THE UNIVERSITY OF MANITOBA

EFFECTS OF URBAN RUNOFF ON THE DISSOLVED OXYGEN RESOURCES OF THE RED RIVER AT WINNIPEG, MANITOBA

by

Barry D. MacBride

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE

DEGREE OF MASTER OF SCIENCE

DEPARTMENT OF CIVIL ENGINEERING

WINNIPEG, MANITOBA

OCTOBER 1979

EFFECTS OF URBAN RUNOFF
ON THE DISSOLVED OXYGEN RESOURCES
OF THE RED RIVER AT WINNIPEG, MANITOBA

BY

BARRY DOLAN MACBRIDE

A thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

MASTER OF SCIENCE

ABSTRACT

The 5-day biochemical oxygen demand ($B.O.D._5$) contained in wet weather urban discharges from combined sewer overflows and separate storm runoff can result in depletion of dissolved oxygen in receiving streams below acceptable levels.

This study was undertaken to determine the effects of the wet weather and dry weather discharges on minimum dissolved oxygen (D.O.) levels in the Red River, at Winnipeg, Manitoba, and to predict the effects of various pollution control strategies, such as wet weather flow treatment, dry weather flow treatment, and low flow augmentation, on the D.O. levels of the Red River.

The Storage Treatment Overflow Runoff Model (STORM) was used to predict $B.O.D._5$ loadings in urban runoff for 1977. These loadings were input to a computer based planning level river quality model developed for this study, using the Streeter-Phelps formulations to predict minimum D.O. concentrations in the Red River. The effect of continuous discharges were examined using a dry weather flow model. Both models were calibrated to measured data.

The wet weather flow model predicted that the number of violations during 1977 of a minimum D.O. of 5 mg/L are 12, 5, 2, and 1 for existing conditions; 25% treatment of combined sewer overflows (C.S.O.); 50% treatment of C.S.O.; 75% treatment of C.S.O.; and 50% treatment of all wet weather flows

respectively. It predicted that there would be no change in the number of violations if the river flows were one-half of the 1977 flows.

The dry weather flow model predicted average minimum dissolved oxygen levels during the summer of 6.8 mg/L, 2.0 mg/L, 0.1 mg/L, and 7.6 mg/L for secondary treatment, primary treatment, no treatment, and advanced treatment of continuous municipal sewage discharges. It predicted the average minimum D.O. concentration would be 5.2 mg/L with secondary treatment at one-half the river flows.

It was concluded that the D.O. level in the river is sensitive to variations in dry weather and wet weather flow treatment. A minimum of secondary treatment of dry weather flows is necessary to keep average minimum D.O. above 5 mg/L. The treatment of wet weather flows will reduce the number of violations of a D.O. concentration of 5 mg/L.

TABLE OF CONTENTS

TABLE OF CONTENTS
(continued)

TABLE OF CONTENTS
(continued)

TABLE OF CONTENTS
(continued)

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF FIGURES

FREQUENTLY USED NOTATION

$B.O.D._5$	5 day Biochemical Oxygen Demand - 20°C - mg/L
$B.O.D._u$	Ultimate Biochemical Oxygen Demand - 20°C mg/L
cfs	Cubic feet per second
C.S.O.	Combined Sewer Overflows
Da	Initial Dissolved Oxygen Deficit in Stream mg/L
D.O.	Dissolved Oxygen - mg/L
D.O.D.	Dissolved Oxygen Deficit - mg/L
D.W.F.	Dry Weather Flow
K_1	Deoxygenation Rate Constant (day^{-1})
K_2	Reaeration Rate Constant (day^{-1}_
La	Ultimate Biochemical Oxygen Demand in River
LOAD	Program to compute Total Stream Loading
N.E.W.P.C.C.	North End Water Pollution Control Centre
RVRQUAL	River Quality Model
STORM	Storage Treatment Overflow Runoff Model
SWMM	Storm Water Management Model
W.W.F.	Wet Weather Flow

EFFECTS OF URBAN RUNOFF
ON THE DISSOLVED OXYGEN RESOURCES
OF THE RED RIVER AT WINNIPEG, MANITOBA

1. INTRODUCTION

Urban runoff contains significant amounts of pollutants, and may constitute a threat to the quality of receiving streams. Stream degradation is a high complex phenomenon that requires considerable research before adequate solutions can be developed.

1.1. STATEMENT OF THE PROBLEM

In the past 50 years, millions of dollars have been spent on sewage treatment in virtually every city in the country in order to protect the receiving streams. This major effort has concentrated on the continuous discharge sources of wastewater.

Over the last 15 years there has been an increasing awareness of the significance of pollutants in runoff from rainfall events. Precipitation falling on urban areas becomes contaminated as it passes through the air, contacts urban surfaces, and mixes with deposits in sewers. The polluted storm water finally discharges to the receiving stream.

In terms of 5-day Biochemical Oxygen Demand ($B.O.D._5$) the strength of combined sewer overflows is approximately one-half the strength of untreated municipal sewage.[(1)*] Separate storm discharges have approximately the same $B.O.D._5$ concentrations as treated municipal effluents.[(1)] During runoff periods the high volume of runoff results in mass loadings to the stream many times that of treated effluents. Urban runoff also contains significant proportions of other pollutants such as solids, coliforms, nutrients, and inorganic chemicals.

Stream degradation may occur when pollutants from these discharges exceed the assimilative capacity of the receiving water body. Treatment of these intermittant discharges has largely been neglected in municipal pollution control strategies. The magnitude of the intermittant pollutant loading increases as a city grows in population. The result is that receiving water quality is degrading even though millions of dollars are being spent on treatment of continuous dry weather discharges.

There is a need to develop comprehensive plans of urban pollution management considering the optimum blend of control of dry weather and wet weather pollutant discharges. In the United States, development of such comprehensive plans are required under law (P.L. 9200) prior to the allocation of Federal funds for pollution control facilities.[(2)] Canada is heading in the same direction.[(3)]

---

* The numbers in parentheses in the text indicate references in the bibliography.

1.2. REASONS FOR THE STUDY

Most of the concern with a sewerage system relates to the impact of the discharge of wastewater to the receiving stream. The location of Winnipeg, Manitoba on the confluence of the Red and Assiniboine Rivers, as shown in Figure 1, makes wastewater discharge a special consideration since the rivers are a resource for water related recreation in Winnipeg.

At various times during the history of Winnipeg the rivers had become polluted to crisis levels with sewage loads.[4] The first crisis was in the early 1930's resulting in the installation of interceptor sewers and a primary treatment plant. In the early 1960's, the quality of the Red River had again degraded to a crisis point, that resulted in a 10-year program[5] to provide secondary treatment of all continuous discharges, ending in 1974 with the opening of the South End Water Pollution Control Centre. The City of Winnipeg is committed to preservation of the quality of the rivers.[5]

The City currently directs its complete pollution control budget to the collection and treatment of continuous dry weather flow discharges. However, the adequacy of the existing pollution control program is unknown under the following conditions;

1) low river flows where the assimilative capacity of the river is low; and
2) wet weather conditions, when pollutant loadings from combined sewer overflows and storm sewer discharges are many

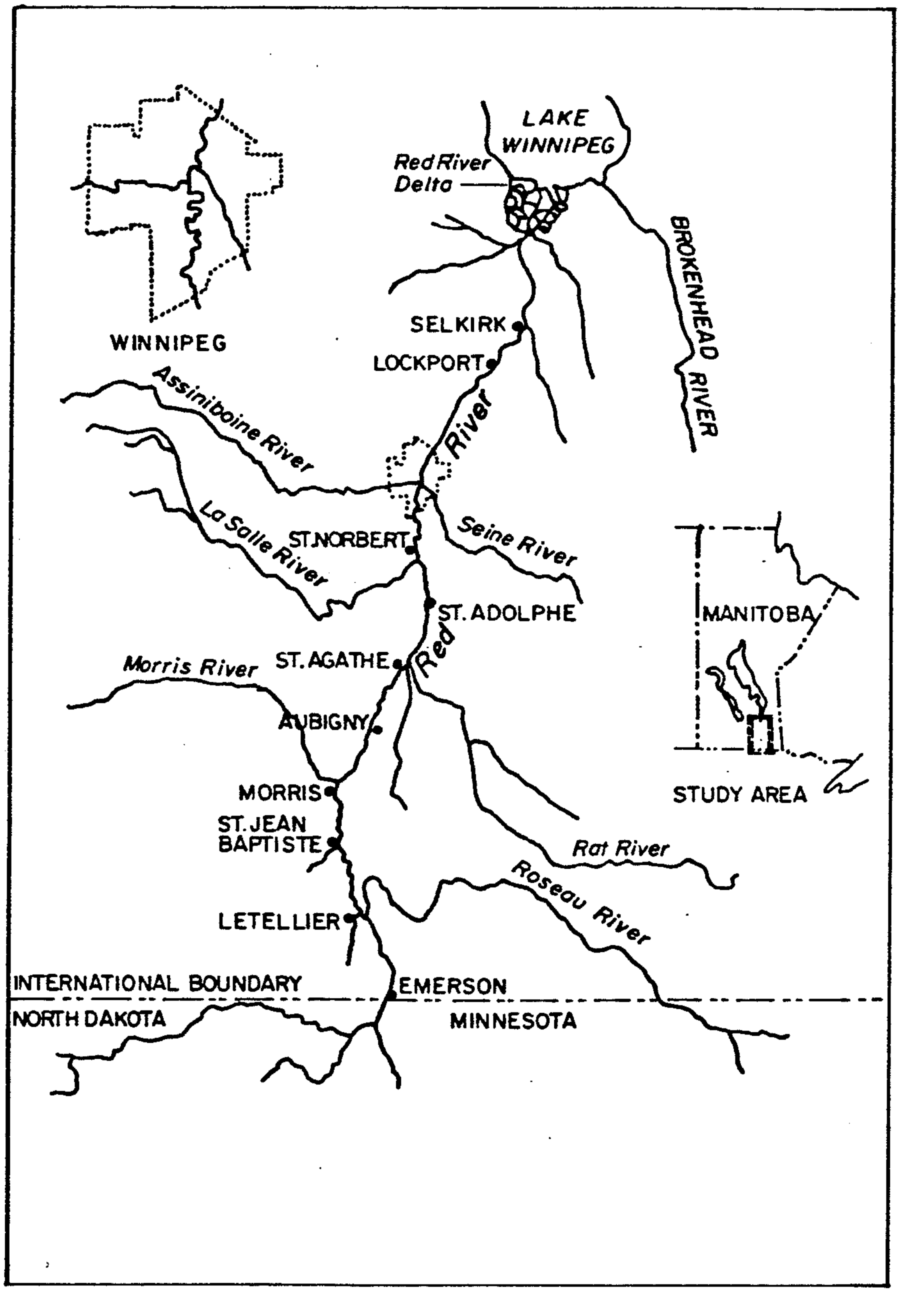


FIG. 1. LOCATION PLAN

times greater than that discharged from the treatment plants.

Although no fish kills have been reported in recent years, it is possible that the oxygen reserves of the river may be depleted during these conditions, resulting in injury to aquatic life.

In addition, the direction of future pollution control efforts in Winnipeg can only be optimized, when the conditions of the receiving stream are known under a range of possible control strategies. The control strategies range from the "no treatment" alternative to complete secondary treatment of all dry weather and wet weather flows.

1.3. OBJECTIVES

The objectives of the study are as follows:

1) to determine the effects of;
   a) treatment plant effluents,
   b) combined sewer overflows,
   c) storm sewer discharges,

   from the City of Winnipeg on the quality of the Red River, using dissolved oxygen (D.O.) as the quality parameter;

2) to determine the effects of various pollutant control strategies on oxygen levels in the Red River at Winnipeg including;
   a) dry weather flow treatment,
   b) wet weather flow treatment,

c) low flow augmentation of Red River flows.

1.4. STUDY AREA

The City of Winnipeg, the capital of Manitoba, has a population of 560,000, approximately one-half of the population of Manitoba. The City of Winnipeg has both combined and separate sewer systems as shown in Figure 2. The older central area of the City is served by combined sewers. The dry weather flow and a nominal fraction of the wet weather flow is diverted to an interceptor sewer which conveys the sewage to the NEWPCC treatment plant. All wet weather flow in excess of the 2.75 times dry weather flows overflows to the River. There are 41 individual combined sewer districts which total approximately 26,000 acres.

Since about 1961, all new developments in the City have been built using the separate sewer system.[6] The City of Winnipeg has approximately 16,000 acres of separate sewered area.

1.5. EXTENT OF INVESTIGATION

In order to achieve the objectives, the study was carried out within the following bounds.

1. The Storage Treatment Overflow Runoff Model 'STORM'[7] was used to generate estimates of pollutant washoff from the City of Winnipeg for subsequent use in the river quality analysis. STORM is a continuous simulation model which facilitated the

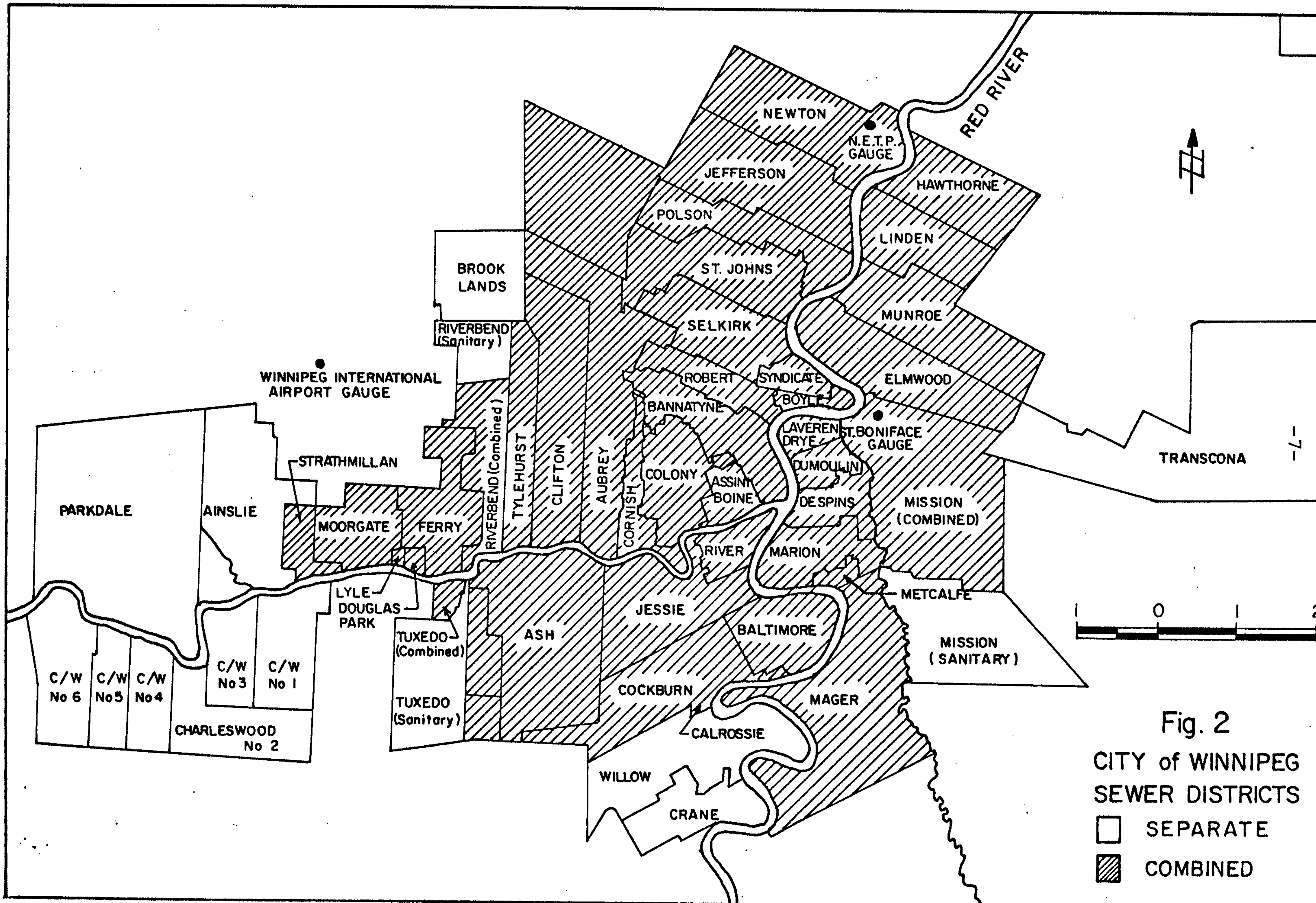


Fig. 2

CITY of WINNIPEG SEWER DISTRICTS

examination of runoff quantity and quality.

The period of record used for the study was May, June, July, August, September, and October of 1977. This was the first year in which comprehensive dissolved oxygen measurements were available for the Red River.[8]

2. A computer based model was developed using the Streeter-Phelps formulations to model the B.O.D.-D.O. relationships. This model was used to predict minimum D.O. levels for each rainfall event. A dry weather flow model was developed for analysis of continuous discharge of sewage treatment plant effluents.

3. The wet weather and dry weather loadings were developed for various pollution control strategies and the frequency of minimum dissolved oxygen levels were predicted for wet weather and dry weather using the river quality models. The specific strategies investigated were:

1) no treatment of dry weather flows;
2) primary treatment of dry weather flows;
3) secondary treatment of dry weather flows (existing conditions);
4) advanced treatment of dry weather flows;
5) minimal treatment of wet weather flows (existing conditions 2.75 x dry weather flows);
6) 25% B.O.D.$_5$ removal of combined sewer overflows;
7) 50% B.O.D.$_5$ removal of combined sewer overflows;

8) 75% B.O.D.$_5$ removal of combined sewer overflows;

9) 50% B.O.D.$_5$ removal of all wet weather flows.

The effects of low river flows were also investigated to allow evaluation of low flow augmentation using water diverted from another source (e.g. Lake Manitoba), as a pollution control strategy.

2. LITERATURE REVIEW

2.1. EFFLUENT AND STREAM STANDARDS

Wastewater is of concern with respect to pollution of the streams in that it carries components which may deplete the oxygen resources of the stream, stimulate undesirable growth of plants or organisms and/or have undesirable aesthetic or health effects on downstream users. Wastewater can contain bacteria and viruses which may transmit diseases.

Traditionally, regulatory agencies have promoted "effluent standards" as a means of protection of water quality. In this approach an effluent concentration limit of for example 30 mg/L $B.O.D._5$ was required. This method of regulation is known as the "best practicable technology" approach[10] and is currently used by the Federal Government in their guidelines for Federal installations.[9] Proponents of this approach argue that this is a reasonably achievable standard and provides for the minimal practicable discharge of pollutants to the environment.

The inherent weaknesses of the approach is that it does not recognize the relative capability of the receiving stream to assimilate pollutants, while preserving other uses of the specific stream. An approach based on finding the optimum use of a stream is referred to as the "best resource allocation"[10] approach.

The Province of Manitoba has proposed surface water quality objectives and stream classifications [10] consistent with the resource use approach. This approach has been taken in many states in the United States.[11]

The objectives [10] recognize six use categories for each stream as follows:

1) domestic consumption;
2) fisheries and recreation;
3) industrial consumption;
4) agriculture and wildlife;
5) navigation and waste disposal; and
6) other uses.

A number of sub-classes are defined for the first four classes. For example, under the principal class 1, domestic consumption, the following sub-classes are defined:

1A: Raw water meets Canadian Drinking Water Standards (C.D.W.S.) [12] with no treatment;

1B: Raw water will meet C.D.W.S. with disinfection;

1C: Raw water will meet C.D.W.S. with conventional treatment; and

1D: Raw water will meet C.D.W.S. with advanced treatment.

Stream reaches are classified according to each category.

For example the Red River is classified as shown in Table 1.

TABLE 1.

STREAM CLASSIFICATIONS - RED RIVER

Reach		Classification
U.S. Border to Winnipeg South Limits	-	1B, 2C, 3B, 4A, 4B, 5, 6
City of Winnipeg	-	2C, 3B, 4A, 4B, 5, 6
Winnipeg North Limits to end of recovery zone	-	2C, 3B, 4A, 4B, 5, 6
Recovery zone to Lake Winnipeg	-	1C, 2B, 3B, 4A, 4B, 5, 6

Limits are set for a range of constiuents under each such-category, including D.O. and fecal coliforms, and based on knowledge of water quality criteria from standard references.(11)(12)

A major criteria of interest in sanitary engineering is dissolved oxygen. Inadequate dissolved oxygen may lead to an undesirable environment for fish and other aquatic life. The absence of dissolved oxygen will result in odours from products of anaerobic decomposition. Depletion of dissolved oxygen results from a biodegradable organic addition. This is described in the next section. Some important D.O. values and B.O.D. interpretations common for a stream are shown in Table 2.

2.2. CHARACTERISTICS OF URBAN DISCHARGES

Sanitary Engineers have recognized the characteristic pollutant loads in municipal sewage for hundred of years. Recognition of pollutant loads from combined sewer overflows has led to the development of the separate sewer system. In The District of

TABLE 2.

IMPORTANT D.O. VALUES AND B.O.D. INTERPRETATIONS [10][11]

Dissolved Oxygen	
Value	
14 mg/L	Saturation at 0°C.
8 mg/L	Saturation at 24°C.
5 mg/L	Minimum for trout species Typical Stream Standard
4 mg/L	Minimum for pickerel
2 mg/L	Minimum for rough species
0 mg/L	Anaerobic Conditions - Odours
35% - 100% Saturation	Manitoba Objective - Class 2C (Red River, Winnipeg Recovery Zone)
B.O.D.$_5$	
1 mg/L	Very Clean Stream
2 mg/L	Clean Stream
5 mg/L	Doubtful Quality
10 mg/L	Bad - will likely result in significant depletion
Stream Standard	
5 mg/L	Typical Stream Standard for Minimum D.O. minus B.O.D.$_5$

Columbia, U.S.A., separate sewers were installed in new areas of the City beginning in 1890.[13] The widespread installation of separate sewer systems did not begin until the 1950's, and in Winnipeg after 1961.[6]

Sewer separation in older combined areas was thought to be the best solution to the problem of combined sewers. More recently there has been a realization that separate storm sewers also carry significant pollutant concentrations. The result is that sewer separation as an abatement strategy is being replaced by a wide range of alternatives including source control, storage and treatment.[1]

The relative characteristics of pollutant concentrations in municipal sewage and urban runoff is shown in Table 3. This data, as presented in a comprehensive report released by the Environmental Protection Agency (E.P.A.) in 1974[13] and updated in 1977,[14] represents average values for 2,500 separate sewer samplings and 2,200 combined sewer samplings in cities across the United States.

The City of Winnipeg has also been active in sampling of combined and separate storm sewer discharges. The first monitoring program took place in the years from 1969 to 1971. The results of more recent sampling programs[15][16] are shown in Table 4. These are compared with results of tests at the North End Water Pollution Control Centre (N.E.W.P.C.C.).

TABLE 3.

CHARACTERISTICS OF URBAN DISCHARGES[13][14]

	$B.O.D._5$ mg/L	S.S. mg/L	Total Coliforms MPN/100ml	Total Nitrogen mg/L as N	Total Phosphorous mg/L as P
Untreated Municipal Sewage	200	200	5×10^7	40	10
Treated Municipal Sewage					
Primary Effluent	135	80	2×10^7	35	8
Secondary Effluent	25	15	1×10^3	30	5
Combined Sewage Overflows	115	370	5×10^6	11	4
Separate Storm Sewer Discharges	20	415	4×10^5	3	1
Background Levels	0.5 - 3	5 - 100	-	0.05 - 0.5	0.01 - 0.2

TABLE 4.

CHARACTERISTICS OF URBAN DISCHARGES AT WINNIPEG

	B.O.D.$_5$ mg/L	S.S. mg/L	Nitrogen mg/L	Phosphorous mg/L
N.E.W.P.C.C. (City data)				
Raw	294	317	36	6.8
Final Effluent	46	46	24	2.9
St. John's Polson[16] Munroe Combined Districts	14 - 191	120 - 720	8 - 23	1 - 4
Southdale, Baldry[15] Separate Systems	12	578	5.3	1.5

2.3. URBAN STORMWATER QUANTITY AND QUALITY MATHEMATICAL MODELS

2.3.1. General

A mathematical model is a system of equations that transform an input to an output. In terms of urban runoff, a typical model is shown in Figure 3.(3) The model is a representation of the physical phenomena. More complex mathematical models are computer based since a large number of computations are made during a "run".

In the field of urban stormwater management, a large number of models have been developed in response to analysis requirements in the United States.(2) This model technology has been adopted by Canadian engineers.(3)

A model is used where experiments on the real system are not feasible. For example, it may be virtually impossible to test a drainage system under certain conditions such a one in ten-year rainfall. However, the modeller can "experiment" with a system under those conditions and many others using a model calibrated under more normal conditions.

It is important to note that the development and use of models increase the understanding of the phenomena being modelled and give the modeller a feeling for the system being modelled.

A range of models have been developed for planning, design, and operational control.(3)

a) Planning models are used for overall assessment of the urban runoff problem. Even if

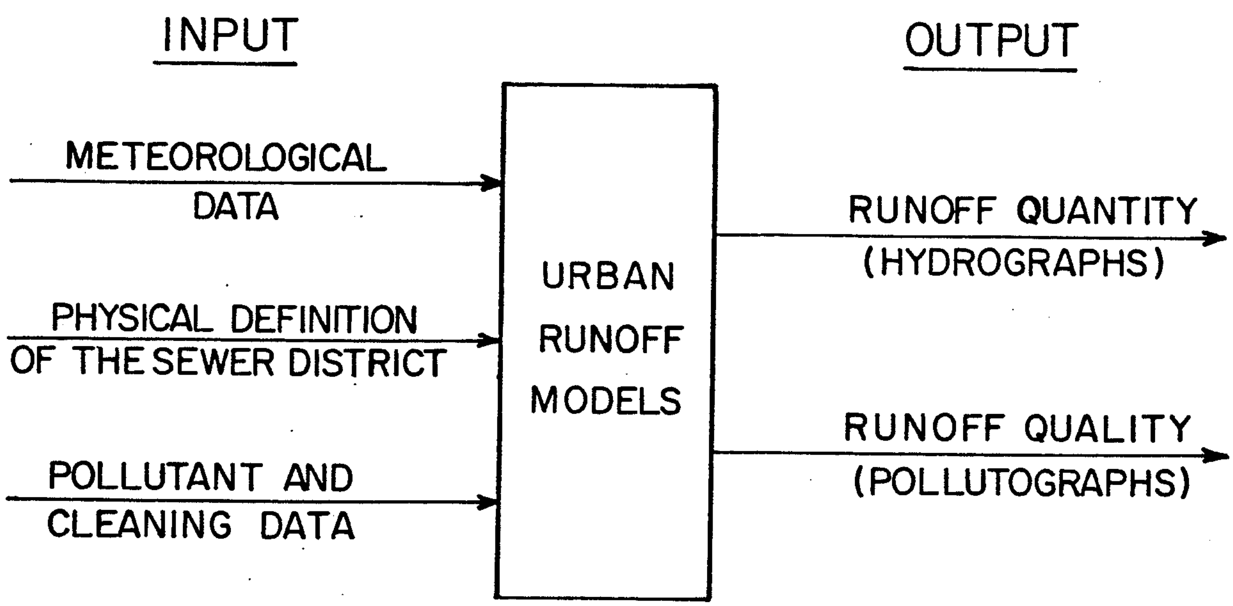


FIG. 3. URBAN RUNOFF MODEL

the results from such a model are not exact, they can serve to indicate which alternative systems are most promising in terms of broad objectives;

b) Design/Analysis models are typically more complex than planning models but the results are accurate enough for detailed design of systems;

c) Operational models have been developed to allow actual real time control of a system during a rainfall event. They serve to make predictions and actuate controls to optimize the system response during an event.

Planning models are typically used to analyze a large number of events at low cost. Design models are run for a single design event, or up to several design events.

With any model, the question arises as to how well the model represents the physical system. Sensitivity analysis, calibration and verification are required to gain confidence in the results. These steps increase the reliability of the results. This is especially important when the input values are not accurately known.

Sensitivity analysis involves the systematic independent variation of parameters used in the computation, in order to ascertain the effects of such variations on the results, and to decide whether or not the model responds in a logical manner. This analysis serves to increase knowledge and understanding of the model, and even the physical system. The variation of the parameters is kept within usual known limits of the parameters.

Calibration is the adjustment of model parameters such that the output closely matches an observed record. A model that is not calibrated can not be used with any confidence, and a model that can not be calibrated is a poor representation of the physical system. Calibration requires measurements on the real system.

Verification involves testing the calibrated model on a separate data set to insure it is not biased.

2.3.2. Urban Stormwater Models

A recent study for Environment Canada[3] identifies eighteen urban runoff models. The characteristics of eight of the more widely used urban runoff models are shown in Table 5.[2] Of these, the Canadian Government[3] has selected a design model SWMM and a planning model STORM as most suited for Canadian conditions. These models are the most widely used and best documented of those studied. They are being continually improved and updated through the U.S.E.P.A. (SWMM) and the Corps of Engineers (STORM). SWMM is described briefly below. STORM is described in detail in Section 2.4. since it is the model selected for use in developing pollutant loadings for this thesis.

TABLE 5

URBAN DRAINAGE MODELS (2)

Catchment Hydrology

MODEL ORIGIN	MODEL ACRONYM	Multiple Catchment Inflow	Dry-Weather Flow	Input of Several Hyetographs	Snowmelt	Runoff From Impervious Areas	Runoff From Pervious Areas	Water Balance Between Storms
Corps of Engineers	STORM				●	●	●	●
Env Protection Agency	SWMM	●	●	●		●	●	
Hydrocomp	HSP	●	●	●	●	●	●	●
Massachusetts Inst of Technology	MITCAT	●	●	●	●	●	●	
Dorsch Consult	HVM-QQS	●	●	●		●	●	●
Metcalf & Eddy		●			●	●	●	●
Water Resources Engineers	AGRUN	●	●	●		●	●	
Ill. State Water Survey	ILLUDAS	●	●	●		●	●	

Sewer Hydraulics

MODEL ORIGIN	MODEL ACRONYM	Flow Routing In Sewers	Upstr and Downstr Flow Control	Surcharging and Pressure Flow	Diversions	Pumping Stations	Storage	Prints Stage	Prints Velocities
Corps of Engineers	STORM				●		●		
Env Protection Agency	SWMM	●	●	●	●	●	●		
Hydrocomp	HSP	●	●		●		●	●	●
Massachusetts Inst of Technology	MITCAT	●		●	●		●	●	●
Dorsch Consult	HVM-QQS	●	●	●	●		●	●	●
Metcalf & Eddy							●		
Water Resources Engineers	AGRUN	★	★	★	★	★	★		
Ill. State Water Survey	ILLUDAS	●					●	●	

Wastewater Quality

MODEL ORIGIN	MODEL ACRONYM	Dry-Weather Quality	Stormwater Quality	Quality Routing	Sedimentation and Scour	Quality Reactions	Wastewater Treatment	Quality Balance Between Storms	Receiving Water Flow Simulation	Receiving Water Quality Simulation
Corps of Engineers	STORM		●			●		●		
Env Protection Agency	SWMM	●	●	●	●	●	●		●	●
Hydrocomp	HSP	●	●	●		●		●	●	●
Massachusetts Inst of Technology	MITCAT								●	
Dorsch Consult	HVM-QQS	●	●	●		●	●	●	●	●
Metcalf & Eddy			●				●	●		
Water Resources Engineers	AGRUN	★	★	★	★	★	★		★	★
Ill. State Water Survey	ILLUDAS									

Miscellaneous

MODEL ORIGIN	MODEL ACRONYM	Continuous Simulation	Can Choose Time Interval	Design Computations	Real Time Control	Applied to Real Problems	Computer Program Available
Corps of Engineers	STORM	●				●	●
Env Protection Agency	SWMM		●	●		●	●
Hydrocomp	HSP	●	●		●	●	
Massachusetts Inst of Technology	MITCAT		●			●	
Dorsch Consult	HVM-QQS		●			●	
Metcalf & Eddy		●				●	●
Water Resources Engineers	AGRUN		●			●	
Ill. State Water Survey	ILLUDAS		●	●			●

★ AGRUN is an alternative "Runoff" block for use with SWMM, and these features are available in the SWMM

2.3.3. SWMM

The Storm Water Management Model (SWMM) is a comprehensive "single-event" urban runoff model first released by the U.S.E.P.A. in 1971.[17] The latest release SWMM 7 was issued in November of 1977.

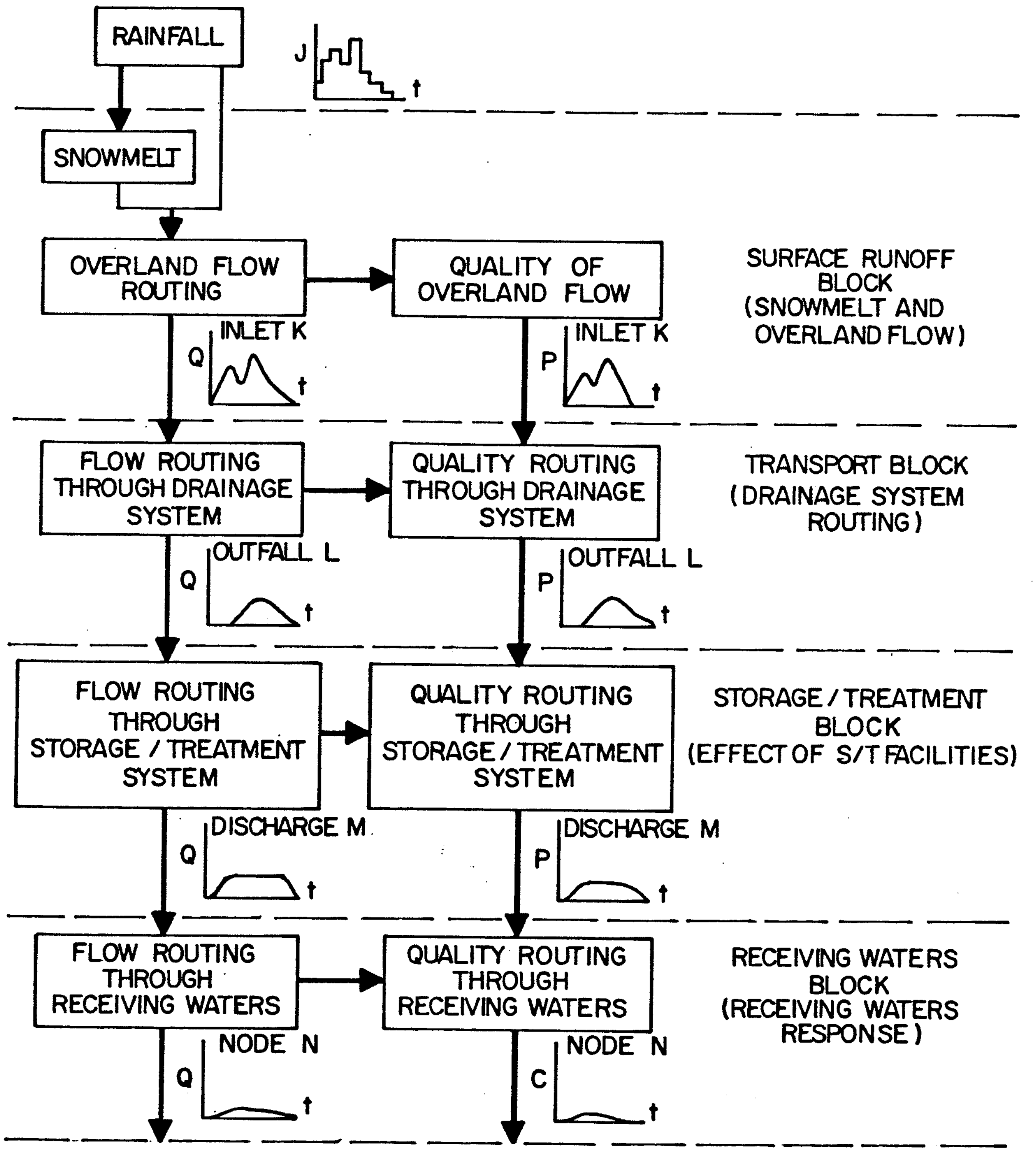
Figure 4 shows an overview of SWMM. SWMM is a simulation program that accounts for rainfall and snowmelt, infiltration, overland flow, conduit flow, storage, treatment facilities, and even the receiving water response. Receiving water models are discussed in Section 2.5.

The program consists of over ten thousand Fortran statements and requires the use of a large-scale computer such as the CDC 6600 or IBM 370.

SWMM has been calibrated and verified on many subcatchments.[3] SWMM quantity simulations are considered accurate enough for design purposes. SWMM quality simulations are able to produce pollutant concentrations and loadings within the same order of magnitude as measured values. This lack of accuracy in quality results as compared to accurate quantity results is typical of all models. It is an indication that the "state-of-the-art" of quality modelling is behind that of quantity modelling.

2.4. STORM

The Storage Treatment Overflow Model (STORM)[7] is a continuous simulation model that can be used for prediction of the quantity and quality of stormwater and dry-weather



SOURCE: ENVIRONMENT CANADA[3]

Fig. 4. OVERVIEW OF THE STORM WATER MANAGEMENT MODEL.

flow. The model considers the following phenomena, as shown in Figure 5:

- rainfall/snowmelt;
- pollutant accumulation;
- runoff and pollutant washoff;
- effects of storage and treatment; and,
- overflows to the receiving stream.

The model operates with an hourly record of precipitation and temperature, which may extend over a large number of years. The catchment is described in terms of land use and imperviousness. Different pollutant accumulation rates are associated with the various land uses. The rainfall or snowmelt in excess of the available depression storage is transformed directly to runoff at the outlet from the catchment. Flow and quality routing is not considered; the pollutograph being directly related to the runoff rate in any hour. A treatment rate for this runoff may be supplied. Flows in excess of this rate may be stored or considered as direct overflow. The water balance between storms is very simply considered as a recovery of depression storage by evaporation, while the surface pollutant accumulation is modified by street cleaning at a specific frequency. For a given rainfall-snowmelt record, the quantity, quality and number of overflows will vary as the treatment rate, storage capacity and land use is changed.

The description shown herein is limited to those facets of STORM used in the present study. For a complete description of the many other STORM features, the reader is referred

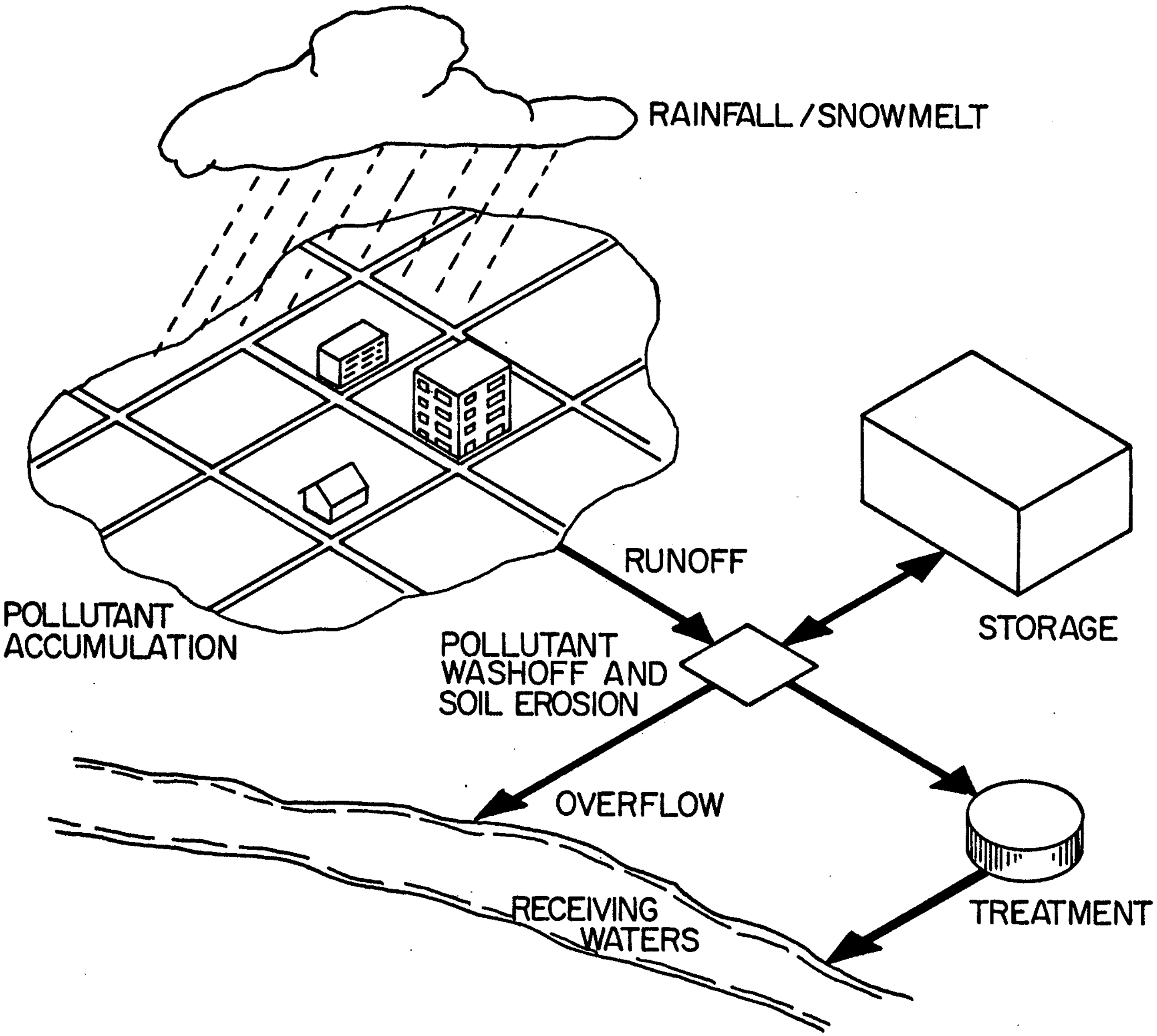


Fig. 5. CONCEPTUALISED VIEW OF URBAN SYSTEM IN STORM.

to the Users Manual.[7]

2.4.1. Quantity

The quantity algorithm is easily represented pictorially as in Figure 6. The Runoff quantity is calculated using the following equation:

$$r = C\ (P - f)$$

where,

r = runoff in inches per hour;

C = composite runoff coefficient dependent on land use;

P = rainfall/snowmelt in inches per hour;

f = available depression storage in inches.

The composite runoff coefficient represents losses due to infiltration and is computed as follows:

$$C = C_P + (C_I - C_P) \sum_{i=1}^{L} X_i\ F_i$$

where,

C_P = runoff coefficient for pervious surfaces (0.20);

C_I = runoff coefficient for impervious surfaces (0.90);

X_i = area in land use "i" as a fraction of total area;

F_i = fraction of land use "i" that is impervious;

L = total number of land uses.

The depression storage available, f, is calculated as follows:

$$f = f_o + N_D\ k\ ; \qquad f < D$$

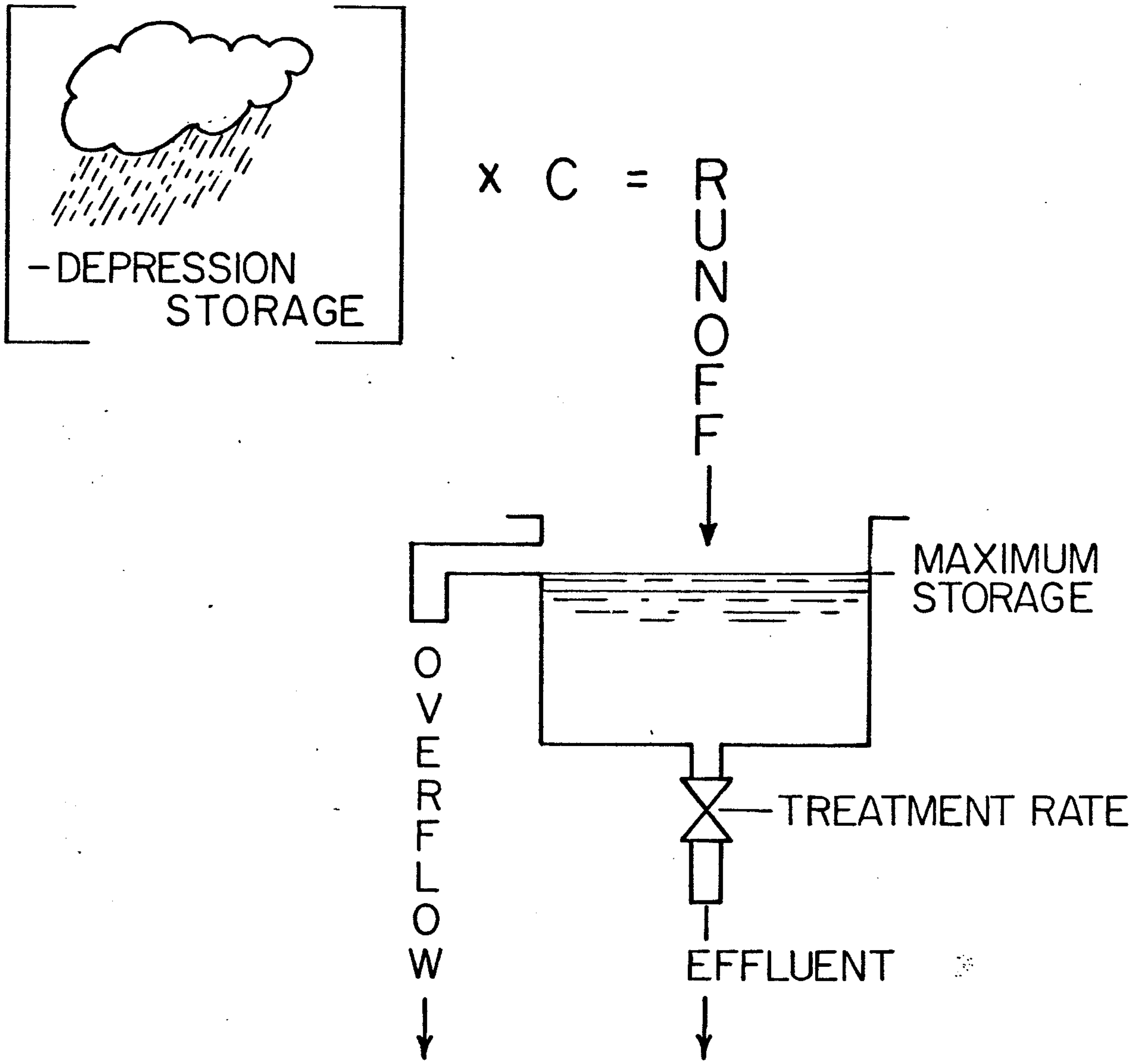


Fig. 6. CONCEPT OF STORM PROGRAM.

where,

f_o = available depression storage in inches, at end of previous event;

N_D = number of dry days since end of previous event;

k = pan evaporation rate, inches/day;

D = maximum depression storage.

In the case of combined sewered areas, dry weather flow is added to the runoff to calculate the total outflow from the urban area. The average dry weather flow is modified for diurnal variations and for the day of the week, according to the following equation:

$$DWF(I,J) = ADWF \times DVAR(I) \times HVAR(J)$$

where,

DWF(I,J) = dry weather flow, day (I), hour (J);

ADWF = average dry weather flow in mgd;

DVAR(I) = ratio for day I to the average;

HVAR(I) = ratio for hour J to the average.

Tables 6 and 7 show the daily and diurnal variations used for this study, taken from the Users Manual.[7]

The quantity of the system overflows are computed for each hour by:

$$Q_o = r - Q_t - Q_s$$

where,

Q_o = runoff overflow (inches);

Q_t = runoff treated (inches) which is the minimum of the actual runoff or the maximum treatment

TABLE 6.

DEFAULT VALUES FOR RATIO OF DAILY FLOWS TO AVERAGE - STORM

Daily Flows

Day	Ratio
Monday	1.08
Tuesday	1.04
Wednesday	0.92
Thursday	1.03
Friday	1.00
Saturday	0.96
Sunday	0.95

TABLE 7.

RATIO OF HOURLY FLOW TO AVERAGE HOURLY FLOW - STORM

Hour	Ratio
1	0.6
2	0.5
3	0.5
4	0.5
5	0.5
6	0.8
7	0.8
8	1.4
9	1.5
10	1.5
11	1.4
12	1.4
13	1.3
14	1.3
15	1.3
16	1.2
17	1.2
18	1.1
19	1.1
20	1.0
21	1.0
22	0.8
23	0.7
24	0.6

rate in inches/hour; where there is excess treatment capacity, stored quantities are treated; and,

Q_s = runoff stored (inches); this is added to the existing storage until the maximum storage capacity is reached.

2.4.2. Quality

STORM handles quality as a accumulation of pollutants during dry periods which are washed off during wet periods. The rate of dust and dirt accumulated is given by:

$$DD_L = dd_L \ (G_L/100) \ A_L$$

where,

DD = rate of dust and dirt accumulation in pounds/ day;

dd = rate of accumulation in pounds/day/100 feet of gutter;

G = feet of gutter per acre;

A = area in acres; and,

L = subscript for each land use.

If the number of dry days since the last storm is less than the street sweeping interval, the initial quantity of pollutant (say B.O.D.) is calculated as follows:

$$P_{BOD} = F_{BOD} \, DD_L \ N_D + P_{BOD}$$

where,

P_{BOD} = total pounds of B.O.D. on land use L at the beginning of the storm;

F_{BOD} = pounds of B.O.D. per pound of dust and dirt;

N_D = number of dry days; and,

P_{BOD} = total pounds of B.O.D. remaining after last storm.

If the number of dry days exceeds the street sweeping interval, then the accumulated amount is reduced by a factor (1-E) every N_s days where:

E = efficiency of street sweeping; and,

N_s = number of days between street sweepings.

A first-order wash off equation is used which is based on a 90% wash off of pollutants in one hour when the runoff rate is 0.5 inches/hour:

$$M_{BOD} = P_{BOD} \; (1 - e^{-KR})$$

where,

M_{BOD} = pollutant washoff pounds/hour;

R = runoff rate in inches per hour;

K = washoff decay coefficient = 4.6 for conditions stated above.

The above equation has been modified in the model so that predicted results will more often agree with measured data. These include an availability function, and pollutant relationships. A typical pollutant relationship is that B.O.D. of the runoff includes a portion equal to one-tenth of the suspended solids runoff.

The pounds of pollutants are then mixed with the runoff for a given period and routed through the storage treatment cycle in direct proportion to the quantity algorithm.

2.4.3. Limitations of STORM

Some of the limitations of the STORM model are listed below:

1) STORM requires a great deal of data with respect to climate, land use, and pollutants. Much of this data does not exist for a particular city (i.e. pounds B.O.D.5/day/100 feet of gutter). As a result, the user must use data collected in a few studies in a few U.S. cities;

2) The model was developed to model urban runoff from separate areas. Therefore, in order to use it for combined sewers the user must:
   a) adjust surface loading rates to account for deposition in the sewers,
   b) adjust street sweeping efficiency since this does not affect sewer depositions;

3) The model uses accumulation as pounds per day per 100 feet of gutter. Accumulations on parking lots and grassed areas are not explicitly accounted for. There is an option to use a pounds per acre accumulation rate, but there is even less base data for this option;

4) Street sweeping is important only if it is as frequent as the storms themselves. The street sweeping cycle starts again after each storm.

2.5. RECEIVING WATER QUALITY MODELS

2.5.1. General

In addition to the urban runoff models discussed earlier, a number of receiving water quality models have been developed to predict receiving water quality in response to various loadings. A major input to the receiving water quality models are the pollutant discharges from urban areas. In this respect they are often used in conjunction with models that predict urban runoff quantity and quality. These water quality models are a most important link in the chain of models used for environmental assessment.

Table 8 lists the characteristics of several water quality models.[2] The river quality models are generally composed of two sections: (1) hydrodynamic, and (2) kinetics.

Hydrodynamics refers to the analysis of mixing, advection and dispersion in the receiving water stream. The hydrodynamic section is typically a function of the type of water body, i.e., stream, estuary, or lake, and the spatial frame i.e., one, two, or three dimensional.

The kinetic section models the interaction of constituents, such as B.O.D_5-D.O. in the stream.

River Quality models are further classified according to time variability, that is, steady-state, or dynamic.

TABLE 8

WATER QUALITY MODELS (2)

Model Origin	Acronym	Water Bodies Modeled[1]			Time Variability		Spatial Discretization			Miscellaneous			Constituents Modeled
		Stream	Estuary	Lake	Steady-State	Dynamic	One-Dimensional	Two-Dimensional	Stratified	Documentation Available	Computer Program Available	Applied to Real Problems	
Environmental Prot. Agency	DOSAG-I	●			●		●			●	●	●	DO, BOD (Carbonaceous and nitrogenous)
EPA	QUAL-II	●			2 ●		●			●	●	●	BOD, DO, temperature, NH_3, NO_3, NO_2, algae, phosphorus, benthic demand, coliforms, radioactive materials, 3 conservative constituents.
EPA	RECEIV	●	●			●		●		●	●	●	Any six constituents, including DO, BOD, conservative constituents and non-conservative constituents with first order decay.
Raytheon (EPA)	RECEIV-II	●	●			●		●		●	●	●	BOD, DO, coliforms, nutrients, salinity, conservative constituents, non-conservative constituents with first order decay, chlorophyll a.
Systems Control Inc.	SRMSCI	●	●			●		●		●	●	●	BOD, DO, coliforms, excess temperature, NH_3, NO_3, NO_2, OPO_4, Cu, Pb, and two conservatives.
Water Resources Engineers (EPA)	WRECEV	●	●			●		●		●	●		BOD-DO (linked), any four conservative or first order non-conservative.
Hydrocomp, Inc.	HWQM	●		●		●		●	●	●	3	●	BOD, DO, coliforms, temperature, algae, zooplankton, sediment, organic nitrogen, nutrients and conservative constituents.
Office of Water Resources Research	LAKECO			●		●	●		●	●	●	●	Zooplankton, benthic animals, fish, pH, nutrients, conservative constituents, non-conservative constituents with first order decay.

1. Stream models can simulate shallow, well-mixed impoundments.
2. Weather inputs may be dynamic.
3. Available for a fee.

Dynamic models differ from steady-state models in that they calculate the state of all components for variable inputs at each time increment. The time step may vary from a few seconds to a day depending on the finite difference solution technique. The numerical techniques presently in use for hydrodynamic simulation of estuaries require very short time steps (thirty seconds for RECEIVE). This results in very high computer costs.

2.5.2. B.O.D.-D.O. Interaction

All the models use some form of the Streeter-Phelps formulations(18) for B.O.D_5-D.O. interaction. The oxygen balance and the Streeter-Phelps equation are shown in Figure 7. The general form of the equation at a point is as follows:

$$\frac{\partial C}{\partial t} = K_2 \text{ (D.O.D.)} - K_1 L - K_n N + P - R - B$$

where,

$\frac{\partial C}{\partial t}$ = rate of change of dissolved oxygen content;

D.O.D. = dissolved oxygen deficit (mg/L), $C_s - C$;

C_s = D.O. concentration at saturation (function of temperature);

K_2 = reaeration coefficient (day^{-1});

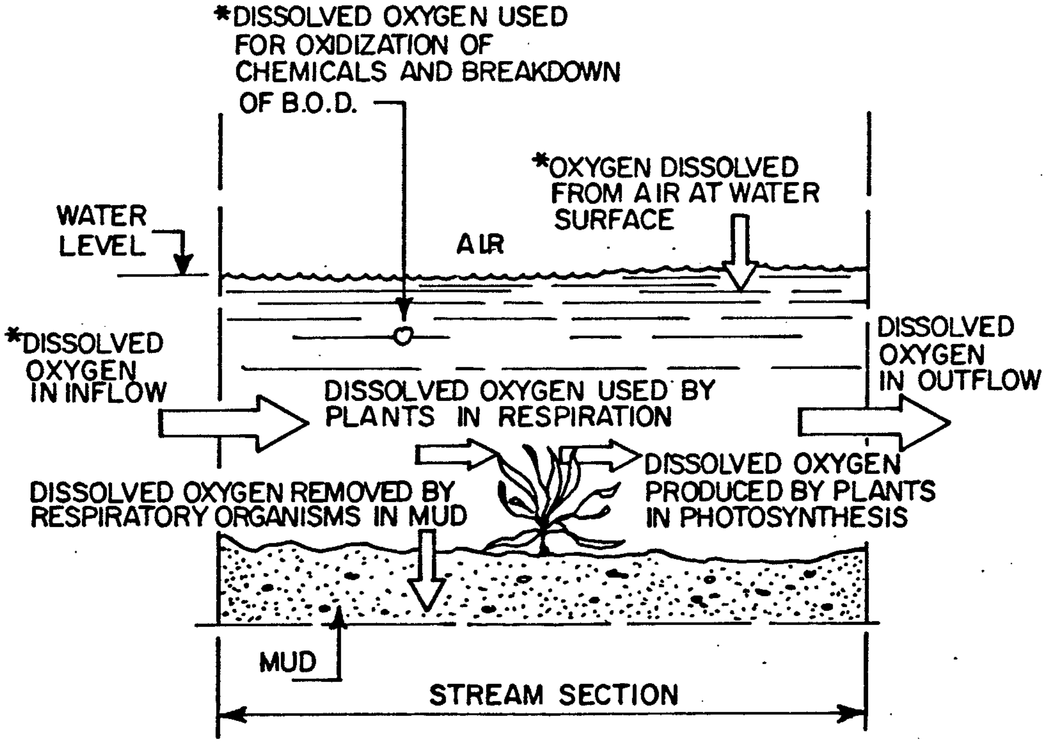
L = ultimate B.O.$D._u$ concentration (mg/L);

K_1 = deoxygenation rate constant (day^{-1})

N = NH_3 concentration expressed as N (mg/L);

K_n = nitrification rate constant;

P = overall rate at which oxygen is released by photosynthesis (mg/L/day);



STREETER - PHELPS EQUATION*

$$\text{D.O. deficit} = \frac{K_1 L_a}{K_2 - K_1}\left[e^{-K_1 t} - e^{-K_2 t}\right] + D_a e^{-K_2 t}$$

where: K_1 = deoxygenation rate constant

K_2 = re-oxygenation rate constant

L_a = BOD ultimate in inflow to system (mg/L)

D_a = D.O. deficit in inflow to system (mg/L)

N.B. D_a = saturation concentration - actual concentration

t = travel time (days)

N.B. for simple system distance = velocity x time

Note : Form shown only processes and boundary conditions marked in diagram. Parameters are adjusted to account for effects occuring in the stream and not included in the model.

Fig. 7. OXYGEN BALANCE AND THE STREETER - PHELPS EQUATION.

R = overall rate at which oxygen is used by algae respiration (mg/L/day); and,

B = overall rate at which oxygen is used by benthic deposits (mg/ L/day).

Many of the parameters and "K" factors used in the above equation are not known for most streams. Various procedures are available to estimate these from stream characteristics.[18] [19] The modeller must decide which processes are significant for his application. For example, where a treatment effluent contains large quantities of NH_3, and the nitrifying bacteria can grow in the stream, oxidation of NH_3 can be a major oxygen sink. This is because it takes 4.57 mg/L of oxygen to oxidize 1 mg/L NH_3 as N.

In many cases only the first two terms of the equation are used as: $\frac{\partial C}{\partial t} = K_2 \text{ (D.O.D.)} - K_1 L$

This equation is used directly for the dynamic models. The steady state models use the integrated form of the equation:

$$\text{D.O.D.} = \frac{K_1 L_a}{K_2 - K_1} \left(e^{-k_1 t} - e^{-k_2 t} \right) + D_a e^{-k_2 t}$$

where,

t = time (day);

La = initial $B.O.D._u$ concentration (mg/l); and,

Da = initial D.O.D. (mg/l).

This is the classical Streeter-Phelps dissolved oxygen sag equation. The time of critical dissolved oxygen deficit is given by:

$$t_{crit} = \frac{1}{K_2 - K_1} \ln \left(\frac{K_2}{K_1} \left(1 - \frac{(K_2 - K_1) D_a}{K_1 L_a} \right) \right)$$

and the critical dissolved oxygen deficit is given by:

$$D_{crit} = \frac{La\ K_1}{K_2} \left(e^{-K_1 t_{crit}}\right)$$

The values of K_1 and K_2 can be estimated from stream characteristics[19] or from graphs[20] as shown in Figures 8 and 9. The values of the reaction rate constants vary with temperature. The following equation is used to estimate this effect.

$$K_T = K_{20^oC}\ \theta^{(T-20)}$$

where,

T = temperature; and,

θ = temperature coefficient.

Reported values of the temperature coefficient are shown in Table 9 and Table 10 for reaeration and deoxygenation respectively. It is important to note that these apply for a limited temperature range only used by the original researcher.

The limitations of the simplified oxygen sag equation using only the deoxygenation and reaeration terms are:

1) it ignores many of the oxygen sources and sinks which could be important in any given situation;

2) the reaction constants of the theory are difficult to measure or establish from stream characteristics;

3) in its integrated form, the equation is limited to a single source of pollutants;

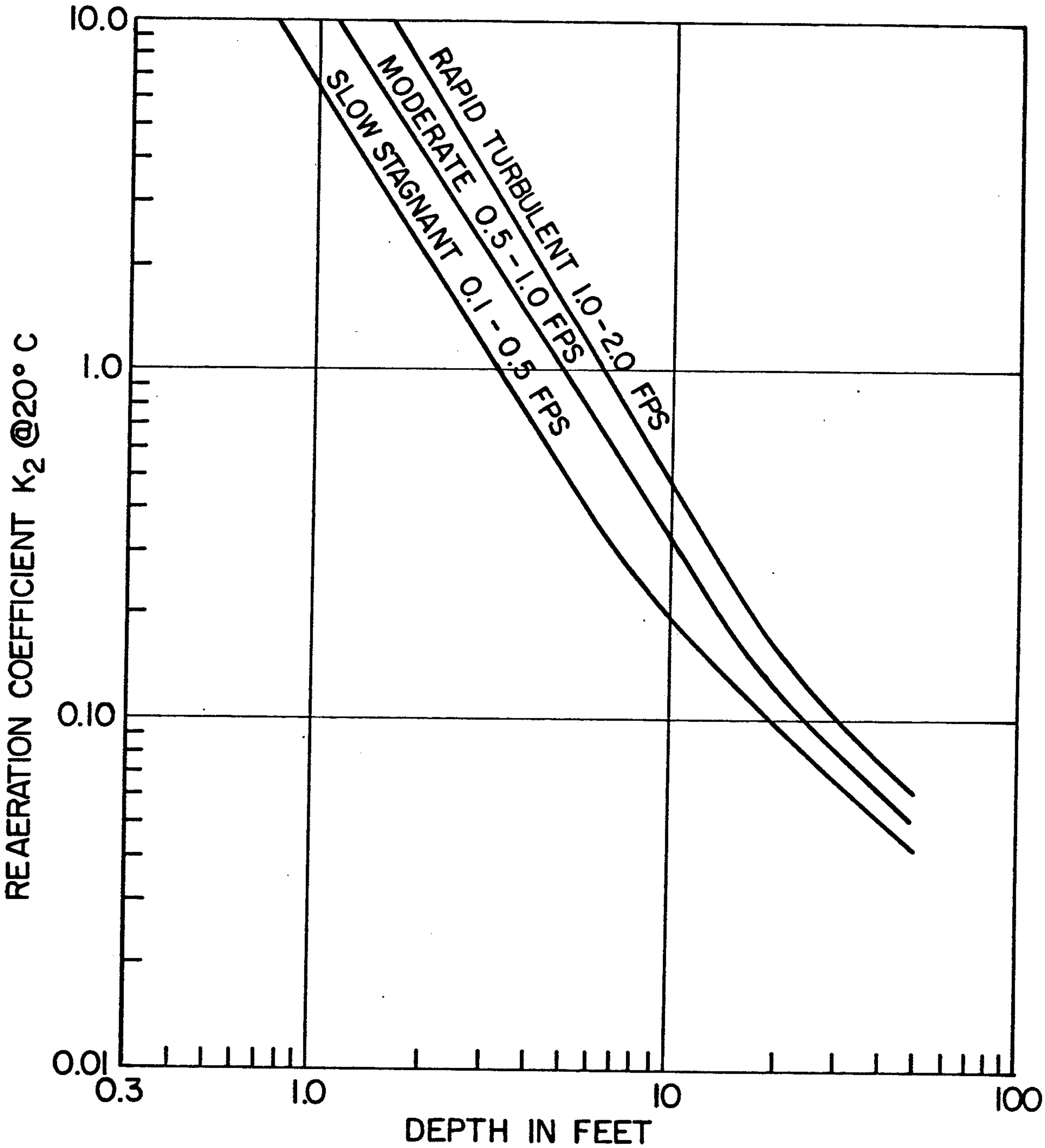


Fig. 8. REAERATION COEFFICIENT (K_2) AS A FUNCTION OF DEPTH.

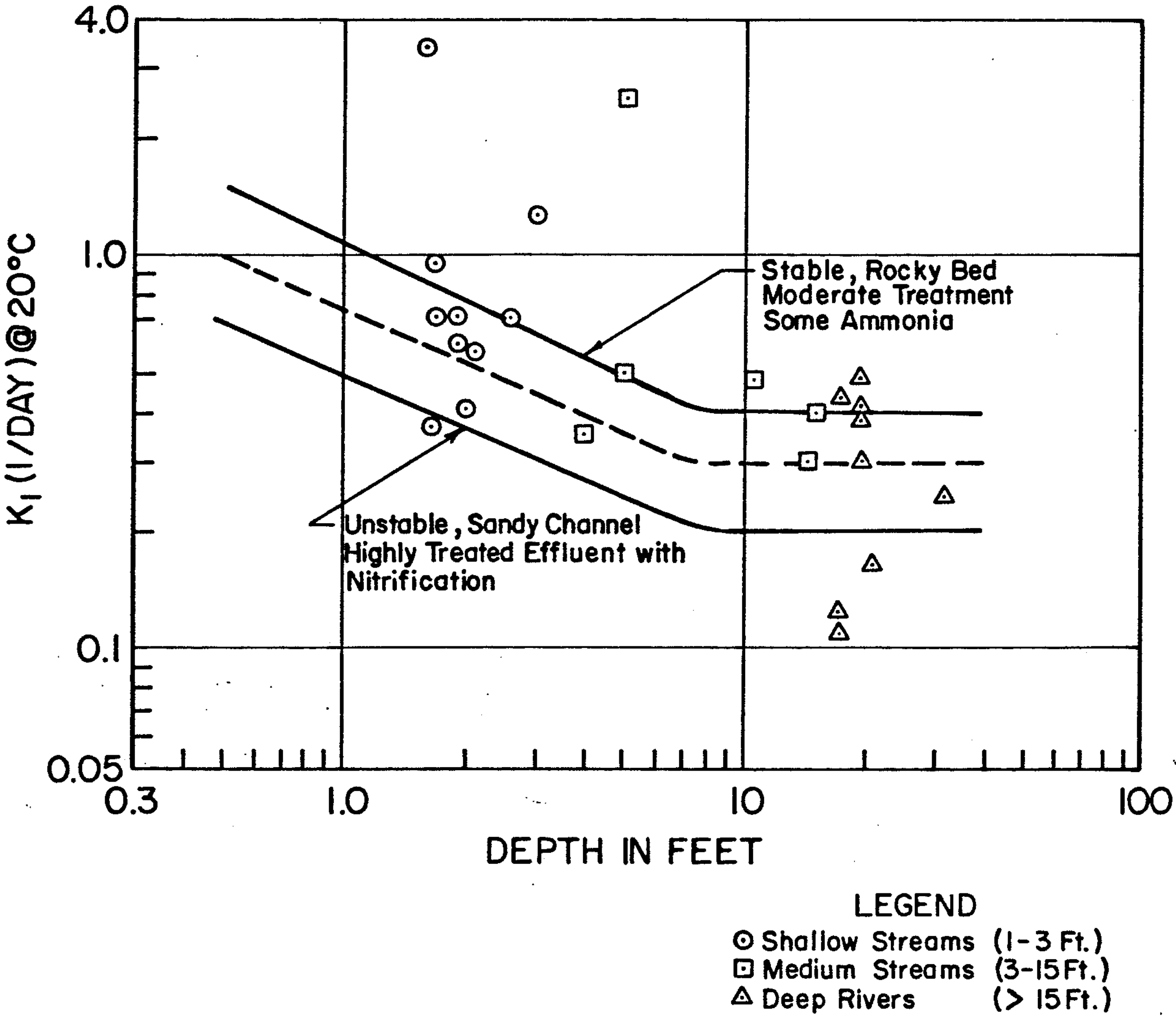


Fig. 9. DEOXYGENATION COEFFICIENT (K_1) AS A FUNCTION OF DEPTH.

TABLE 9

REPORTED VALUES OF TEMPERATURE COEFFICIENT θ [18]
FOR REAERATION RATE CONSTANT

Temperature Coefficient, θ	Aeration System	Reference [18]
1.047	Channel	Streeter, et.al. (1936)
1.0241	Stirred	Elmore and West (1961)
1.0226	Stirred	Elmore and West (1961)
1.020	Stirred	Downing and Truesdale (1955)
1.024	Stirred	Downing and Truesdale (1955)
1.016	Stirred	Downing and Truesdale (1955)
1.016	Stream	Streeter (1926)
1.018	Channel	Truesdale and Van Dyke (1958)
1.015	Channel	Truesdale and Van Dyke (1958)
1.008	Channel	Truesdale and Van Dyke (1958)

TABLE 10

VALUES OF TEMPERATURE CORRECTION FACTOR,θ[18]
FOR DEOXYGENATION RATE CONSTANT

Location	Temperature Coefficient,θ	Reference
--	1.02 - 1.09	Baca and Arnett, 1976
--	1.075	Lombardo, 1972
Boise River, Idaho	1.047	Chen and Wells, 1975
San Francisco Bay Estuary	1.047	Chen, 1970
--	1.05	Crim and Lovelace, 1973

this is overcome in dynamic simulations; and,

4) in its integrated form, it assumes that coefficients, river cross-section, velocity, etc., are constant over long reaches of a river.

2.5.3. Applicability

The available river quality models are more suited for the detailed examination of a stream response to a given set of loadings. They require a high degree of input data and output detailed results. They are not suited for continuous simulation planning studies where the investigator is interested in analyzing effects of a large number of pollution control strategies for a large number of storm events.

A planning type of river quality model has recently been developed in the United States in recognition of this gap in model technology and is expected to become available from the U.S.E.P.A. in the near future.[1]

3. METHODOLOGY

3.1. BASIC APPROACH

The five major phases of Stream Analysis, as paraphrased from Velz[18], that form the structure of the approach used herein for river quality modelling of the Red River, are:

1) determine waste loadings;
2) define hydrologic and climatic factors;
3) develop and calibrate river quality model;
4) forecast variations in stream loadings for various pollution abatement strategies; and,
5) predict impact on river quality of various pollution abatement strategies for a range of stream flows.

The water quality parameter chosen for quality evaluation for this work was dissolved oxygen in the River. The approach can be extended to other water quality indices such as coliform populations.

The various pollution control strategies that were investigated are combinations of dry weather and wet weather treatment rates as follows:

1) Dry Weather Flow

   a) no treatment,

   b) primary treatment,

   c) secondary treatment,

   d) advanced treatment;

2) Wet Weather Flow

   a) no treatment,

   b) treatment of combined sewer overflows,

   c) treatment of separate sewer overflows;

3) Low Flow Augmentation.

The sensitivity of D.O. levels to river flows was also investigated which allows the evaluation of low flow augmentation as a pollution control strategy.

The basic approach used is summarized in Figure 10. The major output was a prediction of the minimum dissolved oxygen concentrations in the receiving stream for the various control strategies.

Low flow augmentation involves the control of the minimum stream flow usually by addition of water from another source. For the Red River, this could be accomplished through diversion of water from Lake Manitoba through the Assiniboine River.[21]

In order to determine the waste loadings from each runoff event, and to predict the receiving stream response, mathematical models were employed. The programs used are summarized in Table 11.

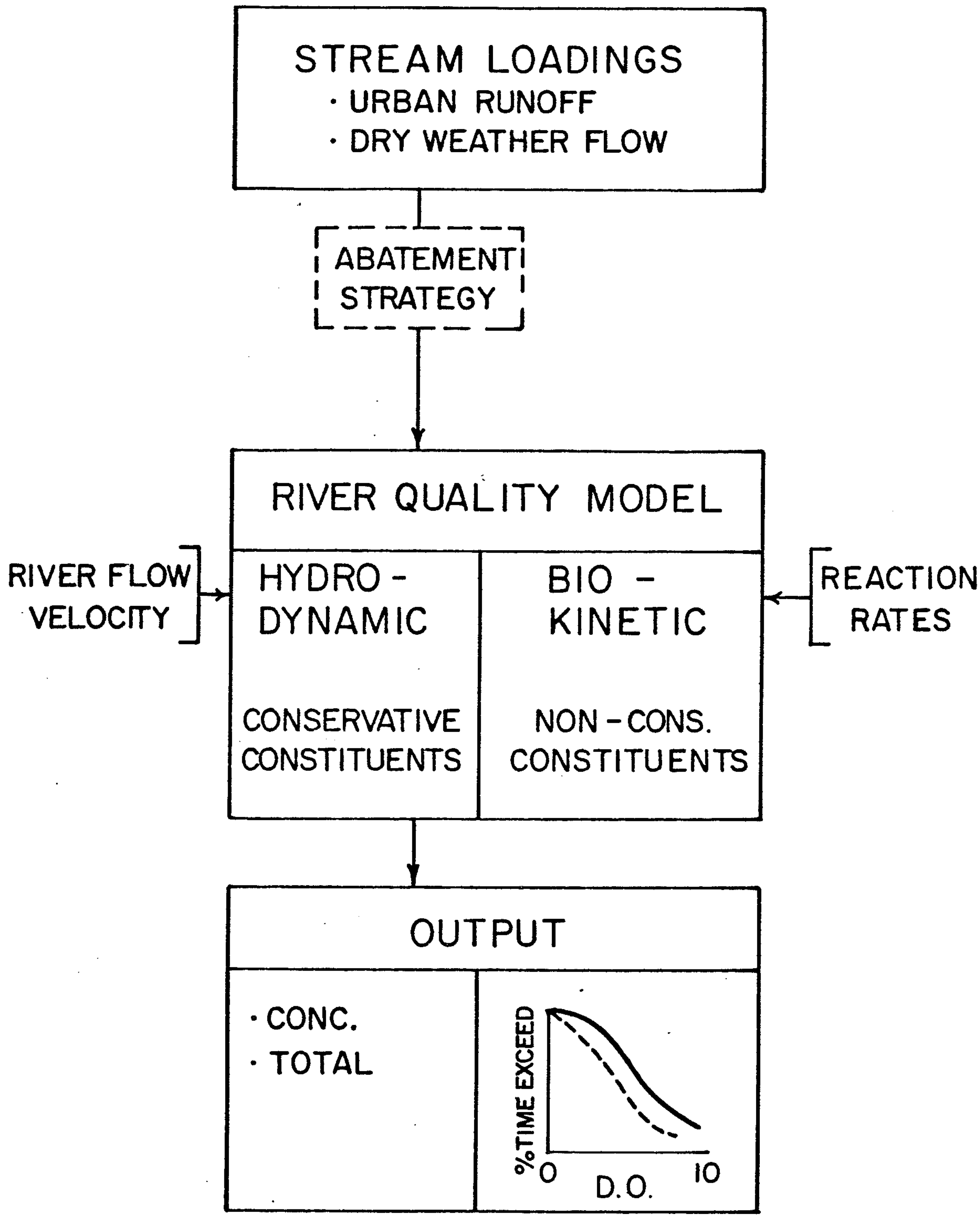


Fig. 10. STUDY APPROACH

TABLE 11.

PROGRAMS USED IN ANALYSIS

Name	Description	Remarks
STORM	Storage Treatment Overflow Runoff Model	Developed by U.S. Army Corps of Engineers[7]
LOAD	Combines Urban Runoff Loadings and Sewage Treatment Plant Loadings into Total Loading Profile for Various Pollution Control Strategies	Developed for this Study
RVRQUAL	Predicts Minimum Dissolved Oxygen Occurrences in Red River for Wet Weather Events	Developed for this Study
Dry Weather Model	Predicts Minimum Dissolved Oxygen Concentration for Continuous Discharge	Developed for this Study

3.2. STORM INPUT

The input to STORM was developed for both a "typical" 100-acre combined area and separate area. The input is summarized on Tables 12 and 13.

Areas of 100 acres were used recognizing the results would have to be pro-rated according to the total combined area and separate area. This was done to keep the output numbers small enough to fit in the computer format. The land use percentages were taken to represent the City-wide average as taken from a previous report.[22] The runoff coefficients and depression storage are typical values and were those developed in the previous calibration.[22] The low street

TABLE 12.

COMBINED SEWER AREA STORM INPUT DATA

A. Area 100 acres   Runoff coefficients - Pervious Area = 0.20 inches
Impervious Area = 0.90 inches

Depression Storage = 0.08 inches

B. Land Use and Pollutants
Washoff Decay Coefficient = 4.6

	Percent	Fraction Impervious	Gutter Length /Acre Feet	Dust/Dirt Accum. Rts. lbs/100ft/day	Pollutant Percent of Dust/Dirt S.S.	B.O.D.
Single	55.0	35.0	300	2.25	80	15
Multiple	5.0	60.0	430	6.90	80	15
Commercial	15.0	80.0	100	9.90	80	15
Industrial	10.0	50.0	60	13.80	80	15
Open	15.0	10.0	20	4.50	80	15

C. Street Cleaning Frequency - 5 days   Efficiency - 0.20

D. Dry Weather Flow - 0.25 MGD   Treatment Rate = 2.6 x DWF = 0.652 MGD (.01 in/hour)
Suspended Solids - 300 mg/litre
B.O.D. - 240 mg/litre

E. Base System Storage = 0.03 inches

F. Daily Evaporation Rate = 0.04 inches/day

TABLE 13.

SEPARATE SEWER AREA STORM INPUT DATA

A. Area 100 acres   Runoff coefficients - Pervious Area = 0.20 inches
Impervious Area = 0.90 inches

Depression Storage = 0.08 inches

B. Land Use and Pollutants
Washoff Decay Coefficient = 4.6

	Percent	Fraction Impervious	Gutter Length /Acre Feet	Dust/Dirt Accum. Rts. Lbs/100ft/day	Pollutant Percent of Dust/Dirt S.S.	B.O.D.
Single	55.0	35.0	300	2.25	70	0.50
Multiple	5.0	60.0	430	6.90	70	0.36
Commercial	15.0	80.0	100	9.90	70	0.77
Industrial	10.0	50.0	60	13.70	70	0.30
Open	15.0	10.0	20	4.50	70	0.50

C. Street Cleaning Frequency - 14 days   Efficiency - 0.50

D. Dry Weather Flow (not used - separate area)

E. Base System Storage = 0.00 inches

F. Daily Evaporation Rate = 0.04 inches/day sweeping efficiency of (0.20) for the combined area is due to the deposition in combined sewers which is not affected by sweeping.

The pollutant accumulation data, street sweeping data for the combined area were taken from the same report.(22) The importance of using calibrated figures is borne out by the fact that the accumulation rates are approximately three times and the pollutant fractions are about thirty to eighty times the values recommended in the STORM manual.(7)

For the combined area the small storage parameter (0.03 inches) used as a base was also from the previous calibration.(22) Conceptually, it represents the storage available in the sewer system from average to peak dry weather flow.

For the separate area, the input data for pollutant accumulation was initially taken from the Users Manual.(7) However, except for $B.O.D_5$, the accumulation rates were adjusted sharply upward so that the pollutant concentrations in the overflow approximated literature figures and City measurements.

Another input to STORM is hourly rainfall records which were obtained from the monthly summaries for the summer months of 1977 obtained from the Atmospheric Environment Service.

3.2.2. Calibration

STORM is a widely used and completely tested model. As such, there are many references on the sensitivity and calibration of the model.(2) (3) (23) For this study calibration was effected by comparing the average results in terms of overflow

$B.O.D._5$ concentrations with measurements from the literature and in Winnipeg.

3.3. STREAM LOADINGS

While STORM can be used to develop pollutional loadings from combined and separate sewer overflows, it does not give a complete picture of the stream loadings. It does not consider treatment effluents and by-passes. In order to calculate total stream loadings during events, a computer program called "LOAD" was used.

3.3.1. Basic Description

LOAD was developed in order to combine the results of STORM with treatment plant effluents and by-passes as shown in Figure 11. The basic steps taken by the program are listed below.

1) The STORM results for quantity, quality, and duration are read for each event and manipulated according to the relative area of combined and separate sewers, since the results of STORM were on a per 100 acre basis;

2) The quality results are multiplied by factors K_{SEP} and K_{COMB}, where calculated externally as,

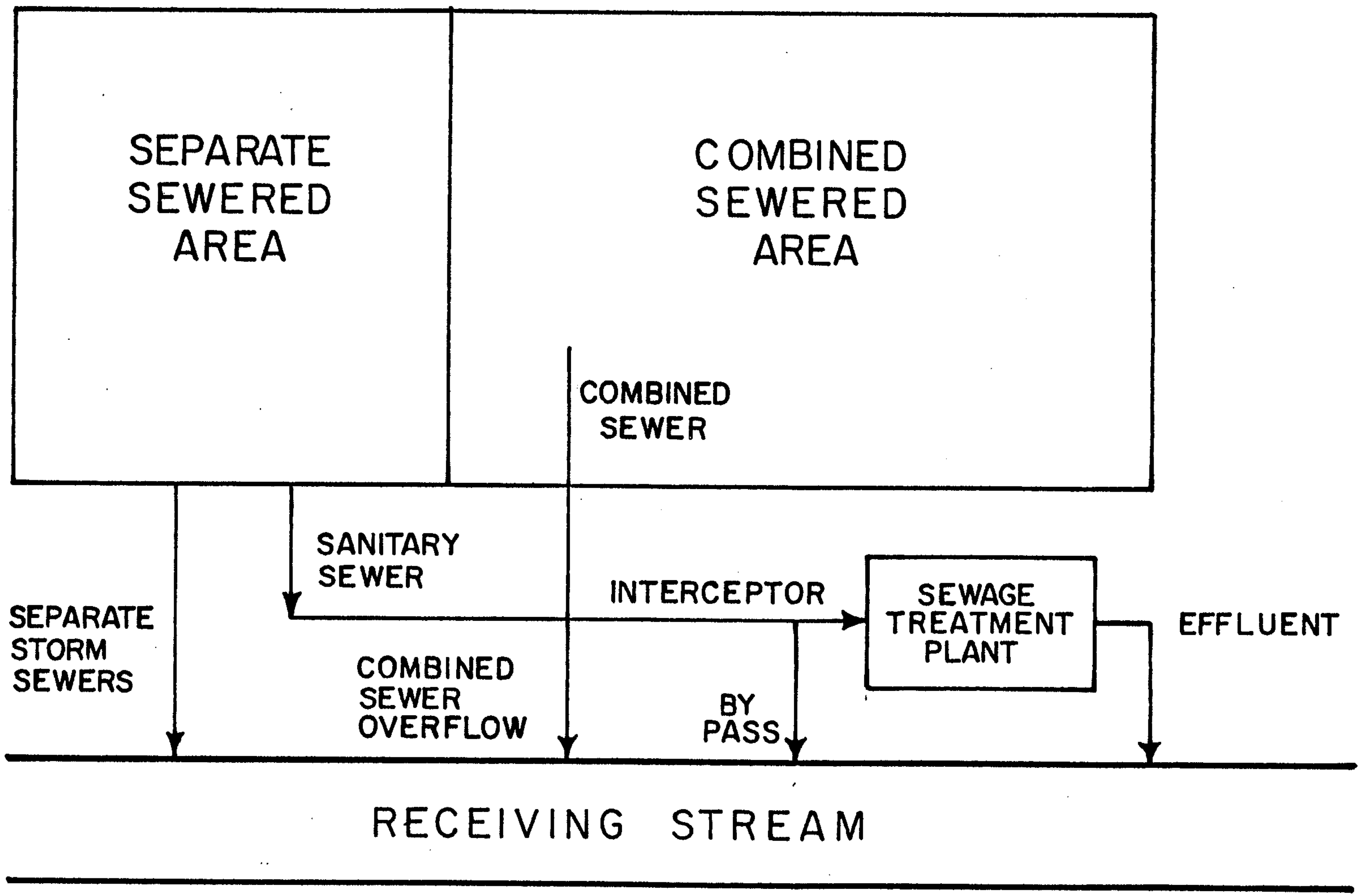


Fig. 11. OVERVIEW OF STREAM LOADING COMPONENTS COMBINED IN "LOAD".

$$K_{SEP} = K_1{}^s \times K_2{}^s$$

$$K_{COMB} = K_1{}^c \times K_2{}^c$$

where,

K_1 = ratio of B.O.D. ultimate to B.O.D.$_5$ (1.5 for B.O.D. reaction rate constant = 0.23);

K_2 = fraction of pollutant removed by some unspecified mechanism; for later use in evaluating effects of pollutant removal on River Quality;

s, c = superscripts for separate and combined respectively.

3) For each treatment plant specified, the flow, by-pass and quality characteristics are read. This data was available on a daily basis. The program calculates the load per event as follows;

$$L = A \sum_{i=1}^{n} \left(K_i^1 F_i + K_i^2 F_i^B \right) t/24$$

where,

L = total load during the event, pounds;

n = number of treatment plants;

F = flow rate - MGD;

F^B = by-pass flow rate - MGD;

K^1 = ultimate B.O.D. concentration in final effluent, mg/l;

K^2 = ultimate B.O.D. concentration in by-pass flow;

t = duration of event - hours;

A = unit conversion = 10 lbs/mg/l·MGD.

4) The stream loadings resulting are printed for each event along with a summary of the relative contribution from each source.

Once the data was input to LOAD, the 'K' factors were changed to develop a new set of stream loadings for a different pollution strategy. For example, for existing conditions there is no treatment of combined sewer overflows and K_2^c would equal 1. To model stream loadings for 60% removal of pollution from combined sewer overflows K_2^c would be revised to 0.4.

3.3.2. Input Data

The results from STORM discussed in the previous section are a major input to LOAD. The second major input is the records of plant flow and performance. These were obtained from the City of Winnipeg, Waterworks, Waste and Disposal Division who operate three plants, the North End, South End, and West End Water Pollution Control Centres. The data obtained were daily flow rates, influent and effluent $B.O.D._5$ for the summer months of 1977. The annual averages for these plants are shown in Table 14.

The operating staff indicated that there is no by-passing of sewage at the South End and West End Plants, since the flows do not exceed the capacity. These plants serve separate sewered areas. At the North End Plant by-passing of the primary clarifiers occurs at 100 MGD, and by-passing of secondary treatment occurs at 60 MGD. The frequency of by-passing is unknown since there is no metering facility on the raw sewage pumps. The final effluent B.O.D_5 is measured in the outfall downstream of this by-passing, and therefore by-pass effects are included.

TABLE 14.

AVERAGE OPERATING DATA - 1977
SEWAGE TREATMENT PLANTS

Plant	Type	Daily Average Flow - MGD	Raw	B.O.D. (mg/L) Final Effluent
North End	Step Aeration	59.7	294	46
South End	Pure Oxygen	8.9	293	39
West End	Extended Aeration Aerated Lagoons Facultative Lagoons	5.5	171	54

3.3.3. LOAD Program Listing

Appendix 2 includes a listing of the program.

3.4. RIVER QUALITY MODEL - WET WEATHER

The 'STORM' program gave the B.O.D. washoff for both combined and separate sewered areas. This was combined with the treatment plant effluents in 'LOAD' to develop the total wet weather loading for each event.

In the river quality model ('RVRQUAL') initial conditions were based upon complete mixing of effluents over a reach of the River. The Streeter-Phelps formulation was then used to account for B.O.D. and Dissolved Oxygen (D.O.) changes.

3.4.1. Basic Description

The River Quality Model developed specifically for this study can be divided into two major sections; (1) Hydrodynamics (mixing model), and (2) kinetics (B.O.D.-D.O. interaction model).

3.4.1.1. Hydrodynamics

The basic hydrodynamic model is shown in Figure 12. The basic process in the model is described as follows. The wet weather loads in terms of quantity and quality are assumed to enter uniformly along a reach of the Red River. The length of the reach is twenty miles, roughly being the length of the River through the major discharge points in the City. The pollutant initial concentration is calculated as follows:

$$La = \frac{B.O.D._L + B.O.D._U \, V_{River}}{V_{River} + V_{Runoff}}$$

where,

La = initial ultimate B.O.D. concentration in the River after mixing;

$B.O.D._L$ = ultimate B.O.D. loading this event from 'LOAD';

$B.O.D._U$ = ultimate B.O.D. concentration in the upstream base flow;

V_{River} = volume of water in river reach before the runoff event as calculated from river evaluation this event and cross-section; and,

V_{Runoff} = volume of runoff this event from 'LOAD'.

The model included several intrinsic assumptions as discussed below:

1) The River "stands still" while the LOAD is added. The assumption should lead to very small errors since the River velocity is very small, typically less than 0.3

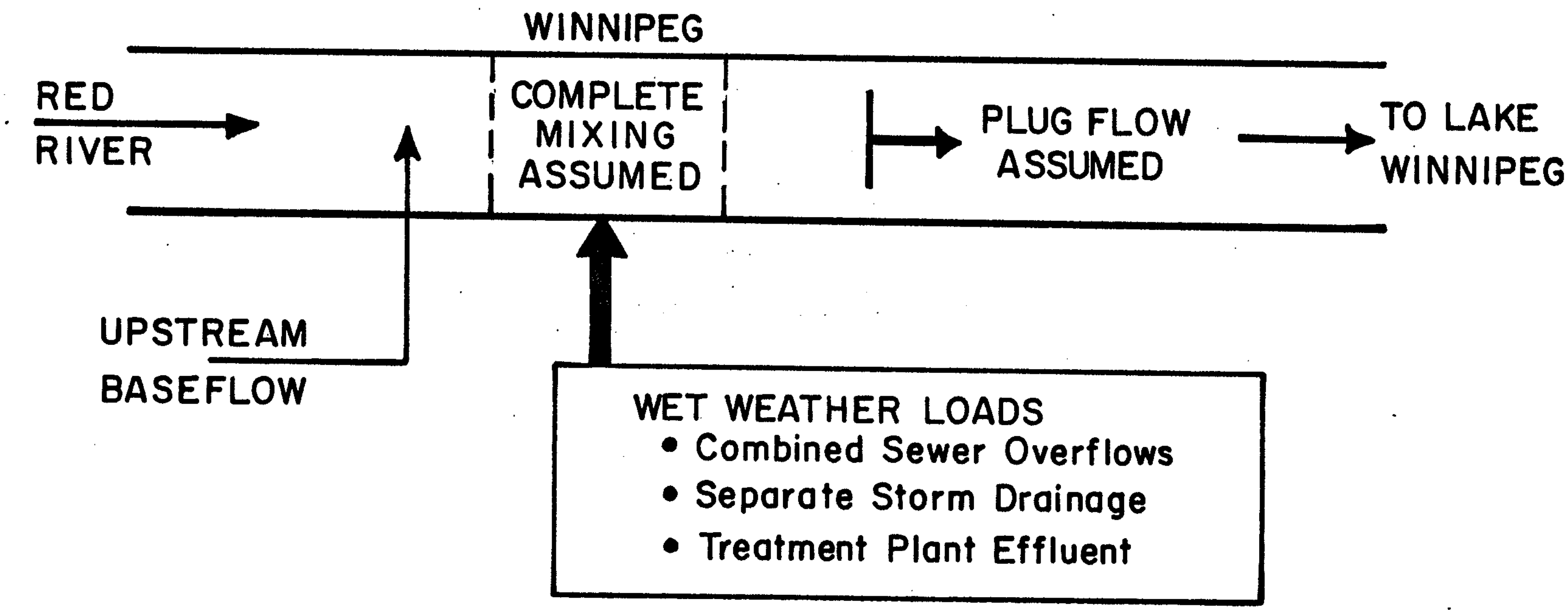


Fig. 12. RIVER QUALITY MODEL WET WEATHER SYSTEM SCHEMATIC.

miles per hour (.5 feet per second). Storm durations are normally less than 6 hours. The velocity is slow since the elevation is controlled for navigation purposes during the summer months.

2) The model assumes that all the LOAD is completely mixed along the length and width of the River reach. The multiplicity of outfalls along the reach support this assumption. In practice there will be variations from the mean B.O.D. concentration as calculated in the model.

3) The model does not consider the effects of continuous discharges. The model assumes that the 'LOAD' comes in during the storm duration and stops. This is an important assumption in terms of large continuous dry weather flows such as from the North End Water Pollution Control Centre. The dry weather flow is handled by a separate model (see Section 3.5.).

4) Plug flow is assumed downstream. The effects of longitudinal dispersion and mixing are ignored. This assumption is supported by the length of the reach involved. Longintudinal dispersion may

be significant at the fringes only.

The velocity of the river is so slow, and the length of reach affected by any given event is so long, that overlapping of events was also considered. An adjustment was made when a second 'LOAD' is added to the reach by another event, affecting the same slug of water. The 'LOAD' for the second event was increased according to the B.O.D. remaining in the reach from the first event.

3.4.1.2. Model Kinetics

The basics used for the model kinetics was the Streeter-Phelps equation. This approach was chosen for its simplicity which is consistent with the limited data available on the River.

The basic equations used in the model were:

1) $$\text{D.O.D.} = \frac{K_1 \, La}{K_2 - K_1} \left(e^{-K_1 t} - e^{-K_2 t} \right) + Da \, e^{-k_2 t} \; ;$$

2) $$t_{crit} = \frac{1}{k_2 - k_1} \; n \left[\frac{K_2}{K_1} \left(1 - \frac{(K_2 - K_1) Da}{K_1 \; La} \right) \right] ;$$

3) $$\text{D.O.D.}, t_{crit} = \frac{La \; K_1}{K_2} \left(e^{-(K_1)(t_{crit})} \right) \; ;$$

4) $$\text{D.O.}_{MIN} = \text{D.O.}_{SAT} - \text{D.O.}_{DEF.} t_{crit} \; ;$$

5) $$K_{1,T} = K_{1,20} \; \theta_1^{(T-20)} \; ;$$

6) $K_{2,T} = K_{2,20} \; \theta_2^{(T-20)}$;

7) $D.O._{SAT} = 14.652 - 0.41022T + 0.0079910\, T^2 - 0.000077774\, T^3$;

where,

$D.O._{SAT}$ = Dissolved Oxygen Concentration - at Saturation (mg/l);

$D.O._{DEF}$ = Dissolved Oxygen Deficit (mg/l);

$D.O._{MIN}$ = Minimum Dissolved Oxygen (mg/l);

Da = Initial Dissolved Oxygen Deficit (mg/l);

K_1 = Deoxygenation Rate Constant (day^{-1});

K_2 = Reaeration Rate Constant (day^{-1});

L_a = Initial Ultimate B.O.D. Concentration, (mg/l);

T = Temperature (^oC);

t = Time (days);

t_{crit} = Time of critical (maximum) deficit;

θ_1 = Deoxygenation Rate Constant - Temperature;

θ_2 = Reaeration Rate Constant - Temperature.

Using these relationships, the model calculated the minimum dissolved oxygen from each wet-weather event. These were then placed in numerical order so that a percent exceeded graph such as shown in Figure 13 could be drawn.

3.4.2. Input to River Quality Model

The inputs to RVRQUAL included:

1) results of 'LOAD' program;

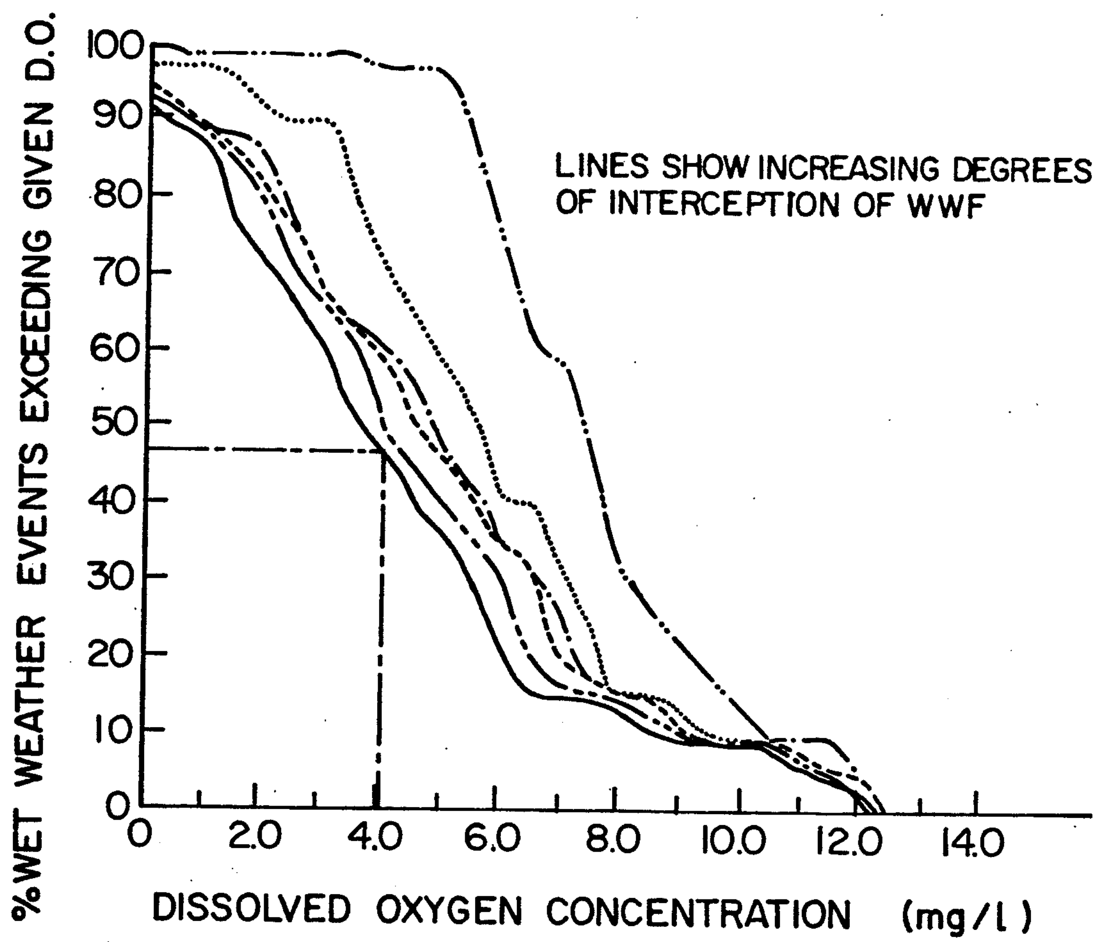


Fig. 13. ILLUSTRATIVE DISSOLVED OXYGEN FREQUENCY CURVE FOR VARIOUS CONTROL ALTERNATIVES.

2) physical properties of the river; and,

3) biochemical properties of the river;

as summarized in Table 15.

TABLE 15.

INPUT TO RIVER QUALITY MODEL

1. <u>"LOAD" Results for each event</u>
   - date, hour, duration
   - total volume
   - total B.O.D.$_U$ loading

2. <u>Physical Properties of River</u>
   a) General
      - length of reach
      - elevation versus surface width

   b) Per event
      - flow
      - elevation of water surface
      - temperature

3. <u>Biochemical Characteristics</u>
   - upstream B.O.D.
   - upstream D.O. deficit
   - deoxygenation rate constant
   - reaeration rate constant
   - temperature coefficient

3.4.3. Sensitivity and Calibration

For the river quality model, sensitivity was tested for the following parameters:

1) B.O.D. of upstream baseflow;
2) D.O. deficit of upstream baseflow;
3) deoxygenation rate constant; and,
4) reaeration rate constant.

Calibration data was taken from a 1977 dissolved oxygen monitoring program undertaken by the City of Winnipeg on the Red River.(8)

Specifically the measurements at Site No. 10, which is located approximately five river miles north of the perimeter and fifteen river miles downstream of the centroid of Winnipeg were used. This site had the lowest average D.O. concentration of all sites tested. The site was also in the area where the model predicted the lowest concentration to occur.

Verification of the model was not undertaken in this study.

3.4.4. RVRQUAL Program Listing

A listing of the RVRQUAL program is contained in Appendix 3.

3.5. DRY WEATHER FLOW MODEL

The wet weather river quality model described in the previous section was not considered to adequately describe the effects of continuous discharges. This resulted from the fact that the dry weather flow regime (continuous discharge) was significantly different from the wet weather flow regime (intermittent discharge). Although the major effort of the study was placed on wet-weather flows, a study of continuous discharges was necessary to clarify the effects of pollution abatement strategies such as no dry weather flow treatment.

3.5.1. Basic Description

3.5.1.1. Hydrodynamics

During dry weather, continuous discharges in Winnipeg occur at the three main plants as shown in Table 14. From a pollution point of view the North End Plant is the most significant. The other plants are so far upstream that their effects were minimal and could be ignored for an initial planning level overview study.

The basic hydrodynamic model is shown on Figure 14. The model assumed complete mixing as follows:

1) $$La = \frac{B.O.D._R\ Q_R + B.O.D._P\ Q_P}{Q_R + Q_P}$$; and,

2) $$Da = \frac{Da_R\ Q_R + Da_P\ Q_P}{Q_R + Q_P}$$;

where,

$B.O.D._R, B.O.D._P$ = ultimate B.O.D. concentration in River upstream and treatment plant effluent respectively (mg/l);

Da = initial dissolved oxygen deficit (mg/l);

La = initial completely mixed ultimate B.O.D. concentration (mg/l); and,

Q_R, Q_P = upstream flow in River (ft^3/s) and discharge rate from treatment plant (ft^3/s) respectively.

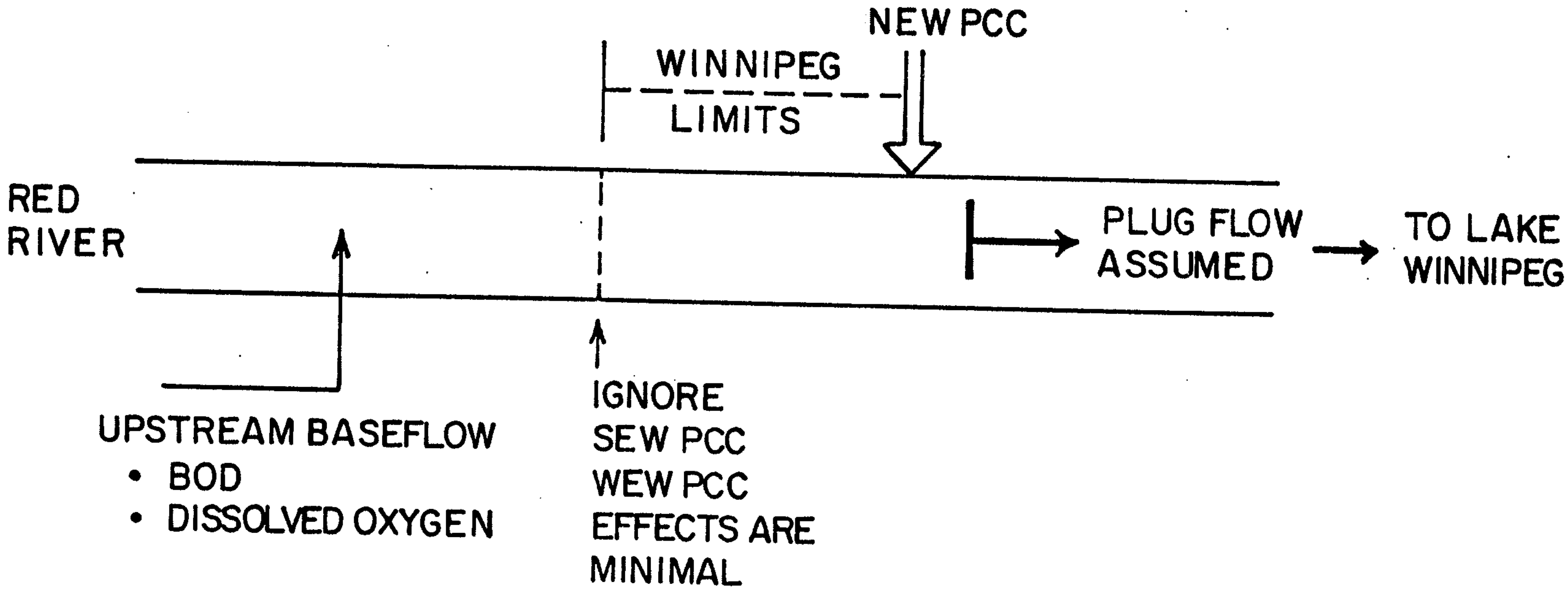


Fig. 14. DRY WEATHER FLOW RIVER QUALITY MODEL SCHEMATIC.

3.5.1.2. Model Kinetics

The kinetic formulation of the dry weather model was identifical to the wet weather model described earlier.

3.5.2. Input Data

Table 16. shows the input data required for the dry weather flow model.

3.5.3. Program Listing

The dry weather flow model was programmed on a Texas Instrument IT 58 programmable calculator. The Program Record and Coding form is included in Appendix 4.

TABLE 16.

DRY WEATHER FLOW MODEL - INPUT DATA

1. River Data
   a) Physical
      - flow in river
      - temperature
   b) Biochemical
      - deoxygenation rate constant
      - reaeration rate constant
      - temperature correction coefficients
      - upstream ultimate B.O.D.
      - upstream ultimate D.O. deficit
2. Treatment Plant Data
   - treatment plant flow
   - ultimate B.O.D. of effluent
   - D.O. deficit of effluent

4. PRESENTATION OF RESULTS

4.1. URBAN RUNOFF - STORM

The results of the STORM Model runs are summarized for combined and separate areas in Table 17 for both $B.O.D._5$ and S.S. Table 18 shows the breakdown of runoff and $B.O.D._5$ loadings on a per event basis. A sample run of STORM is included in Appendix 1.

4.2. STREAM LOADINGS 'LOAD'

4.2.1. Existing Conditions

The results of the LOAD run for the existing conditions by event are shown in Table 19. A sample run is included in Appendix 2.

4.2.2. Results of Various Pollution Abatement Strategies

The effects of various pollutant control strategies on the B.O.D. loading to the stream, as summarized from the LOAD program results for presentation purposes, are shown in Table 20. The total annual ultimate B.O.D. load to the receiving stream during wet weather varied from 4.3 to 10.9 million pounds depending on the degree of treatment for each pollution abatement strategy. The results were also calculated on a per event basis for input to the river quality model. (See

TABLE 17.

STORAGE TREATMENT OVERFLOW RUNOFF MODEL RESULTS
AVERAGE ANNUAL STATISTICS

Item	Combined Sewered Area		Separate Sewered Area	
Quantity				
1. Precipitation - inches	24.44		24.44	
2. Surface Runoff - inches	9.94		9.94	
3. Dry Weather Flow - inches	1.90		0.00	
4. Overflow to Stream - inches	7.30		9.94	
Quality	B.O.D.	S.S.	B.O.D.	S.S.
5. Total Pounds Washoff (lbs/acre)	367	937	93	789
6. Total Pounds Overflow (lbs/acre)	180	647	93	789
7. Concentration (mg/L)	109	391	41	350

TABLE 16.

STORM RESULTS BY EVENT

Event	Year	Month	Day	Runoff Inches Separate	Runoff Inches Combined	$B.O.D._5$ Loadings/100 Acres Combined Pounds	$B.O.D._5$ Loadings/100 Acres Separate Pounds
1	1977	5	4	0.95	0.88	2078.00	763.00
2	1977	5	5	0.21	0.14	91.00	6.00
3	1977	5	14	0.15	0.09	379.00	101.00
4	1977	5	18	0.49	0.41	989.00	604.00
5	1977	5	26	0.67	0.62	1086.00	478.00
6	1977	5	28	0.09	0.05	92.00	27.00
7	1977	5	28	0.27	0.23	222.00	127.00
8	1977	5	29	0.08	0.01	17.00	20.00
9	1977	6	10	0.22	0.16	805.00	253.00
10	1977	6	13	0.40	0.28	520.00	239.00
11	1977	6	17	0.51	0.43	707.00	359.00
12	1977	6	30	0.13	0.08	397.00	163.00
13	1977	7	2	0.16	0.10	334.00	198.00
14	1977	7	5	0.07	0.02	102.00	70.00
15	1977	7	13	0.74	0.64	1663.00	1192.00
16	1977	7	30	0.11	0.06	466.00	86.00
17	1977	7	30	0.09	0.04	162.00	47.00
18	1977	8	2	0.05	0.01	46.00	35.00
19	1977	8	4	0.14	0.08	297.00	110.00
20	1977	8	6	0.24	0.18	466.00	221.00
21	1977	8	9	0.09	0.04	148.00	76.00
22	1977	8	25	0.14	0.14	1117.00	382.00
23	1977	8	29	0.32	0.26	958.00	515.00
24	1977	8	31	0.14	0.05	120.00	85.00
25	1977	9	3	0.35	0.30	1067.00	756.00
26	1977	9	5	0.25	0.18	206.00	65.00
27	1977	9	8	1.11	0.99	767.00	380.00
28	1977	9	24	0.46	0.36	905.00	412.00
29	1977	9	24	0.08	0.03	43.00	26.00
30	1977	9	25	0.13	0.06	69.00	43.00
31	1977	10	17	0.11	0.05	428.00	188.00
32	1977	10	30	0.25	0.18	1296.00	757.00

TABLE 19. STORM RESULTS PER EVENT

ULTIMATE BOD LOADINGS IN POUNDS PER EVENT

EVENT	YEAR	MO	DY	HR	DURATION	RUNOFF	COMBINED	SEPARATE	STPLANTS	TOTAL RATE
1	1977	5	4	18	6.00	142200768.	810420.	183120.	24154.	1017694.
2	1977	5	5	5	6.00	10365930.	35490.	1440.	17417.	54347.
3	1977	5	14	15	3.00	18888894.	147810.	24240.	9675.	181725.
4	1977	5	18	2	3.00	69622944.	385710.	144960.	19444.	550114.
5	1977	5	26	14	3.00	99129904.	423540.	114720.	11109.	549369.
6	1977	5	28	14	1.00	10500420.	35880.	6480.	2449.	44809.
7	1977	5	28	23	1.00	37943220.	86580.	30480.	2449.	119509.
8	1977	5	29	20	2.00	6631866.	6630.	4800.	3085.	14515.
9	1977	6	10	11	3.00	29841536.	313950.	60720.	12903.	387573.
10	1977	6	12	22	9.00	54009360.	202800.	57360.	16634.	276794.
11	1977	6	17	10	9.00	77950600.	275730.	86160.	42313.	404203.
12	1977	6	30	12	2.00	16330766.	154830.	39120.	6974.	200924.
13	1977	7	2	15	2.00	19815200.	130260.	47520.	3660.	181440.
14	1977	7	5	18	2.00	7192516.	39780.	16800.	5413.	61993.
15	1977	7	13	13	2.00	104990296.	648570.	286080.	9208.	943858.
16	1977	7	30	4	2.00	13157368.	181740.	20640.	6765.	209145.
17	1977	7	30	17	2.00	10108169.	63180.	11280.	6765.	81225.
18	1977	8	2	21	2.00	4912170.	17940.	8400.	6178.	32518.
19	1977	8	4	14	3.00	17218060.	115830.	26400.	13488.	155718.
20	1977	8	6	21	3.00	32401960.	181740.	53040.	11956.	246736.
21	1977	8	9	16	1.00	9566668.	57720.	18240.	3436.	79396.
22	1977	8	25	8	4.00	23855082.	435630.	91680.	18528.	545838.
23	1977	8	29	18	4.00	45442772.	373620.	123600.	16915.	514136.
24	1977	8	31	9	5.00	16345792.	46800.	20400.	29251.	96451.
25	1977	9	3	20	2.00	49694352.	416130.	181440.	5948.	603518.
26	1977	9	5	6	6.00	36043660.	80340.	15600.	23336.	119276.
27	1977	9	8	17	12.00	166935456.	299130.	91200.	54291.	444621.
28	1977	9	24	3	9.00	67592632.	352950.	98880.	34733.	486563.
29	1977	9	24	21	3.00	9777478.	16770.	6240.	11578.	34588.
30	1977	9	25	16	3.00	16095811.	26910.	10320.	11176.	48406.
31	1977	10	17	7	4.00	13492948.	166920.	45120.	19147.	231187.
32	1977	10	30	21	4.00	33458186.	505440.	181680.	14399.	701519.

TABLE 20.

STREAM LOADINGS
(Wet Weather)

Pollution Control Strategy	Percent B.O.D. Removal D.W.F.	C.S.O.	S.R.	Run	Total Load 10^6-Lbs.	% Combined	% Separate	% Treatment Plants
(i) Effects of D.W.F. Treatment During Events (Fig.4)								
Status Quo	72%	0%	0%	002	9.62	73	22	5
Primary	30%	0%	0%	003	10.34	68	20	12
No Treatment	0%	0%	0%	004	10.85	65	19	16
Tertiary	90%	0%	0%	010	9.32	76	23	2
(ii) Effects of W.W.F. Treatment During Events (Fig.5)								
Status Quo	72%	0%	0%	002	9.62	73	22	5
25% C.S.O.	72%	25%	0%	005	7.86	67	27	6
50% C.S.O.	72%	50%	0%	006	6.10	58	35	8
75% C.S.O.	72%	75%	0%	007	4.34	41	49	11
50% W.W.F.	72%	50%	0%	008	5.05	70	21	9

Appendix 2 for sample results.)

4.3. RIVER QUALITY MODEL RESULTS

All the model results are based on 1977 precipitation records with a total of 32 overflow events. The detailed printouts for each "run" (as referred to by a number in the text) are included in Appendix 5.

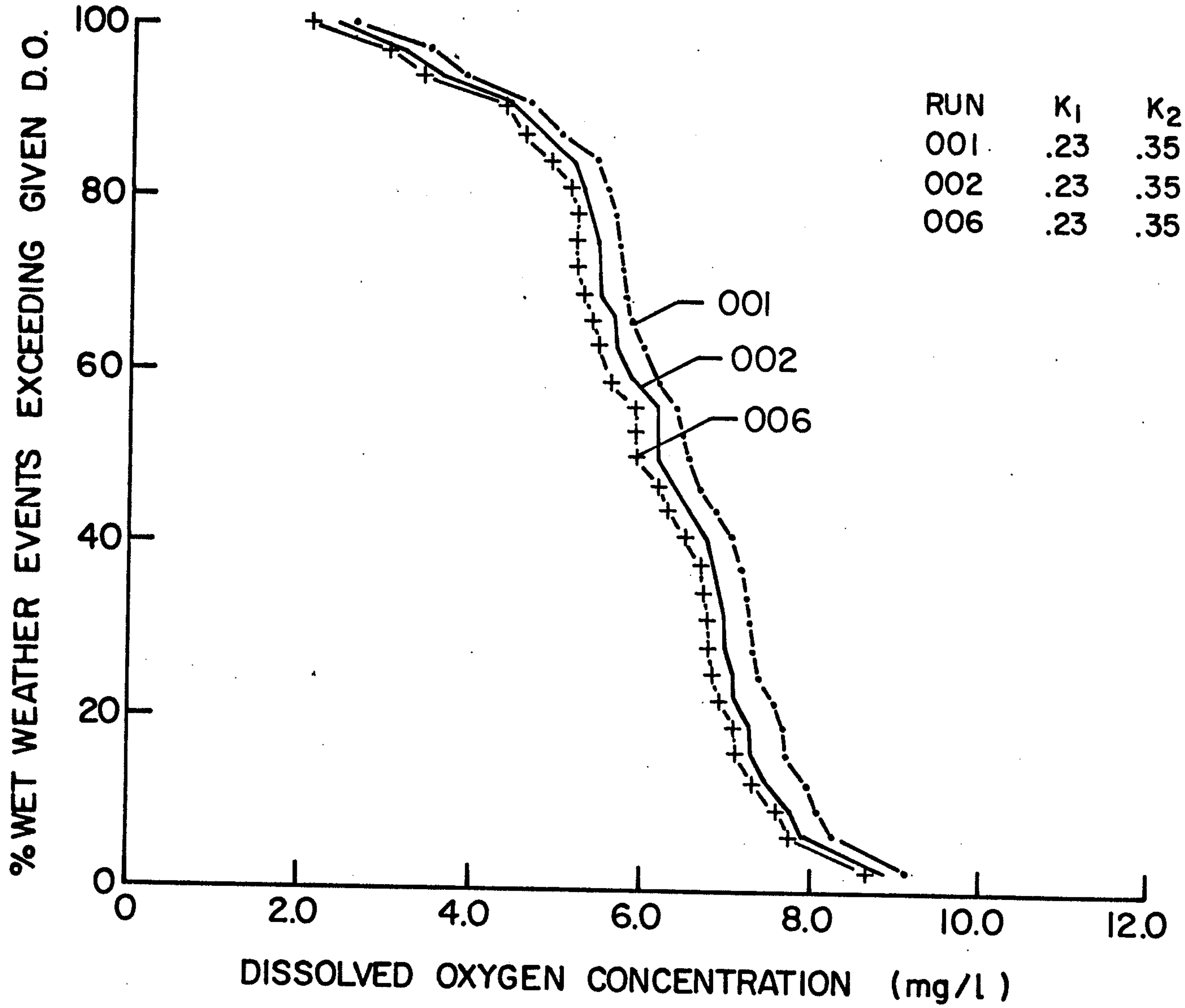
4.3.1. Sensitivity Analysis

4.3.1.1. Sensitivity to Baseflow Conditions

The sensitivity of the model to upstream baseflow quality ($B.O.D._U$, D.O.) is shown in Figure 15. When the initial D.O. deficit was increased form 0.0 mg/L to 1.0 mg/L, the minimum D.O. at the critical time were about 0.3 mg/L less for each event. When the initial $B.O.D._U$ was increased from 1.0 mg/L to 2.0 mg/L, the initial fully mixed La is also increased almost 1.0 mg/L and the minimum D.O. are about 0.3 mg/L less.

4.3.1.2. Sensitivity to Deoxygenation Rate Constant

The sensitivity of the model to variation in the deoxygenation rate constant (K_1) is shown in Table 21. and Figure 16.



RUN	K_1	K_2	INITIAL BOD	INITIAL D.O.DEF
001	.23	.35	1.0	0.0
002	.23	.35	1.0	1.0
006	.23	.35	2.0	1.0

Fig. 15. SENSITIVITY TO INITIAL CONDITIONS.

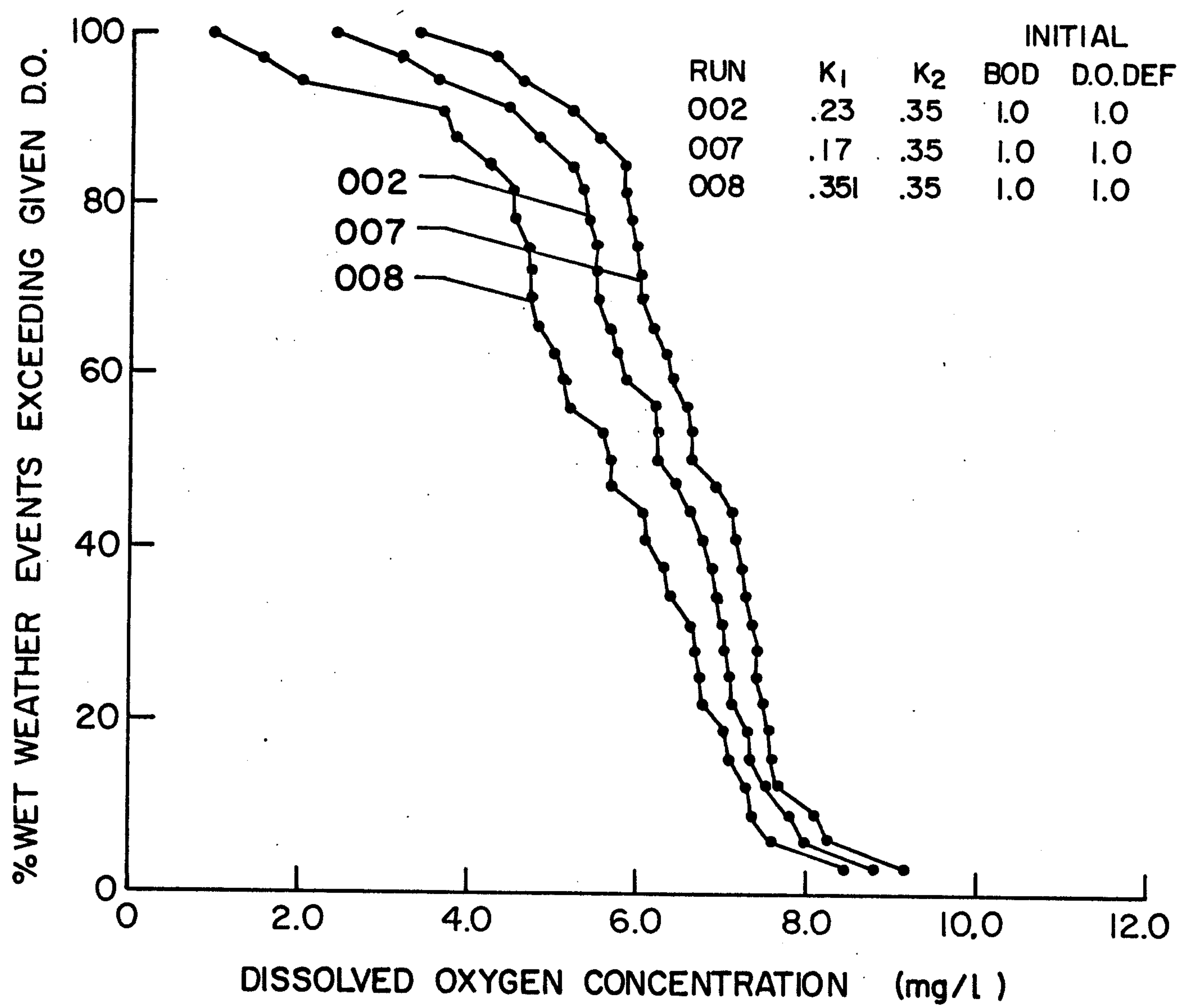


Fig. 16. MODEL SENSITIVITY TO K_1 - DEOXYGENATION RATE CONSTANT.

TABLE 21.

SENSITIVITY TO DEOXYGENATION COEFFICIENT

Run	K_1	No. of Events With D.O. Less Than 5.0	4.0
002	.23	5	3
007	.17		
008	.351		

When K_1 was decreased from 0.23 day^{-1} to 0.17 day the minimum D.O. increased from 0.4 mg/L per event to 1.0 mg/L per event, and the number of violations of D.O. equal 5.0 mg/L dropped from 5 to 3. When K_1 was increased from 0.23 day^{-1} to 0.351 day^{-1} the minimum D.O. dropped and the number of violations of D.O. equal 5.0 mg/L increased from 5 to 12.

4.3.1.3. Sensitivity to Reaeration Rate Constant

The sensitivity to variations in the reaeration rate constant is shown in Table 22 and Figure 17.

TABLE 22.

SENSITIVITY TO REAERATION COEFFICIENT

Run	K_2	No. of Violations of D.O. Level 5.0 mg/L	4.0 mg/L
002	.35	5	3
003	.175	15	12
004	.26	12	5
005	.44	3	1

With the variations in K_2 shown the number of events with violations of a 5.0 mg/L D.O. criteria ranged from 3 to 15 of the 32 events.

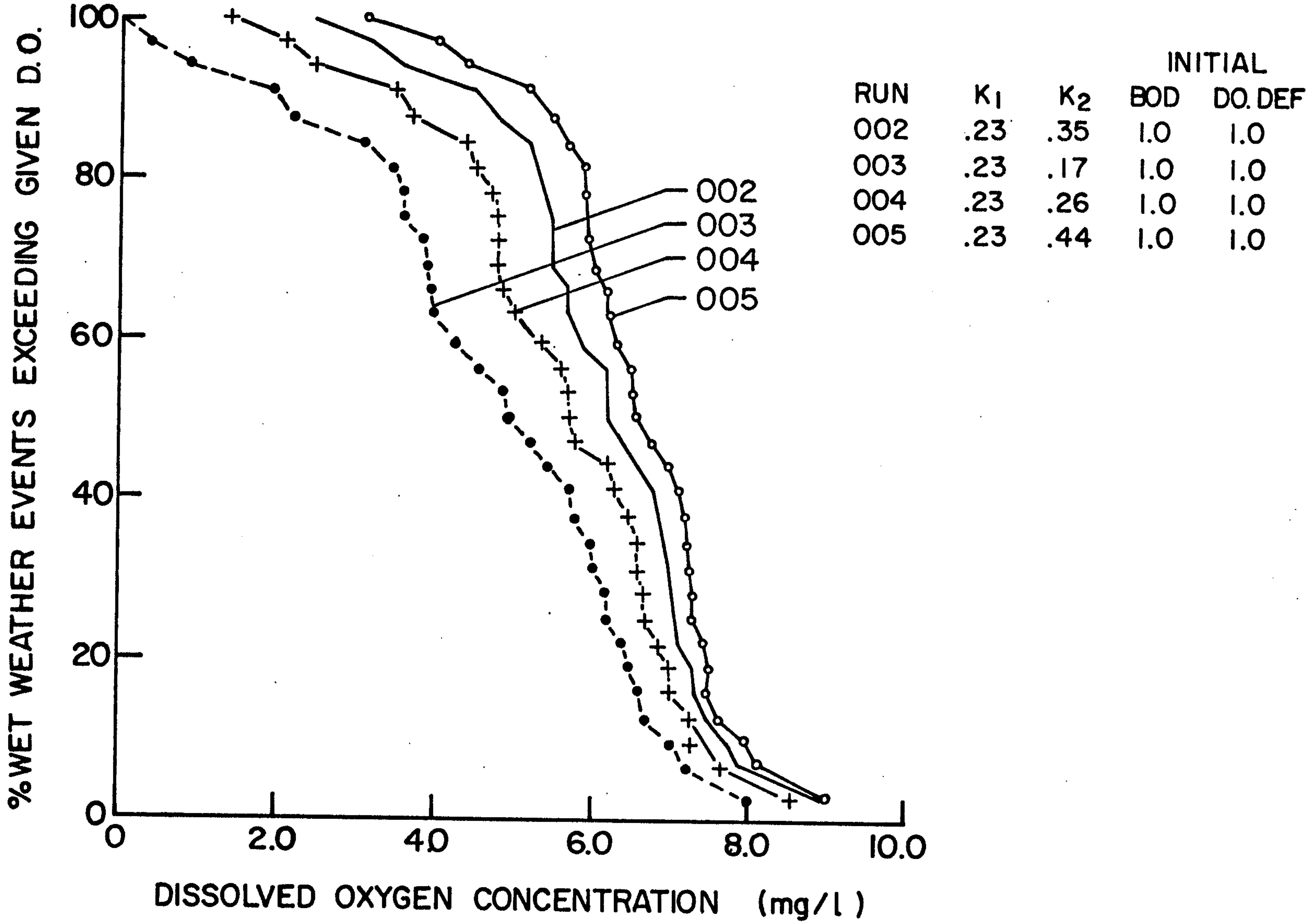


Fig. 17. SENSITIVITY TO K_2 REAERATION RATE CONSTANT.

4.3.2. Calibration

The results of the final calibration run are shown in Figure 18. The predicted minimum dissolved oxygen concentration is plotted on a graph showing the measured results.

4.3.3. Pollution Abatement Strategies

The results of the wet weather river quality model runs are summarized in Table 23. for:

1) effects of dry weather flow treatment strategies;
2) effects of wet weather flow treatment strategies; and,
3) effects of low river flows.

4.3.3.1. Effects of Dry Weather Flow Treatment

The effects of dry weather flow treatment strategies, predicted by the model, are shown in Figure 19.

4.3.3.2. Effects of Wet Weather Flow Treatment

The results of the investigation of effects of wet weather flow treatment on dissolved oxygen levels is shown on Figure 20.

4.3.3.3. Effects of Low River Flows

The model for existing conditions was re-run with one-half of the measured River flows and the results are shown in Figure 21.

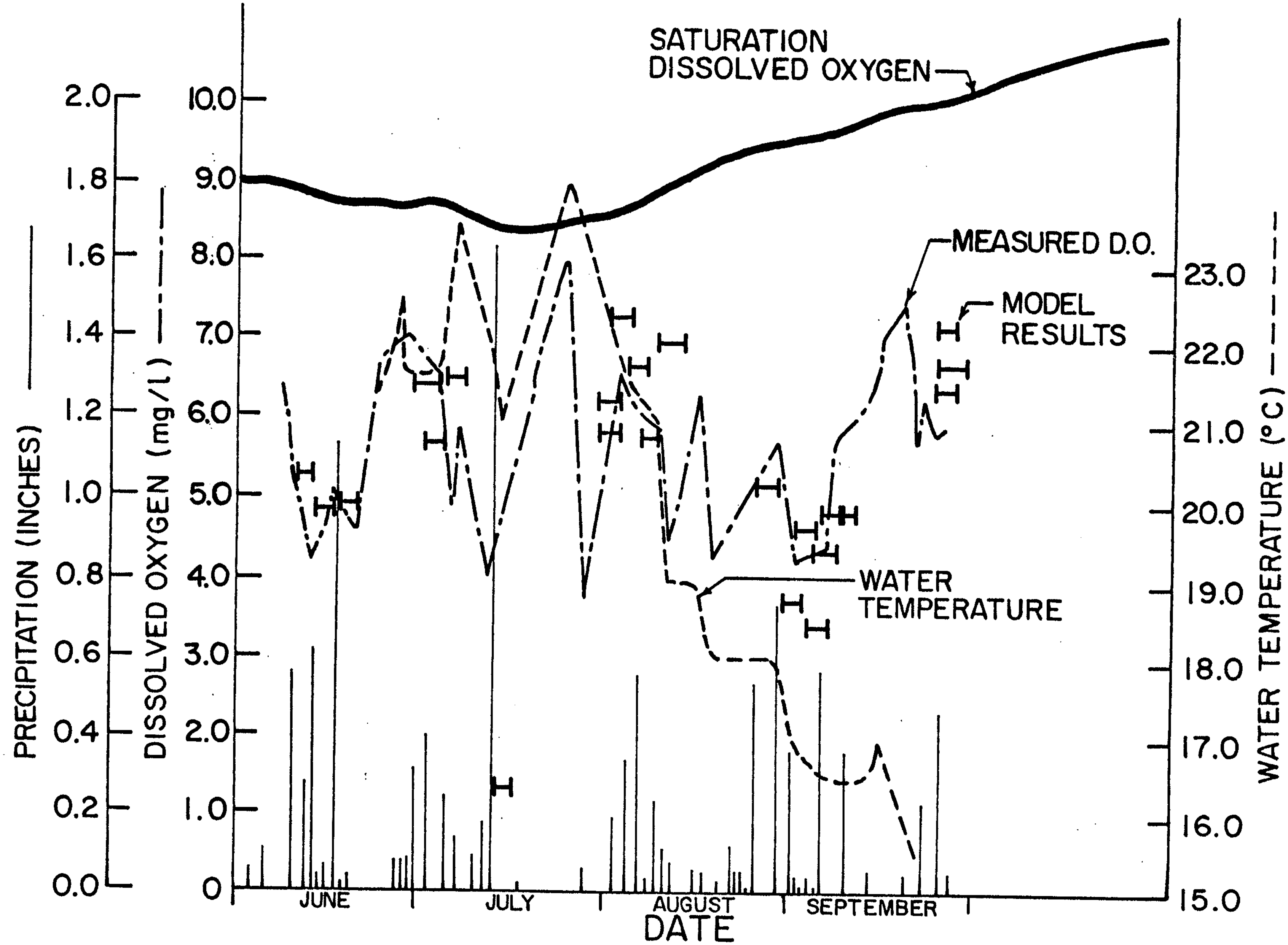


Fig. 18. RIVER QUALITY MODEL CALIBRATION RESULTS.

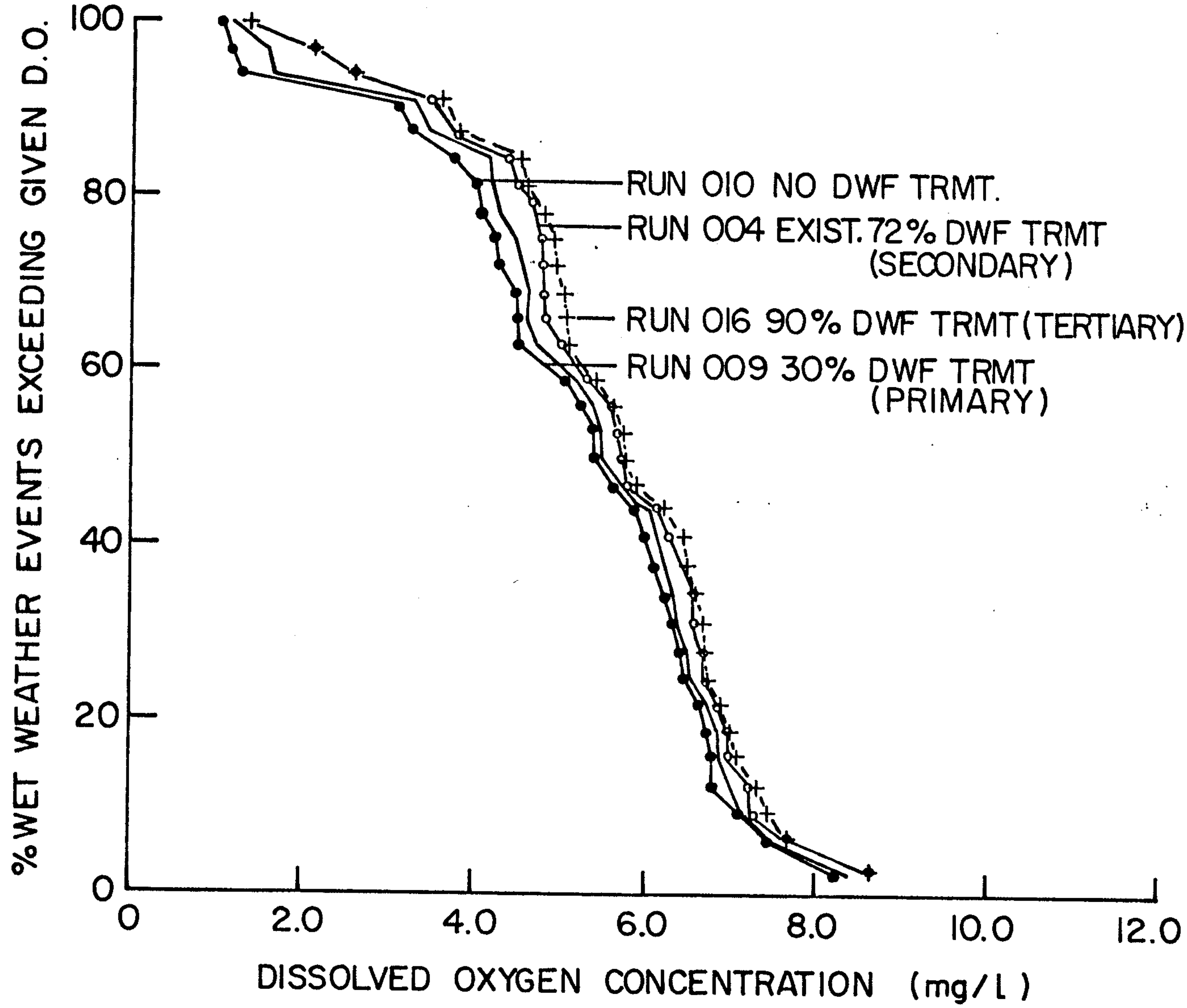


Fig. 19. EFFECTS OF DRY WEATHER FLOW TREATMENT

TABLE 23.

RIVER QUALITY MODEL RESULTS - WET WEATHER

Purpose	Treatment D.W.F.	C.S.O.	S.R.	'LOAD' Run	Total Load 10^6 lbs.	% Combined	% Separate	% Trt.Plts.	'RVRQUAL' Run	Minimum D.O. < 6	< 5	< 4	< 3	Remarks
(i) Effects of D.W.F. Treatment During Events														
Status Quo	72%	0%	0%	002	9.62	73	22	5	004	18	12	5	3	Base
Primary	30%	0%	0%	003	10.34	68	20	12	009	18	13	5	3	Min. D.O. $\downarrow$ 0.2
No Treatment	0%	0%	0%	004	10.85	65	19	16	010	19	13	6	3	Min. D.O. $\downarrow$ 0.5
Tertiary	90%	0%	0%	010	9.32	76	23	2	016	18	10	5	3	Min. D.O. $\uparrow$ 0.1
(ii) Effects of W.W.F. Treatment During Events														
Status Quo	72%	0%	0%	002	9.62	73	22	5	004	18	12	5	3	Base
25% C.S.O.	72%	25%	0%	005	7.86	67	27	6	011	14	5	3	1	Min. D.O. $\uparrow$ 0.3-1.0
50% C.S.O.	72%	50%	0%	006	6.10	58	35	8	012	7	2	1	0	Min. D.O. $\uparrow$ 1.5
75% C.S.O.	72%	75%	0%	007	4.34	41	49	11	013	1	1	0	0	Min. D.O. $\uparrow$ 2.0
50% W.W.F.	72%	50%	0%	008	5.05	70	21	9	014	3	1	0	0	
(iii) Effects of Low River Flows														
Status Quo	72%	0%	0%	002	9.62	73	22	5	004	18	12	5	3	Base
½ River Flows	72%	0%	0%	002	9.62	73	22	5	015	20	12	7	4	Min. D.O. $\downarrow$ 0.4

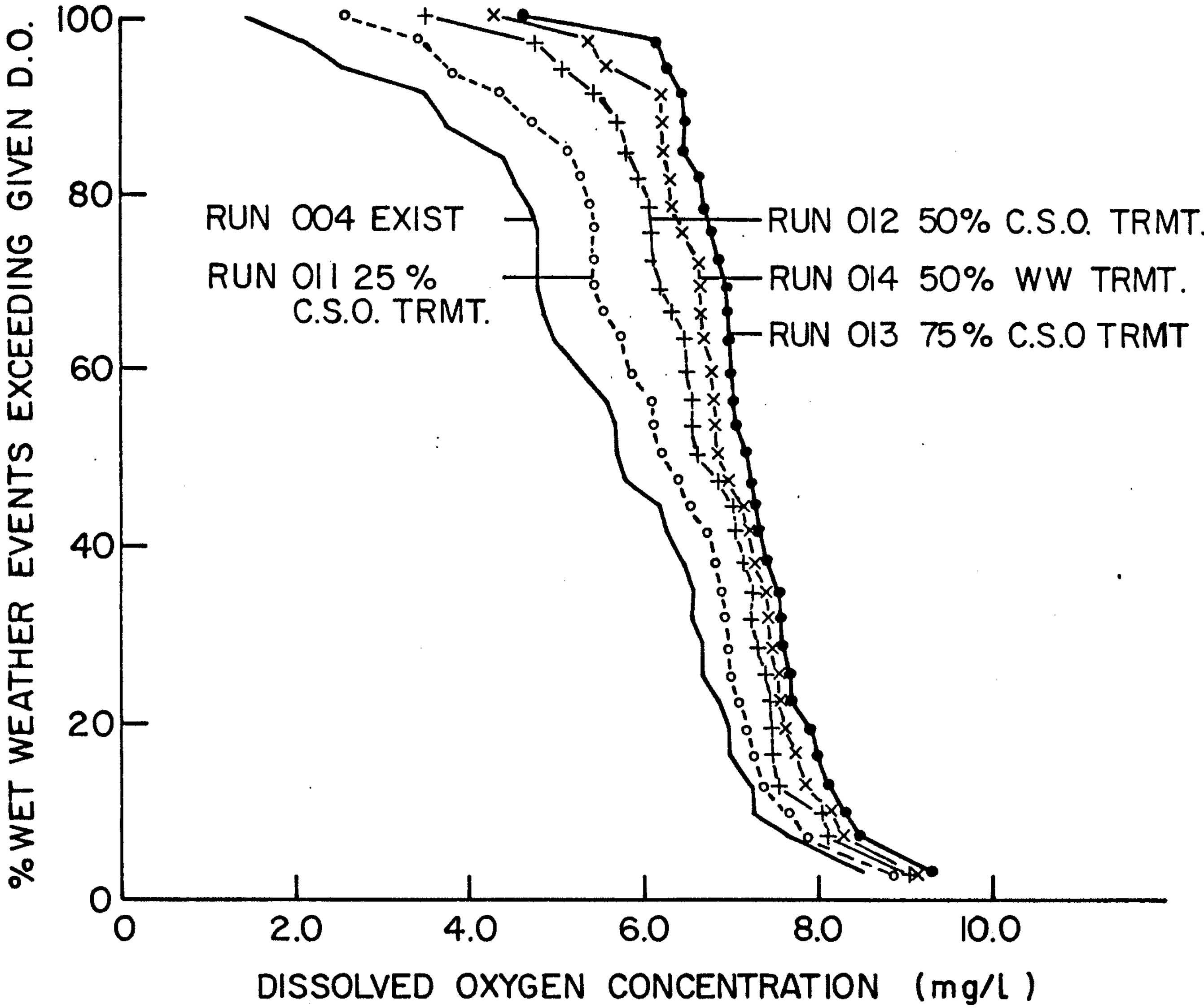


Fig. 20. EFFECT OF TREATMENT OF WET WEATHER FLOW.

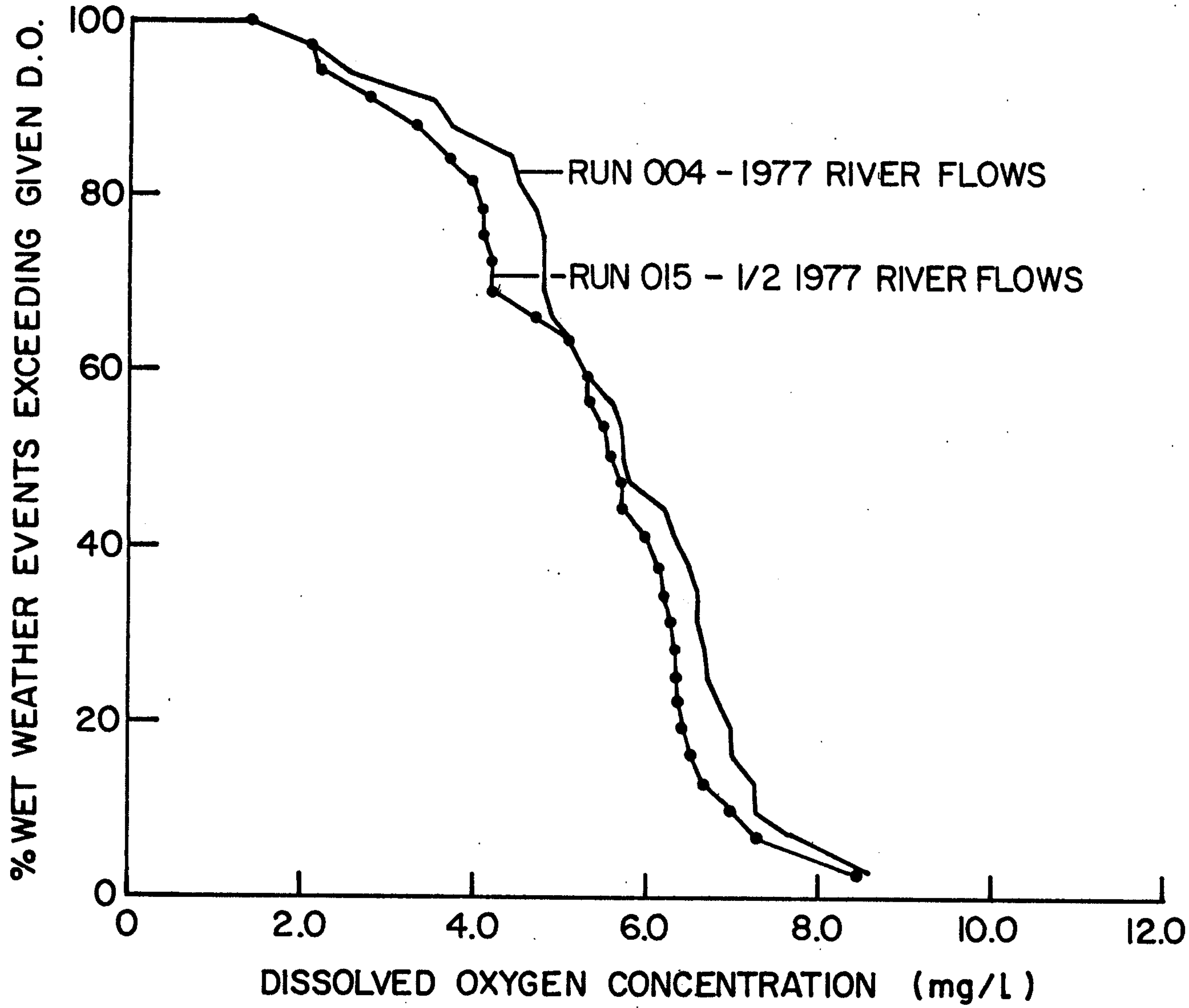


Fig. 21. EFFECT OF LOW RIVER FLOWS.

4.4. DRY WEATHER FLOW MODEL RESULTS

The results of the dry weather flow model analysis are shown in Table 24. The results for existing conditions are that D.O. levels should be greater than 5.0 mg/ during dry weather.

TABLE 24.

DRY WEATHER FLOW MODEL RESULTS

Condition	$B.O.D._5$ Removal	Minimum D.O. 1977 May	June	July	Aug.	Sept.	Avg.
Existing Conditions	80%	7.09	6.67	5.96	6.24	7.77	6.75
Primary Treatment Only	30%	2.19	2.09	1.30	1.12	3.21	1.98
No Treatment	0%	0.00	0.00	0.00	0.00	0.40	0.08
Advanced Treatment	90%	7.47	7.18	6.73	7.62	8.77	7.55
One Half River Flows	80%	5.93	5.40	4.45	4.07	6.06	5.18

5. DISCUSSION OF RESULTS

5.1. STREAM LOADINGS

The determination of the stream loadings provided the base data for assessment of the impact of these loadings on the receiving stream. The existing stream loadings are discussed as well as the revised stream loadings for various pollution control strategies.

5.1.1. Existing Stream Loadings

The STORM results for existing conditions, from Table 17 , are compared to figures from the literature, and from actual measurements in Table 25 , in terms of pollutant concentrations. These concentrations are the major output of STORM and are often reported in the literature because they are easily measured in the field.

The results are in general agreement with the reported values. This type of correlation is easily achieved by adjusting the pollutant accumulation rates in STORM. The result for $B.O.D._5$ concentration for separate storm sewers (41 mg/L) is much higher than the reported values (20 mg/L). This results from the STORM algorithm which assumes that the $B.O.D._5$ load includes 10% of the suspended solids load. This could be overcome in future work by either adjusting the

TABLE 25.

COMPARISON OF STORM RESULTS WITH

REPORTED VALUES

	STORM Results	Literature	Measurements in Winnipeg
A. Combined Sewer Overflows			
Suspended Solids Conc. (mg/L)	391	370	120 - 720
B.O.D.$_5$ (mg/L)	109	115	14 - 191
B.O.D.$_5$ (lbs/acre/year)	180	137	
B. Separate Storm Sewer Discharge			
Suspended Solids Conc. (mg/L)	350	415	578
B.O.D.$_5$ (mg/L)	41	20	12
B.O.D.$_5$ (lbs/acre/year)	93	31	

program or by multiplying the results by a reduction factor. As discussed later, the separate storm runoff B.O.D. loading is minor when compared to Combined Sewer Overflow loadings under most conditions. Therefore the use of the higher figure does not affect the results to a great extent.

The results in terms of pounds per acre per year computed for Winnipeg are considerably higher than the literature figures show taken from a large U.S. study of 248 urbanized areas.[24] The reason for this descrepancy is that the U.S. study included undeveloped lands (46%) in the calculations. The literature figures would be significantly higher had the undeveloped land been excluded.

It is noted that the $B.O.D_5$ loadings from separate sewered areas is one-half of that from combined storm sewered areas for similar land uses. This indicates that sewer separation cannot achieve any more than a 50% reduction in $B.O.D_5$ loadings. The high cost of sewer separation is recognized as generally not justifiable for the limited benefit obtained, and other methods such as storage and treatment are more economical.[22][24]

The comparison above is for annual averages. The river quality analysis required the information for each event. STORM provided this (Table 18). The average concentration of pollutants varies for each event and during each event according to the STORM representation of the real system as shown in Appendix 1.

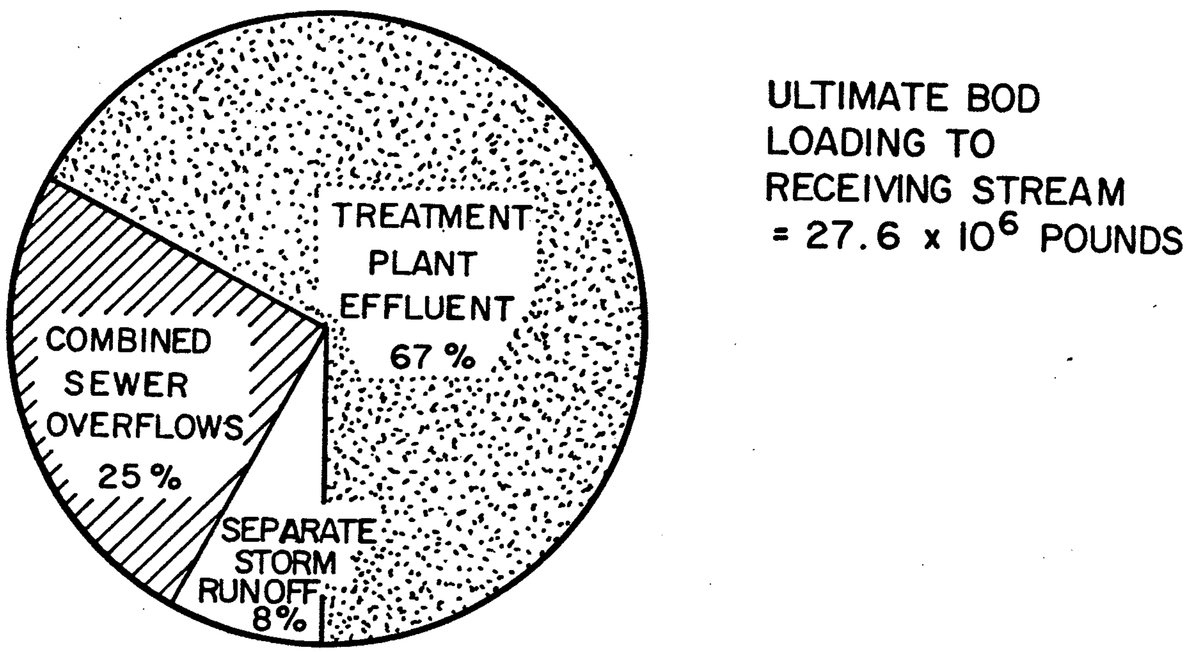
For the event of June 12, 1977 the hourly combined sewer overflow $B.O.D._5$ concentration results varied from 46 mg/L to

205 mg/L during the 12 hour period. This variation is also consistent with reported variations. This is evidence that STORM not only gives reasonable results for the annual averages, but in addition gives a reasonable distribution of loading results for each runoff event. This is required for an accurate assessment of each event on river quality.

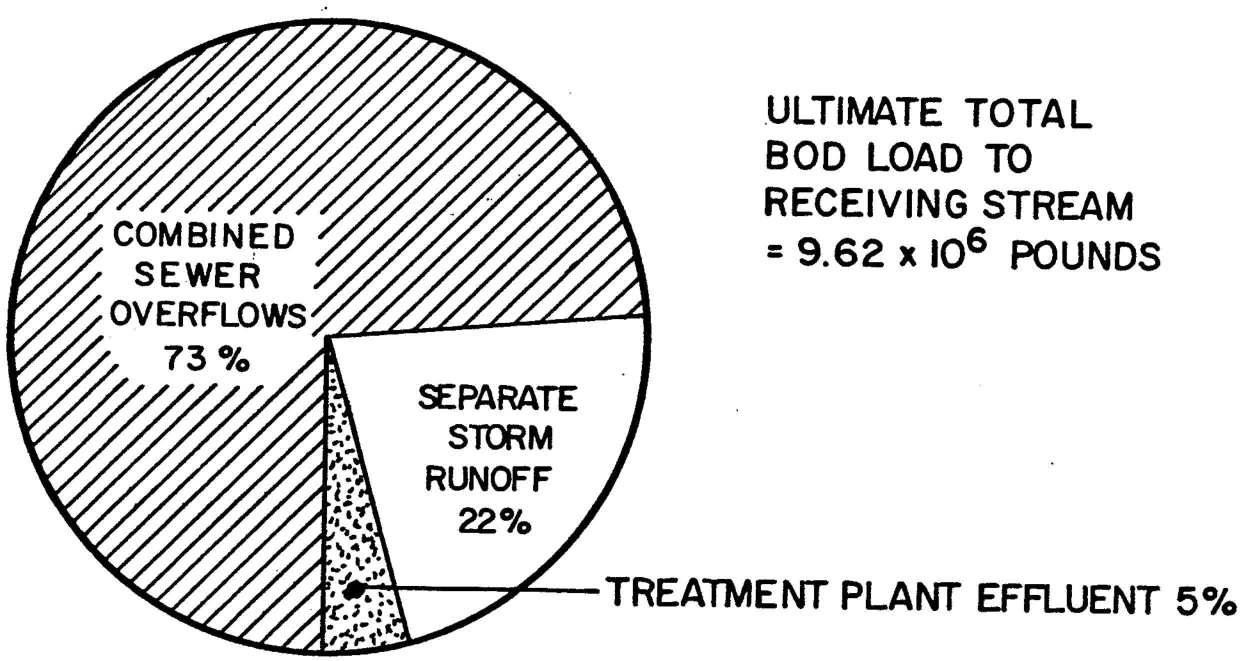
Figure 22 shows graphically the contributions of $B.O.D._U$ loadings from urban runoff relative to the $B.O.D_U$ loadings from sewage treatment plant effluents. On an annual basis, the results indicate that urban runoff contributes 33% of the total load to the receiving stream. This is consistent with an average of 33% reported for the 248 urbanized areas in the United States.(1) On this basis, urban runoff loadings are significant on an annual basis, but not the major component.

However, the urban runoff $B.O.D_U$ loadings become much more significant as shock loadings to the receiving stream during wet weather shown on Figure 22. It can be seen that the urban runoff loading is 95% of the loading during wet weather events. This is especially significant since the dissolved oxygen resources in the River respond to each event. not to annual averages.

The large $B.O.D_U$ contribution from urban runoff are widely recognized in the pollution control field as discussed in the Introduction. Knowledge of this fact sparked the need to study their impact on river quality. These results were the input data to the river quality model.



a) ANNUAL BASIS - INCLUDING DRY WEATHER



b) ANNUAL BASIS - DURING WET WEATHER

Fig. 22. 'LOAD' RESULTS ULTIMATE BOD STREAM LOADINGS EXISTING CONDITIONS.

5.1.2. Pollution Abatement Strategies

The resultant modified loadings for the various pollution control strategies, e.g. removal of 50% of $B.O.D_5$ loading from combined sewers, as shown in Table 17 result from direct multiplication of the "Existing Conditions" data.

The significance of these results is reflected in the impact of the pollution control strategies on river quality as discussed in Section 5.2.

While on paper it is easy to simulate the effects of a 50% removal of $B.O.D._5$ from a combined sewer, in reality this is difficult and expensive to achieve. For example, the capital cost removal of 50% of $B.O.D_5$ loadings nationwide in the U.S. was estimated to cost $1,400 per acre of urbanized area, based on the optimal combination of storage and treatment.(24) A demonstration project is currently being undertaken by the City of Winnipeg to reduce $B.O.D_5$ loadings by 50% in the Clifton Combined Sewer Relief Project.(25) "In-System" Storage of combined sewer overflows in the trunk sewers for subsequent treatment will be used. The capital cost for that system is estimated to be $340/acre since the storage volume already exists. At $1,000/acre the capital cost of removal of 50% of the $B.O.D_5$ loading for Winnipeg would be $40 million dollars.

5.2. WET WEATHER RIVER QUALITY MODEL

5.2.1. Sensitivity

The results of the sensitivity analysis as presented in

Section 4.3.1. demonstrate that the model behaves in a logical and predictable manner to changes in: (1) upstream baseflow characteristics (B.O.D.$_U$, D.O.D.); (2) Deoxygenation Rate Constant (K_1); and, (3) Reaeration Rate Constant (K_2).

The model is relatively non-sensitive to changes in the upstream B.O.D.$_U$ or D.O.D. within the normal range of expected value for these parameters, i.e., B.O.D.$_U$ of 0.0, 1.0, and 2.0 mg/L and D.O.D. of 0.0 and 1.0 mg/L.

The model is much more sensitive to a range of changes in K_1 and K_2. This is significant since actual measurements of these parameters in the Red River are not available and indeed are very difficult to obtain. Further the literature indicates that these factors are highly variable and highly site specific depending on velocity, depth, and turbulence. This is considered to be a weakness in the model since the sensitivity analysis shows that errors in the estimate of these variables can lead to significant differences in the results.

The sensitivity of the model to the rate constants indicates the need for calibration against measured data. Without this calibration, model predictions could be significantly erroneous.

5.2.2. Calibration

Figure 18 shows the comparison between the measured data and predicted results after the calibration was complete. Table 26 shows the input parameters used in the calibration run.

TABLE 26.

INPUT PARAMETERS - CALIBRATION RUN

$K_1 = 0.23$	Upstream Base Flow
$\theta_1 = 1.047$	$B.O.D._U = 1.0$
$K_2 = 0.26$	D.O.D. = 1.0
$\theta_2 = 1.016$	

The following can be observed from Figure 18 :

1) both the measured data and the model showed a wide variation in dissolved oxygen values, i.e., not steady state;

2) both the data and the model showed an approximately equal range of dissolved oxygen values;

3) the actual and modelled values showed many violations of a D.O. level of 5 mg/L;

4) for actual data not all effects seemed to be related to precipitation;

5) the correlation between the dissolved oxygen predicted by the model and those measured in situ was poor. Two factors contributed to this descrepancy;

   a) the measured data was not taken at the proper location and time to be used for this purpose, and

b) the model was an oversimplification of the processes involved and therefore discrepancies are predictable even if the measured data was more suitable.

Nevertheless, the calibrated model did predict the same kind of range and variability of minimum dissolved oxygen levels as was actually observed. It is important that both the model and the measured data did show violations of a minimum D.O. criteria of 5 mg/L. These observations lead to the conclusion that the river quality model is suitable to give a planning level overview of D.O. water quality impacts of wet weather overflows. In order to use the model for design of pollution control works, more development would be required.

It is also noted that the final values of $K_1 = 0.23$ and $K_2 = 0.26$ are within the usual range of values reported in the literature for a large slow moving River.[19][20] This indicates that the basic Streeter-Phelps model is a satisfactory representation of the real phenomena. Data from the City of Winnipeg[8] indicates that a value of the $B.O.D._U$ of 1.0 mg/L and D.O.D. of 1 mg/L are indicative of actual upstream baseflow conditions.

5.2.3. Existing River Water Quality

Typical criteria for minimum dissolved oxygen concentration for rivers is 4 to 5 mg/L. In Manitoba, the Proposed Water Quality Objectives,[10] an objective of a minimum of 35%

of the saturated D.O. value is indicated for the Red River from "Winnipeg North Limits to the end of the recovery zone". This corresponds to about 3.0 mg/L for the warmest period.

From the calibration results it can be seen that violations of a criteria of 5 mg/L were predicted by the model and did occur frequently in the measured data. Violations of 4 mg/L were much less frequent but do occur. There were no recorded violations of a 3.0 mg/L but three such violations were predicted by the model.

On the basis of these measured and predicted violations of reasonable D.O. limits, the river quality status of the Red River must be considered as "marginal". That is, the existing quality is good enough to pass the regulations but not good enough to pass criteria levels for higher species of fish. Any relaxation of existing pollution control efforts in the City of Winnipeg may result in unacceptable dissolved oxygen levels. It can be seen that the violations were predictable and were a result of untreated urban runoff pollutant loadings.

5.2.4. Impacts of Pollution Control Strategies

5.2.4.1. Effects of Dry Weather Flow Treatment

The wet weather river quality model predicted that there would be very little change in minimum dissolved oxygen concentrations as shown in Figure 19, even if the treatment plants were shut down. This is in agreement with the 'LOAD' results which showed that the treatment plant load is very small during storm events. However, it is not possible to conclude that treatment of the continuous discharges is not necessary. The wet weather flow model was a poor representation of the river regime under continuous flow conditions. In order to deal with continuous flow conditions a separate dry weather flow river quality model was used and the results, as discussed in Section 5.3., indicate that the River Quality would deteriorate significantly under conditions of no treatment.

5.2.4.2. Effects of Wet Weather Flow Treatment

The results as shown in Table 23 and Figure 20 show that the model predicted dramatic improvements in River Quality with increasing treatment of wet weather flow. With 50% treatment of combined sewer overflows, the number of violations of D.O. equal 4.0 mg/L dropped to 1 from 5 for existing conditions. The number of violations of 5.0 mg/L dropped from 12 to 2. These results demonstrate the importance of wet weather loadings, which was the premise around which this thesis was developed. Beyond this, the results show the potential benefits of treatment of wet weather flows. The treatment of wet weather flows may provide an avenue to maintain water quality for future growth of the City.

5.2.4.3. Effects of Low River Flows

The effects of low river flows are significant since low river flows do occur over the life of treatment works and also low flow augmentation is often considered as a pollution control strategy.[21]

The wet weather River Quality model results showed that the flow in the River has only a minor effect on the minimum dissolved oxygen levels as presented in Figure 21. This is contrary to a traditional thinking on the effect of low River flow since conventionally a higher river flow should result in more dilution. This is explained by the fact that the discharge of storm runoff occurs in a relatively short period of time, and therefore, it is the volume of dilution water in the river reach that is important. In actual fact, the river elevation and volume was relatively constant regardless of flow since the elevation was controlled for navigational reasons. In other words, the river behaves more like a reservoir.

With the same cross-sectional area, the velocity in the river is reduced in direct proportion to the flow. Thus with the same critical time of minimum dissolved oxygen concentration, the location of the point of minimum dissolved oxygen will occur closer to the centroid of pollutant discharge.

The minor effect shown in the results was due to increased "overlapping" of storm loadings. The effects of one event had not travelled out of the reach prior to the occurrence of the next event.

For continuous discharge point sources such as from the treatment plants, the effects of low river flows are much more pronounced since the flow, and not volume, provides the dilution. This is illustrated in Section 5.3.

5.3. DRY WEATHER FLOW MODEL

The dry weather flow model is developed around the theory for a continuous point source. This dry weather flow model is important in this study of pollution control since it allows an appraisal of continuous discharges, which cannot be seen from the wet weather river quality model.

For existing conditions D.O. levels were predicted to exceed 5.0 mg/L throughout the study period. This is consistent with measurements for dry weather periods as shown in Figure 18. However, if the plant was revised to provide only primary treatment the minimum D.O. levels in the River were predicted to drop below 2.0 mg/L in the months of July and August when river temperatures are highest. This effect was also observed in the early 1960's in Winnipeg prior to the addition of secondary treatment at the North End Water Pollution Control Centres. At that time, fish kills and odours had reached a near crisis level(4). From these results, it appears that the model is a reasonable representation of the river response.

With no treatment, the D.O. levels were predicted to drop to zero for four months, which is clearly unacceptable. Advanced treatment would result in an improved minimum D.O. from 6.0 to 6.7 for July.

The predicted effects of low river flows that were not significant for wet weather loadings, were more pronounced for continuous discharges with the July minimum D.O. dropping from 5.9 mg/L to 4.5 mg/L for one-half river flows. For August, the minimum D.O. dropped from 6.2 to 4.1. August is of interest since the 1977 mean river flow was 1240 cfs. One half of that flow is 620 cfs. This is very close to the lowest weekly summer flow with a one in ten year recurrence frequency for the Red River of 630 cfs.[26] This is the flow below which the stream standards[10] would not be applied. From the results, it is significant that the City of Winnipeg should be able to meet the Stream Standards in terms of dry weather flows. Recall however that the wet weather model predicted seven violations of 4 mg/L due to the wet weather loads under the one-half river flow run.

6. CONCLUSIONS

The following conclusions result from an investigation in which the STORM model was used to predict B.O.D. loading input for a Red River quality model developed specifically for use in the City of Winnipeg.

1) The contribution of wet weather loadings is significant on an annual basis. During runoff periods the runoff contributes 95% of the total loadings. Treatment plant effluents, combined sewer overflows, and separate storm sewer discharges contributed 67%, 25% and 8% respectively of the total ultimate Biochemical Oxygen Demand loadings of 27 million pounds to the Red River from the City of Winnipeg in 1977. Combined sewer overflows, separate storm sewers, and treatment plant effluents contributed 73%, 22%, and 5% respectively of the total ultimate B.O.D. of 9.6 million pounds during periods of wet weather.

2) The existing river quality is significantly affected by wet weather flows which cause violations of desirable minimum D.O. concentrations. The wet weather river quality model

developed for this study and calibrated to measured data predicted for twelve violations of a minimum D.O. of 5 mg/L and four violations of a minimum D.O. of 4 mg/L in 1977 due to wet weather B.O.D. loading events. The dry weather river quality model developed for this study predicted an average minimum D.O. of 6.8 mg/L during the summer months due to B.O.D. loadings from treatment plant effluents only.

3) The need to provide secondary treatment of continuous discharges in Winnipeg is substantiated. The dry weather flow river quality model predicted that the average minimum D.O. would drop to 2.0 mg/L with primary treatment only, and to 0.1 mg/L with no treatment of continuous sewage discharges. The minimum D.O. was predicted to increase to 7.6 mg/L with advanced treatment.

4) Wet weather flow treatment has major impacts on the frequency of violations of dissolved oxygen limits. The wet weather river quality model predicted that the number of violations of a minimum D.O. of 5 mg/L and 4 mg/L would drop to;

   a) 5 and 3 respectively for 25% treatment of combined sewer overflows;

b) 2 and 1 respectively for 50% treatment of combined sewer overflows;

c) 1 and 0 respectively for 75% treatment of combined sewer overflows or 50% treatment of all wet weather flows.

5) Low flow augmentation to increase the minimum flows in the Red River would not have an effect on the frequency of low D.O. levels due to wet weather discharges. The wet weather river quality model predicted that the number of violations of a minimum D.O. of 5 mg/L and 4 mg/L would remain at 5 and 3 with one-half the river flows during 1977. For the same condition the dry weather flow model predicted the average minimum D.O. would drop from 6.8 mg/L to 5.2 mg/L due to continuous discharges from the treatment plants.

7. RECOMMENDATIONS FOR FUTURE WORK

The following are recommendations for further work in the analysis of river quality at Winnipeg, Manitoba.

Model Development

1) The wet weather and dry weather river quality models used separately in this analysis should be combined using time as a sequencing parameter. Such a model would be a continuous simulation model which could predict frequency of occurrences of dissolved oxygen levels over an entire year or many years. The one in ten year minimum dissolved oxygen level would thus be determined. In the long term as more data becomes available the model could be expanded to include oxygen sources and sinks not included in the Streeter-Phelps formulation.

Calibration Data

2) The in-stream measurements program for dissolved oxygen should be implemented especially for model calibration. Sampling locations and times should be concentrated around the area and time of predicted minimum dissolved

oxygen levels. This data could be used more effectively for calibration than periodic samples at a single location.

3) Data should be collected so that the relative effects of all oxygen sources and sinks can be better evaluated in the stream. This involves in-stream analyses for K_1, K_2, nitrification, benthic demand, and photosynthesis.

Coliform Levels

4) While B.O.D. levels and minimum dissolved oxygen concentrations may govern the suitability of the receiving stream for various species of life, bacterial populations (i.e., coliform levels) are an important water quality parameter for suitability of the receiving stream in terms of water supply and recreational uses. This is especially important for the Red River downstream of Winnipeg since the River is a source of drinking water for Selkirk, Manitoba a community of 10,000 people. The City of Winnipeg is presently under pressure to disinfect continuous discharge sewage effluents for this reason.[27] The success of this strategy will be suspect until the effects of coliforms in urban runoff are understood.

Costs

5) The improvement of river quality through treatment of wet weather flows is known to be expensive. The actual costs should be better defined in order to select the optimum expansion path for improved quality.

8. ACKNOWLEDGEMENTS

The writer received valuable assistance from many sources including: Dr. B. H. Topnik, P. Eng. who was the Chief advisor; Mr. G. Rempel, P. Eng. who assisted in identifying the need for the study; James F. MacLaren Limited who donated the computer time; The City of Winnipeg, Waterworks, Waste and Disposal Division, and The Province of Manitoba, Water Resources Division, who provided data for the study; Patricia Goertzen who typed the thesis; and Margo MacBride who provided encouragement.

9. BIBLIOGRAPHY

(1) American Public Works Association and University of Florida, "Nationwide Evaluation of Combined Sewer Overflows and Urban Stormwater Discharges: Volume I, Executive Summary", U.S.E.P.A. (1977).

(2) "Areawide Assessment Procedures Manual, Volumes I and II." U.S.E.P.A. Report No. EPA-600/9-76-014. July (1976).

(3) Proctor and Redfern Limited and James F. MacLaren Limited, "Storm Water Management Model Study - Volume 1 Final Report", Environment Canada, Sept. (1976).

(4) James F. MacLaren Associates, "Report on Expansion of Sewage Works in the North District of Metropolitan Winnipeg" City of Winnipeg (1961).

(5) The Metropolitan Corporation of Greater Winnipeg, "A Continuing Program for Stream Pollution Control in Metro Winnipeg", Waterworks and Waste Disposal Division, March (1971).

(6) James F. MacLaren Limited, "Report on Levels of Service - Sewerage and Pollution Control System", City of Winnipeg, October (1978).

(7) U.S. Army Corps of Engineers "Storage, Treatment, Overflow, Runoff Model 'STORM' Users' Manual" H.E.C. July (1976).

(8) City of Winnipeg, "River Study (1977)", Waterworks, Waste and Disposal Division, July (1978).

(9) Environment Canada, "Guidelines for Effluent Quality and Wastewater Treatment at Federal Establishments" E.P.S. Report EPS-1-EC-76-1, April (1976).

(10) Manitoba Clean Environment Commission, "Report on a Proposal Concerning Surface Water Quality Objectives and Stream Classification for the Province of Manitoba," May (1978).

(11) McKee, J.E., and Wolf, H.W. "Water Quality Criteria", California State Water Resources Control Board (1963).

(12) Joint Committee on Drinking Water Standards, "Canadian Drinking Water Standards and Objectives 1968", Department of National Health and Welfare, Canada. October (1969).

BIBLIOGRAPHY
(continued)

(13) Lager, J. A., and Smith, W. G. "Urban Stormwater Management and Technology: An Assessment", U.S. Environmental Protection Agency, Dec. (1974).

(14) Lager, J. A., et.al. "Urban Stormwater Management and Technology: Update and Users' Guide", U.S. Environmental Protection Agency, Sept. (1977).

(15) Chambers, G. M.,and Tottle, C. H., "Evaluation of Stormwater Impoundments in Winnipeg", City of Winnipeg, Dec. (1978).

(16) Chambers, G. M., and Borlase, W. J., "Sewer Surcharging and Combined Sewer Overflows in the St. John's, Polson, and Munroe Sewer Districts", City of Winnipeg. Mar. (1979).

(17) Metcalfe and Eddy, Inc., et.al., "Storm Water Management Model", Environmental Protection Agency, July (1971).

(18) Velz, C. J. Applied Stream Sanitation, Wiley-Inter-Science, New York, (1970).

(19) Zison, S. W., et.al. "Rates Constants and Kinetic Formulations in Surface Water Quality Modelling", U.S.E.P.A. Report No. EPA-600/3-78-105. Dec. (1978).

(20) Hamilton, F. N. "Stream Assimilative Capacity - A Graphical Approach", Ontario M.O.E. April (1976).

(21) Water Resources Division, "Lake Manitoba Supply Canal Preliminary Report", Province of Manitoba, March (1968).

(22) James F. MacLaren Limited, "An Assessment of Combined Sewer Overflows in the City of Winnipeg", City of Winnipeg June (1977).

(23) U.S. Army Corps of Engineers, "Guidelines of Calibration and Application of STORM", Hydrologic Engineering Centre, Dec. (1977).

(24) Heaney, J.P., Huber, W.C. et.al. "Nationwide Evaluation of Combined Sewer Overflows and Urban Stormwater Discharges - Volume II: Cost Assessment and Impacts" U.S. Environmental Protection Agency. March (1977).

(25) James F. MacLaren Limited, "Conceptual Design Report for the Clifton Combined Sewer Relief Project", City of Winnipeg, Jan. (1979).

(26) Water Resources Division - Letter from N. Mudry to A. Permut, City of Winnipeg, dated April 6 (1979).

BIBLIOGRAPHY
(continued)

(27) Bell, J. B., et.al., "The Microbiology of the Red River in Manitoba, Canada" Environmental Protection Services, Draft Report, April (1979).

10. APPENDICES

10.1 APPENDIX 1

SAMPLE STORM RUN

```
 $$$$   $$$$$   $$$   $$$$   $$   $$
$         $    $   $  $   $  $ $ $ $
 $$$      $    $   $  $$$$   $  $  $
    $     $    $   $  $  $   $     $
$$$$      $     $$$   $   $  $     $
```

```
**************************************************
S T O R M        L7520      VERSION 2.0      JULY 1976
THE HYDROLOGIC ENGINEERING CENTER   DAVIS, CALIFORNIA
FOR ASSISTANCE  CALL 916-440-3286  OR 448-3286 (FTS)
**************************************************
```

* MSC THESIS-EFFECTS OF WET WEATHER RUNOFF ON THE QUALITY OF THE RED RIVER
B.MACBRIDE -ADVISOR-DR.B.TOPNIK-U OF MANITOBA-CIVIL ENGINEERING
STREAM LOADINGS-WET WEATHER EVENTS-CITY OF WINNIPEG-1977-B.MACBRIDE-RUN003

NWSHD	ISNO	ISED	IQUAL	IEVNT	IODWF	IDVAR	IHVAR	IHPVAR
1	0	0	1	1	1	2	2	0

NSUMR	LEXT	LINE	LDATE	LHR	NHYDRO	METRIC
30	3	0	-6	0	0	2

TITLE OF RAIN GAGE
WPG.INT.AIRPORT 1977 DATA

IN	IFILE	ISTART	IEND	IR
7	0	0	999999	1

RAINFALL DATA FOR [illegible].INT.AIRPORT 1977 DATA
HOURLY RAINFALL, IN HUNDREDTHS OF AN INCH

YEAR	MO	DAY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	TOTAL
1977	4	17	1	0	0	0	0	0	0	0	0	8	5	0	0	0	0	0	0	0	0	0	0	0	0	0	14
1977	4	22	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1977	4	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
1977	4	29	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1977	5	3	0	0	0	6	0	0	1	4	0	0	0	2	0	0	0	0	4	0	0	0	0	0	0	0	17
1977	5	4	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	84	40	17	20	30	7	0	200
1977	5	5	0	0	0	0	1	1	1	0	3	3	5	12	8	7	1	3	0	0	0	0	1	3	5	4	58
1977	5	6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1977	5	13	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1977	5	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	6	6	0	15	0	0	0	0	0	39
1977	5	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	1	0	0	0	0	4
1977	5	18	2	11	14	5	75	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	5	116
1977	5	19	1	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	4
1977	5	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	6
1977	5	23	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
1977	5	26	0	0	0	0	0	0	0	0	0	0	0	0	3	52	43	48	0	0	0	0	0	0	0	0	146
1977	5	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
1977	5	28	0	0	0	0	0	0	0	0	0	0	0	0	1	24	0	0	0	0	0	0	0	0	57	1	83
1977	5	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	6	4	0	4	19
1977	5	30	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
1977	6	3	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
1977	6	5	0	0	0	0	0	0	0	0	9	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	13
1977	6	10	2	0	0	0	0	0	0	0	0	5	4	15	26	2	0	0	0	0	0	0	0	0	0	0	54
1977	6	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	1	2	3	3	16	29
1977	6	13	12	8	4	9	9	13	4	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	62
1977	6	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0	0	0	4
1977	6	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	2	0	0	0	0	0	6
1977	6	17	0	0	0	4	0	0	0	0	0	11	8	26	12	6	0	8	29	6	2	0	0	0	0	0	112
1977	6	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2
1977	6	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	4
1977	6	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	8
1977	6	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	1	0	0	0	0	0	0	0	0	8
1977	6	29	0	0	0	0	0	0	0	0	0	0	0	0	0	1	6	0	1	0	0	0	0	0	0	0	8
1977	6	30	0	0	0	0	0	0	0	0	0	0	0	5	14	11	0	0	0	0	0	1	0	0	0	0	31
1977	7	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	1	0	13	18	0	0	0	0	0	40
1977	7	5	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	19	3	0	0	0	0	0	23
1977	7	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	3	0	0	0	14
1977	7	10	0	0	0	0	0	0	0	0	0	0	0	5	1	0	4	0	0	0	0	0	0	0	0	0	10
1977	7	11	0	6	1	0	0	1	0	5	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	16
1977	7	13	0	0	0	0	0	0	0	1	8	0	0	0	80	0	0	0	0	0	1	69	1	1	0	0	161
1977	7	28	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	6
1977	7	30	0	0	4	18	8	1	0	0	0	0	0	0	0	0	0	0	8	6	7	0	0	2	3	0	57
1977	7	31	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
1977	8	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	6	9	2	0	0	19
1977	8	4	0	0	0	0	0	0	1	0	0	0	0	0	0	22	6	4	1	1	0	0	0	0	0	0	35
1977	8	5	0	0	0	1	0	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	5
1977	8	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	11	11	0	54
1977	8	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
1977	8	8	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
1977	8	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23	1	0	0	0	0	0	0	0	24

RAINFALL DATA FOR VRG.IST.AIRPORT 1977 DATA
HOURLY RAINFALL, IN HUNDREDTHS OF AN INCH

YEAR	MO	DAY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	TOTAL
1977	8	10	0	0	0	0	0	0	0	0	0	0	0	7	2	0	0	0	0	0	0	2	0	0	0	0	11
1977	8	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	7
1977	8	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
1977	8	15	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	5
1977	8	16	0	0	0	0	0	0	0	0	0	0	0	0	1	0	4	0	0	0	0	0	0	0	0	0	5
1977	8	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
1977	8	20	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1977	8	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	1	0	0	0	0	0	12
1977	8	22	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
1977	8	25	0	0	0	0	0	0	0	37	0	0	0	0	7	4	4	0	0	0	0	0	0	0	0	0	52
1977	8	28	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
1977	8	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	31	12	11	0	12	0	0	74
1977	8	31	0	0	0	0	0	0	0	0	8	9	4	3	1	3	0	4	1	1	0	0	0	0	0	0	34
1977	9	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	4
1977	9	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	74	4	0	0	0	80
1977	9	4	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1977	9	5	0	0	0	0	2	8	18	7	8	7	1	4	0	1	0	0	0	0	0	0	0	0	0	0	56
1977	9	8	0	0	0	0	1	9	3	0	0	0	0	0	0	0	0	0	25	42	47	54	10	6	1	8	206
1977	9	9	12	17	5	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38
1977	9	13	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
1977	9	19	0	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
1977	9	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	3
1977	9	22	0	0	5	3	3	1	0	1	5	1	1	0	0	0	0	1	1	1	0	0	0	0	0	0	23
1977	9	23	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2
1977	9	24	0	0	7	24	23	7	10	7	13	4	1	1	0	0	0	0	0	0	1	0	3	4	6	3	114
1977	9	25	0	0	1	2	4	2	6	0	0	0	0	0	0	0	0	2	2	5	7	4	7	0	1	0	43
1977	9	26	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	4
1977	10	4	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
1977	10	5	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	4
1977	10	6	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1977	10	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	1	1	0	0	0	0	0	5
1977	10	10	0	0	0	0	0	0	0	4	6	1	0	0	1	0	0	1	1	0	0	0	1	0	0	0	15
1977	10	17	0	0	0	2	3	3	2	7	10	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	31
1977	10	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	18	27	11	2	59

END OF RAINFALL DATA.

84 RAINFALL DAYS PROCESSED ENCOMPASSING 203 DAYS (1 YEARS) OF RECORD.

WATERSHED DATA

NAMEWS	MXLG	EXPTE	REFF	TRTP	TSUBC	IPACUM
COMBINED	5	4.600	0.200	0.00	0.00	1

AREA	RFU	IQU	DVU	DVUMX	WU	POPULA
100.00	1.00	0	0.00	0.00	0.00	0.

DAILY EVAPORATION RATES FOR EACH MONTH,JAN-DEC IN INCHES/DAY
0.04 0.04 0.04 0.04 0.04 0.04 0.04 0.04 0.04 0.04 0.04 0.04

LOSSEQ	CPERV	CIMP	DEPRESSION STORAGE (INCHES)	EERC	EPRC
1	0.20	0.90	0.08	0.0	0.0

INPUT DATA DESCRIBING LAND USE AND POLLUTANTS

LNDUSE	PRCNT	FIMP	STLEN	NCLEAN	DD	POUNDS POLLUTANT PER 100LB DD					BMPN/100LB DD
						SUSP	SETL	BOD	N	PO4	COLI
SINGLE	55.0	35.0	300.0	5	2.25	80.000	40.000	15.000	0.048	0.005	59.0
MULTPL	5.0	60.0	430.0	5	6.90	80.000	40.000	15.000	0.061	0.005	122.6
COMRCL	15.0	80.0	100.0	5	9.90	80.000	40.000	15.000	0.041	0.005	77.2
INDSTR	10.0	50.0	60.0	10	13.80	80.000	40.000	15.000	0.043	0.003	45.4
OPENSP	15.0	10.0	20.0	5	4.50	80.000	40.000	15.000	0.048	0.005	3.0

COMPUTED RUNOFF COEFFICIENT FOR WATERSHED IS0.48525

FRACTION OF WATERSHED THAT IS IMPERVIOUS IS0.4075

DRY-WEATHER FLOW COMPUTATIONS

	OPTION NO.
QUANTITY COMPUTATIONS	1
QUALITY COMPUTATIONS	1
DAILY VARIATIONS	2
HOURLY VARIATIONS	2
HOURLY POLLUTANT LOAD	0

TOTAL LOADJ

FLOW (MGD)	SUSP	SETL	BOD (LBS/DAY)	N	PO4	COLI (BMPN/DAY)
0.25	624.0	310.0	500.0	83.0	21.0	4.7300E+03

DRY-WEATHER FLOW POLLUTION CONCENTRATION

SUSP	SETL	BOD (MG/L)	N	PO4	COLI (1000 MPN/L)
299.1	148.6	239.7	39.8	10.1	4999.

DRY-WEATHER FLOWS

HOUR	MON	TUE	WED	THUR	FRI	SAT	SUN
	CUBIC FEET PER SECOND						
1	0.2506	0.2413	0.2135	0.2390	0.2321	0.2228	0.2204
2	0.2088	0.2011	0.1779	0.1992	0.1934	0.1856	0.1837
3	0.2088	0.2011	0.1779	0.1992	0.1934	0.1856	0.1837
4	0.2088	0.2011	0.1779	0.1992	0.1934	0.1856	0.1837
5	0.2088	0.2011	0.1779	0.1992	0.1934	0.1856	0.1837
6	0.3342	0.3218	0.2846	0.3187	0.3094	0.2970	0.2939
7	0.3342	0.3218	0.2846	0.3187	0.3094	0.2970	0.2939
8	0.5848	0.5631	0.4981	0.5577	0.5415	0.5198	0.5144
9	0.6265	0.6033	0.5337	0.5975	0.5801	0.5569	0.5511
10	0.6265	0.6033	0.5337	0.5975	0.5801	0.5569	0.5511
11	0.5848	0.5631	0.4981	0.5577	0.5415	0.5198	0.5144
12	0.5848	0.5631	0.4981	0.5577	0.5415	0.5198	0.5144
13	0.5430	0.5229	0.4626	0.5179	0.5028	0.4827	0.4776
14	0.5430	0.5229	0.4626	0.5179	0.5028	0.4827	0.4776
15	0.5430	0.5229	0.4626	0.5179	0.5028	0.4827	0.4776
16	0.5012	0.4827	0.4270	0.4780	0.4641	0.4455	0.4409
17	0.5012	0.4827	0.4270	0.4780	0.4641	0.4455	0.4409
18	0.4595	0.4424	0.3914	0.4382	0.4254	0.4084	0.4042
19	0.4595	0.4424	0.3914	0.4382	0.4254	0.4084	0.4042
20	0.4177	0.4022	0.3558	0.3984	0.3868	0.3713	0.3674
21	0.4177	0.4022	0.3558	0.3984	0.3868	0.3713	0.3674
22	0.3342	0.3218	0.2846	0.3187	0.3094	0.2970	0.2939
23	0.2924	0.2816	0.2491	0.2788	0.2707	0.2599	0.2572
24	0.2506	0.2413	0.2135	0.2390	0.2321	0.2228	0.2204

1 TREATMENT RATE(S) WILL BE INVESTIGATED

TREATMENT RATE	NO. OF STORAGES	NO. OF POLLUTOGRAPHS	PLOT	PRINT	IPRTS	IERDMX	IAGE
0.0100	1	20	1	3	0	0	0

STORAGES TO BE USED WITH ABOVE TREATMENT RATE 0.030

STORM POLLUTOGRAPHS WILL BE PRINTED FOR THESE EVENTS]

1	2	3	4	5
6	7	8	9	10
15	16	18	29	35
41	42	43	47	50

PAGE 1

STREAM LOADINGS-WET WEATHER EVENTS-CITY OF WINNIPEG-1977-B.MACBRIDE-RUN003

QUANTITY ANALYSIS

TREATMENT RATE = 0.0100 IN/HR, 1.0 CFS, 0.652 MGD
STORAGE CAPACITY= 0.0300 INCHES, 0.3 AC-FT, 0.081 MG

WPG.INT.AIRPORT 1977 DATA
COMBINED

EVENT	---D A T E---				HRS NO	---RAINFALL---			RUNO	OUTF	HRSTO	--STORAGE--		----O V E R F L O W----					---TREATMENT----		--AGE OF STORAGE---				
	YEAR	MO	DY	HR	STORAG	DRTN	HRS	INCH	INCH	INCH	EMPTY	DURTN	MAX	NO	ST	DUR	WASTE	INITL	HRS	INCH	AGE1	AGE2	AGE3	AGE4	AGE5
****1	*********			*2	*3 *****4	***5	***6	***7	**7A	**7B	****8	****9	***10	*11	*12	*13	***14	***15	***16	***17	**18	**19	**20	**21	**22
1	77	4	17	11	153	1	1	0.05	0.02	0.03	4	5	0.01		1	NO OVERFLOW			5	0.04	0.0	0.0	0.0	0.0	0.0
2	77	5	3	8	376	5	2	0.06	0.02	0.03	1	6	0.00		1	NO OVERFLOW			6	0.05	0.0	0.0	0.0	0.0	0.0
3	77	5	3	17	3	1	1	0.04	0.02	0.02	2	3	0.01		1	NO OVERFLOW			3	0.02	0.0	0.0	0.0	0.0	0.0
4	77	5	4	18	22	6	6	1.98	0.95	0.97	4	10	0.03	1	1	6	0.88	0.62	11	0.10	0.0	0.0	0.0	0.0	0.0
5	77	5	5	9	5	17	13	0.56	0.27	0.33	4	21	0.03	2	3	6	0.14	0.09	24	0.22	0.0	0.0	0.0	0.0	0.0
6	77	5	14	15	201	5	4	0.39	0.15	0.17	5	10	0.03	3	2	3	0.09	0.09	10	0.09	0.0	0.0	0.0	0.0	0.0
7	77	5	18	2	73	5	5	1.06	0.49	0.50	6	11	0.03	4	2	3	0.41	0.41	12	0.11	0.0	0.0	0.0	0.0	0.0
8	77	5	18	24	11	2	2	0.06	0.03	0.03	2	4	0.01		1	NO OVERFLOW			6	0.04	0.0	0.0	0.0	0.0	0.0
9	77	5	26	14	178	3	3	1.43	0.67	0.68	6	9	0.03	5	1	3	0.62	0.62	10	0.09	0.0	0.0	0.0	0.0	0.0
10	77	5	28	14	39	1	1	0.24	0.09	0.10	6	7	0.03	6	1	1	0.05	0.05	7	0.06	0.0	0.0	0.0	0.0	0.0
11	77	5	28	23	2	2	2	0.58	0.27	0.28	4	6	0.03	7	1	1	0.23	0.23	6	0.05	0.0	0.0	0.0	0.0	0.0
12	77	5	29	20	15	10	6	0.22	0.09	0.10	1	11	0.03	8	3	2	0.01	0.01	11	0.10	0.0	0.0	0.0	0.0	0.0
13	77	6	5	9	146	1	1	0.09	0.00	0.01	1	2	0.00		1	NO OVERFLOW			2	0.01	0.0	0.0	0.0	0.0	0.0
14	77	6	5	14	3	2	2	0.04	0.02	0.03	2	4	0.00		1	NO OVERFLOW			4	0.03	0.0	0.0	0.0	0.0	0.0
15	77	6	10	11	113	4	4	0.47	0.22	0.24	6	10	0.03	9	2	3	0.16	0.16	10	0.09	0.0	0.0	0.0	0.0	0.0
16	77	6	12	22	49	15	12	0.84	0.40	0.44	4	19	0.03	10	3	9	0.28	0.13	19	0.18	0.0	0.0	0.0	0.0	0.0
17	77	6	15	19	50	1	1	0.02	0.01	0.01	1	2	0.00		1	NO OVERFLOW			2	0.01	0.0	0.0	0.0	0.0	0.0
18	77	6	17	10	37	10	9	1.08	0.51	0.56	5	15	0.03	11	1	9	0.43	0.16	15	0.14	0.0	0.0	0.0	0.0	0.0
19	77	6	28	15	254	2	2	0.08	0.02	0.03	3	5	0.01		1	NO OVERFLOW			5	0.04	0.0	0.0	0.0	0.0	0.0
20	77	6	29	15	19	3	2	0.07	0.02	0.03	1	4	0.01		1	NO OVERFLOW			4	0.03	0.0	0.0	0.0	0.0	0.0
21	77	6	30	12	17	9	4	0.31	0.13	0.15	0	9	0.03	12	2	2	0.08	0.08	9	0.08	0.0	0.0	0.0	0.0	0.0
22	77	7	2	18	45	2	2	0.31	0.15	0.16	5	7	0.03	13	1	2	0.10	0.10	9	0.08	0.0	0.0	0.0	0.0	0.0
23	77	7	5	18	65	2	2	0.22	0.07	0.08	5	7	0.03	14	1	2	0.02	0.02	7	0.06	0.0	0.0	0.0	0.0	0.0
24	77	7	7	20	43	2	2	0.14	0.03	0.04	3	5	0.01		2	NO OVERFLOW			5	0.04	0.0	0.0	0.0	0.0	0.0
25	77	7	10	15	62	1	1	0.04	0.01	0.01	1	2	0.00		1	NO OVERFLOW			2	0.01	0.0	0.0	0.0	0.0	0.0
26	77	7	11	2	9	2	2	0.07	0.03	0.03	2	4	0.01		1	NO OVERFLOW			5	0.04	0.0	0.0	0.0	0.0	0.0
27	77	7	11	8	2	8	4	0.08	0.03	0.06	1	9	0.01		1	NO OVERFLOW			9	0.08	0.0	0.0	0.0	0.0	0.0
28	77	7	13	9	40	1	1	0.08	0.01	0.02	2	3	0.00		1	NO OVERFLOW			3	0.02	0.0	0.0	0.0	0.0	0.0
29	77	7	13	13	1	10	5	1.52	0.73	0.75	4	14	0.03	15	1	2	0.64	0.64	14	0.13	0.0	0.0	0.0	0.0	0.0
30	77	7	30	4	385	3	3	0.27	0.11	0.12	6	9	0.03	16	1	2	0.06	0.06	9	0.08	0.0	0.0	0.0	0.0	0.0
31	77	7	30	17	4	10	7	0.29	0.13	0.15	2	12	0.03	17	2	2	0.04	0.04	12	0.11	0.0	0.0	0.0	0.0	0.0
32	77	8	2	21	64	2	2	0.11	0.05	0.06	4	6	0.03	18	1	2	0.01	0.01	6	0.05	0.0	0.0	0.0	0.0	0.0
33	77	8	4	14	35	5	5	0.34	0.14	0.16	5	10	0.03	19	1	3	0.08	0.08	10	0.09	0.0	0.0	0.0	0.0	0.0
34	77	8	5	10	10	2	2	0.04	0.01	0.02	1	3	0.00		2	NO OVERFLOW			3	0.02	0.0	0.0	0.0	0.0	0.0
35	77	8	6	21	32	3	3	0.54	0.24	0.24	4	7	0.03	20	1	3	0.18	0.18	7	0.06	0.0	0.0	0.0	0.0	0.0
36	77	8	9	16	60	2	2	0.24	0.09	0.10	5	7	0.03	21	1	1	0.04	0.04	8	0.07	0.0	0.0	0.0	0.0	0.0
37	77	8	10	12	13	2	2	0.09	0.03	0.04	4	6	0.01		2	NO OVERFLOW			6	0.05	0.0	0.0	0.0	0.0	0.0
38	77	8	11	21	27	1	1	0.07	0.01	0.02	2	3	0.00		1	NO OVERFLOW			4	0.03	0.0	0.0	0.0	0.0	0.0
39	77	8	21	16	232	1	1	0.11	0.01	0.02	2	3	0.00		1	NO OVERFLOW			4	0.03	0.0	0.0	0.0	0.0	0.0
40	77	8	22	8	13	1	1	0.01	0.00	0.01	1	2	0.00		1	NO OVERFLOW			3	0.02	0.0	0.0	0.0	0.0	0.0
41	77	8	25	8	70	8	4	0.52	0.21	0.23	6	14	0.03	22	1	4	0.14	0.12	14	0.13	0.0	0.0	0.0	0.0	0.0
42	77	8	29	18	92	5	4	0.66	0.32	0.34	4	9	0.03	23	1	4	0.26	0.21	9	0.08	0.0	0.0	0.0	0.0	0.0
43	77	8	31	9	30	10	9	0.34	0.14	0.18	5	15	0.03	24	2	5	0.05	0.03	15	0.14	0.0	0.0	0.0	0.0	0.0
44	77	9	3	20	68	2	2	0.78	0.35	0.36	4	6	0.03	25	1	2	0.30	0.30	6	0.05	0.0	0.0	0.0	0.0	0.0
45	77	9	5	6	28	9	8	0.54	0.25	0.29	5	14	0.03	26	2	6	0.18	0.13	15	0.14	0.0	0.0	0.0	0.0	0.0

PAGE 2

STREAM LOADINGS-WET WEATHER EVENTS-CITY OF WINNIPEG-1977-B.MACBRIDE-RUN003
QUANTITY ANALYSIS

TREATMENT RATE = 0.0100 IN/HR, 1.0 CFS, 0.652 MGD
STORAGE CAPACITY= 0.0300 INCHES, 0.3 AC-FT, 0.081 MG

WPG.INT.AIRPORT 1977 DATA
COMBINED

EVENT	---D A T E---				HRS NO	---RAINFALL---			RUNO	OUTF	HRSTO	--STORAGE--		----O V E R F L O W----					---TREATMENT---		--AGE OF STORAGE---				
	YEAR	MO	DY	HR	STORAG	DRTN	HRS	INCH	INCH	INCH	EMPTY	DURTN	MAX	NO	ST	DUR	WASTE	INITL	HRS	INCH	AGE1	AGE2	AGE3	AGE4	AGE5
****1	*********2			*3	*****4	***5	***6	***7	**7A	**7B	****8	****9	***10	*11	*12	*13	***14	***15	***16	***17	**18	**19	**20	**21	**22
46	77	9	8	6	58	2	2	0.12	0.02	0.03	3	5	0.01		2	NO OVERFLOW			5	0.04	0.0	0.0	0.0	0.0	0.0
47	77	9	8	17	6	13	13	2.31	1.11	1.15	6	19	0.03	27	1	12	0.99	0.49	19	0.18	0.0	0.0	0.0	0.0	0.0
48	77	9	22	5	305	2	2	0.04	0.02	0.02	1	3	0.00		1	NO OVERFLOW			4	0.03	0.0	0.0	0.0	0.0	0.0
49	77	9	22	9	1	8	4	0.08	0.04	0.06	0	8	0.02		3	NO OVERFLOW			9	0.08	0.0	0.0	0.0	0.0	0.0
50	77	9	24	3	34	10	10	0.97	0.46	0.49	6	16	0.03	28	2	9	0.36	0.21	17	0.16	0.0	0.0	0.0	0.0	0.0
51	77	9	24	21	2	11	9	0.31	0.15	0.17	7	18	0.03	29	3	3	0.03	0.03	18	0.17	0.0	0.0	0.0	0.0	0.0
52	77	9	25	17	2	7	6	0.26	0.13	0.15	3	10	0.03	30	3	3	0.06	0.06	11	0.10	0.0	0.0	0.0	0.0	0.0
53	77	9	26	9	6	1	1	0.03	0.01	0.01	1	2	0.00		1	NO OVERFLOW			2	0.01	0.0	0.0	0.0	0.0	0.0
54	77	10	10	9	334	2	2	0.07	0.01	0.03	2	4	0.00		2	NO OVERFLOW			5	0.04	0.0	0.0	0.0	0.0	0.0
55	77	10	17	7	162	5,	5	0.23	0.11	0.14	7	12	0.03	31	2	4	0.05	0.05	15	0.14	0.0	0.0	0.0	0.0	0.0
56	77	10	30	21	314	4	4	0.58	0.25	0.26	4	8	0.03	32	1	4	0.18	0.18	8	0.07	0.0	0.0	0.0	0.0	0.0
AVE OF 56 EVENTS					78.9**	4.7	3.9	0.39	0.18	0.19	3.4	8.1	0.02		1.3*				8.6	0.08	0.0	0.0	0.0	0.0	0.0
AVE OF 32 OVRFLW EVENTS						6.6	5.4	0.64	0.29	0.32	4.6	11.2	0.01*		1.6	3.8	0.23	0.18	11.7	0.11	0.0	0.0	0.0	0.0	0.0

* NON-OVERFLOW EVENTS ONLY.
**EXCLUDING 0 DRY PERIODS

AVERAGE ANNUAL STATISTICS FOR 1 YEARS OF RECORD FOR THE PERIOD BEGINNING 770417 AND ENDING 771030

NUMBER OF EVENTS = 56.0

NUMBER OF OVERFLOWS = 32.0

	INCHES	
PRECIPITATION ON WATERSHED	24.44	
SURFACE RUNOFF FROM WATERSHED	9.94	FRACTION OF RAINFALL =0.41
OUTFLOW (SURFACE RUNOFF + DRY WEATHER FLOW)	11.84	
DRY WEATHER FLOW DURING TIMES OF RUNOFF OR STORAGE	1.90	FRACTION OF OUTFLOW =0.16
OVERFLOW TO RECEIVING WATER	7.30	FRACTION OF RAINFALL =0.30, OF RUNOFF =0.73, OF OUTFLOW =0.62
INITIAL OVERFLOW TO RECEIVING WATER	5.81	FRACTION OF RAINFALL =0.24, OF RUNOFF =0.58, OF OUTFLOW =0.49

PAGE 3

STREAM LOADINGS-WET WEATHER EVENTS-CITY OF WINNIPEG-1977-H.MACBRIDE-RUN003
QUANTITY ANALYSIS

TREATMENT RATE = 0.0100 IN/HR, 1.0 CFS, 0.652 MGD
STORAGE CAPACITY= 0.0300 INCHES, 0.3 AC-FT, 0.081 MG

WPG.INT.AIRPORT 1977 DATA
COMBINED

AVERAGE STORAGE REQUIRED AT EACH HOUR OF ALL EVENTS (INCHES).
VALUES BEGIN FOR HOUR 1 AND CONTINUE TO THE MAXIMUM EVENT DURATION = 21 HOURS.

0.016	0.019	0.017	0.015	0.013	0.010	0.008	0.007	0.006	0.005
0.004	0.003	0.002	0.001	0.001	0.001	0.001	0.000	0.000	0.000
0.000									

AVERAGE ANNUAL NUMBER OF HOURS EACH HUNDRETH OF AN INCH OF STORAGE WAS UTILIZED.

166.000 96.000 193.000

PERCENTAGE OF TIME LESS THAN OR EQUAL TO EACH STORAGE AMOUNT, IN PERCENT OF CAPACITY.

0. 0. 33. 36. 67. 58. 100.100.

-117-

PAGE 4

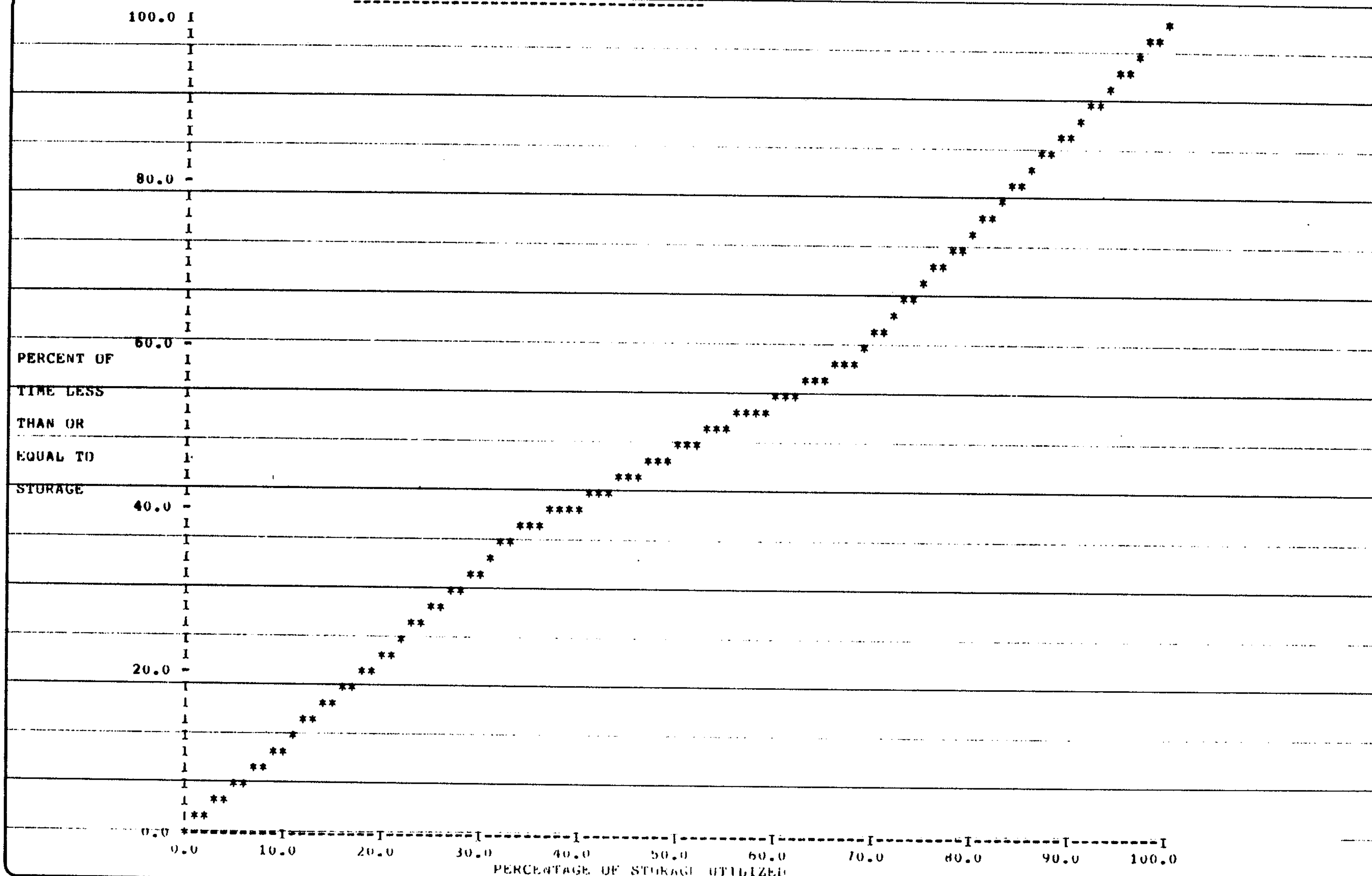
STREAM LOADINGS-WET WEATHER EVENTS-CITY OF WINNIPEG-1977-B.MACBRIDE-RUN003

QUANTITY ANALYSIS

TREATMENT RATE = 0.0100 IN/HR, 1.0 CFS, 0.652 MGD
STORAGE CAPACITY= 0.0300 INCHES, 0.3 AC-FT, 0.081 MG

WPG.INT.AIRPORT 1977 DATA
COMBINED

NORMALIZED STORAGE UTILIZATION CURVE



DEFINITIONS OF QUANTITY COLUMN HEADINGS

```
 1   EVENT    = SEQUENCING NUMBER.
 2   DATE     = DATE THIS EVENT BEGAN.
 3   HR       = NUMBER OF HOURS PAST MIDNIGHT THIS EVENT BEGAN.
 4   HRS NO
     STORAG   = NUMBER OF HOURS SINCE END OF LAST EVENT, EXCLUDING SUMMER (MORE THAN,  720 HOURS).

 5   DRTN     =DURATION OF STORM FROM FIRST HOUR OF RAIN, TO LAST HOUR OF RAIN.
 6   HRS      = NUMBER OF HOURS IN WHICH RAINFALL OCCURRED DURING EVENT.
 7   INCH     = AMOUNT OF RAINFALL DURING THE EVENT IN INCHES.
7A   RUNO
     INCH     = SURFACE RUNOFF DURING EVENT IN INCHES.
7B   OUTF
     INCH   = TOTAL OUTFLOW (SURFACE RUNOFF + DRY WEATHER FLOW).

 8   HRSTO
     EMPTY    = NUMBER OF HOURS FROM LAST RAINFALL TO END OF EVENT.
 9   DURTN    = TOTAL NUMBER OF HOURS STORAGE WAS UTILIZED.  IE, LENGTH OF THE EVENT.

10   MAX      = MAXIMUM AMOUNT OF STORAGE UTILIZED, IN INCHES.

11   NO       = OVERFLOW EVENT SEQUENCING NUMBER.
12   ST       = NUMBER OF HOURS ELAPSED BEFORE OVERFLOW STARTED.  OR, IF NO OVERFLOW, HOUR OF MAXIMUM STORAGE.
13   DUR      = NUMBER OF HOURS IN WHICH OVERFLOW OCCURED.

14   WASTE    = QUANTITY OF WATER RELEASED UNTREATED, IN INCHES.
15   INITL    = QUANTITY OF WATER RELEASED UNTREATED DURING THE FIRST  3 HOURS OF OVERFLOW.
16   HRS      = NUMBER OF HOURS WATER WAS TREATED DURING THE PRESENT EVENT AND SINCE THE PREVIOUS EVENT.
17   INCH     = QUANTITY OF WATER TREATED DURING THE EVENT AND SINCE THE PREVIOUS EVENT.
18   AGE1     = AVERAGE AGE (HOURS) OF TREATED RUNOFF.
19   AGE2     = MAXIMUM AGE (HOURS) OF STORAGE ON FIRST IN, FIRST OUT BASIS.
20   AGE3     = MAXIMUM AGE (HOURS) OF STORAGE ON FIRST IN, LAST OUT BASIS.
21   AGE4     = QUANTITY WEIGHTED AVERAGE AGE (HRS) OF STORAGE ON FIRST IN, FIRST OUT BASIS.
22   AGE5     = QUANTITY WEIGHTED AVERAGE AGE (HRS) OF STORAGE ON FIRST IN, LAST OUT BASIS.
```

PAGE 1

STREAM LOADINGS-WET WEATHER EVENTS-CITY OF WINNIPEG-1977-B.MACBRIDE-RUN003

QUALITY ANALYSIS

TREATMENT RATE = 0.0100 IN/HR, 1.0 CFS, 0.652 MGD
STORAGE CAPACITY= 0.0300 INCHES, 0.3 AC-FT, 0.081 MG

WPG.INT.AIRPORT 1977 DATA
COMBINED

EVNT	DATE				RAIN *---------	STORM RUNOFF + DWF						---------*	*--S T O R A G E		O V E R F L O W						*	*---FIRST 3 HOURS OVERFLOW---*						
	EVENT			BEG	FALL	QNTY		TOTAL POUNDS++					SEQ	INCH		TOTAL POUNDS++					QOUT		TOTAL POUNDS++				
	YR	MO	DY	HR	INCH	INCH	SUSP	SETL	BOD	N	PO4	COLI	NO	QNTY	SUSP	SETL	BOD	N	PO4	COLI	INCH	SUSP	SETL	BOD	N	PO4	COLI
**1			*******2	*3	****4	****5	******6	****7	****8	****9	**10	*****11	12	**13	**14	**15	**16	*17	*18	***19	**20	**21	**22	*23	*24	*25	**26
1	77	4	17	11	0.05	0.03	90	23	144	7	1	756		NO OVERFLOW													
2	77	5	3	8	0.06	0.03	157	46	293	13	2	1535		NO OVERFLOW													
3	77	5	3	17	0.04	0.02	120	29	198	9	1	995		NO OVERFLOW													
4	77	5	4	18	1.98	0.97	8981	3275	2307	498	53	7066	1	0.88	8090	2963	2078	448	48	6349	0.62	7967	2743	2012	435	45	5829
5	77	5	5	9	0.56	0.33	395	265	311	49	12	2718	2	0.14	123	95	91	14	3	770	0.09	72	60	53	8	2	429
6	77	5	14	15	0.39	0.17	855	203	801	55	8	3858	3	0.09	505	113	379	31	4	1756	0.09	505	113	379	31	4	1756
7	77	5	18	2	1.06	0.50	5791	2267	1310	324	35	3853	4	0.41	5246	2104	989	289	30	2281	0.41	5246	2104	989	289	30	2281
8	77	5	18	24	0.06	0.03	70	42	62	8	2	484		NO OVERFLOW													
9	77	5	26	14	1.43	0.68	4012	1871	1260	228	24	4270	5	0.62	3536	1687	1086	201	22	3653	0.62	3536	1687	1086	201	22	3653
10	77	5	28	14	0.24	0.10	255	106	158	16	2	741	6	0.05	149	62	92	9	1	433	0.05	149	62	92	9	1	433
11	77	5	28	23	0.56	0.28	1096	740	281	67	8	977	7	0.23	912	619	222	54	6	664	0.23	912	619	222	54	6	664
12	77	5	29	20	0.22	0.10	225	121	190	25	6	1458	8	0.01	20	11	17	2	0	126	0.01	20	11	17	2	0	126
13	77	6	5	9	0.09	0.01	37	17	48	4	1	323		NO OVERFLOW													
14	77	6	5	14	0.04	0.03	92	38	129	9	2	791		NO OVERFLOW													
15	77	6	10	11	0.47	0.24	2261	499	1234	129	15	5242	9	0.16	1723	375	805	95	10	3202	0.16	1723	375	805	95	10	3202
16	77	6	12	22	0.84	0.44	2553	716	893	160	22	4330	10	0.28	1719	465	520	104	14	2302	0.13	919	223	319	53	6	1317
17	77	6	15	19	0.02	0.01	48	22	40	5	1	276		NO OVERFLOW													
18	77	6	17	10	1.08	0.56	3700	1223	987	217	26	3853	11	0.43	3011	1002	707	174	21	2523	0.16	1461	414	408	82	9	1431
19	77	6	28	15	0.08	0.03	154	55	213	13	2	1168		NO OVERFLOW													
20	77	6	29	15	0.07	0.03	152	54	193	13	2	1071		NO OVERFLOW													
21	77	6	30	12	0.31	0.15	1226	290	744	74	10	3407	12	0.08	726	162	397	42	5	1696	0.08	726	162	397	42	5	1696
22	77	7	2	18	0.31	0.16	1541	359	523	86	10	1965	13	0.10	1071	252	334	59	7	1210	0.10	1071	252	334	59	7	1210
23	77	7	5	18	0.22	0.08	603	156	300	36	5	1362	14	0.02	202	54	102	12	2	478	0.02	202	54	102	12	2	478
24	77	7	7	20	0.14	0.04	217	75	166	16	3	909		NO OVERFLOW													
25	77	7	10	15	0.04	0.01	79	30	76	6	1	437		NO OVERFLOW													
26	77	7	11	2	0.07	0.03	239	76	196	17	3	1042		NO OVERFLOW													
27	77	7	11	8	0.08	0.06	348	119	249	27	5	1466		NO OVERFLOW													
28	77	7	13	9	0.08	0.02	103	36	85	8	1	469		NO OVERFLOW													
29	77	7	13	13	1.52	0.75	11133	6496	1961	638	67	4236	15	0.64	9868	5741	1663	556	57	2909	0.64	9868	5741	1663	556	57	2909
30	77	7	30	4	0.27	0.12	943	197	944	58	7	4370	16	0.06	471	96	466	28	3	2121	0.06	471	96	466	28	3	2121
31	77	7	30	17	0.29	0.15	822	239	582	59	10	3142	17	0.04	256	65	162	16	2	787	0.04	256	65	162	16	2	787
32	77	8	2	21	0.11	0.06	478	128	304	34	6	1662	18	0.01	73	18	46	5	1	225	0.01	73	18	46	5	1	225
33	77	8	4	14	0.34	0.16	1356	317	577	82	11	2647	19	0.08	720	161	297	42	5	1268	0.08	720	161	297	42	5	1268
34	77	8	5	10	0.04	0.02	104	43	70	10	2	504		NO OVERFLOW													
35	77	8	6	21	0.54	0.24	2617	636	634	144	16	2066	20	0.18	1921	469	466	106	12	1533	0.18	1921	469	466	106	12	1533
36	77	8	9	16	0.24	0.10	876	226	304	51	6	1246	21	0.04	448	111	148	25	3	546	0.04	448	111	148	25	3	546
37	77	8	10	12	0.09	0.04	183	69	110	14	2	657		NO OVERFLOW													
38	77	8	11	21	0.07	0.02	96	36	67	7	1	382		NO OVERFLOW													
39	77	8	21	16	0.11	0.02	134	41	174	10	1	878		NO OVERFLOW													
40	77	8	22	8	0.01	0.01	56	22	69	5	1	411		NO OVERFLOW													
41	77	8	25	8	0.52	0.23	4064	937	1667	224	25	6413	22	0.14	2771	629	1117	152	16	4216	0.12	2677	599	1070	145	15	3975
42	77	8	29	18	0.66	0.34	5064	1393	1299	281	31	4349	23	0.26	3818	1043	958	209	23	3023	0.21	3434	925	881	187	20	2767
43	77	8	31	9	0.34	0.18	1018	406	418	74	12	2481	24	0.05	320	123	120	22	3	651	0.03	239	88	88	16	2	455
44	77	9	3	20	0.78	0.36	7202	3892	1222	404	41	2268	25	0.30	6326	3415	1067	354	36	1930	0.30	6326	3415	1067	354	36	1930
45	77	9	5	6	0.54	0.29	770	529	376	61	10	2274	26	0.18	484	336	206	35	6	1141	0.13	390	267	161	27	4	822

STREAM LOADINGS-WET WEATHER EVENTS-CITY OF WINNIPEG-1977-B.MACBRIDE-RUN003
QUALITY ANALYSIS

TREATMENT RATE = 0.0100 IN/HR, 1.0 CFS, 0.652 MGD
STORAGE CAPACITY= 0.0300 INCHES, 0.3 AC-FT, 0.081 MG

WPG.INT.AIRPORT 1977 DATA
COMBINED

EVNT	DATE YR	EVENT MO	DY	BEG HR	RAIN FALL INCH	QNTY INCH	STORM RUNOFF + DWF SUSP	SETL	TOTAL POUNDS++ BOD	N	PO4	COLI	STORAGE OVERFLOW SEQ NO	INCH QNTY	SUSP	SETL	TOTAL POUNDS++ BOD	N	PO4	COLI	FIRST 3 HOURS OVERFLOW QOUT INCH	SUSP	TOTAL POUNDS++ SETL	BOD	N	PO4	COLI
**1	*******2			*3	***4	***5	*****6	****7	****8	***9	**10	*****11	12	**13	**14	**15	**16	*17	*18	***19	**20	**21	**22	*23	*24	*25	**26
46	77	9	8	6	0.12	0.03	104	61	107	10	2	683		NO OVERFLOW													
47	77	9	8	17	2.31	1.15	3628	3781	975	247	32	4026	27	0.99	3148	3416	767	209	25	2776	0.49	2478	2148	569	151	16	1625
48	77	9	22	5	0.04	0.02	128	47	222	11	2	1225		NO OVERFLOW													
49	77	9	22	9	0.08	0.06	258	92	344	23	4	1963		NO OVERFLOW													
50	77	9	24	3	0.97	0.49	3550	959	1331	210	26	5713	28	0.36	2726	719	905	156	18	3571	0.21	2085	512	739	116	13	2772
51	77	9	24	21	0.31	0.17	625	271	270	52	10	1966	29	0.03	123	50	43	9	2	287	0.03	123	50	43	9	2	287
52	77	9	25	17	0.26	0.15	509	211	200	40	7	1361	30	0.06	207	82	69	15	2	426	0.06	207	82	69	15	2	426
53	77	9	26	9	0.03	0.01	40	20	26	4	1	216		NO OVERFLOW													
54	77	10	10	9	0.07	0.03	127	47	198	11	2	1107		NO OVERFLOW													
55	77	10	17	7	0.23	0.14	1176	262	1110	74	10	5267	31	0.05	551	111	428	33	4	1932	0.05	548	110	425	32	4	1913
56	77	10	30	21	0.58	0.26	4449	885	2004	252	29	8274	32	0.18	3395	652	1296	184	20	4763	0.18	3383	648	1289	183	19	4719
AVE OF 56 EVENT					0.39	0.19	1552	625	553	93	11	2297															
AVE OF 32 OVRFL					0.64	0.32	2618	1058	859	155	19	3402		0.23	2021	850	564	115	13	1923	0.18	1880	762	527	106	11	1737

++ COLIFORM TOTALS IN BILLION MPN,
AND CONCENTRATION IN 10**3 MPN PER LITER

AVERAGE ANNUAL STATISTICS FOR 1 YEARS OF RECORD FOR THE PERIOD BEGINNING 770417 AND ENDING 771030

	SUSP	SETL	BOD	N	PO4	COLI++
TOTAL POUNDS WASHOFF FROM WATERSHED AND DRY-WEATHER FLOW	93727	38395	36678	5879	910	180069
TOTAL POUNDS OVERFLOW TO RECEIVING WATER	64661	27202	18040	3693	410	61545
CONCENTRATION OF POLLUTANTS IN OVERFLOW TO RECEIVING WATER (MG/L)	390.85	164.42	109.04	22.32	2.48	820.559
FRACTION OF TOTAL LOAD OVERFLOWING TO RECEIVING WATER	0.690	0.708	0.492	0.628	0.451	0.3418
FRACTION OF TOTAL LOAD INITIALLY OVERFLOWING TO RECEIVING WATER	0.642	0.635	0.460	0.576	0.402	0.3087

++ COLIFORM TOTALS IN BILLION MPN,
AND CONCENTRATION IN 10**3 MPN PER LITER

PAGE 1

STREAM LOADINGS-WET WEATHER EVENTS-CITY OF WINNIPEG-1977-B.MACBRIDE-RUN003
POLLUTOGRAPH ANALYSIS

TREATMENT RATE = 0.0100 IN/HR, 1.0 CFS, 0.652 MGD
STORAGE CAPACITY= 0.0300 INCHES, 0.3 AC-FT, 0.081 MG

WPG.INT.AIRPORT 1977 DATA
COMBINED

YR	MO	DY	HR	T(0)	RAIN (INCHES)	RUNOF (INCHES)	DWF (CFS)	QTOT (CFS)	**OUTFLOW POLLUTANT LOAD, IN LBS/HR**** SUSP	SETL	BOD	N	PO4	COLI ++	**** AVE CONCENTRATION, IN MG/L ********** SUSP	SETL	BOD	N	PO4	COLI ++
EVENT] 1																				
77	4	17	11	1	0.05	0.02	0.5	3.0	90.2	22.8	144.1	7.1	1.2	756.1	135.6	34.3	216.6	10.7	1.9	2506.7
EVENT] 2																				
77	5	3	8	1	0.04	0.01	0.6	1.9	96.0	25.7	185.8	7.6	1.3	946.6	228.7	61.3	442.7	18.1	3.1	4974.4
77	5	3	12	5	0.02	0.01	0.6	1.3	60.9	20.1	106.7	5.5	1.1	587.9	208.9	69.1	366.1	19.0	3.7	4449.0
EVENT] 3																				
77	5	3	17	1	0.04	0.02	0.5	2.1	120.1	29.3	198.5	8.9	1.4	995.2	252.8	61.7	417.9	18.7	3.0	4621.8
EVENT] 4																				
77	5	4	18	1	0.84	0.40	0.4	40.5	8643.5	2672.0	2130.7	464.8	47.0	5885.2	949.4	293.5	234.0	51.1	5.2	1425.8
77	5	4	19	2	0.40	0.19	0.4	20.0	149.9	296.6	72.5	12.6	1.8	356.8	33.4	66.1	16.2	2.8	0.4	175.4
77	5	4	20	3	0.17	0.08	0.4	8.7	46.8	62.8	27.9	5.0	1.0	216.1	24.0	32.2	14.3	2.6	0.5	244.6
77	5	4	21	4	0.20	0.10	0.4	10.1	49.4	76.9	26.7	5.3	1.1	207.6	21.7	33.7	11.7	2.3	0.5	200.9
77	5	4	22	5	0.30	0.15	0.3	15.0	62.2	141.9	28.3	6.6	1.2	202.9	18.5	42.2	8.4	2.0	0.4	133.1
77	5	4	23	6	0.07	0.03	0.2	3.7	29.0	24.8	21.5	3.7	0.9	197.7	35.1	30.0	26.0	4.5	1.1	528.1
EVENT] 5																				
77	5	5	9	1	0.03	0.01	0.6	2.0	28.2	17.5	24.1	3.6	0.9	211.5	63.3	39.2	54.1	8.1	2.0	1046.4
77	5	5	10	2	0.03	0.01	0.6	2.1	28.3	17.8	24.0	3.6	0.9	210.6	61.1	38.3	51.6	7.8	1.9	1000.8
77	5	5	11	3	0.05	0.02	0.6	3.0	30.6	21.2	25.4	3.8	0.9	216.2	45.3	31.5	37.7	5.6	1.3	706.4
77	5	5	12	4	0.12	0.06	0.6	6.4	42.3	38.1	29.7	4.5	1.0	229.6	29.3	26.4	20.6	3.1	0.7	350.6
77	5	5	13	5	0.08	0.04	0.5	4.4	34.3	27.1	24.9	4.0	0.9	211.3	34.4	27.2	25.0	4.0	0.9	468.0
77	5	5	14	6	0.07	0.03	0.5	3.9	32.5	24.8	23.6	3.9	0.9	206.2	36.7	28.0	26.7	4.4	1.0	513.4
77	5	5	15	7	0.01	0.00	0.5	1.0	26.5	14.5	21.1	3.5	0.9	198.2	117.2	63.9	93.4	15.5	3.9	1931.5
77	5	5	16	8	0.03	0.01	0.5	1.9	28.0	17.5	21.8	3.6	0.9	200.1	64.0	40.1	49.7	8.2	2.0	1009.5
77	5	5	21	13	0.01	0.00	0.4	0.6	26.2	13.4	21.2	3.5	0.9	198.7	208.0	106.6	168.0	27.6	7.0	3473.2
77	5	5	22	14	0.03	0.01	0.3	1.8	28.9	17.7	24.0	3.7	0.9	210.4	72.1	44.1	59.7	9.1	2.2	1155.8
77	5	5	23	15	0.05	0.02	0.3	2.7	31.8	21.1	25.5	3.8	0.9	215.9	51.9	34.5	41.6	6.3	1.5	777.4
77	5	5	24	16	0.04	0.02	0.2	2.2	30.2	19.3	24.0	3.7	0.9	209.5	61.1	39.1	48.5	7.6	1.8	936.5
77	5	6	1	17	0.01	0.00	0.2	0.7	26.8	14.5	21.5	3.5	0.9	199.9	165.1	89.3	132.8	21.7	5.4	2720.0
EVENT] 6																				
77	5	14	15	1	0.12	0.02	0.5	2.4	95.5	29.0	163.0	7.5	1.3	844.7	174.2	52.9	297.2	13.7	2.3	3398.2
77	5	14	16	2	0.06	0.03	0.4	3.4	116.3	35.1	196.1	10.3	1.6	988.0	192.6	50.1	260.7	13.5	2.0	2868.0
77	5	14	17	3	0.06	0.03	0.4	3.4	143.3	37.9	161.5	10.0	1.5	814.0	188.6	49.8	212.6	13.1	2.0	2363.0

77	5	14	19	5	0.15	0.07	0.4	7.7	469.7	98.3	278.2	27.2	3.2	1211.6	272.7	57.0	161.5	15.8	1.9	1551.3

EVENT 1 7

77	5	18	2	1	0.11	0.02	0.2	2.6	143.2	38.3	146.2	9.9	1.5	742.0	242.8	64.9	247.9	16.9	2.6	2775.3

STREAM LOADINGS-WET WEATHER EVENTS-CITY OF WINNIPEG-1977-B.MACBRIDE-RUN003
POLLUTOGRAPH ANALYSIS

TREATMENT RATE = 0.0100 IN/HR, 1.0 CFS, 0.652 MGD
STORAGE CAPACITY= 0.0300 INCHES, 0.3 AC-FT, 0.081 MG

WPG.INT.AIRPORT 1977 DATA
COMBINED

YR	MO	DY	HR	T(0)	RAIN (INCHES)	RUNOF (INCHES)	DWF (CFS)	QTOT (CFS)	**OUTFLOW POLLUTANT LOAD, IN LBS/HR**** SUSP	SETL	BOD	N	PO4	COLI ++	**** AVE CONCENTRATION, IN MG/L ********** SUSP	SETL	BOD	N	PO4	COLI ++
EVENT] 7																				
77	5	18	3	2	0.14	0.07	0.2	7.0	551.1	110.1	291.6	31.4	3.7	1239.4	348.9	69.7	184.7	19.9	2.3	1730.9
77	5	18	4	3	0.05	0.02	0.2	2.6	130.8	37.6	83.3	9.1	1.4	445.2	221.8	63.7	141.3	15.5	2.4	1665.3
77	5	18	5	4	0.75	0.36	0.2	36.9	4939.1	2065.3	767.1	270.3	27.6	1227.8	596.0	249.2	92.6	32.6	3.3	326.8
77	5	18	6	5	0.01	0.00	0.3	0.8	27.1	15.3	21.4	3.5	0.9	199.0	155.8	87.9	123.0	20.3	5.1	2524.4
EVENT] 8																				
77	5	18	24	1	0.05	0.02	0.2	2.7	41.8	26.4	38.6	4.4	1.0	273.7	70.0	44.2	64.5	7.4	1.6	1010.0
77	5	19	1	2	0.01	0.00	0.2	0.7	28.1	15.5	23.9	3.6	0.9	210.6	171.8	94.7	146.0	22.0	5.4	2838.2
EVENT] 9																				
77	5	26	14	1	0.52	0.23	0.5	23.5	2337.3	791.9	927.7	128.9	13.4	3360.9	442.3	149.9	175.6	24.4	2.5	1402.9
77	5	26	15	2	0.43	0.21	0.5	21.6	1022.4	534.3	222.4	58.8	6.4	635.5	211.1	110.3	45.9	12.1	1.3	289.4
77	5	26	16	3	0.48	0.23	0.5	24.0	652.3	544.8	110.1	40.1	4.5	273.8	121.1	101.2	20.4	7.5	0.8	112.2
EVENT] 10																				
77	5	28	14	1	0.24	0.09	0.5	9.7	254.9	106.1	158.2	16.2	2.1	740.7	117.0	48.7	72.6	7.4	1.0	749.7
EVENT] 15																				
77	6	10	11	1	0.04	0.01	0.5	1.4	59.1	21.9	97.6	5.4	1.1	549.5	193.8	71.9	320.1	17.8	3.5	3974.6
77	6	10	12	2	0.15	0.07	0.5	7.9	709.3	133.8	566.1	40.4	4.6	2478.9	400.5	75.6	319.6	22.8	2.6	3087.5
77	6	10	13	3	0.26	0.13	0.5	13.2	1437.9	320.8	531.5	78.3	8.4	1944.5	483.8	107.9	178.9	26.4	2.8	1443.3
77	6	10	14	4	0.02	0.01	0.5	1.5	54.7	22.7	38.8	5.0	1.0	268.9	164.2	68.3	116.6	15.1	3.1	1781.6
EVENT] 16																				
77	6	12	22	1	0.03	0.01	0.3	1.2	58.7	23.3	55.1	5.3	1.1	345.5	219.2	87.0	205.9	19.8	4.0	2847.8
77	6	12	23	2	0.03	0.01	0.3	1.7	85.8	30.0	72.8	6.8	1.2	417.0	221.4	77.3	187.7	17.5	3.1	2372.5
77	6	12	24	3	0.16	0.08	0.2	8.0	683.6	152.8	256.5	38.3	4.4	1002.5	377.9	84.5	141.8	21.2	2.4	1222.5
77	6	13	1	4	0.12	0.06	0.3	6.1	404.4	99.6	130.0	23.5	2.9	532.8	293.9	72.4	94.5	17.1	2.1	854.1
77	6	13	2	5	0.08	0.04	0.2	4.1	217.5	61.7	71.5	13.6	1.9	344.2	234.7	66.6	77.1	14.7	2.0	819.3
77	6	13	3	6	0.04	0.02	0.2	2.2	95.1	34.6	40.0	7.2	1.2	254.3	195.3	71.1	82.2	14.7	2.6	1152.2
77	6	13	4	7	0.09	0.04	0.2	4.6	242.3	68.9	64.1	14.9	2.0	295.8	233.8	66.5	61.8	14.4	1.9	629.5
77	6	13	5	8	0.09	0.04	0.2	4.6	232.5	68.2	56.7	14.4	2.0	265.1	224.3	65.8	54.7	13.9	1.9	564.2
77	6	13	6	9	0.13	0.06	0.3	6.7	369.8	105.2	70.1	21.6	2.7	259.8	245.8	69.9	46.6	14.4	1.8	380.9
77	6	13	7	10	0.04	0.02	0.3	2.3	83.2	33.6	29.7	6.5	1.2	210.5	161.6	65.2	57.8	12.7	2.3	901.8
77	6	13	8	11	0.02	0.01	0.6	1.6	19.3	23.0	24.6	4.7	1.0	203.0	140.3	65.4	70.0	13.5	2.9	1274.6
77	6	13	12	15	0.01	0.00	0.6	0.8	31.0	15.5	22.0	3.7	0.9	199.9	166.3	83.0	117.9	20.0	4.8	2365.8

EVENT) 18

77	6	17	10	1	0.11	0.04	0.6	4.9	299.8	78.3	181.9	18.2	2.4	835.9	272.1	71.1	165.1	16.5	2.1	1673.8
77	6	17	11	2	0.08	0.04	0.5	4.5	252.0	69.8	129.1	15.6	2.1	605.0	251.6	69.7	128.9	15.6	2.1	1332.8

PAGE 3

STREAM LOADINGS-WET WEATHER EVENTS-CITY OF WINNIPEG-1977-B.MACBRIDE-RUN003

POLLUTOGRAPH ANALYSIS

TREATMENT RATE = 0.0100 IN/HR, 1.0 CFS, 0.652 MGD

STORAGE CAPACITY= 0.0300 INCHES, 0.3 AC-FT, 0.081 MG

WPG.INT.AIRPORT 1977 DATA

COMBINED

YR	MO	DY	HR	T(0)	RAIN (INCHES)	RUNOF (INCHES)	DWF (CFS)	QTOT (CFS)	**OUTFLOW POLLUTANT LOAD, IN LBS/HR**** SUSP	SETL	BOD	N	PO4	COLI ++	**** AVE CONCENTRATION, IN MG/L ********** SUSP	SETL	BOD	N	PO4	COLI ++
EVENT] 18																				
77	6	17	12	3	0.26	0.13	0.5	13.3	1312.3	375.0	298.6	71.9	7.7	882.0	440.3	125.8	100.2	24.1	2.6	652.7
77	6	17	13	4	0.12	0.06	0.5	6.4	336.0	104.5	82.4	20.0	2.5	335.7	234.6	73.0	57.5	13.9	1.8	517.0
77	6	17	14	5	0.06	0.03	0.5	3.4	129.3	49.3	41.7	9.0	1.4	244.5	167.3	63.8	54.0	11.7	1.9	697.9
77	6	17	16	7	0.08	0.04	0.5	4.3	175.2	62.9	47.7	11.5	1.7	250.0	181.5	65.1	49.4	11.9	1.7	571.1
77	6	17	17	8	0.29	0.14	0.5	14.7	1055.1	414.0	151.8	59.0	6.4	293.7	320.4	125.7	46.1	17.9	2.0	196.7
77	6	17	18	9	0.06	0.03	0.4	3.4	97.9	45.8	30.6	7.4	1.3	206.2	129.6	60.6	40.5	9.8	1.7	602.3
77	6	17	19	10	0.02	0.01	0.4	1.4	42.5	23.1	23.2	4.4	1.0	199.7	134.7	73.2	73.6	13.9	3.1	1395.9
EVENT] 29																				
77	7	13	13	1	0.80	0.39	0.5	39.4	10531.3	4757.9	1715.2	578.0	58.3	2846.9	1190.6	537.9	193.9	65.3	6.6	709.9
77	7	13	19	7	0.01	0.00	0.4	0.5	26.2	13.7	21.2	3.5	0.9	198.6	246.7	128.6	199.3	32.7	8.3	4121.5
77	7	13	20	8	0.69	0.33	0.4	34.1	471.2	1668.0	140.7	42.4	4.8	400.9	61.5	217.6	18.3	5.5	0.6	115.3
77	7	13	21	9	0.01	0.00	0.4	0.8	26.2	15.5	21.0	3.5	0.9	197.6	138.1	81.4	110.6	18.4	4.6	2294.9
77	7	13	22	10	0.01	0.00	0.3	0.8	26.2	15.5	21.0	3.5	0.9	197.6	150.8	88.9	120.8	20.1	5.1	2505.7
EVENT] 35																				
77	8	6	21	1	0.32	0.13	0.4	13.3	1846.0	432.0	446.5	99.4	10.5	1332.1	615.9	144.1	149.0	33.2	3.5	980.3
77	8	6	22	2	0.11	0.05	0.3	5.7	396.7	102.9	102.8	23.0	2.8	405.2	310.9	80.6	80.6	18.0	2.2	700.2
77	8	6	23	3	0.11	0.05	0.3	5.6	374.1	101.4	84.8	21.8	2.7	329.0	295.0	80.0	66.9	17.2	2.1	572.4
EVENT] 41																				
77	8	25	8	1	0.37	0.14	0.6	14.7	3457.4	755.6	1352.4	185.6	19.1	4878.2	1043.3	228.0	408.1	56.0	5.8	3246.8
77	8	25	13	6	0.07	0.03	0.5	3.6	287.9	78.2	149.4	17.5	2.3	683.3	354.2	96.2	183.9	21.6	2.8	1854.5
77	8	25	14	7	0.04	0.02	0.5	2.5	160.3	51.6	86.5	10.7	1.6	444.6	288.2	92.9	155.5	19.3	2.9	1763.3
77	8	25	15	8	0.04	0.02	0.5	2.5	158.4	51.5	78.5	10.6	1.6	406.8	284.8	92.5	141.1	19.1	2.9	1613.4
EVENT] 42																				
77	8	29	18	1	0.31	0.15	0.5	15.6	3395.0	891.7	881.9	182.3	18.8	2639.7	966.7	253.9	251.1	51.9	5.3	1658.0
77	8	29	19	2	0.12	0.06	0.5	6.3	601.7	168.2	157.5	34.0	3.9	563.7	422.9	118.2	110.7	23.9	2.8	873.9
77	8	29	20	3	0.11	0.05	0.4	5.8	495.3	147.2	113.7	28.4	3.4	405.5	380.0	113.0	87.2	21.8	2.6	686.2
77	8	29	22	5	0.12	0.06	0.3	6.1	520.0	160.1	104.1	29.7	3.5	346.0	377.8	116.3	75.6	21.6	2.5	554.5
EVENT] 43																				
77	8	31	9	1	0.08	0.01	0.5	1.7	80.0	35.8	46.1	6.4	1.2	291.0	212.4	95.2	122.6	17.1	3.1	1704.7
77	8	31	10	2	0.09	0.04	0.5	4.9	367.3	116.5	116.7	21.8	2.7	485.1	331.1	105.0	105.2	19.6	2.4	964.3
77	8	31	11	3	0.04	0.02	0.5	2.5	128.6	52.3	52.0	9.0	1.4	294.4	233.0	94.9	94.3	16.4	2.6	1177.0

77	8	31	12	4	0.03	0.01	0.5	2.0	95.2	41.9	41.4	7.3	1.3	260.2	215.6	95.0	93.7	16.4	2.8	1299.1
77	8	31	13	5	0.01	0.00	0.5	1.0	44.5	22.5	26.9	4.5	1.0	216.4	208.2	105.3	125.7	21.0	4.6	2232.0
77	8	31	14	6	0.03	0.01	0.5	1.9	94.4	41.8	39.3	7.2	1.2	250.6	217.6	96.4	90.7	16.6	2.9	1274.1
77	8	31	16	8	0.04	0.02	0.4	2.3	119.8	50.2	44.0	8.6	1.4	259.8	231.4	97.0	84.9	16.5	2.7	1107.6
77	8	31	17	9	0.01	0.00	0.4	0.9	44.1	22.5	25.9	4.5	1.0	211.9	214.3	109.0	125.8	21.7	4.7	2269.8

PAGE 4

STREAM LOADINGS-WET WEATHER EVENTS-CITY OF WINNIPEG-1977-B.MACBRIDE-RUN003
POLLUTOGRAPH ANALYSIS

TREATMENT RATE = 0.0100 IN/HR, 1.0 CFS, 0.652 MGD
STORAGE CAPACITY= 0.0300 INCHES, 0.3 AC-FT, 0.081 MG

WPG.INT.AIRPORT 1977 DATA
COMBINED

YR	MO	DY	HR	T(0)	RAIN (INCHES)	RUNOF (INCHES)	DWF (CFS)	QTOT (CFS)	**OUTFLOW POLLUTANT LOAD, IN LBS/HR**** SUSP	SETL	BOD	N	PO4	COLI ++	**** AVE CONCENTRATION, IN MG/L ********** SUSP	SETL	BOD	N	PO4	COLI ++
EVENT J 43																				
77	8	31	18	10	0.01	0.00	0.4	0.9	44.1	22.4	25.8	4.5	1.0	211.3	222.7	113.4	130.2	22.6	4.9	2354.8
EVENT J 47																				
77	9	8	17	1	0.25	0.11	0.5	12.0	701.3	355.8	283.8	41.3	4.7	1107.7	260.6	132.2	105.5	15.3	1.7	907.8
77	9	8	18	2	0.42	0.20	0.4	21.0	1275.1	984.6	259.7	75.9	8.1	653.2	270.4	208.7	55.1	16.1	1.7	305.5
77	9	8	19	3	0.47	0.23	0.4	23.4	835.0	1018.2	139.1	54.0	5.9	280.4	158.6	193.3	26.4	10.3	1.1	117.5
77	9	8	20	4	0.54	0.26	0.4	26.8	496.3	1053.0	91.2	37.4	4.3	209.5	82.3	174.7	15.1	6.2	0.7	76.7
77	9	8	21	5	0.10	0.05	0.4	5.3	41.5	52.4	23.3	4.6	1.0	197.6	34.9	44.0	19.6	3.9	0.8	366.5
77	9	8	22	6	0.06	0.03	0.3	3.3	32.9	33.3	22.0	4.0	0.9	197.3	45.0	45.6	30.1	5.5	1.3	595.1
77	9	8	23	7	0.01	0.00	0.3	0.8	26.7	16.1	21.0	3.5	0.9	197.1	154.7	93.2	121.5	20.4	5.1	2518.8
77	9	8	24	8	0.08	0.04	0.2	4.2	36.2	41.6	22.5	4.3	1.0	197.3	38.8	44.6	24.1	4.6	1.0	466.2
77	9	9	1	9	0.12	0.06	0.2	6.1	44.1	62.5	23.7	4.9	1.0	197.3	32.1	45.5	17.3	3.5	0.7	317.3
77	9	9	2	10	0.17	0.08	0.2	8.5	54.6	97.3	25.4	5.7	1.1	197.2	28.6	50.9	13.3	3.0	0.6	227.5
77	9	9	3	11	0.05	0.02	0.2	2.6	30.1	28.4	21.6	3.8	0.9	197.1	50.8	47.9	36.3	6.4	1.5	732.9
77	9	9	4	12	0.02	0.01	0.2	1.2	27.2	18.8	21.1	3.6	0.9	197.1	103.4	71.5	80.0	13.6	3.4	1650.7
77	9	9	5	13	0.02	0.01	0.2	1.2	27.2	18.8	21.1	3.6	0.9	197.1	103.3	71.4	80.0	13.6	3.4	1650.7
EVENT J 50																				
77	9	24	3	1	0.07	0.02	0.2	2.1	122.5	36.6	152.0	8.9	1.4	780.1	254.4	76.0	315.7	18.5	2.9	3573.4
77	9	24	4	2	0.24	0.12	0.2	11.9	1359.4	304.4	583.4	74.4	8.0	2235.8	507.1	113.6	217.6	27.8	3.0	1839.7
77	9	24	5	3	0.23	0.11	0.2	11.4	1028.1	267.1	279.0	56.6	6.2	933.1	399.9	103.9	108.5	22.0	2.4	800.7
77	9	24	6	4	0.07	0.03	0.3	3.7	161.8	52.6	59.4	10.7	1.6	313.4	193.4	62.9	71.0	12.8	1.9	826.6
77	9	24	7	5	0.10	0.05	0.3	5.2	249.2	75.3	68.8	15.3	2.1	314.4	213.7	64.6	59.0	13.1	1.8	594.7
77	9	24	8	6	0.07	0.03	0.5	3.9	150.6	51.7	46.0	10.1	1.5	254.6	169.9	58.3	51.9	11.4	1.7	633.6
77	9	24	9	7	0.13	0.06	0.6	6.9	330.9	102.3	67.9	19.6	2.5	268.4	212.8	65.8	43.7	12.6	1.6	380.8
77	9	24	10	8	0.04	0.02	0.6	2.5	76.7	32.9	29.5	6.2	1.1	212.3	135.8	58.2	52.2	11.0	2.0	829.0
77	9	24	11	9	0.01	0.00	0.5	1.0	35.3	17.8	22.6	4.0	0.9	200.5	155.5	78.5	99.5	17.5	4.1	1950.5
77	9	24	12	10	0.01	0.00	0.5	1.0	35.2	17.8	22.5	4.0	0.9	200.4	155.3	78.5	99.4	17.5	4.1	1949.1

++ COLIFORM TOTALS IN BILLION MPN,
AND CONCENTRATION IN 1000 MPN PER LITER

10.2 APPENDIX 2

"LOAD PROGRAM LISTING AND

SAMPLE RUN"

```
             C      LOADER PROGRAM --COMPUTES TOTAL POLLUTANT LOAD PER RUNOFF EVENT GIVEN
             C      COMBINED AND SEARATE SEWER LOADINGS AND SEWAGE TREATMENT EFFLUENT AND
             C      BY-PASS DATA---B.MACBRIDE---DEC1978
0001                DIMENSION NAME(8),NTITLE(20),KDATE(100),KHOUR(100),DUR(100),
                   1RUNOFF(2,100),EFF(100,5),PNAME(10,5)
0002                DIMENSION COMBOD(100),SEPBOD(100),FLOW(100,5),RAW(100,5)
0003                DIMENSION BYPASS(100,5),TRUN(2)
0004                REAL KCOMB,KSEP,PLTOTAL,KRAW(5),KEFF(5),PLTRATE,KBYPAS(5)
0005                WRITE(6,100)
0006            100 FORMAT('1','ENTRY MADE TO STREAM LOADING PROGRAM-TO COMPUTE ULT
                   1BOD LOADING PER RUNOFF EVENT')
0007                WRITE(6,110)
0008            110 FORMAT('0','PROGRAM DEVELOPED BY B.MACBRIDE-FOR MSC.C.E.THESIS----
                   1DECEMBER 1978'/////)
0009                DO 140 I=1,3
0010                READ(5,120) (NTITLE(N),N=1,20)
0011            120 FORMAT(20A4)
0012                WRITE(6,130) (NTITLE(N),N=1,20)
0013            130 FORMAT(20X,20A4//)
0014            140 CONTINUE
0015                READ(5,150)NAME,COMBARA,SEPARA
0016            150 FORMAT(8A4,2F10.2)
0017                WRITE(6,160)NAME,COMBARA,SEPARA
0018            160 FORMAT('-','WATERSHED NAME---   ',8A4,/' ','COMBINED SEWER AREA=',
                   1F10.3,
                   1/' ','SEPARATE SEWERED AREA= ',F10.3)
             C
             CREAD IN STORM LOADING DATA
             C
0019                WRITE(6,170)
0020            170 FORMAT('1','EVENT',9X,'DATE',18X,'OVERFLOW',10X,'RUNOFF',13X,'BOD
                   15 LOADINGS PER 100ACRES',
                   1/' ',9X,'YEAR   MONTH  DAY  HOUR ---DURATION',10X,'INCHES ---',10X,
                   2'COMBINED    SEPARATE'/38X,'HOURS',5X,'SEPARATE',
                   33X,'COMBINED',8X,'POUNDS',6X,'POUNDS'//)
0021                DO 200  K=1,100
0022                READ(5,180)KDATE(K),KHOUR(K),DUR(K),RUNOFF(1,K),RUNOFF(2,K),
                   1COMBOD(K),SEPBOD(K)
0023                IF (KDATE(K).EQ.0)GO TO 201
0024            180 FORMAT(2I10,5F10.2)
0025                KYR=KDATE(K)/10000+1900
0026                KMO=MOD(KDATE(K)/100,100)
0027                KDY=MOD(KDATE(K),100)
0028                WRITE(6,190)K,KYR,KMO,KDY,KHOUR(K),DUR(K),RUNOFF(2,K),
                   1RUNOFF(1,K),COMBOD(K),SEPBOD(K)
0029            190 FORMAT(' ',I5,I9,3X,I2,5X,I2,I6,F10.2,F11.2,2X,F10.2,6X,F10.2,
                   1F12.2)
0030            200 CONTINUE
0031            201 CONTINUE
0032                IEVENT=K-1
             C
0033                READ(5,210)KCOMB,KSEP
0034            210 FORMAT(2F10.2)
0035                WRITE(6,215)KCOMB,KSEP
0036            215 FORMAT(//' ','   KCOMB=',F10.2,'   KSEP=',F10.2)
             C
```

```
0037          READ(5,220)NPLANTS
0038      220 FORMAT(I10)
0039          DO 237 K=1,NPLANTS
0040          READ(5,231)(PNAME(J,K),J=1,10)
0041      231 FORMAT(10A4)
0042          WRITE(6,240)K,(PNAME(J,K),J=1,10)
0043      240 FORMAT('1','PLANT DATA',10X,'PLANT NO  ',I2,'  NAME  ',10A4/' ',
             1'EVENT',
             13X,'DATE',5X,'FLOW-MIGD',5X,'BOD5-RAW',5X,'BOD5-EFFLUENT'
             2,5X,'BY-PASS-MIGD'//)
0044          DO 236 I=1,IEVENT
0045          READ(5,230)FLOW(I,K),RAW(I,K),EFF(I,K),BYPASS(I,K)
0046      230 FORMAT(4F10.2)
0047          WRITE(6,235)I,KDATE(I),FLOW(I,K),RAW(I,K),EFF(I,K),BYPASS(I,K)
0048      235 FORMAT(' ',I4,I8,4F14.2)
0049      236 CONTINUE
0050      237 CONTINUE
        C
0051          DO 280 I=1,NPLANTS
0052          READ(5,270)KRAW(I),KEFF(I),KBYPAS(I)
0053      270 FORMAT(3F10.2)
0054          WRITE(6,275)I,KRAW(I),KEFF(I),KBYPAS(I)
0055      275 FORMAT(//' ','PLANT NO.',I2,' KRAW=',F10.2,' KEFF=',F10.2,
             1'  KBYPAS=',F10.2)
0056      280 CONTINUE
        C
0057          WRITE(6,250)
0058      250 FORMAT ('1','ULTIMATE BOD LOADINGS IN POUNDS PER EVENT'//)
0059          WRITE(6,260)
0060      260 FORMAT(' ','EVENT YEAR   MO   DY   HR  DURATION',8X,'RUNOFF',7X,
             1'COMBINED       SEPARATE        STPLANTS     TOTAL RATE'//)
0061          CTOTAL=0
0062          STOTAL=0
0063          PLTOTAL=0
0064          TDUR=0
0065          TRUN(1)=0
0066          TRUN(2)=0
0067          GTOTAL=0
0068          WRITE(7,300)NAME,IEVENT
0069      300 FORMAT(' ',8A4,I5)
0070          DO 400 I=1,IEVENT
0071          VOLUM=0.
0072          TLOAD=0
0073          TRATE=0
0074          CRATE=KCOMB*COMBARA/100.*COMBOD(I)
0075          TRUN(1)=TRUN(1)+RUNOFF(1,I)
0076          VOLUM=VOLUM+COMBARA*RUNOFF(1,I)/12.*43560.
0077          VOLUM=VOLUM+SEPARA*RUNOFF(2,I)/12.*43560.
0078          TRUN(2)=TRUN(2)+RUNOFF(2,I)
0079          CTOTAL=CTOTAL+CRATE
0080          SRATE=KSEP*SEPARA/100.*SEPBOD(I)
0081          STOTAL=STOTAL+SRATE
0082          PLTRATE=0
        C
0083          DO 410 K=1,NPLANTS
0084          PLTRATE=PLTRATE+FLOW(I,K)*KRAW(K)*RAW(I,K)*10.+FLOW(I,K)*KEFF(K)
```

```
                      1*EFF(I,K)*10.+KBYPAS(K)*RAW(I,K)*BYPASS(I,K)*10.
0085                   VOLUM=VOLUM+FLOW(I,K)*DUR(I)/24.*10000000./62.4
0086               410 CONTINUE
0087                   PLTRATE=PLTRATE*DUR(I)/24.
0088                   PLTOTAL=PLTOTAL+PLTRATE
0089                   TRATE=CRATE+SRATE+PLTRATE
0090                   GTOTAL=GTOTAL+TRATE
0091                   KYR=KDATE(I)/10000+1900
0092                   KMO=MOD(KDATE(I)/100,100)
0093                   KDY=MOD(KDATE(I),100)
             C
0094                   WRITE(6,420)I,KYR,KMO,KDY,KHOUR(I),DUR(I),VOLUM,CRATE,
                      1SRATE,PLTRATE,TRATE
0095               420 FORMAT(' ',5I5,1F10.2,5F15.0)
0096                   TDUR=TDUR+DUR(I)
0097                   WRITE(7,425)I,KDATE(I),KHOUR(I),DUR(I),VOLUM,TRATE
0098               425 FORMAT(' ',3I10,3F15.2)
0099               400 CONTINUE
0100                   WRITE(6,430)IEVENT,TDUR,TRUN(1),TRUN(2)
0101               430 FORMAT('1','QUANTITY SUMMARY-NO OF EVENTS',I10/' ',16X,
                      1'TOTAL DURATION',F10.2,/' ',16X,'COMBINED RUNOFF',F9.2,
                      2/' ',16X,'SEPARATE RUNOFF',F9.2)
0102                   WRITE(6,440)IEVENT,CTOTAL,CTOTAL/IEVENT,CTOTAL/GTOTAL*100,
                      1              STOTAL,STOTAL/IEVENT,STOTAL/GTOTAL*100,
                      2             PLTOTAL,PLTOTAL/IEVENT,PLTOTAL/GTOTAL*100,
                      3             GTOTAL
0103               440 FORMAT('1','QUALITY SUMMARY-NO OF EVENTS',I10/' ',
                      118X,'TOTAL LOAD',10X,'AVE. PER EVENT',10X,'PERCENT'
                      2/' ','COMBINED',3F20.0/' ','SEPARATE',3F20.0/
                      3' ','  PLANTS',3F20.0/' ','   TOTAL',1F20.0)
0104                   END
```


PROGRAM SECTIONS

Name	Bytes	Attributes
0 $CODE	2255	PIC CON REL LCL SHR EXE RD NOWRT LONG
1 $PDATA	1255	PIC CON REL LCL SHR NOEXE RD NOWRT LONG
2 $LOCAL	11296	PIC CON REL LCL NOSHR NOEXE RD WRT LONG

ENTRY POINTS

Address Type Name

```
ENTRY MADE TO STREAM LOADING PROGRAM-TO COMPUTE ULT BOD LOADING PER RUNOFF EVENT
PROGRAM DEVELOPED BY B.MACBRIDE-FOR MSC.C.E.THESIS----DECEMBER 1978

                  MSC C.E. THESIS -- STREAM LOADINGS--

                  ULTIMATE BOD LOADINGS WET WEATHER CITY OF WINNINPEG

                  RUN 002  JAN 14 1979 FIRST RUN WITH REVISED LOAD PROGRAM

WATERSHED NAME---  WINNIPEG  MANITOBA
COMBINED SEWER AREA= 26000.000
SEPARATE SEWERED AREA=  16000.000
```

EVENT	DATE YEAR	MONTH	DAY	HOUR	OVERFLOW DURATION HOURS	RUNOFF INCHES SEPARATE	COMBINED	BOD 5 LOADINGS PER 100ACRES COMBINED POUNDS	SEPARATE POUNDS
1	1977	5	4	18	6.00	0.95	0.88	2078.00	763.00
2	1977	5	5	5	6.00	0.21	0.14	91.00	6.00
3	1977	5	14	15	3.00	0.15	0.09	379.00	101.00
4	1977	5	18	2	3.00	0.49	0.41	989.00	604.00
5	1977	5	26	14	3.00	0.67	0.62	1086.00	478.00
6	1977	5	28	14	1.00	0.09	0.05	92.00	27.00
7	1977	5	28	23	1.00	0.27	0.23	222.00	127.00
8	1977	5	29	20	2.00	0.08	0.01	17.00	20.00
9	1977	6	10	11	3.00	0.22	0.16	805.00	253.00
10	1977	6	12	22	9.00	0.40	0.28	520.00	239.00
11	1977	6	17	10	9.00	0.51	0.43	707.00	359.00
12	1977	6	30	12	2.00	0.13	0.08	397.00	163.00
13	1977	7	2	15	2.00	0.16	0.10	334.00	198.00
14	1977	7	5	18	2.00	0.07	0.02	102.00	70.00
15	1977	7	13	13	2.00	0.74	0.64	1663.00	1192.00
16	1977	7	30	4	2.00	0.11	0.06	466.00	86.00
17	1977	7	30	17	2.00	0.09	0.04	162.00	47.00
18	1977	8	2	21	2.00	0.05	0.01	46.00	35.00
19	1977	8	4	14	3.00	0.14	0.08	297.00	110.00
20	1977	8	6	21	3.00	0.24	0.18	466.00	221.00
21	1977	8	9	16	1.00	0.09	0.04	148.00	76.00
22	1977	8	25	8	4.00	0.14	0.14	1117.00	382.00
23	1977	8	29	18	4.00	0.32	0.26	958.00	515.00
24	1977	8	31	9	5.00	0.14	0.05	120.00	85.00
25	1977	9	3	20	2.00	0.35	0.30	1067.00	756.00
26	1977	9	5	6	6.00	0.25	0.18	206.00	65.00
27	1977	9	8	17	12.00	1.11	0.99	767.00	380.00
28	1977	9	24	3	9.00	0.46	0.36	905.00	412.00
29	1977	9	24	21	3.00	0.08	0.03	43.00	26.00
30	1977	9	25	16	3.00	0.13	0.06	69.00	43.00
31	1977	10	17	7	4.00	0.11	0.05	428.00	188.00
32	1977	10	30	21	4.00	0.25	0.18	1296.00	757.00

KCOMB= 1.50 KSEP= 1.50

PLANT DATA PLANT NO 1 NAME NORTH END TREATMENT PLANT

EVENT	DATE	FLOW-MIGD	BOD5-RAW	BOD5-EFFLUENT	BY-PASS-MIGD
1	770504	73.80	400.00	78.00	100.00
2	770505	96.90	270.00	42.00	0.00
3	770514	67.00	220.00	70.00	0.00
4	770518	105.40	380.00	94.00	0.00
5	770526	69.70	310.00	79.00	0.00
6	770528	66.50	270.00	52.00	0.00
7	770528	66.50	270.00	52.00	0.00
8	770529	61.50	180.00	31.00	0.00
9	770610	81.00	230.00	80.00	0.00
10	770612	55.40	110.00	44.00	0.00
11	770617	108.90	140.00	65.00	0.00
12	770630	76.40	230.00	68.00	0.00
13	770702	65.90	280.00	34.00	0.00
14	770705	74.10	250.00	48.00	0.00
15	770713	93.70	320.00	63.00	0.00
16	770730	67.50	140.00	70.00	0.00
17	770730	67.50	140.00	70.00	0.00
18	770802	64.50	252.00	70.00	0.00
19	770804	63.40	252.00	108.00	0.00
20	770806	58.10	280.00	100.00	0.00
21	770809	72.40	280.00	69.00	0.00
22	770825	78.40	390.00	84.00	0.00
23	770829	63.60	230.00	81.00	0.00
24	770831	82.80	170.00	100.00	0.00
25	770903	61.80	180.00	65.00	0.00
26	770905	96.20	100.00	55.00	0.00
27	770908	83.10	260.00	60.00	0.00
28	770924	90.60	140.00	56.00	0.00
29	770924	90.60	140.00	56.00	0.00
30	770925	119.70	97.00	40.00	0.00
31	771017	72.50	350.00	96.00	0.00
32	771030	58.50	300.00	80.00	0.00

PLANT DATA PLANT NO 2 NAME SOUTH END TREATMENT PLANT

EVENT	DATE	FLOW-MIGD	BOD5-RAW	BOD5-EFFLUENT	BY-PASS-MIGD
1	770504	18.90	310.00	22.00	0.00
2	770505	20.40	140.00	15.00	0.00
3	770514	10.60	250.00	19.00	0.00
4	770518	11.40	280.00	17.00	0.00
5	770526	8.80	260.00	17.00	0.00
6	770528	10.10	250.00	19.00	0.00
7	770528	10.10	250.00	19.00	0.00
8	770529	10.10	230.00	29.00	0.00
9	770610	10.70	227.00	14.00	0.00
10	770612	10.70	190.00	25.00	0.00
11	770617	13.70	227.00	14.00	0.00
12	770630	9.40	227.00	14.00	0.00
13	770702	9.40	194.00	48.00	0.00
14	770705	12.80	190.00	42.00	0.00
15	770713	20.80	260.00	59.00	0.00
16	770730	9.40	194.00	48.00	0.00
17	770730	9.40	194.00	48.00	0.00
18	770802	9.80	220.00	26.00	0.00
19	770804	7.90	180.00	22.00	0.00
20	770806	10.10	251.00	39.00	0.00
21	770809	9.70	220.00	34.00	0.00
22	770825	10.20	330.00	64.00	0.00
23	770829	17.80	240.00	81.00	0.00
24	770831	16.50	190.00	55.00	0.00
25	770903	10.60	264.00	50.00	0.00
26	770905	10.60	250.00	68.00	0.00
27	770908	23.20	230.00	88.00	0.00
28	770924	17.80	264.00	50.00	0.00
29	770924	17.80	264.00	50.00	0.00
30	770925	17.80	200.00	54.00	0.00
31	771017	11.30	350.00	38.00	0.00
32	771030	9.00	330.00	90.00	0.00

PLANT DATA PLANT NO 3 NAME WEST END TREATMENT PLANT

EVENT	DATE	FLOW-MIGD	BOD5-RAW	BOD5-EFFLUENT	BY-PASS-MIGD
1	770504	6.40	198.00	42.00	0.00
2	770505	6.40	198.00	42.00	0.00
3	770514	6.40	198.00	42.00	0.00
4	770518	6.40	198.00	42.00	0.00
5	770526	6.40	198.00	42.00	0.00
6	770528	6.40	198.00	42.00	0.00
7	770528	6.40	198.00	42.00	0.00
8	770529	6.40	198.00	42.00	0.00
9	770610	6.30	189.00	40.00	0.00
10	770612	6.30	189.00	40.00	0.00
11	770617	6.30	189.00	40.00	0.00
12	770630	6.30	189.00	40.00	0.00
13	770702	5.90	183.00	40.00	0.00
14	770705	5.90	183.00	40.00	0.00
15	770713	5.90	183.00	40.00	0.00
16	770730	5.90	183.00	40.00	0.00
17	770730	5.90	183.00	40.00	0.00
18	770802	5.40	167.00	32.00	0.00
19	770804	5.40	167.00	32.00	0.00
20	770806	5.40	167.00	32.00	0.00
21	770809	5.40	167.00	32.00	0.00
22	770825	5.40	167.00	32.00	0.00
23	770829	5.40	167.00	32.00	0.00
24	770831	5.40	167.00	32.00	0.00
25	770903	6.40	192.00	33.00	0.00
26	770905	6.40	192.00	33.00	0.00
27	770908	6.40	192.00	33.00	0.00
28	770924	6.40	192.00	33.00	0.00
29	770924	6.40	192.00	33.00	0.00
30	770925	6.40	192.00	33.00	0.00
31	771017	5.50	170.00	49.00	0.00
32	771030	5.50	170.00	49.00	0.00

PLANT NO. 1 KRAW= 0.00 KEFF= 1.50 KBYPAS= 0.00

PLANT NO. 2 KRAW= 0.00 KEFF= 1.50 KBYPAS= 0.00

PLANT NO. 3 KRAW= 0.00 KEFF= 1.50 KBYPAS= 0.00

ULTIMATE BOD LOADINGS IN POUNDS PER EVENT

EVENT	YEAR	MO	DY	HR	DURATION	RUNOFF	COMBINED	SEPARATE	STPLANTS	TOTAL RATE
1	1977	5	4	18	6.00	142200768.	810420.	183120.	24154.	1017694.
2	1977	5	5	5	6.00	30365930.	35490.	1440.	17417.	54347.
3	1977	5	14	15	3.00	18888894.	147810.	24240.	9675.	181725.
4	1977	5	18	2	3.00	69622944.	385710.	144960.	19444.	550114.
5	1977	5	26	14	3.00	99129904.	423540.	114720.	11109.	549369.
6	1977	5	28	14	1.00	10500420.	35880.	6480.	2449.	44809.
7	1977	5	28	23	1.00	37943220.	86580.	30480.	2449.	119509.
8	1977	5	29	20	2.00	6631866.	6630.	4800.	3085.	14515.
9	1977	6	10	11	3.00	29841536.	313950.	60720.	12903.	387573.
10	1977	6	12	22	9.00	54009360.	202800.	57360.	16634.	276794.
11	1977	6	17	10	9.00	77950600.	275730.	86160.	42313.	404203.
12	1977	6	30	12	2.00	16330766.	154830.	39120.	6974.	200924.
13	1977	7	2	15	2.00	19815200.	130260.	47520.	3660.	181440.
14	1977	7	5	18	2.00	7192516.	39780.	16800.	5413.	61993.
15	1977	7	13	13	2.00	104990296.	648570.	286080.	9208.	943858.
16	1977	7	30	4	2.00	13157368.	181740.	20640.	6765.	209145.
17	1977	7	30	17	2.00	10108169.	63180.	11280.	6765.	81225.
18	1977	8	2	21	2.00	4912170.	17940.	8400.	6178.	32518.
19	1977	8	4	14	3.00	17218060.	115830.	26400.	13488.	155718.
20	1977	8	6	21	3.00	32401960.	181740.	53040.	11956.	246736.
21	1977	8	9	16	1.00	9566668.	57720.	18240.	3436.	79396.
22	1977	8	25	8	4.00	23855082.	435630.	91680.	18528.	545838.
23	1977	8	29	18	4.00	45442772.	373620.	123600.	16915.	514136.
24	1977	8	31	9	5.00	16345792.	46800.	20400.	29251.	96451.
25	1977	9	3	20	2.00	49694352.	416130.	181440.	5948.	603518.
26	1977	9	5	6	6.00	36043660.	80340.	15600.	23336.	119276.
27	1977	9	8	17	12.00	166935456.	299130.	91200.	54291.	444621.
28	1977	9	24	3	9.00	67592632.	352950.	98880.	34733.	486563.
29	1977	9	24	21	3.00	9777478.	16770.	6240.	11578.	34588.
30	1977	9	25	16	3.00	16095811.	26910.	10320.	11176.	48406.
31	1977	10	17	7	4.00	13492948.	166920.	45120.	19147.	231187.
32	1977	10	30	21	4.00	33458186.	505440.	181680.	14399.	701519.

QUANTITY SUMMARY-NO OF EVENTS		32
	TOTAL DURATION	123.00
	COMBINED RUNOFF	7.15
	SEPARATE RUNOFF	9.20

QUALITY SUMMARY-NO OF EVENTS 32

	TOTAL LOAD	AVE. PER EVENT	PERCENT
COMBINED	7036770.	219899.	73.
SEPARATE	2108160.	65880.	22.
PLANTS	474779.	14837.	5.
TOTAL	9619712.		

10.3 APPENDIX 3

"RVRQUAL" LISTING AND SAMPLE RUN

```
          C  RIVER QUALITY MODEL*******************************************
          C   DEVELOPED BY B.MACBRIDE FOR MSCCE THESIS-SPECIFICALLY FOR ANALYSIS
          C  OF EFFECTS OF URBAN RUNOFF ON THE RED RIVER IN WINNIPEG
          C  COMPUTES MINIMUM DISSOLVED OXYGEN
          C
0001            REAL DUR(100),VOL(100),TOTAL(100),BODU(100),LENR,AREA(100),
               1     ELEV(100),SRWDTH(100),LEVL(100),FLOW(100),TEMP(100),
               2     XAREA(100),VEL(100),DOMIN(100),SMALL(100),DUM(100)
0002            INTEGER NTITLE(20),NAME(8),RNAME(15),
               1         KHOUR(100),JDATE(100)
0003            COMMON I,KDATE(100),IFACT(100)
0004            WRITE(6,100)
0005        100 FORMAT('1','ENTRY MADE TO RIVER QUALITY PROGRAM'/
               1')','TO COMPUTE MINIMUM DISSOLVED OXYGEN IM RIVER DUE TO URBAN
               2 RUNOFF',/')','DEVELOPED BY B.MACBRIDE FOR MSCCE THESIS'/'0',
               3'*************VER 1.0----JAN 1979***************************'
               4///////////)
          C
0006            DO 140 I=1,3
0007            READ(5,120) (NTITLE(N),N=1,20)
0008        120 FORMAT(20A4)
0009            WRITE(6,130)(NTITLE(N),N=1,20)
0010        130 FORMAT('-',20A4//)
0011        140 CONTINUE
          C
          C  READ IN URBAN RUNOFF DATA
          C
0012            READ(7,145)NAME,IEVENT
0013        145 FORMAT(1X,8A4,I5)
0014            WRITE(6,150)
0015        150 FORMAT('1',10X,'WATERSHED NAME',20X,'NO. OF EVENTS')
0016            WRITE(6,155)NAME,IEVENT
0017        155 FORMAT(' ',8A4,I20//)
0018            WRITE(6,157)
0019        157 FORMAT(' ','EVENT LOADING DATA INPUT TO RECEIVING STREAM'/
               1' ','EVENT',4X,'DATE',5X,'HOUR',2X,'DURATION',2X,'VOLUME-
               2CUBIC FEET',2X,'BOD LOAD-POUNDS',2X,'BOD-MG/L'//)
0020            DO 180 I=1,IEVENT
0021            READ(7,160)K,KDATE(I),KHOUR(I),DUR(I),VOL(I),TOTAL(I)
0022        160 FORMAT(1X,3I10,3F15.2)
0023            BODU(I)=TOTAL(I)/VOL(I)/62.4*1000000.
0024            WRITE(6,170)I,KDATE(I),KHOUR(I),DUR(I),VOL(I),TOTAL(I),BODU(I)
0025        170 FORMAT(' ',I5,I10,I6,F10.2,F19.0,F17.0,F10.0)
0026        180 CONTINUE
          C
          C      READ IN RIVER DATA
          C
0027            READ(5,200)RNAME,LENR
0028        200 FORMAT(15A4,F10.2)
0029            WRITE(6,205)
0030        205 FORMAT('1',10X,'NAME OF RIVER REACH',40X,'LENGTH(FEET)')
0031            WRITE(6,210)RNAME,LENR
0032        210 FORMAT(' ',15A4,F20.2)
0033            WRITE(6,215)
0034        215 FORMAT(' ','ELEVATION VERSUS SURFACE WIDTH'/
               1' ','ELEVATION-FEET',4X,'SURFACE WIDTH-FEET',2X,'AREA-
```

```
                   2SQ.FEET'/)
            C
            C READ ELEV. VS. SURFACE WIDTH  CROSS-SECTION
            C
0035              AREA(1)=0.0
0036              DO 250 I=1,100
0037              READ(5,220)ELEV(I),SRWDTH(I)
0038          220 FORMAT(2F10.2)
0039              IF(ELEV(I).EQ.0.0)GO TO 251
0040              IF(I.EQ.1)GO TO 230
0041              AREA(I)=AREA(I-1)+(ELEV(I)-ELEV(I-1))*(SRWDTH(I)+SRWDTH(I-1))/2
0042          230 WRITE(6,240)ELEV(I),SRWDTH(I),AREA(I)
0043          240 FORMAT(' ',F14.2,F17.2,F15.2)
0044          250 CONTINUE
0045          251 NPTS=I-1
            C
            C READ DEOXYGENATION K1 =REAERATION K2 = TEMP FACTOR
            C
0046              READ(5,260)AK1,AK2,THETA1,THETA2
0047          260 FORMAT(4F10.4)
0048              WRITE (6,270)
0049          270 FORMAT('1',5X,'REACTION RATES AND TEMPERATURE CORRECTIONS'/
                 1' ',3X,'DEOXYGENATION',15X,'REAERATION'/
                 2' ',3X,'RATE     TEMP.COR.',10X,'RATE    TEMP.COR.')
0050              WRITE (6,280)AK1,THETA1,AK2,THETA2
0051          280 FORMAT(' ',F7.4,F12.4,10X,F7.4,F12.4//)
            C
            C    READ INTIAL ULT BOD AND DO DEFICIT
            C
0052              READ(5,290)BOD,DOD
0053          290 FORMAT(2F10.2)
0054              WRITE(6,300)
0055          300 FORMAT(' ','INITIAL RIVER BODULT',10X,'INITIAL D.O. DEFICIT'/)
0056              WRITE(6,310)BOD,DOD
0057          310 FORMAT(' ',6X,F10.2,15X,F12.2)
            C
            C     READ EVENT DATA FOR RIVER
            C
0058              WRITE(6,320)
0059          320 FORMAT('1','RIVER DATA FOR EACH EVENT'//
                 1' ','EVENT',4X,'DATE',4X,'ELEVATION',4X,'FLOW',4X,'AREA',4X,
                 2'VELOCITY',4X,'TEMPERATURE'/
                 3' ',8X,'YYMMDD',6X,'FEET',7X,'CFS',3X,'SQ.FT.',3X,'FT./HR.',
                 46X,'DEG.C'/)
0060              DO 400 J=1,IEVENT
0061              READ(5,330)JDATE(J),LEVL(J),FLOW(J),TEMP(J)
0062          330 FORMAT(I10,3F10.2)
0063              IF(KDATE(J).EQ.JDATE(J))GO TO 350
0064              WRITE(6,340)J,KDATE(J),JDATE(J)
0065          340 FORMAT(' ','WARNING DATES DO NOT MATCH',I5,2I10)
0066          350 CONTINUE
            C
            C   INTERPOLATE TO FIND X-SECT AREA
            C
0067              DO 360 I=2,NPTS
0068              IF(LEVL(J).GT.ELEV(I))GO TO 360
```

```
0069          XAREA(J)=AREA(I-1)+(LEVL(J)-ELEV(I-1))/(ELEV(I)-ELEV(I-1))*
             1(AREA(I)-AREA(I-1))
0070          GO TO 380
0071      360 CONTINUE
0072          WRITE(6,370)
0073      370 FORMAT(' ','WARNING LEVEL EXCEEDS RIVER DATA')
0074          XAREA(J)=1.0
0075      380 CONTINUE
0076          VEL(J)=FLOW(J)/XAREA(J)*3600.
0077          WRITE(6,390)J,KDATE(J),LEVL(J),FLOW(J),XAREA(J),VEL(J),TEMP(J)
0078      390 FORMAT(' ',I4,I10,F11.2,F9.0,F10.2,F9.2,F10.2)
0079      400 CONTINUE
        C
        C     CALCULATE FACTOR FOR DATE DIFFERENCES
        C
0080          DO 401 I=1,IEVENT
0081          CALL DTFCTR
0082      401 CONTINUE
        C
        C  MAIN COMPUTATIONAL LOOP
        C
0083          WRITE(6,405)
0084      405 FORMAT('1','RESULTS  DISSOLVED OXYGEN EACH EVENT'/
             1' ','EVENT',4X,'DATE',2X,'INTERVAL',2(4X,'INITIAL'),6X,'K1',6X,
             2'K2',4X,'CRITICAL',4X,'CRITICAL',4X,'SATURATION',4X,'MINIMUM'/
             3' ',7X,'YYMMDD',6X,'DAYS',4X,'BODULT',5X,'D.O.DEF',18X,'TIME-DAYS'
             3,4X,'DEFICIT',
             44X,'DISS.OXYG.',4X,'DISS.OXYG.'/)
0085          TIME=0.0
0086          DO 420 I=1,IEVENT
        C
        C     COMPUTE INITIAL BOD,DO BASED ON TIME SINCE LAST EVENT
        C
0087          FBOD=BOD
0088          FDOD=DOD
0089          IF(I.EQ.1)GO TO 409
0090          DELT=KHOUR(I)-KHOUR(I-1)
0091          IF(DELT.GE.0.0)ADD=DELT/24.
0092          IF(DELT.LT.0.0)ADD=(24.+DELT)/24.-1.0
0093          TIME=IFACT(I)-IFACT(I-1)+ADD
0094          DIST=TIME*24.*VEL(I)
0095          IF(LENR-DIST)409,409,406
0096      406 FBOD=BODIN*EXP(-1.*BK1*TIME)
0097          FDOD=(BK1*BODIN/(BK2-BK1))*(EXP(-1.*BK1*TIME)-EXP(-1*BK2*TIME))
             1+FDOD*EXP(-1.*BK2*TIME)
0098          FBOD=(FBOD*(LENR-DIST)+BOD*DIST)/LENR
0099          FDOD=(FDOD*(LENR-DIST)+DOD*DIST)/LENR
0100      409 RVOL=XAREA(I)*LENR
0101          BODIN=(RVOL*FBOD+BODU(I)*VOL(I))/(RVOL+VOL(I))
0102          BK1=AK1*THETA1**(TEMP(I)-20.)
0103          BK2=AK2*THETA2**(TEMP(I)-20.)
0104          TCR=(1./(BK2-BK1))*ALOG(BK2/BK1*(1.-FDOD*(BK2-BK1)/BK1/BODIN))
0105          DCR=BODIN*BK1/BK2*EXP(-1.*BK1*TCR)
0106          DOSAT=14.652-0.41022*TEMP(I)+0.0079910*TEMP(I)**2.
             1-0.000077774*TEMP(I)**3.
0107          DOMIN(I)=DOSAT-DCR
```

```
0108          WRITE(6,410)I,KDATE(I),TIME,BODIN,FDOD,BK1,BK2,TCR,DCR,DOSAT,
             1DOMIN(I)
0109      410 FORMAT(' ',I4,I9,2F10.2,F11.2,F9.3,F9.3,F10.2,F12.2,F12.2,F12.2)
0110      420 CONTINUE
0111          DO 510 I=1,IEVENT
0112          DUM(I)=DOMIN(I)
0113          SMALL(I)=100.
0114      510 CONTINUE
0115          DO 530 J=1,IEVENT
0116          DO 520 I=1,IEVENT
0117          IF(SMALL(J).LT.DUM(I))GO TO 520
0118          SMALL(J)=DUM(I)
0119          JJ=I
0120      520 CONTINUE
0121          DUM(JJ)=100.
0122      530 CONTINUE
0123          WRITE(6,540)
0124      540 FORMAT('1','NUMBER',4X,'MIN. D.O.',4X,'DYS EXCEED.',4X,
             1'% EXCEED.'//)
0125          DO 560 I=1,IEVENT
0126          DYS=IEVENT-I+1.
0127          PER=DYS/IEVENT*100.
0128          WRITE(6,550)I,SMALL(I),DYS,PER
0129      550 FORMAT(' ',I5,F10.2,F15.2,F15.2)
0130      560 CONTINUE
0131          END
```

```
ENTRY MADE TO RIVER QUALITY PROGRAM
TO COMPUTE MINIMUM DISSOLVED OXYGEN IN RIVER DUE TO URBAN RUNOFF
DEVELOPED BY B.MACBRIDE FOR MSCCE THESIS

**************VER 1.0----JAN 1979**************************

MSC C.E. THESIS MINIMUM D.O. IN RED RIVER DUE TO URBAN RUNOFF

ADVISOR B.H.TOPNIK***************** 1977 DATA

RUN 004 WITH K2=0.26 EXIST. COND  RUN DATE 04MAR79
```

	WATERSHED NAME	NO. OF EVENTS
WINNIPEG	MANITOBA	32

EVENT LOADING DATA INPUT TO RECEIVING STREAM

EVENT	DATE	HOUR	DURATION	VOLUME-CUBIC FEET	BOD LOAD-POUNDS	BOD-MG/L
1	770504	18	6.00	142200768.	1017694.	115.
2	770505	5	6.00	30365930.	54347.	29.
3	770514	15	3.00	18888894.	181725.	154.
4	770518	2	3.00	69622944.	550114.	127.
5	770526	14	3.00	99129904.	549369.	89.
6	770528	14	1.00	10500420.	44809.	68.
7	770528	23	1.00	37943220.	119509.	50.
8	770529	20	2.00	6631866.	14515.	35.
9	770610	11	3.00	29841536.	387573.	208.
10	770612	22	9.00	54009360.	276794.	82.
11	770617	10	9.00	77950600.	404203.	83.
12	770630	12	2.00	16330766.	200924.	197.
13	770702	15	2.00	19815200.	181440.	147.
14	770705	18	2.00	7192516.	61993.	138.
15	770713	13	2.00	104990296.	943858.	144.
16	770730	4	2.00	13157368.	209145.	255.
17	770730	17	2.00	10108169.	81225.	129.
18	770802	21	2.00	4912170.	32518.	106.
19	770804	14	3.00	17218060.	155718.	145.
20	770806	21	3.00	32401960.	246736.	122.
21	770809	16	1.00	9586668.	79396.	133.
22	770825	8	4.00	23855082.	545838.	367.
23	770829	18	4.00	45442772.	514136.	181.
24	770831	9	5.00	16345792.	96451.	95.
25	770903	20	2.00	49694352.	603518.	195.
26	770905	6	6.00	36043660.	119276.	53.
27	770908	17	12.00	166935456.	444621.	43.
28	770924	3	9.00	67592632.	486563.	115.
29	770924	21	3.00	9777478.	34588.	57.
30	770925	16	3.00	16095811.	48406.	48.
31	771017	7	4.00	13492948.	231187.	275.
32	771030	21	4.00	33458186.	701519.	336.

NAME OF RIVER REACH

RED RIVER IN WINNIPEG

LENGTH(FEET)

105600.00

ELEVATION VERSUS SURFACE WIDTH

ELEVATION-FEET	SURFACE WIDTH-FEET	AREA-SQ.FEET
713.00	0.00	0.00
714.00	30.00	15.00
715.00	35.00	47.50
718.00	100.00	250.00
719.00	140.00	370.00
720.00	280.00	580.00
725.00	450.00	2405.00
730.00	500.00	4780.00
735.00	600.00	7530.00
740.00	620.00	10580.00
745.00	660.00	13780.00
750.00	680.00	17130.00

REACTION RATES AND TEMPERATURE CORRECTIONS

DEOXYGENATION		REAERATION	
RATE	TEMP.COR.	RATE	TEMP.COR.
0.2300	1.0470	0.2600	1.0160

INITIAL RIVER BODULT	INITIAL D.O. DEFICIT
1.00	1.00

RIVER DATA FOR EACH EVENT

EVENT	DATE YYMMDD	ELEVATION FEET	FLOW CFS	AREA SQ.FT.	VELOCITY FT./HR.	TEMPERATURE DEG.C
1	770504	732.24	1500.	6011.99	898.20	17.00
2	770505	733.82	1510.	6881.00	790.00	17.00
3	770514	734.29	1580.	7139.49	796.70	17.00
4	770518	734.28	2040.	7134.02	1029.43	20.00
5	770526	734.30	2790.	7144.99	1405.74	20.00
6	770528	734.06	2960.	7013.00	1519.46	20.00
7	770528	734.06	2960.	7013.00	1519.46	20.00
8	770529	733.86	2650.	6902.99	1382.01	20.00
9	770610	733.75	1900.	6842.50	999.63	20.50
10	770612	733.65	1750.	6787.51	928.17	21.50
11	770617	733.92	1390.	6935.99	721.45	21.50
12	770630	733.90	1160.	6925.01	603.03	21.50
13	770702	733.71	1090.	6820.51	575.32	21.50
14	770705	733.96	1110.	6958.01	574.30	21.50
15	770713	734.43	1700.	7216.50	848.06	23.50
16	770730	733.92	1800.	6935.99	934.26	22.50
17	770730	733.92	1800.	6935.99	934.26	22.50
18	770802	733.73	2040.	6831.49	1075.02	21.50
19	770804	733.82	1930.	6881.00	1009.74	21.50
20	770806	733.76	1810.	6848.01	951.52	21.50
21	770809	733.77	1650.	6853.51	866.71	19.50
22	770825	734.03	850.	6996.52	437.36	17.50
23	770829	733.86	670.	6902.99	349.41	17.00
24	770831	734.04	790.	7001.99	406.17	17.00
25	770903	733.91	880.	6930.49	457.11	16.50
26	770905	734.14	910.	7057.01	464.22	16.00
27	770908	733.76	845.	6848.01	444.22	16.00
28	770924	734.12	1580.	7046.00	807.27	15.00
29	770924	734.12	1580.	7046.00	807.27	15.00
30	770925	734.12	1820.	7046.00	929.89	14.00
31	771017	734.15	2650.	7062.51	1350.79	12.00
32	771030	732.68	2150.	6254.00	1237.61	11.00

RESULTS DISSOLVED OXYGEN EACH EVENT

EVENT	DATE YYMMDD	INTERVAL DAYS	INITIAL BODULT	INITIAL D.O.DEF	K1	K2	CRITICAL TIME-DAYS	CRITICAL DEFICIT	SATURATION DISS.OXYG.	MINIMUM DISS.OXYG.
1	770504	0.00	21.81	1.00	0.200	0.248	4.25	7.52	9.61	2.08
2	770505	0.46	18.75	2.56	0.200	0.248	3.79	7.10	9.61	2.51
3	770514	9.42	4.74	1.00	0.200	0.248	3.40	1.94	9.61	7.67
4	770518	3.46	11.87	1.18	0.230	0.260	3.65	4.53	9.02	4.49
5	770526	8.50	11.20	1.00	0.230	0.260	3.70	4.23	9.02	4.79
6	770528	2.00	3.79	1.85	0.230	0.260	1.89	2.17	9.02	6.85
7	770528	0.38	5.46	1.18	0.230	0.260	3.14	2.35	9.02	6.67
8	770529	0.88	3.80	1.50	0.230	0.260	2.33	1.97	9.02	7.05
9	770610	11.63	9.22	1.00	0.235	0.262	3.56	3.58	8.93	5.35
10	770612	2.46	8.55	2.16	0.246	0.266	2.87	3.91	8.75	4.85
11	770617	4.50	9.33	1.60	0.246	0.266	3.20	3.92	8.75	4.83
12	770630	13.08	5.29	1.00	0.246	0.266	3.13	2.26	8.75	6.49
13	770702	2.13	6.40	1.85	0.246	0.266	2.72	3.03	8.75	5.72
14	770705	3.13	3.48	1.98	0.246	0.266	1.55	2.20	8.75	6.55
15	770713	7.79	18.32	1.00	0.270	0.275	3.47	7.06	8.42	1.36
16	770730	16.63	5.48	1.00	0.258	0.271	3.07	2.36	8.58	6.22
17	770730	0.54	6.02	1.47	0.258	0.271	2.84	2.76	8.58	5.82
18	770802	3.17	2.08	1.35	0.246	0.266	1.20	1.44	8.75	7.32
19	770804	1.71	4.55	1.12	0.246	0.266	2.89	2.06	8.75	6.69
20	770806	2.29	6.96	1.49	0.246	0.266	3.03	3.05	8.75	5.70
21	770809	2.79	3.83	1.82	0.225	0.258	1.96	2.15	9.11	6.97
22	770825	15.67	12.44	1.00	0.205	0.250	4.01	4.48	9.50	5.02
23	770829	4.42	14.04	3.25	0.200	0.248	3.29	5.87	9.61	3.74
24	770831	1.63	10.62	3.42	0.200	0.248	2.81	4.89	9.61	4.71
25	770903	3.46	15.90	2.81	0.196	0.246	3.62	6.23	9.71	3.48
26	770905	1.42	12.36	3.49	0.191	0.244	3.08	5.38	9.82	4.44
27	770908	3.46	11.66	3.14	0.191	0.244	3.15	5.00	9.82	4.81
28	770924	15.42	10.52	1.00	0.183	0.240	4.23	3.70	10.03	6.34
29	770924	0.75	8.68	1.92	0.183	0.240	3.50	3.48	10.03	6.55
30	770925	0.79	7.31	1.74	0.175	0.236	3.48	2.94	10.26	7.32
31	771017	21.63	5.86	1.00	0.159	0.229	4.09	2.12	10.75	8.62
32	771030	13.58	17.15	1.00	0.152	0.225	4.98	5.43	11.00	5.57

NUMBER	MIN. D.O.	DYS EXCEED.	% EXCEED.
1	1.36	32.00	100.00
2	2.08	31.00	96.88
3	2.51	30.00	93.75
4	3.48	29.00	90.63
5	3.74	28.00	87.50
6	4.44	27.00	84.38
7	4.49	26.00	81.25
8	4.71	25.00	78.13
9	4.79	24.00	75.00
10	4.81	23.00	71.88
11	4.83	22.00	68.75
12	4.85	21.00	65.63
13	5.02	20.00	62.50
14	5.35	19.00	59.38
15	5.57	18.00	56.25
16	5.70	17.00	53.13
17	5.72	16.00	50.00
18	5.82	15.00	46.88
19	6.22	14.00	43.75
20	6.34	13.00	40.63
21	6.49	12.00	37.50
22	6.55	11.00	34.38
23	6.55	10.00	31.25
24	6.67	9.00	28.13
25	6.69	8.00	25.00
26	6.85	7.00	21.88
27	6.97	6.00	18.75
28	7.05	5.00	15.63
29	7.32	4.00	12.50
30	7.32	3.00	9.38
31	7.67	2.00	6.25
32	8.62	1.00	3.13

10.4 APPENDIX 4

DRY WEATHER FLOW MODEL
AND DETAILED RESULTS

TITLE DWF MODEL - RED RIVER PAGE 1 OF 1 **TI Programmable Program Record**

PROGRAMMER B. D. MacBride DATE 25 March 79

Partitioning (Op 17) 2,3,9.2,9 Library Module ______ Printer ______ Cards ______

PROGRAM DESCRIPTION

DWF MODEL - RED RIVER

$$K^1 = K\ \theta^{(T-20)}$$

$$D_{crit} = La \frac{K_1}{K_2} e^{-K_1 x T_{ert}}$$

$$La = \frac{Q_R \times BOD_R + Q_P \times BOD_P}{Q_R + Q_P}$$

$$Da = \frac{Q_R \times D_R + Q_D \times D_P}{Q_R + Q_D}$$

$$T_{crit} = \left(\frac{1}{K_2 - K_1}\right) \ln \left(\frac{K_2}{K_1} \left(1 - \frac{Da(K_2-K_1)}{K_1(La)}\right.\right.$$

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS			DISPLAY
	K1		STO	00		
	K2		STO	01		
	θ1		STO	02		
	θ2		STO	03		
	Q River		STO	04		
	B.O.D. River Ultimate		STO	05		
	D.O.D. River		STO	06		
	Temp		STO	07		
	Q Plant		STO	08		
	B.O.D. Plant Ultimate		STO	09		
	D.O.D. Plant		STO	10		
	Calculate Tc			A		K1'
				R/S		K2'
	Note: ULT B.O.D. = 1.5 x $B.O.D._5$			R/S		La
				R/S		Da
				R/S		T_{crit}
				B		D_{crit}

USER DEFINED KEYS	
A	
B	
C	
D	
E	
A'	
B'	
C'	
D'	
E'	

DATA REGISTERS (INV List)

0	K1	10	DO Deficit Plant
1	K2	11	K1 (Temp Corr)
2	θ1	12	Temp - 20
3	θ2	13	K2 (Temp Corr)
4	QR	14	$Q_R + Q_P$
5	$B.O.D._{RIVER}$	15	Mixed $B.O.D._{ULT}$
6	D.O. Det_R	16	Mixed D.O $_{DEF}$
7	$Temp_R$	17	K2 - K1
8	Q_{PLANT}	18	$Time_{crit}$
9	$B.O.D._{PLANT\ ULT}$	9	

LABELS (Op 08)

INV lnx CE CLR x⇌t x² √x 1/x STO RCL SUM yˣ EE ( ) ÷ GTO × SBR − RST + R/S . +/− = CLR INV log CP tan Pgm P→R sin cos CMs Exc Prd |x| Eng Fix Int Deg Pause x=t Nop Op Rad Lbl x≥t Σ+ x̄ Grad St flg If flg D.MS π List Write Dsz Adv Prt

FLAGS 0	1	2	3	4	5	6	7	8	9

E______________________ PAGE ____ OF ____

GRAMMER B. D. MacBride DATE ____________

TI Programmable Coding Form

LOC	CODE	KEY	COMMENTS
		2nd	
		Lbl	
		A	
		RCL	
		00	Calculate
		X	
		RCL	K1'
		02	
		y^x	
		(	
		RCL	
		07	
		-	
		2	
		0	
		)	
		STO12	Temp-20
		=	
		STO11	K1'
		R/S	
		RCL	
		01	Calculate
		x	
		RCL	K2'
		03	
		y^x	
		RCL	
		12	
		=	
		STO13	K2'
		R/S	
		RCL	
		04	Calculate
		x	Initial
		RCL	B.O.D.
		05	ULT
		+	MIXED
		RCL	
		08	
		x	
		RCL	
		09	
		=	
		÷	
		(	
		RCL	
		04	
		+	
		RCL	
		08	
		)	
		STO14	$Q_R + Q_P$
		=	
		STO15	La
		R/S	

LOC	CODE	KEY	COMMENTS
		RCL	
		04	
		x	
		RCL	
		06	Calculate
		+	Initial
		RCL	Deficit
		08	
		x	
		RCL	
		10	
		=	
		÷	
		RCL	
		14	
		=	
		STO16	Da
		R/S	
		1	
		÷	
		(	Calculate
		RCL	
		13	$T_{Critical}$
		-	
		RCL	
		11	
		)	
		STO17	$K_2 - K_1$
		x	
		(	
		RCL	
		13	
		÷	
		RCL	
		11	
		x	
		(	
		1	
		-	
		RCL	
		16	
		x	
		RCL	
		17	
		÷	
		RCL	
		11	
		÷	
		RCL	
		15	
		)	
		)	
		lnx	
		=	
		STO18	TC

LOC	CODE	KEY	COMMENTS
		R/S	
		2nd	
		Lbl	
		B	
		RCL	
		15	Calculate
		x	Critical
		RCL	Deficit
		11	
		÷	
		RCL	
		13	
		x	
		(	
		-	
		1	
		x	
		RCL	
		11	
		x	
		RCL	
		18	
		)	
		2nd Inv	
		lnx	
		=	
		R/S	

MERGED CODES

62 Pgm Ind	72 STO Ind	83 GTO Ind
63 Exc Ind	73 RCL Ind	84 Op Ind
64 Prd Ind	74 SUM Ind	92 INV SBR

TEXAS INSTRUMENTS INCORPORATED

TI-24151

DWF MODEL

SUMMARY OF RESULTS

May - September 1977

	Min. D.O. Concentration Range	Average
1. Existing (Secondary)	5.96 - 7.77	6.75
2. 30% Removal (Primary)	1.12 - 3.21	1.98
3. No DWF Treatment	0 - 0.40	0.08
4. Advanced Treatment (90% Removal)	6.73 - 8.77	7.55
5. Existing ½ River Flows	4.07 - 6.06	5.18

	RIVER				PLANT			INITIAL RESULTS							
Month	Q	BOD	DQ-DEF	TEMP	Q	BOD	DO-DEF	BOD	DO DEFICIT	K1	K2	T_{crit}	D_{crit}	DO SAT.	DO MIN.
May	2040	1.0	1.0	20.0	118	45* (68)	4	4.67	1.16	0.23	0.26	2.98	2.08	9.17	7.09
June	1670	1.0	1.0	21.5	127	38 (57)	4	4.96	1.21	0.246	0.266	2.90	2.24	8.91	6.67
July	1540	1.0	1.0	24.0	126	41 (62)	4	5.61	1.23	0.276	0.277	2.82	2.57	8.53	5.96
August	1240	1.0	1.0	18.0	118	58 (87)	4	8.47	1.26	0.210	0.252	3.62	3.30	9.54	6.24
Sept.	1450	1.0	1.0	13.5	149	46 (69)	4	7.34	1.28	0.171	0.235	3.92	2.73	10.49	7.77

$K1 = 0.23$
$K2 = 0.26$
$\theta 1 = 1.047$
$\theta 2 = 1.016$

DRY WEATHER FLOW MODEL
RESULTS FOR EXISTING
CONDITIONS

Month	RIVER Q	RIVER BOD	RIVER DO-DEF	RIVER TEMP	PLANT Q	PLANT BOD	PLANT DO-DEF	INITIAL RESULTS BOD	INITIAL RESULTS DO DEFICIT	INITIAL RESULTS K1	INITIAL RESULTS K2	INITIAL RESULTS T_{crit}	INITIAL RESULTS D_{crit}	DO SAT.	DO MIN.
May	2040	1.0	1.0	20.0	118	330	4.0	18.99	1.16	0.23	0.26	3.82	6.98	9.17	2.19
June	1670	1.0	1.0	21.5	127	242	4.0	18.03	1.21	0.246	0.266	3.63	6.82	8.91	2.09
July	1540	1.0	1.0	24.0	126	231	4.0	18.39	1.23	0.276	0.277	3.37	7.23	8.53	1.30
August	1240	1.0	1.0	18.0	118	264	4.0	23.85	1.26	0.210	0.252	4.09	8.42	9.54	1.12
Sept.	1450	1.0	1.0	13.5	149	227	4.0	22.06	1.28	0.171	0.235	4.63	7.28	10.49	3.21

$K1 = 0.23$
$K2 = 0.26$
$\theta 1 = 1.047$
$\theta 2 = 1.016$

DRY WEATHER FLOW MODEL
RESULTS
PRIMARY TREATMENT ONLY
30% REMOVAL

Month	RIVER				PLANT						INITIAL RESULTS				
	Q	BOD	DO-DEF	TEMP	Q	BOD	DO-DEF	BOD	DO DEFICIT	K1	K2	T_{crit}	D_{crit}	DO SAT.	DO MIN.
May	2040	1.0	1.0	20.0	118	471	4.0	26.70	1.16	0.230	0.260	3.90	9.64	9.17	--
June	1670	1.0	1.0	21.5	127	345	4.0	25.31	1.21	0.246	0.266	3.71	9.39	8.91	--
July	1540	1.0	1.0	24.0	126	330	4.0	25.88	1.23	0.276	0.277	3.44	9.97	8.53	--
August	1240	1.0	1.0	18.0	118	378	4.0	33.76	1.26	0.210	0.252	4.17	11.74	9.54	--
Sept.	1450	1.0	1.0	13.5	149	324	4.0	31.10	1.28	0.171	0.235	4.73	10.09	10.49	0.40

$K1 = 0.23$
$K2 = 0.26$
$\Theta 1 = 1.047$
$\Theta 2 = 1.016$

DRY WEATHER FLOW MODEL
RESULTS
NO DWF TREATMENT

	RIVER				PLANT			INITIAL RESULTS							
Month	Q	BOD	DO-DEF	TEMP	Q	BOD	DO-DEF	BOD	DO DEFICIT	K1	K2	T_{crit}	D_{crit}	DO SAT.	DO MIN.
May	2040	1.0	1.0	20.0	118	47	4.0	3.52	1.16	0.23	0.26	2.62	1.70	9.17	7.47
June	1670	1.0	1.0	21.5	127	35	4.0	3.40	1.21	0.246	0.266	2.44	1.73	8.91	7.18
July	1540	1.0	1.0	24.0	126	33	4.0	3.42	1.23	0.276	0.277	2.32	1.80	8.53	6.73
August	1240	1.0	1.0	18.0	118	38	4.0	4.22	1.26	0.210	0.252	2.87	1.92	9.54	7.62
Sept.	1450	1.0	1.0	13.5	149	32	4.0	3.89	1.28	0.171	0.235	2.92	1.72	10.49	8.77

K1 = 0.23
K2 = 0.26
$\theta 1 = 1.047$
$\theta 2 = 1.016$

DRY WEATHER FLOW MODEL
RESULTS
90% REMOVAL ADVANCED
TREATMENT

	RIVER				PLANT			INITIAL RESULTS							
Month	Q	BOD	DO-DEF	TEMP	Q	BOD	DO-DEF	BOD	DO DEFICIT	K1	K2	T_{crit}	D_{crit}	DO SAT.	DO MIN.
May	1020	1.0	1.0	20.0	118	68	4.0	7.94	1.31	0.23	0.20	3.36	3.24	9.17	5.93
June	835	1.0	1.0	21.5	127	57	4.0	8.39	1.40	0.246	0.266	3.22	3.51	8.91	5.40
July	770	1.0	1.0	24.0	126	62	4.0	9.58	1.42	0.276	0.277	3.08	4.08	8.53	4.45
August	620	1.0	1.0	18.0	118	87	4.0	14.75	1.48	0.210	0.252	3.86	5.47	9.54	4.07
Sept.	725	1.0	1.0	13.5	149	69	4.0	12.59	1.51	0.171	0.235	4.26	4.43	10.49	6.06

$K1 = 0.23$
$K2 = 0.26$
$\Theta 1 = 1.047$
$\Theta 2 = 1.016$

DRY WEATHER FLOW MODEL
RESULTS
½ RIVER FLOWS

10.5 APPENDIX 5

DETAILED PRINTOUTS

"RVRQUAL" RESULTS

RESULTS DISSOLVED OXYGEN EACH EVENT

EVENT	DATE YYMMDD	INTERVAL DAYS	INITIAL BODULT	INITIAL D.O.DEF	K1	K2	CRITICAL TIME-DAYS	CRITICAL DEFICIT	SATURATION DISS.OXYG.	MINIMUM DISS.OXYG.
1	770504	0.00	21.81	0.00	0.200	0.334	3.83	6.08	9.61	3.52
2	770505	0.46	18.75	1.63	0.200	0.334	3.38	5.72	9.61	3.89
3	770514	9.42	4.74	0.00	0.200	0.334	3.83	1.32	9.61	8.28
4	770518	3.46	11.87	0.25	0.230	0.350	3.41	3.56	9.02	5.46
5	770526	8.50	11.20	0.00	0.230	0.350	3.50	3.29	9.02	5.73
6	770528	2.00	3.79	0.89	0.230	0.350	2.41	1.43	9.02	7.59
7	770528	0.38	5.46	0.26	0.230	0.350	3.29	1.68	9.02	7.34
8	770529	0.88	3.80	0.62	0.230	0.350	2.76	1.32	9.02	7.70
9	770610	11.63	9.22	0.00	0.235	0.353	3.45	2.73	8.93	6.20
10	770612	2.46	8.55	1.25	0.246	0.358	2.73	3.00	8.75	5.75
11	770617	4.50	9.33	0.64	0.246	0.358	3.06	3.02	8.75	5.74
12	770630	13.08	5.29	0.00	0.246	0.358	3.35	1.59	8.75	7.16
13	770702	2.13	6.40	1.05	0.246	0.358	2.65	2.29	8.75	6.46
14	770705	3.13	3.48	1.14	0.246	0.358	1.91	1.50	8.75	7.26
15	770713	7.79	18.32	0.00	0.270	0.370	3.15	5.71	8.42	2.70
16	770730	16.63	5.48	0.00	0.258	0.364	3.25	1.68	8.58	6.90
17	770730	0.54	6.02	0.57	0.258	0.364	2.87	2.04	8.58	6.55
18	770802	3.17	2.08	0.42	0.246	0.358	2.49	0.78	8.75	7.98
19	770804	1.71	4.55	0.32	0.246	0.358	3.06	1.47	8.75	7.28
20	770806	2.29	6.96	0.65	0.246	0.358	2.96	2.31	8.75	6.45
21	770809	2.79	3.83	0.93	0.225	0.347	2.39	1.45	9.11	7.67
22	770825	15.67	12.44	0.00	0.205	0.336	3.77	3.50	9.50	6.00
23	770829	4.42	14.04	2.24	0.200	0.334	2.98	4.64	9.61	4.97
24	770831	1.63	10.62	2.52	0.200	0.334	2.54	3.84	9.61	5.77
25	770903	3.46	15.90	1.89	0.196	0.331	3.25	4.98	9.71	4.73
26	770905	1.42	12.36	2.59	0.191	0.328	2.76	4.25	9.82	5.56
27	770908	3.46	11.66	2.19	0.191	0.328	2.89	3.91	9.82	5.91
28	770924	15.42	10.52	0.00	0.183	0.323	4.06	2.83	10.03	7.20
29	770924	0.75	8.68	1.03	0.183	0.323	3.38	2.65	10.03	7.39
30	770925	0.79	7.31	0.86	0.175	0.318	3.47	2.19	10.26	8.08
31	771017	21.63	5.86	0.00	0.159	0.308	4.43	1.50	10.75	9.25
32	771030	13.58	17.15	0.00	0.152	0.303	4.56	4.30	11.00	6.71

RUN 001

CALIBRATION & SENSITIVITY

K1 = 0.23 B.O.D.$_U$ = 1.0

K2 = 0.35 D.O.D. = 0.0

RESULTS DISSOLVED OXYGEN EACH EVENT

EVENT	DATE YYMMDD	INTERVAL DAYS	INITIAL BODULT	INITIAL D.O.DEF	K1	K2	CRITICAL TIME-DAYS	CRITICAL DEFICIT	SATURATION DISS.OXYG.	MINIMUM DISS.OXYG.
1	770504	0.00	21.81	1.00	0.200	0.334	3.59	6.37	9.61	3.23
2	770505	0.46	18.75	2.50	0.200	0.334	3.13	6.01	9.61	3.59
3	770514	9.42	4.74	1.00	0.200	0.334	2.69	1.66	9.61	7.94
4	770518	3.46	11.87	1.12	0.230	0.350	3.08	3.84	9.02	5.18
5	770526	8.50	11.20	1.00	0.230	0.350	3.10	3.61	9.02	5.42
6	770528	2.00	3.79	1.74	0.230	0.350	1.22	1.88	9.02	7.14
7	770528	0.38	5.46	1.15	0.230	0.350	2.53	2.01	9.02	7.02
8	770529	0.88	3.80	1.43	0.230	0.350	1.68	1.70	9.02	7.33
9	770610	11.63	9.22	1.00	0.235	0.353	2.97	3.05	8.93	5.88
10	770612	2.46	8.55	1.97	0.246	0.358	2.36	3.29	8.75	5.46
11	770617	4.50	9.33	1.43	0.246	0.358	2.70	3.30	8.75	5.45
12	770630	13.08	5.29	1.00	0.246	0.358	2.54	1.94	8.75	6.81
13	770702	2.13	6.40	1.67	0.246	0.358	2.22	2.55	8.75	6.21
14	770705	3.13	3.48	1.74	0.246	0.358	1.04	1.85	8.75	6.90
15	770713	7.79	18.32	1.00	0.270	0.370	2.95	6.04	8.42	2.38
16	770730	16.63	5.48	1.00	0.258	0.364	2.51	2.03	8.58	6.55
17	770730	0.54	6.02	1.41	0.258	0.364	2.29	2.36	8.58	6.22
18	770802	3.17	2.08	1.26	0.246	0.358	0.47	1.28	8.75	7.48
19	770804	1.71	4.55	1.04	0.246	0.358	2.37	1.75	8.75	7.01
20	770806	2.29	6.96	1.37	0.246	0.358	2.51	2.58	8.75	6.18
21	770809	2.79	3.83	1.65	0.225	0.347	1.38	1.82	9.11	7.29
22	770825	15.67	12.44	1.00	0.205	0.336	3.37	3.80	9.50	5.70
23	770829	4.42	14.04	2.74	0.200	0.334	2.78	4.83	9.61	4.78
24	770831	1.63	10.62	3.17	0.200	0.334	2.17	4.13	9.61	5.47
25	770903	3.46	15.90	2.45	0.196	0.331	3.05	5.18	9.71	4.53
26	770905	1.42	12.36	3.27	0.191	0.328	2.41	4.54	9.82	5.27
27	770908	3.46	11.66	2.75	0.191	0.328	2.59	4.14	9.82	5.68
28	770924	15.42	10.52	1.00	0.183	0.323	3.52	3.13	10.03	6.91
29	770924	0.75	8.68	1.84	0.183	0.323	2.79	2.95	10.03	7.09
30	770925	0.79	7.31	1.67	0.175	0.318	2.73	2.49	10.26	7.77
31	771017	21.63	5.86	1.00	0.159	0.308	3.27	1.80	10.75	8.95
32	771030	13.58	17.15	1.00	0.152	0.303	4.17	4.56	11.00	6.44

RUN 002

CALIBRATION & SENSITIVITY

K1 = 0.23 B.O.D.$_U$ = 1.0

K2 = 0.35 D.O.D. = 1.0

RESULTS DISSOLVED OXYGEN EACH EVENT

EVENT	DATE YYMMDD	INTERVAL DAYS	INITIAL BODULT	INITIAL D.O.DEF	K1	K2	CRITICAL TIME-DAYS	CRITICAL DEFICIT	SATURATION DISS.OXYG.	MINIMUM DISS.OXYG.
1	770504	0.00	21.81	1.00	0.200	0.248	4.25	7.52	9.61	2.08
2	770505	0.46	18.75	2.56	0.200	0.248	3.79	7.10	9.61	2.51
3	770514	9.42	4.74	1.00	0.200	0.248	3.40	1.94	9.61	7.67
4	770518	3.46	11.87	1.18	0.230	0.260	3.65	4.53	9.02	4.49
5	770526	8.50	11.20	1.00	0.230	0.260	3.70	4.23	9.02	4.79
6	770528	2.00	3.79	1.85	0.230	0.260	1.89	2.17	9.02	6.85
7	770528	0.38	5.46	1.18	0.230	0.260	3.14	2.35	9.02	6.67
8	770529	0.88	3.80	1.50	0.230	0.260	2.33	1.97	9.02	7.05
9	770610	11.63	9.22	1.00	0.235	0.262	3.56	3.58	8.93	5.35
10	770612	2.46	8.55	2.16	0.246	0.266	2.87	3.91	8.75	4.85
11	770617	4.50	9.33	1.60	0.246	0.266	3.20	3.92	8.75	4.83
12	770630	13.08	5.29	1.00	0.246	0.266	3.13	2.26	8.75	6.49
13	770702	2.13	6.40	1.85	0.246	0.266	2.72	3.03	8.75	5.72
14	770705	3.13	3.48	1.98	0.246	0.266	1.55	2.20	8.75	6.55
15	770713	7.79	18.32	1.00	0.270	0.275	3.47	7.06	8.42	1.36
16	770730	16.63	5.48	1.00	0.258	0.271	3.07	2.36	8.58	6.22
17	770730	0.54	6.02	1.47	0.258	0.271	2.84	2.76	8.58	5.82
18	770802	3.17	2.08	1.35	0.246	0.266	1.20	1.44	8.75	7.32
19	770804	1.71	4.55	1.12	0.246	0.266	2.89	2.06	8.75	6.69
20	770806	2.29	6.96	1.49	0.246	0.266	3.03	3.05	8.75	5.70
21	770809	2.79	3.83	1.82	0.225	0.258	1.96	2.15	9.11	6.97
22	770825	15.67	12.44	1.00	0.205	0.250	4.01	4.48	9.50	5.02
23	770829	4.42	14.04	3.25	0.200	0.248	3.29	5.87	9.61	3.74
24	770831	1.63	10.62	3.42	0.200	0.248	2.81	4.89	9.61	4.71
25	770903	3.46	15.90	2.81	0.196	0.246	3.62	6.23	9.71	3.48
26	770905	1.42	12.36	3.49	0.191	0.244	3.08	5.38	9.82	4.44
27	770908	3.46	11.66	3.14	0.191	0.244	3.15	5.00	9.82	4.81
28	770924	15.42	10.52	1.00	0.183	0.240	4.23	3.70	10.03	6.34
29	770924	0.75	8.68	1.92	0.183	0.240	3.50	3.48	10.03	6.55
30	770925	0.79	7.31	1.74	0.175	0.236	3.48	2.94	10.26	7.32
31	771017	21.63	5.86	1.00	0.159	0.229	4.09	2.12	10.75	8.62
32	771030	13.58	17.15	1.00	0.152	0.225	4.98	5.43	11.00	5.57

RUN 003

CALIBRATION & SENSITIVITY

K1 = 0.23 B.O.D.$_U$ = 1.0

K2 = 0.175 D.O.D. = 1.0

RESULTS DISSOLVED OXYGEN EACH EVENT

EVENT	DATE YYMMDD	INTERVAL DAYS	INITIAL BODULT	INITIAL D.O.DEF	K1	K2	CRITICAL TIME-DAYS	CRITICAL DEFICIT	SATURATION DISS.OXYG.	MINIMUM DISS.OXYG.
1	770504	0.00	21.81	1.00	0.200	0.167	5.23	9.18	9.61	0.43
2	770505	0.46	18.75	2.62	0.200	0.167	4.77	8.66	9.61	0.95
3	770514	9.42	4.74	1.00	0.200	0.167	4.43	2.35	9.61	7.26
4	770518	3.46	11.87	1.25	0.230	0.175	4.52	5.52	9.02	3.50
5	770526	8.50	11.20	1.00	0.230	0.175	4.58	5.13	9.02	3.90
6	770528	2.00	3.79	1.97	0.230	0.175	2.84	2.60	9.02	6.43
7	770528	0.38	5.46	1.21	0.230	0.175	4.03	2.84	9.02	6.18
8	770529	0.88	3.80	1.57	0.230	0.175	3.26	2.36	9.02	6.66
9	770610	11.63	9.22	1.00	0.235	0.176	4.44	4.33	8.93	4.60
10	770612	2.46	8.55	2.38	0.246	0.179	3.65	4.78	8.75	3.97
11	770617	4.50	9.33	1.81	0.246	0.179	3.97	4.82	8.75	3.93
12	770630	13.08	5.29	1.00	0.246	0.179	3.99	2.72	8.75	6.03
13	770702	2.13	6.40	2.04	0.246	0.179	3.50	3.72	8.75	5.04
14	770705	3.13	3.48	2.25	0.246	0.179	2.32	2.70	8.75	6.05
15	770713	7.79	18.32	1.00	0.270	0.185	4.25	8.50	8.42	-0.08
16	770730	16.63	5.48	1.00	0.258	0.182	3.90	2.84	8.58	5.74
17	770730	0.54	6.02	1.52	0.258	0.182	3.65	3.33	8.58	5.25
18	770802	3.17	2.08	1.46	0.246	0.179	2.14	1.69	8.75	7.06
19	770804	1.71	4.55	1.21	0.246	0.179	3.70	2.52	8.75	6.24
20	770806	2.29	6.96	1.63	0.246	0.179	3.82	3.73	8.75	5.02
21	770809	2.79	3.83	2.01	0.225	0.174	2.84	2.62	9.11	6.49
22	770825	15.67	12.44	1.00	0.205	0.168	4.99	5.45	9.50	4.05
23	770829	4.42	14.04	3.87	0.200	0.167	4.12	7.39	9.61	2.21
24	770831	1.63	10.62	3.68	0.200	0.167	3.78	5.98	9.61	3.62
25	770903	3.46	15.90	3.22	0.196	0.166	4.53	7.75	9.71	1.96
26	770905	1.42	12.36	3.73	0.191	0.164	4.09	6.58	9.82	3.23
27	770908	3.46	11.66	3.60	0.191	0.164	4.06	6.25	9.82	3.56
28	770924	15.42	10.52	1.00	0.183	0.162	5.30	4.52	10.03	5.51
29	770924	0.75	8.68	2.00	0.183	0.162	4.57	4.26	10.03	5.78
30	770925	0.79	7.31	1.81	0.175	0.159	4.59	3.60	10.26	6.67
31	771017	21.63	5.86	1.00	0.159	0.154	5.31	2.60	10.75	8.15
32	771030	13.58	17.15	1.00	0.152	0.152	6.20	6.70	11.00	4.30

RUN 004

FINAL CALIBRATION

K1 = 0.23 B.O.D.$_U$ = 1.0

K2 = 0.26 D.O.D. = 1.0

RESULTS DISSOLVED OXYGEN EACH EVENT

EVENT	DATE YYMMDD	INTERVAL DAYS	INITIAL BODULT	INITIAL D.O.DEF	K1	K2	CRITICAL TIME-DAYS	CRITICAL DEFICIT	SATURATION DISS.OXYG.	MINIMUM DISS.OXYG.
1	770504	0.00	21.81	1.00	0.200	0.420	3.14	5.55	9.61	4.05
2	770505	0.46	18.75	2.43	0.200	0.420	2.67	5.24	9.61	4.36
3	770514	9.42	4.74	1.00	0.200	0.420	2.18	1.47	9.61	8.14
4	770518	3.46	11.87	1.07	0.230	0.440	2.68	3.35	9.02	5.67
5	770526	8.50	11.20	1.00	0.230	0.440	2.68	3.16	9.02	5.86
6	770528	2.00	3.79	1.64	0.230	0.440	0.70	1.69	9.02	7.33
7	770528	0.38	5.46	1.12	0.230	0.440	2.10	1.76	9.02	7.26
8	770529	0.88	3.80	1.36	0.230	0.440	1.20	1.51	9.02	7.51
9	770610	11.63	9.22	1.00	0.235	0.444	2.56	2.68	8.93	6.25
10	770612	2.46	8.55	1.81	0.246	0.451	2.01	2.85	8.75	5.91
11	770617	4.50	9.33	1.31	0.246	0.451	2.35	2.86	8.75	5.89
12	770630	13.08	5.29	1.00	0.246	0.451	2.12	1.71	8.75	7.04
13	770702	2.13	6.40	1.52	0.246	0.451	1.89	2.20	8.75	6.55
14	770705	3.13	3.48	1.55	0.246	0.451	0.70	1.60	8.75	7.15
15	770713	7.79	18.32	1.00	0.270	0.465	2.58	5.30	8.42	3.12
16	770730	16.63	5.48	1.00	0.258	0.458	2.11	1.79	8.58	6.79
17	770730	0.54	6.02	1.36	0.258	0.458	1.91	2.08	8.58	6.51
18	770802	3.17	2.08	1.19	0.246	0.451	-0.19	1.19	8.75	7.56
19	770804	1.71	4.55	0.97	0.246	0.451	2.00	1.52	8.75	7.23
20	770806	2.29	6.96	1.26	0.246	0.451	2.16	2.24	8.75	6.52
21	770809	2.79	3.83	1.50	0.225	0.437	0.96	1.59	9.11	7.52
22	770825	15.67	12.44	1.00	0.205	0.423	2.91	3.32	9.50	6.18
23	770829	4.42	14.04	2.35	0.200	0.420	2.45	4.11	9.61	5.50
24	770831	1.63	10.62	2.94	0.200	0.420	1.73	3.59	9.61	6.01
25	770903	3.46	15.90	2.16	0.196	0.416	2.67	4.44	9.71	5.27
26	770905	1.42	12.36	3.06	0.191	0.413	1.95	3.95	9.82	5.87
27	770908	3.46	11.66	2.42	0.191	0.413	2.23	3.53	9.82	6.29
28	770924	15.42	10.52	1.00	0.183	0.406	3.02	2.73	10.03	7.31
29	770924	0.75	8.68	1.77	0.183	0.406	2.29	2.57	10.03	7.46
30	770925	0.79	7.31	1.60	0.175	0.400	2.20	2.17	10.26	8.09
31	771017	21.63	5.86	1.00	0.159	0.388	2.67	1.58	10.75	9.17
32	771030	13.58	17.15	1.00	0.152	0.381	3.61	3.95	11.00	7.05

RUN 005

CALIBRATION & SENSITIVITY

K1 = 0.23 B.O.D.$_U$ = 1.0

K2 = 0.26 D.O.D. = 1.0

RESULTS DISSOLVED OXYGEN EACH EVENT

EVENT	DATE YYMMDD	INTERVAL DAYS	INITIAL BODULT	INITIAL D.O.DEF	K1	K2	CRITICAL TIME-DAYS	CRITICAL DEFICIT	SATURATION DISS.OXYG.	MINIMUM DISS.OXYG.
1	770504	0.00	22.62	1.00	0.200	0.334	3.60	6.60	9.61	3.00
2	770505	0.46	19.49	2.56	0.200	0.334	3.14	6.24	9.61	3.37
3	770514	9.42	5.72	1.00	0.200	0.334	2.90	1.92	9.61	7.68
4	770518	3.46	12.69	1.17	0.230	0.350	3.09	4.10	9.02	4.92
5	770526	8.50	12.08	1.00	0.230	0.350	3.13	3.86	9.02	5.16
6	770528	2.00	4.64	1.81	0.230	0.350	1.61	2.11	9.02	6.91
7	770528	0.38	6.23	1.21	0.230	0.350	2.61	2.25	9.02	6.78
8	770529	0.88	4.52	1.51	0.230	0.350	1.90	1.92	9.02	7.10
9	770610	11.63	10.18	1.00	0.235	0.353	3.02	3.34	8.93	5.59
10	770612	2.46	9.27	2.10	0.246	0.358	2.37	3.55	8.75	5.20
11	770617	4.50	10.05	1.49	0.246	0.358	2.72	3.53	8.75	5.22
12	770630	13.08	6.26	1.00	0.246	0.358	2.67	2.23	8.75	6.52
13	770702	2.13	7.08	1.86	0.246	0.358	2.21	2.82	8.75	5.93
14	770705	3.13	4.07	1.86	0.246	0.358	1.26	2.05	8.75	6.70
15	770713	7.79	19.20	1.00	0.270	0.370	2.96	6.31	8.42	2.11
16	770730	16.63	6.46	1.00	0.258	0.364	2.63	2.32	8.58	6.26
17	770730	0.54	6.88	1.52	0.258	0.364	2.35	2.66	8.58	5.92
18	770802	3.17	2.94	1.32	0.246	0.358	1.30	1.47	8.75	7.29
19	770804	1.71	5.27	1.17	0.246	0.358	2.39	2.01	8.75	6.75
20	770806	2.29	7.63	1.47	0.246	0.358	2.53	2.81	8.75	5.94
21	770809	2.79	4.52	1.73	0.225	0.347	1.64	2.03	9.11	7.09
22	770825	15.67	13.41	1.00	0.205	0.336	3.40	4.07	9.50	5.43
23	770829	4.42	14.61	2.92	0.200	0.334	2.76	5.05	9.61	4.56
24	770831	1.63	11.11	3.27	0.200	0.334	2.19	4.30	9.61	5.30
25	770903	3.46	16.38	2.54	0.196	0.331	3.05	5.34	9.71	4.37
26	770905	1.42	12.80	3.35	0.191	0.328	2.43	4.69	9.82	5.13
27	770908	3.46	12.06	2.82	0.191	0.328	2.60	4.27	9.82	5.54
28	770924	15.42	11.44	1.00	0.183	0.323	3.56	3.37	10.03	6.66
29	770924	0.75	9.50	1.93	0.183	0.323	2.85	3.19	10.03	6.84
30	770925	0.79	8.05	1.75	0.175	0.318	2.81	2.70	10.26	7.56
31	771017	21.63	6.84	1.00	0.159	0.308	3.45	2.04	10.75	8.70
32	771030	13.58	18.11	1.00	0.152	0.303	4.19	4.80	11.00	6.20

RUN 006

CALIBRATION & SENSITIVITY

K1 = 0.23 B.O.D.$_U$ = 2.0

K2 = 0.35 D.O.D. = 1.0

RESULTS DISSOLVED OXYGEN EACH EVENT

EVENT	DATE YYMMDD	INTERVAL DAYS	INITIAL BODULT	INITIAL D.O.DEF	K1	K2	CRITICAL TIME-DAYS	CRITICAL DEFICIT	SATURATION DISS.OXYG.	MINIMUM DISS.OXYG.
1	770504	0.00	21.81	1.00	0.148	0.334	4.06	5.31	9.61	4.30
2	770505	0.46	19.18	2.09	0.148	0.334	3.59	5.00	9.61	4.60
3	770514	9.42	4.74	1.00	0.148	0.334	2.72	1.41	9.61	8.20
4	770518	3.46	11.95	1.07	0.170	0.350	3.46	3.23	9.02	5.80
5	770526	8.50	11.20	1.00	0.170	0.350	3.46	3.02	9.02	6.00
6	770528	2.00	4.07	1.55	0.170	0.350	1.15	1.63	9.02	7.40
7	770528	0.38	5.74	1.10	0.170	0.350	2.76	1.75	9.02	7.28
8	770529	0.88	4.15	1.30	0.170	0.350	1.76	1.49	9.02	7.53
9	770610	11.63	9.22	1.00	0.174	0.353	3.29	2.56	8.93	6.37
10	770612	2.46	8.93	1.72	0.182	0.358	2.67	2.79	8.75	5.96
11	770617	4.50	9.59	1.37	0.182	0.358	2.99	2.83	8.75	5.93
12	770630	13.08	5.29	1.00	0.182	0.358	2.69	1.64	8.75	7.11
13	770702	2.13	6.72	1.45	0.182	0.358	2.51	2.16	8.75	6.59
14	770705	3.13	3.97	1.59	0.182	0.358	1.07	1.66	8.75	7.09
15	770713	7.79	18.32	1.00	0.200	0.370	3.34	5.07	8.42	3.34
16	770730	16.63	5.48	1.00	0.191	0.364	2.68	1.72	8.58	6.86
17	770730	0.54	6.18	1.27	0.191	0.364	2.53	2.00	8.58	6.59
18	770802	3.17	2.25	1.20	0.182	0.358	-0.29	1.20	8.75	7.55
19	770804	1.71	4.71	0.99	0.182	0.358	2.55	1.51	8.75	7.25
20	770806	2.29	7.21	1.26	0.182	0.358	2.79	2.20	8.75	6.55
21	770809	2.79	4.20	1.50	0.166	0.347	1.35	1.61	9.11	7.51
22	770825	15.67	12.44	1.00	0.152	0.336	3.76	3.17	9.50	6.33
23	770829	4.42	14.86	2.39	0.148	0.334	3.16	4.13	9.61	5.48
24	770831	1.63	11.91	2.71	0.148	0.334	2.57	3.61	9.61	5.99
25	770903	3.46	16.99	2.29	0.145	0.331	3.42	4.53	9.71	5.18
26	770905	1.42	13.82	2.80	0.141	0.328	2.84	3.99	9.82	5.83
27	770908	3.46	12.77	2.54	0.141	0.328	2.87	3.66	9.82	6.15
28	770924	15.42	10.52	1.00	0.135	0.323	3.88	2.60	10.03	7.43
29	770924	0.75	8.97	1.59	0.135	0.323	3.13	2.46	10.03	7.58
30	770925	0.79	7.75	1.48	0.129	0.318	3.04	2.12	10.26	8.14
31	771017	21.63	5.86	1.00	0.118	0.308	3.36	1.51	10.75	9.24
32	771030	13.58	17.15	1.00	0.112	0.303	4.65	3.77	11.00	7.24

RUN 007

CALIBRATION & SENSITIVITY

$K1 = 0.17$ $\quad B.O.D._U = 1.0$

$K2 = 0.35$ $\quad D.O.D. = 1.0$

RESULTS DISSOLVED OXYGEN EACH EVENT

EVENT	DATE YYMMDD	INTERVAL DAYS	INITIAL BODULT	INITIAL D.O.DEF	K1	K2	CRITICAL TIME-DAYS	CRITICAL DEFICIT	SATURATION DISS.OXYG.	MINIMUM DISS.OXYG.
1	770504	0.00	21.81	1.00	0.306	0.334	2.98	8.04	9.61	1.57
2	770505	0.46	17.93	3.29	0.306	0.334	2.52	7.59	9.61	2.01
3	770514	9.42	4.74	1.00	0.306	0.334	2.43	2.07	9.61	7.54
4	770518	3.46	11.74	1.19	0.351	0.350	2.57	4.79	9.02	4.24
5	770526	8.50	11.20	1.00	0.351	0.350	2.60	4.51	9.02	4.51
6	770528	2.00	3.33	2.05	0.351	0.350	1.10	2.27	9.02	6.75
7	770528	0.38	5.00	1.23	0.351	0.350	2.15	2.35	9.02	6.67
8	770529	0.88	3.23	1.63	0.351	0.350	1.42	1.97	9.02	7.05
9	770610	11.63	9.22	1.00	0.359	0.353	2.51	3.81	8.93	5.12
10	770612	2.46	7.94	2.35	0.376	0.358	1.94	4.02	8.75	4.74
11	770617	4.50	9.01	1.47	0.376	0.358	2.29	3.99	8.75	4.76
12	770630	13.08	5.29	1.00	0.376	0.358	2.22	2.40	8.75	6.35
13	770702	2.13	5.87	2.01	0.376	0.358	1.82	3.11	8.75	5.65
14	770705	3.13	2.81	1.90	0.376	0.358	0.95	2.06	8.75	6.70
15	770713	7.79	18.32	1.00	0.412	0.370	2.43	7.51	8.42	0.91
16	770730	16.63	5.48	1.00	0.394	0.364	2.18	2.51	8.58	6.07
17	770730	0.54	5.73	1.68	0.394	0.364	1.90	2.93	8.58	5.65
18	770802	3.17	1.86	1.33	0.376	0.358	0.85	1.42	8.75	7.34
19	770804	1.71	4.32	1.11	0.376	0.358	2.04	2.10	8.75	6.65
20	770806	2.29	6.59	1.53	0.376	0.358	2.11	3.13	8.75	5.63
21	770809	2.79	3.30	1.83	0.343	0.347	1.27	2.11	9.11	7.01
22	770825	15.67	12.44	1.00	0.313	0.336	2.82	4.78	9.50	4.72
23	770829	4.42	12.88	3.16	0.306	0.334	2.32	5.81	9.61	3.80
24	770831	1.63	8.71	3.88	0.306	0.334	1.64	4.83	9.61	4.78
25	770903	3.46	14.53	2.51	0.299	0.331	2.59	6.04	9.71	3.67
26	770905	1.42	10.31	4.03	0.292	0.328	1.85	5.33	9.82	4.48
27	770908	3.46	10.27	2.88	0.292	0.328	2.25	4.73	9.82	5.08
28	770924	15.42	10.52	1.00	0.279	0.323	2.98	3.95	10.03	6.08
29	770924	0.75	8.14	2.33	0.279	0.323	2.28	3.72	10.03	6.31
30	770925	0.79	6.50	1.99	0.266	0.318	2.24	2.99	10.26	7.27
31	771017	21.63	5.86	1.00	0.243	0.308	2.93	2.27	10.75	8.48
32	771030	13.58	17.15	1.00	0.232	0.303	3.50	5.82	11.00	5.18

RUN 008

CALIBRATION & SENSITIVITY

K1 = 0.351 B.O.D.$_U$ = 1.0

K2 = 0.35 D.O.D. = 1.0

RESULTS DISSOLVED OXYGEN EACH EVENT

EVENT	DATE YYMMDD	INTERVAL DAYS	INITIAL BODULT	INITIAL D.O.DEF	K1	K2	CRITICAL TIME-DAYS	CRITICAL DEFICIT	SATURATION DISS.OXYG.	MINIMUM DISS.OXYG.
1	770504	0.00	23.29	1.00	0.200	0.248	4.26	8.01	9.61	1.59
2	770505	0.46	21.26	2.67	0.200	0.248	3.84	7.96	9.61	1.65
3	770514	9.42	5.05	1.00	0.200	0.248	3.47	2.04	9.61	7.57
4	770518	3.46	12.65	1.20	0.230	0.260	3.67	4.81	9.02	4.21
5	770526	8.50	11.61	1.00	0.230	0.260	3.71	4.37	9.02	4.65
6	770528	2.00	4.02	1.89	0.230	0.260	1.98	2.26	9.02	6.77
7	770528	0.38	5.78	1.19	0.230	0.260	3.18	2.46	9.02	6.56
8	770529	0.88	4.20	1.53	0.230	0.260	2.46	2.11	9.02	6.91
9	770610	11.63	9.56	1.00	0.235	0.262	3.58	3.70	8.93	5.23
10	770612	2.46	9.05	2.22	0.246	0.266	2.90	4.10	8.75	4.65
11	770617	4.50	10.05	1.65	0.246	0.266	3.23	4.19	8.75	4.56
12	770630	13.08	5.53	1.00	0.246	0.266	3.16	2.35	8.75	6.41
13	770702	2.13	6.83	1.90	0.246	0.266	2.76	3.20	8.75	5.55
14	770705	3.13	3.90	2.06	0.246	0.266	1.71	2.37	8.75	6.39
15	770713	7.79	18.74	1.00	0.270	0.275	3.47	7.21	8.42	1.21
16	770730	16.63	5.56	1.00	0.258	0.271	3.09	2.39	8.58	6.19
17	770730	0.54	6.18	1.48	0.258	0.271	2.85	2.82	8.58	5.76
18	770802	3.17	2.34	1.36	0.246	0.266	1.47	1.50	8.75	7.25
19	770804	1.71	4.88	1.16	0.246	0.266	2.93	2.19	8.75	6.56
20	770806	2.29	7.34	1.54	0.246	0.266	3.04	3.21	8.75	5.54
21	770809	2.79	4.06	1.88	0.225	0.258	2.02	2.25	9.11	6.87
22	770825	15.67	13.33	1.00	0.205	0.250	4.04	4.78	9.50	4.73
23	770829	4.42	14.63	3.44	0.200	0.248	3.27	6.14	9.61	3.46
24	770831	1.63	11.20	3.53	0.200	0.248	2.84	5.12	9.61	4.48
25	770903	3.46	16.22	2.92	0.196	0.246	3.60	6.38	9.71	3.33
26	770905	1.42	12.81	3.55	0.191	0.244	3.11	5.54	9.82	4.28
27	770908	3.46	13.47	3.23	0.191	0.244	3.32	5.60	9.82	4.22
28	770924	15.42	11.28	1.00	0.183	0.240	4.27	3.94	10.03	6.10
29	770924	0.75	9.52	2.00	0.183	0.240	3.57	3.77	10.03	6.26
30	770925	0.79	8.12	1.83	0.175	0.236	3.56	3.22	10.26	7.04
31	771017	21.63	6.58	1.00	0.159	0.229	4.22	2.34	10.75	8.41
32	771030	13.58	17.69	1.00	0.152	0.225	4.99	5.59	11.00	5.41

RUN 009

PRIMARY TREATMENT

OF DRY WEATHER FLOW

RESULTS DISSOLVED OXYGEN EACH EVENT

EVENT	DATE YYMMDD	INTERVAL DAYS	INITIAL BOD ULT	INITIAL D.O.DEF	K1	K2	CRITICAL TIME-DAYS	CRITICAL DEFICIT	SATURATION DISS.OXYG.	MINIMUM DISS.OXYG.
1	770504	0.00	24.14	1.00	0.200	0.248	4.27	8.29	9.61	1.31
2	770505	0.46	22.66	2.74	0.200	0.248	3.87	8.44	9.61	1.16
3	770514	9.42	5.27	1.00	0.200	0.248	3.51	2.11	9.61	7.50
4	770518	3.46	13.16	1.21	0.230	0.260	3.68	4.99	9.02	4.03
5	770526	8.50	11.87	1.00	0.230	0.260	3.72	4.47	9.02	4.56
6	770528	2.00	4.16	1.91	0.230	0.260	2.03	2.31	9.02	6.71
7	770528	0.38	5.97	1.20	0.230	0.260	3.20	2.53	9.02	6.49
8	770529	0.88	4.43	1.56	0.230	0.260	2.52	2.19	9.02	6.83
9	770610	11.63	9.83	1.00	0.235	0.262	3.59	3.79	8.93	5.14
10	770612	2.46	9.45	2.26	0.246	0.266	2.92	4.25	8.75	4.50
11	770617	4.50	10.74	1.68	0.246	0.266	3.26	4.45	8.75	4.31
12	770630	13.08	5.70	1.00	0.246	0.266	3.19	2.40	8.75	6.35
13	770702	2.13	7.07	1.94	0.246	0.266	2.78	3.30	8.75	5.45
14	770705	3.13	4.14	2.11	0.246	0.266	1.79	2.47	8.75	6.29
15	770713	7.79	19.00	1.00	0.270	0.275	3.48	7.30	8.42	1.11
16	770730	16.63	5.66	1.00	0.258	0.271	3.10	2.43	8.58	6.15
17	770730	0.54	6.35	1.49	0.258	0.271	2.87	2.89	8.58	5.69
18	770802	3.17	2.51	1.38	0.246	0.266	1.63	1.56	8.75	7.20
19	770804	1.71	5.17	1.19	0.246	0.266	2.96	2.31	8.75	6.45
20	770806	2.29	7.66	1.59	0.246	0.266	3.05	3.34	8.75	5.42
21	770809	2.79	4.23	1.92	0.225	0.258	2.06	2.32	9.11	6.79
22	770825	15.67	13.88	1.00	0.205	0.250	4.06	4.96	9.50	4.55
23	770829	4.42	15.07	3.56	0.200	0.248	3.27	6.33	9.61	3.27
24	770831	1.63	11.82	3.62	0.200	0.248	2.89	5.35	9.61	4.25
25	770903	3.46	16.53	3.05	0.196	0.246	3.58	6.53	9.71	3.18
26	770905	1.42	13.31	3.60	0.191	0.244	3.15	5.72	9.82	4.10
27	770908	3.46	14.75	3.33	0.191	0.244	3.40	6.04	9.82	3.78
28	770924	15.42	11.90	1.00	0.183	0.240	4.29	4.13	10.03	5.90
29	770924	0.75	10.20	2.06	0.183	0.240	3.62	4.01	10.03	6.03
30	770925	0.79	8.79	1.90	0.175	0.236	3.62	3.45	10.26	6.81
31	771017	21.63	7.05	1.00	0.159	0.229	4.29	2.48	10.75	8.27
32	771030	13.58	18.06	1.00	0.152	0.225	5.00	5.70	11.00	5.30

RUN 010

NO DRY WEATHER

FLOW TREATMENT

RESULTS DISSOLVED OXYGEN EACH EVENT

EVENT	DATE YYMMDD	INTERVAL DAYS	INITIAL BODULT	INITIAL D.O.DEF	K1	K2	CRITICAL TIME-DAYS	CRITICAL DEFICIT	SATURATION DISS.OXYG.	MINIMUM DISS.OXYG.
1	770504	0.00	17.63	1.00	0.200	0.248	4.19	6.15	9.61	3.46
2	770505	0.46	15.21	2.24	0.200	0.248	3.73	5.82	9.61	3.78
3	770514	9.42	3.98	1.00	0.200	0.248	3.18	1.70	9.61	7.91
4	770518	3.46	9.92	1.13	0.230	0.260	3.59	3.85	9.02	5.17
5	770526	8.50	9.21	1.00	0.230	0.260	3.61	3.55	9.02	5.47
6	770528	2.00	3.22	1.68	0.230	0.260	1.74	1.91	9.02	7.11
7	770528	0.38	4.58	1.14	0.230	0.260	2.99	2.04	9.02	6.98
8	770529	0.88	3.25	1.39	0.230	0.260	2.17	1.74	9.02	7.28
9	770610	11.63	7.54	1.00	0.235	0.262	3.46	3.00	8.93	5.93
10	770612	2.46	7.08	1.91	0.246	0.266	2.79	3.29	8.75	5.46
11	770617	4.50	7.85	1.47	0.246	0.266	3.14	3.35	8.75	5.40
12	770630	13.08	4.46	1.00	0.246	0.266	2.98	1.98	8.75	6.78
13	770702	2.13	5.35	1.67	0.246	0.266	2.62	2.59	8.75	6.16
14	770705	3.13	2.98	1.76	0.246	0.266	1.45	1.93	8.75	6.82
15	770713	7.79	15.33	1.00	0.270	0.275	3.43	5.97	8.42	2.45
16	770730	16.63	4.50	1.00	0.258	0.271	2.92	2.02	8.58	6.56
17	770730	0.54	4.94	1.36	0.258	0.271	2.71	2.34	8.58	6.24
18	770802	3.17	1.88	1.27	0.246	0.266	1.09	1.33	8.75	7.43
19	770804	1.71	3.85	1.09	0.246	0.266	2.74	1.81	8.75	6.94
20	770806	2.29	5.80	1.38	0.246	0.266	2.93	2.61	8.75	6.15
21	770809	2.79	3.26	1.64	0.225	0.258	1.82	1.89	9.11	7.23
22	770825	15.67	10.15	1.00	0.205	0.250	3.92	3.72	9.50	5.78
23	770829	4.42	11.54	2.75	0.200	0.248	3.25	4.86	9.61	4.74
24	770831	1.63	8.88	2.94	0.200	0.248	2.76	4.13	9.61	5.48
25	770903	3.46	13.24	2.45	0.196	0.246	3.58	5.23	9.71	4.48
26	770905	1.42	10.32	3.04	0.191	0.244	3.01	4.55	9.82	5.27
27	770908	3.46	9.76	2.73	0.191	0.244	3.10	4.23	9.82	5.59
28	770924	15.42	6.78	1.00	0.183	0.240	4.12	3.15	10.03	6.89
29	770924	0.75	7.30	1.74	0.183	0.240	3.40	2.98	10.03	7.05
30	770925	0.79	6.19	1.60	0.175	0.236	3.35	2.55	10.26	7.71
31	771017	21.63	4.98	1.00	0.159	0.229	3.89	1.87	10.75	8.88
32	771030	13.58	14.24	1.00	0.152	0.225	4.90	4.56	11.00	6.44

RUN 011

25% TREATMENT OF COMBINED

SEWER OVERFLOWS

RESULTS DISSOLVED OXYGEN EACH EVENT

EVENT	DATE YYMMDD	INTERVAL DAYS	INITIAL BODULT	INITIAL D.O.DEF	K1	K2	CRITICAL TIME-DAYS	CRITICAL DEFICIT	SATURATION DISS.OXYG.	MINIMUM DISS.OXYG.
1	770504	0.00	13.45	1.00	0.200	0.248	4.10	4.78	9.61	4.83
2	770505	0.46	11.66	1.92	0.200	0.248	3.64	4.55	9.61	5.06
3	770514	9.42	3.21	1.00	0.200	0.248	2.86	1.46	9.61	8.14
4	770518	3.46	7.98	1.09	0.230	0.260	3.49	3.16	9.02	5.86
5	770526	8.50	7.22	1.00	0.230	0.260	3.48	2.87	9.02	6.15
6	770528	2.00	2.64	1.50	0.230	0.260	1.52	1.65	9.02	7.37
7	770528	0.38	3.70	1.10	0.230	0.260	2.77	1.73	9.02	7.29
8	770529	0.88	2.69	1.29	0.230	0.260	1.94	1.52	9.02	7.50
9	770610	11.63	5.87	1.00	0.235	0.262	3.29	2.43	8.93	6.50
10	770612	2.46	5.60	1.66	0.246	0.266	2.69	2.67	8.75	6.08
11	770617	4.50	6.37	1.33	0.246	0.266	3.05	2.78	8.75	5.97
12	770630	13.08	3.63	1.00	0.246	0.266	2.77	1.70	8.75	7.06
13	770702	2.13	4.30	1.48	0.246	0.266	2.48	2.16	8.75	6.60
14	770705	3.13	2.48	1.55	0.246	0.266	1.31	1.66	8.75	7.09
15	770713	7.79	12.33	1.00	0.270	0.275	3.37	4.88	8.42	3.54
16	770730	16.63	3.52	1.00	0.258	0.271	2.68	1.68	8.58	6.90
17	770730	0.54	3.86	1.26	0.258	0.271	2.51	1.93	8.58	6.66
18	770802	3.17	1.67	1.18	0.246	0.266	0.96	1.22	8.75	7.53
19	770804	1.71	3.14	1.05	0.246	0.266	2.52	1.56	8.75	7.19
20	770806	2.29	4.64	1.27	0.246	0.266	2.78	2.16	8.75	6.59
21	770809	2.79	2.68	1.47	0.225	0.258	1.61	1.63	9.11	7.49
22	770825	15.67	7.86	1.00	0.205	0.250	3.78	2.97	9.50	6.53
23	770829	4.42	9.05	2.26	0.200	0.248	3.19	3.86	9.61	5.75
24	770831	1.63	7.13	2.46	0.200	0.248	2.68	3.37	9.61	6.24
25	770903	3.46	10.58	2.09	0.196	0.246	3.51	4.24	9.71	5.47
26	770905	1.42	8.27	2.58	0.191	0.244	2.91	3.71	9.82	6.10
27	770908	3.46	7.85	2.31	0.191	0.244	3.01	3.46	9.82	6.36
28	770924	15.42	7.04	1.00	0.183	0.240	3.96	2.60	10.03	7.44
29	770924	0.75	5.92	1.57	0.183	0.240	3.24	2.49	10.03	7.55
30	770925	0.79	5.07	1.46	0.175	0.236	3.17	2.16	10.26	8.11
31	771017	21.63	4.10	1.00	0.159	0.229	3.59	1.61	10.75	9.14
32	771030	13.58	11.32	1.00	0.157	0.225	4.77	3.70	11.00	7.31

RUN 012

50% TREATMENT OF COMBINED

SEWER OVERFLOWS

RESULTS DISSOLVED OXYGEN EACH EVENT

EVENT	DATE YYMMDD	INTERVAL DAYS	INITIAL BODULT	INITIAL D.O.DEF	K1	K2	CRITICAL TIME-DAYS	CRITICAL DEFICIT	SATURATION DISS.OXYG.	MINIMUM DISS.OXYG.
1	770504	0.00	9.27	1.00	0.200	0.248	3.93	3.41	9.61	6.20
2	770505	0.46	8.12	1.61	0.200	0.248	3.47	3.28	9.61	6.33
3	770514	9.42	2.45	1.00	0.200	0.248	2.33	1.24	9.61	8.37
4	770518	3.46	6.03	1.04	0.230	0.260	3.33	2.48	9.02	6.54
5	770526	8.50	5.23	1.00	0.230	0.260	3.25	2.19	9.02	6.83
6	770528	2.00	2.07	1.33	0.230	0.260	1.17	1.40	9.02	7.62
7	770528	0.38	2.82	1.06	0.230	0.260	2.41	1.43	9.02	7.59
8	770529	0.88	2.14	1.18	0.230	0.260	1.59	1.31	9.02	7.71
9	770610	11.63	4.20	1.00	0.235	0.262	3.00	1.86	8.93	7.07
10	770612	2.46	4.13	1.41	0.246	0.266	2.50	2.06	8.75	6.69
11	770617	4.50	4.89	1.20	0.246	0.266	2.90	2.22	8.75	6.54
12	770630	13.08	2.80	1.00	0.246	0.266	2.43	1.42	8.75	7.33
13	770702	2.13	3.25	1.30	0.246	0.266	2.25	1.73	8.75	7.03
14	770705	3.13	1.98	1.33	0.246	0.266	1.10	1.40	8.75	7.36
15	770713	7.79	9.33	1.00	0.270	0.275	3.27	3.79	8.42	4.63
16	770730	16.63	2.55	1.00	0.258	0.271	2.25	1.36	8.58	7.22
17	770730	0.54	2.78	1.15	0.258	0.271	2.16	1.52	8.58	7.06
18	770802	3.17	1.46	1.09	0.246	0.266	0.78	1.12	8.75	7.64
19	770804	1.71	2.44	1.02	0.246	0.266	2.18	1.32	8.75	7.43
20	770806	2.29	3.49	1.16	0.246	0.266	2.54	1.73	8.75	7.03
21	770809	2.79	2.11	1.29	0.225	0.258	1.30	1.37	9.11	7.74
22	770825	15.67	5.57	1.00	0.205	0.250	3.52	2.22	9.50	7.28
23	770829	4.42	6.55	1.77	0.200	0.248	3.09	2.85	9.61	6.75
24	770831	1.63	5.38	1.98	0.200	0.248	2.56	2.60	9.61	7.00
25	770903	3.46	7.93	1.73	0.196	0.246	3.40	3.24	9.71	6.47
26	770905	1.42	6.23	2.12	0.191	0.244	2.75	2.88	9.82	6.93
27	770908	3.46	5.95	1.89	0.191	0.244	2.87	2.69	9.82	7.12
28	770924	15.42	5.30	1.00	0.183	0.240	3.69	2.05	10.03	7.98
29	770924	0.75	4.53	1.39	0.183	0.240	2.99	2.00	10.03	8.04
30	770925	0.79	3.96	1.32	0.175	0.236	2.87	1.77	10.26	8.49
31	771017	21.63	3.22	1.00	0.159	0.229	3.11	1.36	10.75	9.38
32	771030	13.58	8.40	1.00	0.152	0.225	4.56	2.83	11.00	8.17

RUN 013

75% TREATMENT OF COMBINED

SEWER OVERFLOWS

RESULTS DISSOLVED OXYGEN EACH EVENT

EVENT	DATE YYMMDD	INTERVAL DAYS	INITIAL BODULT	INITIAL D.O.DEF	K1	K2	CRITICAL TIME-DAYS	CRITICAL DEFICIT	SATURATION DISS.OXYG.	MINIMUM DISS.OXYG.
1	770504	0.00	11.56	1.00	0.200	0.248	4.04	4.16	9.61	5.45
2	770505	0.46	10.13	1.78	0.200	0.248	3.58	3.99	9.61	5.61
3	770514	9.42	2.96	1.00	0.200	0.248	2.72	1.39	9.61	8.22
4	770518	3.46	6.54	1.07	0.230	0.260	3.37	2.67	9.02	6.35
5	770526	8.50	6.14	1.00	0.230	0.260	3.37	2.50	9.02	6.52
6	770528	2.00	2.37	1.41	0.230	0.260	1.39	1.52	9.02	7.50
7	770528	0.38	3.18	1.08	0.230	0.260	2.57	1.56	9.02	7.47
8	770529	0.88	2.33	1.23	0.230	0.260	1.72	1.39	9.02	7.63
9	770610	11.63	5.23	1.00	0.235	0.262	3.20	2.21	8.93	6.72
10	770612	2.46	4.84	1.56	0.246	0.266	2.58	2.38	8.75	6.38
11	770617	4.50	5.46	1.26	0.246	0.266	2.96	2.44	8.75	6.31
12	770630	13.08	3.21	1.00	0.246	0.266	2.62	1.56	8.75	7.20
13	770702	2.13	3.61	1.39	0.246	0.266	2.31	1.89	8.75	6.86
14	770705	3.13	2.11	1.40	0.246	0.266	1.13	1.48	8.75	7.27
15	770713	7.79	9.69	1.00	0.270	0.275	3.29	3.92	8.42	4.50
16	770730	16.63	3.30	1.00	0.258	0.271	2.60	1.61	8.58	6.97
17	770730	0.54	3.57	1.23	0.258	0.271	2.43	1.82	8.58	6.76
18	770802	3.17	1.55	1.16	0.246	0.266	0.78	1.18	8.75	7.57
19	770804	1.71	2.81	1.03	0.246	0.266	2.39	1.44	8.75	7.31
20	770806	2.29	3.99	1.21	0.246	0.266	2.65	1.92	8.75	6.83
21	770809	2.79	2.34	1.37	0.225	0.258	1.43	1.48	9.11	7.64
22	770825	15.67	6.90	1.00	0.205	0.250	3.69	2.65	9.50	6.85
23	770829	4.42	7.53	2.05	0.200	0.248	3.07	3.29	9.61	6.32
24	770831	1.63	6.00	2.17	0.200	0.248	2.59	2.88	9.61	6.72
25	770903	3.46	8.39	1.86	0.196	0.246	3.38	3.44	9.71	6.27
26	770905	1.42	6.76	2.20	0.191	0.244	2.84	3.08	9.82	6.73
27	770908	3.46	6.62	2.00	0.191	0.244	2.97	2.94	9.82	6.87
28	770924	15.42	6.06	1.00	0.183	0.240	3.83	2.29	10.03	7.74
29	770924	0.75	5.13	1.47	0.183	0.240	3.11	2.21	10.03	7.83
30	770925	0.79	4.41	1.38	0.175	0.236	3.01	1.93	10.26	8.34
31	771017	21.63	3.62	1.00	0.159	0.229	3.36	1.48	10.75	9.27
32	771030	13.58	9.22	1.00	0.152	0.225	4.63	3.07	11.00	7.93

RUN 014

50% TREATMENT OF

WET WEATHER FLOW

RESULTS DISSOLVED OXYGEN EACH EVENT

EVENT	DATE YYMMDD	INTERVAL DAYS	INITIAL BODULT	INITIAL D.O.DEF	K1	K2	CRITICAL TIME-DAYS	CRITICAL DEFICIT	SATURATION DISS.OXYG.	MINIMUM DISS.OXYG.
1	770504	0.00	21.81	1.00	0.200	0.248	4.25	7.52	9.61	2.08
2	770505	0.46	19.50	2.63	0.200	0.248	3.79	7.37	9.61	2.24
3	770514	9.42	5.03	1.53	0.200	0.248	2.90	2.27	9.61	7.33
4	770518	3.46	12.45	1.61	0.230	0.260	3.52	4.90	9.02	4.12
5	770526	8.50	11.20	1.00	0.230	0.260	3.70	4.23	9.02	4.79
6	770528	2.00	5.86	2.80	0.230	0.260	1.94	3.32	9.02	5.70
7	770528	0.38	7.30	1.34	0.230	0.260	3.28	3.04	9.02	5.98
8	770529	0.88	5.56	1.85	0.230	0.260	2.61	2.70	9.02	6.32
9	770610	11.63	9.22	1.00	0.235	0.262	3.56	3.58	8.93	5.35
10	770612	2.46	9.56	2.79	0.246	0.266	2.70	4.54	8.75	4.21
11	770617	4.50	10.17	2.67	0.246	0.266	2.82	4.68	8.75	4.08
12	770630	13.08	5.22	1.02	0.246	0.266	3.11	2.25	8.75	6.50
13	770702	2.13	6.66	1.99	0.246	0.266	2.67	3.19	8.75	5.56
14	770705	3.13	3.97	2.38	0.246	0.266	1.41	2.60	8.75	6.16
15	770713	7.79	18.23	1.04	0.270	0.275	3.46	7.04	8.42	1.38
16	770730	16.63	5.48	1.00	0.258	0.271	3.07	2.36	8.58	6.22
17	770730	0.54	6.24	1.50	0.258	0.271	2.85	2.85	8.58	5.73
18	770802	3.17	2.78	2.00	0.246	0.266	0.89	2.06	8.75	6.69
19	770804	1.71	4.98	1.31	0.246	0.266	2.82	2.30	8.75	6.45
20	770806	2.29	7.51	1.83	0.246	0.266	2.90	3.40	8.75	5.36
21	770809	2.79	4.71	2.45	0.225	0.258	1.74	2.77	9.11	6.34
22	770825	15.67	12.25	0.87	0.205	0.250	4.06	4.37	9.50	5.13
23	770829	4.42	14.65	3.81	0.200	0.248	3.14	6.31	9.61	3.29
24	770831	1.63	11.69	3.76	0.200	0.248	2.81	5.38	9.61	4.22
25	770903	3.46	17.03	3.59	0.196	0.246	3.44	6.92	9.71	2.79
26	770905	1.42	13.91	3.93	0.191	0.244	3.08	6.05	9.82	3.77
27	770908	3.46	12.96	4.11	0.191	0.244	2.88	5.86	9.82	3.96
28	770924	15.42	10.52	1.00	0.183	0.240	4.23	3.70	10.03	6.34
29	770924	0.75	9.24	1.99	0.183	0.240	3.54	3.68	10.03	6.35
30	770925	0.79	8.27	1.88	0.175	0.236	3.55	3.29	10.26	6.97
31	771017	21.63	5.86	1.00	0.159	0.229	4.09	2.12	10.75	8.62
32	771030	13.58	17.15	1.00	0.152	0.225	4.98	5.43	11.00	5.57

RUN 015

ONE-HALF RIVER

FLOWS

RESULTS DISSOLVED OXYGEN EACH EVENT

EVENT	DATE YYMMDD	INTERVAL DAYS	INITIAL POLLUT	INITIAL D.O.DEF	K1	K2	CRITICAL TIME-DAYS	CRITICAL DEFICIT	SATURATION DISS.OXYG.	MINIMUM DISS.OXYG.
1	770504	0.00	21.59	1.00	0.200	0.248	4.25	7.45	9.61	2.15
2	770505	0.46	18.45	2.54	0.200	0.248	3.78	6.99	9.61	2.61
3	770514	9.42	4.62	1.00	0.200	0.248	3.37	1.90	9.61	7.71
4	770518	3.46	11.64	1.17	0.230	0.260	3.65	4.45	9.02	4.57
5	770526	8.50	11.08	1.00	0.230	0.260	3.69	4.19	9.02	4.83
6	770528	2.00	3.75	1.84	0.230	0.260	1.88	2.15	9.02	6.87
7	770528	0.38	5.41	1.18	0.230	0.260	3.13	2.33	9.02	6.69
8	770529	0.88	3.74	1.49	0.230	0.260	2.31	1.94	9.02	7.08
9	770610	11.63	9.03	1.00	0.235	0.262	3.55	3.52	8.93	5.42
10	770612	2.46	8.27	2.14	0.246	0.266	2.84	3.80	8.75	4.96
11	770617	4.50	8.69	1.58	0.246	0.266	3.16	3.69	8.75	5.06
12	770630	13.08	5.19	1.00	0.246	0.266	3.12	2.23	8.75	6.52
13	770702	2.13	6.34	1.83	0.246	0.266	2.72	3.00	8.75	5.75
14	770705	3.13	3.41	1.96	0.246	0.266	1.51	2.17	8.75	6.58
15	770713	7.79	18.24	1.00	0.270	0.275	3.47	7.03	8.42	1.39
16	770730	16.63	5.37	1.00	0.258	0.271	3.06	2.32	8.58	6.26
17	770730	0.54	5.83	1.45	0.258	0.271	2.81	2.69	8.58	5.89
18	770802	3.17	1.98	1.34	0.246	0.266	1.09	1.40	8.75	7.35
19	770804	1.71	4.29	1.11	0.246	0.266	2.85	1.97	8.75	6.78
20	770806	2.29	6.71	1.45	0.246	0.266	3.02	2.95	8.75	5.80
21	770809	2.79	3.73	1.78	0.225	0.258	1.95	2.10	9.11	7.02
22	770825	15.67	12.23	1.00	0.205	0.250	4.01	4.41	9.50	5.09
23	770829	4.42	13.74	3.20	0.200	0.248	3.28	5.76	9.61	3.85
24	770831	1.63	9.94	3.36	0.200	0.248	2.72	4.66	9.61	4.94
25	770903	3.46	15.61	2.67	0.196	0.246	3.65	6.08	9.71	3.63
26	770905	1.42	11.81	3.44	0.191	0.244	3.03	5.19	9.82	4.63
27	770908	3.46	10.91	3.03	0.191	0.244	3.11	4.72	9.82	5.09
28	770924	15.42	10.04	1.00	0.183	0.240	4.20	3.55	10.03	6.49
29	770924	0.75	8.15	1.87	0.183	0.240	3.45	3.30	10.03	6.73
30	770925	0.79	6.76	1.69	0.175	0.236	3.41	2.76	10.26	7.51
31	771017	21.63	5.62	1.00	0.159	0.229	4.04	2.05	10.75	8.69
32	771030	13.58	16.95	1.00	0.152	0.225	4.97	5.37	11.00	5.63

RUN 016

ADVANCED TREATMENT OF

DRY WEATHER FLOW