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Summary Pilot Watershed Report: Saugeen River Basin, Ontario

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INTERNATIONAL REFERENCE GROUP ON GREAT LAKES POLLUTION FROM LAND USE ACTIVITIES

INTERNATIONAL
JOINT
COMMISSION

SUMMARY PILOT WATERSHED REPORT
SAUGEEN RIVER BASIN, ONTARIO

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SUMMARY PILOT WATERSHED REPORT

Submitted to

INTERNATIONAL REFERENCE GROUP
ON
GREAT LAKES
POLLUTION FROM LAND USE ACTIVITIES
INTERNATIONAL JOINT COMMISSION
by
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Ontario Ministry of the Environment
Toronto, Ontario
April 24, 1978

3.0 DISCLAIMER

The study discussed in this document was carried out as part of the efforts of the Pollution from Land Use Activities Reference Group, an organization of the International Joint Commission, established under the Canada-US Great Lakes Water Quality Agreement of 1972. Funding was provided through the Ontario Ministry of the Environment and the International Joint Commission. Findings and conclusions are those of the authors and do not necessarily reflect the views of the Reference Group or its recommendations to the Commission.

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5.0 TABLE OF CONTENTS

6.0 LIST OF TABLES

7.0 LIST OF FIGURES

8.0 SUMMARY

Water-quality data collected under the PLUARG program during the period 1975-1976 indicate that while variations across the Saugeen River basin are not dramatic, they broadly reflect increased agricultural activity in the lower reaches of the basin. Streams draining the headwater reaches which are mainly in swamp, non-productive woodland and permanent pasture, are of relatively better quality than the waters at the mouth of the basin. The pollutant impact of the Saugeen River basin on the water quality of the Great Lakes is minimal.

The major sources of pollution from land uses studied in the Saugeen River basin have been tentatively identified as follows:

Urban	*metals*
Point Sources	*metals, organic chemicals, phosphorus, nitrogen*
Transportation	*lead, chloride*
Private-waste Disposal	*phosphorus*
Agriculture	*sediment, phosphorus, nitrogen*

The Saugeen River basin with an urban population density of approximately 8 people per hectare lacks the urban population concentration found in other parts of the Great Lakes basin. The urban impact on the pollution load at the mouth of the river is approximately the same as the percentage of land in urban land use (i.e. one percent). Phosphorus removal does not exist at sewage treatment plants in the basin and this results in a high per capita yield (2.64 g/day/capita) of phosphorus discharged to the receiving waters of the Saugeen River. Significant inputs of total phosphorus (7% of the load at the mouth) are estimated to be from point-source discharges.

Pollutant ranking suggest that urban runoff relative to drainage from agriculture and wooded land yields greater unit-area loads of total phosphorus, sediment, chlorides and metals. However, the impact from urban runoff in the Saugeen River basin is not significant because of the small area of urban land use. The ranking also suggests that agricultural runoff compared to urban and wooded areas is the major contributor in the basin for nitrogen and filtered reactive phosphate.

Highway deicing agents were identified as being the major contributor of the chloride at the mouth of the Saugeen River. The chloride load due to deicing agents is estimated to be in the order of 40% of the total load at the mouth.

In addition to significant inputs of phosphorus from agricultural activities and private-waste disposal systems increased levels of nitrogen creating localized ground-water problems may also occur as a result of these land uses and practices in the basin. Private-waste disposal systems which are properly constructed are of minor concern.

Minimal impacts on stream-water quality have been monitored from waste disposal practices such as sanitary landfills, processed organic waste and spray irrigation. This is in part due to the limited areal extent of these land uses and practices in the watershed. Increased land usage of these practices could create an ultimate health hazard if proper design and management of the sites are not observed.

Monitoring data suggest that the bulk of the river loads (up to 95%) are transported during the months of February, March, April and May. Toxic materials such as heavy metals, pesticides and organic chemicals have a strong affinity for the clay-size sediment fraction which is transported as suspended material in the water. PLUARG monitoring data indicate that the percentage of the total load due to the particulate fraction varies from 10 to 50% for copper, 50 to 70% for lead and 20 to 70% for zinc. Management strategies for these toxic elements should consider sediment control.

Monitoring data demonstrate that in-stream deliveries of sediment and sediment associated pollutants can be extremely variable and less than 100% in some river reaches. Gross estimates of in-stream transport functions, to determine the proportion of the pollutant input that is transported downstream, were prepared for subwatersheds in the Grand River basin. These functions ranged from 32-100% for in-stream transport of pollutants within selected river reaches.

Data from a small river reach near the headwaters of the adjoining Grand River watershed suggest that up to 50% of the soluble phosphorus can be retained on a daily basis by the aquatic weeds due to biological uptake during growth periods. In terms of the Grand River basin, aquatic weed growth may have a significant impact on the phosphorus export from the watershed during the active growth periods of the biomass.

Extrapolation of the pilot watershed data to unmonitored areas in the Great Lakes basin is possible provided the characteristics of the unmonitored areas are similar to those in the pilot watershed. In terms of extrapolation to other parts of the Great Lakes basin, the critical diffuse sources of pollutant contribution have been identified as being urban and agricultural land uses and practices. Based on the pilot watershed information, the most cost-effective remedial measures for the Great Lakes basin will be those that control runoff from agriculture and urban areas.

9.0 INTRODUCTION

9.1 STUDY OBJECTIVES

As a result of the Great Lakes Water Quality Agreement of April 15, 1972, the International Joint Commission (IJC) established the Pollution from Land Use Activities Reference Group (PLUARG). The Reference Group was requested to conduct studies on the impact of land-use activities and practices on the water quality of the Great Lakes basin and to recommend remedial measures for maintaining or improving Great Lakes water quality.

The PLUARG study program consisted of four major tasks as outlined in the Reference Group's February 1974 study plan.

> "*Task A is devoted to the collection and assessment of management and research information and, in its later stages to the critical analysis of implications of potential recommendations. Task B is first the preparation of a land-use inventory, largely from existing data, and, second, the analysis of trends in land-use patterns and practices. Task C is the detailed survey of selected watersheds to determine the sources of pollutants, their relative significance and the assessment of the degree of transmission of pollutants to boundary waters. Task D is devoted to obtaining supplementary information on the inputs of materials to the boundary waters, their effect on water quality and their significance in these waters in the future and under alternative management schemes.*"

As part of the Task C program, several pilot watersheds were chosen in the United States and Canada for intensive study, to cover a wide variety of potential sources of pollution to the boundary waters of the Great Lakes. Using criteria based on climate, geology, soil characteristics and land uses, and information available from completed or ongoing studies, the Saugeen River basin was chosen as a pilot watershed for intensive study under Task C in Canada. Land use in the Saugeen River basin is primarily agricultural with a large area of the basin as permanent pasture. Urban development is sparce and much of the land, particularly in the headwater areas, is swamp or unproductive woodland.

The land uses not adequately represented in the pilot watersheds were incorporated into the study by including additional subwatersheds in different parts of the Great Lakes basin. The magnitude and significance of material inputs from the following land uses and practices were identified for further study and measurement under the PLUARG activities in Canada:

> *agriculture, urban, transportation, sanitary landfills, processed organic-waste disposal, spray-irrigation, extractive industries and private-waste disposal.*

9.2 STUDY APPROACH

Monitoring networks were established in the Saugeen River basin for the purpose of collecting quality and quantity data to derive pollutant loading estimates from various land uses in the watershed. Monitoring stations were established upstream and downstream of selected land uses, at the outlets of sub-watersheds with relatively homogeneous land uses, at downstream main-stem localities and at the mouth of the pilot watershed. The water-quality data that were collected at these stations were utilized as part of a mass-balance approach to answer the PLUARG reference:

> *"1) Are the boundary waters of the Great Lakes system being polluted by land drainage from ....?*
> *2) .... to what extent, by what causes, and in what localities is the pollution taking place?*
> *3) .... what remedial measures .... be most practicable, and .... the probable cost thereof?"*

Some of the land-use studies were conducted outside of the pilot watershed and the information thus generated was extended to the basin using unit-area loads and land-use inventories. Land-use inventories of the basin were assembled for extrapolation purposes using the Canada Land Inventory (CLI) system, which is based on census (enumeration) data from 1968-1974.

In order to answer the PLUARG reference; the causes, sources and extent of pollutant contribution have been identified in the Saugeen River basin. The relative significance of the sources in the basin have also been identified by proportioning the monitored load at the mouth of the Saugeen River and attributing these loads to the various land uses in the basin. A simple mass-balance approach was utilized by assigning unit-area loads from PLUARG monitoring data to the land-use inventory compiled for the basin. This approach assumes that the long-term delivery is unity; which therefore implies that all land-use activities regardless of their distance from the lakes or the receiving waters will ultimately have an impact upon the boundary waters. Information on overland and in-stream transport processes are generally lacking and only general observations from the pilot watershed studies are applicable to other parts of the Great Lakes basin where similar conditions exist.

Possibilities for pollutant control from various land uses and practices have been tabulated (Task A) and the technical feasibility of these measures have been assessed, where applicable, using information from the Task C studies. Detailed demonstration projects will be required if further assessment of control management strategies and their cost effectiveness are necessary.

9.3 METHODS

9.3.1 WATER QUANTITY MEASUREMENT

Continuous records of water level (stage) were obtained from newly constructed streamflow gauging stations for the PLUARG program. Where possible, existing Water Survey of Canada gauging stations were incorporated into the PLUARG water-quantity network.

Field staff developed relationships between stage and discharge for all of the streamflow gauging stations that were newly constructed for the PLUARG program. Standard procedures for discharge measurements and rating of controls as outlined in Corbett et al, (1962) were implemented for the PLUARG Task C study.

9.3.2 WATER QUALITY COLLECTION

In conjunction with the streamflow data, event-oriented surface water samples were collected for chemical analyses to provide pollutant loadings for the Task C study. Representative samples of suspended sediment and sediment-associated parameters were usually collected by the "equal transit rate method" as described in Guy and Norman (1970). Uniformity in sample-container storage, sample preservation and handling techniques were maintained throughout the duration of the Task C study.

9.3.3 SEDIMENT COLLECTION

Studies involving the chemical and physical characterization of fluvial suspended sediment were carried out at selected stations in the Saugeen River basin during 1976 and 1977. A minimum of 5 grams of material was required to perform all the analyses on the lengthy PLUARG parameter list (IJC-PLUARG, Quality Control Handbook for Pilot Watershed Studies, 1976). This precluded the use of conventional suspended-sediment sampling techniques. A special large-volume sampling system was used in order to recover a sufficient quantity of suspended material for the required chemical and physical analyses.

The sampling system, which was made available through the Canada Centre for Inland Waters (CCIW), consisted of a sample collection unit and a processing unit. Using a submersible pump, approximately 1000 litres of stream water, including the suspended sediment (referred to as a bulk suspended-sediment sample), was collected at each station and stored in plastic sample containers (40 litre volume). All the usual sample-handling precautions were observed in order to ensure the collection of a representative, uncontaminated sample. The bulk suspended-sediment sample was transported to the processing unit which consisted of a continuous-flow centrifuge and supporting equipment. The bulk suspended-sediment sample was processed through the centrifuge and the sediment recovered for chemical and physical analyses. The supernatant (decanted water sample) was also analysed.

In addition to the bulk suspended-sediment sample, routine water-quality samples were also collected for chemical analyses to verify those concentrations derived from the bulk suspended sediment and supernatant samples.

Bed-material samples were also collected at selected sites in the Saugeen River basin. A 1-1/2" I.D. coring device (Sutton, 1974) was used to collect the sample. A minimum of five sub-samples from the top 5-10 cm of the streambed were collected at equally-spaced intervals in the sampling cross section. These sub-samples were composited to form a single sample for chemical and physical analyses.

9.3.4 POINT SOURCE ESTIMATES

9.3.4.1 Municipal

Studies were undertaken to supplement the existing effluent-quality information on file with the Ontario Ministry of the Environment for municipal sewage treatment plants in the Saugeen River basin. Municipal effluents were sampled under the PLUARG program at six major sewage treatment plants representing 84% of the municipal sewage treated in the Saugeen River basin. Loadings were calculated by determining the product of actual sewage flow and an average concentration from samples collected every six hours during that 24-hour period. An annual loading estimate was obtained by multiplying the daily concentration estimate by the annual waste volume at each sewage treatment plant.

The historic information that exists on the quality of municipal effluent varies with each sewage treatment plant. The effluent discharges from all sewage treatment plants are routinely analysed for total phosphorus, suspended solids and biochemical oxygen demand. Some of the treatment plants also have the effluent analysed for Kjeldahl nitrogen, nitrate + nitrite nitrogen and ammonium nitrogen. Data were compiled for 1975 and 1976 and loads were calculated for each of the measured parameters on an annual basis (tonnes per year). Total annual flow (cubic metres per year) and average concentration (milligrams per litre) of the effluent samples for each sewage treatment plant were used in calculating the annual loads. Only one PLUARG municipal survey was conducted in the Saugeen River basin and this survey was influenced by rainfall. Where ample comparison samples exist with those from routine Ministry of the Environment monitoring, these data suggest that loading estimates may be significantly higher than the actual load.

9.3.4.2 Industrial

Compared to the Grand River basin, industrial activity is nearly absent in the Saugeen River basin. Most of the industrial waste volume produced in the watershed is processed by sewage treatment plants in the basin. The quality of the waste volume was measured as part of the municipal effluent sampling in the point-source studies conducted under PLUARG (Section 9.3.4.1).

Supplementary monitoring for the PLUARG program was conducted in the Teeswater River tributary to estimate annual loading from only one major industry in the Saugeen River basin not discharging to the sanitary sewer system. Chemical analyses of these supplementary samples were undertaken for the complete PLUARG water-quality parameter list.

Loading estimates were calculated by obtaining a product of total annual discharge and average pollutant concentrations from the supplementary PLUARG monitoring that was undertaken in 1976. The quality and quantity of industrial effluents vary with time and some parameters were analysed for the first time as part of the PLUARG study. As a result, the reliability of these loading estimates are considered to be poor. The supplementary PLUARG monitoring was conducted when waste volume was high and as a result, loading estimates may be significantly higher than the actual long-term load.

9.3.5 LOAD ESTIMATES

In order to evaluate the significance of pollution from land drainage, the water quality and quantity data generated at the sampling sites must be merged to produce quantitative estimates of pollutant mass transport (i.e. loadings). Although both streamflow and concentration are variables, only flow is normally monitored continuously. At the eight locations within the Saugeen basin for which loads were estimated, the number of samples collected at each location over the period 1975 to 1976, ranged from 75 to 450. Some problems were encountered in obtaining unbiased load estimates because of biases introduced by event-oriented monitoring; however, the results appear to be quite good in most cases.

9.3.5.1 IJC Recommended Method

As suggested in the IJC-PLUARG, Quality Control Handbook for Pilot Watershed Studies, March 1977 Revision, a stratified, random sampling model employing a ratio estimator was adopted as a suitable method of load calculation. The method provides estimates of both mean and variance and was recommended in order to make broad comparisons of tributary loadings across the entire Great Lakes basin.

The model assumes that random sampling has been conducted within non-overlapping sub-populations or strata and that supplemental information in the form of a continuous flow record is available. While the latter condition was readily satisfied, the former was not generally met, largely because of the emphasis directed towards event sampling at most sites.

In light of these considerations a simplified scheme involving the subdivision of concentration records according to an arbitrary classification of high and low flows was applied wherever possible. Based on duration analysis of mean daily flow records, high flows were assumed to be those equalled or exceeded 15% of the time. The results of the approach were generally satisfactory at sites within the Saugeen basin except for one case in particular (Station SR-2) where the load estimates appear to be biased towards the high flow data (i.e. loads are overestimated).

9.3.5.2 Regression Method

In an effort to obtain a better appreciation of the potential bias inherent in the application of the previously discussed method of load estimation, alternative means of computation were sought. Developing regression relationships between flow and concentration or possibly flow and loading appeared to be an obvious choice since this approach also furnished a means of examining monthly and seasonal loadings. The regression relationships can be applied to mean daily flow records to yield daily load estimates which can then be summed to produce monthly, seasonal or annual estimates. The assumption inherent to this approach is that either concentration or load obeys a fixed relationship with respect to flow. In general the assumption holds only to a limited degree and individual daily load estimates may have little meaning. Over a longer term, however, it may be reasonably assumed that deviations from the regression model tend to average so that estimates for longer time periods may be reasonable. Because both concentration and flow data span several orders of magnitude, regression on the logarithms of the variables was considered most appropriate. Initial results employing the complete data set were not always satisfactory; however, subdividing the data set into high and low flow categories yielded acceptable relationships in most cases.

Currently only a few preliminary loading estimates have been derived by the regression method. The comparison data (in kg/ha/yr) are presented below and illustrate the best and worst case situations:

Site	Method	Total Phosphorus	Filtered Reactive Phosphate	Nitrate + Nitrite	Suspended Sediment
SR-6 (75-76)	IJC	.422	.064	4.95	-
	Regression	.372	.057	5.10	-
SR-2 (75-76)	IJC	1.083	.060	5.07	1740.
	Regression	.620	.038	4.77	930.

Good agreement between the two methods was observed at site SR-6 which is located at the mouth of the Saugeen basin and possesses an excellent sampling record.

Site SR-2 located on the South Saugeen River illustrates the potential biases which may be introduced by the arbitrary application of the IJC approach. Loads obtained by the IJC method appeared to be unreasonably high for suspended solids and total phosphorus as well as other sediment-associated parameters not shown here. Examination of the calculations revealed the estimates to be contingent on a few extremely high concentration values observed only on the highest flow days of the period.

Good regression relationships were developed for the SR-2 data, yielding load estimates considered to be fairly reliable. Comparison of the two methods reveals that the greatest discrepancies are experienced with suspended solids and sediment-associated parameters. Discrepancies for soluble parameters such as filtered reactive phosphate and filtered nitrate plus nitrite are much less significant. The IJC estimates would have been improved if the data had been sufficient to permit a more precise definition of strata but this was not generally the case. With the exception of SR-2, loads computed by the IJC method are felt to be reasonable in most cases.

9.3.5.3 Suspended Sediment Loads - SR-6

Although some sediment analyses were conducted by the Ministry of the Environment at SR-6, it was decided to rely on suspended-sediment data collected by the Water Survey of Canada (WSC) which operate an intensive sampling program at that site. Estimated mean daily suspended sediment concentrations were supplied by the WSC and these were combined with mean daily flow records to produce the load figures presented in this report.

9.3.5.4 Unit Load Estimates

Monitoring data from predominantly homogeneous land-use areas, were used to estimate the unit-area loads for rural, urban and wooded areas. A watershed was considered to be homogeneous when the major land use occupied more than 70% of the area for the wooded, 80% for the rural and more than 60% for the urban categories. The total load at each of the selected land-use stations was calculated according to the IJC recommended method.

The unit-area loads from 12 stations having more than 80% of the area in agricultural land were averaged to determine unit-area loads for the rural category. Similarily, the loads from predominantly urban and wooded areas (two stations in each land-use category, respectively) were used to estimate the unit-area loads for these land uses. With the exception of one station in the Saugeen River basin, which is predominantly wooded, all the data for the unit-area load calculations were derived from stations located in the Grand River watershed. These unit area loads were used to estimate the diffuse source of pollutant load from the three major land-use categories in the Saugeen River watershed.

9.3.5.5 Other Methods

In addition to the tributary loading estimates, a number of generalized loading estimates have been drawn together for specialized land uses and practices. Loadings were estimated for sanitary landfills, processed organic waste disposal, private-waste disposal and spray irrigation land uses and practices, using land-use inventories of these practices in the basin coupled with data from specific Task C studies conducted by the Ontario Ministry of the Environment. These studies are ground-water associated and involve certain worst-case assumptions concerning the attentuation of pollutants within the ground-water flow system. The private-waste disposal estimate further assumes that 30% of the septic systems are faulty and discharge eventually to receiving streams.

Load estimates for road deicing salts were based on a comprehensive PLUARG Task C survey of salt usage by municipalities and the Ontario Ministry of Transportation and Communications across southern Ontario during the winter of 1975-76.

9.3.6 DATA TRANSFERABILITY

Data transfer within the Saugeen River basin was tested on a subwatershed basis. The land-use distribution, physiography and the tributary monitoring network were used to divide the basin into six subwatersheds. Pollutant loads from the diffuse sources in each subwatershed were estimated using the unit-area load values compiled for the pilot watershed study (Section 9.3.5.4). All the inputs, including the point sources and upstream loads, were added to the total estimated diffuse-source loads for the subwatershed and compared with the monitored load at the outlet of the subwatershed, for each of the key parameters considered.

As a rough approximation, the ratio between measured load and estimated load is an indicator of the pollutant transport phenomenon; however, the reliability of this ratio would depend upon the accuracy of the unit-area load values used in the computation of the estimated load.

9.3.7 IN-STREAM POLLUTANT TRANSPORT

Investigations of the annual, in-stream, pollutant transport functions in the Saugeen River watershed are based on a mass-balance approach. The monitored load of a pollutant at the outlet of a watershed or sub-watershed is assumed to be equal to the sum of the loads from the inflow, point sources and diffuse land-drainage sources in the watershed. The total input load to the stream is modified by a transport function which consists of physical, chemical and biological processes usually resulting in an entrapment of a portion of the input load.

The mass balance equation is expressed below:

$$LO_a = f(T_a) \cdot (\Sigma LI_a + \Sigma PS_a + \Sigma D_a + C_a)$$

where: LO_a is the monitored pollutant load at the outlet of watershed A.

$f(T_a)$ is the in-stream transport function of a pollutant in watershed A.

ΣLI_a is the sum of the monitored pollutant loads influent to watershed A.

ΣPS_a is the sum of the pollutant loads from point sources in watershed A.

ΣD_a is the sum of the pollutant loads from diffuse land-drainage sources in watershed A.

C_a is the pollutant load from the stream channel in watershed A (streambank erosion, scour, etc.).

Rearranging the above equation to isolate the transport function yields:

$$f(T_a) = \frac{LO_a}{\Sigma LI_a + \Sigma PS_a + \Sigma D_a + C_a}$$

Values for the monitored load at the outlet of the subwatershed (LO_a) and some of the monitored pollutant loads influent to the subwatershed (LI_a) including the point-source inputs in the subwatershed (PS_a) are obtained from monitoring data. The load from the diffuse sources (D_a) is estimated using unit-area load functions derived from monitoring data (Section 9.3.5.4) and the land-use inventory for the subwatershed. The streambank erosion and channel scour parameter (C_a) is generally unknown at this time. For the purpose of obtaining a gross initial estimation of the annual pollutant transport function, streambank scour and erosion (C_a) were assumed to be zero. Studies by other PLUARG investigators indicate that streambank erosion may contribute a significant load, locally.

The Saugeen River was subdivided into six segments based on the location of monitoring stations in the watershed. A transport function was calculated for each segment using the equation stated above and was assumed to be linear along each river segment. A more realistic transport function such as a time decay function incorporating particle size, peak flow and time of travel parameters has been suggested by Williams (1975) but, in consideration of the PLUARG time constraints, was not developed for the Saugeen River.

9.4 PARAMETERS

To date, the two major in-lake problems have been identified as being; 1) the acceleration of the natural aging processes in the lakes (eutrophication) and 2) those toxic materials which constitute an environmental health hazard (human and/or biological). Eutrophication is principally controllable by phosphorus and to a lesser extent by nitrogen. As a result of its capacity to adsorb phosphorus and other contaminants, sediment is an important aspect of eutrophication and toxicity problems. Materials may either be removed from solution ("scavenged") by adsorption to the sediment and deposited on the lake bottom or they may be released from the sediment (desorption) and become available to the lake biota. The hazardous lake problems are attributable to pesticides, organic chemicals, heavy metals and bacterial contamination.

The parameters identified for intensive study in the Saugeen River pilot watershed are as follows:

Total Phosphorus (TP)
Filtered Reactive Phosphate (FRP)
Filtered Nitrite + Nitrate, $F(NO_2 + NO_3)$
Total Kjeldahl (TKN)
Total Nitrogen (TN)
Suspended Sediment (SS)
Lead (Pb)
Copper (Cu)
Zinc (Zn)
Chloride (Cl)

Although not discussed in this report, additional information is available on the major cations and anions, phenols, carbon, mercury, chromium, arsenic, nickel, cadmium and cobalt. These data are summarized in the detailed technical reports as part of the supporting documentation for this pilot watershed report.

10.0 TABULATED RESULTS OF DATA COLLECTION

TABLE 1: MEAN LOADING ESTIMATES FOR THE COMBINED 1975 and 1976 PERIOD AT SAUGEEN BASIN MONITORING SITES

Column 1 Monitoring Site

LOCATION CODE lists the monitoring site as depicted in Figure 4.

DRAINAGE AREA (ha) is the surface area of the land drained by the monitoring site in hectares.

MEAN ANNUAL STREAMFLOW (m^3/s) is the annual flow for 1975 and 1976 expressed as the average daily flow rate.

Column 2 Pollutant Loading Estimates

TOTAL ANNUAL LOAD (t/yr) is the estimate of total mass transport computed by the IJC recommended method based on monitoring data from 1975 and 1976. (± figures are the 95% confidence limits defined according to the procedures outlined in the Quality Control Handbook for Pilot Watershed Studies, March 1977 Revision.)

UNIT AREA LOAD (kg/ha/yr) is the total annual load averaged over the drainage area upstream of the monitoring site.

TABLE 1

MONITORING SITE			POLLUTANT LOADING ESTIMATES									
			SUSPENDED SEDIMENT		TOTAL PHOSPHORUS		FILTERED REACTIVE PHOSPHATE -P		KJELDAHL - N		FILTERED (NITRATE + NITRITE) -N	
LOCATION CODE	DRAINAGE AREA (ha)	MEAN ANNUAL STREAM FLOW (m^3/s)	TOTAL ANNUAL LOAD (t/yr)	UNIT AREA LOAD (kg/ha/yr)	TOTAL ANNUAL LOAD (t/yr)	UNIT AREA LOAD (kg/ha/yr)	TOTAL ANNUAL LOAD (t/yr)	UNIT AREA LOAD (kg/ha/yr)	TOTAL ANNUAL LOAD (t/yr)	UNIT AREA LOAD (kg/ha/yr)	TOTAL ANNUAL LOAD (t/yr)	UNIT AREA LOAD (kg/ha/yr)
SR-1*	39,100	6.0	5,380 ± 4,480	138	5.6 ± 1.6	0.143	0.7 ± 0.13	0.018	87 ± 9	2.22	36 ± 8	2.19
UL-12	10,600	1.3	466 ± 222	44	0.9 ± 0.4	0.086	0.1 ± 0.03	0.007	16 ± 2	1.51	34 ± 2	3.20
SR-2	60,100	9.9	105,000 ± 86,600	1,740	65.1 ± 52.8	1.083	3.6 ± 2.6	0.060	244 ± 105	4.05	305 ± 43.0	5.07
SR-3*	212,000	34.5	69,000 ± 66,200	326	68.0 ± 49.8	0.322	6.6 ± 3.7	0.031	544 ± 106	2.57	889 ± 73	4.20
SR-4	65,800	12.1	7,570 ± 2,170	115	13.9 ± 3.4	0.211	2.3 ± 0.7	0.035	228 ± 16	3.46	397 ± 30.0	6.03
SR-5	24,800	4.7	4,590 ± 991	184	7.1 ± 1.8	0.286	1.2 ± 0.5	0.050	61 ± 8	2.47	87 ± 16	3.50
AG-14	4,380	0.8	1,060 ± 1,940	243	3.4 ± 2.3	0.781	1.3 ± 0.3	0.294	18 ± 6	4.02	22 ± 10	5.06
SR-6*	397,000	64.8	195,000**	488**	167.6 ± 32.7	.422	25.5 ± 4.2	0.064	1,210 ± 102	3.04	1,970 ± 116	4.95

* MAIN STEM MONITORING SITES

** SEDIMENT DATA AT SR-6 PROVIDED BY WATER SURVEY OF CANADA.

TABLE 2: SOURCES, EXTENT AND RELATIVE SIGNIFICANCE OF POLLUTANT CONTRIBUTION.

Column 1 Water Quality Parameter

ANNUAL MEAN STREAMFLOW (m^3/s) is the annual flow expressed as the average daily flow rate.
FLOW WEIGHTED MEAN CONCENTRATION (mg/L) is the product of the total annual load (concentration x flow) divided by the total annual flow.
MONITORED/ESTIMATED LOAD RATIO is the ratio of mean annual load (t/yr), based on the addition of best annual loading estimates reported (in column 3) for all watershed sources.
DRAINAGE AREA (hectares) is the total watershed area, including the area downstream of the outlet monitoring station at SR-6.
UNIT AREA LOAD (kg/ha/yr) at the watershed outlet (column 2), is the total annual load averaged over the basin area.
UNIT AREA LOAD (kg/ha/yr) at the watershed sources (column 3), is the best estimate of average unit-area contributions from each diffuse source in the basin.
TOTAL ANNUAL LOAD (t/yr) at the watershed outlet (column 2), is the estimate of total mass transport at the outlet computed by the IJC recommended method. (± figures are the 95% confidence limits defined according to the procedures outlined in the Quality Control Handbook for Pilot Watershed Studies, March 1977 Revision.)
TOTAL ANNUAL LOAD (t/yr) at the watershed sources (column 3), is the best estimate of total mass transported due to runoff from the land uses in the basin.

Column 2 Watershed Outlet

MONITORED 1975 AND 1976 are data reported for those respective years, based on the monitoring activities undertaken in support of Task C studies at the outlet station SR-6 including all point sources downstream of this station.

Column 3 Watershed Sources

TOTAL is the total pollutant contribution from all of the watershed sources.

POINT SOURCES
MUNICIPAL is the final liquid effluent from 9 sewage treatment plants that treat domestic and industrial waste entering the sanitary sewer system in the basin.
INDUSTRIAL is the process water discharged after any required treatment from industry directly into a surface watercourse in the basin.

DIFFUSE SOURCES
URBAN GENERAL is commercial, industrial, residential and recreational land, parking lots and all road systems in the urban areas.
PRIVATE WASTE (urban) is the septic tank systems within urban boundaries (i.e. unsewered).
AGRICULTURAL GENERAL is the actively farmed areas, row crops including livestock, barnyard areas and rural dwellings.
PRIVATE WASTE (rural) is the septic tank systems outside urban boundaries (rural or farm areas).
WOODED/IDLE is the perennial vegetative cover, woodlots, swamps and idle land (unimproved pasture).
TRANSPORTATION is the rural land devoted to all road systems. Note: Table 2g (chloride estimate) includes all (rural and urban) road systems.
PROCESSED ORGANIC WASTE is the agricultural land on which sewage sludge is spread.
SANITARY LANDFILL is domestic and industrial solid waste disposal (buried and covered) areas.
EXTRACTIVE is comprised of sand and gravel pits and limestone quarries.
SPRAY IRRIGATION is industrial liquid waste disposal on land.
STREAM BANK EROSION is the amount of sediment estimated to have been produced by the erosion of streambanks in the Saugeen River basin, from the Canadian Agricultural studies.

Table 2a

WATER QUALITY PARAMETER	WATERSHED OUTLET		WATERSHED SOURCES													
SUSPENDED SEDIMENT	MONITORED 1975	MONITORED 1976	TOTAL	POINT SOURCES		DIFFUSE SOURCES										
			Estimate, based on the sum of all Point and Diffuse Sources	Municipal	Industrial	Urban General	Private Waste (urban)	Agricultural General †	Private Waste (rural)	Wooded/Idle	Transportation	Processed Organic Waste	Sanitary Landfill	Extractive	Stream Bank Erosion
Annual Mean Stream Flow (m^3/s)	61.1	68.5													
Number of Samples	366	236													
Flow Weighted Mean Concentration (mg/L)	108	83.8													
Monitored/Estimated Load Ratio	1.28	1.11													
Drainage Area (hectares)	400,000	400,000	400,000	* 24,500		3,970	** 4,380	258,000	** 28,400	131,000	6,750	109	230	79	
Percentage of Watershed Drainage Area	100	100	100	*** 9	*** 1	1	*** 1,190	64	*** 7,750	33	2	< 1	< 1	< 1	/
Unit Area Load (kg/ha/yr)	518	453	403	/	/	400	/	569	/	54.2	/	/	/	/	17.0
Total Annual Load (t/yr)	207,000	181,000	161,000	117	1C	1,590	/	145,000	/	7,100	/	/	/	1C	6,750
Percentage Contribution of Total Estimated Load	/	/	100	1C	1C	1.0	/	90.3	/	4.4	/	/	/	1C	4.2

* sewered population, ** unsewered population, *** number of systems, IC insignificant contribution (<0.1%), / not estimated

† Other mothods and results of estimating the agricultural load are discussed in the Final Summary Report, Canadian Agricultural Watershed Studies, May 1, 1978.

Table 2b

WATER QUALITY PARAMETER	WATERSHED OUTLET		WATERSHED SOURCES													
TOTAL PHOSPHORUS	MONITORED 1975	MONITORED 1976	TOTAL	POINT SOURCES		DIFFUSE SOURCES										
			Estimate, based on the sum of all Point and Diffuse Sources	Municipal	Industrial	Urban General	Private Waste (urban)	Agricultural General †	Private Waste (rural)	Wooded/Idle	Transportation	Processed Organic Waste	Sanitary Landfill	Extractive	Spray Irrigation
Annual Mean Stream Flow (m^3/s)	61.1	68.5													
Number of Samples	101	271													
Flow Weighted Mean Concentration (mg/L)	0.104	0.073													
Monitored/Estimated Load Ratio	0.75	0.59													
Drainage Area (hectares)	400,000	400,000	400,000	* 24,500	/	3,970	** 4,380	258,000	** 28,400	131,000	6,750	109	230	79	10
Percentage of Watershed Drainage Area	100	100	100	*** 9	*** 1	1	*** 1,190	64	*** 7,750	33	2	< 1	< 1	< 1	< 1
Unit Area Load (kg/ha/yr)	0.510	0.400	0.683	/	/	0.73	/	0.899	/	0.099	/	0.19	/	/	0.08
Total Annual Load (t/yr)	204 ± 98.2	160 ± 32.0	273	17.7	0.14	2.9	1.2	229	7.8	13.0	/	IC	IC	/	0.8
Percentage Contribution of Total Estimated Load	/	/	100	6.5	IC	1.1	0.4	84.0	2.9	4.8	/	IC	IC	/	0.3

* sewered population, ** unsewered population, *** number of systems, IC insignificant contribution (<0.1%), / not estimated

† Other methods and results of estimating the agricultural load are discussed in the Final Summary Report, Canadian Agricultural Watershed Studies, May 1, 1978.

Table 2c

WATER QUALITY PARAMETER	WATERSHED OUTLET		WATERSHED SOURCES													
FILTERED REACTIVE PHOSPHATE -P	MONITORED 1975	MONITORED 1976	*TOTAL*	POINT SOURCES		DIFFUSE SOURCES										
			Estimate, based on the sum of all Point and Diffuse Sources	Municipal	Industrial	Urban General	Private Waste (urban)	Agricultural General	Private Waste (rural)	Wooded/Idle	Transportation	Processed Organic Waste	Sanitary Landfill	Extractive	Spray Irrigation
Annual Mean Stream Flow (m³/s)	61.1	68.5													
Number of Samples	103	352													
Flow Weighted Mean Concentration (mg/L)	0.019	0.011													
Monitored/Estimated Load Ratio	0.53	0.34													
Drainage Area (hectares)	400,000	400,000	400,000	* 24,500	/	3,970	** 4,380	258,000	** 28,400	131,000	6,750	109	230	79	10
Percentage of Watershed Drainage Area	100	100	100	*** 9	*** 1	1	*** 1,190	64	*** 7,750	33	2	< 1	< 1	< 1	< 1
Unit Area Load (kg/ha/yr)	0.099	0.064	0.187	/	/	0.05	/	0.202	/	0.009	/	0.006	/	/	/
Total Annual Load (t/yr)	39.4 ± 12.4	25.7 ± 4.46	74.6	14.1	0.1	0.2	0.9	51.5	6.0	1.2	/	0.63	IC	/	/
Percentage Contribution of Total Estimated Load	/	/	100	18.9	0.1	0.3	1.2	69.0	8.0	1.6	/	0.8	IC	/	/

* sewered population, ** unsewered population, *** number of systems, IC insignificant contribution (<0.1%), / not estimated

Table 2d

WATER QUALITY PARAMETER	WATERSHED OUTLET		WATERSHED SOURCES											
	MONITORED	MONITORED	*TOTAL*	POINT SOURCES		DIFFUSE SOURCES								
TOTAL NITROGEN	1975	1976	*Estimate, based on the sum of all Point and Diffuse Sources*	Municipal	Industrial	Urban General	Private Waste (urban)	Agricultural General	Private Waste (rural)	Wooded/Idle	Transportation	Processed Organic Waste	Sanitary Landfill	Extractive	Spray Irrigation
Annual Mean Stream Flow (m^3/s)	61.1	68.5													
Number of Samples	101	352													
Flow Weighted Mean Concentration (mg/L)	1.62	1.58													
Monitored/Estimated Load Ratio	0.81	0.88													
Drainage Area (hectares)	400,000	400,000	400,000	* 24,500	/	3,970	** 4,380	258,000	** 28,400	131,000	6,750	109	230	79	10
Percentage of Watershed Drainage Area	100	100	100	*** 9	*** 1	1	*** 1,190	64	*** 7,750	33	2	< 1	< 1	< 1	< 1
Unit Area Load (kg/ha/yr)	7.83	8.56	9.68	/	/	6.65	/	11.7	/	5.15	/	11.2		/	177
Total Annual Load (t/yr)	3,130 ± 608	3,420 ± 263	3,870	120.	1C	26.4	10.5	2,970	67.5	675	/	1C	1C	/	1.7
Percentage Contribution of Total Estimated Load	/	/	100	3.1	1C	0.7	0.3	76.7	1.7	17.4	/	1C	1C	/	1C

* sewered population, ** unsewered population, *** number of systems , IC insignificant contribution (<0.1%), / not estimated

Table 2e

WATER QUALITY PARAMETER	WATERSHED OUTLET		WATERSHED SOURCES													
KJELDAHL-N	MONITORED 1975	MONITORED 1976	*TOTAL*	POINT SOURCES		DIFFUSE SOURCES									
			Estimate, based on the sum of all Point and Diffuse Sources	Municipal	Industrial	Urban General	Private Waste (urban)	Agricultural General	Private Waste (rural)	Wooded/Idle	Transportation	Processed Organic Waste	Sanitary Landfill	Extractive	Spray Irrigation
Annual Mean Stream Flow (m^3/s)	61.1	68.5													
Number of Samples	101	352													
Flow Weighted Mean Concentration (mg/L)	0.669	0.581													
Monitored/Estimated Load Ratio	0.98	0.95													
Drainage Area (hectares)	400,000	400,000	400,000	* 24,500	/	3,970	** 4,380	258,000	** 28,400	131,000	6,750	109	230	79	10
Percentage of Watershed Drainage Area	100	100	100	*** 9	*** 1	1	*** 1,190	64	*** 7,750	33	2	< 1	< 1	< 1	< 1
Unit Area Load (kg/ha/yr)	3.23	3.13	3.30	/	/	3.65	/	4.0	/	1.85	/	0.19	/	/	/
Total Annual Load (t/yr)	1,290 ± 295	1,250 ± 129	1,320	57.1	IC	14.5	IC	1,010	IC	243.0	/	IC	IC	/	IC
Percentage Contribution of Total Estimated Load	/	/	100	4.3	IC	1.1	IC	76.2	IC	18.3	/	IC	IC	/	IC

* sewered population, ** unsewered population, *** number of systems, IC insignificant contribution (<0.1%), / not estimated

Table 2f

WATER QUALITY PARAMETER	WATERSHED OUTLET		WATERSHED SOURCES													
FILTERED (NITRATE + NITRITE)-N	MONITORED 1975	MONITORED 1976	*TOTAL*	POINT SOURCES		DIFFUSE SOURCES										
			Estimate, based on the sum of all Point and Diffuse Sources	Municipal	Industrial	Urban General	Private Waste (urban)	Agricultural General	Private Waste (rural)	Wooded/Idle	Transportation	Processed Organic Waste	Sanitary Landfill	Extractive	Spray Irrigation
Annual Mean Stream Flow (m^3/s)	61.1	68.5													
Number of Samples	101	352													
Flow Weighted Mean Concentration (mg/L)	0.946	0.998													
Monitored/Estimated Load Ratio	0.72	0.85													
Drainage Area (hectares)	400,000	400,000	400,000	* 24,500	/	3,970	** 4,380	258,000	** 28,400	131,000	6,750	109	230	79	10
Percentage of Watershed Drainage Area	100	100	100	*** 9	*** 1	1	*** 1,190	64	*** 7,750	33	2	< 1	< 1	< 1	< 1
Unit Area Load (kg/ha/yr)	4.58	5.38	6.35	/	/	3.0	/	7.7	/	3.3	/	11.0	/	/	8.4
Total Annual Load (t/yr)	1,830 ± 313	2,150 ± 134	2,540	62.9	IC	11.9	10.5	1,960	67.5	432.0	/	IC	IC	/	IC
Percentage Contribution of Total Estimated Load	/	/	100	2.5	IC	0.5	0.4	77.0	2.7	17.0	/	IC	IC	/	IC

* sewered population, ** unsewered population, *** number of systems, IC insignificant contribution (<0.1%), / not estimated

Table 2g

WATER QUALITY PARAMETER	WATERSHED OUTLET			WATERSHED SOURCES											
CHLORIDE	MONITORED 1975	MONITORED 1976	*TOTAL*	POINT SOURCES		DIFFUSE SOURCES									
			Estimate, based on the sum of all Point and Diffuse Sources	Municipal	Industrial	Urban General	Private Waste (urban)	Agricultural General	Private Waste (rural)	Wooded/Idle	Transportation	Processed Organic Waste	Sanitary Landfill	Extractive	Spray Irrigation
Annual Mean Stream Flow (m^3/s)	61.1	68.5													
Number of Samples	98	321													
Flow Weighted Mean Concentration (mg/L)	7.44	6.83													
Monitored/Estimated Load Ratio	0.88	0.90													
Drainage Area (hectares)	400,000	400,000	400,000	* 24,500	/	3,970	** 4,380	258,000	** 28,400	131,000	6,750	109	230	79	10
Percentage of Watershed Drainage Area	100	100	100	*** 9	*** 1	1	*** 1,190	64	*** 7,750	33	2	< 1	< 1	< 1	< 1
Unit Area Load (kg/ha/yr)	36.0	36.8	40.8	/	/	20	/	20	/	20	/	8.1	2,640	/	/
Total Annual Load (t/yr)	14,400 ± 965	14,700 ± 526	16,300	647	IC	79.0	23.6	5,100	152	2,620	7,100	0.9	607	/	/
Percentage Contribution of Total Estimated Load	/	/	100	4.0	IC	0.5	0.1	31.2	0.9	16.0	43.5	IC	3.7	/	/

* sewered population, ** unsewered population, *** number of systems, IC insignificant contribution (<0.1%), / not estimated

Table 2h

WATER QUALITY PARAMETER	WATERSHED OUTLET		WATERSHED SOURCES													
LEAD	MONITORED 1975	MONITORED 1976	*TOTAL*	POINT SOURCES		DIFFUSE SOURCES									
			Estimate, based on the sum of all Point and Diffuse Sources	Municipal	Industrial	Urban General	Private Waste (urban)	Agricultural General	Private Waste (rural)	Wooded/Idle	Transportation	Processed Organic Waste	Sanitary Landfill	Extractive	Spray Irrigation
Annual Mean Stream Flow (m^3/s)	61.1	68.5													
Number of Samples		341													
Flow Weighted Mean Concentration (mg/L)		0.003													
Monitored/Estimated Load Ratio		0.58													
Drainage Area (hectares)	400,000	400,000	400,000	* 24,500	/	3,970	** 4,380	258,000	** 28,400	131,000	6,750	109	230	79	10
Percentage of Watershed Drainage Area	100	100	100	*** 9	*** 1	1	*** 1,190	64	*** 7,750	33	2	< 1	< 1	< 1	< 1
Unit Area Load (kg/ha/yr)		0.018	0.032	/	/	0.4	/	0.033	/	0.02	/	0.006	/	/	/
Total Annual Load (t/yr)		7.26 ± 1.87	12.6	0.014	IC	1.6	IC	8.4	IC	2.6	/	IC	IC	/	IC
Percentage Contribution of Total Estimated Load	/	/	100	0.1	IC	12.7	IC	66.6	IC	20.6	**** /	IC	IC	/	IC

* sewered population, ** unsewered population, *** number of systems, IC insignificant contribution (<0.1%), / not estimated

1975 lead data not reported due to biased analytical technique

**** Studies of Transportation Corridors were not undertaken in the Saugeen River basin.

Table 2i

WATER QUALITY PARAMETER	WATERSHED OUTLET		WATERSHED SOURCES													
ZINC	MONITORED 1975	MONITORED 1976	*TOTAL*	POINT SOURCES		DIFFUSE SOURCES									
			Estimate, based on the sum of all Point and Diffuse Sources	Municipal	Industrial	Urban General	Private Waste (urban)	Agricultural General	Private Waste (rural)	Wooded/Idle	Transportation	Processed Organic Waste	Sanitary Landfill	Extractive	Spray Irrigation
Annual Mean Stream Flow (m^3/s)	61.1	68.5													
Number of Samples	97	340													
Flow Weighted Mean Concentration (mg/L)	0.013	0.018													
Monitored/Estimated Load Ratio	0.78	1.21													
Drainage Area (hectares)	400,000	400,000	400,000	* 24,500	/	3,970	** 4,380	258,000	** 28,400	131,000	6,750	109	230	79	10
Percentage of Watershed Drainage Area	100	100	100	*** 9	*** 1	1.0	*** 1,190	64	*** 7,750	33	2	< 1	< 1	< 1	< 1
Unit Area Load (kg/ha/yr)	0.062	0.097	0.080	/	/	0.48	/	0.107	/	0.02	/	0.24	/	/	/
Total Annual Load (t/yr)	24.8 ± 9.82	38.6 ± 16.6	32.0	0.23	IC	1.9	IC	27.3	IC	2.6	/	IC	IC	/	IC
Percentage Contribution of Total Estimated Load	/	/	100	0.7	IC	5.9	IC	85.2	IC	8.1	**** /	IC	IC	/	IC

* sewered population, ** unsewered population, *** number of systems, IC insignificant contribution (<0.1%), / not estimated
**** Studies of Transportation Corridors were not undertaken in the Saugeen River basin.

Table 2j

WATER QUALITY PARAMETER	WATERSHED OUTLET		WATERSHED SOURCES												
COPPER	MONITORED 1975	MONITORED 1976	*TOTAL*	POINT SOURCES		DIFFUSE SOURCES									
			Estimate, based on the sum of all Point and Diffuse Sources	Municipal	Industrial	Urban General	Private Waste (urban)	Agricultural General	Private Waste (rural)	Wooded/Idle	Transportation	Processed Organic Waste	Sanitary Landfill	Extractive	Spray Irrigation
Annual Mean Stream Flow (m^3/s)	61.1	68.5													
Number of Samples	97	341													
Flow Weighted Mean Concentration (mg/L)	0.009	0.007													
Monitored/Estimated Load Ratio	1.34	1.04													
Drainage Area (hectares)	400,000	400,000	400,000	* 24,500	/	3,970	** 4,380	258,000	** 28,400	131,000	6,750	109	230	79	10
Percentage of Watershed Drainage Area	100	100	100	*** 9	*** 1	1	*** 1,190	64	*** 7,750	33	2	< 1	< 1	< 1	< 1
Unit Area Load (kg/ha/yr)	0.046	0.036	0.034	/	/	0.09	/	0.036	/	0.029	/	0.005	/	/	/
Total Annual Load (t/yr)	18.2 ± 4.0	14.2 ± 3.68	13.6	0.23	1C	0.40	1C	9.2	1C	3.8	/	1C	1C	/	1C
Percentage Contribution of Total Estimated Load	/	/	100	1.7	1C	2.9	1C	67.5	1C	27.9	**** /	1C	1C	/	1C

* sewered population, ** unsewered population, *** number of systems, IC insignificant contribution (<0.1%), / not estimated

**** Studies of Transportation Corridors were not undertaken in the Saugeen River basin.

TABLE 3: LAND USES AND UNIT AREA LOAD ESTIMATES

Column 1 Land Use Category

URBAN GENERAL is commercial, industrial, and residential land, parking lots and all road systems in the urban area.
RURAL GENERAL is the actively farmed areas, row crops including livestock, barnyard areas and rural dwellings.
WOODED/IDLE is the perennial vegetative cover, woodlots, swamps and idle land (unimproved pasture).

Column 2 Unit Area Loading (UAL) Estimation Method

MEAN AND RANGE are estimates based on PLUARG Task C monitoring of selected sites in the Saugeen and Grand River basins using the IJC recommended method for computing loads. Monitoring sites with more than 60% urban land, were used to estimate the urban general contribution. Monitoring sites from the Grand River watershed GR-9, GR-20, TU-3, TU-4, GR-10, GR-12, GR-14, GR-19, AG-4, GR-6, GR-7 and EX-3 draining subwatersheds with more than 80% agricultural land, were used to estimate the rural general contribution (Grand River Summary Report 1977). Monitoring sites GR-8 from the Grand River watershed and UL-12, from the Saugeen River watershed draining subwatersheds with more than 70% of the area in perennial cover, were used to estimate the wooded/idle contribution.

$$\text{AREA WEIGHTED MEAN (UAL)} = \frac{\text{sum of monitored loads at each site}}{\text{sum of drainage areas at each site}}$$

Table 3

LAND USE CATEGORY	UNIT AREA LOADING ESTIMATION METHOD	UNIT AREA LOAD (KG/HA/YR)								
		SUSPENDED SEDIMENT	TOTAL PHOSPHORUS	FILTERED REACTIVE PHOSPHATE -P	TOTAL NITROGEN	FILTERED (NITRATE + NITRITE) -N	CHLORIDE	LEAD *	ZINC	COPPER
URBAN GENERAL	MEAN	1,070	1.39	0.085	8.45	3.03	200	0.4	0.48	0.092
	RANGE	400-1,750	0.73-2.05	0.05-0.12	6.65-10.2	3.00-3.06	132-268	0.33-0.47	0.33-0.62	0.053-0.130
	AREA WEIGHTED MEAN	1,380	1.63	0.107	9.48	3.05	239	0.45	0.561	0.114
RURAL GENERAL	MEAN	569	0.899	0.202	11.7	7.70	47.2	0.015	0.107	0.036
	RANGE	2.9-2,230	0.05-2.30	0.008-0.533	0.62-23.5	0.198-16.7	5.0-124	0.004-0.037	0.005-0.28	0.002-0.093
	AREA WEIGHTED MEAN	961	1.29	0.233	14.3	8.86	51.8	0.019	0.14	0.052
WOODED/IDLE PERENNIAL COVER	MEAN	40.7	0.083	0.007	5.15	3.30	33.5	0.0125	0.02	0.029
	RANGE	29.8-54.2	0.069-0.099	0.007-0.009	4.76-5.54	0.29-3.52	-	0.012-0.013	0.013-0.03	0.023-0.034
	AREA WEIGHTED MEAN	40.6	0.084	0.008	5.05	3.37	33.5	0.012	0.021	0.027

* 1975 LEAD DATA NOT REPORTED DUE TO BIASED ANALYTICAL TECHNIQUE.

TABLE 4: ESTIMATED PERCENTAGE OF THE TOTAL ANNUAL LOAD DELIVERED MONTHLY FOR 1975 AND 1976.

Column 1 Survey Time Period

SURVEY TIME PERIOD denotes when the monitoring data were collected at the Saugeen River Watershed outlet, site SR-6 (Table 4a) and a selected subwatershed outlet, site SR-2 (Table 4b).

Column 2 Annual Load Percentage Delivered Monthly

ANNUAL LOAD PERCENTAGE DELIVERED MONTHLY was calculated by dividing the monthly load by the annual load and multiplying by 100.

Table 4a

SURVEY TIME PERIOD		ANNUAL LOAD PERCENTAGE DELIVERED MONTHLY - (SR-6) WATERSHED OUTLET									
		FLOW	SUSPENDED SEDIMENT	TOTAL PHOSPHORUS	FILTERED REACTIVE PHOSPHATE -P	KJELDAHL -N	FILTERED (NITRATE + NITRITE) -N	CHLORIDE	LEAD*	ZINC	COPPER
1975	January	8.9	7.6*	6.5	6.2	8.7	9.7	9.6	8.8	6.9	6.2
	February	6.9	3.7	4.9	5.2	6.6	7.0	7.5	6.8	5.2	5.0
	March	15.7	11.1	14.7	13.9	16.0	20.9	15.7	15.5	14.1	12.4
	April	27.3	54.0	41.8	39.9	27.3	29.5	20.7	28.9	37.9	36.0
	May	9.0	3.8	6.0	5.8	8.5	8.2	9.4	8.9	6.3	10.0
	June	3.7	1.8	1.3	1.0	2.9	2.0	4.2	3.5	2.0	3.0
	July	2.4	1.0	0.7	0.5	1.8	0.9	2.9	2.3	1.2	1.3
	August	3.1	2.0	1.6	1.2	2.7	1.6	3.6	3.0	1.9	1.9
	September	4.7	2.2	3.0	1.7	4.0	2.7	5.5	4.5	3.1	3.3
	October	3.4	1.1	1.1	1.3	2.7	1.6	4.2	3.2	1.8	2.0
	November	4.2	1.6	1.5	1.8	3.8	2.9	5.3	4.1	3.3	6.0
	December	10.8	10.2	18.0	21.7	15.1	13.0	11.5	10.6	16.3	12.4
1976	January	4.1	1.8	2.9	1.6	4.2	4.0	5.4	3.6	3.1	6.2
	February	11.1	6.7	8.8	16.9	11.5	17.9	12.9	13.6	8.5	25.5
	March	36.3	66.0	56.5	55.2	42.2	43.0	28.3	37.0	29.4	38.3
	April	12.4	6.3	9.3	4.4	9.3	10.0	11.8	18.2	27.5	12.2
	May	7.9	2.5	4.4	3.8	7.2	5.8	7.9	4.4	18.7	3.1
	June	3.2	1.7	1.6	0.9	2.8	1.7	3.6	1.9	1.6	1.5
	July	4.8	3.4	4.4	3.7	5.3	4.5	5.0	3.1	1.9	2.8
	August	2.2	0.6	0.6	0.5	1.6	0.7	2.7	1.5	0.7	0.8
	September	2.9	0.8	1.0	1.1	2.0	1.1	3.7	3.2	0.9	1.3
	October	3.8	1.2	1.0	1.0	2.7	1.9	4.9	3.0	1.3	1.3
	November	6.8	7.2	8.1	9.1	7.7	5.6	8.3	6.1	5.0	3.0
	December	4.5	1.8	1.4	1.8	3.5	3.8	5.5	4.5	1.4	3.9

* DATA SUPPLIED BY WATER SURVEY OF CANADA.

Table 4b

SURVEY TIME PERIOD		ANNUAL LOAD PERCENTAGE DELIVERED MONTHLY - (SR-2) SUBWATERSHED OUTLET								
		FLOW	SUSPENDED SEDIMENT	TOTAL PHOSPHORUS	FILTERED REACTIVE PHOSPHATE -P	KJELDAHL -N	FILTERED (NITRATE + NITRITE) -N	CHLORIDE	LEAD	ZINC	COPPER
1975	January	7.8	1.4	2.0	2.6	6.2	7.4	8.6	5.2	3.5	4.4
	February	5.6	0.6	1.3	1.6	4.3	5.3	6.6	3.3	2.2	3.1
	March	16.2	3.6	5.2	6.5	13.5	20.1	17.3	12.2	8.3	9.2
	April	38.4	90.5	85.1	80.8	52.0	43.5	30.5	60.5	73.3	61.0
	May	7.5	0.6	1.2	1.6	5.9	6.9	8.5	4.0	2.2	5.5
	June	2.6	0.1	0.2	0.4	1.7	1.1	3.1	1.3	0.7	1.8
	July	1.4	0	0.1	0.2	0.8	0.3	1.8	0.7	0.6	1.6
	August	1.9	0.1	0.2	0.3	1.2	0.7	2.3	0.9	0.5	1.1
	September	3.3	0.2	0.4	0.5	2.3	1.6	4.1	1.7	1.0	1.9
	October	2.2	0.1	0.2	0.3	1.4	0.8	2.8	1.1	1.2	1.1
	November	2.9	0.1	0.3	0.4	1.9	1.4	3.5	1.5	1.0	2.2
	December	10.2	2.9	3.8	4.7	9.0	10.8	10.9	7.5	5.4	6.6
1976	January	3.3	0.2	0.4	0.7	2.2	1.9	3.9	1.6	1.0	2.0
	February	8.0	2.1	2.9	4.4	6.5	10.1	9.2	4.6	4.0	5.0
	March	41.2	88.7	83.7	76.6	53.7	48.7	34.3	64.8	73.1	60.8
	April	12.9	3.2	4.5	6.3	10.8	13.1	13.6	9.1	7.3	12.2
	May	7.7	1.2	1.6	2.1	6.1	5.6	8.3	4.1	2.8	3.3
	June	2.0	0.1	0.2	0.4	1.3	0.8	2.4	1.0	0.6	1.3
	July	5.2	1.1	1.5	2.2	4.1	4.6	5.8	3.4	2.6	3.0
	August	1.3	0	0.1	0.2	0.7	0.3	1.6	0.6	0.4	0.9
	September	2.8	0.2	0.4	0.6	2.0	1.8	3.3	1.3	0.9	1.6
	October	4.8	0.5	0.9	1.3	3.7	4.2	5.6	2.4	1.6	2.7
	November	7.4	2.7	3.4	4.5	6.4	6.9	7.7	5.5	4.7	5.0
	December	3.5	0.2	0.5	0.7	2.5	2.0	4.2	1.7	1.1	2.1

TABLE 5: TOTAL, DISSOLVED AND SEDIMENT-ASSOCIATED LOADS AT THE WATERSHED OUTLET, 1976.

Column 1 Water and Sediment - Quality Parameters

PARAMETERS which were analysed using the suspended-sediment fraction only (Section 9.3.3).

Column 2 1976 Loading Breakdown at the Watershed Outlet

MEAN SEDIMENT-ASSOCIATED LOAD (t/yr) is the product of the mean pollutant concentration measured in the suspended-sediment fraction and the annual sediment load (181,000 t) at the watershed outlet in 1976.
MAXIMUM SEDIMENT-ASSOCIATED LOAD (t/yr) is the product of the maximum pollutant concentration measured in the suspended-sediment fraction and the annual sediment load (181,000 t) at the watershed outlet in 1976.
MINIMUM SEDIMENT-ASSOCIATED LOAD (t/yr) is the product of the minimum pollutant concentration measured in the suspended-sediment fraction and the annual sediment load (181,000 t) at the watershed outlet in 1976.
PERCENTAGE OF TOTAL LOAD is calculated as follows:

$$\text{Sediment associated} = \frac{SSC_W \cdot PC_{SS}}{(SSC_W \cdot PC_{SS} + PC_W} \times 100$$

where:

SSC_W is the mean suspended-sediment concentration in water

PC_{SS} is the mean pollutant concentration in suspended sediment

PC_W is the mean pollutant concentration in water

DISSOLVED LOAD (t/yr) is the difference between the mean (arithmetric) sediment-associated load and the total load.
TOTAL LOAD (t/yr) is the mean sediment-associated load, divided by the sediment associated percentage of the total load, multiplied by 100. Estimates of total load, computed by the IJC recommended method from water-quality monitoring are included in parentheses for comparison with the appropriate parameters that were analysed in the sediment fraction.

Table 5

1976 LOADING BREAKDOWN AT THE WATERSHED OUTLET

PARAMETER	SEDIMENT ASSOCIATED MEAN (t/yr)	MAXIMUM (t/yr)	MINIMUM (t/yr)	PERCENTAGE OF TOTAL	DISSOLVED (t/yr)	TOTAL (t/yr)
PHOSPHORUS	200.0	326.0	110.0	82	44.0	245.0 (158)
NITROGEN	712.0	1540.0	216.0	17	3,474	4,190 (3,410)
IRON	3810.0	4170.0	3260.0			
MANGANESE	130.0	181.5	95.5			
ALUMINUM	2050.0	2170.0	1810.0			
ARSENIC	1.8	9.1	0.6	20	7.2	9.0
CHROMIUM	6.5	10.5	3.7	59	9.5	11.0
SELENIUM	0.2	0.3	0.2			
NICKEL	3.7	4.9	2.5	42	5.1	8.8
CADMIUM	0.3	0.5	0.0	9	3.0	3.3
MERCURY	0.0	0.0	0.0			
COPPER	7.6	15.4	3.7	49	7.9	15.5 (14.2)
LEAD	15.8	29.0	3.0	54	13.5	29.3 (7.3)
ZINC	44.6	72.4	12.7	73	16.5	61.1
COBALT	1.4	2.2	1.1			
ORGANIC MATTER	20,200	38,100	6,880	100.0	0.0	20,200
PCBs	0.0115	0.0162	0.0037	100.0	0.0	0.0115
pp DDT	0.0003	0.0003	0.0000	100.0	0.0	0.0003
pp DDD	0.0003	0.0003	0.0000	100.0	0.0	0.0003
op DDT	0.0002	0.0003	0.0000	100.0	0.0	0.0002
pp DDE	0.0000	0.0000	0.0000	100.0	0.0	0.0000
α CHLORDANE	0.0003	0.0003	0.0000	100.0	0.0	0.0003
γ CHLORDANE	0.0003	0.0005	0.0000	100.0	0.0	0.0003

11. DATA INTERPRETATIONS AND CONCLUSIONS

The Saugeen River originates in a swampy upland south of Georgian Bay at an elevation of 518 m above sea level and runs a course of 184 km to Lake Huron at Southampton (Figure 1). The river falls about 335 m over its reach for an average gradient of .000988 metres per metre. Four major tributaries - the North Saugeen, the Rocky Saugeen, the South Saugeen and the Teeswater rivers, and numerous smaller streams-feed the main channel. The total drainage area of the basin is approximately 397,900 ha.

The headwater areas of the Saugeen River are adjacent to the Grand River, the divides between them being somewhat indistinct, often consisting of a sprawling swamp from which drainage occurs in two directions. The upper stream reaches consist of rough and rocky land with large areas of swamp and non-productive woodlands. Cleared areas in the headwaters are primarily used for permanent pasture.

Above Walkerton (Figure 2), the branches of the Saugeen River flow in old glacial spillways with broad gravel terraces. Below Walkerton the river turns northward and flows in a valley, about 800 m wide and 45 m deep, through a glacial moraine. The river meanders northward from the moraine through a sand plain to Paisley where it cuts through a ridge of clay till and enters a former lagoon which was created by a high-level glacial lake at Port Elgin.

Land use (Figure 3) in the Saugeen River basin is primarily agricultural (62%) with large areas of the basin in permanent pasture. Intensive livestock and poultry operations and a wide variety of crops are also found in the area. Much of the land is swamp or unproductive woodland (33%). Urban development is restricted to a handful of small communities. The entire population of the watershed is about 57,280 of which 28,880 are concentrated in towns and villages (Figure 2).

In recent years continuous streamflow records have been maintained at seven locations by the Water Survey of Canada (WSC). Two of these stations possess records dating back at least 60 years. The gauge nearest the outlet of the Saugeen is located near Port Elgin, 11.8 km upstream of Lake Huron. The long term mean annual discharge, based on 63 years of record at this site, is approximately 56 m^3/s which corresponds to a runoff of 44.4 cm. Generally, peak discharges ranging from 300 to 850 m^3/s occur during the spring-melt period. Over the two years of the PLUARG study (1975 and 1976) mean daily discharges were respectively 61.2 and 68.4 m^3/s. Frequency analyses of the annual means indicate recurrence intervals of 3.3 and 5.6 years for 1975 and 1976, respectively. In 1975 a daily peak discharge of 670 m^3/s with an instantaneous peak of 694 m^3/s occurred and during 1976 a daily peak of 750 m^3/s with an instantaneous peak of 895 m^3/s was observed. The peak discharge data correspond to return periods of 5.3 and 10.5 years for 1975 and 1976, respectively. Only a few minor impoundments are present and the Saugeen River system may be regarded as essentially unregulated. Strong summer flows from 7 to 14 m^3/s are naturally maintained.

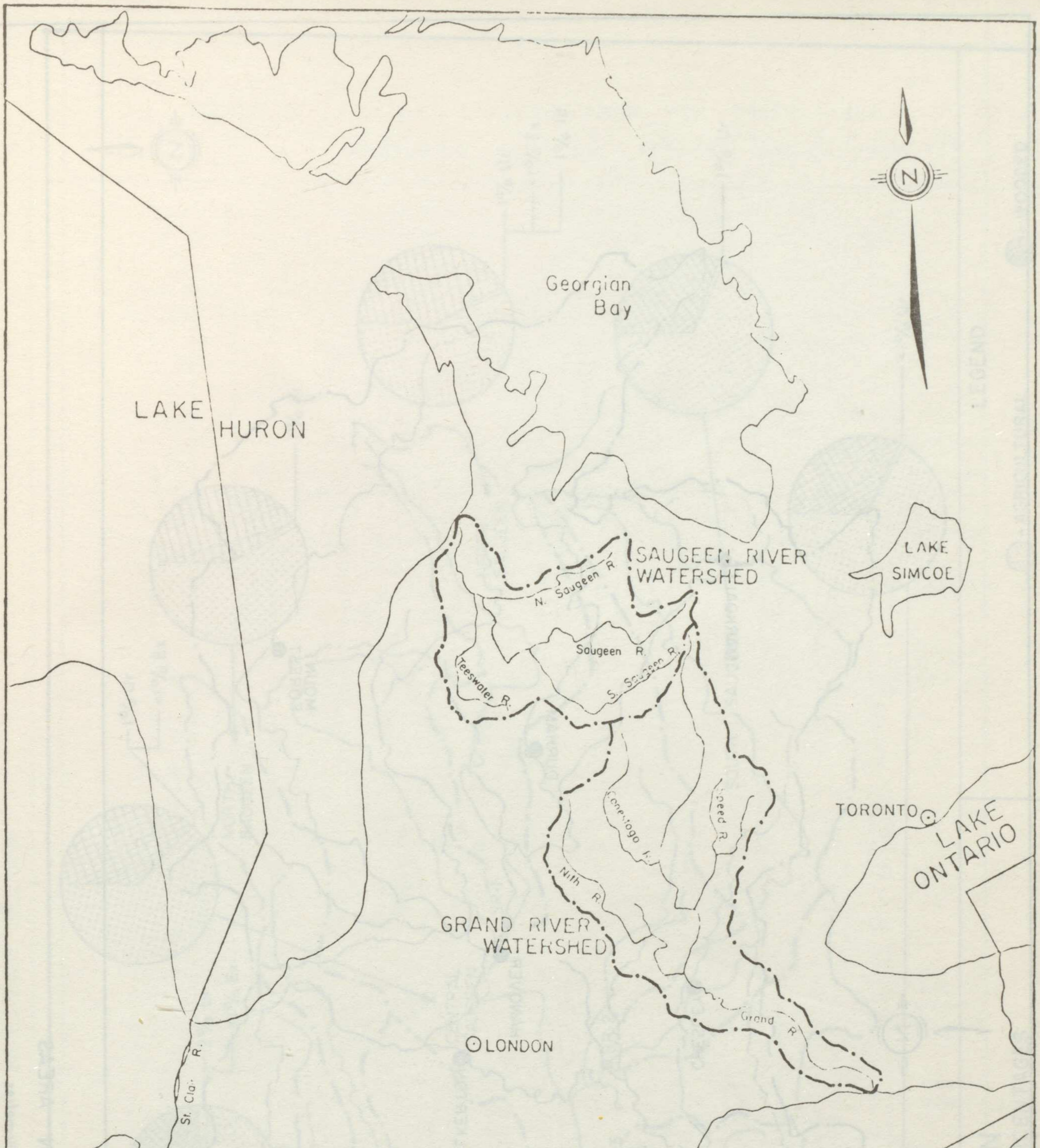
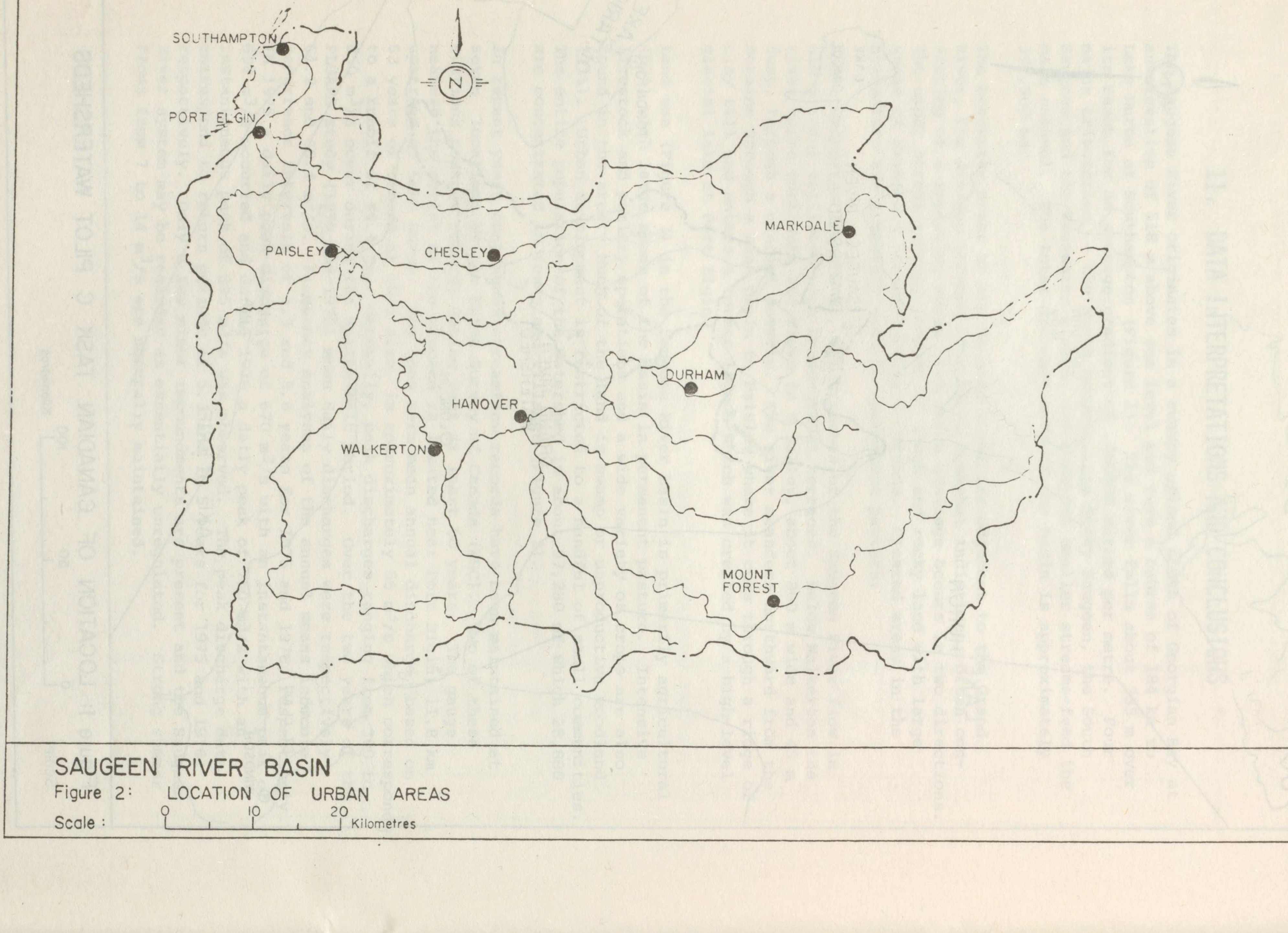


Figure I: LOCATION OF CANADIAN TASK C PILOT WATERSHEDS

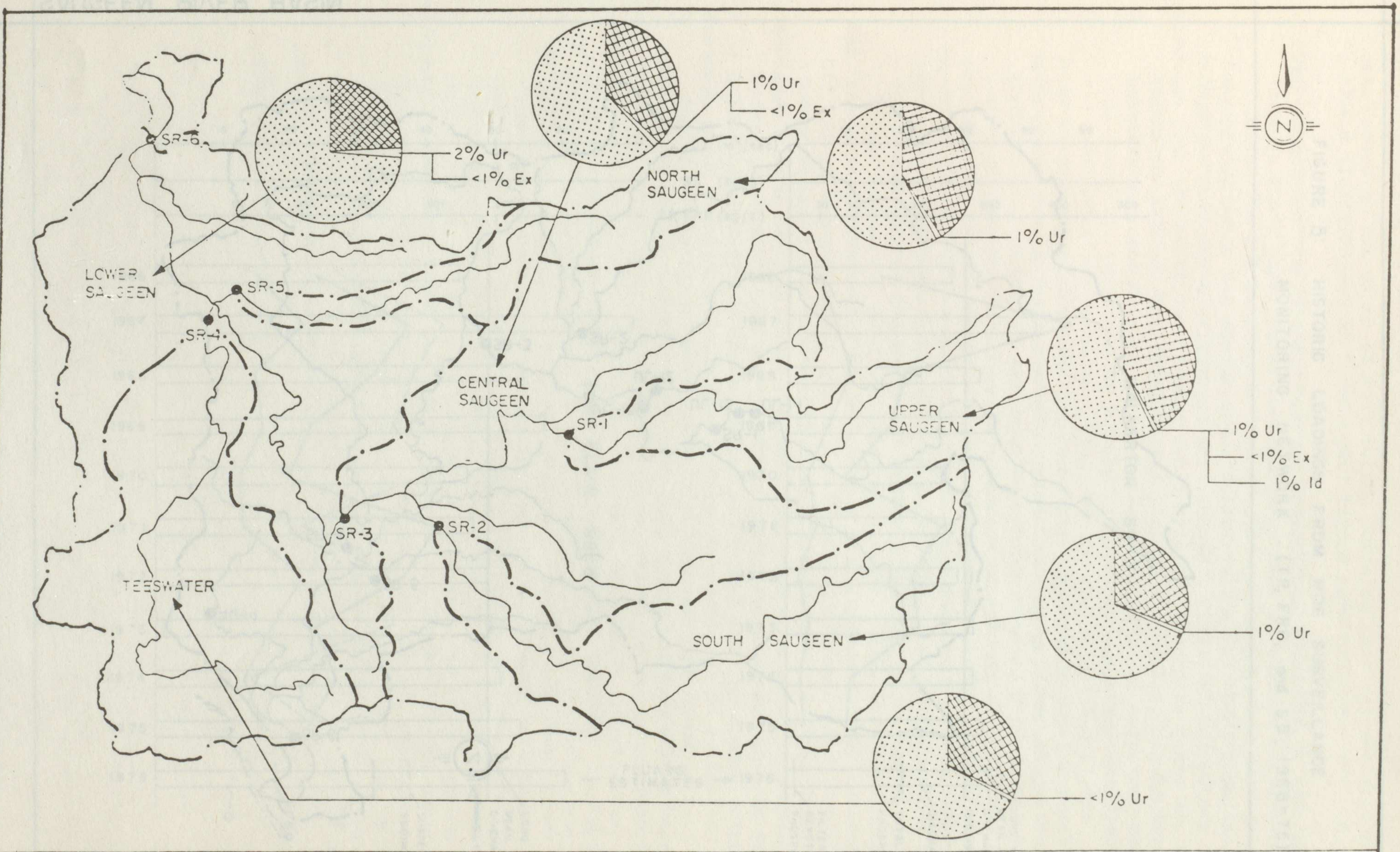
Scale: 0 50 100 Kilometres



SAUGEEN RIVER BASIN

Figure 2: LOCATION OF URBAN AREAS

Scale : 0 10 20 Kilometres



SAUGEEN RIVER BASIN

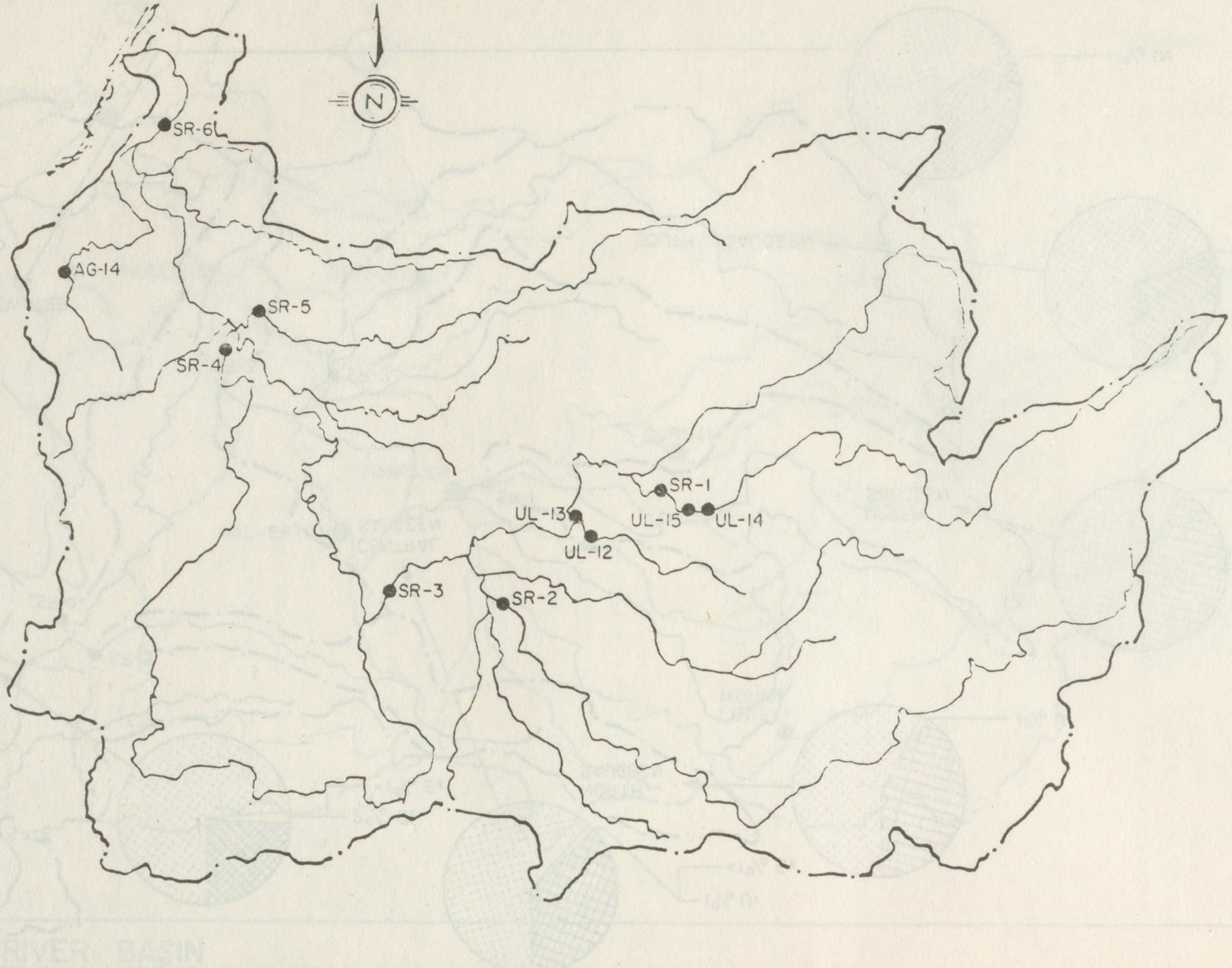
Figure 3: SECTOR LAND USE PERCENTAGES

Scale: 0 10 20 Kilometres

LEGEND

▨ - AGRICULTURAL ▩ - WOODED

Ur - URBAN Ex - EXTRACTIVE Id - IDLE

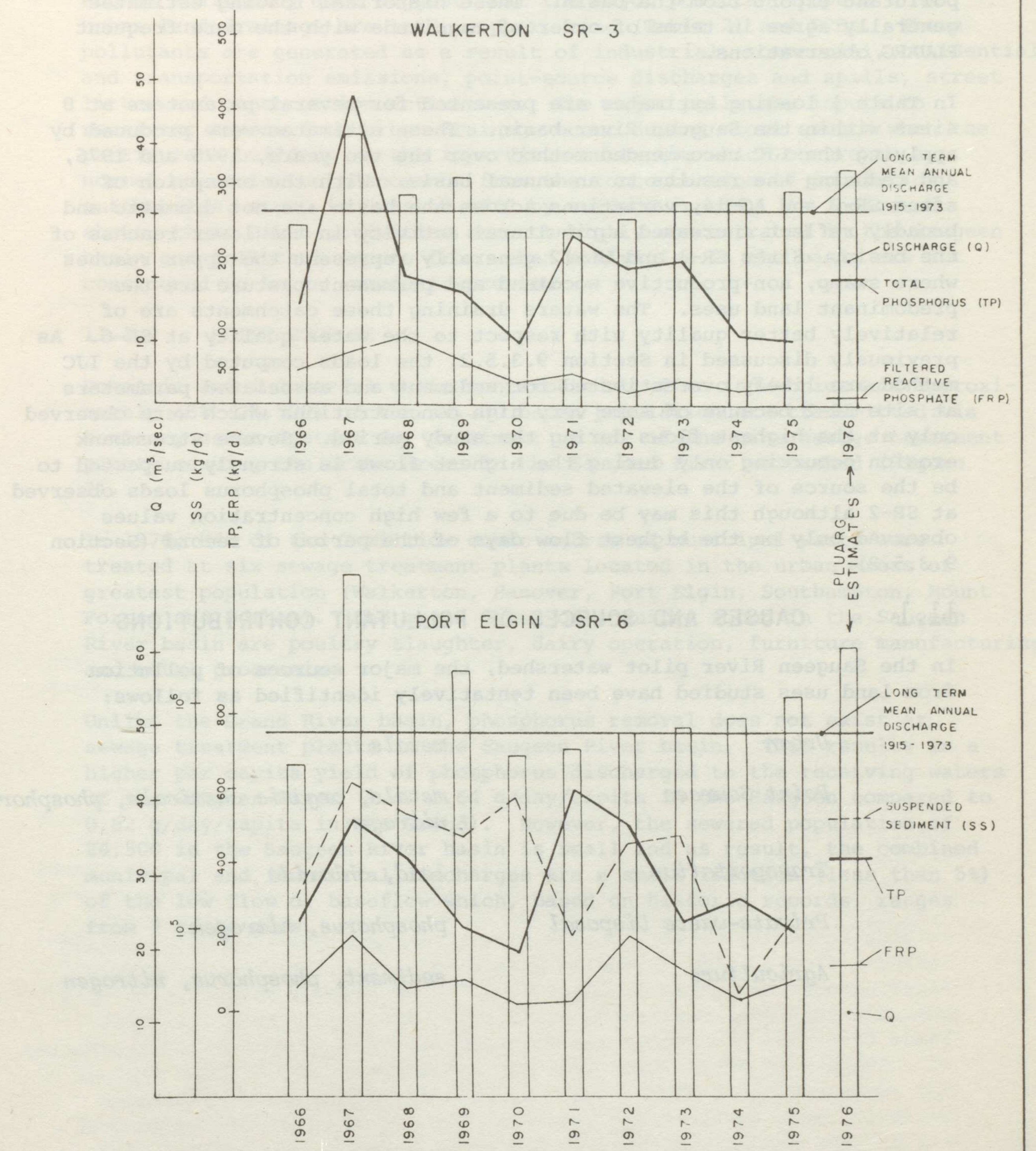


SAUGEEN RIVER BASIN

Figure 4: STREAM WATER QUALITY MONITORING NETWORK

Scale: 0 10 20 Kilometres

FIGURE 5: HISTORIC LOADINGS FROM MOE SURVEILLANCE MONITORING NETWORK (TP, FRP, and SS, 1966-75)



Long term average precipitation varies from 84 cm to 101 cm across the basin. The long-term mean annual temperature is approximately 6.4°C.

Long-term flow records and routine Ontario Ministry of Environment (MOE) surveillance monitoring data were employed to estimate loads at two sites, SR-6 and SR-3 (Figure 4). Annual mean flows and estimated, annual mean loads for a few available parameters are shown in Figure 5 for the period 1966-1975. Because the surveillance sampling was sparse and not event oriented, the historical loading estimates may only approximate pollutant export from the basin. These historical loading estimates generally agree in terms of order of magnitude with the more frequent PLUARG observations.

In Table 1 loading estimates are presented for several parameters at 8 sites within the Saugeen River basin. These estimates were produced by applying the IJC recommended method over the two years, 1975 and 1976, and reducing the results to an annual basis. With the exception of sites SR-2 and AG-14, variations across the basin are not dramatic and broadly reflect increased agricultural activity in the lower reaches of the basin. Sites SR-1 and UL-12 generally represent the upper reaches where swamp, non-productive woodland and permanent pasture are the predominant land uses. The waters draining these catchments are of relatively better quality with respect to the water quality at SR-6. As previously discussed in Section 9.3.5.2, the loads computed by the IJC method are likely overestimated for sediment and associated parameters at site SR-2 because of some very high concentrations which were observed only at the highest flows during the study period. Severe streambank erosion occurring only during the highest flows is strongly suspected to be the source of the elevated sediment and total phosphorus loads observed at SR-2 although this may be due to a few high concentration values observed only on the highest flow days of the period of record (Section 9.3.5.2).

11.1 CAUSES AND SOURCES OF POLLUTANT CONTRIBUTIONS

In the Saugeen River pilot watershed, the major sources of pollution from land uses studied have been tentatively identified as follows:

Urban	*metals*
Point Sources	*metals, organic chemicals, phosphorus, nitrogen*
Transportation	*lead, chloride*
Private-waste Disposal	*phosphorus, nitrogen*
Agriculture	*sediment, phosphorus, nitrogen*

11.1.1 URBAN LAND DRAINAGE

The largest towns in the Saugeen River watershed (Figure 2) are Hanover (population 5,300), Walkerton (4,500), Mount Forest (3,300) and Durham (2,500). The percentage of the basin classified as urban land use is approximately 0.7%. The Saugeen watershed has an urban population of 22,100 and an urban population density of 7.9 people/hectare.

PLUARG monitoring data suggest that the major pollutant inputs from urban land drainage are lead, copper, zinc (Table 2) and PCBs. These pollutants are generated as a result of industrial, commercial, residential and transportation emissions, point-source discharges and spills, street litter and construction activities. The major pollutant inputs to receiving stream from urban drainage occur during storm events when the particulate build-up on the impervious surfaces, which occurs as a normal accumulation phenomenon from the concentration of population, automobiles, etc., is "washed off" by surface runoff. As indicated above, these urban activities are not highly concentrated in the Saugeen basin and pollutant inputs from urban activities in the basin are not considered to be an immediate problem.

11.1.2 POINT SOURCES

Domestic and industrial waste contributed by five industries and approximately 43% (24,500) of the 57,300 basin population are transmitted via sanitary sewer systems for treatment at one of the nine sewage treatment plants serving the urban areas in the Saugeen River watershed (Figure 2).

In 1976, 84% of the 7 million cubic metres of municipal waste were treated at six sewage treatment plants located in the urban areas of greatest population (Walkerton, Hanover, Port Elgin, Southampton, Mount Forest and Durham). The major types of industry found in the Saugeen River basin are poultry slaughter, dairy operation, furniture manufacturing and metal processing.

Unlike the Grand River basin, phosphorus removal does not exist at sewage treatment plants in the Saugeen River basin. This results in a higher per capita yield of phosphorus discharged to the receiving waters of the Saugeen River (i.e. 2.64 g/day/capita in the Saugeen compared to 0.82 g/day/capita in the Grand). However, the sewered population of 24,500 in the Saugeen River basin is small and as result, the combined municipal and industrial discharges are a small fraction (less than 5%) of the low flow or baseflow which, based on historic records, ranges from 7 to 14 m^3/s.

The PLUARG monitoring data, obtained from sampling the outfalls of the six major sewage treatment plants in the basin during 1977 suggest that the major pollutant inputs from point sources are phosphorus, nitrogen and chloride. Trace amounts of PCBs at four of the sewage treatment plants were detected where supplementary sampling was undertaken for the PLUARG program. Traces of various pesticides (dieldrin and heptachlor epoxide) have also been detected.

11.1.3 TRANSPORTATION CORRIDORS

Provincial, County and Township highways occupy approximately 2% of the land (6,700 ha) in the Saugeen River watershed. The major pollutants produced as a result of the maintenance of these transportation corridors are chloride and sodium from highway deicing operations. Literature studies (Ontario Ministry of the Environment, 1974) report that other pollutants such as oil and grease, pesticides and heavy metals may be produced as a result of routine maintenance operations. One study (Laxen et al, 1977) reported that airborne lead was accumulating in the soil downwind of major highways. Special studies on transportation corridors in the Saugeen basin were not undertaken for the PLUARG study.

11.1.4 PRIVATE WASTE DISPOSAL

In the Saugeen River basin, approximately 18% (4,380) of the urban population use private-waste disposal systems (i.e. unsewered) throughout the year. A total (both urban and rural) population of 32,800 people use approximately 8,940 private-waste disposal systems throughout the basin. An additional 7,250 systems are used in seasonal dwellings and their pollutant input to the watershed is minimal in relation to the permanent systems.

Monitoring studies suggest that the only pollutants of concern from private-waste disposal systems are phosphorus and to a lesser extent nitrogen. Bacterial contamination may occur as a result of runoff from faulty private-waste disposal systems (seepage of septic-tank effluent) and create localized problems in the receiving waters.

11.1.5 AGRICULTURAL LAND

Agricultural watershed information indicates that the nature and type of agricultural activity is reflected on the water quality of receiving streams. Increased sediment loads will occur as a result of disturbance of natural conditions by various agricultural practices. Approximately 66% (Figure 3) of the Saugeen River watershed is in agriculture of varying intensity which produces significant amounts of phosphorus and sediment from runoff. Elevated phosphorus levels have been reported (Agricultural Watershed Studies, 1977) to be related primarily to soil characteristics or manure-use practices. Relatively high unit-area loads for total phosphorus and filtered reactive phosphate are noteworthy at subwatershed AG-14 which is a small catchment in the lower reaches of the Saugeen River system. The catchment drained by AG-14 is almost entirely under agricultural practice which is atypical of the general mix of land uses represented by the other sites in the basin. As a result, the elevated levels of phosphorous are assumed to be due to the agricultural influence in the catchment.

Runoff from moderate to high-density livestock operations, manure application and waste from wild animals appears to be the main source of bacterial contamination.

11.1.6 SOLID AND LIQUID WASTE DISPOSAL

On the basis of studies in the Grand River and Wilton Creek basins minimal impacts on stream-water quality are expected from waste-disposal practices (sanitary landfills, processed organic waste and spray irrigation). The limited areal extent of these land uses in the Saugeen River basin is also minimal. Increased land usage of these particular practices could create an impairment in stream-water quality with respect to nutrients and chlorides. If the waste is enriched with heavy metals and organic chemicals, accumulations in the soil could ultimately create an environmental health hazard if proper design and management procedures are not observed.

11.1.7 EXTRACTIVE INDUSTRIES

Sand and gravel pits and limestone quarries occupy only 79 hectares in the Saugeen River watershed (Figure 3). The major pollutant from these extractive industries is sediment from the washing of the aggregates. Monitoring data from the Grand River basin imply that extractive operations which utilize some method of waste-water treatment (such as settling ponds) do not affect receiving-stream water quality.

11.1.8 UNDISTURBED LAND

Monitoring data suggest that subwatersheds which are in relatively undisturbed states (woodlots and idle land) have a minimal impact on the receiving streams. Approximately 33% of the Saugeen River watershed is wooded or idle land (Figure 3). Runoff from these areas of perennial vegetation cover is considered to represent natural conditions. Monitoring at the outlets of subwatersheds with large proportions of their area in an undisturbed state suggest that heavy-metal inputs are occurring naturally from chemical and physical weathering of the limestone and dolomite (carbonate) bedrock in the basin. These carbonate rocks are naturally high in lead, cadmium and zinc. Soils may also contain natural levels of phosphorus formed from the decomposition of the parent materials containing minerals such as apatite and collophane.

11.1.9 OTHER LAND USES

Pollutant inputs from land uses and practices such as mine tailings and radiological waste disposal were not studied as these land uses were not located in the pilot watershed.

11.2 EXTENT OF POLLUTANT CONTRIBUTIONS IN UNIT AREA LOADINGS FROM LAND DRAINAGE WITHIN THE WATERSHED

The extent of pollutant contribution from a specific land use or practice is dependent on the proportion of land in that particular use or practice and the magnitude of the input (unit-area load) during a given period of time. In general, if the proportion of a particular land use in any watershed is large, the contribution from that land use will be relatively large even if the unit-area load is small. Unit-area loads can also assist in determining what land uses or practices can be best adapted for cost-effective control measures. Examination of the seasonal loading distribution can identify critical periods of the year during which controls should be applied (i.e. spring melt).

Annual unit-area loads for those parameters which are considered to be important by the PLUARG in terms of impairment of Great Lakes water quality, have been tabulated for the land uses in the Saugeen River watershed. These data are presented in Table 3.

Based on the unit-area loads listed in Table 4, pollutant ranking of the three major land-use categories in the watershed has been undertaken. The ranking is based on unit-area load comparison with each of the land uses, using the smallest unit-area load as unity. These ratios are presented below.

	TP	FRP	TN	SS	Cl	Pb	Zn	Cu
Urban	17	12	1	26	6	20	25	3
Rural	10	29	2	14	1	1	5	1
Wooded	1	1	1	1	1	1	1	1

where: TP = total phosphorus
FRP = filtered reactive phosphate;
TN = total nitrogen;
SS = suspended solids;
Cl = chloride
Pb = lead
Zn = zinc
Cu = copper

The above ranking suggests that urban runoff relative to drainage from rural and wooded land is potentially the largest contributor of total phosphorus, sediment, chlorides and metals. However, the impact from urban runoff in the Saugeen River basin is not significant because of the small area of urban land use. The ranking also suggests that rural runoff compared to urban and wooded areas is the major contributor for nitrogen and filtered reactive phosphate.

PLUARG monitoring data suggest that the bulk of the annual pollutant loads are delivered during the months of February, March, April and May which is normally the spring melt or high-flow period of the year. This marked seasonality of pollutant transport is illustrated in Table 4a and 4b. The percentages of monthly contribution of total annual loads are based on daily load estimates derived from sampling and supplemented by regression estimates where daily sampling did not exist. In Table 4a values for the watershed outlet, site SR-6, demonstrate that significant proportions of all parameters are delivered during the spring melt. In 1975 during the months of February, March, April and May, approximately 59% of the total annual flow occurred and 60% to 73% of the total annual load for each parameter except chloride was exported. During the same months of 1976, 68% of the flow occurred resulting in deliveries of 75% to 95% of the total annual loads for each parameter but chloride. Athough chloride as a conservative parameter tends to decrease in concentration as flow increases, substantial proportions of the total annual load were delivered during the spring melt (53% for 1975 and 61% for 1976, respectively).

Table 4b presents percentages of monthly contribution of the total annual loads for site SR-2, located on a tributary draining the upper reaches of the basin. The data for sediment and sediment-associated parameters show more sharply pronounced seasonal dependencies than appear at SR-6. In both study years, the month of highest flow (April of 1975 and March of 1976) accounts for about 40% of the total annual flow, yet approximately, 90% of the total annual sediment load and 75% to 85% of the annual phosphorus load were delivered in this month. Severe streambank erosion occurring only during the highest flows recorded over the PLUARG study period is believed to account for the disproportionately large sediment and phosphorus loads which occur at SR-2. In terms of percentage, both total phosphorus and filtered reactive phosphate exhibit similar patterns of delivery; however, analysis of the loading data presented in Table 1 shows the filtered reactive phosphate load to represent a significantly smaller fraction of the total phosphorus load at SR-2 than occurs generally at other sites within the Saugeen basin. This fact would indicate that although the total phosphorus load at SR-2 is high, a greater than normal fraction of this load consists of phosphorus forms which are very likely bound to the sediment and not readily available for biological uptake. The data at SR-2 are generally illustrative of conditions in which streambank erosion may play a significant role in generating sediment, phosphorus and sediment-associated parameter loadings.

11.3 RELATIVE SIGNIFICANCE OF SOURCES WITHIN THE WATERSHED

Ranking of the critical land-use categories in the Saugeen River watershed has been established using the data presented in Table 2. These data are summarized as follows:

Phosphorus	*- agriculture*
	- point sources
	- private waste disposal
Nitrogen	*- agriculture*
	- wooded
	- point sources

Sediment - agriculture
- wooded
- streambank erosion

Metals - urban
- point sources

Chloride - transportation

11.3.1 PHOSPHORUS

Agriculture and point-source discharges are the primary contributors of phosphorus as indicated by the proportion of the total estimated load (Table 2b) at the mouth of the Saugeen River. However, in terms of available phosphorus for biological uptake (filtered reactive phosphate); point-source estimates remained the same, agriculture decreased to 70% from 83% whereas private waste disposal increased to 9% from 3% of the total phosphorus load at the mouth. The significance and control of phosphorus from the above-mentioned land uses and practices appears not to be as critically important as in the case of the Grand River in terms of boundary-water impairment.

11.3.2 NITROGEN

Agriculture, point-source discharges private-waste disposal and wooded areas are the major contributors of various nitrogen forms (Table 2). Both agricultural practices and private-waste disposal systems may contribute significant amounts of nitrite + nitrate to the ground-water system. This form of nitrogen is highly soluble and once in the ground water can be transported rapidly. Fortunately most problems with the pollution of ground water by nitrogen are usually localized in areal extent at the present time; however, the number of occurrences appears to be increasing.

Nitrogen from point-source discharges is predominantly in the form of Kjeldahl and ammonia. Biochemical transformations (nitrification/denitrification) normally take place downstream of the point-source outfalls and supplement the dilution effects of the receiving streams in assimilating the waste effluent.

11.3.3 SEDIMENT

Excessive sediment will impact on receiving waters in terms of aesthetics, photosynthesis and ecosystems (inhibiting bottom organisms and fish spawning). In addition, the adsorptive capability of finer-grain sediment is extremely important in scavenging and transporting potentially hazardous materials (i.e. organic chemicals, metals, etc.). Accumulation and later release of these materials may occur under changing equilibrium conditions.

In the Saugeen River watershed the single most important source of sediment is the agricultural land use contributing as much as 90% of the total load at the mouth (Table 2). Streambank erosion contributed about 4% of the sediment load in this watershed.

11.3.4 TOXIC MATERIALS (METALS, PESTICIDES AND ORGANIC CHEMICALS)

Toxic materials such as heavy metals, pesticides and organic chemicals have a strong affinity for the clay-size sediment fraction and as a result suspended sediment is a major transporter of these pollutants. Monitoring data indicate that the percent of the total load due to the particulate fraction varies from; 10-50% for copper, 50-70% for lead and 20-70% for zinc (Figure 6).

11.3.5 CHLORIDE

Highway deicing salt appears to be the most significant source of chloride delivered to the boundary waters via land drainage. A comprehensive inventory of deicing salt usage in southern Ontario for the winter of 1975-76 revealed that approximately 7100 metric tonnes of chloride were applied on streets, roads and highways within the Saugeen River basin. The figures of Table 2g show road salting to account for approximately 45% of the chloride load arriving at the watershed outlet. Background levels of chloride contribution were estimated conservatively to be about 20 kg/ha/yr for both agricultural and wooded/idle land use categories. A higher unit lead input would be identified if transportation corridor inputs were considered as part of these categories. Taken together, the natural inputs from land in the agricultural and wooded/idle categories contribute approximately 49% of the total chloride load at the watershed outlet. Municipal point source discharges account for about 4% and the remaining land uses produce insignificant contributions to the basin total.

11.3.6 BACTERIA

Agricultural and urban areas that are contaminated by animal (wild and domestic) wastes, are responsible for most of the microbial pollution. Bacterial populations derived from these land-use areas are principally of local concern, since die-off rates limit actual in-stream transport. Microbial contamination is considered significant to Great Lakes water quality only where runoff is discharged directly to the lakes and in areas where the lakes are used for body-contact recreation.

11.4 TRANSMISSION OF POLLUTANTS FROM SOURCE AREAS TO BOUNDARY WATERS

An understanding of the in-stream transport of pollutants is essential if the importance of source areas to the degradation of boundary waters is to be assessed. Several PLUARG Technical Committees have recognized that deficiencies in existing land-use loading models and process-response studies exist in linking water quality at upstream source areas to river-mouth loadings. Although the principles of sediment-transport mechanics are well known, the downstream movement and modification of sediment-associated pollutants from upstream source areas is poorly understood. In-stream chemical and biological processes operating in addition to the physical processes tend to confound a clear understanding of pollutant transport phenomena. As an example, phytoplankton growth converts nutrients from soluble to organic sediment forms which may be released when the biomass decays. Other processes such as chemical precipitation under favourable conditions or colloidal coalescence may also occur.

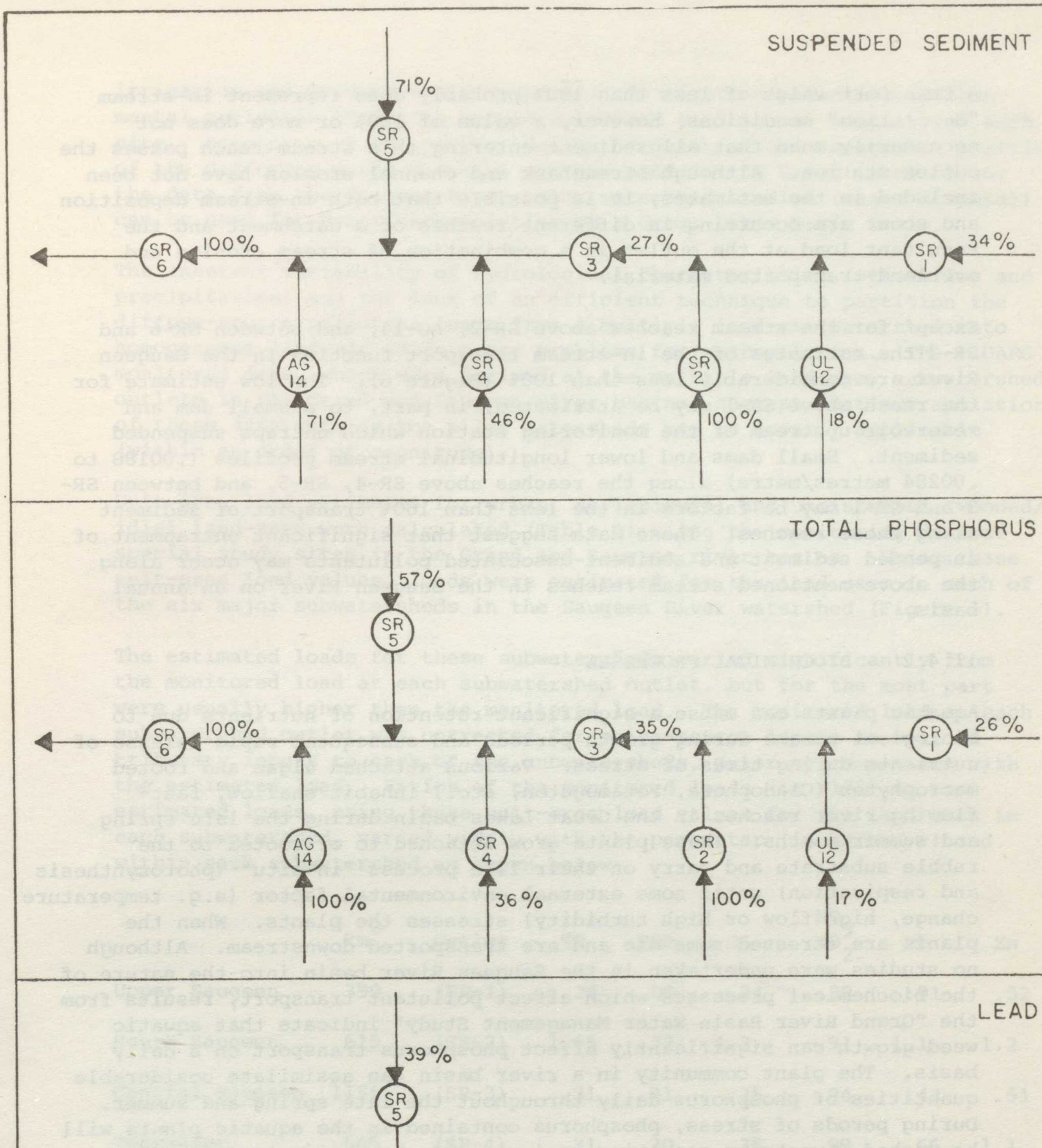
11.4.1 PHYSICAL PROCESSES

Pollutants may be transported in solution or in association with particulate matter (suspended and bed load). Dissolved materials and clay-sized particles are rapidly transported through the watershed system and will have an immediate impact on boundary waters. A 100% in-stream delivery for dissolved and clay-sized particles seems reasonable both on annual and long-term (50-year) delivery basis. In the Saugeen River system for example, the time of travel from the headwaters to the mouth of the river, excluding reservoir-residence time, is estimated to be in the order of a week at low-flow conditions.

The coarser particulates (silt and sand) are transported intermittently by suspension and bed-load movement. Flow-regulation structures and stream reaches with low stream velocities may temporarily trap coarser sediment. Subsequent high flows often result in remobilization of coarser materials.

In the absence of detailed information on the in-stream transport of coarse sediment and sediment-associated pollutants, a technical committee of the PLUARG assumed that the long-term (50-year) delivery of material to the lakes is 100%. This implies that land-use activities regardless of their distance from the Great Lakes will have an eventual impact on the Great Lakes. On an annual basis, however, monitoring data in the Saugeen River watershed demonstrate that the in-stream transport of contaminants can be extremely variable and substantially less than 100% in some areas, especially for sediment-associated contaminants.

Estimated annual in-stream transport functions for suspended sediments, total phosphorus and lead along stream reaches in the Saugeen River watershed for 1976 are shown in Figure 6. The transport functions are expressed as percentages which were calculated as described previously (in Section 9.3.7). These values should be viewed with extreme caution at this stage because the assumption that stream-bank erosion does not contribute any material is likely in error, and therefore, the total load estimate (using the method described in Section 9.3.7) is probably too low. Inaccuracies in estimating point and diffuse source loads and calculating monitored loads also contribute to the poor reliability of the derived transport-function values. Further study will be required to refine the loading estimates used in the mass balance equation (Section 9.3.7).



SAUGEEN RIVER BASIN

Figure 6: ESTIMATED ANNUAL IN-STREAM TRANSPORT FUNCTIONS, 1976

A transport value of less than 100% probably does represent in-stream "deposition" conditions; however, a value of 100% or more does not necessarily mean that all sediment entering this stream reach passes the outlet station. Although streambank and channel erosion have not been included in the estimates, it is possible that both in-stream deposition and scour are occurring in different reaches of a catchment and the resultant load at the outlet is a combination of stream erosion and overland-transported material.

Except for the stream reaches above SR-2, AG-14, and between SR-6 and SR-3 the estimates of the in-stream transport function in the Saugeen River are considerably less than 100% (Figure 6). The low estimate for the reach above SR-1 may be attributed, in part, to a small dam and reservoir upstream of the monitoring station which entraps suspended sediment. Small dams and lower longitudinal stream profiles (.00188 to .00284 metres/metre) along the reaches above SR-4, SR-5, and between SR-3 and SR-1 may be factors in the less than 100% transport of sediment along these reaches. These data suggest that significant entrapment of suspended sediment and sediment-associated pollutants may occur along the above-mentioned stream reaches in the Saugeen River on an annual basis.

11.4.2 BIOCHEMICAL PROCESSES

Aquatic plants can cause a significant retention of nutrients due to biological uptake during growth periods and subsequent rapid release of nutrients during times of stress. Various attached algae and rooted macrophytes (Cladophora, Potamogeton, etc.) inhabit shallow, fast-flowing river reaches in the Great Lakes basin during the late spring and summer months. These plants grow attached to or rooted to the rubble substrate and carry on their life process "in-situ" (photosynthesis and respiration) until some external environmental factor (e.g. temperature change, high flow or high turbidity) stresses the plants. When the plants are stressed some die and are transported downstream. Although no studies were undertaken in the Saugeen River basin into the nature of the biochemical processes which affect pollutant transport, results from the "Grand River Basin Water Management Study" indicate that aquatic weed growth can significantly affect phosphorus transport on a daily basis. The plant community in a river basin can assimilate cosiderable quantities of phosphorus daily throughout the late spring and summer. During perods of stress, phosphorus contained in the aquatic plants will be washed downstream resulting in increased phosphorus load at the watershed outlet.

11.5 DATA TRANSFERABILITY

Extrapolation of the pilot watershed data to unmonitored areas outside the PLUARG pilot watersheds is possible provided the characteristics of the unmonitored areas are similar to those in the pilot watersheds. In terms of extrapolation to other parts of the Great Lakes basin, the critical sources of pollutant contribution have been identified as being runoff from urban and agricultural land and point-source inputs. Waste disposal (sanitary landfills, processed-organic waste disposal, spray irrigation and private-waste disposal) constitute a potential environmental pollution threat to ground water and soil in the vicinity of each site. Depending on the nature, design, regulation and management practices of the different waste disposal systems used in the Great Lakes basin, the data from the Saugeen River pilot watershed studies (waste disposal) can be used for gross extrapolation on a Great Lakes basin basis.

The inherent variability of hydrological characteristics (streamflow and precipitation) and the lack of an efficient technique to partition the diffuse-source pollutant loads from a multiple land-use watershed into homogeneous land-use loads cause problems for extrapolation. The PLUARG monitored data, which were derived at the multiple land use, subwatershed outlets in the Grand and Saugeen river basins, suggest that extrapolation of these data outside the pilot watersheds may be grossly applicable (within an order of magnitude).

Unit-area load estimates for urban, agricultural and undisturbed (wooded/idle) land-uses were calculated (Table 3) using the monitoring data at special study sites in the Grand and Saugeen river basins. Using these unit-area load values, loads were estimated for the land uses in each of the six major subwatersheds in the Saugeen River watershed (Figure 3).

The estimated loads for these subwatersheds varied significantly from the monitored load at each subwatershed outlet, but for the most part were usually higher then the monitored load. The monitored load at each subwatershed outlet was corrected for point-source inputs as well as tributary inputs to each of the subwatersheds, prior to comparison with the estimated load. Ratios of the monitored loads (in 1976) to the estimated loads, using these unit-area load values for the land uses in each subwatershed, varied widely with the parameter (in kg/ha/yr) and within each subwatershed as shown below:

	km^2	Outlet	TP	FRP	SS	NO_3 + NO_2	Pb	Zn
Upper Saugeen	390	(SR-1)	.24	.08	.24	.38	.91	.52
South Saugeen	615	(SR-2)	1.65	.32	4.3	.91	1.1	1.2
Central Saugeen	1155	(SR-3)	.31	.21	.25	.84	.43	.51
Teeswater	665	(SR-4)	.31	.20	.35	.99	.66	1.1
North Saugeen	250	(SR-5)	.49	.46	.54	.61	.47	.33
Lower Saugeen	895	(SR-6)	1.15	.94	1.24	1.04	1.00	1.36
Total Saugeen R.	3970		.59	.38	1.1	.86	.58	1.20

where: TP = total phosphorus;
FRP = filtered reactive phosphate;
SS = suspended sediment;
$NO_3 + NO_2$ nitrate + nitrite-nitrogen
Pb = lead
Zn = zinc

The monitored/estimated ratios were less than one for the upper Saugeen River subwatershed (SR-1), which represents the headwater area of the Saugeen River basin. Similar ratios were found in the case of headwater areas of the Grand River basin which are adjacent to the headwaters of the Saugeen River basin. The estimated loads for the South Saugeen and the lower Saugeen were lower than the monitored loads for most of the parameters as shown above (i.e. ratios greater than one). These anomalies might have arisen because the streambank erosion which appears to be active in these regions was not accounted for in the estimated load calculations. The above reason seems to be more probable because not only sediment but the sediment associated parameters like TP and metals were also underestimated showing a higher ratio of more than one. Inclusion of the streambank erosion loads (obtained from personal communications with other PLUARG investigators) for the entire Saugeen River basin monitored the estimated loads (Table 2a) and the ratios, as shown above, appear reasonable (the ratio for the suspended solids was slightly more than one).

The transferability or extrapolation of the unit-area loadings data outside the pilot watershed cannot be alone with high accuracy because of the data limitations. These limitations consist of a paucity of information on the in-stream transport of materials and biochemical transformations, and inadequacies of the monitoring program and the resulting loadings estimate biases. However, subjective selection of unit-area loads within the ranges shown in Table 3 for similar land-use situations in unmonitored areas of the Great Lakes basin may provide a reasonable initial estimate of loadings.

12.0 RECOMMENDATIONS

In addition to determining the impact of land-use activities on the water quality of the Great Lakes, the Reference Group was requested to recommend remedial measures or alternative strategies for maintaining or improving Great Lakes water quality. Sound water--management strategies require consideration of the environment as a whole including land, air and water aspects as well as the consequence on the social fabric of the basin. The implementation of any water-management practice also has the potential for creating secondary problems, some of which could be as serious as those being solved by the recommended control strategy. Public acceptability, costs, benefits, maintenance and adverse effects require evaluation and study prior to implementing any control strategy in the Great Lakes basin.

The two major in-lake problems have been identified as the acceleration of the natural aging process in the lakes (eutrophication) and those toxic materials which constitute an environmental health hazard (human and/or biological). Eutrophication is principally controlled by phosphorus and to a lesser extent by nitrogen. The hazardous lake problems are attributable to pesticides, organic chemicals, heavy metals and bacterial contamination. Sediment is an important aspect of both eutrophication and toxicity problems as a result of the sediment's capacity to adsorb phosphorus and other contaminants.

Control strategies for sediment may be at least partially effective in controlling other contaminants such as pesticides, organic toxicants and trace elements which are adsorbed to the sediment. Alternatively, the presence of sediment, finer-grained materials in particular, may concentrate significant quantities of these materials which may then be removed from the aquatic system by sediment transport and deposition. However, accumulation and later release of these materials may also occur under changing equilibrium conditions creating other problems requiring further control.

Remedial or preventative strategies would be most cost effective if the pollutant is controlled where it is found at its highest concentration. Generally, this is usually the source area of the pollutant discharge or emission. Treatment costs will probably increase as the pollutant becomes dispersed as a result of the larger area requiring control; however, the degree of treatment that is required may vary if concentration levels decrease (with dispersion) away from the source.

The nature of the pollutant requiring control will also be an important factor in dictating the required degree of treatment. Small amounts and/or infrequent inputs of toxic and persistent materials, such as some pesticides, organic toxicants and trace elements can create long-term problems. Residues of these materials or their degradation products may not decline below acceptable limits for a long period of time because of their persistent nature. Bioaccumulation in the food chain may further aggravate the problem of controlling these kinds of materials.

Loading distributions suggest that seasonal application of remedial measures will be most cost effective, particularly during high-flow periods such as the spring melt when the bulk of the contaminant load is transported to the Great Lakes. Ranking of source areas in terms of relative concern may also be appropriate as a control strategy in that contaminants from some urban areas, for example, may be more varied and at higher levels than those from rural or forested lands. Furthermore, some source areas may also only represent a small portion of the total land area in the watershed and consequently, remedial measures may not be required for large areas of land.

Obvious control strategies are the retention of contaminants and their prevention from reaching the receiving waters. For sediment, this can be accomplished by reducing soil erosion rates and eliminating transport of the eroded soil. Strict regulation of pesticides and organic chemicals to avoid careless handling, misuse and spillage would also eliminate many of the potentially hazardous problems created by these materials reaching the receiving waters.

12.1 FEASIBLE REMEDIAL MEASURES

The effectiveness of remedial measures and alternative strategies to control non-point sources of water pollution were not assessed under the PLUARG studies; however, a catalogue of remedial measures was prepared under the Task A program. On the basis of this catalogue and the findings contained in this pilot watershed report, possible alternative strategies for pollutant control are presented in the following sections. Prior to the implementation of any recommended strategy, demonstration projects should be undertaken to determine their cost effectiveness, public acceptability, maintenance requirements and potential adverse effects.

12.1.1 URBAN

Sediment and sediment-associated contaminants are the most serious problems requiring control in urban runoff. The following measures should be assessed to determine their effectiveness in controlling pollution from urban runoff:

a. The use of mulches, sedimentation ponds, etc. to reduce sediment loads due to erosion from urban construction sites,

b. The use of bank stabilization techniques to reduce sediment loads due to streambank erosion,

c. The reduction of atmospheric emissions which subsequently accumulate on impervious surfaces and are washed off during rainstorm or melt periods,

d. Reduction or replacement of salt as a deicing agent on highways to reduce chloride loads from urban areas,

e. The initiation of public-education programs designed to reduce the accumulation of litter and animal waste on streets, and to promote the proper use of pesticides and fertilizers on residential property, would reduce the pollutant inputs of phosphorus, bacteria and pesticides from urban areas,

f. The implementation of street sweeping practices to remove accumulated contaminants from streets,

g. Improve collection and treatment systems and promote new storage and infiltration systems for urban storm runoff such as on-site storage of contaminants, porous pavement to promote infiltration, separation and recovery basins, traps, etc.

h. Control of atmospheric fallout of PCBs from waste incineration at low temperatures and leakage from disposal sites is required.

i. Reduce pesticides washoff from utility corridors and residential, recreation and agricultural lands.

j. Reduce washoff of accumulated bacterial contaminants (i.e. organic debris, animal excreta) from pervious surfaces and industrial point sources (i.e. food processing plants).

12.1.2. RURAL

Erosion of agricultural land is a major contributor of sediment to streams. The major controlling factors in the rate of erosion are soil type, slope, cover, climate and cropping practices. The reduction of erosion rates can be realized by various control strategies to maintain soil structure (i.e. minimum tillage methods) and the use of cover crops to lessen the erodibility of soil from the impact of rain. Other alternative strategies such as contour cropping, diversion terraces, etc., will reduce the transport of eroded soil into the drainage channel. Field borders (i.e. buffer strips of vegetation on the drainage way) will reduce the velocity of runoff water and the amount of material that can be held in suspension. Restriction of livestock access to streams during periods of high soil moisture will reduce the incidence of streambank instability and subseqeunt slumping of materials into the stream.

Excessive fertilizer and manure applications can elevate natural nutrient levels in the streams which drain areas of active fertilization. Proper use of fertilizer and manure for optimum crop production and plant growth should be encouraged (i.e. immediate plow down). Runoff or seepage from manure sewage or livestock feeding areas should be discouraged. Restriction of livestock access and defecation in the streams may be necessary in some areas to reduce both nutrient and bacterial contamination from livestock.

12.1.3 PRIVATE WASTE DISPOSAL

Proper designed and constructed septic systems utilize the natural sorption characteristics of the soil to minimize pollution. System failures can result in the impairment of receiving-stream water quality with respect to phosphorus inputs. Although attenuation of phosphorus by soil adsorption is a natural control, abatement at the source in private-waste disposal systems (i.e. alum additives in the septic tank or holding tanks) may be an environmentally satisfactory solution where insufficient soil is available for natural attenuation. An alternative strategy is the use of other suitable soils with high exchange capacities; however, the cost of this alternative will be directly related to the cost of transporting these materials to the site.

Human waste also contains naturally high levels of organic nitrogen forms and significant amounts of organic nitrogen will accumulate in the septic system. The attenuation of most organic nitrogen forms by soil mineral particles is reasonably good (up to 81%); however, the septic system leachate may contain large amounts of the highly soluble nitrate ion. Nitrate is formed as a result of mineralization and nitrogen transformations (i.e. nitrification) of organic nitrogen. Consequently, localized ground-water problems can occur as a result of nitrate leaching from the septic system.

Bacterial contamination may occur as a result of runoff from faulty private-waste disposal systems (seepage of septic tank effluent) and create localized problems in the receiving waters.

Providing the septic-tank/tile field system is designed and constructed according to current regulations, the proposed minimum distances between tile fields, wells and surface waters are considered adequate to avoid contamination of drinking water and to protect the surface waters.

12.1.4. SOLID AND LIQUID WASTE DISPOSAL

If waste is enriched with heavy metals and organic chemicals, accumulations in the soil from land disposal of the wastes could ultimately create an environmental health hazard. Proper design and management of solid waste-disposal sites (utilizing the natural attenuating capacity of soil for removing pollutants from the leachates generated by the solid waste) will minimize pollutant transmission to receiving waters. However, local impairment of ground water may occur and as a result stringent site-specific controls may be required.

Guidelines for sewage sludge utilization on agricultural lands have been developed for use in the Province. Providing implementation of the guidelines is strictly enforced with respect to application rates, site selection and sludge content, environmental hazards will be minimized as a result of spreading sewage sludge on agricultural lands.

Treatment and recycling of waste materials is the ultimate solution to waste disposal rather than storage and concentration as presently exists (i.e. sanitary landfills, etc.). Schemes should be encouraged which renovate the natural environment (i.e. infiltration and recharge to ground water systems, etc.).

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