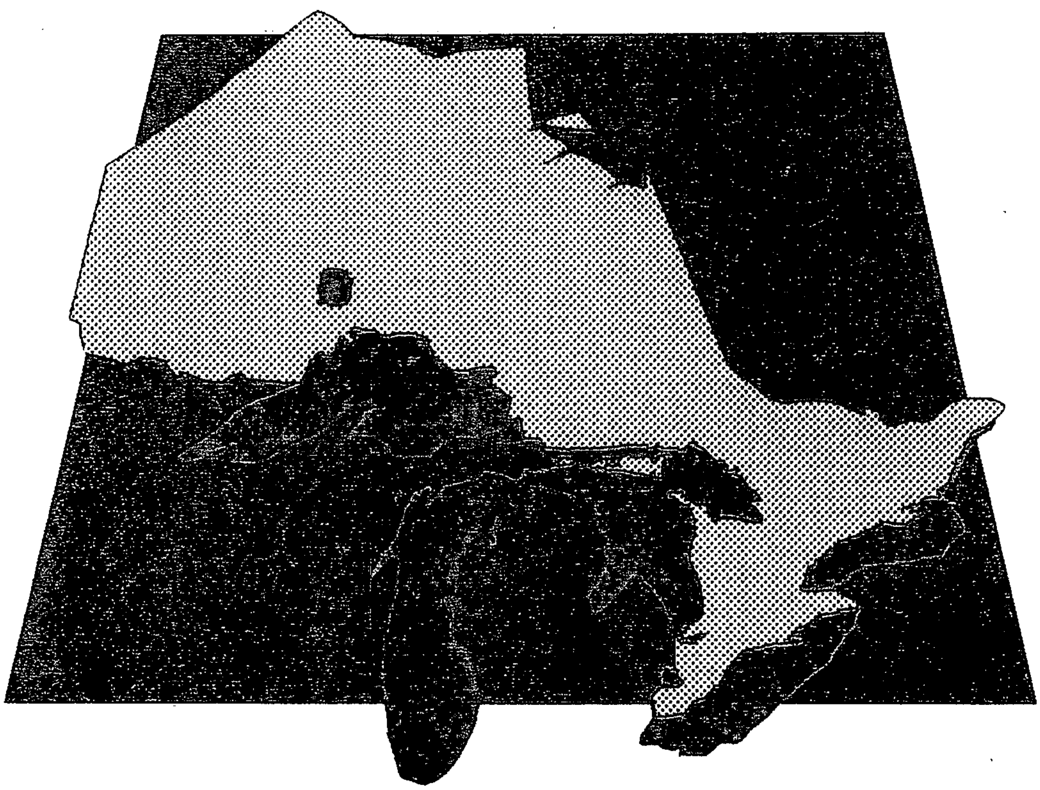
THE APPLICATION OF AN INTERDISCIPLINARY APPROACH TO THE SELECTION OF POTENTIAL WATER QUALITY SAMPLING SITES



Bear Creek Drainage 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 BEAR CREEK RIVER BASIN

A Report Prepared For

Mr. N. D. Warry
Head, Monitoring and Agreements Division
Water Quality Branch
Inland Waters Directorate
Canada Centre for Inland Waters
867 Lakeshore Rd.
Burlington, Ontario
L7R 4A6

by

Geomatics International
3370 South Service Road
Burlington, Ontario
L7N 3M6

Copies of this report may be obtained by contacting:

Head, Monitoring and Agreements Division
Water Quality Branch, Ontario Region

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EXECUTIVE SUMMARY

1.0 Introduction

The Bear Creek basin is one of four 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 eutrophication, pesticides, urbanization, acid rain, pristine/baseline, and development/resource extraction. Stations are being located to monitor appropriate issues within sub-basins of each watershed.

This report is part of the third phase of Ontario river basin analyses. Other rivers basins being examined in this phase include the Welland, Ganaraska and Saganash. The prior two phases of the study involved the analyses of fourteen additional Ontario river basins. Previously studied river basins include the Pukaskwa, Shamattawa, Kwataboahegan, Wabigoon, Seine, Goulais, White, Blanche, Magnetawan, Grand, Rouge, Thames, Saugeen and the South Nation.

1.1 Approach and Limitations

Data for existing provincial water quality stations were obtained from the Ministry of the Environment (MOE). Flow data were provided by the Inland Waters Directorate of Environment Canada. Existing reports and maps were obtained from federal, provincial and municipal levels of government, as well as from conservation authorities.

Agricultural Land Use Systems and Agricultural Resource Inventories, from the Ontario Ministry of Agriculture and Food (OMAF), were used to determine land use within the basins. Information summarized on a township or county basis was apportioned to that area of the township/county which lies within the watershed.

The issues of concern in the Bear Creek basin are: (1) agricultural eutrophication; (2) pesticides; and (3) baseline/pristine conditions. Four sub-basins were identified for this study: Upper Bear Creek; Petrolia; Little Bear Creek; and Lower Bear Creek. Ideally, one provincial water quality station and one federal flow station would be located within each sub-basin. In reality this rarely occurs.

2.0 Brief Description of the Bear Creek Basin

Bear Creek and its tributaries drain 617.5 km^2 of Lambton County in southwestern Ontario, northeast of Lake St. Clair. The creek flows from northeast to southwest, with headwaters around Warwick, where it is bounded by a glacial moraine. The creek drains a small sand plain before crossing an extensive bevelled till plain, where it joins with Black Creek to form the North Sydenham River. The largest tributaries are Little Bear Creek and Buttermilk Creek. Also notable are the large areas of artificial drainage such as the Burton Drain, Stonehouse Drain and the area around the eastern edge of the basin surrounding Little Bear Creek.

The Bear Creek watershed lies entirely within the Erie Ecoregion. The region experiences humid, warm to hot summers with mean daily temperatures in excess of 0 °C from April to November.

The town of Petrolia is the major urban centre in the basin with a population of 4,168. The major land use is intensive cash crop farming, accounting for almost 80 percent of the area land use. Livestock production is also a major economic component of the area.

3.0 Major Impacts on Water Quality

Four sewage treatment plants were in operation within the Bear Creek watershed in 1988. All discharges were in compliance with MOE guidelines during 1988. There are no direct industrial discharges within the basin.

Petrolia was once a major producing area for oil and natural gas. Although production has been significantly reduced through the years production wells still exist in the area. As recently as the spring of 1991, oil spills have been reported in the area. These accidents, unless completely contained, will have an impact on water quality, either directly into the water course or through groundwater seepage and movement.

Due to the large amount of area under high intensity row cropping, fertilizers and pesticides contained in surface runoff and ground waters are a concern for water quality. Livestock operations along the upper section of Bear Creek result in degradation of regional water quality.

4.0 Present Water Quality

Metal concentrations recorded at one MOE water quality monitoring station indicated that levels were below MOE guidelines with minor exceptions. Median concentrations of Total Kjeldahl Nitrogen, total phosphorous, chloride and copper were calculate to be above the MOE water quality criteria for the last ten years. Occasional exceedences were recorded for lead, copper and zinc.

Microbacterial pollutants from both animal and human wastes are abundant and pose a significant water quality threat in the upper reaches of the basin.

5.0 Evaluation of Available Water Quality and Flow Stations

Three MOE water quality monitoring stations were in operation in the basin between 1980 and 1990. Only two of these were chosen for the study, as the third ceased operation in 1983. One of these two stations monitored metal concentrations consistently over the past ten years.

Two federal flow stations were recording water flow conditions in the Bear Creek watershed for the past ten years. The station at Petrolia records input form the northern end of the basin while the other, just south of Brigden, records flow dynamics for nearly the entire watershed.

6.0 Conclusions and Recommendations

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

1) The Upper Bear Creek sub-basin is selected for monitoring water quality for agricultural eutrophication. Over 80 percent of the land use in this sub-basin is under corn/row cropping. In addition, this area has the highest number of animals per hectare and the highest percentage of hay/grazing area. Historical data on water quality are available for this sub-basin. A water quality monitoring station needs to be established.

2) The Little Bear Creek sub-basin is selected for monitoring the effects of pesticide applications in the watershed of Bear Creek. This sub-basin has 89 percent of land use under corn/row cropping systems. A water quality monitoring station needs to be established.

3) Due to the abundance of high intensity farming, extensive artificial drainage systems and a lack of significant idle or forested areas, there is no location that is suitable for the

establishment of an NRN water quality station to monitor pristine and baseline conditions within the Bear Creek 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 a Geographic Information System (GIS) (Warry and Hanau, in press; Geomatics International, 1990). These reports detail 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 (Wickware and Associates, 1990a-d) and ten watersheds in northern Ontario (Geomatics International, 1991a-i; Wickware and

Associates, 1989) have been completed using this methodology. Previously studied river basins include the Pukaskwa, Shamattawa, Kwataboahegan, Wabigoon, Seine, Goulais, White, Blanche, Magnetawan, Grand, Rouge, Thames, Saugeen and the South Nation.

The present study will utilize a similar methodology focusing on four river basins, three in southern Ontario and one in northern Ontario. Potential sampling sites within the Bear Creek basin as identified in this document will be field verified to determine the practical constraints on their potential for field collection.

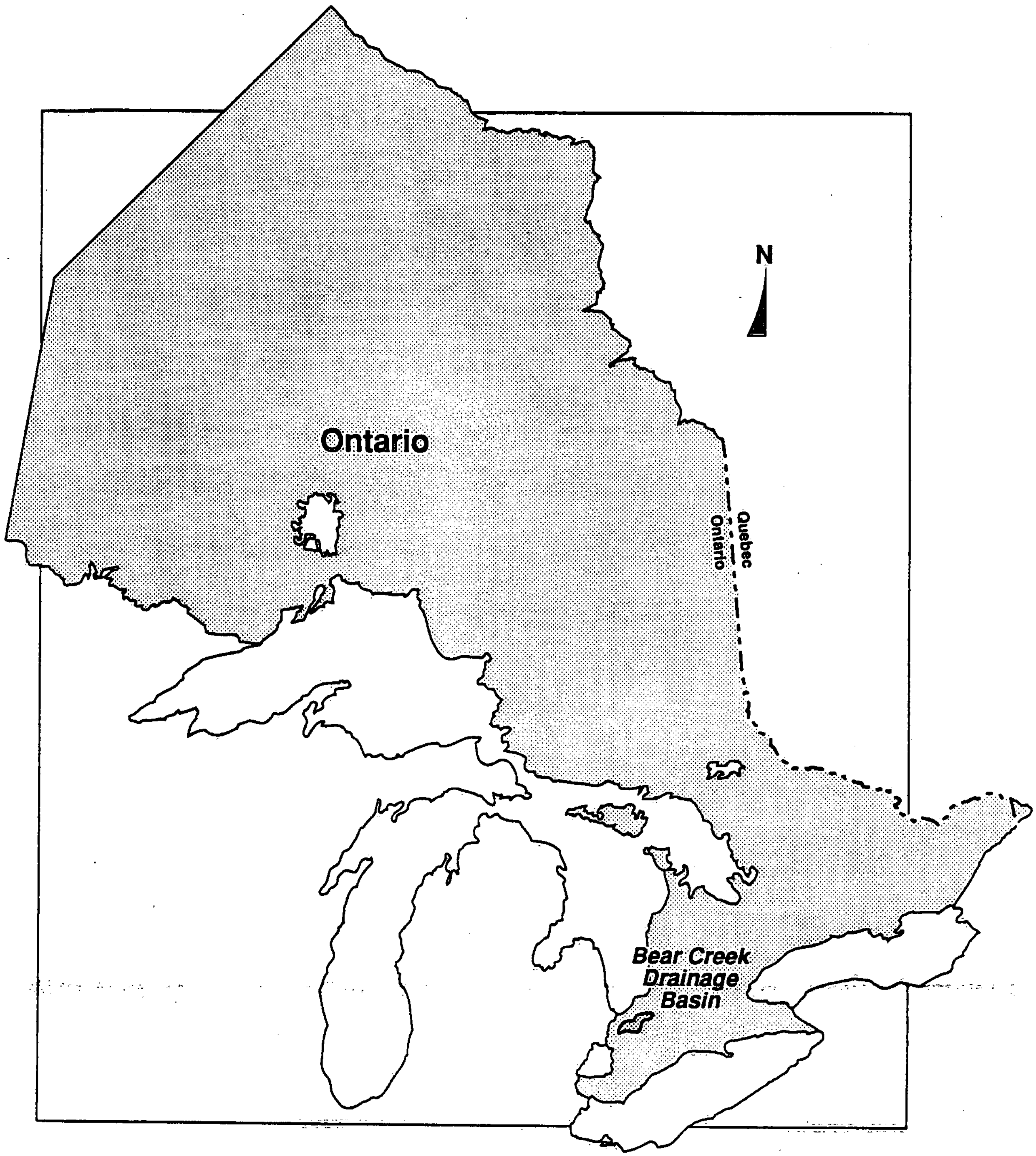
1.1 Resource Summary Description

1.1.1 Location

The Bear Creek drainage basin, located in southwestern Ontario, drains approximately 21 percent of Lambton County (Figure 1). The town of Petrolia marks the approximate centre of the basin, located 25 km southeast of Sarnia and 75 km west of London. Bear Creek and its tributaries drain an area from Birnam, in the north, to south of Wilkesport, where Bear Creek and Black Creek join to form the North Sydenham River. Agriculture is the primary activity supporting the region. Several oil and natural gas fields are also under production in this area. Road access to the basin is excellent with a grid-network of township roads. A CNR track runs through the northern portion of the basin from Sarnia to London.

Figure 1

Location of the Bear Creek Drainage Basin



1.1.2 Climate

The Bear Creek basin lies in Ecodistrict 1 of the Erie Ecoregion of Canada (Wickware and Rubec, 1989). This region characteristically has humid and warm to hot summers, with mean daily temperatures above 0 °C from April through November.

Thirty years of climatic data has been compiled from the meterological station at Petrolia (Figure 2a,b). The average annual temperature for this region is 8.1 °C, with the highest monthly temperature occurring in July (21.3 °C), and the lowest in January (-5.7 °C). Annual precipitation over the thirty years averaged approximately 905 mm, with 113.9 days of rain and 32.3 days of snow. Monthly precipitation ranges from an average of 63.9 mm in January to 90.5 mm in June (Environment Canada, 1991).

1.1.3 Hydrology

Bear Creek and its tributaries flow in a southwesterly direction and drain an area of approximately 618 km^2. The waters of Bear Creek join with Black Creek at Wilkesport to form the North Sydenham River. The North Sydenham joins the Sydenham River at Wallaceburg.

The drainage network is shown in Figure 3. The watershed consists of Bear Creek and three main tributaries; Little Bear Creek, Buttermilk Creek and Nichol Creek. A large

Figure 2a. Temperature and Precipitation Profile for Petrolia, Ontario.

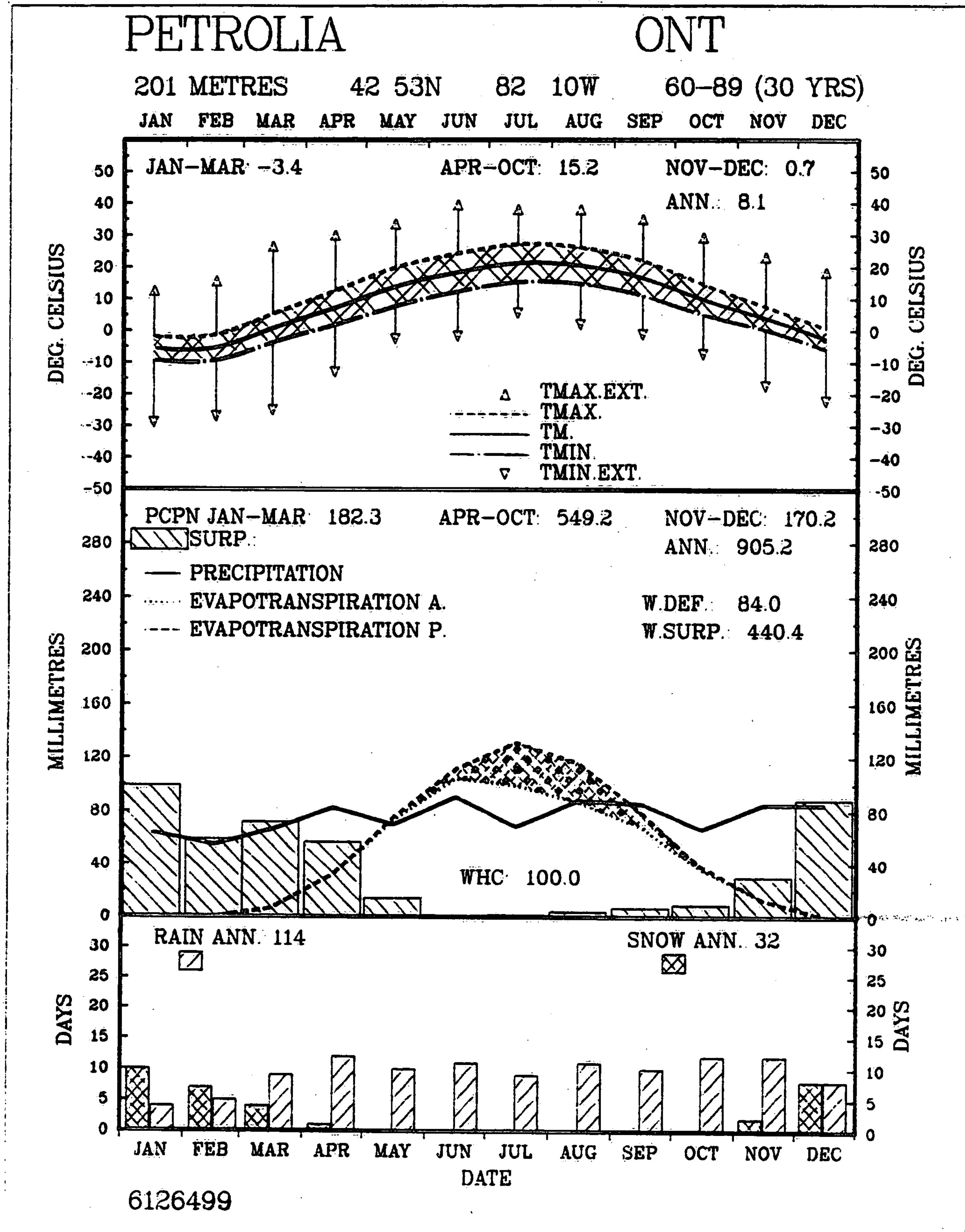
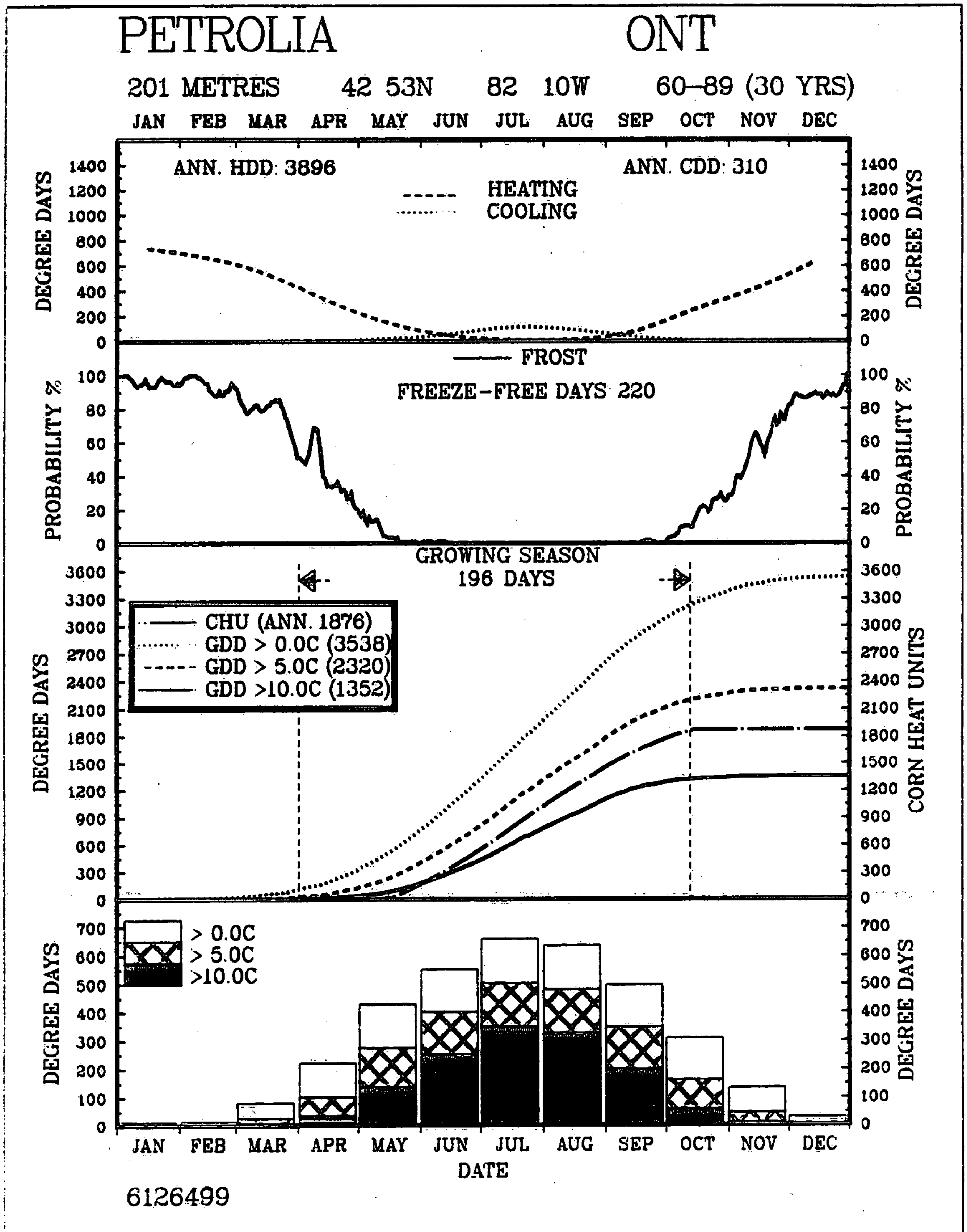


Figure 2b. Degree Day and Heat Unit Profile for Petrolia, Ontario.



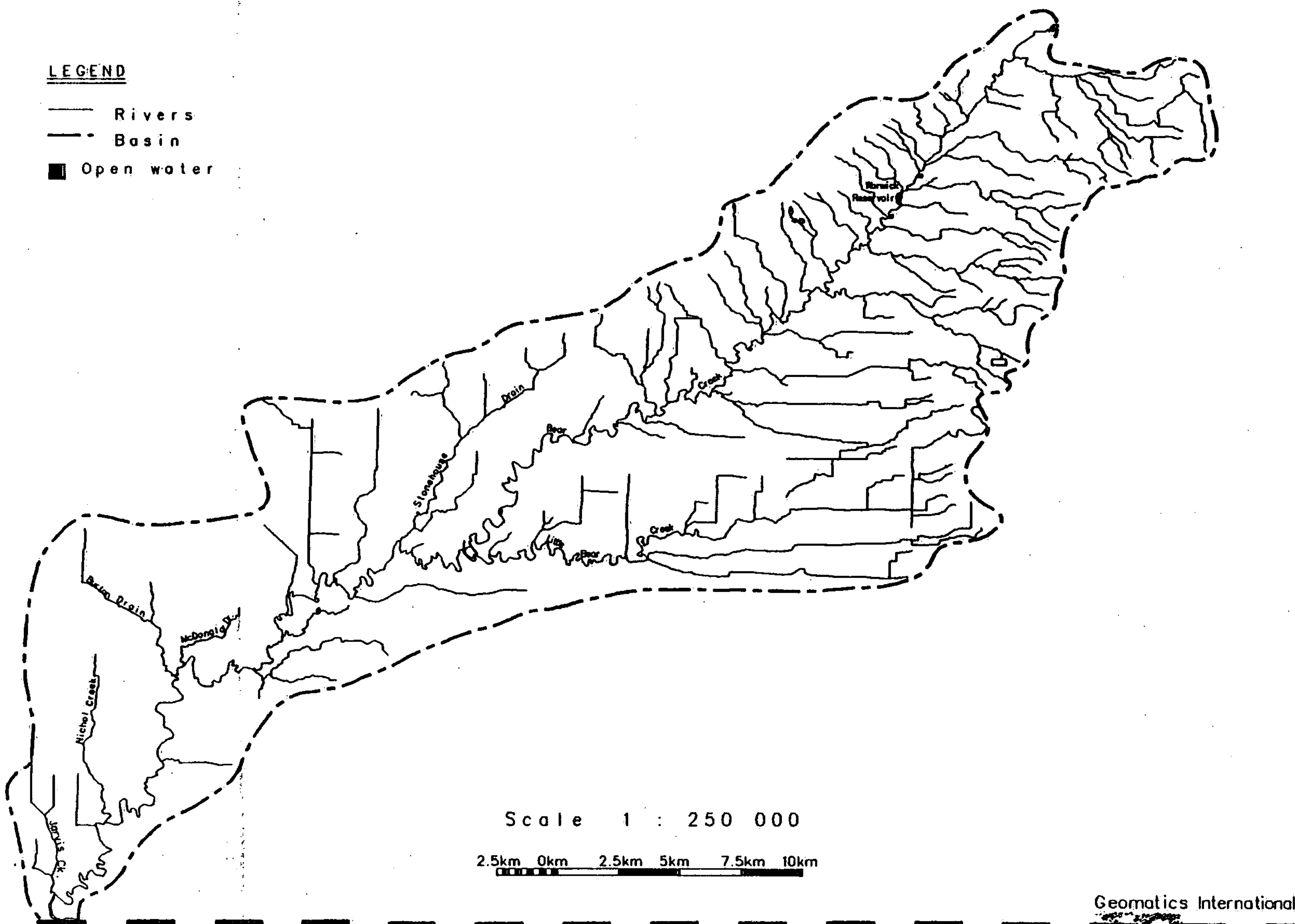
portion of the basin is under the influence of artificial drainage. Some of the larger systems supplying Bear Creek are Stonehouse, McDonald and Burton Drains.

Topography in the basin is quite gentle. The upper reaches flow from an elevation of between 230 and 250 metres above sea level (asl), while the confluence of Bear and Black Creeks at the North Sydenham lies at 190 metres asl. Maximum relief is thus 80 metres along a distance of approximately 55 km, producing a slope of only 1:688. The combination of the flat topography and the poorly drained clay plains results in the need for extensive artificial drainage networks.

The headwaters of Bear Creek originate south of the town of Arkona between the Wyoming and Seaforth Moraines. From the till moraines and till plain the water course moves southwest over a sand plain at Warwick, before emerging onto a large bevelled till plain.

The combination of the shallow slope and the semi-impervious till plain produce a meandering course for the river system to follow. Gullying is most common along the slopes of the moraines in the northern section of the watershed, while the remainder of the basin undergoes the slow process of downcutting by the waters of Bear Creek. The moraines, with their coarse sediments, provide the area with adequate supplies of ground water at shallow depth. The Warwick area had, at one time, several productive artesian

Figure 3
MAJOR RIVERS OF THE BEAR CREEK BASIN



wells. However, heavy consumption by the town of Thedford has greatly lowered the water table, and flow has all but ceased (Quinlan, 1989).

As part of the evaluation of this watershed for the establishment of federal water quality monitoring stations, four sub-basins were delineated. Sub-basin boundaries within the Bear Creek basin are shown in Figure 4, and their corresponding area presented in Table 1. These sub-basins were identified based on a preliminary assessment of land use (OMAF, 1990), drainage patterns (National Topographic Series Maps), and location of existing water flow and water quality monitoring stations (Environment Canada/MOE).

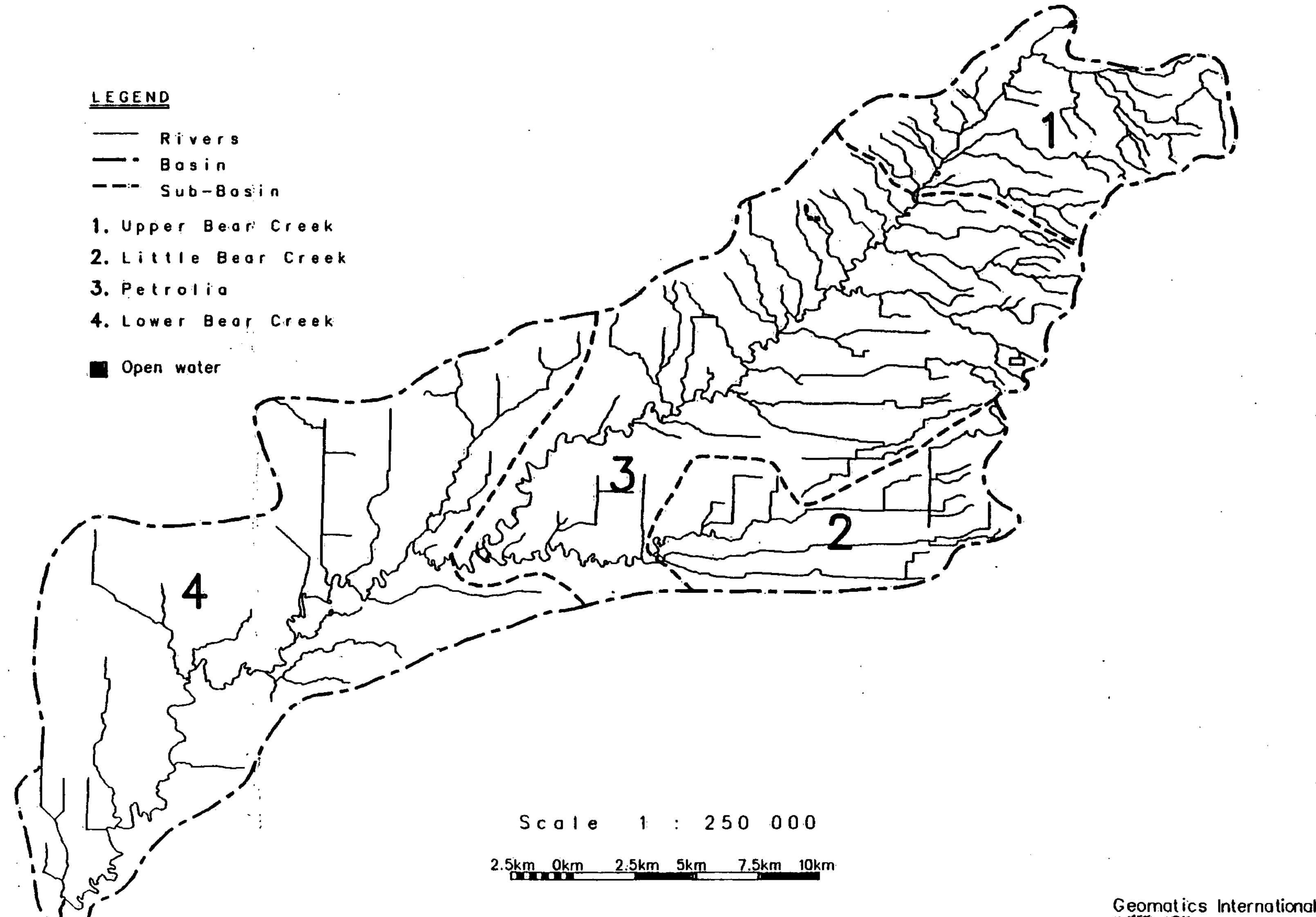
Table 1: Sub-basin Areas Within the Bear Creek Basin

SUB-BASIN	AREA (ha)	% TOTAL BASIN
LITTLE BEAR CREEK	6595	10.7
UPPER BEAR CREEK	7972	12.9
LOWER BEAR CREEK	24578	39.8
PETROLIA	22608	36.6
TOTAL BASIN	61753	100.0

1.1.4 Bedrock Geology

The surface deposits of the Bear Creek basin are underlain by three separate Paleozoic bedrock units: the Hamilton Formation; the Kettle Point Formation; and the Port

Figure 4
SUB-BASINS WITHIN THE BEAR CREEK BASIN



Lambton Group (Figure 5). Sub-basin percentages of underlying bedrock types are provided in Table 2.

Table 2: Bedrock Geology of Bear Creek Watershed by Sub-basin

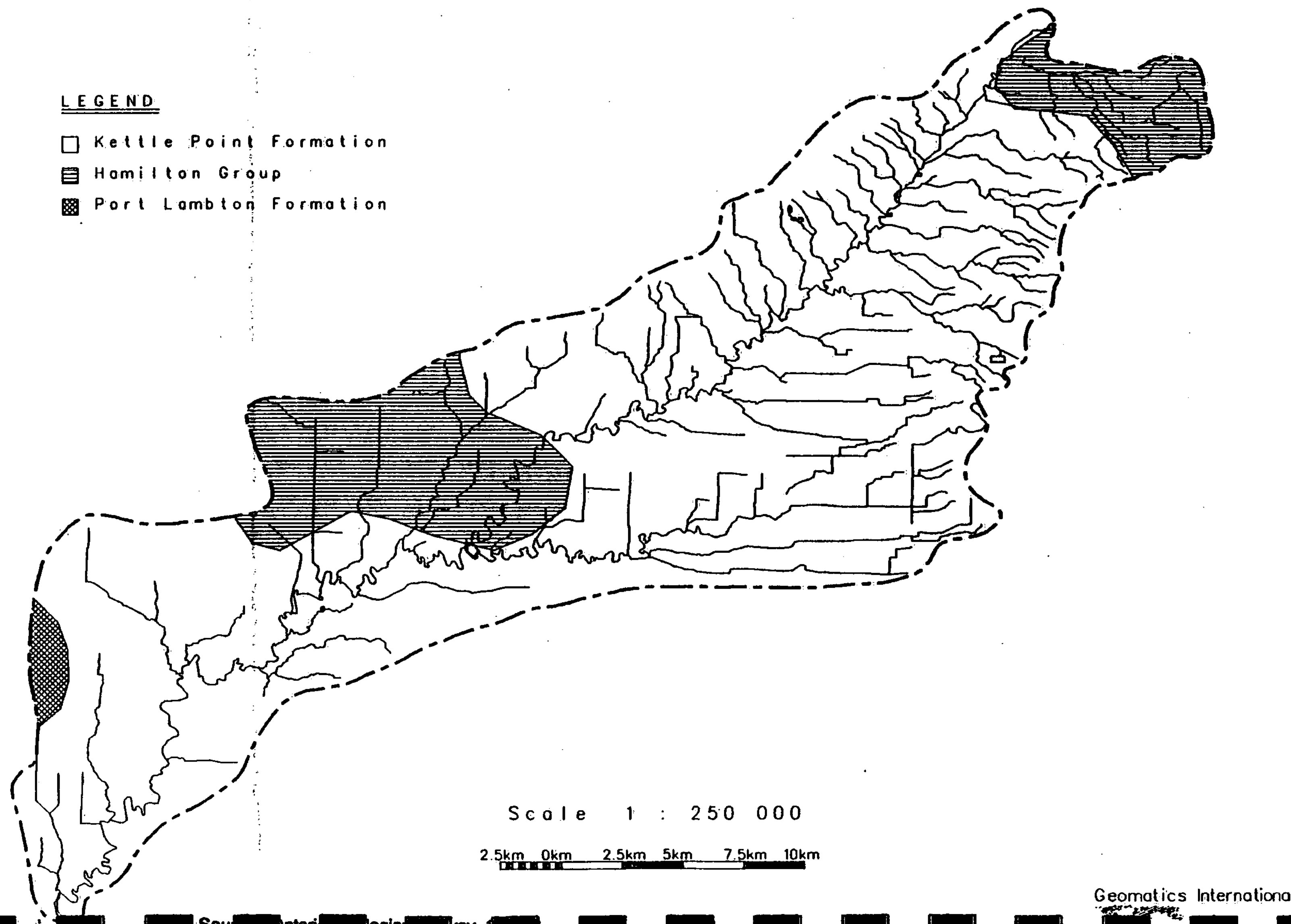
	LITTLE BEAR CREEK (%)	UPPER BEAR CREEK (%)	LOWER BEAR CREEK (%)	PETROLIA (%)	TOTAL BEAR CREEK BASIN (%)
KETTLE POINT FORMATION	100	65.9	75.1	93.9	83.5
HAMILTON GROUP	0.0	34.1	22.5	6.1	15.6
PORT LAMBTON FORMATION	0.0	0.0	2.3	0.0	0.9
TOTAL SUB-BASIN (ha)	6595.1	7972.2	24578.0	22607.9	61753.2

Source: OGS, 1991; Hewitt, 1972.

The upper reaches of Bear Creek are underlain by the Middle Devonian Hamilton Formation. Composed primarily of grey shale with interbeds of cherty limestone, this Formation ranges in thickness from 5 to 100 m (Hewitt, 1972). The shales are quarried to the north of the drainage basin, around Thedford and Arkona, for brick and tile production.

Flowing southwest, the creek enters an area underlain by the Upper Devonian black shales of the Kettle Point Formation. This Formation varies in thickness between approximately 10 and 90 metres and consists of thin bedded, fissile, grey to black, bituminous shale (Hewitt, 1972).

Figure 5
BEDROCK GEOLOGY OF THE BEAR CREEK BASIN



Sou[redacted]ntari[redacted]ogica[redacted]vey, 1[redacted]

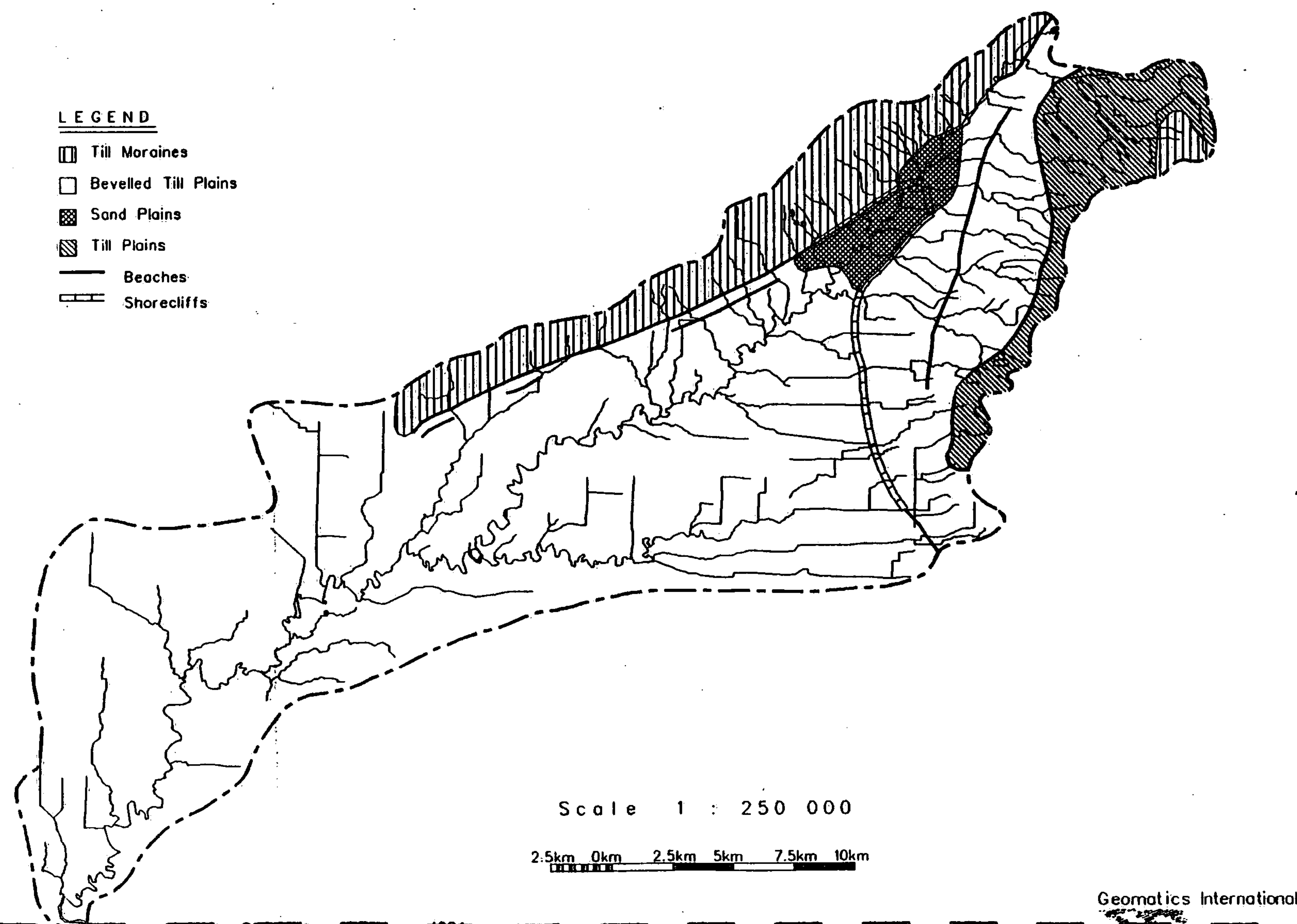
Inliers of older Hamilton Formation shales can be found in the Kettle Point Formation (Ontario Geological Survey, 1991). The largest of these inliers surrounds the town of Petrolia.The Port Lambton Group shales are found to the west of Brigden south of a fault line (Ontario Geological Survey, 1991). Hewitt (1972) describes this group of Upper Devonian rocks as light-grey fissile shales, siltstones, and light-grey sandstones.

1.1.5 Surficial Geology

The surface morphology of the Bear Creek drainage basin reflects significant glacial influence with minor lacustrine deposition (Figure 6). This region of Southwestern Ontario was under the cover of the Huron Ice lobe of the Laurentian Ice sheet, followed by inundation of glacial Lakes Maumee, Whittlesey and Warren, along with several smaller lakes. Low lying gravel beach ridges can be found flanking moraines in this drainage basin. Areal distribution of the surficial features are broken down by sub-basin in Table 3.

The headwaters of Bear Creek originate between the Seaforth Moraine to the east and the Wyoming Moraine to the northwest. These surface features are part of the physiographic region of the Horseshoe Moraines (Chapman and Putnam, 1984). The Seaforth Moraine, deposited pre-Port Huron advance, is the older of the two and consists of a brown clay till. Much of the southern extent of this moraine was originally

Figure 6
SURFICIAL GEOLOGY OF THE BEAR CREEK BASIN



[redacted]s: C[redacted]n ar[redacted]ham, [redacted] deposited under the waters of glacial Lake Maumee resulting in a suppressed topography. Surrounding the Seaforth Moraine lies an area of undrumlinized till plain.

The Wyoming Moraine was formed during the Port Huron re-advance and serves as an important marker of one stage of ice retreat (Chapman and Putnam, 1984). The moraine was deposited as a single broad, clay till ridge, under the waters of Lake Whittlesey. At Warwick, a small sand plain was formed as outwash along the front of the retreating glacier.

Chapman and Putnam (1984) classified the remainder of the basin as part of the St. Clair Clay Plains physiographic region. This region consists of bevelled clay-till plains of little relief, with undulations between 175 and 215 metres above sea level. Most of the area has been smoothed by shallow deposits of lacustrine clay lying between till knobs.

Table 3: Surficial Geology of Bear Creek Watershed by Sub-basin

	LITTLE BEAR CREEK (%)	UPPER BEAR CREEK (%)	LOWER BEAR CREEK (%)	PETROLIA (%)	TOTAL BEAR CREEK BASIN (%)
MORAINE	0.0	29.0	5.7	13.6	11.0
BEVELLED TILL PLAIN	95.2	26.5	94.3	78.6	79.9
SAND PLAIN	0.0	6.8	0.0	4.5	2.5
TILL PLAIN	4.8	37.7	0.0	3.3	6.6
TOTAL SUB-BASIN (ha)	6595.0	7972.2	24578.1	6595.0	61753.2

Source: Chapman and Putnam, 1984.

1.1.6 Soils

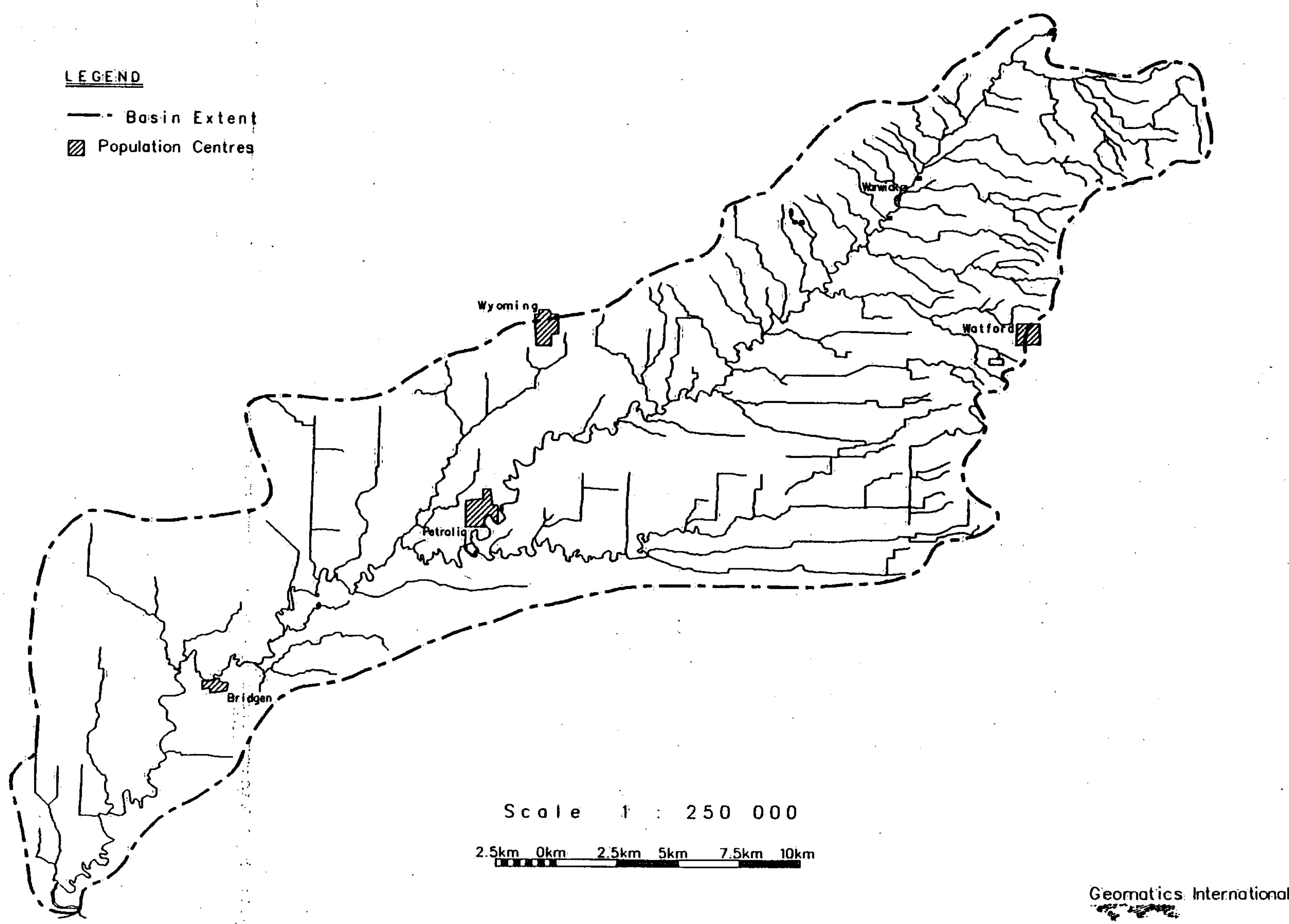
The soils of the Bear Creek watershed are comprised primarily of very fine textured soils formed on till or lacustrine deposits. Four soil families dominate in the basin: Perth; Renfrew; Lincoln-Haldiman; and Lincoln (Hoffman et al., 1964).

The Perth soils, found in the northern portion of the basin, are classified as grey-brown podzolic with a clay loam texture and imperfect drainage. The Renfrew family of soils are described as grey humic gleysols, consisting of clay loam, imperfect drainage and located in the areas of Little Bear Creek. The main portion of the Bear Creek basin consist of the Lincoln-Haldiman soil family and are characterized by clay, poor to imperfect drainage, ranging from dark grey gleysolic to grey-brown podzolic soils. The Lincoln soil series are found to the south of the watershed on the clay plain. These dark grey gleysolic soils have clay texture and are poorly drained.

1.1.7 Land Use Characteristics

The Bear Creek watershed drains portions of seven townships in Lambton County. The town of Petrolia, population 4,168, is the largest urban centre within the basin. Other villages include Watford (1,467), Wyoming (1,824) and Bridgen (647) (Ministry of Municipal Affairs, 1990). The rural population thrives at over 6500 people. Urban centres, located within the basin, are illustrated in Figure 7.

Figure 7
POPULATION CENTRES WITHIN THE BEAR CREEK BASIN



Lambton County accounts for approximately 69 percent of all natural gas and oil production in the Ministry of Natural Resources district of Chatham (MNR, 1983). Bear Creek and its tributaries overlie several producing pools of both types of fossil fuels. The first commercial oil field in North America was operational in 1858 to the south of the Bear Creek basin in the town of Oil Springs.

1.1.8 Agriculture

Land Use System Classification

Agricultural Land Use Systems maps based on the Agricultural Resource Inventory (ARI) (OMAF, 1988) have been used to describe land use within each of the sub-basins examined during this study. Until recently, land use information tended to be general in scope and valid for a short period of time. The ARI evaluates the mix of crops in a region and classifies their proportion, thereby identifying systems that are valid over a long period of time. Up to twenty different land uses are classified by the ARI. These are summarized in Table 4. Generalized land uses are outlined by sub-basin for the watershed in Table 5. Complete land use by sub-basin is provided in Appendix I.

Between the years of 1981 and 1986 the total number of census farms in Lambton County decreased by 7.1 percent from 3,151 to 2,923 ha. During the same period the

Table 4. Agriculture Land Use System Classification Scheme.

Symbol	Land Use System	Description
P	Monoculture	A contiguous arrangement of four or more fields, or a minimum of 16 ha. of corn or small grains.
C	Corn System	A contiguous arrangement of four or more fields of uniform size. 40-75% of the area is corn, the remainder is a mixture of hay, pasture and sometimes grain.
M	Mixed System	A contiguous arrangement of four or more fields of uniform size. There must be some corn, but less than 40% of the area. The remainder is a mixture of hay, grain and pasture.
H	Hay System	A contiguous arrangement of four or more fields with a mixyure of hay, grain, and pasture, the largest portion being hay.
HG	Pasture System	A contiguous arrangement of two or more fields with a mixture of hay and pasture, about equal quanitites of each.
G	Grazing System	A contiguous arrangement of four or more fields or a minimum of 16 ha with no field separation of either permanent pasture or native grass pasture, or a combination. It may have minor amounts (< 10%) of hay.
A1	Idle Agricultural	Land idle for 1-10 years and in a state of reversion Land to natural vegetation.
A2	Idle Agricultural Land	Land idle for more than 10 years and supporting native vegetation.
Z	Woodland	Forest cover with a minimum of 45% crown closure density and not less than half a hectare in area.
Zp	Pastured Woodland	Woodlands that are grazed by livestock.
Zr	Reforestation	Land supporting a stand of artificially stocked trees.
B	Built up	Urban related land uses.
X	Swamp, Marsh	Supports vegetation characteristic of a poorly drained area.
E1	Extraction	Sand and gravel pits and quarries.
E2	Extraction	Topsoil removal.
T	Sod Farms	Public or commercial sales.
R	Recreation	Parks, golf courses, campgrounds, etc.
K	Specialty Agriculture	Orchards, market gardens, etc.
W	Water	Rivers, streams, etc.

area of census farms in Lambton County decreased from 234,151.5 ha to 229,541.7 ha, or by 4,609.8 ha (2%).

Table 5: Generalized Land Use Percentages for the Bear Creek Sub-Basins

	LITTLE BEAR CREEK	UPPER BEAR CREEK	LOWER BEAR CREEK	PETROLIA	Total Basin
% OF SUB-BASIN UNDER PCM: P,C,M,MG	89.4	80.3	77.8	76.9	79.1
% OF SUB-BASIN UNDER HHG: H,HG,G,Zp	1.0	5.4	5.7	5.0	4.8
% OF SUB-BASIN UNDER MG: PE,CH,PC,O,V,OV, VO,Be,KF,KM,KN	0.0	0.7	0.3	0.0	0.2
% OF SUB-BASIN UNDER IDLE	0.6	0.4	1.8	0.8	1.1
% OF SUB-BASIN UNDER URBAN	0.0	1.1	2.0	5.6	3.0
% OF SUB-BASIN UNDER RECREATION	0.0	0.0	0.1	0.0	0.1
% OF SUB-BASIN UNDER SOD FARM	0.0	0.0	0.0	0.1	0.0
% OF SUB-BASIN UNDER TOBACCO	0.0	0.0	0.0	0.0	0.0
% OF SUB-BASIN UNDER FOREST	9.0	11.2	12.1	11.1	11.3
EXTRACTION	0.0	0.2	0.0	0.0	0.1
NOT CLASSIFIED	0.0	0.6	0.1	0.4	0.3

Source: OMAF, 1989a

Corn/row cropping accounts for 79.1 percent of total land use in the Bear Creek drainage basin, by far the largest area classification. Forest cover is found on 11.3 percent of the area while hay/grazing systems cover 4.8 percent and urban centres 3.0 percent.

Each of the four sub-basins have land use values for corn/row cropping systems exceeding 70 percent of their total areas. The Little Bear Creek sub-basin tops the list at 89.4 percent and the Upper Bear Creek is second with 80.3 percent. Lower Bear Creek sub-basin has the largest cover of hay/grazing systems at 5.7 percent. The Lower Bear Creek sub-basin has the highest forest cover at 12.1 percent of the area, while the Little Bear Creek sub-basin has the lowest amount of forested land at 9.0 percent.

Livestock Operations

Table 6 lists the 1988 livestock population figures for Lambton County (OMAF, 1989a). Livestock operations within Lambton County are limited as indicated by the population table. For each of the different livestock categories, Lambton county accounts for approximately ten to twelve percent of the total animal population in southwestern Ontario. With respect to the total land coverage Lambton County accounts for approximately 14 percent of southwestern Ontario.

Table 6: 1988 Livestock Population by County

COUNTY	TOTAL CATTLE	TOTAL PIGS	TOTAL SHEEP & LAMBS	TOTAL CHICKENS	TOTAL TURKEYS
LAMBTON	52500	249100	5000	960349	220635

Source: OMAF, 1989a

With an increase in livestock productivity the removal of animal waste becomes increasing difficult. Intensive operations and confinement housing means the manure must be collected and disposed of, instead of being naturally absorbed in barnyards or pastureland. Storage is difficult and wastes often get dumped as opposed to being saved as fertilizer for growing crops.

The Upper Bear Creek sub-basin lies within a region known as "hogs-triangle" (Quinlan, 1989), which runs from Watford north to Thedford and west to Forest. This triangle contains approximately two thirds of Lambton Counties hog operations. As of 1989, the St. Clair Region Conservation Authority had identified 28 hog farms, 14 dairy operations, 14 beef cattle, 8 poultry farms and 3 sheep/goat outfits in the Upper Bear Creek watershed. Several manure spills have been identified over the past several years in the Upper Bear Creek sub-basin (Quinlan, 1989).

Fertilizer Use

Table 7 lists the total 1985 tonnage of fertilizer applied to agricultural lands within Lambton County. In 1985 Lambton County ranked eleventh in Ontario for Fertilizer application rates (Environment Canada, 1991a).

According to the St. Clair Region Conservation Authority (Quinlan, 1989) as many as one quarter of the farmers may be over-fertilizing their lands. Conservation tillage practices, buffer strips along drains, and windbreaks are not widely used in this watershed.

Many farmers are utilizing manure as fertilizer. Application rates were reported and calculated to be approximately 3,000 to 4,000 gallons per acre, which is within the MOE guidelines for agricultural land spreading of liquid manure. Unfortunately, in order to keep manure storage tanks from overflowing, farmers spread manure during the winter months. This application onto frozen ground does not absorb and often ends up as part of the spring freshet, causing pollution problems (Quinlan, 1989).

Table 7: Usage of Fertilizer in Lambton County in 1985

COUNTY	IMPROVED LAND (ha)	TOTAL APPLIED (tonnes)	N APPLIED (tonnes)	P APPLIED (tonnes)	K APPLIED (tonnes)	APPLICATION RATE (kg/ha)
LAMBTON	203364	57035	12034	6958	10380	280.5

Source: OMAF, 1989a; The Fertilizer Institute of Ontario. 1989.

Agricultural/Artificial Drainage

Negative effects on both water quantity and quality may potentially result from artificial drainage. Flood peaks on river systems may increase and baseflow decline. The reaction time of the river system becomes shorter thus magnifying flood peaks. Effects on water quality vary considerably depending on soil type and land use practices. The most noticeable change in water quality resulting from increased drainage is elevated levels of turbidity and suspended solids from increased erosion within the watercourses. Improperly installed tile drains can also lead to water quality impairment (Saugeen Valley Conservation Authority, 1983).

The St. Clair Region Conservation Authority identified 310 tile outlets of various sizes in the Upper Bear Creek sub-basin alone. As this sub-basin makes up approximately 13% of the watershed the total number of tile beds could be upwards of 2000. The implications of this many tile drain outlets on water quality could be very significant.

The areas of artificial drainage outlined on Figure 8 and the accompanying area values on Table 8, are obtained from the NTS map sheets for the Bear Creek drainage basin. Areas of obvious man-made drains were mapped and areas calculated. This is a rough estimate of artificial drainage, as not all drains are labelled or obvious.

Table 8: Drainage Types by Percent Area in the Bear Creek Basin

DRAINAGE TYPE	LITTLE BEAR CREEK	UPPER BEAR CREEK	LOWER BEAR CREEK	PETROLIA	BEAR CREEK BASIN
NATURAL	8.4	94.4	44.1	70.8	56.5
ARTIFICIAL	91.6	5.6	55.9	29.2	43.5

1.1.9 Municipal and Industrial Discharges

Municipal

In 1988 and 1989 there were a total of four sewage treatment facilities operating within the Bear Creek watershed. These include a lagoon at Brigden (Moore Twnshp.), a Water Pollution Control Plant (WPCP) and lagoon at Petrolia (Enniskillen Twnshp.), a

Figure 8

ARTIFICIAL DRAINAGE SYSTEMS OF THE BEAR CREEK BASIN

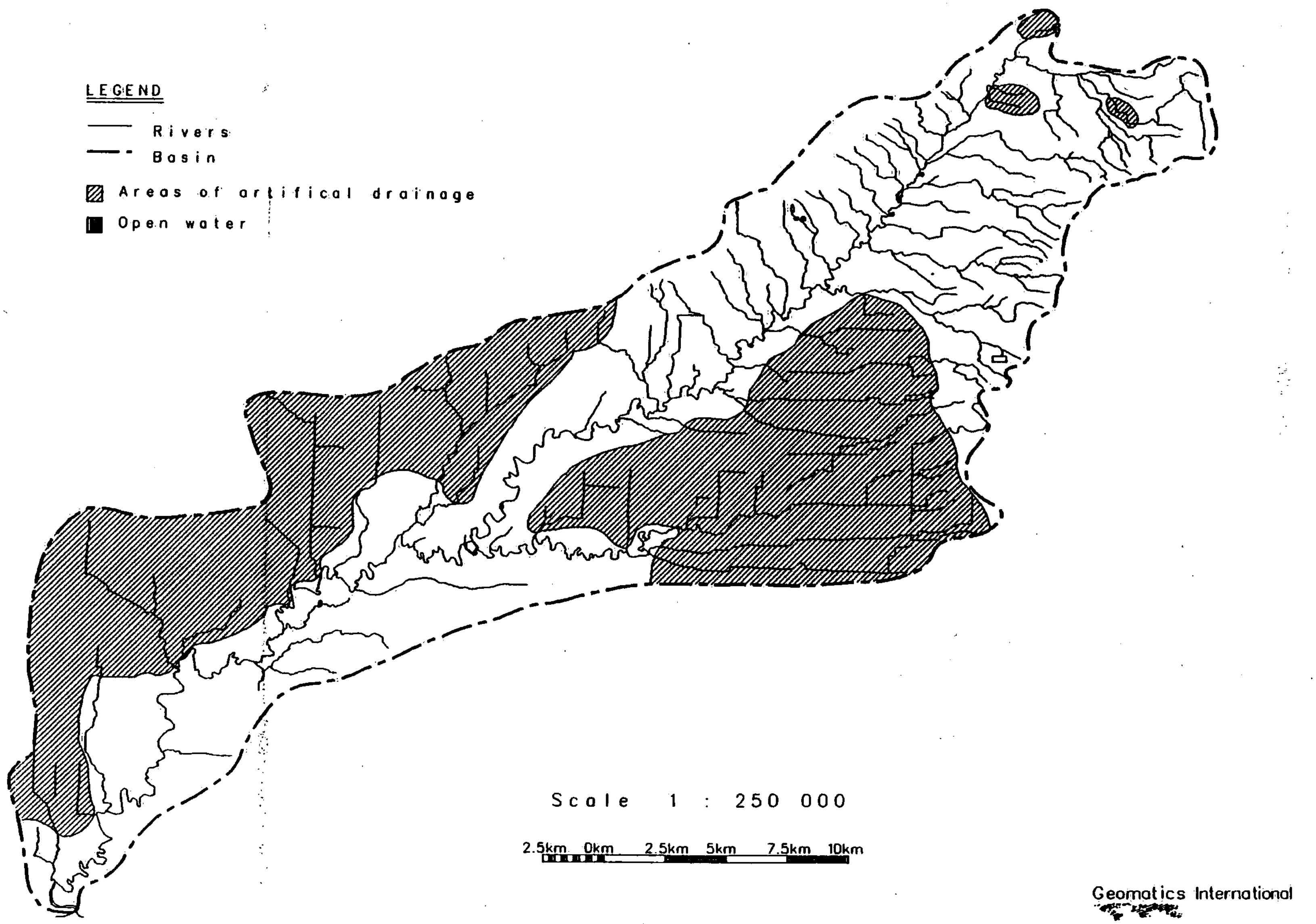
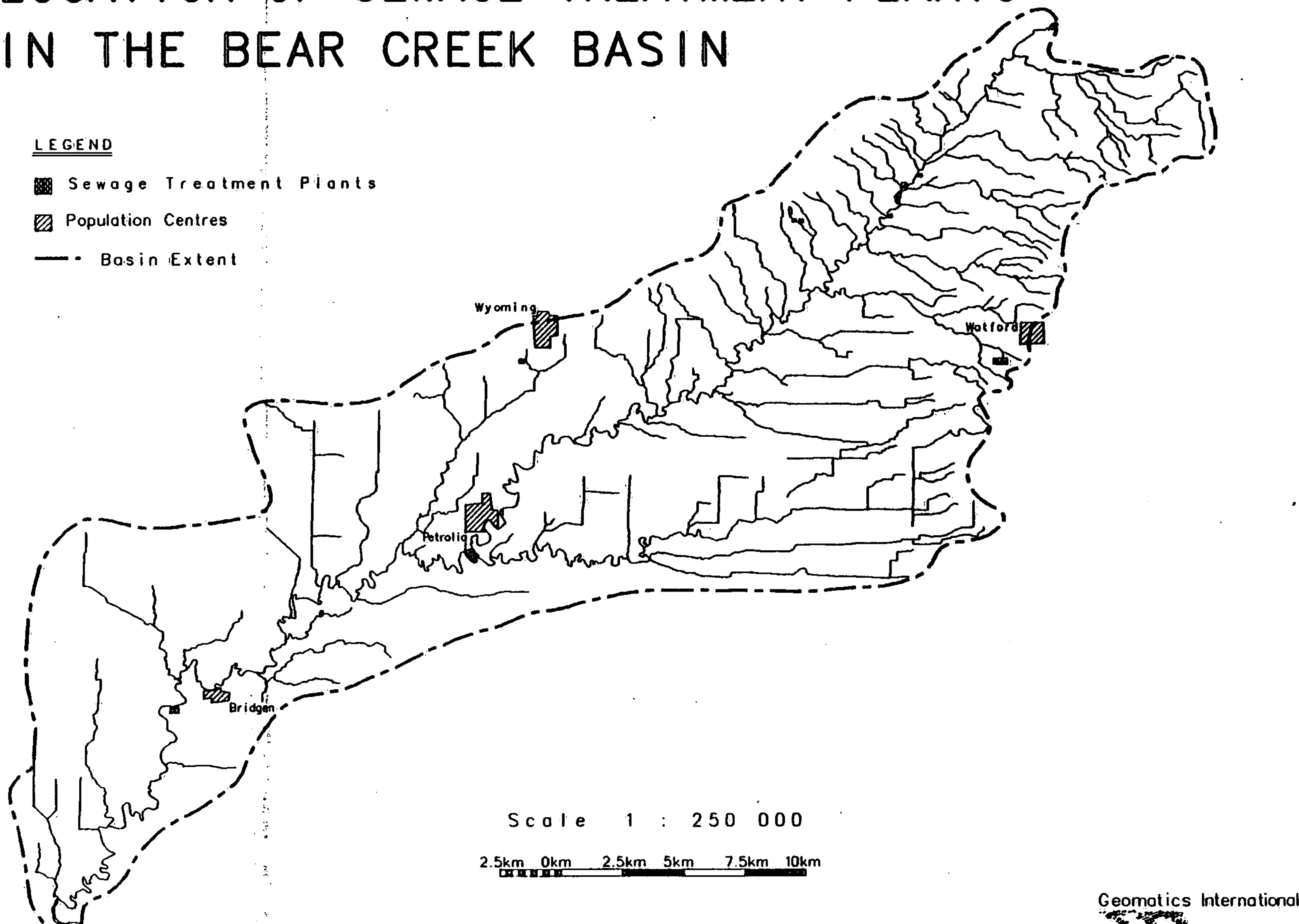


Figure 9
LOCATION OF SEWAGE TREATMENT PLANTS IN THE BEAR CREEK BASIN



Source: Ministry of the Environment, 1989a

WPCP Wyoming (Plympton Twnshp.), and a lagoon at Watford (Warwick Twnshp.) (Figure 9).

The Brigden lagoon is the only one discharging directly into Bear Creek. Petrolia discharges to Little Bear Creek, Wyoming to Stonehouse Drain and Watford discharges into a small headwater tributary of Bear Creek. Effluent from all four facilities was in compliance with MOE criteria for total phosphorous, suspended solids and BOD5 during 1988 (MOE, 1989a).

These sewage treatment facilities service a total population of 8,067, making up approximately 53.6% of the watershed population. The remaining population of the watershed (approximately 6,976) rely on septic systems or tile beds.

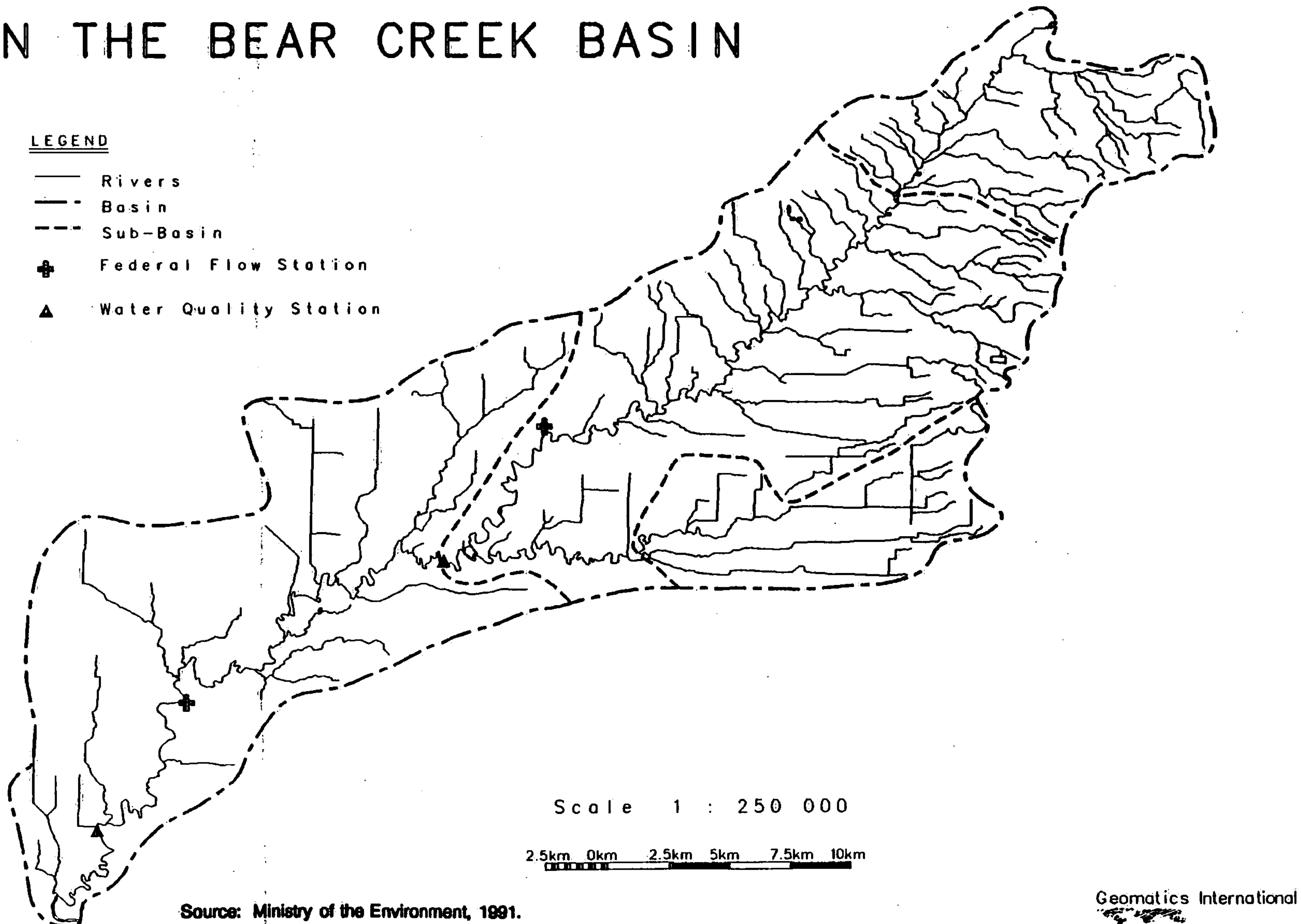
Industrial

No industrial direct discharge was identified by the MOE within the Bear Creek watershed during 1988 (MOE, 1989b).

1.1.10 Water Quantity

Two federal hydrometric stations are in operation within the Bear Creek drainage basin. The first is near Petrolia and the second below Brigden (Figure 10). Figure 11 illustrates

Figure 10
LOCATION OF WATER MONITORING STATIONS IN THE BEAR CREEK BASIN



Source: Ministry of the Environment, 1991.
Environment Canada, 1990.

mean annual flow data and average monthly flow data for the station near Petrolia. Monthly and annual flow data for the station south of Brigden are shown in Figure 12. The stations record unregulated flows from drainage areas of 267 km^2, near Petrolia, and 533 km^2, below Brigden (Environment Canada, 1990b).

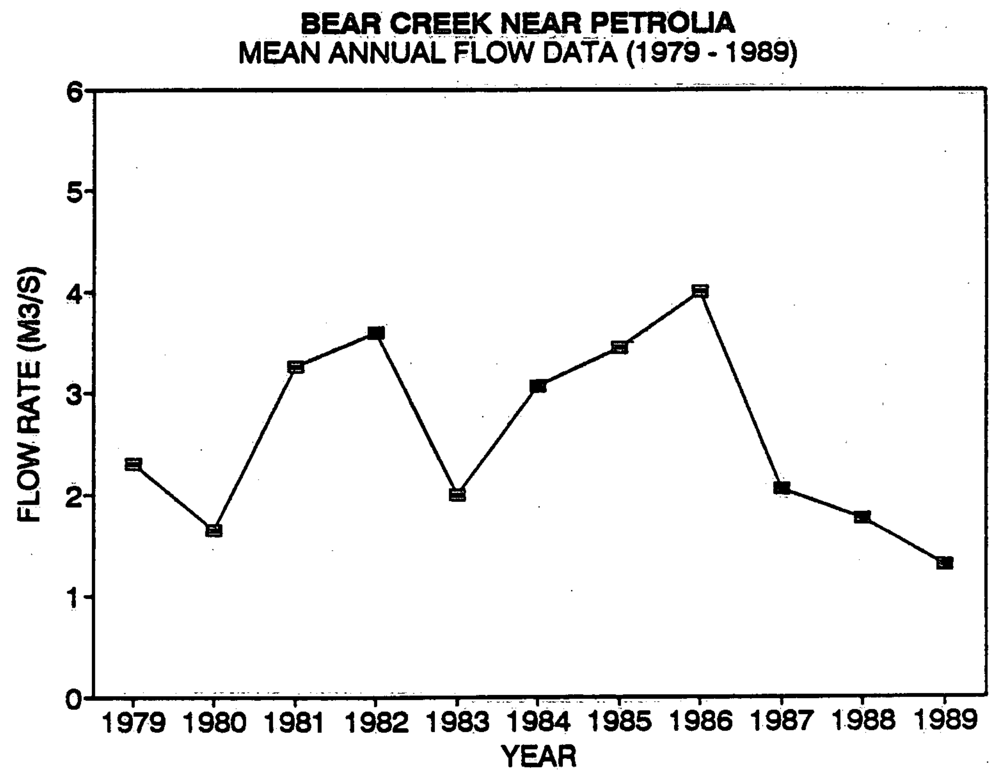
The average monthly flow data produce similar profiles for both monitoring stations. Peak flow during spring run off in March, is followed by a sharp decline and low precipitation during the summer. A slow rise in flow rates takes place through the fall and into the winter. The Brigden station consistently records flow rates at almost double those of the station near Petrolia.

The mean annual flow data show small scale variability between the two stations. Both recorded periods of low precipitation during 1983 and 1987, with continued decline from 1987 to 1989. The station near Petrolia indicated peak flow during 1986, while the station below Brigden documented 1985 as a peak flow year.

1.1.11 Water Quality

Water quality was sampled at two provincial water quality monitoring stations in the Bear Creek basin in 1991 (MOE, 1991). These stations, located west of Petrolia and northeast of the town of Avonry, have both been in operation for over ten years and were selected for this study. Figure 10 shows the locations of the selected MOE

Figure 11. Flow Data for the Petrolia Station



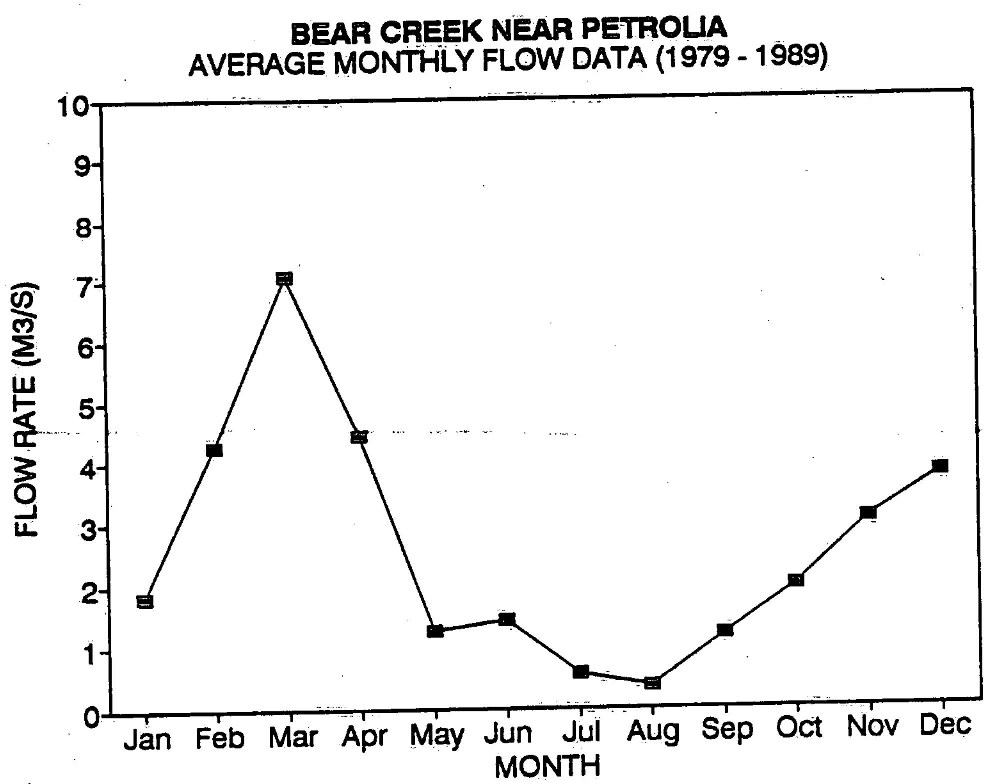
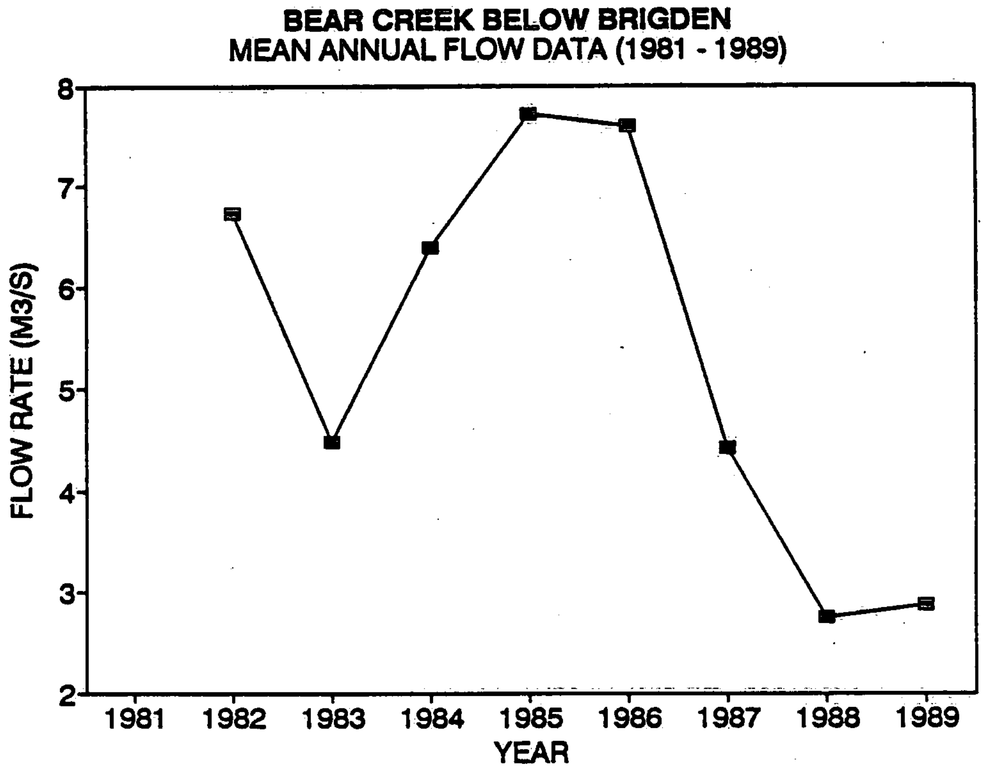
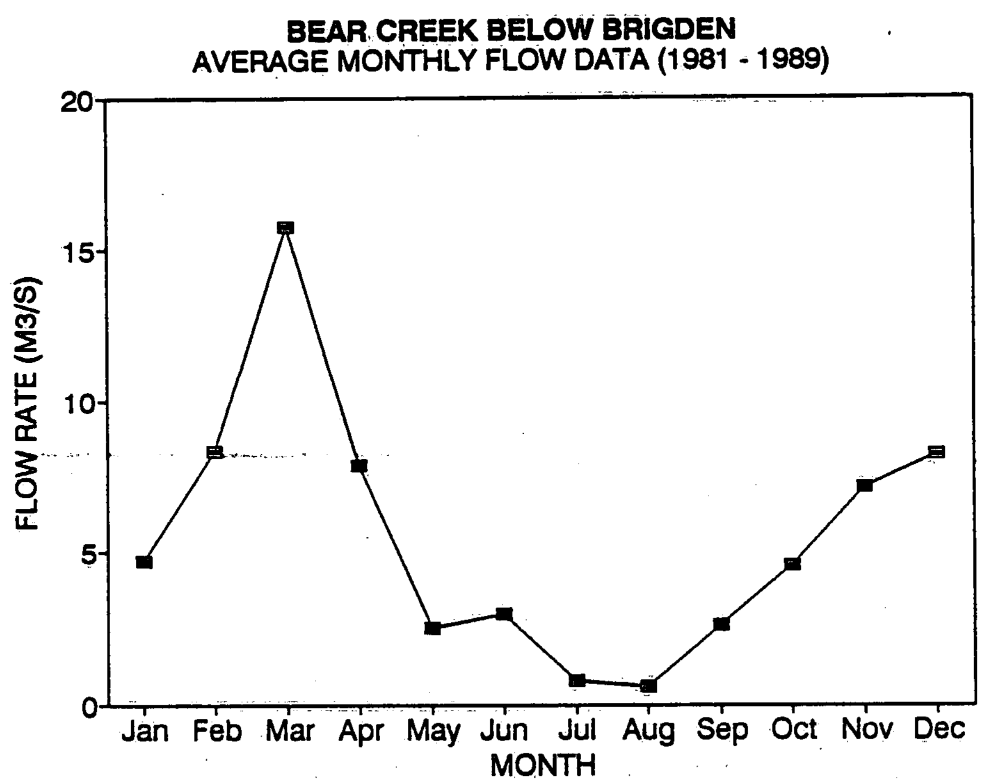


Figure 12. Flow Data for the Station South of Brigden.





monitoring stations. A third water quality station located two miles north-east of Petrolia ceased operation in 1983 and was therefore not utilized in this study. The MOE water quality monitoring stations within the study basin are set-up to analyze up to 40 parameters, however, only 13 of these parameters have been measured consistently at the Petrolia station, and only 10 were available from Avonry. The Avonry station had no metals data for the ten year period between 1980 and 1991. The limitations of the MOE water quality monitoring station data, noted by G.M. Wickware and Associates (1990a,b,c,d), are prevalent in this study. Limitations include: gaps in sampling history; variation in water sampling frequency; and changes in analytical methods.

Based on data from the period 1980-1991 (MOE, 1991), summary tables have been prepared for 13 water quality parameters, grouped into three categories: nutrients and major dissolved ions, field measurements, and metals. Metals were in fact only monitored at the Petrolia station over the ten years of record.

Nutrients and Major Dissolved Ions

Ammonia

The provincial water quality objective for un-ionized ammonia is 0.02 mg/L for protection of aquatic life (MOE, 1984). The values recorded from the water quality monitoring station are for total ammonia and must be normalized based on pH and water temperature, at the time of collection, to determine the true un-ionized ammonia value. The Petrolia station recorded a median value of 0.0013 mg/L ranging from trace amounts to 0.054 mg/L. The Avonry station showed slightly lower values for un-ionized ammonia ranging from trace amounts to 0.049 mg/L and a median value of 0.0011 mg/L (Table 9). Both stations had minor exceedences of the MOE objective.

Table 9: Chemical and Physical Analysis - Nutrients, Major Dissolved Ions

Station		Chloride (mg/L)	Un-ionized Ammonia (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Total Phosphorous (mg/L)	Sulphate (mg/L)
PETROLIA	# Obs.	122	115	122	122	83
	Mean	175.4	0.003	1.33	0.2	90.0
	Median	85.8	0.0013	1.3	0.17	82.5
	Range	13.5-1510	0.00001-0.054	0.46-4.15	0.04-1.93	22-300
AVONRY	# Obs.	122	117	122	122	84
	Mean	150.4	0.0021	1.4	0.2	97.2
	Median	92.5	0.0011	1.3	0.19	84.8
	Range	16.0-920	0.00003-0.049	0.235-3.92	0.05-0.71	12-980

Source: MOE, 1991.

Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen (TKN) measures both ammonia and organic nitrogen. Both are present in nitrogenous organic detritus from natural biological activities. No specific federal guidelines have been proposed for TKN (CCREM, 1987). Normal river waters without excessive organic inputs have a TKN range of 0.1 to 0.5 mg/L (MOE, 1984). Environmental concentrations in Canadian surface waters were recorded as ranging from 0.004 to 31.70 mg/L between 1980 and 1983 in central Canada (CCREM, 1987).

TKN values ranged between 0.46 and 4.15 mg/L at Petrolia, while Avonry ranged from 0.235 to 3.92 mg/L (Table 9). Both stations recorded a median value of 1.3 mg/L. Figure 13 plots a graph of TKN values over time. Records from both stations indicate that the Bear Creek watershed experiences excessive organic inputs.

Total Phosphorous

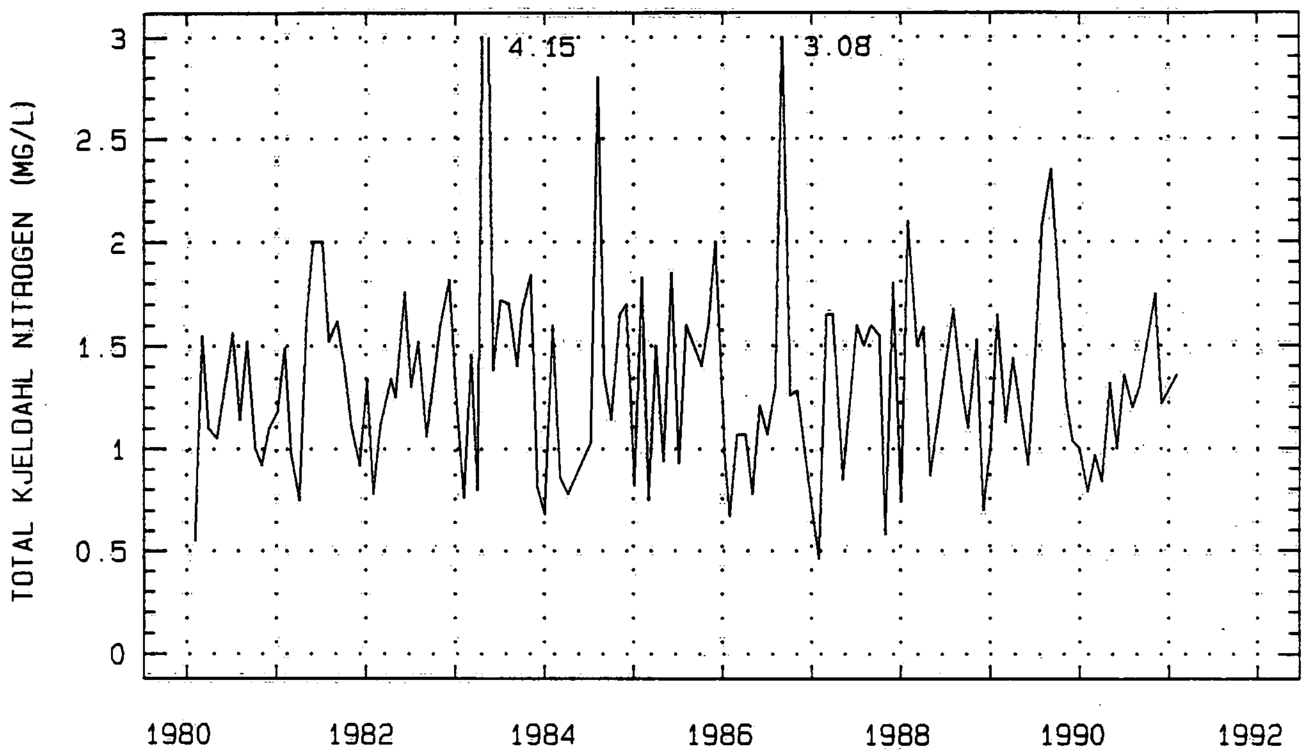
The MOE guideline for total phosphorus in a river or stream is 0.03 mg/L to eliminate excess plant growth. The readings from the Bear Creek basin for the Petrolia station indicated a median value of 0.175 mg/L, while the Avonry station was slightly higher at 0.19 mg/L. Petrolia ranged from 0.04 to 1.93 mg/L, while Avonry values ranged from 0.046 and 0.71 mg/L. Environmental concentrations in surface waters of Central Canada between 1980 and 1985 were recorded as falling between 0.001 and 0.21 mg/L (CCREM, 1987). The graph in Figure 14 indicates the phosphorous variations with time. The median values for both stations indicate that excessive plant growth may be a problem within the Bear Creek basin.

Chloride

According to the MOE (1984) drinking water guidelines, the maximum desirable concentration of chloride related to aesthetic water quality is 250 mg/L. Environmental

FIGURE 13A

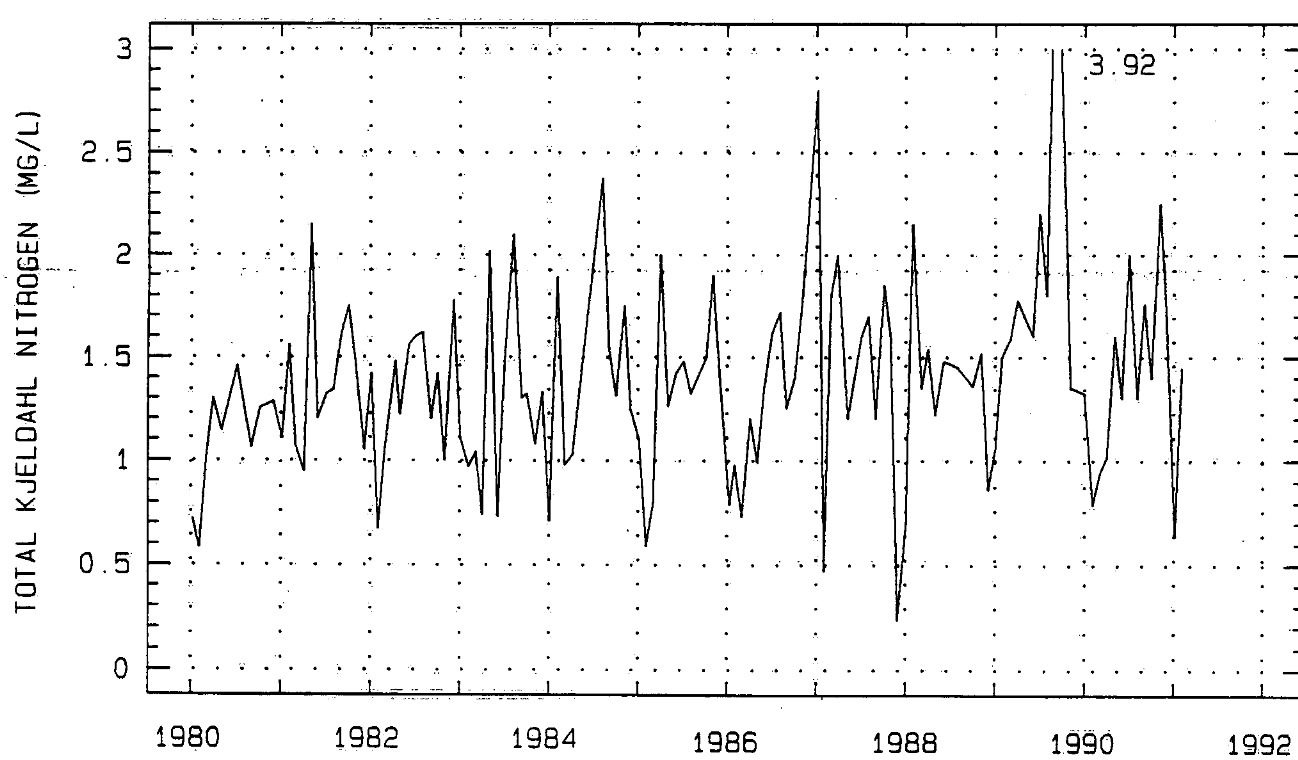
PETROLIA STATION
TOTAL KJELDAHL NITROGEN CONCENTRATION



Source: Ministry of the Environment, 1991.

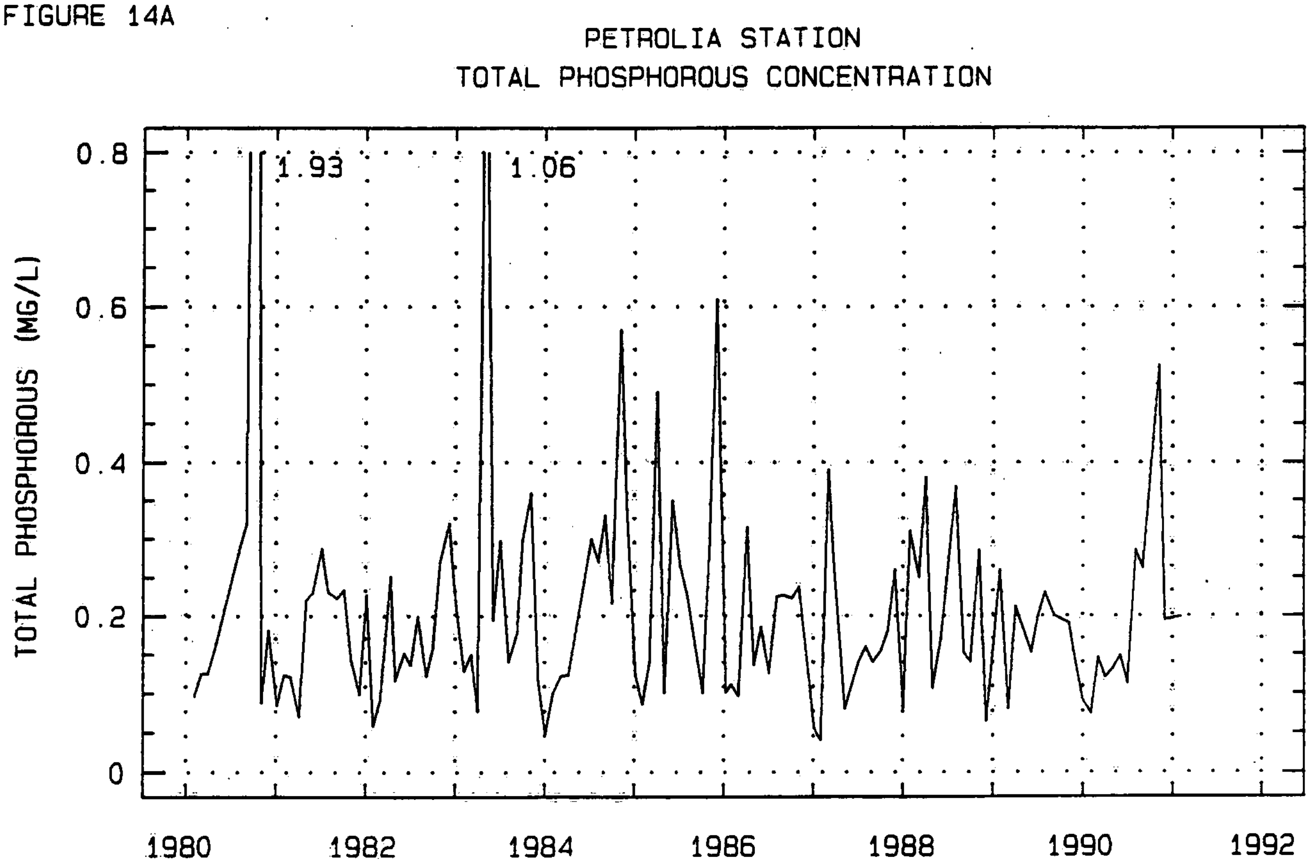
FIGURE 13B

AVONRY STATION
TOTAL KJELDAHL NITROGEN CONCENTRATION



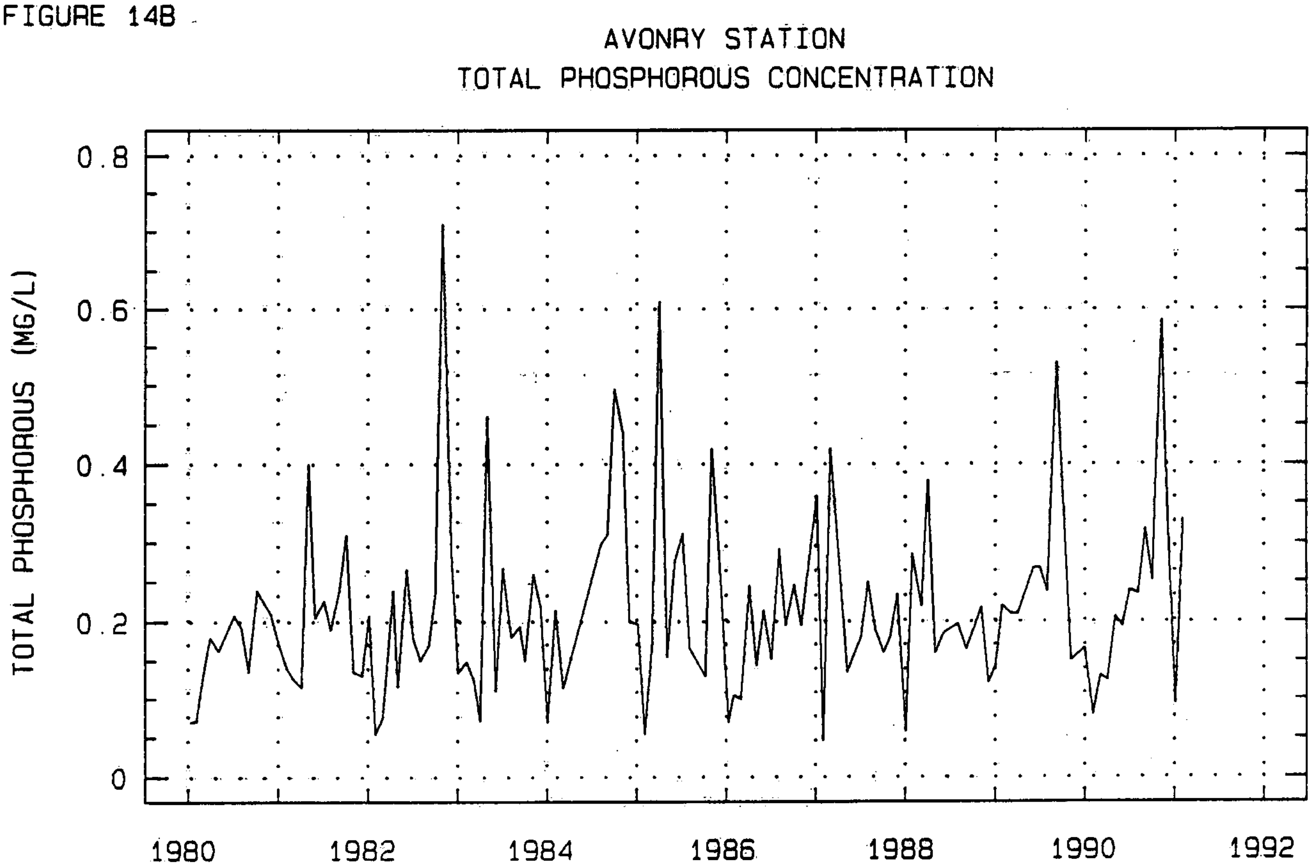
Source: Ministry of the Environment, 1991.

FIGURE 14A



Source: Ministry of the Environment, 1991.

FIGURE 14B



Source: Ministry of the Environment, 1991.

concentrations for dissolved chloride between 1980 and 1984 were 0.1 to 450 mg/L (CCREM, 1987). The Avonry station has higher chloride concentrations than does the Petrolia station (Table 9). Median values are 92.5 mg/L and 85.8 mg/L respectively. Bear Creek concentrations exhibited a wide range of values from 13.5 to 1510 mg/L at Petrolia and from 16 to 920 mg/L for Avonry. The maximum value at Petrolia occurred on September 6, 1990, while the minimum was recorded May 3, 1983. The Avonry maximum took place August 4, 1981 and the minimum on October 6, 1981. Figure 15 illustrates the chloride concentrations through time at the two monitoring stations.

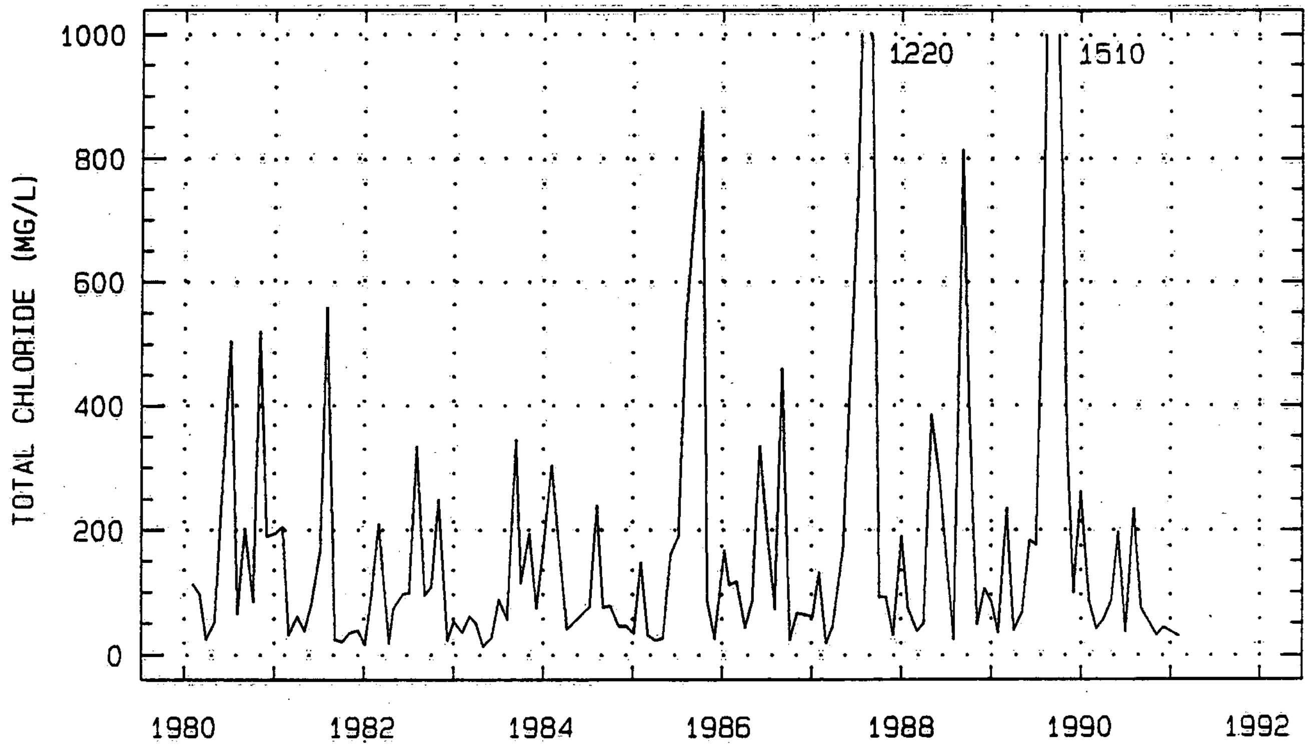
Sulphate

The maximum desirable concentrations of sulphate related to aesthetic quality for drinking water is 500 mg/L (MOE, 1984). Environmental concentrations range from non-detectable to 77.3 mg/L in central Canadian surface waters between 1980 and 1985 (CCREM, 1987).

The Petrolia water quality monitoring station recorded a median sulphate value of 82.5 mg/L, and a range from 22 to 300 mg/L over the ten year period of 1980 to 1991. During the same time period the station at Avonry had a range of values between 12 and 980 mg/L and a median of 84.8 mg/L. The maximum value at Avonry was recorded on July 9, 1985, and was the only recorded exceedence of the MOE drinking water

FIGURE 15A

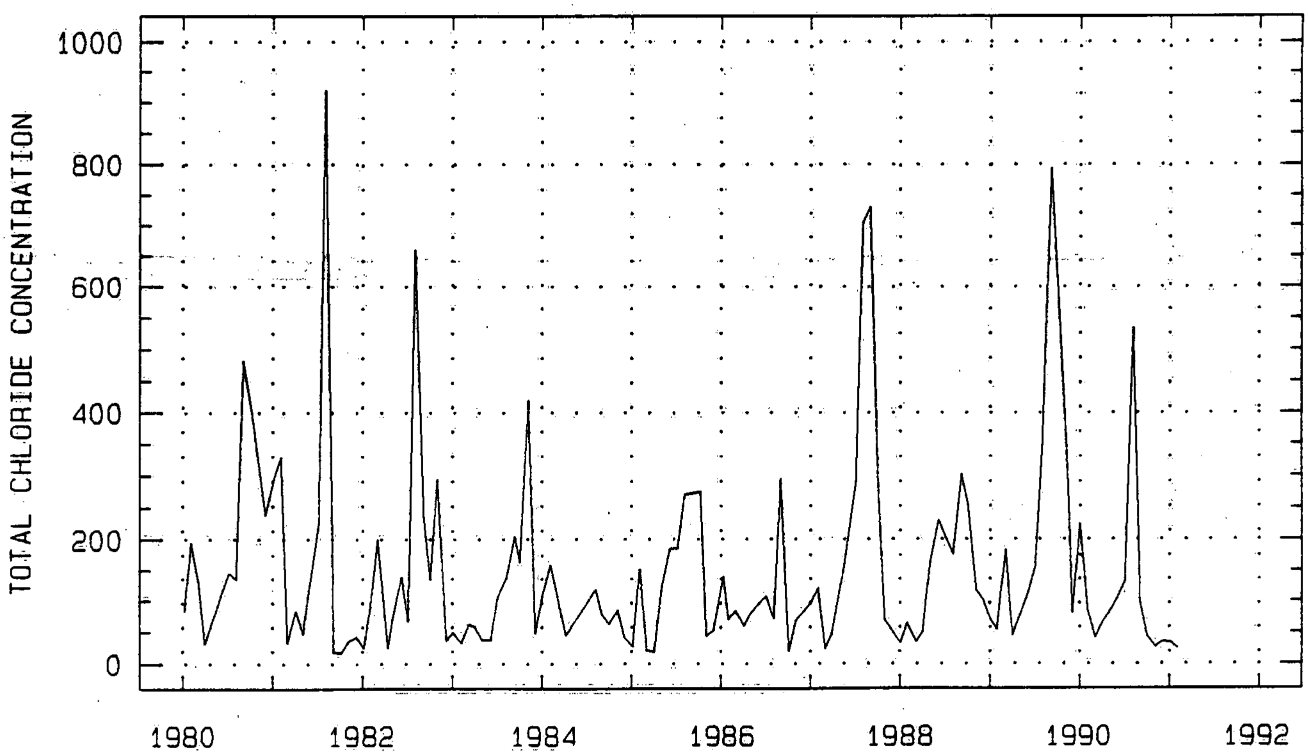
PETROLIA STATION
TOTAL CHLORIDE CONCENTRATION



Source: Ministry of the Environment, 1991.

FIGURE 15B

AVONRY STATION
TOTAL CHLORIDE CONCENTRATION



Source: Ministry of the Environment, 1991.

guideline. Both stations registered median values outside the environmental range recorded for surface waters in central Canada, but within the MOE drinking water guidelines (Table 9).

Field Measurements

Table 10: Chemical and Physical Analysis - Field Data

Station		Alkalinity (as mg/L $CaCO_3$)	Conductivity (μmho/cm @ 25 °C)	Temperature (°C)	pH	Turbidity (FTU)
PETROLIA	# obs.	87	122	116	123	108
	Mean	184.8	1061	11.6	7.87	79.9
	Median	186.0	855	11.0	7.86	57.0
	Range	92.2-383	327-4,700	0.1-29	7.46-8.37	3.9-880
AVONRY	# Obs.	83	123	119	123	107
	Mean	182.1	1,018	11.2	7.87	107.8
	Median	179.0	880	10.0	7.88	92.0
	Range	63.6-298	368-3,340	0.3-26	7.39-8.20	6.1-550

Source: MOE, 1991.

Alkalinity

Waters with high alkalinity have elevated concentrations of sodium salts or excessive hardness and are therefore undesirable. A guideline range of 30 to 500 mg/L for alkalinity is acceptable to ensure capability of water treatment processes to maintain a chemical balance of water; to alleviate corrosive or encrusting problems; and to eliminate human health problems such as gastro-intestinal irritation (CCREM, 1987). To protect the aquatic environment alkalinity must be sustained at background levels avoiding sudden variations (CCREM, 1987).

Median values for both the Petrolia and the Avonry stations are well within the guideline specifications at 186 and 179 mg/L respectively (Table 10). Ranges are also within the tolerant levels, however fluctuations are found. The Petrolia station ranges from 92.2 to 393 mg/L. The maximum value occurred on February 6, 1983 and involved a gradual increase and decrease in alkalinity values. The station at Avonry showed a range of 63.6 to 298 mg/L, with the maximum occurring on February 2, 1987.

Conductivity

Conductivity measured at 25 °C had a median value of 855 μmho/cm at Petrolia and 880 μmho/cm at Avonry (Table 10). Variations in conductivity from 327 to 4,700 μmho/cm occurred over the ten period from 1980 to 1991 for Petrolia. The maximum was recorded on September 6, 1989. In conjunction with this were high values recorded for chloride, sulphate and filtered residue in the system. The Avonry station displayed a range of recorded values between 368 to 3,340 μmho/cm at 25 °C. Here the maximum value was found on August 4, 1981, again in conjunction with high values for chloride and filtered residue.

Turbidity

Turbidity values will fluctuate seasonally, with typically low values during mid winter or late summer when flows are low, and high values during peak spring run-off. Water quality guidelines suggest that discharges resulting from human activity should not alter ambient turbidity levels.

Turbidity varied greatly throughout the recorded 10 year period in the Bear Creek watershed (Table 10). The range of values recorded at Petrolia increase from 3.9 FTU up to 880 FTU. The maximum turbidity was observed on May 3, 1983, while minimum values were recorded on February 3, 1981. The Avonry station varied from a turbidity of 6.1 FTU on May 4, 1982, to 550 FTU on April 3, 1985. Due to widespread artificial drainage and intensive agricultural activities, without buffers or conservation practices, it is likely that human activity has altered ambient turbidity.

Temperature

Water temperatures were slightly higher at the Avonry water quality monitoring station than at the Petrolia station. Median temperatures averaged for the period 1980 to 1991 were recorded at 10.0 and 11.5 °C respectively. Temperatures ranged from 0.1 to 20 °C at Petrolia and from 0.3 to 26 °C at Avonry (Table 10).

pH

For recreational purposes the pH of a water system should not fall below 6.5 or rise above 8.5 (MOE, 1984). Both water quality monitoring stations show a median pH value of 7.9. Ranges are between 7.46 and 8.37 for Petrolia and 7.39 to 8.2 for Avonry (Table 10).

Metals

Lead

The toxicity of lead is dependant on the alkalinity of the water. For alkalinity values exceeding 80 mg/L as in the Bear Creek basin lead values should not exceed 0.025 mg/L (MOE, 1984). The Petrolia station recorded a median total lead value of 0.003 mg/L over the ten year period (Table 11). The range of values varied from 0.0018 mg/L to 0.061 mg/L. Exceedences of the 0.025 mg/L objective were recorded in February 1984 and June 1986.

Table 11: Chemical and Physical Analysis - Metals

Station		Total Copper (mg/L)	Total Lead (mg/L)	Total Zinc (mg/L)
PETROLIA	# Obs.	80	81	80
	Mean	0.0084	0.0055	0.017
	Median	0.006	0.003	0.014
	Range	0-0.081	0-0.061	0.0001-0.07

Source: MOE, 1991.

Copper

To protect aquatic life copper values in an unfiltered system should not exceed 0.005 mg/L (MOE, 1984). Environmental concentrations for copper in central Canadian surface waters for the years 1981 to 1983, ranged between 0.0001 mg/L and 0.068 mg/L (CCREM, 1987). Copper values for the past ten years at the Petrolia station, ranged from a minimum value of 0.0012 mg/L to a maximum of 0.081 mg/L on November 4, 1986 (Table 11). The median at the Petrolia station was calculated as 0.006 in exceedence of the MOE objective. Copper concentrations were recorded in exceedence of the MOE objectives for 68 percent of samples taken.

Zinc

Zinc concentrations should not exceed 0.03 mg/L for the protection of aquatic life (MOE, 1984). Zinc values in the Bear Creek system, as recorded at the Petrolia water quality station, ranged from trace levels to 0.07 mg/L, with a median value over ten years of 0.014 mg/L (Table 11). The maximum value was recorded April, 1985. Environmental concentrations ranged from 0.001 to 1.170 mg/L between 1980 to 1985 for central Canadian surface waters (CCREM, 1987). Seven percent of the samples taken over the ten year period at the Petrolia station registered zinc concentrations in exceedence of the MOE objective.

1.1.12 Conservation Authority Water Quality

During 1988-1989 the St. Clair Region Conservation Authority (SCRCA) conducted a water quality study in the Upper Bear Creek sub-basin, north of the Warwick

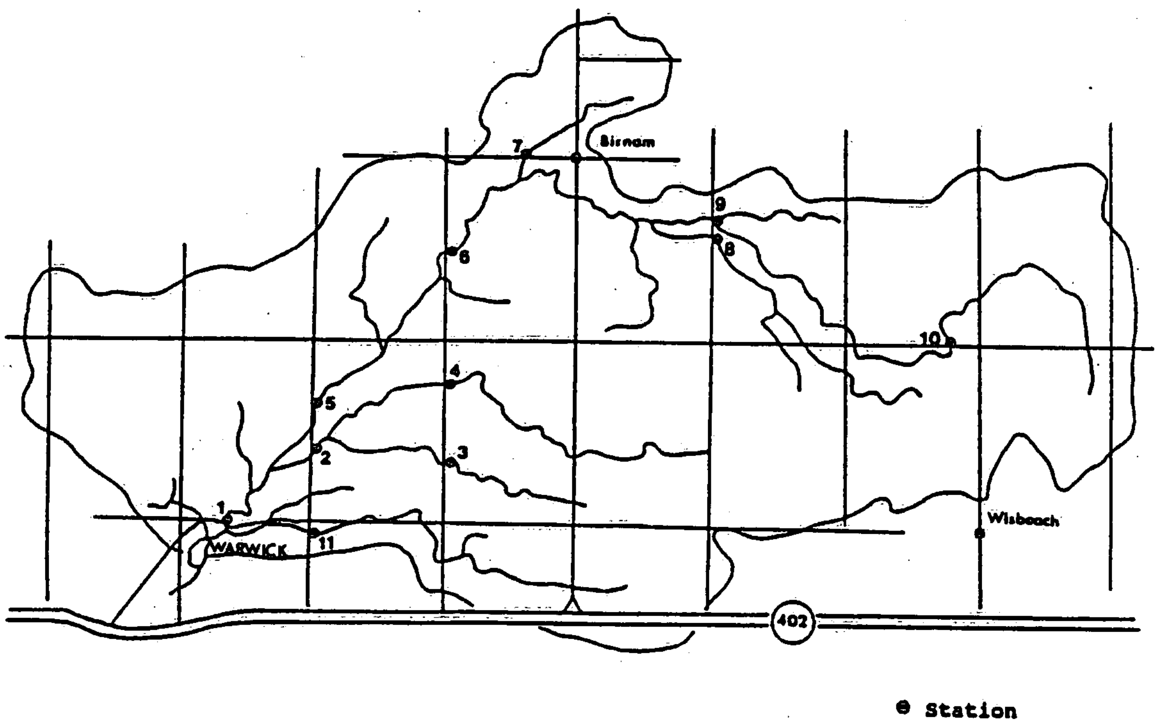
Conservation Area (Quinlan, 1989). This study was undertaken to determine the influence of intensive livestock operations on water quality. Both microbiological and chemical quality of the water was assessed.

Ten MOE approved sites were sampled along the course of Bear Creek. An eleventh station was sampled at the mouth of the river as it entered Warwick Conservation Area (Figure 16). Over the nine month period (late June 1988, to late March 1989), each site was tested weekly for a total of approximately 38 samples per site. The test sites account for a drainage area of approximately 77 km^2.

Bacterial analyses were performed and the results are expressed as geometric means, calculated per season of testing (ie: summer, fall, winter). All of the tested sites reported fecal coliform counts in excess of the 100 organisms per 100 mL MOE guideline for recreational purposes, throughout the test period. Only one station indicated an acceptable fecal coliform level during the winter. Values ranged from 1567 organisms/100 mL at station 9 during the fall to 54 organisms/100 mL at site 10 during the winter.

Station 1, taken at the mouth of Bear Creek as it enters the Warwick Reservoir is the furthest downstream sample point for the tested area. At Station 1, fecal coliform counts were highest during the summer (785 org./100 mL), dropping through the fall (357 org./100 mL), to a low geometric mean in the winter of 158 org./100 mL. The

Figure 16. Water Quality Sampling Sites for Fecal Coliform Counts
Upper Bear Creek Sub-basin



Source: Quinlan, 1989

geometric mean for the entire test period for station 1 was 347 org./100 mL, approximately three and a half times the MOE guideline.

Other microbiological parameters tested at the eleven sites include *Escherichia coli* and fecal *Streptococci*. Recorded values for these parameters over the test period also exceeded the MOE water quality guidelines. A complete list of results is supplied in Appendix II.

Chemical analyses indicated that Total Kjeldahl Nitrogen and total phosphorous were in exceedence of MOE criteria on numerous occasions during the test period. TKN concentrations reached levels of twice the guideline values, while phosphorous exceeded the guidelines by three times during the winter. The SCRCA determined that there was not a great deal of correlation between the stations with the highest bacterial concentrations and those with the highest nutrient levels (Quinlan, 1989).

The Conservation Authority also tested fourteen individual tile drainage outlets throughout the Upper Bear Creek sub-basin. At four of these sites pollution levels were below the MOE objectives for recreational purposes. Three sites were labelled polluted, with the remaining seven deemed very polluted with bacteria levels at around 100 times the acceptable water quality levels. Results are provided in Appendix II.

1.1.13 Pesticide Use

Table 12: Quantities of Active Ingredients of Each Type of Pesticide Used in the Bear Creek Basin, by County in 1988 (weights in kg)

Lambton County	PESTICIDES USED ON FIELD CROPS	PESTICIDES USED ON FRUIT CROPS (GENERAL)	PESTICIDES USED ON VEGETABLE CROPS (GENERAL)	TOTAL
TRIAZINE HERBICIDES	119520	80	790	120390
PHENOXY HERBICIDES	22920	10	20	22950
OTHER HERBICIDES	264750	160	2150	267060
INSECTICIDES	9840	2250	4230	16320
NEMATOCIDES	—	60	2010	2070
GROWTH REGULATORS	—	30	60	90
FUNGICIDES	—	6730	8990	15720
TOTAL PESTICIDES	417030	9320	18250	444600
PERCENT CONTRIBUTION TO TOTAL SOUTHWESTERN ONTARIO	10.5	2.2	7.8	9.7

Source: OMAF, 1989b

Table 12 outlines the pesticide use in Lambton County for 1988, and how it relates to the rest of southwestern Ontario. Figures 17 - 23 show the location of the Bear Creek basin and the agricultural use of pesticides throughout the basin in 1988. Compilation and calculation of total pesticides applied, and application rates were determined by the Economics and Policy Coordination Branch of OMAF using their established methodology (OMAF, 1989b). Due to extreme drought conditions experienced during

1988, pesticide use was most certainly reduced. This factor should be considered if comparison is made to previous years data (OMAF, 1989b).

Lambton county makes up approximately 14 percent, by area, of southwestern Ontario. Table 12 indicates that pesticide application quantities, for all three categories are less than comparably sized areas of southwestern Ontario. This suggests that Lambton County has a lower pesticide application rate than other counties in the southwest.

1.2 Issue Identification

On the basis of information compiled during this study and previous work done by MOE, SCRCA, Environment Canada and other organizations, it is evident that water quality conditions are variable in the basin, and that the collection of data is inconsistent and making sub-basin level assessment difficult.

Information has been obtained from several sources over numerous years. Water quality information is based on 1991 MOE data. Stream flow data were provided by Environment Canada in 1991. Land use information within each sub-basin is obtained from digital land use files on a Geographic Information System figures supplied by OMAF, 1991. Fertilization and pesticide application areas were based on OMAF figures from 1988. Application rates for fertilizer and pesticides within the basin were calculated from figures provided by the Fertilizer Institute of Ontario (1989) and OMAF

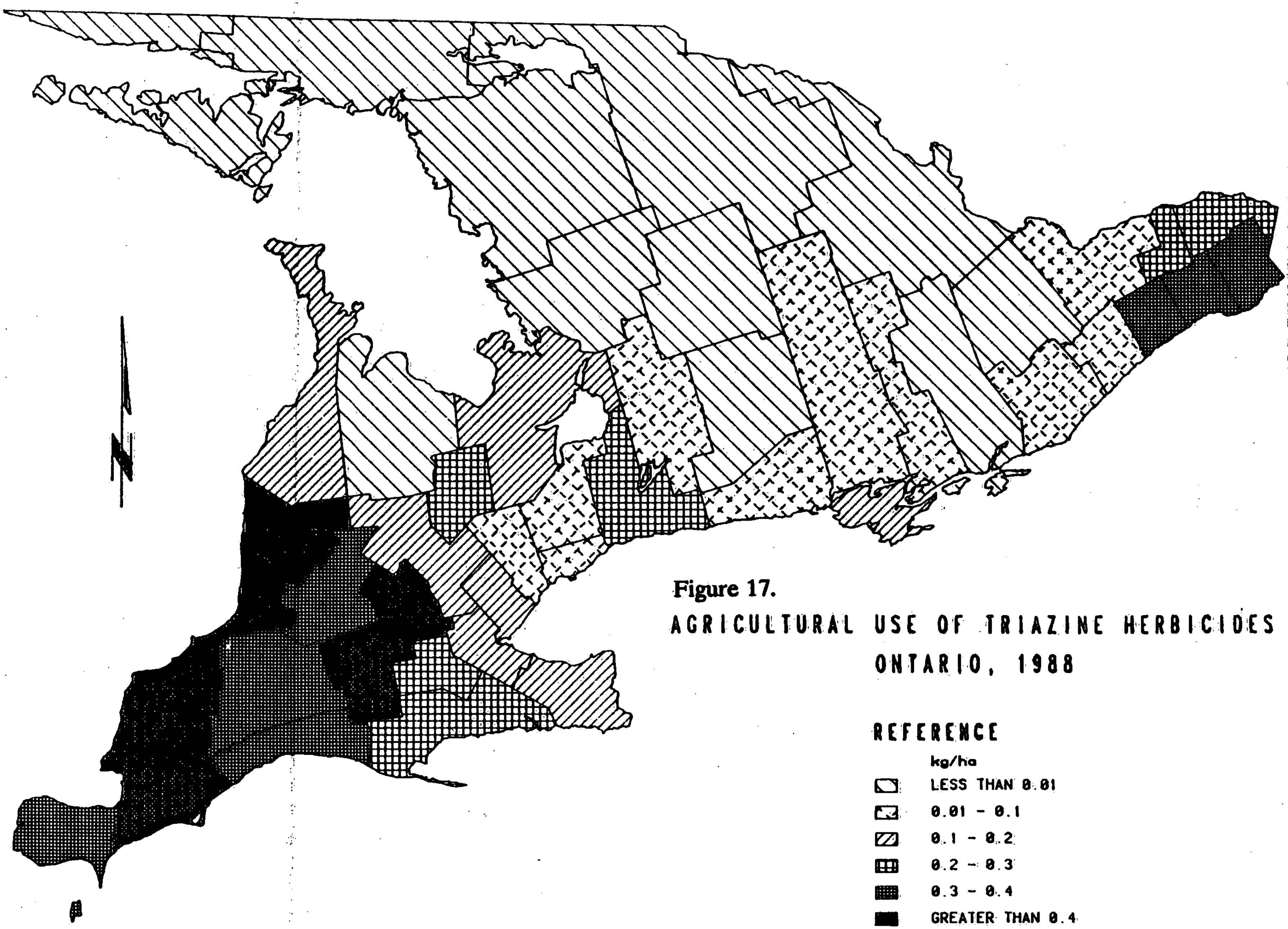


Figure 17.
AGRICULTURAL USE OF TRIAZINE HERBICIDES
ONTARIO, 1988

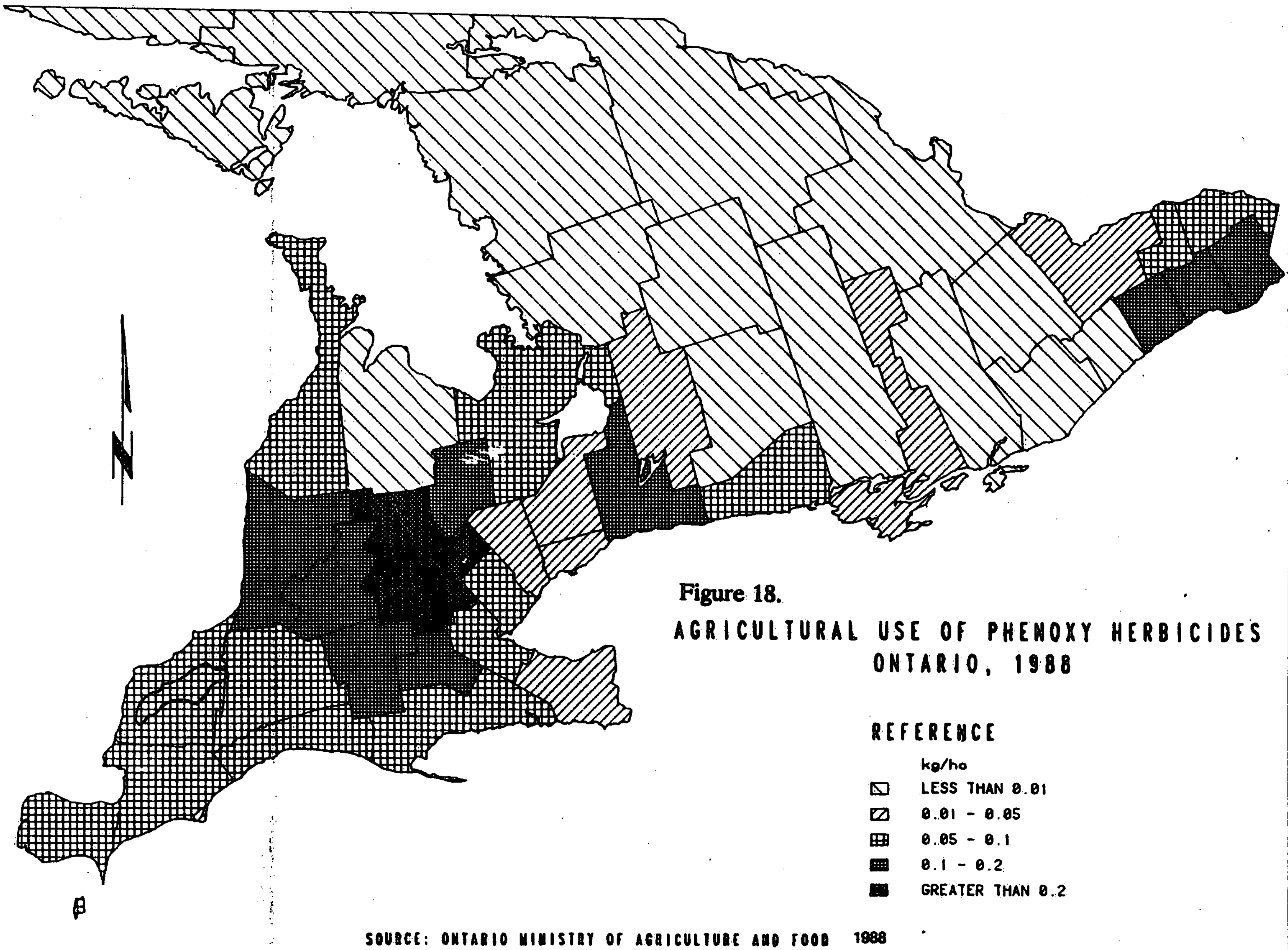


Figure 18.
AGRICULTURAL USE OF PHENOXY HERBICIDES
ONTARIO, 1988

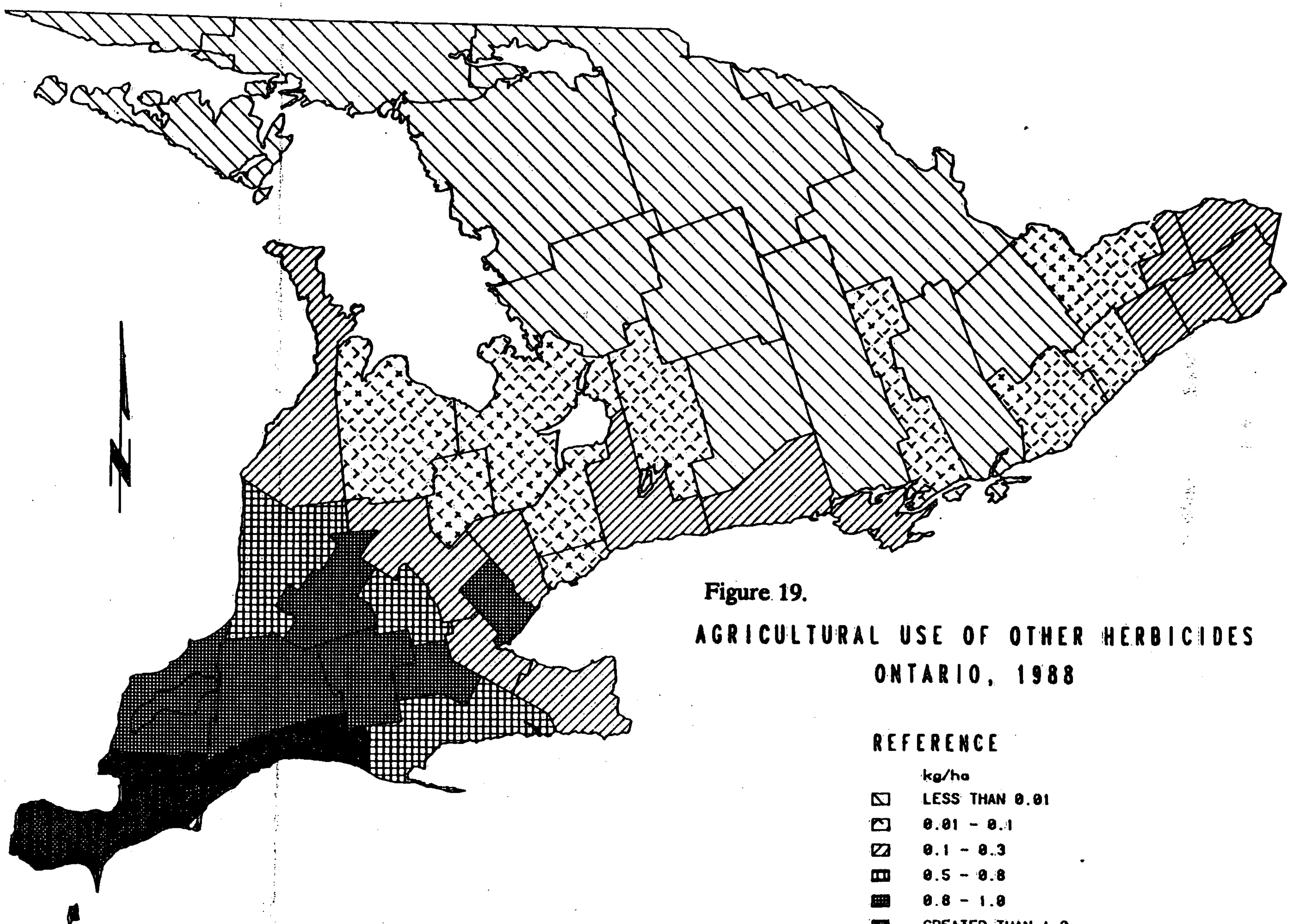


Figure 19.

AGRICULTURAL USE OF OTHER HERBICIDES
ONTARIO, 1988

SOURCE: ONTARIO MINISTRY OF AGRICULTURE AND FOOD 1988

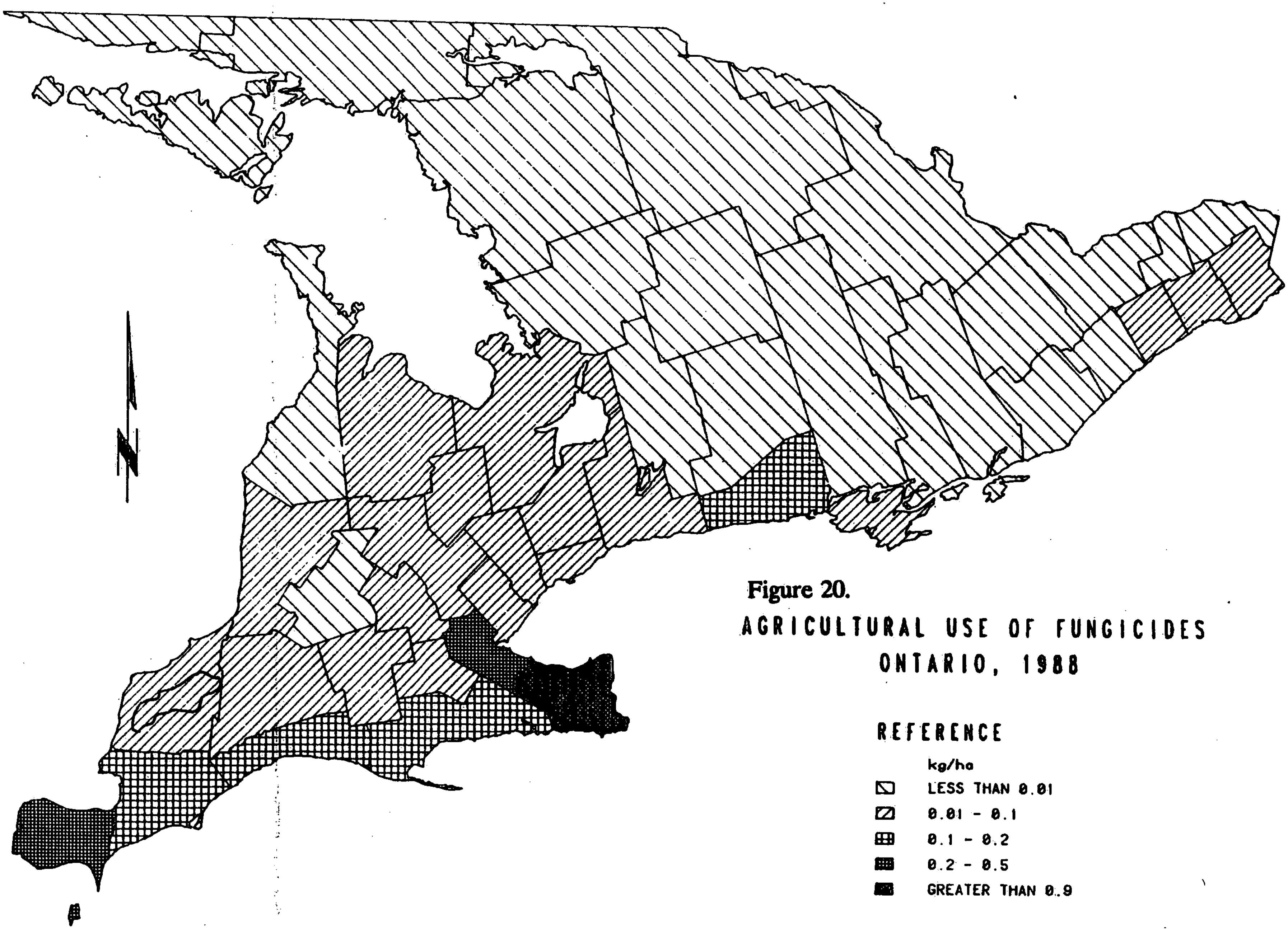


Figure 20.
AGRICULTURAL USE OF FUNGICIDES
ONTARIO, 1988

SOURCE: ONTARIO MINISTRY OF AGRICULTURE AND FOOD 1988

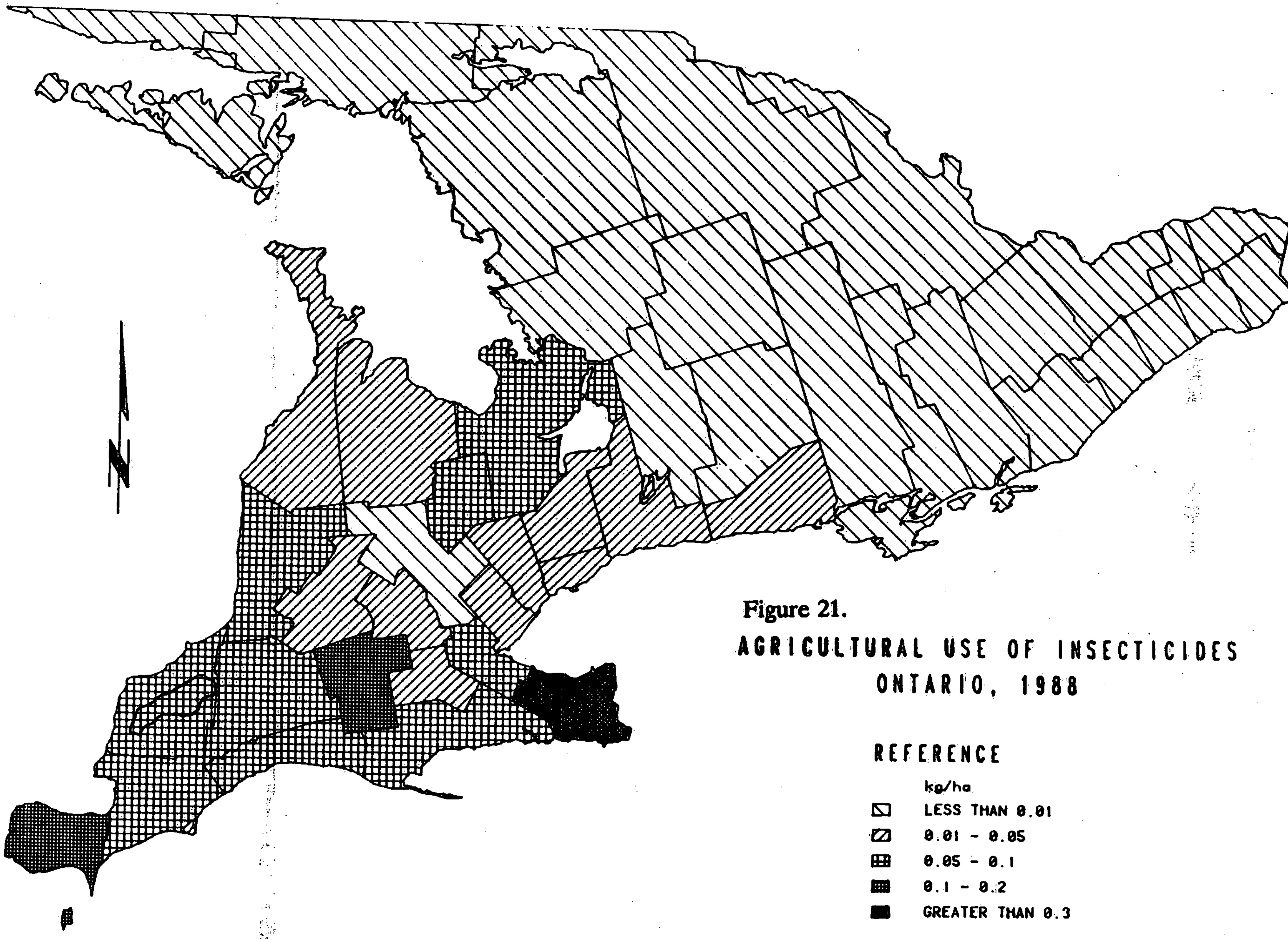


Figure 21.
AGRICULTURAL USE OF INSECTICIDES
ONTARIO, 1988

SOURCE: ONTARIO MINISTRY OF AGRICULTURE AND FOOD 1988

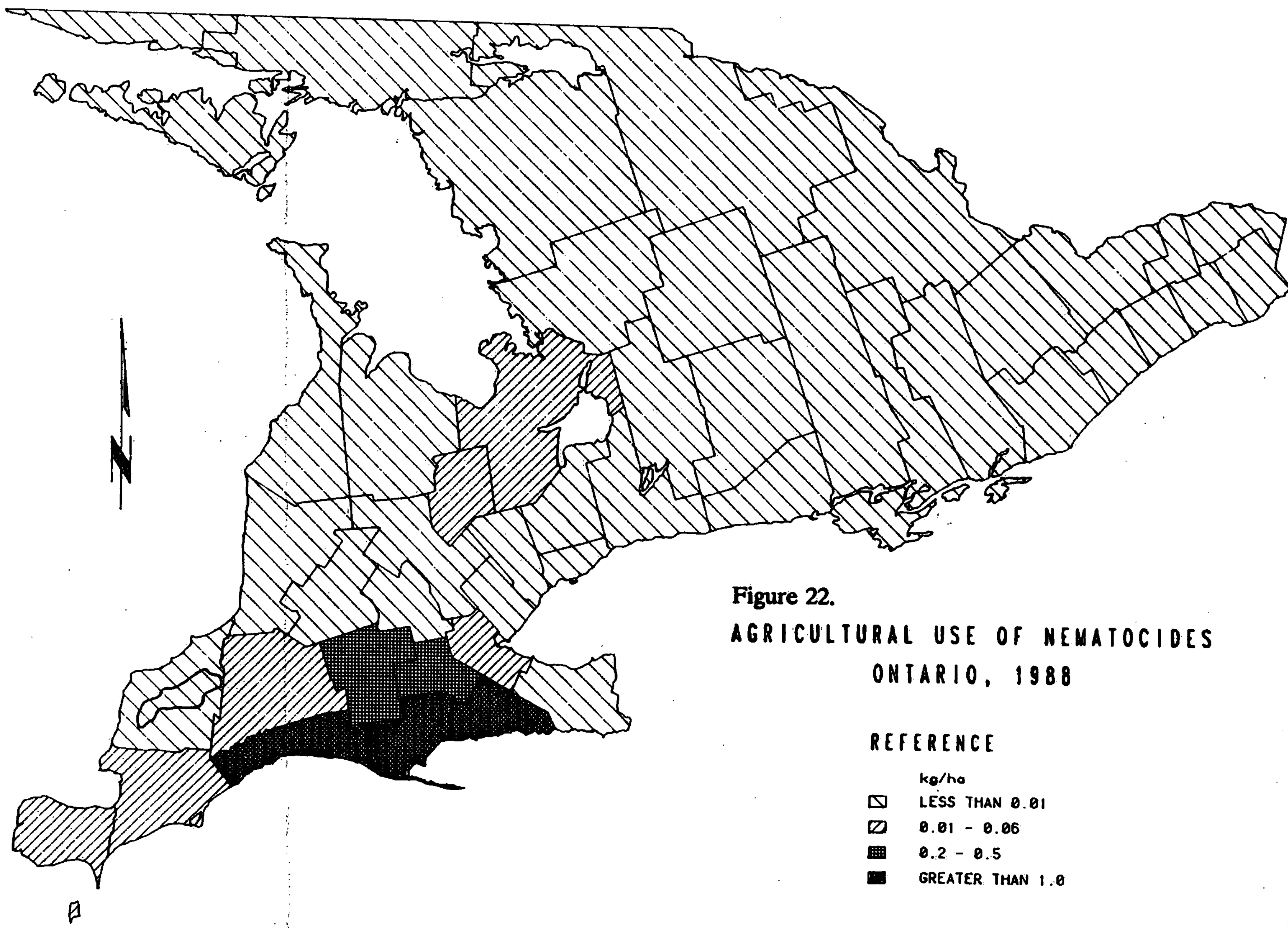


Figure 22.

AGRICULTURAL USE OF NEMATOCIDES
ONTARIO, 1988

SOURCE: ONTARIO MINISTRY OF AGRICULTURE AND FOOD 1988

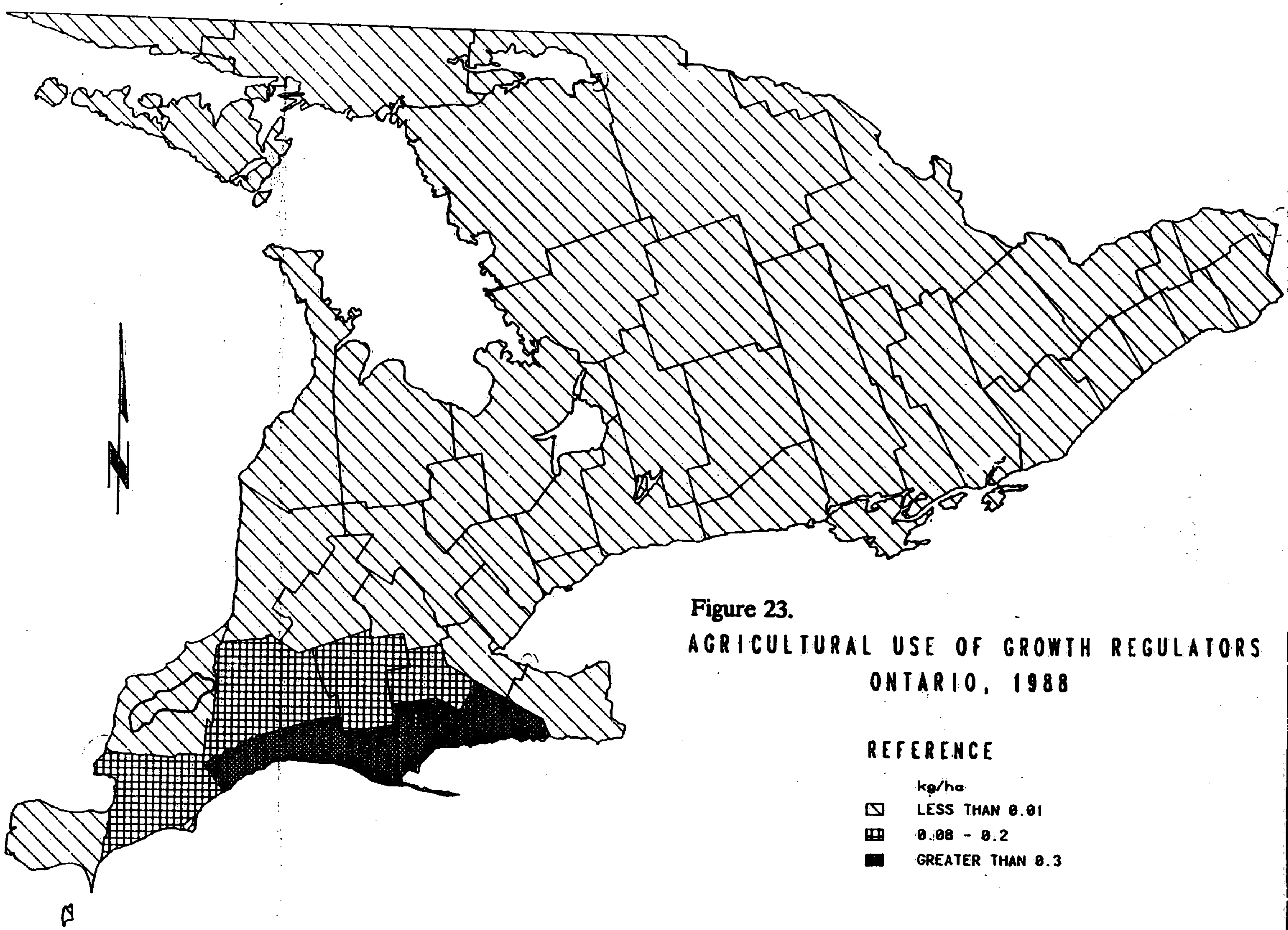


Figure 23.
AGRICULTURAL USE OF GROWTH REGULATORS
ONTARIO, 1988

SOURCE: ONTARIO MINISTRY OF AGRICULTURE AND FOOD 1988

statistics for 1988, respectively. Livestock figures were calculated from OMAF's agricultural statistics for 1988. Sewage treatment facility data for 1988 was obtained from MOE reports (1989a).

This assessment is a qualitative one based on the nature and availability of data. Relating water quality to land use activities requires that a common spatial or geographic framework be used. Theoretically, the drainage basin provides such a framework. In practice, land use information is rarely collected on a basin or sub-basin level and needs to be converted from a county or township base. Errors can result in estimating land use activity since this conversion typically assumes that land use is evenly distributed within political boundaries. The application of digital Agricultural Land Use Systems helps to remove some of these discrepancies because area calculations are performed by the computer.

The limitations of existing water quality data have been noted previously. The sub-basins defined in this study which lack suitably located water flow and quality monitoring stations are assessed primarily on the basis of land use and agricultural statistics.

The primary selection matrix for variables in the Bear Creek basin are provided in Table 13.

Table 13: Primary Sub-basin Selection Matrix

	LITTLE BEAR CREEK	UPPER BEAR CREEK	LOWER BEAR CREEK	PETROLIA
AREA OF SUB-BASIN (km^2)	65.95	79.72	245.78	226.08
FEDERAL FLOW STATION	NO	NO	YES	YES
MOE MONITORING STATION	NO	NO	YES	YES
QUANTITY/QUALITY OF WATER QUALITY DATA	POOR	GOOD	MODERATE	GOOD
% SOIL TYPE - COARSE	0	0	0	0
- MEDIUM	10	20	5	20
- FINE	90	80	95	80
% OF SUB-BASIN UNDER CORN/ROW CROPPING SYSTEM	89.4	80.3	77.8	76.9
% OF SUB-BASIN UNDER HAY/GRAZING SYSTEM	1.0	5.4	5.7	5.0
% OF SUB-BASIN UNDER FOREST COVER/IDLE	9.6	11.6	12.1	11.1
% OF URBANIZATION IN SUB-BASIN	0.0	1.1	2.0	5.6
% ARTIFICIAL DRAINAGE	91.6	5.6	55.9	29.2
FERTILIZED AREA (ha)	5,936	6,855	50,645	18,312
TONNES OF FERTILIZER APPLIED	1,665.0	1,922.8	5,790.9	5,136.5
FERTILIZER APPLICATION RATE (kg/ha)	280.5	280.5	280.5	280.5
TOTAL PESTICIDE APPLIED (kg)	12,977.4	14,986.6	45,134.7	40,034.2
PESTICIDE APPLICATION RATE (kg/ha)	2.19	2.19	2.19	2.19
TOTAL # OF CATTLE	1,532	1,770	5,330	4,727
TOTAL # OF HOGS	5,335	30,573	18,555	16,458
TOTAL LIVESTOCK (animals/ha)	1.2	4.7	1.2	1.2
# OF SEWAGE TREATMENT PLANTS WITHIN SUB-BASIN	0	0	2	2

1.2.1 Agricultural Eutrophication

Basis for Concern

Intensive agriculture and surface runoff/erosion were identified as contributors to eutrophication in the Bear Creek basin. The most important land related factors affecting the magnitude of loads from non-point sources were soil type, land use intensity and material usage (MOE, 1986). Despite the long term knowledge of the severity and extent of the eutrophication problem, a water quality collecting program that is consistent and comparable on a national basis is still required (Environment Canada, 1990a).

The problem of 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, and feedlots). The nature of soil within an area and the distribution of artificial drainage systems also influence the transport of nutrients.

Sub-basin Selection Criteria

Classification was based on the percent land use, rate of fertilizer application, and soil type within the sub-basins. Table 14 outlines the sub-basin selection matrix for agricultural eutrophication. The variables hay/grazing systems and forest cover were evaluated in terms of their relative potential contribution to eutrophication. hay/grazing systems were evaluated based on their percentage area as potential for surface run-off which may include both sediments and animal wastes. In addition, livestock access to watercourses increases the possibilities of erosion and manure input to the system. Therefore, the higher percentage of land use under hay/grazing systems the larger the likelihood of agricultural eutrophication in the system. Alternatively, the greater the percentage of forest cover or idle land, the lower the threat of agricultural eutrophication. Both hay/grazing systems and forest or idle land uses have low area percentages in the Bear Creek sub-basins. The largest contributing factor to the agricultural eutrophication issue is therefore the amount of land under corn/row cropping systems, and it's associated run-off and related erosion.

The Little Bear Creek and the Upper Bear Creek sub-basin both exhibit characteristics suitable to establish a water quality monitoring station for the eutrophication issue. Both have high potential soil types, over 80% of their areas under corn/row cropping systems, and approximately 10% under forest/idle coverage. Hay/grazing systems indicate more intensive livestock operations. The Upper Bear Creek sub-basin is selected as slightly superior for the location of the monitoring station due to the high number of animals per hectare and the availability of previous water quality studies undertaken by the St. Clair Region Conservation Authority. These studies indicated that eutrophication was a problem in the Upper Bear Creek sub-basin.

Table 14: Agricultural Eutrophication Matrix

	LITTLE BEAR CREEK	UPPER BEAR CREEK	LOWER BEAR CREEK	PETROLIA
SOIL TYPE	HIGH	HIGH	HIGH	HIGH
% OF SUB-BASIN UNDER CORN/ROW CROPPING SYSTEM	HIGH	MED	MED	MED
% OF SUB-BASIN UNDER HAY/GRAZING SYSTEM	LOW	HIGH	HIGH	MED
% OF SUB-BASIN UNDER FOREST COVER/IDLE	HIGH	MED	LOW	MED
FERTILIZER APPLICATION RATES (kg/ha)	MED	MED	MED	MED
TOTAL LIVESTOCK (animals/ha)	LOW	HIGH	LOW	LOW
% ARTIFICIAL DRAINAGE	HIGH	LOW	MED	MED
	4 HIGH 1 MED 2 LOW	3 HIGH 3 MED 1 LOW	2 HIGH 3 MED 2 LOW	1 HIGH 5 MED 1 LOW

1.2.2 Pesticides

Basis for Concern

Pesticide use within the Bear Creek basin is of particular concern as the area is under heavy agricultural use. "Pesticides can reach water supplies through a number of avenues including, but not limited to, overspray, aerial drift, surface runoff, leaching and spills" (Environment Canada, 1989b). Sub-basins containing large areas of agricultural activity, high proportions of row crops and high pesticide application rates would have the greatest potential for impact. Information with respect to the types and amounts of the various pesticides purchased within the province are compiled on a county basis and information on recommended application rates are available. The MOE surface water sampling program does not include analysis for pesticides.

Sub-basin Selection Criteria

Characteristics used for the selection of the most suitable sub-basin for the monitoring of the pesticide issue include soil type, pesticide application rate, and percentage land cover under corn/row cropping. Table 15 provides the data used in the sub-basin selection matrix. Soil was evaluated in the same way as for the eutrophication problem. Potential for erosion of particles onto which pesticide chemicals have adhered, and the level of surface runoff were the concern. Pesticide application rates are available by county for southern Ontario. The entire Bear Creek watershed lies within the borders of Lambton County, therefore, one rate of application is provided for all sub-basins. The main factor in determining the most suitable sub-basin for pesticide monitoring is the percentage of land under corn/row cropping systems.

Table 15: Pesticide Matrix

	LITTLE BEAR CREEK	UPPER BEAR CREEK	LOWER BEAR CREEK	PETROLIA
SOIL TYPE	HIGH	HIGH	HIGH	HIGH
% OF SUB-BASIN UNDER CORN/ROW CROPPING SYSTEM	HIGH	MED	MED	MED
PESTICIDE APPLICATION RATES (kg/ha)	MED	MED	MED	MED
	2 HIGH 1 MED	1 HIGH 2 MED	1 HIGH 2 MED	1 HIGH 2 MED

The Little Bear Creek sub-basin is the most suitable location for a water quality monitoring station to determine the effects of pesticide application on the fluvial system. This sub-basin has the highest percent of land influenced by corn/row cropping systems.

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 these 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, 1989c). The identification of a relatively pristine sub-basin within the Bear Creek watershed would allow for the establishment of such water quality goals.

Sub-basin Selection Criteria

Listed below are the factors which are available for use in sub-basin selection. Variables used for determining the sub-basin possessing the most pristine conditions were (Environment Canada, 1989c):

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

2) area represented (km^2)

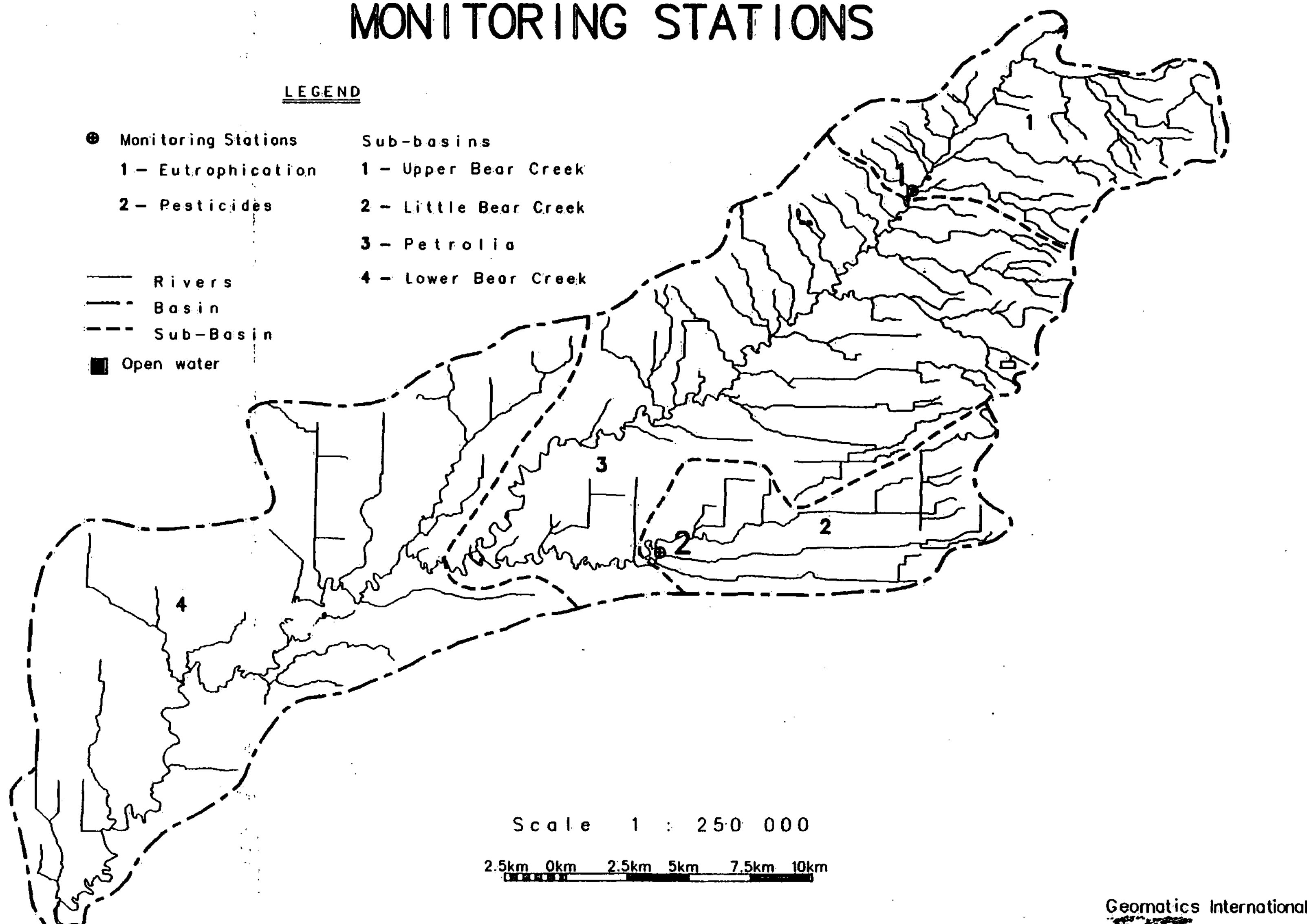
3) range of surficial deposits represented

4) proximity of gauging station

5) quantity/quality of existing water quality information

The selection of a sub-basin for baseline water quality monitoring is extremely difficult in the Bear Creek basin. Agricultural activities are so intensive that there is little or no pristine area within the entire drainage basin. Most of the upper reaches of tributaries have been artificially extended to enable drainage of agricultural areas. With the high number of tile drains pollution levels would be high. It is therefore, recommended that there does not exist a suitable location for the establishment of an NRN water quality station to monitor the baseline and pristine conditions within the Bear Creek watershed.

Figure 24
RECOMMENDED SITES FOR NRN WATER QUALITY MONITORING STATIONS



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APPENDICES

APPENDIX I

Land Uses for Bear Creek Sub-basins										
SUB-BASIN	LITTLE BEAR CREEK		UPPER BEAR CREEK		LOWER BEAR CREEK		PETROLIA		TOTAL BEAR CREEK BASIN	
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
A1	29.5	0.4	6.1	0.1	13.1	0.1	116.5	0.5	165.2	0.3
A2	8.4	0.1	23.6	0.3	435.5	1.8	62.6	0.3	530.1	0.9
B	0.0	0.0	91.2	1.2	504.4	2.0	1274.7	5.6	1870.3	3.0
BE	0.0	0.0	3.8	0.0	5.4	0.0	0.0	0.0	9.2	0.0
C	2532.6	38.4	2275.6	28.7	7524.1	30.6	7263.7	32.1	19596.0	31.7
E1	0.0	0.0	17.7	0.2	0.0	0.0	11.2	0.0	28.9	0.0
E2	0.0	0.0	0.0	0.0	2.1	0.0	0.0	0.0	2.1	0.0
G	0.0	0.0	0.0	0.0	0.0	0.0	32.1	0.1	32.1	0.1
H	45.0	0.7	420.6	5.3	1261.7	5.1	750.8	3.3	2432.6	3.9
HG	20.8	0.3	0.0	0.0	98.3	0.4	322.6	1.4	441.6	0.7
KM	0.0	0.0	17.9	0.2	17.5	0.1	2.3	0.0	37.7	0.1
KN	0.0	0.0	28.3	0.4	31.6	0.1	0.0	0.0	59.9	0.1
M	499.3	7.6	600.7	7.6	3150.3	12.8	1951.5	8.6	6201.8	10.0
MG	80.5	1.2	609.7	7.7	1069.9	4.3	765.4	3.4	2525.5	4.1
NC	0.0	0.0	0.0	0.0	27.1	0.1	86.2	0.4	159.2	0.3
OR	0.0	0.0	5.8	0.1	7.5	0.0	0.0	0.0	13.3	0.0
P	2785.7	42.2	2919.6	36.8	7406.9	30.1	7405.6	32.8	20517.8	33.2
R	0.0	0.0	0.0	0.0	34.2	0.1	0.0	0.0	34.2	0.1
T	0.0	0.0	0.0	0.0	0.0	0.0	14.8	1.0	14.8	0.0
W	0.0	0.0	0.0	0.0	8.1	0.0	20.4	0.1	28.5	0.0
Z	593.3	9.0	892.1	11.3	2981.5	12.1	2498.4	11.1	6965.3	11.3
ZP	0.0	0.0	12.1	0.2	44.5	0.2	27.8	0.1	84.4	0.1
ZR	0.0	0.0	1.5	0.0	0.0	0.0	1.0	0.0	2.5	0.0
TOTAL SUB-BASIN	6595.1	100	7926.3	100	24623.7	100	22607.6	100	61753.0	100

APPENDIX II

St. Clair Region Conservation Authority Water Quality Sampling Results (1988-89).

Summary of Geometric Means of bacterial populations by season

(no. of organisms per 100 mL)

i) SUMMER

	f.colif	E.COL	PSEUDOM.	F.STREP	No. of samples
Objectives	100	100	4	100	
Station 1	785	495	7	537	13
Station 2	856	549	41	1005	13
Station 3	288	135	47	1293	11
Station 4	179	94	3	474	12
Station 5	884	686	7	556	13
Station 6	554	458	4	512	13
Station 7	917	482	15	503	13
Station 8	693	556	9	816	13
Station 9	804	631	5	922	13
Station 10	1042	666	3	1592	13
Station 11	544	400	13	974	11

ii) FALL

	f.colif	E.COLI	PSEUDOM.	F.STREP	No. of samples
Objectives	100	100	4	100	
Station 1	357	306	1	560	13
Station 2	675	618	4	566	13
Station 3	156	114	9	820	11
Station 4	357	251	4	408	12
Station 5	430	340	2	530	13
Station 6	483	395	2	495	11
Station 7	839	495	2	353	13
Station 8	193	145	1	279	13
Station 9	1567	1094	5	1495	13
Station 10	412	340	1	654	13
Station 11	876	506	3	813	13

III) WINTER

Objectives	f.colif 100	E.COLI 100	PSEUDOM. 4	F.STREP 100	No. of samples
Station 1	158	156	1	236	11
Station 2	218	119	1	94	11
Station 3	246	150	1	467	10
Station 4	336	224	1	169	11
Station 5	433	265	4	1109	5
Station 6	1086	694	6	2760	4
Station 7	106	80	0	71	13
Station 8	415	301	2	426	11
Station 9	401	298	1	1116	9
Station 10	54	31	1	80	10
Station 11	236	152	4	145	11

IV) SUMMER, FALL AND WINTER

Objectives	f.colif 100	E.COLI 100	PSEUDOM. 4	F.STREP 100	No. of samples
Station 1	347	267	2	409	38
Station 2	505	352	6	379	38
Station 3	216	130	6	756	35
Station 4	276	175	2	304	37
Station 5	527	400	3	597	32
Station 6	593	422	3	660	29
Station 7	446	256	2	233	38
Station 8	348	262	3	436	36
Station 9	696	522	3	1162	37
Station 10	450	292	1	771	38
Station 11	431	281	4	478	36

Tile outlet sample results

TILE (Obj.)	# SAMP.	FECAL COLIF. (100)	E.COLI (100)	FECAL STREP. (100)	PSEUD. AERUG. (4)	BOD	S.S.
A	2	44	44	28	4	7.29	5.0
B	2	36946	32863	959	452	10.06	7.7
C	1	20	20	10	4	11.20	5.0
D	2	2540	866	1068	57	1.35	3.2
E	2	130000	100000	2324	290	2.22	5.0
F	1	5400000	4600000	19000	4700	72.00	270.0
G	3	3235	2384	557	6	1.68	8.1
H	2	271662	144492	11292	2258	6.48	5.0
I	3	7	7	13	0	2.00	6.4
J	1	10	10	10	0	0.47	5.0
K	2	16000	11402	7785	111	9.65	23.9
L	2	155	65	715	1		
M	2	1612451	1341641	6372	6	53.81	19.8
N	1	11000	10000	1000	144		