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UPPER GREAT LAKES WASTE LOADINGS TRENDS  
SIMULATION MODEL:  
MODEL STRUCTURE AND SOFTWARE

By

D. E. Coleman  
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Inland Waters Directorate - Ontario Region

January 1976

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## CHAPTER ONE

### GEOGRAPHICAL BASIS OF THE PROBLEM

During 1972, the International Joint Commission, an international body with powers to investigate problems of mutual concern to Canada and the United States of America, asked Environment Canada, in co-operation with the Province of Ontario, to investigate whether the Upper Great Lakes were likely to become polluted and to suggest measures to alleviate such pollution if it were expected to occur.

The simulation model described here represents only a small fraction of the effort devoted to responding to those questions, yet it forms an integral step in the process.

The focus of this study is directed toward river basins as a result of man's ubiquitous use of natural river networks as the mechanisms to dilute and carry away domestic and industrial liquid wastes. The ability to focus on a smaller geographic unit than the lake basin offers many advantages.

The large Lake Huron and Lake Superior lake basins (see Maps 1 and 2) possess diverse physiography, in that the Lake Superior Basin exists mainly on the Canadian Shield, whereas the Lake Huron Basin is located primarily in the sedimentary lowlands. The economic development of the two lake basins differs in mix and concentration by locality. Table 1 shows Value of Output for Selected Industry Groups in both the Lake Superior and Lake Huron basins. These figures show that, except for forestry production in which the Lake Superior Basin surpasses the Lake Huron Basin by

virtually 50 percent, the Lake Huron Basin value of output exceeds that of the Lake Superior Basin by at least 300 percent. These figures provide some insight into the magnitudes involved, but just how representative are they with respect to their basins? Tables 2 and 3 provide a partial answer.

Tables 2 and 3 represent the Value of Output for Selected River Basin Groups in the Lake Superior and Lake Huron Basins, both in absolute terms and as a percentage of the total basin. Agriculture, manufacturing and construction dominate Basins 1 and 4 (Thunder Bay and Sault Ste. Marie, respectively), whereas mining and forestry dominate Basins 2 and 3 (Nipigon-Long Lac, and Marathon-Michipicoten), as shown by Table 2.

Table 3 shows just how deceptive aggregate lake basin figures can be. The value of output in mining for the Lake Huron Basin, from Table 1, is 456.119 million dollars. Table 3 shows that the output is distributed 88.7 percent in the Sudbury Basin, 8.1 percent in the Muskoka-Parry Sound Basin and 3.1 percent in the Saugeen-Maitland River Basin.

These very large disparities in the distribution of output make it imperative that some finer areal breakdown be used. The following section points out the derivation of the final areal basis for tackling the problem.

The basins referred to in Table 2 are river basin groups (that is, river basins which are aggregations of a number of smaller river basins which discharge at least 1,000 cubic feet/second mean annual flow). The aggregation took place based upon four criteria: a) urbanization; b) economic development; c) recreation; and d) proximity to each other. Data

regarding the first three criteria were obtained from the Ontario Government Design for Development series [1, 2, 3, 4].

The analysis of this data proceeded along these lines. General information regarding items a), b), and c) were located in the primary set of nineteen 1,000 C.F.S. basins listed in Table 4. An analysis then took place using a strategy similar to that used by hierarchical grouping analysis routines [5]. The difference in this case is that the procedure is manual rather than computerized. The fact that members had to be physically proximate to the other members prevented a computerized analysis from being carried out.

The attributes of the grouping procedure assure that an individual river basin is added into a group in which the between group variation is maximized and the within group variation is minimized. The method also attempts to form the smallest number of groups possible while maintaining between group variation as much as possible. Maps 1 and 2 show the location and extent of the basin groups, while Table 5 shows the river basin groups and the original river basins which are contained in each.

The final point to be made, with respect to selection of a geographical basis for the subsequent analysis, is to recognize that in practically no sense are the regions self-contained with respect to social and economic activities. If these basins are to be treated as waste production and delivery systems, it must be recognized explicitly that they are open systems with flows of materials, labour, capital and migrants crossing the boundaries of the system. The interaction of the regional systems with supra-regional systems will be elaborated on in a later chapter.

## CHAPTER TWO

### METHODOLOGY

The production of forecasts over a fifty-year forecast horizon is an extremely difficult task, one in which available methodologies are few and ill-suited for the purpose of this study. The one methodology which is suitable is a composite drawn from several disciplinary areas.

The driving forces for the forecasting exercise are population and economic activities. Since these activities are part of the larger surrounding provincial and national milieu, population and economic activities can be treated as being exogenous to the river basins used in forecasting. The implication here is that population growth and economic development occur in hierarchically higher sub-systems through processes, the details of which are of no consequence here except that measures of population and economic activity are available which correspond to the river basin group's share of the growing (declining) population and economic activity. Thus, the primary components of the methodology include exogenously provided estimates of future population and economic activity and an allocative or distributive mechanism through which each region receives its quota of population and economic activity. This set of conditions satisfies Lowry's edict: "His [the model builder's] second task is to make sure that those variables which stand at the beginning (prime causes, often called exogenous) can be plausibly evaluated as far into the future as may be necessary." [6]

The evaluation of the future exogenous variables is derived as follows. A macro-economic model of the Canadian economy, a variant of the CANDIDE Model 1.1 [7] developed by the Economic Council of Canada, is used to produce the national estimates of economic activity over the period 1972 to 2020 A.D. [8].

The key assumptions used in producing the economic projections are that:

- (a) the government will continue to view full employment with moderate price increases as a main objective;
- (b) fertility trends will follow their current pattern of decline and stabilize from 1985 onward at approximately 1,900 births per 1,000 females; and
- (c) immigration will be sufficient to make up any shortages in the labour supply [9].

The assumption that full employment will be maintained is crucial to the projections in three ways. First, it is a realistic and reproducible solution to the CANDIDE Model in that sufficient parameters are constrained to provide a feasible solution (no mean feat in a non-linear dynamic model of over 2,000 equations, one-third of which are simultaneous). Second, removing the full employment assumption leaves an infinite range of solutions to choose from while lacking any real basis for choice. Third, from an environmental point of view, a full employment scenario corresponds to a worst case situation. There will be maximum output, maximum production and, other things being equal, maximum pollution.

under these circumstances. Any deficiencies in pollution abatement will become readily apparent.

Population is the second exogenous variable used in the model. Fortunately, estimates of population are available for Census Division in Ontario so that a need to work from the national population estimates did not occur. The Economic Analysis Branch of what is now the Ministry of Treasury, Economics and Inter-Governmental Affairs produced, for the 1973 Ontario Statistical Review [10], estimates of population based on various assumptions about fertility, mortality and net migration. The estimates used in this study were medium estimates, that is estimates which assumed medium fertility and medium net migration. These estimates were extrapolated from 2001 to 2020 based on the continuation of the 1990 to 2001 growth trends. The population estimates by Census Divisions were then re-aggregated into the river basin groups shown earlier.

It is customary in modelling work to include a break-down of population by age or by age and sex, since the composition of the population has many implications for the labour force, school enrolment and migration. While CANDIDE has such a breakdown, and its impacts are felt in terms of value of output in a region, the waste loading model includes no specific break-down by age and sex. This situation arises because the only function of the population in the waste loading model is as one of the components of municipal waste production calculations. Because municipal waste production, from the empirical observations of the Ontario Ministry of the Environment, is reported in per capita terms, additional detail in the population sector is superfluous.

At the regional level, the economic data used corresponds to the Standard Industrial Classification code used by Statistics Canada [11]. The level of disaggregation is at the S.I.C. Division for all sectors except mining and manufacturing, which are broken down into their respective major groups (that is, to the two-digit level). A complete specification of the industrial components of the regional economies is shown in Table 6. These data are derived as follows.

For each region, Statistics Canada produced employment figures for all of the industries in the regions by S.I.C. classes. The data were retrieved by enumeration areas and re-aggregated into the river basin groups by Statistics Canada using the geo-coding facility [12]. These employment figures, when compared with the national employment figures by industry group, produced a regional distribution matrix giving the proportion of national employment by industry group in a region.

The next major segment of the model structure involves two parallel phases, the computation of municipal raw sewage and the corresponding calculation of industrial raw sewage. The industrial calculation will be outlined here since, in conceptual terms at least, municipalities can be viewed as just another waste producing "industry".

For municipalities and for industries, coefficients of waste production were obtained. The municipal waste production coefficients were supplied by the Ontario Ministry of the Environment from special studies performed at selected municipal sewage treatment facilities where little industrial usage occurred. The resulting figures indicate the number of pounds per capita of thirty chemicals and ions in raw sewage, that is, before treatment (see Table 7).

On the other hand, the only data available for use in calculating industrial discharge coefficients, a study by the Industrial Waste Management Branch of the Ministry of the Environment [13], provided the actual post-treatment discharges to the Canadian Great Lakes. These data were used with Statistics Canada data on Value-Added in Ontario in each of the thirty-one industry groups.

For each time period and each region, the value of output in each industrial group was multiplied by the industrial waste production coefficient for each waste loading substance. The weight of each waste loading substance is converted to tons.

For industries, the waste loads produced are final waste loads (post-treatment); municipal waste loads are pre-treatment loads. A description of the manipulations to simulate the municipal treatment process follows.

In each region, several pieces of information are required to perform the calculation which derives treated municipal sewage from raw municipal sewage; the major requirements are the municipal treatment capacity and the treatment efficiency. Estimates of treatment capacity with respect to primary, secondary and tertiary treatment types were provided for each region by the Ministry of the Environment. These data are shown in Table 8. The treatment inefficiency is derived from treatment efficiency measures (Treatment Inefficiency = 1 - Treatment Efficiency) which, in turn, were collected from the literature on pollution abatement [14].

The municipal sewage treatment sector is strongly linked to the municipal treatment investment equations by the use of a simple capital-

output model to determine capacity. In this model, there is a relationship between the capital stock used to produce a commodity and the output which can be produced. This relationship is expressed in the capital-output ratio. In economic terms, a firm producing a commodity will have a certain amount of capital and produce a certain number of units of output. Correspondingly, a sewage treatment plant has a capital stock in terms of equipment and so on and, with this capital stock, there is a certain amount of untreated waste. Thus the capital-output ratio in this case expresses the ratio of pollution abatement capital to pollution output. From the data, the 1972 proportion treated (by treatment type) is known and, given the raw sewage production figures, the first year calculation is trivial. The difficulty occurs only in the second and successive years, wherein the population and hence the raw sewage production have increased.

Since the 1972 proportion treated corresponds to the capital-output ratio and since, in the first scenario, it is desired to maintain a constant capital-output ratio despite output (raw sewage production) having increased, the increase in the capacity (capital stock) required to maintain the capital-output ratio can be calculated. At given unit cost, total expenditures required to maintain a constant capital-output ratio follows directly.

The capital-output ratio can be increased, as a matter of policy, and the additional expenditures required to increase the treatment capacity to the higher levels proceeds similarly. The fundamental difference in this case is twofold:

- (a) the unit cost of additional capacity is assumed to remain constant until the 90 percent treatment efficiency is reached, whereupon the unit cost becomes exponential; and
- (b) the investments to increase the capital-output ratio result in impacts upon employment, output and prices in a fashion which is not accounted for in the CANDIDE "Control Solution".

The implications of these differences will be explored later.

All of the essential ingredients to determine the total river basin calculation have been determined previously. By adding the untreated municipal sewage (that portion which receives no treatment because of inadequate capacity), the loads remaining after a less than totally efficient municipal treatment and the loads resulting from economic activity, the total basin loads on each of the waste loading substances are produced.

These then are the fundamental calculations to produce the desired waste loading information. There are, however, several other items to be considered, namely, what are the economic and social impacts associated with the desired degree of cleanup?

These impacts can be measured in terms of additional and total investments required to effect a given degree of cleanup, in terms of the economic impacts of changes in Gross National Product and prices, or in terms of social impacts as measured by increases or decreases in employment. As mentioned earlier, the municipal investments are calculated by multiplying the required increase in capacity by treatment type by its

unit cost. The increases in capacity result from maintaining (or increasing) the capital-output ratio.

In the municipal treatment sector, these calculations are rather straightforward and require few assumptions since data on treatment capacity, treatment cost and treatment efficiency exist. On the other hand, for industrial investments, much less complete data exists. Data on installed capacity in each region is not available directly, but the dollar values spent on abatement are available. Similarly, no data exist on the treatment efficiency of industrial abatement, and only post-treatment waste load coefficients are available. Hence, the model user must make a clearly stated assumption about what the base year treatment efficiencies are and what the desired efficiency will be at the end of the simulation run. Of course, default values are provided initially, and these may be modified or replaced as suits the model user.

The expenditures on industrial abatement over the 1967-1972 period were accumulated and depreciated at an assumed rate of 5 percent per year to form a stock variable which served as a proxy for industrial treatment capacity. Capital-output ratios were calculated, given the initial assumptions about treatment efficiency. From these data, the investments required to maintain the capital-output ratio when pollution output is increasing can be calculated.

To increase the treatment efficiency, it is not sufficient simply to state what the desired treatment level is; one also has to provide an indication of when the increase is to occur. This is done by means of a matrix of dummy variables provided for each year of the simulation. The values in the matrix are zero everywhere except in those years and those

industries in which treatment efficiency is deemed to increase. In a year in which no treatment efficiency increases occur, the investment transactions correspond to depreciation and replacement investment. When efficiency increases, there is depreciation, replacement investment and a one-time net investment to increase the capital stock to a higher level. In following years, the elevated stock levels are maintained by replacement investment.

The total investments by business and government are useful indicators of economic impact, however, these rather large expenditures result in a complex set of direct and indirect economic effects. Some of the effects might be to raise interest rates as money is bid for in the capital markets, or to raise industry prices since abatement investments are in essentially non-productive capital.

Indirect effects result from the purchase of capital equipment, services, materials, and so on from other sectors of the economy than where the investments were made. Because these kinds of transactions result in increased goods and services being produced, Real Domestic Product and Gross National Product may increase.

To assess these effects upon the national economy, a set of impact multipliers were calculated in the CANDIDE model and built into the waste loading model. The term impact multiplier as it is used here requires some explanation. CANDIDE is a dynamic model and, hence, the multipliers produced give the difference between the base value and the resulting value of a given variable when an investment "shock" is fed through the economy. The dynamic nature of CANDIDE results in non-zero shock effects lasting between eight and thirteen years. In summary, the

impact multipliers give the magnitude of the change in a response (output) variable over an eight to thirteen-year period following a single year investment impact.

This short discussion may have given a clue to the complexity of the computation carried out here. First, for a single investment, the impacts must be calculated on every other industry, GNP, employment, and the Consumer Price Index. The amount of the investment must be saved for use in successive years. At the same time, there may be investment in other industries, and the impacts must be accumulated over the industrial categories. It is also necessary to keep track of which dynamic impact multiplier is being used since the magnitude of the impact varies temporally. All of this may transpire in a single simulated year. Needless to say, investments can, and do, occur in successive years so that a very complex impact structure results.

A strong feedback exists between the economic impact of investment and the following year's output (RDP) by industry group at the national level.

All of the major areas of the model have been discussed except one, namely, the simulation capability of the model. There are approximately ten variables which give the user the ability to simulate various scenarios. These adjustments affect population, urbanization rates, technical change in industrial and municipal waste treatment, capital efficiency, the degree of pollution cleanup, and so on.

In computational terms, all of these adjustments are made to the original data by means of a simulation pre-processor. That is, with the exception of capital efficiency which is used directly in the model stock

equations, a small stand-alone program reads all the data which may be changed, solicits changes from the user, and writes out the adjusted data. Where no changes are required, the data are simply copied over. This facility, without being specific about the cause of the adjustment, allows the user to set the scene for the model runs as he sees fit.

On this basis, the model user can implement the effect of any legislative, social or technological change which he can assess with respect to the magnitude of its impact upon the current input variables. There is, as yet, only one comprehensive study which has attempted to express foreseen developments in the future of water management alternatives in terms that can be translated directly for use with the waste loading model [15].

The purpose of this chapter has been to present an overview of the methodology used in the waste loading model in terms which are fairly general and non-technical. The next chapter will outline in some detail the model equations, the various software systems used, how data files are managed during computation, and other related details of the model.

## CHAPTER THREE

### MODEL STRUCTURE

This chapter outlines the detailed structure of the model. Each of the active modules is described to provide an understanding of their functional forms. This information is provided for the economic sector, the population module, technology and waste treatment, waste loading calculation, as well as the economic impact module.

#### Economics

The economic sector, as outlined previously, uses an allocative structure which assigns a specified proportion of the national output in an industry to a region. The economic module is, then, a simple spatial allocation model in which the values of real domestic product in each industry are supplied as exogenous variables from the CANDIDE Model of the Canadian economy [16].

The national output in each industry group is allocated to a region based on a coefficient which is defined by the proportion of employment in region  $j$  in the  $i$  th industry group, relative to the total employment in the  $i$  th industry in Canada, assuming spatially constant labour force productivity.

#### Population

The population module reads the population forecast and transforms it to urban population,

$$\text{URBPOP}(j) = \text{POP}(j) * \text{URBR}(j)$$

where,

$\text{URBPOP}(j)$  is the urban population in the  $j$  th region,

$\text{POP}(j)$  is the total population of the  $j$  th region,

$\text{URBR}(j)$  is the proportion of the total population living in urban centres in the  $j$  th region

The population sub-model plays a fairly minor role in this model relative to the roles of other population sectors in other models. This is so in this application because we are only interested in how much waste load is generated per person. Differences with respect to age, sex or other factors common in most population models have no substantive bearing, and thus, total population for each region is supplied directly as an exogenous forecast developed by the Ontario Government [17]. Since the real variable of interest is urban (or serviced) population, the total population figure is scaled by the proportion urban in the  $j$  th region.

#### Municipal Waste Treatment

The equations for the municipal waste treatment sub-model are:

- 1)  $\text{MWWFL}(j) = \text{URBPOP}(j) * \text{PCWATR}(t) / 1000000.$
- 2)  $\text{MWL}(j, k) = \text{URBPOP}(j) * \text{MWLFAC}(k) / 200.$
- 3)  $\text{ZC}(j) = 1. - \text{ZB}(j)$
- 4)  $\text{ZZ}(j) = \text{ZB}(j) + \text{MXSIM}(j, t) * \text{ZC}(j)$
- 5)  $\text{ZN}(j) = 1. - \text{zz}(j)$
- 6)  $\text{UNTRT}(j, k) = \text{ZN}(j) * \text{MWL}(j, k)$
- 7)  $\text{MSTR}(j, k) = \text{ZZ}(j) * \text{MWL}(j)$
- 8)  $\text{DISTLD}(j, k, n) = \text{MSTR}(j, k) * \text{PRPCAP}(j, n)$
- 9)  $\text{TRULOD}(j, k, n) = \text{DISTLD}(j, k, n) * \text{CTIFF}(k, n)$
- 10)  $\text{MWLF}(j, k) = \sum_{n=1}^N \text{TRULOD}(j, k, n)$

where,

MWFL(j)	is the municipal waste water flow in region j,
URBPOP(j)	is as previously defined,
PCWATR(t)	is the per capita water consumption,
MWL(j,k)	is the municipal waste load; raw waste load in the j th region for the k th wasteloading substance,
ZB(j)	is the proportion of the total waste load passing through treatment plants in the j th region in the base year. ZB(j) is given,
ZC(j)	is the proportion of the total waste load not treated in the base year in the j th region,
MXSIM(j,t)	is the proportion of the load over and above the ZB(j), treated in the j th region in the t th year as a result of a policy decision to increase treatment,
ZZ(j)	is the total proportion of the municipal waste load treated in the j th region,
ZN(j)	is the proportion of municipal waste not treated in the j th region,
UNIRT(j,k)	the untreated waste load of the k th substance in the j th region,
MSTR(j,k)	the pre-treatment waste load of the k th substance in the j th region,
DISTLD(j,k,n)	the treated waste load of the k th substance, treated by the n th treatment process, in the j th region,
PRPCAP(j,n)	the proportion of the total capacity in the j th region that is in the n th treatment process,
CTIFF(k,n)	the treatment inefficiency of the n th treatment process with respect to the k th waste loading substance,
TRULOD(j,k,n)	the treated waste load remaining after treatment by the n th treatment process, for the k th substance, in the j th region,
MWLF(j,k)	the final waste load after treatment, summed across the treatment types, for the k th substance in the j th region

The constants in the equations are scaling factors to maintain dimensional accuracy.

In this module, municipal waste flows are calculated, the degree of treatment in terms of capacity and in terms of efficiency are considered separately for each of the seven regions.

In detail, the calculation proceeds as follows. Equation 1) calculates the municipal waste water flow in millions of gallons per day. Equation 2) calculates the loading of raw sewage before treatment. The urban population (see Table 9) and the per capita waste loading coefficients for each of the substances under consideration, are used. Equation 3) calculates the base year proportion untreated, that is, the proportion which, because of insufficient sewage treatment capacity, is not treated. The value of ZB for each region is given, and Equation 4) calculates the current year proportion treated as the sum of the base year proportion treated and a proportion of that part which was not treated in the base year. A zero value for MXSIM produces  $ZZ(j)=ZB(j)$ , while a value of MXSIM in the range  $0 < MXSIM < 1$  produces a value of ZZ approaching 100 percent as MXSIM approaches 1. Since the value of MXSIM is supplied exogenously as a simulation variable, the proportion treated in the current year can be manipulated at will. The consequences of such changes appear in the TECHN subroutine as costs for additional plant capacity.

Equation 5) maintains consistency in the current year proportion not treated. ZN(j) is then used in Equation 6) to calculate the waste load not treated in the current year for each substance in each region. In turn, Equation 7) calculates the loads of municipal sewage being treated by waste load type for each region.

The total load being treated is broken down into proportions being treated by primary, secondary or tertiary treatment. The basic

assumption is made that each treatment type is used to its capacity and that overloading of one type of treatment is not permitted while there is still capacity of another type available to treat it. The assumption corresponds to a rational management scheme whereby when one treatment facility is used to capacity, other under-utilized facilities are brought to bear until all available treatment capacity is utilized. Only at that point will overloading occur.

Once the load has been distributed by treatment type, this information is used in conjunction with the efficiency of treatment figures for each treatment type in order to calculate the after treatment waste loads by treatment type for each substance in the region. The final municipal waste loads, in Equation 10), are the summation over the treatment types of the post treatment waste loads by treatment type. Final waste loads are provided for each substance in each region.

#### Industrial Waste Treatment

Industrial waste loads are calculated by the following equations.

Table 10 provides the waste coefficients.

$$IWL(j,i,k) = (RO(i,j)*IWLFAC(i,k)*1.-DESTRL(j,i,t)/1.-BASTRL(j,i,t))/2000.$$

$$IWLSUM(j,k) = \sum_i IWL(j,i,k)$$

where,

$IWL(j,k)$  is the industrial waste load, in tons, of the  $k$  th substance after treatment, in the  $j$  th region

$RO(i,j)$  is the real domestic product of the  $i$  th industry in the  $j$  th region, in millions of 1961 constant dollars,

$DESTRL(j,i,t)$  is the desired treatment level in the  $i$  th industry, in the  $j$  th region, for the  $t$  th year.  $DESTRL$  is a simulation variable,

BASTRL(i,j) the base year treatment level in the i th industry in the j th region,

IWLSP(j,k) is the sum of the industrial waste loads, summed across the industry types. one value occurs for each waste loading type in each region.

The equations for the industrial waste loading calculation are deceptively simple but have wide ranging implications for many other sectors of the model. The consequences of this situation will be mentioned later as the point of effect in the model is reached.

The real domestic product in each industry in each region, calculated by the economic spatial allocation model, is used in conjunction with the post-treatment industrial waste loading coefficient. This, in turn, is modified by the expression  $1.-DESTR(j,i,t)/1.-BASTRL(j,i,t)$ . The first part represents the inefficiency of treatment at the desired treatment level, while the second part represents the treatment inefficiency at base year treatment levels. Thus, the whole expression is the ratio of the desired treatment inefficiency to the base year treatment inefficiency. When progress in cleanup is occurring, the desired treatment inefficiency will approach zero as the cleanup proceeds. Calculation of the industrial waste loads are made much simpler by the fact that post-treatment waste loads are directly observable for the period prior to the base year. Industrial output in dollar terms is readily available, making the waste loading coefficient (pounds of waste load per constant dollar of output) easy to calculate. Please note here that the use of these waste load coefficients in calculations of future waste loads implicitly assumes that the treatment efficiency is at base year levels. Hence, an adjustment must be made to the coefficients if the treatment efficiency is not at base year levels. This is one of the deceptively simple parts mentioned earlier. Projections of regional domestic product are all that are

required to calculate industrial waste loads. The only other factor, changing treatment efficiencies, is compensated for in the latter half of the first equation. The second equation simply totals each industry's contribution to the regional total of that waste loading substance.

#### Total Waste Loads

Until this point, waste loads from industry and from municipal sources have been calculated separately. These are now brought together to obtain total river basin waste loads:

$$MWLT(j,k) = MWLF(j,k) + UNTRT(j,k)$$

$$TBLD(j,k) = MWLT(j,k) + IWLSUM(j,k)$$

$$CALIBR(j,k) = TBLD(j,k) - OBSERV(j,k)$$

$$TTBLD(j,k) = TBLD(j,k) + CALIBR(j,k)$$

$$MAXS02(k) = \text{maximum } (TTBLD(j,k))$$

Next, calculate the lake basin loadings from the river basin loads,

$$MUNSUP(k) = \sum_j^j MWLT(j,k) \quad (j=1, \dots, 4)$$

$$IWLSUP(k) = \sum_j^j IWLSUM(j,k) \quad (j=1, \dots, 4)$$

$$MWLHRN(k) = \sum_j^j MWLT(j,k) \quad (j=5, \dots, 7)$$

$$IWLHRN(k) = \sum_j^j IWLSUM(j,k) \quad (j=5, \dots, 7)$$

where,

$MWLT(j,k)$  is the total regional municipal waste load for each region by waste loading substance

$MWLF(j,k)$  is the final municipal waste loads after treatment in each region for each waste loading substance

TBLD(j,k)	is the total river basin waste load of the k th substance; MWLT(j,k) and IWLSUM(j,k) are as defined previously
OBSERV(j,k)	is the base year observed loading of the k th substance in the river basin
CALIBR(j,k)	is a calibration variable used to adjust the output to a 1973 base; this variable accounts for certain uncontrollable factors such as the contribution of agricultural runoff, the assimilative capacity of the water body, atmospheric inputs and other uncontrollable sources
TTBLD(j,k)	is the calibrated final waste loads by region, by waste loading substance
TBLD(j,k)	is as previously defined
MAXS02(k)	is the maximum value of the waste load of any substance in any region
MUNSUP(k)	is the final municipal waste loads in the Superior Basin, by substance
MUNHRN(k)	is the final municipal waste loads in the Huron Basin, by substance
IWLSUP(k)	is the final industrial waste loads in the Superior Basin, by substance
IWLHRN(k)	is the final industrial waste loads in the Lake Huron Basin, by substance

In this procedure, accounting summaries of total waste load by waste loading type are calculated for each river basin and for the Lake Superior and Lake Huron lake basins. These data are the primary results of the modelling process, which the modelling task sought to achieve. It was also felt that the maximum discharge of each substance in any region, MAXS02, would be a key policy variable in that the whole gamut of industrial waste dischargers may face increased regulation because of abnormally (or significantly) higher discharges of a substance in a single region and, perhaps, even in a single industry. For example, all lead

dischargers in Ontario face regulation because of the actions of a single Toronto firm.

Investment in Treatment

The next series of calculations are performed in the module TECHN. First, municipal treatment capacity is calculated:

$$MGAL03(j,nt) = EFFDLR(t) * MTMI03(j) / MTCOST(nt)$$

where,

$MGAL03(j,nt)$  is the number of gallons of treatment capacity by treatment type in the  $j$  th region,

$EFFDLR(t)$  is the capital efficiency in the  $t$  th year,

$MTCOST(nt)$  is the unit cost of municipal treatment capacity, of type nt.

The summation occurs in each time period and adds the incremental capital cost for new capacity to the existing cost.

Industrial treatment capacity increases in proportion to increases in R.D.P. under the base scenario (the one in which the capital-output ratio is held constant). The adjustment made to the coefficients because of increased treatment levels is made as follows:

$$TEMP2(j,i,t) = (RO(j,i,t) / RO(j,i,t-1)) / CHWFAC(t)$$

where,

$TEMP2(j,i,t)$  is the proportional change in real domestic product in the  $j$  th region, in the  $i$  th industry at time  $t$ ,

$RO(j,i,t)$  is the real domestic product of the  $i$  th industry, in the  $j$  th region, at time  $t$ ,

RO(j,i,t-1) is the RDP a year earlier,

CHWFAC(j,i,t) is the change in industrial waste load coefficients in the i th industry, in the j th region at time t

Using this information, the calculation of industrial treatment cost occurs:

$$ITMI01(j,k) = \text{EFFDLR}(t) * (\text{STOCK1}(j,k) * \text{TEMP2}(j,i,t) + \text{STOCK1}(j,k) * \text{DEPR}(t)) - \text{STOCK1}(j,k)$$

where,

ITMI01(j,k) is the additional treatment investment which is necessary to maintain the pollution capital-waste output ratio at its 1973 value,

EFFDLR(t) is the capital efficiency in year t,

STOCK1(j,k) is the stock of pollution capital in the previous year (t-1),

TEMP2(j,i,t) is as previously outlined,

DEPR(t) is the depreciation rate of the capital stock

This equation functions as follows; net investment is calculated by STOCK(j,k) \* TEMP2(j,i,t), replacement investment is calculated by STOCK1(j,k) \* DEPR(t) and STOCK1(j,k) is subtracted to avoid double counting (because additional investment, not total investment, is required).

Then, the value of the pollution capital stock in the present year is:

$$\text{STOCK2}(j,k) = \text{STOCK1}(j,k) + \text{ITMI01}(j,k) - \text{STOCK1}(j,k) * \text{DEPR}(t)$$

Now the current year capital stock, STOCK2(j,k), equals last years stock, STOCK1(j,k), plus gross investment including that to replace depreciated capital stock (STOCK1(j,k)\*DEPR(t)) which is subtracted out.

Next, the additional investment to increase the capital-output ratio above its previous value is calculated. In the situation which occurs when the capital-output ratio is not changed, the result of the calculation has the same numerical value as does ITMI01.

Thus,

$$\text{ITMI03}(j,k) = \text{EFFDLR}(t) * (A(j,k) * Z * \text{STOCP1}(j,k) * \text{TEMP2}(j,i,t) + (\text{STOCP1}(j,k) * \text{TEMP2}(j,i,t)) + (\text{STOCP1}(j,k) * \text{DEPR}(t)) - \text{STOCP1}(j,k))$$

where,

$\text{ITMI03}(j,k)$  is the additional investment to finance industrial treatment capacity sufficient to change the capital-output ratio to that corresponding to the new desired treatment level,

$A(j,k)$  is a dummy variable (1's or 0's) controlling the expression consisting of  $A(j,k)$  and the next two terms. When  $A(j,k)$  is zero, the expression is always zero, and when  $A(j,k)$  is one, the expression has the value  $Z * \text{STOCP1}(j,k)$ ,

$Z$  is the industrial treatment efficiency. If the desired treatment efficiency is above 90 percent,  $Z$  increases exponentially,

$\text{STOCP1}(j,k)$  is as defined previously,

$\text{TEMP}(j,i,t)$  is as defined previously,

$\text{DEPR}(t)$  is as defined previously

The rule for calculating  $Z$  is as follows:

IF DESTRL < 91 percent THEN  $Z = \text{DESTRL} - \text{BASTRL}$ ,

ELSE  $Z = \text{EXP}(.5 * ((\text{DESTRL} - 90.) * 100.))$

The new value of the stock variable associated with this investment is:

$$\begin{aligned} \text{STOCP2}(j,k) &= \text{STOCP1}(j,k) + \text{ITMI03}(j,k) - \\ &\quad \text{STOCP1}(j,k) * \text{DEPR}(t) \end{aligned}$$

Since, at this point, we know the value of the additional investment to maintain a constant capital-output ratio, and we also know the value of ITMI03, the investment required to maintain and improve the capital-output ratio, hence we can subtract the second from the first to obtain the investment which is necessary to move from the old desired treatment level to the new desired treatment level:

$$\text{ITMI02}(j,k) = \text{ITMI03}(j,k) - \text{ITMI01}(j,k)$$

where ITMI02(j,k) is termed the "impact creating investment". In the CANDIDE econometric model, a certain amount of government investment in pollution abatement is captured in the government expenditure equations. But because the additional expenditures in the simulation model result from "policy" decisions not accounted for in the CANDIDE control solution, the effects must be accounted for separately by the use of impact multipliers. These multipliers function as outlined in the previous chapter. Subroutine SPEND handles the impact calculations.

First, the additional investments are totalled by industry group across river basins:

$$\text{INVEST}(i) = \sum^j \text{ITMI02}(i,j)$$

Next, ignoring the selection of the proper interim multiplier (which is simply a messy programming problem), the total additional investment is multiplied by a vector of impact multipliers, one for each industry, and summed across the impact producing industries:

$$\text{IMPACT}(j) = \sum^j (\text{INVEST}(i) * \text{NIM}(i,j))$$

where,

IMPACT( $i$ ) is the additional RDP in the  $i$  th industry in Canada, generated by additional investment in other sectors of the economy,

INVEST( $i$ ) is as defined previously,

NIM( $i,j$ ) is the national impact multiplier for the  $j$  th industry when impacted by investment in the  $i$  th industry ( $i \neq j$ ). There is an implicit time subscript which has selected the proper interim multiplier from the set of possible values. Each multiplier represents RDP in millions per 25 million of investment.

Finally, measures of economic impact are calculated. These measures are the change in the Consumer Price Index, the change in employment nationally, and the change in Gross National Product.

With this description of the model structure, the results of applying the model to several large river basins in Ontario will be described in the next chapter.

## CHAPTER FOUR

### APPLICATION TO SELECTED ONTARIO WATERSHEDS

As outlined in earlier chapters, the impetus to develop such a policy oriented waste loading simulation model was the need to answer such basic questions as to whether Lake Huron and Lake Superior were likely to become polluted, and what the social, economic and limnological consequences of our choices would be.

To answer these questions, or at least provided the basis for them being answered, the model was used to simulate three sets of conditions, that is three possible futures. These are to: 1) maintain the degree of waste treatment at a base year (1973) level; 2) make several changes in various parts of society, the economy, in technological progress, as well as investing in waste treatment; and 3) attempt to match, in Canada, the stated U.S. intention to achieve a "zero discharge" policy by 1985 as legislated in Public Law 92-500.

Only two of these policies provided interesting results. As expected, the zero discharge scenario resulted in industrial waste loadings falling to zero in 1985 with the requisite need for enormous and increasing capital expenditures to maintain zero discharge. These sums of money (see Table 10.1) are annual investments which are required each year. From this point of view, the Canadian economy could not generate that type of investment, nor could it stand the inflation caused by it. For example, Federal government spending in 1974 was approximately 45 billion dollars, with GNP at over 140 billion dollars in current terms. In real terms,

these correspond to 26.8 and 89.4 billions, respectively, in 1961 dollars. By 1885, real GNP is projected to reach 143 billion dollars [19], whereas the total investment required for both lake basins is 6.5 billion dollars or 4.5 percent of real GNP. Please note that here we are only talking about Lake Huron and Lake Superior which are relatively clean in comparison to the Lower Great Lakes.

The first scenario, to maintain the level of waste treatment at 1973 levels, provides a situation in which a decision is made that an adequate level of effort is being made to fight water pollution and that no increase in effort is required. Thus, it is an attempt to maintain the status quo in terms of 1973 waste treatment. Tables 11 through 17 give the results of the model run for lake basins from 1974 to 2020 A.D.

The loads of three key substances, phosphorus, nitrogen and dissolved solids, are graphed for the Lake Superior Basin in Figures One, Two and Three. Beside each line corresponding to the first scenario is marked a (1) for identification. Each substance discharged by industrial polluters increases in value from its 1974 value as expansion of the economy, coupled with a set degree of treatment, cause waste loads to grow over the interval. Phosphorus increases from 1,157 metric tonnes per year in 1974 to 1,834 tonnes per year in 2020. Nitrogen increases from 97,911 tonnes in 1974 to 110,865 tonnes by 2020, while dissolved solids increase from 3.0 million tonnes in 1974 to 5.375 million tonnes by 2020. The annual investment in waste treatment increases from 1.8 million 1961 dollars to 15.7 million 1961 dollars for industrial treatment in the Lake Superior Basin. Because there is little in the way of population in the Upper Great Lakes Basin, municipal treatment investment does not climb much beyond the quarter-million mark per year.

The second scenario is one in which several factors are varied so as to allow waste loads to remain constant, or virtually constant, over time. In this scenario, urbanization rates are altered, as are the municipal and industrial waste coefficients and the desired treatment level for industry.

In Region 1 (Thunder Bay), the population is initially 115,748 and increases at 1.11 percent per year; Region 2 population starts at 26,391 and increases at the same rate as the first region. Region 3 begins with 6,417 inhabitants and grows at .99 percent per year. Like Regions 1 and 2, Regions 4 and 5 also grow at 1.11 percent per year but they have 261,304 and 407,120 inhabitants, respectively. Most slow growing is Region 7 with a growth rate of .64 percent per year. A full summary of the population projections used in the second scenario is shown in Table 18.

Tables 19 and 20 give the values for CHWFAC and CHMFAC, respectively. Table 21 shows the new values of the desired treatment level, DESTRL. In this scenario, CHWFAC has a value of zero from 1972 through 1976; in 1977, CHWFAC changes the waste loading coefficients by 2.061 percent. Each successive year, until 2020, the waste treatment coefficients improve by 2 percent of their value the previous year. Naturally, over the forecast horizon, 2 percent when compounded corresponds to over one hundred percent change in the waste discharge coefficients.

Similarly, CHMFAC, the change in the municipal waste loading coefficient, has a value of one (signifying no change) for the first five years. After 1977, CHMFAC first rises to 1.15, corresponding to a decrease

in the quality of waste discharges, and then decreases over the years to a value of 0.40.

The changes in both of these variables can be ascribed to disembodied technological progress, that is technological progress which is not ascribed to labour or capital but simply occurs. These changes in CHMFAC and CHWFAC represent major technological improvements in waste treatment technology at the rate of one percent to two percent per year over the forecast horizon.

The effects of such a policy can be seen in Tables 22 to 28 which show waste loads for the second scenario over the forecast horizon. Figures One, Two and Three show the loads of phosphorus, nitrogen and dissolved solids, graphed in relation to the waste loads from the first scenario. Investments for both scenarios are shown in Figures Four, Five and Six.

The effect of the changes with respect to the variables above results in substantial changes compared to the output from the first scenario. First, waste loads for all substances are reduced from their previous values, showing little if any growth over the forecast period. Second, because of decreased population growth (relative to the first scenario), and increased technological progress, the smaller waste loads generated resulted in decreased expenditures on pollution abatement of from fifty percent to sixty-six percent less than in corresponding periods of the previous scenario (see Table 29).

In many ways, the results shown here are exemplary of what can be done using the simulation model. In the first scenario, the input variables were set up and the run produced a set of waste loadings and

corresponding requisite expenditures. The second scenario attempts to keep the absolute waste loads constant over time. This is achieved through an iterative process of setting up the input variables, running the model and checking to see if the requisite output is produced. If it is not, the process is repeated until success is achieved. This procedure results from asking a question along the lines of — what must one do (in terms of adjusting policies) to achieve a given level of waste loadings?

Using these two types of analysis, one can see: a) the changes in output for given changes in input variables; or b) the changes in the input variables necessary to achieve a given state of the output variables. Naturally, b) can be achieved in many ways. It is the assessment of the viability of these alternatives that allows the formulation of sensible policy.

## CHAPTER FIVE

### CONCLUSIONS

This paper has attempted to present a large FORTRAN-based simulation model which was prepared during 1974 and 1975 to analyse the effects of population and economic activity upon the water quality of the Upper Lakes.

The model itself is interesting from several points of view. It is one of very few attempts at regional water quality modelling to account for social and economic variables in a meaningful way. It represents the state-of-the-art in computing terms with the combined use of a high-level language (FORTRAN) in conjunction with a data-base management system to store results, print reports, and allow direct accessing of the data-base, through time-sharing, to obtain information not available in the standard reports printed by the model. Finally, it produces results which are reliable, and consistent with intuitive reasoning and empirical observation.

The full set of results produced by the model cannot directly answer the question of whether the Upper Lakes are likely to become polluted. This answer must come from the limnologists who have the skills to interpret what the addition of waste loads of these magnitudes mean to the water quality of the Upper Great Lakes.

Thus, it is clear why the waste loading simulation model is such a key element in responding to questions on these serious matters, for, without knowledge of the future waste loads generated by human activities, the questions cannot be answered.

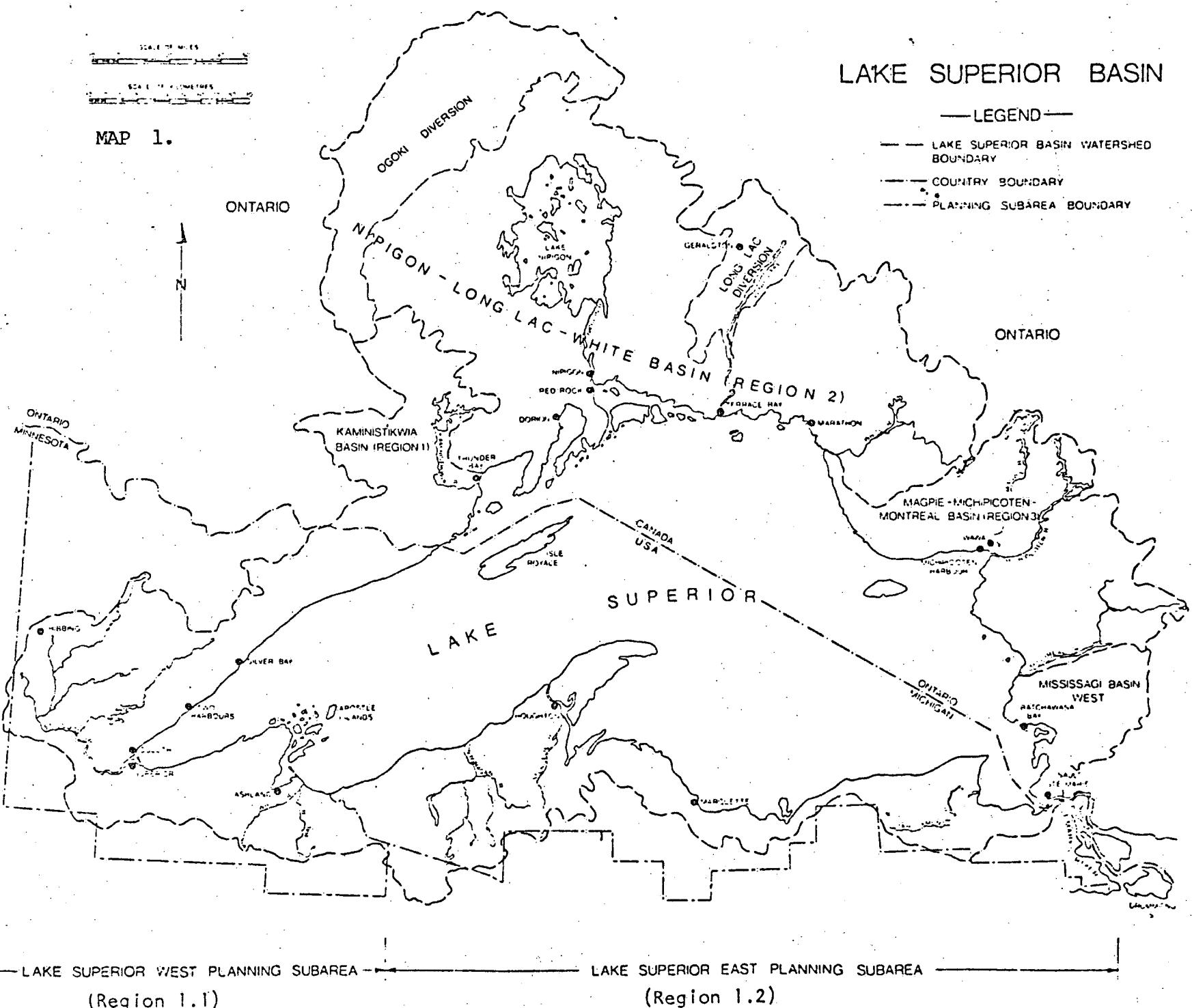
MAPS

# LAKE SUPERIOR BASIN

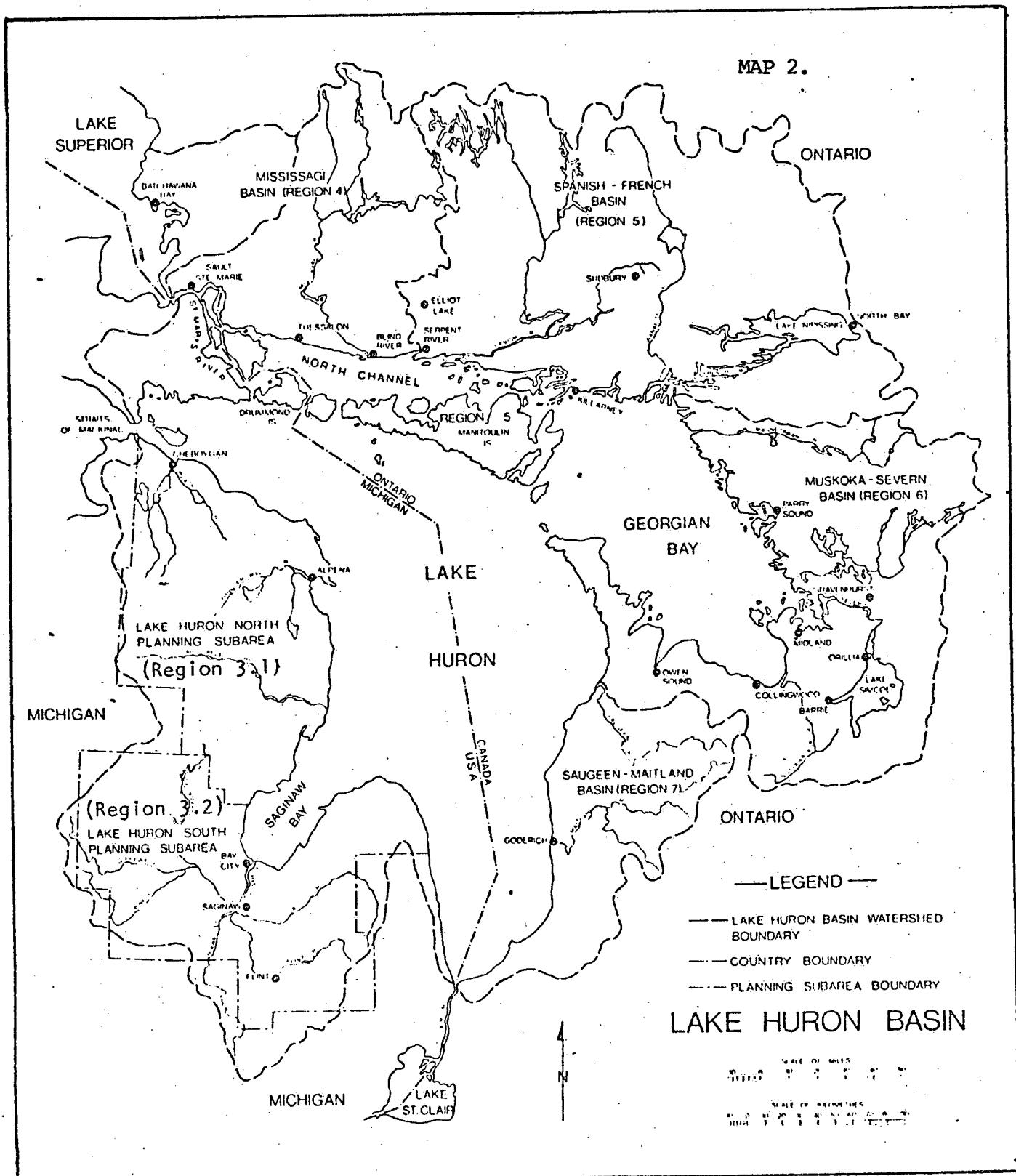
## —LEGEND—

- LAKE SUPERIOR BASIN WATERSHED BOUNDARY
- COUNTRY BOUNDARY
- - - PLANNING SUBAREA BOUNDARY

MAP 1.



MAP 2.



TABLES

TABLE I  
VALUE OF OUTPUT IN 1972  
(SELECTED INDUSTRY GROUPS)

	IN MILLIONS OF 1961 DOLLARS	
	Lake Superior Basin	Lake Huron Basin
Agriculture	1.430	35.153
Forestry	15.101	10.188
Mining	45.579	456.119
Manufacturing	320.095	1099.231
Construction	40.230	198.482

Source: C. A. Sonnen and P. M. Jacobson,  
"Estimates of Economic Activity in  
Regions of the Canadian Great Lakes  
Basin for the Period 1972 - 2020".  
Prepared for the Social Sciences Division,  
IWD - Ontario Region. Unpublished  
report. December 1974.

TABLE 2  
 VALUE OF OUTPUT IN 1972  
 FOR REGIONS OF THE LAKE SUPERIOR BASIN  
 (SELECTED INDUSTRY GROUPS)

IN MILLIONS OF 1961 DOLLARS AND AS PERCENT OF BASIN									
SIC Div	Name	Region 1 \$M	Region 1 (%)	Region 2 \$M	Region 2 (%)	Region 3 \$M	Region 3 (%)	Region 4 \$M	Region 4 (%)
1	Agriculture	0.665	(47.0)	0.064	(4.5)	0.000	(0.0)	0.701	(49.0)
2	Forestry	9.071	(60.1)	5.927	(39.2)	0.310	(2.0)	2.793	(18.5)
4	Mining	7.592	(16.7)	21.748	(47.7)	13.707	(30.1)	2.532	(5.6)
5	Manufacturing	124.600	(38.9)	33.115	(10.3)	0.405	(0.1)	161.975	(50.6)
6	Construction	21.615	(53.7)	2.772	(6.9)	0.770	(1.9)	15.073	(37.5)

Source: C. A. Sonnen and P. M. Jacobson, "Estimates of Economic Activity in Regions of the Canadian Great Lakes Basin for the Period 1972 - 2020". Prepared for the Social Sciences Division, IWD - Ontario Region. Unpublished report. December 1974.

TABLE 3  
 VALUE OF OUTPUT IN 1972  
 FOR REGIONS OF THE LAKE HURON BASIN  
 (SELECTED INDUSTRY GROUPS)

IN MILLIONS OF 1961 DOLLARS AND AS PERCENT OF BASIN							
SIC Div.	Name	Region 5 \$M	(%)	Region 6 \$M	(%)	Region 7 \$M	(%)
1	Agriculture	0.994	(2.8)	20.374	(58.0)	13.785	(39.2)
2	Forestry	6.620	(65.0)	2.534	(24.9)	1.034	(10.1)
4	Mining	404.626	(88.7)	37.165	(8.1)	14.328	(3.1)
5	Manufacturing	157.456	(14.3)	687.752	(62.6)	254.023	(23.1)
6	Construction	53.911	(27.2)	97.408	(49.1)	47.163	(23.8)

Source: C. A. Sonnen and P. M. Jacobson, "Estimates of Economic Activity in Regions of the Canadian Great Lakes Basin for the Period 1972 - 2020". Prepared for the Social Sciences Division, IWD - Ontario Region. Unpublished report. December 1974.

TABLE 4

RIVER BASINS WITH MEAN ANNUAL DISCHARGE EXCEEDING  
1000 CUBIC FEET/SECOND

---

Kaministikwia River  
Nipigon River  
Ogoki Diversion  
Long-lac Diversion  
White River  
Magpie River  
Montreal River  
Michipicoten River  
Mississagi River  
Spanish River  
Serpent River  
French River  
Muskoka River  
Severn River  
Saugeen River  
Maitland River

TABLE 5

RIVER BASIN GROUPS AND COMPONENT RIVER BASINS

RIVER NUMBER	BASIN GROUP NAME	COMPONENT RIVER BASINS
1	Kaministikwia	Kaministikwia River
2	Nipigon-Long lac	Ogoki Diversion Long-lac Diversion Nipigon River White River
3	Magpie-Montreal	Magpie River Montreal River Michipicoten River
4	Sault-Mississagi	Mississagi River
5	French-Spanish	French River Spanish River Serpent River
6	Muskoka-Georgian Bay	Muskoka River Severn River
7	Saugeen-Maitland	Saugeen River Maitland River

TABLE 6

REGIONAL ECONOMIC DISAGGREGATION  
BY S.I.C. GROUP

S.I.C.	NAME
Division 1	Agriculture
Division 2	Forestry
Division 3	Fisheries
Division 4	Mining
Major Group 1	Metal Mines
Major Group 2	Coal, Petroleum, Gas
Major Group 3, 4, 5	Non-Metal Mines
Division 5	Manufacturing
Major Group 1	Food Processing
Major Group 2	Tobacco
Major Group 3	Rubber
Major Group 4	Leather
Major Group 5	Textiles
Major Group 8	Wood
Major Group 9	Furniture
Major Group 10	Pulp and Paper
Major Group 12	Primary Metals
Major Group 13	Metal Fabricating
Major Group 14	Machinery
Major Group 15	Transport Equipment
Major Group 16	Electrical Products
Major Group 17	Non-Metal Minerals
Major Group 18	Petroleum and Coal
Major Group 19	Chemicals
Major Group 6, 7, 11, 20	Miscellaneous
Division 6	Construction
Division 7	Transportation & Utilities
Division 8	Trade
Division 9	Finance
Division 10	Services
Division 11	Public Administration

TABLE 7

MUNICIPAL RAW SEWAGE PRODUCTION COEFFICIENTS

(Lbs/Capita)

Phosphorus	2.0	Calcium	0.39
Nitrogen	9.0	Chromium	61.0
Dissolved Solids	200.0	Copper	0.52
Chloride	30.0	Fluoride	0.75
Silica	3.0	Iron	12.0
Suspended Solids	99.0	Lead	0.30
Oil	9.0	Magnesium	18.0
Sulphate	70.0	Manganese	19.0
NH <sub>3</sub>	5.6	Mercury	0.001
Rhenols	0.003	Nickel	0.28
Cyanide	0.180	Potassium	8.1
Aluminum	6.0	Sodium	64.0
Boron	0.0006	Titanium	0.0
Bromine	0.0	Zinc	0.78
Cadmium	0.02	BOD	99.0

TABLE 8

MUNICIPAL SEWAGE TREATMENT CAPACITY  
BY REGION AND TREATMENT TYPE

1972

BASIN	CAPACITY (M.G.D.)	PRIMARY	SECONDARY	TERTIARY
		(Percent of Basin)		
1	14.0	100.0	0.0	0.0
2	1.265	71.1	28.9	0.0
3	0.4	0.0	100.0	0.0
4	12.3	97.6	2.4	0.0
5	25.47	5.5	78.0	16.5
6	25.66	0.0	13.7	86.3
7	6.97	0.0	88.3	11.7

TABLE 9

RIVER BASIN POPULATION

YEAR	1	2	3	4	5	6	7
1972	115748.	26391.	6417.	102503.	261304.	407120.	167408.
1973	116255.	26515.	6500.	103825.	266158.	412598.	167971.
1974	116809.	26650.	6588.	105232.	271201.	418347.	168660.
1975	117406.	26795.	6681.	106716.	276415.	424347.	169466.
1976	118040.	26949.	6778.	108271.	281786.	430575.	170377.
1977	118706.	27111.	6880.	109890.	287298.	437012.	171385.
1978	119397.	27279.	6984.	111565.	292935.	443637.	172479.
1979	120110.	27452.	7092.	113290.	298682.	450428.	173648.
1980	120839.	27628.	7203.	115059.	304524.	457365.	174885.
1981	121578.	27808.	7316.	116863.	310444.	464427.	176177.
1982	122322.	27989.	7431.	118697.	316427.	471593.	177516.
1983	123066.	28170.	7547.	120552.	322458.	478843.	178891.
1984	123805.	28350.	7664.	122423.	328522.	486155.	180292.
1985	124533.	28528.	7781.	124303.	334601.	493508.	181710.
1986	125245.	28702.	7899.	126184.	340682.	500882.	183135.
1987	125935.	28872.	8017.	128060.	346748.	508256.	184556.
1988	126599.	29035.	8133.	129923.	352784.	515609.	185964.
1989	127231.	29191.	8249.	131767.	358775.	522920.	187348.
1990	127825.	29339.	8362.	133585.	364704.	530168.	188699.
1991	128377.	29477.	8474.	135370.	370556.	537333.	190007.
1992	128691.	29560.	8568.	136875.	375688.	543643.	190938.
1993	128963.	29633.	8660.	138347.	380750.	549873.	191826.
1994	129200.	29698.	8751.	139795.	385764.	556048.	192680.
1995	129408.	29757.	8841.	141226.	390754.	562192.	193510.
1996	129120.	29696.	8895.	142080.	394164.	566552.	193605.
1997	129337.	29758.	8987.	143559.	399336.	572894.	194489.
1998	129573.	29824.	9082.	145080.	404652.	579392.	195425.

TABLE 9  
CONTINUED

RIVER BASIN POPULATION

YEAR	1	2	3	4	5	6	7
1999	129828.	29896.	9180.	146641.	410109.	586044.	196409.
2000	130099.	29971.	9280.	148242.	415704.	592845.	197441.
2001	130386.	30051.	9383.	149881.	421435.	599792.	198517.
2002	130687.	30134.	9488.	151556.	427299.	606880.	199637.
2003	131001.	30220.	9595.	153266.	433293.	614106.	200797.
2004	131327.	30310.	9704.	155010.	439414.	621466.	201998.
2005	131662.	30401.	9815.	156786.	445660.	628956.	203235.
2006	132007.	30495.	9928.	158593.	452029.	636572.	204509.
2007	132359.	30590.	10043.	160428.	458516.	644311.	205816.
2008	132718.	30687.	10160.	162292.	465121.	652168.	207155.
2009	133081.	30784.	10278.	164182.	471839.	660140.	208524.
2010	133448.	30883.	10398.	166097.	478668.	668222.	209921.
2011	133817.	30981.	10519.	168035.	485606.	676412.	211344.
2012	134187.	31079.	10642.	169995.	492650.	684705.	212792.
2013	134557.	31177.	10766.	171976.	499796.	693097.	214262.
2014	134924.	31274.	10891.	173976.	507043.	701585.	215752.
2015	135289.	31369.	11017.	175994.	514388.	710164.	217262.
2016	135649.	31463.	11145.	178028.	521827.	718831.	218788.
2017	136004.	31555.	11273.	180077.	529359.	727582.	220329.
2018	136351.	31644.	11402.	182140.	536980.	736413.	221883.
2019	136690.	31731.	11532.	184214.	544688.	745321.	223448.
2020	137019.	31814.	11663.	186299.	552480.	754301.	225022.

TABLE 10

## INDUSTRIAL WASTE COEFFICIENTS

populn	2.7	15.0	220.0	30.0	5.5	72.0	9.0	25.0	8.5	0.01
	0.18	6.0	.0006	00.0	0.003	25.0	0.01	0.06	0.75	1.1
	0.05	7.5	0.07	.00015	0.01	4.1	21.0	0.0	0.1	65.0
agy	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
foy	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
fsy	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
miy	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
mi0ly	.00000441	.0142	.269	.0331	.0	.0383	.0763	.0452	.0235	.0
	.00118	.0	.0	.0	.0	.169	.0	.0000198	.0491	.0
	.0	.055	.00109	.00000191	.0000986	.0101	.0233	.0	.0000401	.0
mi02+03y	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
mi04y	.0000756	.00234	6.77	.0368	.0	.0596	.0448	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
may	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
ma0ly	.00207	.0869	.156	.0442	.0	.0611	.00408	.0188	.00678	.0
	.0	.0	.0	.0	.0	.000521	.0	.0	.0	.000272
	.0	.0028	.0	.0	.0	.0101	.0241	.0	.0	.138
ma02y	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

TABLE 10  
(continued)

mal7y	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
mal8y	.0000403	.25	13.0	.0125	.0	1.43	.361	.712	.00453	8.59
	.0	.0	.0	.0	.0	.063	.000164	.00501	.138	.000126
	.0	.098	.000701	.0	.000865	.0183	.482	.0	.0	.0157
mal9y	.0000803	.000104	.0577	.0144	.0	.00683	.000794	.27	.000321	.0000578
	.0	.000935	.0182	.0111	.0	.751	.0	.0000217	.000272	.00236
	.0000823	.093	.0000421	.00000845	.000065	.0	.0	.0	.0	.00318
671120y*	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
coy	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
uty+tsy	.0097376	.0455976	19.99585	.0589549	0.	.994751	.0015698	.0129263	0.	0.
	0.	.0000385	0.	.0000385	.0000057	0.	.0000038	.0000035	.0001453	.0000162
	.0000004	0.	.0000038	.0000004	0.	0.	0.	0.	0.	.0115009
try	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
fiy	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
csy	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
ady	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
tey	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

TABLE 10  
(continued)

ma03y	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
ma04y	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
ma05y	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
ma08y	.000000082	.00000899	.000339	.000013	.0	.00148	.000152	.0	.0	.000000644
	.0	.0	.0	.0	.0	.0	.0	.000334	.0	.0
	.0	.0	.0	.0	.000111	.0	.0	.0	.000297	.0
ma09y	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
101+102	.00217	.109	8.33	.387	.0	.495	.0362	4.4	.728	.000343
	.00000611	.0	.0	.00399	.0	.230	.000184	.0000336	.0	.0138
	.000184	0.0	.0000061	.00000119	.00184	0.0	.285	0.0	.000571	2.15
mal2y	.00182	.0411	.493	.0368	0.0	.0398	2.6	.00378	.000446	.00257
	.0000001	.00049	.0	.0	.0	.0	.0	.0000984	.000116	.0164
	.0	.0	.000344	.00000328	.000746	.0107	.0188	.0	.000594	.0284
mal3y	.00000728	.00107	.000117	.0000518	.0	.0567	.00234	.00103	.000964	.0
	.0000001	.00000046	.00000964	.00825	0.0	.00473	0.0	.00000246	0.0	.000046
	.0000002	.00141	.0	.0000001	.0000021	.0	.0	.0000487	.0000061	.000122
mal4y	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
mal5y	.00000601	.0000483	.00366	.466	.0	.00947	.000185	.00201	.00000407	.000000872
	.00000107	.0000198	.0	.0	.0	.0	.00000581	.000000388	.0000218	.0000466
	.0000914	.0	.00000213	.0	.000000698	.0	.827	.0	.000000678	.000245
mal6y	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

TABLE 10.1

ENVIRONMENT CANADA. INLAND WATERS DIRECTORATE, ONTARIO REGION.  
 UPPER LAKES REFERENCE GROUP  
 WASTELOADING SIMULATION MODEL

DATE 04/20/76

ECONOMIC SUMMARY  
 CAPITAL INVESTMENT ONLY  
 SYNERGISTIC SCENARIO  
 1961 CONSTANT DOLLARS

## CANADA

151

YEAR	LAKE SUPERIOR				LAKE HURON			
	INDUSTRIAL	MUNICIPAL	INDUSTRIAL	MUNICIPAL	ITMI01	ITMI03	MTMI01	MTMI03
1974.	\$1,882,528	\$1,882,528	\$210,939	\$210,939	\$4,587,481	\$4,587,481	\$508,824	\$508,824
1980.	\$2,254,356	\$2,667,256	\$230,006	\$1,689,447	\$4,450,738	\$5,258,881	\$619,756	\$1,644,162
1985.	\$2,817,921	\$3,050,397	\$245,911	\$266,719	\$5,269,830	\$5,700,114	\$868,150	\$717,392
1990.	\$2,199,387	\$2,429,205	\$252,214	\$1,222,439	\$4,899,723	\$5,406,001	\$972,796	\$746,614
2000.	\$2,570,013	\$2,953,097	\$252,819	\$887,243	\$6,245,292	\$7,168,260	\$1,085,835	\$904,959
2010.	\$3,328,839	\$3,980,255	\$287,075	\$731,195	\$8,474,368	\$10,117,391	\$1,356,942	\$1,233,627
2020.	\$4,688,702	\$5,833,737	\$319,106	\$571,010	\$12,230,924	\$15,187,308	\$1,999,397	\$857,690

UPPER LAKES REFERENCE GROUP  
WASTELOADING SIMULATION MODEL  
CANADA

PAGE 1

## LAKE LOADINGS SUMMARY. 1973 TREATMENT EFFORT

LOADINGS FOR 1974. IN METRIC TONNES.

PARAMETER	LAKE SUPERIOR			LAKE HURON				
	MUNICIPAL	INDUSTRIAL	TOTAL	CALIBRATED TOTAL	MUNICIPAL	INDUSTRIAL	TOTAL	CALIBRATED TOTAL
PHOSPHORUS	172	114	285	1,157	169	279	449	3,083
NITROGEN	1,123	2,388	3,510	97,911	1,436	10,412	11,848	20,913
DISS SOLID	19,828	440,561	460,388	3,012,698	24,949	717,772	742,720	3,604,189
CHLORIDE	2,705	2,784	5,489	233,666	3,487	75,352	78,838	227,591
SILICA	411	2,379	2,790	153,461	453	27,478	27,930	89,975
SUSP SOLID	3,263	29,286	32,549	307,265	4,549	55,407	59,955	211,113
OIL	144	177,183	177,327	0	526	184,631	185,158	0
SULPHUR	2,254	6,411	8,664	310,542	2,849	65,388	68,237	609,923
NH3	767	34,075	34,842	6,650	1,627	21,405	23,033	1,246
PHENOL	1	189	190	364	2	201	203	121
CYANIDE	16	19	35	990	34	31	65	263
ALUMINUM	541	681	1,222	26,145	1,149	266	1,415	3,569
DOPON	0	23	23	0	0	1,061	1,061	0
BROMINE	0	14	14	0	0	646	646	0
CAIUM	0	1	1	273	0	14	14	541
CALCIUM	2,255	12,454	14,710	179,069	4,787	95,373	100,160	3,223,463
CHROMIUM	1	13	14	848	1	99	101	322
COPPER	5	16	22	345,088	5	14	19	2,076
FLUORIDE	68	61	129	2,537	144	377	521	5,406
IRON	83	1,346	1,428	12,500	98	3,034	3,133	10,272
LEAD	4	3	7	1,382	4	30	34	2,263
MAGNESIUM	677	1,557	2,233	132,139	871	16,736	17,609	162,988
MANGANESE	6	21	27	5,760	14	264	277	1,288
MERCURY	0	0	0	4	0	1	1	2
NICKEL	1	58	58	1,493	1	95	96	3,374
POTASSIUM	370	1,267	1,636	75,574	785	12,180	12,965	32,922
SODIUM	1,894	24,394	26,287	146,840	4,021	75,789	79,810	199,102
TITANIUM	0	703	703	0	0	208	208	0
ZINC	9	59	68	498	10	89	99	2,150
BOD	5,863	99,001	104,864	171,469	12,446	40,567	53,013	62,000

TABLE 11

UPPER LAKES REFERENCE GROUP  
WASTELOADING SIMULATION MODEL  
CANADA

PAGE 2

## LAKE LOADINGS SUMMARY, 1973 TREATMENT EFFORT

LOADINGS FOR 1980, IN METRIC TONNES.

## LAKE SUPERIOR

## LAKE KUROK

PARAMETER	MUNICIPAL	INDUSTRIAL	TOTAL	CALIBRATED TOTAL	MUNICIPAL	INDUSTRIAL	TOTAL	CALIBRATED TOTAL
PHOSPHORUS	185	157	341	1,212	195	379	574	3,208
NITROGEN	1,208	3,213	4,421	98,822	1,610	13,509	15,129	24,195
DISS SOLID	21,335	613,763	635,098	3,187,408	28,178	1,009,874	1,038,051	3,899,519
CHLORIDE	2,912	3,805	6,717	234,894	3,935	105,827	109,762	258,515
SILICA	443	3,340	3,783	154,453	516	38,675	39,190	101,236
SUSP SOLID	3,505	40,362	43,867	318,583	5,240	73,490	78,730	229,887
OIL	154	256,032	256,186	78,858	607	266,787	267,395	82,237
SULPHUR	2,425	8,897	11,321	313,199	3,218	92,183	95,400	637,087
NH3	825	47,313	48,137	19,947	1,791	29,770	31,561	9,774
PHENOL	1	273	274	447	2	290	292	210
CYANIDE	17	28	45	999	38	43	82	280
ALUMINUM	582	945	1,527	26,451	1,265	372	1,635	3,789
BORON	0	33	33	10	0	1,501	1,501	441
BRONINE	0	20	20	6	0	915	915	268
CAIUM	0	1	2	273	0	21	21	547
CALCIUM	2,426	17,252	19,678	184,037	5,267	133,136	138,403	3,261,706
CHROMIUM	1	17	18	852	1	139	140	362
COPPER	5	22	28	345,094	5	19	25	2,083
FLUORIDE	73	88	161	2,569	158	535	694	5,579
IRON	89	1,932	2,021	13,092	112	4,331	4,443	11,582
LEAD	4	4	8	1,382	5	42	42	2,276
MAGNESIUM	728	2,175	2,903	132,809	984	23,543	24,527	169,907
MANGANESE	7	29	35	5,769	14	373	388	1,398
MERCURY	0	0	0	4	0	1	1	2
NICKEL	1	82	83	1,517	1	135	137	3,416
POTASSIUM	398	1,766	2,164	76,100	864	17,043	17,907	37,864
SODIUM	2,038	33,895	35,932	156,484	4,424	107,029	111,453	230,745
TITANIUM	0	976	976	273	0	289	289	81
ZINC	10	84	93	522	12	126	137	2,188
BOU	6,308	137,402	143,710	210,316	13,694	55,632	69,326	78,313

TABLE 12

UPPER LAKES REFERENCE GROUP  
WASTELOADING SIMULATION MODEL  
CANADA

PAGE 3

## LAKE LOADINGS SUMMARY, 1973 TREATMENT EFFORT

LOADINGS FOR 1985. IN METRIC TONNES.

## LAKE SUPERIOR

## LAKE HURON

PARAMETER	MUNICIPAL	INDUSTRIAL	TOTAL	CALIBRATED TOTAL	MUNICIPAL	INDUSTRIAL	TOTAL	CALIBRATED TOTAL
PHOSPHORUS	196	208	403	1,274	220	479	698	3,332
NITROGEN	1,283	4,141	5,424	99,824	1,808	16,768	18,577	27,643
DISS SOLID	22,682	815,049	837,731	3,390,041	31,387	1,299,205	1,330,592	4,192,060
CHLORIDE	3,095	4,879	7,974	236,151	4,382	134,489	138,871	287,624
SILICA	471	4,367	4,837	155,507	576	50,388	50,965	113,010
SUSP SOLID	3,715	53,100	56,895	331,611	5,878	92,382	98,260	249,417
OIL	162	331,525	331,687	154,359	682	345,299	345,981	160,823
SULPHUR	2,578	11,726	14,304	316,183	3,584	117,435	121,012	662,705
NH3	877	63,116	63,993	35,802	1,992	39,198	41,189	19,402
PHEOL	1	354	355	528	3	374	377	294
CYANIDE	19	36	55	1,009	42	56	98	297
ALUMINUM	619	1,263	1,882	26,805	1,406	491	1,896	4,050
BORON	0	42	42	19	0	1,921	1,921	860
DRUGINE	0	26	26	12	0	1,171	1,171	525
CALCIUM	0	2	2	274	0	26	27	553
CALCIUM	2,579	22,602	25,181	189,540	5,857	170,610	176,468	3,299,771
CHROMIUM	1	23	23	858	2	176	178	400
COPPER	6	28	33	345,100	6	24	31	2,088
FLUORIDE	77	114	192	2,600	176	683	859	5,745
IRON	95	2,513	2,607	13,678	125	5,556	5,681	12,821
LEAD	5	4	10	1,384	5	54	60	2,289
MAGNESIUM	774	2,851	3,625	133,531	1,095	30,445	31,541	176,920
MANGANESE	7	38	45	5,778	16	482	499	1,508
MERCURY	0	0	0	4	0	2	2	2
NICKEL	1	106	107	1,542	2	175	176	3,454
POTASSIUM	423	2,303	2,726	76,664	960	21,923	22,883	42,840
SODIUM	2,166	45,132	47,299	167,851	4,920	137,027	141,947	261,239
TITANIUM	0	1,303	1,303	600	0	386	386	178
ZINC	10	109	119	547	13	162	175	2,225
DOU	6,706	183,290	189,996	256,602	15,229	72,940	88,169	97,156

TABLE 13

UPPER LAKES REFERENCE GROUP  
WASTELOADING SIMULATION MODEL  
CANADA

PAGE 4

## LAKE LOADINGS SUMMARY, 1973 TREATMENT EFFORT

LOADINGS FOR 1990. IN METRIC TONNES.

## LAKE SUPERIOR

## LAKE HURON

PARAMETER	MUNICIPAL	INDUSTRIAL	TOTAL	CALIBRATED TOTAL	MUNICIPAL	INDUSTRIAL	TOTAL	CALIBRATED TOTAL
PHOSPHORUS	207	243	450	1,320	244	585	829	3,462
NITROGEN	1,356	4,918	6,274	100,675	2,017	20,361	22,377	31,442
DISS SOLID	24,004	952,815	976,819	3,529,129	34,831	1,572,004	1,606,835	4,468,303
CHLOPIDE	3,276	5,887	9,163	237,340	4,863	166,390	171,253	320,006
SILICA	498	5,350	5,847	156,518	640	62,024	62,664	124,709
SUSP SOLID	3,918	62,400	66,317	341,033	6,529	111,757	118,285	269,442
OIL	168	400,658	400,826	223,499	759	417,541	418,299	233,141
SULPHUR	2,728	13,833	16,561	318,440	3,977	146,467	150,444	692,131
NH3	928	73,517	74,444	46,254	2,237	46,939	49,175	27,348
PHENOL	1	426	427	601	3	454	456	374
CYANUUE	20	43	63	1,017	48	68	116	314
ALUMINUM	655	1,468	2,123	27,046	1,579	585	2,164	4,317
BORON	0	54	55	32	0	2,475	2,475	1,414
BRONITE	0	33	33	19	0	1,508	1,508	862
CADMUM	0	2	3	274	1	32	33	559
CALCIUM	2,730	26,903	29,633	193,991	6,577	212,602	219,178	3,342,481
CHROMIUM	1	27	27	862	2	212	213	435
COPFER	6	32	39	345,105	7	30	36	2,094
FLUORICE	82	136	220	2,628	197	843	1,040	5,926
IRON	100	3,021	3,121	14,192	139	6,837	6,976	14,116
LEAD	5	5	11	1,305	6	68	74	2,302
MAGNESIUM	819	3,452	4,271	134,177	1,216	38,110	39,325	184,705
MANGANESE	7	45	53	5,786	18	595	613	1,624
MERCURY	0	0	0	4	0	2	2	3
NICKEL	1	128	129	1,563	2	213	215	3,493
POTASSIUM	447	2,778	3,226	77,163	1,078	27,123	28,202	48,159
SCLIUM	2,293	52,694	54,987	175,539	5,525	170,205	175,730	295,021
TITANIUM	0	1,515	1,515	812	0	449	449	240
ZINC	11	129	140	568	14	196	211	2,261
BCD	7,097	213,258	220,355	286,961	17,101	85,913	103,014	112,001

TABLE 14

UPPER LAKES REFERENCE GROUP  
WASTELOADING SIMULATION MODEL  
CANADA

PAGE 5

LAKE LOADINGS SUMMARY, 1973 TREATMENT EFFORT  
LOADINGS FOR 2000. IN METRIC TONNES.

PARAMETER	LAKE SUPERIOR			LAKE HURON				
	MUNICIPAL	INDUSTRIAL	TOTAL	CALIBRATED TOTAL	MUNICIPAL	INDUSTRIAL	TOTAL	CALIBRATED TOTAL
PHOSPHORUS	223	331	554	1,425	292	845	1,137	3,770
NITROGEN	1,466	6,849	8,315	102,715	2,419	28,980	31,399	40,465
DISS SOLID	25,979	1,304,032	1,330,011	3,882,321	41,472	2,254,578	2,296,050	5,157,518
CHLORIDE	3,545	8,434	11,979	240,156	5,789	245,246	251,035	399,788
SILICA	537	8,189	8,727	159,397	764	94,961	95,725	157,771
SUSP SOLID	4,213	65,767	89,981	364,697	7,812	159,013	166,824	317,082
OIL	177	592,573	592,750	415,422	910	617,853	618,763	433,605
SULPHUR	2,953	19,159	22,112	323,990	4,735	218,120	222,854	764,541
NH3	1,004	100,007	101,012	72,821	2,699	68,108	70,807	49,019
PHENOL	1	626	627	801	4	670	674	591
CYANIDE	22	65	86	1,040	58	102	156	356
ALUMINUM	709	1,986	2,696	27,618	1,905	822	2,727	4,881
BORON	0	85	85	61	0	3,842	3,843	2,782
CHROMIUM	0	51	51	37	0	2,343	2,343	1,696
CAIDIUM	0	4	4	275	1	49	50	576
CALCIUM	2,955	38,196	41,151	205,510	7,938	322,376	330,314	3,453,617
CHROMIUM	1	38	39	873	2	310	311	534
COPPER	7	45	52	345,119	8	42	50	2,109
FLUORIDE	88	203	291	2,699	239	1,244	1,482	6,367
IRON	108	4,414	4,522	15,593	166	10,136	10,301	17,441
LEAD	6	7	14	1,388	7	100	107	2,336
MAGNESIUM	886	5,088	5,973	135,880	1,447	58,538	59,985	205,365
MANGANESE	8	68	76	5,809	23	898	921	1,031
MERCURY	0	0	0	4	0	4	4	4
NICKEL	1	188	189	1,624	2	317	319	3,597
POTASSIUM	484	4,067	4,551	78,489	1,302	40,882	42,183	62,140
SODIUM	2,482	71,800	74,363	194,914	6,668	252,487	259,155	378,446
TITANIUM	0	2,049	2,049	1,346	0	607	607	399
ZINC	12	181	193	622	16	287	304	2,354
BOU	7,681	289,185	296,867	363,473	20,639	118,442	139,082	148,068

TABLE 15

## ENVIRONMENT CANADA. INLAND WATERS DIRECTORATE, ONTARIO REGION.

DATE 03/11/76  
TIME 09:57:44UPPER LAKES REFERENCE GROUP  
WASTELOADING SIMULATION MODEL  
CANADA

PAGE 6

## LAKE LOADINGS SUMMARY, 1973 TREATMENT EFFORT

LOADINGS FOR 2010. IN METRIC TONNES.

## LAKE SUPERIOR

## LAKE HURON

PARAMETER	MUNICIPAL	INDUSTRIAL	TOTAL	CALIBRATED TOTAL	MUNICIPAL	INDUSTRIAL	TOTAL	CALIBRATED TOTAL
PHOSPHORUS	243	469	712	1,582	351	1,238	1,590	4,224
NITROGEN	1,601	9,788	11,390	105,791	2,920	41,548	44,468	53,534
DISS SOLID	28,417	1,854,211	1,882,626	4,434,936	49,765	3,293,512	3,343,278	6,204,747
CHLORIDE	3,878	12,381	16,259	244,436	6,945	366,493	373,438	522,191
SILICA	587	13,050	13,637	164,308	920	150,666	151,586	213,631
SUSP SOLID	4,579	122,210	126,788	401,504	9,421	229,550	238,971	390,128
OIL	188	916,958	917,146	739,819	1,099	956,155	957,253	772,096
SULPHUR	3,229	27,508	30,738	332,617	5,682	329,451	335,133	876,820
NH3	1,099	141,576	142,675	114,484	3,270	103,036	106,305	84,518
PHENOL	1	963	965	1,139	4	1,035	1,039	957
CYANIDE	23	100	123	1,077	69	155	224	422
ALUMINUM	776	2,795	3,571	28,494	2,308	1,193	3,501	5,655
BORON	0	132	132	109	0	6,016	6,016	4,954
BRONINE	0	81	81	67	0	3,667	3,667	3,020
CALCIUM	0	5	5	277	1	77	78	604
CALCIUM	3,232	56,580	59,812	224,171	9,617	503,407	513,023	3,636,327
CHROMIUM	1	58	58	893	3	485	488	709
COPPER	8	67	75	345,141	10	64	74	2,131
FLUORIDE	97	310	407	2,815	289	1,870	2,158	7,043
IRON	118	6,744	6,862	17,933	199	15,419	15,618	22,757
LEAD	6	11	17	1,391	9	149	158	2,387
MAGNESIUM	969	7,784	8,753	138,660	1,736	92,169	93,905	239,285
MANGANESE	9	104	113	5,847	27	1,396	1,423	2,433
MERCURY	0	0	0	4	0	4	5	5
NICKEL	1	289	291	1,725	3	487	490	3,767
POTASSIUM	530	6,187	6,717	80,654	1,577	63,184	64,761	84,718
SODIUM	2,714	101,930	104,644	225,196	8,078	380,483	388,562	507,853
TITANIUM	0	2,884	2,884	2,181	0	854	854	646
ZINC	13	267	280	708	20	432	452	2,503
BOU	8,402	407,846	416,249	482,855	25,004	168,651	193,655	202,642

TABLE 16

UPPER LAKES REFERENCE GROUP  
WASTELOADING SIMULATION MODEL  
CANADA

PAGE 7

## LAKE LOADINGS SUMMARY: 1973 TREATMENT EFFORT

LOADINGS FOR 2020, IN METRIC TONNES.

PARAMETER	LAKE SUPERIOR				LAKE HURON			
	MUNICIPAL	INDUSTRIAL	TOTAL	CALIBRATED TOTAL	MUNICIPAL	INDUSTRIAL	TOTAL	CALIBRATED TOTAL
PHOSPHORUS	266	700	967	1,838	427	1,887	2,314	4,948
NITROGEN	1,757	14,706	16,464	110,864	3,584	61,818	65,402	74,468
DISS SOLID	31,234	2,792,005	2,823,239	5,375,549	60,505	5,003,948	5,064,453	7,925,921
CHLORIDE	4,262	19,028	23,290	251,467	8,444	567,763	576,207	724,960
SILICA	644	21,744	22,388	173,058	1,120	249,455	250,574	312,620
SUSP SOLID	5,000	184,244	189,245	463,961	11,457	345,418	356,875	508,033
OIL	201	1,504,538	1,504,738	1,327,411	1,339	1,568,480	1,569,819	1,384,661
SULPHUR	3,550	41,799	45,348	347,227	6,907	518,731	525,639	1,067,325
NH3	1,208	212,534	213,742	185,550	4,073	164,320	168,393	146,606
PHENOL	2	1,572	1,573	1,748	4	1,690	1,695	1,613
CYANIDE	25	163	189	1,143	86	249	336	534
ALUMINUM	892	4,172	5,026	29,948	2,876	1,837	4,712	6,866
BORON	0	218	218	194	0	9,911	9,912	8,851
BRONINE	0	133	133	119	0	6,042	6,042	5,395
CADMIUM	0	8	9	281	1	127	127	653
CALCIUM	3,552	88,898	92,450	256,809	11,980	829,364	841,344	3,964,648
CHROMIUM	1	95	95	930	3	814	817	1,040
COPPER	8	104	113	345,179	13	101	113	2,171
FLUORIDE	106	503	610	3,018	359	2,925	3,285	8,170
IRON	130	10,934	11,063	22,135	242	24,580	24,822	31,061
LEAD	7	16	23	1,398	11	233	244	2,472
MAGNESIUM	1,066	12,534	13,600	143,507	2,111	152,166	154,276	299,656
MANGANESE	10	171	181	5,914	33	2,259	2,292	3,303
MERCURY	0	1	1	4	0	8	8	8
NICKEL	2	472	473	1,907	3	787	791	4,069
POTASSIUM	582	9,913	10,495	84,433	1,965	101,920	103,883	123,840
SODIUM	2,984	153,208	156,191	276,744	10,063	597,676	607,739	727,031
TITANIUM	0	4,302	4,302	3,599	0	1,274	1,274	1,066
ZINC	14	419	433	861	24	681	706	2,756
EDD	9,236	609,957	619,194	685,799	31,146	253,376	284,523	293,510

TABLE 17

TABLE 18  
BASIN POPULATION  
SYNERGISTIC SCENARIO

YEAR	1	2	3	4	5	6	7
1972	115748.	26391.	6417.	102503.	261304.	407120.	167408.
1973	117033.	26684.	6481.	103641.	264204.	410621.	168479.
1974	118332.	26980.	6545.	104791.	267137.	414153.	169558.
1975	119645.	27280.	6609.	105954.	270102.	417714.	170643.
1976	120973.	27582.	6675.	107130.	273100.	421307.	171735.
1977	122316.	27889.	6741.	108320.	276132.	424930.	172834.
1978	123674.	28198.	6808.	109522.	279197.	428584.	173940.
1979	125047.	28511.	6875.	110738.	282296.	432270.	175053.
1980	126435.	28828.	6943.	111967.	285430.	435988.	176174.
1981	127838.	29148.	7012.	113210.	288598.	439737.	177301.
1982	129257.	29471.	7081.	114466.	291801.	443519.	178436.
1983	130692.	29798.	7151.	115737.	295040.	447333.	179578.
1984	132143.	30129.	7222.	117022.	298315.	451180.	180727.
1985	133609.	30463.	7294.	118320.	301626.	455060.	181884.
1986	135092.	30802.	7366.	119634.	304975.	458974.	183048.
1987	136592.	31144.	7439.	120962.	308360.	462921.	184220.
1988	138108.	31489.	7513.	122304.	311783.	466902.	185399.
1989	139641.	31839.	7587.	123662.	315243.	470917.	186585.
1990	141191.	32192.	7662.	125035.	318743.	474967.	187779.
1991	142758.	32549.	7738.	126423.	322281.	479052.	188981.
1992	144343.	32911.	7814.	127826.	325858.	483172.	190190.
1993	145945.	33276.	7892.	129245.	329475.	487327.	191408.
1994	147565.	33645.	7970.	130679.	333132.	491518.	192633.
1995	149203.	34019.	8049.	132130.	336830.	495745.	193866.
1996	150859.	34397.	8129.	133597.	340569.	500009.	195106.
1997	152534.	34778.	8209.	135079.	344349.	504309.	196355.
1998	154227.	35164.	8290.	136579.	348171.	508646.	197612.
1999	155939.	35555.	8372.	138095.	352036.	513020.	198876.
2000	157670.	35949.	8455.	139628.	355944.	517432.	200149.
2001	159420.	36348.	8539.	141178.	359894.	521882.	201430.
2002	161190.	36752.	8623.	142745.	363889.	526370.	202719.
2003	162979.	37160.	8709.	144329.	367928.	530897.	204017.
2004	164788.	37572.	8795.	145931.	372012.	535463.	205322.

TABLE 18  
(continued)

YEAR	1	2	3	4	5	6	7
2005	166617.	37989.	8882.	147551.	376142.	540068.	206636.
2006	168466.	38411.	8970.	149189.	380317.	544712.	207959.
2007	170336.	38837.	9059.	150845.	384539.	549397.	209290.
2008	172227.	39268.	9149.	152519.	388807.	554122.	210629.
2009	174139.	39704.	9239.	154212.	393123.	558887.	211977.
2010	176072.	40145.	9331.	155924.	397486.	563693.	213334.
2011	178026.	40591.	9423.	157655.	401898.	568541.	214699.
2012	180002.	41041.	9516.	159405.	406359.	573431.	216073.
2013	182000.	41497.	9610.	161174.	410870.	578362.	217456.
2014	184020.	41957.	9706.	162963.	415431.	583336.	218848.
2015	186063.	42423.	9802.	164772.	420042.	588353.	220249.
2016	188128.	42894.	9899.	166601.	424704.	593413.	221658.
2017	190217.	43370.	9997.	168450.	429419.	598516.	223077.
2018	192328.	43852.	10096.	170320.	434185.	603663.	224504.
2019	194463.	44338.	10196.	172211.	439005.	608855.	225941.
2020	196621.	44830.	10297.	174122.	443878.	614091.	227387.

TABLE 19

MUNICIPAL CHANGE FACTORS  
SYNERGISTIC SCENARIO

1972	chmfac	1.0
1973		1.0
1974		1.0
1975		1.0
1976		1.0
1977		1.08
1978		1.1
1979		1.13
1980		1.15
1981		1.14
1982		1.13
1983		1.11
1984		1.1
1985		1.09
1986		1.07
1987		1.06
1988		1.05
1989		1.04
1990		1.03
1991		1.01
1992		0.99
1993		0.97
1994		0.94
1995		0.92
1996		0.89
1997		0.87
1998		0.85
1999		0.83
2000		0.81
2001		0.79
2002		0.78
2003		0.76
2004		0.74
2005		0.72
2006		0.70
2007		0.68
2008		0.66
2009		0.64
2010		0.62
2011		0.60
2012		0.57
2013		0.55
2014		0.53
2015		0.51
2016		0.48
2017		0.46
2018		0.44
2019		0.42
2020		0.40

TABLE 20

INDUSTRIAL CHANGE FACTORS  
SYNERGISTIC SCENARIO

1972	chwfac	0.0
1973		0.0
1974		0.0
1975		0.0
1976		0.0
1977	chwfac	0.02061
1978		0.02061
1979	chwfac	0.02061
1980		0.02061
1981	chwfac	0.02061
1982		0.02061
1983	chwfac	0.02061
1984		0.02061
1985	chwfac	0.02061
1986		0.02061
1987	chwfac	0.02061
1988		0.02061
1989	chwfac	0.02061
1990		0.02061
1991	chwfac	0.02061
1992		0.02061
1993	chwfac	0.02061
1994		0.02061
1995	chwfac	0.02061
1996		0.02061
1997	chwfac	0.02061
1998		0.02061
1999	chwfac	0.02061
2000		0.02061
2001	chwfac	0.02061
2002		0.02061
2003	chwfac	0.02061
2004		0.02061
2005	chwfac	0.02061
2006		0.02061
2007	chwfac	0.02061
2008		0.02061
2009	chwfac	0.02061
2010		0.02061
2011	chwfac	0.02061
2012		0.02061
2013	chwfac	0.02061
2014		0.02061
2015	chwfac	0.02061
2016		0.02061
2017	chwfac	0.02061
2018		0.02061
2019	chwfac	0.02061
2020		0.02061

TABLE 21

## **DESIRED TREATMENT LEVEL SYNERGISTIC SCENARIO**

UPPER LAKES REFERENCE GROUP  
WASTELOADING SIMULATION MODEL  
CANADA

PAGE 1

## LAKE LOADINGS SUMMARY, SYNERGISTIC SCENARIO

LOADINGS FOR 1974. IN METRIC TONNES.

## LAKE SUPERIOR

## LAKE HURON

PARAMETER	MUNICIPAL	INDUSTRIAL	TOTAL	CALIBRATED TOTAL	MUNICIPAL	INDUSTRIAL	TOTAL	CALIBRATED TOTAL
PHOSPHORUS	172	114	285	1,157	169	279	449	3,083
NITROGEN	1,123	2,380	3,510	97,911	1,436	10,412	11,848	20,913
DISS SOLID	19,628	440,561	460,388	3,012,693	24,949	717,772	742,720	3,604,189
CHLORIDE	2,705	2,784	5,489	233,666	3,487	75,352	78,838	227,501
SILICA	411	2,379	2,790	153,461	453	27,478	27,930	89,975
SUSP SOLID	3,263	29,286	32,549	307,265	4,549	55,407	59,955	211,113
OIL	144	177,183	177,327	0	526	184,631	185,158	0
SULPHUR	2,254	6,411	8,664	310,542	2,849	65,388	68,237	609,923
NH3	767	34,075	34,842	6,650	1,627	21,405	23,033	1,246
PHENOL	1	189	190	364	2	201	203	121
CYANIDE	16	19	35	990	34	31	65	263
ALUMINUM	541	681	1,222	26,145	1,149	266	1,415	3,569
BORON	0	23	23	0	0	1,061	1,061	0
BRONMINE	0	14	14	0	0	646	646	0
CALCIUM	0	1	1	273	0	14	14	541
CALCIUM	2,255	12,454	14,710	179,069	4,787	95,373	100,160	3,223,463
CHROMIUM	1	13	14	849	1	99	101	322
COPPER	5	16	22	345,088	5	14	19	2,076
FLUORIDE	68	61	129	2,537	144	377	521	5,406
IRON	83	1,346	1,428	12,500	98	3,034	3,133	10,272
LEAD	4	3	7	1,382	4	30	34	2,263
MAGNESIUM	677	1,557	2,233	132,139	871	16,736	17,609	162,988
MANGANESE	6	21	27	5,760	14	264	277	1,288
MERCURY	0	0	0	4	0	1	1	2
NICKEL	1	58	58	1,493	1	95	96	3,374
POTASSIUM	370	1,267	1,636	75,574	785	12,180	12,965	32,922
SODIUM	1,894	24,594	26,287	146,840	4,021	75,789	79,810	199,102
TITANIUM	0	703	703	0	0	208	208	0
ZINC	9	59	68	498	10	89	99	2,150
BOD	5,803	99,001	104,864	171,469	12,446	40,567	53,013	62,000

TABLE 22

UPPER LAKES REFERENCE GROUP  
WASTELOADING SIMULATION MODEL  
CANADA

PAGE 2

## LAKE LOADINGS SUMMARY, SYNERGISTIC SCENARIO

LOADINGS FOR 1980. IN METRIC TONNES.

## LAKE SUPERIOR

## LAKE HURON

PARAMETER	MUNICIPAL	INDUSTRIAL	TOTAL	CALIBRATED TOTAL	MUNICIPAL	INDUSTRIAL	TOTAL	CALIBRATED TOTAL
PHOSPHORUS	126	122	248	1,120	179	296	475	3,109
NITROGEN	1,026	2,513	3,539	97,940	1,617	10,565	12,182	21,247
DISS SOLID	22,078	480,002	502,079	3,054,389	27,709	789,784	817,493	3,678,962
CHLORIDE	3,082	2,976	6,057	234,234	3,878	82,763	86,641	235,395
SILICA	367	2,012	2,979	153,650	491	30,246	30,738	92,783
SUSP SOLID	2,682	31,566	34,248	308,964	4,848	57,474	62,322	213,479
OIL	158	200,233	200,390	23,063	566	208,644	200,210	24,052
SULPHUR	2,521	6,957	9,478	311,357	3,165	72,093	75,258	616,944
NH3	949	37,002	37,951	9,760	1,971	23,202	25,254	3,467
PHENOL	1	213	214	388	3	226	229	147
CYANIDE	20	22	42	996	41	34	76	275
ALUMINUM	670	740	1,409	26,332	1,391	291	1,682	3,836
BORON	0	26	26	3	0	1,175	1,175	113
URIDINE	0	15	15	2	0	715	715	69
CAIUM	0	1	1	273	0	16	16	543
CALCIUM	2,793	13,492	16,285	180,644	5,798	104,121	109,919	3,233,221
CHROMIUM	1	14	14	849	1	108	110	331
COPPER	4	17	22	345,088	5	15	21	2,078
FLUORIDE	84	69	153	2,561	174	419	593	5,478
IRON	80	1,511	1,591	12,663	108	3,388	3,495	10,634
LEAD	4	5	6	1,381	4	33	38	2,266
MAGNESIUM	770	1,701	2,471	132,377	969	18,412	19,382	164,762
MANGANESE	8	23	31	5,764	16	292	308	1,319
MERCURY	0	0	0	4	0	1	1	2
NICKEL	1	64	66	1,500	1	106	107	3,386
POTASSIUM	458	1,381	1,839	75,776	950	13,329	14,280	34,237
SODIUM	2,345	26,508	28,854	149,405	4,870	83,704	88,574	207,865
TITANIUM	0	763	763	60	0	226	226	18
ZINC	9	66	74	503	11	98	110	2,160
BOO	7,261	107,457	114,719	181,324	15,074	43,508	58,582	67,569

TABLE 23

UPPER LAKES REFERENCE GROUP  
WASTELOADING SIMULATION MODEL  
CANADA

PAGE 3

## LAKE LOADINGS SUMMARY, SYNERGISTIC SCENARIO

LOADINGS FOR 1985, IN METRIC TONNES.

## LAKE SUPERIOR

## LAKE HURON

PARAMETER	MUNICIPAL	INDUSTRIAL	TOTAL	CALIBRATED TOTAL	MUNICIPAL	INDUSTRIAL	TOTAL	CALIBRATED TOTAL
PHOSPHORUS	122	138	259	1,130	164	318	482	3,115
NITROGEN	1,010	2,747	3,757	98,157	1,563	11,122	12,685	21,750
DISS SOLID	21,992	540,598	562,590	3,114,900	27,398	861,725	889,123	3,750,592
CHLORIDE	3,072	3,236	6,307	234,484	3,843	89,203	93,046	241,799
SILICA	361	2,096	3,256	153,928	469	33,421	33,890	95,936
SUSP SOLID	2,559	35,273	37,831	312,548	4,442	61,275	65,717	216,874
OIL	140	219,091	220,030	42,702	511	229,027	229,538	44,379
SULPHUR	2,511	7,778	10,289	312,168	3,131	77,891	81,023	622,709
NH3	949	41,063	42,811	14,621	1,985	25,998	27,984	6,196
PHENOL	1	234	236	410	3	248	251	168
CYANIDE	20	24	44	998	42	37	79	277
ALUMINUM	670	838	1,507	26,429	1,401	326	1,727	3,881
BORON	0	28	28	4	0	1,274	1,274	213
BRONINE	0	17	17	3	0	777	777	130
CAIUMIUM	0	1	2	273	0	17	18	544
CALCIUM	2,789	14,991	17,780	182,138	5,839	113,161	119,001	3,242,304
CHROMIUM	1	15	16	850	1	117	118	340
COPPER	4	18	23	345,089	5	16	22	2,079
FLUORIUE	84	76	159	2,568	176	454	628	5,513
IRON	79	1,067	1,746	12,817	104	3,686	3,789	10,929
LEAD	4	3	7	1,382	4	36	40	2,269
MAGNESIUM	768	1,891	2,659	132,566	961	20,193	21,154	166,533
MANGANESE	8	25	32	5,766	16	320	336	1,346
MERCURY	0	0	0	4	0	1	1	2
NICKEL	1	70	71	1,506	1	116	117	3,396
POTASSIUM	457	1,528	1,985	75,922	958	14,541	15,499	35,455
SODIUM	2,343	29,935	32,278	152,829	4,905	90,887	95,792	215,083
TITANIUM	0	865	865	161	0	257	257	48
ZINC	9	72	81	509	11	107	118	2,168
BUU	7,250	121,571	128,822	195,428	15,183	48,379	63,562	72,549

TABLE 24

## LAKE LOADINGS SUMMARY, SYNERGISTIC SCENARIO

LOADINGS FOR 1990, IN METRIC TONNES.

## LAKE SUPERIOR

## LAKE HURON

PARAMETER	MUNICIPAL	INDUSTRIAL	TOTAL	CALIBRATED TOTAL	MUNICIPAL	INDUSTRIAL	TOTAL	CALIBRATED TOTAL
PHOSPHORUS	65	136	201	1,071	148	328	475	3,109
NITROGEN	759	2,756	3,515	97,916	1,503	11,408	12,911	21,977
DISS SOLID	19,521	533,887	553,407	3,105,717	27,002	880,834	907,836	3,769,304
CHLORIDE	2,772	3,299	6,071	234,248	3,796	93,233	97,029	245,782
SILICA	260	2,998	3,258	153,928	445	34,753	35,199	97,244
SUSP SOLID	1,643	34,964	36,607	311,324	4,016	62,620	66,636	217,793
OIL	125	224,499	224,624	47,297	454	233,959	234,413	49,255
SULPHUR	2,237	7,751	9,987	311,866	3,087	82,069	85,157	626,843
NRD	944	41,193	42,137	13,946	1,994	26,301	28,295	6,508
PHENOL	1	239	239	413	3	254	257	175
CYANIDE	20	24	44	998	42	39	81	279
ALUMINUM	666	823	1,489	26,411	1,408	328	1,735	3,889
BORON	0	31	31	7	0	1,387	1,387	326
BRONINE	0	19	19	4	0	845	845	199
CAIUMIUM	0	1	2	273	0	18	19	544
CALCIUM	2,777	15,074	17,851	182,210	5,865	119,126	124,991	3,248,294
CHROMIUM	1	15	16	850	1	119	120	341
COPPER	3	18	21	345,087	4	16	22	2,079
FLUORIDE	84	77	160	2,569	176	473	648	5,533
IRON	62	1,093	1,755	12,827	100	3,831	3,931	11,071
LEAD	3	3	5	1,380	4	38	42	2,271
MAGNISIUM	693	1,934	2,627	132,534	949	21,354	22,303	167,683
MANGANESE	8	25	33	5,766	16	333	349	1,360
MERCURY	0	0	0	4	0	1	1	2
NICKEL	1	72	73	1,508	1	120	121	3,399
POTASSIUM	455	1,557	2,012	75,949	962	15,198	16,160	36,116
SODIUM	2,332	29,526	31,858	152,410	4,927	95,370	100,297	219,588
TITANIUM	0	649	849	146	0	251	251	43
ZINC	7	72	79	508	11	110	121	2,171
BUO	7,219	119,494	126,713	193,318	15,249	48,139	63,388	72,375

TABLE 25

## ENVIRONMENT CANADA, INLAND WATERS DIRECTORATE, ONTARIO REGION.

DATE 03/11/76  
TIME 10:10:08UPPER LAKES REFERENCE GROUP  
WASTELOADING SIMULATION MODEL  
CANADA

PAGE 5

## LAKE LOADINGS SUMMARY, SYNERGISTIC SCENARIO

LOADINGS FOR 2000. IN METRIC TONNES.

## LAKE SUPERIOR

## LAKE HURON

PARAMETER	MUNICIPAL	INDUSTRIAL	TOTAL	CALIBRATED TOTAL	MUNICIPAL	INDUSTRIAL	TOTAL	CALIBRATED TOTAL
PHOSPHORUS	36	131	167	1,037	94	333	428	3,061
NITROGEN	550	2,701	3,251	97,652	1,166	11,427	12,594	21,659
DISS SOLID	13,240	514,206	527,447	3,079,757	20,552	889,026	909,580	3,771,048
CHLORIDE	1,686	3,326	5,212	233,389	2,900	96,706	99,606	248,359
SILICA	168	3,229	3,398	154,068	318	37,445	37,762	99,808
SUSP SOLID	988	33,020	34,808	309,524	2,585	62,702	65,286	216,444
OIL	82	233,063	233,745	56,417	286	243,632	243,918	58,760
SULPHUR	1,518	7,555	9,073	310,951	2,352	86,009	88,361	630,048
NH3	824	39,435	40,259	12,068	1,772	26,856	28,628	6,841
PHENOL	1	247	248	422	2	265	266	185
CYANIDE	17	25	43	997	38	40	77	275
ALUMINUM	581	783	1,365	26,288	1,251	324	1,575	3,729
BORON	0	33	33	10	0	1,516	1,516	455
BRONINE	0	21	21	6	0	923	923	277
CALCIUM	0	1	2	273	0	20	20	545
CALCIUM	2,424	15,062	17,485	181,844	5,212	127,120	132,332	3,255,635
CHROMIUM	1	15	15	850	1	122	123	345
COPPER	2	18	20	345,086	4	17	20	2,078
FLUORIDE	73	80	152	2,561	157	491	647	5,532
IRON	41	1,741	1,782	12,853	73	3,997	4,070	11,209
LEAD	2	3	4	1,379	4	40	42	2,271
MAGNESIUM	472	2,006	2,478	132,384	725	23,082	23,808	169,187
MANGANESE	7	27	33	5,766	14	355	369	1,1,379
MERCURY	0	0	0	4	0	1	1	2
NICKEL	1	74	75	1,509	1	125	126	3,404
POTASSIUM	398	1,604	2,002	75,938	855	16,121	16,975	36,931
SODIUM	2,036	28,344	30,380	150,932	4,378	99,561	103,939	223,231
TITANIUM	0	808	808	105	0	239	239	32
ZINC	4	71	76	505	8	113	121	2,172
BOD	6,302	114,032	120,334	186,939	13,552	46,705	60,256	69,243

TABLE 26

UPPER LAKES REFERENCE GROUP  
WASTELOADING SIMULATION MODEL  
CANADA

PAGE 6

## LAKE LOADINGS SUMMARY: SYNERGISTIC SCENARIO

LOADINGS FOR 2010. IN METRIC TONNES.

PARAMETER	LAKE SUPERIOR				LAKE HURON			
	MUNICIPAL	INDUSTRIAL	TOTAL	CALIBRATED TOTAL	MUNICIPAL	INDUSTRIAL	TOTAL	CALIBRATED TOTAL
PHOSPHORUS	19	127	146	1,016	46	336	382	3,015
NITROGEN	391	2,052	3,043	97,443	825	11,256	12,082	21,147
DISS SOLID	7,792	502,359	510,152	3,062,462	12,213	892,308	904,521	3,765,049
CHLORIDE	1,111	3,354	4,465	232,642	1,727	99,293	101,021	249,773
SILICA	98	3,935	3,634	154,304	182	40,819	41,001	103,046
SUSP SOLID	533	33,110	33,644	308,359	1,308	62,192	63,499	214,657
OIL	47	248,431	248,477	71,150	150	259,050	259,200	74,042
SULPHUR	894	7,453	8,347	310,225	1,398	89,258	90,656	632,343
NH3	700	38,357	39,057	10,866	1,534	27,915	29,449	7,662
PHENOL	1	261	262	436	2	280	282	200
CYANIDE	14	27	41	996	32	42	75	273
ALUMINUM	494	758	1,252	26,175	1,083	323	1,406	3,560
BORON	0	36	36	13	0	1,630	1,630	569
BRONITE	0	22	22	7	0	994	994	347
CALCIUM	0	2	2	273	0	21	22	547
CALCIUM	2,059	15,329	17,389	181,748	4,512	136,388	140,899	3,264,202
CHROMIUM	0	15	16	850	1	131	132	354
COPPER	1	18	19	345,085	2	17	19	2,077
FLUORIDE	62	84	146	2,554	135	507	642	5,527
IRON	24	1,027	1,851	12,922	42	4,177	4,219	11,359
LEAD	1	3	4	1,378	2	40	42	2,271
MAGNESIUM	277	2,109	2,387	132,293	432	24,971	25,403	170,782
MANGANESE	5	29	34	5,767	13	378	391	1,401
MERCURY	0	0	0	4	0	1	2	2
NICKEL	0	78	78	1,513	1	132	132	3,411
POTASSIUM	338	1,076	2,014	75,951	740	17,118	17,858	37,814
SODIUM	1,730	27,016	29,345	149,897	3,790	103,084	106,873	226,165
TITANIUM	0	781	781	78	0	231	231	23
ZINC	3	72	75	504	4	117	122	2,172
BOD	5,354	110,498	115,852	182,458	11,730	45,692	57,422	66,409

Table 27

UPPER LAKES REFERENCE GROUP  
WASTELOADING SIMULATION MODEL  
CANADA

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## LAKE LOADINGS SUMMARY, SYNERGISTIC SCENARIO

LOADINGS FOR 2020. IN METRIC TONNES.

## LAKE SUPERIOR

## LAKE HURON

PARAMETER	MUNICIPAL	INDUSTRIAL	TOTAL	CALIBRATED TOTAL	MUNICIPAL	INDUSTRIAL	TOTAL	CALIBRATED TOTAL
PHOSPHORUS	5	128	131	1,003	11	339	351	2,984
NITROGEN	227	2,047	2,874	97,275	482	11,127	11,610	20,676
DISS SOLID	2,905	502,548	505,534	3,057,844	4,971	900,688	905,659	3,767,128
CHLORIDE	425	3,425	3,849	232,026	705	102,195	102,900	251,653
SILICA	39	3,914	3,953	154,624	70	44,901	44,971	107,016
SUSP SOLID	187	33,163	33,350	308,066	374	62,174	62,548	213,705
OIL	22	270,010	270,032	93,504	51	282,319	282,371	97,213
SULPHUR	342	7,523	7,866	309,744	570	93,370	93,938	635,625
NH3	501	38,255	38,757	10,565	1,120	29,577	30,696	8,909
PHENOL	1	283	284	457	1	304	305	223
CYANIDE	11	30	40	994	23	45	68	267
ALUMINUM	354	751	1,105	26,028	790	330	1,121	3,275
BORON	0	40	40	16	0	1,784	1,784	724
BROMINE	0	24	24	10	0	1,087	1,087	441
CAIUMIUM	0	2	2	273	0	23	23	549
CALCIUM	1,475	16,001	17,476	181,835	3,293	149,282	152,575	3,275,879
CHROMIUM	0	17	17	851	0	147	147	369
COPPER	0	19	19	345,085	1	18	19	2,076
FLUORIDE	44	91	135	2,543	99	526	625	5,511
IRON	10	1,968	1,977	13,049	16	4,424	4,441	11,580
LEAD	0	3	4	1,378	1	42	42	2,271
MAGNESIUM	106	2,256	2,363	132,269	176	27,389	27,565	172,945
MAR.GANESE	4	31	35	5,768	9	407	416	1,427
MERCURY	0	0	0	4	0	2	2	2
NICKEL	0	85	85	1,520	0	142	142	3,420
POTASSIUM	242	1,784	2,026	75,964	540	18,345	18,885	38,841
SODIUM	1,239	27,577	28,815	149,368	2,766	107,579	110,345	229,637
TITANIUM	0	774	774	71	0	230	230	21
ZINC	1	76	77	505	2	122	124	2,175
BOD	3,835	109,790	113,624	180,230	8,562	45,607	54,168	63,156

TABLE 28

TABLE 29

ENVIRONMENT CANADA, INLAND WATERS DIRECTORATE, ONTARIO REGION.  
 UPPER LAKES REFERENCE GROUP  
 WASTELOADING SIMULATION MODEL

DATE 04/20/76

ECONOMIC SUMMARY  
 CAPITAL INVESTMENT ONLY  
 SYNERGISTIC SCENARIO  
 1961 CONSTANT DOLLARS

CANADA

YEAR	LAKE SUPERIOR				LAKE HURON			
	INDUSTRIAL		MUNICIPAL		INDUSTRIAL		MUNICIPAL	
	ITMI01	ITMI03	MTMI01	MTMI03	ITMI01	ITMI03	MTMI01	MTMI03
1974.	\$1,882,528	\$1,882,528	\$210,939	\$210,939	\$4,587,481	\$4,587,481	\$508,824	\$508,824
1980.	\$2,254,356	\$2,667,256	\$230,006	\$1,689,447	\$4,450,738	\$5,258,881	\$619,756	\$1,644,162
1985.	\$2,817,921	\$3,050,397	\$245,911	\$266,719	\$5,269,830	\$5,700,114	\$868,150	\$717,392
1990.	\$2,199,337	\$2,429,205	\$252,214	\$1,222,439	\$4,899,723	\$5,406,001	\$972,796	\$746,614
2000.	\$2,570,013	\$2,953,097	\$252,819	\$887,243	\$6,245,292	\$7,168,260	\$1,085,835	\$904,959
2010.	\$3,328,839	\$3,980,255	\$287,075	\$731,195	\$8,474,368	\$10,117,391	\$1,356,942	\$1,233,627
2020.	\$4,688,702	\$5,833,737	\$319,106	\$571,010	\$12,230,924	\$15,187,308	\$1,999,397	\$857,690

FIGURES

- 73 -

METRIC  
TONNES  
PER  
YEAR

TOTAL PHOSPHORUS  
LAKE SUPERIOR

2000

1500

1000

800

600

400

1970

1980

1990

2000

2010

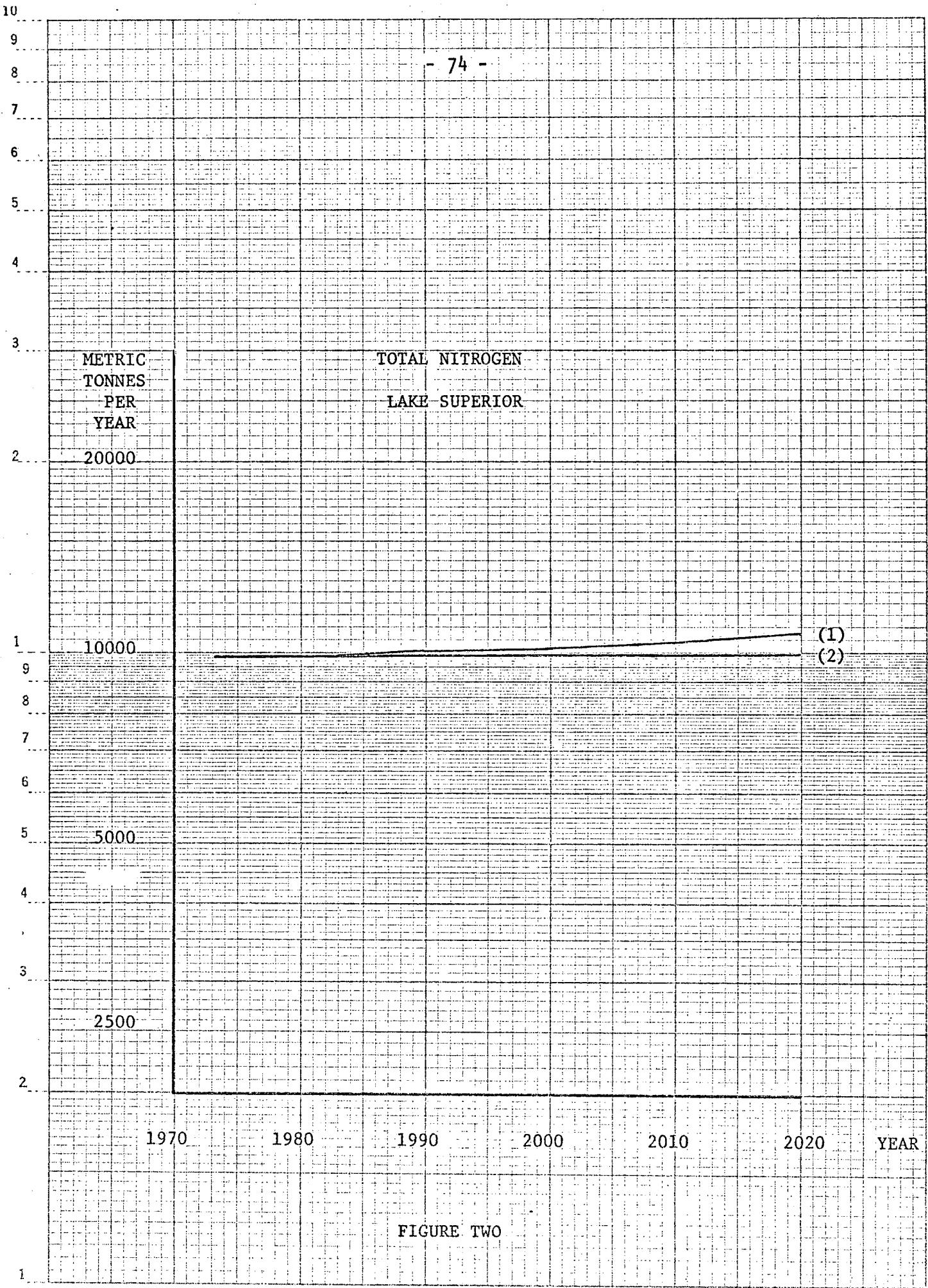
2020

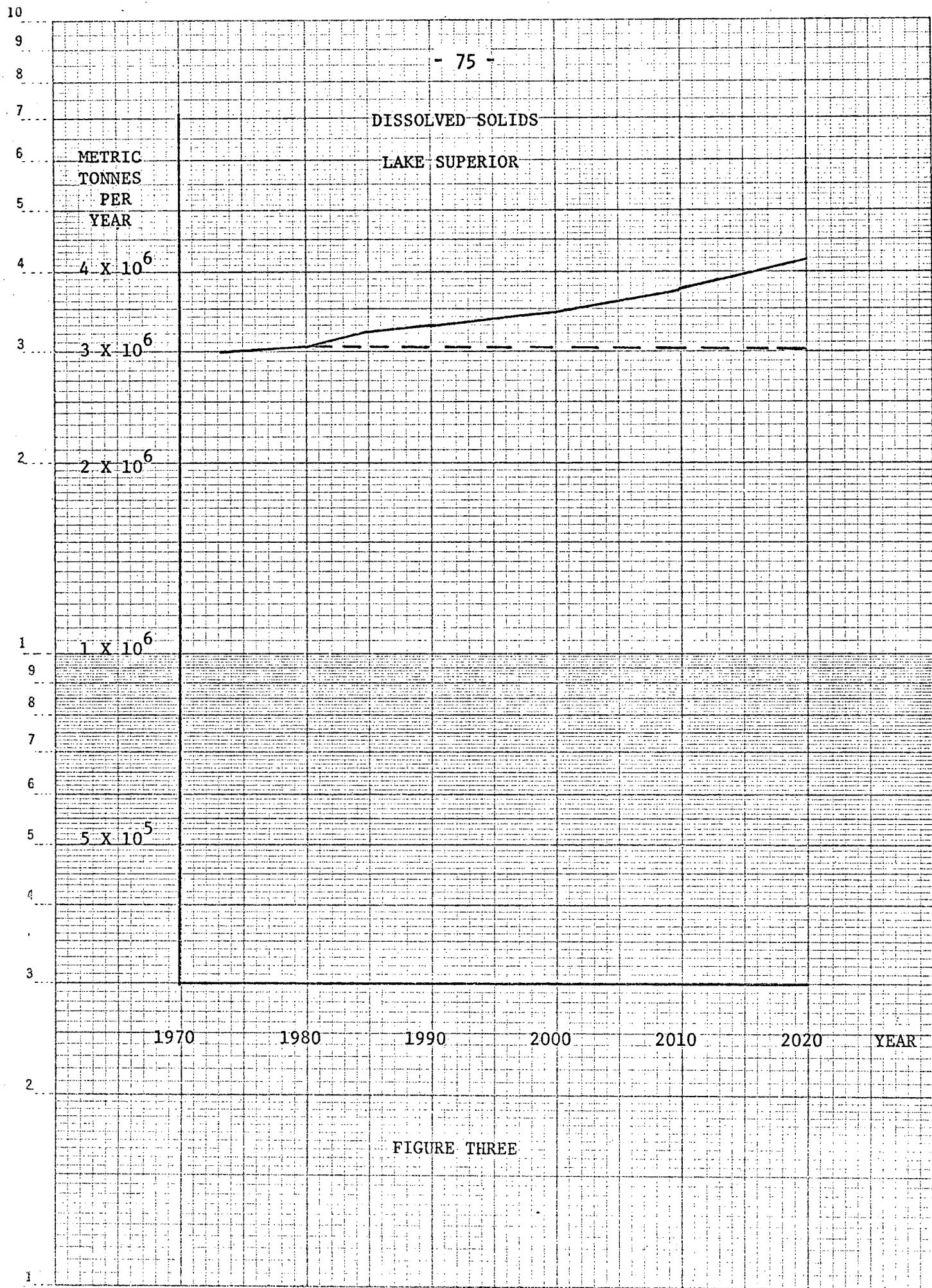
YEAR

(1)

(2)

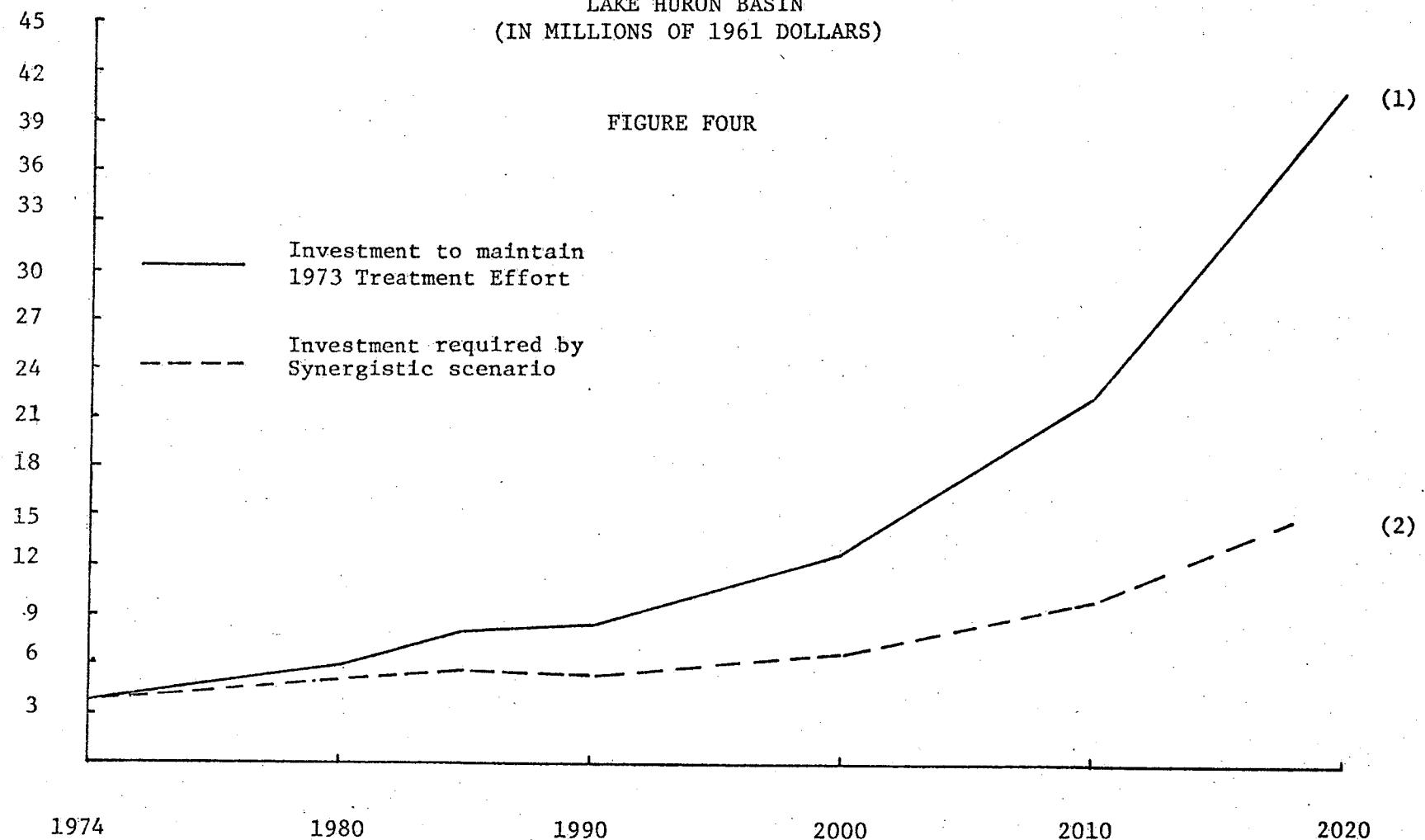
FIGURE ONE





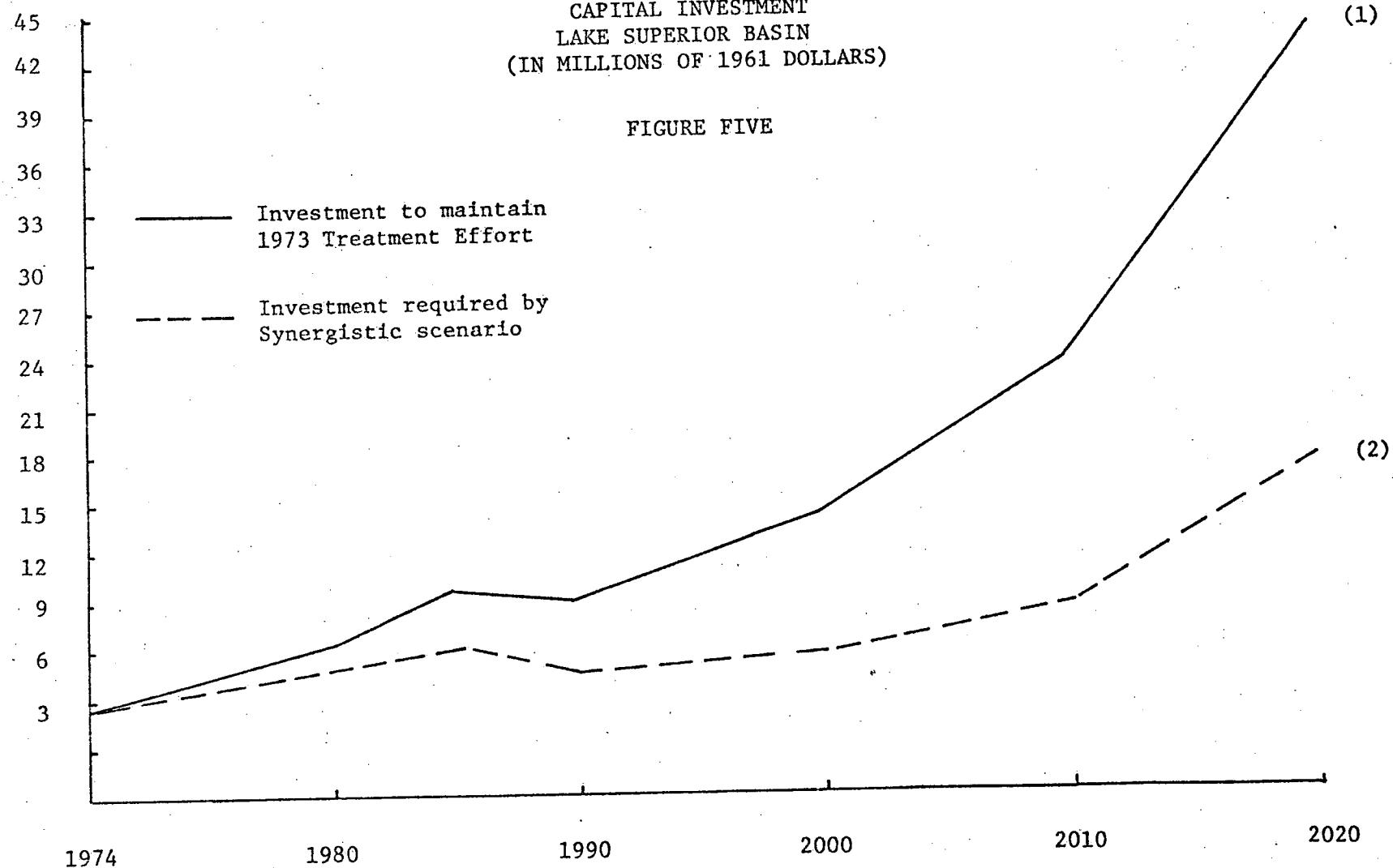
INDUSTRIAL  
CAPITAL INVESTMENT  
LAKE HURON BASIN  
(IN MILLIONS OF 1961 DOLLARS)

FIGURE FOUR



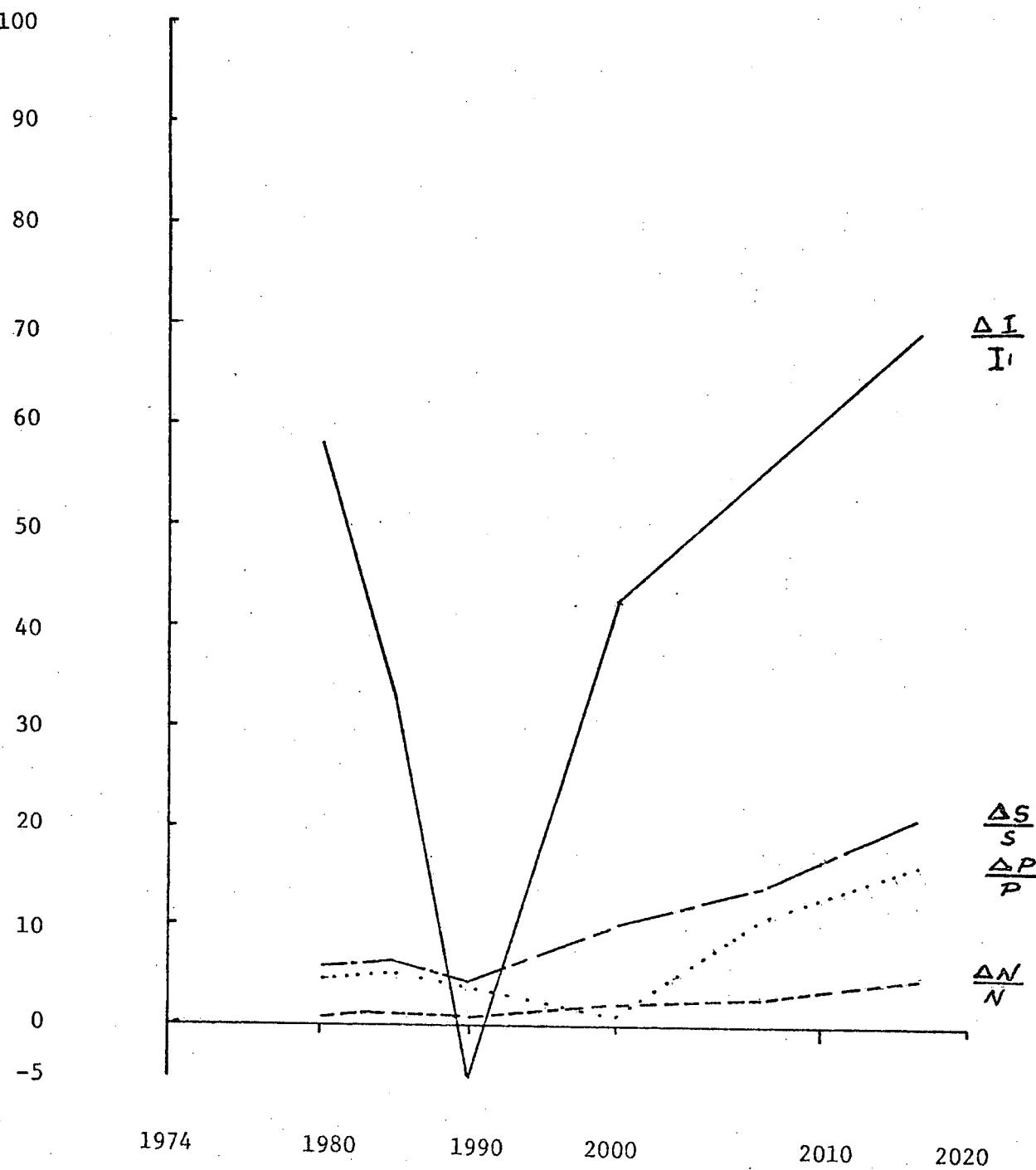
INDUSTRIAL  
CAPITAL INVESTMENT  
LAKE SUPERIOR BASIN  
(IN MILLIONS OF 1961 DOLLARS)

FIGURE FIVE



ANNUAL CHANGE IN  
INDUSTRIAL INVESTMENT  
1972 - 2020

%  
CHANGE  
LAKE SUPERIOR BASIN



APPENDIX 1

**COMPUTER PROGRAMS**

---

MAIN is the main program which reads in data, calls subroutines: POPUL8, WLINT, TECHN, ECON, SPEND, CLOCK, CALBBB, to calculate results.  
The results are written to file INFILE which is then reported by DML report writing programs.

---

LIST OF VARIABLES

b	R.D.P. multiplier
bastr2	treatment level of base year
bastr1	treatment level of previous year
c	multiplier constant of 1's & 0's for ITMI03
calibr	calibrated total loading
chmfac	adjustment value for MWLFAC
chwfac	adjustment value for IWLFAC
cno	canadian national economic forecasts
ctiff	treatment inefficiency
ddistl	discrepancy of DISTLD & TDISTL
depr	stock depreciation rate
destrl	treatment level desired
distld	type distributed municipal loading current year
effdlr	dollar efficiency
ilook	industry code number that invest in treatment
impact	economic impact values.
index	year number
itm101	base industry investment of the year
itm103	additional industry investment of the year
itmih1	huron ITMI01
itmih3	huron ITMI03
itmisl	superior ITMI01
itmisi3	superior ITMI03
iwl	industry loading per industry
iwlfac	industrial wasteloading coefficient
iwlhrn	industry loading huron
iwlsum	total industry loading
iwlsup	industry loading superior
jflag	scenario number choice
mgal02	municipal treatment capacity
mtcost	treatment marginal cost
mtmi01	base municipal investment of the year
mtmi03	additional municipal investment of the year
mtmih1	huron MTMI01
mtmih3	huron MTMI03
mtmis1	superior MTMI01
mtmis3	superior MTMI03

munhrn	municipal loading huron
munsup	municipal loading superior
mw1	total municipal loading
mw1fac	municipal wasteloading coefficient
mwfl	municipal waste water flow
mxsim	faction of additional municipal treatment desired
ni	number of industries
nim	economic impact index
nj	number of impact groups
nkind	number of chemical parameters
now	calendar year
np	policies number
npolst	number of initial & interim multipliers
nr	number of regions
ntype	number of treatment types
nz	number of population sub-groups
observ	observed loadings
olvalc	municipal investment MTMI01 current year
olvalp	municipal investment MTMI01 previous year
pcapbs	base year proportions of treatment
pcwatr	per capita water consumption
pop	regional population
prev	previous year r.d.p.
prpcap	proportions of treatment
ro	canadian regional economic forecasts
sdestr	simulated industry treatment level desired
smwfac	simulated municipal waste coefficient
stockl	ITMI01 stock previous year
stock2	ITMI01 stock current year
stocpl	ITMI03 stock previous year
stocp2	ITMI03 stock current year
sumiti	base year industry expenditure on treatment
tbld	total region loading
tblhrn	industry & municipal loadings huron
tblsup	industry & municipal loadings superior
tdist1	type distributed municipal loading previous year
temp2	R.D.P. (current.year/previous.year) ratio
trulod	municipal loading, treated residue
ttbhrn	calibrated total loadings huron
ttbld	calibrated total region loading
ttbsup	calibrated total loadings superior
untrt	untreated municipal loading
untrt	untreated portion of municipal loading
uratio	urban/total population ratio
urban	urban population
urbpop	urban population
valcur	municipal investment MTMI03 current year
valpre	municipal investment MIMI03 previous year
zb	municipal fraction treat
zc	percentage of municipal waste not treated
zn	that portion of total not to be treated

% zz additional treatment with base treatment

%  
%  
%  
% PARM is a list subscript variables for dimension control.  
include parm ,list

%  
% COMBLK is a list of variables & their dimensions common  
% to all subroutines.  
include comblc ,list

%  
% Rewind data

24

% File INOUTF is for set up of input/output files.  
call obey('!do inoutf',3)

%  
% Read treatment inefficiencies, by parameter, by type.

in=10  
.do 41 k=1,nkind  
41 read(in,42) (ctiff(k,nt) ,nt=1,ntype)  
42 format(10x,8f10.6)

%  
% Read municipal treatment costs, by type.

in=11  
read(in,1202) (mtcost(nt) ,nt=1,ntype)  
1202 format(10x,f10.6)  
1201 continue

%  
% Read municipal waste coefficients, by parameter.

in=12  
read(in,10) (mwlfac(l,n) ,n=1,nkind)  
10 format(2(10x,10f10.6/),10x,10f10.6)

%  
% Read industry waste coefficients.

in=13  
do 11 i=1,ni  
11 read(in,7614) (iwlfac(i,n) ,n=1,nkind)  
7614 format(2(10x,10f11.8/),10x,10f11.8)

```
%  
%  
%  
%      Read municipal capacities, by region.  
in=14  
do 12 j=1,nr  
read(in,502) mgal02(j)  
502 format(12f10.6)  
12 continue  
%  
%  
%  
%      Code for economic impact indices.  
%  
%      Read economic impact.  
% in=xx  
% 1193 format(//2(10x,5e14.7),10x,5e14.7)  
% do 1190 k=1,8  
% do 1191 i=1,nj  
% 1191 read(in,1193) (nim(k,i,ny),ny=1,npolst)  
% 1190 continue  
%  
%  
%  
%      Read 1972 industrial expenditures, by region, by industry.  
in=15  
read(in,1185) ((sumiti(j,k),j=1,nr),k=1,ni)  
1185 format(10x,7f10.0)  
%  
%  
%  
%      Read observed loadings.  
in=16  
read(in,1211) ((observ(j,k),j=1,nr),k=1,nkind)  
1211 format(10x,7f10.1)  
%  
%  
%  
%      Read stock depreciation percentage.  
in=17  
read(in,8757) depr  
8757 format(10x,f10.4)  
%  
%      Read in polluting industry code  
read(in,8557)(ilook(k),k=1,11)  
8557 format(10x,lli5)  
%  
%      Read fractions of municipal waste to be treated.  
read(in,8756)(zb(k),k=1,nr)  
%
```

```
%  
%      Read choice of scenario number  
in=18  
read(in,8188) jflag  
8188 format(il)  
%  
%  
%  
%      Initialization.  
do 9011 k=1,ni  
do 9012 j=1,nr  
stock1(j,k)=0.  
stock2(j,k)=0.  
stocpl(j,k)=0.  
9012 stocp2(j,k)=0.  
9011 continue  
%  
do 4762 j=1,nr  
do 4763 k=1,nkind  
calibr(j,k)=0.  
do 4764 nt=1,ntype  
tdistl(j,k,nt)=0.  
valpre(j,nt)=0.  
4764 olvalp(j,nt)=0.  
4763 continue  
4762 continue  
%  
temp2=1.  
index=0  
%  
%  
%  
%  
%  
%  
%  
%      Start simulation  
%  
%      Year loop. - operates year by year.  
%  
%  
%  
%  
%  
%      Subroutine CLOCK controls calculation & print period.  
%      It terminates execution of MAIN at end of period.  
700 call clock  
%  
%  
%  
%      Index is increase by 1 for each year loop.  
index=index+1  
%
```

```
%  
%  
%      Read in change factor for municipal waste coefficient, MWLFAC  
in=19  
2021 format(10x,f10.5)  
read(in,2021) chmfac(index)  
%  
%  
%  
%      Read in change factor for industry waste coefficient, IWLFAC  
in=20  
read(in,2021) chwfac(index)  
%  
%  
%  
%      Read base treatment level, by region  
in=21  
read(in,9315) (bastrl(j,index),j=1,nr)  
%  
%      Store base treatment level in BASTR2  
do 123 j=1,nr  
123 bastr2(j,index)=bastrl(j,index)  
%  
%  
%  
%      Read MTMI01 for scenarios 2 & 3 only.  
if(jflag .eq. 1) goto 8654  
in=22  
read(in,8656) (mtmi01(j),j=1,nr)  
8656 format(f10.0)  
8654 continue  
%  
%  
%  
%      Read simulated desired treatment level, by region.  
in=23  
read(in,9315) (sdestr(j,index),j=1,nr)  
9315 format(7f10.7)  
%  
%  
%  
%      Initialization.  
do 99 k=1,ni  
do 98 j=1,nr  
urbpop(j)=0.  
mw1(j,k)=0.  
itm101(j,k)=0.  
itm103(j,k)=0.  
tbld(j,k)=0.  
98 itm102(j,k)=0.  
99 continue
```

```
%  
%  
%  
%      Read per capita water consumption.  
in=24  
read(in,1107) (pcwatr(j,index),j=1,nr)  
1107 format(10x,7f10.0)  
%  
%  
%  
%      Read dollar efficiency  
in=25  
read(in,8757) effdlr(index)  
%  
%  
%  
%      Mxsim is simulation variable for additional  
%      municipal treatment.  
in=26  
read(in,8756) (mxsim(j,index),j=1,nr)  
8756 format(10x,7f10.7)  
%  
%  
%  
%      Read national forecast, by industry  
in=27  
read(in,17) (cno(i),i=1,ni)  
17 format(3(10d10.3/),d10.3)  
do 777 i=1,ni  
777 cno(i)=cno(i)*1e6  
%  
%  
%  
%      C is simulation variable for additional industry treatment.  
in=28  
read(in,1106) (c(i),i=1,nd)  
1106 format(124i1/93i1)  
%  
%  
%  
%      OUT is output file  
%      PRTIME is year for print.  
%      Write calendar year, number of regions.  
out=90  
if(prtime .ne. 0) go to 1170  
write(out,1110) now  
1110 format(1x,i4)  
write(out,1110) nr  
1170 continue  
%
```

```
%  
%      Read population, by region.  
in=29  
read(in,14) (pop(j),j=1,nr)  
14 format(12f10.0)  
%  
%-  
%  
%      Read urban/total ratios, by region.  
in=30  
read(in,19) (uratio(j),j=1,nr)  
19 format(12f10.6)  
%  
%-  
%  
%  
%      Subroutine POPul8 calculates population data.  
call popul8 (pop,urbpop,uratio,nr)  
%  
%-  
%  
%      Change waste coefficients by their change factors.  
do 3021 i=1,ni  
do 4021 k=1,nkind  
smwfac(l,k)=mwlfac(l,k)*chmfac(index)  
4021 iwlfac(i,k)=iwlfac(i,k)*(1.-chwfac(index))  
3021 continue  
%  
%-  
%  
%  
%      Initialization.  
do 1001 k=1,nkind  
1001 maxs02(nz,k)=10e-20  
itmisl=0.  
itmisi=0.  
itmihl=0.  
itmih3=0.  
mtmisl=0.  
mtmis3=0.  
mtmihl=0.  
mtmih3=0.  
%      Initialization.  
do 8461 k=1,nkind  
munsup(k)=0.  
iwlsp(k)=0.  
tblsup(k)=0.  
ttbsup(k)=0.  
munhrn(k)=0.  
iwlhrn(k)=0.  
tblhrn(k)=0.
```

8461 ttbhrn(k)=0.

%

do 8547 j=1,nr

itmirl(j)=0.

itmirl3(j)=0.

8547 continue

%

%

%

%

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%

%

do 500 j=1,nr

%

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Regional loop. - operates region by region.

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Initialization.

do 8765 k=1,nkind

untrt(nz,k)=0.

do 8766 nt=1,ntype

distld(k,nt)=0.

distl(k,nt)=0.

8766 trulod(k,nt)=0.

8765 continue

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Base, desire treatment levels determination.

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This year's base level is last year's desired level.

if(index .eq. 1) go to 3961

bastrl(j,index)=destrl(j,index-1)

3961 continue

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```
%  
%      Read regional industry product multiplier.  
in=31  
read(in,82) (b(i),i=1,ni)  
82 format(8d10.8)  
%  
%  
%  
%      Call subroutine econ. - calculates r. d. p. for each region.  
call econ (j)  
%  
%  
%  
%      Read proportions of capacity, by region, by type.  
in=32  
read(in,42) (prpcap(j,nt) ,nt=1,ntype)  
%  
if(index .ne. 1) goto 4148  
do 4158 nt=1,ntype  
4158 pcapbs(j,nt)=prpcap(j,nt)  
4148 continue  
%  
%  
%  
%      Subroutine TECHN calculates technical investment.  
call techn (j,index)  
%  
%  
%  
%      Subroutine WLINT calculates wasteloadings.  
call wlint (j,index)  
%  
%  
%  
%      Create MTMI01 file from scenario 1.  
if(jflag .ne. 1) goto 2935  
write(22,3935) mtmi01(j)  
3935 format(f10.0)  
2935 continue  
%  
%  
%  
%  
%      End of region loop.  
500 continue  
%  
%  
%  
%  
%      Subroutine SPEND calculates impact from investment.  
call spend
```

```
%  
%  
%  
%  
%  
% Write results to file INFILE, by year.  
%  
% If not print, go to calculation.  
if(prtime .ne. 0) go to 1171  
%  
% Write number of chemical parameters.  
write(out,1110) nkind  
%  
% write municipal loadings for regions, & lakes.  
do 3001 j=1,nr  
3001 write(out,1112) j,(mw1(j,k),k=1,nkind)  
write(out,1114)(munsup(k),k=1,nkind)  
write(out,1114)(munhrn(k),k=1,nkind)  
1114 format(1x,f12.0)  
%  
% Write industry loadings for regions, & lakes.  
do 3002 j=1,nr  
3002 write(out,1112) j,(iwlsum(j,k),k=1,nkind)  
1112 format(1x,i2,2(10f12.0/),10f12.0)  
write(out,1114)(iwlsup(k),k=1,nkind)  
write(out,1114)(iwlhrn(k),k=1,nkind)  
%  
% Write total basin loadings, & for lakes.  
do 3003 j=1,nr  
3003 write(out,1112) j,(tbld(j,k),k=1,nkind)  
write(out,1114)(tblsup(k),k=1,nkind)  
write(out,1114)(tblhrn(k),k=1,nkind)  
%  
% Write calibrated total loadings for regions and for lakes.  
do 3004 j=1,nr  
3004 write(out,1112) j,(ttbld(j,k),k=1,nkind)  
write(out,1114)(ttbsup(k),k=1,nkind)  
write(out,1114)(ttbhrn(k),k=1,nkind)  
write(out,1114)(maxs02(nz,k),k=1,nkind)  
%  
% Write economic impact numbers.  
data comma',/'  
write (out,9875) impact(32),comma,impact(33),comma,impact(34)  
9875 format(f10.4,al,f15.0,al,f12.0)  
%  
% Write municipal, & industry investments.  
write(out,1115) itmisl,itmis3,itmihl,itmih3  
write(out,1115) mtmisl,mtmis3,mtmihl,mtmih3  
1115 format(4i12)  
%  
1171 rewind 24  
go to 700
```

%

%

%

End of year loop.

%

%

end

---

```
%  
% Subroutine clock controls calculation, & print period.  
% It terminates execution of MAIN at the end of simulation period.  
%
```

```
% Usage: call clock  
%
```

---

```
subroutine clock  
%
```

```
common /time/ now,length,prnptr,ptime,iend  
%
```

```
% length      length of simulation period  
% prnptr      output printing interval  
% ptime       output printing year  
% now         calendar year  
% istart      starting year of simulation  
% iend        ending year of simulation  
%
```

---

```
% Increase calendar year by 1.  
now=now+1  
%
```

```
% Stop execution at end of simulation year  
if(now .gt. iend) stop ': results calculated'  
%
```

```
% Adjustment of year for print interval.  
% Print if PRTIME=0  
ptime=mod(now,prnptr)  
if(now .eq. iend) ptime=0  
if(now .eq.1974) ptime=0  
if(now .eq. 1985)ptime=0  
if(ptime .ne. 0) return  
%
```

---

```
%  
%  
end
```

```
c
c
c Common Block COMBLK
c list of variables for all subroutines.
c dimensions of these variables are specified
c in data block PARM
c
c
c dimension a(ni,nr)
double precision cno,b,nim,itmi01,itmi02,itmi03
real mgal03,mgal02,mtmi01,mtmi02,mtmi03
real mxsim,munsup,munhrn,iwlsup,iwlhrn,olvalc,olvalp
real mwlfac,iwlfac,mwl,iwl,mwwf1,mtcost,impact,iwlsum,invest
real mtmir1,mtmir3,mtmisl,mtmis3,mtmih1,mtmih3,itmir1,itmir3,itmisi
11,itmisi3,itmih1,itmih3
integer prtime,prnptr,out,in
integer a,c
equivalence(a(1,1),c(1))
common /time/ now,length,prnptr,prtime,iend
common /iunit/ in,out,int
common /names/ itmi01(nr,ni),itmi02(nr,ni),itmi03(nr,ni),c(nd)
common /vars10/ mgal02(11),tbl0(nr,nkind)
common /blk1/ ro(nr,ni),pop(nr),mwlfac(nz,nkind),mwl(nr,nkind),iwl
1fac(ni,nkind),iwl(ni,nkind),smwfac(nz,nkind),siwfac(ni,nkind),pre
lv(nr,ni)
common /blk2/ distld(nkind,ntype),prpcap(nr,ntype),ctiff(nkind,nty
lpe),trulod(nkind,ntype)
common /blk3/ untrt(nz,nkind),sumvst(nj),impact(nj),chmfac(100),ch
lwfac(100)
common /blk4/iwlsum(nr,nkind),b(ni),sumiti(nr,ni),mtcost(ntype)
common /blk5/ cno(nj),mwwf1(nr),effdlr(100),pcwatr(nr,100),depr
common /blk6/ uratio(nr),urbpop(nr),pl(np,npolst),nowyr(np,npolst
1),lastyr(np,npolst),nim(np,nj,npolst),invest(np,npolst)
common /blk7/ mgal03(nr,ntype),mtmi01(nr),mtmi02(nr),mtmi03(nr),ma
lxs02(nz,nkind)
common /ten/ destrl(nr,100),bastrl(nr,100),sdestr(nr,100),bastr2(n
lr,100)
common /eleven/ munsup(nkind),munhrn(nkind),iwlsup(nkind),iwlhrn(n
kind),tblsup(nkind),tblhrn(nkind),ttbsup(nkind),ttbhrn(nkind),cali
lbr(nr,nkind),ttbld(nr,nkind),observ(nr,nkind)
common /twelve/ stock1(nr,ni),stock2(nr,ni),stocpl(nr,ni),stocp2(n
```

```
lr,ni)
common /thirt/ mtmir1(nr),mtmir3(nr),mtmis1,mtmis3,mtmih1,mtmih3,i
ltmir1(nr),itmirl(nr),itmisl,itmisl3,itmihl,itmih3
common /fort/ zb(nr),zc(nr),mxsim(nr,100),ddistl(nkind,ntype),tdis
ltl(nr,nkind,ntype),jflag,temp2,ilook(15)
common /fift/ pcapbs(nr,ntype), valcur(nr), valpre(nr,60), olvalc(
lnr), olvalp(nr,60)
```

```
subroutine econ(j)
c
c PARM is a list of subscript variables for dimensions
c include parm,list
c
c COMBLK is a list vraiables common to all subroutines.
c
c Subroutine ECON
c Calculates regional output from national forecast
c
c Usage :    call econ(region)
c
c
c
c
c Parameter Block PARM
c Contains the dimensions for all the variables.
c
c
c
c nr      number of regions/basins
c ni      number of industries
c nkind   number of kinds of wasteloading substances
c
c Common Block COMBLK
c list of variables for all subroutines.
c dimensions of these variables are specified
c in data block PARM
c
c
c
c b      regional r.d.p. matrix multiplier.
c ro     regional output.
c
c
c dimension a(ni,nr)
double precision cno,b,nim,itmi01,itmi02,itmi03
real mgal03,mgal02,mtmi01,mtmi02,mtmi03
real mxsim,munsup,munhrn,iwlsup,iwlhrn,olvalc,olvalp
real mwlfac,iwlfac,mwl,iwl,mwwfl,mtcost,impact,iwlsum,invest
real mtmir1,mtmir3,mtmisl,mtmis3,mtmih1,mtmih3,itmir1,itmir3,itmisi
11,itmisi3,itmih1,itmih3
integer prtime,prntp,prntpr,out,in
integer a,c
equivalence(a(1,1),c(1))
common /time/ now,length,prntp,prtime,iend
```

```
common /iunit/ in,out,int
common /names/ itmi01(nr,ni),itmi02(nr,ni),itmi03(nr,ni),c(nd)
common /vars10/ mgal02(l1),tbld(nr,nkind)
common /blk1/ ro(nr,ni),pop(nr),mwlfac(nz,nkind),mwl(nr,nkind),iwl
lfac(ni,nkind),iwl(ni,nkind),smwfac(nz,nkind),siwfac(ni,nkind),pre
lv(nr,ni)
common /blk2/ distld(nkind,ntype),prpcap(nr,ntype),ctiff(nkind,nty
lpe),trulod(nkind,ntype)
common /blk3/ untrt(nz,nkind),sumvst(nj),impact(nj),chmfac(100),ch
lwfac(100)
common /blk4/iwlsum(nr,nkind),b(ni),sumiti(nr,ni),mtcost(ntype)
common /blk5/ cno(nj),mwwfl(nr),effdlr(100),pcwatr(nr,100),depr
common /blk6/ uratio(nr),urbpop(nr),pl(np,npolst),nowyr(np,npolst
1),lastyr(np,npolst),nim(np,nj,npolst),invest(np,npolst)
common /blk7/ mgal03(nr,ntype),mtmi01(nr),mtmi02(nr),mtmi03(nr),ma
lxs02(nz,nkind)
common /ten/ destrl(nr,100),bastrl(nr,100),sdestr(nr,100),bastr2(n
lr,100)
common /eleven/ munsup(nkind),munhrn(nkind),iwlsum(nkind),iwlhrn(n
kind),tblsup(nkind),tblhrn(nkind),ttbsup(nkind),ttbhrn(nkind),cali
lbr(nr,nkind),ttbld(nr,nkind),observ(nr,nkind)
common /twelve/ stock1(nr,ni),stock2(nr,ni),stocpl(nr,ni),stocp2(n
lr,ni)
common /thirt/ mtmir1(nr),mtmir3(nr),mtmis1,mtmis3,mtmih1,mtmih3,i
ltmir1(nr),itmirl(nr),itmisl,itmisl,itmih1,itmih3
common /fort/ zb(nr),zc(nr),mxsim(nr,100),ddistl(nkind,ntype),tdis
ltl(nr,nkind,ntype),jflag,temp2,ilook(15)
common /fift/ pcapbs(nr,ntype),valcur(nr),valpre(nr,60),olvalc(
lnr),olvalp(nr,60)
```

c  
c LIST OF VARIABLES.  
do 5 i=1,ni  
5 ro(j,i)=cno(i)\*b(i)  
c  
return  
end

---

```
%  
%  
% Data Block HERMAN  
% Contains data for adjustment of length of simulation  
%
```

---

```
%  
% block data herman  
%
```

```
%  
% LIST OF VARIABLES.  
%
```

```
% length length of simulation period  
% prnptr output printing interval  
% prtime output printing year  
% now the year for output printing  
% iend ending year of simulation  
%
```

```
% implicit integer (p)  
%
```

```
common /time/now,length,prnptr,prtime,iend  
%
```

```
data now/1971/,prnptr/10/,lnmax/60/,pagcnt/1/  
data iend/2020/  
%
```

```
end
```

---

```
%  
%  
% Subroutine POPUL8  
% Calculates population ratios.  
%  
% Usage: call popul8 (regpop,urbpop,uratio,nr)  
%
```

---

```
%  
%  
% LIST OF VARIABLES.  
% regpop regional population  
% uratio urbanization ratio  
% urbpop urban population  
% nr number of regions  
%
```

---

```
%  
% subroutine popul8 (regpop,urbpop,uratio,nr)  
%  
% dimension regpop(nr) ,urbpop(nr) ,uratio(nr)  
%  
%  
do 101 l=1,nr  
urbpop(l)=regpop(l)*uratio(l)  
101 continue  
%  
return  
end
```

---

```
%  
% Subroutine SPEND  
% Calculates impacts created by additional  
% investment each year.
```

```
%  
% Usage: call spend  
% Variable declarations are in COMBLK, & PARM  
% Variable definitions are in MAIN
```

---

```
%  
% subroutine spend  
%  
% PARM is a list subscript variables for dimensions  
include parm,list
```

```
%  
% COMBLK is a list of variables common to all subroutines.  
include comblk,list
```

```
%  
%  
% Calculation of Impact for each year.
```

```
%  
% for each industry  
do 10 i=1,nj
```

```
%  
% initialize impact  
impact(i)=0.  
sumvst(i)=0.
```

```
%  
% for each investment channel  
do 20 k=1,np
```

```
%  
% for each year of impact.  
do 30 m=1,npolst
```

```
%  
% select correct multiplier  
ny=nowyr(k,m)
```

```
%  
% if investment is zero, forget about impact  
if(invest(k,m) .eq. 0.) go to 30
```

```
%  
% calculate impact of investment  
% impact(i)=impact(i)+(invest(k,m)/25e6)*nim(k,i,ny)  
sumvst(i)=sumvst(i) + invest(k,m)  
nowyr(k,m)=nowyr(k,m)+1  
if(nowyr(k,m) .gt. lastyr(k,m)) nowyr(k,m)=1  
30 continue  
20 continue
```

```
%  
%      sum up effect on this industry  
%      scale the impact to proper units  
if( i=34) 9873,9874,9873  
9874 impact(i)=impact(i)*le3  
go to 9876  
%  
9873 if(i .eq. 32) go to 9876  
impact(i)=impact(i)*le6  
9876 cno(i)=cno(i)+impact(i)  
10 continue  
%  
%  
return  
end
```

Subroutine TECHN calculates industrial treatment costs, & additional treatment costs.

Usage: call techn(region, year)  
variable declarations are in COMBLK, & PARM.  
variable definitions are in MAIN.

subroutine techn(j,index)

Parm is a list of subscript variables for dimension control.  
include parm,list

COMBLK is a list variables & their dimensions common to  
all subroutines.

include comblc,list

Calculate municipal treatment capacity.

do 10 nt=1,ntype  
mgal03(j,nt)=mgal02(j)\*prpcap(j,nt)  
mgal03(j,nt)=mgal03(j,nt)+((effdlr(index)\*mtmi03(j))/mtcost(nt))  
10 continue

Industrial treatment costs calculation sector.

Calculate r.d.p. ratio (current yr/previous yr)  
do 100 k=1,ni  
  
if(index .eq. 1) prev(j,k)=ro(j,k)  
if(prev(j,k) .ne. 0.) goto 6  
temp2=0.  
goto 7  
  
TEMP2 change by CHWFAC.  
6 temp2=(ro(j,k)/prev(j,k))-chwfac(index)

```
if (temp2 .lt. 0.) temp2=0.  
7 prev(j,k)=ro(j,k)  
%  
%  
% Calculate base industrial treatment costs, ITMI01.  
if(index .eq. 1) stock2(j,k)=sumiti(j,k)  
if(index .eq. 1) stocp2(j,k)=stock2(j,k)  
%  
stock1(j,k)=stock2(j,k)  
itmi01(j,k)=effdlr(index)*(stock1(j,k)*temp2+stock1(j,k)*depr)-stock1(j,k)  
if(temp2 .eq. 0.) itmi01(j,k)=0.  
%  
%  
% Calculate additional industrial treatment costs, ITMI03.  
if(destrl(j,index) .le. .90) z=(destrl(j,index)-bastrl(j,index))  
if(destrl(j,index) .gt. .90) z=exp(.5*((destrl(j,index)-.90)*100.))  
%  
stocpl(j,k)=stocp2(j,k)  
itmi03(j,k)=effdlr(index)*((a(k,j)*z*stocpl(j,k)*temp2)+stocpl(j,k)* %  
temp2+stocpl(j,k)*depr)-stocpl(j,k)  
if(temp2 .eq. 0.) itmi03(j,k)=0.  
stocp2(j,k)=stocp2(j,k)+itmi03(j,k)-stocp2(j,k)*depr  
itmi02(j,k)=itmi03(j,k)-itmi01(j,k)  
%  
%  
% Sum industrial treatment costs for regions.  
itmirl(j)=itmirl(j)+itmi01(j,k)  
itmirl3(j)=itmirl3(j)+itmi03(j,k)  
%  
100 continue  
%  
%  
%  
% Sum industrial treatment costs for lakes, Superior, & Huron.  
if(j .gt. 4) go to 301  
itmisl=itmisl+itmirl(j)  
itmisl3=itmisl3+itmirl3(j)  
go to 302  
%  
301 itmihl=itmihl+itmirl(j)  
itmih3=itmih3+itmirl3(j)  
302 continue  
%  
%  
%  
return  
end
```

---

```
%  
%  
% Subroutine WLINT - Wasteloading Integrator.  
% Calculates municipal wasteloading & municipal investment,  
% and industrial wasteloading.
```

```
% Usage: call wlnt(region,year)  
% variable declarations are in COMBLK & PARM.  
% variable definitions are in MAIN.
```

---

```
%  
%  
% subroutine wlnt(j,index)
```

```
% PARM - a list of variables for variable dimensions.  
include parm,list
```

```
%  
% COMBLK - a list of variables & their dimensions common to  
% all subroutines.
```

```
include comblc,list
```

---

```
%  
% Municipal Wasteloading Calculation Sector.
```

---

```
%  
% Municipal waste calculation.
```

```
% Calculate population waste water flow.  
mwwfl(j)=urbpop(j)*pcwatr(j,index)
```

```
% Initialize
```

```
do 9 k=1,nkind
```

```
9 mw1(j,k)=0.
```

```
% Calculate municipal wasteloading in tons per year.
```

```
do 10 k=1,nkind
```

```
if(smwfac(nz,k) .eq. 0.) go to 10
```

```
mw1(j,k)=(urbpop(j)*smwfac(nz,k))/2000.
```

```
10 continue
```

```
% Calculate fractions to be treated, or not to be treated.  
% For 'Zero discharge 1985 policy' , 100 % gets treated.
```

```
zc(j)=1.-zb(j)
```

```
if(jflag .ne. 3) goto 2018
if(now .gt. 1984) mxsim(j,index)=1.
2018 zz=zb(j)+mxsim(j,index)*zc(j)
zn=1.-zz
%
%
%
%
%
Municipal treatment investment calculation sector.

%
%
%
%
% Calculate municipal investment MTMI01 for base scenario only.
if(jflag .ne. 1) goto 7163
mtmi01(j)=0.
olvalc(j)=0.
do 6163 nt=1,ntype
6163 olvalc(j)=olvalc(j)+(mwwf1(j)*zb(j)*pcapbs(j,nt)*mtcost(nt))
olvalp(j,index)=olvalc(j)
if(index .gt. 1) goto 5163
mtmi01(j)=olvalp(j,index)
goto 7163
%
5163 mtmi01(j)=olvalc(j)-olvalp(j,index-1)+0.02*olvalp(j,index-1)
if(mtmi01(j) .lt. 0.) mtmi01(j)=0.
7163 continue
%
%
%
Initialize
mtmi02(j)=0.
mtmi03(j)=0.
valcur(j)=0.
%
%
Calculate additional municipal treatment investment MTMI02
MTMI03.
do 7597 nt=1,ntype
valcur(j)=valcur(j)+(mwwf1(j)*zz*prpcap(j,nt)*mtcost(nt))
7597 continue
%
valpre(j,index)=valcur(j)
if(index .gt. 1) goto 6597
mtmi03(j)=valpre(j,index)
goto 5597
%
6597 mtmi03(j)=valcur(j)-valpre(j,index-1)+0.02*valpre(j,index-1)
5597 if(mtmi03(j) .lt. 0.) mtmi03(j)=0.
mtmi02(j)=mtmi03(j)-mtmi01(j)
%
%
Sum investments for lakes: Superior, & Huron.
if(j .gt. 3) go to 501
```

```
% superior: regions 1-3
%
%      huron : regions 4-7
mtmis1=mtmis1+mtmi01(j)
mtmis3=mtmis3+mtmi03(j)
go to 502
%
501 mtmih1=mtmih1+mtmi01(j)
mtmih3=mtmih3+mtmi03(j)
502 continue
%
%
%
%
%      Calculate portions of municipal waste treated, untreated.
do 824 k=1,nkind
untrt(l,k)=zn*mwl(j,k)
mwl(j,k)=zz*mwl(j,k)
824 continue
%
%      Calculate municipal loading after treatment by the 3 types.
do 7001 k=1,nkind
do 7002 nt=1,ntype
7002 distld(k,nt)=mwl(j,k)*prpcap(j,nt)
7001 continue
%
do 613 k=1,nkind
mwl(j,k)=0.
do 614 nt=1,ntype
trulod(k,nt)=distld(k,nt)*ctiff(k,nt)
mwl(j,k)=mwl(j,k)+trulod(k,nt)
ddistl(k,nt)=distld(k,nt)-tdistl(j,k,nt)
tdistl(j,k,nt)=distld(k,nt)
if(ddistl(k,nt) .lt. 0.) ddistl(k,nt)=0.
614 continue
613 continue
%
%
%
%
%      Industrial wasteloading calculation sector.
%
%
%
%
%      Initialize
983 do 20 k=1,nkind
iwlsum(j,k)=0.
%
%      Calculate industrial loading.
do 30 i=1,ni
```

```
iwl(i,k)=0.  
if(iwlfac(i,k) .eq. 0.) go to 982  
iwl(i,k)=(ro(j,i)*(iwlfac(i,k)*((l.-destrl(j,index))/(l.-bastr2(j,index)))))/2000.  
982 iwlsum(j,k)=iwlsum(j,k)+iwl(i,k)  
30 continue  
%  
% Integrate municipal, total, calibrated loadings, & maxima.  
% Subroutine CALBBB is for calculation of calibrated total.  
mw1(j,k)=mw1(j,k)+untrt(nz,k)  
tbld(j,k)=mw1(j,k)+iwlsum(j,k)  
if(now .eq. 1974) call calbbb(nr,nkind,observ,tbld,calibr)  
ttbld(j,k)=calibr(j,k)+tbld(j,k)  
maxs02(nz,k)=amax1(maxs02(nz,k),tbld(j,k))  
20 continue  
%  
%  
% Sum loadings for lakes: Superior, & Huron.  
if(j .gt. 3) go to 1001  
% superior : regions 1-3  
% huron : regions 4-7  
do 1002 k=1,nkind  
munsup(k)=munsup(k)+mw1(j,k)  
iwlsum(k)=iwlsum(k)+iwlsum(j,k)  
tblsup(k)=tblsup(k)+tbld(j,k)  
1002 ttbsup(k)=ttbsup(k)+ttbld(j,k)  
go to 1004  
%  
1001 do 1003 k=1,nkind  
munhrn(k)=munhrn(k)+mw1(j,k)  
iwlhrn(k)=iwlhrn(k)+iwlsum(j,k)  
tblhrn(k)=tblhrn(k)+tbld(j,k)  
1003 ttbhrn(k)=ttbhrn(k)+ttbld(j,k)  
1004 continue  
%  
%  
%  
100 return  
end
```

FOOTNOTES

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