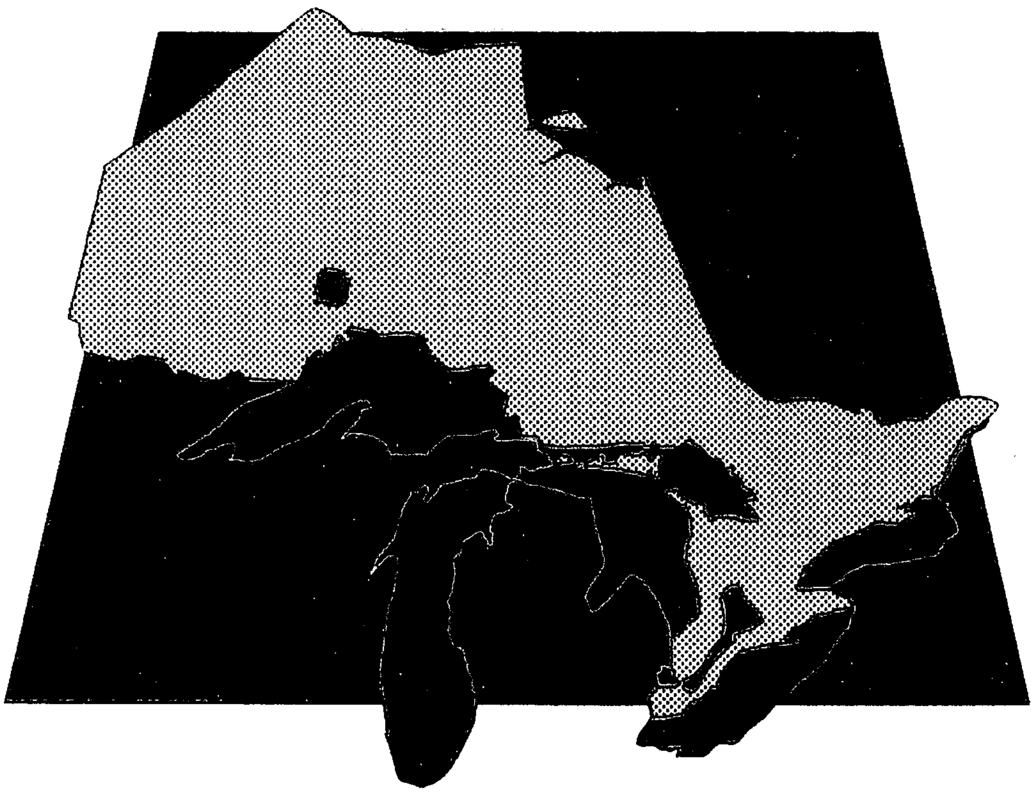
THE APPLICATION OF AN INTERDISCIPLINARY APPROACH TO THE SELECTION OF POTENTIAL WATER QUALITY SAMPLING SITES



Thames River Basin

Water Quality Branch
Ontario Region

1989

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Canada

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

A Report Prepared For

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EXECUTIVE SUMMARY

1.0 Introduction

The Thames 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, Wabigoon, Seine, Goulais, White, Blanche, Magnetawan, Saugeen, Grand, Rouge and the South Nation.

1.1 Approach and Limitations

Existing provincial water quality data were obtained from the Ministry of Environment (MOE), and used to describe historical water quality conditions within the basin. Streamflow data were provided by the Inland Waters Directorate of Environment Canada. Existing reports and maps were obtained from federal and provincial government agencies, conservation authorities and municipalities.

Agricultural Land Use Systems, mapped by the Ontario Ministry of Food and Agriculture (OMAF), were used to describe land use within the Thames River basin. Information summarized on a township or county basis was apportioned to the area of the township/county which lies within the watershed.

The issues of concern in the Thames River basin include: (1) agricultural and cultural eutrophication; (2) pesticides; and (3) urbanization. Ten sub-basins were selected for evaluation as part of this study: the Big Creek, Jeannette Creek, McGregor Creek, Newbiggen Creek, Lower Main, Fish Creek, North Thames, East Thames, Middle Thames, and Upper Main. At least one provincial water quality station and one federal streamflow station in each sub-basin would be considered in order to undertake comparative analyses. However, in practice this situation seldom occurs.

2.0 The Thames River Basin

The Thames River system drains an area of 5,876 km^2 extending from Lake St. Clair in the west to the highlands of Perth and Oxford counties northeast of London. It is the second largest watershed in Southwestern Ontario. The lower portion of the basin is rectangular in shape with a main stream gradient of approximately 0.18 m/km. The largest tributaries in the lower basin are Jeannette, McGregor and Big Creeks. In contrast, the upper portion of the basin is almost round in shape with steep stream gradients varying from 1.03 to 2.10 m/km. The main branch of the Thames River, North Thames and Middle Thames rivers radiate out from the confluence at London. Total watershed population in the late 1980's was approximately 618,000. The basin has a temperate climate with mean annual precipitation ranging from 91 - 94 cm. It is underlain by limestone and dolomite to the east and shales and shaley limestones to the west. Lacustrine sands, silts and clays overlie glacial till in the lower portion of the watershed; the upper basin is dominated by clay till.

The primary land use and the major component of the Thames basin economy is agriculture. Intense cash crop farming dominates the Lower Thames watershed. Livestock production and dairying are the major agricultural activities in the upper portion of the basin. Centrally located, The City of London is the major metropolitan centre of the basin. The cities of Woodstock, Chatham and Stratford serve as subregional centres.

3.0 Major Impacts on Water Quality

Water quality impairment due to run-off from agricultural lands and rural septic systems are the major management concerns of the basin conservation authorities. Discharges from industries and sewage treatment plants can also lead to degradation of water quality. In 1988 22 sewage treatment plants and two industries were discharging into the Thames River and its tributaries. The majority of these operations are located in the upper portion of the watershed.

Intensive studies on the effects of surface run-off from agricultural lands and artificial drainage have been carried out in some sub-basins in the upper portion of the basin. These studies have highlighted the water quality impacts associated with: tile drainage systems; wastewater drains; manure storage and spreading practices; and insufficient soil conservation practices. Row cropping systems account for 88% of the land use in the Big and Jeannette creeks study sub-basins; 75% of the land in both the Fish Creek and North Thames sub-basins is under this system. Fertilizer application rates are highest in the Big Creek (488 kg/ha) and Jeannette Creek (467 kg/ha) sub-basins. Jeannette Creek sub-basin also has one of the highest pesticide application rates at 4.88 kg/ha. Livestock production is of greater importance in the upper portion of the watershed as reflected by the livestock densities (animals/ha) in the North Thames (2.86) and East Thames (2.48) sub-basins.

4.0 Present Water Quality

Over the past decade, many efforts have been made to improve water quality throughout the basin. Despite these efforts, poor water quality still exists in localized areas. Mean ammonia concentrations in all sub-basins exceeded the Federal freshwater aquatic life guidelines. The Lower Main, McGregor Creek and East Thames sub-basins' mean total phosphorous concentrations also exceeded guidelines for drinking water. All mean iron concentrations exceeded guidelines with the exception of the Middle Thames sub-basin. Mean aluminum levels were exceeded in the Lower Main sub-basin only. Mean concentrations of copper were in exceedance of the aquatic guidelines at the McGregor Creek, Lower Main and Upper Main sub-basins. Further efforts to improve local and basin-wide water quality are required.

5.0 Evaluation of Available Water Quality and Flow Stations

Sixteen of 55 MOE water quality parameters have been consistently monitored at the seven provincial water quality monitoring stations selected for this study. Further sampling of major dissolved ions and metals is required. Four federal streamflow stations were utilized to describe water flow within the basin. The hydrometric stations of the conservation authorities may serve as an alternate source of flow data. Federal streamflow stations should be established in conjunction with recommended water quality stations.

6.0 Conclusions and Recommendations

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

(1) The Big Creek sub-basin is recommended for monitoring agricultural eutrophication. This sub-basin has one of the highest percentage of land area devoted to row cropping systems (88%) and the highest fertilizer application rate (488 kg/ha). Two MOE water quality monitoring stations located in the headwaters of Big Creek may be used to study smaller sub-basins within the Big Creek basin. The Upper Main sub-basin is recommended for the monitoring of cultural eutrophication. A relatively high percentage of urban land use (10%), combined with eight sewage treatment plants make this sub-basin the most susceptible to the effects of cultural eutrophication.

(2) The establishment of a pesticides monitoring station in Big Creek is also recommended. The reasons for this selection are similar to those given for the agricultural eutrophication station location, namely: high percentage of land under row crop system; relatively high pesticide application rate (4.16 kg/ha); and the existence of additional MOE monitoring stations upstream.

(3) Although the Upper Main sub-basin has the highest population density and concentration of industrial activity it is also the most complex sub-basin, representing the outflow from the whole of the upper Thames basin. The North Thames sub-basin is the recommended location for a station to monitor the urbanization issue. Smaller and less complex than the Upper Main sub-basin, the North Thames sub-basin exhibits similar urbanization characteristics.

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.

An initial screening to identify large-scale river basins has been undertaken using GIS based technology (Geomatics, 1990). This report summarizes the information requirements of the second hierarchical level (Environment Canada, 1989a,b; 1990) wherein the large-scale river basins are to be represented by their component sub-basins. Potential sampling sites identified in this document will be field verified to determine the practical constraints on their potential for field data collection.

1.1 Resource Description

1.1.1 Climate

The climate of the Thames River basin is temperate with Lake Erie to the south and Lake Huron to the west moderating temperatures in the basin. In general, temperatures decrease from the lower reaches at Lake St. Clair to the headwaters (Figure 1). Mean January temperatures range from -4 ° C in Chatham to -7 ° C at London. Mean July temperatures decrease from 22 ° C in Chatham to 21 ° C at London.

Prevailing westerly winds dominate the region. Normal annual precipitation in the basin follows a trend similar to temperature. In the lower basin Chatham receives 91 cm of annual precipitation including 25 days snowfall whereas London, in the upper basin, receives 94 cm and 67 days snowfall (Figures 2 and 3). There is little seasonal variation in precipitation, with the difference between maximum and minimum, normal monthly precipitation being generally less than 2.5 cm. The average, annual potential and actual evapotranspiration is about 61 cm and 56 cm in the western and eastern portions of the basin respectively (Ministry of the Environment (MOE), Ministry of Natural Resources (MNR), 1975).

Violent windstorms, hailstorms and occasional tornadoes can be expected in this region during the summer months.

Figure 1

Location of the Thames River Drainage Basin in Southern Ontario

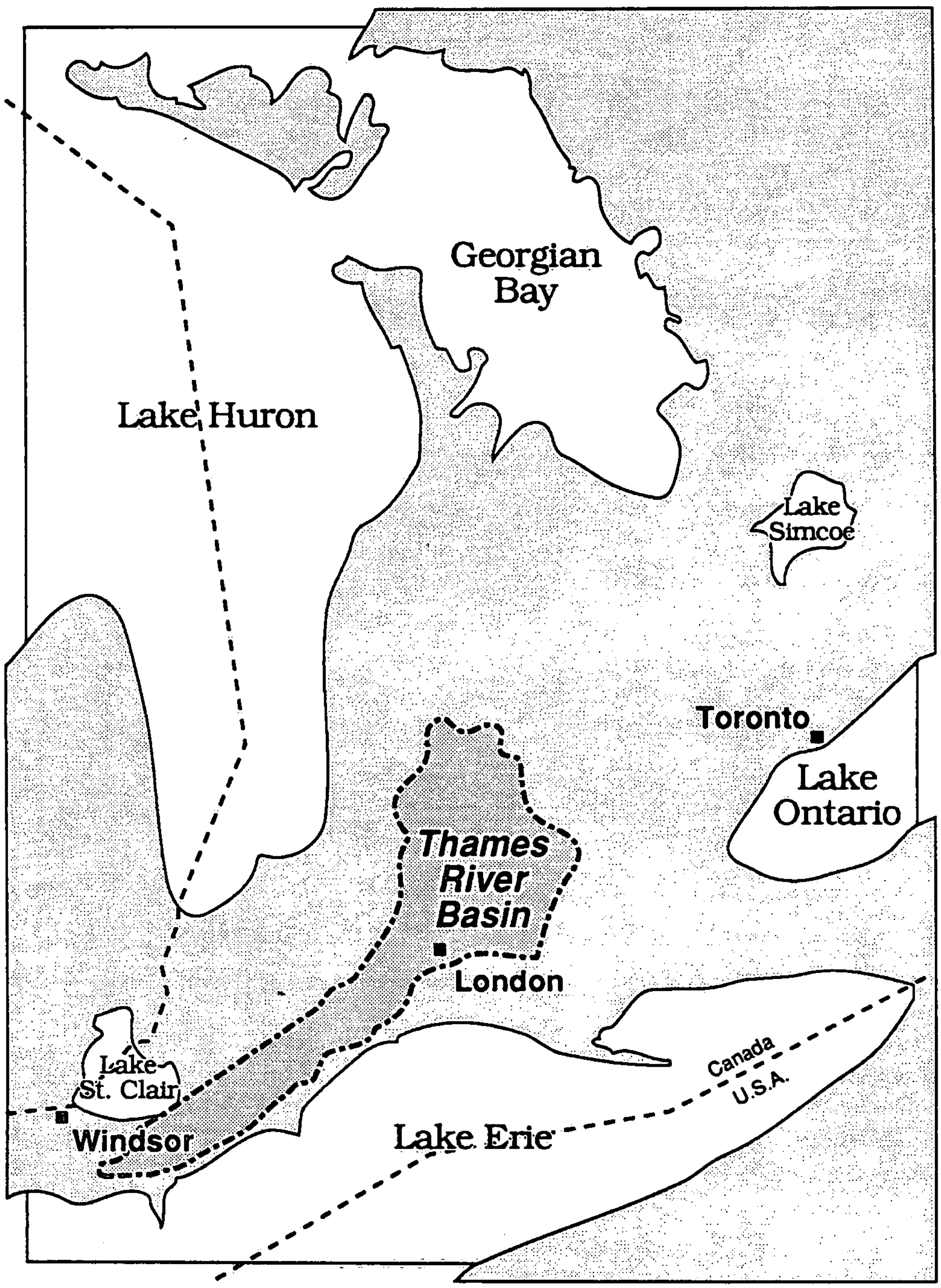
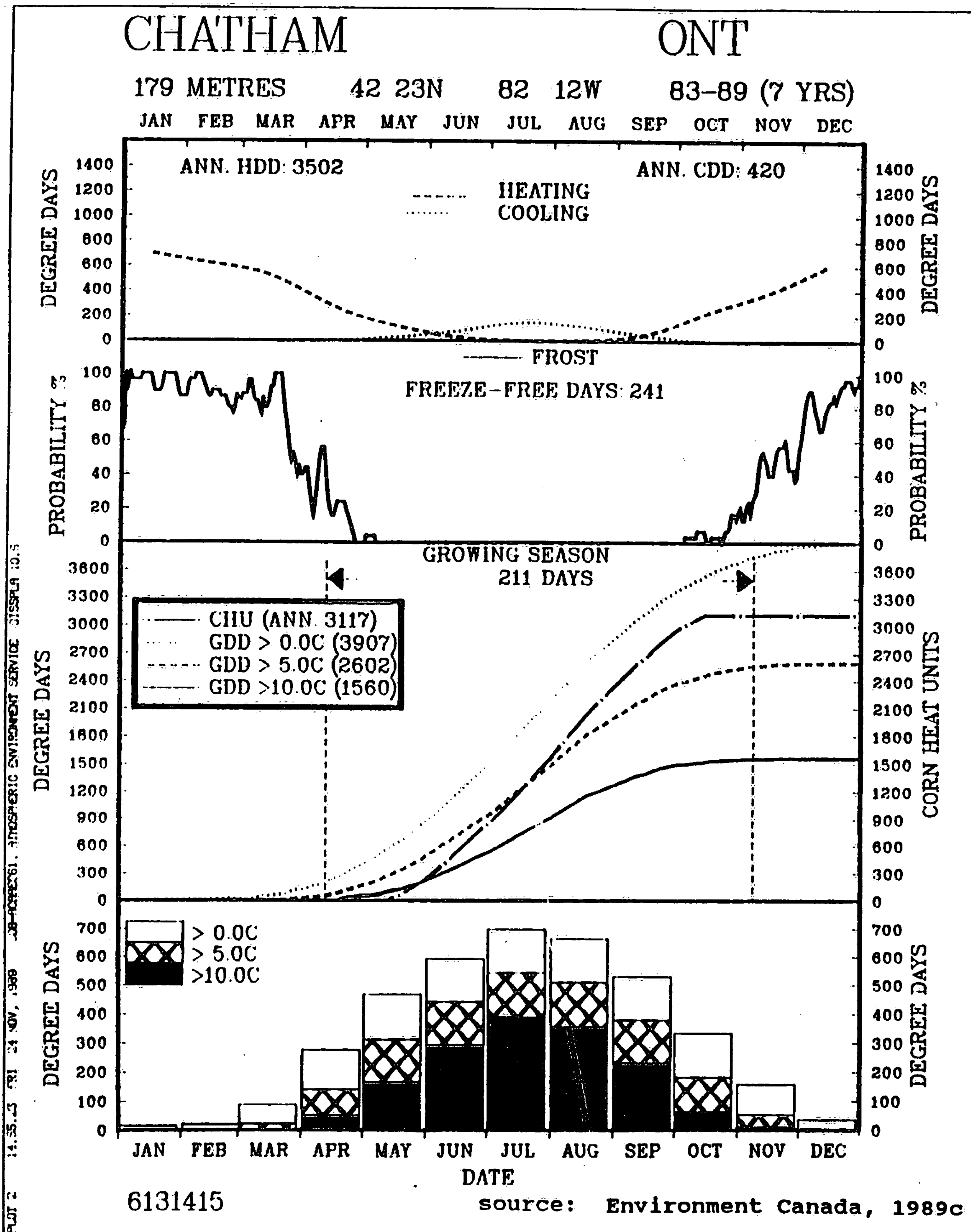
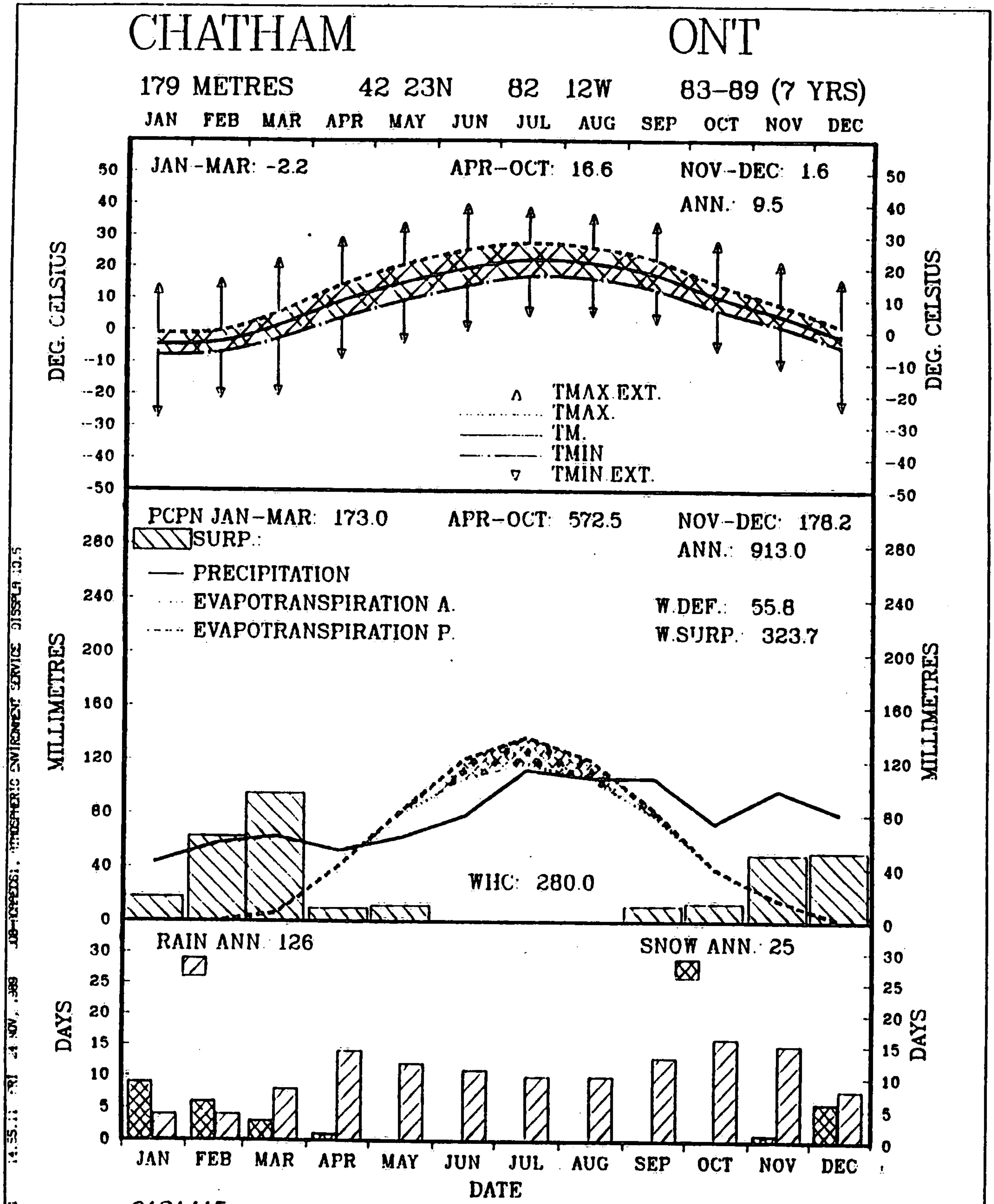


Figure 2A. Degree Day and Heat Unit Profile for Chatham, Ontario



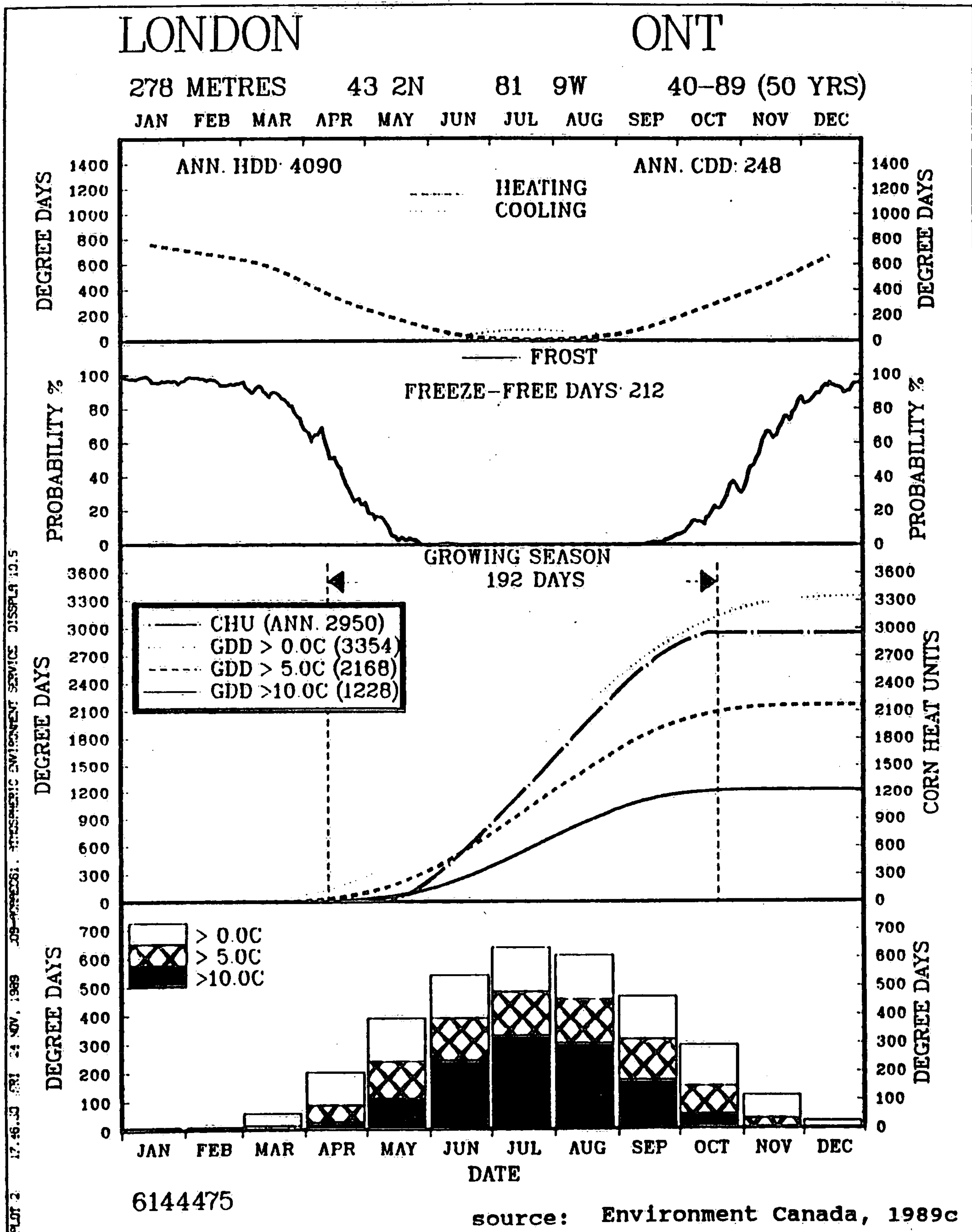
source: Environment Canada, 1989c

Figure 2B. Temperature and Precipitation Profile for Chatham, Ontario



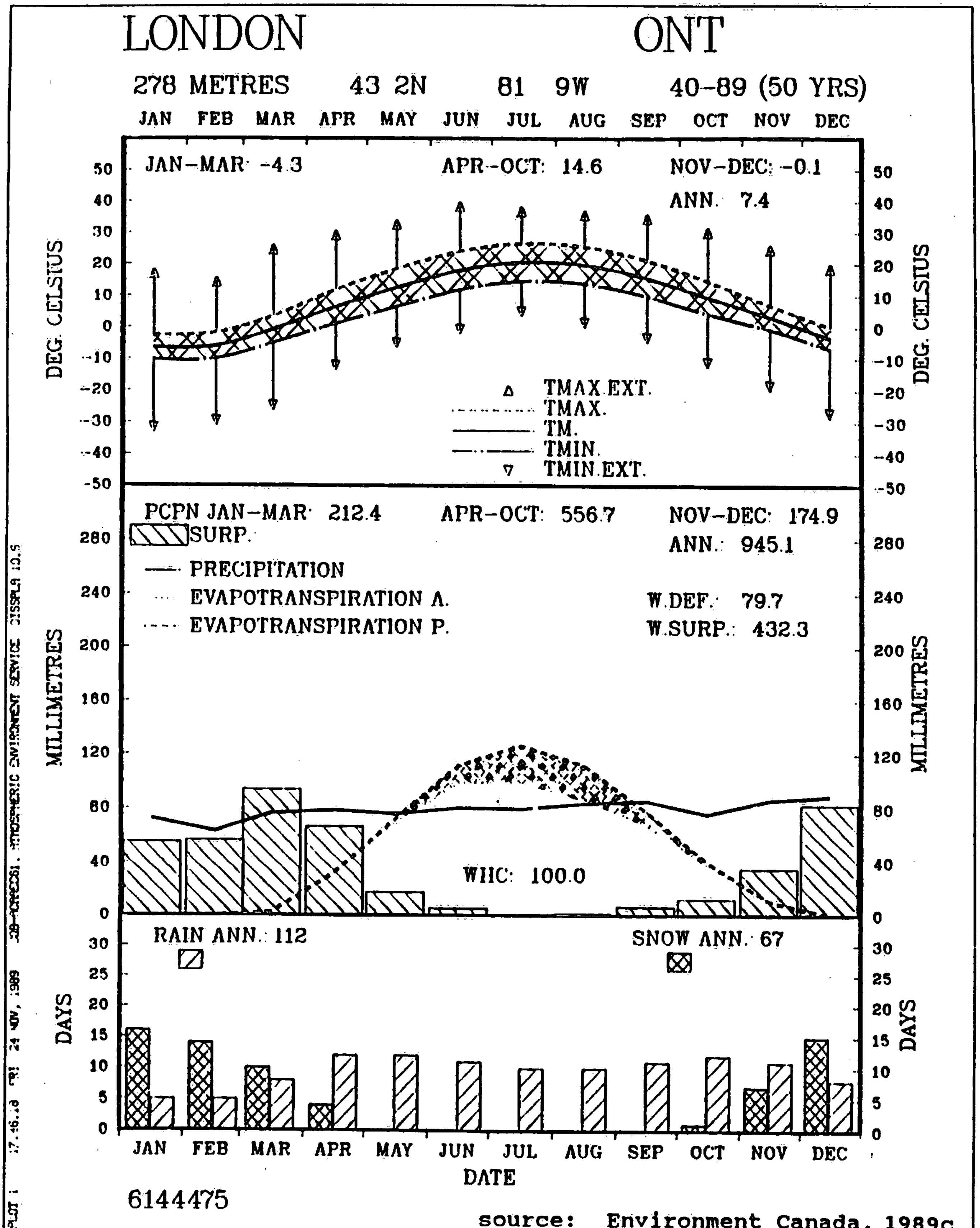
source: Environment Canada, 1989c

Figure 3A. Degree Day and Heat Unit Profile for London, Ontario



source: Environment Canada, 1989c

Figure 3B. Temperature and Precipitation Profile for London, Ontario



source: Environment Canada, 1989c

1.1.2 Geology

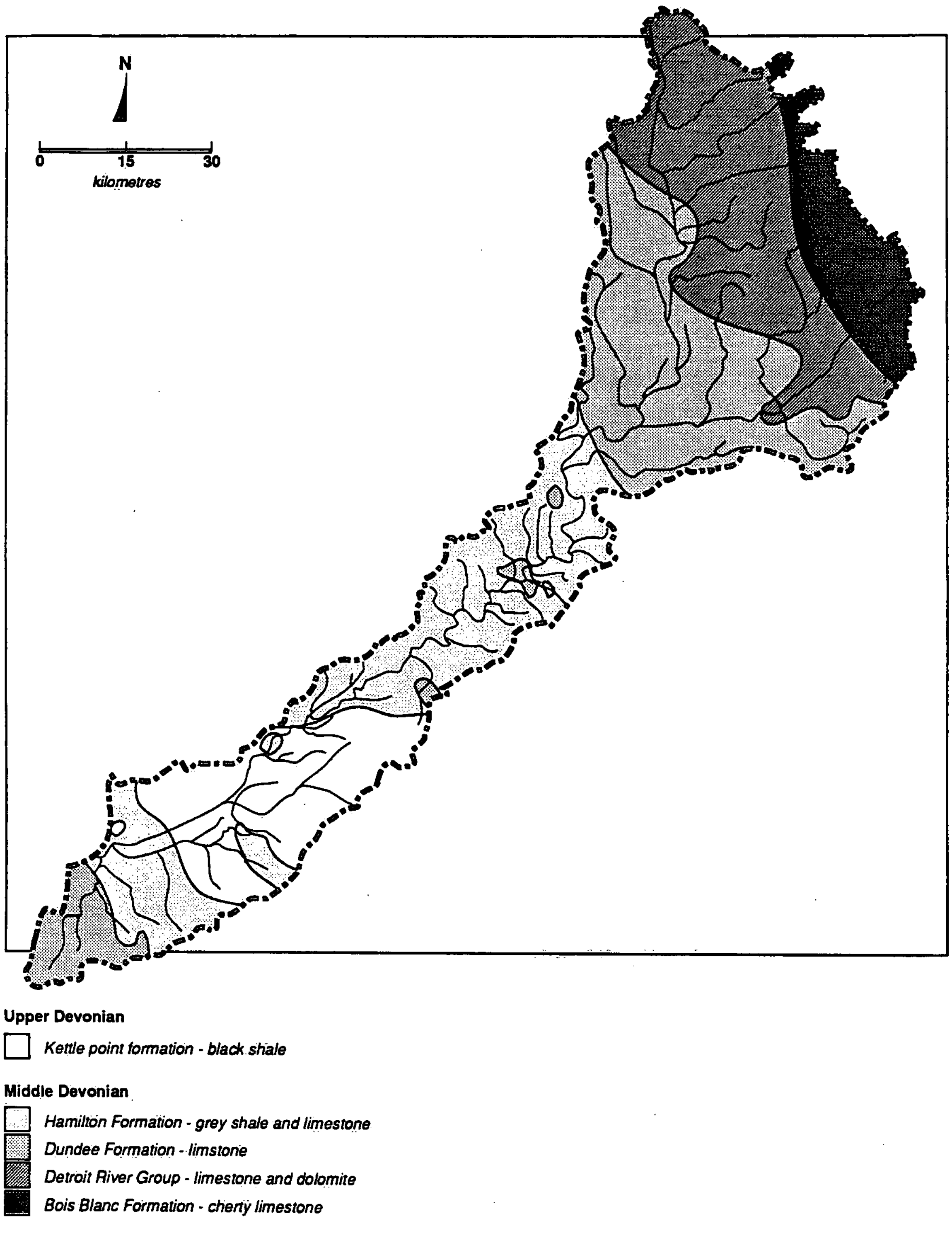
Sedimentary rocks of the Upper and Middle Devonian ages formed in ancient seas underlie this portion of southwestern Ontario (Figure 4). These sediments were deposited on the undulating surface of the Precambrian igneous rocks and form successive layers. Continuous erosion exposed formations in a northwest trending outcrop/suboutcrop distribution. The dolomitic limestones of the Bois Blanc Formation, limestones and dolomites of the Detroit River group of formations, and dolomites and limestones of the Dundee Formation underlie the central portion of the basin with their southwest edge along a line through Komoka and Delaware. West of this area, a significant change in rock type occurs, and the essentially carbonate sections of limestone and dolomite give way to shales and shaley limestones of the Hamilton formation and shales of the Kettle Point formation, which underlie the southwest portion of the basin. The change in rock is accompanied by dramatic changes in quantity and quality of ground waters obtained from the bedrock and is discussed in section 1.1.10 of this report (MOE, MNR, 1975).

1.1.3 Surficial Deposits

The Lower Thames basin consists primarily of lacustrine sands, silts and clays which overlie glacial till (Figure 5). The Blenheim and Charing Cross moraines which protrude through the lacustrine material consist primarily of clay. Beach deposits of sand and gravel occur

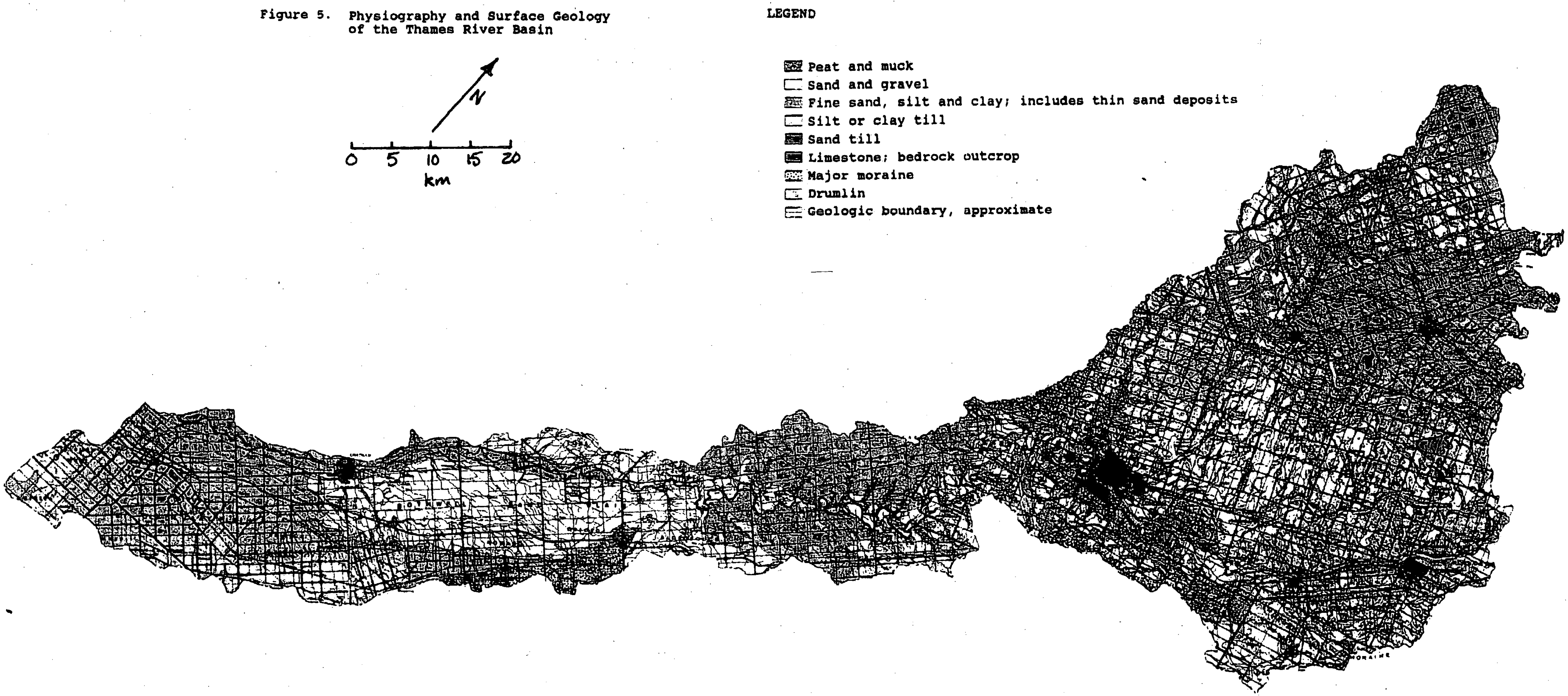
Figure 4

Geology of the Thames River Basin



Source: Ministry of Natural Resources, 1972

Figure 5. Physiography and Surface Geology of the Thames River Basin



Source: Ontario Ministry of the Environment, 1981 on the northern flank of the Blenheim moraine. The upper basin is dominated by a clay till. Long, sinuous moraines extend to the north and east of London. These moraines are comprised primarily of clay; however, inter-lobate moraine deposits of sand and gravel are common, especially along the Ingersoll moraine. The structural character of the moraine is complex reflecting a dynamic depositional environment. The thickness and nature of the deposits change rapidly and are generally discontinuous.

Spillways, which served to drain meltwaters from the receding ice sheet are characterized by sandy, gravelly outwash deposits. These channels, many of which contain contemporary drainage, flank the moraines and converge at London. Sand and gravel deposits in the London area were transported by meltwaters and deposited as deltas where the spillways entered glacial Lake Whittlesey. These deposits are locally thick and extend to bedrock in the vicinity of the Fanshawe Dam.

Overburden covers all of the lower basin and minor bedrock outcrops occur only at Beachville and St. Marys in the upper basin. The overburden thickness varies throughout the basin with a maximum reported thickness of approximately 90 m in the moraine south of London (MOE, MNR, 1975).

1.1.4 Hydrology

The Thames River system drains an area of 5,876 km^2 extending from Lake St. Clair in the west to the highlands of Perth and Oxford counties northeast of London. It is the second largest watershed in Southwestern Ontario, and drains approximately 25% of the Ontario portion of the Lake Erie drainage basin. The basin is 200 km long with a maximum width of 56 km. The drainage characteristics of the upper and lower parts of the basin are significantly different.

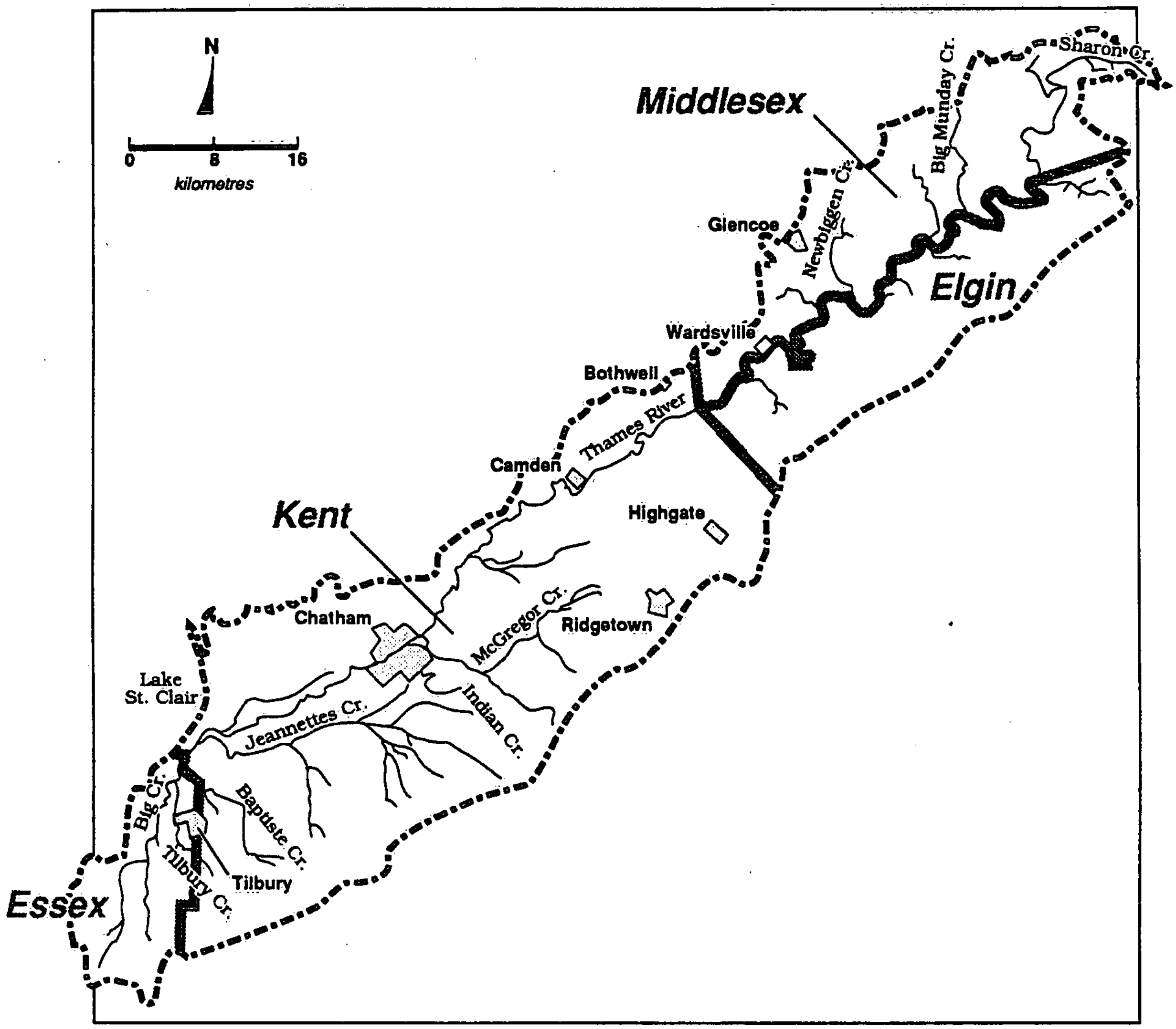
Lower Thames

The lower part of the Thames River basin is 2,480 km^2 in area and extends from Lake St. Clair to Delaware. The basin is roughly rectangular in shape, with a length of 136 km and a maximum width of 23 km (Figure 6). For the first 29 km from Lake St. Clair to Chatham, there is an elevation difference of less than 30 cm and the river level is controlled by water levels in Lake St. Clair. Downstream from Chatham, dikes have been constructed along the river to control flooding of adjacent agricultural lands. For the first 19 km above Chatham, the gradient of the main stream is about 0.15 m/km, while for the remaining 125 km, it averages 0.22 m/km.

There are numerous short tributaries to the Lower Thames, all of which have steeper

Figure 6

Lower Thames Drainage Basin



Basin boundary

County boundary

gradients than the main stream. Those entering the main stream from the north are generally less than 15 km long, while those from the south are generally longer and drain larger areas. The largest of these tributaries are Jeannette, McGregor and Big creeks.

Upper Thames

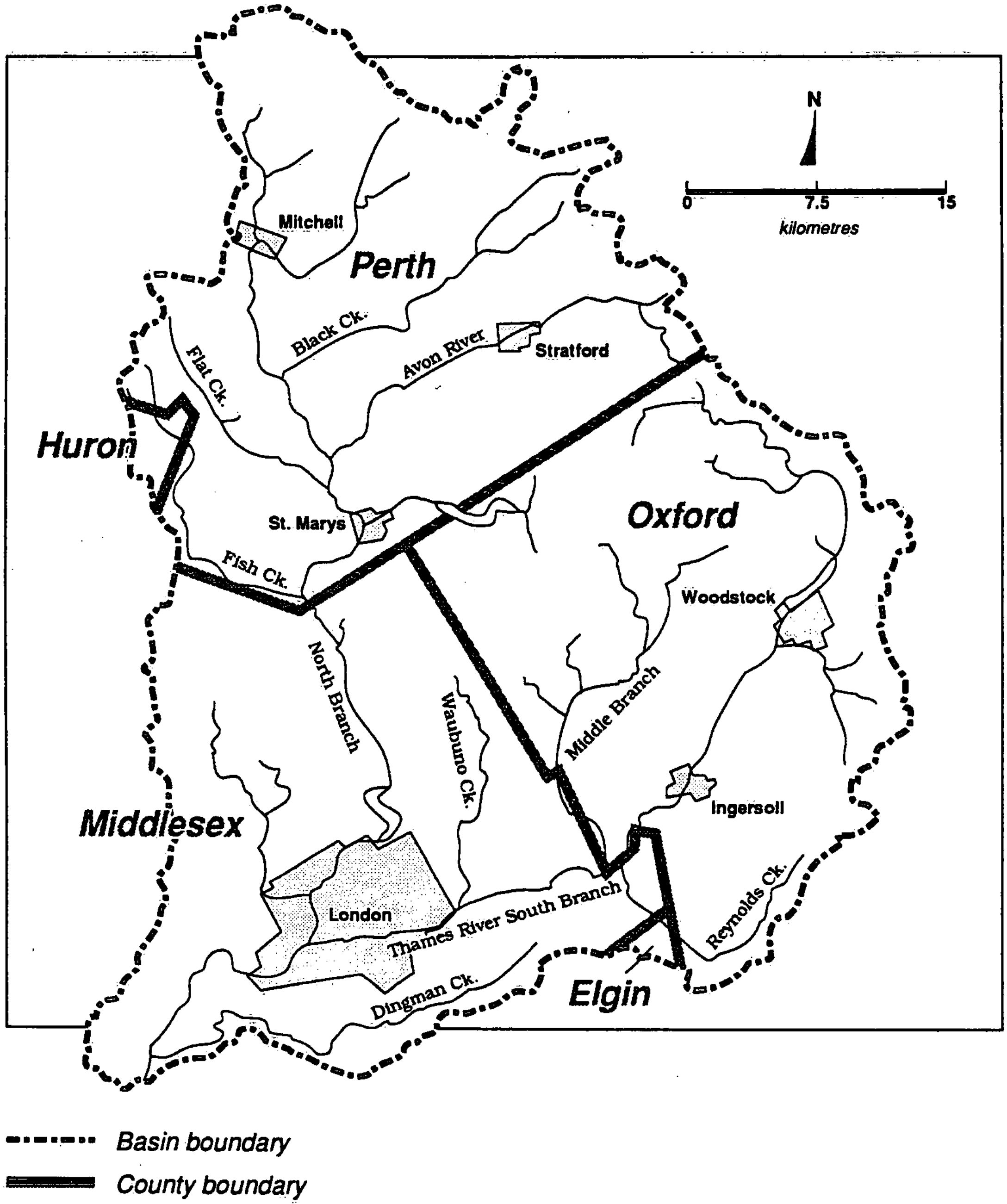
In contrast to the lower basin, the Upper Thames watershed is almost round in shape with a drainage area of 3,395 km^2 (Figure 7). The stream gradients in the upper basin are relatively steep, varying from 1.03 to 2.10 m/km. Several long tributaries radiate outward from the confluence at London. The North Thames River drains 1,719 km^2 in the northwest section of the basin; its major tributaries include the Avon and Medway rivers. The main branch of the Thames river above London drains 1,378 km^2 in the northeast part of the basin. The Middle Thames River and Waubuno, Reynolds and Cedar creeks are its main tributaries.

1.1.5 Land Use Characteristics

The Thames watershed includes 18 urban municipalities (four cities, seven towns and seven villages) and all or parts of 48 rural townships in seven counties. In 1975, urban municipalities accounted for 5% of the total area of the watershed; farmland occupied

Figure 7

Upper Thames Drainage Basin



approximately 85%; other non-farm rural uses including roads, industries and hamlets approximately 10% (MOE, MNR, 1975).

Rural Land Use

The primary land use and the major component of the Thames basin economy is agriculture. Figures 8A and 8B show the generalized rural land use in the Lower and Upper Thames respectively. Agricultural activity includes livestock production, dairying, selected field crops, fruits, vegetables and tobacco. These activities are grouped in high concentrations in the following areas: dairy farming in Oxford and eastern Middlesex counties; tobacco in south-central Middlesex county; mixed farming in Perth and Middlesex counties; corn, soybeans, wheat and cannery crops such as tomatoes and peaches in Kent and eastern Essex counties; and livestock raising in eastern Huron and Perth counties (MOE, MNR, 1975).

Intensive and extensive agricultural land use have become dominant trends throughout the watershed. Intensive agriculture involves the raising of increasing number of livestock in high-density, feedlot operations or increased use of fertilizers, pesticides, and mechanization in the case of row cropping. These practices have resulted in a steady increase of phosphorous and nitrogen inputs to the Thames River (G.E. Bangay, 1974). PLUARG studies indicated that some of the highest livestock phosphorous loadings for the entire Great Lakes Basin are attributable to the Upper Thames basin. PLUARG studies also

Figure 8a

General rural land use in the Lower Thames Basin

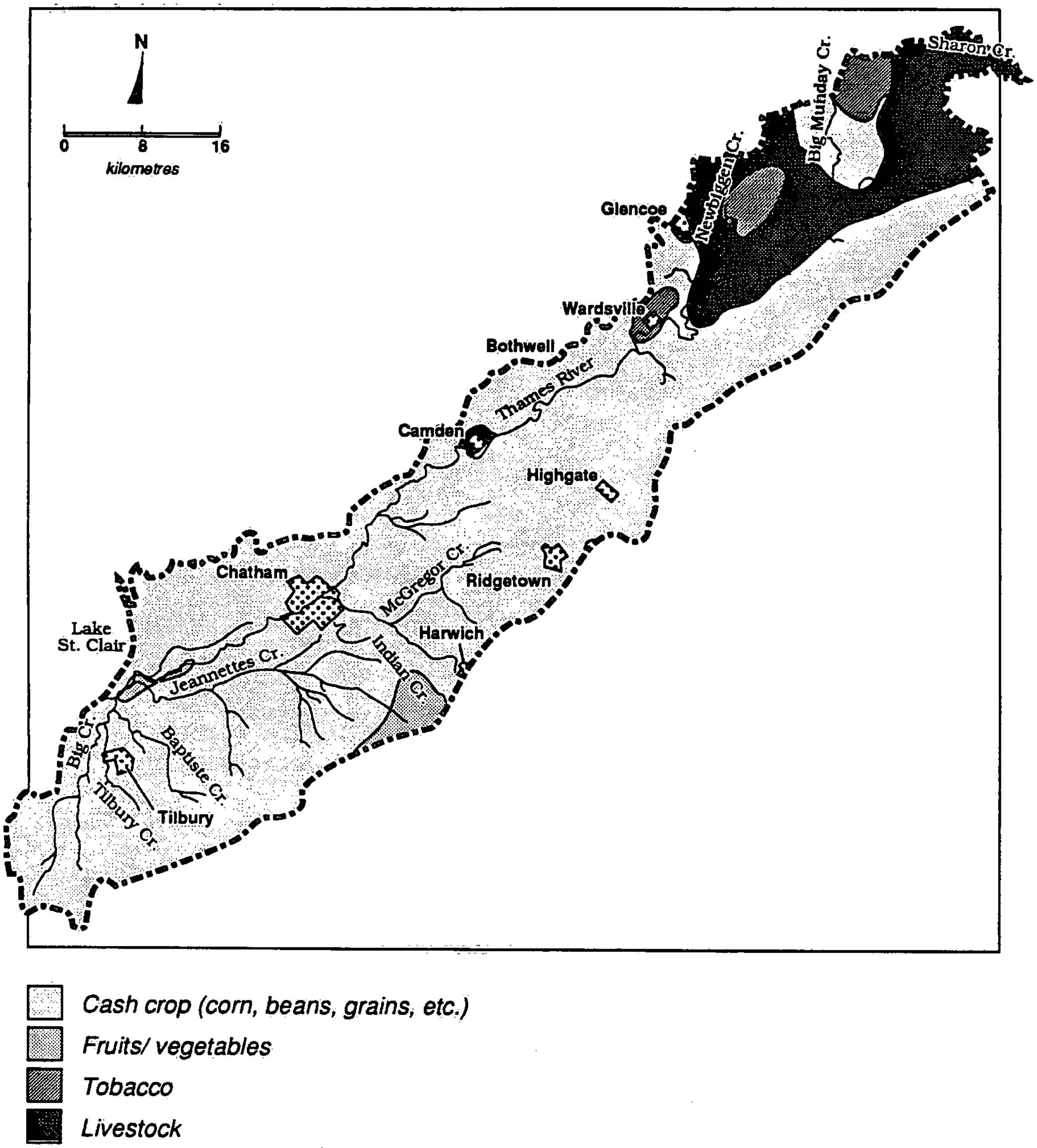
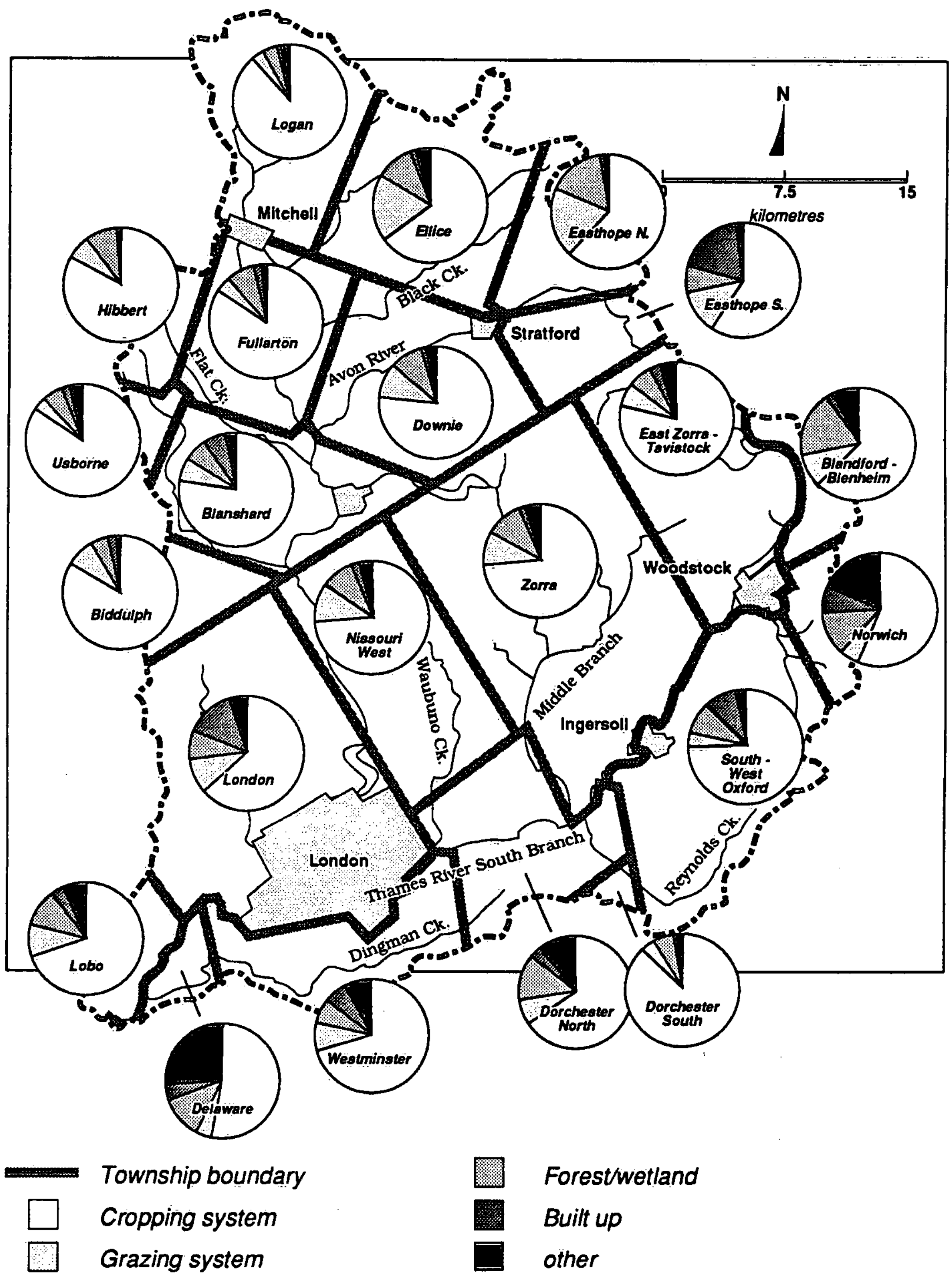


Figure 8b

General rural land use in the Upper Thames Basin



estimated that phosphorous inputs from croplands are estimated to be from 4 to 6 times the input from livestock in the Upper Thames basin (International Joint Commission (IJC), 1978). Water quality impairment due to elevated fecal coliform densities result from free cattle access to the waterways. "Livestock in this watershed, in 1971, generated waste equivalent to a human population of more than 3.4 million, ... this compares to an actual 1971 population of 414,000 people in the basin" (MOE, MNR, 1975). More recent data is not available on a basin-wide level. Studies related to the problem of pesticide runoff have only recently been initiated by Environment Canada in the Kintore Creek sub-basin.

Extensive agriculture involves the clearing of forest cover to increase the area of agricultural land and the upgrading of marginal land to higher agricultural productivity. The removal of forest cover and undesirable vegetation typically results in more rapid runoff, increased peak flows and increased soil and streambank erosion. Upgrading of marginal lands through artificial drainage can lead to similar problems (Haussmann, 1981).

Urban Land Use

The agricultural base of the Thames watershed is complemented by industry and commerce in several urban centres. The City of London is the centrally located, metropolitan centre of the basin covering roughly 156 km^2. The cities of Woodstock, Chatham and Stratford serve as subregional centres of roughly the same population and function. The fertile soils throughout the watershed have limited urban growth, and the general policy of the municipalities in the basin is to develop within municipal boundaries rather than to expand beyond them. This, coupled with the fact that many of the urban municipalities contain agricultural and vacant lands within their boundaries, suggest that insignificant changes will occur in the present urban land use patterns on the Thames region (LTVCA, 1983). Figures 9A and 9B show overall land use for both the upper and lower basins.

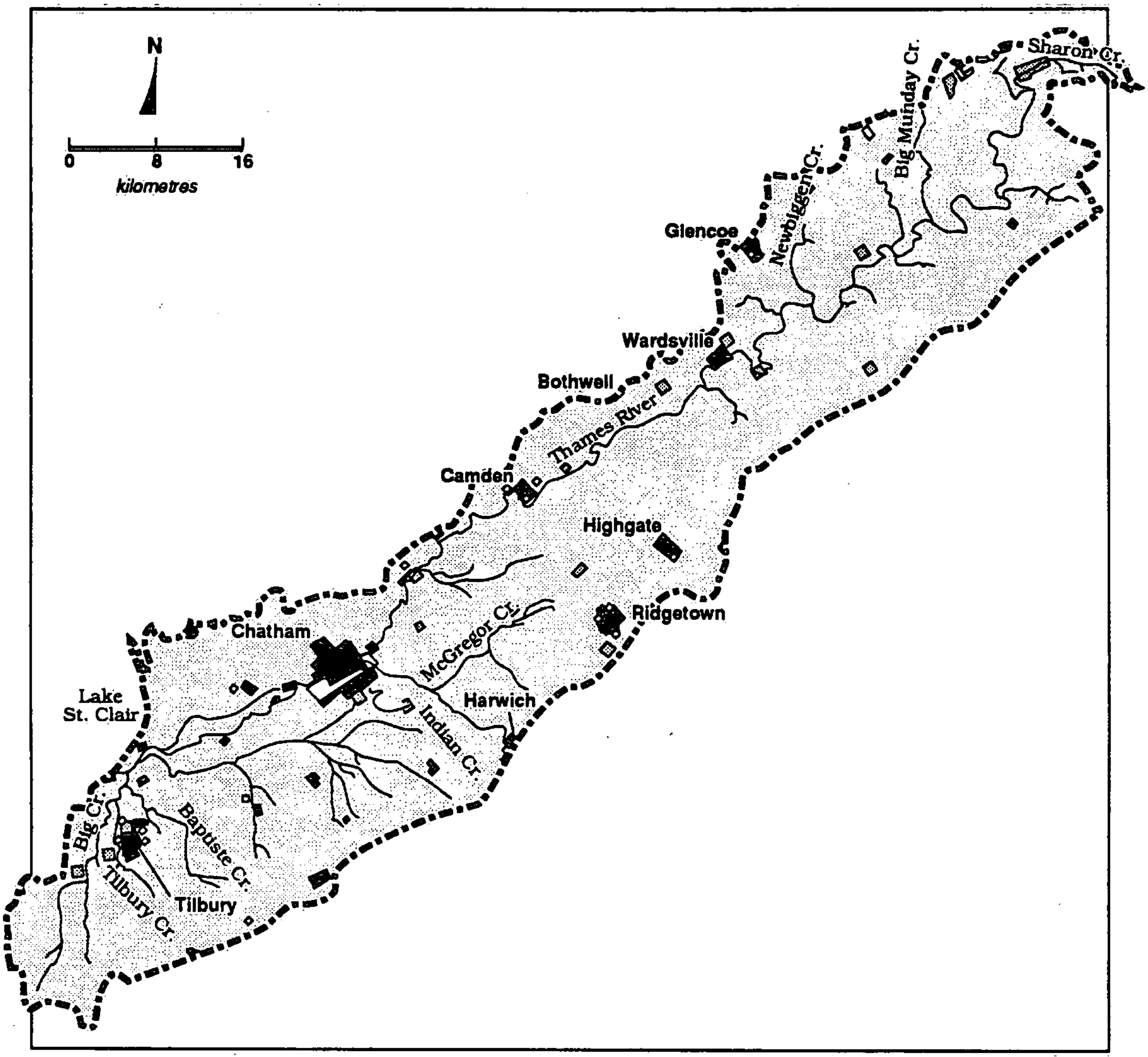
1.1.6 Agriculture

Lower Thames

The dominant agricultural land use in the Lower Thames watershed is intense cash crop farming. On average, 93% of the total farmland is cropped in any one year. The main crops include corn, soybeans, wheat, hay, and other spring grain and seed crops. Corn is by far the dominant crop covering about 107,000 ha or nearly one third of the total cropland in the Lower Thames (LTVCA, 1983).

Figure 9a

Overall land use in the Lower Thames Basin



- ■ ***Residential***
- ▦ ***Recreation***
- ░ ***Agriculture/Woodland***
- □ ***Industrial***

Figure 9b

Overall land use for the Upper Thames Basin

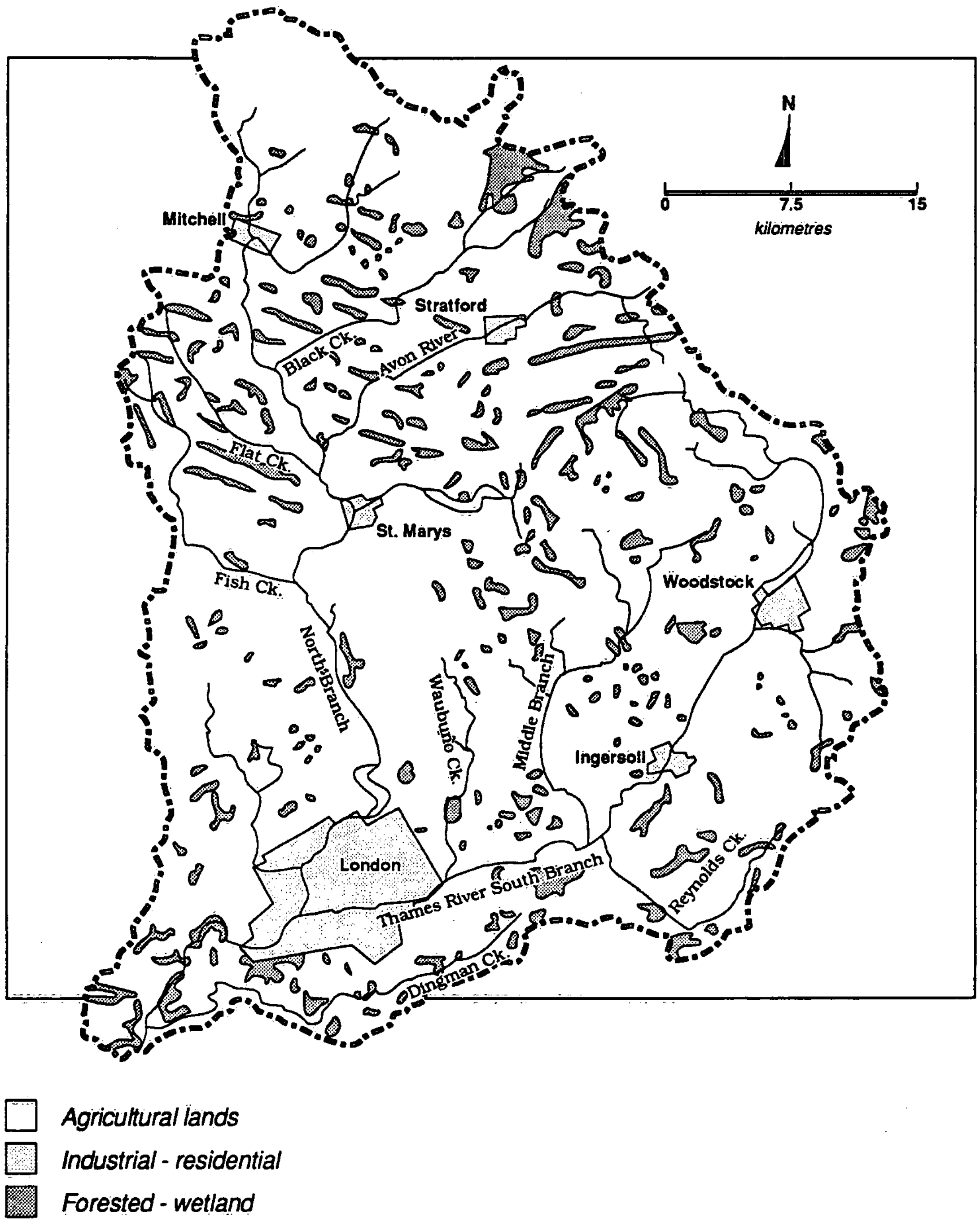


Table 1. Agricultural Land Use in the LTVCA

land use	area (ha)	% of total agricultural land	% of total watershed
crop production	319,800	93%	82%
pasture	21,765	6.4%	5.6%
summer fallow	2,134	0.6%	0.5%
total	343,699	100%	88.1%

Upper Thames

The Upper Thames, in contrast, is dominated by livestock production and dairying, with some mixed farming and tobacco production. The general trend over the past decade has been away from the dairy sector of the livestock industry with pigs showing the greatest increase both in absolute numbers and in rate of increase.

Land Use System Classification

Agricultural Land Use Systems have been used as the basis for describing land use within each of the sub-basins examined during this study (Ontario Ministry of Agriculture and Food (OMAF), 1986).

Land Use Systems have been developed to improve the nature of rural land use analysis. Land Use Systems are defined as: Monoculture, Corn System, Mixed System, Hay System, and Grazing System. Each of these Systems are relatively stable through time, i.e. annual rotational changes in cover crop do not affect their classification. Real changes in land use, however, such as occurs when a mixed farm moves to a livestock operation, are readily detected. Although the Agricultural Land Use Systems maps were based on a 1983 survey, the nature of the Land Use Systems are such that not only are the classes relevant for a longer period of time, but the type of information is more easily related (qualitatively) to water quality information than is the more traditionally used crop summary information. In this latter case information is provided on a crop by crop, field by field basis and as such is frequently out of date by the following year because of crop rotation. Further, there are difficulties analyzing several years data as it is difficult to determine whether a change in cover crop is simply a rotational change or a real change in land use.

Table 2 describes the Land Use Systems classification as applied to most of southern Ontario. Table 3A outlines the percent of each class of land use in each sub-basin. Table 3B aggregates similar land use classes and shows the major soil textures within each sub-basin.

Generally, the percentage of land under monoculture systems decreases from the mouth of the Thames towards the headwaters. An average of 30% of the area within the sub-basins of the Lower Thames is monoculture whereas roughly 17% of the Upper Thames sub-basins

Table 2

Agricultural Land Use Systems used to characterized land use throughout Ontario.

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.

Table 3a Land Use Classification System for the Thames River Sub-basins.
Values are expressed as percent of total area of sub-basin.

	LOWER THAMES					UPPER THAMES				
Code	BIG CREEK	JEANNETTES CREEK	McGREGOR CREEK	NEWBIGGEN CREEK	LOWER MAIN	FISH CREEK	NORTH THAMES	EAST THAMES	MIDDLE THAMES	UPPER MAIN
P	26.7	33.7	31.7	26.2	32.0	15.9	12.4	18.4	17.8	18.5
C	58.5	52.9	33.3	38.7	32.3	38.2	35.5	27.3	33.9	34.4
M	1.9	1.3	1.2	7.1	4.3	17.5	24.9	24.0	20.8	15.5
MG	0.4	0.3	0.2	0.6	0.3	3.1	2.7	1.4	1.2	1.5
H	0.2	1.0	1.0	8.7	3.0	6.2	8.5	4.8	6.8	5.6
HG	0.0	0.1	0.9	0.0	0.4	0.8	0.5	0.2	0.2	0.5
G	0.0	0.0	0.4	1.9	1.2	1.4	1.0	1.7	1.9	1.6
PE	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OR	0.1	0.3	0.5	0.1	0.1	0.0	0.0	0.5	0.1	0.2
V	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OV	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
VO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BE	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
KF	3.9	3.9	7.0	0.1	1.1	0.4	0.6	0.2	0.8	0.4
KM	0.7	0.4	0.0	0.0	0.0	0.1	0.0	0.3	0.1	0.1
KT	0.1	0.3	5.1	0.3	2.8	0.0	0.0	3.7	0.2	0.7
KN	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0
A1	0.3	0.4	1.6	0.7	0.8	0.5	0.4	0.3	0.3	0.7
A2	0.3	0.1	0.3	1.3	1.1	0.6	0.4	0.3	0.9	0.7
Z	1.1	1.4	7.5	11.9	13.2	7.1	7.7	8.7	10.3	9.2
ZP	0.0	0.0	0.1	0.2	0.1	0.1	0.1	0.0	0.1	0.1
ZR	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.2	0.4	0.1
B	3.6	1.9	4.5	1.3	4.0	6.0	4.5	5.4	1.8	10.0
X	0.4	0.2	2.4	0.0	0.2	0.0	0.9	2.4	0.0	0.0
E1	0.1	0.0	0.5	0.0	0.2	0.7	0.3	0.2	0.9	0.8
E2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T	0.2	0.0	0.0	0.7	0.1	0.1	0.0	0.0	0.0	0.2
R	1.0	0.1	2.3	0.1	0.4	0.6	0.1	0.8	0.6	0.8
W	0.6	0.4	0.0	0.0	0.1	0.4	0.1	0.3	0.5	0.4
NC	0.4	0.6	0.2	0.1	0.4	0.0	0.8	0.3	0.2	0.6
IR	0.0	0.0	0.0	0.0	3.5	0.0	0.0	0.0	0.0	0.3

Table 3b Conglomerated Land Uses for the Thames River Sub-basins

SUB-BASIN	PCM %	HGG %	MG %	TOBACCO %	IDLE %	FOREST %	URBAN %	WETLAND %	SOIL TEXTURE COARSE %	MEDIUM %	FINE %
UPPER THAMES											
BIG CREEK	88	0.2	4.77	0.09	0.6	1.2	3.6	0.38	50	0	50
JEANNETTES CREEK	88	1.2	4.96	0.29	0.6	1.5	1.9	0.17	50	0	50
McGREGOR CREEK	66	2.4	7.64	5.11	1.8	7.5	4.5	2.40	100	0	0
NEWBIGGEN CREEK	73	10.9	0.20	0.33	2.0	11.9	1.3	0.00	100	0	0
LOWER MAIN	69	4.6	1.38	2.82	1.9	13.3	4.0	0.23	80	2	19
LOWER THAMES											
FISH CREEK	75	8.4	0.59	0.00	1.1	7.3	6.0	0.00	0	70	30
NORTH THAMES	75	10.1	0.65	0.00	0.8	7.8	4.5	0.91	0	25	75
EAST THAMES	71	6.8	1.14	3.69	0.6	8.9	5.4	2.22	2	88	10
MIDDLE THAMES	74	9.0	1.09	0.22	1.3	10.7	1.8	0.01	20	80	0
UPPER MAIN	70	7.8	0.78	0.68	1.4	9.3	10.0	0.01	20	50	30

PCM: P, C, M, MG
HGG: H, HG, G, Zp
MG: PE, CH, PC, O, V, OV, Be, KF, KM, KN
IDLE: A1, A2
*: general estimate only for soil texture

are under monoculture systems. Corn systems account for over 50% of the land use in the Big Creek and Jeannette Creek basins. Corn systems cover roughly 34% of all Upper Thames sub-basins. Mixed systems average 20% of the Upper sub-basins while less than 10% of the Lower sub-basins are under this system. The greater emphasis on livestock production in the Upper Thames is reflected by an approximate doubling in the amount of land use devoted to hay, pasture and grazing systems.

Agricultural Drainage

The UTRCA estimated that by 1950, at least 850 miles of drains had been constructed in the Upper Thames (MOE, MNR, 1975). The UTRCA has expressed concern over the detrimental effects of tile drainage as related to increased runoff (peak flows), correct vs. incorrect installation, improper/illegal connections to municipal drains, potential leaching of fertilizers and pesticides into the tiles and thus into the water courses, and connection of milkhouse wastewater drains to tile systems (Briggs, Pers. Com.). Maps of tile drained areas in the Upper Thames basin are recorded on a township basis only and have not yet been examined on an overall basin level (Briggs, Pers. Com.).

It is estimated that between 60 - 70% of the farmland is artificially drained in the Lower Thames (Kalinauskas, 1981). Available data provided a breakdown of area tile drained at the county level only. Most recent estimates suggest that in 1981 Kent county, with 69% of the land tile drained, had the highest percentage of artificial drainage in southwestern Ontario. Middlesex and Elgin both had approximately 43% of their area tile drained, Perth 39% and Oxford 25% (MOE, 1986).

Livestock Operations

Table 4 lists 1988 livestock population figures for those counties whose borders lie within the Thames basin (OMAF, 1989a). Table 5 lists, by township, the number and type of livestock related pollution sources in the Upper Thames basin during 1987.

Table 4. 1988 Livestock Population by County

COUNTY	TOTAL CATTLE	TOTAL PIGS	TOTAL SHEEP & LAMBS	TOTAL CHICKENS
ELGIN	33900	87200	3000	535198
ESSEX	6400	3[illegible]500	800	225017
HURON	130100	396000	9000	2900870
KENT	20100	139000	1500	1510042
MIDDLESEX	98600	329000	7900	1821580
OXFORD	100400	268800	3500	1086348
PERTH	112300	404500	3300	1751221

Source: OMAF, 1989a

Table 4

Summary by Township of Identified Pollution Sources from the 1987 Survey of High Priority Livestock Operations in the Upper Thames

	BIDDULPH	BLANSHARD	DOWNIE	EAST ZORRA TAVISTOCK	ELLICE	FULLARTON	HIBBERT	LOGAN	NORTH EASTHOPE	SOUTH EASTHOPE	USBORNE	WEST NISSOURI	TOTAL
FARM SURVEY													
CONFIRMED HIGH-PRIORITY	2	33	54	63	31	31	5	30	37	7	4	13	315
NO LONGER HIGH PRIORITY	1	37	26	71	19	29	6	24	58	10	2	18	301
MANURE STORAGE													
LIQUID	0	2	10	4	10	3	0	3	2	0	0	3	37
SEMI SOLID	0	3	5	3	2	5	0	0	2	0	0	6	23
DRY	2	37	47	56	25	27	5	30	28	7	4	6	274
GAL/YR of CONTAMINATED RUNOFF	147,623	2,561,541	2,876,165	3,437,895	907,082	1,607,036	236,384	714,477	2,568,828	1,060,457	200,506	115,130	16,433,124
LIVESTOCK ACCESS (# of animals)													
NO ACCESS	3,442	4,103	5,791	5,577	3,442	5,777	130	3,104	4,236	525	145	10	36,287
LIMITED	0	175	0	0	0	314	39	90	183	0	0	65	866
UNLIMITED	335	415	487	660	335	0	35	0	140	69	128	40	2,644
LENGTH OF FENCE REQUIRED (FT.)	12,953	23,424	20,229	33,710	12,953	10,510	1,320	1,650	5,280	7,326	14,305	4,290	147,950
MILKHOUSE WASH WATER													
MILKHOUSES	2	24	45	61	16	19	3	26	34	6	1	30	267
PARLOURS	0	3	1	0	5	1	0	2	0	0	0	0	9
No. with treatment	0	3	12	5	9	6	2	6	13	0	0	9	62
No. to water	2	24	34	56	12	14	1	20	21	6	1	21	205
GAL/YEAR to water	36,354	753,363	843,880	1,226,400	359,160	367,920	18,250	554,800	797,160	87,600	29,200	345,290	5,419,382

Source: Merkley, 1987 for MOE

Fertilizer Use

Table 6 lists, by county, the total tonnage of fertilizer applied to agricultural lands within the Thames River basin. The higher percentage of land under small monoculture corn systems (P) and large corn systems (C) are reflected in the high fertilizer application rates in Elgin, Essex and Kent counties.

1.1.7 Land Erosion

Erosion in the Thames watershed can be classified into two categories: soil erosion and channel erosion. In the upper watershed, soil erosion is of relatively greater significance, while channel erosion is a greater problem in the lower watershed (MOE, MNR, 1975).

Soil erosion in the Thames watershed is most frequently the result of runoff from cultivated land. Slope, rainfall and land use are the primary factors affecting this type of erosion. Removal of forest cover as a result of agricultural expansion or urban development has also contributed to soil erosion. Soil erosion can lead to the impairment of water quality by increasing the levels of suspended or dissolved solids and carrying adsorbed nutrients and chemicals into watercourses. Prior to the 1880's over 80% of the basin was forested, this figure dropped to slightly more than 10% in 1957 and rose slightly to roughly 11% by the mid-1970's (MOE, MNR, 1975). Currently, forests cover averages 8% within sub-basins.

Table 6 AMOUNT OF FERTILIZER APPLIED WITHIN THE THAMES RIVER BASIN (1985, COUNTY BASIS)

COUNTY	FERTILIZED LAND (ha)	TOTAL APPLIED (tonnes)	N APPLIED	P APPLIED	K APPLIED	TOTAL/HA (kg)
Elgin	108019	50506	10657	6162	9192	467.5
Essex	91240	41326	8720	5042	7521	452.9
Huron	203632	77421	16336	9445	14091	380.2
Kent	162911	76139	16065	9289	13857	467.4
Middlesex	183289	79085	16687	9648	14393	431.4
Oxford	125253	58134	12266	7092	10580	464.1
Perth	139548	45371	9573	5535	8258	325.1

Source: Fertilizer Institute of Ontario, 1989
Environment Canada, 1990

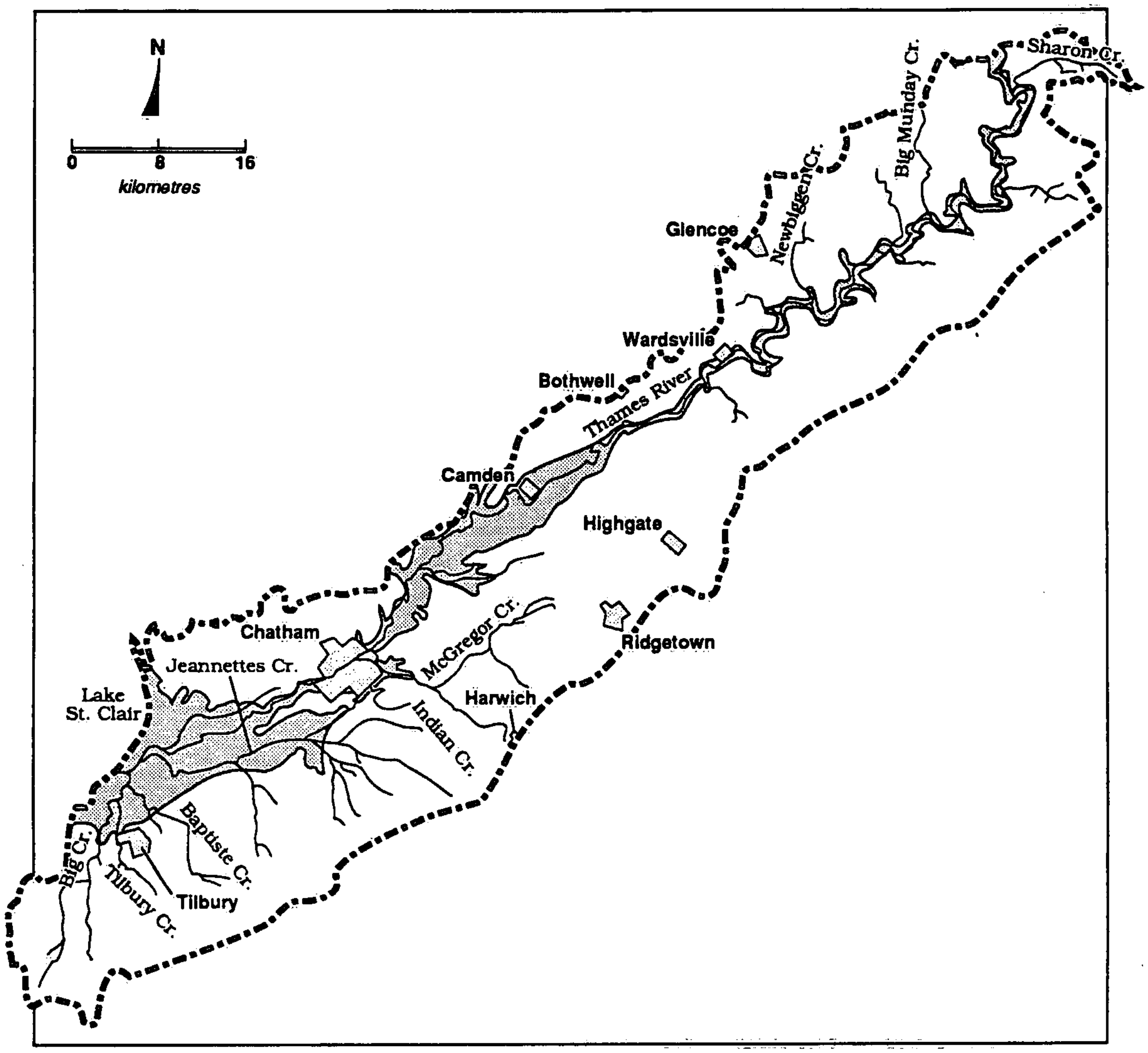
The primary cause of channel erosion is scouring by flood waters of material from the bed and banks of streams. The movement of large masses of ice down the river during spring breakup is another important factor. Other causes of channel erosion include cattle access, variations in the level of Lake St. Clair, and erosion from surface waves, particularly those caused by the wake of watercraft (MOE, MNR, 1975).

In the Upper Thames two studies illustrate the problem of channel erosion. At Mill Pond Road, prior to 1979, the South Branch of the Thames River was undercutting the bank causing erosion to occur at rates up to 4 m per year along a 400 m slope. The problem was rectified at a cost of $1 million. 1982 studies along some stretches of Medway and Dingman creeks have revealed erosion rates from 0.05 - 0.6 m per year with damages along Dingman Creek of $1,000 per year or more (UTRCA, 1983).

Erosion problems in the lower reaches of the Thames River are mostly the result of flooding (Figure 10). A large portion of the fertile lands in the townships of Dover, Raleigh, Tilbury East, Tilbury West, and Tilbury North, lie below the high water levels of both the Thames River and Lake St. Clair. To control flooding, a system of dikes, drainage ditches and pumping stations have been developed to protect the agricultural lands from normal high water

Figure 10

Flood prone areas in the Lower Thames Basin



Areas subject to flooding

levels. Not withstanding these structures, under extreme conditions, extensive flooding still occurs.

Table 7 lists the distribution of potential erosion areas in the Upper Thames Basin based on overlaying areas with high potential for gross erosion and high terrain capability to transport sediment.

Table 7. Distribution of Potential Erosion Areas in the Upper Thames Basin

Gross Erosion : Terrain Capability to Transport	Area in Hectares	Percentage of Total Watershed
High:High	15,613	4.6
High:Medium	13,669	4.0
Medium:High	38,220	11.1
Total	67,502	19.7

Source: UTRCA, 1983

1.1.8 Municipal and Industrial Discharges

Municipal

As of 1971, 93% of the urban basin population was serviced by waste treatment systems discharging to the Thames River. A further 4% had treatment systems in various stages of development for a total of 97% of the urban population (MOE, MNR, 1975). The remainder of the population in rural areas and unserviced municipalities used septic tank and tile field systems. Municipal waste treatment systems provide secondary treatment of wastes designed to remove more than 90% of the suspended solids and oxygen utilizing organisms. Phosphorous guidelines concentrations of 1 mg/L are now required at all municipal treatment plants in the Thames basin because of the adverse effects of phosphorous in Lake Erie. Some systems for smaller municipalities and private institutions utilize waste stabilization lagoons to store sewage effluent for discharge in periods of high streamflow (MOE, MNR, 1975).

Table 8 lists the municipal sewage treatment facilities discharging into tributaries of the Thames basin during 1989 and their record of compliance from 1985 to 1988. Locations of stations in operation prior to 1975 are shown in Figure 18 (page 54).

Sewage collection systems in the urban areas are either combined or separated. Newly urbanized areas have separate systems for storm runoff and sanitary sewage. Combined

TABLE 8. SEWAGE TREATMENT PLANTS IN THE THAMES RIVER BASIN AND COMPLIANCE STATUS FROM 1985-1988 (MOE, 1988a, 1989a)

	1988			1987			1986	1985
FACILITY	BOD	SS	TP	BOD	SS	TP		
BLENHEIM		X	X		X		X	X
CHATHAM			X		X	X		X
GLENCOE		X						
INGERSOLL -								
OLD								
NEW			X			X	X	
LOBO								
LONDON -								
ADELAIDE								
GREENWAY						X		
OXFORD						X	X	
POTTERSBURG								
VAUXHALL								
MITCHELL			X		X			
RALEIGH TILBURY EAST					X		X	
RIDGETOWN		X	X	X	X	X	X	X
ST.MARYS			X					
STRATFORD						X	X	
THAMESVILLE						X		
TILBURY			X					
TILBURY WEST (COMBER)					X	X		
WESTMINSTER -								
SOUTHLAND								
WESTMINSTER								
WOODSTOCK			X					

X - exceeded criteria
BOD - Biological Oxygen Demand
SS - Suspended Solids
TP - Total Phosphorous
1986, 1985 - criteria exceeded not specified

systems in older areas of many municipalities were designed to carry both storm water and sanitary sewage. During storm events, combined sewage outflows often occur because of hydraulic constraints in collection and treatment systems. This results in a pollution load of urban storm drainage plus untreated waste to local watercourses. Major municipalities in the Thames basin have a policy of separating combined sewer systems; however, these programmes are expensive and long term (MOE, MNR, 1975).

Industrial

Generally, industries discharge wastes to local sewer systems for treatment at municipal treatment facilities. Sewer bylaws are enforced by the municipalities to ensure that wastes sewered by industries are not toxic or corrosive. If corrosive or toxic wastes are produced, the industry is required to neutralize harmful waste characteristics prior to discharge. In certain cases, industries pay a surcharge to the municipality to compensate for the treatment of high-strength wastes.

Two industries within the basin were identified as direct dischargers of industrial waste waters by the MOE in 1988 and 1989. Blackstone International Products Ltd. of Stratford manufactures automobile radiators and heater cores. Effluent from the plant is batch discharged directly into the Avon River and contains dissolved metals including copper, zinc and nickel. The effluent is sampled for chromium, copper, lead, pH, suspended solids and zinc. In 1987 the company was in compliance with MOE requirements 93% of the time with two exceedences in both suspended solids and zinc levels. In 1988 the company's compliance declined to 86% with 3 exceedences in pH and 8 exceedences in zinc levels. MOE and company officials are reviewing the need for improved operation and/or treatment facilities (MOE, 1988b, 1989b).

The Campbell Soup Co. Ltd. in St. Marys has been identified as a source of organic wastes and phosphorous loading (MOE, MNR, 1975). Poultry and small game dressing is the primary activity of the Company with effluent continuously discharged to the North Thames River. Changes in water waste management at the site however, have been slowly implemented. During 1987 the company was in compliance with MOE requirements 60% of the time. Biological Oxygen Demand [5 day] (BOD_5) and suspended solid requirements were exceeded during 9 and 11 months respectively. BOD_5 exceedences were in the order of 1.1 to 1.8 times the requirement while suspended solids ranged from 1.2 to 20.1 times. Work to upgrade the sewage works commenced in July 1988 and was completed in late 1988. During 1988 the company was in compliance only 42% of the time. BOD_5 and suspended solids exceeded required levels during 11 and 10 months respectively. BOD_5 exceedences ranged from 1.3 to 3.7 times the required levels; suspended solids exceedences ranged from 1.4 to 5.8 times. Although the suspended solid levels seem to have been substantially reduced, the BOD_5 levels have become more of a concern. Due to continuing effluent quality problems the company is currently reviewing operating procedures.

1.1.9 Water Quantity

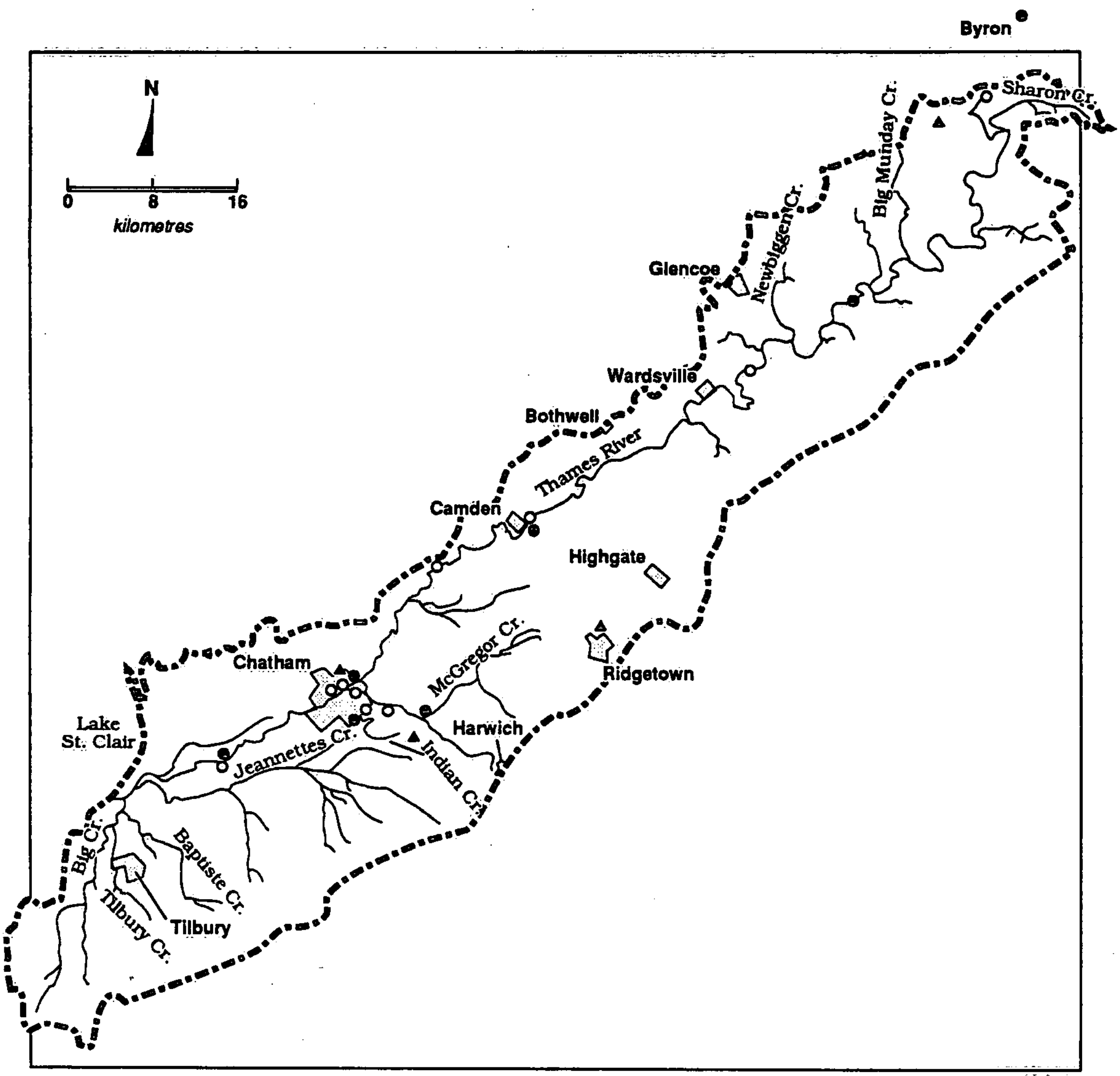
A total of 22 federal hydrometric stations were in operation in the Thames watershed in 1986. Nineteen monitored streamflow only whereas the remaining 3 monitored both sediments and streamflow. The UTRCA monitors streamflow at 21 stations within its jurisdiction, the LTVCA 16. Figures 11A and 11B show the locations of the LTVCA and UTRCA flow monitoring stations.

During low flow periods, more dependable flows generally occur in streams with a significant ground water component. Such streams provide a relatively consistent base flow compared to streams not receiving ground water inputs. The latter exhibit greater fluctuations in response to weather conditions.

Significant quantities of ground water contribute to the streamflow in the Thames River and its tributaries. Approximately 35% of the total annual discharge originates as baseflow; however, the proportion of baseflow in a given stream is seasonally dependant. During the spring runoff, baseflow constitutes 10 - 20% of the observed flow. From June to October baseflow accounts for 70 - 90% of total flow. Baseflow is a particularly important component of streamflow at several locations on the North Thames River including the

Figure 11A

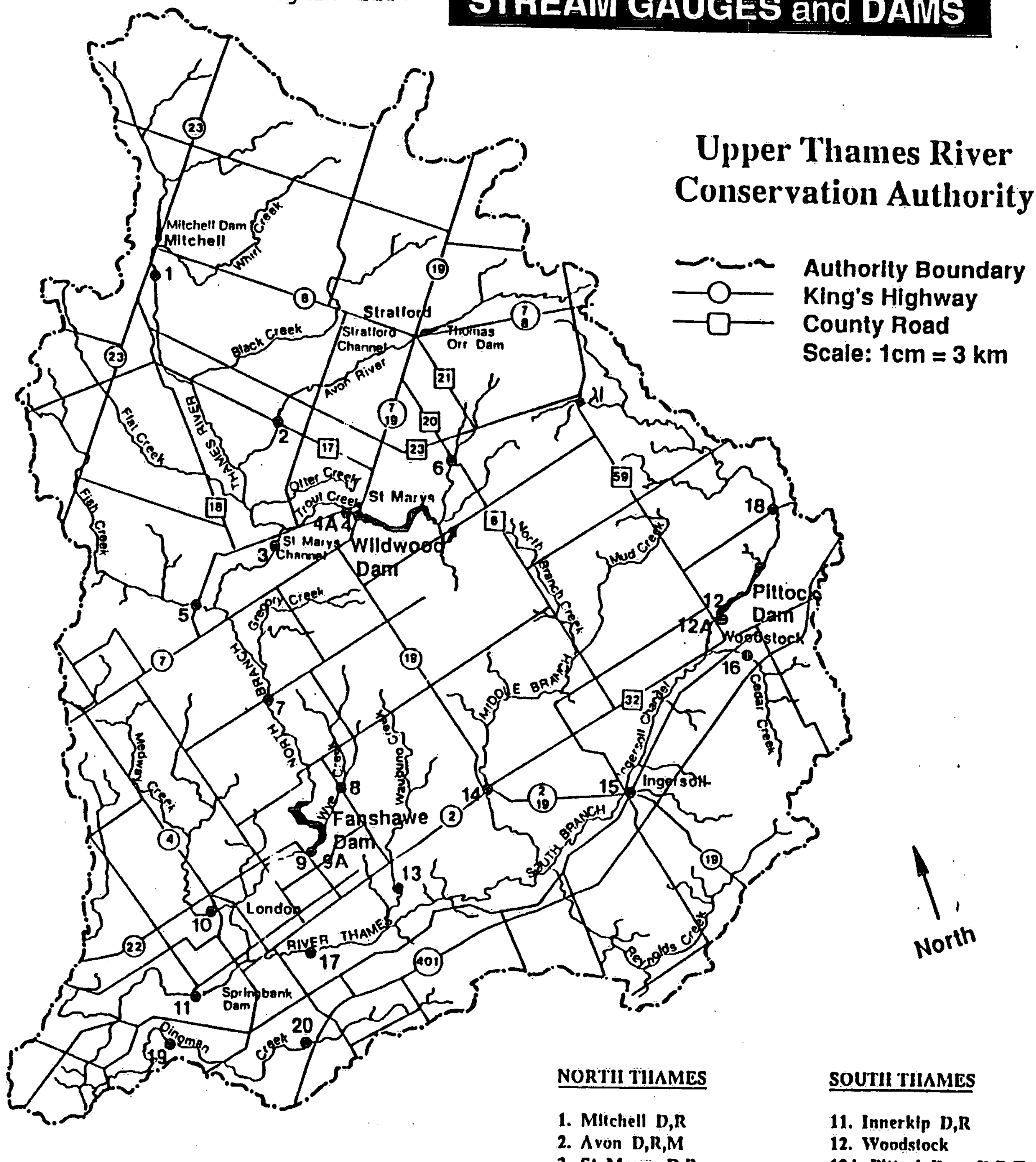
L.T.V.C.A Hydrometeorology Network



L.T.V.C.A. Hydrometeorology Network

- ● *Telemark gauges*
- ○ *Staff gauges*
- ▲ *Rain gauges*

Figure 11B. **STREAM GAUGES and DAMS**



NORTH THAMES

1. Mitchell D,R
2. Avon D,R,M
3. St. Marys D,R
4. Trout Creek
4A. Wildwood Dam D,T
5. Fish Creek
6. Fairview
7. Plover Mills D,R
8. Wye Creek
9. Fanshawe
9A. Fanshawe Dam D,R,T
10. Medway D,R

SOUTH THAMES

11. Innerkip D,R
12. Woodstock
12A. Pittock Dam D,R,T
13. Cedar Creek D
14. Ingersoll D,R
15. Thamesford D,R
16. Waubuno Creek D,R,M
17. Ealing D
18. Byron D,T
19. Dingman
20. Dingman R
21. Tavistock

D - Computerized Data Logger
(stream water level/flow)
R - Continous Recording Raingauge
T - Telemark Telephone Coupler
(stream water level)
M - Meteoriogial Station
(solar radiation, temperature,wind speed)
* - all others not denoted, have records kept
by Environment Canada

south branch of the Thames River and Trout Creek at St. Marys. Significant incremental flow on the North Thames results from water being pumped from a quarry operated by the St. Marys Cement Company downstream from St. Marys (MOE, MNR, 1975).

Extensive sand and gravel deposits along the Thames River above London, especially south of the river, are sources of ground-water discharge to the river. In addition to direct ground-water seepage to the river, water is pumped continually into the Thames River between Woodstock and Ingersoll by three quarries, Beachville Lime, Domtar and Stelco. The percentage of this pumpage that is groundwater is not known (MNR,MOE, 1975). Impacts on water quality resulting from these activities are not reported in the literature.

Bedrock aquifers are important throughout the Thames River basin, but particularly in the upper part of the basin where Middle Devonian limestones and dolomites are exploited for large quantities of good quality ground water (MOE, 1981). Bedrock well yields commonly exceed 3.75 L/s in this region (MOE, MNR, 1975). In the lower part of the basin, subcropping bedrock consists primarily of shales with yields commonly less than 0.15 L/s. Overburden aquifers also predominate in the upper basin. In this region, the bedrock is buried typically by 30 - 60 m of overburden which commonly include one or more sand and/or gravel deposits. These units provide ground water to domestic, commercial, agricultural, industrial and municipal wells in quantities of up to several tens of litres per second. The overburden in the lower part of the Thames River basin is generally thinner, however, the overburden aquifers are common sources of water because of inadequate supplies available from the bedrock (MOE, 1981).

For the purposes of this study, four federal hydrometric stations were selected: McGregor Creek, Fish Creek, North Thames and Upper Main (Figure 12). These four stations were selected based on their proximity to MOE surface water quality monitoring stations and the sub-basins as delineated in this study. Figures 13A - D present average annual flow data while figures 14A - D show average monthly flow data for each of the four stations. The average annual flow rate patterns are similar across all four stations with the magnitude of flow reflecting the size and nature of each basin. McGregor Creek station represents a relatively small watershed in the Lower Thames; the Fish Creek sub-basin is a narrow basin located in the headwater area of the Upper Thames; the North Thames sub-basin is the third largest sub-basin and consists of numerous primary and secondary rivers; the Upper Main station records the total flow for the whole Upper Thames prior to entering the Lower Thames. The uncommonly dry summers of 1987 and 1988 are clearly illustrated in the reduced annual flow rates at all stations.

Average monthly flow patterns are very similar across the four stations. Peak flows in March show the high flow rates associated with spring runoff, flows decline through the summer months. Flow rates increase again in September and are associated with higher rainfall during the fall period. Flows in the Upper Thames are controlled by a network of 6 dams (Figure 11B) which also aid in moderating event related flow increases.

Figure 12

Thames River Basin - Location of study sub-basins and selected flow stations

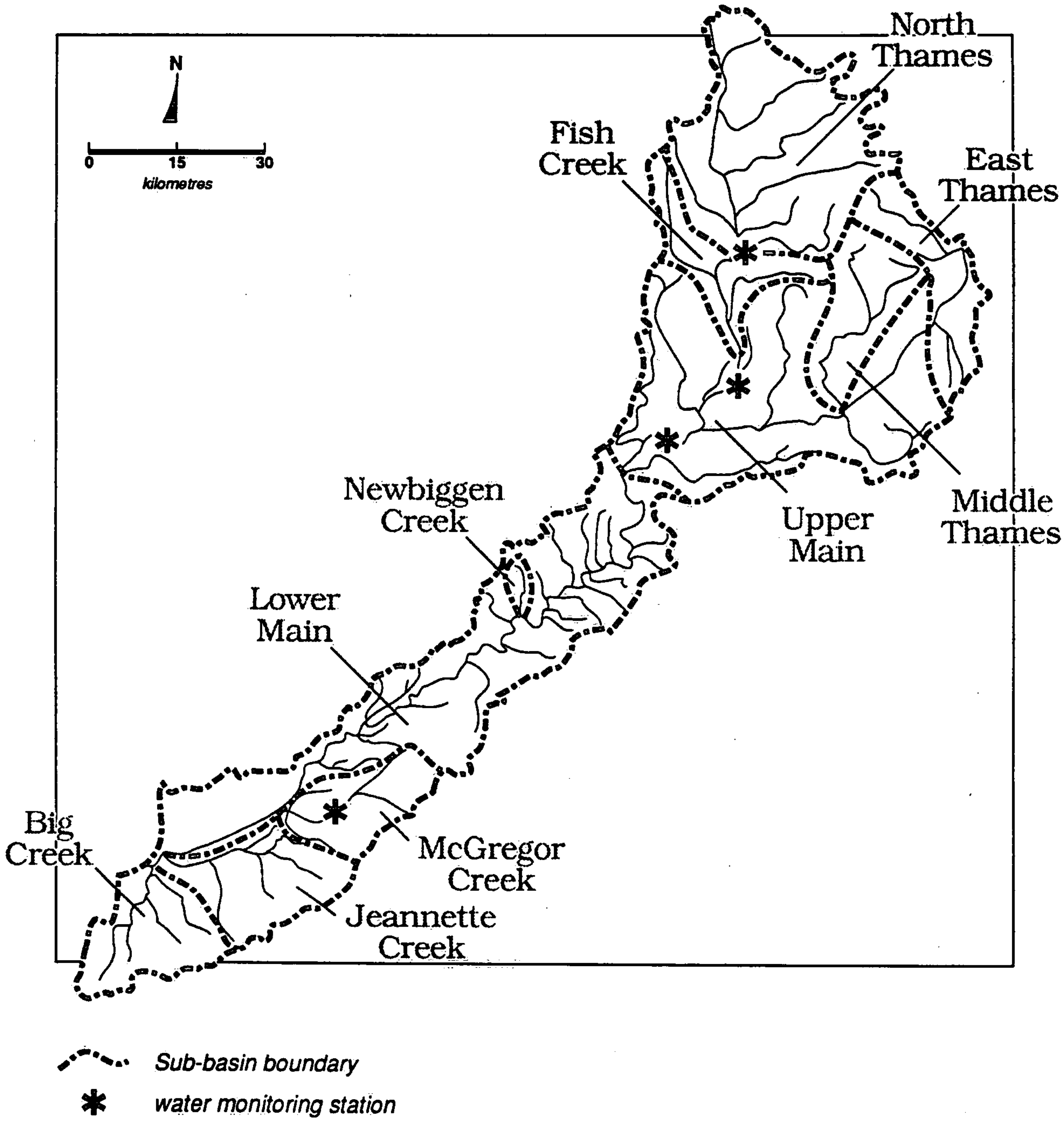


Figure 13A

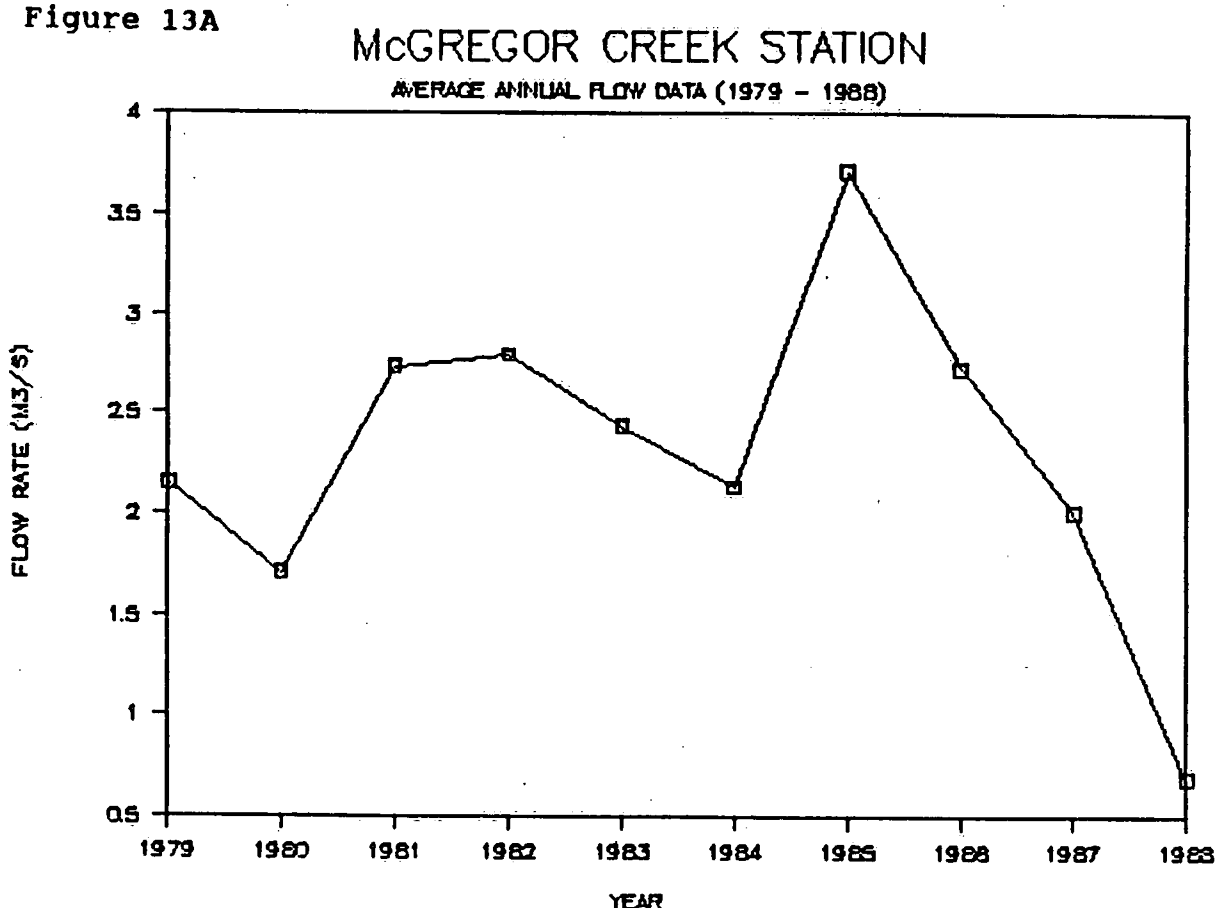


Figure 13B

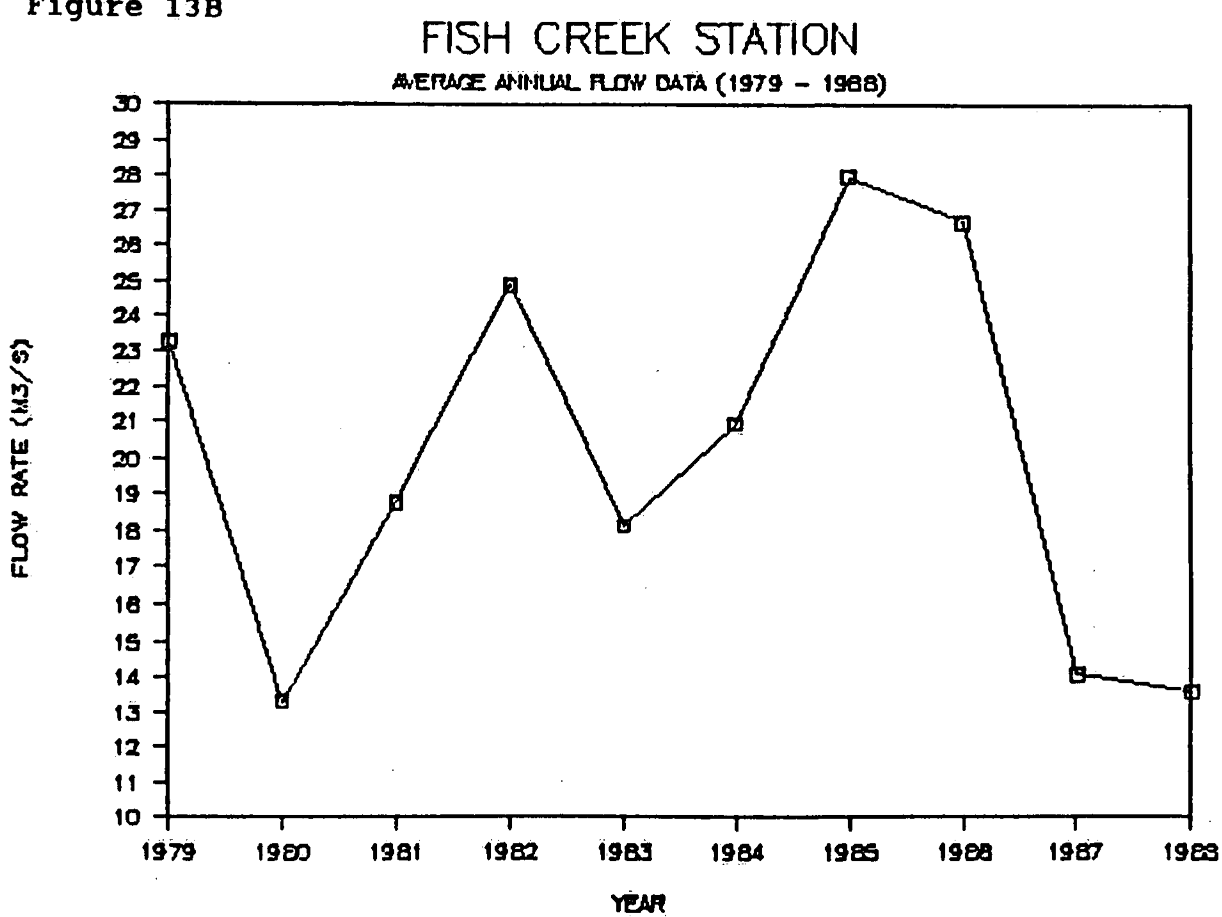


Figure 13C

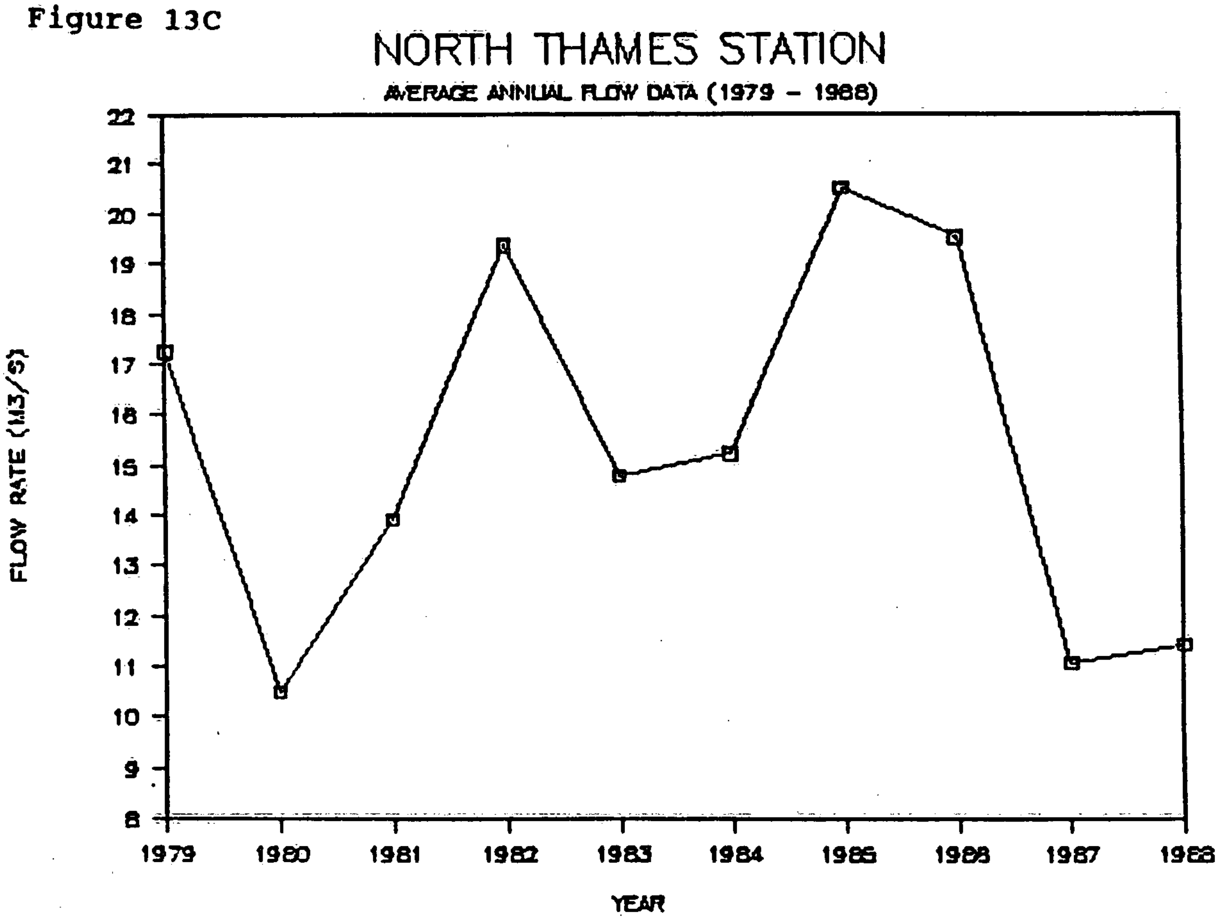


Figure 13D

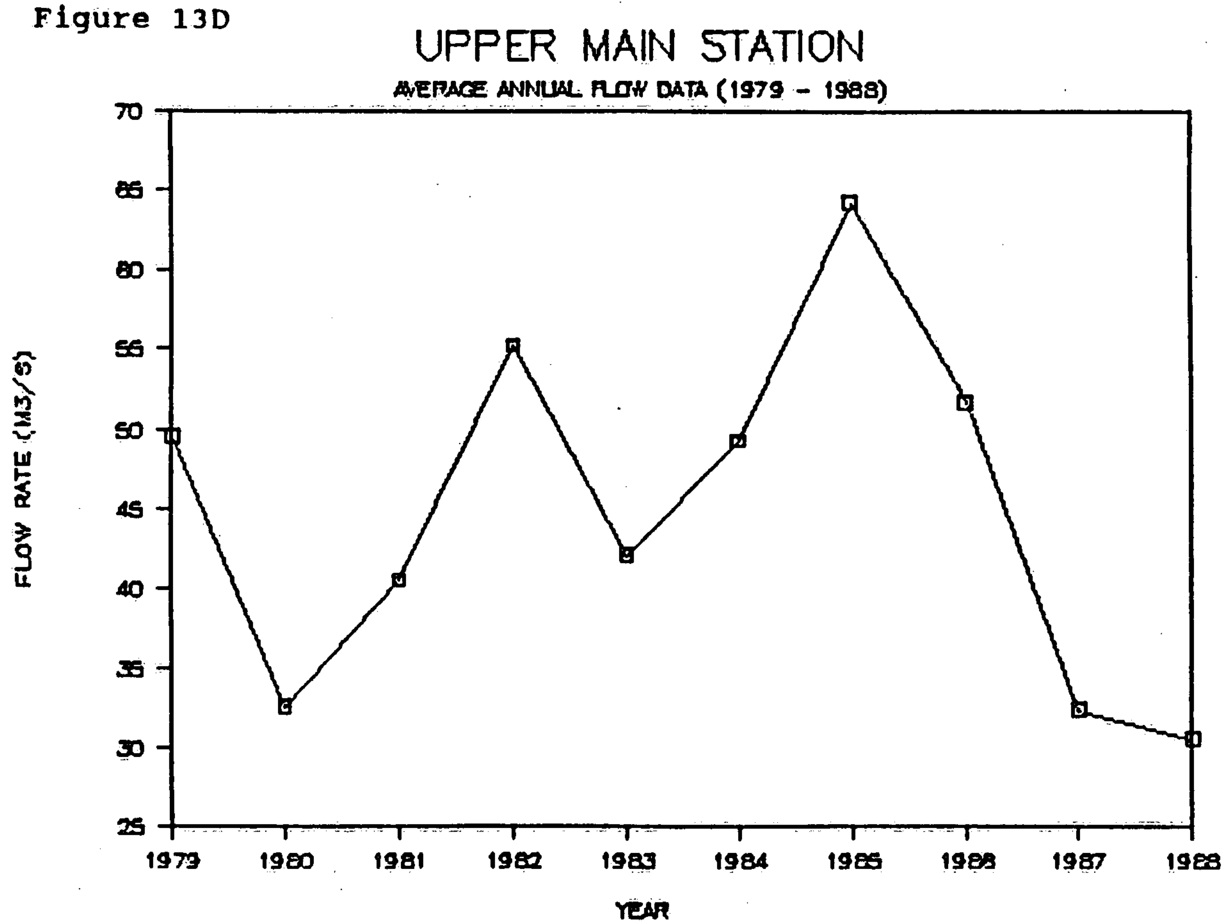


Figure 14A

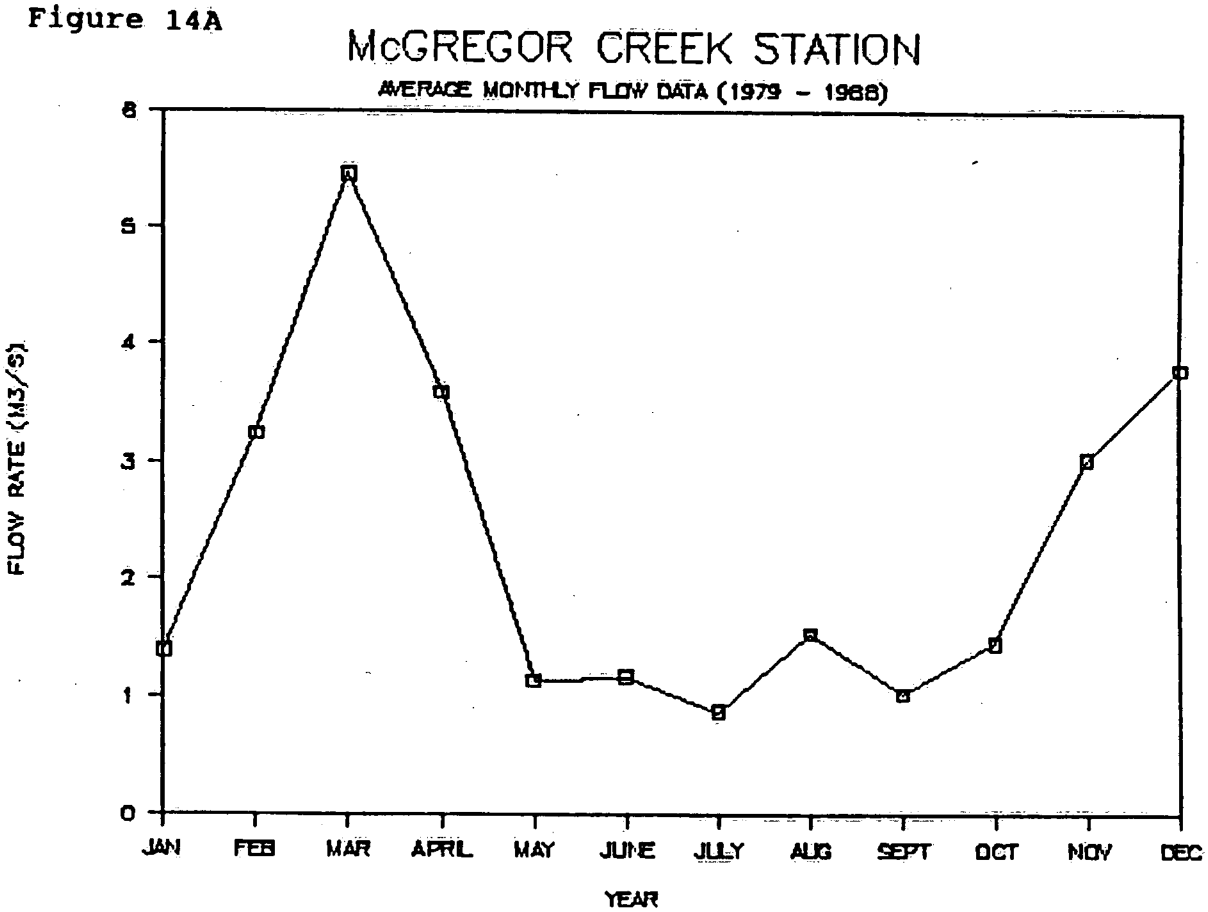


Figure 14B

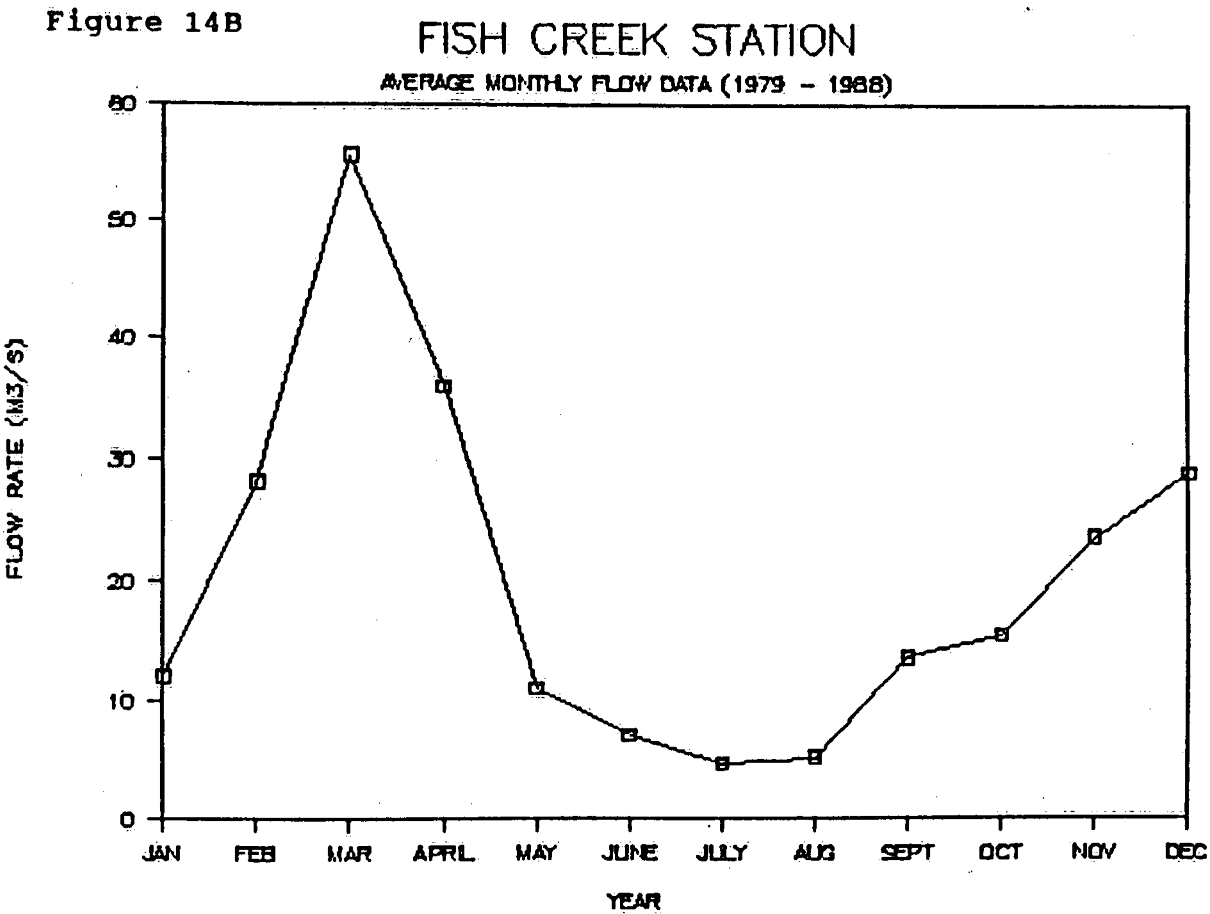


Figure 14C

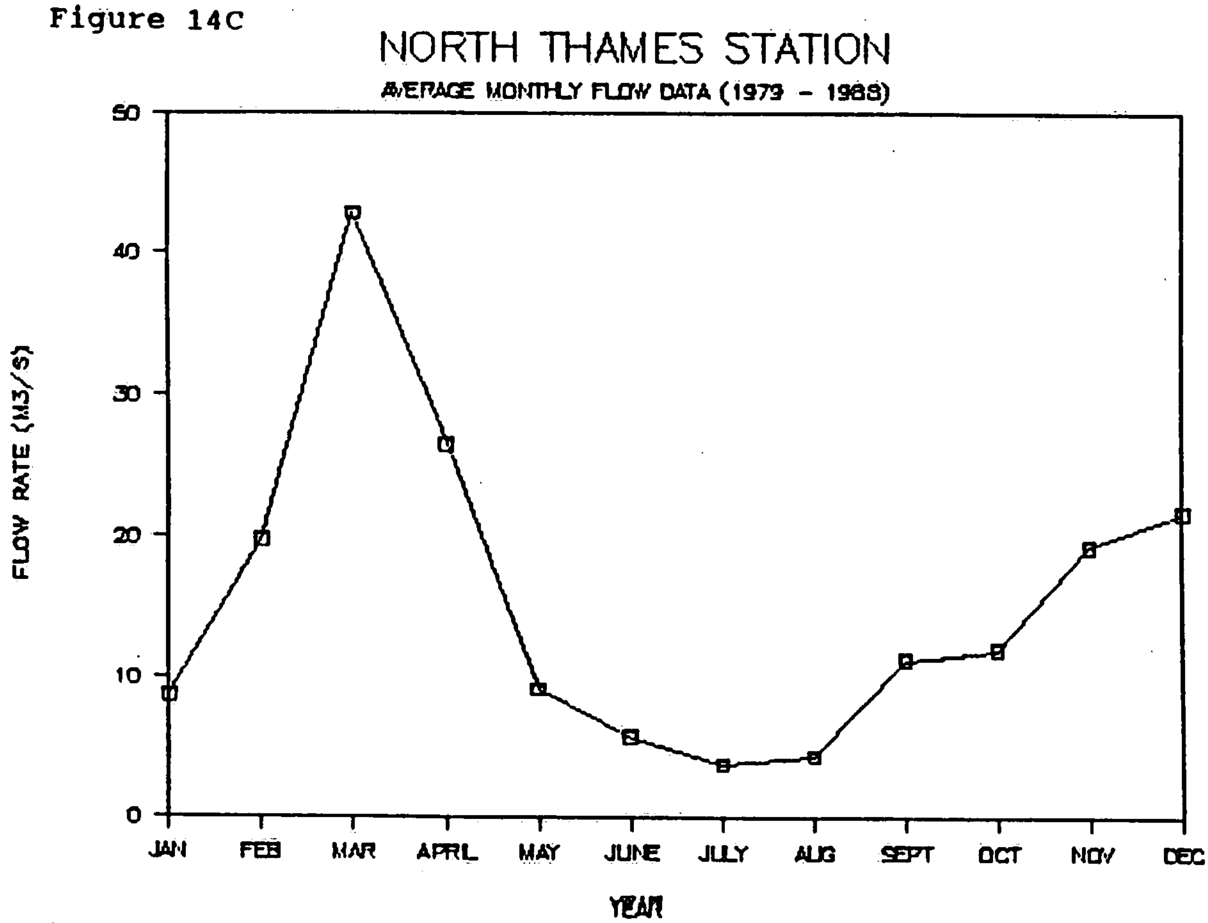
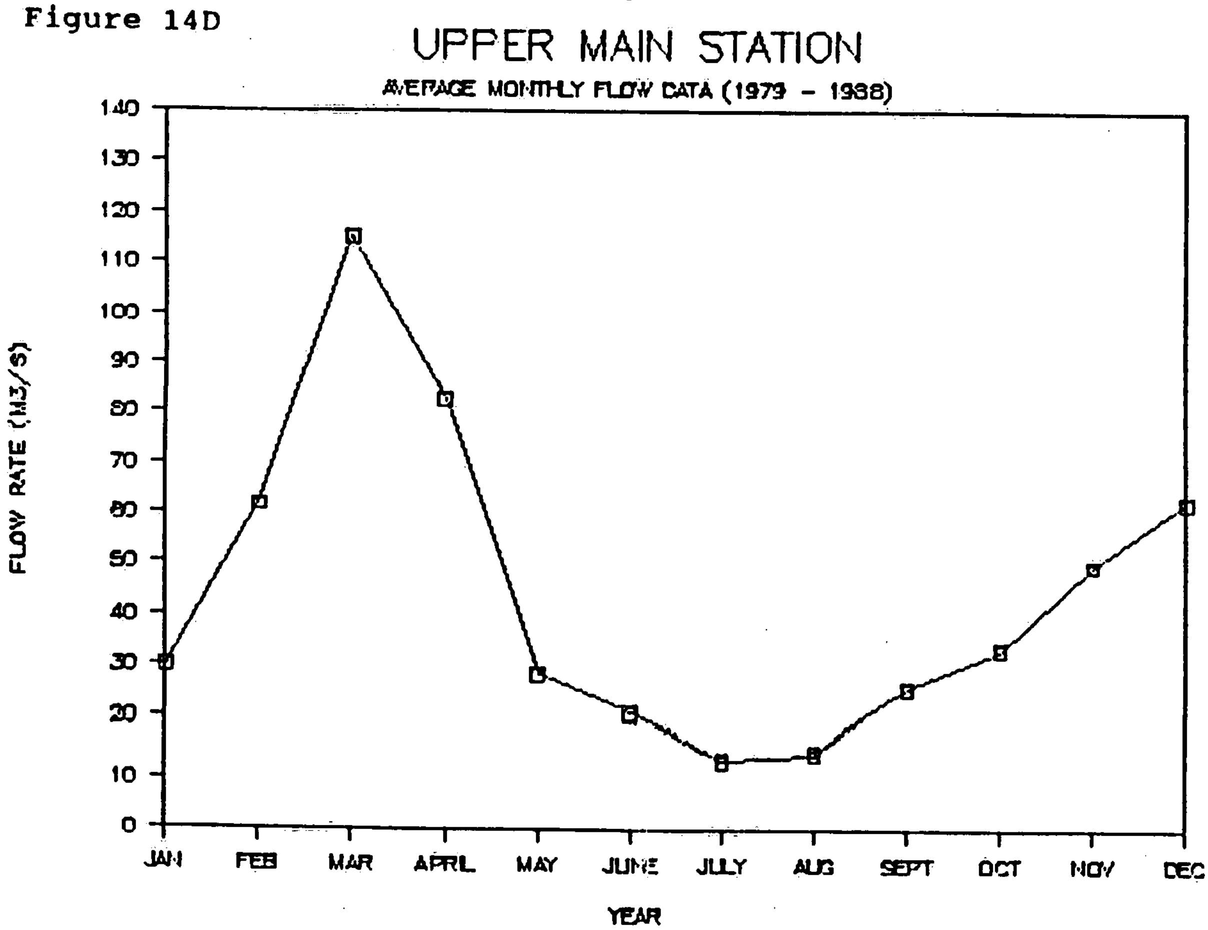


Figure 14D



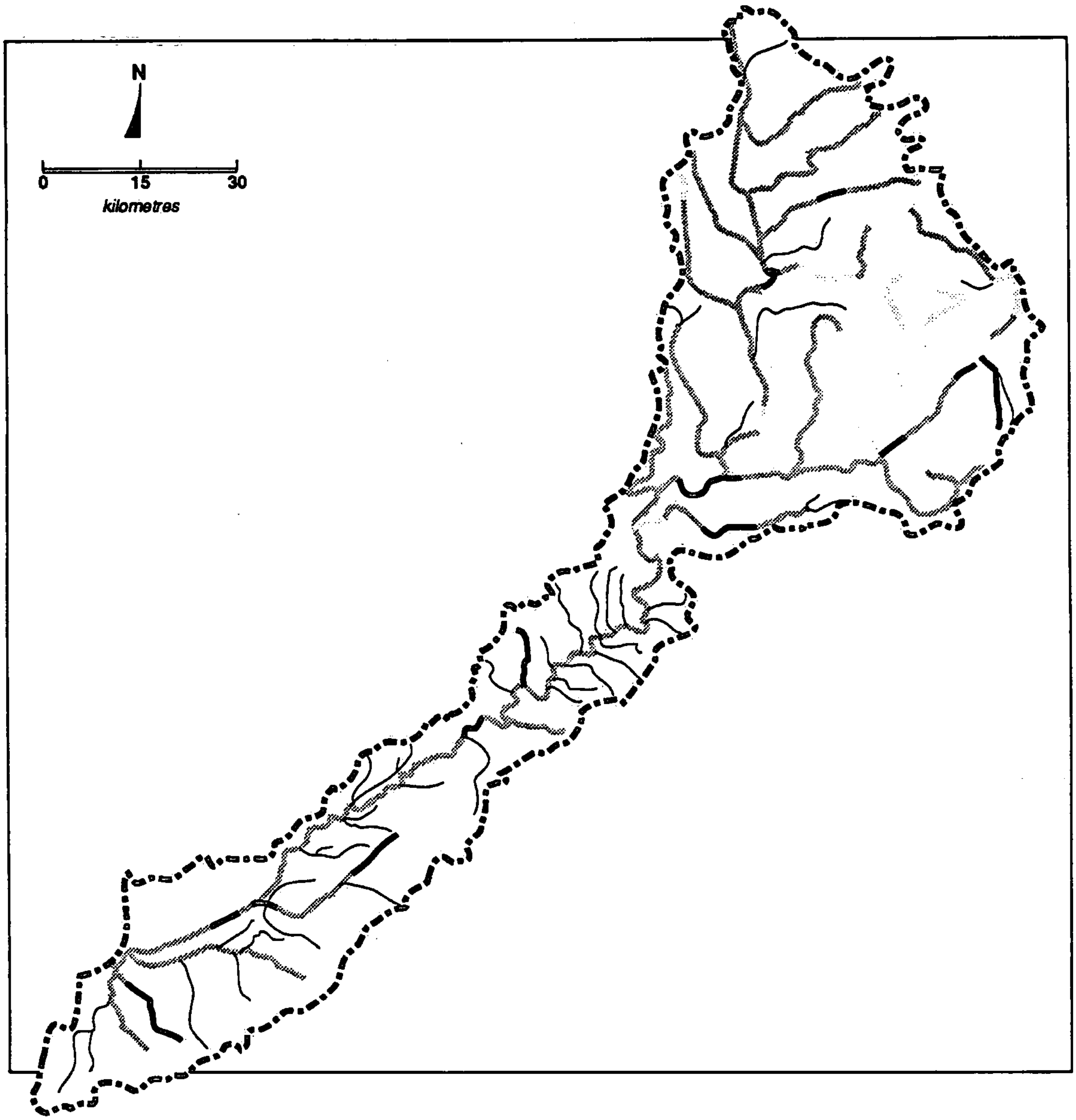
1.1.10 Water Quality

In 1972 the Ontario Ministries of the Environment and Natural Resources launched a detailed study of the Thames River System. This study was initiated in response to growing concern over existing problems relating to water quality, flooding and erosion in the watershed, and other potential problems anticipated as a result of future growth and economic development (MOE, MNR, 1975). Completed in 1975, the study made 29 recommendations for water management practices within the watershed. Figures 15, 16, 17 and 18 illustrate the levels of total coliform, nitrogen, phosphorous and biological oxygen demand respectively, at the time of that study. Land-use practices, particularly agricultural, were recognized to be major contributors to water quality degradation. This study, however, failed to look specifically at pesticide use and pristine areas.

As part of the MNR, MOE study ground water chemistry was also examined. Ground water from bedrock and overburden sources in the middle and upper basin was chemically similar. Chlorides were low (range from 5 - 25 mg/L) and hardness was relatively high. In contrast, ground water in the lower basin was characterized by higher chloride concentrations, in the range of 200 to 2,000 mg/L with relatively low hardness. Calcium-bicarbonate type waters were typical of the upper basin while sodium-bicarbonate and sodium-chloride types were most common in the lower basin. These differences are a direct consequence of the geochemical differences between the limestones and shales and the overburden which has been formed from them (MOE, MNR, 1975).

Figure 15

Total coliform levels in the Thames River Basin

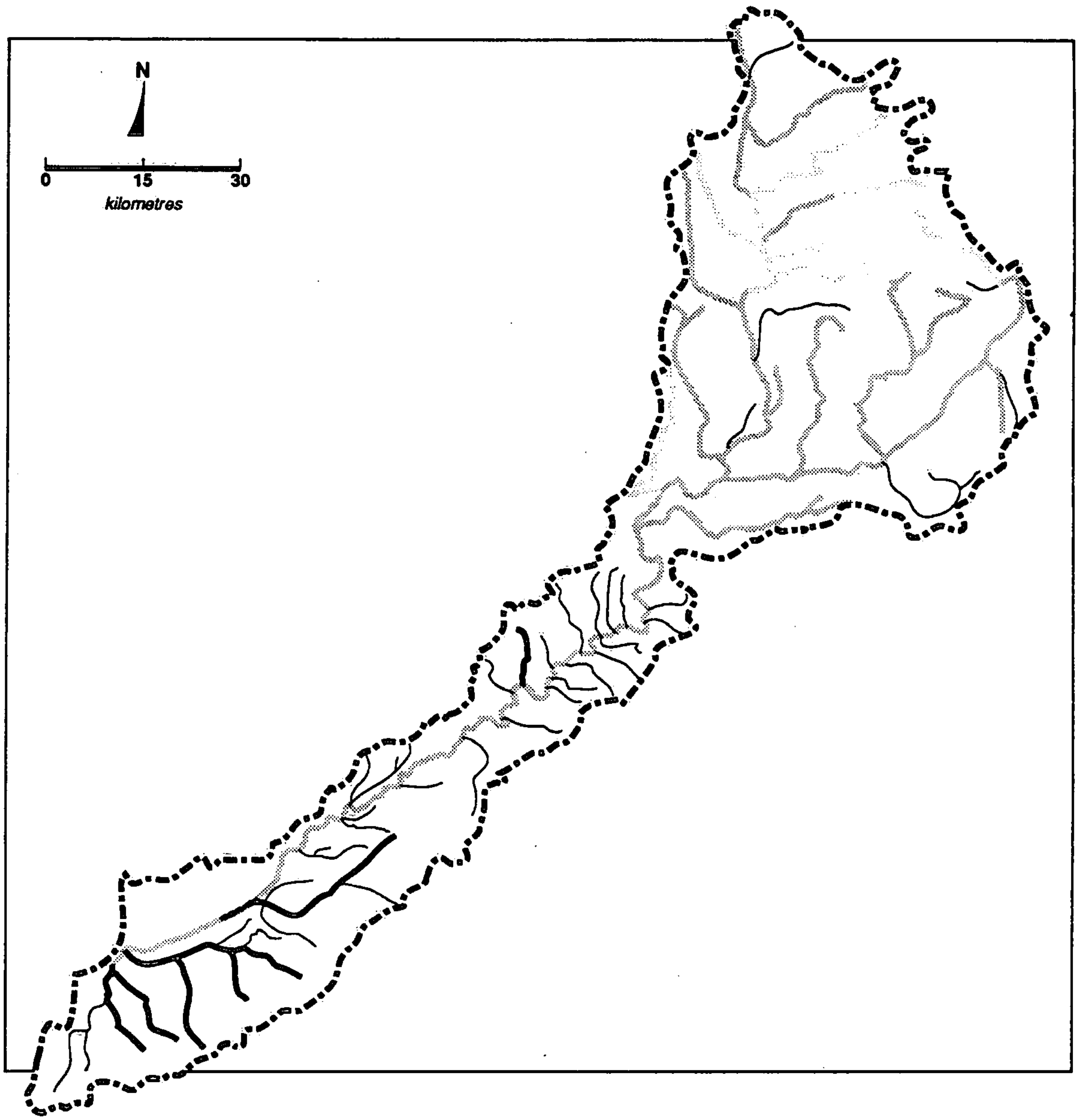


Total coliform bacteria as of 1975 (geometric mean density)

- $>10^4$ per 100 ml
- 10^3 - 10^4 per 100 ml
- $<10^3$ per 100 ml

Figure 16

Total nitrogen levels in the Thames River Basin

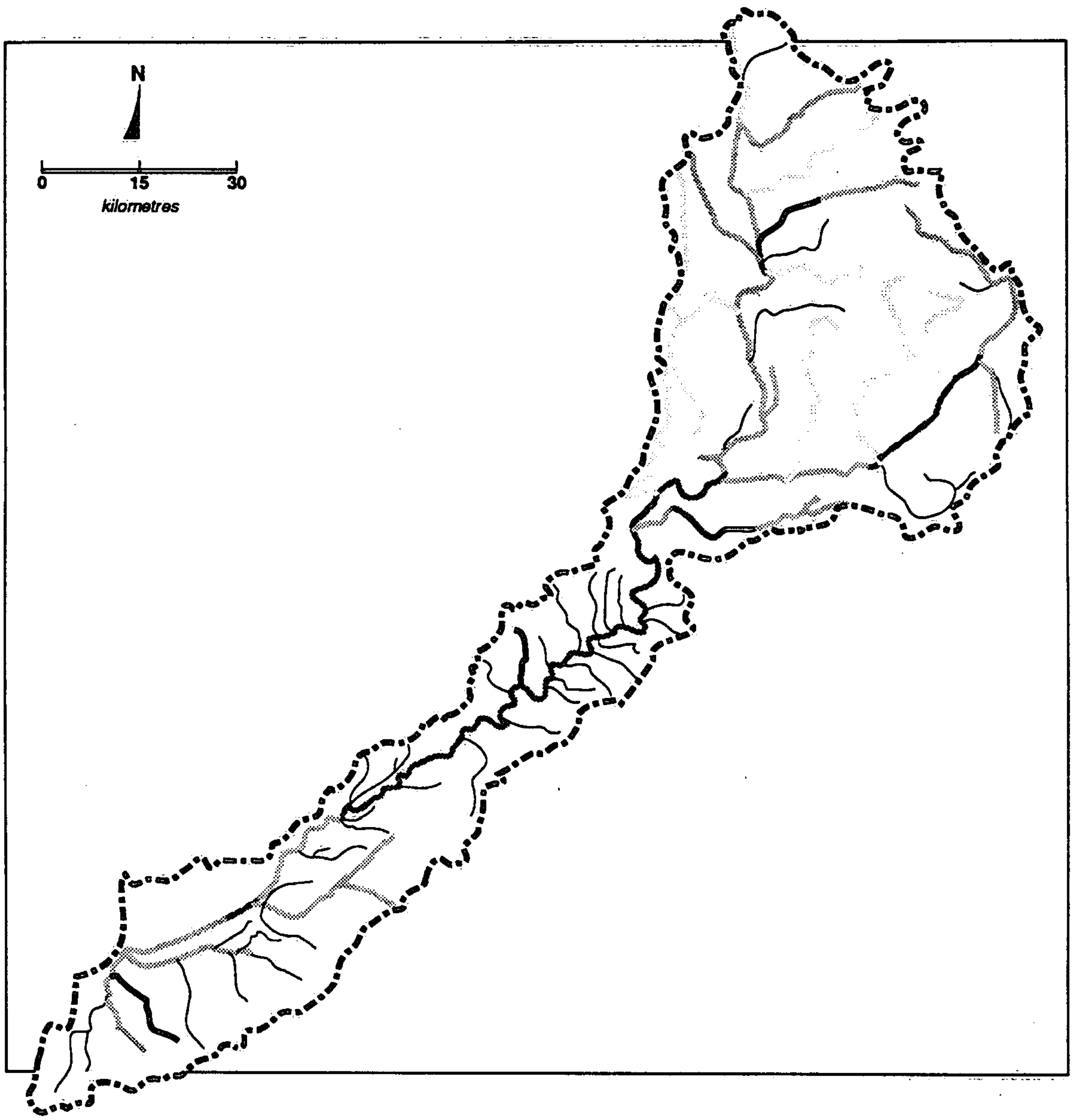


Total nitrogen as of 1975

- *>6 ppm*
- *5 - 6 ppm*
- *3.5 - 5 ppm*
- *<3.5 ppm*

Figure 17

Total phosphorous levels in the Thames River Basin

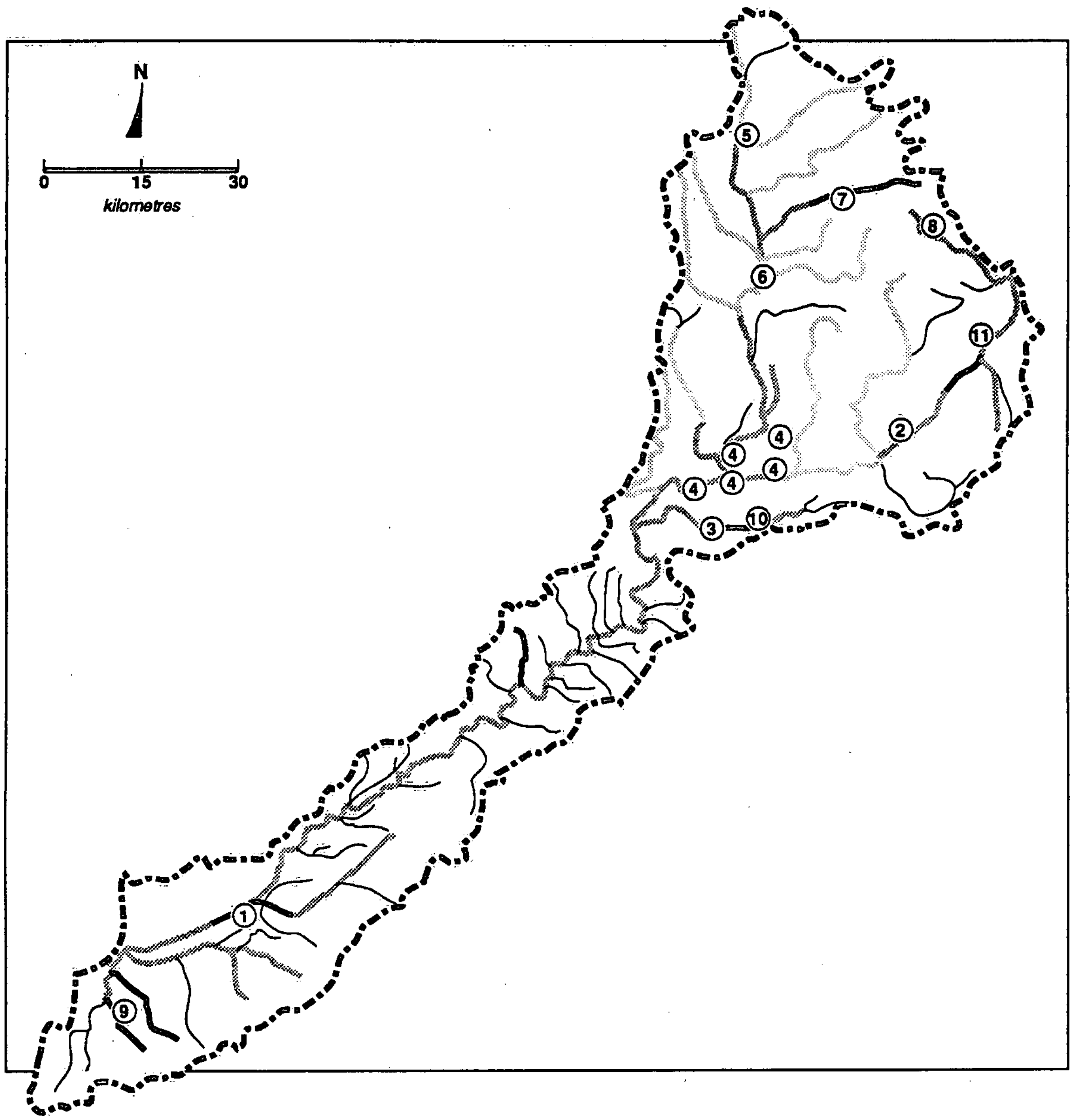


Total phosphorous as of 1975

- >0.60 ppm
- 0.31 - 0.60 ppm
- 0.11 - 0.30 ppm
- <0.10 ppm

Figure 18

Levels of BOD_5 and location of sewage treatment plants in the Thames River Basin



BOD_5 as of 1975

- *>4 ppm*
- *2 - 4 ppm*
- *<2 ppm*
- ⑩ *Sewage treatment plants (as of 1975)*

1. Chatham
2. Ingersoll
3. Lambeth
4. London: Adelaide
   Greenway
   Oxford
   Pottersburg
   Vauxhall
5. Mitchell
6. St. Marys
7. Stratford
8. Tavistock
9. Tilbury
10. Westminster
11. Woodstock

Forty eight provincial water quality monitoring stations were sampled in the Thames watershed during 1989. Thirty four of these stations have been in operation for over 10 years and of these, seven have been selected to assess the water quality data from the basin (2 in the Lower, and 5 in the Upper Thames basins). Selected stations represent larger sub-basins within the watershed (Figure 19) and for which more continuous sampling records are available. Table 9 lists the sub-basins and their corresponding drainage areas.

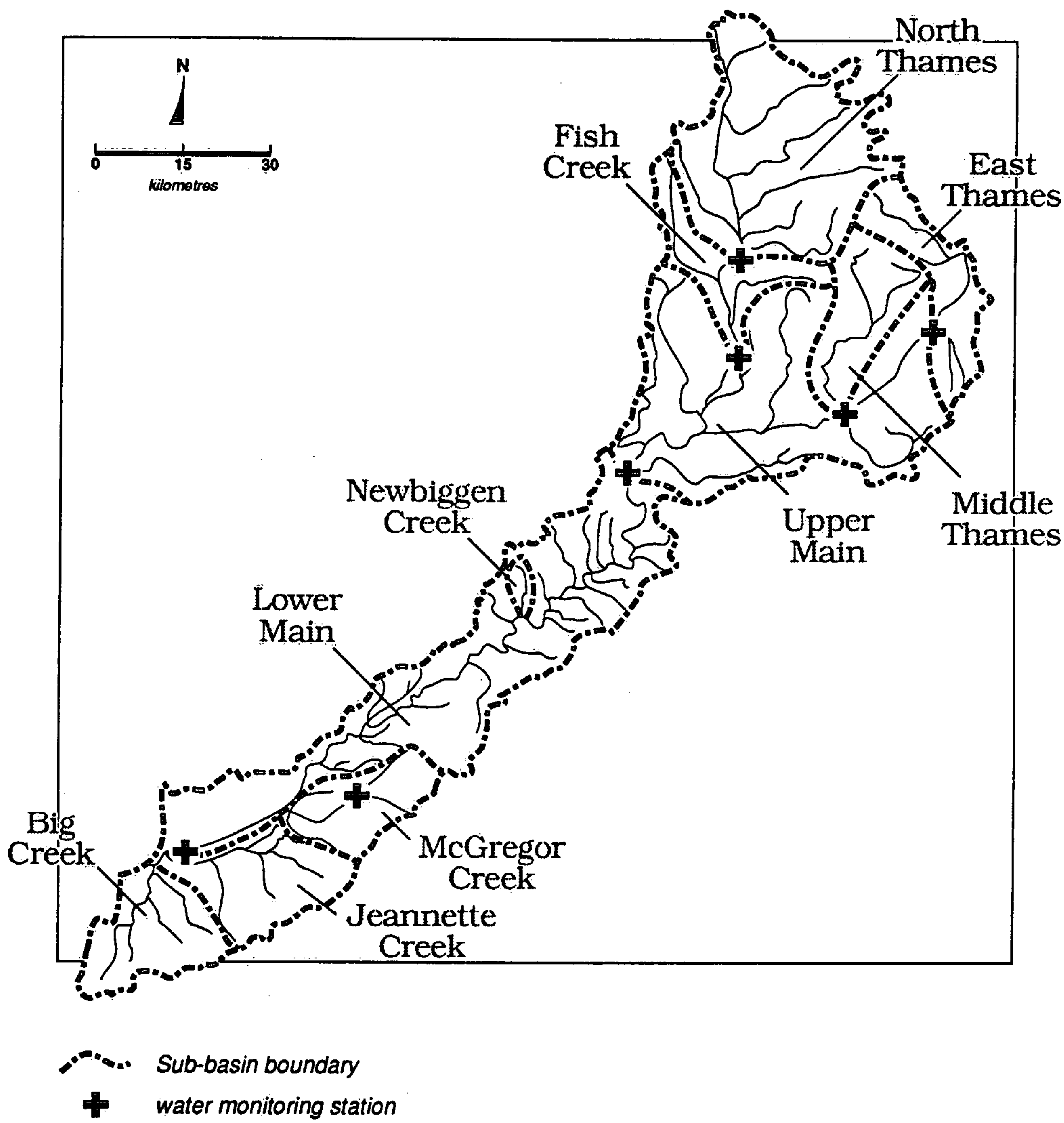
Table 9. Sub-basins used in the Thames River Basin Study

Sub-basin	Drainage Area (km^2)
Lower Thames	
* Big Creek	352.6
* Jeannette Creek	387.2
McGregor Creek	291.9
* Newbiggen Creek	29.4
Lower Main	1419.1
Upper Thames	
Fish Creek	301.0
North Thames	1053.6
East Thames	337.9
Middle Thames	350.2
Upper Main	1351.5

* not represented by a MOE water quality station

Figure 19

Thames River Basin - Location of study sub-basins and selected water quality monitoring stations



Previous Studies

In the last decade a number of water quality and land use/water quality studies have been undertaken within the Upper Thames basin. In 1980 a two-year Stratford-Avon River Environmental Management Project commenced (Fortin and Demal, 1983). The purpose of the project was to provide a comprehensive water quality management strategy for the Avon River Basin. A total of 42 publications were prepared during this study. The Pittock Watershed Manure Management and Water Quality Sub-Basin Study in 1984 focused on the reduction of the environmental impact of agricultural practices on water quality in the Pittock Watershed of the Thames River Basin. This was to be accomplished through the implementation of "individual farm soil conservation and water quality improvement plans" (Glasman and Hawkins, 1985). This study highlighted the problems that existed within the Pittock watershed which included: deleterious nature of sub-surface tile drainage systems on water quality; illegal farmstead hookups (milkhouse wastewater drains); improper manure storage and spreading practices; livestock access to watercourses; and insufficient soil conservation practices. Total phosphorous and total coliform concentrations were sampled and were found to be substantially above the level of MOE's objectives.

In 1984 an extensive study was undertaken in the Kintore Creek Watershed in the township of Nisourri West. It was found in this basin that total phosphorous, reactive phosphorous and total suspended solids consistently exceeded water quality standards. Similar in nature to the Pittock Watershed study, this study concentrated on ongoing water quality monitoring, remedial measures and corrective actions in crop tillage practices and livestock management. A control basin and a demonstration sub-basin were established and have been monitored for the past five years. This area is also one of the few watersheds to be monitored for the effects of pesticide use under a contract from Environment Canada's SWEEP programme in 1988 (Merkley, 1989).

The UTRCA has also been involved in the MOE's Provincial Rural Beaches Strategy Programme. This programme arose due to the frequent beach closures experienced in Ontario resulting from high levels of coliform and algal blooms. The Fanshawe, Pittock and Wildwood reservoir beaches were involved in the UTRCA's efforts. Total phosphorous and fecal coliform levels and sources were identified in a UTRCA's 1989 report. Table 10 lists the sources of total phosphorous for the reservoirs involved.

Table 10. Relative Annual Contributions of Total Phosphorous to Fanshawe, Pittock and Wildwood Reservoirs

Source (%)	Fanshawe	Pittock	Wildwood
erosion	50	43	58
industry	15		
milkhouse wastewater	15	33	33
sewage	10	3	
septic beds	5	11	5
manure runoff	2	3	
urban	1		
manure spreading	1	3	3
livestock access	1	2	

source: Hayman, 1989

Chemical and Physical Analysis

The MOE's surface water quality monitoring network is set-up to analyze for up to 55 parameters, however, only approximately 16 are measured on a consistent basis among the stations selected for this study. The reported MOE data is also subject to a variety of limitations arising from:

1) significant gaps in sampling history over a ten year period;
2) sampling frequency (daily/weekly/monthly) is variable depending on the location of the station. Data is then subject to the influence of "event" occurrences. This is of particular concern for sediment-associated variables such as turbidity or phosphorous which are significantly influenced by stormfall events, floods, industrial discharges etc.;
3) changes in analytical methods.

Summary tables have been prepared for 32 water quality parameters grouped into four categories: nutrients (Table 11), major dissolved ions (Table 12), field measurements (Table 12), and metals (Table 14). Observations have been plotted for total Kjeldahl nitrogen (Figure 20A - G) and total phosphorous (Figures 21A - G) for all 7 stations. Only 3 stations have been plotted for total lead (Figures 22A - C) and 4 for total copper (Figures 23A - D). Plotting of individual observations was carried out to best evaluate fluctuations of these 4 parameters given the high variability in their frequency of collection.

Nutrients

Nitrate + Nitrite

Values for both filtered and unfiltered nitrate + nitrite appear in Table 11. Both values are stated to reflect the change in analyses techniques from filtered to unfiltered nitrate + nitrite which occurred in 1984. Filtered mean values range from 4.243 mg/L at the North Thames station to 5.106 mg/L at the Lower Main station. Unfiltered means range from 4.527 mg/L at the Lower Main to 6.21 mg/L at the Middle Thames station. The federal guideline of 10 mg/L (Environment Canada, 1979) is not exceeded. Unfortunately, changes in sampling procedures do not allow for comparison of a station's 10 year data record. Those stations exhibiting the highest means under one sampling method do not have higher means under another. It is unlikely that such a change in nitrate + nitrite levels between stations would occur over such a short time span. The generally higher mean values for the Upper Main, East Thames and Middle Thames stations are likely a result of the number of sewage treatment plants within each sub-basin, combined with the fairly high proportion (> 70%) of land under row crop and corn systems.

Ammonia

Mean filtered and unfiltered ammonia values are presented in Table 11. The analyses techniques for ammonia were changed at the same time as the nitrate + nitrite techniques. The Middle Thames station has the lowest mean value of 0.113 mg/L and 0.078 mg/L for filtered and unfiltered ammonia, respectively. Both McGregor Creek and the East Thames

TABLE 11. PHYSICAL AND CHEMICAL ANALYSIS - NUTRIENTS

NUTRIENTS	STATS	LOWER THAMES: McGREGOR CREEK	LOWER THAMES: LOWER MAIN	UPPER THAMES: FISH CREEK	UPPER THAMES: NORTH THAMES	UPPER THAMES: EAST CREEK	UPPER THAMES: MIDDLE THAMES	UPPER THAMES: UPPER MAIN
NITRATE + NITRITE (FILT.)	MEAN (#OBS)	4.473 (71)	5.106 (432)	4.438 (79)	4.243 (74)	4.532 (80)	4.838 (75)	4.475 (80)
	MEDIAN (#OBS)	4.01 (71)	5.205 (475)	4.737 (79)	4.287 (75)	4.417 (80)	4.83 (75)	4.439 (80)
	RANGE	0.129 - 21.4	0.355 - 10.6	0.165 - 12.5	0.543 - 19.4	0.534 - 12.5	1.081 - 10.7	1.249 - 9.42
NITRATE + NITRITE (UN-FILT.)	MEAN (#OBS)	4.661 (53)	4.527 (54)	4.982 (58)	5.10 (58)	6.044 (55)	6.21 (54)	5.103 (57)
	MEDIAN (#OBS)	4.566 (57)	4.33 (57)	4.597 (62)	4.340 (61)	6.164 (59)	5.71 (58)	4.563 (61)
	RANGE	0.110 - 12.0	0.319 - 12.0	0.070 - 15.2	0.60 - 17.49	1.91 - 14.97	1.11 - 18.63	0.370 - 12.9
AMMONIA (FILT.)	MEAN (#OBS)	0.405 (71)	0.178 (54)	0.157 (78)	0.173 (72)	0.409 (80)	.113 (72)	0.214 (81)
	MEDIAN (#OBS)	0.115 (71,	0.11 (51)	0.13 (49)	0.09 (75)	0.235 (80)	0.045 (75)	0.11 (81)
	RANGE	0.005 - 8.75	0.005 - 0.90	0.010 - 0.58	0.005 - 1.00	0.[illegible] - 3.20	0.005 - 1.12	0.005 - 1.68
AMMONIA (UN-FILT.)	MEAN (#OBS)	0.180 (52)	0.119 (53)	0.179 (58)	0.176 (52)	0.183 (54)	0.078 (51)	0.127 (56)
	MEDIAN (#OBS)	0.055 (57)	0.09 (57)	0.132 (62)	0.063 (61)	0.1625 (58)	0.0355 (58)	0.08 (61)
	RANGE	0.005 - 1.60	0.006 - 0.37	0.010 - 0.65	0.005 - 0.90	0.01 - 0.882	0.005 - 0.52	0.005 - 0.57
TKN	MEAN (#OBS)	1.48 (125)	1.12 (114)	0.91 (137)	0.176 (52)	1.28 (136)	0.73 (129)	0.99 (136)
	MEDIAN (#OBS)	1.02 (128)	1.015 (166)	0.87 (141)	0.865 (136)	1.165 (140)	0.61 (133)	0.92 (140)
	RANGE	0.440 - 9.25	0.640 - 5.45	0.060 - 2.10	0.005 - 0.90	0.46 - 3.70	0.098 - 2.84	0.540 - 2.66
TOTAL PHOSPHOROUS	MEAN (#OBS)	0.250 (125)	0.223 (692)	0.089 (137)	0.087 (133)	0.201 (136)	0.079 (129)	0.15 (137)
	MEDIAN (#OBS)	0.151 (128)	0.1475 (696)	0.071 (141)	0.0685 (136)	0.176 (140)	0.044 (133)	0.137 (141)
	RANGE	0.023 - 3.98	0.019 - 1.36	0.029 - 0.98	0.016 - 0.53	0.088 - 0.54	0.007 - 0.77	0.058 - 0.71
SiO2	MEAN (#OBS) MEDIAN (#OBS) RANGE	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA

stations have the highest mean values under both sampling techniques. Although the mean ammonia values for all stations, under both sampling techniques, do not exceed the federal guideline of 0.5 mg/L for drinking water, all are well above the freshwater aquatic life guideline of 0.02 mg/L. Sources of ammonia within the Thames basin include sewage treatment plant effluent, fertilizer application to row crops and livestock operations with the associated spreading of manure and livestock access to watercourses.

Total Kjeldahl Nitrogen (TKN)

Total Kjeldahl nitrogen (TKN) concentrations for each of the seven stations are shown in Figures 20A-G and their mean values appear in Table 11. TKN values have been measured in a consistent manner and with frequency over the study period. McGregor Creek station has the highest mean value of 1.48 mg/L and also exhibits the greatest range of fluctuations of all stations. The Middle Thames and Fish Creek stations have the lowest mean values (0.73 and 0.91 mg/L respectively) with the Middle Thames showing fluctuations of slightly greater magnitude. Measured TKN concentrations appear to be relatively stable throughout the study period with no noticeable increasing or decreasing trends.

Total Phosphorous

Concentrations of total phosphorous at each station are shown in Figures 21A-G. Mean phosphorous concentrations are presented in Table 11. The Lower Main station has been sampled with very high frequency compared to the other stations and has the second highest mean concentration of 0.223 mg/L. McGregor Creek has the highest mean total

Figure 20A

McGREGOR CREEK STATION

NITROGEN CONCENTRATION

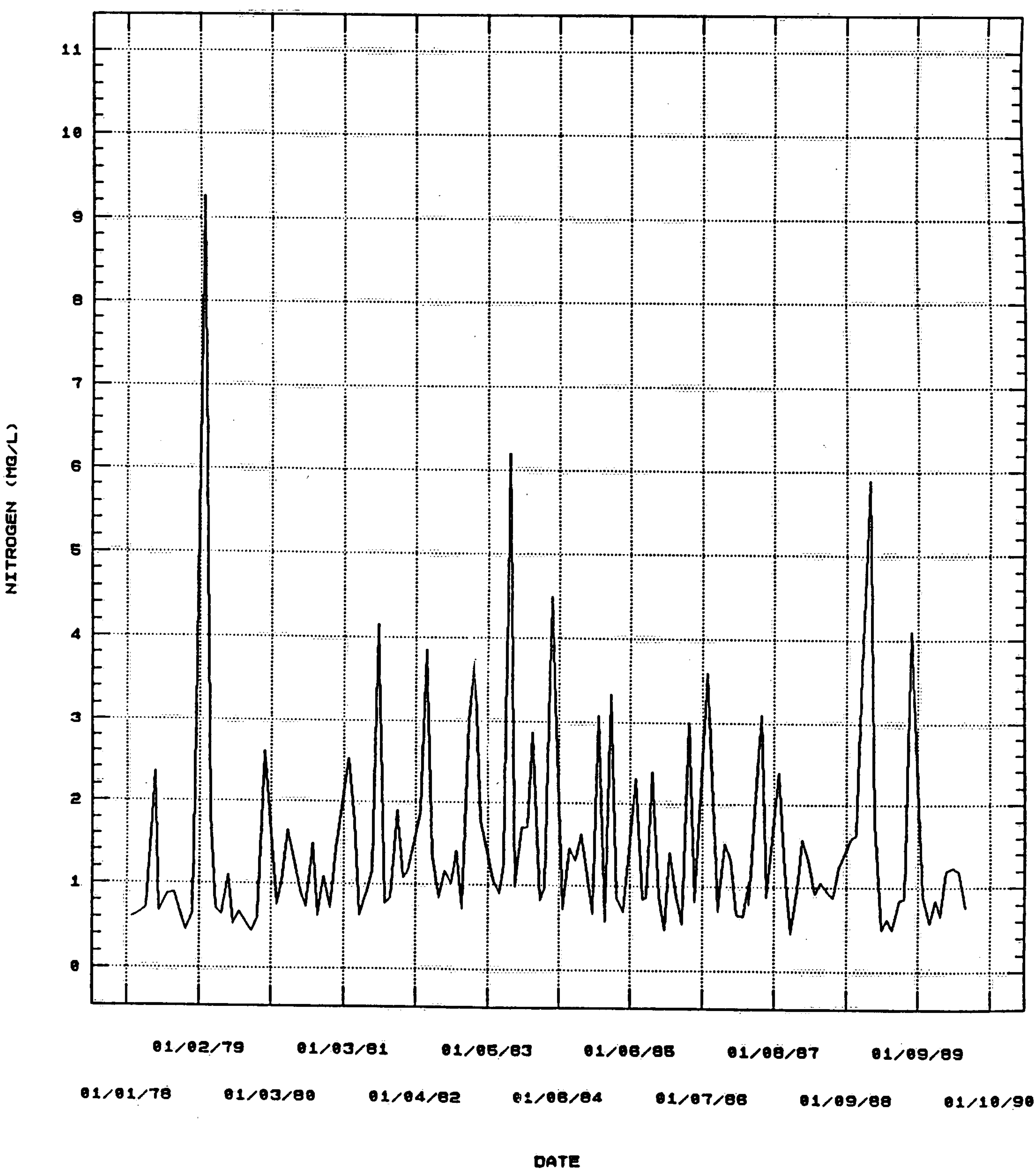


Figure 20B

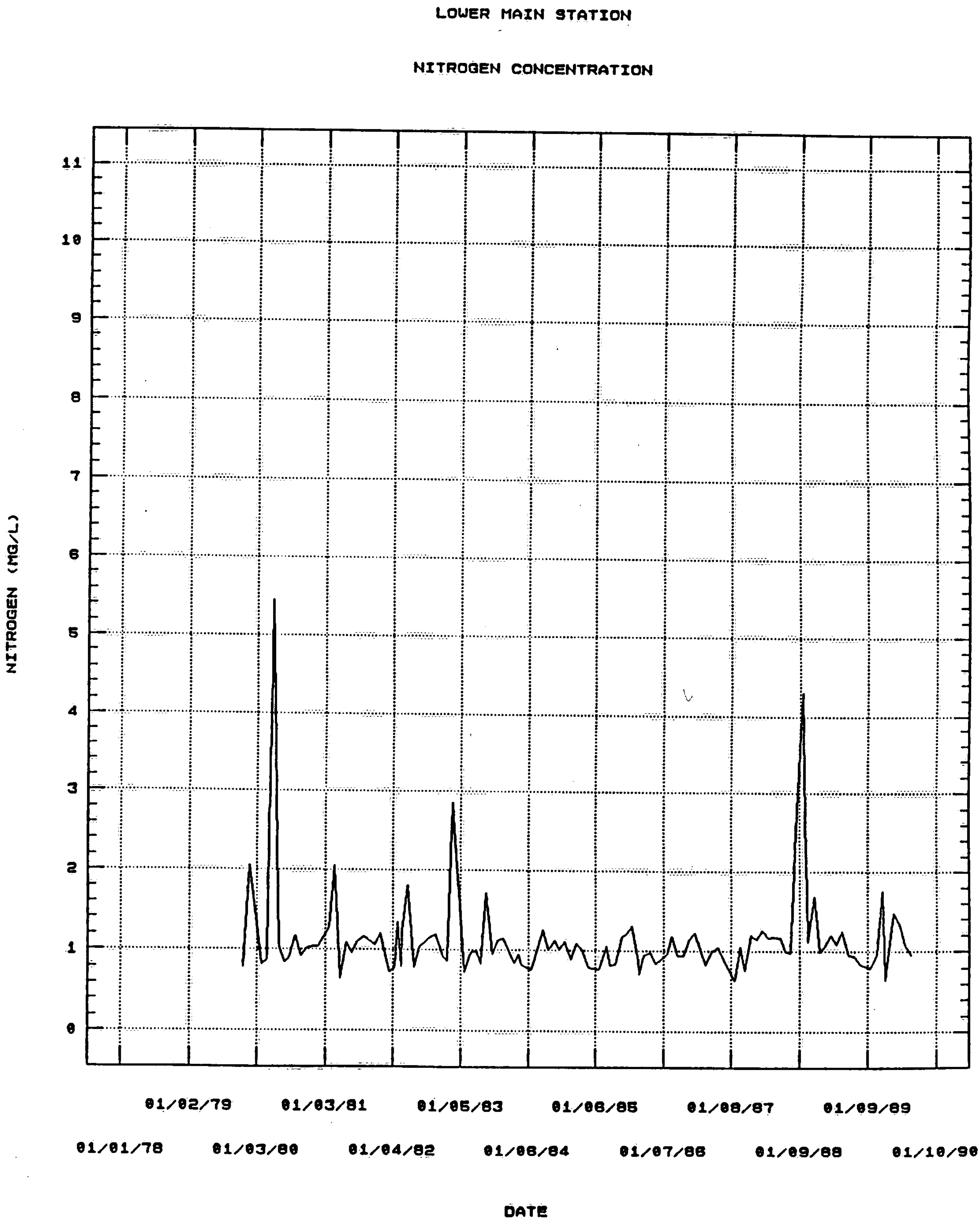

LOWER MAIN STATION
NITROGEN CONCENTRATION
NITROGEN (MG/L)
0
1
2
3
4
5
6
7
8
9
10
11
01/02/79
01/03/81
01/05/83
01/06/85
01/08/87
01/09/89
01/01/78
01/03/80
01/04/82
01/06/84
01/07/86
01/09/88
01/10/90
DATE

Figure 20C

FISH CREEK STATION

NITROGEN CONCENTRATION

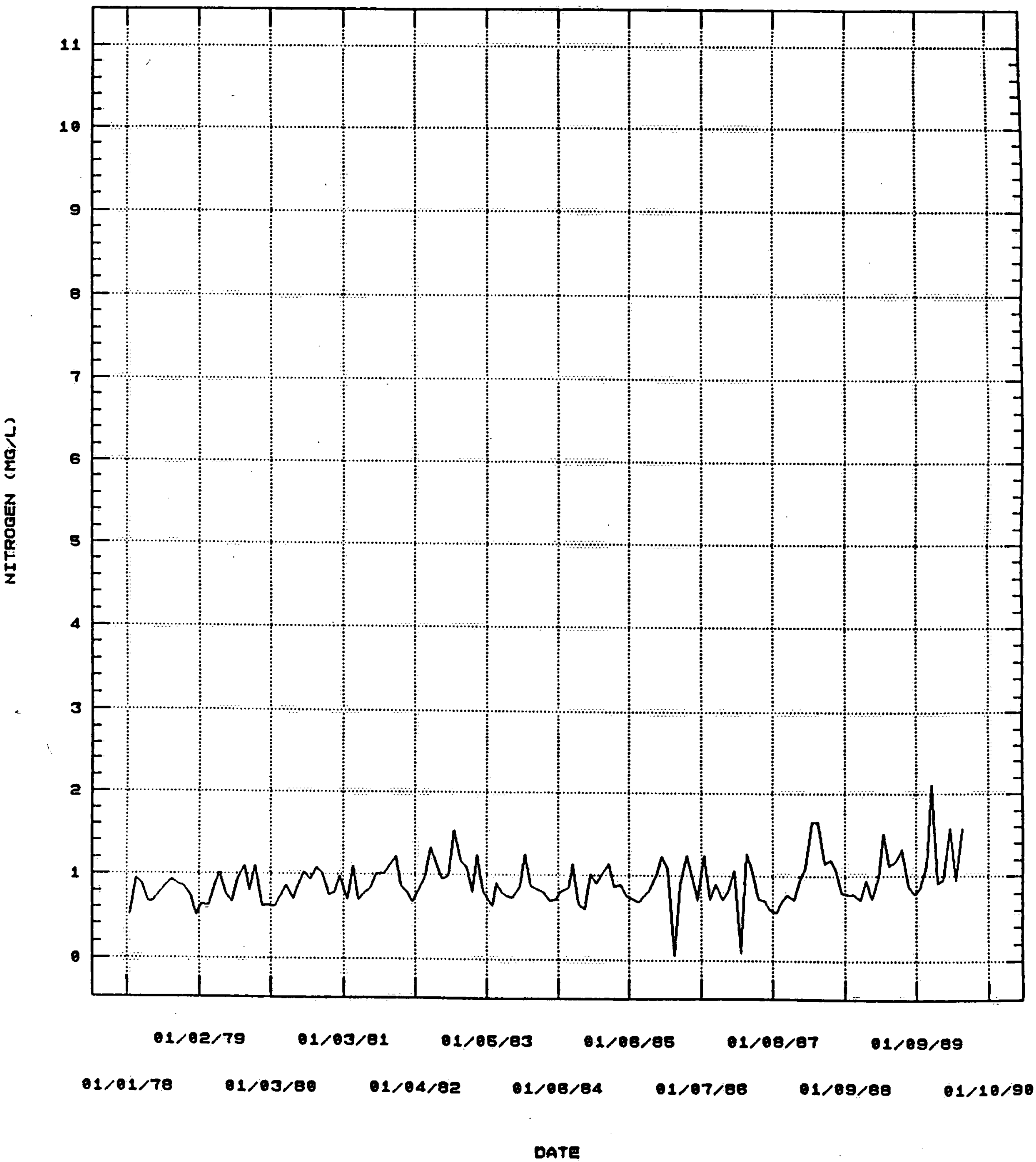


Figure 20D

NORTH THAMES STATION

NITROGEN CONCENTRATION

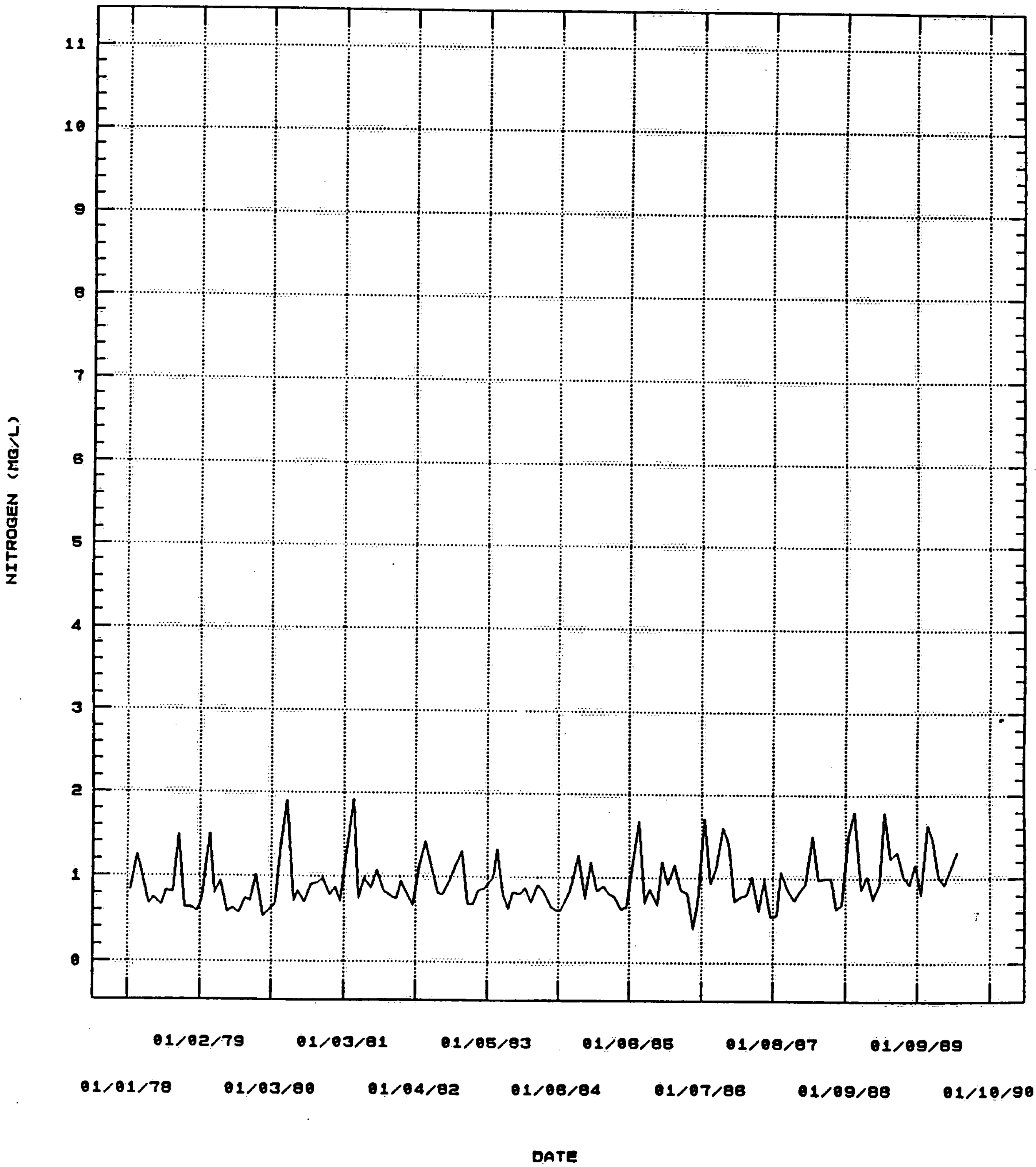


Figure 20E

EAST THAMES STATION

NITROGEN CONCENTRATION

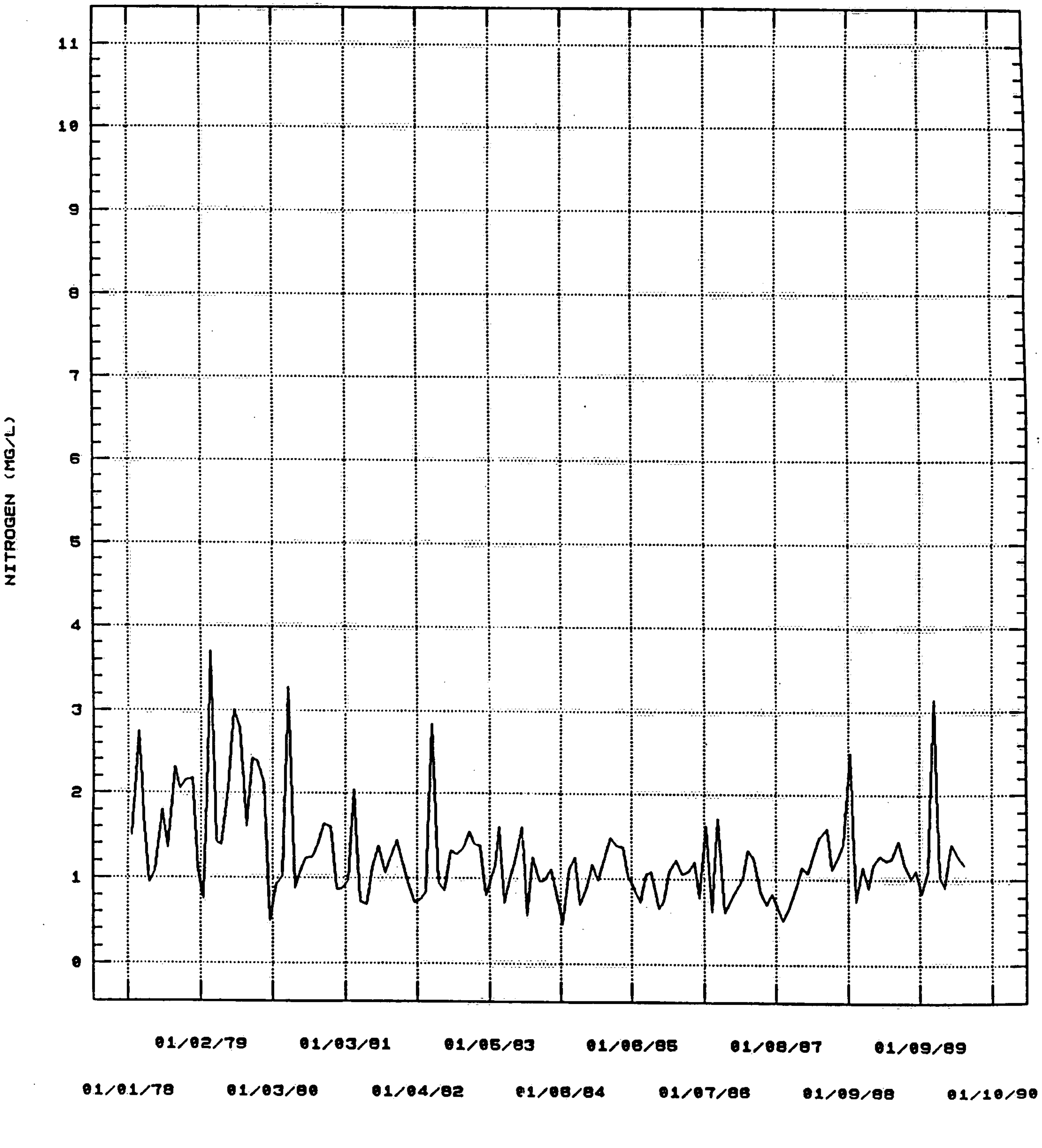


Figure 20F

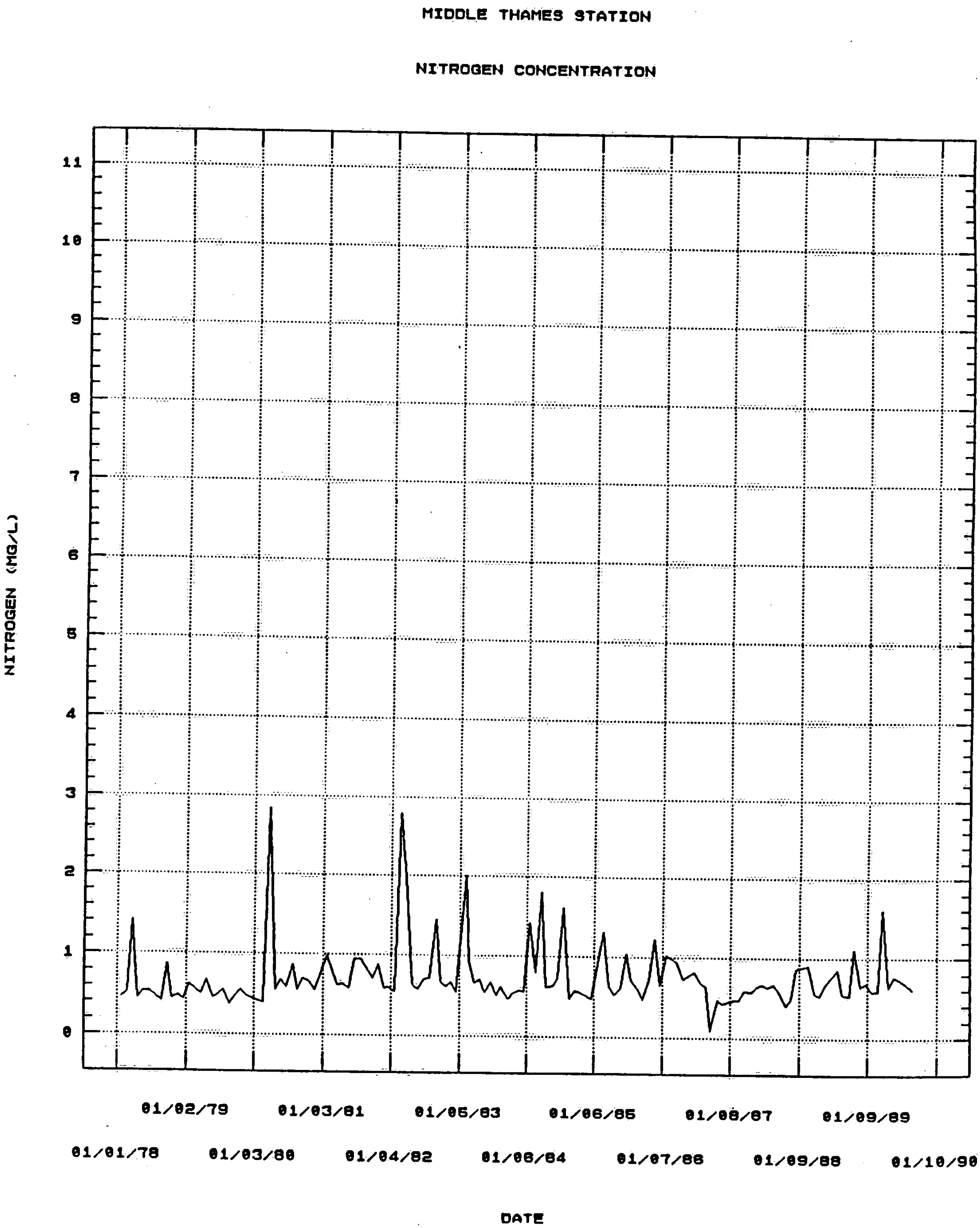

MIDDLE THAMES STATION
NITROGEN CONCENTRATION
NITROGEN (MG/L)
11
10
9
8
7
6
5
4
3
2
1
0
01/02/79
01/03/81
01/05/83
01/06/85
01/08/87
01/09/89
01/01/78
01/03/80
01/04/82
01/06/84
01/07/86
01/09/88
01/10/90
DATE

Figure 20G

UPPER MAIN STATION

NITROGEN CONCENTRATION

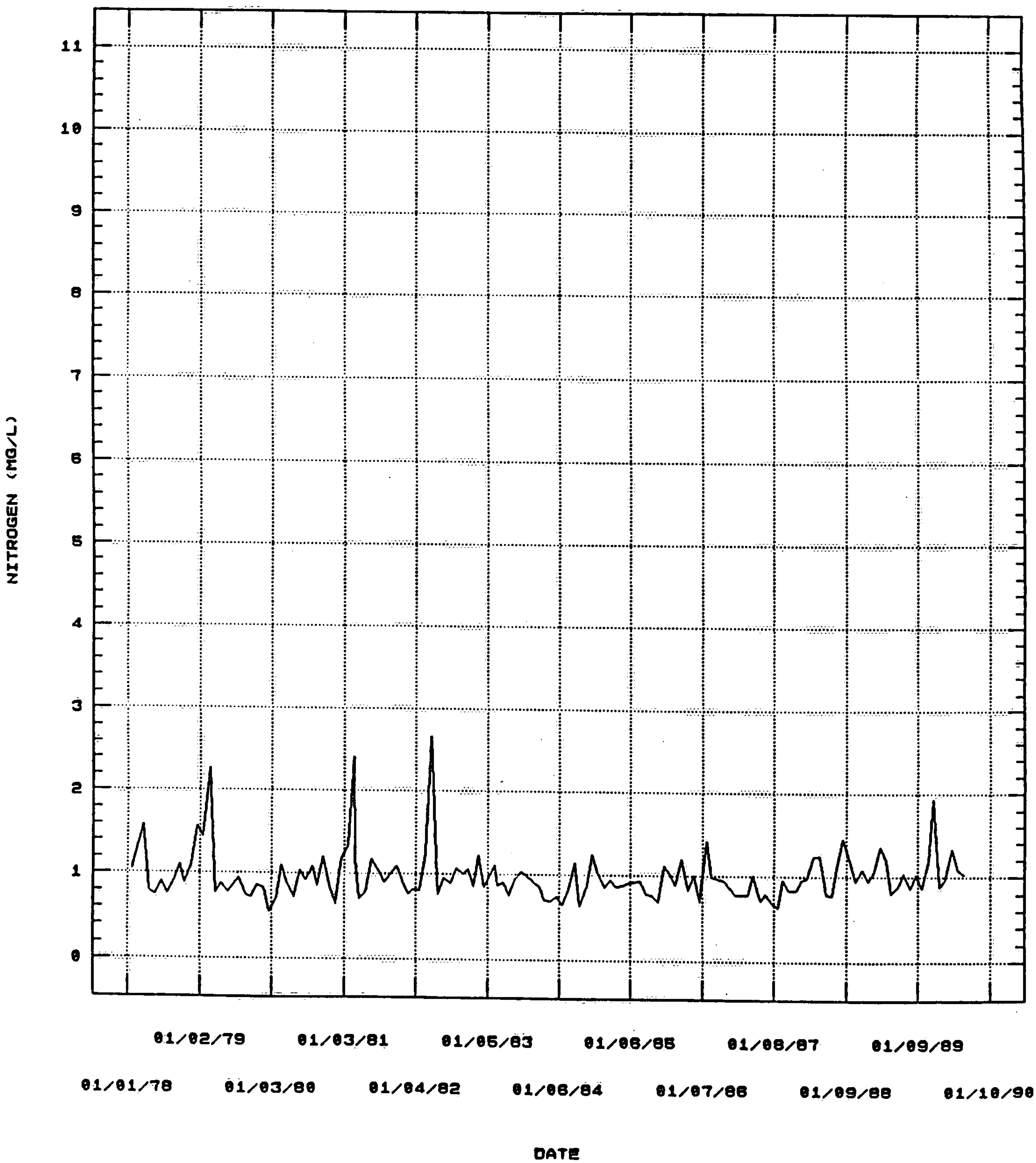
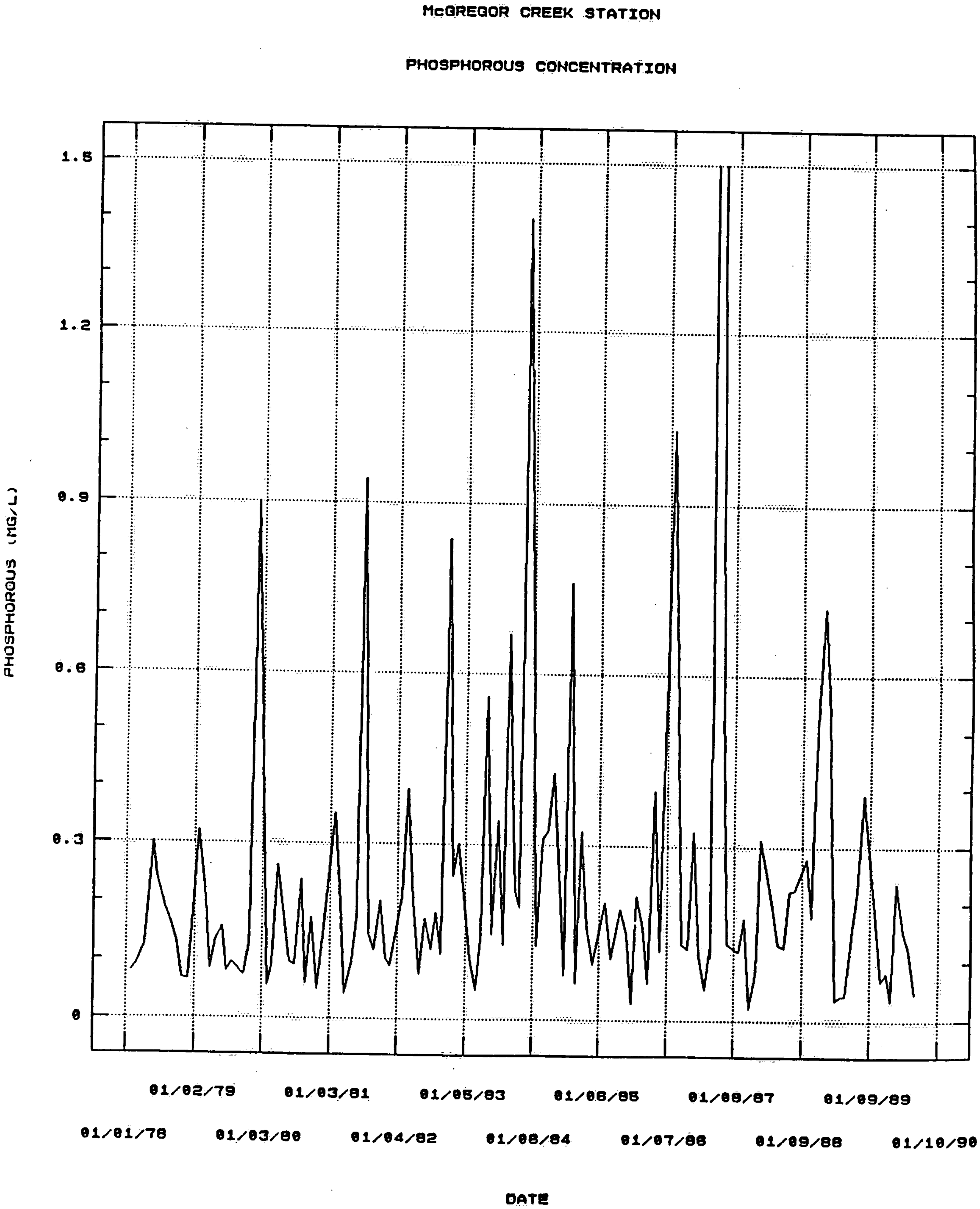


Figure 21A



McGREGOR CREEK STATION
PHOSPHOROUS CONCENTRATION
1.5
1.2
0.9
0.6
0.3
0
PHOSPHOROUS (MG/L)
01/02/79
01/03/81
01/05/83
01/06/85
01/08/87
01/09/89
01/01/78
01/03/80
01/04/82
01/08/84
01/07/86
01/09/88
01/10/90
DATE

Figure 21B

LOWER MAIN STATION

PHOSPHOROUS CONCENTRATION

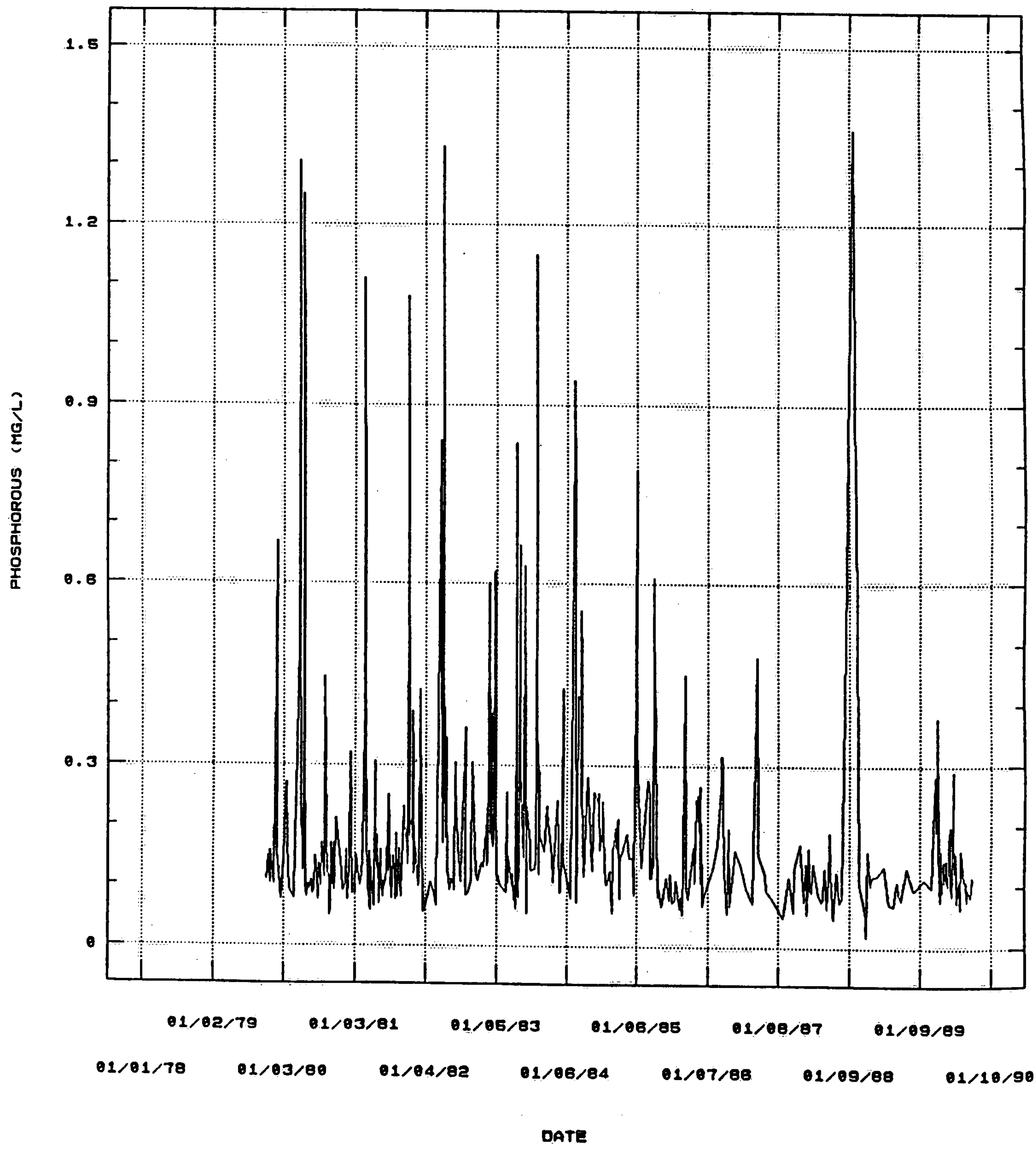


Figure 21C

FISH CREEK STATION

PHOSPHOROUS CONCENTRATION

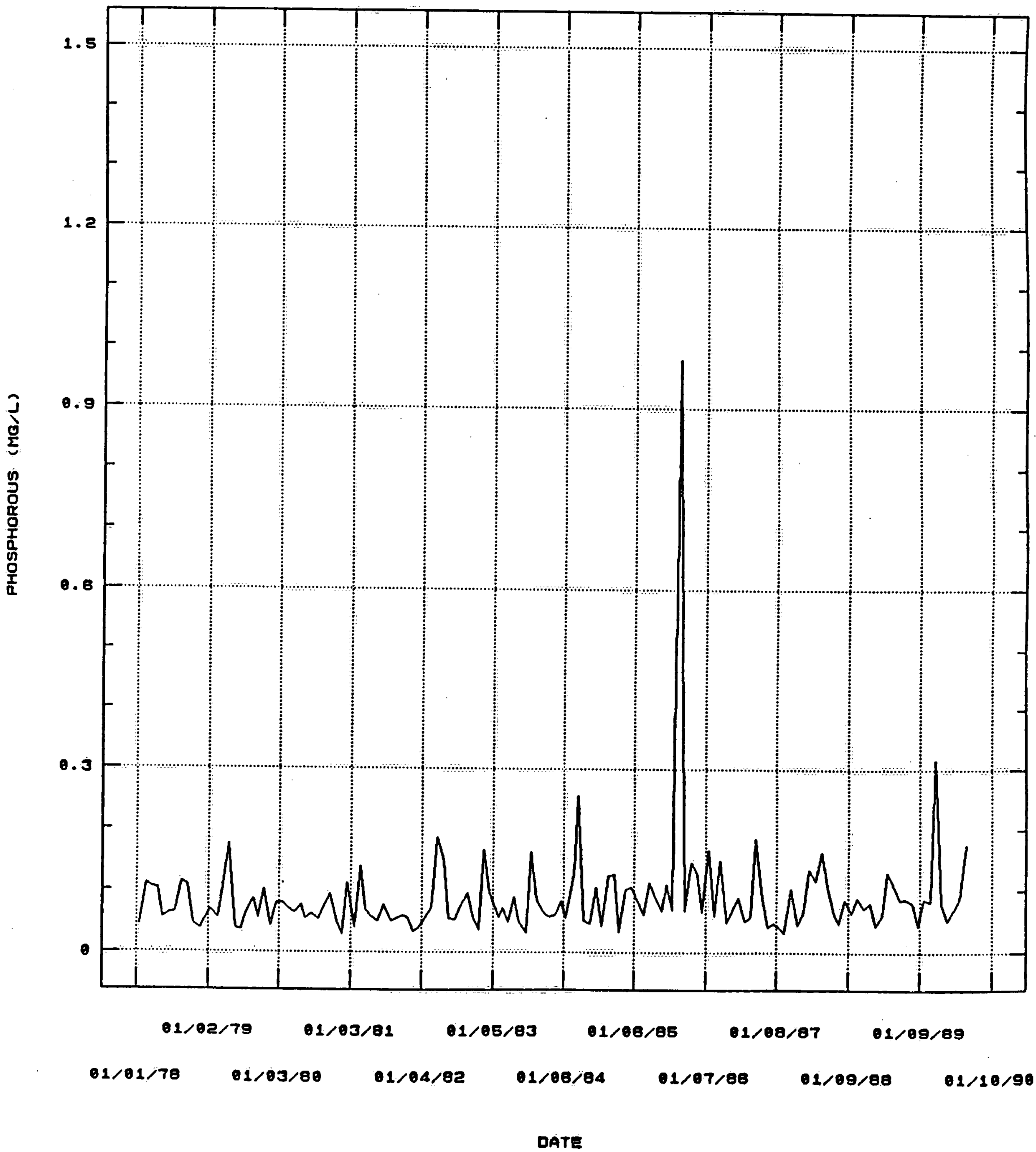


Figure 21D

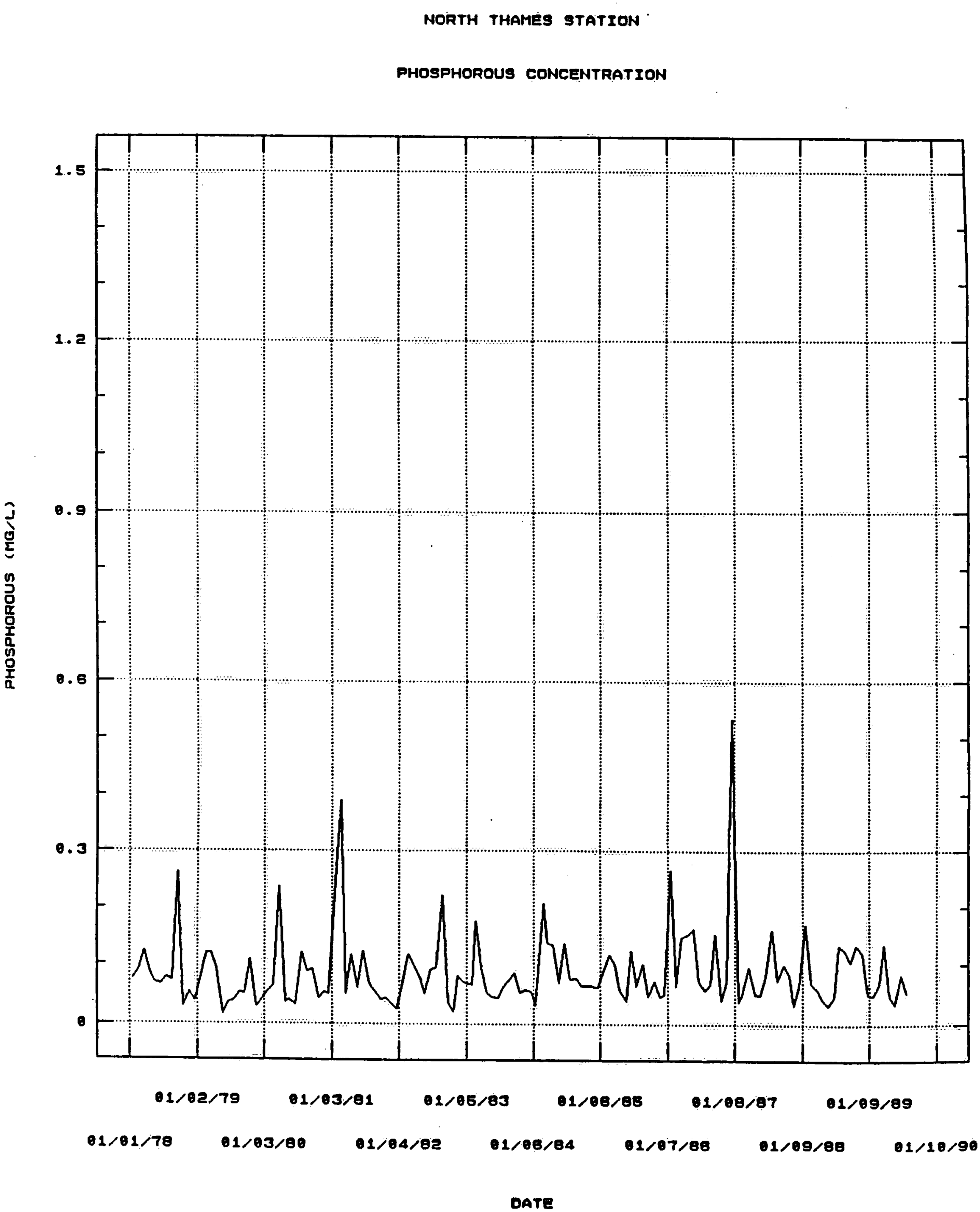

NORTH THAMES STATION
PHOSPHOROUS CONCENTRATION
PHOSPHOROUS (MG/L)
1.5
1.2
0.9
0.6
0.3
0
01/02/79
01/03/81
01/05/83
01/06/85
01/08/87
01/09/89
01/01/78
01/03/80
01/04/82
01/06/84
01/07/86
01/09/88
01/10/90
DATE

Figure 21E

EAST THAMES STATION

PHOSPHOROUS CONCENTRATION

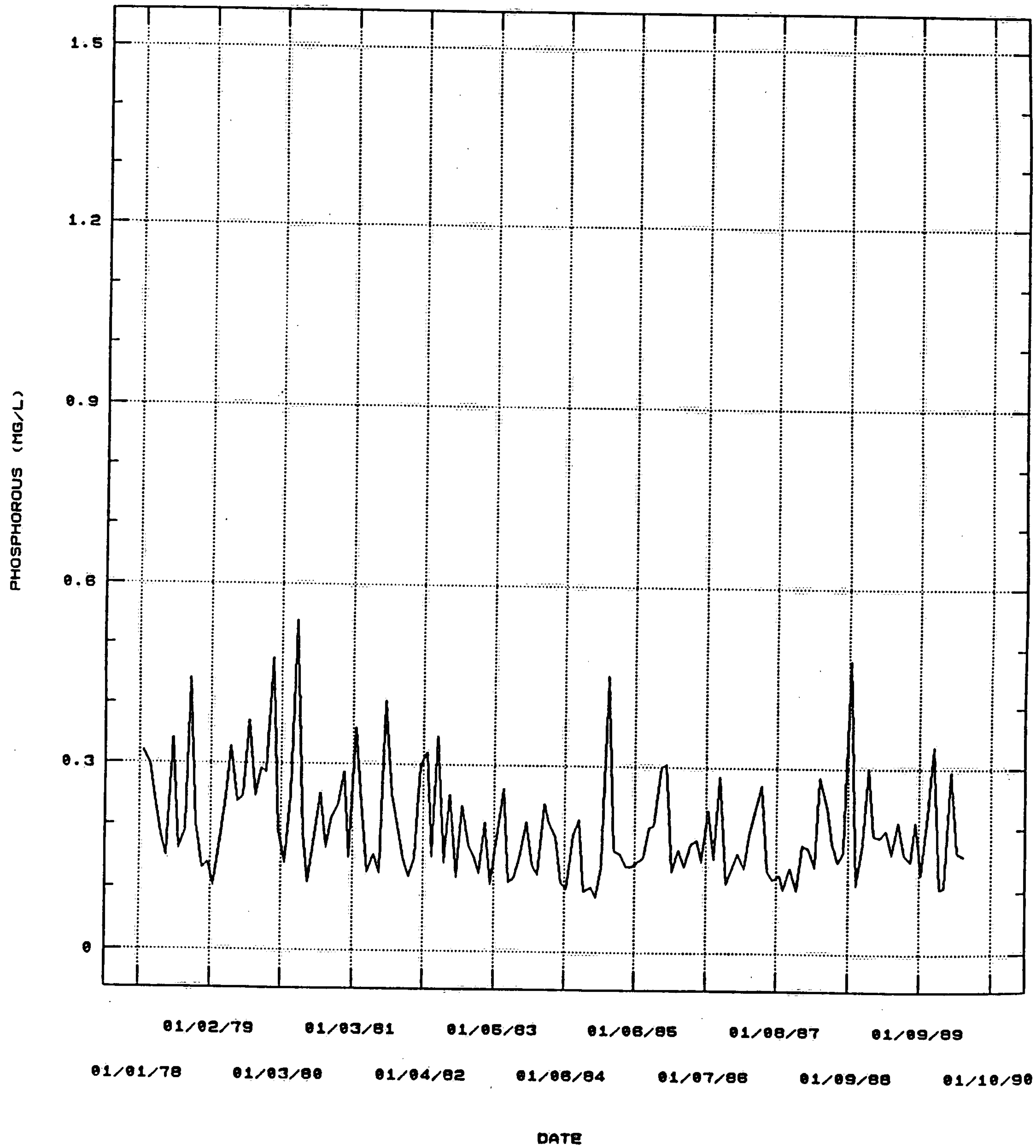


Figure 21F

MIDDLE THAMES STATION

PHOSPHOROUS CONCENTRATION

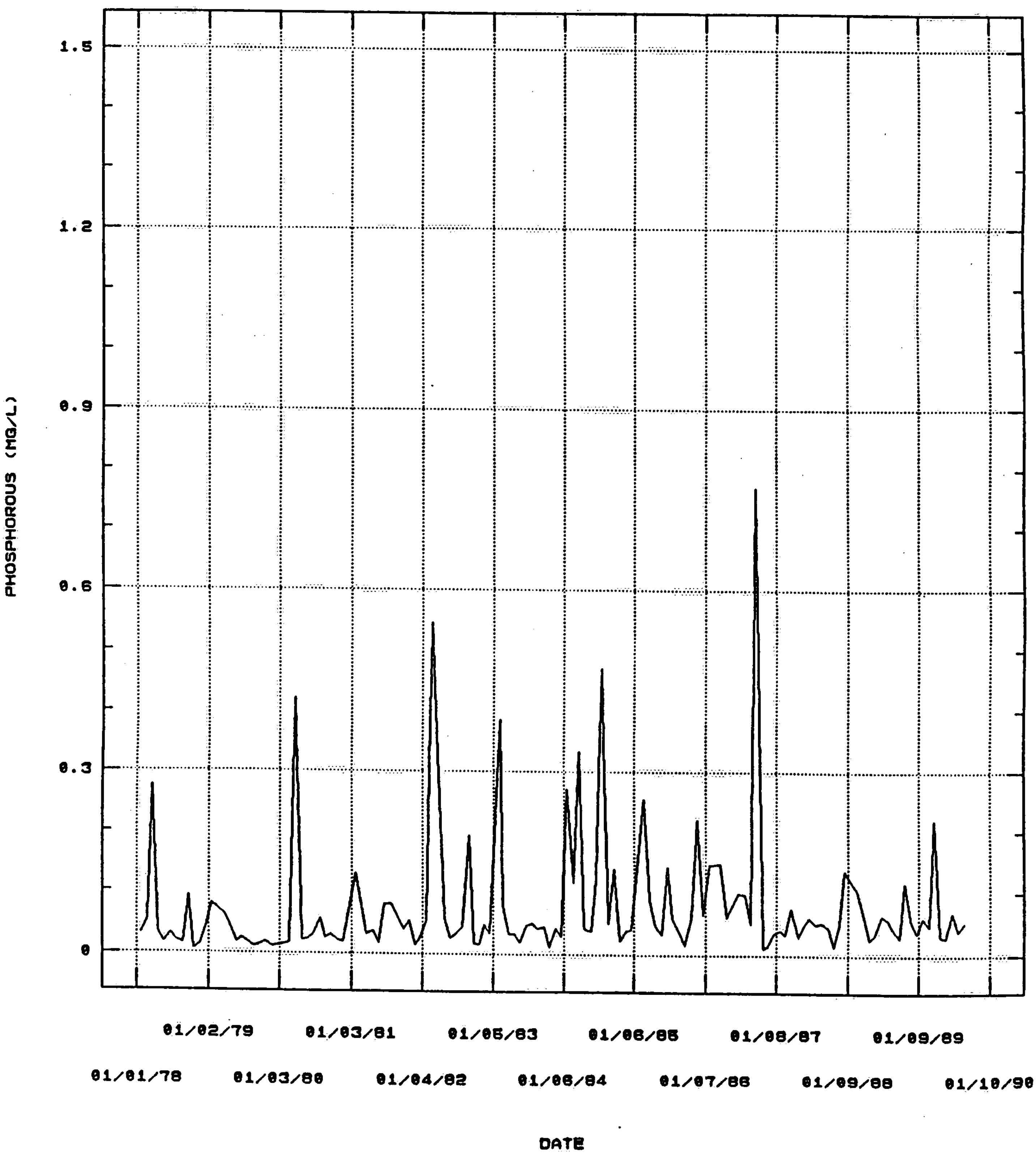
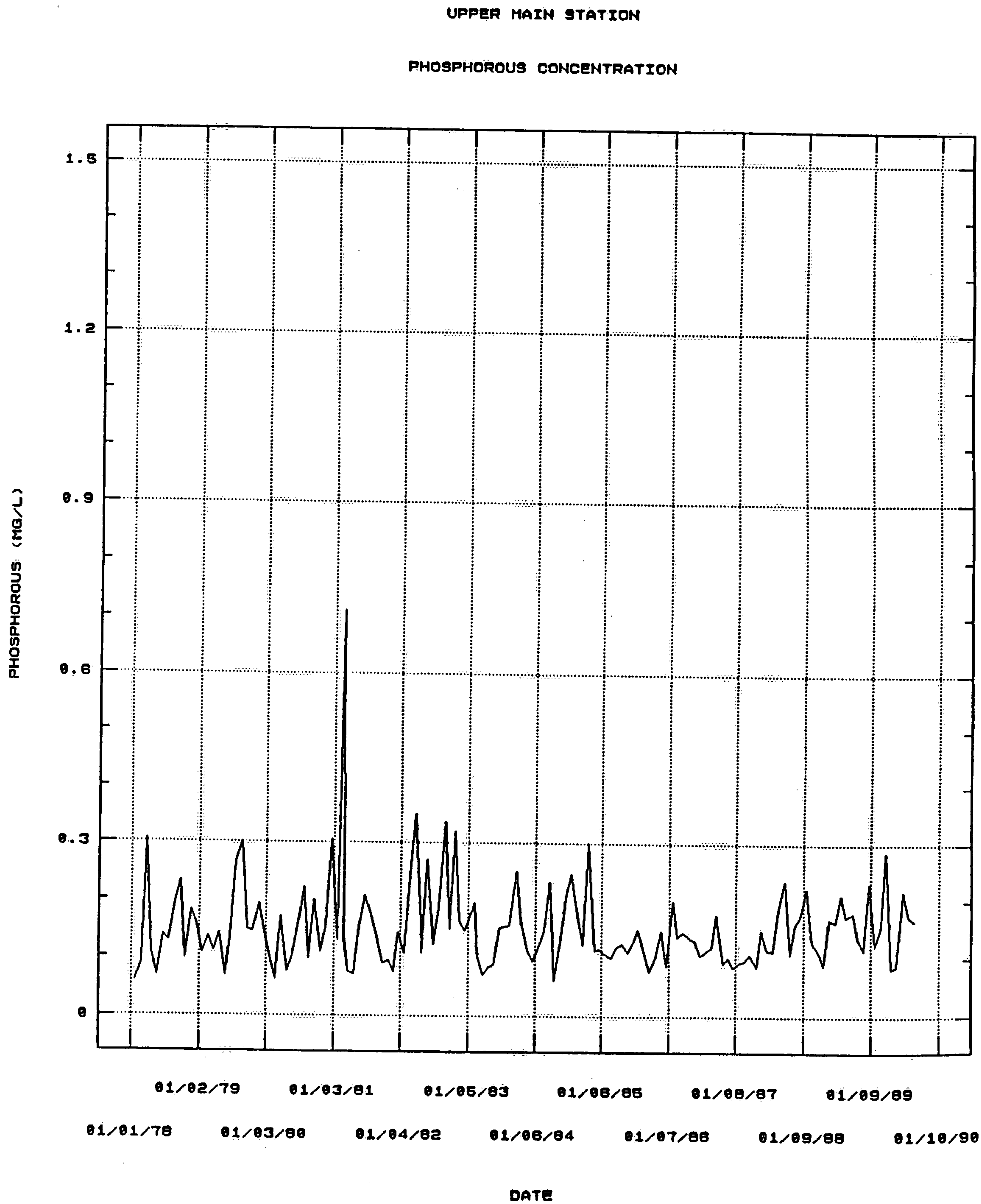


Figure 21G


UPPER MAIN STATION
PHOSPHOROUS CONCENTRATION
PHOSPHOROUS (MG/L)
1.5
1.2
0.9
0.6
0.3
0
01/02/79
01/03/81
01/05/83
01/06/85
01/08/87
01/09/89
01/01/78
01/03/80
01/04/82
01/06/84
01/07/86
01/09/88
01/10/90
DATE

phosphorous level of 0.250 mg/L with numerous fluxes. The Middle Thames, North Thames and Fish Creek stations have the lowest mean concentrations of all stations. With the exception of one event, phosphorous levels at the Fish Creek station exhibit minor fluctuations and are similar to those observed at the North Thames station.

The high levels of total phosphorous at the Lower Main and McGregor Creek stations may be attributed to the relatively high proportion of the sub-basins under corn systems (64% and 65% respectively), the high fertilizer application rates in the associated counties and the susceptibility of the Lower Thames basin to flooding. These two stations and the East Thames station all exceed the federal guideline of 0.2 mg/L for drinking water.

<u>Silica</u>

The MOE surface water quality network is set up to analyze for silicate (SiO3), however, no data has been collected for the stations included in this study.

Major Dissolved Ions

<u>Chloride</u>

Chloride is the only major dissolved ion to be sampled with any frequency for the study stations. Chloride values range from 24.0 mg/L at the Fish Creek station to 55.8 mg/L at the East Thames station (Table 12). These values are well below the federal guidelines for drinking water of 250 mg/L.

TABLE 12. PHYSICAL AND CHEMICAL ANALYSIS - MAJOR DISSOLVED IONS

MAJOR IONS (DISSOLVED)	STATS	LOWER THAMES		UPPER THAMES				
		McGREGOR CREEK	LOWER MAIN	FISH CREEK	NORTH THAMES	EAST CREEK	MIDDLE THAMES	UPPER MAIN
CHLORIDE	MEAN (#OBS)	46.0 (125)	47.3 (109)	24.0 (137)	30.0 (133)	55.8 (135)	25.8 (129)	39.2 (136)
	MEDIAN (#OBS)	43 (128)	37 (112)	23 (141)	26.5 (136)	54.5 (139)	25.5 (133)	34.75 (140)
	RANGE	14.0 - 172	14.0 - 900	8.0 - 58.6	8.0 - 94.4	15.5 - 213	9.0 - 45.5	14.0 - 183.0
SULPHATE	MEAN (#OBS)		51.65 (1)					
	MEDIAN (#OBS)	NO DATA		NO DATA	NO DATA	NO DATA	NO DATA	NO DATA
	RANGE							
CALCIUM	MEAN (#OBS)		58.10 (1)					
	MEDIAN (#OBS)	NO DATA		NO DATA	NO DATA	NO DATA	NO DATA	NO DATA
	RANGE							
MAGNESIUM	MEAN (#OBS)		14.85 (1)					
	MEDIAN (#OBS)	NO DATA		NO DATA	NO DATA	NO DATA	NO DATA	NO DATA
	RANGE							
SODIUM	MEAN (#OBS)		26.20 (1)					
	MEDIAN (#OBS)	NO DATA		NO DATA	NO DATA	NO DATA	NO DATA	NO DATA
	RANGE							
POTASSIUM	MEAN (#OBS)		4.56 (1)					
	MEDIAN (#OBS)	NO DATA		NO DATA	NO DATA	NO DATA	NO DATA	NO DATA
	RANGE							
FLUORIDE	MEAN (#OBS)							
	MEDIAN (#OBS)	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA
	RANGE							
TDS	MEAN (#OBS)							
	MEDIAN (#OBS)	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA
	RANGE							

Field Measurements

Alkalinity

Mean alkalinity values for six of the seven stations are shown in Table 13. Values range from 185 mg/L $CaCO_3$ at the Lower Main station to 221.2 mg/L $CaCO_3$ at the Middle Thames station. These values are a direct result of the surficial and underlying geology and associated ground water, as mentioned at the beginning of this section.

pH

Values for mean pH are all within the federal guideline range of 6.5 - 8.5. Table 13 shows that all stations are basic with the North Thames station being more basic (pH 8.21) and the East Thames least basic (pH 7.91).

Conductivity

Table 13 lists mean conductivity values measured at 25° C for all stations. High conductivity values are characteristic of the McGregor Creek and East Thames stations. The Fish Creek station has the lowest mean conductivity at 539 uS/cm.

Temperature

Mean temperature values range form 10.2° C at the North Thames station to 13.1° C at the McGregor Creek station (Table 13). Generally, the Upper Thames' stations have lower temperatures due to both the cooler climate and shorter 'in-stream' distances travelled.

TABLE 13. PHYSICAL AND CHEMICAL ANALYSIS - FIELD MEASUREMENTS

FIELD MEASUREMENTS	STATS	LOWER THAMES		UPPER THAMES				
		McGREGOR CREEK	LOWER MAIN	FISH CREEK	NORTH THAMES	EAST CREEK	MIDDLE THAMES	UPPER MAIN
ALKALINITY (AS CACO3)	MEAN (#OBS)	201 (73)	185 (4.3)	NO DATA	209.7 (65)	211.2 (76)	221.9 (74)	204 (101)
	MEDIAN (#OBS)	203 (76)	184.5 (407)		207.75 (68)	206 (80)	222.75 (78)	204 (105)
	RANGE	63.5 - 273.0	2.0 - 382.0		115.5 - 349	138.0 - 285	108.3 - 301	94.5 - 270.0
pH	MEAN (#OBS)	8.00 (125)	8.06 (430)	8.11 (121)	8.21 (117)	7.91 (121)	8.20 (129)	8.08 (137)
	MEDIAN (#OBS)	8.04 (128)	8.08 (434)	8.11 (125)	8.23 (120)	7.29 (125)	8.22 (133)	8.12 (141)
	RANGE	7.46 - 8.56	5.70 - 8.61	7.09 - 8.58	7.44 - 8.80	7.31 - 8.35	7.45 - 8.57	7.09 - 8.44
CONDUCTIVITY (@ 25 C)	MEAN (#OBS)	768 (125)	552 (519)	539 (137)	594 (133)	720 (135)	615 (129)	615 (138)
	MEDIAN (#OBS)	782.5 (128)	570 (523)	525 (141)	589.5 (136)	721 (139)	620 (133)	605 (142)
	RANGE	454 - 1084	163 - 1020	373 - 740	333 - 860	217 - 1420	246 - 995	302 - 1048
TEMPERATURE	MEAN (#OBS)	13.1 (123)	12.3 (108)	10.4 (134)	10.2 (135)	10.7 (138)	11.6 (132)	10.5 (138)
	MEDIAN (#OBS)	14 (124)	12 (109)	11 (138)	10.5 (127)	11 (139)	13 (127)	11 (130)
	RANGE	0.0 - 32.0	0.0 - 29.0	0.0 - 26.0	0.0 - 26.5	0.0 - 26.0	0.0 - 29.0	0.0 - 29.5
DISSOLVED ORGANIC CARBON	MEAN (#OBS)	NO DATA	4.1 (4)	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA
	MEDIAN (#OBS)		4.1 (3)					
	RANGE		4.1 - 4.2					
TURBIDITY (NTU)	MEAN (#OBS)	81 (118)	64 (102)	8 (59)	9 (130)	11 (133)	9.2 (128)	14 (134)
	MEDIAN (#OBS)	45 (120)	32 (105)	5.5 (59)	5.8 (133)	8.4 (137)	2.9 (132)	8.1 (138)
	RANGE	3.7 - 1020	5.1 - 820	1.1 - 49	0.93 - 50	2.00 - 100	0.50 - 194	1.20 - 200
ACIDITY	MEAN (#OBS)	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA
	MEDIAN (#OBS)							
	RANGE							

Turbidity

Turbidity values measured in Nephelometric Turbidity Units are presented in Table 13 and range from 8 NTU at the Fish Creek station to 81 NTU at the McGregor Creek Station. The North and Middle Thames and Fish Creek sub-basins represent faster flowing headwater areas with relatively low turbidity. The East and Upper Main sub-basins are characterized by slower moving water and increased turbidity. The McGregor Creek sub-basin is typified by a slower moving, sediment laden stream/river system.

Metals

Generally, information on metal concentrations within the Thames basin is limited. The Lower Main station is the only station with mean values for all 10 metals; a number of these means are based on less than 10 observations. More extensive data collection is required in order to establish meaningful statistics prior to the formation of conclusions.

Cadmium

Mean total cadmium concentrations in mg/L are available for the Upper and Lower Main stations only and appear in Table 14. Both values are below the guideline figure of 0.005 mg/L.

TABLE 14. PHYSICAL AND CHEMICAL ANALYSIS - METALS

METALS	STATS	LOWER THAMES: McGREGOR CREEK	LOWER THAMES: LOWER MAIN	UPPER THAMES: FISH CREEK	UPPER THAMES: NORTH THAMES	UPPER THAMES: EAST CREEK	UPPER THAMES: MIDDLE THAMES	UPPER THAMES: UPPER MAIN
	MEAN		0.001< (194)			0.00002< (1)		0.0003< (67)
CADMIUM	RANGE	NO DATA	NA (NA)	NO DATA	NO DATA		NO DATA	NA (NA)
(TOTAL)	# OBS.		.0001 - 0.06					0.0001 - 0.001
	MEAN	4.758 (7)	2.119 (71)			0.640 (1)	0.246< (74)	0.51 (85)
IRON	RANGE	2.98 (7)	1.00 (73)	NO DATA	NO DATA		0.14 (76)	0.35 (86)
(TOTAL)	# OBS.	0.880 - 18.80	0.077 - 46.0				0.014-3.05	0.033 - 2.00
	MEAN	0.007< (125)	0.021< (332)	0.005< (1)	0.005< (24)	0.005< (54)	0.006< (25)	0.007< (43)
LEAD	RANGE	NA (NA)	NA (NA)		NA (NA)	NA (NA)	NA (NA)	NA (NA)
(TOTAL)	# OBS.	0.003 - 0.034	0.003 - 0.58		0.001 - 0.019	0.003 - 0.008	0.003 - 0.03	0.003 - 0.02
	MEAN		0.039 (4)					
MANGANESE	RANGE	NO DATA	0.029 (3)		NO DATA	NO DATA	NO DATA	NO DATA
(TOTAL)	# OBS.		0.028 - 0.069					
	MEAN		3.0 (5)					
ALUMINUM	RANGE	NO DATA	0.64 (4)		NO DATA	NO DATA	NO DATA	NO DATA
(TOTAL)	# OBS.		0.560 - 13					
	MEAN		0.001< (37)		NO DATA			0.001< (29)
ARSENIC	RANGE	NO DATA	NA (NA)			NO DATA	NO DATA	NA (NA)
(TOTAL)	# OBS.		0.001 - 0.007					0.001 - 0.005
	MEAN		0.004 (8)		0.0048 (1)	0.0062 (1)		0.005 (82)
CHROMIUM	RANGE	NO DATA	0.003 (7)	NO DATA			NO DATA	0.004 (82)
(TOTAL)	# OBS.		0.001 - 0.005					0.001 - 0.020
	MEAN	0.008 (65)	0.01< (594)	0.0012< (1)	0.004< (72)	0.005< (74)	0.004< (56)	0.007 (91)
COPPER	RANGE	0.006 (68)	0.0075 (556)		0.003 (73)	0.004 (76)	0.03 (57)	0.005 (91)
(TOTAL)	# OBS.	0.002 - 0.051	0.001 - 0.090		0.0005 - 0.01	0.002 - 1.010	0.001 - 0.02	0.001 - 0.050
	MEAN		0.005< (7)		0.003< (1)	0.005< (1)		0.006< (84)
NICKEL	RANGE	NO DATA	0.006 (5)	NO DATA			NO DATA	0.005 (84)
(TOTAL)	# OBS.		0.002 - 0.008					0.002 - 0.034
	MEAN	0.020< (66)	0.04< (72)	0.005< (1)	0.019< (72)	0.018 (72)	0.011< (66)	0.013< (95)
ZINC	RANGE	0.013 (69)	0.008 (73)		0.006 (73)	0.013 (74)	0.004 (68)	0.0095 (94)
(TOTAL)	# OBS.	0.0017 - 0.18	0.001 - 2.00		0.001 - 0.48	0.003 - 0.096	0.001 - 0.09	0.001 - 0.055

THE FOLLOWING PARAMETERS ARE NOT SAMPLED BY THE MOE'S SURFACE WATER QUALITY NETWORK:

MERCURY (TOTAL)
ANTINOMY (DISSOLVED)
ARSENIC (DISSOLVED)
LEAD (DISSOLVED)
MOLYBDENUM (DISSOLVED)
SELENIUM (DISSOLVED)
SILVER (DISSOLVED)
VANADIUM (DISSOLVED)
ZINC (DISSOLVED)

Iron

Data for total iron concentration (mg/L) for five stations is presented in Table 14. Means of 4.758 and 2.119 mg/L for the McGregor Creek and Lower Main stations (based on the available data) greatly exceed the federal drinking water guidelines of 0.3 mg/L. The Middle Thames station is the only station that does not exceed guidelines with a mean value of less the 0.246 mg/L.

Lead

Table 14 and Figures 22A-C present total lead concentrations for the available stations. The North, East and Middle Thames stations were not plotted due to data gaps in the study period. Mean lead concentrations range from less than 0.005 mg/L (detection limit) at the North and East Thames stations to less the 0.021 mg/L at the Lower Main station. All mean concentrations are below the federal guideline value of 0.05 mg/L. Figure 22B, however, shows that lead concentrations regularly exceeded the guideline level in the early to mid-1980's.

Manganese, Aluminum

Total manganese and total aluminum (mg/L) have only been measured at the Lower Main station (Table 14). Based on the limited data, total manganese concentrations are below the federal guidelines of 0.05 mg/L while aluminum exceeds the concentration guideline of 0.05 mg/L. More data are required for determining the levels of both metals in the sub-basins and for the identification of sources.

Figure 22A

McGREGOR CREEK STATION

LEAD CONCENTRATION

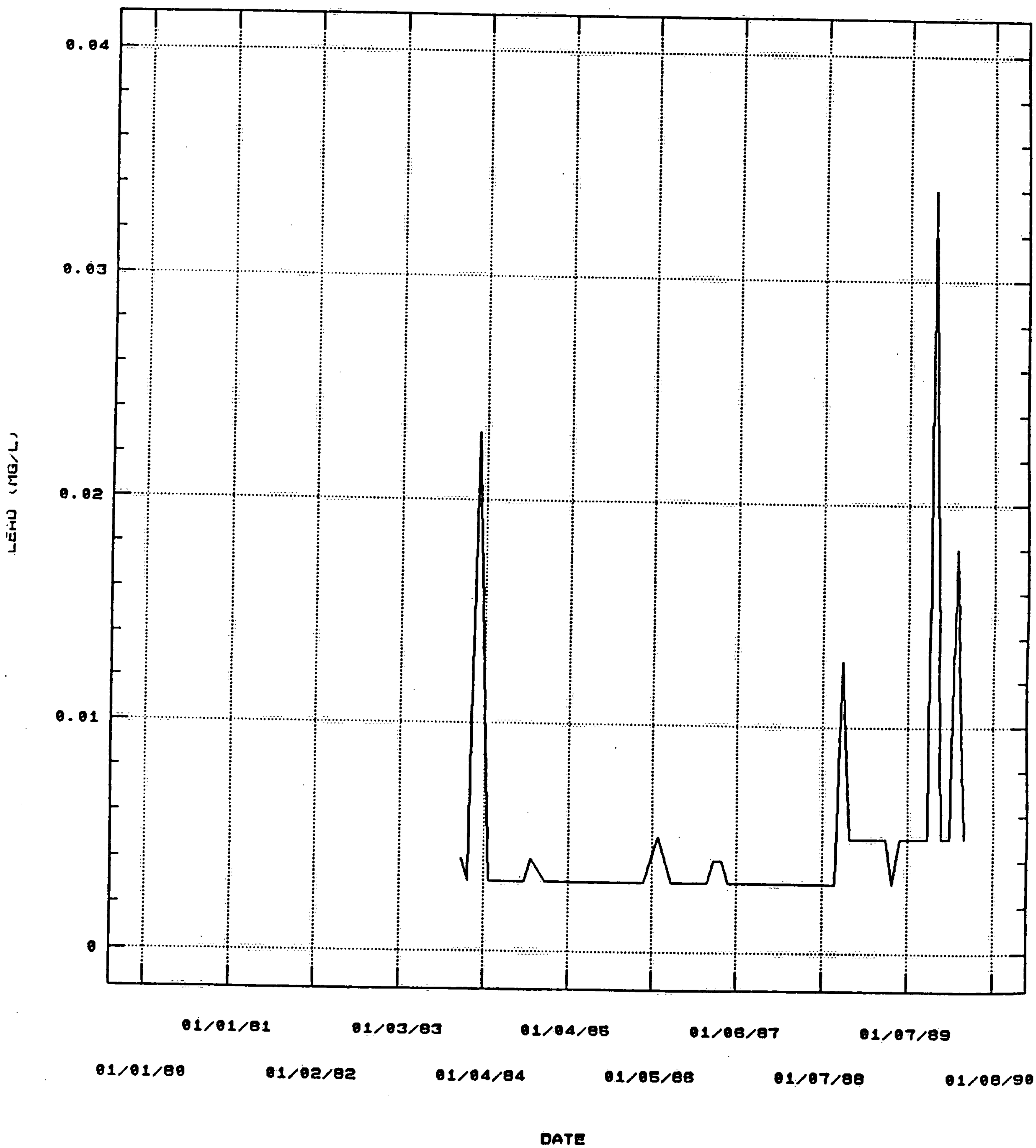


Figure 22B

LOWER MAIN STATION

LEAD CONCENTRATION

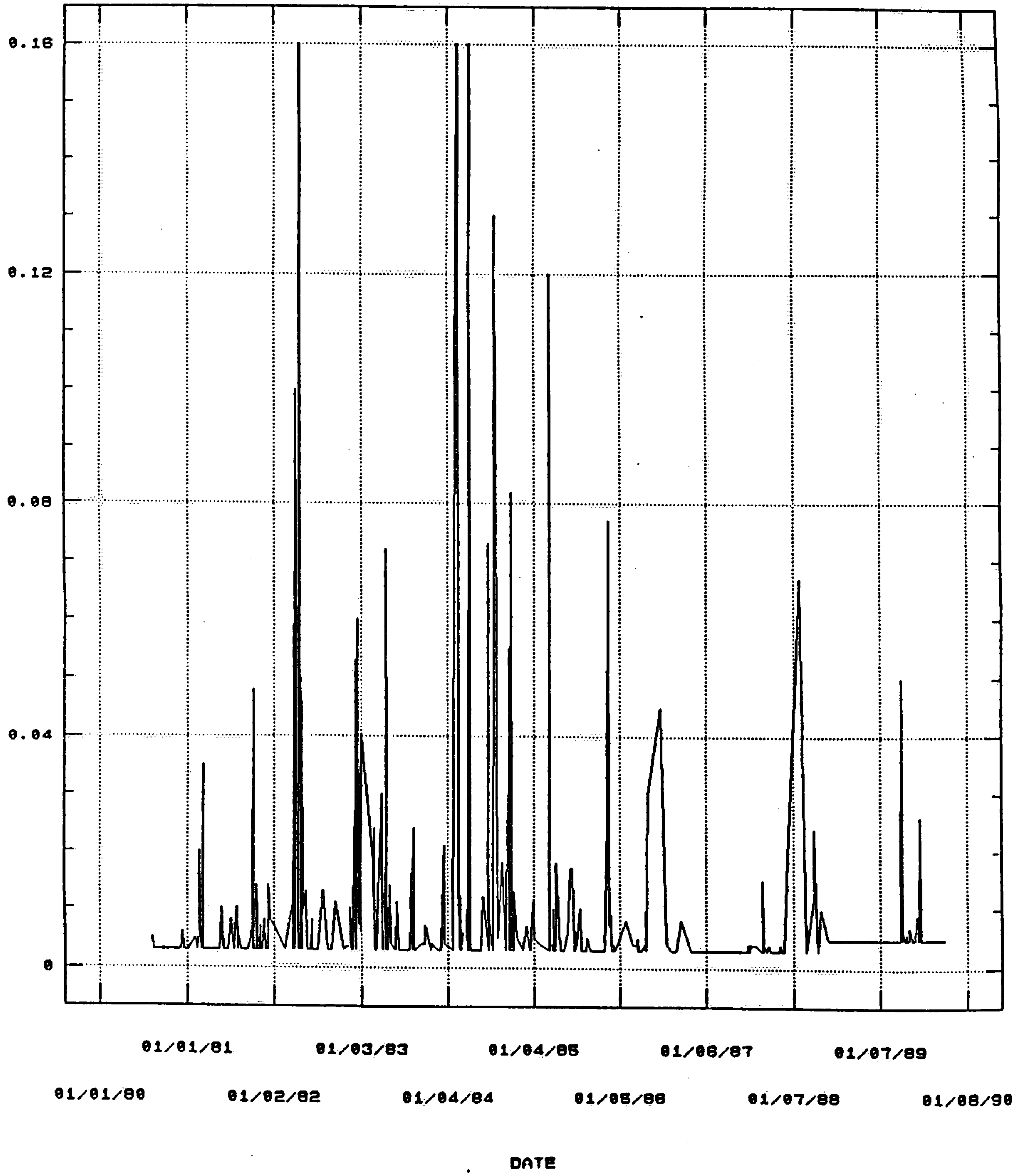
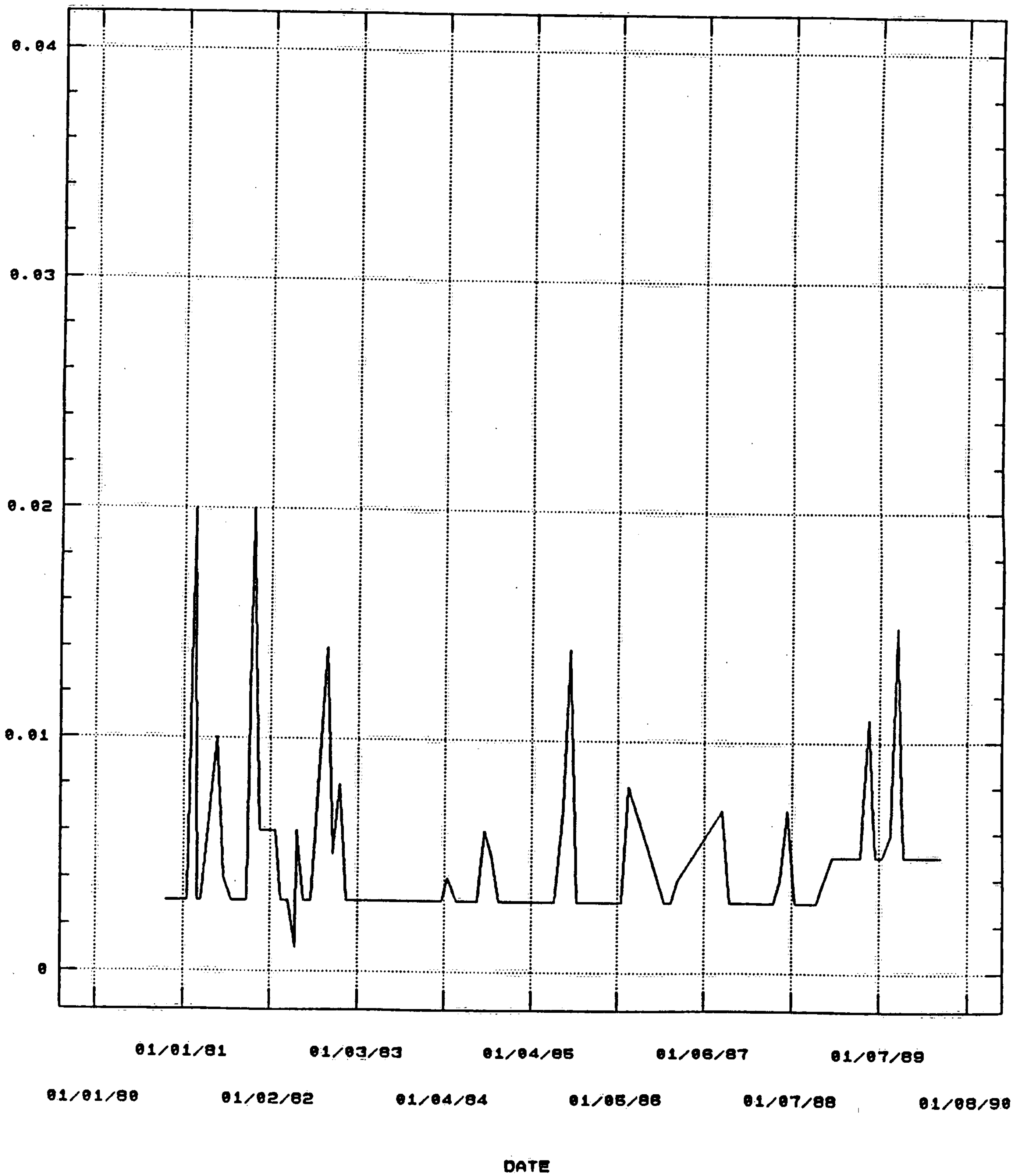


Figure 22C

UPPER MAIN STATION

LEAD CONCENTRATION



Arsenic, Chromium

Table 14 lists total arsenic and chromium concentrations (mg/L) for stations for which data are available. Mean total arsenic concentrations are similar across three stations and are well below the 0.05 mg/L guideline. Mean total chromium values range from 0.004 mg/L at the Lower Main station to 0.0062 mg/L (1 observation) at the East Thames station. All chromium values are below the guideline concentration of 0.05 mg/L.

Copper

Graphs have been produced for four of the seven stations for which data exist (Figures 23A-D) with mean concentrations shown in Table 14. Reliable total copper concentrations range from less than 0.004 mg/L at the Middle and North Thames stations to less the 0.01 mg/L at the Lower Main station. All mean concentrations fall below the 1.0 mg/L federal guideline for drinking water but the mean concentrations at the McGregor Creek, Lower Main and Upper Main stations are in excess of the 0.004 mg/L guideline for aquatic life. Figure 22B shows the high fluctuations experienced at the Lower Main station, however, total copper concentrations generally appear to have decreased during the study period.

Nickel

Total nickel concentrations have been measured frequently only at the Upper Main station. Based on the limited data, nickel concentrations appear to be similar at all stations. The federal guideline for freshwater aquatic life is 0.15 mg/L at the associated alkalinity. Nickel concentrations would appear to be well below the guideline level.

Figure 23A

McGREGOR STATION

COPPER CONCENTRATION

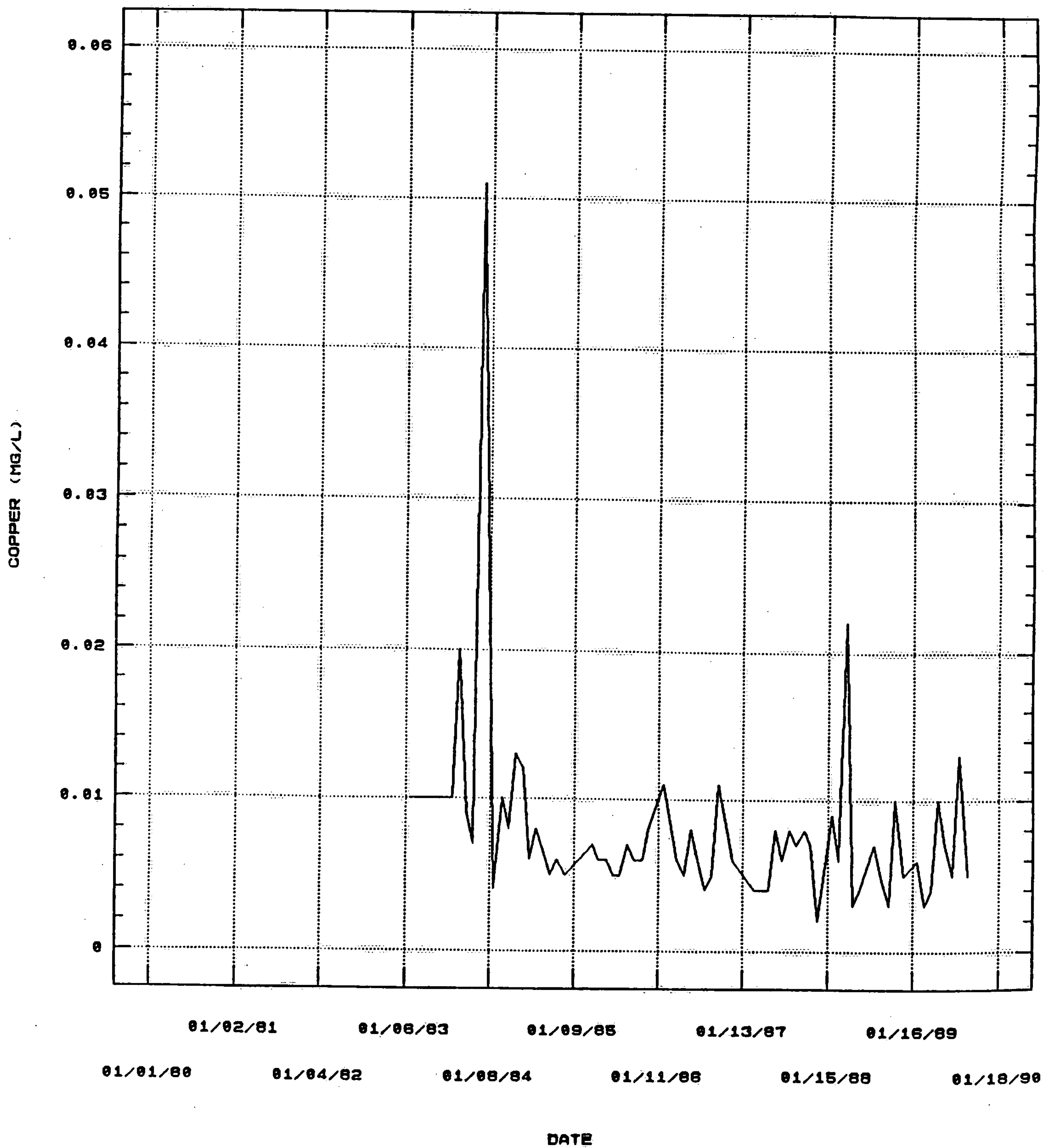


Figure 23B

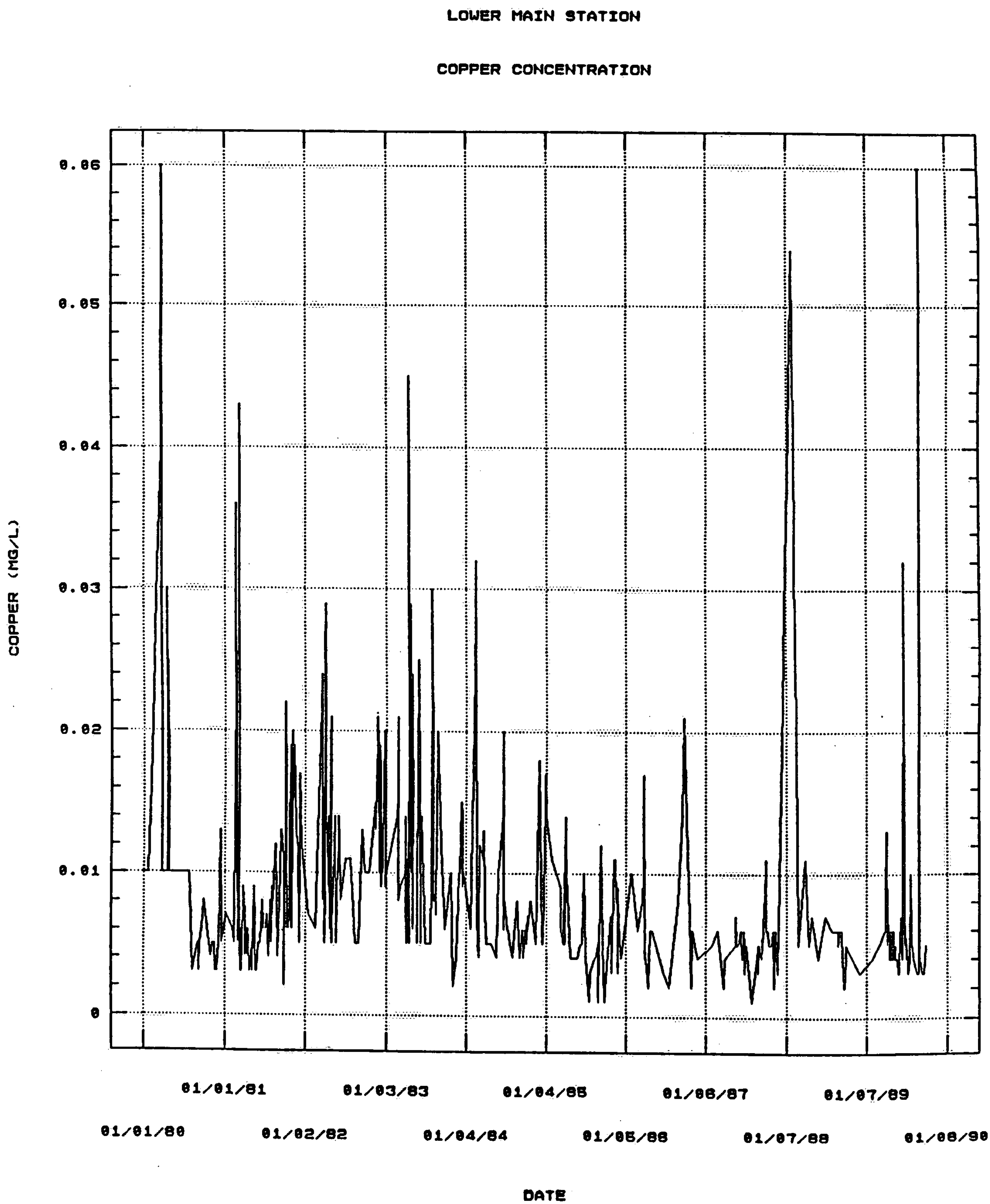

LOWER MAIN STATION
COPPER CONCENTRATION
COPPER (MG/L)
0.06
0.05
0.04
0.03
0.02
0.01
0
01/01/81
01/03/83
01/04/85
01/06/87
01/07/89
01/01/80
01/02/82
01/04/84
01/05/86
01/07/88
01/08/90
DATE

Figure 23C

MIDDLE THAMES STATION

COPPER CONCENTRATION

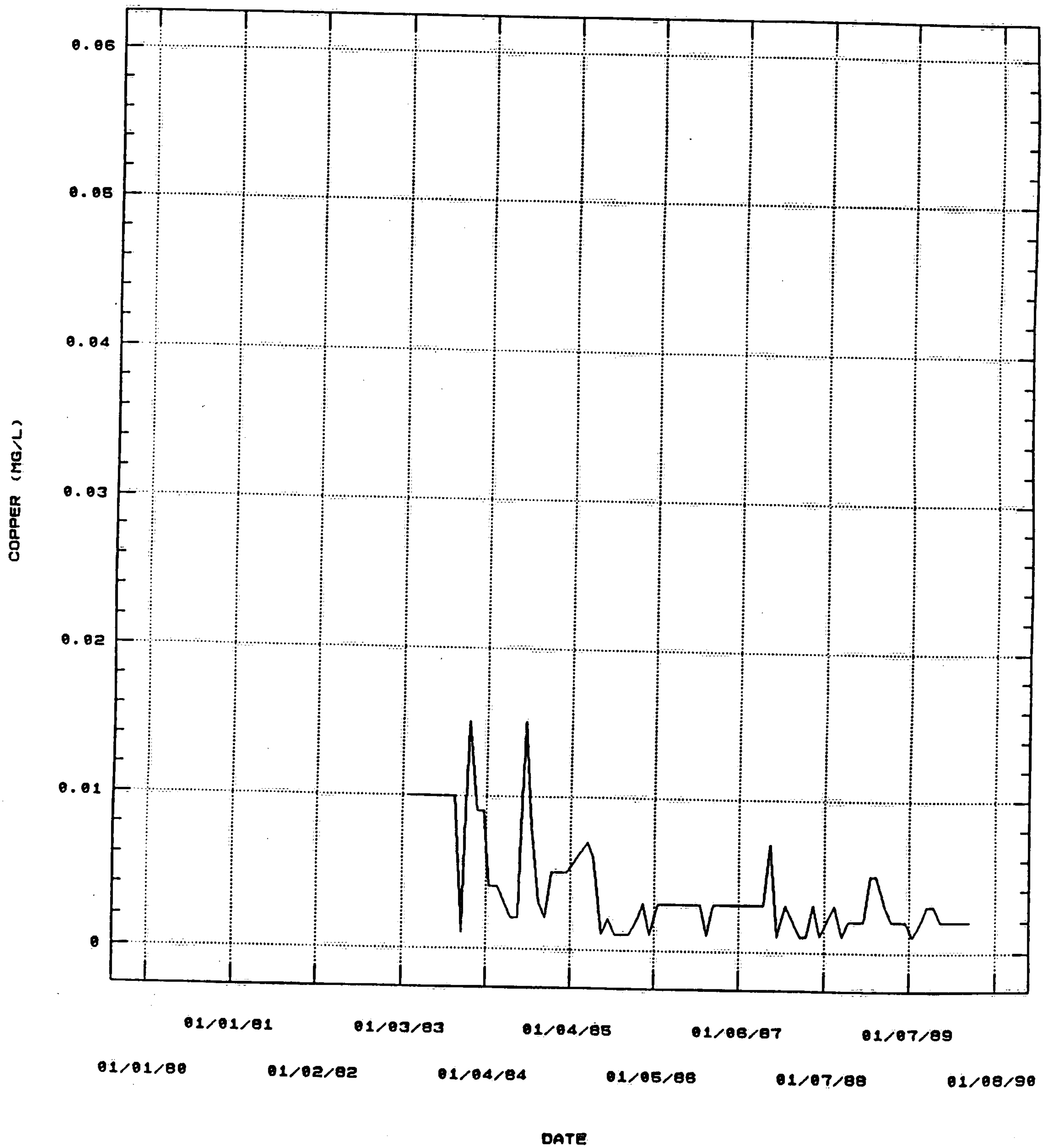
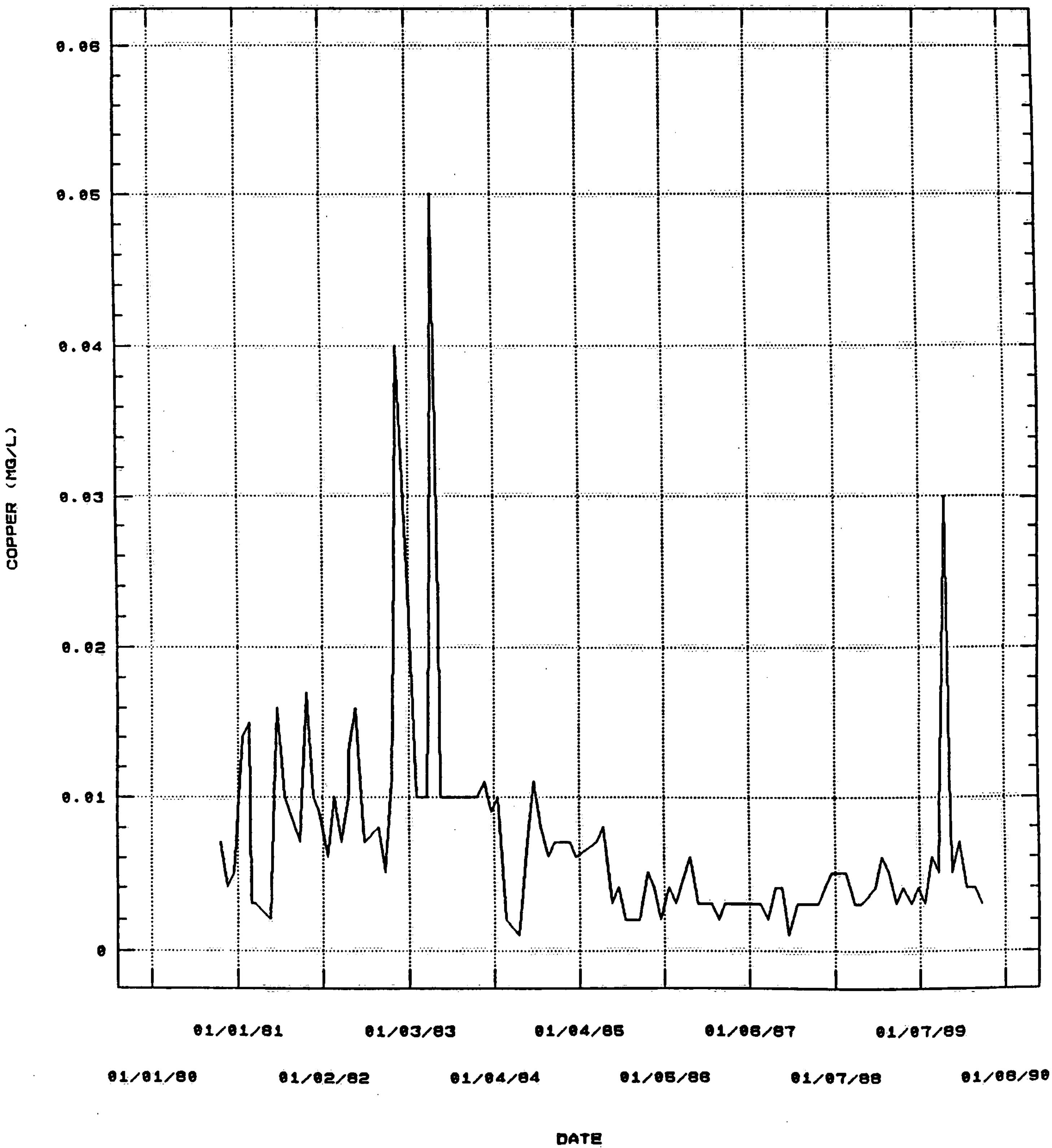


Figure 23D

UPPER MAIN STATION

COPPER CONCENTRATION



Zinc

Mean total zinc concentrations range from less than 0.005 mg/L at the Fish Creek station (1 observation) to less than 0.04 mg/L at the Lower Main station (Table 14). With the exception of Fish Creek, all Upper Thames stations have similar mean total zinc levels. Zinc levels generally increase in the Lower Thames. Mean zinc levels throughout the Thames basin are far below the federal guideline of 5.0 mg/L.

1.1.11 Pesticide Use

The high agricultural land-use component within the Thames Basin has resulted in high application rates and frequent use of pesticides. Southern Ontario received 64% of all pesticides applied in the Province in 1988. On a county basis, use of pesticides was highest in Elgin, Kent and Middlesex counties. Tables 15A and 15B list the quantities of pesticides applied to field, fruit and vegetable crops in the Thames River Basin in 1988. Figures 24 - 30 show the location of the Thames River Basin and the agricultural use of pesticides throughout the basin in 1988. Compilation and calculation of total pesticides applied and applications rates were determined by the Economics and Policy Coordination Branch of OMAF using their established methodology (OMAF, 1989b). Due to the extreme drought conditions experienced during 1988, pesticide use was most certainly reduced (OMAF, 1989b). This factor should be considered if comparison is made to previous years data (OMAF, 1989).

TABLE 15A

QUANTITIES OF SPECIFIC ACTIVE INGREDIENTS APPLIED IN THE FORM OF HERBICIDES IN THE THAMES RIVER BASIN IN 1988
(WEIGHTS IN KILOGRAMS)

	Specfic Pesticides Used on Field Crops	Pesticides Used on Fruit Crops (General)	Pesticides Used on Vegetable Crops (General)	TOTAL	Approx. Date of Application
TRIAZINE HERBICIDES					
atrazine	189,910				early May
cyanazine	30,650				early May
metribuzin	52,670				early May
simazine	890				May
TOTAL	274,120	140	3,370	277,630	
PHENOXY HERBICIDES					
2,4-D	16,680				through season
2,4-DB	6,080				through season
MCPA	12,420				June
MCPB	1,660				June
dicamba	35,590				May-June
mecoprop	1,110				May
TOTAL	70,540	30	870	71,440	
OTHER HERBICIDES					
EPTC	93,600				May-June
alachlor	690				n/a
bentazon	37,190				Late May
bromoxynil	5,990				Late May
butylate	23,930				Season Long
chloramben	7,090				Season Long
dicofop-methyl					Late May
difenzoquat	630				Late May
diphenamid					Early May
diquat	140				Late May/Early June
ethalfluralin	9,240				Mid May
fenoxaprop-ethyl	120				Late May/Early June
glyphosate	26,010				Season Long
linuron	55,890				Season Long
maleic hydrazide	310				Late May
metobromuron	8,600				Mid May
metolachlor	435,320				first 2 weeks of May
monolinuron	1230				Mid May
napropamide	320				Early May
sethoxydim	2,070				Early May/Late June
trifluralin	24,950				Mid May
TOTAL	733,320	360	11,090	744,770	
TOTAL HERBICIDES	1,077,980	530	15,330	1,093,840	

SOURCE: OMAF, 1989B

TABLE 15B

QUANTITIES OF SPECIFIC ACTIVE INGREDIENTS APPLIED IN THE FORM OF OTHER PESTICIDES IN THE THAMES RIVER BASIN IN 1988 (WEIGHTS IN KILOGRAMS)

	Specfic Pesticides Used on Field Crops	Pesticides Used on Fruit Crops (General)	Pesticides Used on Vegetable Crops (General)	TOTAL
INSECTICIDES				
Bacillus thuringiensis	520			
acephate	2,270			
azinophos-methyl	330			
carbofuran	40			
chlorpyrifos	1,190			
cypermethrin	30			
deltamethrin	20			
dimethoate	500			
fonofos	7,030			
permethrin	30			
phorate	2,290			
primicarb	90			
terbufos	17,120			
TOTAL	31,460	4,820	6,880	43,160
NEMATOCIDES				
chloropicrin				
dichloropropenes + dichloropropanes	63,480			
methylisothiocyanate	11,870			
TOTAL	73,350	270	40	73,660
GROWTH REGULATORS				
decyl alcohol	82,560			
ethephon	60			
TOTAL	82,620	60	970	83,650
TOTAL FUNGICIDES		14,730	31,460	46,190
TOTAL OTHER PESTICIDES	187,430	19,880	39,350	246,660
TOTAL HERBICIDES	1,077,980	530	15,330	1,093,840
TOTAL ALL PESTICIDES	1,265,410	20,410	54,680	1,340,500

SOURCE: OMAF, 1989B

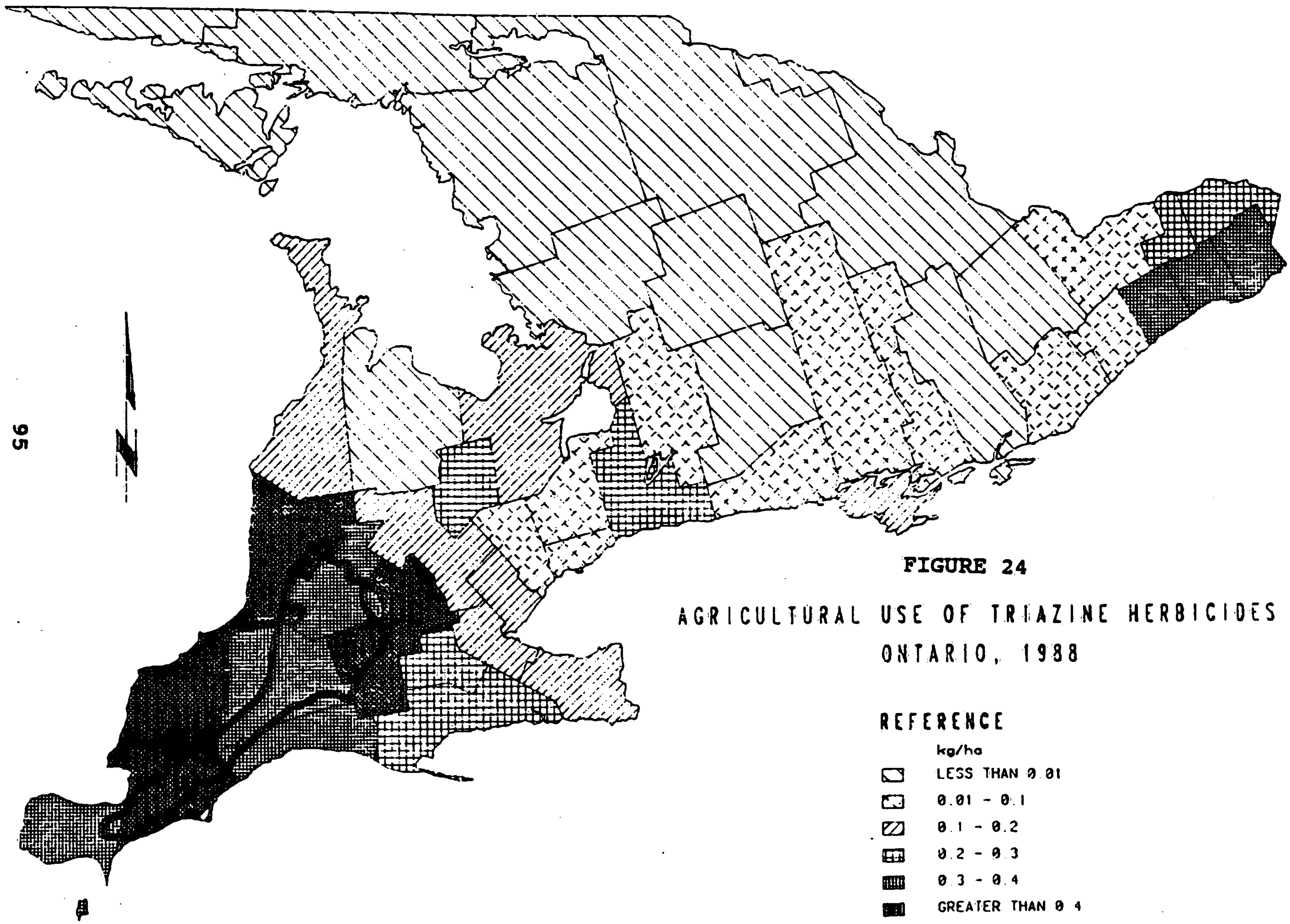


FIGURE 24

AGRICULTURAL USE OF TRIAZINE HERBICIDES
ONTARIO, 1988

SOURCE: ONTARIO MINISTRY OF AGRICULTURE AND FOOD

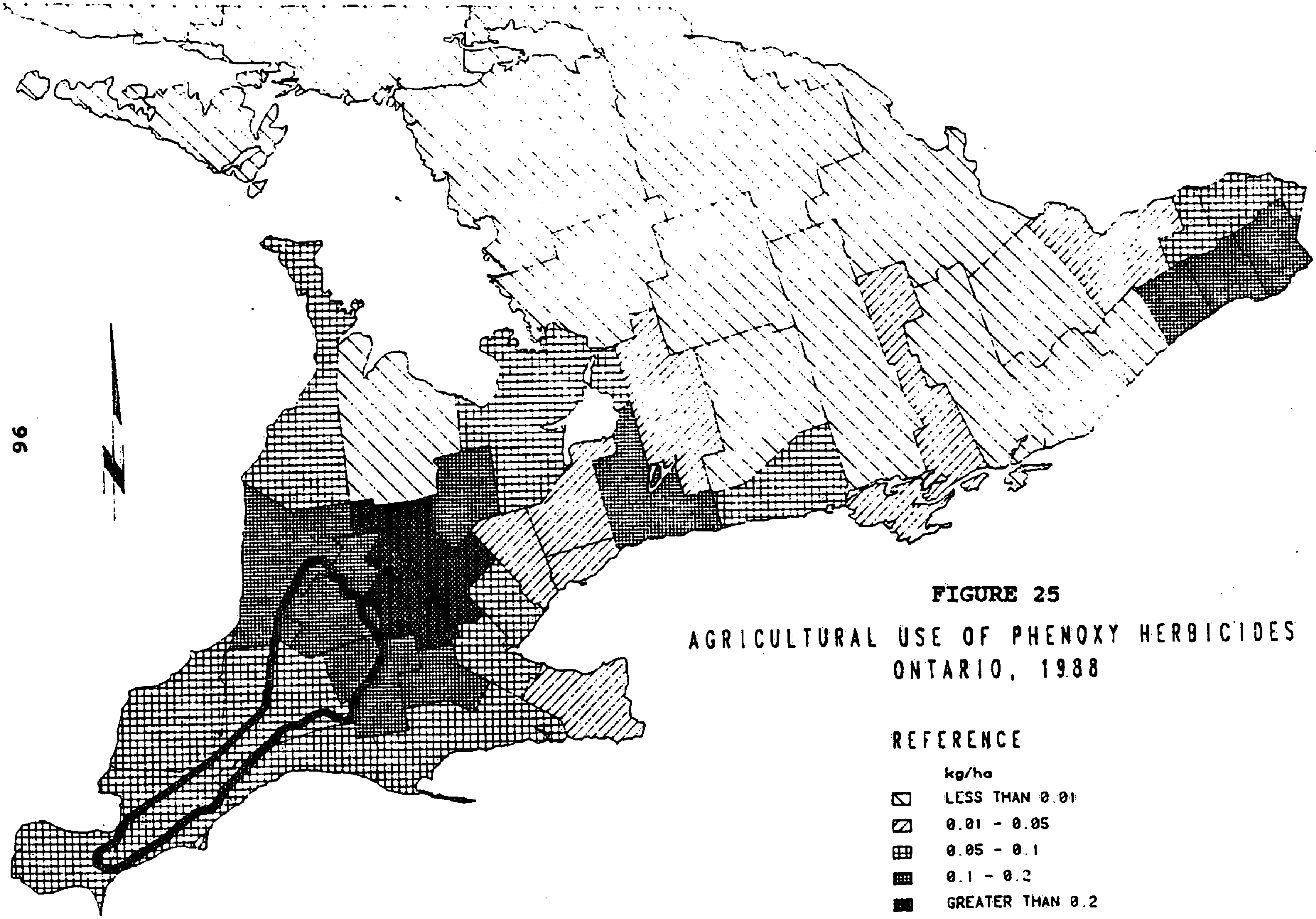


FIGURE 25

AGRICULTURAL USE OF PHENOXY HERBICIDES
ONTARIO, 1988

SOURCE: ONTARIO MINISTRY OF AGRICULTURE AND FOOD

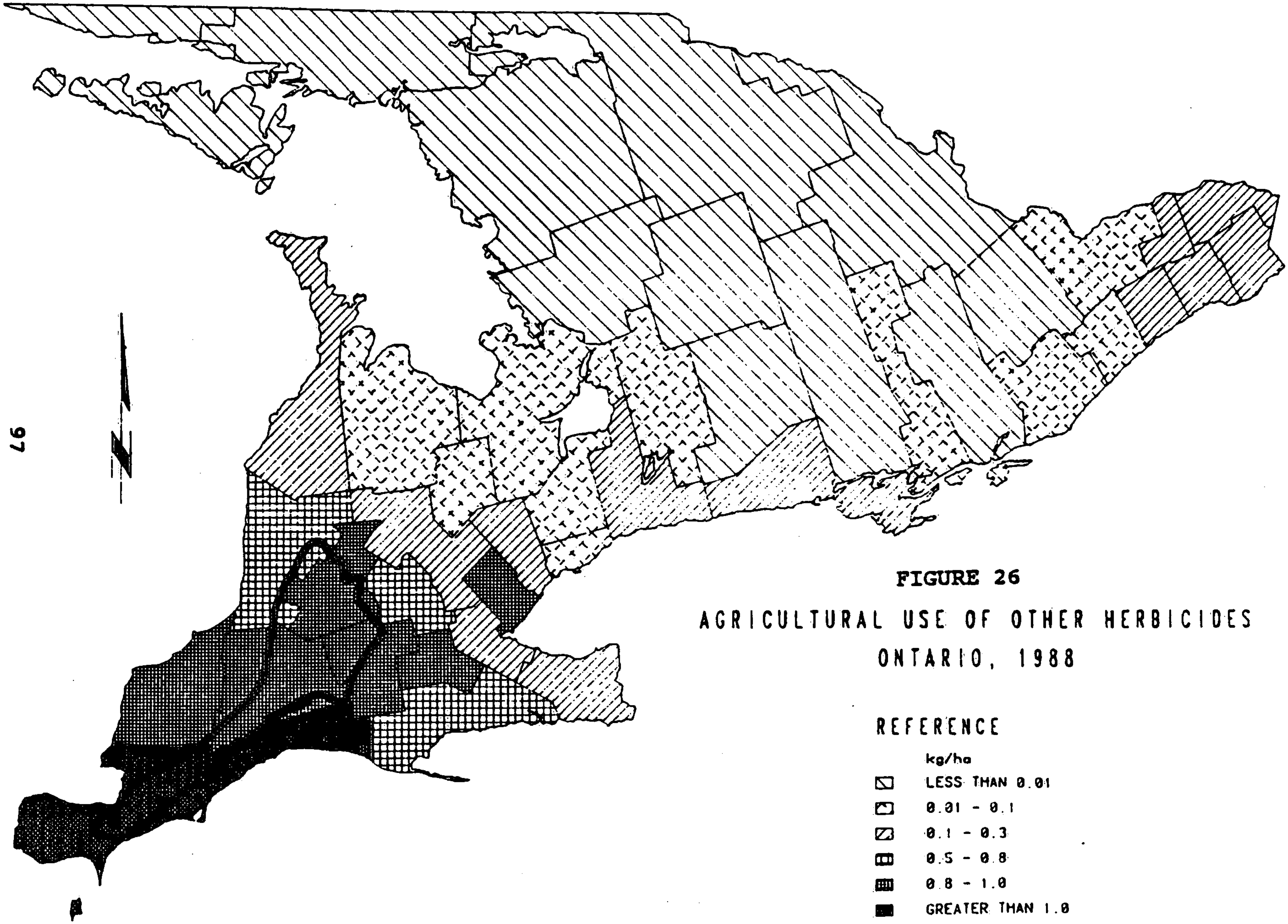


FIGURE 26

AGRICULTURAL USE OF OTHER HERBICIDES
ONTARIO, 1988

SOURCE: ONTARIO MINISTRY OF AGRICULTURE AND FOOD

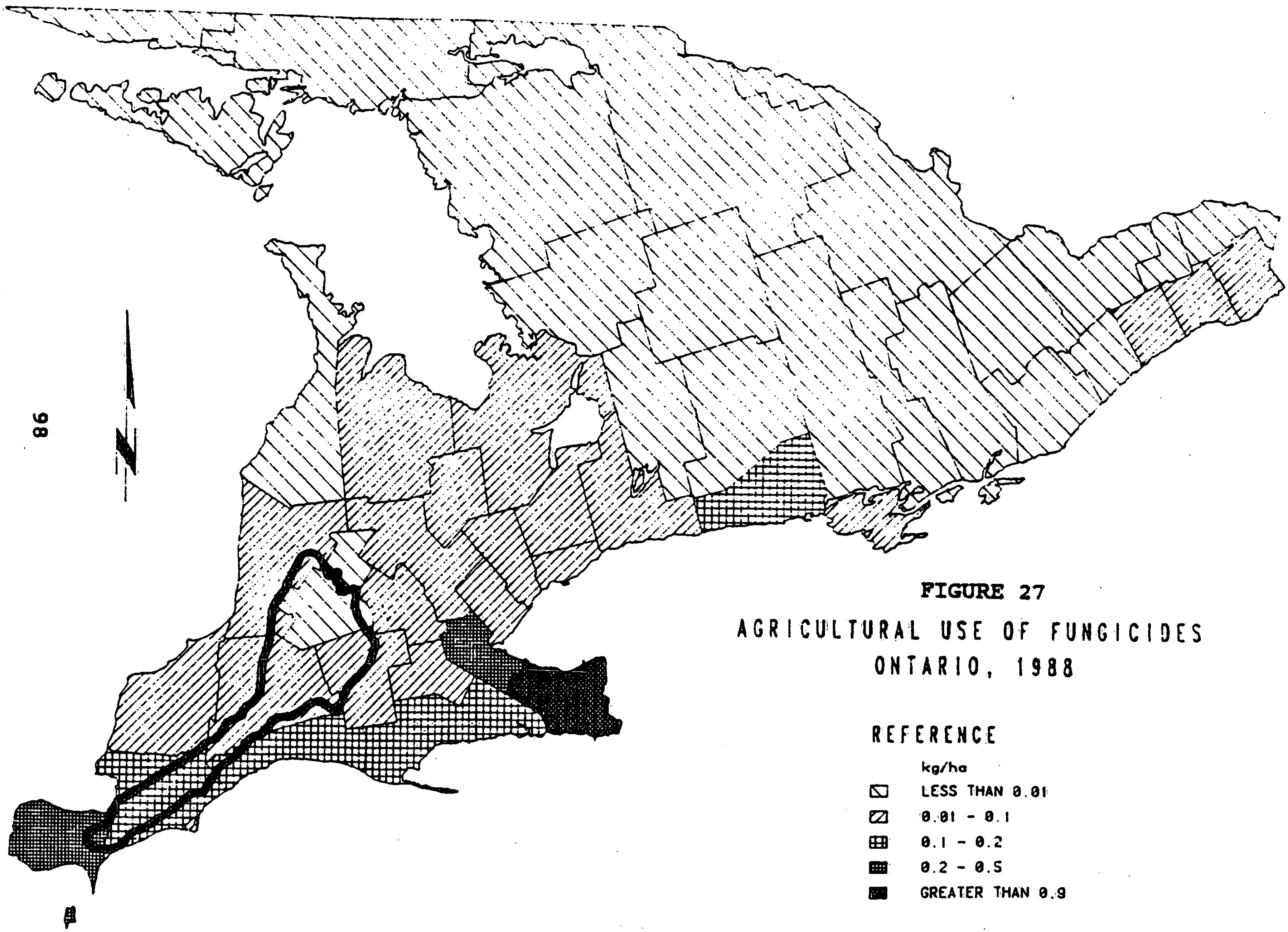


FIGURE 27

AGRICULTURAL USE OF FUNGICIDES
ONTARIO, 1988

SOURCE: ONTARIO MINISTRY OF AGRICULTURE AND FOOD

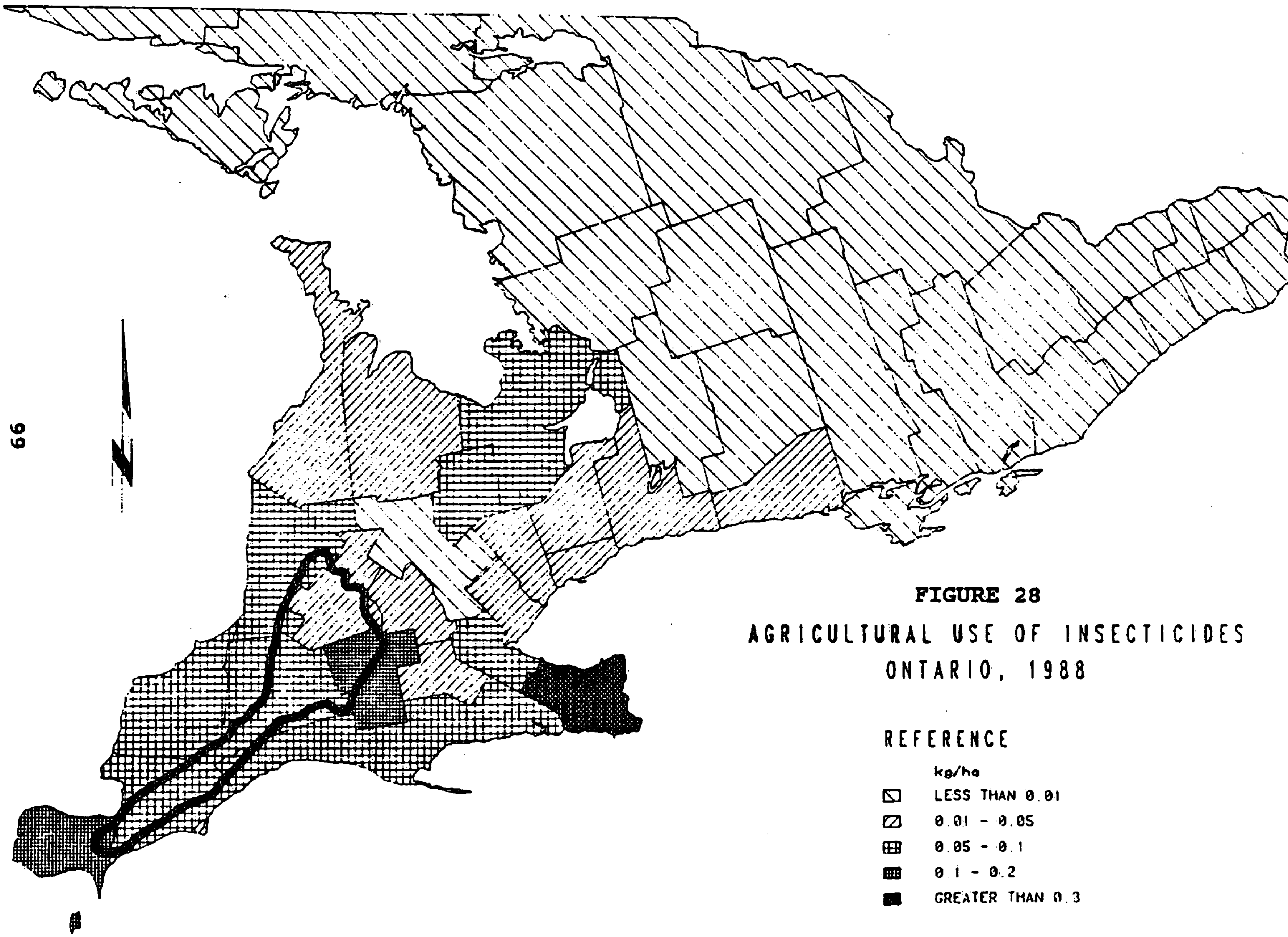


FIGURE 28
AGRICULTURAL USE OF INSECTICIDES
ONTARIO, 1988

SOURCE: ONTARIO MINISTRY OF AGRICULTURE AND FOOD

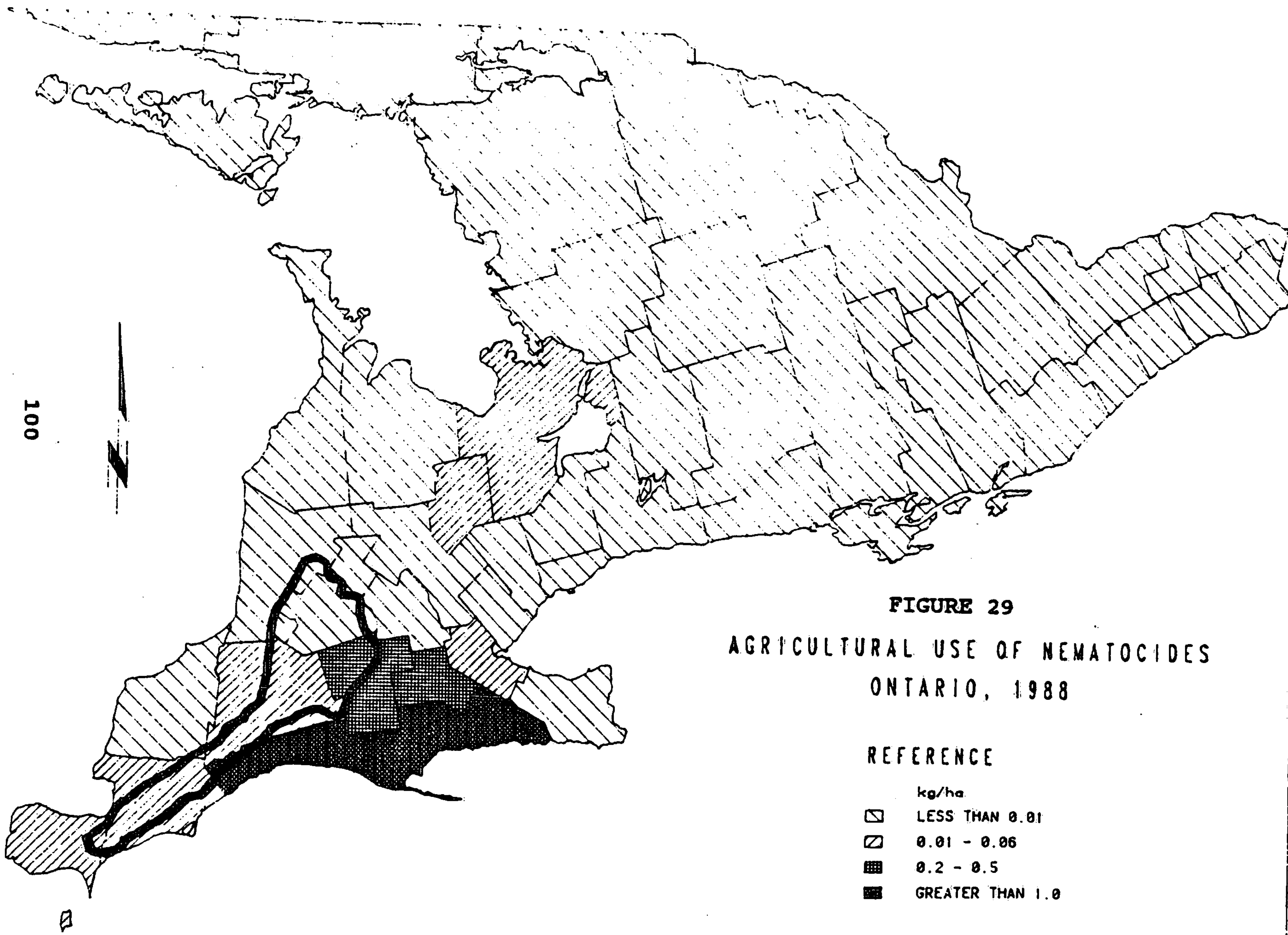


FIGURE 29

AGRICULTURAL USE OF NEMATOCIDES
ONTARIO, 1988

SOURCE: ONTARIO MINISTRY OF AGRICULTURE AND FOOD

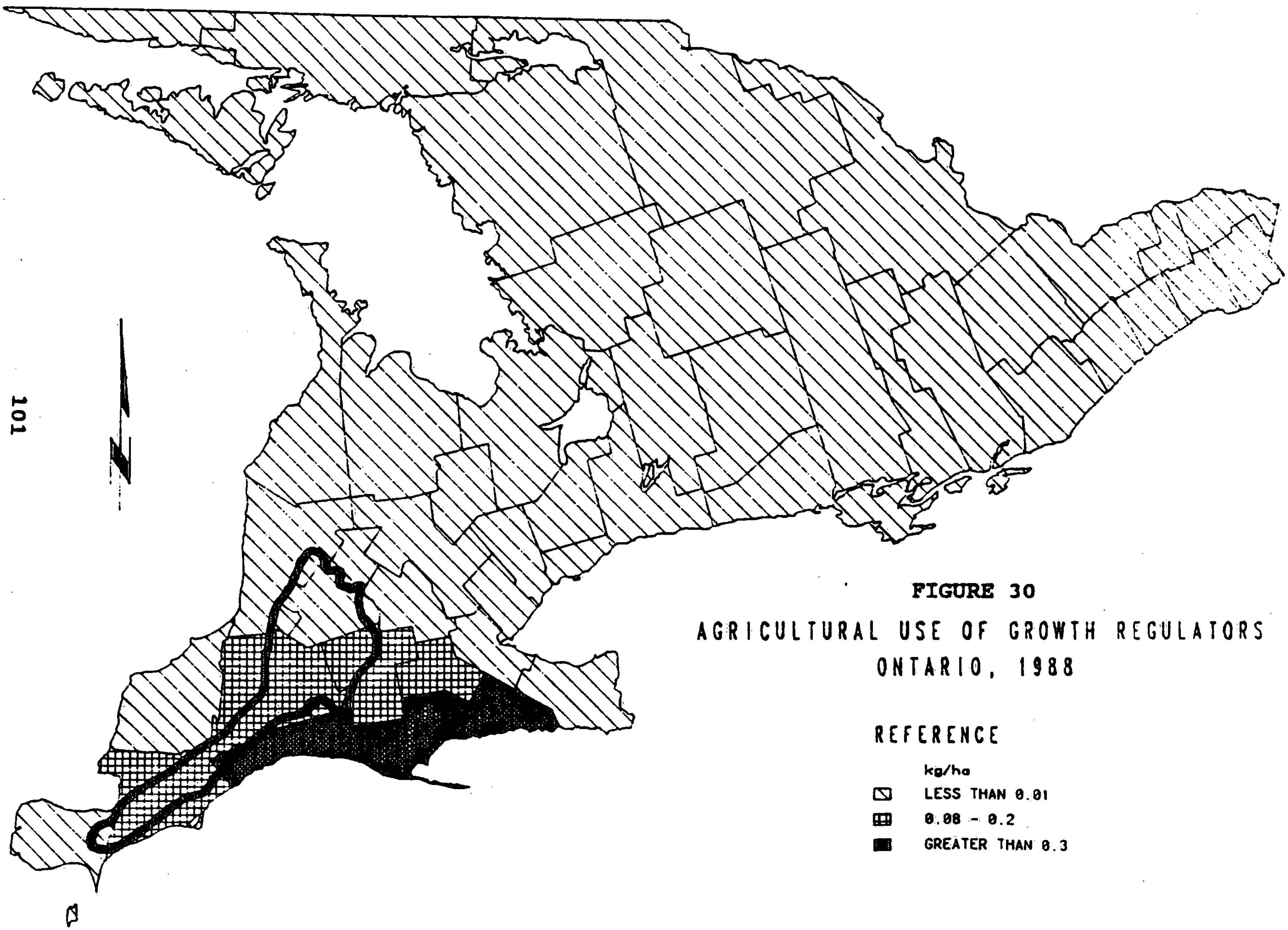


FIGURE 30

AGRICULTURAL USE OF GROWTH REGULATORS
ONTARIO, 1988

SOURCE: ONTARIO MINISTRY OF AGRICULTURE AND FOOD

Generally, the use of all types of pesticides is concentrated in the upper reaches of the Upper Thames and in the lower portion of the Lower Thames. The basin, as a whole, leads the province in the use of triazine herbicides. Rates of greater than 0.4 kg/ha are common in Kent, Oxford and Perth counties while Middlesex and Elgin have rates averaging between 0.3 and 0.4 kg/ha. Phenoxy herbicide use is concentrated in Oxford and Perth counties at rates of 0.1-0.2 kg/ha; Middlesex, Elgin and Kent follow with 0.05-0.1 kg/ha. Agricultural use of 'other herbicides' increases from Perth, Oxford and Middlesex (0.8-1.0 kg/ha) to Elgin and Kent (greater than 1.0 kg/ha). The application of fungicides, insecticides, nematocides and growth regulators was more county specific. Fungicide use was minimal in Perth, while Oxford and Middlesex, followed by Elgin and Kent, showed increasing rates of 0.01-0.1 kg/ha and 0.1-0.2 kg/ha respectively. Oxford led the region in use of insecticides with rates of 0.1-0.2 kg/ha. Nematocides were used extensively in Elgin (greater than 1.0 kg/ha), with reduced use in Oxford (0.2-0.5 kg/ha). The growing of tobacco in Elgin county is reflected by the highest rate of growth regulator application (greater than 0.3 kg/ha).

1.1.12 Socio-Economic Characteristics

Lower Thames

<u>Demographic Characteristics</u>

The population within the boundaries of the LTVCA was estimated to be 114,000 in the early 1980's. Table 16 gives the population figures for cities, towns and villages within the Lower Thames. Considering the size of the Lower Thames basin and its location in southwestern Ontario, the area has a relatively small population. The slow growth rate of the area can be attributed mostly to the agriculture potential of the watershed, which generally dictates the conservation of farmland. The lack of a major secondary economic base in the Lower Thames region has deterred population shifts to the area (LTVCA, 1983).

The City of Chatham is the major population centre in the area. Thirty eight per cent of the areas population live in Chatham which offers the most in terms of employment opportunities, living accommodations, and recreational facilities. The remaining population is spread evenly throughout the Authority in towns and villages located along Highways 2 and 401. Rural populations are also fairly homogeneous throughout the LTVCA. A declining farm population does not reflect the stable agricultural land base (LTVCA, 1983).

Table 17 lists the cities and towns and the corresponding sub-basins in which they are located.

Table 16. LTVCA Watershed Population Figures

Municipality	1964	Population 1976	1988
Kent			
Chatham (C)	30,116	41,000 *	41,840
Blenheim (T)	1,666	4,190 *	4,336
Bothwell (T)	409	440	876
Ridgetown (T)	2,690	3,220	3,152
Tilbury (T)	3,107	4,300	4,186
Erieau (V)	NM	480	440
Erie Beach (V)	NM	264	229
High Gate (V)	379	480 *	451
Thamesville (V)	981	1,180 *	995
Wheatly (V)	NM	1,600	1,539
Elgin			
Dutton (V)	NM	990	1,058
Rodney (V)	NM	943	992
West Lorne (V)	NM	1,150	1,314
Middlesex			
Glencoe (V)	1,179	1,752	1,801
Wardsville (V)	322	440	443

(C) = city (T) = town (V) = village NM = non-member of LTVCA
* = 1980 population figures

- after LTVCA, 1983

Table 17. Cities, Towns and Villages within Lower Thames Sub-Basins

Big Creek - Tilbury
McGregor - Blenheim
Newbiggen - Glencoe

Lower Main - Wardsville, Chatham, Thamesville, Bothwell, Ridgetown, Highgate

Economic Base

Presently, approximately 82% of the Authority's total land base is under crop cultivation. The 1980 total gross farm income from crops and livestock in the basin is estimated to be in the area of $300 million. About 20% of the watershed's labour force is employed directly in farming, while another 20% is employed in the food processing and farm sales and service industries. Chatham's primary role in the economic base of the area is that of a service centre for the surrounding agricultural region. The importance of agriculture in the watershed is not expected to decline due to a significant rise in production in the early 1980's (LTVCA, 1983).

Upper Thames

Demographic Characteristics

The major population centres within the Upper Thames are London, Woodstock, Stratford and Ingersoll with the more rural areas represented by the towns of St. Marys, Mitchell and Thamesford. The rural population is spread evenly throughout the basin with industry and manufacturing predominating in the southern and eastern portion. Population growth in the ex-urban areas has declined over the past 3 decades while London, Woodstock and Ingersoll have experienced moderate growth. Table 18 shows changes in population composition over the past 30 years. Table 19 lists the cities and towns which occur in the Upper Thames sub-basins.

Table 18. Changes in the Rural/Urban Population Composition in the Upper Thames Basin

County		Rural		Urban	Urban Population as a % of Total Population		
		non-farm	farm		1956	1976	1986
	1956	15,388	15,751	28,025			
Elgin	1976	25,515	8,370	35,210			
	1986	24,705	6,130	39,500	47	51	56
% change 56-76		+66	-88	+26			
% change 76-86		-3	-37	+12			
	1956	10,732	19,385	160,780			
Middle-	1976	30,925	12,455	260,370			
sex	1986	31,315	10,245	290,915	84	86	88
% change 56-76		+188	-36	+62			
% change 76-86		+1	-22	+12			
	1956	11,610	20,147	33,471			
Oxford	1976	24,520	10,860	49,960	51	59	60
	1986	25,105	8,655	51,605			
% change 56-76		+111	-46	+49			
% change 76-86		+2	-25	+3			
	1956	4,764	18,607	31,686			
Perth	1976	14,165	12,350	39,765	58	60	62
	1986	14,810	10,620	41,180			
% change 56-76		+197	-34	+25			
% change 76-86		+5	-16	+4			

- after Haussmann, 1981

Table 19. Cities, Towns and Villages within Upper Thames Sub-Basins

North Thames - Mitchell, Stratford, St. Marys

East Thames - Woodstock

Upper Main - London, Ingersoll

Economic Base

Although agriculture leads the area in land-use, secondary and tertiary industries dominate the region in terms of dollars generated. It is estimated that between 22 and 30% of the labour force within the Upper Thames basin is employed in manufacturing. The centres of London, Woodstock and Stratford account for 79% of all manufacturing in the surrounding area (Haussmann, 1981).

In 1976, the industries of greatest importance to Essex and Middlesex Counties were the food and beverage industry (21%), the machinery industry (18.3%), the transportation equipment industry (28.3%) and the electrical products industry (13.9%). Percentages indicated were percent of total value added by the manufacturing industry sector. For Oxford County, major industries were the machinery industry (20.9%) and the non-metallic minerals product industry (23.5%). For Perth County, the food and beverage industry (16.2%), the metal fabricating industry (19%), the machinery industry (16.2%) and the transportation equipment industry (21.2%) formed the manufacturing base (Haussmann, 1981).

The tertiary sector of the economy has been rapidly expanding in this region. The County of Middlesex (i.e., the City of London) is the service centre for the Upper Thames area; in 1971 Middlesex County contained 57% of the total population of the four counties yet accounted for 72% of the net sales and receipts in the service industries, and 61% of net retail sales and receipts.

1.2 Issue Identification

On the basis of information compiled during this study and previous work done by MOE, MNR, LTVCA, UTRCA and other organizations, it is evident that water quality conditions are variable throughout the basin and that the collection and analysis of data is both inconsistent and generally insufficient to warrant a detailed assessment on an issue by issue basis. In order to address those water quality issues established for the National Reference Network, however, we have prepared a matrix which incorporates factors of significance to each of the national water quality issues of interest (Table 20). These issues include: agricultural and cultural eutrophication; pesticides; and urbanization.

Information contained in Table 20 has been compiled from a number of sources and years. Water quality information is based on MOE data from 1989. Stream flow data were provided in 1989 by Environment Canada. The source of percentage land use within each sub-basin is compiled from 1986 OMAF figures; fertilization and pesticide application areas were based on 1988 OMAF figures. Fertilizer and pesticide application rates were calculated based on figures provided by the Fertilizer Institute of Ontario (1989) and OMAF's statistics for 1988, respectively. Livestock figures were also calculated using OMAF's agricultural statistics for 1988. Information on sewage treatment plants was found in MOE literature (MOE, 1989a, MOE, 1989b). Explanations of how Table 20 values were determined are presented in Appendix A.

TABLE 20 PRIMARY SUB-BASIN SELECTION MATRIX

	LOWER THAMES					UPPER THAMES				
	BIG CREEK	JEANNETTE CREEK	McGREGOR CREEK	NEWBIGGEN CREEK	LOWER MAIN	FISH CREEK	NORTH THAMES	EAST THAMES	MIDDLE THAMES	UPPER MAIN
AREA OF SUB-BASIN (KM2)	352.6	387.2	291.9	29.4	1419.1	301.0	1053.6	337.9	350.2	1351.5
FEDERAL FLOW STATION			YES	YES		YES	YES			YES
MOE MONITORING STATION			YES		YES	YES	YES	YES	YES	YES
QUANTITY/QUALITY OF WATER QUALITY DATA	NONE	NONE	MOD.	V. POOR	GOOD	MOD.	MOD.	MOD.	MOD.	GOOD
% SOIL TYPE - COARSE	50	50	100	100	80	0	0	2	20	20
- MEDIUM	0	0	0	0	19	70	25	88	80	50
- FINE	50	50	0	0	2	30	75	10	0	30
% OF SUB-BASIN UNDER CORN/ROW CROPPING SYSTEM	88	88	66	73	69	75	75	71	74	70
% OF SUB-BASIN UNDER HAY/GRAZING SYSTEM	0.2	1.2	2.4	10.9	4.6	8.4	10.1	6.8	9.0	7.8
% OF SUB-BASIN UNDER FOREST COVER	1.2	1.5	7.5	11.9	13.3	7.3	7.8	8.9	10.7	9.3
% OF URBANIZATION IN SUB-BASIN	3.6	1.9	4.5	1.3	4.0	6.0	4.5	5.4	1.8	10.0
FERTILIZED AREA (HA)	17,016	23,570	17,774	1,692	83,743	20,095	71,917	22,749	23,422	79,021
TONNES OF FERTILIZER APPLIED	8,307	11,015	7,851	730	38,232	7,724	23,757	10,181	10,855	34,944
FERTILIZER APPLICATION RATE (KG/HA)	488.2	467.3	441.7	431.4	456.5	384.4	330.3	447.5	463.5	442.2
AREA OF IMPROVED LAND (HA)	22,978	30,381	22,910	2,043	104,023	24,820	91,330	27,499	28,112	95,206
TOTAL PESTICDES APPLIED (KG)	95,565	148,227	111,778	5,308	442,223	54,183	157,509	80,925	87,550	264,701
PESTICIDE APPLICATION RATE (KG/HA)	4.16	4.88	4.88	2.60	4.25	2.18	1.72	2.94	3.11	2.78
TOTAL # OF CATTLE	2,022	3,442	2,595	981	26,848	15,534	62,692	19,679	20,093	52,983
TOTAL # OF HOGS	9,896	16,440	12,397	2,412	78,319	43,647	198,143	48,629	47,695	128,371
TOTAL LIVESTOCK (ANIMALS/HA)	0.52	0.65	0.65	1.66	1.01	2.38	2.86	2.48	2.41	1.90
# OF SEWAGE TREATMENT PLANTS WITHIN SUB-BASIN	2	1	2	1	4	0	3	1	0	8

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 use of Agricultural Land Use Systems helps to remove some of these discrepancies since land use maps are available and can be used to allocate information effectively.

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

1.2.1 Agricultural and Cultural 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. The most important land related factors affecting the magnitude of loads from non-point sources were identified as being soil type, land use intensity and materials usage (MOE, 1986). In spite of the long term knowledge of the severity and extent of the eutrophication problem, a water quality collection programme that is consistent and comparable on a national basis is still required (Environment Canada, 1990).

Agricultural and cultural eutrophication are of concern in the Thames 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. Cultural eutrophication typically results from the outfall of municipal and industrial sewage treatment plants.

Sub-basin Selection Criteria

Table 20 presents the factors which are available for use in sub-basin selection. Factors considered for assessing the sub-basin which offers the greatest potential for agricultural eutrophication were extracted from Table 20, assigned classes, and presented in Table 21. The variables were assigned to one of three classes: high, medium, low. Classification was based on the percent land use or rate of fertilizer application within the sub-basin relative to other sub-basins. The variables, hay/grazing systems and forest cover were evaluated in terms of their relative potential contribution to eutrophication. This was done to highlight

TABLE 21 AGRICULTURAL EUTROPHICATION MATRIX

	LOWER THAMES					UPPER THAMES				
	BIG CREEK	JEANNETTE CREEK	McGREGOR CREEK	NEWBIGGEN CREEK	LOWER MAIN	FISH CREEK	NORTH THAMES	EAST THAMES	MIDDLE THAMES	UPPER MAIN
SOIL TYPE	MED.	MED.	LOW	LOW	LOW	HIGH	HIGH	HIGH	HIGH	HIGH
% OF SUB-BASIN UNDER CORN/ROW CROPPING SYSTEM	HIGH	HIGH	LOW	MED.	LOW	MED.	MED.	LOW	MED.	LOW
% OF SUB-BASIN UNDER HAY/GRAZING SYSTEM	HIGH	HIGH	HIGH	LOW	MED.	LOW	LOW	MED.	LOW	LOW
% OF SUB-BASIN UNDER FOREST COVER	HIGH	HIGH	MED.	LOW	LOW	MED.	MED.	MED.	LOW	LOW
FERTILIZER APPLICATION RATE (KG/HA)	HIGH	HIGH	HIGH	MED.	HIGH	MED.	LOW	HIGH	HIGH	MED.
TOTAL LIVESTOCK (ANIMALS/HA)	LOW	LOW	LOW	MED.	LOW	HIGH	HIGH	HIGH	HIGH	MED.
	4 HIGH 1 MED. 1 LOW	4 HIGH 1 MED. 1 LOW	2 HIGH 1 MED. 3 LOW	3 MED. 3 LOW	1 HIGH 1 MED. 4 LOW	2 HIGH 3 MED. 1 LOW	2 HIGH 2 MED. 2 LOW	3 HIGH 2 MED. 1 LOW	3 HIGH 1 MED. 2 LOW	1 HIGH 2 MED. 3 LOW

the negative effects that arise from having small areas under forest cover (more direct input access to waterbodies) and the smaller contribution to eutrophication associated with grazing/pasture systems versus corn/row cropping systems.

Table 21 suggests that Big Creek and Jeannette Creek sub-basins exhibit the greatest potential for agricultural eutrophication to occur. Both sub-basins have the same amount of land area devoted to row cropping systems (88%) and minor amounts of forested land, 1.2% and 1.5% respectively. The Big Creek sub-basin also has the highest fertilizer application rate of all sub-basins. Flow stations have not been established in either sub-basin although two MOE water quality monitoring stations have been in operation in the headwaters of Big Creek since the mid-1970's. Because these stations represent a limited area within the basin they were not selected as being representative for the basin as a whole. Both sub-basins are readily accessible for sampling purposes. On the basis of these criteria, the Big Creek sub-basin would be a suitable candidate for agricultural eutrophication monitoring.

In order to assess cultural eutrophication in the Thames River basin, the Upper Main sub-basin is recommended as it has the highest percentage of area under urban land use and the highest density of sewage treatment plants. This sub-basin has a flow station and water quality monitoring station, both of which have long and fairly consistent data collection records. Additional flow stations and MOE monitoring stations are located throughout the sub-basin if the monitoring of smaller sub-basins within the Upper Main is required.

1.2.2 Pesticides

Basis for Concern

Pesticide use within the Thames River Basin is of particular concern in light of its proximity to counties with high application rates (Figures 24 - 30). "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 is available. MOE surface water sampling programme does not include analysis for pesticides.

Sub-basin Selection Criteria

Table 22 lists the parameters developed in this study which would indicate the sub-basin showing the highest potential for adverse effects of pesticides on water quality. The Big Creek and Jeannette Creek sub-basins are again identified as candidate sub-basins. This is not unexpected as the factors contributing to this selection are similar to those used in agricultural eutrophication issue. The Big Creek sub-basin rather than the Jeannette Creek basin sub-basin is recommended because of existing water quantity and quality monitoring stations.

TABLE 22 PESTICIDE MATRIX

	LOWER THAMES					UPPER THAMES				
	BIG CREEK	JEANNETTE CREEK	McGREGOR CREEK	NEWBIGGEN CREEK	LOWER MAIN	FISH CREEK	NORTH THAMES	EAST THAMES	MIDDLE THAMES	UPPER MAIN
SOIL TYPE	MED.	MED.	LOW	LOW	LOW	HIGH	HIGH	HIGH	HIGH	HIGH
% OF SUB-BASIN UNDER CORN/ROW CROPPING SYSTEM	HIGH	HIGH	LOW	MED.	LOW	MED.	MED.	LOW	MED.	LOW
PESTICIDE APPLICATION RATE (KG/HA)	HIGH	HIGH	HIGH	LOW	HIGH	LOW	LOW	MED.	MED.	MED.
	2 HIGH 1 MED.	2 HIGH 1 MED.	1 HIGH 2 LOW	1 MED. 2 LOW	1 HIGH 2 LOW	1 HIGH 1 MED. 1 LOW	1 HIGH 1 MED. 1 LOW	1 HIGH 1 MED. 1 LOW	1 HIGH 2 MED.	1 HIGH 1 MED. 1 LOW

1.2.3 Urbanization

Basis for Concern

The issue of urbanization is complex and incorporates the effects of cultural eutrophication, industrial effluent, the clearing of land for industrial and residential development, and the increased demands for high water quality for recreational pursuits.

Sub-basin Selection Criteria

Although the Upper Main sub-basin has the highest population density and concentration of industrial activity it also is the most complex basin, representing the outflow from the whole of the upper Thames basin. As a result, the North Thames sub-basin is the recommended location for a station to monitor the urbanization issue. The North Thames sub-basin is both smaller and less complex than the Upper Main sub-basin, although it exhibits similar urbanization characteristics. St. Marys, Stratford and Mitchell represent growing urban centres including associated industrial development (ie. Blackstone International Products and Campbell Soup Co.), residential development and sewage treatment plants. The water discharge and water quality monitoring station selected for this study could serve as the monitoring location for this sub-basin. Existing stations could be selected to evaluate smaller sub-basins.

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APPENDIX A

DETERMINATION OF VALUES GIVEN IN SUB-BASIN SELECTION MATRIX

APPENDIX A

Area of sub-basin - Calculated using dot grid method

Federal flow station - Is a federal flow station, selected in this study, located in the sub-basin?

MOE monitoring station - Is a Ministry of the Environment water quality monitoring station, selected in this study, located in the sub-basin?

Quality/quantity of water quality data - If there is a long period of record with no gaps in the sampling period then the data would be ranked 'good'. If there was only a brief period of record with numerous gaps in the period of record then the data would be ranked 'poor'.

% soil type - Visual estimates of percentage of each soil texture were made based on OMAF county soils maps.

% under corn/row and hay/grazing systems, % idle, wetland and urbanized - Based on conglomerating similar OMAF land use systems types within each township then apportioning that value among sub-basins (see Tables 3A,B).

Fertilized area - County values supplied by the Fertilizer Institute of Ontario were apportioned among sub-basins (see Table 6).

Tonnes of fertilizer applied - County values supplied by the Fertilizer Institute of Ontario were apportioned among sub-basins (see Table 6).

Fertilizer application rate - tonnes of fertilizer applied ÷ fertilized area

Area of improved land - County figures from OMAF agricultural statistics were apportioned within the Thames River Basin then among each sub-basin.

Total pesticides applied - County figures from OMAF survey of pesticide use statistics were apportioned within the Thames River Basin then among each sub-basin.

Pesticide application rate - total pesticides applied ÷ area of improved land

Total # of cattle and hogs - County figures from OMAF agricultural statistics were apportioned within the Thames River Basin then among each sub-basin (see Table 4).

Total livestock - total # of cattle and hogs ÷ area of improved land

# of sewage treatment plants - Based on MOE listing of sewage treatment plants and their locations.