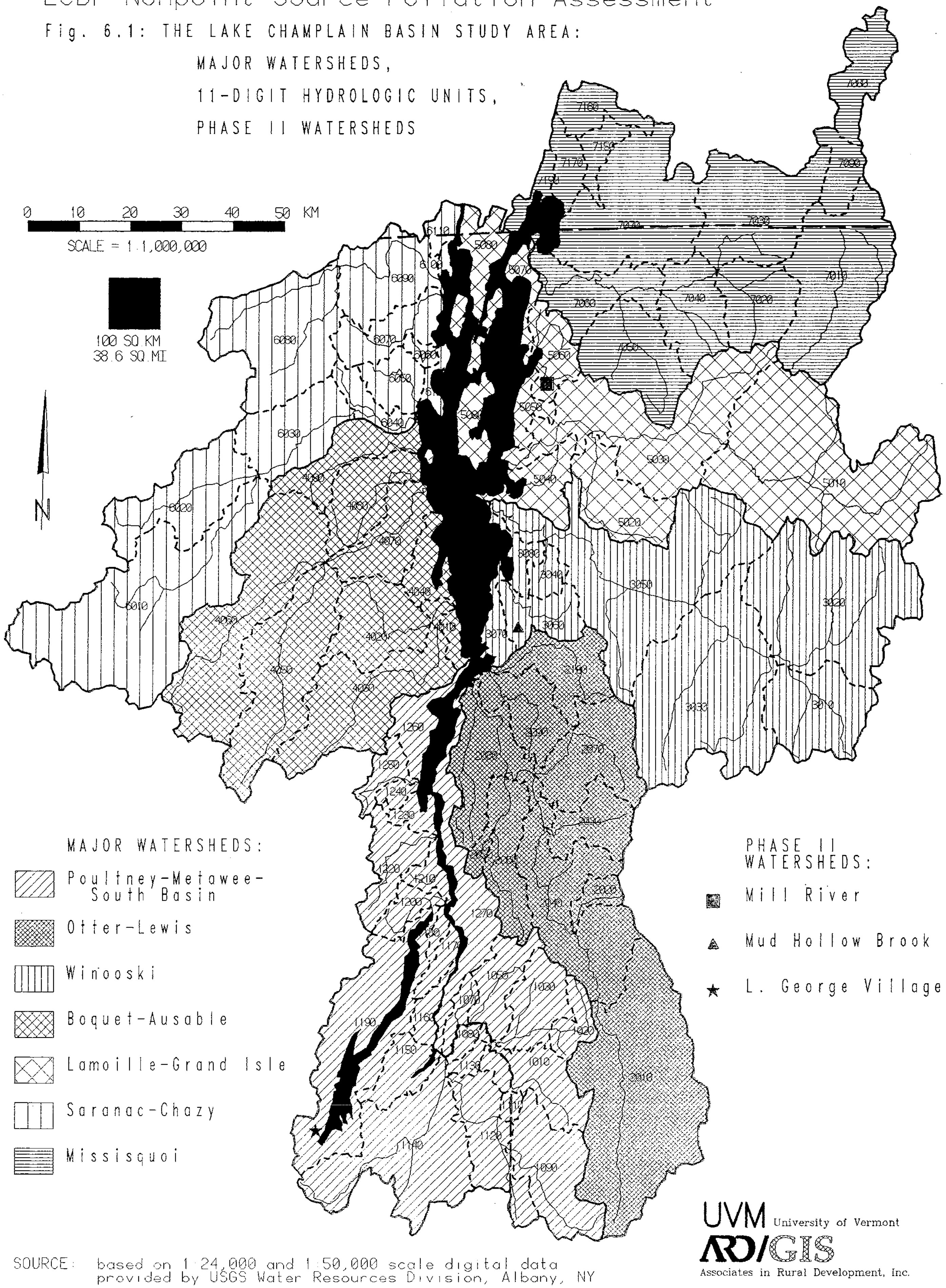

Table 6.1LAND USE CLASSES OCCURRING WITHIN THE LC BASIN*

Code	Definition	% Area
11	Residential	1.3
12	Commercial and services	0.3
13	Industrial	0.1
14	Transportation, communications and services	0.5
15	Industrial and commercial complexes	0.0
16	Mixed urban or built-up land	0.1
17	Other urban or built-up land	0.2
21	Cropland or pasture	27.0
22	Orchards, groves, vineyards, nurseries, ornamental horticultural	0.1
23	Confined feeding operations	0.0
24	Other agricultural land	0.0
32	Shrub-brushland rangeland	0.0
41	Deciduous forest land	27.2
42	Evergreen forest land	7.3
43	Mixed forest land	26.9
51	Streams and canals	0.1
52	Lakes	6.9
53	Reservoirs	0.2
61	Forested wetland	1.0
62	Nonforested wetland	0.5
73	Sandy areas (other than beaches)	0.0
74	Bare exposed rock	0.1
75	Strip mines, quarries, gravel pits	0.1
76	Transitional areas	0.0
		99.9

**Does not include Canadian portion of the basin.*

Table 6.2. **LAND USE CLASSES FOR LC BASIN-WIDE ANALYSIS**

<u>URBAN</u>: 3% of basin

11 Residential
12 Commercial and services
13 Industrial
14 Transportation, communications and services
15 Industrial and commercial complexes
16 Mixed urban or built-up land
17 Other urban or built-up land
75 Strip mines, quarries, and gravel pits
76 Transitional areas

<u>AGRICULTURE</u>: 28% of the basin

21 Cropland or pasture
22 Orchards, groves, vineyards, nurseries, ornamental horticultural areas
23 Confined feeding operations
24 Other agricultural land
32 Shrub-brushland rangeland
62 Nonforested wetland

<u>FOREST</u>: 62% of the basin

41 Deciduous forest land
42 Evergreen forest land
43 Mixed forest land
61 Forested wetland

<u>WATER</u> (or no nonpoint load contribution): 7%

51 Streams and canals
52 Lakes
53 Reservoirs
73 Sandy areas (other than beaches)
74 Bare exposed rock

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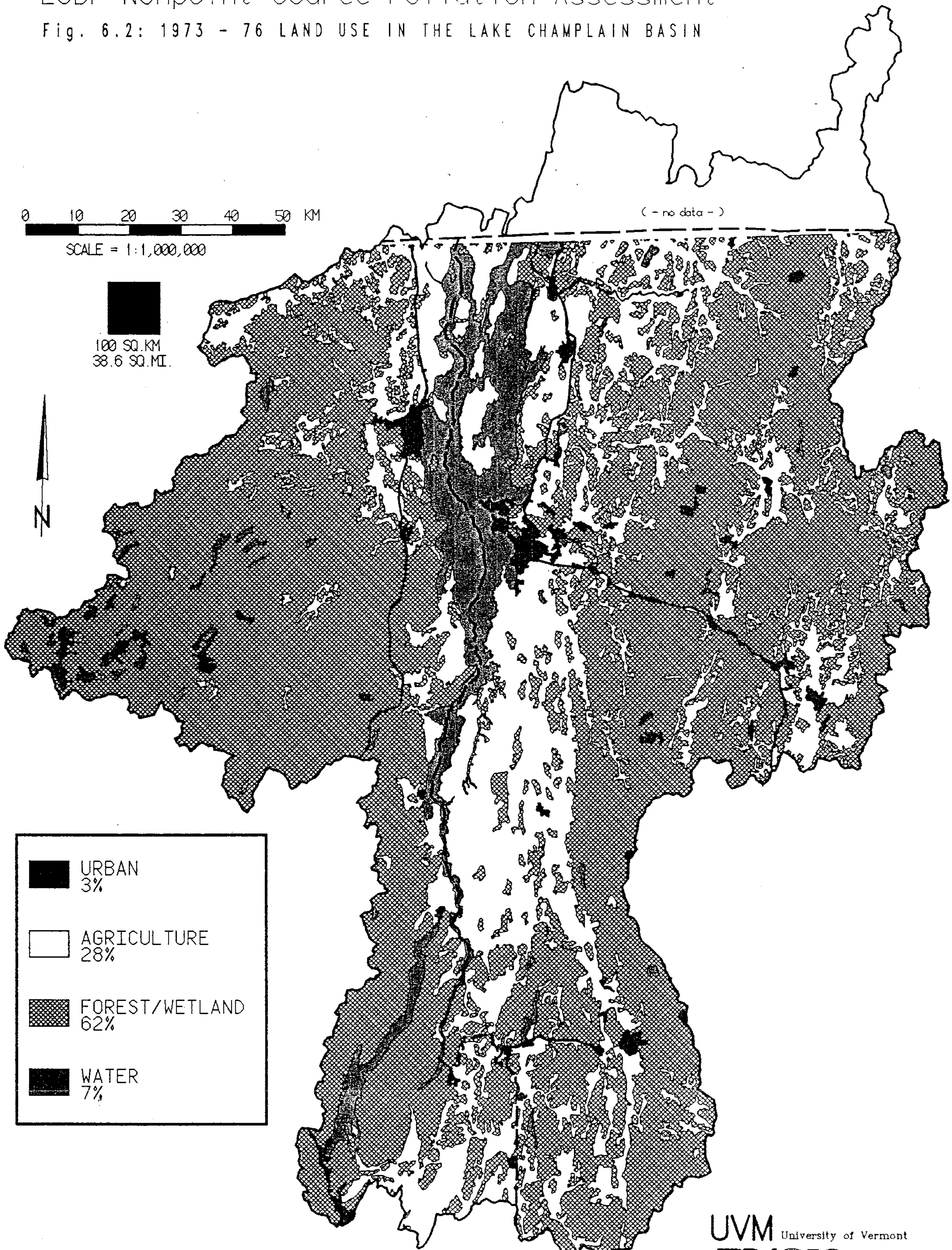
Fig. 6.2: 1973 - 76 LAND USE IN THE LAKE CHAMPLAIN BASIN



SOURCE: Land Use aggregated from digital USGS GIRAS data

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In the 1973-76 era, the LCB was composed of 62% forested land, 28% agricultural, 3% urban and 7% water. Forested land comprised the bulk of the basin in New York and the uplands in Vermont. Agricultural uses were concentrated in relatively flat areas near the lake, primarily in Vermont. Urban uses were concentrated around Burlington in Vermont and Plattsburgh in New York. The land use composition of individual HUs is detailed in tables in Section 6.4.

6.2 Nonpoint Source Loading Coefficients.

More than 250 references were reviewed during the literature search for appropriate nonpoint source loading coefficients for the LCB. Following the screening criteria described in Section 5.1, about 180 references were included in a data base of pollutant export coefficient and loading function concentration values for land uses ranging from 100% forested land to urban central business districts.

Values were sought for major nonpoint source pollutants, including suspended solids (TSS), total phosphorus (TP), soluble reactive phosphorus (SRP), total nitrogen (TN), nitrate nitrogen (NO_3-N), ammonia nitrogen (NH_3-N), and bacteria. The nonpoint source literature for the past two decades has clearly emphasized phosphorus and nitrogen. Despite the importance of bacteria as a nonpoint source pollutant, very little relevant data concerning bacteria have been reported that met the screening criteria for this study and those values that were found show tremendous variability. The data base was also very scant for suspended solids and for nitrate and ammonia nitrogen. The relatively few coefficient values that were obtained for TSS, NO_3-N, and NH_3-N are cataloged and reported, but no loading estimates were made for these pollutants. This study will address only those pollutants for which there appears to be an adequate data base from which to make reasonable selections: total phosphorus, soluble phosphorus, and total nitrogen.

Values for both export coefficients and loading function concentrations were cataloged by both general and specific land use category. All of the coefficients thus obtained are organized in six tables (Appendix B), representing areal export or concentration values for each of the general land use categories in the LCB used for Phase I of this study: Forest, Agriculture, and Urban. Within the agriculture and urban tables, values are listed first that were reported for the general category (e.g. "mixed agriculture" or "mostly urban"), then by more specific land use (e.g. row crops, pasture, residential, commercial). These values were used in Phase II of this study. Some studies reported mean or median values for either concentration or export, while other studies reported a range of values; both types are included in the tables. Other information listed in the tabulation of coefficients includes location, type (e.g. monitoring, literature review), citation, and notes concerning any special circumstances.

The process for selecting appropriate values to be applied in the LCB was outlined in Section 5.2. Because of the inherent variability and uncertainty of nonpoint source processes, no simple average or single value could easily be selected from this data base. First, the most commonly reported range for each pollutant and each land use was identified, representing approximately the 25th and 75th percentile of the range of reported values. Within this range, a single baseline value was chosen, representing the best judgement of an appropriate value to be applied in the LCB.

The range of values chosen for TP and TN from general land use categories is shown graphically in Figures 6.3 through 6.6. In these figures, the overall range in reported coefficients is represented by the entire bar, with the most commonly reported range shaded. Note that the horizontal scale is logarithmic due to the extreme range of reported values. Total N concentrations reported from urban land, for example, ranged from 0.3 to 75.0 mg/l.

The lowest concentrations and export coefficients for both P and N tend to be reported for forest land. While there is some overlap, phosphorus values reported for urban land tend to be higher than those for agricultural land. The reverse is true for reported nitrogen levels, possibly due to high fertilizer N inputs on agricultural land.

The baseline values selected for this study are indicated in Figures 6.3 - 6.6 by the stars. The values representing the low end of the most common range, the baseline values, and the values at the high end of the most common range will be used as low, baseline, and high coefficient values, respectively. These values for TP, SRP, and TN from general land use categories are presented in Tables 6.3 and 6.4. Estimated nonpoint source loads were calculated subsequently based on this range of literature values.

6.3 <u>Hydrology</u>.

6.3.1 <u>Precipitation</u>. Annual total precipitation values from 1951 through 1992 for each of the 47 stations applicable to the LCB are tabulated in Appendix C, along with summary statistics including years of record, minimum and maximum annual precipitation, standard deviation, and $\pm$ 95% confidence limits. A few stations had virtually complete record, such as Burlington and Montpelier, VT and Dannemora and Glens Falls, NY. Other stations, e.g. Essex Junction, VT and Ray Brook, NY, had large gaps and included as few as 17 years of record. The lowest average annual precipitation (740 mm, 29.12 inches) occurred at Peru, NY (Station #6538); the highest average annual precipitation of 1588 mm (62.51 inches) occurred at Mt. Mansfield, VT (Station #5416).

The Thiessen polygons developed in ARC/INFO for the array of precipitation stations covering the LCB is shown in Figure 6.7. Area weighting factors used in calculating precipitation for each HU were derived from overlaying the polygon coverage with the HU boundary coverage, as shown in the example for HU -7050 in Figure 6.8. Annual area-weighted precipitation totals for each year of complete record for each 11-digit HU (see discussion of missing data in Section 5.3.1) are tabulated in Appendix D. For each HU, similar summary statistics are also shown, including mean and $\pm$ 95% confidence limits. The lowest area-weighted mean annual precipitation (741 mm, 29.17 inches) occurred in a HU within the lower Ausable River, NY. The highest area-weighted mean annual precipitation of 1282 mm (50.46 inches) occurred in a HU in the lower Lamoille River, VT.

Values for the lower 95% confidence limit, the mean, and the upper 95% confidence limit will be used as low, average, and high HU precipitation, respectively. These values are summarized in Table 6.6 below.

FIGURE 6.3

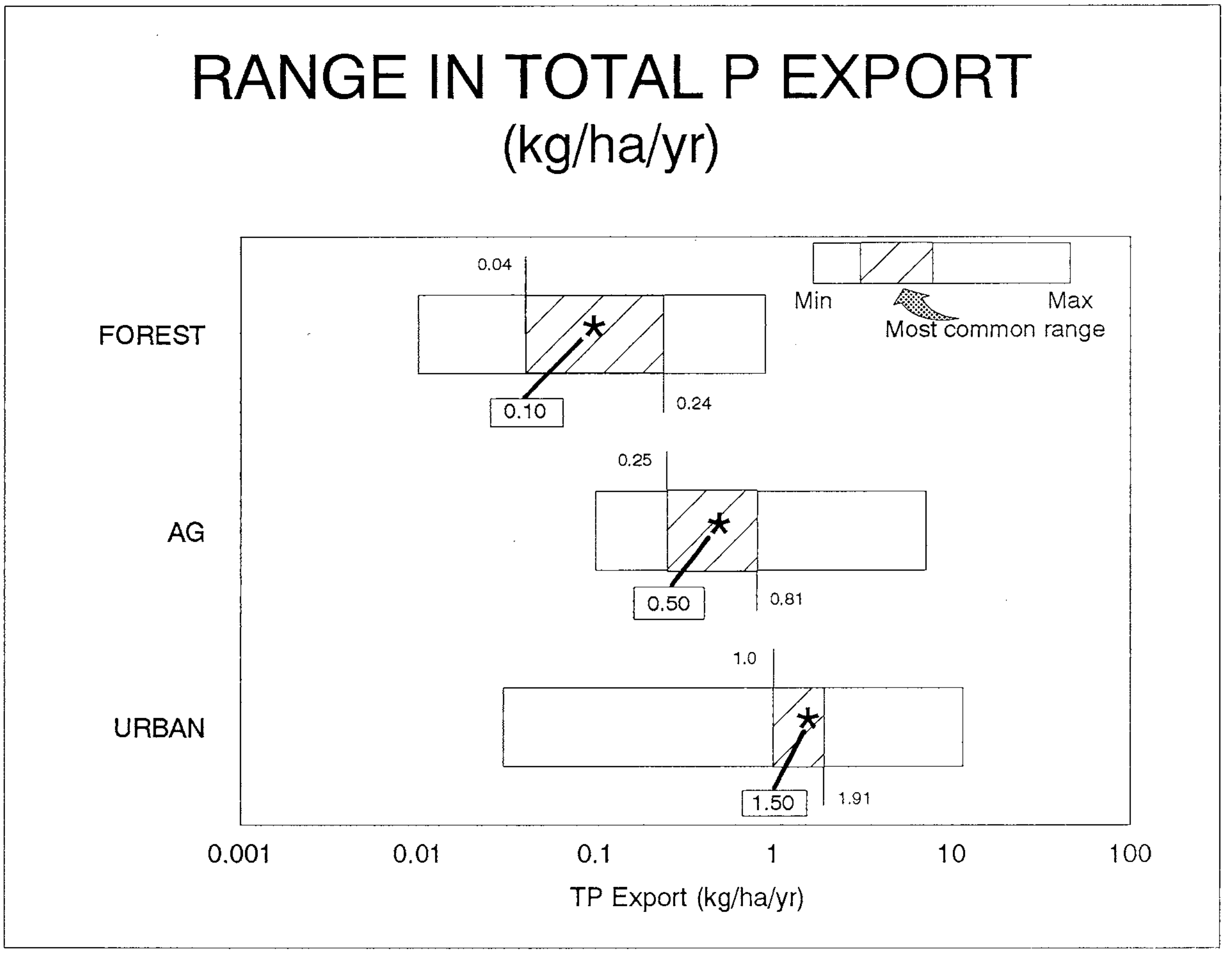

FIGURE 6.4

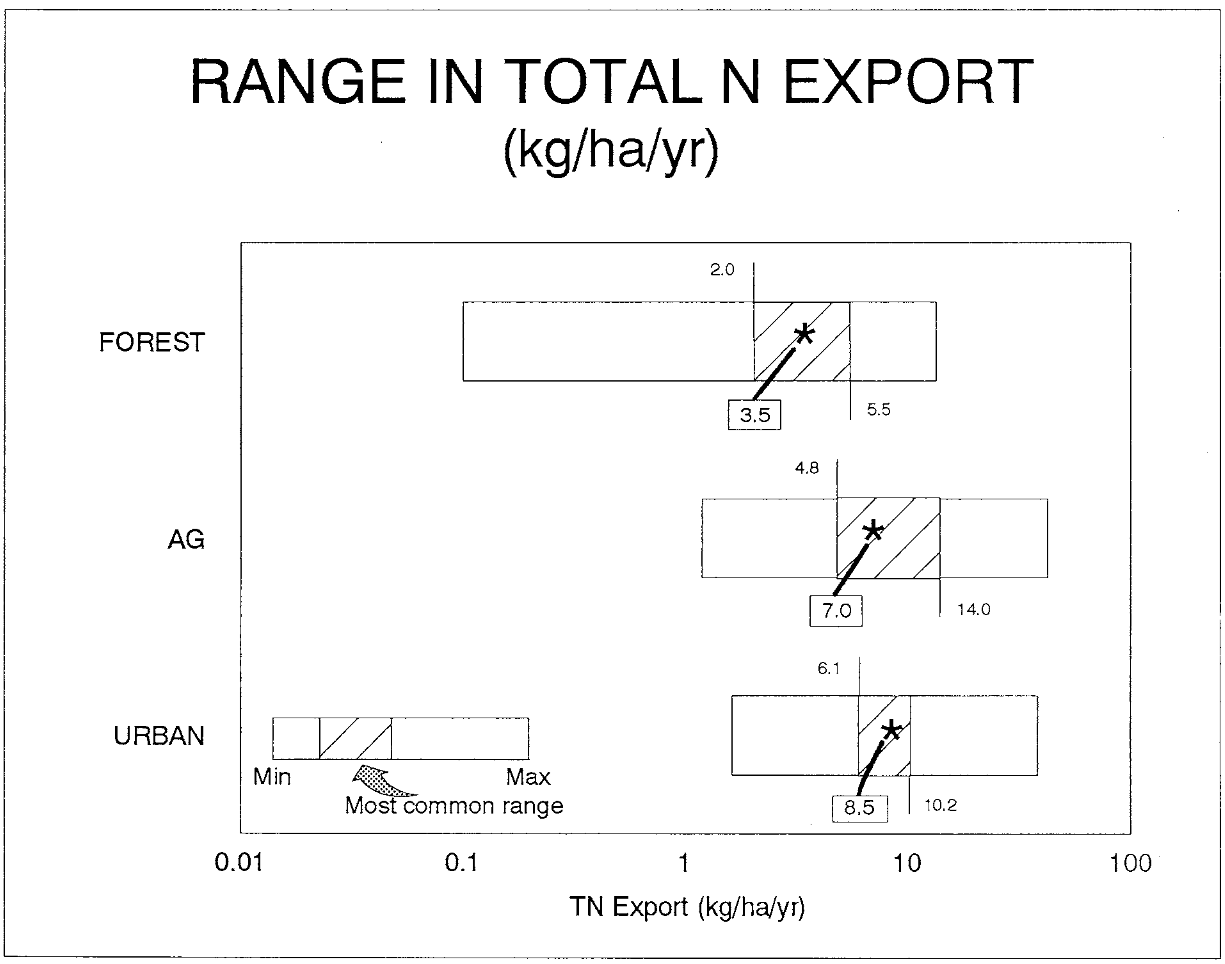

FIGURE 6.5

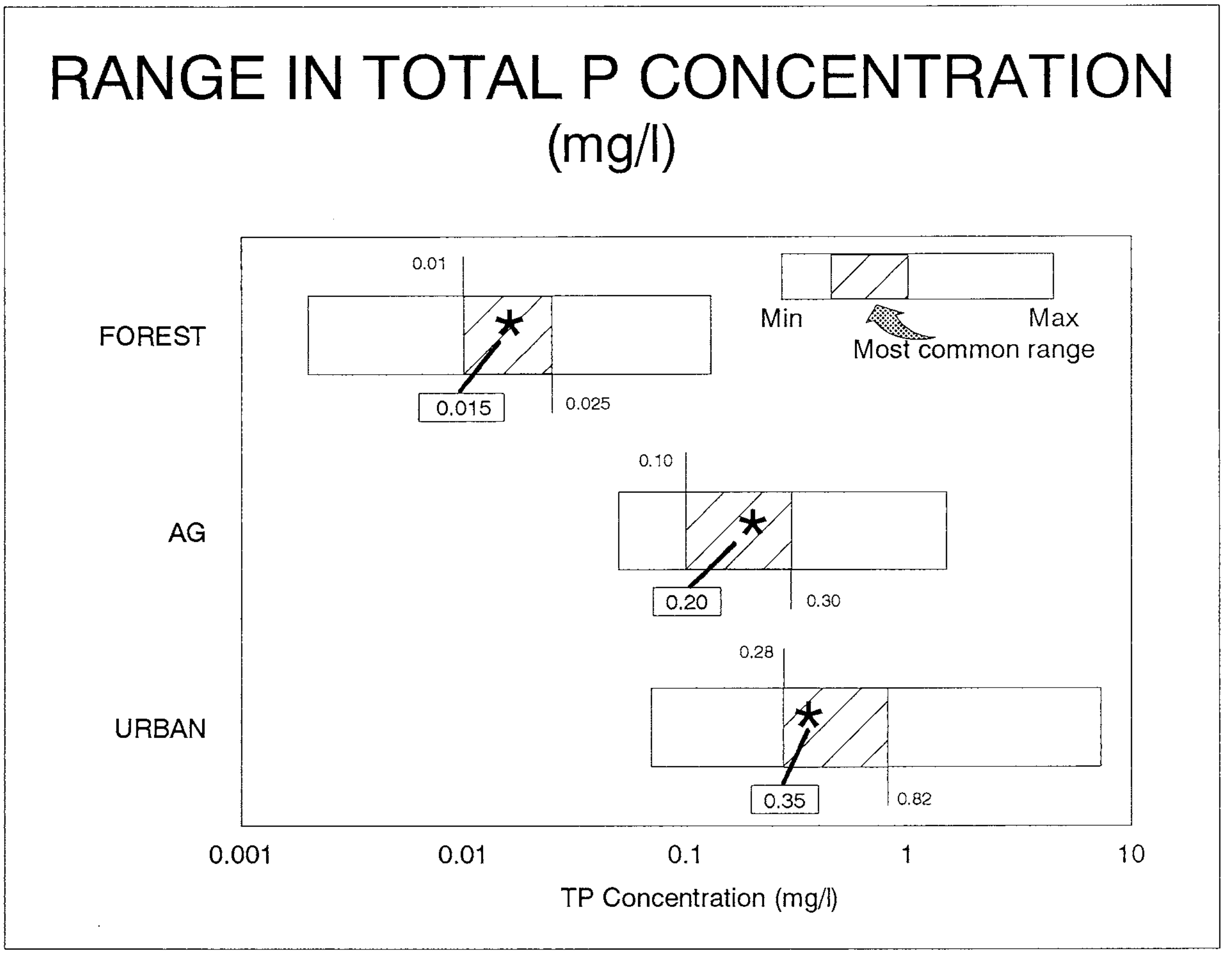

FIGURE 6.6

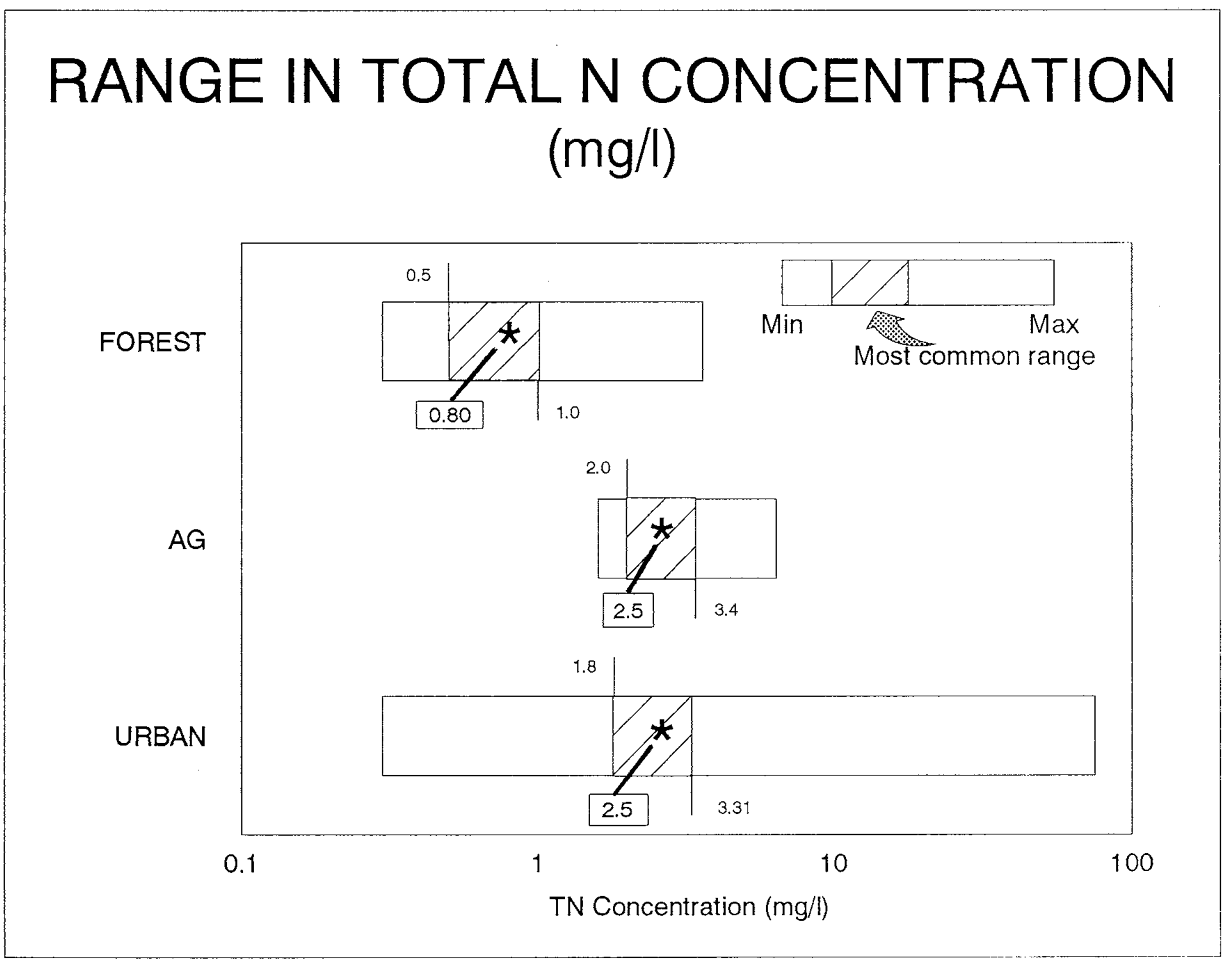

TABLE 6.3

LITERATURE EXPORT VALUES
(kg/ha/yr)

FORESTED LAND

PARAMETER	TOTAL RANGE	MOST FREQUENTLY REPORTED	SELECTED
TP	0.01-0.90	0.04-0.24	**0.10**
SRP	0.007-0.170	0.03-0.07	**0.05**
TN	0.10-13.45	2.0-5.5	**3.5**

AGRICULTURAL LAND

PARAMETER	TOTAL RANGE	MOST FREQUENTLY REPORTED	SELECTED
TP	0.10-7.17	0.25-0.81	**0.50**
SRP	0.09-4.48	0.09-0.22	**0.15**
TN	1.2-42.6	4.8-14.0	**7.0**

URBAN LAND

PARAMETER	TOTAL RANGE	MOST FREQUENTLY REPORTED	SELECTED
TP	0.03-11.6	1.00-1.91	**1.50**
SRP	0.03-2.00	0.21-1.00	**0.50**
TN	1.6-38.5	6.1-10.2	**8.5**

TABLE 6.4

LITERATURE CONCENTRATION VALUES
(mg/l)

FORESTED LAND

PARAMETER	TOTAL RANGE	MOST FREQUENTLY REPORTED	SELECTED
TP	0.002-0.130	0.01-0.025	**0.015**
SRP	0.001-0.023	---	**0.007**
TN	0.30-3.60	0.5-1.0	**0.80**

AGRICULTURAL LAND

PARAMETER	TOTAL RANGE	MOST FREQUENTLY REPORTED	SELECTED
TP	0.05-1.50	0.10-0.30	**0.20**
SRP	0.01-0.61	0.05-0.7	**0.06**
TN	1.6-6.4	2.0-3.4	**2.5**

URBAN LAND

PARAMETER	TOTAL RANGE	MOST FREQUENTLY REPORTED	SELECTED
TP	0.07-7.3	0.28-0.82	**0.35**
SRP	0.04-10.0	0.12-0.32	**0.20**
TN	0.3-75.	1.80-3.31	**2.5**

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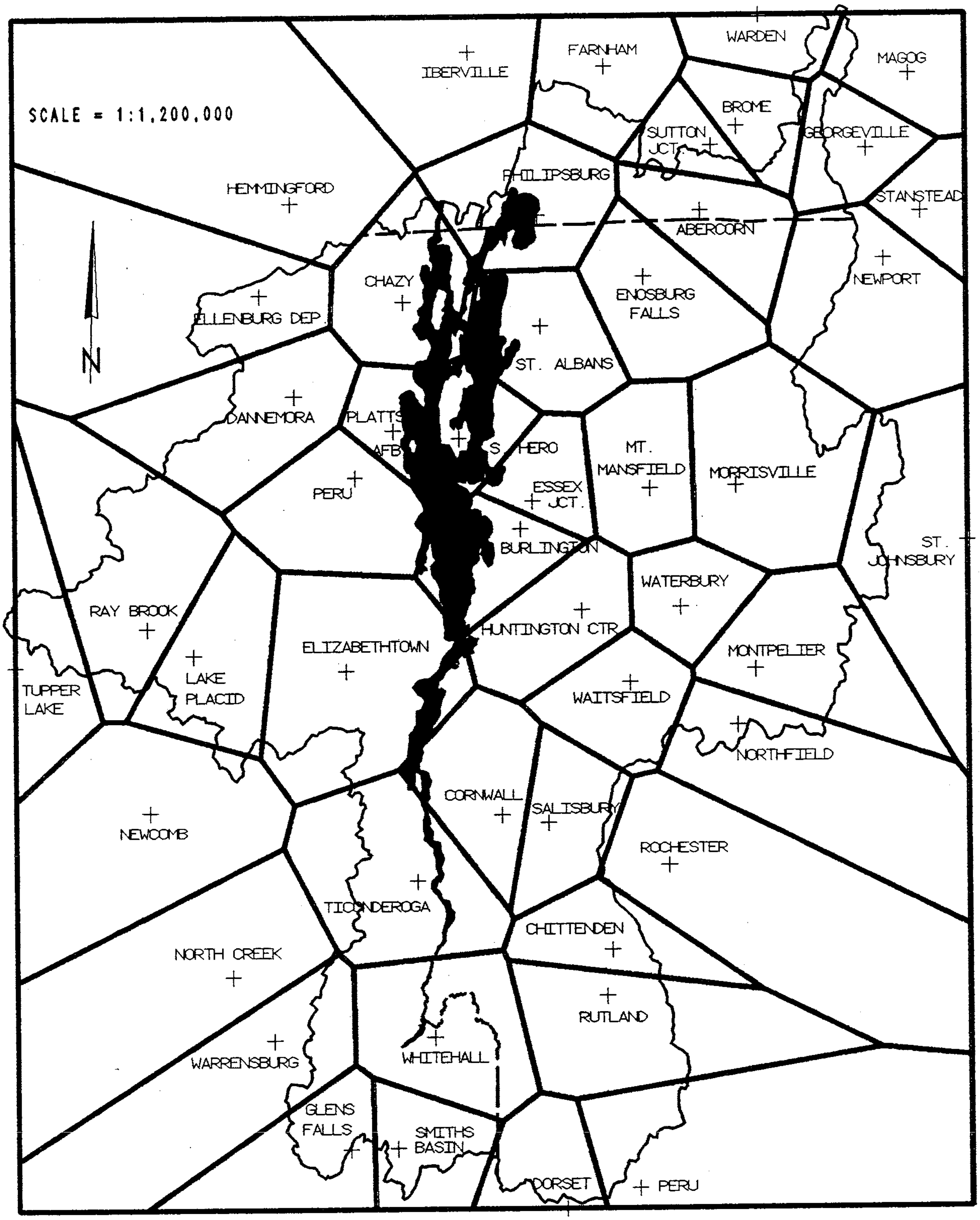
Fig. 6.7: PRECIPITATION STATIONS AND POLYGONS



Using IDRISI GIS software, Thiessen polygons were generated around the sites of long term precipitation recording stations in order to calculate area-weighted annual precipitation for each 11-digit HU.

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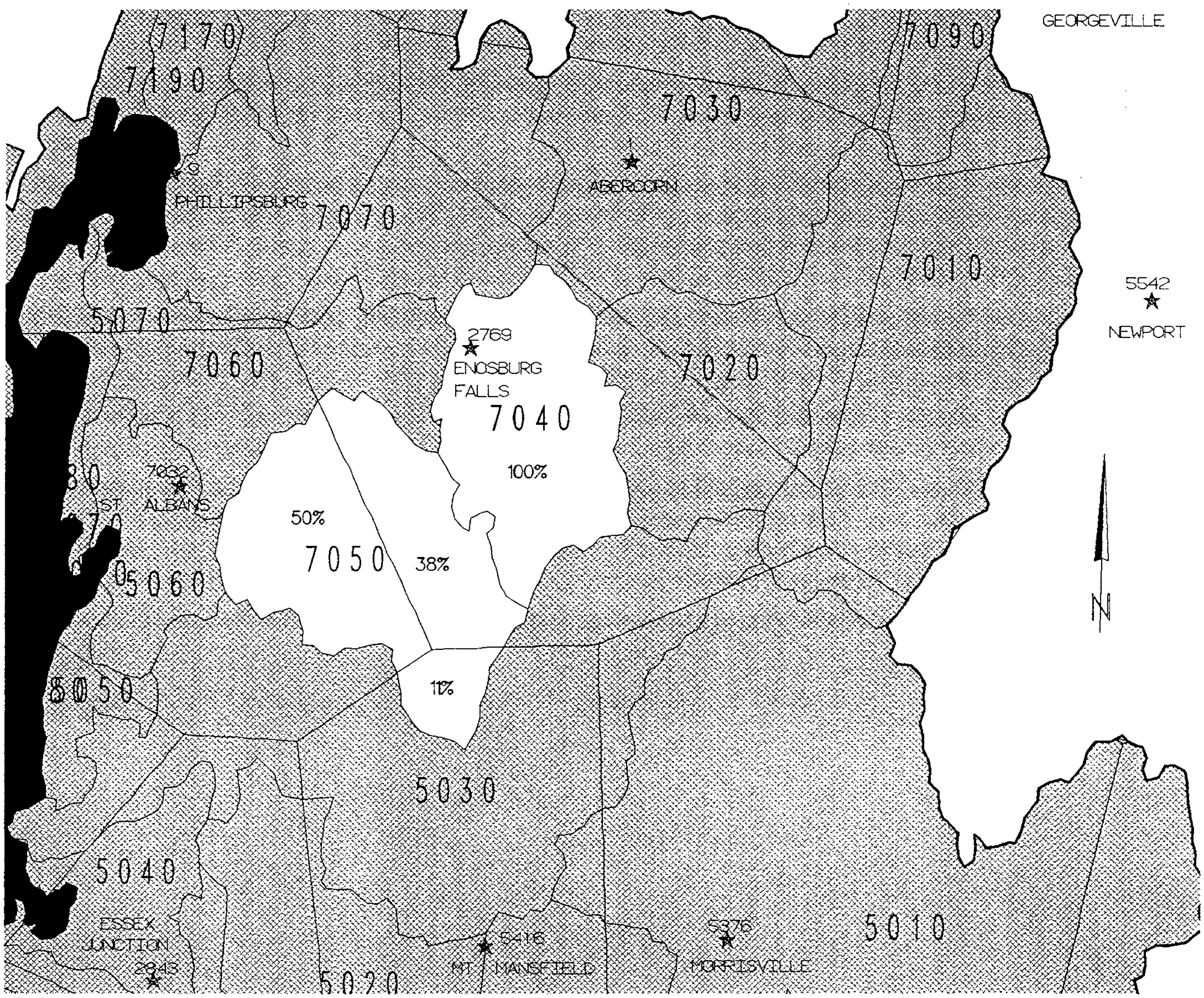
Fig. 6.8: DETERMINING AREA WEIGHTING FACTORS USING THIESSEN POLYGONS

APPROXIMATE SCALE = 1:470,000



The weighted average annual precipitation for HU -7050 is calculated as follows:

P = (0.50 x precip at gage #7032) +
(0.38 x precip at gage #2769) +
(0.11 x precip at gage #5416)

Because HU -7040 is entirely within the Thiessen polygon generated around gage #2769, its weighted average annual precipitation is simply (1.00 x precip at gage #2769).

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6.3.2 Runoff. Runoff coefficients (C_r, the average percent of total annual precipitation expressed as annual streamflow), estimated for each 11-digit HU as described in Section 5.3.2, are shown in Table 6.5, along with the average annual area-weighted precipitation and the long-term average annual stream discharge from the nearest gaging stations. Recent streamflow data (water year 1991) from applicable Diagnostic/Feasibility stations were used by applying a correction factor based on a regression relationship (r^2=0.84) between water year 1991 discharge and long-term average discharge at the long-term USGS stations in the LCB to the short-term D/F data to approximate an average annual runoff value from the D/F stations. When record of more than one gaging station applied to a HU, an average of the station values was used to represent the HU.

The estimated runoff coefficients ranged from a low of 0.33 to a high of 0.66, with a median value of 0.56. These runoff coefficients are somewhat higher than the average value of 0.37 reported by Coote, et al. (1982) for small (1800-6200 ha) agricultural watersheds in southern Ontario, but similar to the range of 0.28 to 0.77 observed over ten years of monitoring in small watersheds in Vermont (Meals, 1990; VT RCWP Coord. Comm., 1991). It should be noted that both of these sets of values were based on just a few years of data, while the estimates in Table 6.5 represent long-term averages. Sutherland, et al. (1990) used long-term precipitation and streamflow data to estimate average runoff coefficients for the Adirondack Region and reported values ranging from 0.41 to 0.66 for the Adirondack drainages within the LCB. Thus, the estimated runoff coefficients shown in Table 6.5 appear to be reasonable and are therefore used in the next step in the process of estimating streamflow from the 11-digit HUs.

Estimates of discharge from each of the 11-digit HUs in the LCB are shown in Table 6.6. For each HU, each of the three levels of annual precipitation - low, average, and high - were multiplied by the estimated runoff coefficient to obtain an estimate of runoff under each precipitation scenario. Finally, estimates of low, average, and high discharge were computed as the product of runoff depth and HU area. For example, in the first line of Table 6.6, average precipitation for HU -1010 is 36.95 inches/year (940 mm). With a C_r of 0.61, average runoff would be 22.54 inches (573 mm). For the HU area of 20104 ha, this represents 1.15×10^8 m^3/year.

The values shown in the columns labeled "DISCHARGE" in Table 6.6 represent estimates of the average and the range of water volume that can reasonably be expected as annual discharge from each of the HUs in the LCB. These values are to be applied to pollutant concentration values to estimate pollutant loadings using the loading function approach. The range in discharge reflects the range in expected annual precipitation, a major basis of the variability to be expected in nonpoint source export in any particular year.

TABLE 6.5
ESTIMATED RUNOFF COEFFICIENTS FOR 11-DIGIT HUs
LAKE CHAMPLAIN BASIN

Basin/HU #	Precip.(in.)	Runoff(in.)	C_r	USGS Gage[1]
POULTNEY-METAWEE/SOUTH BASIN				
1010	36.95	22.63	0.61	04280350
1020	36.27	20.64	0.57	04280000,04280350
1030	38.43	18.66	0.49	04280000
1050	35.03	18.66	0.53	04280000
1070	36.08	18.66	0.52	04280000
1080	37.68	18.66	0.50	04280000
1090	45.25	22.63	0.50	04280350
1110	37.68	18.66	0.50	04280000
1120	39.19	20.04	0.51	04280000,D/F[2]
1130	37.68	19.92	0.53	04280000,D/F
1140	36.72	20.62	0.56	04280000,04278300
1150	37.64	17.93	0.48	0428000,D/F
1160	35.99	16.88	0.47	0428000,D/F
1170	32.69	16.72	0.51	0428000,D/F
1180	32.28	16.72	0.52	0428000,D/F
1190	38.34	22.59	0.59	04278300
1200	32.28	18.04	0.56	04278300,D/F
1210	32.28	19.68	0.61	04278300,D/F
1220	32.28	19.68	0.61	04278300,D/F
1230	32.49	19.68	0.60	04278300,D/F
1240	33.76	18.84	0.56	04278300,D/F
1250	34.27	18.84	0.55	04278300,D/F
1260	35.38	14.66	0.41	04276500,D/F
1270	33.31	18.00	0.54	04280000,04282500,D/F
OTTER/LEWIS BASIN				
2010	42.55	24.51	0.58	04282000
2020	36.33	21.56	0.59	04282500
2030	35.55	21.56	0.61	04282500
2040	38.21	21.56	0.56	04282500
2050	33.52	21.56	0.64	04282500
2060	33.60	21.56	0.64	04282500
2070	40.22	21.56	0.54	04282500
2080	32.81	21.56	0.66	04282500
2090	36.48	17.70	0.49	04282500,D/F
2100	38.35	19.30	0.50	04282500,D/F
WINOOSKI				
3010	36.07	19.24	0.53	04284000
3020	35.82	20.31	0.57	04286000
3030	43.40	23.76	0.55	04287000,04288000
3040	34.22	18.40	0.54	04290500,D/F
3050	44.24	22.43	0.51	04290500
3060	36.20	18.40	0.51	04290500,D/F
3070	35.22	19.10	0.54	04290500,D/F
3080	35.10	18.40	0.52	04290500,D/F

[1] Numbers refer to USGS stations listed in Table 5.3
[2] Adjusted data from one or more recent stations from Diagnostic/Feasibility study used

TABLE 6.5
ESTIMATED RUNOFF COEFFICIENTS FOR 11-DIGIT HUs
LAKE CHAMPLAIN BASIN

Basin/HU #	Precip.(in.)	Runoff(in.)	C_r	USGS Gage
BOQUET/AUSABLE				
4010	35.26	14.38	0.41	04276500
4020	34.88	14.38	0.41	04276500
4030	35.37	14.38	0.41	04276500
4040	31.06	14.08	0.45	04276500,D/F
4050	36.62	21.61	0.59	04275000
4060	35.20	20.87	0.59	04275000,04275500
4070	29.17	18.51	0.63	04275000,04275500,D/F
4080	29.54	20.17	0.69	04275000,04275500,04273500
4090	31.13	20.17	0.65	04275000,04275500,04273500
LAMOILLE/GRAND ISLE				
5010	40.28	23.52	0.58	04292000
5020	43.40	24.63	0.57	04292500
5030	50.46	24.63	0.49	04292500
5040	34.69	18.07	0.52	04292500,D/F
5050	33.27	13.18	0.40	04292700
5060	34.15	12.97	0.38	04292700,D/F
5070	37.12	12.37	0.33	04292700,D/F
5080	32.40	12.37	0.38	04292700,D/F
5090	40.07	12.37	0.33	04292700,D/F
SARANAC/CHAZY				
6010	40.25	21.76	0.54	04273500,04266500
6020	38.53	21.22	0.55	04273500,04270000
6030	34.30	18.78	0.55	04273500
6040	33.15	18.78	0.57	04273500
6050	31.90	18.78	0.59	04273500
6060	32.53	18.78	0.58	04273500
6070	32.54	16.58	0.51	04273500,D/F
6080	31.65	18.39	0.58	04271500,04270510
6090	32.33	18.39	0.57	04271500,04270510
6100	32.53	17.48	0.54	04271500,D/F
6110	32.47	17.48	0.54	04271500.D/F
6120	31.90	18.78	0.59	04273500
MISSISQUOI				
7010	42.17	27.16	0.64	04293000,04293500
7020	44.86	26.34	0.59	04293500
7030	51.47	26.34	0.51	04293500
7040	41.45	24.25	0.58	04293500,04292500,D/F
7050	40.61	24.25	0.60	04293500,04292500,D/F
7060	37.37	24.25	0.65	04293500,04292500,D/F
7070	42.18	24.25	0.57	04293500,04292500,D/F
7080	47.34	27.99	0.59	04293000
7090	48.09	27.99	0.58	04293000
7150	40.78	26.34	0.64	04293500
7160	41.36	26.34	0.64	04293500
7170	40.36	26.34	0.65	04293500
7190	40.07	26.34	0.66	04293500

[1] Numbers refer to USGS stations listed in Table 5.3
[2] Adjusted data from one or more recent stations from Diagnostic/Feasibility study used

TABLE 6.6

LAKE CHAMPLAIN BASIN HYDROLOGIC UNITS VERMONT

HU NAME	HU NUMBER	AREA(ha)	PRECIP (in)			Cr	RUNOFF (in)			DISCHARGE (m3/yr)		
			LOW	AVE	HIGH		LOW	AVE	HIGH	LOW	AVE	HIGH
POULTNEY-METAWEE												
Upper Poultney R	02010001-010	20104	25.55	36.95	48.35	0.61	15.59	22.54	29.49	7.9568E+07	1.1507E+08	1.5057E+08
Castleton	02010001-020	8301	24.48	36.27	48.06	0.57	13.95	20.67	27.39	2.9414E+07	4.3580E+07	5.7746E+07
Lake Bomoseen	02010001-030	17407	26.95	38.43	49.91	0.49	13.21	18.83	24.46	5.8373E+07	8.3238E+07	1.0810E+08
Hubbardton River	02010001-050	14560	24.05	35.03	46.00	0.53	12.75	18.57	24.38	4.7129E+07	6.8645E+07	9.0142E+07
Main Stem Poultney	02010001-070	4756	25.40	36.08	46.77	0.52	13.21	18.76	24.32	1.5952E+07	2.2659E+07	2.9373E+07
Mettawee River	02010001-090	29650	32.81	45.25	57.69	0.50	16.41	22.63	28.85	1.2352E+08	1.7035E+08	2.1718E+08
Direct to L CH	02010001-270	24849	23.41	33.31	43.20	0.54	12.64	17.99	23.33	7.9770E+07	1.1350E+08	1.4720E+08
OTTER-LEWIS												
Otter/Rutland	02010002-010	93760	27.97	42.55	57.12	0.58	16.22	24.68	33.13	3.8625E+08	5.8759E+08	7.8880E+08
Neshobe River	02010002-020	5254	22.03	36.33	50.64	0.59	13.00	21.43	29.88	1.7342E+07	2.8598E+07	3.9863E+07
Middlebury River	02010002-030	16274	22.31	35.55	48.80	0.61	13.61	21.69	29.77	5.6241E+07	8.9618E+07	1.2302E+08
Mid-Otter Creek	02010002-040	47937	23.91	38.21	52.52	0.56	13.39	21.40	29.41	1.6299E+08	2.6048E+08	3.5803E+08
Bridport	02010002-050	2847	23.43	33.52	43.62	0.64	15.00	21.45	27.92	1.0841E+07	1.5510E+07	2.0183E+07
Lemon Fair River	02010002-060	20670	23.23	33.60	43.98	0.64	14.87	21.50	28.15	7.8037E+07	1.1287E+08	1.4774E+08
New Haven River	02010002-070	30131	27.30	40.22	53.14	0.54	14.74	21.72	28.70	1.1280E+08	1.6618E+08	2.1956E+08
Lwr Otter/Dead Cr.	02010002-080	27852	21.18	32.81	44.44	0.66	13.98	21.65	29.33	9.8869E+07	1.5316E+08	2.0745E+08
Little Otter Creek	02010002-090	18738	25.89	36.48	47.06	0.49	12.69	17.88	23.06	6.0365E+07	8.5056E+07	1.0972E+08
Lewis Creek	02010002-100	20999	27.12	38.35	49.59	0.50	13.56	19.18	24.80	7.2309E+07	1.0225E+08	1.3222E+08
WINOOSKI												
Stevens/Jail Brnch	02010003-010	29842	24.49	36.07	47.64	0.53	12.98	19.12	25.25	9.8362E+07	1.4487E+08	1.9134E+08
N Branch	02010003-020	72520	25.48	35.82	46.16	0.57	14.52	20.42	26.31	2.6746E+08	3.7600E+08	4.8454E+08
Dog/Mad River	02010003-030	79983	29.25	43.40	57.56	0.55	16.09	23.87	31.66	3.2675E+08	4.8482E+08	6.4300E+08
Shelburne Pond	02010003-040	5505	23.85	34.22	44.59	0.54	12.88	18.48	24.08	1.8004E+07	2.5832E+07	3.3661E+07
Lower Winooski R.	02010003-050	87539	30.99	44.24	57.48	0.51	15.80	22.56	29.31	3.5134E+08	5.0156E+08	6.5166E+08
LaPlatte River	02010003-060	13722	25.49	36.20	46.91	0.51	13.00	18.46	23.92	4.5299E+07	6.4332E+07	8.3365E+07
Dir L Ch Shel/Char	02010003-070	6099	25.13	35.22	45.31	0.54	13.57	19.02	24.47	2.1017E+07	2.9456E+07	3.7895E+07
Dir L Ch Burl	02010003-080	5615	24.29	35.10	45.92	0.52	12.63	18.25	23.88	1.8010E+07	2.6025E+07	3.4048E+07
LAMOILLE-GRAND ISLE												
Upper Lamoille R.	02010005-010	97406	28.27	40.28	52.29	0.58	16.40	23.36	30.33	4.0558E+08	5.7788E+08	7.5018E+08
Lee/Browns River	02010005-020	23908	34.70	43.40	52.11	0.57	19.78	24.74	29.70	1.2008E+08	1.5019E+08	1.8033E+08
Lower Lamoille R.	02010005-030	66183	35.18	50.46	65.75	0.49	17.24	24.73	32.22	2.8972E+08	4.1555E+08	5.4147E+08
Malletts Bay	02010005-040	13643	23.99	34.69	45.39	0.52	12.47	18.04	23.60	4.3219E+07	6.2496E+07	8.1772E+07
Lwr NE Arm Direct	02010005-050	6091	24.71	33.27	41.84	0.40	9.88	13.31	16.74	1.5288E+07	2.0584E+07	2.5886E+07
St. Albans Bay	02010005-060	12966	23.33	34.15	44.97	0.38	8.87	12.98	17.09	2.9190E+07	4.2728E+07	5.6266E+07
So Main Lake Direc	02010005-070	5488	28.32	37.12	45.92	0.33	9.35	12.25	15.15	1.3024E+07	1.7071E+07	2.1118E+07
Islands	02010005-080	25328	24.56	32.40	40.25	0.38	9.33	12.31	15.30	6.0027E+07	7.9189E+07	9.8375E+07
Foucault, Que	02010005-090	23	29.91	40.07	50.23	0.33	9.87	13.22	16.58	5.7649E+04	7.7231E+04	9.6814E+04
MISSISQUOI												
Uppr Mississquoi R	02010007-010	54194	30.52	42.17	53.82	0.64	19.53	26.99	34.44	2.6881E+08	3.7142E+08	4.7403E+08
Trout River	02010007-020	21647	32.70	44.86	57.02	0.59	19.29	26.47	33.64	1.0605E+08	1.4549E+08	1.8493E+08
Mid Missisquoi R.	02010007-030	42526	42.14	51.47	60.81	0.51	21.49	26.25	31.01	2.3209E+08	2.8347E+08	3.3491E+08
Tyler Branch	02010007-040	22444	28.90	41.45	54.00	0.58	16.76	24.04	31.32	9.5534E+07	1.3702E+08	1.7851E+08
Black Creek	02010007-050	31105	30.30	40.61	50.92	0.60	18.18	24.37	30.55	1.4360E+08	1.9246E+08	2.4133E+08
Lowr Mississquoi R	02010007-060	23410	28.63	37.37	46.12	0.65	18.61	24.29	29.98	1.1063E+08	1.4440E+08	1.7821E+08
Rock R./Pike R.	02010007-070	55276	32.69	42.18	51.67	0.57	18.63	24.04	29.45	2.6155E+08	3.3748E+08	4.1341E+08
Bolton, Que	02010007-080	17713	38.28	47.34	56.39	0.59	22.59	27.93	33.27	1.0159E+08	1.2563E+08	1.4965E+08
Mansonville, Que	02010007-090	10222	38.30	48.09	57.88	0.58	22.21	27.89	33.57	5.7663E+07	7.2402E+07	8.7142E+07
Wallbridge Ck, Que	02010007-150	7086	30.56	40.78	51.00	0.64	19.56	26.47	32.64	3.5194E+07	4.7632E+07	5.8733E+07
Morpion, Que	02010007-160	11529	30.07	41.36	52.66	0.64	19.24	25.83	33.70	5.6343E+07	7.5623E+07	9.8670E+07
Pike R., Que	02010007-170	8557	30.32	40.36	50.41	0.65	19.71	26.05	32.77	4.2825E+07	5.6596E+07	7.1201E+07
Miss. Bay Dir, Que	02010007-190	4819	29.91	40.07	50.23	0.66	19.74	26.45	33.15	2.4157E+07	3.2363E+07	4.0569E+07

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TABLE 6.6

LAKE CHAMPLAIN BASIN HYDROLOGIC UNITS — NEW YORK

HU NAME	HU NUMBER	AREA(ha)	PRECIP (in)			Cr	RUNOFF (in)			DISCHARGE (m3/yr)		
			LOW	AVE	HIGH		LOW	AVE	HIGH	LOW	AVE	HIGH
SOUTH BASIN												
	02010001-080	2814	24.60	37.68	50.75	0.50	12.30	18.84	25.38	8.7895E+06	1.3463E+07	1.8133E+07
Hampton	02010001-110	2097	24.60	37.68	50.75	0.50	12.30	18.84	25.38	6.5499E+06	1.0033E+07	1.3513E+07
Mettawee River	02010001-120	22752	27.71	39.19	50.67	0.51	14.13	19.99	25.84	8.1651E+07	1.1548E+08	1.4930E+08
Whitehall	02010001-130	2741	24.60	37.68	50.75	0.53	13.04	19.97	26.90	9.0751E+06	1.3900E+07	1.8722E+07
Halfway Ck/Ch Can	02010001-140	52585	24.14	36.72	48.30	0.56	13.52	20.56	27.05	1.8052E+08	2.7459E+08	3.6119E+08
Mt Hope Br/So Bay	02010001-150	12114	24.61	37.64	50.66	0.48	11.81	18.07	24.32	3.6339E+07	5.5579E+07	7.4804E+07
Clemons	02010001-160	5081	25.36	35.99	46.62	0.47	11.92	16.92	21.91	1.5379E+07	2.1825E+07	2.8272E+07
Putnam	02010001-170	4795	22.18	32.69	43.21	0.51	11.31	16.67	22.04	1.3774E+07	2.0300E+07	2.6833E+07
	02010001-180	2283	21.51	32.28	43.04	0.52	11.19	16.79	22.38	6.4846E+06	9.7314E+06	1.2975E+07
Lake George	02010001-190	59888	27.64	38.34	49.03	0.59	16.31	22.62	28.93	2.4801E+08	3.4401E+08	4.3993E+08
Ticonderoga	02010001-200	7385	21.51	32.28	43.04	0.56	12.05	18.08	24.10	2.2590E+07	3.3900E+07	4.5201E+07
Fort Ticonderoga	02010001-210	4879	21.51	32.28	43.04	0.61	13.12	19.69	26.25	1.6257E+07	2.4396E+07	3.2529E+07
Putnam Br/Crown P	02010001-220	16005	21.51	32.28	43.04	0.61	13.12	19.69	26.25	5.3328E+07	8.0030E+07	1.0671E+08
Bulwaga Bay	02010001-230	4793	21.99	32.49	42.98	0.60	13.19	19.49	25.79	1.6059E+07	2.3727E+07	3.1388E+07
Moriah	02010001-240	3015	23.20	33.76	44.31	0.56	12.99	18.91	24.81	9.9471E+06	1.4475E+07	1.8998E+07
Port Henry	02010001-250	7203	22.86	34.27	45.67	0.55	12.57	18.85	25.12	2.2998E+07	3.4476E+07	4.5945E+07
Westport	02010001-260	10885	22.51	35.38	48.25	0.41	9.23	14.51	19.78	2.5511E+07	4.0096E+07	5.4682E+07
BOQUET-AUSABLE												
Dir to L Ch/Essex	02010004-010	3265	22.91	35.26	47.61	0.41	9.39	14.46	19.52	7.7880E+06	1.1986E+07	1.6184E+07
No Branch Boquet	02010004-020	25496	22.11	34.88	47.66	0.41	9.07	14.30	19.54	5.8692E+07	9.2590E+07	1.2652E+08
Boquet River	02010004-030	45185	22.56	35.37	48.19	0.41	9.25	14.50	19.76	1.0613E+08	1.6640E+08	2.2671E+08
Dir to L Ch/Wboro	02010004-040	9066	21.13	31.06	41.00	0.45	9.51	13.98	18.45	2.1891E+07	3.2178E+07	4.2476E+07
E. Br. Ausable R.	02010004-050	50716	24.95	36.62	48.29	0.59	14.72	21.61	28.49	1.8958E+08	2.7826E+08	3.6693E+08
W Br Ausable/L Pla	02010004-060	63686	24.78	35.20	45.61	0.59	14.62	20.77	26.91	2.3644E+08	3.3587E+08	4.3520E+08
Lower Ausable R.	02010004-070	20733	19.14	29.17	39.19	0.63	12.06	18.38	24.69	6.3486E+07	9.6755E+07	1.2999E+08
Little Ausable R.	02010004-080	20856	19.28	29.54	39.81	0.69	13.30	20.38	27.47	7.0456E+07	1.0795E+08	1.4548E+08
Salmon River	02010004-090	18592	20.05	31.13	42.21	0.65	13.03	20.23	27.44	6.1530E+07	9.5533E+07	1.2954E+08
SARANAC-CHAZY												
Upper Saranac R.	02010006-010	91342	30.26	40.25	50.24	0.54	16.34	21.74	27.13	3.7902E+08	5.0415E+08	6.2928E+08
N Branch	02010006-020	33202	29.41	38.53	47.65	0.55	16.18	21.19	26.21	1.3638E+08	1.7867E+08	2.2096E+08
Mid Saranac R.	02010006-030	26587	22.96	34.30	45.64	0.55	12.63	18.87	25.10	8.5258E+07	1.2737E+08	1.6948E+08
Lower Saranac R.	02010006-040	8593	20.75	33.15	45.56	0.57	11.83	18.90	25.97	2.5809E+07	4.1232E+07	5.6668E+07
Beekmantown	02010006-050	11346	19.26	31.90	44.53	0.59	11.36	18.82	26.27	3.2740E+07	5.4227E+07	7.5697E+07
Ingraham	02010006-060	2596	22.59	32.53	42.48	0.58	13.10	18.87	24.64	8.6374E+06	1.2438E+07	1.6242E+07
Chazy River	02010006-070	16565	22.78	32.54	42.30	0.51	11.62	16.60	21.57	4.8871E+07	6.9809E+07	9.0748E+07
Gt Chazy/Graves R	02010006-080	49434	21.81	31.65	41.49	0.58	12.65	18.36	24.06	1.5880E+08	2.3044E+08	3.0209E+08
Corbeau Creek	02010006-090	27162	22.48	32.33	42.17	0.57	12.81	18.43	24.04	8.8382E+07	1.2711E+08	1.6580E+08
Rouses Pt Direct	02010006-100	1185	22.59	32.53	42.48	0.54	12.20	17.57	22.94	3.6708E+06	5.2860E+06	6.9029E+06
Lacolle, Que.	02010006-110	4415	25.07	32.47	39.86	0.54	13.54	17.53	21.52	1.5178E+07	1.9658E+07	2.4132E+07
North Plattsburg	02010006-120	2904	19.82	31.90	43.98	0.59	11.69	18.82	25.95	8.6235E+06	1.3879E+07	1.9135E+07

LCHHYDRO.WK3

6.4 Lake Champlain Basin Nonpoint Source Load Estimates.
Nonpoint source loads of total phosphorus (TP), soluble phosphorus (SRP), and total nitrogen (TN) to Lake Champlain were estimated by the two different methods as outlined in Section 5.4: the **export coefficient (EC) method**, applying areal loading values (kg/ha/yr) to the land area in each HU for each general land use; and the **loading function (LF) method**, applying the selected concentration values (mg/l) for each land use to the estimated water volume from each HU for each general land use.

Because of the natural variability of nonpoint source loads, the uncertainty in coefficient selection, and the age and quality of the land use information for the LCB, a variety of scenarios were examined in the load estimation process. For both methods, low, baseline, and high coefficient values were applied separately. For the LF method, separate estimates were also calculated for the low, average, and high precipitation/streamflow conditions for each level of concentration coefficients. Finally, as an attempt to adjust for the age of the land use information, agricultural land was decreased and urban/developed land was correspondingly increased in two "ag build-out" scenarios: 10% and then 20% of agricultural land within each 11-digit HU was re-allocated to the urban category. Both land use change scenarios were evaluated using both the EC and the LF method.

Nonpoint source loads were calculated within each 11-digit HU, then summed within each larger basin (8-digit HU). The Vermont and New York "sides" of the lake were separated in order to attribute estimated loads separately to each state. While this is obviously hydrologically incorrect and somewhat arbitrary in the case of the Poultney-Mettawee/South Basin (HU #02010001-), it is at least somewhat justified in that the two states have different water quality regulations and management policies, as well as different general land use patterns. Hydrologic units in Quebec were also combined with those of the two states; the Rock and Pike River watersheds, for example, were included with the Missisquoi Basin (HU #02010007-).

Calculations were done in a Lotus 1-2-3 (release 3.1, Lotus Development Corp., 1990) spreadsheet. A separate spreadsheet was generally required for each scenario, although all three hydrologic conditions were combined in the LF method. Because of the number of HUs considered and the number of different scenarios evaluated, all scenario outputs for both methods for all three pollutants cannot be presented here in the body of this report. Therefore, only results of a baseline scenario for TP for each of the two methods will be fully presented in this section of the report. Overall results for SRP and TN will be discussed, but the detailed spreadsheets for SRP and TN are found in Appendices.

6.4.1 Export Coefficient Method. Estimates of nonpoint source TP load from each of the 11-digit HUs under the baseline coefficient, baseline land use scenario are detailed in Table 6.7. In this table, the land use distribution within each individual HU is noted and estimated TP loads from the HU are shown separately for each land use category. These three values are summed in the "TOTAL LOAD" column for each HU. For each major basin, total land area, area for each land use category, estimated TP load from each land use category, and total basin estimated TP load are shown in the "TOTALS" row at the end of each block. Totals for the

TABLE 6.7

NPS LOAD ESTIMATE - EXPORT COEFFICIENTS

TOTAL PHOSPHORUS

AREAL EXPORT (kg/ha/yr)		
FOREST	AG	URBAN
0.1	0.5	1.5

BASELINE COEFFCIENTS

POULTNEY-METAWEE

HU NAME	HU NUMBER	AREA(ha)	LAND USE (ha)			POLLUTANT LOAD (kg/year)			TOTAL LOAD	SOURCE OF NPS LOAD		
			FOR	AG	URBAN	FOREST	AGRICULTURE	URBAN	kg/year	% FOREST	% AG	% URBAN
Upper Poultney R	02010001-010	20104	13163	6713	218	1316	3357	327	5000	26.3	67.1	6.5
Castleton	02010001-020	8301	6719	1108	474	672	554	711	1937	34.7	28.6	36.7
Lake Bomoseen	02010001-030	17407	11585	3896	672	1159	1948	1008	4115	28.2	47.3	24.5
Hubbardton River	02010001-050	14560	7800	5986	190	780	2993	285	4058	19.2	73.8	7.0
Main Stem Poultney	02010001-070	4756	2381	2302	25	238	1151	38	1427	16.7	80.7	2.6
Mettawee River	02010001-090	29650	20088	8647	412	2009	4324	618	6950	28.9	62.2	8.9
Direct to L CH	02010001-270	24849	5198	18867	101	520	9434	152	10105	5.1	93.4	1.5
TOTALS		**119627**	**66934**	**47519**	**2092**	**6693**	**23760**	**3138**	**33591**	**19.9**	**70.7**	**9.3**

OTTER-LEWIS

HU NAME	HU NUMBER	AREA(ha)	LAND USE (ha)			POLLUTANT LOAD (kg/year)			TOTAL LOAD	SOURCE OF NPS LOAD		
			FOR	AG	URBAN	FOREST	AGRICULTURE	URBAN	kg/year	% FOREST	% AG	% URBAN
Otter/Rutland	02010002-010	93760	70126	20548	2464	7013	10274	3696	20983	33.4	49.0	17.6
Neshobe River	02010002-020	5254	3997	1072	185	400	536	278	1213	32.9	44.2	22.9
Middlebury River	02010002-030	16274	13407	2538	259	1341	1269	389	2998	44.7	42.3	13.0
Mid-Otter Creek	02010002-040	47937	23315	18112	585	2332	9056	878	12265	19.0	73.8	7.2
Bridport	02010002-050	2847	265	2126	19	27	1063	29	1118	2.4	95.1	2.5
Lemon Fair River	02010002-060	20670	3952	16661	18	395	8331	27	8753	4.5	95.2	0.3
New Haven River	02010002-070	30131	21644	8029	286	2164	4015	429	6608	32.8	60.8	6.5
Lwr Otter/Dead Cr.	02010002-080	27852	2414	23452	642	241	11726	963	12930	1.9	90.7	7.4
Little Otter Creek	02010002-090	18738	4737	13171	203	474	6586	305	7364	6.4	89.4	4.1
Lewis Creek	02010002-100	20999	10704	9356	203	1070	4678	305	6053	17.7	77.3	5.0
TOTALS		**284462**	**154561**	**115065**	**4864**	**15456**	**57533**	**7296**	**80285**	**19.3**	**71.7**	**9.1**

WINOOSKI

HU NAME	HU NUMBER	AREA(ha)	LAND USE (ha)			POLLUTANT LOAD (kg/year)			TOTAL LOAD	SOURCE OF NPS LOAD		
			FOR	AG	URBAN	FOREST	AGRICULTURE	URBAN	kg/year	% FOREST	% AG	% URBAN
Stevens/Jail Brnch	02010003-010	29842	14981	12197	2388	1498	6099	3582	11179	13.4	54.6	32.0
N Branch	02010003-020	72520	53735	16514	987	5374	8257	1481	15111	35.6	54.6	9.8
Dog/Mad River	02010003-030	79983	62258	14574	3130	6226	7287	4695	18208	34.2	40.0	25.8
Shelburne Pond	02010003-040	5505	1257	3520	284	126	1760	426	2312	5.4	76.1	18.4
Lower Winooski R.	02010003-050	87539	64007	15865	5865	6401	7933	8798	23131	27.7	34.3	38.0
LaPlatte River	02010003-060	13722	3409	9459	541	341	4730	812	5882	5.8	80.4	13.8
Dir L Ch Shel/Char	02010003-070	6099	351	5689	11	35	2845	17	2896	1.2	98.2	0.6
Dir L Ch Burl	02010003-080	5615	337	2438	2782	34	1219	4173	5426	0.6	22.5	76.9
TOTALS		**300825**	**200335**	**80256**	**15988**	**20034**	**40128**	**23982**	**84144**	**23.8**	**47.7**	**28.5**

LAMOILLE-GRAND ISLE

HU NAME	HU NUMBER	AREA(ha)	LAND USE (ha)			POLLUTANT LOAD (kg/year)			TOTAL LOAD	SOURCE OF NPS LOAD		
			FOR	AG	URBAN	FOREST	AGRICULTURE	URBAN	kg/year	% FOREST	% AG	% URBAN
Upper Lamoille R.	02010005-010	97406	69845	23838	1254	6985	11919	1881	20785	33.6	57.3	9.1
Lee/Browns River	02010005-020	23908	15951	7207	605	1595	3604	908	6106	26.1	59.0	14.9
Lower Lamoille R.	02010005-030	66183	44926	18267	1259	4493	9134	1889	15515	29.0	58.9	12.2
Malletts Bay	02010005-040	13643	5829	5648	1606	583	2824	2409	5816	10.0	48.6	41.4
Lwr NE Arm Direct	02010005-050	6091	1903	3979	152	190	1990	228	2408	7.9	82.6	9.5
St. Albans Bay	02010005-060	12966	2113	8968	1369	211	4484	2054	6749	3.1	66.4	30.4
So Main Lake Direc	02010005-070	5488	504	2789	325	50	1395	488	1932	2.6	72.2	25.2
Islands	02010005-080	25328	5796	15884	1016	580	7942	1524	10046	5.8	79.1	15.2
Foucault, Que	02010005-090	23	17	5	1	2	3	2	6	29.8	43.9	26.3
TOTALS		**251036**	**146884**	**86585**	**7587**	**14688**	**43293**	**11381**	**69361**	**21.2**	**62.4**	**16.4**

MISSISQUOI

HU NAME	HU NUMBER	AREA(ha)	LAND USE (ha)			POLLUTANT LOAD (kg/year)			TOTAL LOAD	SOURCE OF NPS LOAD		
			FOR	AG	URBAN	FOREST	AGRICULTURE	URBAN	kg/year	% FOREST	% AG	% URBAN
Uppr Missisquoi R.	02010007-010	54194	37242	15547	965	3724	7774	1448	12945	28.8	60.0	11.2
Trout River	02010007-020	21647	17688	3773	186	1769	1887	279	3934	45.0	48.0	7.1
Mid Missisquoi R.	02010007-030	42526	29698	11084	794	2970	5542	1191	9703	30.6	57.1	12.3
Tyler Branch	02010007-040	22444	12452	9712	204	1245	4856	306	6407	19.4	75.8	4.8
Black Creek	02010007-050	31105	15910	14025	152	1591	7013	228	8832	18.0	79.4	2.6
Lowr Missisquoi R	02010007-060	23410	8641	11724	1095	864	5862	1643	8369	10.3	70.0	19.6
Rock R./Pike R.	02010007-070	55276	33221	18845	1062	3322	9423	1593	14338	23.2	65.7	11.1
Bolton, Que	02010007-080	17713	12753	4074	354	1275	2037	531	3843	33.2	53.0	13.8
Mansonville, Que	02010007-090	10222	7360	2351	204	736	1176	306	2218	33.2	53.0	13.8
Wallbridge Ck, Que	02010007-150	7086	5102	1630	142	510	815	213	1538	33.2	53.0	13.8
Morpion, Que	02010007-160	11529	8301	2652	231	830	1326	347	2503	33.2	53.0	13.8
Pike R., Que	02010007-170	8557	6161	1968	171	616	984	257	1857	33.2	53.0	13.8
Miss. Bay Dir, Que	02010007-190	4819	3470	1108	96	347	554	144	1045	33.2	53.0	13.8
TOTALS		**310528**	**197999**	**98493**	**5656**	**19800**	**49247**	**8484**	**77530**	**25.5**	**63.5**	**10.9**

TOTAL VT/QUE	**1266478**	**766713**	**427918**	**36187**	**76671**	**213959**	**54281**	**344911**	**22.2**	**62.0**	**15.7**

EXPTP.WK3

TABLE 6.7

NPS LOAD ESTIMATE - EXPORT COEFFICIENTS

TOTAL PHOSPHORUS

AREAL EXPORT (kg/ha/yr)		
FOREST	AG	URBAN
0.1	0.5	1.5

BASELINE COEFFCIENTS

SOUTH BASIN, NY

HU NAME	HU NUMBER	AREA(ha)	LAND USE (ha)			POLLUTANT LOAD (kg/year)			TOTAL LOAD	SOURCE OF NPS LOAD		
			FOR	AG	URBAN	FOREST	AGRICULTURE	URBAN	kg/year	% FOREST	% AG	% URBAN
	02010001-080	2814	1222	1591	0	122	796	0	918	13.3	86.7	0.0
Hampton	02010001-110	2097	640	1363	93	64	682	140	885	7.2	77.0	15.8
Mettawee River	02010001-120	22752	11026	11207	423	1103	5604	635	7341	15.0	76.3	8.6
Whitehall	02010001-130	2741	911	1753	78	91	877	117	1085	8.4	80.8	10.8
Halfway Ck/Ch Can	02010001-140	52585	26621	23107	2111	2662	11554	3167	17382	15.3	66.5	18.2
Mt Hope Br/So Bay	02010001-150	12114	11432	19	0	1143	10	0	1153	99.2	0.8	0.0
Clemons	02010001-160	5081	4448	493	0	445	247	0	691	64.3	35.7	0.0
Putnam	02010001-170	4795	3060	1677	0	306	839	0	1145	26.7	73.3	0.0
	02010001-180	2283	1605	678	0	161	339	0	500	32.1	67.9	0.0
Lake George	02010001-190	59888	45736	926	1059	4574	463	1589	6625	69.0	7.0	24.0
Ticonderoga	02010001-200	7385	5890	1121	354	589	561	531	1681	35.0	33.4	31.6
Fort Ticonderoga	02010001-210	4879	2007	2712	137	201	1356	206	1762	11.4	76.9	11.7
Putnam Br/Crown P	02010001-220	16005	13992	1546	14	1399	773	21	2193	63.8	35.2	1.0
Bulwaga Bay	02010001-230	4793	2915	1874	0	292	937	0	1229	23.7	76.3	0.0
Moriah	02010001-240	3015	1975	800	241	198	400	362	959	20.6	41.7	37.7
Port Henry	02010001-250	7203	6105	639	366	611	320	549	1479	41.3	21.6	37.1
Westport	02010001-260	10885	7697	2913	242	770	1457	363	2589	29.7	56.3	14.0
	TOTALS	**221315**	**147282**	**54419**	**5118**	**14728**	**27210**	**7677**	**49615**	**29.7**	**54.8**	**15.5**

BOQUET-AUSABLE

HU NAME	HU NUMBER	AREA(ha)	LAND USE (ha)			POLLUTANT LOAD (kg/year)			TOTAL LOAD	SOURCE OF NPS LOAD		
			FOR	AG	URBAN	FOREST	AGRICULTURE	URBAN	kg/year	% FOREST	% AG	% URBAN
Dir to L Ch/Essex	02010004-010	3265	946	2219	86	95	1110	129	1333	7.1	83.2	9.7
No Branch Boquet	02010004-020	25496	23286	1697	446	2329	849	669	3846	60.5	22.1	17.4
Boquet River	02010004-030	45185	37277	6336	948	3728	3168	1422	8318	44.8	38.1	17.1
Dir to L Ch/Wboro	02010004-040	9066	7168	1491	192	717	746	288	1750	41.0	42.6	16.5
E. Br. Ausable R.	02010004-050	50716	47555	2185	594	4756	1093	891	6739	70.6	16.2	13.2
W Br Ausable/L Pla	02010004-060	63686	57219	1818	1991	5722	909	2987	9617	59.5	9.5	31.1
Lower Ausable R.	02010004-070	20733	15189	3493	1253	1519	1747	1880	5145	29.5	33.9	36.5
Little Ausable R.	02010004-080	20856	14015	6343	460	1402	3172	690	5263	26.6	60.3	13.1
Salmon River	02010004-090	18592	13157	3547	1581	1316	1774	2372	5461	24.1	32.5	43.4
	TOTALS	**257595**	**215812**	**29129**	**7551**	**21581**	**14565**	**11327**	**47472**	**45.5**	**30.7**	**23.9**

SARANAC-CHAZY

HU NAME	HU NUMBER	AREA(ha)	LAND USE (ha)			POLLUTANT LOAD (kg/year)			TOTAL LOAD	SOURCE OF NPS LOAD		
			FOR	AG	URBAN	FOREST	AGRICULTURE	URBAN	kg/year	% FOREST	% AG	% URBAN
Upper Saranac R.	02010006-010	91342	77268	1564	1467	7727	782	2201	10709	72.2	7.3	20.5
N Branch	02010006-020	33202	30549	922	161	3055	461	242	3757	81.3	12.3	6.4
Mid Saranac R.	02010006-030	26587	19890	6017	478	1989	3009	717	5715	34.8	52.6	12.5
Lower Saranac R.	02010006-040	8593	4991	1611	1747	499	806	2621	3925	12.7	20.5	66.8
Beekmantown	02010006-050	11346	3424	6292	1164	342	3146	1746	5234	6.5	60.1	33.4
Ingraham	02010006-060	2596	575	1818	123	58	909	185	1151	5.0	79.0	16.0
Chazy River	02010006-070	16565	8028	7728	333	803	3864	500	5166	15.5	74.8	9.7
Gt Chazy/Graves R	02010006-080	49434	35088	12761	367	3509	6381	551	10440	33.6	61.1	5.3
Corbeau Creek	02010006-090	27162	10033	12833	787	1003	6417	1181	8600	11.7	74.6	13.7
Rouses Pt Direct	02010006-100	1185	0	771	142	0	386	213	599	0.0	64.4	35.6
Lacolle, Que.	02010006-110	4415	2822	1384	92	282	692	138	1112	25.4	62.2	12.4
North Plattsburg	02010006-120	2904	31	2095	123	3	1048	185	1235	0.3	84.8	14.9
	TOTALS	**275331**	**192699**	**55796**	**6984**	**19270**	**27898**	**10476**	**57644**	**33.4**	**48.4**	**18.2**
	TOTAL NY/QU	**754241**	**555793**	**139344**	**19653**	**55579**	**69672**	**29480**	**154731**	**35.9**	**45.0**	**19.1**

	AREA(ha)	LAND USE (ha)			POLLUTANT LOAD (kg/year)			TOTAL LOAD	SOURCE OF NPS LOAD		
		FOR	AG	URBAN	FOREST	AGRICULTURE	URBAN	kg/year	% FOREST	% AG	% URBAN
TOTAL BASIN	**2020719**	**1322506**	**567262**	**55840**	**132251**	**283631**	**83760**	**499642**	**26.5**	**56.8**	**16.8**

EXPTP.WK3

Vermont/Quebec side of the LCB are given at the bottom of the first page; New York/Quebec totals are given on the second page. Grand totals for the entire LCB are presented in the last block on the second page.

In addition to these load estimates, the percentage of the TP load attributable to each of the general land use categories are calculated in the last set of columns labeled "SOURCE OF NPS LOAD." These percentages are simply the result of dividing the load from each land use by the total load from that HU. These percentages were calculated for each 11-digit HU, for each major basin (based on totals within the 11-digit HUs), for each "side" of the lake (based on totals of the component major basins), and for the LCB as a whole (based on LCB totals).

The baseline set of export coefficients represented in Table 6.7, yields an estimated TP load to Lake Champlain from the entire Basin of 499,642 kg/yr (499.6 mt/yr). Of this estimated total, Vermont contributed 344.9 mt/yr (69%) and 154.7 mt/yr (31%) arose from the New York side. Estimated contributions from major basins within the LCB range from 47.5 mt/yr from the Boquet-Ausable HU up to 84.1 mt/yr from the Winooski. Estimated loads from individual 8-digit HUs are highly variable, due to variability in HU area as well as land use. HU -5090 (Foucault, Quebec), just 23 ha in area, is estimated to contribute just 6 kg/yr TP, while the 88,000 ha Lower Winooski HU (-3050) contributes an estimated 23,131 kg/yr TP to the Lake. Comparisons of contributions from specific HUs based on estimated areal loads (kg/ha/yr) are discussed in Section 6.6.

The estimated source of the nonpoint source TP load varied widely among the HUs and not surprisingly corresponded well to land use distribution. Forest land contribution was obviously very low in the most urbanized HUs around Burlington and Plattsburg and in highly agricultural areas in Addison and Franklin Counties of Vermont, but proportionally high in the most forested HUs, such as the Lake George and Adirondack regions of New York. Agricultural contributions dominated in the Champlain Valley region of the LCB and urban contributions were highest in the HUs which included Burlington and Plattsburg, the major urban centers in the LCB. Overall, of the TP load estimated by the EC method under the baseline coefficient scenario, 26% came from forested land, 57% from agricultural land, and 17% from urban/developed land.

Results of TP load estimates under other scenarios and for SRP and TN load estimates under all scenarios are detailed in Appendix E and summarized in Table 6.8 and Figure 6.9. Estimates of TP load ranged from 250 mt/yr using the low coefficients to 884 mt/yr with the high coefficients, compared to the baseline TP load estimate of 500 mt/yr. TP load estimates for the two scenarios of shifting land from agriculture to urban use, which used the baseline export coefficients, gave estimated TP loads about 10% to 25% higher than with baseline land use, but the estimates were still lower than with the high-end coefficients.

The distribution of estimated loads between the two states was consistent between scenarios: about 70% of the estimated TP load originated in Vermont HUs, 30% in New York. The estimated contribution by the general land use categories varied somewhat among the three sets of coefficients; about 21-36% of the estimated TP load

TABLE 6.8

NONPOINT SOURCE LOADS ESTIMATED BY EXPORT COEFFICIENT METHOD

TOTAL PHOSPHORUS

SCENARIO	NPS TP LOAD (mt/yr)	SOURCE OF NPS LOAD % VERMONT	% NEW YORK	% FOREST	% AG	%URBAN
Low-end coefficients	250.6	69.0	31.0	21.1	56.6	22.3
Baseline coefficients	499.6	69.0	31.0	26.5	56.8	16.8
High-end coefficients	883.5	68.0	32.0	35.9	52.0	12.1
10% AG==>URB	556.4	69.7	30.3	23.8	45.9	30.3
20% AG==>URB	626.3	70.8	29.2	21.1	39.3	39.6

SOLUBLE PHOSPHORUS

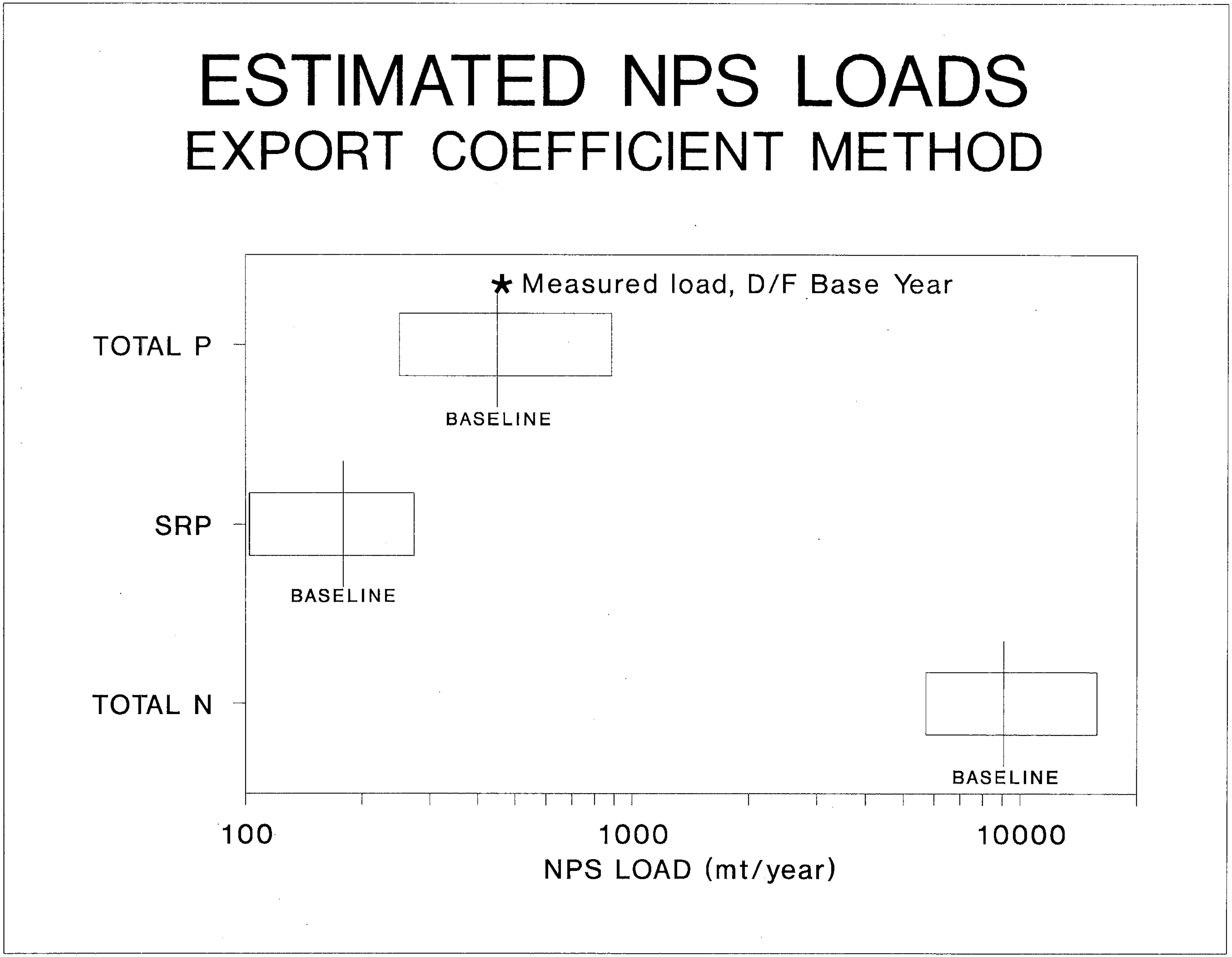
SCENARIO	NPS SRP LOAD (mt/yr)	SOURCE OF NPS LOAD % VERMONT	% NEW YORK	% FOREST	% AG	%URBAN
Low-end coefficients	102.4	67.5	32.5	38.7	49.8	11.4
Baseline coefficients	179.1	67.3	32.7	36.9	47.5	15.6
High-end coefficients	273.2	67.3	32.7	33.9	45.7	20.4
10% AG==>URB	200.0	67.8	32.2	33.2	38.5	28.3
20% AG==>URB	218.8	68.8	31.2	30.2	31.1	38.7

TOTAL NITROGEN

SCENARIO	NPS TN LOAD (mt/yr)	SOURCE OF NPS LOAD % VERMONT	% NEW YORK	% FOREST	% AG	%URBAN
Low-end coefficients	5708.5	66.7	33.3	46.3	47.7	6.0
Baseline coefficients	9074.2	66.0	34.0	51.0	43.8	5.2
High-end coefficients	15785.0	67.0	33.0	46.1	50.3	3.6
10% AG==>URB	9159.3	66.1	33.9	50.5	39	10.4
20% AG==>URB	9244.4	66.1	33.9	50.1	34.4	15.6

EXPSUMM.WK3

FIGURE 6.9


ESTIMATED NPS LOADS
EXPORT COEFFICIENT METHOD
★ Measured load, D/F Base Year
TOTAL P
SRP
TOTAL N
BASELINE
BASELINE
BASELINE
100
1000
10000
NPS LOAD (mt/year)

was contributed by forest land, 52-57% by agricultural land, and 12-22% by urban land. Of course the two build-out scenarios shifted a higher proportion of the load into the urban category.

Estimated SRP loads followed a similar pattern. Estimated SRP loads ranged from 102 mt/yr using the low coefficients to 273 mt/yr with the high coefficients; baseline SRP load was estimated as 179 mt/yr. SRP load estimates for the two scenarios of shifting land from agriculture to urban use, using the baseline coefficients, gave estimated SRP loads about 12% to 22% higher than with baseline land use, but the estimates were still lower than with the high-end coefficients.

The distribution of estimated SRP loads between Vermont and New York was similar to that for TP for all scenarios: about 67% of the estimated SRP load originated in Vermont HUs, 33% in New York. The estimated contribution by the general land use categories varied somewhat among the three sets of coefficients; about 30-39% of the estimated SRP load was contributed by forest land, 46-50% by agricultural land, and 11-20% by urban land. The two build-out scenarios shifted a higher proportion of the load into the urban category.

Estimated TN loads ranged from 5708 mt/yr using the low coefficients to 15785 mt/yr with the high coefficients; estimated baseline TN load was 9074 mt/yr. Shifting land from agriculture to urban use, using the baseline coefficients, increased estimated TN loads by only 1-2% compared to baseline land use, since the nitrogen export coefficients selected for agricultural and urban land were of similar magnitude.

The distribution of estimated TN loads between Vermont and New York was essentially the same as that for phosphorus for all scenarios: about 66% of the estimated TN load originated in Vermont HUs, 34% in New York. The estimated contribution by the general land use categories was quite consistent among the three sets of coefficients; about 46-51% of the estimated TN load was contributed by forest land, 44-50% by agricultural land, and just 4-6% by urban land. The two build-out scenarios shifted a only a slightly higher proportion of the load into the urban category, due to the similarity of export coefficients.

In summary, the high and low load estimates calculated using the range of export rates defined in Section 6.3 above, varied by roughly ±50% in absolute value around an estimate based on the "baseline" most appropriate coefficients. Shifting 10-20% of 1973-1976 agricultural land into urban use to reflect likely shifts over the last two decades increased the baseline load estimates somewhat, but estimates remained within the overall range suggested by the range in export coefficients selected. The geographic distribution of the estimated nonpoint source load was fairly consistent among all scenarios and all pollutants - about two-thirds of the nonpoint source load appears to arise from the Vermont side of the LCB, one-third from the New York side. Agricultural land was estimated to contribute the majority of phosphorus and nitrogen. Estimated phosphorus loads from urban land comprised up to slightly more than 20% of the total; urban land appeared to contribute less than 10% of the estimated nitrogen load in the LCB.

6.4.2 Loading Function Method. Estimated nonpoint source TP load from each of the 11-digit HUs under baseline coefficients and baseline land use are shown in Table 6.9. In this table, each of three levels of estimated discharge for each HU are shown under the "DISCHARGE" heading and the area of the HU in each general land use category given as in Table 6.7. Then, reading from left to right, estimated loads calculated from the low, average, and high discharge levels within each of the forest, agriculture, and urban categories are shown. In the first row, for example, the estimated TP load from forest land in the Poultney River HU (#-010) is 781 kg/yr under low flow, 1130 kg/yr under average flow, and 1479 kg/yr under high flow conditions. Under the heading "TOTAL NPS LOAD," estimated contributions from each of the three land use categories are summed within each flow condition, yielding a low, average, and high estimate of TP load from that HU. As in the export coefficient tables, land use areas and estimated loads for the 11-digit HUs are totaled within the larger basins, totaled again for the Vermont and New York "sides" of the lake, then finally totalled for the entire LCB.

As in the EC method tables, the percentage of the TP load attributable to each of the general land use categories is shown in the last set of columns, calculated by dividing the load from each land use by the total load from that HU. (The average flow condition loads were used to calculate the percentages; the results are essentially the same using low or high estimates.)

The baseline concentration values shown in Table 6.9 give an estimated TP load for the LCB ranging from 570,993 kg/yr under low flows to 1,059,282 kg/yr under high flows; a TP load of 815,440 kg/yr (815.4 mt/yr) was estimated under average hydrologic conditions. About 74% of this average TP load comes from the Vermont side, and 26% from the New York side. The Boquet-Ausable basin contributes an estimated TP load of 54.4 mt/yr while the Winooski basin contributes 131.7 mt/yr. Contributions from individual HUs varied tremendously, from an estimated average 5 kg/yr from Foucault, Quebec (-5090) to an average 37,751 kg/yr from Otter/Rutland (-2010). Low and high flow estimates of annual TP load varied by about ±25-35% around the average condition.

The source of the nonpoint source TP load estimated by the LF method again varied widely according to the land use distribution. Contributions from forest land were negligible in the more urbanized and agricultural areas, but as high as 40-55% in the Lake George and Adirondack regions. Agriculture contributed an estimated 75-90% of the annual TP load from the Champlain Valley region of the Basin. Contributions from urban/developed land were as high as 30-40% in the most urbanized HUs. Overall, of the TP load estimated by the LF method under baseline concentrations and baseline land use, 74% was estimated to come from agricultural land, with the remainder split about evenly between forest and urban land.

Results of TP loads estimated by the LF method under other scenarios and of SRP and TN loads under all scenarios are detailed in Appendix F and summarized in Table 6.10 and Figure 6.10. Average estimated TP loads ranged from 456.8 mt/yr using the low coefficients to 1,328.2 mt/yr with the high coefficients, compared to the baseline TP load estimate of 815.4 mt/yr. For all scenarios, estimated loads varied by about ±30% from average conditions using the low and high flow conditions. Shifting agricultural land to the urban category by 10%, then 20% increased the

NPS LOAD ESTIMATE - LOADING FUNCTIONS

TOTAL PHOSPHORUS

TABLE 6.9

RUNOFF CONCENTRATIONS (mg/l)		
FOREST	AG	URBAN
0.015	0.2	0.35

BASELINE COEFFICIENTS

POULTNEY-METAWEE

HU NAME	HU NUMBER	AREA(ha)	DISCHARGE (m3/yr)			LAND USE (ha)			FOREST (kg/yr)			AGRICULTURE (kg/yr)			URBAN (kg/yr)			TOTAL NPS LOAD (kg/yr)			SOURCE OF NPS LOAD		
			Q(low)	Q(ave)	Q(high)	FOR	AG	URBAN	LOW	AVE	HIGH	LOW	AVE	HIGH	LOW	AVE	HIGH	LOW	AVE	HIGH	% FOREST	% AG	% URBAN
Upper Poultney R.	02010001-010	20104	7.9568E+07	1.1507E+08	1.5057E+08	13163	6713	218	781	1130	1479	5314	7685	10055	302	437	571	6397	9252	12106	12.2	83.1	4.7
Castleton	02010001-020	8301	2.9414E+07	4.3580E+07	5.7746E+07	6719	1108	474	357	529	701	785	1163	1542	588	871	1154	1730	2563	3397	20.6	45.4	34.0
Lake Bomoseen	02010001-030	17407	5.8373E+07	8.3238E+07	1.0810E+08	11585	3896	672	583	831	1079	2613	3726	4839	789	1125	1461	3984	5682	7379	14.6	65.6	19.8
Hubbardton River	02010001-050	14560	4.7129E+07	6.8645E+07	9.0142E+07	7800	5986	190	379	552	724	3875	5644	7412	215	314	412	4469	6509	8548	8.5	86.7	4.8
Main Stem Poultne	02010001-070	4756	1.5952E+07	2.2659E+07	2.9373E+07	2381	2302	25	120	170	221	1544	2193	2843	29	42	54	1693	2405	3118	7.1	91.2	1.7
Mettawee River	02010001-090	29650	1.2352E+08	1.7035E+08	2.1718E+08	20088	8647	412	1255	1731	2207	7205	9936	12667	601	828	1056	9061	12496	15931	13.9	79.5	6.6
Direct to L CH	02010001-270	24849	7.9770E+07	1.1350E+08	1.4720E+08	5198	18867	101	250	356	462	12113	17235	22353	113	161	209	12477	17753	23024	2.0	97.1	0.9
TOTALS		119627	4.3373E+08	6.1704E+08	8.0031E+08	66934	47519	2092	3725	5299	6873	33449	47583	61712	2637	3778	4918	39812	56660	73502	9.4	84.0	6.7

OTTER-LEWIS

HU NAME	HU NUMBER	AREA(ha)	DISCHARGE (m3/yr)			LAND USE (ha)			FOREST (kg/yr)			AGRICULTURE (kg/yr)			URBAN (kg/yr)			TOTAL NPS LOAD (kg/yr)			SOURCE OF NPS LOAD		
			Q(low)	Q(ave)	Q(high)	FOR	AG	URBAN	LOW	AVE	HIGH	LOW	AVE	HIGH	LOW	AVE	HIGH	LOW	AVE	HIGH	% FOREST	% AG	% URBAN
Otter/Rutland	02010002-010	93760	3.8625E+08	5.8759E+08	7.8880E+08	70126	20548	2464	4333	6592	8850	16930	25755	34574	3553	5405	7255	24816	37751	50679	17.5	68.2	14.3
Neshobe River	02010002-020	5254	1.7342E+07	2.8598E+07	3.9863E+07	3997	1072	185	198	326	455	708	1167	1627	214	352	491	1119	1846	2573	17.7	63.2	19.1
Middlebury River	02010002-030	16274	5.6241E+07	8.9618E+07	1.2302E+08	13407	2538	259	695	1107	1520	1754	2795	3837	313	499	685	2762	4402	6043	25.2	63.5	11.3
Mid-Otter Creek	02010002-040	47937	1.6299E+08	2.6048E+08	3.5803E+08	23315	18112	585	1189	1900	2612	12316	19683	27055	696	1113	1529	14202	22696	31196	8.4	86.7	4.9
Bridport	02010002-050	2847	1.0841E+07	1.5510E+07	2.0183E+07	265	2126	19	15	22	28	1619	2316	3014	25	36	47	1660	2374	3090	0.9	97.6	1.5
Lemon Fair River	02010002-060	20670	7.8037E+07	1.1287E+08	1.4774E+08	3952	16661	18	224	324	424	12580	18196	23817	24	34	45	12828	18554	24286	1.7	98.1	0.2
New Haven River	02010002-070	30131	1.1280E+08	1.6618E+08	2.1956E+08	21644	8029	286	1215	1791	2366	6012	8856	11701	375	552	729	7602	11199	14796	16.0	79.1	4.9
Lwr Otter/Dead Cr.	02010002-080	27852	9.8869E+07	1.5316E+08	2.0745E+08	2414	23452	642	129	199	270	16650	25793	34935	798	1236	1674	17576	27228	36879	0.7	94.7	4.5
Little Otter Creek	02010002-090	18738	6.0365E+07	8.5056E+07	1.0972E+08	4737	13171	203	229	323	416	8486	11957	15425	229	323	416	8944	12602	16257	2.6	94.9	2.6
Lewis Creek	02010002-100	20999	7.2309E+07	1.0225E+08	1.3222E+08	10704	9356	203	553	782	1011	6443	9111	11782	245	346	447	7241	10239	13240	7.6	89.0	3.4
TOTALS		284462	1.0560E+09	1.6013E+09	2.1466E+09	154561	115065	4864	8780	13366	17951	83499	125630	167767	6471	9896	13320	98749	148892	199038	9.0	84.4	6.6

WINOOSKI

HU NAME	HU NUMBER	AREA(ha)	DISCHARGE (m3/yr)			LAND USE (ha)			FOREST (kg/yr)			AGRICULTURE (kg/yr)			URBAN (kg/yr)			TOTAL NPS LOAD (kg/yr)			SOURCE OF NPS LOAD		
			Q(low)	Q(ave)	Q(high)	FOR	AG	URBAN	LOW	AVE	HIGH	LOW	AVE	HIGH	LOW	AVE	HIGH	LOW	AVE	HIGH	% FOREST	% AG	% URBAN
Stevens/Jail Brnch	02010003-010	29842	9.8362E+07	1.4487E+08	1.9134E+08	14981	12197	2388	741	1091	1441	8040	11842	15641	2755	4057	5359	11536	16991	22441	6.4	69.7	23.9
N Branch	02010003-020	72520	2.6746E+08	3.7600E+08	4.8454E+08	53735	16514	987	2973	4179	5385	12181	17124	22068	1274	1791	2308	16428	23094	29761	18.1	74.1	7.8
Dog/Mad River	02010003-030	79983	3.2675E+08	4.8482E+08	6.4300E+08	62258	14574	3130	3815	5661	7508	11908	17668	23433	4475	6640	8807	20198	29969	39747	18.9	59.0	22.2
Shelburne Pond	02010003-040	5505	1.8004E+07	2.5832E+07	3.3661E+07	1257	3520	284	62	88	115	2302	3303	4305	325	466	608	2689	3858	5028	2.3	85.6	12.1
Lower Winooski R.	02010003-050	87539	3.5134E+08	5.0156E+08	6.5166E+08	64007	15865	5865	3853	5501	7147	12735	18180	23621	8239	11761	15281	24827	35442	46049	15.5	51.3	33.2
LaPlatte River	02010003-060	13722	4.5299E+07	6.4332E+07	8.3365E+07	3409	9459	541	169	240	311	6245	8869	11493	625	888	1150	7039	9997	12954	2.4	88.7	8.9
Dir L Ch Shel/Char	02010003-070	6099	2.1017E+07	2.9456E+07	3.7895E+07	351	5689	11	18	25	33	3921	5495	7070	13	19	24	3952	5539	7126	0.5	99.2	0.3
Dir L Ch Burl	02010003-080	5615	1.8010E+07	2.6025E+07	3.4048E+07	337	2438	2782	16	23	31	1564	2260	2957	3123	4513	5904	4703	6796	8892	0.3	33.3	66.4
TOTALS		300825	1.1462E+09	1.6529E+09	2.1595E+09	200335	80256	15988	11647	16809	21970	58896	84742	110586	20830	30136	39442	91373	131687	171998	12.8	64.4	22.9

LAMOILLE-GRAND ISLE

HU NAME	HU NUMBER	AREA(ha)	DISCHARGE (m3/yr)			LAND USE (ha)			FOREST (kg/yr)			AGRICULTURE (kg/yr)			URBAN (kg/yr)			TOTAL NPS LOAD (kg/yr)			SOURCE OF NPS LOAD		
			Q(low)	Q(ave)	Q(high)	FOR	AG	URBAN	LOW	AVE	HIGH	LOW	AVE	HIGH	LOW	AVE	HIGH	LOW	AVE	HIGH	% FOREST	% AG	% URBAN
Upper Lamoille R.	02010005-010	97406	4.0558E+08	5.7788E+08	7.5018E+08	69845	23838	1254	4362	6216	8069	19851	28285	36718	1827	2604	3380	26041	37104	48167	16.8	76.2	7.0
Lee/Browns River	02010005-020	23908	1.2008E+08	1.5019E+08	1.8033E+08	15951	7207	605	1202	1503	1805	7240	9055	10872	1064	1330	1597	9505	11888	14274	12.6	76.2	11.2
Lower Lamoille R.	02010005-030	66183	2.8972E+08	4.1555E+08	5.4147E+08	44926	18267	1259	2950	4231	5513	15993	22939	29890	1929	2767	3605	20872	29937	39008	14.1	76.6	9.2
Malletts Bay	02010005-040	13643	4.3219E+07	6.2496E+07	8.1772E+07	5829	5648	1606	277	401	524	3578	5174	6770	1781	2575	3369	5636	8150	10664	4.9	63.5	31.6
Lwr NE Arm Direct	02010005-050	6091	1.5288E+07	2.0584E+07	2.5886E+07	1903	3979	152	72	96	121	1997	2689	3382	134	180	226	2203	2966	3729	3.3	90.7	6.1
St. Albans Bay	02010005-060	12966	2.9190E+07	4.2728E+07	5.6266E+07	2113	8968	1369	71	104	138	4038	5911	7783	1079	1579	2079	5188	7594	10000	1.4	77.8	20.8
So Main Lake Direc	02010005-070	5488	1.3024E+07	1.7071E+07	2.1118E+07	504	2789	325	18	24	29	1324	1735	2146	270	354	438	1612	2112	2613	1.1	82.1	16.7
Islands	02010005-080	25328	6.0027E+07	7.9189E+07	9.8375E+07	5796	15884	1016	206	272	338	7529	9932	12339	843	1112	1381	8578	11316	14058	2.4	87.8	9.8
Foucault, Que	02010005-090	23	5.7649E+04	7.7231E+04	9.6814E+04	17	5	1	1	1	1	3	3	4	1	1	1	4	5	7	15.9	62.3	21.8
TOTALS		251036	9.7619E+08	1.3658E+09	1.7555E+09	146884	86585	7587	9159	12847	16538	61553	85724	109905	8926	12501	16077	79638	111073	142520	11.6	77.2	11.3

MISSISQUOI

HU NAME	HU NUMBER	AREA(ha)	DISCHARGE (m3/yr)			LAND USE (ha)			FOREST (kg/yr)			AGRICULTURE (kg/yr)			URBAN (kg/yr)			TOTAL NPS LOAD (kg/yr)			SOURCE OF NPS LOAD		
			Q(low)	Q(ave)	Q(high)	FOR	AG	URBAN	LOW	AVE	HIGH	LOW	AVE	HIGH	LOW	AVE	HIGH	LOW	AVE	HIGH	% FOREST	% AG	% URBAN
Uppr Missisquoi R.	02010007-010	54194	2.6881E+08	3.7142E+08	4.7403E+08	37242	15547	965	2771	3829	4886	15423	21310	27198	1675	2315	2954	19869	27454	35038	13.9	77.6	8.4
Trout River	02010007-020	21647	1.0605E+08	1.4549E+08	1.8493E+08	17688	3773	186	1300	1783	2267	3697	5072	6447	319	438	556	5316	7292	9269	24.5	69.5	6.0
Mid Missisquoi R.	02010007-030	42526	2.3209E+08	2.8347E+08	3.3491E+08	29698	11084	794	2431	2969	3508	12098	14777	17458	1517	1852	2189	16046	19599	23155	15.2	75.4	9.5
Tyler Branch	02010007-040	22444	9.5534E+07	1.3702E+08	1.7851E+08	12452	9712	204	795	1140	1486	8268	11858	15449	304	436	568	9367	13434	17502	8.5	88.3	3.2
Black Creek	02010007-050	31105	1.4360E+08	1.9246E+08	2.4133E+08	15910	14025	152	1102	1477	1852	12950	17356	21763	246	329	413	14297	19162	24027	7.7	90.6	1.7
Lowr Missisquoi R	02010007-060	23410	1.1063E+08	1.4440E+08	1.7821E+08	8641	11724	1095	613	800	987	11081	14463	17850	1811	2364	2918	13505	17627	21754	4.5	82.1	13.4
Rock R./Pike R.	02010007-070	55276	2.6155E+08	3.3748E+08	4.1341E+08	33221	18845	1062	2358	3042	3727	17834	23011	28188	1759	2269	2780	21950	28323	34695	10.7	81.2	8.0
Bolton, Que	02010007-080	17713	1.0159E+08	1.2563E+08	1.4965E+08	12753	4074	354	1097	1357	1616	4673	5779	6884	711	879	1047	6481	8015	9547	16.9	72.1	11.0
Mansonville, Que	02010007-090	10222	5.7663E+07	7.2402E+07	8.7142E+07	7360	2351	204	623	782	941	2652	3330	4008	403	506	609	3678	4618	5558	16.9	72.1	11.0
Wallbridge Ck, Que	02010007-150	7086	3.5194E+07	4.7632E+07	5.8733E+07	5102	1630	142	380	514	634	1619	2191	2702	247	334	412	2246	3040	3748	16.9	72.1	11.0
Morpion, Que	02010007-160	11529	5.6343E+07	7.5623E+07	9.8670E+07	8301	2652	231	609	817	1066	2592	3479	4539	395	530	692	3596	4826	6297	16.9	72.1	11.0
Pike R., Que	02010007-170	8557	4.2825E+07	5.6596E+07	7.1201E+07	6161	1968	171	463	611	769	1970	2603	3275	300	396	498	2732	3610	4542	16.9	72.1	11.0
Miss. Bay Dir, Que	02010007-190	4819	2.4157E+07	3.2363E+07	4.0569E+07	3470	1108	96	261	350	438	1111	1488	1866	168	226	283	1540	2063	2587	16.9	72.1	10.9
TOTALS		310528	1.5360E+09	2.0220E+09	2.5113E+09	197999	98493	5656	14801	19471	24176	95968	126719	157627	9854	12874	15917	120623	159063	197721	12.2	79.7	8.1

TOTAL VT/QUI	1266478	5.1482E+09	7.2590E+09	9.3732E+09	766713	427918	36187	48112	67792	87508	333365	470399	607597	48718	69184	89673	430195	607375	784779	11.2	77.4	11.4

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TABLE 6.9

NPS LOAD ESTIMATE - LOADING FUNCTIONS

TOTAL PHOSPHORUS

RUNOFF CONCENTRATIONS (mg/l)		
FOREST	AG	URBAN
0.015	0.2	0.35

BASELINE COEFFICIENTS

SOUTH BASIN, NY

HU NAME	HU NUMBER	AREA(ha)	DISCHARGE (m3/yr)			LAND USE (ha)			FOREST (kg/yr)			AGRICULTURE (kg/yr)			URBAN (kg/yr)			TOTAL NPS LOAD (kg/yr)			SOURCE OF NPS LOAD		
			Q(low)	Q(ave)	Q(high)	FOR	AG	URBAN	LOW	AVE	HIGH	LOW	AVE	HIGH	LOW	AVE	HIGH	LOW	AVE	HIGH	% FOREST	% AG	% URBAN
	02010001-080	2814	8.7895E+06	1.3463E+07	1.8133E+07	1222	1591	0	57	88	118	994	1522	2050	0	0	0	1051	1610	2169	5.4	94.6	0.0
Hampton	02010001-110	2097	6.5499E+06	1.0033E+07	1.3513E+07	640	1363	93	30	46	62	851	1304	1757	102	156	210	983	1506	2028	3.1	86.6	10.3
Mettawee River	02010001-120	22752	8.1651E+07	1.1548E+08	1.4930E+08	11026	11207	423	594	839	1085	8044	11376	14708	531	751	972	9169	12967	16765	6.5	87.7	5.8
Whitehall	02010001-130	2741	9.0751E+06	1.3900E+07	1.8722E+07	911	1753	78	45	69	93	1161	1778	2395	90	138	186	1296	1986	2675	3.5	89.5	7.0
Halfway Ck/Ch Can	02010001-140	52585	1.8052E+08	2.7459E+08	3.6119E+08	26621	23107	2111	1371	2085	2743	15865	24132	31743	2536	3858	5075	19772	30075	39561	6.9	80.2	12.8
Mt Hope Br/So Bay	02010001-150	12114	3.6339E+07	5.5579E+07	7.4804E+07	11432	19	0	514	787	1059	11	17	23	0	0	0	526	804	1082	97.8	2.2	0.0
Clemons	02010001-160	5081	1.5379E+07	2.1825E+07	2.8272E+07	4448	493	0	202	287	371	298	424	549	0	0	0	500	710	920	40.4	59.6	0.0
Putnam	02010001-170	4795	1.3774E+07	2.0300E+07	2.6833E+07	3060	1677	0	132	194	257	963	1420	1877	0	0	0	1095	1614	2134	12.0	88.0	0.0
	02010001-180	2283	6.4846E+06	9.7314E+06	1.2975E+07	1605	678	0	68	103	137	385	578	771	0	0	0	454	681	907	15.1	84.9	0.0
Lake George	02010001-190	59888	2.4801E+08	3.4401E+08	4.3993E+08	45736	926	1059	2841	3941	5040	767	1064	1360	1535	2129	2723	5143	7134	9123	55.2	14.9	29.8
Ticonderoga	02010001-200	7385	2.2590E+07	3.3900E+07	4.5201E+07	5890	1121	354	270	406	541	686	1029	1372	379	569	758	1335	2003	2671	20.2	51.4	28.4
Fort Ticonderoga	02010001-210	4879	1.6257E+07	2.4396E+07	3.2529E+07	2007	2712	137	100	151	201	1807	2712	3616	160	240	320	2067	3102	4137	4.9	87.4	7.7
Putnam Br/Crown P	02010001-220	16005	5.3328E+07	8.0030E+07	1.0671E+08	13992	1546	14	699	1049	1399	1030	1546	2062	16	25	33	1746	2620	3494	40.1	59.0	0.9
Bulwaga Bay	02010001-230	4793	1.6059E+07	2.3727E+07	3.1388E+07	2915	1874	0	147	216	286	1256	1855	2454	0	0	0	1402	2072	2741	10.4	89.6	0.0
Moriah	02010001-240	3015	9.9471E+06	1.4475E+07	1.8998E+07	1975	800	241	98	142	187	528	768	1008	278	405	532	904	1315	1726	10.8	58.4	30.8
Port Henry	02010001-250	7203	2.2998E+07	3.4476E+07	4.5945E+07	6105	639	366	292	438	584	408	612	815	409	613	817	1109	1663	2216	26.4	36.8	36.9
Westport	02010001-260	10885	2.5511E+07	4.0096E+07	5.4682E+07	7697	2913	242	271	425	580	1365	2146	2927	199	312	425	1835	2883	3932	14.7	74.4	10.8
	TOTALS	221315	7.7326E+08	1.1300E+09	1.4791E+09	147282	54419	5118	7732	11266	14743	36421	54285	71488	6236	9196	12050	50388	74747	98281	15.1	72.6	12.3

BOQUET-AUSABLE

HU NAME	HU NUMBER	AREA(ha)	DISCHARGE (m3/yr)			LAND USE (ha)			FOREST (kg/yr)			AGRICULTURE (kg/yr)			URBAN (kg/yr)			TOTAL NPS LOAD (kg/yr)			SOURCE OF NPS LOAD		
			Q(low)	Q(ave)	Q(high)	FOR	AG	URBAN	LOW	AVE	HIGH	LOW	AVE	HIGH	LOW	AVE	HIGH	LOW	AVE	HIGH	% FOREST	% AG	% URBAN
Dir to L Ch/Essex	02010004-010	3265	7.7880E+06	1.1986E+07	1.6184E+07	946	2219	86	34	52	70	1059	1629	2200	72	110	149	1164	1792	2419	2.9	90.9	6.2
No Branch Boquet	02010004-020	25496	5.8692E+07	9.2590E+07	1.2652E+08	23286	1697	446	804	1268	1733	781	1233	1684	359	567	775	1945	3068	4192	41.3	40.2	18.5
Boquet River	02010004-030	45185	1.0613E+08	1.6640E+08	2.2671E+08	37277	6336	948	1313	2059	2805	2976	4667	6358	779	1222	1665	5069	7948	10828	25.9	58.7	15.4
Dir to L Ch/Wboro	02010004-040	9066	2.1891E+07	3.2178E+07	4.2476E+07	7168	1491	192	260	382	504	720	1058	1397	162	239	315	1142	1679	2216	22.7	63.1	14.2
E. Br. Ausable R.	02010004-050	50716	1.8958E+08	2.7826E+08	3.6693E+08	47555	2185	594	2666	3914	5161	1634	2398	3162	777	1141	1504	5077	7452	9827	52.5	32.2	15.3
W Br Ausable/L Pla	02010004-060	63686	2.3644E+08	3.3587E+08	4.3520E+08	57219	1818	1991	3186	4526	5865	1350	1918	2485	2587	3675	4762	7123	10119	13112	44.7	18.9	36.3
Lower Ausable R.	02010004-070	20733	6.3486E+07	9.6755E+07	1.2999E+08	15189	3493	1253	698	1063	1428	2139	3260	4380	1343	2047	2750	4180	6370	8558	16.7	51.2	32.1
Little Ausable R.	02010004-080	20856	7.0456E+07	1.0795E+08	1.4548E+08	14015	6343	460	710	1088	1466	4286	6566	8849	544	833	1123	5540	8488	11439	12.8	77.4	9.8
Salmon River	02010004-090	18592	6.1530E+07	9.5533E+07	1.2954E+08	13157	3547	1581	653	1014	1375	2348	3645	4943	1831	2843	3855	4832	7503	10173	13.5	48.6	37.9
	TOTALS	257595	8.1599E+08	1.2175E+09	1.6190E+09	215812	29129	7551	10325	15367	20409	17292	26374	35457	8455	12677	16898	36072	54417	72764	28.2	48.5	23.3

SARANAC-CHAZY

HU NAME	HU NUMBER	AREA(ha)	DISCHARGE (m3/yr)			LAND USE (ha)			FOREST (kg/yr)			AGRICULTURE (kg/yr)			URBAN (kg/yr)			TOTAL NPS LOAD (kg/yr)			SOURCE OF NPS LOAD		
			Q(low)	Q(ave)	Q(high)	FOR	AG	URBAN	LOW	AVE	HIGH	LOW	AVE	HIGH	LOW	AVE	HIGH	LOW	AVE	HIGH	% FOREST	% AG	% URBAN
Upper Saranac R.	02010006-010	91342	3.7902E+08	5.0415E+08	6.2928E+08	77268	1564	1467	4809	6397	7985	1298	1726	2155	2131	2834	3537	8238	10957	13677	58.4	15.8	25.9
N Branch	02010006-020	33202	1.3638E+08	1.7867E+08	2.2096E+08	30549	922	161	1882	2466	3050	757	992	1227	231	303	375	2871	3761	4652	65.6	26.4	8.1
Mid Saranac R.	02010006-030	26587	8.5258E+07	1.2737E+08	1.6948E+08	19890	6017	478	957	1429	1902	3859	5765	7671	536	801	1066	5352	7996	10639	17.9	72.1	10.0
Lower Saranac R.	02010006-040	8593	2.5809E+07	4.1232E+07	5.6668E+07	4991	1611	1747	225	359	494	968	1546	2125	1836	2934	4032	3029	4839	6651	7.4	31.9	60.6
Beekmantown	02010006-050	11346	3.2740E+07	5.4227E+07	7.5697E+07	3424	6292	1164	148	245	343	3631	6014	8396	1176	1947	2718	4955	8207	11456	3.0	73.3	23.7
Ingraham	02010006-060	2596	8.6374E+06	1.2438E+07	1.6242E+07	575	1818	123	29	41	54	1210	1742	2275	143	206	269	1382	1990	2598	2.1	87.6	10.4
Chazy River	02010006-070	16565	4.8871E+07	6.9809E+07	9.0748E+07	8028	7728	333	355	507	660	4560	6514	8467	344	491	638	5259	7512	9765	6.8	86.7	6.5
Gt Chazy/Graves R	02010006-080	49434	1.5880E+08	2.3044E+08	3.0209E+08	35088	12761	367	1691	2453	3216	8199	11897	15596	413	599	785	10302	14950	19598	16.4	79.6	4.0
Corbeau Creek	02010006-090	27162	8.8382E+07	1.2711E+08	1.6580E+08	10033	12833	787	490	704	919	8351	12011	15667	896	1289	1681	9737	14004	18267	5.0	85.8	9.2
Rouses Pt Direct	02010006-100	1185	3.6708E+06	5.2860E+06	6.9029E+06	0	771	142	0	0	0	478	688	898	154	222	290	632	910	1188	0.0	75.6	24.4
Lacolle, Que.	02010006-110	4415	1.5178E+07	1.9658E+07	2.4132E+07	2822	1384	92	146	188	231	952	1232	1513	111	143	176	1208	1564	1920	12.0	78.8	9.2
North Plattsburg	02010006-120	2904	8.6235E+06	1.3879E+07	1.9135E+07	31	2095	123	1	2	3	1244	2003	2761	128	206	284	1373	2210	3048	0.1	90.6	9.3
	TOTALS	275331	9.9137E+08	1.3843E+09	1.7771E+09	192699	55796	6984	10733	14794	18856	35507	52131	68751	8099	11976	15852	54338	78901	103459	18.8	66.1	15.2
	TOTAL NY/QU	754241	2.5806E+09	3.7318E+09	4.8753E+09	555793	139344	19653	28789	41428	54007	89220	132789	175696	22790	33849	44800	140798	208065	274504	19.9	63.8	16.3

	AREA(ha)	DISCHARGE (m3/yr)			LAND USE (ha)			FOREST (kg/yr)			AGRICULTURE (kg/yr)			URBAN (kg/yr)			TOTAL NPS LOAD (kg/yr)			SOURCE OF NPS LOAD		
		Q(low)	Q(ave)	Q(high)	FOR	AG	URBAN	LOW	AVE	HIGH	LOW	AVE	HIGH	LOW	AVE	HIGH	LOW	AVE	HIGH	% FOREST	% AG	% URBAN
TOTAL BASIN	2020719	7.7289E+09	1.0991E+10	1.4248E+10	1322506	567262	55840	76901	109219	141515	422585	603188	783293	71508	103033	134474	570993	815440	1059282	13.4	74.0	12.6

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TABLE 6.10

NONPOINT SOURCE LOADS ESTIMATED BY LOADING FUNCTION METHOD

TOTAL PHOSPHORUS

	NPS LOAD (mt/yr)			SOURCE OF NPS LOAD				
SCENARIO	LOW	AVERAGE	HIGH	% VERMONT	% NEW YORK	% FOREST	% AG	%URBAN
Low-end coefficients	318.4	456.8	593.6	74	26	15.9	66.0	18.0
Baseline coefficients	571.0	815.4	1059.3	74	26	13.4	74.0	12.6
High-end coefficients	925.6	1328.2	1725.8	74	26	13.7	68.1	18.2
10% AG==>URB	599.0	860.7	1118.0	75	25	12.7	63.1	24.2
20% AG==>URB	628.2	905.9	1176.8	76	24	12.1	53.3	34.7

SOLUBLE PHOSPHORUS

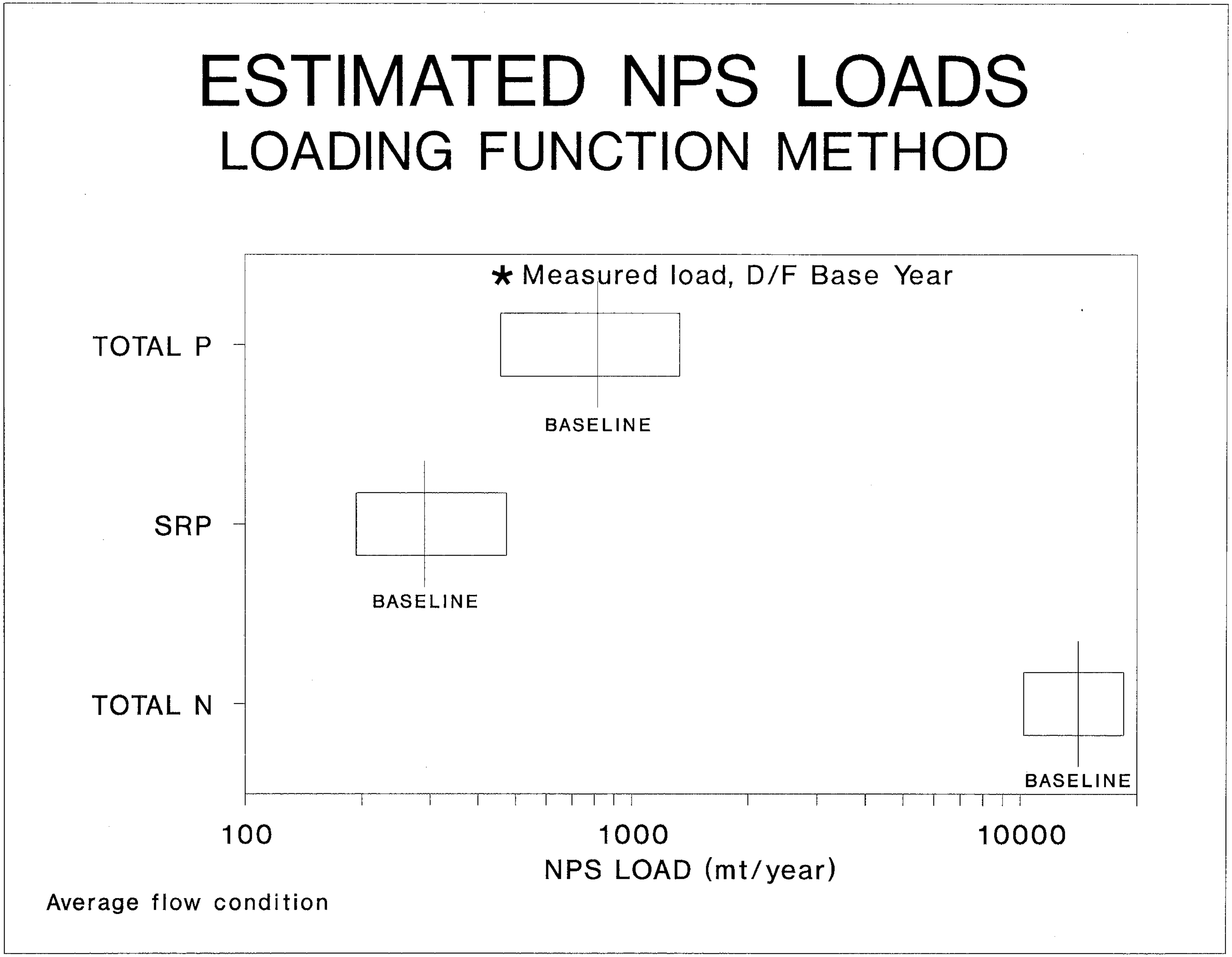
	NPS LOAD (mt/yr)			SOURCE OF NPS LOAD				
SCENARIO	LOW	AVERAGE	HIGH	% VERMONT	% NEW YORK	% FOREST	% AG	%URBAN
Low-end coefficients	134.8	193.4	251.4	75	25	3.8	78.0	18.3
Baseline coefficients	202.5	290.8	377.9	73	27	17.5	62.2	20.2
High-end coefficients	329.3	472.8	614.1	70	30	35.4	44.7	19.9
10% AG==>URB	229.7	333.0	432.7	74	26	15.3	48.9	35.8
20% AG==>URB	256.9	375.2	487.5	74	26	13.6	38.6	47.8

TOTAL NITROGEN

	NPS LOAD (mt/yr)			SOURCE OF NPS LOAD				
SCENARIO	LOW	AVERAGE	HIGH	% VERMONT	% NEW YORK	% FOREST	% AG	%URBAN
Low-end coefficients	7158	10202	13242	72	28	35.7	59.1	5.2
Baseline coefficients	9894	14101	18299	71	29	41.3	53.5	5.2
High-end coefficients	12988	18510	24022	71	29	39.3	55.4	5.3
10% AG==>URB	9894	14101	18299	71	29	41.3	48.1	10.6
20% AG==>URB	9894	14101	18299	71	29	41.3	48.1	15.9

LFSUMM.WK3

FIGURE 6.10


ESTIMATED NPS LOADS
LOADING FUNCTION METHOD
* Measured load, D/F Base Year
TOTAL P
SRP
TOTAL N
BASELINE
BASELINE
BASELINE
100
1000
10000
NPS LOAD (mt/year)
Average flow condition

estimated average TP loads by about 6% and 11%, respectively. Increased estimated loads under these two build-out scenarios were still lower than estimates based on high coefficients.

The distribution of estimated loads between the two states was consistent among the scenarios: about 75% of the estimated TP load originated from Vermont HUs, 25% from New York HUs. Shifting agricultural land into urban resulted in a slight increase in the Vermont share, since there was more agricultural land on the Vermont side to be converted into urban. The estimated contribution by the general land use categories was fairly consistent among the three sets of coefficients; some 14-16% of the estimated TP load was contributed from forest land, 66-74% by agricultural land, and 13-18% by urban land. The two build-out scenarios naturally increased the urban share and decreased the agriculture shares.

Estimated SRP loads followed a very similar pattern. Average flow load estimates ranged form 193 mt/yr using the low coefficients to 473 mt/yr with the high coefficients; baseline SRP load was estimated at about 291 mt/yr. Shifting agricultural land to the urban category increased the SRP loads by about 14-29%.

The geographic distribution of estimated SRP loads was nearly identical to that of TP loads. About 70-75% of the average SRP load originated in Vermont, compared to 25-30% from New York. The estimated contributions by the general land use categories varied widely among the three sets of coefficients: about 4-35% of the estimated SRP load was contributed by forest land, 45-78% by agricultural land, and 18-20% by urban land. The large shift in the percent contribution by forest (4% to 35%) and by agricultural land (78% to 45%) between the low and high coefficient sets was due primarily to the very wide range between the low and high SRP concentration values (0.001-0.023 mg/l), compared to the relatively narrow range for agriculture (0.05-0.07 mg/l). Thus, the forest contribution was effectively multiplied by a factor of 23 between the two extremes, while the agricultural component increased by only a factor of 1.4. Estimates based on the two build-out scenarios resulted in a very strong shift of SRP load to the urban category.

Estimated TN loads ranged from 10,202 mt/yr under the low coefficients to 18,510 mt/yr with the high coefficients; estimated baseline TN load was 14,101 mt/yr. Shifting land from agriculture to urban use had no effect on the load estimates since baseline TN concentration coefficients selected for agriculture and urban were identical. While not shown in the table, using either low or high coefficient sets in the two built-out scenarios would suggest an overall decrease in TN loads, since the literature suggests that runoff from urban land contains lower TN concentrations than runoff from agricultural land, on the average (see Section 6.3).

The distribution of estimated TN loads between Vermont and New York was essentially the same as that for the estimated phosphorus loads: about 71% of the estimated TN load originated in Vermont, 29% in New York. The estimated contribution by land use type was consistent among the three sets of coefficients; some 36-41% of the estimated TN load was contributed by forested land, 54-59% by agricultural land, and about 5% by urban land. The two build-out scenarios led to a proportional shift in TN load from agricultural to urban source.

In summary, the load estimates calculated by the LF method using the range in concentration values defined in Section 6.3 varied by roughly -40% to +60% in absolute value around an estimate based on the "baseline" most appropriate concentration values. The variability in phosphorus load estimates was slightly greater than that for TN estimates (±30%), reflecting the variability in reported phosphorus concentrations. Variability in estimated loads attributable to variation in flows was about ±30% for all three pollutants. Shifting up to 20% of the 1973-1976 agricultural land into the urban category had no effect on estimated nitrogen loads, but increased the estimated baseline phosphorus loads by about 10-30%, but these estimates were within the range bracketed by the range of concentration coefficients and within the range bracketed by natural hydrologic variability.

While the values presented in Table 6.10 do show a tremendous range from the lowest estimate to the highest, the sources and meaning of this broad range should be kept in mind. The variability of estimates from low to high runoff/streamflow conditions approximate the natural variability to be expected from year to year in the LCB based on natural precipitation patterns. Within the LF method, load estimates vary in direct proportion to variations in flow; that is, a ±10% change in estimated flow yields a corresponding ±10% change in estimated load. Consequently, an error of 5%, for example, in estimating the value of a runoff coefficient for a HU would only have a 5% effect on the resulting load estimate from that HU.

The variability in load estimates between scenarios reflects the differences between the sets of coefficients and/or land use distribution selected for the LF method. It is this source of variability that will be most important in selecting the "best" nonpoint source load estimates for the LCB.

The geographic distribution of the estimated nonpoint source load was consistent among all of the scenarios and all of the pollutants: about 70% of the nonpoint source load appears to arise from the Vermont "side" of the LCB, and just 30% from the New York "side." Agricultural land was estimated to be the largest source of phosphorus and nitrogen under all baseline land use scenarios, contributing an estimated 66-74% of the TP load, 45-78% of the SRP load, and 54-59% of the TN load. Urban land generally contributed less than 20% of the estimated phosphorus load and less than 10% of the nitrogen load in the LCB.

Load estimates based on the loading function method were clearly higher than estimates based on export coefficients. Estimated TP loads were 50-80% higher using the LF method, depending on which coefficient set is used; SRP loads estimated by LF were 30-89% higher. Estimated TN loads by the LF method were about 20-80% higher than EC-estimated loads. The reasons for this substantial difference are not clear. Comparison of both types of load estimates with measured TP loads will provide a basis for selecting the best load estimations for the LCB. It should be noted that despite the differences in absolute magnitude, the two estimation methods were essentially in agreement on both the geographic distribution of nonpoint source loads - 66-75% from Vermont, 25-33% from New York. The two methods both suggest that the majority of the nonpoint source load tended to come from agricultural land.

6.5 Septic System Impacts.
Although they are not, by strict definition, a nonpoint source, septic systems have often been cited as significant sources of pollutants to both surface and ground waters. While residential on-site wastewater systems can provide effective treatment where soils of appropriate depth and permeability exist, there are areas of the LCB where soils are not suitable for standard septic systems. High groundwater table, shallow depth to bedrock, slowly permeable soils, or excessively permeable soils , as well as over-use, lack of maintenance, and simple age, are factors that can contribute to septic system failure. When a septic system fails, the release of untreated or inadequately treated wastewater can deliver phosphorus, nitrogen, and bacteria to surface or groundwater via surfacing and overland flow of effluent or by subsurface percolation.

In addition to loading from the major extensive land uses discussed above, it is thus important to evaluate the likely importance of septic systems to the water quality of Lake Champlain. Unfortunately, while anecdotal evidence of septic system failure in the LCB is plentiful, a basin-scale assessment of the significance of this pollution source to LC is difficult. The process followed in this study was: 1) estimate the number of septic systems in the LCB; 2) estimate the likely failure rate of septic systems in the LCB; 3) use literature values to estimate the likely phosphorus load from failed septic systems; and 4) evaluate the significance of the resulting phosphorus load.

It should be noted that, while good data exist on the number of septic systems in the basin, there are no good data on the spatial distribution of septic systems, failed or functional, in the basin. Therefore, estimates of loading from septic systems could be allocated only by state and province, not by hydrologic unit.

6.5.1 Basin septic systems. Based on 1990 U.S. census data, as compiled and interpreted in the Lake Champlain Economic Database Project (Holmes, et al., 1993), there are over 150,000 septic systems in the LCB. This figure, detailed in Table 6.11 below, is based on a count of housing units in the basin and the reported percentage of housing units using on-site septic systems:

TABLE 6.11
ESTIMATED BASIN SEPTIC SYSTEMS

State	# Housing Units	% on Septic	# Septic Systems
NY	95,925	60.1	57,651
VT	167,841	53.0	88,956
QUE	11,964	50.0	5,982
TOTAL	275,730	55.0	152,589

(from Holmes, et al., 1993)

Using housing units rather than population numbers as a basis for estimating the number of septic systems was preferred because housing units accounted for all dwellings, including vacant, temporarily unoccupied, and all seasonal camps and cottages counted by the 1990 census; seasonal population, which basic population numbers did not count are thus included in the estimate (Holmes, 1993).

6.5.2 Septic System Failure Rate. Estimation of a basin-wide rate of septic system failure was by far more difficult. According to a recent water quality inventory of Malletts Bay, 40% of lakeshore septic systems do not have current permits, i.e. were installed before the early 1970's (Skenderian, 1992). While there is no documentation of actual failure among these systems, the age and density of the systems, and their proximity to the Lake suggest that the potential exists for significant contribution to the Lake. The figure of 40%, however, could be taken as an extreme upper limit to a general estimated failure rate, in the absence of other, better estimates.

On a broader scale, recent surveys by the Vermont Department of Environmental Conservation suggest a general failure rate of less than 5% in Vermont (VTDEC, 1992). In the Missisquoi River and White River basins, considered areas with strong likelihood of septic system failure because they were never surveyed or last surveyed in the early 1960s, just 121 notices of alleged violation (NOAVs) were filed out of 2960 contacts, a failure rate of 4.1%. Issuance of a NOAV indicates actual documentation of a failed system or a direct discharge to surface waters. In the LCB portion of the state, 144 NOAVs were issued out of 3278 contacts, representing a failure rate of 4.4%. Statewide, VTDEC issued 227 NOAVs out of 4815 contacts, a 4.7% failure rate.

In New York, a 1980 sanitary survey of Essex County (within the LCB) found 204 reported problems among some 3870 systems surveyed in selected towns, a failure rate of 5.3% (Cahn Engineers, Inc., 1981). In the town of Chesterfield, for example, 6.25% of the systems surveyed reported problems; in Crown Point, problems were found with 4% of the systems. In towns not selected for detailed study, 8.7% of septic systems reported problems. It should be noted that problems reported in the surveys included slow drains, sewage back-up, sewage odors, visible sewage, and raw discharge, not all of which are necessarily symptoms of system failure resulting in pollutant loading to water. Furthermore, the sanitary survey was not a random or representative sample; the areas studied were already identified as having major problems with on-site wastewater treatment.

In Hamilton County, New York, just west of the LCB boundary, a higher septic system failure rate has been documented. Based on an intensive inspection program in operation since 1973, an average of 15% system failure has been reported, with annual rates ranging from 4% to 40% of systems tested (Flanagan, 1993). This testing program included dye testing in many cases, which provides fairly clear evidence of system failure.

These values of septic system failure are consistent with values reported in the literature. Failure rates in Fairfax County, Virginia, for example, ranged from 0 to 8%, with an average rate of 5.1% for systems more than ten years old (Clayton, 1975). In the Pacific northwest, Gilliom (1982) found that only lakeshore septic systems more than 40 years old added significant quantities of phosphorus to lakes; even these systems showed 80% retention of phosphorus in the soil.

Based on available data, a general septic system failure rate of 5 to 10% for the LCB was assumed. Using two scenarios, this estimate works out as follows:

TABLE 6.12
ESTIMATED SEPTIC SYSTEM FAILURE

State	# Total Systems	# Failed @ 5% rate	# Failed @ 10% rate
NY	57,651	2,882	5,765
VT	88,956	4,448	8,896
QUE	5,982	299	598
TOTAL	152,589	7,629	15,259

Thus, for the purpose of this study, it is estimated that there are 7,629 to 15,259 failed septic systems in the LCB.

6.5.3 Phosphorus Contributions from Failed Septic Systems. Effluent from a septic tank without treatment by soil contact and filtration is a powerful pollutant, at best comparable to municipal wastewater after only primary treatment. Total phosphorus concentrations range from 7 to 40 mg/l and total N levels of 30 to 60 mg/l have been reported (Hall, 1975; Hansel and Machmeier, 1980; Cogger and Carlile, 1984).

Annual loads from failed septic systems are less well documented. A loading rate of 0.5 kg TP/year/system is assumed in Maine (Dennis, 1989). In the state of Washington, Gilliom (1982) used the same figure, pointing out that even in failed systems, 80% of the phosphorus leaving the septic tank was captured by soil adsorption. Based on a broad literature review, Uttormark (1974) cited an annual loading rate of 1.0 kg TP/system. Finally, Haith, et al. (1992) employ a value of 1.5 kg TP/year/system in the GWLF model, based on the assumption of 2.6 persons/system and **zero** attenuation of phosphorus after leaving the tank. This should be considered essentially a worst-case scenario for phosphorus loading from a failed septic system.

6.5.4 Phosphorus Load from LCB Septic Systems. The total phosphorus load contributed to LC from failed septic systems was estimated under several different scenarios, including the highest reasonable estimates of basin-wide failure rate and the worst-case phosphorus load from each failed system:

TABLE 6.13
ESTIMATED TOTAL P CONTRIBUTION OF FAILED SEPTIC SYSTEMS
TO LAKE CHAMPLAIN

Failure rate:	---5%---		---10%---	
TP load (kg/system/yr):	0.5	1.5	0.5	1.5
NY	1,441	4,323	2,882	8,648
VT	2,224	6,672	4,448	13,344
QUE	150	448	299	897
TOTAL(kg/yr)	3,815	11,443	7,629	22,889

Based on the range of estimated failed systems in the basin and on values of 0.5 to 1.5 kg/year/system, and on the assumption that each failed system delivers all of its phosphorus to LC regardless of location in the basin, **failed septic systems in the LCB may contribute 3,815 to 22,889 kg (3.8 - 22.9 mt) of total phosphorus per year.**

It is worthwhile to put this estimated phosphorus load in perspective. According to the best recent information, average annual total phosphorus load to LC from all sources is on the order of 646.7 mt/year, of which 458 mt/year comes from nonpoint sources (VTDEC and NYSDEC, 1992; Smeltzer, 1993). Thus, **the estimated septic system contribution amounts to 0.8 to 5% of the annual total phosphorus load to Lake Champlain from nonpoint sources, and just 0.6 to 3.5% of annual load from all sources.** Based on census data cited earlier, about 58% of this load can be attributed to Vermont households, 38% to New York households.

This small estimated contribution of phosphorus from septic systems is consistent with what little information is available from field studies in the region. Ground water sampling downgradient from lakeshore septic systems showed that septic systems contributed just 1% of the total external supply of phosphorus to Lake Morey, Vermont (Morgan, et al., 1984). Similar investigations of shoreline septic systems around Lake Iroquois, Vermont (within the LCB), showed that phosphorus retention in soils exceeded 95% and septic systems did not contribute significant quantities of phosphorus reaching the lake (Roesler and Regan, 1985). In that study, even wells showing evidence of contamination based on elevated nitrogen, chloride, and conductivity values had phosphorus concentrations similar to background levels. Finally, a recent study in St. Albans Bay of Lake Champlain estimated that only 1.4% of the phosphorus load to the Bay is contributed by lakeshore septic systems (TWM Northeast, 1991).

Even under worst-case conditions - the highest reasonable failure rate, zero attenuation of pollutants after leaving the tank, and 100% delivery to the Lake - failed septic systems can likely be responsible for only up to 5% of the total annual phosphorus load to Lake Champlain. This is comparable to the 15.4 mt/year of phosphorus estimated to be delivered to the Lake by direct precipitation (Smeltzer, 1993). Thus, while failed septic systems can be serious threats to public health and water quality on a local or county scale, at the scale of the LCB, they appear to represent only a very small portion of the phosphorus load to the lake.

6.7 Validation.

In order to have confidence in the nonpoint source loading estimates presented in this report, some assessment of their accuracy is required. Few assessments of the accuracy of either export coefficient or loading function projections have been presented. Rast and Lee (1983) determined that most phosphorus load estimates using export coefficients reported in the literature were within a factor of ±2 of measured loads. More recently, Reckhow and Coffey (1990) cited an error rate of ±30-40% in load estimates derived from export coefficients and ±25-35% using loading functions.

As outlined earlier, validation consisted of comparing estimated nonpoint source TP loads to Lake Champlain to measured tributary TP loads determined in the Lake

Champlain Diagnostic/Feasibility (D/F) Study (VTDEC and NYSDEC, 1994). That study reported both point and nonpoint source annual TP loads measured at tributary mouths over the period 1990-1992. Loads were reported first as the average annual load based on the entire monitoring period, then from the 1991 "hydrologic base year" which is believed to best represent loads delivered under average hydrologic conditions (Smeltzer, 1993).

Annual total phosphorus loads to Lake Champlain estimated by both the EC and LF (average flow condition) methods under a variety of scenarios are summarized in Table 6.14 and in Figure 6.11, along with the nonpoint source TP loads reported by the D/F study for both 1990-1992 and the 1991 base year. Clearly, the estimated annual TP loads are in the same order of magnitude as the measured load, regardless of estimation scenario. Based on simple visual comparison (Figure 6.11), the TP load estimates generated by the baseline export coefficients and the low-end loading function concentrations under average flow conditions were remarkably similar to the measured base year TP load.

To make a more informative validation of estimated TP loads, estimated and measured loads were compared for the individual tributary basins draining to each of the D/F monitoring stations, where feasible. In some cases, such comparison was either impossible or inappropriate. Several D/F tributary stations, for example the Great Chazy, included HUs in which other, ungaged streams or direct runoff to the lake were not captured by actual monitoring. Such cases, and others where significant **estimation** of streamflow or load was involved, were not included in the validation exercise. Only tributary basins where D/F monitoring data and HU estimations aligned well were included in the validation comparisons.

These comparisons are shown in detail in Appendix G and summarized in Table 6.15 for both the EC and LF methods for four scenarios: low values with baseline land use, low values with 10% ag built-out, baseline values with baseline land use, and baseline values with 10% ag built-out. From Table 6.15 it can be seen that use of the low export coefficients appears to underestimate annual TP load from most of the monitored basins, while the baseline coefficients yield estimates that compare fairly well with D/F base year or overall average annual load. In the loading function estimates, however, baseline concentration values tend to overestimate TP load from most of the monitored basins, and the low concentration values give estimates that appear to be reasonably close to measured loads.

To quantitatively evaluate these comparisons, both measured and estimated loads were standardized to **areal loads** (kg/ha/yr) and each of the estimation scenarios was compared to base year D/F data using a paired t-test. The paired t-test compares two groups (e.g. estimated and measured loads) based on the difference (d) between paired values (i.e., from the same basin) and tests the null hypothesis that the two groups do not differ significantly. In this case, the critical absolute values of t are 2.12 and 2.92, for probability levels of 0.95 and 0.99, respectively. Thus, if the absolute value of t **exceeds** these critical values, the null hypothesis is rejected and a significant difference between the two groups is indicated. Results are shown in Table 6.16.

TABLE 6.14

TOTAL PHOSPHORUS NPS LOADING ESTIMATES

SCENARIO	NPS TP LOAD (mt/yr)	% FOREST	% AG	%URBAN
D/F BASE YEAR (1991)	458.2	--	--	--
D/F 1990 - 1992	704.1	--	--	--
EXPORT COEFFICIENTS				
Baseline coefficients	499.6	26.5	56.8	16.8
Low-end lit. coefficients	250.6	21.1	56.6	22.3
High-end lit. coefficients	886.5	35.9	52.0	12.1
10% AG==>URB	556.4	23.8	45.9	30.3
20% AG==>URB	626.3	21.1	39.3	39.6
LOADING FUNCTIONS (ave.)				
Baseline coefficients	815.4	13.4	74.0	12.6
Low-end lit. coefficients	456.8	15.9	66.0	18.0
High-end lit. coefficients	1328.2	13.7	68.1	18.2
10% AG==>URB	860.7	12.7	63.1	24.2
20% AG==>URB	905.9	12.1	53.3	34.7

FIGURE 6.11

MEASURED vs ESTIMATED TP LOADS TO LAKE CHAMPLAIN

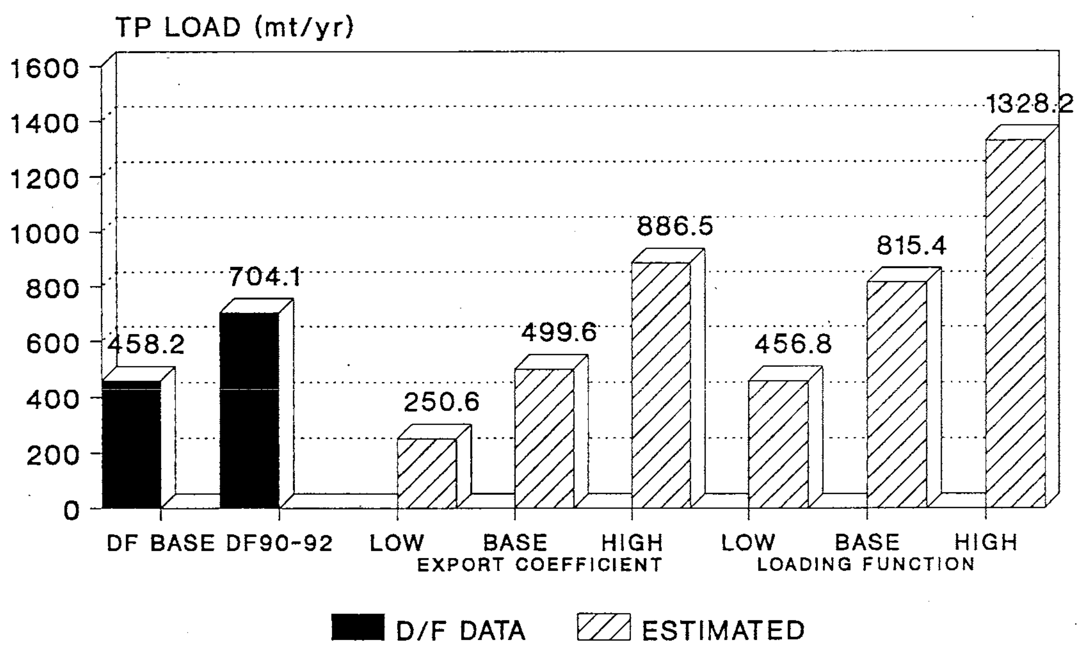


TABLE 6.15

TP LOAD ESTIMATES vs D/F LOADING DATA

D/F BASIN	EXPORT COEFFICIENT ESTIMATES (kg/yr)				D/F LOAD (kg/yr)	
	LOW	LOW/AG-10%	BASELINE	BASE/AG-10%	**BASE YEAR**	1990-1992
METT/BARGE	17008	20463	33643	38250	**33700**	**45800**
POULTNEY	8693	10313	17454	19613	**14100**	**29300**
OTTER	33157	40098	66868	76122	**48100**	**80100**
LEWIS	2970	3672	6053	6989	**5200**	**10400**
L. OTTER	3685	4673	7364	8681	**5400**	**9800**
LAPLATTE	3042	3752	5882	6828	**7600**	**10300**
WINOOSKI	36171	40871	69940	76207	**59500**	**129400**
LAMOILLE	20675	24373	42405	47336	**26600**	**44200**
MISSISQUOI	27696	33118	56250	63479	**76300**	**107800**
PUTNAM	960	1076	2193	2348	**1300**	**2300**
MILL/PT HNR	770	818	1479	1543	**600**	**1300**
BOQUET	5825	6427	12164	12967	**13500**	**21700**
AUSABLE	10511	11073	21501	22251	**11200**	**18600**
L. AUSABLE	2606	3082	5263	5897	**3800**	**3200**
SALMON	2994	3260	5461	5815	**1700**	**2000**
SARANAC	11689	12448	24106	25118	**7700**	**10500**
L. CHAZY	2586	3166	5166	5939	**3200**	**4200**

D/F BASIN	LOADING FUNCTION-AVERAGE (kg/yr)				D/F LOAD (kg/yr)	
	LOW	LOW/AG-10%	BASELINE	BASE/AG-10%	**BASE YEAR**	1990-1992
METT/BARGE	32030	36379	59030	62670	**33700**	**45800**
POULTNEY	15397	17371	28022	29667	**14100**	**29300**
OTTER	67837	77247	126050	133892	**48100**	**80100**
LEWIS	5354	6174	10239	10923	**5200**	**10400**
L. OTTER	6452	7528	12602	13499	**5400**	**9800**
LAPLATTE	5305	6103	9997	10662	**7600**	**10300**
WINOOSKI	64846	70976	109355	114464	**59500**	**129400**
LAMOILLE	43466	48892	78929	83450	**26600**	**44200**
MISSISQUOI	63692	72147	117200	124246	**76300**	**107800**
PUTNAM	1492	1631	2620	2736	**1300**	**2300**
MILL/PT HNR	1089	1144	1663	1709	**600**	**1300**
BOQUET	6599	7130	11016	11458	**13500**	**21700**
AUSABLE	15613	16295	23941	24509	**11200**	**18600**
L. AUSABLE	4675	5266	8488	8980	**3800**	**3200**
SALMON	4773	5101	7503	7776	**1700**	**2000**
SARANAC	17614	18517	27554	28306	**7700**	**10500**
L. CHAZY	3899	4574	7512	8001	**3200**	**4200**

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TABLE 6.16

COMPARISON OF ESTIMATED AREAL NPS TP LOADS TO D/F MEASURED TP LOADS PAIRED t TEST

LOADING FUNCTION METHOD

D/F RIVER BASIN	D/F BASE YR	ESTIMATION SCENARIO - AVERAGE CONDITION							
		BASELINE		LOW-END		BASE/AG-10%		LOW/AG-10%	
	kg/ha/yr	kg/ha/yr	d	kg/ha/yr	d	kg/ha/yr	d	kg/ha/yr	d
METTAWEE	0.31	0.54	-0.23	0.29	0.02	0.57	-0.26	0.33	-0.02
POULTNEY	0.20	0.41	-0.21	0.23	-0.03	0.44	-0.24	0.26	-0.06
OTTER	0.20	0.52	-0.32	0.28	-0.08	0.55	-0.35	0.32	-0.12
LEWIS	0.25	0.49	-0.24	0.25	0	0.52	-0.27	0.29	-0.04
LITTLE OTTER	0.29	0.67	-0.38	0.34	-0.05	0.72	-0.43	0.40	-0.11
LAPLATTE	0.56	0.73	-0.17	0.39	0.17	0.78	-0.22	0.44	0.12
WINOOSKI	0.21	0.40	-0.19	0.24	-0.03	0.42	-0.21	0.26	-0.05
LAMOILLE	0.14	0.42	-0.28	0.23	-0.09	0.45	-0.31	0.26	-0.12
MISSISQUOI	0.34	0.52	-0.18	0.29	0.05	0.56	-0.22	0.32	0.02
PUTNAM	0.08	0.16	-0.08	0.09	-0.01	0.17	-0.09	0.10	-0.02
MILL	0.09	0.23	-0.14	0.15	-0.06	0.24	-0.15	0.16	-0.07
BOQUET	0.19	0.16	0.03	0.09	0.1	0.16	0.03	0.10	0.09
AUSABLE	0.08	0.18	-0.1	0.12	-0.04	0.18	-0.1	0.12	-0.04
LITTLE AUSAB	0.20	0.41	-0.21	0.22	-0.02	0.43	-0.23	0.25	-0.05
SALMON	0.10	0.40	-0.3	0.26	-0.16	0.42	-0.32	0.27	-0.17
SARANAC	0.05	0.17	-0.12	0.11	-0.06	0.18	-0.13	0.12	-0.07
LITTLE CHAZY	0.23	0.45	-0.22	0.24	-0.01	0.48	-0.25	0.28	-0.05
Critical t , d.f.=16:		n	17	n	17	n	17	n	17
P = 0.95 t = 2.12		mean d	-0.19647	mean d	-0.01765	mean d	-0.22059	mean d	-0.04471
P = 0.99 t = 2.92		std. dev.	0.098358	std. dev.	0.075127	std. dev.	0.1094	std. dev.	0.072294
		t value	**-8.23594**	**t value**	**-0.9685**	**t value**	**-8.3136**	**t value**	**-2.54968**

EXPORT COEFFICIENT METHOD

D/F RIVER BASIN	D/F BASE YR	ESTIMATION SCENARIO - AVERAGE CONDITION							
		BASELINE		LOW-END		BASE/AG-10%		LOW/AG-10%	
	kg/ha/yr	kg/ha/yr	d	kg/ha/yr	d	kg/ha/yr	d	kg/ha/yr	d
METTAWEE	0.31	0.31	0	0.15	0.16	0.35	-0.04	0.19	0.12
POULTNEY	0.20	0.26	-0.06	0.13	0.07	0.29	-0.09	0.15	0.05
OTTER	0.20	0.27	-0.07	0.14	0.06	0.31	-0.11	0.16	0.04
LEWIS	0.25	0.29	-0.04	0.14	0.11	0.33	-0.08	0.17	0.08
LITTLE OTTER	0.29	0.39	-0.1	0.20	0.09	0.46	-0.17	0.25	0.04
LAPLATTE	0.56	0.43	0.13	0.22	0.34	0.50	0.06	0.27	0.29
WINOOSKI	0.21	0.25	-0.04	0.13	0.08	0.28	-0.07	0.15	0.06
LAMOILLE	0.14	0.23	-0.09	0.11	0.03	0.25	-0.11	0.13	0.01
MISSISQUOI	0.34	0.25	0.09	0.12	0.22	0.28	0.06	0.15	0.19
PUTNAM	0.08	0.14	-0.06	0.06	0.02	0.15	-0.07	0.07	0.01
MILL	0.09	0.21	-0.12	0.11	-0.02	0.21	-0.12	0.11	-0.02
BOQUET	0.19	0.17	0.02	0.08	0.11	0.18	0.01	0.09	0.1
AUSABLE	0.08	0.16	-0.08	0.08	0	0.16	-0.08	0.08	0
LITTLE AUSAB	0.20	0.25	-0.05	0.12	0.08	0.28	-0.08	0.15	0.05
SALMON	0.10	0.29	-0.19	0.16	-0.06	0.31	-0.21	0.18	-0.08
SARANAC	0.05	0.15	-0.1	0.07	-0.02	0.16	-0.11	0.08	-0.03
LITTLE CHAZY	0.23	0.31	-0.08	0.16	0.07	0.36	-0.13	0.19	0.04
Critical t , d.f.=16:		n	17	n	17	n	17	n	17
P = 0.95 t = 2.12		mean d	-0.04941	mean d	0.078824	mean d	-0.07882	mean d	0.055882
P = 0.99 t = 2.92		std. dev.	0.076278	std. dev.	0.096234	std. dev.	0.071141	std. dev.	0.086318
		t value	**-2.67088**	**t value**	**3.377153**	**t value**	**-4.56837**	**t value**	**2.669313**

At the 0.95 probability level, the t value obtained exceeded the critical t for every scenario except the low-end loading function estimation. That is, for all other estimation scenarios, the estimates differed significantly from the measured loads. **Estimates of annual areal TP export derived from the low concentrations using the loading function method did not differ significantly from TP export measured in the D/F study.**

Using the more restrictive 0.99 probability level (accepting only a 1% chance of error), changes the picture somewhat. In this case, estimates based on the low concentration, 10% ag build-out loading function and on two export coefficient scenarios (the baseline and low/10% ag build-out) did not differ significantly from measured TP export.

It should be noted that using the higher probability level gives a higher critical t value and requires a higher calculated t value to reject the null hypothesis. In this case, this has the effect of accepting estimates as not significantly different that are, in fact, more "different" than at the lower 0.95 probability level. Thus in this case, the estimation scenario not significantly different at the **lower** probability level is actually the better "fit" compared to the measured loads. In other words, based on the paired t-test, the loading function method using low-end concentration values gives the best estimate of annual areal TP load, an estimate that does not significantly differ from measured TP loads.

The final approach to testing the comparison between predicted and observed data was simple linear regression in which the coefficient of determination (r^2) provides a measure of the strength of the relationship between predicted and observed values. The absolute accuracy of the predicted values was evaluated by comparing the observed/predicted regression line to the ideal line (slope of 1, intercept of 0) expected if the predictions were perfect.

Simple linear regressions were calculated between observed base-year D/F tributary areal TP loads and the estimated areal TP loads for the same basins generated by the four scenarios that were accepted at the 0.99 probability level by paired t-test (Table 6.16). In each case, the regression was statistically significant (P=0.99):

EC Baseline: $TP_{est} = 0.52(TP_{D/F}) + 0.15$ $r^2=0.64$

EC Baseline, 10%ag->urb: $TP_{est} = 0.36(TP_{D/F}) + 0.08$ $r^2=0.66$

LF Low: $TP_{est} = 0.56(TP_{D/F}) + 0.11$ $r^2=0.65$

LF Low, 10%ag->urb: $TP_{est} = 0.66(TP_{D/F}) + 0.11$ $r^2=0.66$

While the regressions indicate that there is a significant, positive linear relationship between estimated and measured areal TP loads, none of the scenarios result in an acceptable absolute match. Both the slopes and the intercepts in each of the above regression equations are significantly different from one and zero, respectively, indicating that the distribution of "modeled" loads differs significantly from that of the measured loads.

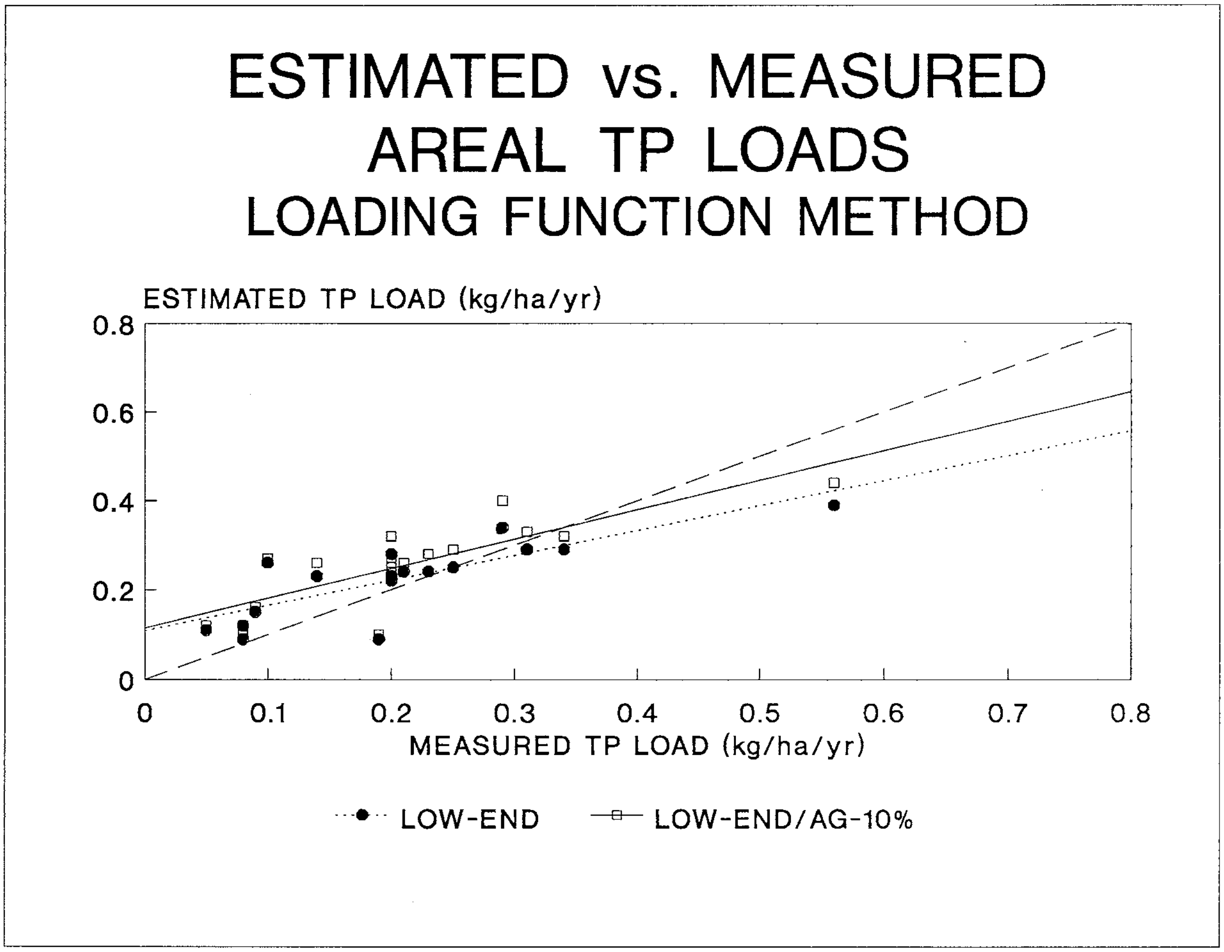
Thus, while results from some of the estimation models (particularly the loading function, low-end value scenario) seem to agree well with measured total loads and, as a group, the tributary load estimates from the models do not differ significantly from measured values, none of the models seem to offer a precise fit to the pattern of observed values. Visual examination of the observed vs. predicted loads offers some insight into this lack of fit.

Estimated areal TP loads are plotted against measured loads for each of the four estimation scenarios in Figure 6.12. In each graph, the ideal match between measured and estimated is shown as the heavier dashed line with an intercept of zero and a slope of one. As suggested by the regression equations presented earlier, the loading function estimates appear to give a slightly closer fit to the ideal line than do the export coefficient estimates. Perhaps the key feature of these plots, however, is the pattern of deviations from the ideal line (i.e. the residuals). In both EC and LF estimations, the middle range of measured loads (about 0.2 - 0.35 kg/ha/yr) seem to be estimated fairly well. However, in all the estimation scenarios, the highest measured load from one basin - the LaPlatte River Watershed (HU -3060) - seems to be significantly **underestimated.** Conversely, the lowest measured loads from several basins - mostly New York tributaries, including the Saranac, the Ausable, and the Salmon - appear to be significantly **overestimated.**

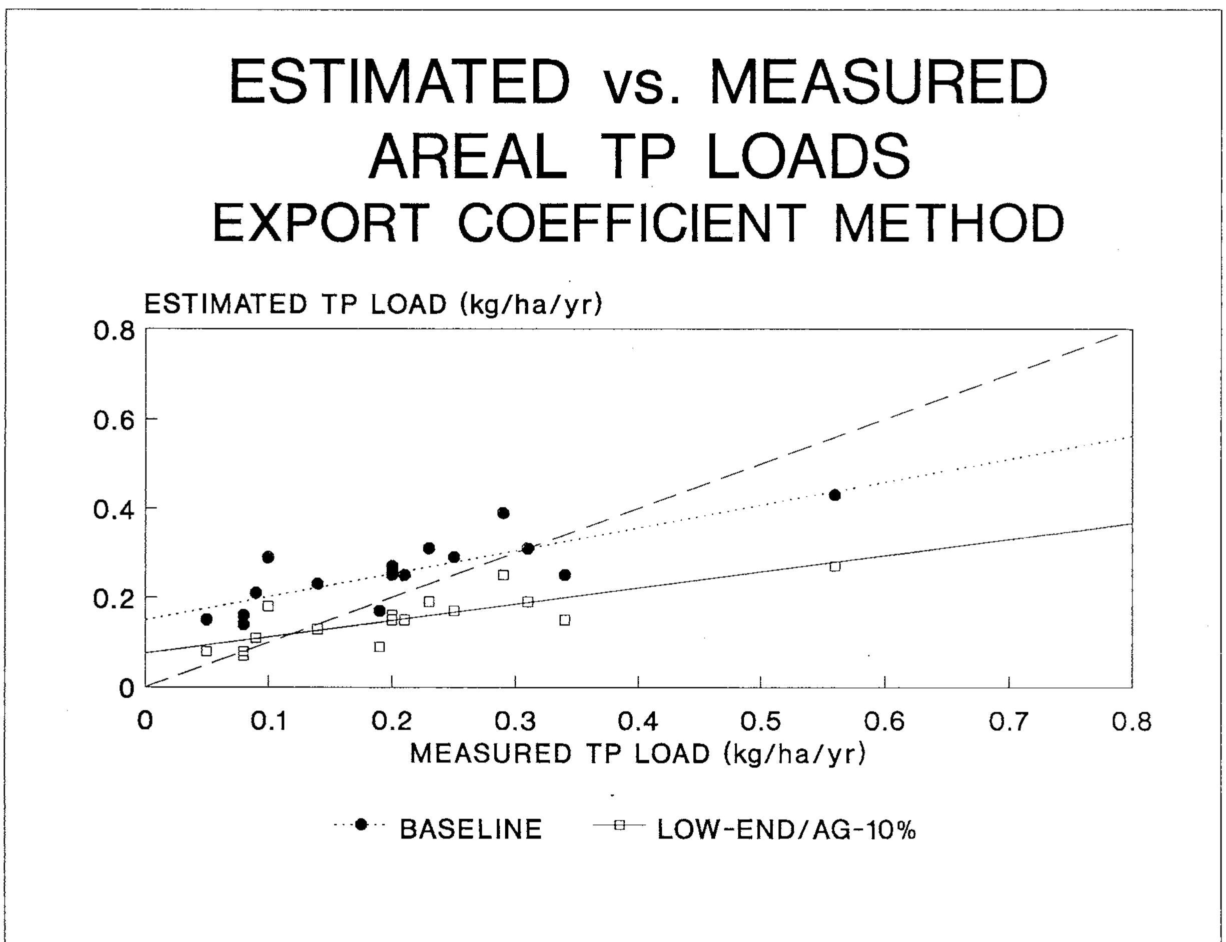
One possible explanation for the poor fit of the estimates to the measured values may be that these tributaries do not fit the "average" conditions upon which the estimates are based. The LaPlatte River watershed, for example, has been among the highest TP contributors (both concentration and areal load) in the basin throughout the D/F study (VTDEC and NYSDEC, 1994). In the 1980s, measured areal TP loading rates from monitored LaPlatte River subwatersheds were substantially higher than loading rates reported in other watersheds (Meals, 1990). Thus, the LaPlatte HU may in fact be an outlier, contributing above average TP loads, and would be expected to be underestimated by average coefficients. The explanation for the overestimation of TP loads in the New York tributaries is unknown.

In summary, the analyses discussed above show that there is reasonable general agreement between estimated TP loads and measured TP loads, in terms of both total load to the lake and for areal loads from 17 major tributary basins to the lake. Furthermore, the fact that estimates of areal TP load from tributaries by the loading function method using low-end concentration values did not differ significantly from measured loads should give substantial confidence in the nonpoint source estimates generated by this approach. Because of this agreement and because the method accounts for some natural meteorologic variation, the loading function method with the low coefficients is deemed to be the most suitable model for estimation of nonpoint source loads from the LCB. While the match between observed and predicted was not exact, the pattern of deviations suggests a not surprising conclusion that estimates based on average conditions do not always do a good job with extremes.

FIGURE 6.12



ESTIMATED vs. MEASURED
AREAL TP LOADS
LOADING FUNCTION METHOD
ESTIMATED TP LOAD (kg/ha/yr)
0.8
0.6
0.4
0.2
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
MEASURED TP LOAD (kg/ha/yr)
LOW-END
LOW-END/AG-10%



ESTIMATED vs. MEASURED
AREAL TP LOADS
EXPORT COEFFICIENT METHOD
ESTIMATED TP LOAD (kg/ha/yr)
0.8
0.6
0.4
0.2
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
MEASURED TP LOAD (kg/ha/yr)
BASELINE
LOW-END/AG-10%

Finally, the estimated areal TP loads are compared with measured loads for each of the 17 tributary stations in Figure 6.13. Note the underestimation of the load from the LaPlatte and the tendency to overestimate loads from many of the New York tributaries. It is also interesting to note that the TP load from Boquet River basin appears to be significantly underestimated (measured=0.19 kg/ha/yr; estimated=0.09 kg/ha/yr). A possible explanation may be TP contributed by sediment from streambank erosion; this is not considered in the loading function estimates, but has been reported as an important phenomenon in the Boquet River (Ulmer, 1993). Streambank erosion and other specific factors not accounted for in estimation models may also be important contributors to nonpoint source loads in other river basins in the LCB and lead to differences between estimated and measured loads.

6.7 Phase II.

The purpose of Phase II was to further test and refine the nonpoint source load estimation approach using higher resolution land use data and concurrent water quality data. This part of the project provided an opportunity to utilize more detailed land use categories than was possible at the basin scale and to compare estimated and measured loads for other pollutants in addition to total phosphorus.

6.7.1 Land Use. In the Lake George, New York drainage area, both the Sheriff's Dock (LG39) and the Marine Village (LG40) watersheds were composed primarily of forested land in 1978. Commercial land use was concentrated along the shoreline of Lake George. Between the commercial area and a limited-access highway was a residential area which included interspersed commercial, institutional, and forested parcels. The upland section of each watershed, west of the highway, was almost completely forested. Although not exactly concurrent with the 1980-1982 water quality data, this land use data set was used as the best approximation for both years of water quality data used in the Phase II analysis.

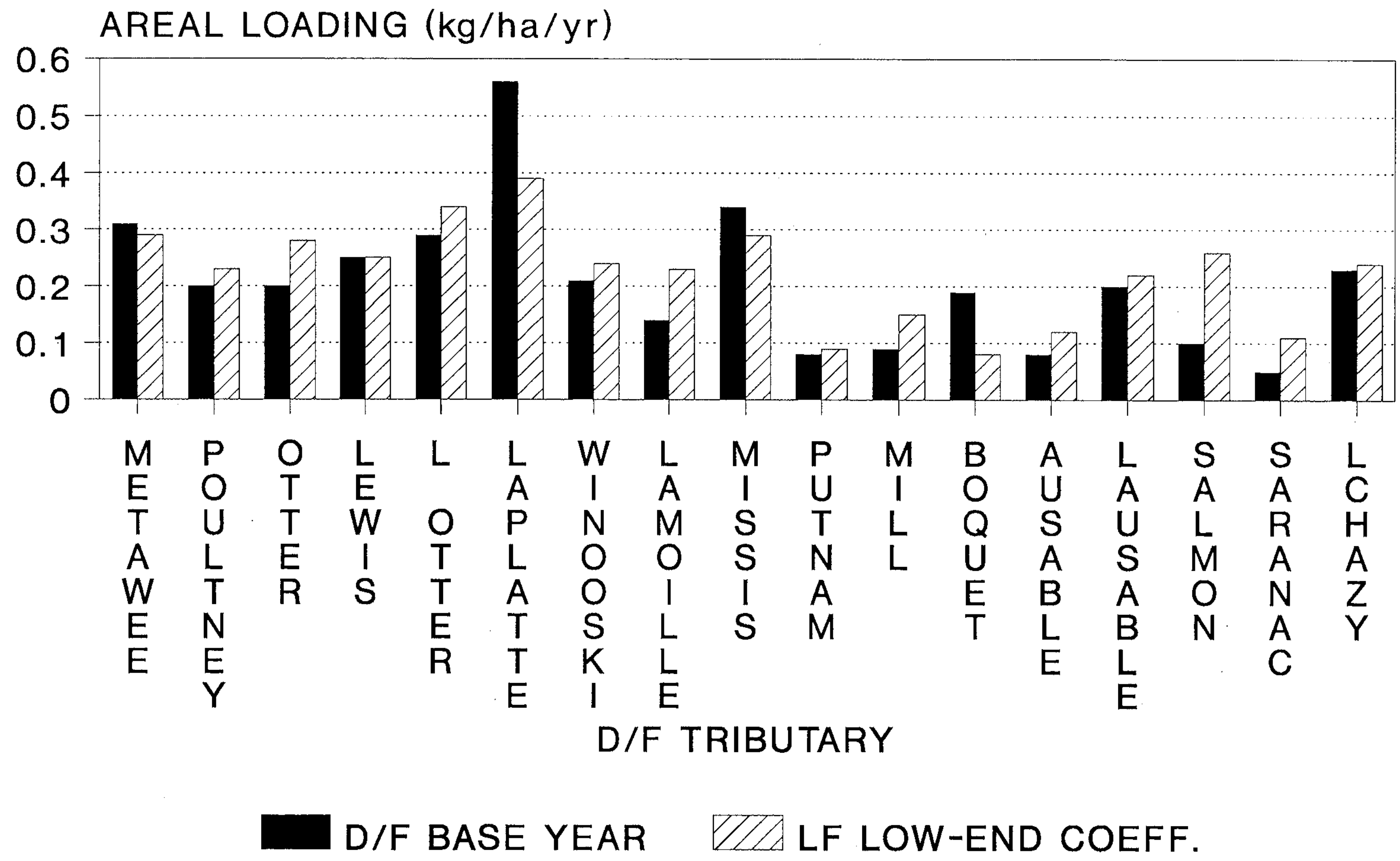
There was some difficulty in assigning a few parcels to the appropriate land use class because of their large size and diverse land use. For example, some school properties included both buildings and large areas of playing fields. For the purpose of predicting water quality, such parcels should be split into an institutional portion (buildings) and an urban/open portion (playing fields) to more accurately reflect land use at this detailed scale. Because this project relied on an existing digital data set, individual parcels could not be split and such areas were included in the institutional category.

Land use in the Vermont watersheds - WS 2 in the LaPlatte River Watershed and WS 24 in the St. Albans Bay Watershed - was primarily agricultural (75-80%). Hayland and pasture land tended to be the dominant agricultural land uses, with less than 10% of the agricultural land in row crops (corn). Forests covered less than 20% of either watershed. Urban land use was more prevalent in WS 24, representing about 10% of the watershed area, and including significant residential and commercial land, as well as roads.

Land use for the four Phase II watersheds is shown in Table 6.17

FIGURE 6.13

LAKE CHAMPLAIN TRIBUTARY TP LOADING
MONITORED vs ESTIMATED



t=-0.97, not sig. diff @ P=0.95

TABLE 6.17
LAND USE FOR PHASE II WATERSHEDS

LAND USE	LG39	LG40	WS 2[1]	WS 24[2]
	ha(%)			
FOREST	139(74%)	47(49%)	323(19%)	1548(27%)
AGRICULTURE				
Corn	0	0	50(3%)	325(6%)
Hay	0	0	650(39%)	1191(21%)
Pasture	0	0	347(21%)	2069(36%)
Mixed	0	0	210(12%)	28(<1%)
Open/Idle	0	0	22(1%)	82(1%)
URBAN				
L.D. Res.	2(1%)	3(3%)	0	0
Residential	0	0	68(4%)	328(6%)
H.D. Res.	15(8%)	9(9%)	0	0
Comm./Res.	0	0	0	62(1%)
Commercial	7(4%)	4(4%)	0	10(<1%)
Comm./Ind.	0	0	0	19(<1%)
Open/Rec.	4(2%)	6(6%)	0	21(<1%)
Institutional	2(1%)	6(6%)	0	8(<1%)
Mixed	0	0	0	1(<1%)
Roads	19(10%)	21(22%)	6(<1%)	53(1%)

[1]Land use for 1986
[2]Land use for 1985

6.7.2 Nonpoint Source Loading Coefficients. Export coefficients and loading function concentration values chosen for the land use categories in the Phase II watersheds are shown in Appendix H (and are shown in calculation tables). These values were drawn from the literature review described in Section 5.1 and were selected at three levels - low, average, and high - according to the same protocols outlined earlier. At this more detailed level of land use, there were some categories with too little reported data to strictly follow the procedures used earlier for defining the range of coefficients. In such cases, judgement was exercised in selecting a low-end or high-end value that bracketed an appropriate range for that land use.

6.7.3 Hydrology. As outlined in Section 5.6.4, streamflow was estimated by applying the runoff coefficient value estimated for the particular 11-digit HU which included each individual Phase II watershed to measured precipitation for the monitored year, rather than long-term average precipitation. Estimated, rather than measured, streamflow was used because this approach represented a more complete test of the overall load estimation procedure. The results are shown below:

	MEASURED	ESTIMATED		MEASURED
WS/YR	PRECIP.	C_r	Q (m^3/yr)	Q (m^3/yr)
LG39/WY80	95.3 cm	0.59	1.05×10^6	2.39×10^5
LG39/WY81	104.7 cm	0.59	1.16×10^6	6.26×10^5
LG40/WY80	95.3 cm	0.59	5.37×10^5	4.22×10^5
LG40/WY81	104.7 cm	0.59	5.90×10^5	6.36×10^5
LPWS2/86	93.1 cm	0.51	7.99×10^6	1.27×10^7
LPWS2/87	53.9 cm	0.51	4.62×10^6	5.10×10^6
StAWS24/85	74.7 cm	0.38	1.65×10^7	7.08×10^6
StAWS24/90	89.4 cm	0.38	1.97×10^7	1.16×10^7

In most cases, estimated streamflow was reasonably close to measured streamflow, usually within a factor of two. One Lake George watershed, LG39, was an exception; streamflow in water year 1980-81 was overestimated by a factor of four. The lack of close agreement between estimated and measured flow is not surprising, since average runoff coefficients estimated from large watersheds cannot be expected to represent each subwatershed equally well. However, simple comparison using a paired t-test shows that estimated and measured flow groups are not significantly different ($t = 1.41$; critical $t_{(P=0.99,d.f.=7)} = 3.49$). Thus, these estimated flows, as well as flows similarly estimated in Phase I, can be used with some confidence.

6.7.4 Loading Estimates. Total phosphorus, soluble phosphorus, and total nitrogen loads from the two Lake George, NY watersheds and the two Vermont agricultural watersheds were estimated using both the export coefficient and loading function methods. Estimates of TP load from LG39 by the EC and the LF method are shown in Tables 6.18 and 6.19, respectively and estimates for SRP and TN, as well as estimated loads of all three pollutants from LG40 are presented in detail in Appendix I. In Table 6.18, export coefficients used are shown in the box labeled "Model Parameters." In the main box, area in each land use category is given, followed by loads estimated using the low, baseline, and high sets of coefficients. Estimates are shown for the detailed land use categories, then for the same general land use categories used in the basin-wide.

TABLE 6.18

PHASE II - LAKE GEORGE NURP WATERSHEDS
LG39 - SHERIFF'S DOCK WATERSHED
TOTAL P by EXPORT COEFFICIENTS

MODEL PARAMETERS

LAND USE	TP EXPORT (kg/ha/yr) Low	Ave.	High
Forest	0.04	0.10	0.24
Corn	0.75	2.00	2.42
Hay	0.45	1.00	1.27
Pasture	0.10	0.45	0.82
Mixed Ag	0.25	0.50	0.81
Open/Idle	0.07	0.25	0.50
Low-density Res.	0.40	0.60	0.90
High-density Res.	0.80	0.90	1.20
Comm./Res.	0.90	1.10	1.50
Commercial	0.70	1.30	1.90
Comm./Ind.	1.27	2.00	2.50
Open/Recreation	0.30	0.50	0.70
Institutional	1.40	1.60	1.80
Mixed Urban	1.00	1.50	1.91
Roads	1.00	1.20	1.40

	LG39 WY 80/81 & 81/82*		LOW COEFF.		BASELINE COEF.		HIGH COEF.	
	SUBTOTAL	TOTAL	TP LOAD (kg/yr)		TP LOAD (kg/yr)		TP LOAD (kg/yr)	
LAND USE	(ha)	(ha)	Detailed LU	General LU	Detailed LU	General LU	Detailed LU	General LU
FOREST	139	139	6	6	14	14	33	33
AG		0		0		0		0
Corn	0		0		0		0	
Hay	0		0		0		0	
Pasture	0		0		0		0	
Mixed	0		0		0		0	
Open/Idle	0		0		0		0	
URBAN		49		49		74		94
L.D.Res.	2		1		1		2	
H.D.Res.	15		12		14		18	
Comm/Res	0		0		0		0	
Comm.	7		5		9		13	
Comm/Ind	0		0		0		0	
Open/Rec	4		1		2		3	
Instit.	2		3		3		4	
Urban	0		0		0		0	
Roads	19		19		23		27	
TOTAL		188	46	55	66	87	99	127

* No change in land use for WY 1981/82

P2XNY39.WK

TABLE 6.19

PHASE II - LAKE GEORGE NURP WATERSHEDS
LG39 - SHERIFF'S DOCK WATERSHED
TP by LOADING FUNCTION

MODEL PARAMETERS

	Estimated	Actual
WY 80/81 Q (m3/y	1.05E+06	2.39E+05
WY 81/82 Q (m3/y	1.16E+06	6.26E+05
	TP CONCENTRATION (mg/l)	
LAND USE	Low	Baseline
Forest	0.01	0.02
Corn	0.04	0.40
Hay	0.02	0.22
Pasture	0.10	0.20
Mixed Ag	0.10	0.20
Open/Idle	0.06	0.06
Low-density Res.	0.20	0.26
High Density Res.	0.30	0.40
Comm./Res.	0.30	0.50
Commercial	0.20	0.25
Comm./Ind.	0.17	0.22
Open/Recreation	0.03	0.10
Institutional	0.20	0.25
Mixed Urban	0.28	0.35
Roads	0.25	0.25

	LG39 WY80/81		LOW COEFFICIENTS						BASELINE COEFFICIENTS					
			ESTIMATED FLOW			ACTUAL FLOW			ESTIMATED FLOW			ACTUAL FLOW		
	SUBTOTAL	TOTAL	Q	TP LOAD (kg/yr)		Q	TP LOAD (kg/yr)		Q	TP LOAD (kg/yr)		Q	TP LOAD (kg/yr)	
LAND USE	(ha)	(ha)	(m3/yr)	Detailed LU	General LU	(m3/yr)	Detailed LU	General LU	(m3/yr)	Detailed LU	General LU	(m3/yr)	Detailed LU	General LU
FOREST	139	139	7.76E+05	8	8	1.77E+05	2	2	7.76E+05	12	12	1.77E+05	3	3
AG		0			0			0			0			0
Corn	0		0.00E+00	0		0.00E+00	0		0.00E+00	0		0.00E+00	0	
Hay	0		0.00E+00	0		0.00E+00	0		0.00E+00	0		0.00E+00	0	
Pasture	0		0.00E+00	0		0.00E+00	0		0.00E+00	0		0.00E+00	0	
Mixed	0		0.00E+00	0		0.00E+00	0		0.00E+00	0		0.00E+00	0	
Open/Idle	0		0.00E+00	0		0.00E+00	0		0.00E+00	0		0.00E+00	0	
URBAN		49			77			17			96			22
L.D. Res.	2		1.06E+04	2		2.42E+03	0		1.06E+04	3		2.42E+03	1	
H.D. Res.	15		8.57E+04	26		1.95E+04	6		8.57E+04	34		1.95E+04	8	
Comm/Res	0		0.00E+00	0		0.00E+00	0		0.00E+00	0		0.00E+00	0	
Comm.	7		4.09E+04	8		9.31E+03	2		4.09E+04	10		9.31E+03	2	
Comm/Ind	0		0.00E+00	0		0.00E+00	0		0.00E+00	0		0.00E+00	0	
Open/Rec	4		1.96E+04	1		4.46E+03	0		1.96E+04	2		4.46E+03	0	
Instit.	2		9.35E+03	2		2.13E+03	0		9.35E+03	2		2.13E+03	1	
Urban	0		0.00E+00	0		0.00E+00	0		0.00E+00	0		0.00E+00	0	
Roads	19		1.08E+05	27		2.46E+04	6		1.08E+05	27		2.46E+04	6	
TOTAL		188	1.04E+06	71	85	2.37E+05	16	19	1.04E+06	88	108	2.37E+05	20	25

	LG39 WY81/82		LOW COEFFICIENTS						BASELINE COEFFICIENTS					
			ESTIMATED FLOW			ACTUAL FLOW			ESTIMATED FLOW			ACTUAL FLOW		
	SUBTOTAL	TOTAL	Q	TP LOAD (kg/yr)		Q	TP LOAD (kg/yr)		Q	TP LOAD (kg/yr)		Q	TP LOAD (kg/yr)	
LAND USE	(ha)	(ha)	(m3/yr)	Detailed LU	General LU	(m3/yr)	Detailed LU	General LU	(m3/yr)	Detailed LU	General LU	(m3/yr)	Detailed LU	General LU
FOREST	139	139	8.57E+05	9	9	4.63E+05	5	5	8.57E+05	13	13	4.63E+05	7	7
AG		0			0			0			0			0
Corn	0		0.00E+00	0		0.00E+00	0		0.00E+00	0		0.00E+00	0	
Hay	0		0.00E+00	0		0.00E+00	0		0.00E+00	0		0.00E+00	0	
Pasture	0		0.00E+00	0		0.00E+00	0		0.00E+00	0		0.00E+00	0	
Mixed	0		0.00E+00	0		0.00E+00	0		0.00E+00	0		0.00E+00	0	
Open/Idle	0		0.00E+00	0		0.00E+00	0		0.00E+00	0		0.00E+00	0	
URBAN		49			85			46			96			57
L.D. Res.	2		1.18E+04	2		6.35E+03	1		1.18E+04	3		6.35E+03	2	
H.D. Res.	15		9.47E+04	28		5.11E+04	15		9.47E+04	38		5.11E+04	20	
Comm/Res	0		0.00E+00	0		0.00E+00	0		0.00E+00	0		0.00E+00	0	
Comm.	7		4.52E+04	9		2.44E+04	5		4.52E+04	11		2.44E+04	6	
Comm/Ind	0		0.00E+00	0		0.00E+00	0		0.00E+00	0		0.00E+00	0	
Open/Rec	4		2.17E+04	1		1.17E+04	0		2.17E+04	2		1.17E+04	1	
Instit.	2		1.03E+04	2		5.58E+03	1		1.03E+04	3		5.58E+03	1	
Urban	0		0.00E+00	0		0.00E+00	0		0.00E+00	0		0.00E+00	0	
Roads	19		1.20E+05	30		6.46E+04	16		1.20E+05	30		6.46E+04	16	
TOTAL		188	1.15E+06	79	93	6.20E+05	42	50	1.15E+06	97	109	6.20E+05	52	64

P2LNY39.WK

The EC-estimated TP load from LG39 ranged from 46 to 99 kg/yr; this estimate applied to both study years, since the EC method is based solely on land use areas and there was no change in land use applied from 1980 to 1981. Of this estimated load, one-third or less was derived from forest land, despite the fact that forest land made up nearly three-quarters of the watershed area. Urban/developed land was the principal contributor of TP, with the greatest loads originating from roads (27-41%), high-density residential (18-26%), and commercial (11-14%) areas. Estimated SRP and TN loads followed a similar pattern, as did export of all three pollutants from the LG40 watershed. Load estimates for TP and SRP based on detailed land use tended to be about 10-20% lower than estimates derived from just the general land use categories; estimates for TN were similar for the two levels of land use classification.

In Table 6.19, concentrations used in the loading function calculation are shown in the "Model Parameters" box; high-end concentrations yielded load estimates greatly exceeding measured loads and were not included. In the main area of the table, estimated loads are shown for both estimated flow and measured flow under both the low-end and baseline concentrations. As in the EC method, load estimates were also calculated using the general land use breakdown for comparison. Separate estimates were made for the two water-years (water year = October-September) considered, since precipitation and thus streamflow differed between the two years.

The LF-estimated TP load from LG39 ranged from 71-88 kg/yr for WY 80/81 and 79-97 kg/yr for WY 80/82. As in the estimates by the EC method, forest land contributed a very minor proportion of the estimated TP load (11-13%); urban/developed land contributed the majority of the TP, with the greatest loads from roads, high-density residential, and commercial land. The same pattern was shown for SRP and TN in LG39 and for TP, SRP, and TN in LG40. Open/recreation and institutional land appeared to be significant contributors of TN by this method. Estimated loads from both watersheds were slightly higher for WY 81/82, since precipitation was higher in the second year. It is worth noting that loads estimated on the basis of estimated flow were higher than those based on measured flow, particularly in LG39 where estimated flow was much higher than measured flow. Estimates of TP load from the WS 2 subwatershed of the LaPlatte River Watershed, Vermont by the EC and the LF method are shown in Tables 6.20 and 6.21, respectively; estimates for SRP and TN, as well as estimated loads of all three pollutants from the WS 24 subwatershed of the St. Albans Bay Watershed are presented in detail in Appendix J.

The EC-estimated TP load from WS 2 was 476-1607 kg/yr for 1986 and 502-1645 kg/yr for 1987. The slightly higher load estimated for 1987 was driven by a near doubling of land in corn (although total agricultural land decreased by 4%) and a 49% increase in urban land; this land use change alone caused the increase in estimated load, since the EC method did not account for the fact that 1987 was a very dry year compared to a slightly wet 1986. In both years, most of the estimated TP load was derived from agriculture; within this category, most of the TP load appeared to be contributed by hayland, which was the dominant agricultural land use by area. Land in corn, although making up just 3-6% of the total watershed area, contributed an estimated 9-17% of the total watershed TP load. A similar pattern was shown for estimated SRP and TN loads from WS 2.

TABLE 6.20

PHASE II - VERMONT MONITORED AGRICULTURAL WATERSHEDS
LAPLATTE RIVER WATERSHED - MUD HOLLOW BROOK SUBWATERSHED
TOTAL P by EXPORT COEFFICIENTS

MODEL PARAMETERS

LAND USE	TP EXPORT (kg/ha/yr) Low	Ave.	High
Forest	0.04	0.10	0.24
Corn	0.75	2.00	2.42
Hay	0.45	1.00	1.27
Pasture	0.10	0.45	0.82
Mixed Ag	0.25	0.50	0.81
Open/Idle	0.07	0.25	0.50
Residential	0.56	1.00	1.60
Comm./Res.	0.90	1.10	1.50
Commercial	0.70	1.30	1.90
Comm./Ind.	1.27	2.00	2.50
Open/Recreation	0.30	0.50	0.70
Institutional	1.40	1.60	1.80
Mixed Urban	1.00	1.50	1.91
Roads	1.00	1.20	1.40

	LP WS 2 1986		LOW COEFF.		BASELINE COEF.		HIGH COEF.	
	SUBTOTAL	TOTAL	TP LOAD (kg/yr)		TP LOAD (kg/yr)		TP LOAD (kg/yr)	
LAND USE	(ha)	(ha)	Detailed LU	General LU	Detailed LU	General LU	Detailed LU	General LU
FOREST	323	323	13	13	32	32	78	78
AG		1279		320		640		1036
Corn	50		38		100		121	
Hay	650		293		650		826	
Pasture	347		35		156		285	
Mixed	210		53		105		170	
Open/Idle	22		2		6		11	
URBAN		74		74		111		141
Res.	68		38		68		109	
Comm/Res	0		0		0		0	
Comm.	0		0		0		0	
Comm/Ind	0		0		0		0	
Open/Rec	0		0		0		0	
Instit.	0		0		0		0	
Urban	0		0		0		0	
Roads	6		6		7		8	
TOTAL		1676	476	407	1124	783	1607	1255

Pasture=Pasture(05)+Hay/Pasture(03)+Woodland/Pasture(45)
Mixed=Farmstead(06)+Barn(07)+AgLUseUnknown(79+89+99)

	LP WS 2 1987		LOW COEFF.		BASELINE COEF.		HIGH COEF.	
	SUBTOTAL	TOTAL	TP LOAD (kg/yr)		TP LOAD (kg/yr)		TP LOAD (kg/yr)	
LAND USE	(ha)	(ha)	Detailed LU	General LU	Detailed LU	General LU	Detailed LU	General LU
FOREST	337	337	13	13	34	34	81	81
AG		1229		307		615		995
Corn	97		73		194		235	
Hay	607		273		607		771	
Pasture	188		19		85		154	
Mixed	198		50		99		160	
Open/Idle	139		10		35		70	
URBAN		110		110		165		210
Res.	104		58		104		166	
Comm/Res	0		0		0		0	
Comm.	0		0		0		0	
Comm/Ind	0		0		0		0	
Open/Rec	0		0		0		0	
Instit.	0		0		0		0	
Urban	0		0		0		0	
Roads	6		6		7		8	
TOTAL		1676	502	431	1164	813	1645	1286

Pasture=Pasture(05)+Hay/Pasture(03)+Woodland/Pasture(45)
Mixed=Farmstead(06)+Barn(07)+AgLUseUnknown(79+89+99)

P2XVTLP.WK

TABLE 6.21

PHASE II - VERMONT MONITORED AGRICULTURAL WATERSHEDS
LAPLATTE RIVER WATERSHED - MUD HOLLOW BROOK SUBWATERSHED
TP by LOADING FUNCTION

MODEL PARAMETERS

	Estimated	Actual
1987 Disch. (m3/y	4.62E+06	5.10E+06
1986 Disch. (m3/y	7.99E+06	1.27E+07
	TP CONCENTRATION (mg/l)	
LAND USE	Ave.	High
Forest	0.02	0.03
Corn	0.40	0.82
Hay	0.22	0.82
Pasture	0.20	0.38
Mixed Ag	0.20	0.81
Open/Idle	0.06	0.07
Residential	0.35	0.40
Comm./Res.	0.50	0.60
Commercial	0.25	0.35
Comm./Ind.	0.22	0.32
Open/Recreation	0.10	0.12
Institutional	0.25	0.30
Mixed Urban	0.35	0.82
Roads	0.25	0.30

	LP WS 2		BASELINE COEFFICIENTS						HIGH COEFFICIENTS					
	1986		ESTIMATED FLOW			ACTUAL FLOW			ESTIMATED FLOW			ACTUAL FLOW		
	SUBTOTAL	TOTAL	Q	TP LOAD (kg/yr)		Q	TP LOAD (kg/yr)		Q	TP LOAD (kg/yr)		Q	TP LOAD (kg/yr)	
LAND USE	(ha)	(ha)	(m3/yr)	Detailed LU	General LU	(m3/yr)	Detailed LU	General LU	(m3/yr)	Detailed LU	General LU	(m3/yr)	Detailed LU	General LU
FOREST	323	323	1.53E+06	23	23	2.44E+06	37	37	1.53E+06	38	38	2.44E+06	61	37
AG		1279			1215			1931			4921			7822
Corn	50		2.38E+05	95		3.78E+05	151		2.38E+05	195		3.78E+05	310	
Hay	650		3.09E+06	679		4.91E+06	1080		3.09E+06	2532		4.91E+06	4024	
Pasture	347		1.65E+06	330		2.62E+06	524		1.65E+06	626		2.62E+06	996	
Mixed	210		9.98E+05	200		1.59E+06	317		9.98E+05	808		1.59E+06	1284	
Open/Idle	22		1.05E+05	6		1.66E+05	10		1.05E+05	7		1.66E+05	12	
URBAN		74			123			196			288			458
Res.	68		3.23E+05	113		5.13E+05	180		3.23E+05	129		5.13E+05	205	
Comm/Res	0		0.00E+00	0		0.00E+00	0		0.00E+00	0		0.00E+00	0	
Comm.	0		0.00E+00	0		0.00E+00	0		0.00E+00	0		0.00E+00	0	
Comm/Ind	0		0.00E+00	0		0.00E+00	0		0.00E+00	0		0.00E+00	0	
Open/Rec	0		0.00E+00	0		0.00E+00	0		0.00E+00	0		0.00E+00	0	
Instit.	0		0.00E+00	0		0.00E+00	0		0.00E+00	0		0.00E+00	0	
Urban	0		0.00E+00	0		0.00E+00	0		0.00E+00	0		0.00E+00	0	
Roads	6		2.85E+04	7		4.53E+04	11		2.85E+04	9		4.53E+04	14	
TOTAL		1676	7.96E+06	1453	1361	1.27E+07	2309	2164	7.96E+06	4345	5248	1.27E+07	6906	8317

Pasture=Pasture(05)+Hay/Pasture(03)+Woodland/Pasture(45)
Mixed=Farmstead(06)+Barn(07)+AgLUseUnknown(79+89+99)

	LP WS 2		BASELINE COEFFICIENTS						HIGH COEFFICIENTS					
	1987		ESTIMATED FLOW			ACTUAL FLOW			ESTIMATED FLOW			ACTUAL FLOW		
	SUBTOTAL	TOTAL	Q	TP LOAD (kg/yr)		Q	TP LOAD (kg/yr)		Q	TP LOAD (kg/yr)		Q	TP LOAD (kg/yr)	
LAND USE	(ha)	(ha)	(m3/yr)	Detailed LU	General LU	(m3/yr)	Detailed LU	General LU	(m3/yr)	Detailed LU	General LU	(m3/yr)	Detailed LU	General LU
FOREST	337	337	9.26E+05	14	14	1.02E+06	15	15	9.26E+05	23	23	1.02E+06	26	15
AG		1229			675			745			2734			3018
Corn	97		2.66E+05	107		2.94E+05	118		2.66E+05	218		2.94E+05	241	
Hay	607		1.67E+06	367		1.84E+06	405		1.67E+06	1367		1.84E+06	1509	
Pasture	188		5.16E+05	103		5.70E+05	114		5.16E+05	196		5.70E+05	217	
Mixed	198		5.44E+05	109		6.00E+05	120		5.44E+05	441		6.00E+05	486	
Open/Idle	139		3.82E+05	23		4.21E+05	25		3.82E+05	27		4.21E+05	30	
URBAN		110			106			117			248			273
Res.	104		2.86E+05	100		3.15E+05	110		2.86E+05	114		3.15E+05	126	
Comm/Res	0		0.00E+00	0		0.00E+00	0		0.00E+00	0		0.00E+00	0	
Comm.	0		0.00E+00	0		0.00E+00	0		0.00E+00	0		0.00E+00	0	
Comm/Ind	0		0.00E+00	0		0.00E+00	0		0.00E+00	0		0.00E+00	0	
Open/Rec	0		0.00E+00	0		0.00E+00	0		0.00E+00	0		0.00E+00	0	
Instit.	0		0.00E+00	0		0.00E+00	0		0.00E+00	0		0.00E+00	0	
Urban	0		0.00E+00	0		0.00E+00	0		0.00E+00	0		0.00E+00	0	
Roads	6		1.65E+04	4		1.82E+04	5		1.65E+04	5		1.82E+04	5	
TOTAL		1676	4.60E+06	826	795	5.08E+06	912	877	4.60E+06	2391	3005	5.08E+06	2640	3307

Pasture=Pasture(05)+Hay/Pasture(03)+Woodland/Pasture(45)
Mixed=Farmstead(06)+Barn(07)+AgLUseUnknown(79+89+99)

P2LVTLP.WK

In WS 24 in the St. Albans Bay Watershed the picture was different. Urban land made up nearly 10% of total watershed area and contributed 15-25% of the total estimated load. Agricultural land was still the dominant source of the estimated TP load, contributing about 80% of the total estimated load; hayland and pasture land were the principal contributors and the principal land use by area. However, corn land contributed a disproportionate 18-20% of total TP load, while making up just 6-7% of total watershed area. Within the urban category, residential, roads, and commercial land uses were the major TP sources. A similar pattern was shown for SRP and for TN; the open/recreation and institutional categories were also significant contributors of TN among the urban categories. Load estimates based on detailed land use were similar to estimates based on general land use for TP and SRP, but were slightly lower for TN.

The LF-estimated TP load from WS 2 was 1453-4345 kg/yr for 1986 and 826-2391 kg/yr for 1987. The 1987 estimate was substantially lower than that for 1986, despite the land use changes in this watershed noted earlier; this reflects the significantly lower precipitation and streamflow in 1987, underlining the importance of hydrology as a driving force in the LF method. As in the EC-estimate, agriculture was the major source of estimated TP load, with hayland the dominant source by land area (36-38%) and total load (44-58%). Corn land contributed 6-13% of total TP load, but comprised just 3-6% of the watershed area. A similar pattern was observed for estimated SRP and TN loads from this watershed.

Consistent with the EC estimates, LF estimates from WS 24 showed that hayland and pasture land were dominant sources of the phosphorus and nitrogen loads; corn land contributed 12-14% of the estimated TP load although it comprised 6-7% of the watershed area. Urban land delivered about 10-20% of the TP load; roads, residential, and commercial land were important contributors. Similar patterns were shown for SRP and for TN; open/recreation and institutional land were also important sources of nitrogen. Load estimates based on detailed land use were similar to estimates from general and use for TP and for TN, but estimates of SRP loads based on detailed land use were substantially higher than those based on the three general land use categories.

Loading estimates for all four watersheds by all methods are summarized in Tables 6.22 and 6.23, along with indications of precipitation conditions and land use for the years considered. For the Lake George watersheds (Table 6.22), the LF estimates tended to be slightly higher than the EC estimates. It is worth noting again that the EC-based estimates were identical for the two years considered, even though precipitation and streamflow did differ. For the Vermont agricultural watersheds (Table 6.23), LF estimates were also higher that EC estimates. The EC method tended to predict slightly higher loads in drier years, since these estimates were driven only by shifts in land use; the LF estimates tended to follow the precipitation pattern more realistically. With the exception of SRP from the Vermont watersheds, the two methods yielded estimated loads of generally comparable magnitude; LF estimates of SRP loads from the Vermont watersheds were approximately an order of magnitude higher that EC-estimated loads. This pattern may reflect the comparatively weaker data base for SRP coefficients which introduced more judgement (and hence more uncertainty) into the selection of SRP coefficient values.

TABLE 6.22

PHASE II RESULTS

LAKE GEORGE NURP WATERSHEDS

TOTAL P (kg/year)

WS	YEAR	PRECIP	LAND USE	MEASURED EXPORT	LOADING FUNCTION		EXPORT COEFFICIENT		
					LOW	BASELINE	LOW	BASELINE	HIGH
LG 39	WY 80/81	+2%	74%F/26%UR	57.8	71	88	46	66	99
LG 39	WY 81/82	+12%	74%F/26%UR	31.5	79	97	46	66	99
LG 40	WY 80/81	+2%	49%F/51%UR	21.4	60	72	44	58	77
LG 40	WY 81/82	+12%	49%F/51%UR	21.0	66	79	44	58	77

SRP (kg/year)

WS	YEAR	PRECIP	LAND USE	MEASURED EXPORT	LOADING FUNCTION		EXPORT COEFFICIENT		
					LOW	BASELINE	LOW	BASELINE	HIGH
LG 39	WY 80/81	+2%	74%F/26%UR	11.6	20	34	19	26	37
LG 39	WY 81/82	+12%	74%F/26%UR	3.8	22	38	19	26	37
LG 40	WY 80/81	+2%	49%F/51%UR	-n d-	14	24	16	21	28
LG 40	WY 81/82	+12%	49%F/51%UR	-n d-	15	27	16	21	28

TOTAL N (kg/year)

WS	YEAR	PRECIP	LAND USE	MEASURED EXPORT	LOADING FUNCTION		EXPORT COEFFICIENT		
					LOW	BASELINE	LOW	BASELINE	HIGH
LG 39	WY 80/81	+2%	74%F/26%UR	420.0	689	1055	604	1031	1477
LG 39	WY 81/82	+12%	74%F/26%UR	296.0	762	1166	604	1031	1477
LG 40	WY 80/81	+2%	49%F/51%UR	-n d-	378	583	407	703	950
LG 40	WY 81/82	+12%	49%F/51%UR	-n d-	415	640	407	703	950

TABLE 6.23

PHASE II RESULTS

VERMONT MONITORED AGRICULTURAL WATERSHEDS

TOTAL P (kg/yr)

WS	YEAR	PRECIP	LAND USE	MEASURED EXPORT	LOADING FUNCTION		EXPORT COEFFICIENT		
					BASELINE	HIGH	LOW	BASELINE	HIGH
LP WS2	1986	+9%	76%ag/4%urb	3450	1453	4345	476	1124	1607
LP WS2	1987	-37%	73%ag/6%urb	1360	826	2391	502	1164	1645
StA WS24	1985	-12%	64%ag/9%urb	5700	2869	6520	1403	3497	5220
StA WS24	1990	+5%	59%ag/10%ur	13900	3723	7658	1497	3566	5209

SOLUBLE REACTIVE P (kg/yr)

WS	YEAR	PRECIP	LAND USE	MEASURED EXPORT	LOADING FUNCTION		EXPORT COEFFICIENT		
					BASELINE	HIGH	LOW	BASELINE	HIGH
LP WS2	1986	+9%	76%ag/4%urb	1179	794	2160	119	218	430
LP WS2	1987	-37%	73%ag/6%urb	544	417	1148	120	223	407
StA WS24	1985	-12%	64%ag/9%urb	900	1734	3774	432	745	1668
StA WS24	1990	+5%	59%ag/10%ur	5500	1854	4292	427	756	1554

TOTAL N (kg/yr)

WS	YEAR	PRECIP	LAND USE	MEASURED EXPORT	LOADING FUNCTION		EXPORT COEFFICIENT		
					BASELINE	HIGH	LOW	BASELINE	HIGH
LP WS2	1986	+9%	76%ag/4%urb	13608*	16890	21045	4319	9153	16144
LP WS2	1987	-37%	73%ag/6%urb	5352*	9361	11974	4275	9163	16338
StA WS24	1985	-12%	64%ag/9%urb	43200	31969	41441	15376	30804	53079
StA WS24	1990	+5%	59%ag/10%ur	113100	36343	47545	15049	30709	52903

*TKN, not TN

P2CMPVT.WK

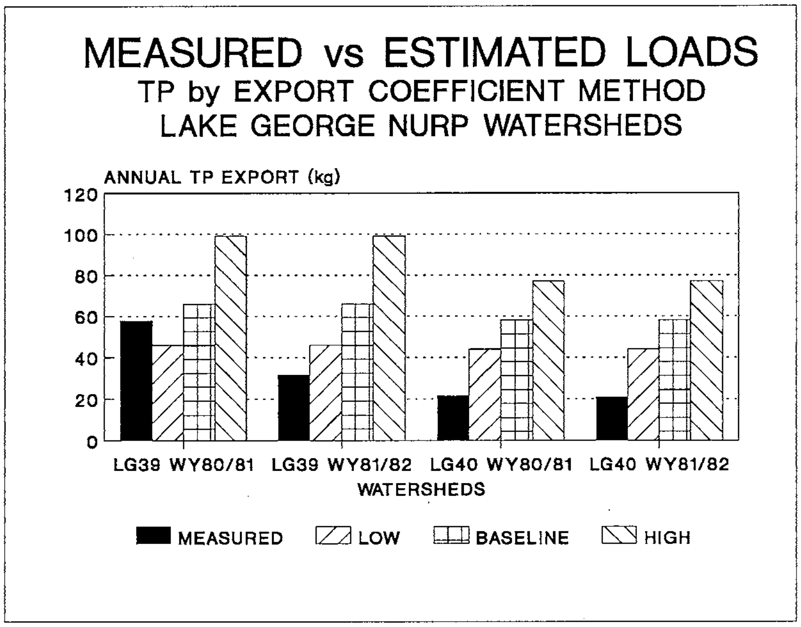
6.7.5 Validation. Measured loads from the Lake George, NY and the Vermont agricultural watersheds are also shown in Tables 6.22 and 6.23, respectively, along with the corresponding load estimates. Since statistical validation was not possible with this small data set, estimated and measured loads were simply compared visually. Measured and estimated loads for the Lake George watersheds LG39 and LG40 are shown in Figures 6.14 and 6.15, for the export coefficient estimates and the loading function estimates, respectively. Unfortunately, complete measured loads for SRP and TN from LG40 were unavailable due to missing data (Sutherland, 1993). It is apparent from Figure 6.14 that phosphorus and nitrogen loads were somewhat overestimated by the EC method. Estimated loads were within the correct order of magnitude in several cases, but differed greatly from observed loads in other cases, particularly for SRP. Furthermore, as pointed out earlier, the insensitivity of the EC method to hydrologic variation resulted in identical load estimates for the two years considered, which amplified the differences between observed and estimated loads in water year 1981/82.

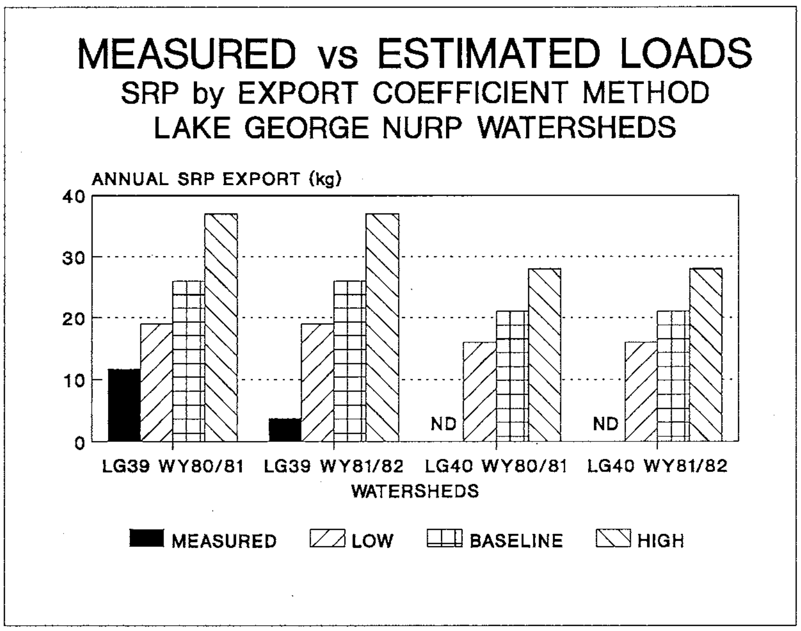
Estimates of loads by the LF method did not give a dramatically better fit to the measured loads (Figure 6.15). Estimates based on the low-end coefficients were within an order of magnitude in most cases, but agreement was not very good. While the LF estimates for water year 1981/82 were higher in response to the higher precipitation and streamflow, measured loads were actually lower in that year compared to the previous water year. This unusual behavior by these watersheds may be due to the effects of strong seasonal differences in precipitation on delivery of nonpoint source pollutants. (WY 1980/81 had a dry winter and wet summer, while WY 1981/82 had a wet winter and dry summer.) However, such within-year variability is obviously not handled at all by either method and the match of predicted to observed load suffers as a result.

Measured and estimated loads from the Vermont agricultural watersheds are compared in Figures 6.16 and 6.17. Loads for all pollutants were generally underestimated by the EC method in both watersheds in both years, but estimates agreed reasonably well with measured loads in WS 2, 1987 and WS 24, 1985. Interestingly, both of these years received below-average precipitation, while the loads measured under nearly average precipitation (WS 2, 1986 and WS 24, 1990) were strongly underestimated by the EC method. Recall that the EC method actually projected increases in loads in a below-average precipitation year due to land use changes, the reverse of what was actually measured.

The LF-based estimates presented in Figure 6.17 appear to show reasonable match with measured loads in most cases. Except for unusually high loads from WS 24 in 1990, TP loads estimated with baseline and high-end concentrations seemed to bracket measured TP loads fairly well. Estimated SRP loads showed similar agreement with measured SRP loads in WS 2, but were somewhat overestimated in WS 24 in 1985. Total N loads were slightly overestimated in WS 2, but underestimated in WS 24. In summary, nonpoint source loads were not estimated very well by either of the techniques that gave reasonably good estimates at the basin scale. By very simple visual comparison, nonpoint source load estimates based on either detailed land use classification or general land use categories in the small watersheds in New York and Vermont did not match measured loads as well as did the general estimates for the

FIGURE 6.14


MEASURED vs ESTIMATED LOADS
TP by EXPORT COEFFICIENT METHOD
LAKE GEORGE NURP WATERSHEDS
ANNUAL TP EXPORT (kg)
120
100
80
60
40
20
0
LG39 WY80/81
LG39 WY81/82
LG40 WY80/81
LG40 WY81/82
WATERSHEDS
MEASURED
LOW
BASELINE
HIGH


MEASURED vs ESTIMATED LOADS
SRP by EXPORT COEFFICIENT METHOD
LAKE GEORGE NURP WATERSHEDS
ANNUAL SRP EXPORT (kg)
40
30
20
10
0
ND
ND
LG39 WY80/81
LG39 WY81/82
LG40 WY80/81
LG40 WY81/82
WATERSHEDS
MEASURED
LOW
BASELINE
HIGH

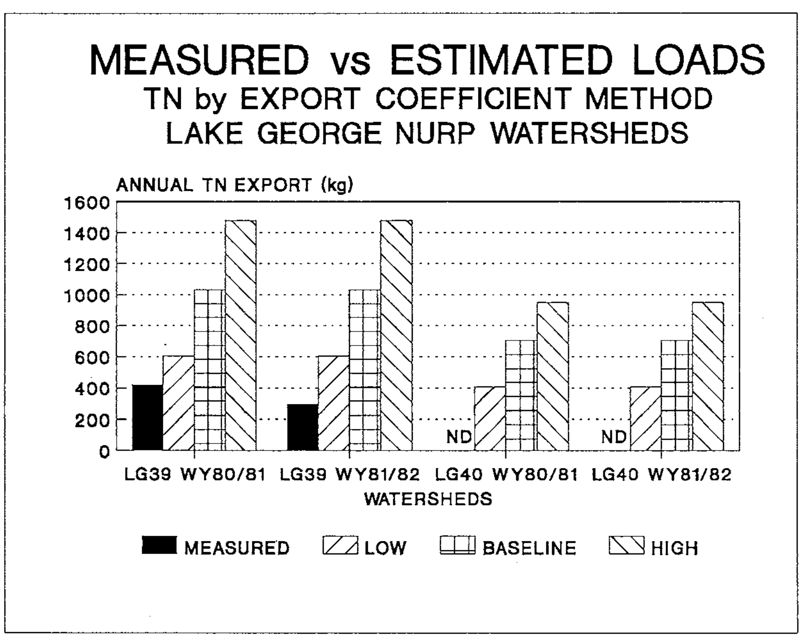
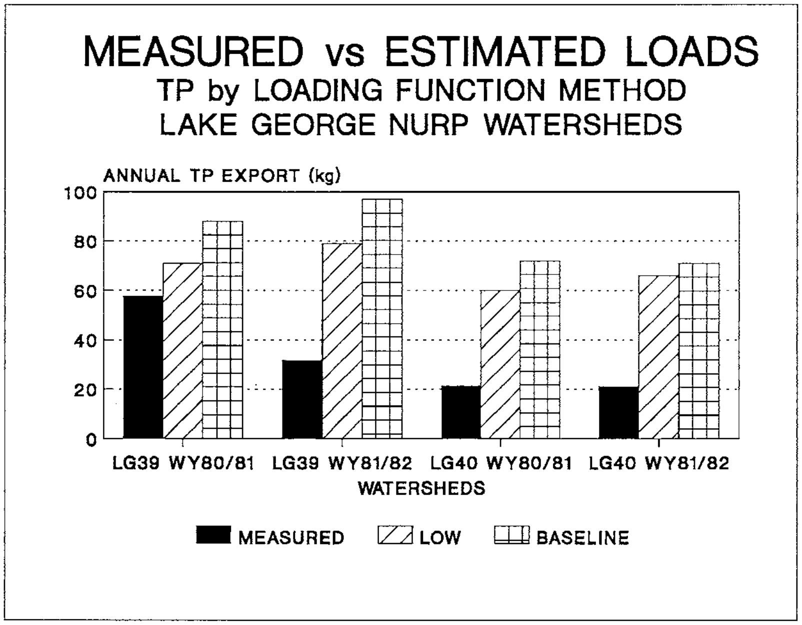
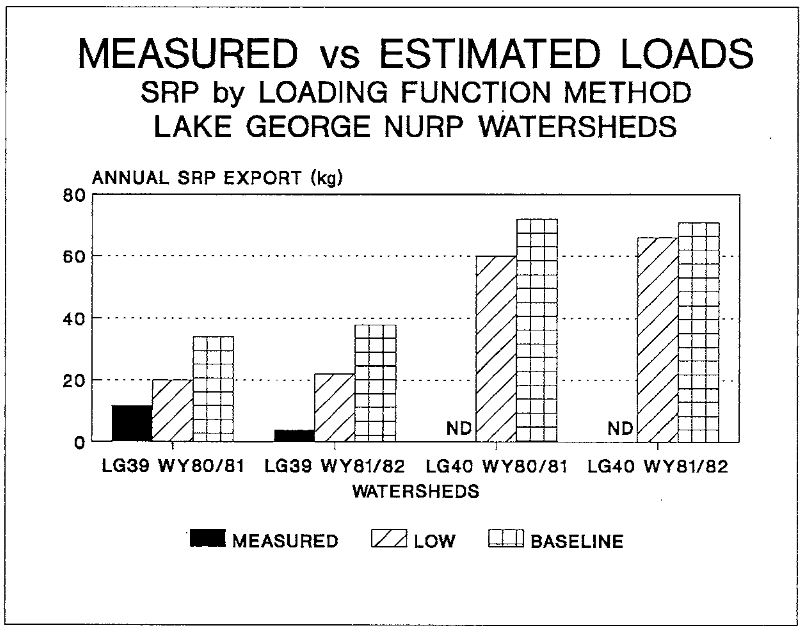

MEASURED vs ESTIMATED LOADS
TN by EXPORT COEFFICIENT METHOD
LAKE GEORGE NURP WATERSHEDS
ANNUAL TN EXPORT (kg)
1600
1400
1200
1000
800
600
400
200
0
ND
ND
LG39 WY80/81
LG39 WY81/82
LG40 WY80/81
LG40 WY81/82
WATERSHEDS
MEASURED
LOW
BASELINE
HIGH

FIGURE 6.15


MEASURED vs ESTIMATED LOADS
TP by LOADING FUNCTION METHOD
LAKE GEORGE NURP WATERSHEDS
ANNUAL TP EXPORT (kg)
100
80
60
40
20
0
LG39 WY80/81
LG39 WY81/82
LG40 WY80/81
LG40 WY81/82
WATERSHEDS
MEASURED
LOW
BASELINE


MEASURED vs ESTIMATED LOADS
SRP by LOADING FUNCTION METHOD
LAKE GEORGE NURP WATERSHEDS
ANNUAL SRP EXPORT (kg)
80
60
40
20
0
ND
ND
LG39 WY80/81
LG39 WY81/82
LG40 WY80/81
LG40 WY81/82
WATERSHEDS
MEASURED
LOW
BASELINE

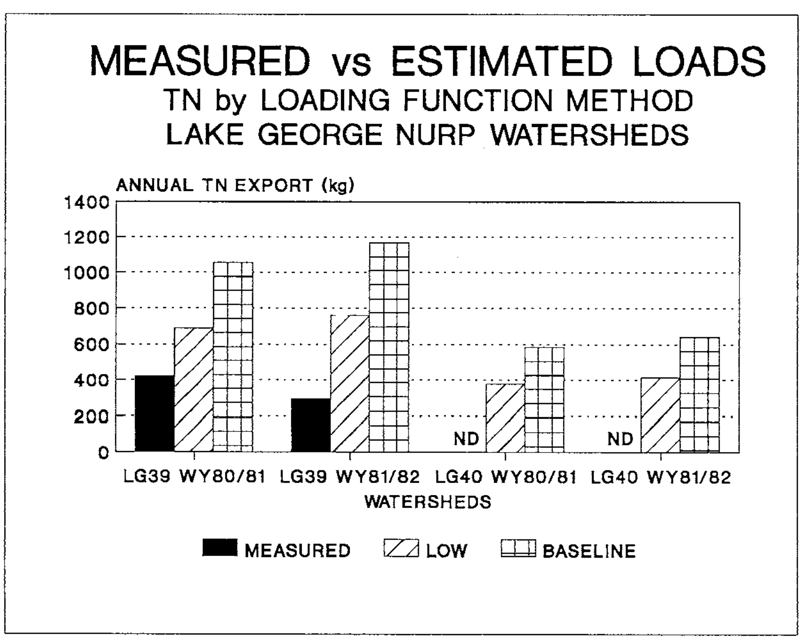
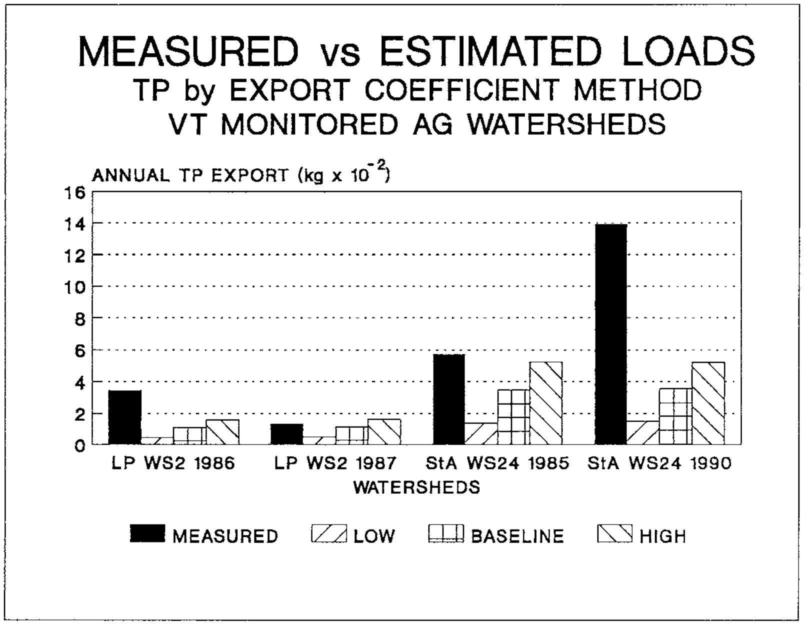
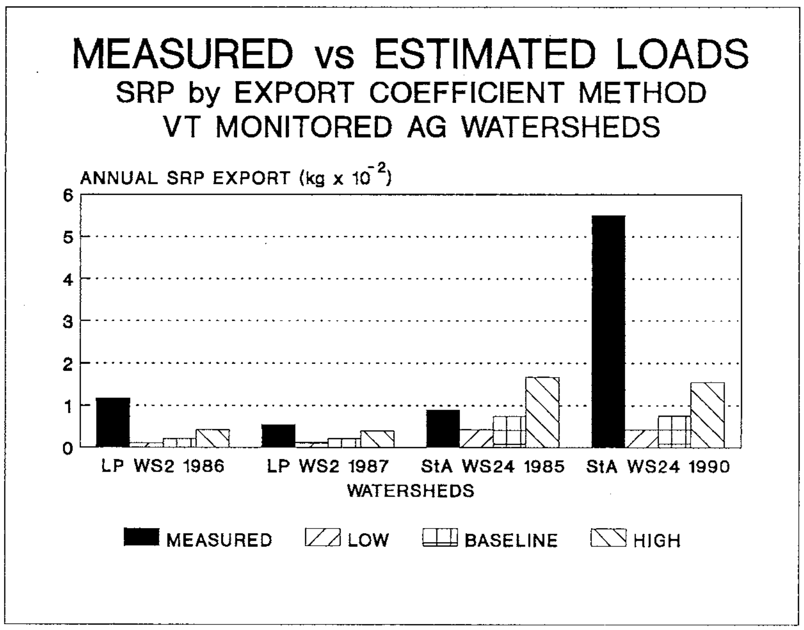

MEASURED vs ESTIMATED LOADS
TN by LOADING FUNCTION METHOD
LAKE GEORGE NURP WATERSHEDS
ANNUAL TN EXPORT (kg)
1400
1200
1000
800
600
400
200
0
ND
ND
LG39 WY80/81
LG39 WY81/82
LG40 WY80/81
LG40 WY81/82
WATERSHEDS
MEASURED
LOW
BASELINE

FIGURE 6.16


MEASURED vs ESTIMATED LOADS
TP by EXPORT COEFFICIENT METHOD
VT MONITORED AG WATERSHEDS
ANNUAL TP EXPORT (kg x 10^-2)
16
14
12
10
8
6
4
2
0
LP WS2 1986
LP WS2 1987
StA WS24 1985
StA WS24 1990
WATERSHEDS
MEASURED
LOW
BASELINE
HIGH


MEASURED vs ESTIMATED LOADS
SRP by EXPORT COEFFICIENT METHOD
VT MONITORED AG WATERSHEDS
ANNUAL SRP EXPORT (kg x 10^-2)
6
5
4
3
2
1
0
LP WS2 1986
LP WS2 1987
StA WS24 1985
StA WS24 1990
WATERSHEDS
MEASURED
LOW
BASELINE
HIGH

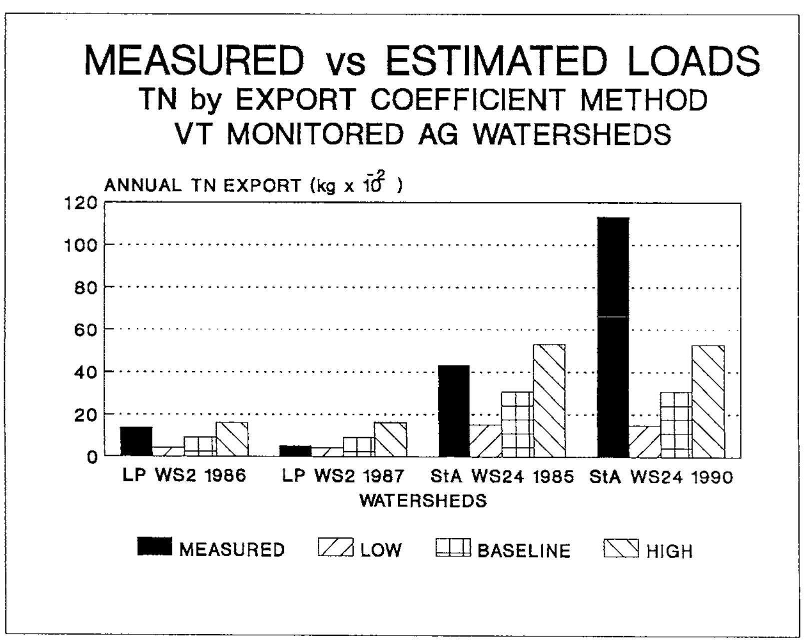
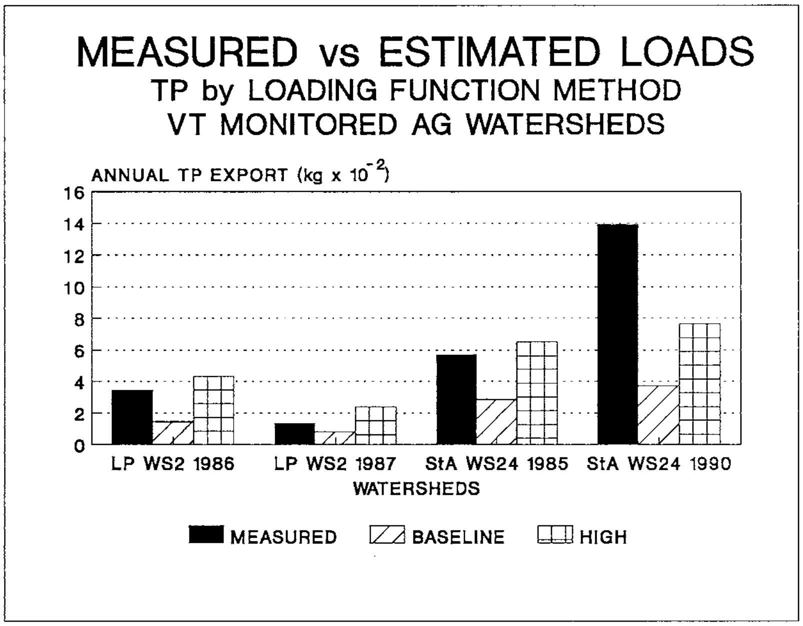
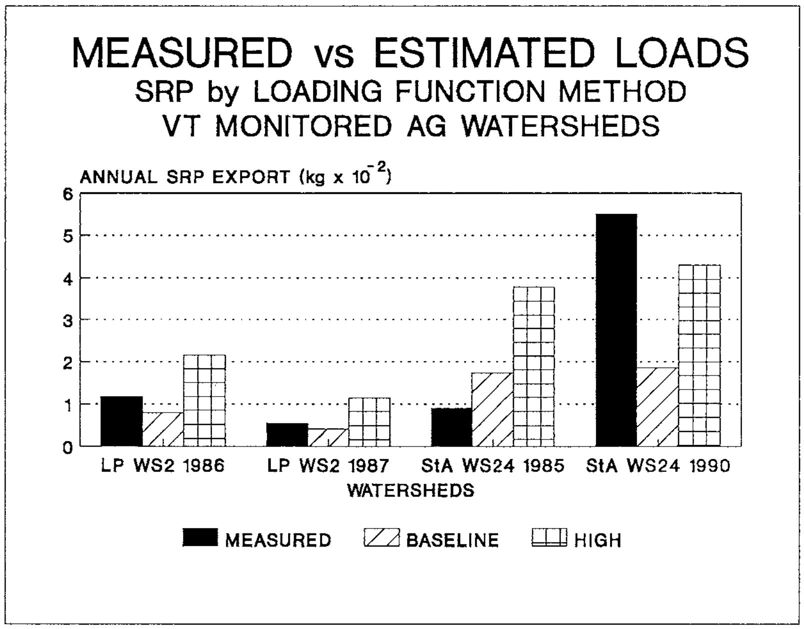
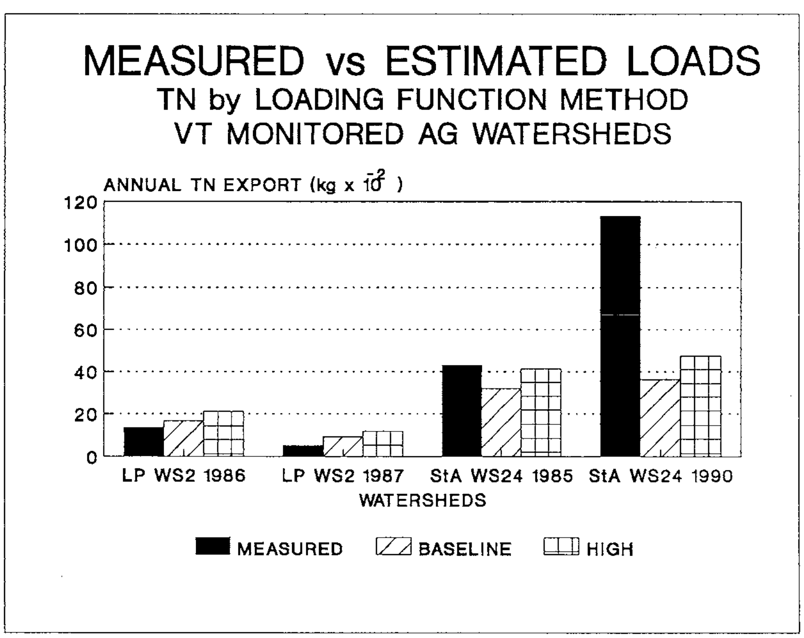

MEASURED vs ESTIMATED LOADS
TN by EXPORT COEFFICIENT METHOD
VT MONITORED AG WATERSHEDS
ANNUAL TN EXPORT (kg x 10^-2)
120
100
80
60
40
20
0
LP WS2 1986
LP WS2 1987
StA WS24 1985
StA WS24 1990
WATERSHEDS
MEASURED
LOW
BASELINE
HIGH

FIGURE 6.17


MEASURED vs ESTIMATED LOADS
TP by LOADING FUNCTION METHOD
VT MONITORED AG WATERSHEDS
ANNUAL TP EXPORT (kg x 10⁻²)
16
14
12
10
8
6
4
2
0
LP WS2 1986
LP WS2 1987
StA WS24 1985
StA WS24 1990
WATERSHEDS
MEASURED
BASELINE
HIGH


MEASURED vs ESTIMATED LOADS
SRP by LOADING FUNCTION METHOD
VT MONITORED AG WATERSHEDS
ANNUAL SRP EXPORT (kg x 10⁻²)
6
5
4
3
2
1
0
LP WS2 1986
LP WS2 1987
StA WS24 1985
StA WS24 1990
WATERSHEDS
MEASURED
BASELINE
HIGH


MEASURED vs ESTIMATED LOADS
TN by LOADING FUNCTION METHOD
VT MONITORED AG WATERSHEDS
ANNUAL TN EXPORT (kg x 10⁻²)
120
100
80
60
40
20
0
LP WS2 1986
LP WS2 1987
StA WS24 1985
StA WS24 1990
WATERSHEDS
MEASURED
BASELINE
HIGH

LCB developed in Phase I. Loads from the Lake George, New York watersheds in particular were predicted poorly, while the loading function method, using baseline or high-end concentrations, predicted measured loads fairly well for most of the Vermont agricultural watersheds. However, the reasonably good agreement of estimated and measured SRP and TN loads does lend some confidence to the basin scale SRP and TN estimates that could not be validated with D/F data.

Because it can account for year-to-year differences in precipitation and streamflow, the loading function method appears to offer more promise for load estimation at this scale than does the more simplified export coefficient approach. However, the apparently extreme sensitivity of the very small Lake George watersheds to precipitation patterns suggests that simplified approaches to nonpoint source load estimation that are effective at a larger scale may not be appropriate at a very small scale.

7.0 DISCUSSION

7.1 Contributions to Nonpoint Source Loads by Land Use.
The nonpoint source TP, SRP, and TN load estimates developed for different scenarios are summarized in Table 7.1, along with the percentages of the total contributed by each of the three major land uses. Results of the best-fit scenario - the loading function model using low-end concentrations - are highlighted. **Clearly, most of the estimated nonpoint source phosphorus and nitrogen loads were contributed by agricultural land. Urban land contributed nearly 20% of phosphorus and just 5% of total nitrogen. Forest land contributed very little to the estimated phosphorus load, but was the source of a significant proportion of nitrogen load.** As discussed in Section 6.6, septic systems were not seen to be significant contributors of phosphorus to Lake Champlain.

The land use within the Lake Champlain Basin and the percentages of total estimated pollutant loads contributed by the major land use categories are compared in Figure 7.1. While forest land was the dominant land use in the LCB in this study, it was the source of very little of the estimated nonpoint source load to the Lake. Agriculture, occupying 28% of the Basin, contributed an estimated 66% of the TP, 78% of the SRP, and 59% of the TN to the Lake. Urban land, comprising just 3% of the Basin, contributed 18% of the estimated TP and SRP loads.

There are several ways to look at these results. Because forests are generally not intensively managed (e.g. fertilized, extensively harvested) in the LCB, the nonpoint source loads contributed by forest land could be viewed as "natural" or "background" loads, not easily subject to reduction or control. If this is true, then agriculture represents not 66%, but **79%** of the cultural nonpoint source TP load, and urban **21%**. **Since agricultural land contributes the majority of nonpoint source phosphorus and nitrogen to Lake Champlain any strategy to reduce nonpoint source loads must deal with agricultural sources. However, urban/developed land comprises just 3% of the basin, yet contributes an estimated 18% of the nonpoint source phosphorus load. This suggests that relatively high efficiencies in nonpoint source load reductions might be achieved by also addressing urban nonpoint source controls.**

While certainly not definitive, the results of Phase II suggest that within the general category of agriculture, hayland and pasture land may be the largest contributors of nonpoint source loads, primarily because they are the dominant agricultural land use by area. Corn land, however, was estimated to contribute a disproportionate share of phosphorus and nitrogen compared to its land area. Within the urban category, residential and commercial land, along with roads, appear to be the most important contributors of nonpoint source pollutants.

7.2 Contributions to Nonpoint Source Loads by Region.
It is also useful to assess where the estimated nonpoint source loads may come from. **Based on the loading function calculations, 73% of the TP load originated from the Vermont/Quebec side of the lake and 27% from New York/Quebec.** This is very similar to the 77%/23% split between Vermont/Quebec and New York observed in the D/F monitoring (VTDEC and NYSDEC, 1994). Considering background vs controllable nonpoint source loades (i.e. forest vs agriculture+urban), Vermont/Quebec

TABLE 7.1

TOTAL PHOSPHORUS NPS LOADING ESTIMATES

SCENARIO	NPS TP LOAD (mt/yr)	% FOREST	% AG	%URBAN
EXPORT COEFFICIENTS				
Baseline coefficients	499.6	26.5	56.8	16.8
Low-end lit. coefficients	250.6	21.1	56.6	22.3
High-end lit. coefficients	886.5	35.9	52.0	12.1
10% AG==>URB	556.4	23.8	45.9	30.3
20% AG==>URB	626.3	21.1	39.3	39.6
LOADING FUNCTION (ave.)				
Baseline coefficients	815.4	13.4	74.0	12.6
Low-end lit. coefficients	**456.8**	**15.9**	**66.0**	**18.0**
High-end lit. coefficients	1328.2	13.7	68.1	18.2
10% AG==>URB	860.7	12.7	63.1	24.2
20% AG==>URB	905.9	12.1	53.3	34.7

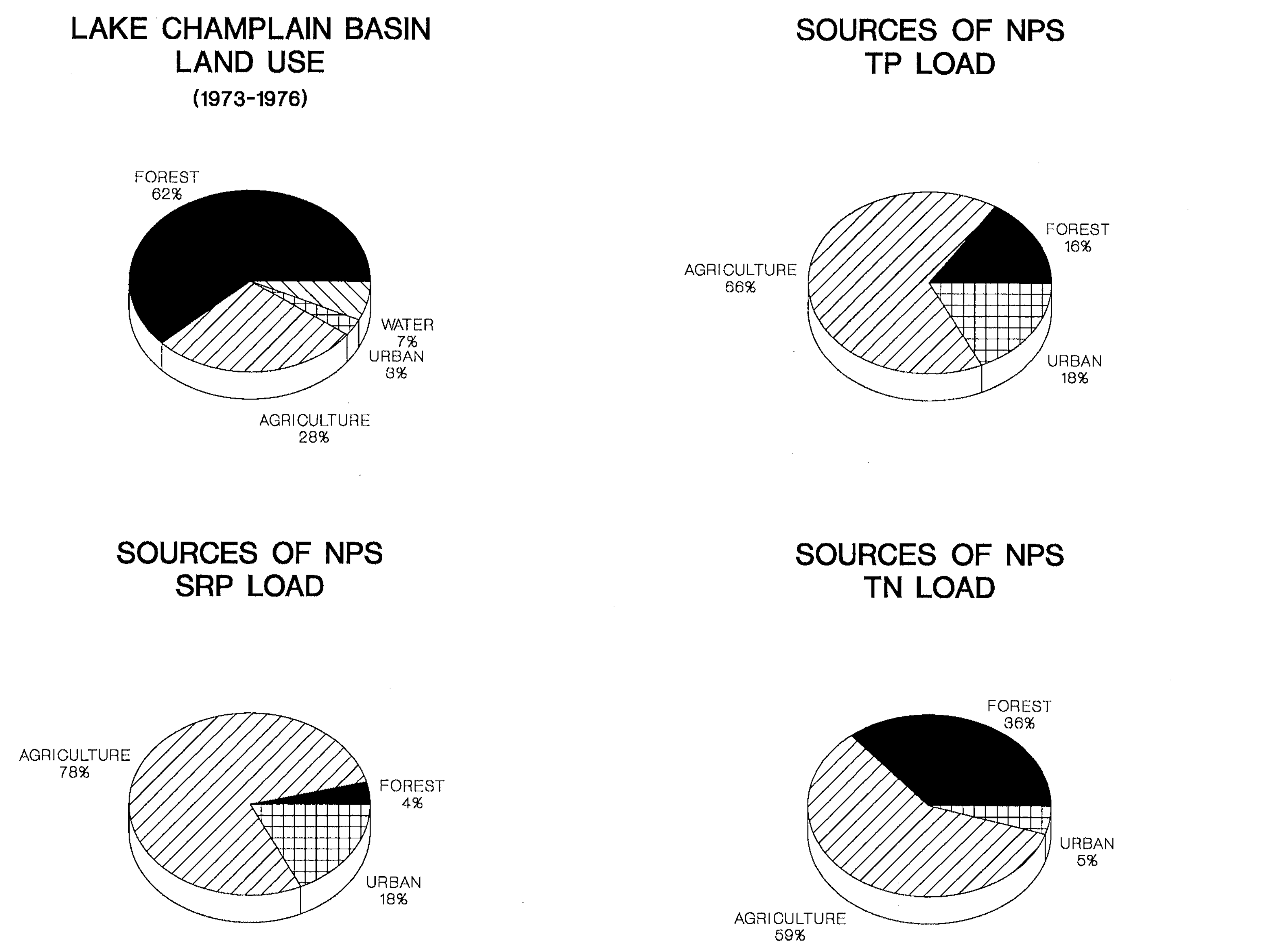
SOLUBLE PHOSPHORUS NPS LOADING ESTIMATES

SCENARIO	NPS SRP LOAD (mt/yr)	% FOREST	% AG	%URBAN
EXPORT COEFFICIENTS				
Baseline coefficients	179.1	36.9	47.5	15.6
Low-end lit. coefficients	128.9	51.3	39.6	9.1
High-end lit. coefficients	273.2	33.9	45.7	20.4
10% AG==>URB	199.0	33.2	38.5	28.3
20% AG==>URB	218.8	30.2	31.1	38.7
LOADING FUNCTION (ave.)				
Baseline coefficients	290.8	17.5	62.2	20.2
Low-end lit. coefficients	**193.4**	**3.8**	**78.0**	**18.3**
High-end lit. coefficients	472.8	35.4	44.7	19.9
10% AG==>URB	333.0	15.3	48.9	35.8
20% AG==>URB	375.2	13.6	38.6	47.8

TOTAL NITROGEN NPS LOADING ESTIMATES

SCENARIO	NPS TN LOAD (mt/yr)	% FOREST	% AG	%URBAN
EXPORT COEFFICIENTS				
Baseline coefficients	9074.2	51.0	43.8	5.2
Low-end lit. coefficients	5708.5	46.3	47.7	6.0
High-end lit. coefficients	15785	46.1	50.3	3.6
10% AG==>URB	9159.3	50.5	39	10.4
20% AG==>URB	9244.4	50.1	34.4	15.6
LOADING FUNCTION (ave.)				
Baseline coefficients	14100.8	41.3	53.5	5.2
Low-end lit. coefficients	**10202.4**	**35.7**	**59.1**	**5.2**
High-end lit. coefficients	18509.9	39.3	55.4	5.3
10% AG==>URB	14100.8	41.3	48.1	10.6
20% AG==>URB	14100.8	41.3	42.8	15.9

FIGURE 7.1



(Load estimates from LF, low coeff. values, average flows) contributed an estimated 76% of the TP load and New York an estimated 24%.

The geographic distribution of estimated nonpoint source TP loads is further broken down by major drainage basin in Figure 7.2. The diameter of each pie in Figure 7.2 represents the relative magnitude of the total estimated load contributed by each major drainage basin (8-digit HU). The origin of the estimated TP load for that basin is shown within each pie.

The Missisquoi River 8-digit HU (#02010007-) was the major contributor to nonpoint source TP to Lake Champlain, delivering an estimated average 86.6 mt/yr (19% of total load), of which 73% was attributed to agriculture. The Boquet-Ausable 8-digit HU (#02010004-) made the smallest contribution, an average 33.6 mt/yr (7% of total load); forest, agriculture, and urban land contributed nearly equally in this basin. The Winooski, Otter-Lewis, and Poultney-Metawee 8-digit HUs were also major contributors of nonpoint source TP, with agricultural land the dominant source in each basin and urban land making a major contribution in the Winooski which includes the most urbanized land in the Vermont portion of the LCB.

The rank-order of 17 tributary basins[1] by total basin TP load and by areal TP loading rate is shown in Figures 7.3 and 7.4, respectively for both estimated loads and loads measured in the D/F study. With respect to total basin load, there is remarkable agreement between ranks based on estimated and measured loads. In both cases, the Otter, Winooski, Missisquoi, Lamoille, and Metawee/Barge basins comprise the top five contributors, while the Salmon, Little Ausable, Little Chazy, Putnam Creek, and Mill Brook basins deliver the lowest TP loads to the Lake. The basins also sort similarly on the basis of estimated and measured areal TP load, although with the interesting exceptions noted earlier. Estimated load from the Boquet basin, for example, falls at the lowest end of the distribution, while its measured load falls more in the middle of the D/F distribution. Contributions by sediment from streambank erosion not included in the estimated may account for this disparity.

In order to more specifically focus on where nonpoint source loads may come from within the LCB, estimated nonpoint source TP loads from each 11-digit HU were converted into areal loads (kg/ha/yr) and are presented in Table 7.2. (SRP and TN loads are not discussed due to the lack of verification at the basin scale.) Estimated areal TP loads ranged from a low of 0.04 kg/ha/yr from HU #1150 in the Lake George region of New York to a high of 0.85 kg/ha/yr from HU #3080 in Burlington, Vermont. The areal loads were grouped into six classes; these classes are mapped in Figure 7.5. The highest unit area contributors of nonpoint source TP tended to be HUs in the Vermont Champlain Valley, although a few New York HUs fell into the higher classes. The HU containing the most urbanized area in the LCB contributed the highest rate of nonpoint source TP. HUs in the Lake George and Adirondack regions generally fell into the lower categories of areal load.

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[1] Note that there are several disparities between 8-digit HUs and major river basins monitored in the D/F study. For example, the Missisquoi River 8-digit HU includes both the Pike and Rock River watersheds which are not included in the area monitored by the Missisquoi River D/F tributary station. Thus, there will be some differences between values/statistics reported for the "Missisquoi River 8-digit HU" and the "Missisquoi River" tributary station.

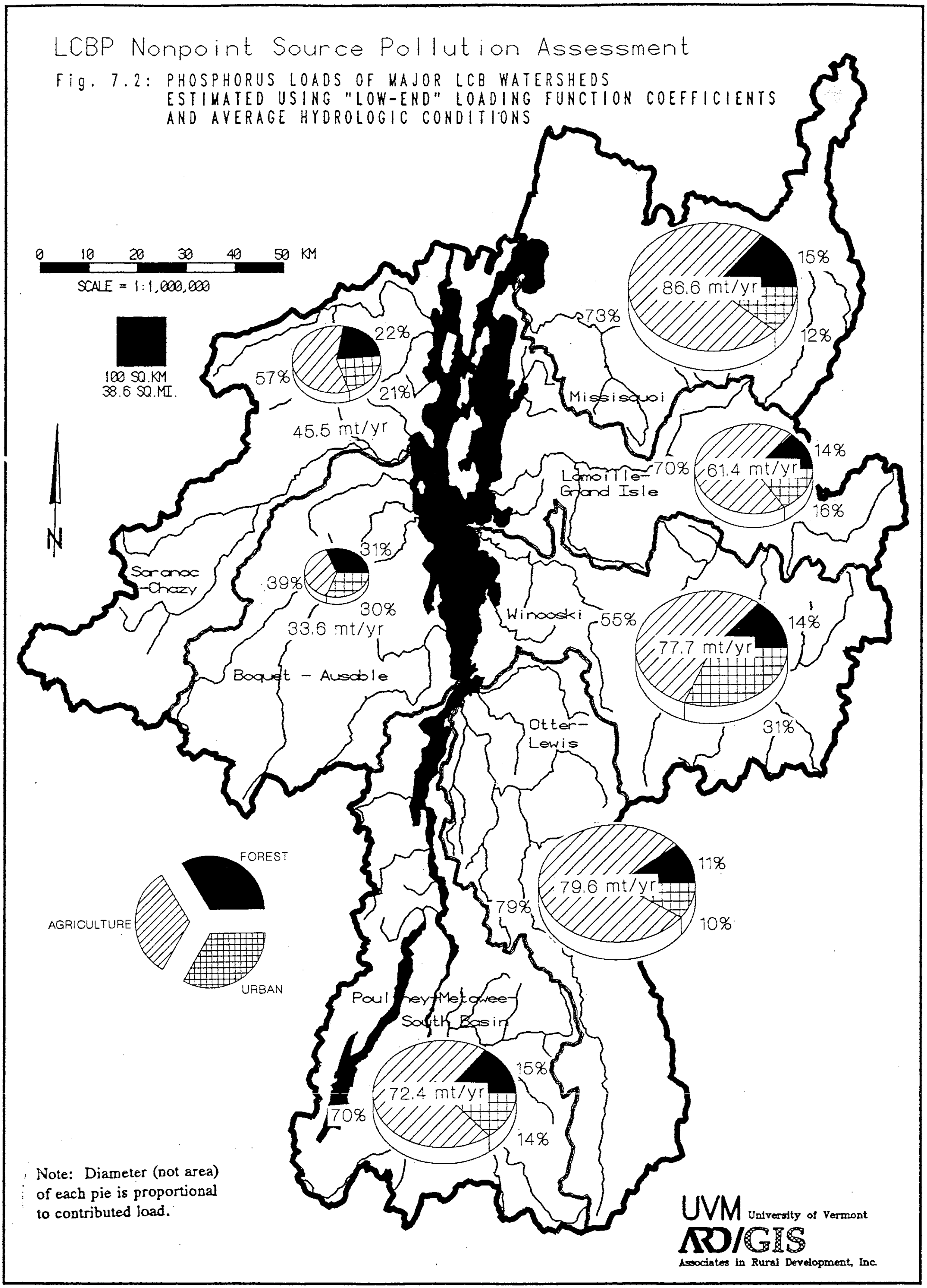

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Fig. 7.2: PHOSPHORUS LOADS OF MAJOR LCB WATERSHEDS ESTIMATED USING "LOW-END" LOADING FUNCTION COEFFICIENTS AND AVERAGE HYDROLOGIC CONDITIONS

FIGURE 7.3

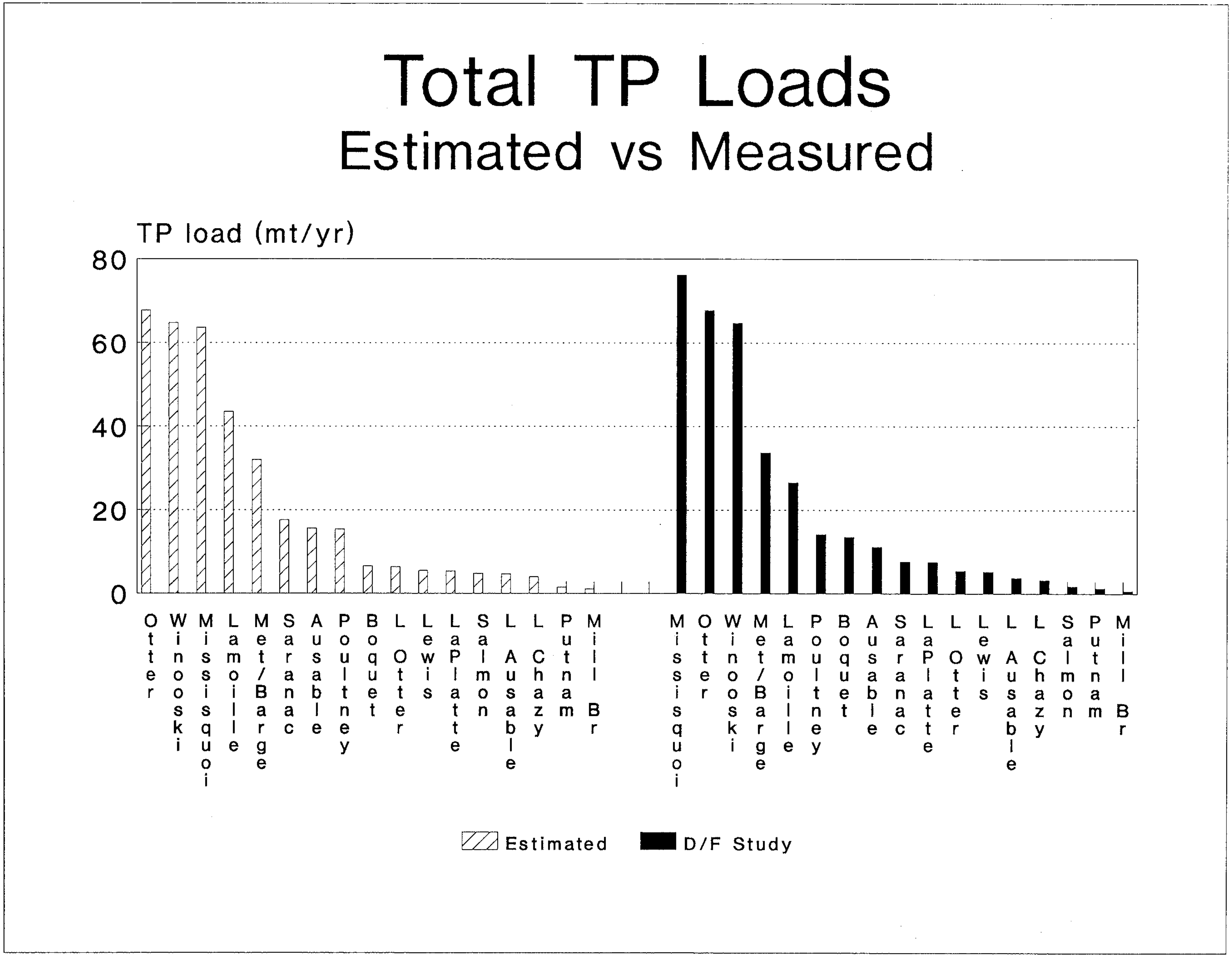

Total TP Loads
Estimated vs Measured
TP load (mt/yr)
80
60
40
20
0
Otter
Winooski
Missisquoi
Lamoille
Met/Barge
Saranac
Ausable
Poultney
Boquet
L Otter
Lewis
LaPlatte
Salmon
L Ausable
L Chazy
Putnam
Mill Br
Missisquoi
Otter
Winooski
Met/Barge
Lamoille
Poultney
Boquet
Ausable
Saranac
LaPlatte
L Otter
Lewis
L Ausable
L Chazy
Salmon
Putnam
Mill Br
Estimated
D/F Study

FIGURE 7.4

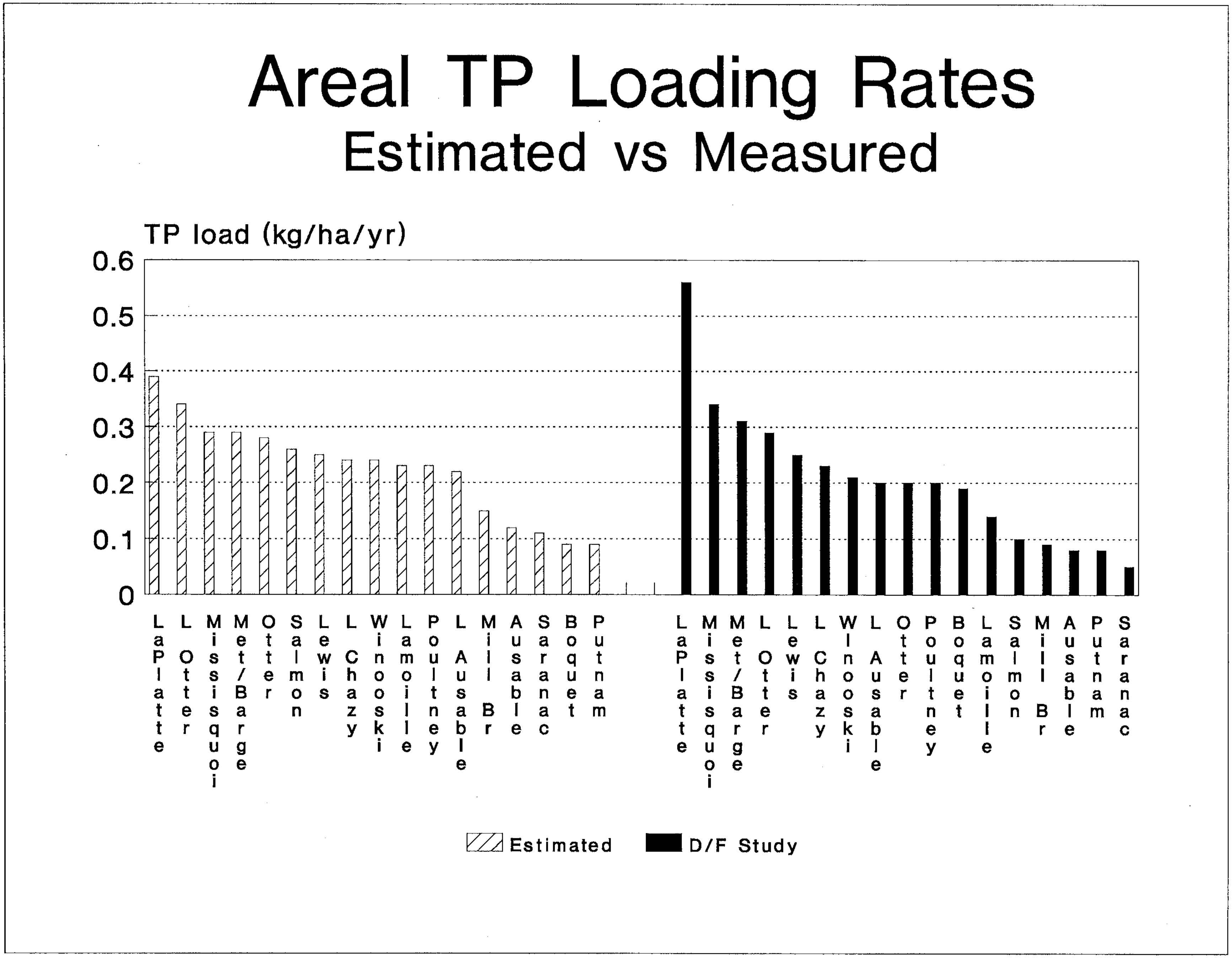

Areal TP Loading Rates
Estimated vs Measured
TP load (kg/ha/yr)
0.6
0.5
0.4
0.3
0.2
0.1
0
LaPlatte
L Otter
Missisquoi
Met/Barge
Otter
Salmon
Lewis
L Chazy
Winooski
Lamoille
Poultney
L Ausable
Mill Br
Ausable
Saranac
Boquet
Putnam
LaPlatte
Missisquoi
Met/Barge
L Otter
Lewis
L Chazy
Winooski
L Ausable
Otter
Poultney
Boquet
Lamoille
Salmon
Mill Br
Ausable
Putnam
Saranac
Estimated
D/F Study

TABLE 7.2

NPS TP LOAD ESTIMATE - AREAL LOADS

RUNOFF CONCENTRATIONS (mg/l)		
FOREST	AG	URBAN
0.01	0.1	0.28

LOW COEFFICIENTS

POULTNEY-METAWEE

HU NAME	HU NUMBER	AREA(ha)	AREAL EXPORT (kg/ha/yr)		
			LOW	AVE	HIGH
Upper Poultney R.	02010001-010	20104	0.16	0.25	0.32
Castleton	02010001-020	8301	0.10	0.20	0.26
Lake Bomoseen	02010001-030	17407	0.11	0.19	0.25
Hubbardton River	02010001-050	14560	0.15	0.24	0.31
Main Stem Poultney	02010001-070	4756	0.18	0.26	0.34
Mettawee River	02010001-090	29650	0.16	0.23	0.29
Direct to L CH	02010001-270	24849	0.25	0.36	0.47
	TOTALS	**119627**	**0.17**	**0.25**	**0.33**

OTTER-LEWIS

HU NAME	HU NUMBER	AREA(ha)	AREAL EXPORT (kg/ha/yr)		
			LOW	AVE	HIGH
Otter/Rutland	02010002-010	93760	0.15	0.23	0.31
Neshobe R.	02010002-020	5254	0.12	0.21	0.29
Middlebury River	02010002-030	16274	0.10	0.16	0.21
Mid-Otter Creek	02010002-040	47937	0.16	0.25	0.34
Bridport	02010002-050	2847	0.30	0.42	0.55
Lemon Fair River	02010002-060	20670	0.31	0.45	0.59
New Haven River	02010002-070	30131	0.14	0.20	0.27
Lwr Otter/Dead Cr.	02010002-080	27852	0.32	0.50	0.68
Little Otter Creek	02010002-090	18738	0.24	0.34	0.44
Lewis Creek	02010002-100	20999	0.18	0.25	0.33
	TOTALS	**284462**	**0.19**	**0.28**	**0.37**

WINOOSKI

HU NAME	HU NUMBER	AREA(ha)	AREAL EXPORT (kg/ha/yr)		
			LOW	AVE	HIGH
Stevens/Jail Branch	02010003-010	29842	0.23	0.33	0.44
N Branch	02010003-020	72520	0.13	0.18	0.23
Dog/Mad River	02010003-030	79983	0.15	0.22	0.30
Shelburne Pond	02010003-040	5505	0.26	0.38	0.49
Lower Winooski R.	02010003-050	87539	0.18	0.25	0.33
LaPlatte River	02010003-060	13722	0.27	0.39	0.50
Dir L Ch Shel/Char	02010003-070	6099	0.33	0.46	0.59
Dir L Ch Burl	02010003-080	5615	0.59	0.85	1.11
	TOTALS	**300825**	**0.18**	**0.26**	**0.34**

LAMOILLE-GRAND ISLE

HU NAME	HU NUMBER	AREA(ha)	AREAL EXPORT (kg/ha/yr)		
			LOW	AVE	HIGH
Upper Lamoille R.	02010005-010	97406	0.15	0.21	0.27
Lee/Browns River	02010005-020	23908	0.22	0.28	0.33
Lower Lamoille R.	02010005-030	66183	0.17	0.25	0.32
Malletts Bay	02010005-040	13643	0.25	0.36	0.47
Lwr NE Arm Direct	02010005-050	6091	0.19	0.25	0.32
St. Albans Bay	02010005-060	12966	0.23	0.33	0.44
So Main Lake Direc	02010005-070	5488	0.16	0.21	0.26
Islands	02010005-080	25328	0.18	0.24	0.30
Foucault, Que	02010005-090	23	0.10	0.14	0.17
	TOTALS	**251036**	**0.18**	**0.24**	**0.31**

MISSISQUOI

HU NAME	HU NUMBER	AREA(ha)	AREAL EXPORT (kg/ha/yr)		
			LOW	AVE	HIGH
Uppr Missisquoi R.	02010007-010	54194	0.20	0.28	0.35
Trout River	02010007-020	21647	0.14	0.19	0.24
Mid-Missisquoi R.	02010007-030	42526	0.21	0.26	0.30
Tyler Branch	02010007-040	22444	0.22	0.31	0.41
Black Creek	02010007-050	31105	0.24	0.32	0.40
Lowr Missisquoi R	02010007-060	23410	0.32	0.41	0.51
Rock R./Pike R.	02010007-070	55276	0.22	0.28	0.34
Bolton, Que	02010007-080	17713	0.21	0.25	0.30
Mansonville, Que	02010007-090	10222	0.20	0.25	0.31
Wallbridge Ck, Que	02010007-150	7086	0.18	0.24	0.30
Morpion, Que	02010007-160	11529	0.18	0.23	0.31
Pike R., Que	02010007-170	8557	0.18	0.24	0.30
Miss. Bay Dir, Que	02010007-190	4819	0.18	0.24	0.30
	TOTALS	**310528**	**0.21**	**0.28**	**0.35**

TOTAL VT/QUE	**1266478**	**0.19**	**0.27**	**0.34**

TABLE 7.2

NPS LOAD ESTIMATE - LOADING FUNCTIONS

RUNOFF CONCENTRATIONS (mg/l)		
FOREST	AG	URBAN
0.01	0.1	0.28

LOW COEFFICIENTS

SOUTH BASIN, NY

HU NAME	HU NUMBER	AREA(ha)	AREAL EXPORT (kg/ha/yr)		
			LOW	AVE	HIGH
	02010001-080	2814	0.19	0.29	0.39
Hampton	02010001-110	2097	0.25	0.38	0.52
Mettawee River	02010001-120	22752	0.21	0.30	0.39
Whitehall	02010001-130	2741	0.25	0.38	0.51
Halfway Ck/Ch Can	02010001-140	52585	0.21	0.31	0.41
Mt Hope Br/So Bay	02010001-150	12114	0.03	0.04	0.06
Clemons	02010001-160	5081	0.06	0.08	0.10
Putnam	02010001-170	4795	0.12	0.18	0.23
	02010001-180	2283	0.10	0.16	0.21
Lake George	02010001-190	59888	0.06	0.08	0.10
Ticonderoga	02010001-200	7385	0.11	0.17	0.22
Fort Ticonderoga	02010001-210	4879	0.23	0.34	0.45
Putnam Br/Crown P	02010001-220	16005	0.06	0.09	0.12
Bulwaga Bay	02010001-230	4793	0.15	0.22	0.30
Moriah	02010001-240	3015	0.18	0.27	0.35
Port Henry	02010001-250	7203	0.10	0.15	0.20
Westport	02010001-260	10885	0.09	0.15	0.20
	TOTALS	**221315**	**0.13**	**0.19**	**0.25**

BOQUET-AUSABLE

HU NAME	HU NUMBER	AREA(ha)	AREAL EXPORT (kg/ha/yr)		
			LOW	AVE	HIGH
Dir to L Ch/Essex	02010004-010	3265	0.19	0.29	0.39
No Branch Boquet	02010004-020	25496	0.05	0.08	0.10
Boquet River	02010004-030	45185	0.07	0.10	0.14
Dir to L Ch/Wboro	02010004-040	9066	0.07	0.11	0.14
E. Br. Ausable R.	02010004-050	50716	0.06	0.09	0.12
W Br Ausable/L Pla	02010004-060	63686	0.08	0.11	0.14
Lower Ausable R.	02010004-070	20733	0.13	0.19	0.26
Little Ausable R.	02010004-080	20856	0.15	0.22	0.30
Salmon River	02010004-090	18592	0.17	0.26	0.35
	TOTALS	**257595**	**0.09**	**0.13**	**0.17**

SARANAC-CHAZY

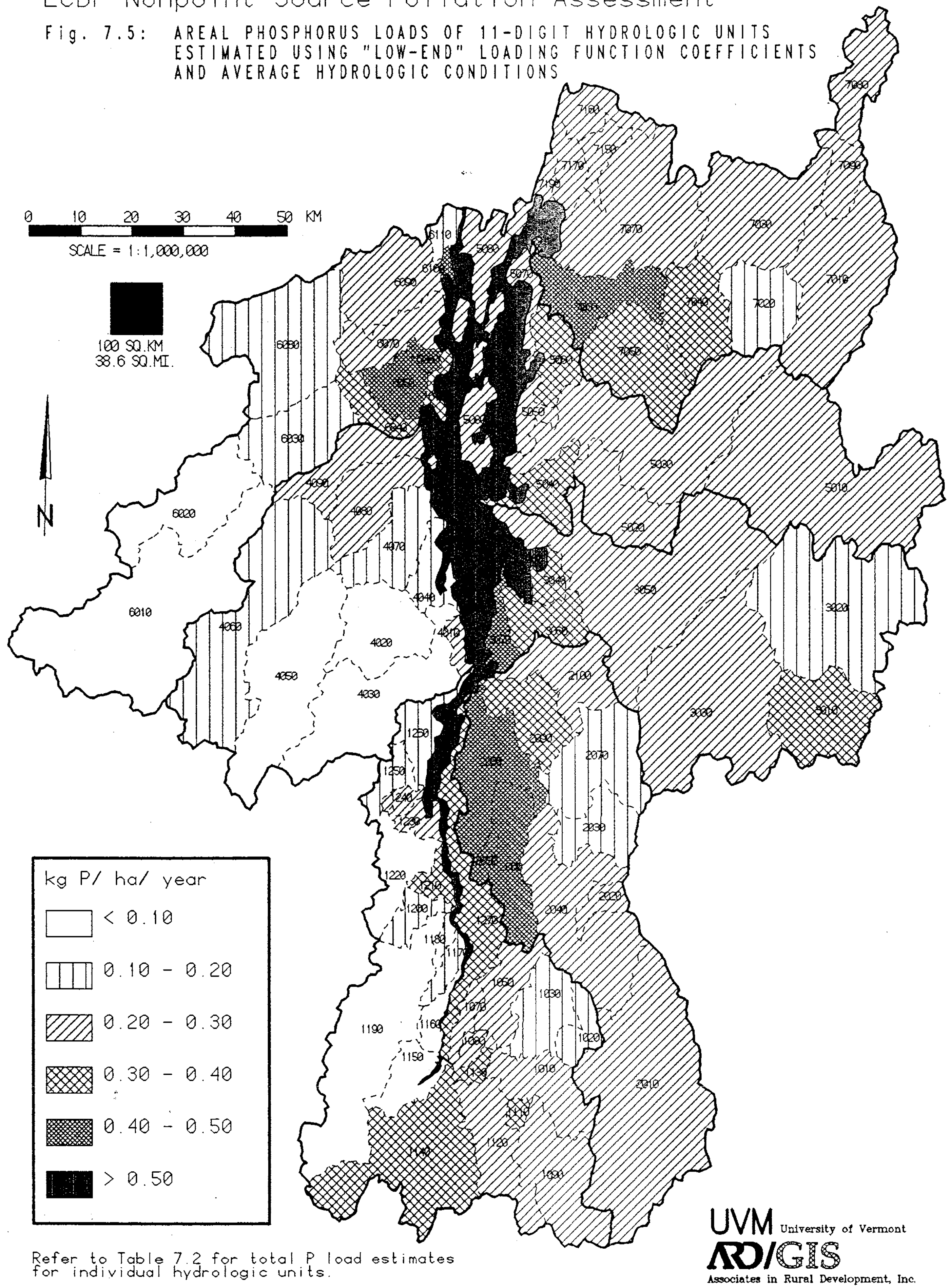
HU NAME	HU NUMBER	AREA(ha)	AREAL EXPORT (kg/ha/yr)		
			LOW	AVE	HIGH
Upper Saranac R.	02010006-010	91342	0.06	0.08	0.10
N Branch	02010006-020	33202	0.05	0.07	0.09
Mid Saranac R.	02010006-030	26587	0.11	0.17	0.22
Lower Saranac R.	02010006-040	8593	0.24	0.39	0.54
Beekmantown	02010006-050	11346	0.25	0.42	0.58
Ingraham	02010006-060	2596	0.28	0.41	0.54
Chazy River	02010006-070	16565	0.17	0.24	0.31
Gt Chazy/Graves R	02010006-080	49434	0.11	0.16	0.21
Corbeau Creek	02010006-090	27162	0.19	0.28	0.36
Rouses Pt Direct	02010006-100	1185	0.31	0.44	0.57
Lacolle, Que.	02010006-110	4415	0.15	0.19	0.24
North Plattsburg	02010006-120	2904	0.25	0.40	0.55
	TOTALS	**275331**	**0.11**	**0.17**	**0.22**

TOTAL NY/QUE	**754241**	**0.11**	**0.16**	**0.21**

	AREA(ha)	AREAL EXPORT (kg/ha/yr)		
		LOW	AVE	HIGH
TOTAL BASIN	**2020719**	**0.16**	**0.23**	**0.29**

LCBP Nonpoint Source Pollution Assessment

Fig. 7.5: AREAL PHOSPHORUS LOADS OF 11-DIGIT HYDROLOGIC UNITS ESTIMATED USING "LOW-END" LOADING FUNCTION COEFFICIENTS AND AVERAGE HYDROLOGIC CONDITIONS



The "top 10" HUs, contributing TP at rates well-above the average (0.23 kg/ha) for the LCB, were :

HU	AREAL TP LOAD
-3080 Burlington Direct	0.85 kg/ha/yr
-2080 Lwr Otter/Dead Ck	0.50
-3070 Shelb/Charl. Direct	0.46
-2060 Lemon Fair	0.45
-6100 Rouses Pt. Direct	0.44
-6050 Beekmantown	0.42
-2050 Bridport	0.42
-7060 Lwr Missisquoi	0.41
-6060 Ingraham	0.41
-6120 North Plattsburg	0.40

It should be noted that while many of these areas were highly agricultural, urban land is well represented.

While there is some uncertainty concerning exactly which parts of the LCB contribute the highest rates of nonpoint source TP, it is clear that not all land areas contribute equally. **Targeting** of control efforts to areas of greatest nonpoint source contribution is therefore critical and will yield more cost-effective treatment than simple blanket programs applied uniformly across the entire LCB.

7.3 Limitations of Methodology and Interpretation of Results.

It is important to recognize that the procedures used to arrive at the estimates of nonpoint source loads from the LCB represent, at best, a very crude model of basin processes. There are numerous sources of uncertainty and bias which include selection of appropriate concentration or export coefficient values for the various land uses, estimation of HU discharge, natural hydrologic variability, and land use change. While a formal sensitivity analysis was not conducted, it is worthwhile to make a general assessment of the relative significance of these sources of error.

7.3.1 Sources of Error and Variability. Since nonpoint source pollution is driven strongly by weather, natural hydrologic variation is obviously important. The "best-fit" estimate of 457 mt/yr TP under average precipitation, for example, actually falls within a two-fold range of 318 - 594 mt/yr, simply due to natural climatological variation. This represents not error, but an approximation of the natural variability to be expected in nonpoint source loads. The variability in estimated loads in response to selection of coefficients (which may represent either error or source variability) is greater, yielding a nearly three-fold difference between the low-end 457 mt/yr and the high-end 1328 mt/yr. In contrast, the effects of land use shifts with time (or similar magnitude mistakes in land use interpretation) are small: a 10% shift (or error) from agricultural to urban category caused just a 6% change in estimated TP load. The influence of error in estimation of discharge is only slightly greater; as outlined in Section 6.5, a 10% change in estimated flow yields a corresponding 10% change in estimated load. Thus, selection of coefficient values probably represents the most important source of error or bias in this study. This was the reason for the use of different scenarios for loading function concentrations or export coefficients.

While the obvious sensitivity of the load estimates to the selection of coefficients introduced significant uncertainty into the absolute value of the load estimates, it must be noted that the relative contributions of the three general land use categories was not radically affected by coefficient selection. Excluding the ag build-out scenarios which projected deliberate shifts in relative contributions, the range of relative contributions to TP load by land use was surprisingly narrow, e.g. Forest: 13-16%; Agriculture: 66-74%; Urban: 12-18%, for the loading function estimates. This pattern, combined with the reasonable match of the loading function TP load estimates to measured TP loads, provides confidence in the conclusions of this report with regard to the relative contributions to nonpoint source loads by land use.

7.3.2 Relative vs. Absolute Load Estimates. It should be cautioned that while the overall conclusion concerning the relative contributions to nonpoint source loads is valid, the absolute validity of the loading function concentration values selected cannot be assured. Despite the relative insensitivity of load estimates to moderate shifts in land use classification, the fact that load estimates based on 20 year-old land use data matched measured loads at all is remarkable. Why did the low-end concentration values give the best fit? It could be that since agriculture in the LCB is less intensive than in the midwest, where many of the runoff concentrations were derived, and likewise urbanization in the LCB is less extreme than in major metropolitan centers like Washington, D.C. or Detroit, the lower pollutant runoff concentrations are, in fact, more appropriate to the LCB. Alternatively, it is also possible that the use of low-end concentrations may have helped to account for the impact of known losses in total agricultural land in the LCB between 1976 and 1991 by underestimating 1976 agricultural contributions. Thus, the selection of the specific "correct" export coefficients or runoff concentrations cannot be made with a great deal of confidence until this load estimation approach can be applied to current land use data and thereby be calibrated against comparable measured loads.

The absolute validity of the estimated geographic distribution of nonpoint source contributions by HU, river basin, region, etc. should be viewed with similar reservations. While the breakdown of estimated TP loads between Vermont and New York and the rank-order of the major tributaries' estimated contributions compared very well with D/F tributary mouth loading data, the relative contributions of the smaller 11-digit HUs are far less certain. Important natural processes such as streambank erosion, transport attenuation, and pollutant retention/processing in wetlands and impoundments are totally ignored by the estimation methods used. Cultural influences, such as region-to-region variations in land management, use of agricultural management practices, urban street-sweeping, etc., are also not accounted for. Furthermore, the estimated areal TP loads discussed earlier refer to export from HU outlets, not necessarily to loads actually delivered to the Lake. Thus, it is difficult to evaluate the contributions of individual 11-digit HUs to Lake Champlain.

7.3.3 Models Based on Average Conditions. It should also be stressed that the load estimation approaches used in this project were, of necessity, based on broad generalizations and average conditions: average export coefficients, average runoff concentrations, average precipitation, average runoff coefficients, average streamflow, etc.. While this approach works at the LCB or major river basin scale, it does not seem to work well at a very local scale. It was seen, for example, in Section 6.6, that some drainage areas did not behave according to the average pattern. Measured TP load from the LaPlatte River watershed, for example, was substantially higher than was estimated from average conditions, while measured TP loads from several predominantly forested watersheds in New York were significantly lower than predicted. Such variability is to be expected in a large, complex basin that encompasses a wide variety of different land uses, land cover, soils, slopes, and cultural practices.

Results from Phase II underline this point. The very small Lake George watersheds, for example, behaved very differently from expectations, probably because of variations in seasonal or even individual precipitation event patterns. In the Vermont WS 24, the underestimation of TN export may have been due to extensive tile drainage in that watershed; tile drainage can represent a direct input of nitrogen to surface waters that is not accounted for in surface runoff export coefficients or loading functions. Furthermore, transient sources of nonpoint source pollutants, such as logging, construction, or storms of unusual magnitude were not addressed in this broad scale assessment, but could be very important sources at a small scale. While such factors probably tend to "average out" in large drainage areas, they are likely to be more significant in small watersheds, confounding the accuracy of load estimations at a small scale.

7.3.4 Detailed vs. General Land Use. Finally, the question of detailed vs. general land use classification must be addressed. In Phase II, the use of detailed land use classifications did not seem to significantly improve load estimates derived from the general land use categories used in Phase I. It may be, therefore, that little improvement of overall basin-scale nonpoint source load estimates could be expected from application of highly detailed land use classifications.

However, use of detailed land use categories does permit some inferences to be drawn concerning the specific sources of nonpoint source loads, e.g. residential vs. commercial or row crop vs. hayland. Such inferences would be extremely important in targeting nonpoint source reduction efforts within specific watersheds. Unfortunately, given the relative inaccuracy of estimated loads derived in Phase II, reliable application of such detailed load estimations in small watersheds will depend on better documentation of runoff concentration coefficients or improvements in estimation procedures.

In summary, the results of this assessment provide reasonable estimates of the contributions to nonpoint source loads by forest, agricultural, and urban land in the LCB and a reasonable evaluation of the regional geographic distribution of nonpoint source loads to Lake Champlain. These estimates are, however, based on very broad, average conditions and are subject to increasing uncertainty as they are applied at finer spatial and/or temporal resolution. Reliable application of the methods and coefficients used in this assessment to small drainages at specific times will depend on further research and monitoring.

7.4 GIS Methodology and Database.

This type of analysis could not have been done without a GIS. Simply determining the area of each of the 85 HUs in the LCB would require a Herculean and error-prone effort of planimetering all the pieces of each HU occurring on different topographic maps, then summing the pieces. Manually intersecting the HU boundaries with both land use data and the precipitation polygons would have been even more difficult. While generating the precipitation polygons from the point locations of the precipitation gages is conceptually easy, it would again require laborious and error-prone manual work spread out over many map sheets.

Clearly, GIS technology provides a powerful tool that was necessary for accomplishing the quantitative spatial analysis required for this study. However, because of major deficiencies in the available source data, the results should be interpreted only in the general way. The main weaknesses in the original data were the age and classification scheme of the land use data. Obviously, it would be preferable to compare observed water quality data to estimates based on contemporaneous land use data. However, even with a 20 year discrepancy between the date of the estimated and observed P loads, the study has shown that, using GIS along with the other elements of this approach, land use can be a good predictor of nonpoint source phosphorus loads at the basin scale. Moreover, because of the use of GIS technology, the assessment can be easily replicated using improved land use data when available, since the HUs and hydrologic parameters have already been defined and will not change substantially.

7.5 Recommendations for additional research and monitoring

7.5.1. HU Mapping. The level of detail and the accuracy with which HUs have been defined by USGS and SCS were sufficient for the purposes of this study. However, to facilitate more specific phosphorus load allocation and eventual reduction, the HUs should be re-defined and coded hierarchically starting at the lake and working upstream, systematically subdividing major watersheds based on river branching to reflect hydrology. With the current scheme it is impossible to do accurate watershed accounting, i.e. sum the areas, flow, and pollutant loads from the various tributaries to a major river. Some examples of problems with the current USGS-SCS hydrologic mapping scheme are:

- The Rock and Pike Rivers and their tributaries are included in the Missisquoi basin instead of each having their own basin and code.

- HU-7070 that includes Lake Carmi should be numbered -7170 because it flows into the Rock River, not the Missisquoi. The -7070 code indicates that this HU is part of the Missisquoi basin.

- The Dog River and the Mad River, two major tributaries to the Winooski River, are combined along with a stretch of the Winooski itself, into one HU (-3030) yet Shelburne Pond has its own HU (-3040).

- At the southern end of the study area, HU -1090 actually contributes to the Mettawee drainage and so should have a number such as -1190. Its current code of -1090 indicates it contributes to the Poultney basin.

- The boundaries of HUs -1080, -1070, and -1050 need to be checked. Currently the Poultney River itself is indicated as a watershed boundary.

- Watersheds should not be split merely because they span political boundaries. Neither the United States - Canada border nor the New York - Vermont should not be treated as a watershed divide. The HUs along the international border need to be re-coded based on the river into which they drain.

7.5.2 New land use mapping. The weakest aspect of this study was its reliance on twenty year old land use data of unknown accuracy. As was pointed out earlier, the GIRAS land use database does not include the Canadian portion of the watershed and even excludes a small strip of New York and Vermont just south of the border with Canada. Although the results indicate that the approach is valid, using a current, comprehensive land use dataset would allow results to be interpreted with much more confidence. Several recommendations can be made with regard to accuracy, resolution, and classification schemes for any new land use mapping effort that is undertaken for the LCB.

The accuracy of the GIRAS land use data is unknown; presumably there was no ground verification involved. The more accurate the land use data, the more confidence there will be in any pollutant load estimates or any other conclusions generated from the land use data. Classification accuracy of 90% is a worthwhile goal. Regardless of the accuracy level achieved, it is essential that accuracy be reported along with the method of verification and information on typical classification problems encountered so that if the land use data must be made to fit the available loading coefficients this can be done in a logical fashion.

For a basin-wide assessment the spatial resolution of the GIRAS data set (4 hectares for urban uses and 16 hectares for other uses) was appropriate. If this type of assessment is to be pursued at the river basin or individual HU level, then the spatial resolution of the land use classification should be increased to something like two hectares to capture typically small but potentially high-P contributing land uses such as barn yards, roads, and construction sites.

For a first basin-wide assessment of nonpoint sources of pollution, the land use classes urban, agriculture, and forest were sufficient. The surprisingly close agreement between measured tributary P loads and loads estimated using twenty year old land use data indicates that a second iteration of the model using current land use data, even if it consists of only these same four classes, would be extremely worthwhile. Agreement a second time would further validate the approach and give more confidence in the runoff concentrations selected from the literature and the absolute values of the loads estimated for the basin and the major sub-basins.

Ultimately, to manage P and other nonpoint pollutants more detailed land use information will be needed for the basin or for specific study areas within the basin. However, unless runoff concentration values or export coefficients can be matched to detailed land use classes, a more detailed land use mapping effort will not result in a more refined estimate of nonpoint loads. These values could be selected from the nonpoint literature as was done in this study or, preferably, should be the result of field work completed within the LCB. For example, a very specific class, such as "potatoes", suggested for the new proposed land use mapping effort for the LCBP

(VCGI, 1993), will have to be lumped into the class "mixed agriculture" to run the model unless a suitable value for P runoff concentrations from potatoes is determined.

For a more refined basin-wide nonpoint load assessment or for assessments at the level of sub-basins or individual HUs, it would be desirable to distinguish the following land use classes:

Urban

- low density residential - < 2 units/acre
- high density residential - > 2 units/acre
- commercial/industrial/ institutional
- urban open - parks, cemeteries, golf courses, athletic fields
- roads and highways
- other paved areas
- construction

Agriculture

- row crops
- hay
- pasture
- orchards/tree farms
- farmsteads - includes house, barn, manure pits, silos, etc.
- open idle - reverting ag land; includes brush

Forest - > 50% canopy closure

Wetlands

Water

Barren land - bare rock, soil

Quarries, gravel pits

Note that for some very localized activities, such as construction sites and farmsteads, detailed on-site investigations may be required to assess pollution potential, since actual loading from such sources is highly dependent on specific use and management conditions. Detailed category definitions and decision-making rules must be provided to this (or any other) classification scheme so it can be applied consistently and the results interpreted correctly. The category definitions should take into consideration the field work done to produce the runoff concentrations (or export coefficients). The definitions and the size of the minimum mapping unit would also depend on the size of the study area and the means of data collection.

7.5.3 Nonpoint source runoff concentrations/export coefficients. The selection of appropriate runoff concentration values or export coefficients is critical to accurate estimation of nonpoint source loads. However, without new data from within the LCB, there is little value in further evaluation of the available literature to refine coefficients. Neither is there much value in attempting to exhaustively "calibrate" coefficients to measured loads; there are nearly an infinite number of possible combinations that could be forced into such a calibration.

Accurate runoff concentrations (or export coefficients) for specific land uses within the LCB should be derived from actual monitoring within the basin. **It is recommended that selected small watersheds or drainage areas of relatively homogeneous land use be monitored in order to develop improved nonpoint source runoff coefficients for the LCB.** These coefficients could then be applied to the land use mapping categories described above. Monitored areas could include an undisturbed forested watershed in the Adirondacks, small agricultural watersheds, individual crop fields, residential neighborhoods, and highway drainages. Such monitoring efforts could be relatively easily integrated with efforts of state or provincial agencies, universities, or regional entities such as the APA or the Vermont Monitoring Cooperative (Wilmot and Scherbatskoy, 1993) and could draw from ongoing work, not necessarily new projects.

One obvious advantage of such an effort would be the ability to evaluate land uses specific to the LCB, as well as pollutants of specific importance that are not well represented in the literature, such as bacteria or pesticides. Such a program would have additional value in long-term evaluation of the effectiveness of nonpoint source management efforts in the basin. As management activities changed, for example, on corn land or on residential lawns, new data on runoff quality could be incorporated into load estimates to assess progress toward the achievement of management goals for the lake.

7.5.4 Model Refinement. The model developed in this study has successfully identified the dominant land use contributor of nonpoint source phosphorus to Lake Champlain and has very generally identified regions of the LCB that appear to be major areas of concern. However, Phase II results indicate that this approach to estimating nonpoint loads is not yet reliably applicable at the much higher level of resolution that will ultimately be needed for allocation of phosphorus load reductions, i.e. individual small watersheds. Therefore, several improvements in the load estimation model developed in this project can be recommended.

The first step should be refinement of basin-scale nonpoint source load estimates based on **development of well-documented, comprehensive, contemporary land use data and the continuation of tributary mouth load measurement**, perhaps for additional pollutants beyond total phosphorus. The same general forest-agriculture-urban classification is probably appropriate for basin scale application. Such a land use data base, combined with more accurate and reliable runoff coefficients, would probably take the general basin-scale nonpoint source load estimation model as far as such a simple, empirical model should logically go.

Refinement of the load estimation procedures in small watersheds using detailed land use data should be the next step. A reliable, accurate procedure for estimating nonpoint source loads in small watersheds, and for determining their source, will be invaluable in the river basin load reduction allocation process that is a critical element in the phosphorus management strategy for the Lake. This process will depend on the development of the kind of detailed land use classifications and specific concentration coefficients discussed above and will require **additional land use and water quality monitoring** in small (i.e. 11-digit HU or smaller), heterogeneous watersheds within the LCB for validation. The database will need to include a greater number of sites and a longer duration of monitoring than currently exist in the LCB.

Beyond the above recommendations, there are limits to the application of the type of simplified procedure employed in this study. This type of model cannot, for example, account well for variations in hydrology, soils, topography, etc., across the LCB; it cannot account for natural phenomena such as transport loss/attenuation or extreme events or for cultural factors such as changes in management practices.
If a more detailed allocation of nonpoint source pollutant loads to their sources is desired, a more sophisticated model will be needed that can account for such influences.

For this reason, **it would be ultimately desirable to strive for the development of a linked watershed-lake, calibrated, physical process simulation model that could be used to reliably estimate nonpoint source loads to the lake and to evaluate the impacts of changes in land-based management practices.** An example of this type of model is the Chesapeake Bay Watershed Model (Donigian, et al., 1991). Such a model would provide the knowledge necessary to bridge the gap between the results of this study and specific phosphorus management recommendations. While this is an ambitious goal, it would provide a tool of major significance for the long-term management of Lake Champlain and its Basin.

8.0 SUMMARY AND CONCLUSIONS

1 While nonpoint sources are known to contribute roughly 80% of the nutrient load to Lake Champlain, there is little firm knowledge or agreement concerning the importance and relative contributions of general nonpoint source categories - forest, agriculture, and urban land - to the total nonpoint source load. Some understanding of what land activities and which drainage areas contribute most nonpoint source pollutants is essential for cost-effective management of Lake Champlain.

2 This study combined literature values for nonpoint source loadings with existing land use and hydrologic data, along with GIS technology to estimate the relative contributions of nonpoint source pollutants by land use and by drainage area to Lake Champlain. Two techniques were employed - export coefficients and loading functions - to estimate annual phosphorus and nitrogen loads from the entire Lake Champlain Basin to the Lake under a variety of scenarios. Phosphorus loads measured in the Diagnostic/Feasibility study were used to validate the load estimation models.

3 The load estimation procedures were also tested on four small watersheds in order to utilize more detailed land use information that was contemporaneous with the available water quality data.

4 An extensive review of the nonpoint source literature yielded runoff concentration values and export coefficients for total phosphorus (TP), soluble reactive phosphorus (SRP), and total nitrogen (TN) that are appropriate for the Lake Champlain Basin, but only very limited values for other nonpoint source pollutants.

5 The average values for TP selected as appropriate for the Basin were:

	Export Coefficient	Runoff Concentration
Forest	0.1 kg/ha/yr	0.015 mg/l
Agriculture	0.5 kg/ha/yr	0.20 mg/l
Urban	1.5 kg/ha/yr	0.35 mg/l

6 In 1973-1976, the most recent existing land use baseline for this assessment, the Lake Champlain Basin (excluding the Canadian portion) consisted of 62% forested land, 28% agricultural land, 3% urban land, and 7% water.

7 At the Lake Champlain Basin scale, a variety of scenarios of coefficient selection, hydrologic condition, and land use change were evaluated. The loading function method using "low-end" coefficient values not only predicted total load to the lake extremely well but also predicted individual tributary loads accurately.

8 The loading function method of nonpoint source load estimation is preferred over the export coefficient approach because it is sensitive to natural variations in precipitation and stream flow and allows predictions of a range of expected nonpoint source loads, rather than a single "average" value.

9 Based on the best-fit nonpoint source estimation model, agriculture contributes 66% of the average annual TP load to Lake Champlain, urban land contributes an estimated 18% of the annual TP load, and forest land contributes 16% of load. A generally similar pattern emerged for SRP and for TN loads.

10 Approximately 73% of the nonpoint source TP load is estimated to come from the Vermont/Quebec side of the Lake Champlain Basin, and 27% from the New York portion. Large drainage basins which include much agricultural land, such as the Missisquoi River basin, tend to contribute the largest loads to the lake. Predominantly forested drainage basins such as the Boquet-Ausable, contributed the smallest estimated loads.

11 The 11-digit hydrologic unit (HU) containing the most urbanized area in the Lake Champlain Basin -Burlington, Vermont - showed the highest estimated areal TP export rate (0.85 kg/ha/yr). In general, the highest-contributing 11-digit HUs included highly urban areas as well as predominantly agricultural land.

12 Because the simple loading function model does not account for important natural and cultural processes that influence nonpoint source activity and because the model was run using twenty year old land use data, little reliance should be placed on the absolute estimates of nonpoint source contributions to the lake by individual 11-digit HUs.

13 Since agricultural land contributes the majority of nonpoint source P and N to Lake Champlain, any strategy to reduce nonpoint source loads must deal with agricultural sources. However, urban land, comprising just 3% of the basin, contributed 18% of the estimated load; this disproportionate contribution suggests that relatively high efficiencies in nonpoint source load reductions might be achieved by also addressing urban nonpoint source controls.

14 Even under worst-case assumptions, failed septic systems are likely to be responsible for only up to about 5% of the total annual phosphorus load to Lake Champlain. While failed septic systems can be serious threats to public health and water quality on a local or county scale, at the scale of the Lake Champlain Basin, they appear to represent only a very small portion of the phosphorus load to the lake.

15 The relatively good agreement between measured and estimated stream flow in the Phase II watersheds provides confidence in the overall flow estimation procedures used in the loading function model in both Phase I and Phase II.

16 In Phase II, nonpoint source loads from the small Lake George watersheds were not estimated very well by either of the techniques that seemed to work at the basin scale. Load estimations in the Vermont small watersheds were somewhat better and reasonably good agreement between estimated and measured SRP and TN loads in these watersheds does lend some confidence to the basin-scale SRP and TN estimates that could not otherwise be validated.

17 The load estimation models used in Phase I of this assessment were based on average conditions: average export coefficients, average runoff concentrations, average precipitation, average runoff coefficients, average stream flow, etc. While this approach works at the Lake Champlain Basin or major river basin scale, it does not seem to work well at a very local scale. Very small watersheds can behave very differently from average expectations in response to individual storm events, transient activities such as construction, or particular cultural practices. While such factors probably tend to average out in large watersheds, they are very likely to be more significant in small watersheds, confounding the accuracy of load estimates.

18 The choice of coefficient values and natural hydrologic variability were the most important sources of uncertainty in the load estimations. Errors in estimation of discharge from the HUs and errors or shifts in land use distribution have relatively small influence on load estimates.

19 At the basin scale, relative contributions of the three general land use categories were not radically affected by coefficient selection or hydrologic variability. The range of relative contributions to annual TP load was consistent: Forest 13-16%; Agriculture, 66-74%; and Urban 12-18%.

20 The use of 20 year old land use data was a major weakness of this study and limits the conclusions that can be drawn regarding specific land uses and areas of the basin to be targeted for nonpoint source management. It must be emphasized that land use patterns have undoubtedly changed since 1976; farm numbers in the Vermont portion of the LCB, for example, may have declined by almost 50% since 1976.

21 Without contemporary land use data, it is not possible to evaluate, in an absolute sense, what the "correct" nonpoint source runoff coefficients are for the Lake Champlain Basin.

22 Future basin-scale nonpoint source load estimates should be refined through the development of better, contemporary land use data and by the continuation of tributary mouth load measurements. Any new land use mapping effort for the Lake Champlain Basin should select and define land use categories to coincide with available loading/concentration coefficient values if it is expected to provide a more specific indication of significant nonpoint sources.

23 GIS was an indispensable tool for this assessment and will facilitate additional iterations as better data, particularly land use, become available.

24 The SCS-USGS hydrologic unit mapping scheme was adequate for the purposes of this basin-wide assessment. However, a hierarchical coding of watersheds and surface water based on river branching would be much more useful and accurate for studying and managing water quality.

25 Because the selection of nonpoint source runoff coefficients is the largest source of uncertainty in this load estimation methodology, estimating loads more

accurately will require developing coefficients that are specific to conditions and practices in the Lake Champlain Basin. Developing such coefficients will involve monitoring small watersheds with relatively homogeneous land use over several years.

26 In view of the inherent limitations of simplified, empirical estimation models, it would be ultimately desirable to develop a linked watershed-lake, calibrated physical process simulation model of the type now in use for the Chesapeake Bay. Such a model could be used to reliably estimate nonpoint source loads to the lake and to evaluate the impacts of changes in land-based management practices on water quality in Lake Champlain.

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10.0 Appendices

A Project Advisory Committee Members

B Nonpoint Source Export Coefficients and Concentration Values

C Annual Total Precipitation Gage Data for LCB

D Area-Weighted HU Annual Total Precipitation

E Export Coefficient NPS Load Estimates for TP, SRP, and TN

F Loading Function NPS Load Estimates for TP, SRP, and TN

G River Basin NPS Load Estimates vs D/F Tributary Loading Data

H Phase II Export Coefficients and Loading Function Values

I Lake George Watersheds Phase II Load Estimates

J Vermont Watersheds Phase II Load Estimates