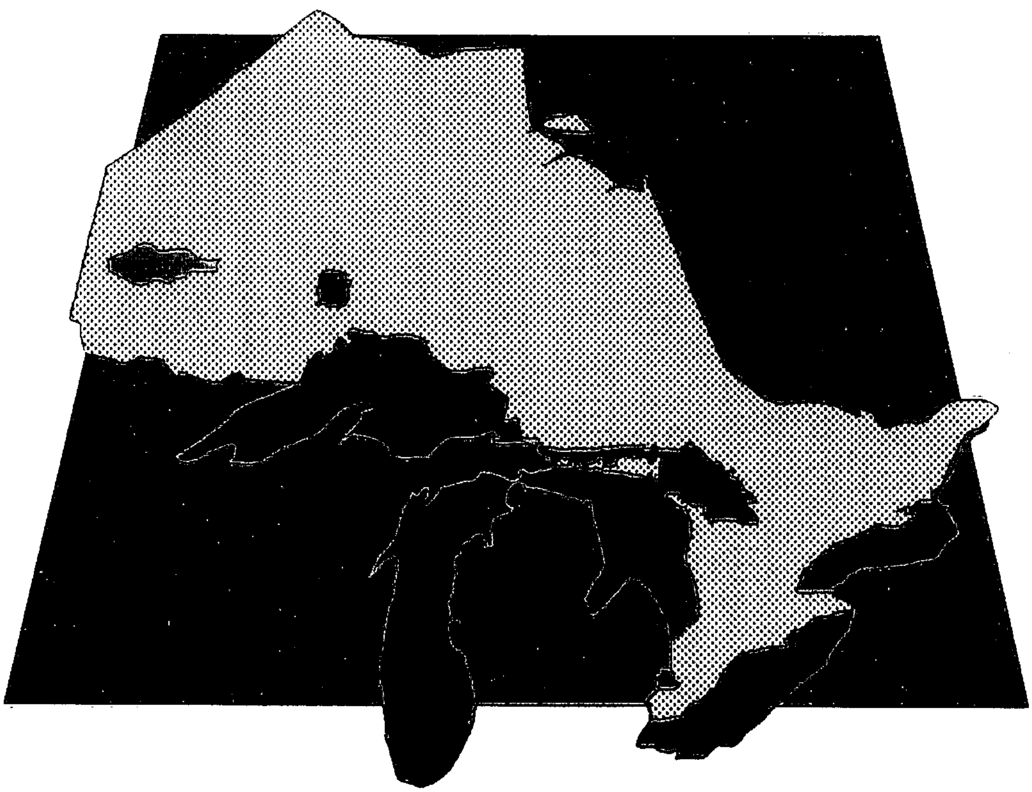
THE APPLICATION OF AN INTERDISCIPLINARY APPROACH TO THE SELECTION OF POTENTIAL WATER QUALITY SAMPLING SITES



Wabigoon River Basin

Water Quality Branch
Ontario Region

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THE APPLICATION OF AN INTERDISCIPLINARY APPROACH TO THE SELECTION OF POTENTIAL WATER QUALITY SAMPLING SITES IN THE WABIGOON RIVER BASIN

A Report Prepared For

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EXECUTIVE SUMMARY

1.0 Introduction

The Wabigoon River basin is one of 13 Ontario river basins being evaluated for Environment Canada's proposed National Reference Network (NRN) for water quality. The purpose of this study is to provide reference documents which summarize the influences of ecological diversity and human activity on water quality, and to provide a framework with which potential water quality monitoring sites can be selected to address specific federal water quality issues. Issues identified for the NRN are: agricultural and cultural eutrophication, agricultural pesticides, urbanization, acid rain, pristine/baseline, and development/resource extraction. Stations are being located to monitor appropriate issues within sub-basins of each watershed. Other basins being examined are the Shamattawa, Kwataboahegan, Seine, Goulais, White, Blanche, Magnetawan, Thames, Grand, Saugeen, Rouge and the South Nation.

1.1 Approach and Limitations

Existing reports, maps and data were obtained from government sources. Provincial water quality data were obtained from the Ministry of Environment (MOE), and used to describe historical water quality conditions within the basin. Stream flow data were provided by the Inland Waters Directorate of Environment Canada. Ideally, one provincial water quality station and one federal stream flow station would be located in each sub-basin, however, in practice this situation occurs infrequently. The Ministry of Natural Resources Forest Resources Inventory data and Land Use Guidelines were also utilized in the study.

The issues of concern in the Wabigoon River basin are: (1) development/resource extraction; (2) agricultural eutrophication; and (3) baseline/pristine conditions. Seven sub-basins were selected for evaluation as part of this study: Revell River, Wabigoon Lake, Gullwing Lake, South Eagle River, Eagle Lake, Canyon Lake, and Lower Wabigoon.

2.0 The Wabigoon River Basin

The centre of the Wabigoon River basin is located approximately 130 km east of the Ontario/Manitoba border and 345 km northwest of Thunder Bay in northwestern Ontario. The Wabigoon River and its tributaries flow in a northwesterly direction and outlet into the English River, a secondary watershed of the Lake Winnipeg watershed. The Wabigoon River and Canyon, Eagle, Wabigoon and Dinorwic lake complexes are the primary waterbodies within this 8187 km^2 watershed. The Revell and Gullwing rivers are important secondary tributaries.

The climate of the Wabigoon River basin is modified continental. Dryden, the primary community within the watershed, experiences mean annual temperatures of 2.0° C and receives an annual average of 695.6 mm of precipitation. Portions of four ecoregions are represented within the Wabigoon River basin: Berens Plains, Lake of the Woods Plains, Nipigon Plains and Lake St. Joeseph Plains. The Berens Plains Ecoregion, situated in the central and northern portion of the watershed, represents 63% of the total basin area. The Lake of the Woods Plains Ecoregion represents the next largest portion of the watershed at 33%.

Undifferentiated early felsic igneous and metamorphic rock cover 68% of the watershed; mafic metavolcanics and metasediments underlie 23% and 7% of the basin, respectively. Bedrock (60%) and glaciolacustrine (21%) landforms are the two dominant surficial deposits. The greatest proportion of developed agricultural land occurs in the Gullwing Lake sub-basin (4.3%). Productive forests cover over 78% of the watershed.

Forestry is the dominant economic activity in the watershed. Bosie Cascade Canada Ltd. and Canadian Pacific Forest Products are the two largest forestry companies currently operating within basin boundaries. Canadian Pacific Forest Product's pulp and mill and sawmill located in Dryden, are the primary industries in this area. Also important to the basin economy are tourism, agriculture and, to a lesser extent, mining. Dryden, Vermilion Bay, the Township of Barclay and the Municipality of Machin are the primary population centres in the basin. The 1988 population of the watershed was approximately 8,582.

3.0 Major Impacts on Water Quality

The sewage treatment at Dryden is the only operational plant within the watershed. Compliance with MOE criteria was 100% in 1987 and 1988. In the early 1970's a chlor-alkali plant associated with the Dryden pulp and paper mill was identified as the primary source of mercury pollution in the Wabigoon River. Extensive studies were undertaken to examine various mercury amelioration measures. No large-scale 'clean-up' of mercury contaminated sediments was undertaken and the majority of river system was left to naturally rehabilitate. The Canadian Pacific Forest Products pulp and paper mill in Dryden is currently the only industrial direct discharger within the basin. Effluent from this mill did not exceed MOE criteria in either 1987 or 1988.

Timber harvesting operations and clear-cutting systems in particular can also lead to water quality impairment. Increased peak flows leading to flooding and/or streambank erosion and increased sedimentation and nutrient enrichment of waterbodies are only a few of the effects that forestry activity may have on water quality. Surface runoff and erosion from agricultural lands may also lead to deteriorating water quality. Recent timber management operations have focused on areas in the vicinity of Clay Lake and the South Eagle River.

4.0 Present Water Quality

With the exception of the mercury contamination investigations, there have been no watershed-wide water quality studies completed for the Wabigoon River basin. Of the five operational MOE water quality monitoring station in the watershed only two were selected for use on this study. The location of the established MOE stations fail to represent water quality in the watershed as a whole or specific water quality in individual study sub-basins.

Based on water quality data from the period 1980 - 1990, mean total iron and copper concentrations are higher than the federal guidelines for protection of aquatic life at both stations. The mean total manganese concentrations at the Quibell station is above the guideline established for drinking water.

5.0 Evaluation of Available Water Quality and Flow Stations

Twenty-six of thirty-three MOE water quality parameters were consistently monitored at the provincial water quality monitoring stations selected for this study. Two federal stream flow stations were utilized to describe water flow within the basin. Federal stream flow stations should be established in conjunction with the recommended water quality stations.

6.0 Conclusions and Recommendations

The following locations are recommended for NRN water quality monitoring stations:

(1) The Lower Wabigoon sub-basin is recommended for monitoring the development/resource extraction issue. Seventy percent of this sub-basin's land area has been classed as production forest. Of this forest, over 40% falls within the two highest potential timber productivity classes. The station must be established off the Wabigoon River itself in order to avoid mercury contaminated sediments. An existing road network offers access for the establishment of water quality and stream flow monitoring stations.

(2) The Gullwing Lake sub-basin is the recommended location for monitoring of the agricultural eutrophication issue as it has the highest concentration of agricultural activity. This station also must be established off the Wabigoon River itself in order to avoid mercury contaminated sediments.

(3) Monitoring of baseline conditions in the Revell River sub-basin is recommended. Eighty-eight percent of the area within this sub-basin is classified as idle land and the full range of surficial deposits present within the Wabigoon watershed are represented here. Finally, no mercury contaminated sediments have been identified in this sub-basin.

1.0 Introduction

In 1989, the Ontario Region Water Quality Branch of Environment Canada embarked on a program to objectively develop a network of ecologically representative water quality monitoring stations. The network was developed using an "Ecological Land Survey" (ELS) classification scheme for terrestrial ecosystems, particularly with respect to its hierarchical approach towards site selection. This study details the information to be assessed at the second hierarchical level of spatial resolution - the major river basin level.

The study was undertaken for 2 reasons: 1) To provide a single reference document where the two main influences on water quality (ecological diversity and human activity) have been summarized; and, 2) To provide an objective information framework from which potential water quality monitoring sites can be selected to address specific water quality issues of federal interest.

The initial screening for large-scale river basins has been attempted using GIS based technology (Geomatics, 1990). This report details the information requirements of the second hierarchical level wherein large-scale river basins are to be represented by their component sub-basins. Reports on four river basins in southern Ontario have been completed utilizing this methodology (G.M. Wickware and Associates, 1990a,b,c,d). The present study will utilize similar methodology with the focus on eight river basins in northern Ontario. Potential sampling sites within the Wabigoon River basin as identified in this document will be field verified to determine the practical constraints on their potential for field data collection.

1.1 Resource Summary Description

1.1.1 Location

The centre of the Wabigoon River basin is located approximately 130 km east of the Ontario/Manitoba border and 345 km northwest of Thunder Bay in northwestern Ontario (Figure 1). The Wabigoon River drains into the English River, a secondary watershed of the Lake Winnipeg watershed. The greatest population concentration is within and surrounding the Town of Dryden. Vermilion Bay, to the west of Dryden, is also an important population centre. Forestry, mining and agriculture were the primary activities supporting the initial development of the area. Mining activity has since declined in importance; forestry is currently the main industry within the watershed. The Trans-Canada Highway and Canadian Pacific Railway line bisect the central portion of the basin while highways 105 and 502 offer access to the northern and southern portions of the watershed. An extensive network of forest access roads also exists within the basin. Figure 2 shows the major rivers and lakes that comprise the watershed.

1.1.2 Climate

The climate of the Wabigoon River basin is modified continental and is characterized by warm, short summers and long, cold winters (Ministry of Natural Resources [MNR], 1983). Portions of four ecoregions are represented within the Wabigoon River basin (Wickware and Rubec, 1989). Table 1 lists the ecoregions which occur in the watershed and the area (km^2) that each represents in the basin. Appendix A lists the area of each ecoregion on a square kilometre and percent basis. Ecoregion boundaries are shown in Figure 3.

Figure 1

Location of the Wabigoon River Basin

Figure 2
Major rivers and lakes of the Wabigoon River Watershed

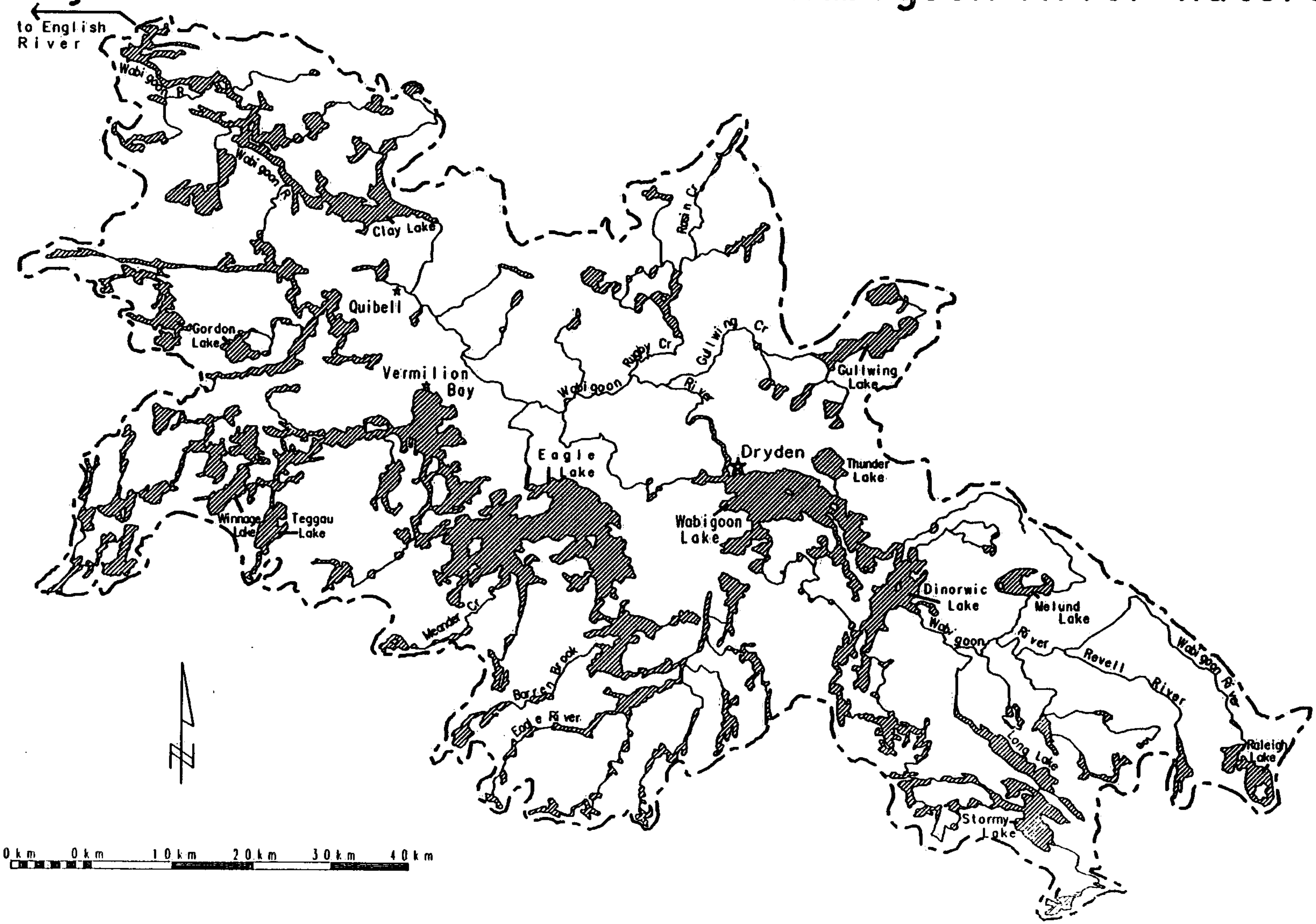


Figure 3
Ecoregions of the Wabigoon River Basin

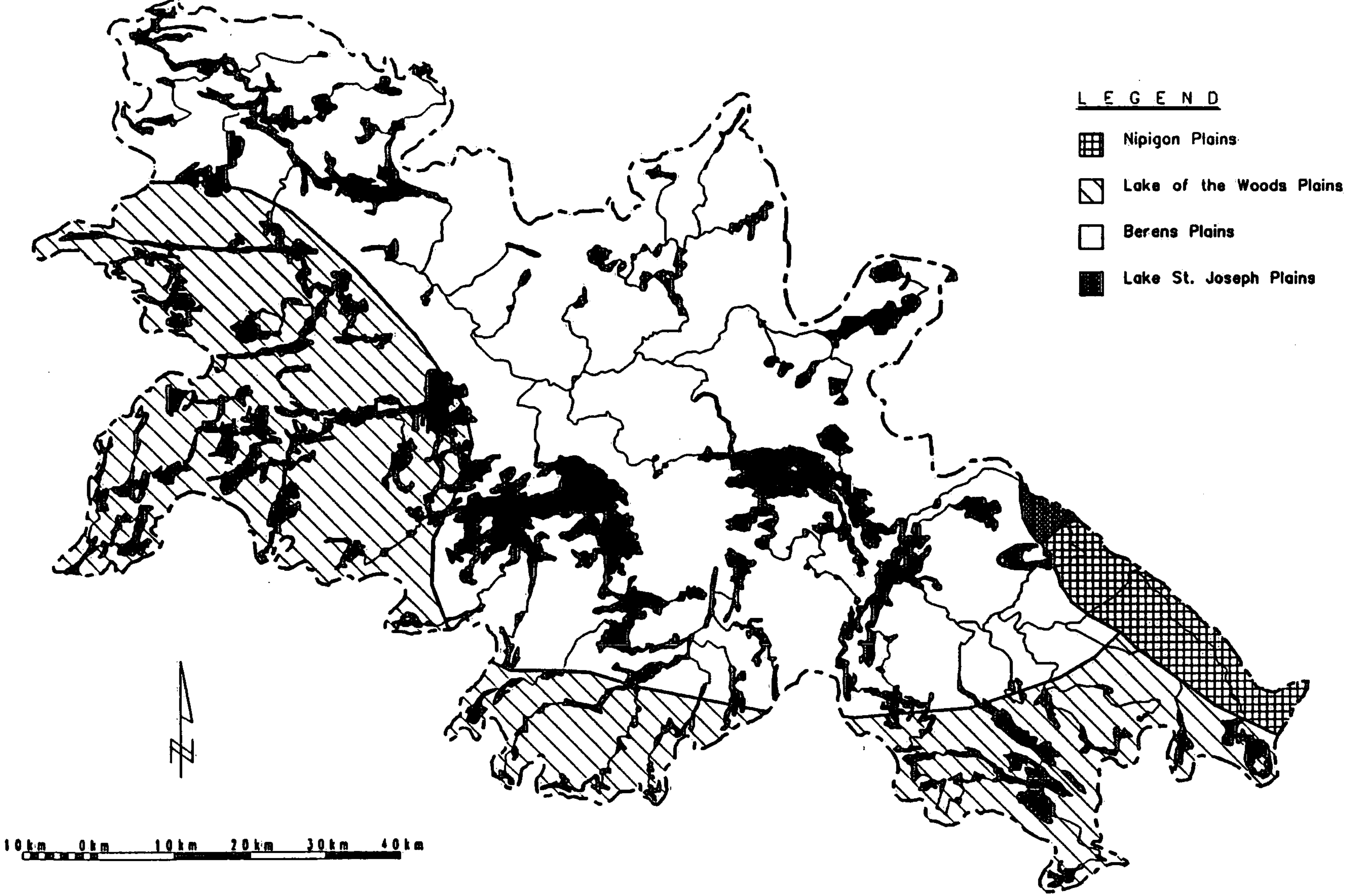


Table 1. Ecoregions of the Wabigoon River Basin

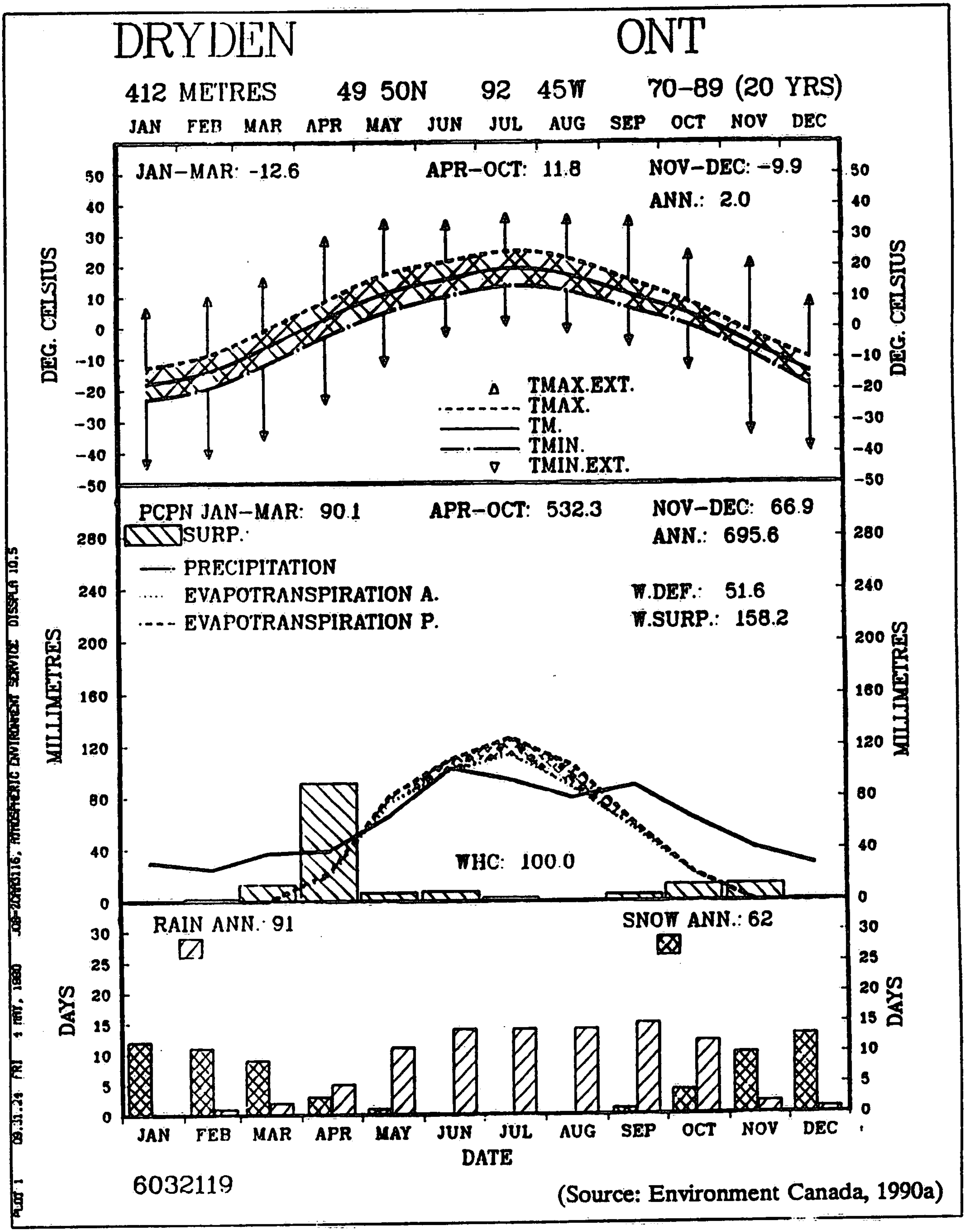
Ecoregion	Area (km^2)
Berens Plains	5195.7
Lake of the Woods Plains	2706.4
Nipigon Plains	257.4
Lake St. Joesph Plains	27.8

Mean annual daily temperatures range from 0.6° C in the eastern portion of the watershed to 1.6° C and 2.1° C to the northern and southern portions, respectively. Twenty years of climate data from Dryden, Ontario were compiled to produce bioclimatic profiles (Figures 4A,B) (Environment Canada, 1990a). Dryden, located just east of the centre of the watershed, experiences mean annual temperatures of 2.0° C. Highest and lowest mean monthly temperatures in Dryden occur in July (19° C) and January (-17° C), respectively (Figure 4A). Average annual precipitation at Dryden is 695.6 mm, most of which falls during the period from May to September. Agriculture within the watershed is supported by a relatively long growing season (162 days) which commences in mid-April (Figure 4B).

1.1.3 Hydrology

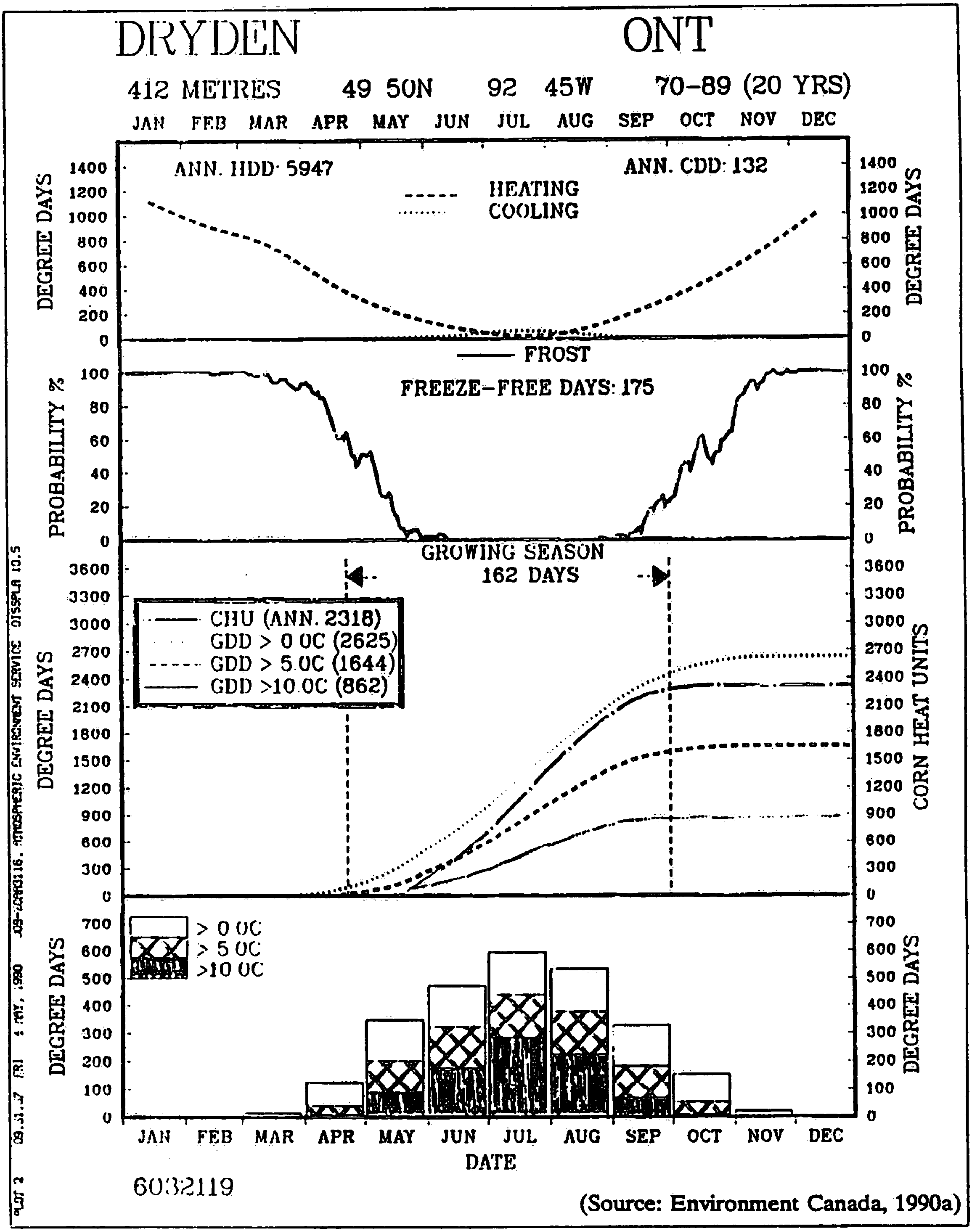
The Wabigoon River and its tributaries flow in a northwesterly direction and combine to drain a total area of 8187 km^2. The Wabigoon outlets into the English River system approximately 7 km northeast of the Grassy Narrows Indian Reserve. Lakes and rivers within the watershed cover roughly 19% of the total basin area.

Figure 4A. Temperature and Precipitation Profile for Dryden, Ontario



(Source: Environment Canada, 1990a)

Figure 4B. Degree Day and Heat Unit Profile for Dryden, Ontario



(Source: Environment Canada, 1990a)

Topography within the watershed ranges from rugged bedrock terrain of high relief to undulating lowlands with low relief. Wabigoon Lake, Dinorwic Lake and the eastern branch of the Wabigoon River occupy lowlands of varved clay with elevations in the order of 366 to 396 m (Roed, 1980b). Rolling and rocky rugged terrain lie in the southeastern and southwestern portions of the watershed. The highest elevations within the river basin are to the southwest in the vicinity of Porcus Lake (≈513 m).

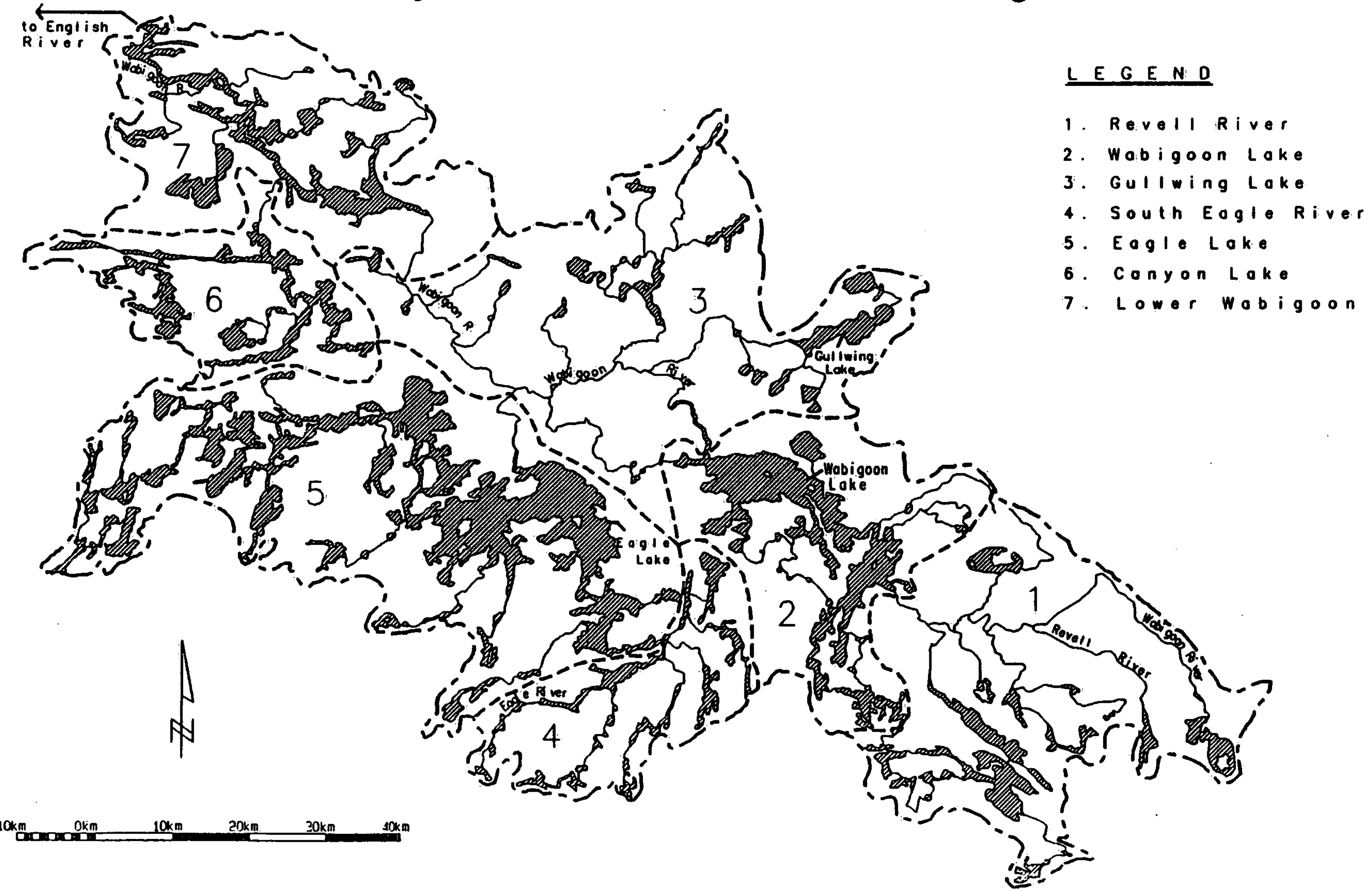
Major rivers and lakes within the basin are shown in Figure 2. The Wabigoon River and Canyon, Eagle, Wabigoon and Dinorwic lake complexes are the primary waterbodies within the watershed. The Revell and Gullwing rivers are important secondary tributaries.

As part of the evaluation of this watershed for the establishment of federal water quality monitoring stations, seven sub-basins were delineated within the Wabigoon River basin. Study sub-basin boundaries are shown in Figure 5 and their corresponding areas presented in Table 2 and Appendix B. Sub-basin boundaries were largely determined by natural drainage patterns, land use and size.

Table 2. Sub-basins used in the Wabigoon River Basin Study

Sub-basin	Drainage Area (km^2)
Revell River	1294.4
Wabigoon Lake	961.5
Gullwing Lake	1700.4
South Eagle River	578.3
Eagle Lake	1982.7
Canyon Lake	620.3
Lower Wabigoon	1049.8

Figure 5
Location of Study Sub-basins in the Wabigoon River Basin



1.1.4 Bedrock Geology

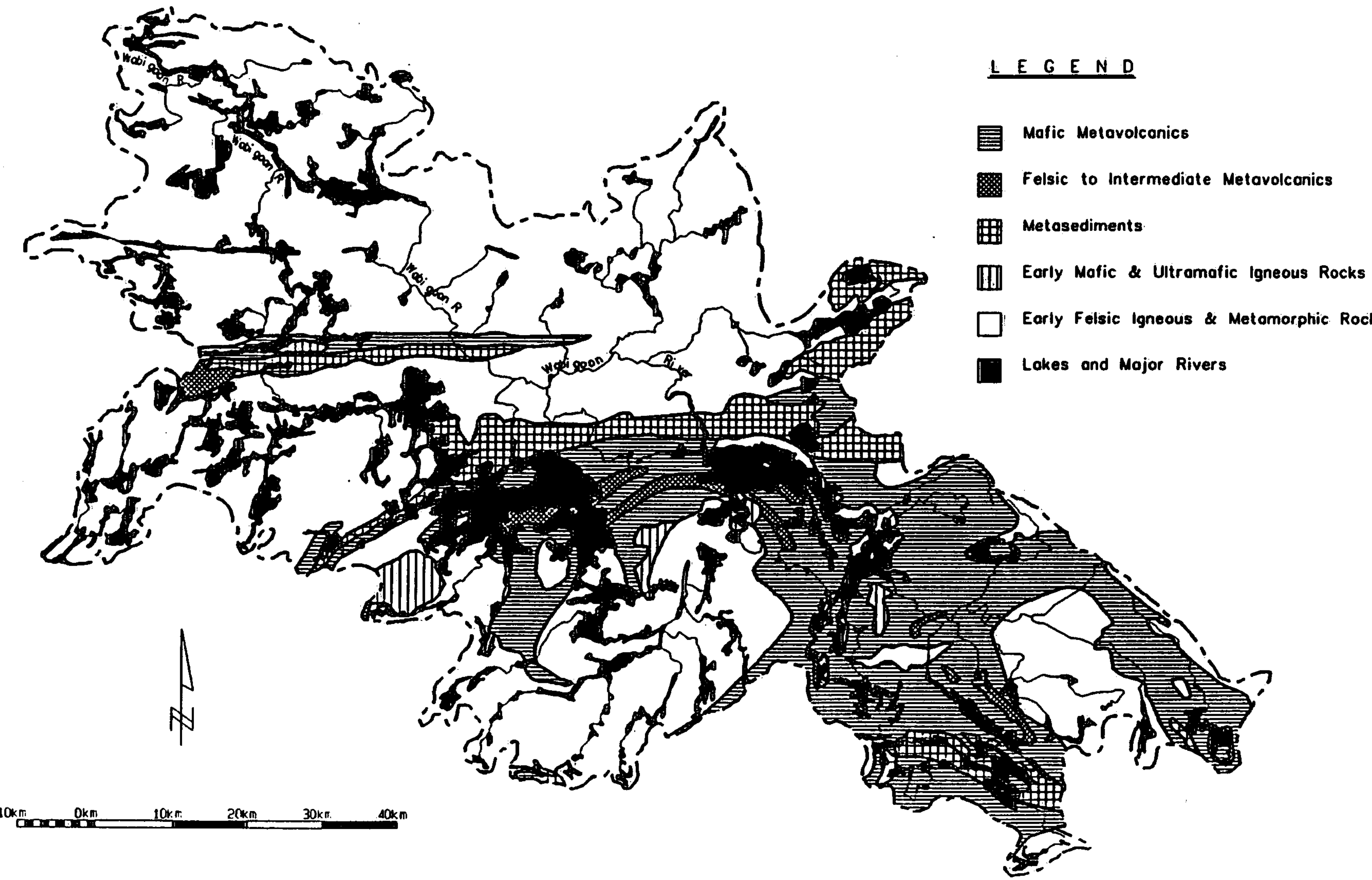
Bedrock knob terrain of the Early Precambrian age dominates the Wabigoon watershed (Figure 6) [Dept. Mines and N. Affairs, 1971]. Undifferentiated early felsic igneous and metamorphic rock cover 68% of the watershed; mafic metavolcanics and metasediments underlie 23% and 7% of the basin, respectively (Table 3). Appendix C lists the percent and square kilometres of each bedrock type. Mafic metavolcanic bedrock is found to the southeast of both Eagle and Wabigoon lakes and in a thin east-west strip to the north of Vermilion Bay. A large band of Early Precambrian metasediments run west from the watershed boundary across the northern edges of Wabigoon and Eagle Lakes. These metavolcanic-metasedimentary belts have medium to high potential for gold, silver and base metals (Roed, 1980a,b). The largest occurrence of early mafic and ultramafic igneous rock lies adjacent to the southwestern-most portion of Eagle Lake.

TABLE 3. BEDROCK GEOLOGY OF THE WABIGOON RIVER BASIN AND STUDY SUB-BASINS

LEGEND	REVELL RIVER	WABIGOON LAKE	GULLWING LAKE	SOUTH EAGLE RIVER	EAGLE LAKE	CANYON LAKE	LOWER WABIGOON	TOTAL BASIN
PRECAMBRIAN								
SUPERIOR AND SOUTHERN PROVINCES								
EARLY PRECAMBRIAN								
Early Felsic Igneous and Metamorphic Rocks	30.4	14.5	81.8	97.4	72.4	86.2	100.0	67.8
Early Mafic and Ultramafic Igneous Rocks	0.9	0.8	0.1	0.0	4.9	1.5	0.0	1.4
Metasediments	4.9	12.8	10.7	0.3	7.6	5.3	0.0	6.6
Felsic to Intermediate Metavolcanics	1.6	3.2	0.9	0.0	2.3	1.2	0.0	1.4
Mafic Metavolcanics	62.3	68.7	6.5	2.3	12.8	5.8	0.0	22.8

NOTE: ALL VALUES EXPRESSED AS PERCENT COVERAGE OF BASIN/SUB-BASIN AREA

Figure 6
Bedrock Geology of the Wabigoon River Basin



1.1.5 Surficial Geology

Virtually all of the surficial geology in the area is glacial in origin resulting, for the most part, from the southwesterly ice advances and inundation of glacial Lake Agassiz during the final stages of the Wisconsin glaciation (MNR, 1983). There are three dominant terrain types represented in the watershed (Figure 7). Rugged, highly dissected, wave-washed bedrock knobs dominate the southern and southwestern regions while relatively thick, flat-lying glaciolacustrine clay plains cover roughly 21% of the central and northern areas. The band of glaciofluvial material running northwest from Eagle Lake represents a raised beach of glaciofluvial origin. Organic deposits are generally scattered throughout the basin and smaller morainal deposits occur along the watershed boundaries. Alluvial deposits underlie portions of the Gullwing River and Wabigoon River upstream of Dinorwic Lake. Figure 7 is a simplified surficial geology map derived from Northern Ontario Engineering Geology Terrain Study base maps of the area (Roed, 1980a,b,c,d; Neilson, 1989; Mollard, 1980a,b; Gorman, 1989). Table 4 lists the percentage of each landform present within the Wabigoon River watershed. Square kilometre values are shown in Appendix D.

1.1.6 Land Use Characteristics

The Wabigoon River watershed includes all or parts of 36 townships (25 surveyed and 11 unsurveyed townships), the Town of Dryden, the Corporation of the Township of Barclay, the Corporation of the Municipality of Machin, two Indian Reserves (Eagle Lake and Wabigoon), and unsurveyed lands, all within the District of Kenora. Over 50% of the

Figure 7
Surficial Geology of the Wabigoon River Basin

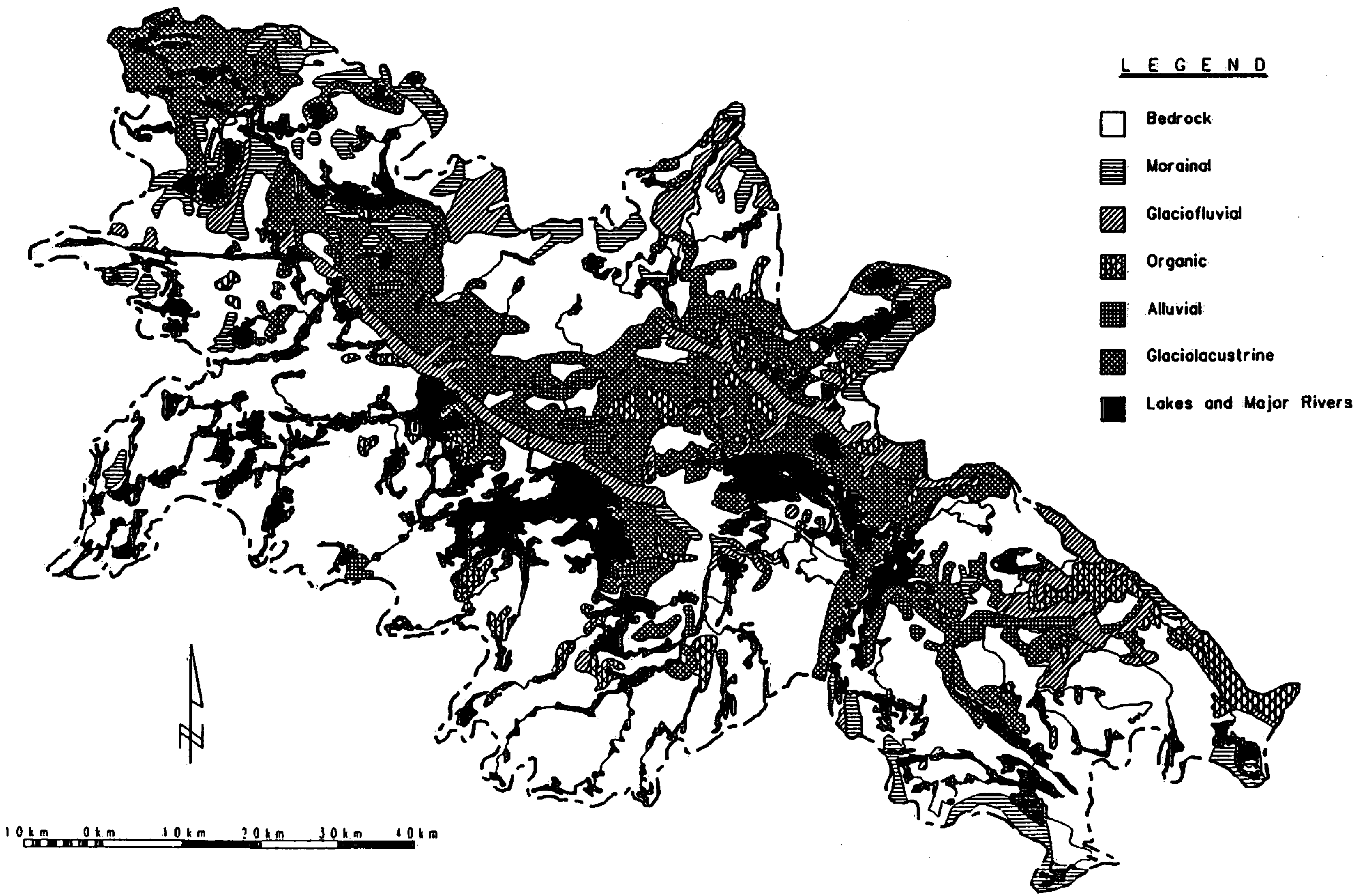


TABLE 4. SURFICIAL LANDFORM COVERAGE FOR THE WABIGOON RIVER BASIN AND STUDY SUB-BASINS

	BEDROCK	MORAINAL	GLACIO-FLUVIAL	GLACIO-LACUSTRINE	ALLUVIAL	ORGANIC
WABIGOON RIVER BASIN	60.50	5.73	7.19	20.55	1.90	4.14
SUB-BASINS						
REVELL RIVER	61.29	4.31	10.42	9.52	4.22	10.25
WABIGOON LAKE	53.69	2.41	7.80	32.85	0.05	3.20
GULLWING LAKE	40.31	7.73	9.38	35.82	3.62	3.14
SOUTH EAGLE RIVER	89.87	0.44	1.39	2.06	1.39	4.86
EAGLE LAKE	81.37	0.57	4.51	9.01	1.08	3.45
CANYON LAKE	75.84	6.00	6.34	8.76	0.23	2.84
LOWER WABIGOON	37.95	18.32	7.09	36.48	0.17	0.00

NOTE: ALL VALUES EXPRESSED AS PERCENT COVERAGE OF BASIN/SUB-BASIN AREA

watershed consists of unsurveyed lands. Dryden is by far the largest community in the area with a 1988 population of 6,219. The Township of Barclay, located immediately to the east of Dryden, has a population of 1,293; 1,070 people reside within the Municipality of Machin, which contains the community of Vermilion Bay. The forest, agriculture, mining and tourism industries provide the economic base for these communities.

Forest Resources Inventory Classification

The Forest Resources Inventory (FRI) is prepared by MNR staff in co-operation with forest companies on a 20-year cycle. The FRI includes maps, aerial photographs and a computerized data base which provides a picture of the nature and condition of the forests of Ontario as well as identifying areas of developed agricultural land (MNR, 1986).

Information is compiled on a forest stand basis and summarized at a variety of levels (township/basemap, 'working circle', management unit, province). In large, less populated areas in northern Ontario, the FRI is one of the few means of determining general land use. Where fairly intensive agriculture is occurring, more specific information on the proportion and type of crop may be available through Agricultural Land Use Systems Classification prepared by the Ministry of Agriculture and Food (OMAF). Agricultural activity within the basin is primarily located along the Trans Canada highway and around the community of Quibell.

For the purposes of this study, FRI township/basemap summaries were obtained for the watershed. Table 5 shows the percent of each FRI category within the White River basin and study sub-basins. Corresponding square kilometre values are shown in Appendix E. Crown land within a township is classified as 'non-forested', 'non-productive forested land' or 'productive forested land'. The four broad FRI groups are briefly defined below (MNR, 1987).

Non-forested land consists of developed agricultural land, grass and meadowlands and unclassified lands (towns, villages, roads, etc.).

Non-productive forested land can be described as land incapable of growing trees for commercial purposes because of very low productivity, and includes areas of muskeg, brush and alder, and barren rock.

Productive forested land is described as forest lands which are capable of growing trees for commercial purposes and is sub-divided into two categories: protection forest and production forest.

Protection forest includes forested lands on which timber management activities cannot normally be practised without incurring deleterious environmental effects, because of obvious physical limitations such as steep slopes and shallow soils over bedrock.

Production forest can be described as productive forest lands at various stages of growth, with no obvious physical limitations on the ability to practice timber management.

TABLE 5. FOREST RESOURCES INVENTORY CLASSIFICATION FOR THE WABIGOON RIVER BASIN AND STUDY SUB-BASINS

	NON-FORESTED		NON-PRODUCTIVE				PRODUCTIVE	
	DAL	TOTAL	TREED	OPEN MUSKEG	ROCK	TOTAL	PRODUCTION	PROTECTION
WABIGOON RIVER BASIN	1.2	2.6	2.2	2.6	1.4	9.0	68.1	2.3
SUB-BASINS								
REVELL RIVER	0.2	1.2	3.8	2.8	0.1	9.6	72.5	3.3
WABIGOON LAKE	1.4	4.1	1.1	4.3	0.2	7.7	65.7	1.0
GULLWING LAKE	4.3	6.9	2.9	2.0	0.5	9.1	72.7	0.7
SOUTH EAGLE RIVER	0.0	0.2	2.3	3.4	0.3	7.6	70.6	2.2
EAGLE LAKE	0.5	1.3	1.8	2.1	1.7	7.5	64.4	1.6
CANYON LAKE	0.1	1.3	1.3	2.0	8.0	12.6	55.9	8.8
LOWER WABIGOON	0.2	0.8	1.3	2.4	1.7	11.0	70.2	2.4

NOTE: ALL VALUES EXPRESSED AS A PERCENT OF SUB-BASIN AREA
DAL - DEVELOPED AGRICULTURAL LAND

SOURCE: MNR, 1990

1.1.7 Mining

The mining of gold, silver and clay was one of the primary factors leading to early development in the Dryden area. Gold was first discovered in the Dryden area in the 1890's and by 1895, a number of mines had developed in the Eagle Lake area and Van Horne Township (MNR, 1983). By 1912, however, all mining activity in the area had ceased as more prosperous gold fields were developed elsewhere.

There are currently no active metallic mining operations within the Wabigoon watershed.

International market demand, however, can turn an inactive mine into an active one within the space of weeks or months. Exploration for other precious and base metallic minerals continues within the region and the intensity of exploration is also driven by international economic conditions. Numerous metallic mineral prospects and occurrences have been recorded within a wide band running roughly through the centre of the watershed and to the north of Wabigoon and Eagle lakes (Figure 8) (MNR, 1985). Mineral types for prospects and occurrences within the Wabigoon River basin are listed in Table 6. Four gold mines which were productive in the past are located as follows: between Mennin and Long Rivers (1); the southwest corner of Wabigoon Lake (2); the southwest corner of Eagle Lake (1). Although these mines are no longer active environmental concerns still exist. Large quantities of waste rock and tailings are produced as a result of the mining and refining process. Leachate of high acidity containing a variety of metals can migrate from tailing ponds and abandoned mines, resulting in contamination of both ground and surface waters.

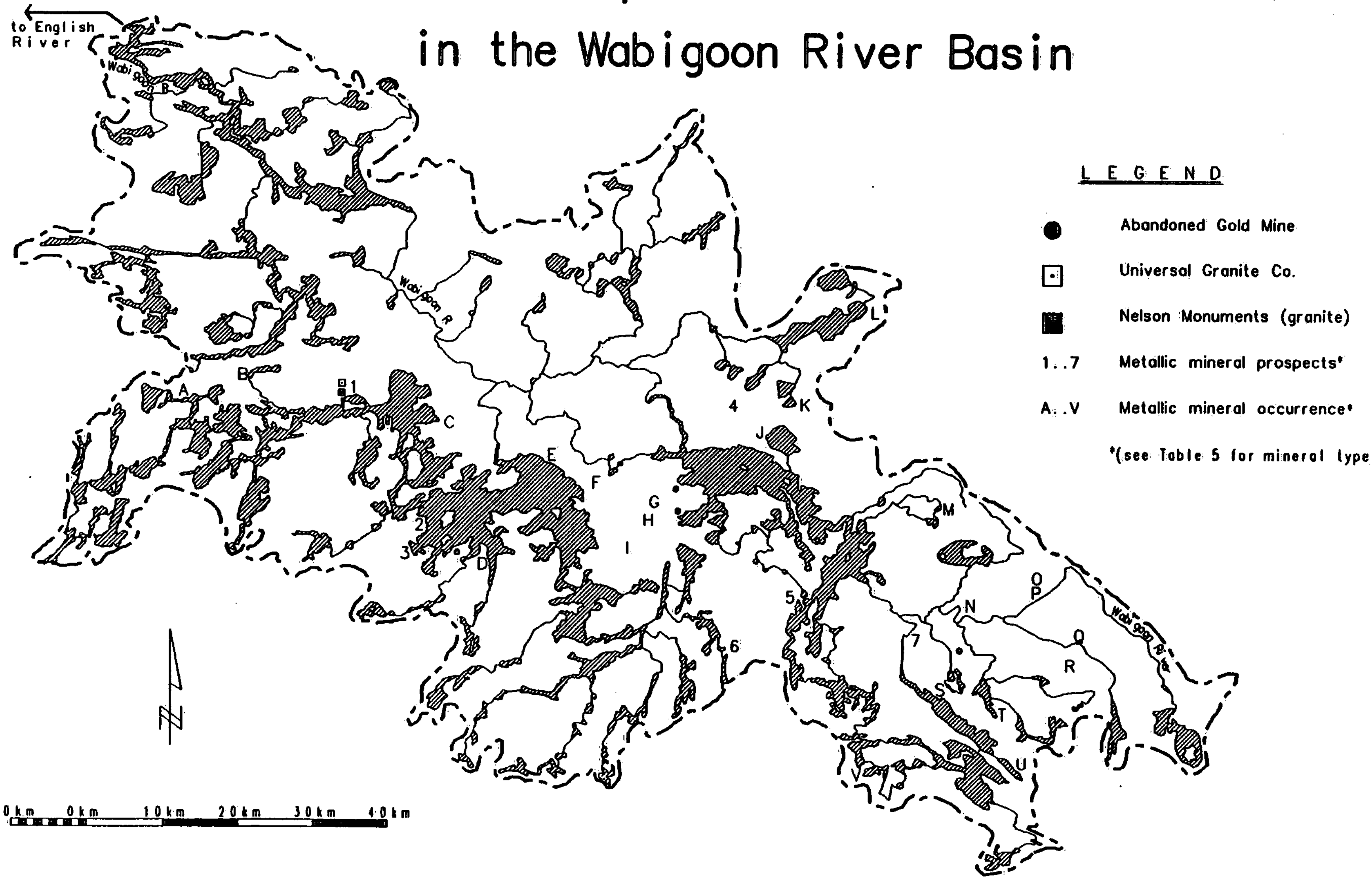
TABLE 6. MINERAL FOR PROSPECTS AND OCCURRENCES IN THE WABIGOON RIVER BASIN (LOCATIONS SHOWN IN FIGURE 8)

PROSPECTS	MINERAL	OCCURRENCES			
1. M. JENSEN	GOLD	A.	URANIUM	L.	CESIUM, LITHIUM
2. GRACE MINING CO.	GOLD, TALC	B.	URANIUM	M.	GOLD
3. ELDORADO MINING CO.	GOLD	C.	URANIUM	N.	GOLD
4. MAVIS LAKE PROSPECT	NICKEL	D.	GOLD	O.	GOLD
5. VAN HOUTEN GOLD SYNDICATE	GOLD, COPPER, MOLYBDENUM	E.	GOLD	P.	GOLD
6. EMMONS LAKE PROJECT	COPPER, NICKEL	F.	GOLD	Q.	GOLD
7. TAYLOR LAKE GOLD MINES LTD.	GOLD	G.	GOLD	R.	GOLD
		H.	GOLD	S.	LEAD, ZINC, SILVER
		I.	COPPER, NICKEL	T.	GOLD
		J.	IRON	U.	GOLD
		K.	LITHIUM	V.	GOLD

AFTER MNR, 1985

Figure 8

Location of Mineral Prospects, Occurrences and Mines in the Wabigoon River Basin



Non-metallic minerals are quarried at numerous locations within the watershed. Quarrying of granite for monument stone occurs at two locations just west of Vermilion Bay (Figure 8). Extensive mineral aggregate supplies exist within the area (MNR, 1983).

1.1.8 Agriculture

The potential for agriculture in the Dryden area was first recognized in 1894 with the establishment of an experimental clover farm (MNR, 1983). Farming has continued in the area since that time, with the greatest concentration now occurring north and south of Highway 17 between Dryden and Vermilion Bay. The agricultural products produced range from mutton, beef and pork to dairy products and clover seed (MNR, 1983). Agricultural land use is primarily devoted to grain, hay and pasture systems and ranges from 3% to 8% on a township basis (OMAF, 1986).

Tables 7 and 8 briefly summarize agricultural activity and fertilization rates at the District level. Statistics for the Dryden area are based on the Territorial District of Kenora. These statistics are considered directly applicable to the Dryden area due to the known agricultural inactivity in the Territorial District of Kenora with the exception of the area around Dryden (MNR, 1983). The area of improved agricultural land within Kenora district declined by 10% in both the 1976-1981 and 1981-1986 period (Statistics Canada, 1986).

Fertilizer use in this area is significantly lower than in other agricultural areas of Ontario. The district of Kenora, with a total application rate of 90.1 kg/fertilized hectare, had the fourth lowest ranking in a survey of provincial application rates (Environment Canada, 1990b). In comparison, average application rates of 281 kg/ha are common in the Saugeen River basin, an area of less intensive farming in southern Ontario.

TABLE 7. SUMMARY OF AGRICULTURAL ACTIVITY IN THE DISTRICT OF KENORA IN 1988

DISTRICT	IMPROVED LAND	OATS	BARLEY	MIXED GRAIN	HAY	CATTLE	SHEEP/ LAMBS	CHICKENS
	(ha)	(kg/ha)				(number/ha)		
KENORA	7,442	40.3	94.1	40.3	2822	0.36	0.22	0.53

Source: OMAF, 1989a

TABLE 8. AMOUNT OF FERTILIZER APPLIED IN THE DISTRICT OF KENORA IN 1985

DISTRICT	IMPROVED LAND (ha)	TOTAL APPLIED	N APPLIED	P APPLIED	K APPLIED	APPLICATION RATE (kg/ha)
		(tonnes)				
KENORA	7,742	481	101	59	88	62.1

Source: OMAF, 1989; Fertilizer Institute of Ontario, 1989

Deterioration of water quality can stem from many agricultural activities. Although the majority of farming in the Wabigoon basin is focused on the less erosive grasses and grain crops, the contribution of suspended solids and sediments from agricultural lands is of concern. Overland erosion from cropland can carry soil, fertilizers and pesticides into adjacent streams leading to increased phosphorous and nitrogen loadings. Water quality impairment due to elevated fecal coliform densities can arise from free cattle access to waterways. Finally, the removal of forest cover and undesirable vegetation typically results in more rapid runoff, increased peak flows and increased soil and streambank erosion (G.M. Wickware and Associates, 1990a).

1.1.9 Forestry

The watershed covers portions of three forest sections, two in the Boreal Forest Region (Upper and Lower English River Sections) and one in the Great Lakes-St. Lawrence Forest Region (Quetico Section) [Rowe, 1972]. The Quetico Section extends southward from a line running roughly from Vermilion Bay to the south end of Dinorwic Lake; the Boreal forest sections lie to the north of this line. Large areas within the Quetico section are dominated by white and red pine although harvesting and fires have allowed boreal species to increase in prominence. Pure or mixed stands of jack pine, poplar, white birch, balsam fir and white and black spruce are frequent in this section. The boundary of the Upper English River Section extends slightly westward into the Wabigoon basin and follows closely the eastern boundary of the watershed. The majority of the forest consists of black spruce and jack pine with mixtures of white spruce, balsam fir, trembling aspen and white birch. Extensive stands of jack pine occur on the dry sand plains while black spruce dominate lowland areas. Species within the Lower English River are similar to those in the Upper section but here poplar and white spruce form the chief dominant forest cover (Rowe, 1972).

The first logging in the Dryden area took place following the 1882 arrival of the Canadian Pacific Railway. In order to support the agricultural development of the area a number of sawmills were established to supply the settlers with building materials. The first pulp and paper company was established in 1911 and has changed hands numerous times (MNR, 1983). Canadian Pacific Forest Products currently operates a bleach kraft pulp and specialty papers mill and studmill in Dryden. A total of nine other smaller, independent sawmills are in operation within the watershed (MNR, 1989).

Approximately 40% of the land within the Wabigoon watershed lies in Canadian Pacific Forest Products' Forest Management Unit (FMU). The Boise Cascade Canada Ltd. FMU covers roughly 20% of the northwestern portion of the watershed and supplies material to Boise Cascade's pulp and paper mill and sawmill in Kenora. The remainder of the watershed falls within the Dryden Crown FMU. The bulk of the sawlogs and fibre from the Great Lakes and Crown FMU's are destined for Dryden's mills.

Extensive networks of tertiary roads have been developed throughout most of the watershed in order to access timber resources. Recent timber management activities, as evidenced by the construction of new forest access roads, have focused on areas in the vicinity of Clay Lake and the South Eagle River.

Although the location of sawmills and pulp and paper mills are generally fixed, the areas of logging and regeneration activity tend to shift over time. An area may be treated to aid or improve regeneration following logging and then not be considered for harvesting for forty to sixty years. Ideally, forest management practices will allow for 1/40 or 1/60 of the productive forest to be cut annually thus creating cyclic harvesting of areas within a given boundary. Losses of productive forests due to insects, fire, regeneration failure, and withdrawals of land for other purposes, in combination with economic considerations, further influence harvesting cycles. The Dryden area has experienced particularly high fire losses over the past decade (MNR, 1983).

Numerous studies have shown that effluent from pulp and paper mills may degrade water quality. Effluent from these mills can contain high levels of suspended solids and chemicals from pulping and bleaching liquors. Forest management related activities may also have deleterious effects on water quality. Large clear-cut areas can result in: increased peak flows leading to flooding and/or streambank erosion; increased overland soil erosion and sedimentation of streams; higher nutrient loading from soilbound particles and logging debris; and leaching of soil nutrients into groundwater. Forest regeneration, maintenance and protection can require the aerial spraying of pesticides which may enter watercourses. Access roads used by both forest companies and the public can also result in increased sedimentation and require the regulation of streamflow.

In order to determine the long term effects of timber harvesting on water quality an approach that considers the frequency of cutting is required. Forest productivity is primarily a result of soil nutrients, drainage and local climate. Stands growing on more productive sites will reach 'economic' maturity sooner and be harvested more frequently than stands on less productive areas. Timber Use Capability maps produced by the Ontario Land

Inventory present information of this nature based on land capability. Theoretically, those areas indicated as having the highest potential timber productivity will be logged most often. Figure 9 shows potential timber productivity within the White River basin; Table 9 shows the proportion of each productivity class within study sub-basins. See Appendix F for square kilometre values of potential timber productivity classes by sub-basin.

TABLE 9. POTENTIAL TIMBER PRODUCTIVITY WITHIN THE WABIGOON RIVER BASIN AND STUDY SUB-BASINS

	POTENTIAL TIMBER PRODUCTIVITY (M^3/HA/YEAR)			
	3.6 - 4.9	2.2 - 3.5	0.8 - 2.1	LESS THAN 0.8
WABIGOON RIVER BASIN	4.90	14.48	54.74	25.88
SUB-BASINS				
REVELL RIVER	0.00	11.51	55.00	33.49
WABIGOON LAKE	6.36	9.50	72.32	11.81
GULLWING LAKE	6.38	24.40	49.78	19.45
SOUTH EAGLE RIVER	0.00	6.79	93.21	0.00
EAGLE LAKE	0.13	13.45	55.74	30.69
CANYON LAKE	0.00	1.88	22.13	75.99
LOWER WABIGOON	21.08	19.69	43.32	15.91

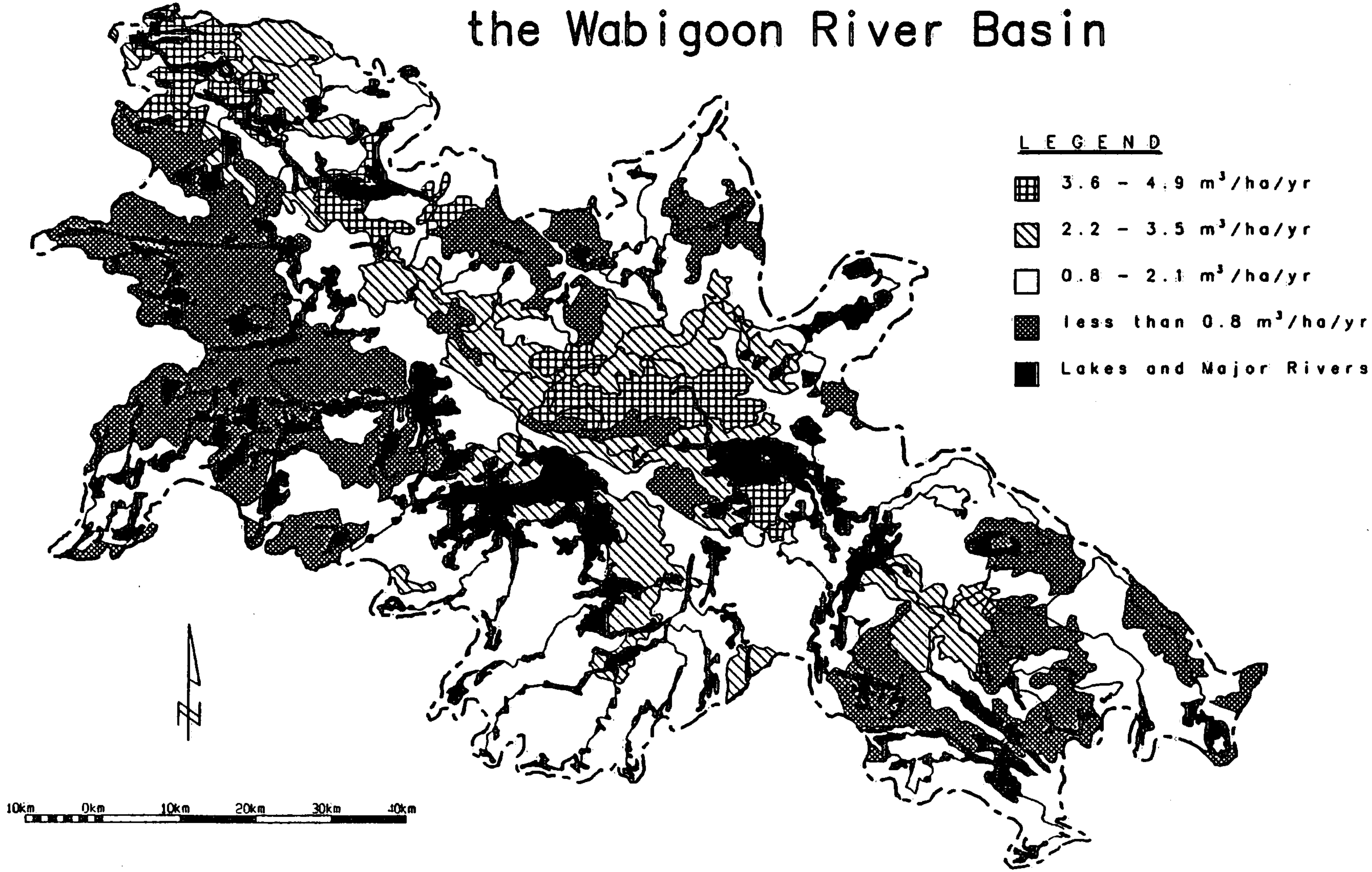
NOTE: ALL VALUES EXPRESSED AS PERCENT OF BASIN/SUB-BASIN AREA

1.1.10 Tourism

The tourist industry in the Dryden area is largely based on fishing and hunting resources. Sport fishing generates the greater proportion of the income, with non-residents (Americans from Wisconsin, Illinois, Indiana, Iowa, Minnesota and Ohio) taking approximately 81% of the total sport fish catch (MNR, 1983). In 1980, non-resident demand for sport fish was

Figure 9

Potential Timber Productivity within the Wabigoon River Basin



projected to increase by 25% to 616,000 kg/year by the year 2000 (MNR, 1983). Moose hunting is also very popular in this area. To this end, an emphasis has been placed on increasing the moose population and thus moose harvest levels (MNR, 1983). Fishing and hunting lodges in the area are increasingly concerned with sport fish and moose population levels, the environmental effects of timber harvesting, and the construction of roads allowing access to once 'remote' areas.

In addition to the hunting and fishing, provincial parks also contribute to the tourism industry. Two recreation class parks are established in the watershed; Blue Lake to the northwest of Vermilion Bay, and Aaron 10 km east of Dryden on Thunder Lake. Two more areas have been recommended for park status. The first area, Butler Lake, is a 3,300 ha parcel of land on the south shore of Lake Wabigoon to be set aside as a nature reserve. The second area is Winnange Lake which is slated to become a Natural Environment park. This 4,450 ha area lies in the East Stewart Lake, Winnange Lake and Crabclaw Lake area, roughly 15 km west of Vermilion Bay.

In 1983 there were an estimated 800 cottages in MNR's Dryden district. Roughly 34% of these cottages were located on Eagle Lake, Thunder Lake and Wabigoon Lake while 18% were located on the interconnecting lakes of Blue, Alexandra, Edward and Canyon. The remaining cottages are scattered throughout the region and concentrated along major access roads (MNR, 1983).

Large concentrations of cottages, campgrounds and outpost camps may lead to deteriorating water quality. Wastewaters from these operations may enter lakes and rivers directly via either a lack of septic systems or improper septic system hookups. Although MOE personnel are aware that these situations may occur, no specific areas of concern have been identified within the watershed (Hollinger, Pers. Comm.).

1.1.11 Municipal and Industrial Discharges

Municipal

The Town of Dryden sewage treatment plant is the only operational plant within the Wabigoon watershed (MOE, 1988a, 1989a). Municipal sewage undergoes contact stabilization prior to discharge to the Wabigoon River. Compliance with MOE criteria was 100% in both 1987 and 1988.

Industrial

The Canadian Pacific Forest Products mill in Dryden is the only direct discharger of industrial wastes in the Wabigoon River basin, as identified by the MOE (MOE, 1988b, 1989b). "Total effluent is treated by treated by a clarifier prior to biological treatment (aeration lagoon), stabilization basin and a foam barrier" (MOE, 1989b). Effluent is sampled for BOD_5 and suspended solids. No exceedances were recorded in these parameters during 1987 and 1988. Three 1987 MOE trout bioassays were acutely lethal at concentrations from 4.6% to 71.9%. Company bioassays in 1987 indicated a reduction in effluent toxicity (MOE, 1988b). In 1988, 6 trout bioassays were carried out by the MOE and

11 by the Company. MOE LC_{50}'s ranged from 49% to 100%; Company LC_{50}'s ranged from 50% to 100% (MOE, 1989b).

1.1.12 Water Quantity

Three federal hydrometric stations were in operation within the Wabigoon River basin in 1986 (Figure 10). The stations are located as follows: Wabigoon River at Dryden [≈8 km downstream of Dryden]; Eagle River Station [≈3 km south of Hwy 17 on Eagle River]; and Wabigoon River near Quibell [≈22 km north of Vermilion Bay]. Stream flow recorded at the three stations represent drainage areas of 2300 km^2, 2510 km^2, and 6370 km^2, respectively (Environment Canada, 1990c). Flow rates at the Eagle River and Dryden stations are based on power plant ratings.

Average annual flow data (Figures 11A-C) at all three stations show similar patterns with high average annual flows occurring in 1982 and 1985. The particularly low flows recorded in 1987 correspond with the high incidence of forest fires in the region at that time. Average monthly flow data for the three stations are plotted in Figures 12A-C. Flow rates at all stations increase from March/April to maximum levels in June/July, decrease through to September, then rise again in October. These monthly flow patterns correspond well with the onset of spring thaw and the precipitation patterns recorded at the Dryden weather station (Figure 4A).

Figure 10
Wabigoon River Basin – federal flow and active MOE water quality monitoring stations

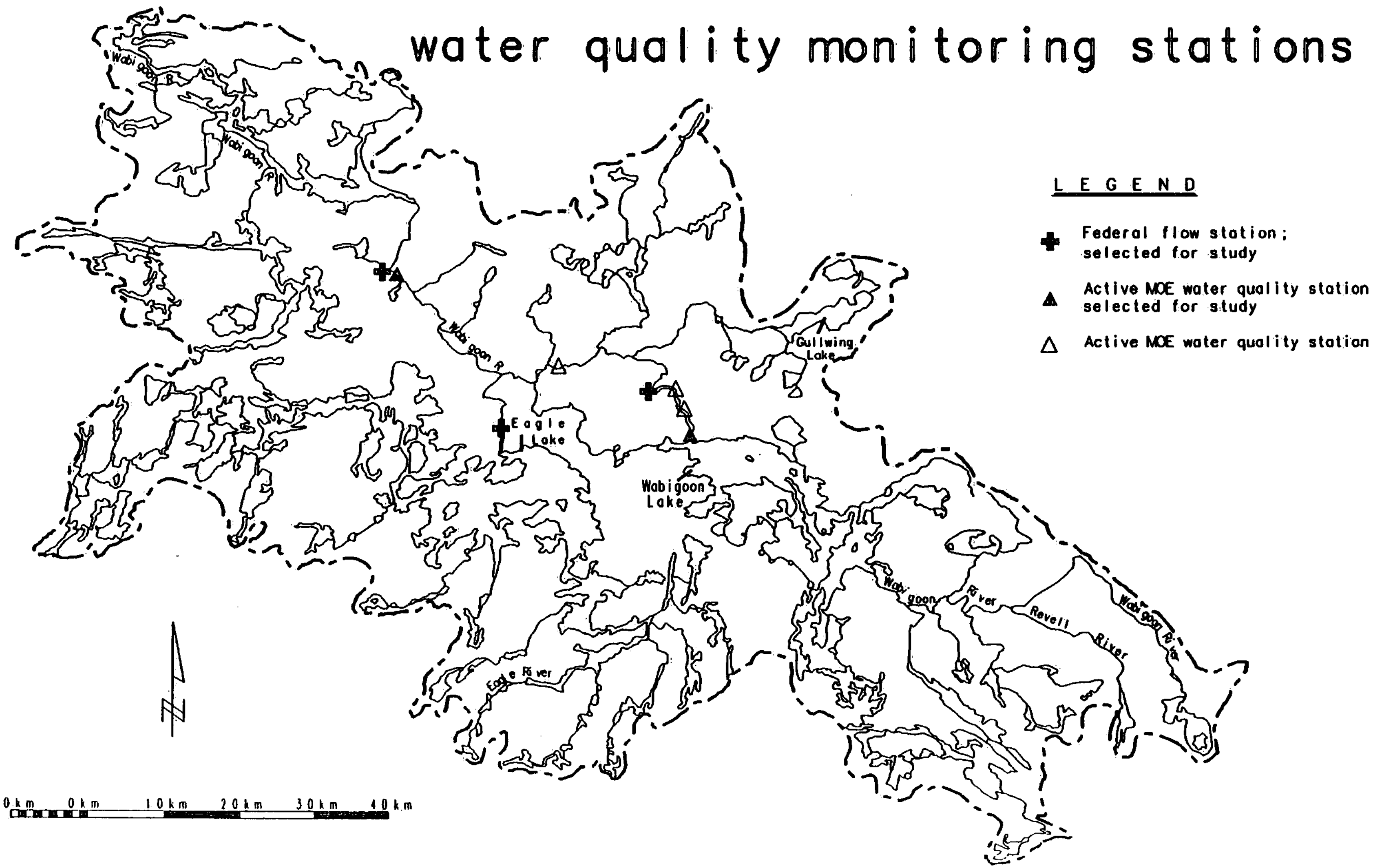
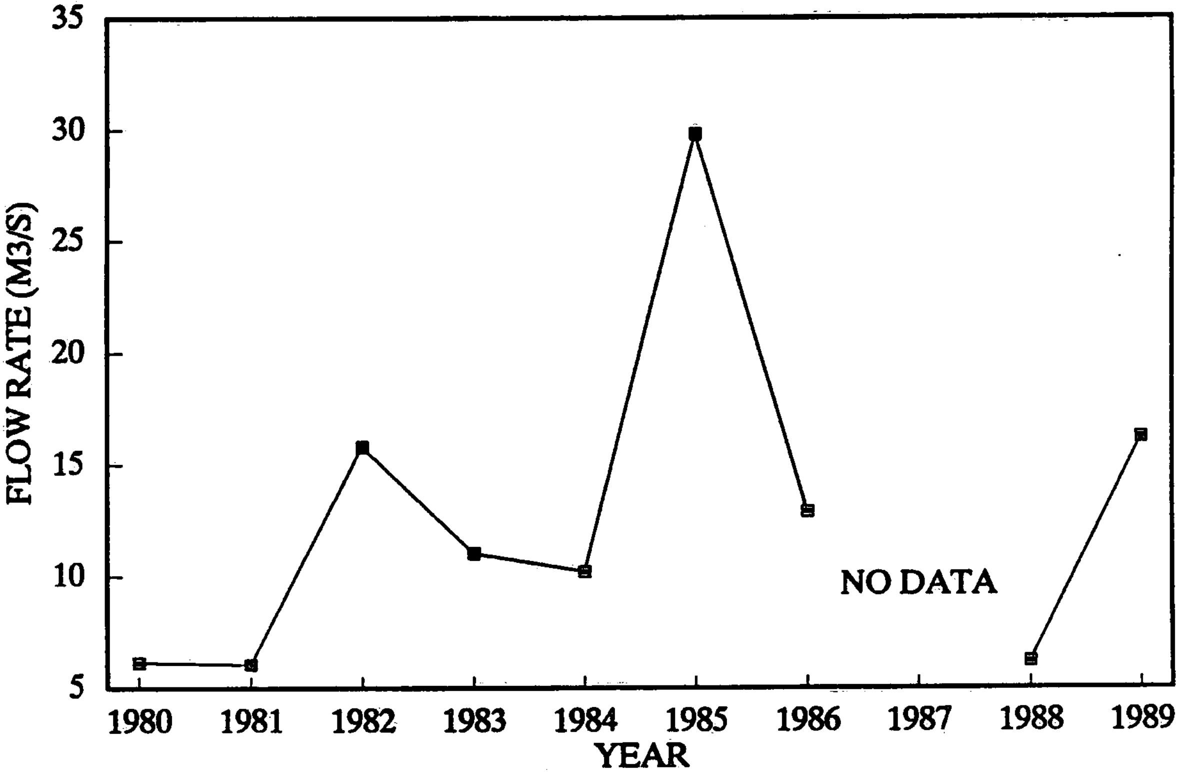
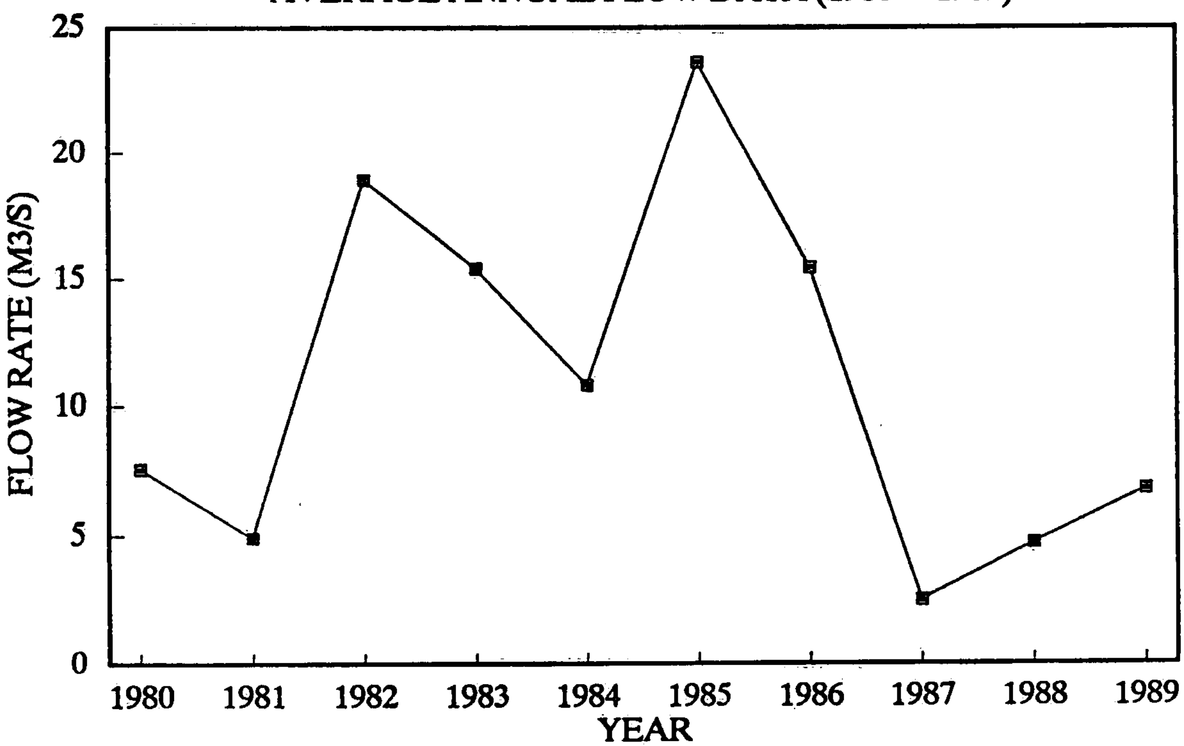


Figure 11A. WABIGOON RIVER AT DRYDEN
AVERAGE ANNUAL FLOW DATA (1980 – 1989)



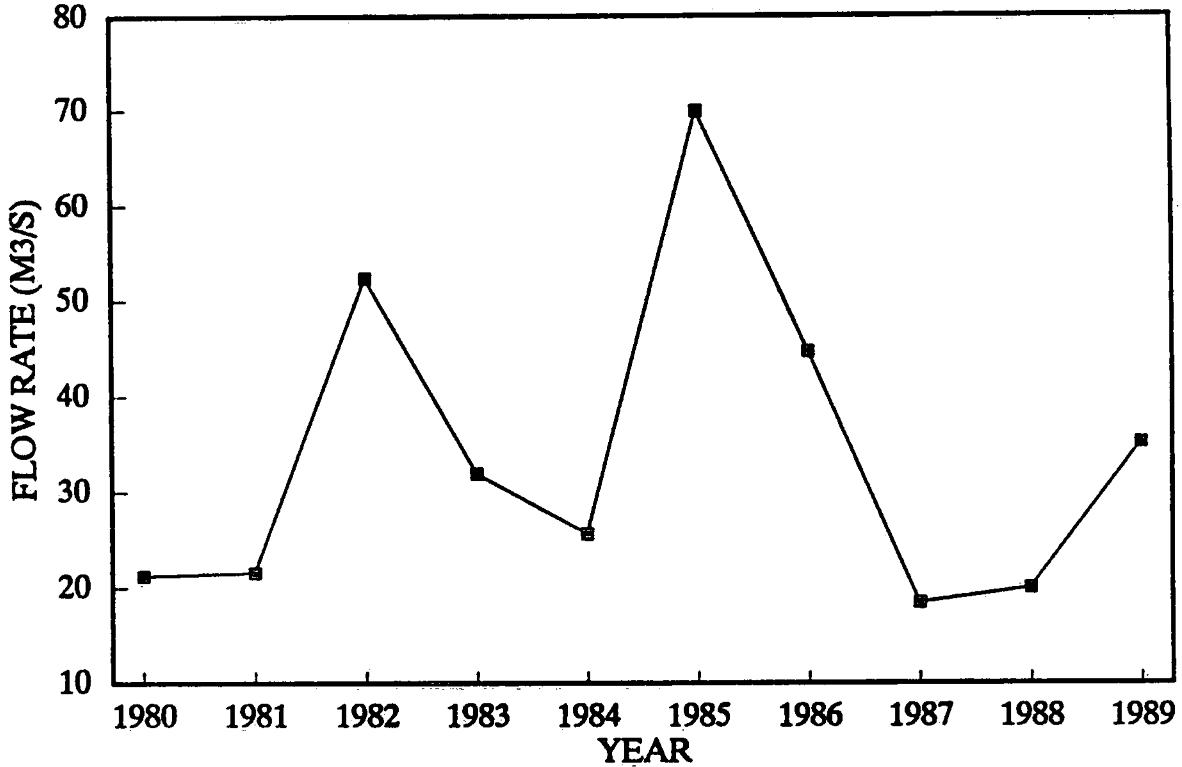
(Source: Environment Canada, 1990c)

Figure 11B. EAGLE RIVER STATION
AVERAGE ANNUAL FLOW DATA (1980 – 1989)



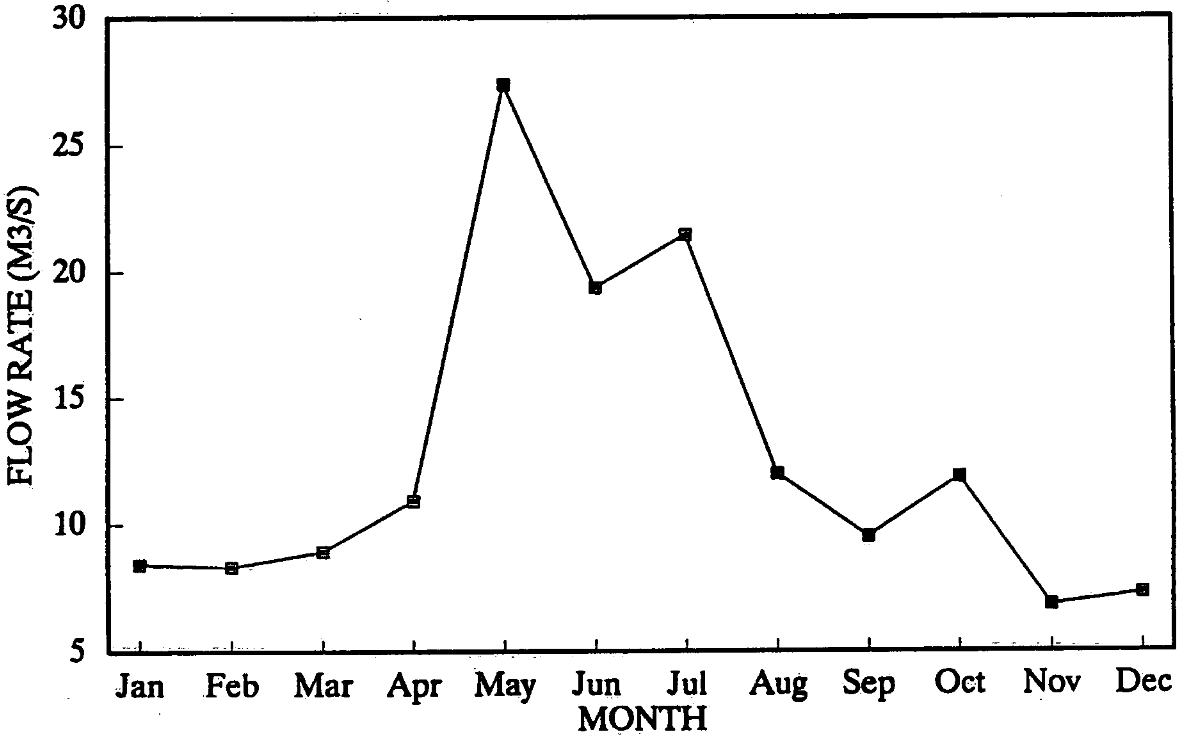
Note: data not available for May, Sept, Oct 1983; May – Oct 1984
(Source: Environment Canada, 1990c)

Figure 11C. WABIGOON RIVER NEAR QUIBELL
AVERAGE ANNUAL FLOW DATA (1980 – 1989)



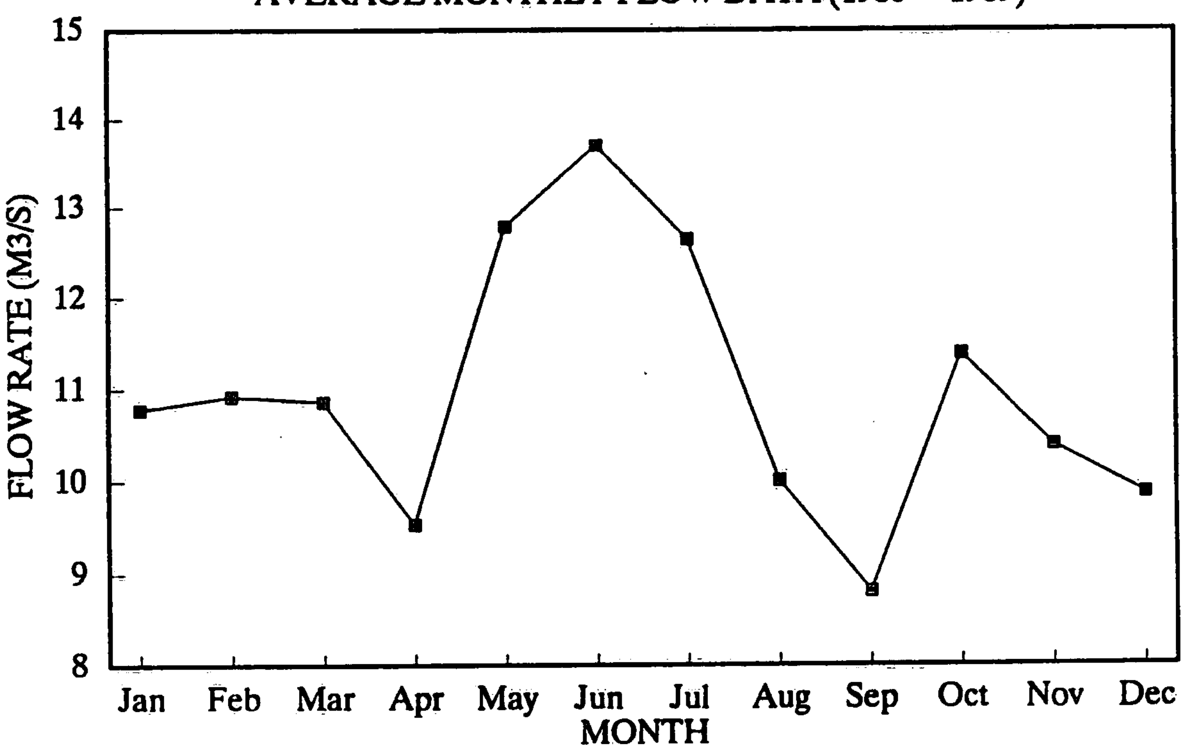
(Source: Environment Canada, 1990c)

Figure 12A. WABIGOON RIVER AT DRYDEN
AVERAGE MONTHLY FLOW DATA (1980 – 1989)



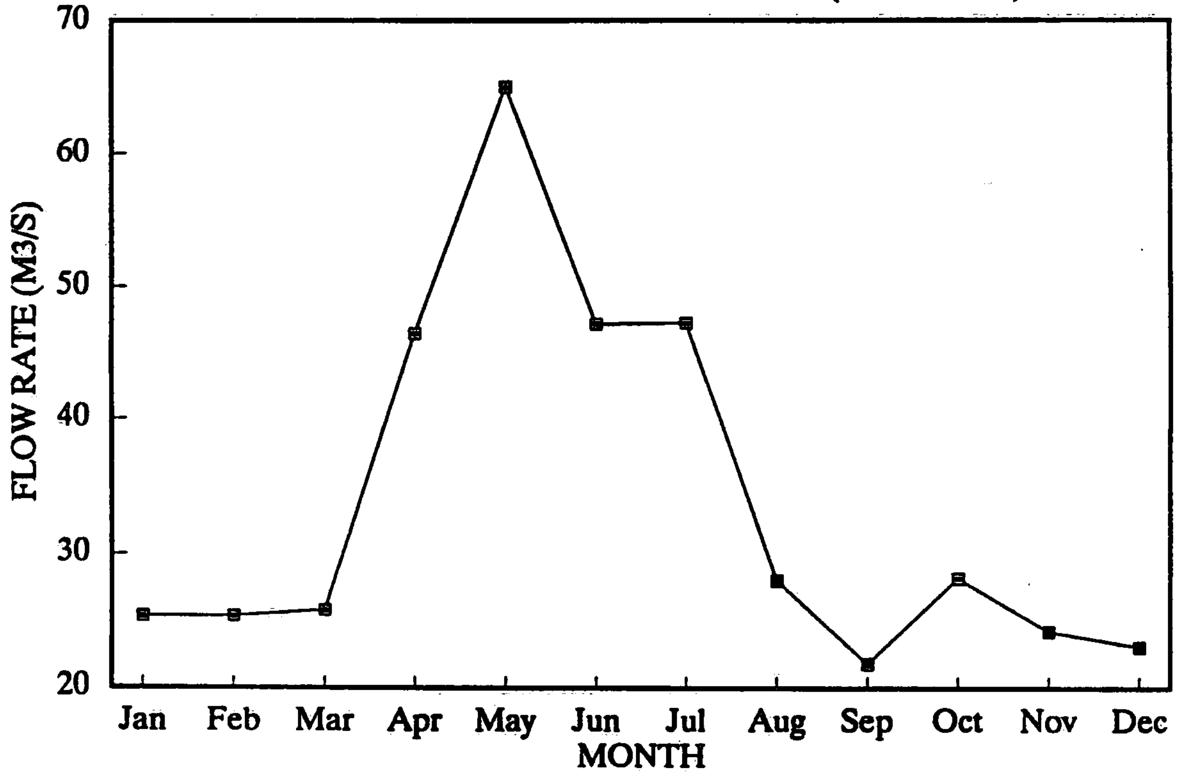
Note: data not available for 1987
(Source: Environment Canada, 1990c)

Figure 12B. EAGLE RIVER STATION
AVERAGE MONTHLY FLOW DATA (1980 – 1989)



Note: data not available for May, Sept, Oct 1983, May – Oct 1984
(Source: Environment Canada, 1990c)

Figure 12C. WABIGOON RIVER NEAR QUIBELL
AVERAGE MONTHLY FLOW DATA (1980 – 1989)



(Source: Environment Canada, 1990c)

1.1.13 Water Quality

Previous Studies

In the early 1970's the Wabigoon-English River system was considered one of the most severely mercury polluted waterways in the world (Armstrong and Hamilton, 1973). Extensive studies of mercury levels in the Wabigoon River downstream of Dryden were carried out through the 1970's and the early 1980's. These studies determined that the mercury pollution was mostly derived from a chlor-alkali plant operated from 1963 to 1975 in association with the Dryden pulp and paper mill. Between 1963 and 1970, unrestricted quantities of mercury, ranging from 9 to 11 metric tonnes were released into the river (Canada-Ontario Steering Committee [COSC], 1983). The chlor-alkali plant was converted to a non-mercury process in 1975, although traces of mercury are still present in mill effluent. As of 1983, mill discharges were no longer considered to be an important sources of mercury. Mercury contained in the near-surface and deep riverbed sediments were identified as the primary source.

Studies determined that the mercury pollution had led to high mercury levels in fish throughout the river system, from Dryden downstream to at least the Manitoba border (COSC, 1983). Commercial fishing in the river system was banned in 1971 as mercury levels in fish exceeded the Canada Food and Drug Directorate edible fish level of 0.5 parts per million (ppm). Sport fishing, however, was allowed to continue. Large decreases in mercury levels in most biota were recorded between the early 1970's and 1980's but levels were predicted to remain unacceptably high for many years (COSC, 1983). A portion of the

COSC's mandate was to develop mitigative measures to respond to continuing high mercury levels.

Projects to determine the effectiveness of various mercury amelioration measures investigated a variety of procedures (COSC, 1983). Methodologies explored included: the addition of sulphate to immobilize mercury; the addition of selenium to reduce the toxicity of the mercury; the addition of algal nutrients to enhance fish growth thus reducing the mercury concentration in fish via dilution; resuspension of lake or river bed sediments to accelerate the rate of sedimentation and reduce the bioavailability of mercury in the water column; and dredging of ploughing of riverbed sediments.

Although extensive in scope and valuable in its contribution to the understanding of fate of mercury in the lake/river and biotic environment, a large scale 'clean-up' of the mercury laden sediment was not undertaken. The majority of the river system has been allowed to naturally rehabilitate. No official watershed-wide follow-up studies have been undertaken to determine the effectiveness the system's natural rehabilitation (Hollinger, Pers. Comm.). The MOE annually samples fish at four locations on the Wabigoon River system for determination of mercury concentration. Mercury levels have continued to decline in the sport fish population through the 1980's with some smaller sport fish now considered acceptable for consumption based on fisheries guidelines (Hollinger, pers. comm.).

Crayfish are valuable 'indicator species' for aquatic mercury levels. Annual sampling of crayfish populations in the Clay Lake area has been carried out over the past two decades. This sampling has created an extensive database of mercury levels in the abdominal muscles of crayfish within the Wabigoon River system (McRae, Pers. Comm.). Over the sampling period, mercury concentrations in wet-weight abdominal muscles have declined from 11.0 ppm to 0.4-0.7 ppm (McRae, Pers. Comm.). This decline would suggest that some level of natural rehabilitation has taken place over the sampling period.

With the exception of the mercury studies, there have been no watershed-wide water quality studies completed for the Wabigoon River basin. The quality and quantity of fisheries within the area, however, offer some reflection of general water quality. Of the total lake area in the region, 70% is classed as warm water lakes, 20% is classed as cold water lakes, and the remaining 10% as unproductive waters (MNR, 1983).

The predominant sport and commercial species sought after include yellow pickerel, lake trout, pike and white fish. Lake trout are particularly sensitive to sedimentation of spawning beds and nutrient enrichment of their habitat yet have been identified within 102 lakes within the MNR Dryden District (MNR, 1983). These lakes account for 5% of all lake trout lakes in the province. With the exception of mercury contamination of the Wabigoon River itself, fisheries in the region are generally of good quality. Decreases in fish catches experienced in the early 1980's resulted from increased fishing demand, reductions in suitable habitat, and the cessation of fishing in the Wabigoon River due to contamination.

Current Study

Water quality was sampled at five provincial water quality monitoring stations in the Wabigoon watershed in 1989. Four of these stations had been in operation for over 10 years. Two of these stations were selected for this study to assess water quality within the watershed. Figure 10 shows the location of selected and unselected MOE water quality monitoring stations. The selected station near Dryden is upstream of Canadian Pacific's pulp mill and is generally representative of water quality conditions in the Wabigoon Lake and Revell River study sub-basins. The other selected station is located near Quibell and reflects general water quality for the majority of the watershed, excluding the Canyon Lake and Lower Wabigoon study sub-basins. The location of established MOE monitoring stations fail to represent water quality in the watershed as a whole or specific water quality in individual study sub-basins.

The MOE's surface water quality monitoring stations on the Wabigoon River are set-up to analyze for up to 39 parameters. Twenty-six of these parameters have been sampled on a consistent basis at the selected stations. These parameters have been measured in a much more consistent fashion than those in other river basins. This is perhaps due to the high profile the area has received from mercury pollution problems mentioned previously. The limitations of the MOE water quality monitoring station data that were noted by (G.M. Wickware and Associates (1990a,b,c,d) are less prevalent in this study.

Based on data from the period 1980 - 1990, summary tables have been prepared for 18 water quality parameters, grouped into three categories: nutrients and major dissolved ions (Table 10), field measurements (Table 11), and metals (Table 12). Observations have been plotted for total Kjeldahl nitrogen (Figures 13A,B), total phosphorous (Figures 14A,B), total copper (Figures 15A,B) and total mercury (Figures 16A,B). Plotting of individual observations was carried out to aid in evaluating fluctuations and trends in the levels of these parameters.

Nutrients and Major Dissolved Ions

Filtered Nitrite + Nitrate

Mean filtered nitrite + nitrate values for both stations are presented in Table 10. The Quibell station has a substantially higher mean concentration (0.11 mg/L) than the Dryden station (0.03 mg/L). Mean, median and maximum recorded concentrations at both stations are well below the federal guideline of 10 mg/L (Environment Canada, 1979).

Table 10. Chemical and Physical Analysis - Nutrients, Major Dissolved Ions

Station		Filtered Nitrite+Nitrate (mg/L)	Filtered Ammonia (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Total Phosphorous (mg/L)	Chloride (mg/L)	Sulphate (mg/L)
	# obs.	15	100	99	100	99	99
Dryden	Mean	0.03	0.027	0.49	0.04	2.0	3.45
Station	Median	0.01	0.02	0.46	0.03	1.5	2.90
	Range	0 - 0.16	0 - 0.26	0.026 - 1.3	0.011 - 0.4	1.0 - 20	0.1 - 43
	# obs.	15	95	93	94	95	93
Quibell	Mean	0.11	0.068	0.66	0.067	27.0	9.17
Station	Median	0.09	0.05	0.62	0.053	23.0	7.89
	Range	0.03 - 0.41	0.001 - 0.29	0.048 - 1.8	0.026 - 0.66	1.3 - 116	2.6 - 38

Filtered Ammonia

Mean filtered ammonia concentrations for both stations are shown in Table 10. The mean ammonia concentration at the Quibell station (0.068 mg/L) is also higher than that at the station just upstream of Dryden (0.027 mg/L). Higher ammonia levels at the Quibell station may be the result two factors, industrial ammonia discharges from Dryden, and the contribution of clay minerals through overland soil erosion of the underlying clay plain. No guidelines have been established for filtered ammonia concentrations.

Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen (TKN) concentrations for both stations are shown in Figures 13A,B and their mean values appear in Table 10. Mean TKN values of 0.49 mg/L and 0.66 mg/L have been calculated for the stations at Dryden and Quibell, respectively. Both mean concentrations are above the 0.1-0.5 mg/L range indicating excessive organic inputs (Environment Canada, 1979). No federal guidelines have been established for TKN levels.

The frequency of fluctuations in TKN concentrations at both stations are similar although the magnitude is generally greater at the Dryden station (Figures 13A,B). The TKN levels at the Quibell station are slightly higher for the period of record despite representing a larger stream flow volume. These higher concentrations likely reflect nitrogen inputs from Dryden as well as upstream agricultural inputs. TKN concentrations at both stations appear to be relatively constant throughout the study period although a mild increase in levels may be occurring at the Quibell station.

FIGURE 13A

DRYDEN STATION

TOTAL KJELDAHL NITROGEN CONCENTRATION

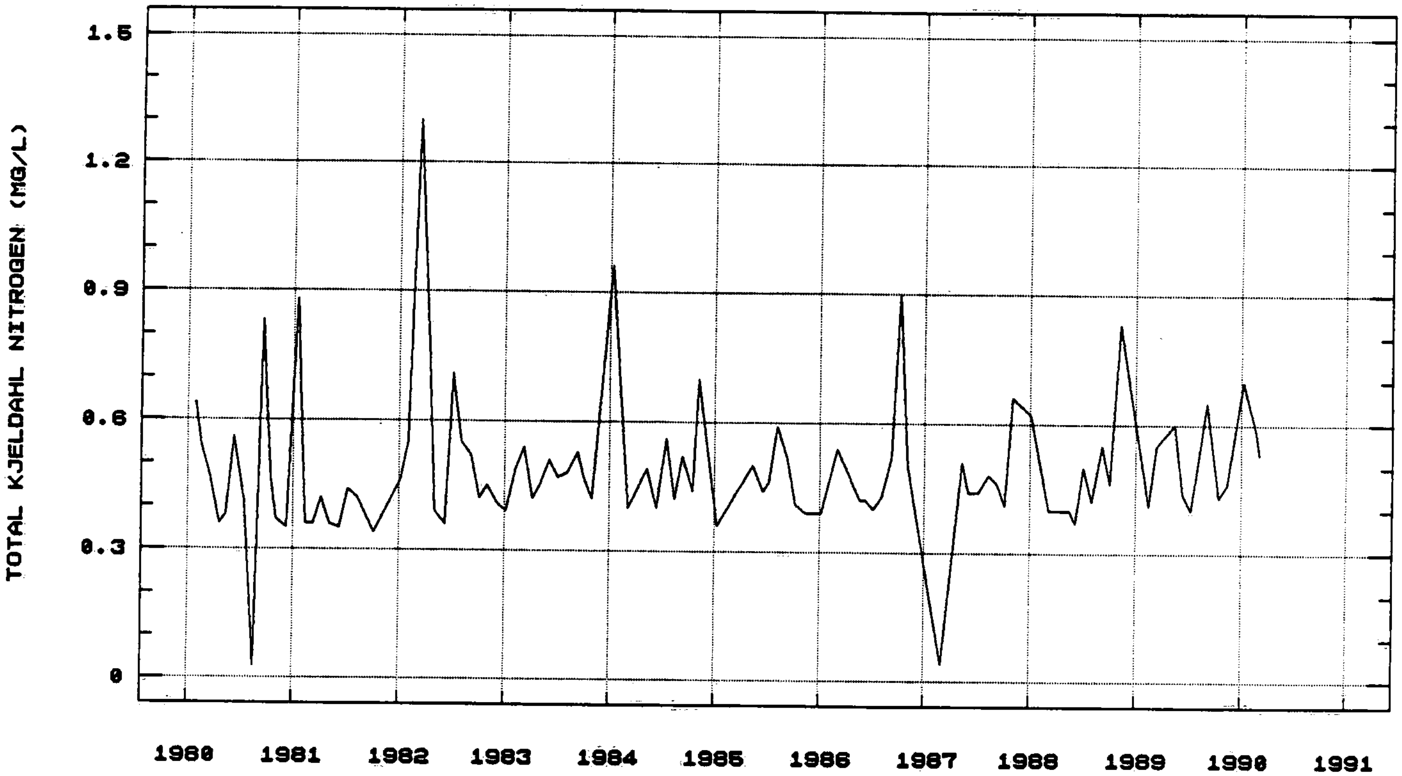
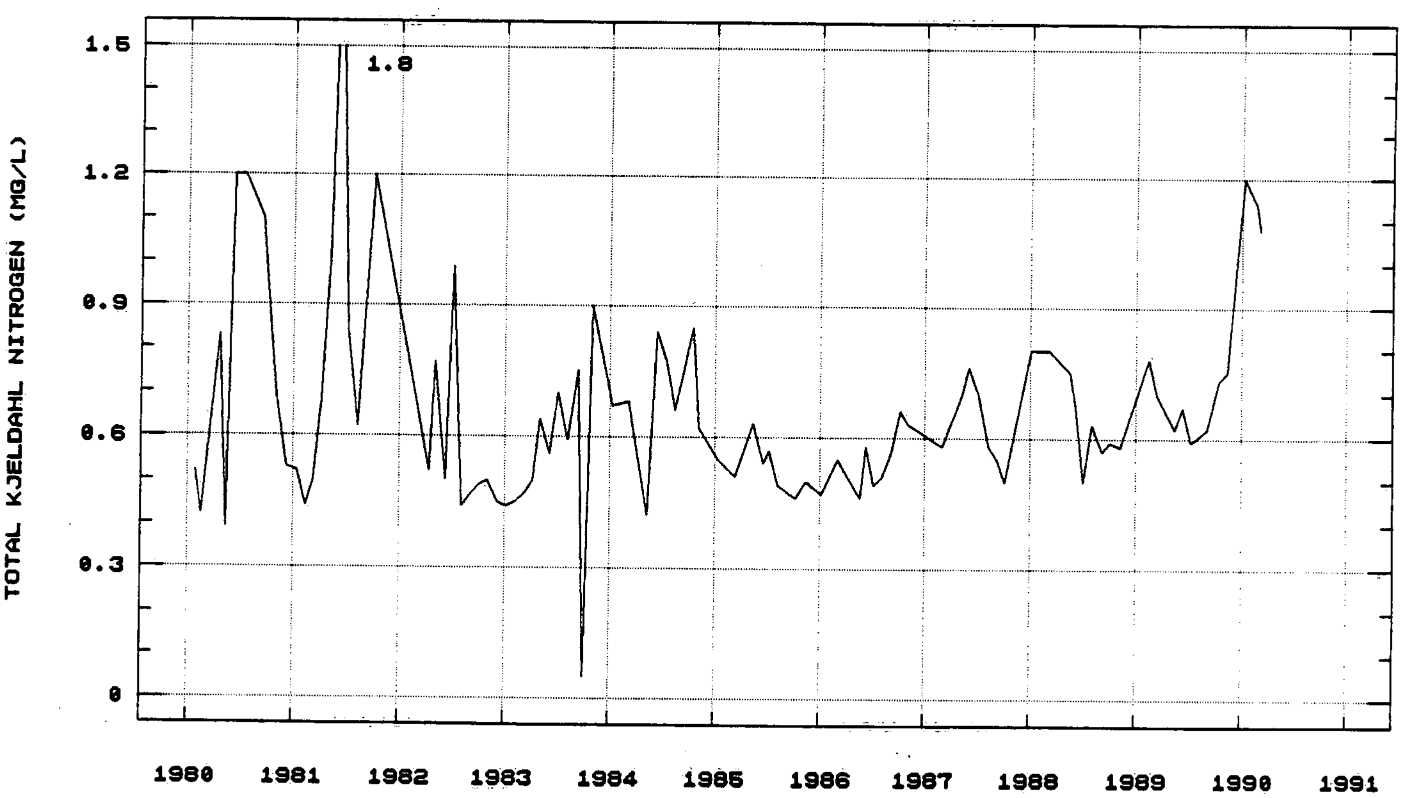


FIGURE 13B

QUIBELL STATION

TOTAL KJELDAHL NITROGEN CONCENTRATION



Total Phosphorous

Mean, median and the range of total phosphorous values appear in Table 10 and individual observations are plotted in Figures 14A,B. Mean and median concentrations at both Dryden (0.04 and 0.03 mg/L) and Quibell (0.067 and 0.053 mg/L) stations are both below the 0.2 mg/L guideline for drinking water. Leaching and weathering of igneous rocks is a primary natural source of phosphorous. Increased levels of phosphorous also arise from agricultural and industrial sources (Environment Canada, 1979).

Only one reading at the Dryden station and two readings at the Quibell station have exceeded the drinking water guideline (Figures 14A,B). With the exception of these readings, fluctuations in total phosphorous have been few and small in magnitude.

Chloride

Chloride is one of only two major dissolved ions to be sampled at these two stations (Table 10). Mean chloride values at the Dryden station (2.0 mg/L) and Quibell station (27.0 mg/L) are well below the 250 mg/L federal guideline for drinking water.

Sulphate

Values for sulphate, the second major dissolved ion sampled, appear in Table 10. The mean concentrations at both stations (3.45 mg/L, Dryden; 9.17 mg/L, Quibell) are below the objective level of 150 mg/L and the guideline level of 500 mg/L for drinking water. Areas of acid mine drainage may exhibit elevated sulphate concentrations (Environment Canada, 1979).

FIGURE 14A

DRYDEN STATION

TOTAL PHOSPHOROUS CONCENTRATION

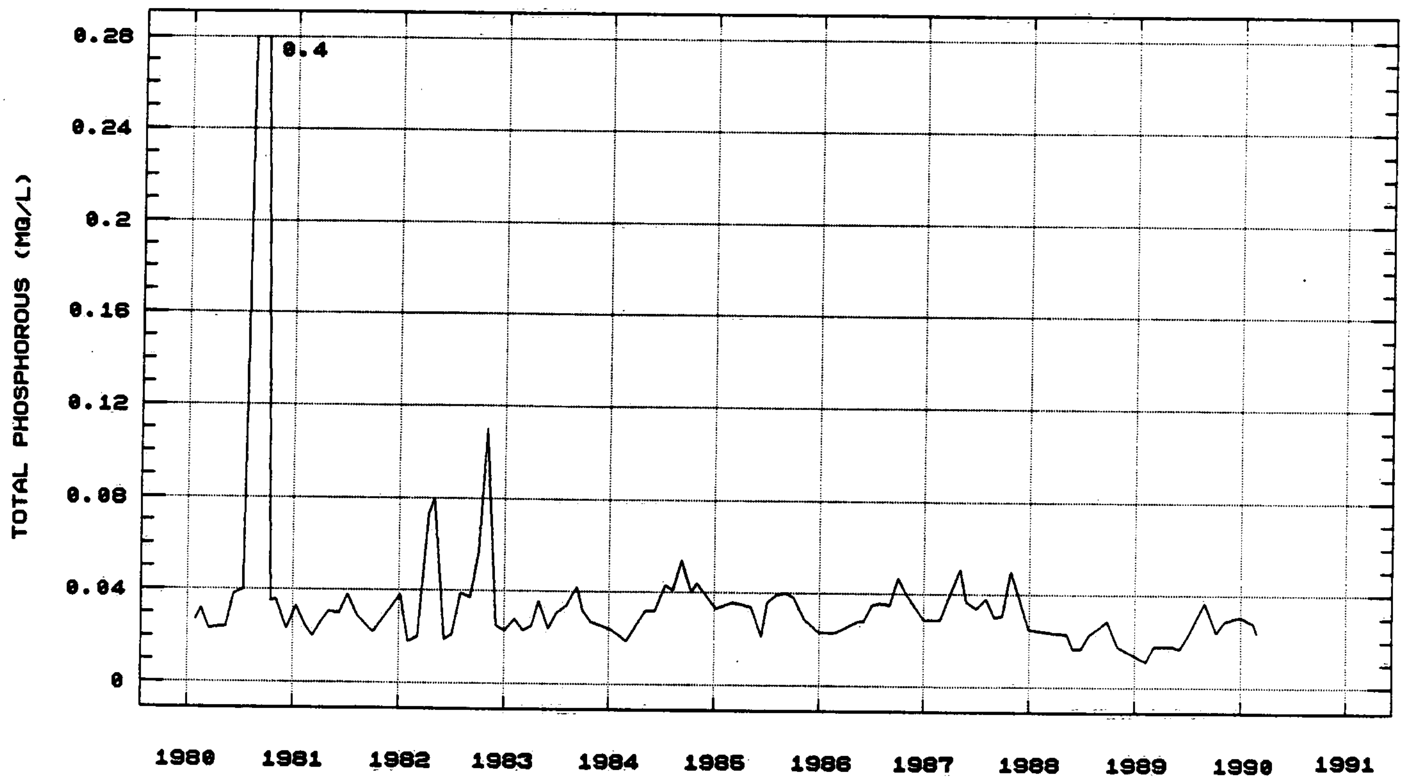
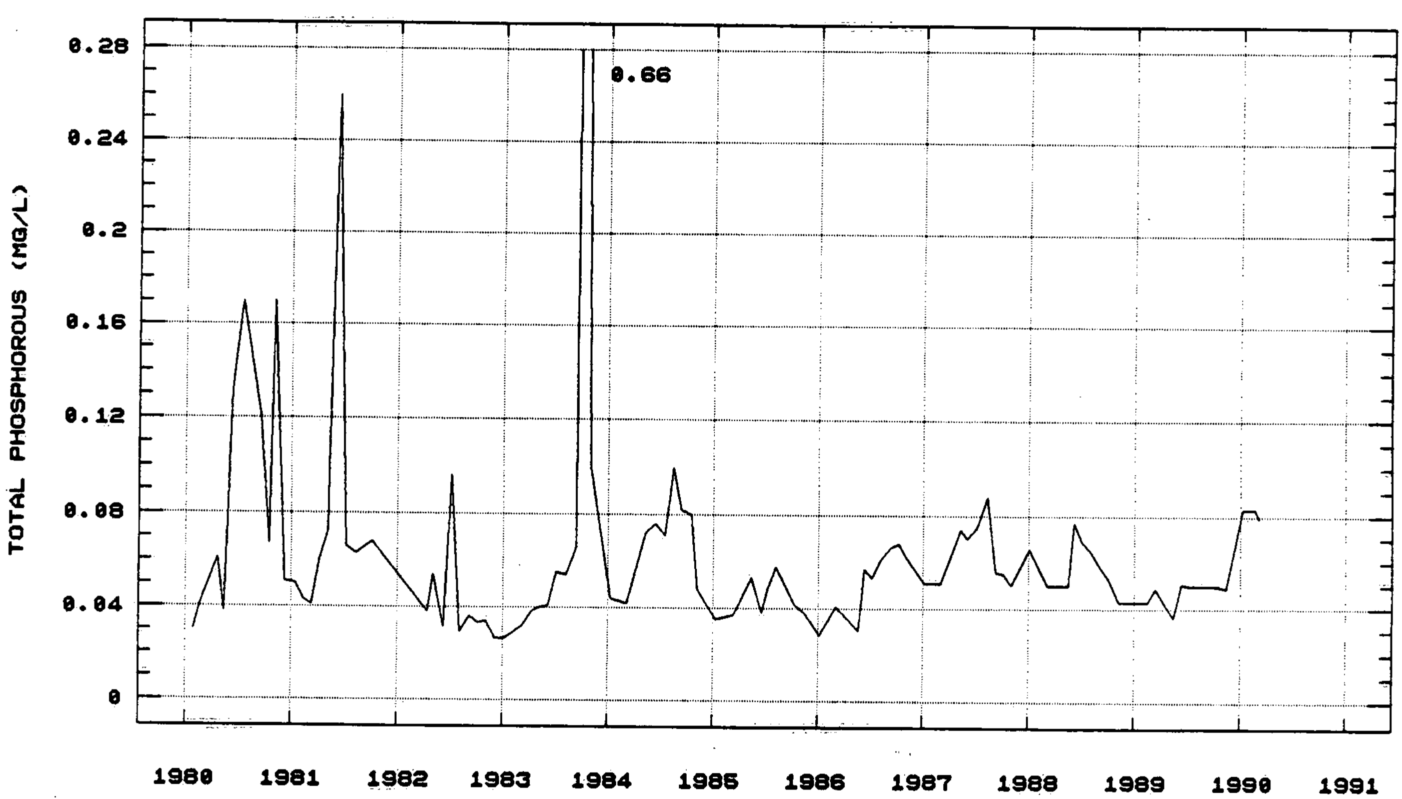


FIGURE 14B

QUIBELL STATION

TOTAL PHOSPHOROUS CONCENTRATION



Field Measurements

Alkalinity

Summary statistics for alkalinity at the Dryden and Quibell stations are presented in Table 11. Mean alkalinity values at Quibell (48.97 mg/L of $CaCO_3$) are only slightly more alkaline than those at Dryden (47.22 mg/L of $CaCO_3$). The reverse is true for the median value (48.0 mg/L of $CaCO_3$ at Dryden vs. 47.0 mg/L of $CaCO_3$ at Quibell). These four values fall within the 30-500 mg/L federal guideline range for drinking water.

Table 11. Chemical and Physical Analysis - Field Measurements

Station		Alkalinity (as mg/L CaCO3)	pH	Conductivity (µS/cm @ 25 C)	Temperature (degrees C)	Turbidity (FTU)
Dryden Station	# obs.	100	100	100	94	99
	Mean	47.22	7.63	108	10.5	13.3
	Median	48.0	7.70	108	10.0	13.0
	Range	16 - 57	6.6 - 8.3	81 - 132	0.1 - 26.0	2.7 - 33
Quibell Station	# obs.	95	94	95	93	93
	Mean	48.97	7.23	211	10.6	10.8
	Median	47.0	7.30	196	10.0	11.0
	Range	33 - 88	7.6 - 7.9	94 - 490	0.1 - 25.0	0.8 - 41

pH

Mean pH levels of 7.63 and 7.23 at the Dryden and Quibell stations, respectively, are within the federal guideline range of 6.5 - 8.5 (Table 11). Both the mean and median pH at Dryden are slightly more acidic than at the Quibell station.

Conductivity

Table 11 lists conductivity statistics measured at 25° C at the study stations. Mean conductivity is much higher at the Quibell station (211 μS/cm) than at the Dryden station (108 μS/cm).

Temperature

The mean, median and range of water temperatures (Table 11) at both stations are extremely similar. The mean water temperature of 10.5° C at Dryden is 0.5° C cooler than at Quibell. Median temperatures are the same at both stations. The maximum recorded temperature of 26.0° C at Dryden is only 1.0° warmer than the maximum at Quibell. Slightly warmer temperature at Quibell may be the result of warmer surface waters flowing from the Eagle Lake complex.

Turbidity

Turbidity summary statistics recorded in Formazin Turbidity Units (FTU) are show in Table 11. Mean turbidity is higher, on average, at the Dryden station (13.3 FTU mean, 13.0 FTU median) than at the Quibell station (10.8 FTU mean, 11.0 FTU median).

Metals

Iron

Data for total iron concentrations for the two study stations are shown in Table 12. The station at Dryden has slightly higher mean and median concentrations of 0.765 mg/L and

0.80 mg/L while the Quibell station has mean and median concentrations of 0.687 mg/L and 0.60 mg/L, respectively. These mean and median concentrations are more than double the aquatic life and drinking water guidelines of 0.3 mg/L. Weathering of minerals from igneous, sedimentary and metamorphic rocks and sulphide ores and industrial effluent contribute to these high iron concentrations (Environment Canada, 1979).

Table 12. Chemical and Physical Analysis - Metals

Station		Total Iron (mg/L)	Total Arsenic (mg/L)	Total Copper (mg/L)	Total Nickel (mg/L)	Total Mercury (µg/L)	Total Manganese (mg/L)	Total Zinc (mg/L)
	# obs.	99	44	100	98	90	99	99
Dryden Station	Mean	0.765	0.0018	0.004	0.002	0.018	0.012	0.006
	Median	0.80	0.0001	0.003	0.0002	0.005	0.015	0.004
	Range	0.11 - 1.5	0.0001 - 0.049	0 - 0.027	0 - 0.013	0 - 0.35	0 - 0.226	0 - 0.038
	# obs.	96	42	96	95	86	96	95
Quibell Station	Mean	0.687	0.0006	0.004	0.001	0.030	0.064	0.005
	Median	0.60	0.0001	0.003	0.0002	0.017	0.048	0.004
	Range	0.0001 - 2.6	0.0001 - 0.004	0 - 0.034	0 - 0.013	0.001 - 0.17	0.011 - 0.939	0 - 0.041

Arsenic

Data for total arsenic concentrations (mg/L) for the Dryden and Quibell stations are shown in Table 12. Mean and median concentrations at the Dryden station (0.0018 and 0.0001 mg/L) are higher than those at the Quibell station (0.0006 and 0.0001 mg/L). These values are well below the aquatic life guideline of 0.05 mg/L. Arsenic can be created as a by-product of paper manufacturing and the smelting and "roasting" of ores containing gold and silver. It may also occur naturally through the weathering of igneous rocks (Environment Canada, 1979).

Copper

Individual total copper concentrations have been plotted for both stations (Figures 15A,B) and mean and median concentrations are shown in Table 12. Mean and median total copper concentrations at both stations are 0.004 mg/L and 0.003 mg/L, respectively. These concentrations are both below the 1.0 mg/L federal drinking water guideline, however, all are in excess of the 0.002 mg/L guideline for aquatic life at the associated alkalinity [Environment Canada, 1987]).

Large and fairly frequent fluctuations in total copper concentrations were prevalent at both stations between 1980 and 1983 (Figures 15A,B). The source of copper responsible for the high concentrations recorded at both stations in 1982 is not known. Although total copper concentrations generally declined through the study period, it is clear that the current aquatic life guideline was exceeded regularly at both stations until 1988.

Nickel

Table 12 list the mean, median and range of nickel concentrations recorded at the Dryden and Quibell stations. Only the mean values differ between the two stations - Dryden with a mean of 0.002 mg/L and Quibell with a mean of 0.001 mg/L. These values are well below the aquatic life guideline level of 0.025 mg/L at the associated alkalinity (Environment Canada, 1987).

FIGURE 15A

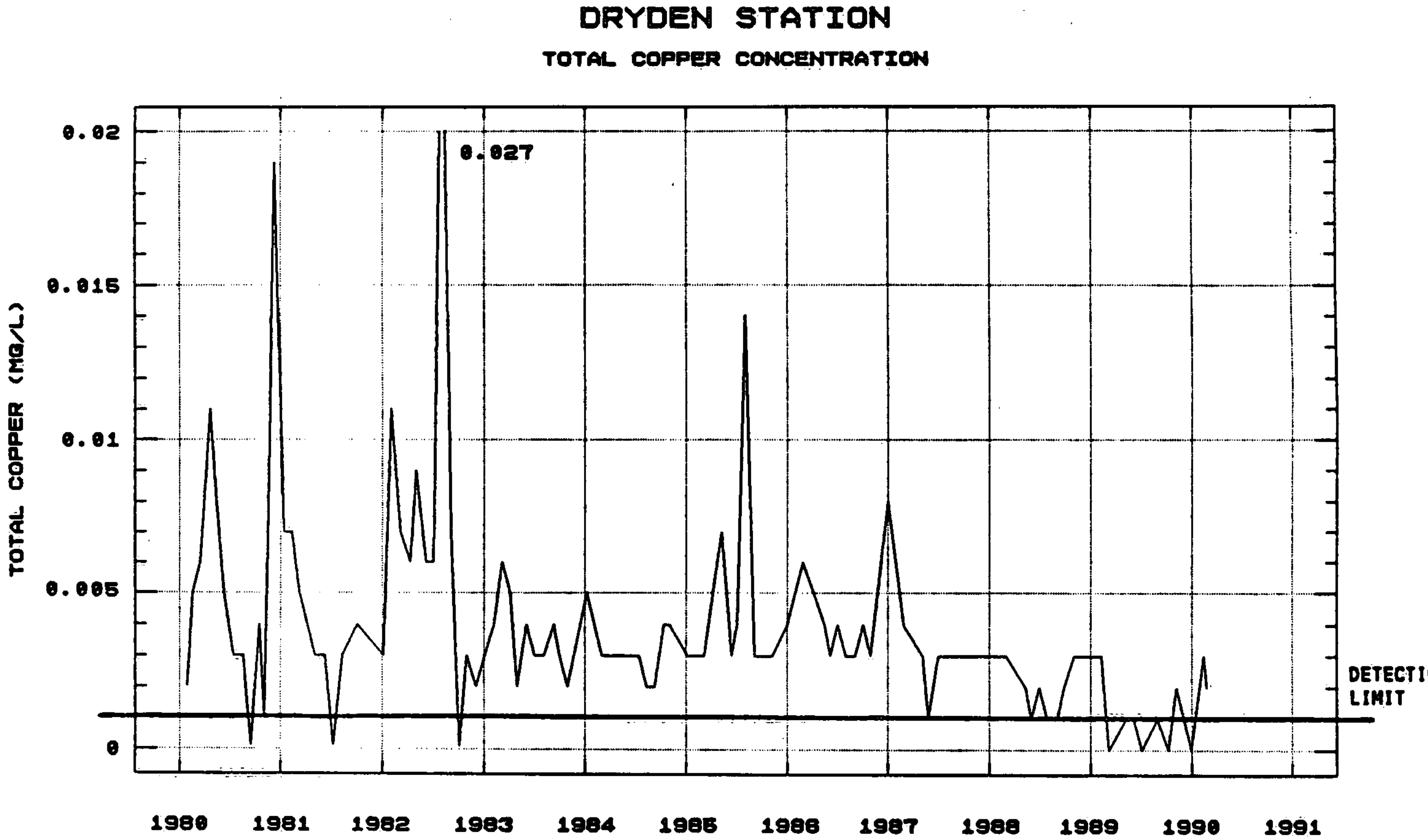
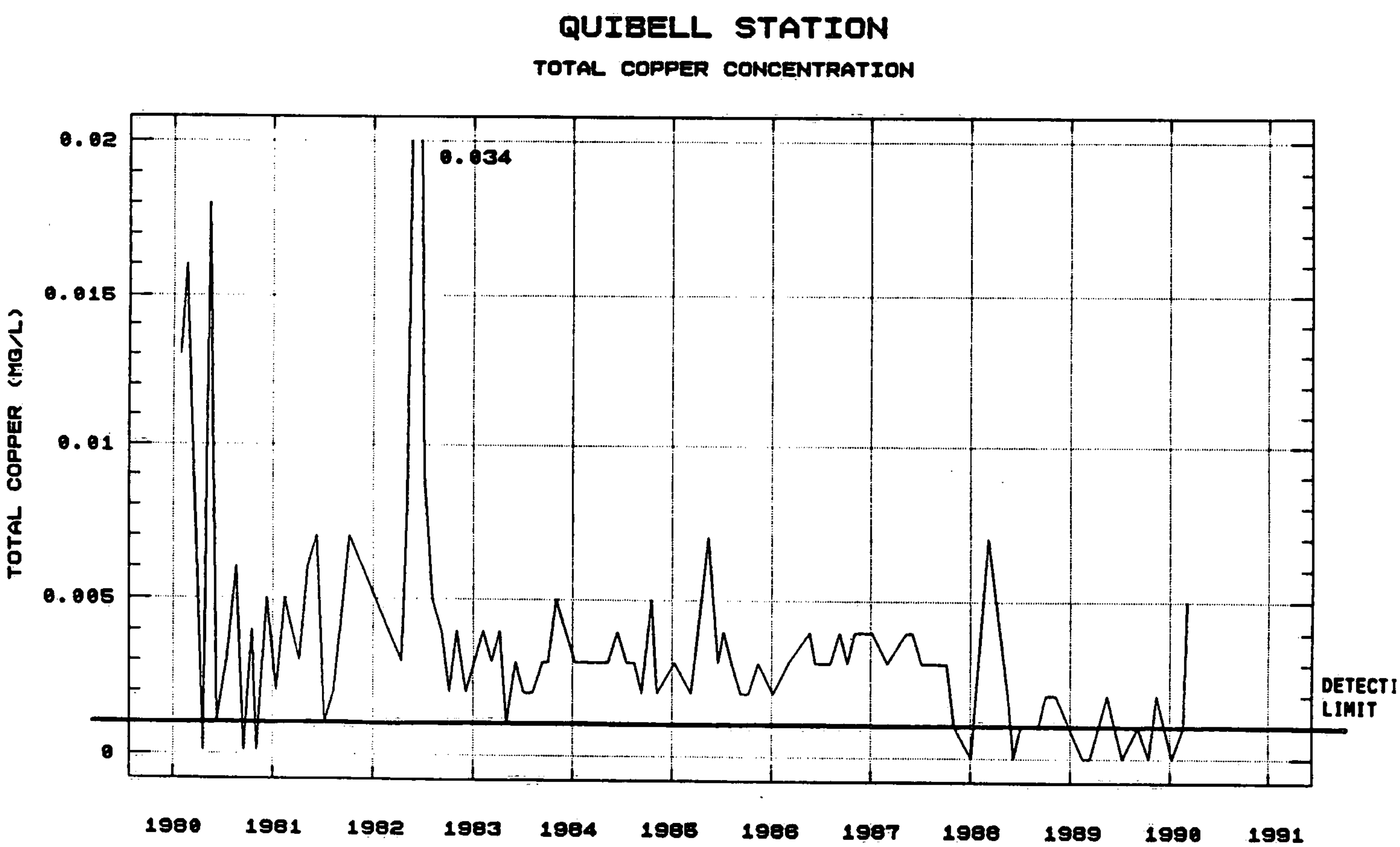


FIGURE 15B



Mercury

Table 12 and Figures 16A,B present total mercury concentrations for the study stations. Mean and median total mercury concentrations at the Dryden station (0.018 and 0.005 μg/L) and Quibell station (0.030 and 0.017 μg/L) do not exceed the 0.1 μg/L aquatic or 1.0 μg/L drinking water guideline levels (Environment Canada, 1987). Maximum recorded mercury concentrations for both stations, however, have exceeded the aquatic guideline.

Mercury concentrations at both monitoring stations show marked decreases from 1980 to 1981 (Figures 16A,B). Concentrations at the Dryden station are consistently lower and fluctuations less frequent than at the Quibell station. The higher mercury levels recorded at the Quibell station reflect the residual problems of mercury contamination. The fluctuations are roughly seasonal reflecting high flow periods when sediments are resuspended and carried further downstream.

Manganese

Manganese can arise from both natural and anthropogenic sources and is an essential element for the nutrition of both humans and animals (Environment Canada, 1979). Summary statistics for both stations appear in Table 12. The calculated Dryden mean (0.012 mg/L) and median (0.015 mg/L) concentrations are below the 0.05 mg/L guideline established for drinking water (Environment Canada, 1987). The Quibell mean (0.064 mg/L) concentration exceeds, while the median (0.048 mg/L) is slightly below the guideline value.

FIGURE 16A

DRYDEN STATION

TOTAL MERCURY CONCENTRATION

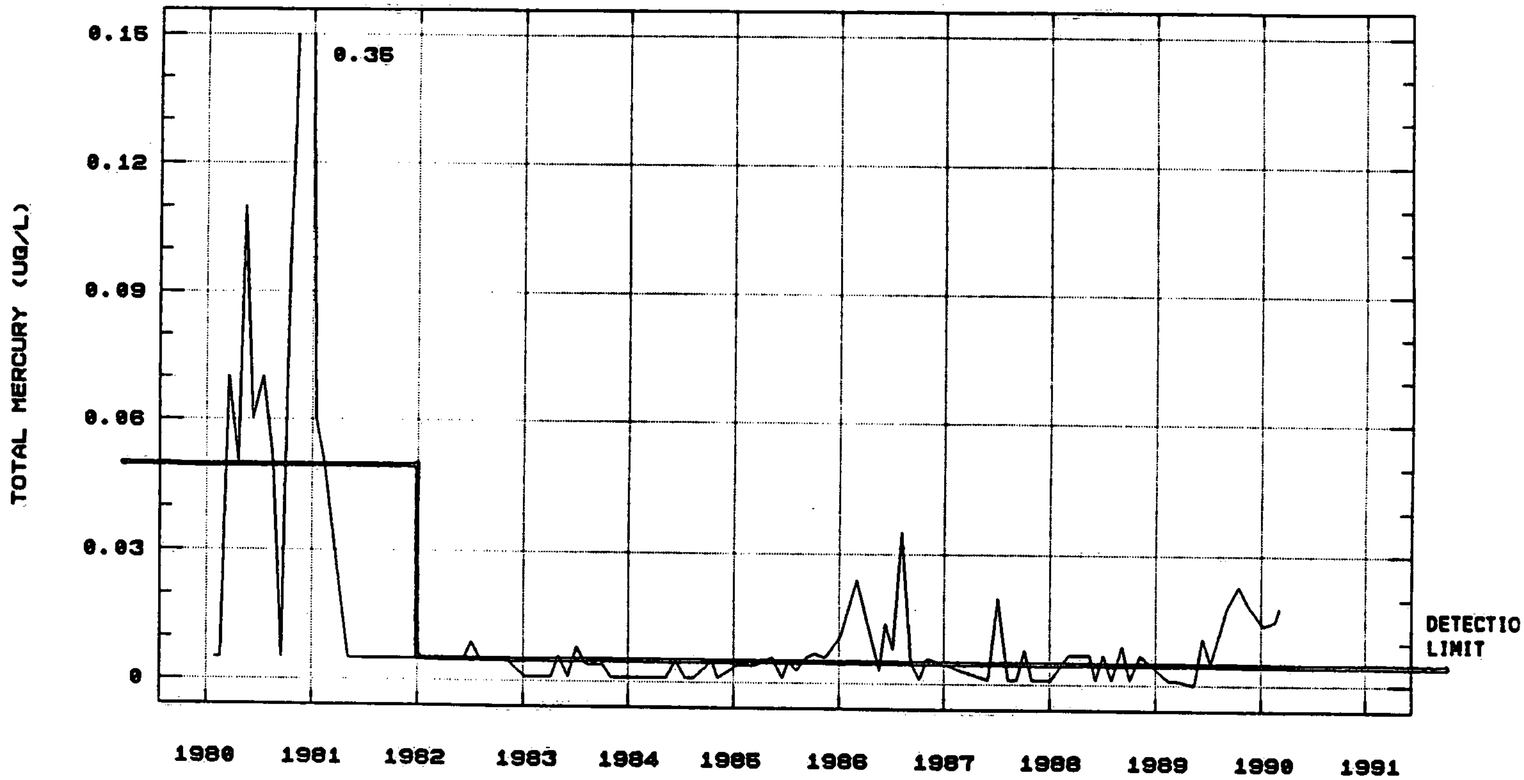
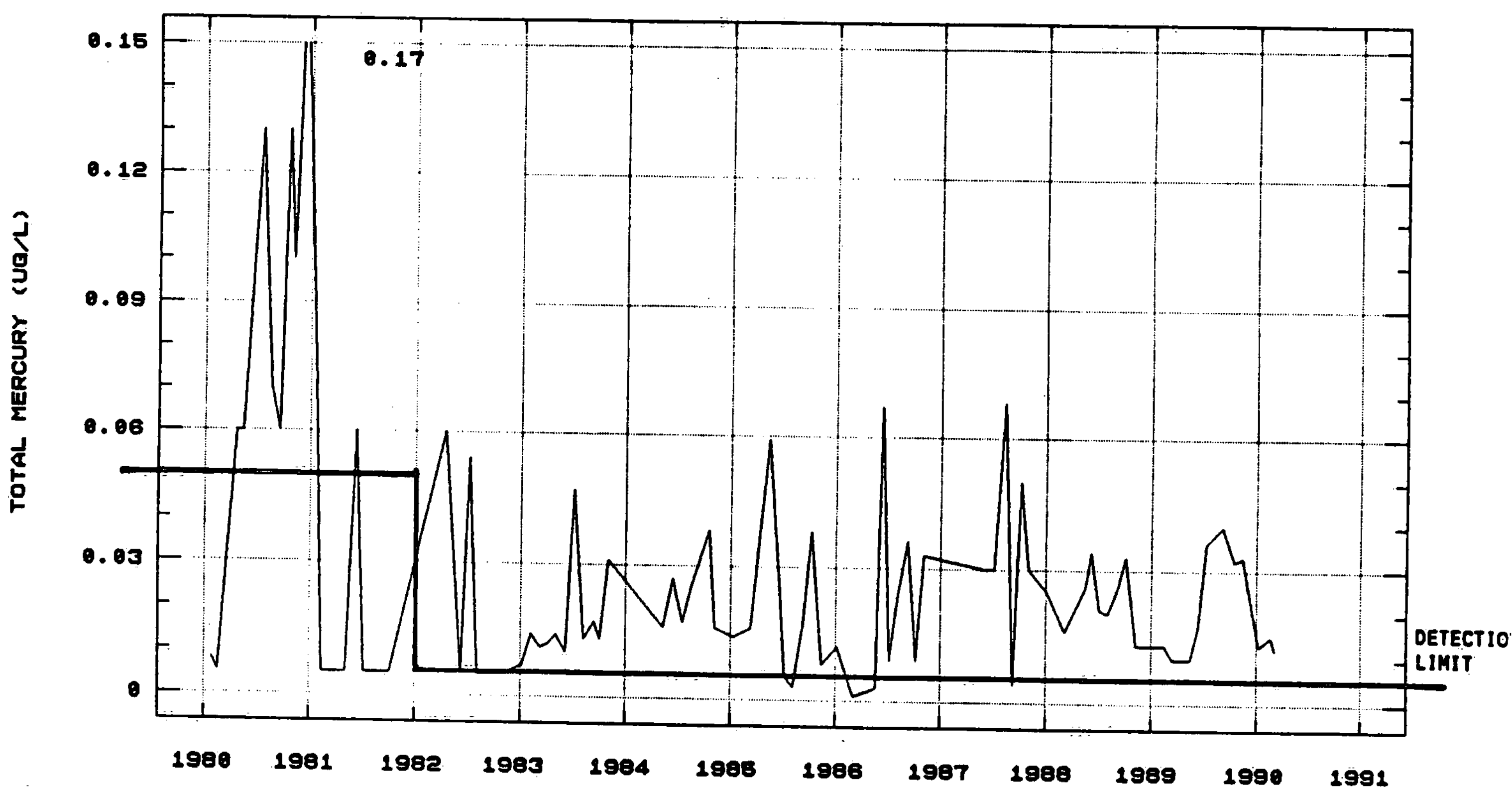


FIGURE 16B

QUIBELL STATION

TOTAL MERCURY CONCENTRATION



Zinc

Mean and median total zinc concentrations of 0.006 mg/L, 0.004 mg/L and 0.005 mg/L and 0.004 mg/L have been recorded at the Dryden and Quibell stations, respectively (Table 12). Mean and median zinc concentrations at these stations are similar and below both the federal drinking water (5.0 mg/L) and aquatic life (0.03 mg/L) guidelines (Environment Canada, 1987). The maximum recorded zinc concentrations at both stations, however, have exceeded the aquatic life guideline.

1.2 Issue Identification

Although the water quality data for the two study stations is relatively complete, water quality within the watershed as a whole is not adequately described. The lack of recent, more specific land use data is also a limitation. Considering these factors the assessment of sub-basins on an issue-by-issue basis must be largely qualitative. Quantitative sub-basin values for geology, forest cover, timber productivity and acid sensitivity have been produced based on mapping at scales from 1:100 000 to 1:1 013 760 and thus contain some margin of error. The water quality data from the Dryden water quality monitoring station can only be considered to reflect general conditions in the Wabigoon Lake and Revell River sub-basins while the Quibell monitoring station represents water quality for a drainage area of over 6500 km^2.

In order to address those water quality issues established for the National Reference Network, a matrix has been prepared which incorporates factors of significance to each of the national water quality issues of interest (Table 13). These issues include: development/resource extraction; agricultural eutrophication; and baseline. Existing water quality and stream flow monitoring stations are not adequately located to address any of these issues.

TABLE 13. PRIMARY SUB-BASIN SELECTION MATRIX

	REVELL RIVER	WABIGOON LAKE	GULLWING LAKE	S. EAGLE RIVER	EAGLE LAKE	CANYON LAKE	LOWER WABIGOON
AREA OF SUB-BASIN (KM2)	1294.4	961.5	1700.4	578.3	1982.7	620.3	1049.8
% MAJOR LANDFORMS							
- BEDROCK	61.29	53.69	40.31	89.87	81.37	75.84	37.95
- MORAINAL	4.31	2.41	7.73	0.44	0.57	6.00	18.32
- GLACIOFLUVIAL	10.42	7.80	9.38	1.39	4.51	6.34	7.09
- GLACIOLACUSTRINE	9.52	32.85	35.82	2.06	9.01	8.76	36.48
- ALLUVIAL	4.22	0.05	3.62	1.39	1.08	0.23	0.17
- ORGANIC	10.25	3.20	3.14	4.86	3.45	2.84	0.00
FRI CLASSIFICATION (%)							
- DEVELOPED AGRICULTURAL LAND	0.2	1.4	4.3	0.0	0.5	0.1	0.2
- TOTAL NON-FORESTED	1.2	4.1	6.9	0.2	1.3	1.3	0.8
- TOTAL NON-PRODUCTIVE	9.6	7.7	9.1	7.6	7.5	12.6	11.0
- PRODUCTION	72.5	65.7	72.7	70.6	64.4	55.9	70.2
% POTENTIAL TIMBER PRODUCTIVITY (M3/HA/YR)							
- 3.6 - 4.9	0.00	6.36	6.38	0.00	0.13	0.00	21.08
- 2.2 - 3.5	11.51	9.50	24.40	6.79	13.45	1.88	19.69
- 0.8 - 2.1	55.00	72.32	49.78	93.21	55.74	22.13	43.32
- LESS THAN 0.8	33.49	11.81	19.45	0.00	30.69	75.99	15.91

Information contained in Table 13 has been compiled from a number of sources and years. Water quality information is based on MOE data from 1990; stream flow data were provided in 1990 by Environment Canada. Areas of the sub-basins and percentage coverage of bedrock geology, landform, and timber productivity units were determined using TYDAC-SPANS (Geographic Information System data base). Bedrock geology and timber productivity mapping were completed by the MNR in 1971 and 1975, respectively. Geological terrain mapping (NOEGTS) of the area was completed by a number of parties between 1980 and 1989. Areas of agricultural lands were based in FRI information provided by the MNR in 1990. Agricultural figures and fertilization rates were calculated using figures from OMAF's 1988 statistics and the Fertilizer Institute of Ontario (1989). Finally, information on sewage treatment plants and industrial direct discharges was found in MOE literature (MOE, 1988a,b, 1989a,b).

1.2.1 Development/Resource Extraction

Basis for Concern

This complex issue encompasses the impacts of accessing timber and mineral sources, extraction and processing of these resources, and the associated human infrastructure required to support these operations.

Increased sedimentation and nutrient enrichment of waterbodies can arise from both the timber harvesting operations as well as the required road construction. These activities may also have negative effects on stream flow patterns. Effluent from pulp and paper mills can contain suspended solids, high levels of metals, organic and inorganic chemicals, whereas sawmilling effluent tends to be high in suspended solids. Such effluent can lead to serious deleterious impacts on water quality and aquatic life. The labourforce involved with these activities require residential and commercial establishments. Construction of such establishments and disposal of the associated wastes (construction and sanitary) can also contribute to water quality deterioration.

Sub-basin Selection Criteria

Timber harvesting and processing are the driving economic forces in this watershed. Large portions of the watershed have already been harvested, while other areas remain uneconomic to harvest due to access and topography constraints, particularly bedrock areas. The Town of Dryden itself is the primary manufacturing area centre and has already led to a deterioration in water quality. In order to address this issue it is appropriate to consider timber harvesting as the activity of interest and to locate a station in the sub-basin which offers productive, unconstrained forests which have not been affected by development of the Dryden area. Factors considered for determining the sub-basin which offers the greatest potential to exhibit the effects of timber harvesting are: percentage of productive forest; productivity of that forest; and existing access to the forest resources.

Based on the above criteria, the establishment of a water quality monitoring station in the Lower Wabigoon sub-basin is recommended. This sub-basin has the lowest percentage of bedrock coverage (38%) and just over 70% of its area is classified as production forest. Of this forest, over forty percent falls within the upper two productivity classes. Accessibility within this sub-basin is expected to improve as evidenced by recent road construction. The station must be established off the Wabigoon River itself to avoid mercury contaminated sediments. The preferred station location would be north of Clay Lake, in the vicinity of Beaton Creek or Fluke Lake.

1.2.2 Agricultural Eutrophication

Basis for Concern

Between 1972 and 1978 studies carried out by PLUARG found that eutrophication of Great Lake drainage basins and thus the Great Lakes themselves was the result of diffuse and point sources of phosphorous. Intensive agricultural operations were identified as the major diffuse source contributor of phosphorous. Despite the long term knowledge of the severity and extent of the eutrophication problem, a water quality collection program that is consistent and comparable on a national basis is still required (Environment Canada, 1990b).

Although eutrophication from agricultural sources is of much greater prevalence in southern Ontario, eutrophication arising from agricultural sources is also of concern in the Wabigoon River basin. Agricultural eutrophication arises primarily from two sources: excessive nutrient loading of rivers through fertilizer run-off and inputs from livestock operations (livestock access to watercourses, improper manure handling practices, feedlots). The nature of soils within an area and distribution of artificial drainage systems also influence the transport of nutrients.

Sub-basin Selection

Based on the Forest Resources Inventory analysis of the Wabigoon watershed, some developed agricultural land occurs in all but one study sub-basin. Agricultural activities, however, are most concentrated to the north and west of Dryden within the Gullwing Lake sub-basin. It is for this reason that the Gullwing sub-basin is the preferred location for establishment of a monitoring station to address this issue. The station should be located on a primary or secondary river which outlets to the Wabigoon River, between the confluences of Beaver and Colenso creeks with the Wabigoon River. The station must be located off the Wabigoon River to avoid the effects of mercury contaminated river sediments.

1.2.3 Baseline

Basis for Concern

The ability to make comparisons between different sub-basins within a watershed is of particular importance for the management of water quality. Consistent and comparable information over an extended time period is required in order to determine quantitative 'yardsticks' for desirable water quality goals. The determination of desirable water quality goals for a watershed requires that some measurement of attainable water quality be established as a reference point against which all other conditions in a watershed can be compared (Environment Canada, 1989). The identification of a relatively pristine sub-basin within the Wabigoon River watershed would allow for the establishment of such water quality goals.

Sub-basin Selection Criteria

The factors available for use in sub-basin selection are shown in Table 13. Variables available for use in determining the sub-basin possessing the most pristine conditions were:

1) total % of idle land = (% forest cover + % wetland + % idle)

2) area represented (km^2)

3) range of surficial deposits represented

4) presence of mercury contaminated soils

5) accessibility (Environment Canada, 1989).

The Revell River sub-basin is the most suitable candidate based on these criteria. This sub-basin is the third largest in the watershed with 86.4% of its land area classified as idle. The full range of surficial deposits within the Wabigoon watershed are represented in this sub-basin and in similar ratios. No mercury contaminated sediments have been identified in this sub-basin. Although lacking areas of highly productive forests, the ratio of timber productivity classes in the Revell Lake area are comparable to those at the watershed level. Accessibility to this sub-basin is provided by forest access roads and Highway 17.

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APPENDICES A - F

TYDAC-SPANS ANALYSIS TABLES

APPENDIX A: WABIGOON RIVER BASIN - ECOREGIONS

Ecoregion	Area (%)	Cum Area	Area (km sq)
Berens Plains	63.46	63.46	5195.72
Lake of the Woods Plains	33.06	96.52	2706.39
Lake St. Joseph Plains	0.34	96.86	27.81
Nipigon Plains	3.14	100.00	257.39
Total of 4 classes	100.00		8187.31

Note: 1. Area of water is included in analysis.
2. Variation in area totals (km^2) arise from digitizing of maps of different scales.

APPENDIX B: WABIGOON RIVER BASIN - SUB-BASIN AREAS

Area (km sq) Total % Row % Col %	Land Area	Water Area	Total
Revell River	1156.69 14.13 89.36 17.41	137.67 1.68 10.64 8.93	1294.36 15.81
Wabigoon Lake	720.86 8.80 74.97 10.85	240.61 2.94 25.03 15.60	961.47 11.74
Gullwing Lake	1422.73 17.38 83.67 21.41	277.63 3.39 16.33 18.00	1700.36 20.77
South Eagle River	499.81 6.10 86.43 7.52	78.45 0.96 13.57 5.09	578.26 7.06
Eagle Lake	1452.07 17.74 73.24 21.85	530.64 6.48 26.76 34.41	1982.71 24.22
Canyon Lake	504.95 6.17 81.41 7.60	115.32 1.41 18.59 7.48	620.26 7.58
Lower Wabigoon	888.09 10.85 84.59 13.36	161.73 1.98 15.41 10.49	1049.82 12.82
Total	6645.19 81.17	1542.05 18.83	8187.25

APPENDIX E: WABIGOON RIVER BASIN - FOREST RESOURCES INVENTORY

SUB-BASIN	NON-FORESTED DAL	NON-FORESTED TOTAL	NON-PRODUCTIVE TREED	NON-PRODUCTIVE OPEN MUSK	NON-PRODUCTIVE ROCK	NON-PRODUCTIVE TOTAL	PRODUCTIVE PRODUCTION	PRODUCTIVE PROTECTION	TOTAL
REVELL RIVER	2.26	14.25	46.11	34.93	1.17	117.69	890.95	40.08	1229.34
WABIGOON LAKE	13.02	39.83	10.77	41.74	2.30	73.86	631.81	8.17	961.47
GULLWING LAKE	72.79	117.50	48.75	34.58	8.63	154.18	1232.57	11.18	1694.89
S. EAGLE RIVER	0.00	1.22	13.48	19.75	2.00	44.11	408.34	12.54	578.26
EAGLE LAKE	9.64	26.06	35.58	42.41	33.65	148.51	1277.85	31.39	1982.71
CANYON LAKE	0.63	8.25	8.27	12.17	49.46	78.16	346.45	54.84	620.25
LOWER WABIGOON	2.22	7.91	14.13	25.03	17.63	115.89	736.56	24.80	1049.82
WATERSHED	100.56	215.03	177.10	210.61	114.83	732.39	5524.53	184.00	8116.74

Note:
1. Values expressed as km^2.
2. Area of water not include in analysis.
3. Variation in area totals (km^2) arise from digitizing maps of different scales.

APPENDIX F: WABIGOON RIVER BASIN - POTENTIAL TIMBER PRODUCTIVITY

Area (km sq) Total % Row % Col %	3.6-4.9 (m3/ha/yr)	2.2-3.5 (m3/ha/yr)	0.8-2.1 (m3/ha/yr)	Less than 0.8 (m3/ha/yr)	Total
Revell River	0.00	133.12	636.21	387.36	1156.69
	0.00	2.00	9.57	5.83	17.41
	0.00	11.51	55.00	33.49	
	0.00	13.83	17.49	22.52	
Wabigoon Lake	45.87	68.49	521.36	85.15	720.86
	0.69	1.03	7.85	1.28	10.85
	6.36	9.50	72.32	11.81	
	14.09	7.12	14.33	4.95	
Gullwing Lake	90.75	347.10	708.17	276.71	1422.73
	1.37	5.22	10.66	4.16	21.41
	6.38	24.40	49.78	19.45	
	27.87	36.07	19.47	16.09	
South Eagle River	0.00	33.96	465.85	0.00	499.81
	0.00	0.51	7.01	0.00	7.52
	0.00	6.79	93.21	0.00	
	0.00	3.53	12.81	0.00	
Eagle Lake	1.85	195.31	809.33	445.58	1452.07
	0.03	2.94	12.18	6.71	21.85
	0.13	13.45	55.74	30.69	
	0.57	20.30	22.25	25.91	
Canyon Lake	0.00	9.49	111.74	383.72	504.95
	0.00	0.14	1.68	5.77	7.60
	0.00	1.88	22.13	75.99	
	0.00	0.99	3.07	22.31	
Lower Wabigoon	187.18	174.87	384.73	141.30	888.09
	2.82	2.63	5.79	2.13	13.36
	21.08	19.69	43.32	15.91	
	57.48	18.17	10.58	8.22	
Total	325.65	962.35	3637.38	1719.81	6645.19
	4.90	14.48	54.74	25.88	

Note: 1. Area of water not included in analysis.

APPENDIX C: WABIGOON RIVER BASIN - BEDROCK GEOLOGY

Area (km sq) Total % Row % Col %	Mafic M. Volcan.	Felsic to Intermed. M. Volcan.	Meta- sediments	E. Mafic- Ultra Maf. Igneous	E. Felsic Igneous & Metamorph	Total
Revell River	720.53	18.21	56.07	10.38	351.50	1156.69
	10.92	0.28	0.85	0.16	5.33	17.53
	62.29	1.57	4.85	0.90	30.39	
	47.96	19.76	12.93	10.85	7.86	
Wabigoon Lake	462.78	21.51	86.37	5.40	97.73	673.80
	7.01	0.33	1.31	0.08	1.48	10.21
	68.68	3.19	12.82	0.80	14.50	
	30.80	23.34	19.92	5.65	2.18	
Gullwing Lake	92.58	12.69	153.00	1.03	1163.43	1422.73
	1.40	0.19	2.32	0.02	17.63	21.56
	6.51	0.89	10.75	0.07	81.77	
	6.16	13.76	35.29	1.08	26.00	
South Eagle River	11.45	0.00	1.51	0.00	486.85	499.81
	0.17	0.00	0.02	0.00	7.38	7.57
	2.29	0.00	0.30	0.00	97.41	
	0.76	0.00	0.35	0.00	10.88	
Eagle Lake	185.74	33.76	110.01	71.16	1051.40	1452.07
	2.82	0.51	1.67	1.08	15.93	22.01
	12.79	2.33	7.58	4.90	72.41	
	12.36	36.63	25.37	74.42	23.50	
Canyon Lake	29.21	6.00	26.62	7.65	435.46	504.95
	0.44	0.09	0.40	0.12	6.60	7.65
	5.78	1.19	5.27	1.51	86.24	
	1.94	6.51	6.14	8.00	9.73	
Lower Wabigoon	0.00	0.00	0.00	0.00	888.09	888.09
	0.00	0.00	0.00	0.00	13.46	13.46
	0.00	0.00	0.00	0.00	100.00	
	0.00	0.00	0.00	0.00	19.85	
Total	1502.29	92.18	433.59	95.62	4474.45	6598.13
	22.77	1.40	6.57	1.45	67.81	

Note: 1. Area of water not included in analysis.
2. Variation in area totals (km^2) arise from digitizing of maps of different scales.

APPENDIX D: WABIGOON RIVER BASIN - SURFICIAL GEOLOGY

Area (km sq) Total % Row % Col %	Bedrock	Morainal	Glacio-fluvial	Organic	Alluvial	Glacio-lacustrine	Total
Revell River	708.95 10.67 61.29 17.63	49.85 0.75 4.31 13.09	120.50 1.81 10.42 25.24	118.56 1.78 10.25 43.11	48.77 0.73 4.22 38.72	110.06 1.66 9.52 8.06	1156.69 17.41
Wabigoon Lake	386.99 5.82 53.69 9.63	17.39 0.26 2.41 4.57	56.25 0.85 7.80 11.78	23.07 0.35 3.20 8.39	0.39 0.01 0.05 0.31	236.77 3.56 32.85 17.34	720.86 10.85
Gullwing Lake	573.50 8.63 40.31 14.27	110.04 1.66 7.73 28.90	133.44 2.01 9.38 27.94	44.64 0.67 3.14 16.23	51.47 0.77 3.62 40.86	509.64 7.67 35.82 37.32	1422.73 21.41
South Eagle River	449.18 6.76 89.87 11.17	2.18 0.03 0.44 0.57	6.93 0.10 1.39 1.45	24.28 0.37 4.86 8.83	6.93 0.10 1.39 5.50	10.30 0.15 2.06 0.75	499.81 7.52
Eagle Lake	1181.61 17.78 81.37 29.39	8.33 0.13 0.57 2.19	65.47 0.99 4.51 13.71	50.12 0.75 3.45 18.23	15.72 0.24 1.08 12.48	130.81 1.97 9.01 9.58	1452.07 21.85
Canyon Lake	382.96 5.76 75.84 9.53	30.28 0.46 6.00 7.95	31.99 0.48 6.34 6.70	14.34 0.22 2.84 5.21	1.17 0.02 0.23 0.93	44.21 0.67 8.76 3.24	504.95 7.60
Lower Wabigoon	337.05 5.07 37.95 8.38	162.66 2.45 18.32 42.72	62.93 0.95 7.09 13.18	0.00 0.00 0.00 0.00	1.51 0.02 0.17 1.20	323.93 4.87 36.48 23.72	888.09 13.36
Total	4020.24 60.50	380.74 5.73	477.51 7.19	275.01 4.14	125.98 1.90	1365.72 20.55	6645.19

Note: 1. Area of water not included in analysis.