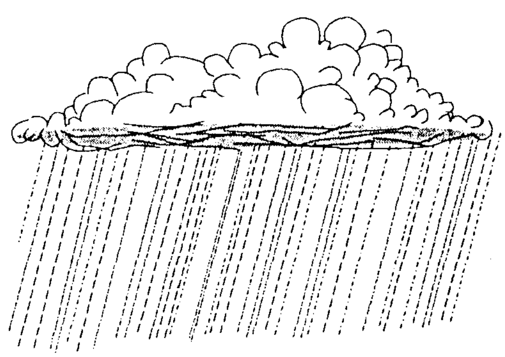
City of Winnipeg
Waterwork, Waste
and Disposal Department

Phase 1 Technical Memorandum for

Combined Sewer Overflow Management Study

PROBLEM DEFINITION

Technical Memorandum No. 1



Internal Document by:

WARDROP Engineering Inc. and TetrES CONSULTANTS INC.

In Association With:

Gore & Storrie Limited and EMA Services Inc.

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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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1.0 INTRODUCTION

This technical memorandum on Problem Definition will identify and quantify the dry and wet weather sources of discharges to the receiving streams and their impacts on Lake Winnipeg south basin. Current information will be used to estimate the impacts of loadings on the Red and Assiniboine rivers and place the relative impacts of various sources (i.e., land drainage, CSOs and WPCCs) into perspective. This perspective will be updated in this study in subsequent study phases by considering the temporal and spatial distribution of rainfall across the City of Winnipeg. Wet weather quality data has been collected by the City in more detail since 1989 to better characterize the concentration of constituents in discharges to the Rivers. The combination of areal-distributed rainfall and quality concentrations of dry and wet weather discharges will be used to assess the reach specific loadings on the rivers and more accurately quantify the fraction of loading on Lake Winnipeg attributable to Winnipeg.

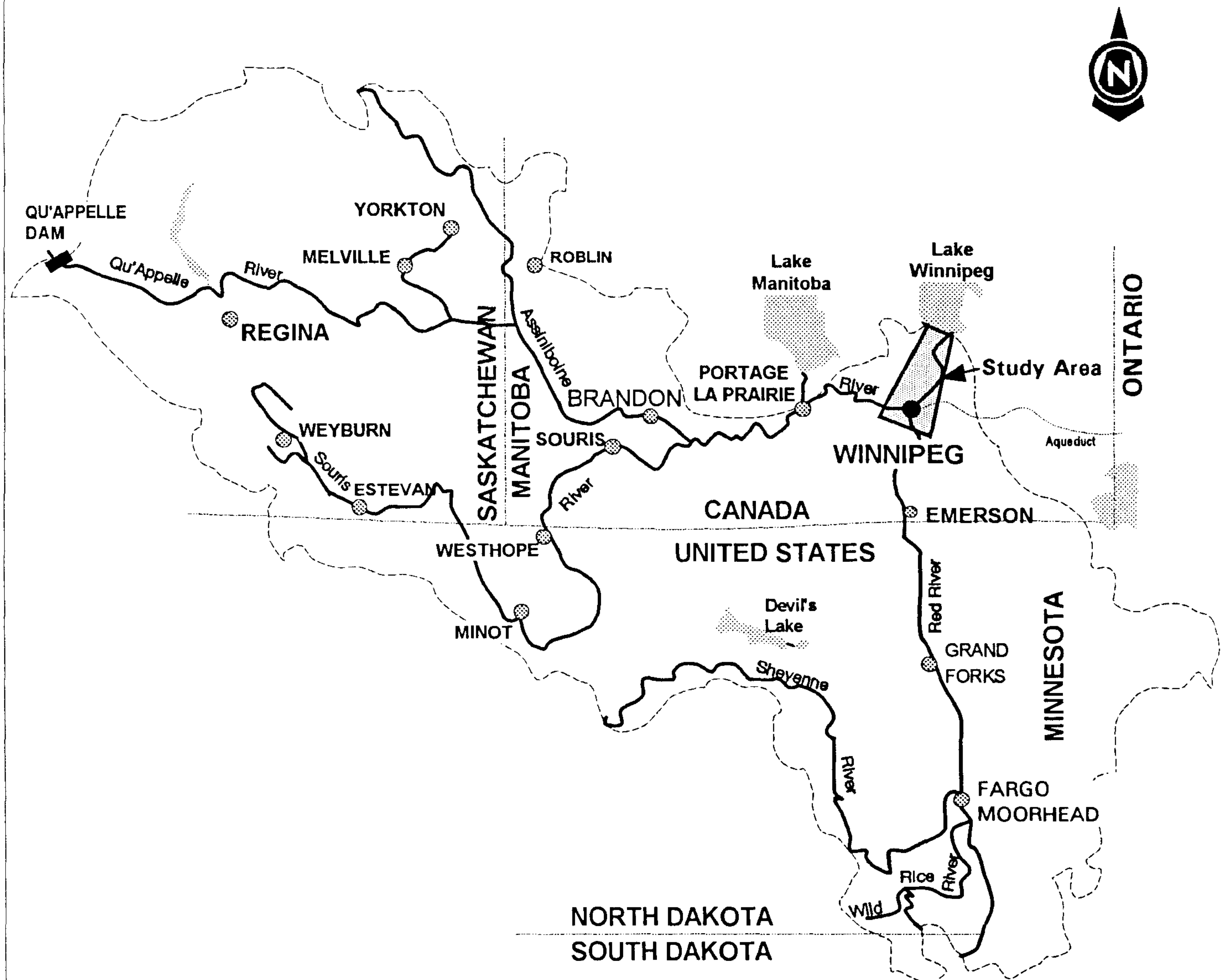
1.1 RED AND ASSINIBOINE RIVERS

Water quality and river uses are essential factors in this study. The evaluation of surface water quality within the study area must be placed in the context of the overall Red and Assiniboine watersheds (Figure 1-1). More information on the hydrology and land use of the basin is given in Technical Memorandum #4, Receiving Stream.

The Red and Assiniboine Rivers drain the prairie regions of southern Manitoba, southeastern Saskatchewan, North Dakota, northern South Dakota, and northwestern Minnesota.

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]). The flow in the rivers is dominated by spring runoff. Snowmelt, in combination with spring rains, has been responsible for major floods.

The Winnipeg Floodway and the St. Andrews Locks are the major hydraulic structures on the Red River in Manitoba. As can be seen from the vast drainage area and Winnipeg's location (near the tail-end of the watershed drainage basin) that upstream runoff and drainage can



The Red and Assiniboine Rivers Watershed

watrshed
csoprob

Figure 1-1

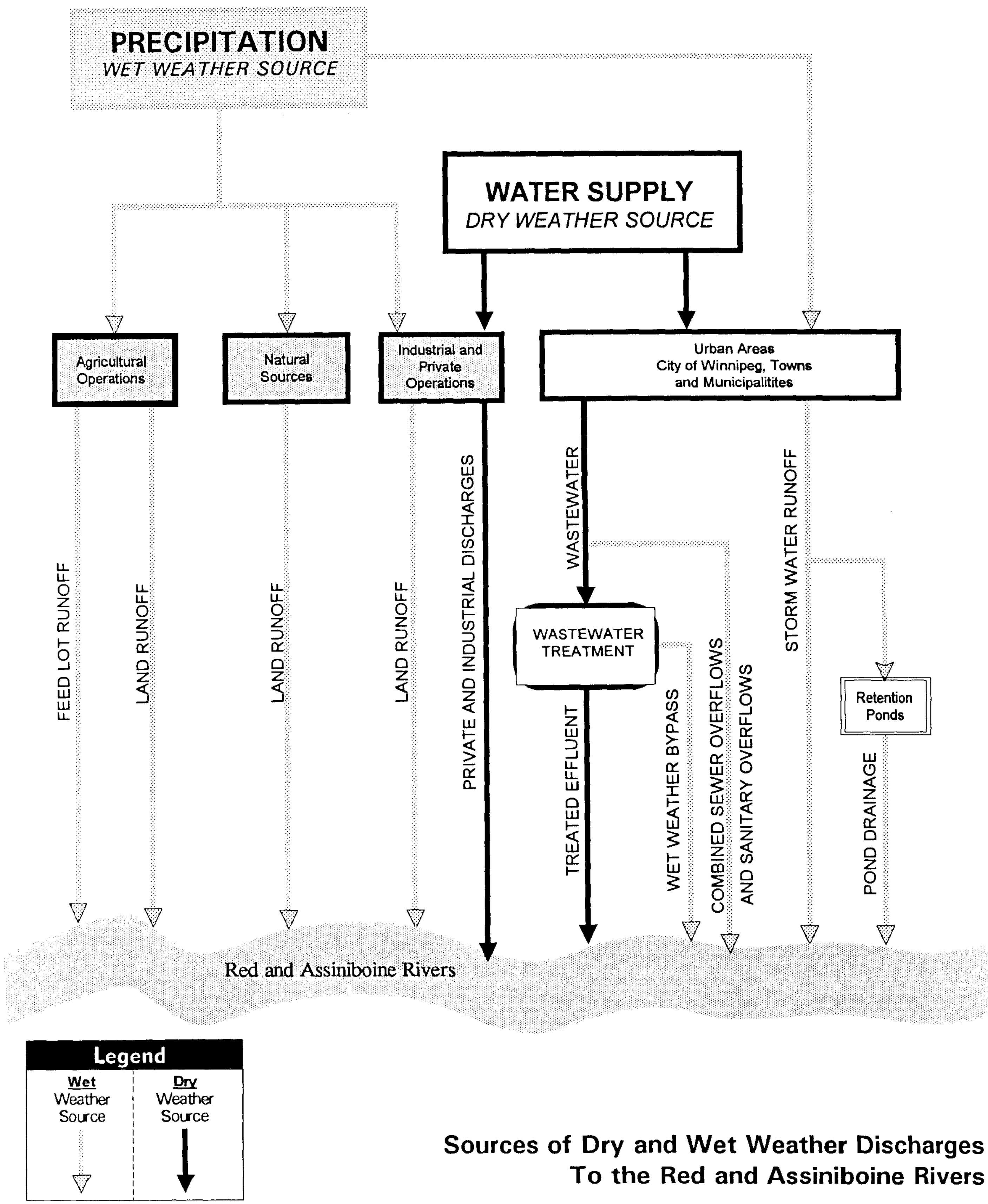
significantly influence the water quality and rivers before reaching Winnipeg. This is an important consideration when assessing the compliance with Manitoba Surface Water Quality Objectives (MSWQO) pre- and post-discharges from Winnipeg.

1.2 LAKE WINNIPEG SOUTH BASIN

Land use in the drainage basins is principally agricultural, but numerous cities and towns are located on the riverbanks. Agricultural use affects water quality through the run-off of nutrients, pesticides and sediments. Algae concentrations increased from upstream to downstream of Winnipeg, suggesting nutrient enrichment. Concern has been raised in the past regarding water quality in the lake, and possible contamination by the Red River. A limited number of studies have indicated elevated nutrient concentrations (particularly phosphorus). Accordingly, it is important to determine the fraction of nutrient loading on Lake Winnipeg from the City of Winnipeg as a result of dry and wet weather discharges and place this in context relative to other major sources. The improvement that could be realized in response to CSO control can then be put in perspective.

1.3 SOURCES OF DISCHARGE

There are many dry and wet weather sources of discharges to the Red and Assiniboine Rivers inside and outside of the City of Winnipeg. Continuous dry weather discharges from the three WPCCs are the largest concern with respect to water quality impacts on the receiving stream on an annual basis. Wet weather discharges to the rivers is also a concern with respect to river quality, but more specific to seasonal and single event conditions. The rivers receive a wide range of discharges as shown on Figure 1-2. To illustrate, runoff from agricultural operations and undeveloped land can contribute to bacterial contamination and low levels of pesticides and fertilizers. Industrial operations often have individual discharges to the river.



Sources of Dry and Wet Weather Discharges To the Red and Assiniboine Rivers

Figure 1-2

dischg
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The major sources of dry weather discharges to the rivers from Winnipeg can be attributed to:

- continuous point source loading of treated effluent from WPCCs;
- continuous/intermittent point source loading from tributary streams; and
- possible intermittent point source loading(s) from combined sewer districts (this aspect will need to be verified and is part of the activities of subsequent study phases).

There are no industries which directly discharge to the rivers within the City.

Wet weather discharges can originate from a number of point and non-point sources and can occur during rainfall or snowmelt events. These discharges may consist of simple land drainage, urban runoff from land drainage sewers or overflow from sanitary sewers or combined sewers when the runoff is significant and exceeds interceptor carrying capacity (i.e. 2.75 time DWF). The total volume and discharge rate of wet weather flows is extremely variable. The different wet weather sources can be classified as:

- land drainage sewer runoff;
- retention pond drainage;
- separate sanitary sewer overflows;
- combined sewer overflows;
- wastewater plant by-passes;
- tributary streams.

2.0 CURRENT PERSPECTIVE OF LOADINGS TO THE RIVERS

Developing strategies for CSO management requires an understanding of the land use patterns in Winnipeg since land use can significantly affect the characteristics of the discharges to the rivers. Accordingly, this section will present information on current and future land use in Winnipeg, existing discharges to the river, and estimate future discharges to develop a current perspective on dry and wet weather discharges.

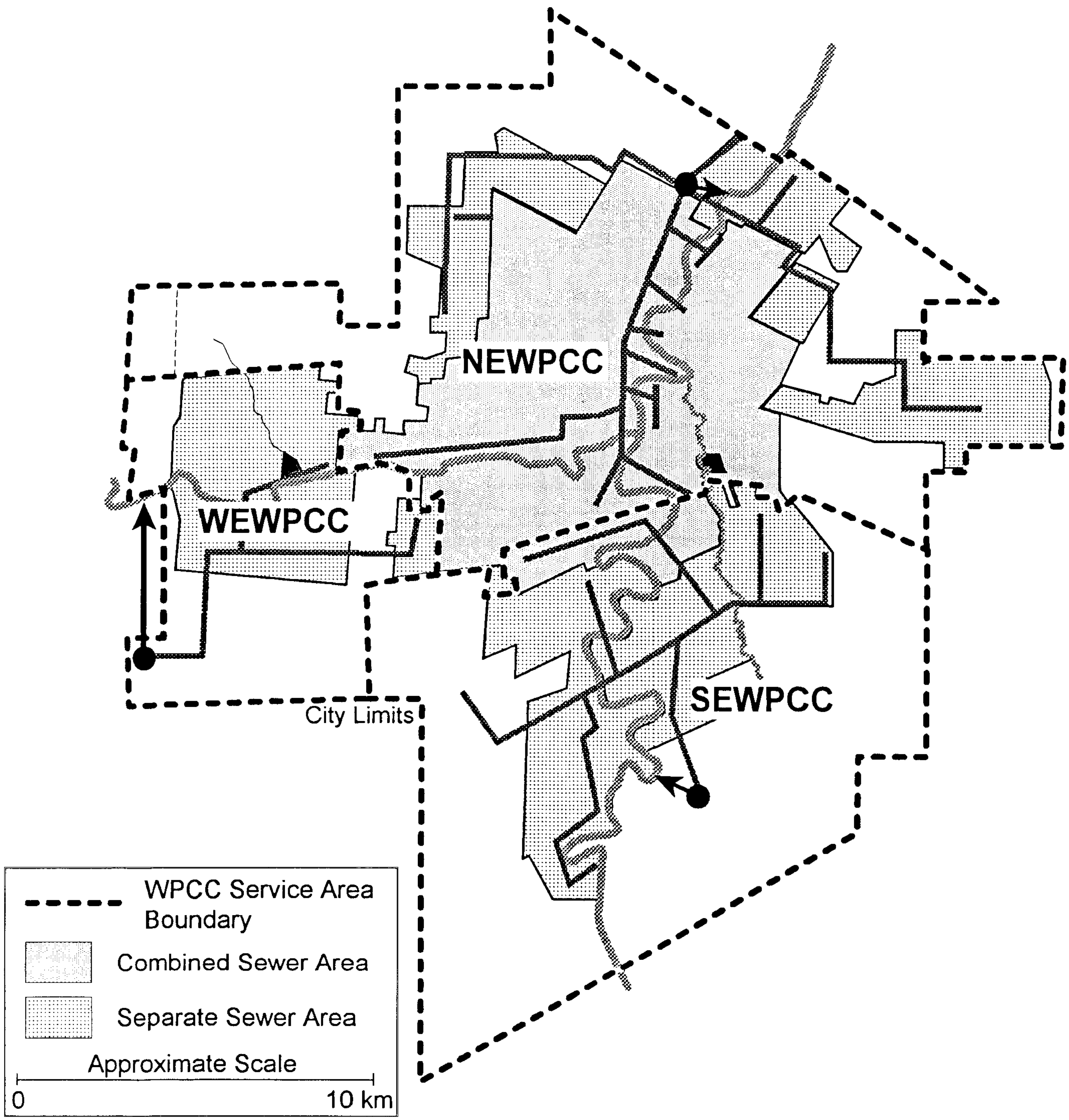
The current perspective presents the loadings to the rivers from dry and wet weather discharges (volumes). Locally measured quality concentrations typical for Winnipeg were compared with monitored values elsewhere to help put the values into perspective. These concentrations were then combined with discharges that were based on a uniform city-wide rainfall to estimate the frequency, duration of loadings to the rivers.

It is useful to classify the wastewater discharges in terms of dry weather (year-round, such as effluent from treatment plants) and wet weather (land drainage, overflows and treatment plant by-passes) which discharge during rainfall or snowmelt. The impacts of these sources and the ability to manage the discharge quality depends upon many factors, such as the total volume of wastewater and the rate at which it is discharged to the river. The following sections will discuss the city discharges in these categories.

2.1 DRY WEATHER LOADINGS

The major dry weather wastewater discharge to the rivers are the treated effluent from the three Water Pollution Control Centres (WPCC). The City of Winnipeg has directed significant attention in its pollution control programs towards establishing best practicable secondary treatment of all continuous dry-weather wastewater. This has resulted in the construction and operation of three major pollution control centres. The location of the three pollution control centres are shown in Figure 2-1.

Wastewater collected in the approximate 2,200 km of combined and sanitary sewers is conveyed to three pollution control centres (NEWPCC, SEWPCC, and WEWPCC). The NEWPCC is the largest of the three plants, has an existing service area of 16,200 ha, and accepts about 70% of the wastewater generated within Winnipeg. The SEWPCC is the second largest of the three regional treatment plants and has an existing service area of 7,700 ha. This plant treats about 20% of the city-wide wastewater flow at present. The WEWPCC is the smallest of the three plants, has an existing service of about 3,900 ha, and treats about 10% of the city-wide wastewater flow. The NEWPCC and SEWPCC plants are located on the Red River while the WEWPCC is located on the Assiniboine River. The historic and projected average dry weather flows (ADWF) and average annual flows (AAF) from the three WPCCs are given in Table 2-1.



WPCC Service Boundaries
Figure 2-1

wpccboun
csoprob

TABLE 2-1

HISTORIC AND PROJECTED TREATMENT PLANT DISCHARGES

TREATMENT PLANT	TREATED EFFLUENT DISCHARGES (ML/d)					
	1989		2011[a]		2040	
	ADWF	AAF	ADWF	AAF	ADWF	AAF
NEWPCC	216	250	311	365	344[b]	396[c]
SEWPCC	48	54	87	97	140[d]	157[e]
WEWPCC	30	32	33	36	49[f]	58[f]

a) From Wardrop/Tetr*ES* 1991 Red and Assiniboine SWQO
b) Based on estimate of PDWF used in QUALZE modelling for the Pembina Valley Water Cooperative Intervenor Submission
c) Assumes a multiplier of 1.16 to estimate AAF
d) Extrapolated projection from flow estimates contained in the SEWPCC Expansion Stage I Evaluation Study (Draft Report, 1993)
e) Assumes a multiplier of 1.12 to estimate AAF
f) From RCPL 1990 WEWPCC FDR

Quality characteristics of the final effluent from these pollution control centres are monitored regularly to aid in monitoring plant performances and discharge loading to the rivers. Some of the analytical parameters include the following:

- pH;
- suspended solids;
- grease;
- Biochemical Oxygen Demand (BOD_5), 5-day total and inhibited @ 20°C;
- total organic carbon;
- suspended solids (total and volatile);
- ammonia;
- total kjeldahl nitrogen;
- nitrite-nitrate nitrogen;
- total phosphorus;
- total alkalinity;
- heavy metals; cadmium, lead, nickel, copper, chromium, zinc, iron;
- microscopic examinations.

Quality characteristics of the plant effluent that are of most relevance to the river quality assessment are listed in Table 2-2 and demonstrate an ability to produce a high-quality secondary process effluent.

2.2 WET WEATHER LOADINGS

Wet weather discharges to the Red and Assiniboine rivers from within Winnipeg occur during rainfall events or snowmelt conditions. Surface runoff is strongly dependent upon depression storage, percent pervious and impervious areas, and rainfall intensity and duration. The key parameters effecting the volume and frequency of overflows are:

- runoff;
- catchment area size and shape;

TABLE 2-2

FINAL EFFLUENT QUALITY CHARACTERISTICS ANNUAL AVERAGES 1989

	CBOD (mg/L)	SS (mg/L)	AMMONIA (mg/L-N)	NITRATE (mg/L-N)	TOTAL PHOSPHORUS (mg/L-P)	FECAL[1] COLIFORM (10^6/100 mL)
NEWPCC	< 10	17.0	22.8	2.2	1.5	0.4
WEWPCC	< 10	19.3	8.3	7.5	5.5	0.4
SEWPCC	< 10	19.0	22.3	0.8	4.6	0.4

Source: City of Winnipeg; Proposals for the NEWPCC, SEWPCC, and WEWPCC under the Manitoba Environment Act (March 1990).

WHERE:

$CBOD_5$ is the total Carbonaceous Biochemical Oxygen Demand after a five day period.

SS is Suspended Solids

[1] Estimated densities based on 1986 Disinfection Report

- interceptor pump capacities; and
- system storage (currently of limited capacity except for land drainage systems with storm retention basins [SRBs]).

As indicated earlier, wet weather discharges can originate from a number of sources. The characteristics and extent of each of these sources will be discussed separately and then the quality and volumes of discharges will be reviewed.

2.2.1 Separate and Combined Sewered Areas

The sewered areas within Winnipeg include separated systems (with and without storm retention basins) and combined sewered systems. Figure 2-1 depicts the service boundaries of the three WPCCs. Table 2-3 lists the land use by WPCC boundaries for current and ultimate developed conditions. This table indicates that most of the combined sewered areas, about 92% are tributary to the NEWPCC. Most of the projected growth is planned to occur in the SEWPCC service area, about 80% of the total growth. This area has relatively little combined sewered areas and is mainly served by a separate sewered system. New developments in this area will likely use land drainage systems with storm retention basins because of the gentle slope of the land and distance from the rivers.

2.2.2 City-wide Analysis

As discussed earlier, wet weather discharges can occur from a number of sources. The main sources of runoff to the rivers come from combined sewered systems and separated sewered systems (with and without SRBs), and, to a minor extent, sanitary sewer overflows.

A city-wide study done in 1978 by J.F. MacLaren (1979) used a STORM model and estimate combined sewer overflows at 30 to 50 times per year. Overflows occur when rainfall or snowmelt is significant enough to cause runoff at a larger rate than can be intercepted (2.75 times the average dry weather flow rate can be intercepted). Tables 2-4 and 2-5 presents the analysis of this study with respect to volume and frequency of overflows. However, in reality, overflows do not occur at the same time or from all overflow points during a rainstorm

TABLE 2-3

SEPARATE AND COMBINED SEWERED AREAS OF WINNIPEG

- Land inventory by WPCC service area (ha)

TREATMENT PLANT	COMBINED SEWERS	SEPARATED SEWERS	TOTAL AREA
NEWPCC			
- 1990	9178	6989	16166
- ULTIMATE	9178	7833	17011
SEWPCC			
- 1990	622	7082	7704
- ULTIMATE	622	10483	11106
WEWPCC			
- 1990	243	3677	3919
- ULTIMATE	243	3862	4105
TOTAL			
- 1990	10043	17747	27790
- ULTIMATE	10043	22178	32221

TABLE 2-4

STORM MODEL RESULTS (QUANTITY)

PERIOD: 1974 11 01 TO 1978 11 04 (4 YEARS)

AVERAGE ANNUAL QUANTITY STATISTICS

	COMBINED	SEPARATE	SEPARATE/PONDS
Precipitation on Watershed (mm)	562.25	562.25	562.25
Surface Runoff (mm)	225.70	225.70	215.62
Surface Runoff + Dry Weather Flow During Events (mm)	244.05	225.70	215.62
Overflow to Stream (mm)	144.11	225.70	215.62
Number of Overflow Events	30	68	64

1992 Annual Meteorological Summary

Normal Rainfall 411.0 mm
Normal Snowfall 125.5 mm
Normal Total 525.5 mm

Source: MacLaren 1979
Pollution Abatement and River Quality Study

TABLE 2-5

SUMMARY OF AVERAGE ANNUAL OVERFLOW MODEL RESULTS

COMBINED SEWER DISTRICT	AREA (ACRES)	NO. OF OVERFLOWS	COMBINED SEWER DISTRICT	AREA (ACRES)	NO. OF OVERFLOWS
Ash	2050	28	Marion	575	28
Assiniboine	219	26	Metcalf	110	27
Aubrey	1409	29	Mission Combined	1500	28
Baltimore	600	28	Moorgate[3]	325	28
Bannatyne	542	21	Munroe	1200	28
Boyle	110	32	Newton	265	22
Clifton	1100	29	Olive[4]	600	23
Cockburn	903	28	Polson	620	29
Colony	562	23	River	284	25
Cornish	328	28	Riverbend Combined	460	27
Despins	190	20	Roberts	356	22
Dumoulin	150	27	Selkirk	700	26
Elmwood[1]	1200	24	St. Annes[5]	835	26
Ferry[2]	480	27	St. Johns	835	28
Hawthorne	650	28	St. Mary's[5]	150	27
Jefferson	2380	28	Strathmillan	160	31
Jessie	817	30	Syndicate	150	31
Kingston-St. Mary's[5]	465	29	Tuxedo Combined[6]	585	26
LaVerendrye	75	23	Tylehurst	550	31
Linden	750	26	Woodhaven	120	24
Lodge[4]	215	27			

Source: MacLaren, 1977
An Assessment of Combined Sewer Overflows in the City of Winnipeg

(i.e., intensity, duration and distribution will be an important factor to consider in updating the current perspective).

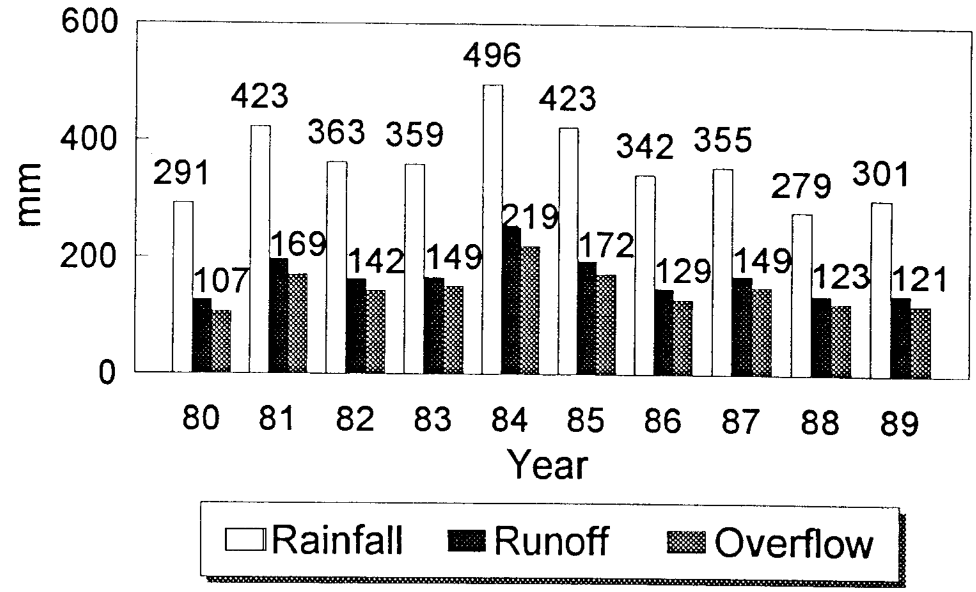
A recent relief sewer study was performed for the Linden and Hawthorne combined sewer district (Wardrop/Tetr*ES* 1993/94) and considered various wet weather control technologies to minimize discharges to the rivers. A modified STORM model was used to estimate the frequency and volume of overflows to the rivers for several years of actual rainfall histories. It was confirmed that the frequency and volume of discharges is strongly dependent on the frequency, intensity and duration of the rainfall events and not substantially by the interception rates. As can be seen from Figures 2-2 and 2-3, the frequency (number of overflows) per year is highly variable and can range from 26 to 53 events per year depending on the annual rainfall. These results confirm the assessment done in 1977. It is important to note that Linden is a smaller sewer district than Hawthorne and has a greater interception capacity (4.8 times DWF versus 2.3 times DWF). However, in both districts the rate of wet weather flow is much greater than the interception capacities and therefore the interception rate had little impact on volume or frequency of overflows.

2.2.3 Discharge Volumes

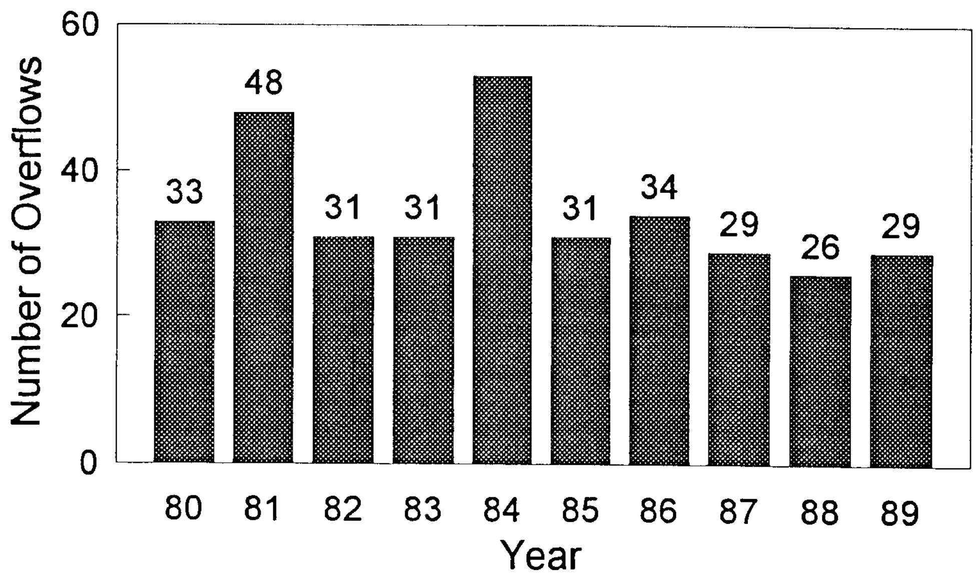
The previous study (based on a city-wide uniform rainfall assumption), was used to estimate discharge volumes on an annual, seasonal and single event basis for both dry and wet weather discharges.

Annual Volumes

The actual and projected annual volume of wastewater to the year 2040 from each treatment plant and from each wet weather source is shown in Table 2-6. Actual plant discharges for Average Annual Flows (AAF) were estimated to be approximately 12% higher than ADWF based on 1989 wastewater data summary (NEWPCC, SEWPCC, WEWPCC Environmental submission, March 1990). It was assumed that this relationship would remain the same for projected flows. The total volume from each plant was calculated using the AAF. The overflow to the stream for each land use was obtained from previous studies (MacLaren 1977) on pollution abatement and river quality. This study estimated discharge volumes to



(a) Volumes of Rainfall, Runoff and Overflow

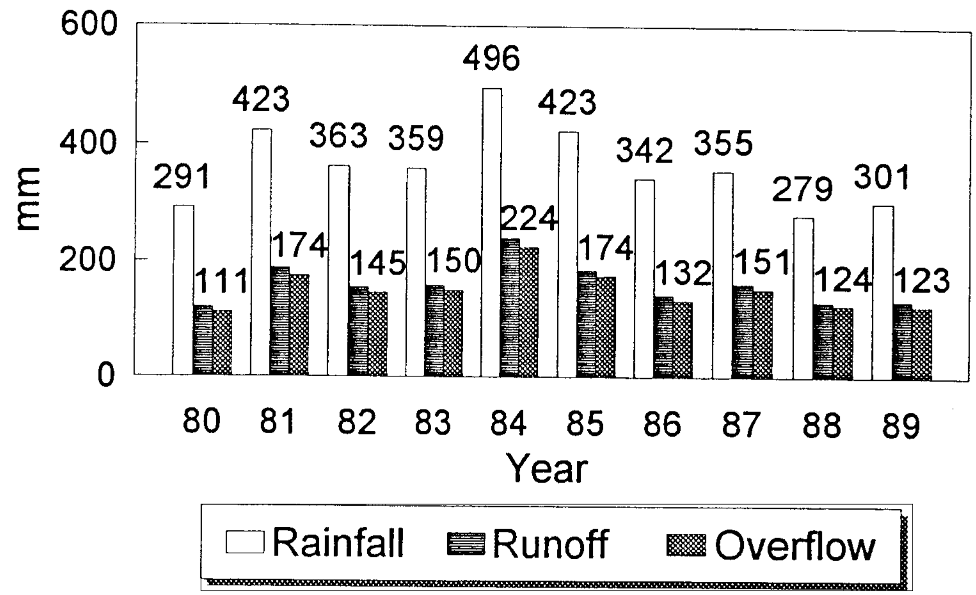


(b) Number of Overflows

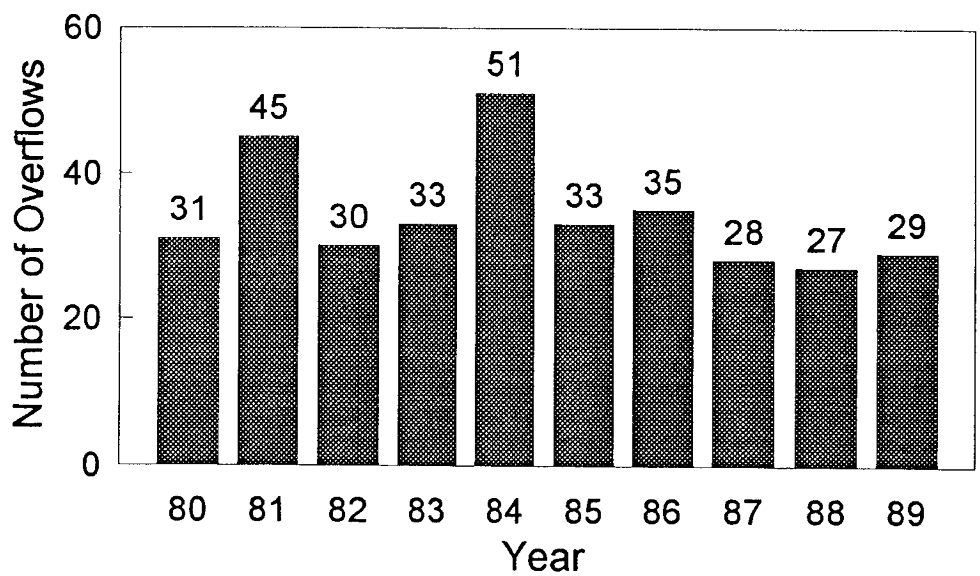
Note: 1980-1989 Rainfall Record and STORM Model

Current Level of Service for Linden District: Number and Volumes of Overflows per Year

Figure 2-2



(a) Volumes of Rainfall,Runoff And Overflow



(b) Number of Overflows

Note: 1980-1989 Rainfall Record and STORM Model

Current Level of Service in Hawthorne District:
Number and Volumes of Overflow per Year

Figure 2-3

TABLE 2-6

PROJECTED ANNUAL DISCHARGES TO THE RED AND ASSINIBOINE RIVERS

SOURCE	DISCHARGE QUANTITIES ($m^3 \times 10^6$)		
	ACTUAL (1989)	PROJECTED (2011)	PROJECTED (2040)
TREATMENT PLANTS[a]			
• NEWPCC[b]	91.5	131.7	145.6
• SEWPCC[c]	19.6	35.6	57.2
• WEWPCC[d]	11.7	13.1	21.2
	122.8	180.7	223.0
SEPARATE SEWERS			
• Land Drainage	29.6[e]	29.6	29.6
• Sanitary	4.0	4.4	4.9
RETENTION POND DISCHARGES			
	10.0	14.0	19.5[f]
	43	47.3	53.9
COMBINED SEWER OVERFLOWS			
	14.4[e]	14.4	14.4
TOTAL	180.2	242.8	292.6

a) Projected 2011 average annual flows (AAF) based on 1989 actual plant discharge data.
b) AAF = 1.16 x ADWF
c) AAF = 1.12 x ADWF
d) AAF = 1.08 x ADWF
e) STORM model predicted discharges (MacLaren, 1979).
f) Assumed that all new developments will utilize stormwater retention ponds.

the rivers from a range of urban sources through model simulation of four years of actual rainfall (MacLaren 1978). The results for combined sewers, separate sewers and separate sewers with ponds are noted in Table 2-6. Using these discharge volumes, final effluent quality and the average wet weather quality characteristics the total annual loading were estimated.

Similar information is not available for sanitary overflows. However, Rempel and Tottle (1973) estimated that extraneous flow, on an annual basis, may represent about 10% of the runoff in a separate sewered area. From this estimate, it can be inferred that sanitary sewer overflows are no more than 10% of separate storm drainage for the same area. Using this relationship, an estimate of the total annual volume of sanitary overflow was made.

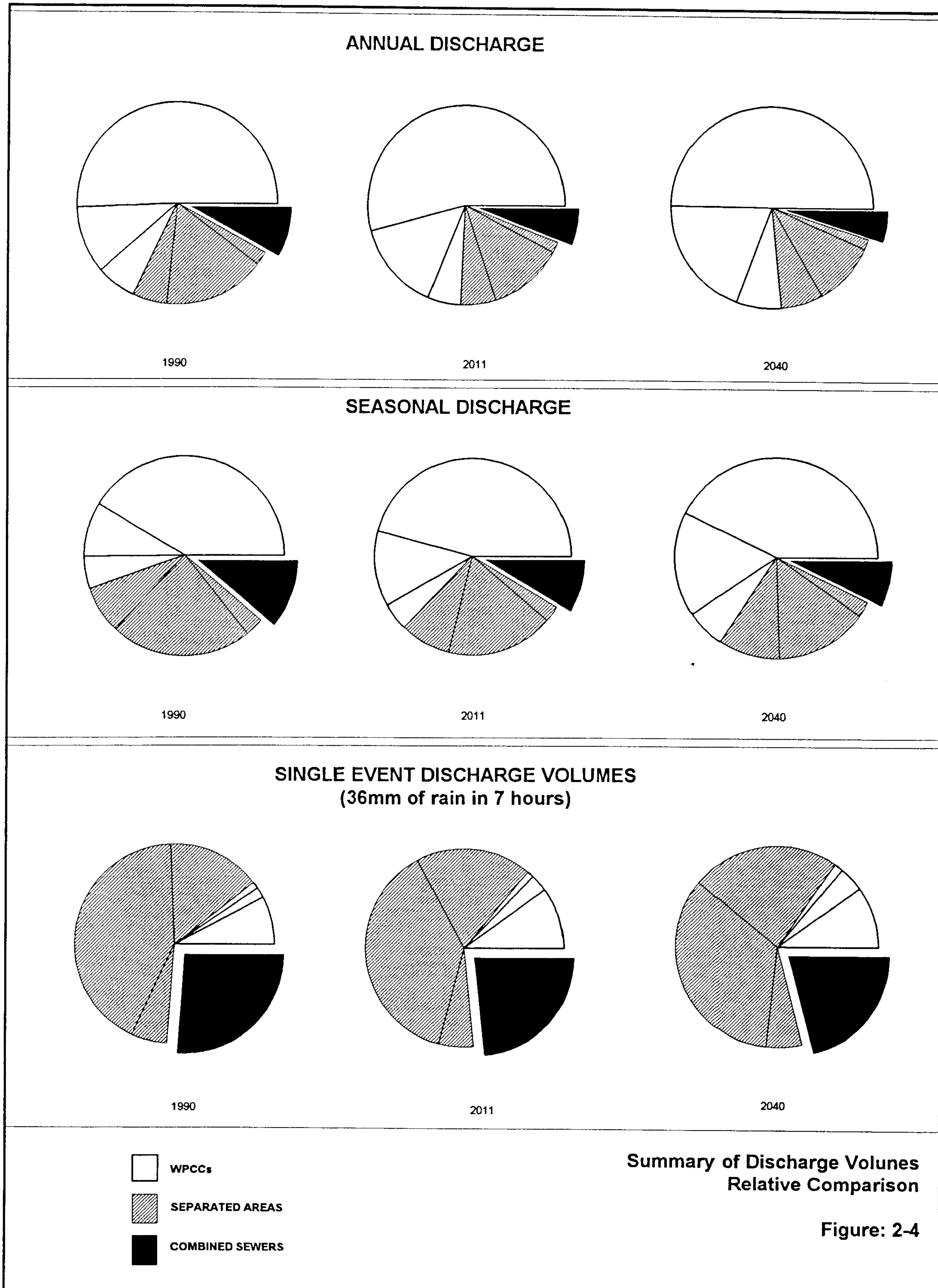
Figure 2-4 compares the annual volumes of discharges from the various sources. While wet weather flow (WWF) sources represent large volumes, the dry weather flows (DWF) sources, on an annual basis, are much larger.

Seasonal Loadings

The seasonality of the discharges are important. Very little wet weather flow occurs in the winter months (November to March). Figure 2-4 shows a comparison of sources during the runoff months (April to October). On a seasonal basis, wet weather flows tend to dominate the flows from the smaller treatment plants (SEWPCC and WEWPCC). The North End Water Pollution Control Centre is still a significant discharge in comparison to the wet weather flows even in the summer period.

Single Event

In order to compare wastewater discharges to the river on a short-term basis, a single storm event of 36 mm of rain in 7 hours was analyzed. This rainfall has a frequency of occurrence of about once in two years. The runoff estimates were obtained again from the STORM model (MacLaren 1979). This model was developed by the US Army Corps of Engineers for calculating runoff from urban areas (US Army Corps of Engineers 1976). The discharge volumes to the rivers during such an event are shown in Figure 2-4. This figure illustrates that for a severe single rainstorm event, sewer overflows completely dominate discharges to the



Summary of Discharge Volunes
Relative Comparison

Figure: 2-4

river. In this case, treatment plant flows were taken as 2 times ADWF to reflect their increase for one day due to wet weather effects. The runoff from a one-in-two year return storm will continue for several hours after the rainfall event has ended.

The analysis illustrates that the relative volumes to the rivers from the various sources will not change significantly in the future. The review of sources, dry weather and wet weather, provides a perspective on the volume, rate, and seasonal patterns of certain discharges to the rivers. Clearly, wet weather discharges are very important events in determining the receiving stream quality.

2.2.4 Quality Concentrations

The quality of discharges can vary significantly during a rainfall event and from outfall to outfall. The wet weather quality characteristics for various sources of discharge are shown in Table 2-7. The concentrations recorded in this table encompass the range of values recorded in several reports and studies, (locally and elsewhere). The table shows that the quality of wet weather discharges are highly variable. Typical values for $CBOD_5$, total suspended solids, nitrogen, phosphorus and fecal coliforms monitored by the City and representative of local conditions are shown in Table 2-8. Several reports were examined to identify the range of concentrations for quality parameters from various discharge sources. The most relevant sources pertaining to this study are:

- "National Urban Runoff Program" (NURP), U.S. EPA 1982;
- "Red and Assiniboine SWQO" (Wardrop/Tetr*ES* 1991);
- City of Winnipeg monitoring information at selected sewer districts overflow outfalls;
- "Disinfection Evaluation: City of Winnipeg Wastewater Treatment Plant Effluent", prepared for the City of Winnipeg and the Province of Manitoba, MacLaren 1986.

An extensive nationwide study on sewer discharges to water bodies was conducted by the United States Environmental Protection Agency. A report titled "Nationwide Urban Runoff Program (NURP)" was released in 1982. This comprehensive study has formed the basis for many evaluations and studies on water quality impacts in the United States and Canada since its release. The report finds that discharge quality can have a wide concentration range for

TABLE 2-7

WET WEATHER QUALITY CHARACTERISTICS FOR VARIOUS SOURCES (MEDIAN VALUE RANGES)

PARAMETER	SANITARY SEWER AND PLANT BYPASS[3]	COMBINED SEWER OVERFLOW	URBAN LAND DRAINAGE	RETENTION PONDS
Total Suspended Solids (mg/L)	177-300	184-720	100-578	50-76
$CBOD_5$ (mg/L)	164-247	14-191	9-41	6-8
Total Nitrogen (mg/L-N)	30-50	8-26	3-20	1.8-3.8
Total Phosphorus (mg/L-P)	4.9-10	1-4	0.3-2.1	0.3-0.4
Fecal Coliforms (10^6/100 mL)	1-63	0.1-34	0.04-0.12	0.04
Cadmium (μg/L)	2-6	6-10	1-13	-
Lead (μg/L)	22-182	130-400	144-280	-
Chromium (μg/L)	24-100	190	22	-
Copper (μg/L)	50-160	60-530	34-110	-
Zinc (μg/L)	130-300	300-660	160-500	-
Total PCB (μg/L)	0.9	0.3	-	-

Sources:

1. Nationwide Urban Runoff Program (NURP), USEPA 1982.
2. St. Johns/Polson/Munroe Sampling Program, City of Winnipeg 1977-1978.
3. Mager Sampling Program, City of Winnipeg 1989.
4. Seattle, GVRD
5. Disinfection Evaluation, MacLaren 1986.
6. Clifton Pre-Design Report, MacLaren 1978.
7. Thoman and Mueller, Principles of Surface Water Quality Modelling 1987.
8. Canadian Ontario Agreement (COA), 1980.
9. Metcalf and Eddy, Wastewater Engineering 1978.
10. Storage Treatment Overflow Runoff Model (STORM), US Army Corps 1978.

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[3] All influent entering the treatment plants receive primary treatment.

TABLE 2-8

TYPICAL QUALITY CHARACTERISTICS FOR WET WEATHER FLOW DISCHARGES

	TREATMENT PLANTS	LAND DRAINAGE SEWERS	COMBINED SEWERS	SANITARY SEWERS
$CBOD_5$ (mg/L)	15	25	100	200
Total Suspended Solids (mg/L)	20	350 (700)[a]	300 (700)	200
Total Nitrogen (mg/L-N)	25	10	15	40
Total Phosphorus (mg/L-P)	5	1	3	8
Fecal Coliforms[4] (10^6/100 mL)	0.4	0.08	5	10

a) (700) - based on recent monitoring programs.

[4] Average conditions, Fecal densities can vary significantly based on raw wastewater densities, dilution from runoff, and treatment processes, (MacLaren 1986).

selected parameters on a nationwide scale. Discharge quality is particular to local site conditions and can also vary significantly from one discharge location to another depending on land use. The City of Winnipeg sewer overflow quality data provides substantially more information to specifically address receiving stream issues for the Red and Assiniboine Rivers.

Many of the studies prepared for the City of Winnipeg on sewer overflow abatement are based on monitoring information collected in 1977 and 1978. The City conducted additional overflow monitoring at several other sewer overflow locations since then and help place the results of the historic values in proper context. Recent monitoring programs were conducted during dry weather, wet weather, and spring runoff conditions. The district name and year of monitoring for the recent programs are listed below.

• Marion	1993	• Baltimore	1990
• Syndicate	1993	• Colony	1990
• Despins	1992	• Hawthorne	1990
• Alexander	1992, 1991, 1990	• Linden	1990
• Clifton	1992	• Mager	1990, 1989
• Boyle	1992	• Munroe	1978
• Crane	1991, 1990	• Polson	1978
• Strathmillan	1991, 1990	• St. Johns	1978
• Dumoulin	1991, 1990	• Ash	1974
• Moorgate	1991, 1990	• Mission	1974

Water quality data were collected on the following parameters:

• BOD	(mg/L)	• Sus. Solids	(mg/L)
• T. Coli.	10^5/100 mL	• Conductance	(mg/L)
• F. Coli.	10^5/100 mL	• Sulfate	(mg/L)
• pH		• Cadmium	(mg/L)
• T.O.C.	(mg/L)	• Chromium	(mg/L)
• Chloride	(mg/L)	• Copper	(mg/L)
• Ammonia	(mg/L)	• Nickel	(mg/L)
• Nitrate	(mg/L)	• Lead	(mg/L)
• T.K.N.	(mg/L)	• Zinc	(mg/L)
• T. Phos.	(mg/L)	• Turbidity	(ntu)
• T. Solids	(mg/L)	• Flow data	

An inspection of the recent quality data revealed that the monitored values fell within the bracketed ranges and compared well with typical concentrations listed in Table 2-8 except for suspended solids. Suspended solids were found to be much higher than originally estimated and found to range around 700 mg/L. The review of local combined sewer data found that overflow concentrations of $CBOD_5$ and fecal coliforms varied significantly at outfall locations. Dilution of raw wastewater from rainfall events will cause overflow concentrations to fluctuate. The values shown in Table 2-8 agree well with recent monitoring data and are representative values for seasonal discharges from land drainage, combined sewer overflows and annual discharges from treatment plants.

It should be noted that coliform densities for all sources are highly variable and uncertain. Two tests done on the same sample often vary by an order of magnitude. Raw influent to the NEWPCC, SEWPCC and WEWPCC can have significant variations in fecal coliform concentrations. The treatment processes themselves are inhospitable to bacterial growth and promote die-off. The hydraulic retention time, approximately 6 hours at the WPCCs, retains the wastewater long enough for a significant reduction in fecal densities (about 90%). The NEWPCC plant discharge concentrations were found to be higher, in general than the other two plants, (i.e. 400×10^3 as compared to 250×10^3). For this study, the "average" NEWPCC final effluent concentration was also used for the SEWPCC and WEWPCC.

The fecal coliform density measurements from wet weather sources are also highly variable, however CSOs and sanitary overflow concentrations are significantly higher than land drainage. The values shown in Table 2-8 should be considered as representative concentrations rather than absolute values.

2.2.5 Loadings

Loadings to the rivers for current and projected 2011 conditions were estimated by combining quality characteristics and discharge volumes on annual, seasonal, and single events basis. Table 2-9 illustrates a summary of the river loadings for projected 2011 conditions. Figure 2-5 comparatively displays annual, seasonal, and single event percentages for individual quality parameters for projected 2011 conditions. These loading estimates should be considered as representative of the relative contributions of constituents from urban sources.

TABLE 2-9

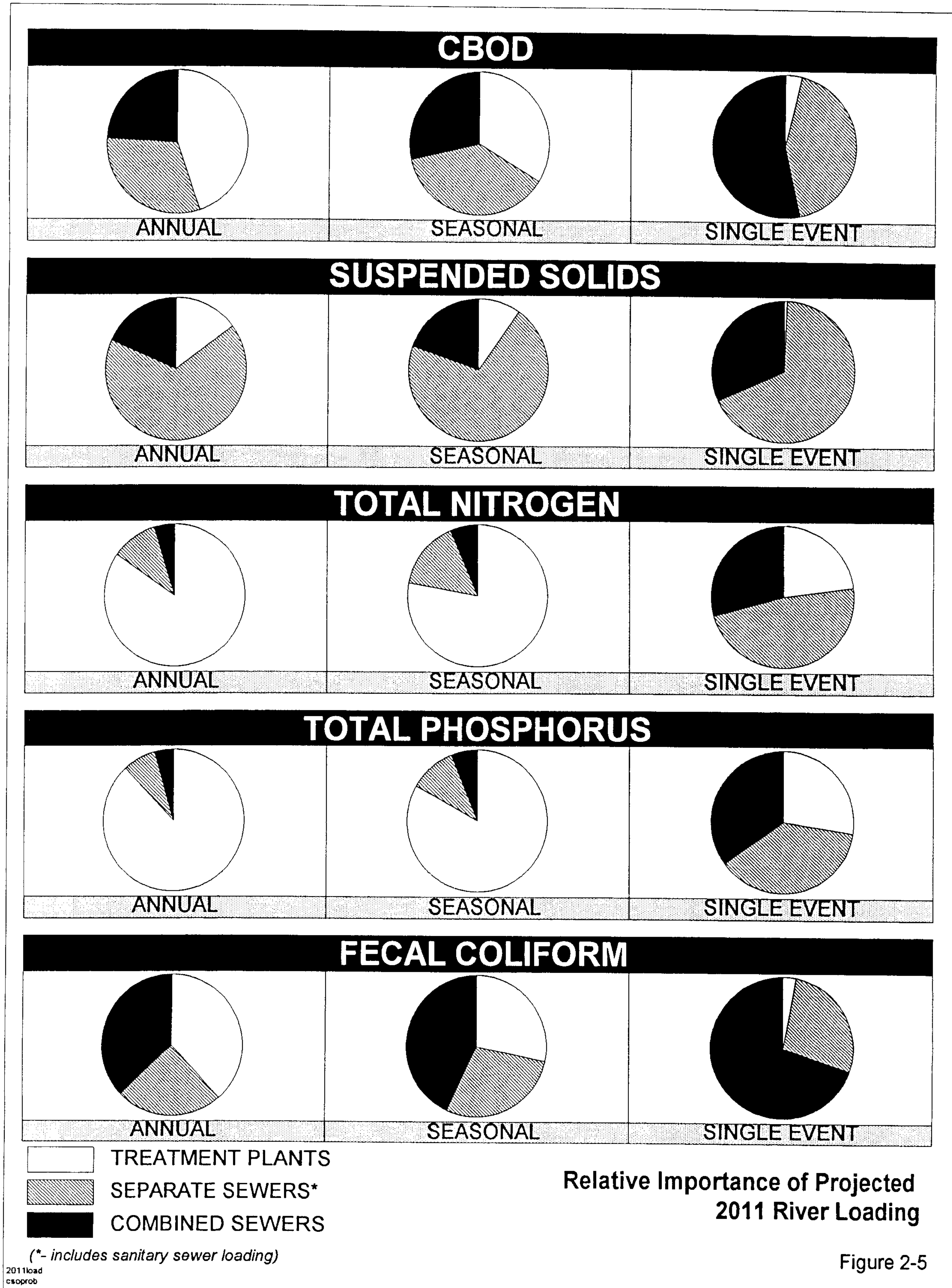
ESTIMATED RIVER LOADING FOR PROJECTED 2011 CONDITIONS

	ANNUAL	SEASONAL [e]	SINGLE EVENT [f]
1. CARBONACEOUS BIOCHEMICAL OXYGEN DEMAND ($CBOD_5$), TONNES			
• Treatment Plants	1800	1100	13
• Land Drainage [g]	1900	1900	150
• Combined Sewers	1400	1400	180
TOTAL	5,100	4,400	343
2. TOTAL SUSPENDED SOLIDS, TONNES			
• Treatment Plants	3600	2300	17
• Land Drainage [c]	16000	16000	1200
• Combined Sewers	4300	4300	550
TOTAL	23,900	22,600	1,767
3. TOTAL NITROGEN, TONNES			
• Treatment Plants	4500	2800	22
• Land Drainage [c]	600	600	46
• Combined Sewers	220	220	28
TOTAL	5,320	3,620	96
4. TOTAL PHOSPHORUS, TONNES			
• Treatment Plants	900	570	4.3
• Land Drainage [c]	77	77	6.0
• Combined Sewers	43	43	5.5
TOTAL	1,020	690	15.8
5. FECAL COLIFORM x 10^{16}			
• Treatment Plants	72	46	0.35
• Land Drainage [c]	46	46	3.6
• Combined Sewers	72	72	9.2
TOTAL	190	164	13.15

[e] Final effluent discharge quality. Plant bypasses are considered as combined sewer overflows.

[f] One-in-two year return frequency with a rainfall intensity of 36 mm in 7 hours.

[g] Includes sanitary sewer discharges.



Relative Importance of Projected 2011 River Loading

Figure 2-5

2.2.6 Overview of Loadings

On an annual and seasonal basis, the discharge volume from the WPCCs are the major governing sources. The major loading of total suspended solids to the rivers for current and future conditions originate from urban runoff, especially land drainage discharges. The seasonal total suspended solids loadings from land drainage are significantly greater than the annual loading from all WPCCs.

WPCCs are the major factors that influence water quality during dry weather conditions. The annual and seasonal discharges from WPCC effluent discharges to the rivers are the major loadings of total nitrogen and total phosphorus for current and projected conditions. The $CBOD_5$ loading on the Rivers are about equal from WPCC, CSO, and land drainage on an annual basis. A major single rainfall event would cause a large BOD load which may cause dissolved oxygen suppression in the river. It will be important to estimate the maximum BOD load possible from WWF in one day. This would be used to estimate whether such a BOD load could cause a low DO violation in the river. Nitrogen and phosphorous loading are dominated by plant discharges on an annual and seasonal basis. Nutrients generally cause problems on a seasonal basis and therefore CSO control is not the most effective control measure.

The fecal coliform loadings to the river originate from the WPCC effluent discharges and combined sewer overflows and land drainage. WPCCs are the major source of fecal coliforms to the rivers under dry weather conditions. Fecal coliform levels from combined sewer discharges and land drainage during wet weather events completely mask the influence of WPCC discharges during the short-term. It should be pointed out that fecal coliform levels typically decay in the stream in about 3 to 4 days. Accordingly, mass loading analysis for annual or seasonal discharges are not representative of stream conditions for fecal coliforms and are useful for comparative purposes only. The short-term impacts of fecal coliforms from CSOs and LDS runoff are important.

Significant rainstorms result in large discharges and peak loading in a short period of time. These discharges can completely dominate the effects of treatment plant loadings during such episodes. Discharges from land drainage and combined sewers are major factors in influencing surface water quality on a wet weather basis. Combined sewer overflows and land drainage are peak loading events that occur only during a rainstorm. Loading of $CBOD_5$, total nitrogen, total phosphorus, and fecal coliforms from combined sewer overflows and land drainage during these events completely dominate discharges to the rivers. Wet weather discharges from land drainage and combined sewers can significant impact on physical characteristics (i.e., turbidity, suspended solids, grease and oils, floatables...) and microbial characteristics (i.e. fecal coliform). The aesthetic impact of these wet weather discharges can give the impression that the rivers are "polluted".

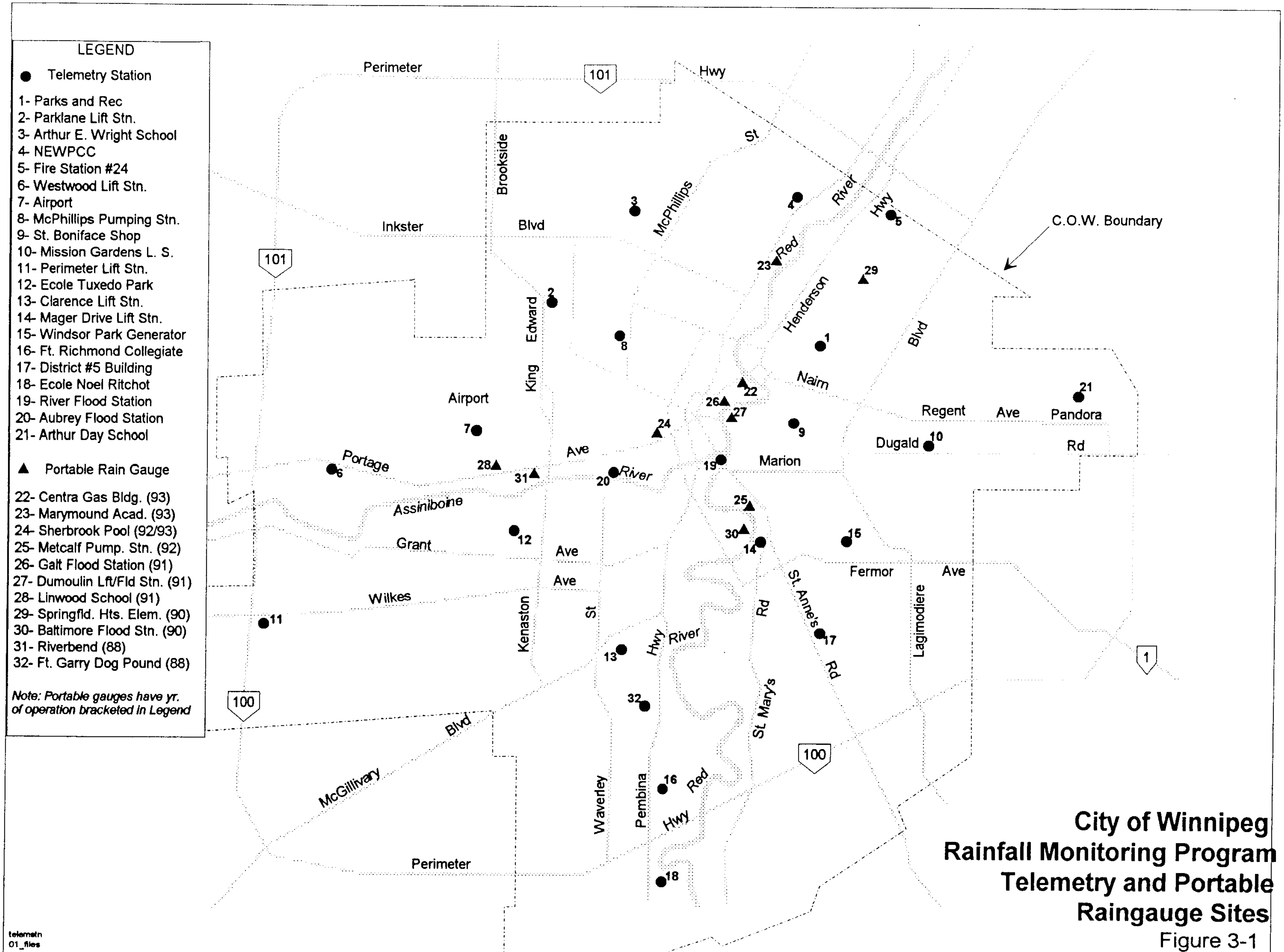
In summary, discharges from the treatment plants are the most significant factor influencing river quality on an annual and seasonal basis, for nitrogen and phosphorus concentrations. Combined sewer overflows and land drainage are significant factors that can elevate the average fecal coliform densities in the rivers. The river flow strongly influences instream concentration and the extent of impact downstream of outfalls. Wet weather discharges from combined sewer overflows and land drainage are peak loading events that most significantly impact on fecal coliform concentrations and aesthetics on a single event basis.

3.0 UPDATING THE PERSPECTIVE ON LOADINGS

The current perspective is based on a city-wide uniform rainfall assumption. Previous studies of Manitoba rainstorms have shown that there is "practically no reduction in point intensity of rainfall for areas less than 26 km^2 or 2600 ha (about 10 sq. miles), City of Winnipeg Drainage Criteria Manual (MacLaren 1974[2]). Winnipeg's combined sewered area covers a total area of approximately 100 km^2 or 10,000 ha and will accordingly experience variations in rainfall across this area. The City of Winnipeg has recognized this variability and has established a rain gauge network to collect data on the temporal and spatial variability of rainfall across Winnipeg. Updating of the current perspective will involve considering the areal distribution of rainfall data.

3.1 CITY OF WINNIPEG RAIN GAUGE NETWORK

The City of Winnipeg maintains a rainfall network that consists of 21 permanent stations. These stations are distributed throughout the City, as shown in Figure 3-1. Data from the



City of Winnipeg
Rainfall Monitoring Program
Telemetry and Portable
Raingauge Sites
Figure 3-1

stations is collected by electronic telemetry. These stations have remote data loggers connected to the tipping bucket type rain gauges. The data loggers are accessed from the Waterworks, Waste and Disposal Department by phone hook-ups. The stored data is dumped onto a computer and reviewed by City staff.

The permanent stations are fairly reliable, requiring little maintenance. The most common problem is associated with the electronic equipment, i.e., connecting to the station to transfer the data. However this is not a serious problem, and does not result in the loss of data, to any significant degree.

In addition to the permanent stations, there are three portable rain gauges. These gauges are used in conjunction with the ongoing Basement Flooding Relief Program. These gauges are generally situated in the middle of a sewer district that is also being hydraulically monitored (i.e., sewer level recording). The rainfall data is used in conjunction with the sewer data for future hydraulic analysis of the district sewer system.

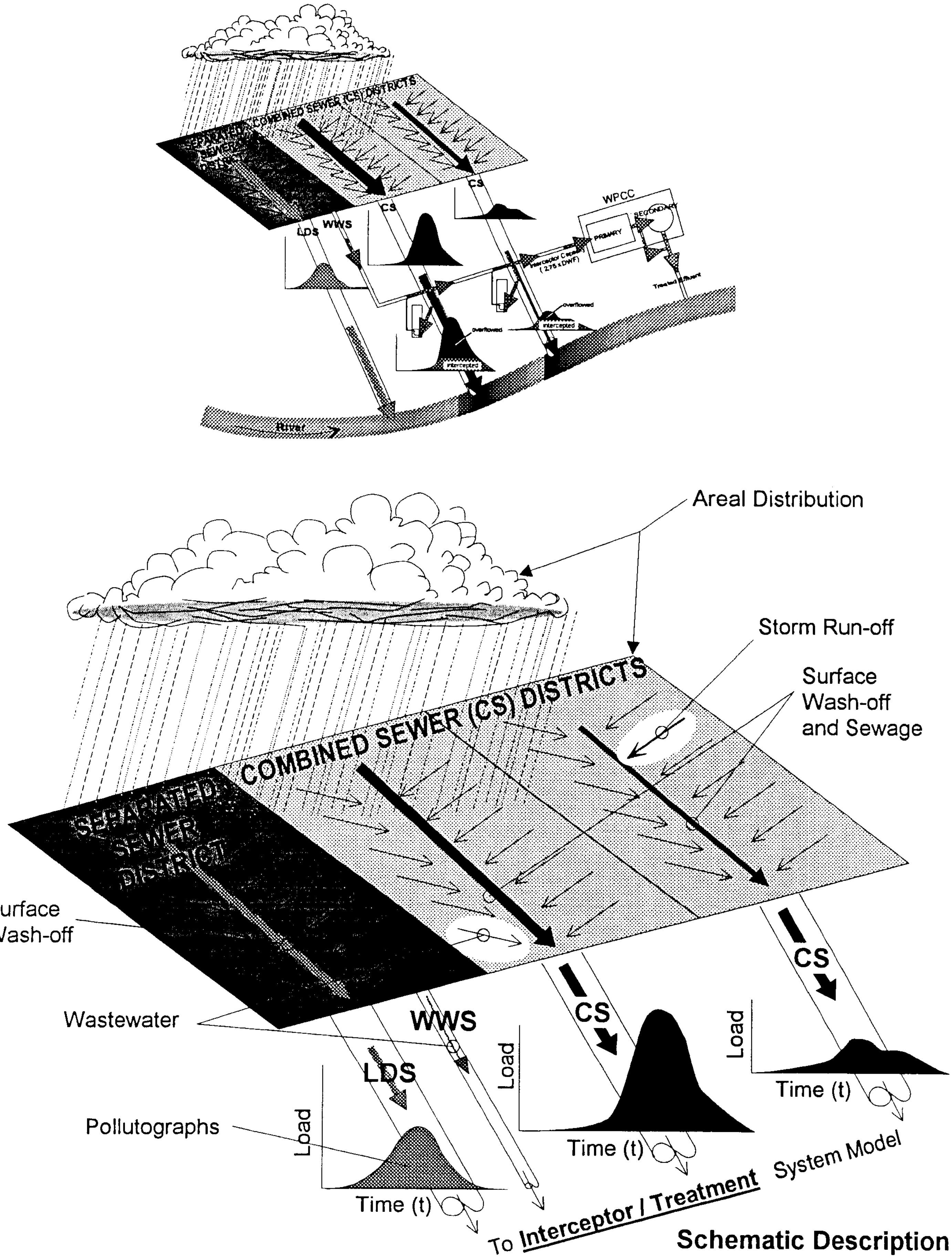
The portable rain gauges require weekly maintenance. This includes strip chart replacement and winding up the mechanism.

The present system of rainfall monitoring has been in place since 1988 and has been successfully used to assemble a large database of rainfall and its variability. Appendix A contains sample information collected by the rain gauge network and processed to describe the specific event in terms of intensity-duration, return frequency and city-wide isohyetals.

3.2 TECHNICAL APPROACH TO RUNOFF MODELLING

A land use/runoff model of the urban developments of Winnipeg which will consider existing land developments and topography along with actual periods of rainfall and their areal distribution. This model will generate hydrographs and pollutographs. This information will be used in the interceptor model and the river model, as schematically illustrated in Figure 3-2.

The urban runoff model will provide the interceptor/treatment model with dry weather flows and area-distributed wet weather inflows from rainfall. Rainstorm patterns, surface



Schematic Description
Urban Runoff Model
Figure 3-2

runoff
csoprob

characteristics (area, percentage pervious/impervious), service system, water consumption to wastewater, land use (industrial, commercial, residential, green space, undeveloped, etc.), dust and dirt accumulation, etc. will all be considered to generate the hydrographs and pollutographs before interception. Actual area-distribution of rainfall will be an important factor and considered in long-term continuous simulations.

Essentially, the urban runoff model will need to provide runoff hydrographs, specific to the rainfall distribution and the sewer system, over a number of years of actual rainfall events. The resulting hydrographs can be converted to "pollutographs" very readily, especially if the focus is fecal coliforms, as these are not likely to exhibit a "first-flush" phenomenon. Pollutographs to be generated by the runoff model are dependent upon the water quality impacts that need to be simulated by the receiving stream model. As discussed in the Receiving Stream Technical Memorandum #4, fecal coliforms are likely the only parameter to be modelled by the river model.

Synchronization of the runoff model with the interceptor model will involve the selection of an appropriate time step to adequately discretize the inflow hydrographs from the runoff model for meaningful hydraulic analysis by the interceptor model. Too large a time step may introduce numerical instability or unreal hydraulic description of system behaviour. Too small a time step can result in long computational times and no substantial increase in accuracy. It will be necessary to test this synchronization on a small scale between the interceptor/treatment and runoff model to determine the appropriate protocol to satisfy hydraulic continuity and stability.

Candidate models for urban runoff modelling are:

- XP-SWMM (RUNOFF)
- EPA-SWMM (RUNOFF)
- QUALHYMO
- STORM

The evaluation of models for runoff must consider the integration of data with other system models, namely, Interceptor/Treatment and Receiving Stream. Aspects of each of the models listed and their potential application to runoff modelling are discussed in the Technical Framework for System Assessment Technical Memorandum No. 7.

3.3 INFORMATION REQUIREMENTS

Information requirements and level of detail required in the urban land use runoff model is dictated by the parameters to be simulated in the interceptor/treatment model and receiving stream model. The core CSO issues are microbiological contamination (i.e., fecal coliform levels) of the rivers, aesthetics, and basement flooding. Associated CSO issues relevant to the receiving stream relate to:

- dissolved oxygen/BOD;
- ammonia;
- nutrients;
- sedimentation;
- persistent toxic substances; and
- mixing zones.

In order to provide this information from the runoff model it must be capable of generating accurate hydrographs for interceptor hydraulics and pollutographs for receiving stream water quality simulations. Therefore it is important to assess the available data required to calibrate a runoff model.

3.3.1 <u>CSO Quantity and Quality Data</u>

The City of Winnipeg has gathered a substantial database on the water quality and quantity of combined sewer overflows. The combined sewer districts are comprised of residential, commercial, and industrial land use sectors to varying degrees. Districts monitored were reviewed to determine if any data gaps existed in the characterization of these land use sectors. It was found that overflow quantity and quality for a primarily commercial district is lacking. A specific recommendation was made to the City to monitor the Tylehurst combined sewer district, a primarily commercial based land use sector. Otherwise, sufficient quantity and quality data exists to accurately describe hydrographs and pollutographs for several rain events. The City will continue to monitor overflow quality during the course of this study and will provide sufficient opportunity to gather specific data on runoff that may be required.

3.3.2 Land Drainage Data

The City has collected data on land drainage quantity and quality but not to the same extent as for CSOs. An extensive study was conducted in the early 1970s by the City to characterize the treatment efficiencies of storm retention basins. The results of this study are still valid and have been used to estimate the wet weather quality characteristics of land drainage discharges. It was recommended to the City that quantity and quality data from land drainage systems be specifically collected just upstream and downstream of an SRB. This information would be used to extend their database to broaden the local understanding of quality characteristics and improve the confidence of loading estimates from land drainage discharges. The combination of such data would help characterize land drainage quality pre- and post- of an SRB. This will provide information specific to:

- land drainage loading;
- land drainage with SRB loading; and
- a current perspective on the efficiency of SRB to reduce the concentration in urban runoff.

3.3.3 Catchment Data

The sewer infrastructure of most sewer districts is well-documented along with their tributary catchment areas. The key factor influencing the quality of runoff and its time of concentration is the percent of pervious and impervious areas within the catchment area. The City prepared a "Basement Flooding Relief Study" (D. Girling and E. Sharp 1986[3]) which examined 36 out of the 41 sewer districts to assess alternatives, costs, and priorization of actions. This study along with its SWMM RUNOFF and EXTRAN files provides a wealth of technical data on these 36 combined sewer districts and is a valuable resource for this study. The SWMM modelling was prepared on a coarse scale and is well-suited to be directly reused in a planning level analysis of the runoff component of this study. This information will be examined to determine whether it provides an adequate level of detail to accurately describe runoff hydrographs and pollutographs based on the recent wet weather data collected since the Basement Flooding Relief Study. This will likely involve a sensitivity analysis to help improve model calibration, if it is required, by testing the influence of key factors such as the percent pervious and impervious coefficients and areas, initial abstraction, antecedent conditions, depression storage and the division of the sewer districts into an adequate number of catchment areas. A sensitivity analysis will be performed on a representative number of districts to verify that the previous runoff modelling sufficiently describes the runoff characteristics. No additional information will be required.

3.3.4 Dry Weather Flows

The City of Winnipeg has initiated water conservation program to most effectively utilize available resources by slowing the growth in water consumption and postponing large capital expenditures related to a new supplementary supply. In particular, a city-wide water consumption database was prepared to assess current demands and the effectiveness of various conservation initiatives. The actual metered water can be used to estimate the quantity of wastewater generated. This information can be compared with the total wastewater received at the WPCCs to approximate the extraneous inflow and infiltration during dry weather periods. Accordingly, the combination of this information with the monitored dry weather and wet weather CSO quality data can be effectively used to assist in quantifying the dry weather flows to the WPCCs and wet weather loadings to the WPCCs and receiving stream during long-term simulations. No additional information will be required.

3.3.5 Land Use

Land use data has been well-characterized for the separated and combined sewer districts. The Basement Flooding Relief Study (City of Winnipeg 1986[4]) provides a detailed description of the surficial area of land use for each of the 36 CSO districts examined in terms of:

- residential;
- commercial;

- multiple housing/apartments;
- industrial;
- public;
- parks;
- vacant;
- school;
- hospital;
- utilities; and
- miscellaneous.

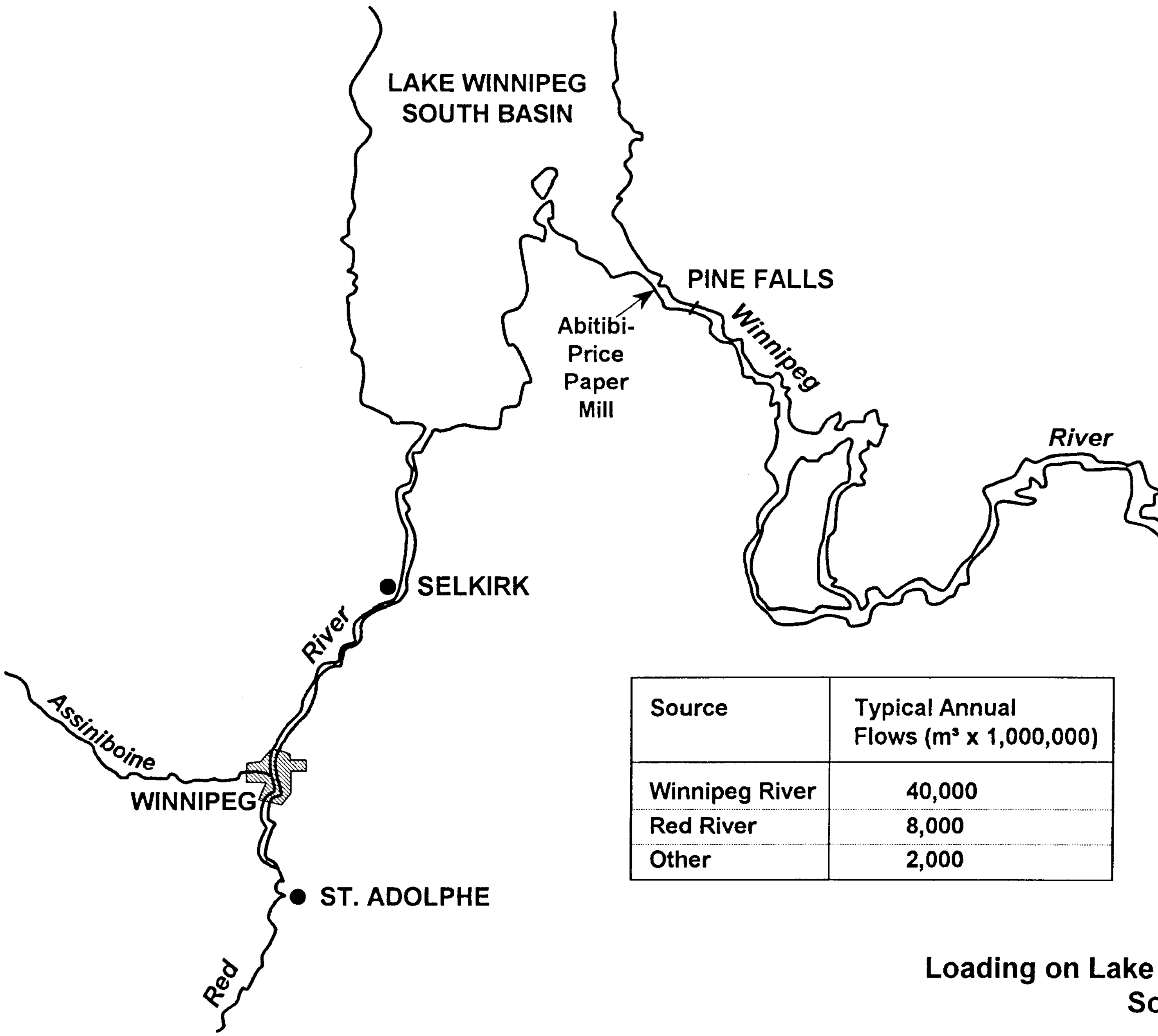
Due to the variability of the activities associated with the trade and commerce of industrial and commercial businesses it will be important to individually characterize the sources of dry weather loadings and surface characteristics in terms of dust and dirt accumulation. No additional land use data will be required.

3.3.6 Summary

In summary, the City of Winnipeg has collected a substantial database of information that is fully satisfactory to characterize the quantity and quality of urban runoff. Additional information on land drainage loading needs to be collected before and after a storm retention basin to update and expand the local understanding of this source and is currently being undertaken by the City. CSO monitoring in the near future should be on a district which is primarily commercial in nature to assess if its CSO quality is significantly different from other industrial or residential districts.

4.0 REGIONAL PERSPECTIVE

The Stage I CEC Hearing raised concerns that discharges from Winnipeg may be significantly contributing to the eutrophication of Lake Winnipeg, and in particular its south basin. Lake Winnipeg south basin is located downstream of Winnipeg and the Red River and also accepts flows from the Winnipeg River and other minor sources as shown in Figure 4-1.



Source	Typical Annual Flows (m^3 x 1,000,000)
Winnipeg River	40,000
Red River	8,000
Other	2,000

Loading on Lake Winnipeg South Basin

Figure 4-1

sthbasin
cso1

4.1 RED RIVER SOURCES

Monitoring performed on the Red River is sparse downstream of Winnipeg and does not provide adequate information to definitively quantify the additional influence of runoff and discharges to the Red River downstream of Winnipeg. The City actively monitors the quality of the Red and Assiniboine Rivers upstream, within, and downstream of Winnipeg extensively and has assembled a large database on local river water quality (see Receiving Stream Technical Memorandum). The upstream monitoring is performed at the most upstream reaches of the rivers before it enters the city and is not influenced by WPCC discharges. This provides an excellent baseline to gauge the localized impacts of dry and wet weather discharges from within Winnipeg. The City also monitors river quality downstream of the last city discharge outfall at the North Perimeter Bridge which is just outside of the City boundary. This information has been used to assist in river quality modelling and to quantify the incremental nutrient loading from the City of Winnipeg. As indicated before, only sparse information exists downstream of Winnipeg on the Red River. The ability to quantify the additional contribution from other sources and to quantify the total loading on Lake Winnipeg south basin attributable to all sources of the Red and Assiniboine rivers is therefore limited.

As part of the Red and Assiniboine Surface Water Quality Study conducted for the City of Winnipeg in preparation for the Stage I CEC Hearings (Wardrop/Tetr*ES* 1991), a survey was conducted to identify other dry weather discharge sources to the Red and Assiniboine rivers upstream, within and downstream of Winnipeg, within the study area. The survey revealed that there were several dry weather discharges to the rivers with Winnipeg's three WPCCs and Selkirk's single WPCC as being the major sources. Table 4-1 lists the common information available for the identified sources. Figure 4-2 shows the location of these sources.

4.2 WINNIPEG RIVER

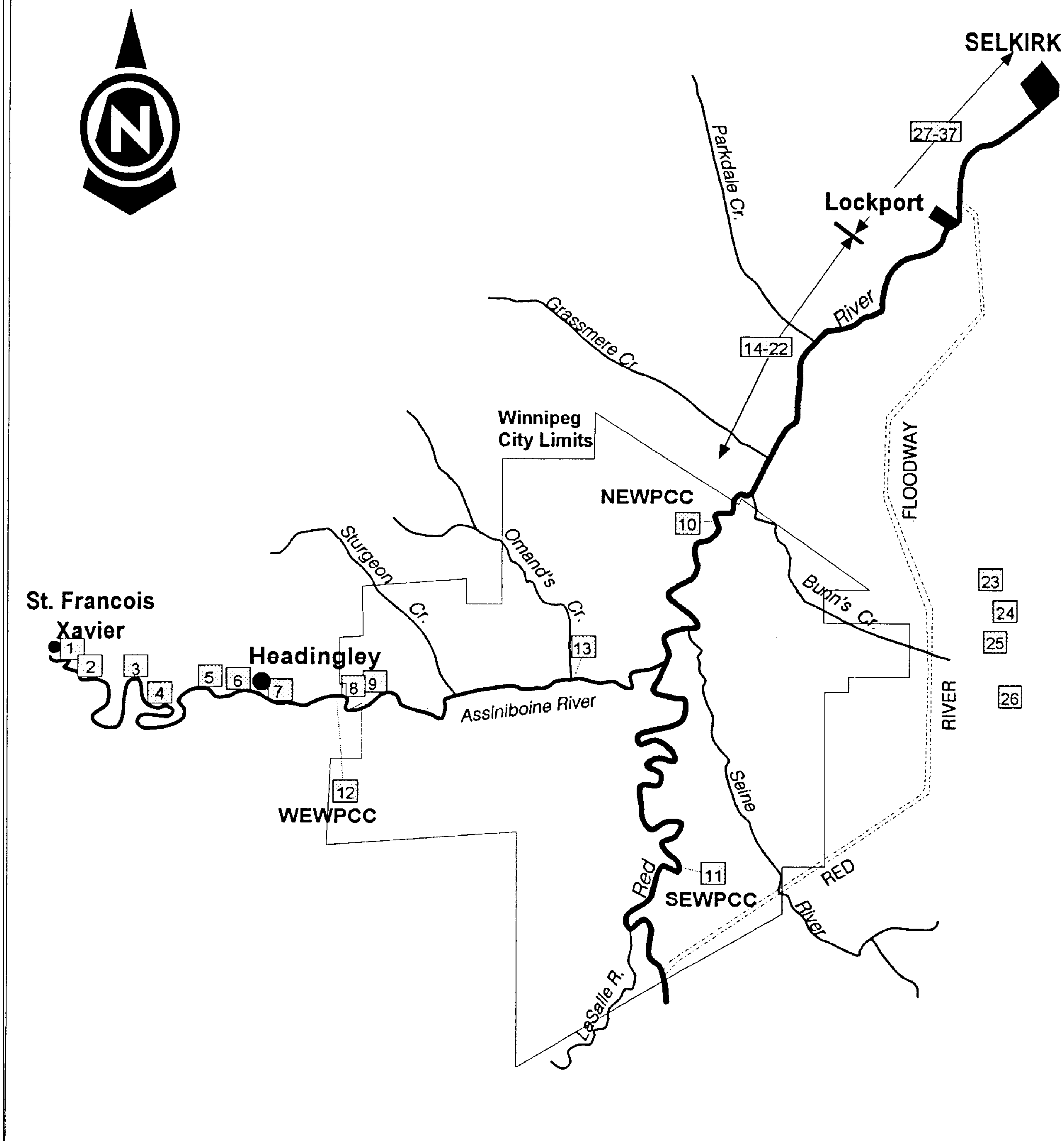
The Winnipeg river contributes the greatest annual flow to Lake Winnipeg south basin at an average flow of 40,000 $m^3 \times 10^6$, and by comparison is about 5 times larger than flows from the Red River. Typically, the Winnipeg River flows are 4 to 9 times greater than those contributed to Lake Winnipeg south basin from the Red River (International Garrison Diversion

TABLE 4-1

DISCHARGE SOURCES WITHIN STUDY AREA

	WASTE TREATMENT SYSTEM	WASTEWATER CHARACTERISTICS					
		FLOW (m^3/d)	BOD (mg/L)	TOC (mg/L)	SS (mg/L)	T.COLI (MPN/100mL)	F.COLI (MPN/100mL)
Upstream of Zone Monitored by City (Assiniboine River)							
1. Glenorchie Trailer Park	SBR/Disf.	28	110		67	$1.5x10^5$	$1.5x10^5$
2. Tansi Resort	Ext.Aer./Disf.	34	7.5		7.5		
Zone Monitored by City - Upstream of Winnipeg (Assiniboine River)							
3. Camp Manitou	Ext.Aer.	25.5		21	20		
4. Headingley Jail	Ext.Aer.	546		29	17		
5. Big Sky Travel Shop							
6. Husky Car/Truck Stop	RBC/Lagoon						
7. Blumberg Golf Course	Ext.Aer.	47.3		34	26		
8. Odeon Drive-In Theatre	Ext.Aer./Lagoon	25.5					
9. Zielke Residence				15	13		
City of Winnipeg							
10. NEWPCC (1989)	Oxy.Act.Sludge	216,000	<10		17		
11. SEWPCC (1989)	Oxy.Act.Sludge	47,800	<10		19		
12. WEWPCC (1989)	Ext.Aer./Lagoon	29,500	<10		25		
Zone Monitored by City - In Winnipeg (Assiniboine River)							
13. CFB Winnipeg	Trick.Filt.	910		35	16		
Zone Monitored by City - Downstream of Winnipeg (Red River)							
14. Middlechurch	Ext.Aer.	76.4		50	54		
15. St. Benedict	Ext.Aer.	36.4		46	92		
16. Rivercrest	Aerobic	91		39	64		
17. Riverdale	Ext.Aer	255		21	14		
18. Lister Rapids	Ext.Aer.	127		17	12		
19. Seven Oaks School	Ext.Aer.	36.4		36	68		
20. Birds Hill (West)	Aerobic	546		32	18		
21. Dr. Hamilton School	Ext.Aer.	36.4		18	18		
22. Birds Hill East (Village)	Ext.Aer.	346		6	16		
23. Oak Bank (N)	Lagoon			35	42		
24. Oak Bank (S)	Lagoon			18	17		
25. Oak Bank (E)	Lagoon			36	26		
26. Dugald	Lagoon			33	16		
27. Highway Gardens	Lagoon						
28. Birds Hill Park	Lagoon						
29. Pine Ridge Village	Lagoon						
30. Happy Thought School	WTP/Lagoon						
31. Teulon	Lagoon						
32. Melody Lane Trailer Park	Ext.Aer./Disf.	46	67	84		$1.5x10^5$	$1.5x10^5$
33. Lockport School	Lagoon						
34. Tyndall	Lagoon						
35. Interlake Colony Farms	Lagoon						
36. Hoddinott	RBC/Aer./Disf.	850	14		17	59,000	1,410
37. Selkirk	Ext.Aer.	7,500	11		25	11,800	310

Source: Red and Assiniboine Surface Water Quality Objectives (Wardrop/Tetr*ES* 1991).



Sewage Treatment Facilities in the Study Area

Figure 4-2

sewtreat
csoprob

Study Board Report 1976). This was verified with more recent information contained in the Historical Stream Flow Summary 1990 (Inland Waters Directorate 1991) and information received from Manitoba Hydro (A. Cormie *pers. comm.* 1994).

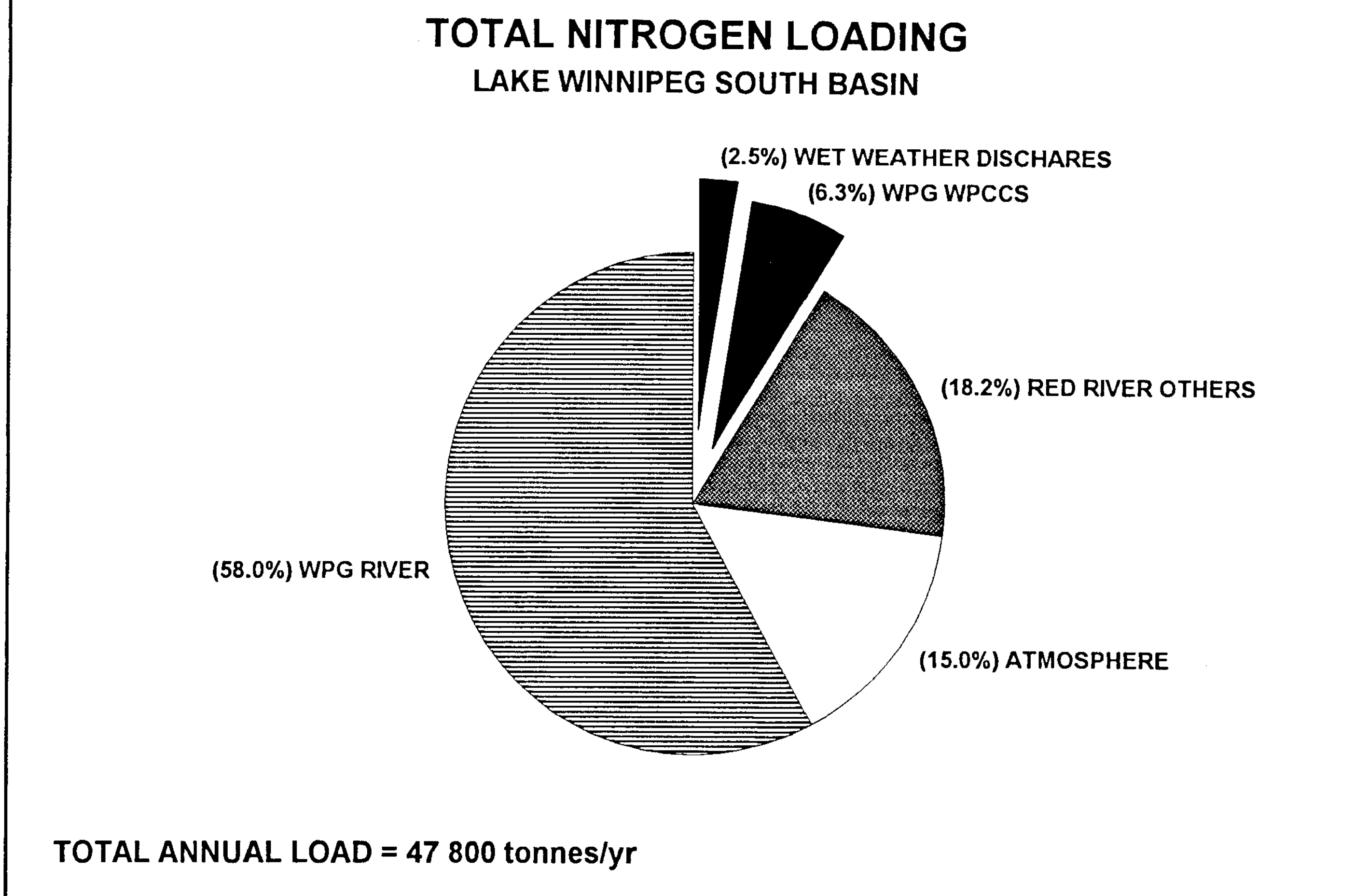
Historical water quality data was collected at Pine Falls near the mouth of the Winnipeg River between 1970 and 1974. The sampling location was located upstream of a major pulp and paper industry, Abitibi-Price, and does not consider the influence of this source on loading to Lake Winnipeg south basin. The processes associated with pulp and paper manufacturing can result in substantial nutrient loading to the Winnipeg River and ultimately to Lake Winnipeg. The plants average daily discharge is about 23,000 m^3 or on an annual basis, about 8.4 $m^3 \times 10^6$. Winnipeg's three WPCCs combined average daily discharge is about 290,000 m^3. The main difference aside from the flows for these two major sources is the concentration of nutrients in the discharges. Insufficient information exists on effluent quality or instream river quality downstream of this pulp and paper plant to definitively quantify its incremental contribution to nutrient loading. It can be a significant source and therefore needs to be monitored to determine its relative contribution to Lake Winnipeg south basin. The available information on water quality in the Winnipeg River, although sparse and missing a major loading source, was used to estimate its contribution of nutrient loading to Lake Winnipeg south basin.

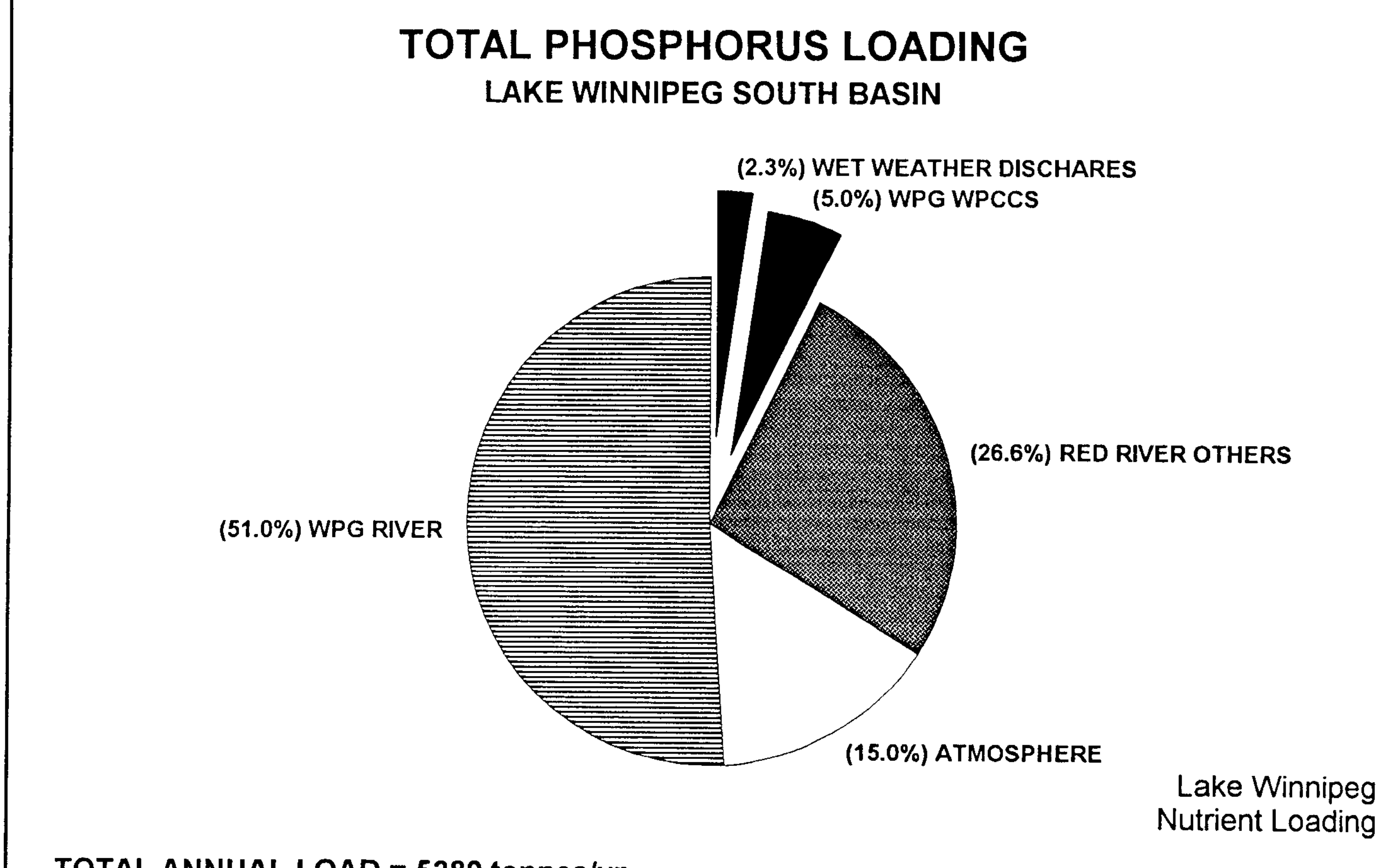
4.3 ATMOSPHERIC FALLOUT

A potentially large nutrient source on Lake Winnipeg is dry and wet atmospheric fallout of nitrogen and phosphorous. The large surface area of the lake and rate of fallout were used to estimate the relative contribution from this source. Literature values for atmospheric washout of total nitrogen was found to range between 0.5 to 9.9 g/m^3 and total phosphorous between 0.001 to 0.35 g/m^3 (Henderson-Markland 1987[5]). Applying an average annual rainfall of 0.5 m and a surface area of about 2780 km^2 for the south basin it was possible to estimate a range of total nitrogen between 6,000 to 120,000 tonnes/year and 10 to 4,000 tonnes/year for total phosphorous. The International Garrison Diversion Study Board Report stated that atmospheric nutrient loading on Lake Winnipeg comprised between 15% to 20% of the total nutrient loading or about 7,000 to 9,500 tonnes of nitrogen per year and 800 to 1,100 tonnes of phosphorous per year. The loadings from the atmosphere tend towards the low end of the literature values and tend to be indicative of a relatively remote setting, such as that for Lake Winnipeg.

4.4 LOADING ON LAKE WINNIPEG SOUTH BASIN

The loading on Lake Winnipeg south basin was estimated based on available information in terms of flows, concentrations, and atmospheric fallout. Figure 4-3 clearly illustrates that the amount contributed to the south basin is in the order of 7% to 9% of the total nutrient loading on an annual basis, of which 2% is attributable to wet weather source from Winnipeg.





Lake Winnipeg
Nutrient Loading

Figure:4-3

APPENDIX A

SAMPLE RAIN GAUGE INFORMATION PROCESSED

- PROCESSED DATA
- HYETOGRAPH
- FREQUENCY CURVE
- CITY-WIDE ISOHYETALS

GREATEST RAINFALL INTENSITY FOR VARIOUS DURATIONS * PARKS & REC
93-08-14

INTERVAL DURATION	GREATEST INTENSITY	
5 MINUTES	72.0 mm/hr	2.835 in/hr
10 MINUTES	66.0 mm/hr	2.598 in/hr
15 MINUTES	54.4 mm/hr	2.142 in/hr
30 MINUTES	45.6 mm/hr	1.795 in/hr
1 HOUR	33.6 mm/hr	1.323 in/hr
2 HOURS	22.5 mm/hr	0.886 in/hr
6 HOURS	9.7 mm/hr	0.381 in/hr
12 HOURS	4.9 mm/hr	0.194 in/hr

AVERAGE RAINFALL INTENSITY OVER FIVE MINUTE INTERVALS * PARKS & REC
93-08-14

FIVE MINUTE INTERVAL STARTING TIME	RAINFALL INTENSITY	
08/14 - 08:40:00	2.4 mm/hr	0.094 in/hr
08/14 - 08:45:00	2.4 mm/hr	0.094 in/hr
08/14 - 08:50:00	4.8 mm/hr	0.189 in/hr
08/14 - 08:55:00	4.8 mm/hr	0.189 in/hr
08/14 - 09:00:00	4.8 mm/hr	0.189 in/hr
08/14 - 09:05:00	4.8 mm/hr	0.189 in/hr
08/14 - 09:10:00	4.8 mm/hr	0.189 in/hr
08/14 - 09:15:00	4.8 mm/hr	0.189 in/hr
08/14 - 09:20:00	7.2 mm/hr	0.283 in/hr
08/14 - 09:25:00	4.8 mm/hr	0.189 in/hr
08/14 - 09:30:00	2.4 mm/hr	0.094 in/hr
08/14 - 09:35:00	4.8 mm/hr	0.189 in/hr
08/14 - 09:40:00	2.4 mm/hr	0.094 in/hr
08/14 - 09:45:00	4.8 mm/hr	0.189 in/hr
08/14 - 09:55:00	2.4 mm/hr	0.094 in/hr
08/14 - 10:00:00	2.4 mm/hr	0.094 in/hr
08/14 - 10:05:00	4.8 mm/hr	0.189 in/hr
08/14 - 10:10:00	12.0 mm/hr	0.472 in/hr
08/14 - 10:15:00	7.2 mm/hr	0.283 in/hr

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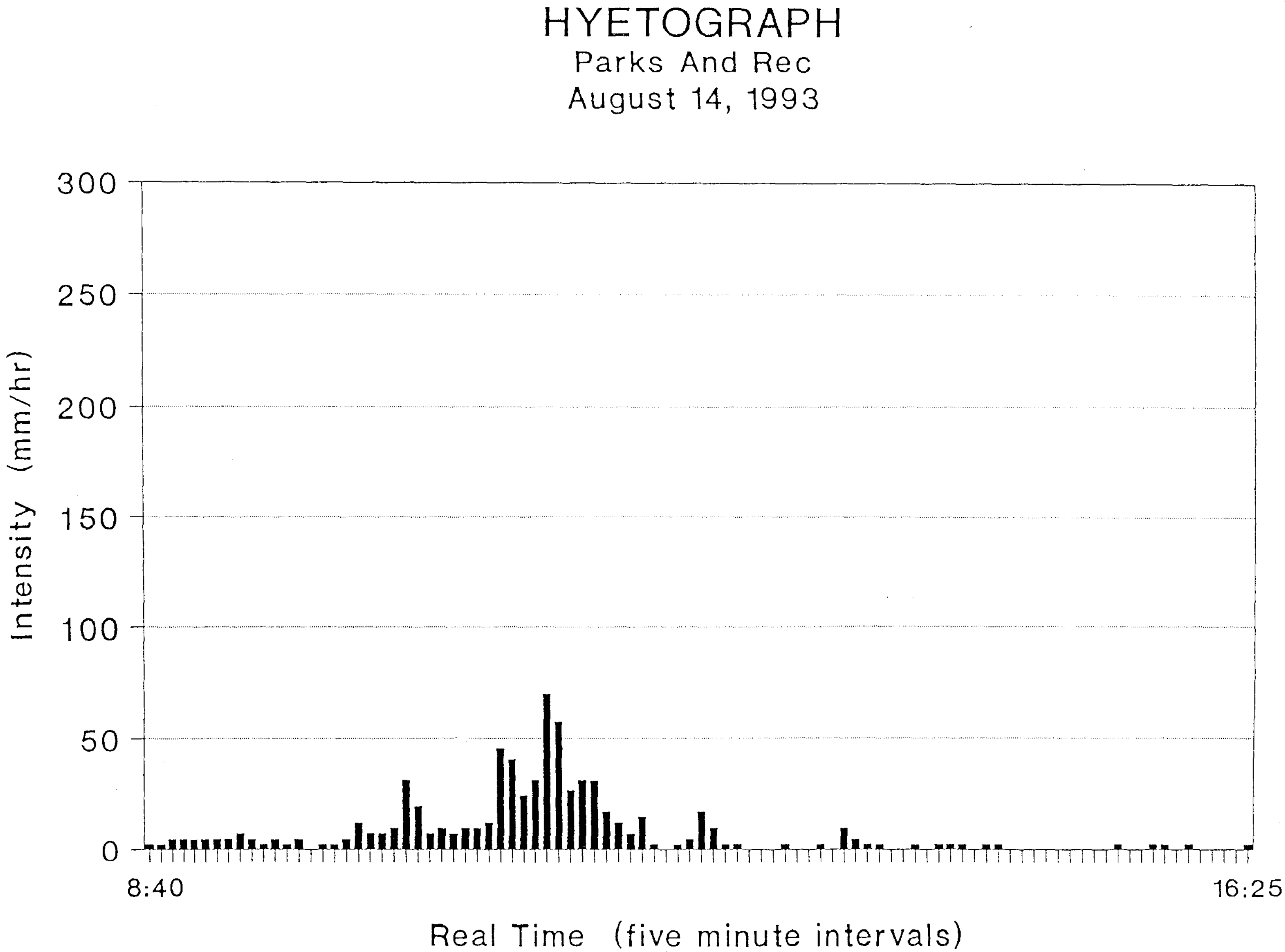
08/14 - 10:20:00	7.2 mm/hr	0.283 in/hr
08/14 - 10:25:00	9.6 mm/hr	0.378 in/hr
08/14 - 10:30:00	31.2 mm/hr	1.228 in/hr
08/14 - 10:35:00	19.2 mm/hr	0.756 in/hr
08/14 - 10:40:00	7.2 mm/hr	0.283 in/hr
08/14 - 10:45:00	9.6 mm/hr	0.378 in/hr
08/14 - 10:50:00	7.2 mm/hr	0.283 in/hr
08/14 - 10:55:00	9.6 mm/hr	0.378 in/hr
08/14 - 11:00:00	9.6 mm/hr	0.378 in/hr
08/14 - 11:05:00	12.0 mm/hr	0.472 in/hr
08/14 - 11:10:00	45.6 mm/hr	1.795 in/hr
08/14 - 11:15:00	40.8 mm/hr	1.606 in/hr
08/14 - 11:20:00	24.0 mm/hr	0.945 in/hr
08/14 - 11:25:00	31.2 mm/hr	1.228 in/hr
08/14 - 11:30:00	69.6 mm/hr	2.740 in/hr
08/14 - 11:35:00	57.6 mm/hr	2.268 in/hr
08/14 - 11:40:00	26.4 mm/hr	1.039 in/hr
08/14 - 11:45:00	31.2 mm/hr	1.228 in/hr
08/14 - 11:50:00	31.2 mm/hr	1.228 in/hr
08/14 - 11:55:00	16.8 mm/hr	0.661 in/hr
08/14 - 12:00:00	12.0 mm/hr	0.472 in/hr
08/14 - 12:05:00	7.2 mm/hr	0.283 in/hr
08/14 - 12:10:00	14.4 mm/hr	0.567 in/hr
08/14 - 12:15:00	2.4 mm/hr	0.094 in/hr
08/14 - 12:25:00	2.4 mm/hr	0.094 in/hr
08/14 - 12:30:00	4.8 mm/hr	0.189 in/hr
08/14 - 12:35:00	16.8 mm/hr	0.661 in/hr
08/14 - 12:40:00	9.6 mm/hr	0.378 in/hr
08/14 - 12:45:00	2.4 mm/hr	0.094 in/hr
08/14 - 12:50:00	2.4 mm/hr	0.094 in/hr
08/14 - 13:10:00	2.4 mm/hr	0.094 in/hr
08/14 - 13:25:00	2.4 mm/hr	0.094 in/hr
08/14 - 13:35:00	9.6 mm/hr	0.378 in/hr
08/14 - 13:40:00	4.8 mm/hr	0.189 in/hr
08/14 - 13:45:00	2.4 mm/hr	0.094 in/hr
08/14 - 13:50:00	2.4 mm/hr	0.094 in/hr
08/14 - 14:05:00	2.4 mm/hr	0.094 in/hr
08/14 - 14:15:00	2.4 mm/hr	0.094 in/hr
08/14 - 14:20:00	2.4 mm/hr	0.094 in/hr
08/14 - 14:25:00	2.4 mm/hr	0.094 in/hr
08/14 - 14:35:00	2.4 mm/hr	0.094 in/hr
08/14 - 14:40:00	2.4 mm/hr	0.094 in/hr
08/14 - 15:30:00	2.4 mm/hr	0.094 in/hr
08/14 - 15:45:00	2.4 mm/hr	0.094 in/hr
08/14 - 15:50:00	2.4 mm/hr	0.094 in/hr
08/14 - 16:00:00	2.4 mm/hr	0.094 in/hr
08/14 - 16:25:00	2.4 mm/hr	0.094 in/hr

ACCUMULATED RAINFALL= 59.2 mm 2.331 in


HYETOGRAPH
Parks And Rec
August 14, 1993
300
250
200
150
100
50
0
Intensity (mm/hr)
8:40
16:25
Real Time (five minute intervals)

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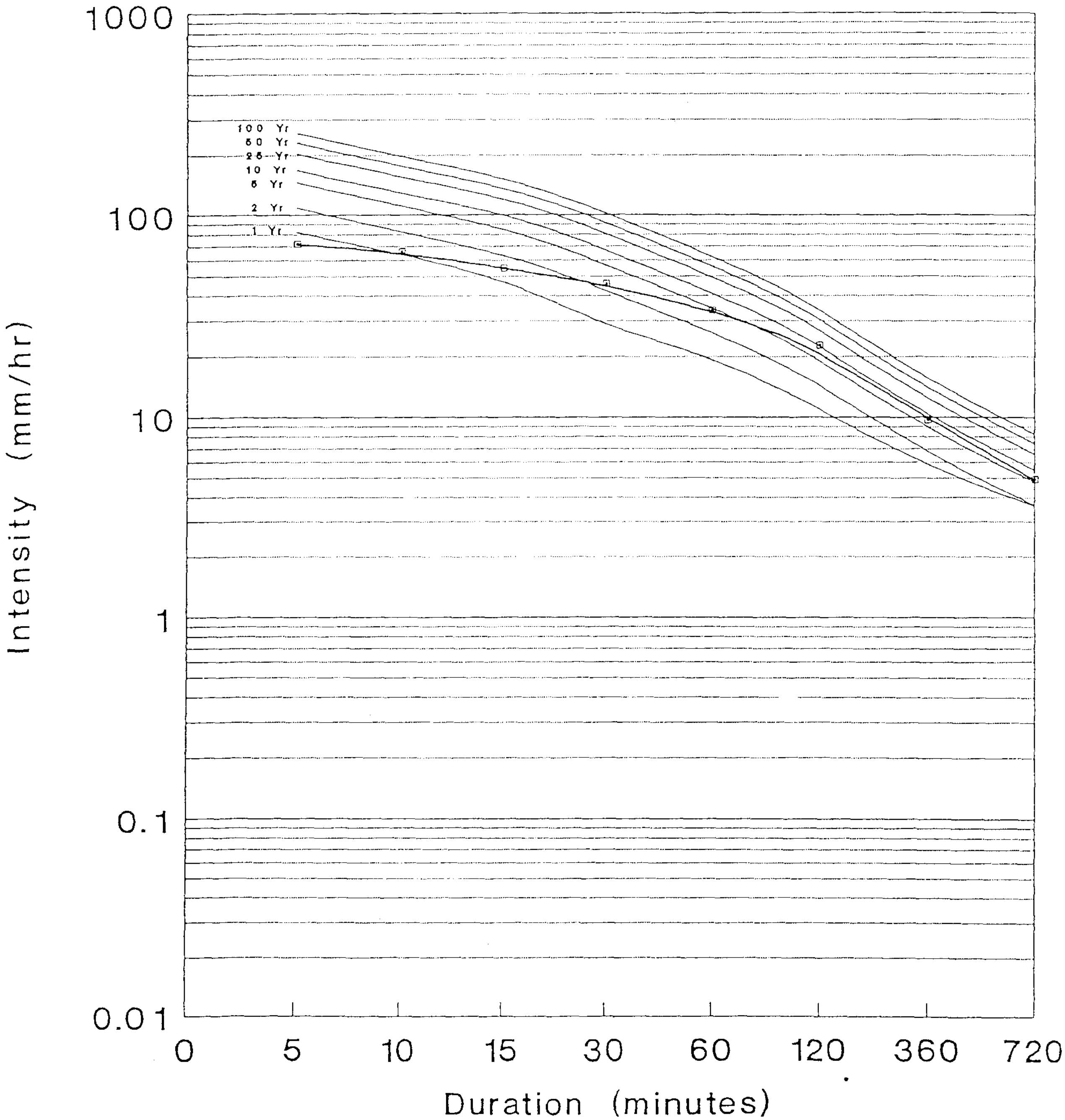
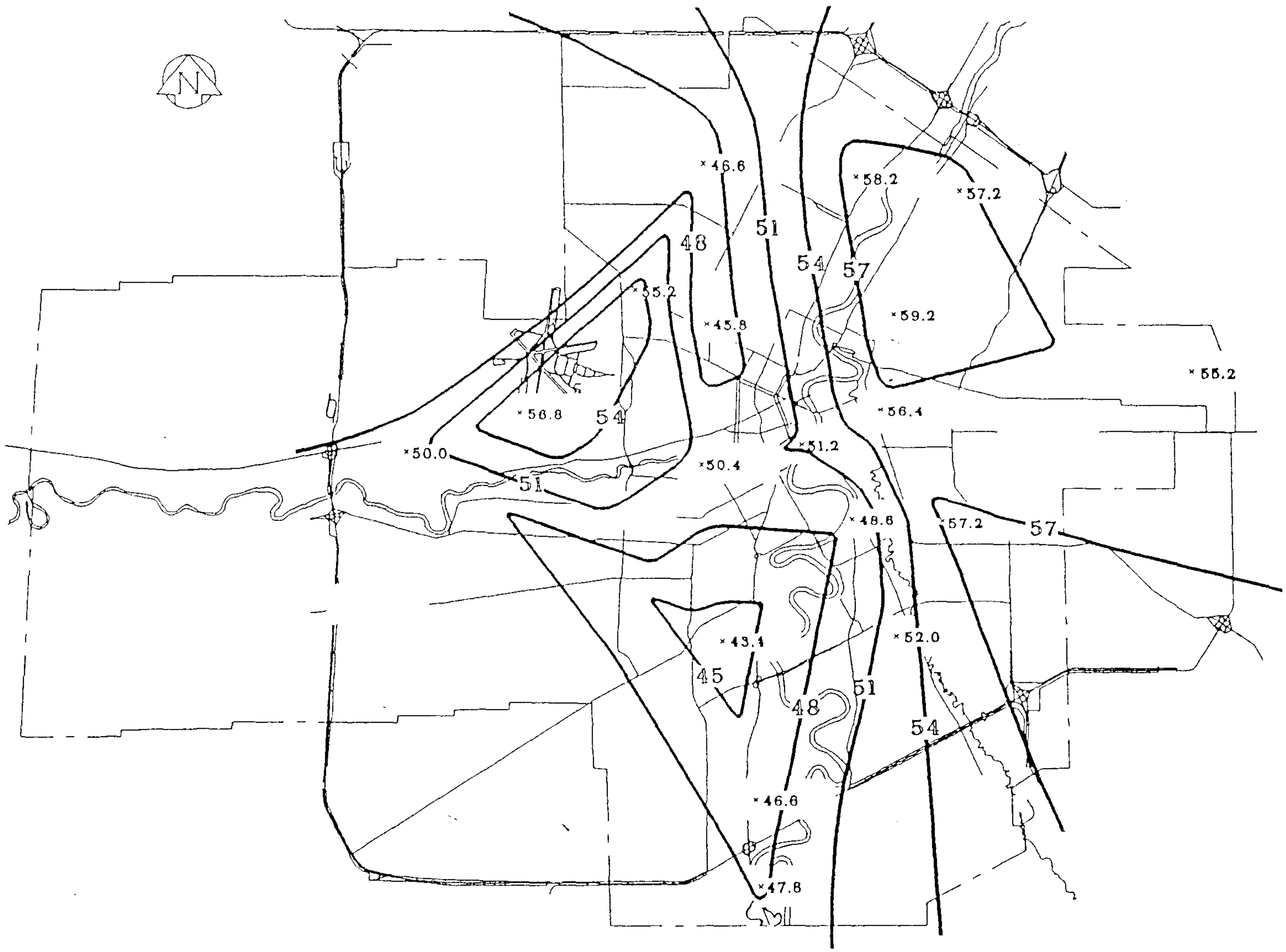
INTENSITY DURATION FREQUENCY CURVE

Parks And Rec

August 14, 1993



OH34



RAINFALL DISTRIBUTION
FOR AUGUST 14, 1993 RAINSTORM

LEGEND

—16— RAINFALL ACCUMULATION ISOHYETAL (mm)

x 10.0 RAINGAUGE LOCATION AND SITE ACCUMULATION (mm)

OH35