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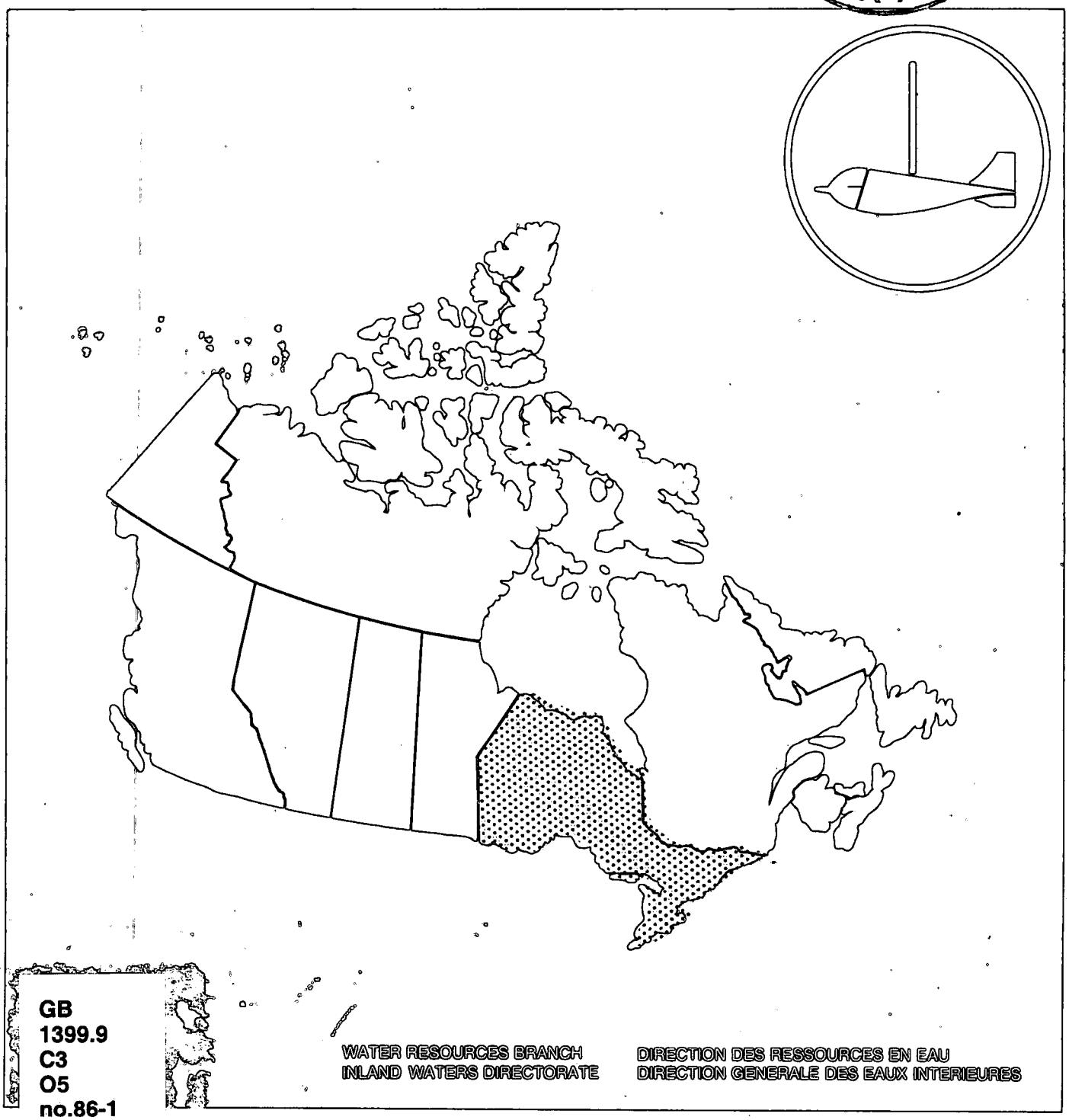
SEDIMENT ISSUES AND DATA NEEDS IN ONTARIO

CONSULTING REPORT



WATER RESOURCES BRANCH
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DIRECTION DES RESSOURCES EN EAU
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SEDIMENT ISSUES AND DATA NEEDS IN ONTARIO

Final Report

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Submitted by

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ABSTRACT

This report presents results obtained from a study of sediment issues and programs in Ontario and is one of several reviews across Canada to establish a national perspective on sediment issues and related program needs for Environment Canada. The Ontario study involved the use of a questionnaire and interviews with a cross section of sediment data users and collectors in the province, a one-day workshop of data users, and an extensive literature review. Results are combined, organized and discussed under the heading of sediment issues, knowledge, data and information systems. The report identifies needs and makes recommendations regarding the data base, sampling strategies and methods, and the sediment information system.

NOTE: A French translation of the text of this report is available upon request.

RÉSUMÉ

Le présent rapport renferme les résultats d'une étude sur des questions et des programmes relatifs aux sédiments en Ontario. Il s'agit de l'une des nombreuses études menées au Canada pour se doter d'une perspective nationale sur les questions relatives aux sédiments et sur les besoins connexes des programmes d'Environnement Canada. En Ontario, on s'est servi d'un questionnaire et on a mené des entretiens avec un transect d'utilisateurs de données et d'échantillonneurs partout dans la province. On a donné un atelier d'un jour pour les utilisateurs de données et on a fait une revue de littérature exhaustive. Les résultats ont ensuite été compilés, organisés et discutés sous différentes rubriques : questions relatives aux sédiments, connaissances, données et systèmes d'information. Le rapport signale des besoins et renferme des recommandations relativement à la base de données, les stratégies d'échantillonnage et les méthodes connexes, et le système d'information sur les sédiments.

NOTE: On peut obtenir sur demande la version française du cette rapport.

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EXECUTIVE SUMMARY

In response to a need expressed by Environment Canada, Conservation Management Systems has undertaken a thorough study of sediment issues and programs in Ontario. This study has involved the use of a questionnaire and interviews with a cross section of sediment data users and collectors in the province, a one-day workshop with representatives from many of the sediment data user groups, and an extensive literature review regarding knowledge gleaned from Ontario sediment data. Results from this multifaceted approach to the topic have been combined, organized, and discussed under the headings of: sediment issues, sediment knowledge, and sediment data. The study has led to a clarification of issues relating to sediment, an assessment of knowledge regarding sediment in Ontario, and the identification of needs and recommendations regarding the data base, sampling strategies and methods, and the sediment information system.

Sediment Issues

The exercise of clarifying sediment issues has clearly revealed that sediment data are being used and are required in the province for the exploration of a wide variety of topics, involving both quantitative and qualitative issues. A number of studies relate to the quantity of sediment deposited in channels, ponds, reservoirs, harbours and lakes. However, most sediment data users are more interested in the quality of the suspended materials being transported through the stream and lake systems.

Further, the issues being addressed reveal a focusing of attention on where the sediment is coming from, what it is carrying in the form of potential contaminants, where it is going, and how both the volume and quality of sediments affect downstream water quality and quantity.

Sediment information is required to ascertain the relative quantities of material originating from agricultural, forested, and urban areas; from streambanks and ditches; and from construction and power project sites; and to evaluate the impact of erosion and sediment control measures at such sources. There is considerable interest in the development of a global perspective of the spatial and temporal distributions of sediment yield in the province, including the development of sediment/streamflow models; and the role of suspended sediment as a transport medium for contaminants is clearly an issue of major concern. Virtually all of the issues being addressed have been precipitated by pressing downstream problems brought about by the quantity and/or quality of suspended sediment arising from and transported through the contributing watershed; and although sediment sources and watershed characteristics vary across the province, the main categories of issues identified by persons from various regions have not been noticeably different.

1. **It is concluded that there is a strongly expressed need for a sediment data base in Ontario which allows the exploration and resolution of a wide variety of sediment related issues. These issues relate to both sediment quantity and sediment quality; and attention is being and needs to be focussed on sources of sediment, associated contamination, transport and deposition mechanisms, and the manner in and extent to which the volume and quality of sediment moving downstream affect water quantity and quality and can be controlled.**

The exercise of clarifying issues has also revealed that a considerable number of people are making use of sediment information, and that a great many and a wide variety of user groups are involved. Most of the user groups are government based (federal, provincial, and municipal), and virtually all users are exploring sediment data on the basis of government funding (i.e. as civil servants, consultants on government contracts, or academics involved in research funded by government grants).

2. **The strong need for a reliable sediment data base in Ontario is confirmed by the large number of data users; and the distribution of user groups reveals the need for an efficient and economical system for collecting, interpreting, and distributing information regarding sediment and sediment issues, in order that costs are minimized for not only the users of the data but also the residents of the province.**

Sediment Knowledge

It is important to note that it is primarily since 1975 (e.g PLUARG studies) that the need for and the collection of sediment data have been addressed in the province; and it is, therefore, during the last decade that our data and knowledge bases regarding sediment have begun to develop. The study review of literature and data has selectively focussed on sediment issues of particular relevance, dealing principally with suspended sediments and conditions in Southern Ontario, and highlighting knowledge and identifying gaps with regard to stream loadings, seasonal variability, extreme events, spatial variability, sources of sediment, and sediment and water quality.

To begin with suspended sediment loadings in the province are revealed to be only a fraction of those experienced in the mountainous and alluvial regions of Canada, and to be orders of magnitude smaller than loadings observed in many major rivers of the world. It is important to recognize then that the quantity of sediment itself transported in Ontario streams is generally not of major proportions or of major significance.

3. **The development of a provincial sediment program focussed solely on the determination of sediment volumes is not justified.**

The annual suspended sediment loads, although relatively moderate, can nevertheless vary considerably from year to year. However, the skewness of the annual loads appears to be relatively insignificant. These particular characteristics have been shown to be of importance in the estimation of annual sediment loads.

4. **Single year determinations of suspended sediment loads do not provide precise estimates of long-term mean values and should not be considered as such. However, both mean and median values of 10 or more years of data provide good indices of the central tendency of annual suspended sediment loads in the province.**

Daily sediment loads in Ontario streams vary more dramatically than the corresponding annual loads, and vary over a wide range of values. However, the daily loads tend to follow a very distinctive seasonal pattern, the bulk of the annual suspended being transported during the spring period, in concert with the seasonal occurrence of high water flows. Further, in conjunction with the daily suspended sediment loads exhibiting highly skewed frequency distributions, a vary large percentage of the annual load is transported downstream in a vary small percentage of the time (in many cases, 80 to 90 percent of the annual load is delivered in less than 40 days). Therefore, the movement of suspended sediment in Ontario streams may be considered to be an event-oriented process, and reliable estimates of suspended loads are contingent upon the application of a sampling scheme in time that ensures the obtaining of good sediment samples during the brief periods when most of the load is delivered. A few of the groups collecting sediment data in the province have already adopted such an approach to sampling (e.g. the Water Resources Branch), but a number of others unfortunately have not.

5. **It is strongly recommended that sediment sampling programs in Ontario key on significant runoff events during the season when these events may be expected to occur. Sampling could be greatly reduced or virtually omitted during low flow periods throughout the year. The importance of event and seasonal sampling, acknowledged by the Sediment Survey Program, needs to be strongly advocated to all sediment data collectors in the province.**

6. **It is further recommended that the Water Resources Branch continue to develop more efficient and economical sediment sampling strategies, in light of existing knowledge regarding the highly event-oriented temporal characteristics of Ontario sediment data.**

Further knowledge about the significance of sediment peak events has been revealed in extreme-value analyses. Daily sediment loads with return periods of two years or greater account for approximately 40 percent of the total sediment loads transported by Ontario streams, and annual peak events contribute a similar, or slightly larger, significant portion of the total load. These results regarding extreme values confirm that the reliable estimation of sediment loads requires careful sampling of significant events.

From a temporal point of view, therefore, it can be concluded that the available periods of sediment record of up to 20 years in length have been extremely useful for the ascertaining of temporal and duration characteristics and extremal properties of stream suspended sediment loads. And periods of record in the order of 10 years have been useful and sufficient for the confirmation of seasonal patterns and the estimation of average annual loads. Therefore, much has been learned regarding the temporal variability of Ontario sediment loads, and there is little reason to develop long-term sediment records in the province.

7. **Sediment records maintained for long periods of time would now appear to offer very little additional information, with the exception of indications regarding long-term trends and a data base for developing stochastic sediment models. However, there is little need to monitor more than one or two stations for possible long-term trends; and unless trends in other associated variables such as land use were also monitored closely, there may be little point in maintaining a long-term record at any sediment station in Ontario.**

Regarding the spatial variability of sediment, it has been noted in the literature that the sediment yield of basins may be related to factors such as climate, basin geomorphology, soil type, and land use. For Ontario conditions, there appears to be no simple relationship between annual suspended sediment load and readily measurable geomorphologic parameters. Annual sediment yields from agricultural watersheds in

Southern Ontario have been linked to land use and surface soil characteristics; and variations in yields have been further attributed to differences in the quantity of sheet and rill erosion, in the sediment transport systems, and in the amount of streambank erosion. The bulk of suspended sediment in rural Southern Ontario streams has been linked to agricultural cropland, with material delivered from sheet and rill erosion from such areas contributing 70 to 100 percent of the annual load. The remaining 0 to 30 percent emanates from the streambanks.

It has also been discovered that the suspended sediment amounts yielded by field-sized areas within agricultural watersheds in the province can be extremely variable, particularly in rolling upland regions. As a result, a great majority of the suspended sediment leaving upland watersheds emanates from a very small percentage of the area. Sediment yield from lowland areas appears to be considerably more uniform in space.

The literature regarding spatial variability and sources of suspended sediment in Ontario reveals that we have been able to develop a preliminary picture of the spatial distribution of sediment loads. However, although significant progress has been made in understanding some of the linkages between watershed sediment yields and source characteristics, it is not yet possible to estimate stream sediment loads with sufficient reliability in terms of readily measurable watershed parameters.

8. **There is a need for an improved spatial coverage of sediment data in Ontario, and it is recommended that in the selection of sediment stations more regard be given to factors associated with the determination of sources and transport mechanisms of the sediment and associated variables.**

9. **Further, it is recommended that there be continued emphasis placed on the development of spatial patterns and cause-and-effect relationships between sediment and other variables, in order to optimize the use of monitored data and minimize the need for additional sediment stations.**

Regarding the relationship between sediment and water quality, it has now been clearly determined that many of the Ontario water bodies including the Great Lakes are being polluted from land drainage sources, and that sediment effects the pollution primarily as a carrier of phosphorus, industrial organic compounds, pesticides, and heavy metals. On the one hand, sediment can be a pollutant carrier or source, keeping potential contaminants bound to the surface of sediment particles during transport through some part of the watershed drainage system and releasing the contaminants at a downstream location. On the other hand, sediment can act as a sink or trap, scavenging pollutants from the water column of stream and lake systems and depositing the undesirable materials in bottom sediments.

Much has been learned in recent years about many of the contaminants which are associated with stream and lake sediments in Ontario, and a start has been made in understanding the processes involved in the binding and releasing of contaminants from sediment particles. However, knowledge regarding the spatial and temporal variability of these linkage processes is yet in its infancy.

10. **It is vital that carefully conceived data sets involving sediment, various contaminant, and other biochemical variables be assembled for studies to ascertain the nature of linkages among the variables and the manner in which these linkages vary in time and space in stream and lake systems in the province.**

11. **As the linkages noted in 10 become better understood, it is recommended that combined sediment and water quality sampling strategies be devised for the efficient and accurate estimating of not only sediment concentrations and loads but also various contaminant concentrations and loads.**

Sediment Data

A review of available sediment information in Ontario reveals that there are a great many groups, primarily federal and provincial civil servants,

involved in the collection. The information includes a great deal of data involving primarily suspended sediment and stream or lakebed deposits, and much of the data has been collected in relation to specific projects. There has not been a complete inventory of sediment stations available, except for separate mappings of the Water Resources Branch and Ontario Ministry of the Environment stations. Partial combined maps of these and a number of other stations have been prepared as a part of this study, and are included in the report.

At first glance, the maps would indicate that many sediment stations are widely distributed across the province, with obvious concentrations in the southern part, suggesting a reasonable spatial coverage of information. However, a closer look at the periods of record available reveals substantial incompatibility of the data.

12. **There is an urgent need for the development of an ongoing coordinated inventory of sediment data for purposes of clarifying both the spatial and the temporal coverage of information.**

13. **Further, in light of the multitude of groups involved in sediment data collection, there is also a need for a mechanism to coordinate the data made available from the many sources.**

Upon further scrutiny, the sediment data in Ontario are found to be collected by many different methods at a wide variety of sampling frequencies, and there is no readily available description of the measurement or analytical techniques used.

14. **There is definitely a need for fuller documentation regarding the approaches and methods employed by sediment data collectors in the province.**

And it also becomes apparent that the wide variety of sampling, measurement, and analytical techniques employed by the various data collectors is yielding data outputs that are extremely difficult if not impossible to compare.

15. **Future sediment data must be collected and analyzed in more compatible ways! It is, therefore, recommended that a mechanism be developed to establish standards and/or guidelines for sediment data collection in the province and to offer advisory services regarding the collection and use of sediment data.**

Discussions with both sediment data collectors and users have revealed that the range of accuracy and the possible sources of error for sediment data are not well understood and have not been adequately evaluated. Most collectors have not identified the accuracy of their sediment data base, and sediment data users have generally not specified the accuracy required for their projects. However, an increasing number of users have become interested in ascertaining the accuracy associated with the data, either because they need better data for more critical decision making or because they have become aware of gross errors in existing data.

It is now known that the sampling frequency of sediment concentrations and the method of computation of annual sediment loads can have significant effects on both the accuracy and precision of sediment load estimates. For example, most computational methods used for determining annual loads result in an underestimation of the suspended loads; and infrequent sampling of suspended sediment concentrations can lead to gross underprediction of the loads. Further, the relative level of accuracy for a particular computational method applied to a selected sampling frequency does not necessarily correspond to the relative level of precision for the same combination of method and frequency. Therefore, both accuracy and precision need to be considered when methods and sampling frequencies regarding sediment data are reviewed.

16. **It is imperative that the accuracy and precision of sediment data collected by various groups in Ontario be ascertained in relation to sampling and analytical procedures employed, and in light of the accuracy and precision warranted in user projects. It is also vital that sediment data users be clearly informed about the nature and extent of errors present in sediment data.**

It has also been informative to explore which sediment data are being used in the province. A majority of users have been found to employ Water Resources Branch data as one of their sources of information. However, almost one third of users sampled had not used this source, most of this group collecting their own data. It was further discovered that many sediment data users in the province are unfamiliar with Water Resources Branch and other sediment information; and many of the users who are aware of Water Resources Branch information do not have a very complete picture of the range of data and services available from that source. This is further evidence that the sources of sediment data need to be clarified for users (see Conclusion/Recommendation 14).

It has become clear that a wide variety of sediment data are used. Sediment data users seem generally satisfied with the type of data available; however, it would appear that many data users are somewhat uncertain about their sediment data needs. Where data preferences have been clarified, users have specified more frequent sampling, at more stations, in locations more appropriate to specific problems and issues.

17. **It is recommended that the Water Resources Branch, in conjunction with other sediment data collectors in Ontario, continue to develop their network strategy for sampling sediment information over the extent of the province, in light of spatial information and models already available, apparent gaps in knowledge, and identified needs.**

It has also become apparent that many sediment data users need or would appreciate basic interpretations provided in conjunction with published data. Although there is a diversity of opinion regarding desired interpretations, the more fundamental ones include individual station analysis and descriptions of the temporal variability of the data, regional patterns, linkages to other variables, and linkages to sediment sources.

18. **It is recommended that the Water Resources Branch explore more fully the need for basic interpretations regarding collected sediment data, and examine requirements for and implications of including such information as an integral part of an accumulated sediment data base for the province.**

A consideration of the program objectives of the various sediment collection groups, in light of the sediment problems and issues clarified earlier, has revealed that the current objectives are in general in tune with the concerns of the user groups. However, it is clear that a number of collection programs and the Sediment Survey Program in particular have been directed principally towards the determination of the quantity of suspended and deposited sediments, with little reference to the quality of such sediments or to other programs involved in monitoring other water quality variables.

19. **Sediment data should be collected in Ontario with more regard given to water quality variables of local and temporal interest, and to other data collection programs regarding such variables.**

20. **The Water Resources Branch Sediment Sampling Program should examine the relevance of their sampling methodology in time and space as well as associated laboratory analyses to not only sediment quantity but also sediment quality and associated water quality issues.**

Sediment Information Systems

It is evident from the analysis of sediment issues, knowledge, and data, that there is a substantial need for a much more coordinated approach to the collection and dissemination of sediment information in Ontario. The development of an integrated sediment information system is proposed here, in the context of the following set of recommendations, re-emphasizing some of the previously identified recommendations.

With regard to a more coordinated approach to data collection:

21. **It is recommended that sediment and sediment related data continue to be collected in Ontario by a number of agencies, groups, and individuals; and that these various data collectors work together in a coordinated fashion to develop a more integrated sediment data acquisition system.**

22. **It is recommended that cost-sharing (i.e. among the data collectors) be investigated by the collective group of sediment data collectors in the development of the data acquisition system.**

23. **It is recommended that guidelines and/or standards be developed by the collective group for the acquisition of sediment and sediment-related data in Ontario.**

24. **It is recommended that one of the agencies intimately involved with the development of the integrated sediment data acquisition system (i.e. the Water Resources Branch) be responsible for providing advisory services to data collectors and users regarding the collection, analysis, and interpretation of sediment data, continually ascertaining those interpretations deemed to be most useful to user groups.**

25. **It is recommended that the sediment data acquisition system be established to be more responsive to requests regarding specific project needs.**

26. **It is recommended that cost-recovery methods (i.e. involving sediment data users) be investigated by the collective group of sediment data collectors in the development of the acquisition system.**

And towards the development of a centralized sediment data base for the province:

27. **It is recommended that a mechanism be developed by the collective group of sediment data collectors to coordinate the various sediment and sediment-related data bases which have been and are to be assembled. The coordination should address at least information regarding the data sets available, sources of the data, and methods of data collection and analysis.**

To encourage enhanced knowledge regarding and intelligent usage of the integrated acquisition system and the centralized data base:

28. **It is recommended that information available regarding sediment in Ontario (e.g. data, collection and analysis methods, agencies involved, advisory services) be made more readily available to users.**

29. **It is recommended that the Water Resources Branch explore more fully ways of publishing and transferring sediment information to user groups (e.g. considering not only data publications, but also workshops, newsletters, etc.).**

And finally, to ensure that steps towards the development of a sediment information system will indeed be taken:

30. **It is recommended that the Water Resources Branch take the initiative in bringing together the various agencies, groups, and individuals involved in the collection of sediment and sediment-related data to consider the feasibility of and approaches for developing a better coordinated and more integrated sediment acquisition system in Ontario.**

1.0 INTRODUCTION

1.1 Background

This report presents results obtained from a study of sediment issues and programs in the Province of Ontario. Conservation Management Systems, a division of Ecologistics Limited, was retained in January, 1985, to undertake the study in response to a need expressed by Environment Canada, Ontario Region, and the Sediment Survey Section of the Water Resources Branch to acquire a better understanding of the role and importance of sediment data in Ontario.

The study has involved two phases. Phase I focused attention on the identification of existing uses of sediment data, evaluation of the data base, and clarification of issues associated with sediment. Preliminary results obtained during the first phase were presented in an interim report to Environment Canada (Conservation Management Systems, 1985). Phase II of the study has assessed the state of knowledge regarding sediment in Ontario, and identified future data needs and approaches to meet those needs. The results from the second phase have been combined with those obtained during the first phase in this final report. It has been the intent that these results, when assembled with outputs from similar studies undertaken in four other regions of the country (Kellerhals Engineering Services Ltd., 1985; Hydrotech Inc., 1985; Washburn and Gillis Associates Ltd., 1985; Northwest Hydraulic Consultants Ltd., 1985) would provide a base for the establishment of a national perspective on sediment issues.

1.2 Relevance of the Study

It seemed evident at the outset of the study, and has become increasingly clear throughout the study, that the exercise of reviewing the sediment

program in Ontario at this time is particularly relevant. The existing sediment data base has been assembled for upwards of 20 years, providing a sufficiently long period of record to allow useful analysis and examination of questions such as: What have we learned? Where to now? Much has already been done with sediment data in recent years (e.g. data inputs to local reservoir and harbour studies, and to regional water quality projects undertaken under the auspicies of groups such as the Pollution from Land Use Activities Reference Group [PLUARG], the Grand River Implementation Committee, and the Thames River Implementation Committee). Such projects have led to the development of both temporal and spatial perspectives regarding sediment generation and transport, prompting the question: Where are the gaps in our information and knowledge now?

It has also become evident that whereas sediment data were used 20 years ago primarily for sediment volume related studies, the data are now being critically examined with regard to quality oriented issues. Further, it is evident that the users of the data are no longer solely engineers but also biologists, agrologists, geographers, farmers, etc. Therefore, it is indeed timely and important to review the issues, users, and uses associated with sediment in the province, and to resolve the questions: Do present sediment data meet our needs? How should sediment programs be modified to insure that most future needs can be addressed?

1.3 Study Objectives

Objectives for the Ontario study were established with regard to those developed for the comparable studies in British Columbia, the Prairie Provinces, Quebec and the Maritime Provinces. The objectives were :

(i) to clarify issues in which sediment is a concern,

(ii) to assess the state of knowledge regarding sediment in Ontario, and

(iii) to identify possible future needs and make recommendations regarding strategies and methodologies.

1.4 Plan of Approach

The plan of approach for the study has been directed towards:

1. Identification of users of and uses for sediment data.

   a) developing contacts (e.g. federal, provincial and municipal civil servants; consultants; and researchers) who are familiar with issues involving sediment and/or who use sediment information; and

   b) by means of interviews with selected contacts, identifying users and uses of current data, identifying the nature of data currently used and needed, and developing a list of possible future issues, data needs, and users.

2. Evaluation of the sediment information base.

   a) identifying and contacting agencies with responsibilities to collect sediment data (e.g. Environment Canada, OMOE, OMNR, Conservation Authorities, Agriculture Canada, and OMAF);

   b) clarifying objectives of sediment sampling programs;

   c) ascertaining sediment station networks, including locations and periods of record;

   d) ascertaining information assembled in the networks (e.g. sediment concentrations, loads, textures and nutrients);

   e) identifying methods of sampling and of analyzing data; and

   f) evaluating the accuracy of the data base.

3. Clarification of issues associated with sediment.

   a) reviewing literature regarding issues associated with sediment (e.g. sediment concentrations which are too high for water intakes and fish; sediment loads which are detrimentally deposited in streams, harbours, ponds and lakes; sediment particles which are carriers of contaminants such as nutrients, herbicides, heavy metals and toxics), and relating information to issues identified in (1) above; and

   b) evaluating to what extent Water Resources Branch sediment data has addressed issues of concern.

4. Assessment of the state of knowledge regarding sediment.

   a) reviewing literature on information acquired in Ontario regarding such topics as temporal variability in sediment parameters, spatial variability, extremal characteristics and sediment sources (e.g. agricultural areas, urban settings, and streambanks); and

   b) evaluating to what extent Water Resources Branch sediment data have contributed to our knowledge.

5) Identification of future needs and approaches to meet needs.

   a) summarizing possible future sediment issues and related data needs;

   b) identifying and evaluating alternative methodologies for sediment sampling in time and space; and

   c) identifying and evaluating alternative strategies for implementing sediment sampling programs (including consideration of possible cooperation amongst agencies for collecting and processing information).

Implementation of the above plan has been facilitated by use of a questionnaire in conjunction with telephone and personal interviews, and a workshop. The questionnaire approach provided an efficient and economical means of soliciting a good deal of information in a relatively short period of time (about one month), and of using interview time in an optimum manner for clarification of information. The workshop proved to be an extremely effective way of confirming information assembled by means of the questionnaire and the interviews, exploring thoughts and opinions of sediment data collectors and users regarding strengths and weaknesses of the current sediment program, and generating ideas and recommendations regarding program needs and strategies for implementing changes suggested for the program. The workshop also facilitated the taking of a significant step in the improvement of communication among various users and collectors of sediment information in the province. Outlines of both the questionnaire process and the workshop are provided in the following sections.

1.4.1 Questionnaire Process

For the purpose of soliciting basic data regarding sediment programs in Ontario, a questionnaire was developed and circulated in close cooperation with personnel in the Guelph Office of the Water Resources Branch. The questionnaire (see Appendix A) was arranged in three parts: Part A - General, Part B - Sediment Data Users, and Part C - Sediment Data Collectors, to permit its use for both users and collectors of sediment data in the province. The format allowed responses to only Parts A and B (for users only); only Parts A and C (for collectors only); or Parts A, B and C (for collectors who were also users).

On the basis of the Sediment Survey Report mailing list for Ontario acquired from the Water Resources Branch (Guelph Office), and additional names considered to be useful contacts, an initial list of 11 possible sediment data collectors and 85 possible sediment data users was developed, i.e. a total initial mailing list of 96 persons. The 11 possible collectors were contacted by phone prior to circulation of the questionnaires to encourage cooperation with and participation in the questionnaire process. As completed questionnaires began to be received by return mail, additional phone calls to users and collectors alike were undertaken for purposes of clarification of information and encouragement to respond. Further, in response to suggestions offered by questionnaire respondents and to requests from interested persons, an additional 17 questionnaires were mailed, bringing the total circulation to 113.

A total of 60 of the 113 persons receiving questionnaires responded with information (see Appendix B). Of the 60, 35 identified themselves as both collectors and users of sediment data in Ontario, this number including most of the 11 initially identified as possible collectors but also a number of those initially identified as possible users only. Twenty-five persons responded as users only.

Persons were most cooperative in providing information on completed questionnaires and in interviews. The response rate of 53 percent is considered to be excellent for the relatively short duration questionnaire exercise; and the information collected, later confirmed and augmented in the workshop, has been extremely useful for the preparation of many sections in this report.

1.4.2 Workshop

To complement the questionnaire and interview process conducted in Phase I of the study, a workshop was held as a part of Phase II. The purpose of the workshop was to critically review results obtained during Phase I; to ascertain sediment data, information, and service needs; and to suggest and consider alternative approaches/actions that could be taken to meet these needs.

All persons who had responded to the questionnaire process were invited to attend the workshop, and a group of 32 participated, including six observers from the Water Resources Branch and three workshop leaders/organizers from Conservation Management Services (see Appendix C). The structure of the one-day program was developed in cooperation with personnel in the Guelph Office of the Water Resources Branch and involved four components: i) background presentations regarding the objectives of the Canadian and Ontario studies being conducted for Environment Canada, and an overview of the existing Sediment Survey Program; ii) a working session on present and future needs for sediment data; iii) a working session on strengths and weaknesses of Sediment Survey data; and iv) a working session on methods of coordinating the collection and dissemination of sediment information in Ontario.

The questions addressed during the working sessions are summarized in Appendix D. The mechanism employed for these sessions involved small groups of participants (five groups of approximately six members) considering each question, summarizing their responses on flip-chart sheets, and then orally presenting highlights of their responses to the total workshop group. The group as a whole often discussed the shared responses further, the flip-chart sheets were collected for subsequent collation and summary, and the small groups moved on to their next question.

The workshop participants responded enthusiastically to the process selected, becoming actively involved in discussion and debate, and eagerly suggesting and developing their ideas, thoughts, and opinions. All of these responses have received careful consideration, in conjunction with the questionnaire and interview responses, for the development of the perspective offered in this report.

1.5 Organization of Report

The format of the report relates closely to the study objectives, combining information gleaned in the various components and processes used in the plan. Following this introductory chapter, Chapter 2 addresses the topic of sediment issues. Chapter 3 presents a review of much of the literature and data pertaining to sediment information collected in Ontario, drawing implications for future research studies and sediment program requirements. Chapters 4 and 5 deal with sediment data and the system required for the collection, management, and dissemination of sediment information (a topic discussed thoroughly in the workshop), identifying needs and suggesting approaches to meet these needs.

2.0 SEDIMENT ISSUES

2.1 Introduction

It is important at the outset to ascertain the need for sediment information in the province of Ontario. Have available sediment data been used? Extensively? Is there an ongoing demand for sediment information? For what purpose are data being used? What persons are using the data? What issues involving sediment have been addressed to date, and what issues are seen to require attention in the coming years? Questions such as these have been asked in the questionnaire and workshop processes of this study, and the responses are summarized and discussed in the following sections.

2.2 Current and Future Issues

Sediment issues identified by respondents to the questionnaire to be currently important and requiring attention in the near future have been summarized in Tables 1 and 2, and input in this regard from the workshop has been included in Appendix E. It is quite evident from these summaries that sediment data are being used and are required for the exploration of a wide variety of topics, involving both quantitative and qualitative dimensions. A number of existing studies relate to the quantity of sediment deposited in reservoirs, ponds, channels, harbours and lakes. However, most of the sediment data users are interested in the quality of the suspended materials being transported through stream and lake systems; and even the depositional studies are related more to sediment quality that quantity. The list of current and future sediment related issues further reveals a focussing of attention on where the sediment is coming from (i.e. sources, and the impact of remedial measures), what it is carrying in the form of potential contaminants, where it is going, and how both the volume and quality of sediments affect downstream water quality and quantity.

TABLE 1

CURRENT USES OF AVAILABLE SEDIMENT DATA

Current Uses	Number of Users
Reservoir, lake, or pond sedimentation analysis	20 (15)*
Harbour or canal sedimentation analysis	14 (10)
Natural or artificial channel sedimentation analysis	11 (5)
Water quality studies	29 (20)
Aquatic habitat studies	9 (6)
Recreation planning studies	4 (3)
Academic, scientific research, and other	28 (16)
(e.g. Phosphorus loadings to the Great Lakes; sources of soil erosion and trace metals; channel erosion; coastal evolution research; environmental impact studies; dredging; dredging projects; history of airborne pollution, hydraulic and mathematical modelling, to compile information sheets on on soil erosion)	

* Users who also collect sediment data.

TABLE 2

CURRENT AND FUTURE SEDIMENT-RELATED ISSUES

IDENTIFIED BY USERS OF SEDIMENT DATA IN ONTARIO

Current and Future Issues	Number of Respondents
Sediment Quantity Issues	
Deposition in lakes, reservoirs, harbours	15
Deposition and/or scour in rivers (as it relates to dredging, flood potential, and power projects)	7
Deposition and/or concentration in aquatic environments	11
Concentrations at water intakes	2
	35
Sediment Quality Issues	
Source and/or sink of nutrients	22
Carrier of toxics	10
Carrier of bacteria	7
	39
Sediment Processes	
Sediment sources (e.g. land, streambanks, urban areas, forests)	25
Transport processes	2
	27
Teaching and Academic Research	
Global picture of sediment yield	2
Sediment models	2
	4

Regarding the source of stream and lake sediments in Ontario, there have been and continue to be requests for information to ascertain the absolute and relative quantities of material emanating from agricultural, forested, and urban areas; from streambanks and ditches; and from specific locations such as construction and power project sites. Questions of interest include: What are the sources of sediment, and sediment-associated contaminant (e.g. phosphorus, heavy metals, pesticides)? Are the sources localized or broadly distributed on the landscape? Where sediment loads and/or associated contaminant loads are deemed to be excessive, what remedial measures are most effective? Where should they be targeted for maximum impact and minimum cost? Work relating to sediment sources in Ontario, and to their management, deals almost exclusively with suspended sediment, the transport capacity of such material for various chemical pollutants being of prime concern.

The role of suspended sediment as a transport medium for contaminants is very clearly a major issue. There is concern about the nature and magnitude of contaminant loads associated with suspended loads; and there remain questions regarding the relation of sediment characteristics to contaminant transport, including the role of sediment as a source and/or sink for contaminants. Determining the impact of suspended sediment on pollution, and of pollution on suspended sediment, is a requirement for studies being undertaken by a number of people.

Another category of sediment issues involves topics such as the development of a global picture of the spatial and temporal distributions of sediment yield in the province, and the development of sediment/streamflow models. Input from sediment data users has clarified that these are issues, and that there is now a need to link such developments to the distributions and movement of other water quality parameters, such as those noted in Table 3.

TABLE 3

VARIABLES WITH WHICH USERS ASSOCIATE SEDIMENT DATA

Associated Variables	Number of Users
None	4 (1)*
Streamflow	36 (19)
Runoff, soil loss	27 (14)
Nutrients	28 (21)
Metals	21 (18)
Dissolved solids	10 (9)
Oxygen demanding materials	15 (14)
Trace organics	17 (14)
Other (e.g. bacteria, fish spawning areas microbiology)	5 (4)

* Users who also collect sediment data

Most of the issues identified above have been precipitated by downstream problems brought about by the quantity and/or quality of suspended sediment arising from and transported through the contributing watershed. Persons are requesting data to quantify the volumes of sediment available for deposition in (i) stream channels - to determine the possible need for dredging and the possible impact on the habitats and populations of fish and stream biota; (ii) ponds and reservoirs - to determine the rate of decline of available flood storage and the life expectancy of the site; (iii) harbours - to determine the need for,

location, and cost of dredging; and (iv) the Great Lakes - to determine temporal and spatial loading patterns. Concentrations of suspended sediment , and their variability in time, are also quantities being determined by engineers designing and operating water supply intakes and by persons concerned about the improvement of stream ecology. In addition to these quantitative issues, the quality of the sediments transported through and/or deposited in stream channels, ponds and reservoirs, harbours, and the Great Lakes is of increasing concern to both managers and scientists. All of these downstream problems require resolution of many of the upstream watershed issues and/or accurate information regarding the downstream conditions relating to sediment and associated variables of interest.

Although at this point, the information available regarding current and future sediment issues has been predominantly influenced by input from persons interested in the southern part of the province (i.e. peninsular Ontario), issues raised by persons from Northern Ontario have not been noticeably different. They too are involved with sediment quantity and quality matters from the sources to the downstream consequences. Understandably, the importance and management of forest source areas are of prime interest in the north, as opposed to the impact of agricultural areas in the south.

The extent to which some of the above sediment issues have already been resolved is explored in the subsequent chapter, with the intent of clarifying gaps in our knowledge and highlighting major issues. Nonetheless, consideration of sediment issues identified by users and collectors of sediment information in the province reveals very clearly that **there is a strongly expressed need for a sediment data base in Ontario which allows the exploration and resolution of a wide variety of sediment-related issues. These issues relate to both sediment quantity and sediment quality; and attention is being and needs to be focussed on**

sources of sediment, associated contamination, transport and deposition mechanisms, and the manner in and extent to which the volume and quality of sediment moving downstream affect water quantity and quality and can be controlled.

2.3 Users of Sediment Data

All persons who responded to the questionnaire and who attended the study workshop identified themselves as users of sediment data collected in Ontario by various groups and agencies. It is acknowledged that the questionnaire respondents and the workshop participants constitute only a sample of the sediment data users, and that some individuals and groups may have been overlooked, albeit not intentionally. Nonetheless, this sample has provided not only much useful input to the identification of current and future issues discussed above but also valuable insights into the number and types of organizations using sediment data in the province.

The distribution of the sediment data user sample with regard to categories of parent organization is presented in Table 4. The sample size alone reveals that a considerable number of people are presently making use of existing sediment information; and the distribution reveals that a great many, and a wide variety, of user groups are involved. It is also evident from the sample that most of the groups are government based (federal, provincial and municipal); and virtually all users are exploring sediment data on the basis of government funding (i.e. as civil servants, consultants on government contracts, or academics involved in research funded by government grants).

The strong need for a reliable sediment data base in Ontario is confirmed by the large number of users of sediment data; and the distribution of user groups reveals the need for an efficient and economical system for collecting, interpreting, and distributing information regarding sediment, in order that costs be minimized for not only the users of the data but also the residents of the province.

TABLE 4

SAMPLE OF SEDIMENT DATA USERS IN ONTARIO, ACCORDING TO ORGANIZATION INVOLVED

Category of Organization	Number of Users	
Federal Department[1]	15	(12)[2]
Provincial Ministry[3]	16	(8)
Conservation Authority	8	(6)
Engineering Consultant	8	(2)
Environmental Consultant	2	(2)
Academic (college, university)	8	(4)
Other (e.g. Hydro)	3	(1)
	60	(35)

1 e.g. Environment Canada - Water Resources Branch
Environment Canada - Water Quality Branch.
2 Users who are also collectors of sediment data.
3 e.g. Ontario Ministry of the Environment.

3.0 SEDIMENT KNOWLEDGE

3.1 Introduction

What have we learned about sediment conditions and processes in Ontario? To what extent and how can we make use of acquired knowledge to resolve issues concerning sediment? The development of an effective sediment program for the province requires consideration of such questions in order that existing information can be put to best use and that knowledge gaps requiring attention can be identified, prioritized, and pursued.

It is interesting and important to note at the outset of a review of literature regarding Ontario conditions that most of the sediment data have been collected and analyzed during the past 10 years. In 1975, the statement was made that "there has been very little work done on the analysis of sediment production and transportation for streams in Southern Ontario" (Dickinson et al., 1975). At that time, the Water Resources Branch (WRB) of Environment Canada was virtually the only collector of sediment information in the province; there were published sediment data on only 14 streams; the longest period of record was about 10 years; the average period of record was approximately four years; and the spatial distribution of measuring sites was largely restricted to Southwestern Ontario, west of Toronto and south of Listowel. Therefore, it is primarily since 1975 that the need for and the collection of sediment data have been addressed in the province; and it is during the last decade that our data and knowledge bases regarding sediment have begun to develop.

Although the state of knowledge regarding sediment in Ontario is still in an early stage of development, a great deal of information has been assembled. It is therefore beyond the scope of this report to present a comprehensive review of the literature regarding all aspects of fluvial sedimentation. Rather, the following sections will focus on some aspects

which have been deemed to be of particular relevance to a number of sediment issues identified earlier. Therefore, this review deals primarily with suspended sediments and with conditions in Southern Ontario, highlighting knowledge and indentifying gaps with regard to stream loadings, seasonal variability, extreme events, spatial variability, sources of sediment, and sediment and water quality.

3.2 Annual Suspended Sediment Loads

The order of magnitude of the volume of sediment transported in Ontario stream systems can be determined from a consideration of annual suspended sediment loads, as the bedload component of the total load has been estimated to be relatively insignificant. The mean annual suspended sediment loads per unit area are presented in Table 5 for a number of selected rivers in Southern Ontario (i.e. sediment stations established and monitored by the Water Resources Branch of the Inland Waters Directorate). These sediment yields are in the order of 75 t km^{-2} yr^{-1}, ranging from 16 for the Thames River at Ingersoll to 181 for Big Otter Creek near Vienna and Calton. These numbers are consistent in order of magnitude with estimates and computed values published earlier by Fournier (1960), Strackhou (1967), Holeman (1968), Stichling (1973), and Dickinson et al., (1975). Suspended sediment loadings in the province are revealed to be only a fraction of those experienced in the mountainous and alluvial regions of Canada, and to be orders of magnitude smaller than loadings observed in many major rivers of the world.

The relatively small volume of material moving through Ontario streams has been confirmed by local reservoir studies and a sediment budget developed for the Great Lakes, including consideration of northern rivers. Bottom surveys of such reservoirs as those behind the Shand and Conestogo Dams on the Grand River have revealed insignificant deposition of sediment; and the Pollution from Land Use Activities Reference Group (PLUARG, 1978),

TABLE 5

MEAN, MEDIAN AND RANGE STATISTICS REGARDING ANNUAL SUSPENDED SEDIMENT LOAD VALUES FOR SELECTED RIVERS IN SOUTHERN ONTARIO

Sediment Station Name	WRB Station Number	Watershed Area (km^2)	Years of Record	Mean Annual Suspended Sediment Load ($t\ km^{-2}\ yr^{-1}$)	Median Annual Suspended Sediment Load ($t\ km^{-2}\ yr^{-1}$)	Range of Annual Loads ($t\ km^{-2}\ yr^{-1}$)
Ausable River near Springbank	02FF002	334	1970-83	63.9	61.0	31.1 to 108
Big Creek near Walsingham	02GC007	228	1966-83	40.2	40.2	19.9 to 57.3
Big Otter Creek near Vienna/Calton*	02GC004/ 02GC026	269	1966-83	181	184	58.8 to 308
Canagagigue Creek near Floradale	02GA036	6.9	1974-83	70.1	62.8	25.9 to 122
Credit River at Erindale	02HB002	320	1973-83	60.6	50.7	24.1 to 160
Humber River at Elder Mills	02HC025	117	1966-83	81.8	79.9	28.8 to 123
South Nation River near Plantagenet Springs	02LB005	1470	1972-83	170	226	50.4 to 398
Thames River at Ingersoll	02GD016	200	1963-73	16.3	13.7	7.74 to 28.7

* Combined record of Big Otter Creek stations at Vienna and Calton.

while acknowledging that stream sediments entering the Great Lakes can affect nearshore areas through localized siltation of fish habitat, drainage channels, harbours and bays, concluded that the quantity of sediment transported to the lakes does not constitute a problem in terms of volume of material.

Sediment loads of sufficient volume to create depositional problems in localized areas at specific times can occur, and even low to moderate sediment loads can provide a transport medium for significant pollutant loads, as will be discussed in a later section. However, it is important to recognize that **the quantity of sediment transported in Ontario streams is generally not of major proportions. Therefore, the development of a provincial sediment program focussed solely on the determination of sediment volumes is not justified.**

It is also evident from Table 5 that the annual suspended sediment load on many of the selected rivers vary considerably from year to year, the maximum annual load being 3 to 8 times the minimum annual load (even for the relatively small sample sizes involved, from 9 to 17 years). Although these annual loading values are somewhat positively skewed, revealed by the means being greater than the median values (with the exception of Big Otter Creek), the skewness of annual suspended sediment loads appears to be relatively insignificant. Therefore, the mean and median values afford good estimates of both the central tendency of the annual suspended sediment loading values.

From these observations regarding the variability of annual sediment loads from year to year, it can be concluded that **single year determinations of suspended sediment loads do not provide precise estimates of the long term mean and should not be considered as such; and both mean and median values of 10 or more years of data provide good indices of the central tendency of annual suspended sediment loads in the province.**

3.3 Seasonal Variability

Individual suspended sediment load hydrographs, such as those shown in Figures 1 and 2, provide a basis for examining seasonal trends; and a composite of the annual hydrographs available for the selected rivers, noted in Table 5, provides the summary seasonal pattern shown in Figure 3. (The monthly percentages are means of the median monthly percentage values determined for each month for each selected river, the median values being most indicative of the central tendency of the highly skewed monthly data.) The seasonal pattern for individual rivers varies somewhat but not significantly from that shown in Figure 3.

It is evident from the sample suspended sediment load hydrographs in Figures 1 and 2, and from the composite suspended sediment load hydrograph in Figure 3, that daily sediment loads in Ontario streams vary dramatically over a wide range of values. However, they tend to follow a very distinctive seasonal pattern: the bulk of the annual suspended load is transported during the spring period, 65 percent moving downstream during March and April. This pattern closely parallels the seasonal distribution of flood occurrences in Southern Ontario, 60 percent of the annual extremes occurring during the same two months (Dickinson, 1972). Seasonal percentages for the individual selected rivers are summarized in Table 6, further exemplifying the strong seasonal pattern, and revealing some of the variability to be expected among the river basins.

Seasonal patterns in suspended sediment loads in Northern Ontario rivers have not received the attention of those in the south. However, from the Water Resources Branch stations and the data base assembled during the PLUARG studies, it is generally known that the northern rivers exhibit a seasonal pattern similar to that noted above, but with a peak occurring somewhat later, corresponding to the northern peak runoff period.

FIGURE 1: SAMPLE SUSPENDED SEDIMENT LOAD HYDROGRAPH FOR THE THAMES RIVER AT INGERSOLL

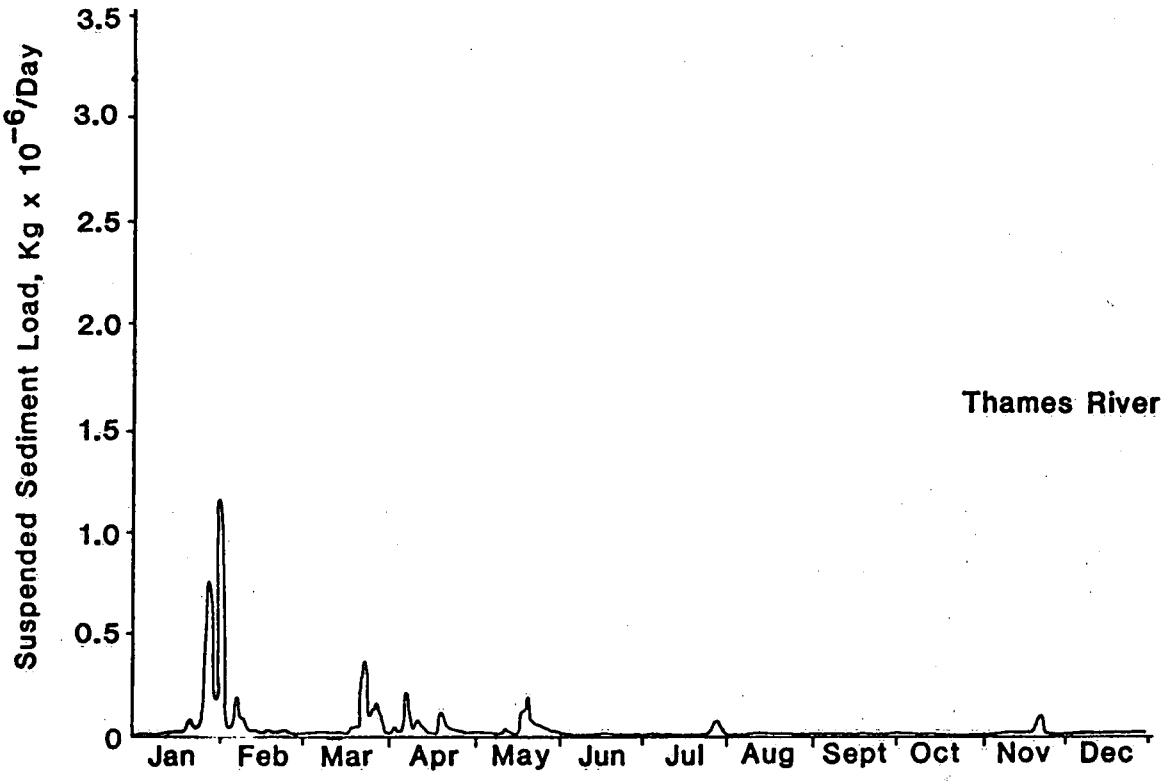


FIGURE 2: SAMPLE SUSPENDED SEDIMENT LOAD HYDROGRAPH FOR BIG OTTER CREEK NEAR VIENNA

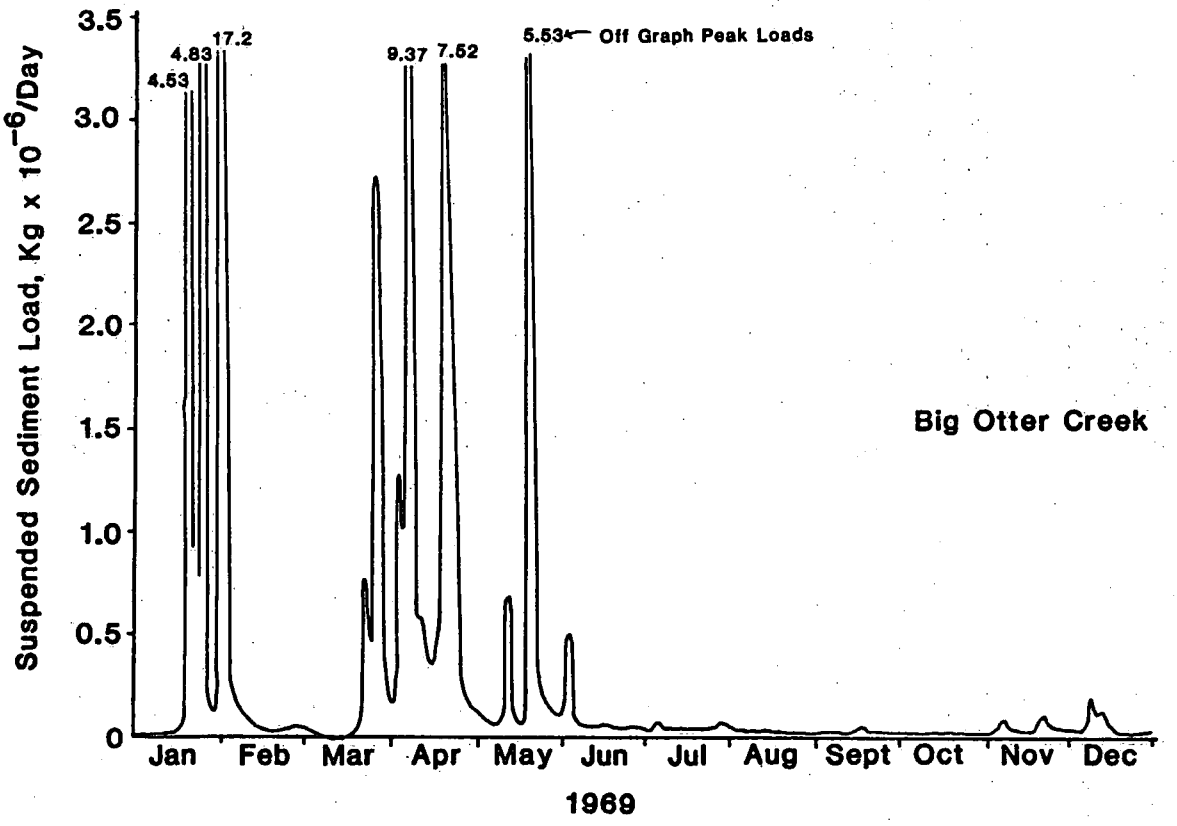


FIGURE 3: ANNUAL DISTRIBUTION OF SUSPENDED SEDIMENT LOADS FOR SELECTED RIVERS IN SOUTHERN ONTARIO

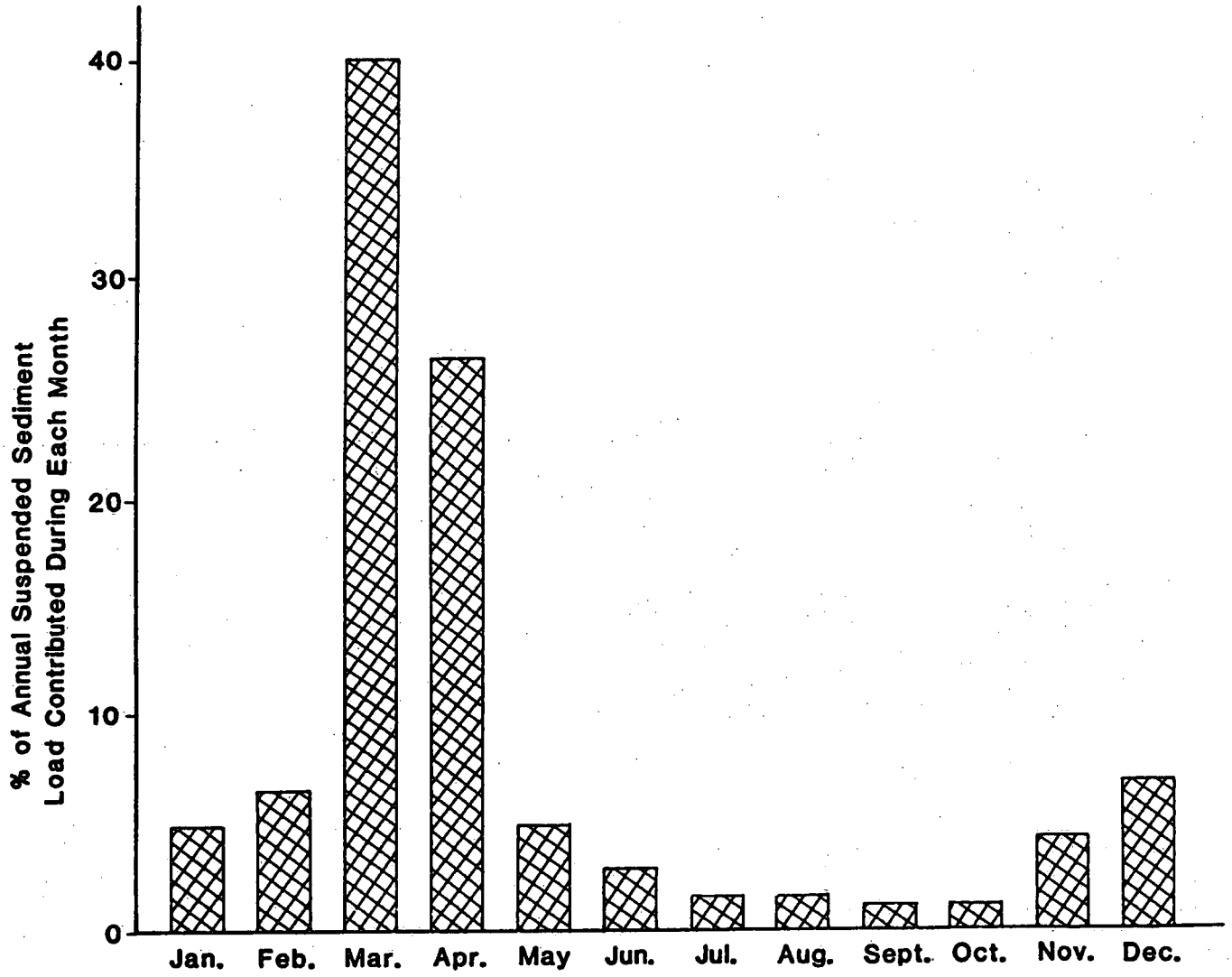


TABLE 6

SEASONAL DISTRIBUTION OF SUSPENDED SEDIMENT LOADS FOR SELECTED RIVERS IN SOUTHERN ONTARIO

(Data Source: Published records of the Water Resources Branch, Inland Waters Directorate)

Sediment Station*	Seasonal Load, as a % of the Annual Load		
	Spring**	Summer**	Fall/Winter**
Ausable	74.2	7.1	18.7
Big	68.2	13.9	17.9
Big Otter	76.0	6.9	17.1
Canagagigue	83.7	1.2	15.1
Credit	84.3	6.5	9.2
Humber	85.4	6.0	8.6
South Nation	83.7	2.4	13.9
Thames	63.5	6.7	29.8
Mean Values	77.4	6.3	16.3

* Station names abbreviated after Table 5.

** Spring = February through May; Summer = June through September; Fall/Winter = October through January.

The variability in seasonal and daily suspended sediment loads noted above can be further explored in terms of the sediment duration curves presented in Figures 4 and 5. Figure 4 is a conventional plotting of the percentage of time which daily suspended sediment loads (expressed per unit area) can be expected to be equalled or exceeded over the long term. Figure 5 offers another representation of the same data, plotting the percentage of the total suspended load (carried by each river) contributed by suspended loads greater than or equal to selected values versus the percentage time that these selected values might be expected to be equalled or exceeded.

From Figures 4 and 5 it is abundantly clear that daily suspended sediment loads in Ontario streams exhibit highly skewed frequency distributions, of somewhat different shapes. The mean daily loads (i.e. the values presented in Table 5 divided by 365) can be seen to be equalled or exceeded less than 20 percent of the time. As a result, mean daily suspended sediment loads do not provide good indications of the central tendency of the daily data.

A logical consequence of the occurrence of daily loads which exhibit highly skewed distributions is, as revealed in Figures 4 and 5, that a large percentage of the annual load is transported downstream in a very small percentage of the time. For example, a majority of the annual load (i.e. >65 percent) - and, in most cases, the vast majority of the annual load (i.e. 80 to 90 percent) - is expected to be delivered in less than 10 percent of the time (i.e. less than 36.5 days each year). For all selected rivers except the Thames River at Ingersoll, more than 60 percent of the annual load is transported in less than 16 days each year; for the Thames, more than 50 percent is transported in 16 days.

The duration curves of Figures 4 and 5, therefore, reveal not only that the daily suspended sediment loads are extremely variable and highly skewed, but also that the movement of suspended sediment in Ontario streams may be considered to be an event-oriented process. When these

FIGURE 4: DAILY SUSPENDED SEDIMENT LOAD DURATION CURVES FOR SELECTED STATIONS IN SOUTHERN ONTARIO

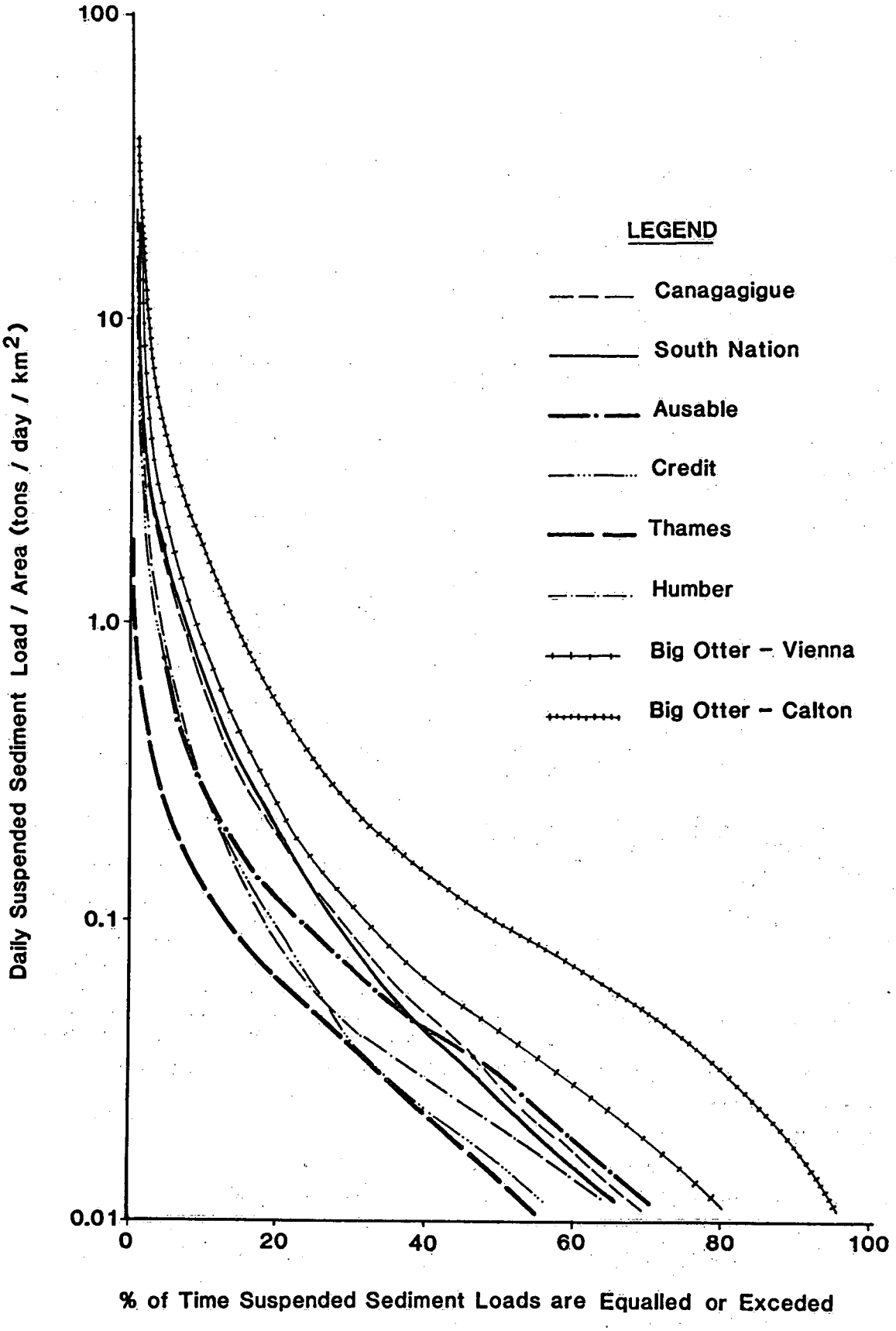
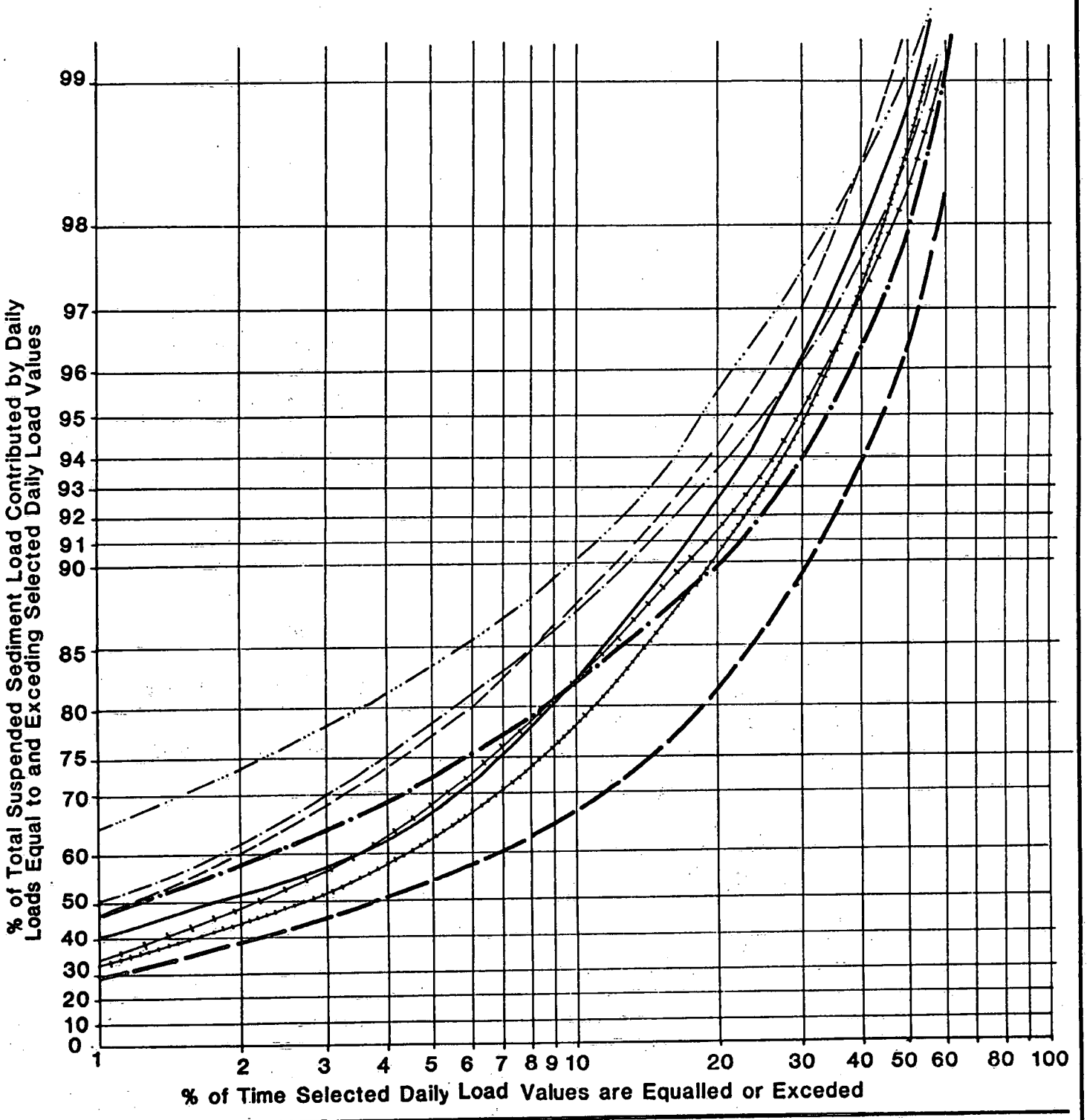


FIGURE 5: DIMENSIONLESS SEDIMENT LOAD DURATION CURVES FOR SELECTED STATIONS IN SOUTHERN ONTARIO



LEGEND

- Canagagigue
- South Nation
- Ausable
- Credit
- Thames
- Big Otter – Vienna
- Humber
- Big Otter – Calton

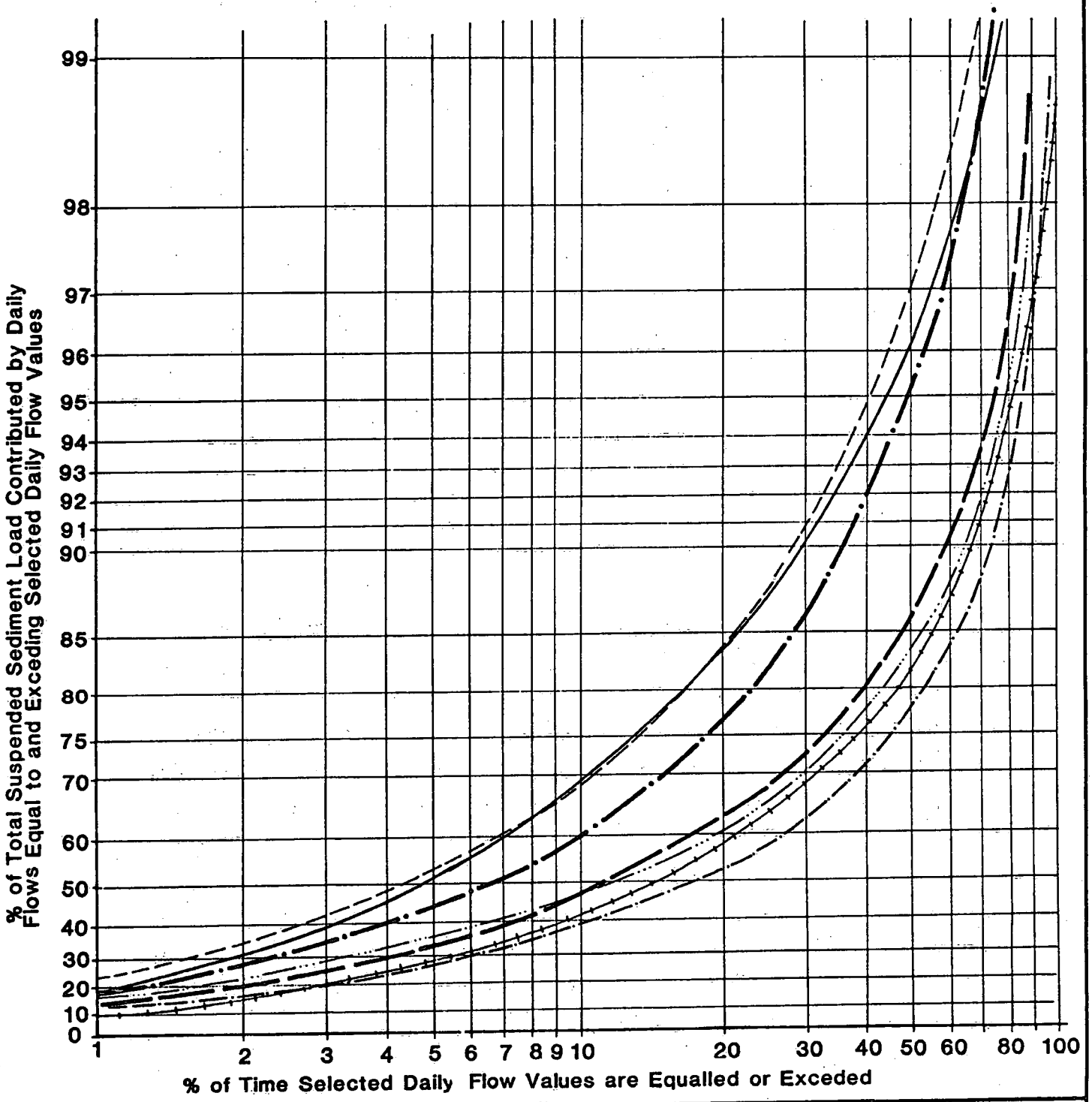
results are compared with similar statistics for streamflow itself, the extent to which suspended loads are event-oriented and linked to extremal events is revealed. Figure 6, a diagram comparable to Figure 5 but developed from streamflow data, reveals that daily streamflow equalled or exceeded 10 percent of the time accounts for only 40 to 70 percent of the total flow; and flows equalled or exceeded 5 percent of the time account for but 25 to 55 percent of the flow. So although suspended sediment flows may be strongly linked to or determined by streamflow, it is clear from Figures 5 and 6 that the daily suspended sediment load variable is more extreme-event oriented than the equivalent flow variable.

From the above results, it is clear that reliable estimates of suspended sediment loads in Ontario streams are contingent upon the application of a sampling scheme in time that ensures the obtaining of good sediment samples during the brief periods when most of the suspended load is delivered. A few of the groups collecting sediment data in the province have already adopted such an approach to sampling, (e.g. Water Resources Branch), but a number of others unfortunately have not.

It is strongly recommended that sediment sampling programs in the province key on significant runoff events during the season when these events may be expected to occur. Sampling could be greatly reduced or virtually omitted during low flow periods throughout the year. The importance of event and seasonal sampling, acknowledged by the Sediment Survey Program, needs to be strongly advocated to all sediment data collectors in Ontario.

Further, it is recommended that the Water Resources Branch continue to develop more efficient and economical sediment sampling strategies, in light of existing knowledge regarding the highly event-oriented temporal characteristics of Ontario sediment data.

FIGURE 6: DIMENSIONLESS STREAMFLOW DURATION CURVES FOR SELECTED STATIONS IN SOUTHERN ONTARIO



LEGEND

- Canagagigue
- South Nation
- Ausable
- Credit
- Thames
- Big Otter
- Humber

3.4 Extreme Values

The duration curve analysis, indicating that the bulk of suspended sediment is transported during major events, begs the questions: How much of the load can be expected to be transported by events with longer return periods? Is there any point measuring loads during much of the rest of the time? To explore answers to these questions, extreme value analyses were performed on the annual series of maximum daily suspended sediment loads determined for the selected river stations. A simple log-normal probability distribution was assumed to apply to each case. Figure 7 presents an example plot, and Table 7 summarizes suspended loads for selected return periods.

A study of the extreme suspended sediment loads for selected return periods (i.e. Figure 7) in conjunction with Figure 5 reveals that the daily sediment loads with return periods of two years or greater (i.e. loads which can be expected to be equalled or exceeded 0.5 percent of the time) account for approximately 40 percent of the total sediment load. Annual peak events contribute a similar, or slightly larger, significant portion of the total load. In comparison, on the basis of Figure 6, daily streamflows with return periods of two years or greater account for about 8 to 20 percent of the total flow. These results confirm the similar but less specific observations of Archer (1960), Wolman and Miller (1960), and Piest (1965).

These results regarding extreme values confirm that **the reliable estimation of sediment loads requires careful sampling of signficant events, including sediment load occurrences with return periods of two years or greater and annual peak events.**

With regard to the data and literature presented to this point in relation to the temporal characteristics associated with suspended sediment in Ontario, it can be concluded that the available periods of record up to 20

FIGURE 7: SAMPLE EXTREME VALUE ANALYSIS PLOT FOR DAILY SEDIMENT LOADS ON BIG CREEK NEAR WALSINGHAM. (16 YEARS OF RECORD)

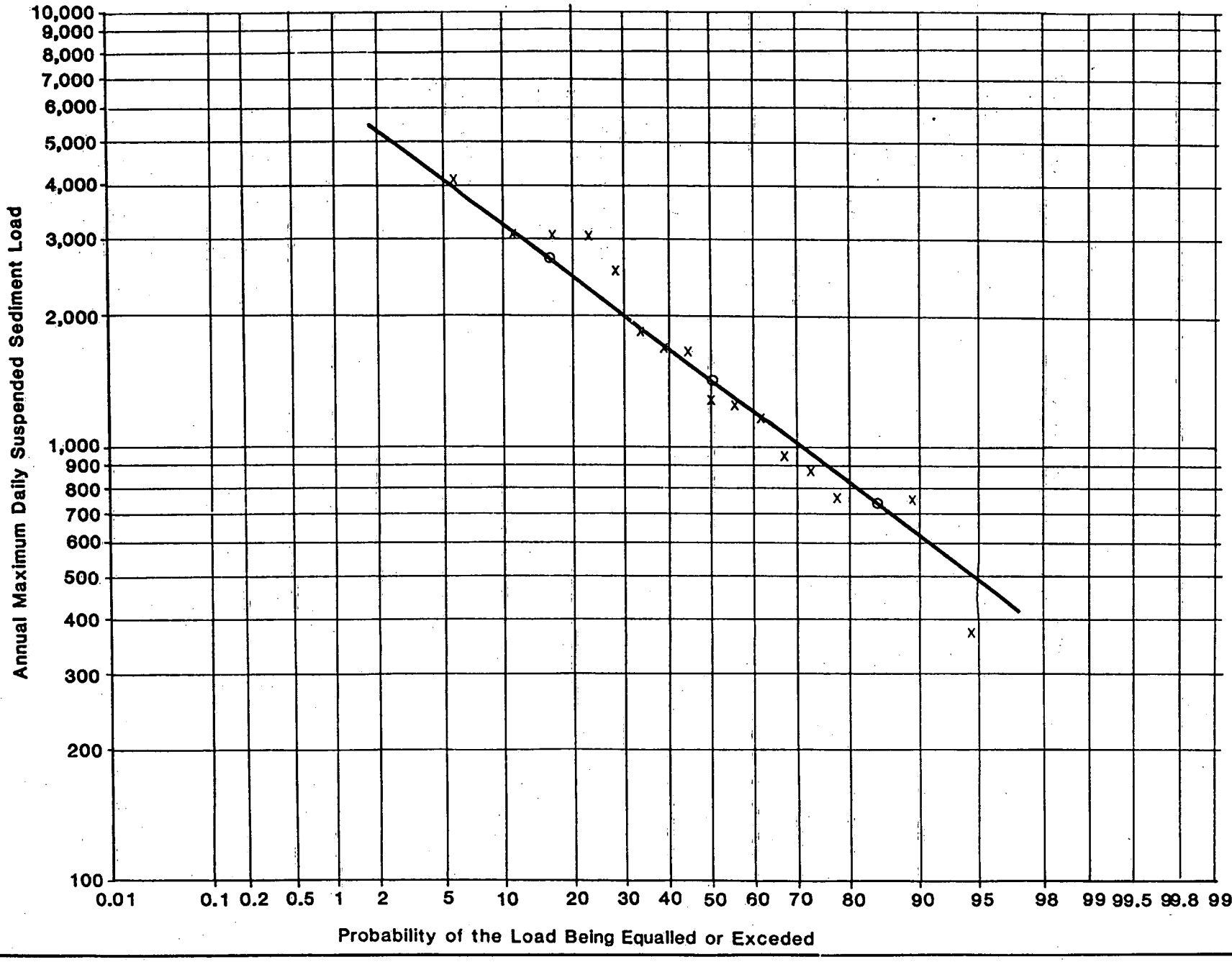


TABLE 7

EXTREME DAILY SUSPENDED SEDIMENT LOADS

IN SELECTED ONTARIO STREAMS

(Data Source: Published records of the Water Resources Branch, Inland Waters Directorate)

Sediment Station*	Daily Suspended Sediment Loads ($t\ km^{-2}\ day^{-1}$) for Return Periods of 2 years	5 years	10 years	25 years
Ausable	8.44	15.3	20.6	28.8
Big	6.21	10.7	14.2	19.1
Big Otter	47.6	74.4	92.9	119
Canagagigue	62.6	104	135	181
Credit	37.6	103	172	303
Humber	35.0	55.1	68.4	88.0
South Nation	16.8	38.8	59.2	93.2
Thames	4.30	8.35	11.8	17.2

* Station name abbreviated after Table 5.

years in length have been extremely useful in the ascertaining of temporal and duration characteristics and extremal properties of stream sediment loads. Periods of record of in the order of 10 years have also been useful for the improved estimation of average annual loads.

Sediment records maintained for long periods would now appear to offer very little additional information, with the exception of indications regarding long-term trends and a data base for developing stochastic sediment models. However, there is little need to monitor more than one or two stations for possible long-term trends; and unless trends in other associated variables such as land-use were also monitored closely, there may be little point in maintaining a long-term record at any sediment station in Ontario.

3.5 Spatial Variability and Sources of Suspended Sediment

The suspended sediment loads presented earlier for the selected river stations in the province (i.e. Table 5) exemplify the range of variability which can be expected spatially, at least in the southern portion of the province. The question arises: Can variations in sediment loads in Ontario be explained by variations in geomorphologic, physiographic, climatic, and/or land use characteristics?

The sediment yield of a basin has been noted in the literature to be a function of a number of factors, including climate, basin geomorphology, soil type and land use. Schumm (1954) and Maner (1958) have noted apparent relationships between basin sediment yield and relief ratio. Williams and Knisel (1971) have found that sediment yield can be related to drainage density. However, there appears to be no simple relationship between average annual suspended sediment load and either relief ratio or drainage density in the province (Dickinson et al., 1975; Ongley, 1976).

For information in the province regarding the possible relationship of watershed sediment yield to more specific soil and land use variables, one must turn to a suspended sediment data set assembled in conjunction with the PLUARG studies. This data set was developed from the sampling of suspended sediments discharged from 11 small (<6000 ha) agricultural watersheds in Southern Ontario (Wall et al., 1982). (The research basin locations are noted in Figure 8.) The unit area suspended sediment yields ranged from <100 to 1000 kg ha^{-1} yr^{-1} in a two year study during 1975 and 1976, corresponding to the orders of magnitude identified earlier in this section and by Dickinson et al. (1975).

Wall et al. (1982) found that the annual suspended sediment yield from the 11 small agricultural watersheds in Southern Ontario could be related to land use and physiographic parameters, specifically the percentage row crop in the watershed and the percentage clay in the surface soil, according to the expression:

$$y = -204 + 7.9\ (\%\ \text{Row Crop}) + 11.0\ (\%\ \text{Clay})$$

where y = predicted sediment yield, kg ha^{-1} yr^{-1}. This relationship explained 64 percent of the total variation in the sediment yield data (i.e. $R^2 = 0.64$). This relationship was used as a basis for estimating the mean suspended sediment yield to the Great Lakes from Canadian agricultural land to be 201 kg ha^{-1} yr^{-1} (Wall et al., 1978). When compared to the mean suspended sediment load determined earlier in this section (on the basis of I.W.D.-W.R.B. data), this value is somewhat low but plausible, considering that it is meant to apply to a very large area. Wall et al. (1982) went further, on the basis of this figure, to estimate the total agricultural suspended yield to the Lower Great Lakes from the Canadian side to be approximately 650 x 10^3 t/yr.

Variations in the PLUARG watershed sediment yields were further attributable to differences in the quantity of sheet and rill erosion, in the sediment transport systems, and in the amounts of streambank erosion. To explore the relative significance of some of these causes, sediment yields were partitioned into streambank and cropland yield components, affording results such as those shown in Table 8 (Wall et al., 1982).

FIGURE 8 : LOCATION MAP FOR IJC – PLUARG AGRICULTURAL WATERSHEDS

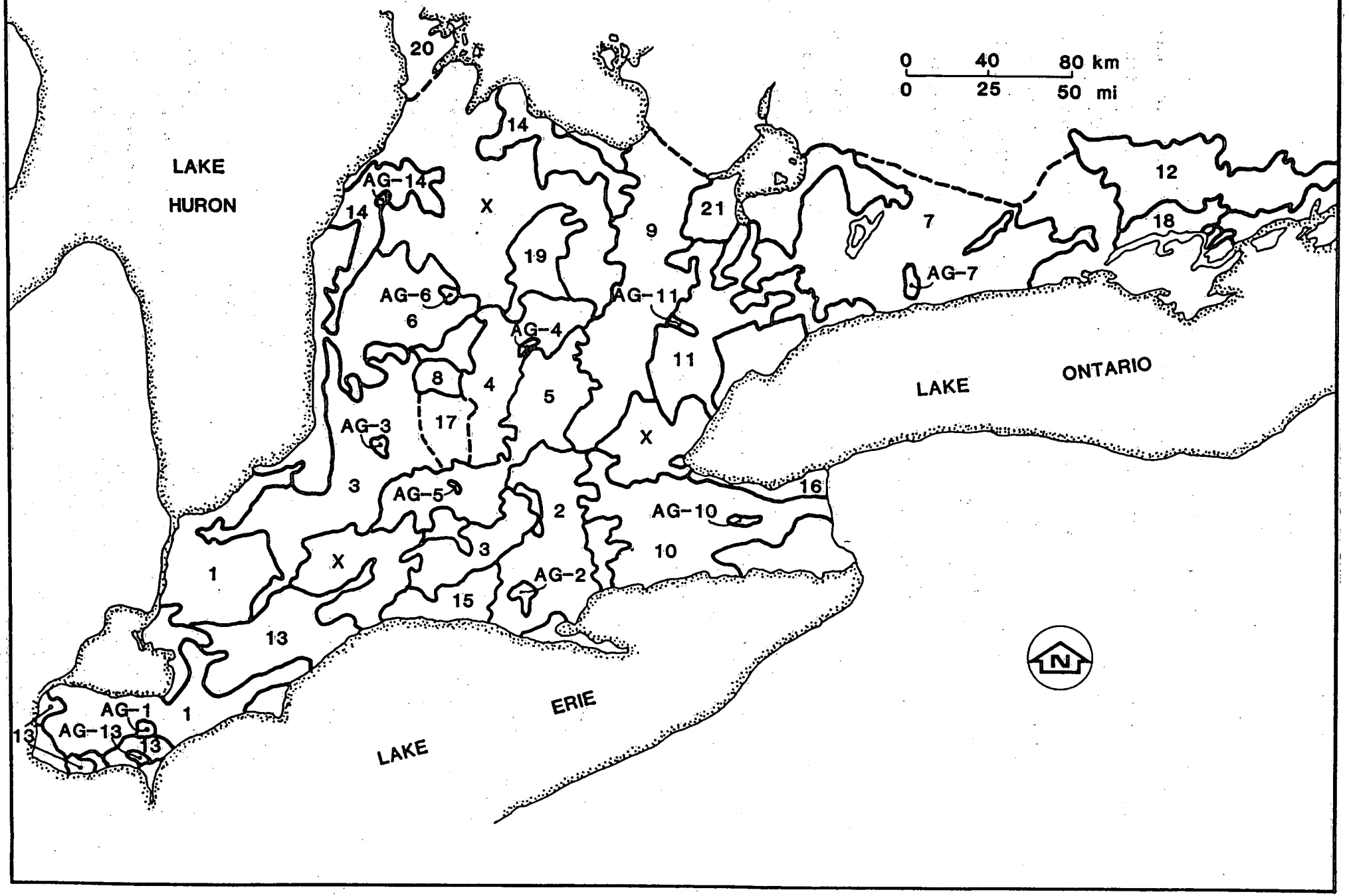


TABLE 8

MEASURED AND PARTITIONED SUSPENDED SEDIMENT YIELDS

(Data Source: IJC-PLUARG Canadian Agricultural Watershed Studies)

Watershed	Mean Stream Sediment Yields[1]		1976 Streambank Erosion Estimates[2]	1976 Cropland Sediment Yield Estimates[3]	Streambank Yield as Proportion of Total Sediment Yield	Cropland Yield As Proportion of Total Sediment Yield
	1975-1977	1976				
	kg ha^{-1} $year^{-1}$				%	
AG-1	961	998	223	775	22	78
AG-2	153	140	10	130	7	93
AG-3	197	258	24	234	9	91
AG-4	464	419	137	282	33	67
AG-5	274	351	5	346	2	98
AG-6	60	64*	10	54	16	84
AG-7	98	43	7	36	16	84
AG-10	300	375	17	358	5	95
AG-11	- -	19*	65	- -	--	--
AG-13	499	310	41	269	13	87
AG-14	139	135	75	60	--	--

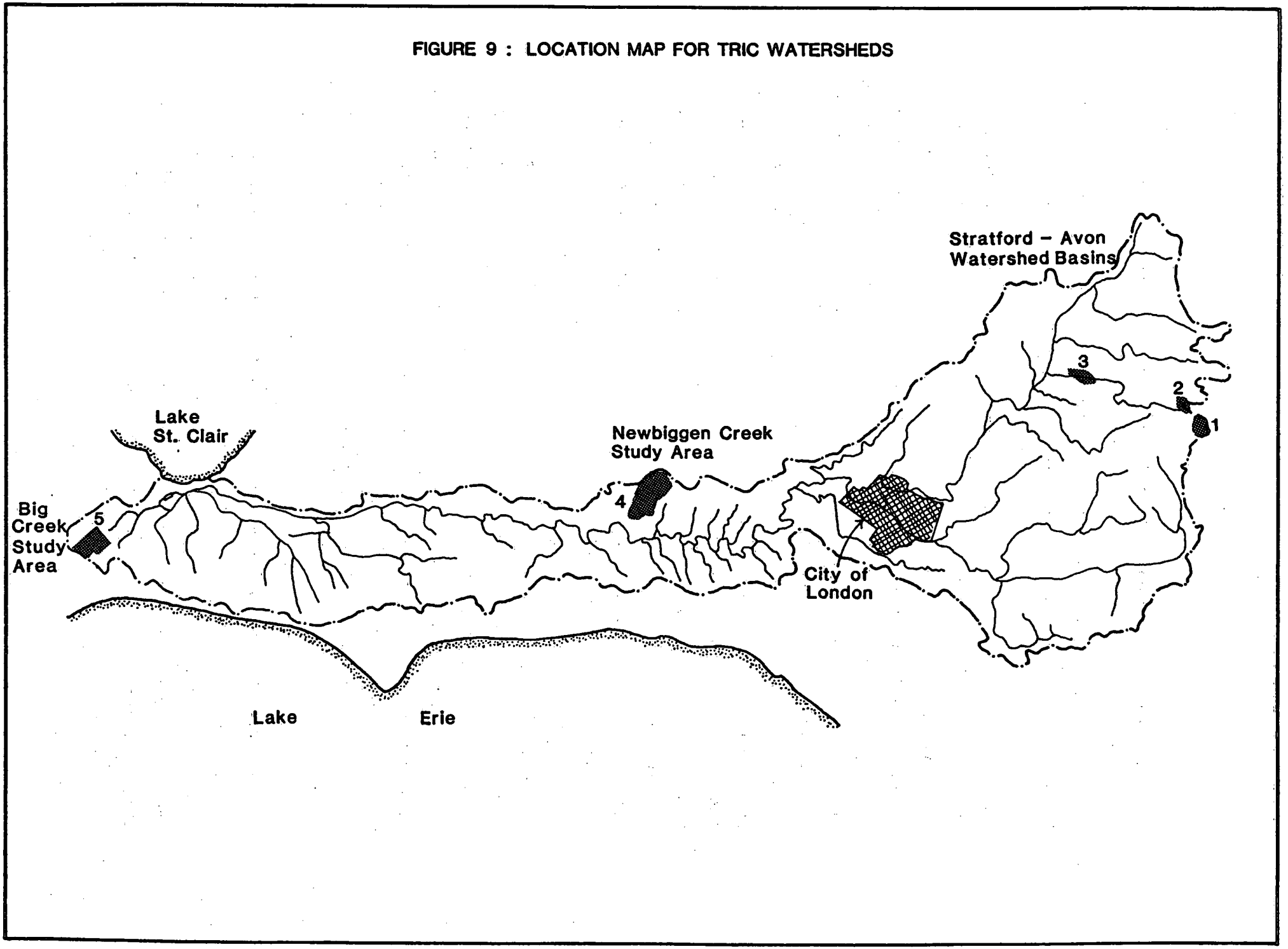
1 Using NAQUADT method of sediment yield computation (Demayo and Hunt, 1975).
2 Knap et al. (1979).
3 1976 Stream sediment yields minus 1976 streambank erosion estimates.
* Problems with streamflow measurements account for the very low sediment yield.

The tabulated values reveal considerable variability from basin to basin with regard to both the absolute and relative quantities of sediment yielded by the watersheds. It is clear that the bulk of suspended sediment in rural Southern Ontario streams emanates from cropland, with sediment delivered from sheet and rill erosion contributing 70 to 100 percent of the annual load. Bank erosion was estimated to contribute between 0 and 30 percent of the annual sediment load. Watersheds with highly erodible soils, erosion-sensitive land uses, and an efficient sediment transport system (e.g. watersheds AG-1 and AG-5) generated relatively high sediment yields. The lowest yielding basins (e.g. (AG-6 and AG-11) were those with soils that were not prone to erode, land uses that protected the soil against erosion forces, and features to minimize sediment transport. Factors such as stream buffering by grass or trees and stream channel density appeared to have considerable effect on the determination of sediment yields, causing areas with highly erodible soils and erosion-sensitive land uses (e.g. AG-3 and AG-7) to yield surprisingly low sediment loads.

The PLUARG studies, like the earlier-noted results in this section, also revealed that about 75 percent of the annual suspended sediment yield is transported in February, March and April. Streambank erosion is also maximum during this period (Knap and Mildner, 1978).

A Post-PLUARG study by Dickinson and Pall (1982) explored the question of spatial variability of suspended sediment yields further on the basis of a data set developed in conjunction with the Thames River Implementation Committee (TRIC). Sediment data were assembled for five small agricultural watersheds in the Thames River Watershed during 1980 and 1981 (a location map is given in Figure 9); and an erosion and sediment modelling exercise involving GAMES (Guelph model for evaluating the effects of Agricultural Management systems on Erosion and Sedimentation) was used to explore spatial variations in sediment yield and to identify sources of significant suspended sediment. Coleman (1982) employed a similar but more qualitative model on a larger basin in the same area.

FIGURE 9 : LOCATION MAP FOR TRIC WATERSHEDS

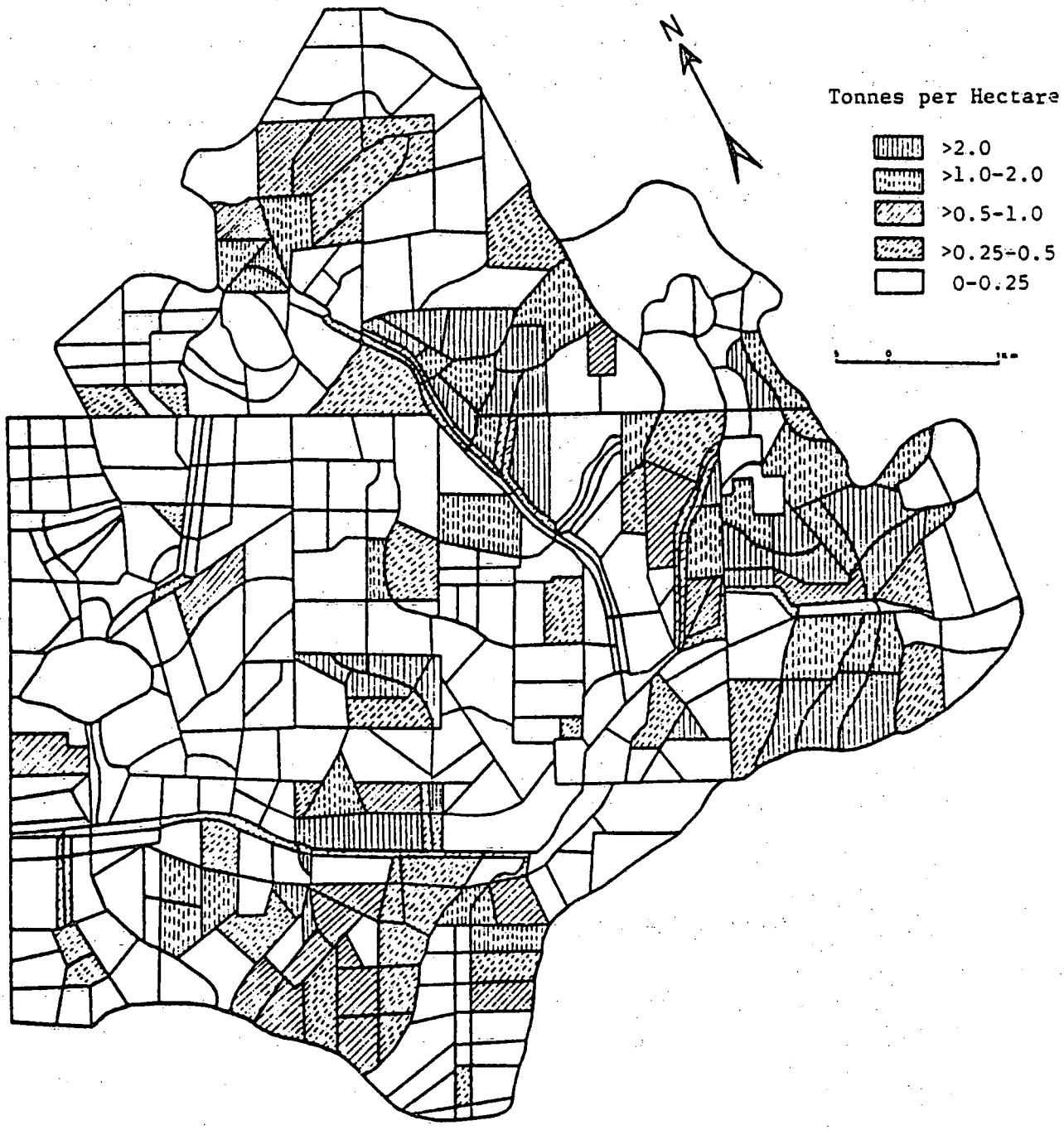


The results of this Post-PLUARG study have generated many insights into the generation of suspended sediment loads in rural parts of Southern Ontario. Although the average sediment yield per unit of watershed area for the Thames River agricultural watersheds was not large (i.e. 0.8 t ha^{-1} yr^{-1}), the suspended sediment amounts estimated to be yielded by field-sized areas within the small watersheds were extremely variable (i.e. 0 to 14 t/ha for the spring months), particularly in the rolling upland watersheds. It followed from these results, that a great majority of the suspended sediment leaving the upland watersheds emanated from a very small percentage of the areas. For example, 62 percent of the spring sediment load in the Stratford-Avon Basin 1 was generated in 15 percent of the watershed area (14 percent of the load was generated in 1 percent of the area). Figure 10 reveals this spatial distribution of sediment yield. Fifty-five percent of the spring load in Basin 2 was generated in 9 percent of the watershed area (35 percent of the load was generated in 4 percent of the area); and 71 percent of the spring load in Basin 3 was generated in 19 percent of the watershed (23 percent of the load was generated in 2 percent of the area). Sediment yield from lowland areas was found to be much more uniform.

The models and applications of Dickinson and Pall (1982) and Coleman (1982) are the most definitive to date to link suspended sediment yields in Ontario to watershed physiographic and land use factors. These models and others are presently undergoing extensive verification in a number of locations in the province. However, only after further testing in a yet wider variety of conditions, will existing sediment yield models or modifications of them be broadly applicable for estimating sediment loads and sources.

Very few detailed studies (e.g. Lane, 1971; Carson et al., 1973) in relation to physiographic and land use variables have been undertaken in Northern Ontario conditions. When PLUARG projects in northern basins revealed extremely low suspended sediment loads, no more detailed studies were undertaken. Therefore, the relative impacts of bank erosion and of

FIGURE 10: SPATIAL VARIATION OF SPRING SEDIMENT YIELD ON STRATFORD / AVON BASIN 1, AS GENERATED BY GAMES



typical northern land use development (e.g. timber cutting) on downstream sediment loads are not well documented.

From this brief overview of literature regarding spatial variability and sources of suspended sediment Ontario, it can be concluded that the long- and short-term sediment records which have been available from various provincial sources have provided useful information for the development of a preliminary picture of the spatial distribution of sediment loads. Although significant progress has been made in understanding linkages between some physiographic and land use factors and associated sediment yields, it is not yet possible to estimate stream sediment loads with sufficient reliability in terms of readily measurable watershed parameters.

Therefore, there is a need for an improved spatial coverage of sediment data in the province; and there is a need to continue to strive to develop generalized spatial patterns and cause-and-effect relationships between sediment and other variables in order to optimize the use of monitored data and minimize the need for additional sediment stations.

It is recommended that sediment data continue to be acquired widely across the province, with more regard given to factors (such as topography, soil geology, land use and watershed size) associated with the determination of sources and transport mechanisms of the sediment and associated variables.

3.6 Sediment and Water Quality

The International Joint Commission report on the "Pollution in the Great Lakes Basin from Land Use Activities" (I.J.C., 1980) reported: "PLUARG finds that the Great Lakes are being polluted from land drainage sources by phosphorus, sediments, some industrial organic compounds, some previously-used pesticides, and potentially some heavy metals. ... Sediment affects the Great Lakes System primarily as a carrier of

phosphorus and the other contaminants, contributing to the overall pollution of the lakes." These summary statements from the PLUARG findings, identifying suspended sediment as a prime transport medium for the delivery of pollutants, have placed sediment and programs for its measurement and control in a new, higher level of importance. What do we know about sediment as a transport medium? And what are the ramifications for sediment monitoring programs?

We have come to realize that sediment on the one hand can be a pollutant carrier or source, and on the other a pollutant sink or trap. This phenomenon applies to virtually all pollutants mentioned above by PLUARG, and depends to a great extent on the chemical conditions in the water. In some biochemical situations, sometimes identified with well-oxygenated conditions, many chemical substances become bound to the surface of sediment particles, especially the clay-sized particles. This is the case in agricultural environments for phosphorus, trace metals (e.g. copper, lead, zinc), and some pesticides (particularly the chlorinated hydrocarbons such as DDT and HCB). When these soils erode, the suspended sediment becomes a pollutant carrier for the bound contaminants, transporting them to downstream locations. If and when such sediment experiences a change in the biochemical conditions in the water, the contaminants may be released more or less quickly depending on the conditions. In such cases, the suspended sediment has served as not only the carrier but the contaminant source; and such is the case in Ontario for the delivery of phosphorus (Allan, 1979; Logan, 1979; Depinto et al., 1981; Coleman, 1982; Culley et al., 1983), trace metals (Miles et al., 1977; Ihnat, 1978; Logan, 1979; Whitby et al., 1979; Ihnat, 1982), and pesticides (Miles et al., 1977; Burton, 1978) from farmlands to streams and lakes.

Relatively contaminant-free sediment may also act as a sink in some biochemical water conditions, contaminants from other sources and travelling in solution becoming bound to the available sediment. This situation has been observed in the Detroit and Niagara Rivers (Frank

et al., Environment Canada and the Ontario Ministry of the Environment, 1980; Warry and Chan, 1981; Fox et al., 1983; Halfon, 1983; Kuntz and Warry, 1983), where organochlorine insecticides and PCB's have become bound to the sediment; and in northern rivers including the English-Wabigoon (Bahnick et al., 1978; Rudd and Turner, 1983), where mercury, copper, manganese, nickel, zinc, and lead have been scavenged by sediment. If the biochemical conditions remain similar where the sediment ultimately settles out, the contaminants may remain bound to the sediment and it remains a sink. However, should biochemical conditions alter sufficiently, be it in stream, harbour, or lake bottom, or during resuspension, the sediment material could revert to being a source of contamination.

So, much has been learned about many of the contaminants which are associated with stream and lake sediments in Ontario, and a start has been made in understanding the processes involved in the binding and/or releasing of the contaminants from the sediment particles. However, knowledge regarding the spatial and temporal variability of these linkage processes as a means of managing pollution, is yet in its infancy. The amount of data appropriate for exploring the linkages between sediment and most of the contaminants has been sparse or non-existent, and the number of carefully structured studies has been few.

In light of the urgency associated with the determination and control of contaminant loads associated with suspended sediment, and in light of our obvious elementary state of knowledge in this area, **it is vital that carefully conceived data sets involving sediment quantity, various contaminant, and other biochemical variables be assembled for studies to ascertain the nature of linkages among the variables and the manner in which these linkages vary in time and space in stream and lake systems in the province. Once such linkages have been established, then combined sediment and water quality sampling strategies will have to be devised for the efficient and accurate estimating of not only sediment concentrations and loads but also various contaminant concentrations and loads.**

4.0 SEDIMENT DATA

4.1 Introduction

In Chapter 2, it became clear that there are a great many and a wide variety of sediment issues which require attention in Ontario. Chapter 3 introduced a spectrum of the knowledge available for addressing the issues, drawing attention to some of the gaps which must be filled. The question remains: Do we have a sediment data base and a system for collecting and disseminating sediment information in the province which allows the development of an effective and efficient approach to the expansion of our knowledge and the resolution of the issues? In this chapter, a critical look is taken at the available sediment data and information system.

4.2 Amount and Nature of Data

The task of assembling information regarding sediment stations soon reveals that there are a great many groups, primarily federal and provincial civil servants, collecting sediment data in Ontario. Thirty-five of the persons replying to the questionnaire reported involvement in sediment data collection. The federal Sediment Survey Program and the Ontario Ministry of the Environment Enhanced Tributary Monitoring Program have been identified by approximately one third of the user respondents as the prime sources of sediment information. However, these groups represent only two of the 35 collecting groups sampled, and there are many users relying on other sediment data sources as well.

Responses to the questionnaire have indicated that the information collected in Ontario on sediment includes a great deal of data involving primarily suspended sediment (21 respondents) and stream or lakebed deposits (22 respondents), bedload data reported to be collected by only

five respondents. Suspended sediment sampling programs have been identified to include more than 300 primarily project-related stations, installed in from very small settings (e.g. one km of river channel, 750 ha watershed) to watersheds of 3000 km^2 and larger. Stream and lakebed sampling programs have been identified to involve more than 200 stations, also primarily project related and installed to sample from small (e.g. 2 km^2) to very large (e.g. 65,000 km^2) watershed settings.

Because the number of sediment stations in Ontario is so large, and because the majority have been established primarily for project purposes (some involving sampling only once or for a very short period of time), it has been extremely difficult to develop either a full listing or mapping of reported sediment stations. Except for separate mappings of the Water Resources Branch and Ontario Ministry of the Environment stations, there is no inventory of sediment stations in the province. Partial combined maps of sediment stations reported by respondents in Southern and Northern Ontario have been developed during this project and are included as Maps 1 and 2, respectively (inside back cover).

Even from these initial maps, it is clear that the many sediment stations are widely distributed across the province, with an obvious concentration in the southern region. From such a number and distribution of stations, one might quickly conclude that the spatial coverage of sediment information is very good. However, before all or much of the data was explored collectively, the data from the various sources would have to be shown to be sufficiently compatible in period of record and methods of collection and analysis to be integrated into a single data base. The partial listing of sediment stations (presented in Appendix F) reveals that the periods of record are far from compatible, duration of record varying widely.

The exercise of attempting to assemble even this partial set of station information has revealed that **there is an urgent need for the development of an ongoing coordinated inventory of sediment data. In order for such a goal to be achieved in the province, in light of the many groups collecting sediment data, there is also a need for a mechanism to coordinate the data available from the many sources.**

Information from many of the sediment data collectors regarding their sampling programs has indicated that sediment data are collected in Ontario by various methods, at a wide range of sampling frequencies. For example, the various suspended sediment data collectors reported that they take grab, or depth-integrated, or centrifugally-pumped samples at frequencies ranging from every five minutes during events, to event, daily, weekly, and seasonal samples for periods of one month, one season, and one year, to three or ten year project durations. Similarly, for stream or lakebed sediment programs, grab samples, scoop samples, cores, or cross-sectional surveys have been taken once only, monthly, once a year, or several years apart, during a particular season or for several years. The methods of laboratory analyses used by the sediment collecting programs are likewise quite variable, as evidenced in the simplified summary of Table 9.

A full description of the various sampling programs and methods in Ontario is beyond the scope of this study. However, some discussion regarding the methods used by the prime source of sediment data (i.e. Water Resources Branch) is warranted. A rather detailed overview of the Water Resources Branch approach was prepared by Mr. Barry Smith, for the workshop part of the study. A point-form and flow chart format of his overview has been included in Appendix G. It includes notes on the types of sediment stations, site selection, the selection of sampling verticals, suspended sediment samplers, bed material samples, bedload samplers, types of data collected, laboratory analyses, sediment station analyses, and quality assurance.

TABLE 9

TYPES OF LABORATORY ANALYSES PERFORMED

ON SEDIMENT SAMPLES COLLECTED IN ONTARIO

Lab Analysis	Number of Respondents dealing with		
	Suspended Sediment	Bedload	Stream or Lake Bed
Concentration	19	2	6
Density	4	-	5
Particle Size	12	2	16
Nutrient Content	10	1	14
Metal Content	9	-	16
Organic Content	11	1	14
Oxygen Demand	7	1	6
Other (e.g. oils, greases, pesticides microbiology, hazardous contaminants)	3	-	6

Presentation of the overview of the Water Resources Branch approach at the workshop was enthusiastically received by the persons in attendance. These sediment data users, many of them reasonably familiar with Water Resources Branch data, applauded the rigour with which the data were collected and analyzed, and the manner in which information has been made readily available. There was no question that the Water Resources Branch sediment information is held in high regard! However, the workshop participants did wonder where they could get such a clear and informative description of the whole approach, as had just been presented. It was noted that such a description until then had not been assembled. This presentation and the subsequent response made it abundantly clear that **no description of sediment data collection methods employed in Ontario has been readily available to sediment data users. There is a definite need for fuller documentation regarding the approaches and methods generally employed by the collectors of sediment data in the province.**

The overview of the Water Resources Branch approach also reveals just how involved the collection, analysis, and presentation of high quality sediment data is. And it becomes apparent that the wide variety of sampling, measurement, and analytical techniques employed by the various sediment data collectors is yielding data outputs that are extremely difficult if not impossible to compare. In order that sediment data collected by a number of groups can be assimilated into a coordinated data base, **future sediment data must be collected and analyzed in more compatible ways. To approach such compatibility, there is a need for a mechanism to establish standards and/or guidelines and to offer advisory services for sediment data collection in the province.**

4.3 Accuracy and Precision of Data

How accurate and/or precise are the sediment data collected in the province? Notions which the sampled sediment collectors have offered on

the accuracy of their sediment data and on the sources of errors are summarized briefly in Table 10. These results considered in conjunction with the respondents' almost unanimous comment that the level of accuracy of sediment data (whatever it may be!) is accepted without question, suggest that the range of accuracy and the sources of error for sediment data are not well understood and have not been adequately evaluated. Most of the collectors do not appear to have identified the accuracy of their sediment data base, and sediment data users (including users who are also collectors) have generally not specified the accuracy required in projects undertaken.

TABLE 10

ACCURACIES AND ERRORS ASSOCIATED WITH COMPILED SEDIMENT DATA

Range of Accuracy Source of Error	Number of Respondents
Range of Accuracy	
<1%	1
<10%	8
<25%	4
<50%	1
Don't know	14
Sources of Error	
Field measurements	19
Measurement frequency	12
Assumptions and computations	11
Other (e.g. lab analysis)	9

It would appear, however, that an increasing number of sediment data users are interested in the accuracy associated with the data. The interest in accuracy stems from a need for better data to aid in more critical decision making, and from a growing realization that suspended sediment data, and associated contaminant data, can be grossly in error. Walling (1977) has noted that annual sediment loads can be overestimated by as much as 30% and errors in estimation on monthly loads can vary between +900% and -80%. Kleiber and Erlebach (1977) have reported that loading estimates are biased as well as imprecise when suspended sediment concentrations are sparsely sampled and used as estimates of mean monthly or quarterly concentrations. Significant effects of sampling frequency on the accuracy of several types of mass discharge estimates have also been demonstrated by Weber et al. (1979). Hore and Ostry (1978) have noted that differences in unit area load estimates of suspended solids may be as great as 300% due to computational procedures alone.

The accuracy and precision associated with the application of various sediment load computational methods to various sampling frequencies of suspended sediment concentrations have received preliminary exploration by Dickinson (1981). The computational methods and sampling frequencies selected are ones which have been used by sediment collecting groups in Ontario. A summary of the analysis and results are presented here:

(a) Three years of daily suspended sediment loading data for the Big Otter Creek were selected as a base population (i.e. WRB data). In addition to the daily suspended sediment loads, daily streamflow values, sampled concentration values, and estimated mean daily concentrations were available.

(b) Four sampling frequencies were selected for application to the base population. These frequencies included:

    (i) one concentration sample per month for only the summer months of April to October,

(ii) one sample per month for the year,

(iii) one sample per week for the year, and

(iv) one sample per week plus one sample per day when the daily flow exceeded a selected extreme value.

The three year population was sampled three times at each frequency, yielding nine effective years of sampling.

(c) Five computational methods were applied to the various samples of suspended sediment concentration values in conjunction with the record of daily flow to determine estimates of annual sediment loads. Each method is identified below:

(i) Simple equation - One approach to the estimation of annual sediment loads, which has been used and reported by Ongley (1976), involved application of the simple equation,
$\hat{Q}_s = c\,Q$ (1)
where $\hat{Q}_s$ = the estimated annual suspended sediment load, c = the mean of suspended sediment concentration samples obtained during the year, and Q = the annual streamflow.

(ii) Linear interpolation - This computation methodology involved the relationship,
$\hat{Q}_s = \sum_{i=1}^{365} c_i\,Q_i$ (2)
where c_i = the estimated mean daily sediment concentration (i.e. the sampled value for a sampled day, and a linearly interpolated value between sampled values for those days when concentration was not sampled), and Q_l = the mean daily streamflow.

(iii) Beale ratio estimator - This procedure was recommended for use in the IJC-PLUARG studies (PLUARG, 1977). It involved the subdivision of the concentration samples according to an arbitrary classification of high and low flows. High mean daily flows were assumed to be those equalled or exceeded 15% of the time. The mean of the suspended sediment concentrations sampled during days of high flow was applied to all days exhibiting a high flow; the mean of concentrations sampled during low flow days was applied to all days exhibiting a low flow. This approach, based on the notion of stratified sampling, involved only two strata.

(iv) Single rating curve - For this method, equation (2) was applied with the c_1 values determined from an annual sediment concentration versus streamflow rating curve developed from the sampled concentrations for each year of sampling.

(v) Moving rating curve - This method was similar to the single rating curve in that sediment rating curves were used. However, many curves were developed for each year of sampling on the basis of small groups of successive concentration samples appropriate to the associated flow conditions. This method has also been referred to as the Integration Method (van Vliet et al., 1978).

(d) The mean ratio of the estimated annual suspended sediment load to the population suspended sediment load, $\hat{Q}_s/Q_s$, was determined for each sampling frequency in conjunction with each computational method as an index of accuracy.

(e) The standard deviation of the $\hat{Q}_s/Q_s$ ratio was also computed for each sampling frequency and methodology as an index of precision.

The computed indices of accuracy and precision have been summarized in Figures 11 and 12, respectively. These figures yield the following observations regarding the estimation of annual suspended loads in Big Otter Creek:

(a) Most computational methods result in an underestimation of the annual sediment load for the sampling frequencies analyzed. Infrequent sampling of suspended sediment concentrations can lead to gross underprediction of the annual load.

(b) The moving rating curve method is the most accurate and the most precise method of those tested for all but the lowest sampling frequency.

FIGURE 11: MEAN RATIO OF $\hat{Q}s/Qs$ COMPUTED USING FIVE METHODS vs. SAMPLING FREQUENCY, AS AN INDEX OF ACCURACY

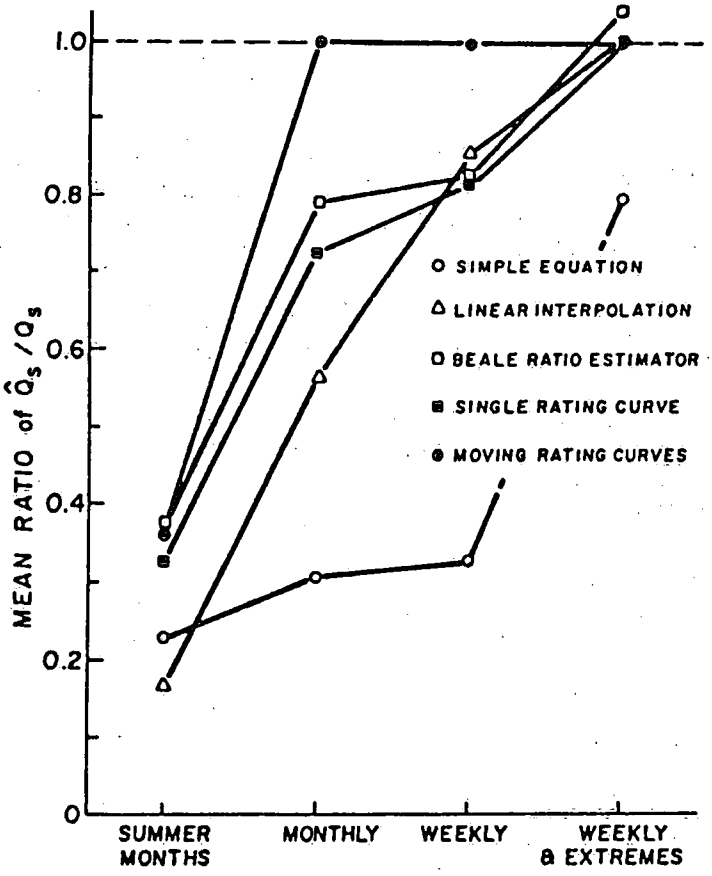
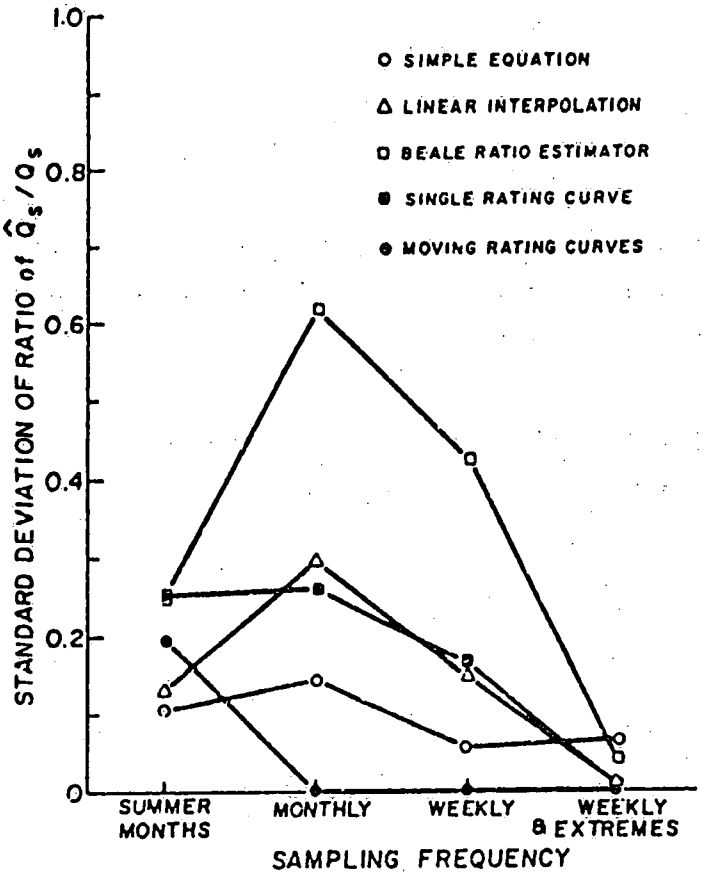


FIGURE 12: STANDARD DEVIATION OF $\hat{Q}s/Qs$ COMPUTED USING FIVE METHODS vs. SAMPLING FREQUENCY, AS AN INDEX OF PRECISION



(c) The simple annual equation is reasonably precise but very inaccurate. If the inaccuracy were found to be consistent, a simple correction factor would be applied to render the annual estimate more accurate.

(d) The Beale ratio estimator is reasonably accurate at the highest sampling frequencies, is the only method to overpredict on the average at the highest frequency, and is the least precise of the methods tested. The last observation is of particular significance when the method is applied to only 1 or 2 years of record.

(e) The linear interpolation and single rating curve methods are reasonably accurate and moderately precise at the highest sampling frequencies.

The results reveal that for many hydrological and suspended sediment regimes in Ontario, akin to those of Big Otter Creek, the sampling frequency of sediment concentrations and the method of computation of annual sediment loads can have significant effects on both the accuracy and precision of sediment load estimates. The relative level of accuracy for a particular computational method applied to a selected sampling frequency does not necessarily correspond to the relative level of precision for the same combination of method and frequency. Therefore, the topics of both accuracy and precision need to be considered when methodologies and sampling frequencies regarding the collection of sediment data are being reviewed.

In light of the general lack of knowledge about errors in Ontario sediment data (on the part of data collectors and data users alike), and in light of the analysis and results presented above, **it is imperative that the accuracy and precision of sediment data collected by various groups in the province be ascertained in relation to sampling and analytical procedures employed, and in light of the accuracy and precision warranted in user projects. It is also vital that sediment data users be clearly informed about the nature and extent of errors in sediment data.**

4.4 Usage of Data

The sources of the sediment data used by the groups identified in Chapter 2 (Table 4) are presented in Table 11 according to the category of organization providing the information. The Water Resources Branch has been identified as the largest single source of sediment data in Ontario, with 39 users. Nineteen of the 35 users who also identified themselves as collectors have not made any use of the WRB data; and 21 users in all have not used this set of information. On the other hand, most of the users who are not also collectors (i.e. 23 of 25) have made use of the WRB sediment data base.

An implication of these results is that a majority of users of sediment data in the province use WRB data as one of their sources of information. However, a considerable number, almost one third of the sample of respondents, have not used these data; and most of this group in fact have collected their own sediment data. From the questionnaire results alone, it was unclear whether users have not used particular sources of sediment data (e.g. WRB) because they have not had knowledge of that source, or because the data available have been inappropriate for their purposes.

It became quite clear at the follow-up workshop that many of the sediment data users in the province are unfamiliar with WRB sediment information and with much of the information available from the other sediment data sources. Further, many of the users who are aware of WRB information do not have a very complete picture of the range of data and services available from that source.

In light of the wide variety of sediment data users in Ontario, the number of sources of data available, and the lack of awareness of available information and services, it is evident again that the sources of sediment data should be clarified for users.

TABLE 11

SOURCES OF SEDIMENT DATA IDENTIFIED BY USERS IN ONTARIO

Source of Data	Number of Users
Water Resources Branch (Sediment Survey Program)	39 (16)[1]
Other Government Ministry or Department[2]	16 (9)
Private Organization	6 (2)
User's Own Sampling Program	33 (33)
Other (e.g. academic institution)	6 (4)

[1] Users who are also collectors of sediment data.

[2] e.g. Ontario Ministry of the Environment, Canada Centre for Inland Waters, International Joint Commission.

The types of data which users have used are identified in Table 12. It is clear from the results in this table that there is a wide variety of sediment data used. There is some evidence that the prime interest has been in suspended sediment data (including concentrations, loads, and composition), with considerable use also made of stream or lake bed depositional information (particularly as it relates to reservoirs and harbours). There has been relatively little interest in stream bedloads, which is not surprising in light of the almost insignificant amount of bedload carried in the majority of Ontario streams. Users have tended to focus on annual and/or event-based data, although a good number have expressed interest in seasonal and/or monthly information as well.

TABLE 12

TYPES OF SEDIMENT DATA USED IN ONTARIO

Types of Data	Number of Users
Form	
Concentration (suspended sediment)	39 (20)*
Loading	27 (16)
Composition (particle size and/or chemistry)	25 (21)
Location	
Suspended	42 (12)
Bedload	14 (5)
Stream or Lake Bed	26 (22)
Period	
Annual	30 (12)
Seasonal	22 (11)
Monthly	18 (9)
Daily	8 (23)
Event-based	31 (19)
Extremes	11 (6)

* Users who also collect sediment data.

To explore further the extent to which currently available data are meeting users' needs, the types of data identified by the sample of users to be preferably added to the currently available data, and data preferences regarding sampling frequencies and numbers of sediment stations, are summarized in Tables 13 and 14, respectively. As virtually all respondents included their items of data presently used as minimum requirements, only those items identified in the preferences to be additional have been included in Table 13.

It should first be noted from the relatively low numbers in Table 13 that most users have suggested that their preferred data requirements are virtually identical to the types of data which are now available to them. Possible exceptions include a number of requests for additional bedload and seasonal data. These results suggest that sediment data users are generally satisfied with the type of data available, are beginning to realize the seasonal nature of the Ontario sediment picture, and have an interest in ascertaining not only sediment quantity budgets but also sediment quality budgets. However, the results are also an indication that many users are somewhat uncertain just what their data needs are.

The results presented in Table 14 reveal very clearly that there is a desire for more sediment stations and more frequent sampling. Further, from comments added on the questionnaires and offered at the workshop, it is evident that users would like to have data in locations and form that are more appropriate for their particular problems and issues. In some cases, that might mean the addition of stations to offer a better localized spatial coverage, but the period of record required at such additional stations might be very brief.

Because much of the information regarding sediment data in the province has not yet been coordinated into a convenient and readily available form (as noted in Section 4.2), and because specific needs for sediment data have also not been fully assembled and documented, it has not been

TABLE 13

TYPES OF DATA IDENTIFIED BY USERS
TO BE PREFERABLY ADDED TO DATA CURRENTLY AVAILABLE

Types of Data	Number of Users
Form	
Concentration (suspended)	6
Loading	4
Composition (particle size and/or chemistry)	6
Location	
Suspended	4
Bedload	15
Stream or Lake Bed	3
Period	
Annual	10
Seasonal	12
Monthly	7
Daily	6
Event-based	3
Extremes	7

TABLE 14

DATA PREFERENCES REGARDING SAMPLING
FREQUENCY AND NUMBERS OF SEDIMENT STATIONS

Data Requested	Number of Users
More frequent sampling	11 (9)*
More numerous station locations	18 (12)
User-specific station locations	10 (5)

* Users who also collect sediment data.

possible in this project to ascertain needs regarding numbers and locations of sediment stations. However, in light of the importance of specifying such needs, **it is recommended that the Water Resources Branch, in conjunction with other sediment data collectors in Ontario, continue to develop their network strategy for sampling sediment information over the extent of the province, in light of spatial information and models already available, apparent gaps in knowledge, and identified needs.**

Many users would also like the collectors and suppliers of sediment information in the province to provide some basic interpretations along with their data. An indication of the user needs is reflected in the range of methods of analysis presently performed by users (shown in Table 15). Although there is a diversity of opinion regarding the interpretations required, the more fundamental ones include descriptions of the temporal variability of the data, regional patterns, linkages to other variables (and in particular, other water quality variables), and linkages to sediment sources. In light of the apparent widespread interest in this aspect of sediment information, **it is recommended that the Water Resources Branch explore more fully the need for basic interpretations regarding collected sediment data, and examine requirements for and implications of including such information as an integral part of the accumulated sediment data base for the province.**

In a consideration of the usage of the sediment data available in the province, it is also useful to explore the program objectives of the various sediment collection groups, and to view these objectives in light of the problems and issues identified earlier by the sediment data users.

The sediment sampling program objectives offered by the various sediment data collection groups responding to the questionnaire were summarized, and examples of the objectives have been presented in Table 16. The objectives are very diverse, just like the issues of Table 1, in

TABLE 15

METHODS OF ANALYSIS PERFORMED BY USERS
ON AVAILABLE SEDIMENT DATA

Method of Analysis	Number of Users	
No further analysis	7	(4)*
Statistical analysis	27	(19)
Loading calculations	29	(19)
Yield calculations	21	(11)
Simulation of continuous records	7	(4)
Simulation of ungauged stations	10	(4)
Other	5	(3)

* Users who also collect sediment data

TABLE 16

EXAMPLES OF SEDIMENT SAMPLING PROGRAM OBJECTIVES

Category	Sampling Objective
Sediment Quantity Issues	- to explore dredging programs on rivers
	- to evaluate life expectancy of reservoirs
	- to evaluate dredging proposals for disposal of sediments
Sediment Quality Issues	- to define nutrient budgets in forest ecosystems and the effects of forest management
	- to determine Phosphorus loading picture to Lake Simcoe
	- to ascertain nutrient and toxic loads to the Great Lakes from connecting channels
	- to characterize bacterial and other pollutant levels
Sediment Process Issues	- to prioritize tributaries contributing greatest sediment loads
	- to quantify channel erosion rates
	- to monitor land development activities
	- to determine impacts of remedial measures on stream sediment loads
	- to determine relationships between sediment loads and watershed parameters
	- to monitor the deprivation of aquatic habitat
	- to study relationship of microbial populations to various sediments
	- to determine chemical processes in sediments
	- to provide data for mineral exploration and resource assessment
	- to monitor diffuse source pollution

Chapter 2; and there are program objectives relating to each of the main issue topic areas. These results would seem to indicate that the current sediment program objectives are, in general, in tune with the concerns of the user groups.

It is also revealing to consider whether and how objectives for sediment programs have changed over the years during which sediment data have been collected in Ontario. In particular, it is informative to consider the objectives of the WRB Sediment Survey Program, as that program, now spanning about 20 years, is of the longest duration in the province.

Stichling (1972), a leading figure in the establishment of the federal sediment program across Canada, has clarified the early objectives. The sediment data collection program was essentially designed on a network or a project-specific basis to assess sediment transportation and deposition relative to engineering works. A typical example study relating to this objective would have been a reservoir survey to determine the deposition rate and the life expectancy of the reservoir. It is only recently, beginning with the collection of sediment baseline information for environmental assessment purposes regarding the proposed Pickering Airport, that the Sediment Survey Program in Ontario has considered water quality as opposed to water quantity issues.

Although the example program objectives have generally been noted to relate well to current issues, and although there has been some shift in the WRB program objectives, it is important to raise the question: How well do WRB sediment data address current and predicted future issues? The Sediment Survey Program has been directed principally towards determination of the quantity of suspended and deposited sediments rather than the quality of such sediments. Further, there is not much evidence of the program being related very strongly either to the program of the Water Quality Branch of Environment Canada or to the Ontario Ministry of

the Environment water quality monitoring program. The Sediment Survey Program has certainly proven to provide useful data, as evidenced by the large number of users referring to it. However, in light of the increased focus on water quality concerns, the Water Resources Branch Sediment Survey Program should examine the relevance of their sampling methodology in time and space as well as associated laboratory analyses to not only sediment quantity but also sediment quality and associated water quality issues. Sediment data should be collected in Ontario with more regard given to water quality variables of local and temporal interest, and to other data collection programs regarding such variables.

5.0 A SEDIMENT INFORMATION SYSTEM

5.1 Introduction

From the preceding discussions, of sediment issues, sediment knowledge, and sediment data, it is very evident that there is a substantial need for a much more coordinated approach to the collection and dissemination of sediment information in Ontario. In this section, recommendations are proposed (including many presented earlier) for the development of an integrated sediment information system.

5.2 Coordinated Data Collection

There is a strong desire on the part of sediment data user groups for a much more coordinated approach to data collection. The desire is for an approach that would not only coordinate the main ongoing monitoring programs (e.g. sediment programs of the Water Resources Branch and the Ontario Ministry of the Environment), but would also develop linkages with special projects. It is believed that such an approach would:

- lead to the collection of more compatible data sets;
- lead to a greater availability of more, and more compatible, data;
- lead to improved spatial distribution of sediment stations;
- lead to the development and acceptance of standardized field and laboratory methods;
- lead to the development of a user-oriented handbook regarding methods of sediment data collection and suggestions/cautions for data use;
- encourage and facilitate interaction and improved communication among sediment collecting groups;
- reduce duplication among studies;

- lead to improved efficiency of operation within collecting groups; and
- facilitate the development of linkages between sediment and other programs e.g. water quality programs.

It is also believed that a more coordinated approach to data collection would benefit from the provision of advisory services for data collectors and for data users. The users generally agree that one of the main collecting agencies (i.e. the Water Resources Branch) should have the mandate for providing such services, and that provision of such services would:

- improve the quality control regarding sediment data;
- encourage and support more comparative analyses;
- keep collectors and users abreast of changes in state of the art techniques; and
- improve the flow of information regarding available data and services to user groups.

It is, therefore, recommended:

- **that sediment and sediment-related data continue to be collected in Ontario by a number of agencies, groups and individuals; and that these various collectors work together in a coordinated fashion to develop a more integrated sediment data acquisition system;**
- **that cost-sharing (i.e. among sediment data collectors) be investigated by the collective group of sediment data collectors in the development of the data acquisition system;**
- **that guidelines and/or standards be developed by the collective group for the acquisition of sediment and sediment-related data in Ontario; and**
- **that one of the agencies intimately involved with the development of the integrated sediment data acquisition system (i.e. the Water Resources Branch) be responsible for providing advisory services to data collectors and users regarding the collection, analysis and interpretation of sediment data, continually ascertaining those interpretations deemed to be most useful to user groups.**

It has also become clear that there is a need for the sediment data acquisition system to be more responsive to specific problem requests.

Therefore, it is recommended that the sediment data acquisition system be established to be more responsive to requests regarding specific project needs; and that cost-recovery methods (i.e. involving sediment data users) be investigated by the collective group of sediment data collectors in the development of the acquisition system.

5.3 Centralized Data Base

It is apparent that sediment data users are enthusiastic about the idea of developing a centralized sediment data base, such a base offering more data in a readily available form. Such a base would also provide invaluable feedback to sediment collectors regarding network planning. However, there are a number of problems associated with the development of such a data base, including:

(i) assembling the massive volume of data;

(ii) clarifying differences among the various types of data collected and among the various methods used for collection and analysis; and

(iii) making statements regarding the relative quality of the data.

In light of such problems, a number of possible courses of action might well be considered in the development of a centralized sediment data base:

- a summary of data sources, collection and analysis methods used by each source, and a listing of station locations and periods of record, might serve as an initial form of centralized information;
- data might be grouped in a sort of hierarchy, according to accuracy and/or level of detail;

- the assembling of a complete set of sediment data for Ontario might be initiated from this point in time, or at a time when common standards have been established for data collection;

- a feasibility study could be initiated to explore further the need for, the ramifications of, and mechanisms to develop a centralized data base; and/or

- the possible utility of NAQUADAT and/or WATDOC could be explored.

It is recommended that a mechanism be developed by the collective group of sediment data collectors to coordinate the various sediment and sediment-related data bases which have been and are to be assembled. The coordination should address at least information regarding the data sets available, sources of the data, and methods of data collection and analysis.

And in light of the general lack of knowledge regarding available sediment data and services:

It is recommended that information available regarding sediment in Ontario (e.g. data, collection and analysis methods, agencies involved, advisory services) be made more readily available to users; and that the Water Resources Branch explore more fully ways of publicizing and transferring sediment information to user groups (e.g. considering not only publications, but also workshops, newsletters, etc.).

5.4 Initiatives

Since it has been deemed very desirable for sediment data collection to be coordinated across collecting agencies across the province, and for a centralized sediment data base to be established, the question arises: Who, or what group or agency, should take such initiatives? Again, a

number of alternative possibilities have been suggested and explored. These include:

(i) the Water Quality Branch of Environment Canada should be the lead agency:

- information could be assembled through the available network of WQB laboratories.
- the sediment data collection program could be implemented by both federal and provincial agencies.

(ii) the Water Resources Branch should have the lead role:

- this group has already established standard techniques and a sediment information network perspective.
- they should and could readily take initiatives to arrange agency participation, including the possibility of cost-sharing (after the existing federal: provincial agreement regarding streamflow data).
- they could use their well established techniques as a basis to encourage and support the standardization of collection and analysis methods.
- with their own station networks (streamflow and sediment), they could initiate the development of a geographical perspective of sediments in Ontario.
- they have an opportunity to maximize the use of existing sediment and associated programs.

(iii) the Conservation Authorities, within the Ontario Ministry of Natural Resources, should collectively be a lead agency:

- the watershed divides provide natural boundaries for the assembling of information.
- each Authority is knowledgeable about local areas of jurisdiction, and about local special studies.
- the Authorities could provide a multidisciplinary approach.

(iv) a Task Force should be established to initiate the development of a coordinated sediment program:

- the Task Force should include representatives from Water Resources Branch, the Ontario Ministry of the Environment, the Ontario Association of Conservation Authorities, and the Water Quality Branch of Environment Canada.

- the Task Force could and should use mechanisms such as workshops to initiate the standardization of sediment data collection methods and analysis techniques, cooperation and standardization of sediment-related publications, and development of a centralized sediment information system.

Although there have been strong advocates for each of the above alternatives, the approach receiving the broadest acceptance and support involves the formation of a Task Force, this formation to be initiated by the Water Resources Branch.

It is recommended that the Water Resources Branch take the initiative in bringing together the various agencies, groups and individuals involved in the collection of sediment and sediment-related data to consider the feasibility of and approaches for developing a better coordinated and more integrated sediment data acquisition system.

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APPENDIX A

ONTARIO SEDIMENT SURVEY PROGRAM REVIEW

Environment Canada, Ontario Region, and the Sediment Survey Section, Water Resources Branch, Ottawa, wish to acquire a better understanding of the role and importance of sediment data in Ontario. Conservation Management Systems, a division of Ecologistics Limited, has been retained to identify the existing uses of sediment data, evaluate the present data base, and clarify the issues associated with sediment.

Various agencies, firms and groups are being contacted by means of the following questionnaire for both the users and collectors of sediment data in Ontario. The information obtained from the questionnaires will be used in the assessment of the current sediment survey program.

We would appreciate you taking time to help us with our study.

The questionnaire has three major parts. All respondents please complete Part A. Part B is to be completed by the users of sediment data while Part C is for collectors of sediment data. It is possible that both Part B and C may apply to you. If you have any questions regarding this questionnaire, please contact Doug Green of Conservation Management Systems in Waterloo at (519) 886-0522.

Please return the questionnaire to the following address. We would appreciate a response as soon as possible.

Conservation Management Systems
50 Westmount Road North, Suite 225
Waterloo, Ontario
N2L 2R5
ATTENTION: Mr. Douglas Green, P.Eng.

Part A - General

All respondents please answer the following questions.

1. Respondents Name: _____
   Organization Name: _____
   Address: _____
   _____
   _____
   Telephone: _____

2. Type of organization:
[ ] Federal Department
[ ] Provincial Ministry
[ ] Municipality
[ ] Conservation Authority
[ ] Engineering Consultant
[ ] Environmental Consultant
[ ] Researcher
[ ] Academic (college, university)
Other: _____

Part B – Sediment Data Users

Please answer the following questions as completely as possible if you are a user of sediment data.

1. What is the source of your sediment data?

[ ] Water Resources Branch (Sediment Survey, Ontario Region)
[ ] Other Government Ministry or Department (specify): _____
[ ] Private Organization (specify): _____
[ ] Academic or Research Institute (specify): _____
[ ] Your own sampling (remember to fill out Part C)
Other: _____

2. What are you currently using sediment data for?

[ ] Reservoir, lake or pond sedimentation analysis
[ ] Harbour or canal sedimentation analysis
[ ] Natural or artificial drainage channel sedimentation analysis
[ ] Water quality studies
[ ] Aquatic habitat studies
[ ] Recreation planning studies
[ ] Academic or Scientific research (specify): _____
Other: _____

3. What type of available sediment data are you currently using? (check each column)

Form	Location	Period
[ ] Concentration (suspended)	[ ] Suspended	[ ] Annual
[ ] Loading	[ ] Bedload	[ ] Seasonal
[ ] Composition (particle size and sediment chemistry)	[ ] Streambed or lake bed	[ ] Monthly
		[ ] Daily
		[ ] Event based
		[ ] Extremes

Other: _____

4. What type of sediment data would you prefer?
   A. Type of Data (check each column):

Form	Location	Period
[ ] Concentration (suspended)	[ ] Suspended	[ ] Annual
[ ] Loading	[ ] Bedload	[ ] Seasonal
[ ] Composition (particle size and sediment chemistry)	[ ] Streambed or lake bed	[ ] Monthly
		[ ] Daily
		[ ] Event based
Other: _____		[ ] Extremes

   B. Other comments:
[ ] More frequent sampling (specify): _____
[ ] More numerous station locations (specify): _____
[ ] User specific station locations (specify): _____
   Other: _____

5. How do you analyze the available sediment data to develop the sediment information you require?

[ ] No further analysis
[ ] Statistical analysis
[ ] Loading calculations
[ ] Yield calculations
[ ] Simulation of continuous records using partial records
[ ] Simulation of stations not monitored
   Other: _____

6. Do you associate sediment data with other data?

[ ] No association
[ ] Dissolved solids
[ ] Oxygen demanding materials
[ ] Metals
[ ] Nutrients
[ ] Trace organics
[ ] Soil loss, runoff
[ ] Streamflow
   Other: _____

7. What are your future sediment data uses or needs?

[ ] Same as current
[ ] No future needs
   Likely future needs (specify): _____

8. Outline both current and future sediment related issues as you see them (e.g. sediment concentrations which are too high for water intakes and fish; sediment loads which are detrimentally deposited in streams, harbours, ponds, and lakes; sediment particles which are carriers of contaminants such as nutrients, herbicides, heavy metals, and toxics): _____

Part C - Sediment Data Collectors

Please answer the following questions as completely as possible if you are sampling for sediment.

1. What is the objective of your sampling program?

2. Outline your sampling program:
   A. Suspended sediment

   Sampling method: _____
   Frequency: _____
   Period: _____
   Routine or intensive survey? _____
   Ongoing or project related? _____
   Number of stations: _____
   Size of network being sampled: _____
   Other information: _____

   B. Bedload

   Sampling method: _____
   Frequency: _____
   Period: _____
   Routine or intensive survey? _____
   Ongoing or project related? _____
   Number of stations: _____
   Size of network being sampled: _____
   Other information: _____

C. Streambed or Lake Bed

Sampling method: _____
Frequency: _____
Period: _____
Routine or intensive survey? _____
Ongoing or project related? _____
Number of stations: _____
Size of network being sampled: _____
Other information: _____

D. Other (specify): _____

3. How were the stations referred to in question 2 selected?

_____

4. What types of laboratory analysis are performed on the collected sediment samples?

	Suspended Sediment	Bedload	Streambed or Lake Bed
Concentration	[ ]	[ ]	[ ]
Density	[ ]	[ ]	[ ]
Particle size	[ ]	[ ]	[ ]
Nutrient content	[ ]	[ ]	[ ]
Metal content	[ ]	[ ]	[ ]
Organic content	[ ]	[ ]	[ ]
Oxygen demand	[ ]	[ ]	[ ]
Other:	_____	_____	_____

5. What are the accuracies and errors associated with your compiled data?

Accuracy: within
[ ] 1%
[ ] 10%
[ ] 25%
[ ] 50%
[ ] Do not know
Other: _____

Sources of error:
[ ] field measurements
[ ] measurement frequency
[ ] assumptions and computations
Other: _____

6. Are the accuracies and errors referred to in question 5 acceptable to you or do you need more accuracy and less error in your data but are currently unable to achieve it?

_____

_____

_____

_____

7. Identify the users of your data. (Please attach a list if available. If you use the data yourself, please remember to fill out Part B): _____

_____

_____

_____

8. In what form do you supply the data to users? (Please attach any available information on sediment station network, including locations, periods of record, sampling frequency, and type of data available.)

[ ] Regular publications or release
[ ] Project related data reports and appendices
[ ] As requested
[ ] Data not available to others
Other: _____

Please attach a general location map of your sampling stations indicating:

- location
- period of record
- type of sample (from Part C #2)

APPENDIX B

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APPENDIX C

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APPENDIX D

SEDIMENT SURVEY WORKSHOP QUESTIONS

Session A: Present and Future Needs for Sediment Data

- Why are you interested in sediment data? What do you use it for?
- What data do you use? Your own? Sediment survey? Concentrations? Loads? Annual values?
- Will you continue to need sediment data? For what? Same as now? Different?
- What data are you going to need that you do not have (or cannot get) now?

Session B: Sediment Survey Data - Strengths and Shortcomings

- Look at Sediment Survey handout. Have you seen it? Have you used it? Were you aware of all that is available? What weren't you aware of?
- What's the matter with the existing information? With the existing methods?
- What do you like about it? If you did not have it, what would you miss? What do you want continued? Why?
- If you were director for sediment survey, what should it do? What should it provide?

Session C:

- Should one agency collect data? Should one agency provide advisory services to insure similar collection techniques? Would you be willing to pay for such services?
- Should one agency assemble all (most) data collected? Perhaps do preliminary analysis of all data?
- Is there a need for Sediment Survey? Should Water Quality Branch pick up tasks? Or MOE?

APPENDIX E

SEDIMENT SURVEY WORKSHOP QUESTION RESPONSES

Session A: Present and Future Needs for Sediment Data

Question 1 Why are you interested in Sediment Data? What do you use it for?

- stream erosion
- fisheries habitat deterioration
- contaminant transportation
- sediment loadings in harbours, lakes and reservoirs
- environmental impact assessment
- sediment quality and quantity
- soil erosion rates
- channel dredging
- water quality
- water chemistry
- identify sediment sources
- effects of sedimentation on wetlands
  - macrophyte growth
  - contaminant uptake
  - invertebrate populations
  - fish populations especially spawning and nursery areas
- impacts of highway construction on water courses
- lake sediment budget
- impact of pesticides/phosphorus on water quality
- biotic effects i.e. fish and recreation
- impact of pre and post mining operations
- management programs - impacts of soil erosion and pond pesticides
- impact of land use changes
  - land fill disposal (short-term impacts)

- input for mathematical modelling of river processes i.e. Qu'Appelle, S. Sakatchewan
  - output needed as initial boundary condition for model
- used for targeting for remedial measures
- water treatment
- navigation
- selected sampling
- toxics
- biochemical processes of lake sediment
- to study how sediment processes take place
- global need - sources from landforms
- nutrients - wash load
- environmental baseline studies

Question 2 What data do you use? Your own? Sediment Survey? Concentrations? Loads? Annual Values?

- Ministry of the Environment
  - concentrations
  - loads
  - annual values
  - grab samples
  - suspended sediment data
- Conservation Authorities (work done by individual Authority)
  - loadings
  - project oriented data
  - annual loadings - modelling
  - MNR data for habitats
  - use WSC annual loading data
  - urban vs agriculture
- Public Works Canada
  - quality characteristics
  - physical characteristics
  - project basis

- NWRI/CCIW
  - use own data i.e. lake sediment data plus loadings and annual values
- Environment Canada
  - uses own data
- Canadian Wildlife Service
  - uses Water Survey of Canada data
- Small Craft Harbours
  - harbour surveys data
- Environmental Protection Service
  - project basis
- Consultants/Private Contractors
  - use own data
- Water Survey of Canada
  - not used extensively by private sector because program is small
- type of data used
  - sediment survey
  - concentrations
  - annual load
  - seasonal load
  - event load
  - mean daily load
- other
  - contaminant concentrations
  - sediment and microbe interaction
  - bed materials and depth
  - bedload concentration and particle size
  - turbidity

Question 3 Will you continue to need sediment data? For what? The same as now? What data are you going to need that you do not have now?

- all groups will continue to need sediment data
- general future needs
  - not specific to one organization
  - need same types of data, but greater extent, i.e. watersheds, land use and soils
  - better documentation of collected data
  - interpretation of historical data
    - long term
    - regional trends
  - use of miscellaneous stations to complement site-specific projects
  - selective sampling
    - network of stations to characterize watersheds
    - general regional principles
  - identify locations of problem pollutants
  - expanded program
- monitor improvements due to land management improvements (OMAF)
- Environment Canada
  - continue use of bedload data
  - may ignore WSC data for loadings in future
  - harbour siltation - continue monitoring on project basis
  - contaminant monitoring in harbours
- specific needs
  - monthly/yearly loads; event and seasonal loads
  - what nutrients/toxics are tied together
  - bio availability interpretation
  - grain size distribution for various magnitude events
  - hydraulic geometry

  - outline of sampling methods with data to assist interpretations
  - flows with sediment concentrations
  - more sites
- need for more data to identify sources
- forecast loading - statistical - return period for specified load
- differentiate watersheds
- how are data collected?
- interpretation done by data collector?
- examine physiographic regions - for station/network planning

Session B

Question 5 What is the matter with the existing information? With the existing methods?

- more coordination of sampling locations (inter-agency)
- too few stations in given watershed to provide information on point sediment loading
- no further information on related parameters i.e. chemical loads not collected
- coverage to small - small stream coverage?
- data not specific to location - (when available for a specific site it is most valuable)
- use of a sample bank to store samples for future studies
- current data seems to be oriented toward engineering studies
- no sediment quality data provided
- no interpretation or synthesis of data
- there should be geographic orientation of data base
- there should be maps of sediment distribution and/or structures along watercourses
- no total dissolved solids
- could use more data on organic content
- how are interpolations made?
- impact of equipment malfunction during important periods (spring, storms)
- data reliability and accuracy
- no documentation of station conditions (e.g. to explain abnormal loads)
- indication of other agencies providing data at or near stations on same river
- reference to A.E. Service meteorlogical records
- documentation of sampling techniques and data processing

- project orientation requirements for quicker provision of sediment data - electronic data acquisition
- methods
  - could improve size characterization of suspended sediments by use of centrifuge
  - rationale for selection of existing and future sample sites
- frequency of sampling
- grab sampling - how good is it?
- more emphasis on network planning

Question 6 What do you like about Sediment Survey data? If you did not have it, what would you miss? What do you want continued? Why?

- Likes
  - daily loading values
  - relationship between daily flows and mean daily concentrations
  - mean, max. and min. daily values and annual summaries
  - systematic collection and reporting style (procedures in manuals by WSC on national standards)
  - footnotes at bottom of data sheets are useful
  - particle size distribution data
  - temperature data
  - continuity of methods and station locations (as allows for historical interpretation)
  - sediment survey group is well identified and accessible for training and advisory services
  - depth integrated vs grab samples
- all the above data should be continued
- of the provided data some groups prefer general loadings - long-term loadings, i.e. 10 years

- some groups would not miss the daily loadings, if these could be obtained on special request - doesn't need to be in document
- would like to know particle size breakdown, to relate to types of contaminants and other water quality parameters
- would like miscellaneous stations to be placed in areas of project activity
- could not do without sediment survey data as would be to expensive for individual groups
- would miss data on suspended sediments
  - sensitivity loading
  - timing of construction
- would like silt/clay breakdown - water quality

Session C

Question 7 Is there a need to coordinate data collection for compatibility? Should there be advisory services on how to collect good sediment data? (Would you pay for such services?)

Yes, there is a need to coordinate for compatibility

- should coordinate specific studies with ongoing monitoring programs (i.e. MOE, WSC, Conservation Authority)
- coordination may avoid duplication of studies and make available historical information
- coordination between groups could lead to standardization
  - user oriented handbook - guidelines for collection and data use
- central agency could publish data, state of the art approach
- could use existing data survey program as a base for coordination
- publish work by WSC
- interaction between groups is important need a Task Force to standardize methods and to oversee laboratory analysis (ensure collection and analysis meet standards)
- coordinate to obtain
  - better coverage
  - information network
- simultaneous studies on water quality are already coordinated (Water Quality Branch)

Yes, there is a need for advisory services for:

- quality control
- comparative analysis
- keep pace with state of the art techniques
- advisory services are very useful
- they ensure outside agencies are aware of what services are available

- advisory board would be able to set methods and criteria
- advisory services could look at mechanisms to pull material together
- who should pay? - good question

Question 8 Is there a need for a central data base? to assemble all sediment data and perhaps do preliminary analysis?

Yes, there should be a central data base

- for data centralization
  - feasibility study
  - heirachy of data types - higher quality given priority
  - nominate an existing agency to coordinate
  - feedback to network planning
  - should have abstract of study overviews rather than data itself - references should be by watershed
  - library could be developed over long term if needed
- should have a data base for information of equal quality, standards developed by a task force would have to be set first
- central data base would enable all agencies to be aware of what data is available - and all data in one location
- use of information would need to be limited to those who are aware of its limited applications
- data should be accompanied by description of sampling techniques and conditions at time of sampling
- document all historical data and where it can be found
- document who has data rather than have all data in one bank
- would need a system of classifying data
- NAQUADAT or WATDOC are possible examples

Question 9 Who should take the initiative? What should the initiatives be?

- Federal Water Quality Branch should be lead agency
  - implemented by both federal and provincial agencies
  - assemble information through labs
- Water Survey of Canada should have lead role
  - have standard techniques and a natural perspective
  - initiatives
    - assign agency participation (to review and share costs)
    - decide who pays
    - standardize methods
    - develop geographical view of sediments
    - must maximize use of existing programs
- Task Force should be formed as lead agency
  - should include:
    - Sediment Survey
    - Ontario Ministry of the Environment
    - Ontario Association of Conservation Authorities
    - Water Quality Branch
  - initiatives
    - standardization workshop for
      methodologies
      analysis
      publications
      data bank
    - the next step would be decided in workshop
- Conservation Authorities/MNR should be lead agency
  - because
    - have defined boundaries
    - local knowledge of areas of jurisdiction
    - know of special studies done by consultants
    - is a multi-disciplinary agency

- initiatives
  - joint effort with WSC in determining monitoring station locations
  - extension of water quality program
  - Conservation Authority would need to be informed of studies done by other agencies
    - Federal/Provincial institutions

APPENDIX F

SEDIMENT STATION DATA REPORTED BY RESPONDENTS

Agency	Location of Stations	Type of Sediment Sample Period and Frequency
Sediment Survey		Suspended Sediment: Continuous
B. Smith	Halfway Creek near Moosonee (04KA002)	1978-1983
	Nottawasaga River near Baxter (02ED003)	1980-1984
	Lucknow River at Lucknow (02FD002)	1981-1984
	Ausable River at Springbank (02FF002)	1970+
	South Maitland River near Summerhill (02EA010)	1984+
	North Magnetawan River above Pickeral Lake (02EA010)	1978-1982
	Saugeen River at Port Elgin (02FC001)	1975-1982
	Maitland River near Dannybrook (02FE004)	1970-1974
	Thames River near Innerkip (02GD021)	1984-1985
	Thames River at Ingersol (02GD016)	1963-1973
	Thames River at Thamesville (02GE002)	1973-1976
	Camagagigue Creek near Elmira (02GA023)	1967-1973
	Big Otter Creek near Vienna (02GC004)	1966-1975
	Big Otter Creek near Calton (02GC026)	1975+

SEDIMENT STATION DATA REPORTED BY RESPONDENTS

Agency	Location of Stations	Type of Sediment Sample Period and Frequency
Sediment Survey		Suspended Sediment: Continuous
	Sturgeon River near Leamington (02GH001)	1971-1976
	Big Otter Creek near Walsingham (02GC007)	1966+
	OAC No. 5 Farm Gauge at Guelph (02GA032)	1969-1984
	East Canagagigue Creek near Floradale (02GA035)	1974-1984
	Canagagigue Creek near Floradale (02GA036)	1974-1984
	Credit River at Erindale (02HB002)	1973+
	Humber Riber at Oshawa (02HC025)	1966+
	Harmony Creek at Oshawa (02HD013)	1980-1985 (bed load sampled)
	Farewell Creek at Oshawa (02HD014)	1980-1985
	Humber River at Weston (02HC003)	1965-1976
	West Duffins Creek at Green River (02HC026)	1974-1976
	Stouffville Creek below Stouffville (02HC035)	1974-1976
	West Duffins Creek above Green River (02HC038)	1974-1976
	Reesor Creek above Green River (02HC039)	1974-1976
	Reesor Creek near Altona (02HC040)	1974-1976

SEDIMENT STATION DATA REPORTED BY RESPONDENTS

Agency	Location of Stations	Type of Sediment Sample Period and Frequency
Sediment Survey		Suspended Sediment: Continuous
	West Duffins Creek near Altona (02HC014)	1974-1976
	Brougham Creek at Brougham (02HC044)	1975-1976
	Michell Creek below Claremont (02HC045)	1974-1976
	Wixon Creek below Altona (02HC046)	1974-1976
	West Duffins Creek near Pickering (02HC106)	1974-1975
	Ottawa River at Britannia (02KF005)	1971-1976
	Ottawa River at Cumberland (02LB010)	1977-1979
	South Nation River at Casselman (02LB013)	1976-1982
	South Nation River below Casselman (02LB014)	1972-1975
	South Nation River at Lemieux (02LB015)	1972-1982
	South Nation River near Plantagenet Springs (02LB005)	1972-1983
	Sydenham River at Dresden (02GG007)	1985+
	Sydenham River at Florence (02GG003)	1985+
	MacGregor Creek near Chatham (02GE007)	1985+
	Don River at Todmorden (02HC024)	1985+
	South Nation River near Plantogenet Springs (02LB005)	1984+

SEDIMENT STATION DATA REPORTED BY RESPONDENTS

Agency	Location of Stations	Type of Sediment Sample Period and Frequency
Sediment Survey		Suspended Sediment: Miscellaneous
	Albany River near Hat Island (04HA001)	1975+
	Attawapiskat River below Muketei River (04FC001)	1975+
	Moose River above Moose River (04LG004)	1975+
	Roseberry River above Roseberry Lakes (04CA003)	1975, 1984
	Severn River at Limestone Rapids (04CC001)	1975, 1984
	Winisk River below Asheweig River Trib. (04DC001)	1978, 1984
	Abitibi River near Onakawana (04ME003)	1978, 1984+
	Gravel River near Cavers (02AE001)	1985+
	Black River near Marathon (02BB002)	1985+
	Pic River near Marathon (02BB003)	1985+
	Bayfield Creek near Varna (02FF007)	1985+
	Parkhill Creek above Parkhill Reservoir (02FF008)	1985+
	North Thames near Thorndale (02GD015)	1985+
	Kettle Creek at St. Thomas (02GC002)	1985+
	Catfish Creek near Sparta (02GC018)	1985+
	Nanticoke Creek at Nanticoke (02GC022)	1985+

SEDIMENT STATION DATA REPORTED BY RESPONDENTS

Agency	Location of Stations	Type of Sediment Sample Period and Frequency
Sediment Survey		Suspended Sediment: Miscellaneous
	Nith River near Canning (02GAD10)	1974, 1985+
	Conestoga River above Drayton (02GA039)	1985+
	Grand River at Brantford (02GB001)	1974, 1985+
	Fairchild Creek near Brantford (02GB007)	1985+
	McKenzie Creek near Caledonia (02GB010)	1985+
	Grand River at Galt (02GA003)	1975
	Little Otter Creek near Stratfordville (02GC015)	1985+
	Redhill Creek at Hamilton (02HA014)	1985+
	Etobicoke Creek below Q.E.W. (02HC030)	1985+
	Highland Creek at West Hill (02HC013)	1985+
	Ganaraska River above Dale (02HD012)	1985+
	Moira River at Foxboro (02HL001)	1985+
	Napanee River at Camden East (02HM007)	1985+
	Salmon River near Shannonville (02HM003)	1985+
	Mississippi River at Appelton (02KF006)	1985+
	Raisin River near Williamstown (02MC001)	1985+

SEDIMENT STATION DATA REPORTED BY RESPONDENTS

Agency	Location of Stations	Type of Sediment Sample Period and Frequency
Sediment Survey		Suspended Sediment: Miscellaneous
Water Quality Branch, Environment Canada		
Contributed Data		
B. Smith	Albany Rier above Nottick Island (04DG001)	1983
	Asheweig River at Straight Lake (04DB001)	1983
	Cat River below Wesleyan Lake (04GA002)	1983
	Ekwan River below North Washagami River (04EA001)	1983
	Fawn River below Big Trout Lake (04CE002)	1983
	Kenogami River near Mammamattawa River (04JG001)	1983
	Kwotaboahegan River near the mouth (04KA001)	1983
	Little Current River at Percy Lake (04JF001)	1983
	North French River near the mouth (04MF001)	1983
	Ogoka River above White Clay lake (04GB004)	1983
	Pineimuta River at Eyes Lake (04FA003)	1983

SEDIMENT STATION DATA REPORTED BY RESPONDENTS

Agency	Location of Stations	Type of Sediment Sample Period and Frequency
Water Quality Branch, Environment Canada Contributed Data	Pipestone River at Karl Lake (040A001)	Suspended Sediment: Miscellaneous 1983
	Sachigo River below outlet of Sachigo Lake (04CD002)	1983
	Sandy Lake at Sandy Lake (04CA001)	1983
	Severn River below outlet of Deer Lake (04CA004)	1983
	Severn River at outlet of Muskrat Dam Lake (04CA002)	1983
	Windigo River above Muskart Dam Lake (04CB001)	1983
MOE, L. Logan	Ausable River cut Lambton Road Number 18	Suspended Sediment and Bedload sampling
	Don River - Pottery Road	
	Grand River - Dunnville Bridge	
	Humber River - Old Mill Road	Suspended Sediment - Routine Spring
	Kaministiquia River - Highway 61B - T. Bay	centrifugal clarified sampler, runoff samples
	Little Pie River - Highway 17	Bedload - routine fall samples (grab)
	Black River - Highway 17	program initated in 1979/80

SEDIMENT STATION DATA REPORTED BY RESPONDENTS

Agency	Location of Stations	Type of Sediment Sample Period and Frequency
	Pic River - Highway 17 Spanish River - Town of Massey Sydneham River - Highway 40 Wallaceburg Thames River - Prairie Siding Trent River - Trenton Twelve Mile Creek - St. Catharines Welland River - Montrose Bridge Saugeen River - Bruce County Road Number 3	
M.T.R.C.A. B. Hindley	19 stations on Humber River	Suspended Sediment - event related (depth integrated 1 yr. project Streambed - one collection (grab) 1 yr. project
Wilfred Laurier University Dr. G. Subins	Avon tributaries Grand River at KW, Bridgeport Lower Nottawasga Nith River - New Hamburg	Suspended Sediment - event related project basis - Hertsmeter sampler Automatic

SEDIMENT STATION DATA REPORTED BY RESPONDENTS

Agency	Location of Stations	Type of Sediment Sample Period and Frequency
Environment Canada Water Quality Branch K.W. Kuntz	Niagara River - 3 stations	Suspended Sediment - sampler Westfalia continuous
	Ottawa River - 2 stations	flow centrifuge
	St. Lawrence River - 10 stations	program began 1979 extended in 1982 & 1983 - biweekly and monthly
	Severn River - 10 stations	sampling - routine
	Winisk River - 10 stations	ongoing testing
	Attawapiskat River - 10 stations	
	Albany River - 10 stations	
	Moose River - 10 stations	
	Niagara River - 16 stations	Stream/Lake Bed using
	St. Lawrence River - 60 stations	dredge or core
	- 10 stations	samplers - special projects only 1981
MOE WC Region S.M. Irwin	Cootes Paradise 14 2 yr program	Suspended Sediment - grab routines
	Hamilton Harbour 23 1 yr program	lakebed - cores or
	Windermere Basin 20 2 yr program	ekman dredges project
	IJC 5 1976 - continuous	specific
	Orangeville 8 1 yr program	

SEDIMENT STATION DATA REPORTED BY RESPONDENTS

Agency	Location of Stations	Type of Sediment Sample Period and Frequency
OMAF/UTRCA Art Boss	Kintore 7 Pittock 53 Avon 18	Suspended Sediment Sampler: automated and grab Event based and weekly for special projects
McMaster University W. James	Chedorke Creek (Hamilton) 10 stations	Suspended Sediment - depth integrated
Canadian Forestry Service J.A. Nicolson	Kenora Area (Experimental Lakes Area) 15 stations/3 yr program Orient Bay (L. Nipigon) 8 stations/3 yr program Turkey Lake Watershed (S.S. Marie) 20 stations/1 yr program	Suspended Sediment - grab
Niagara Penn. Cons. Auth. Marg Miller	Welland River (6 stations) Virgil Reservoirs (2 stations)	Streambed/lakebed Project related during 1965, 1983 reservoir sampling June/Sept., 1984

SEDIMENT STATION DATA REPORTED BY RESPONDENTS

Agency	Location of Stations	Type of Sediment Sample Period and Frequency
Maitland Valley Cons. Auth. Jane Taylor	Maitland Valley watershed 16 continuous stations 7 event, project related stations	Suspended Sediment - grab continuous depth integrated - event related special studies; streambed - scoop sampling used for special projects
NWRI/CCIW Dr. N. Rukavina	Burlington Bar - Hamilton area of Lake Ontario (6-15 stations)	Bedload - point measurement of lakebed elevation (acoustically) Sampled fall-winter 1979-1982 Projected related
Ontario Hydro	Lake Ontario - Pickering, Burlington Lake Huron - Bruce Lake Superior - Thunder Bay 12 stations Mississagi River	Suspended Sediment - sampler - van dorn, surface grab sedimentation tubes 10 year period Bedload sampling by Echo Sounder during 1984 for specific project

SEDIMENT STATION DATA REPORTED BY RESPONDENTS

Agency	Location of Stations	Type of Sediment Sample Period and Frequency
MNR (London) W.J. Lenson	5 stations Dalewood Reservoir C.A. Kettle Creek C.A.	bottom sampling of bedload and lakebed
Trent University C.H. Taylor	4 stations on Sucker Creek north of Lindasy	Suspended Sediment - project related; 1 yr sampling; sampler - US DH 49
MOE - Water Resources Branch G. Robinson	Lake Simcoe - 25 stations	Lakebed Sampler: coring with 6.7 cm (I.D.) plastic pipe done Oct., 1983 and Jan., 1985 project specific
GRCA P. Mason	City of Cambridge (Galt) Grand River - 4 stations	Suspended Sediment sampled by x-sections Across Grand River - project related
MOE Dorset Research Centre Jane Scholer	Algonquin, Muskoka-Haliburton 15 lakes	Lakebed - modified K-B corere continuous ongoing sampling

SEDIMENT STATION DATA REPORTED BY RESPONDENTS

Agency	Location of Stations	Type of Sediment Sample Period and Frequency
NWRI/CCIW Dutka and Rao	Lake Erie and Lake Ontario Windy Lake Hannah Lake Silver Lake Lohi Lake Wavy Lake McFarlane Lake Ramsey Lake Richard Lake	Lakebed sediments Sampler - corer project specific - seasonal sampling
Catfish Creek Cons. Auth. M. Snowsell	Catfish Creek (Port Bruce) 6 stations	Streambed - bottom sediment core sampler project related

SEDIMENT STATION DATA REPORTED BY RESPONDENTS

Input Not Mapped

Agency	Data
NWRI/CCIW Dr. N. Rukavina	Streambed/Lakebed shipek sampler, benthos corer, impact corer 1968-1978 - continuous, project related after 1978; approximately 3300 stations - 0-20 m zone in Lakes Ontario, Erie, S. Huron and S. Georgian Bay
Ontario Hydro C.W. Stevens	Lakebed sampling by side scan sonar, twice/yr for 10 years on project basis Area covered north shore Lake Ontario
Public Works Canada Ansar Khan	Lakebed sampler - grab (surface) and cores project related in ice free season in all small craft harbours of Ontario
Gore and Storrie Consulting Engineers M. Palmer	Suspended sediment data collected for specific events on Ottawa River, Lake Deskain, Ridea River downstream of Hoggs Back, Eastern Beaches Toronto
Geologic Survey of Canada E.H. Hornbrook	Streambed/lakebed samples by GSC sampler routine sampling during summer months of lakes and streams; approximately 1100 stations per NTS map sheet
Environment Canada, NWRI P.G. Sly	Lakebed sampling using shipek grab, ponar grab event related for selected sites in Lake Ontario Finger Lakes and Algonquin Lakes

APPENDIX G

OVERVIEW OF THE CURRENT SEDIMENT SURVEY APPROACH

Types of Sediment Stations

1. Continuous
   - daily loads produced
   - annual loads derived
   - costly program
   - involves gauge reader samples
   - involves suspended sediment discharge measurements to apply corrections (if any) to reader samples at higher flows

2. Seasonal
   - records produced for a selected time frame (usually freshet to end of May)
   - involves gauge attendant samples
   - involves suspended sediment measurements
   - less costly program
   * - used at stations where 70-90% of loads occur during this period

3. Miscellaneous
   - inexpensive program
   - technician sampling per visit
   - are to appear in a new publication
   - more watersheds covered at less cost

4. Project Oriented - Goderich Harbour, Oshawa Marsh, Pickering Airport, reservoirs, small watershed studies, gamma radiation soil moisture study

Site Selection

- should be at or near a gauging station
- preferably located at highway or railroad bridges
- easy access to cableway, bridges, and stage recorders
- preferably locate sampling verticals on upstream side of bridges to facilitate observation of debris
- sampling verticals should be located where stream discharges are measured (on same bridge side)

Sites should not be located at:

- channel bends or constrictions
- channel constriction from bedrock
- channel constriction by piers - massive or skewed
- where floodplains are constricted by embankments
- where debris accumulation zones are known to occur
- at tributary junctions with main channels

Selection of Sampling Verticals

- daily or individual location at midstream, at the thalweg or from a series of flow measurements where 20% flow curves are used to locate the daily as well as the verticals used in a sediment discharge measurement.

- the daily may also be located from sediment discharge measurements results that yield a concentration most nearly equal to the cross sections average concentration.

- another simple method is to locate the daily where 40% of the flow occurs - measured from the bank which has the deepest channel adjacent to it.

- daily locations should not be changed once a sampling program has been started.

Bed Material Samplers

- U.S. BMH-53 - piston type)
- U.S. BMH-60 - 14 kg.)
- U.S. BMH54 - 45 kg.
- Shippek - 61 kg.
- Lane - 6 kg.
- Scoop - 8 kg
- PH leger cover
- grid-air photo interpretation
- hand measured in situ

Bedload Samplers

- Ainhem - fine sand, find gravel
- Basket - fine gravel, fine cobble
- Sphinx - find sand, coarse gravel
- Bogardi - sand, gravel
- Vuv - sand, cobble

Helley Smith very fine sand, gravel
- mathematical

* - choices depend on depth, velocity, if in rivers

- bed material to be sampled, at top 2-5 cm of streambed or lake reservoir bottom

- maybe sampled by wading, bridge and reel, or from boat.

SUSPENDED SEDIMENT SAMPLERS

Instantaneous

-traps
-not used to compute loads
-rarely used in Ontario region

Time Integrated Samplers

-2 bottles per sample
-surface to bottom transit rate
-average vertical concentration
-samples isokinetically (velocity same in as out)

Point Integ. (>6m.)

P61, P63

Depth Integ. (<6m.)

D74, DH48, DH59, D49, D77

-choice depends on depth and stream velocity
-nozzle selection on DI samplers depends on stream velocity
-choice of pint or quart size samples

*-avoid sample over filling
-maintain equal transit rate
-do not exceed allowable depth

Pumping

-PS82, PWS
-fixed orifice
-must be calibrated by DI sampling
-limited in numbers of samples used for small watershed or site specific projects

-effective sampling technique once calibration done
-maybe programmed to sample on stage or at time intervals

Surface-Dip-Emergency

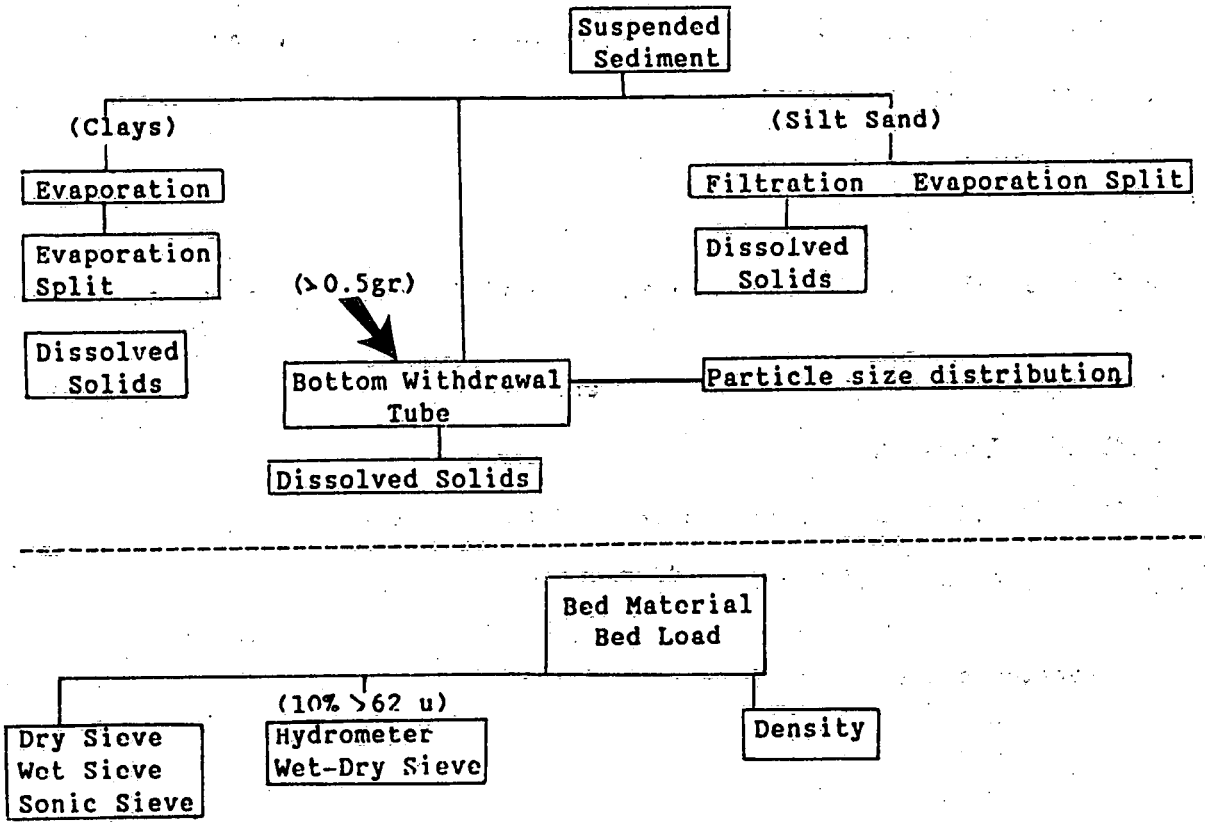
- used to obtain samples when conditions are too dangerous to use time integration

- must be calibrated by time integration samples at the first opportunity

Types of Data Collected

1. Suspended sediment concentrations (mg. l.)
2. Particle size distributions of suspended sediment (5 finder)
3. Temperature of water (^{o}C)
4. Dissolved solids data (mg. l.)
5. Hydraulic parameters
6. Bed material - channel and bank - particle size distributions (% finer m.m.)
7. Density of bed material - in situ-reservoirs
8. Bedload volumes (kg. Tne.)
9. Bedload particle size distributions (% finer m.m.)
10. Morphologic data and trends - degradation
    - aggradation
11. Instantaneous discharges (C.M.S.)

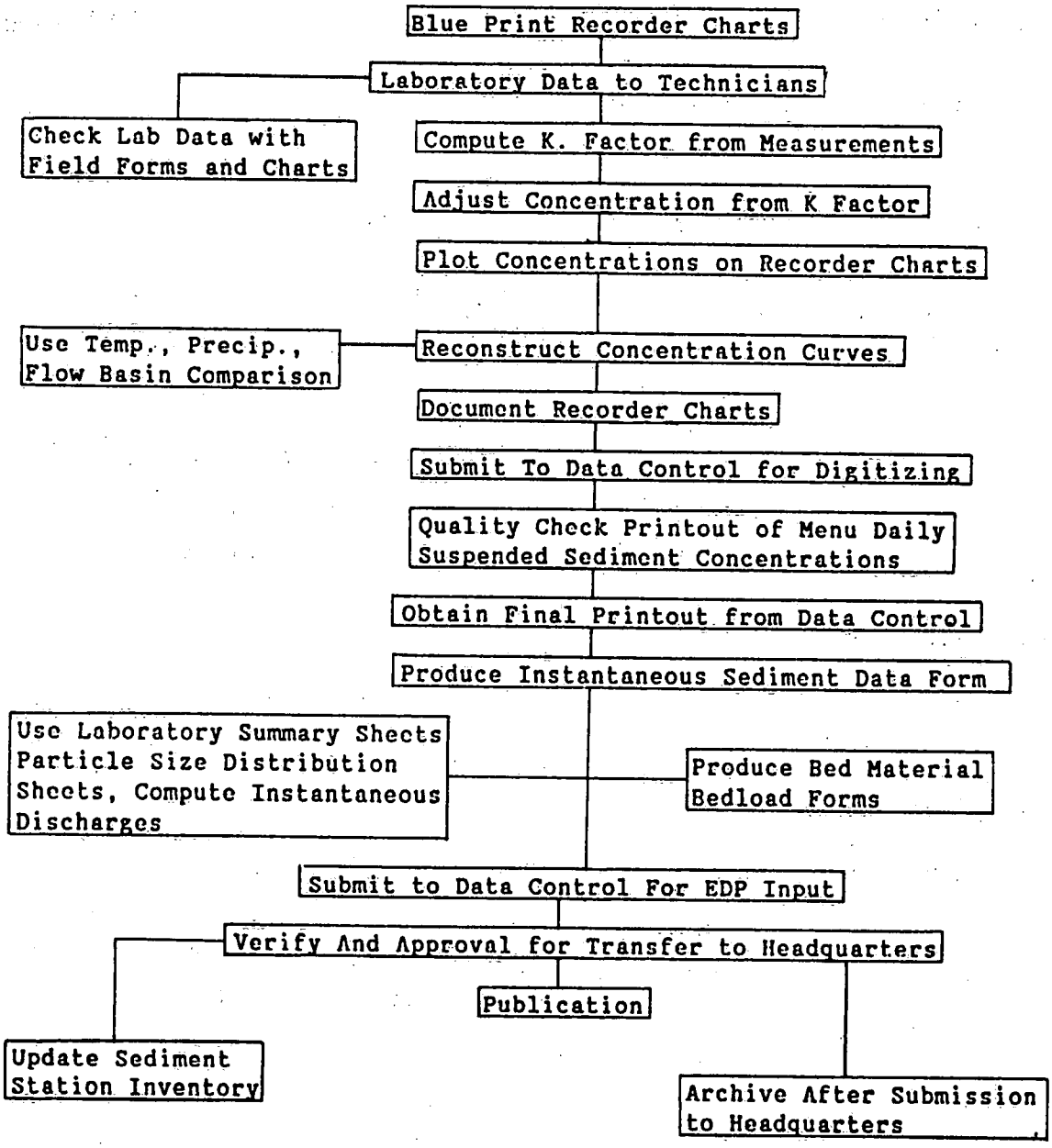
SEDIMENT LABORATORY ANALYSES



Note * Samples are pre-programmed as to analysis type upon lab receipt.

* Samples may be analyzed as per data user on cost recovered projects.

SEDIMENT COMPUTATIONS FLOW CHART



DATA OUTPUT

Sediment Data Canadian Rivers	Hist. Sediment Data Summary - Canadian Rivers	Sediment Data Reference Index

*Three Major Data User Publications

DATA ANALYSIS AND INTERPRETATION

Morphological Studies	E.A.R.P.	Projects	Reservoir Studies
-Fraser River	-Oshawa Marsh	-Goderich Harbour	-Fanshawe
-Edwards Creek	-Pickering Airport	-St. Clair River	-Shand Dam
			-Conestoga Etc.
	-Agric. Canada Small Watershed		-Lake Diefenbaker

Internal Reports
-Costing
-Network Evaluation

SEDIMENT STATION ANALYSIS (New)

- Big Creek Walsingham
- Old Man River Brockett
- Highwood River nr. Mouth

- analysis of long term records to determine trends, results, comparisons, evaluations, interpretations, predictions.

QUALITY ASSURANCE

Field

- sampler check and calibrations
- observer and technician techniques and procedures
- clean bottles

Laboratory

- analysis technique verification
- calibration of scales and equipment
- proper selection of samples for analysis type
- comparison of A & B suspended sediment sample
- controlled environment - dust free, temperature

Computations

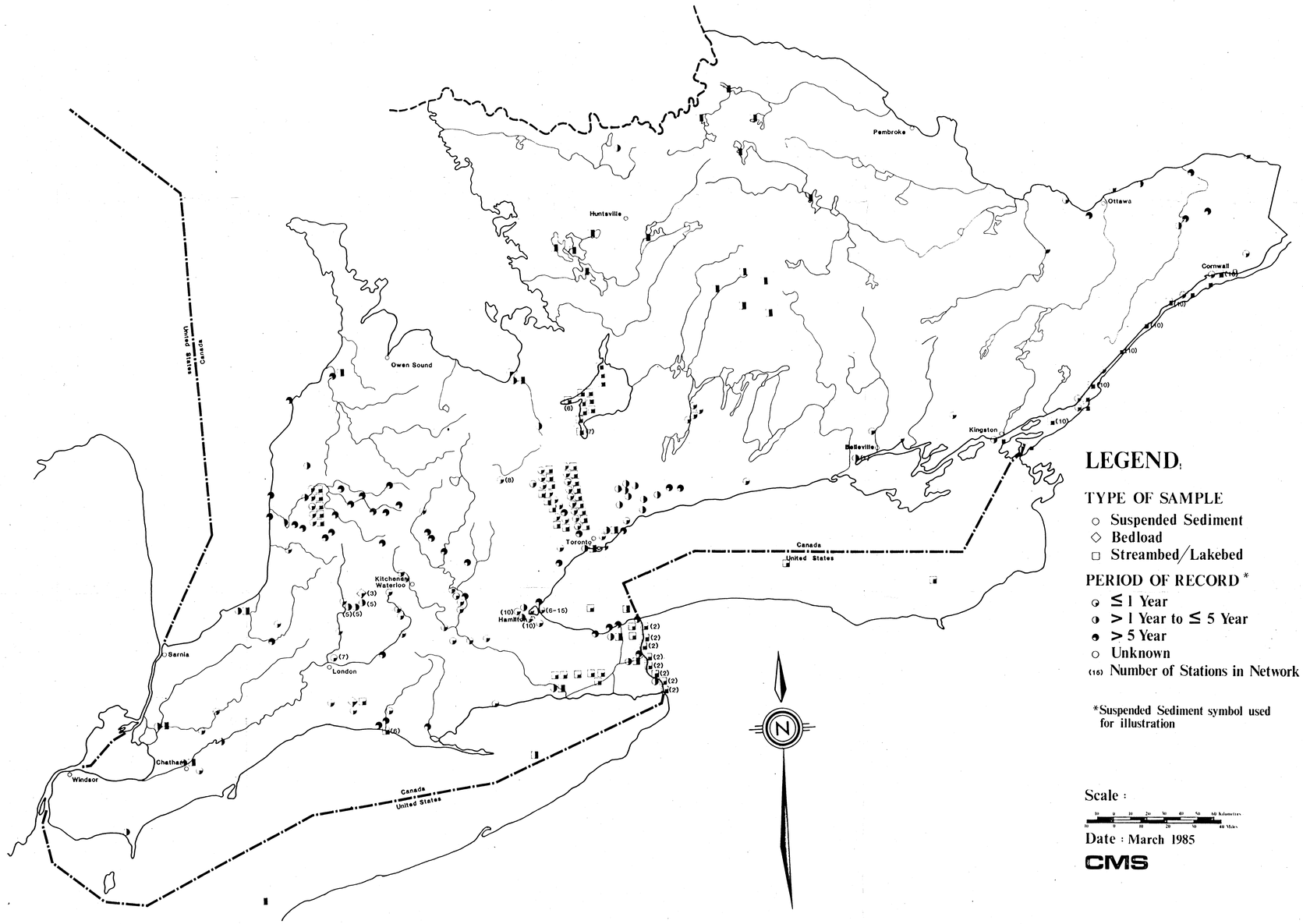
- standards adherence as set out in manuals
- verification and approval of data as it progresses through computation system
- comparison of field to laboratory data before computations begin
- computer verification prior to publication submission

Data Control

- verification of computer printouts to original submissions
- quality assurance of all data entries before submission to publication

MAP 1

SEDIMENT SAMPLING STATIONS REPORTED BY QUESTIONNAIRE RESPONDANTS ~ SOUTHERN ONTARIO



LEGEND:

TYPE OF SAMPLE

- ○ Suspended Sediment
- ◇ Bedload
- □ Streambed/Lakebed

PERIOD OF RECORD *

- ◔ ≤ 1 Year
- ◑ > 1 Year to ≤ 5 Year
- ◕ > 5 Year
- ○ Unknown
- (16) Number of Stations in Network

*Suspended Sediment symbol used for illustration

Scale :

Date : March 1985

CMS

MAP 2

SEDIMENT SAMPLING STATIONS REPORTED BY QUESTIONNAIRE RESPONDANTS ~ NORTHERN ONTARIO

Manitoba
Ontario

Kenora
(15)

Thunder Bay

Canada
United States

(20)

Sault Ste Marie

(12)

Canada
United States

Sudbury

Timmins

Kapuskasing

Moosonee

Ontario
Quebec

Kirkland Lake

N

LEGEND

TYPE OF SAMPLE

- ○ Suspended Sediment
- ◇ Bedload
- □ Streambed/Lakebed

PERIOD OF RECORD *

- ◔ ≤ 1 Year
- ◑ > 1 Year to ≤ 5 Year
- ◕ > 5 Year
- ○ Unknown
- (15) Number of Stations in Network

* Suspended Sediment symbol used for illustration

Scale :

Date : March 1985

CMS