water management study

thames river basin

Ministry of the Environment

Ministry of Natural Resources

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INTRODUCTION

This report presents the findings of the Thames River basin water management study, undertaken jointly by the Ontario ministries of the Environment and Natural Resources. The study was initiated in response to growing concern over existing problems relating to water quality, flooding and erosion in the watershed, and over potential problems anticipated as a result of future population growth and economic development.

The Thames River basin is the second largest in Southwestern Ontario (Map 1), and drains an area of approximately 2,250 square miles. Its total length from the source of the North Thames River to Lake St. Clair is approximately 125 miles. Major water uses in the basin include water supply for agricultural, domestic, municipal and industrial purposes; waste disposal and assimilation; recreation, and fish and wildlife habitat. Inherent conflicts among these uses are prevalent in the basin. Moreover, proposed solutions to the problems may themselves create additional conflicts.

BACKGROUND

Extensive studies of water resource problems in the Thames watershed have been carried out by the Conservation Authorities Branch for the Upper Thames River Conservation Authority (UTRCA) and the Lower Thames Valley Conservation Authority (LTVCA), established in 1947 and 1961 respectively. A major flood control program was undertaken involving the construction of dams and channel improvements, which, together with the existing dike system along the river, provided a partial solution to the flooding problems.

Since its creation in 1957, the Ontario Water Resources Commission, (now a part of the Ministry of the Environment), has been actively involved in water supply and pollution control programs in the basin. As population growth in the watershed continued, the surface and ground water supplies of the basin became inadequate to meet municipal water requirements and major water supply pipelines were developed. Extensive construction of municipal sewage treatment plants was also undertaken. The Ministry of Natural Resources has been extensively involved in fish, wildlife and forestry resource management in the basin.

However, a variety of water management problems remained to be resolved. In several reaches of the river, water uses such as recreation and water supply were significantly curtailed because of stream water quality degradation. Additional water quality problems due to the continued growth of municipalities were foreseen. Flooding continued to be a problem at several locations in the basin. Record high water levels in the Great Lakes aggravated existing erosion problems.

The conservation authorities and local and provincial governments all undertook studies of the continuing water resource problems facing the basin. However, it became apparent that resolution of these complex, inter-related problems required a co-ordinated, interdisciplinary effort. As a result, in early 1972, the Ontario ministries of the Environment and Natural Resources launched a detailed study of the Thames River System.

STUDY OBJECTIVE

The overall objective of this study is:

> *to develop guidelines for management of the basin's water resources to ensure that adequate quantities of water of satisfactory quality are available for the recognized uses at the lowest possible cost, and that erosion and flood control are provided consistent with appropriate benefit-cost criteria*.

In order to develop effective and realistic water management guidelines, a detailed, comprehensive study has been undertaken. This involved an assessment of the availability and quality of both surface and ground water, an inventory of water uses and related land uses, and an evaluation of existing and potential water resource problems in the basin. This information was used to select and evaluate water management alternatives on which recommended water management guidelines are based. The report has been structured on this basis.

One feature of the study is the extensive use of mathematical modelling in the evaluation of waste treatment and reservoir alternatives with regard to the effect on water quality parameters and flood control benefits.

Another feature of the study is the Public Consultation Program (PCP), designed to provide municipal officials and the residents of the basin with an opportunity to express their views concerning the management of their water resources. During the first phase of the PCP, interviews and meetings were held with municipal officials and a variety of interest groups. Phase 2 involved a series of ten meetings in five municipalities held under the auspices of the Environmental Hearing Board.

This report summarizes the findings of the study and outlines recommended courses of action for water management in the Thames River basin. More detailed information concerning the study can be found in the main report, and in technical reports to be published on such topics as water quality data, hydrologic data, water uses, mathematical models, and the Public Consultation Program.

Two aspects of the report should be noted. First, the planning horizon to which the conclusions and recommendations herein are directed is the year 2001. Factors arising beyond this period which may affect present day decisions, for example, a change in population growth and distribution patterns, are too far in the future to be predicted with any degree of accuracy.

Secondly, it should be noted that this is a water management study, which has considered land use planning, urban population and industrial growth from a water management point of view. Several other provincial ministries and agencies, including Treasury, Economics and Intergovernmental Affairs, Transportation and Communications, Housing, Hydro, and Agriculture and Food are also concerned with land use, population and industrial development planning. Nevertheless, the water resources of the basin are now well defined and their limitations are known. If the objectives of good water quality and adequate flood control are to be met, then the conclusions and recommendations in this report can be considered to form a basis for further planning in the Thames River basin.

STREAM TERMINOLOGY

In this report, the names of streams in the Thames River basin as designated by the Geographic Names Board have been followed. As this terminology does not always coincide with local usage, particularly upstream from London, the following points should be noted (Map 2).

Above London, the channel which flows through Dorchester, Ingersoll and Woodstock is called the Thames River. The stream on which Mitchell, St. Marys and the Fanshawe Reservoir are located is called the North Thames River. The stream on which Thamesford is located is designated as the Middle Thames River.

CHAPTER 1

SUMMARY AND RECOMMENDATIONS

The two main water management problems in the Thames River basin are water quality impairment and flooding. Impairment of surface water quality is primarily caused by excessive inputs of nutrients, oxygen consuming materials, bacteria and suspended solids. Major urban sources of these contaminants include sewage treatment plant effluent, storm and combined sewer discharges and runoff from urban areas. Municipal drains, field tile systems, surface runoff from fertilized fields, drainage from intensive feedlots, treated effluent from rural industries, and the free access of cattle to streams are major rural sources of water quality impairment. Excessive aquatic plant growth and unpleasant aesthetic conditions are the most visible signs of water quality impairment; however, the less visible problems of low dissolved oxygen levels and high bacteria levels are also significant. This impairment has led to the curtailment or restriction of legitimate water uses in the watershed. Most severely affected by this impairment are fish and aquatic life and recreational water uses.

Recurrent flooding is the other most significant problem in the watershed, particularly in St. Marys, Woodstock, London, and the area from Thamesville through Chatham to Lake St. Clair. Average annual flood damages in the watershed were calculated to be over 1.5 million 1975 dollars, of which 57 percent is in Chatham and 20 percent in the vicinity of London. Related in part to flooding is erosion of streambanks and dikes, primarily in the lower watershed. Erosion of topsoil is also a significant problem.

The inadequacy of water-based recreational facilities to meet demands and the potential loss of prime agricultural land were also identified as problems common to the watershed. Other water management problems of local importance include negative effects of artificial land drainage, water supply interference and ground water quality impairment. Communication and co-ordination problems were also noted.

In order to develop effective courses of action to resolve these problems, water management objectives were developed and alternative courses of action were evaluated. With respect to water quality objectives, it was concluded that the short term objective should be to maintain existing water quality where it is satisfactory for fish and aquatic life and recreation, and to improve quality to this level where it is presently degraded. The long term objective is to upgrade water quality as much as possible in order to enhance conditions for fish and aquatic life, as well as to maximize other beneficial water uses. Dissolved oxygen criteria and other specific water quality criteria which would allow this objective to be met were developed.

It was concluded that flood control in the basin would require the construction of one or more large dams, and a detailed flood control benefit-cost analysis of proposed major dams was carried out. Moreover, as flood control and water quality improvement options are closely interrelated, various combinations of the proposed reservoirs and waste management options were examined in a systems context.

As provincial studies of both the Lake Erie and Southwestern Ontario regions recognized London to be a major growth centre, and recommended it continue in that role, one objective was to develop a water management plan which would allow London to expand to its projected 2001 population while maintaining satisfactory stream water quality. This will also allow for the re-direction to London of population growth from other areas of the watershed where the capacity of resources to sustain growth will be reached within the planning horizon.

However, it is recognized that a variety of other considerations must be taken into account in determining the most desirable distribution of growth. Population projections based on official plans and 1961-71 trends, giving a 2001 population of 500,000 at London, were used in evaluating water management options. However, a significantly lower growth rate, such as a recent TEIGA estimate of a 2001 population at London of 338,000 to 350,000, would fundamentally alter the evaluation of options. Thus, options which would meet water quality objectives at lower projected populations were also considered. On this basis, the major waste management options available to. the City of London were reduced to: tertiary treatment (to stream quality effluent); diversion of sewage by pipeline to Lake Erie; or the operation of the Glengowan dam, primarily for flow augmentation, with the continued use of conventional sewage treatment.

The proposed reservoirs and the sewage treatment options for London were then evaluated in system configurations. The primary evaluation criteria for this analysis were flood control benefit-cost ratios and the total system net cost in present value terms. Twenty-two system options were evaluated in detail. The next analytical stage involved evaluation of non-quantifiable factors such as recreation and environmental effects of capital works. Additional objectives utilized at this stage were: to minimize both the loss of prime agricultural land and environmental disturbance due to capital construction projects, especially dams; and to increase water-based recreational facilities in the basin.

When all these factors had been considered, it was concluded that the preferred option is to construct the Thamesford dam primarily for flood control, the Glengowan dam primarily for flow augmentation, and to utilize conventional treatment at London. However, if it is decided that development of a limestone deposit precludes construction of the Thamesford dam, the preferred option is to construct the Wardsville dam for flood control, the Glengowan dam primarily for flow augmentation, and to utilize conventional treatment at London. If the growth limitation of 480,000 for London associated with this option is decided to be unacceptable, then other options, such as provision of tertiary treatment or construction of a sewage pipeline to Lake Erie can be considered.

As the Glengowan dam is common to each of the preferred options, construction of the Glengowan dam first would offer maximum flexibility in choosing other capital construction projects. Decisions as to whether to construct the Wardsville dam or the Thamesford dam could then be made. The decision as to whether to utilize conventional treatment or eventually a sewage pipeline from London to Lake Erie could be deferred to the early 1990's. **Accordingly, it is recommended that the Glengowan dam should be constructed first, for the primary purpose of flow augmentation. Furthermore, a study should be made of what type and level of recreational use, if any, could be provided at the reservoir.**

...Recommendation no. 1

It is further recommended that the Upper Thames River Conservation Authority and the Ministry of Natural Resources investigate in detail, as soon as possible, the question of the limestone deposit at the Thamesford dam site to determine the opportunity cost associated with its development, so that a decision can be made as to the feasibility of constructing the Thamesford dam.

...Recommendation no. 2

If construction of the Thamesford dam is feasible, then the Thamesford dam should be built primarily for flood control purposes. Furthermore, a study should be made of the desirable level of recreational use of the reservoir, ensuring that such use would not seriously constrain the primary use of the reservoir.

...Recommendation no. 3

If construction of the Thamesford dam is not feasible, then the Wardsville dam should be constructed for flood control purposes only. A flow retarding structure rather than a conventional dam should be constructed to minimize the loss of agricultural land and to protect the yellow pickerel runs and spawning grounds. Detailed studies should be undertaken to ensure the design will permit the safe passage offish, and to determine on a benefit-cost basis whether a 43,000 acre-foot or a larger retarding structure is the more economical. The environmental effects and the effects on road communications of the larger versus the smaller structure should be considered. There should also be close consultation with Indian bands concerning the effects on reservation lands.

...Recommendation no. 4

Prior to construction of any major dam, detailed studies should be undertaken to examine environmental effects, to determine methods of minimizing such effects, and to determine what type of discharge structure and operating practices would best protect both reservoir and downstream water quality.

...Recommendation no. 5

As noted above, implementation of any one of the preferred options allows deferral for several years of a decision by the City of London as to whether to continue discharging treated sewage to the Thames River or to utilize a sewage diversion pipeline to Lake Erie. **Accordingly, the City of London should immediately institute plans to upgrade its sewage treatment facilities to meet the waste loading guidelines outlined in this report. Specifically, this involves providing an effluent from all treatment plants equivalent in quality to the effluent from the Greenway sewage treatment plant as defined in this report.**

...Recommendation no. 6

Although the major options have great significance to basin wide water management, they by no means deal with all the basin's water resource problems. Local water management problems can have a cumulative effect, so that a localized type of problem, recurring at several different locations, can have basin wide implications. A wide range of management options to deal with urban, rural, reservoir-related and flooding problems has been considered and applied on a stream reach and municipality basis.

Urban oriented options include varying levels of treatment of sewage and industrial wastes, and growth restrictions. In areas where the remaining waste assimilative capacity of streams is limited, municipalities proposing additional growth can consider the installation of advanced tertiary waste treatment plants producing a highly polished effluent equivalent to stream water quality, or waste storage for summer spray irrigation or discharge during periods of adequate flow. However, for smaller municipalities, the costs of the required tertiary treatment may be prohibitive. Moreover, the costs of property acquisition for waste storage can make this uneconomical and this approach often involves the use of prime agricultural land. The alternative to the above treatment options is growth restrictions. **At several municipalities in the basin, the waste assimilative capacity of the receiving stream has been reached or exceeded. Accordingly, it is recommended that the municipalities of Mitchell, Stratford, Tavistock, Glencoe, Tilbury and Ridgetown should not increase their waste loadings from all sources to the receiving stream, and in some cases should reduce these loadings, as described in chapter 8 of this report.**

...Recommendation no. 7

Receiving streams at other municipalities in the basin have varying capacities to assimilate additional waste loadings. The additional assimilative capacity at the municipalities of Woodstock, Beachville, Ingersoll and Lambeth is limited and long term growth would be inadvisable from a water quality viewpoint. At the municipalities of Dorchester, St. Marys, Bothwell, Thamesville, and Chatham the additional waste assimilative capacity is not as limited. **Accordingly, these municipalities should adopt sewage treatment techniques selected from approved options as described in this report, either to provide immediately required upgrading or to accommodate additional growth if such growth is found to be desirable when other factors are considered.**

...Recommendation no. 8

Control of urban runoff is an important consideration in the basin. Although the significance of pollution loads from this source at each municipality was not documented during this study, urban runoff is recognized as a source of stream impairment. **Thus, all municipalities should immediately undertake studies to determine the significance of existing urban runoff and runoff associated with future development as a source of pollutants, and take steps to control this waste input where it is found to constitute a water quality problem.**

...Recommendation no. 9

Most industries in the basin lie within municipal boundaries and discharge wastes and non-polluted process waters to municipal sanitary and storm sewage systems respectively. Most municipalities have enacted sewer use bylaws to control the volumes and strength of these wastes in order to prevent polluting materials from gaining direct access to watercourses. **It is recommended that all affected municipalities enact and enforce sewer use bylaws to prevent industrial pollution problems. Industries discharging treated wastes and process waters directly to watercourses in the basin should implement waste treatment necessary to meet water quality objectives as outlined in this report.** **...Recommendation no. 10**

Rural oriented management practices for water quality improvement include limiting fertilizer application rates, channel protection programs, restricting free access of cattle to streams, control of farm waste discharges, particularly from intensive feedlot operations, and control of illegal septic tank connections to drains. Surface runoff to streams from fertilized land is a significant diffuse source of nutrients which contribute to excessive aquatic weed growth. Although accurate statistical information is not available, fertilization of cropland beyond recommended rates was found to be a general practice in the basin. **It is therefore recommended that fertilizer application rates be limited to those recommended by the Ontario Ministry of Agriculture and Food, using services such as those at the University of Guelph for determining appropriate rates. Individual and group activity by the agricultural community and the active support of government agencies is important to implement this practice.**

...Recommendation no. 11

A program of restricting free access of livestock to streams should be commenced. It is recommended that the Ontario Department of Agriculture and Food take the lead role in undertaking detailed study of the implications of such a program to farmers, of the best methods such as fencing or vegetative barriers, and of the feasibility of provincial subsidies to encourage such a program.

...Recommendation no.12

It is recommended that increased environmental surveillance and enforcement be undertaken by appropriate government agencies to control farm waste discharges, particularly from intensive feedlot operations, and illegal septic tank connections to municipal drains.

...Recommendation no. 13

It is recommended that channel protection programs as described in this report be implemented, with initial emphasis on areas of greatest need which should be identified in detail by appropriate government agencies.

...Recommendation no. 14

Recommendations 11 to 14 are generally relevant to the entire watershed; however, particular attention is drawn to headwater areas, where the need to maintain streamflows at the best possible quality and quantity is especially important. Any lessening of flows and stream quality in these areas will aggravate downstream problems. **Rural oriented management practices and conservation practices should be applied with special rigor in headwater areas, and municipalities in these areas must pay special attention to sewage disposal practices to safeguard both local and downstream water uses.**

...Recommendation no.15

It is recommended that resolution of water quality problems in existing reservoirs be achieved by the two conservation authorities through appropriate combinations of bottom draw, destratification, algae control, disinfection of swimming areas, or modified operating policies as outlined in this report for each reservoir.

...Recommendation no. 16

In evaluating water management options, the assumption was made that, as specified in operation manuals, discharges from Wildwood and Pittock reservoirs would be maintained at minimum rates of 40 cfs and 15 cfs respectively for flow augmentation, and that Fanshawe Dam would be operated on a flow-through basis during low flow periods. An analysis of historical flow data indicated that these rates of flow have generally been maintained on a monthly basis, but that on a daily basis, flows have been less than specified for significant periods. **Accordingly, it is recommended that these reservoirs be operated in such a manner as to ensure the maintenance of the specified minimum flows on a daily basis. It is also recommended that there be close liaison between the Ministry of Natural Resources and the Ministry of the Environment to ascertain if alterations to these operating schedules would optimize the use of existing reservoirs for flow augmentation, without adversely affecting other uses.**

...Recommendation no. 17

Water based recreation relates largely to existing and proposed reservoirs. Improved water quality will enhance recreational use of streams, but this use is restricted by limited public access. Although a significant increase in recreational use of existing reservoirs is not practical without jeopardizing their primary use for flood control and flow augmentation**, it is recommended that the Upper Thames River Conservation Authority and the Ministry of Natural Resources undertake a detailed computer analysis to determine what modifications of reservoir operating practices would optimize their flood control and flow augmentation use and enhance their recreational use potential.**

...Recommendation no. 18

Channel erosion problems in the lower watershed below Chatham are presently the subject of a $7 million streambank and dike stabilization and rehabilitation project. **It is recommended that a program of corrective action concerning bank erosion from Chatham, upstream as far as Delaware, should be initiated by the Lower Thames Valley Conservation Authority in line with the recommendations in the 1971 report by James F. MacLaren Limited entitled "Flood And Erosion Control Works On The Lower Thames River From Chatham To Delaware".**

...Recommendation no. 19

Soil erosion control programs including strip cropping, crop rotation, diversion terraces, grassed waterways and vegetative buffer zones or reforestation should be implemented throughout the watershed, with initial emphasis on areas that should be identified by staff of the Ministries of Agriculture and Food, Natural Resources, and Environment.

...Recommendation no. 20

It is recommended that environmental impact assessments of land drainage proposals be undertaken to screen out or modify proposals which would damage the environment and that selected wetlands of ecological importance, such as the Zorra swamp, be protected from further drainage.

...Recommendation no. 21

Prevention of water supply interference and ground water quality impairment, rather than remedial action after the problem has occurred, should be practised using procedures detailed in chapter 7 of this report.

...Recommendation no. 22

To overcome communication and co-ordination problems relating to water management in the basin, and to implement planning on a watershed basis, a joint committee of government agencies and other appropriate bodies should be established. The committee should include representatives of the Ministries of Agriculture and Food, Environment, Housing, Natural Resources, and Treasury, Economics and Intergovernmental Affairs, the two conservation authorities, municipalities, citizen groups and the agricultural community.

...Recommendation no. 23

Another aspect of communication and co-ordination, raised during the Public Consultation Program, related to the division of the watershed into two conservation authorities, **because of the interrelationships of water resource problems and solutions in the upper and lower watershed, and in order to further the basin wide approach to water management advocated in this report, it is recommended that consideration be given to the amalgamation of the Upper Thames River Conservation Authority and the Lower Thames Valley Conservation Authority into a single authority.**

...Recommendation no. 24

Regulation of new floodplain development is a vital aspect of flood control. Controls of such development have already been implemented in some areas of the watershed. **It is recommended that further controls of floodplain development under the planning act and through regulations administered by the conservation authorities be developed.**

...Recommendation no. 25

Flood warning, which can be an effective measure in reducing flood losses through temporary evacuation of people and damageable goods, requires an efficient flood warning system to be successful. **It is recommended that the Conservation Authorities Branch and The Conservation Authorities consider the development of an improved flood warning system.**

...Recommendation no. 26

For long term flood control, flow augmentation and erosion control benefits, it is recommended that sound conservation measures such as reforestation, sound agricultural tillage, use of appropriate ground cover, and preservation of water retaining areas be encouraged and implemented. Reforestation and establishment of shrub cover along stream-banks should be directed to areas where they would specifically aid in erosion control, streambank stabilization, and the improvement of fish habitats.

...Recommendation no. 27

It is recommended that municipalities and government agencies encourage and enforce careful construction practices during drainage ditch installations and other construction activities in and along watercourses.

...Recommendation no. 28

It is recommended that development in areas of sand and gravel not be permitted to hinder infiltration or to degrade the quality of infiltrating water. This is particularly true of areas of municipal water supply, such as the Woodstock well field. In addition, areas providing significant baseflow such as the Harrington-Lakeside moraine should be protected.

...Recommendation no. 29

CHAPTER 2

DESCRIPTION OF THE THAMES RIVER BASIN

2.1 PHYSIOGRAPHY

For discussion purposes, the Thames River basin can be physiographically divided at Delaware into upper and lower portions (Map 2). The Lower Thames basin has little relief, except for the incised Thames channel from Delaware to Thamesville. Much of the land surface is sand and clay plains and topography is flat to gently rolling. The Bothwell and Caradoc sand plains are delta outwash deposits while the Ekfrid clay plain is lacustrine. The Essex bevelled till plain has a very thin veneer of lacustrine clays and in poorly drained portions, deposits of peat and muck have developed. Two relatively minor moraines occur in the lower basin. The Blenheim moraine between Rodney and Blenheim has a maximum relief of 100 feet and forms a part of the watershed boundary. A second, lesser moraine passing by Charing Cross is a long, gently-rolling feature of low relief. The Chatham clay plain, of lacustrine origin, lies below Chatham and extends almost to the river's mouth in a long narrow strip along the river.

The Upper Thames basin is characterized by three lengthy moraines, numerous outwash deposits. drumlin fields and till plains. In general. the upper basin has more varied physiography with substantial relief. Till plains with rolling topography constitute almost 60 percent of the land surface in this part of the basin. Drumlin fields are superimposed on the till plains in West Oxford and East Zorra townships. Moraines protrude through the till plains and form much of the western, southern and southeastern basin boundaries. Another moraine passes through St. Marys. Elginfield and on to Fullarton where it divides—one part going north to Mitchell and the other to Wartburg. Relief is generally less than 50 feet and the moraines are discontinuous where they are dissected by drainage.

2.2 DRAINAGE

The Thames River system drains 2,250 square miles of land extending from Lake St. Clair to the highlands of Perth and Oxford counties northeast of London. It is one of the main watersheds in Southern Ontario, and drains approximately 25 percent of the Ontario portion of the Lake Erie drainage basin. The basin is 125 miles long with a maximum width of 35 miles. The drainage characteristics of the upper and lower parts of the basin differ significantly.

2.2.1 Lower Thames

The lower part of the Thames River basin is 870 square miles in area and extends from Lake St. Clair to Delaware. The basin is roughly rectangular in shape, with a length of 85 miles and a maximum width of 14 miles. For the first 18 miles from Lake St. Clair to Chatham, there is an elevation difference of less than one foot and the river level is essentially controlled by Lake St. Clair. Downstream of Chatham. the river level is above the neighbouring land, and dikes have been developed to prevent flooding of the agricultural land. For the first 12 miles above Chatham. the gradient of the main stream is about 0.8 feet per mile, while for the remaining 78 miles. it averages 1.2 feet per mile.

There are numerous short tributaries to the Lower Thames. all of which have steeper average gradients than the main stream. Those entering the main stream from the north are generally less than 10 miles long. while those from the south are generally longer and drain larger areas. The largest of the latter are Jeanette, McGregor and Big creeks.

2.2.2 Upper Thames

In contrast to the lower basin, the upper Thames watershed is almost round in shape with a drainage area of 1.380 square miles. The stream gradients in the upper basin are relatively steep, varying from 4.5 to 11 feet per mile. Several long tributaries radiate outwardly from the confluence at London. The North Thames River drains 661 square miles 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 530 square miles in the northeast part of the basin. The Middle Thames River and Waubuno, Reynolds and Cedar creeks are its main tributaries.

2.2.3 Artificial Drainage

An extensive network of drainage ditches has been developed to dispose of water either on the surface or within the soil to enable more land to be brought under cultivation, to increase yields. to improve crop quality. and in some cases to permit farmers to work the land earlier in the spring. The total number and mileage of drains in the watershed is not known. The Upper Thames Valley Conservation Report (1952) estimated that by 1950, at least 850 miles of drains had been constructed in the upper Thames watershed. Many acres have also been drained with tile systems. Large areas of land have been reclaimed as farmland in the lower watershed by diking with associated drainage ditch installation and with pumping stations on some ditches near Lake St. Clair. While many drainage schemes may be necessary and beneficial, others can cause significant problems as outlined in Chapter 6 of this report.

2.3 GEOLOGY

2.3.1 Surficial Geology

The lower Thames basin consists primarily of lacustrine sands, silts and clays which overlie glacial till. The Blenheim and Charing Cross moraines which protrude through the lacustrine material consist primarily of clay. Beach deposits of sand and gravel occur on the northern flank of the Blenheim moraine. The upper basin is comprised essentially of clay till. Long, sinuous moraines extend to the north and east of London. These moraines are comprised primarily of clay: however, inter-moraine deposits of sand and gravel are common, especially on the Ingersoll moraine. Geology within the moraines is complex. The thickness and nature of the deposits change rapidly and deposits are generally discontinuous.

Spillways, which served to drain meltwaters from the melting ice to the glacial lakes, contain 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 the glacial lake. The sand and gravel deposits are locally thick and extend to bedrock in the vicinity of the Fanshawe Dam.

Overburden covers all of the lower basin and restricted 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 300 feet in the moraine south of London.

2.3.2 Bedrock Geology

Sedimentary rocks of Cambrian. Ordovician. Silurian and Devonian ages formed in ancient seas underlie this portion of southwestern Ontario. These sediments were deposited on the sloping surface of the Precambrian igneous rocks and form successive layers. Subsequent erosion produced the northwest trending rock formations seen on geological maps of this area. The younger rocks occur in the southwest portion of the basin while the older are found in the northeast. The older rocks occur at increasing depths below the surface toward the southwest where they are overlain by geologically younger formations. The oldest rocks found at the bedrock surface are dolomite, shales, gypsum. anhydrite and salt of the Salina formation of upper Silurian age. Dolomites of the Bass Island formation are the youngest Silurian rocks which occur in the basin and their subcrop edge occurs along a roughly northwest trending line through New Durham. Innerkip and Shakespeare.

Rocks of Devonian age form the bedrock in the remainder of the basin. 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 (Norfolk} 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. These changes are discussed in Chapter 3.

2.4 CLIMATE

The climate of the Thames River basin is temperate, and the proximity of lakes Erie and Huron exert a moderating influence on temperature extremes in the basin. In general, temperatures decrease from the lower reaches at Lake St. Clair to the headwater area. The lowest mean monthly temperature occurs in January, ranging from about 25°F at Chatham to 20°F at Stratford, while the highest mean monthly temperature decreases from 72°F at Chatham to 68°F at Stratford.

The prevailing winds in the region are westerly. Normal annual precipitation in the basin generally increases from the lower reaches to the headwaters, ranging from 32 inches at Chatham to 39 inches at Stratford. There is notably little seasonal variation in precipitation, with the difference between maximum and minimum, normal monthly precipitation being generally less than one inch. The snow belt area of southern Ontario is centred north of the Thames watershed, but its effect extends into the basin, causing an annual average snowfall of approximately 40 inches in the western end of the basin and approximately 68 inches in the eastern end. The average, annual potential and actual evapotranspiration in the basin are about 24 and 22 inches, respectively.

Violent windstorms, hailstorms and occasional tornadoes are not uncommon during the summer months, especially in the western portion of the watershed.

2.5 RESERVOIRS

There are several dams and reservoirs in the Thames River basin which have been established for flood control, flow augmentation and recreational purposes. The major structures (Wildwood, Fanshawe, and Gordon Pittock dams) are all located upstream from London (Map 2) and are operated by the Upper Thames River Conservation Authority. Wildwood and Fanshawe reservoirs are located near St. Marys and London, respectively in the North Thames watershed. The Gordon Pittock dam is situated on the Thames River at Woodstock. Pertinent reservoir data are presented in Table 2.1.

Table 2.1: Physical Data at Normal Operating Levels for Wildwood, Fanshawe and Pittock Reservoirs

		Wildwood	Fanshawe	Pittock
Surface areas (acres)		960	645	610
Volume (acre-feet)	- normal	14,480	10,033	4,750
	- maximum	20,100	39,000	13,400
Depth - average (feet)		15.0	15.5	7.8
Drainage Area (sq. mi)		54.6	56.0	93.5
First Operating Year		1966	1953	1967
Mode of Discharge		Surface or low-level	Surface or low-level	Surface or low-level

At Wildwood, storage of 14,480 acre-feet for recreation and stream flow augmentation is obtained in early summer, leaving 5,620 acre-feet of storage available for flood control during the summer. In winter, only 1,950 acre-feet of water are stored, thereby reserving 18,150 acre-feet of low-level or controlling winter and spring floods.

Water in the reservoir is released according to a predetermined schedule to satisfy recreational requirements and to augment streamflows. Drawdown begins during mid-June and continues until about mid-December, when the winter holding level in the reservoir is reached. The volume of stored water available for release is 12,530 acre-feet, so that a minimum downstream flow of 40 cfs can maintained.

Fanshawe darn is operated during periods of potential flood when one of two criteria is used to determine how and when the dam is to operated. One criterion is based on the rate of rise of the water level in the reservoir, and the other on the rate of increase in flow at the gauge on the North Thames River near Thorndale. Water stored during periods of high flow is released after the danger of flooding subsides, usually within a few days. Storage in the reservoir is continually maintained at 10,000 acre-feet when the dam is not operated. During exceptionally dry summers some water is released from the reservoir by a control valve, thereby lowering the water level below the normal holding level.

A maximum of 4,750 acre-feet of storage at the Gordon Pittock reservoir is used to retain water in the spring for summer recreation and streamflow augmentation. The remaining 8,650 acre-feet of storage are reserved for flood control. In winter, the reservoir is maintained empty. thus making the entire 13,400 acre-feet available for flood control. The maximum storage for recreation and streamflow augmentation is reached in late spring and reservoir drawdown begins on about June 20, according to a predetermined schedule. This schedule indicates that storage in the reservoir is reduced from 4,750 acre-feet to 2,550 acre-feet from June 20 to September 10. As a result, downstream flow is maintained at about 15 cfs. Drawdown continues until the reservoir is empty on about December 1.

Four additional dams situated in the basin have insignificant impact on downstream flows during low flow periods, because of their smaller size and method of operation.

Thomas Orr dam, built on the Avon River in Stratford. serves to store water for recreation and control local floods. The total reservoir capacity is 670 acre-feet and normally about 300 acre-feet of water are retained in the reservoir for recreational use. The water level in the reservoir, known as Lake Victoria. is raised in the spring and is maintained at a more or less constant level throughout the summer and fall. The reservoir is emptied in late fall to provide storage for flood control during the winter and spring.

Located on the North Thames River at Mitchell is the Mitchell dam and reservoir. The reservoir capacity is 620 acre-feet. but no discharge control is available above the 185 acre-feet level. Below this level. stop logs provide a limited capability for controlling discharge. The reservoir provides local flood control and recreational opportunity.

The Springbank dam raises and maintains a stable water level in the Thames River in Springbank Park at London from May to September each year. The impoundment created facilitates boating and other recreational activities in the park during the summer and fall.

Sharon Creek dam, located on Sharon Creek near Delaware. is the only multi-purpose streamflow control structure in the Lower Thames River basin. Total capacity of the reservoir is 3.500 acre-feet, of which 2,100 acre-feet are used for flood control and 1,400 acre-feet for conserving water intended to serve both recreation and the irrigation of tobacco. However, no water taking permits have been issued for irrigation takings either from the reservoir or from the stream. The reservoir is lowered in winter.

2.6 LAND USE

The Thames River watershed contains 18 urban municipalities (four cities, seven towns and seven villages) and occupies to varying degrees the areas of 48 rural townships in seven counties. Urban municipalities account for 5 percent (112 square miles) of the total area of the watershed. Farmland occupies approximately 85 percent (1,924 square miles) and other non-farm rural uses, including roads. industries and hamlets cover approximately 10 percent (214 square miles) of the basin. It should noted that census statistics in the following description were compiled using political rather than watershed boundaries. Thus, the data included portions of townships outside the watershed.

2.6.1 Rural Land Use

The major land use and the major component of the Thames basin economy is agriculture. Agricultural activity, which is diversified and varies from area to area depending on soil and climatic conditions. includes livestock raising, dairying, selected field crops. fruits. vegetables and tobacco. These activities appear in high concentrations in certain 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.


Ontario
MINISTRY OF THE ENVIRONMENT
THAMES RIVER BASIN STUDY
MAP 2
LOCATION OF EXISTING AND PROPOSED CONSERVATION AUTHORITY RESERVOIRS
Scale 1:500,000
LEGEND
LAKE ST. CLAIR
CHATHAM
LONDON
STRATFORD
WOODSTOCK
Mitchell
St. Marys
Ingersoll
Ridgetown
Blenheim
LAKE ERIE
LOCATION OF EXISTING AND PROPOSED CONSERVATION AUTHORITY RESERVOIRS
MAP 2727-34

Approximately 88 percent of the farmland in the basin is classified as improved farmland, including productive land used for crops, improved pasture, summer fallow, and other uses as defined by the Canada Census. The unimproved farmland category includes woodlots and managed forests representing approximately 7 percent of the total farmland acreage.

The rural land use of the Thames River basin between 1961 and 1971 proved to be relatively stable in terms of total farmland acreage. The 2.9 percent decline experienced in total farmland acreage was mainly due to various forms of urban encroachment, a phenomenon not unique to this watershed. Two factors have tended to minimize the loss of improved agricultural land, which declined by only 0.04 percent. In some cases, urban expansion has taken unimproved farmland, while in others, unimproved land has been improved to offset the loss of improved farmland to urbanization.

Despite the slight decline in acreage of the improved farmland sector noted above, acreage devoted to crops increased between 1961 and 1971 in every township in the watershed. giving an aggregate increase of 13.2 percent. Concurrently, all other land use categories showed aggregate declines for the decade: pasture by 40.3 percent. summer fallow by 28.9 percent, and "other" by 17.3 percent. There was a 10.9 percent decline in total unimproved farmland in the basin during the decade. Clearly, the trend has been toward increasing crop acreages, perhaps even at the expense of other uses of improved farmland.

It is of interest to compare these agricultural land use trends in the basin to provincial trends. At the provincial level, there was a 10 percent reduction in improved agricultural land and a 22 percent reduction in unimproved agricultural land between 1961 and 1971 (Bangay, 1974). Thus it can be seen that the rate of loss of agricultural land, and particularly improved agricultural land in the Thames basin has been much less than the provincial average.

There has also been an apparent trend towards intensive livestock operations. Agriculture Canada has estimated the number of these operations in the Thames basin, based on air-photo interpretation. This information is summarized in the following table:

Table 2.2: Large Livestock Operations In the Thames River Basin *

Type of Livestock	Number of Operations		
	Upper Thames	Lower Thames	Total
Dairy Cattle (more than 75 head)	59	7	66
Beef Cattle (more than 150 head)	138	87	225
Hogs (more than 300 head)	156	73	229
Poultry (more than 30,000 birds)	13	7	20

* A Selective Inventory of Large Livestock Operations in Southern Ontario. Agriculture Canada 1974; Unpublished report

It should be noted that the majority of these operations are located in the upper part of the watershed.

While the dairy sector of the livestock industry is of decreasing importance in the Thames watershed, pigs show the greatest increase both in absolute numbers and in rate of increase, and this watershed also exhibits the greatest move to intensive feeding of beef in the Lake Erie basin (Bangay, 1974). An additional agricultural trend in the basin is that of farm consolidation, in which marginal operations have been absorbed. Between 1961 and 1971, there was a 22 percent decline in the number of farms in the watershed, while the average farm size increased from 115 acres to 143 acres.

2.6.2 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 an area of over 60 square miles. The cities of Woodstock, Chatham and Stratford serve as subregional centres of roughly the same population and function, and dominate their respective counties. The seven towns and seven villages tend to be oriented toward more local situations and needs.

Land within the boundaries of the basin's urban municipalities includes significant acreage classed as agricultural or vacant that can accommodate future growth. This is demonstrated in the following table:

Table 2.3: Designated Urban Land Uses-1971

Present Designation of Urban Land	Percentage of Total Urban Area
Agricultural and Vacant	40
Residential	33
Industrial	10
Institutional	8
Open Space	5
Commercial	3

Similar statistics for each of the four largest municipalities are given below:

Table 2.4: Existing Urban Land Uses in Acres and Percent of Total Urban Area

Present Use	London	Chatham	Woodstock	Stratford*
Agricultural and Vacant	17,029A	1,556A	2,628A	1,076A
	44.0%	27.7%	43.0%	33.0%
Residential	12,324	2,059	1.712	988
	31.8%	36.7%	28.0%	30.3%
Commercial	1,257	208	206	81
	3.2%	3.7%	3,4%	2.5%
Industrial	3,162	969	552	530
	8.2%	17.3%	9.0%	16.2%
Institutional	3,433	473	285	242
	8.9%	8.4%	4.7%	7.4%
Open Space	1,495	346	728	346
	3.9%	6.2%	11.9%	10.6%

* Data for 1966; thus excluding the 1970 annexation of 747 acres.

The general growth philosophy of municipalities in the basin is to develop within municipal boundaries rather than to expand beyond them. As can be seen from the above two tables, significant acreages classified as agricultural and vacant are available for future expansion. The implications of growth possibilities relating increased sewage loads to receiving watercourses are dealt with later in this report.

2.6.3 Other

The provincial park planned for the Komoka area will increase the acreage of land within the basin now devoted to recreational activities. This park, particularly in view of its proximity to London, will provide valuable additional recreation land within the watershed.

In the last quarter century, a significant effort has been expended on the development of flood control facilities to reduce the risk of flooding throughout the basin. This has included the construction of three major dams, of which the accompanying reservoirs take up 3,720 acres of land. If proposed dams at Wardsville, Thamesford, Glengowan and Cedar Creek are constructed, as much as 10,190 acres of additional land could be flooded for reservoirs.

To date, common utility corridors have not been developed in this section of the province. The recent controversy over Highway 402, to link Sarnia and London, and the present concern over the construction of a Sarnia to Montreal crude oil pipeline, indicate the development of trends that may culminate in greater use of common utility corridors.

2.7 POPULATION PATTERNS

Between 1941 and 1971, the population of the Thames River watershed rose from about 214,000 to 415,000 and grew at an average annual rate of approximately 2.2 percent. The fastest growth occurred during the decade 1951 to 1961 with a population increase of 31 percent and growth rate of 2.8 percent per year over the ten years. During the 1961-71 decade, the total population increased by 23 percent at the rate of 2.1 percent per year. In 1971, 333,300 persons or 80 percent of the total population of the watershed lived in cities, towns and villages. The City of London is the largest urban centre with a 1971 population of 219,900 or about 53 percent of the total population in the watershed. Other significant population centres are Chatham, Woodstock and Stratford.

In 1971, there were 81,600 persons in the rural townships. representing close to 20 percent of the total population of the watershed. Middlesex County had the highest proportion of the rural population with 5.7 percent, followed by Oxford (4.4 percent) and Kent (4.4 percent). These counties were not only the largest in area, but also contained the largest urban centres. Non-farm residents (or urban commuters) living adjacent to urban centres contributed to the rural population increases.

Over the period 1961 to 1971, the urban population increased by 21.8 percent at a rate of 2.5 percent per year. The rural population increased 7.6 percent at a rate of 0.7 percent per year. More and more of the growth in the watershed population during the last decade was in the urban centres with the focus of expansion in the City of London which grew at an average of 3.1 percent per year. Only Bothwell, Thamesville, St. Marys and Wardsville experienced negative annual growth rates. The rural townships comprised 22.5 percent of the total watershed population in 1961, but only 19.6 percent of the total population in 1971. The percentage of the basin's residents living on farms dropped from 56 percent in 1961 to 42 percent in 1971.

As the rural farm population and number of farms decline, the number of rural non-farm people in the watershed is increasing, particularly in those townships adjacent to cities. It is estimated that by 1991, the total population of the basin will be 671,000, comprising 556,000 urban residents and 115,000 rural residents (see Table 2.5).

Table 2.5: Estimated Population for Urban and Rural Areas. 1971-2001 [1]

Municipality	1971[2]	1976	1981	1986	1991	1996	2001
London (C)	219,921	254,400	293,500	338,600	390,000	450,000	500,000
Chatham (C)	33,671	36,800	40,200	44,000	48,000	52,300	57,000
Woodstock (C)	25,081	28,000	31,400	35,000	39,100	43,800	49,000
Stratford (C)	23,380	25,800	28,500	31,500	35,000	38,200	42,000
Blenheim (T)	3,431	3,800	4,190	4,630	5,110	5,640	6,230
Bothwell (T)	813	880	950	1,030	1,110	1,190	1,290
Ingersoll (T)	7,755	8,360	9,000	9,700	10,440	11,250	12,130
Mitchell (T)	2,553	2,760	2,970	3,200	3,450	3,710	4,000
Ridgetown (T)	2,826	3,020	1220	3,410	3,600	3,790	4,000
St. Marys (T)	4,495	4,840	5,220	5,620	6,050	6,520	7,030
Tilbury (T)	3,613	3,950	4,300	4,700	5,120	5,580	6,090
Beachville (V)	991	1,070	1,150	1,240	1,340	1,440	1,550
Embro (V)	692	740	610	870	930	1,000	1,080
Glencoe (V)	1,392	1,550	1,730	1,920	2,130	2,370	2,630
Highgate (V)	420	450	480	520	560	610	660
Tavistock (V)	1,356	1,460	1,570	1,690	1,820	1,960	2,120
Thamesvllle (V)	1,017	1,100	1,180	1,270	1,370	1,480	1,600
Wardsville (V)	330	380	440	510	590	680	800
Total Urban	333,737	379,360	430,810	489,410	555,720	631,520	699,210
Total Rural	81,573	88,670	97,340	106,270	115,730	123,600	138,510
TOTAL POPULATION	415,310	468,030	528,150	595,680	671,450	755,120	837,720

(C) = City (T) = Town (V) = Village

[1] Population Projections based on Official Plans

[2] Source TEIGR—Ontario Population Statistics

Provincial studies of both the Lake Erie and Southwestern Ontario planning regions recognize London as a major growth centre and recommend it continue at that rate. Continued growth of its industry and commerce to support a population of 390,000 by 1991, and an ultimate maximum population of between 500,000 to 600,000, is anticipated, based on official plan projections.

The continued growth of Chatham to 48,000 in 1991 is contingent upon the encouragement of industrial and commercial activities. Assuming continued residential development and industrial growth, the projected 1991 population of Woodstock is 39,100. The projected population for Stratford in 1991 is estimated at 35,000, with industrial expansion and the continued attraction of the Shakespearean Festival being the prime components of future growth.

2.8 IMPLICATIONS OF AGRICULTURAL AND POPULATION TRENDS

In evaluating the implications of agricultural and population trends in the Thames watershed, it is necessary to look beyond the basin boundaries to the provincial, national and international situation. A variety of studies have been carried out recently and even when projections are based on conservative estimates, the results are disturbing.

At the provincial level, for example. the removal of farmland from production in Ontario has accelerated in recent years. Census statistics show that between 1941 and 1971, improved farmland in the province declined by 2.5 million acres (from 13.4 to 10.9 million acres), and of this, 48 percent or 1.2 million acres was lost between 1966 and 1971. In southern Ontario, an average of 200,000 acres of improved farmland per year was lost between 1966 and 1971. Meanwhile, the provincial population increased by more than 100 percent from 3.8 million to 7.7 million, and conservative estimates indicate that Ontario's population will reach 12 million by the year 2,000, a 56 percent increase over 1971.

After evaluating, in various combinations, projections for such factors as increases in agricultural productivity, food consumption trends and land use trends it can be concluded that by the year 2,000, to provide even 50 percent of the province's food requirements will prove to be a major task for the people of Ontario.

A review of the Canadian food situation, and of the major problems encountered by the developing nations demonstrates that agricultural land conservation for food production in the Thames basin is a basic issue which must be considered when evaluating water management proposals.

CHAPTER 3

WATER AVAILABILITY

3.1 SURFACE WATER

An assessment of water availability in the Thames River system is a basic consideration of the study. While detailed analyses of streamflow data have been carried out and will be published in a separate technical report, it is the extreme conditions of flood and drought flows that are usually of primary concern to the residents of the watershed. A brief description of these hydrologic characteristics of the basin is given below. The implications of these characteristics to such matters as water quality, flood control and flow augmentation are dealt with in greater detail in chapters 6 and 7.

3.1.1 Peak Flows and Flooding

Floods may occur at any time of the year, but spring floods, caused by a combination of ice, snowmelt, and rain, are most frequent. Severe summer floods caused by major thunderstorms have occurred in the past, and the probability exists that due to a tropical hurricane, a severe flood could occur in the autumn (Acres Consulting Services Limited, 1973). Generally, the highest monthly streamflows occur in March, with a few streams discharging peaks in April. Usually, much higher flows occur during the March and April freshets than in other months. Typically, summer floods have sharper peaks than the more frequent spring runoff floods.

Downstream from Byron, the magnitude of the peak flood discharge tends to decrease rather than increase. Extensive overbank storage and limited lateral inflow are the main reasons for this characteristic. Further downstream, south of Chatham, flood waters over-topping the north bank actually leave the watershed and flow into Lake St. Clair.

Major floods occurred in 1937, 1947, 1948, 1963 and 1968. The 1937 flood was caused by heavy rainfall, mainly in the south branch portion of the Thames River. In 1947, a large flood occurred with floodwaters originating largely in the North Thames River basin. Extensive documentation of this flood includes mapping of the area under water at the flood peak.

Many local floods have also occurred such as the McGregor Creek flood in 1968. These floods have been documented in various newspaper accounts. Documentation *of* floods which have resulted from overtopping and breaching of dikes is not available. The main areas which have been regularly subjected to flooding are St. Marys on the North Thames River; Woodstock on the south branch of the Thames River; London; and the stretch from Thamesville through Chatham to Lake St. Clair.

In order to reduce the flood hazard, reservoirs have been constructed in the upper Thames basin near St. Marys, London and Woodstock, creating storage volumes of 20,100, 39,100 and 13,400 acre-feet respectively. Of the total 72,600 acre-feet of storage, about 43,270 acre-feet are available for flood control storage. Other flood control projects include the Mitchell Dam and channel improvement at Mitchell, the Thomas Orr Dam and channel improvement at Stratford, the Ingersoll-Beachville channel improvement, and dikes in sections of London and along the lower reaches of the Thames River.

Downstream from Chatham, dikes have been constructed to protect the rich delta agricultural land from flooding. These dikes are overtopped regularly due to high stages that frequently occur during the spring break-up. Other floods have occurred because of the malfunction of flap gates. In recent years, erosion caused by natural river processes and the wave action of power boats has made the dikes unstable.

3.1.2 Low Flows

The lowest mean monthly discharges at individual stations in the Thames basin generally occur during July, August or September. The difference between the average discharges for these months is usually small. Potential over-use of stream water is most likely to occur during this period, particularly since demands for stream water are usually highest at this time.

Estimates of minimum flows in cfs for the period May 1 to November 30 at continuous record gauging stations in the basin are shown on Map 3. The data are provided for 1, 7, 15 and 30 days duration, and for recurrence intervals of 1.575, 5, 10, 15 and 20 years. The effects of dam regulations have been excluded, and the data thus represent unregulated flows. Sewage treatment plant discharges have been included as they represent a relatively constant input over time.

An analysis of available streamflow data indicates that zero flow conditions have been documented at the following locations:

Stream	*Location*
Medway River	London
Fish Creek	Prospect Hill
North Thames River	Mitchell
Trout Creek	Fairview
Waubuno Creek	Dorchester
Dingman Creek	Lambeth
Middle Thames River	Thamesford
Big Creek	Tilbury
Tilbury Creek	Tilbury
Jeannette Creek	Merlin
McGregor Creek	Richardson
Ardevell Creek	Highgate
Newbiggen Creek	Glencoe
Pottersburg Creek	Hamilton Road
North Branch Creek	Embro Creek
Thames River	Tavistock
Avon River	Stratford

Low flow conditions are significant to such water management considerations as the waste assimilative capacity of a stream, the siting of sewage treatment plants, and the availability of water for irrigation. At some municipalities, seasonally low streamflows may limit the amount of sewage effluent that can be safely discharged to a watercourse, thus acting as a constraint on municipal growth. In other areas, the assimilative capacity of streams during low flow periods has already been exceeded, necessitating low flow augmentation or a higher degree of treatment.

3.1.3 Ground Water Component of Streamflow

During low flow periods, more dependable flows generally occur in streams with a significant ground-water component. Such streams can be relied on to provide a relatively consistent flow, compared to streams which do not receive ground-water runoff and which exhibit greater fluctuations in response to weather conditions.

Significant quantities of ground water contribute to the streamflows in the Thames River and its tributaries. Approximately 35 percent of total annual discharge originates as baseflow (water of ground-water origin); however, the proportion of baseflow in a given stream is seasonally dependant. During spring runoff period, baseflow constitutes 10-20 percent of the observed flow, while during the low flow period of June to October it is in the 70-90 percent range. Baseflow is a particularly important component of streamflow at several locations on the North Thames River, the south branch of the Thames River and Trout Creek at St. Marys. A large portion of the water being continually pumped into the river downstream from St. Marys by the St. Marys Cement Company to dewater its quarry, is of ground-water origin.

One source of ground-water discharge to Trout Creek is a series of springs in and near the Harrington swamp, about two miles from Harrington West. During extremely dry periods, total flow in this creek is believed to be sustained by these springs. 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 ground-water seepage directly 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 ground water is not known.

In the lower reach of the Thames River, ground-water discharge potential to tributaries is relatively high since this area is largely sand covered. However, due to the flatness of the land in this area, there is a low hydraulic gradient, and only a limited amount of ground water actually flows to the streams.

3.1.4 Low Flow Augmentation

Three reservoirs in the watershed are operated in part to augment low flows: Wildwood. Gordon Pittock and Fanshawe. Water released from storage in the Gordon Pittock reservoir has successfully maintained downstream flows at 15 cfs during summer and fall. During the period July to November, 1967 to 1971, daily discharges immediately downstream from the dam were less than 15 cfs only four percent of the time.

Water released from Wildwood reservoir during summer and autumn has not always maintained downstream flows at 40 cfs as expected. For approximately 27 percent of the time, average daily flow was less than 40 cfs and 7 percent of the time, flow was less than 20 cfs. During July to November, an average monthly discharge of 40 cfs has been maintained for most of the time since the reservoir operation commenced.

During exceptionally dry summers, some water is released from Fanshawe reservoir, thereby lowering the water level below the normal holding level. On many occasions, however, Fanshawe dam and reservoir has reduced downstream flow during low flow periods. For the period 1954 to 1971, from June to November, monthly average inflow to the reservoir exceeded outflow for 51 out of the 108 months. Possible causes of this situation include evaporative losses from the reservoir, infiltration through the bottom of the reservoir, gauging station measurement errors, reservoir operating procedures, or some combination of these factors.

3.2 GROUND WATER

Ground water is a widely used natural resource in the basin. Once precipitation infiltrates to the water table, it becomes ground water. Below the water table all materials are saturated, and it is the character of the sub-surface material which determines the availability of a suitable ground-water supply. In essence, therefore, a geological knowledge of overburden and bedrock materials forms the basis of any groundwater study.

Ground-water conditions in this watershed are described briefly in the following section. A technical report, to be published separately, will provide detailed information on ground-water conditions in the basin. A series of maps will provide data on locations of water-bearing deposits, estimated well yields, and chemical quality of ground water in a form which can be readily applied to problems of water supply and resource evaluation.

3.2.1 Ground Water in the Overburden

The overburden ranges in thickness from zero near Innerkip and Ingersoll, where bedrock is at surface, to approximately 300 feet south of London. Water bearing zones commonly occur near the base of the overburden: however, extensive aquifers are present throughout the overburden section as well as at the surface. Surficial sand and/or gravel deposits flank the Thames River over most of its course. These deposits broaden significantly to form outwash deposits in the vicinity of Woodstock, London and Komoka and an extensive sand plain between Wardsville and Thamesville. Yields to wells in surficial deposits vary from more than 1000 gpm for the Woodstock municipal wells to 1-2 gpm from shallow private wells constructed in less permeable zones.

Aquifers in the overburden are essentially flat-lying sand and gravel deposits. In the central and north portions of the basin, aquifers tend to be smaller and more discontinuous, in contrast to the lower basin where they are more extensive.

In the northern portion of the watershed, occasional sand and gravel deposits are reported but they appear to be discontinuous and are not usually utilized for water supply. In the Milverton vicinity, sand and gravel deposits occur, with well yields commonly in excess of 50 gpm, but they do not appear to extend far into the basin. Around Mitchell and south of' Highway 8 to Sebringville, there is an essentially sand and gravel formation, with a reported average thickness of less than 10 feet. Another buried deposit extends from St. Marys to the eastern basin boundary with yields in the Tavistock area of 10-50 gpm.

Sand and gravel aquifers in the London-Woodstock area are too abundant to discuss individually. Most significant are the White Oak aquifer and the Woodstock shallow aquifer.

In the lower part of the basin. surficial sand deposits extend from the vicinity of Chatham upriver to Wardsville. In the Bothwell area. the yield from the sand is usually in the range of 2-10 gpm. At depth in the Chatham area is a relatively thin hut very persistent sand deposit which, in most instances, directly overlies bedrock. It extends to the basin boundaries and is reported as far up river as Thamesville and beyond although it becomes disjointed. This aquifer produces yields primarily in the range of 2-10 gpm. Higher yields are not uncommon, although no pattern in yields can be discerned.

3.2.2 Ground Water in Bedrock

Unlike the overburden where aquifers are identified by delimiting sand and gravel deposits, aquifers in rock are comprised of fractures. The mechanical properties of various rock types determine their ability to fracture and therefore their worth as aquifers. Fractures are plentiful in the limestones but rare in the shales; thus, limestones are superior sources of ground water. In the Thames basin, limestones underlie the upper basin while shales characterize the lower portion of the watershed. This geologic difference is the basis for the striking changes in ground-water quantity between the upper and lower parts of the basin. In general. there is little problem in obtaining suitable quantities from bedrock in the upper basin. The lower part of the Thames basin is underlain by the Hamilton Group of formations which consists of interbedded shales and limestones, with yields commonly less than 2 gpm. There are numerous failure wells in the lower basin and most wells obtain water supplies from the overburden.

Most supplies from bedrock are obtained within a few feet of the bedrock surface: however, in the region between Elginfield and Mitchell along the north-western basin boundary. penetration depths into rock in the range of 150 to 200 feet are common. Elsewhere in the northern part of the basin, penetration depths average 40-60 feet, and estimated bedrock well yields commonly exceed 50 gpm.

3.2.3 Water Level Fluctuations

Ten observation wells in the basin are presently monitored. These wells vary in depth from 20 to 455 feet, and five have periods of record in excess of ten years. Eight of these wells are constructed in overburden and two in bedrock.

Groundwater levels reach a maximum in early spring, usually April, followed by a gradual decline to a minimum in late fall, usually October. It is uncommon for summer precipitation to result in a water level rise, although rates of decline may be slowed. This annual trend applies to most wells but the magnitude of the annual fluctuation depends in part on depth. Based on observation well hydrographs, shallow aquifers have annual fluctuations in the range of 3 to 10 feet. Annual water level fluctuation in deeper overburden aquifers are between 1 and 2 feet while water levels in deeper bedrock wells vary only a few inches.

3.2.4 Ground Water Chemistry

Groundwater from bedrock and overburden sources in the middle and upper basin is chemically similar. Chlorides are very low (in the range of 5 to 25 mg/L) and hardness is relatively high. By contrast. ground water in the lower basin is characterized by higher chloride concentrations, in the range of 200 to 2000 mg/L with relatively low hardness. Calcium-bicarbonate type waters are typical of the upper basin, while sodium-bicarbonate and sodium-chloride types are most common in the lower basin. These differences are a direct consequence of the geochemical differences between limestones and shales and the overburden which has been formed from them.

In the northern part of the basin, water quality is usually reported as fresh except in the London area, where 15-20 percent of the wells report hydrogen sulphide. and in the Woodstock area. The problem of sulphurous water is generally most severe in wells where the pumping rate is high. For example, sulphurous water has restricted the use of two of Woodstock's high capacity municipal wells.

CHARTER 4

WATER USES

The water resources of the Thames River basin are used for a wide variety of purposes. Major uses. which include water supply. waste disposal, recreation, and fish and wildlife habitat, are described below and are summarized in Table 4.1. The table indicates the level of existing water uses in various sections of the basin and does not describe potential uses.

4.1 WATER SUPPLY

4.1.1 Municipal

Water taking for municipal purposes together with private domestic takings in rural areas represent the greatest consumptive use of water in the basin. Demand is such that not all communities can be adequately serviced by the resources within the watershed itself, with the result that water is imported to several communities from the Great Lakes. The Lake Huron pipeline meets the water demand of London, and the West Elgin and the Blenheim area water systems pipe water from Lake Erie to overcome inadequate local ground-water supplies. The Chatham pipeline from Lake Erie provides a more reliable and better quality supply of water for that city than did the former source, the Thames River.

Eighty-three percent of the population of the Thames River watershed relies on municipal and communal systems for its domestic water supply. An average of over 38 MGD (28 MGD from the Great Lakes and about 10 MGD from ground-water sources within the basin) are required to meet domestic. industrial and commercial water demands. The remaining 17 percent of the population residing in rural areas use close to 4 MGD from ground-water sources for domestic purposes.

In general, municipal water takings in the basin do not have a significant deleterious impact on other takings. However, caution must exercised when developing new or additional ground-water takings to avoid localized interference with previously existing well supplies.

4.1.2 Industrial

Water consumption data for industries obtaining water from municipal sources have not been separately compiled. However, it is estimated that between 33 percent and 45 percent of municipal water consumption in the basin is for industrial service. Industrial water takings from non-municipal sources use a total of about 25 MGD, of which about 14 MGD are recirculated with some loss to the atmosphere.

Water use for mineral extraction and processing (sand, gravel and limestone) represents the major industrial water use in the basin. About 6 MGD are used in mineral processing and gravel washing. but most of this water is recirculated so that approximately 1 MGD make-up water is required. Approximately 11 MGD withdrawn for pit and quarry dewatering are discharged to nearby watercourses.

Over one-half MGD, most of which is obtained from wells, is pumped into the Devonian formation in the Elgin County oil fields to aid in the secondary recovery of oil. None of this water is returned to source or to surface.

Food processing industries with their own water supplies use a total of about 1.8 MGD, all of which is obtained from wells. About one third of this total is for cooling purposes and is discharged to streams after use. Other manufacturing industries use a total of 700,000 gpd. About 90 percent of this amount is obtained from wells, and most is used for cooling purposes.

As with municipal takings, care must be taken when new industrial withdrawals are contemplated to avoid serious interference with existing ground-water takings.

Table 4.1: Existing Surface Water Uses

REACH	Fishery		Aesthetics	Body Contact Recreation	Boating	Irrigation	Livestock Watering	Water Supply	Industrial Taking	Waste Assimilation
	Warm Water	Cold Water								
N. THAMES RIVER										
Mitchell to St. Marys	minor	nil	mod.	minor	minor (Mitchell & St. Marys Dam)	nil	major	nil	nil	Mitchell
Avon R	minor	nil	major	minor	major (Lake Victoria)	minor (golf course)	major	nil	nil	Stratford
St. Marys to London	major	nil	major	mod. (Fish Creek)	major (spring)	nil	major	nil	St. Marys Quarries	St. Marys industrial
Wildwood Dam and Trout Cr	mod.	minor	major	major	major	nil	minor	nil	nil	nil
Fanshawe Dam	mod.	nil	major	major	major	minor (golf course)	nil	nil	nil	nil
THAMES River										
Headwaters to Ingersoll	mod.	minor	mod. (Zorra Swamp)	minor	minor	minor (tobacco)	mod.	nil	cooling	Woodstock Tavistock Beachville industrial
Pittock Dam	mod.	nil	major	major	major	nil	nil	nil	nil	nil
Ingersoll to London	major	minor	major	minor	minor	minor	minor	nil	nil	Ingersoll Dorchester industrial
Middle Thames	mod.	minor	major	minor	minor	mod.	mod.	nil	nil	industrial
City of London	mod.	nil	major	minor	mod.	nil	nil	nil	nil	London industrial
LOWER THAMES										
London to Wardsville	major	minor	major	minor	minor	mod-	nil	nil	nit	London Lambeth (Dingman Cr) Glencoe (Newbiggen Cr)
Wardsville to Mouth	major	nil	major	minor	mod.	minor	nil	nil	nil	Chatham Ridgetown Tilbury industrial
Sharon Dam	mod.	nil	mod.	mod.	mod.	minor	minor	nil	nil	nil

4.1.3 Agricultural

Water used for livestock is estimated to be about 6.5 MGD. This figure is based on the number of stock in the basin. Water supplies for feedlot and large poultry-farm operations are primarily obtained from deep wells. Pastured cattle and mixed herds on small farms are watered from a variety of sources, including streams, ponds, springs and drilled or dug wells. Based on 1971 census data from Statistics Canada, the total number of livestock in the basin are estimated to be 3.1 million (256,000 cattle, 365,000 pigs, 9,200 sheep 5,100 horses, and 2.5 million poultry).

Of greater potential demand is water use for farm crop irrigation. Considerable acreages of tobacco are grown on sandy loam soils in parts of Blandford, North Dorchester, Lobo and Caradoc townships: the same soil supports market-garden crops in these areas. Southeast of Dorchester, intensive truck-crop farming is carried out on an area of organic soil. Spray irrigation is practised on many of these farms, and on several golf courses.

A total of 120 water-taking permits issued by the Ministry of the Environment authorize a maximum irrigation taking of about 35 MGD in the basin; 21 MGD from surface water sources. These amounts represent maximum potential water taking, which is much greater than actual water taking in any given year.

Studies indicate that on the average, approximately 25 percent of the irrigation takings occur simultaneously. The most intensive crop irrigation occurs in a relatively short time period when the crops are nearing maturity. Tobacco is the crop most commonly irrigated. From a water resource management view, irrigation water demands tend to coincide with the period of lowest water availability in streams and therefore represents a significant potential impact on the surface water regime.

In summary, the known withdrawal uses in the basin total an average of 108 MGD (assuming maximum withdrawal for irrigation). About 28 MGD of this total is imported into the watershed.

4.2 WASTE DISPOSAL

4.2.1 Municipal

As of 1971, 93 percent of the urban basin population was serviced by waste treatment systems discharging to the Thames River. A further 4 percent have treatment systems in various stages of development for a total of 97 percent of the urban population. The remainder of the population in rural areas and in unserviced municipalities use septic tank and tile field systems. Municipal waste treatment systems provide secondary treatment of wastes designed to remove more than 90 percent of the suspended solids and oxygen utilizing organic materials (expressed as 5 day biochemical oxygen demand - BOD_5). Chlorination for waste effluent disinfection is practised. Additional treatment in the form of effluent filtration is provided at two treatment plants (Stratford, Southland Park and Westminster Township). Phosphorus removal is now required at all municipal treatment plants in the Thames basin because of the adverse effects of phosphorus 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.

Table 4.2 gives a detailed description of the municipal waste treatment facilities discharging to streams in the Thames watershed. Treatment plant locations are shown on Map 4.

Sewage collection systems in urban areas are either combined or separated. Newly urbanized areas have separate systems for storm runoff and sanitary sewage. Combined systems in older areas of many municipalities were designed to carry both storm water and sanitary sewage. During storm events, combined sewage overflows often occur because of hydraulic constraints in collection and treatment systems. This results in a pollution load of urban storm drainage plus untreated domestic waste to local watercourses.

Major municipalities in the Thames River basin have a policy of separating combined sewer systems; however, these programs are expensive and long term. Urban storm discharges alone may be a significant source of pollution load to watercourses as indicated by data collected by the Urban Drainage Subcommittee Canada-Ontario (1975), concerning-storm-sewer discharges in Southern Ontario.

4.2.2 Industrial

Generally, industries discharge wastes to local sewer systems for treatment at municipal treatment facilities. Usually sewer use bylaws are enforced by the local municipality to ensure that wastes sewered by industries are not toxic or corrosive. If such corrosive or toxic wastes are produced. the industry is required to neutralize harmful waste characteristics prior to discharge to the sewer system. In some cases,

Table 4.2: Municipal Waste Treatment Facilities

Municipality	Type of Treatment	Design Capacity (MGD)	1973 Average Flow (MGD)	Effluent Quality Average BOD_5 1973 (ppm)	Status of Treatment Facilities
St Marys	Activated Sludge	0.8	0.31	6	Recently completed. No expansion planned
Stratford	Activated Sludge	6	3.6	8	Tertiary treatment facilities recently completed No expansion planned
Mitchell	Lagoon	67 acres	0.69	15	Hydraulically overloaded—loading study underway
P V/ Township of Dorchester	Activated Sludge		NOT KNOWN TO DATE		Provincial protect conceptual brief received
Ingersoll	Activated Sludge	2.25	1.27	10	Expansion completed recently based on projected 20 year population figures
Beachville	Activated Sludge		NOT KNOWN TO DATE		Provincial project conceptual brief received.
Woodstock	Activated Sludge	4.5	5	20	Hydraulically overloaded Funds have been allocated for plant expansion Interim measures including additional chlorination facilities and increasing capacities of pump stations have been implemented
Tavistock	Lagoon	32 acres	0.18	29	Expansion proposed
P V of Lambeth (Southland Park)	Activated Sludge	0.058	0.028	17	No expansions planned but requires improvement in operation
Westminster Township	Extended Aeration with sand filters	0.3	0.34	7	No expansion planned
London					
Oxford	Activated Sludge	1.5	0.75	15	No expansion planned
Greenway	Activated Sludge	18.3	19.4	11	Expansion proposed—from 18.3 to 27.5 MGD
Adelaide	Activated Sludge	2	3.25	23	Expansion planned.
Pottersburg	Activated Sludge	4	3.27	18	Expansion underway—from 4 0 to 5.2 MGD
Vauxhall	Activated Sludge	3.5	3.91	20	Hydraulically overloaded
Glencoe	Lagoon	28 acres	—	—	Under construction
Bothwell	Extended Aeration	0.2	—	—	Proposed provincial project
Thamesville	Extended Aeration	0.25	—	—	Proposed provincial project
Ridgetown	Lagoons	0.35	No data	No data	
Tilbury	Lagoons	0.36	No meter	25	Hydraulically overloaded
Chatham	Activated Sludge	4.50	4.7	10	Hydraulically overloaded

the industry pays a surcharge to the municipality to compensate the city for treatment of high-strength wastes. Several dairy product companies in the watershed use land disposal of waste, resulting in negligible impact upon the river.

A number of quarries discharge water during the dewatering process. Usually this water is treated for solids removal and, if necessary, pH control prior to discharge. Several industries discharge uncontaminated cooling water directly to the river. Although there are no significant problems currently, care is needed to ensure that future cooling water discharges do not cause thermal pollution.

Several industries produce a waste effluent that is discharged to the river following chemical or biological treatment. Some of these discharges will be directed to sewage treatment facilities being developed for municipalities. Map 4 indicates the location of existing and proposed municipal waste treatment plants as well as those industries which discharge treated organic wastes to the watercourse.

4.2.3 Agricultural

As a general rule, waste disposal from livestock operations takes place on land. The increasing trend, described in Chapter 2, to feedlot operations where cattle, hogs and poultry are raised in small, confined areas, means their waste materials are more likely to gain access to watercourses, unless special care is exercised in waste disposal.

The significance of animal wastes as a source of pollutants in the basin can be demonstrated through a comparison with human waste equivalents. In terms of BOD alone, livestock in this watershed, in 1971, generated waste equivalent to a human population of more than 3.4 million, based on estimates by the U.S. Environmental Protection Agency (1971) of the average BOD of livestock manures. This compares to an actual 1971 population of 414,000 people in the basin.

Various "non-point" sources of wastes also gain access to the Thames. Such inherent factors as basin geology, land- use practices and vegetation cover have a considerable bearing on the contribution of "non-point" sources. Included in this area is the illegal discharge of private wastes and farmyard drainage to municipal drains. Although a quantification of flows and loadings from this source has not been attempted, studies indicate a significant burden of organics and nutrients are routed to the Thames and its tributaries via municipal drains.

4.3 RECREATION

Recreation covers a wide variety of activities undertaken by people in their spare time. It has been found that, on the average, people of Ontario have over five hours of free time per day with three-quarters of an hour of this time spent on recreational activities. Their diverse interests are exemplified by the fact that 73 recreational activities are listed in the Ontario Recreation Survey progress report by the Ontario Ministry of Natural Resources (1973). Some of the top ranked activities include recreational driving, swimming, fishing. picnicking. camping. hiking and canoeing with the most preferred being swimming, fishing and camping.

The Thames River watershed provides a variety of recreational opportunities ranging from passive non-consumptive to active consumptive practices. Lands under public ownership and administered by provincial, regional or municipal bodies in the Thames River watershed are geared in part towards water related recreation. The Upper and Lower Thames Conservation Authorities are the principal operators of recreational facilities, administering over 8,500 acres and 700 acres of land respectively. The three largest areas are found at Wildwood, Gordon Pittock and Fanshawe reservoirs, all of which have camping and swimming facilities. Estimated 1973 attendance was approximately 289,000 at Fanshawe, 149.000 at Wildwood and 42,000 at Gordon Pittock. In addition, facilities are available at 19 other conservation areas in the watershed for many other activities. The first provincial park in the watershed is now being developed in the Komoka-Kilworth area. The park. to occupy approximately 1,300 acres in the Thames valley about eight miles west of London. will be oriented to the needs of the urban users from the London area. Angling, walking, viewing and canoeing are foreseen as the principal river oriented uses within the park.

Municipalities in the basin provide a variety of day use areas. Large contributors are Stratford, with its park on Lake Victoria, and London, with its Springbank Park. There are 26 campgrounds within the watershed (23 of which are privately owned), bringing the total tent and trailer sites to approximately 2,200. The relative scarcity of camping facilities within the basin necessitates campers to rely on the provincial and private parks bordering lakes Erie and Huron.

The Thames River fishery resource is significant for its recreational value. It should be noted that species ranked as most preferred in public surveys (yellow pickerel. small mouth bass and northern pike) are extremely common in the Thames watershed. Minimum estimates by the Ministry of Natural Resources of the participation of anglers is approximately 200,000 angler days a year with a potential of 800,000 angler days or more a year, and over 40 percent of that effort is exerted on the three top rated species. Studies of the average amount of money spent for one angler-day in Southwestern Ontario indicate the value of the fishery in these terms is presently over $4 million and potentially over $17 million per year. This total is even higher when the contribution from the Thames River spawning grounds to the Great Lakes fishery is considered.

In certain parts of the watershed various forms of boating take place. Power boating occurs at Wildwood. Springbank Park. and in the lower reaches of the river as far upstream as Thamesville. There are two marinas in Chatham and one at Tilbury. Sailboating and canoeing are popular on the wider and deeper sections of the river, especially in the Fanshawe. Wildwood and Gordon Pittock reservoirs. Spring canoeing races on the river in the London and Chatham areas attract a large number of entrants.

At places where public access is available people hike, fish, picnic or view the scenery and the plant and animal life in the Thames valley. Winter activities such as skiing. skating and snowmobiling are provided on both private and public areas. Winter recreation. although limited due to relative) flat terrain and low snowfall, still attracts many users.

4.4 FISH AND WILDLIFE

Over 47 different species of fish have been captured in the Thames River basin. Yellow pickerel, small-mouth bass, northern pike, channel catfish and the group known as panfish all contribute to the sport fishery. The greatest variety of fish species occurs downstream from London where artificial barriers do not interfere with the movement of fish between river and lake environments.

The Thames River is the most important contributor to the Lake St. Clair-lower Lake Huron-western Lake Erie yellow pickerel fishery. Suitable spawning areas located on gravel-bottomed riffles as far upstream as London produce fish which in turn drift downstream to enter the lake. Most of the major spawning areas occur from Wardsville to the Komoka area. Channel catfish. white bass and freshwater drum are additional lake species which utilize the lower Thames for spawning. In upper branches of the Thames beyond London. the sport fishery is dependent upon resident species. maintenance stocking by the Ministry of Natural Resources, and impoundment fisheries. Fanshawe Lake and Wildwood Lake have sustaining populations of panfish and smallmouth bass: the Gordon Pittock Reservoir sustains northern pike. Although trout stocking programs have been relatively unsuccessful throughout the basin, it is hoped that the introduction of largemouth bass to the Sharon Reservoir will establish a viable fishery. Coldwater streams have become fewer over the years and only a few support rainbow, brook and/or brown trout populations.

A brief study of fish populations at 52 sites on the watershed in 1971, to provide an indirect indication of water quality, yielded a general inventory of species present. For the North Thames, smallmouth bass were found at 10 of the 18 stations sampled. The majority of smallmouth bass were limited to stations on the main stream. where they occurred at eight of nine stations between Mitchell and London. Rock bass replaced smallmouth bass as the dominant game fish in streams tributary to the North Thames.

In the Thames River between the Highway 97 bridge and the Pittock reservoir, smallmouth and rock bass were captured. However, with the exception of a solid representation of sports fish immediately upstream of Beachville, no further occurrence of smallmouth bass was found in the south branch of the Thames. Desirable species were captured upstream and downstream from Thamesford in the Middle Thames River and at the mouth of Waubuno Creek. Smallmouth bass, largemouth bass, yellow pickerel. channel catfish, white bass, carp and yellow perch are common catches in the lower reaches.

Although year-round use of the Thames by water oriented species of birds and mammals is limited. ravines and flood plains provide excellent habitat for a variety of wildlife species. Waterfowl habitat is adequate to support only small populations of birds and waterfowl. Breeding areas are restricted to the Wildwood and Gordon Pittock reservoirs. During spring and fall migration periods, many varied forms of migratory birds pass through and stop over in the Thames watershed. Large water areas and slow moving sections of the river attract waterfowl and shorebirds. Such occurrences are of great interest to naturalist groups and individuals. The Dorchester, Ellice and Zorra swamps have potential for increased production of waterfowl. Muskrats are common throughout the basin and the sale of muskrat furs constituted a major portion of the $42,000 received in 1972 by the 288 trappers licensed in Kent. Elgin and Middlesex counties. Species such as squirrels, chipmunks. field mice. cottontail rabbits, ruffed grouse. bob white quail, pheasants, raccoons, fox, mink, hawks, owls and white-tailed deer inhabit the river valley. Rabbit hunting accounts for over one-half of the small game hunting.

CHAPTER 5

PUBLIC CONSULTATION PROGRAM

The manner in which the public was consulted during the course of this study is described in a separate technical report by the Ministry of the Environment entitled, "The Public Consultation Program: Thames River Basin Study". The following is a summary of the findings and the conclusions drawn from these consultations. The discussion is presented in two sections corresponding to Phase I and Phase II of the Public Consultation Program. For more detailed information and data, the reader is referred to two other sources:

1. Report of the Environmental Hearing Board on public hearings regarding the Thames River Basin Study Bulletin: Ministry of the Environment: 1974.
2. Transcript of the public hearings regarding the Thames River Basin Study Bulletin: Ministry of the Environment; 1974.

5.1 PHASE I

This section summarizes the findings of Phase 1, which involved meetings with municipal and government officials and citizen groups, and the distribution of a questionnaire.

5.1.1 Water Resources

There was little concern expressed by all parties consulted with regard to water quantity in the Thames River basin. This item ranked consistently last on the list of water management priorities.

Water quality was a major point of concern for virtually everyone. Overall, water quality in the Thames River was perceived to range from "very poor" to "fair" with little or no change over the past ten years, with the following qualifications. Downstream from London to approximately Wardsville (Region 2) water quality was evaluated to be slightly poorer than other areas. Water quality within the City of London (Region 3) was seen to have improved somewhat over the ten-year period. This accurately reflects the fact that quality has improved since the city began its pollution control plant upgrading and expansion program some ten years ago. The quality of the Thames River (Region 4) was perceived to be deteriorating significantly. Water quality of the Avon River around Stratford (Region 5) was viewed to be deteriorating. Studies have shown that this is an area of relatively poor water quality. Water quality within Region 5, however, was reported ranging from "poor" to "good". This may reflect the headwaters nature of this region where few urban and industrial contaminants have yet entered the river.

Farmers, and to a lesser extent municipal officials, the large majority of whom live in non-urban areas, evaluated water quality to be somewhat better than the primarily urban general public respondents. This indicates water quality is perceived to be better in rural areas.

All Medical Officers of Health in the basin expressed concern with the health hazard presented by high levels of bacteria in the Thames surface waters and expressed the need for improved water quality to meet increasing recreational water uses. Urban and agricultural runoff, improper feedlot waste management and inadequate septic tank design and construction were cited as causes of bacterial contamination. Danger to health from bacterial water pollution also received strong and consistent emphasis as a major problem from the public throughout the study area.

There was some variation from region to region as to other water-quality related problems. Floating materials and shoreline debris—aesthetic pollution—were reported to be the major problem in Region 1, the lower portion of the river basin. Moving upstream to London, poor taste and odour and excessive growths of weeds and algae emerged as major problems with colour, floating materials, dead fish and shoreline debris as secondary problems. Excessive weeds and algae were viewed as major problems throughout the Thames and North Thames branches and "poor taste and odour" were seen as a major problem in the south Thames. Poor water colour was reported as a problem in the headwaters (Region 5).

Some water quality problems with well water were also reported by the Indian Bands of the lower Thames River and by Biddulph Township. Apparently nitrates have been found in this ground water. Woodstock and Ingersoll have reported sulphur in their well water, and Ingersoll in particular, expressed concern with securing an adequate water supply for its growing industry.

Combined and ranked. the major perceived problems in the basin are health hazard from bacterial pollution, excessive growths of weeds and algae and unpleasant taste, odour and colour, in that order.

5.1.2 Water and Related Land Uses

Statements as to both actual and desired uses of the Thames River basin water resources were solicited from the general public and municipalities. These were then compared to give an indication of which uses are adequately met and which are not.

Actual and desired water uses reported were highly consistent throughout the study area for all regions. The predominant actual uses reported are aesthetic. hiking, sightseeing and picnicking. while secondary uses are recreational. fishing, swimming and boating. Moderate use of the Thames River for irrigation and livestock watering was reported.

The most desired uses reported are those noted as aesthetic and recreational. Aesthetic uses appear to be adequately met. Swimming was reported as the most inadequately met use in all regions of the basin. Boating is also poorly met in all regions except Region 1 where the river is navigable from its mouth to somewhat beyond the City of Chatham. Fishing is reported to be inadequately met in the upper river basin, i.e. all areas upstream from Delaware.

With reference to recreational boating. two specific points were made repeatedly in Regions 1 and 5. In Region 1, erosion along river banks is a consistent problem. It was requested that boat wake control be imposed in order to reduce erosion caused by the many pleasure craft that navigate the channel downstream from Chatham. Wildwood Lake is the major water recreation area in Region 5. Many complaints were received about deteriorating water quality of this lake. It was repeatedly requested that motor boating be restricted to 10 hp or less, as it was argued that Wildwood Lake is simply not large enough to accommodate high powered motor boats.

While water uses reported are fairly consistent throughout the study area, some trends are distinguishable. The largely urban general public respondents placed a higher priority on recreational water and land uses than did the largely rural municipal official respondents. This latter group, while agreeing that improved and expanded recreational land and water use is a priority. placed more emphasis on water supply for domestic purposes than did the general public. The West Elgin Planning Council expressed concern at the high cost of regional water supply systems which they feel they have been forced into as a result of the poor water quality of the Thames River caused by upstream pollution. They suggest upstream polluters be assessed a portion of the resulting increased costs borne by downstream communities.

Closely related to recreation is protection of aquatic life and wildlife, which provides for fishing, hunting and also nature appreciation. The importance ascribed to protection of fish and wildlife varies somewhat from region to region. but when water management priority ratings were combined for the entire study area, fish and wildlife protection emerged as the third management priority after municipal and industrial waste treatment.

Some concrete suggestions to promote protection of fish, wildlife and unique natural areas were made. Preservation of the Ellice and Zorra swamps was urged and the planning of utility corridors to minimize land consumption for transportation and hydro uses was recommended. Also suggested was the creation of a river parkway, especially along the lower reaches of the Thames, and construction of smaller dams on tributaries of the main rivers for purposes of recreation and flood control to minimize the need for large dams which are perceived by the public to have a much greater ecological impact.

The land use priority in the Thames River basin as expressed in official plans for the area, where they exist, is unquestionably agriculture with the exception of those lands within existing urban municipal boundaries. Land use priorities expressed by the people of the watershed through the questionnaire and during interviews, are divided along the lines of urban and rural residents. Urban residents consistently gave priority to recreational land use while rural residents and farmers insisted upon the priority of agriculture as the major land use. People in urban areas however, did recognize the agricultural nature of the watershed by choosing agriculture as the second most important land use. Only in the City of London did residential land use receive a significant vote. Industrial and commercial land use was not considered significant in any region.

Rapidly increasing demands for recreation emphasize the above-stated need for improved water quality. Municipal and industrial wastes are perceived to be the major cause of water quality deterioration of the Thames waters. Agricultural runoff is also seen to be a major contributor to water pollution. Municipal and industrial waste treatment were rated as the top two priorities with strong consistency from one region to the next.

Domestic and agricultural waste treatment did not receive the same order of priority, being rated as fifth or sixth of ten water management items. However, some specific comments pointing to problems with agricultural waste management were frequently made. The need for more stringent control and monitoring of feedlot waste disposal practices was emphasized in Regions 4 and 5. Farmers themselves mentioned need for further study of the effects upon water quality of chemical fertilizer and pesticide applications to soil and the need to monitor closely municipal drain water quality to determine to what extent these waters are in fact polluted. Municipal officials urged stronger enforcement of environmental protection legislation and stiffer legislation where present laws are inadequate.

5.1.3 Water Management

The objectives of water management are to provide sufficient quantities of water of satisfactory quality for the above discussed uses and to provide adequate flood and erosion control. Several additional dams have been proposed to control flooding and to augment flow in summer months in the Thames watershed, and the people of the basin have had something to say about them.

Considerable opposition to the proposed Wardsville and Thamesford dams has been voiced by those who live in the area of the proposed dam sites. This opposition is based primarily on the reasoning that significant portions of prime agricultural land would be taken up by dams and their corresponding reservoirs: that it is inequitable to flood upstream lands for the benefit of downstream communities and lands which have been reclaimed from the floodplain initially: and that significant fish and wildlife habitat would be disrupted or destroyed by major dam construction. This is not to say that the need for flood protection is not recognized by the opponents of these dams, but they urged that every possible alternative to construction of major dams be investigated, including the following:

1. Construction of small dams on tributaries where less prime agricultural land would be taken up.
2. Preservation and restoration of natural water retaining land formations including swamps. This would also include a review of optimum levels of land drainage and municipal drain management.
3. Better operation of existing dams to maximize flood protection from these structures.
4. Restriction of all development in the floodplain.

After these alternatives have been investigated and if it is still decided to continue with major dam construction, a detailed benefit-cost analysis is demanded by the people who live in the areas of the proposed dam sites. While there has been no significant opposition expressed to the proposed Glengowan dam, the Township of Fullarton has asked to be provided with more details about the ecological effects and proposed operating policy of the dam.

Flooding is a problem the people of the Thames have lived with for many years. In many parts of the basin flooding has been minimized through established control programs. Residents in potential flood areas, in particular those in Ingersoll and that portion of the basin downstream from Thamesville, have clearly indicated that their first priority is to control this flooding.

A comment made several times throughout the meetings and hearings was that government policy must be better co-ordinated. In particular, it was suggested that the ministries of Agriculture and Food, Natural Resources and Environment, co-ordinate programs and policies within a given area to assure compatible objectives. Several municipalities, in particular those in the upper Thames basin, suggested the provincial government work more directly and establish closer liaison with municipalities in order to develop programs for specific areas. Finally, it was suggested that further research into erosion control programs be conducted and education programs be carried out using television.

Water management depends considerably upon the rate of growth in any particular area. The faster an area grows. the more people need to be serviced, the more industry requires water for its facilities and the greater the demands placed upon water resources in the area. Growth rate of the population in the Thames River basin has been fairly stable over the past 20 years at approximately 3 per cent/annum. From Phase I consultations with the people of the basin, it was concluded that the majority of people prefer to maintain the present growth rate. However, there was a higher preference for a decreased growth rate among respondents from the urban areas than from rural areas. General public respondents from urban areas expressed equal preference for a decreased growth rate as for continuation of the present rate. Municipal officials consistently expressed a greater preference for an increased growth rate than did the general public.

5.2 PHASE II

This section presents a summary discussion of the written and oral submissions made before the Environmental Hearing Board during Phase II of the Public Consultation Program (PCP). Hearings were held in five centres throughout the study area corresponding to each of' the five regions identified for the purposes of the PCP.

5.2.1 Region 1

Major presentations at the hearing in Chatham came from the Lower Thames Valley Conservation Authority (L.T.V.C.A.) and the agricultural community represented by the Ontario Federation of Agriculture and the Ministry of Agriculture and Food.

The interim bulletin noted major opposition to the Wardsville Dam, on the grounds that agricultural land would be flooded and the pickerel fishery and spawning grounds would be destroyed. In response, the L.T.V.C.A, stated that according to its proposed construction and operating policy, the dam would be considered as a flood control project only; would not impound waters for any significant length of time; therefore, would not destroy the fishery or spawning grounds and would only take up a small acreage of agricultural land at the dam site. The Authority's brief went on to support a reforestation program along stream banks to restrict cattle stream access and to protect against wind and river bank erosion. The Authority approves of a review of the operation of existing flood control structures in the Upper Thames Valley, with a view to maximizing flood control. The practicality of earth dike stabilization through vegetative protection is questioned in light of the wide variation of water levels of the Lower Thames River.

The agricultural community addressed itself to several statements made in the Water Management Bulletin. The statement that as much as 50 percent over fertilization occurs was questioned. Emphasis was given to the need for fertilization to yield high crop production in a time of world food shortages. Questioning of the statement concerning over fertilization was again encountered in later meetings at Woodstock and Stratford. Opponents stated fencing of streams could reduce land values up to 25 percent and if fencing did occur, it should be the government's responsibility to maintain the fences.

The Ontario Federation of Agriculture further noted that land drainage, within 24 hours, is essential for crop continuation and on that basis opposed any blocking or restriction of drainage ditches. The Federation recommended that further research be conducted in three areas with the following objectives: to determine the effects of dumping sewage sludge onto farmland; to develop techniques of controlling ditch erosion; to determine the quantity of land drainage relative to total surface waterflow.

In its report. the Environmental Hearing Board noted the agricultural community felt it was being made the scapegoat for water quality problems in the Thames River Basin. This feeling was also perceived throughout Phase I Consultations and suggests that more and closer communication among the ministries of Natural Resources, Agriculture and Food, Environment and farmers themselves is necessary.

5.2.2 Region 2

By far the major issue that concerned participants at the hearing in Glencoe was the proposed Wardsville dam project.

Opposition to the project was based on the views that agricultural land would be taken and fish and wild life adversely affected. It was also noted that major disruption of road communication by blockage of bridges between Elgin and Middlesex counties, during peak river flow could occur if the dam was constructed. It was recommended that this aspect be more closely considered.

The difficulty in obtaining land for the project from Indian Reservations and high costs relative to benefits of the project were also cited as reasons not to build the dam.

With respect to flood control, the Township of Aldborough, in a brief endorsed by Southwold and Dunwich townships, comments that continuation of dike improvements downstream, optimization of dam management upstream and construction of small dams on tributaries could go a long way towards relieving the flooding problem. This brief stressed need for continued upgrading of municipal and industrial waste treatment, and for controls over livestock operation to ensure good water quality. In the area of conservation, this Township recommended monitoring of sand and gravel operations and the preservation of wooded areas along the river. Finally, it was recommended that the Thames watershed be placed under a single conservation authority in place of the two that now exist.

5.2.3 Region 3

Briefs by the City of London, the Upper Thames River Conservation Authority (U.T.R.C.A.). the National Farmers Union (N.F.U.) and the Ontario Federation of Anglers and Hunters were given at this hearing.

London City's brief concerned itself with three major issues:

1. The cost of sewage treatment and other water management alternatives, particularly as they relate to the city.
2. Long term sewage assimilation policy with respect to the Thames River.
3. The pressures exerted upon and facilities available to basin communities from outside the watershed.

The City asked for an opportunity to respond to water management alternatives once benefit-cost figures were available and expressed the need for long term forecasts of sewage assimilation capacity of the Thames River for the purposes of its own planning needs. Examples of outside pressures and facilities affecting basin communities might population immigration and recreational facilities along nearby Great Lakes shorelines. London also questioned the feasibility of improving river waters to the level required to permit swimming and asked if it were possible to get more flow augmentation from the Gordon Pittock Reservoir. Many other comments and specific suggestions were made by the City in its brief to which reference should made for details.

The Upper Thames River Conservation Authority, in its brief, stated that flood control has always been the priority in the management of its reservoir program, and that in general, prime agricultural lands have not been taken up by reservoirs. Wherever possible, agricultural lands under the Authority's control are leased to neighbouring farmers to be continued in production. The Authority's brief expressed concern over water quality in reservoirs and asked for advice from the Ministry of Environment as to how water quality could be improved. Also, with respect to reservoir management, the Authority suggested that summer flow periods be carefully studied so that maximum flow augmentation may be provided to the extent consistent with other uses. The Authority considers proposed dams to be for flood control and flow augmentation purposes only and not for recreational development. The brief supported reforestation programs.

The National Farmers Union emphasized the need to "feed the people of the world" and therefore to maintain the maximum amount of arable land in production. This brief suggested control and shifting of populations to unarable land and plantation of as many trees as possible. where such planting does not interfere with agriculture. Industrial and residential sprawl must be stopped. especially near rivers, and dikes or walls would be the preferred means of flood control according to the N.F.U.

Mr. Chambers, of the Ontario Federation of Anglers and Hunters, cautioned against human intervention in the affairs of nature and opposed all dam construction in the interest of preserving fish and wildlife. The Federation, said, would prefer a diversion channel to Lake Erie over construction of the Wardsville dam.

A representative of the London Board of Education. Resource Centre for Science, urged the development of better education programs to teach conservation to school children.

The major concerns expressed at this hearing can be summarized as follows:

1. That a comprehensive approach be taken to urban growth and services in relation to quality of life and the environment, taking into consideration financial constraints upon urban municipalities.
2. That the maximum flood protection be provided from existing and proposed reservoirs.
3. That continued and increased agricultural production be a major land and water management priority, even if it means shifting populations to unarable lands.
4. That conservation and fish and wildlife preservation are important and speak against the construction of dams.

It should be noted that points (2) and (4) above are in direct contradiction to each other. Such conflicts indicate conflicting interests which are very real within the river basin community, and emphasize the need for open communication and discussion to arrive at mutually acceptable solutions.

5.2.4 Region 4

The major concerns expressed at the hearing in Woodstock dealt with water quality, the Gordon Pittock Reservoir. the proposed Thamesford Dam project and urban growth and sewage treatment.

With respect to water quality, it was felt that bacterial contamination and low oxygen levels in Cedar Creek, Gordon Pittock Reservoir and the Thames River were intolerable. To deal with these problems, upgraded sewage treatment, lake aeration and strict monitoring of water quality and enforcement of legislation were recommended. The deepening of Gordon Pittock Reservoir was also suggested to cool water temperatures and prevent the formation of unsightly sludge mats and algae blooms. Several speakers at the hearing recommended the City of Woodstock be restricted in its growth to ensure adequate servicing in future and to protect surrounding agricultural lands from urban sprawl.

The Union Drawn Steel Company, which holds land in the area of the proposed Thamesford dam project. indicated its concern that construction of the dam would flood its lands. thereby preventing the future mining of limestone deposits in the area. The company was supported in its recommendation that the dam not be constructed until after the limestone has been mined by Mr. Fleming. West Zorra representative to the U.T.R.C.A.

Complete drawdown of existing dams to maximize flood control and minimize the need for further dams and the implementation of a wetlands acquisition program for the same purposes was recommended. The development of educational programs for schools, libraries and other agencies in the basin was also suggested. Some criticism was levelled at the City of Stratford for polluting the Avon River. Complaints were heard about the unsightliness of Gordon Pittock and Wildwood reservoirs in the fall when they are drawn down to a low level.

5.2.5 Region 5

The major concern at the hearing in Stratford dealt with water quality of the Avon River, land drainage. conservation measures. urban growth restrictions and Wildwood Reservoir.

Several briefs presented urged a variety of conservation measures including the following:

1. The construction of many small dams rather than a few large ones to provide flood control and recreation areas.
2. The preservation and restoration of wetlands. especially the Ellice Swamp, to maintain groundwater levels and help provide flood control.
3. The fencing of streams and restriction of cattle access to streambed areas underlain with gravel. Farmers questioned this suggestion and wondered who would be responsible for construction and maintenance of the fences and how far back from the stream's edge fences would be constructed.
4. The planting of riverbank vegetation to protect against erosion and provide wildlife habitat.

The City of Stratford was singled out as the cause of severe water quality problems in the Avon River and it was urged that the City do something to improve the quality of its sewage effluent. In the City's defence, the City Engineer noted the main problem was one of low flow and that the City was doing everything that it could to provide good sewage treatment. Related to this, the Stratford Citizens for the Environment recommended the City not be allowed to grow further, in view of the already strained water resources and the need to protect agricultural land from urban encroachment.

Some comments were made concerning the Wildwood reservoir. In particular. it was noted the only causes of reservoir water quality degradation could be from agricultural land runoff and motor boats on the lake. It was recommended that over-fertilization be investigated and controlled and that motor boats on the lake be restricted to 10 HP or less.

The U.T.R.C.A. was criticized for allowing motor boats on the clean upriver waters at Wildwood while restricting them on the dirtier downstream waters at Fanshawe Lake.

5.3 CONCLUSIONS

As is apparent from a review of the findings of the Public Consultation Program, the residents of the basin have diverse and frequently conflicting views concerning water resource problems in the basin and proposals for their solution. Disagreements exist on certain issues between groups, such as the farming and urban communities, and even within occupational groups. depending on the location in the basin.

As pointed out in the Report of the Environmental Hearing Board on public hearings in the Thames River basin, water quality was the common concern. Water management priorities stated by the people of the basin indicate that improvement of water quality should be a major priority of any management program for the Thames River watershed. More specifically. a reduction in bacterial contamination of waters and an improvement of those parameters affecting fish life and the aesthetics of the river are desired.

The next item receiving most consensus was that of water and related land use. It was agreed that agriculture is the overall primary land use in the watershed. Nevertheless, more facilities for recreation, particularly swimming, were consistently reported to be a primary need. especially near high population density areas. and water uses reported show that recreation uses are inadequately met.

One of the major concerns which instigated the Thames River Basin Study was that of flooding. While the importance of flood control was definitely given more emphasis by public officials, it is clear that the general public is also concerned with this factor, especially in the Lower Thames valley. However, the public is apparently not convinced that major dam construction is the best means of flood control as evidenced by the considerable opposition voiced against the proposed Wardsville and Thamesford dam projects and also by the frequent suggestions of alternate means of flood control. It was asked that consideration be given to alternatives to major dams, such as small dam construction, and that the feasibility of a wetlands acquisition and preservation program be investigated. In this connection, special mention was made of the Ellice and Zorra swamp.

The main reasons given in opposition to major dam construction were related to preservation of fish and wildlife and agricultural land. Even in areas where dam construction was not an issue, however, more widespread, visible and forceful conservation measures were urged, specifically with respect to wetlands preservation, development of more brushland and woodlots in the basin, and designation of utility corridors for highways, railroads and power transmission lines.

Many comments were received and much discussion was entertained concerning the effects of the agricultural industry and farming practices upon the water resources of the basin. Most frequently mentioned were practices of land drainage, municipal drain management, erosion control, intensive livestock operation waste management, stream fencing, farm pond management and application of chemicals to soil and crops. These matters were not investigated in the course of the study to any great extent. From comments received, it can be concluded that further detailed study should be made of these matters, as discussed in Chapter 7 of this report.

It was frequently stated that much could be achieved if only those in a position to do something to prevent water pollution and erosion were familiar with the most up-to-date findings and techniques. In this regard, it was suggested that highly visible education programs using all media be developed to teach conservation techniques in general, and in particular, to promote erosion control and ecologically sound farming techniques.

While education was considered to be an important tool for an improved environment, it was frequently stated that this was not enough and that stricter enforcement of legislation was required. It was felt that there was simply no adequate mechanism of tracking down and penalizing offenders. It was frequently recommended that stricter enforcement of the Environmental Protection Act and Ontario Water Resources Act be implemented.

The Public Consultation Program also addressed itself to the question of rate of growth within the watershed. The report of the Environmental Hearing Board points out that restrictions on large urban developments when more sophisticated sewage treatment processes have been utilized must be considered. According to PCP results. the general public seems more likely to accept restricted growth than do municipal officials.

Among many other points raised during the PCP was that of provincial-municipal liaison. Municipalities were most receptive to the approaches of the study team for consultation and urged that such liaison continue and be expanded to include all provincial programs and studies affecting them.

CHAPTER 6

WATER RESOURCE PROBLEMS

6.1 SURFACE WATER QUALITY IMPAIRMENT

Problems related to the quality of surface water have been identified as the major water resource problem in the watershed. The results of the Public Consultation Program showed that this view is shared by residents of the basin, and that water quality was the only concern for which there was an obvious consensus of opinion throughout the watershed.

Cause-and-effect situations concerning water quality problems frequently involve complex inter-relationships. For example. Figure 6.1 shows the eventual effect of urban and agricultural activity on aesthetics and fisheries in the watershed. In the example, nutrients from urban and rural sources over-fertilize the stream, resulting in profuse growths of algae and aquatic plants in summer when other conditions are favourable for growth. Excess aquatic plants are unsightly and adversely affect the aesthetics of the watercourse. As aesthetic enjoyment is a subjective measure, quantitative analysis of this effect is difficult. However, the effect of excess plants and algae on dissolved oxygen levels in the stream is quantifiable. and the resulting effect on the fishery can be identified. Plant life, together with organic wastes from urban and rural sources which utilize oxygen in the river in the process of decomposition, also adversely affect the fishery. Although the example is simplistic compared to reality, it demonstrates the complexity of the situation.

Water quality problems are most severe in summer months when a combination of natural and man made factors magnify adverse water quality effects. Lack of river bank vegetative cover, increases in sunlight energy and excess quantities of plant nutrients provide ideal conditions for aquatic cover and algae growth. The steady build-up of plant biomass is typically accompanied by a steady recession of natural

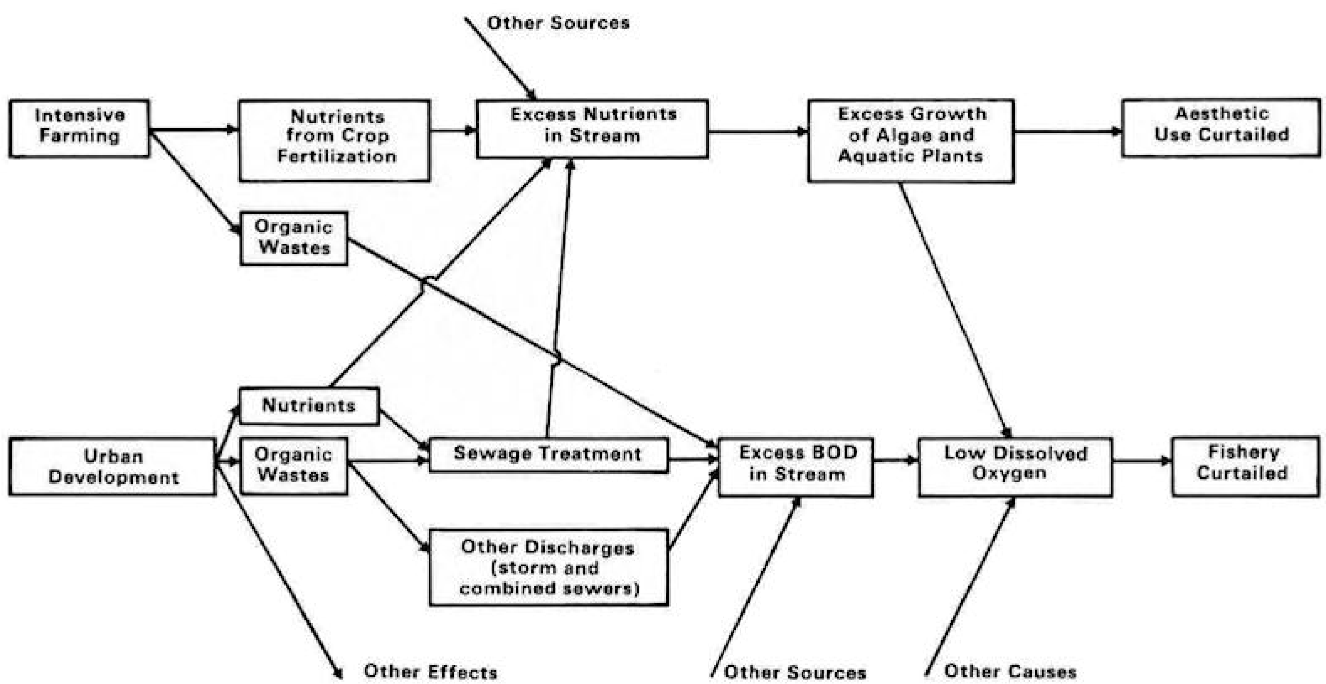


Figure 6.1: Effect of urban and agricultural activities on aesthetics and fisheries in the Thames River basin.

streamflows which magnifies the effects of the biomass. and also provides less water to dilute waste materials continuously discharged from urban and rural areas.

Water temperature increases in summer and causes increased respiration rates of all organisms in the water. At the same time, oxygen saturation values decrease with increasing temperature so that less oxygen is available in the water for the competing organisms.

The combined meteorological, physical. and biological conditions described above can lead to crucial stress conditions for fish life. Symptomatic of extreme stress conditions in the aquatic environment is the sudden localized appearance of large numbers of dead fish. In the five year period from 1969 to 1973, 22 fish kills were reported and investigated in the Thames basin. Five were caused by accidents associated with farm operations and an additional four were caused by inputs from industries related to agribusiness (fertilizer plants. etc.). Discharges from other industries accounted for four fish kills while municipal and private wastes caused three. Natural phenomena (high water temperature, parasitism, etc.) and undetermined causes accounted for the remaining six fish kills.

Water quality impairment can be described by comparing measured water quality conditions to water quality criteria. Criteria are scientifically established numerical or verbal descriptions of the water quality required for particular uses. Existing criteria are contained in the booklet "Guidelines and Criteria for Water Quality Management in Ontario", published by the Ontario Ministry of the Environment.

The two major trends in the basin of urbanization and intensified agricultural practices are the underlying causes of surface water quality impairment. The problems are manifest as an excessive input of nutrients, oxygen consuming materials, bacteria, toxic materials and suspended solids. A general description of the sources and effects of these material inputs is given below, followed by a detailed evaluation of water quality by stream reach in Section 6.1.7.

6.1.1 Nutrients

Urban Sources

From urban areas, nutrient materials such as nitrogen and phosphorus originate from treated sanitary and industrial effluents and from surface runoff and the bypassing of sewage treatment plants during storm conditions. Municipal sewage facilities in the Thames basin now reduce phosphorus concentrations to 1 mg/L to conform to International Joint Commission guidelines for the protection of the lower Great Lakes. However, the remaining phosphorus plus the input from urban runoff, especially during storms, may be adequate to support troublesome levels of aquatic weed growth. The significance of the timing of such inputs is discussed in more detail in Chapter 8.

Nutrient inputs have resulted in unsightly masses of aquatic vegetation and critical fluctuations in dissolved oxygen downstream from several municipalities. Notably bad stretches of the watershed in this regard are the Avon River downstream from Stratford, the North Thames River below St. Marys, the Thames River from Woodstock to Beachville and localized areas within London.

Rural Sources

Fertilizing agents such as nitrogen and phosphorus gain access to watercourses in the basin from municipal drains, field tile and surface runoff, and from rural industrial concerns which may generate such wastes. These materials originate as fertilizers leached from the soil, animal wastes applied to fields prior to or during spring thaw, drainage of such wastes from feedlot compounds. and nutrients associated with soil particles eroded during periods of high flow or heavy precipitation.

The previously noted trend to intensive livestock operations and a steady reduction of improved pasture traditionally used to support livestock and poultry has resulted in increased manure handling costs, so that manure now frequently constitutes a disposal problem to farmers, rather than an asset as a fertilizer. Other changes in agriculture such as monoculture of specialized feed crops and the growing use of commercial fertilizers have also occurred (Bangay. 1974).

These factors, together with the Thames basin climate (a cold winter season followed by rapid spring runoff) have increased the danger of nutrient runoff in spring during snow melt (often under frozen ground conditions), and in summer during high intensity storms.

Phosphorus and nitrogen can reach streams from agricultural land in a variety of ways, but as most soils have a high potential for fixing phosphorus, soil erosion is the most significant mechanism in rural areas for the transport of phosphorus to surface waters.

Nitrogen is largely water soluble and can readily reach streams by infiltration through the soil and percolation via shallow ground water, or through interception by tile drains. In a study of nitrogen concentrations in tile drain effluents, it was found that fertilization of land with continuous corn planting, resulted in a 100 percent increase in nitrogen in the effluent compared to unfertilized conditions (Bolton, Aylesworth, Hore, 1974). Nitrogen can also gain ready access to a stream if manure or commercial fertilizers are applied to frozen or saturated surfaces. Two areas significantly enriched by nutrient inputs from rural areas are the Avon River upstream from Stratford and Medway River above London.

Effects

As in terrestrial plant culture, nutrients act as "fertilizers" and promote the excessive growth of aquatic plants and algae. In the presence of abundant sunlight and with suitable physical conditions of temperature, substrate, and current, growth of aquatic plants is limited only by space. This leads to problems of wide fluctuations in dissolved oxygen and aesthetic problems described in Section 6.1.

Nutrient Budget

As part of the water quality study of the Thames River, streamflow and levels of nutrients were monitored routinely at several locations in the system throughout 1972. Regular surveillance of point source inputs of phosphorus and nitrogen was also maintained to allow determination of the relative significance of urban loads and rural runoff as contributors to the system. The budget or balance of total phosphorus and total nitrogen is described in detail in Appendix G and summarized in Table 6.1.

Table 6.1: Summary of the Nutrient Budget-Thames River [1]

(a) Total Phosphorus Budget - (Thousands of pounds year)

	Point Source		Diffuse Source		Total	Reservoir	Net
Section	Load	% Total	Load	% Total	Load	Storage	Load
North Thames R.	70.3	*23.2*	234.2	76.8	303.6	109.1	195.5
Thames R-S. Br.	73.1	47.6	80.5	52.4	153.6	0	153.6
London Area	282.7	47.6	310.3	52.4	593.1	-	593.1
Lower Thames	70.1	8.4	765.0	91.6	835.1	-	835.1
Total	496.3	26.3	1390.1	*73.1*	1886.3	109.1	1777.2[2]

(b) Total Nitrogen Budget - (Thousands of Pounds/Year)

	Point Source		Diffuse Source		Total	Reservoir	Net
	Load	% Total	Load	% Total	Load	Storage	Load
North Thames R.	201.3	3.1	6395.5	96.9	6596.8	313.4	6283.4
Thames R-S Br.	219.3	4.5	4688.6	95.5	4907.9	0	4907 9
London Area	1309.1	36.5	2275.6	63.5	3584.6	-	3584.6
Lower Thames	199.7	1.0	20416.7	99.0	20615.7	-	20615.1
Total	1943 6	5.4	33761.7	94.6	35705	313.4	35391.7[2]

North Thames River - Area upstream from FanShawe Dam
Thames R-South Branch- Area upstream from city limits of London
London Area - Area drained to river by London (including Medway River)
Lower Thames-Area downstream from London
[1] Based on 1972 data. [2] Discharged to Lake St Clair

It should be noted that the data are based on surveys prior to the implementation of the phosphorus removal program at municipal sewage treatment plants. The budget indicates that 74 percent of the total phosphorus and 95 percent of the total nitrogen load or burden in the watershed comes from diffuse sources.

Diffuse sources are defined as sources other than point source discharges from treatment plants and include the diffuse load from urban runoff. It is estimated as shown in Appendix G, Table G4, that in 1972, Wildwood and Fanshawe reservoirs "trapped" 47 percent and 35 percent respectively of the phosphorus and 1.3 percent and 5 percent, respectively of the nitrogen loadings entering the reservoirs. The North Thames River (excluding sources from London) contributed 304,000 lbs. per year of the total phosphorus load and 6.6 million lbs. per year of the nitrogen load. Point sources accounted for only 15.8 percent of the phosphorus burden and I.7 percent of the nitrogen input. In contrast to the North Thames, the Thames River above London contributed considerably lower total loadings of both nutrients but the proportion from point sources was much more significant. Essentially, half of the 154,000 lbs. of phosphorus and 1/20 of the annual total nitrogen burden from the south branch of the Thames River originated from point sources, particularly from the Woodstock area.

Inputs from sewage treatment facilities in the City of London accounted for 16 percent of the total phosphorus net load to Lake St. Clair. It is important to note that requirements in effect in 1974 will reduce phosphorus loadings in discharges from municipal sewage treatment plants.

In an unpublished study by Agriculture Canada on Fertilizer Nutrients and Animal Husbandry Operations, a comparison of fertilizer sales statistics with recommended rates for different crops grown throughout Ontario showed the amount of fertilizer sold was twice that required to meet recommended rates in four out of five counties in the Thames River basin. As the data were derived by indirect methods. the study results should be considered as approximations rather than exact estimates. It is obvious, however, that fertilization beyond recommended rates is a general practice. When the combined input of manure and fertilizer nutrients were considered, East Zorra Township in Oxford County, and Camden and Howard townships in Kent County appeared to present high potential nutrient contributions from agriculture. The townships of Blandford and Harwich also showed a high total manure and fertilizer density.

A series of samples from municipal drains in the Township of East Zorra indicated that levels of nutrients far exceeded the concentration known to support nuisance amounts of aquatic plants. Additional studies will be required to determine whether these findings are representative of conditions throughout the basin. However, the results of the East Zorra study demonstrate that rural areas can be significant sources of nutrient inputs to the Thames drainage system.

6.1.2 Oxygen Consuming Materials

Urban Sources

Oxygen consuming materials from urban sources originate from treated sanitary and industrial sewage discharges and combined or separate storm sewage inputs. Average BOD_5 loadings from sewage treatment plants are presented in Table 4.2 in Chapter 4. At most sewage facilities in the basin, 90 percent of the BOD is removed. Unrecorded urban runoff has been documented as roughly equivalent to the load produced by a secondary sewage treatment plant servicing the same population (Whipple, 1974). These two sources contribute to oxygen depletion near several Thames River municipalities.

One form of oxygen demand not necessarily measured by the BOD_5 test is the demand of unoxidized forms of nitrogen (organic and ammonia nitrogen). Treatment plants in the Thames basin vary in the degree to which they oxidize this portion of the oxygen demand. In some cases, the nitrogeneous oxygen demand represents a large proportion of the total oxygen demand. To date, no treatment objective has been stated for this constituent of sewage.

Critical oxygen levels partially attributable to municipal wastes were observed in the Avon River below Stratford, through London downstream from the Adelaide, Vauxhall and Oxford sewage facilities, and in the Thames River below Woodstock, Ingersoll and at Chatham. Unrecorded urban runoff including sewage bypasses during storms are critical sources of organic wastes from Woodstock, Chatham, Stratford and London.

Rural Sources

Problems relating to inputs of oxygen consuming materials from rural areas are localized in the watershed and are limited to: illegal septic tank connections to municipal drains; inadequate precautions in the management of livestock wastes; and careless handling of highly organic feeds such as corn silage. Treated effluent of industries in rural areas, such as Campbell Soup Company Limited in Blanshard Township, represent an additional source of oxygen consuming materials. Algae and weeds consume oxygen when they decay and thus contribute to the BOD in the river.

Inputs of oxygen consuming materials from rural areas have led to isolated water quality impairment problems at several locations in the basin. Oxygen depletion because of the input of highly organic silage and livestock waste from a feedlot has resulted in three documented fish kills in the period 1969-73. Accidental spills of dairy wastes and decomposing grains from a feed mill caused two additional incidents of fish mortality during the same period.

Effects

Oxygen consuming materials represent one of the major oxygen demands in the Thames River system. The decomposition of organic material is achieved through the action of bacteria. The respiratory demand exerted by large bacterial populations can reduce oxygen levels in the receiving stream to concentrations critical to fish and aquatic life. Bacterial populations decrease with progress downstream as their food supply is gradually used up, so that oxygen depletion due to bacterial respiration is usually a localized phenomenon.

Superimposed on the oxygen demand associated with organic decomposition is the photosynthesis-respiration phenomenon. While oxygen may be added to the stream by aquatic plants during daylight hours. respiration by these same plants during darkness often results in temporary oxygen depletion.

Where oxygen is depleted to critical levels in surface waters, fish are asphyxiated and desirable fish-food organisms are eliminated. Under less critical conditions, reduced dissolved oxygen levels represent a stress on fish. The presence of other stress factors such as toxic materials or high temperature can combine to be lethal, or to severely reduce fish reproduction.

6.1.3 Bacteria

Urban Sources

Bacterial contaminants from urban sources originate from sewage treatment plant effluents, discharges from storm sewers and combined sewers during storms, and illegal discharges of sanitary wastes directly to watercourses and storm sewers. As a result of ineffective chlorination or bypassing of combined sewerage systems, bacteriological impairment of surface waters from urban sources has occurred in minor proportions at Mitchell and in major proportions at Woodstock, Beachville, Glencoe and Chatham. Within London, the Adelaide and Vauxhall sewage treatment facilities along with drainage from Medway River caused increased bacterial levels. Although chlorination of the Greenway and Oxford STP effluents reduced bacterial concentrations in the river. levels still exceeded guidelines for body contact recreation behind the Springbank Dam. Aftergrowth (regrowth of bacteria following chlorination) was evident downstream from London and Stratford.

Rural Sources

Rural sources of bacterial contamination include runoff from intensive livestock operations. defecation by livestock directly into streams, and illegal connections of individual septic tank systems to municipal drains. The East Zorra municipal drain study revealed widespread bacterial contamination, primarily of livestock origin, through the entire drainage area. Although only one other rural area, the Avon River upstream from Stratford. was clearly documented as contributing to bacterial water quality impairment, such contamination is considered to be widespread throughout the basin.

Effects

The abundance of coliform bacteria has long been used to evaluate water quality in relation to public health. Although coliforms are not normally regarded as pathogenic, their presence in water indicates the potential presence of scarcer. and much more difficult to isolate, pathogenic organisms such as those causing typhoid fever, dysentry and cholera. Other pathogenic bacteria detrimental to public health can cause a variety of physiological disorders, such as minor skin infections, or ear, eye. nose and throat infections. Direct discharge of animal manures to watercourses can be hazardous to the health of both animals and humans if the receiving water is used for drinking or bathing.

6.1.4 Toxic Materials

A detailed study of toxic materials was not included in the basin study. In general, however, problems relating to materials toxic to aquatic life do not appear to be common in the watershed. Most documented occurrences of discharges causing acute toxicity have been the result of accidental incidents such as ammonia spills or sewage treatment plant breakdowns.

Urban Sources

One possible toxicity problem relating to urban sources is the effects of free chlorine and chloramines from sewage treatment plants on fish and aquatic life. Also, heavy metals and cyanides from industrial inputs to London's Vauxhall sewage facility caused a severe fish kill in the south branch of the Thames River in 1969.

Rural Sources

Toxic materials from rural sources gain access to watercourses through the careless handling of pesticides and potent fertilizers such as aqueous ammonia. From rural sources, three accidental spills of aqueous ammonia and a single incident involving the careless handling of pesticides resulted in fish kills in the Thames basin in the period 1969-1973.

Effects

Depending upon the toxic agent, its chemical form. its concentration. and the quality and flow of the water to which it is discharged. effects on aquatic life may vary from sub-lethal to acute. Acute toxicity results in the direct mortality of organisms. Sub-lethal effects include reduced spawning success or impaired growth rates in fish.

Although detailed studies of residual chlorine conditions in the Thames basin have not yet been undertaken, the chlorinated sewage effluent of the London Greenway Plant created conditions toxic to aquatic life on a minor scale. Although disinfection for the protection of public health is achieved. it has been shown that total chlorine residual concentrations as low as 0.01 mg/L would harm sensitive fish species and important fish-food organisms (Brungs, 1973). Total chlorine residuals as far as 900 feet and 300 feet downstream of the Vauxhall and Greenway sewage treatment plants respectively exceeded this level. Studies by the Ministry of the Environment are presently underway to determine the optimum rate of chlorine application to achieve both public health protection. which is the paramount consideration, and protection of fish and aquatic life. In the case of new sewage treatment plants. protection of fish life may influence the location and type of disinfection procedure used. Additional studies are in progress to evaluate possible alternatives to chlorine as a disinfectant.

6.1.5 Suspended Solids

Urban Sources

Suspended solids from urban sources appear in storm and combined sewer runoff during storm events. and in effluent from sewage treatment plants, which normally remove 80 to 90 percent of the suspended solids. Solids may be organic or inorganic in nature.

Rural Sources

Erosion of soil from cultivated land, elimination of soil stabilizing vegetation along watercourses to maximize acreage in production. and unrestricted cattle access to streams contribute significantly to the production of turbid surface waters in the basin. Construction activities, such as the installation of drains, and stream crossings, such as pipelines, are also a source of suspended solids. Natural erosion of the streambed and banks also contributes to turbid conditions. particularly in the lower basin from Muncey to Wardsville, where the river flows through a clay plain.

Effects

Suspended solids in a watercourse render the water aesthetically displeasing because of the resultant muddy appearance. Subsequent deposition of the material can foul the stream bottom and endanger fish spawning beds. Organic solids from sewage treatment plants, storm sewers and combined sewers, which can represent a significant oxygen demand, often settle out to form sludge banks in slow moving sections of the river. It can be interred from modelling studies that a respiratory demand is exerted by bottom deposits accumulating behind London's Springbank Park Dam and at Chatham.

6.1.6 Effects of Reservoirs on Water Quality

Dam construction on watercourses can have significant effects on water quality and use.

A new dam usually results in the flooding of fertile topsoil previously unexposed to the watercourse. The additional nutrients in the topsoil enrich reservoir waters and ultimately downstream reaches.

In retarding flow and exposing a greater surface area to the sunlight, reservoirs have the effect of increasing water temperatures both within the reservoir and downstream. Temperature increases in the impoundment contribute to an accelerated development of bacteria, algae and micro-organisms parasitic to fish. Such proliferations often cause interference with recognized uses of impounded waters such as swimming, aesthetics and fish culture. An upward shift in the downstream temperature regime can result in a simultaneous shift in aquatic life forms from cold water trout associations to warm water bass and sucker populations.

Depending upon physical conditions, many reservoirs become thermally stratified during the summer storage period and bottom waters can become low in dissolved oxygen levels and critically high in concentrations of many other parameters. Surface waters contain satisfactory' oxygen levels as a result of photosynthetic activity by phytoplankton populations which often multiply to troublesome levels. Discharge of bottom waters releases cooler, but more highly enriched, oxygen-depleted and organic waters to downstream reaches. These characteristics plus elevated levels of products of decomposition can create toxic conditions downstream. Surface discharge results in the release of algae laden water which, as the algae cells decompose. exerts an organic burden on downstream dissolved oxygen levels and causes nutrient release.

Reservoirs can be managed to minimize their effects on water quality within and downstream from the structure. Each must be reviewed individually since internal and downstream water use and physical characteristics vary among different locations and reservoirs. It is imperative that these factors are determined well in advance of construction so structural modifications may be incorporated in reservoir plans to minimize or avoid use interference.

6.1.7 Evaluation of Water Quality by Stream Reach

Previous sections of this chapter have outlined in general terms the sources and effects of materials which impair surface water quality. In the following section. the existing water quality in the Thames River and its major tributaries is evaluated for five parameters and illustrated in Maps 4 to 7. Map number 4 also shows the location of sewage treatment plants. The information is based on studies of chemical, bacteriological and biological surveys conducted during the period 1970-73 and reported in separate technical reports.

North Thames River and Tributaries

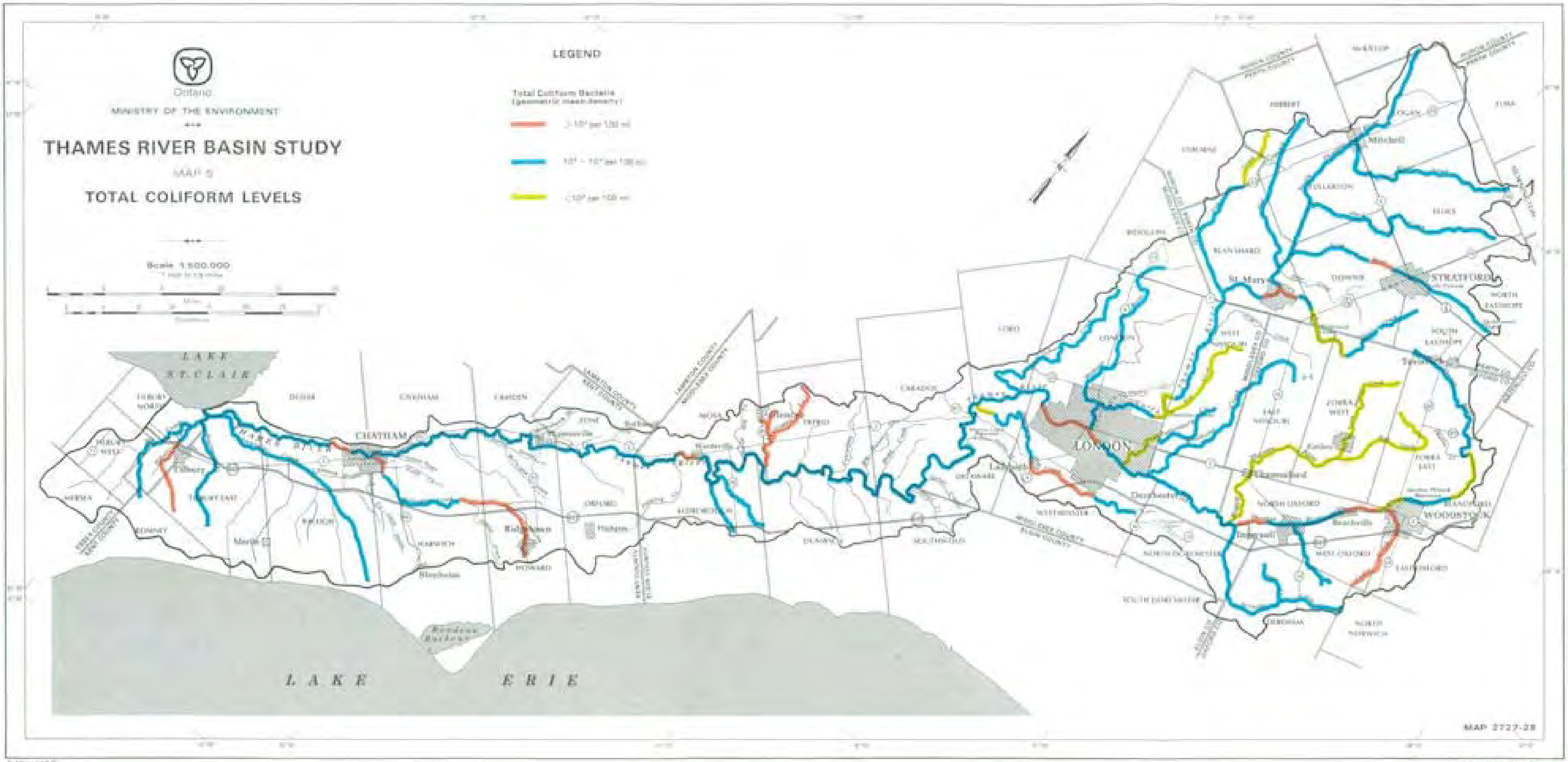
Upstream from Mitchell, bottom fauna associations contained a good variety of pollution intolerant forms but the small populations suggested intermittent streamflow. Water quality in the Mitchell reservoir presented a health hazard in the summer of 1973. forcing prohibition of its use for swimming and bathing. Populations of bottom dwelling organisms downstream from Mitchell were low, probably the result of intermittent streamflow. This factor also contributed to the depression of levels of dissolved oxygen well below the 5 mg/L guideline downstream from Mitchell. Levels of nutrients and bacteria increased significantly below the Town. The water quality of the North Thames River gradually improved from below Mitchell to the confluence with the Avon River.

Immediately upstream from St. Marys, the waters of the North Thames were rich in nutrients but because of physical stream characteristics, contained adequate levels of dissolved oxygen. From St. Marys downstream to Fanshawe Dam. biological and chemical parameters reflected a nutrient rich environment. This condition was indicated by a disruption of the biological community, excessive aquatic weed growth and extreme dissolved oxygen fluctuations. The level of dissolved oxygen fell well below the 5 mg/L guideline to 1.7 mg/L downstream from St. Marys although qualitative recovery in bottom fauna communities was evident at the Highway 7 bridge. Bacteriological degradation found in St. Marys was attributed to malfunctioning septic tank systems. Since the time of the survey, the Town of St. Marys has constructed new sewage treatment facilities, and downstream water quality has improved.

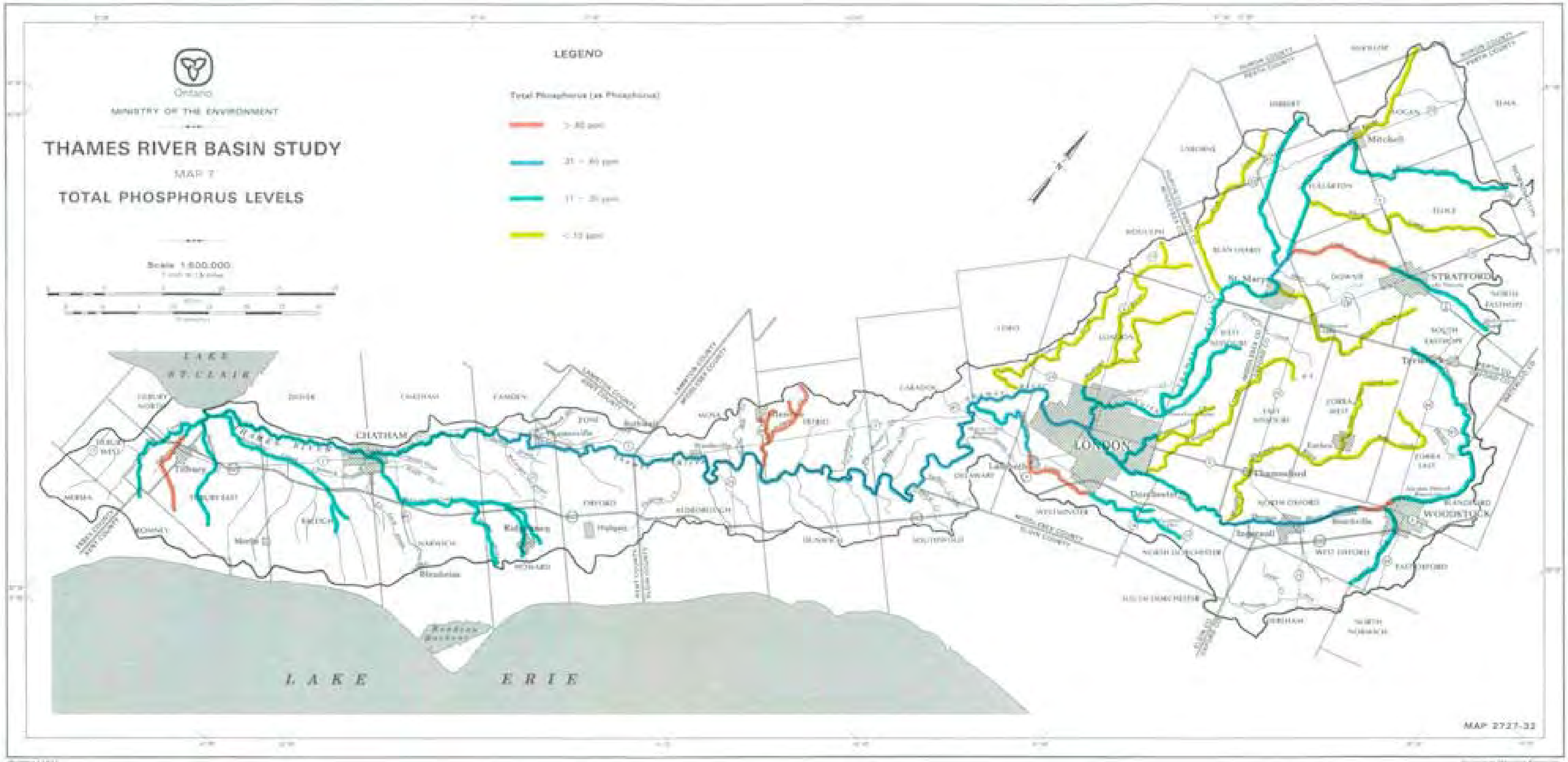
Nutrient rich waters of Fanshawe Lake were found to support average summer phytoplankton populations equivalent to those of western Lake Erie. On occasion. severe algae blooms have interfered with recreational use of the reservoir. Low concentrations of dissolved oxygen occur in deeper waters of the impoundment during summer months. As indicated by heavy growths of aquatic weeds, impaired bottom fauna associations, increased bacterial counts and substandard dissolved oxygen levels, water quality was impaired downstream from the Adelaide sewage treatment plant to the North Thames mouth, although considerable recovery of aquatic life occurred at Blackfriars Bridge. Additional oxygen demand exerted by waste materials discharged by the Adelaide sewage treatment plant, coupled with diurnal dissolved oxygen fluctuations attributable to the extensive algal growth in the river, caused violations of dissolved oxygen guidelines.

Degradation of the Avon River starts upstream from Stratford. where high bacteriological levels exist from human and animal sources. and heavy growths of algae have been noted. However, the greatest variety of fish at any station on the North Thames was exhibited upstream of the City, an indication of at least satisfactory dissolved oxygen concentrations. Although some nutrient removal occurs in Lake Victoria, nutrient levels increased below the City. Extended low summer flows in the Avon River have contributed to


Ontario
MINISTRY OF THE ENVIRONMENT
THAMES RIVER BASIN STUDY
MAP 4
BOD5 LEVELS AND
WASTE TREATMENT PLANTS
Scale 1:500,000
LEGEND
BOD5
> 4 ppm
2 – 4 ppm
< 2 ppm
Treatment Plants
Sewage treatment plant
Seasonal lagoon
Continuously discharging lagoon
Discontinued 1972
LAKE ST. CLAIR
THAMES RIVER
CHATHAM
Tilbury
LONDON
Dorchester
Thamesford
Ingersoll
WOODSTOCK
STRATFORD
St. Marys
Mitchell
LAKE ERIE
MAP 4
BOD5 LEVELS AND WASTE TREATMENT PLANTS
MAP 2727-29


Ontario
MINISTRY OF THE ENVIRONMENT
THAMES RIVER BASIN STUDY
MAP 5
TOTAL COLIFORM LEVELS
Scale 1:500,000
LEGEND
Total Coliform Bacteria (geometric mean density)
$>10^4$ per 100 ml
$10^2 - 10^4$ per 100 ml
$<10^2$ per 100 ml
LAKE ST. CLAIR
THAMES RIVER
CHATHAM
Tilbury
Ridgetown
LONDON
St. Marys
Mitchell
STRATFORD
Thamesford
Dorchester
Ingersoll
Beachville
WOODSTOCK
LAKE ERIE
MAP 2727-28

Ontario
MINISTRY OF THE ENVIRONMENT
THAMES RIVER BASIN STUDY
MAP 6
TOTAL NITROGEN LEVELS
Scale 1:600,000
LEGEND
Total Nitrogen
> 8 ppm
5 - 8 ppm
3.5 - 5.0 ppm
< 3.5 ppm
LAKE ST. CLAIR
THAMES RIVER
CHATHAM
Tilbury
Ridgetown
LONDON
St. Marys
Mitchell
STRATFORD
Thamesford
Dorchester
Ingersoll
WOODSTOCK
LAKE ERIE
MAP 2727-30


Ontario
MINISTRY OF THE ENVIRONMENT
THAMES RIVER BASIN STUDY
MAP 7
TOTAL PHOSPHORUS LEVELS
Scale 1:600,000
LEGEND
Total Phosphorus (as Phosphorus)
LAKE ST. CLAIR
CHATHAM
LONDON
STRATFORD
WOODSTOCK
Mitchell
St. Marys
Tilbury
Ingersoll
Dorchester
LAKE ERIE
MAP 2727-32

the frequent recurrence of poor water quality downstream from the City of Stratford, where streamflow is almost totally derived from treated sewage effluent. Bacteriological levels decreased below Stratford as a result of the chlorine residual in the treated sewage effluent, but were still at sufficiently elevated levels to preclude swimming and bathing. Heavy beds of algae and aquatic weeds persist downstream from the Stratford sewage treatment plant to the confluence with the North Thames River. Extreme daily high and nightly low levels of dissolved oxygen were observed below Stratford. Variety in fish populations was markedly reduced and preferred species were rare or absent at stations downstream from the City.

Trout Creek—Wildwood Reservoir is located on this tributary. Flow entering the reservoir contains elevated levels of bacteria but is otherwise of excellent quality within and downstream from the reservoir. Levels of bacterial organisms decrease to acceptable levels for swimming and bathing, although an algae bloom in 1973 interfered with body contact recreation. Depressed levels of dissolved oxygen and impaired bottom fauna populations have been found downstream from the dam. Although most chemical parameters indicated water of good quality, the bacteriological quality of Trout Creek in St. Marys was extremely poor at the time of the survey. Since that time, municipal wastes have been directed to a new sewage treatment plant and the discharge of untreated wastes to Trout Creek has been significantly reduced.

Medway River —Although nutrient rich waters exist both upstream from and within the City of London. bottom fauna populations indicated that water quality was not seriously impaired. High bacterial levels in the stream contributed to bacterial contamination of the Thames within London.

Other North Thames River Tributaries —Samples collected near the mouths of Whirl. Fish. Black and Flat creeks revealed good biological and chemical water quality. Fish Creek appeared to improve the bacteriological quality of the North Thames below St. Marys, while Otter Creek appeared to contribute to bacterial impairment of the North Thames.

Thames River and Tributaries above London

In the upper reaches of the Thames River above London, intolerant farms were poorly represented in bottom fauna associations. In the vicinity of Tavistock, dissolved oxygen levels fell as low as 2.7 mg/L during July, 1971. Water quality progressively improved to immediately downstream from Innerkip as indicated by the increasing variety of intolerant mayfly and caddisfly larvae, well balanced bottom fauna associations and the occurrence of warm water species of sports fish. Levels of bacteria were slightly higher below Innerkip than levels upstream.

In the Gordon Pittock Reservoir, a seriously degraded aquatic environment was illustrated by heavy algae blooms, black floating sludge mats and chronic fish kills which can be attributed to: the highly enriched bottom deposits that have accumulated in the reservoir, nutrient rich waters, high temperatures and minimal flows during the summer. Furthermore, the physical characteristics of the reservoir, including the shallow depth and its relatively small size, tend to encourage algae growth. Aquatic life was severely impaired immediately downstream from the Highway 59 bridge, probably the result of combined sewage bypasses from a storm sewer below the reservoir.

Woodstock proved to be a significant contributor of phosphorus and organic material to the Thames River upstream from London. The effects of nutrient enrichment and organic wastes were evident in the form of heavy weed growths. limited variety in fish population, sedimentation and virtual elimination of pollution intolerant organisms from Woodstock to Beachville. Black discolouration of the water and odour emanation typical of process water from a textile industry were detected during one of the surveys. Improved water quality just above Beachville was illustrated by a strong representation of sports fish. Water quality appeared to support increasingly diverse bottom fauna associations with progress downstream to Ingersoll, although variety of fish populations was limited. Two fish kills in 1969 and 1970 may have influenced results in this reach. Organic wastes and nutrients from Ingersoll impaired the stream biology by limiting the variety of bottom dwelling organisms, markedly reducing numbers and variety of fish, and causing heavy growths of *Cladophora.* Smallmouth bass were not found in the main stream from Beachville to London, signifying unfavourable water quality conditions. Biological. bacteriological and chemical data indicated that the river recovered to an excellent quality upon entry to London. However, communities of bottom dwelling organisms were severely impaired downstream from the Vauxhall sewage facility and to a lesser extent below the Pottersburg plant.

Neither number nor variety of organisms approached upstream reference levels as far downstream as the confluence with the North Thames River.

Middle Thames River—The healthy stream benthos and excellent water chemistry indicated some of the best water quality in the entire watershed. Upstream and downstream from Thamesford, preferred species were represented in a fish association usually found in good quality water.

Pottersburg Creek —Although chemical analyses showed no significant quality impairment at the time of sampling, biological parameters which better reflect long term conditions showed severe impairment, probably from local storm sewer discharges. During the study, oily films were noticed on the water surface and odours characteristic of domestic wastes emanated from the creek.

Waubuno Creek —Benthic populations at the mouth were well balanced although the bottom was cluttered with garbage. Chemical tests revealed a possible organic burden on the stream. Bacteriological levels were also slightly elevated.

Cedar Creek—Cedar Creek in Woodstock was suffering from severe bacteriological pollution from combined storm and sanitary sewer discharges. A severe reduction in numbers and types of aquatic macroinvertebrates was found near the mouth of the stream, indicating toxic conditions. Very low levels of dissolved oxygen (1.0 mg/L) were recorded. Since the survey, wastes have been rerouted to the sewage treatment facility by the City of London.

Thames River and Tributaries—London to Lake St. Clair

A pollution tolerant benthic community was observed along the Thames River throughout London. indicating some impairment. Downstream from the Greenway sewage treatment plant. reductions in bottom fauna and bacterial numbers indicated a possible toxic effect of chlorine residuals in the Greenway effluent. Downstream from Springbank Park Dam and Oxford sewage treatment plant, water quality impairment continued to persist with no major recovery from the effects of the effluent discharges to the river in the London area until Muncey. Aquatic vegetation became more prevalent from Komoka to Delaware. Dissolved oxygen levels immediately downstream from London were marginally acceptable under streamflows during the survey, which were well above possible low flow conditions.

From Muncey to Wardsville, bottom fauna populations were extremely productive and the excellent variety of organisms found at most points in this stretch indicated water of good quality. Higher levels of turbidity in the river are the result of accelerated bank erosion as the river enters a clay plain at Muncey. The resulting reduction in light penetration effectively eliminated problems associated with extensive beds of aquatic vegetation. Between Wardsville and Thamesville, somewhat enriched conditions were illustrated by chemical and biological data.

From Kent Bridge to Chatham, the numbers of organisms were low but intolerant mayflies and clams were found, reflecting favourable water quality. The low numbers are most likely the result of river bottom sand mining operations which are active from Thamesville to the river mouth and the substrate type which is unsuitable for most aquatic invertebrates.

Within Chatham upstream from the sewage treatment facility, a fine organic detritus yielded a solitary midge, indicative of sterile conditions probably resulting from combined sewage inputs. Persistent impairment downstream from the Chatham sewage treatment plant was illustrated by low numbers of tolerant midges and sludgeworms and septic odour of sediments. Investigations indicated that a significant portion of the water quality and biological degradation in the Chatham vicinity may be attributable to the sludge banks that have accumulated because of raw sewage bypasses.

Unproductive bottom fauna populations extended from Chatham to Lake St. Clair in what could best be described as an ooze which constituted the upper layer of the river bottom. Such depressed populations are likely the result of constant sedimentation and dredging and diking activities. This, coupled with reversible flows in the lower reaches, probably produces a very unstable benthic environment for aquatic organisms.

Water quality of the tributaries in the Lower Thames basin varies significantly. Springers (Oxbow) and Komoka creeks are good quality streams and support cold water fisheries. The following tributaries experience varying degrees of water quality impairment:

Dingman Creek —Water quality below the Westminster and Southland Park sewage treatment plants was impaired bacteriologically. Treated sewage effluent volumes equal streamflow during summer low flow periods, causing periodic depletion of dissolved oxygen. Downstream at the mouth, the dominance by facultative forms of bottom fauna populations indicate that complete recovery had not occurred. Since 1969. three severe fish mortalities have occurred in Dingman Creek. Investigations showed that different forms of agribusiness caused two of the incidents, while the other originated from a plating firm.

Sharon Creek —A sulphur spring entering the Sharon Reservoir has caused hydrogen sulphide levels in the reservoir to be high. Sealing of the spring and use of the bottom drawoff approach has resulted in improved water quality in the reservoir and downstream reaches of the creek.

Newbiggen Creek —Severe bacterial contamination and dissolved oxygen depletion was found downstream of Glencoe.

McGregor Creek —Near the mouth of McGregor Creek, water quality was impaired aesthetically. In addition, a limited population of benthic animals. high levels of total nitrogen and total phosphorus and severe bacterial contamination of the water were caused by occasional discharges of combined sanitary and storm sewage.

Jeannette Creek —Bottom fauna populations were found to be unproductive in the creek, likely the result of unfavourable bottom conditions which were similar to those in adjacent sections of the Thames River.

6.2 FLOODING

Any inundation from the river may be regarded as flooding, but it becomes of real significance only when the water causes, or has potential to cause, loss of life or property damage because of residential, commercial or other development in the area. The most frequent type of floods in the Thames basin are spring floods caused by a combination of ice, snowmelt and rain. However, severe summer floods due to major thunderstorms can occur, and major autumn floods due to a tropical hurricane are also possible. The topography, soils and other natural features of the watershed contribute in great measure to flooding. The impervious clay soils and the high gradient of the river channels in the upper portion of the basin, together with extensive artificial drainage of agricultural and swamp land, increase the rate of runoff.

The basin's shape is another significant factor. A roughly circular upper watershed, with three main channels and numerous major tributaries, results in cumulative flood peaks at the confluence in London, giving higher flood peaks downstream. In the elongated lower part of the watershed, there is much less lateral inflow. Because of these physical characteristics, most of the water flowing through the lower basin originates in the upper part of the watershed.

Flooding problems can be said to be the result of encroachment, that is, man made works built on the natural flood plain. If development were not located on flood plains, there would be no flooding problem. However, with a long established settlement pattern and millions of dollars of real estate located on the flood plain, existing development must be considered as a factor to be dealt with in the Thames watershed. Agricultural development on the flood plain must also be considered. Encroachments such as factories, building and bridge abutments aggravate the flood situation, not only by preventing the free passage of water and reducing the natural storage effect of the valley, but also by causing ice jams during spring breakup. During the past century, the flooding problem has been further aggravated by increased urbanization along the river and by increased spring runoff due to clearing of woodlands and the installation of drainage systems on farmlands.

Flooding problems in the basin have been reduced considerably as a result of the Fanshawe, Gordon Pittock and Wildwood reservoir construction. channel improvements at Mitchell, Stratford, St. Marys and Ingersoll, and dikes in London and along the lower reaches of the Thames River. Areas which are still regularly subject to flooding include Woodstock, St. Marys, London, and the stretch of the river from Thamesville through Chatham to Lake St. Clair.

6.2.1 Flood Damages

Flood damage estimates for the Thames River basin have been calculated with existing reservoirs in operation. The results of this study updated to 1975 dollars, are summarized in the following table (Acres Consulting Service Limited. 1973):

AVERAGE ANNUAL DAMAGE ESTIMATES (Thousands of 1975 Dollars)

AREA	DAMAGES
North Side of Thames River—Lake St. Clair to Chatham	11.9
South Side of Thames River—Lake St Clair to Chatham	4.8
Chatham	853.2
Chatham to Thamesville	210.6
Thamesville	52.4
Thamesville to London	13.1
London—Main Branch of Thames River	195.2
London—South Branch of Thames River	52.4
London—North Branch of Thames River	55.9
St. Marys	55.9
Total	1505.4

The average annual damage due to flooding in the watershed is $1.5 million, of which 57 percent is in Chatham and 20 percent is in the vicinity of London.

With respect to damage to agricultural land, the Acres Consulting Services Limited report summarized conditions as follows:

"In the case of the Thames River, it appears that flooding is not a significant variable in land costs. It is recognized as a problem, but its impact on land values is not pronounced. This may indicate that the severity of flood damage to agricultural crops is not significant.

In previous assessments of agricultural flood damage, a figure of 20 to 25 percent in yield reduction has been used for spring floods, with damages up to 100 percent caused by summer floods. These values appear to be grossly exaggerated. It is felt that losses of this magnitude would result in a recognizable economic cost of owning flood prone land.

As flooding in the Thames River Valley occurs mainly in the months of February, March and April, the damage to agricultural lands from the floods appears to be of a minor nature. Most of the damage is probably in the nature of clean-up costs. The fields are often covered with debris, some topsoil is moved and drainage ditches require repairs. Some costs may be associated with planting delays. However, it is felt that no major reduction occurs in yields unless the planting is delayed until after May 10."

6.3 EROSION

Erosion problems 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. The effects of channel erosion receive greater publicity and have a greater short term impact because of accompanying dike failures and flooding. However, soil erosion, while a less visible problem, is of greater long term significance due to its effects on water quality, runoff and cropland productivity.

6.3.1 Soil Erosion

Soil erosion in the Thames watershed is most frequently the result of water runoff from cultivated land. Slope, rainfall and land use are primary factors affecting this type of erosion. Removal of forest cover due to urbanization and development of agricultural land has also contributed to soil erosion. According to the Ministry of Natural Resources, over 80 percent of the basin was forested in the 1880's; by 1957 this figure was reduced to slightly more than 10 percent. A recent study estimated that 11 percent of the Thames watershed is presently forested (International Joint Commission, 1975). In addition to the loss of valuable topsoil, soil erosion can result in water-quality impairment, as described in Sections 6.1.1 and 6.1.5. Moreover, topsoil erosion results in the reduced ability of land to retain moisture. Consequently, runoff is increased and both erosion and accelerated runoff are aggravated.

6.3.2 Channel Erosion

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 significant factor. Other causes of channel erosion include the burrowing activities of animals such as muskrats, variations in the level of Lake St. Clair, and erosion from surface waves, particularly those caused by the wake of motorized watercraft.

Erosion problems in the lower reaches of the Thames River are closely related to flooding. A large portion of the fertile lands in the townships of Dover. Raleigh, Tilbury East, Tilbury West, and Tilbury North, lie well below the high water marks of both the Thames River and Lake St. Clair. These areas are presently protected by a system of dikes mostly constructed early in this century by the local inhabitants, extending some 16½ miles from Chatham to Lake St. Clair. The low-lying areas on both sides of the river downstream of Chatham are drained by an extensive system of drainage ditches and pumping stations.

Since its formation in 1961, the Lower Thames Valley Conservation Authority has pursued a vigorous program of streambank erosion control works. In 1967, the Authority commissioned a study of the Thames River from the river mouth to the easterly limits of the City of Chatham. This study (James F. MacLaren Limited, 1967), set forth the areas along both sides of the rivers that required immediate erosion protection, and also classified the remaining areas according to need for protection. A second report (James F. MacLaren, 1971) documented bank erosion problems between Chatham and Delaware.

The 1967 report indicated that two conditions, flood flows and wave action, are responsible for erosion of the river banks and dikes. Flood flows scour the full face of the dikes and in severe cases overtop the dikes and river banks, thereby washing out portions of the dikes and inundating lands bordering the river. Wind generated wave action, which is the most continuous erosive force acting on river banks and dikes, and power boat wakes undercut the slope face and result in slope failures. Continual repetition of these failures represents the more serious threat to the overall stability of dikes and river banks. If dikes and river banks are not continually protected from detrimental wave action, they become susceptible to failure with consequent inundation of bordering lands during high river stages.

6.4 ARTIFICIAL DRAINAGE

As indicated in Section 2.2.3, extensive artificial drainage schemes have been undertaken in the Thames watershed. In the lower basin, many acres of cropland have been brought into production by diking and draining land at a lower elevation than the river. In the upper watershed, over 850 miles of drains had been installed by 1950.

Drainage can increase crop yields in poorly drained areas, give better quality crops, and extend the growing season by allowing earlier planting. However, drainage schemes can also cause significant problems. For example, natural water storage areas such as swamps and bogs may be drained, thus reducing the amount of water previously available for natural streamflow maintenance, and destroying fish and wildlife habitat. The lowering of the water table as a result of drain installation can seriously interfere with nearby shallow wells. Erosion and sedimentation problems can occur both during and after the construction of open drainage ditches. Existing streambank cover may also be removed during drain installation.

6.5 WATER SUPPLY INTERFERENCE

Water supply interference, where one water taking interferes with other uses of water, is another water resource problem in the basin. A study of over 120 complaints of water supply interference investigated in the Thames River basin between 1961-1973 showed the following results:

1. The use of water for urban supply, and water use associated with urban development is the primary cause of water supply interference. Widespread ground-water interference occurred in the White Oaks well field prior to the completion of the Lake Huron pipeline and the cessation of groundwater takings by the City of London. The impact of road construction, industrial activity, and mineral extraction and processing is a significant part of the problem. Both temporary and prolonged interference with shallow wells can occur due to the installation of water mains, sewers, and drainage ditches.
2. Surface water storage for private recreational purposes through the construction of small dams or on-stream ponds often conflicts with other water uses.
3. Gravel pit and quarry operations are frequently perceived as a cause of interference or potential interference with local water supplies due to dewatering or the interception of aquifers, even though actual water use conflicts attributable to this activity in the basin have been infrequent.
4. The taking of water for irrigation can cause serious localized interference problems, particularly through the reduction of streamflow in smaller streams in the watershed.

6.6 GROUND WATER QUALITY IMPAIRMENT

Ground-water quality impairment can be locally significant in the watershed. Phosphorus readily fixes to soils and with the exception of sandy areas, does not infiltrate through soil to ground water. Nitrogen can be readily leached into ground water in the form of nitrates. Possible contaminant sources include improper handling or application of manure and commercial fertilizer, and improper installation of septic tanks. Installation of septic tanks in surficial sands and gravels has caused bacterial contamination of shallow domestic wells in the Komoka and Granton areas. High nitrate concentrations have been found in water wells on the Moraviantown Indian Reserve, and in the Komoka area. Localized well contamination due to gasoline or other petroleum products has also occurred.

6.7 USE CONFLICTS IN RESERVOIRS

The three large multi-purpose reservoirs on the Thames River were built for the prime purpose of flood control with secondary purposes of low flow augmentation and recreation. Wildwood and Gordon Pittock Reservoirs are operated to provide for all three uses, while Fanshawe Reservoir is not operated for flow augmentation except during severe low flow conditions. These uses are inherently in conflict because of the conflicting specific requirements for operation of the reservoir which each use demands.

For flood control alone, a reservoir would remain empty in anticipation of flood level flows and contain water only at times when these flows were being routed through it. For flow augmentation alone, a reservoir would store water during high flows for gradual release during the period of natural low flows. This would result in a gradual drawdown of the reservoir with a reduction in surface area and depth as summer progresses. For recreation alone, a reservoir would maintain a constant level and a large surface area of water at adequate depth to provide for multiple recreation uses.

Reservoirs may also become fish and waterfowl habitats which again require different reservoir operations for optimum conditions to prevail. Fish life in general require stable water levels in order that fish food organisms can develop in the shallow shoreline areas. Waterfowl require marshy areas which are maintained ideally by initial flooding in spring to curtail encroachment of woody species, thus providing increased nesting areas. Complete drying of marsh areas is not desirable because the waterfowl habitat would be eliminated.

Reservoirs, by their nature, tend to retain a large proportion of materials flowing into them, leading to a buildup of sediments, nutrients and bacteria in the water. This can result in impairment of body contact recreation because of the bacterial health hazard and aesthetic impairment from unsightly algae blooms. Fish life is imperilled in cases where a combination of temperature elevation and anoxic conditions in deeper zones occurs.

Operation of the reservoirs to completely satisfy these conflicting uses is clearly impossible. The Conservation Authorities Branch has published operating schedules which attempt to provide for all uses, but as clearly indicated by the Public Consultation Program, the public is not entirely happy with the result. This is partially because recreation is a personal and clearly perceived use by individuals while flood control and flow augmentation uses have a less direct or visible impact upon the public. As population and recreation demands increase, this conflict will become more apparent.

The conflicts described above cannot be completely resolved in favour of any one use without adversely affecting other uses. To maintain levels for recreation means that downstream flows cannot be augmented, resulting in water quality degradation. In addition, reservoirs provide less flood protection when maintained at optimal conservation pool level for recreational purposes. Efforts can be made to minimize conflicts without changing existing use priorities. Techniques are under development which may in future allow optimization of all uses. Additional reservoirs, if built, may allow more flexibility in operation of existing reservoirs. It must be realized, however, that conflicts are inherent in the multiple use of reservoirs. Perhaps the only realistic way to avoid conflicts in future is to restrict the uses of proposed reservoirs.

6.8 COMMUNICATION AND CO-ORDINATION PROBLEMS

During the Thames River study public hearings, the belief was expressed that lack of communication and co-ordination contribute significantly to water management problems in the basin. The poor attendance at the public hearings, whether due to inadequate planning by the study team, or lack of interest by the public and municipal officials, was symbolic of communication problems concerning water management in the basin. The Environmental Hearing Board concluded from the hearings that the people of the Thames River basin do not perceive the basin as an entity. The Board also expressed the view that there is a serious lack of communication between various formal organizations and the citizens of the watershed.

Difficulties associated with the division of the watershed into two separate conservation authorities were noted. The Board also observed that even occupational groups can be expected to disagree on certain issues depending on their geographical location, and cited a reference to the lack of communication between the agricultural and urban communities as an example.

CHAPTER 7

DESCRIPTION AND EVALUATION OF WATER MANAGEMENT PROPOSALS

This chapter outlines various possible approaches to resolving the water resource problems of the Thames River basin. Water management objectives, which provide a basis for evaluating management options, are outlined. Where alternative techniques are available to resolve a given problem, these alternatives are compared and evaluated. Selection of recommended alternatives is based on consideration of study objectives, the wishes expressed by the public, and economic and environmental criteria.

Economic studies of alternative approaches for sewage treatment in the City of London and for the construction of various flood control reservoirs are presented. Where possible, benefit-cost evaluations are made.

7.1 WATER MANAGEMENT OBJECTIVES

Since environmental and study objectives are fundamental to the selection of effective water management proposals, a restatement of these objectives is warranted. The overall objective of the study is:

To develop guidelines for water management planning in the Thames River basin which would ensure that an adequate quantity of water at a satisfactory quality is provided for the recognized water uses in the river basin at the lowest cost, and that flood and erosion protection is provided consistent with appropriate benefit-cost criteria.

7.1.1 General Water Quality Objectives

As indicated earlier in this report, stream water quality is perceived to be the major water resource problem in the basin. Water quality improvement depends upon the identification of appropriate objectives and supporting implementation of courses of action.

The basic philosophy of the Ministry of the Environment is that there should be a constant effort to improve water quality, recognizing that improving the quality of water makes it available for increased uses. However, there are certain minimum levels of water quality generally acceptable to the province which must be met. In this regard, water quality requirements established for the protection of aquatic life are normally selected. Higher levels of some quality parameters are required in areas where more demanding uses, such as swimming and bathing, occur.

Specific guidelines for given water uses are outlined in the Ontario Ministry of the Environment's publication "Guidelines and Criteria for Water Quality Management in Ontario". Reference will be made to those guidelines in the discussion of water quality improvement proposals.

In evaluating the water management alternatives for the Thames River system, it is necessary to define water uses which should be safeguarded. Water uses in the Thames watershed were summarized previously in Table 4.1. The issue of attempting to maximize various water uses, some of which conflict, makes water management on a basin-wide basis extremely complex. For example, the uses of water for aquatic life, recreation and waste assimilation are highly interdependent. While certain combinations of these uses can be compatible, others may be in conflict. Maximizing protection of aquatic life, while desirable in itself, would severely limit the use of streams for waste assimilation. Maximizing waste assimilation would have the reverse effect, as well as limiting recreational use of the watercourse.

Maintaining water quality for protection of aquatic life is desirable not only for the stated purpose, but because it also provides considerable protection for other uses such as aesthetics and recreation.

In relatively simplistic terms, there are three alternative courses of action for water quality management in the Thames basin:

1) allowing further degradation of water quality below the requirements for aquatic life but still not creating a health hazard;

2) maintaining existing water quality where it is satisfactory for fish and aquatic life and recreation, and improving quality to that level in those areas where it is presently degraded;
3) upgrading water quality significantly beyond that required by fish and aquatic life to a point where it is satisfactory for all legitimate uses.

Alternative 1 is incompatible with the minimum requirements of the Ministry of the Environment as described above. In addition, the public has expressed a strong interest in protecting and enhancing recreational water use. On the basis of money spent per angler day, it has been estimated by the Ministry of Natural Resources that the minimum value of the Thames sports fishery is $4,000,000 1975 dollars per year. This total does not consider the contribution of the Thames River spawning ground to the Great Lakes fishery. The non-monetary value of the quality of life associated with the existence of a fishery is another significant factor.

Alternative 3 would provide a definite benefit in terms of an upgraded fishery. The Ministry of Natural Resources has estimated the value in terms of money spent by anglers would increase to over $17,000,000 1975 dollars annually. However, this alternative would have serious repercussions by severely limiting river use for waste assimilation. The costs of implementing this alternative would impose a heavy financial burden on several municipalities, and would severely restrict utilization of municipal funds for other projects.

Moreover, modelling studies described in Appendix A have shown that, with the current level of technology, use of the best practicable methods of controlling point-source discharges from municipalities would not guarantee achievement of this alternative. Furthermore, diffuse sources of pollutants and uncontrolled point sources have sufficient impact on water quality to impede implementation of this alternative, even if all municipal sewage discharges were eliminated.

Alternative 2 would require maintaining areas of presently high-quality waters and upgrading water quality elsewhere to a level that would support a viable fishery by removing stresses on fish species. In some areas. this would require significant improvement in water quality. Future population growth or economic development in the basin would require significant expenditures to meet this objective. Achieving water quality conditions suitable for fish and aquatic life would also mean that, in general, water quality would also be adequate for recreational uses.

After evaluating the three alternatives, and their implications to other water uses, it was concluded that alternative 2 represents a realistic and obtainable objective. It must be stressed, however, that the long-term objective of the Ministry of the Environment is to upgrade water quality in the basin as much as possible to improve and enhance conditions for aquatic life, as well as to maximize other beneficial uses.

7.1.2 Specific Water Quality Objectives

Having established the objective of maintaining water quality necessary for the protection of fish and aquatic life, appropriate criteria to achieve this objective were identified. Criteria for protection of other uses such as recreation and aesthetics were also identified. Water quality criteria are numerical or narrative statements of the quality of water required for particular uses.

Specific water quality objectives for the Thames River basin outlined below are based on the water quality criteria in the Ministry of the Environment publication "Guidelines and Criteria for Water Quality Management in Ontario".

A basin wide study of fish distribution and corresponding dissolved oxygen requirements was carried out. It was then estimated, in probabilistic terms, what the minimum dissolved oxygen concentrations should be on a daily, monthly and seasonal basis to maintain a viable fishery. Specific dissolved oxygen objectives are defined by application of criteria to specific stream reaches as discussed in Appendix B, "Dissolved Oxygen Criteria". Other specific water quality objectives are outlined below in numerical or narrative form for the Thames River, including all tributaries and reservoirs:

(i) Nutrients from unnatural sources which will stimulate the over production of algae, nuisance vegetation, or offensive slime growths shall not be discharged to the river.

(ii) Temperature—the normal daily and seasonal temperature variations that were present before the addition of heat due to other than natural causes shall be maintained. Heated discharges to the river will not be permitted unless it is clearly demonstrated that heated effluents will enhance the usefulness of the water resource without endangering the production and optimum maintenance of wildlife, fish and aquatic species. It shall be the responsibility of the user to provide evidence to support the acceptability of the discharge under these terms.
Heat may not be discharged in the vicinity of spawning areas or where increased temperature might interfere with recognized movements of spawning or migrating fish populations.

(iii) Dissolved materials may not be added to the river to increase the concentration of dissolved solids by more than one-third of the background condition of the receiving water.

(iv) Settleable materials—substances shall not be added that will adversely affect the aquatic biota or will create objectionable deposits on the bottom or shore of the river.

(v) Toxic substances, including pesticides and radionuclides, must not be added to water in concentrations and/or combinations that are toxic or harmful to human, animal, plant or aquatic life, except where application of approved substances for the control of nuisance organisms has been authorized by the Ontario Ministry of the Environment.

(vi) Oil, petrochemicals or other immiscible substances that will cause visible films or toxic, noxious, or nuisance conditions shall not be discharged to the river.

(vii) Tainting substances—all materials that impart odour or taste to fish or edible invertebrates shall be excluded from the river at levels determined to produce tainting.

(viii) Water uses should be controlled to prevent significant increases in concentration of hardness, chlorides, suspended materials, turbidity and other parameters indicative of water quality degradation.

(ix) pH should be maintained with a range of 6.5 and 8.3.

(x) Materials which will form floating debris, scum. and substances producing objectionable colour, odour, taste or turbidity which may impair aesthetic or recreational use should not be added to the river.

(xi) Microbiology—(Microbiological criteria are based upon requirements for body contact recreation; other uses are protected by these criteria.)

(xii) Water should be free from pathogens including any bacteria, fungi or viruses that may produce enteric disorders or eye, ear, nose, throat or skin infections.
The following geometric mean densities must not be exceeded in a series of at least 10 samples per month, including weekend samples.
- total coliforms not to exceed 1,000/ 100 ml;
- fecal coliforms not to exceed 100/100 ml
- enterococci not to exceed 20/100 ml.

7.1.3 Flood Control Objectives

The objective of flood control activity is to minimize the average annual flood damage with the least cost. The primary constraint on this evaluation is that the average annual flood damage reduction must exceed the average annual cost of achieving that reduction. The cost must reflect the actual cost of constructing a flood control facility, and the conflict cost which may be allocated to any interference that the flood control facility may have with other uses or any other part of the system. This cost figure is reduced appropriately by other benefits which accrue, such as flow augmentation and recreation.

The main emphasis in planning water control facilities in the Thames River basin to date has been on flood protection. However, final design and operations have usually involved the multiple purposes of flood control, water supply. pollution abatement, and recreation. Emphasis in this study has been towards the integration of all water management activities to reflect the optimum system and operating policy. With this concept in mind, various possible water control structures were evaluated as to both their beneficial and detrimental effects on the socio-economic and environmental systems rather than focusing on flood control as an isolated problem.

Mathematical modelling by computer was utilized extensively as an analytical tool in evaluating both water quality and flood control management options. Dissolved oxygen models are a valuable tool for evaluating the effectiveness of options in meeting dissolved oxygen objectives. Models used in this study take account of the effects of organic waste discharges from treatment plants, streamflow, and the biochemical and physical processes occurring in the streams. Models were used in evaluation of water management alternatives for the Avon River at Stratford, the North Thames from St. Marys to Fanshawe Lake, the Thames River from Woodstock to downstream from Ingersoll, the Thames River in the vicinity of London, and the Thames River from Chatham to Lake St. Clair. A description of these models and their application is given in Appendix A. Flood control modelling is described in Appendix D.

7.2 WATER RESOURCE MANAGEMENT OPTIONS

The management options described in this section are essentially a listing of alternative courses of action which could be taken to resolve the major water resource problems identified in Chapter 6. Reference should be made to Appendices C and E for a detailed description and discussion of these options. The following three major management option categories, namely urban. rural and reservoirs, primarily relate to water quality improvement. Two additional major categories of options relate to flood control and erosion control. Other management options applicable to local areas include land drainage proposals, water supply interference and ground water quality impairment.

Urban oriented options include removal of pollutants from sewage and urban drainage, population and urban growth restrictions and stream flow augmentation. These and other options are discussed in greater detail in Appendix C. One important assumption concerning urban runoff associated with future development should be noted. Water quality modelling described in Appendix A assumes that present levels of urban runoff will remain constant with time. However, urban runoff will increase with future development, implying that municipalities will be required to control these loadings where it is demonstrated that urban runoff constitutes a water quality problem.

Options for management of rural oriented problems include limiting fertilizer application rates, improving tilling practices, increasing buffer zones, expanding channel protection programs and restricting cattle access to streams. These options are described in detail in Appendix C.

Improvement of water quality in existing reservoirs can be achieved through bottom draw (releasing flow through low level discharge pipes), destratification, algae control, disinfection of swimming areas or generally changing operating policies or reservoir uses.

The issue of water based recreation was frequently raised during the Public Consultation Program. Water quality improvement. if sonic of the options are implemented, will enhance the potential of streams in the basin for recreation. The general public will have only limited benefit, however, because of limited public access. This situation places emphasis on and has obvious implications for the operation of both existing and new reservoirs. With regard to the existing three major reservoirs, there appears to be little room for improving their recreational use potential by maintaining more constant water levels without seriously jeopardizing their primary purposes of flood protection and flow augmentation. However, refinement in operating practices, through alterations in drawdown and storage schedules, may be options which would enhance their recreational use potential. A computer model presently being developed by the Ministry of Natural Resources will permit a sophisticated analysis of the possible benefits of modifying reservoir operating practices to optimize reservoir uses. A more detailed discussion of this issue. and of recreational use of proposed reservoirs, is included in Appendix C under the heading "Reservoir Options".

Flood control can be achieved either through structural means or non-structural methods. Structural options include construction of large or small dams, modification of drainage schemes, construction of diversion channels to another drainage basin and dike construction. Non-structural methods for the control of floods include modified operation of existing reservoirs, regulation of flood plain development, flood proofing, flood warning and flood insurance. These options are discussed in detail in Appendix E. It can be concluded that major additional flood control structures are required and that non-structural methods provide valuable complementary flood protection.

As indicated in Section 6.3, two types of erosion problems, channel erosion and soil erosion, occur in this basin. With regard to channel erosion, extensive programs for stream and river bank rehabilitation have been initiated through the Lower Thames Valley Conservation Authority, the Province and the Government of Canada. At present, this on-going program, which will not be completed before 1976, emphasizes the lands which are below the level of the Thames River and are subject to flooding. While the remedial measures underway represent the major option for solution of this problem below Chatham, remedial action is required concerning bank erosion problems as described in detail in the 1971 MacLaren report for locations between Chatham and Delaware. In addition, careful construction practices and maintenance of grass cover or other soil stabilization techniques can help to minimize channel erosion.

The options available for combatting and controlling soil erosion include strip cropping and crop rotation, diversion terraces or ditches. grass or other vegetative buffer zones or reforestation. An excellent reference for these options is contained in Chapter 4 of the 1952 Upper Thames Valley Conservation report.

7.3 OTHER WATER MANAGEMENT CONSIDERATIONS

In Chapter 6, artificial land drainage, water supply interference, ground water quality impairment and communication and co- ordination problems were described. Proposals for dealing with these problems are outlined below.

7.3.1 Land Drainage Proposals

An environmental impact assessment of land drainage proposals, as recommended by the Select Committee on Land Drainage (Final Report, June, 1974) would screen out or modify those proposals which would damage the environment. The assessment would consider problems associated with drainage of swamps, well interference, and destruction of fish and wildlife habitats. In some cases, slight changes in routes of drains may minimize the negative effects of the drainage proposals.

Because of the widespread wetland drainage carried out in the Thames River basin, the few remaining wetland areas have considerable ecological importance by the very reason of their scarcity. These areas should identified and protected. either through prohibition of drain construction or through acquisition by the local conservation authority or other appropriate bodies. One significant example of this type of area is the Zorra Swamp.

7.3.2 Water Supply Interference

Problems of water supply interference are localized within the basin. Large water takings are controlled by permits issued under the Ontario Water Resources Act, and interference problems caused by such takings can be resolved through enforcement of the permit requirements or the associated legislation.

Prevention of water supply interference through careful planning rather than restoration of affected supplies is highly desirable, both to avoid the problems and inconvenience associated with water supply disruption and because it is commonly less costly than undertaking remedial action after interference has occurred. Test drilling and test pumping to obtain information on potential interference should precede any firm commitment to develop a large ground water taking. Proposed stream withdrawals should be considered in the light of possible effects on downstream users and of any available streamflow data. Particular attention should be paid to flow rates that can be expected during seasonal low flow periods.

Prior to sewer, watermain or drainage ditch installation, studies should undertaken to anticipate the likelihood of well interference. These studies should include water level monitoring in nearby wells to facilitate evaluation of any subsequent well interference problems.

7.3.3 Ground Water Quality Impairment

Remedial action to restore ground water quality after impairment has occurred can be extremely difficult, time consuming and costly. Preventive measures such as the intelligent siting of operations with high pollution potential and sound water well construction practices will aid in maintaining the good ground water quality on which many of the basin residents depend. Continued upgrading of the water well inspection program and the existing water well regulations administered by the Ministry of the Environment will assist in preventing ground water contamination.

Where possible, activities such as landfills, feedlots, sludge spreading, and lagoons should located on soil and material which have significant clay mineral content (specifically, the clay mineral illite and montmorillonite having high absorption capacity to capture dissolved pollutants). An additional important advantage to the high clay content is reduced percolation rates which allow the bacterial reduction of organic substances.

7.3.4 Communication and Co-ordination Proposal

The significance of communication problems was noted in Section 6.8. Possible methods of improving communication and co-ordination are summarized below.

The Environmental Hearing Board recommended that consideration be given to the establishment of a joint committee to investigate the whole matter of improving water management co-ordination in the watershed. It was suggested that the committee made up of representatives of the ministries of the Environment and Natural Resources, the two conservation authorities, municipalities and others. Other membership could include the ministries of Agriculture and Food, Housing, Treasury, Economics and Intergovernmental Affairs, and citizen group representatives.

There are a variety of matters to which such a committee and/or its individual member organizations could address itself. For example, the implementation of the recommendations of this report will a major task involving considerable co-ordination which could be handled by such a committee.

Several issues discussed in this report particularly relating to rural oriented options require detailed follow-up. The committee could arrange for the study (or review and apply the findings of studies presently being undertaken by other agencies) of such topics as:

1. Land drainage works, with a view to determining the proportion of river flow originating from this source and establishing guidelines for optimum levels of land drainage.
2. The operation and maintenance of municipal drains and the quality of municipal drain effluent to determine the most suitable means of maintaining them free of obstruction and pollution.
3. Techniques of farm erosion control.
4. Waste management of intensive livestock operations with a view to establishing closer controls to ensure that waste from these operations does not enter rivers and streams without prior treatment.
5. The implications of stream fencing to farmers.
6. The effects of on-stream ponds on surface water quantity and quality.
7. The effects and optimum levels of application of all chemicals to soil and crops.

Co-ordination could be assisted significantly through any action the committee could take to increase an awareness among the basin's municipalities and residents that the watershed is an entity, and that the river forms a natural link between them. Related to this is the need for improved communication among the organizations directly involved in water management, between these organizations and the public, and between groups such as the agricultural and urban communities.

A variety of groups are involved in promoting sound conservation practices, such as the Ministry of Natural Resources through the Woodlands Improvement Act and the Ministry of Agriculture and Food through a farm-pond subsidy program. Many of these conservation practices can be implemented by individual property owners and collectively can significantly assist sound water resource management. Joint effort to publicize, encourage and direct such practices to areas of the watershed where they will have the most direct impact would be invaluable. For example, tree planting could be directed to areas where it would specifically aid in erosion control and streambank stabilization. Other examples include the siting and design of farm or recreational ponds, and the promotion of sound agricultural techniques.

A related issue raised during the Public Consultation Program was the division of the Thames basin into two conservation authorities. The complexity of water management on a watershed basis, and the interrelationships of water resource problems and solutions in the upper and lower watershed is obvious. Notwithstanding the historical problems surrounding this issue, it is felt that amalgamation of the two conservation authorities into a single authority could significantly assist the basin wide approach to water management advocated in this report.

7.4 ANALYSIS OF MAJOR WATER MANAGEMENT OPTIONS

Earlier sections of this chapter have presented water management objectives and a variety of options available for water resource management in the Thames River basin. In addition, several individual options have been evaluated as to their applicability to conditions in the watershed.

Selected major options having implications for the greater portion of the basin in terms of water quality improvement and flood control. the two primary objectives of this study, were then analysed in a systems context. Essentially, this involves a detailed evaluation of the Glengowan, Thamesford, Wardsville, Cedar Creek and Zorra Swamp dams, and of the sewage disposal options for the City of London, as these options represent the major tools for water management in the watershed.

At the secondary stage of the analytical process, non- quantifiable considerations such as the environmental effects of capital construction projects and recreation are evaluated.

Although these major options have great significance to water management in the Thames basin, they by no means deal with all the water resource problems of the watershed. Local water management issues are dealt with in Chapter 8.

7.4.1 Evaluation Criteria and Procedures

The application of water management objectives and criteria, and water quality and flood control modelling as evaluative tools have been described previously in this chapter and in Appendices A and D. respectively.

The primary evaluation criteria used in the following analysis were the flood control benefit-cost ratio and total system net cost in present value terms of the major management options considered. This approach was complicated by the interrelationship of the various individual options with respect to the flood control and water quality benefits derived. For example, construction of a dam provides economic benefits in terms of both flood control and water quality, the latter accruing from deferral of capital expenditures for sewage treatment facilities downstream from the dam due to flow augmentation provided from the reservoir. This means that all major options had to be evaluated in terms of total system configurations. Some configurations could be immediately dismissed for one of two reasons:

1. They totally failed to meet one or both of the required primary objectives of improving water quality and increasing flood control; or
2. They placed severe growth restrictions upon the City of London.

The reason for discarding options falling into category 2 above requires some explanation. The approach taken toward the overall water resource management of the basin was to optimize water resource use. Accordingly. in areas where the limit to the capacity of resources to sustain growth is reached within the planning horizon, a policy of growth limitations may be appropriate with excessive growth redirected to designated centres, primarily the City of London. Provincial planning studies have recognized London to be a major growth centre of this region and have recommended that it continue in that role. In this way, economies of scale in the provision of water supply and sewage treatment services can achieved. Thus, only those options which would allow London to expand to its 2001 projected population were considered.

However, it is recognized that a variety of other considerations must taken into account in determining the most desirable distribution of growth. Population projections based on official plans and populations trends from 1961 to 1971 suggest a 2001 population in London of 500,000. and this figure was used in evaluating water management options. However, it is important to note that a significantly lower growth rate would fundamentally affect the evaluation of waste treatment options at London. It should be noted in particular that recent calculations by the Regional Planning Branch of the Ministry of Treasury, Economics and Intergovernmental Affairs, based on trends projections, suggest a 2001 population for London of 338,000 to 350,000. Thus, consideration was also given to options which would meet water quality objectives at lower projected populations.

Once the major option configurations had been determined and evaluated on the total system cost basis, secondary evaluation of major options began. At this stage, as yet unquantified parameters as well as those factors which cannot be quantified were considered. The results of the Public Consultation Program provided considerable support in this procedure by removing some of the subjectivity from the evaluation process. An imputed value for non-quantifiable factors can derived, however. If the decision maker chooses an option which is not least-cost on the basis of the total system cost analysis, then the added cost of the option chosen must be equal to or less than the net unquantified benefits which the chosen option offers over the least-cost option.

7.4.2 Costing

At the primary evaluation stage. capital construction costs and flood control benefits have been used in deriving total net costs for each system option. In simplified terms this consists of estimating the capital costs for construction of engineering works (dams, pipelines, treatment plants) and the year in which they are to be constructed. The total cost in present value terms is then calculated using various discount rates --2, 4, and 7 percent. Flood control benefits in similar present value terms are then subtracted as they represent negative costs, to produce the total net cost for each system option. Costs are presented in present value terms so that they can be compared at a single point in time. The present value takes account of the time when costs and benefits occur by weighting near-term dollars more heavily than those far off in the future. This procedure is described by an example in Appendix F. Inflation is ignored in the analysis since the rate of inflation of prices is neutral and is assumed to affect benefits and costs equally.

Costs for pollution control works include components for construction, land acquisition, engineering and contingencies, and financing during construction. The works costed include only those required to treat or transport sewage which are in addition to internal collection costs of the city. Conventional treatment costs have been included to the point in time when a pipeline is built or a tertiary treatment plant is operational. Water quality from pollution control works can be considered equal for all system options. since each one is assumed to meet minimum water quality objectives.

Costs for dam construction include components for construction, land acquisition. engineering and contingencies, and financing during construction. Flood control benefits are estimated through the use of computer modelling described in Appendix D, and constitute the flood damage reduction occurring down-stream. Flow augmentation benefits are included indirectly in the staging of capital construction works for pollution control. Additional flow augmentation results in deferral of construction cost and thus reduces the net cost in present value terms.

Operation. maintenance and amortization of capital debt for all projects is not included in the cost analysis. Operation and maintenance charges for the tertiary treatment and pipeline options are presented in Appendix F, and it is felt that their inclusion in the cost analysis would not change the ordering of options. No consideration has been given in the cost analysis to possible subsidies which might accrue to individual communities or agencies.

Intangible benefits and costs are introduced at the secondary evaluation stage later in this chapter.

The costs used in this analysis should be considered approximate reconnaissance estimates only, since they are not based on detailed engineering studies. Care has been taken, however, to use consistent assumptions in estimating the costs for each system option. Accordingly, it is felt that while the absolute costs may not be accurate, the least-cost ordering of options is correct.

7.4.3 Evaluation of Options

The five dams which have been proposed in the past and the sewage treatment options for London are discussed below both individually and in system configurations such that all associated benefits and costs, economic, environmental and social, are brought to light. Preliminary screening of several hundred theoretical combinations reduced to 22 the number of options to evaluated in detail. These 22 systems options are listed in Table 7.4. For brevity of presentation, all planning options in this section are presented in compact notation form as follows:

- Gg: Construct Glengowan dam and reservoir primarily for flood control;
- Gg*: Construct Glengowan dam and reservoir primarily for flow augmentation;
- Th: Construct Thamesford dam and reservoir:
- W: Construct Wardsville retarding structure;
- CC: Construct Cedar Creek dam and reservoir;
- ZS: Construct Zorra Swamp dam and reservoir;
- P: Construct a sewage trunk pipeline from London to Lake Erie with secondary treatment plus phosphorus removal at Lake Erie:
- T: Provide tertiary sewage treatment for the City of London in order to meet effluent requirements.

In all cases, dam construction is assumed to be completed in 1981. For "T" and "P", the number following the notation refers to the year when that option would be operational. A system option is designated by a combination of two or more single options. Thus, for example, option Gg + Th + P:94 indicates that the Glengowan and Thamesford dams would be constructed to be operational in 1981 and the London-Lake Erie pipeline and accompanying treatment plant would be constructed to be operational in 1994.

7.4.4 Flood Control Benefit-Cost Analysis

Table 7.1 presents the benefit-cost analysis of the single and system options for flood control derived from computer analysis described in Appendix D. All figures are discounted to present value at 2 percent, 4 percent and 7 percent rate as shown. The cost or outlay for each of the dams is estimated as follows in 1975 dollars: Glengowan. $12.2M; Thamesford. $7.6M: Wardsville, $11.7M; Cedar Creek. $2.6M; Zorra Swamp, $4.7M.

Table 7.1: Flood Control Benefits-Cost Evaluation (in $1,000; 1975)

Option (operational in 1981)	Present Value of Reservoir Cost*			Average Annual Benefit	Net Present Value for 50 Yrs			Benefit/Cost		
	2%	4%	7%		2%	4%	7%	2%	4%	7%
Gg	10,900	9,700	6,200	530	14,800	9,000	4,900	124	0.9	0.6
Th	6,700	6,000	5,000	1116	31,100	18,900	10,300	4.6	3.2	21
W	10,400	9,300	7,800	1016	28,400	17,300	9,300	2.7	1.9	1.2
CC	2,344	2,086	1,760	13	366	222	120	0.16	0.1	0.07
ZS	4,165	3,707	3,125	0	0	0	0	0	0	0
Gg + Th	17,600	15,700	13,200	1208	33,700	20,500	11,100	1.9	1.3	0 8
Gg + W	21,300	19,000	16,000	1048**	39,300	17,800	9,500	1.4	0 9	0.6
Th + W	17,100	15,300	12,800	1396*	39,000	23,700	12,800	2.3	1.5	1.0
Gg + Th +W	28,000	25,000	21,000	1428	39,900	24,200	13,100	1 4	1 0	0.6

* Assuming construction in 1981

** Derived from (Gg + Th + W)-((Gg + W)-W) = Th + W

i.e. (1428)-(1048-1016)= 1396. In this calculation. the maximum possible marginal benefit is ascribed to Gg. In reality, where Th is in the system, the marginal benefit of Gg would be less than 32 (1048-1016) and therefore, the Average Annual Benefit, Net Present Worth and Benefit-Cost of Th + W is likely higher than stated.

In those options requiring more than one dam, a further analysis has been carried out to determine the marginal benefit-cost ratio of building the second and/or third dam after the first has been completed (see Table 7.2). Zorra Swamp and Cedar Creek reservoirs are not included in this second analysis since their flood control benefits were non- existent or negligible.

Table 7.2: Marginal Flood Control Benefit—Cost Evaluation (in $1,000: 1975)

Additional Construction	Present Value of Reservoir Cost			Average Annual Marginal Benefit	Present Value 50 Yrs.			Benefit Cost Ratio		
	2%	4%	7%		2%	4%	7%	2%	4%	7%
1. Assume "Th" built and operating										
Gg	10,900	9,700	8,200	92	2,600	1,600	800	0.2	0.2	0.1
W	10,400	9,300	7,800	280	7,800	4,800	2,600	0.8	0.5	0.3
2. Assume "W' built and operating										
Th	6,700	6,000	5,000	380	10,600	6,400	3,500	1.6	1.1	0.7
Gg	10,900	9,700	8,200	32	900	500	300	0.1	0.1	0.0
3. Assume “Gg" built and operating										
W	10,400	9,300	7,800	518	14,500	8,800	4,800	1.4	0.9	0.6
Th	6,700	6,000	5,000	678	18,900	11,500	6,200	2.8	1.9	1.2

From the flood control aspect only, the above analysis indicates that the preferred option is to construct the Thamesford dam alone. Not only is it the least costly. but it also provides the most flood protection of any single dam, resulting in a high benefit-cost ratio. Construction of the Thamesford dam would eliminate 75 percent of the $1.5 M average annual flood damages. Furthermore, once the Thamesford dam is operational, the construction of either the Wardsville or the Glengowan dam cannot be justified on the basis of a flood control benefit-cost evaluation.

However, the benefit-cost ratio of the Thamesford Dam option will be reduced if its construction prevents the mining of limestone deposits situated there, in which case an "opportunity cost", the cost of foregoing the opportunity to mine these deposits, would have to be added to this option. This is reportedly the only unexploited deposit of this high chemical grade limestone remaining in Southwestern Ontario. The opportunity costs would include royalties to the Province, wages and profits associated with the mining, and the lack of alternative sources of this grade of limestone close to markets in Southern Ontario. Mining would reportedly not commence for at least five years, and could take 20 to 25 years to complete. Decisions on exploitation of the deposit would based on future economic conditions including demand and the prevailing market price in relation to the costs of extraction. Because this opportunity cost has not been included in the evaluation, the following analyses fall into two categories. The first assumes that any option including the Thamesford dam is not eliminated by this opportunity cost: the second assumption that the Thamesford dam options are no longer feasible because of this added cost.

If those options including Thamesford dam are not feasible, then on the basis of the above flood control benefit-cost evaluation, the only other feasible option is to construct the Wardsville dam alone. Table 7.2 shows that, once "W" is built and operating, it is not advantageous to construct "Gg". Table 7.1 shows that to construct "Gg" alone is not advantageous because it has a benefit-cost ratio less than I at discount rates of 4 percent or higher, and eliminates only 35 percent of the $1.5M annual flood damages. In contrast, the "Th" and "W" options eliminate 75 percent and 68 percent of the flood damages respectively.

One further comment regarding Wardsville dam option is necessary. The above analysis is carried out for the proposed retarding basin having a capacity of 43,000 acre-feet. A higher dam with a retarding basin capacity of 80,000 acre-feet has also been proposed. According to estimates, approximately 75 percent of flood damages occur downstream of Wardsville. An analysis shows that a low dam at Wardsville would eliminate 68 percent of all flood damages, leaving only 7 percent of damages remaining downstream of Wardsville. The advantage of constructing the higher Wardsville Dam would have to be carefully evaluated in light of the minimal additional benefit it would provide.

7.4.5 London Sewage Disposal Options

As indicated in Appendix H. the waste management alternatives available to the City of London in order to meet and maintain water quality objectives in future. can be reduced to the following options:

1. Implement tertiary treatment (discharging an effluent of approximately stream quality) and continue discharging to the Thames River,
2. Export sewage via pipeline to Lake Erie for secondary treatment and phosphorus removal prior to

discharge.

3. Build and operate Glengowan reservoir primarily for flow augmentation, and continue discharging to the Thames River using conventional treatment providing an effluent equivalent in quality to the Greenway plant.

In either case, expansion of existing sewage treatment plants is required to handle sewage flows until the option can be implemented.

An economic analysis of these options similar to that for flood control options is not possible. The benefit of water quality improvement or maintenance cannot be readily quantified, unlike flood control benefits, and hence, benefit-cost analysis is not possible. Minimum water quality criteria must be met, however. Given this objective, economic analysis is applied to determine the least-cost method of achieving it. As previously explained, the costs of sewage treatment alternatives for London are related to upstream reservoir construction options and must therefore be evaluated in a total system context. This total system analysis is carried out in Section 7.5 below.

Tertiary Treatment

Tertiary treatment as discussed here is taken to include traditional secondary sewage treatment plus the following processes:

- phosphorus removal
- carbon adsorption
- filtration
- ammonia stripping

The cost of providing tertiary treatment for a 2001 population of 500,000 at London in present value 1975 dollars computed at 4 percent interest rate (plant completion assumed in stages, 1981 and 1991) is $97M. As only one precedent for such treatment exists (South Tahoe Public Utilities District Reclamation Plant), this figure cannot be considered very accurate.

From results of the water quality computer simulation model developed for this study, waste loading guidelines for the City of London have been generated (Table 7.3, discussed also in Appendix H). The total allowable load (total oxygen demand) varies with the amount of river flow. Hence, loading guidelines are increased for those options which include flow augmentation from Glengowan, Thamesford, or both.

Table 7.3: London Waste Loading Guidelines

Option	Total Allowable Load Oxygen Demand lbs day			Year Load Limitation Reached [1]	Year Dilution Ratio Reached	
	Total	N. Thames	S. Branch		1.5:1	1:1
Present Conditions(no additional flow augmentation)	8,000	1,000	2,500	1993	1971	1984
Gg	11,000	2,000	2,500	2001 +	1983	1997
Gg	17,000	4,000	2,500	2001 +	1999	2001 +
Th	11,500	1,000	3,500	2001 +	1986	2001
Gg + Th	14,500	2,000	3,500	2001 +	1994	2001 +
Gg* + Th	21,000	4,000	3,500	2001 +	2001 +	2001 +

1. At treatment to stream quality

Gg —Glengowan operated primarily for flow augmentation

In addition to providing total load guidelines, specific limitations have also been placed on discharges to the North Thames and the south branch of the Thames within the city. Furthermore, loading figures apply only to sewage treatment plant effluents and are based upon the assumption that effects of urban runoff do not increase with time. This can only be achieved by control of discharges from combined sewer overflows and, as population increases, by storm water treatment.

Table 7.3 also shows dilution ratios (streamflow/sewage flow) which can be expected to occur under low flow conditions. This factor is important since the effects of pollutants which have not been modelled such as heavy metals and other toxicants are not precisely known and must also be controlled. The current dilution ratio in London is approximately 1.5:1. With increased levels of treatment, this ratio may be allowed to decrease. However, the ratio should not be allowed to decrease below 1:1, at least until the effects of this flow ratio upon water quality and fishlife have been determined. For that reason, implementation of additional remedial action is required by the dates at which this dilution ratio is reached.

Population projections based on official plans indicate a 2001 population of 500,000 for London. If this figure is accepted as the maximum population for the city as has been suggested, then it can be seen from Table 7.3 that, with an allowable dilution ratio of 1: 1 and construction of one additional dam upstream, tertiary treatment is a viable option. An advantage of this option is that it completely avoids any environmental effects that export of sewage might have upon Lake Erie and any pipeline right-of-way.

Sewage Pipeline Diversion to Lake Erie

For the diversion of London sewage to Lake Erie, two choices have been considered with respect to the phasing out of existing treatment plants. In the first option, P(a), all existing treatment plants in London and Lambeth would be abandoned in 1981. and all sewage would receive secondary treatment with phosphorus removal at a new sewage treatment plant (constructed in phases: 1981 and 1991) on the shores of Lake Erie. In the second choice, P(b), the diversion sewer is used as an effluent pipeline for existing treatment plants from 1981 to 1986, at which time these plants would abandoned and treatment at the lake would commence as in the first option. In the following analyses, costs based on the second choice are taken for the pipeline option "P", as described in greater detail in Appendix F.

According to the water quality simulation model. the sewage diversion option resulted in higher dissolved oxygen levels in the river than those obtained by advanced secondary treatment to Greenway STP quality (Appendix A, Section 7). Some criteria violations still occurred, however, indicating that combined sewer overflows will have to controlled and storm water treatment may eventually be required. The positive effects of removing London's waste loads from the river are partially offset by the reduced flow in the river resulting from diversion.

The advantages of this option are threefold:

1. It removes growth limitations that would be placed on London within the planning period if it were to continue discharging to the Thames River, assuming a 2001 population of 500,000.
2. It could allow the municipalities of Lambeth and St. Thomas along the pipeline corridor to be serviced by the same facility.
3. It removes all sewage constituents including residual toxicants from the river.

An additional benefit is that it may be possible to use the existing sewage treatment plants, once abandoned as conventional treatment plants, to treat storm water if this is found to necessary.

There are also disadvantages, inasmuch as the pipeline option would possibly have some negative environmental effects upon Lake Erie. Moreover, the attendant environmental effects and pressures for additional urban development that the pipeline would generate along the right-of-way must be considered. Detailed planning studies and firm planning controls would essential to determine the type and location of urban development, if any, desired along the pipeline corridor and to prevent uncontrolled development.

Also, flows in the Thames River downstream of London would be reduced. In a sense, this represents a return to the original flow regime of the river, as London's water supply is now piped in from Lake Huron.

Glengowan Dam Operation Primarily for Flow Augmentation

Previous discussions have considered the primary purpose of the Glengowan dam to be flood control. However, consideration has also been given to operating this dam primarily for flow augmentation. For this analysis. it was assumed that 22,000 of the 27,000 acre-feet of total storage would be used for this purpose. The reservoir would operated to be full in spring with water released during the summer low flow period. Flood control storage would be available for early spring runoff, and for late summer and fall floods, but no flood control could be provided for late spring floods. Little recreational use, if any, of the reservoir would be possible using the reservoir primarily for flow augmentation.

For a 2001 population of 500,000, treatment to Greenway quality would be acceptable until 1999, when a pipeline to Lake Erie would be needed. Alternatively, by limiting growth at London to 480,000, treatment to Greenway quality would sufficient.

7.5 TOTAL SYSTEMS COST ANALYSIS

7.5.1 Least Cost Analysis

Table 7.4 presents the net cost and least cost order of the various systems options evaluated in this manner. Table 7.5 summarizes the capital construction costs (outlay), and the total cost, flood control benefits and net cost in present value terms for the 4 percent discount rate.

Table 7.4: Total System Net Costs

Option	Net Cost Present Value ($M)			Least Cost Order		
	2%	4%	7%	2%	4%	7%
1. W+T:81	95.4	89.4	77.2	19	19	22
2. W + Gg + T:83	101.1	91.5	75.8	21	22	20
3. W+ Gg + P:83	82.1	71.2	62.6	16	14	16
4 W + P:81	75.2	71.5	61.8	8	15	15
5 W + Th + T:86	83.3	78.7	66.6	17	18	18
6. W + Th + P:86	67.7	65.0	55.2	5	11	12
7. Th + T:86	807	74.2	61.4	14	16	14
8. Th + P:86	65.2	60.5	49.9	4	7	10
9 Th + Gg + T:94	76.6	63.7	47.4	11	9	8
10. Th + Gg + P:94	71.1	58.8	43.5	7	5	6
11. Gg +T.83	105.3	91.1	72.7	22	21	20
12. Gg + P:83	86.3	74.7	59.5	18	17	13
13. W + Gg + Th + T:94	81.2	69.3	53.5	15	13	11
14. W + Gg + Th + P:94	75.3	64.4	49.3	9	10	9
15. W + Gg* + P:99	77.3	60.2	41.3	12	6	4
16. W + Gg* + Conventional Treatment**	23.1	27.0	26.2	3	3	2
17. Th + Gg° + Conventional Treatment	16.6	22.0	22.5	1	1	1
18. W + CC + ZS + T:82	98.9	90.7	76.2	20	20	21
19. W + CC+ ZS + P:82	80.0	67.5	63.2	13	12	17
20. Th + CC+ZS + T:93	75.8	63.1	46.4	10	8	7
21. Th + CC+ZS + P:93	70.3	58.2	42.5	6	4	5
22. Th + Gg + CC + ZS + Conventional Treatment	20.1	26.1	26.8	2	*2*	3

* Involves operation of Glengowan darn primarily for flow augmentation

** Option 16 involves growth limitation of 480,000 at London. Note: W, Gg and Th -assume construction in 1981.

Table 7.5: Summary of Cost Analysis for System Options at a 4 Percent Discount Rate In 1975 Dollars

Option	Total Cost Outlay	Present Value at 4 Percent of Total Cost	Flood Control Benefits	Net Cost
	$M	$M	$M	$M
1. W + T:81	144.9	106.6	17.3	89.4
2. W + Gg + T:83	157.1	109.3	17.8	91.5
3. W + Gg + P:83	133.9	89.0	17.8	71.2
4 W + P:81	121.7	88.7	17.3	71.5
5 W + Th + T:86	147.0	102.4	23.7	78.7
6. W + Th + P:86	129.0	88.7	23.7	65.0
7. Th + T:86	135.3	93.1	19.0	74.2
8. Th + P:86	117.5	79.5	19.0	60.5
9 Th + Gg + T:94	147.6	84.3	20.5	63.7
10. Th + Gg + P:94	141.3	79.3	20.5	58.8
11. Gg +T.83	145.4	100.0	9.0	91.1
12. Gg + P:83	122.2	83.7	9.0	74.7
13. W + Gg + Th + T:94	159.3	93.5	24.2	69.3
14. W + Gg + Th + P:94	153.1	88.6	24.2	64.4
15. W + Gg* + P:99	153.1	782.1	17.3	60.2
16. W + Gg* + Conventional Treatment**	61.1	44.3	17.3	27.0
17. Th + Gg° + Conventional Treatment	57. 0	41.0	19.0	22.0
18. W + CC + ZS+ T:82	154.0	108.2	17.5	90.7
19. W + CC+ ZS+ P:82	131.0	88.0	17:5	70.5
20. Th + CC+ ZS+ T:93	146.5	82.3	19.2	63.1
21. Th + CC+ ZS+ P:93	140.3	77.3	19.2	58.2
22. Th + Gg + CC + ZS + Conventional Treatment	64.3	46.8	20.7	26.1

* Involves operating Glengowan dam primarily for flow augmentation.

** Option 16 involves a growth limitation of 480,000 at London. Note: W. Gg and Th - assume construction in 1981

As well as taking into account flood control benefits, the figures in Table 7.4 include benefits (negative costs) to London attributable to the flow augmentation, which defers capital construction of a pipeline "P" or tertiary sewage treatment plants "T". For example, with no upstream dam construction as in option 1, "T" is required in 1981; with one upstream dam as in option 2, "T" is required in 1983: and with two upstream dams as in option 13, "T" is not required until 1994. The net costs of options 18 to 22 exclude both the economic benefits of flow augmentation to Woodstock in terms of deferred treatment expenditures and the increased water supply costs resulting from flooding of the Woodstock well field as described in Section 7.5.2.

It should be noted that the economic analysis undertaken to arrive at the total system least-cost ordering is extremely sensitive to population projections and associated sewage flows and hence, to deferral times of capital expenditures. For example, it can be seen from Table 7.4 for options 3 and 4 that the added expenditure of "Gg" construction in option 3 is totally balanced out by a two year deferral of"P" construction. Hence, system options 4 and 5 emerge as having an almost identical "net cost". In view of this the phase-timing of each option, and especially of "P" and "T" should be carefully noted as any change in this timing will significantly affect the net cost of the option concerned.

Related to this sensitivity is the relationship of actual capital outlay to net cost. Greater savings result from deferral of expenditures the higher the interest rate chosen. Thus, options offering a long deferral of "P" or "T" become *increasingly* favourable with increasing discount rates in the least-cost analysis. It can be seen from Table 7.1 that the reverse is true with dam construction where the benefit- cost ratio decreases with increasing discount rate. This is so because benefits are being discounted in this case rather than costs (i.e. average annual benefit over 50 years). Since the expenditure associated with dam construction is considerably smaller than that associated with either the pipeline or treatment options, total system options which include the "Th" and "Gg" and thus offer the longest deferral of or "T" continue to increase in favour with increasing discount rates. At this point, in order to further reduce the list of options, non-quantifiable costs and benefits are considered.

7.5.2 Evaluation of Non-Quantified Factors

Given the primary objectives of achieving good water quality throughout the watershed at the lowest cost and providing flood control consistent with benefit-cost criteria. there were three additional objectives clearly defined by the public and elected officials of the river basin:

1. To minimize the loss of prime agricultural land.
2. To increase recreational facilities within the watershed, particularly for swimming.
3. To minimize environmental disturbance due to capital construction projects, especially dams.

These objectives were taken into consideration in the following evaluation.

A preliminary review of the anticipated ecological and environmental effects of the proposed Glengowan, Thamesford, Wardsville, Cedar Creek and Zorra Swamp reservoirs has been carried out. Input to this study was obtained from the regional offices of the ministries of the Environment and Natural Resources and from presentations to the Environmental Hearing Board during its public hearings. As only preliminary engineering studies and limited field data were available, additional detailed studies will be required to evaluate the environmental effects in considerably greater detail.

The Thamesford reservoir would flood an area with extensive stream cover and a resting area for migrant geese. The latter presumably would not be impaired by the presence of a reservoir. Both the Glengowan and Thamesford reservoirs would flood ruffed grouse and European hare habitat. However, as there are extensive habitats for these species elsewhere in the Upper Thames watershed, this is not considered to be a serious constraint.

The Thamesford and Glengowan reservoirs would have surface areas of 1100 and 1280 acres respectively. A considerable amount of the flooded area is improved pasture and range land. Of the two reservoirs, it appears that the Thamesford reservoir would take up a relatively higher proportion of unproductive farmland. Depending on the type of discharge structures and operating practices, some water temperature elevation and water quality impairment would likely occur, particularly in and immediately downstream from the Glengowan reservoir.

The initial proposal for the Wardsville reservoir called for a permanent storage dam. Construction of such a reservoir would take up more than 6300 acres, much of it prime agricultural land. It would also have serious detrimental effects on the valuable yellow pickerel commercial fishery for Lake St. Clair-lower Lake Huron-western Lake Erie, to which the Thames River spawning beds from Wardsville to Komoka are the greatest contributors.

During the Thames basin study public hearings, considerable opposition to the Wardsville dam was expressed by municipalities, citizen groups. and individuals. In addition to the above-mentioned factors, effects of the impoundment on roads and bridges, agricultural drains, and rare flora and fauna were reported.

As an alternative to a permanent storage dam, the Ministry of Natural Resources has proposed construction of a retarding basin. This type of structure would provide downstream flood protection by retarding peak flows. During flood flows, it would cause temporary flooding of agricultural land and ruffed grouse. European hare, and pheasant habitat; however, a permanent reservoir would not be created, and the permanent loss of agricultural land would be minimal. It is also reported that this structure would be designed so as not to interfere significantly with the yellow pickerel spawning runs. There are several fundamental objections to the construction of the Cedar Creek and Zorra Swamp reservoirs, which would have major effects contrary to the objectives of this study.

The most obvious negative effect of construction of the Cedar Creek reservoir is the flooding of the aquifer in which the Woodstock municipal wells are located. Inundation of this aquifer may result in some impairment of ground water quality, as some of the sand and gravel aquifer is exposed at surface. Reservoir water, which would likely be highly organic, would gain access to the aquifer, possibly causing taste and odour problems and bacterial contamination. In addition, the municipal wells themselves would be flooded, and their continued use, while likely feasible from an engineering viewpoint, would involve modifications at an unknown cost and would hamper their operation and maintenance. Although flooding of the aquifer would likely increase the amounts of water that could be withdrawn, it is possible that water quality impairment of the aquifer could preclude its use for municipal water supply. If this happened, substantial costs would be incurred in locating and obtaining an alternative water supply for the City of Woodstock. (These economic costs are not included in the costs of options involving Cedar Creek and Zorra Swamp dams given below.) Thus, there are major uncertainties as to the continued use of this aquifer and to related municipal supply costs if the Cedar Creek reservoir is constructed.

Environmental effects of the Cedar Creek reservoir include detrimental effects on a stocked and natural coldwater fishery (brown and brook trout) and a major deer-yarding area (Curries) in the proposed reservoir area. The reservoir would occupy the largest surface area of any existing or proposed Upper Thames impoundment (1,460 acres including some agricultural land), and yet provide a relatively small storage capacity. The likelihood that the impounded waters in the Cedar Creek and Zorra Swamp reservoirs would be impaired is another significant objection to their construction. The shallow depth and swampy nature of portions of Cedar Creek and all of the Zorra Swamp reservoir would result in the discharge of warm and highly organic waters. Operation of the Cedar Creek reservoir for flow augmentation would involve the exposure of large tracts of useless and unsightly mud flats as the reservoir is drawn down.

The Zorra Swamp reservoir would be used solely for flow augmentation purposes, providing no flood control benefits. Only limited flood control benefits (an average of $22 thousand per year) would be obtained from the Cedar Creek reservoir. Neither reservoir would provide recreational benefits, in contrast to the objective of maximizing recreational facilities in the watershed.

As noted in Section 7.3.1, preservation of the Zorra Swamp has been recommended in view of its ecological importance as one of the few remaining wetlands in the watershed. Inundation of the swamp would fundamentally alter its natural ecological characteristics. The following table summarizes the unquantified costs and benefits associated with construction of each single option and which are elaborated upon elsewhere in this report. Where a system option includes more than one capital construction proposal, these costs and benefits are additive.

Summary of Unquantified Costs and Benefits of Major Options

Option	Unquantified Costs	Unquantified Benefits
Glengowan Dam	1. Agricultural land permanently inundated. 2. Water quality deterioration in and immediately downstream from the reservoir 3. Increased water temperatures 4. Disruption and destruction of some fish and wildlife habitat	1. Improved recreational opportunities, either directly through provision of facilities at Glengowan reservoir or indirectly through improved water quality in the Fanshawe reservoir. 2. Improved water quality through flow augmentation in downstream areas. Flow augmentation benefits to London have been included in the economic analysis. 3. Flood control benefits. not included in the economic analysis, if Glengowan is used primarily for flow augmentation.
Thamesford Dam	1. Agricultural land permanently inundated. 2. In-reservoir water quality deterioration 3. Water temperature increased 4. Sports fishery disruption 5. Some disruption and destruction of fish and wildlife habitat. 6. Public opposition voiced. 7. Foregone opportunity to extract limestone deposits.	1. Possible recreation benefits if facilities provided. 2. Water quality improvement through flow augmentation to downstream areas. This benefit to London was included in the economic analysis
Wardsville Retarding Dam	1. Disruption of road links between Elgin and Middlesex counties during high flows, possibly requiring new bridge construction. 2. Strong public opposition expressed 3. Occasional inundation of Indian Reserve lands.	

Option	Unquantified Costs	Unquantified Benefits
Cedar Creek Dam	1. Inundation of the Woodstock well field. 2. Disruption of a stocked and natural coldwater fishery. 3. Destruction of a major deer-yarding area. 4. Agricultural land permanently inundated 5. In-reservoir and downstream water quality impairment. 6. No recreational benefits	1. Additional dilution flow for Woodstock and downstream areas through low flow augmentation
Zorra Swamp	1. In-reservoir and downstream water quality impairment 2. No recreational benefits 3. Major changes in the natural ecology of the swamp.	1. Additional dilution flow for downstream areas through low flow augmentation
Pipeline	1. Environmental effect upon Lake Erie and pipeline corridor. and pressure for urban development along the corridor. 2. Reduction of flow in the Thames River	1. Possible advantages to municipalities along the pipeline corridor outside the watershed should they tie in to the system. 2. Removal of all London sewage effluent from the river giving improved water quality downstream 3. Possible benefit of direction of controlled growth away from more sensitive areas.
Tertiary Treatment	1. Eventual growth restraints on London City due to dilution ratio limitations.	1. Allows for any advantages future sewage treatment technology improvements may offer.

Having outlined both the economic and unquantified benefits and costs of various systems options, an evaluation of their relative merits is presented below. It is important to note that the cost and benefit calculations in this study are based on reconnaissance design and preliminary data only.

7.5.3 Options Involving the Thamesford Reservoir

The following evaluation assumes that construction of the Thamesford dam is not ruled out by the added "opportunity cost" of foregoing mining of the limestone deposit at the reservoir site. The deposit and the associated opportunity costs are described in Section 7.4.4. On this basis, options involving the Thamesford reservoir are listed below in least net-cost order at 4 percent discount rate.

Table 7.6: Ranking In Net Cost Order of Options including the Thamesford Dam

Option No. (from Table 7.4)	Option	Net Cost Present Value ($M) @ 4%	Order (from Table 7.4)
17.	Th + Gg* + Conventional treatment	22.0	1
22.	Th + Gg + CC + ZS + Conventional treatment	26.1	2
21.	Th + CC + ZS + P:93	58.2	4
10.	Th + Gg + P:94	58.8	5
8.	Th + P:86	60.5	7
20.	Th + CC + ZS + T:93	63.1	8
9.	Th + Gg + T:94	63.7	9
14.	W + Gg + Th + P:94	64.4	10
6.	w + Th + P:86	65.0	11
13.	W + Gg + Th + T:94	69.3	13
7.	Th + T:86	74.2	16
5.	W + Th + T:86	78.7	17

Involves operations of Glengowan dam primarily for flow augmentation.

When both economic and environmental factors are considered, option 17 is the most attractive of all systems options which include the Thamesford dam. This option involves construction of the Thamesford dam primarily for flood control, the Glengowan dam primarily for flow augmentation and conventional treatment for London. In net cost terms, it is the least costly of all systems options in Table 7.4 (which excludes the opportunity costs associated with the Thamesford limestone deposits), and represents a net saving at 4 percent of $4.1M over the second-least costly option. number 22. It is also the least costly option in terms of total cost at 4 percent.

Option 17 is also superior to option 22 on environmental grounds as it involves the construction of two fewer dams and thus avoids the environmental problems related to the Zorra Swamp and Cedar Creek dams.

This option also provides considerable flexibility as to the waste treatment facilities that would be needed at London. Based on water quality predictions. neither the sewage pipeline nor tertiary treatment would required during the planning period. Decisions as to the type of new treatment facilities and the dates by which they would be required could be made in stages. depending on actual population trends and water quality conditions, and on planning decisions as to the desirable size of the City of London. This option should allow growth to 500,000 persons at London by 2001 if necessary.

Flood protection consistent with benefit-cost criteria would also provided for St. Marys, London, and all areas downstream. Flood control benefits would largely accrue to the Thamesford dam as it provides the most flood control benefits for the largest portion of the basin of any single reservoir. Some flood storage would be available at Glengowan to control flooding in early spring, summer and fall. However. Glengowan dam would not provide flood storage for late spring floods.

Some recreational use of the Thamesford reservoir would be possible. Although operation for flow augmentation would severely curtail recreational use of the Glengowan reservoir, an indirect benefit in the form of enhanced recreation at Fanshawe due to possible water quality improvement may occur.

Disadvantages of this option include some loss of agricultural land, the previously noted environmental effects associated with the construction of these two dams, and the foregone opportunity to mine the Thamesford limestone deposits.

7.5.4 Options Excluding the Thamesford Reservoir

If it is decided that the limestone opportunity costs eliminate consideration of options involving construction of the Thamesford dam. then options 1, 2. 3, 4. 11. 12. 15. 16, 18, and 19 should be considered. These are listed below in least-cost order of net costs at 4 percent:

Table 7.7: Ranking In Net Cost Order of Options excluding the Thamesford Dam

Option No. (from Table 7.4)	Option	Net Cost Present Value ($M) @ 4%	Order (from Table 7.4)
16.	W + Gg* + Conventional treatment	27.0	3
15.	W + Gg* + P:99	60.2	6
19.	W + CC + ZS + P:82	67.5	12
3.	W + Gg + P:83	71-2	14
4.	W + P:81	71.5	15
12.	Gg + P:83	74.7	17
1.	W + T.81	89.4	19
18.	W + CC + ZS + T:82	90.7	20
11.	Gg + T:83	91.1	21
2.	W + Gg + T:83	91.5	22

* Involves operation of Glengowan dam primarily for flow augmentation.

From an economic viewpoint, option 16 is the least costly in terms of net costs of this group of options. It involves construction of the Wardsville retarding dam for flood control, the Glengowan dam primarily for flow augmentation, and conventional treatment at London. Water quality predictions for this option require a growth limitation of 480,000 persons for the City of London. Provided that such a growth restriction is acceptable, option 16 represents a significant saving in terms of net cost of more than $33 million over option 15, the next least costly option. Option 16 is also the most favourable of the "non-Thamesford" options in terms of total cost (present value at 4 percent).

From an environmental viewpoint, option 16 is also an acceptable option. Options 1 and 11 would have less environmental impact as they involve only one dam rather than two and tertiary treatment rather than the pipeline. However, the additional net cost at 4 percent of at least $62M over option 16 is significant.

Under option 16, the Wardsville retarding dam would provide flood control for the lower watershed, while some flood protection would be provided by the Glengowan reservoir for the North Thames River against early spring, summer and fall floods. but not for late spring floods. While recreational use of the Wardsville reservoir would not be possible, recreational use of the Fanshawe reservoir may be enhanced by possible water quality improvement due to flow augmentation from the Glengowan dam.

One significant advantage of option 16 is the valuable flexibility it offers to decision makers, as it provides a basis for a variety of future courses of action. For example, if a growth limitation of 480,000 is found to be unacceptable, consideration could be given to construction of a sewage pipeline to Lake Erie in 1999 as in option 15, which is the second least costly of the "non-Thamesford" options.

Moreover, using option 16 as a basis. there are a variety of approaches to sewage disposal at London which have not been costed. For example, tertiary treatment processes, less expensive than the tertiary treatment system costed in Appendix F, could be evaluated to determine if they could meet water quality objectives and provide for additional growth of London to the size determined to be the most desirable when other factors in addition to water management consideration are taken into account.

7.5.5 Summary

If the Thamesford dam is feasible, the preferred option is to construct the Glengowan dam primarily for flow augmentation, the Thamesford dam primarily for flood control, and to utilize conventional treatment at London (option 17).

If a decision is reached that the limestone opportunity costs are sufficiently great to eliminate options involving the Thamesford dam, then the preferred option is to construct the Wardsville dam for flood control, the Glengowan dam primarily for flow augmentation, and conventional sewage treatment at London (option 16). If the growth limitation of 480,000 at London associated with this option is unacceptable then other options such as provision of tertiary treatment or the construction of a sewage pipeline can be considered.

As the Glengowan dam is common to each of the preferred options, construction of the Glengowan dam first would offer maximum flexibility in choosing other capital construction projects. Decisions as to whether to construct the Wardsville dam or the Thamesford dam could then be made. Decisions as to whether to continue to discharge sewage effluent to the Thames River or to construct a sewage diversion pipeline from London to Lake Erie could be deferred to the 1990's. By that time. actual water quality conditions and other water management trends can be documented, population projections will be refined and further information will be available on the desired size for the City of London. The early construction of the Glengowan dam and the use of sophisticated secondary sewage treatment practices thus provides decision makers with valuable flexibility so that new information can be utilized in future planning decisions.

CHAPTER 8

APPLICATION OF WATER MANAGEMENT OPTIONS TO LOCAL AREAS

In this chapter, water management options for specific stream reaches are described and evaluated in detail.

8.1 NORTH THAMES RIVER

The major water quality problem in the North Thames River is the critical nature of the dissolved oxygen regime. Additional problems include periodic flooding in St. Marys and water quality degradation in the Fanshawe and Wildwood reservoirs.

8.1.1 Mitchell

Low flows and related inadequate year-round waste receiving capabilities, characteristic of the North Thames River at Mitchell, make disposal of municipal wastes from the lagoons at this municipality difficult. This natural limitation contributed to the occurrence of severely low levels of dissolved oxygen measured during a 1972 field survey. Significant increases in phosphorus and bacterial concentrations were observed at various times through the town. Although a recent study indicated that the Mitchell lagoons provide excellent organic waste reductions, the fact that they are hydraulically overloaded necessitates a continuous discharge at present. This operating approach adds to water quality stresses on the North Thames during low flow periods. As a result, improvements in the municipal collector system and a change in the discharge technique from continuous to once- annual are immediate requirements to safeguard water quality in the North Thames. Should the Town of Mitchell expand to the 4,000 population projected for the year 2001, major additions to the waste treatment works would be required. Use of water stored behind the Mitchell dam for augmentation purposes during the summer is not possible without major alterations of the spillway structure, since the dam is not equipped to provide controlled discharge above the normal storage volume of 185 acre-feet.

Reducing the infiltration of water to the collector system will provide some hydraulic relief to the lagoons. However, even at existing populations and assuming a reasonable per-capita hydraulic load of 100 gallons per day, 50 acres of lagoon storage, in addition to the present 67 acres, is required to allow the once-annual March-April discharge necessary to avoid water quality impairment. Population expansion to 4,000 would inflate the total storage requirement to roughly 195 acres and total retention-spray irrigation would involve over 200 acres of land.

To eliminate the need for additional surface area devoted to effluent storage and to provide the town with flexibility for future planning, the existing lagoons should be operated in conjunction with a sewage treatment plant which should be constructed immediately. The mechanical plant would be designed to produce an effluent BOD_5 of 10 mg/L with provision for the possible addition of effluent polishing at a later date. Wastes would be stored in the existing lagoons from June through November for later discharge during high flows in March and April. Discharge from the secondary plant to the river could be continuous from November through May. This approach would satisfy a population of up to 3,500, beyond which tertiary treatment and a slight alteration in discharge timing would be necessary to carry Mitchell to a population of 4,000. Since these calculations are based on a 100 gallon per capita, per day, hydraulic loading to the sewage works, acceptability of the suggested treatment approach is conditional upon the continuous reduction of infiltration to the collector system.

It therefore appears that the most practical approach to minimize water quality impairment of the North Thames River at Mitchell is the addition of a mechanical treatment plant to existing sewage treatment facilities, along with a program designed to reduce infiltration to the municipal waste collector system. Other treatment approaches are costly in terms of use of agricultural land. At some time in the future, growth constraints should be applied at Mitchell since waste assimilative capabilities of the stream are extremely limited.

8.1.2 Stratford

Population projections for the City of Stratford indicate that a population of 47,000 could be expected by the year 2001. Water quality studies have shown that even at the present population and under a streamflow regime 40 times higher than the estimated low flow, minimum dissolved oxygen levels of 2 mg/L severely violate criteria for the entire length of the stream (Appendix A). Although municipal wastes from Stratford receive advanced treatment to reduce organic loadings consisting of secondary treatment with effluent filtration, modelling studies outlined in Appendix A have shown that oxygen guidelines in the entire Avon would not be achieved even through the total elimination of oxygen demanding materials from Stratford. This situation is the result of obnoxious aquatic plant growth caused by a continuous nutrient availability, coupled with extremely low natural streamflows during summer months. As previously stated, it is the long term objective of the Ministry of the Environment to upgrade water quality to make the resource available for broader use. Management approaches directed towards the achievement of dissolved oxygen objectives set for the immediate objective of sustaining fishlife in the Avon River are: harvesting of aquatic vegetation from the receiver; advanced phosphorus removal during critical aquatic vegetation growth periods; further treatment to remove nitrogenous organics; stormwater treatment; exportation of wastes to a more appropriate receiving watercourse; restrict further discharge volumes owing to surface water quality constraints.

Modelled response of the dissolved oxygen regime was most sensitive to reductions in photosynthesis and respiration factors, emphasizing the need for implementation of measures to control aquatic vegetation. Physical removal of heavy vegetation growth from the stream would improve the dissolved oxygen regime and produce a more aesthetically pleasing watercourse. To date, experimental use of aquatic plant harvesting as a water management technique in Ontario has been conducted only in lakes and has not been applied in a stream setting. Hence, this approach would have to be regarded as experimental and should be preceded by an in-depth study of its feasibility.

Removal of phosphorus from the Stratford effluent to lowest possible levels during the critical growth period (May through September) would have indirect positive effects on dissolved oxygen levels by reducing the continuous supply of nutrients available for growth to minimal amounts. Municipal sources accounted for 56 percent of the annual phosphorus loading in the Avon River prior to the implementation of the phosphorus removal program in 1973. It is calculated that this figure has been reduced to 42 percent following reductions in phosphorus levels in the treated sewage effluent.

It must be noted that 80 percent of the annual contribution of phosphorus from Stratford originates from sources other than the municipal waste treatment plant, including sewage bypasses, urban runoff and minor point source inputs. However, as indicated in Table 8.1, the continuous year-round phosphorus input from the sewage facility assumes greater significance in the summer growth period for aquatic vegetation, as the Stratford plant represents the major phosphorus source even with conventional phosphorus removal during this period.

Table 8:1: Monthly contribution of phosphorus from the Stratford sewage treatment plant* relative to the overall burden in the Avon River at its mouth

Month (1972)	Ratio-STP Load to Avon Yield at North Thames River
January	0.14
February	**
March	0.05
April	0.05
May	0.50
June	0.96
July	1***
August	1***
September	1***
October	
November	0.23
December	0.08

* Assuming 80 percent phosphorus removal at the plant.
** Figures inaccurate Owing to Interference In streamflow measurement by ice.
*** Yield figures low because of stream storage of phosphorus through vegetation uptake

A positive response of dissolved oxygen levels to reductions in oxygen demanding loadings was predicted at 0.7 miles downstream from the Stratford STP. Due to the overriding effects of the extensive beds of aquatic vegetation on the dissolved oxygen regime during the study, negligible improvement occurred further downstream. Decreasing the amount of aquatic vegetation, by implementing measures described above, increases the relative influence of organic loadings on the improved oxygen regime. Recent observations on the performance of the Stratford sewage treatment plant indicate excellent reductions in the carbonaceous portion of the organic load, to the lowest practical levels, although further improvement in the oxidation of the nitrogenous fraction is possible.

The exportation of treated water to a receiver with a greater dilution capacity would essentially eliminate flow in the stream during the summer when natural streamflow would be expected to be intermittent. If treated sewage were redirected to the North Thames, downstream from the proposed Glengowan dam site, a significant stress on water quality in the reservoir would be eliminated. However, such a proposal would involve a costly 10 mile long pipeline and the discharged water would bypass the Avon River below Stratford. Current water users along the lower Avon River, who have come to expect a continuous streamflow (e.g. farmers for livestock watering), would be forced to find alternate supplies.

Studies indicate that water quality objectives may never be totally attained on the Avon River downstream from Stratford. Such constituents as chloramines, phenols, and heavy metals may never be completely removed and even low levels of these components assume significance when essentially no dilution is afforded by the receiving stream during low flows. However, by adopting the first three approaches as discussed earlier, the existing situation may be improved and the degree of impairment lessened. Keeping in mind the objective of upgrading water quality where impaired and recognizing that an acceptable sewage to streamflow ratio is grossly exceeded at present sewage flows, the discharge of increased waste loadings to the Avon River should not be allowed. Studies should be conducted to determine the significance of the municipal storm drainage portion of the organic load, and steps taken to correct problems where they exist.

8.1.3 St. Marys; Campbell Soup Company Limited

From St. Marys to Fanshawe Lake, excessive aquatic weed growth has contributed to reductions in levels of dissolved oxygen to critically low concentrations. Treatment of organic wastes at St. Marys has appeared satisfactory based on recent observations of the river and on effluent quality records, although the plant is currently handling only half of' its design capacity of 0.8 MGD. Periodic upsets in the treatment facilities at the Campbell Soup Company Limited chicken-killing and processing plant have in the past resulted in the discharge of excessive organic inputs which further tax the dissolved oxygen regime. With these problems in mind, management options to improve water quality in this reach include: consistent treatment of organic wastes at the Campbell Soup plant; phosphorus removal to lowest possible levels at St. Marys and the Campbell Soup plant; and the provision of increased summer flow through the construction of the Glengowan reservoir. Assuming that the design population of 6,000 at the St. Marys sewage treatment facility will be attained in 1991. expansion before the 2001 planning horizon will required. Since space for expansion is not limiting at the site and streamflow appears adequate, water quality problems due to organic loadings are not anticipated up to the year 2001.

At the Campbell Soup plant, recent improvements in the waste treatment facilities have resulted in reduced organic loadings to the river. Provided there is continued progress towards effective plant operation, organic inputs from Campbell Soup should not become a problem.

Since aquatic weed growth influences the dissolved oxygen regime so significantly from St. Marys to Fanshawe, it is essential that phosphorus inputs from controllable point sources (St. Marys, Campbell Soup plant) reduced to the lowest possible levels. Although the Campbell Soup and St. Marys inputs may appear minor compared to the background burden in the Thames River on an annual basis, these sources attain greater significance when considered on a seasonal basis, particularly during periods of active growth of aquatic vegetation. This is due to the seasonal variability in the ratio of background phosphorus burdens to the virtually constant input from point sources.

Although modelling studies indicate that reductions in aquatic weed growth would result in a more complete improvement of dissolved oxygen to satisfactory levels from St. Marys to Fanshawe, additional streamflow augmentation from June 1 to September 20 would provide significant but incomplete relief to oxygen problems. Depending upon the use priority assigned to the proposed Glengowan Dam, the reservoir could discharge from 36 cfs to 97 cfs for 112 days during critical low flow periods. Combined with a minimum summer low flow of 40 cfs from Wildwood, the minimum flow downstream from St. Marys would be 76 cfs if flood control were assigned use priority, or 136 cfs if flow augmentation were designated the prime purpose of the Glengowan Dam. Water quality investigations indicate that 150 cfs are required to produce satisfactory dissolved oxygen levels under conditions observed in 1971. Coupled with waste treatment improvements at Campbell Soup Limited and St. Marys, the construction of the Glengowan dam for flow augmentation would come close to achieving dissolved oxygen objectives during summer months. Flooding problems are still prevalent in St. Marys. Operation of the proposed Glengowan dam would provide some flood protection. but channelizing the river in St. Marys may still required.

8.1.4 Wildwood Reservoir

In existing North Thames reservoirs, water-use conflicts and impaired water quality pose the major problems. In Wildwood dam, management conflicts have been identified in the Public Consultation Program and the Environmental Hearing Board sessions. Concern has been voiced about high powered motor boats on this reservoir. conflicting with good water quality and safe recreational use. Horsepower restrictions or the possible prohibition of power boats from the reservoir are possible management options to resolve this conflict. Interest in development of an expanded waterfowl management program in the upper reaches of Wildwood reservoir has also been stated. Limited year-round storage of water at a constant level at the upper end of the reservoir would provide a suitable waterfowl habitat. Such a plan would increase the variety of recreational endeavours in the area: however, this use may conflict with water quality and reduce storage available for flood control. Management directed at transient waterflow populations may a more palatable alternative.

8.1.5 Fanshawe Lake

Water quality impairment in Fanshawe Lake has been manifested in the past by troublesome bluegreen algae blooms during the summer high use period for swimming and bathing. During the summers of 1973 and 1974, the partial low level discharge approach, initiated in 1967, was modified to reduce phosphorus recycling from bottom sediments and no algae blooms occurred. This operations approach, coupled with the continuing reduction in phosphorus inputs from upstream point sources, are positive steps which will minimize interference with recreational use.

Along with low streamflows in Wye Creek, the possible detrimental effects of nutrient and bacterial inputs on recreational use in Fanshawe Lake are clearly reasons for discouraging future expansion at Thorndale. Development could be allowed only on the basis of a no-effluent system which would provide water quality protection. The additional flow provided by the proposed Glengowan reservoir would increase the flushing rate during summer months at Fanshawe and reduce the potential for phytoplankton blooms.

8.2 THAMES RIVER UPSTREAM FROM LONDON

Water management problems in the Thames River above London are related mainly to water quality impairment associated with urban and rural inputs, along with flooding at Woodstock and Ingersoll. Some problems which have basin-wide implication have particular pertinence to this stretch of the Thames River.

8.2.1 Tavistock

From the Zorra Swamp to the Pittock reservoir, the problem of water quality impairment appears to be related to a combination of low streamflows and rural runoff. Water management options to upgrade water quality in this reach include flow augmentation and the adoption of alternatives related to rural areas as discussed in Appendix C.

Water resource management options directed towards the solution of problems related to rural areas are particularly important in this reach. One reason is the intensity of cattle and swine production in East Zorra Township, which occupies the major drainage area of this stretch of the river. Federal livestock census figures for 1971 reveal that East Zorra Township carries the largest numbers of cattle and hogs of any township in the Thames River basin. Hence, options described in greater detail previously in this chapter, such as the restriction of range cattle access to watercourses and close surveillance of manure handling practices and water quality of municipal drains, are of particular relevance to this area.

Considering the low waste assimilative capacity of the stream and conflicts with downstream uses, serious consideration should given to limiting urban development in this headwater reach. Constraints on waste discharge methods at Tavistock are imposed mainly by critically low streamflows from May through October and by downstream water uses. During these six months. monthly average streamflows may drop below 1 cfs and discharged wastes would become partially entrapped in the Gordon Pittock reservoir. By the year 2001, it is projected that the population of Tavistock will have increased to approximately 2,100. At the present population (1,400) and operating under the constraints mentioned previously, water quality objectives are barely achieved in this reach of the Thames. In addition, a significant portion of the phosphorus load from the village is discharged at the same time that water is being stored in Gordon Pittock reservoir. Population expansion would therefore require greater waste storage capacity, a change in discharge timing and/or improved treatment to reduce oxygen consuming and phosphorus loadings to acceptable levels.

The option of total retention-spray irrigation, based on the 2,100 population figure, would involve the acquisition of an estimated 200 acres for spray purposes, 55 acres for 265 days of storage plus additional acreage for berms and a buffer zone.

One alternative course of action would increased waste retention for discharge at varying rates during March and April which would involve lagoon expansion from 14 to approximately 60 acres. Although water quality objectives for the Thames River from Tavistock to Woodstock would be attained by this approach, the total load of bacteria and nutrients would be discharged at a time when the Pittock reservoir receives and stores the spring freshet, thus causing possible further interference with aesthetic and recreational uses of the reservoir.

Storing treated wastes from May through October and discharging daily flows from a secondary treatment plant from November through April, only when streamflows exceed 2.2 cfs, is the most practical approach to future waste treatment at Tavistock. Wastes stored in a 35-acre lagoon would be discharged as streamflows permit. The annual burden of nutrients and bacteria originating from Tavistock and being taken into storage by the Gordon Pittock reservoir would be significantly reduced and water quality objectives in this reach of the Thames River would be met.

Conventional phosphorus removal incorporated into the latter two options would reduce Tavistock's present phosphorus contribution to the river from a measured 23 percent of the annual stream burden to 6.6 percent of the burden, using 2001 population figures. Since this source represented only 6.6 percent of the annual stream burden entering Pittock. efforts would be better expended on the control of rural sources, which account for over 90 percent of the phosphorus burden in the stream.

The three waste treatment options suggested for Tavistock are typically considered when a receiving stream is fast approaching or already beyond its ultimate capacity to accept wastes. To further tax the receiving watercourse by loadings beyond the 2001 design figure would seriously jeopardize water quality both in the immediate downstream reaches of the Thames River and in the Gordon Pittock reservoir. Since expansion of Tavistock could proceed only at the expense of well over 200 acres of farmland or construction of two costly sewage facilities, the most logical option available to the Village of Tavistock is the application of growth restraints.

Construction of the Zorra Swamp reservoir is a possibility. If it were built for augmentation purposes, waste treatment requirements for Tavistock would not be as stringent as described above; also, it is unlikely that immediate growth restrictions would be required. The additional 10 cfs of flow provided during the critical low flow period from the reservoir would allow discharge of treated sewage in this period and possibly allow the use of conventional sewage treatment systems, or reduced effluent storage requirements. However, as discussed in Chapter 7, construction of this dam for flow augmentation alone is not felt to be justified.

8.2.2 Gordon Pittock Reservoir

Although the major problem in the Gordon Pittock reservoir identified both from data collection and public consultations is one of water quality impairment, conflicts among uses for which the dam was intended also pose problems. Water quality impairment, manifested by unsightly algae blooms, bacterial contamination, and chronic fish kills, interfere for the most part with the recreational use of the impoundment. The annual drawdown during summer and fall to maximize the major purpose of the reservoir—flood control—exposes unsightly and malodorous mud flats and interferes with fish and waterfowl production. Towards the end of the summer, the use of stored water for low flow augmentation exposes aesthetically unpleasing mud flats and stumps in the upstream portion of the reservoir. Alternatives designed to rectify these conflicts include: (i) limitation of the use(s) of the reservoir and management to satisfy the reduced use(s), (ii) establishment of programs to minimize upstream sources of contaminants, (iii) minor alterations of the reservoir operating procedure to minimize use conflicts, (iv) provision of additional flow through the reservoir during summer months to increase the flushing rate and (v) attack the symptoms of the problems.

The primary function of the Pittock dam is to provide flood protection. To limit use of the dam to this purpose alone would waste a valuable resource and aggravate water level variation both in short term magnitude and frequency. When flows are low, the darn would be emptied completely until no water was available to augment summer low flows. Without flow augmentation and with the continuous discharge of treated wastes from Woodstock, Ingersoll, and London, and periodic inputs from diffuse sources, severe water quality impairment would occur. Management of the Gordon Pittock dam for both flood control and flow augmentation involves the partial storage of water for release when streamflows are low and risk of a major flood is remote. This mode of operation results in a more frugal use of water and provides a more stable and aesthetically pleasing water body.

Since these conditions are somewhat conducive to recreational use, finer tuning of the flood control-flow augmentation operating procedure has minimized the magnitude and frequency of fluctuations in water levels and has increased reservoir use by adding swimming. viewing and boating facilities.

A discussion of some programs designed to minimize upstream sources of contaminants was included in Section 8.2.1. Streambank stabilization programs, judicious surveillance of livestock waste disposal practices, restriction of livestock access to streams and improved municipal waste treatment and/or population constraints at Tavistock would contribute to improved water quality.

The third option which may rectify use conflicts is to alter the reservoir operating procedure without altering the established use priorities. Major alterations in operating policies are discussed in Appendix C. Only minor operational changes which may significantly affect water quality are considered here.

The "bottom-draw" option explained earlier would tend to stabilize the trend of nutrient accumulation in the reservoir by drawing off bottom waters where phosphorus concentrations are double those of the surface waters. At present. discharge through the low flow tube equals the inflow to the dam. Increasing the flow through this device to the required 15 cfs for streamflow augmentation would reduce nutrients available for algae growth and encourage mixing of surface and bottom waters. The only possibility of providing additional flow through the reservoir during summer months is the construction of Zorra Swamp reservoir. The provision of an additional 10 cfs through the Pittock Reservoir would improve circulation in the impoundment and reduce its stagnant nature.

The option of attacking symptoms rather than causes is a viable stop gap measure until longer term proposals have been implemented and begin to show results. The most obvious symptom of over enrichment in the Pittock reservoir is the annual "bloom" of blue-green algae which interferes with swimming and has been known to be associated with stomach disorders upon ingestion of the water and with minor skin and eye irritations. A full scale application of an algicide would be prohibitively expensive and likely provide only short term relief. Application to the swimming area would be more practical. provided it is adequately isolated from subsequent intrusion by algae-laden water.

Swimming at public beaches in Ontario is prohibited when bacteriological levels exceed established guidelines, indicating unhealthy conditions. Disinfection of the swimming area through chlorination as discussed in Appendix C is one approach to allow continued swimming at Pittock. provided intrusion of contaminated water is prevented, and fish life is not adversely affected.

The cause of annual fish kills in the reservoir is thought to be of parasitic and bacterial origin combined with the stress of elevated water temperatures. A reduction in water temperatures is virtually impossible in the shallow impoundment. but parasitic control may be possible once the parasite is identified.

8.2.3 Woodstock

Issues in the Woodstock area are related to options for solution of problems of water quality impairment, water supply and flooding.

(a) Water Quality Impairment Problems

Poor water quality at Woodstock has been attributed to the discharge of inadequately treated municipal sewage originating from sewage treatment plant bypasses and combined sewer overflows. At present, over one-third of the streamflow in the south branch at Woodstock would be treated sewage during extreme low flows, indicating very simply that effective waste treatment is important at this location. Management options to improve water quality downstream from Woodstock include flow augmentation. control of combined sewage overflows, storm water treatment and advanced sewage treatment. as well as the basic option of limiting population growth in the future. Modelling studies (Appendix A) assuming no additional flow augmentation beyond the 15 cfs currently provided by the Gordon Pittock reservoir, indicate that a total oxygen demand of not more than 900 lbs. per day may allowed in order to satisfy dissolved oxygen criteria in immediate downstream reaches. The model prediction also indicates that dissolved oxygen objectives will not be met beyond these immediate downstream reaches, because of the overriding effect of respiration from aquatic plants and algae (and possibly bottom sludge). The dilution ratio of natural low flow to sewage flow is presently at 1.8:1. As already discussed, it is not considered acceptable to allow the dilution ratio to drop below 1:1. A treatment system of the type described in Appendix F for the City of London would be required to allow a treatment plant expansion to 8 MGD.

This level of treatment. which includes phosphorus removal, carbon adsorption. ammonia stripping and effluent filtration, following conventional secondary treatment, can be expected to approximately double the cost of conventional treatment.

Present plans call for expansion of the Woodstock sewage treatment plant to a capacity of 7.85 MGD for an estimated 1993 population of 36,750 (MacLaren, 1974). This is based on a relatively high per capita flow rate of over 200 gallons per day. caused by a high infiltration rate of ground water into the sanitary sewers. In order to maintain the allowable waste load of 900 lbs. per day of total oxygen demand, an advanced treatment system described earlier would be required at the existing low flows. As discussed earlier, expansion of the treatment plant beyond 8 MGD should discouraged since this would result in a low flow dilution ratio of less than 1:1. This implies that the maximum population of Woodstock would be reached with the proposed expansion. A decrease in the per capita flow rate would allow some increase in population. but no increase in the treatment plant size.

In 1972. as described in Appendix G, 39 percent of the annual phosphorus load entering the Thames River (south branch) upstream from London, originated from the Woodstock sewage treatment plant. With conventional phosphorus removal (80 percent reduction. in operation in 1974), Woodstock's contribution was reduced to approximately 8 percent of the annual burden entering London from this section of the river. The effect of this major reduction in annual phosphorus loadings at Woodstock on the photosynthesis-respiration factor of the dissolved oxygen regime from Beachville to Ingersoll while unknown must be beneficial.

Modelling used to derive allowable waste loads was based on the assumption that no increase in urban runoff loads would occur with future growth. The City should implement studies to define approaches to reducing runoff loads from existing urban areas and future growth areas to result in no net increase in urban runoff loads.

Flow augmentation at Woodstock is potentially available from two sources: 10 cfs from the suggested Zorra Swamp reservoir and an estimated 22 cfs from the proposed Cedar Creek reservoir. Combined with the 15 cfs presently provided by the Gordon Pittock reservoir, a theoretical minimum of 47 cfs could be available during summer low flow periods. It should noted that flows downstream from Woodstock during the July. 1972 survey were essentially identical to this figure at 46 cfs. Under this regime. as described in Appendix A part 6. and with 1972 loading rates, dissolved oxygen levels fell below the 5 mg/L criterion from Woodstock to Beachville. This implies that other remedial measures as well as possible flow augmentation would be required to provide satisfactory water quality.

If Zorra Swamp reservoir or Cedar Creek reservoir were built, then the requirement for the tertiary treatment level would not necessary. and the allowable load increased somewhat. lithe added cost of the tertiary treatment system over the system required with flow augmentation were calculated, then the economic benefit of the reservoir for waste dilution could be presumed equivalent to this added cost. However, as discussed in Section 7.5.2, other benefits from these reservoirs are minimal and environmental costs considered to be high. Therefore, construction of either of these reservoirs for flow augmentation alone is not felt to be justified.

(b) Water Supply

In Woodstock, 1973 water use averaged 4.3 MGD and the bulk of this water was obtained from five overburden wells located south of Highway 401 in spillway deposits along Cedar Creek. Two additional bedrock wells in the city are also connected to the system: however, iron and hydrogen sulphide problems limit the use of these wells. The overburden wells south of the city vary in depth from 48 to 98 feet and because of the permeable nature of the spillway deposits which extend to the surface, the pollution potential of this water supply is high. Preservation of this shallow aquifer is important and development plans (housing, landfill, drainage schemes. etc.) adjacent to these well fields should be carefully considered in order that they not jeopardize quality or quantity of this municipal supply. To satisfy future municipal water demand, options available to the City of Woodstock include:

(i) exploitation to the full of the Cedar Creek aquifer:
(ii) further test drilling for aquifers west of Sweaburg and northeast of Woodstock;
(iii) the utilization with appropriate treatment of ground water from the bedrock, and piping water from surface or ground water sources removed from the Woodstock area.

(c) Flooding Problems

In the 1952 Upper Thames Valley Conservation Report. an overall plan of flood control and water conservation was proposed for the Thames River above London in general, and tier the Woodstock area in particular, calling for the construction of Woodstock dam on the Thames River and Cedar Creek dam on the tributary, and the channel improvement of the Thames River from Dundas Street at Woodstock for nearly a mile downstream. As an alternative to two dams on the Thames River and on Cedar Creek with a combined storage of 12,880 acre-feet. Gordon Pittock dam was constructed on the Thames River in 1967. with a storage capacity larger than the two proposed reservoirs. thus removing the need for the Cedar Creek dam as proposed.

In addition to the proposed channel improvement to the South Branch, it was planned to carry out channel improvements to Cedar Creek from the confluence with the South Branch for less than a mile upstream. It would provide local flood protection for the City of Woodstock which would have been provided by a dam on Cedar Creek. However, they remain to be completed.

The completion of channel improvements in the Woodstock area would increase the channel capacity to 4000 cfs and afford more flexibility in the operations of Gordon Pittock dam. The cost of Woodstock and Cedar Creek channel improvements was estimated at $435,300 in 1961. Although their benefits are not evaluated at this time, their completion is justifiable essentially on the same ground as they were originally proposed. In the meantime, restriction of development from land potentially affected by flooding should continue in Woodstock.

8.2.4 Beachville

From Beachville to Ingersoll. modelled response of levels of dissolved oxygen in the south branch of the Thames River was insensitive to the effects of BOD_5 loadings from the village and the William Neilson Limited milk processing plant. even at low flow, because of the overriding effects of respiration of aquatic vegetation which grew luxuriously in the reach. However, dissolved oxygen levels already are less than 5 mg/L between Beachville and Ingersoll. as observed in the field survey in 1972.

At present. plans for a sewage treatment facility at Beachville are being developed to service a design population of 2,500. including the processing wastes from William Neilson Limited. Two treatment systems have been considered temporary storage of wastes and continuous discharge.

A six month retention of wastes (during the summer growth period for aquatic plants) has the advantage of eliminating inputs of growth stimulating nutrients and oxygen demanding substances when the dissolved oxygen regime is critically low. Stored and daily waste flows could then be discharged at varying rates from November through April. This proposal would involve the acquisition of 35 acres of land for sewage retention plus land for berms and a buffer zone. Preliminary studies indicate that plans for expansion in the village would be restricted by this system, because of the high cost of land acquisition.

It has been calculated that under low flow conditions, 38 pounds of BOD_5 may be added continuously to the river without significantly increasing BOD_5 concentrations after mixing. However, it is essential that continuous inputs of phosphorus be limited since aquatic vegetation exerts such an influence on dissolved oxygen levels in this reach. To minimize organic and nutrient loadings to this sensitive reach, a treatment complete with effluent polishing and phosphorus removal for a design population of 2,500, including 30,000 gpd processing wastes from William Neilson Limited, would required. Separation of cooling water and processing waste flows at William Neilson Limited and subsequent treatment of processing wastes at the proposed Beachville plant would remove the present average daily load of 50 lbs. per day of BOD_5 originating from the industry. Urban runoff controls should be enforced.

Water supply for the expanding population at Beachville could obtained from deep bedrock wells. Treatment for hydrogen sulfide and iron will probably required.

8.2.5 Ingersoll

Downstream from Ingersoll. impaired water quality in the form of dissolved oxygen depletion as a result of discharges from the Ingersoll sewage treatment plant was observed during the 1972 survey. Partially responsible for this was a temporary upset in the plant caused by toxic industrial wastes. Options to improve water quality downstream from Ingersoll include streamflow augmentation and improved sewage treatment.

Construction of the Zorra Swamp and Cedar Creek dam for flow augmentation does not appear to be justified, as has been previously discussed. Improved treatment for a 2001 population of 12,100 is the only viable alternative to ensure water of a satisfactory quality for a warm water fishery. Although response of modelled dissolved oxygen levels to waste loading reductions was largely masked by respiration of profuse weed growth and of bottom deposits. modelling studies indicated that for summer low flow conditions of 21 cfs. a maximum total oxygen demand of 400 lbs/day would satisfy dissolved oxygen criteria in downstream reaches. With this fixed loading figure in mind and assuming the 1992 plant design capacity of 2.25 MGD and a well-nitrified (TKN = 1 mg/L) effluent as an example. the required effluent BOD_5 concentration should be 6 mg/L in order to achieve dissolved oxygen objectives in the Thames River. This would require additional treatment processes beyond the conventional secondary treatment now installed. Phosphorus should be removed to lowest practical levels in this stream stretch where weed growth is especially heavy. Treatment requirements can be reassessed in future if the response of the stream to phosphorus removal programs are better understood. Storm water control should be enforced as described earlier. Availability of ground water to meet future demands is not considered a problem at Ingersoll.

8.2.6 Dorchester

The remaining portion of the Thames River from Ingersoll to London did not receive detailed study. General water quality studies indicated that enriched conditions persisted through Dorchester, although water was of satisfactory quality upon entry to London.

Within Dorchester. investigations of existing storm sewer discharges in dry weather indicated that malfunctioning septic tanks were creating health hazards. This problem and proposals for subdivision developments led to proposals for municipal sewage collection and sewage systems. An extended aeration facility with provision for tertiary treatment has been designed to accommodate a population of 4,000 expected in 1993. The organic loading from this plant will have negligible effect on the dissolved oxygen regime of the river and, with phosphorus removal. enrichment effects from this source are expected to localized.

8.2.7 Thamesford

On the Middle Thames River. Thamesford produced no water quality problems. Proximity to both London and Woodstock and proposed improvements in Highway 2 to London can be anticipated to exert growth pressures at Thamesford. and the 1974 population of 1700 can expected to swell to almost 3,000 by the year 2001. Since soils conditions are satisfactory for subsurface disposal and an adequate communal water supply is being developed. properly constructed and maintained septic tank systems on appropriate sized lots may serve the projected population. It may be found that some form of communal waste treatment is justified within the planning period. In either case, the impact on the aquatic environment is expected to inconsequential.

8.3 THAMES RIVER IN THE LONDON AREA

The major options for flood control in the watershed and water quality management in the London area are interdependent and have been evaluated in Section 7.4 and 7.5. Detailed discussion of waste management options for London can be found in Appendix H.

Major options are dependent on dam construction upstream. Table 7.3 in Chapter 7 outlines specific loading guidelines which would allow dissolved oxygen objectives to be met. with different dam options. These guidelines are based on the following two provisions which should followed by the City of London concerning waste loadings to the Thames River:

(i) Existing and future treatment plants discharging to the Thames River should provide a level of treatment equivalent to the quality of effluent from Greenway treatment plant as defined in Appendix A. This specifically requires that sewage receive efficient secondary treatment including nitrification such that average BOD_5 concentration is 11 mg/L or less and that the average total kjeldahl nitrogen level is 1.6 mg/L or less. Alternatively, the total oxygen demand of the effluent as defined in Appendix A should be 27 mg/L or less.

(ii) Other waste loads from the urban area should not increase with future development. The city should accelerate its program of combined sewer separation or institute provision for treatment of sanitary sewage overflows to the Thames River. Studies should be carried out to determine the polluting potential of urban storm runoff and remedial measures undertaken if the problems prove to be significant.

8.4 LOWER THAMES RIVER

Water management options designed to safeguard water quality downstream from most municipalities on the Lower Thames River are not complex due to the physical characteristics of the river and adequate streamflow available for waste assimilation purposes. Only on intermittent tributary streams and in the sluggish lower reaches do water management options for water quality protection become more involved. In most of the lower basin, ground water quality and availability pose localized water supply problems which may represent a constraint on future development unless alternative sources are made available. This section of the chapter will deal with the servicing options open to municipalities in the Lower Thames basin while ensuring that surface water quality is protected and ground water resources are not exploited beyond their capabilities. Other water management options specifically pertinent to this reach (Wardsville flow retarding structure, erosion control options) have been dealt with previously.

8.4.1 Thamesville, Bothwell, Wardsville and Melbourne

Waste treatment and water supplies for Thamesville and Bothwell do not pose major problems up to the 2001 planning year. Should sewage facilities be recommended at Wardsville and Melbourne within the planning period, treated sewage discharges directly to the Lower Thames would have limited effect on water quality. For water supply, the residents of Bothwell, Thamesville and Melbourne presently rely on private wells in shallow or deep aquifers. At each of these locations, test drilling programs have been recommended to establish a municipal supply and at Melbourne, a municipal well has been constructed 1½ miles west of the village. At Thamesville, experimental drilling has been conducted and one test hole provided an adequate water supply although its hydraulic connection to White Ash Creek may cause conflicts with surface water users.

8.4.2 Westminster Township-Lambeth

As a result of limited streamflow in tributary streams or low yield well fields, some municipalities in the lower portion of the basin will be confronted with developmental constraints. On Dingman Creek, both the Westminster Township and Southland Park (Lambeth) sewage treatment facilities tax the capacity of the receiver to assimilate treated sewage. Although the 0.25 MGD Westminster Township plant is producing a well treated effluent, (BOD_5 of 8 mg/L), sewage flows equal or exceed estimated summer low streamflows. By upgrading waste treatment, the dissolved oxygen regime in Dingman Creek may be protected; however, under such low flow conditions, other wastewater constituents such as ammonia and chloramines will be inadequately diluted and create potential interference with downstream water use. A similar situation applies at Lambeth's 0.06 MGD Southland Park sewage treatment facility but because of considerably lower sewage flows combined with increased streamflows from the larger drainage area, waste assimilation conditions are not presently as critical as at the Westminster Township plant upstream. Operational problems have resulted in the discharge of an extremely poor quality effluent even though the plant is handling about one half its design capacity. By upgrading treatment to produce an effluent with a 10 mg/L BOD_5 concentration, the Southland Park plant can be brought to design capacity with insignificant effect on the water quality of Dingman Creek. However, expansion at either the Westminister Township or Southland Park plants should be discouraged owing to the low waste assimilative capabilities of Dingman Creek. Other than restricting development in the areas serviced by these facilities, the only municipal waste treatment option which will allow urban growth is to export wastes for discharge to a more suitable receiver than Dingman Creek.

Subsurface disposal of domestic wastes in Lambeth is not expected to impair quality of the municipal water supply. However, septic tank discharges to the shallow aquifer supplying dwellings in Westminster Township at the eastern boundary of the village have seriously impaired private supplies. Extending municipal watermains to the affected areas would remedy the problem.

8.4.3 Ilderton

Municipal expansion at Ilderton is restricted by the absence of a suitable receiver stream nearby. Although Oxbow Creek could assimilate an annual batched discharge from a lagoon system, limited expansion which such a system would allow hardly justifies its development. The predominantly clay overburden in the area is unsuitable for septic tanks. Total retention and spray irrigation of wastes is the only practical waste disposal option available should the village wish to increase its population.

8.4.4 Komoka-Kilworth

In Komoka, pollution of private wells by septic tank systems discharging to the same shallow aquifer necessitated consideration of development of a provincial waterworks scheme. The suggested system is designed to serve a 1994 population of 1500 persons. Such development could proceed on septic tanks once the public health hazard is eliminated through construction of the new water system. However, should a sewage treatment facility be deemed necessary in the future, various options, depending upon London's approach to future development, are available. London's future figures prominently at Komoka and Kilworth since effects of discharges from London are most critical in the Kilworth-Komoka reach. If London opts for a pipeline to Lake Erie, a continuous discharge to the Thames River from Komoka (and Kilworth) would be acceptable. If London upgrades treatment and continues to discharge to the Thames. the total oxygen demand from Komoka and Kilworth would have to included in London's allotted daily loading figure which will depend upon increased flow augmentation from upstream.

8.4.5 Glencoe

Both limited water supply availability and the lack of a suitable nearby receiving stream are factors which dictate restricted growth at Glencoe. Two well fields which supply the village provide relatively low yields and prospects for developing a high capacity well in the area are poor. Newbiggen Creek is an unsuitable wastewater receiver because of the inadequate streamflows generated by the small drainage area upstream from the village. Even after construction of the 28 acre sewage lagoon, water quality of the creek will be temporarily impaired when the lagoon is discharged during periods of peak flows. Expansion of the village could only be considered if water were piped to Glencoe and if treated sewage were exported to a more appropriate receiver, in this case, the Thames River.

8.4.6 Newbury

The proposed sewage treatment scheme for Newbury has been cancelled. The possibilities of developing a municipal water supply based on ground water sources appear remote, posing a constraint on future development. To expand, the community would probably forced to import water from Lake Erie.

8.4.7 Chatham

Water management problems in Chatham include flooding, erosion, and water quality degradation. Flooding and erosion problems are dealt with in Chapter 7.

Water quality problems in the Chatham area are related to upstream organic loadings but are more directly the result of combined sewer overflows within Chatham and treatment plant bypasses during storms. Reduced flow velocities caused by the backwater effect from Lake St. Clair result in increased sedimentation of organic material and reduced natural aeration. The treatment plant is presently at its hydraulic capacity of 4.5 MGD, and must expanded ii further urban growth is to be allowed. Dissolved oxygen reductions to levels only slightly above criteria requirements were observed during surveys at streamflows much higher than natural low flows.

Options for control of water quality include: control of upstream wastes discharges from urban and rural areas; control of Chatham's discharges from storm and combined sewers, and from the treatment plant; increased flow augmentation; and limitation of urban growth.

It is difficult to predict the effect of upstream management programs on the water quality at Chatham. However, due to the size of the river basin, and the variety of activities which contribute to water quality problems upstream, the water quality at Chatham is felt to relatively insensitive to changes in water management upstream. It is concluded therefore, that management options which can be implemented in Chatham itself for water quality control have the greatest likelihood of a positive effect at Chatham.

As noted in Appendix A, water quality criteria can likely be met within the city limits by control of combined sewer overflows. This may done by a variety of technical means including separation of storm and sanitary sewers; reduction of storm flows to the combined sewage system: higher capacity sewage pumping stations and interceptor sewers: higher treatment plant capacity for storm generated flows; storage of high flows. etc. These proposals are presently under study by a consulting engineering firm and many of them are expected to be implemented by the city. It is expected that dissolved oxygen conditions will improve within the city limits as combined sewage overflows are controlled.

Appendix A also indicates the allowable organic load to the river under low flow conditions at which dissolved oxygen criteria are met. With a treatment plant discharge of 3,300 lbs/day of total oxygen demand, the oxygen model predicts a minimum dissolved oxygen level of 5 mg/L, downstream from the treatment plant. This effluent limit would require nitrification of sewage and some reduction of the BOD_5 levels below the secondary level. Relationships presented in the Appendix can be used to aid in the design of the proposed expansion of capacity in the treatment plant to accept 1994 dry weather flows of 9.0 MGD. If additional flow augmentation from upstream reservoirs increases the low flow, then this loading limitation can be increased. In addition, the effectiveness of management options upstream of and within Chatham can be evaluated in the future.

The effluent limit above assumed that waste loads from storm and combined sewers in the city do not increase with increasing urbanization in Chatham.

It is, therefore, concluded that water quality objectives in and downstream from Chatham can be met by the following:

1. Control of storm generated combined sewer overflows in the sewage system. Controls on storm

runoff in the future should considered.

2. Secondary treatment, including nitrification, following the effluent limitation set out above.

This will allow growth in Chatham to the planned treatment plant expansion capacity of 1994 projected flows. Following this, further options for waste management can be considered, such as higher levels of treatment. if a future assessment of water quality problems prior to 1994 indicates the necessity of this action. If this option proves cost prohibitive, population control measures would appear the only alternative.

8.4.8 Tilbury

At Tilbury, the 36 acre lagoon is hydraulically overloaded. The 17-square-mile drainage basin of Tilbury Creek produces inadequate streamflow to assimilate treated wastes from the town even at the present population of 3,800 and to expand would either cause further degradation of Tilbury Creek or necessitate the implementation of costly waste treatment approaches. Since flows are insufficient for a continuous discharge. the export of wastes to the Great Lakes or total retention—spray irrigation are the only options which will provide acceptable water quality in the Tilbury-Big Creek system. Secondary treatment facilities, a pipeline and extended outran would be extremely expensive for Tilbury itself and the total retention option would be costly in terms of the amount of highly productive farmland required. Pumping treated wastes three miles downstream for discharge to Big Creek below its junction with Baptiste Creek would lessen the degree of water quality impairment. Because most of this watercourse consists mainly of backwater from Lake St. Clair, localized impalement could be expected because of poor waste dispersion characteristics. Growth constraints at such inland communities as Tilbury would redirect development into other centres where water is available for supply and waste disposal purposes and where urban encroachment into prime agricultural areas can be minimized.

8.4.9 Ridgetown

Ridgetown is in a similar situation but as a result of its location on the extreme headwaters of MacGregor Creek, waste discharge constraints are even more critical. Assuming that spray irrigation or waste exportation to Lake Erie is impractical for the town, future development should redirected to other areas.

REFERENCES

Acres Consulting Service Limited: Thank., River Flood Damage; February, 1973.

Agriculture Canada: A Selective Inventory of Large Livestock Operations in Southern Ontario; unpublished report, 1974.

Agriculture Canada, Engineering Branch: Task Force on Fertilizer Nutrients and Animal Husbandry Operations; unpublished report.

Ayers, H.D.: Effects of Agricultural Land Management on Winter Runoff in Guelph; Ontario Region Proc. 4th Hydrol. Sympos., Canadian Natural Resources Counc. Assoc. Comm. on Geodesy and Geophys. Subcomm. on Hydrology, 1964, p. 167- 182.

Bangay, G: Nutrient Accumulation from Livestock and Poultry Operations in the Great Lakes Basin; 1931-71, Canada Centre for Inland Waters, unpublished report. 1974.

Bolton, E.F., Aylesworth, J.W., Hore, F.R.: Nutrient Losses through Tile Drains under Three Cropping Systems and Two Fertility Levels on a Brookston Clay Soil; Canadian J. of Soil Sciences, Vol. 50, 1974.

Brungs, W.A.: Effects of Residual Chlorine on Aquatic Life; J. of Water Pollution Control Federation, Vol. 45, 1973, p. 2180-2193.

Canada-Ontario Agreement on Great Lakes Water Quality: Annual Report; Urban Drainage Subcommittee, 1975.

Chapman, L.J., Putman, D.F.: The Physiography of Southern Ontario; Ontario Research Foundation, University of Toronto Press, 1973, Toronto, Ontario.

Culp, R.L.: Waste Water Reclamation at South Tahoe P.U. District; J.A.W.W.A, Vol.60(1), 1968, p. 84-94. Engineering News Record.

Environment Canada, Policy and Planning: The Basics of Benefit-Cost Analysis; January, 1973.

Canadian National Committee for the International Hydrological Decade: Handbook on the Principles of Hydrology; National Research Council, 1970. Ottawa, Ontario.

International Joint Commission: Pollution of Lake Erie, Lake Ontario and the International Section of the St. Lawrence River; Volumes 1 and 2, 1969.

International Joint Commission: Great Lakes Land Use Inventory; Task B.1, Land Use Activities, Watershed Land Use Composition, 1975.

James F. MacLaren Limited, Consulting Engineers: Preliminary Engineering Report to the Lower Thames Valley Conservation Authority on Flood and Erosion Control Works on the Lower Thames River from Chatham to Delaware; August, 1971, Toronto. Ontario.

James F. MacLaren Limited, Consulting Engineers: Preliminary Report for the Upper Thames River Conservation Authority on the Zorra Swamp Reservoir, 1966, Toronto, Ontario.

James F. MacLaren Limited, Consulting Engineers: Report on the Lower Thames River Channel and Dike System from Chatham to Lake St. Clair for the Lower Thames Valley Conservation Authority; 1967, Toronto, Ontario.

James F. MacLaren Limited, Consulting Engineers: Master Plan for Sewage and Drainage Works for the City of Woodstock; 1974, Toronto, Ontario.

Maass, A., *et al*: Design of Water Resource Systems; Harvard University Press, 1966, Cambridge, Massachusetts.

O'Connor, D.J., DiToro, D.M.: Photosynthesis and Oxygen Balance in Streams; J. of Sanitary Engineering Division, A.S.C.E., Vol. 90, April, 1970.

Ontario Department of Energy and Resources Management: Lower Thames Valley Conservation Report. 1966.

Ontario Department of Planning and Development: Upper Thames Valley Conservation Report, 1952. Ontario Ministry of the Environment: An Assessment of Water Pollution Control in the City of London; October, 1973.

Ontario Ministry of the Environment: Guidelines and Criteria for Water Quality Management in Ontario, 1974.

Ontario Ministry of the Environment: A Guide to Estimating Sewage Treatment Plant Construction Costs in the Province of Ontario; reprint, 1973.

Ontario Ministry of the Environment: Report on Water Pollution Survey of the City of Woodstock; 1972.

Ontario Ministry of Natural Resources: Ontario Recreation Survey, Tourism and Outdoor Recreation Planning Study, Progress Report No. 2; 1973.

Ontario Treasury Board, Management Services Division: Review of Planning for the Grand River Watershed, October, 1971.

Select Committee on Land Drainage: Agricultural Land Drainage in Ontario—Final Report; June, 1974, Toronto, Ontario.

Singer. S.: Daily Streamflow Simulation on the Thames River Basin: Water Res. Paper 7, Ontario Ministry of the Environment, 1974, Toronto, Ontario.

Streeter, H.W., E.B. Phelps: A Study of Pollution and Natural Purification of the Ohio River: Public Health Bulletin, Vol. 146. 1925, Washington, D.C.

U.S. Environmental Protection Agency: Agricultural Pollution of the Great Lakes Basin; Combined Report by Canada and the United States: 1971, p. 45.

United States Environmental Protection Agency: Urban Stormwater Management and Technology—An Assessment: May, 1974.

Warner, K.R.: Public Participation in Water Resources Planning; University of Michigan; 1971.

Whipple, **J.,** et al: Unrecorded Pollution from Urban Runoff; J. of Water Pollution Control Federation, May, 1974, Vol. 46, No. 5, p. 873-885.

APPENDIX A

WATER QUALITY MODELLING

1. INTRODUCTION

Water quality models are used to examine the likely effectiveness of water management alternatives in meeting water quality objectives as determined by specific water use criteria. A mathematical model is a mathematical representation of the processes which relate cause and effect in a real system. Generally, in river systems, it is the effect on dissolved oxygen (DO) resulting from decomposition of biodegradable wastes (typically measured by the biochemical oxygen demand test-BOD) in the process of "self-purification", that is of most concern. The pollution effect can be represented by dissolved oxygen (DO), because DO is the constituent in water used during decomposition of organic material and is also required by aquatic life for survival.

In the stream's self-purification process, bacteria in the water and attached to the bottom utilize the organic material in sewage effluent as food, eventually reducing waste materials to harmless inorganic materials. This process was first modelled, taking into account the effects on the DO concentration, of deoxygenation due to BOD utilization by bacteria and oxygen additions due to atmospheric aeration (Streeter and Phelps, 1925). This model has been expanded and modified by later research to the formulation which is used in the Thames River Study (O'Connor: DiToro, 1970).

2. DISSOLVED OXYGEN MODEL FORMULATION

The dissolved oxygen models used in the Thames River Study take account of the effects of carbonaceous and nitrogenous oxygen demand, atmospheric aeration, aeration at weirs, respiration in bottom sludges, photosynthetic oxygen production, and respiration of aquatic plants and algae. Model parameters are adjusted to account for the effect of changes in temperature and channel flow.

The model expressed as a differential equation, in terms of the oxygen deficit D, is given below as a function of time, t, and distance, x. The oxygen deficit D is the difference between the oxygen saturation concentration and the actual concentration.

$$\delta d/ \delta t + V\delta D/ \delta t = KaD + K\ dL(x) + Kn\ N(x) + S - P(t) + R$$

where:

- D = oxygen deficit, mg/L
- V = velocity of streamflow, ft/sec
- t = time, days
- x = distance, ft
- Ka = aeration coefficient, day^{-1}
- Kd = deoxygenation coefficient, day^{-1}
- L(x) = carbonaceous oxygen demand as a function of x, given by $L(x) = Lo\ e^{-Kr\ (x/v)}$
- Lo = initial concentration of carbonaceous oxygen demand, mg/L
- Kr = oxygen demand removal coefficient, day^{-1}
- N(x) = nitrogenous oxygen demand as a function of x, given by $N(x) = No\ e^{-Kn\ (x/v)}$
- No = Initial nitrogenous oxygen demand, mg/L
- Kn = nitrogenous oxidation coefficient, day^{-1}
- S = benthic bacterial respiration, mg/L/day
- P(t) = photosynthetic oxygen source as a function of time, of the form $P(t) = Pm\ Sin[(\pi/p)\ (t-ts)]$ for daylight hours. A Fourier series expansion of P(t) is used.
- Pm = maximum rate of photosynthesis production, mg/L/day
- p = period of sunlight, days (fraction)
- ts = time of sunrise, days (fraction)
- R = algal respiration, mg/L/day

The solution to this equation is given in the reference and will be presented in the technical report entitled "Water Quality Modelling for the Thames River Study". The solution is a description of the oxygen deficit at any x and any t in the river reach.

The dissolved oxygen levels throughout a river are described by treating the river as a collection of reaches with constant conditions in each reach, calculating the effect of all input conditions at the head of the reach and using the model formulation to calculate the concentrations of dissolved oxygen and waste constituents at the end of the reach. Weir aeration is assumed to take place at the head of the reach. The basic dissolved oxygen model concepts described above are used in two separate models in the Thames River Study: the steady state dissolved oxygen model and the dynamic water quality simulation model. The basic difference between the two models lies in the variation of model input conditions.

The *steady state model* describes the dissolved oxygen distribution during a single 24-hour period for the reaches in the river, with all conditions held constant over time (except the photosynthetic oxygen source). Waste management alternatives defined by different waste loading conditions, streamflow conditions or reach parameter conditions are modelled separately. Steady state modelling is simple and inexpensive to run; however, results are limited by the single set of input conditions. Steady state models were developed and applied to the Avon River downstream from Stratford. the North Thames River from St. Marys to the Fanshawe reservoir, the Thames River from Woodstock to downstream from Ingersoll and the Thames River from Chatham to Lake St. Clair.

The dynamic *water quality simulation model* was developed to take account of the variations of natural and man made conditions which affect water quality to provide increased information about the possible effects of water management planning alternatives in the river basin. The inputs to the system vary with time to reproduce the variations in conditions that occur in the real system.

Water management options receive a more complete evaluation when the simulation model is used because all ramifications (within the limitations of the model) have been accounted for. Decisions regarding options can be reached in fuller knowledge of the water quality predicted from implementation of the alternative. Dynamic simulation, however, can become costly because of the high cost of data collection and computer operations. Application in the Thames River was considered justified only for the river sections in the vicinity of London.

Causes of variation in water quality accounted for in the dynamic simulation model consist of:

(i) Streamflow from the upstream main channel and from tributaries. Daily streamflows were generated for the Adelaide, Ealing and Byron flow gauge locations, based on the historical record. The method generates extensive traces of streamflow data from available historical records using stochastic techniques and thus allows the water quality simulation model to be run for as long a period as is required (Singer, 1974). Channel flow velocities, aeration rates, respiration rates and photosynthetic rates are dependent on streamflow.

(ii) Water quality from upstream and from tributaries. Probability distributions based on observed water quality are used in the model to reproduce daily variations in dissolved oxygen (DO), carbonaceous (CARBOD) and nitrogenous oxygen demand (NOD). Diurnal variations of dissolved oxygen are also included.

(iii) Waste treatment plant loads. Observed daily mean effluent flows are reproduced by mathematically describing seasonal and within-week trends and adding a random component. Within-day variations in treatment plant flows are also included. Daily mean water quality parameter concentrations (DO, NOD, CARBOD) are randomly chosen from probability distributions based on observed data.

(iv) Sunlight energy. A probability distribution of sunlight energy for each month is used to calculate variations in the average photosynthetic rates of plants and algae for each reach, and each day.

(v) Temperature. Mean daily water temperatures are calculated in the model according to observed trends. Oxygen saturation concentrations, aeration rates and respiration rates depend on temperature.

Figure A1 outlines the structure of the dynamic model. More detailed information regarding the model will be presented in the technical report.

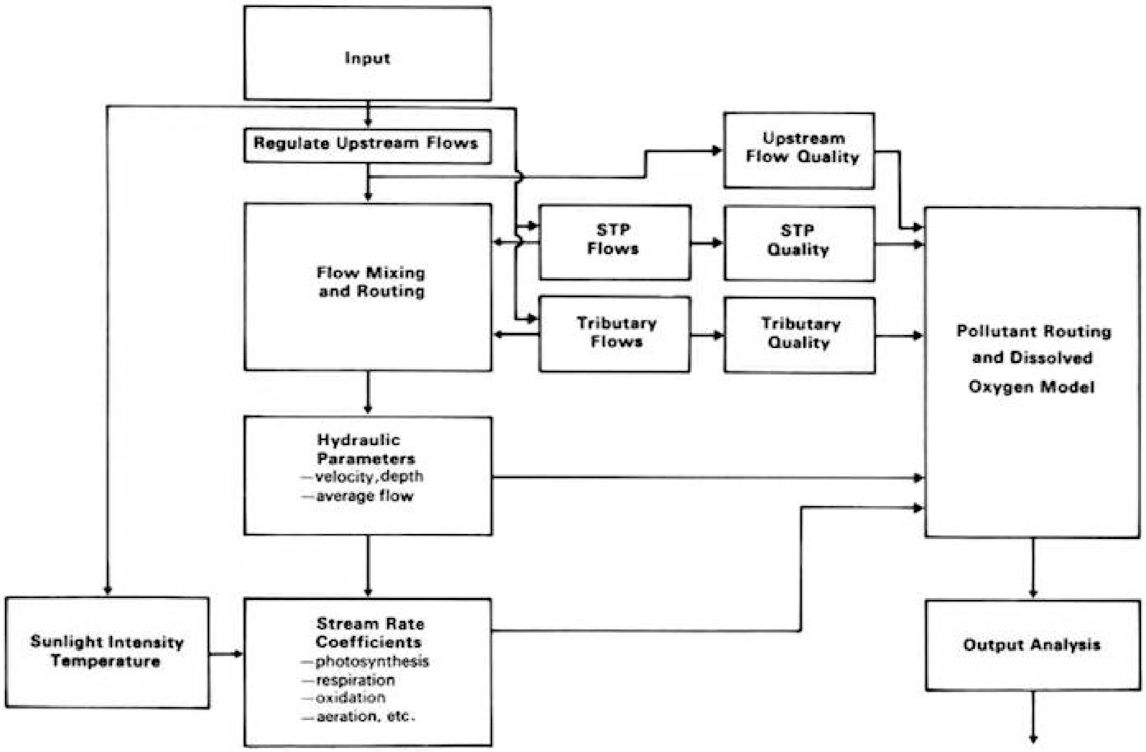


Figure A1: Thames River dynamic water quality simulation model.

The simulation model continuously simulates, for several years. the dissolved oxygen concentration in the stream, taking account of the variations described above. DO output data are generated for each reach, every two hours of every day in each month simulated, for the time period in question. The output is analysed and summarized in statistical terms; this requires that DO criteria be stated in similar statistical (or probabilistic) terms in order that model output and criteria can be compared directly. DO criteria are described in Appendix B.

3. MODEL APPLICATION—GENERAL

Field surveys were carried out to describe the existing conditions of water quality in the river, to determine the river channel geometry and to provide parameter estimates for the water quality models. The models were then calibrated to existing conditions by adjusting parameters within defined limits until dissolved oxygen model output acceptably matched observed data. Additional data collection was required for the dynamic water quality simulation model to describe variations in water quality constituents input to the system from upstream flows, tributary flows and sewage treatment plants. and to provide data for estimating model parameter variations in response to variations of input conditions.

Once the models were calibrated for each location, they were used to predict dissolved oxygen for different conditions of streamflow, levels of waste treatment and effluent volumes. The predicted dissolved oxygen concentrations from models of various options. when compared to dissolved oxygen criteria, indicates the effectiveness of the options.

The steady state model is used to set a waste loading guideline: that is, to determine the organic loading rate (in terms of pounds of BOD_5 per day or pounds of total oxygen demand per day) to the river which just allows dissolved oxygen criteria to be met for a specific design case. The design case typically used consists of summer drought flow (seven day mean flow with a 5 percent probability of occurrence) and stream conditions observed during field surveys. The derived loading rate is used to calculate waste treatment requirements for a given flow of sewage. If flows can augmented from upstream reservoirs, then a different loading rate can be allowed at the higher flow. The effect of a reduction in benthic plant biomass or settled organic sludge can also be modelled. The actual method of reducing biomass or bottom sludges cannot be estimated at present, although predictive tools are under development for estimating urban storm water and nutrient effects on these water quality components.

Waste loading guidelines are set in terms of total oxygen demand (TOD), which is the sum of carbonaceous (CARBOD) and nitrogenous (NOD) oxygen demands. The five day biochemical oxygen demand (BOD_5) and total Kjeldahl nitrogen (TKN-sum of organic nitrogen and ammonia nitrogen) are typically measured in sewage effluents and are related to the total oxygen demand (TOD) as follows:

TOD = NOD + CARBOD

= 4.57 x TKN + R x BOD_S

4.57 milligrams of oxygen are required to completely oxidize one milligram of nitrogen, in the form of organic or ammonia nitrogen, by the process of bacterial nitrification. R is the ratio of ultimate carbonaceous oxygen demand to BOD_5. This is determined by a laboratory incubation of sewage or stream samples over 20 days, measuring oxygen uptake. From an analysis of nitrogen in parallel with oxygen uptake, an estimation of nitrification is made, which allows a calculation of the carbonaceous oxygen demand by subtraction. R varies with the strength of the waste and the degree to which nitrification has already taken place in the sample; however, the value of R measured for each treatment plant was the value used in model studies.

The loading rate is calculated as:

TOD (mg/L) x flow (MGD) x 10 = loading rate (pound/day)

Once an allowable loading rate is determined by model application, the treatment plant designer, given a projected flow for a given population, can design the treatment plant process required to achieve the TOD concentration. The allowable loading rates presented in this report are based on an assumed ratio of NOD to CARBOD, consistent with various levels of treatment. Caution should be exercised by the treatment plant designer, to stay within a reasonable range of these ratios, since in many cases, the nitrogenous and carbonaceous oxygen demands are exerted at different rates (as measured by Kn and Kd).

Specific applications of the models are described below:

4. AVON RIVER

Two field surveys were carried out in the Avon River in June and July 1972. Results of the field survey in June, 1972 indicate that minimum dissolved oxygen concentrations are in severe violation of criteria for the entire length of the river downstream from the Stratford treatment plant. Figure A2 indicates maximum and minimum dissolved oxygen concentrations observed along the river. The wide fluctuations in observed DO values in a single day (1.2 mg/L to 19.7 mg/L) are a result of the profuse algae growths observed in the river during the survey.

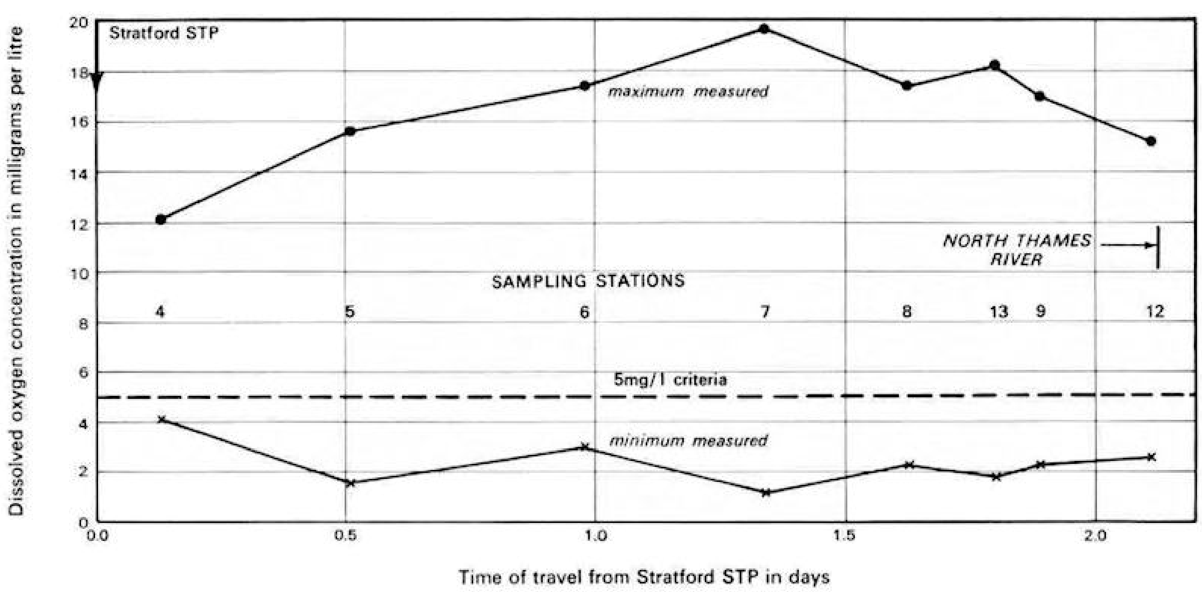


Figure A2: Maximum and minimum measured dissolved oxygen concentrations versus time of travel for the Avon River, June, 1972.

Figure A3 presents the concentrations of the tour nitrogen forms (Kjeldahl, free ammonia, nitrite and nitrate) and of soluble phosphorus, versus distance in the river. The figure indicates the increase in these nutrients due to the influence of the STP effluent. Rapid nitrification is evident in the stream as shown by the initial increases in oxidized forms of nitrogen (nitrite and nitrate) and the decrease in unoxidized forms of nitrogen (Kjeldahl and free ammonia). The effect of plant and algae growth is strongly evident in the rapid removal of both nitrogen and soluble phosphorus along the river.

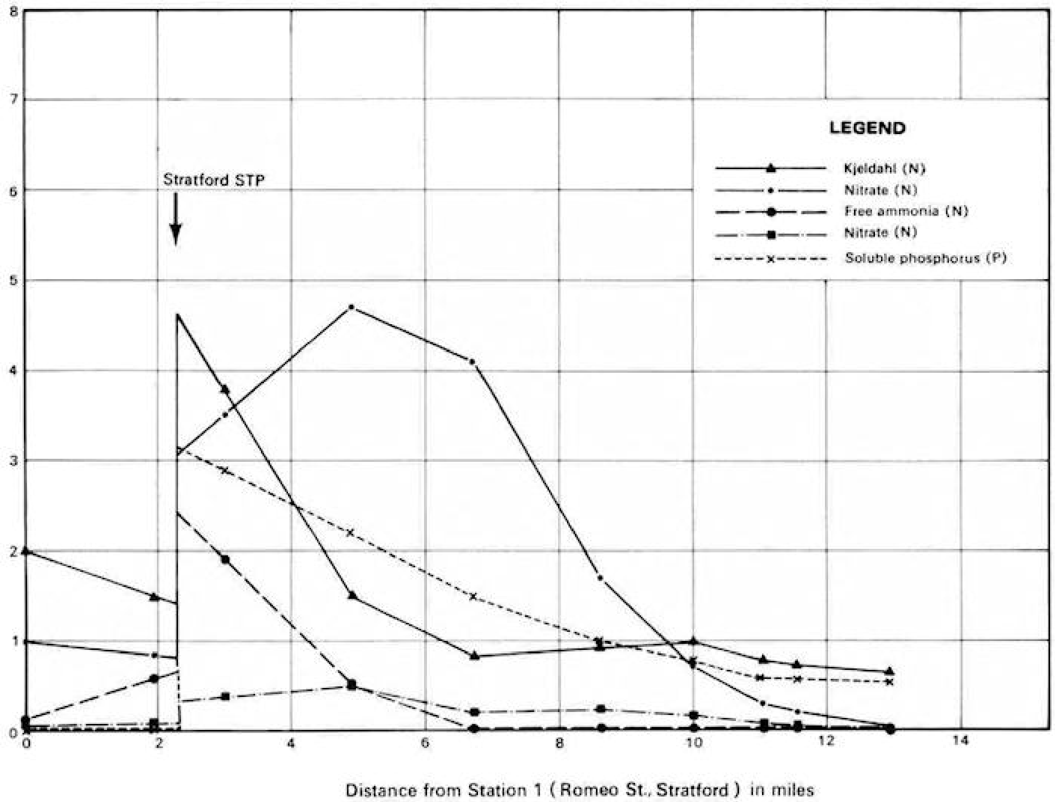


Figure A3: Nutrient concentration versus distance in the Avon River, June, 1972.

Streamflow during the June survey at the flow gauge (Water Survey of Canada gauge 2GD018) downstream from Stratford, was 12.5 cfs, including 4.4 cfs (2.4 MGD) of sewage flow. Analysis of flow records from this gauge indicates that the seven day mean flow with a 20-year recurrence interval is 0.2 cfs. Since this gauge includes the sewage flow, it can be concluded that the natural low flow in the river is zero.

The BOD_5 and total Kjeldahl nitrogen concentrations observed in the effluent during the June survey were 22.3 mg/L and 7.8 mg/L respectively. The total oxygen demand of the effluent is given by the following:

TOD= (4.57 x 7.8 + 1.63 X 22.3) = 72 mg/L

or 72 x 2.4 x 10 = 1727 pounds per day

Since the 1972 survey, the treatment plant has added additional treatment consisting of effluent filtration and phosphorus removal. Effluent filtration is designed to reduce the BOD_5 concentration in the final effluent to 8 mg/L. Using the above relationships, the design BOD_5, assuming nitrification (TKN = 2 mg/L), and the 1973 average sewage flow rate of 3.6 MGD, the treatment plant would discharge approximately 530 pounds per day of TOD.

Findings derived from application of the oxygen model to the Avon River are as follows:

(i) A waste loading rate that allows criteria to be met could not be derived at estimated low flows (0.2 cfs natural flow). Even at streamflow values observed during the field survey in June (8.1 cfs), criteria cannot be met. Figure A4 graphically indicates the minimum dissolved oxygen levels predicted at a point 2.6 miles downstream from the Stratford STP, for different waste loading and flow conditions. The plot shows some improvement when waste loads are reduced but confirms that the DO criteria requirement of 5 mg/L is not met. The model was run under the assumption that plant and algae biomass was the same as observed during the June survey.

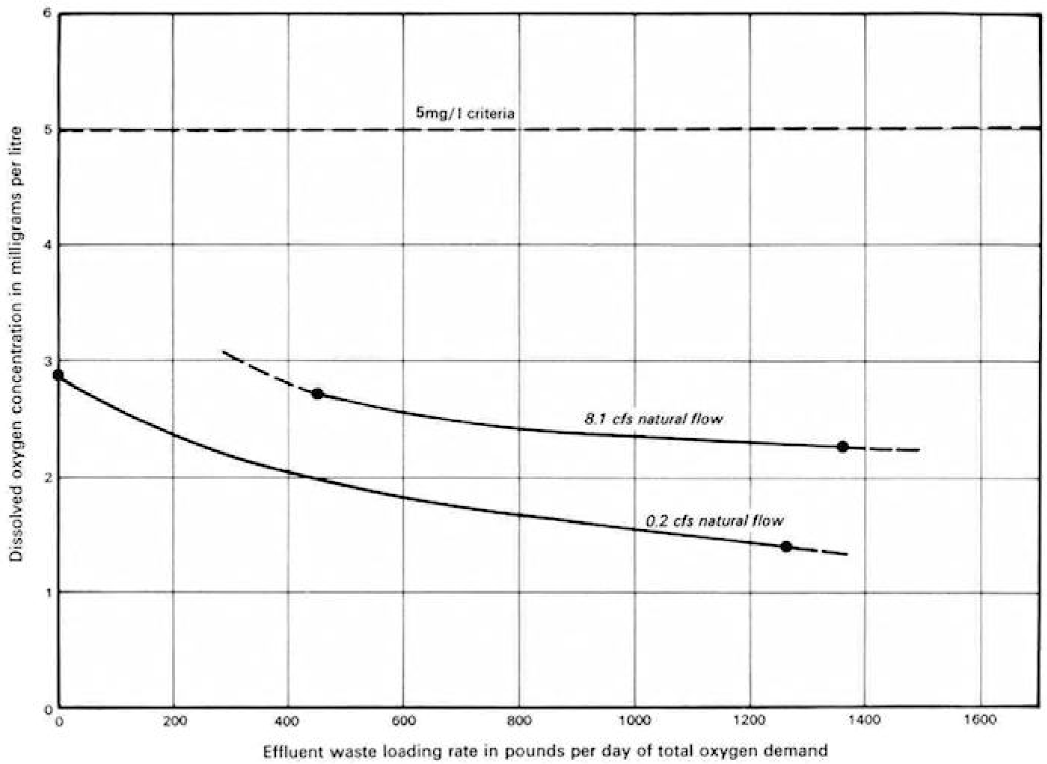


Figure A4: Minimum dissolved oxygen concentrations predicted for Station 5 on the Avon River, 2.6 miles downstream from Stratford STP, at various natural flows and effluent waste loading rates.

(ii) Plant and algae biomass had an overriding effect on the dissolved oxygen model. This explains lack of response of oxygen levels to waste load reductions as described above. To illustrate this effect, the values of the photosynthesis and plant respiration terms were reduced by one-half. For several waste loading conditions this resulted in generally acceptable dissolved oxygen levels with concentrations meeting or almost meeting criteria in all reaches.

(iii) Nitrification of sewage effluent has a positive effect on water quality. The effect of nitrification in the stream was modelled by reducing waste loads observed during the June survey conditions consistent with the level of the treatment now available, including nitrification, in the treatment plant. This increased the DO concentrations at the end of the first reach (0.7 miles downstream from the treatment plant) by 2 mg/L but had a negligible effect on downstream reaches, where low DO concentrations persisted.

The recommended course of action, discussed in the main text of the report, takes the above findings into account. It is difficult to propose a course of action which will fully meet water quality objectives for the Avon River, however, positive steps should be taken which will reduce stress on the watercourse. This includes additional phosphorus removal, nitrification, as well as consideration of storm water treatment and growth restraints.

5. NORTH THAMES RIVER

Field surveys were carried out in the North Thames River in June 1971 and September 1972 to provide data for water quality modelling. Results of the field survey of June 1971 indicate minimum dissolved oxygen levels are well below dissolved oxygen criteria for the protection of fish and wildlife for the entire length of the river section surveyed. Figure A5 indicates minimum and maximum dissolved oxygen concentrations measured in the river during the survey. The wide fluctuations in dissolved oxygen are a result of the profuse growths of aquatic plants and algae observed in the river during the survey.

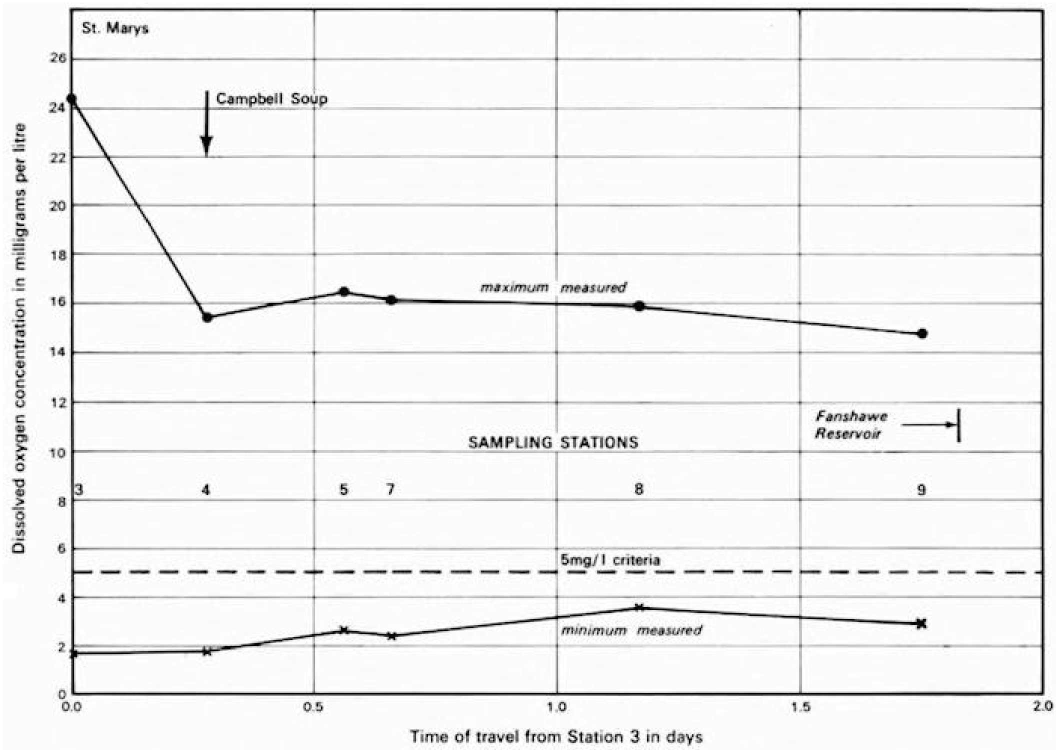


Figure A5: Maximum and minimum measured dissolved oxygen concentrations versus time of travel for the North Thames River. June. 1971.

Streamflow measured at the flow gauge on the North Thames River at Thorndale (Water Survey of Canada flow gauge 02GD015) during the June survey was 42 cfs. The Wildwood Dam, when operated for low flow augmentation, discharges 40 cfs to the North Thames River upstream from St. Marys. The survey, therefore, represents very closely the worst low flow conditions likely to occur under present dam operating practices.

The survey was undertaken prior to the completion of the St. Marys sewage treatment plant and therefore did not contain the direct effects of the municipal sewage. However, continuous flow to the river through storm sewers was observed during the survey period and this flow is suspected to contain effluent from malfunctioning septic tanks. This condition probably affects downstream water quality although the effect could not be quantified in the survey. The condition of direct sanitary waste discharges appears largely corrected now that the St. Marys treatment plant is in operation and residences are connected to the sanitary sewer system. The treatment plant, with a capacity of 0.8 MG D received an average of 0.3 MGD in 1973.

The treatment plant for the Campbell Soup Company Limited (Blanchard Township) had an unsatisfactory quality of effluent. Discussions between Ministry of the Environment Regional Industrial Abatement staff and the company are underway with the objective of increasing the efficiency of the treatment system. Phosphorus removal of the effluent has not been required in the past for this industry. Treatment plant capacity is reported to be 0.35 MGD, although some expansion is foreseen.

Flow augmentation from the proposed Glengowan Dam and Reservoir on the North Thames River upstream from St. Marys could provide an additional 36 cfs flow to the river if the reservoir is operated with flood control the first priority. This flow is based on the allocation of 8000 acre-feet of storage for flow augmentation. discharged over a 112 day period, from June 1 to September 20. If flow augmentation was the first priority use of the reservoir then 21.800 acre-feet of storage could be utilized for this purpose, providing 97 cfs over a 112 day period. The minimum flow available downstream from St. Marys. if the dam is built, is 76 cfs and 137 cfs. respectively, depending on the use priority for Glengowan dam.

The observed major water quality problem in the North Thames River is low dissolved oxygen, resulting primarily from an over-abundance of plant nutrients (phosphorus and nitrogen) in the water and associated favourable physical conditions for plant and algae growth.

Application of the steady state dissolved oxygen model indicates the following:

(i) The direct effect of waste discharges from the Town of St. Marys and from Campbells Soup Company on the oxygen levels is negligible, largely because of the high dilution ratio of natural flow to sewage flow. In the model, oxygen demanding constituents in the waste effluent were removed, without a significant predicted increase in dissolved oxygen in the stream. The effect of plant (including algae) respiration far outweighs the effect of oxidation of organic materials in waste effluents. The model does not indicate the indirect effects of nutrients in the effluents of the industry and the town, nor the effect of possible build-up of sludge beds from the observed discharges of suspended solids from Campbell Soup Company.

(ii) Plant (including algae) biomass reductions would allow dissolved oxygen criteria to be met throughout the river. This is illustrated by reducing the photosynthesis and respiration terms by one-half, in the model.

(iii) Increased streamflow (from flow augmentation) results in a significant increase in the dissolved oxygen in the water. The model indicates that a flow of more than 150 cfs is required in the stream for conditions similar to those observed in the June 1971 survey, for criteria to be met. Any increase in flow results in an increase in dissolved oxygen levels.

It is clear that the most favourable option for the North Thames River downstream from St. Marys consists of construction of Glengowan Dam for flow augmentation alone. While the treatment plants do not appear to have a large direct effect on the dissolved oxygen levels, consistently high quality effluent from these plants would have a beneficial effect on the river quality.

6. THAMES RIVER FROM WOODSTOCK TO INGERSOLL

Field surveys to assess water quality and to provide information for modelling were carried out in the Thames River in this section in June and July 31-August 4, 1972. Figure A6 indicates that dissolved oxygen criteria were violated in the river during the August survey at several locations, downstream from Woodstock, between Beachville and Ingersoll, and downstream from Ingersoll.

Mean streamflows observed during the July survey were 39 cfs at the flow gauge downstream from Gordon Pittock reservoir in Woodstock (02GD016), 6.8 cfs at the Cedar Creek flow gauge (02GD011) and 64 cfs at the Ingersoll flow gauge (02GD016). Analysis of flow data prior to operation of the Gordon Pittock dam indicates natural drought flows (seven day mean flow with a 5 percent probability of occurrence) of 3.7 cfs, 0.4 cfs, and 6 cfs for the Woodstock, Cedar Creek and Ingersoll gauges respectively. Scheduled drawdown of the reservoir can provide 15 cfs flow augmentation to the Thames River at Woodstock. For the purpose of this analysis, loading guidelines developed are based on streamflows of 15 cfs at Woodstock and 21 cfs at Ingersoll.

Following application of the model based on the July 1972 survey, the following was found in three sections of the river from Woodstock to Beachville, from Beachville to Ingersoll and downstream from Ingersoll.

(i) For low streamflow conditions (15 cfs), a waste loading rate which would allow dissolved oxygen criteria (5 mg/L) to be met could be derived only for the initial reaches downstream from Woodstock. Further downstream, reductions in waste load had negligible effect on the dissolved oxygen levels. This result is illustrated in Figure A7 which gives the minimum dissolved oxygen concentration predicted at two locations 2.8 and 5.3 miles downstream from the Woodstock STP. as a result of different waste effluent loads. The different response to waste load reduction is due to the greater effect of benthic respiration (from plants, including algae, and sludge) in the downstream reach. Reduction of the benthic respiration and photosynthetic production terms in the model resulted in criteria being met at all reaches between Woodstock and Beachville. It is likely that a portion of the benthic respiration is due to bottom sludge resulting from the significant discharge of inadequately treated sewage running directly to the river, from combined sewer overflows and treatment plant bypasses during storms. This problem was defined and recommendations were made in a water pollution survey of the City of Woodstock (MOE, 1972).

A waste loading guideline based on dissolved oxygen predictions at low flows for the reach 2.8 miles downstream from the treatment plant (as shown in Figure A7) would allow an effluent waste load of approximately 900 lbs per day of total oxygen demand (TOD). The relationship for the Woodstock

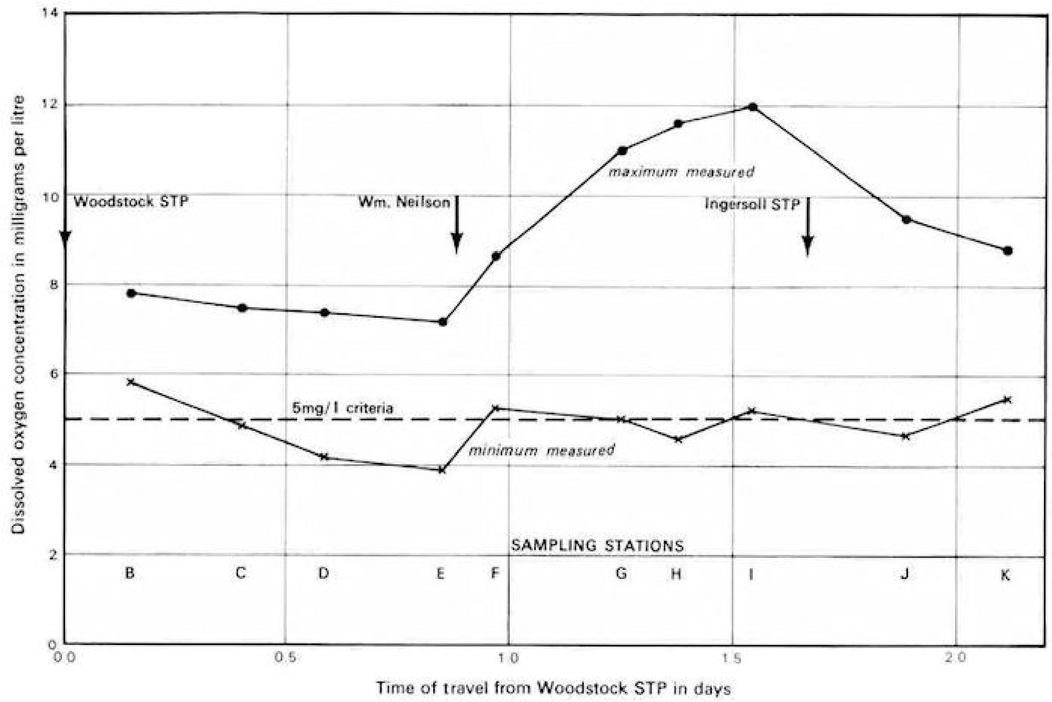


Figure A6: **Maximum and minimum measured dissolved oxygen concentrations versus time of travel for the Thames River downstream from Woodstock, July, 1972.**

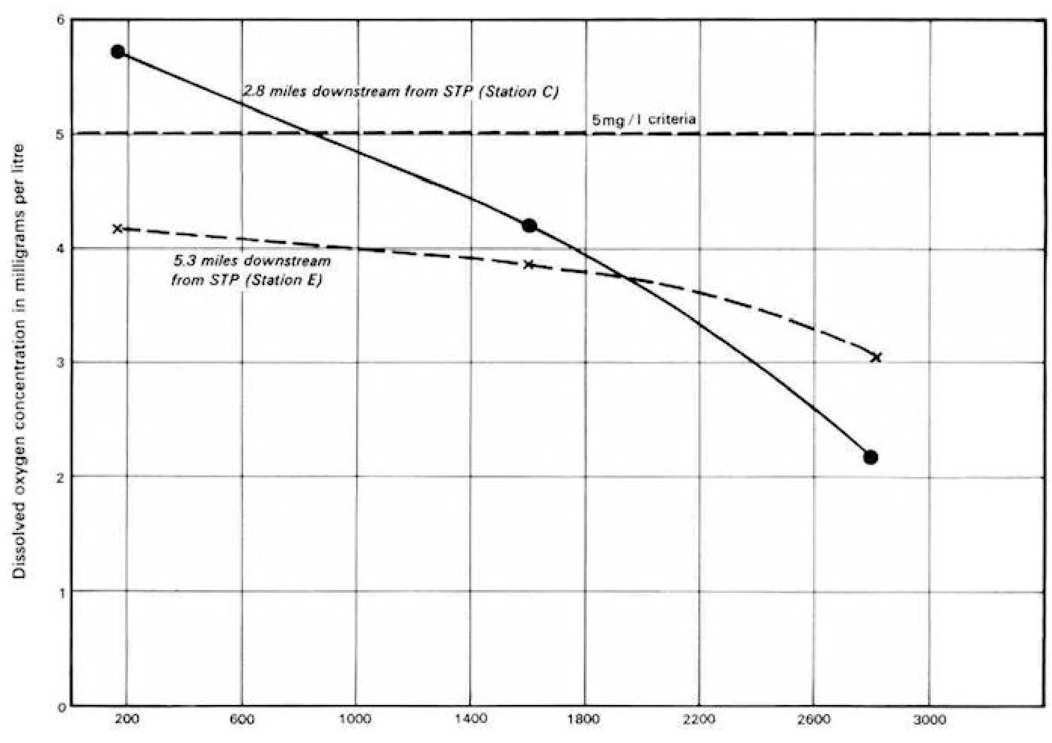


Figure A7: **Minimum dissolved oxygen concentrations predicted for two locations in the Thames River downstream from Woodstock, at various effluent waste loading rates.**

treatment plant effluent between the TOD, BOD_5 and Kjeldahl nitrogen (TKN) concentrations in the effluent, used in the model, is as follows:

(NOD + CARBOD) x flow(MGD) x 10 = TOD (lbs per day)

(4.57 x TKN + 1.16 x BOD_5) x Q x 10 = 900 lbs per day

The average sewage flow to the Woodstock treatment in 1973 was 5 MGD compared to a plant capacity of 4.5 MG D. Plans are underway for expansion of the plant to 7.85 MG D for a 1993 population of 36,700. Using this flow rate in the above relationship indicates that treatment to provide an effluent concentration of 11.5 mg/L TOD is required. This can be achieved only with an advanced treatment system which at a minimum would include effluent filtration and nitrification. Consideration of the dilution ratio at low flows of 1:1, indicates a possible requirement for even higher treatment levels, when other constituents in sewage are taken into account. This is discussed in the text of the report.

(ii) Beachville: In the section from Beachville to Ingersoll, model predictions indicate that the dissolved oxygen criteria of 5 mg/L cannot be met unless benthic respiration reduction is assumed or streamflow is increased considerably. The model was run with and without the effluent loadings of an assumed continuous discharge from a secondary treatment plant at Beachville (2,500 people, 0.25 MG D) with a negligible difference (in the order of 0.1 mg/L) in predicted downstream dissolved oxygen concentrations. The model could not account for the effects of nutrients (nitrogen and phosphorus) which would be discharged from a treatment plant. The above model predictions were made for a streamflow of 21 cfs, consisting of the sum of releases from Gordon Pittock (15 cfs). local inflow and discharge from the Woodstock STP. The minimum dissolved oxygen concentration predicted for the above conditions was 4.3 mg/L. in the section of the river between Beachville and Ingersoll.

(iii) Ingersoll: In a section of the river downstream from Ingersoll. the dissolved oxygen depletion observed during the survey was partially due to the Ingersoll sewage treatment plant, which was discharging inadequately treated sewage. The problem in the treatment plant was reportedly due to toxic industrial waste which adversely affected the biological treatment system. The problem is now reported to be under control.

Figure A8 indicates the predicted variation of the minimum dissolved oxygen concentration with waste loading variations for the Thames River, 2.5 miles downstream from the Ingersoll treatment plant, during low flow conditions of 21 cfs. The figure shows that the improvement in dissolved oxygen with oxygen demanding waste load reductions from the treatment plant is small. This lack of improvement is due to the combined effects of upstream conditions, and profuse aquatic growth in the reach, which outweigh the effect of the waste discharge. However, it is felt that a total oxygen demand loading rate of 400 lbs/day (TOD) would protect the minimum DO quality.

The Ingersoll treatment plant was recently expanded to 2.25 MGD, with 1973 flows averaging 1.27 MGD. At the present design capacity of 2.25 MGD. a TOD concentration of 18 mg/L would be required to meet the loading objective. This can be achieved by a combination of nitrification of the effluent and increased BOD_5 removal beyond the present design efficiencies.

7. THAMES RIVER IN THE VICINITY OF LONDON

Because of the basin-wide impact of management options considered for London. and the use of dynamic simulation modelling, a more detailed description of the basic considerations and assumptions is presented below.

A schematic diagram of the river system modelled by the dynamic simulation model is shown in Figure A9. Data to define parameters in the model and inputs to the model were collected during intensive surveys in May 1972. June 1970, July 1972, August 1973, September 1972 and October 1972. As an example of the data collected, the range of observed dissolved oxygen concentrations for the survey in August 1973, is shown in Figure A10. It can be seen that the criteria of 5 mg/L was violated during the survey in the south branch, in the North Thames River and in the Thames River immediately downstream from the confluence of the two branches. Further downstream in the vicinity of the Kilworth Bridge. levels of 5.5 mg/L were observed. The measured flow at the Byron Bridge flow gauge (02GE002). during the survey, was 270 cfs including the sewage flow from the London treatment plants (except Oxford STP). This is considerably above the natural low flow level of 125 cfs, which included releases from reservoirs and average 1972 sewage flows of 50 cfs.

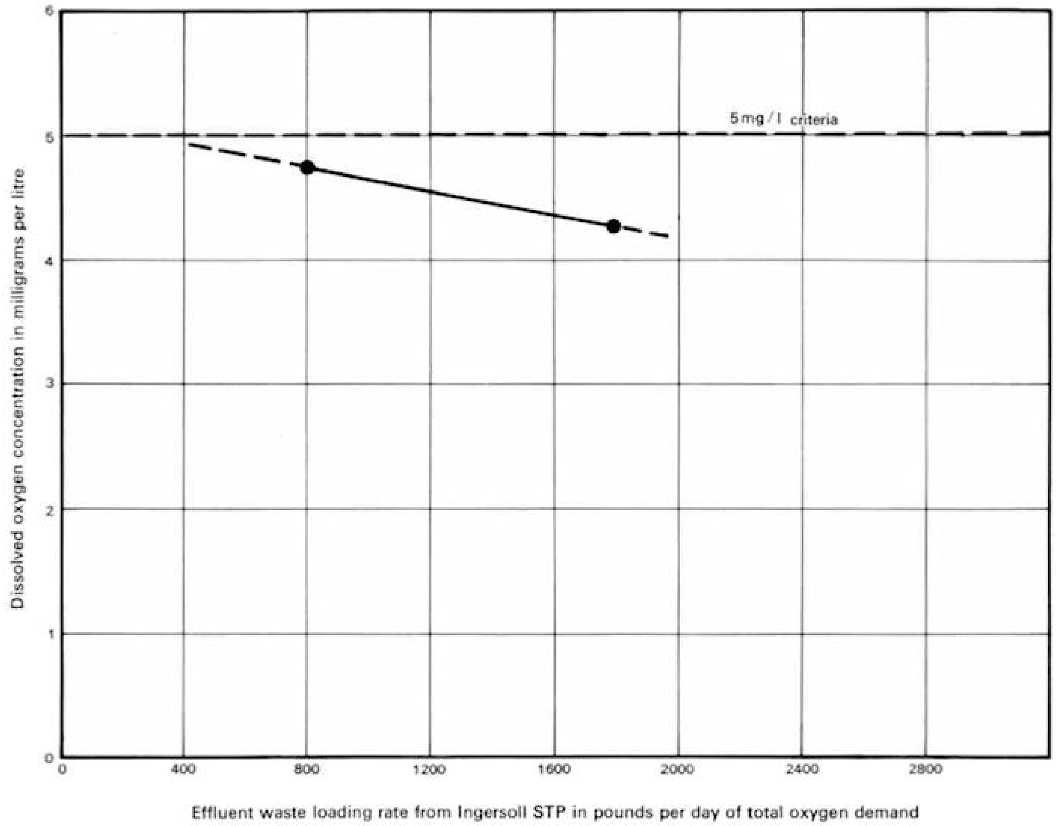


Figure A8: Minimum dissolved oxygen concentrations predicted for the Thames River. 2.5 miles downstream from Ingersoll STP (Station J), at various effluent waste loading rates.

Inputs to the model which are subject to changes as a result of management options for London, are described briefly below.

Probability distributions of oxygen demanding substances (nitrogenous and carbonaceous) were derived for the five treatment plants in the City of London, and the North Thames and Thames rivers, from data collected during 1972 by the City of London and the Ministry of the Environment. These are summarized in Table A1. The mean daily flow for the period May to October 1972 for the five sewage treatment plants is also indicated in this table.

Table A1: Thames River Simulation-Water Quality Inputs-Description of Probability Distributions and Mean Sewage Flows

Input Location	Carbonaceous O.D. [1]		Nitrogenous O.D. [2]		Daily Mean Flow [4]
	Median (mg/L)	90% [3] (mg/L)	Median (mg/L)	90% (mg/L)	1972 MIGD
Adelaide SIP	30.0	68.0	98.0	125.0	2.74
Pottersburg STP	35.0	109.0	45.0	114.0	3.55
Vauxhall STP	40.0	98.0	64.0	98.0	3.40
Greenway STP	20.0	54.0	7.0	23.0	17.20
Oxford STP	20.0	44.0	123.0	180.0	0.74
North Thames R.	1.8	5.2	3.2	6.6	-
Thames R. (S. Branch)	1.6	3.3	3.2	4.9	-

Notes.

1. Carbonaceous oxygen demand, (CARBOD) estimated by multiplying BOD, data by the CARBOD /BOD ratio determined through laboratory analysts. Ratios of 2 for the STP's and 1 for the stream inputs were used.
2. Nitrogenous oxygen demand, (NOD) determined by multiplying Kjeldahl nitrogen data by 4.57, the ratio of NOD to unoxidized nitrogen. determined by stoichiometric balance.
3. 90 percent of observations did not exceed value.
4. Based on the period from May to October 1972.

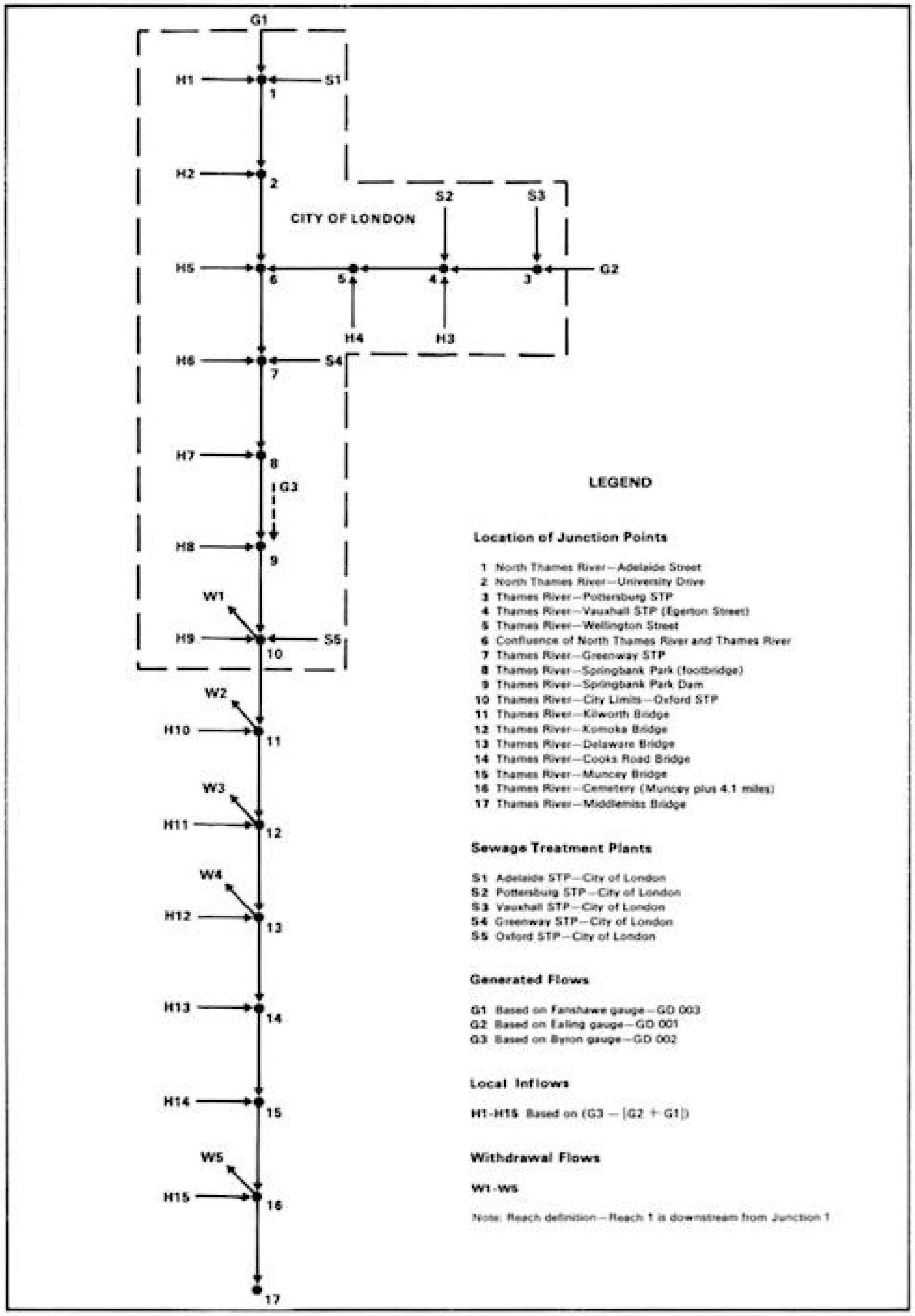


Figure A9 **Thames River water quality simulation model—Geometry of river system.**

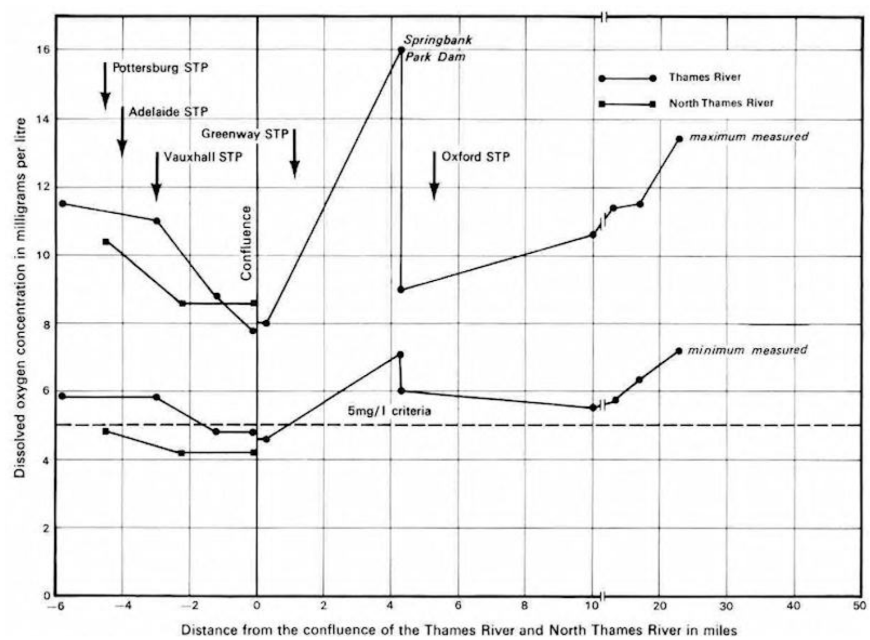


Figure A10: Maximum and minimum measured dissolved oxygen concentrations in the Thames River, August 13-16, 1973.

Generated flows, based on the historical record of the three stream flow gauges at Fanshawe (02GD003), Ealing (02GD001), and Byron (02GE002), were used as inputs to the model. Table A2 provides a comparison between the means and standard deviations of the historic record for the periods 1923-1930 and 1956-1970 for the 50 years of synthetic data on a monthly basis (May to November)(Singer, 1974).

Table A2: Comparison of Average Means and Standard Deviations of Daily Streamflows at Fanshawe, Ealing and Byron Flow Gauges

		Historical Period 1923-1930		Historical Period 1956-1970		Synthetic Data based on Historical Period 1923-1930 50 Years	
Station	Month	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
02GE002	May	1161	1036	1162	886	1322	896
02GD001	May	461	329	481	294	489	352
02GD003	May	514	544	548	497	596	475
02GE002	June	452	302	499	370	478	338
02GD001	June	222	147	224	134	218	140
02GD002	June	175	186	199	195	193	165
02GE002	July	387	382	331	172	367	326
02GD001	July	172	169	170	80	164	117
02GD003	July	170	304	108	81	147	178
02GE002	August	285	205	366	231	349	217
02GD001	August	127	75	195	143	142	83
02GD003	August	101	131	119	92	135	121
02GE002	September	326	242	346	196	274	246
02GD001	September	146	114	173	99	131	125
02GD003	September	106	118	117	80	82	102
02GE002	October	457	213	479	394	430	262
02GD001	October	193	90	183	83	182	101
02GD003	October	169	154	216	253	165	90
02GE002	November	1183	844	1019	808	1000	762
02GD001	November	460	325	325	202	397	376
02GD003	November	574	593	516	537	519	541

(a) Byron Gauge—Thames River at Byron Bridge - 02GE002
(b) Ealing Gauge—Thames River, south branch at Egerton Street, City of London - 02GD001
(c) Fanshawe—downstream from Fanshawe Dam - 02GD003

Other inputs to the model are described below.

Computer Model Runs for London Waste Management Options

Computer simulation runs were undertaken to define existing conditions of water quality more fully and to evaluate water management options. Additional runs were made to test model accuracy and sensitivity to various parameters. Input conditions altered to describe various options included: streamflow, sewage treatment levels, sewage flow related to population projections, sewage outfall location, and upstream water quality. Specific definitions of the input conditions used in the model are given below. Combinations which were modelled are summarized in Table A3.

Table A3: Thames River Simulation Model, Summary of Input Combinations

	A Stream-flow			B Treatment level			C Sewage Flow		D Sewage Outfall			E Upstream Quality		Months Simulated				Description
Input Conditions	Unregulated	Dam	Add. Dams	1972	Greenway	Zero	1972	1991	Existing	New Plant	Lake Erie	1972	Improved	May	June	July	August	
Run Number	1	2	3	1	2	3	1	2	1	2	3	1	2					
1	x			x			x		x			x		x	x	x	x	Base Conditions
2		x		x			x		x			x				x	x	Dam Operation (existing dams) plus Base Conditions
3	x				x		x		x			x				x	x	Greenway Treatment plus Base Conditions
4		x			x		x		x			x		x	x	x	x	Greenway Treatment plus Dam Operation
5			x		x		x		x			x				x	x	Greenway Treatment plus Additional Flow Augmentation
6			x			x	x		x			x				x	x	Zero Pollutants plus Dam Operation
7		x			x			x	x			x				x	x	1991 STP Flows, Greenway Treatment plus Dam Operation
8		x			x			x		x		x				x	x	1991 STP Flows, 'New Plant', as 7
9		x			x		x		x				x			x	x	Improved Upstream Quality
10		x									X	x				x	x	Diversion of all sewage to Lake Erie

Note: Input Conditions defined in text

A. Streamflow

1. Unregulated. Generated flows, described previously in this appendix, were used.
2. Dam Operation. Minimum flows based on the published operating schedules of existing reservoirs were assumed, resulting in a minimum flow in the North Thames of 40 cfs from Wildwood Reservoir and a minimum flow in the south branch of 35 cfs, from Gordon Pittock (15 cfs) and natural flow.
3. Additional Dams. Additional flow augmentation of 36 cfs from the Glengowan Dam on the North Thames and 45 cfs from the Thamesford Dam on the Middle Thames were assumed. This resulted in a minimum flow in the North Thames River of 76 cfs and a minimum flow of 85 cfs in the south branch.

B. Waste Treatment Levels

1. Existing treatment (1972) as described by probability distributions of pollutants were summarized in Table A1.
2. Greenway. This treatment level is assumed to consist of a highly efficient secondary treatment providing nitrification, possibly followed by effluent filtration. The effluent from Greenway STP was assumed equivalent to this treatment level on the average. The probability distribution of pollutants in Table A1 for Greenway STP was used to describe this treatment level, with a reduction in the occurrence of high concentrations. This is indicated in Figure A11 which shows the probability distribution of pollutants in

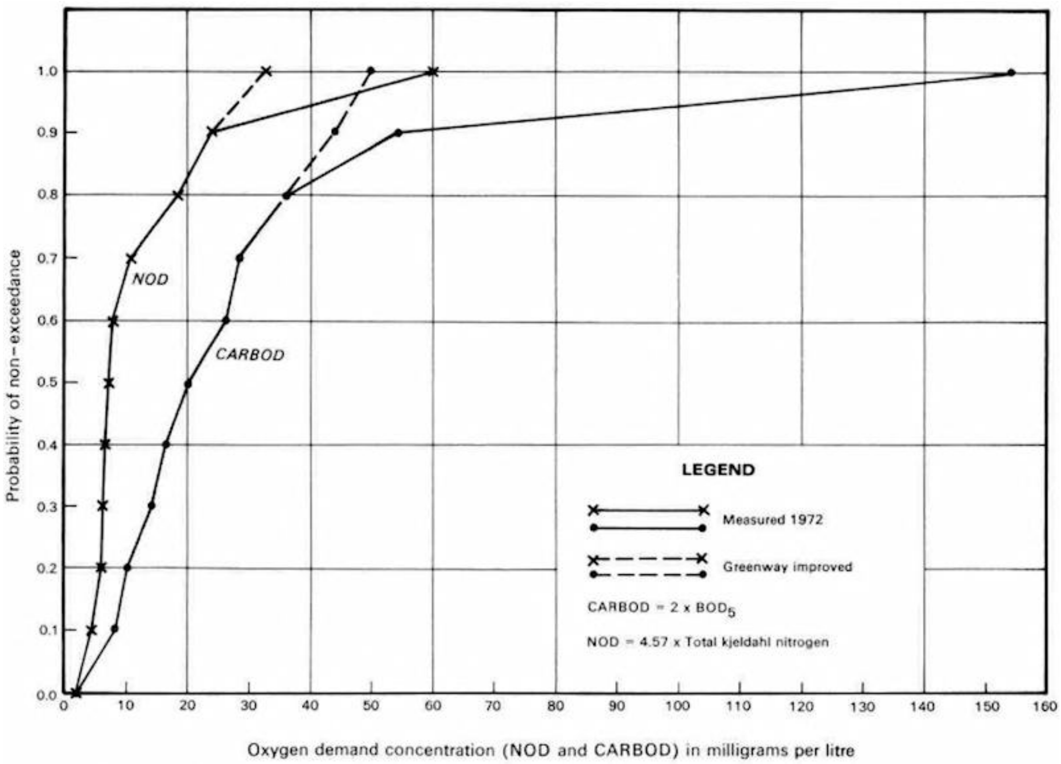


Figure A11: Probability distribution of NOD and CARBOD in the final effluent of Greenway STP.

the Greenway STP effluent in 1972 and the modifications used to describe improved treatment.

3. Zero Pollutants. This was assumed to be equivalent to treatment to drinking water standards. Negligible concentrations of pollutants (0.1 mg/L) and a high oxygen concentration (8.4 mg/L) were assumed to occur in the effluent of all STP's.

C. Sewage Flow Rate

1. 1972. Existing sewage flow rate as observed in 1972. The mean daily flow rate is shown in Table Al and Table A4. Average total flow from all treatment plants is estimated to be 27.6 MGD (51.2 cfs).
2. 1991. A total daily average flow rate of 49.5 MGD was used based on predictions of the population and per capita daily consumption. Distribution of flows to various treatment plants is indicated below.

Table A4: Average Daily Sewage Flow Rates Used in the Thames River Simulation Model

STP	1972 Flow (MIGD)	1991[1] Flows Outfall Location 1[2] (MIGD)	1991 Flows Outfall Location 2 (MIGD)
Adelaide	2.74	4.4	4.0
Pottersburg	3.55	6.2	5.2
Vauxhall	3.40	5.8	3.5
Greenway	17.16	31.6	21.3
Oxford	0.74	1.5	1.5+14
TOTAL	27.60	49.5	49.5

Notes:

1. 1991 flows based on population of 390.000 at a daily per capita use of 127 Imperial gallons
2. See text for explanation of outfall locations.

D. Sewage Outfall Locations

1. As is. 1991 flows were distributed to the five existing treatment plants equally on a proportional basis, as indicated in Table A4.
2. New Plant. For 1991 flows, existing treatment plants were left at existing or approved (expanded) capacity. Additional flows were directed to a new plant assumed to be constructed in the vicinity of the Oxford STP, as indicated in Table A4.
3. Lake Erie. All sewage flows are assumed to diverted to Lake Erie.

E. Upstream Water Quality

1. Observed water quality. Data collected in 1972 was used as described in Table A1, for the pollutant concentrations of the North Thames and south branch of the Thames River.
2. Improved. Pollutant concentrations were reduced for the North Thames and the south branch of the Thames. The concentrations of NOD shown in Table A1 were reduced by approximately one-half; median CARBOD concentrations were not changed.

The ten computer runs described in Table A3 can be used to evaluate existing conditions and the effects of: improved treatment, additional flow augmentation, projected waste loadings, changes in STP outfall location within the city. improved upstream water quality, and diversion of sewage to Lake Erie.

(i) Existing Conditions. Described by Run 1. "Base Conditions" and Run 2, "Dam Operation plus Base Conditions". Results for the two runs were virtually identical. Criteria were met in all reaches in May and all but two reaches in June. In July, oxygen levels were below 5 mg/L for greater than 5 percent of the time in eight of the sixteen reaches, and as low as 1 mg/L for a significant length of time in eight reaches. In August. predicted conditions were not as severe as July—oxygen levels were below 5 mg/L for greater than 5 percent of the time in five reaches. Results for the month of July are presented graphically in Figure A12 which indicates the percentage of time that the dissolved oxygen concentration is less than the indicated value at the end of the reach. The horizontal line labelled "criteria" indicates the 5 percent condition of the dissolved oxygen criteria C and D. Dissolved oxygen criteria C and D are applied to the study sections simulated as discussed in Appendix B.

Results described above indicate that unacceptable quality of water prevails under 1972 conditions of sewage treatment plant flow and quality, river flow and quality, and biological conditions in the river channel. Dissolved oxygen conditions in the months of July and August, for the North Thames and south branch within the city limits, and especially Springbank Park reservoir on the main branch, are such that severe stresses are placed on fish life inhabiting these areas. Fish kills are likely to occur.

(ii) Effect of Improved Treatment. Run 3. "Greenway Treatment plus Base Conditions", Run 4, "Greenway Treatment plus Dam Operation" and Run 6, `Zero Pollutants plus Dam Operation", when compared to Runs 1 and 2, indicate the effect that levels of improved treatment have on the quality of the Thames River.

Greenway treatment at all treatment plants resulted in a significant improvement in dissolved oxygen concentrations for the month of July as indicated in Figure A13 compared to Figure A12. Six reaches still had dissolved oxygen concentrations less than 5 mg/L more than 5 percent of the time: however, total time of the violations was greatly reduced and the severity of violations decreased. The most marked improvement occurred in the North Thames River, downstream from the Adelaide STP, where the percent time with dissolved oxygen below 5 mg/L was reduced from 17.3 percent to 5.4 percent—almost to the acceptable level. Other reaches, where problems were predicted to continue, include the main Thames River from the confluence to the Springbank Park dam, and downstream from the Oxford STP, In August, the number of reaches in violation was reduced from five (Run 3) to two (Run 4) and conditions were generally greatly improved.

Treatment to the zero pollutant level is probably not economically feasible or justifiable. The model, however, was run with this condition to indicate the full range of response of the dissolved oxygen output to treatment options. Zero pollutant levels in the discharge resulted in further improvements in the dissolved oxygen levels as indicated in Figure A14. In July, however, four reaches still had occurrences of dissolved oxygen concentrations less than 5 mg/L for more than 5 percent of the time. Violations of criteria are predicted to continue in spite of reductions of pollutants in sewage treatment

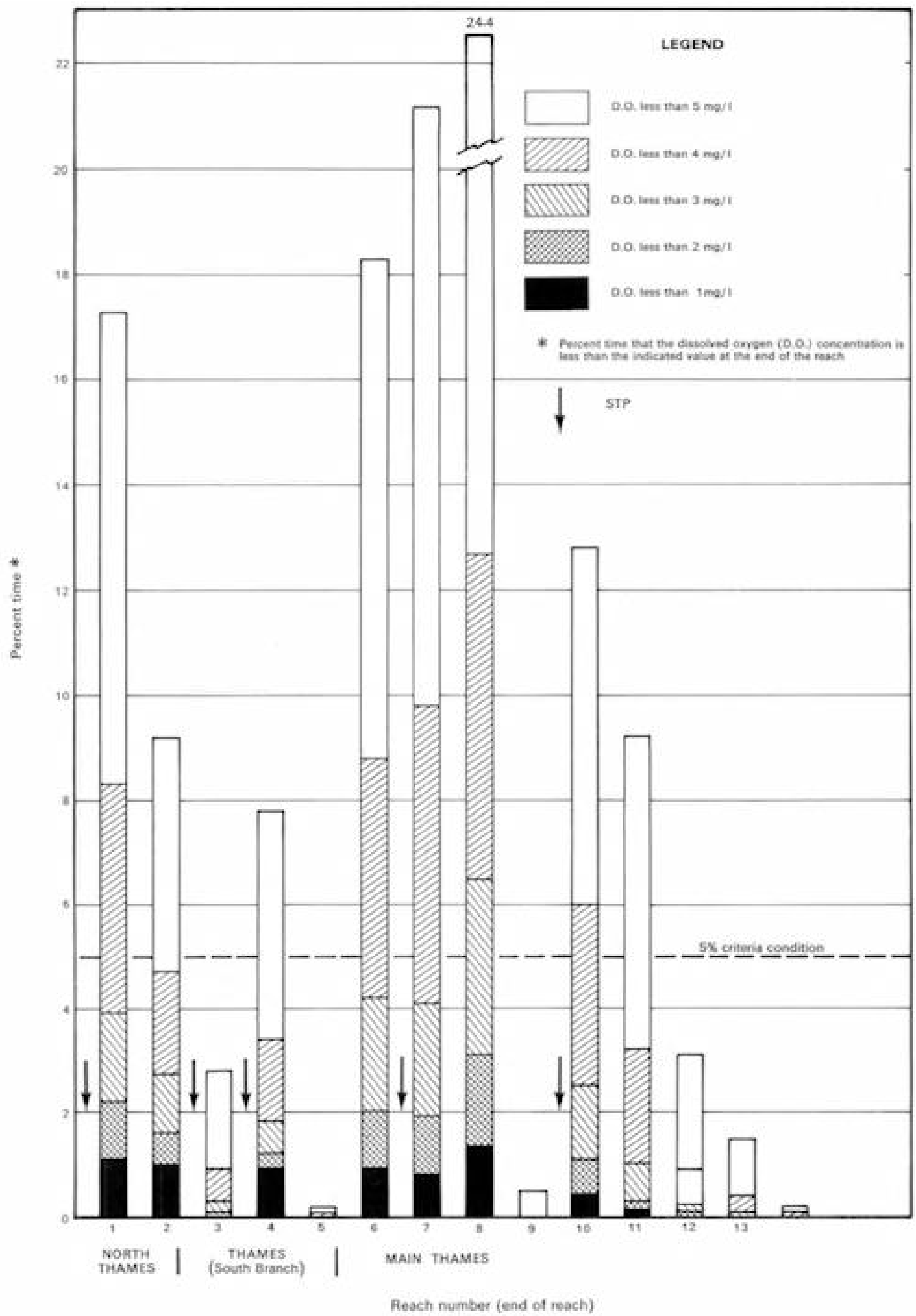


Figure A12: Thames River water quality simulation model—Dissolved oxygen output summary for the month of July—Run 2 "Dam Operation".

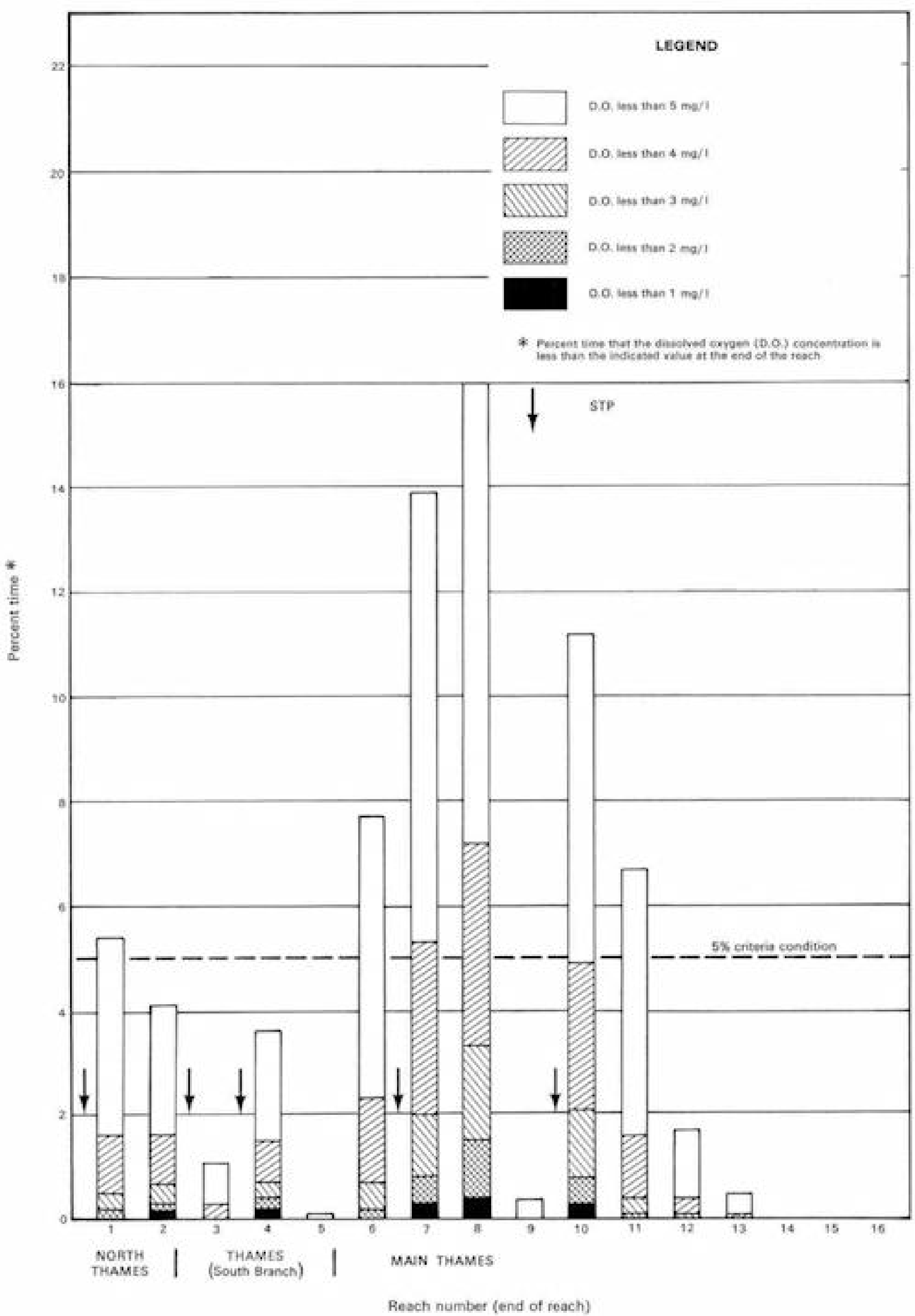


Figure A13: Thames River water quality simulation model—Dissolved oxygen output summary for the month of July—Run 4"Greenway Treatment Plus Dam Operation".

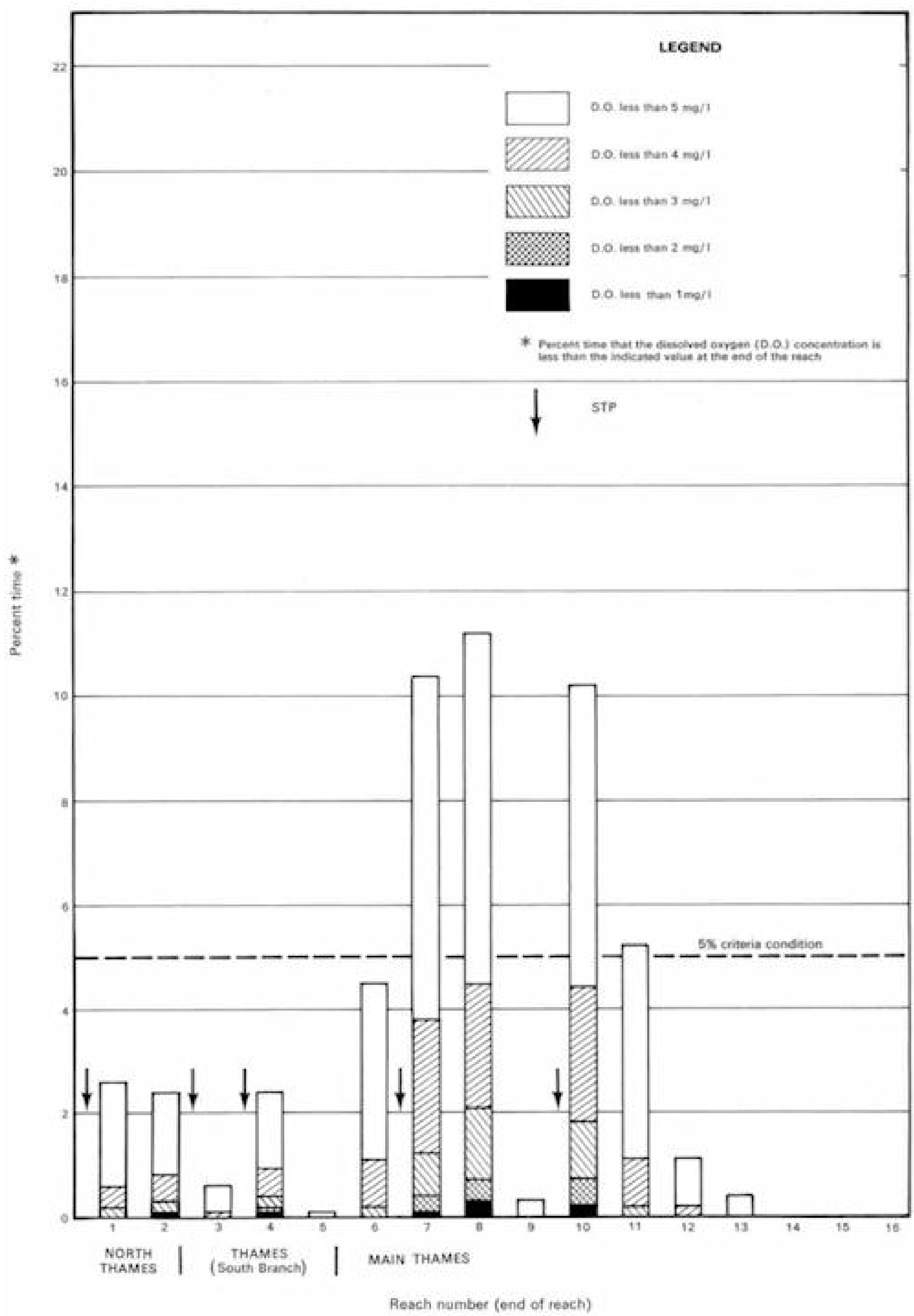


Figure A14: Thames River water quality simulation model—Dissolved oxygen output summary for the month of July—Run 6 "Zero Pollutants Plus Darn Operation".

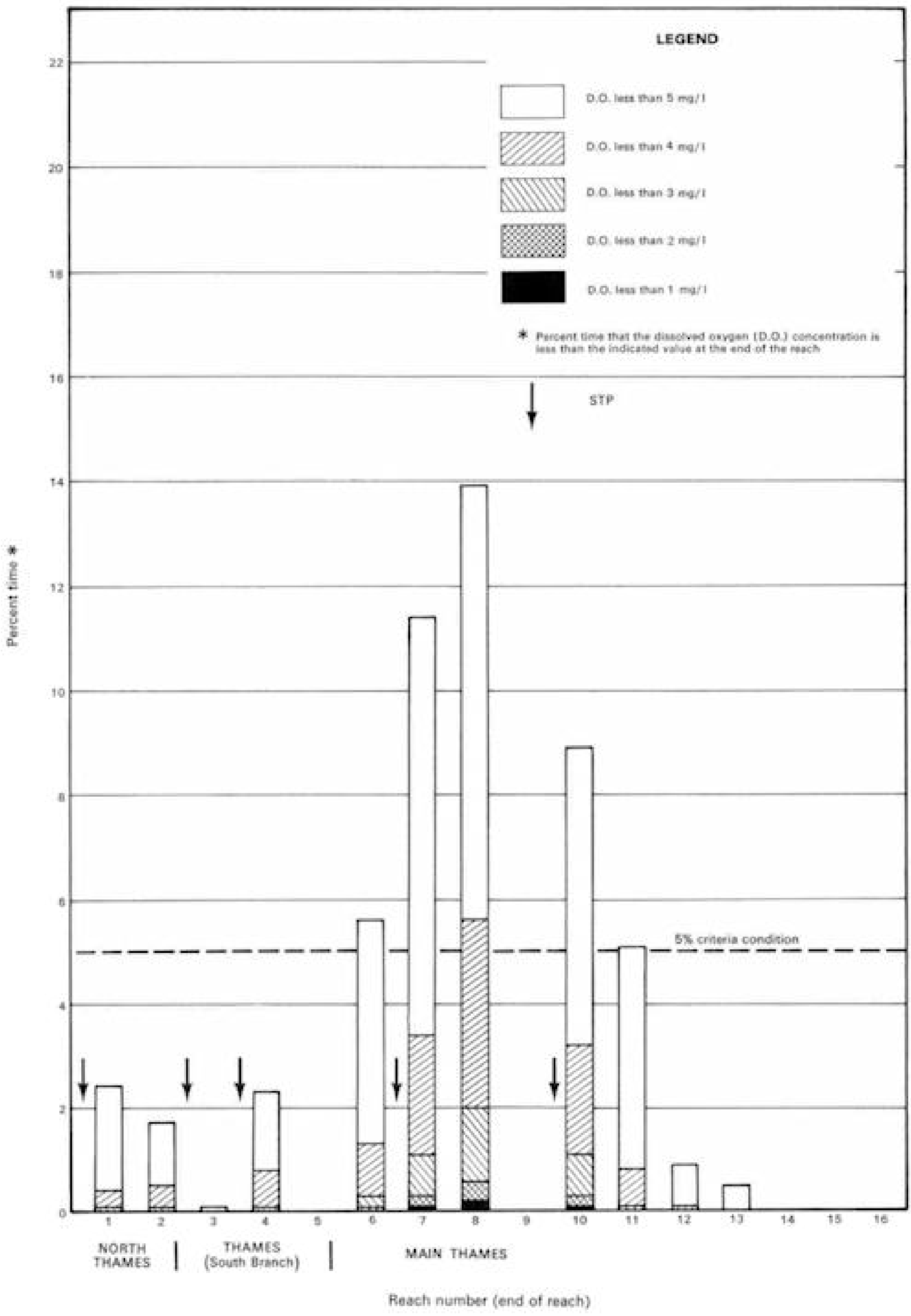


Figure A15: Thames River water quality simulation model—Dissolved oxygen output summary for the month of July—Run 5"Greenway Treatment Plus Additional Flow Augmentation".

plant discharges. largely because of the continued respiratory oxygen demand presumable from benthic (bottom dwelling) sludge organisms and the respiration of aquatic algae and plants. Problems in Springbank Park are partially a result of the reduced atmospheric aeration in the deeper. slower moving water in the reservoir.

(iii) Effect of Additional Flow Augmentation. Run 5, "Greenway Treatment plus Additional Flow Augmentation", compared to Run 4 (described above), indicates the effect of flow augmentation from the Glengowan and Thamesford dams.

The predicted distribution of dissolved oxygen criteria violations is indicated in Figure A15 for the month of July. Conditions are much improved compared to Run 4. with the number of reaches in violation of the criteria reduced to 5 in July and the severity of violations also reduced. The additional flow augmentation had almost the same effect in reducing violations as did treatment to the "zero pollutants" level, as can be seen by comparing Figure A14 to Figure A15.

(iv) Effect of Projected Waste Loadings. Run 7. "1991 STP Flows", compared to Run 4 indicates the effect of increased sewage flows in 1991. In both cases. Greenway treatment as defined previously, is assumed to be in operation at the treatment plants.

The predicted dissolved oxygen criteria violations for the 1991 projected sewage flows are very similar to the violations from 1972 flows at the same treatment level as described by Run 4. The same number of reaches (six), have occurrences of dissolved oxygen below 5 mg/L for greater than 5 percent of the time in July, although the percent time in violation increased by up to 2 percent in two reaches within the city limits. Reaches downstream from the city limits (Reaches 10 to 16) were not affected significantly at all. Results for August were similar for the two runs.

Apparently, increased discharges of relatively high quality effluent to the river do not have a major impact on the dissolved oxygen levels. This impact lack is presumably because the effects of increased loading of organic pollutants are partially offset by the increased volume of water with the sewage.

The effect of possibly increased discharge of pollutants in storm runoff from an enlarged urban area was not included in the model because of lack of quantitative information concerning this source. It is possible that dissolved oxygen conditions will be worse than predicted with this run. if present urban runoff practices are in effect in the future.

(v) Effects of Changes in STP Outfall Location within the City. Run 7. "1991 STP Flows" and Run 8, "1991 STP Flows, New Plant", are equivalent except that a new treatment plant in the vicinity of Oxford STP is assumed to be in operation, as described previously in this appendix. Only minor differences in dissolved oxygen violations were noted in comparing the two runs, largely related to the different hydraulic effects of the two options and as to the organic loading. The increased discharge from the new plant had an insignificant effect on conditions downstream from the City (reaches 10 to 16). It is noted, however, that both runs produced reaches in violation of criteria as described immediately preceding in "The Effect of Projected Waste Loadings".

(vi) Effect of Improved Upstream Water Quality. Run 9. "Improved Upstream Quality" compared to Run 4 described above, indicates the effect that an improvement in the poor upstream water quality has on the dissolved oxygen conditions in the study section.

The predicted dissolved oxygen criteria violations for Run 9 show an improvement over Run 4. The number of reaches that have occurrences of dissolved oxygen below 5 mg/L for greater than 5 percent of the time was reduced from six to four, in July. The severity of violations in the reaches was reduced significantly. In reach 8, the percent time that the dissolved oxygen is below 5 mg/L was reduced from 16 percent to 12 percent of the time. The effect was more noticeable in the upstream reaches (1 to 8) than in the lower reaches downstream from the Springbank Park dam.

(vii) Effects of Diversion of all Sewage to Lake Erie. Results for this option (Run 10) are presented in Figure A16 for the month of July. Compared to Run 4 "Greenway treatment", conditions were improved, but not quite to the level of improvement shown by Run 6, "Zero Pollutants". This is because the diversion of sewage reduces both the organic load and the flow in the river. Plant and algae oxygen production and respiration were not changed in the model as it was assumed that sufficient nutrients are available in the streamflow from other sources to allow biological activity to continue at observed rates.

The implications of the model findings and a discussion of options not specifically modelled is included in Appendix H, "Sewage Disposal Options for the City of London".

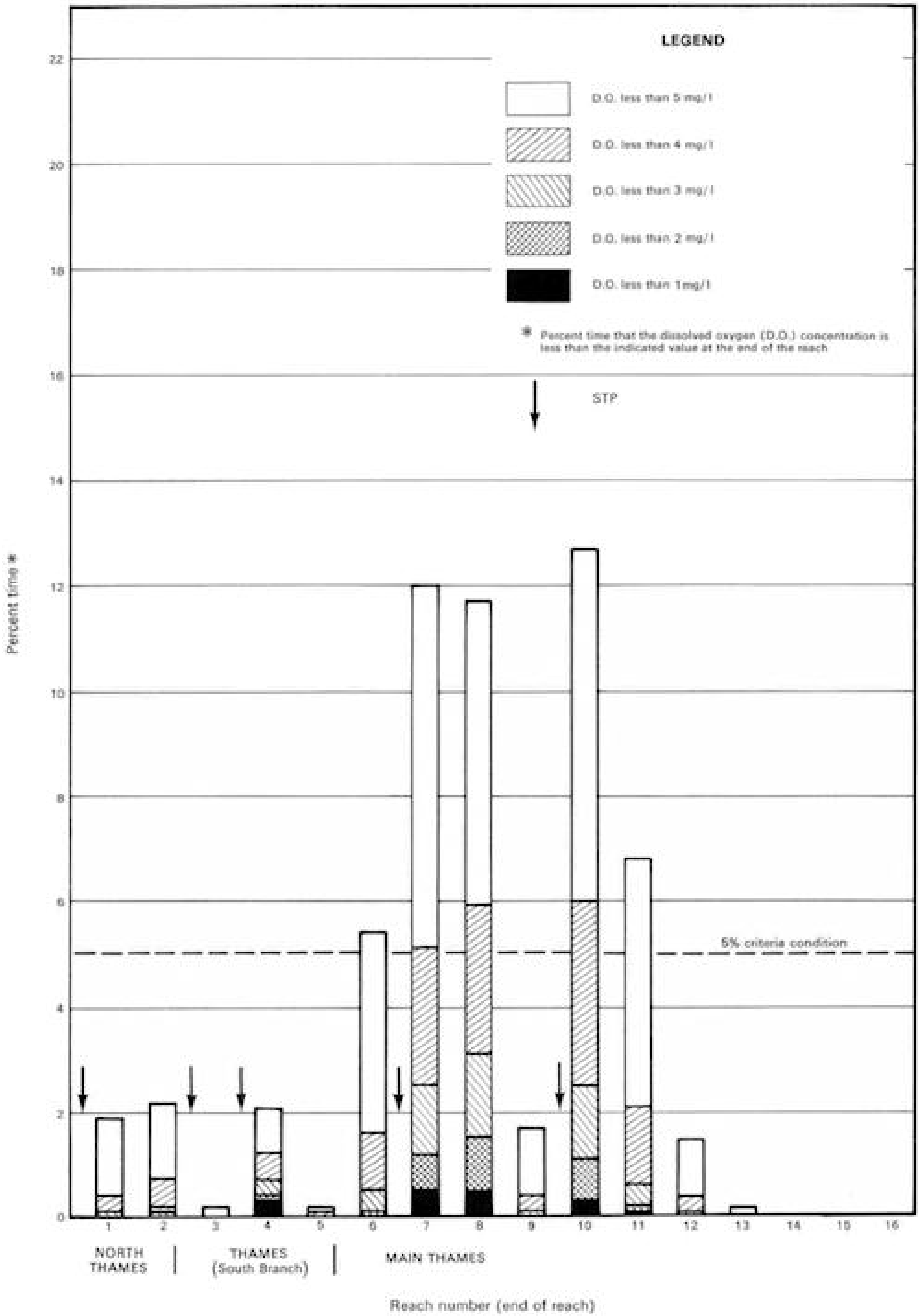


Figure A16: Thames River water quality simulation model—Dissolved oxygen output summary for the month of July—Run 10 "Diversion of All Sewage to Lake Erie".

8. THAMES RIVER AT CHATHAM

Field surveys of the Thames River, in and downstream from Chatham were carried out on June 14-16 and September 7-9, 1971. Figure A17 shows the maximum and minimum dissolved oxygen concentrations measured in the September, 1971 survey. Oxygen concentrations were above the 5 mg/L criteria requirement for this section of the river; however, a significant drop in dissolved oxygen levels is evident within the city limits of Chatham. upstream from the treatment plant. In addition, oxygen levels approach 5 mg/L close to the mouth of the river. The flow in the river, measured upstream at Thamesville (gauge 02GE003) ranged from 227 to 239 cfs during the survey. The estimated low flow (7 day mean flow with a 20 year recurrence interval) for Chatham is assumed to be equal to the low flow at Thamesville-100 cfs.

Dissolved oxygen modelling for the Thames River from Chatham to Lake St. Clair was complicated by the fact that the river level is controlled by the Lake St. Clair level and is a backwater to a point upstream from Chatham. The greater depth of flow and reduced flow velocities contribute to the water quality problems in this section by reducing the atmospheric aeration rate of the water and increasing the sedimentation rate of solid materials in the flow. This leads to a build up of decaying organic solids on the river bottom from sources upstream of and within the city.

Findings derived from application of the oxygen model for model parameters based on the September 1971 survey in the Chatham area are as follows:

(i) Combined sewer controls will improve water quality within the city limits. Within the city limits the dissolved oxygen model predicts severe violations of dissolved oxygen criteria at a low flow of 100 cfs. The major sink of oxygen in this section is benthic respiration, suspected to be largely from sludge dwelling organisms. (since the deep, turbid water does not support significant growths of attached or floating algae). This is supported by records of frequently occurring combined sewage overflows. Combined sewage typically contains a large proportion of solid organic wastes which could easily settle on the river bottom. This is suspected to be the source of the dissolved oxygen problem. Reduction of the respiration term (R) in the model produced acceptable dissolved oxygen levels within the city limits. No quantitative relationship could be developed to link the combined sewer overflows to the respiration rate. It is considered reasonable, however, to make the assumption that reduction in overflows would eventually reduce the benthic sludge respiration rate.

(ii) An effluent waste loading rate of 3,300 pounds of total oxygen demand per day would allow dissolved oxygen criteria to be met downstream from the Chatham STP at low flows. Figure A18 indicates the minimum dissolved oxygen predicted for Station 2 (2.75 miles downstream from the Chatham STP) at various effluent loading rates and upstream flows. This figure indicates that, if additional flow augmentation is provided to increase low flows above 100 cfs, then a higher loading rate would be acceptable.

The implications of the model findings to waste management options for Chatham are discussed in Chapter 8

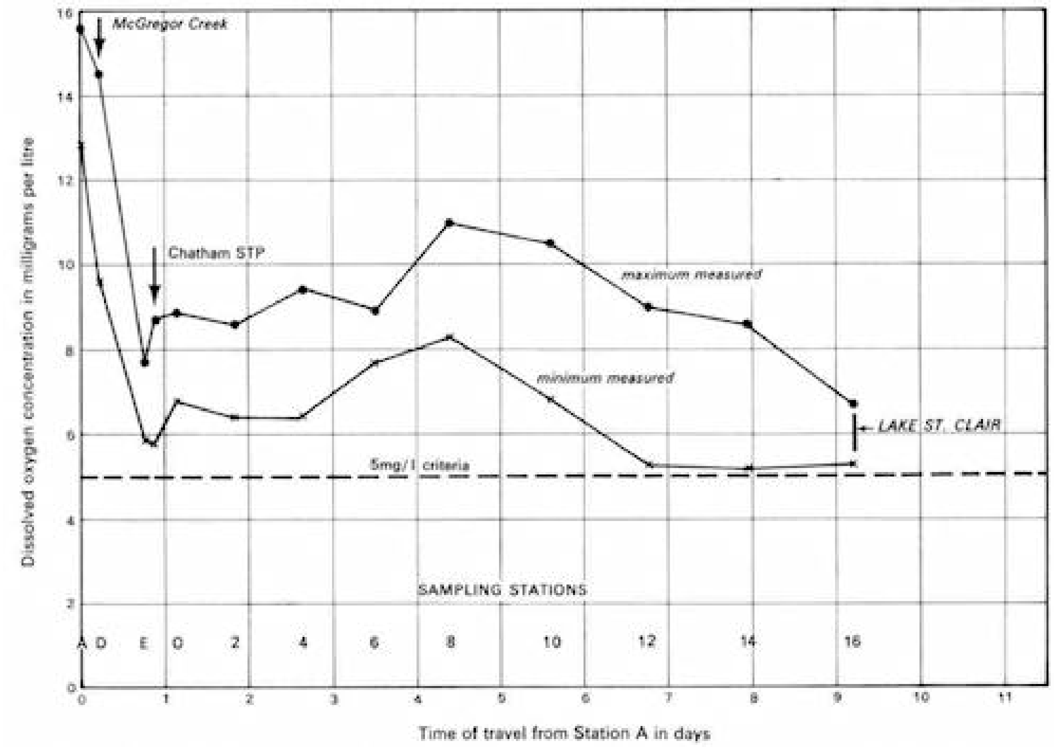


Figure A17: Maximum and minimum measured dissolved oxygen concentrations versus time of travel in the Thames River downstream from Chatham, September, 1971.

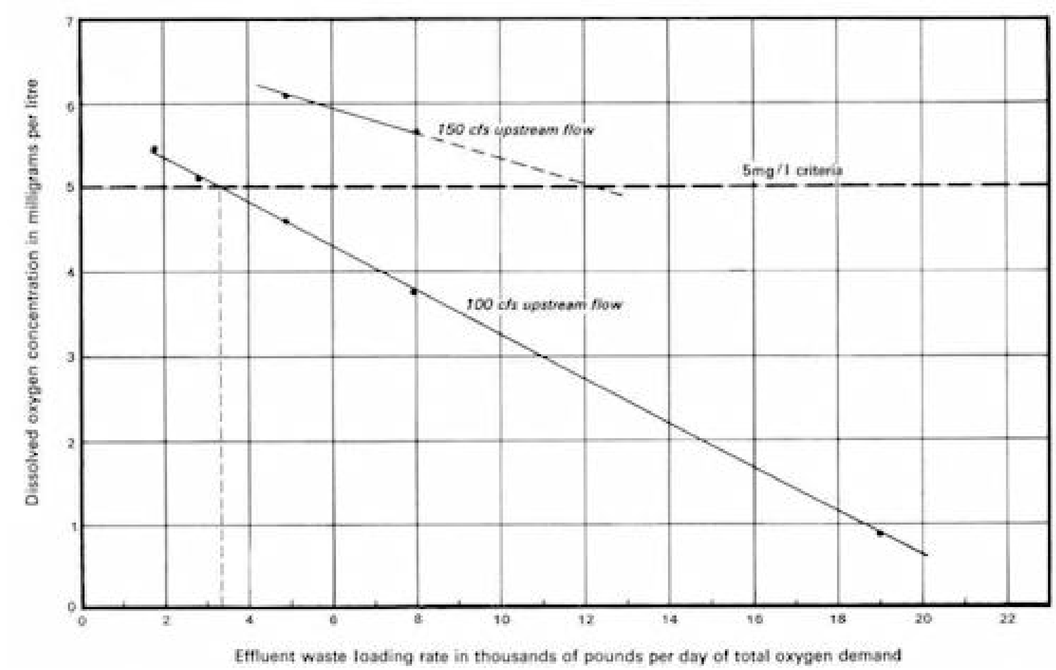


Figure A18: Minimum dissolved oxygen concentrations predicted at Station 2, 2.75 miles downstream from Chatham STP, at various effluent waste loading rates.

APPENDIX B

DISSOLVED OXYGEN CRITERIA

Dissolved oxygen criteria are narrative definitions of concentrations of dissolved oxygen below which unacceptable stress conditions exist for different species of fish. It is necessary to define for how long and in what period of the year the concentration should be exceeded. Biologists realize that true optimum conditions of dissolved oxygen for fish are those of saturation. Any reduction from saturation represents some stress on fish: different stresses occur for different species at different times of the year. The presence of other stress conditions such as toxic materials, high temperatures. etc., can magnify stress conditions on fish. Dissolved oxygen criteria are chosen high enough so that some safety factor is included to account for chance occurrences of other stress factors.

The criteria defined below were derived from criteria for the protection of fish and aquatic life published in "Guidelines and Criteria for Water Quality Management in Ontario" (Ontario Ministry of the Environment, 1974). Some revision in terminology was necessary because of the requirement that criteria be stated in statistical terms so that output from the water quality simulation model could be evaluated.

Criteria A: "The dissolved oxygen concentration should be above 7 mg/L 95 percent of the time in a given month. Concentrations may range between 7 mg/L and 6 mg/L for periods up to four hours in length within any 24 hour period, provided that water quality is favourable in all other respects."
Criteria A represent a high quality of water with a minimum of stress, to be applied in the spawning periods of sensitive fish species such as pickerel and trout.

Criteria B: "The dissolved oxygen concentration should be above 6 mg/L 95 percent of the time in a given month. Concentrations may range between 6 mg/L and 5 mg/L for periods up to four hours in length within any 24 hour period, provided that the water quality is favourable in all other respects."

Criteria B represent a high quality of water with a minimum of stress, to be applied for warm water fish species in spawning periods and for cold water fish species in non- spawning periods.

Criteria C: "The dissolved oxygen concentration should be above 5 mg/L 95 percent of the time in a given month. Concentrations may range between 5 mg/L and 4 mg/L for periods up to four hours in length within any 24 hour period, provided that water quality is favourable in all other respects".

Criteria C represent an acceptable quality of water with some stress, to be applied for warm water fish species in non-spawning periods.

Criteria D: "The dissolved oxygen concentration should be above 5 mg/L 95 percent of the time in a given month. Concentrations may range between 5 mg/L and 3 mg/L for periods up to eight hours in length within any 24 hour period, provided that water quality is favourable in all other respects".

Criteria D represent a marginally acceptable quality of water with some stress, to be applied for warm water fish species. The criteria would be applied in presently degraded areas where the result would be an upgrading of the water quality to remove existing severe stresses on fish species.

Interpretation

The meaning of the criteria can be shown by considering an example for June. Criteria C would allow dissolved oxygen concentration to fall below 5 mg/L for a total of 36 hours as long as any single occasion does not exceed four hours in duration and as long as the concentration did not fall below 4 mg/L. All three conditions, therefore. must be met. Meeting the criteria implies that concentrations are much higher than the critical level most of the time and that occurrences of stress conditions would be rare.

Criteria Application

These objectives can be translated into specific dissolved oxygen criteria for a given watercourse by referring to existing and potential aquatic life in a watercourse. Objectives for each watercourse in this watershed can be met if the criteria defined above are applied as outlined in Table B1. Separate criteria are applied in different seasons of the year only where the requirements of the fishery warrant it.

The expression of criteria in terms of "concentration should be above x mg/L 95 percent of the time in a given month", implies that continuous data are required in the form of observations or computer model predictions for full application of the criteria. In locations where continuous data are not available, criteria stated as above are still applied, although a simpler interpretation of the criteria is used.

For example, in setting waste loading guidelines in cases where steady state dissolved oxygen models are used, it will be required that the 95 percent value (e.g. 5 mg/L for Criteria C) be met or exceeded in the design case. The design case typically consists of mean waste treatment loads and a 7-day mean flow with a 95 percent chance of non-exceedance. The design procedure implies that occurrences of dissolved oxygen concentrations below the 95 percent level are possible but with an unknown frequency.

Definition of Seasons

The seasons referred to in Table BI are defined as follows: Spring-March 16 to May 31; Summer-June 1 to September 15; Fall-September 16 to November 30; Winter-December 1 to March 15. These dates have been selected according to fish life cycles with particular emphasis on spawning and nursery periods.

Table B1: Dissolved Oxygen Criteria

(a) Criteria Definition	Criteria A	Criteria B	Criteria C	Criteria D
Concentration exceeded 95% of time in a given month	7 mg/L	6 mg/L	5 mg/L	5 mg/L
Max. allowable duration	4 hrs	4 hrs	4 hrs	8 hrs
Critical level, concentration not to tall below	6 mg/L	5 mg/L	4 mg/L	3 mg/L
(b) Criteria Application				
North Thames River				
Channel Section or Tributary	Spring	Summer	Fall	Winter
Headwaters to the mouth of Avon River	D	D	D	D
Avon River upstream from Lake Victoria	C	C	C	C
Avon River-Lake Victoria to mouth	D	D	D	D
Avon River mouth to St Marys	C	C	C	C
Trout Creek	A	B	A	B
St Marys to Fanshawe Reservoir	B	C	C	C
Fish Creek	C	C	C	C
Fanshawe Reservoir	B	C	C	C
Wye Creek	D	D	D	D
Thames River above London				
Channel Section or Tributary	Spring	Summer	Fall	Winter
Headwaters to Gordon Pittock Reservoir	B	C	C	C
Gordon PIttock Reservoir	B	C	C	C
Gordon Pittock Dam to the mouth of the Middle Thames	C	C	C	C
Cedar Creek	A	B	B	B
Reynolds Creek	C	C	C	C
Middle Thames River	A	B	B	B
Mouth of the Middle Thames to London	B	C	C	C
Thames River—London to Lake St. Clair				
Channel Section or Tributary	Spring	Summer	Fall	Winter
North Thames-Fanshawe Dam to the confluence of the North and South branches	C	C	C	C
South branch to the confluence with the North Branch	C	D	0	D
Medway River	C	C	C	C
Confluence to Springbank Park Darn	A	D	D	D
Springbank Park Dam at Wardsville	A	C	C	C
Oxbow (Springers) Creek	A	B	B	B
Dingman Creek	D	D	D	D
Sharon Creek	D	D	D	D
Newbiggen Creek - Komoka Creek	A	B	A	B
Wardsville to Chatham	A	C	C	C
Chatham to Lake St Clair	A	C	C	C
McGregor Creek	C	C	C	C
Jeannette Creek	C	C	C	C
Big, Tilbury and Baptiste Creeks	C	C	C	C

APPENDIX C

WATER QUALITY MANAGEMENT OPTIONS

As indicated in Section 7.2, certain water quality management options are oriented to either urban areas, rural areas or existing reservoirs. These options are described below.

URBAN OPTIONS

Management options for urban areas include: treatment or diversion of pollutants: population and urban growth restrictions; and alteration of stream assimilative characteristics.

Treatment Levels

Sanitary wastes in urban areas already receive a minimum of secondary treatment, as described in section 4.2.1. During dry weather How, secondary treatment systems. with effluent chlorination and phosphorus removal, effectively remove most of the pollutants described as problems in sanitary sewage (suspended solids, BOD_5. phosphorus and bacteria). Additional treatment can be achieved by the following:

Nitrification: This technique lowers the oxygen demand of the effluent by oxidizing the nitrogen compounds (organic and ammonia nitrogen) to the nitrate form. This can be achieved during the summer in many treatment plants by making minor operational changes in the treatment process. Future treatment plants can be designed to provide nitrification at minimal additional expense. Additional benefits would be a possible reduction in carbonaceous BOD_5, more capacity to handle wasteload fluctuations and more effective chlorination. One type of secondary treatment plant utilizing the extended aeration process, is likely to provide nitrification routinely.

Filtration: The installation of sand filtration units following secondary treatment provides for additional removal of suspended solids and BOD_5 associated with the solids. This is especially effective in handling variations in effluent quality due to failures in the final settling process of the treatment plant.

Nitrogen Removal: This could be achieved by two processes— ammonia stripping or nitrification followed by denitrification. This would remove most of the nitrogen in the effluent and thus lower both the oxygen demand and the ability of the effluent to support algae.

Carbon Adsorption: Activated carbon columns take out refractory soluble organics not removed by other processes. These substances include non-biodegradable organics, colour, COD, taste-and odour-producing components, and residual BOD_5.

Lagoon Polishing: Storage of secondary effluent in lagoons for some period of time can provide additional oxidation of organic material and solids removal. In addition, effluents can be retained during periods of low natural assimilative capacity in the stream. and released when more favourable conditions prevail.

Other Treatment Processes: Other advanced treatment processes are available. but are not dealt with here as they are largely experimental and very costly.

The above processes are often referred to singly or collectively as tertiary treatment or advanced treatment. In this report, tertiary treatment refers to the combination of phosphorus removal, nitrogen removal, carbon adsorption and filtration, following secondary treatment. The cost of this system is described in Appendix F for the City of London.

Storm and Combined Sewer Control

Problems associated with urban storm water have been described in Chapter 6. These may be controlled by the following options, depending on whether the sewage systems are combined or separated.

Increased Sewage Treatment Capacity: This would allow treatment of storm flows arriving at the treatment plant in combined sewage systems and in sanitary systems which experience flow increases due to storm water infiltration.

Sewer Separation: With separation of combined sewers into storm and sanitary sewers. sanitary waste in combined sewer overflow can be eliminated.

Combined Sewer Overflow- Control Structures: Most pollutants in sewage overflows are associated with solid particles. Techniques are available to concentrate solids in the portion of flow that continues on to the treatment plant, while allowing the cleaner portion to overflow.

Storage of Combined Sewage and/or Storm Water: Many pollutants are washed from the land surface. catch basins and the bottom of sewers in the "first flush" of rainfall. If this portion of storm and combined sewage flow is stored for later release into the treatment system, then great reductions can be made in the amounts of pollutants discharged to the receiving watercourse.

Combinations of storage and treatment would likely prove to the most feasible for controlling pollution from urban runoff. In some cases, particularly downtown core areas. it may be less costly to store or treat the combined sewer overflows rather than to separate combined sewers.

Diversion

This option consists of transporting treated sewage or raw sewage for treatment and discharge to some location other than the local watercourse. This could involve either transportation by pipeline to a downstream location where greater dilution is available or transportation out of the basin entirely. One factor that must considered is that the treated sewage itself may represent a significant proportion of the flow in the river, and its removal may affect downstream water uses.

Population or Urban Growth Restrictions

In some cases where technical options are limited or too costly, the only realistic means of curtailing further degradation may be to curtail the production of wastes by halting or restricting urban development. In a growing urban area, the pollution load from diffuse sources will continue to increase and can result in further degradation, even if sanitary sewage is treated to a very high degree.

Low Flow Augmentation

This consists of increasing natural low flows by storage and subsequent release of water from upstream reservoirs to dilute sewage. In addition to reducing the concentration of pollutants, increased flows usually have higher velocities which provide for better aeration and more rapid transport of pollutants downstream. Increased volume of water may also offset the respiratory oxygen demand of weeds and algae. However, increased flow could provide more space for algae and stimulate growth of algae species. These relationships are not fully understood at present and are the subject of further study by the Ministry of Environment.

Four of the reservoirs, proposed by the conservation authorities, (Map 3) would provide low flow augmentation for water quality improvement. The following analysis assumes release of allocated storage over 112 days. in the same manner as Gordon Pittock dam is operated.

Zorra Swamp Reservoir—Located at the headwaters of' the Thames River. this reservoir would provide an additional flow of 10 cfs for 112 days during the summer low flow period. The project, which would cost 4.9 million. 1975 dollars would provide flow augmentation benefit only and would have no flood control benefits.

Cedar Creek Reservoir—This reservoir, located at the headwaters of Cedar Creek, would provide an additional 22 cfs during low flow conditions. and would provide minor local flood protection at a cost of 2.4 million, 1975 dollars.

Glengowan and Thamesford Reservoirs—A secondary purpose of the Glengowan and Thamesford reservoirs is flow augmentation for water quality management purposes. The additional 36 cfs from the Glengowan reservoir and 45 cfs from the Thamesford reservoir would improve dissolved oxygen conditions downstream, reduce downstream nutrient levels by acting as partial "trap" for phosphorus from upstream sources, and provide greater flows for water quality improvement in the City of London. The Glengowan reservoir might also improve water quality in Fanshawe Lake by increasing summer flows through the reservoir. The detrimental effects of the proposed reservoirs on water quality must also be considered. These effects were described in general terms in Section 6.1.6. Inputs of nutrients and organics from upstream sources could result in water quality problems, particularly in the Glengowan reservoir.

Consideration has also been given to the option of operating the Glengowan dam primarily for flow augmentation. For example, utilizing 22,000 acre-feet of available storage for this purpose would provide 97 cfs during low flow periods.

In-Stream Aeration

This consists of installation of mechanical or diffused air systems in the river at locations where the dissolved oxygen levels are depressed. to meet dissolved oxygen criteria. Aeration is most effective when oxygen levels are severely depressed. since the efficiency of oxygen transfer is dependent on the oxygen deficit (difference between oxygen saturation level and existing concentration level). Weirs and dam overflow structures can also be used to improve oxygen conditions.

Rural Options

Water quality management options for rural areas include: restricting cattle access to streams; limiting fertilizer application rates; channel protection programs; and environmental surveillance and enforcement.

Restrict Cattle Access

Restriction of free access of cattle to streams by fences or shrub barriers would reduce direct additions of nutrients, BOD_5 and bacteria from cattle feces, and the suspended solids input that occurs when cattle disturb the stream bottom and trample stream banks. Cattle could be watered at limited access points where conditions are ideal, or at off-stream watering troughs or ponds.

Limit Fertilizer Application Rates

Guidelines given by the Ontario Ministry of Agriculture and Food should be followed in determining fertilizer application rates for each crop and soil type. Services are available at the University of Guelph for determination of background nutrient levels in soils. Increases in fertilizer application beyond recommended rates result in increased losses of nutrients to streams.

Programs for Channel Protection

Stream banks can be stabilized artificially by applying riprap or gabion protection. Shrubs planted along stream banks stabilize the banks and trees will shade the water and improve fish and wildlife habitats. Buffer zones of vegetation along small streams in agricultural areas would reduce soil erosion and accompanying suspended solid and nutrient additions to streams.

Environmental Surveillance and Enforcement

Programs of surveillance by the Ministry of the Environment will continue with emphasis on pollution sources described in this report. Storm drains in rural municipalities are routinely checked for indications of septic tank drainage from illegal connections or malfunctioning systems. Correction procedures range from building modern sewage collection and treatment systems to correction on an individual household basis. Increased surveillance of rural drains and watercourses could be undertaken to identify the inputs of pollutants from rural households and farm wastes, including intensive livestock operations.

Reservoir Options

Management options to alleviate water quality problems in existing reservoirs consist of: managing releases of water from reservoirs to improve water quality: algae control: and disinfection of swimming areas.

Bottom Draw

Reservoir release can be managed to improve water quality by releasing a greater proportion of flow through low level discharge pipes at critical times. This mode of operation encourages mixing of surface and bottom waters (destratification) thus increasing concentrations of dissolved oxygen with depth and reducing the recycling of algae stimulating nutrient materials from reservoir sediments. Bottom waters have been shown to be oxygen-poor, if not anaerobic, and contain higher average levels of nutrients than surface waters. This condition is due to the settling out of dead algae cells and suspended solids; hence, their release stabilizes the trend of nutrient accumulation with time and reduces the amount of phosphorus available. These improvements in reservoir quality must be balanced against possible increases in downstream phosphorus levels.

Bottom draw has been utilized at Fanshawe, Wildwood and Pittock reservoirs since 1967; however, modifications to timing and proportions of flow discharge through bottom draw facilities may assist in improving water quality.

Destratification

Reservoirs which stratify can destratified by increasing the volumetric mixing of bottom waters (hypolimnion) with surface waters (epilimnion), thus preventing anoxic conditions from occurring in the hypolimnion. Methods also exist for aerating the hypolimnetic waters without breaking the stratification.

Algae Control

Chemicals can be applied to the reservoir at the onset of algal blooms. The algae would die. sink and decay, utilizing oxygen and releasing nutrients for further growth. This method represents a short term solution to the eutrophication problem and must be repeated possibly several times a year. Chemical costs are high and thus this method may only practical for selected areas of large reservoirs.

Disinfection of Swimming Areas

Chlorination around bathing beaches to kill pathogenic organisms and thus provide safe swimming is an approach that treats pollution symptoms and not the source. The toxicity of chlorine to aquatic life must be considered: however, disinfection may be a viable stop gap option in view of the ubiquitous sources of bacterial pollution and the desirability of keeping beach areas open for swimming.

Alter Operating Policies or Reservoir Uses

Generally, operating policies (release schedules) of existing reservoirs can be changed to benefit a single use only at the expense of other uses. Thus, consideration of this option involves an evaluation of altering the current uses of reservoirs.

During the Public Consultation Program, the issue of water based recreation was raised frequently. While it was recognized that agriculture is the primary land use in the basin, the need for additional recreation facilities was consistently reported.

Improvement of stream water quality will enhance the stream use for recreation; however, the general public will have only a small direct benefit because of limited public access. Thus, the recreational use of existing and proposed reservoirs is a fundamental consideration, involving an evaluation of existing reservoir operations. The basic options include operation of existing reservoirs:

(i) with no recreational use
(ii) with increased recreational use
(iii) with present recreational use

Allowing no recreational use would optimize the use of reservoirs for flood control and flow augmentation, at the expense of recreation. Although recreation facilities are available at Wildwood and Pittock reservoirs, these two dams are operated primarily for flood control and flow augmentation purposes. As a result, elimination of recreation at these sites would not have significant flood control or flow augmentation benefits.

Eliminating recreational use of Fanshawe reservoir would provide additional water for flow augmentation and additional flood storage during the summer. However, extensive recreational facilities have been developed at Fanshawe and there is a heavy demand for them as outlined in Chapter 4. It is felt that water based recreation at Fanshawe is sufficiently important to justify the continued use of the reservoir for this purpose.

Increased recreational use could be achieved at Wildwood and Pittock reservoirs by maintaining a relatively high water level to provide a large surface area of adequate depth. However, this approach cannot be justified as it would seriously reduce or eliminate the use of these reservoirs for their primary purposes of flood control and flow augmentation.

Similar evaluations were made of altering in various combinations the current uses of the three reservoirs. It was found that any significant change to benefit one use would seriously jeopardize or eliminate another valid use. As a result, maintaining the existing level of recreation appears to be the most feasible alternative. Based on comments obtained during the Public Consultation Program, it is recognized that this will not satisfy all criticisms of problems relating to existing conditions at Wildwood and Pittock reservoirs. However, it is possible that changes or refinement of current operating practices can be made to alleviate some existing problems still utilizing reservoirs for their present purposes.

For example, alteration of existing drawdown and storage schedules may improve recreational conditions while maintaining existing flood protection and flow augmentation. A computer model is presently being developed by the Conservation Authorities Branch. which will permit a sophisticated analysis of the possible benefits of modifying reservoir operating practices and thus allow optimization of water uses.

No detailed information is available as to the nature and scope of recreational facilities at the three proposed reservoirs. However, recreation could be provided at the Glengowan and Thamesford reservoirs, if used primarily for flood control, whereas the Wardsville dam would be used solely for flood control purposes.

Three points should be noted concerning the recreational use of proposed reservoirs. Recreation would be a third priority use, following flood control and augmentation. This will impose constraints on any recreational use of proposed reservoirs. As a result. these priorities must be recognized from the outset, so that pressure does not develop subsequently for expansion of recreational uses that would conflict with flood control and flow augmentation. Secondly. some water quality impairment, particularly in the Glengowan reservoir, is likely because of nutrient and organic inputs and the effects of a reservoir on water quality described in Chapter 6. This would act as another constraint on recreation. Thirdly, if Glengowan reservoir is used primarily for flow augmentation, virtually no water-based recreational use of the reservoir would be possible.

APPENDIX D

FLOOD CONTROL MODELLING

To develop guidelines for flood control in the Thames River basin. it was necessary to prepare and evaluate several alternative plans. The complexity of the situation necessitated the use of computers to permit quantitative evaluation of various combinations of alternative measures.

The computer program used in the analysis is a refinement of the 1970 version developed by the Conservation Authorities Branch for the Grand River Watershed Planning Review. Numerous options have been added to the former version of the program and the input structure has been altered.

The program develops synthetic hydrographs in accordance with the Soil Conservation Service procedure for the sub-watersheds in the river system. It combines and routes these hydrographs through the system. The effects of various water control structure operating procedures may be considered, as well as various methods of channel routing. Flood damage figures may be derived and compared for watershed management analysis.

The program plots (by printer) and prints out hydrograph tables, summary tables and flood damage tables. The principal use of the program is to develop synthetic storm hydrographs and analyse flood control structure benefits.

DETAILS OF THE PROGRAM

In accordance with the Soil Conservation Service procedure, a synthetic hydrograph can be generated the following variables:

(a) Watershed Characteristics
- (i) Size of drainage area.
- (ii) Lag time, the time from the midpoint of excess rainfall to the time of peak discharge.
- (iii) Runoff curve number, which expresses the runoff producing potential of soil groups and land use and treatment on a watershed. The antecedent moisture condition of the watershed is also included in the curve number.

(b) Design Storm Characteristics
- (i) Type of rainstorm, its areal and temporal distribution.
- (ii) Amount of rainfall.

For simulation purposes, a watershed is divided into sub-watersheds, with outlets or flowpoints being river confluences, existing and proposed dam sites and flood vulnerable areas. Physical characteristics are determined for each sub-watershed, with additional information on the allocation of flood storage and operating method for each reservoir. The frequency and intensity of rainstorms for the area are also determined.

Simulation starts at the upstream end of the watershed and follows the natural river system sequence. A local inflow hydrograph for a sub-watershed is generated first. The hydrograph is then routed either through a reservoir or through a channel reach. It is then combined with an outflow hydrograph from upstream reservoirs or hydrographs from other tributaries.

The program provides for the continuous simulation of different storms over a watershed under present conditions and with various reservoir combinations. The flood damage reduction or benefits which may be assigned to any system consist of both tangible benefits, those to which a dollar value can be assigned; and intangible benefits, or those which are not fully measurable in monetary terms. The benefits used for this analysis are tangible benefits and may be further sub-divided into benefits achieved by reduction of direct damages, i.e. damage to structures and contents; and indirect damage, i.e. business disruptions, temporary unemployment, traffic disruptions and general relief of flood victims.

The optimum benefits from flood control due to reservoirs depend on both the flood storage capacity of the reservoir and its location with respect to the area susceptible to flooding.

Sub-hydrographs can be generated at all points of interest such as the key area of flooding and the existing and proposed reservoir sites. For this study, the Thames River watershed has been divided into 42 subwatersheds or flow points. By studying the effect that a sub-hydrograph from a proposed reservoir has on the key flood locations, various combinations of flood control facilities can be selected and evaluated.

With this concept in mind, the major reservoirs proposed for the Thames River basin were analysed for storms with various probability of occurrence. From the basic damage data provided in the report on “Thames River Flood Damages” prepared by Acres Consulting Services Limited in 1973, it was thus possible to carry out an analysis of the expected annual benefits to be derived from each of the reservoir alternatives. This information was then used as part of the basis for evaluating different water management options for the basin.

Since the effectiveness of a proposed reservoir is measured by possible reductions in flood damages over and above those due to existing reservoirs, the effectiveness of the existing reservoirs at Woodstock, Wildwood and Fanshawe was first evaluated. As the flood control storage available in each of the reservoirs varies throughout the year, those levels of flood storage during the summer, fall and winter were considered. Existing conditions of the Thames watershed were then simulated for seven different storms (10 year, 15 year, 25 year, 50 year, 100 year, 200 year and 500 year return periods). Since the Chatham area accounts for 57 percent of the average annual flood damage in the Thames watershed, the simulated peak flows at Chatham were plotted for comparison on the flood frequency curve prepared by Acres.

The probabilities of simulated peak flows for summer conditions when all reservoirs are filled to their holding levels were calculated. The probabilities of the design storms were then adjusted to those of observed floods with the same magnitudes. The average annual flood damage for the present conditions with all reservoirs at their summer level (i.e. the conservation pool) was calculated. The damage figure calculated from the simulation was only 2 percent higher than the figure derived by Acres Consulting Services Limited using frequency analysis and was accepted as the base for evaluating the effectiveness of proposed reservoirs.

Consideration was given to four major proposed reservoirs: Cedar Creek, Thamesford, Glengowan and Wardsville. Zorra Swamp Reservoir was assigned no flood storage capability. Since all the reservoirs except Wardsville would be used for multiple purposes, the reservoirs were considered to be maintained at their conservation pool level. The storage available for flood control is thus the difference between storage capacity at the maximum water level and at the conservation pool level.

Table D1 summarizes the maximum storage, flood storage, maximum conservation and flow augmentation storage available in the existing and proposed reservoirs. Glengowan reservoir is shown with two optional allocations for flood control storage. The option with 13,800 acre-feet flood control storage was used in the flood control benefit calculation. Figure D1 presents a simplified operating schedule for the reservoirs which aids in defining terminology used in describing reservoir use.

The flood control benefit calculations derived from this analysis, are presented in Table 7.1 of Chapter 7.

Table D1: Summary of Storage Allocations for Existing and Proposed Reservoirs in the Thames River Basin

Reservoir	Maximum Storage	Maximum Conservation Pool Storage	Flood Control Storage **	Flow Augmentation Storage **
	acre-ft	acre-ft	acre-ft	acre-ft
Wildwood	20,100	14,480	5,620	12,500
Fanshawe	39,000	10,000	29,000	0
Pittock	13,400	4,700	8,650	3,360
Cedar Creek	7,700	5,600	2,100	4,900
Thamesford	17,500	11,600	5,900	10,050
Glengowan	27,000	13,200	13,800	8,000
Glengowan*	27,000	27,000	0	21,800
Wardsville	43,500	0	43,500	0
Zorra Swamp	3,200	3,200	0	2,400

* Glengowan Reservoir used primarily for flow augmentation.

** At maximum conservation pool level—values used in the analysis of flood control benefits and flow augmentation effects.

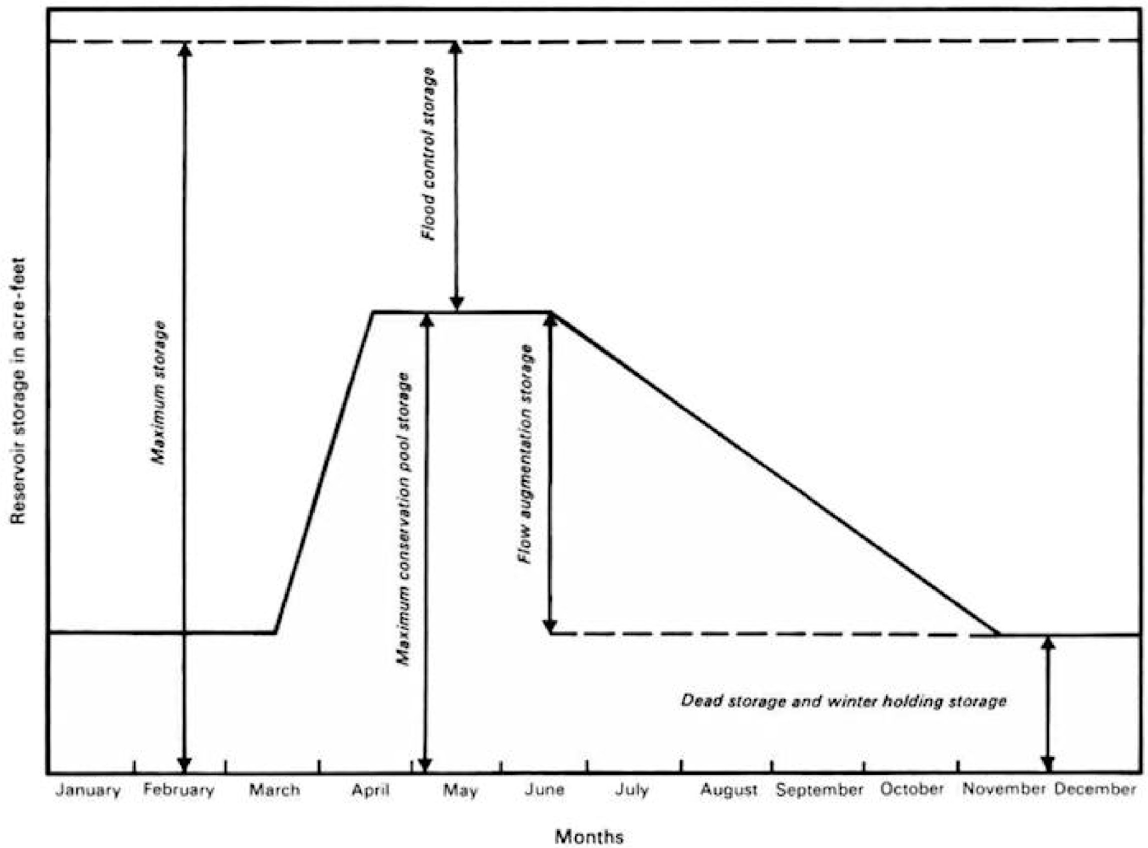


Figure D1: Schematic seasonal reservoir operating schedule.

APPENDIX E

FLOOD CONTROL OPTIONS

Flood control options can be classified under two headings: structural methods and non-structural methods. The option of constructing one or more large dams is described and evaluated in Chapter 7. Other flood control options are outlined below.

STRUCTURAL METHODS

Construction of Small Dams

During the Public Consultation Program. it was suggested on several occasions that consideration should be given to the construction of several small dams on tributaries for recreation and flood control, to minimize the need for large dams on main streams. Opponents of large dams reportedly recognized the need for flood protection. but based their opposition on the following points: loss of prime agricultural land taken up by large reservoirs: damage to fish and wildlife: and the inequity of flooding upstream lands to benefits downstream communities.

On the surface, the proposal to construct several small dams rather than a few large ones may appear to be an attractive alternative. However, when reviewed in some detail, the following factors must be considered.

With respect to comments concerning the inequity of flooding upstream lands to benefit downstream communities, it must be recognized that this practice is an inherent aspect of flood control on a watershed basis. During the Public Hearings, it was pointed out that downstream property owners in and below Chatham could argue that their lands are flooded because of increased runoff rates caused by the activities of headwater land owners.

With respect to the loss of prime agricultural lands. the amount of land flooded per acre-foot of storage obtained is less with large dams than with small dams. This is important in terms of minimizing the loss of agricultural land. If, for example, the average depth of small reservoirs is one third that of the proposed Glengowan reservoir then the flooded land area of the small reservoirs would be three times that of Glengowan to secure equal flood water storage.

Another significant factor is the question of suitable sites for small dams. For example. it would be necessary to construct 54 dams, each with a capacity of 500 acre feet. to provide the amount of storage that would be available in the Glengowan reservoir alone. Surveys for the conservation authorities have shown that there is not a sufficient number of suitable reservoir sites to provide additional effective storage required for flood protection.

Even if there were a sufficient number of suitable small dam sites to provide the equivalent storage of a large dam. operational problems would be encountered in operating several small reservoirs for flood control purposes. Manpower and co-ordination would be considerably more costly and complex utilizing several small reservoirs.

A further cost consideration is that in general. the cost per acre foot of storage declines as the height of the dam increases. Thus, the cost of a single large dam is less than the cost of several small dams with the same total storage capacity. Furthermore, low flow augmentation is more difficult using several small reservoirs, because of the difficulty of controlling and co-ordinating numerous discharge sites and because of increased loss of water due to evaporation from the larger surface area of the small reservoirs.

Another factor to consider is water quality problems resulting from the installation of reservoirs, as described in Section 6.1.2. In general, small reservoirs would be relatively shallow, with considerably more surface area than a single large reservoir with similar total storage capacity. The net effect of several small reservoirs would be to create problems of elevated temperature. greater evaporation losses, and blocked fish movements in several tributaries throughout the basin, rather than to minimize and isolate these conditions at a single site.

In summary, an evaluation of the relative merits of many small reservoirs compared to large reservoirs, suggests that the latter would be more effective for flood control, would have less adverse environmental effects and would have the additional advantage of providing additional low flow augmentation.

Modification of Drainage Schemes

Related to the proposal for several dams on tributaries is the proposed modification of drainage schemes and channel improvements to retard runoff until after critical flood peaks have passed. This could take the form of gated weirs, for example, which would temporarily store water in drainage ditches. During the public hearings, opposition to this proposal by the agricultural community centred on the contention that drainage systems are needed for crop production and that any water that lies on the land in the crucial growing period for more than 24 hours would be disastrous for the farmer (Ontario Environmental Hearing Board, 1974a).

At present, there is not sufficient information available to evaluate this option in detail. Additional data are needed concerning total extent, mileage, and storage capacity of existing municipal drains: the degree to which municipal drains contribute to the flooding problem; and the implications to agricultural protection.

It is conceivable that this proposal, together with the construction of many small dams on tributaries might provide adequate flood control. However, in view of the limitations in the small dam alternative, and of the reported serious effects on agricultural land uses, it is felt that this was not a feasible alternative.

Wardsville Diversion

Another alternative for reducing flood damage in the Lower Thames watershed is the construction of a diversion channel from the Thames River above Wardsville to Lake Erie. A study was made of this proposal for the Lower Thames Valley Conservation Authority (James F. MacLaren Ltd., 1970).

The study compared the cost of a dam at Wardsville with three types of diversion works. Cost estimates for these diversion alternatives, compared to a dam and reservoir at Wardsville, are shown in the following table.

Table E1: Cost Comparison of a Dam and Diversion Works near Wardsville

Structure	Cost (in 1970 Dollars)
Wardsville Dam	$ 7,500,000.
Pumping Station and Open Channel	15,000,000.
Tunnel and Open Channel	48,500.000,
Deep Open Channel	53,500,000.

The MacLaren report also noted that diversion works would offer no benefits other than flood control. It pointed out that open channel excavation would sever farm lands, limiting access and causing inconvenience to farmers along the channel route. The channel could not be used for boating or recreational purposes as it would be dry during summer months. In the case of the tunnel or diversion alternatives, the presence of ice in the river during the spring break-up period could pose serious problems with respect to the diversion of flows.

During the Public Consultation Program, some persons expressed a preference for a diversion channel to avoid the environmental effects of a dam. However, in order to direct flood flows to the diversion channel, diversion works would have to be built on the Thames River which would have similar effects to a dam.

On the basis of this information, it appears that construction of diversion works near Wardsville is not a viable alternative for flood protection in the Lower Thames watershed.

Construction of Additional Dikes

The possibility was considered that extensive additional dike construction in the lower watershed, coupled with non-structural measures, could provide flood protection equivalent to that available from proposed reservoirs. No benefit-cost analysis or detailed feasibility evaluation of this possibility has been carried out.

However, an indirect indication of the benefit-cost of an extensive diking system in the lower watershed can be obtained. Current dike repair cost and construction from Lake St. Clair to Prairie Siding, nine miles below Chatham. is $7,000,000. Substantially greater costs would be incurred in constructing a dike system to protect property and structures in various municipalities along the longer river reach from Prairie Siding to Wardsville, than in constructing proposed reservoirs. In addition, the 1967 MacLaren report indicated there are physical difficulties in providing dike heights in Chatham to contain flows greater than 30,000 cfs.

It is apparent that extensive diking plus non-structural measures are not viable alternatives to reservoir construction as a means of flood protection for the lower watershed. Moreover, it would not offer additional flood protection for the upper watershed that could be obtained from the proposed Glengowan or Thamesford reservoirs.

NON-STRUCTURAL METHODS

The non-structural approach to flood control has been gaining recognition as a means of improving the social and economic well-being of flood-prone areas. The various methods described below are best used as a group or in combination with a structural program of flood control. They are particularly applicable in areas where benefit-cost studies dictate against an investment in flood control structures.

Modified Operation of Existing Dams

The option of modifying current operating practices of existing dams has been discussed in the section on existing reservoir options. It appears if other uses of existing reservoirs are to be retained, no significant increase in flood control could achieved by means of this proposal. However, a detailed evaluation of current operating practices. combined with any future improvements in flood forecasting techniques, would facilitate maximizing the flood control benefits of existing reservoirs.

Conservation Practices

Certain conservation methods such as sound agricultural tillage practices. use of appropriate ground cover, and preservation of water retaining areas can provide a valuable supporting role both for flood control and flow augmentation. However, as indicated in the Upper Thames Valley Conservation Report of 1952, such measures are not sufficient in themselves to solve flooding problems and must supplemented by storage facilities to reduce flood crests.

With respect to reforestation and agricultural land cover, it is important to recognize that results are highly dependent on geographic location, climatic conditions. and local hydrogeology. As a result, studies of the most appropriate reforestration practice. for example. may show significantly different results in different geographic areas. This also applies to studies of runoff as affected by agricultural practice. For example, studies at the University of Guelph of runoff rates from watersheds with sod cover compared to ploughed or corn stubble areas showed completely different results to similar studies in more temperate climates (Ayers, 1964). Because of this difference such programs for the Thames watershed should be based on the latest available information, and on studies appropriate to this area.

Regulation of Flood Plain Development

Potential flood damages may be minimized by prohibiting and/or restricting development on flood-prone lands. Regulations of this kind do not necessarily prohibit development, but define the type of development permissible within the framework of comprehensive urban planning, ensuring the most judicious use of the land compatible with the aim of minimizing potential flood damages.

Restriction of new flood plain development is a vital aspect of flood control to prevent further development in unsuitable areas which would merely aggravate current potential flood damage. Such development can be controlled under the Planning Act, and through regulations administered by the conservation authorities. These controls have already been implemented in some areas of the watershed: additional efforts in this regard would be most worthwhile.

Relocation of Structures

The option of relocating all structures presently in flood-prone areas is not considered to be a viable alternative. The extent of current urban development, particularly in Chatham and London, is such that this approach would cost-prohibitive. Serious social-cultural effects of such a dislocation are another significant disadvantage. It is possible that in conjunction with other flood control techniques, the selective removal of a few strategic structures might economically justified.

Flood Proofing

If buildings are constructed to withstand flooding, the required protection and flood reduction works may be greatly minimized. Many types of changes can be made in existing development on flood plains to reduce flood losses, such as landfilling; design and layout of' buildings; raising vulnerable parts of equipment, such as motors; and provisions for emergency installations of water-tight doors.

Rood Warning

Temporary evacuation of people and damageable goods can an effective measure in reducing immediate flood losses. The success of this method is dependent on development of an efficient flood warning system.

Flood Insurance

Flood insurance, under which property owners could make claims for damages caused by flooding. has been reviewed as a possible basic, non-structural alternative to flood protection for the watershed.

Owners of properties situated in flood-prone areas in the United States have been able to purchase flood insurance for a number of years, under the U.S. National Flood Insurance Program. As a result, the question has been raised a number of times as to the desirability of introducing a flood insurance program in Ontario.

In 1973, the Flood Damage Working Group. an inter-ministry Task Force established to co-ordinate Provincial shore property assistance programs on the Great Lakes. was asked to consider a proposal for flood insurance in Ontario. After giving the matter detailed consideration, including thorough examination of the U.S. program, the Working Group recommended that:

- the Province should not establish a flood insurance program because natural flooding is not viewed by the insurance industry as an insurable risk and heavy Provincial subsidy would be required; therefore, it would impose an unfair tax burden upon unaffected tax payers.

It should be noted that under current conditions, if serious flooding occurs despite existing flood control programs, Provincial financial assistance may be made available under the Disaster Relief Assistance Program. This program was designed to help cover losses suffered as a result of damage to provincial year-round residences and their furnishings and equipment. farm buildings, and small business structures. in areas designated by Cabinet as Disaster Relief Areas.

Based on the findings and recommendations of the Flood Damage Working Group, flood insurance does not appear to be a feasible flood protection option for the Thames River basin.

APPENDIX F

COST ANALYSIS OF LONDON SERVICING OPTIONS

To provide an economic analysis of system options, cost estimates for various London servicing options are required. This appendix presents detailed construction cost estimates for two basic servicing options—sewage diversion (pipeline) option and the tertiary treatment option. Operation and maintenance for the two options are discussed separately. A discussion of the net cost derivation in present value terms is also presented for system options discussed in Chapter 7 of the main report. Assumptions used in staging construction of components of the two basic servicing options, as affected by various dam construction and operation options, are also presented.

The two servicing options are based on population projections and sewage flow estimates presented in Table F1. Estimates for St. Thomas and Lambeth are also included as the pipeline is assumed to service these municipalities. Planning, design, and construction of the two systems are presumed to take six years, with the system operational in 1981 at the earliest. The planning horizon is assumed to be 2001.

Table F1: Estimated Average Daily Flow (Million Imperial Gallons)

	1981	1986	1991	1996	2001
London	37.0	43.0	50.0	58.5	65.0
Lambeth	0.4	0.5	0.7	0.85	1.0
St. Thomas	3.8	5.2	5.7	6.7	7.8
Total	41.2	48.7	56.4	66.05	73.8
Estimated Service Population					
	1981	1986	1991	1996	2001
London	293,500	338,600	390,000	450,000	500,000
Lambeth	4,000	5,500	7,000	8,500	10,000
St. Thomas	30,000	37,500	45,000	52,500	60,000
Total	327,500	381,600	442,000	511,000	570,000

Costs of the treatment portion of the two servicing options are based on 1965 data (Ministry of the Environment, 1973) and updated to 1975 by use of the Engineering News Record Construction Cost Index:

1975 cost = 1965 cost x (1975 ENR) / (1965 ENR)

January 1975 ENR for Toronto = 2004, 1965 ENR = 800

Engineering and contingency costs of 25 percent have been included as well as a cost for financing during construction at the interest rate of 9 percent. Cost of internal collection of sewage in the city has not been included since this cost is common to both the treatment and pipeline options.

The two servicing options are described below.

Sewage Diversion to Lake Erie (Pipeline)

All sewage would be diverted by pipeline to Lake Erie. The pipeline would follow a route that allows servicing of the Police Village of Lambeth and the City of St. Thomas. A treatment plant built on the shore of Lake Erie, west of Port Stanley, would provide secondary treatment and phosphorus removal prior to discharge. A major pumping station would be located at the Greenway STP site to pump water to the height of land separating the Thames River basin from the Kettle Creek basin. From the height of land a gravity sewer would carry the sewage to Lake Erie, including an inverted siphon to cross Kettle Creek. Assuming the pipeline is constructed for operation in 1981, two choices are available for abandoning the existing treatment plants in London.

(a) Abandon existing treatment plants in 1981 and provide treatment at the lake. Treatment plant costs are estimated on the basis of construction in two stages— (1) operating in 1981 for a 1991 population-capacity of 60 MGD; (2) operating in 1991 for a 2001 population- capacity of 15 MGD. Total capacity would 75 MGD.

(b) Abandon existing treatment plants in 1986, utilizing the pipeline as a treated sewage pipeline from

1981 to 1986. Treatment at the lake would begin in 1986 at which time St. Thomas and Lambeth could also be serviced. Treatment plant costs are based on building a single plant in 1986 with a capacity of 75 MGD for a 2001 population of 570,000.

Costs for this option are presented in Table F2a and F2b for the two choices of abandoning existing treatment plants in London. London's share of the total cost is estimated at 89 percent, based on the proportional share of the total capacity of the system as indicated in Table F1. Subsidies for projects servicing more than one municipality are not included, although these likely would be available. London's share is indicated to show costs which are internal to the Thames basin.

Table F2a: Construction Cost Estimate for Sewage Diversion to Lake Erie Assuming Abandonment of Existing STP In 1981

Cost Item		1981	1991
Pumping Station at Greenway STP		$ 0.908	$0.490
Forcemain (66" x 14,4001		2.114	
Gravity Sewer (including Tunnels and inverted Siphon)		26.101	
STP	60 MGD	39.014	
	15 MGD		12.004
Phosphorus Removal Facilities		0.391	0.130
Outfall		4.349	
Sub-Total		$72.878	$12.625
Engineering & Contingency (25 percent)		18.220	3.153
Land Costs (Right-of-Way)		0.357	
Sub-Total		$91.454	$15.781
Financing during construction (91% over 3 years except 2 years for 15 MGD STP		13.037	1.499
Sub-Total		$104.491	$17.280
Total		$121.770	
London's Share (89 percent)		$108.376	

Table F2b: Construction Cost for Sewage Diversion to Lake Erie Assuming the Use of Pipeline as Effluent Sewer to 1986 and then Abandon Existing Plants and Construct 75 MGD STP at Lake

	1981	1986	1991
Pumping Station at Greenway STP	0.908		0.490
Forcemain	2.114		
Gravity Sewer	26.101		
STP 75 MGD		45.017	
Phosphorus Removal		0.477	
Outfall	4.349		
Sub-Total	$33.472	$45.494	$0.490
Engineering & Contingency (25 percent)	8.368	11.374	0.123
Land (Right-of-Way)	0.357		
Sub-Total	$42.197	$56.868	$0.613
Financing (during construction)	6.130	8.104	0.058
Sub-Total	$48.327	$64.972	$0.671
Total	$113.970		
London's Share (89 percent)	$101.433		

Note: All costs in millions of 1975 dollars. Toronto ENR = 2004

Tertiary Treatment

Tertiary treatment as an option is assumed to consist of treatment to the level of stream quality. This specifically consists of the following quality of effluent:

Biochemical Oxygen Demand (5 day) -3 mg/L
Suspended Solids -3 mg/L
Nitrogen-Organic as N -2 mg/L
Nitrate as N -3 mg/L

A treatment plant producing this quality of effluent has been operating for several years in the United States-the Lake Tahoe Public Utilities District Reclamation Plant. From studies of this system, it is estimated that the cost for additional advanced waste treatment is equal to the cost for conventional treatment alone (Culp, 1967). In other words, it costs twice as much to produce reclaimed water as it does to produce secondary quality effluent. Cost estimates from the Lake Tahoe work have been used in developing cost estimates for London. The following processes beyond the secondary treatment process have been provided for: phosphorus removal: ammonia stripping: filtration: carbon adsorption.

As indicated, cost of these processes approximates that of conventional treatment. Since costs are lacking for larger systems as proposed here, the conventional treatment costs have simply been factored by two.

For purposes of design, a single treatment plant site has been chosen downstream, west of London. The site size would be double that for the conventional plant (200 Ac.). Existing treatment plants are assumed to be abandoned by 1981. All necessary collection and transmission systems to take sewage to the "new plant" would be constructed by 1981. Costs are estimated on the basis of construction of plant facilities in two stages:

1. 1981 with capacity for 1991 population - 50 MGD
2. 1991 with capacity for 2001 population - 15 MGD

Total - 65 MGD

Table F3 presents the construction costs for this option.

Table F3: Construction Cost for Tertiary Treatment

	1981	1991
Additional cost to transfer flow to "new plant"	$1.087	
Conventional treatment plant plus phosphorus removal, filtration carbon adsorption and ammonia stripping-		
50 MGD	65.024	
15 MGD		24 009
Sub-Total	$66.111	$24.009
Engineering & Contingency (25 percent)	16.528	6.002
Land costs (200 Acre x $2000)	0.435	
Sub-Total	$83.074	$30.011
Financing	11.838	2.851
Sub-Total	194.912	$32.862
TOTAL	$127.774	

Note: All costs in millions of 1975 dollars

Operation and Maintenance Costs

A preliminary review has been made of the operation and maintenance costs.

For the pipeline alternative, the annual costs for the operation and maintenance of the following components were estimated:

(i) Pumping Station
(ii) Forcemain
(iii) Gravity Trunk Collector
(iv) Conventional Activated Sludge
(v) Phosphorus Removal
(vi) Outfall
(vii) Power Cost at the Pumping Station

For the tertiary treatment option the annual costs for the operation and maintenance of the following components were estimated:

(i) Additional Collection
(ii) Conventional Activated Sludge
(iii) Phosphorus Removal
(iv) Filtration
(v) Carbon Adsorption
(vi) Ammonia Stripping

No cost was estimated for amortization of capital debt.

Table F4 presents the annual operation and maintenance costs for the years 1981, 1986, 1991, 1996 and

2001. The ultimate treatment alternative was slightly more expensive for each year and the amount increased in the later years. This reflects the higher per gallon operation and chemical costs despite increasing flows. The pipeline also had 11 to 14 percent greater service population.

Table F4: Operation and Maintenance Costs for London Servicing Options Diversion to Lake Erie (Pipeline)

Year	Plant Capacity	Population Served	Total Operation and Maintenance Annual Costs
1981	60	327.500	$2,204,040
1986	60	381,600	2,572,825
1991	75	442,000	2,781.777
1996	75	511,000	3,221,870
2001	75	570,000	3.575,609
Tertiary Treatment			
1981	50	293,500	$2,316,248
1986	50	338,600	2,691,304
1991	65	390,000	3,128.871
1996	65	450,000	3,660,287
2001	65	500,000	4,066,513

Note: All costs in 1975 dollars. London's share has not been separated for the pipeline option

Discussion of Cost Estimates

The cost estimates for the servicing options should be considered reconnaissance or order-of magnitude estimates only. Systems cost estimates discussed below are based on consistent assumptions such that the ordering of least cost options is accurate. In other words, a change or error in the cost estimates should affect all options in equal proportion, and not change the ordering of the options.

In general, the cost estimates for the pipeline option can be considered more reliable than the tertiary treatment option. The pipeline and accompanying secondary treatment are conventional engineering works and many similar works are available in Ontario. However, the tertiary treatment system costs are based on a single treatment plant in the United States and thus no similar type of plant exists in Ontario for comparison.

Cost Analysis for Total System Options

Primary evaluation criterion will be total system net cost in present value terms. Other criteria will be introduced in the evaluation section of Chapter 7. The net cost consists of all capital construction costs for dams, pipelines, and treatment works. Operation, maintenance and amortization costs were not included. Quantified economic benefits from flood control are included by subtraction as they can be considered negative costs.

Costs are presented in present value terms so that they can be compared at a single point in time. The present value takes account of the time when benefits and costs occur by weighting near-term dollars more heavily than those far off in the future.

The present value (PV) of an amount of a cost (benefit), A, occurring n years in the future, compounded annually at an discount rate, i, is calculated as follows:

$$\text{PV of A} = A / (1+i)^n.$$

Thus, the present value of A decreases both with increasing discount rate and the number of years into the future the cost (benefit) occurs. Consequently, present value of an option is sensitive to the choice of the discount rate and the staging of capital works construction.

The discount rate should reflect the risk inherent in a project as well as the inflationary trends in the economy. The normal way of choosing the discount rate is to use the average return on long term Federal Government Bonds, (Maniante, 1973). The average return for the last 6 years for this type of bond issued by the Government of Canada is 7 percent. Arguments exist for using a lower discount rate, a social rate of discount, to reflect the preference for public investment which benefits all society (Maass, 1966). It is not in the scope of this report to choose a discount rate, consequently, net costs are presented for discount rates of

2 percent, 4 percent and 7 percent, and discussion in the text is on the basis of a 4 percent rate.

Net Cost Calculation—An Example

To illustrate the net cost calculation procedure, an example is presented in Table F5 for total system option number 4— Wardsville Dam plus Pipeline in 1981.

Table F5: Cost Calculation tor System Option 4—Wardsville Dam plus Pipeline in 1981

Component	Amount	Date Operating	Present Value 1975 @ 2%	@ 4%	@ 7%
Wardsville Dam	11.72	1981	10.407	9.262	7.81
Interim Treatment	8.64	1978	8.142	7.681	7.053
Pipeline	42.907	1981	38.100	33.91	28 591
Treatment at lake	57.825	1986	46.507	37.562	27.472
Pumping Station	0.572	1991	0.417	0.305	0.194
Total Cost	121.664		103.573	88.720	71.12
Flood Control Benefits for Wardsville			28.357	17.254	9.345
Total Net Cost (total cost minus benefits)			75.466	71.466	61.775

All costs (benefits) in millions of 1975 dollars

Dam costs and benefits are presented in Table 7.1 and discussed in Section 7.4.

In this example, interim treatment costs up to 1986 are assumed to be one-half the cost of providing a new secondary treatment plant sized to provide additional capacity to 1986. Costs are reduced by one-half to account for savings from construction of a short term project. 'Pipeline' options include interim treatment costs based on similar assumptions. Savings for short term projects decrease with increasing deferral times. Interim treatment costs for tertiary treatment options are assumed to be at full cost, which is subtracted from the tertiary treatment plant costs when constructed in the future, since it is assumed that interim conventional plants would eventually become part of the tertiary treatment plant when it is constructed.

In options including a pipeline the cost figures presented in Table F2b are used, adjusted to include London's share of the costs. In cases where construction of the pipeline option is deferred until 1986 or later, then the pipeline and treatment plant at the lake are assumed to be operational in the same year.

Staging of capital construction projects is based on the rationale presented in Appendix H.

Table 7.4 presents a summary of the total system net cost at three discount rates and Table 7.5 presents a breakdown of the outlay, total cost, flood control benefits and net cost for the 4 percent discount rate.

APPENDIX G

Nutrient Budget Thames River

Figure G1 —Sub-Basin Designation

Table G1—Sub-Basin Land Use

Table G2—Total Phosphorus Budget

Map G1—Map of Sub-Basins

Table G3—Total Nitrogen Budget

Table G4—Reservoir Effects

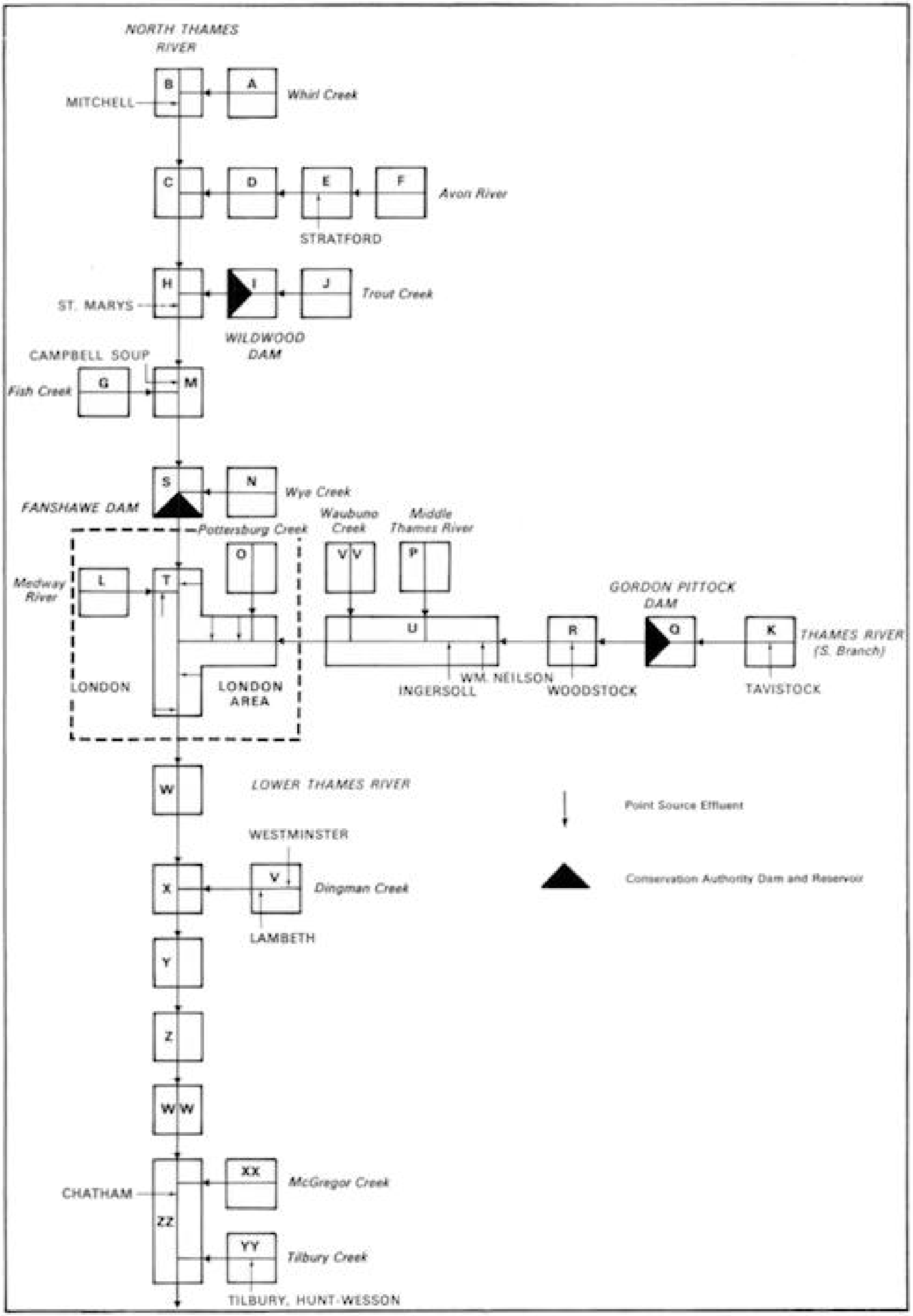


Figure G1: Sub-basin designation for the Thames River nutrient budget.

Table G1: Sub-Basin Land Use

Sub-Basin	Total Area Square Miles	% Urban [1]	% Agriculture [2]	% Other [3]
A	42.1	0.88	92.19	6.84
B	75.4	1.99	92.46	5.50
C	159.7	0.98	88.06	10.92
D	21.4	0.90	91.71	7.35
C	10.1	43.33	52.00	4.55
F	33.7	2.56	84.50	12.89
G	59.1	1.29	90.89	7.78
H	19.7	7.36	87.25	5.35
I	17.0	0.96	83.40	15.60
J	28.0	0.29	86.07	12.65
K	78.3	1.12	92.12	6.74
L	76.2	2.47	88.94	9.30
M	43.8	2.49	90,72	6.72
N	13.5	1.07	92.89	5.99
0	19.7	25.37	67.54	7.30
P	106.1	1.84	75.71	21.95
Q	26.4	6.13	83.85	10.15
R	11.8	22.62	69.59	7.18
S	28.9	3.37	86.09	12.38
T	41.5	47.92	44.70	7.35
U	211.8	3.42	66.87	9.65
V	62.5	3.01	87-96	9.01
W	57.3	2.39	86.33	11.21
X	86.2	0.37	87.40	12.54
Y	150.8	0.44	87.89	11.61
Z	95.1	0.60	89.35	10.01
XX	13.5	6.76	89.23	3.38
YY	112.3	1.14	95.63	3.16
ZZ	396.0	0.21	92.46	5.13
WW	21.8	2.37	76.29	21.80
VV	38.0	0.37	92.06	7.53

1. Urban land use consisting of urban built-up mines, quarries and gravel pits, urban outdoor recreation
2. Agriculture and use consisting of cropland, orchards and vineyards, improved pasture. forage crops and range land.
3. Other land consisting of woodlands, swamps and marsh; unproductive and water surface

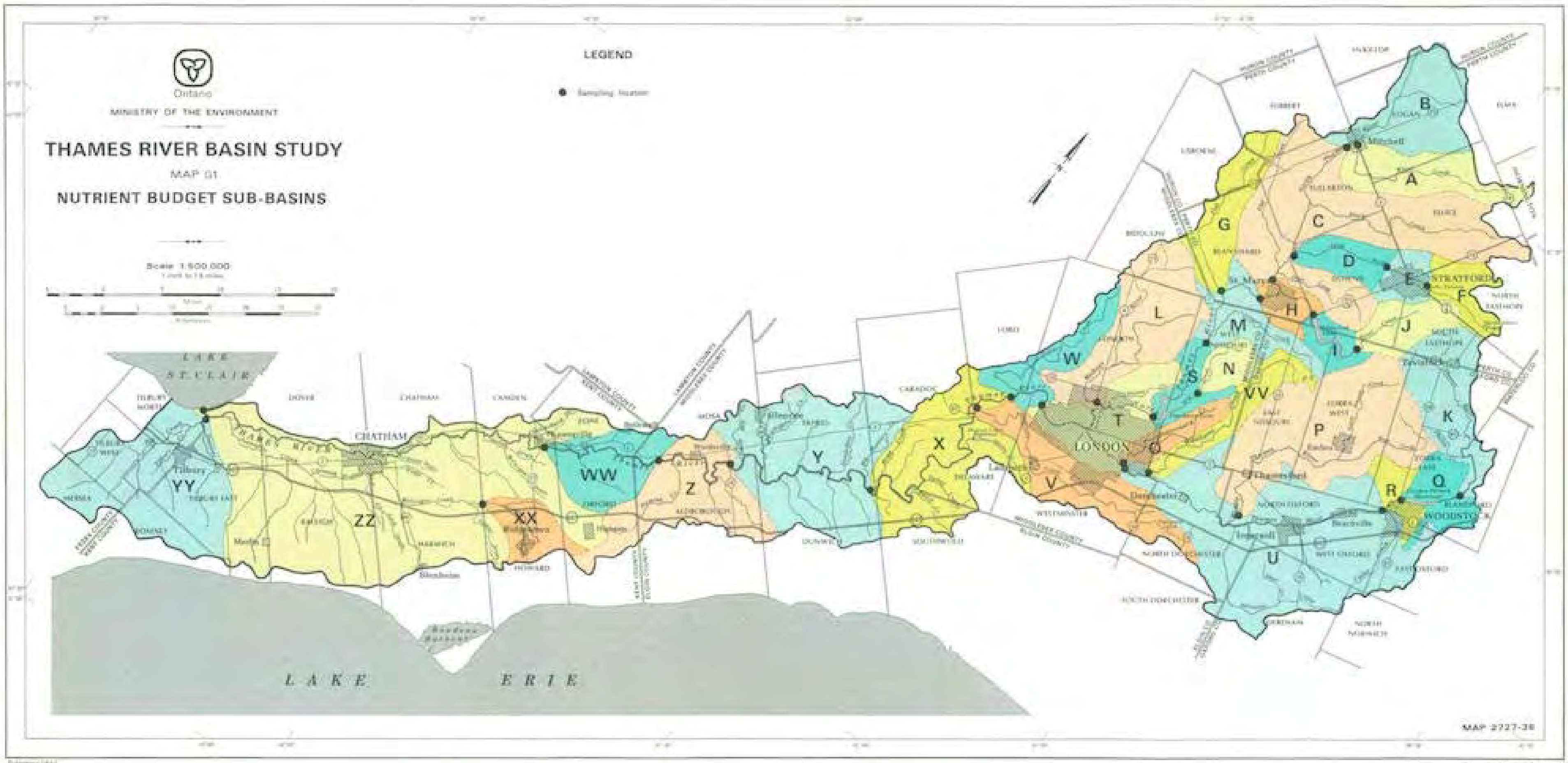
Table G2: Total Phosphorus Budget-Thames River (Thousands of Pounds/Year) Based on 1972 Data

	Channel Inputs		Sub-Basin Effects				Main Channel Output
Sub-Basin	Main	Tributary	Diffuse Sources	Point Sources	Storage	Net Basin Load	
North Thames River							
A			21.96			21.96	21.96
B		21.96	18.39	8.78 Mitchell		27.17	49.13
F			24.81			24.81	24.81
E	24.81		7.36	53.75 Stratford		61.10	85.92
D	85.92		24.10			24.10	110.02
C	49.13	110.02	22.75			22.75	181.89
J			5.85			5.85	5.85
I	5.85		3.55*		--4.38 Wildwood	- 0.82	5.02
H	181.89	5.02	29.07			29.07	215.99
G			18.77			18.77	18.77
M	215.99	18.77	32.25	7.80 Campbell Soup		40.05	274.80
N			4.08			4.08	4.08
S	274.80	4.08	21.27*		-104.68 Fanshawe	-83.41	195.46
Sub-total			234.21	70.33	-109.06	195.48	

Table G2 (continued)

Thames River-South Branch							
K			14.22	4.20 Tavistock		18.42	18.42
Q	18.42		12.94*		0 Pittock	1.94	31.36
R	3136		5.80	59.84		65.64	97.00
P			33.40			33.40	33.40
VV			6.14			6.14	6.14
U	97.00	39.54 (VV + P)	8.04	9.06 (Wm. Neilson + Ingersoll)		17.10	153.64
Sub-Total			80.54	73.10	0	153.64	
Thames River-London Area							
O			5.56			5.56	5.56
L			26.28			26.28	26.28
T	195.46 + 153.64	31.80	278.50	282.72 London		561.22	942.15
Sub-total			310.34	282.72		593.06	
Thames River-Downstream from London							
W	94216		121.19			121.19	1063.34
V			1719	3.56 Lambeth & Westminster		20.75	20.75
X	1063.35	20.75	218.11			218.11	1302.20
Y	1302.20		60.07			60.07	1362.27
Z	1362-27		143.52			143.52	1505.79
WW	1505.79		50.29			50.29	1556.06
XX			13.38			13.38	13.38
Y			77.36	7.06 Tilbury		84.42	84.42
ZZ	1556.06	97.79 (XX + YY)	63.93	59.50 Chatham		123.43	1777.22
Sub-total			765.04	70.12		835.17	
Total			1390.13	496.27	109.06	1777.30	

* Estimated



Ontario
MINISTRY OF THE ENVIRONMENT
THAMES RIVER BASIN STUDY
MAP G1
NUTRIENT BUDGET SUB-BASINS
Scale 1:500,000
LEGEND
Sampling location
LAKE ST. CLAIR
LAKE ERIE
CHATHAM
LONDON
STRATFORD
WOODSTOCK
Mitchell
St. Marys
Ingersoll
Tilbury
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R
S
T
U
V
W
X
Y
Z
VV
WW
XX
YY
ZZ
MAP 2727-39

Table G3: Total Nitrogen Budget-Thames River (Thousands of Pounds/Year) Based on 1972 Data

	Channel Inputs		Sub-Basin Effects				Main Channel Output
Sub-Basin	Main	Tributary	Diffuse Source	Point Sources	Storage	Net Basin Load	
North Thames River							
A			1064.82			1064.82	1064.82
B		1064.82	485.52	18.36 Mitchell		503.88	1568.70
F			370.91			370.91	370.91
E	370.91		0.70	160.40 Stratford		161.08	531.99
D	531.99		295.12			295.12	827.11
C	1568.70	827.11	1982.31			1982.31	437812
J			139.83			139.83	139.83
I	139.83		84.90*		-2.81 Wildwood	82.10	221.91
H	4378.10	221.90	569.90			569.90	5169.94
G			881.80			881.80	881.80
M	5169.94	881 80	13.13	22.58 Campbell Soup		35.71	6087.44
N			168.75			168.75	168 75
S	6087.44	168.75	337.84*		-310.63 Fanshawe	27.21	6283.40
Sub-total			6395.77	201.34	313.44	6283.40	
Thames River-South Branch							
K			675.53	14.14 Tavistock		689.66	689.66
0	689.66		232.53°		0 Pittock	232.53	922.13
R	922.13		168.12	178.68 Woodstock		346.80	1268.94
P			1244.50			1244.50	1244.50
VV			436.31			436.31	436.31
U	1768.94	1680.81	1917.51	40.61 Ingersoll		1958.11	4907.86
Sub-total			4688.64	219.29	0	4907.92	
Thames River-London Area							
L			999.51			999.51	999.51
O			183.01			183.01	183.01
T	4907.86 + 6283.39	1182.52	1093.11	1309.12 London		2402.12	14775.89
Sub-total			2275.63	1309.12		3584.64	
Thames River-Downstream from London							
W	14775.89		3095.56			3095.56	17871.44
V			393.99	19.60 Westminster		413.60	413.60
X	17871.44	413.60	280.63			280.63	18565.66
Y	18565.66		2648.39			2648.39	21214.05
Z	21214.05		1619.84			1619.84	22833.89
WW	22833.89		1454.30			1454.30	24288.19
XX			352.90			352.90	352.90
YY			2878.61	23.03 Tilbury		2901.64	2901.64
ZZ	24288.19	3254.54	7691.78	157.10 Chatham		7848.88	35391.61
Sub-total			20416.00	199.73		20615.72	
Total			33761.66	1943.62	313.44	35391.68	

* Estimated

Table G4: Reservoir Effects

	Total Phosphorus Budget			
Reservoir	Total Input*	Storage*	%	Reduction
Wildwood	9.4	4.38		46.6
Fanshawe	300.15	104.7		34 9
Pittock	31.4	0		0
	Total Nitrogen Budget			
Reservoir	Total Input*	Storage*	%	Reduction
Wildwood	224.7	2.81		1.3
Fanshawe	6594.0	310.6		4.7
Pittock	922.19	0		0

* Thousands of pounds per year

APPENDIX H

SEWAGE DISPOSAL OPTIONS FOR THE CITY OF LONDON

Water quality modelling is described in detail in Appendix A. Besides evaluating existing conditions. the modelling effort specifically assessed the effects on dissolved oxygen of improved treatment, additional low flow augmentation, increased waste loadings from treatment plants from an increased population, alternative future treatment plant locations within the city, improved upstream water quality and diversion of all sewage to Lake Erie. Results can also be used to evaluate options not specifically modelled.

London's water quality problems are primarily a result of the discharge of pollutants from sewage treatment plants and from other sources in the urban area. Background levels of pollutants in the river entering the city are relatively high: however, pollutant discharges from the urban area aggravate the problem. Projected growth of the population of London from 219,921 in 1971 to 500,000 in 2001 will bring about an equivalent increase in the discharge of pollutants to the watercourse, if present waste disposal practices continue.

A report released by the Ministry of the Environment in October, 1973, entitled "An Assessment of Water Pollution Control in the City of London" examined the state of the city's storm sewer system. sewage treatment plant operation and sub-division development. The report acknowledged that the City of London had achieved a significant reduction in the pollution loads being directed to the Thames River and commended the city's co-operation regarding pollution control. The report recommended the following measures for controlling the remaining pollution problems:

- control of storm sewer quality by checking for discharge of pollutants to the storm sewers;
- enforcement of the sewer use bylaw controlling industrial waste discharges to the sanitary sewer system, to eliminate upsets at sewage treatment plants;
- control of development to ensure adequate sewage treatment capacity. thus avoiding overloading treatment plants:
- reduction of raw or partially treated sanitary sewage discharges to the river by separation of sewers in the core area of the city, by controlling excessive infiltration into sanitary sewers in areas with separated systems. and by increasing maintenance of combined sewer relief (overflow) points.

Water quality modelling of present conditions is based on field surveys, observed treatment plant quality and flows prior to the above report. The model predicts significant dissolved oxygen criteria violations during July and August and minor violations in June, under 1972 conditions of effluent quality and discharge volumes. Figure A13 in Appendix A illustrates predicted dissolved oxygen criteria violations in July, in eight of the sixteen reaches of the river modelled, notably in the North Thames River downstream from the Adelaide STP, in the south branch downstream from the Vauxhall STP, in Springbank park and downstream from the western city limits for several miles. These violations are in part due to pollution problems discussed in the above report and can be partially alleviated by implementing the recommendations of the report.

Water quality objectives for the London area are related to the protection of valuable fish species, protection of public health. and maintenance of aesthetic quality for general recreation.

Various waste management options for the City of London are discussed below in light of these objectives.

Improve Effluent Treatment

Water quality modelling indicates that a significant improvement in water quality, as shown by dissolved oxygen predictions. can be achieved by improving sewage effluent quality over that observed in 1972. The case modelled as Run 4 in Appendix A. assuming an effluent quality approximately equivalent to that of the Greenway STP for all treatment plants. showed a marked reduction in the occurrence of violations of dissolved oxygen criteria. Based on data presented in Table A1, (Appendix A), it can be seen that in 1972, on the average, the discharge from the Greenway STP represented 62 percent of total sewage volume, but only 30 percent of the total oxygen demanding materials discharged to the Thames. The total oxygen demand load is based on the sum of the median concentrations of carbonaceous and nitrogenous oxygen demand. The median total loading rate from all STP's of 15,600 lbs. per day observed in 1972 could be reduced to 7,500 lbs. per day if all sewage received treatment similar to that at the Greenway STP. A major portion of this reduction would come about from reducing the nitrogenous oxygen demand of the effluent by oxidizing nitrogen compounds to the nitrate form (nitrification). It is realized that in 1972, certain of the treatment plants were not operating efficiently, because of hydraulic overloading and upsets caused by industrial discharges. The City reports that improvements were made in effluent quality at the Pottersburg. Vauxhall and Greenway treatment plants by acting on recommendations made to the city in the 1973 Ministry of the Environment report. The Adelaide treatment plant is still experiencing problems related to hydraulic overloads: however, programs are underway to alleviate this problem. Thus, the city is already on the path towards reducing loads of oxygen demanding substances.

Appendix A also describes the effect of waste loadings projected to 1991, at an assumed level of treatment equivalent to Greenway STP in 1972. This resulted in an increase in the severity of violations within the city limits, but had negligible effect on downstream water quality. Effluent treatment to stream quality, projected to 1991, would further degrade the dissolved oxygen levels to some extent, compared to the effect of 1972 loadings at the same treatment level. Model runs included only the effects of treatment plant discharges and did not account for probable increases in waste loads from urban runoff. Therefore, predicted effects are based on the assumption that urban runoff loads will not increase with time.

The effects of phosphorus removal at the treatment plants were not included in model predictions, largely because of lack of knowledge regarding the relationships between nutrients, plant growth and dissolved oxygen. Since model parameters were derived from surveys prior to phosphorus-removal programs, the model predictions are based on the conservative assumption that phosphorus removal has no effect on the plant and algae growth in the river. This premise is consistent with a presumption that an overabundance of phosphorus is already in the river. The nutrient budget summarized in Table 6.1 indicates that 30 percent of the annual load of total phosphorus in the river downstream from London was contributed by the STP's in 1972. On a seasonal basis, the virtually constant phosphorous loads from the treatment plants achieved a greater significance in the critical growing season from May to October. If studies presently underway indicate that further reductions of phosphorus would have added benefits in the river for this critical season, then it is expected that this could achieved at the cost of increased dosages of chemical precipitants utilizing existing equipment.

Present and projected waste loads from treatment plants in London under various treatment assumptions are given in the following Table.

Table H1: Waste Load Summary—City of London

Treatment Level	Total Oxygen Demand	Load—Pounds Per Day			
	mg/L	1972	1981	1991	2001
1972 observed	27 to 143	15,600	—	—	—
Greenway quality	27	7,500	10,000	13,500	17,600
Tertiary (Lake Tahoe)	14	3.900	5,200	7,000	9.100
Zero Pollutant	0	0	D	0	0
Sewage Flow Rates:		27.6 MGD	37 MGD	50 MGD	65 MGD

Appendix A also describes the effect of complete treatment— (‘Zero Pollutants'—Run 6) i.e. complete removal of oxygen consuming materials before discharge. In this case, the model predicted a further reduction in dissolved oxygen criteria violations: however, violations still occurred. Remaining criteria violations are a result of high oxygen uptakes from the respiratory processes of benthic organisms— bacteria, weeds and algae. To treat to the level of zero pollutants is likely not economically feasible or justifiable. The model indicates there is a limit to the effectiveness of higher levels of treatment alone in relation to dissolved oxygen levels. Of course, the model describes only the oxygen consuming materials in the sewage effluent and their effect on the dissolved oxygen in the stream. Other constituents are not considered in the model.

Section 7.4 outlines a tertiary waste treatment system which would discharge essentially stream water quality to the Thames River. This system is described in greater detail in Appendix F. The additional cost over conventional secondary treatment is estimated to be approximately equal to the secondary system costs. Therefore, the total cost of treatment would be approximately double the treatment costs with conventional systems. This case was not specifically tested with the computer model, but the results would be very close to the "zero pollutant" case modelled as Run 6 in Appendix A.

Additional Flow Augmentation

Model runs indicate that most violations of dissolved oxygen criteria occur at lower flows; consequently, augmentation of low flows can be expected to reduce violations and give acceptable dissolved oxygen levels in the stream. Drought flows for the flow gauges in the Thames River are discussed in Chapter 3. It is noted that prior to dam operation. the estimated 7 day mean flow with a 20-year return period for the Thames River at Byron is 65 cfs. The simulation model described in Appendix A accounts for the effect of the operation of Wildwood. Pittock and Fanshawe dams. The low flow at Byron that occurs under the assumption that reservoirs are operating to provide committed flows, is 125 cfs: based on 40 cfs from the North Thames, 35 cfs from the south branch and approximately 50 cfs sewage flow (27.6 MGD average in 1972). Additional flow augmentation could be provided from new reservoirs and possibly from re-activation of old water supply well fields in the London area. Table D1 (Appendix D) outlines the reservoir storage allocations to flow augmentation for existing and proposed reservoirs. Flow augmentation as an option is discussed in Appendix C. If proposed reservoirs are operated in the same manner as Gordon Pittock reservoir, with allocated storage released over 112 days, then additional flow could be provided in the summer as follows: Glengowan-36 cfs: Thamesford-45 cfs; Cedar Creek-22 cfs: Zorra Swamp - 11 cfs. Glengowan could provide up to 97 cfs if flow augmentation were to be the primary use.

The well fields supplying London pumped an average of 15 MGD the year that the Lake Huron pipeline began to used for water supply. If all these fields were operated, an additional 28 cfs could be added to the river in low flow periods.

Figure H1 indicates the present and projected dilution ratios (streamflow to sewage flow) which would occur in the future if Glengowan and/or Thamesford reservoirs are built and operated as described above (flood control primary use). It is difficult to attach a specific probability of occurrence to the low flow used in the calculation other than indicating that it is the lowest flow likely to occur if the reservoirs provide the stated flows. Model runs described in Appendix A indicate that flow augmentation from Glengowan and Thamesford of 81 cfs has almost the same effect in reducing dissolved oxygen criteria violations as does further treatment beyond the "Greenway" level. The use of Zorra Swamp and Cedar Creek reservoirs for flow augmentation was not evaluated in a computer model run. nor was the use of Glengowan reservoir primarily for flow augmentation. The effect of these options on the water quality can be estimated for those combinations where the resultant flow is close to the case modelled. This is discussed later in this Appendix.

Model runs assumed that additional water from proposed reservoirs had the same quality as the present river quality, which is relatively poor. Water from the well fields would of considerably better quality than the river, with low concentrations of BOD and nutrients. Aeration of the well water before discharge may required. As interference problems occurred when the wells were the sole water supply for London. it would necessary to correct any serious interference problems remaining if the wells were pumped for only a portion of the year. This option would require detailed study if it is to be considered, to assess possible interference problems and the costs of operating the system.

Treat Storm Water Runoff

The effect of storm water treatment could not be modelled directly because of lack of knowledge at present relating urban discharges to water quality. Information presented earlier leads to the belief that urban runoff loads are a significant source of pollution problems in the Thames River. The nutrient budget discussed in Section 6.1.1 indicated that in 1972. approximately equal loads of total phosphorus were produced from sewage treatment plants and from diffuse sources in the City of London. It is possible that a portion of the pollutant load would be in the form of suspended solids, which would settle out in the river where they would exert an oxygen demand and release nutrients over time. This possibility is supported by the predicted violations of dissolved oxygen criteria in the river with the "zero pollutant" assumption for treatment plants. largely because of respiratory oxygen demands from algae and bottom sludges. The remaining criteria violations in the Springbank Park reservoir probably can be attributed to bottom sludge alone since the deeper water prevents growth of benthic algae. The organic material along the stream bottom could be from a variety of sources including combined sewer overflows, urban runoff, sewage discharge, upstream sources and decaying algae cells from the reservoir. Quantitative relationships between urban runoff and water quality are under study in the Ministry of the Environment to define this problem. Model runs for projected populations in the future were made on the basis of no increase in the effect of urban runoff. The methods and costs of achieving this are not known at present. Conclusions from studies by the United States

Year	Sewage Flow / River Flow MGD/CFS	a) Present Dams 75cfs	b) Glengowan*** 110cfs	c) Thamesford** 120cfs	d) Glengowan and Thamesford 155cfs
		Dilution Ratios* with			
1972	27.6/51.3	1.46	2.1	2.4	3.0
1981	37.0/68.8	1.1	1.6	1.74	2.3
1986	43.0/80.0	0.94	1.375	1.5	1.93
1991	50.0/93.0	0.81	1.2	1.3	1.66
1996	58.5/108.8	0.69	1.0	1.1	1.4
2001	65.0/121.0	0.62	0.9	1.0	1.3

*Dilution ratio of river flow to sewage flow
**Thamesford—10,000 acre-ft released over 112 days
***Glengowan—8,000 acre-ft released over 112 days

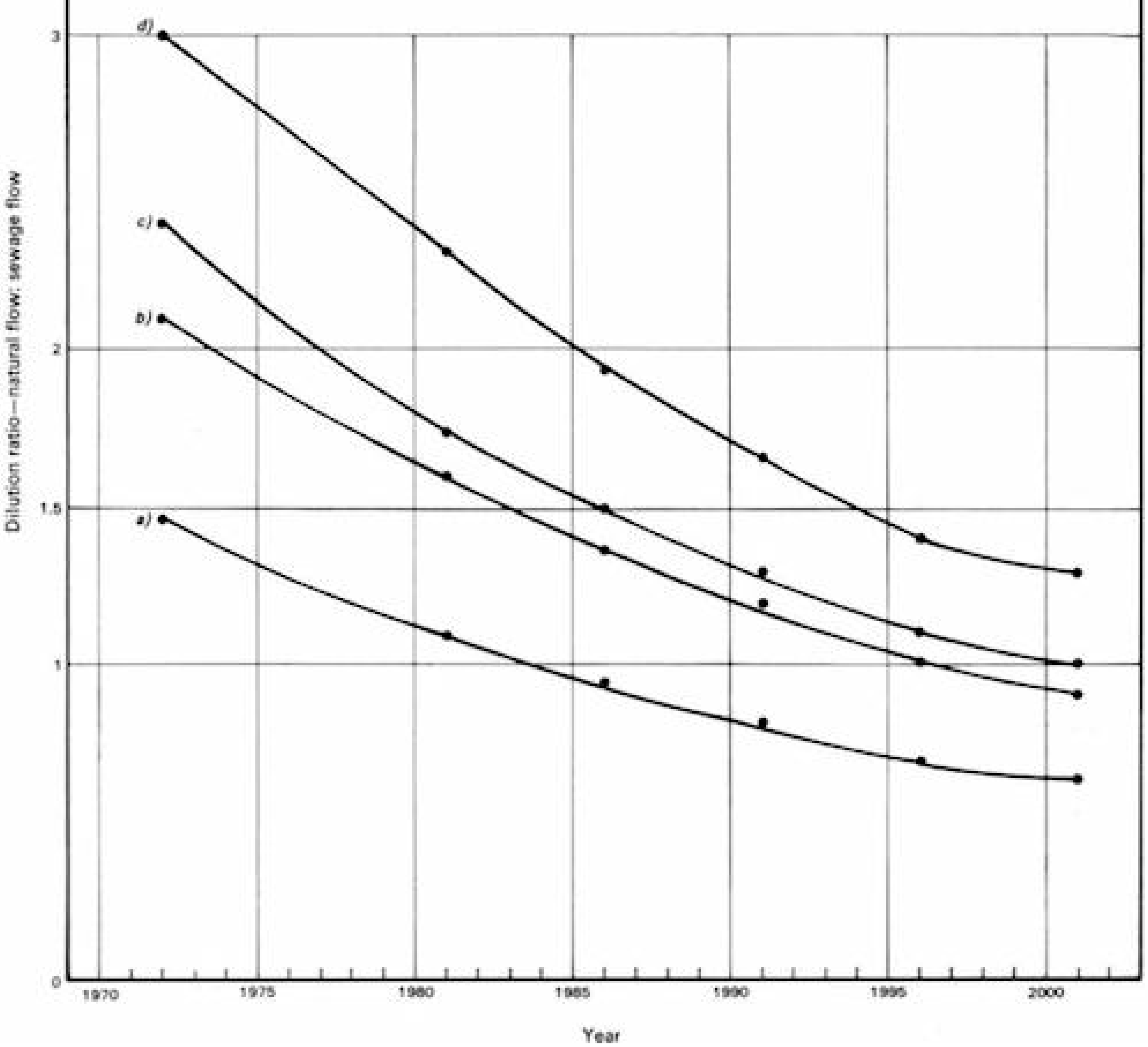


Figure H1: Projected sewage dilution ratios' for low-flow conditions in the Thames River downstream from the City of London.

Environmental Protection Agency indicate that in some cases it may be cheaper to treat combined sewage in downtown areas. rather than separate the combined sewers and treat both separately.

Improved Background Quality

The effect of improved upstream quality is described by computer model run 9 discussed in Appendix A. It is difficult to predict the likelihood of achieving an improvement in upstream quality, since it is based on so many factors. However, if options discussed in various sections of this report are implemented for control of urban and rural sources of pollutants upstream. then an improvement can be expected. This option is not really available to the city itself but must be exercised by the basin as a whole. Since the feasibility of achieving this option cannot be readily assessed, it is not considered further. In future, if a definite improvement in upstream quality results in improved conditions within the city and downstream, then recommendations relating to the City of London can be reassessed.

Divert Sewage to Lake Erie

The effect of sewage diversion on the dissolved oxygen levels of the Thames River was modelled and described in Appendix A. This option gave results which were between results for the options of tertiary treatment and treatment to the zero pollutants level. Diversion of course would effectively prevent all constituents in sewage from gaining access to the river. including heavy metals. nutrients and chlorine residuals, as well as removing the oxygen consuming material considered in the model. Diversion presumably would have no effect on other waste discharges from the urban area.

In Stream Aeration

Diffused air or mechanical aeration systems could probably be employed successfully in the Springbank Park reservoir to reduce the occurrence of dissolved oxygen criteria violations. Natural aeration is reduced in this section because of the deeper, slow moving water of the reservoir. Model predictions in Appendix A for the case of "Tertiary Treatment" (Run 4) indicate that aeration would be required in July from 14 percent to 16 percent of the time in the reservoir—about 112 hours and lesser amounts of time in June, August and September.

It must be realized that while aeration offsets the effects of respiration of bottom sludges and sewage discharges, it does not remove these materials from the river. Aeration may not be aesthetically acceptable in the park area during high use periods; however, since aeration would most likely be required during the early morning hours it would probably not conflict with recreation. In-stream aeration is generally not acceptable as an alternative to treatment--except as an interim measure—because it does nothing about the basic problem of the discharge of pollutants to the watercourse.

No estimates have been made of the cost of aeration systems. although it is thought that they would be relatively inexpensive compared to the other options discussed. Additional aeration in faster moving stretches of the river by the creation of artificial ripples are not considered to be effective.

Discussion of Options for the City of London

One conclusion is clear from the above analysis—no single option described above meets the defined dissolved oxygen criteria. In order to maintain acceptable quality in the Thames River and allow urban growth, more than one option must be implemented. The management options reduce to choices at various times in the future. of: discharging to the river: diverting sewage to Lake Erie: or urban growth limitations.

Waste Loading Guidelines

Based on model results discussed above, and the objectives for water quality control, waste loading guidelines have been set for sewage discharges from the City of London as follows. These guidelines are based on certain assumptions with regard to control of urban runoff discussed below.

(a) Present Dams and Operating Conditions

Total load of oxygen demanding material from all treatment plants should not exceed 8000 lbs/day (total oxygen demand) under present dam operating schedules. This criteria allow for a sewage flow of approximately 30 MGD with treatment to the quality of Greenway effluent (27 mg/L TOD).

(b) Glengowan Dam

With Glengowan Dam providing additional flow augmentation of 36 cfs, the allowable load should not exceed 11.000 pounds per day (TOD). With Glengowan dam providing 97 cfs, the allowable load should not exceed 17,000 pounds per day (TOD).

(c) Thamesford Dam

With Thamesford dam providing additional flow augmentation of 45 cfs, the allowable load should not exceed 11,500 pounds per day.

(d) Thamesford and Glengowan Dams

With both dams providing additional flow augmentation of 81 cfs, the allowable load should not exceed 14,500 pounds per day (TOD). With additional flow augmentation of 142 cfs (utilizing Glengowan primarily for flow augmentation), the allowable load should not exceed 21,000 pounds per day (TOD).

In addition, specific limitations should be placed on discharges to the North Thames and the south branch of the Thames within London as summarized in the table below:

Table H2: Waste Loading Guidelines for London

	Allowable Load—Total Oxygen Demand			Year Dilution Ratio Reached	
Option	Total	N Thames	S Branch	1.5:1	1:1
Present Dams	8000	1000	2500	1971	1984
Glengowan	11000	2000	2500	1983	1997
Glengowan*	17000	4000	2500	1999	2001+
Thamesford	11500	1000	3500	1986	2001
Glengowan and Thamesford	14500	2000	3500	1994	2001+
Glengowan* and Thamesford	21000	4000	3500	2001+	2001+

* Glengowan operated primarily for flow augmentation

Cedar Creek and Zorra Swamp reservoirs could provide an additional 22 and 11 cfs, respectively with an accompanying increase in the allowable load from London and deferral of dates that dilution ratios are reached, depending on, ultimately, reservoir combinations are added.

Combined sewer separation or treatment along with storm sewer treatment will be required in the future as urban growth proceeds. The loading guidelines given above assume that the effects of urban runoff do not increase with time. This can be achieved only by control of discharges from combined sewer overflows, and ultimately, from storm sewers. The city should implement studies to determine the magnitude of the problem and develop treatment methods for reducing storm generated effects on the Thames River.

It is difficult 1.5:1.to categorically what the ultimate assimilative capacity of the river is, based on dissolved oxygen criteria alone. This question could be answered in the future when management plans recommended herein are implemented and response in the river system can be measured directly. With the limit to the sewage dilution ratio (natural flow to sewage flow) at 1.5:1. chosen on the basis of aesthetics and required dilution of residual organics and toxicants with conventional treatment, then dates can be predicted when this ratio will be reached. Based on Table H2, it can be seen that this dilution ratio can be maintained to various dates in the future by utilizing flow augmentation from the proposed Glengowan reservoir, Thamesford reservoir or both. If a lower dilution ratio is allowed as treatment levels increase (and more sewage constituents are removed) then these dates can be extended. For example. if the system described in Appendix F, which treats sewage to approximately stream quality is built, then a 1:1 low flow dilution ratio would be considered acceptable. This would allow growth to dates as above with the various dam options.

Staging of Construction Options

The loading guidelines above along with the dilution ratio dates can be used to estimate the staging of construction of higher levels of treatment or sewage diversion. The following rationale was followed to derive this staging, which applies to the London area. With conventional treatment systems a minimum dilution ratio of 1.5:1 is allowed, at which point either growth should be halted, sewage diverted or tertiary treatment initiated. The limit to tertiary treatment discharge rate occurs when a 1:1 dilution ratio is reached, at which point either growth should be halted or sewage diverted.