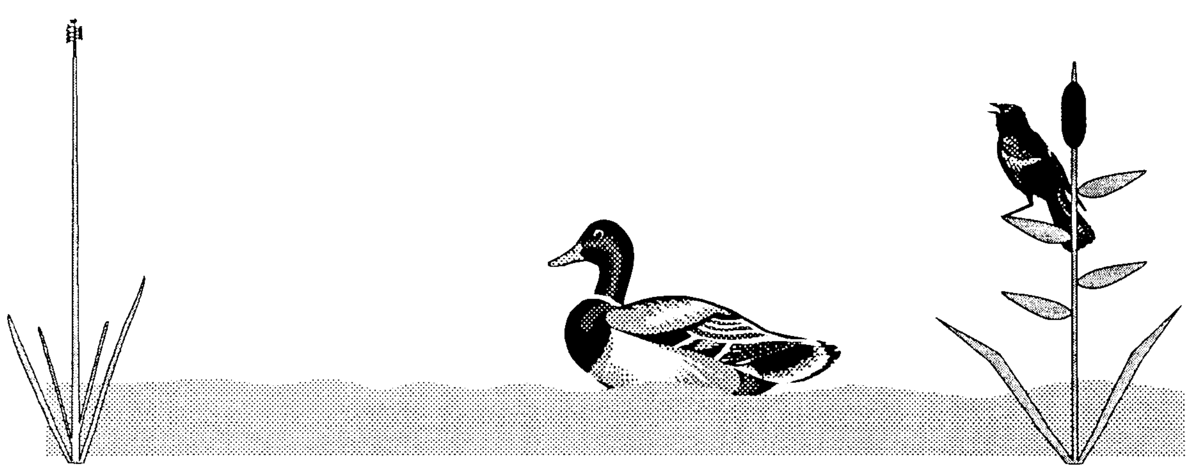
City of Winnipeg
Waterwork, Waste
and Disposal Department

Phase 1 Technical Memorandum for

Combined Sewer Overflow Management Study

RECEIVING STREAM

Technical Memorandum No. 4



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In Association With:

Gore & Storrie Limited and EMA Services Inc.

June 1994

DISCLAIMER

This Technical Memorandum is for information to the Phase 1 Workshop participants. It is a draft document intended for internal discussion and is not intended as a report representing the policy or direction of the City of Winnipeg.

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LIST OF ILLUSTRATIONS

1.0 INTRODUCTION

This technical memorandum reviews previous studies and more recent monitoring done on the Red and Assiniboine rivers. It is intended to provide background for the Phase 1 workshop of the City of Winnipeg's Combined Sewer Overflow Management Study. This draft document is intended for internal discussion and is not intended as a report representing the policy or direction of the City of Winnipeg.

Section 2 provides a physical description of the watershed and its hydrology. Section 3 reviews the river uses pertinent to the CSO Management Study, while Section 4 reviews the relevant water quality monitoring programs to date. A brief description of the past river modelling done for the City of Winnipeg. Section 6 provides conclusions which are to be the key discussion points for the workshop.

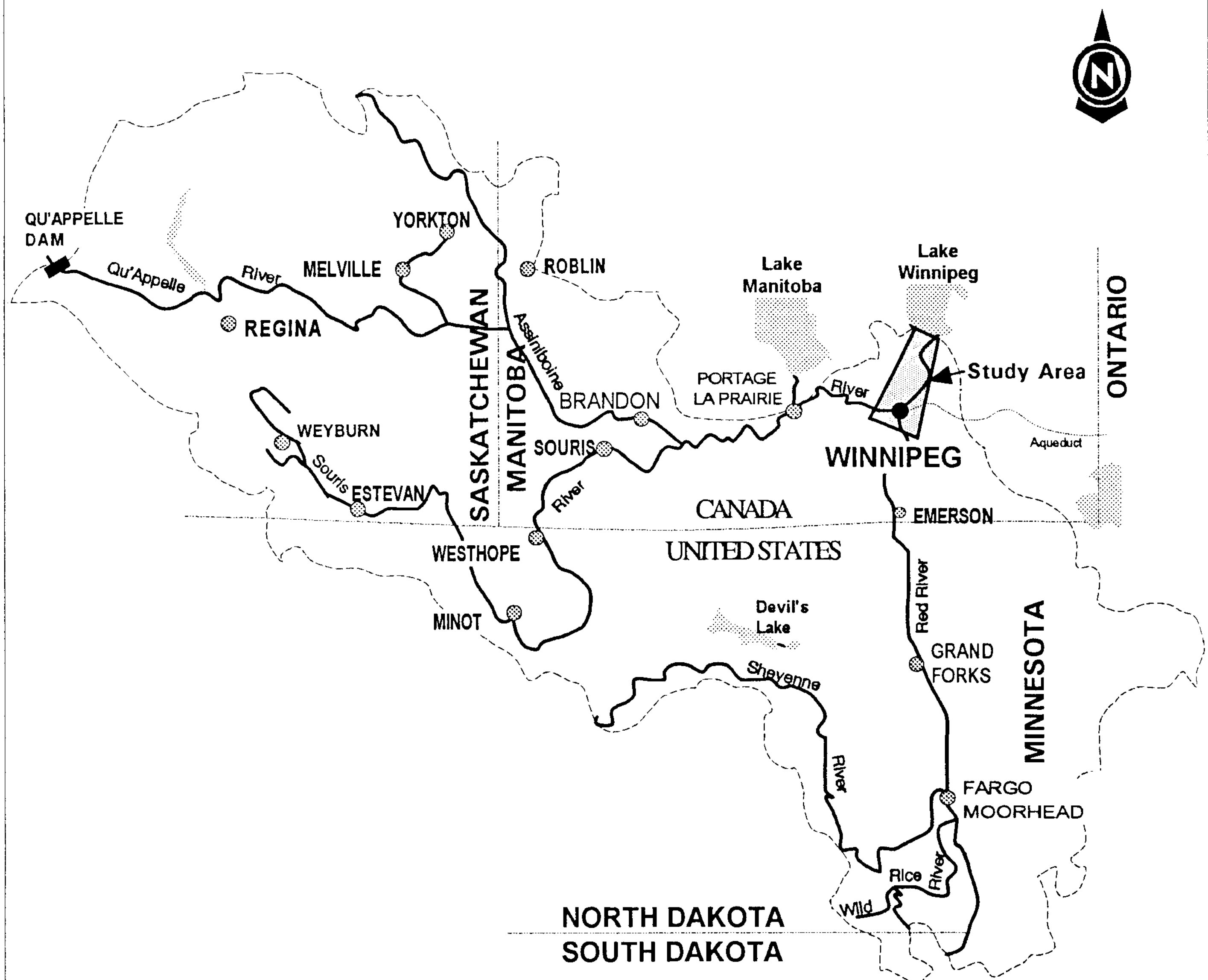
2.0 OVERVIEW OF THE RIVERS

2.1 THE RIVER BASINS

The study area comprises a small fraction of the overall river basins (Figure 2-1). The Red and Assiniboine Rivers drain the prairie regions of southern Manitoba, southeastern Saskatchewan, North Dakota, northern South Dakota, and northwestern Minnesota. The basin is almost entirely underlain by limestone bedrock. The bedrock is covered with a thick deposit of clay. Soils in the region are black and fine-textured. The Red River valley plain is virtually level, while the Assiniboine River passes through the Manitoba Escarpment in the western portion of the Province.

2.2 HYDROLOGY

The main tributaries of the Red and Assiniboine Rivers include the Ottertail, Sheyenne, Red Lake, Pembina, Roseau and Souris Rivers, plus numerous smaller rivers and streams. The total drainage area exceeds 270,000 km^2 (MacLaren 1986[1]). Much of the tributary area has been extensively drained.



The Red and Assiniboine Rivers Watershed

Figure 2-1

watrshed
csorec

The flow in the rivers is dominated by spring runoff. Snow melt, in combination with spring rains, has been responsible for major floods. Flows usually decrease steadily during the summer. Minimum annual flow month often occurs in February. Annual average flows on the Red River at the US border (at Emerson) are 96.4 m^3/s. Flows at Lockport, which include the contribution of the Assiniboine River, average annually 222 m^3/s (Williamson 1988b[2]).

Water flows and levels are regulated throughout the drainage basin, with over 15 control structures (Manitoba Water Resources Branch *pers. comm.* 1990[3]). On the Assiniboine River system, important control structures include the Shellmouth Dam and the Portage Diversion. The Rivers Reservoir is located on a tributary of the Assiniboine, and five small structures control flows on the Qu'Appelle River in Saskatchewan. The Winnipeg Floodway and the St. Andrews Locks are the major hydraulic structures on the Red River in Manitoba, although many smaller ones have been built on tributaries such as the LaSalle River. In the U.S.A., five major reservoirs are located on tributaries of the Red River: the Red Rock Reservoir on the Red Rock River; Orwell on the Ottertail River; Baldhill on the Sheyenne River; Homme Dam on the Park River and Lake Traverse.

Additional regulation of the Red and Assiniboine Rivers and their drainage basins may occur in the future. Current proposals include a control structure on the Red at Aubigny, intermittent diversion of the Pembina River into Pelican Lake, diversion of water from the Assiniboine River to southeastern Manitoba, and the regulation of the Souris River in Saskatchewan.

2.3 REGIONAL LAND USE

Land use in the drainage basins is principally agricultural, but numerous cities and towns are located on the riverbanks. The principal urban centres are: Fargo-Moorhead, Grand Forks, Minot, Brandon, Portage la Prairie, Winnipeg and Selkirk. Agricultural use affects water quality through the run-off of nutrients, pesticides and sediments. Towns, cities and residential areas discharge domestic and industrial sewage which has received varying levels of treatment. Sections of the river banks still remain in their natural state, and support a variety of birds and mammals, while many aquatic species are present in the river. Waterfowl conservation projects in the region are a major water user in the Red River Basin (CEC 1981[4]).

2.4 WATER QUALITY OVERVIEW

The water quality monitoring in the study area will be discussed in detail in Chapter 5.0. A brief general description on water quality in the Canadian reaches of the Red and Assiniboine Rivers is provided here. Very few general reviews on this topic are available and one of these is summarized briefly below (Williamson 1988b):

Water quality is influenced by many natural and anthropogenic factors. An important characteristic of the two rivers is the high sediment load, largely attributable to the underlying clay in the stream beds. Sediment is also contributed by runoff from rural and urban land. Nutrients and pesticides are also contributed from agricultural runoff. Phosphorus and various forms of nitrogen are the most common plant nutrients in the Red and Assiniboine Rivers. Long term trends in data collected at Selkirk suggest a slight decline in phosphorus, but an increase in nitrogen levels. With a few rare exceptions, dissolved oxygen has always been present at levels to maintain a healthy aquatic community, and concentrations of this critical parameter appear to be increasing over the long term. Microbiological indicators of wastewater discharges are also present in most reaches of the rivers. In general, toxic materials such as trace metals and organics, are present at acceptably low levels.

Water quality on the Red River as it enters Manitoba is monitored by the International Red River Pollution Board (IRRPB) under the auspices of the International Joint Commission. Several additional comments regarding water quality have been summarized from the 1990 report of water quality at Emerson (IRRPB 1990[5]). The pH (a measure of acidity or alkalinity) of the Red River ranges between 7.4 and 8.7, with most fluctuations attributed to algae activity or the impacts of runoff. Total suspended solids concentrations are generally very high in the river, typically ranging between 400-800 mg/L as compared to average WPCC effluent concentrations of 20 mg/L. Exceptionally warm water temperatures were also experienced during recent low flows in the river, although dissolved oxygen levels continued to meet objectives.

Another recent report of the IRRPB (Red River Toxic Profile Study: 1988) highlights water quality concerns along the Red River and its major tributaries. The study, using bioassay techniques, suggests that chronic toxicity problems may occur at several locations. Zinc and copper were suspected of causing toxicity to aquatic life at the Park River, the Red River at Selkirk, and at several locations on the Assiniboine River. Algae concentrations increased from upstream to downstream sampling stations, suggesting nutrient enrichment. However, algae assay tests indicate that the Red River may be limiting in phosphorus for algae. Un-ionized ammonia concerns were noted for sewage treatment plants at West Fargo, Moorhead, Wahpeton, and the NEWPCC and SEWPCC in Winnipeg. Provincial monitoring programs have occasionally found elevated levels of mercury in fish from the Red and Assiniboine Rivers, as well as the Souris and Winnipeg Rivers (D. Williamson *pers. comm.* 1990[6]).

The Red and Assiniboine Rivers are valued as aesthetic and sports fishing rivers. The rivers support a variety of water-based recreation of activities (discussed in Section 3.0) and there appears to be a trend towards greater public and regulatory concern towards protection of water quality in these streams.

2.5 LAKE WINNIPEG

Although outside of the study area, Lake Winnipeg deserves mention. Concern has been raised in the past regarding water quality in the lake, and possible contamination by the Red River.

The main rivers contributing inflow to Lake Winnipeg are the Red River (approximately 6% of total in flow), the Winnipeg River (32%), and the Saskatchewan River (39%). The latter is believed to contribute relatively little in terms of nutrients, because of the settling effects of Cedar Lake (Crowe 1977[7]). Although there are no urban centres directly on the lake, the numerous towns and many cottage developments may contribute to increases in nutrient and microbiological levels in the water. Agricultural runoff in other small inflowing rivers may also be a factor.

A limited number of studies have shown indications of elevated pollution levels. High nutrient levels, particularly phosphorus have been recorded. A comparison of aquatic invertebrates sampled in the 1930's and in the 1960's suggest a decline in pollution sensitive species and an increase in pollution-tolerant organisms (Crowe 1977). Microbiological levels in excess of the provincial objectives have been periodically recorded for beaches on the east and west shores of the lake (Williamson 1985[8]). However, no clear linkages can be made with the discharges for the City of Winnipeg (Williamson 1988b). Nonetheless, water quality in Lake Winnipeg is far superior to other eutrophic lakes, possibly attributable to the relatively short residence time of the lake which prevents the accumulation of nutrients and contaminants (Crowe 1977).

2.6 HYDRAULICS OF THE RED AND ASSINIBOINE IN THE STUDY AREA

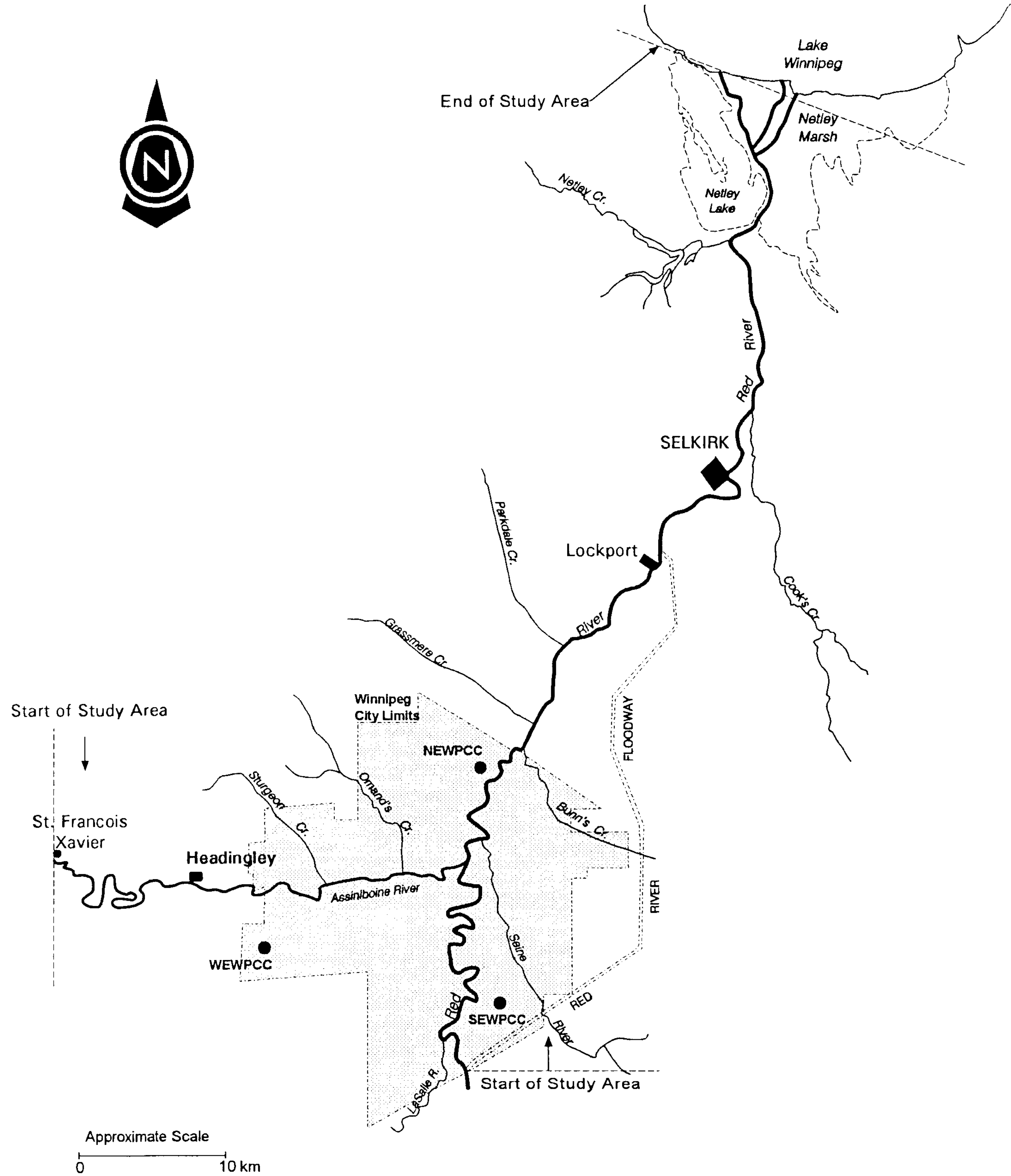
The hydraulic characteristics of the Red and Assiniboine Rivers are important in defining the modelling required to assess water quality. The key hydraulic structure in the study area is the St. Andrews Lock and Dam located at Lockport (see Figure 2-2). This dam is used to control the level of the Red River for recreational purposes during the summer. The elevation is maintained at 734.0 feet Above Sea Level (ASL) in Winnipeg from late April until October. This creates a backwater from Lockport up to the south side of the City on the Red River and until about Omands Creek within the City on the Assiniboine River. The hydraulic gradient in this region is very flat thereby creating low flow velocity on the Red River. By contrast, the hydraulic gradient of the Assiniboine River from the West End Pollution Control Centre to Omand's Creek is relatively steep. This creates a shallower and faster-moving river which therefore has greater BOD assimilation potential due to high re-aeration.

3.0 RIVER USE

River use is an important consideration in defining the potential improvement caused by combined sewer overflows (CSOs) and therefore the benefits of CSO control.

3.1 MANITOBA SURFACE WATER QUALITY OBJECTIVES

The Province has set Manitoba Surface Water Quality Objectives (MSWQO) which define the minimum levels of quality which will protect various uses of surface waters (Williamson 1988a[9]). Compliance with the objectives should protect organisms or a community of organisms, designated river use or uses, and public health, to an adequate degree of safety.



Study Area
Figure 2-2

stdyarea
csorec

Over eighty substances are listed in the objectives, which cover six classes of use. Several general requirements are also noted for surface water quality.

The full set of MSWQO may not be applicable to all surface waters in Manitoba and the objectives are intended to be applied on a site-specific basis (Williamson 1990[10]). The natural water quality of rivers and lakes are an important consideration in applying the objectives.

The MSWQO have been derived by review of guidelines, objectives or standards from other jurisdictions (mainly the U.S. EPA). This information may be adopted directly or may be modified based on applicability to Manitoba conditions (Williamsom 1990). The applicability of objectives derived from other areas may depend upon factors such as the species used in testing, environmental test conditions such as water temperature, and on the means by which units or circumstances for applicability are translated to those used in Manitoba.

In the fall of 1991 and winter of 1992 the Manitoba Clean Environment Commission (CEC) held public hearings on the proposed Surface Water Quality Objectives (SWQO) for the Red and Assiniboine Rivers. In these hearings, the Department of the Environment proposed the SWQO for the Red and Assiniboine Rivers and the City of Winnipeg presented information as a key participant. Members of the public health and scientific community as well as the general public also made presentations to the CEC. The CEC then prepared a recommendation to the Minister who endorsed the recommendations.

The various classes of use were reviewed with respect to an array of water quality guidelines and the type and extent of use in the study area. A summary of the uses and water quality parameters used in the MSWQO is shown in Table 3-1. The classes of use are also shown on Table 3-2. For each class of use, the City of Winnipeg (COW) researched the use and presented a position to the CEC (Column 1 of Table 3-2). The Manitoba Environment proposal indicated that the Department considered all uses classified by the MSWQO to be appropriate for the Red and Assiniboine Rivers. After deliberation, the CEC developed a recommendation for each use. The water quality objectives and water quality monitoring records for each class of uses were screened to obtain key objectives for each class. The proposed objectives and the City position on whether that objective is appropriate are also shown on Table 3-2. The

TABLE 3-1
SUMMARY OF USES AND PARAMETERS INCLUDED IN
THE MANITOBA SURFACE WATER QUALITY OBJECTIVES

PARAMETERS	GENERAL	CLASS 1	CLASS 2		CLASS 3	CLASS 4				CLASS 5		CLASS 6
		DOMESTIC CONSUMPTION	AQUATIC LIFE		INDUSTRIAL	AGRICULTURE				RECREATION		OTHER
			COLD	COOL		A	B	C	D	PRIMARY	SECONDARY	
1. PHYSICAL												
- pH		●	●	●		●	●	●	●	●		
- dissolved oxygen			●	●					●	●	●	
- temperature			●	●							●	
- colour	●	●										
- odour	●	●										
- clarity										●		
- taste	●	●										
- turbidity	●	●								●		
- non-filterable residues			●	●								
- other	●					●	●	●	●			
2. INORGANIC COMPOUNDS												
- metals		●	●	●		●	●	●	●			
- ammonia	●		●	●								
- nitrates/nitrites	●	●							●			
- phosphorus	●											
- other	●	●	●	●		●	●	●				
3. ORGANIC COMPOUNDS												
- pesticides		●	●	●								
- other		●	●	●								
4. MICROBIOLOGICAL & BIOLOGICAL												
- bacterial indicators		●				●	●	●	●	●	●	
- toxic algae									●			
5. AESTHETIC/OTHER CONSIDERATIONS	●											
6. RADIONUCLIDES		●				●	●	●	●			

TABLE 3-2

ASSESSMENT OF RIVER USE AND OBJECTIVES

RIVER USE			KEY OBJECTIVES		REMARKS
USE	CITY POSITION	CEC	MSWQO PROPOSAL	CITY POSITION	
Domestic Consumption	Yes	Yes	None	Yes	Red and Assiniboine River waters require complete treatment for background conditions
Aquatic life	Yes	Yes	D.O. (47% saturation, 5 mg/l winter)	Yes	D.O. satisfied by best practicable secondary treatment at WPCC. **No challenge from MB Environment**
			Ammonia	Uncertain	COW recommended additional studies essential prior to regulation (high costs, uncertain benefits). **CEC recommends Ammonia study**
Industrial	Yes	Yes	No specific requirements	Yes	Users have varying needs
Recreation: - Primary	Limited	Red only for DWF **Uncertain** for WWF	Microbiological (200 f.c./100 mL	Yes	Technical benefits limited, issue relates to costs/benefits, environmental policy, public perception (WPCC disinfection practicable, **COW recommends CSO needs study and CEC concurs**)
- Secondary	Yes	Red and Assinboine for DWF **Uncertain** for WWF	Microbiological (1000 f.c./100 mL)	Not Required	Issue relates to public perception, environmental policy. **CEC recommends further study.**
Agricultural (Irrigation)	Limited	Yes for DWF	Microbiological (200-1000 f.c./100 mL	Not Required	Issue will be attended to by **resolving recreation issue**
Other: (Drainage, Wastewater Assimilation)	Yes	Yes	None required	Yes	Rivers are used for drainage, wastewater assimilation by many users (best practicable secondary treatment should be used)
General (Aesthetics)	Yes	Yes	Floating debris	Yes	COW recommends additional studies needed to define **CSO management strategy** (high costs, benefits subjective, environmental policy issue)

final column indicates whether the City and/or the CEC considered that further study was necessary before deciding on the appropriateness of objective.

Domestic water use of the Rivers (with proper treatment) and the key Objectives for this case, are considered appropriate. Aquatic life is recognized as an important use of the Red and Assiniboine Rivers. The City position was that the Objective for dissolved oxygen are reasonable and the City commitment to upgrading the secondary treatment processes is expected to achieve compliance with the Objective. Manitoba Environment did not challenge this assessment. It is recognized that an Objective for un-ionized ammonia to protect fish is needed, however, additional site-specific study is considered mandatory prior to establishing specific objectives, considering the very high costs of control and the uncertain benefits. Manitoba Environment proposed using the general objective but the CEC recommended study of this objective and that an un-ionized ammonia study be completed by 1997.

The City and the CEC agreed the use of the Rivers for industrial use is appropriate as it suits the various needs of industry.

The City position was that the use of the Rivers for irrigation is considered limited but appropriate if the user takes appropriate care. The need for a microbiological Objective is considered to be questionable in providing protection for this use. The CEC recommended protecting the use during dry weather flow at the MSWQO.

The City position was that the use of the Assiniboine River for primary recreation is not deemed appropriate. It's shallow depth restricts swimming and water skiing is not allowed by the City. The use of the Red River for primary recreation is relatively limited due to its natural unsuitability for this use (high turbidity, muddy banks, eratic currents, etc.). The key microbiological objective is appropriate if the use warrants increased protection. Technically, the benefits for protecting this use by greater microbiological control are low and the issue relates chiefly to environmental policy and public perception. Disinfection of plant effluents is practicable, whereas CSO disinfection is extremely costly, difficult to implement, would need significant study to identify appropriate programs.

The use of the Rivers for secondary recreation is very popular. The key objective for fecal coliform is not required based on technical evaluation, since ingestion of river water is only by accident and the risks are very low. Most regulatory agencies do not require such an Objective. Again the issue relates to environmental policy. The CEC recommended that the Red River be protected for primary recreation during dry weather flow (DWF) and both Rivers be protected for secondary recreation during DWF. The CEC recommended a "Fecal Coliform Study" to assess the impacts and control strategies for WWF (the CSO Management Study).

3.2 RECREATIONAL USE

The potential impairment of primary and secondary recreation was identified as the reason for the CEC recommending a "Fecal Coliform Study" which this CSO management study will embody. The extent of these river uses are expanded upon in this memorandum by drawing upon the information developed from the Red and Assiniboine Rivers Surface Water Quality Objectives Report (Wardrop/Tetr*ES* 1991[11]).

Five sources of data were used to estimate recreational use of the rivers:

- Anecdotal information (from clubs, harbour master and other users) gathered for a study on the benefits of treatment plant disinfection in 1986.

- Counting of boats and water skiers made during several flight surveys over the river in 1990. The flights occurred at various times, including long weekends and evenings when river use is at its peak.

- Information received from recreational clubs (water skiing, rowing, etc.) that use the river (1990).

- Interviews with the harbour master in 1990.

- A city-wide telephone survey on river use in 1990.

3.2.1 Primary Recreation

Primary contact recreation on the Red River within the study area is principally swimming, water skiing and related activities. Wind surfing is considered to occur rarely, if at all, as rivers are not amenable to the sport. Scuba diving is extremely limited throughout the study area due to the high sediment load, and is likely done exclusively by investigative teams from the City of Winnipeg Police and the RCMP.

The five sources of data consistently identify swimming as an infrequent or rare event within the study area. Use estimates range between less than ten to a few hundred per summer, while annual immersion frequency is estimated between 100 and 1,000 events.

Several reasons contribute to the limited extent of swimming upstream, within, and downstream of Winnipeg. There are no beaches on the Red River and no organized programs. The river itself is considered to have limited aesthetic appeal, because of the high level of turbidity, and the steep and muddy banks and bottoms. The City Medical Officer considers the use of the Red River as unsafe for swimming due to poor clarity and high turbidity of the waters (Dr. R. Stanwick *pers. comm.* 1991[12]). The high turbidity and poor clarity of the Red River upstream of Winnipeg dominates the physical characteristics within and downstream of Winnipeg. Few people are likely to be regular users, although the telephone survey identified one frequent swimmer.

Water skiing is another primary recreation activity in the study area to a limited extent. Several variations of the sport have appeared in the last few years, including kneeboarding, barefoot skiing and tubing. A few jet skis or water skidoos are also present on the rivers. Although the chance of immersion may be less than for the other activities, jet skiing has been included under the general category of "water skiing".

Most information sources suggest that use for water skiing is generally low, and based on a small core of regular users. However, the anecdotal information collected in 1990 from clubs, indicate a higher club use, and frequent rental of equipment by the general public. The use estimates place the core group of regular users between 10 and 60, while 500 users have been identified by one source. When converted to immersion frequencies, most estimates for both water skiing and jet skiing range between 2,300 and 3,000 although a possible maximum of 6,000 annual events has been estimated. The responses from the telephone survey were so low as to be statistically uninterpretable, although responses to other questions suggest that Winnipeggers travel outside of the city to both water ski and swim.

No specific areas have been associated with swimming. Water skiing appears to be concentrated on the Red River in the southern portion of the city, and near the North Perimeter Bridge. Downstream of the city, water skiing appears to be limited on the Red River. This activity is now prohibited on the Assiniboine River through a City by-law.

3.2.2 Secondary Recreation

The MSWQO define secondary recreation as including boating, fishing, camping, hunting and hiking. This discussion focuses on boating, a frequent activity in the study area and for which the potential for accidental immersion exists. Fishing is also discussed here, as it often overlaps with boating. Hiking and other riverbank activities are discussed in the section below.

All sources of data consistently agree that motor boating is the most common recreational use of the Red and Assiniboine Rivers within the study area. Use estimates range up to 70,000 people annually, with several estimates close to 25,000. The Harbour Master estimates that roughly 60% are regular river users, perhaps with their boats moored at private docks or in marinas. In Winnipeg in 1986, there were 275 commercial berths. The number of commercial berths in Selkirk has increased in the last few years. Access is also gained through 12 public docks and launches in Winnipeg. Calculated immersion frequencies for motor boating range up to 3,300 events annually, with many in the range of approximately 1,500. Motor boating was observed by the aerial surveys to occur throughout the region between Selkirk and the Floodway Control Structure at St. Norbert. Five cruise boats operate within this area and are popular with residents and tourists. No immersion events were assumed to occur with these boats.

Canoeing and rowing are less common than motor boating, although the Harbour Master believes that canoeing is increasing in popularity. This activity occurs both through club use, organized events such as races, and individual activity. Use estimates range up to 1,600 people annually with few immersion events. Rowing is almost exclusively a club activity with up to 200 participants. In combination with canoeing, immersion events range up to 121 annually. Data from the telephone survey was so small as to be statistically uninterpretable.

Sports and bait fishing is an important use of the study area rivers, as apparent from the anecdotal information and the telephone survey. Estimates of numbers of resident and non-resident fishermen range up to 50,000 annually. There is likely considerable overlap with boating. Although not quantitative, the aerial counts observed many stopped motor boats, which may have been fishing, particularly near Lockport. Approximately half of the telephone survey respondents indicated that they had both fished and boated during 1990.

No immersion events are indicated for fishing. Accidental immersions from boats would be included in the boating numbers. The rate of full body immersion for shore-fishermen is unknown. Splashes of water or wading would not constitute an immersion event and health risk from epidemiological studies. Fishing occurs throughout the study area, but is most common downstream of the City, particularly in the Lockport area.

The key factor in assessing the public health risk associated with recreational use is to estimate the total number of immersions. A summary of the extent of use and annual immersion events for river recreation in the study area is given in Table 3-3. The total estimated number of immersions per year is 6,500.

3.2.3 Other Recreational Use

Riverbank use within Winnipeg primarily involves walking, but may include photography, cycling, jogging, etc. These also occur downstream of the City, and near the Netley Marshes there are opportunities for camping, hiking, and hunting.

Riverbank use in Winnipeg has been promoted in the last few years, particularly with development of The Forks and the construction of walking paths along the banks at the water's edge. Approximately 60% of respondents to the telephone survey (Section 3.4.2) noted walking and cycling as riverbank activities they pursued. No other quantitative data is

TABLE 3-3

SUMMARY OF EXTENT OF USE AND ANNUAL IMMERSION EVENTS FOR RIVER RECREATION IN THE STUDY AREA

ACTIVITY	WINNIPEG		SELKIRK		TOTAL
	RANKING	IMMERSIONS	RANKING	IMMERSIONS	IMMERSIONS
Primary Recreation					
Swimming	Low	300	Low	30	330
Waterskiing & Jetskiing	Low to Moderate	3,500	Low	350	3,850
TOTAL		3,800 *use:* *3,800*		380 *say:* *400*	4,180 *say:* *4,200*
Secondary Recreation					
Motor Boating	High	1,800	High	400	2,200
Canoeing & Rowing	Low to Moderate	100	Low	10	110
Fishing	High	-	High	-	-
TOTAL		1,900 *use:* *1,900*		410 *say:* *400*	2,310 *say:* *2,300*
TOTAL		**5,700**		**800**	**6,500**

available. This activity is important in considering the benefits of improving aesthetics with CSO controls.

3.3 CSO ISSUES

The preceding review of river uses indicates that the reduction of fecal coliform concentration is the key CSO issue. Aesthetic impact on the river from CSOs are a motivating issue since the aesthetic appearance of the rivers this has a large impact on public perception of water quality.

Aquatic health is always an issue in water quality management. Improving dissolved oxygen resources in the river has always been a prime motivation in the City of Winnipeg's overall water management plan, hence hundreds of millions of dollars has been invested in secondary treatment. As will be discussed in the next section, the dissolved oxygen concentrations have been above MSWQO continuously at the locations monitored for the past decade. The incremental benefits of removing additional Biochemical Oxygen Demand (BOD) through improving CSO control, and thereby further improving dissolved oxygen resources, should be considered in evaluation of CSO control alternatives. Dissolved oxygen, however, is not a prime motivating issue for CSO control.

Emerging aquatic health issues relevant to CSOs may relate to accumulation of toxics in sediments and bioaccumulation. This potential concern should be investigated further with members of the scientific community and by reviewing experience elsewhere.

4.0 EXISTING RIVER WATER QUALITY

This section reviews the City of Winnipeg river water quality monitoring programs, the results of the monitoring data, and then indicates the nature of additional monitoring required.

4.1 MONITORING PROGRAM

The monitoring programs cover four areas:

- Long-term biweekly monitoring on the Red and Assiniboine rivers.
- A special program conducted along the tributaries to the Red and Assiniboine which flow through the City.
- Special programs on: mixing downstream of the treatment plants; priority pollutant monitoring; and intensive $Q_{7\text{-}10}$ monitoring.
- Monitoring of the rivers following a CSO event.

The various monitoring programs are described briefly below and summarized in Table 4-1.

4.1.1 Bi-weekly Monitoring

Bi-weekly monitoring of the Red and Assiniboine rivers has been done year-round by the City of Winnipeg since 1977. The locations are selected at nine bridges throughout the study area (Figure 4-1). This program allows for long-term monitoring of the river for key parameters which indicated the potential for impairment of aquatic health. Such parameters are:

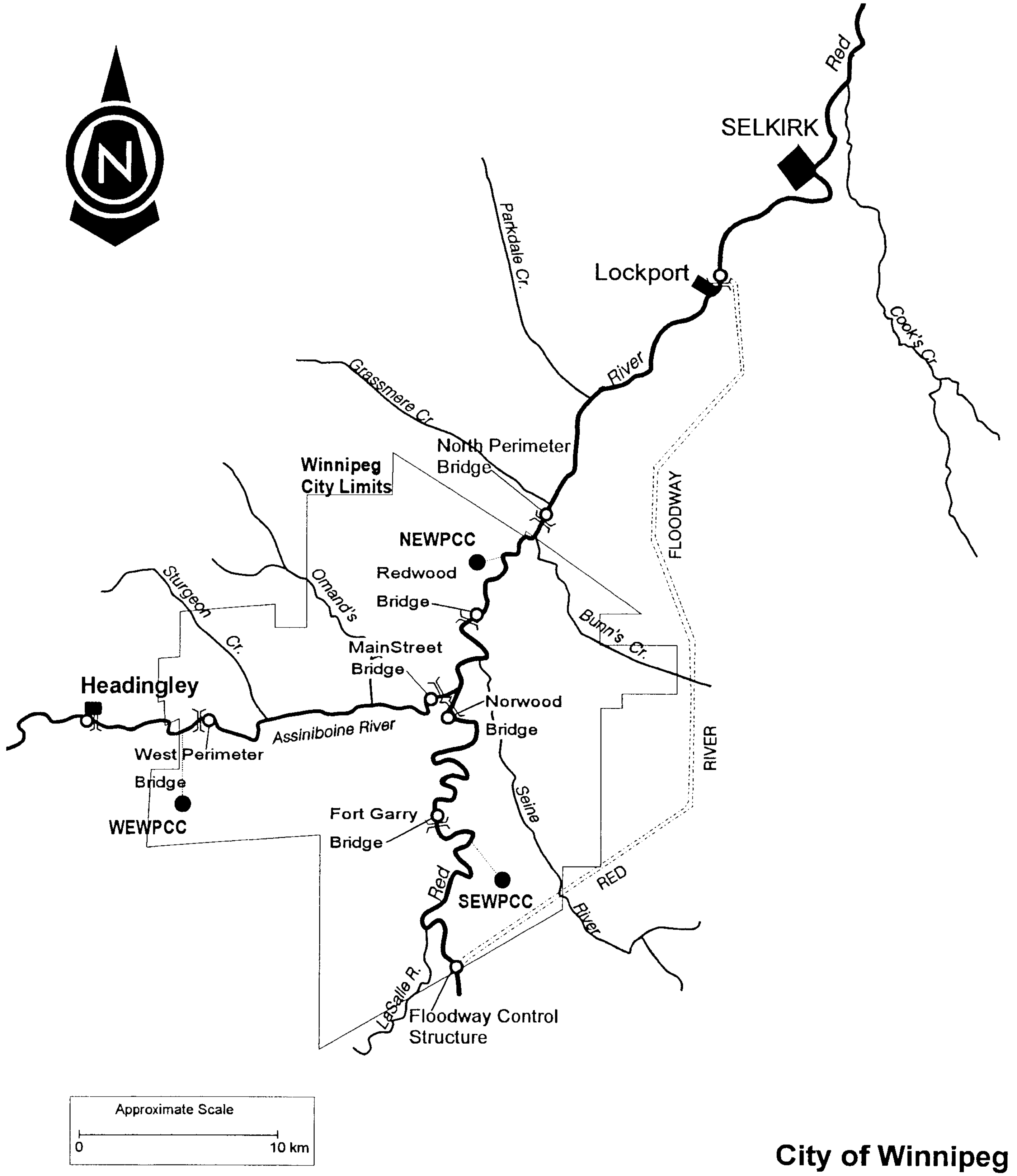
- dissolved oxygen; and
- ammonia (and pH).

Other parameters such as total and fecal coliforms are monitored as indicators of public health concerns. Since 1988, Entorococci has also been monitored regularly. Physical parameters (solids, turbidity and temperature), as well as nutrients (nitrogen phosphorus), are also monitored in this program. The Province of Manitoba also monitors water quality upstream and downstream of the City of Winnipeg.

Table 4-1
Summary of General River Monitoring Programs

	Red And Assiniboine Biweekly-Year Round Since 1977	1988 Flow near Q 7-10 12 locations 3 Days every 2 to 4 Hours	1992 Ammonia Mixing at SE & NE Each hour for 1 Day	Small Streams at Mouth Monthly May to Oct Since 1977	Small Streams 5 to 7 Along Stream 1991
Temperature	●	●●	●●●	●	●
Total Solids	●				
Suspended Solids	●	●			
Turbidity	●			●	
pH	●	●●	●●●	●	
Dissolved Oxygen	●	●●	●●●	●	●
BOD(5 &20,Inhib,Uni)		●			
Total Organic Carbon	●			●	
Total Phosphorus	●	●	●○	●	●
Dissolved Phosphorus		●			●
Total Kjeldhal Nitrogen	●	●	●○		●
Nitrate	●	●	●○	●	●
Ammonia	●		●○		●
Chlorophyl-A		●	●○		●
Light Pentration per Depth		●			
Algal Productivity		●			
Total Coliforms	●	●		●	●
Fecal Coliforms	●	●		●	●
Enterococci	Since 1988				
E- Coli	1977-78				

●● 3 points accross the river and three depths
●●● 3 points accross the river and five depths
●○ Center of the river and five depths



City of Winnipeg
Bi-Weekly Routine
Sampling Locations

splocs
csorec

Figure 4-1

4.1.2 Intensive Monitoring at Low Flow

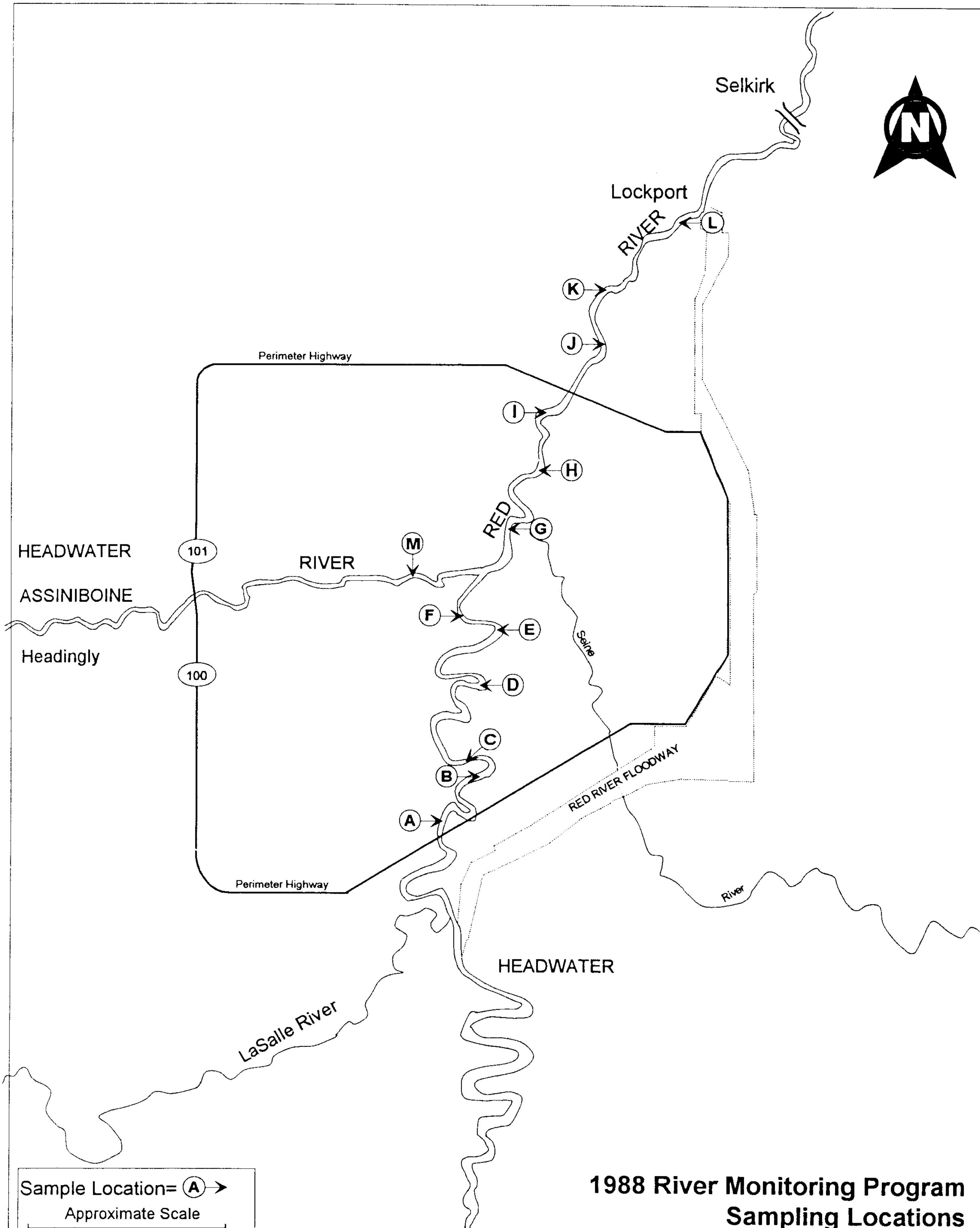
The database from the bi-weekly monitoring provided a valuable record of the water quality regime throughout the City. These data were used to calibrate a river water quality model (QUAL2E). Following this 1986 modelling study, (MacLaren 1986a)[13] (see Section 5) it was recommended that an intensive monitoring study be performed along the Red River with special emphasis on improving the understanding of the algae dynamics in the river and their effect on DO levels. The Red River is slower moving than the Assiniboine River and, therefore, has lower assimilative capacity for Biochemical Oxygen Demand (BOD) and typically lower dissolved oxygen (DO) concentrations. A reconnaissance study was performed in 1987, however, river flows where too high in August of that year to warrant a full program. In 1988, however, the river flow approached the $Q_{7\text{-}10}$ flow (the seven day low flow with a probability of occurrence of 10%), which presented an excellent opportunity to assess water quality under this low flow. This special program continued for three days in August with samples taken every 2 to 4 hours (depending upon the parameter). The samples were taken at 12 locations (Figure 4-2) along the river.

The program focussed on the nutrient, algae, dissolved oxygen and coliforms. A summary of the parameters sampled is shown in Table 4-1. In addition to nutrients, this study collected information on chlorophyll-a concentrations, algal productivity and light penetrations in the river. Five- and twenty-day biochemical oxygen demand tests were performed for conditions in which the nitrifying bacteria were inhibited and uninhibited.

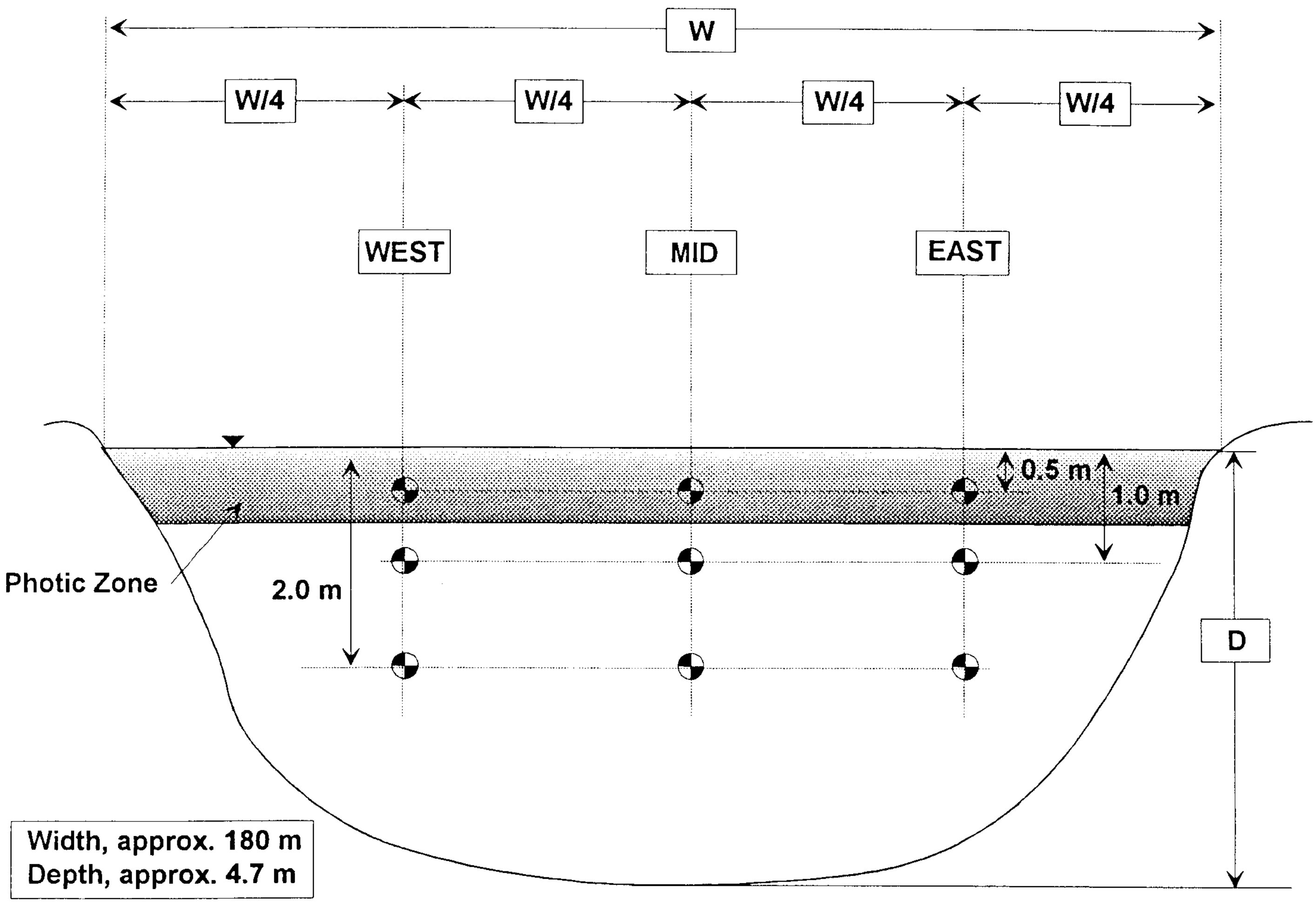
Very intensive monitoring at three depths and three locations across the river was done for pH, temperature and dissolved oxygen (Figure 4-3). Total and fecal coliform concentrations were also monitored in this program. These data proved to be very valuable for improving calibration and verification of the QUAL2E model in 1990 (Section 5).

4.1.3 Mixing Zones Downstream of Plants

Understanding the mixing of the effluent of treatment plants in the river is important in determining the water quality impacts. To obtain this understanding, detailed monitoring of the river was performed in 1992. In two programs downstream of both the North End Water



1988 River Monitoring Program
Sampling Locations
Figure 4-2



Cross-Sectional Schematic of Sampling Locations "I' and "J"
Figure 4-3

ipxsec
csorec

Pollution Control Centre (NEWPCC) and the South End Water Pollution Control Centre (SEWPCC), effluents were monitored at four cross-sections downstream, as well as upstream of the plants. The sampling occurred every hour for 24 hours at five different depths. For pH, temperature and dissolved oxygen, sampling was done at three locations across the river, while phosphorus, algae and the nitrogen cycle sampling was taken only in the centre of the river. A summary of the sampling program is shown on Table 4-1.

The results of the mixing study showed that although dissolved oxygen was slightly higher in the top half metre of the water column due to algal activity, the river is well mixed vertically. Typical vertical profiles showed DO at 8.5 mg/L in the top half metre decreasing to 8.0 mg/L in the lower strata. These lower strata samples were from 1.5 metres to the bottom (at about 4 to 5 metres).

Complete lateral mixing at the river bend downstream of the SEWPCC and WEWPCC occurs within a few kilometres. At WEWPCC the first monitoring station (the West Perimeter Bridge) is prior to the complete mixing of the WEWPCC effluent. The NEWPCC effluent mixed quickly downstream of the discharge location.

4.1.4 Small Stream Surveys

There are five tributaries to the Red and Assiniboine rivers which pass through the City of Winnipeg. These streams are shown on Figure 4-1 and include:

- Sturgeon Creek;
- Omand's Creek;
- La Salle River;
- Seine River; and
- Bunn's Creek.

These tributaries are generally not impacted by CSOs. Only Omand's Creek and the Seine River have CSOs and those outfalls are located at the mouth of the stream. These creeks are receiving streams for WWF from within land drainage systems, undeveloped land and rural runoff.

The City has monitored these streams regularly since 1977. This program consists of one sample taken at the mouth of the stream each month from May to October, inclusive. About nine water quality parameters, such as nutrients, DO and coliforms, are measured, as shown in Table 4-1.

In addition to this long-term program, a more extensive study of these streams was conducted in 1991. For each of June, July and August sampling was conducted at five to seven stations along the streams. The parameters sampled were similar to the long-term program with more emphasis on the nutrient and algae (see Table 4-1).

4.1.5 Priority Pollutant Monitoring

Monitoring for "priority pollutants" has been performed twice in the Red and Assiniboine rivers in July and August 1991. These pollutants are pesticides and other complex organic compounds. There are about 150 parameters in this list, as shown in Appendix A. The monitoring occurred upstream of the City at Headingly (on the Assiniboine River) and the Floodway entrance (on the Red River), as well as downstream of the City and the North Perimeter Bridge. The priority pollutant scan was also performed on each of the three pollution control centre effluents.

4.1.6 CSO Monitoring

Since 1990 the City of Winnipeg has conducted special monitoring campaigns on the Red River to assess the impacts of CSO events. The parameters monitored in each of the years is summarized in Table 4-2. Each year, the program varied depending upon available resources and upon the previous year's results.

1990 Monitoring

In 1990 twelve locations within the City were monitored once on three consecutive days following CSO events in July and September. The key parameters monitored were DO and coliforms, however, temperatures, pH and algae were also monitored.

Table 4-2
Summary of CSO Event River Monitoring Programs

	1990 CSO Monitoring 3 Consecutive Days In July and Sept. 12 Locations Along Red in City	1991 CSO Monitoring 3 Events-5 Consecutive days 10 Locations Along Red to Lockport	1992 CSO Monitoring 3 Events-4 Consecutive days 11 Location Along Red to Lockport	1993 CSO Monitoring One Day each Week 11 Locations Along Red to Lockport
Temperature	●	●	●	●
Total Solids				
Suspended Solids				
Turbidity				
pH	●	●	●	●
Dissolved Oxygen	●	●	●	●
BOD(5 &20,Inhib,Uni)				
Total Organic Carbon				
Total Phosphorus		●		●
Dissolved Phosphorus		●		
Total Kjeldhal Nitrogen		●		●
Nitrate		●	●	●
Ammonia			●	●
Chlorophyl-A	●	●	●	●
Light Pentration per Depth				
Algal Productivity				
Total Coliforms	●	●		
Fecal Coliforms	●	●	●	●
Enterococci				
E- Coli				

1991 Monitoring

In 1991, three events were monitored at ten locations on the Red River. In this year, the sampling locations extended to Lockport to better assess the impact of BOD on DO downstream of the City. The monitoring was done daily for five consecutive days and continued less frequently for up to 20 days. In addition to the key parameters done in 1991, nutrients were added to the list of water quality tests performed.

1992 Monitoring

In 1992, three CSO events were monitored for four consecutive days at eleven locations on the Red River. As in 1991, the monitoring was performed daily from Winnipeg to Lockport. Seven water quality parameters were measured with dissolved oxygen, coliform and ammonia being the key parameters.

1993 Monitoring

In 1993 the intensity of the programs was reduced to once a week for June and July. In July, the program was discontinued until October, due to flooding of the Red River. Nine parameters and eleven locations were monitored (see Table 4-2).

4.2 DISCUSSION OF RIVER WATER QUALITY

The monitoring done over the past 15 years provides a wealth of information to assess water quality in the Red and Assiniboine Rivers. This section describes the water quality for several key parameters:

- dissolved oxygen
- fecal coliforms
- nutrients
- ammonia
- heavy metals and pesticides

4.2.1 Dissolved Oxygen

4.2.1.1 Bi-weekly Monitoring

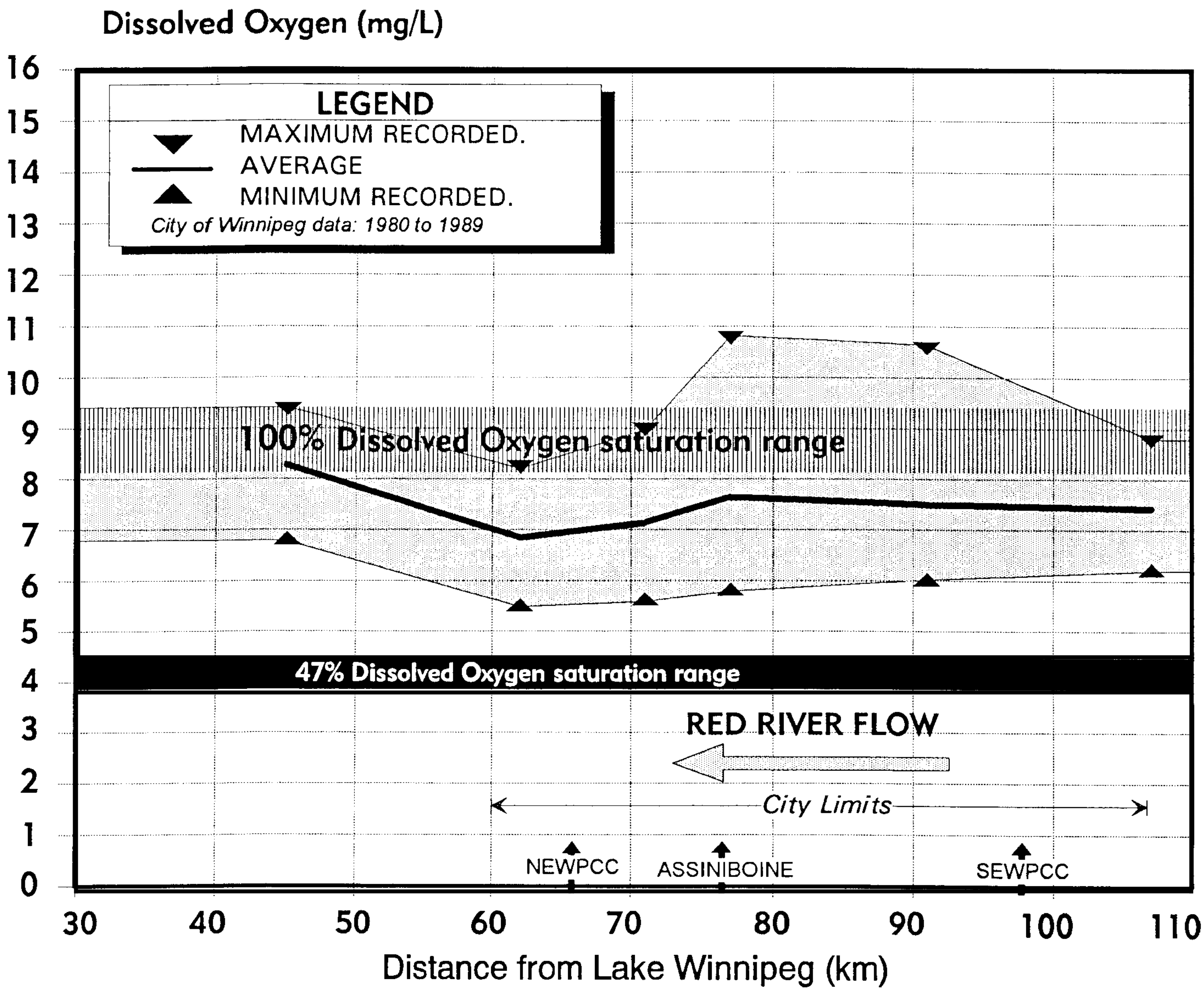
The guidelines require DO levels to be at least 47% of the saturation level for protection of cool water aquatic life. From discussions with the Environment Management Division (EMD), it was learned that this objective is intended to apply to summer conditions, when saturation levels are about 9.1 to 7.6 mg/L at water temperatures of 20°C to 30°C, respectively (ref). Minimum DO levels of 4.3 to 3.6 mg/L, respectively, would be allowable for these water temperatures. In periods when the fish are not spawning, such as winter, the EMD indicated that a minimum DO of 5 to 6 mg/L is acceptable. This is consistent with the requirements of many other jurisdictions.

The DO data of the Red and Assiniboine Rivers are shown in Figure 4-4 and Figure 4-5 for the month of August. These profiles show that DO levels along the entire length of the rivers from the headwaters to Lockport are well above the objectives. Measurements have been consistently above the 47% Objective in the open water period between 1980 to 1989. DO levels in the winter months have consistently been above 5 mg/L and should be acceptable to the EMD.

DO levels were modelled for projected 2011 WPCC discharges at a range of low river flows to examine future water quality compliance with MSWQO. It was predicted that DO levels will be adequate for these future dry weather flow conditions.

The historical data was also reviewed to determine if wet weather discharges adversely affect the DO levels in the river. The CSO and other urban storm runoff have the potential to exert DO demand. The historical DO data for the Red River were reviewed at several locations susceptible to CSO during and after rainfall events.

DO levels that were recorded on days of rainfall or within 2 days after a rainfall event were compared to the amount of rainfall to determine if discharges as a result of rainstorms affected DO levels in the river. Figure 4-6 illustrates these data as monitored at the Redwood Bridge. Instream DO levels during or after a rainstorm event were found to be well above the MSWQO minimum requirement of 47% saturation for the open water period recorded between

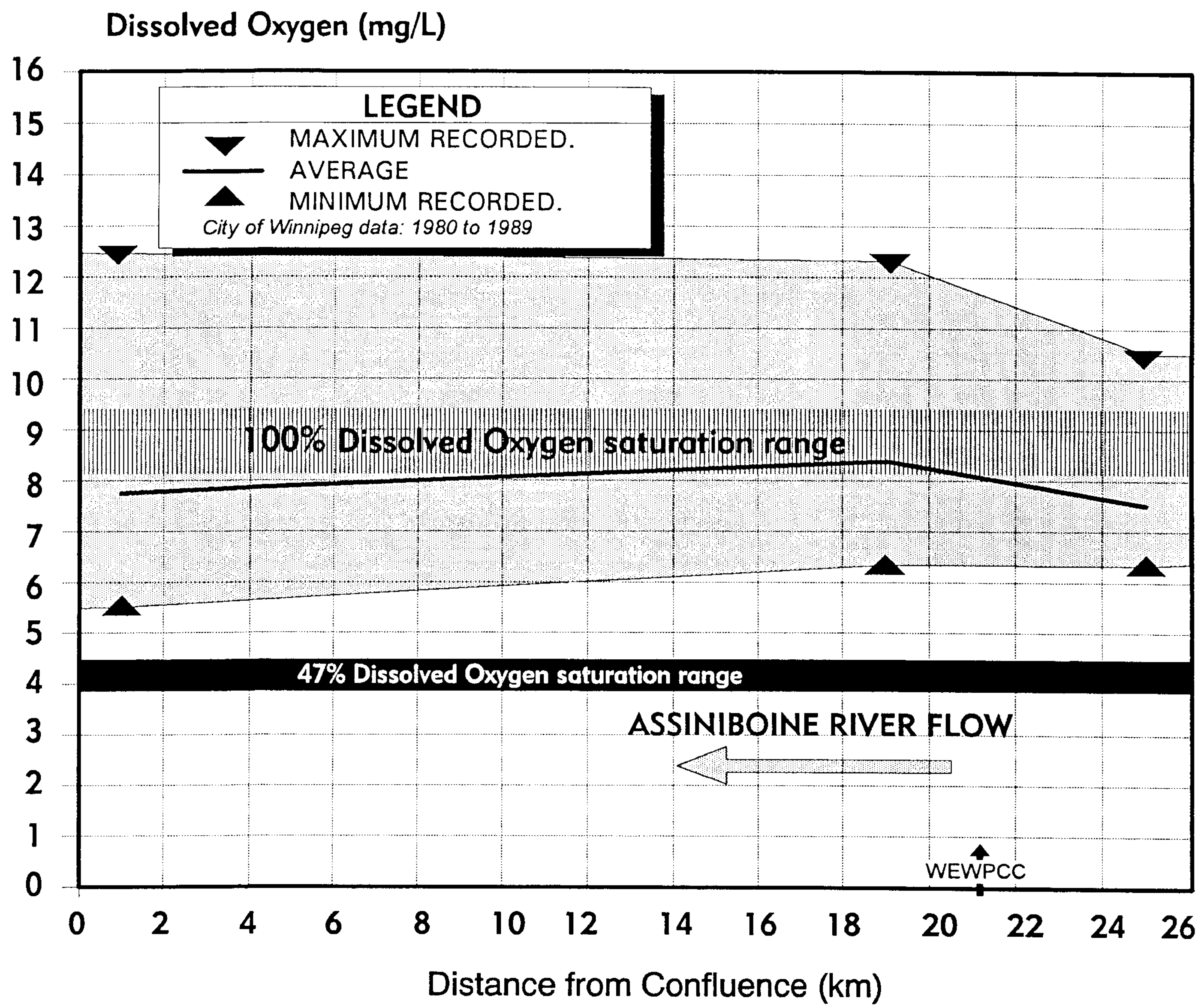


Monitored August Dissolved Oxygen
Red River Profile

Water Quality Data 1980-89
Source: City of Winnipeg

augdo
csorec

Figure 4-4

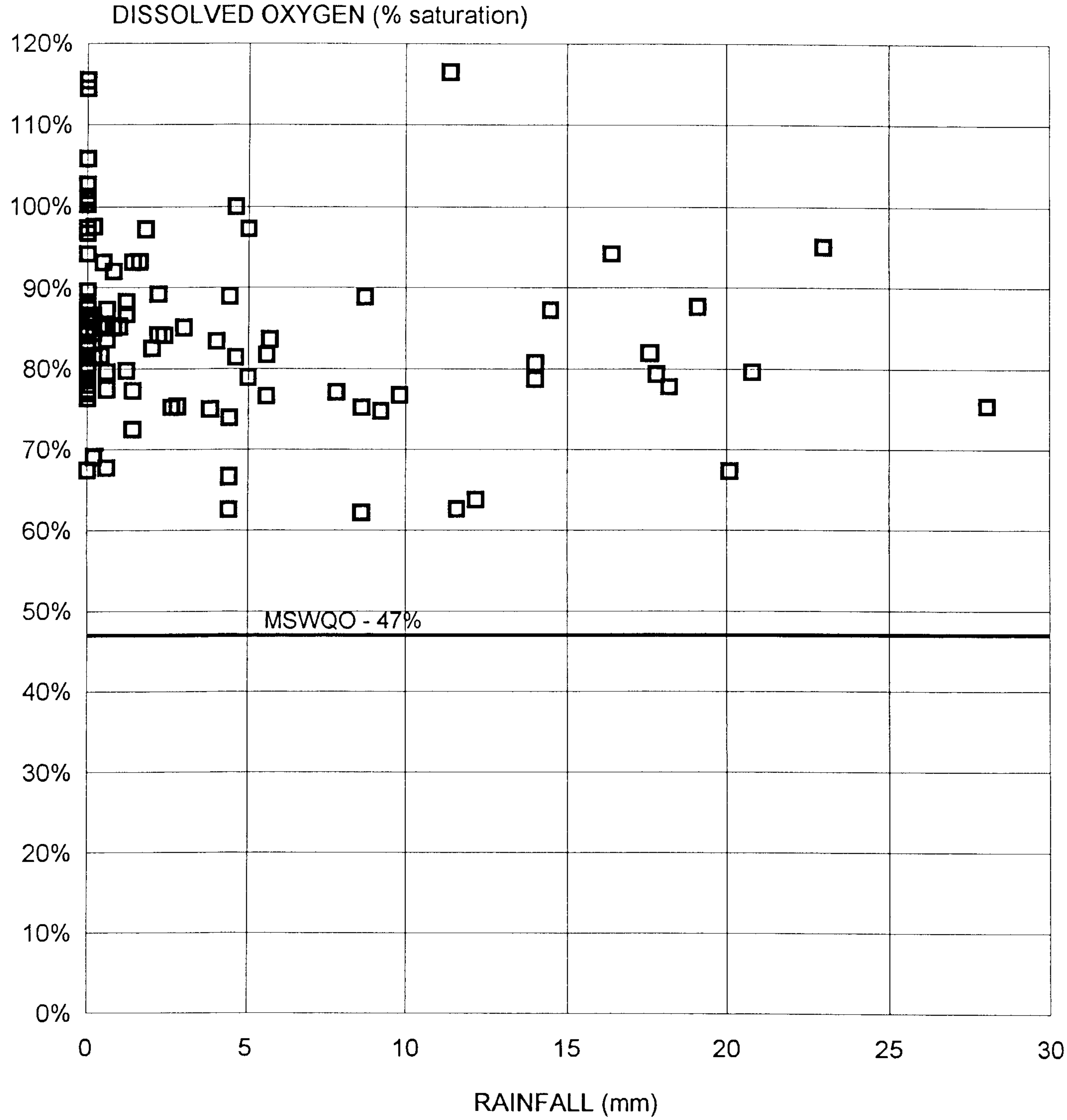


Water Quality Data 1980-89
Source: City of Winnipeg

Monitored August Dissolved Oxygen
Assiniboine River Profile

asbndo
csorec

Figure 4-5



Red River - Redwood Bridge
Wet Weather Dissolved Oxygen Levels

Source: COW Historic Data (1980-89)

redwddo
csorec

Figure 4-6

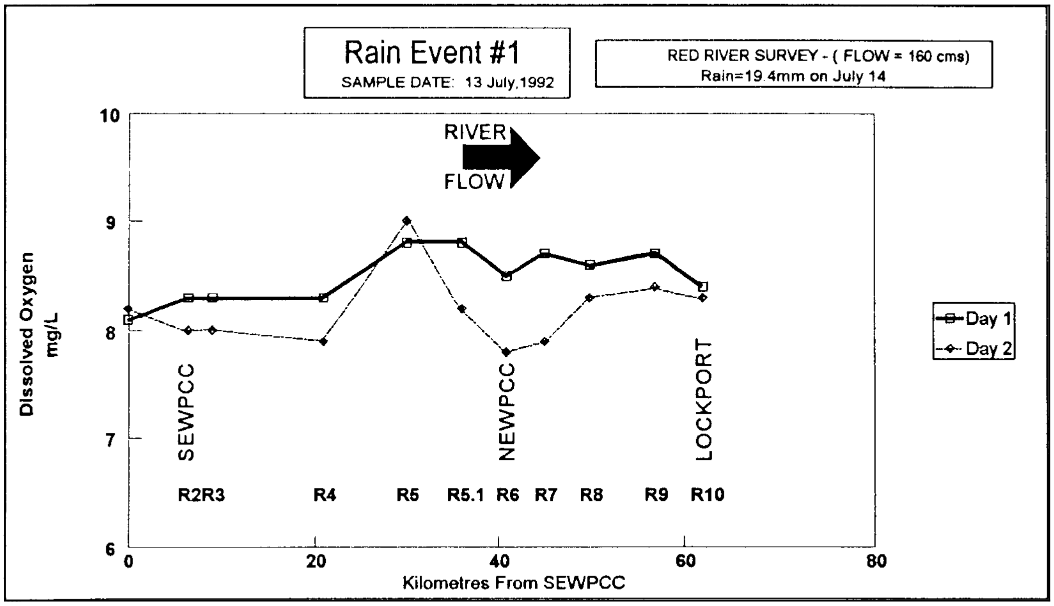
1980 to 1989, inclusive. The recorded DO levels were found to be tightly clustered between 75 to 95% saturation and remained at these levels regardless of rainfall. The data indicates that DO levels in the rivers are not significantly affected from rainstorm-induced run-off at any of the monitoring locations.

4.2.1.2 Special Monitoring

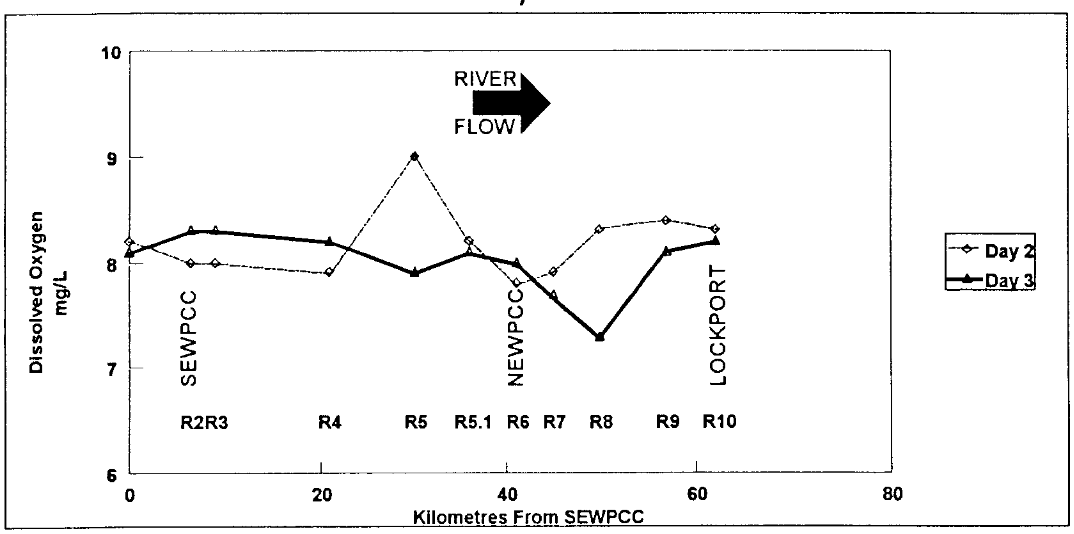
The special CSO monitoring results from 1990 to 1993 were reviewed to assess whether impacts on water quality specific to CSOs could be observed. The 1990 monitoring did not show any identifiable impact on dissolved oxygen, however, the monitoring did not extend downstream as far as Lockport. The biochemical oxygen demand (BOD) may not exert its full impact until the mass of combined sewer effluent travels as far as Lockport.

In 1991, there was a measurable impact on DO following one of the rainfall events. Four days after a CSO event, the dissolved oxygen in the stream was suppressed by 1.2 mg/L. The 1992 results show the impact of CSO on dissolved oxygen most clearly. This can be shown by assessing the dissolved oxygen profile prior to and following a rainfall of 19.4 mm on July 14. Profiles of dissolved oxygen along the river are shown on Figure 4-7. The majority of the BOD loading from the CSO event would enter the river between R4 (kilo 20) and R6 (kilo 42) on Figure 4-7a. As can be seen on Figure 4-7a from Day 1 to Day 2 the DO at station R6 decreased by 0.5 mg/L. Figure 4-7b shows that by Day 3 the "DO sag" has moved from kilometre 40 to kilometre 50 and decreased an additional 0.5 mg/L. On Day 4 (Figure 4-7c), the location of minimum DO moved further downstream to Lockport (kilometre 60). This analysis indicates that the river behaves as expected after a CSO event. There is likely enough data available from the three monitoring events in 1992 to calibrate a dynamic DO model (if this is required).

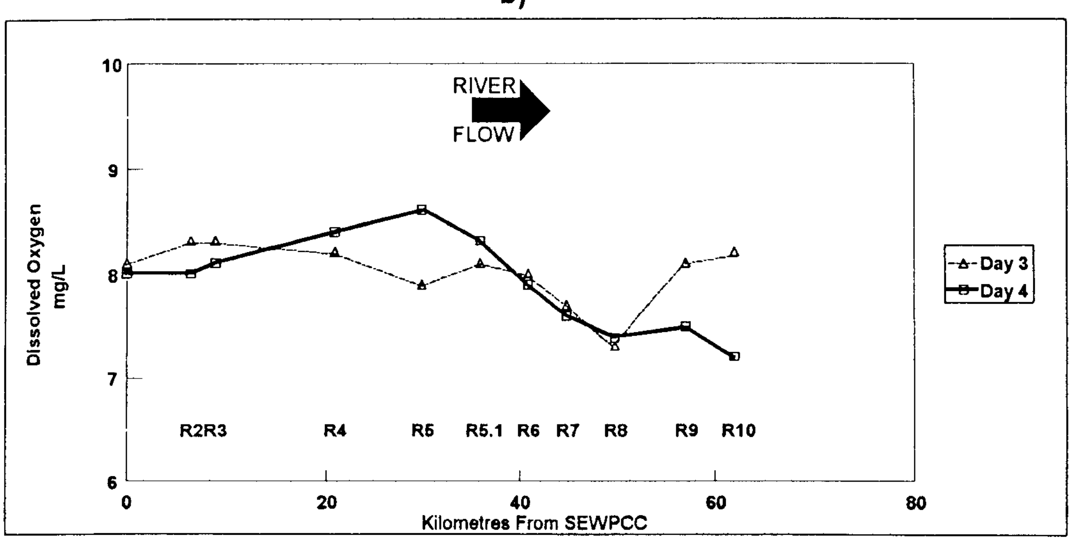
The two other events in 1992 were analyzed in the same manner as the July 14 CSO event. The maximum suppression of DO from Day 1 to Day 4 for each event was plotted against the total rainfall from the event (Figure 4-8). Although there are only three data points, there appears to be a direct correlation between volume of rainfall and DO depression. Further modelling of runoff and overflow could produce an estimate of total BOD discharge per event. It should be recognized that as the rainfall increases beyond 25 mm, the mass of BOD will not



a)



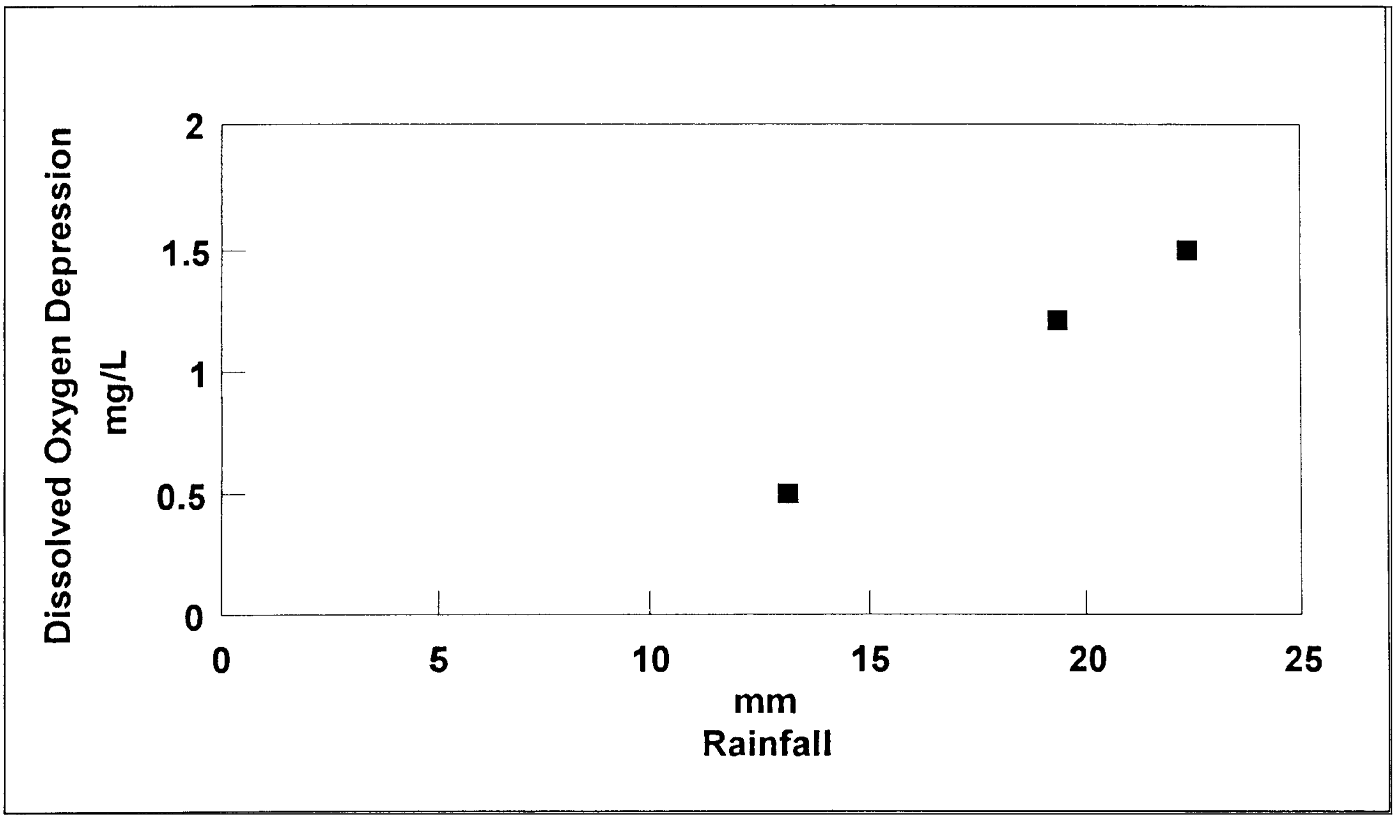
b)



c)

1992 Dissolved Oxygen Profiles Following CSO Event

Figure 4-7



1992 DO depression vs. Rainfall

Figure 4-8

dodepres
csorec

increase proportionally to the rainfall. Therefore, Figure 4-8 should not be used to extrapolate past 25 mm of rainfall to estimate expected DO depression.

4.2.1.3 Summary of Dissolved Oxygen Monitoring

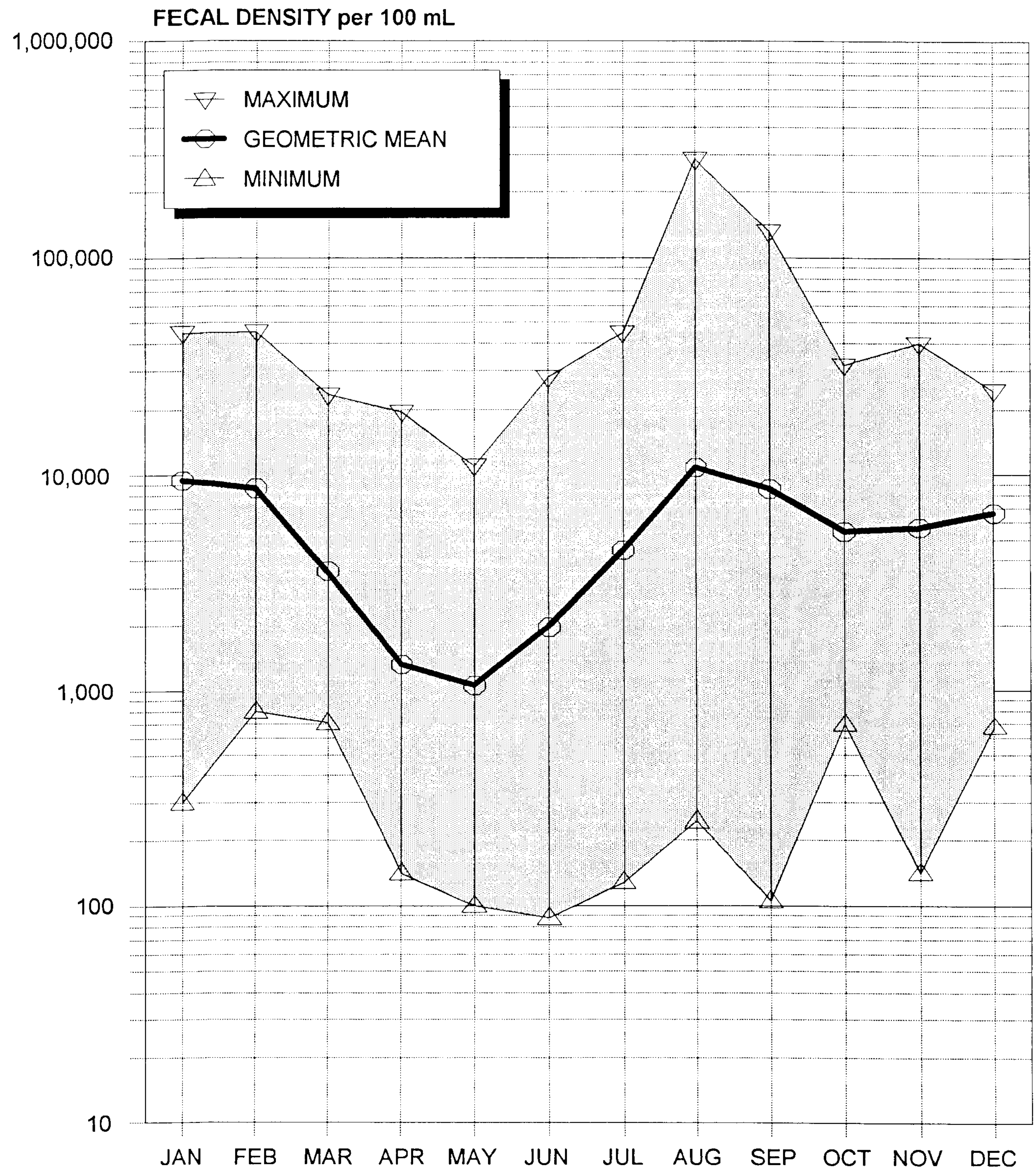
The preceding data review demonstrates that historical DO concentrations in the rivers comply with objectives and are ample for support of healthy aquatic communities. The DO levels remain high throughout the Winnipeg area due to the consistently high level of treatment provided at the WPCC for all DWF, combined with active oxygen production from algae photosynthesis in the Rivers. Active sport fishing along the river also attests to the existence of strong aquatic life in the river. Accordingly, DO is not considered to be a water quality issue. The data following WWF events indicate that CSOs do not significantly depress DO levels and therefore DO is not considered a CSO issue.

4.2.2 Fecal Coliforms

The 1980 to 1989 data on fecal coliform measured through the Winnipeg area were reviewed. The data analysis shows a high degree of variance which is to be expected considering the many factors affecting these measurements. Pertinent factors include:

- coliform densities in the sources (i.e. variance of densities in the discharges);
- volume and rate of discharge;
- river flows;
- coliform density test variations;
- antecedent rainfall conditions;
- environmental factors (i.e., temperature, pH, sunlight, predation, etc.).

A seasonal variation of the fecal coliform density history, as derived from these data, is shown in Figure 4-9 for the first routine sampling station (North Perimeter bridge) downstream of the NEWPCC on the Red River.



Fecal Coliform Seasonal Pattern
North Perimeter Bridge
Red River: Downstream of NEWPCC

Source: City of Winnipeg
Water Quality Data 1980-1989

nperfeco
csorec

Figure 4-9

The historical data analysis shows that the effluent from the Winnipeg WPCC's are major reasons for the bacterial counts exceeding the primary and secondary objectives in the Winnipeg area. The SEWPCC and NEWPCC are dominant contributors to coliform levels in the Red River during dry weather as shown in Figure 4-10. The river is an inhospitable environment for fecal microorganisms and these gradually die-off within several days. During wet weather, fecal coliform levels in the rivers are elevated due to the discharges from CSO's which contain high numbers of coliforms. The coliform objectives are exceeded occasionally in the headwaters for both primary and secondary recreation objectives, objectives set for secondary recreation, primary recreation are exceeded frequently in the Winnipeg area. The Winnipeg discharges are clearly a major water quality issue with respect to microbiological quality.

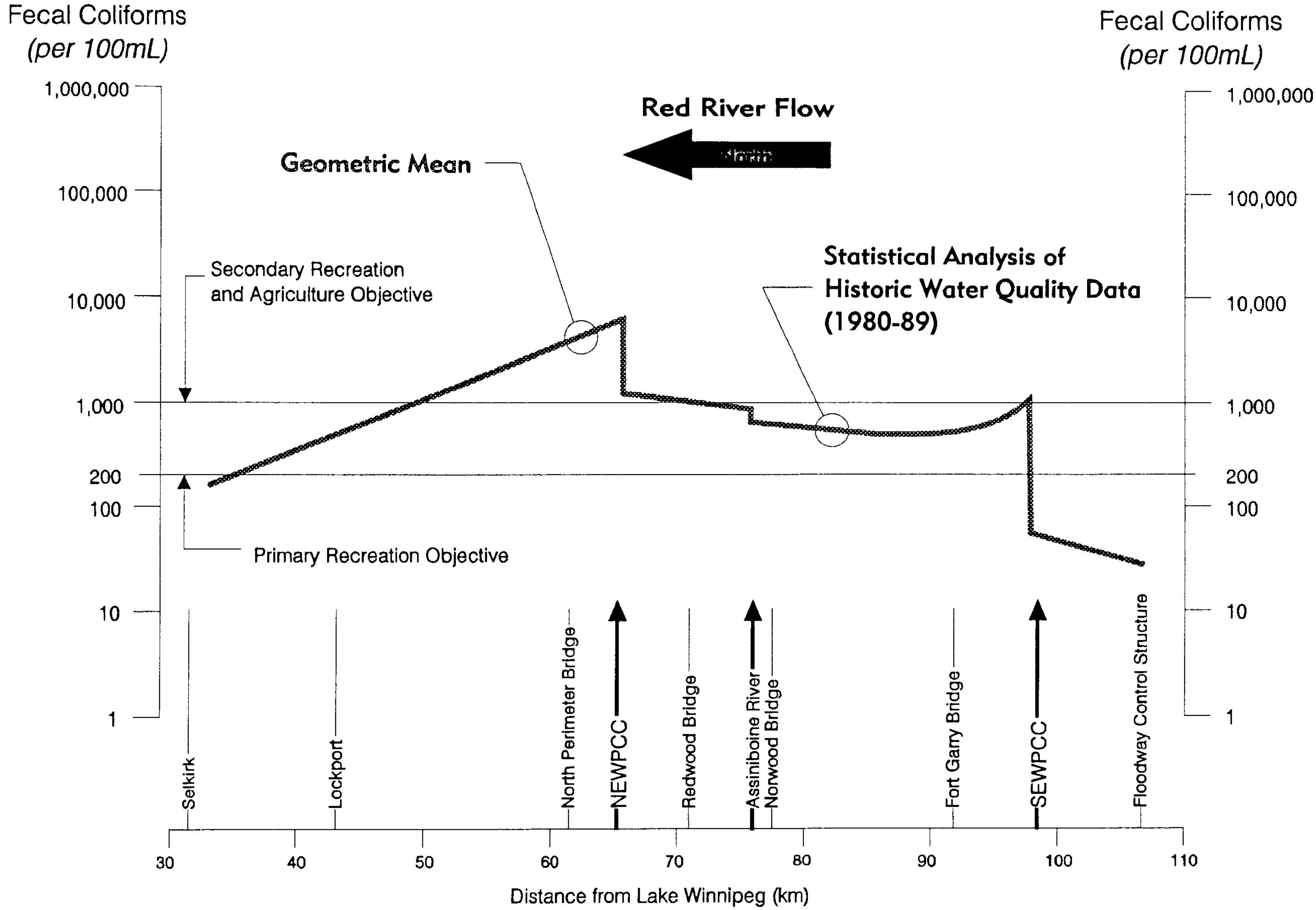
Previous studies (Red and Assiniboine 1992) estimated the effect of disinfecting the Pollution Control Centre effluents. The impact of the PCC effluent on fecal coliform concentrations in the river was estimated using a river water quality model (see Section 5.0) for average conditions. The influence of the WPCC effluents was subtracted from the geometric mean of measured fecal coliform concentrations during the 1980 to 1989 period. The results are shown in Figure 4-11. Immediately downstream of the treatment plants, the geometric mean of the fecal coliform concentration would be reduced significantly. The area within the City and downstream would still be significantly influenced by CSO events. The disinfection of CSO, in conjunction with WPCC effluent disinfection, would further reduce the fecal coliform densities significantly. The fecal coliform geometric profile for this condition is difficult to predict, however urban runoff would be expected to increase concentrations during wet weather. A profile was estimated as shown in Figure 4-11.

One of the goals of this CSO study will be to predict the geometric mean of fecal coliforms, as well as the peak duration and extent of fecal coliform concentrations for various control options.

Monitoring CSO Events

In order to calibrate a dynamic river model for fecal coliform prediction, CSO events must be monitored. An example of fecal coliform monitoring during a CSO event is shown in Figure 4-12. The mass of fecal coliform increases and moves downstream following a WWF event.

Red River : Fecal Coliform Profile



fecoprof
csorec

Figure 4-10

Red River: Fecal Coliform Profile With Disinfection

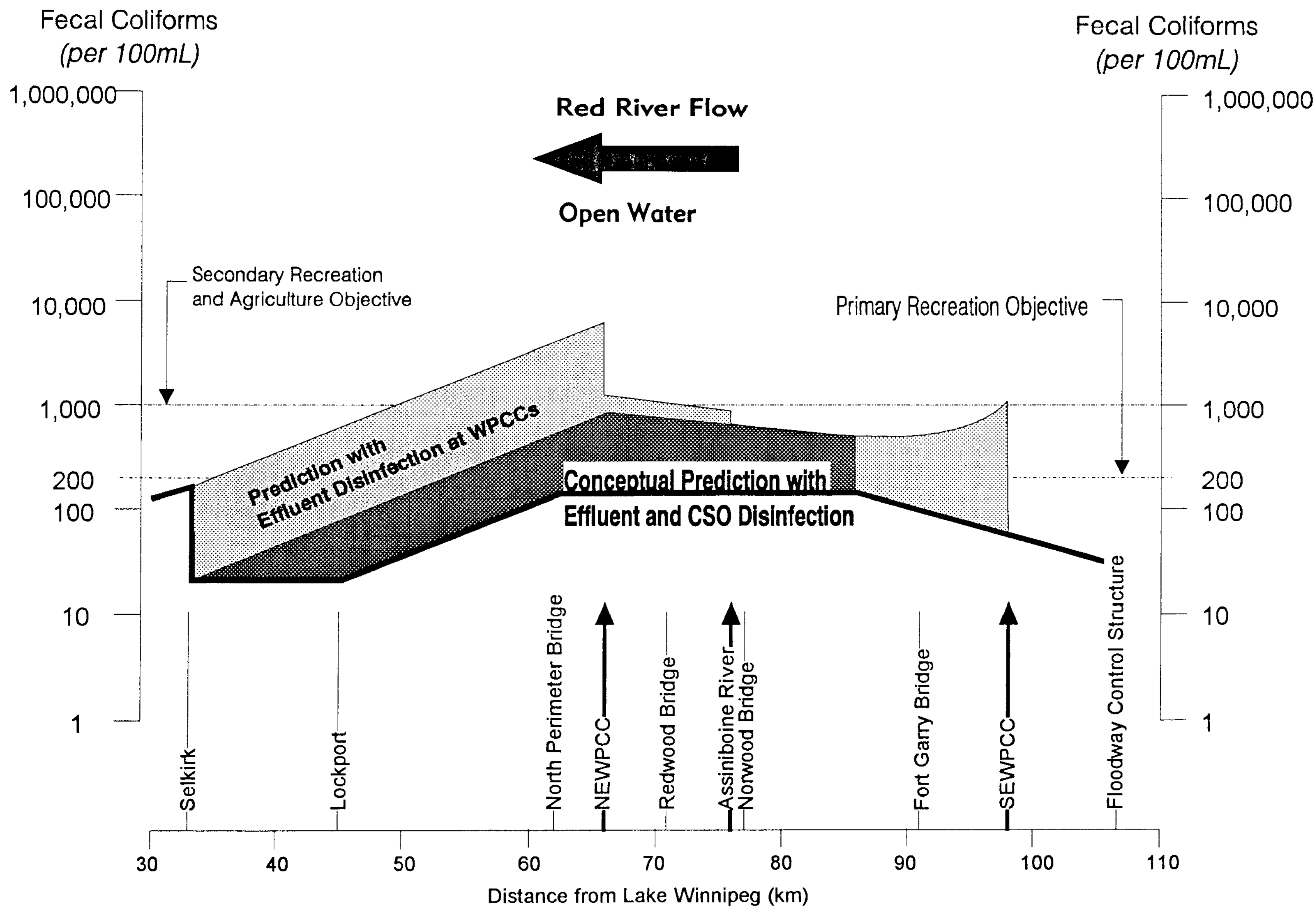
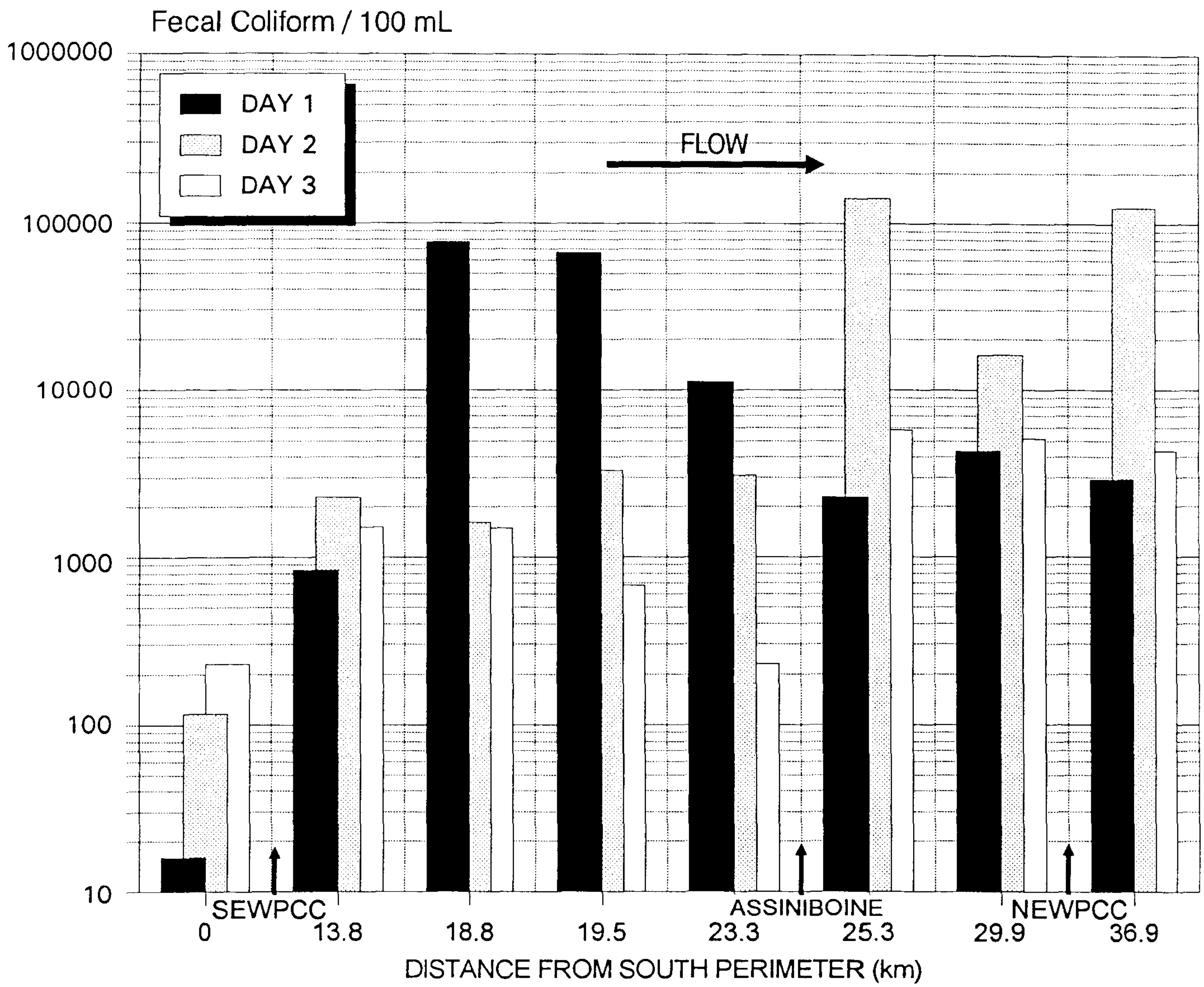


Figure 4-11



Red River-Fecal Coliform
Wet Weather Monitoring Program
Starting Sept. 18, 1990

redrfeco
csorac

Figure 4-12

Much of the variation of fecal coliform during a single sampling period is due to the sampling uncertainty, i.e., two measurements from the same sample can often vary by an order of magnitude. This variation makes it difficult to measure the fecal coliform profile in any given time period. It should be recognized that precise calibration of a dynamic model to a single event will be difficult. A more likely calibration procedure is to use multiple events and adjust the model parameters to minimize the total error between the model runs and the monitoring data. Such calibration makes it necessary to have several years of monitoring data for CSO events, which is provided by the 1990 to 1992 CSO monitoring.

4.2.3 Nutrients

Nitrogen and phosphorus are measured routinely upstream, within and downstream of the City of Winnipeg.

With respect to the general guidance for nutrient levels, namely phosphorus, the total phosphorus concentrations in the Red and Assiniboine headwaters, as well as throughout the study area, exceed the MSWQO of 0.05 mg/L year-round. The Winnipeg discharges of total phosphorus increase the instream concentration by about 0.1 mg/L on average year-round. Headwater concentrations typically average about 0.2 mg/L in both rivers. The Winnipeg discharges alone would cause exceedance of the objective but are largely overshadowed by headwater conditions. Rural land use practices, especially the use of chemical fertilizers, can contribute to significant phosphorus loading during wet weather run-off. Excessive growth of aquatic plants and algae do not appear to be a problem within the study area and phosphorus is not likely a limiting nutrient. On this basis, phosphorus loading from Winnipeg is not considered to be a water quality issue with respect to the Red and Assiniboine Rivers and specifically, not a CSO issue.

The fraction of phosphorus contributed to Lake Winnipeg by the Red River by the City of Winnipeg is relatively small and is discussed in more detail in another Technical Memorandum, "Problem Definition".

4.2.4 Ammonia

High ammonia concentrations are a water quality issue in the Red and Assiniboine Rivers. The CEC has recommended an "Ammonia Study" to assess this problem and the City is addressing this in a separate study. Ammonia limits are generally high downstream of the plant discharges. The treatment plants are not designed for nitrification thus all ammonia in the wastewater brought to the plants is concentrated at the discharge point during DWF. During WWF, the same mass of ammonia will be discharged from many overflow points, i.e., CSOs and plant effluents. It is likely that the wide distribution of ammonia during WWF will cause lower ammonia concentrations in the river. This should be investigated further in this CSO management study.

4.2.5 Heavy Metals/Pesticides

The City does not routinely collect information on heavy metals and pesticides. Water quality data collected by the Province indicate that instream concentrations for parameters in these categories do not change appreciably through Winnipeg (see Table 4-3). Mercury and Manganese were found to be the only two measured heavy metal parameters that exceeded MSWQO. Mercury and Manganese concentrations upstream of Winnipeg exceeded MSWQO and did not change in concentration appreciably downstream of Winnipeg. The pesticide "2,4-D", a common form of herbicide used in agriculture, was found to exceed MSWQO downstream of Winnipeg. The mean concentrations upstream of Winnipeg were marginally below the numerical limit of 0.10 mg/L. Since this parameter is not measured within or directly downstream of Winnipeg (i.e., North Perimeter Bridge) it is not possible to determine whether Winnipeg discharges or downstream agricultural run-off was responsible for this exceedance. Additional seasonal sampling at the North Perimeter Bridge should be performed by the City or Province if the non-compliance is deemed to be a concern. It is not considered a CSO issue.

TABLE 4-3

MEAN CONCENTRATIONS OF HEAVY METALS AND PESTICIDES IN THE RED AND ASSINIBOINE RIVERS UPSTREAM AND DOWNSTREAM OF WINNIPEG

	UPSTREAM		DOWNSTREAM	
	RED RIVER: FLOODWAY CONTROL STRUCTURE	ASSINIBOINE RIVER HEADINGLEY	RED RIVER SELKIRK	MSWQO
HEAVY METALS				
Mercury (mg)/L)	0.022	0.020	0.020	0.001
AS (total) (mg/L)	0.004	0.004	0.004	0.05
Cadmium (mg/L)	0.001	0.002	0.003	0.005
Lead (mg/L)	0.006	0.008	0.009	0.05
Magnesium (mg/L)	34.92	39.59	33.38	-
Manganese (mg/L)	0.012	0.15	0.12	0.05
PESTICIDES				
Bromoxynil (mg/L)	0.04	0.04	0.04	(a)
Diclofop-Methyl (mg/L)	0.12	0.05	0.07	(a)
2, 4-D (mg/L)	0.08	0.07	0.31	(a)
Lindane (mg/L)	0.009	0.008	0.013	(a)

(a) The sum of all pesticides, when more than one is present should not exceed 0.1 mg/L

4.3 MONITORING REQUIREMENTS

The water quality monitoring of the rivers done by the City of Winnipeg appears to be extensive. The key parameters (e.g., fecal coliforms, dissolved oxygen, ammonia and nutrients) have been monitored over the long-term and intensively in special programs. Additional monitoring of dissolved oxygen at the likely minimum point (the DO "sag point") may be beneficial to increase the confidence in the existing water quality management program.

Two alternatives to collect information on DO at the likely minimum point can be considered:

- Intensive monitoring by boat for four days following a CSO event. This would be similar to the 1992 program.

- Installation of a continuous DO probe about 3 km upstream of Lockport. This equipment could be purchased or rented by the City.

Either method could provide information however each has a different impact on City Laboratory Resources (i.e., man power or capital budgets).

Aesthetics is important to the public and any CSO monitoring program should note the visual impact on the rivers.

The monitoring of priority pollutants has been limited to one year and there has been very little monitoring of sediments and aquatic species for toxic accumulation. The importance of additional monitoring for the CSO study should be pursued further at the Phase 1 workshop and with the scientific advisory committee.

The impact of LDS runoff may be difficult to differentiate from CSO in the river. Another monitoring location within the City, but upstream of the CSO area on the Assiniboine River, could be used to assess LDS impacts. The Assiniboine Park Bridge is the next bridge downstream of the West Perimeter Bridge, however it is directly downstream of Moorgate CSO district. This station would then be influenced by CSOs. The Fort Garry Bridge station on the Red River could already provide this information and the Elm Park Bridge could also be monitoring in summer after a rainfall. At the present time, both are impacts by treatment plant effluent.

The service loading (CSO and effluent quality and quantity) are provided in a separate Technical Memorandum: Problem Definition.

5.0 FORECASTING FUTURE WATER QUALITY OF THE RED AND ASSINIBOINE RIVERS

This section gives a brief description of the forecasts of the future water quality done for the Red and Assiniboine rivers over the past 15 years. Water quality modelling has not been used as the sole method to assess future water quality, however, it is significant that five studies have used river modelling as a framework to assess water quality.

In each study, of the studies that used water quality models to simulate water quality for various future scenarios, it was important for the modeller to understand the principles behind the equations which created the model. The key steps in any modelling study are:

- an accurate description of the system in terms of hydraulic and biokinetic parameters;
- calibration of model parameters using available local data and experience elsewhere;
- verification of the model on a set of local data different from that set used for calibration;
- sensitivity analysis to determine which parameters are key to accurate predictions;
- review of data monitoring requirements to improve the accuracy of future models;
- selection of appropriate prediction scenarios in which to design engineering systems (i.e., treatment plant effluent objectives, etc.);
- peer review of model calibration and results by practitioners outside the core modelling team.

It is these steps rather than the selection of a particular model or computer code which ensure reliability of the model predictions and recommendations.

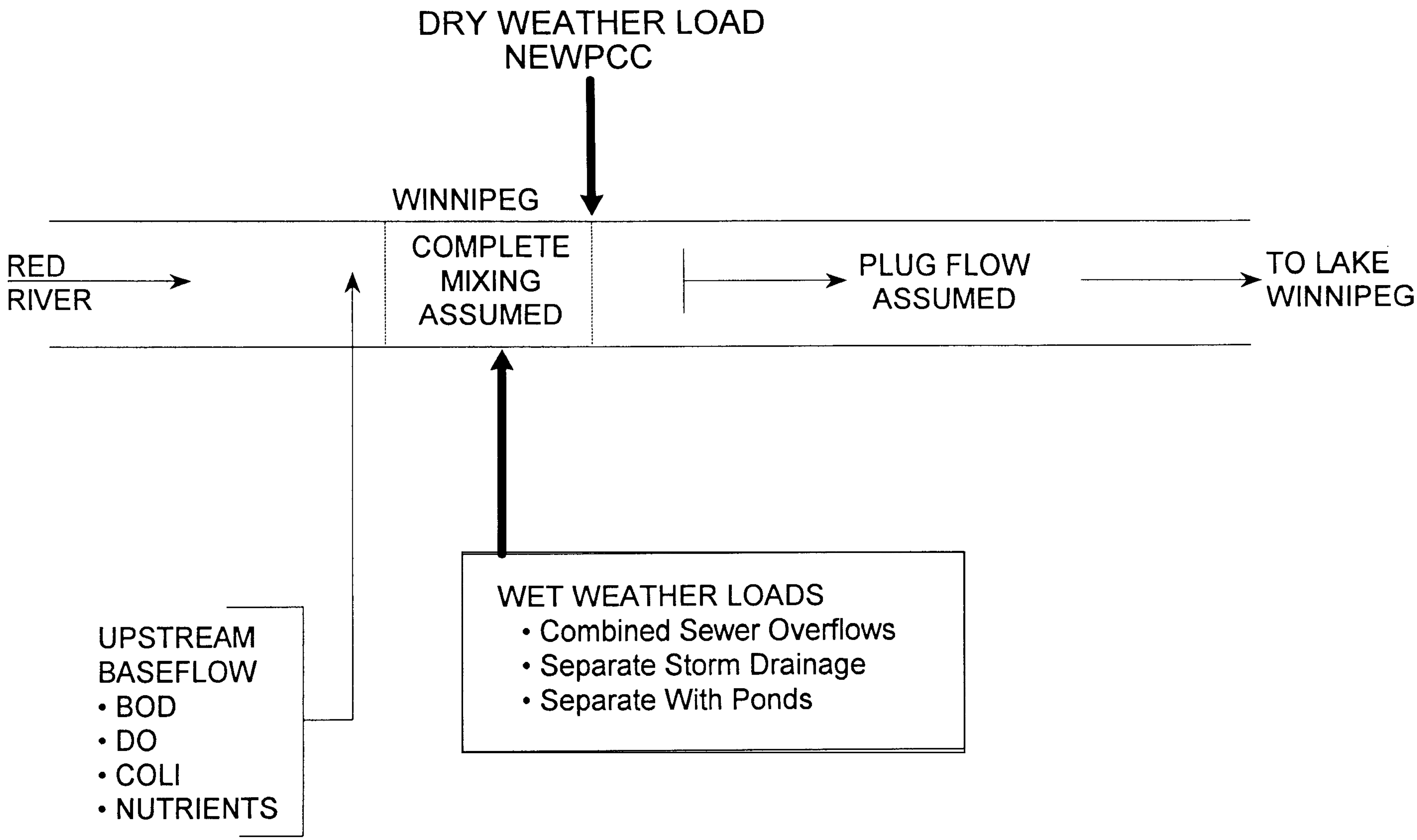
The river modelling done in the past for the City of Winnipeg has involved both developing custom computer code and using "open" U.S. EPA models. The selection of the models used was generally dependant upon the level of sophistication required for the project. This section will briefly describe the modelling done on the local rivers in the past 15 years and discuss the key findings of each study. The City has invested substantial effort in fitting water quality modelling to the local situation. The resulting data on water quality dynamics is a valuable resource regardless of which model is used in the future.

5.1 DESCRIPTION OF PREVIOUS MODELLING

5.1.1 1979 - RVRQUAL

A study was done by J.F. MacLaren (1979) to assess future river water quality under various scenarios. This model was a dynamic custom model developed for the City to assess both WWF and DWF impacts. The mass transport simulation was performed using plug flow analysis and the City of Winnipeg was considered as a single point source (Figure 5-1). Wet weather loads were estimated combining STORM model results from previous runoff modelling studies (for each CSO and LDS district). The NEWPCC effluent discharge was considered in the model, but the SEWPCC and WEWPCC discharges were not modelled. The objective of the modelling was to consider water quality impacts i.e., DO sequence downstream of the NEWPCC. The biokinetic modelling consisted of first-order decay for coliforms and the Streeter-Phelps model was used to simulate BOD-DO interaction. The focus of the model was to predict dissolved oxygen and coliform concentrations within and downstream of the City.

This study found that during DWF dissolved oxygen concentrations will remain around 5 mg/L and that WWF may suppress dissolved oxygen concentrations to below 4 mg/L. The study recommended an upgrade of the NEWPCC secondary treatment capacity to improved river water quality. At that time, the City was still undecided about the cost-effectiveness of CSO control. Tertiary treatment (nitrification) was not considered justified to improve dissolved oxygen quality in the river.



modschem
csorec

1979 River Quality Model
System Schematic
Figure 5-1

5.1.2 1984-85 QUAL2E

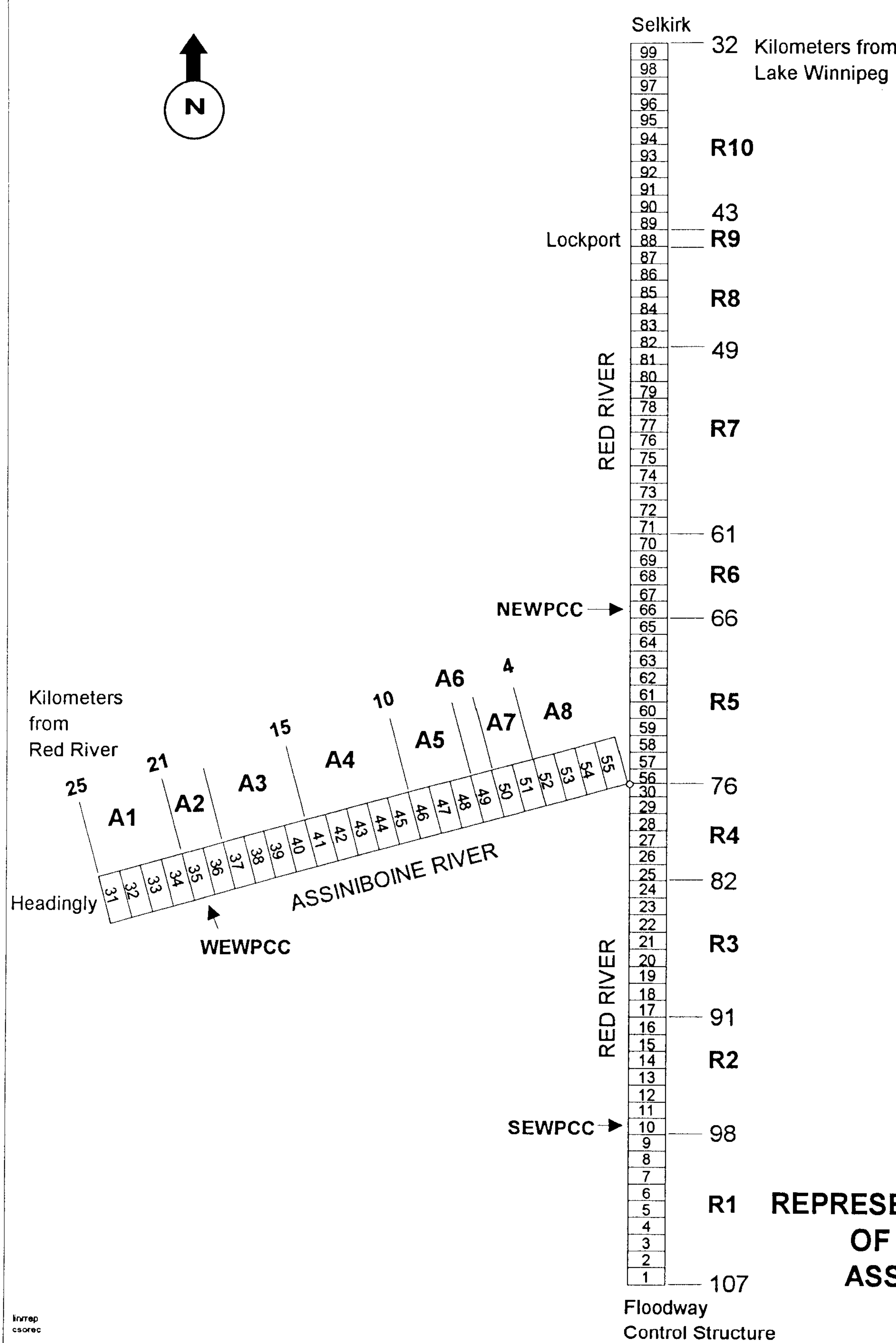
A study by MacLaren Engineers (1986[14]) considered the expansion requirements for the SEWPCC and WEWPCC. Various treatment scenarios, including the possibility of diverting to WE flow to the SEWPCC were considered.

A U.S. EPA model QUAL2E was setup and calibrated for the Red and Assiniboine rivers. This model was used to simulate dry weather flow conditions from the City. The river's hydraulics were simulated for each reach of the river using a stage discharge relationship and the mass transport was simulated using a finite difference numerical approach (Thomann 1987)[15]. Finite difference methods, although more complex simulated phenomena such as longitudinal dispersion. This model provided prediction of water quality by kilometre from upstream of the City to Selkirk 30 kilometres downstream (Figure 5-2). This model simulated dissolved oxygen concentrations by considering the complex interactions of BOD, nutrients and algae (Figure 5-3). Fecal coliforms were considered independent of other parameters and continued to be modelled by the first-order decay model.

The main focus of this study was to determine if the WEWPCC should be abandoned and flow diverted to the SEWPCC, i.e., central treatment. The modelling showed that it was a benefit to the river system to distribute the discharges in two locations. The City concluded that the WEWPCC should be maintained at its present location and upgraded. It was recommended that secondary treatment be improved to meet 15 mg/L carboneous BOD at all the plants. It was recommended that detailed, intensive monitoring be conducted on the Red River during low flow. Again, tertiary treatment was not justified for improving dissolved oxygen.

5.1.3 1986 - Disinfection QUAL2E and Custom Models

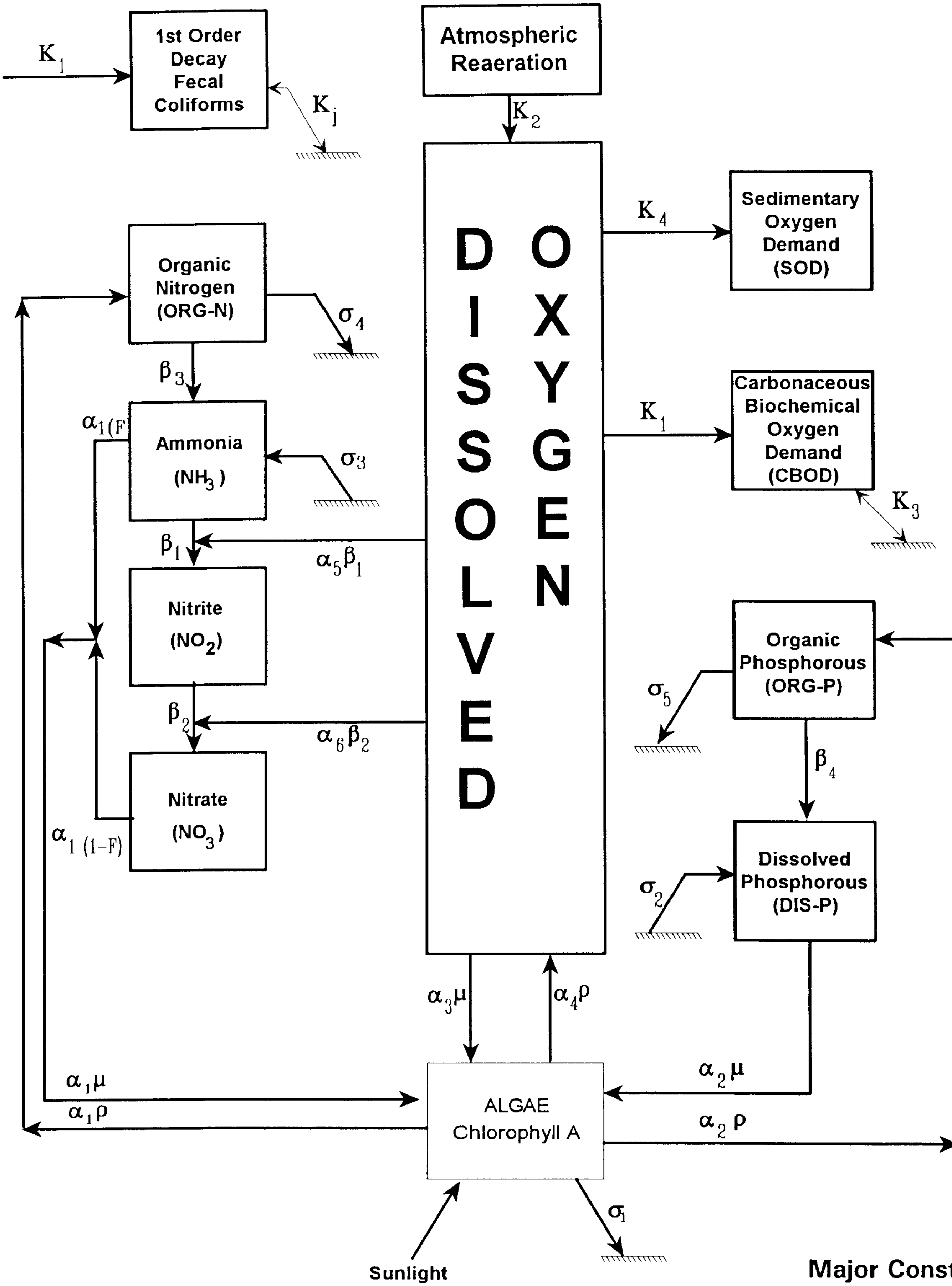
A 1986 study by MacLaren was commissioned by the City and Province to assess the benefits of effluent disinfection at the treatment plants. As part of this study, the QUAL2E model was extended to simulate WWF for one month. The purpose was to simulate fecal coliform concentration in the river with and without disinfection of the plant effluent. Since only one month of data was used this model was considered "illustrative" of future river conditions, rather than "predictive". An example of this model's prediction for disinfection



LINEAR REPRESENTATION OF RED AND ASSINIBOINE RIVER

Figure 5-2

linrep
csorec



Major Constituent Interactions in QUAL2E

Figure 5-3

versus no disinfection is shown in Figure 5-4. In addition, a simple first-order decay-plug model was used to estimate fecal coliform concentrations at Selkirk for various river flows.

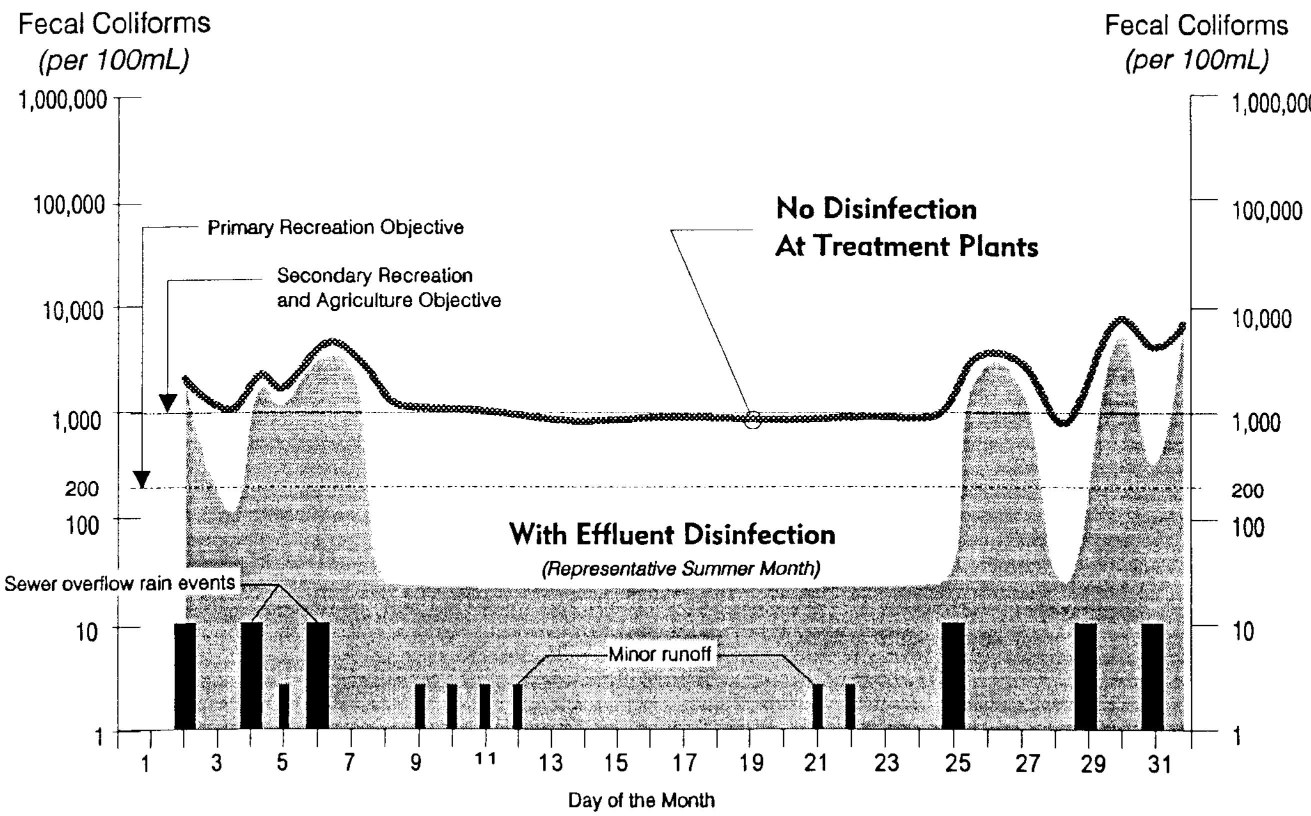
Fecal coliform concentration were found to be above MSWQO due to both plant effluent and WWF (especially CSOs). However, river use studies indicated that, because there was relatively little primary recreation, there was a low overall health risk to the community.

5.1.4 1990-92 QUAL2E Modelling

The City of Winnipeg engaged Wardrop Engineers and Tetr*ES* Consultants to prepare a report on the cost and benefits of various pollution control alternatives. The purpose of the report was to present information to the Clean Environment Commission which was considering the proposed Surface Water Quality Objectives for the Red and Assiniboine Rivers.

Therefore in 1990, the QUAL2E model was revisited for the simulation of Red and Assiniboine water quality. Dry weather flow conditions were simulated using more refined hydraulic representations and calibrated using the detailed monitoring of 1988 (see Section 4.0). The major improvement in the calibration set was the addition of algae (chlorophyll-a) concentrations, which confirmed the importance of algae influence on the dissolved oxygen calculation. This model was used to predict water quality for future dry weather flow conditions.

The present effluent design criteria for all WPCCs was estimated to be sufficient to protect the dissolved oxygen resource with respect to the MSWQO, i.e., over 47% saturation of DO in summer, therefore tertiary treatment would not be required for protecting DO. Ammonia concentrations in the river exceed the proposed MSWQO due to treatment plant discharges. Since there is a healthy fishery in the river there is some uncertainty as to whether the frequency, duration and extent of the exceedance of the MSWQO with respect to the un-ionized ammonia objective is significant. Another study will investigate this issue.



Predicted Fecal Coliform Density at Redwood Bridge with Effluent Disinfection

Figure 5-4

5.1.5 1992-93 Coli-model

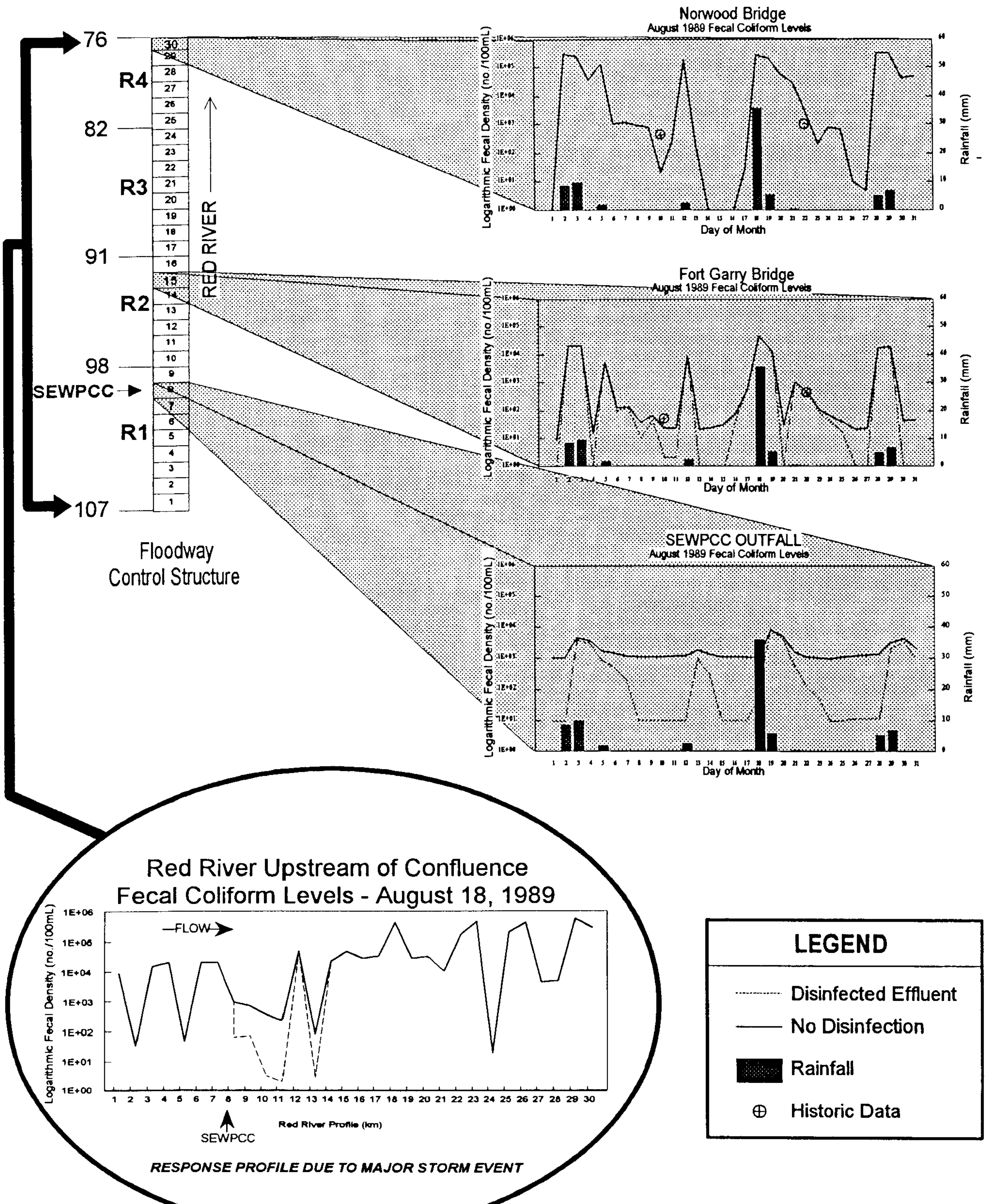
The City engaged Tetr*ES* Consultants (1993) to develop a dynamic model to simulate the fecal coliform concentrations in the river. The model was to assess the benefits of disinfection at the treatment plants. A custom model was developed to dynamically simulate fecal coliform concentrations in the Red and Assiniboine rivers. The hydraulic analysis was done using the same stage discharge relationship as developed for the QUAL2E modelling of 1990 to 1992. The model was discretized to one kilometre segments, as was done for the QUAL2E model. The simpler mass transport plug flow analysis was used rather than the finite difference analysis used in QUAL2E. Mass balance and first-order of decay analysis for fecal coliforms were used for each river element.

The model was used to predict the fecal coliform for each kilometre of the river under various DWF and WWF scenarios. The impacts of CSO and other wet weather flow were simulated and an illustrative scenario considering selected CSO disinfection was simulated.

This model illustrated the peaks and die-off of fecal coliforms during and after WWF (Figure 5-5). The river flow and extent, intensity, duration and frequency of rainfall events will have an influence on compliance during WWF. This study confirmed that CSOs are a key influence on coliform concentrations in the river.

5.2 MODELLING REQUIREMENTS

For the CSO study, the key parameter to be modelled is fecal coliforms. It will be necessary to estimate DWF and WWF water quality profiles and differentiate effects of different sources, i.e., CSOs. A "RIVER" model must consider mass balance, transport and first-order decay of fecal coliforms, and be integrated with a RUNOFF model for river quality simulation in a CSO study. The modelling of fecal coliforms is not complex relative to dissolved oxygen and algae, however it is important that the hydraulic model, which calculates the time of travel of constituents in the river, be accurate. The stage discharge relationships developed for the City of Winnipeg (i.e., for QUAL2E model) are accurate representations and this information can be used in future models. The model should be able to consider various inputs (i.e., CSO, LDS, treatment plants). The model must accept multiple inputs (i.e., it must accept



Fecal Coliform Dynamic Modelling
Red River - South of Confluence

Figure 5-5

dynmod
csorec

hydrographs and pollutographs from a RUNOFF model). The impacts of reducing overflow at individual locations or disinfecting the overflows (or plant effluent) must also be considered (i.e., must integrate with RUNOFF model). It is important that the "RIVER" model be able to run a continuous simulation for at least one summer. Several, up to five, years of data may need to be assessed for each CSO management alternative to assess the benefits in terms of improving compliance. The output should be fecal coliform profiles of the river, which vary with time. Statistical summaries of the fecal coliform concentration profiles over five summers could be used to assess each alternative.

The non-compliance of dissolved oxygen objective is a rare event therefore continuous modelling is likely not necessary. Modelling a single severe event may show that the maximum DO suppression caused by a CSO event does not cause non-compliance. Another alternative to detailed modelling of dissolved oxygen is more monitoring, as discussed in Section 4.0. Dissolved oxygen is not considered a key parameter to be considered in modelling.

Aesthetics are not to be modelled explicitly, however, by reviewing the fecal coliform results, an indication of the areas most affected by CSOs can be assessed for each alternative.

6.0 CONCLUSIONS

1) The key river uses potentially affected by CSOs are recreational (e.g., swimming, water skiing and boating) aesthetics, and aquatic life.

2) The key water quality parameters to assess relative to these uses are fecal coliforms (for recreation), floatables, ammonia and dissolved oxygen (for aquatic life).

3) Fecal coliforms are frequently above the proposed MSWQO. CSOs are a major influence on this non-compliance. In order to assess the benefits of various control alternatives a "RIVER" model must simulate the peak, duration and extent of non-compliance with the fecal coliform objective.

4) Current ammonia concentrations do not comply with the proposed MSWQO, however there will be a separate study dealing with this issue. The ammonia concentration in the river is likely no higher during or following WWF conditions, since ammonia is not removed by the treatment plants currently. Ammonia levels are not considered a CSO issue.

5) Monitoring has shown the dissolved oxygen is above MSWQO during DWF and WWF for current conditions and predicted to be adequate for future flow conditions. DO is therefore likely not an issue relative to CSOs.

   Any uncertainty with respect to CSO and DO impacts can be addressed by either additional monitoring of specific modelling as discussed below. More DO monitoring may be required between the North Perimeter Bridge and Lockport, the reach where the minimum DO concentration is likely located. Two possible monitoring options are:

   - a continuous DO monitoring;
   - additional CSO event monitoring as done in 1991 and 1992.

   It is likely that the impact of CSO events on DO can be assessed without a continuous dynamic model. One approach would be to use a Streeter-Phelps model and estimate travel times for selected event analyses. This option should be investigated further in Phase 2.

6) Aesthetic issues such as floatables will not be modelled.

7) There is limited monitoring information on the impact of CSOs on sediment in the rivers. It is likely that monitoring of sediment quality is required.

8) The required water quality model will need to accept "pollutographs" (especially fecal coliform loadings with time) for different reaches, different reach fills and differentiated as to source (i.e., LNS, CSO, WPCC).

APPENDIX A

PRIORITY POLLUTANT TEST

PRIORITY POLLUTANTS SURVEY #1

JULY 18, 1991 Q_{NE} = 230 ML/d

MISA TEST GROUP AND COMPONENTNAME	DETECTION LIMIT	RED RIVER AT SOUTH FLOODWAY RU	RED RIVER AT NORTH PERIMETER RD	ASSINIBOINE RIVER AT HEADINGLEY AU	NEWPCC EFFLUENT NE	SEWPCC EFFLUENT SE	WEWPCC EFFLUENT WE
GROUP #2 - CYANIDE 1	0.0002 ppm	N.D.	0.0010	N.D.	0.0190	0.0050	0.0120
GROUP#9 - METALS 17							
Aluminum	0.009 ppm	6.400	2.000	3.600	0.160	0.049	0.070
Beryllium	0 ppm	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Boron	0.004 ppm	0.080	0.083	0.110	0.210	0.200	0.230
Cadmium	0.001 ppm	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Chromium	0.001 ppm	0.012	0.004	0.006	0.033	0.003	0.052
Cobalt	0.001 ppm	0.011	0.006	0.009	0.004	0.002	0.003
Copper	0.002 ppm	0.033	0.025	0.021	0.031	0.030	0.025
Iron	0.01 ppm	8.20	2.30	4.50	0.24	0.12	0.12
Lead	0.01 ppm	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Molybdenum	0.003 ppm	0.005	N.D.	N.D.	0.015	0.004	N.D.
Nickel	0.009 ppm	0.011	N.D.	N.D.	N.D.	N.D.	N.D.
Silver	0.001 ppm	N.D.	N.D.	N.D.	0.002	N.D.	N.D.
Strontium	0.002 ppm	0.200	0.200	0.270	0.210	0.290	0.290
Thallium	0.01 ppm	0.01	0.01	N.D.	N.D.	0.01	N.D.
Vanadium	0.001 ppm	0.029	0.011	0.016	N.D.	N.D.	N.D.
Zinc	0.004 ppm	0.031	0.011	0.024	0.058	0.063	0.043
GROUP #10 - HYDRIDES 3							
Antimony	0.003 ppm	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Arsenic	0.003 ppm	0.008	0.006	0.010	N.D.	N.D.	N.D.
Selenium	0.003 ppm	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
GROUP #12 - MERCURY 1	0.00002 ppm	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
GROUP #14 - PHENOLS 1	0.001 ppm	N.D.	N.D.	N.D.	0.005	0.003	N.D.

COPY

PRIORITY POLLUTANTS SURVEY #1
JULY 18, 1991

MISA TEST GROUP AND COMPONENT NAME	DETECTION LIMIT	RED RIVER AT SOUTH FLOODWAY RU	RED RIVER AT NORTH PERIMETER RD	ASSINIBOINE RIVER AT HEADINGLEY AL	NEWPCC EFFLUENT NE	SEWPCC EFFLUENT SE	WEWPCC EFFLUENT WE
GROUP #16 - VOLATILES 26							
Cl-Methane	2.3 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Br-Methane	2.4 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Vinyl Chloride	2.9 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
1,1 Cl2-Ethylene	0.4 ppb	N.D.	N.D.	N.D.	1.0	1.0	N.D.
Cl3-F-Methane	0.3 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
trans-1,2 Cl2-Ethylene	0.4 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Methylene chloride	0.3 ppb	N.D.	N.D.	N.D.	N.D.	27.0	N.D.
Chloroform	0.4 ppb	N.D.	N.D.	N.D.	18.0	20.0	2.0
1,1-Cl2-Ethane	0.5 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
1,2-Cl2-Ethane	0.4 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Carbon tetrachloride	0.3 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
BrCl2-Methane	0.4 ppb	N.D.	N.D.	N.D.	0.6	N.D.	N.D.
1,1,2-Cl3-Ethane	0.6 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
cis-1,3 Cl2-Propylene	0.7 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
trans-1,3 Cl2-Propylene	0.1 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
1,2-Cl2-Propane	0.5 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
ClBr2-Methane	0.4 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Ethylene dibromide	0.6 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Cl3-Ethylene	0.3 ppb	N.D.	N.D.	N.D.	0.9	N.D.	N.D.
Bromoform	0.3 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Cl4-Ethylene	0.2 ppb	N.D.	N.D.	N.D.	3.0	N.D.	N.D.
1,1,2,2-Cl4-Ethane	0.4 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Cl-Benzene	0.6 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
1,2-Cl2-Benzene	0.4 ppb	N.D.	N.D.	N.D.	2.1	N.D.	N.D.
1,3-Cl2-Benzene	0.3 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
1,4-Cl2-Benzene	0.2 ppb	N.D.	N.D.	N.D.	1.6	0.7	N.D.

PRIORITY POLLUTANTS SURVEY #1

JULY 18, 1991

MISA TEST GROUP AND COMPONENT NAME	DETECTION LIMIT	RED RIVER AT SOUTH FLOODWAY RU	RED RIVER AT NORTH PERIMETER RD	ASSINIBOINE RIVER AT HEADINGLEY AU	NEWPCC EFFLUENT NE	SEWPCC EFFLUENT SE	WEWPCC EFFLUENT WE
GROUP #17 - VOLATILES 6							
Benzene	0.2 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Toluene	0.4 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Ethyl Benzene	0.4 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
m,p-Xylenes	0.5 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
o-Xylene	0.4 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Styrene	0.4 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
GROUP #18 - VOLATILES 2							
Acrolein	3 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Acrylonitrile	1.9 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
GROUP #19 - BASE NEUTRAL EXTRACTABLES 19							
Acenaphthene	0.7 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
5-Nitro Acenaphthene	1.8 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Acenaphthylene	0.4 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Anthracene	0.2 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Benz(a)anthracene	0.2 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Benzo(a)pyrene	0.5 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Benzo(b)fluoranthene	0.4 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Benzo(k)fluoranthene	0.4 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Benzo(ghi)perylene	0.4 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Biphenyl	0.4 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Camphene	1 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
1-Cl Naphthalene	0.8 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
2-Cl Naphthalene	0.9 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Chrysene	0.3 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

COPY

PRIORITY POLLUTANTS SURVEY #1

JULY 18, 1991

MISA TEST GROUP AND COMPONENT NAME	DETECTION LIMIT	RED RIVER AT SOUTH FLOODWAY RU	RED RIVER AT NORTH PERIMETER RD	ASSINIBOINE RIVER AT HEADINGLEY AU	NEWPCC EFFLUENT NE	SEWPCC EFFLUENT SE	WEWPCC EFFLUENT WE
GROUP #19 CONTINUED							
Dibenz(ah)anthracene	0.4 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Diphenyl ehter	0.6 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Fluoranthene	0.2 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Fluorene	0.3 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Indeno(123-cd)pyrene	0.6 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Indole	0.6 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
1-Me Naphthalene	2.2 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
2-Me Naphthalene	1.5 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Naphthalene	0.3 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Perylene	0.3 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Phenanthrene	0.3 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Pyrene	0.3 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Benzylbutyl phthalate	0.6 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Bis(2-ethylhexyl)phthalate	1.4 ppb	N.D.	N.D.	1.8	4.0	3.1	4.9
Di-n-butyl phthalate	1.1 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Di-n-octyl phthalate	0.4 ppb	N.D.	1.1	1.2	N.D.	N.D.	N.D.
4-Br Phenyl phenyl ether	0.3 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
4-Cl Phenyl phenyl ether	0.9 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Bis(2-Cl Isopropyl)ether	1.5 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Bis(2-Cl Et)ether	1.8 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
2,4-Dinitrotoluene	0.5 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
2,6-Dinitrotoluene	0.6 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Bis(2-Cl ethoxy)methane	1.3 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Diphenylamine	1.9 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
N-Nitrosodiphenylamine	1.9 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
N-Nitrosodi-n-propylamine	2.1 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

COPY

PRIORITY POLLUTANTS SURVEY #1
JULY 18, 1991

MISA TEST GROUP AND COMPONENT NAME	DETECTION LIMIT	RED RIVER AT SOUTH FLOODWAY RU	RED RIVER AT NORTH PERIMETER RD	ASSINIBOINE RIVER AT HEADINGLEY AU	NEWPCC EFFLUENT NE	SEWPCC EFFLUENT SE	WEWPCC EFFLUENT WE
GROUP #20 - ACID EXTRACTABLES 20							
2,3,4,5-Tetrachlorophenol	0.4 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
2,3,4,6-Tetrachlorophenol	0.7 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
2,3,5,6-Tetrachlorophenol	0.7 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
2,3,4-Trichlorophenol	0.5 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
2,3,5-Trichlorophenol	0.4 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
2,4,5-Trichlorophenol	0.6 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
2,4,6-Trichlorophenol	1.2 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
2,4-Dimethylphenol	1.7 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
2,4-Dinitrophenol	4.8 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
2,4-Dichlorophenol	1.2 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
2,6-Dichlorophenol	1.1 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
4,6-Dinitro-o-cresol	1.5 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
2-Chlorophenol	2.7 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
4-Chloro-3-methylphenol	1.4 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
4-Nitrophenol	1.4 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
m-Cresol	3 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
o-Cresol	1.7 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
p-Cresol	3.5 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Pentachlorophenol	1.1 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Phenol	1.1 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
GROUP #22 - ORGANOCHLORINE PESTICIDES 15							
Aldrin	0.01 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
a-BHC	0.01 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
b-BHC	0.01 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
g-BHC (Lindane)	0.01 ppb	N.D.	N.D.	N.D.	0.02	N.D.	N.D.
d-BHC	0.01 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

COPY

PRIORITY POLLUTANTS SURVEY #1

JULY 18, 1991

MISA TEST GROUP AND COMPONENT NAME	DETECTION LIMIT	RED RIVER AT SOUTH FLOODWAY RU	RED RIVER AT NORTH PERIMETER RD	ASSINIBOINE RIVER AT HEADINGLEY AU	NEWPCC EFFLUENT NE	SEWPCC EFFLUENT SE	WEWPCC EFFLUENT WE
GROUP #22 CONTINUED							
a-Chlordane	0.01 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
g-Chlordane	0.01 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Heptachlor	0.01 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Heptachlor Epoxide	0.01 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Methoxychlor	0.01 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
o,p'-DDT	0.01 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
p,p'-DDD	0.01 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
p,p'-DDE	0.01 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
p,p'-DDT	0.01 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
GROUP #23 - NEUTRAL CHLORINATED EXTRACTABLES							
1,2,3,4-Tetrachlorobenzene	0.009 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
1,2,3,5-Tetrachlorobenzene	0.005 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
1,2,4,5-Tetrachlorobenzene	0.005 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
1,2,3-Trichlorobenzene	0.008 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
1,2,4-Trichlorobenzene	0.006 ppb	N.D.	N.D.	N.D.	0.023	N.D.	N.D.
2,4,5-Trichlorotoluene	0.002 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Hexachlorobenzene	0.003 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Hexachlorobutadiene	0.002 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Hexachlorocyclopentadiene	0.004 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Hexachloroethane	0.001 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Octachlorostyrene	0.002 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Pentachlorobenzene	0.002 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
GROUP #27 - PCB's (Total)	0.05 ppb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

COPY