TORONTO AREA WATERSHED MANAGEMENT STRATEGY STUDY

HUMBER RIVER PILOT WATERSHED PROJECT

FINAL REPORT

VOLUME ONE

PREPARED FOR

THE ONTARIO MINISTRY OF THE ENVIRONMENT

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PROJECTS 83-56 &
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JUNE, 1986

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June 25, 1986.

Ministry of the Environment,
1 St. Clair Avenue West,
Toronto, Ontario.
M4V 1P5

Attention: Mr. W. Wong,
Water Resources Branch

Dear Sirs:

Re: Humber River Watershed Pilot Watershed Project
GLAL 83-56

We are pleased to forward the Final Report for the Humber River Watershed Pilot Watershed project. The report and its Technical Appendix cover the documentation of the project noted above and the Snowmelt Project that followed. The information gathered during these projects is the technical basis of Toronto SLAMM, currently in preparation.

The report has been completed mainly by Robert Pitt with technical and editorial support from Gartner Lee Associates Limited. It is based on the draft report reviewed by MOE staff in 1984, and addresses comments made during the review. It includes the results of the Snowmelt Project.

We trust that you will find this report useful in developing urban runoff strategies for the Toronto area.

Yours very truly,
GARTNER LEE ASSOCIATES LIMITED

D. S. Osmond, B.Sc., Agr.,
Project Director.

JJM:dc
cc: Robert Pitt

ACKNOWLEDGEMENTS

The success of any project is based on the efforts of a large team of people each contributing their expertise. This project was organised under the auspices of TAWMS, itself a cooperative effort from the municipalities of Metro and and several provincial agencies.

The authors would like to thank several groups and people for their work and support during this project.

The Ministry of the Environment is not only the "client" for this Project but was also the major provider of people and logistical support. The authors would like to acknowledge the support of Wan Wong, Fritz Engler, Henry Kronus, Casey Kennedy, Sandy Weston and Alex Borkoff from the Ministry's staff.

The City of North York provided the use of the Emery Works yard for the location of the outfall monitoring equipment and the rain gauge.

The City of Etobicoke assisted with the provision of water at the washoff site and coordination of the street sweeping during the field program. The sweeping was undertaken by the City's contractor, Breuell Contracting Ltd.

The authors wish to acknowledge the assistance as "mentor" by Professor Ken Potter of the University of Wisconsin-Madison.

Finally, we would like to acknowledge the contributions of Dave Osmond, Ted O'Neill, Clifford Syroid, Kathy Pitt and Mary McLean who reviewed, coordinated, collected, typed or generally supported the authors during this Project.

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FOREWORD

This report was prepared by Robert Pitt and Gartner Lee Associates Limited (GLAL) as part of their contract with the Ontario Ministry of the Environment (MOE) to conduct the Humber River Pilot Watershed Study. The Humber River Pilot Watershed Study is part of the Toronto Area Watershed Management Study (TAWMS). This Pilot Watershed Report also includes selected summaries of the results of several related studies conducted for the MOE by the same study team. Previous reports prepared and submitted to the MOE documented the modelling procedures used, the land use characteristics for the study area, and the performance of the candidate control measures. These reports included:

"Particulate Accumulation and Washoff Relationships" by Robert Pitt, June 15, 1984.

"Summary of Toronto Area Rainfall Analyses" by Robert Pitt, June 24, 1984.

"Humber River Pilot Watershed Project, Draft Report" by Robert Pitt and Jamie McLean, November 16, 1984.

"Urban Runoff Controls Manual of Practice - for use with Toronto/SLAMM" by Robert Pitt, April 1985.

"Toronto / Source Loading and Management Model - Operations Manual" by Robert Pitt, June 7, 1985.

"Land Use Characteristics for the Humber River Study Area" by Robert Pitt in conjunction with Gartner Lee Associates Ltd., September 1985.

"Toronto / Source Loading and Management Model - Supplement to Operations Manual" by Robert Pitt, October 7, 1985.

"Toronto / Source Loading and Management Model - Sensitivity Analysis" by Robert Pitt, October 13, 1985.

This final Pilot Watershed Study Report therefore relies on many related efforts. It does not completely summarize these previously submitted reports. Instead, the interested reader is referred to the reports listed above for more detailed information.

ABSTRACT

The Humber River Pilot Watershed Project was part of the Toronto Watershed Management Study (TAWMS). The objectives of this Pilot Watershed Project were to:

1) obtain significant outfall characterization data for stormwater from a variety of land uses in the urban Humber River catchment,

2) determine the important land surface sources for a variety of pollutants for each of the land uses studied, and

3) identify potential stormwater controls that would be applicable for each land use studied for Toronto conditions.

4) The scope of the project was later expanded to examine snowmelt runoff as a potential pollutant source.

The project involved intensive monitoring in two test areas. These were known as Emery, an industrial catchment of approximately 154 ha, and Thistledown, a mixed residential and commercial catchment of approximately 39 ha. Warm weather stormwater runoff quality was monitored for a total of approximately 60 storm events between May and November, 1983. Monitoring included automatic water quality sampling and continuous flow measurements. Baseflow samples were obtained on an approximately weekly basis in the industrial catchment and approximately every two weeks in the residential / commercial catchment. Many water quality constituents were analysed for all of the events, including common residue (solid), nutrient, heavy metal, and bacteria pollutants. Selected samples were also analysed for major ions, dissolved metals, pesticides and phenols, and organic "priority" pollutants.

Approximately 70 warm weather sheetflow samples were obtained from many source areas (e.g. roofs, landscaped areas, paved and unpaved parking and storage areas, driveways, walkways, streets, and gutters) during three storms. These sheetflow samples were supplemented with dry particulate samples obtained from the same source areas. The particulate samples were analysed for the major pollutants as a function of particle size.

A series of special paved area washoff tests were conducted to determine the relationships between the dry particulates found on the paved areas, the sheetflow runoff quality, and the outfall stormwater runoff quality.

Special street dirt accumulation measurements were made for a one month interval on an industrial street and on a residential street. The street dirt loadings were observed every few days, including

immediately before and after a series of initial intensive street cleanings and periodic rain events.

An expansion of the scope of the Pilot Watershed Project to include snowmelt runoff was added later. The same two study areas were monitored between January and March, 1984. A total of 33 snowmelt events and 14 periods of cold weather baseflow were monitored for water quality with continuous flow monitoring. The same water quality constituents that were analysed during warm weather samples were also generally analysed during cold weather periods. Approximately 100 snowmelt sheetflow samples were also obtained from the same general locations as the warm weather sheetflow samples.

These source area and washoff test results were later used (along with information obtained from earlier urban runoff studies) in another related study for the Ontario Ministry of the Environment to prepare the Toronto / Source Loading and Management Model (Toronto/SLAMM).

This final report supersedes the draft pilot watershed report submitted to the MOE in November, 1984. It also includes appropriate summaries of several interim technical reports submitted as part of the project with the MOE to develop and use Toronto/SLAMM.

EXECUTIVE SUMMARY

1.0 INTRODUCTION AND SUMMARY

1.1 INTRODUCTION

Recent Ministry of the Environment (MOE) studies of the water quality in the Humber River and along the Lake Ontario waterfront within the Regional Municipality of Metropolitan Toronto (Metro) have shown that the impact of the urban tributary watersheds on Lake Ontario nearshore water is substantial.

The Toronto Area Watershed Management Study (TAWMS) was initiated in 1981 to develop a management strategy for pollution control within the tributary watersheds and along the lakeshore. TAWMS is a cooperative multidisciplinary study supported by the Ministry of the Environment, metropolitan and municipal governments, and the Metropolitan Toronto and Region Conservation Authority (MTRCA).

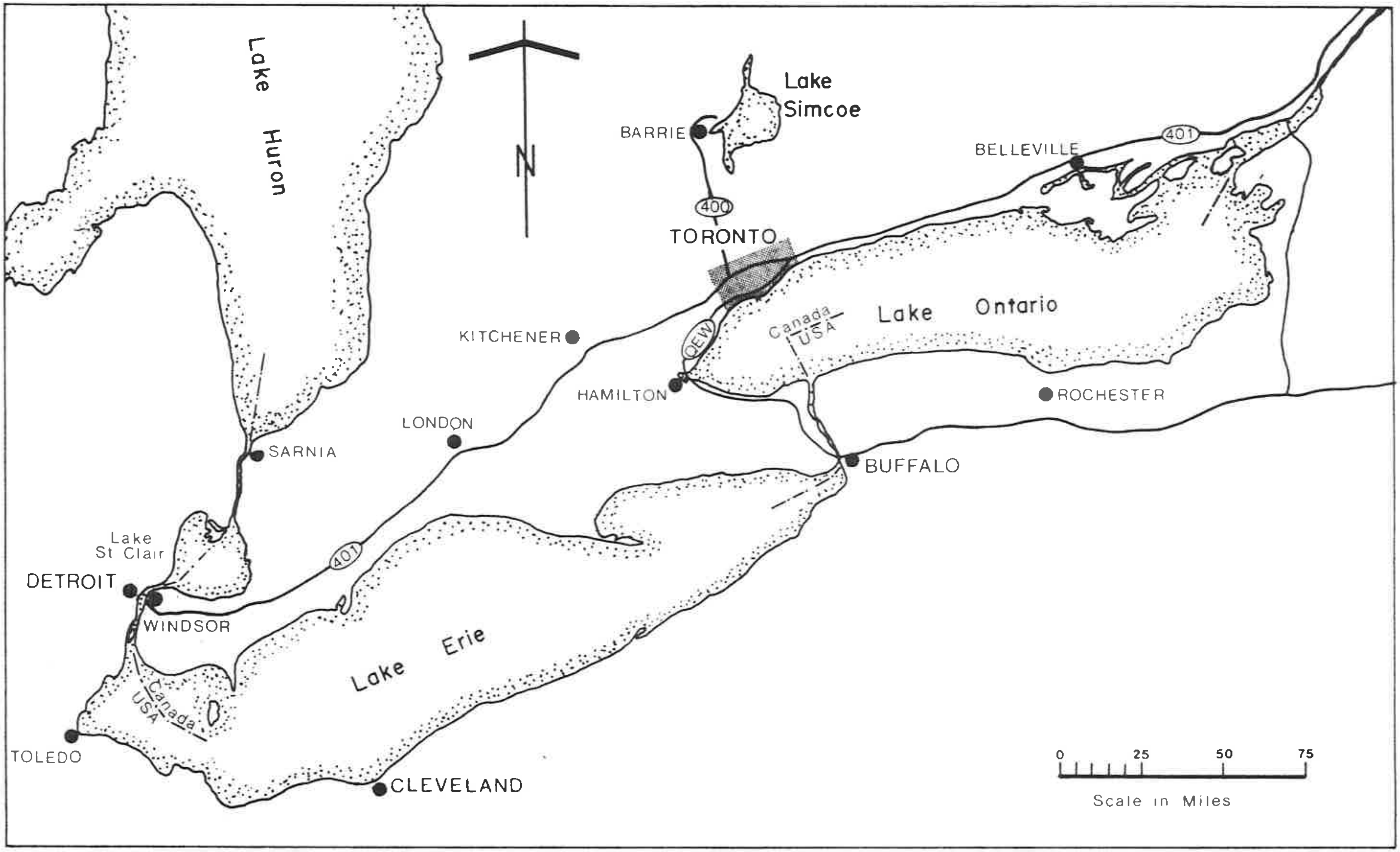
This Pilot Watershed Project was designed to investigate the sources of contamination in storm water originating within the urban landscape. The identification of source areas contributing potential problem pollutants and flows of storm water was addressed in detail during this project. The information collected during this Project specifically addresses three topics that are required for the design of an urban runoff program. The first topic concerns the documentation of existing or potential urban runoff problems. The second topic describes the sources of the problem pollutants. The third topic identifies potential control measures that can be used to reduce discharges of problem pollutants.

Two pilot watersheds were selected for study; one in the industrial Emery Creek neighbourhood and the other in the predominantly residential neighbourhood of Thistledown. The locations of these catchments are shown on the Key and Site Maps of Figures 1.1 through 1.5.

The study consisted of a series of data gathering activities designed to investigate the several washoff/runoff subsystems that can be aggregated together into the hydraulic system of storm water drainage in an urban watershed.

Dry weather source area particle sampling was conducted to quantify the potential contaminant load available from the many land surfaces or source areas within the urban watershed. A large number of land surfaces were sampled to quantify the quality and magnitude of source area pollutants available for washoff, and thus, possible control. These surfaces included different pavement surfaces with a variety of textures and conditions.

The rate at which dirt particles accumulate on a street surface affects the load of contaminants in runoff from this source, and was monitored. The effects of mechanical street cleaning on street



KEY MAP

Figure 1·1

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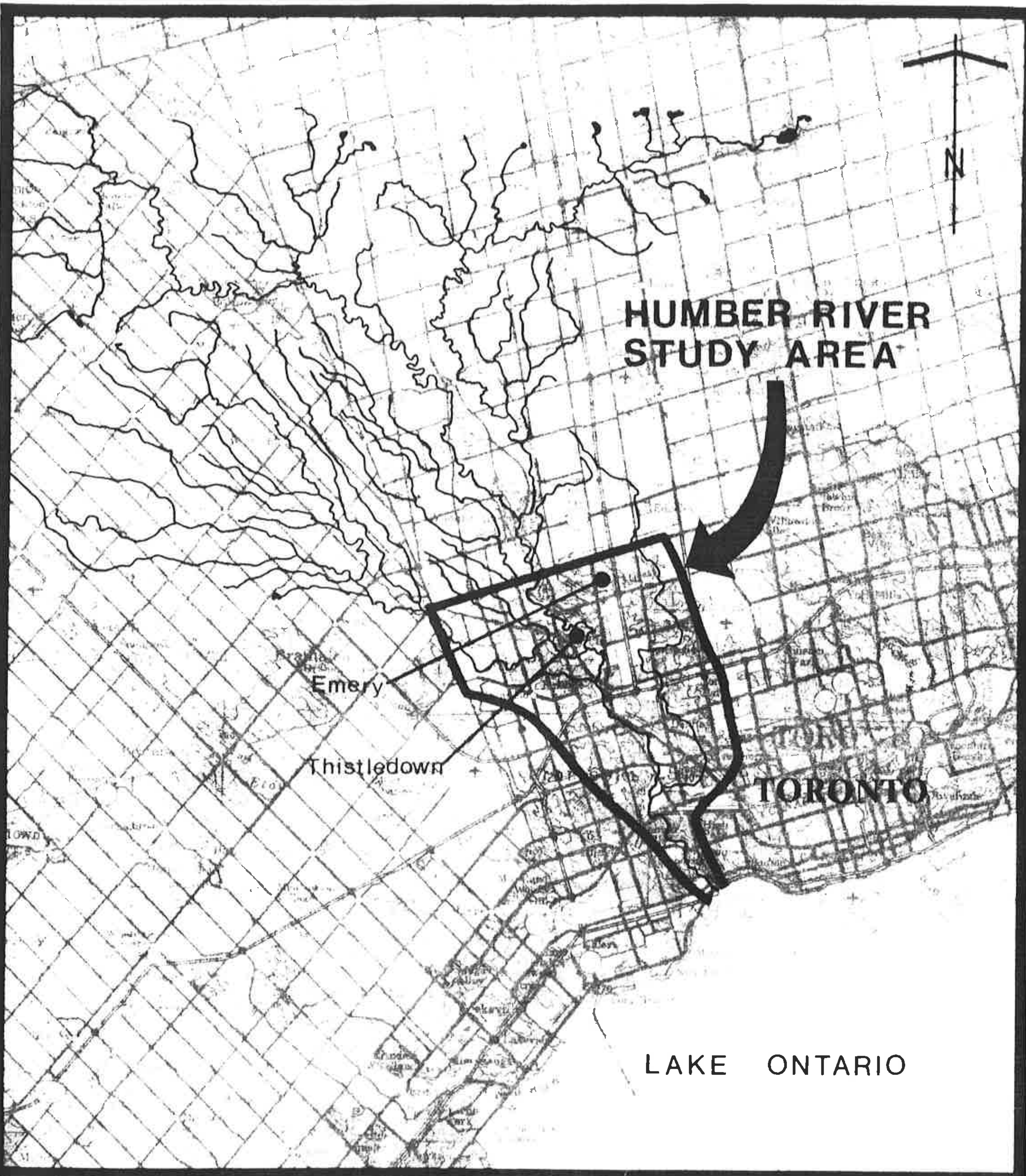

KEY MAP

Figure 1·2

Scale in Kilometres

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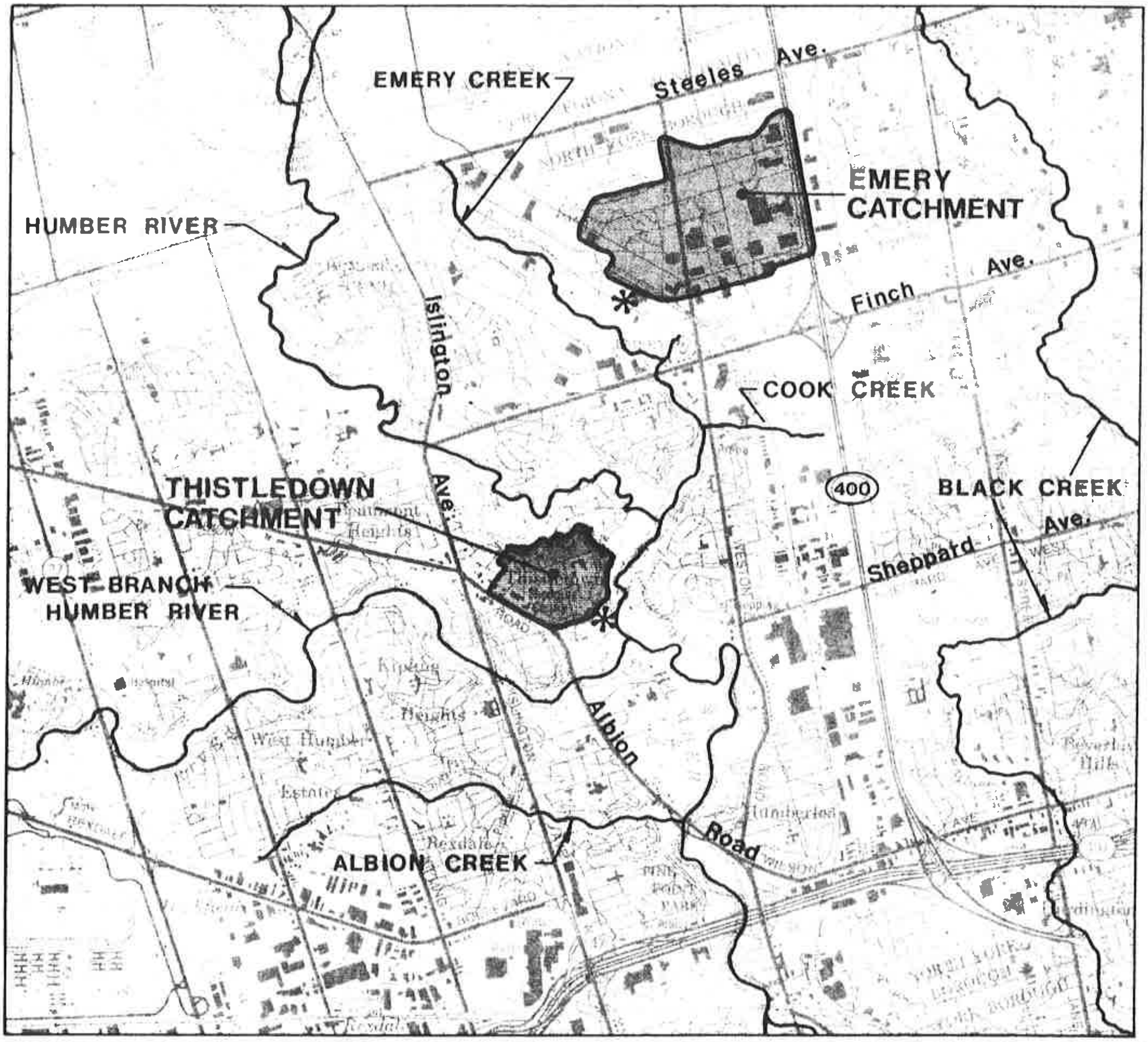
TAWMS - STORMWATER 1983
KEY MAP



LEGEND

FIGURE 1·3

Pilot Catchment Boundary

* Outfall Sampling Location

Stream, River

Scale in Kilometres (1, 0, 2)

SCALE 1:50,000
PROJECT 83·56

dirt accumulation rates were also monitored in residential and industrial land uses.

Washoff tests, using artificial rain making equipment, were used to identify and quantify the factors that govern the physical mechanisms of the washoff of street dirt from impervious (paved) surfaces. The mathematical expression of washoff is critical for the accurate simulation of urban runoff quality.

Sheetflow water samples were collected from many source areas during runoff events and during periods of snowmelt to verify the importance of these sources.

The distribution of contaminants in roadside snow accumulations was also investigated to estimate the extent of snow contamination related to traffic in urban snow packs.

Water quality and flow rates were monitored at the outfall during many storm events, snowmelt events and periods of baseflow as the final link in the hydraulic system of the two test catchments. Hydrographs of urban runoff from storm water, snowmelt and baseflow, and rain hyetographs were analysed in conjunction with the water quality data to determine overall loads of selected contaminants to the receiving waters.

1.2 REPORT STRUCTURE

This report is divided into seven sections. Each section has a selection of tables and figures to illustrate the text. The larger and / or more detailed tables and figures have been aggregated into seven technical appendices, in a separate volume.

Section 1 contains an Introduction to the project with the background to the approach taken by the study team. Included in this section is a Summary of the results of the study. The methodology of the study is described separately in Appendix A.

Section 2 contains the Conclusions and Recommendations that have been drawn from the study.

Section 3 contains site descriptions of the two watersheds that were studied. The details of the characteristics of the individual watersheds are given in Appendix B.

Section 4 describes the analysis of the precipitation and runoff data for this project. Included is a description of the statistical development of a hydraulic model to characterise the response of the watersheds to precipitation.

Precipitation is a very important independent variable that is of paramount importance to a water quality study. During this Project the study team undertook an exhaustive characterization of the precipitation in the Toronto area. The description of the rainfall variation over Toronto and its effect on the raingauge calibration is given in Appendix C. The details of the rainfall and runoff flow data is given in Appendix D.

The results of the hydraulic aspects of the washoff tests using artificial rain are described in this section.

Section 5 contains the description of the quality of the runoff sampled during the study. Included are the characterization of both baseflow and stormwater, during both cold and warm weather and sheetflow from both snowmelt and rain events in both watersheds. the results are described in terms of concentrations of water quality constituents and yields. A comparison to Ontario Provincial Water Quality Objectives is given.

The detailed data to support this section are contained in Appendix E.

Section 6 describes the areas within different landuses that are sources of a range of water pollutants. Included is further discussions of the sheetflow quality, the quality of dry particulates within the watershed and the "quality" aspects of the washoff tests.

The detailed data to support this section is contained in Appendix F.

Section 7 describes some of the potential options that could be applied to the watersheds to control the contamination of storm water. Included are the results of the street cleaning tests. The effects and the relative costs of the options are briefly described.

This section is supported by Appendix G.

Section 8 contains the references used in this Report.

1.3 BACKGROUND

The underlying structure of this Project has been based on the three topics of:

1) problem pollutants,

2) sources of problem pollutants, and

3) controls on urban runoff.

The problem pollutant identification process was briefly addressed during this current project, but was examined in more detail by other TAWMS projects. Problems with pollutants must be well described. Which pollutants (or flows) are creating, or have the potential to create interferences with established or desired beneficial uses? Where do these problems occur and during what conditions?

Urban runoff includes warm and cold weather dry weather baseflows, stormwater runoff, and snowmelt. Warm and cold weather sheetflows from the source areas defined the runoff conditions. The data were analysed to identify trends with time, rain characteristics, and land use. The concentrations observed were compared with Ontario Provincial Surface Water Objectives to determine if the urban runoff may contribute to violations of the objectives in the receiving waters. Pollutant loadings were also calculated to aid in assessing the relative significance of different pollutants.

The identification of source areas contributing potential problem pollutants and flows of storm water was addressed in detail during this project.

A thorough discussion of alternative urban runoff controls was presented in the "Manual of Practice" prepared as part of this project and the project to develop the Toronto / Source Loading and Management Model (Toronto / SLAMM). The results of these other projects are partially summarized in this report.

The analysis of the data was undertaken with the objective of characterizing the quality of the runoff from the several source areas within urban watersheds. It was designed to highlight the significant variables in the flow system. The outcome of the analysis is a qualitative description of where the current problems lie within the two Pilot Watersheds and the quantification of the yield in terms of the significant hydraulic and contaminant variables.

The use of mathematical expressions for the yield has allowed the outcome to be statistically tested against the original field data. The equations derived from these analyses can be used with other related projects and the development of a computerized model to simulate the quality of storm water flowing from urban watersheds. The model based on this Pilot Watershed Project is the Toronto / Source Loading and Management Model (Toronto / SLAMM), currently in preparation.

1.4 TERMINOLOGY

Some of the technical expressions used in this report have a variety of synonyms, also used occasionally. This subsection is written to clarify the extent to which some of the terms can be used as generic descriptors.

The words "watershed", "catchment", and "sewershed" are considered to be synonymous, with similar scales of magnitude within this report. A "drainage basin" is used in a similar sense to the words listed above, but on a larger scale.

The expressions "total residue", "particulate residue" and "filtrate residue" are defined by the laboratory procedures used, and replace the older terms "total solids", "suspended solids" and "dissolved solids", respectively.

Generally, metric units are used. However, readers are cautioned that some of the figures have been quoted from American publications and, consequently, may have imperial units.

1.5 SUMMARY

The information collected during this Pilot Watershed Project specifically addresses three topics that are required for the characterization of stormwater quality and the design of an urban runoff quality programme. The first topic concerns the documentation of existing or potential urban runoff quality problem pollutants. The second topic describes the sources of the problem pollutants. The third topic identifies potential control measures that can reduce discharges of problem pollutants.

1.5.1 PROBLEM POLLUTANTS

Table 1.1 shows median concentrations of some of the pollutants monitored in the Thistledown (mixed residential and commercial catchment) and Emery (industrial) baseflow discharges, stormwater runoff and snowmelt. The baseflows had surprisingly high concentrations of several pollutants, e.g. filtrate residue and fecal coliforms from the residential catchment. The concentrations of some constituents in the stormwater from the industrial watershed were typically much greater than the concentrations of the same constituents in the residential stormwater. The industrial warm weather baseflows were also much closer in quality to the industrial stormwater quality than the residential baseflows were to the residential stormwater quality. The data collected for pesticides and PCBs indicate that the industrial stormwater and baseflows typically contained much greater concentrations of these pollutants than the residential waters. Similarly, the more commonly analysed heavy metals were also more prevalent in the industrial stormwater. Herbicides were only detected in residential urban runoff.

During cold weather, the increases in filtrate residue were quite apparent for both study catchments and for both baseflows and snowmelt. These increases were probably caused by high chlorides from road salt applications. In contrast, bacteria populations were noticeably lower in all outfall discharges during cold weather. Few changes were noted in concentrations of nutrients and heavy metals at the outfall, between cold and warm weather periods.

Table 1.2 compares the observed urban runoff quality with the Ontario Provincial Surface Water Quality Objectives. This table shows the Objectives, and summaries of the observed data. The number of samples analysed for each water quality constituent is given for each sampling site and "type" of urban runoff. A weighted

Table 1.1 MEDIAN CONCENTRATIONS OBSERVED (mg/L) FOR SEVERAL CONSTITUENTS MONITORED

Constituent	Warm Weather Baseflow		Warm Weather Stormwater	
	Residential	Industrial	Residential	Industrial
Total Residue	979	554	256	371
Filterable Residue	973	454	230	208
Particulate Residue	<5	43	22	117
Total Phosphorus	0.09	0.73	0.28	0.75
Total Kjeldahl N	0.9	2.4	2.5	2.0
Phenolics (ug/L)	<1.5	2.0	1.2	5.1
COD	22	108	55	106
Fecal Coliforms (#/100mL)	33,000	7,000	40,000	49,000
Fecal Strep (#/100mL)	2,300	8,800	20,000	39,000
Chromium	<0.06	0.42	<0.06	0.32
Copper	0.02	0.045	0.03	0.06
Lead	<0.04	<0.04	<0.06	0.08
Zinc	0.04	0.18	0.06	0.19

Constituent	Cold Weather Baseflow		Cold Weather Melting Periods	
	Residential	Industrial	Residential	Industrial
Total Residue	2,230	1,080	1,580	1,340
Filterable Residue	2,210	1,020	1,530	1,240
Particulate Residue	21	50	30	95
Total Phosphorus	0.18	0.34	0.23	0.50
Total Kjeldahl N	1.4	2.0	1.7	2.5
Phenolics (ug/L)	2.0	7.3	2.5	15.0
COD	48	68	40	94
Fecal Coliforms (#/100mL)	9,800	400	2,320	300
Fecal Strep (#/100mL)	1,400	2,400	1,900	2,500
Chromium	<0.01	0.24	<0.01	0.35
Copper	0.015	0.04	0.04	0.07
Lead	<0.06	<0.04	0.09	0.08
Zinc	0.065	0.15	0.12	0.31

Table 1.2 PERIODS WHEN RUNOFF EXCEEDS ONTARIO PROVINCIAL WATER QUALITY OBJECTIVE (1)(2)

Constituent	Ontario OBJECTIVE	Warm Weather: Base Flows: # of observ.	# of observ. exceed. criteria	% of observ. exceed. criteria	approx. contrib. to annual problem period	Stormwater: # obs.	# exc.	% exc.	approx. contrib.
Emery (Industrial)									
Phenolics	1 ug/L	29	20	69	49%	33	32	97	4%
Fecal Coliform Bacteria	100#/100mL	24	24	100	71	33	33	100	4
Chromium	0.1 mg/L	30	28	93	66	35	31	89	4
Copper	0.005 mg/1	30	29	97	69	34	33	97	4
Lead	0.025 mg/L	30	5	17	12	34	28	82	3
Zinc	0.03 mg/L	30	30	100	71	35	33	94	4
Dieldrin (3)	1 ng/L	9	0	0	0	12	0	0	0
Endrin (3)	2 ng/L	9	0	0	0	12	0	0	0
Heptachlor (3)	1 ng/L	9	0	0	0	12	0	0	0
Polychlorinated Biphenyls (3)	1 ng/L	9	1	11	8	12	7	58	2
Thistledown (Resid. & Commer.)									
Phenolics	1 ug/L	5	1	20	14%	22	13	59	2%
Fecal Coliform Bacteria	100#/100mL	4	4	100	71	19	19	100	4
Chromium	0.1 mg/L	7	0	0	0	25	0	0	0
Copper	0.005 mg/L	7	4	57	40	25	21	84	3
Lead	0.025 mg/L	7	2	29	21	25	12	48	2
Zinc	0.03 mg/L	7	4	57	40	25	21	84	3
Dieldrin (4)	1 ng/L	1	1	100	71	7	2	29	1
Endrin (4)	2 ng/L	1	0	0	0	7	1	14	1
Heptachlor (4)	1 ng/L	1	0	0	0	7	1	14	1
Polychlorinated Biphenyls (4)	1 ng/L	1	0	0	0	7	0	0	0

Table 1.2 PERIODS WHEN RUNOFF EXCEEDS ONTARIO PROVINCIAL WATER QUALITY OBJECTIVE[1][2] continued

Constituent	Ontario Objective	Cold Weather: Base Flows: # of observ.	# of observ. exceed. criteria	% of observ. exceed. criteria	approx. contrib. to annual problem period	Snowmelts: # obs.	# exc.	% exc.	approx. contrib.
Emery (Industrial)									
Phenolics	1 ug/L	8	8	100	21%	16	16	100	4%
Fecal Coliform Bacteria	100#/100mL	8	8	100	21	17	12	71	3
Chromium	0.1 mg/L	10	8	80	17	17	12	71	3
Copper	0.005 mg/1	10	10	100	21	17	16	94	4
Lead	0.025 mg/L	10	4	40	8	17	14	82	3
Zinc	0.03 mg/L	10	10	100	21	17	17	100	4
Dieldrin[3]	1 ng/L	1	0	0	0	2	0	0	0
Endrin[3]	2 ng/L	1	0	0	0	2	0	0	0
Heptachlor[3]	1 ng/L	1	0	0	0	2	0	0	0
Polychlorinated Biphenyls[3]	1 ng/L	1	0	0	0	2	1	50	2
Thistledown (Resid. & Commer.)									
Phenolics	1 ug/L	4	3	75	11	12	10	83	7%
Fecal Coliform Bacteria	100#/100mL	4	4	100	17	15	15	100	8
Chromium	0.1 mg/L	4	0	0	0	16	1	6	1
Copper	0.005 mg/L	4	4	100	17	16	14	88	7
Lead	0.025 mg/L	4	2	50	7	16	12	75	6
Zinc	0.03 mg/L	4	4	100	17	16	16	100	8
Dieldrin[4]	1 ng/L	0	-	-	-	2	1	50	4
Endrin[4]	2 ng/L	0	-	-	-	0	-	-	-
Heptachlor[4]	1 ng/L	0	-	-	-	0	-	-	-
Polychlorinated Biphenyls[4]	1 ng/L	0	-	-	-	0	-	-	-

Table 1.2 PERIODS WHEN RUNOFF EXCEEDS ONTARIO PROVINCIAL WATER QUALITY OBJECTIVE[1][2] continued

Constituent	Ontario Objective	# of observ.	Total Annual: # of observ. exceed. criteria	Total Annual: % of observ. exceed. criteria	Total Annual: approx. % of year when criteria is exceeded
Emery (Industrial)					
Phenolics	1 ug/L	86	76	88	78%
Fecal Coliform Bacteria	100#/100mL	82	77	94	99
Chromium	0.1 mg/L	92	79	86	90
Copper	0.005 mg/1	91	88	97	98
Lead	0.025 mg/L	91	51	56	26
Zinc	0.03 mg/L	92	90	98	100
Dieldrin[3]	1 ng/L	24	0	0	0
Endrin[3]	2 ng/L	24	0	0	0
Heptachlor[3]	1 ng/L	24	0	0	0
Polychlorinated Biphenyls[3]	1 ng/L	24	9	38	12
Thistledown (Resid. & Commer.)					
Phenolics	1 ug/L	43	27	63	34
Fecal Coliform Bacteria	100#/100mL	42	42	100	100
Chromium	0.1 mg/L	52	1	2	1
Copper	0.005 mg/L	52	43	83	97
Lead	0.025 mg/L	52	28	54	36
Zinc	0.03 mg/L	52	45	87	68
Dieldrin[4]	1 ng/L	10	4	40	76
Endrin[4]	2 ng/L	10	1	10	1
Heptachlor[4]	1 ng/L	10	1	10	1
Polychlorinated Biphenyls[4]	1 ng/L	10	0	0	0

Table 1.2 PERIODS WHEN RUNOFF EXCEEDS ONTARIO PROVINCIAL WATER QUALITY OBJECTIVE[(1)(2)] continued

Footnotes

(1)

Emery	warm weather base flows occur about	260 days a year	(71%)
	stormwater runoff	14 days	(4%)
	cold weather base flows	77 days	(21%)
	snowmelts	14 days	(4%)
Thistledowns	warm weather base flows occur about	260 days a year	(71%)
	stormwater runoff	14 days	(4%)
	cold weather base flows	62 days	(17%)
	snowmelts	29 days	(8%)

(2) Very few "organic priority pollutant" samples were analysed, and few Ontario Objective Limits exist for any. However, phthalate compounds, benzene, chloroform, ethylbenzene, methylene chloride, fluoranthene, phenanthene, and pyrene were found in most of the nine samples analysed.

(3) The few number of cold weather samples analysed for these pesticides and PCBs significantly reduce their importance when estimating any problems associated with them.

(4) Again, the few base flow (cold and warm weather) and snowmelt samples analysed for pesticides and PCBs make it difficult to arrive at major annual conclusions for these constituents.

annual condition (by period of occurrence) is included on this table. A total of ten to 92 analyses were conducted for each of the listed constituents in the runoff waters from each pilot watershed. Few cold weather baseflow and snowmelt samples, and few residential baseflow samples, were analysed for pesticides and PCBs in either study area. However, the relatively frequent occurrence of high concentrations of PCBs in the stormwater and snowmelt from the industrial watershed should be cause for future studies.

Fecal coliforms always exceeded the objective in warm and cold weather baseflows and stormwater from both watersheds. Fecal coliform counts in the snowmelt from the industrial watershed exceeded the objective approximately 70 percent of the time. Phenolics, zinc, chromium, and copper concentrations nearly always exceeded the objectives in the warm and cold weather baseflows, stormwater and snowmelts from the industrial watershed. Phenolics, copper, lead, and zinc concentrations frequently exceeded the objectives during all urban runoff flow conditions from the residential watershed. Potential problems with the concentrations of chromium were restricted to the industrial watershed, especially during baseflows. The few samples analysed for Dieldrin indicated a potential problem in the residential / commercial catchment.

Table 1.3 summarizes similar "exceedance of objective" information for sheetflows from cold and warm weather source areas from both watersheds. Almost all constituents compared on this table (for both land uses) exceeded the objectives frequently. The exception was chromium which had fewer "exceedances" during both warm and cold weather conditions and in sheetflow from almost all source areas. However, chromium frequently exceeded the Objectives in sheetflow originating on large paved areas. Significant decreases in the potential for fecal coliform problems were noted in the industrial watershed during cold weather conditions (compared to warm weather conditions).

1.5.2 SOURCES OF PROBLEM POLLUTANTS

Table 1.4 compares the estimated annual discharges from the residential and industrial catchments during the different runoff periods. The unit area annual yields for many of the heavy metals and nutrients are greater from the industrial catchment. The industrial catchment monitored corresponds in character to approximately 25 percent of the urban Humber watershed and the residential catchment corresponds to approximately 75 percent. Industrial catchments contribute most of the chromium to the local receiving waters, and approximately equal amounts with the residential and commercial catchments for phosphorus, COD, copper, and zinc. This table also shows the great importance of warm weather baseflow discharges to the annual urban runoff pollutant yields, especially for industrial areas. Cold weather bacteria discharges are insignificant when compared to the warm weather bacteria discharges, but chloride (and filtrate residue) loadings are much more important during cold weather.

Table 1.3 WARM AND COLD WEATHER SHEETFLOW OBSERVATIONS EXCEEDING OBJECTIVE

	Phenolics (1 ug/L)			Fecal Coliform Bact. (100/100mL)			Chromium (0.1mg/L)			Copper (0.005 mg/L)			Lead (0.025 mg/L)			Zinc (0.03 mg/L)		
Emery (Industrial)	# of obs.	# of obs. exc. crit.	% of obs. exc. crit.	# obs.	# exc.	% exc.	# obs.	# exc.	% exc.	# obs.	# exc.	% exc.	# obs.	# exc.	% exc.	# obs.	# exc.	% exc.
Warm weather																		
(rain runoff)																		
Bare ground	0	-	-	0	-	-	1	0	0	1	0	0	1	0	0	1	1	100
Grass	1	0	0	1	1	100	1	0	0	1	0	0	1	0	0	1	0	0
Unpaved driveways	1	1	100	1	1	100	1	0	0	1	1	100	1	1	100	1	1	100
Unpaved park./stor.	4	4	100	4	3	75	5	0	0	5	5	100	5	4	80	5	5	100
Roof runoff	2	1	50	2	2	100	2	0	0	2	1	50	2	0	0	2	2	100
Paved parking	6	6	100	6	5	83	7	1	14	7	7	100	7	6	86	7	7	100
Paved storage	1	1	100	2	2	100	2	0	0	2	2	100	2	2	100	2	2	100
Paved driveways	1	1	100	1	1	100	2	0	0	1	1	100	1	1	100	1	1	100
Sidewalks	2	2	100	2	2	100	2	0	0	1	1	100	1	0	0	1	1	100
Paved roads	7	6	86	6	6	100	7	1	14	7	7	100	7	7	100	7	6	86
Road gutters	4	4	100	7	7	100	7	1	14	7	6	86	7	7	100	7	7	100
No. Telecon Drain	4	4	100	5	5	100	5	0	0	5	3	60	5	1	20	5	5	100
Cold weather																		
(snowmelt)																		
Grass//open space	11	8	73	14	0	0	12	0	0	12	7	58	12	5	42	12	10	83
Unpaved storage	7	7	100	8	2	25	8	1	13	8	8	100	8	8	100	8	8	100
Unpaved parking	3	3	100	4	1	25	4	3	75	4	4	100	4	4	100	4	4	100
Paved stor./loading	2	2	100	2	0	0	2	0	0	2	2	100	2	2	100	2	2	100
Paved parking	4	4	100	6	1	17	4	0	0	4	4	100	4	4	100	4	4	100
Sidewalks	2	2	100	2	0	0	2	0	0	2	2	100	2	2	100	2	2	100
Paved driveways	4	4	100	4	2	50	4	2	50	4	3	75	4	3	75	4	4	100
Roadside gutters	6	6	100	8	1	13	7	1	14	7	7	100	7	7	100	7	7	100
No. Telecon Drain	2	1	50	2	0	0	2	0	0	2	0	0	2	1	50	2	2	100
Total Observations	74	67	91	87	42	48	87	10	11	85	71	84	85	65	76	85	81	95

(1) No warm weather sheetflow samples were analysed for pesticides, PCBs, or priority pollutants, but nine cold weather samples were analysed for pesticides and PCBs. Of these nine samples, one (an unpaved storage yard) exceeded the PCB criteria of 1 ng/L. The other eight were all below the detection limit (20 ng/L). The detected PCB resembled Aroclor 1260.

Table 1.3 WARM AND COLD WEATHER SHEETFLOW OBSERVATIONS EXCEEDING OBJECTIVE continued

Thistledown: (Resid. & Commer.)	Phenolics (1 ug/L)			Fecal Coliform Bact. (100/100mL)			Chromium (0.1mg/L)			Copper (0.005 mg/L)			Lead (0.025 mg/L)			Zinc (0.03 mg/L)		
	# of obs.	# of obs. exc. crit.	% of obs. exc. crit.	# obs.	# exc.	% exc.	# obs.	# exc.	% exc.	# obs.	# exc.	% exc.	# obs.	# exc.	% exc.	# obs.	# exc.	% exc.
Warm weather (rain runoff)																		
Dirt footpath	1	0	0	0	-	-	1	0	0	1	1	100	1	1	100	1	1	100
Roof runoff	4	3	75	3	3	100	4	0	0	4	2	50	4	0	0	4	2	50
Paved parking	6	6	100	4	4	100	6	1	17	6	4	67	6	4	67	6	5	83
Paved storage	1	1	100	1	1	100	1	0	0	1	1	100	1	1	100	1	1	100
Paved driveways	2	2	100	1	1	100	1	0	0	1	1	100	1	1	100	1	1	100
Sidewalks	1	1	100	1	1	100	1	0	0	1	1	100	1	1	100	1	1	100
Paved roads	6	6	100	6	3	50	6	0	0	6	4	67	6	5	83	6	6	100
Sealed ditches	4	4	100	4	3	75	4	0	0	4	4	100	4	2	50	4	4	100
Catchbasins	1	1	100	1	1	100	1	0	0	1	0	0	1	0	0	1	1	100
Cold weather (snowmelt)																		
Grass/open space	5	4	80	5	1	20	5	1	20	5	2	40	5	2	40	5	1	20
Paved stor./loading	2	2	100	2	2	100	2	0	0	2	2	100	2	2	100	2	2	100
Paved parking	4	4	100	4	1	25	4	0	0	4	4	100	4	4	100	4	4	100
Sidewalks	6	5	83	6	3	50	6	0	0	6	6	100	6	5	83	6	6	100
Paved driveways	5	4	80	5	1	20	5	1	20	5	5	100	5	4	80	5	5	100
Paved roads	6	6	100	6	3	50	6	0	0	6	6	100	6	6	100	6	6	100
Grass swales	8	7	88	8	3	38	8	0	0	8	5	63	8	6	75	8	7	88
Sealed swales (3)	2	2	100	2	1	50	2	0	0	2	2	100	2	2	100	2	2	100
Roadside gutters	7	7	100	7	3	43	7	0	0	7	7	100	7	7	100	7	7	100
Total Observations	71	65	92	66	35	53	70	3	4	70	57	81	70	53	76	70	62	89

(2) Nine cold weather samples were analysed for pesticides and PCBs. Only one (T2, a paved loading area) exceeded an established criteria. The Dieldrin value observed for this sample was 4 ng/L, while the criteria is 1 ng/L. The other eight samples were all below the Dieldrin detection limit of 2 ng/L.

(3) Approximately 50% of the swale area was sealed with asphalt.

Table 1.4 <u>ESTIMATED ANNUAL DISCHARGES</u>

Constituent	(units)	Thistledown (Residential/Commercial)					Emery (Industrial)					approx. Indus./Resid. total yield ratios	weighted Indus./Resid. total yield ratios (1)
		warm		cold			warm		cold				
		base flow	storm-water	base flow	melt water	approx. Total	base flow	storm-water	base flow	melt water	approx. Total		
Runoff volume	m^3/ha	1700	950	1100	1800	5600	2100	1500	660	830	5,100	0.9	0.3
Total residue	kg/ha	1700	240	2400	1700	6100	1100	670	710	1500	4,000	0.7	0.2
Chlorides	kg/ha	480	33	1200	720	2400	160	26	310	700	1,200	0.5	0.2
Total phosphorus	g/ha	150	290	200	570	1200	1500	1300	220	540	3,600	3.0	1.0
Total Kjeldahl N	g/ha	1500	2800	1500	3500	9300	4900	3400	1300	2800	12,000	1.3	0.4
Phenolics	g/ha	<2.6	1.2	2.3	23	26	4.1	8.1	4.8	14	31	1.2	0.4
COD	kg/ha	38	51	52	130	270	220	170	45	91	530	2.0	0.7
Chromium	g/ha	<100	21	<10	15	36	860	600	160	290	1,900	50	18
Copper	g/ha	35	30	16	77	160	92	120	26	76	310	1.9	0.7
Lead	g/ha	<70	41	<70	170	210	<75	170	<25	150	320	1.5	0.5
Zinc	g/ha	70	74	70	270	480	370	430	100	350	1,200	2.5	0.8
Fecal Colif. Bact.	10^9 org/ha	560	480	110	62	1200	144	760	3	6	910	0.8	0.3

"Warm weather" is for the period from about March 15 through December 15, while "cold weather" is for the period from about December 15 through March 15.

(1) If basin is 25% Industrial and 75% Residential and Commercial.

Tables 1.5 and 1.6 summarize the sheetflow concentrations observed during warm and cold weather. In some cases, the concentrations observed were not sufficient to account for the concentrations observed at the outfall. This may be due to significant subsurface sources of pollutants, such as leaking sanitary sewerage, or industrial discharges to the storm drainage system. Because Toronto rain events are of typically short duration, many of the warm weather manual sheetflow samples were obtained in the later portions of the runoff events. This may have allowed settleable pollutants to be reduced in concentration before the sheetflow samples could be collected. In most cases, the observed trends in quality between the different areas were typical:

1) roof runoff had generally good water quality (with the exception of zinc from galvanized roof gutters),

2) parking areas and street sheetflows had poor water quality, and

3) bare ground and landscaped areas had high concentrations of residue and nutrients, and low concentrations of heavy metals.

Warm weather sheetflow fecal coliform populations were lower than the observed outfall populations, except for industrial sidewalk sheetflow values. It is expected that significant subsurface sources of fecal coliforms occur in both of the study areas. This is especially evident when the cold weather snowmelt sheetflow bacteria observations are also examined (Table 1.6). Significant subsurface sources of chromium in the industrial watershed are also expected.

During cold weather snowmelts, chloride concentrations in the sheetflows from residential areas were also much lower than were measured at the outfall. The chloride concentrations in snowmelt sheetflows from industrial areas were also lower than observed at the outfall, but not by as large a margin. These differences in chloride concentrations may be caused by the significant chloride gradient found in roadside snowpacks. The chlorides found in very high concentrations next to the roads (and drainage systems) would be much more efficiently transported to the outfall than the less concentrated chlorides found further from the roads.

Similar trends were observed for fecal coliforms. These trends are possibly due to people "curbing" their dogs, causing greater concentrations of dog faeces near the drainage system. However, subsurface sources of bacteria are still thought to be significant because the few dogs that are walked in the industrial catchment in cold weather are not expected to cause such large outfall bacteria populations as were observed.

The subsurface sources of chromium in the industrial catchment are expected to be caused by process wastes being directly discharged into the storm drainage system. Metal plating operations disposing

Table 1.5 WARM WEATHER SOURCE AREA SHEETFLOW QUALITY (median observed concentrations, mg/L)

Source Area	total solids	total phos.	TKN	phenolics (ug/L)	COD	fecal coliforms (10^3/100mL)	Lead	Zinc
Industrial								
Pervious Areas								
Bare ground	488	0.62	2.7	0.8	40	3.3	§0.3	0.05
Unpaved driveways & park./storage	1148	1.09	2.8	9.0	247	26	0.25	0.50
Impervious Areas								
Roofs	113	§0.05	1.7	1.2	55	1.6	§0.04	0.07
Sidewalks	580	0.82	4.7	8.7	98	55	0.04	0.06
Paved park./stor. & driveways	315	0.9	3.1	8.6	132	2.8	0.19	0.34
Paved roads	992	0.9	3.5	14.7	326	19	0.51	0.59
Outfall (1)	371	0.75	2.0	5.1	106	49	0.08	0.19
Residential								
Pervious Areas								
Bare ground	1240	0.20	1.3	§0.4	66	-	0.03	0.04
Impervious Areas								
Roofs	44	§0.04	0.8	2.8	36	0.5	§0.03	0.31
Sidewalks	49	0.8	1.1	8.6	62	11	0.08	0.06
Paved driveways & parking	952	0.62	2.2	11.8	67	2.0	0.35	0.45
Paved roads	185	0.49	1.6	6.3	66	4.8	0.13	0.16
Outfall (1)	256	0.28	2.5	1.2	55	40	§0.06	0.06

Note: § means "less than".
(1) outfall measurements during sheetflow sampling only

Table 1.6 COLD WEATHER SNOWMELT SOURCE AREA SHEETFLOW QUALITY (median observed concentrations, mg/L)

Source Area	total residue	reactive chlorides	total phos-phorus	TKN	phenolics (ug/L)	COD	fecal coliforms (10^3/100mL)	Lead	Zinc
Industrial (Emery)									
Pervious Areas									
Grass/open areas	390	100	0.33	1.4	3.0	47	§20	0.01	0.06
Unpaved storage/parking	1450	113	1.1	5.3	9.0	160	§100	0.26	0.51
Impervious Areas									
Sidewalks	1050	48	0.45	1.6	3.7	63	§50	0.19	0.47
Paved park./stor. & driveways	1690	260	0.55	3.8	4.0	135	§100	0.20	0.40
Road gutters	1320	230	0.60	1.8	9.0	230	§100	0.45	0.66
Outfall (1)	1340	621	0.50	2.5	15	94	2500	0.08	0.31
Residential/Commercial (Thistledown)									
Pervious Areas									
Grass/open areas	94	4.0	0.29	1.2	1.4	26	§20	0.04	0.02
Impervious Areas									
Sidewalks	390	6.4	0.63	2.6	1.4	98	75	0.15	0.16
Paved park., driveways & loading	918	81	0.64	2.5	2.6	110	§20	0.23	0.23
Paved roads	890	56	0.30	1.8	3.2	140	50	0.26	0.26
Road gutters	530	25	0.54	2.3	1.8	66	60	0.12	0.09
Roadside grass swales	380	37	0.59	1.8	1.6	40	60	0.05	0.08
Outfall (1)	1580	660	0.23	1.7	2.5	40	2320	0.09	0.12

Note: § means "less than".
(1) outfall measurements during sheetflow sampling only.

of their spent plating solutions in the storm drainage system may be responsible. Although other industrial process wastes may also be entering the storm drainage system, chromium was the only "subsurface" constituent monitored that appeared to pose a significant threat.

Table 1.7 shows the estimated contributions of pollutants from the different source areas to the yield at the outfall during warm and cold weather. The quality of runoff from a small 2 mm rain was mostly affected by impervious areas (streets, parking areas, and connected roofs), while the quality of runoff from an average (but still small) rain of 10 mm was affected more by pervious areas. Larger rains would contribute significantly more pollutants from pervious areas. During warm weather, total residue is considered to be coming mostly from landscaped areas in residential catchments, and from parking and storage areas and roofs in industrial catchments. Lead is coming mainly from streets and parking areas, while roofs are significant sources of zinc.

1.5.3 URBAN RUNOFF CONTROLS

The source area contribution information defines the limit of application of the potential controls. If a control can reduce the discharge from a contributing source area by 50 percent, and the contributing area is responsible for 30 percent of the discharge of the outfall, then the control will reduce the discharge at the outfall by only 15 percent. Many controls can be applied to several source areas, but may only cause significant reductions in pollutant yield in a few areas. The effectiveness of the various controls also varies significantly depending on different land uses and seasons. The following paragraphs summarize the effectivenesses of several different controls for the residential and industrial catchments studied, and for the urban Humber River study area. The discussion is based on the premises that:

1) any reduction in the volume of stormwater will reduce the yield of pollutants at the outfall, and

2) any reduction in the available load in the source areas will also reduce the yield of pollutants at the outfall.

<u>Controls In Residential Catchments</u>

Street cleaning in most residential catchments may cause significant reductions in the loads of phosphorus, fecal coliforms, and to a lesser extent, lead, at the outfall (compared to no street cleaning). Relatively little further improvement may occur if frequent street cleaning is compared to the current infrequent street cleaning efforts. It is difficult to justify increasing street cleaning frequency beyond approximately one pass every two weeks in residential catchments. Intensive spring cleanup and fall leaf removal are considered very important and should be continued and encouraged.

Table 1.7 CONTRIBUTIONS OF STORMWATER POLLUTANTS AND FLOWS FOR SMALL AND MODERATE RAINS AND SNOWMELT

	Total rain 2mm	Residual rain 10mm	melt	Reactive[2] Chlorides 2mm	10mm	melt	Total Phosphorus 2mm	10mm	melt	TKN 2mm	10mm	melt	Phenolics 2mm	10mm	melt
Resid./Commer.															
streets	23%	5%	26%	?	?	22%	18%	3%	9%	24%	10%	13%	13%	4%	20%
paved park. & playgrounds	39	11	14	?	?	17	29	6	10	11	5	9	8	3	10
driveways	14	6	11	?	?	14	10	3	8	4	3	8	3	2	9
walks	14	6	3	?	?	0	21	6	6	38	27	6	43	25	2
roofs[1]	10	11	?	?	?	?	22	16	?	23	43	?	33	66	?
front yards	0	26	5	?	?	3	0	28	16	0	5	15	0	0	12
large turf, backyards & open areas	0	35	7	?	?	4	0	38	23	0	7	22	0	0	17
Industrial															
streets	10%	3%	6%	?	?	7%	8%	2%	5%	3%	1%	3%	7%	3%	10%
driveways & loading	2	2	3	?	?	3	2	1	2	2	2	3	3	3	2
paved park./stor.	64	35	26	?	?	27	45	23	20	61	38	23	78	66	16
unpaved park./stor.	0	13	17	?	?	9	0	8	28	0	3	25	0	7	29
walks	0	0	0	?	?	0	0	0	0	0	0	0	0	0	0
roofs[1]	24	26	?	?	?	?	45	44	?	34	43	?	12	19	?
landscaped & open areas	0	21	8	?	?	13	0	22	13	0	13	11	0	2	16

Table 1.7 CONTRIBUTIONS OF STORMWATER POLLUTANTS AND FLOWS FOR SMALL AND MODERATE RAINS AND SNOWMELT continued

	COD rain 2mm	rain 10mm	melt	Fecal Coliforms 2mm	10mm	melt	Lead 2mm	10mm	melt	Zinc 2mm	10mm	melt	Flow 2mm	10mm	melt
Resid./Commer.															
streets	21%	8%	27%	15%	7%	-	27%	15%	26%	15%	5%	29%	45%	41%	12%
paved park. & playgrounds	7	3	10	2	1	-	34	23	12	14	5	13	14	12	6
driveways	3	2	9	1	1	-	12	12	10	5	3	11	5	6	5
walks	47	32	5	80	64	-	17	16	4	13	7	6	5	6	4
roofs(1)	22	41	?	2	6	-	10	27	?	53	78	?	31	30	22
front yards	0	6	9	0	9	-	0	3	7	0	1	4	0	2	21
large turf, backyards & open areas	0	8	12	0	12	-	0	4	10	0	1	6	0	3	30
Industrial															
streets	8%	3%	11%	17%	4%	-	9%	3%	16%	6%	2%	12%	10%	10%	6%
driveways & loading	2	2	2+	2	1	-	2	2	2	3	3	3	1	2	2
paved park./stor.	63	45	22	49	26	-	59	41	22	75	59	23	34	33	20
unpaved park./stor.	0	8	20	0	25	-	0	10	22	0	9	23	0	1	15
walks	0	0	0	3	3	-	0	0	0	0	0	0	0	0	0
roofs(1)	27	37	?	29	29	-	30	40	?	16	24	?	54	53	31
landscaped & open areas	0	5	10	0	12	-	0	4	2	0	3	4	0	1	25

(1) Roof snowmelt samples were not obtained directly, but were obtained in combination with snowmelt samples from roof draining areas.

(2) Reactive chloride samples were not obtained during the warm weather sheetflow sampling program.

If roof runoff is not currently directed towards pervious areas, then a "retrofit" program to encourage the infiltration of roof runoff can be very cost effective in terms of reducing pollutant loads. High rise apartments have large paved parking areas. The infiltration of the associated discharges of storm water from these areas, after pretreatment with grit chambers and oil and grease traps, would significantly reduce many discharges of pollutants and stormwater to surface water.

The most practical runoff control for lower density use areas (including low and medium density residential areas) is grass swales in place of concrete curb and gutter systems. These have been shown in monitoring programs to be as much as 90 percent effective in reducing discharges and pollutant yields. Grass swales in residential catchments pose little threat to groundwater. If grass swales currently exist in an area, changing to curb and gutter systems should be strongly discouraged.

Controls In Industrial Catchments

Some increases in street cleaning frequency may be needed in industrial catchments. The existing cleaning frequencies (next to nothing) should be increased to at least once per month. Intensive spring cleaning and leaf removal is also warranted.

Several discharges from source areas in industrial land use areas were found to be highly polluted during this study. Infiltration of runoff from paved parking and storage areas may be advisable, depending on the quality of the discharges and the potential for groundwater contamination. These discharges would need to be passed through pretreatment with grit chambers and oil and grease traps. The infiltration of roof runoff is important, depending on the potential for contamination of the groundwater from galvanized metal roofs or gutter systems.

Wet detention basins can produce significant reductions in discharges of pollutants during both wet and dry weather. Because of the potential for heavily contaminated baseflow discharges from industrial catchments wet detention basins at the outfalls of industrial developments should be strongly encouraged. More importantly, wet detention basins offer an opportunity to control spills that enter the storm drainage system.

Grass swale drainages currently occur in industrial catchments in the urban Humber River drainage area and may contribute to a potential contamination threat to the groundwater. If the discharges from roadside drainage from a specific area are found to be relatively clean, then keeping the grass swales should be strongly encouraged. If the discharges are found to be excessively polluted, then the inappropriate sources of pollutants discharging into the roadside drainage should be found and corrected.

Humber River Watershed Controls

Calculations of pollutant yields were made for the urban Humber River study area and were reported in the "Sensitivity Analysis" report (Pitt, 1985) . When total Kjeldahl nitrogen, phosphorus, chemical oxygen demand, copper, and zinc "cost effectiveness" plots were examined, it was clear that a combination of infiltration and detention allows a much greater removal of pollutants to be obtained at a relatively low unit cost compared to the other control programs that were examined. If flow, total residue, filtrate residue, fecal coliform bacteria, and *pseudomonas aeruginosa* are the most important constituents, then infiltration (with appropriate pretreatment) was the most cost effective solution. The most general recommended control program is therefore infiltration with wet detention. In order to obtain significant reductions in bacteria, it may be necessary to use disinfection in conjunction with wet detention basins.

Analyses of Individual Humber River Sewersheds

Fifteen separate sewersheds in the Humber River study area were evaluated to estimate current levels of pollutant yields. These same sewersheds were evaluated for reductions in discharges of pollutants and flow possible using the recommended control program. The recommended control program includes the use of wet detention basins serving 25 percent of the drainage area plus infiltration of approximately one half of the residential roofs currently draining to pavement, and infiltration of approximately one half of paved parking and storage areas and roofs in high rise residential, industrial, and commercial areas. The total annual cost for this program in the Humber River study area was estimated to be approximately $5.7 million per year, or $410 per hectare per year.

The reductions in pollutant yields expected from this program are estimated to be:

1) five to ten percent for bacteria,

2) 15 to 20 percent for flow, total residue and filtrate residue, and

3) 30 to 45 percent for particulate residue, nutrients, chemical oxygen demand, phenols, and heavy metals.

If higher bacteria removals are needed, substantial increases in cost may be needed for disinfection in conjunction with wet detention basins.

2.0 CONCLUSIONS AND RECOMMENDATIONS

2.1 CONCLUSIONS

The data collected in an intensive multi-source sampling program provides a good characterisation of the discharges from a storm water system. Such programs need to be continued all year to "complete the annual picture" before a complete characterisation can be completed. By monitoring virtually all of the runoff events, one is provided with a sufficiently detailed data base to allow a calibrated model for predicting the quality of the discharges from a sewer system to be empirically prepared. Care must be taken during the experimental design and data collection effort to ensure that critical data, e.g. records of precipitation, are duplicated using standard procedures and that laboratories are sufficiently organized to accept the water samples when they are collected.

The following major conclusions can be drawn from the results of this study and personal observations made in the watersheds. The Conclusions are structured in a similar manner to the Summary; pollutants, sources and controls.

Pollutants

1) The baseflows during warm weather had surprisingly high concentrations of several pollutants, e.g. filtrate residue and fecal coliforms from the residential catchment.

2) The concentrations of some constituents (including metals and organic compounds) in the stormwater from the industrial watershed were typically much greater than the concentrations of the same constituents in residential stormwater.

3) In some cases, the concentrations of constituents observed in the sheetflow were not sufficient to account for the concentrations observed at the outfall.

4) Almost all constituents frequently exceeded the Provincial Water Quality Objectives.

5) Fecal coliforms always exceeded the objective in warm and cold weather baseflows and stormwater from both watersheds. It is expected that significant subsurface sources of fecal coliforms occur in both of the study areas, even though sheetflows were sufficient to cause significant problems. Fecal coliform counts in the snowmelt from the industrial watershed exceeded the objective approximately 70 percent of the time.

6) Cold weather bacteria discharges are insignificant when compared to the warm weather bacteria discharges.

Sources

7) Construction sites can discharge significant amounts of residue and other pollutants to the sewer system, and hence to the receiving waters.

8) Warm weather baseflow discharges contribute a significant proportion of the annual yield, especially from the industrial watershed. Warm weather baseflows account for 70 percent of the flow duration in a year.

9) Industrial catchments contribute most of the chromium to the local receiving waters, and approximately equal amounts with the residential and commercial catchments for phosphorus, COD, copper, and zinc.

10) The quality of runoff from a small (2mm) rain events was mostly affected by impervious areas (streets, parking areas, and connected roofs), while the quality of runoff from an average (10 mm) rain events was affected more by pervious areas.

11) Lead is coming mainly from streets and parking areas, while roofs are significant sources of zinc.

Controls

12) Street cleaning in most catchments once per month may cause significant reductions in the loads of phosphorus, fecal coliforms, and to a lesser extent, lead, at the outfall (compared to no street cleaning). Relatively small further improvement would occur if street cleaning frequency is increased beyond twice per month.

13) The infiltration of storm water from paved parking areas, after pretreatment with grit chambers and oil and grease traps, would significantly reduce many discharges of pollutants (and stormwater) to local streams.

14) The most practical runoff control for lower density use areas (including low and medium density residential areas) is grass swales in place of concrete curb and gutter systems. If grass swales currently exist in an area, changing to curb and gutter systems should be strongly discouraged.

15) Wet detention basins can produce significant reductions in discharges of pollutants during both wet and dry weather.

16) The recommended control program includes the use of wet detention basins serving at least 25 percent of the drainage area plus infiltration of at least one half of the residential roofs currently draining to pavement, and infiltration of at least one half of paved parking and storage areas and roofs in high rise residential,

industrial, and commercial areas. The total annual cost for this recommended program in the Humber River study area was estimated to be approximately $5.7 million per year or $410 per hectare per year.

17) The reductions in pollutant yields expected from this recommended program are estimated to be:

a) five to ten percent for bacteria,

b) 15 to 20 percent for flow, total residue and filtrate residue, and

c) 30 to 45 percent for particulate residue, nutrients, chemical oxygen demand, phenols, and heavy metals.

18) If higher bacteria removals are needed, substantial increases in cost may be needed for disinfection in conjunction with wet detention basins.

2.2 RECOMMENDATIONS

Based on the Conclusions described above the following Recommendations are made.

1) Prepare and implement a more stringent bylaw covering stormwater and runoff controls from construction sites.

This source area must be controlled first before any consideration is given to stormwater management for new developing areas and existing areas. Many model bylaws exist that can be effectively used to control construction site erosion, if enforced.

2) A stormwater management plan that specifies control requirements for proposed developments should be prepared and adopted. A stormwater management plan for new developing areas should require the following items:

a) the infiltration of all roof runoff,

b) the infiltration of runoff from "large" parking areas (after pretreatment with grit chambers and oil and grease traps),

c) street cleaning at least once a month, including a more intensive spring cleanup and leaf removal effort in the fall,

d) the cleaning of catchbasins twice per year,

e) the use grass swale or perforated pipe drainage instead of conventional curb and gutter systems, expect in areas having highly polluted gutter discharges that may cause contamination of the groundwater , and

f) the use of wet detention (retention) basins at outfalls from industrial land uses and other very large parking areas, e.g. shopping centres.

An important feature of a "stormwater and construction site erosion control plan" is the use of a storm drainage utility. This utility could be supported by user service fees and would be responsible for the review of both storm water control plans and their implementation during construction, along with the maintenance of control facilities.

The implementation or "retrofitting" of an appropriate stormwater management plan for existing developments can be very expensive. However, it is recommended that:

3) The existing storm water management plan for existing land uses be reviewed. The review should address the following items:

a) the disconnection of all roof drains from the sewer system and redirection of the storm water to pervious surfaces or infiltration devices,

b) the use of infiltration sites for runoff from large paved areas,

c) the modifications to existing catchbasin sumps to make them porous,

d) the pretreatment of runoff from with grit chambers and oil and grease traps before infiltration,

e) the potential for groundwater contamination from infiltrated stormwater,

f) the location and disconnection of (illegal) point or diffuse sources of industrial or sanitary contaminants, and

g) if the discharges from roadside drainage from a specific source area are found to be relatively clean, then keeping the grass swales should be strongly encouraged. If the discharges are found to be excessively polluted, then the inappropriate sources of pollutants discharging into the roadside drainage should be found and corrected.

4) The recommended control program for the urban Humber River study area includes the following items:

   a) the use of wet detention basins serving at least 25 percent of the drainage area,

   b) the infiltration of runoff from at least one half of the residential roofs currently draining to pavement, and

   c) the infiltration of runoff from at least one half of paved parking and storage areas and roofs in high rise residential, industrial, and commercial land use areas.

This study highlighted several unexplainable sources of industrial contamination. These included such pollutants as dissolved metals, soluble organics, and bacteria thought to originate in process wastewaters, polluted floor drains, leaking sanitary sewerage, etc. It is considered better to locate and disconnect inappropriate sources of industrial pollutants from the storm sewer system and to correct sanitary sewage infiltration or connections than it is to choose whether one should sacrifice either local streams or groundwater.

"Soil" treatment systems (such as occurs with infiltration) have been found to be very effective at renovating storm water quality and generally pose little threat to the groundwater.

5) The potential locations of wet detention basins at outfalls in existing areas should also be identified.

With the use of wet detention basins, the quality of runoff from existing areas may be controlled to similar levels as are proposed for new developments.

6) The location of wet detention basins at existing industrial outfalls should also be considered to help control dry weather discharges, snowmelt discharges and spills.

7) Disinfection at wet detention basins may be needed in order to obtain significant bacteria reductions, especially considering the potential of subsurface bacteria sources.

8) Future Studies

Several field studies are also recommended for the future as logical extensions of the current TAWMS efforts. The following studies are proposed for consideration:

   a) The most important project would involve a decision analysis procedure to formally select a stormwater management program,

b) Monitoring of the implemented program would be necessary to document progress and to make revisions to the plan,

c) Prepare a model construction site and stormwater runoff bylaw and modify the "Manual of Practice", to reflect its requirements,

d) Conduct controlled washoff tests for pervious areas (to supplement the work conducted during this project on impervious surfaces),

e) Collect early spring (after snowmelt) runoff from residential and industrial catchments,

f) Study sources of baseflow pollutants, especially chromium and fecal coliforms,

g) Collect runoff samples from a commercial (downtown) site,

h) Investigate the groundwater contamination potential of various infiltration controls for different source areas, and

i) Investigate the relative frequent occurrence of high concentrations of PCBs in the stormwater and snowmelt from the industrial watershed.

TECHNICAL REPORT

3.0 SITE DESCRIPTIONS

3.1 THISTLEDOWN CATCHMENT

The Thistledown catchment covers approximately 39 ha of residential and commercial land uses surrounding Thistledown Boulevard in the Thistletown district of the City of Etobicoke. It is approximately bounded by the Humber River to the east and north, and Albion Road on the southwestern side. Figure 1.4 is a street map of the catchment showing the watershed boundary and the location of the outfall sampling station. The bulk of the catchment consists of single family dwellings in the 10-20 year age group. Table 3.1 characterizes the land uses within the catchment. It was compiled from measurements made on an airphoto at a scale of 1:2500. Tables B.1 through B.3 of Appendix B describe the Thistledown catchment in more detail.

TABLE 3.1 THISTLEDOWN LAND USE

LAND USE	AREA (ha)	AREA (%)
Single family dwellings	29.50	75.9
Multi-family dwellings - townhouses	2.43	6.3
Shopping centre	2.11	5.4
Open space	0.21	0.5
Schools (2)	4.52	10.9
Church	0.37	1.0
Totals	38.87	100.0

Approximately nine percent of the catchment area is used for roadways. These roads are generally two lanes wide (one in each direction), with parking allowed, and have a total length of approximately 4.8 km. The roads are generally of smooth to intermediate texture and are in good condition. However, approximately 35% of the roads are in moderately poor or worse condition.

Approximately 20% of the roof drainage is directly connected to the storm sewer system, with the remaining roofs draining to driveways (40%) or lawns (40%).

The road drainage system is mixed. Approximately 57% of the roads have grass swales connected to the storm sewer system by gratings and catch basins. These swales occur only on the flat eastern half of the catchment. There are approximately 90 m of sealed swales and approximately 2000 m of concrete curb and gutter drainage forming the other 43% of the drainage system. The concrete curbs are placed on the steeper grades of the catchment where road slopes of up to an estimated 5% were estimated. During this study, runoff was frequently observed on the concrete gutters. However, it was rarely observed in the grass swales, even during high intensity thunderstorms.

The bulk of the land described as schools consists of grass play grounds.

A small complex of townhouses is located at #63 Thistledown Blvd. This medium density residential land use covers almost 2.4 ha (6%) of the catchment.

A shopping centre is located on the southwestern boundary of the watershed. It covers approximately two ha (5%) of the catchment. The bulk of this shopping centre (72%) is covered by a paved carpark. Located within the carpark is a small service station and the loading bay for a supermarket.

3.2 EMERY CATCHMENT

The Emery catchment was selected for study based on the results of the Humber River and Tributary Dry Weather Outfall Study (GLAL, 1984). This study identified the Emery catchment as one of the more significant contributors of contaminants to the Humber River system.

The Emery catchment area covers approximately 154 ha. It has predominantly industrial land use and a relatively flat terrain. It is located in the City of North York, in the southeast corner of the block surrounded by Highway 400, Finch Avenue, Islington Avenue and Steeles Avenue (Figure 1.5).

The Emery catchment can be divided into several areas with different industrial groups, as described in Table 3.2. There is little heavy industry, such as power plants or steel mills, in the catchment. Most of the industry is of the medium type i.e. processing goods for final consumption. Within these areas there are some blocks of vacant land that could be classified as open space. Tables B.1 through B.4 of Appendix B contain more detailed descriptions of the Emery catchment.

The catchment has 7.3 km of roadways, including two major arterial roads (Signet Drive and Weston Road). Traffic counts of 600-800 vehicles per hour are typical on these major roads. Road textures are predominantly smooth and are in moderately good to very good condition. All roads have concrete curbs and concrete or asphalt gutters. On street parking only occurs on 7% of the roads.

This catchment also contains 4.1 km of main line railway track. Several industries have their own spur lines.

TABLE 3.2 **EMERY INDUSTRIAL LAND USE**

INDUSTRIAL GROUP	NUMBER OF BUSINESS	TOTAL AREA (ha)	TOTAL AREA (%)	AVERAGE SIZE (ha)
Chemicals	13	20.62	13.5	1.5
Metal dealers and manufacturers	14	10.43	6.8	0.75
Contractors, machinery	5	5.49	3.6	1.1
Printer	3	2.81	1.8	0.9
Utilities	1	1.4	1.0	1.4
Furniture Manufacturing	4	6.86	4.5	1.7
Mixed Industries Hardware & Bldg. Supplies)	3	2.96	1.9	1.0
Food Industry	11	12.44	8.1	1.1
Offices & Warehouses	17	12.84	8.4	0.75
Vehicle Repair	5	2.04	1.3	0.4
Miscellaneous Manufacturing	9	7.67	5	0.85
Electronics	4	30.43	19.8	7.6
Foundries & Welding	3	1.05	0.7	0.35
Metal Plating	2	1.15	0.7	0.57
Waste Dealers	4	8.87	5.8	2.2
Tiles	2	0.71	0.5	0.35
Textiles	2	2.11	1.5	1.1
Glass	2	2.25	1.5	1.1
Totals / Averages	104	153.7		1.5

4.0 TORONTO PRECIPITATION AND RUNOFF

This section discusses the analysis of the precipitation and runoff data. The analysis of the rain pattern over Toronto and the calibration of the rain gauge is described in Appendix C. This section is supported by the more detailed meteorological and hydrological data provided in Appendix D.

4.1 TORONTO METEOROLOGICAL CONDITIONS

Long term monthly mean air temperatures for Toronto (Pearson International Airport or PIA) for the period 1951 to 1980 are shown on Table 4.1. During this 30 year period, only January and February had consistently freezing temperatures. Any precipitation that would fall during the other months would likely be rain. Rain can occur during any month.

Table 4.2 shows a 15 year rain record from Toronto (PIA) from 1960 to 1974. During this period, the annual rainfall ranged from approximately 420 mm to approximately 710 mm per year. A typical storm depth was approximately four mm, while the maximum one day storm ever recorded was 67 mm. This storm was based on a one hour interevent period. However, it is also likely that precipitation events during a single storm period occurring over several days would be substantially greater than this value. The durations of these single storms were between two and three hours and the average rain intensities were approximately 1.3 mm/hr. The maximum rain intensity during this period of time (1960 to 1974) was more than 40 mm in one hour. The average interevent periods were quite consistent, with an average value of slightly over two days. The maximum interevent periods can be quite long. The values shown include the time period between adjacent rain events and do not consider snowfalls. The typical snowfall period varied between one and two months every year.

An average of 137 rain events per year affected Toronto during this 15 year period, based on a one hour interevent period. If the minimum interevent period was increased, the number of rain events per year would substantially decrease. In this urban runoff study, an interevent period of six hours was used. This period of time usually allows the urban hydrographs to decrease to close to baseflow conditions after the rain events have stopped. Six hours is also typically the minimum time necessary to dry street surfaces for subsequent sampling.

During this 15 year period, the earliest day of observed rain was January 2nd, while the latest was April 9th. In some years, no rain fell for the first three months of the year. The median date of first recorded rain was the January 26th.

The latest day of recorded rain was December 31st, while the earliest last date of recorded rain was November 28th. A median date for the last recorded rain of the year was December 9th. Therefore, approximately three to four weeks of snow may occur in

Table 4.1 Toronto Temperature Conditions (^{o}C) (30 year average 1951-1980, except for extreme values over 140 years)

	daily max.	daily min.	daily ave. of min.&max.	extreme maximum overall record	extreme minimum overall record
January	-1.3	-7.9	-4.6	16.1	-32.8
February	-0.5	-7.2	-3.9	14.5	-31.7
March	4.1	-2.6	0.7	26.7	-26.7
April	11.7	3.4	7.6	32.2	-15.0
May	18.2	8.9	13.6	34.4	-3.9
June	23.7	14.3	19.1	36.7	-2.2
July	26.7	17.2	22.0	40.6	3.9
August	25.6	16.6	21.2	38.9	4.4
September	21.3	12.7	17.1	37.8	-2.2
October	14.7	7.2	11.0	30.0	-8.9
November	7.8	2.0	4.9	23.9	-20.6
December	1.4	-4.6	-1.6	16.1	-30.0
Annual	12.8	5.0	8.9	40.6	-32.8

Source: Environment Canada, 1982

Table 4.2 Long Term Rain Record at Toronto International Airport

year	Storm Depth (min 0.25 mm) ave	max	total	Duration (min 1 hr) ave	max	Ave. Int. (min 0.25 mm/hr) ave	max	Interevent Period (min 1 hr) ave	max	Number of Rain Events per year
1960	3.1	43.9	467	2.29	10	1.1	11.4	50.1	1258	153
1961	3.1	29.2	457	2.31	18	1.1	11.7	38.3	296	150
1962	3.1	38.6	460	2.29	15	1.4	20.3	58.9	1303	129
1963	3.6	33.5	417	2.63	17	1.3	15.0	53.3	605	117
1964	5.3	46.5	518	3.01	18	1.5	12.2	78.1	792	97
1965	4.1	41.9	617	2.78	18	1.3	12.2	49.1	1274	152
1966	3.3	36.6	455	2.52	19	1.0	10.7	41.9	419	138
1967	3.6	30.7	549	2.58	21	1.1	7.4	49.6	1094	154
1968	5.1	67.3	660	2.91	14	1.4	8.9	53.7	869	130
1969	4.1	47.5	508	2.78	19	1.2	11.9	48.2	603	125
1970	4.1	58.7	462	2.33	16	1.6	40.4	57.1	609	114
1971	4.6	32.5	531	2.73	13	1.5	16.3	55.3	1076	116
1972	3.8	38.4	625	2.76	23	1.1	11.9	49.8	480	164
1973	4.1	33.5	706	2.86	18	1.1	6.6	47.0	595	174
1974	4.6	33.0	658	2.94	18	1.4	10.4	51.3	457	144
ave	4.1	40.9	538	2.65	17	1.3	14.0	52.8	782	137
min	3.1	29.2	417	2.29	10	1.0	6.6	38.3	296	96
max	5.3	67.3	706	3.01	23	1.6	40.4	78.1	1303	174

Source: Environment Canada, 1979

5.5
(~~4.1~~%)
137x2.65 = 363 hrs of rain/year
of 8,766 hrs/yr x 3/4 = 6575
94.5
baseflows ≈ ~~95.9~~%

the beginning of the year with approximately three weeks of snow at the end of the year.

The rain records for each of these 15 years was compared with the average rain characteristics in order to identify a reasonably typical year for more detailed analyses. The year 1967 was selected for further analysis on a monthly basis. Table 4.3 shows how the rain characteristics at Toronto PIA varied by month during 1967. All of March, most of February, and probably much of January had only snowfall with no rain. The total number of storms reported for that year was 154. Most of the rain occurred in June and April. October was the driest, nonfrozen month. The storm durations ranged from approximately one to 21 hours based on a one hour interevent period. The longer rain events appeared to occur in September and October. The more intense rain events appeared to occur during June and July, while the least intense rain events occurred in May and November. Typical interevent periods ranged from a little more than one day in May to approximately three days for several of the other months.

The 30 year average rain and snowfall conditions in the Humber River basin (from 1951 to 1980) is shown on Table 4.4. These data are based upon rainfall monitoring information from twelve locations near and in the Humber River basin. The locations of these stations are shown on Figure C.6 in Appendix C. Table 4.4 shows the likely average variations in precipitation conditions. It shows an approximate 20 percent maximum difference in the annual precipitation conditions over the study area. The Black Creek and Downsview A locations both had the lowest annual recorded rainfalls during this 30 year period of time, while the Kingsway Station had the greatest recorded rainfall.

Much rain data was obtained during 1983 as part of this study. The one rain gauge available was located in the Emery catchment (Figure 1.5) and controlled the runoff sampler at that outfall. During the data analysis, it was found that the initial calibration factor for this rain gauge was incorrect, or had changed. Accurate rain values are very important in an urban runoff study in order to analyse runoff flows and source contributions. Therefore, an extensive data analysis effort was needed to identify the most reasonable calibration factor and to correct the recorded rain volumes. Appendix C is a summary of the analytical procedures that were used in examining the rain gauge data.

Appendix D contains the corrected rain and snowfall data. Table 4.5 is a summary of the Toronto rain events observed in 1983. Sixty eight rain events were observed, based on a six hour interevent period. A total of 556 mm of rain was recorded. The average depth of rain was 8.2 mm. The Emery rain gauge was in operation by May, 1983, and was taken down in November, 1983. Early and late 1983 rain conditions were therefore estimated using data obtained from Toronto PIA. These data differ from those shown on Table 4.3 and

Table 4.3 1967 Toronto Airport Rain Record

Month	Number of Storms	Storm Depth (min. 0.25 mm) max.	ave.	total	Storm Duration (min. 1hr) max.	ave.	Storm Intensity (min. 0.25 mm/hr) max.	ave.	Rain Interevent Period (min. 1 hr) max.	ave.
January	4	2.5	1.1	4.6	2	1.5	1.3	0.8	45	17
February (1)	1	-	1.8	1.8	-	1.0	-	1.8	-	-
March (1)	0	-	-	-	-	-	-	-	-	-
April	23	27.9	3.8	85.1	9	2.3	4.1	1.0	1090	74
May	18	16.0	2.5	46.9	12	3.1	1.8	0.5	110	26
June	20	30.7	7.4	148.1	10	3.0	7.4	2.3	390	45
July	16	13.5	4.1	65.0	4	1.7	4.8	2.0	170	44
August	25	8.6	1.8	45.7	3	1.6	3.3	1.0	200	28
September	9	29.7	7.6	68.9	21	5.0	3.3	1.0	500	72
October	5	5.8	2.0	10.7	5	5.0	2.0	0.8	240	80
November	21	15.8	1.8	38.1	13	2.9	1.3	0.5	380	43
December	12	28.2	4.1	49.8	11	3.3	2.5	0.8	150	48
Annual	154	30.7	3.6	563.9	21	2.5	7.4	1.0	1090	48 (2)

(1) February and March precipitation occurs mostly as snow.
(2) excluding February and March.

Source: Environment Canada, 1979

Table 4.4 30 Year Average (1951-1980) Monthly Rain and Snowfall in Humber River Basin

Range of 30 yr Averages for 12 Monitoring Locations:

Month	Total Rainfall(mm) min.	ave.	max.	Total Snowfall(cm) min.	ave.	max.	Days with Rain min.	ave.	max.
January	16.9	23.1	26.2	25.3	33.0	37.7	3	4	5
February	17.6	23.5	25.7	20.5	26.7	32.0	3	4	4
March	32.8	40.3	47.9	17.5	21.6	25.6	4	7	9
April	60.0	63.6	68.2	3.5	6.2	8.9	7	10	11
May	61.4	66.1	69.8	0.0	0.1	0.4	8	11	11
June	62.5	66.6	72.2	0.0	0.0	0.0	8	10	11
July	64.2	73.9	83.8	0.0	0.0	0.0	8	9	10
August	70.7	76.2	84.2	0.0	0.0	0.0	7	10	11
September	56.6	63.7	74.5	0.0	0.0	0.0	8	9	10
October	56.8	61.3	66.0	0.3	0.7	1.0	8	10	11
November	55.2	59.3	61.1	2.5	6.8	9.7	8	10	10
December	33.1	38.2	44.7	24.8	30.6	36.8	3	6	8
Annual	627	656	721	97	126	148	74	97	111
Annual (in)	24.7	25.8	28.4	38.0	49.5	58.2			

Stations included in above description and years of record for each:
(ranks shown for lowest rain to highest):

(8) Toronto : 30 yrs
(11) Toronto Agincourt: varies
(1-1/2) Toronto Black Creek: varies
(1-1/2) Toronto Downsview A: varies
(5) Toronto Downsview S: varies
(6) Toronto Etobicoke: varies
(3-1/2) Toronto International A: 30 yrs
(10) Toronto Islington: 25 to 29 yrs
(12) Toronto Kingsway: varies
(3-1/2) Toronto Old Weston Road: varies
(7) Toronto West Deane Park: varies
(9) Toronto Wilson Heights: varies

Source: Environment Canada, 1982

Table 4.5 OBSERVED 1983 TORONTO RAIN CONDITIONS[1]

Month	# of Rain Storms	Total Rain (mm)	Rain Depth Per Storm (0.2mm min.) min.	aver.	max.	Storm Duration (hours) min.	aver.	max.	Average Rain Intensity (mm/hr) min.	aver.	max.	Peak 5-min. Rain Intensity (mm/hr) min.	aver.	max.	Rain Interevent Period (6 hr. min.)[4] (days) min.	aver.	max.
Jan.	1	15.5	-	15.5	-	-	17	-	-	0.91	-	-	-	-	-	27	-
Feb.	3	25.9	0.4	8.6	13.6	5	12	23	0.08	0.66	1.32	-[2]	-	-	6	14	23
Mar.	7	45.3	0.2	6.5	31.8	1	10	25	0.09	0.57	1.50	-	-	-	0.7	4	11
Apr.	8	70.3	0.6	8.8	21.2	1	7	17	0.20	1.15	3.53	-	-	-	1.5	5	16
May	12	87.1	0.2	7.3	14.0	0.2	5.1	14	0.20	2.52	11.76	6[3]	18	39	0.4	2.5	8
Jun.	6	34.5	1.0	5.8	11.0	0.3	5.2	16.7	0.54	2.50	7.58	3	9	24	1.0	5	11
Jul.	5	20.0	2.0	4.0	7.0	0.2	1.1	3.2	2.13	6.48	11.76	1.5	10	15	0.5	6	17
Aug.	6	73.5	1.3	12.3	23.5	0.5	7.3	16.2	0.43	3.51	12.33	6	20	57	3	5	11
Sep.	4	48.3	2.3	12.1	25.3	1.9	5.5	12.3	0.70	2.45	4.21	3	15	30	2	6.5	17
Oct.	8	78.5	2.5	9.8	18.3	0.6	5.5	14.3	0.91	5.17	30.42	3	16	63	0.6	4	9
Nov.	6	38.0	0.2	6.3	12.0	1.0	9.3	18.0	0.20	0.64	1.15	3[3]	5	6	1.0	6	10
Dec.	2	19.2	1.0	9.6	18.2	4.0	11.5	19.0	0.25	0.61	0.96	-	-	-	1.1	8	14
Annual	68	556.1	0.2	8.2	31.8	0.2	6.8	25.0	0.08	2.51	30.42	1.5	18	63	0.4	5	27

(1) January 1 to May 7 rains (corrected) were recorded at the Toronto International Airport. May 8 through Nov. 15 rains (corrected) were recorded at the Emery catchment site. Nov. 16 through Dec. 31 rains were again recorded at the Airport.

(2) Data not available.

(3) Partial data for May and November.

(4) Time between adjacent rains only, does not include snow.

Table 4.4, mostly because of the different interevent time period used. The total rain volume during 1983 was quite close to the 30 year average (and the 1967 value), but the number of rain events was much less.

Snowfall data was also obtained at Toronto PIA during the snowmelt study period, of January through March, 1984. No on-site weather or snowpack observations were obtained during the snowmelt period of the study. Tables D.4 through D.6 in Appendix D show the amount and type of precipitation, the snowpack depth, minimum and maximum air temperatures, and relative humidities for each day of these three months. Also shown on these three tables are notes indicating the potential of snowmelts for each day, based on air temperatures and changes in observed snowpack depths as recorded at the airport. Hourly temperature observations were studied to determine the possibility of afternoon melts caused by afternoon warming, versus major snowmelts that were caused by temperature rises of longer duration. This information was used to determine if the observed outfall runoff was cold weather baseflow, snowmelt induced by rain, minor afternoon melts, or major snowmelts.

Snowpack depths and "water equivalents" are measured twice a month at many locations throughout Ontario, including several locations in the Toronto area. Table 4.6 summarizes those observations that were available during the period of the snowmelt study, for four sampling locations near the Humber River basin (Albion Hills, Cold Creek, Claireville and Boyd). The approximate snowpack age (days since previous major snowfall) is also shown. Snow depths of up to 50 cm were recorded in early February, but the range observed at these four sites varied considerably. By mid February, much of the snow had melted. The snowpack then increased during March, with depths up to 30 cm observed. The snowpack densities (percentage of snowpack that is water) varied from lows of approximately 18 percent for deep and fresh snowpacks, to highs of 40 percent for old and thin snowpacks. Fresh snow densities (i.e. falling snow) were observed at Toronto PIA and averaged approximately eight percent. These data were used to estimate the water equivalents of the daily snowpack melts as recorded at the airport. Variations in snowpack depths and water equivalents between the airport observation site and the runoff monitoring sites could be a cause of errors. These potential errors are measured in the next subsection, based on water and snowmelt mass balance calculations.

4.2 TORONTO OUTFALL RUNOFF OBSERVATIONS

4.2.1 WARM WEATHER RUNOFF OUTFALL HYDROLOGY

Rv is the ratio of outfall runoff volume divided by rainfall volume. A low Rv value indicates high runoff losses, while a high Rv value (approaching 1) indicates very low runoff losses. Tables D.6 and D.7 show the observed runoff flows for the Thistledown and Emery catchments. Tables D.8 and D.9 list the observed Rv value for each event monitored at the two monitoring sites.

Table 4.6 SNOWPACK DENSITIES

Aged Snow (in snowpack):

observation date	snow depth (cm)	approx. snow age (days)	density (water as a percentage of snow depth)*
Jan. 3, 1984	9 to 36	5	18%
16	11 to 42	8	20
Feb. 1	21 to 50	6	18
15	TR to 19	20	40
Mar. 2	9 to 31	3	19
15	11 to 32	10	23

* averaged for four Humber River watershed sites: Albion Hills, Cold Creek, Claireville, and Boyd

Fresh Snow (as falling):**

month	number of observations	range of density	average density
January	13	3 to 15%	8
February	8	6 to 13	8
March	10	5 to 16	9

** Pearson Airport observations

Figure 4.1 is a probability plot of paired observations of unit area runoff volumes from the two catchments. The data points for each catchment are for the same rain events, so any differences in runoff response should be little affected by rain differences. The residential catchment had 60 to 70 percent of the runoff volume as the industrial catchment for the same rain events. This difference did not vary significantly for different size events.

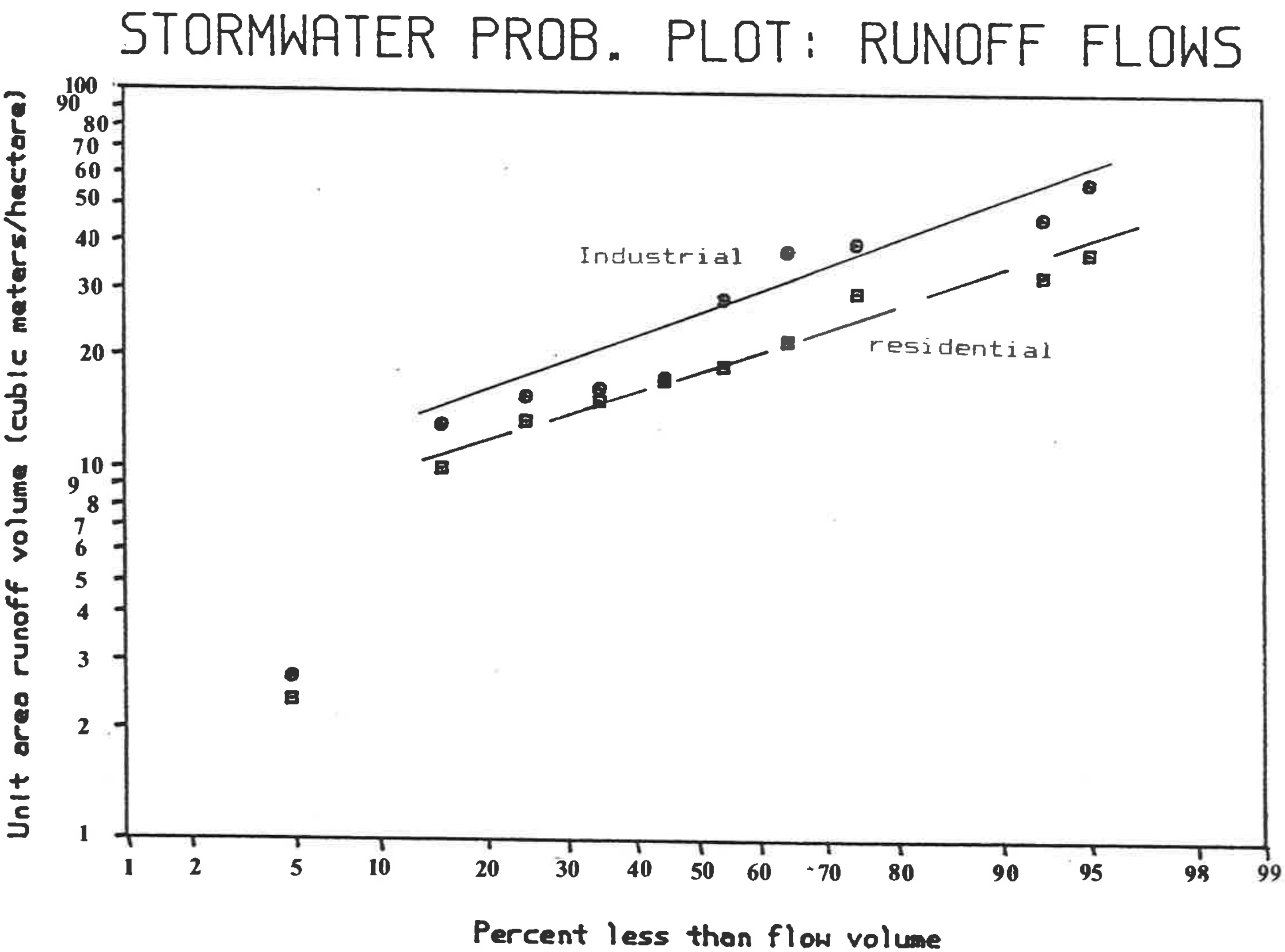
Figure 4.2 is a histogram showing seasonal variations in total baseflow and stormwater flows from the two catchments for each month. The total runoff volume is seen to vary significantly from month to month, again with the industrial catchment having greater runoff volumes.

Detailed analyses of the Rv ratios were conducted in order to estimate sources of stormwater from different areas. Table 4.7 shows the resulting equations and values for predicting runoff from rain for the complete Thistledown (residential / commercial) and Emery (industrial) watersheds. The regression coefficients were approximately 0.9, indicating a good fit of the data to these equations. Figure 4.3 is a plot of rain versus runoff for the two catchments to show how the runoff response varies for rain events of different depths. The runoff response for the residential area is quite linear, while the Rv values for the industrial area significantly increase as the rain depth increases. This changing Rv value indicates changes in runoff losses for different rain events. The Thistledown residential catchment was drained with grass swales for approximately one half its area, which would result in significant runoff losses. In fact, "grab" water samples in swales for water quality analyses were very difficult to obtain as runoff was not observed in them very often. These swales are expected to absorb all "gutter" flows for rain events less than approximately 15 mm in depth. After approximately 30 mm of rain, little additional runoff losses were observed compared to typical drainage systems.

4.2.2 COLD WEATHER BASEFLOW AND SNOWMELT HYDROLOGY

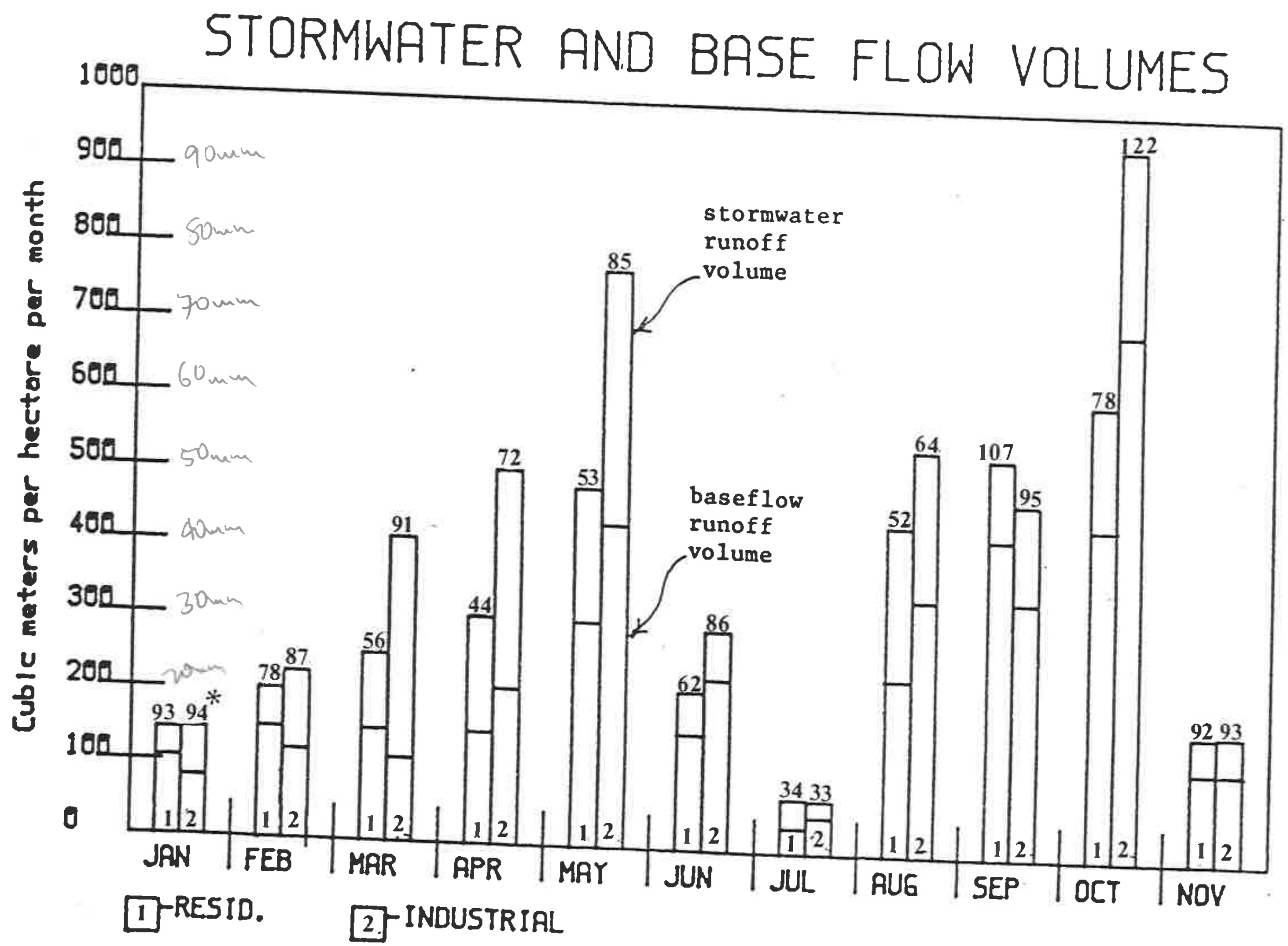
The Emery (industrial) monitoring station was used to monitor cold weather baseflows and snowmelts from January 4th through March 22nd, 1984. The Thistledown (mixed residential and commercial catchment) monitoring station was used to monitor cold weather baseflows and snowmelts from February 2nd through March 25th, 1984. Tables D.10 and D.11 summarize each snowmelt runoff event monitored. A total of 27 events were sampled in the industrial catchment and 26 events sampled in the residential / commercial catchment. Flow rates were continuously monitored in both catchments. These tables shows the following data:

FIGURE 4.1



STORMWATER PROB. PLOT: RUNOFF FLOWS
Industrial
residential
Unit area runoff volume (cubic meters/hectare)
Percent less than flow volume
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99

FIGURE 4.2



* percentage of monthly rain runoff as total runoff (stormwater plus baseflow)

Table 4.7 RAIN/~~RAINFALL~~ Runoff RELATIONSHIPS FOR TOTAL TEST CATCHMENTS

Emery (Industrial) data analysis (for 1 to 15 mm rains):

$$Y = 0.285 - 0.00191X + 0.0228X^2 \qquad R^2 = 0.88$$

Thistledown (Residential) data analysis (for 1 to 22 mm rains):

$$Y = -0.255 + 0.216X \qquad R^2 = 0.91$$

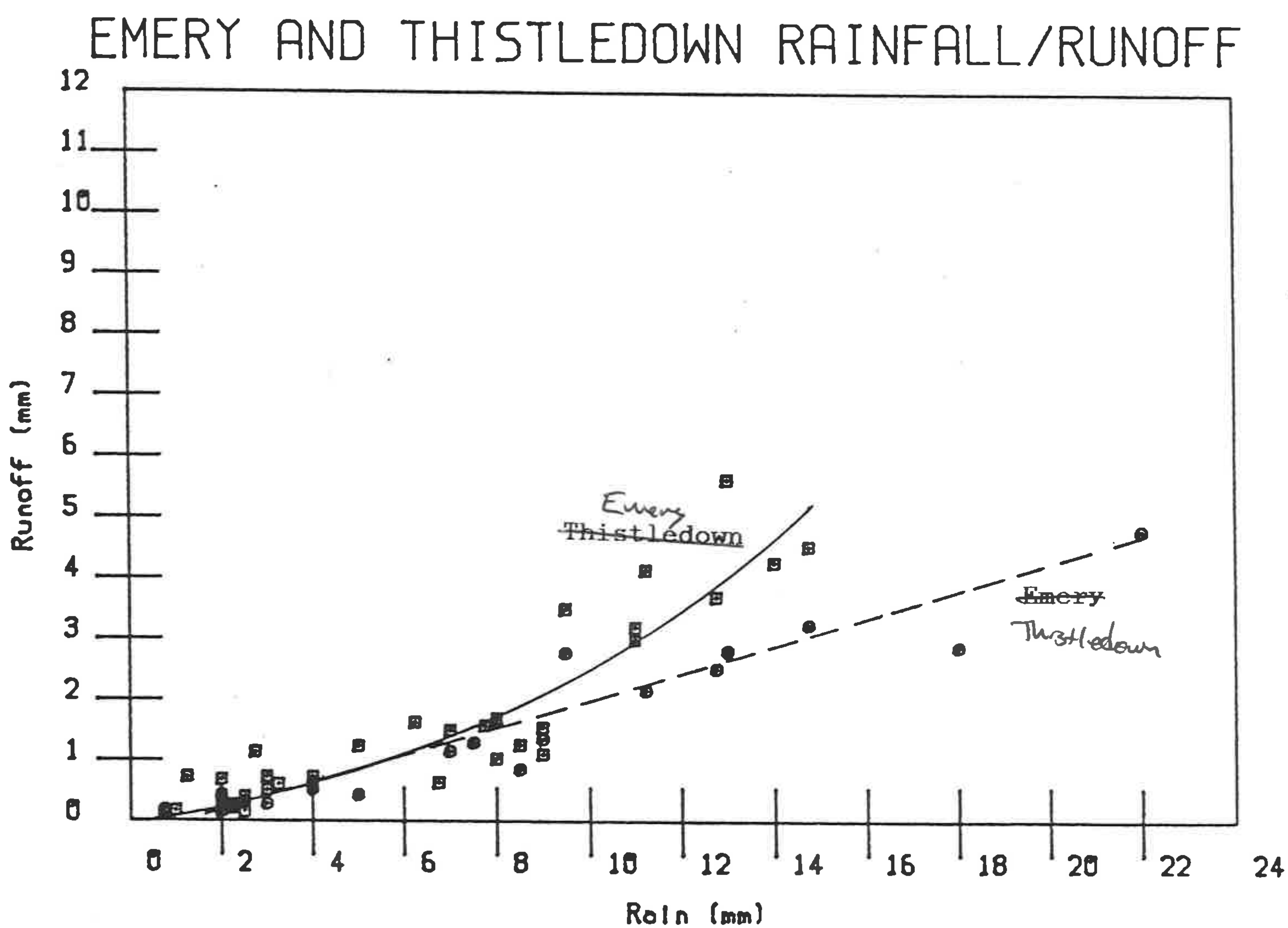
Model results (with estimated extrapolations):

rain (mm)	Emery runoff (mm)	Rv	Thistledown runoff (mm)	Rv	ratio of Emery/Thistledown runoff (mm)
1[1]	0	0	0	0	-
2	0.52	0.26	0.22	0.11	2.4
5	1.65	0.33	0.85	0.17	1.9
10	3.68	0.37	1.84	0.18	2.0
15	5.84	0.39	2.99	0.20	2.0
20	8.22	0.41	4.34	0.22	1.9
25	10.9	0.44	5.78	0.23	1.9
40[2]	19.6	0.49	10.4	0.26	1.9
65[2]	36.3	0.56	21.6	0.33	1.7
90[2]	55.7	0.62	37.4	0.42	1.5

(1) assumed runoff values are zero for 1 mm rains
(2) extrapolated runoff values beyond observed data range

Y = runoff (mm)
X = rain (mm)

FIGURE 4.3


EMERY AND THISTLEDOWN RAINFALL/RUNOFF
Runoff (mm)
0
1
2
3
4
5
6
7
8
9
10
11
12
Rain (mm)
0
2
4
6
8
10
12
14
16
18
20
22
24
Emery
~~Thistledown~~
~~Emery~~
Thistledown

1) start and finish times for runoff and melt events,

2) runoff duration,

3) peak and average runoff flows,

4) total runoff volumes,

5) snowpack depth melt equivalent.

6) Toronto PIA temperature and precipitation, and

7) Toronto PIA wind and humidity.

Each snowmelt event is also characterized by type, i.e. snowmelt, baseflow, afternoon melt, or rain induced melt. These designations were determined from Toronto PIA weather data, snowpack measurements and local snowmelt hydrographs. It was quite difficult to predict when a period of "only baseflow", or "only afternoon melt" would occur. Many water quality samples were combinations of several types of events. The sample designations were especially useful when interpreting the water quality data presented in Section 5.

Table 4.8 shows the runoff volumes associated with snowmelts alone and the runoff volumes associated with snowmelts mixed with rain. Except for January, snowmelts with rain accounted for more than 70 percent of the total cold weather event runoff volumes. Very little rain occurred in January, but substantial rain occurred in February and March during warm periods. Most runoff events generally had low peak flow rates, especially when compared with the warm weather flows. However, several major snowmelt events in Thistledown (residential / commercial) had peak flow rates from 20 to more than 60 times the beginning or initial flow rates. The ratios of initial to peak flow rate for the Emery (industrial) catchment were not as great, with few ratios exceeding 20. The snowmelt yields (mm runoff equivalent) were much larger for the residential / commercial area than for the industrial area. The Thistledown snowmelt yields were from approximately 1.5 to 6 times the yields observed from Emery. There are several possible explanations for this difference. For example, more snow and rain may have fallen in Thistledown, or Thistledown may have had much less "other" flow losses when to Emery (especially infiltration during snowmelt). Alternatively, the melting efficiency at Thistledown was much greater than at Emery. The smaller lot sizes and the more dense drainage system in Thistledown probably was responsible for better melting conditions and more efficient snowmelt transport.

Cold weather inter-event baseflow volumes were continuously recorded at each monitoring station and are summarized on Tables D.12 and D.13. From 15 to 60 mm of baseflow were discharged from each catchment per month during the monitoring period. Thistledown recorded greater baseflow discharges than Emery. Generally, cold weather baseflow occurred approximately 80 to 90 percent of the

Table 4.8 <u>SNOWMELT PERIODS</u>

	snowmelt alone mm	%	rain with snowmelt mm	%	total mm
January					
Emery	7.2	81%	1.7	19%	8.9
February					
Emery	6.1	13	40.0	87	46.1
Thistledown	9.7	14	62.1	86	71.8
March					
Emery	2.9	11	24.6	89	27.5
Thistledown	23.4	28	61.6	72	85.0

time, with snowmelt events occurring during 10 to 20 percent of the time. The exception to this generalisation was in Thistledown during February.

Tables 4.9 and 4.10 summarize these cold weather baseflows and snowmelts from Thistledown and Emery in the form of water mass balances. The Thistledown runoff discharges were substantially greater than for Emery, as noted above. It was assumed that the rain and snowfall, plus the changes in snowpack volume were the same for each catchment. The monthly "baseflows plus errors" shown vary from approximately -20 to 66 mm per month. The negative values may be cancelled by positive values in adjacent months. These values include the combined effects of baseflow, measurement errors, unmeasured sublimation and infiltration losses, uneven snowpack depths and water densities, uneven snowfalls and unevenly distributed rain events over the study area. Considering these potential error sources, it is surprising that these "baseflow plus error" values are as close to the baseflow measurements as they are. Thistledown cold weather baseflows were measured to be approximately 0.9 to 1.6 mm per day, while the Emery cold weather baseflows were measured to be approximately 0.5 to 0.8 mm per day.

The Emery warm weather discharges were also substantially greater than the Thistledown warm weather discharges, possibly accounting for the decreased winter Emery discharges. The Thistledown discharges could therefore be more evenly spread throughout the year. The potential errors listed above could possibly cause the baseflow estimates to vary by approximately 50 percent.

4.3 RUNOFF FLOWS FROM SOURCE AREAS

Typically, urban area hydrology components are accepted as the most accurate components of urban runoff models. This is especially so for small impervious areas of a watershed. Novotny and Chesters (1981) state that these analyses are accurate to within a few percent. If there are any inaccuracies in the hydrology portions of a model, then the other related model components magnify these errors. Lazaro (1979) reports that if researchers could gain a better understanding of the hydrology of small inlet areas, then it would be a simple procedure to simulate hydrographs for larger areas.

Surface runoff occurs when "losses" cannot keep up with the rainfall rate. Various models address these losses somewhat differently, but typically include an infiltration relationship for pervious areas (the Horton equation is common) and an empirical relationship for surface detention / storage for impervious areas. Some models also address evaporation, snow accumulation and snowmelt.

The differences between the volumes of rain that fall and the volumes of runoff generated are the losses associated with various mechanisms. The way different urban runoff models deal with these losses is important. The runoff models that are used in urban

Table 4.9 WINTER WATER BALANCE FOR THISTLEDOWN

	February 1984	March 1984
	(equivalent water depth, mm)	
discharges:		
snowmelt events	73.6mm	85.2mm
cold baseflows	26.6	50.9
total	100.2mm	136.1mm
rain and snow:		
rain	39.2mm	35.4mm
snow	19.8	24.1
total	59.0mm	59.5mm
snowpack change:	5mm accumulation	34mm melt
total "inputs"(1):	54.0mm	93.5mm
minus snowmelt events:	-73.6	-85.2
total baseflows and errors(2):	-19.6mm	8.3mm
monthly averages:	-0.7mm/day	0.3mm/day
	-0.08L/sec/ha	0.04L/sec/ha
	$-6.9m^3$/day/ha	$3.5m^3$/day/ha
	$-200m^3$/month/ha	$83m^3$/month/ha

(1) inputs = rain + snow - snowpack accumulation + snowpack melt

(2) "Baseflows and errors" is the combined effect of baseflows; sublimation; and uneven snowfall, rain, and snowpack water content in the study areas and between the study areas and locations of measurements. It also includes measurement and other errors, of course.

Table 4.10 WINTER WATER BALANCE FOR EMERY

	January 1984	February 1984	March 1984
	(equivalent water depth, mm)		
discharges:			
snowmelt events	9.3mm	47.2mm	27.6mm
cold baseflows	16.3	18.0	25.0
total	25.6mm	65.2mm	52.6mm
rain and snow:			
rain	3.6mm	39.2mm	35.4mm
snow	26.6	19.8	24.1
total	30.2mm	59.0mm	59.5mm
snowpack change:	6mm accumulation	5mm accumulation	34mm melt
total "inputs"(1):	24.2mm	54.0mm	93.5mm
minus snowmelt events:	-9.3	-47.2	-27.6
total baseflows and errors(2):	14.9mm/month	6.8mm/month	65.9mm/month
monthly averages:	0.5mm/day	0.2mm/day	2.1mm/day
	0.06L/sec/ha	0.02L/sec/ha	0.24L/sec/ha
	5m^3/day/ha	2m^3/day/ha	21m^3/day/ha
	150m^3/month/ha	68m^3/month/ha	660m^3/month/ha

(1) inputs = rain + snow - snowpack accumulation + snowpack melt

(2) "Baseflows and errors" is the combined effect of baseflows; sublimation; and uneven snowfall, rain, and snowpack water content in the study areas and between the study areas and locations of measurements. It also includes measurement and other errors, of course.

runoff quality studies should be quite different from the runoff models that are used to design drainage facilities. Simple approximations may be adequate for some users, while others require more complex models. This study used urban hydrology data to obtain needed information concerning the sources of urban runoff pollutants.

4.3.1 RUNOFF LOSSES FROM IMPERVIOUS AREAS

When rain falls on an impervious surface, much of the rain will flow off the surface and contribute to the total urban runoff. Some of the rain may be intercepted by vegetation before it reaches the surface. The heat of the surface may cause some flash evaporation. This flash evaporation would be most important in areas experiencing sudden showers on hot summer days. Other losses would be associated with depression storage, where rain is captured in surface depressions for evaporation later or infiltration. Depression storage is most important for unevenly paved (rough) surfaces. Particulates may also absorb significant quantities of water before they become saturated. Different types of particles would absorb different quantities of water. Water may also infiltrate through pavement, or through cracks or seams in the pavement. If the impervious surface is not directly connected to the drainage system, overland flow away from the paved area would be further reduced by infiltration through the adjacent pervious material. If the impervious area is located some distance away from the drainage system, substantial water may infiltrate. For small rain events, a much greater portion of the rain will be lost than for large rain events. The ratio of observed runoff volume to rain volume is the total area average runoff coefficient (Rv). The total losses are therefore equal to 1.0 minus the Rv value.

4.3.2 RUNOFF LOSS MODEL

The Toronto outfall runoff monitoring results can give important insight into the potential sources of the runoff pollutants in the pilot watersheds. The first step is to determine the sources of the runoff flows. This was done by first quantifying the changing runoff coefficients, Rv (the runoff volume divided by the rain volume), for different rain events. Normally, the small rain events have the smallest runoff coefficients, while the large rain events have larger runoff coefficients. The changes in Rv with different rain events implies varying water losses and different runoff sources contributing to the outfall discharges. These changes can be described by plotting observed total runoff versus total rain for individual rain events.

Figure 4.4 is the adopted hydrology model describing the shape of this relationship. The controlled washoff tests that were conducted on impervious surfaces (described in Section 6.5) also resulted in flow data that were used to verify this model on a smaller scale. The outfall runoff yields, in contrast, were used to examine this model when all pervious and impervious drainage areas are considered together. With this model, the Rv response curve departs from the x-axis at the time representing first detectable flow (t0). This time lag corresponds to initial rain losses. For

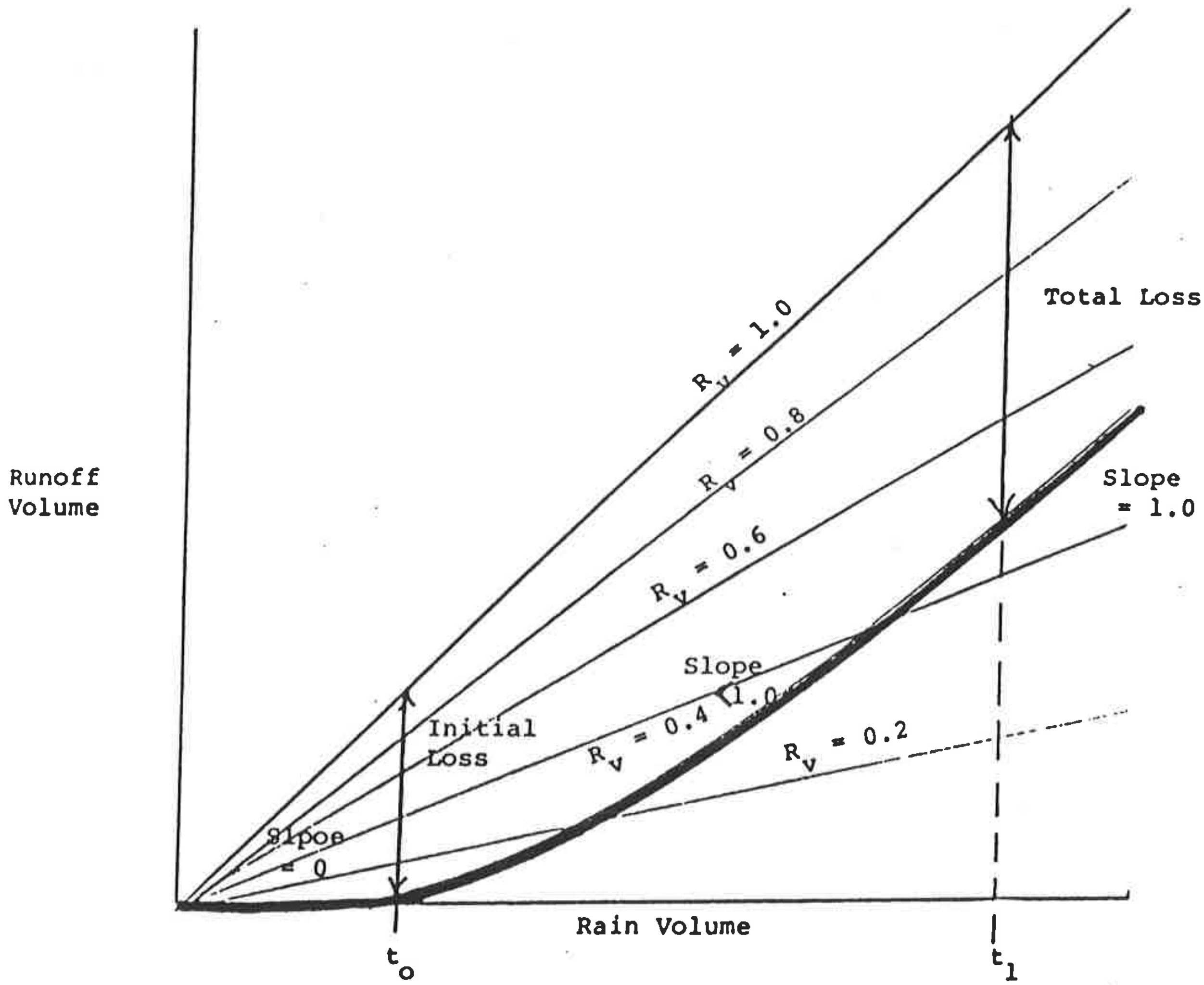


FIGURE 4.4 **Explanation of Changing R_v Value**

impervious areas, this lag is usually associated with flash evaporation, water absorption by street dirt, surface tension capture due to the scale of surface roughness and initial depression storage. For pervious surfaces, these losses are mostly from infiltration and surface detention / storage. At some time (t1), additional water losses become minimal. For impervious areas, this is due to depression storage becoming filled, evaporation becoming insignificant due to pavement cooling, infiltration through the pavement or through cracks slowing due to saturation of the underlying soil and street dirt becoming saturated. Between these times, the Rv value increases dramatically, from nothing to its maximum value, with the time required depending mostly on the intensity of the rain and duration of the storm.

This hydrology model can be used to estimate runoff losses for paved streets, parking lots, sidewalks and driveways. Rooftop losses, along with pervious area losses, were estimated by using the combined data obtained from the outfall. The estimates of losses obtained from outfall data were dominated by pervious area infiltration losses and the impervious area losses that were well documented. Therefore, the pervious area losses were estimated by subtracting the impervious area losses from the total outfall calculated losses.

This model, based on different runoff responses from different land surfaces, can be used to construct the main components of an unit hydrograph. A major difficulty with unit hydrographs, however, is the assumption of similar hydrograph shapes for different size rain events. Figure 4.5 shows how urban source area unit hydrographs are combined to produce a complete hydrograph for the complete drainage area (Amy et al., 1974). Directly connected impervious areas contribute the first flows. More distant impervious areas and pervious areas contribute flows at a later time. Depending on the magnitude of the rain, some of these later components may never contribute to the total flow. Therefore, the overall shape of the outfall unit hydrograph is very dependent on the size of the storm which determines the contributing components.

4.3.3 STREET WASHOFF TESTS

The street washoff tests resulted in detailed runoff response information for street surfaces (and other paved surfaces). Table 4.11 and Figure 4.6 show the resulting Rv relationships for both rough and smooth impervious (street) areas. These values were assumed to be applicable to all directly connected impervious areas (street surfaces, drained paved parking areas, and connected roofs). These responses were compared to the outfall Rv responses described above to determine the Rv relationships for the other areas in the drainage basin. These other areas include pervious areas and inefficiently drained impervious areas. It was assumed that the inefficiently drained impervious areas (walks, driveways, etc.) would lose approximately half of their runoff water to adjacent pervious areas, and the other half would be directly discharged to the storm drain system. Pervious area runoff responses were therefore estimated by difference.

Table 4.11 SOURCE AREA FLOW CONTRIBUTIONS

Street Runoff (used for directly connected impervious areas):

Y = predicted runoff (mm)
X = observed rain (mm)

smooth streets: $Y = -0.288 + 0.631X + 0.00595X^2$

$R^2 = 0.999$ (for 1 to 25 mm rains)

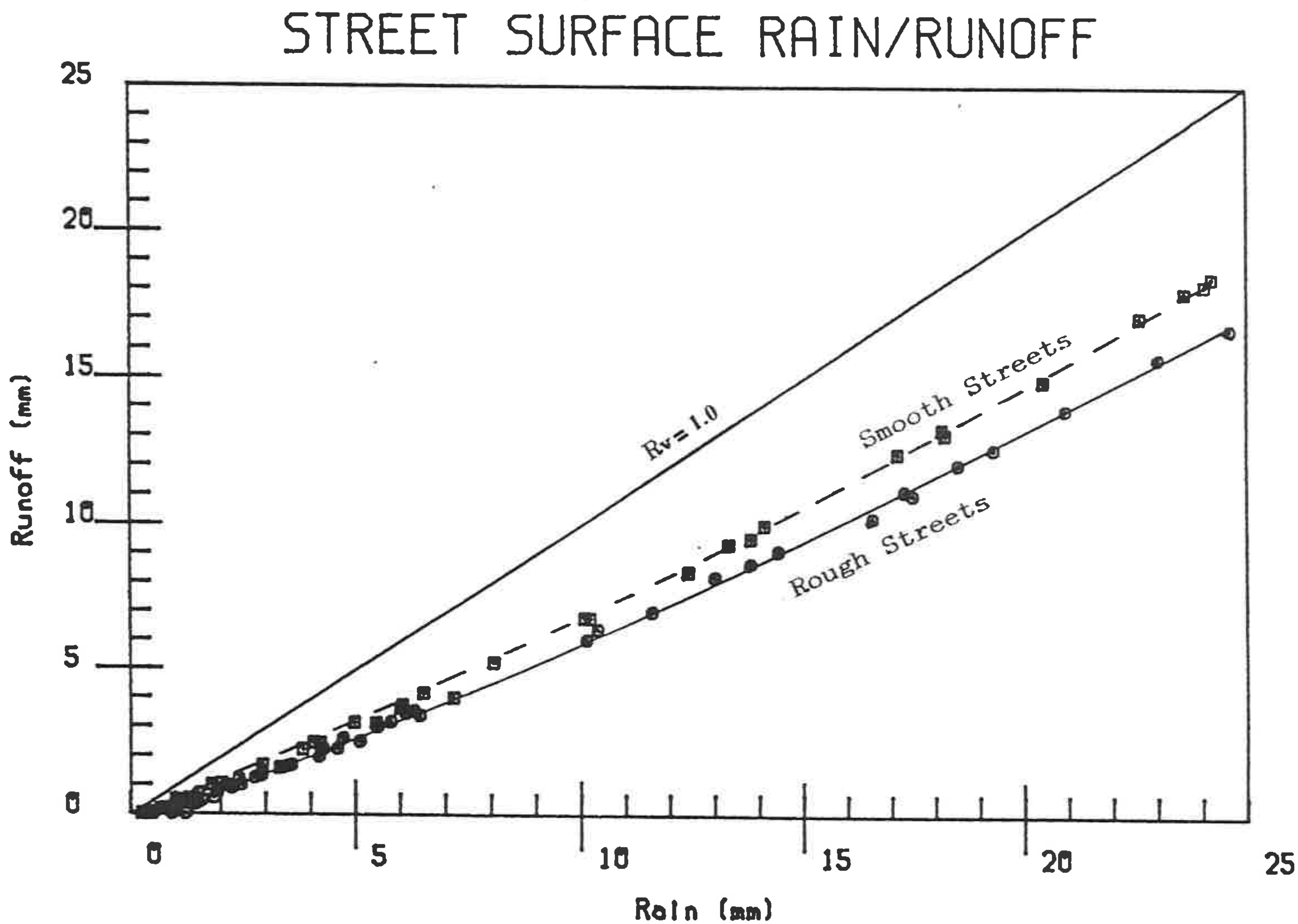
rough streets: $Y = -0.414 + 0.588X + 0.00457X^2$

$R^2 = 0.999$ (for 1 to 25 mm rains)

rain (mm)	Smooth runoff (mm)	Smooth Rv	Rough runoff (mm)	Rough Rv	Average Rv
1	-	0	-	0	0
2	1.0	0.50	0.8	0.39	0.45
5	3.0	0.60	2.6	0.53	0.56
10	6.6	0.66	5.9	0.59	0.63
15	10.5	0.70	9.4	0.63	0.66
20	14.7	0.74	13.2	0.66	0.69
25	19.2	0.77	17.1	0.69	0.73
40(1)	34	0.85	31	0.78	0.82
65(1)	60	0.92	56	0.86	0.89
90(1)	85	0.94	81	0.90	0.92

(1) Beyond limits of observation, the resulting runoff volumes and Rv values were estimated from data obtained in Milwaukee monitoring of large parking lots.

FIGURE 4.6



STREET SURFACE RAIN/RUNOFF
Runoff (mm)
Rain (mm)
0
5
10
15
20
25
Rv=1.0
Smooth Streets
Rough Streets

Figures 4.7 through 4.9 summarize the expected runoff coefficient variations for pervious, intermediate, and impervious areas for all Humber River catchments. The different land surface configurations of the industrial and residential / commercial test catchments allowed these runoff calculations to be made, using the street washoff test results and outfall runoff observations. By assuming similar runoff responses for similar surfaces, irrespective of land use, sufficient information was available to calculate these curves. If additional catchment runoff data for other land uses (especially open space areas and large flat roofs) were available, then further refinements in these predictions could be made. These curves are quite similar to those obtained in other study areas (e.g. Bannerman, et al 1983 for Milwaukee and Pitt, 1984 for Bellevue, Washington).

The same infiltration mechanisms were assumed for pervious areas in both the residential and industrial areas. Since the land surface configuration was very different in both test basins, this assumption allowed the pervious Rv response to be verified.

Figures 4.10 and 4.11 show the predicted runoff coefficient variations for two extreme land uses using these predicted runoff values. Figure 4.10 is for a park and shows the low runoff expected for most rain events. Rv values of less than 0.3 are typical. Figure 4.11 shows the Rv for a mostly pervious shopping center. The relatively high Rv values vary from approximately 0.6 to 0.8 throughout the normal rain range.

Figures 4.12 and 4.13 show how the different land surfaces in the two basins contribute different percentages of the warm weather outfall flows, according to the rain volume. The industrial catchment has quite consistent runoff sources, with paved parking areas and connected roofs contributing almost all of the flow.

Pervious areas would not start contributing flows until after approximately 40 mm of rain has fallen. Runoff sources in the residential area are much more diverse, but pervious areas contribute little runoff, even at 90 mm of rain. Pervious areas contribute only approximately 25 percent of the runoff at this extreme rain value.

Cold weather snowmelt runoff contributions can be assumed to be almost directly related to the surface area of each land surface component. In most cases, delivery of snowmelt water is very efficient because the underlying soils are either usually frozen or saturated resulting in very little infiltration of runoff. If the fall months were dry, then significant soil infiltration may occur during snowmelt. Snowmelt originating close to the drainage system (e.g. near roads) would also be more efficiently transported to the outfall than snowmelt originating further from the drainage system. When snow begins to warm, it first increases in water density before much runoff occurs. The snowpack is said to "shrink". In cities, much of the snowmelt runoff appears to originate from

FIGURE 4.7 RUNOFF COEFICIENTS FOR:

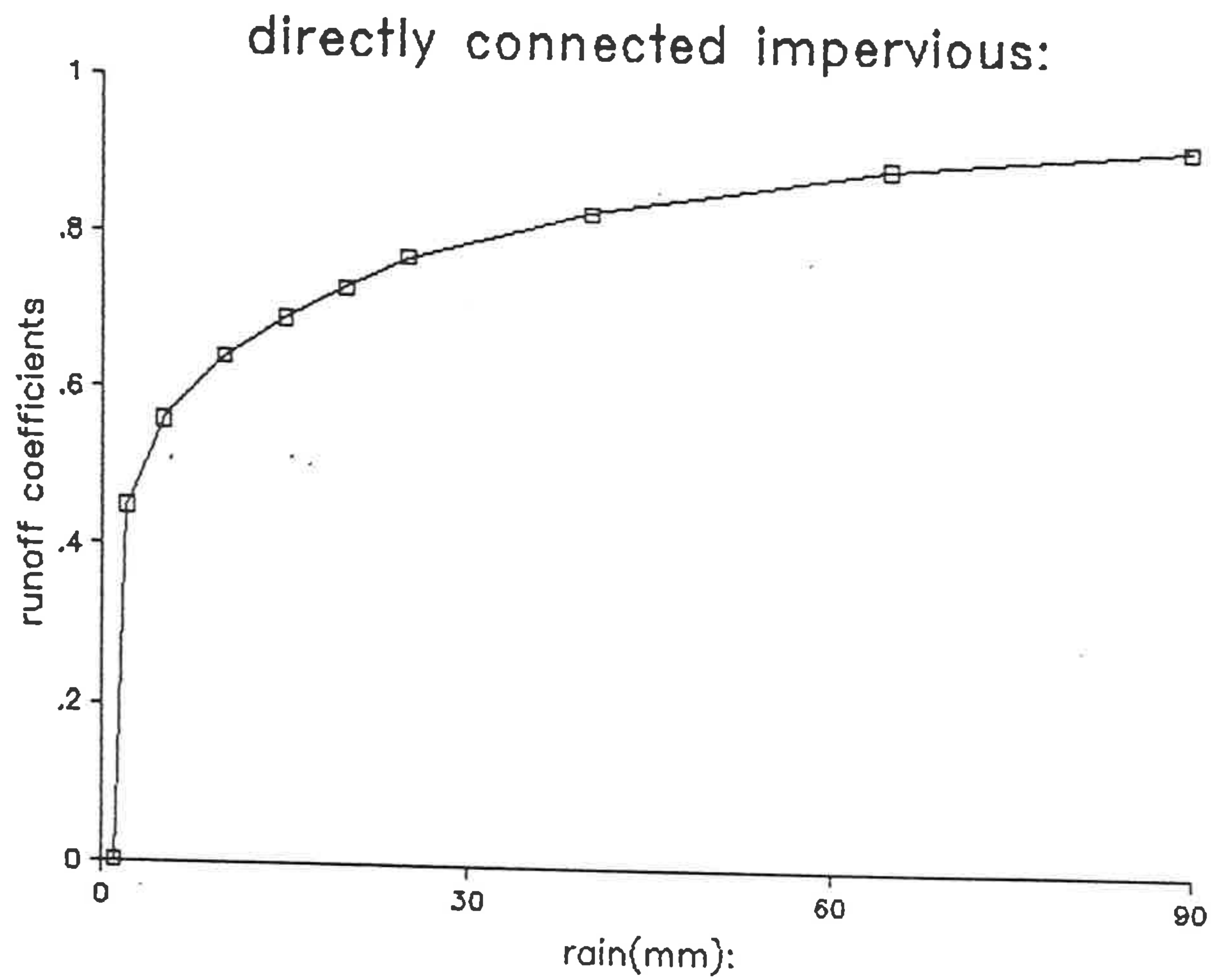


FIGURE 4.8 RUNOFF COEFICIENTS FOR:

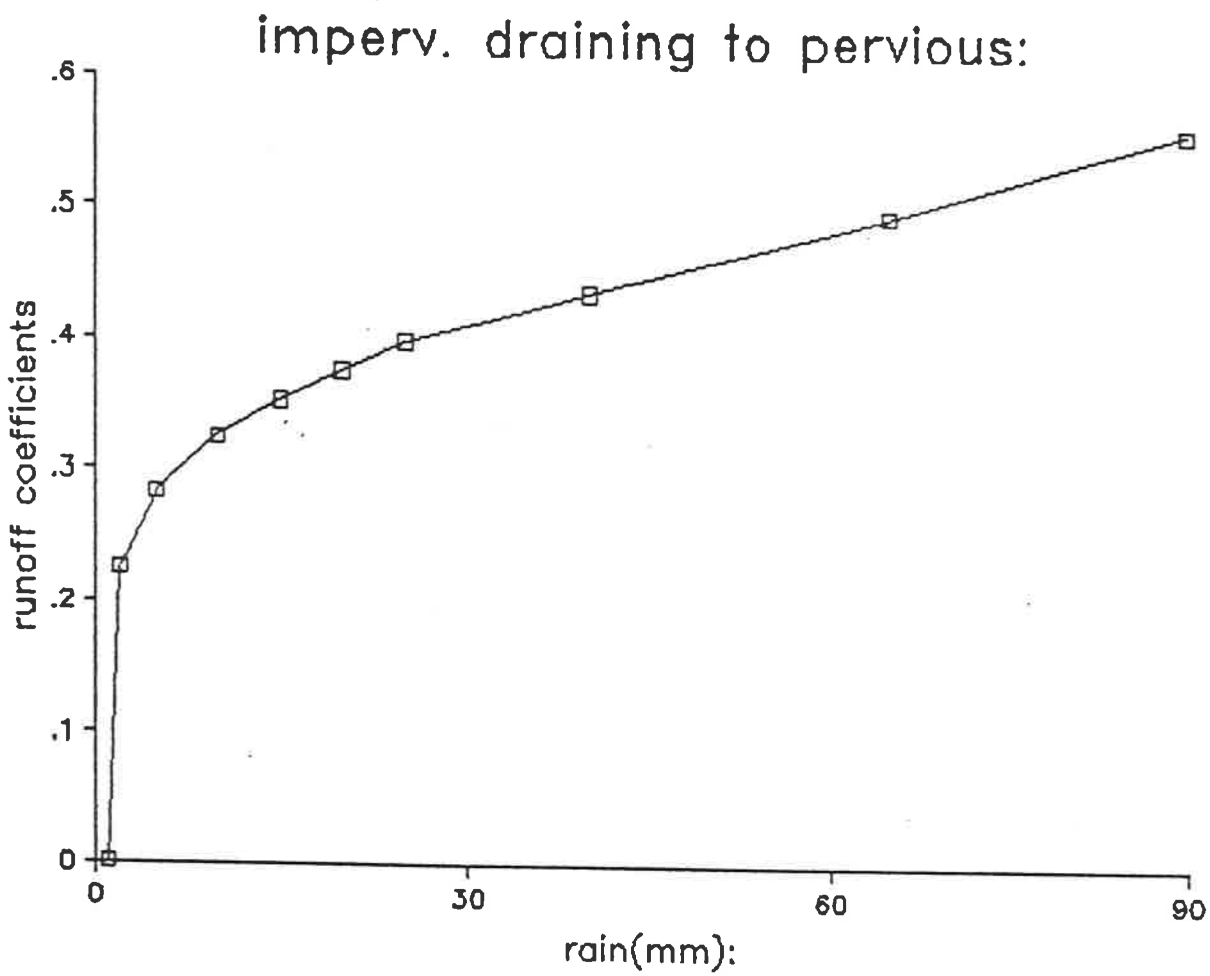


FIGURE 4.9 RUNOFF COEFICIENTS FOR:

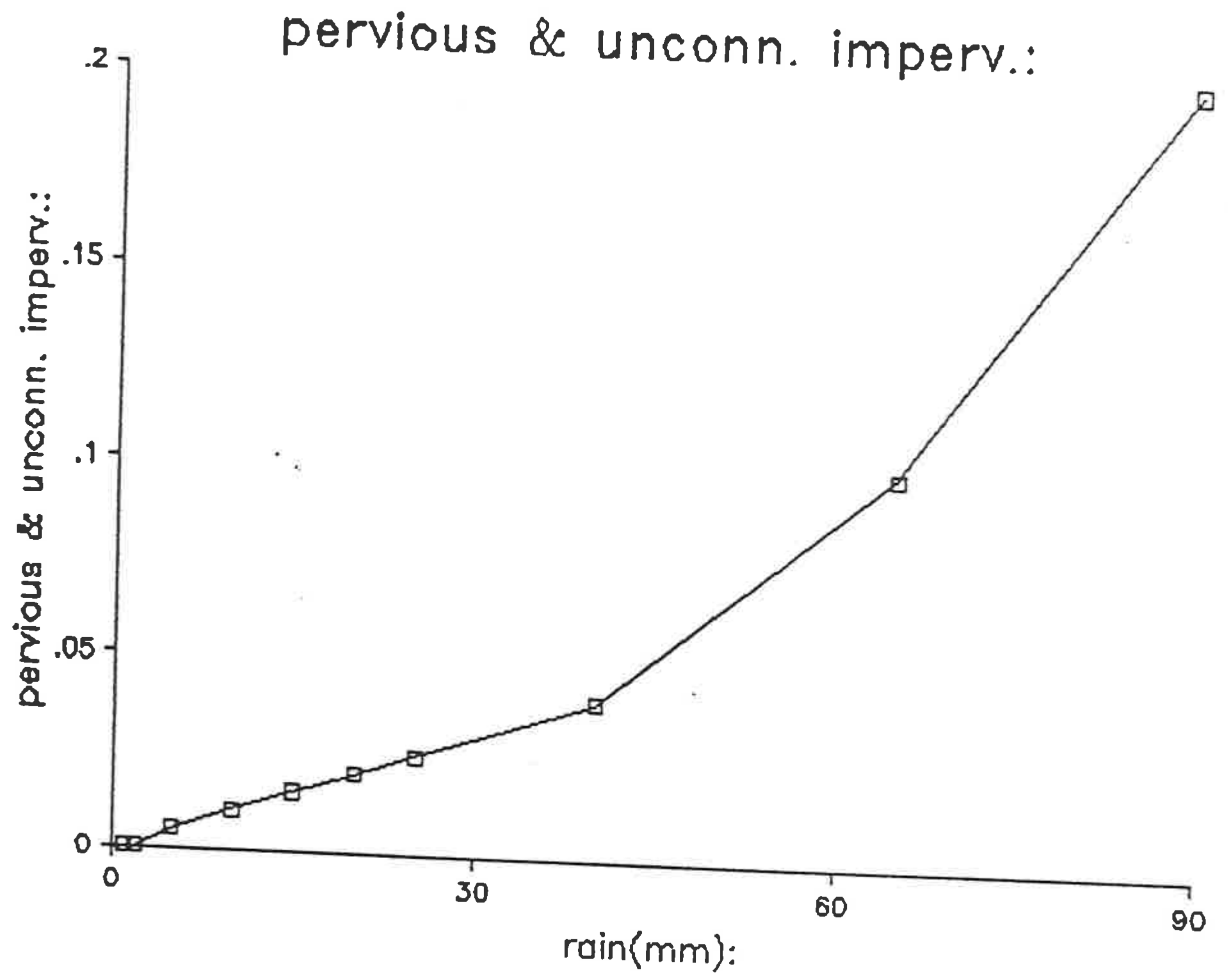


FIGURE 4.10 RUNOFF COEFICIENTS FOR:

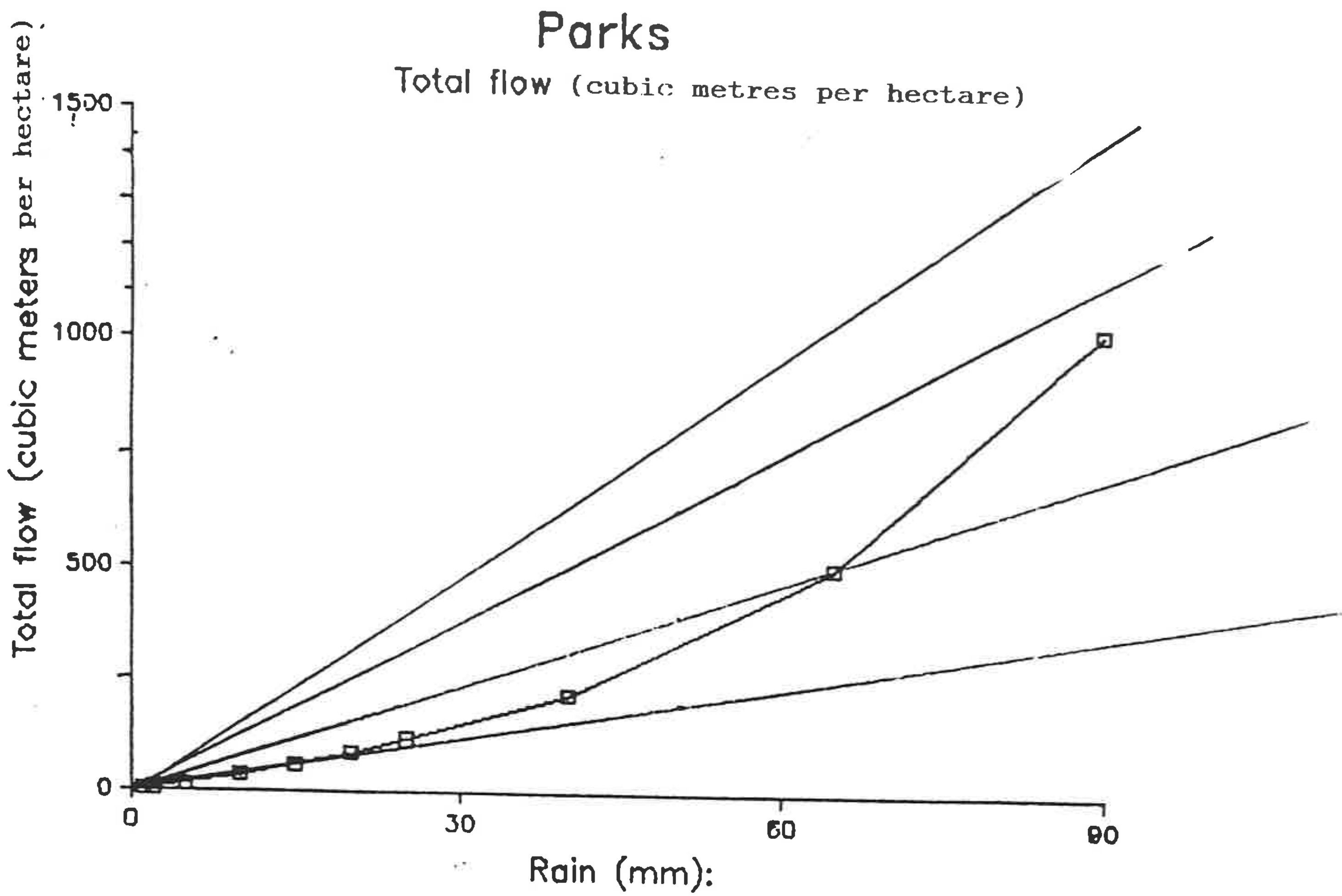


FIGURE 4.11 RUNOFF COEFICIENTS FOR:

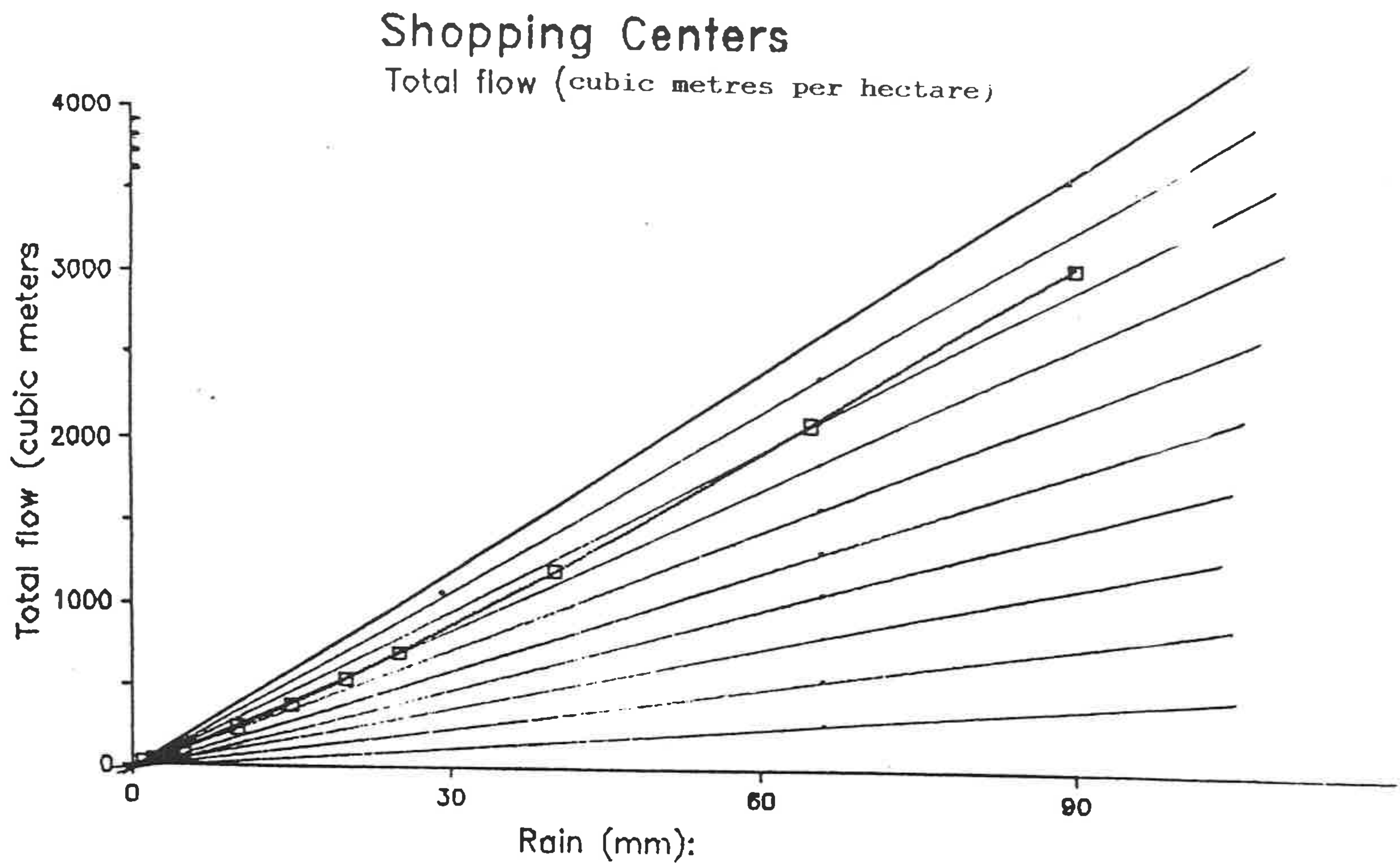
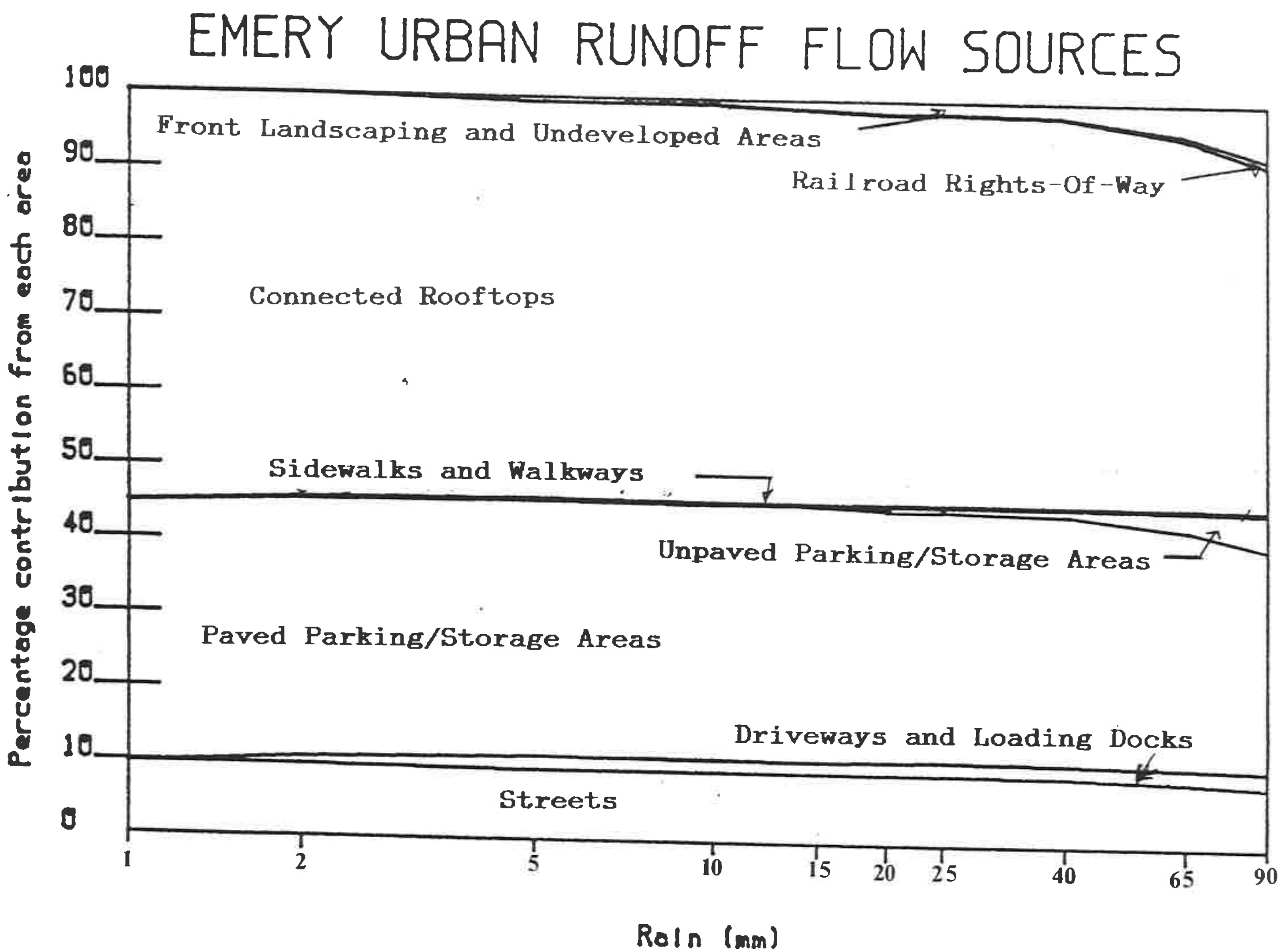
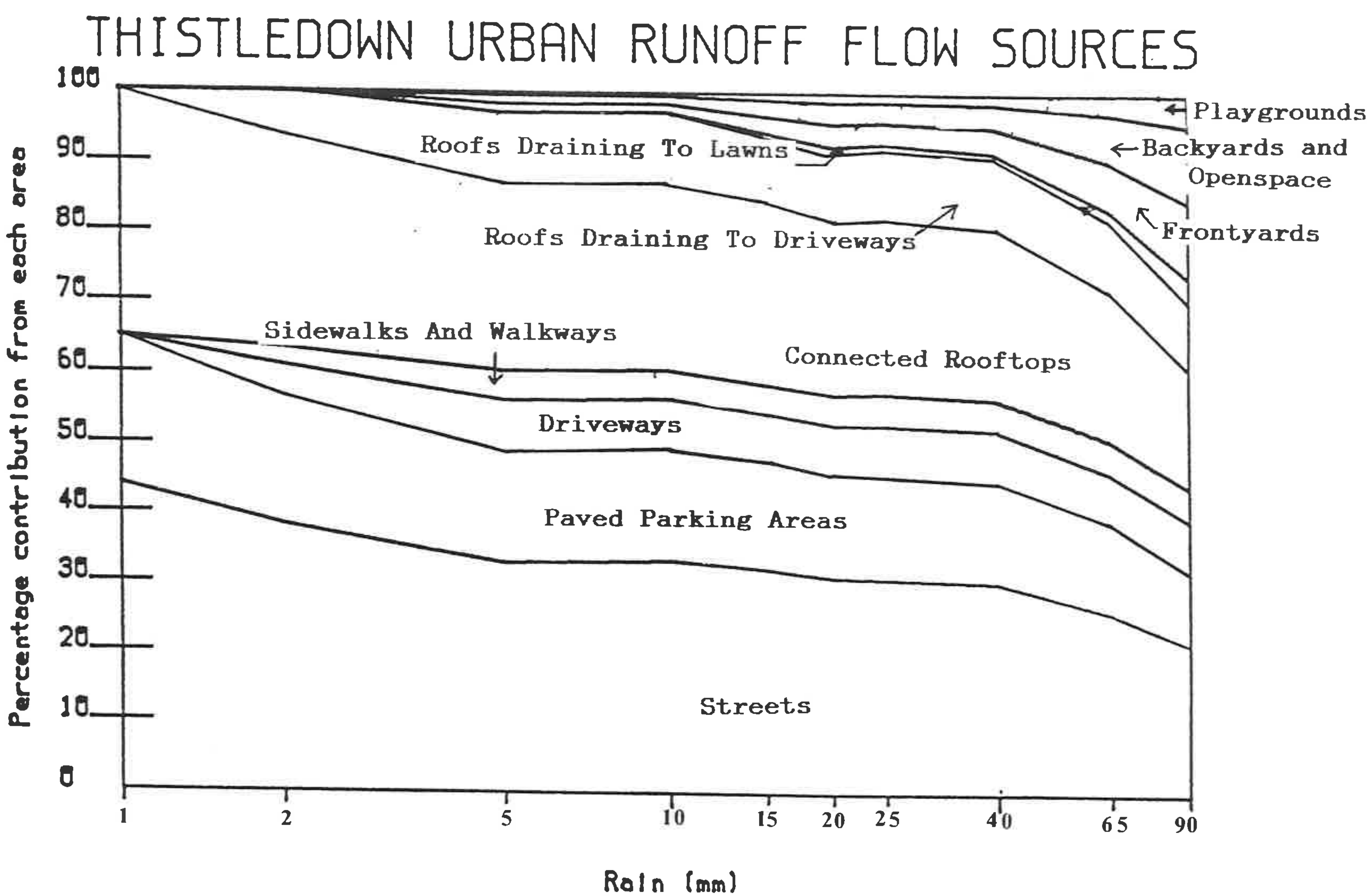


FIGURE 4.12



EMERY URBAN RUNOFF FLOW SOURCES
Front Landscaping and Undeveloped Areas
Railroad Rights-Of-Way
Connected Rooftops
Sidewalks and Walkways
Unpaved Parking/Storage Areas
Paved Parking/Storage Areas
Driveways and Loading Docks
Streets
Percentage contribution from each area
100
90
80
70
60
50
40
30
20
10
0
1
2
5
10
15
20
25
40
65
90
Rain (mm)

FIGURE 4.13


THISTLEDOWN URBAN RUNOFF FLOW SOURCES
Percentage contribution from each area
100
90
80
70
60
50
40
30
20
10
0
Rain (mm)
1
2
5
10
15
20
25
40
65
90
Playgrounds
Backyards and Openspace
Frontyards
Roofs Draining To Lawns
Roofs Draining To Driveways
Sidewalks And Walkways
Connected Rooftops
Driveways
Paved Parking Areas
Streets

beneath the saturated and warmed snowpack, with very little runoff flowing over the top of it. This may be caused by the significant moving and piling of snow that occurs near roads, walks, parking areas, etc., making the snow surface very uneven and flow over the snow surface difficult. In open areas (or large industrial lots), less disturbance of the snow surface occurs and different melting processes probably occur. With much subsurface snowmelt flow, the potential for infiltration into dry and nonfrozen soils is increased.

For common frozen or saturated soil conditions, it makes little difference if the source area is pervious or impervious. Table B.1 in Appendix B can therefore be used to estimate the importance of the different source areas in contributing to snowmelt runoff. Table 2.7 showed the flow (along with pollutant) contributions from snowmelt from different source areas in the residential and industrial study areas. During snow melting periods, roofs, front yards, and backyards in residential areas each contribute approximately 20 to 30 percent of the total runoff volume. In industrial areas, paved parking and storage areas, roofs, landscaped areas and open space each also contribute approximately 20 to 30 percent of the total runoff volume. Therefore, sources of flow are much more related to the more distant source areas during snowmelt than during stormwater runoff. However, during initial periods of snowmelt, or for small afternoon snowmelts, areas adjacent to the drainage system (such as street side snow windrows) probably contribute more melt water (and pollutants) than areas further from the drainage system.

4.4 STATISTICAL ANALYSES FOR HYDROLOGY MODEL DEVELOPMENT

A series of statistical tests were conducted using the warm weather stormwater runoff data. The purpose of these tests were to identify relationships concerning important urban hydrology parameters and to help understand the "structure" of stormwater runoff hydrology. If successful, the structure analysis identifies simplifying interrelationships of the model parameters. Three types of statistical tests were conducted:

1) paired analyses using carefully matched rainfall and runoff data from the two catchments,

2) analyses using all of the related outfall and rain data from the two catchments, and

3) regression analyses to identify simple relationships between selected runoff and rainfall parameters.

The following paragraphs summarize these statistical analyses and present selected examples.

4.4.1 PAIRED ANALYSES

A set of ten carefully matched stormwater runoff outfall and precipitation observations were identified from all of the Thistledown and Emery warm weather data. These storms were characterized by nearly identical starting and ending times and a lack of regional rainfall variations (over the Toronto area). An analysis of Toronto regional rain variation is summarised in Appendix C. The most important statistical procedure performed with this data was making log-normal probability plots. Figure 4.1 is an example of these plots for stormwater runoff volume. Other examples will be shown in Section 5 and Appendix E (Figures E.34 through E.49) for observed water quality constituent concentrations. These descriptive analyses graphically identified significant differences between the two study areas. As an example, Figure 4.1 shows that the runoff yields from the Thistledown catchment were significantly lower (by approximately 30 percent) than runoff yields from the Emery catchment for all rain events in the data set.

A second paired statistical test performed on the hydrology data was an examination of the ratios of the peak to average runoff volumes. These runoff flow rate ratios were plotted against rain volume. A significant (and expected) trend was observed showing that the peak to average runoff rate ratio increased with increasing rain volume and was different for each catchment. These data, along with selected hydrographs for many events, could be used using cluster analyses to construct a predictive procedure to construct "unit" hydrographs, as a function of land use and total rain volume for Toronto.

4.4.2 ALL CATCHMENT OUTFALL DATA

Many statistical tests were performed using the complete set of warm weather rain and hydrology data from each catchment. This data set was assembled after extensive quality control analyses to correct or delete incorrect data. It contained data from 60 storms from Emery and 35 storms from Thistledown. These storms were analysed using five independent rain variables as follows:

1) total rain volume,

2) duration of rain,

3) average rain intensity,

4) peak 5-minute rain intensity, and

5) dry period preceding rain

and five dependent stormwater runoff variables :

6) total runoff volume,

7) duration of runoff,

8) average discharge rate,

9) peak discharge rate, and

10) the lag period to start of runoff since start of rain.

A comprehensive microcomputer statistical package (SYSTAT, The System for Statistics, Version 2, from Systat, Inc., Evanston, Illinois) was used for these analyses.

The first set of analyses included descriptive summaries off all variables. The following examples are a few of the more common procedures that were used. Figure D.1 is a histogram and normal probability plot of the dependent runoff variable, RUNTOT (total runoff volume, normalized by area). These plots show that RUNTOT is not normally distributed and that appropriate transformations would be needed for conventional statistical analyses, or nonparametric statistical procedures (that do not require normally distributed data) should be used on this variable. An example of a suitable transformation is the log-transformation that was used in the paired analyses described above. Conventional statistical analyses would include the Student's "t", and linear regression analyses. Usually, a combination of transformed data and nonparametric procedures provides the best results.

The data was also summarised with sequence correlations by making a sequence series plot. An example of this is shown on Figure D.2. This plot shows little correlation of RUNTOT with the sequence of observation. Therefore, the time period and previous observations had little effect on the RUNTOT variable. Other examples of descriptive statistical analyses that were conducted include box plots and stem and leaf plots (Figure D.3). These plots also demonstrate the distribution pattern of the variable.

One of the most comprehensive procedures to identify the structure of the data is to use cluster analyses. Figure D.4 is a dendogram "tree" that identifies the closeness and complexities of the different variables to each other. As an example, the variables RUNTOT (normalized runoff volume) and RAINTOT (rainfall volume) are closely and simply related to each other. In contrast, AVEDIS (average runoff discharge rate) and AVEINT (average rain intensity) are closely related, but in a complex manner. The relationship requires possibly PEAKINT (peak rain intensity), PEAKDIS (peak runoff discharge rate), and AVEDIS to explain AVEINT. More conventional scatter plots (Figure D.5) also demonstrate the close relationship between RUNDUR and RAINDUR and the poor direct relationship between AVEINT and AVEDIS.

Scatter plots were prepared for each variable combination. Scatter plots are helpful to identify good and simple relationships, but they cannot help in identifying additional variables that may be needed for the more complex relationships.

Further investigations of the structure (and potential model building) between variables is possible using factor analyses of principal components. SYSTAT performs a factor analysis procedure in three parts, as shown in Table D.14. Many options are available in SYSTAT's factor analysis procedures, including different variable rotations and normalizations. The selection of the default options, however, was found to be most useful to determine the benefit of principal components. If found to be useful, then the different options can be quite helpful in fine tuning the resulting model at a later time. The program first calculates a correlation matrix, showing simple correlations between the variables being considered. A obviously high correlation exists between RAINTOT and RUNTOT, as described earlier. This matrix, however, does not show the correlations for the more complicated relationships.

The second part of the factor analysis is the calculation of latent roots to explain the variance between the variables, for a series of factor components. A factor component can be described as a selection of variables (factors) that are grouped together into a "component" for the purpose of an analysis or calculation. As shown on Table D.14, the first three factor components explain 90 percent of the variance. It would be preferable if only one or two factor components explained a satisfactory amount of the variance.

The third part of this analysis calculates the loadings for each factor component. In this example, the first and most important factor component is quite complex (containing four of the seven variables in significant amounts). The first three factor components contain all seven variables. Therefore, the overall structure defined in this example is quite complex and the use of factor analysis would not be a useful simplifying procedure. A satisfactory use of principal components would result in a few simple factors. A factor analysis containing many variables is also bound to be complex. Careful selection of the variables to be analysed is therefore needed. The use of models containing individual independent variables is therefore preferred for this complex example.

4.4.3 REGRESSION ANALYSES

SYSTAT contains several very powerful regression analysis programs. This subsection describes the development of a typical model using regression analysis. In this example, a stepwise (additive) multiple regression analysis is used. A stepwise regression analysis examines each of a list of predictive (independent) variables for inclusion in a model describing the dependent variable. If a variable significantly improves the model, it is added. If the variable does not, it is left out of the model. After each addition to the model, previously added variables are reexamined and removed if redundancy is detected.

Table D.15 is an example of this procedure. The recommended model should contain a constant term and the variables AVEINT, DRYPER, and RAINTOT to predict RUNTOT. A model using these (nontransformed) variables was then developed, as shown on Table D.16. The most significant variable in the model is RAINTOT with a significance exceeding 99 percent. The adjusted correlation coefficient (R^2) of the model is 0.84. Figure D.6 is a scatter plot of the model estimates versus observed values. It is obviously not a perfect model with an R^2 value lower than 1.0.

The correlation matrix for the variables is also calculated to identify redundancies, even though these are unlikely using stepwise regression procedures. However, redundancies can occur through spurious selfcorrelations. For example, if the stepwise regression recommends the variables RAINTOT, AVEINT, and RAINDUR, only two of these three variables are needed because RAINTOT equals AVEINT times RAINDUR. This slightly more complex relationship would probably not be detected by examining a correlation matrix, but by only knowing the origin of the variables and the likely processes being modeled.

Additional checks of the model are needed to confirm that the assumptions required of the modelling technique are met, within reasonable limits. Figure D.6 shows a slight positive bias for low observations of RUNTOT, while a counteracting negative bias may occur for larger observed values. Histograms of the estimates of the model and residuals (observed values minus the associated estimated values) are shown on Figure D.7. The residuals should be normally distributed, as indicated, and are possibly within reasonable limits. However, as a further check, the normal probability plots of expected values and residuals on Figure D.8 show that the residuals are normally distributed over most of their range, except for the tails.

Figure D.9 shows scatter plots of the residuals versus the estimates and of the residuals versus the storm sequence. In both cases, the distribution of the residuals should be in a relatively narrow and even band throughout the estimate and sequence ranges. The residuals indicate a slight spreading in their values as the estimates increase. This is common for untransformed data that are located "close" to the zero value. If close to zero, allowable observed values can only be positive and are small. If large data values are also obtained, however, then there is a much wider range of allowable observations. They are not as severely restrained by "zero". Log-transformations of most runoff and rain variables can be used to reduce this potential cone shape. There does not appear to be any serious trends of residuals with sequence, indicating serial independence of the model variables.

4.4.4 SELECTED MODELS USING MULTIPLE REGRESSION STEPWISE PROCEDURES

A series of simple hydrologic models for the five dependent runoff variables described in Section 4.4.2 were calculated for both the Thistledown and Emery catchments. Table 4.12 is a summary of the variables, their observed ranges and median values. Table 4.13 is a list of the models calculated using stepwise multiple regression analyses, assisted by cluster and factor analyses. These models are all first order equations. No second order polynomial equations (containing variables squared) were obtained. Only statistically significant variables were used. In some cases, the models were corrected by eliminating redundant variables, or simplified by removing variables that made the models overly complex. The "best" (as defined by R^2 values closest to 1.0) models were for runoff duration. The models describing runoff totals were the "next best", having R^2 values of approximately 0.8. As described in the next subsection, an alternative model was selected for use in SLAMM to predict runoff totals for the industrial catchment. This alternative runoff model (shown on Table 4.7) was selected because it fitted the hypothetical model described in Figure 4.4 reasonably well. The hypothetical model was based on many specialized field experiments and assumed a justifiable runoff trend for rain conditions that were beyond the observed values used in developing the models presented on Table 4.13.

4.5 HYDROLOGY MODEL CALIBRATION AND VERIFICATION

The hydrology model was calibrated using the small and large scale tests and verified by examining the differences associated with the two different land use study areas. These estimates of model components were verified by comparing the estimates with the best fit from different, but physically close, land use areas. The mixed residential / commercial catchment had significantly different Rv responses, and land covers, compared to the industrial catchment. The Rv values for similar component areas in these catchments was therefore compared.

The Rv coefficients all increased with increasing rain and decreased relative to each other as their distance from the drainage system increased. The Rv coefficients were also much greater for the impervious areas than for the pervious areas for similar rains, as expected. It should be noted that these Rv values are significantly smaller than the Rational Formula "C" coefficient that is typically used in urban drainage design studies. These differences occur because drainage systems designers are mostly concerned with large storms, and use a single, worst case, runoff coefficient to predict peak runoff rates to compensate for inherent inaccuracies in the Rational Method. Problems arise when researchers, investigating urban runoff quality use these larger values. They then need to overcompensate for expected higher flows and pollutant runoff from impervious areas by substantially decreasing the importance of flows and erosion from pervious areas.

Table 4.12 MODEL PARAMETER RANGES AND MEDIANS

parameter	units	Thistledown (Resid.) min.	Thistledown (Resid.) max.	Thistledown (Resid.) est. median (mean)	Emery (Industrial) min.	Emery (Industrial) max.	Emery (Industrial) est. median (mean)
RAINTOT (rain total volume)	mm	0.75	25.75	6 (8.5)	0.75	25.25	4 (6.9)
RAINDUR (rain duration)	hours	0.20	16.20	3 (4.4)	0.17	16.70	2 (3.8)
AVEINT (average rain intensity)	mm/hr	0.43	30.42	2 (3.4)	0.43	30.42	3 (4.1)
PEAKINT (peak 5-min. rain intensity)	mm/hr	3.00	63.0	6 (13.7)	1.50	63.0	10 (13.6)
DRYPER (dry period preceeding rain)	days	0.01	11.0	1.5 (3.5)	0.06	17.0	2 (3.6)
RUNTOT (total runoff volume)	mm	0.05	6.33	0.7 (1.6)	0.06	7.7	0.8 (1.7)
RUNDUR (runoff duration)	hours	0.80	17.70	3.5 (4.9)	0.67	18.5	3.5 (4.9)
AVEDIS (runoff average discharge rate)	L/sec/ha	0.17	17.48	1 (1.7)	0.12	3.9	0.6 (1.05)
PEAKDIS (runoff peak discharge rate)	L/sec/ha	0.28	46.27	2 (6.3)	0.26	8.2	2 (3.0)
LAG (lag between rain and runoff)	minutes	0.00	90.0	25 (25.9)	0.00	90.0	14 (24.2)

Table 4.13 MODELS SELECTED USING MULTIPLE REGRESSION ANALYSES (STEP-WISE), ASSISTED BY CLUSTER AND FACTOR ANALYSES (only using statistically significant independent variables)

Thistledown (mixed residential and commercial area)

Runoff Total Volume: RUNTOT = -0.213 + 0.217 RAINTOT

n = 35 R^2 = 0.81

Peak Discharge Rate: PEAKDIS = -0.883 + 2.523 AVEDIS + 0.352 RAINTOT

n = 35 R^2 = 0.95

Average Discharge Rate: AVEDIS = -0.791 + 0.182 PEAKINT

n = 34 R^2 = 0.66

Runoff Duration: RUNDUR = 0.554 + 0.991 RAINDUR

n = 35 R^2 = 0.98

Lag Between Start of Rain and Runoff: LAG = 25.9

n = 35 R^2 not applicable

Emery (industrial area)

Runoff Total Volume: RUNTOT = -0.186 + 0.279 RAINTOT

n = 60 R^2 = 0.82

Peak Discharge Rate: PEAKDIS = 0.383 + 1.837 AVEDIS + 0.104 RAINTOT

n = 60 R^2 = 0.75

Average Discharge Rate: AVEDIS = 0.471 + 0.148 RAINTOT - 0.117 RAINDUR

n = 59 R^2 = 0.71

Runoff Duration: RUNDUR = 1.247 + 0.964 RAINDUR

n = 59 R^2 = 0.93

Lag Between Start of Rain and Runoff: LAG = 24.3

n = 53 R^2 not applicable

Table 4.14 and Figures 4.14 and 4.15 show the results of the runoff calibration calculations using Thistledown (mixed residential and commercial area) and Emery (industrial area) data. Table 4.14 shows that the runoff predictions were generally within ten percent of the observed values for most events. The small events in Emery were overpredicted by substantial amounts, however. This was probably due to the differences in the permeability, microdetention/storage, and flash evaporation characteristics of the generally bad pavement in the large industrial parking and storage areas, and the lack of data pertaining to flow losses associated with large flat roofs. These large percentage differences resulted in quite small real differences, as shown on the plots of Figures 4.14 and 4.15. The "predicted" lines for both areas lie very close (in mm of runoff) to the "observed" lines.

The runoff data was extrapolated to cover larger events than were monitored because of the small change in runoff losses expected for the larger events for the important paved urban surfaces. Most of the runoff in an urban area originates from paved areas. For paved areas, most of the runoff losses are associated with the first few millimetres of rain. Infiltration losses through the pavement are relatively constant throughout the rain event. During the washoff tests, the highest pavement runoff coefficients observed were approximately 0.9, restricting the probable errors associated with extrapolation to large rain events to approximately ten percent (the maximum runoff coefficient possible is 1.0).

Pervious area runoff coefficients are much less than for impervious areas. Maximum runoff coefficients of only approximately 0.2 can be expected from pervious areas for large, long duration rain events.This value is based based on literature reports of urban runoff monitoring. The total runoff prediction errors for the large extrapolated rain events are expected to be less than 25 percent.

TABLE 4.14

Runoff Coefficient Calibrations

rain(mm):	Area (%)	1	2	5	10	15	20	25	40	65	90
runoff coefficients											
directly connected impervious:		0	.45	.56	.64	.69	.73	.77	.83	.89	.92
imperv. draining to pervious:		0	.225	.2825	.325	.3525	.375	.3975	.435	.495	.56
pervious & unconn. imperv.:		0	0	.005	.01	.015	.02	.025	.04	.1	.2
disconnected:		0	0	0	0	0	0	0	0	0	0
Thistledown calculations: Area (%):Unit area weighted contributions: (Includes swales)											
directly conn. imperv.	.22	0	.099	.1232	.1408	.1518	.1606	.1694	.1826	.1958	.2024
imperv. to perv.	.145	0	.032625	.0409625	.047125	.0511125	.054375	.0576375	.063075	.071775	.0812
perv. & unconn. imperv.	.631	0	0	.003155	.00631	.009465	.01262	.015775	.02524	.0631	.1262
disconnected:	.004	0	0	0	0	0	0	0	0	0	0
Model (total Rv):		0	.131625	.1673175	.194235	.2123775	.227595	.2428125	.270915	.330675	.4098
Model (mm runoff):		0	.26325	.8365875	1.94235	3.185663	4.5519	6.070313	10.8366	21.49388	36.882
Observed data (total Rv):		0	.09	.17	.19	.2	.2				
Observed data (mm runoff):		0	.18	.85	1.9	3	4				
Observed minus model (mm runoff):		0	-.08325	.0134125	-.04235	-.185663	-.5519				
Percentage difference :			-46.25	1.577941	-2.22895	-6.18875	-13.7975				
Emery calculations: Area (%):Unit area weighted contributions:											
directly conn. imperv.	.567	0	.25515	.31752	.36288	.39123	.41391	.43659	.47061	.50463	.52164
imperv. to perv.	.026	0	.00585	.007345	.00845	.009165	.00975	.010335	.01131	.01287	.01456
perv. & unconn. imperv.	.407	0	0	.002035	.00407	.006105	.00814	.010175	.01628	.0407	.0814
disconnected:	0	0	0	0	0	0	0	0	0	0	0
Model (total Rv):		0	.261	.3269	.3754	.4065	.4318	.4571	.4982	.5582	.6176
Model (mm runoff):		0	.522	1.6345	3.754	6.0975	8.636	11.4275	19.928	36.283	55.584
Observed data (total Rv):		0	.08	.18	.25	.36	.47				
Observed data (mm runoff):		0	.16	.9	2.5	5.4	9.4				
Observed minus model (mm runoff):		0	-.362	-.7345	-1.254	-.6975	.764				
Percentage difference:			-226.25	-81.6111	-50.16	-12.9167	8.127660				

FIGURE 4.14

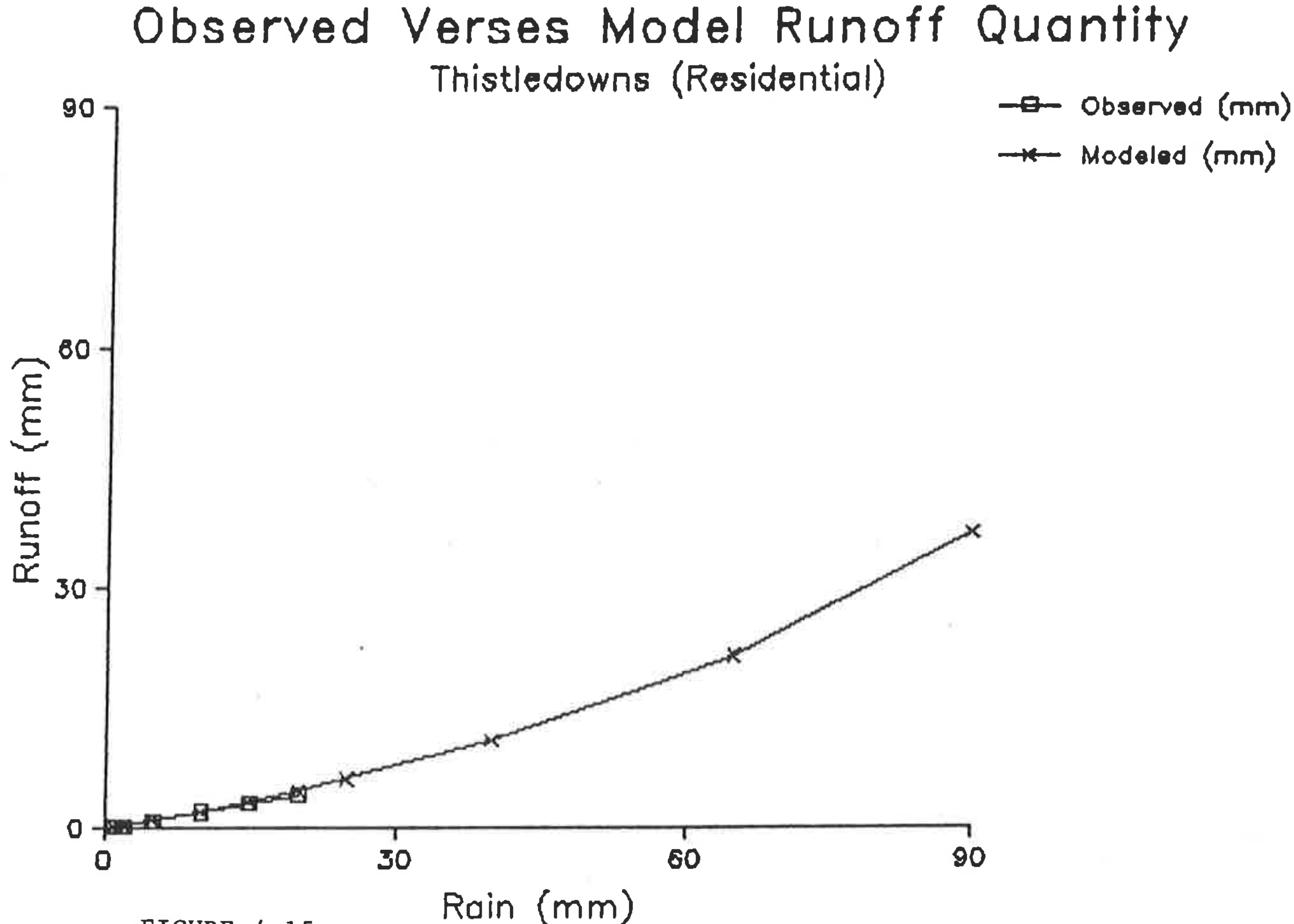
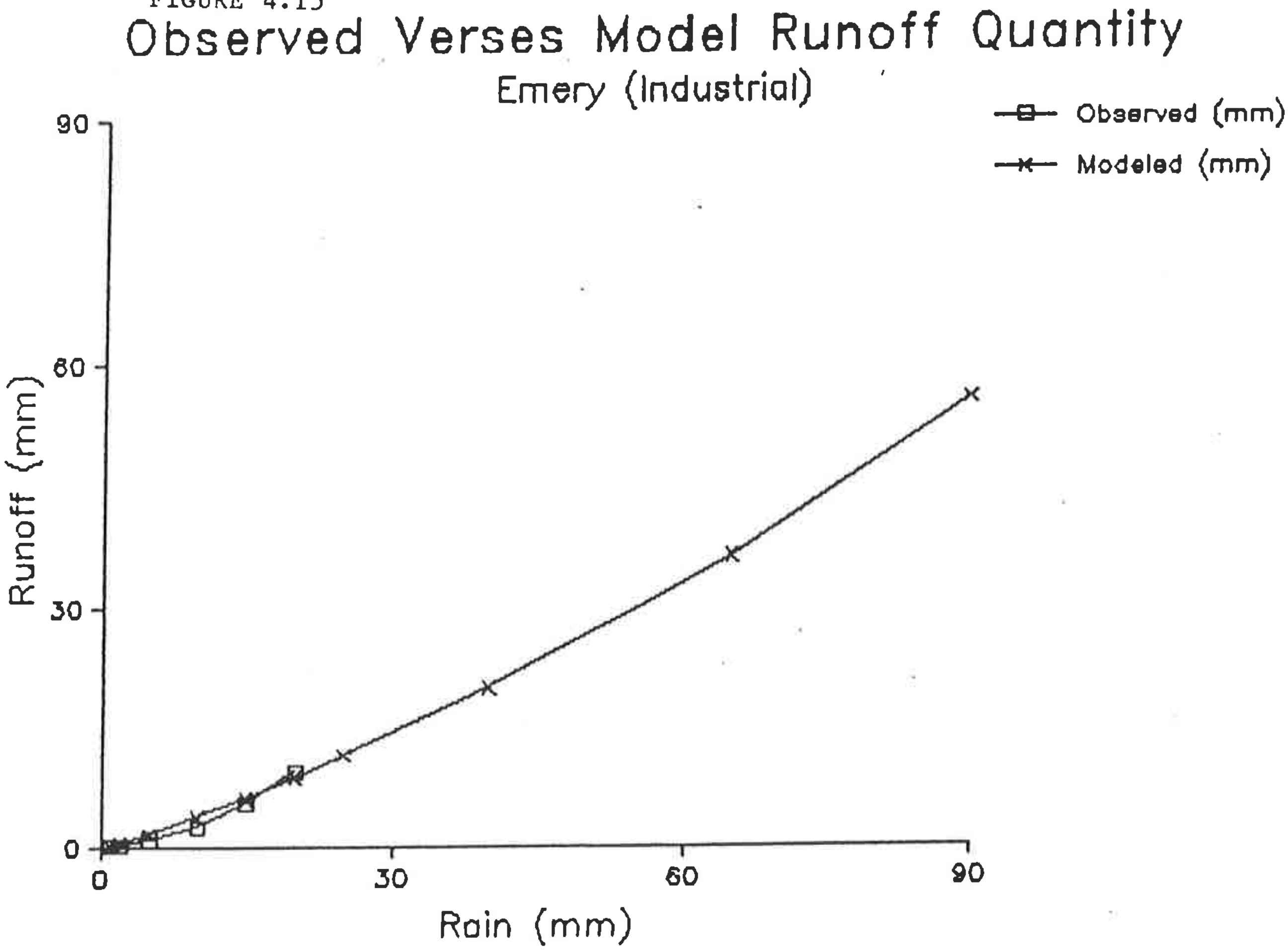


FIGURE 4.15



5.0 URBAN RUNOFF QUALITY

5.1 BASEFLOW WATER QUALITY

5.1.1 WARM WEATHER BASEFLOW WATER QUALITY

Warm weather baseflow was sampled in both catchments during this study. Baseflow was sampled at approximately monthly intervals from the outfall of the Thistledown (residential / commercial) catchment and at approximately weekly intervals from the outfall of the Emery (industrial) catchment. Time-weighted baseflow samples were collected automatically, with subsamples taken at 15 minute intervals. In addition, several grab samples were periodically collected at the Emery outfall because of the frequency the dry weather flows were highly coloured.

Table 5.1 is a summary of warm weather baseflow quality. It shows the minimum, maximum, and median concentrations of constituents analysed, along with the number of analyses performed. The volume and rate of baseflow are also summarised.

The observations given for metals on this table refer to "total metal" concentrations. Most of the chromium and copper, and approximately one third of the aluminum measured in two samples of warm weather baseflow analysed from the Emery outfall was dissolved. The other dissolved metals analysed were close to or below the relevant detection limit. One Thistledown warm weather baseflow sample was analysed for both total and dissolved metals. It showed that most of the copper was dissolved and that concentrations of other metals were mostly below the relevant detection limits.

Most of the concentrations of pesticide and PCB constituents were below the detection limits. The values of the median concentrations observed were used to estimate warm weather baseflow yields in Section 5.3.

Tables E.1 through E.4 in Appendix E present most of the warm weather baseflow water quality observations obtained. In addition, Table E.12 includes the data for the major ion observations, Table E.14 includes the dissolved metal observations, and Table E.16 includes the pesticide and PCB observations for the warm weather baseflow samples analysed. No organic "priority pollutant" analyses were obtained for warm weather baseflow samples. Approximately four to eight Thistledown samples were analysed for most of the major constituents, while only one Thistledown baseflow sample was obtained for pesticides and PCBs. Approximately 25 to 30 Emery samples were analysed for most constituents, and nine were analysed for pesticides and PCBs.

The very uneven sampling efforts makes baseflow water quality comparisons between the two catchments difficult. Simple log-normal probability plots were therefore made by log-transforming the observed data, ranking them by magnitude and plotting them on probability paper. These plots do give an indication of major

Table 5.1 WARM WEATHER BASEFLOW OBSERVATION SUMMARY (April through December)

Constituent	units	Thistledown (residential) # of obs.	min.	max.	median	Emery (industrial) # of obs.	min.	max.	median	Indus./Resid. ratio of medians
Baseflow volume(1)	m^3/ha/season	April to Dec.: 1700 m^3				April to Dec.: 2100 m^3				1.2
Baseflow volume	mm/day	weighted average: 0.7				weighted average: 0.8				1.2
Baseflow rate	L/sec/ha	weighted average: 0.07				weighted average: 0.08				1.2
total residue	mg/L	8	631	1120	979	29	308	5547	554	0.6
filtrate residue	mg/L	6	624	1120	973	29	289	794	454	0.5
particulate residue	mg/L	6	§1.8	10.5	§5	30	§1.7	4770	43	†8.6
phosphorus	mg/L	6	§0.04	0.28	0.09	26	0.1	8.0	0.73	8.1
phosphates	mg/L	6	§0.02	0.18	§0.06	29	§0.02	1.62	0.12	†2
total Kjeldahl N	mg/L	5	0.6	1.9	0.9	25	0.5	27	2.4	2.7
ammonia N	mg/L	5	§0.1	0.3	§0.1	25	§0.1	2.0	§0.1	-
phenolics	ug/L	4	§0.8	3.2	§1.5	29	§0.2	32	2.0	†1.3
COD	mg/L	8	8	1490	22	29	10	2540	108	4.9
fecal coliform bacteria	# org/100mL	3	28,000	35,000	33,000	24	640	650,000	6950	0.2
fecal strep. bacteria	# org/100mL	3	1180	2800	2300	24	§100	1,080,000	8800	3.8
pseudo. aerug. bacteria	# org/100mL	2	1300	4400	2900	15	480	20,000	2380	0.8
aluminum	mg/L	4	§0.04	§0.2	§0.2	24	0.1	120	0.4	†2
arsenic	mg/L	4	§0.03	§0.03	§0.03	24	§0.03	§0.04	§0.03	-
cadmium	mg/L	4	§0.001	§0.006	§0.003	24	§0.004	3.4	§0.01	-
chromium	mg/L	7	§0.01	§0.06	§0.06	30	0.05	45	0.42	†7.0
cobalt	mg/L	4	§0.01	§0.04	§0.03	24	§0.01	0.07	§0.04	-
copper	mg/L	7	§0.02	0.03	0.02	30	0.01	7.1	0.045	2.3
lead	mg/L	7	§0.01	0.09	§0.04	30	§0.01	5.6	§0.04	-
molybdenum	mg/L	4	0.01	§0.06	§0.04	24	§0.01	§0.04	§0.06	-
nickel	mg/L	4	§0.01	§0.04	§0.02	24	§0.01	2.0	0.03	†1.5
selenium	mg/L	4	§0.03	§0.03	§0.03	24	§0.03	0.09	§0.03	†3

Table 5.1 WARM WEATHER BASEFLOW OBSERVATION SUMMARY (April through December) continued

Constituent	units	Thistledown (residential) # of obs.	min.	max.	median	Emery (industrial) # of obs.	min.	max.	median	Indus./Resid. ratio of medians
zinc	mg/L	7	§0.02	0.11	0.04	30	0.04	4.7	0.18	4.5
specific conductance	umhos/cm	1	-	-	710	4	600	2150	542	0.8
total hardness	mg/L	1	-	-	332	2	208	210	209	0.6
calcium	mg/L	2	86	104	95	6	57	91	61	0.6
magnesium	mg/L	2	11.6	17.5	14.6	6	11.3	16.1	13.2	0.9
sodium	mg/L	2	49	77	63	6	23	335	49	0.8
potassium	mg/L	2	3.4	3.9	3.7	6	2.0	8.1	4.2	1.1
total alkalinity	mg/L	2	166	181	91	6	114	174	138	1.5
pH	-	1	-	-	7.81	4	6.44	8.05	7.08	0.9
chloride	mg/L	2	122	440	281	6	51	547	78	0.3
sulfate	mg/L	2	73	110	91	6	43	58	47	0.5
A-BHC	ng/L	1	-	-	17	9	§1	23	§1	§0.1
B-BHC	ng/L	1	-	-	§1	9	§1	§1	§1	-
G-BHC	ng/L	1	-	-	5	9	§1	§1	§1	§0.2
A-chlordane	ng/L	1	-	-	2	9	§2	§2	§2	§1
G-chlordane	ng/L	1	-	-	2	9	§2	§2	§2	§1
Dieldrin	ng/L	1	-	-	4	9	§2	§2	§2	§2
D MDT methoxychlor	ng/L	1	-	-	§5	9	§5	§5	§5	-
Endrin	ng/L	1	-	-	§4	9	§4	§5	§4	-
Endosulfan sulfate	ng/L	1	-	-	§4	9	§4	§4	§4	-
Heptachlor	ng/L	1	-	-	§1	9	§1	§1	§1	-
PCB	ng/L	1	-	-	§20	9	§20	630	§20	†32
PP-DDD	ng/L	1	-	-	§5	9	§5	§5	§5	-
PP-DDE	ng/L	1	-	-	§5	9	§5	§5	§5	-
PP-DDT	ng/L	1	-	-	§5	9	§5	§5	§5	-
2356 tetra chlorophenol	ng/L	1	-	-	§50	9	§50	§50	§50	-
penta-chlorophenol	ng/L	1	-	-	280	9	§50	500	50	1.8

(1) Baseflows are only for periods of no rain/runoff events.

Note: § means "less than" and † means "greater than".

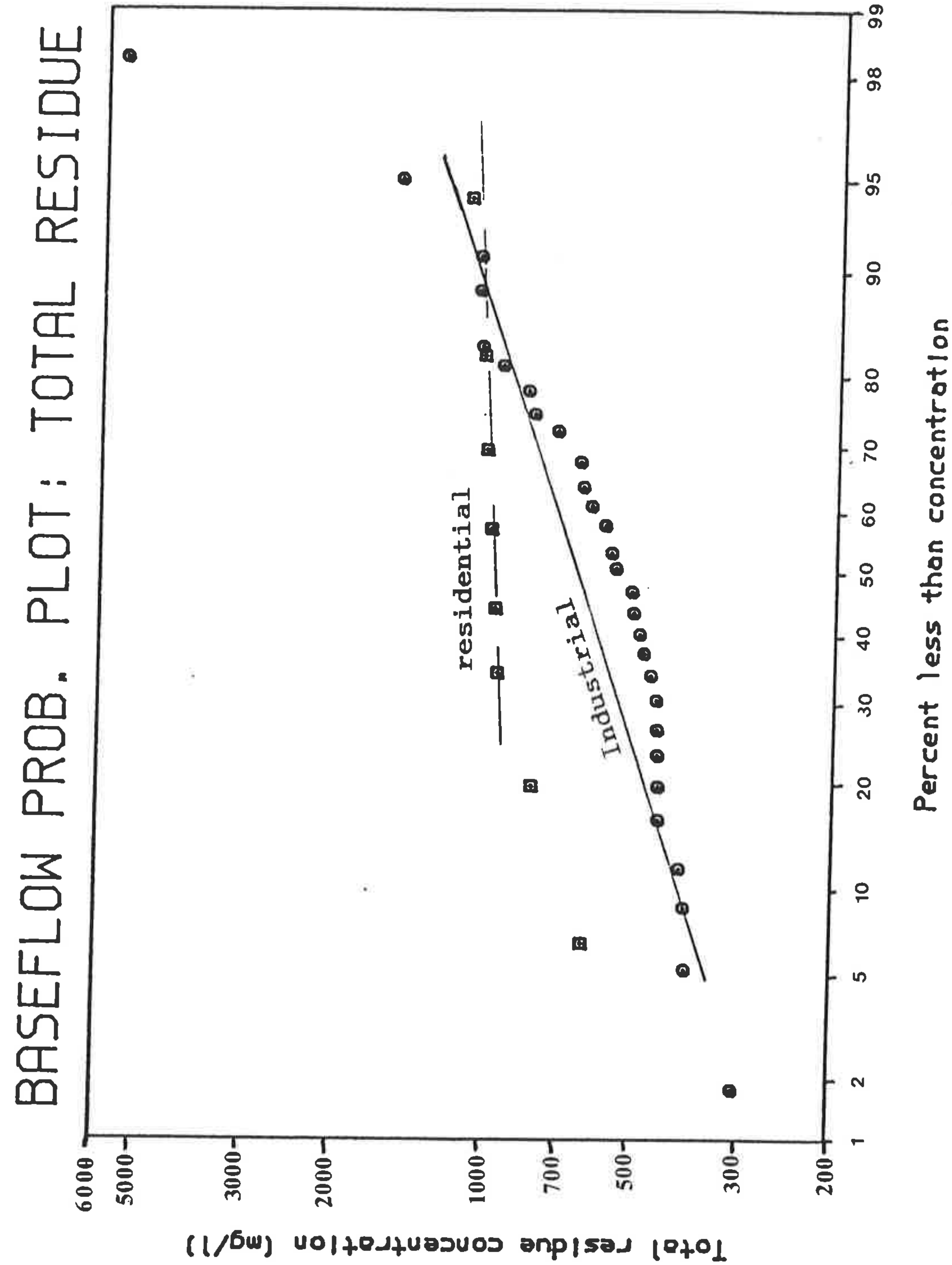
differences in warm weather baseflow water quality between the two sets of observations. If the two probability lines are widely separated throughout the range of observations, then the two data sets are obviously significantly different. If the probability plot lines cross, then the data is more confusing, indicating little significant difference.

Figure 5.1 is the log-normal probability plot for the Thistledown and Emery baseflow total residue concentrations, while Figures E.1 through E.14 are probability plots for some of the other constituents monitored. They show that warm weather baseflow water quality constituent concentrations were probably significantly higher in the Emery catchment than in the Thistledown catchment, for most constituents.The exceptions to this result were total residue, filtrate residue, and fecal coliform bacteria. Filtrate residue concentrations from the Emery catchment were probably significantly lower than the Thistledown observations. The relationships for total residue and fecal coliforms were confused and indicate little difference. The log-normal probability plots for these two constituents are quite linear between approximately 10 to 90 percent, indicating a reasonable log-normal distribution in their occurrence, but are nonlinear outside this range. Therefore, simple parametric data comparison techniques (which require normally distributed data) should not be conducted with this data, unless it is appropriately transformed. Even if transformed, or if using nonparametric tests, the few observations obtained from the Thistledown catchment would add little to the conclusions obtained using the simple probability plots.

The paired analysis technique was also used to characterise a selection of the water quality data, based on carefully matched runoff events. The water quality constituents that were analysed using log-normal plots fell into three general groups. The first group had unclear quality relationships between the two catchments, with the probability line crossing. The constituents in this group include total residue, filterable residue, total Kjeldahl nitrogen, fecal coliform bacteria, pseudomonas aeruginosa bacteria, and lead. In this group, the lowest constituent concentrations were generally observed in the residential / commercial catchment, while the industrial catchment had the highest concentrations. The second group of constituents was the largest, with the residential / commercial catchment consistently having the lowest constituent concentrations all of the time. The constituents in this group include particulate residue, total phosphorus, reactive phosphates, phenolics, chemical oxygen demand, fecal streptococcus bacteria, aluminum, copper, and zinc. In the third group of constituents the lowest concentrations were always found at the industrial catchment. This group contained only specific conductance and nitrates.

Table 1.2 compares the warm weather baseflow observations with the Ontario Provincial Water Quality Objectives. These objectives are for receiving waters. They can also be used to identify discharges that could potentially contribute to existing quality problems in

FIGURE 5.1



BASEFLOW PROB. PLOT: TOTAL RESIDUE
residential
Industrial
Total residue concentration (mg/l)
6000
5000
3000
2000
1000
700
500
300
200
Percent less than concentration
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99

receiving waters, or to identify discharges that may cause receiving water quality problems at some time in the future. This table shows that almost all of the fecal coliform bacteria, chromium, copper, and zinc observations in warm weather baseflow from the Emery (industrial) catchment exceeded the objectives. Almost all of the samples collected at the Thistledown (residential / commercial) outfall exceeded the objective for fecal coliform bacteria. Other potential problem pollutants in the baseflow from the industrial catchment include phenolics, lead, and PCBs.

Potential problem pollutants in the baseflow from the residential / commercial catchment include phenolics, copper, lead, zinc, and Dieldrin. The small number of warm weather baseflow samples from both catchments that were analysed for pesticides and PCBs reduce the confidence of comparisons for these constituents. Similarly, the small number of samples that were analysed for general water quality constituents in the residential / commercial catchment reduce the confidence of these comparisons. However, they do indicate the need for additional analyses, especially when the duration of warm weather baseflows covers more than 70 percent of the year.

Not all of these problem pollutants are expected to originate from surface sources. Process wastewaters discharged to the storm drainage system in the industrial catchment may be responsible for most of the high chromium and some of the copper loadings observed. Similarly, sanitary sewerage leakage may be responsible for some of the bacteria in discharges of warm weather baseflow. The sources of these pollutants will be discussed further in Section 6.

5.1.2 COLD WEATHER BASEFLOW WATER QUALITY

Cold weather baseflow water quality samples were obtained during the special snowmelt sampling effort added to the original Pilot Watershed Project. These samples were collected during January, February and March, 1984.

Table 5.2 is a summary of these observations for both the Thistledown and Emery catchments, with the exception of dissolved metal observations which appear on Table E.15. This table shows the number of samples analysed for each constituent, along with the minimum, maximum, and median concentrations of the constituents analysed. The baseflow rate and volume are also summarised for each catchment. Approximately four Thistledown and eight to ten Emery samples were analysed for most constituents, with approximately one half of these sample numbers obtained for the major ion constituents. Only one cold weather baseflow sample (from Emery) was analysed for pesticides and PCBs. Table E.5 shows the cold weather baseflow observations obtained for all of the samples for the major constituents. Table E.13 includes observations for major ions, Table E.15 includes data for dissolved metals, and Table E.17 includes the results of the pesticide and PCB analysis conducted for the one cold weather baseflow sample analysed from the Emery catchment.

Table 5.2 COLD WEATHER BASEFLOW OBSERVATION SUMMARY (January through March)

Constituent	units	Thistledowns (residential) # of obs.	min.	max.	median	Emery (industrial) # of obs.	min.	max.	median	Indus./Resid. ratio of medians
Baseflow volume(1)	m^3/ha/season	Jan. to March: 1100 m^3				Jan. to March: 660 m^3				0.6
Baseflow volume	mm/day	23	0.5	4.9	1.2	28	0.3	2.7	0.7	0.6
Baseflow rate	L/sec/ha	44	0.05	0.57	0.13	50	0.03	0.33	0.07	0.5
total residue	mg/L	4	690	4150	2230	11	530	2560	1080	0.5
filtrate residue	mg/L	4	670	4130	2210	11	430	2220	1020	0.5
particulate residue	mg/L	4	19	27	21	11	11	343	52	2.5
phosphorus	mg/L	4	0.16	0.35	0.18	10	0.15	6.0	0.34	1.9
phosphates	mg/L	4	§0.02	0.10	§0.05	9	§0.02	0.26	§0.02	–
total Kjeldahl N	mg/L	4	1.3	1.8	1.4	10	0.7	5.0	2.0	1.4
ammonia N	mg/L	4	§0.1	§0.1	§0.1	10	§0.1	3.0	§0.1	–
phenolics	ug/L	4	1.0	3.6	2.0	8	3.0	16	7.3	3.7
COD	mg/L	4	40	50	48	9	34	320	68	1.4
fecal coliform bacteria	# org/100mL	4	360	11,300	9750	8	160	6700	400	0.04
fecal strep. bacteria	# org/100mL	4	440	15,000	1360	8	300	8400	2400	1.8
pseudo. aerug. bacteria	# org/100mL	4	30	†3,000	85	8	§10	1600	55	0.7
cadmium	mg/L	3	§0.005	0.001	§0.005	9	§0.005	0.021	§0.005	–
chromium	mg/L	4	§0.01	§0.01	§0.01	10	0.03	0.65	0.24	†24
copper	mg/L	4	0.01	0.08	0.015	10	0.02	0.18	0.04	2.7
lead	mg/L	4	§0.02	0.10	§0.06	10	§0.02	0.28	§0.04	–
zinc	mg/L	4	0.06	0.10	0.065	10	0.06	0.48	0.15	2.3
specific conductance	umhos/cm	2	1210	7400	4300	4	1870	4100	1960	0.5

Because of the limited scope of the snowmelt portion of this study, no statistical comparisons of the data from the two catchments could be made. The median concentrations were used in estimating discharges of pollutants in cold weather baseflow. These are presented in Section 5.3 and are summarised in Table 5.2. These data show probable significant differences in concentrations of heavy metal (chromium, copper, and zinc) and phenolics between the two catchments, with the Emery (industrial) catchment having the larger concentrations of these constituents. The Thistledown catchment probably had significantly greater specific conductance, filtrate residue, fecal coliform bacteria, and chloride concentrations than Emery. The dissolved metal observations (included on Table E.15) for three samples analysed indicate that large proportions of metals detected in water samples collected in the Emery catchment were dissolved. Similar samples collected in the Thistledown catchment showed mostly undetected dissolved or total metal concentrations.

Table 1.2 compares the cold weather baseflow water quality observations with Ontario Provincial Water Quality Objectives. During cold weather baseflow conditions, almost all of the phenolics and fecal coliform bacteria observed in both catchments exceeded the relevant objectives. Other pollutants that could cause cold weather baseflow water quality problems include chromium, copper, lead, and zinc in the industrial (Emery) catchment, and copper, lead, and zinc in the residential / commercial (Thistledown) catchment.

The limited number of cold weather baseflow samples analysed can be used to only grossly indicate potential problem pollutants. Secondly, not all of these pollutants measured at the outfall are expected to originate on the land surface. Some are probably associated with subsurface discharges, e.g. chromium and some of the copper is most likely to originate from process wastewater discharges, and bacteria from sanitary sewerage leakage. These sources will be discussed further in Section 6. This short list of potential cold weather baseflow problem pollutants can be used as the basis for a much more comprehensive sampling effort.

5.2 STORMWATER RUNOFF WATER QUALITY

5.2.1 WARM WEATHER STORMWATER WATER QUALITY

Many samples of stormwater were obtained during this phase of the study. A total of 37 storm events were monitored at the Emery catchment and 21 events monitored at the Thistledown catchment. These water samples were analysed for a wide range of water quality constituents. Tables E.6 through E.7 list the complete stormwater quality data, while Table 5.3 is a summary. Other tables in Appendix E include stormwater runoff quality data as listed below:

Table 5.3 STORMWATER FLOW AND CONSTITUENT OBSERVATION SUMMARY (April through December)

Constituent	units	Thistledown (residential) # of obs.	min.	max.	median	Emery (industrial) # of obs.	min.	max.	median	Indus./Resid. ratio of medians	
Stormwater volume	m^3/ha/ season	April through Dec.: 950 m^3				April through Dec.: 1500 m^3				1.6	
Stormwater volume	m^3/ha/ event	21	2.1	86.7	18.1	37	1.6	79.6	15.5	0.9	
Average flow rate	L/sec/ ha	21	0.21	17.5	0.67	37	0.12	4.0	0.67	1.0	
Peak 5-min. flow rate	L/sec/ ha	21	0.36	46.4	4.12	37	0.29	8.3	2.61	1.6	
total residue	mg/L	14	134	790	256	27	168	3502	371	1.5	est COD
filtrate residue	mg/L	14	98.4	779	230	27	122	376	208	0.9	0.41
particulate residue	mg/L	14	6.4	263	22.3	27	30.8	3290	117	5.3	1.7
phosphorus	mg/L	7	0.13	0.90	0.28	17	0.2	5.1	0.75	2.7	
phosphates	mg/L	13	§0.02	0.24	0.02	27	§0.04	1.24	0.16	8.0	
total Kjeldahl N	mg/L	8	1.3	20.3	2.5	17	1.2	8.6	2.0	0.8	
ammonia N	mg/L	13	§0.1	0.2	§0.1	19	§0.1	0.4	§0.1	-	
nitrate N	mg/L	7	0.3	1.6	0.8	5	0.2	1.0	0.4	0.5	0.65
phenolics	ug/L	12	§0.2	4.0	1.2	24	1.0	27.6	5.1	4.3	
COD	mg/L	14	14	184	55	27	50	262	106	1.9	0.65
fecal coliform bacteria	# org/ 100mL	10	1500	490,000	39,500	23	1020	520,000	49,000	1.2	
fecal strep. bacteria	# org/ 100mL	10	820	99,000	19,500	23	4150	142,000	39,000	2.0	
pseudo. aerug. bacteria	# org/ 100mL	6	160	5900	2700	15	480	†32,000	11,000	4.1	
aluminum	mg/L	6	§0.2	7.1	0.21	16	0.72	130	2.3	11.0	
chromium	mg/L	13	§0.01	0.04	§0.06	25	§0.06	4.0	0.32	†5.3	
copper	mg/L	13	§0.01	0.14	0.03	24	0.02	0.43	0.055	1.8	1.2
lead	mg/L	13	§0.02	0.57	§0.06	24	§0.02	0.49	0.08	†1.3	1.6

Table 5.3 STORMWATER FLOW AND CONSTITUENT OBSERVATION SUMMARY (April through December) continued

Constituent	units	Thistledown (residential) # of obs.	min.	max.	median	Emery (industrial) # of obs.	min.	max.	median	Indus./Resid. ratio of medians
zinc	mg/L	13	§0.06	0.61	0.06	25	0.03	1.2	0.19	3.2
specific conductance	umhos/cm	11	215	340	880	9	215	340	250	0.3
total hardness	mg/L	NA(1)	–	–	–	2	100	191	–	–
calcium	mg/L	14	17.5	154	39.0	11	25	70	37.5	1.0
magnesium	mg/L	14	1.65	17.7	4.7	11	2.9	6.2	4.0	0.9
sodium	mg/L	14	7.4	105	31.8	11	8.0	143	13.3	0.4
potassium	mg/L	14	1.0	11.5	2.9	11	1.7	15	2.55	0.9
total alkalinity	mg/L	14	34.2	220	89	11	56	306.4	86.6	1.0
pH	–	11	6.90	7.98	7.45	9	7.10	7.57	7.32	1.0
chloride	mg/L	14	10.8	144	34.4	11	9.0	29.0	17.0	0.5
sulfate	mg/L	14	3.5	100	30.2	11	22.0	33.0	27.0	0.9
A-BHC	ng/L	7	§1	13	1	12	§1	10	3.5	3.5
B-BHC	ng/L	7	§1	§1	§1	12	§1	2	§1	–
G-BHC	ng/L	7	§1	2	§1	12	§1	1	§1	–
A-chlordane	ng/L	7	§2	15	§2	12	§2	§2	§2	–
G-chlordane	ng/L	7	§2	17	§2	12	§2	§2	§2	–
Dieldrin	ng/L	7	§2	6	§2	12	§2	§2	§2	–
DMDT methoxychlor	ng/L	7	§5	20	§5	12	§5	§5	§5	–
Endrin	ng/L	7	§4	44	§4	12	§4	§4	§4	–
Endosulfan sulfate	ng/L	7	§4	10	§4	12	§4	§4	§4	–
Heptachlor	ng/L	7	§1	3	§1	12	§1	§1	§1	–
PCB	ng/L	7	§20	§20	§20	12	§20	440	33	†1.7
PP-DDD	ng/L	7	§5	5	§5	12	§5	§5	§5	–
PP-DDE	ng/L	7	§5	22	§5	12	§5	§5	§5	–
PP-DDT	ng/L	7	§5	§5	§5	12	§5	5	§5	–
2356 tetra chlorophenol	ng/L	7	§50	§50	§50	12	§50	60	§50	–

Table 5.3 STORMWATER FLOW AND CONSTITUENT OBSERVATION SUMMARY (April through December) continued

Constituent	units	Thistledown (residential) # of obs.	min.	max.	median	Emery (industrial) # of obs.	min.	max.	median	Indus./Resid. ratio of medians
penta-chlorophenol	ng/L	7	§50	120	70	12	§50	1500	705	10.1
Benzene	ug/L	1	-	-	5	1	-	-	5	1.0
Chloroform	ug/L	1	-	-	§1	1	-	-	5	†5
Trans-1,2-Di-chloroethene	ug/L	1	-	-	§1	1	-	-	6	†6
Methyl chloride	ug/L	1	-	-	§2	1	-	-	5	†2.5
Trichloroethene	ug/L	1	-	-	§1	1	-	-	2	†2
Toluene	ug/L	1	-	-	§2	1	-	-	5	†2.5
B13-(2-Ethyl-hexyl)Phthalate	ug/L	1	-	-	8	1	-	-	18	2.3
Butylbenzyl-phthalate	ug/L	1	-	-	5	1	-	-	58	11.6
Di-N-Butyl-phthalate	ug/L	1	-	-	3	1	-	-	4	1.3
Diethyl-phthalate	ug/L	1	-	-	§2	1	-	-	20	†10
Isophorone	ug/L	1	-	-	§1	1	-	-	2	†2
N-Nitrosodi-phenylamine	ug/L	1	-	-	§1	1	-	-	3	†3

(1) NA: not analysed.

Note: § means "less than" and † means "greater than".

1) Table E.10 lists field specific conductance and pH data,

2) Table E.12 includes major ion data,

3) Table E.14 includes dissolved metal data,

4) Table E.16 includes pesticides and PCB data, and

5) Table E.18 includes organic "priority pollutant" data.

Approximately ten to 20 Thistledown and approximately 15 to 30 Emery warm weather stormwater samples were analysed for the major constituents. Approximately 11 to 14 samples were analysed for major ions, and seven to 12 samples were analysed for pesticides and PCBs. Only one toxic organic sample was analysed from each catchment during warm weather stormwater runoff periods.

Limited statistical analyses were conducted on these data. Figure 5.2 is a log-normal probability plot for total residue stormwater concentrations. Figures E.33 through E.49 are probability plots for the other constituents. Paired storm events are only shown on these plots, so differences in the probability distributions are most likely caused by land use differences and not seasonal or rain characteristics. These plots also show that the stormwater concentrations were log-normally distributed over much of their observed ranges.

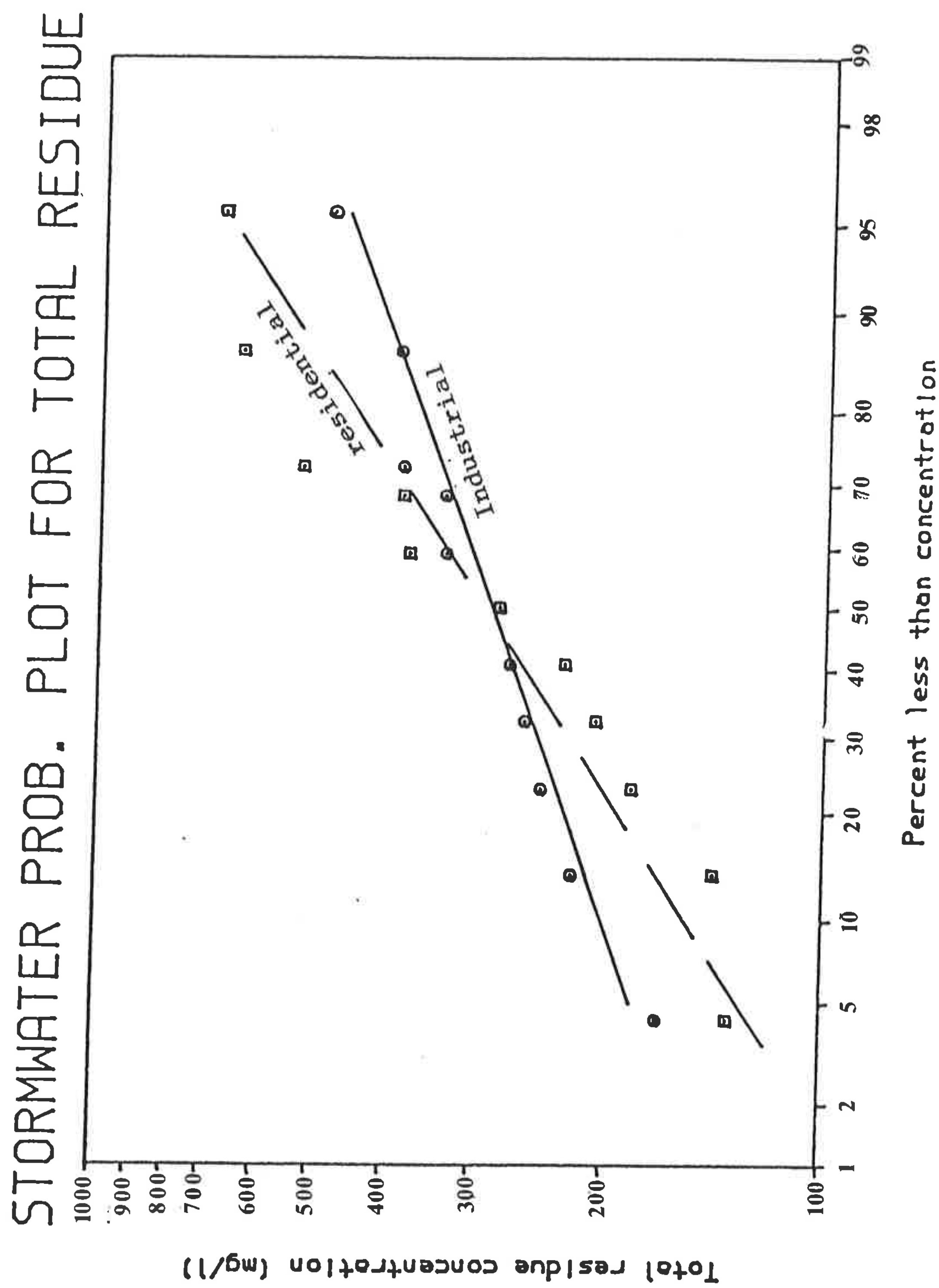
Three sets of constituents were identified. In the first and largest set, the concentrations of constituents measured in the residential / commercial catchment were significantly less than the paired concentration measured in the industrial catchment. This set of constituents includes particulate residue, total phosphorus, reactive phosphates, phenolics, chemical oxygen demand, fecal strep. bacteria, aluminum, copper, and zinc.

The second and smallest set shows that the constituents measured in the residential / commercial catchment had significantly greater concentrations than those measured in the industrial catchment. This set consists of specific conductance and nitrates.

The third set includes those constituents with confusing plots with no apparent significant differences between the two catchments. This set consists of total residue, filtrate residue, total Kjeldahl nitrogen, fecal coliform bacteria, <u>pseudomonas aeruginosa</u> bacteria, and lead. In this last set, the lowest concentrations were generally observed in the residential / commercial catchment, while the industrial catchment had the highest concentrations.

Stormwater quality constituent concentrations were also plotted as a function of rain (storm) volume to identify potential correlations of constituent concentration with the size of the rain event. Figure E.15 is a plot of total residue concentration against rain event volume for Emery and Thistledown. This Figure does not indicate a significant trend for total residue. Figures E.16

FIGURE 5.2



STORMWATER PROB. PLOT FOR TOTAL RESIDUE
Total residue concentration (mg/l)
1000
900
800
700
600
500
400
300
200
100
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
Percent less than concentration
residential
Industrial

through E.33 are similar plots for some of the other constituents studied. The only constituent showing a significant trend of concentration against rain volume was filtrate residue (Figure E.16). The filtrate residue concentrations at the Thistledown outfall were approximately 700 mg/L for very small rains (2 mm), and decreased to approximately 200 mg/L for larger (20 mm) rains. The trend at the Emery outfall was not as obvious. This trend for filtrate residue was also especially evident during the street washoff tests described in Section 6.5. The source area street washoff test results and the source area observations show more significant trends of runoff quality with rain volume for a number of constituents. This trend in the sheetflow results was expected because of the potentially confusing factors, e.g. erosion from other surfaces, that would affect the observations at the outfalls and not the observations made on isolated source areas.

Only two samples were analysed for dissolved heavy metals from each of the residential / commercial and industrial catchments. The results of these analyses are included on Table E.14 and indicate that most of the chromium in storm water from the industrial catchment was in dissolved forms. Some of the copper and zinc measured in the industrial catchment may be also in dissolved forms, along with much of the zinc measured in the residential / commercial catchment. Dissolved metal forms are usually more of a problem in receiving waters than particulate metal forms as they are more readily available to aquatic life. The dissolved metals in the outfall discharges of the industrial catchment also indicate the potential of plating process wastewater discharges entering the storm drainage system. The dissolved zinc measured in the residential / commercial catchment was probably from galvanized roof gutters and downspouts.

Table 1.2 shows the number of warm weather stormwater samples analysed that exceed the Ontario Provincial Water Quality Objectives. This comparison was used to identify potential problem pollutants that may be contributing to water quality problems in receiving water. All of the fecal coliform and most of the copper and zinc observed in both study areas exceeded the objectives. Concentrations of phenolics, chromium, and lead at the outfall of the industrial catchment also exceeded the objectives most of the time. PCBs are another potential problem pollutant in the industrial catchment. Phenolics, lead, Dieldrin, Endrin, and Heptachlor periodically exceeded the objective at the outfall of the residential / commercial catchment.

5.2.2 COLD WEATHER SNOWMELT WATER QUALITY

Cold weather snowmelt samples were collected at the outfalls during the months of January, February and March, and analysed as part of the snowmelt project extension. Table 5.4 is a summary of the concentrations of water quality constituents measured in these samples. Other tables in Appendix E list the cold weather snowmelt water quality data, as listed below:

Table 5.4 COLD WEATHER RUNOFF (snowmelt, some mixed with rain) SUMMARY (Jan. through March)

Constituent	units	Thistledown (residential) # of obs.	min.	max.	median	Emery (industrial) # of obs.	min.	max.	median	Indus./Resid. ratio of medians
Runoff volume	m^3/ha/ season	Jan. through March: 1800				Jan. through March: 830				0.5
Flow volume	m^3/ha	26	2.3	510	10	27	1.8	350	8.2	0.8
Average flow rate	L/sec/ ha	26	0.10	3.4	0.34	27	0.08	4.2	0.26	0.8
Peak 5-min. flow rate	L/sec/ ha	26	0.13	12.6	0.67	27	0.20	7.9	0.29	0.4
total residue	mg/L	16	320	5160	1580	17	610	6720	1340	0.8
filtrate residue	mg/L	16	200	4770	1530	17	340	6140	1240	0.8
particulate residue	mg/L	16	§6	390	30	17	11	580	95	3.2
phosphorus	mg/L	16	0.10	1.5	0.23	17	0.25	4.9	0.50	2.2
phosphates	mg/L	16	§0.02	0.12	§0.06	17	§0.02	0.6	0.14	†2.3
total Kjeldahl N	mg/L	16	0.8	7.3	1.7	17	0.8	23	2.5	1.5
ammonia N	mg/L	16	§0.1	1.3	0.2	17	§0.1	1.8	0.4	2.0
nitrate N	mg/L	7	0.2	3.5	2.5	8	0.1	1.6	0.9	0.4
phenolics	ug/L	12	§0.4	140	2.5	16	5.0	25	15	6.0
COD	mg/L	16	26	440	40	16	48	190	94	2.4
fecal coliform bacteria	# org/ 100mL	15	300	8300	2320	17	40	11,800	300	0.1
fecal strep. bacteria	# org/ 100mL	15	§20	9900	1900	17	860	13,600	2500	1.3
pseudo. aerug. bacteria	# org/ 100mL	15	§10	4120	20	17	§20	180	30	1.5
cadmium	mg/L	12	§0.005	0.008	§0.005	11	§0.005	0.010	0.006	†1.2
chromium	mg/L	16	§0.01	0.30	§0.01	17	0.01	1.8	0.35	†35
copper	mg/L	16	§0.01	0.10	0.04	17	§0.01	0.25	0.07	1.8
lead	mg/L	16	0.03	0.61	0.09	17	§0.04	0.54	0.08	0.9

Table 5.4 COLD WEATHER RUNOFF (snowmelt, some mixed with rain) SUMMARY (Jan. through March) continued

Constituent	units	Thistledown (residential) # of obs.	min.	max.	median	Emery (industrial) # of obs.	min.	max.	median	Indus./Resid. ratio of medians
zinc	mg/L	16	0.04	0.68	0.12	17	0.10	0.85	0.31	2.6
specific conductance	umhos/cm	7	380	8610	2560	8	610	10,900	1440	0.6
calcium	mg/L	7	46	131	110	8	48	120	70	0.6
magnesium	mg/L	7	2.5	19	9.5	8	6.4	23	9	0.9
sodium	mg/L	7	210	3500	400	8	200	2180	300	0.8
potassium	mg/L	7	3.4	4.8	4.0	8	3.9	6.8	4.7	1.2
total alkalinity	mg/L	7	65	204	160	8	75	220	110	0.7
pH	-	7	7.0	7.8	7.5	8	6.6	7.2	7.1	0.9
chloride	mg/L	16	73	2710	660	17	130	3500	620	0.9
sulfate	mg/L	7	61	140	100	8	36	106	57	0.6
A-BHC	ng/L	2	4	4	4	2	4	6	5	1.3
G-BHC	ng/L	2	1	2	1	2	3	4	3	3
A-chlordane	ng/L	2	3	4	4	2	§2	2	1	0.3
G-chlordane	ng/L	2	3	10	7	2	§2	2	1	0.1
Dieldrin	ng/L	2	§2	4	2	2	§2	§2	§2	§1
total PCBs (1)	ng//L	2	§20	§20	§20	2	§20	80	40	†2

(1) Resembles a mixture of Arochlor 1254 and 1260.

Note: § means "less than" and † means "greater than".

1) Tables E.8 and E.9 include all the snowmelt water quality observations for the major constituents,

2) Table E.13 includes the major ion snowmelt observations,

3) Table E.15 includes the snowmelt dissolved metal observations, and

4) Table E.17 includes the pesticides and PCB snowmelt observations.

Approximately 17 snowmelt samples collected in the industrial catchment and from 12 to 16 snowmelt samples collected in the residential / commercial catchment were analysed for major constituents. Seven or eight samples from both catchments were analysed for major ions, but only two snowmelt samples were analysed for pesticides and PCBs from each of the two catchments. No snowmelt samples were analysed for organic "priority pollutants". Eight snowmelt samples were also analysed from each catchment for dissolved metals.

Because of the limited scope of the cold weather sampling effort, only simple data summaries of the snowmelt observations were prepared. The observations were compared to the Ontario Water Quality Objectives in Table 1.2. The concentrations observed were used in Section 5.3 to estimate monthly snowmelt pollutant discharges. As described in the snowmelt hydrology discussion (Section 4.2), many of the snowmelt water quality samples contained a mixture of cold weather baseflow, snowmelt water, and possibly rain. Tables E.8 and E.9 identify the major mixtures of water present in each sample, plus the percentage of snowmelt sample that was baseflow. In most cases, baseflows comprised less than 25 percent of the total sample volume. When the concentrations of constituents in cold weather baseflow were compared to the concentrations in snowmelt, few significant differences in quality were expected. These "contaminations" by baseflow are, therefore, not considered important. They were considered in Section 5.3, however, when annual yields were calculated.

Some differences in snowmelt quality can be estimated between the two catchments without statistical testing. The data indicates that significantly greater concentrations of particulate residues, most of the nutrients, phenolics, chemical oxygen demand, chromium, and zinc may occur in snowmelt water from the industrial catchment compared to the quality of the snowmelt from the residential / commercial catchment. Fecal coliform bacteria populations may be significantly greater in snowmelt from the outfall of the residential / commercial catchment than from the outfall of the industrial catchment.

Most of the chromium and much of the copper and zinc were "dissolved" in the eight samples from the industrial catchment analysed for both dissolved and total metals. Much of the copper and zinc was also "dissolved" in eight similar samples from the residential / commercial catchment. The chromium in samples collected in the residential / commercial catchment was mostly in particulate forms. The observations for lead from both catchments were mixed, with some samples showing large particulate fractions, and other samples showing large dissolved fractions. The results of most of the cadmium and manganese analyses were below the detection limits for samples collected in both catchments.

Table 1.2 can be used to identify potential problem pollutants, indicated by concentration observations exceeding the Ontario Provincial Water Quality Objectives. Almost all of the snowmelt outfall observations from both catchments for fecal coliforms, phenolics, copper, lead, and zinc exceeded the objectives. Chromium observed in the industrial catchment exceeded the objectives for all observations. The relatively large number of analyses performed for these pollutants (approximately 17 in the industrial catchment and 12 to 16 in the residential / commercial catchment) allows a greater amount of confidence to be placed on this list than was possible for the list of potential problem pollutants in cold weather baseflows. Other potential problem snowmelt pollutants may include PCBs in the industrial catchment and Dieldrin in the residential / commercial catchment. However, two samples in each catchment were analysed for organic pollutants.

5.3 URBAN RUNOFF POLLUTANT YIELDS

Annual baseflow and stormwater yields for the Emery and Thistledown catchments were calculated using the observed data and estimates of the precipitation events that were not monitored. Differences in urban runoff pollutant yields may vary from the period of time of study to other periods of interest. The most important factor is the amount of precipitation that occurs. However, during dry years, constituent concentrations in runoff are usually greater than during wet years, mitigating differences in the outfall yield. There has been a surprising similarity in outfall yields for comparable study areas in widely varying climatic regions. Appropriate urban runoff models are useful to evaluate the effects of different study periods. In Section 4.1, it was shown that the period of study for this runoff project had precipitation conditions close to the long term average conditions. Therefore, the runoff yields described in this report may be considered close to "average". It should be noted that extreme weather conditions can be expected to result in runoff yields quite different from those monitored during this study.

Tables 5.5 through 5.7 show these annual estimated yields for warm and cold periods. Tables E.20 through E.22 show the cold weather baseflow and snowmelt yields calculated for individual events and for each cold weather month. Mass yields by month for warm weather baseflows and stormwaters were examined for total residue and the other constituents. In most cases, monthly pollutant yields were very similar to each other. The data also indicates that the total monthly flow volumes were of similar size. These similarities

Table 5.5 ESTIMATED ANNUAL URBAN RUNOFF YIELDS

Thistledown (Residential)

Constituent	units	April through Dec. base flow	April through Dec. storm water	April through Dec. warm sub-total	January through March base flow	January through March daily melt	January through March major melt	January through March rain with melt	January through March cold sub-total	total
runoff volume	m^3/ha	1700	950	2700	1100	340	260	1200	2900	5600
	%	31	17	48	20	6	5	22	52	-
total residue	kg/ha	1700	240	1900	2400	500	350	880	4100	6100
	%	28	4	31	40	8	6	15	69	-
filtrate residue	kg/ha	1700	210	1900	2400	500	380	790	4100	6000
	%	28	4	32	40	8	6	13	68	-
particulate residue	kg/ha	6.8	30	37	23	8.8	6.3	88	130	160
	%	4	18	22	14	5	4	54	78	-
chlorides	kg/ha	480	33	510	1200	220	180	320	1900	2400
	%	20	1	21	49	9	7	13	79	-
phosphorus	g/ha	150	290	440	200	44	39	490	770	1200
	%	12	24	36	16	4	3	40	64	-
phosphates	g/ha	§100	33	33	§50	14	24	68	110	140
	%	§70	24	24	§40	10	17	49	76	-
total Kjeldahl N	g/ha	1500	2800	4300	1500	390	530	2600	5000	9300
	%	16	30	46	16	4	6	28	54	-
ammonia	g/ha	§170	85	85	§100	69	83	160	310	400
	%	§40	21	21	§25	17	21	40	79	-
phenolics	g/ha	§2.6	1.2	1.2	2.3	7.2	0.7	15	25	26
	%	§10	5	5	9	27	3	57	95	-
COD	kg/ha	38	51	89	52	27	16	88	180	270
	%	14	19	33	19	10	6	32	67	-
fecal coliform bacteria	10^9org/ha	560	480	1000	110	4.2	22	36	170	1200
	%	46	40	86	9	§1	2	3	14	-
fecal strep. bacteria	10^9org/ha	40	210	250	15	8.5	8.0	60	92	340
	%	12	61	73	4	2	2	18	27	-
pseudo. aerug. bacteria	10^9org/ha	50	43	93	0.93	0.07	0.05	0.25	1.3	94
	%	53	46	99	1	§1	§1	§1	1	-
chromium	g/ha	§100	21	21	§10	4.1	2.5	8.2	15	36
	%	-	59	59	§30	11	7	23	41	-
copper	g/ha	35	30	65	16	12	7.6	57	93	160
	%	22	19	41	10	8	5	36	59	-
lead	g/ha	§68	41	41	§70	29	12	130	170	210
	%	§30	19	19	§30	14	6	61	81	-
zinc	g/ha	69	74	140	70	54	37	180	340	480
	%	14	15	29	14	11	8	37	71	-
data period:		July 28, 1983 to Nov. 15, 1983			Feb. 2, 1984 to March 25, 1984					

Table 5.5 ESTIMATED ANNUAL URBAN RUNOFF YIELDS continued

Constituent	units	Emery (Industrial)									Industrial to Residential Area Yield Ratios		
		April through Dec.			January through March								
		base flow	storm water	warm sub-total	base flow	daily melt	major melt	rain with melt	cold sub-total	total	warm sub-total	cold sub-total	total
runoff volume	m^3/ha	2100	1500	3600	660	94	75	660	1500	5100	1.33	0.52	0.91
	%	41	29	71	13	2	1	13	29	–	–	–	–
total residue	kg/ha	1100	670	1800	710	210	110	1200	2200	4000	0.95	0.54	0.66
	%	28	17	45	18	5	3	30	55	–	–	–	–
filtrate residue	kg/ha	950	310	1300	570	200	98	1000	1900	3100	0.68	0.46	0.52
	%	30	10	40	18	6	3	32	60	–	–	–	–
particulate residue	kg/ha	110	370	480	34	10	7.9	170	220	700	13	1.7	4.4
	%	16	53	68	5	1	1	24	32	–	–	–	–
chlorides	kg/ha	160	26	190	310	110	50	540	1000	1200	0.37	0.53	0.50
	%	13	2	15	26	9	4	45	85	–	–	–	–
phosphorus	g/ha	1500	1300	2800	220	150	36	350	760	3600	6.4	1.0	3.0
	%	42	36	78	6	4	1	10	22	–	–	–	–
phosphates	g/ha	250	360	610	§15	15	5.5	80	100	710	18	0.91	5.1
	%	35	51	86	§2	2	1	11	14	–	–	–	–
total Kjeldahl N	g/ha	4900	3400	8300	1300	690	340	1800	4100	12,400	1.9	0.82	1.3
	%	39	27	67	10	6	3	14	33	–	–	–	–
ammonia	g/ha	§200	150	150	§65	46	41	380	470	620	1.8	1.5	1.6
	%	§30	24	24	§10	7	7	62	76	–	–	–	–
phenolics	g/ha	4.1	8.1	12	4.8	1.4	1.1	11	18	31	10	0.72	1.2
	%	13	27	39	16	5	4	36	61	–	–	–	–
COD	kg/ha	220	170	390	45	8.2	7.8	75	140	530	4.4	0.78	2.0
	%	42	32	74	9	2	1	14	26	–	–	–	–
fecal coliform bacteria	10^9org/ha	144	760	900	2.6	2.1	0.7	2.7	8.1	910	0.9	0.05	0.76
	%	16	84	99	§1	§1	§1	§1	1	–	–	–	–
fecal strep. bacteria	10^9org/ha	180	640	820	16	3.6	2.8	38	60	880	3.3	0.65	2.6
	%	20	73	93	2	§1	§1	4	7	–	–	–	–
pseudo. aerug. bacteria	10^9org/ha	50	70	120	0.36	0.03	0.02	0.20	0.61	120	1.3	0.12	1.1
	%	41	58	99	§1	§1	§1	§1	1	–	–	–	–
chromium	g/ha	860	600	1500	160	60	12	220	450	1910	71	30	53
	%	45	31	78	8	3	1	12	22	–	–	–	–
copper	g/ha	92	120	210	26	6.3	4.3	65	100	310	3.2	1.1	1.9
	%	29	38	67	8	2	1	21	33	–	–	–	–
lead	g/ha	§75	170	170	§25	8.6	7.1	130	150	320	4.2	0.88	1.5
	%	§20	54	54	§8	3	2	41	46	–	–	–	–
zinc	g/ha	370	430	800	100	36	29	280	450	1200	5.7	1.3	2.5
	%	30	35	64	8	3	2	22	36	–	–	–	–

data period: May 14, 1982 to Nov. 15, 1983 — Jan. 4, 1984 to March 22, 1984

Table 5.6 MAJOR CONTRIBUTING PERIODS BY PARAMETER

	Runoff Volume		total residue		filtrate residue		particulate residue		chlorides	
	resid.	indus.	resid.	indus.	resid.	indus.	resid.	indus.	resid.	indus.
Warm baseflow	31%	41%	28%	28%	28%	30%	4%	16%	20%	13%
stormwater	17	29	4	17	4	10	18	53	1	2
Cold baseflow	20	13	40	18	40	18	14	5	49	26
meltwater	33	16	29	38	27	41	63	26	29	58

	phosphorus		phosphates		total Kjeldahl N		ammonia	
	resid.	indus.	resid.	indus.	resid.	indus.	resid.	indus.
Warm baseflow	12	42	-	35	16	39	-	-
stormwater	24	36	24	51	30	27	21	24
Cold baseflow	16	6	-	-	16	10	-	-
meltwater	47	15	76	14	38	23	78	76

	phenolics		COD		FC		FS		PA	
	resid.	indus.	resid.	indus.	resid.	indus.	resid.	indus.	resid.	indus.
Warm baseflow	-	13	14	42	46	16	12	20	53	41
stormwater	5	27	19	32	40	84	61	73	46	58
Cold baseflow	9	16	19	9	9	-	4	2	1	-
meltwater	87	45	48	17	5	-	22	4	-	1

	Cr		Cu		Pb		Zn	
	resid.	indus.	resid.	indus.	resid.	indus.	resid.	indus.
Warm baseflow	-	45	22	29	-	-	14	30
stormwater	59	31	19	38	19	54	15	35
Cold baseflow	-	8	10	8	-	-	14	8
meltwater	41	16	49	24	81	46	56	27

Data was extrapolated from:
Warm period included samples in Thistledowns from July 28 through Nov. 15, 1983 and in Emery from May 14 through Nov. 15, 1983.
Cold period samples in Thistledowns were from Feb. 2 through March 25, 1984 and in Emery from Jan. 4 through March 22, 1984.

Table 5.7 <u>ESTIMATED WARM WEATHER UNIT AREA YIELDS FOR PCBs, PESTICIDES, PHENOLS, AND PRIORITY ORGANIC POLLUTANTS</u> (mg/ha/yr or g/ha/yr)

PARAMETER	units	Thistledown (residential)			Emery (industrial)		
		base-flow	storm-water	total	base-flow	storm-water	total
A-BHC	mg/ha	39	1.2	40	§2.7	6.4	6.4 to 9.1
B-BHC	mg/ha	§2.3	§1.2	§3.5	§2.7	§1.8	§4.5
G-BHC	mg/ha	11.4	§1.2	11.4 to 12.6	§2.7	§1.8	§4.5
A-chlordane	mg/ha	4.6	§2.3	4.6 to 6.9	§5.5	§3.7	§9.2
G-chlordane	mg/ha	4.6	§2.3	4.6 to 6.9	§5.5	§3.7	§9.2
Dieldrin	mg/ha	9.1	§2.3	9.1 to 11.4	§5.5	§3.7	§9.2
DMDT methoxychlor	mg/ha	§11	§5.8	§17	§14	§9.2	§23
Endrin	mg/ha	§9.1	§4.6	§14	§11	§7.4	§18
Endosulfan sulfate	mg/ha	§9.1	§4.6	§14	§11	§7.9	§19
Heptachlor	mg/ha	§2.3	§1.2	§3.5	§2.7	§1.8	§4.5
PCB	mg/ha	§46	§23	§69	~~1730~~	61	~~1789~~
PP-DDD	mg/ha	§11	§5.8	§17	§14	§9.2	§23
PP-DDE	mg/ha	§11	§5.8	§17	§14	§9.2	§23
PP-DDT	mg/ha	§11	§5.8	§17	§14	§9.2	§23
2365 tetrachlorophenol	mg/ha	§110	§58	§168	§140	§92	§230
pentachlorophenol	mg/ha	640	81	721	1370	1300	2670
Benzene	g/ha	NA*	5.8	-	NA	9.2	-
Chloroform	g/ha	NA	§1.2	-	NA	9.2	-
Trans-1,2-Dichloroethene	g/ha	NA	§1.2	-	NA	11	-
Methyl chloride	g/ha	NA	§2.3	-	NA	9.2	-
Trichloroethene	g/ha	NA	§1.2	-	NA	3.7	-
Toluene	g/ha	NA	§2.3	-	NA	9.2	-
Bis-(2-Ethylhexyl) Phthalate	g/ha	NA	9.3	-	NA	33	-
Butylbenzylphthalate	g/ha	NA	5.8	-	NA	110	-
Di-N-Butylphthalate	g/ha	NA	3.5	-	NA	7.4	-
Diethylphthalate	g/ha	NA	§2.3	-	NA	37	-
Isophorone	g/ha	NA	§1.2	-	NA	3.7	-
N-Nitrosodiphenylamine	g/ha	NA	§1.2	-	NA	5.5	-

* NA: priority pollutant organics were not analysed in any baseflow samples.

Note: § means "less than".

indicate that there are very few variations in concentrations of constituents for the different warm weather months.

Table 5.5 also shows the ratios of expected annual pollutant yields from the industrial catchment divided by the yields from the residential / commercial catchment. Many unit area annual yields from the industrial catchment exceeded the unit area annual yields from the residential / commercial catchment by significant factors, some as high as 50X, as listed below:

particulate residue	(4.4 X),
phosphorus	(3.0 X),
phosphates	(5.1 X),
chemical oxygen demand	(2.0 X),
fecal strep. bacteria	(2.6 X),
chromium	(53 X), and
zinc	(2.5 X).

The only constituents with an annual unit area yield that was lower in the industrial catchment than in the residential / commercial catchment were chloride and filtrate residue. The annual unit area yields from the Thistledown catchment were approximately twice the annual unit area yields from the Emery catchment for these constituents.

The Emery (industrial) catchment is similar to approximately 25 percent of the urban Humber River study area, while the Thistledown (residential / commercial) catchment is similar to approximately 75 percent of the urban Humber River study area. If the industrial to residential / commercial yield ratio was three for a selected constituent, then the industrial catchment yield would equal residential / commercial catchment yield throughout the whole study area. The results of this study indicate that particulate residues, phosphates, and especially chromium were mostly discharged from industrial catchments in the Humber River study area. Table 1.4 showed the weighted yield ratios for other common constituents.

If only warm weather stormwater runoff is considered (and not baseflows and snowmelts) then significant yield and control measure selection errors are probable. As an example, Table 5.5 shows residential / commercial unit area yields for total residue for stormwater alone to be approximately 240 kg/ha compared with approximately 670 kg/ha for the industrial catchment. These yields are similar to yields reported elsewhere for total annual total residue unit area yields. However, these warm weather stormwater runoff yields contributed only approximately five to 20 percent of the total annual total residue yields for these study catchments.

The summary shown on Table 5.6 shows the percentage contributions of each constituent by cold and warm weather baseflow and either stormwater runoff or snowmelt water. This table shows that annual yields of several constituents were dominated by cold weather processes irrespective of the land use monitored. These constituents include total residue, filtrate residue, chlorides, ammonia nitrogen, and phenolics. The only constituents for which the annual yields were dominated by warm weather processes, irrespective of land use were bacteria (fecal coliforms, fecal strep., and _pseudomonas_ _aeruginosa_) and chromium. Lead and zinc were both dominated by either stormwater or snowmelt runoff, with lower yields of these heavy metals originating from baseflows.

Warm weather stormwater runoff, alone, was the most significant contributor to the annual yields for a number of constituents from the industrial catchment. These constituents include particulate residue, phosphorus, phosphates, the three bacteria types, copper, lead and zinc. In the residential / commercial catchment, only fecal streptococcus bacteria and chromium were contributed by warm weather stormwater runoff more than by the other three sources of water shown. Either warm or cold weather baseflows were most responsible for the yields of many constituents from the industrial catchment. These constituents include runoff volume, phosphorus, total Kjeldahl nitrogen, chemical oxygen demand, and chromium. Important constituents that have high yields in the baseflow from the residential / commercial catchment include total residue, filtrate residue, chlorides, and fecal coliform and _pseudomonas_ _aeruginosa_ bacteria. Therefore, when considering a control program, the major contributing source of each pollutant must be considered, as discussed in Section 7.

Table 5.7 is a summary of annual yields of pesticides, PCBs, and organic "priority" pollutants. Because of the limited number of samples analysed for the organic priority pollutants this table should only be used for preliminary guidance. More importance should be placed on those constituents frequently measured above the detection limits, e.g. PCBs from the industrial catchment and pentachlorophenols from both catchments.

6.0 POLLUTANT SOURCES

6.1 IMPORTANCE OF URBAN RUNOFF POLLUTANT SOURCES

Urban runoff is comprised of many separate components that are combined at the outfall before entering the receiving water. It may be adequate to consider the combined outfall conditions alone when evaluating the long term, area wide effects of many separate outfall discharges to a receiving water. However, if better predictions of outfall characteristics or source area controls are needed, then the separate components must be recognized.

Figure 6.1 is a schematic diagram showing the many component sources for an idealized residential and light industrial catchment. This diagram shows three major sets of components: impervious areas, pervious areas, and drainage system components. The drainage system captures runoff from many sources beginning at the roof gutters and downspouts. If this runoff is discharged onto a paved area that in turn drains to the road gutter and storm drain inlet they are considered "directly connected" to the storm drain system. An example of this direct connection is shown at (a) on building H2 on Figure 6.1. Some roof drains are connected to the household sanitary sewer and would not contribute to the storm drain discharges. This practice of combined sewers is currently discouraged and many cities are actively disconnecting roof drains from the sanitary system. If the roof drains are discharged to pervious areas (b), much of the runoff would infiltrate and not contribute to the overland flow. There are also several types of roadside drainage components as listed below:

1) paved or concrete gutters (e),

2) sealed (paved) ditches (c), and

3) grass swale ditches (d).

Overland flow and street runoff enter these roadside drainages which direct the runoff to drainage inlets. Some inlets may be over catchbasins (g1) that have more sediment accumulation potential than other more simple inlets. Catchbasins or inlets are also typically located in large paved areas (g2). Manholes (h) are usually located in intersections where several connectors from nearby inlets are collected, and the runoff drops to the storm sewerage (i). The storm sewerage then discharges through an outfall (j) to the receiving water (k). The outfall may be elevated above the receiving water, with or without bars to restrict unauthorized entry, or it may be submerged, with backwater effects possibly extending great distances up the sewerage.

The various source areas all contribute different quantities of runoff and pollutants, depending on their specific characteristics. Impervious source areas may contribute most of the runoff during small rain events. Examples of these source area include paved parking lots, streets, driveways, roofs, and sidewalks. These are

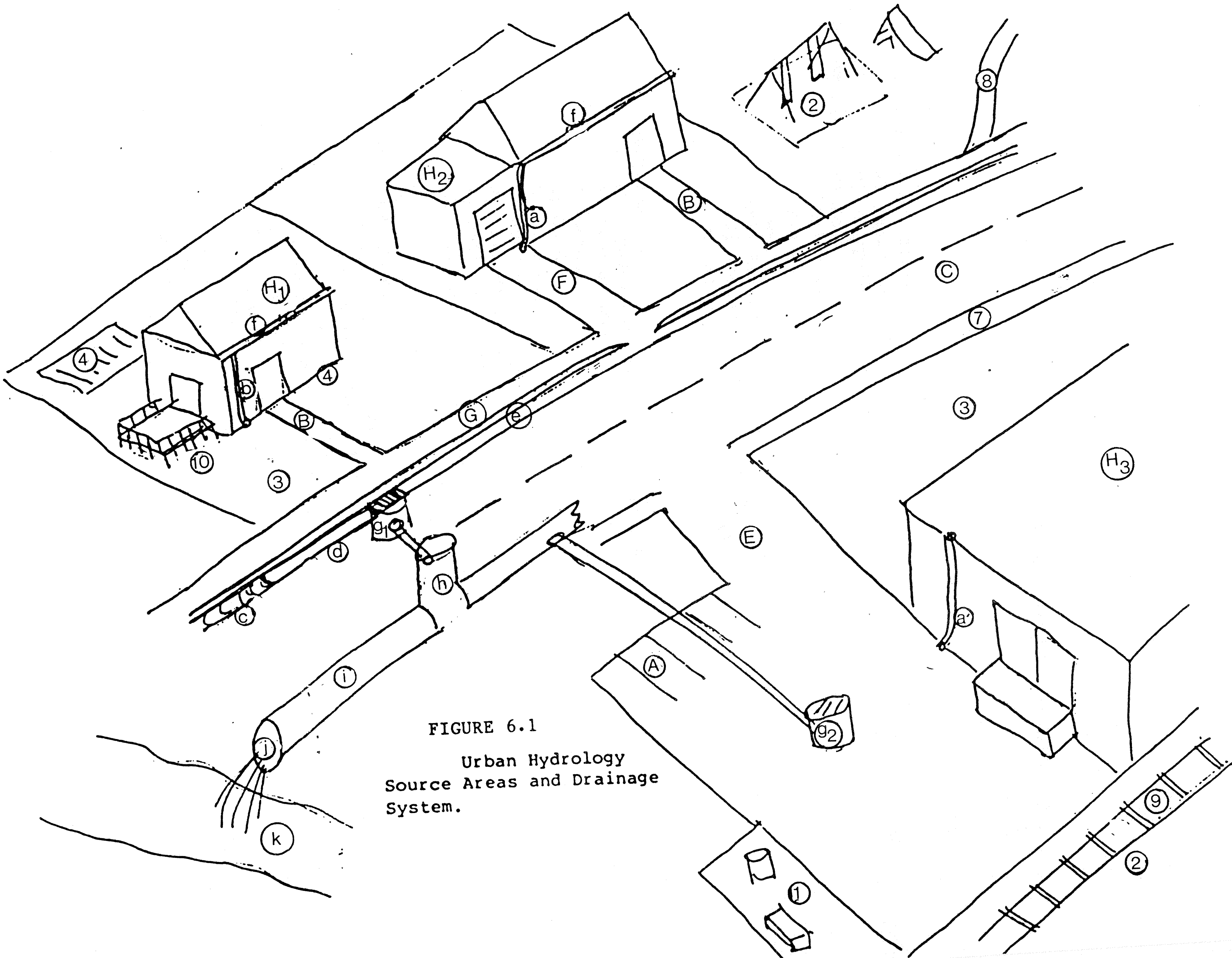


FIGURE 6.1

Urban Hydrology
Source Areas and Drainage
System.

shown as uppercase letters on Figure 6.1. Pervious source areas become important contributors for larger rain events. These pervious source areas include gardens, lawns, bare ground, unpaved parking areas and driveways, and undeveloped areas. They are identified with numbers on Figure 6.1 The relative importance of the sources is a function of their areas, their pollutant washoff potentials, and the rain characteristics. The discharge at the outfall is therefore made up of a mixture of contributions from different source areas. The "mix" depends on the characteristics of the drainage area and the specific rain event. The effectiveness of source area controls is therefore highly site and storm specific.

The deposition and removal of pollutants from the different source areas are shown on Figure 6.2. Unconnected ("upland") sources are affected by atmospheric deposition sources, and specific activities carried out in those areas. Examples of unconnected source areas are listed below:

1) rooftops and paved areas draining to pervious areas,

2) unpaved parking areas, driveways or streets,

3) undeveloped land,

4) landscaped ground, and

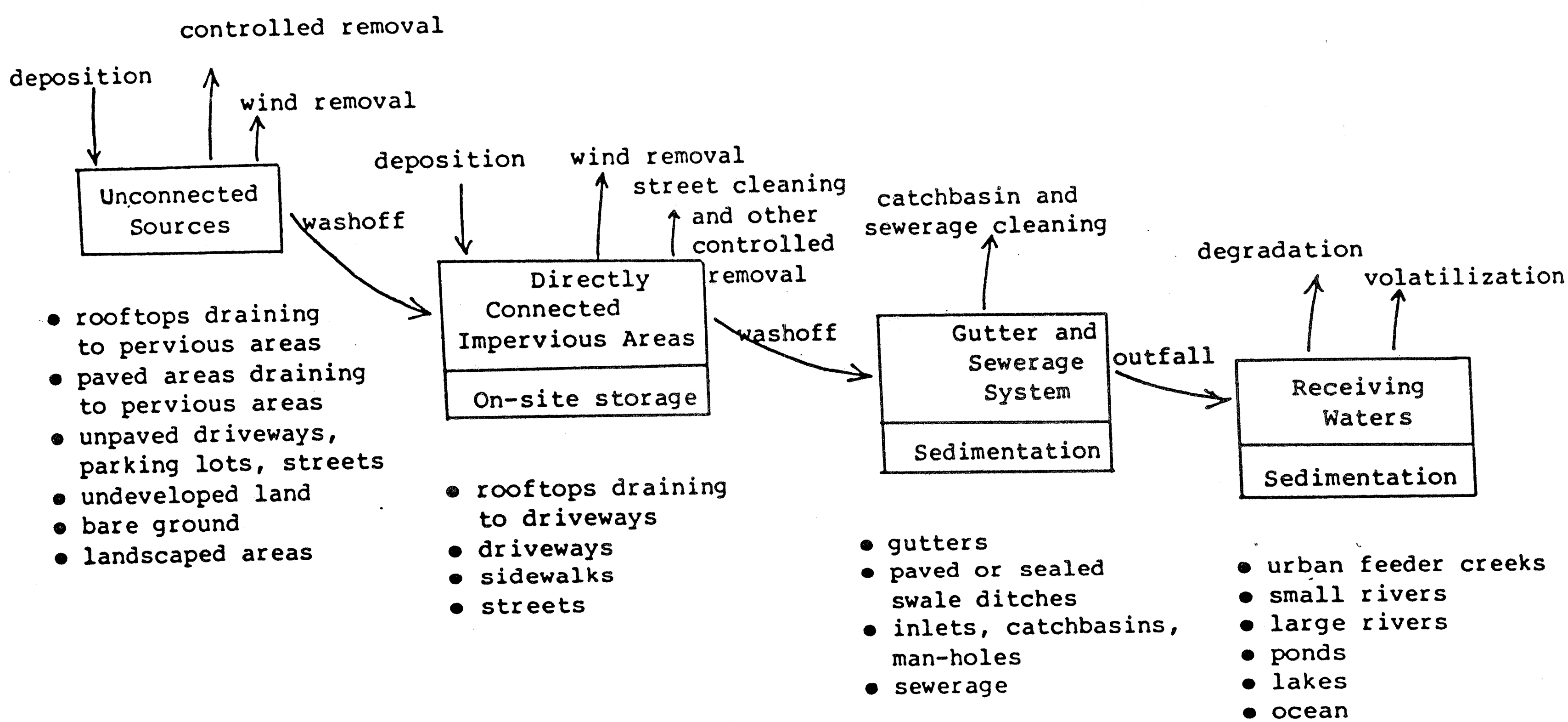
5) bare ground.

If unpaved lots are used for equipment or material storage, the soil can become contaminated by spills and debris. Undeveloped land remaining relatively unspoiled can also contribute residue, organics, and nutrients if eroded. Runoff originates from pervious areas only during relatively large rain events and only after soil infiltration and surface storage (ponding) capacities are exceeded.

The washoff of debris and soil is dependent on the energy of the rain and the properties of the material. Pollutants are also removed from these source areas by winds, litter pickup, or other cleanup activities. The runoff and pollutants from these pervious source areas are likely to directly enter the drainage system, or, more likely, will flow onto impervious areas that are directly connected to the drainage system.

Sources of pollutants on paved areas include on-site particulate storage that cannot be removed by usual processes e.g., rain, winds, or street cleaning, etc. Atmospheric deposition, deposition from activities on these paved surfaces (auto traffic, material storage, etc.) and the erosion of material from the upland unconnected areas are the major sources of pollutants to the directly connected impervious areas. The runoff from these connected areas enters the storm drainage system, where sedimentation, or sewerage cleaning may affect the ultimate discharges to the outfall. In-stream physical, biological, and

FIGURE 6.2 Pollutant Depositions and Removals at Source Areas



chemical processes affect the pollutants after they are discharged to the ultimate receiver.

It is important to know when the different source areas become "active". If pervious source areas are not contributing runoff or pollutants, then the prediction of urban runoff quality is much simplified. The mechanisms of washoff, and delivery yields of runoff and pollutants from paved areas is much better known than from pervious urban areas. In many cases, pervious areas are not active except during rain events greater than approximately five or ten mm. For small rain events, almost all runoff and pollutants originate from impervious surfaces.

In Ontario, most rain events are less than ten mm in depth. These small events generate only approximately 20 percent of the total annual runoff volume. If the number of events exceeding a water quality objective are important, e.g. for bacteria objectives, then the small rain events are of most concern. This is because of the large number of runoff events are associated with small rain events. If annual discharges are more important, e.g. for longterm effects, then the larger rain events are more important. These large rain events produce most of the annual runoff volume. The specific source areas that are important for these different conditions varies widely. Modeling procedures that are sensitive to source contributions as a function of rain characteristics are needed.

Source area contributions can be modeled by assuming the mass balance relationship:

$$L = \sum_{i=1}^{n} (A_i Q_i P_i W_i D_i)$$

for i to n total source areas

where L is the total yield of a specific pollutant at the outfall,

A is the area of the source in the drainage basin,

Q is the total quantity of particulates in a source area where the supply of particulates is limited,

P is the pollutant strength of the source area particulates,

W is the washoff fraction of the source area particulates, and

D is the delivery yield of the washed off source area particulates to the outfall.

The Q parameter is applicable to source areas where the source of particulates is limited. The washoff of particulates from impervious areas is usually limited at source by armouring and the lack of particulates that can be removed (eroded) by rains. For pervious areas, the Q factor is not used because the sources of particulates is usually not limited. These calculations must be separately made for each pollutant and rain event.

6.2 SHEETFLOW QUALITY

6.2.1 WARM WEATHER OBSERVATIONS

A major element of this Pilot Watershed Study was to determine the sources of stormwater runoff pollutants. Approximately 65 sheetflow samples were obtained from a variety of land covers during several rain events in both test catchments. Table F.1 presents this data for the major water quality constituents. No major ions, dissolved metals, or organic "priority" pollutants were analysed for warm weather sheetflow samples. Table E.16 contains the results of pesticides and PCB analyses on five source area samples collected in the industrial (Emery) catchment. Table 6.1 summarizes the data by showing the ranges and medians of the observed concentrations, separated by source area type and land use. The overall range of concentrations observed for each constituent is also shown. The major source categories used are listed below:

1) bare ground (unlandscaped areas, grass fields, and dirt foot paths),

2) unpaved driveways and storage areas,

3) roof runoff,

4) sidewalks,

5) paved parking/storage areas and driveways, and

6) paved roads.

Several drainage system samples were also obtained from source areas listed below:

1) grass swales,

2) sealed roadside ditches,

3) roadside gutters,

4) catchbasins, and

5) the separately drained Northern Telecom area in the Emery catchment.

The warm weather sheetflow water quality data were plotted against "the rain volume that had occurred before the samples were collected" to identify any possible trend of concentration with rain volume. The street runoff data obtained during the special washoff tests was combined with street sheetflow data obtained

Table 6.1 WARM WEATHER SHEETFLOW QUALITY SUMMARY (concentrations in mg/L)

	total residue	filtrate residue	particulate residue	phosphorus	reactive phosphate	total Kjeldahl N	ammonia N	phenolics (ug/L)	COD
Bare ground									
Emery - median	488	241	248	0.62	0.20	2.7	0.2	0.8	40
- range	388-588	196-285	103-392	0.56-0.68	0.14-0.26	1.8-3.6	§0.1-0.4	0.8	26-54
Thistledown	1240	436	807	0.20	0.66	1.3	0.5	§0.4	66
Unpaved driveways, stor. areas									
Emery - median	1148	377	805	1.09	0.09	2.8	§0.1	9.0	247
- range	670-5620	161-1220	309-4670	0.6-3.0	§0.02-0.42	2.0-7.5	§0.1	1.8-14.8	140-440
Roof runoff									
Emery - median	113	107	6	§0.05	§0.02	1.7	0.35	1.2	55
- range	74-151	71-142	3-8.8	§0.06	§0.02	1.3-2	0.3-0.4	0.8-1.6	34-76
Thistledown - median	44	40	4	§0.04	§0.02	0.8	0.1	2.8	36
- range	31-112	30-72	1-40	§0.04-0.13	§0.04	0.5-2.2	§0.1-0.2	0.8-3.0	14-96
Sidewalks									
Emery - median	580	145	435	0.82	0.03	4.7	§0.1	8.7	98
- range	269-890	107-186	86-783	0.34-1.3	§0.04-0.06	3.5-5.8	§0.1	8.2-9.2	58-138
Thistledown	49	28	20	0.8	0.64	1.1	0.3	8.6	62
Paved park./stor. & driveways									
Emery - median	315	112	202	0.9	0.06	3.1	0.3	8.6	132
- range	73-1637	58-427	14-1210	§0.4-10.3	§0.02-2.8	1.0-7.0	§0.1-1.0	2.6-17	52-496
Thistledown - median	952	268	687	0.62	§0.02	2.2	§0.1	11.8	67
- range	73-7930	29-345	41-7880	0.1-1.75	§0.02-0.14	0.8-12	§0.1-0.5	3.6-33.8	12-478
Paved roads									
Emery - median	992	188	871	0.9	0.06	3.5	§0.1	14.7	326
- range	299-2351	97-2440	170-4430	0.2-5.1	§0.02-0.78	1.1-15	§0.1	9.8-74	96-560
Thistledown - median	185	51	137	0.49	0.03	1.6	§0.1	6.3	66
- range	97-1120	41-248	43-870	0.18-1.5	§0.02-0.30	0.9-7.5	§0.1	3.0-9.6	50-696
Overall range	31-7930	28-2440	4-7880	§0.04-10.3	§0.02-0.78	0.5-15	§0.1-0.5	§0.4-74	12-696

Note: § means "less than".

Table 6.1 WARM WEATHER SHEETFLOW QUALITY SUMMARY (concentrations in mg/L) continued

	fecal coliform (1000 org/100 mL)	fecal strep. (1000 org/100 mL)	pseudo. aerug. (1000 org/100 mL)	aluminum	copper	nickel	lead	zinc
Bare ground								
Emery - median	3.3	43	2.1	6.3	§0.2	0.01	§0.3	0.05
- range	-	-	-	1.5-11	§0.02-§0.2	§0.1-0.02	§0.04-§0.3	§0.1-0.1
Thistledown	-	-	-	1.7	0.02	§0.01	0.03	0.04
Unpaved driveways, stor. areas								
Emery - median	26	6.2	0.5	8.8	0.14	0.035	0.25	0.50
- range	0.02-300	0.18-22	0.02-51	2.8-41	0.02-0.25	§0.03-0.4	§0.02-0.37	0.26-0.69
Roof runoff								
Emery - median	1.6	0.69	0.05	§0.2	0.015	§0.02	§0.04	0.07
- range	0.56-2.6	0.38-1.0	§0.02-0.1	§0.2	§0.02-0.03	§0.02	§0.04	0.06-0.08
Thistledown - median	0.5	0.94	0.1	§0.2	§0.02	§0.04	§0.03	0.31
- range	0.12-3.7	0.54-5.1	0.02-90	§0.04-0.15	§0.01-0.03	§0.01-0.12	§0.01-§0.04	0.01-0.66
Sidewalks								
Emery - median	55	3.6	3.6	1.2	0.03	§0.04	0.04	0.06
- range	19-90	3.3-3.9	0.1-7.1	-	-	-	-	-
Thistledown	11	1.8	0.6	0.48	0.02	§0.04	0.08	0.06
Paved park./stor. & driveways								
Emery - median	2.8	0.9	0.7	2.85	0.045	§0.035	0.19	0.34
- range	0.03-66	§0.1-39	0.02-15	0.53-9.5	0.02-2.9	§0.02-0.14	§0.04-0.97	0.08-2.8
Thistledown - median	2.0	1.5	0.52	0.40	0.05	§0.03	0.35	0.45
- range	0.1-980	§0.1-690	0.08-5	§0.08-9.2	§0.01-0.36	§0.01-0.09	§0.02-1.4	0.02-1.1
Paved roads								
Emery - median	19	8.5	5.4	7.3	0.13	0.03	0.51	0.59
- range	1.8-430	0.6-240	1-15	5.6-51	0.07-0.78	§0.02-0.08	0.15-1.0	0.26-2.1
Thistledown - median	4.8	7.9	0.1	0.65	0.02	§0.02	0.13	0.16
- range	0.8-15	1.1-13	0.02-1.7	§0.04-5.4	§0.01-0.14	§0.01-0.04	§0.02-0.45	0.03-0.47
Overall range	0.02-980	§0.1-690	§0.02-90	§0.04-51	§0.01-2.9	§0.01-0.40	§0.01-1.4	0.01-2.8

Note: § means "less than".

during actual rain events to prepare these plots. Figure 6.3 plots total residue versus elapsed rain and shows some definite trends, especially for the street runoff data. Figures F.1 through F.6 show the plots for the source area groups separately. These trends were used with the runoff source information presented earlier to estimate the total residue yield from sources for a variety of events. Figure 6.3 shows that sheetflows from all pervious areas combined had the highest total residue concentrations from any source category, for all rain events. The street surface runoff data were considered separately from other paved areas. Other paved areas had total residue concentrations similar to runoff from smooth industrial streets. The concentrations of total residue in roof runoff were almost constant for all rain events. They were relatively low for small rain events and relatively high for large rain events.

Table 1.5 compared selected warm weather source area median sheetflow concentrations for the different source categories and also showed the median stormwater outfall concentrations for the events when the sheetflow samples were obtained. No clear trends were evident for all the constituents. Lead and zinc concentrations were highest in sheetflows from paved parking areas and streets, with some high zinc concentrations also found in roof drainage samples. High bacteria populations were found in sidewalk, road, and some bare ground sheetflow samples. These are places where dogs would most likely be "walked".

Table E.16 showed that pentachlorophenol was detected (400 to 500 ng/L concentrations) in four of the five industrial source area samples analysed. These samples were collected from the Northern Telecom drain and from a paved storage yard. Two of the five industrial source area sheetflow samples analysed also had detectable PCBs (80 and 190 ng/L), A-BHC (8 and 10 ng/L), and G-BHC (2 and 10 ng/L) concentrations.

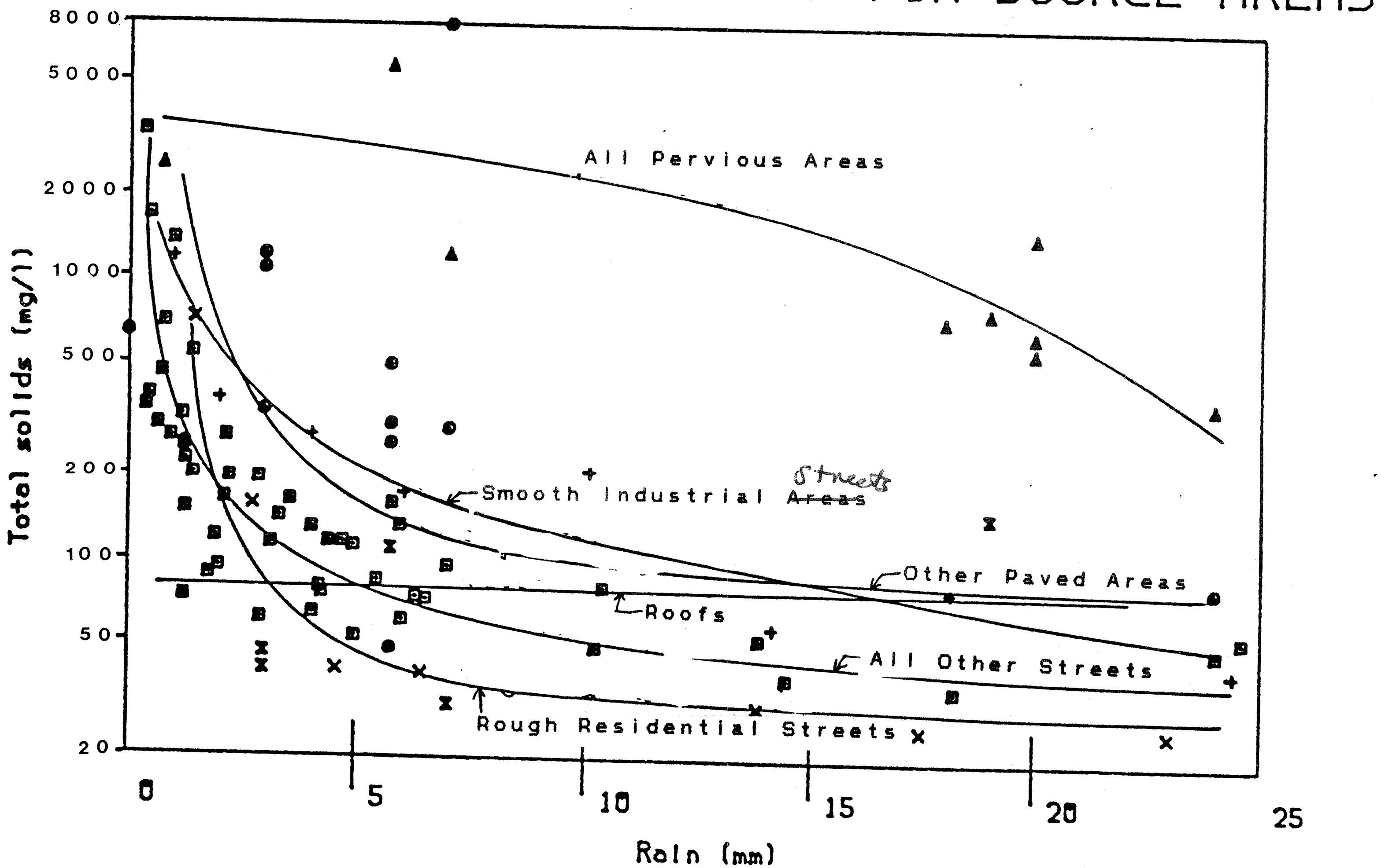
Some of the sheetflow contributions are not sufficient to explain the concentrations of some constituents observed in runoff at the outfall. The low chromium sheetflow contributions from the industrial area indicate the high potential of subsurface contributions of the metal to the stormwater drainage system. Chromium was rarely detected in any sheetflow samples, but was found in potentially problem concentrations at the industrial outfall. Similarly, most of the fecal coliform populations observed in sheetflow were significantly lower than those observed at the outfall. This was especially so for the residential / commercial catchment, indicating potential sanitary sewerage leakage.

6.2.2 SNOWMELT SHEETFLOW OBSERVATIONS

Cold weather snowmelt sheetflow samples were also obtained during the snowmelt extension to this project. Approximately 95 samples were obtained from the same locations that were sampled for warm weather sheetflow samples. Two periods of snowmelt were monitored. Snowmelt sheetflow samples were collected on 15 and 16 February, 1984, in both catchments, on 16 March, 1984, in the Emery catchment

FIGURE 6.3

TOTAL SOLIDS VERSUS RAIN FOR SOURCE AREAS



and on 21 March, 1984, in the Thistledown catchment. No roof snowmelt runoff samples were obtained. Tables F.2 through F.5 present these data for the major constituents, major ions, dissolved metals, and pesticides and phenolics. Table 6.2 summarizes these observations, by source area group. Most of the source area categories had from five to ten analyses each. The improved distribution of analyses during the snowmelt sheetflow sampling program was due to the longer runoff events than were sampled during the warm weather sheetflow program. Snowmelts are also much more predictable than rain storms. Because of the limited scope of the snowmelt effort, detailed statistical comparisons of these data was not attempted, beyond the preparation of data summaries.

As with the warm weather sheetflow samples, the highest concentrations of lead and zinc were found in samples collected from paved parking areas and roads. However, in contrast to the warm weather samples, the pervious areas had the lowest residue concentrations. This was probably because of the influence of road salting on filterable residue concentrations near roads. Only a few roads were salted in the two test areas during the period of study, so the decreased delivery of particulates from the more distant pervious areas to the drainage system during snowmelts must also be considered.

The major ion observations from Table F.3 show that the snowmelt sheetflows from paved areas had sodium and chloride as the major ions. For some unpaved storage yards and open space areas, the sheetflow water type varied from sodium chloride to potassium or calcium chloride. This change in ionic balance indicates a smaller influence of road salting as the distance from the roads or parking areas to the sampling location increases, or the use of alternative de-icing compounds on these paved surfaces.

The dissolved metal observations shown on Table F.4 are difficult to interpret because of the large number of observations that were below detection limits. Six of the eight detectable data sets for chromium indicate mostly particulate forms of chromium. Five of eight copper data sets indicated dissolved copper as being more common than particulate copper. All 13 lead data sets indicate particulate forms of lead. Eleven of the 15 zinc data sets indicate mostly particulate zinc. Eleven of the 14 manganese data sets indicate mostly particulate manganese. Table F.5 presents miscellaneous dissolved metal observations. These data are not paired with simultaneous total metal analyses. It shows that significant concentrations of dissolved aluminum (up to 91 mg/L) were found in most of the ten samples analysed. The other metals had very few detectable concentrations of dissolved metal. Therefore, for the metals analysed, copper and aluminum were the only metals that showed major amounts of dissolved metal forms.

Particulate materials located far from the drainage system may not be easily transported to the drainage system during periods of "low energy" snowmelt runoff. The ease of transportation depends partly

Table 6.2 SNOWMELT SHEETFLOW QUALITY (mg/L, unless noted)

Source Area		approx. # of obs.	total residue	filtrate residue	particulate residue	chlorides	phosphorus	phosphates	total Kjeldahl N	ammonia	phenolics (ug/L)
Grass and Open Areas											
Emery	-median	11 to 14	390	280	77	100	0.33	0.10	1.4	§0.1	3.0
	-range		92-1400	63-1060	13-770	3.6-540	0.1-0.95	0.02-0.34	0.8-4.8	§0.1-0.41	§0.2-8.0
Thistledown	-median	3 to 5	94	75	40	4.0	0.12	0.20	1.2	0.4	1.4
	-range		39-340	32-150	7.8-260	1.4-21.2	0.29-1.10	0.08-0.82	1.0-5.6	0.2-3.0	0.8-8
Unpaved Parking & Storage Areas											
Emery	-median	9 to 12	1450	740	550	113	1.1	§0.02	5.3	§0.1	9
	-range		306-16,900	77-5690	85-15,400	3.6-283	0.08-17.5	§0.02-1.8	0.8-32.5	§0.1-0.3	1.2-100
Sidewalks											
Emery	-median	1 to 2	1050	200	850	48	0.45	0.20	1.6	§0.01	3.7
	-range		780-1320	180-219	590-1100	48	0.40-0.50	0.20	1.3-1.8	§0.01	3.4-4
Thistledown	-median	3 to 7	390	91	280	6.4	0.63	0.38	2.6	0.8	1.4
	-range		136-690	65-240	67-460	2.4-47.6	0.14-1.0	0.08-0.68	1.4-10	§0.1-0.8	§0.6-2.4
Paved Driveways, Loading, & Parking											
Emery	-median	6 to 12	1690	350	390	255	0.55	0.18	3.8	§0.1	4.0
	-range		220-9120	84-8400	90-4760	24-4740	0.20-4.6	0.06-0.36	0.8-11	§0.1-0.2	1.0-27
Thistledown	-median	7 to 11	920	270	380	81	0.64	0.08	2.5	0.01	2.6
	-range		170-4690	84-1330	47-3360	12-720	0.12-2.8	§0.02-0.30	0.8-9.0	§0.1-0.2	0.8-50
Grass Swales											
Thistledown	-median	7 to 10	190	130	50	37	0.59	0.12	1.8	§0.1	1.6
	-range		130-450	69-240	20-290	8.0-72	0.15-1.9	§0.04-0.66	1.0-8.8	§0.1-1.4	§0.6-3.0
Paved Road Gutters											
Emery	-median	4 to 8	1320	580	630	168	0.60	0.14	1.8	§0.01	9.0
	-range		690-2030	240-1130	430-950	71-330	0.45-1.2	0.08-0.18	1.5-3.0	§0.01	4-18
Thistledown	-median	5 to 7	249	190	152	25	0.54	0.28	2.3	§0.1	1.8
	-range		230-6960	98-409	34-6720	14-220	0.22-5.5	§0.06-0.66	1.3-8.5	§0.1-3.2	1.2-4.0
Roads											
Thistledown	-median	3 to 6	890	166	380	56	0.30	0.06	1.8	§0.01	3.2
	-range		150-1430	86-1240	29-950	4.2-590	0.15-1.0	§0.02-0.40	0.8-5.5	§0.01	1.6-19

Note: § means "less than".

Table 6.2 SNOWMELT SHEETFLOW QUALITY (mg/L, unless noted) continued

Source Area	COD	fecal coliforms (#/100mL)	fecal strep. (#/100mL)	pseudo. aerug. (#/100mL)	cadmium	chromium	copper	lead	zinc
Grass and Open Areas									
Emery -median	47	§20	§100	§20	§0.005	0.01	0.01	0.01	0.06
-range	16-170	§10-20	§10-20	§20-20	§0.005	§0.01-0.06	§0.01-0.14	§0.02-0.19	0.01-0.39
Thistledown -median	26	§20	350	§10	§0.005	§0.01	§0.01	§0.04	0.02
-range	16-112	§10-100	30-3000	§10	§0.005	§0.01-0.61	§0.01-0.07	§0.02-0.08	§0.04-0.07
Unpaved Parking & Storage Areas									
Emery -median	160	§100	50	§20	§0.005	0.10	0.12	0.26	0.51
-range	20-4450	§20-1900	§100-2600	§10-80	§0.005-0.013	§0.01-0.38	0.01-0.86	0.04-1.60	0.05-2.80
Sidewalks									
Emery -median	63	§50	§50	§20	§0.005	0.02	0.11	0.19	0.47
-range	36-90	§10-§100	§10-§100	§20	§0.005	§0.01-0.03	0.06-0.16	0.10-0.28	0.15-0.78
Thistledown -median	98	75	730	§20	§0.005	§0.01	0.02	0.15	0.16
-range	34-122	§10-3400	110-1120	§20	§0.005-0.012	§0.01-0.06	0.01-0.06	0.02-0.29	0.07-2.70
Paved Driveways, Loading, & Parking									
Emery -median	135	§100	460	§20	§0.005	0.02	0.05	0.20	0.40
-range	34-1700	§10-5100	§10-26,000	§20	§0.005-0.015	§0.01-0.22	§0.01-0.64	§0.06-1.90	0.04-3.4
Thistledown -median	110	§20	180	§20	§0.005	0.02	0.04	0.23	0.23
-range	4.2-970	§10-21,000	§20-6700	§10-200	§0.005-0.012	§0.01-0.14	0.01-0.28	§0.04-2.8	0.04-2.2
Grass Swales									
Thistledowns-median	40	60	2100	§10	§0.005	§0.01	0.01	0.12	0.08
-range	6.2-110	§10-2700	60-†15,000	§10	§0.005	§0.01-0.01	§0.01-0.03	§0.02-0.23	0.01-0.15
Paved Road Gutters									
Emery -median	234	§100	100	§20	§0.005	0.05	0.12	0.45	0.66
-range	180-360	§10-1500	§100-800	§20	§0.005-0.005	0.02-0.10	0.05-0.85	0.22-1.10	0.25-1.70
Thistledown -median	66	60	4200	§10	§0.005	0.01	0.02	0.12	0.09
-range	28-140	§10-§1600	160-†15,000	§10-10	§0.005-0.006	§0.01-0.06	0.01-0.25	0.03-1.5	0.04-1.6
Roads									
Thistledown -median	140	50	190	§10	§0.005	0.01	0.05	0.26	0.26
-range	30-246	§20-1500	100-1440	§10	§0.005	§0.01-0.08	0.01-0.17	0.07-1.5	0.06-0.99

Note: § means "less than" and † means "greater than".

on the size of the particles. Rain events have much more energy available to dislodge and transport particulates. Channelised flow, either from snowmelts or rain, can be effective in moving particulates. The poor delivery of particulate pollutants during snowmelts is also indicated on Table 6.2. This table indicates that cold weather sheetflow concentrations of lead and zinc in the industrial catchment were much greater than the concentrations observed at the outfall during the same snowmelts. This table also indicates significant subsurface pollutant inputs to the storm drain system. Fecal coliform populations at the outfall were much greater than any of the bacteria populations observed in snowmelt sheetflow. This indicates the possibility of sanitary sewerage leakage. The only fecal coliforms observed during the cold weather sheetflow analyses were on sidewalks, and on and near roads in the residential catchment. Again, these are the areas where dogs would be "walked". No fecal coliforms were found in snowmelt samples collected from open spaces in either study area, decreasing the probability of significant wildlife bacteria sources.

High concentrations of chloride measured at the outfall were puzzling. Relatively high concentrations of chloride were observed in the source areas along with high concentrations of chloride in the snowpack near roads, but these were generally not high enough to account for the high outfall chloride observations (several hundred mg/L) during these periods of sampling. Very high chloride concentrations (several thousand mg/L) were found in the snowpack very close to the roads. During early portions of snowmelts, these very high chloride concentrations would affect the snowmelt long before the more distant very low chloride concentrations further from the road. Therefore, sample timing could have affected these chloride observations. Concentrations of chloride in the shallow ground water are expected to be elevated (but not extremely high) during snowmelt periods. Therefore the potential leakage of ground water into the storm drainage system should not have significant effects on the concentration of chloride at the outfall.

Table F.5 shows the pesticide and PCB concentrations analysed in the nine cold weather sheetflow samples. Three of the nine samples had no detectable pesticides or PCBs, two samples had one constituent observed in each, and two samples had two constituents observed. One sample from an unpaved storage area at a waste storage area had nine constituents above the detection limit. A-BHC was the most commonly detected pesticide and was found in six samples in concentrations ranging from three to seven ng/L. The detection limit for A-BHC was one ng/L. G-BHC was found in four samples and ranged in concentration from one to 16 ng/L.The detection limit for G-BHC was also one ng/L. All the other pesticides and PCBs observed were found in only one sample each. The high concentrations of PCB (3750 ng/L) and pp,DDT (15 ng/L) are disturbing. Both were observed at the same unpaved waste storage area. The PCB was identified by the laboratory as resembling Aroclor 1260. Besides the PCB and pp,DDT concentrations noted above, most of the pesticides observed in samples from the waste storage site were from four to 16 times the relevant detection limits.

6.2.3 SNOW TRANSECT OBSERVATIONS

Another task of the special snowmelt addition to the project involved examining snowpack water quality in both catchments. One monitoring site was located on Calstock Blvd in the Thistledown (residential / commercial) catchment. One side of the street had a school and the area had low traffic densities. The other monitoring site was located on Signet Road in the Emery (industrial) catchment. This site had high traffic densities.

At both sites, trenches were dug from the edge of the snow closest to the road to a point 25 metres from the road, in a perpendicular direction. Samples representing the complete vertical snow profile were collected at various distances from the road. The samples were closely spaced near the road and increasingly widely spaced as the distance from the road increased. The snow samples were slowly melted to an ice / water mixture in an unheated warehouse prior to submission to the laboratory. The results are therefore expressed in terms of concentrations in the meltwater per litre of meltwater.

Tables F.6 through F.11 present the data obtained. Table 6.3 is a summary showing selected snowmelt quality conditions at several locations along the transects. Seventeen samples from each site were analysed for a broad list of constituents. Tables F.6 and F.7 also show the snowpack depth at each sampling location. The snow depth at Calstock Blvd varied from a low of approximately 60 mm near the road edge to a high of 850 mm in the roadside windrow. The snowpack depth 25 m from Calstock Blvd was approximately 200 mm. Snowpack depths were much lower at the Signet Road site, ranging from a thin ice sheet near the road edge to a windrow height of approximately 460 mm. The snow depth 25 m from the Signet Road was only approximately 50 to 100 mm.

Many of the concentrations of constituents decreased substantially as the distance of the sample from the road increased, especially at the Signet Road site. Concentrations were relatively constant after approximately three to five meters from the snowpack edge, at both sites. Most of the constituents (such as total residue, particulate residue, lead, and zinc) had generally higher concentrations at the heavy traffic site on Signet Road in the industrial catchment. Total phosphorus concentrations were typically higher at the light traffic site on Calstock Blvd in the residential / commercial catchment. The bacteria summary shown on Table F.8 shows only one observation of bacteria at the Signet site, and several detectable observations for fecal coliforms near the road at the Calstock site. Many fecal streptococci observations were obtained at the Calstock site with populations ranging from 20 to 500 organisms per 100 ml. There is no apparent trend with distance from the road. The Calstock fecal coliform observations only occurred near the road and were generally low (40 and 320 organisms per 100 mL). The major ion analyses on the meltwater from Signet Road indicates a road salting influence for at least the

Table 6.3 AVERAGED SNOWPACK TRANSECT QUALITY (mg/L[1])

	Distance from Roads (total averaged)[2] 1 m	5 m	10 m	25 m
Total residue				
Emery (Signet)	530	210	120	110
Thistledown (Calstock)	87	60	35	14
Particulate residue				
Emery	220	95	54	20
Thistledown	11	11	8	3
Total phosphorus				
Emery	0.012	0.005	0.003	0.001
Thistledown	0.022	0.015	0.010	0.004
Lead				
Emery	0.024	0.032	0.031	0.011
Thistledown	0.016	0.007	0.004	0.003
Zinc				
Emery	0.010	0.06	0.04	0.01
Thistledown	0.025	0.014	0.008	0.007

(1) as melted snow
(2) averaged for equal distance increments from road edge to distance indicated.

first five meters of the transect. This data is listed in Table F.9.

Table F.10 shows the dissolved metal data for the two Signet samples analysed for these constituents. Most of the observations indicated that most of the metals were in particulate forms. The exceptions to this generalisation are from one observation each of zinc and cadmium that indicated large amounts of these metals in dissolved forms at the sampling location closest to the road. Some of the copper was also in dissolved forms. These dissolved metals could be associated with common heavy metal contamination of the de-icing compound.

Two of the Signet Road samples were also analysed for pesticides and PCBs. the results of these tests are shown on Table F.11. The six compounds detected were all at concentrations quite close to the detection limits and were also generally found in the snowmelt sheetflow samples.

Figures F.7 through F.16 are plots of contaminant loadings for different distances from the edge of the snowpack. The units are expressed as grams per square metre of snow surface. These plots show dramatic decreases in snowpack quality as the distance from the roads increase.

6.2.4 SHEETFLOWS COMPARED TO ONTARIO WATER QUALITY OBJECTIVES

The warm weather sheetflow data was compared to the Provincial Water Quality Objectives on Table 6.4. Discharges from the outfall can be compared to the objectives to identify pollutants that may contribute to existing or future receiving water problems. Most of the warm weather sheetflow samples exceeded the relevant objectives. Phenolics, zinc, copper, lead, phthalates, and PCBs were the most important warm weather sheetflow constituents to exceed the objectives.

Cold weather sheetflow observations were also compared to the Ontario Water Quality Objectives on Table 1.3. In the industrial catchment, almost all of the phenolics, copper, lead, and zinc observations from cold weather sheetflows from all source areas exceeded the objectives. Some of the fecal coliform and chromium observations from the source areas also exceeded the objectives. The most significant difference between the cold and warm weather sheetflow observations from the industrial catchment was the decreased frequency of fecal coliform observations exceeding the objective during cold weather. Similar conclusions can be made concerning cold weather sheetflows exceeding the water quality objectives in the residential / commercial catchment, except that the violations of the chromium objective are much less frequent than in the industrial catchment.

6.2.5 SOURCE AREA CONTRIBUTIONS TO OUTFALL YIELDS

It is possible to estimate the effects that different rain events have on contributions from different source areas to warm weather stormwater runoff yields because different runoff processes are

Table 6.4 WARM WEATHER WATER QUALITY OBSERVATIONS COMPARED TO OBJECTIVES

	Provincial Water Quality Objectives		Ontario Drinking Water Quality Objectives				Ontario Agriculture Water Quality Objective			
			Only if no other supply		Cause for rejection		Livestock watering		Irrigation water	
	limit	% † limit	limit	% † limit	limit	% † limit	limit	% † limit	limit	% † limit
Baseflow Para.										
Filtrate residue	narrative----------		500 mg/L	28%/100%	-	-	-	-	-	-
Phenolics	1 ug/L	66%/20%*	1 ug/L	66%/20%	-	-	-	-	-	-
Fecal coliforms	100/100 mL	100%/100%	-	-	-	-	-	-	-	-
Aluminum	-	-	-	-	-	-	5.0 mg/L	21%/0	5-20 mg/L	4-21%/0
Chromium	0.1 mg/L	93%/0	-	-	0.05 mg/L(1)	?	1.0 mg/L	17%/0	0.1-1.0 mg/L	17-93%/0
Copper	0.005 mg/L	93%/57%	1.0 mg/L	10%/0	-	-	0.5 mg/L	17%/0	0.2-5.0 mg/L	0-20%/ 0-57%
Lead	0.025 mg/L	13%/29%	-	-	0.05 mg/L	13%/14%	0.1 mg/L	13%/0	5-10 mg/L	0-3%/0
Zinc	0.03 mg/L	100%/43%	5.0 mg/L	0/0	-	-	25 mg/L	0/0	2-10 mg/L	0-7%/0
Stormwater Para.										
Filtrate residue	narrative----------		500 mg/L	3%/17%	-	-	-	-	-	-
Phenolics	1 ug/L	100%/64%	1 ug/L	100%/64%	-	-	-	-	-	-
Fecal coliforms	100/100 mL	100%/100%	-	-	-	-	-	-	-	-
Aluminum	-	-	-	-	-	-	5.0 mg/L	39%/8%	5-20 mg/L	0-39%/ 0-8%
Chromium	0.1 mg/L	89%/0	-	-	0.05 mg/L(1)	?/0	1.0 mg/L	11/0	0.1-1.0 mg/L	11-89%/0
Copper	0.005 mg/L	97%/84%	1.0 mg/L	0/0	-	-	0.5 mg/L	0/0	0.2-5.0 mg/L	0-12%/0
Lead	0.025 mg/L	82%/48%	-	-	0.05 mg/L	77%/36%	0.1 mg/L	44%/16%	5-10 mg/L	0/0
Zinc	0.03 mg/L	97%/96%	5.0 mg/L	0/0	-	-	25 mg/L	0/0	2-10 mg/L	0/0
Sheetflow Para.										
Filtrate residue	narrative----------		500 mg/L	4%	-	-	-	-	-	-
Phenolics	1 ug/L	97%	1 ug/L	97%	-	-	-	-	-	-
Aluminum	-	-	-	-	-	-	5.0 mg/L	35%	5-20 mg/L	3-35%
Copper	0.005 mg/L	77%	1.0 mg/L	2%	-	-	0.5 mg/L	3%	0.2-5 mg/L	0-16%
Lead	0.025 mg/L	65%	-	-	0.05 mg/L	61%	0.1 mg/L	56%	5-10 mg/L	0
Nickel	0.025 mg/L	28%	-	-	-	-	1.0 mg/L	0%	0.2-2 mg/L	0-3%
Zinc	0.03 mg/L	88%	5.0 mg/L	0%	-	-	25 mg/L	0%	2-10 mg/L	0-2%

* Emery/Thistledown

(1) The chromium drinking water quality objective is only for the hexavalent form of chromium.
† means "greater than".

Table 6.4 WARM WEATHER WATER QUALITY OBSERVATIONS COMPARED TO CRITERIA AND OBJECTIVES (continued)

Constituent	Ontario Water Quality Objective	Baseflow Emery	Baseflow Thistle-down	Stormwater Emery	Stormwater Thistle-down	Sheet-flows
Dieldrin	1 ng/L	0/9(1)	1/1	0/12	2/7	0/5
Endrin	2 ng/L	0/9	0/1	0/12	1/7	0/5
Heptachlor	1 ng/L	0/9	0/1	0/12	1/7	0/5
Dibutylphthalate(2)	4 ug/L	NA(3)	NA	1/1	0/1	2/3
Other Phthalates	0.2 ug/L	NA	NA	1/1	1/1	2/3
Polychlorinated Biphenyl	1 ng/L	1/9	0/1	7/12	0/7	2/5

(1) number of observations exceeding objective / total number of observations

(2) Di-N-Butylphthalate analysed

(3) NA means "not analysed"

occurring during different rain conditions. These processes were described in Section 6.1.

It should be noted that the urban storm water quality model Toronto/SLAMM is based on organizing the expected runoff processes as a function of rain characteristics for each source area. An early version of SLAMM was used to predict the relative contributions of selected constituents to the yield at the outfall from sheetflow from different source areas during warm weather.

Figures 6.4 and 6.5 shows plots of the relative contributions of total residue from different sources as a function of rain volume. These plots are called source area diagrams. For very small rain events, the impervious areas contribute all of the residue. Pervious areas start to contribute important residue (due to erosion) in the runoff from moderate rain events (about 5 mm).

Relative pollutant strengths were obtained from the sheetflow analyses and dry particulate samples, discussed in Section 6.3. These relative strengths are expressed in units of mg pollutant per kg total residue. They were used to produce source area diagrams for the other constituents. These diagrams are shown as Figures F.17 through F.44 and clearly show the significant effects of different land uses on relative source contributions. Parking and storage areas contribute most of the particulate pollutants from the industrial catchment. Landscaped and open space areas are more important for particulate pollutants in the residential / commercial catchment, but only for the large events. For small events, paved surfaces near the drainage system contribute most of the particulate pollutants from the residential / commercial catchment. For many constituents, paved parking areas and connected roofs contribute most of the pollutants discharged in the industrial area.

Table 6.5 summarizes the important source area contributions to snowmelt runoff during cold weather conditions. This table assumes that losses to infiltration were insignificant. The area (ha) of each source area and the snowmelt sheetflow quality were used to predict the discharges. As noted earlier, cadmium and fecal coliforms were expected to be associated mostly with contributions from the shallow ground water system, and are therefore not included on this table. The effects of roof runoff is contained in areas receiving roof runoff, e.g. driveways, front yards, and parking areas.

Streets are seen to be the most significant source of many pollutants in the residential and commercial catchment, while parking and storage areas are most important for many constituents in the industrial catchment.

The snowpack data was used to estimate the contributions made to snowmelt outfall quality by snowpacks that are different distances from the road edge. Table 6.6 summarizes these estimates, based on the snowpack quality information presented in the previous

FIGURE 6.4

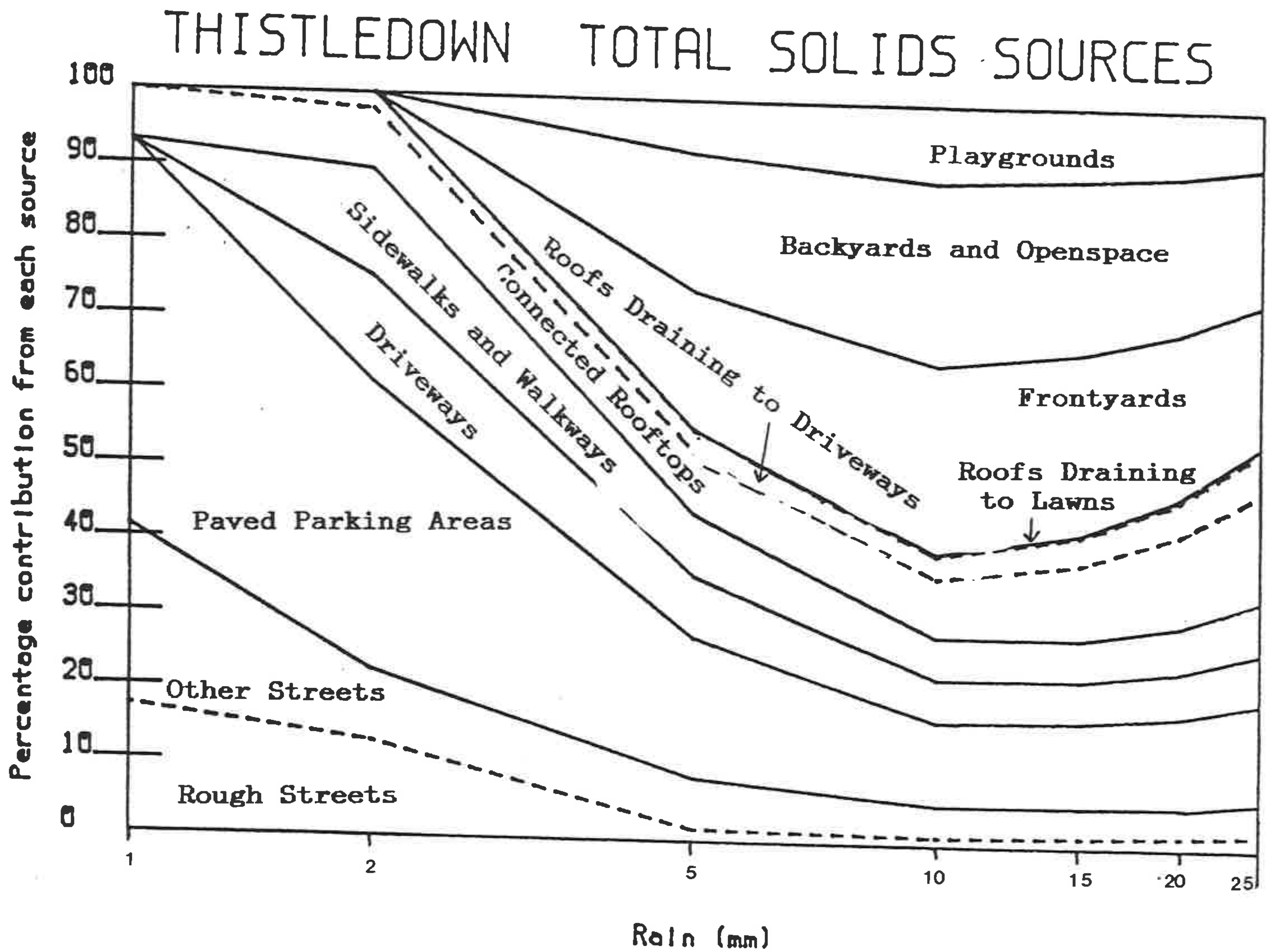

THISTLEDOWN TOTAL SOLIDS SOURCES
Percentage contribution from each source
100
90
80
70
60
50
40
30
20
10
0
Playgrounds
Backyards and Openspace
Frontyards
Roofs Draining to Driveways
Roofs Draining
to Lawns
Connected Rooftops
Sidewalks and Walkways
Driveways
Paved Parking Areas
Other Streets
Rough Streets
1
2
5
10
15
20
25
Rain (mm)

Table 6.5 ESTIMATED COLD WEATHER SNOWMELT SOURCE AREA CONTRIBUTIONS TO OUTFALL YIELDS

Approximate Contributions (Percent)

	total residue	filtrate residue	parti-culate residue	chlorides	phos-phorus	phos-phates	total Kjeldahl N	ammonia
Residential Areas								
streets	26%	15	17	22	9	4	13	§1
paved park. & playgrounds	14	12	13	17	10	3	9	§1
driveways	11	10	12	14	8	2	8	§1
walks	3	3	3	0	6	9	6	10
roofs(1)	?	?	?	?	?	?	?	?
front yards	5	12	13	3	16	25	15	27
backyards, open areas, etc.	7	16	16	4	23	35	22	39
Industrial Areas								
streets	6	8	12	7	5	8	3	?
driveways & loading	3	2	2	3	2	4	3	?
paved parking & storage	26	17	24	27	20	34	23	?
unpaved parking & storage	17	26	25	9	28	§3	25	?
roofs(1)	?	?	?	?	?	?	?	?
landscaped & open space	8	17	6	13	13	24	11	?

Table 6.5 ESTIMATED COLD WEATHER SNOWMELT SOURCE AREA CONTRIBUTIONS TO OUTFALL YIELDS (continued)

	Approximate Contributions (Percent)					
	phenolics	COD	copper	lead	zinc	Flow
Residential Areas						
streets	20%	27	43	26	29	12
paved park. & playgrounds	10	10	14	12	13	6
driveways	9	9	14	10	11	5
walks	2	5	7	4	6	4
roofs (1)	?	?	?	?	?	22
front yards	12	9	0	7	4	21
backyards, open areas, etc.	17	12	0	10	6	30
Industrial Areas						
streets	10	11	12	16	12	6
driveways & loading	2	2	2	2	3	2
paved parking & storage	16	22	18	22	23	20
unpaved parking & storage	29	20	32	22	23	15
roofs (1)	?	?	?	?	?	31
landscaped & open space	16	10	5	2	4	25

(1) Roof snowmelt samples were not obtained, but were included in roof drainage area samples (such as driveways, front yards, and parking areas).

Note: § means "less than".

Table 6.6 TOTAL POLLUTANT LOADS IN SNOWPACKS NEAR ROADS COMPARED TO TOTAL MELT YIELD

		Total Distance From Roads 0 to 1 m	0 to 5 m	0 to 10 m	0 to 25 m
Total residue (kg)					
Emery	- roadside	7800	15,000	18,000	40,000
	- annual melt	49,000	49,000	49,000	49,000
	- road as % of melt	16%	31	37	82
Thistledown	- roadside	840	2900	3400	3400
	- annual melt	33,000	33,000	33,000	33,000
	- road as % of melt	3	9	10	10
Particulate residue (kg)					
Emery	- roadside	3200	7000	8000	8000
	- annual melt	2800	2800	2800	2800
	- road as % of melt	110	250	290	290
Thistledown	- roadside	110	530	770	770
	- annual melt	590	590	590	590
	- road as % of melt	19	90	130	130
Total phosphorus (kg)					
Emery	- roadside	180	370	440	440
	- annual melt	29,000	29,000	29,000	29,000
	- road as % of melt	§1	1	2	2
Thistledown	- roadside	210	720	960	960
	- annual melt	37,000	37,000	37,000	37,000
	- road as % of melt	§1	2	3	3
Lead (kg)					
Emery	- roadside	350	2400	4600	4600
	- annual melt	2500	2500	2500	2500
	- road as % of melt	14	96	180	180
Thistledown	- roadside	150	340	380	720
	- annual melt	1600	1600	1600	1600
	- road as % of melt	9	21	24	45
Zinc (kg)					
Emery	- roadside	1500	4400	5900	5900
	- annual melt	10,000	10,000	10,000	10,000
	- road as % of melt	15	44	59	59
Thistledown	- roadside	240	670	770	1700
	- annual melt	3500	3500	3500	3500
	- road as % of melt	7	19	22	49

Note: § means "less than".

subsection. The particulate residue in snowpacks within five metres of the road can account for 90 percent of the seasonal snowmelt particulate residue discharge. Lead and zinc in the snow within 25 metres of the road only contribute approximately one half of the total seasonal snowmelt yield, indicating that there are other important sources of these constituents, e.g. parking areas. The total residue and phosphorus in the snowpack within 25 metres from the road contributes less than ten percent of the seasonal snowmelt yields for these constituents, clearly indicating other pollutant sources more important than roadside snowmelt for these pollutants.

6.3 DRY PARTICULATE SOURCE AREA SAMPLES

Dry soil samples were obtained from approximately 70 locations in the study areas. These also include several sediment samples obtained from different locations from the Humber River itself. These samples were sieved into nine particle sizes. The particle fractions were then combined into four subsets prior to the chemical analyses. These data were used to confirm the "potency" factors of different source area soils previously obtained from the sheetflow sampling efforts, and to examine the effects of different particle sizes on chemical quality. Dry particle samples could be obtained under more controlled conditions than the sheetflow samples so a better representation of source areas was obtained. The dry soil analysis data was more comparable with data obtained elsewhere.

Table F.12 shows the particle size distributions for the dry particulate samples, including the calculated median particle sizes. Many samples collected in pervious areas had small median particle sizes of several hundred microns. Unpaved parking and storage areas and walkways surfaced with larger materials had much larger particle sizes, up to 2000 microns. Paved areas had median particle sizes of approximately 500 to 1500 microns, depending on the texture and condition of the pavement. The river sediment had a wide range of median particle sizes, from approximately several hundred to almost 4000 microns, depending on location.

Particulate potency factors relate pollutant loadings to the total residue loadings. Table F.13 gives the potency factor information for each sample collected. Table F.14 summarizes these potency factors for many source area particulates collected in the test catchments. These data show the variations in chemical quality between particles from different source areas and different sizes. Typically, the potency factors increase as the use of an area becomes more intensive. Increasing concentrations of heavy metals with decreasing particle sizes is also evident. These concentrations are similar to those found in other studies that have been conducted in North America.

6.4 STREET DIRT ACCUMULATION

Pavement dirt loadings on impervious surfaces are the result of deposition, removal and "permanent storage". The permanent storage component is a function of pavement texture and condition. It is the quantity of dust and dirt that cannot be normally removed (such as by rain or by street cleaning). It is literally trapped in the texture, or cracks, of the pavement. The dirt loading at any time is this permanent loading plus an accumulation component corresponding to the exposure period, wind, street cleaning and rain. Very little removal of street dirt occurs by any process when the dirt loadings are small, but very large amounts can be removed if the street has a high street dirt loading.

A series of street dirt accumulation measurements were conducted as part of this project. An industrial street with heavy traffic (Norseman) and a residential street with light traffic (Glen Roy) were monitored frequently for approximately one month. At the beginning of this period, intensive street cleaning (one pass per day for each of three consecutive days) was conducted to obtain reasonably clean streets for the existing pavement conditions. Street dirt loadings were monitored every few days to measure the accumulation rate of street dirt and to examine the effects of any rain events that may occur during the tests. The monitoring is described in more detail in Appendix A.

Figure 6.6 is a plot of the total observed residue loadings with time, for the Norseman and Glen Roy test areas. Figures F.45 through F.53 in Appendix F are plots of the observed loadings versus time for all particle sizes. Initial loadings were quite high, but were significantly reduced with the intensive street cleaning. The loading on the industrial street increased much faster than for the residential street. Figure 6.7 is a plot of how the median particle size changes with time. Again, right after intensive cleaning, the particle sizes were similar for the two streets. However, the loading of larger particles on the industrial street increased at a much faster rate than on the residential street.

In early street cleaning and urban runoff studies (APWA 1969, Sartor and Boyd 1972, and Shaheen 1975) it was assumed that the initial loading values were zero. Calculated accumulation rates for rough streets were therefore very large. Table 6.7 summarizes some initial loading values and deposition rates for several North American locations. The uncorrected Sartor and Boyd accumulation rates that ignored the initial loading values were almost ten times, the corrected values shown on this Table. Smooth and intermediate textured streets have much smaller loading values and accumulation rates than rough pavement. Land use does not affect the initial loading values nearly as much as it does the accumulation rates. The pavement texture determines the storage capacity (initial loading) of the street, but the activity on and adjacent to the street determines the rate of deposition of material onto the street. Pavement in very poor condition may also degrade, contributing to the "removable" loading values.

A pavement dirt loading equation that can be used to represent the accumulation curve is:

FIGURE 6.6

TOTAL SOLIDS LOADING CHANGES WITH TIME

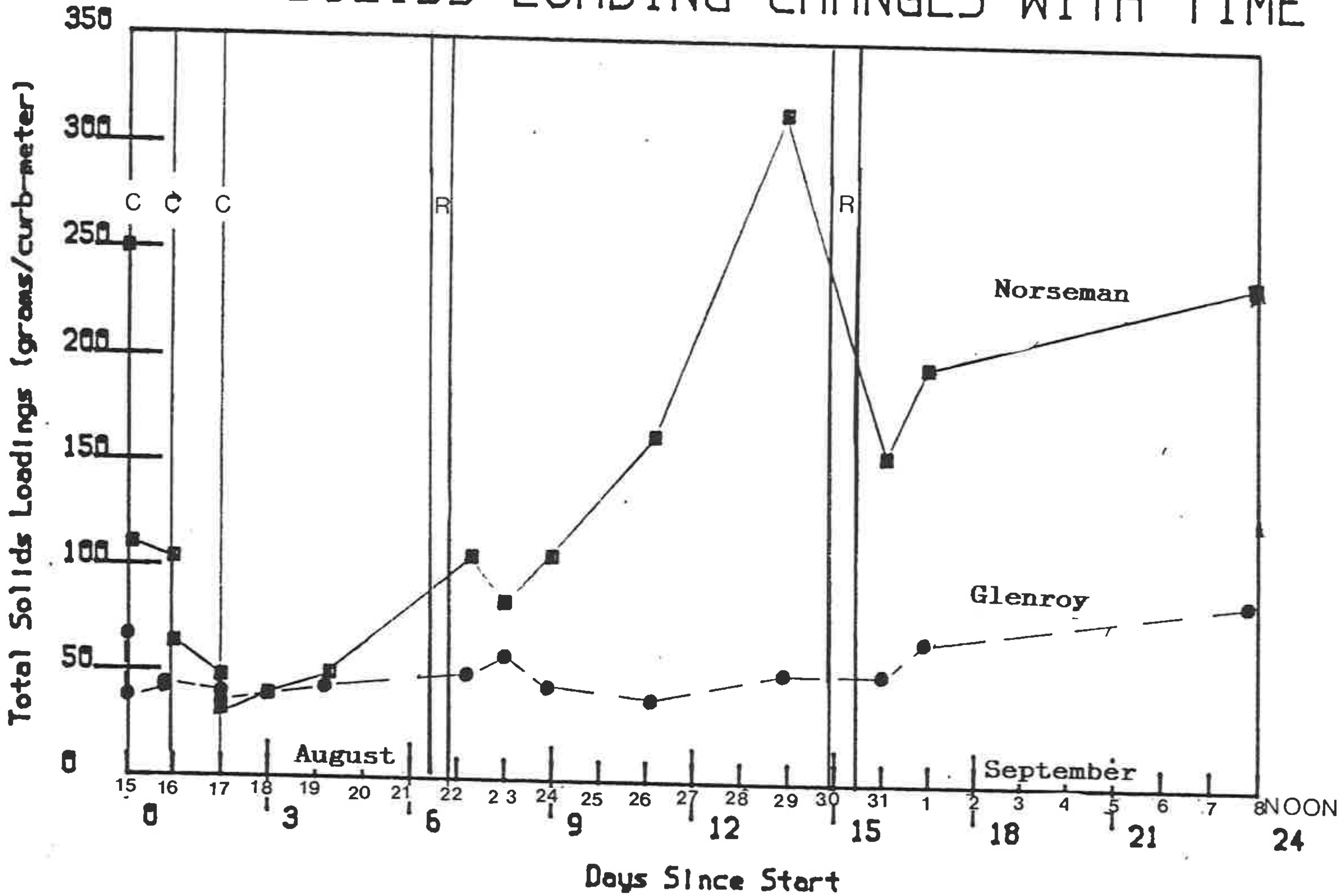


FIGURE 6.7

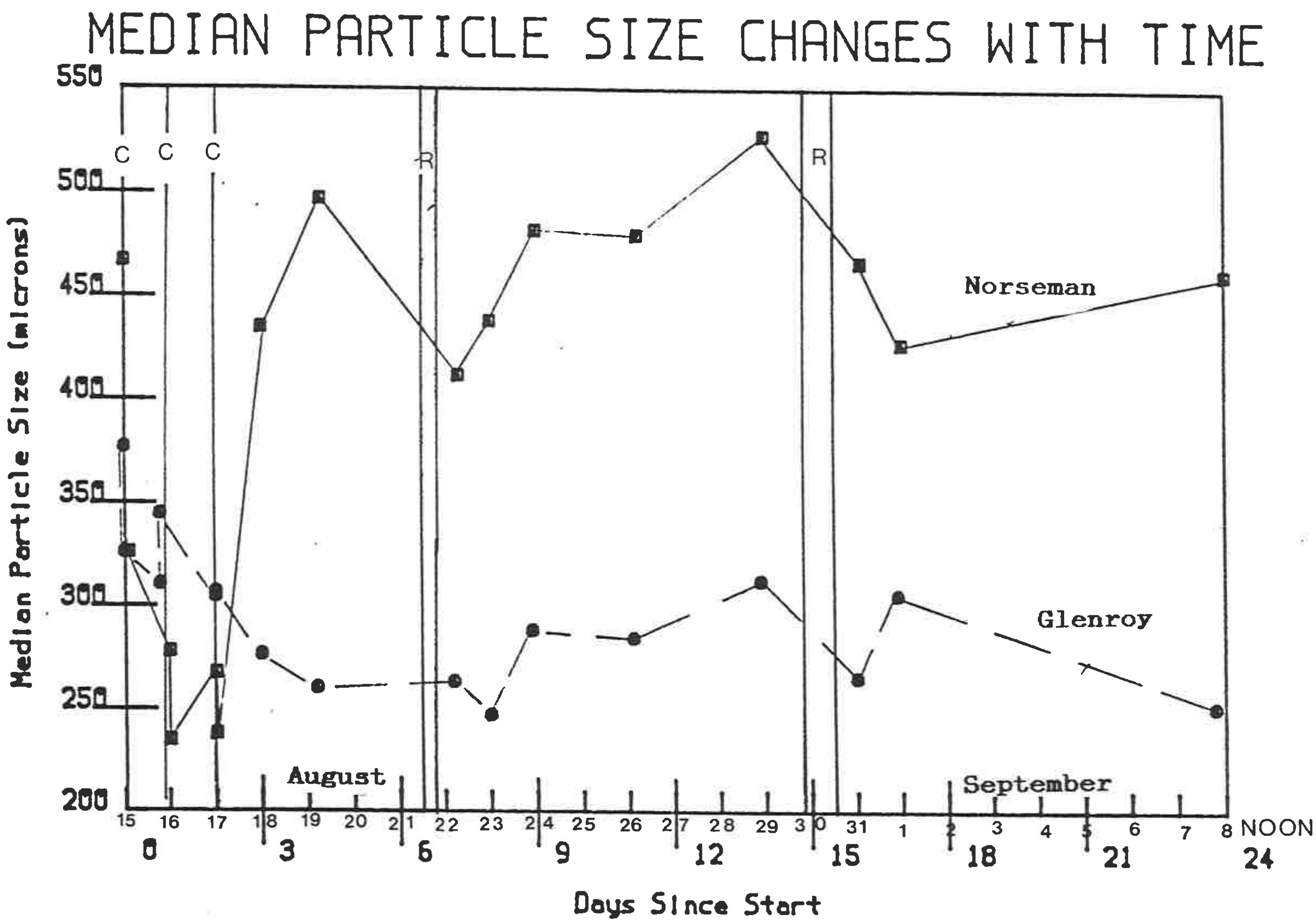

MEDIAN PARTICLE SIZE CHANGES WITH TIME
Median Particle Size (microns)
550
500
450
400
350
300
250
200
C
C
C
R
R
Norseman
Glenroy
August
September
15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 1 2 3 4 5 6 7 8 NOON
0 3 6 9 12 15 18 21 24
Days Since Start

Table 6.7 STREET DIRT LOADINGS AND INITIAL ACCUMULATION RATES

	Approximate Loadings, grams/curb-meter				
	Initial Loading Value	Daily Deposition Rate (g/m/day)	Maximum Observed Loading	Days to Maximum Observed Loading	references
Smooth and Intermediate Textured Streets					
Reno/Sparks - good condition	80	1	85	5	1
Reno/Sparks - good with smooth gutters (windy)	250	7	400	30	1
San Jose - good condition	35	4	140+	50+	2
U.S. nationwide - residential streets, good to fair	110	6	140	5	3
U.S. nationwide - commercial streets, good	85	4	140	5	3
Reno/Sparks - moderate to poor condition	200	2	200	5	1
Reno/Sparks - new residential areas	710	17	910	15	1
Reno/Sparks - poor condition with lipped gutters	370	15	630	35	1
San Jose - fair to poor condition	80	4	230	70	2
Castro Valley - moderate condition	85	10	290	70	4
Ottawa - moderate condition	40	20	NA*	NA	5
Toronto - moderate condition - residential	40	32	100	10+	
Toronto - moderate condition - industrial	60	40	350	10+	
Bellevue - dry period, moderate condition	140	6	230+	20	6
Bellevue - heavy traffic	60	1	110	30	6
Bellevue - other residential sites	70	3	140	30	6
average:	150	9	270+	25+	
range:	35-710	1-20	50-910	2-70	
Rough and Very Rough Textured Streets					
San Jose - oil and screens overlay	510	6	710+	50+	2
Ottawa - very rough	310	20	NA	NA	5
Reno/Sparks	630	10	860	35	1
Reno/Sparks - windy	540	34	1400+	40+	1
San Jose - poor condition	220	6	430	30	2
Ottawa - rough	200	20	NA	NA	5
U.S. nationwide - industrial streets, poor condition	190	10	370	10	3
average:	370	15	750+	30+	
range:	190-630	6-34	370-1400+	10-50+	

Sources:
(1) Pitt and Sutherland 1982
(2) Pitt 1979
(3) Sartor and Boyd 1972 (corrected)
(4) Pitt and Shawley 1981
(5) Pitt 1982
(6) Pitt 1984

* NA means "not analysed".

$$Y = ax - bx^2 + c$$

where Y = pavement dirt loading at time x

a, b, and c are second order polynomial curve coefficients

ax represents the linear deposition loading component

bx^2 represents the amount lost to the air, and

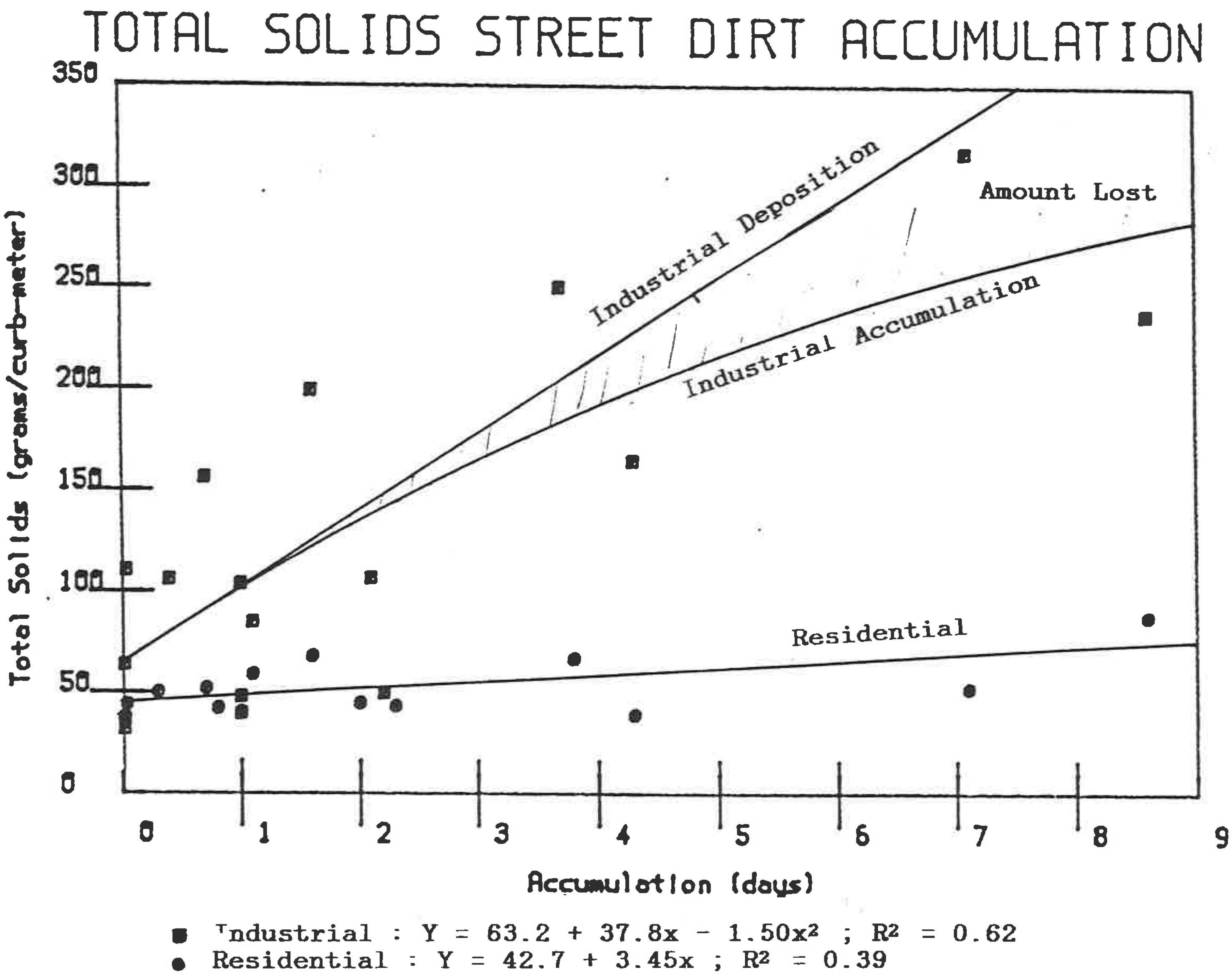
c represents the initial storage loading.

Simple regression curve fitting routines were used to calculate the equation coefficients using this street dirt loading data. Figures 6.8 and 6.9 show the data plotted with appropriate equations for total residue and median particle size. Figures F.55 through F.62 show the same plots for separate particle sizes. These equations should only be used over the range of observed accumulation periods (less than ten days). For long accumulation periods, this quadratic equation may predict decreasing loadings. After periods of accumulation that are long relative to the rain frequency, the wind losses may approximate the deposition rate, resulting in very small loading increases. The accumulation curves for the residential smooth streets are very "flat" and are presented as straight lines. The industrial accumulation curves contain the second order coefficient corresponding to the amount of material lost to the air as the loadings increased.

Loading data is usually difficult to fit to any curve because of measurement and interpretation errors. The field data measurements are usually obtained with 25 percent allowable errors because of the large cost increases needed to collect enough subsamples to significantly reduce these errors. It requires approximately five times as many street dirt subsamples to reduce a 25 percent allowable error to a ten percent allowable error (Pitt, 1979). A 25 percent allowable error is usually considered adequate in the context of errors associated with the other urban runoff study measurements.

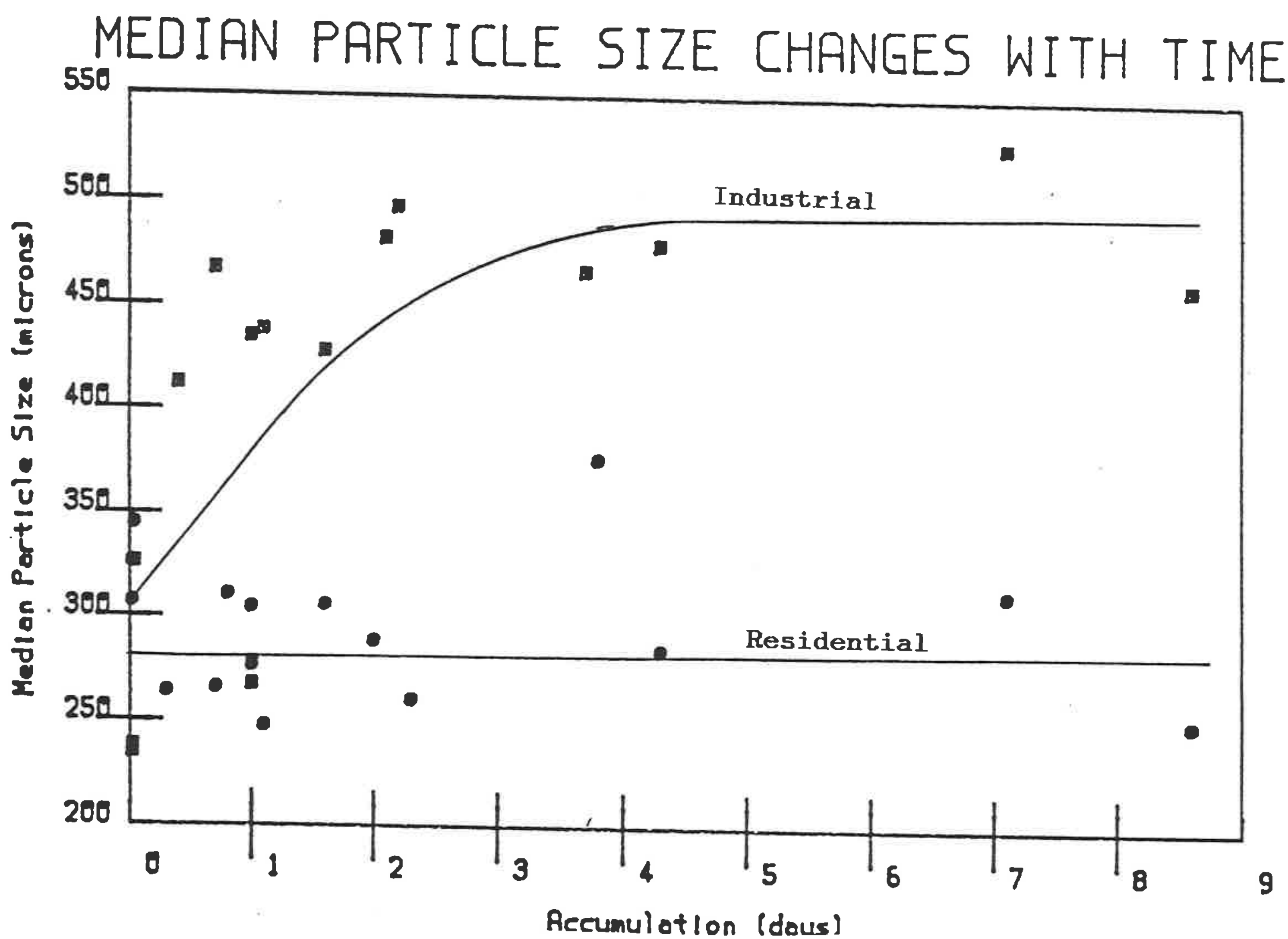
Toronto has frequent rain events, i.e. every few days. In most cases, frequent rain events keep the pavement dirt loadings very close to the initial storage value, with little increase in dirt accumulation observed over time, especially in residential areas. This will result in loading values not well correlated with accumulation time. Least-squares linear regression analyses of street dirt loading data may also be adversely affected by the small number of long periods of observation. This leverage effect is most important if sufficient observations of intermediate length accumulation periods are not available to check the shape of the resulting predicted model.

FIGURE 6.8



TOTAL SOLIDS STREET DIRT ACCUMULATION
350
300
250
200
150
100
50
0
Total Solids (grams/curb-meter)
Industrial Deposition
Amount Lost
Industrial Accumulation
Residential
0
1
2
3
4
5
6
7
8
9
Accumulation (days)
Industrial : Y = 63.2 + 37.8x - 1.50x² ; R² = 0.62
Residential : Y = 42.7 + 3.45x ; R² = 0.39

FIGURE 6.9



Industrial : $Y = 302 + 84.4x - 7.69x^2$; $R^2 = 0.57$
Residential : $Y = 280$

There was a surprising similarity in the loading plots for the different particle sizes. These plots are shown as Figures F.54 through F.62. It was expected that rain would reduce the smaller particle loadings much more than the larger particles. The first large rain occurred when the street dirt loadings were quite small (due to recent intensive street cleaning) and did not affect the loadings of any of the particles much. The second large rain occurred when the street dirt loadings were much greater. This resulted in significant loading reductions for all particle sizes. A separate discussion in Section 6.5 presents the results of the controlled washoff tests and shows the particle size variations that was anticipated.

Tables 6.8 through 6.10 summarize the street dirt accumulation and maximum storage values for smooth and rough residential and industrial pavements. These values can be used as estimates for paved areas other than streets, e.g. driveways, parking lots, and storage areas. Loadings for walkways and sidewalks are estimated to approximately 25 to 50 grams per square metre, with little change with time.

6.5 WASHOFF OF STREET DIRT

A series of eight controlled washoff tests were conducted in Toronto as part of this study. These tests were arranged in a simple three-way, two-level (2^3) factorial experimental design (Box, Hunter, and Hunter 1978) with rain intensity (and total rain), pavement loading (by particle size) and pavement texture as the three main factors, called experimental variables. This experiment was designed to identify the most important experimental variables that affect the outcome of the experiment. It is much superior to the typical "holding all variables constant, except for one" method. Fewer experimental runs are needed for testing many factors, and significant interactions between the main factors can be identified. For example, the individual main factors may not have significant effect on the experimental result, but the simultaneous effect of two or more factors, acting either together or in opposition, may be significant. This effect could not be always identified, except by luck or by conducting very large numbers of experiments or using other procedures.

Simple linear models can be identified using two-level factorial analyses. Models can be expanded by using more sophisticated data analysis procedures in conjunction with carefully selected additional model runs. These will help to detect "curvature" in the experimental results as a function of significant intermediate factors.

Factorial experimental designs work best when the variables can be carefully controlled, such as in a laboratory setting. There are many very powerful factorial designs that can efficiently examine the effects of many factors with relatively few experimental runs. For example, by using two-level fractional factorial designs, it is possible to examine eleven factors for all first order and many

Table 6.8 STREET DIRT ACCUMULATION RATES

	Accumulation Rates, All Textures and Conditions			
	Residential		Industrial	
	initial accum. rate	first week accum. rate	initial accum. rate	first week accum. rate
Unit length values	(grams/curb-meter/day)		(grams/curb-meter/day)	
Total Solids	3.5	3.5	40	25
§37 microns	0.15	0.15	0.9	0.7
37 to 64	0.2	0.2	2.0	1
64 to 125	0.5	0.5	2.4	2
125 to 250	0.9	0.9	3.3	3
250 to 500	0.8	0.8	6.5	5
500 to 1000	0.4	0.4	7.1	5
1000 to 2000	0.4	0.4	4.5	3
2000 to 6450	0.15	0.15	5.4	3.4
†6450	0.16	0.16	5.9	2.7
Unit area values	(kg/ha/day)		(kg/ha/day)	
Total Solids	9.3	9.3	65	43
§37 microns	0.4	0.4	1.5	1.1
37 to 64	0.5	0.5	3.3	1.7
64 to 125	1.3	1.3	4.0	3.3
125 to 250	2.3	2.3	5.5	5
250 to 500	2.0	2.0	11	8
500 to 1000	1.0	1.0	12	8
1000 to 2000	1.0	1.0	7.5	5
2000 to 6450	0.4	0.4	9	6
†6450	0.4	0.4	10	4.5

Note: § means "less than" and † means "greater than".

Table 6.9 INITIAL AND MAXIMUM STORAGE

	Rough Texture Streets and All Streets in Poor Condition			
	Residential		Industrial	
	initial load	maximum load*	initial load	maximum load*
Unit length values	(grams/curb-meter)		(grams/curb-meter)	
Total Solids	100	150	160	440
§37 microns	4	5.5	6	14
37 to 64	6.4	9	11	18
64 to 125	14	20	22	50
125 to 250	23	34	33	80
250 to 500	27	36	35	85
500 to 1000	20	27	30	75
1000 to 2000	7	12	18	60
2000 to 6450	3.5	5	7	35
†6450	1	3.5	2.5	20
Unit area values**	(kg/ha)		(kg/ha)	
Total Solids	280	400	360	980
§37 microns	11	15	13	31
37 to 64	17	24	24	40
64 to 125	37	53	49	110
125 to 250	61	91	73	180
250 to 500	72	96	78	190
500 to 1000	53	72	67	170
1000 to 2000	19	32	40	130
2000 to 6450	9	13	16	78
†6450	2.7	9.4	5.6	44

* Maximum loads occur after about 10 days of accumulation.

** Unit area values can be used as estimates for paved driveways, parking lots, and storage (paved footpath and sidewalks loading values are estimated to be about 25 to 50 g/m^2).

Note: § means "less than" and † means "greater than".

Table 6.10 INITIAL AND MAXIMUM STORAGE

	Smooth and Intermediate Texture Streets in Good to Moderate Condition			
	Residential		Industrial	
	initial load	maximum load*	initial load	maximum load*
Unit length values	(grams/curb-meter)		(grams/curb-meter)	
Total Solids	40	90	65	340
§37 microns	1.6	3	2.5	10
37 to 64	2.6	5	4.4	11
64 to 125	5.7	12	9	35
125 to 250	9.2	20	13	60
250 to 500	11	20	14	65
500 to 1000	8	15	11	55
1000 to 2000	3	8	7	50
2000 to 6450	1.4	3	3	30
†6450	0.4	3	1	20
Unit area values**	(kg/ha)		(kg/ha)	
Total Solids	100	215	110	560
§37 microns	3.9	7.2	4.2	17
37 to 64	6.3	12	7.4	18
64 to 125	14	29	15	58
125 to 250	22	48	22	100
250 to 500	27	48	23	110
500 to 1000	19	36	18	92
1000 to 2000	7.2	19	12	84
2000 to 6450	3.4	7.2	5	50
†6450	1.0	7.2	2	33

* Maximum loads occur after about 10 days of accumulation.

** Unit area values can be used as estimates for paved driveways, parking lots, and storage (paved footpath and sidewalks loading values are estimated to be about 25 to 50 g/m^2).

Note: § means "less than" and † means "greater than".

two-way and three-way factor interactions with only 16 experiments. In "environmental observation" studies, simple full experimental designs should be selected because of the lack of precise control over all of the factors during the experiment. Good experimental designs allow modifications in design and analysis configurations, after the data and factor level measurements are obtained.

Figures F.65 through F.68 show the alternative experimental designs used for examining the loads available for washoff as examples of the factorial experimental designs and analysis procedures used in this project.

Figures F.65 and F.67 are 2^3 designs for two "extreme" levels of three factors. The resulting design resembles a cubic coordinate system, with each of the three factors being one of the axes. The lower values for each factor are placed at the origin of the coordinate system, and the high values for each factor are placed at the other corners. Eight experiments are then run, one representing each corner of the cube. The runs are designated by the numbers 1 through 8. The first three columns on the "Table of Contrast Coefficients" on the figures represent the three main factors (I for rain intensity, C for street cleanliness, and T for street texture). The + and - signs under each column for each of the eight runs designate the experimental conditions for each factor for each run.

The two extreme levels of the cleanliness factor indicate a dirty street (the first sampling run at a site, with obviously dirty streets) and a clean street (the same site, two days after completely flushing the street surface). The two extreme values for the texture category are for smooth and rough textured streets. These were selected using standard photographs of street textures. The extreme values of rain intensity were controlled by the application of artificial rain at rates of approximately two mm/hr and 12 mm/hr. The first run had the control codes I+, C-, and T+, indicating high rain intensity, a clean street, and rough texture. This run is also coded as HCR.

The values of the parameters under analysis that were obtained for each run are also shown on the Table. For example, the load available for washoff, for the conditions occurring during the first run, was 28% of the total load. Appendix A shows the field and calculation sheets that were used to produce the values for each of the eight runs. The "effect" of each factor was calculated by adding, or subtracting, the appropriate values of the parameter for each run, and dividing the total by the number of "plusses" in the factor column (4 in these examples). As an example, the effect of the I (intensity) factor was calculated in the following way:(+28 -50 +12 -13 +58 -35 +20 -63) / 4 = -10.75 rounded to -11. The columns with multi-letter titles on the table of contrast coefficients are for two-way and three-way interactions of the factors. As examples, IC is the two-way factor combining the effects of intensity and cleanliness. ICT is the only three-way factor and includes the combined effects of all three factors considered together. Factorial analysis is the most efficient experimental design that allows these multi-effects to be examined.

The two plots on the figures include the normal distribution plot of the effects of the factors and a simple distribution plot of the effects. These plots are one way of determining which factors (including the main factors and multi-effect factors) are important. If the ranked effects plot on a straight line, then the experimental observations (the values) are not significantly different from random observations. What is wanted is a small number of factors, on the toe or the head of the distribution plot, that do not fit the straight line. These "non-fitting" factors are the significant ones that are used to produce a simple model.

On Figure F.65, the three way factor **ICT** obviously does not fit the normal distribution like the other factors and appears to have a strong effect on the value. A simple model to describe available load is therefore the mean value (35) plus or minus one half of the three way effect (22), or 35 + 11, or 35 - 11, i.e. 24 or 46, depending on the ICT coding value. The values 24 and 46 are called the model values for this set of parameters. The "model value" column in the table includes either of these two values for each run, depending on the ICT "sign". The residuals are calculated from the differences between the observed values and the model values, and are then ranked. The model is then checked with a normal probability plot of these residuals. These should all be normally distributed (i.e. fall on a straight line) for a legitimate model. Unfortunately for this example, the residual associated with the HDR run is a relatively large "outlier".

Figure F.67 is a similar analysis for the percent washoff after two hours of rain. In this case, the main factor T has a weak effect, and the model residual plot shows two outliers. Therefore, the "best" model for this analysis is the mean value alone (18 percent).

Similar analyses were repeated many times for different values of the runs. The experiments allowed many values to be obtained. Washoff values for total residue, filterable residue (particles less than 0.4 microns in diameter), and particulate residue (particles greater than 0.4 microns in diameter) were obtained for nine time periods. The time periods were at approximately 5, 10, 20, 30, 50, 70, 90 and 120 minutes, plus the final rinse. The loading can be expressed in units of grams per square metre and grams per curb-metre, concentrations (mg/L), and the percent of the total initial loading washed off. Therefore, more than 100 different "nested" washoff outcome values were obtained for these eight experiments. In addition, selected analyses were also made for various amounts of elapsed time since the beginning of the "rain".

Very good models were identified, with good residual plots, for several conditions. Typical conditions included the amount of filterable residue washed off (g/m^2), or the percentage washoff of particulate residue after six mm of rain. Some models had no significant effects and therefore the mean values were used. Some models had only one or two factors with very strong effects. However, some poor models were also generated. These were identified during the analysis of residuals. Therefore a simplified version of the experimental design was also used for the analyses. After the monitoring data was collected it was noticed that one of the intended "dirty" street tests (coded as LDS, light rain intensity, dirty street, smooth texture), had significantly cleaner initial dirt loadings than the other "dirty" tests. This was probably due to the smooth street being unable to retain high street dirt loadings due to its lack of texture. As discussed in Section 6.4, smooth streets lose much of their high street dirt loadings as fugitive dust during high winds, or heavy traffic. Therefore, these test observations were eliminated and an alternate design was analysed.

Figures F.66 and F.68 are the analysis worksheets for this alternative design, using replicate observations for three of the four newly designated test runs. Each analysis required three separate analyses to examine all possible two-way factor interactions. The three-way interaction was not investigated in these alternative designs, but the outcomes of the models could be confirmed. In these alternative analyses, pooled standard error values were calculated and used to identify the significant model factors. This was possible because of the replicate observations. Only the factor effects greater than the standard error value are significant.

Figure F.66 shows that when calculating available load as a percentage of total load for intensity (I) and cleanliness (C) factors (plus their interaction factor, IC), only the average value and the cleanliness factor are significantly greater than the standard error. Therefore, the two possible outcomes are 16 percent for dirty streets, and 46 percent for clean streets. Rain intensity and the factor interaction of IC were not significant. This model was confirmed in the other two analyses on this figure. Intensity, texture, and their interaction IT are not significant in the second analysis. Cleanliness was significant in the third analysis. The third analysis (examining C, T, and,CT) produced a model showing 18 percent washoff for dirty streets and 44 percent washoff for clean streets, which are very close to the values produced with the first analysis examining I, C, and IC. Therefore, the two points for a simple washoff model would be approximately 17 percent washoff for dirty streets (12.6 grams per square metre) and 45 percent washoff for clean streets (2.7 grams per square metre). These values were used with data obtained from actual rain and street washoff observations to produce the washoff component of the SLAMM model.

Another two-way, two-level (2^2) example is shown in Figure F.68, This analysis was used to investigate the amount of rain needed to produce 90 percent washoff of the available loading. The only significant factors found were the average values (18 mm of rain) and the combined effect of cleanliness and texture (CT). Rain intensity was not an important factor. Street cleanliness was much more important than texture, resulting in the model of 14.5 mm of rain for clean streets and 21.5 mm of rain for dirty streets to produce 90% washoff of the available loading.

Plots of accumulative washoff are shown on Figures F.63 and F.64. These plots show the asymptotic washoff values observed in most of the tests. The maximum asymptotic values should be considered as the "available" pavement loading in most models. The measured total loadings are also shown on these plots and are seen to be several times larger than these "available" loading values. It is also interesting to note that filtrate residue makes up most of the accumulative total residue weight after approximately 30 to 60 minutes of rain. Figure 6.10 is a plot of the accumulative washoff curves for total residue (g/m^2) for all tests. Figure 6.11 shows the accumulative particulate residue washoff plot, and Figure 6.12 is the plot for filtrate residue. The total loading and available loading values for filtrate residue are quite close, indicating almost complete washoff of the very small particles. Figure 6.11, however, shows quite large differences between available loads and total loads for washoff particles greater than 0.4 microns.

Table 6.11 and Figures 6.13 and 6.14 are plots of available load as a function of particle size (based on actual washoff measurements in Bellevue and Milwaukee). No particles greater than 2000 microns are expected in runoff from pavement under normal conditions.

The factorial analyses of available total residue loadings versus total loadings showed that pavement dirt loadings were a significant factor. The proportion of the total residue loading that is available for washoff increases as the total residue loading decreases. Particles between 125 and 500 microns make up approximately one half of the particulate residue washoff loadings. As was shown on Figures F.67 and F.68, the additional factorial analyses of "the rain quantities needed for 90 percent washoff of the available loadings" showed little variation for any of the factors. Figure 6.15 and Table 6.12 show the slight effect that dirt loadings have on rain quantity needed for 90 percent washoff. It should be noted that no normal rain events are expected to be capable of 90 percent washoff of "total" residue, but many are capable of 90 percent washoff of "available" residue.

6.6 ACTUAL STREET DIRT WASHOFF OBSERVATIONS DURING RAIN EVENTS

The Bellevue, Washington, urban runoff project (Pitt, 1984) included approximately 50 pairs of street dirt loading observations close to the beginnings and ends of rain events. These "before" and "after" loading values were compared to determine significant differences in loadings that may have been caused by the rain events. The observations were affected by rain events falling directly on the streets, along with runoff and particulates originating from nonstreet areas. The net loading differences were therefore affected by street dirt washoff by direct rain events on

FIGURE 6.10

ACCUMULATED TOTAL SOLIDS WASHOFF vs RAIN VOLUME

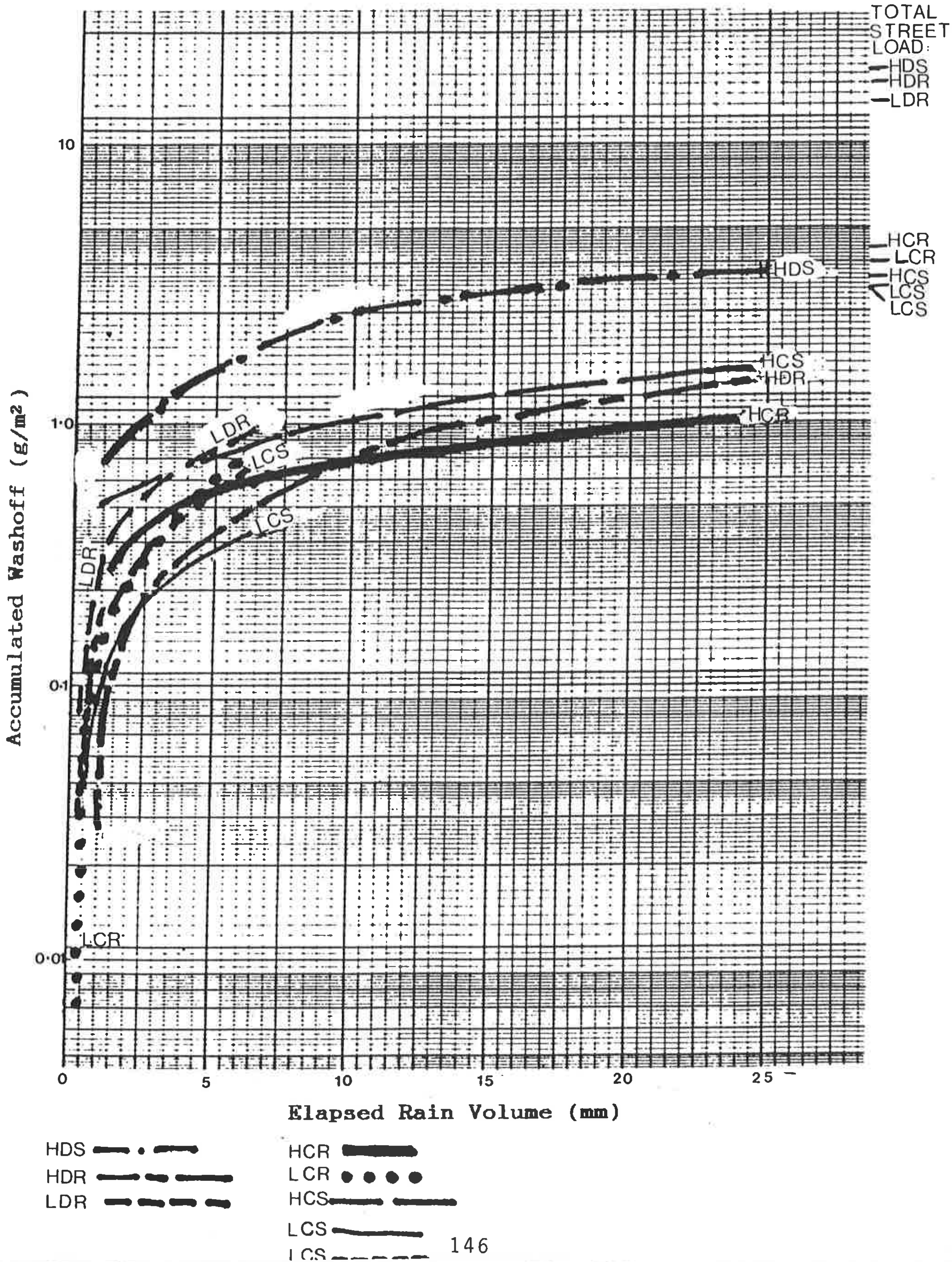


FIGURE 6·11 "SUSPENDED" SOLIDS (>0.4 microns) WASHOFF

vs RAIN VOLUME

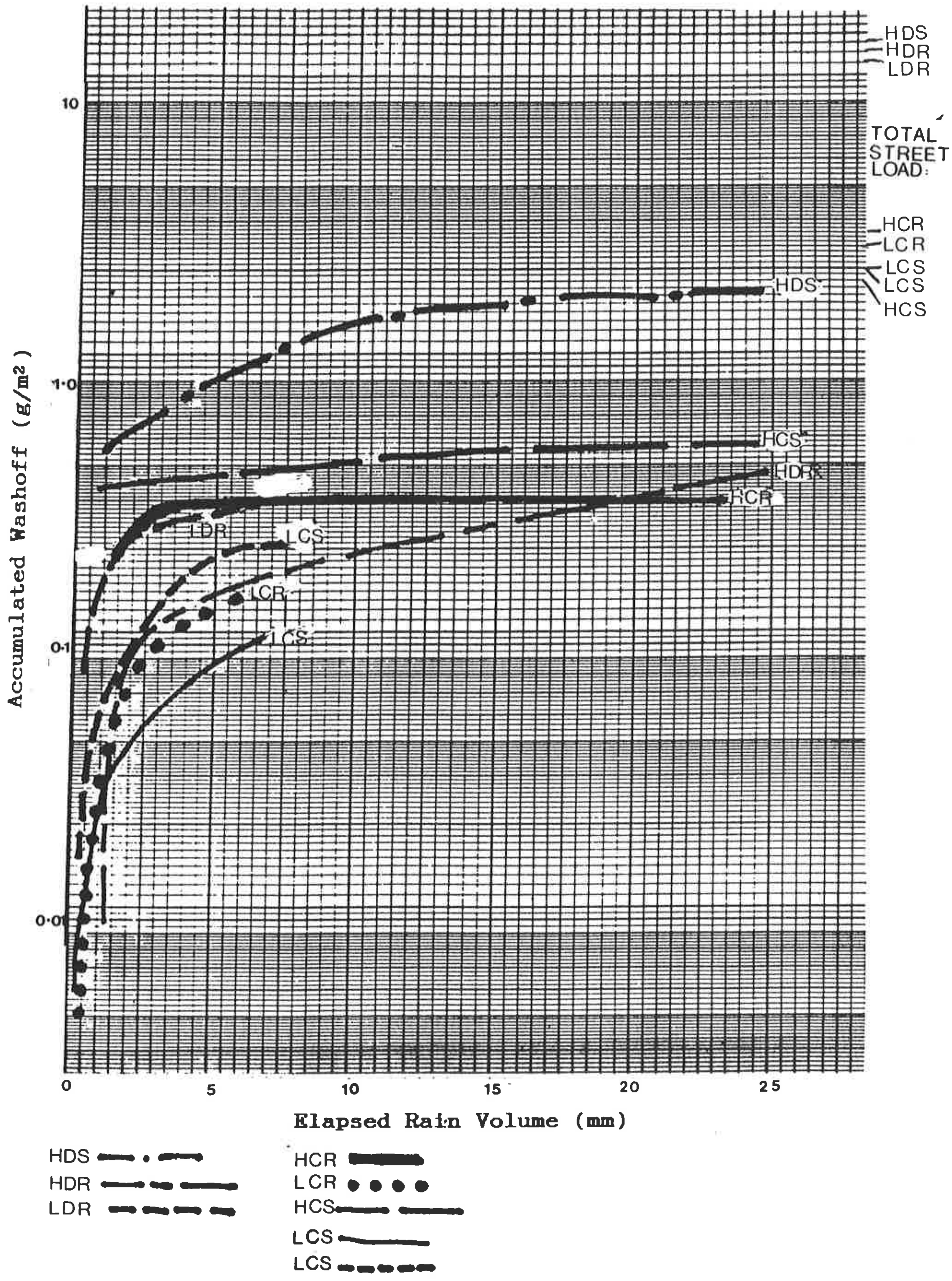


FIGURE 6.12

ACCUMULATED "DISSLOVED" SOLIDS (<0.4 microns) WASHOFF

vs RAIN VOLUME

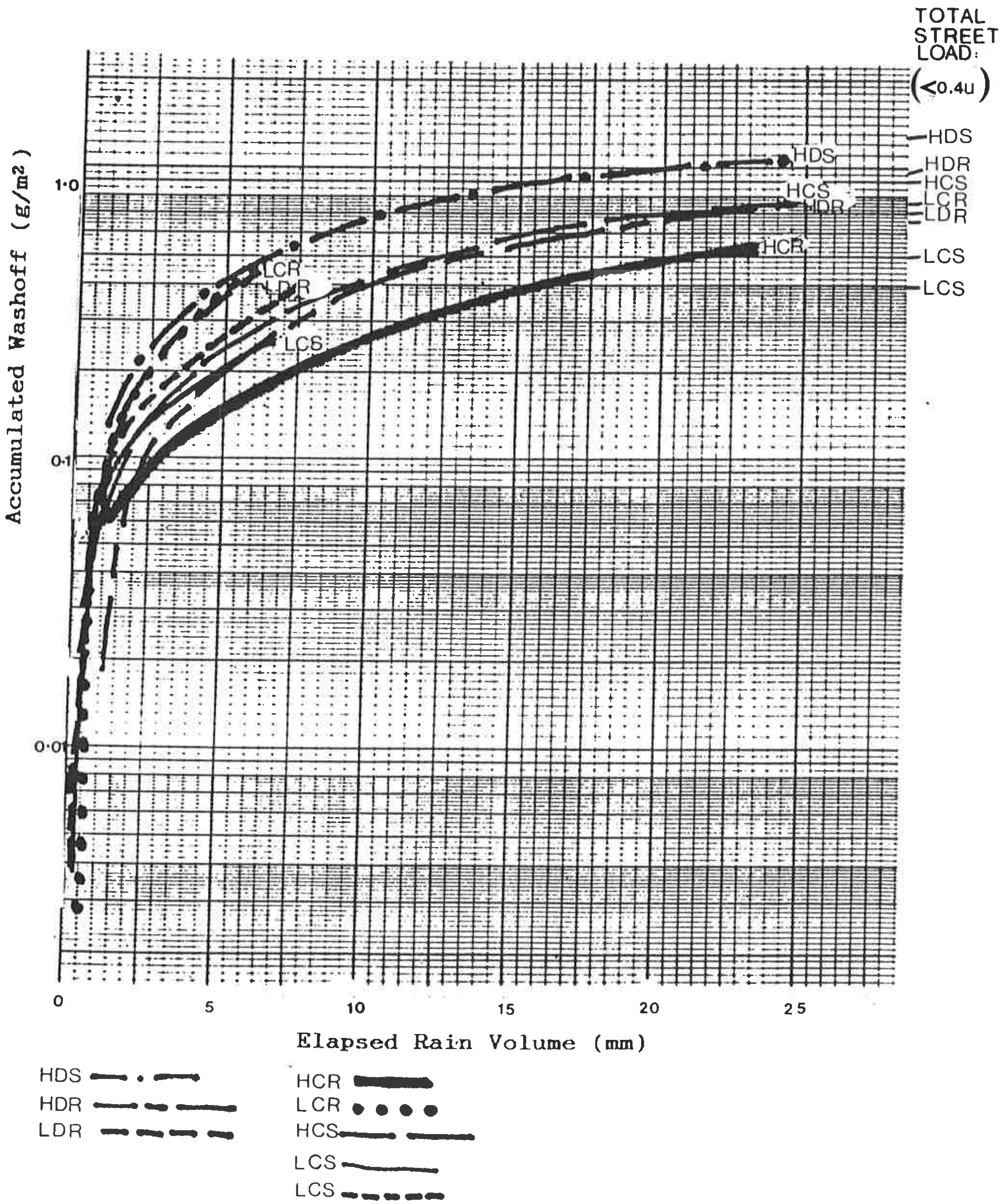


Table 6.11 AVAILABLE LOAD AS A PERCENTAGE OF TOTAL LOAD FOR STREET DIRT WASHOFF

total solids street dirt load (grams/curb-meter)	available load for washoff (grams/curb-meter)	(% of total)
3.4	3.4	100%
6.8	5.1	75
10.2	4.6	45
13.6	4.4	32
17.0	4.9	29
20.4	5.3	26
23.8	5.7	24
27.2	6.1	23
30.6	6.4	21
34.0	6.8	20
40.8	7.3	18
51.0	7.9	16
57.8	8.4	15
68.0	8.8	13
85.0	9.8	12
102	11.0	11
119	12.4	10
136	13.9	10
170	17.2	10
204	20.4	10
238	23.6	10
272	26.9	10

FIGURE 6.13 AVAILABLE LOAD AS A FUNCTION OF PARTICLE SIZE

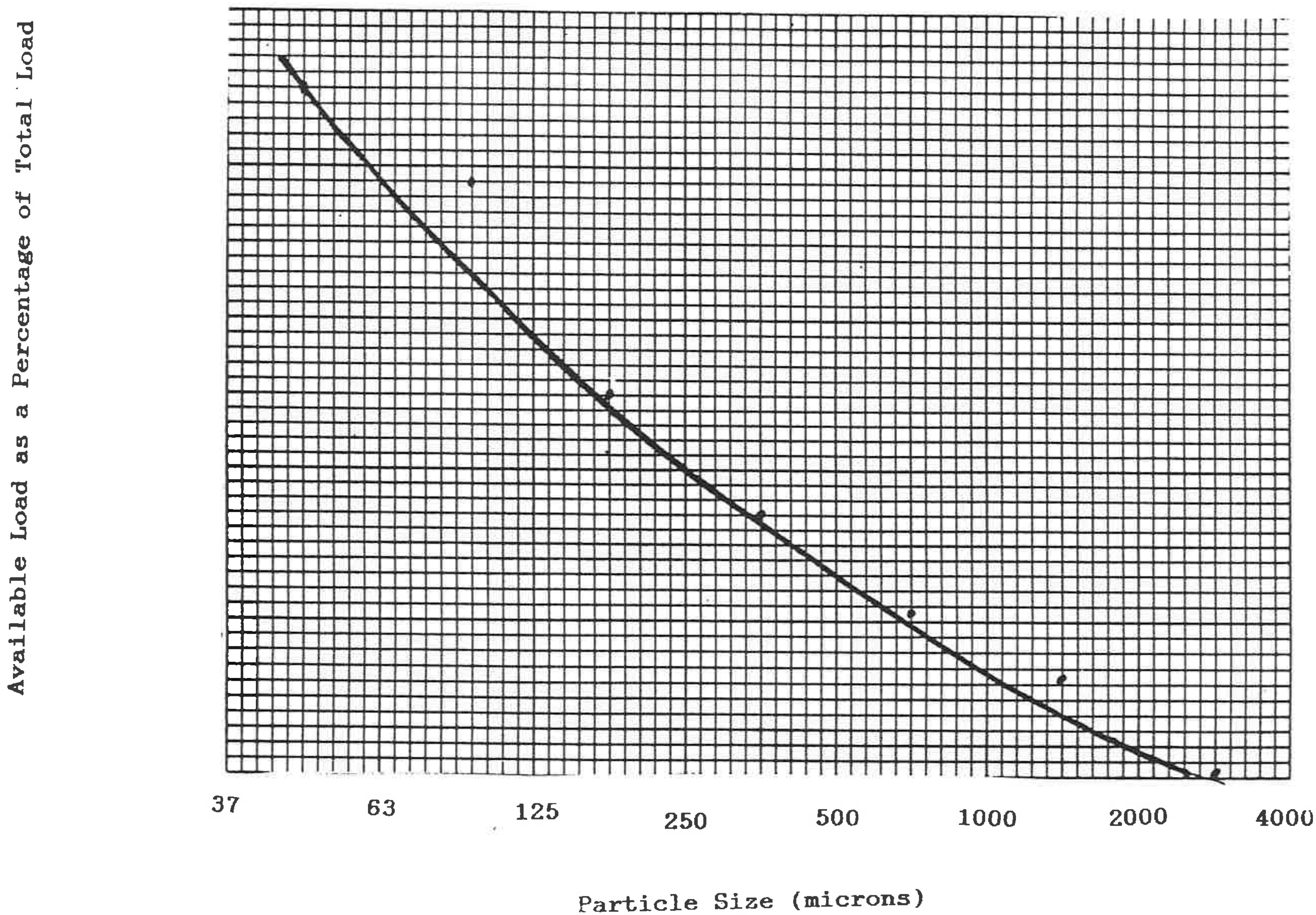


FIGURE 6.14 MAXIMUM TOTAL SOLIDS WASHOFF (AVAILABLE LOAD) AS A FUNCTION OF TOTAL SOLIDS LOADING

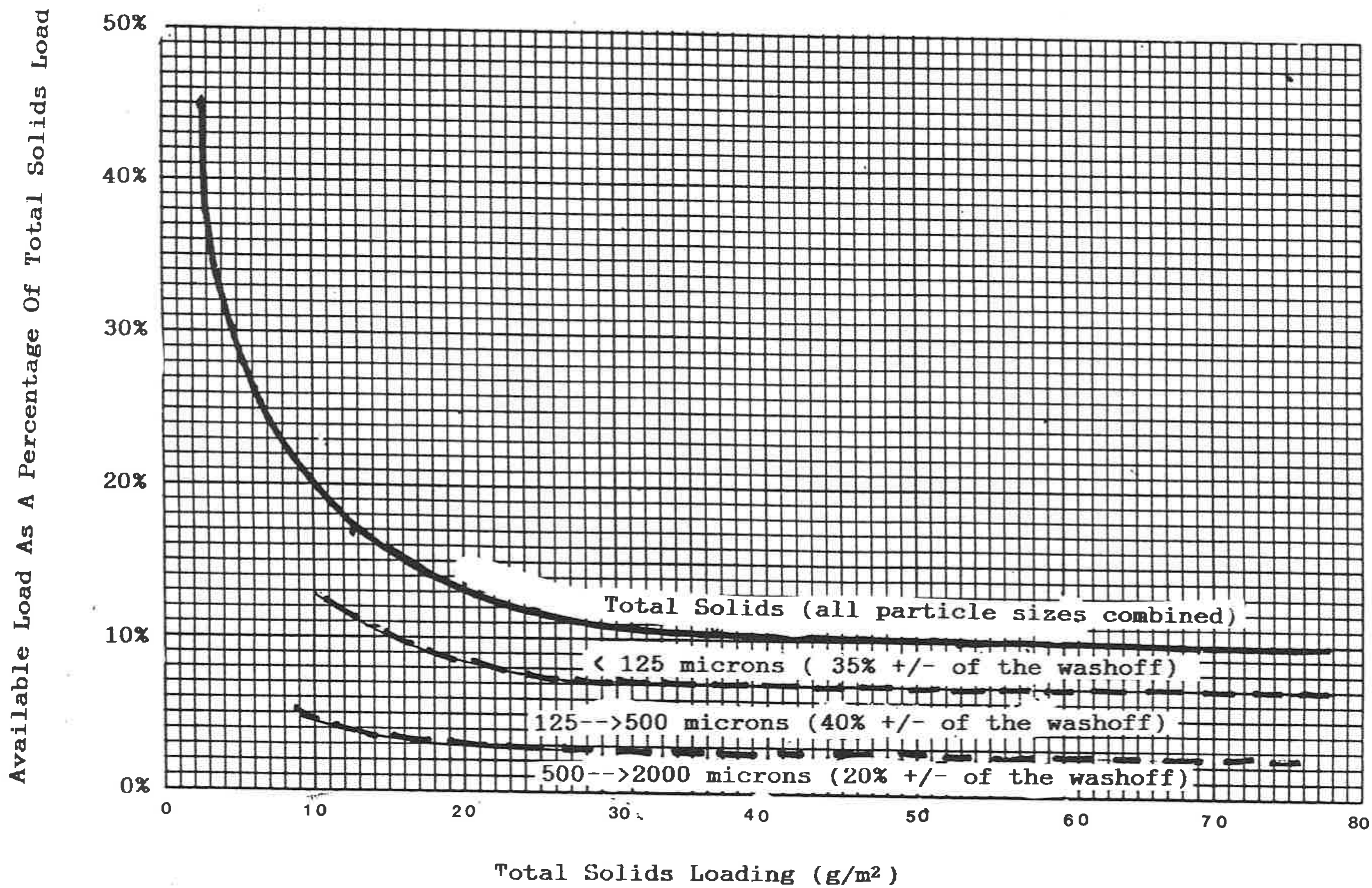


FIGURE 6.15

RAIN VOLUME NEEDED FOR NINETY PERCENT WASHOFF OF

AVAILABLE TOTAL SOLIDS LOAD

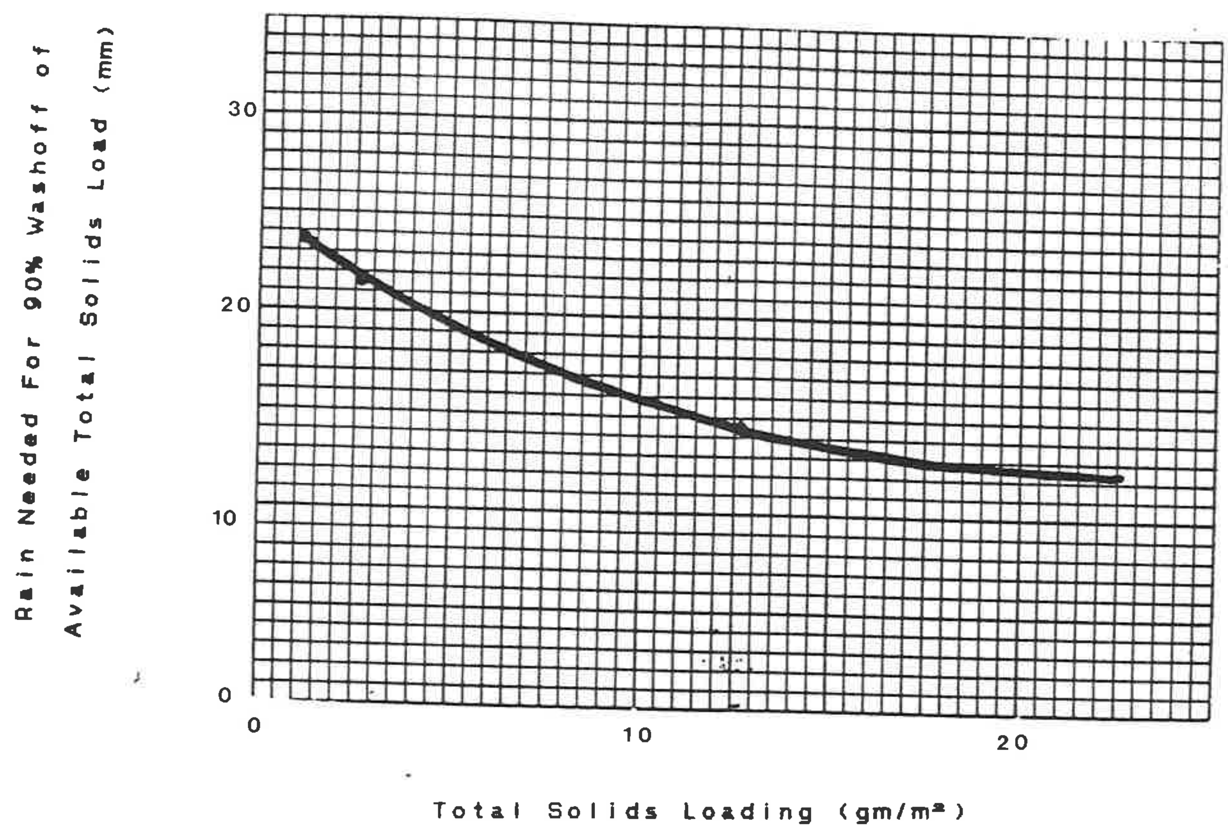


Table 6.12 <u>FINAL WASHOFF MODEL RESULTS</u>

Total Solids Washoff:

	for all except HDS(1):		HDS(1) only:	
total rain (mm)	accum. washoff (grams/m^2)	washoff (% of ~~total~~ available load)	accum. washoff (grams/m^2)	washoff (% of ~~total~~ available load)
0.2	0.08	8%	0.45	16%
0.5	0.12	12	0.50	18
1	0.20	20	0.58	21
2	0.30	30	0.76	27
3	0.36	36	0.90	32
4	0.42	42	1.1	39
5	0.45	45	1.3	45
6	0.50	50	1.4	49
8	0.60	60	1.7	61
10	0.70	70	2.0	71
12	0.80	80	2.2	79
15	0.85	85	2.3	82
20	0.95	95	2.7	95
25	1.00	100	2.8	100

(1) HDS: high rain intensity, dirty street, and smooth street texture (more efficient washoff).

the street surfaces, by gutter flows augmented by "upstream" area runoff and by erosion products that originated from nonstreet areas but may have settled out in the gutters. When all the data were considered together, the net loading difference was approximately 35 to 45 lbs/curb-mile removed. This amounted to a street dirt load reduction of approximately 15 percent, which was much less than predicted using typical urban runoff models. It was, however, comparable to the models produced from the special street dirt washoff tests discussed in the previous subsection.

Figure 6.16 summarizes the Bellevue data and shows very large reductions in loadings for the small particles. It also shows that the loadings of the largest particles actually increased due to settled erosion materials. The particles were not from limited sources, but armour shielding may have been important. Most of the weight of solid material in the runoff was in the fine particle sizes. Very few washoff particles greater than 1000 microns were found. Actual runoff particle size analyses in Bellevue (Pitt and Bissonnette, 1983) found a median particle size of approximately 50 microns. Similar results were obtained in the Milwaukee U.S. Environmental Protection Agency's Nationwide Urban Runoff Program (NURP) study (Bannerman et al., 1983).

Particulate washoff predictions for Bellevue conditions were made using several popular washoff equations (the Sutherland and McCuen modification of the Yalin equation, and the Sartor and Boyd equation). Three particle size groups (<63, 250-500, and 2000-6350 microns), and three rain event sizes (5, 10, and 20 mm) were considered. The rain events were all of three hours duration. The gutter length for the Bellevue test areas was approximately 80 meters per inlet (8000 m of curbs and 100 inlets), the gutter slopes averaged approximately 4.5 percent, and the impervious area used was 100 percent for the streets and gutters. Typical initial total street dirt loadings for the three particle sizes are listed below:

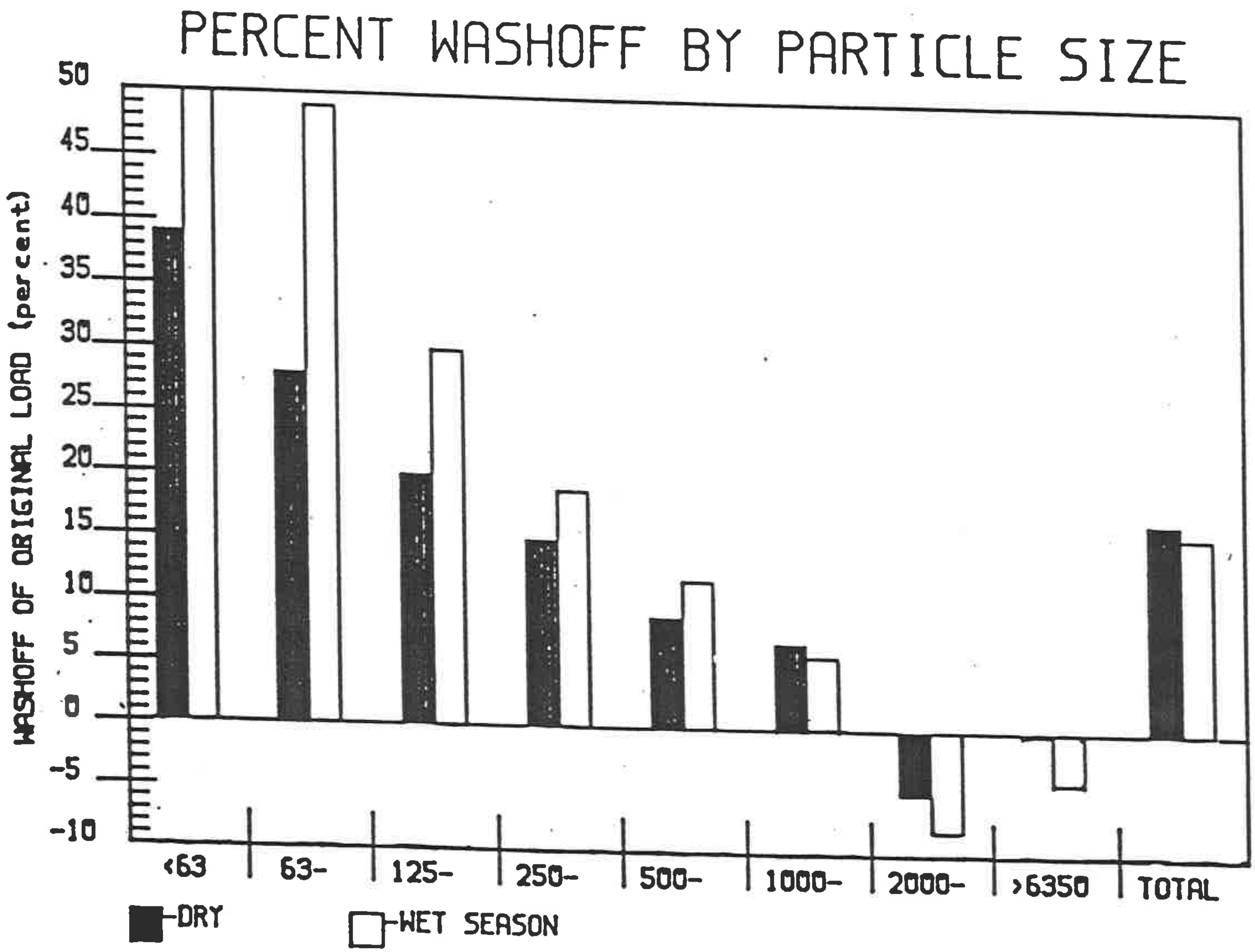
<63 microns : 9 g/curb-metre,

250-500 microns : 18 g/curb-metre, and

2000-6350 microns : 9 g/curb-metre.

The net actual loading removed during the storms in Bellevue was approximately 45 percent for the smallest particle size group, 17 percent for the middle particle size group, and -6 percent (6 percent loading increase) for the largest particle size group. The removals were calculated to be 90 to 100 percent using the Sutherland and McCuen method, 61 to 98 percent using the Sartor and Boyd equation, and 8 to 37 percent using the availability factor with the Sartor and Boyd equation. There were no differences calculated in removal percentages as a function of particle size. The ranges given for these other models reflect the different rain volumes and intensities only. The calculations using the availability factor with the Sartor and Boyd equation resulted in

FIGURE 6.16



Source: Pitt, 1984

the predicted values closest to the field results. However, the great difference in washoff as a function of particle size was not predicted.

6.7 CALIBRATION AND VERIFICATION OF SLAMM QUALITY COMPONENTS

The Toronto/Source Loading and Management Model (Toronto/SLAMM) report prepared for the MOE discussed the stormwater runoff portion of the model. The street total residue sheetflow concentrations were obtained from the washoff tests conducted during this Humber River Pilot Watershed Project and were corrected for background filterable residue (TDS) concentrations. The sheetflow pollutant concentrations (adjusted for delivery efficiency) were then used in conjunction with the sheetflow runoff relationships (previously described in Section 4.3) for the different source areas. Figures 6.17 and 6.18 show the excellent agreement between the warm weather stormwater runoff outfall pollutant concentrations (seasonally adjusted) for many pollutants for both study areas with the predicted values. Sufficient data was not available to attempt a completely independent verification procedure using outfall data from other land uses or study periods.

6.8 SPECIFIC POLLUTANT SOURCES

6.8.1 OTHER POLLUTANT CONTRIBUTIONS TO THE STORM DRAIN SYSTEM

When conducting the various data analyses discussed in the previous sections of this report, it was noted that subsurface contributions to the storm drainage system were probable. High concentrations of dissolved chromium in the industrial outfall during both wet and dry weather, accompanied by appreciable concentrations of dissolved copper and dissolved zinc could not be explained by the wet weather sheetflow observations. Very few detectable chromium observations were obtained in any of the more than 100 surface sheetflow samples analysed. It is expected that some industrial wastes, possibly originating from metal plating operations, are the cause of these high concentrations of dissolved metals at the outfall.

During the field sampling program, many periods of highly coloured (red, brown, grey, etc.) baseflows were also observed flowing from the industrial catchment. Chemical analyses showed elevated concentrations of many pollutants. Probable sources can not be assumed, except that the washing of work areas in cement and stone working plants could have been responsible for some of the cloudy dry weather discharges, and the plating wastes noted above. Other potential dry weather sources of contaminated water from the industrial area could include "non-contact" cooling water, process water (both slug or continuous discharges), equipment and work area cleaning water discharged to floor drains, spills during loading operations (and subsequent washing of the material into the storm drain). These same processes could have also occurred during wet weather in addition to leaching of contaminants from product and material storage piles.

FIGURE 6.17

Observed Vs. Modeled Outfall Pollutant Conc.

Thistledown (Residential)

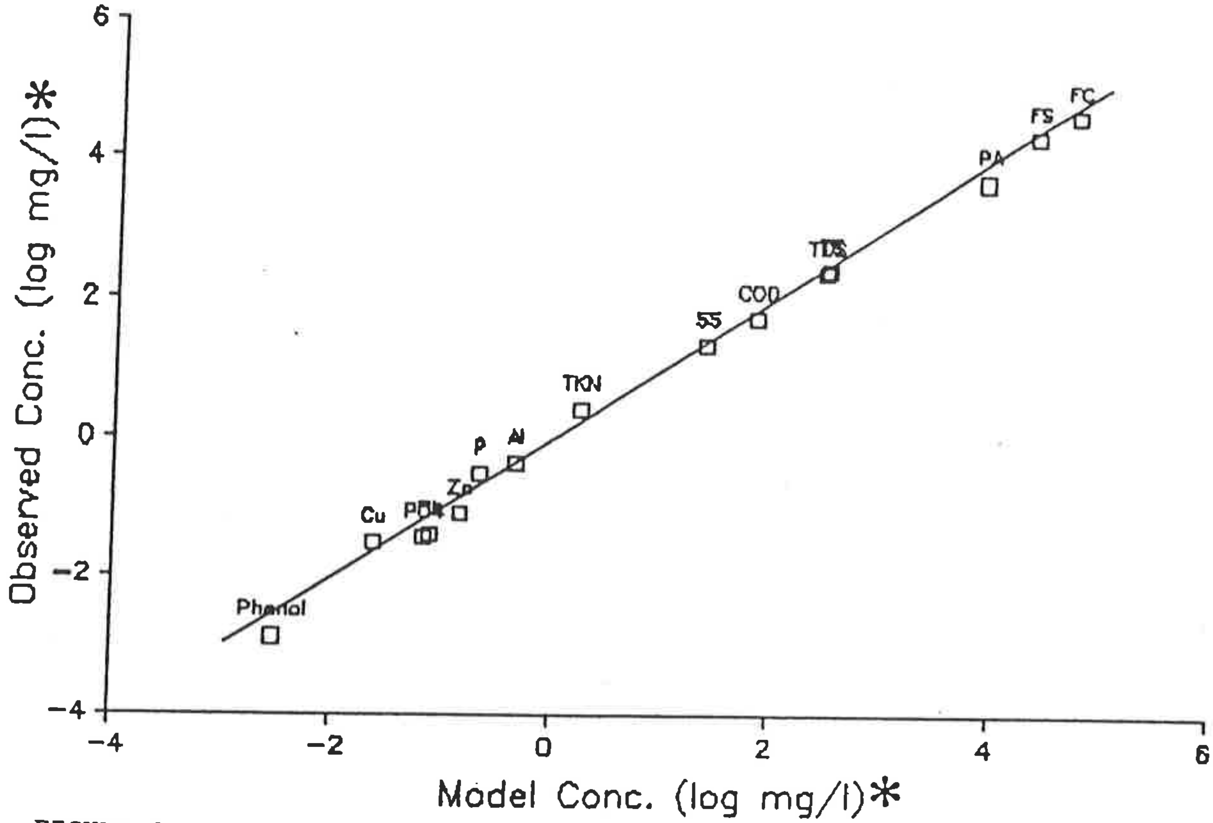
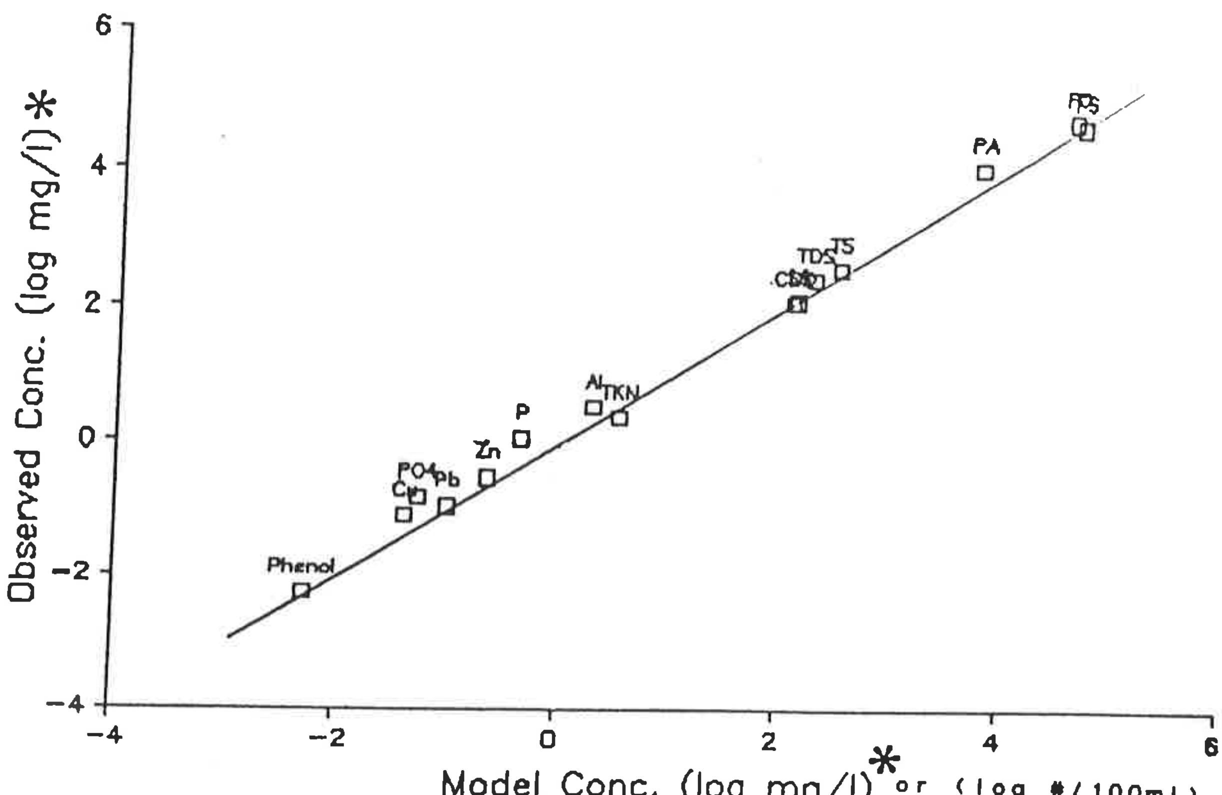


FIGURE 6.18

Observed Vs. Modeled Outfall Pollutant Conc.

Emery (Industrial)



High fecal coliform bacteria populations were also observed at the outfalls in both the industrial and the residential / commercial catchments. During the warm weather sampling period, the surface sheetflows were thought to be responsible for most of the observations of bacteria at the outfalls. However, during cold weather, very few detectable surface snowmelt sheetflow or snow pack fecal coliform observations were obtained, while the outfall observations were still quite high. Leaking sanitary sewerage is therefore suspected at both study areas. Fecal bacteria contaminated sump pump drainage or accumulations of bacteria over long periods in the storm drainage is not thought to be significant.

The frequent detection of pentachlophenols in the relatively few samples analysed indicate important leaching from wood treated with "penta". Frequent detections of polycyclic aromatic hydrocarbon (PAH's) during the U.S. Environmental Protection Agency's Nationwide Urban Runoff Program also possibly indicate important leaching from creosote treated wood . High concentrations of copper, and some chromium and arsenic observations also indicate the potential of leaching from "CCA" treated wood. The significance of these leachate products in the receiving waters is currently unknown, but alternatives to these preservatives should be considered. Many cities use aluminum and concrete utility poles instead of treated wood poles. This is especially important considering that utility poles are usually located very close to the drainage system ensuring an efficient delivery of leachate products. Many homes currently use stains containing "penta" and other wood preservatives. Similarly, the construction of retaining walls, wood decks and playground equipment with treated wood is common. Some preservatives (especially creosote) cause direct skin irritation, besides contributing to potential problems in receiving waters. Many of these wood products are at least located some distance from the storm drainage system, allowing some improvement to surface water quality by infiltration through pervious surfaces.

The use of commercial landscape maintenance services is increasing in urban areas. High concentrations of nutrients and pesticides have been observed for many years in outfall samples and indicate the over use of these products. Commercial landscape maintenance services should be licensed by the municipalities. The types, amounts, and timing of chemical applications need to be carefully monitored and controlled.

6.8.2 BACTERIA SOURCES

Fecal coliform bacteria are possibly one of the most important pollutants originating from urban runoff in the Toronto area. It is therefore important to understand the meanings of the different coliform indicator tests. The fecal coliform test is not specific for any one coliform type, or groups of types, but instead has an excellent positive correlation for coliform bacteria derived from the intestinal tract of warm blooded animals (Geldreich, et al, 1968). The fecal coliform test measures Escherichia coli as well as all other coliforms that can ferment lactose at 44.5 oC and are found in warm blooded fecal discharges. Geldreich (1976) found that the fecal coliform test represents over 96 percent of the coliforms derived from human feces and from 93 to 98 percent of those discharged in feces from other warm blooded animals, including livestock, poultry, cats, dogs, and rodents. The variations in the specific fecal coliform bacteria biotypes are related to both fecal moisture content and diet. Moisture and diet may also affect the variety of bacteria biotypes found in the fecal coliform populations from different animal groups. In many urban runoff studies, all of the fecal coliforms were _E. coli_ (Quresh and Dutka, 1979). Fecal streptococci bacteria are all of the intestinal Streptococci bacteria from warm blooded animal feces (Geldreich and Kenner, 1969). The types and concentrations of different bacteria biotypes varies for different animal sources. Quresh and Dutka (1979) found that pathogenic bacteria biotypes are present in southern Ontario urban runoff and are probably from several different sources.

Van Donzel, Geldreich, and Clarke (1967) reviewed waterborne disease outbreak information for 1946 to 1960. Almost 26,000 cases were listed for almost 230 known outbreaks in the United States and Puerto Rico. At least 29 of these outbreaks, involving more than 9,000 cases, were associated with stormwater runoff caused by runoff washing either human and animal feces or sewage into wells, springs, streams, reservoirs, and open water mains, or by widespread flooding of individual and public water systems. Quresh and Dutka (1979) have mentioned the potential health hazards of stormwater discharges throughout rain events in Southern Ontario.

Several authors, however, did not think that urban runoff may present a significant health problem. Olivieri, Kruse, and Kawata (1977a) did not believe that urban runoff constitutes a major health problem because of the large numbers of viable bacteria cells that must be consumed to establish an infection. For urban runoff, it may be impossible to consume enough bacteria cells to establish the infective dose. The importance of urban runoff in disease transmission in the Ottawa area was also questioned by Gore and Storrie / Proctor and Redfern (1981b). They stated that little or no correlations were found between indicator and pathogenic bacteria in the stormwater runoff and receiving waters.

Pseudomonas aeruginosa is reported to be the most abundant pathogenic bacteria organism in urban runoff and streams (Olivieri, Kruse, and Kawata (1977b). This pathogen is associated with eye and ear infections and is resistant to antibiotics. They also stated that past studies have failed to show any relationships between _P. aeruginosa_ concentrations in bathing waters and ear infections. However, _Pseudomonas_ concentrations in urban runoff are at significantly greater concentrations (approximately 100 times) than the values associated with past bathing beach studies. Cabelli, Kennedy, and Levin (1976) stated that _P. aeruginosa_ is indigenous in approximately 15 percent of the human population. Swimmer's ear or other Pseudomonas infections may, therefore, be caused by trauma to the ear canals associated with swimming and diving, and not exposure to Pseudomonas in the bathing water.

Environment Canada (1980) stated that there is preliminary evidence of the direct relationship between very low levels of P. aeruginosa and an increase in incidents of ear infections in swimmers. They stated that a control level for this Pseudomonas biotype of between 23 and 30 organisms/100 mL is being considered. Cabelli, Kennedy, and Levin (1976) stated that P. aeruginosa densities greater than ten organisms/100 mL were frequently associated with fecal coliform levels considerably less than 200 organisms/100 mL. P. aeruginosa densities were sometimes very low when the fecal coliform levels were greater than 200 organisms/100 mL. An average estimated P. aeruginosa density associated with a fecal coliform concentration of 200 organisms/100 mL is approximately 12/100 mL. They further stated that P. aeruginosa by itself cannot be used as a basis for water standards for the prevention of enteric diseases during recreational uses of surface waters. The determinations of this biotype should be used in conjunction with fecal coliform or other indicator organism concentrations for a specific location. They recommended that bathing beaches that are subject to urban runoff pollution be temporarily closed until the P. aeruginosa concentrations return to a baseline concentration. P. aeruginosa populations of more than 50,000/100 ml have been observed during this study. Typical concentrations in Emery stormwater were approximately 10,000/100 mL, and approximately 3,000/100 mL in Thistledown stormwater. Again, these measurements did not allow the sources of these high concentrations to be found in the catchments. Sidewalks and pervious areas appeared to be major sources of above ground discharges in Thistledown, while paved parking areas and pervious areas in Emery were significant sources.

The sources (animal or human) of bacteria in the test catchments could not be readily determined from the available data. Geldreich and Kenner (1969) caution against using the ratio of fecal coliform to fecal streptococci as an indicator, unless the waste stream is known to be "fresh". Unfortunately, urban runoff bacteria may have been lying on the ground for some time before rain washed it into the runoff waters. This aging process can modify the ratio to make the bacteria appear to be of human origin. In fact, samples collected in the source areas usually have the lowest FC/FS ratio in a catchment, followed by urban runoff, and finally the receiving water. This transition indicates an aging process and not a change in bacteria source (Pitt, 1983). The best way to determine the possible source of bacteria is to monitor for certain specific biotypes. The best biotypes to monitor include S. bovis, S. equinus (only associated with nonhuman animals), and S. faecalis (the predominant human fecal streptococci).

6.8.3 SALT

The de-icing of streets is an important job of public works departments. However, the effects of salts of de-icing compounds on receiving waters has been of concern for many years. Many municipalities have significantly reduced the amounts of salt applied in recent years. Only the major roads in the two test areas were salted during the study period. In the Emery catchment, Signet, Weston, and Toryork Roads were the only roads salted. In the Thistledown catchment, only Albion Road was salted.

Table 6.13 summarizes the estimated salt applications in the two catchments during the winter of 1983 and 1984. Approximately 700 kg of chlorides per hectare were spread in Emery and approximately 400 kg of chlorides per hectare were spread in Thistledown.

In most mass balance attempts of salt applications and runoff yields, approximately only ten percent of the applied salt can be accounted for at the outfall or by snow dumping. However, the annual chloride discharges observed at the Emery outfall were approximately twice the amount of chlorides applied by salting operations. In the Thistledown catchment, the annual chloride discharges were approximately six times the amount applied by salting operations. More than 80 percent of the chloride discharges from these two study areas occurred during the winter months of December through March. Therefore, it would seem that most of the chloride sources are associated with winter activities, with road salting being the prime contributor. In Emery, most of the chloride discharges were associated with snowmelts, while in Thistledown, most of the chloride discharges occurred with cold weather baseflows. The annual unit area chloride discharge observed from Thistledown was approximately twice as great as was observed from Emery, even though the road salt applications in Thistledown were reported to be only one half as much as in Emery. The reason for the great differences in salt applications and monitored discharges is not known.

Table 6.13 ESTIMATED SALT APPLICATION

Emery: about 1400 lb. of salt applied per 2-lane miles, only on Signet, Weston, and Toryork Roads. Total of about 5.4 miles of 2-lane roads.

Thistledown : about 1000 lb. of salt applied per event less than 5 cm snow per 2-lane miles, only on Albion Road. Total of about 1.3 miles of 2-lane roads.

month	# of all snow events (1)	snows §5cm
November 1983	6	6
December	12	10
January 1984	14	13
February	8	6
March	10	8
Total	50	43

(1) excludes "TR" events.

Emery: 5.4 miles X 50 events X 1400 lb/mile-event = 380,000 lb salt
X 0.60 Cl per lb NaCl = 230,000 lb chlorides/154 ha
= 1480 lb chlorides/ha X 0.454 kg/lb = 670 kg chlorides/ha applied for Emery.

Thistledown : 1.3 miles X 43 events X 1000 lb/mile-event = 56,000 lb salt
X 0.60 Cl per lb NaCl = 33,500 lb chlorides/39ha
= 860 lb chlorides/ha X 0.454 kg/lb = 390 kg chlorides/ha applied for Thistledown .

Note: § means "less than".

7.0 URBAN RUNOFF CONTROLS

7.1 INTRODUCTION

One of the main functions of the Toronto / Source Loading and Management Model (Toronto/SLAMM) is to predict the effectiveness of various control options in warm weather stormwater runoff from source areas, sewerage, and at the outfall. Many of the analyses performed as part of this Pilot Watershed Project were used in the development and calibration of the Toronto / SLAMM model. Previous urban runoff research projects conducted throughout the U.S. and Canada also supplied important information concerning various processes that were modeled. Special street cleaning tests were conducted as part of this project in Toronto to allow much of the previous street cleaning information to be applied to the Toronto area.

The Urban Runoff Controls Manual of Practice, prepared for the MOE as part of the Toronto / SLAMM project, extensively documents performance expectations and design procedures for applicable urban runoff controls. The land surface contribution model prepared as a utility to SLAMM was used in the sensitivity analysis report (of the Toronto / SLAMM project) to predict the importance of different source areas for different pollutants (and flows) for storms of different rain depths and land uses. A composite model utility was prepared to predict the effects of combining the different homogeneous land uses into real watershed configurations. Included in the composite model utility is the capability to examine the effects of controls on different source areas and at the outfall for each land use within the watershed. This section summarizes these previous modeling efforts conducted for the urban Humber River catchment that predict how the different controls may be expected to perform in the Thistledown and Emery catchments and in the specific land uses present in the complete urban Humber River catchment.

7.2 STREET CLEANER PERFORMANCE

Street cleaning can significantly affect street dirt loadings. Several tests were conducted in conjunction with the accumulation tests to compare the effectiveness of Toronto street cleaning practices with more extensive data previously collected elsewhere. The Toronto area street cleaning tests results from both the residential (Glen Roy) and the industrial (Norseman) areas were similar to each other. They were also similar to other street cleaning tests conducted elsewhere, after considering the differences in initial (before street cleaning) street dirt loadings.

The main factors affecting street cleaning productivity are initial street dirt loadings and street texture. Both Toronto sites had similarly smooth textured roads. Other factors, such as cleaning equipment type (vacuum, mechanical, or regenerative air), operating conditions, densities of parked cars, etc, all may effect street cleaning performance, but to much lesser extents than street dirt industrial areas, especially if paved parking/storage areas can be effectively cleaned. The pollutant loading can be reduced by up to approximately 70 percent if paved industrial parking / storage areas can be effectively cleaned. However, the more common type of street cleaning program would only reduce the pollutant load by less than 10 percent. Intensive spring cleanup by street cleaning was not evaluated in Toronto. It is assumed to be very important in reducing pollutant discharges from early spring rains.

Figures 7.1 and 7.2 were prepared with the Toronto / SLAMM street cleaning module and demonstrate the major differences in street cleaning effects in industrial and residential land uses, and for smooth and rough textured streets. These curves also show the fast response of street runoff quality to infrequent street cleaning. For example, cleaning streets every two weeks (or 16 times in an eight month non-snow, street cleaning season) is predicted to reduce the total solids load from street sheetflows by approximately 55 percent, compared to no street cleaning. Cleaning approximately once per week (or more frequently) is likely to only slightly improve street runoff quality, compared to cleaning every two weeks. Very infrequent street cleaning (once every two months, or four times during eight months) is predicted to reduce the street washoff of total solids by approximately 35 percent compared with no street cleaning. The condition of the streets was found to be much less important than the street texture, for both residential and industrial areas.

The concentrations of constituents in runoff shown on these figures are for long-term averages. Runoff from individual streets during single storm events would show much more variability. The effects of street cleaning on outfall runoff quality will vary greatly, depending on the importance of contributions from other source areas.

7.3 THE EFFECTIVENESS OF OTHER SOURCE AREA AND OUTFALL CONTROL OPTIONS

On-site infiltration can remove 100 percent of the flows and pollutants from the runoff from contributing source areas, if properly designed and maintained. However, care must be taken to prevent ground water contamination. Infiltration trenches approximately 1.2 m (W) by 1.2 m (D) may safely handle runoff from a tributary area in the order of 20 to 40 m away from the trench, depending on the soil porosity (Lake Tahoe, 1978).

Porous pavement can be an effective control option if properly designed and maintained. Lattice blocks in parking areas show the most promise for the Toronto area. It is estimated that porous pavement can control approximately 75 to 95 percent of the flow (Day, 1980). Porous pavements must be properly constructed with suitable subgrades to drain the percolating water away (Cedergren, 1974).

FIGURE 7.1 Street Cleaning Productivity

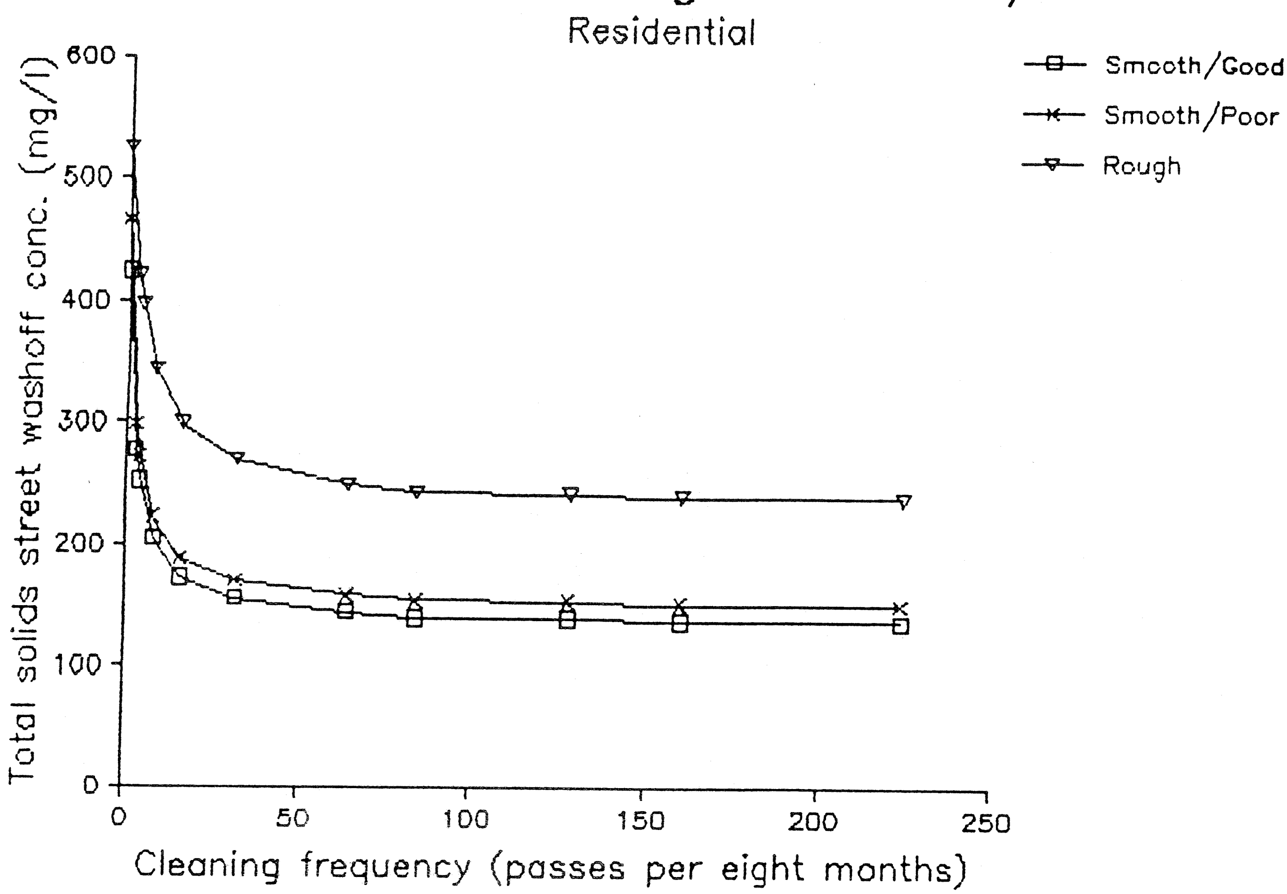
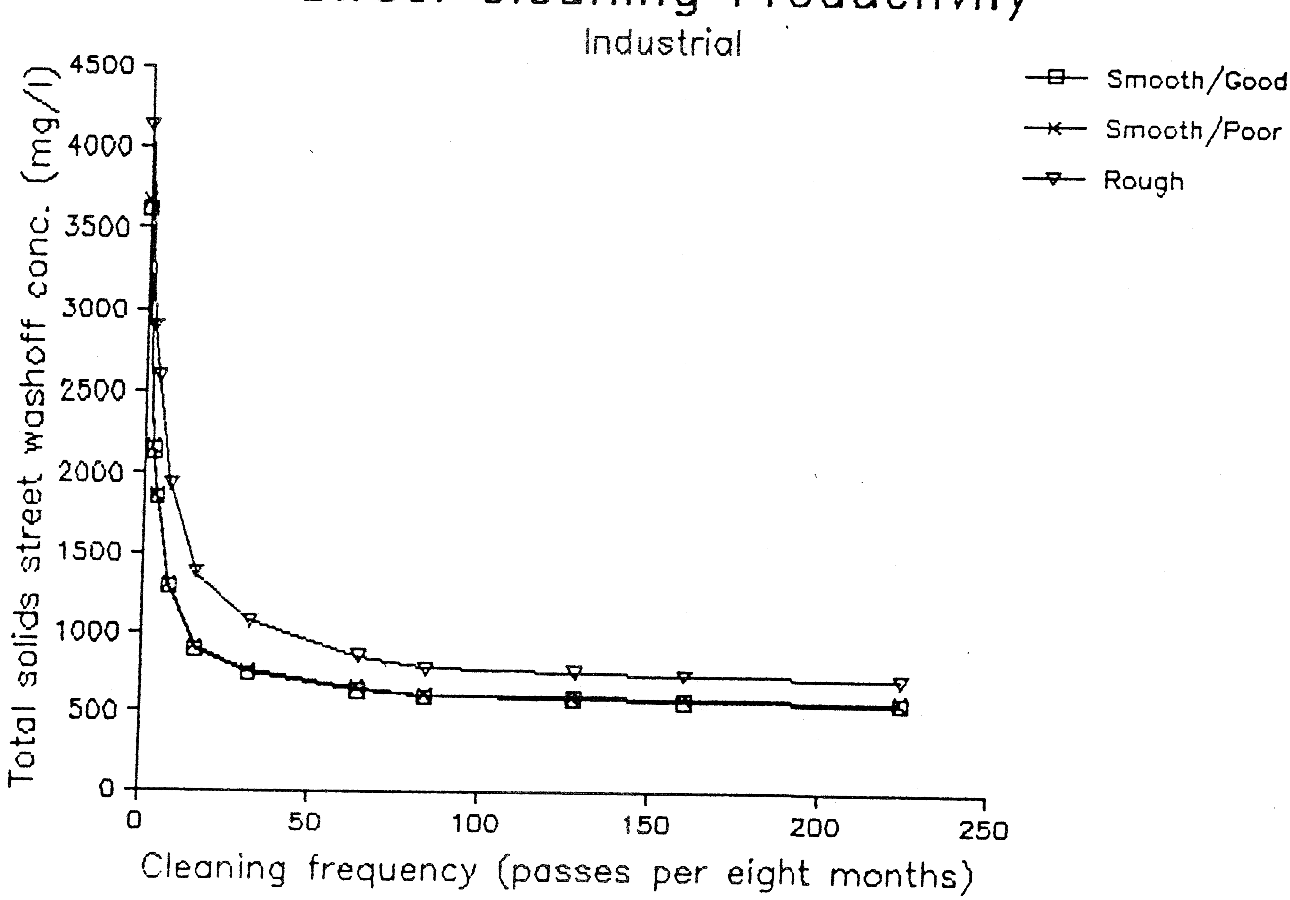


FIGURE 7.2 Street Cleaning Productivity



Pitt (1984) found that cleaning catchbasins twice a year to be partially effective. Residue and lead loads may be reduced by up to 25 percent, while COD, TKN, total phosphorus, and zinc may be reduced by up to 10 percent.

Grassed waterways, swales, and filter strips can be effective, if the water velocity is kept low (0.5 to 2 m/sec), and for nonsubmerged flow conditions. During this study, the swales were quite effective in reducing runoff volumes in the Thistledown catchment. No runoff was found in the swales during rain events up to approximately 13 mm. Novotny and Chesters (1981) say that a filter strip of approximately 30 to 120 meters in length may totally remove runoff pollutants. The filter media must be monitored, and revegetated before the settled material dislodges.

Detention basins received a lot of interest during the Nationwide Urban Runoff Program (EPA, 1983). It was found that dry basins did not remove significant amounts of pollutants due to the flushing out of settled material, but that wet basins reduced pollutant loads by approximately 95 percent. These wet detention basins were sized to cover approximately one percent of the contributing drainage area.

Tables 7.1 through 7.3 summarize the performance of many of the drainage area control measures. The most effective control devices are described in more detail in the following subsections.

7.3.1 INFILTRATION CONTROLS

Infiltration controls should be considered for sidewalks, driveways, paved parking areas, walkways, paved playgrounds, and connected roofs. The effectiveness of infiltration controls is dependent on the design of the infiltration devices and the local soil and subsoil infiltration (percolation) capabilities. The importance of these design parameters is extensively documented in the Manual of Practice. Tables 7.1 and 7.2 show the effectivenesses for alternative infiltration devices for an industrial (e.g. Emery) and a residential/commercial (e.g. Thistledown) catchment.

Typical infiltration devices can include perforated sewerage, grass swales, simple redirection of roof runoff to pervious areas, percolating collection pools, and infiltration trenches. As noted above, almost complete control of surface runoff is possible with well designed infiltration devices. Care must be taken to prevent ground water contamination.

7.3.2 WET DETENTION BASIN SOURCE AREA CONTROLS

Wet detention basins can be effective for treating the runoff from parking areas and connected roofs. The wet basins are most effective for reducing particulate pollutants. Table 7.2 shows the effectiveness of using wet detention source area controls to treat large industrial roofs or parking areas. Table 7.3 shows that wet detention basins, sized to be approximately one percent of the contributing paved area, can control approximately 65 percent of the particulate residue, approximately 40 percent of the COD and

Table 7.1 APPROXIMATE CONTROL EFFECTIVENESS FOR MEDIUM DENSITY RESIDENTIAL AREAS IN THISTLEDOWN (outfall effects, %)

	Flow					Total Solids				
	warm		cold			warm		cold		
Controls Applicable for Residential Areas	base-flow	storm-water	base-flow	melt-water	weighted total annual	base-flow	storm-water	base-flow	melt-water	weighted total annual
Street cleaning on smooth streets										
one or more passes/week	0	0	0	0	0	0	0	0	0	0
one pass/two weeks	0	0	0	0	0	0	0	0	0	0
one pass/month	0	0	0	0	0	0	0	0	0	0
one pass/two months	0	0	0	0	0	0	0	0	0	0
one pass/three months	0	0	0	0	0	0	0	0	0	0
Street cleaning on rough streets										
one or more passes/week	0	0	0	0	0	0	0	0	0	0
one pass/two weeks	0	0	0	0	0	0	0	0	0	0
one pass/month	0	0	0	0	0	0	0	0	0	0
one pass/two months	0	0	0	0	0	0	0	0	0	0
one pass/three months	0	0	0	0	0	0	0	0	0	0
Sidewalks										
total infiltration	0	0	0	0	0	0	0	0	0	0
Driveways										
total infiltration	0	16	0	4	4	0	23	0	6	3
Walkways										
total infiltration	0	0	0	0	0	0	0	0	0	0
Connected roofs										
total infiltration	0	18	0	5	5	0	11	0	3	1
redirect from pavement to lawns	0	14	0	4	4	0	0	0	0	0
Catchbasins										
clean twice per year	0	0	0	0	0	0	18	0	18	6
Roadside drainage systems										
grass swales	0	90	0	13	20	0	90	0	13	7
perforated drainage system	0	90	0	23	23	0	90	0	23	10
Main storm drain lines										
perforated pipe	90	90	90	90	90	90	90	90	90	90
Outfall wet detention basin										
0.8% of contributing resid. area	0	0	0	0	0	0	0	0	0	0
0.3% of contributing resid. area	0	0	0	0	0	0	0	0	0	0
% mass contrib. during period:	30%	17	20	33	100	28	4	40	28	100

Table 7.1 APPROXIMATE CONTROL EFFECTIVENESS FOR MEDIUM DENSITY RESIDENTIAL AREAS IN THISTLEDOWN (outfall effects, %) continued

Controls Applicable for Residential Areas	Chemical Oxygen Demand					Total Phosphorus				
	warm		cold			warm		cold		
	base-flow	storm-water	base-flow	melt-water	weighted total annual	base-flow	storm-water	base-flow	melt-water	weighted total annual
Street cleaning on smooth streets										
one or more passes/week	0	0	0	0	0	0	34	0	0	8
one pass/two weeks	0	0	0	0	0	0	31	0	0	7
one pass/month	0	0	0	0	0	0	27	0	0	6
one pass/two months	0	0	0	0	0	0	21	0	0	5
one pass/three months	0	0	0	0	0	0	18	0	0	4
Street cleaning on rough streets										
one or more passes/week	0	0	0	0	0	0	19	0	0	4
one pass/two weeks	0	0	0	0	0	0	16	0	0	4
one pass/month	0	0	0	0	0	0	12	0	0	3
one pass/two months	0	0	0	0	0	0	9	0	0	2
one pass/three months	0	0	0	0	0	0	7	0	0	2
Sidewalks										
total infiltration	0	0	0	0	0	0	10	0	3	4
Driveways										
total infiltration	0	0	0	0	0	0	23	0	6	8
Walkways										
total infiltration	0	0	0	0	0	0	0	0	0	0
Connected roofs										
total infiltration	0	35	0	9	11	0	0	0	0	0
redirect from pavement to lawns	0	28	0	7	9	0	0	0	0	0
Catchbasins										
clean twice per year	0	8	0	8	5	0	8	0	8	6
Roadside drainage systems										
grass swales	0	90	0	13	23	0	90	0	13	28
perforated drainage system	0	90	0	23	28	0	90	0	23	45
Main storm drain lines										
perforated pipe	90	90	90	90	90	90	90	90	90	90
Outfall wet detention basin										
0.8% of contributing resid. area	55+	55	55+	55	90	55+	55	55+	55	90
0.3% of contributing resid. area	40+	40	40+	40	65	40+	40	40+	40	65
% mass contrib. during period:	14%	19	19	48	100	13	24	17	46	100

Table 7.1 APPROXIMATE CONTROL EFFECTIVENESS FOR MEDIUM DENSITY RESIDENTIAL AREAS IN THISTLEDOWN (outfall effects, %) continued

	Total Kjeldahl Nitrogen					Lead				
	warm		cold			warm		cold		
Controls Applicable for Residential Areas	base-flow	storm-water	base-flow	melt-water	weighted total annual	base-flow	storm-water	base-flow	melt-water	weighted total annual
Street cleaning on smooth streets										
one or more passes/week	0	0	0	0	0	0	25	0	0	5
one pass/two weeks	0	0	0	0	0	0	23	0	0	5
one pass/month	0	0	0	0	0	0	20	0	0	4
one pass/two months	0	0	0	0	0	0	16	0	0	3
one pass/three months	0	0	0	0	0	0	13	0	0	3
Street cleaning on rough streets										
one or more passes/week	0	0	0	0	0	0	15	0	0	3
one pass/two weeks	0	0	0	0	0	0	12	0	0	2
one pass/month	0	0	0	0	0	0	10	0	0	2
one pass/two months	0	0	0	0	0	0	7	0	0	1
one pass/three months	0	0	0	0	0	0	6	0	0	1
Sidewalks										
total infiltration	0	0	0	0	0	0	0	0	0	0
Driveways										
total infiltration	0	0	0	0	0	0	35	0	9	14
Walkways										
total infiltration	0	0	0	0	0	0	0	0	0	0
Connected roofs										
total infiltration	0	32	0	8	13	0	17	0	4	7
redirect from pavement to lawns	0	26	0	7	11	0	14	0	4	6
Catchbasins										
clean twice per year	0	8	0	8	5	0	8	0	8	8
Roadside drainage systems										
grass swales	0	90	0	13	32	0	90	0	13	28
perforated drainage system	0	90	0	23	36	0	90	0	23	36
Main storm drain lines										
perforated pipe	90	90	90	90	90	90	90	90	90	90
Outfall wet detention basin										
0.8% of contributing resid. area	36	36	36	36	36	80	80	80	80	80
0.3% of contributing resid. area	25	25	25	25	25	60	60	60	60	60
% mass contrib. during period:	16%	30	16	38	100	0	20	0	80	100

Table 7.1 APPROXIMATE CONTROL EFFECTIVENESS FOR MEDIUM DENSITY RESIDENTIAL AREAS IN THISTLEDOWN (outfall effects, %) continued

Controls Applicable for Residential Areas	Zinc: warm base-flow	Zinc: warm storm-water	Zinc: cold base-flow	Zinc: cold melt-water	Zinc: weighted total annual	Fecal Coliform Bacteria: warm base-flow	Fecal Coliform Bacteria: warm storm-water	Fecal Coliform Bacteria: cold base-flow	Fecal Coliform Bacteria: cold melt-water	Fecal Coliform Bacteria: weighted total annual
Street cleaning on smooth streets										
one or more passes/week	0	0	0	0	0	0	0	0	0	0
one pass/two weeks	0	0	0	0	0	0	0	0	0	0
one pass/month	0	0	0	0	0	0	0	0	0	0
one pass/two months	0	0	0	0	0	0	0	0	0	0
one pass/three months	0	0	0	0	0	0	0	0	0	0
Street cleaning on rough streets										
one or more passes/week	0	0	0	0	0	0	0	0	0	0
one pass/two weeks	0	0	0	0	0	0	0	0	0	0
one pass/month	0	0	0	0	0	0	0	0	0	0
one pass/two months	0	0	0	0	0	0	0	0	0	0
one pass/three months	0	0	0	0	0	0	0	0	0	0
Sidewalks										
total infiltration	0	0	0	0	0	0	31	0	8	13
Driveways										
total infiltration	0	0	0	0	0	0	0	0	0	0
Walkways										
total infiltration	0	0	0	0	0	0	15	0	4	6
Connected roofs										
total infiltration	0	46	0	12	14	0	0	0	0	0
redirect from pavement to lawns	0	37	0	9	11	0	0	0	0	0
Catchbasins										
clean twice per year	0	8	0	8	6	0	0	0	0	0
Roadside drainage systems										
grass swales	0	90	0	13	21	0	90	0	13	37
perforated drainage system	0	90	0	23	26	0	90	0	23	37
Main storm drain lines										
perforated pipe	90	90	90	90	90	90	90	90	90	90
Outfall wet detention basin										
0.8% of contributing resid. area	55	55	55	55	55	0	0	0	0	0
0.3% of contributing resid. area	40	40	40	40	40	0	0	0	0	0
% mass contrib. during period:	15%	15	15	55	100	46	40	9	5	100

Assumes infiltration is 25% as effective during melting periods compared to warm weather periods.
Assumes grass swales are 15% as effective during melting periods compared to warm weather periods.
Assumes catchbasins, perforated storm lines, and detention basins have the same effectiveness during both warm and cold periods.
Outfall detention basins and perforated main storm drain lines are the only controls that affect baseflows.

Table 7.2 ESTIMATED CONTROL EFFECTIVENESS FOR LIGHT INDUSTRIAL AREAS IN EMERY (outfall control, %)

Controls Applicable for Light Industrial Areas	Flow					Total Solids				
	warm		cold			warm		cold		
	base-flow	storm-water	base-flow	melt-water	weighted total annual	base-flow	storm-water	base-flow	melt-water	weighted total annual
Driveways										
total infiltration	0	0	0	0	0	0	0	0	0	0
Paved parking areas										
total infiltration	0	29	0	15	11	0	43	0	22	11
small wet detention basins	0	0	0	0	0	0	0	0	0	0
large wet detention basins	0	0	0	0	0	0	0	0	0	0
Connected roofs										
total infiltration	0	54	0	27	20	0	33	0	17	9
small wet detention basins	0	0	0	0	0	0	0	0	0	0
large wet detention basins	0	0	0	0	0	0	0	0	0	0
Catchbasins										
clean twice per year	0	0	0	0	0	0	0	0	0	0
Roadside drainage system										
grass swales	0	45	0	7	14	0	45	0	7	10
perforated drainage system	0	45	0	23	17	0	45	0	23	16
Main storm drain lines										
perforated pipes	45	45	45	45	45	45	45	45	45	45
Outfall wet detention basin										
2% of contrib. indus. area	0	0	0	0	0	0	0	0	0	0
0.8% of contrib. indus. area	0	0	0	0	0	0	0	0	0	0
% mass contrib. during period:	42%	29	13	16	100	28	17	18	37	100

Table 7.2 ESTIMATED CONTROL EFFECTIVENESS FOR LIGHT INDUSTRIAL AREAS IN EMERY (outfall control, %) continued

Controls Applicable for Light Industrial Areas	Chemical Oxygen Demand					Total Phosphorus				
	warm		cold			warm		cold		
	base-flow	storm-water	base-flow	melt-water	weighted total annual	base-flow	storm-water	base-flow	melt-water	weighted total annual
Driveways										
total infiltration	0	0	0	0	0	0	10	0	5	4
Paved parking areas										
total infiltration	0	43	0	22	16	0	74	0	37	32
small wet detention basins	0	17	0	17	7	0	30	0	30	15
large wet detention basins	0	23	0	23	17	0	40	0	40	20
Connected roofs										
total infiltration	0	40	0	20	16	0	0	0	0	0
small wet detention basins	0	16	0	16	8	0	0	0	0	0
large wet detention basins	0	22	0	22	11	0	0	0	0	0
Catchbasins										
clean twice per year	0	8	0	8	4	0	8	0	8	4
Roadside drainage system										
grass swales	0	45	0	7	16	0	45	0	7	17
perforated drainage system	0	45	0	23	18	0	45	0	23	20
Main storm drain lines										
perforated pipes	45	45	45	45	45	45	45	45	45	45
Outfall wet detention basin										
2% of contrib. indus. area	55	55	55	55	55	55	55	55	55	55
0.8% of contrib. indus. area	40	40	40	40	40	40	40	40	40	40
% mass contrib. during period:	43%	32	8	17	100	43	36	6	15	100

Table 7.2 <u>ESTIMATED CONTROL EFFECTIVENESS FOR LIGHT INDUSTRIAL AREAS IN EMERY</u> (outfall control, %) continued

Controls Applicable for Light Industrial Areas	Total Kjeldahl Nitrogen					Lead				
	warm		cold			warm		cold		
	base-flow	storm-water	base-flow	melt-water	weighted total annual	base-flow	storm-water	base-flow	melt-water	weighted total annual
Driveways										
total infiltration	0	0	0	0	0	0	0	0	0	0
Paved parking areas										
total infiltration	0	40	0	20	15	0	70	0	35	54
small wet detention basins	0	10	0	10	5	0	42	0	42	42
large wet detention basins	0	14	0	14	7	0	56	0	56	56
Connected roofs										
total infiltration	0	46	0	23	17	0	0	0	0	0
small wet detention basins	0	12	0	12	6	0	0	0	0	0
large wet detention basins	0	17	0	17	8	0	0	0	0	0
Catchbasins										
clean twice per year	0	8	0	8	4	0	8	0	8	8
Roadside drainage system										
grass swales	0	45	0	7	14	0	45	0	7	27
perforated drainage system	0	45	0	23	17	0	45	0	23	35
Main storm drain lines										
perforated pipes	45	45	45	45	45	45	45	45	45	45
Outfall wet detention basin										
2% of contrib. indus. area	36	36	36	36	36	80	80	80	80	80
0.8% of contrib. indus. area	25	25	25	25	25	60	60	60	60	60
% mass contrib. during period:	40%	27	11	22	100	0	53	0	47	100

Table 7.2 ESTIMATED CONTROL EFFECTIVENESS FOR LIGHT INDUSTRIAL AREAS IN EMERY (outfall control, %) continued

Controls Applicable for Light Industrial Areas	Zinc: warm base-flow	Zinc: warm storm-water	Zinc: cold base-flow	Zinc: cold melt-water	Zinc: weighted total annual	Fecal Coliform Bacteria: warm base-flow	Fecal Coliform Bacteria: warm storm-water	Fecal Coliform Bacteria: cold base-flow	Fecal Coliform Bacteria: cold melt-water	Fecal Coliform Bacteria: weighted total annual
Driveways										
total infiltration	0	0	0	0	0	0	0	0	0	0
Paved parking areas										
total infiltration	0	59	0	30	28	0	34	0	17	29
small wet detention basins	0	24	0	24	15	0	0	0	0	0
large wet detention basins	0	32	0	32	20	0	0	0	0	0
Connected roofs										
total infiltration	0	26	0	13	12	0	0	0	0	0
small wet detention basins	0	10	0	10	6	0	0	0	0	0
large wet detention basins	0	14	0	14	9	0	0	0	0	0
Catchbasins										
clean twice per year	0	8	0	8	5	0	0	0	0	0
Roadside drainage system										
grass swales	0	45	0	7	17	0	45	0	7	37
perforated drainage system	0	45	0	23	22	0	45	0	23	38
Main storm drain lines										
perforated pipes	45	45	45	45	45	45	45	45	45	45
Outfall wet detention basin										
2% of contrib. indus. area	80	80	80	80	80	0	0	0	0	0
0.8% of contrib. indus. area	60	60	60	60	60	0	0	0	0	0
% mass contrib. during period:	30%	34	8	28	100	16	83	0	1	100

Assumes infiltration during melting periods is 50% as effective as during warm periods (most below frost depth).
Assumes grass swales during melting periods are 15% as effective as during warm periods.
Assumes catchbasins, perforated main storm lines, and detention basins work as well during warm as duriing cold weather.
Outfall detention basins and perforated main storm drain lines are the only controls that affect baseflows. (All baseflows for these estimates are assumed to originate from sub-surface sources).

phosphorus, and up to approximately 60 percent of the heavy metals. Larger wet basins (sized to be up to approximately three percent of the contributing paved area) can produce larger reductions in pollutants. The Manual of Practice extensively documents the use and design of wet detention basins.

7.3.3 SEWERAGE CONTROLS

The benefits of sewerage controls are shown on Tables 7.1 through 7.3. These controls include catchbasin cleaning and the use of grass swales. The most effective catchbasin cleaning frequency is approximately twice per year. Grass swales reduce runoff flows and pollutant discharges mostly through infiltration and must be properly sized to provide the desired control effectiveness. The design and use of grass swales is discussed in the Manual of Practice. Because grass swales operate as infiltration devices, ground water contamination may occur, especially in industrial areas.

7.3.4 OUTFALL CONTROLS

Outfall controls serving the entire watershed can also be used to reduce the pollutant load. The most common outfall control is the use of a wet detention basin. Tables 7.1 and 7.2 show the effects of outfall wet detention basins for the industrial and the residential catchments. Table 7.3 also summarizes the effectiveness expected from wet detention basins for different land uses and basin sizes. Various outfall controls are also discussed in the Manual of Practice.

7.4 CONTROL EFFECTS FOR DIFFERENT LAND USES

The effects of the different source area controls on outfall runoff quality and flow rate varies greatly, depending on the land uses. Tables G.1 through G.17 summarize the effects at the outfall of the alternative source area controls. The effects are shown as "fractions removed at the outfall" for each control option and pollutant or flow. These fractions should be multiplied by 100 to obtain the reduction as a percentage. When evaluating a control program made up of several components, fractional utilization values are needed for each alternative control. For example, if weekly street cleaning is used on 25 percent of the streets, and monthly street cleaning is used in the other 75 percent of the streets for the same land use area, then a fractional utilization value of 0.25 is given for weekly cleaning and 0.75 is given for cleaning once per month. Obviously, the total of the fractional utilization values cannot exceed 1.0 for any one source area (e.g. smooth streets, parking lots, connected roofs, etc.). These tables all assume 100 percent utilization for each individual control. If a control is not used throughout the whole contributing area, then the expected control benefits must be appropriately adjusted.

Only those controls expected to have significant reductions in the pollutant load at the outfall (usually greater than ten percent) are shown on Tables G.1 through G.17. For example, only street cleaning of smooth streets, and infiltration of runoff from sidewalks, driveways, and connected roofs are expected to be important in low density residential areas (Table G.1). The same restrictions on controls exist for old and recently built, high density residential areas (Tables G.3 and G.4). The specific benefits for each type of control for these three source areas vary greatly. Street cleaning of smooth streets once per week in low density residential source areas is not expected to produce any significant reductions in particulate residue (suspended solids) load at the outfall. The same street cleaning effort in old high density residential areas is expected to produce an approximately 35 percent reduction in total residue load, compared to no street cleaning. In newer, high density residential areas, however, this weekly street cleaning effort may only produce a 20 percent reduction of particulate residue at the outfall. These differences are caused by the varying importance of smooth streets in contributing particulate residue to the outfalls for each land use area.

Recommendations for control options for land uses found in the study area are discussed in the following subsections.

7.4.1 RESIDENTIAL LAND USES

Street cleaning in most residential areas may cause significant reductions in the loads of phosphorus, fecal coliforms, and to a lesser extent, lead, at the outfall, compared to no cleaning. Acknowledging the current, but infrequent, street cleaning efforts, only minor further improvements may occur if the frequency is increased. It is difficult to justify increasing street cleaning beyond approximately one pass every month or every two weeks. Spring cleanup and fall leaf removal are expected to be very important and should be encouraged.

If roof runoff is not currently directed away from building foundations, walkways and driveways towards pervious areas (grass), then a retrofitting program of redirecting this runoff can be very cost effective. High rise apartments have large paved parking areas. Infiltration of the runoff flows associated with these paved areas would significantly reduce the flow and load of many pollutants.

The most practical runoff control for lower density residential land use areas is grass swales instead of concrete curb and gutter systems. These have been shown in monitoring programs to be as much as 90 percent effective in reducing flows and pollutant loads. If grass swales currently exist in an area, changing to curb and gutter systems should be strongly discouraged. Ground water contamination from grass swale infiltration in residential areas is not expected to be important.

7.4.2 INSTITUTIONAL LAND USES

Street cleaning benefits in school and hospital institutional areas would be similar to those previously described for most residential areas. The current levels of street cleaning are important, but increases beyond bi-weekly cleaning would not be justifiable.

These land uses have large areas of parking lots, paved playing areas and connected roofs. Redirection of runoff flows from these areas to pervious areas would encourage infiltration. Redirection would also produce significant reductions in runoff volume and loads of most pollutants. Grass swales are also applicable for institutional land uses and can be very effective.

7.4.3 COMMERCIAL LAND USES

Street cleaning at low levels of effort in strip commercial and office areas is important. However, increases in frequency beyond current levels may not be worthwhile.

The infiltration of runoff from paved parking and roofs is the most effective source area control option for all commercial areas, including shopping centers. Pretreatment of water to be infiltrated may be necessary to reduce the potential for ground water contamination. Grit chambers with oil and grease traps should be the minimum pretreatment required in a commercial setting. Shopping centres may be best treated with wet detention basins, with sealed linings to significantly reduce ground water contamination potential.

7.4.4 INDUSTRIAL LAND USES

Some increases in the frequency of street cleaning in industrial areas may reduce the pollutant loads at the outfall. The existing cleaning frequencies (next to nothing) should be increased to at least once per month.

Infiltration of runoff from paved parking and storage areas and roofs would contribute to a significant reduction in pollutant loads, but would require pretreatment for most source areas. Because of the heavily contaminated dry weather base flows from the industrial area monitored during this Pilot Watershed Project, wet detention basins at the outfalls of industrial parks are strongly encouraged. These basins will produce some attenuation of both wet and dry weather pollutant discharges. More importantly, the basins will offer an opportunity to control spills that enter the storm drainage system.

Grass swale drainage does not currently occur in the monitored industrial area (Emery). The use of grass swales in industrial areas may contribute to the contamination of ground water by the heavily contaminated runoff flows observed.

7.4.5 OPEN SPACE LAND USES

Open space areas are relatively unimportant sources of runoff and pollutants. However, important losses through erosion can occur from bare ground or steep hills, especially if they are located near the storm drainage system. Careful evaluations of erosion potential should be made for open space areas, especially if they are undergoing development. Minimum levels of street cleaning are also necessary for these areas, especially spring cleanup if road de-icing materials were used, along with the effective infiltration of runoff from paved parking areas. Few roofs are expected in these areas. Any roof drains should be directed to the large expanses of landscaped land available in these areas. Grass swales are quite common in open space areas in the urban Humber River basin and are very effective pollutant controls.

7.4.6 FREEWAYS

Street cleaning is the major control option available for freeways. The benefits predicted from freeway street cleaning are not expected to be very accurate because of the lack of street cleaning data for this land use. However, cleaning once every three months could have substantial benefits. Cleanup as soon as possible after snowmelt in the spring is a very important control for freeways because of the extensive use of de-icing materials. Another control measure that should be considered for freeways is the infiltration of runoff water in the pervious areas in the medians and near interchanges.

7.5 <u>COST EFFECTIVENESS OF LARGE SCALE CONTROL APPLICATIONS</u>

7.5.1 CONTROL OPTIONS ANALYSED

Ten different control programs were evaluated for the complete Humber River urban drainage area. These were made up of various combinations of the source area and outfall controls described above. These ten programs are listed below:

1) Increased street cleaning,

2) Increased street and catchbasin cleaning,

3) Large wet detention basins serving 25 percent of the drainage area,

4) Increased street cleaning and some large wet detention basins,

5) Infiltration of 50 % of the runoff from residential roofs, high rise residential, commercial, and parts of the industrial roof and paved parking areas, currently draining to pavement,

6) Increased street cleaning and partial infiltration,

7) Increased street and catchbasin cleaning and partial infiltration,

8) Partial infiltration and some large wet detention basins,

9) Increased street cleaning, partial infiltration, and some large wet detention basins, and

10) Increased street and catchbasin cleaning, partial infiltration, and some large wet detention basins.

The effects of the source area and outfall controls were calculated in the sensitivity analysis report. These calculations were made using Toronto / SLAMM and the associated utility programs, for the complete urban Humber River basin and are summarized in the following paragraphs.

7.5.2 COSTS OF ALTERNATIVE CONTROL PROGRAMS

In order to help select the most appropriate control program, as much information as possible concerning the benefits and problems associated with each complete control program is needed. The Manual of Practice discusses each individual control in detail and will be very important when final selection of project locations and designs are made. A multi-objective decision analysis procedure should be used when selecting the appropriate control program. In order to use this decision analysis procedure, the objectives of concern must be identified and the ability of each alternative control program to meet each objective must be known. After control performance, cost is the most obvious objective. Costs need to include both initial capital cost, and operation and maintenance costs. Other considerations that may affect the selection of a control program include political feasibility, recreation benefits, aesthetics, safety, nuisance potential and labor intensity. The Manual of Practice summarizes many of these considerations for the different controls, including how specific design specifications can be used to minimize the adverse characteristics of the control options.

It was beyond the scope of this project to identify the relative importance of these potential objectives (tradeoff functions) for the Toronto area decision makers. However, it is relatively straight forward to produce a simple cost-effectiveness relationship. This relationship, and the associated total alternative costs, will probably be the most important decision consideration. This discussion therefore briefly summarizes cost estimates used in developing an estimated cost-effectiveness relationship for the ten alternative control programs for the urban Humber River catchment. The cost estimates are expected to be sufficiently accurate for these analyses, but absolute costs for specific Toronto conditions can be expected to be different. These costs are from the discussions in the Manual of Practice and the specific references are not repeated here.

cleaning, infiltration and detention) and results in a smaller reduction of particulate residue. Program #10 (street and catchbasin cleaning, infiltration, and detention) includes all of the individual elements, resulting in the highest cost and the greatest particulate residue removals.

The three cost-effective clusters are therefore programs #3 and #4 at $1 to $2 million per year giving 26 percent control, programs #8 and #9 at approximately $6 million per year giving approximately 44 percent control, and program #10 at approximately $10 million per year giving approximately 47 percent control. Unless the extra level of control was needed, it would be hard to justify program #10 (everything). The most reasonable programs are probably either #8 or #9, depending on other objectives.

This analysis is more clear when Figure 7.4 is examined. This figure plots the unit removal costs ($ per kg "removed" compared to the current control program) against the maximum percentage removal possible for each program. Programs in the "lower right hand" corner of Figure 7.4 are therefore preferable. If relatively low control levels are all that are needed, then the lowest unit cost control giving the desired removal (at least) would be selected. As an example, if removal of 30 percent of the particulate residue is desired, program #3 (detention basins) would be "best". However, if removal of 40 percent of the particulate residue is desired, then the "best" program would be #8 (infiltration and detention basins). As noted earlier, the detention control only assumes that approximately 25 percent of the watershed can be treated using detention basins because of the difficulty of locating detention basins in established urban areas. Because of the substantial added cost associated with infiltration, additional detention basin use should be investigated if the other benefits associated with infiltration, such as flow reductions and control of "soluble" pollutants, are not important.

When total Kjeldahl nitrogen, phosphorus, COD, copper, and zinc "cost-effectiveness" plots are examined, it is clear that program #8 (infiltration and detention) allows much more pollutant removals to be obtained at a relatively low unit cost as compared to the other control programs. If flow, total residue, filtrate residue, fecal coliform bacteria, and pseudomonas aeruginosa are the most important constituents, then program #5 (infiltration alone) is the most cost-effective solution. The most general recommended control program is therefore program #8 (infiltration and wet detention). In order to obtain significant bacteria reductions, it may be necessary to use disinfection in conjunction with wet detention.

7.5.4 ANALYSES FOR INDIVIDUAL HUMBER RIVER SEWERSHEDS

Fifteen separate sewersheds in the urban Humber River catchment were evaluated in the sensitivity analysis report to estimate current levels of pollutant discharge and possible reductions of runoff and pollutant loading using the recommended control program. The recommended control program is listed below:

1) the use of wet detention basins serving 25 percent of the catchment,

2) the infiltration of runoff from approximately one half of the residential roofs currently draining to pavement, and

3) the infiltration of approximately one half of paved parking and storage areas and roofs in high rise residential, industrial, and commercial areas.

The total annual cost for this program in the urban Humber River catchment was estimated to be approximately $5.7 million per year ($410 per hectare per year). The anticipated reductions in pollutants for this program are listed below:

1) five to ten percent for bacteria,

2) fifteen to 20 percent for flow, total residue, and filtrate residue, and

3) 30 to 45 percent for particulate residue, nutrients, COD, phenols, and heavy metals.

If larger reductions in bacteria are required, then substantial cost increases may be needed for disinfection in conjunction with wet detention basins.

The performance of the recommended control program varies substantially for the different sewersheds. For example, flow reductions vary from nothing in sewershed #3.3.50 (mostly medium density residential and open space) to as much as 42 percent for sewershed #3.3.56 (a small watershed mostly of industrial land use). However, reductions of heavy metal discharges by approximately 30 percent are expected in sewershed #3.3.50.

basins is therefore estimated to be approximately $7,600,000. Annual maintenance costs are estimated to be approximately four percent of the initial construction cost, or approximately $300,000 per year.

Table 7.4 summarizes the total initial capital costs, annualized capital costs, annual operating and maintenance costs, and total annual costs for the ten alternative control programs. The total annual costs are also given on a unit area basis. The annual costs for the alternative programs range from $60 to $680 per hectare for the complete study area. Infiltration devices have very large capital costs, but low maintenance costs. Wet detention basins have the next lowest costs, and an increased street cleaning effort has the lowest total costs. The capital costs are amortized assuming 9.5 percent interest over 20 years.

7.5.3 COST-EFFECTIVENESS EVALUATION AND PRELIMINARY RECOMMENDATIONS FOR CONTROL PROGRAMS

The control program effectiveness and cost data described above were used to prepare a simple evaluation of cost/performance for the ten alternative control programs. Figures 7.3 through 7.10 graphically present selected data plots showing total annual costs verses percent pollutant reductions and unit removal costs verses maximum percent pollutant reduction available.

It was shown in the sensitivity analysis report that the different control programs affect the different pollutants and flow differently. For example, only infiltration controls affect flows and those pollutants mostly in filtrate (soluble or dissolved) forms ,such as total residue, filtrate residue, phenols, fecal coliform bacteria, and Pseudomonas aeruginosa, plus the other "dissolved" pollutants. Less expensive wet detention basin controls affect only those pollutants associated with particulate (nonfilterable or suspended) solids, such as particulate residue, phosphorus, total Kjeldahl nitrogen, chemical oxygen demand, copper, lead, and zinc. A combination of controls is therefore most suitable in order to remove a significant amount of pollutants at the lowest cost.

When Figure 7.3 is examined, six "clusters" of alternative programs for "removal effectiveness verses cost" were identified for particulate residue. Only three are "cost effective". Program #2 (increased street and catchbasin cleaning) only removes approximately 13 percent of the particulate residue, but at a cost of almost $4 million per year. Two other programs (#3 detention basins, and #4 street cleaning and large detention basins) can remove much more particulate residue (approximately 26 percent) at much lower cost (one to two million dollars per year). Therefore, program #2 cannot be justified for this situation. Similar observations can be made concerning programs #5 and #6. These programs are much more costly than programs #3 and #4 for similar reductions of particulate residue load. Program #7 (Street and catchbasin cleaning plus infiltration) is also much more expensive than programs #8 (infiltration and detention) and #9 (street

TABLE 7.4

Costs of Urban Runoff Control Programs.

Program Description	Capital Cost	Annualized Capital Cost (note 1)	Annual Operating and Maint. Cost	Total Annualized Cost total	Total Annualized Cost $/ha
1. Increased street cleaning	note 2	note 2	800,000	800,000	60
2. Street and catchbasin cleaning	note 2	note 2	3,800,000	3,800,000	270
3. Wet detention basins	7,600,000	840,000	300,000	1,100,000	80
4. Street cleaning and detention	7,600,000	840,000	1,100,000	1,900,000	140
5. Infiltration	42,000,000	4,600,000	low	4,600,000	330
6. Street cleaning and infiltration	42,000,000	4,600,000	800,000	5,400,000	390
7. Street and catchbasin cleaning and infilt.	42,000,000	4,600,000	3,800,000	8,400,000	600
8. Infiltration and detention	50,000,000	5,400,000	300,000	5,700,000	410
9. Street cleaning, infilt., and detention	50,000,000	5,400,000	1,100,000	6,500,000	460
10. Street and catchbasin cleaning, infilt., and detention	50,000,000	5,400,000	4,100,000	9,500,000	680

note 1: A loan period of 20 years and an interest rate of 9.5% was assumed.
note 2: Street and catchbasin cleaning capital costs are included in the unit annual rate used

FIGURE 7.3 Pollutant Removals for Control Programs

Suspended Solids

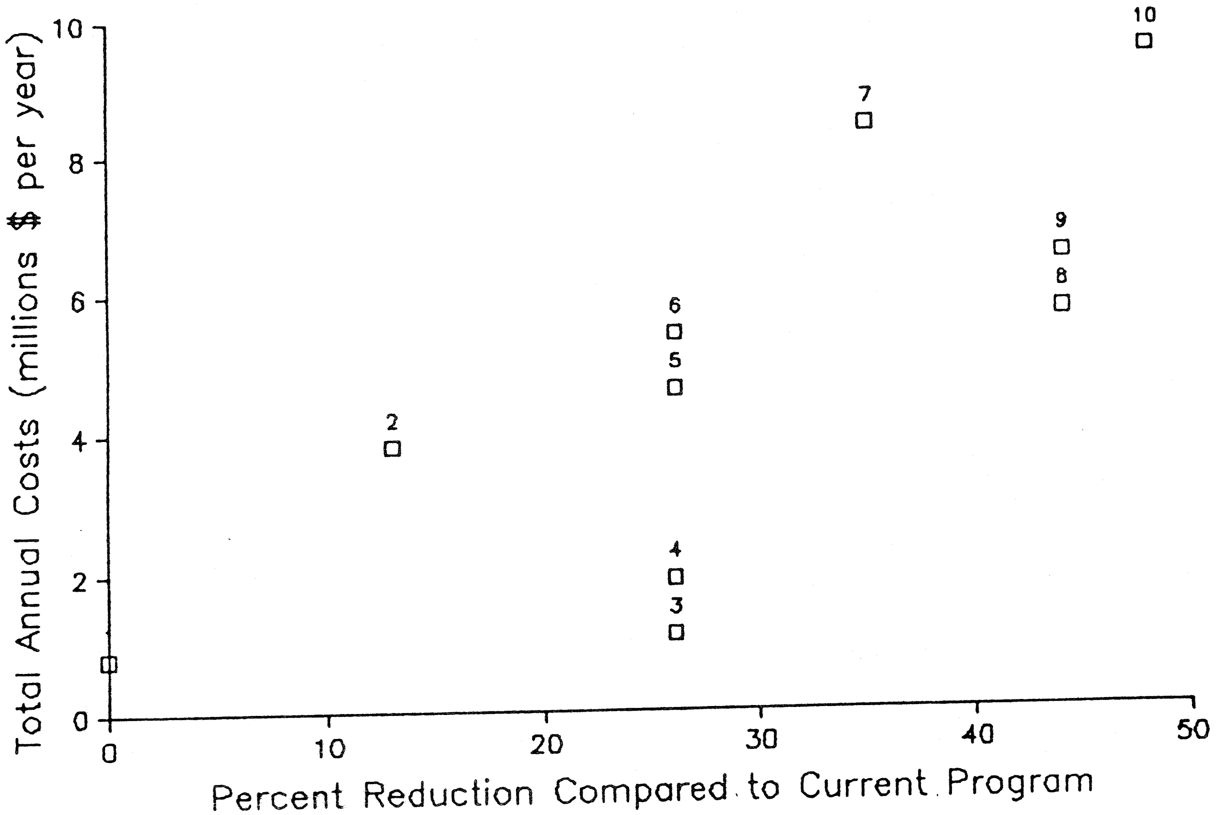


FIGURE 7.4 Unit Removal Costs for Control Programs

Suspended Solids

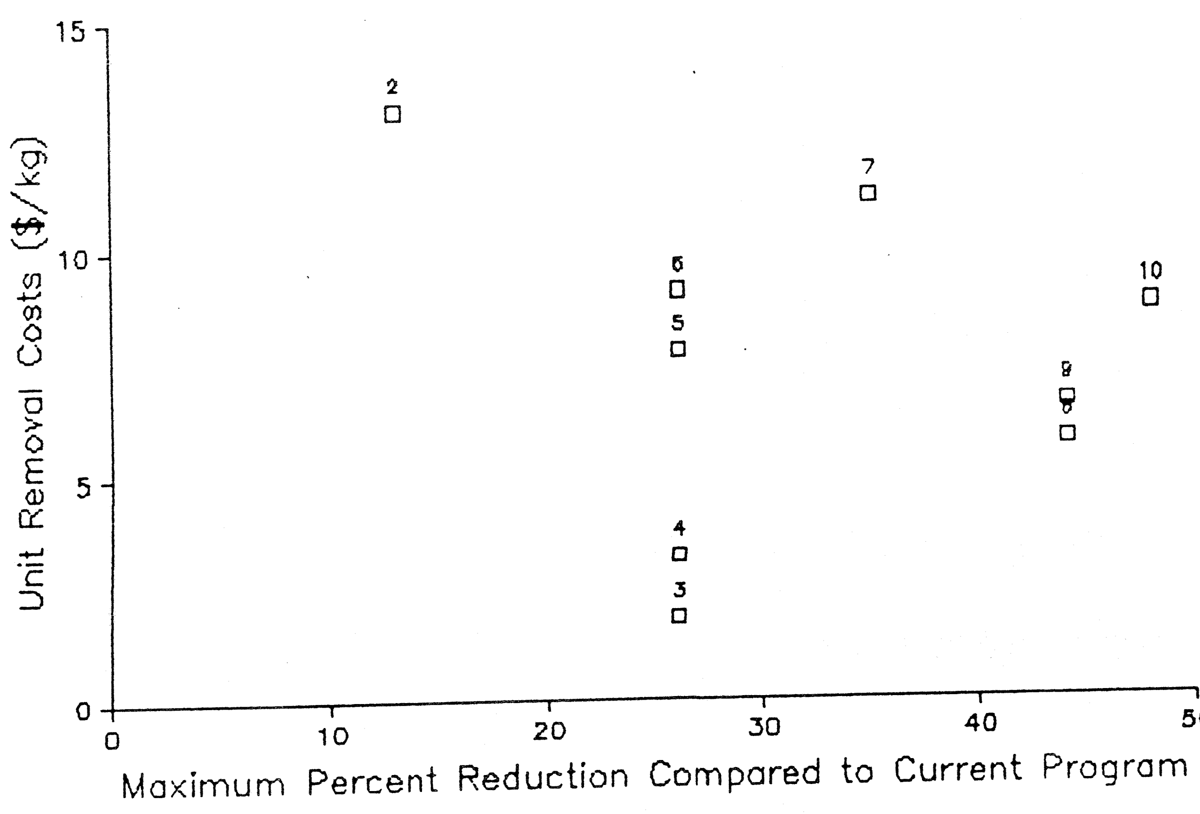


FIGURE 7.5

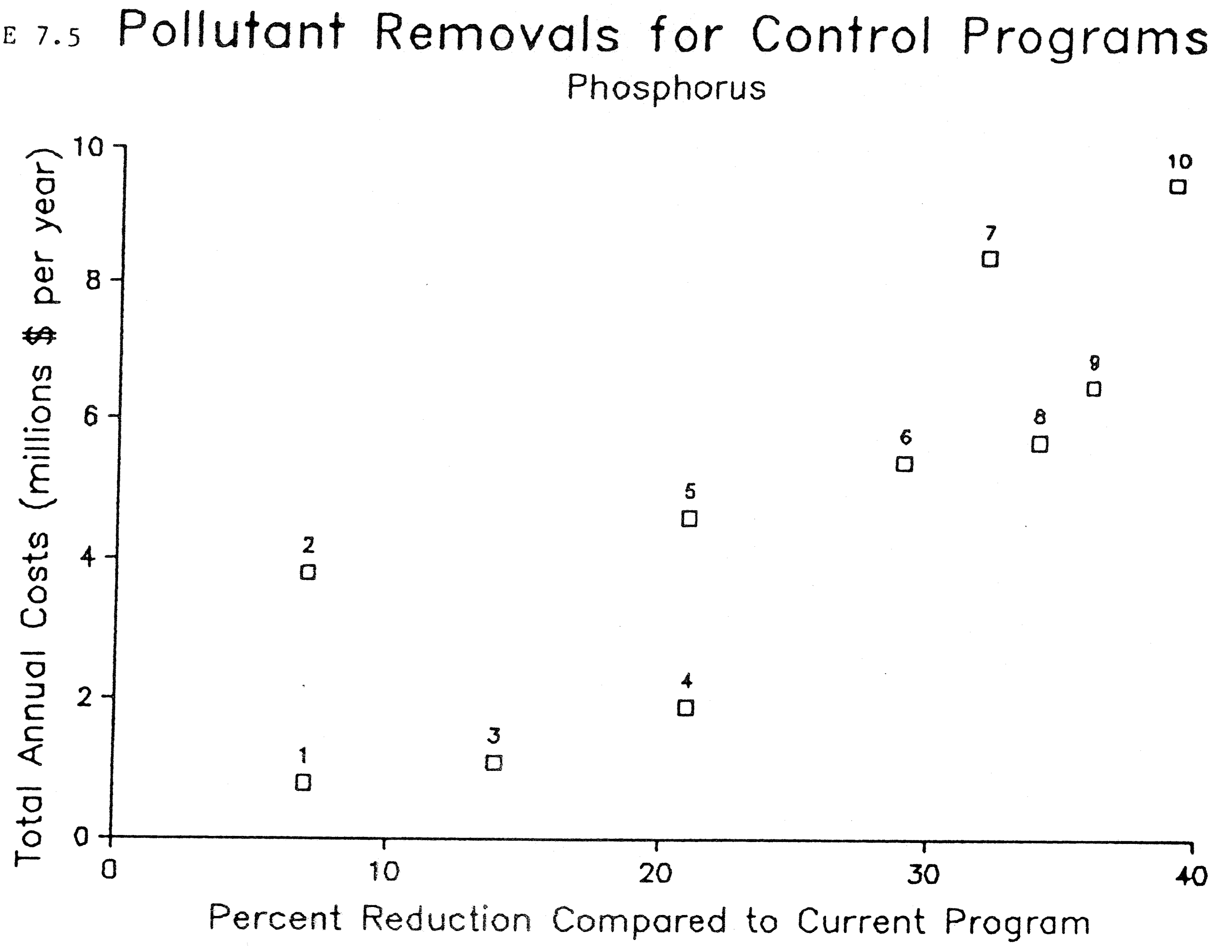


FIGURE 7.6

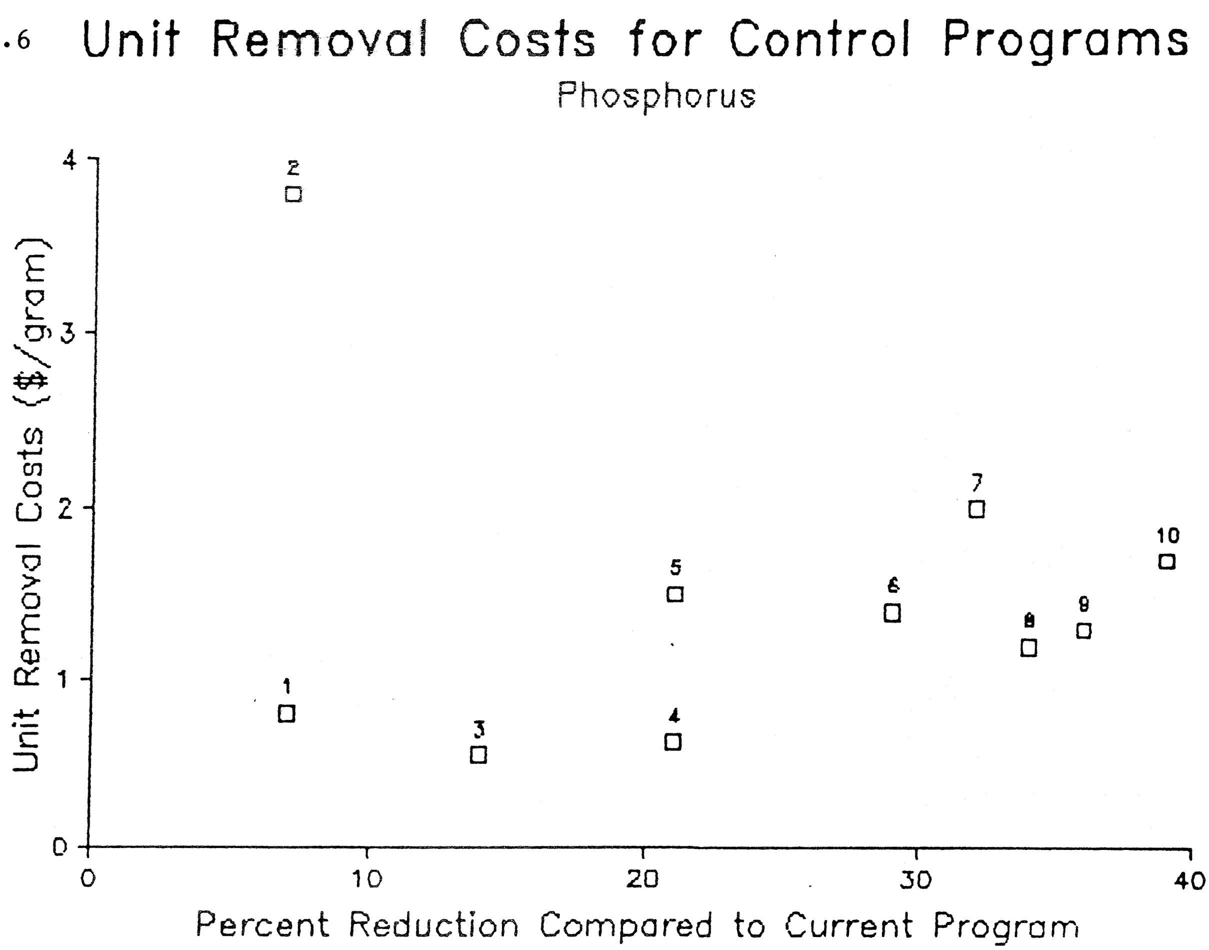


FIGURE 7.7 Pollutant Removals for Control Programs

Fecal Coliform Bacteria

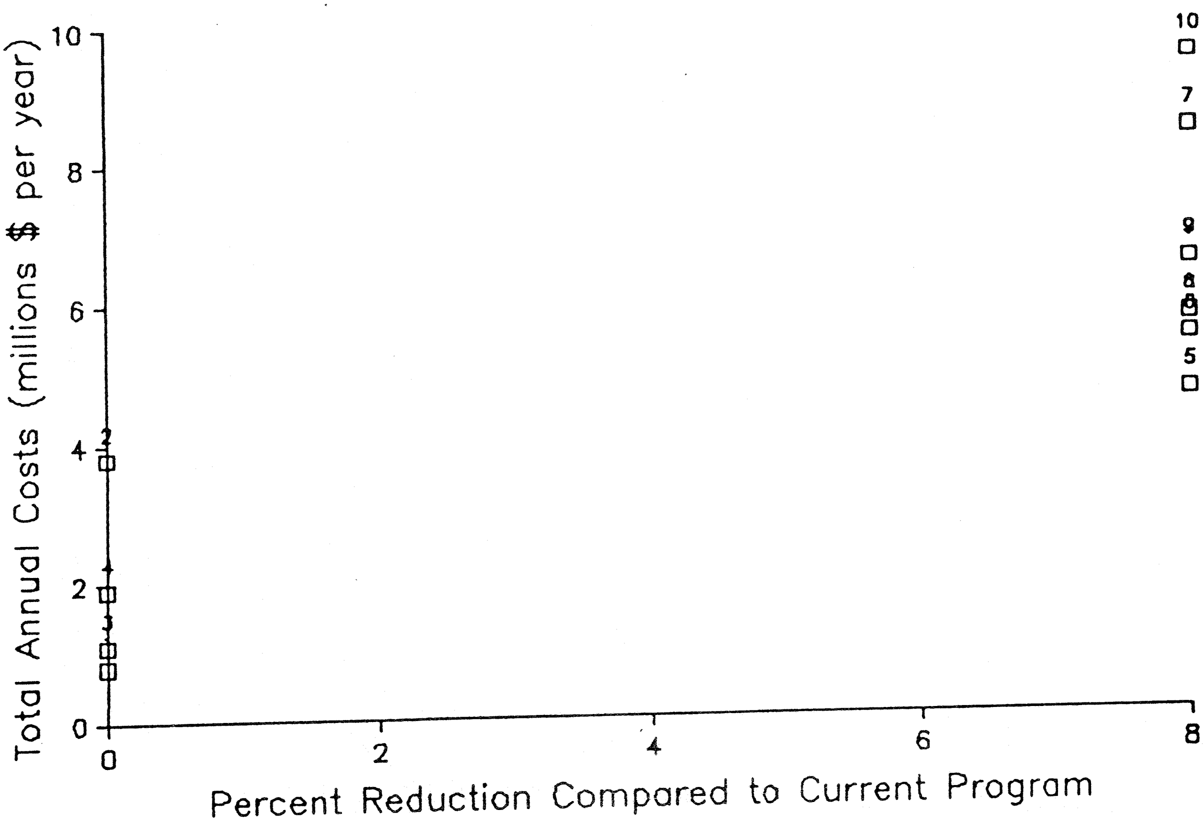
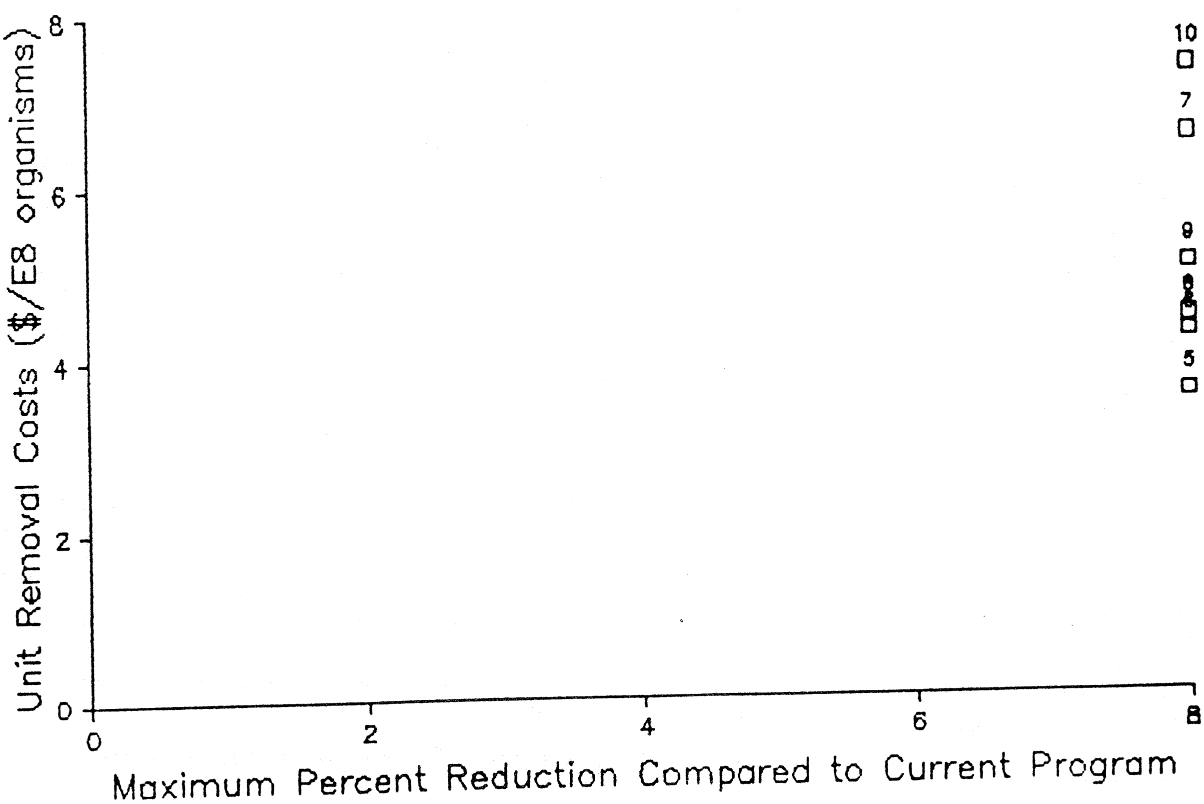


FIGURE 7.8 Unit Removal Costs for Control Programs

Fecal Coliform Bacteria



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SECTION 4. RAINFALL AND RUNOFF

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TORONTO AREA WATERSHED MANAGEMENT STRATEGY STUDY

HUMBER RIVER PILOT WATERSHED PROJECT

FINAL REPORT
VOLUME TWO
TECHNICAL APPENDIX

PREPARED FOR

THE ONTARIO MINISTRY OF THE ENVIRONMENT

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JUNE, 1986

TECHNICAL APPENDIX

This Technical Appendix to the Report on the Humber River Pilot Watershed Project consists of seven appendices. The material contained in the appendices consists primarily of site descriptions, methodology, data and analyses that support the main body of the report.

The following appendices are included:

A. METHODOLOGY

B. DETAILED SITE DATA

C. RAIN GAUGE CALIBRATION PROCEDURES

D. RAINFALL AND RUNOFF FLOW DATA

E. RUNOFF WATER QUALITY DATA

F. SOURCE AREA AND PARTICULATE QUALITY DATA

G. CONTROL EFFECTIVENESS ESTIMATES FOR DIFFERENT LAND USES

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APPENDIX F SOURCE AREA AND PARTICULATE QUALITY DATA

(continued)

FIGURE	TITLE

(continued)

APPENDIX A METHODOLOGY

LIST OF TABLES

METHODOLOGY

The following notes have been prepared to document the six data collection tasks undertaken during the TAWMS Humber River Pilot Watershed Study.

The data collection effort for this study consisted of a series of six different tasks which were undertaken during the summer through winter of 1983-84. These tasks are listed below:

1.0 Street dirt accumulation measurements,
2.0 Artificial precipitation washoff experiments,
3.0 Sheet flow samples collected during runoff and snowmelt events,
4.0 The collection of source area particle samples,
5.0 Outfall water quality and flow rate monitoring during baseflow, runoff and snowmelt conditions, and
6.0 Precipitation data collection.

The following text describes the techniques used during each of these data collection tasks.

1.0 STREET DIRT ACCUMULATION MEASUREMENTS

Two street sections were selected for the measurement of the rate of accumulation of dirt particles on street surfaces. One street (Norseman Street) was located within a mixed industrial land use area. Specific industries included a glass factory, a manufacturer of household appliances, body shops, automobile workshops, contractors and retailers of industrial fittings. The test section was on Norseman Street between Islington Avenue and Kipling Avenue, in the City of Etobicoke. The test section was 900 m long with one lane of traffic in each direction. The street surface was asphalt, in intermediate condition. The curb and channel were both constructed of concrete. Approximately 20% of the driveways leading onto the test section had loose surfaces. The test section included a spur line railway crossing, but no rail traffic was observed during the test period.

The second test site was Glenroy Avenue, between Royal York Road and Prince Edward Drive, also in the City of Etobicoke. The test section consisted of 450 m of asphalt street in a quiet, older residential neighbourhood. Nearby land uses consisted of a primary school and single family dwellings. All driveways were asphalt. The curb and channel were constructed of concrete. The road surface was in good condition, with only occasional cracks.

SAMPLING PROCEDURE

Street dirt loadings were measured by vacuuming a series of narrow (290 mm wide) strips across the street from curb to centre line, or curb to curb. On each testing occasion, a series of ten full width, strips were vacuumed. The locations of the strips randomly varied from day to day to reduce the effects of the sampling on the street loadings. Each test sequence therefore cleared 0.3% of the length of Norseman Street and 0.6% of the length of Glen Roy Avenue.

The vacuum cleaner sampler was a National Super Service Stallion II machine. It had an 86 litre stainless steel tank and was powered by two 0.95 kw electric engines (1.25 hp each). The hose was 50 mm (approx. 2") in diameter and 10.7 m (approx 35') long. The suction head and wand were made of aluminum. The head had a suction opening of 15 by 290 mm. The vacuum cleaner and a generator were used from the back of an open pickup truck.

Prior to each test, the collection can was brushed out with a clean paint rush to remove residual particles. The coarse air filter in the vacuum cleaner was tapped to minimize cross contamination from previous samples. During each test sequence the truck traversed the length of the street, stopping randomly and periodically while test strips were vacuum sampled.

At the end of the vacuuming sequence the particles collected in the can were transferred by scooper and brush into glass jars for weighing and particle size distribution analyses.

TESTING PROCEDURE
The streets were cleaned on each of the first three days of the testing sequence by a mechanical street cleaner. The street cleaner used standard procedures (one pass in each direction, with water spray, against the curb). A street cleaner hopper sample was collected at the end of each test and analysed for particle size distribution. Immediately prior to, and after the mechanical cleaning, each test section was sampled using the vacuum cleaner sampler to measure the level of dirt on the roadway.

Following day three, the street dirt accumulation rate was tested by vacuum sampling on a daily basis for two days, and then sampling less frequently during the remaining three weeks of the study. However, there was significant rain on days 9 and 14. The testing frequency after these storms was therefore increased.

The tests ran for a total of 37 days between August 15 and September 21, 1983.

2.0 ARTIFICIAL PRECIPITATION WASHOFF EXPERIMENTS

These experiments were designed as a 3x2 factorial test to investigate the importance of precipitation intensity, street surface texture and street surface cleanliness on street dirt washoff. A mechanical precipitation apparatus was used to simulate rainfall.

Three sites were chosen in the Thistletown district of the City of Etobicoke. They were near 2 Humberland Court (rough texture), 61 Bankfield Street (rough and smooth textures), and 121 Albert Drive (smooth texture).

The artificial precipitation for the high intensity tests was generated by an array of soaker hoses, suspended upside down at 0.3 m spacings on a wooden frame 3 m wide and 8 m long. The frame was supported 1 m above the road surface. A header connected each soaker hose to the water supply, in this case, a metered fire hydrant. The flow rate was regulated by two valves, one on the hydrant and one on the header. The flow rate was metered using a domestic water meter and a precision ball flow meter. In practice, the array operated at a very low water pressure that just caused the soaker hose to drip in order to produce a high (and even) intensity of 12 mm per hour. Several calibration runs were used to determine the appropriate setting on the control valves. The experiment was designed around a "high intensity" application rate of 12 mm per hour and a "low intensity" of 2-3 mm per hour. Twelve small glass beakers were also placed in the test area to directly measure the "rainfall" rate for each test.

To generate precipitation at the low rate of 2-3 mm per hour, one soaker hose 3 m long was inverted below a spar resting on a frame 1 m above the street. For the duration of the test, the spar was manually moved along the 8 m side of the frame at a frequency of approximately 1 cycle per minute. This back-and-forth movement was necessary to produce the design application flow rate to 2-3 mm per hour. During sunny days, the test area was shaded to reduce evaporation.

A frame of plywood, plastic sheet and caulking compound was used to guide all the runoff from the test surface to a small sump. The water was then removed by either a sump pump (high intensity tests) or by a hand operated vacuum pump (low intensity tests).

The data collected included the following items:

1) the volume of water applied as "rain"

2) the volume of runoff water removed, and

3) water quality samples.

By recording these data at set intervals, the rates of "precipitation" and runoff could be determined for different stages in the test. The field data sheet used is shown as Table A.1. The times used to take intermediate measurements were 0, 5, 10, 20, 30, 50, 70, 90, and 120 minutes from the start of precipitation. At 120 minutes the precipitation was stopped and the remaining runoff collected. A high pressure hose was then used to flush any residual particles into the sump. The volume and quality of the "last flush" was used to determine the volume of residue left after the test precipitation events.

Water quality samples were also taken at these same intermediate times. These water samples were analysed for total, dissolved and suspended solids (total, filtrate and particulate residue, respectively). Two samples were taken after 30 minutes and from

Washoff test

Site :

Date:

Weather:

Pavement type: smooth rough

Street cleanliness: dirty clean

"Rain" intensity: low high

TABLE A.1 WASHOFF FIELD DATA SHEET

Sample Log:

sample number	sample vol. (l)	total runoff volume (l)	increment vol (l)	time	time since last sample (goal)	time since last sample (actual)	notes:
1					5 min. from rain	5	
2					5	10	
3					10	20	
4					10	30	
5					20	50	
6					20	70	
7					20	90	
8					30	120	
last flush	last flush volume (l):						

special bacteria samples:

first approx. 30 min. of runoff: time: total runoff volume (l):

final flush: time: last flush volume (l):

Runoff Flow Summary

total runoff volume (l)	time	volume difference (l)	time diff. (min.)	runoff rate (l/min)	runoff rate (mm/hr)	Rv
∅ (first indication of runoff)						

washoff test (cont) site: date:

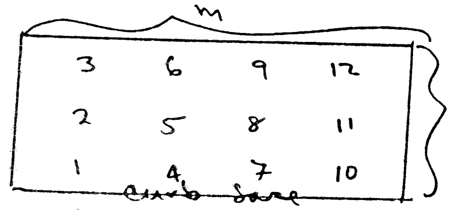
Hydrant Flow

meter reading (Imp. Gal.)	flow rate (sec./Imp.gal.)	time of observation	notes:
		at start of test:	

"Rain" Intensity

(19.6 cm^2 area)

area dimensions:



curb flow direction:

gage number	volume (ml = cm^3)	"rain" depth (mm)	notes:
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
average			

average "rain" intensity (mm/hr):

Rv:

Solids Analyses:

Sample #	Increment runoff vol. (l)	Dissolved Solids conc. (mg/l)	Dissolved Solids mass per unit area (gms/m²)	Dissolved Solids accum. mass per unit area (gms/m²)	Suspended Solids conc (mg/l)	Suspended Solids mass per unit area (gms/m²)	Suspended Solids accum. mass per unit area (gms/m²)	Total Solids conc (mg/l)	Total Solids mass per unit area (gms/m²)	Total Solids accum. mass per unit area (gms/m²)
1										
2										
3										
4										
5										
6										
7										
8										
last flush										

Bacteria Populations (#/100 ml)

		total colis.	fecal colis.	fecal strep.	pseudo. aerog.
"first flush"	5 min.				
last flush	washoff				

Notes and Calculations:

the last flush water for bacteria analyses. Samples of the domestic water used as rain were also analysed for background suspended and dissolved solids concentrations.

At the conclusion of these tests, Plaster-of-Paris "footprints" were made of selected 150 mm square sections of both rough and smooth surfaces. Latex "positives" were constructed from the plaster casts to give a model of the micro topography of the road surface. These were analysed for surface detention characteristics.

3.0 SHEET FLOW SAMPLES COLLECTED DURING RUNOFF AND SNOWMELT EVENTS

As part of the work to characterize the sources of contaminants within urban watersheds, a series of sheet flow water samples were collected during runoff events. These samples were collected from 64 sites within the Emery and Thistledown watersheds. The 64 sites were chosen to be typical of different land uses and surfaces.

The factors used to select the sites were:

1) impervious or pervious surface

2) surface material - asphalt, concrete, gravel, grass, dirt or bitumen shingles,

3) the condition of the surface - in terms of cracking, level of maintenance and loose soil, and

4) nearby land use - waste disposal companies, food industry, metal processing, plastics manufacturing etc., carparks, roofs, footpaths, roadways.

During the snowmelt sampling period, samples of snowmelt sheet flow were also collected at the same sites as were sampled during the summer.

SHEET FLOW SAMPLING

Sheet flow samples during both runoff and snowmelt conditions were collected in two ways. Where there there was sufficient depth of flow, the sample was collected by submerging the sample jars in the conventional manner. At some locations the there was insufficient depth of water to do this. Samples from these locations were collected using hand operated vacuum pumps piped with the collection jar on the inlet (vacuum) side of the pump. The inlet of the suction pipe has then held in the flow in such a manner that the water being sampled did not entrain particles of dirt from the land surface.

During this is study a limited number of samples were filtered, oven dried and analysed later for particle size distribution.

Sheetflow samples were preserved in the field according to MOE guidelines, promptly submitted to the MOE Rexdale Laboratory and analysed for the constituents listed in Table A.2.

A limited number of samples were also analysed for pesticides and other organic compounds.

TABLE A.2 <u>CONSTITUENTS ANALYSED DURING SHEET FLOW SAMPLING</u>

- Conductivity
- pH
- Total, Suspended & Dissolved Solids
  (Total, Particulate and Filtrate Residue, respectively)
- Phosphates
- Total Kjeldahl Nitrogen
- Ammonia - Nitrogen
- Phenolics
- Chemical Oxygen Demand
- Fecal Coliform Bacteria
- Fecal Streptococci Bacteria
- <u>Pseudomonas Aeruginosa</u> Bacteria
- Lead
- Zinc
- Copper

At each sampling location a field data sheet was filled out to describe the surface from which the sample was taken. The sampling times were noted together with the "state of the storm" i.e. beginning, middle, end or after the rain had stopped. The samples were obtained by carefully sucking water from small depressions and flowage using a hand vacuum pump. The samples were immediately placed in sample bottles and appropriately preserved.

4.0 THE COLLECTION OF SOURCE AREA PARTICLE SAMPLES

This dry weather activity was undertaken to determine the potential availability of particles and contaminants within the two test catchments. The sampling locations were the same ones used for the sheet flow samples.

Samples of particles were collected from a measured area by scoop and paint brush or vacuum cleaner. The vacuum cleaner was the same machine as used for the street dirt accumulation study described earlier. The samples were collected in such a manner that only loose material was collected. Care was taken not to scrape, dig or chip material from the source.

The particle samples were collected in glass jars, weighed to determine yield, sieved in stainless steel sieves to determine particle size distribution and analysed for the chemical constituents listed in Table A.3. The list of particle sizes is also given together with the particle size groups used during the chemical analyses.

One composite sample of selected industrial carpark particles was also analysed for organic compounds.

TABLE A.3 SOURCE AREA PARTICLE CONSTITUENTS ANALYSED

Chemical Constituents:

Chromium	Total Phosphorus
Magnesium	Total Carbon
Copper	TKN
Zinc	COD
Lead	

Sieve Sizes Used to Determine the Particle Size Distribution:

37 microns
64 microns
125 microns
250 microns
500 microns
1000 microns
2000 microns
6450 microns

Particle Size Groupings Used for Chemical Analyses:

0 - 125 microns
125 - 500 microns
500 - 2000 microns
> 2000 microns

Note: Relevant fractions were recombined prior to chemical analysis

---

5.0 OUTFALL WATER QUALITY AND FLOW RATE MONITORING DURING BASEFLOW, RUNOFF AND SNOWMELT CONDITIONS

Two outfalls were monitored continually during this study. The Emery outfall drains storm water from the industrial catchment and the Thistledown outfall drains stormwater from the residential catchment. In both catchments separate sanitary sewer systems conveyed sanitary waste water.

EMERY OUTFALL

The outfall from the Emery catchment consists of a 2 m dia. corrugated steel pipe. It discharges into a small stream which eventually joins Emery Creek in the Lindy Lou Greenbelt and flows to the Humber River. A sampling station was constructed at the outfall to house flow rate recorders, water samplers and the recorder for the tipping bucket rain gauge.

Discharge was monitored continuously using an ISCO water level monitor linked to a data recorder. The resulting flow data was transcribed by hand onto hydrographs. Typical base flow discharges of 40 L/s were observed during the summer with peak discharges exceeding 1250 L/s.

The water level recorder was linked to an ISCO model 2100 water sampler. The sampler was operated in two modes, depending on the weather. For one 24-hour period each week, the sampler worked in a time composite mode, taking baseflow samples at 15 minute intervals. The sample was collected in a 25 litre glass jar. After 24 hours, the sample was retrieved and submitted to the laboratory for analysis. For the balance of the time the sampler was in a flow weighted composite sampling mode. Sampling was initiated by three pulse signals within six hours from the tipping bucket rain gauge. This is equivalent to approximately 0.6 mm of precipitation. The sampler then operated in a flow weighed composite mode until six hours after the end of precipitation. Because of the potential for large volumes of samples during large storm events, the sample was collected in a 200 litre teflon lined drum. At the end of sampling the sample was retrieved and submitted for analysis. A grab sample was also taken at the outfall after or during most storm events. This monitoring equipment was placed in operation in May, 1983 and operated until the completion of the study in March, 1984.

THISTLEDOWN OUTFALL

The outfall at Thistledown consists of a 1.2 m dia. concrete pipe which discharges directly to the Humber River. The sampling location was constructed within a manhole approximately 250m upstream from the outfall. The sampling equipment consisted of an ISCO water level monitor and printer and Model 2100 sampler equipped with a 25 litre glass jar. A small flume was constructed within the sewer pipe to provide the necessary hydraulic configuration for the programmed water level monitor. Sewer discharge data was recorded every five minutes, on a 50 mm wide paper tape. These data were used to prepare hydrographs.

The sampler was operated in the same modes as the Emery sampler with the exception of sample initiation. The normal base flow depth at Thistledown was approximately 30 mm. This depth corresponds to a discharge of approximately 2-3 L/s. Sampling was initiated by the water level rising to trigger an alarm built into the flow recorder. The alarm was usually set at 45-60 mm, so that small waves would not trigger the sampler. Sampling ceased when the water level receded below the trigger depth. Each time a sample was taken, the flow data was recorded and highlighted by an asterisk or the chart. Samples were retrieved after each storm event, or base flow sampling sequence.

At both locations some samples were lost when grit punctured the silicon tubing on the peristaltic pumps. Grit as large as 2 mm was retrieved from sample jars after some major storm events. The Emery system had overheating problems and power supply interruptions attributable to voltage surges. The Thistledown sampler also periodically ceased to function. This has been attributed to excessive humidity or moisture in the sampler control box. The Thistledown sampler was installed in July, 1983 and ran until the completion of field work in March, 1984.

SNOW PROFILE SAMPLING

The snow profile transects were trenches dug at right angles to the road way. The depth of the profile was measured from the vertical side of the trench. Snow that was collected for quality analysis was taken as a vertically integrated sample through the entire depth of the snow profile.

SAMPLE PREPARATION

Water samples were collected from the glass / teflon / stainless steel collection vessel, preserved according to MOE guidelines and submitted promptly to the MOE Rexdale Laboratory.

During this is study a limited number of samples were filtered. The filtrate was oven dried and analysed later for particle size distribution.

The samples that were drawn from samples of snow were collected as snow in glass jars and plastic bags. The snow was allowed to melt in an unheated storage area. The samples were drawn off from the ice/water mixture when sufficient volume had melted.

Base flow samples were analysed for the following constituents:

1) major ions (on selected samples),

2) total and filtrate residue,

3) phosphates,

4) COD

5) phenolics,

6) hardness,

7) lead, copper, chromium, zinc

Storm water samples were analysed for the same list of constituents plus:

1) fecal coliforms and fecal streptococci bacteria

2) *pseudomonas aeruginosa* bacteria

Selected samples were also analysed for pesticides and other organic compounds.

6.0 PRECIPITATION DATA

Precipitation data was collected from several sources. A tipping bucket rain gauge was erected on top of a 5 m tower at the Emery site. The gauge was calibrated in the laboratory prior to installation. The recorder for this rain gauge was situated in the same building as the Emery water sampler, and was used to initiate sample collection during storm events.

It was noted during the study that the calibration of this gauge was incorrect. Detailed additional regional rain data analyses were therefore conducted to estimate the correct calibration factor.

Subsequent precipitation analyses have included data from virtually every rain gauge within the Toronto area including continuous records of tipping bucket gauges at Pearson International Airport and the junction of Keele Street and Finch Avenue.

The description of the calibration of the rain gauge is given in Appendix C.

The strip charts from the recording rain gauges were analysed and the data transferred on precipitation summary sheets using 15 minute time units. These data were then plotted onto hyetographs.

APPENDIX B DETAILED SITE DATA

LIST OF TABLES

Table C.1 (acres)

Site Descriptions (ha)

(B soil)

	Emery (153.49)	Thistledown						(38.80)
	Industrial	Single Family	Multiple Family	Shopping center	Open Space	School	Church	Total
Streets (texture/condition)								
very smooth/good		0.24 0.60						0.24
smooth/very good	1.70 4.26							
smooth/good	2.24 5.61	1.03 2.58						1.03
smooth/good-moderate	2.09 5.23	0.19 0.48						0.19
smooth/moderate-poor		0.46 1.15						0.46
medium/good		0.63 1.58	0.32 0.80					0.95
medium/moderate	0.36 0.90	0.39 0.98						0.39
medium/poor		0.19 0.48						0.19
medium-rough/good-moderate	0.50 1.25							
rough/moderate	0.46 1.15	0.06 0.15						0.06
rough/moderate-poor	1.00 2.50	0.16 0.40						0.16
rough/very poor	0.32 0.80							
total (ha)	8.67 21.70	3.35 8.39	0.32 0.80					3.67
percentage of area	5.6%	11.4%	13.5%					9.5%
Grass swale drainages	0	0.90 2.25						0.90
percentage of area	0%	3.1%						2.3%
Grass strip between street/sidewalk	0	2.70 6.76		0.15 0.38				2.85
percentage of area	0% (I P 0.25 ≈ 1.13/1.12 to 0.35)	9.2%		7.1%				7.3%
Walks	0.68 1.70	1.08 2.70 (to walks)						1.08
percentage of area	0.4%	3.7%						2.8%
Front landscaping	15.70 39.30	4.81 12.04	0.33 0.83				0.11 0.28 (to large lands)	5.25
percentage of area	10.2% (I P 4.26/4.25)	16.3%	13.9% (I P 4.89 : 2.45/2.44)				29.7%	13.5%
Driveways	3.40 8.51	1.89 4.73	0.065 0.16				(I P)	1.96
percentage of area	2.2% (I P 38.31/38.31)	6.4%	2.7% (I P 0.04/0.04)			0.63 → 0.32/0.31		5.1%
Paved Parking/Storage	30.61 76.62	0.03 0.08		1.52 3.80		0.16 0.40	0.09 0.23	1.80
percentage of area	19.9%	0.1%		72.0%		3.8%	24.3%	4.6%

Table B.1 (Cont)

	Emery Industrial	Thistledown Single family	Multiple family	Shopping center	Open space	School	Church	Total
Unpaved Parking/Storage	23.57 59.00							0
percentage of area	15.4%							0%
Walkways	0.22 0.55	0.53 0.21	0.01 0.004			0.10 0.04	0.05 0.02	0.28
percentage of area	0.19%	0.7%	0.2%			0.9%	5.4%	0.7%
Paved playground	0					1.45 0.58		0.58
percentage of area	0%					13.6%		1.5%
Backyard landscaping	0	18.07 7.22	2.50 1.00				0.25 0.10	8.32
percentage of area	0%	24.5%	42.2%				27.0%	21.4%
Large turf area	0					7.43 2.97		2.97
percentage of area	0%					69.9%		7.7%
Undeveloped area	18.97 47.48				0.53 0.21			0.21
percentage of area	12.4%				100%			0.5%
Swimming pools	0	0.35 0.14	0.03 0.01					0.15
percentage of area	0%	0.5%	0.4%					0.4%
Decks and small sheds	0	1.50 0.60	0.08 0.03					0.63
percentage of area	0%	2.0%	1.3%					1.6%
Railroad main line	2.60 6.51							0
spur lines	1.36 3.40							0
total	3.96 9.91							0%
percentage of area	2.6%							
Roofs – connected	47.71 119.42	3.60 1.44	1.53 0.61	1.10 0.44		1.25 0.50(?)	0.13 0.05(?)	3.04
percentage of area	31.1%	4.9%	25.7%	20.9%		11.8%	13.5%	7.8%
– to impervious areas	0	6.41 2.56						2.56
percentage of area	0%	8.7%						6.6%
– to pervious areas	0	6.41 2.56						2.56
percentage of area	0%	8.7%						6.6%
TOTAL (ha)	153.49 384.19	29.49 73.81	2.37 5.93	2.11 5.28	0.21 0.53	4.25 10.64	0.37 0.93	38.80 97.12

Table B-2
Street Condition and Texture Cross-Tabulations

Texture:

Condition:		very smooth	smooth	medium	medium-rough	rough	total
Residential (Thistledown)							
Good	curb km length	0.60	2.70	2.48	—	—	5.78
	ha. area	0.24	1.03	0.95	—	—	2.22
	percent of total length	6.2%	28.0%	25.7%	—	—	59.9%
Good-Moderate	curb km length	—	0.32	—	—	—	0.32
	ha. area	—	0.19	—	—	—	0.19
	% of total	—	3.3%	—	—	—	3.3%
Moderate	curb-km	—	—	1.10	—	0.16	1.26
	ha	—	—	0.39	—	0.06	0.45
	%	—	—	11.4%	—	1.7%	13.1%
Moderate-Poor	curb-km	—	1.34	—	—	0.46	1.80
	ha	—	0.46	—	—	0.16	0.62
	%	—	13.9%	—	—	4.8%	18.7%
Poor	curb-km	—	—	0.48	—	—	0.48
	ha	—	—	0.19	—	—	0.19
	%	—	—	5.0%	—	—	5.0%
Total	curb-km	0.60	4.36	4.06	0	0.61	9.64
	ha	0.24	1.68	1.53	0	0.22	3.67
	%	6.2%	45.2%	42.1%	0	6.5%	100.0%
Industrial (Emery							
Very Good	curb-km	—	2.26	—	—	—	2.26
	ha	—	1.70	—	—	—	1.70
	%	—	15.4%	—	—	—	15.4%
Good	curb-km	—	3.04	—	—	—	3.04
	ha	—	2.24	—	—	—	2.24
	%	—	20.7%	—	—	—	20.7%
Good-Moderate	curb-km	—	3.28	—	1.12	—	4.40
	ha	—	2.09	—	0.50	—	2.59
	%	—	22.4%	—	7.6%	—	30.0%
Moderate	curb-km	—	—	0.72	—	1.02	1.74
	ha	—	—	0.36	—	0.46	0.82
	%	—	—	4.9%	—	6.9%	11.8%
Moderate-Poor	curb-km	—	—	—	—	2.52	2.52
	ha	—	—	—	—	1.00	1.00
	%	—	—	—	—	17.2%	17.2%
Very Poor	curb-km	—	—	—	—	0.72	0.72
	ha	—	—	—	—	0.32	0.32
	%	—	—	—	—	4.9%	4.9%
Total	curb-km	0	8.58	0.72	1.12	4.26	14.68
	ha	0	6.03	0.36	0.5	1.78	8.67
	%	0	58.5%	4.9%	7.6%	29.0%	100.0%

Table B.3

Emery Street Characteristics:

texture	condition	width m	length km	% of all streets (by length)	area
smooth	very good	15m	1.13km	15.4%	16,950m²
smooth	good	15	1.52	20.7	22,420
smooth	good-moderate	13	1.64	22.4	20,920
medium	moderate	10	0.36	4.9	3550
medium-rough	good-moderate	9	0.56	7.6	4995
rough	moderate	9	0.51	6.9	4550
rough	moderate-poor	8	1.26	17.2	10,000
rough	very poor	9	0.36	4.9	3195
		12 ave	7.34km	100.0%	86,580m²

Thistledown Street Characteristics:

texture	condition	width m	length km	% of all streets (by length)	area
very smooth	good	8m	0.30km	6.2%	2390m²
smooth	good	8	1.35	28.0	10,310
smooth	good-moderate	12	0.16	3.3	1910
smooth	moderate-poor	7	0.67	13.9	4580
medium	good	8	1.24	25.7	9470
medium	moderate	7	0.55	11.4	3850
medium	poor	8	0.24	5.0	1940
rough	moderate	8	0.08	1.7	630
rough	moderate-poor	7	0.23	4.8	1610
		8 ave	4.82km	100.0%	36,690m²

Table B.4

Emery Site Descriptions

Industrial category and number of sites in categ.	roofs m²	roofs % of area	roofs ave m²/site	paved parking or storage m²	%	m²/site	unpaved parking or storage m²	%	m²/site	front landscaped m²	%	m²/site
Mixed Indus. n=9	42,920	42.6	4,770	41,450	41.2	4,610	3,720	3.7	410	8390	8.3	930
Contractor, equip. storage, n=5	6190	11.3	1240	1450	2.6	290	42,920	78.2	8580	2620	4.8	520
Printers, n=3	7470	26.6	2490	5680	20.2	1890	3280	11.7	1090	2280	8.1	760
Furniture Manuf. n=4	42,090	61.4	10,520	11,250	16.4	2810	6340	9.2	1590	3810	5.6	950
Hardware & Building materials n=3	8660	29.2	2890	2400	8.1	800	14,570	49.0	4840	2500	8.4	830
Offices & Warehouses n=17	53,140	40.6	3070	33,610	25.4	1920	7730	6.0	450	19,330	15.1	1140
Misc. manuf. n=9	29,420	38.3	3270	20,510	26.7	2280	4570	6.0	510	8450	11.0	940
Electronics n=4	76,540	25.2	19,140	69,720	22.9	17,430	3300	1.1	830	46,000	15.1	11,500
Vehicle repair n=5	3350	16.4	670	3890	19.1	780	10,980	53.8	2200	1590	7.8	320
Food processing n=11	46,430	37.3	4220	30,930	24.9	2810	11,000	8.8	1000	22,450	18.0	2040
Foundry and welding n=3	3680	35.0	1230	3220	30.7	1070	1070	10.2	360	1700	16.2	570
Metal Plating n=2	5870	51.0	2940	2410	21.0	1205	1560	13.6	780	1180	10.3	590
Waste Dealers n=4	15,710	17.7	3930	2020	2.3	510	63,450	71.6	15,860	2410	2.7	600
Tile n=2	2150	30.4	1080	1710	24.2	860	2430	34.3	1220	400	5.6	200
Textiles n=2	8010	37.9	4010	7320	34.7	3660	530	2.5	270	2770	31.1	1390
Glass n=2	10,900	48.5	5450	4800	21.3	2400	3070	13.7	1530	2360	10.5	1180
Utility n=1	750	5.4	750	1600	11.4	1600	9170	65.5	9170	1010	7.2	1010
Chemical n=13	59,490	28.8	4580	40,590	19.7	3120	35,660	17.3	2740	17,720	8.6	1360
Metal Dealers and manuf. n=14	55,300	53.0	3950	22,560	21.6	1610	10,390	10.0	740	10,030	9.6	720
Total n=113 m²	477,070			306,120			235,680			157,000		
%	33.5% (5.4→53)			21.5% (2.3→41.2)			16.6% (1.1→78.2)			11.0% (2.7→31.1)		
m²/site	4,220			2,710			2,090			1,390		

Table B.4 Emery Site Descriptions (Cont.)

Industrial category and number of sites in categ.	undeveloped m²	%	m²/site	railroad spurs m²	%	m²/site	sidewalks m²	%	m²/site	walkways m²	%	m²/site
Mixed Indus. n = 9	1770	1.8	200	120	0.1	10	820	0.8	90	120	0.1	10
Contractor, equip. storage, n = 5	280	0.5	60	190	0.3	40	330	0.6	70	90	0.2	20
Printers, n = 3	7860	28.0	2620	900	3.2	300	Ø	Ø	Ø	270	1.0	90
Furniture Manuf. n = 4	2760	4.0	690	Ø	Ø	Ø	200	0.3	50	40	0.1	10
Hardware & Building materials n = 3	380	1.3	130	570	1.9	190	200	0.7	70	170	0.6	60
Offices & Warehouses, n = 17	10,090	7.9	590	2100	1.6	120	1460	1.1	90	230	0.2	10
Misc. manuf. n = 9	10,570	13.8	1170	660	0.9	70	680	0.9	80	60	0.1	10
Electronics n = 4	96,310	31.6	24,080	810	0.3	200	90	0.03	20	530	0.2	130
Vehicle repair n = 5	—	—	—	—	—	—	130	0.6	30	60	0.3	10
Food processing n = 11	6730	5.4	610	1220	1.0	110	1200	1.0	110	170	0.1	10
Foundry and welding n = 3	—	—	—	—	—	—	170	1.6	60	10	0.1	3
Metal Plating n = 2	—	—	—	—	—	—	150	1.3	80	10	0.1	5
Waste Dealers n = 4	4240	4.8	1060	490	0.6	120	—	—	—	100	0.1	30
Tile n = 2	—	—	—	—	—	—	70	1.0	40	—	—	—
Textiles n = 2	1880	8.9	940	—	—	—	150	0.7	80	—	—	—
Glass n = 2	600	2.7	300	—	—	—	210	0.9	110	60	0.3	30
Utility n = 1	640	4.6	640	460	3.3	460	130	0.9	130	—	—	—
Chemical n = 13	42,840	20.8	3300	5410	2.6	420	540	0.3	40	240	0.1	20
Metal Dealers and manuf. n = 14	2760	2.6	200	630	0.6	50	310	0.3	20	70	0.1	5
Total n = 113 m²	189,710			13,560			6,840			2,230		
%	13.3% (0.0→31.6)			1.0% (0.0→3.3)			0.5% (0.0→1.6)			0.2% (0.0→1.0)		
m²/site	1,680			120			60			20		

Table B.4 Emery Site Descriptors (Concluded)

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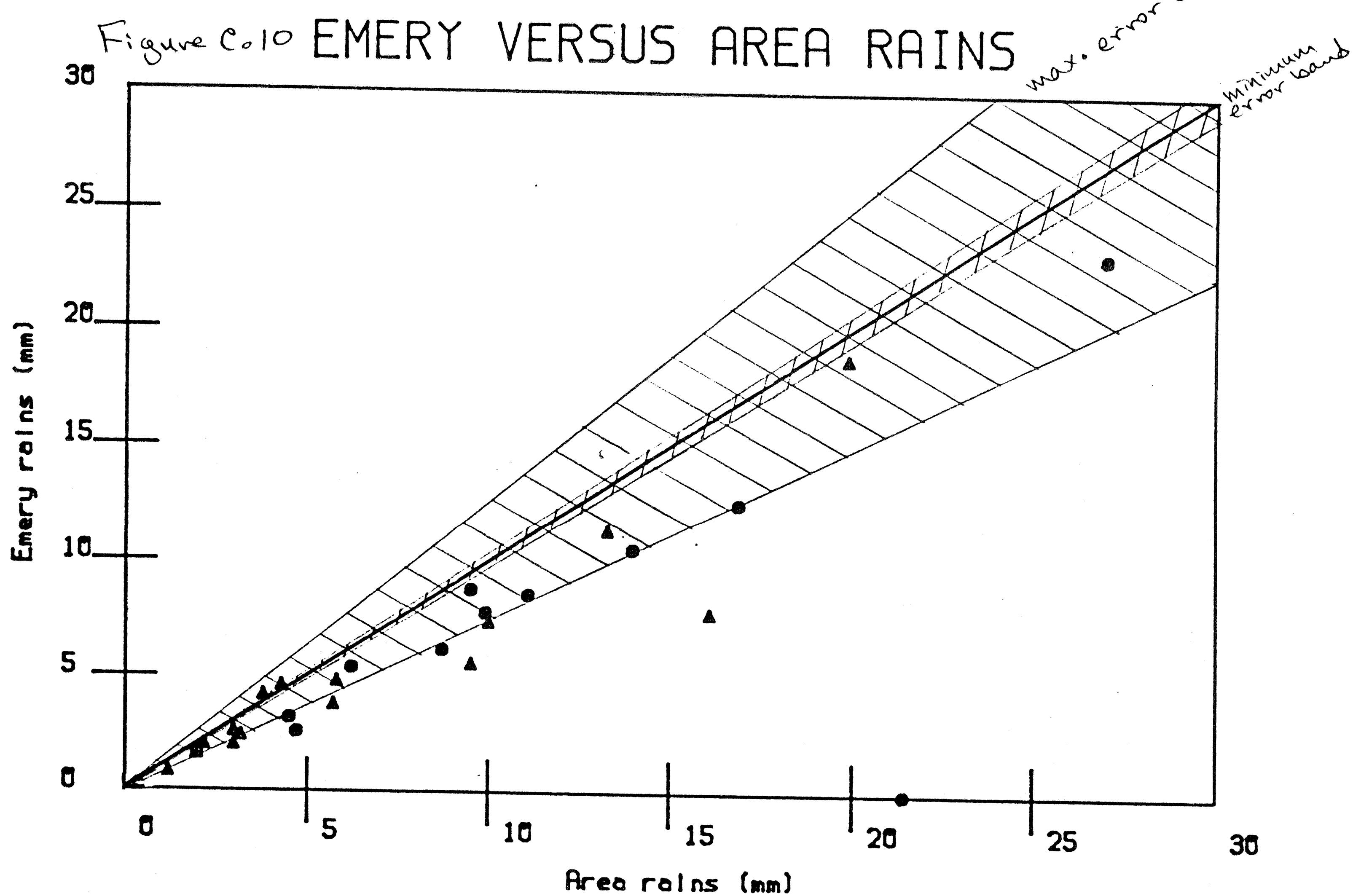
Industrial category and number of sites in categ.	driveways m²	%	m²/site	total area m²	% of total	m²/site
Mixed Indus. n = 9	1390	1.4	150	100,700	6.6%	11,190
Contractor, equip. storage, n = 5	850	1.5	170	54,920	3.6%	10,980
Printers, n = 3	380	1.4	130	28,120	1.8%	9370
Furniture Manuf. n = 4	2110	3.1	530	68,600	4.5%	17,150
Hardware & Building materials n = 3	230	0.8	80	29,620	1.9%	9870
Offices & Warehouses, n = 17	2830	2.2	170	128,380	8.4%	7550
Misc. manuf. n = 9	1800	2.3	200	76,720	5.0%	8520
Electronics n = 4	11,010	3.6	2750	304,310	19.8%	76,080
Vehicle repair n = 5	400	2.0	80	20,400	1.3%	4080
Food processing n = 11	4280	3.4	390	124,410	8.1%	11,310
Foundry and welding n = 3	650	6.2	220	10,500	0.7%	3500
Metal Plating n = 2	320	2.8	160	11,500	0.7%	5750
Waste Dealers n = 4	250	0.3	60	88,670	5.8%	22,170
Tile n = 2	320	4.5	160	7080	0.5%	3540
Textiles n = 2	460	2.2	230	21,120	1.5%	11,060
Glass n = 2	490	2.2	250	22,490	1.5%	11,250
Utility n = 1	240	1.7	240	14,000	0.9%	14,000
Chemical n = 13	3720	1.8	290	206,210	13.4%	15,860
Metal Dealers and manuf. n = 14	2240	2.1	160	104,290	6.8%	7450
Total n = 113 m²	33,970			1,422,040 = 142.20 ha		
%	2.4% (0.3→6.2)			100.0%	plus streets and RR	
m²/site	300			12,590		

portial data; σ/D = 0.08 → 0.62 N = 25

Figure C.10 EMERY VERSUS AREA RAINS



7/6/84
E Area A ○
E Area B △
E Area C □

Figure C.11

partial data; σ/R̄ = 0.08 → 0.62   n = 25

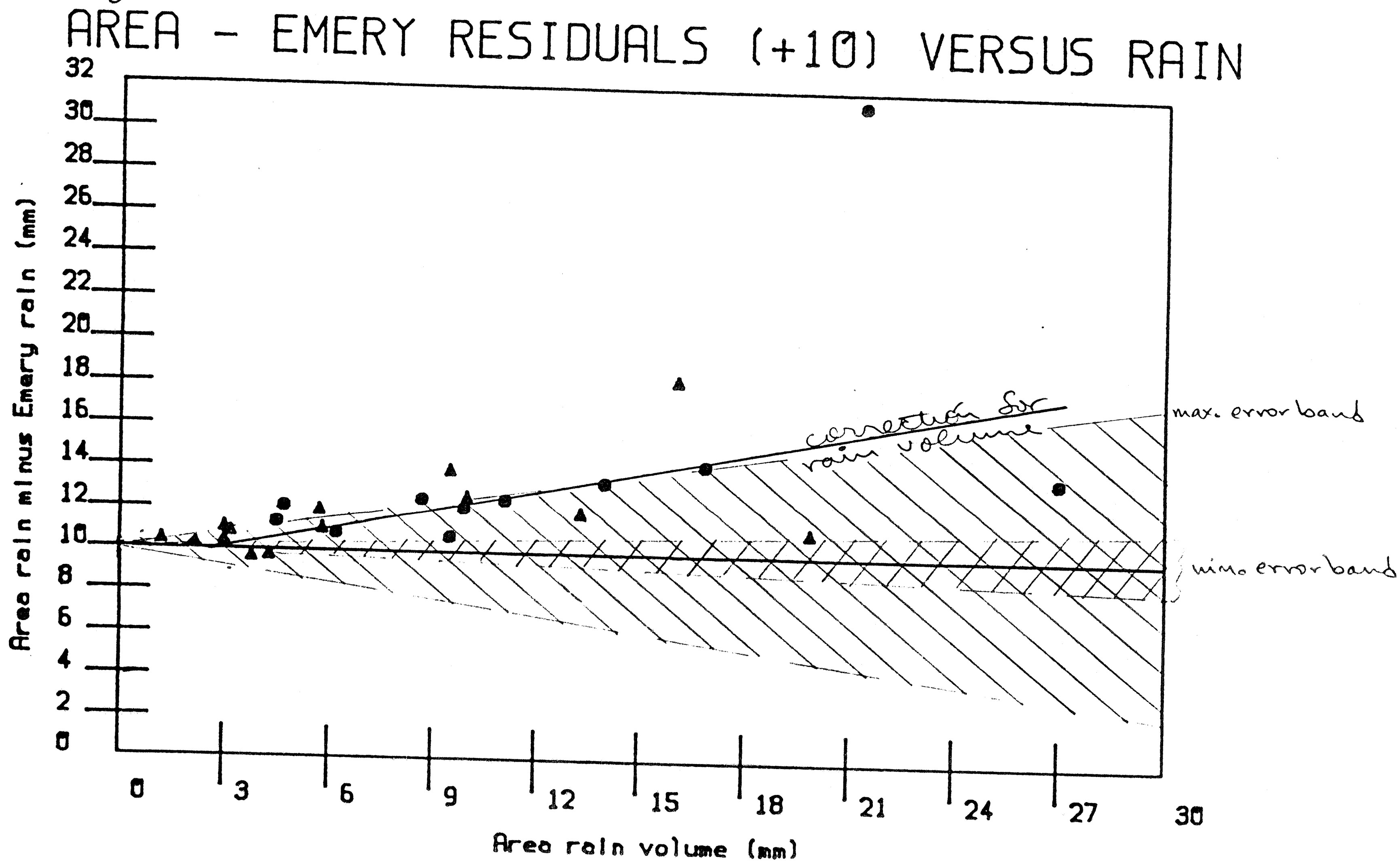


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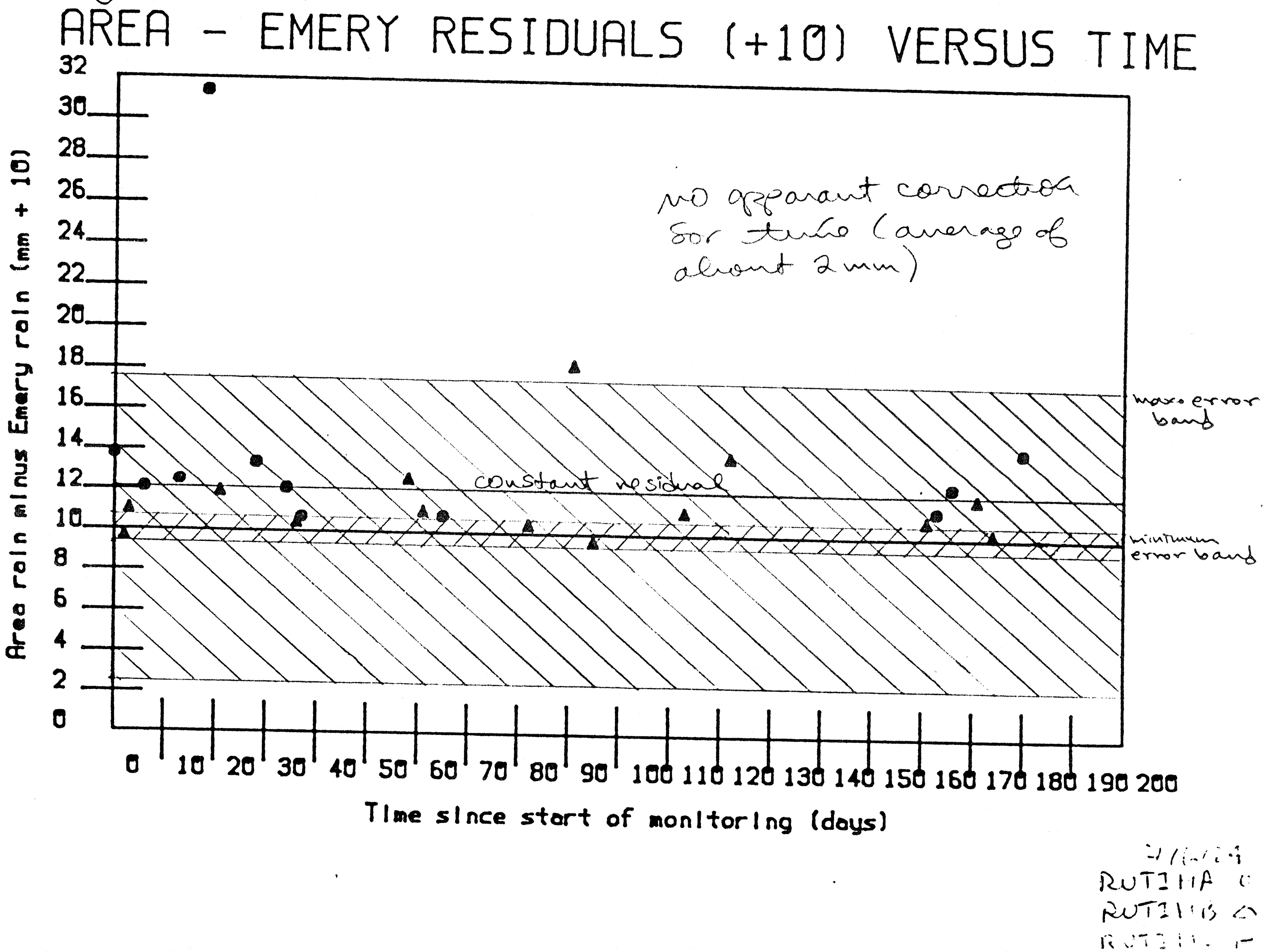
Figure C.12 partial data; σ/√: 0.08 → 0.62 N = 25



The last portion of the analysis was to determine the "best" calibration factor that should be used with the precipitation data. Constant calibration factors ranging from 0.20 to 0.30 mm per tip were examined. Residuals for various Emery data (using six different calibration factors within this range) were calculated using the 25 events and six surrounding monitoring locations as previously identified. Figure C.13 shows three plots of the resultant residual analyses. Three residual relationships were examined, as shown on this figure. The sum of residuals for the 25 events should be zero (middle plot), half of the residuals should be positive and the other half negative (bottom plot), and the sum of the individually squared residuals should be at a minimum value (top plot). In all cases, the resultant "best" calibration factor is seen to vary between 0.25 and 0.26 mm per tipping bucket tip. A constant value of 0.25 mm was therefore chosen.

Figures C.14 through C.16 are the resultant plots of Emery vs Area precipitation using a constant calibration factor of 0.25 mm. When the residuals are plotted against precipitation volume, the correction for the large events is shown to be acceptable, although a minor trend (possibly over corrected) is still evident. The residual plot versus time is quite good, with all values being within a generally parallel band well within the maximum error range expected.

The Emery precipitation observations were therefore "corrected" assuming a constant calibration factor of 0.25 mm. Rains that had been reported with a 0.20 mm factor were increased by 1.25 X, while the rains reported with a 0.28 mm factor were reduced by 0.89 X.

Figure C.14

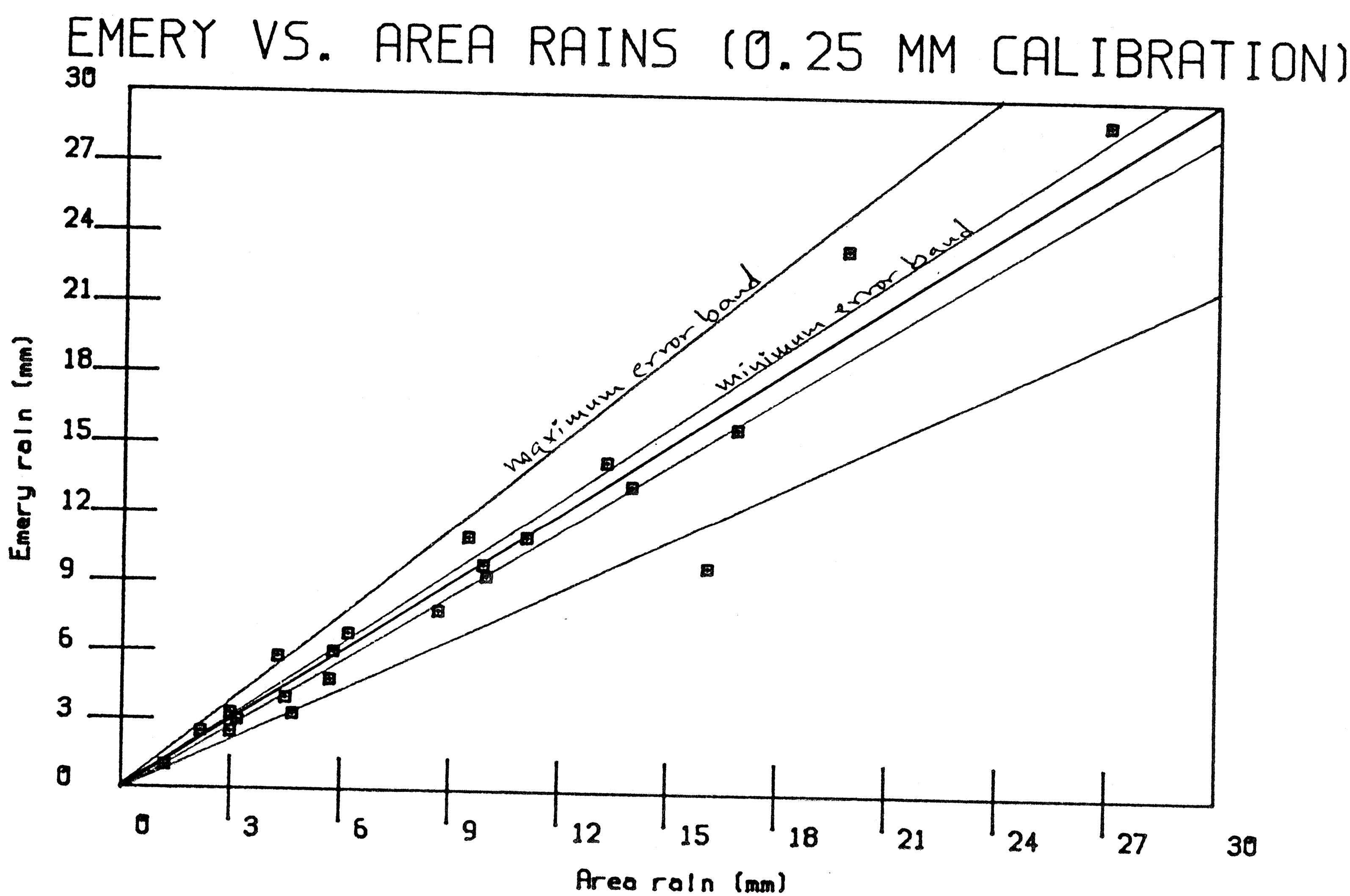

EMERY VS. AREA RAINS (0.25 MM CALIBRATION)
Emery rain (mm)
Area rain (mm)
0
3
6
9
12
15
18
21
24
27
30
maximum error band
minimum error band

Figure C.15

RAIN RESIDUALS VS. AREA RAIN (0.25 MM)

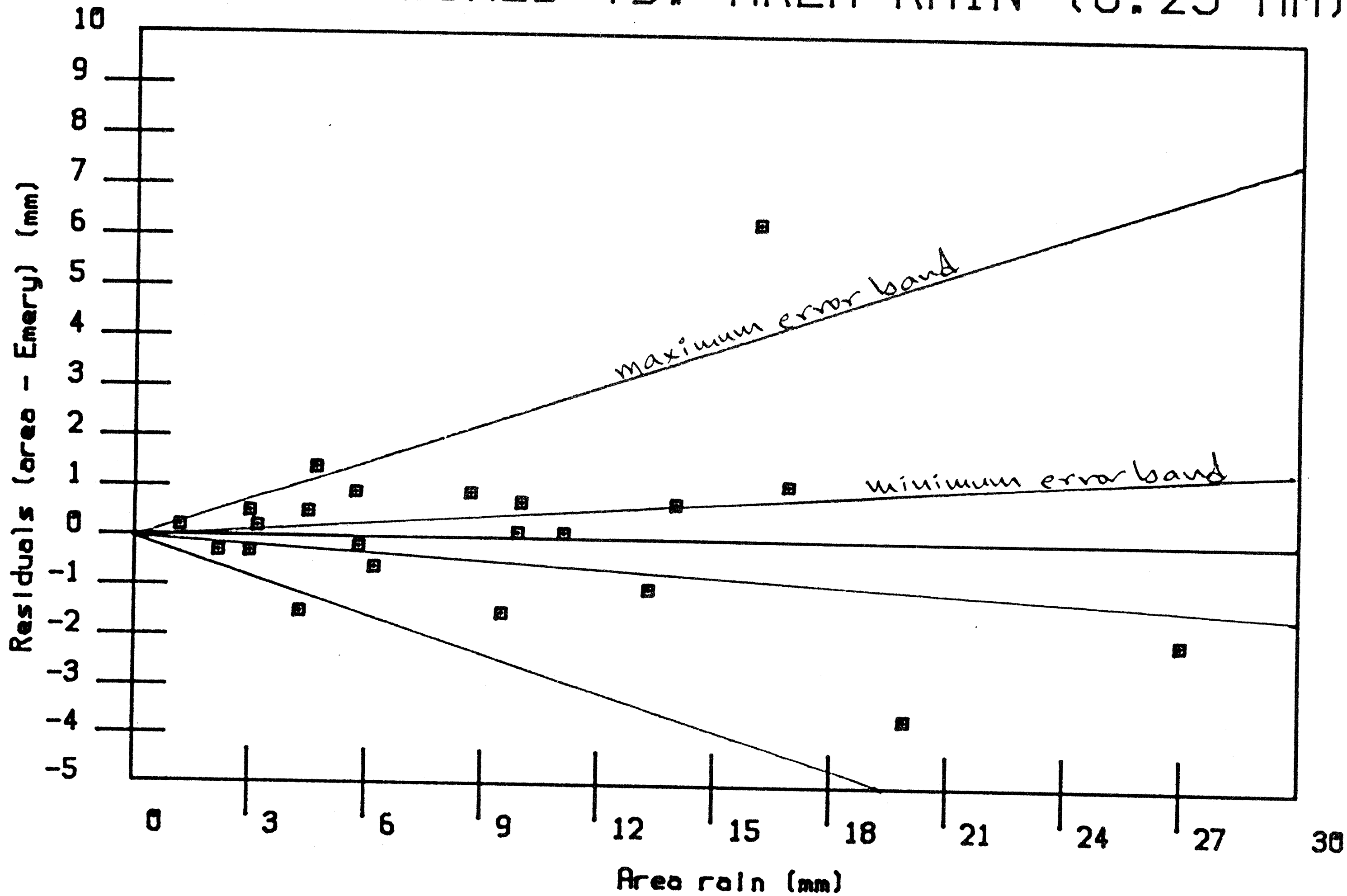


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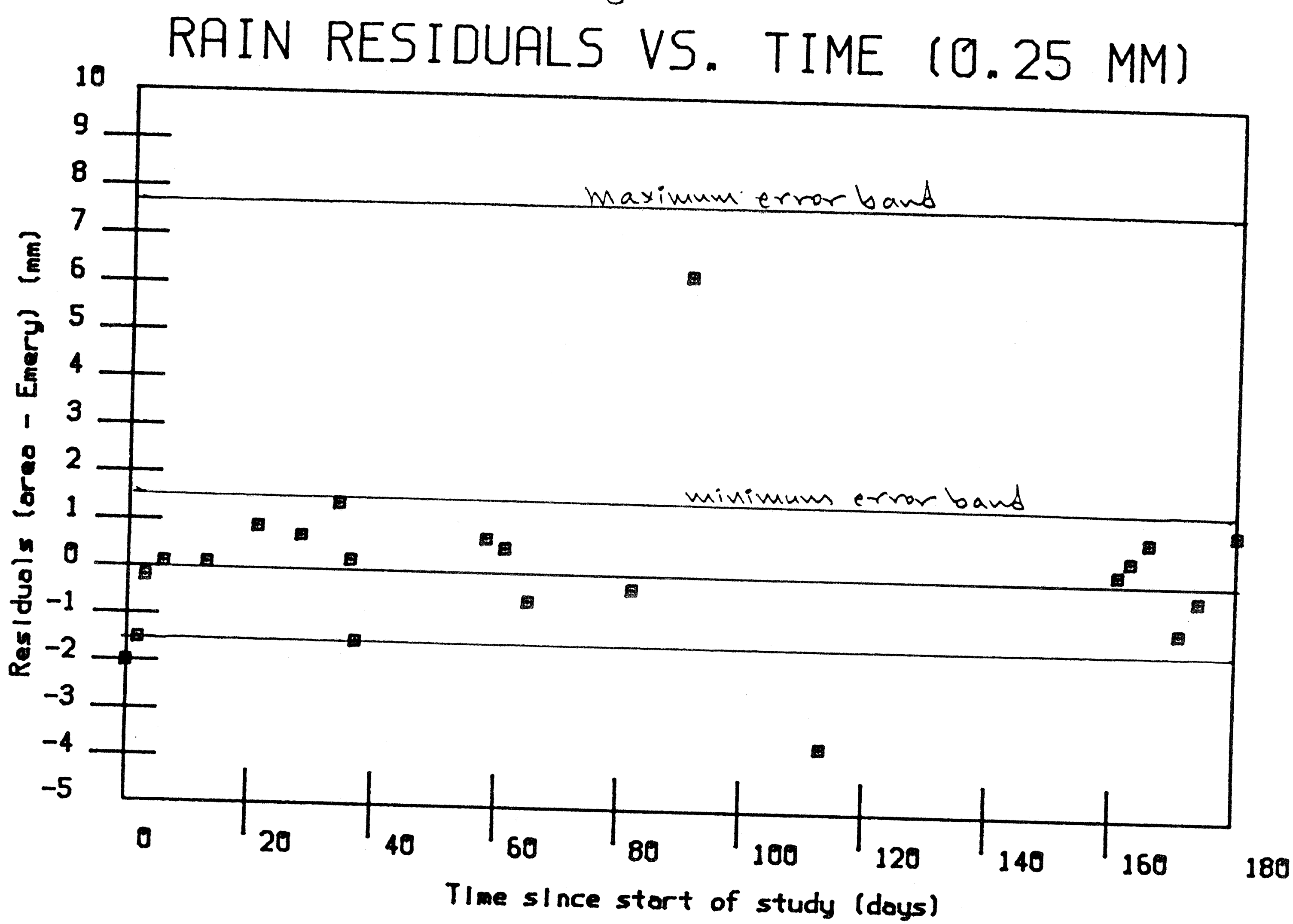
Figure C.16



7/15/84

APPENDIX C RAIN GAUGE CALIBRATION PROCEDURES

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LIST OF FIGURES

RAIN GAUGE CALIBRATION PROCEDURES

Initial compilation of the summary of rainfall data from the Emery rain gauge indicated a problem with the tipping bucket calibration factor. The same precipitation data was used for the Thistledown catchment. There was no additional gauge close to the watersheds that could be easily used to verify the Emery precipitation data. The closest gauges to the watersheds were all of the order of five to ten kilometres away. As indicated in Section 4 of the report, accurate rainfall data was absolutely necessary in order to estimate runoff contributions from the different source areas. Therefore, a substantial investigation of the calibration history of the rain gauge at Emery and of regional Toronto precipitation data was conducted to determine the most appropriate calibration factor for the gauge.

A preliminary report entitled "Summary of Toronto Area Rainfall Analyses" was submitted to the MOE on 24 June, 1984. It contained detailed analyses of the rainfall that had fallen up to that time. This appendix summarizes the several steps that were taken and reported in that report, and the final analyses and conclusions.

The problem was first detected in December, 1983, when summaries were being prepared from the five minute precipitation data tables. It was noted on the data forms that the precipitation calibration factor had abruptly changed from 0.20 mm per tip, to 0.28 mm per tip of the gauge bucket, in early September, 1983. The field personnel felt that the gauge was not responding accurately when compared to the Toronto (Pearson International Airport) recordings and to other rain gauge records in the Toronto area. The Emery gauge was suspected of under reporting the precipitation totals during rains having high intensities.

The rain gauge was recalibrated in the field in October, 1983, when a factor of 0.28 mm per tip was determined. This value was 40 percent greater than the initial calibration factor of 0.20 mm per tip that was obtained in laboratory calibration tests at the beginning of the study. There were no physical reasons why the rain gauge would have suddenly changed its calibration value by so much, e.g. no lightning strikes or evidence of vandalism, etc. The new calibration factor was used to analyze all precipitation events reported from early September, when the data was first questioned by the field personnel, through the end of the precipitation monitoring period in November.

The field calibration procedures were not standard procedures, because of the very large "precipitation" intensities used. The significantly different calibration factor obtained should not have been used without additional verification. The rain gauge was finally recalibrated in the laboratory using standard procedures in March, 1984. A calibration factor of almost 0.40 mm per tip was obtained. This last value was considered unreasonable, as the fragile calibration mechanism on the rain gauge could have been easily moved during transport or packing for storage. The calibration tension screw may have also been faulty, as it had been replaced previously. Therefore, detailed analyses of available Toronto data was conducted to identify a suitable rain gauge calibration factor.

A series of exploratory data analyses were conducted using as much precipitation data obtained during the study period as possible. Initial tests examined the four simple potential calibration values as listed below:

1) using a constant 0.20 mm tip value,

2) using a constant 0.28 mm value,

3) using the data as reported (starting with 0.20 mm and abruptly changing to 0.28 mm), and

4) using a sliding calibration value evenly changing from an initial value of 0.20 mm at the beginning of the study to a value of 0.28 mm on the date of field recalibration.

Regression analyses were used to compare the Emery data (using these four alternative calibrations) to the other precipitation data obtained in the Toronto area. Several large regional storms were found to result in significantly different values of the storm depth being calculated for the Emery catchment, depending on the calibration model used. Occasional outliers can be expected, especially when considering precipitation variations over an area. Unfortunately, few literature references have reported on typical variations in precipitation that can be expected over relatively small distances in urban areas. Precipitation variations over much larger areas (such as on a provincial or state scale) have been commonly examined. The analyses of residuals for the four best calibration models resulted in questionable variations of residuals with precipitation volume (as expected), but not with time.

Additional analyses were conducted using the four potential sets of precipitation data to develop runoff models that could explain deviations for large events. The runoff relationships were all "too good" and did not show any significant differences, especially for the suspected high intensity rains.

Comparisons of paired values of runoff events from Thistledown and Emery were then used to help identify precipitation events that probably had similar rains over the two test catchments and over the study area. The Emery and Thistledown catchments are approximately three km apart and are approximately five to ten km from the Pearson International Airport (P I A). Only runoff events that had similar hydrographs were used in this comparison. Figure C.1 is the log-log plot of these runoff observations for

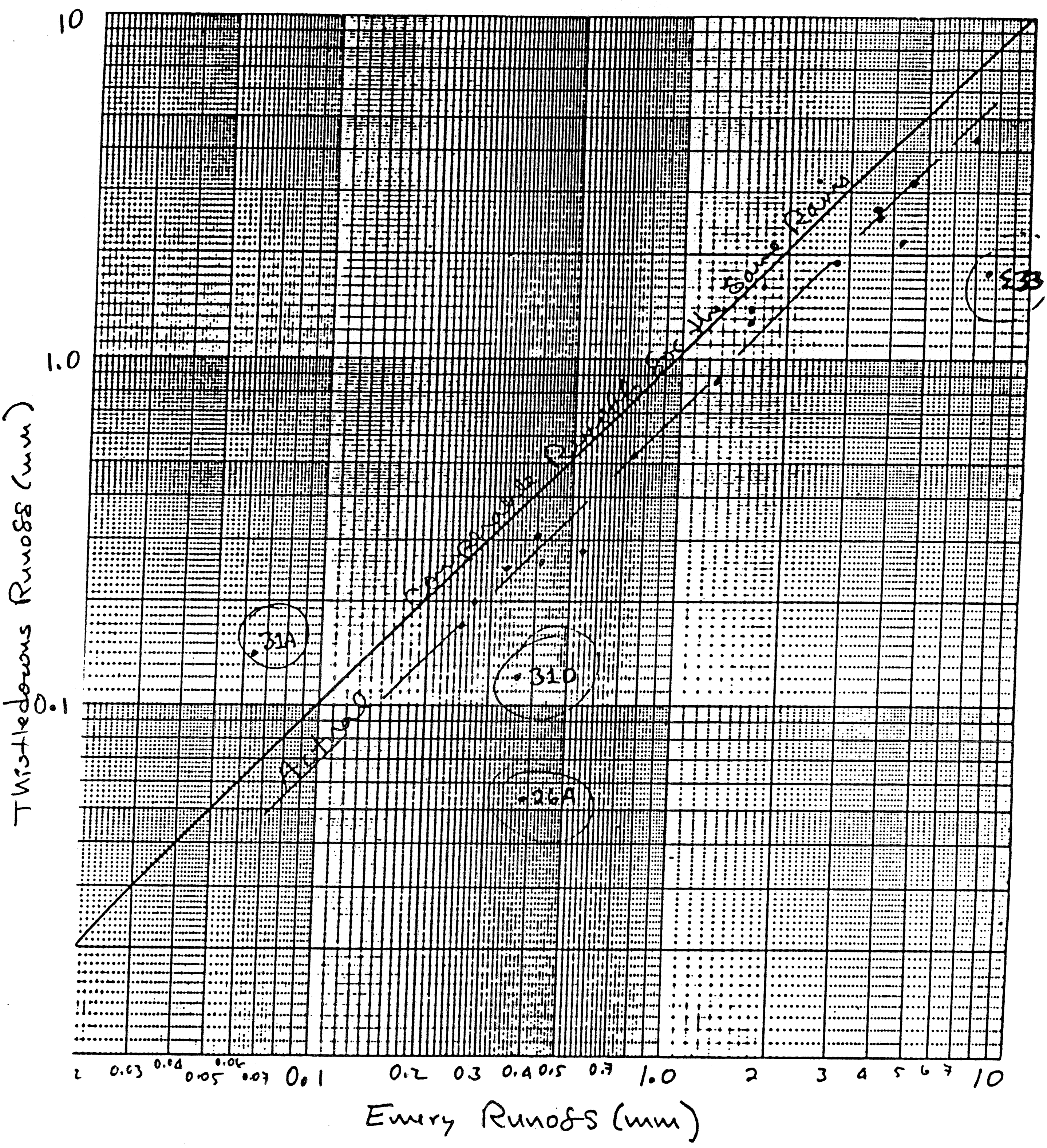


Figure C.1 Runoff Comparisons for Paired Rain Events approximately twenty paired events. Four events were identified as "outliers" that were probably associated with highly variable rains. For most of the other events, the unit area runoff yields for Thistledown were approximately 30 percent less than for Emery. A relatively clean set of approximately 15 events were therefore identified for further analyses. Detailed summaries of the precipitation characteristics for these selected events were then made for all of the MOE local Toronto precipitation data.

Plots recording 15 minute precipitation totals for three additional rain gauge locations (York Works Yard, Rockcliffe, and Glen Park), Emery, and the P I A were then made for all of the monitored rains. Three examples of these plots are shown as Figures C.2 through C.4. These are all fairly complex events and show suprisingly similar precipitation volumes and intensities at all locations. Some events, however, were confirmed as outliers, signifying highly variable precipitation characteristics over the study area.

When the P I A precipitation data were obtained, it was necessary to compare the airport standard rain gauge data with the airport recording tipping bucket results. This comparison is shown as Figure C.5 and shows an excellent correlation between the two airport measurement procedures. The maximum deviations recorded were approximately five percent, well within the errors of the other factors being investigated. The recording gauge data were adjusted for these correction factors.

Further analyses were then made comparing airport and other precipitation observations in the Toronto area. They were found to be in good agreement, except for many Emery observations.

Long term (30 year) average precipitation data were then obtained for 33 rain gauges in the Toronto metropolitan area (Environment Canada, 1979 and 1982). Most of these gauges were not tipping bucket recording gauges. Figure C.6 is a sketch map showing the locations of the stations that are summarized by month on Table C.1. Analyses of these data did not indicate any significant long term precipitation trends over the area, either for total seasonal precipitation or for total annual precipitation. However, these data did indicate the potential of obtaining much more daily, and possibly tipping bucket, precipitation data for the Toronto area than originally expected.

Total daily precipitation volumes were obtained for most of the stations that were operating during 1983. These daily values, organized by monitored event, are shown on Table C.2. Total hourly data (derived from tipping bucket data) were also obtained for seven locations in the Toronto area. The hourly data from these seven locations were combined with the Emery and airport data and recorded by hourly totals and plotted for each monitored runoff event, as shown on Table C.3. From these combined total precipitation volume and tipping bucket data from MOE and Environment Canada sources, it was possible to identify a

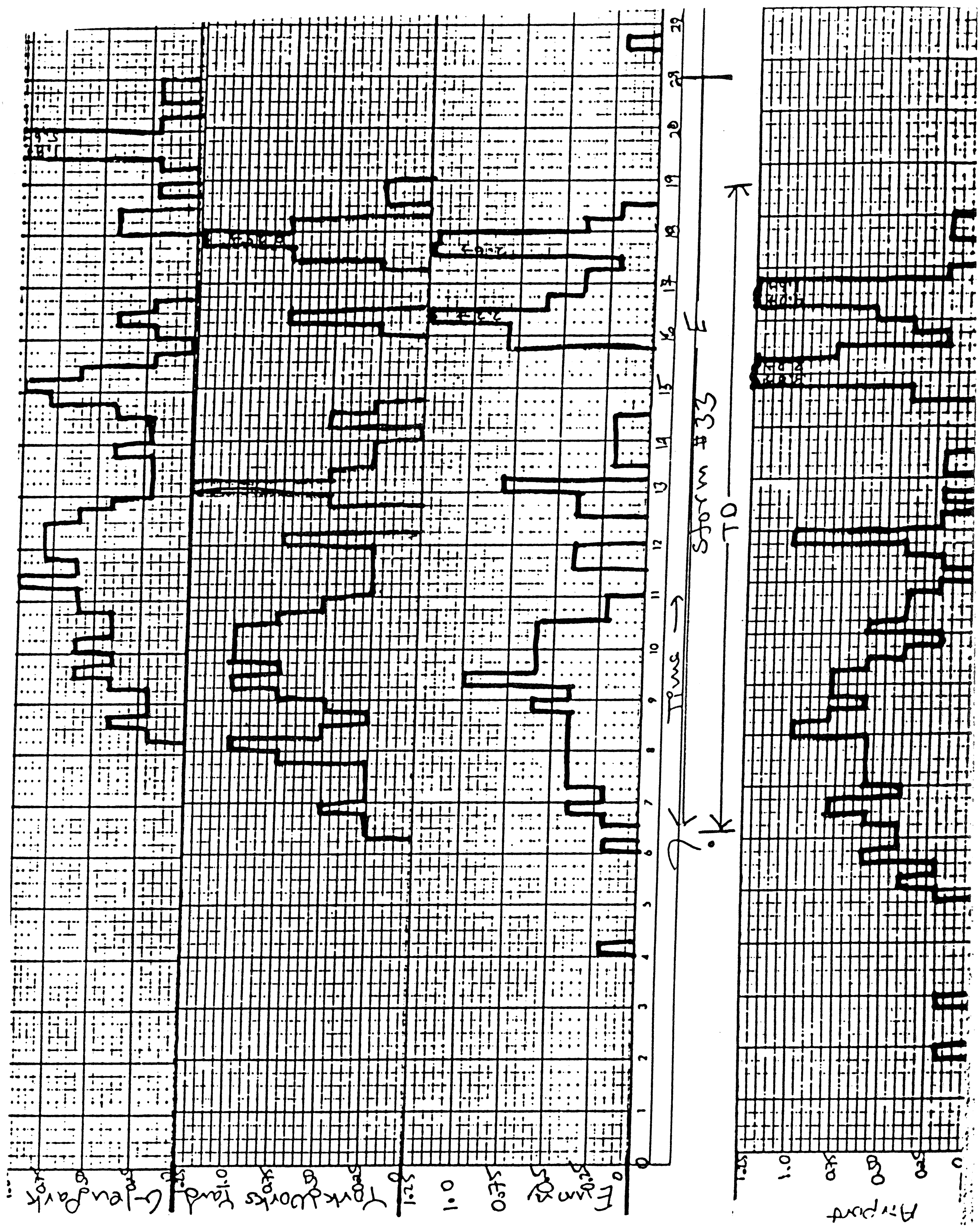


Figure C.2. 15-minute rain comparisons for event #33

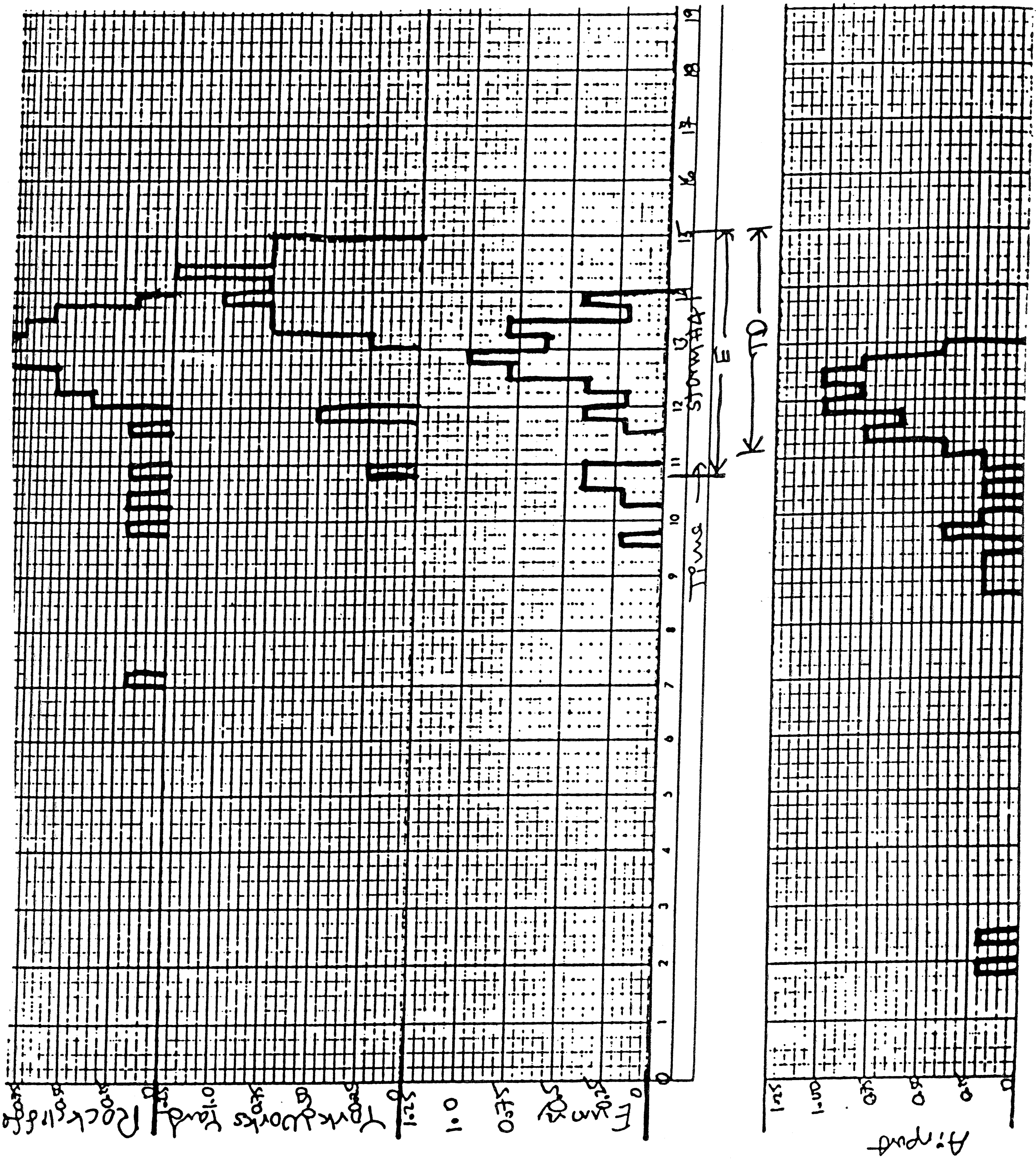


Figure C.3 15-minute rain comparisons for event # 41

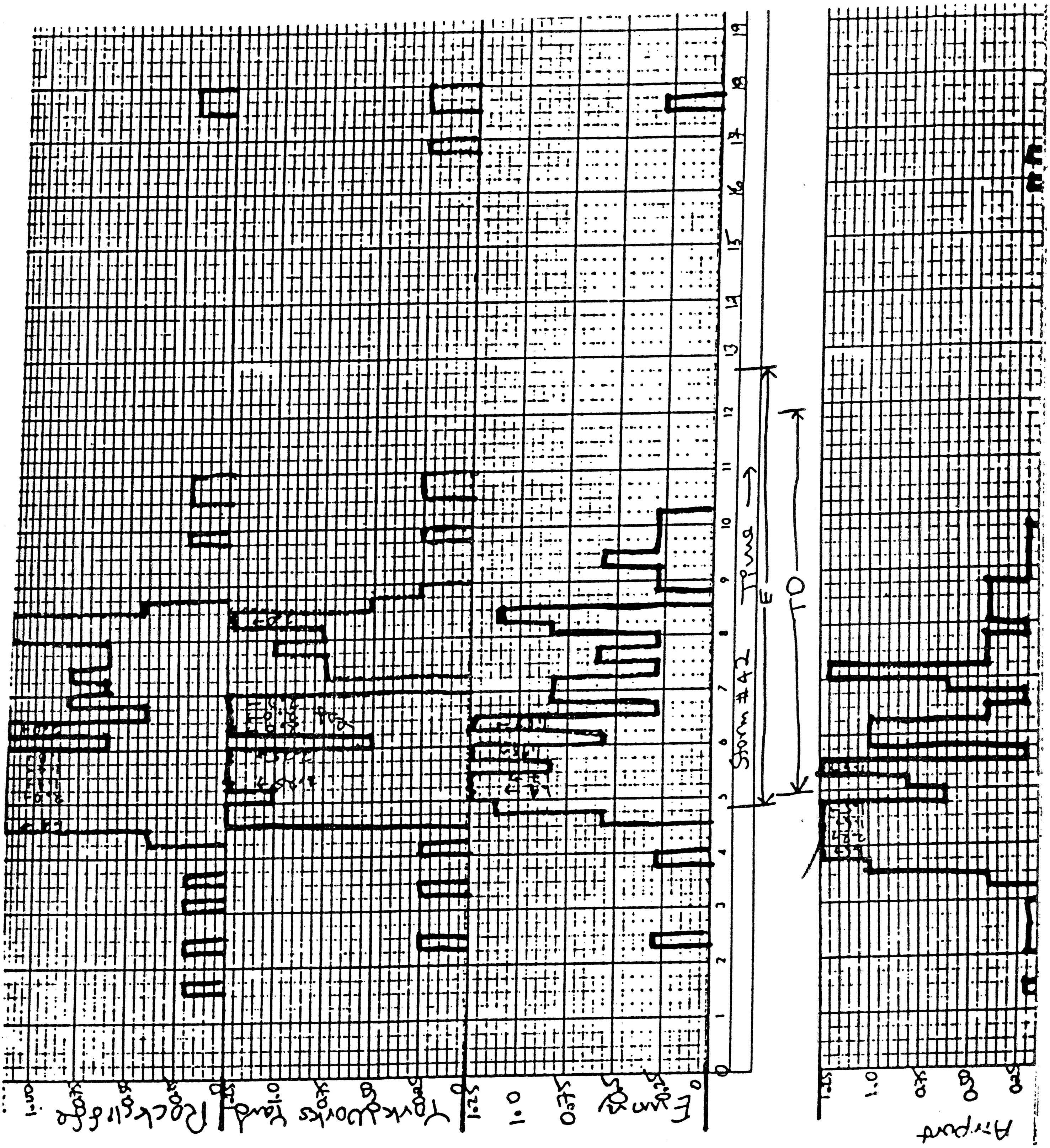
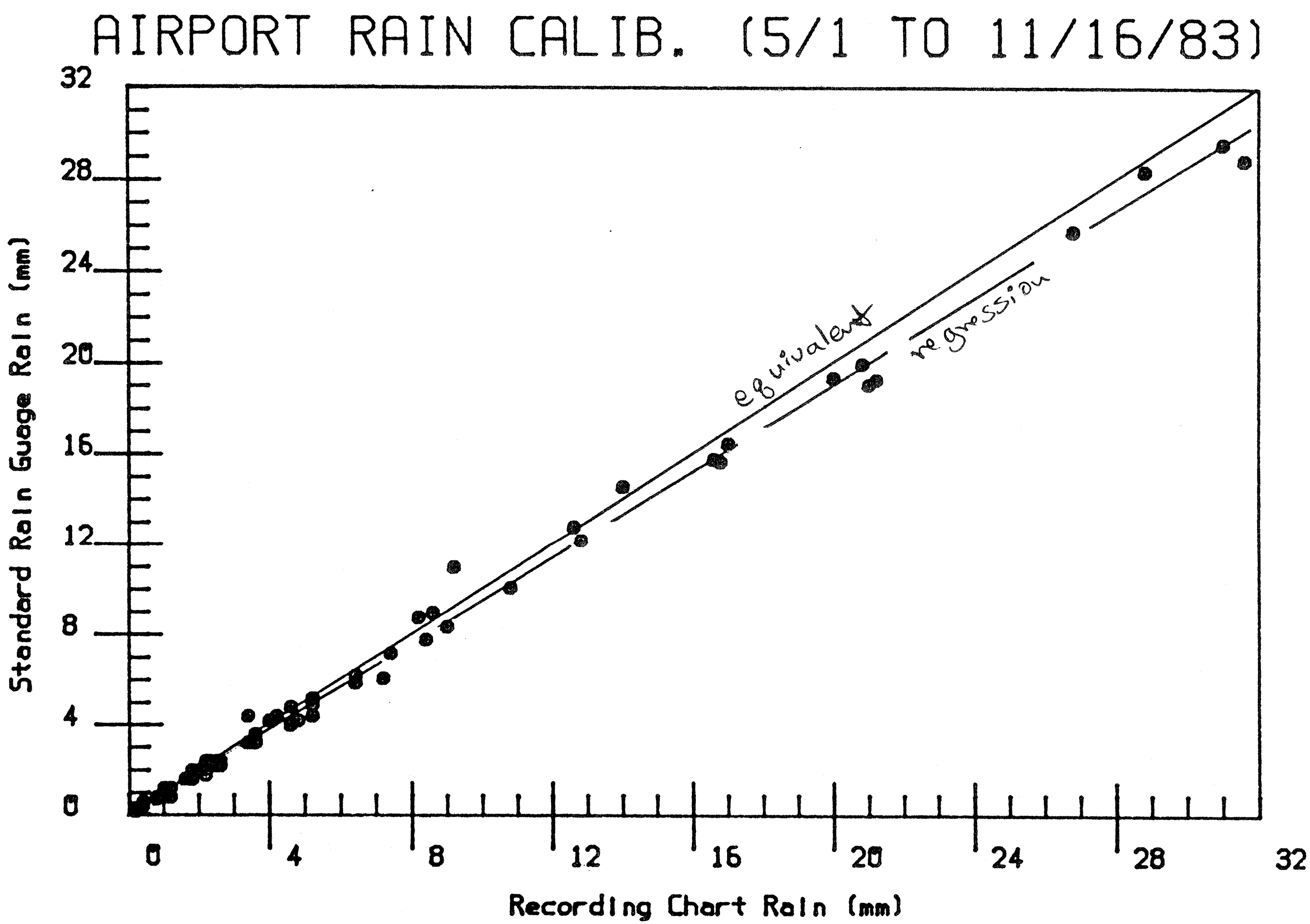


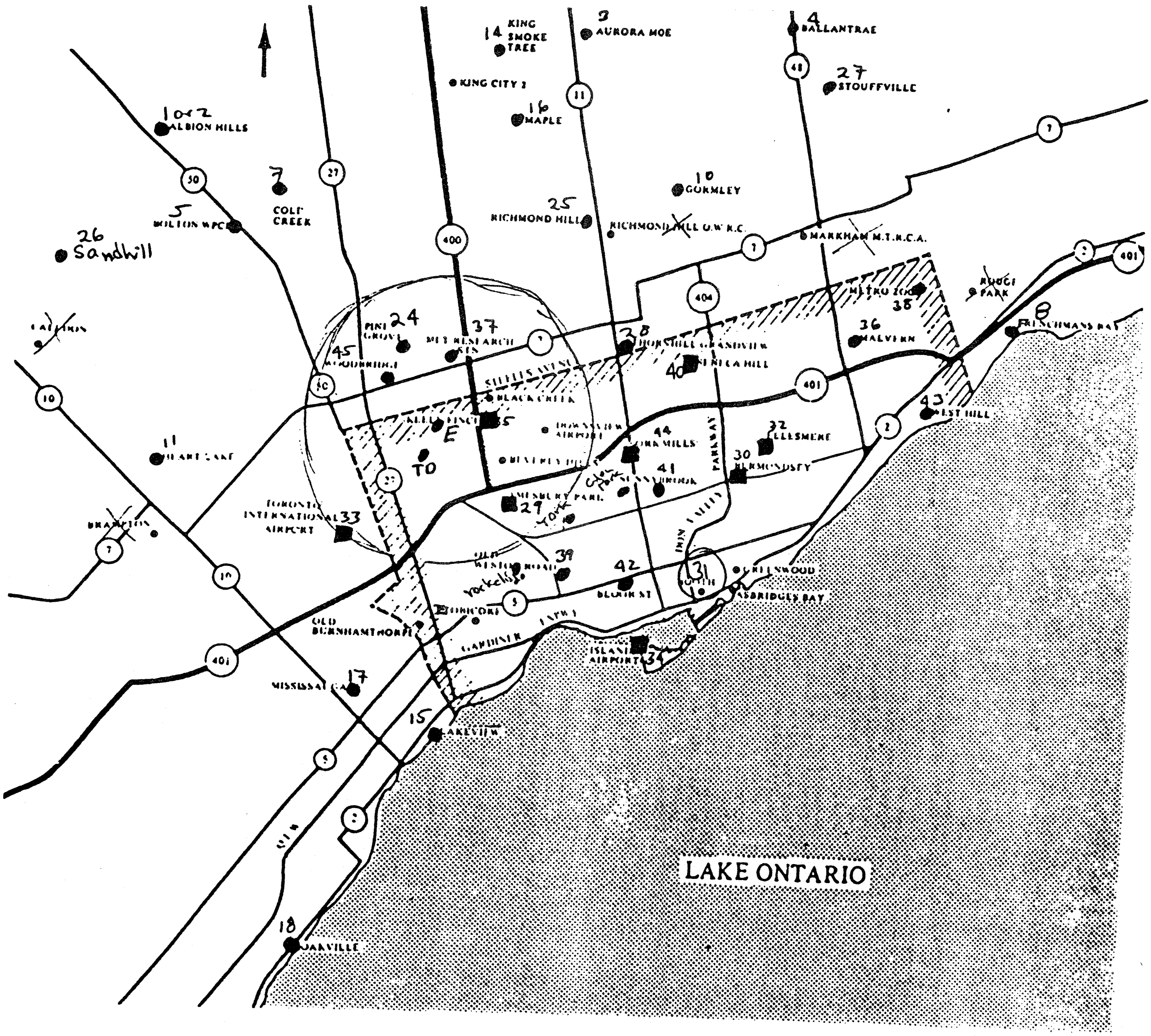
Figure C.4 15-minute rain comparisons
for event # 42

Figure C.5 Airport Recording and Standard Gage Calibration



$\hat{Y} = 0.08 + 0.95X$; $R^2 = 0.996$; $N = 67$

Rec Stand
5/12/84



Source: Envir. Canada 1983

Figure C.6 Map Showing Toronto Area Rain Gage Locations

Table C.1 1951–1980 Toronto Area Average Rainfall (mm)

	Station Location				Monthly Totals (mm)		
name	1 N	2 W	3 elev (m)	rain code (1)	5 Jan	6 Feb	7 Mar
Toronto 1	43°40'	79°24'	111	1	25.9	23.8	43.9
Agincourt 2	43°47'	79°16'	180	8	22.5	25.7	41.5
Ashbridges Bay 3	43°40'	79°19'	75	8	20.1	23.5	39.6
Beacon Road 4	43°45'	79°16'	168	8	27.5	28.3	45.6
Beverley Hills (5)	43°44'	79°30'	145	3	22.5	22.7	37.3
Black Creek (6)	43°46'	79°31'	186	8	16.9	23.6	35.6
Bridlewood 7	43°47'	79°19'	183	8	28.4	22.0	41.4
Castlemere 8	43°47'	79°19'	184	8	23.0	19.8	40.7
Downsview A (9)	43°45'	79°29'	198	8	22.2	17.6	33.9
Downsview (10)	43°43'	79°29'	160	8	25.3	23.3	36.6
Dunn Loring Wood 11	43°48'	79°21'	175	8	28.3	22.0	43.1
Ellesmere 12	43°46'	79°16'	164	8	22.6	29.3	47.3
Etobicoke (13)	43°38'	79°32'	119	8	25.1	24.7	47.2
Fallingbrook 14	43°41'	79°16'	130	8	27.8	29.0	38.2
Glendale 15	43°45'	79°25'	137	8	20.0	21.1	40.4
Glenview (16)	43°42'	79°27'	174	8	24.3	25.7	46.0
Greenwood 17	43°40'	79°19'	99	8	23.4	23.0	42.7
Highland Creek 18	43°47'	79°10'	114	8	25.7	28.8	44.9
High Park (19)	43°39'	79°28'	107	8	24.2	23.0	43.8
International Airport 20	43°40'	79°38'	173	1	21.3	20.6	37.1
Island A 21	43°38'	79°24'	77	3	24.8	24.0	38.2
Islington (22)	43°39'	79°33'	133	2	25.3	24.9	42.3
Kingsway (23)	43°39'	79°31'	114	8	26.2	25.2	47.9
Met. Res. Stn (24)	43°48'	79°33'	194	8	22.9	19.9	35.6
Northcliffe (25)	43°41'	79°27'	168	3	26.3	27.5	43.5
Old Weston Rd (26)	43°39'	79°28'	122	8	19.3	24.7	44.2
Scarborough 27	43°43'	79°14'	157	8	22.4	24.4	37.5
Sherbourne 28	43°39'	79°22'	76	8	26.6	24.4	40.1
Sunnybrook 29	43°43'	79°23'	157	8	23.9	22.0	43.3
West Deane Park (30)	43°40'	79°34'	140	8	24.0	22.1	41.0
Willowdale 31	43°46'	79°25'	191	8	21.2	24.5	43.1
Wilson Heights	43°44'	79°26'	191	8	23.6	25.5	32.8

source: Envir Canada 1982

Table C.1 1951–1980 Toronto Area Average Rainfall (mm) (cont.)

Monthly Rain Totals (mm)

name		Apr	May	June	July	Aug	Sept	Oct
Toronto	1	65.4	65.7	63.9	74.0	73.1	66.2	60.4
Agincourt	2	66.0	68.4	66.6	76.0	79.2	62.1	66.0
Ashbridges Bay	3	57.4	61.5	58.3	63.7	82.0	62.2	56.5
Beacon Road	4	67.0	72.2	65.9	70.7	76.1	60.6	67.1
Beverley Hill	5	57.4	60.8	67.0	72.9	70.2	60.0	55.9
Black Creek	6	62.2	63.7	65.1	73.5	73.1	61.9	60.3
Bridlewood	7	62.3	60.2	60.0	55.4	73.5	60.5	54.1
Castlemere	8	67.3	65.9	67.0	67.8	86.9	63.0	56.7
Downsview A	9	58.7	61.4	70.4	74.1	71.0	65.2	57.8
Downsview S	10	65.2	64.9	62.9	75.8	73.6	56.6	56.8
Dunn Loring Wood	11	61.8	69.3	66.5	65.6	65.4	61.5	58.5
Ellesmere	12	63.2	69.7	74.1	60.9	77.6	63.1	64.6
Etobicoke	13	61.9	65.9	63.5	64.2	73.0	64.1	59.8
Fallingbrook	14	69.0	71.4	71.2	71.8	77.6	75.6	65.2
Glendale	15	62.9	71.4	70.4	75.1	77.3	54.1	58.0
Glenview	16	70.0	66.8	69.6	76.6	80.3	69.0	67.2
Greenwood	17	64.9	61.2	60.8	63.6	72.4	62.5	58.4
Highland Creek	18	73.8	84.8	66.5	—	—	72.7	67.7
High Park	19	65.9	63.7	66.6	72.3	70.8	68.7	58.9
International Airport	20	61.8	65.8	67.1	71.4	76.8	63.5	61.0
Island A	21	59.7	62.7	66.9	70.6	71.2	69.5	56.2
Islington	22	64.0	69.3	68.8	71.0	84.2	60.3	61.9
Kingsway	23	68.2	69.8	72.2	83.8	81.3	74.5	66.0
Met. Res. Stn	24	59.7	63.2	64.8	69.7	74.6	62.0	57.4
Northcliffe	25	64.0	64.3	65.1	77.2	71.7	64.3	58.6
Old Weston Rd	26	63.0	64.9	62.5	69.9	70.7	64.3	59.0
Scarborough	27	58.7	72.0	72.3	72.7	79.8	66.8	67.3
Sherbourne	28	65.8	61.4	60.9	66.0	77.0	65.5	59.1
Sunnybrook	29	62.7	65.9	63.8	69.7	71.2	61.0	59.6
West Deane Park	30	60.0	67.1	65.9	74.0	79.9	65.2	63.0
Willowdale	31	65.9	69.0	76.3	72.0	76.9	65.2	64.6
Wilson Heights		66.9	65.9	70.4	78.5	79.0	60.5	63.3

Table C.1 1951–1980 Toronto Area Average Rainfall (mm) (cont'd)

name	Monthly Totals (mm) 15 Nov	1 Dec	1 Annual Rain (mm)	1 Annual Snow (cm)	Annual Days w/ Rain		2 May-Nov Rain total (mm)
Toronto 1	60.9	40.7	663.9	139.2	102	1	464.2
Agincourt 2	60.5	41.0	675.5	146.2	98	2	478.8
Ashbridges Bay 3	53.3	40.1	618.2	99.0	87	3	437.5
Beacon Road 4	64.6	40.4	686.0	145.0	98	4	477.2
Beverley Hill (5)	58.3	38.9	623.9	109.3	96	5	445.1
Black Creek (6)	57.8	33.1	626.8	111.6	74	c	455.4
Bridlewood 7	58.9	39.2	615.9	140.8	—	7	479.4
Castlemere 8	61.5	40.2	659.8	162.1	98	8	468.8
Downsview A (9)	60.3	33.9	626.5	147.9	103	9	460.2
Downsview S (10)	59.8	38.8	639.6	116.1	100	10	450.4
Dunn Loring Wood 11	61.7	41.3	645.0	135.9	99	11	448.5
Ellesmere 12	64.3	33.2	669.9	107.1	86	12	474.3
Etobicoke (13)	60.6	37.6	647.6	105.1	89	13	451.1
Fallingbrook 14	65.1	45.0	706.9	127.1	98	14	497.9
Glendale 15	61.9	39.0	651.6	116.9	87	15	468.2
Glenview (16)	61.6	42.1	699.2	143.6	99	16	491.1
Greenwood 17	58.8	39.9	631.6	95.6	99	17	438.7
Highland Creek 18	70.2	42.1	—	—	—	18	—
High Park (19)	58.6	41.4	657.9	125.9	101	19	459.6
International Airport 20	55.2	35.6	637.2	131.2	99	20	460.8
Island A 21	58.5	41.8	644.1	119.4	99	21	455.6
Islington (22)	60.0	38.8	670.8	120.6	98	22	475.5
Kingsway (23)	61.1	44.7	720.9	123.6	111	23	508.7
Met. Res. Stn (24)	54.7	34.7	619.2	120.0	97	24	446.4
Northcliffe (25)	62.0	42.7	667.2	119.9	100	25	463.2
Old Weston Rd (26)	58.3	37.6	638.4	96.6	94	26	449.6
Scarborough 27	64.6	40.9	679.4	119.9	95	27	495.5
Sherbourne 28	62.5	45.8	654.9	92.5	99	28	452.2
Sunnybrook 29	59.4	35.8	638.3	139.4	98	29	450.6
West Deane Park (30)	55.9	36.6	654.7	133.7	102	30	471.0
Willowdale 31	63.0	42.6	684.3	101.2	99	31	487.0
Wilson Heights	60.7	39.4	666.5	136.6	96	34	478.3

1) rain code: 1: Complete 30 years of record
2: 25 to 29 years
3: 20 to 24 years
8: "adjusted" normals based on 5 to 19 years from 1951–1980 and any other data from 1931–1950.

Table C.2 Toronto Area Rain Totals by Monitoring Event
Total Rain Observed (mm)

May, 1983

Station Name	#	1+2 #1+2+3	3 #4	4 #5	7+8 #6	14+15 #7	19 ?	22 #8+9	25 #10	29 #11	31 #12
Sandhill	26	37.9	5.0	3.5	14.4	11.4	27.4	7.1	3.4	11.4	3.9
Albion	1	31.8	4.6	2.4	18.0	9.0	27.0	1.7	3.0	Θ	4.2
Bolton	5	55.6	5.0	2.0	15.4	14.6	26.0	6.0	2.0	3.0	2.0
Cold Creek	7	32.6	4.4	1.2	Θ	9.2	24.4	4.6	1.6	4.4	3.6
Heart Lake	11	30.9	2.7	4.6	25.8	10.9	25.9	6.4	6.0	10.8	8.4
King Smoke Tree	14	24.4	6.0	1.4	21.0	13.8	22.2	7.4	4.8	7.2	3.8
Aurora	3	21.9	6.2	0.6	17.7	17.0	24.2	6.8	5.2	7.4	4.0
Maple	16	76.5	Θ	Θ	23.6	12.2	24.8	6.9	6.2	({12.6+)	4.6
Ballantrae	4	21.6	6.0	1.2	14.4	17.2	17.6	7.8	6.0	4.4	2.4
Stouffville	27	102	6.8	Θ	14.0	14.8	25.2	Θ	7.8	3.2	2.3
Gormley Ardmore	10	23.4	6.0	2.4	11.0	14.0	19.2	13.8	6.2	12.0	1.5
Richmond Hill	25	NA									
Pine Grove	24*	31.6	Θ	9.8	11.0	10.0	21.0	10.0	5.0	18.6	Θ
Woodbridge	45*	32.6	5.1	6.6	9.6	14.6	21.4	7.2	6.4	14.5	1.1
Met. Res.	37*	26.4	5.7	3.8	10.6	12.8	18.7	4.8	6.4	13.6	3.4
Thornhill	28	20.8	6.3	3.4	11.4	12.0	19.0	14.6	3.6	10.6	4.2
Keele Finch	35*	9.5	18.2	5.2	9.6	11.1	18.2	6.2	4.8	10.8	6.5
International Airport	33*	21.9	5.2	4.2	8.5	8.4	19.1	5.9	4.4	15.7	2.3
Seneca Hill	40	27.0	6.0	Θ	11.2	10.0	18.2	12.7	5.2	12.5	3.8
Amesbury	29*	26.2	5.6	5.4	9.8	9.4	30.2	Θ	M	11.0	1.9
York Mill	44	Θ	2.5	2.6	11.5	7.3	24.0	15.0	7.0	29.0	0.2
Mississauga	17	26.4	6.6	2.2	7.4	14.8	21.0	11.4	M	17.4	2.6
Frenchman's Bay	8	27.8	7.8	2.4	10.4	6.2	31.8	13.6	4.7	10.6	3.0
Metro Zoo	38	26.0	5.4	1.6	7.2	3.4	24.6	2.6	10.6	11.4	Θ
Malvern	36	26.0	5.6	2.2	10.9	7.4	24.8	12.8	10.2	10.6	4.2
West Hill	43	22.6	6.0	1.8	10.6	3.0	30.8	9.2	6.0	8.8	3.0
Ellesmere	32	NA									
Bermonds	30	M	M	Θ	3.7	15.2	40.4	10.0	0.3	14.6	2.4
Sunnybrook	41	24.2	4.6	Θ	Θ	9.2	30.8	14.8	4.0	11.0	0.3
Broadway	31	21.8	4.5	2.3	{25.6+	10.5	27.1	8.2	6.3	8.3	1.6
Toronto	42	20.2	4.6	3.6	9.1	12.0	28.8	10.4	0.8	13.4	2.0
Old West	39	18.0	5.6	3.8	9.2	7.8	26.6	9.0	3.8	13.8	2.0
Lakeview	15	22.4	5.0	1.8	11.6	15.6	36.0	9.2	2.6	12.8	1.2
Oakville	18	31.1	6.0	2.0	14.2	Θ	27.2	7.6	4.4	13.6	1.6
Island Airport	34	19.2	4.8	3.0	8.6	11.8	27.0	3.4	5.8	12.2	1.2

Table C.2 Toronto Area Rain Totals by Monitoring Event
Total Rain Observed (mm) (cont.)

		June, 1983						July, 1983				
		3+4	5	6	17	27+28	30	1	4	21	28+29	30+31
Station Name	#	#13	#14	#15	#16	#17	#18	#19	#20	#21	#21B(?)	#23+24
Sandhill	26	4.0	1.0	10.9	θ	(Σ16.0+)	0.3	TR	8.6	4.4	2.0	73.2
Albion	1	7.5	θ	12.0	θ	M	1.0	θ	6.0	3.5	θ	34.0
Bolton	5	3.3	3.6	8.0	θ	7.0	θ	0.8	9.6	0.8	0.8	56.0
Cold Creek	7	θ	4.2	7.2	θ	3.0	θ	θ	10.6	3.6	1.2	42.2
Heart Lake	11	no record						θ	5.8	θ	1.8	40.6
King Smoke Tree	14	3.0	3.0	8.0	θ	9.0	θ	1.2	7.0	2.0	6.6	48.6
Aurora	3	2.6	11.0	θ	0.4	3.0	2.1	θ	5.0	1.6	3.8	41.6
Maple	16	no record						no record				
Ballantrae	4	1.6	1.4	10.6	TR	6.8	2.6	TR	6.2	2.6	20.8	46.0
Stouffville	27	3.2	TR	10.2	0.4	7.0	θ	θ	5.0	θ	5.0	17.4
Gormley Arkle	10	10.4	4.0	5.8	7.3	7.8	θ	θ	7.2	1.6	4.8	12.4
Richmond Hill	25	3.0	0.4	9.2	3.8	7.8	2.2	θ	6.0	1.0	11.0	27.6
Pine Grove	24*	6.0	θ	11.6	θ	10.0	3.0	θ	5.0	2.0	0.5	21.0
Woodbridge	45*	5.0	1.0	10.8	TR	10.6	5.8	4.4	7.5	3.1	3.4	27.2
Met. Res.	37*	3.8	1.2	9.4	0.4	8.6	2.8	4.0	6.0	2.2	3.0	22.3
Thornhill	28	3.5	0.2	10.4	3.8	8.4	1.2	1.2	7.6	θ	3.7	18.2
! Keele-Finch	35*	4.9	2.0	9.0	1.6	3.6	2.8	3.0	8.0	4.0	2.5	13.8
International Airport	33*	3.2	1.2	9.0	0.2	15.4	2.4	0.8	4.9	4.0	2.0	4.4
Seneca Hill	40	7.4	2.0	10.2	3.0	7.0	θ	2.2	9.2	3.4	4.9	7.4
Amesbury	29*	5.0	2.0	7.0	θ	12.0	1.2	θ	6.0	2.8	3.6	7.8
York Mill	44	3.4	0.5	4.8	2.6	10.0	1.3	θ	5.5	2.2	0.3	20.0
Mississauga	17	no record						no record				
Frenchman's Bay	8	5.2	TR	3.6	0.3	6.3	3.4	TR	5.0	3.8	4.2	10.2
Metro Zoo	38	4.3	θ	9.0	7.0	4.9	3.2	θ	4.2	1.6	3.6	13.0
Malvern	36	3.5	0.4	9.0	0.3	6.8	5.0	θ	4.0	1.6	2.4	7.0
West Hill	43	4.0	TR	0.4	θ	3.8	2.4	TR	3.6	2.0	2.0	13.6
Ellesmere	32	3.0	2.5	7.0	θ	7.0	4.0	1.2	5.0	2.8	1.6	3.0
Bermonds	30	15.2	1.8	6.8	θ	18.0	2.2	θ	5.2	3.4	4.0	3.4
Sunnybrook	41	C(?)	C(?)	(Σ11.6+)	θ	(Σ8.2+)	0.5	4.0	6.0	2.0	4.8	2.8
Broadway	31	M	M	M	M	M	M	M	M	M	M	M
Toronto	42	6.0	1.0	7.6	θ	14.0	0.6	2.3	4.3	2.2	5.8	4.4
Old West	39	5.1	1.2	7.4	θ	14.0	θ	θ	5.2	3.4	3.6	θ
Lakeview	15	2.5	0.3	8.0	θ	20.2	θ	no record				
Oakville	18	6.7	1.6	7.2	θ	28.3	θ	2.5	10.2	θ	12.8	5.8
Island Airport	34	2.6	1.6	3.2	θ	13.9	4.3	0.2	5.6	2.0	5.8	1.6

Table C.2 Toronto Area Rain Totals by Monitoring Event
Total Rain Observed (mm) (Cont.)
August, 1983

Station Name	#	1 #25	3+4 #26	5 ?	8 #27	11 #28	21+22 #29	27 #30	28 ?	30 #31
Sandhill	26	5.8	6.7	θ	3.6	6.4	19.1	0.7	27.3	15.1
Albion	1	2.0	4.3	θ	2.2	4.0	21.0	θ	θ	θ
Bolton	5	13.8	2.6	θ	0.8	0.4	27.2	θ	7.8	1.2
Cold Creek	7	θ	15.7	θ	θ	7.4	4.2	θ	9.0	14.8
Heart Lake	11	no record								NR
King Smoke Tree	14	3.6	4.0	θ	1.6	3.8	19.8	22.2	θ	2.0
Aurora	3	4.8	1.8	θ	1.2	2.6	18.4	10.2	2.0	θ
Maple	16	10.6	4.2	θ	1.0	5.2	19.6	23.1	2.3	10.9
Ballantrae	4	8.6	2.0	θ	3.6	5.2	28.0	TR	TR	63.4
Stouffville	27	6.0	6.2	θ	4.4	4.2	15.0	35.2	θ	24.6
Gormley Ardendale	10	2.0	2.5	θ	1.0	3.0	20.0	32.5	θ	6.0
Richmond Hill	25	no record								NR
Pine Grove	24*	2.2	4.6	θ	1.4	4.0	10.2	16.8	1.6	8.6
Woodbridge	45*	3.8	5.3	θ	2.5	9.0	19.5	7.2	1.3	9.5
Met. Res.	37*	0.2	2.4	θ	2.2	5.6	18.3	10.8	0.4	6.4
Thornhill	28	11.4	2.2	θ	1.8	0.3	11.2	14.6	0.2	9.7
Keele-Finch	35*	0.2	5.0	0.2	13.1	8.0	21.2	17.0	θ	7.8
International Airport	33*	0.8	3.2	1.6	29.6	25.0	30.0	1.2	0.6	19.4
Seneca Hill	40	10.9	3.0	θ	3.7	8.7	22.2	46.0	θ	5.4
Amesbury	29*	θ	2.4	θ	29.8	12.4	21.0	4.4	θ	5.3
York Mill	44	θ	4.0	θ	31.4	5.0	23.0	16.0	1.3	9.8
Mississauga	17	no record								NR
Frenchman's Bay	8	3.4	1.4	θ	17.2	11.8	28.0	10.2	θ	20.6
Metro Zoo	38	10.0	1.0	θ	θ	9.6	27.0	13.0	θ	6.8
Malvern	36	8.4	2.4	θ	11.2	10.6	30.2	20.4	θ	1.6
West Hill	43	7.6	1.2	θ	27.4	9.0	19.4	34.0	θ	5.8
Ellesmere	32	3.6	1.6	θ	24.0	6.0	16.7	37.0	θ	1.5
Bermonds	30	0.5	3.8	θ	25.0	14.0	21.2	θ	θ	5.0
Sunnybrook	41	θ	3.8	θ	20.8	15.4	23.2	12.0	θ	5.0
Broadway	31	M	M	M	M	M	M	M	M	M
Toronto	42	θ	1.8	0.2	22.2	15.5	30.6	23.6	TR	4.8
Old West	39	θ	θ	θ	—	5.0	26.4	22.0	θ	5.6
Lakeview	15	no record								NR
Oakville	18	θ	5.2	θ	3.4	23.0	20.2	8.8	0.4	12.0
Island Airport	34	0.0	2.0	θ	14.0	16.0	29.2	3.4	TR	10.7

Table C.2 Toronto Area Rain Totals by Monitoring [illegible] = none
Total Rain Observed (mm) (Cont.)

September, 1983

Station Name	#	6 #32	16 #33	18 #34	20 ?	21 #35	22 #36	23 ?	25+26 #37
Sandhill	26	2.4	23.7	10.3	10.2	4.0	0.2	0.2	2.8
Albion	1	3.0	23.7	16.6	Θ	1.4	1.8	Θ	3.1
Bolton	5	2.4	27.0	15.4	13.4	1.4	Θ	1.8	2.6
Cold Creek	7	2.0	27.2	13.8	12.0	1.2	Θ	Θ	5.0
Heart Lake	11	no record							
King Smoke Tree	14	2.4	24.0	8.0	14.4	1.0	Θ	Θ	4.2
Aurora	3	2.8	22.8	8.0	12.6	Θ	Θ	Θ	4.0
Maple	16	Θ	C(?)	(Σ34.2+)	12.6	14.3	2.3	2.6	5.8
Ballantrae	4	0.8	28.8	8.2	4.6	11.2	2.8	TR	3.0
Stouffville	27	Θ	35.0	6.8	4.3	6.8	1.2	2.0	4.2
Gormley Ardmore	10	Θ	29.6	8.8	12.5	1.0	2.4	1.8	3.4
Richmond Hill	25	0.8	31.4	9.2	10.2	4.0	1.6	1.4	3.2
Pine Grove	24*	Θ	27.0	6.0	11.6	Θ	Θ	TR	3.0
Woodbridge	45*	TR	30.6	10.6	7.0	5.7	1.0	Θ	2.0
Met. Res.	37*	0.3	26.6	8.8	10.6	3.6	0.4	Θ	2.6
Thornhill	28	1.6	30.3	7.7	10.2	2.8	0.3	1.0	3.5
Keele-Finch	35*	no record							
International Airport	33*	1.0	28.9	7.8	2.0	12.8	0.2	0.2	1.8
Seneca Hill	40	no record							
Amesbury	29*	no record							
York Mill	44	no record							
Mississauga	17	no record							
Frenchman's Bay	8	1.0	14.8	7.8	1.4	11.4	TR	1.6	1.8
Metro Zoo	38	3.0	27.4	7.0	4.4	8.4	Θ	2.0	1.6
Malvern	36	0.8	26.4	7.8	4.2	9.4	0.8	0.6	2.0
West Hill	43	0.8	15.4	9.6	6.0	7.6	2.0	Θ	2.0
Ellesmere	32	no record							
Bermonds	30	no record							
Sunnybrook	41	0.2	31.0	Θ	4.2	8.8	Θ	Θ	2.2
Broadway	31	M	M	M	M	M	M	M	M
Toronto	42	4.4	18.6	4.6	6.8	4.8	0.4	0.6	3.0
Old West	39	Θ	24.6	8.4	Θ	11.0	Θ	Θ	Θ
Lakeview	15	no record							
Oakville	18	9.2	15.2	8.0	8.0	7.0	Θ	Θ	2.0
Island Airport	34	1.8	15.0	5.4	0.2	11.8	0.3	0.2	[illegible].0

Table C.2 Toronto Area Rain Totals by Monitoring Event
Total Rain Observed (mm) (Cont.)

October, 1983

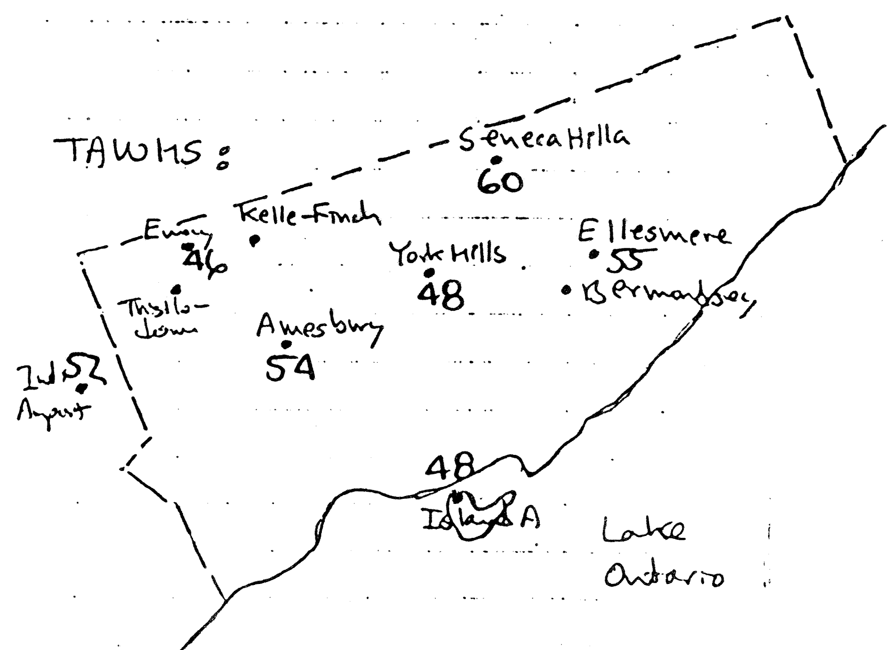
Station Name	#	3 #38	4 #39	5 #40	8 #41	12 #42	13+14 #43	16 #44	22+23 #45	25 ?	26 ?	31 ?
Sandhill	26	2.7	8.0	2.0	7.0	11.5	12.9	2.4	22.2	0.2	1.4	Ø
Albion	1	Ø	6.0	4.0	9.0	23.0	19.2	[illegible]	23.0	Ø	2.0	Ø
Bolton	5	no record										
Cold Creek	7	4.4	3.2	2.6	8.0	11.0	15.4	Ø	22.2	Ø	4.4	Ø
Heart Lake	11	no record										
King Smoke Tree	14	2.6	2.6	3.0	11.2	8.2	15.2	2.0	18.1	1.0	1.5	Ø
Aurora	3	3.0	1.8	4.4	12.4	5.6	14.2	Ø	16.8	0.8	0.6	Ø
Maple	16	C	+(Σ19.3)	C	11.2	8.5	11.6	3.0	15.8	0.4	Ø	Ø
Ballantrae	4	3.8	2.0	5.0	11.6	14.4	16.8	1.8	12.8	1.2	2.2	Ø
Stouffville	27	no record										
Gormley Ark-le	10	3.0	6.8	4.8	10.5	5.0	18.5	2.5	16.2	0.6	Ø	Ø
Richmond Hill	25	3.4	11.0	4.2	9.4	15.4	17.8	2.4	16.4	0.6	0.8	Ø
Pine Grove	24*	2.0	Ø	4.2	8.3	5.0	14.0	Ø	18.6	Ø	Ø	Ø
Woodbridge	45*	2.1	12.6	5.2	11.0	12.7	17.4	3.3	18.7	Ø	Ø	Ø
Met. Res.	37*	1.8	11.2	4.3	9.0	8.2	12.8	2.7	17.1	0.4	0.3	Ø
Thornhill	28	1.6	21.9	5.7	8.7	12.2	16.2	2.6	Ø	0.6	0.6	Ø
Keele-Finch	35*	4.0	17.9	4.6	9.1	7.6	14.3	2.8	19.0	Ø	Ø	Ø
International Airport	33*	4.8	2.0	4.2	7.2	19.3	14.4	2.4	17.3	TR	0.2	Ø
Seneca Hill	40	2.4	17.4	5.3	9.0	7.0	16.2	2.4	13.1	Ø	Ø	Ø
Amesbury	29*	4.2	3.6	4.6	7.3	1.8	7.0	2.0	10.6	0.6	Ø	Ø
York Mill	44	no record										
Mississauga	17	no record										
Frenchman's Bay	8	1.2	9.2	6.8	8.6	12.4	16.2	1.8	21.6	0.6	TR	Ø
Metro Zoo	38	2.2	23.4	6.8	9.6	13.6	20.0	2.4	20.6	0.2	0.2	Ø
Malvern	36	2.8	8.0	7.4	9.2	14.2	15.6	2.0	21.0	0.6	1.0	Ø
West Hill	43	2.4	4.6	6.0	7.8	20.6	22.8	1.2	19.8	0.2	TR	Ø
Ellesmere	32	1.8	1.6	8.0	6.2	14.6	18.0	1.2	18.6	0.2	Ø	Ø
Bermonds	30	2.8	C	+ (Σ6.4)	6.0	5.0	16.0	1.0	14.5	Ø	Ø	Ø
Sunnybrook	41	2.4	2.0	5.0	5.8	17.4	16.0	1.8	18.6	0.4	Ø	Ø
Broadway	31	M	M	M	M	M	M	M	M	M	M	M
Toronto	42	4.8	2.2	6.4	7.8	7.8	18.6	0.6	20.0	0.2	TR	Ø
Old West	39	4.6	Ø	9.0	4.5	5.6	Ø	Ø	12.2	0.6	Ø	Ø
Lakeview	15	no record										
Oakville	18	1.8	1.2	6.0	9.8	11.6	12.4	Ø	25.8	0.8	2.8	Ø
Island Airport	34	4.0	5.4	7.0	7.1	24.2	17.6	0.6	20.6	TR	TR	Ø

Table C-3 Local Rain Comparisons for Event #4
Date: 5/3/83 Emery Storm #: 4

rain (0.1 mm) for hour ending:

	01	02	03	04	05	06	07	08	09	10	11	12
Inter. Airport												
Emery												
Kelle-Finch	all	M										
Amesbury												2
York Mills												
Island A												
Seneca Hill												
Bermondsey												
Ellesmere												

	13	14	15	16	17	18	19	20	21	22	23	24	total
Inter-Airport		2	6	10	20	14							52
Emery			6		20	18	2						46
Kelle-Finch													M
Amesbury		2	4	7	20	15	4						54
York Mills					4	2	24	12	6				48
Island A			2	2	22	12	10						48
Seneca Hill				7	2	32	12	7					60
Bermondsey													Ø
Ellesmere						10	20	18	7				55



reasonably large set of "clean" events practically surrounding the Emery site.

Table C.4 lists the 48 events that were available for analysis from six surrounding locations (Pine Grove, Woodbridge, Met. Research Station, Keele-Finch, P I A, and Amesbury). This table shows the analyses that were made to calculate the rankings of the relative standard deviations for each event, based on corrected event precipitation totals from the six stations. A precipitation event having low relative standard deviations calculated from all six surrounding locations would have little variation in total precipitation over the area within the station locations. A total of 36 complete precipitation event data sets were ranked according to the variations in regional total precipitation. This table also compares the total precipitation recorded at Emery (using the original calibration factor of 0.20 mm per tip), with the local average values and the resulting residual values (local average total minus Emery observation). Various subsets of these events, starting with the event having the smallest precipitation variation, were further analysed.

Figures C.7 through C.9 plot the local area average precipitation data against the observed Emery precipitation total, and the associated residual plots, for three separate sets of relative standard deviation values. When studying these plots, it was decided to only use the best 25 precipitation events for further analyses. These 25 events had relative standard deviations ranging from a very low of 0.08 to a moderate 0.62. The 12 events having precipitation total relative standard deviations greater than 0.62 (ranging from 0.67 to 2.1) were considered as having too much precipitation variation over the area. The data was divided by trial and error, with the results compared for significant differences. This division left a significant amount of the data available (over the complete range of precipitation observations) and was located at a reasonable break point in the residual analyses.

Figures C.10 through C.12 are the residual plots for these 25 remaining events and indicate good residual relationships with the averaged local precipitation volumes, and with time since the start of monitoring. When the residuals are plotted against precipitation volume, a definite trend is apparent, showing large errors in total precipitation for large rain events, as originally noted by the field personnel. A maximum correction factor of approximately 25 percent is seen for the rain events. This is equivalent to a six to eight mm error at 30 mm of precipitation. Similar residual errors (as a percentage) also may have occurred for small events, but the absolute differences (in mm) would not have been as easily noticed. However, the plotting of residuals against time since the beginning of monitoring does not show any significant trend and a calibration shift with time cannot be expected. The average correction with time was a relatively constant two mm. Therefore, a constant calibration factor with time occurred.

Table C.4 "Local" and Emery Rain Comparisons

Stations at Emery to Airport Distance or Less

date:	May 1&2	3	4	7&8	14&15	19	22	25	29	31	June 3&4	5	6	17	27&28	30
storm #:	1+2+3	4	5	6	7	—	8+9	10	11	12	(13)	(14)	(15)	16	(17)	(18)
Pine Grove #24	31.6	∅	9.8	11.0	10.0	21.0	10.0	5.0	18.6	∅	6.0	∅	11.6	∅	10.0	3.0
Woodbridge #45	32.6	5.1	6.6	9.6	14.6	21.4	7.2	6.4	14.5	1.1	5.0	1.0	10.8	TR	10.6	5.8
Met Res Station #37	26.4	5.7	3.8	10.6	12.8	18.7	4.8	6.4	13.6	3.4	3.8	1.2	9.4	0.4	8.6	2.8
Keller Finch #35	9.5	18.2	5.2	9.6	11.1	18.2	6.2	4.8	10.8	6.5	4.9	2.0	9.0	1.6	3.6	2.8
Inter. Airport #33	21.9	5.2	4.2	8.5	8.4	19.1	5.9	4.4	15.7	2.3	3.2	1.2	9.0	0.2	15.4	2.4
Amesbury #29	26.2	5.6	5.4	9.8	9.4	30.2	∅	(M)	11.0	1.9	5.0	2.0	7.0	∅	12.0	1.2
$\bar{x}$	27.0	4.3	5.8	9.9	11.1	21.4	5.7	(5.4)	14.0	2.5	4.7	1.2	9.5	0.38	10.0	3.0
σ	5.7	2.4	2.2	0.88	2.3	4.5	3.3	(0.94)	3.0	2.3	1.0	0.74	1.6	0.61	3.9	1.5
$\sigma/\bar{x}$	0.21	0.56	0.38	0.09	0.21	0.21	0.58	(0.17)	0.21	0.92	0.21	0.62	0.17	1.62	0.39	0.51
$\sigma/\bar{x}$ rank	6	24	16	2	7	8	25	(—)	9	(—)	10	26	4	38	17	20
Emery	23.2	4.6	4.8	7.8	8.6	∅	3.8	5.2	10.6	(4.4+)	2.6	0.8	8.8	6.6	7.4	2.0
residual ($\bar{x}$−E)	3.8	−0.3	1.0	2.1	2.5	21.4	1.9	(0.2)	3.4	(<−1.9)	2.1	0.4	0.7	−6.2	2.6	1.0
time (days) from 5/1	∅	2	3	6	13	18	21	24	28	30	34	36	37	48	58	61

Table C.4 "Local" and Emery Rain Comparisons (cond.)

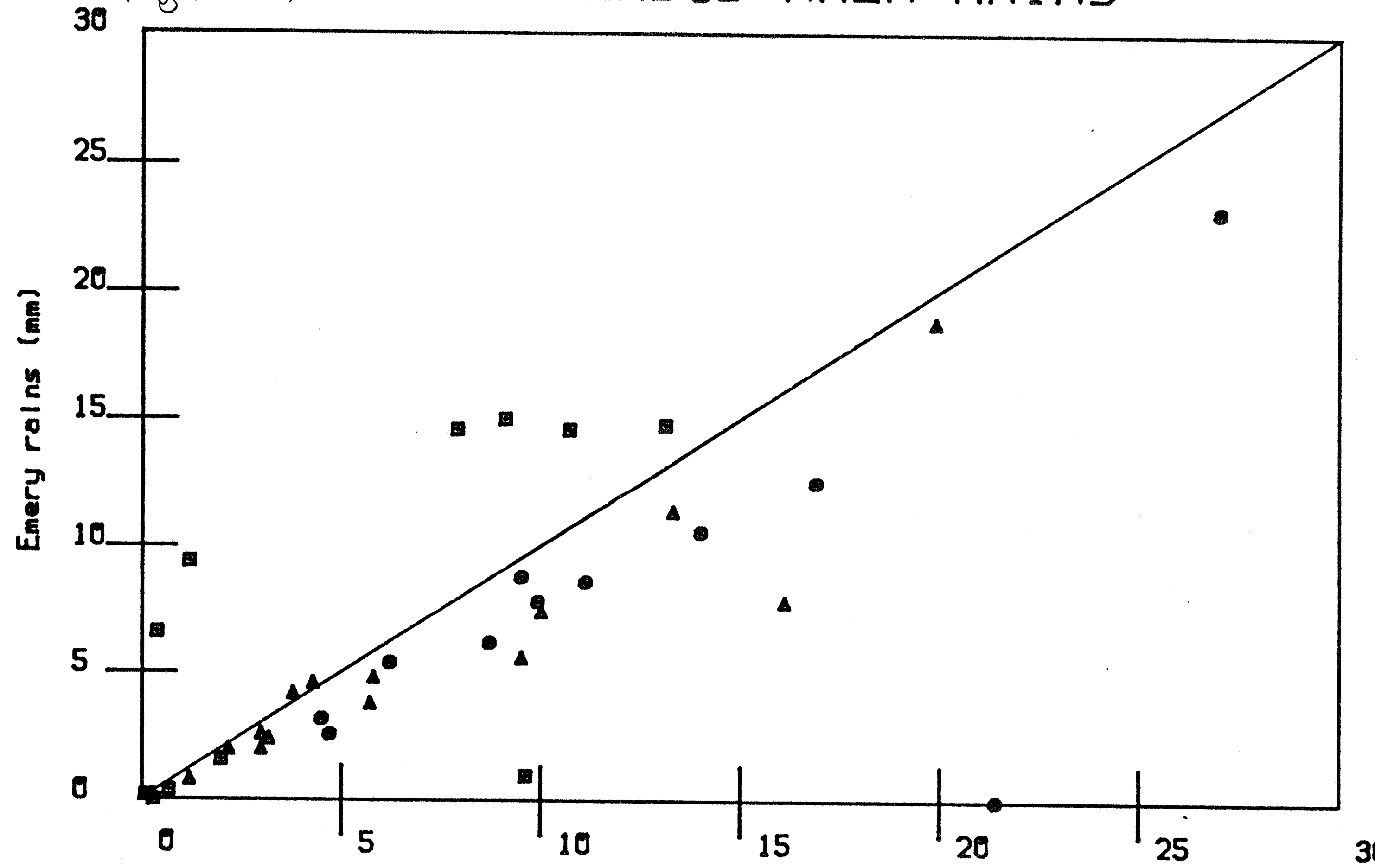
	July					August								
date:	1	4	21	28&29	30&31	1	3&4	5	8	11	21&22	27	28	30
storm #:	19	(20)	(21)	(21B)	(23+24)	25	(26)	(—)	(27)	28	(29)	(30)	(—)	(31)
Pine Grove #24	Ø	5.0	2.0	0.5	21.0	2.2	4.6	Ø	1.4	4.0	10.2	16.8	1.6	8.6
Woodbridge #45	4.4	7.5	3.1	3.4	27.2	3.8	5.3	Ø	2.5	9.0	18.5	7.2	1.3	9.5
Met Res Station #37	4.0	6.0	2.2	3.0	22.3	0.2	2.4	Ø	2.2	5.6	18.3	10.8	0.4	6.4
Kelle-Finch #35	3.0	8.0	4.0	2.5	13.8	0.2	5.0	0.2	13.1	8.0	21.2	17.0	Ø	7.8
Inter. Airport #33	0.8	4.9	4.0	2.0	4.4	0.8	3.2	1.6	29.6	25.0	30.0	1.2	0.6	19.4
Amesbury #29	Ø	6.0	2.8	3.6	7.8	Ø	2.4	Ø	29.8	12.4	21.0	4.4	Ø	5.3
$\overline{x}$	2.0	6.2	3.0	2.5	16.1	1.2	3.8	0.3	13.1	10.7	19.9	9.6	0.7	9.5
σ	2.0	1.3	0.86	1.1	8.9	1.5	1.3	0.64	13.6	7.6	6.4	6.5	0.67	5.1
$\sigma/\overline{x}$	1.0	0.21	0.29	0.46	0.55	1.3	0.35	2.1	1.0	0.71	0.32	0.68	1.0	0.53
$\sigma/\overline{x}$ rank	32	11	13	(—)	23	36	15	39	33	29	14	28	34	21
Emery	1.6	5.4	2.6	(1.2+)	7.8	9.4	4.2	Ø	14.8	14.6	18.8	1.0	0.4	5.6
residual ($\overline{x}$-E)	0.4	0.8	0.4	(<1.3)	8.3	-8.2	-0.4	0.3	-1.7	-3.9	1.1	8.6	0.3	3.9
time (days)	62	65	82	89	91	93	95	97	100	103	113	119	120	122

Table C.4 "Local" and Emery Rain Comparisons (cont).

	September								October									
date:	6	16	18	20	21	22	23	25&26	3	4	5	8	12	13&14	16	22&23	25	26
storm #:	32	33	34	—	35	36	—	37	38	39	40	41	42	43	44	45	—	—
Pine Grove #24	∅	27.0	6.0	11.6	∅	∅	TR	3.0	2.0	∅	4.2	8.3	5.0	14.0	∅	18.6	∅	∅
Woodbridge #45	TR	30.6	10.6	7.0	5.7	1.0	∅	2.0	2.1	12.6	5.2	11.0	12.7	17.4	3.3	18.7	∅	∅
Met Res. Station #37	0.3	26.6	8.8	10.6	3.6	0.4	∅	2.6	1.8	11.2	4.3	9.0	8.2	12.8	2.7	17.1	0.4	0.3
Kelle-Finch #35	(no record)								4.0	17.9	4.6	9.1	7.6	14.3	2.8	19.0	∅	∅
Inter. Airport #33	1.0	28.9	7.8	2.0	12.8	0.2	0.2	1.8	4.8	2.0	4.2	7.2	19.3	14.4	2.4	17.3	TR	0.2
Amesbury #29	(no record)								4.2	3.6	4.6	7.3	1.8	7.0	2.0	10.6	0.6	∅
$\bar{x}$	(0.4	28.3	8.3	7.8	5.5	0.4	0.1	2.4)	3.2	7.9	4.5	8.7	9.1	13.3	2.2	16.9	0.2	0.1
σ	(0.5	1.8	1.9	4.3	5.4	0.43	0.1	0.6)	1.3	7.1	0.38	1.4	6.[illegible]	3.4	1.2	3.2	0.26	0.13
$\sigma/\bar{x}$	(1.3	0.06	0.23	0.56	0.98	1.1	1.3	0.23)	0.41	0.89	0.08	0.16	0.64	0.26	0.53	0.19	1.4	1.3
$\sigma/\bar{x}$ rank	(–	—	—	—	—	—	—	—)	18	30	1	3	27	12	22	5	37	35
Emery	0.8	21.2	6.4	∅	10.2	0.8	∅	1.8	2.4	14.6	3.2	6.2	15.0	11.4	2.0	12.6	0.2	0.2
residual ($\bar{x}$-E)	-0.4	7.1	1.9	7.8	-4.7	-0.4	0.1	0.6	0.8	-6.7	1.3	2.5	-5.9	1.9	0.2	4.3	0.0	-0.1
time (days)	128	138	140	142	143	144	145	147	161	162	163	166	170	171	174	180	183	184

all data: $\sigma/\bar{x} = 0.08 \rightarrow 2.1$; N=37

Figure C.7 EMERY VERSUS AREA RAINS



● N=11 $\sigma/\bar{x} = 0.08 \rightarrow 0.21$

▲ N=14 $\sigma/\bar{x} = 0.26 \rightarrow 0.62$

■ N=12 $\sigma/\bar{x} = 0.67 \rightarrow 2.01$

7/6/84

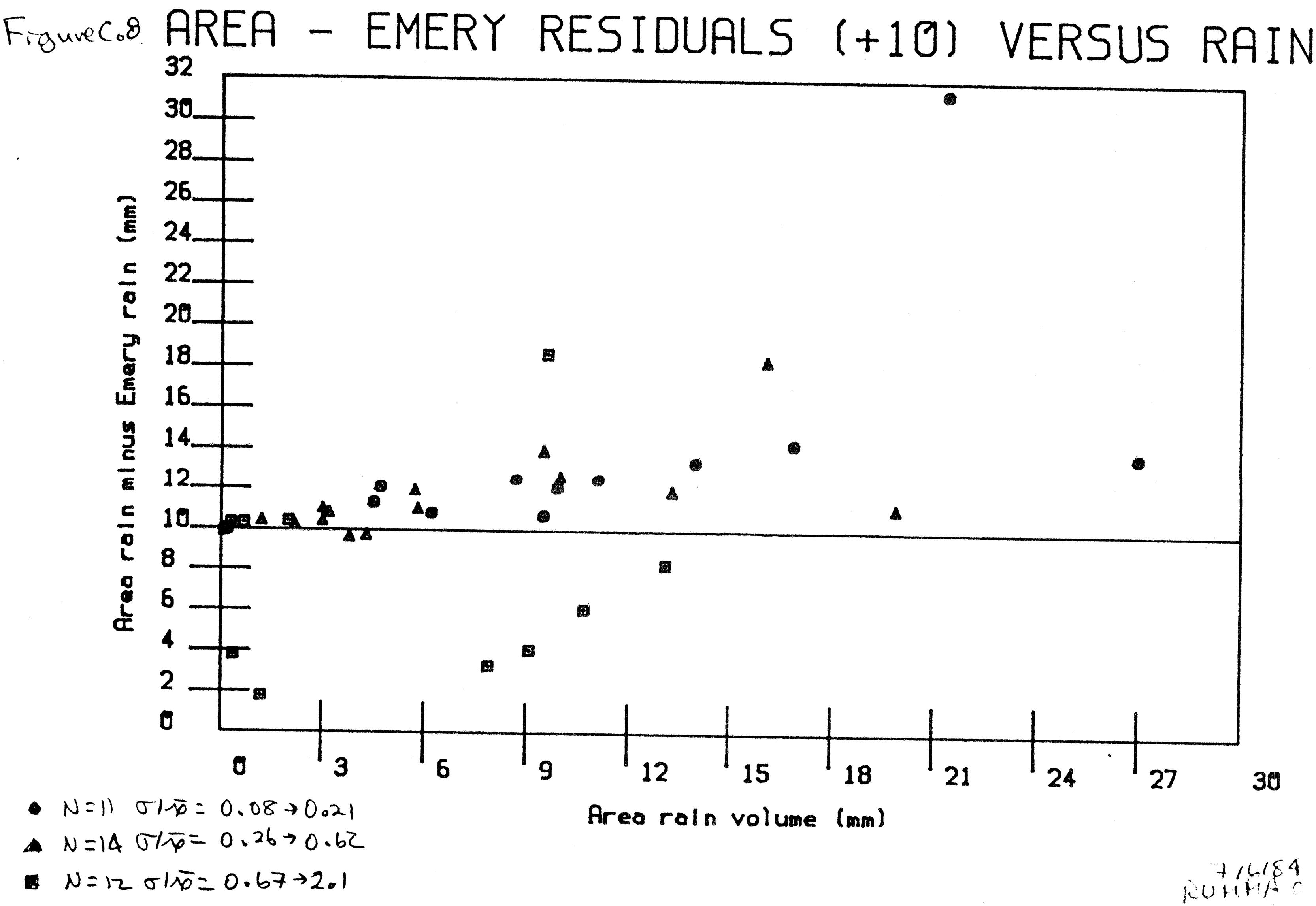
E Area A ○

E Area B △

E Area C □

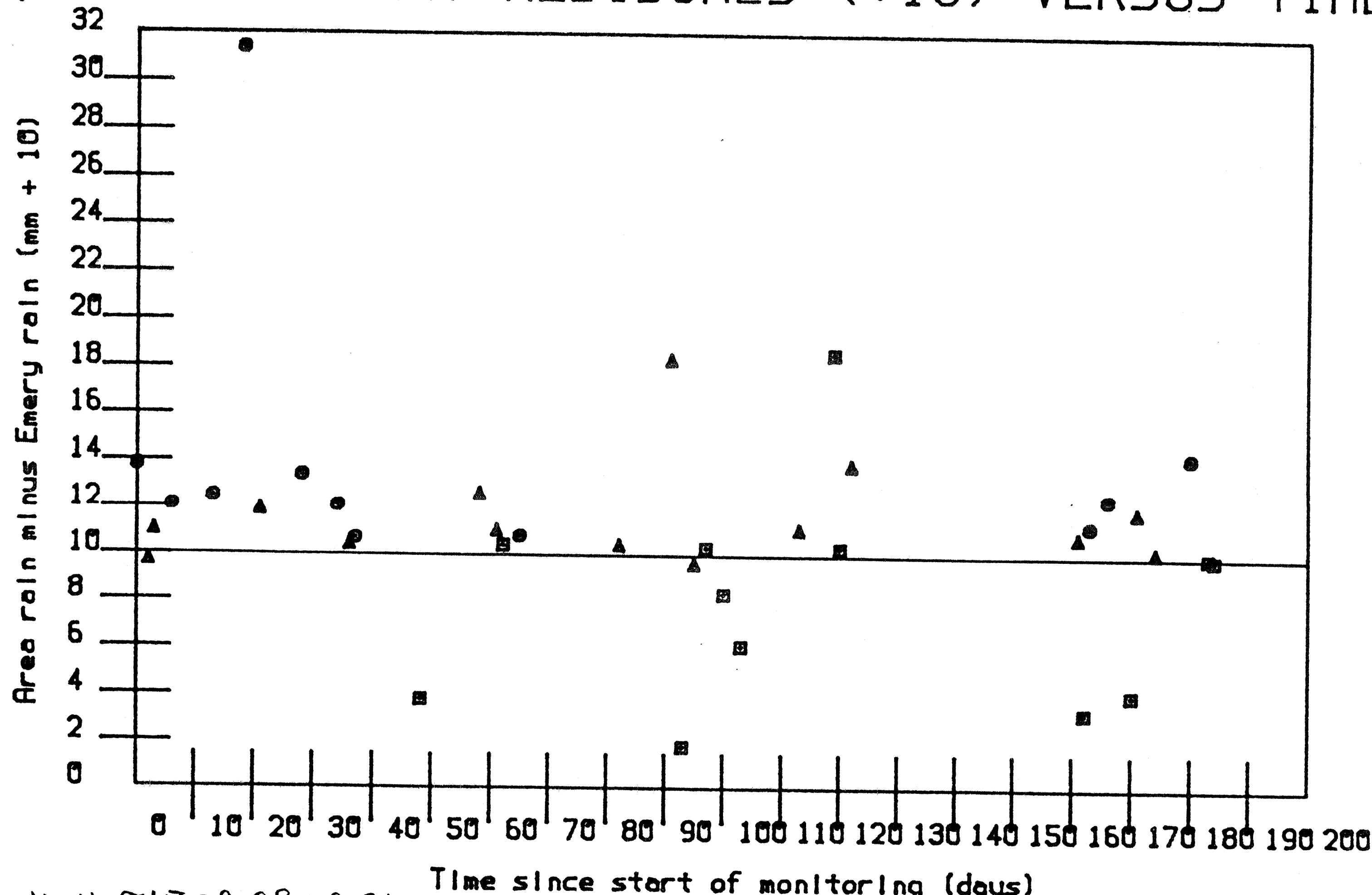
all data $\sigma/\bar{x} = 0.08 \to 2.1$ N=37

Figure C.8



all data: σ/v̄ = 0.08 → 2.1 ; N = 37

Figure C.9 AREA - EMERY RESIDUALS (+10) VERSUS TIME



● N=11 σ/v̄ = 0.08 → 0.21

▲ N=14 σ/v̄ = 0.26 → 0.62

■ N=12 σ/v̄ = 0.67 → 2.1

[illegible]

RUTIHA ○

RUTIHB △

RUTIHC □

APPENDIX D RAINFALL AND RUNOFF FLOW DATA

LIST OF TABLES

LIST OF FIGURES

Table Do1

Early 1983 Toronto Rains Not Monitored (Rains Only - No Sn.

start rain Date		rain volume (mm)	approx. rain start time	approx. rain end time (and date)
January	10	15.5	0800	0100 (Jan. 11)
February	2	13.6	0600	0700 (Feb. 3)
	16	0.4	0600	1100
	22	11.9	2100	0600 (Feb. 23)
March	3	4.6	1600	0300 (March 4)
	4	0.8	1800	0300 (March 5)
	6	3.0	1600	1800
	7	2.1	2200	0600 (March 8)
	8	2.8	2350	1300 (March 9)
	10	0.2	2300	2400
	18	31.8	1700	1800 (March 19)
April	4	0.6	0900	1200
	7	6.6	0300	1100
	9	19.2	1800	1100 (April 10)
	11	1.4	1100	1500
	14	16.2	0200	1800
	27	0.7	0300	0400
	28	4.4	1600	1900
	30	21.2	1000	1600
May	1	12.4	1600	0600 (May 2)
	2	12.2	1500	1900
	3	5.2	1300	1800
	4	0.2	0400	0500
	4	4.0	2000	2200
	7	8.5	2000	0400 (May 8)

(the next rain occured on May 14th and was included in the monitoring program).

Table D.2 Late 1983 Toronto Rains Not Monitored (Rains Only - No Snow)

	start date	rain volume (mm)	approx. rain start time	approx. rain end time (and date)
	19	0.2	1200	1300
	20	3.2	1400	2200
	23	4.1	1400	1900
	28	12.0	0400	2200
December	11	18.2	2300	1800 (December 12)
	14	1.0	2100	0100 (December 15)

Table D3 Toronto Airport Weather Observations for January 1981.

Date	Total 24-hr Precipitation: Rain (mm)	Total 24-hr Precipitation: Snowfall (as water equiv) (mm)	snow-pack (observed at 0800) (cm)	snow-pack (water equiv) (mm)	change in snow pack from previous day (mm, water)	air temp. (°C) min.	air temp. (°C) max	relative humidity (%) min	relative humidity (%) max.	notes: (1)
1		0.8	14	25	0	-8.4	-2.1	67	95	↑ possible period of mid-day (diurnal) melting
2		0.6	14	25	0	-4.6	-1.4	79	95	
3		TR	11	20	-5	-3.3	0.3	82	91	
4	TR	TR	7	13	-7	-0.7	1.2	83	93	
5	TR	1.6	3	5	-8	-0.8	1.7	80	100	
6	TR	0.6	4	7	+2	-10.4	2.3	75	98	↓
7	TR	TR	3	5	-2	-17.8	-9.8	52	85	too cold
8		2.0	5	10	+5	-13.8	-3.2	68	94	?
9		1.8	7	14	+4	-16.3	-9.3	67	90	too cold
10		TR	10	20	+6	-18.9	-4.0	67	88	?
11			10	20	0	-21.1	-13.9	59	83	↑ too cold
12		0.2	9	18	-2	-22.8	-11.5	63	85	↓
13		3.0	10	20	+2	-13.8	-2.3	73	96	?
14		0.4	12	24	+4	-17.7	-6.6	74	93	↑ too cold for "any" melting
15			12	24	0	-26.8	-15.5	65	95	
16		TR	12	24	0	-26.3	-10.6	65	95	
17		TR	12	24	0	-12.5	-5.1	69	90	
18		TR	11	22	-2	-15.0	-7.6	65	91	
19			11	22	0	-18.9	-13.7	61	84	
20		0.2	11	22	0	-20.9	-12.9	67	83	
21			10	20	-2	-24.6	-15.8	62	78	
22			9	18	-2	-18.7	-7.4	69	79	
23		TR	9	18	0	-11.8	-0.8	43	86	↕ possible period of mid-day (diurnal) melting
24	3.6	5.6	12	22	+4	-3.0	2.1	78	100	
25	TR	TR	10	18	-4	-8.5	1.3	67	87	
26		6.6	10	18	0	-11.2	-0.5	70	98	
27	TR	TR	18	32	+14	-17.5	1.8	69	94	
28			17	31	-1	-22.8	-3.1	70	93	
29		3.2	18	32	+1	-4.7	0.9	72	100	
30		TR	19	34	+2	-9.7	-1.7	68	93	↓
31			17	31	-3	-21.3	-8.8	59	88	too cold
total	3.6	26.6	—	—	+6	—	—	—	—	
min.	TR	TR	3	5	-8	-26.8	-15.8	43	78	
max.	3.6	6.6	19	34	+14	-0.7	2.3	83	100	

(1) possible melting if temperature is > -4°C, especially
if [illegible] and/or heavy traffic

Table D.4 Toronto Airport Weather Observations for February, 1984.

Date	Total 24-hr Precipitation: Rain (mm)	Total 24-hr Precipitation: Snow fall (as water equiv.) (mm)	snow-pack (observed at 0800) (cm)	snow-pack (water equiv.) (mm)	change in snow pack from previous day (mm, water)	air temp. (°C) min.	air temp. (°C) max	relative humidity (%) min.	relative humidity (%) max.	notes:
1			16	29	−2	−22.3	−6.7	64	93	too cold
2			15	27	−2	−10.9	4.3	71	95	possible
3	3.0	TR	11	20	−7	−1.0	5.8	77	94	mid-day
4		1.6	7	13	−7	−0.3	2.1	78	100	(diurnal)
5		1.0	8	14	+1	−5.6	1.0	78	99	melt
6		0.4	9	16	+2	−14.8	−5.1	69	87	too cold
7		TR	9	16	0	−19.0	−8.9	61	85	
8		TR	8	14	−2	−13.6	−5.6	69	87	
9			6	11	−3	−8.9	0.8	79	91	possible mid-day (diurnal) melt (days 9–29)
10	TR		6	11	0	−4.8	2.4	77	97	
11	1.4		4	7	−4	0.4	4.9	91	100	
12			1	4	−3	0.5	5.4	80	100	all day
13	20.8		1	4	0	0.2	7.8	87	100	melt
14	13.2		TR	TR	−4	0.0	8.0	80	100	
15			TR	TR	0	−2.6	4.1	85	100	
16			TR	TR	0	−3.0	5.5	57	100	
17			TR	TR	0	1.4	7.4	69	94	all day
18	TR		TR	TR	0	2.0	7.3	76	100	melt
19	0.8		TR	TR	0	2.5	12.2	74	97	
20	TR		TR	TR	0	−1.3	3.2	76	91	
21		0.6	1	4	+4	−3.7	0.3	72	98	
22			TR	TR	−4	−3.5	9.0	56	89	
23			TR	TR	0	0.8	14.9	43	86	all day melt
24		TR	0	0	0	−1.1	10.6	60	92	
25		4.8	3	6	+6	−6.4	0.7	76	100	
26		TR	5	10	+4	−10.5	−1.7	62	95	
27		2.6	3	6	−4	−12.3	−2.6	55	97	
28		8.4	9	17	+11	−10.0	−5.1	83	95	too cold
29		0.4	18	34	+17	−11.9	−9.1	63	85	
total	39.2	19.8	—	—	+5	—	—	—	—	
min.	TR	TR	0	0	−7	−22.3	−9.1	43	85	
max.	20.8	8.4	18	34	+17	2.5	14.9	87	100	

Table D.5 Toronto Airport Weather Observations for March 1984.

Date	Total 24-hr Precipitation: Rain (mm)	Total 24-hr Precipitation: Snow fall (as water equiv) (mm)	snow-pack (observed at 0800) (cm)	snow-pack (water equiv) (mm)	change in snow pack from previous day (mm, water)	air temp. (°C) min.	air temp. (°C) max	relative humidity (%) min.	relative humidity (%) max.	notes:
1		TR	18	34	0	-12.3	-3.5	62	87	possible mid-day (diurnal) melt (days 1–6)
2		0.4	17	32	-2	-9.2	-4.1	59	92	
3			16	30	-2	-11.9	-4.0	52	86	
4			12	23	-7	-16.0	-0.3	47	87	
5	TR	10.0	11	21	-2	-3.8	2.6	70	100	
6		TR	16	37	+16	-14.2	0.5	62	92	
7			14	32	-5	-20.8	-12.4	55	93	too cold for "any" melting (days 7–12)
8			13	30	-2	-23.2	-11.1	50	87	
9			13	30	0	-20.5	-8.7	50	94	
10		0.6	12	28	-2	-16.6	-4.7	56	94	
11		1.4	13	30	+2	-18.6	-5.4	64	92	
12		1.0	14	32	+2	-20.7	-8.9	56	93	
13	0.6	3.5	16	37	+5	-12.7	-2.4	85	99	possible mid-day (diurnal) melting (days 13–31)
14			18	41	+4	-8.1	1.3	67	93	
15	3.0		15	35	-6	-8.3	2.5	72	99	&
16	17.4	1.0	8	18	-17	-9.8	2.7	75	100	
17			6	14	-4	-13.5	-2.6	58	75	
18	TR		6	14	0	-6.4	-2.1	65	91	
19	TR	TR	6	14	0	-3.4	1.5	72	94	
20			5	12	-2	-1.3	4.7	77	100	
21	13.6	0.2	2	5	-7	0.2	5.2	77	100	all day melt
22		4.8	2	5	0	-0.2	2.2	80	100	
23		1.2	3	7	+2	-5.9	0.2	69	94	all day
24			1	2	-5	-6.3	4.0	63	85	
25			TR	TR	-2	-4.4	4.7	62	91	
26			TR	TR	0	-4.3	2.6	58	83	
27			TR	TR	0	-5.5	4.5	58	90	
28			TR	TR	0	-1.4	6.9	46	80	
29	0.8	TR	TR	TR	0	-0.3	5.2	50	98	
30	TR	TR	TR	TR	0	0.0	6.7	45	97	
31			TR	TR	0	-2.1	9.1	37	83	
total	35.4	24.1	—	—	-34	—	—	—	—	
min.	TR	TR	TR	TR	-17	-23.2	-12.4	47	75	
max.	17.4	10.0	18	41	+16	0.2	9.1	85	100	

(7280) 79%

Table D.6 Every Runoff and Rain Data Summary (1983)

	Storm number	Rain Start Date	Total Rain (mm)	Rain Duration (hrs)	Rain Start time	Ave. rain int. (mm/hr)	pk 5 min rain int. (mm/hr)	Runoff Start Time	Total Discharge (m³)	Total Discharge (mm)	Runoff Duration (hrs)	Ave. discharge (l/sec)	Pk 5 min discharge (l/sec)	Runoff Coef (Rc)	Runoff/Rain duration (ratio)	lag time to start of runoff (min)
.43	7	May 19, 1982	11.0	5.75	1910	1.91	21	1945	5057	3.2	5.83	241	1250	0.29	1.01	45
.11	8	May 22	2.75	4.2	0940	0.65	6	1120	1802	1.14	4.9	102	275	0.41	1.17	15?/100(?)
.08	9	May 22	2.00	0.17	2010	11.76	15	2010	1068	0.68	2.8	105	285	0.34	16.5	[illegible]
.19	8+9	May 22	4.75	10.67	0940	0.45	15	1120	3160	2.0	11.67	75	285	0.42	1.09	15?/100(?)
.13	10A	May 25	3.25	1.25	1305	2.60	12	1310	944	0.60	1.5	175	360	0.18	1.20	5
.12	10B	May 25	3.00	1.0	1810	3.00	15	1840	1410	0.89	3.17	124	580	0.30	3.17	30
.25	Σ10	May 25	6.25	6.1	1305	1.02	15	1310	2570	1.63	8.67	82	580	0.26	1.42	5
0.55	11	May 29	14.00	2.6	1400	5.38	12	1415	6741	4.27	3.92	478	960	0.31	1.51	15
0.22	12C	May 31	5.50	0.25	1710	22.00	39	1725	2184	1.38	1.75	347	1060	0.25	7.0	15
0.33	Σ12	May 31	8.50	6.4	1105	1.33	39	1148	6167(?)	3.92(?)	11.75(?)	146(?)	1200	0.46	1.83	
0.03	13A	June 3	0.75	0.33	2000	2.27	3	2010	213	0.13	1.0	59	80	0.17	3.00	10
0.09	13B	June 3	2.25	1.42	2150	1.58	3	2210	812	0.51	2.5	90	140	0.23	1.76	20
0.12	Σ13	June 3	3.00	3.25	2000	0.92	3	2010	1151	0.73	4.5	71	140	0.24	1.38	10
0.04	14	June 5	1.00	0.42	0405	2.38	3	0435	269	0.17	1.6	47	85	0.17	3.8	30
0.43	15	June 6	11.00	5.83	0615	1.89	6	0645	4731	2.99	6.25	210	470	0.27	1.07	30
0.16	16A	June 17	4.00	0.33	1330	12.12	21	1340	1000	0.63	1.42	196	600	0.16	4.3	10
0.15	16B	June 17	3.75	0.33	1750	11.36	24	1800	417	0.26	1.25	93	165	0.07	3.8	10
0.31	Σ16	June 17	8.00	4.7	1330	1.70	24	1340	1629	1.03	5.58	81	600	0.13	1.19	10
0.35	17	June 27	9.00	16.7	1340	0.54	3	1750	1950	1.11	16.5(?)	30	45	0.12	0.99	?
0.10	18	June 30	2.50	0.33	1850	7.58	12	1855	252	0.16	1.25	56	160	0.06	3.8	5
0.08	19	July 1	2.00	0.17	1510	11.76	15	1515	267	0.17	1.08	69	315	0.09	6.4	5
0.27	20	July 4	6.75	3.17	1735	2.13	12	1740	1017	0.64	4.38	65	240	0.09	1.38	5
0.09	21	July 21	2.25	0.25	1420	9.00	1.5	1500	352	0.22	1.17	84	315	0.10	4.7	40
0.28	23	July 31	7.00	?	2325? July 30?	—	—	0225	1010	0.64	3.42	82	540	0.09	?	?
0.08	24	July 31	2.00	0.66	1200	3.03	12	1225	397(?)	0.25	6.25	18	120	0.13	9.5	25
0.09	26A	Aug 3	2.25	0.33	2330	6.82	15	2340	617	0.39	2.0	86	280	0.17	6.0	10
0.11	26B	Aug 4	2.75	5.33	0230	0.52	6	0250	1275	0.81	5.33	66	180	0.29	1.00	20
0.20	Σ26	Aug 3	5.00	4.92	2330	1.02	15	2340	1961	1.24	8.5	64	280	0.25	1.73	10

0.63x
0.37x

Table D.6 Emery Runoff and Rain Data Summary (Cont.)

2&3

(72%)

	Storm number	Rain Start [1] Date	Total Rain [18] (mm)	Rain Duration [3] (hrs)	Rain Start [4] Time	Ave. rain Int. (mm/hr)	Pk 5-min rain Int. [1] (mm/hr)	Runoff Start [7] Time	Total Discharge [8] (m³)	Total Discharge [9] (mm)	Runoff Duration [10] (hrs)	Ave. Discharge (l/sec)	PK-5-min Discharge (l/sec)	Runoff Coeff. (Rc)	Runoff/Rain Duration	lag time to start (min)
0.73	27 [1]	Aug 8	18.50	1.5	1645	12.33	57	1650	3987	2.52	2.75	403	1220	0.14	1.83	5
0.33	28A [2]	Aug 11	8.50	4.75	0245	1.79	6	0335	1989	1.26	4.83	114	360	0.15	1.02	50(15?)
0.38	28B [3]	Aug 11	9.75	5.17	1110	1.89	9	1125	4338	2.75	6.25	193	410	0.28	1.21	15
0.72	Σ28 [4]	Aug 11	18.25	13.58	0245	1.34	9	0335	7071	4.48	14.08	140	410	0.25	1.04	50(15)
0.03	29A [7]	Aug 22	0.75	0.42	0015	1.79	3	0030	158	0.10	0.92	48	60	0.13	2.19	15
0.08	29B [8]	Aug 22	2.00	0.75	0120	2.67	12	0140	243	0.15	0.67	101	175	0.08	0.89	20
0.80	29C [9]	Aug 22	20.25	3.17	0355	6.39	27	0410	7821	4.95	3.75	579	1200	0.24	1.18	15
0.93	Σ29 [10]	Aug 22	23.50	6.83	0015	3.44	27	0030	8558	5.42	7.42	320	1200	0.23	1.09	15
0.05	30 [11]	Aug 27	1.25	0.5	1615	2.50	6	1625	1161	0.73	1.17	276	920	0.58	2.34	10
0.05	31A [12]	Aug 30	1.25	0.33	0240	3.79	6	0305	101	0.064	0.92	30	40	0.05	2.78	25
0.07	31B [13]	Aug 30	1.75	0.67	0830	2.61	6	0835	395	0.25	2.0	55	110	0.14	3.0	5
0.11	31C [14]	Aug 30	2.75	0.67	1205	4.10	6	1230	651	0.41	2.33	78	240	0.15	3.5	25
0.04	31D [15]	Aug 30	1.00	0.75	1805	1.33	3	1850	575	0.36	2.75	58	150	0.36	3.7	45
0.28	Σ31 [16]	Aug 30	7.00	16.2	0240	0.43	6	0305	2373	1.50	18.5	36	240	0.21	1.14	25
0.45	33B [17]	Sept 16	11.50	2.75	1545	4.18	15	1700	6318	4.0	4.0	438	1100	0.35	1.5	75
0.99	Σ33(adj) [18]	Sept 16	25.25	12.33	0610	2.05	15	?	12,200(adj)	7.7(adj)	12.5(adj)	270(adj)	1100(adj)	0.30(adj)	~1	?
0.31	34 [19]	Sept 18	8.00	1.7	0910	4.21	30	1040	2690	1.7	2.1	356	1140	0.21	1.1	90
0.50	35 [20]	Sept 21	12.75	4.5	0400	2.83	12	0420	5810	3.7	5.3	310	710	0.29	1.2	20
0.09	37 [21]	Sept 25	2.25	3.2	2115	0.70	3	2230	420	0.27	2.5	47	75	0.12	0.8	75
0.08	38A [22]	Oct 3	2.00	0.9	1845	2.22	3	1910	467	0.30	2.2	59	115	0.15	2.4	25
0.04	38B [23]	Oct 3	1.00	0.3	2120	3.33	6	2100	345	0.22	1.5	64	115	0.22	5.0	10
0.12	Σ38 [24]	Oct 3	3.00	2.7	1845	1.11	6	1910	812	0.51	3.4	61	115	0.17	1.4	25
0.72	39 [25]	Oct 4	18.25	0.6	1130	30.42	63	1130	6120	3.87	2.8	607	1270	0.21	4.7	Ø
0.16	40 [26]	Oct 5	4.00	2.3	1155	1.74	6	1240	1150	0.73	2.4	133	200	0.18	1.0	45
0.31	41 [27]	Oct 8	7.75	4.4	0930	1.76	6	1045	2510	1.58	4.2	166	400	0.20	0.95	75
0.60	42 [28]	Oct 12	15.25	6.4	0350	2.39	15	0450	11,030	6.93	7.8	390	680	0.45	1.2	60
0.44	43A [29]	Oct 13	11.25	4.5	1435	2.50	26	1445	6550	4.14	5.9	310	670	0.37	1.3	10
0.06	43B [30]	Oct 14	1.50	0.5	0425	3.00	7.5	0430	530	0.33	1.2	125	205	0.22	2.4	5
0.51	Σ43 [31]	Oct 13	13.00	14.3	1435	0.91	26	1445	8910	5.64	14.9	166	670	0.43	1.0	10

Table D.6 Emery Runoff and Rain Data Summary (Concluded)
3 of 3

	Storm number	Rain Start Date (1)	Total Rain (mm) (2)	Rain Duration (hrs) (3)	Rain Start Time (4)	Ave. rain intensity (mm/hr)	Pk 5-min rain int. (mm/hr) (data x 12)	Runoff Start Time (7)	Total Discharge (m3) (8)	Total Discharge (mm) (9)	Runoff Duration (hrs) (10)	Ave discharge (l/sec) (11)	Pk 5-min discharge (l/sec) (12)	Runoff Coeff (Rv) (13)	Runoff/Rain Duration (ratio)	lag time to start of runoff (min)
0.10	44	Oct 16	2.50	1.4	1950	1.79	3	2030	630	0.40	2.25	78	160	0.16	1.6	?
0.58	45	Oct 23	14.75	11.6	0035	1.27	6	0130	7160	4.53	11.67	170	520	0.31	1.0	55
0.35	46	Nov 2	9.00	7.8	1530	1.15	6	1550	2450	1.55	8.17	83	250	0.17	1.0	20
	47A	Nov 4	snow 0.50	0.75	1350	snow 0.67	3	1340	525	0.33	2.0	73	160	snow 0.66	2.7	?
	47B	Nov 4	snow 1.00	1.0	2230	snow 1.00	3	2230	210	0.13	1.2	50	60	snow 0.13	1.2	?
	Σ47	Nov 4	snow 1.50	9.7	1350	snow 0.15	3	1340	1570	0.99	9.6	46	160	snow 0.66	0.99	?
0.37	48	Nov 10	9.50	16.1	2040	0.59	3	2130	5530	3.5	18.3	84	195	0.37	1.1	50
	49	Nov 15	snow 21.00	26.9	1300	snow 0.78	3	1305	25,460	16.1	28.0	253	480	snow 0.77	1.0	5

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AMPAD EFFICIENCY LINE 22-211

Table D.7 Thistledown Runoff and Rain Data Summary (Continued)

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	Storm number	Rain Start Date	Total Rain (mm)	Rain duration (hrs)	Rain Start time	Ave. Rain Int. (mm/hr)	pk 5-min Rain Int. (mm/hr)	Runoff Start Time	Total Discharge (m³)	Total Discharge (mm)	Runoff duration (hrs)	Ave. discharge (l/sec)	Pk 5-min discharge (l/sec)	Runoff Coef. (Rv)	Runoff/Rain duration	lag time to start of runoff (min)
0.05	21b	Jul 28 83	1.25	0.83	1515	1.50	6	1530	85	0.19	2.3	10.4	24	0.15	2.7	15
0.09	26A	Aug 3	2.25	0.66	2330	3.41	15	Aug 4 0000	24.5	0.054	1.0	6.8	13	0.02	1.5	30
0.11	26B	Aug 3	2.75	1.92	0230	1.43	6	0310	138	0.31	2.2	17	36	0.11	1.1	40
0.20	Σ26	Aug 3	5.00	4.92	2330	1.02	15	Aug 4 0000	193	0.43	5.3	10	36	0.09	1.1	30
0.68	27	Aug 8	17.25	1.42	1645	12.15	58	1700	2855	6.33	1.2	680	1800	0.37	0.85	15
0.33	28A	Aug 11	8.50	4.33	0320	1.96	6	0325	386	0.86	4.8	22	58	0.10	1.1	5
0.37	28B	Aug 11	9.50	6.08	1110	1.56	9	1120	854	1.89	5.9	40	190	0.20	0.97	10
0.71	Σ28	Aug 11	18.00	13.9	0320	1.29	9	0325	1300	2.88	13.8	26	190	0.16	0.99	5
0.08	29A	Aug 22	2.00	2.9	0015	0.69	3	0025	193	0.43	3.6	15	28	0.22	1.2	10
0.79	29B	Aug 22	20.00	3.1	0355	6.45	27	0400	1974	4.38	3.1	127	600	0.22	1.0	5
0.87	Σ29	Aug 22	22.00	6.8	0015	3.24	27	0025	2167	4.8	7.9	76	600	0.22	1.2	5
0.05	31A	Aug 30	1.25	0.3	0240	4.17	6	0250	65	0.14	1.5	12	23	0.11	5.0	10
0.07	31B	Aug 30	1.75	0.7	0820	2.50	6	0910	78	0.17	1.4	16	33	0.10	2.0	50
0.11	31C	Aug 30	2.75	0.7	1205	3.93	6	1235	117	0.26	1.4	23	67	0.09	2.0	30
0.04	31D	Aug 30	1.00	0.8	1805	1.25	3	1840	52	0.12	1.8	8	11	0.12	2.3	35
0.28	Σ31	Aug 30	7.00	16.2	0240	0.43	6	0250	517	1.15	17.7	8	67	0.16	1.1	10
0.03	32	Sept 6	0.75	0.2	0810	3.75	6	0810	80	0.18	0.9	24	50	0.24	4.5	0
0.55	33A	Sept 16	14.00	8.2	0610	1.71	6	0630	989	2.19	9.6	29	190	0.16	1.2	20
0.24	33B	Sept 16	6.00	1.3	1545	4.62	15	1610	530	1.18	1.3	111	340	0.20	1.0	25
0.23	33C	Sept 16	5.75	1.2	1720	4.79	18	1730	784	1.74	1.4	156	410	0.30	1.2	10
1.01	Σ33	Sept 16	25.75	12.3	0610	2.09	18	0630	2303	5.10	12.4	52	410	0.20	1.0	20
0.32	34	Sept 18	8.00	1.9	0910	4.21	30	0950	730	1.62	1.3	162	770	0.20	0.7	40
0.50	35	Sept 21	12.75	4.5	0400	2.83	12	0420	1143	2.53	4.8	66	290	0.20	1.1	20
0.09	37	Sept 25	2.25	3.2	2115	0.70	3	2225	92	0.20	2.9	9	14	0.09	0.9	70
0.12	38	Oct 3	3.00	2.8	1845	1.07	6	1910	128	0.28	3.8	9	37	0.09	1.4	25
0.72	39	Oct 4	18.25	0.6	1130	30.42	63	1155	668	1.48	0.8	247	1010	0.08	1.3	25
0.16	40	Oct 5	4.00	2.3	1155	1.74	6	1235	234	0.52	3.3	20	43	0.13	1.4	40
0.30	41	Oct 8	7.50	3.7	1015	2.03	6	1105	584	1.29	3.9	41	160	0.17	1.1	50
0.59	42	Oct 12	15.00	5.8	0430	2.59	12	0500	1945	4.31	6.9	78	240	0.29	1.2	30
0.44	43A	Oct 13	11.25	4.6	1435	2.45	21	1455	976	2.16	5.2	52	270	0.19	1.1	20
0.06	43B	Oct 14	1.50	0.5	0450	3.00	—	0450	112	0.25	1.3	24	40	0.17	2.6	25

Table D.7 (Concluded)

rain (in)		1	2 Total Rain (mm)	3 kg	4	5 Ave. rainfall Int. (mm/hr)	6 Pk 5-min rain Int. (mm/hr)	7	8 m³	9 mm	10 kg	11 [illegible]	12	13 Runoff Coef. (Rv)	14	15
0.51	Σ43	Oct 13	13.00	14.4	1435	0.90	21	1455	1270	2.82	15.3	23	270	0.22	1.1	20
0.10	44	Oct 16	2.5	1.4	1950	1.79	3	2030	141	0.31	2.9	14	43	0.12	2.1	40
0.58	45	Oct 23	14.75	11.7	0030	1.26	6	0200	1468	3.25	10.3	40	194	0.22	0.9	90
0.36	46	Nov 2	9.00	7.8	1530	1.15	6	1600	612	1.36	8.8	19	47	0.15	1.1	30
0.02	47	Nov 4	snow 0.50	0.3	1350	snow 1.67	snow 3	1410	snow 139	0.31	2.0	19	33	snow 0.62	6.7	20
0.37	48	Nov 10	9.50	15.3	2110	0.62	3	2135	1238	2.78	19.4	18	53	0.29	1.3	25
0.83	49	Nov 15	snow 21.00	26.9	1300	snow 0.78	snow 3	1305	3363	7.46	28.9	32	62	snow 0.36	1.1	5

Table D.8
Emery Rain and Runoff Data
(1st peaks and full events)

date	storm #	obs. rain (mm)	obs. runoff (mm)	obs. Rv
Spring (N=14):				
May 12, 1983	7	11.00	3.20	0.29
22	8	2.75	1.14	0.41
22	9	2.00	0.68	0.34
25	10A	3.25	0.60	0.18
25	10	6.25	1.63	0.26
29	11	14.00	4.27	0.31
June 3	13A	0.75	0.13	0.17
3	13	3.00	0.73	0.24
5	14	1.00	0.17	0.17
6	15	11.00	2.99	0.27
17	16A	4.00	0.63	0.16
17	16	8.00	1.03	0.13
27	17	9.00	1.11	0.12
30	18	2.50	0.16	0.06
Summer (N=12):				
July 1	19	2.00	0.17	0.09
4	20	6.75	0.64	0.09
21	21	2.25	0.22	0.10
31	24	2.00	0.25	0.13
Aug 4	26	5.00	1.24	0.25
11	28A	8.50	1.26	0.15
22	29A	0.75	0.10	0.13
27	30	1.25	0.73	0.58
30	31	7.00	1.50	0.21
Sept 18	34	8.00	1.70	0.21
21	35	12.75	3.70	0.29
25	37	2.25	0.27	0.12
Fall (N=10):				
Oct 3	38A	2.00	0.30	0.15
3	38	3.00	0.51	0.17
5	40	4.00	0.73	0.18
8	41	7.75	1.58	0.20
13	43A	11.25	4.14	0.37
14	43	13.00	5.64	0.43
16	44	2.50	0.40	0.16
23	45	14.75	4.53	0.31
[illegible]	46	9.00	1.55	0.17

Table D.9

Thistledown Rain and Runoff Data

(1st peaks and full events)

date	storm #	obs. rain (mm)	obs. runoff (mm)	obs. Rv
Summer (N=10):				
Aug 3, 1983	26	5.00	0.43	0.09
Aug 11	28A	8.50	0.86	0.10
Aug 11	28	18.00	2.88	0.16
Aug 22	29A	2.00	0.43	0.22
Aug 22	29	22.00	4.80	0.22
Aug 30	31	7.00	1.15	0.16
Sept 6	32	0.75	0.18	0.24
Sept 18	34	8.00	1.62	0.20
Sept 21	35	12.75	2.53	0.20
Sept 25&26	37	2.25	0.20	0.09
Fall (N=9):				
Oct 3	38	3.00	0.28	0.09
Oct 5	40	4.00	0.52	0.13
Oct 8	41	7.50	1.29	0.17
Oct 13	43A	11.25	2.16	0.19
Oct 13&14	43	13.00	2.82	0.22
Oct 16	44	2.50	0.31	0.12
Oct 23	45	14.75	3.25	0.22
Nov 2	46	9.00	1.36	0.15
Nov 10	48	9.50	2.78	0.29

Table D.10 Emery Snowmelt Hydrology and Airport Meteorological Data Summary

event #	Runoff Period: Start date	Start time	Start flow rate (l/sec/ha)	End date	End time	End flow rate (l/sec/ha)	runoff characteristics: duration (hrs)	peak flow (l/sec/ha)	ave. flow (l/sec/ha)	total volume (1) (m3/ha)	snowpack depth equivalent melted (cm)	General Runoff type (2)
E1	Jan 4	1000	0.03	Jan 5	0130	0.20	15.5	0.26	0.20	11.6	0.7	M
E2	5	0400	0.20	5	1930	0.13	15.5	0.33	0.26	15.1	0.8	M
E3	5	2200	0.13	Jan 6	2200	0.07	24.0	0.42	0.26	21.9	1.2	M
E4	13	0940	0.07	13	1330	0.07	4.2	0.26	0.13	1.78	0.1	B+D
E5	17	0930	0.07	17	1400	0.10	4.5	0.26	0.13	2.00	0.1	B+D
E6	24	0930	0.07	Jan 25	0400	0.16	18.5	0.026	0.26	16.6	0.9	R+M
E7	25	0830	0.16	25	2000	0.13	10.5	0.33	0.26	10.2	0.6	M
E8	27	0750	0.07	27	1800	0.07	10.2	0.26	0.20	8.24	0.5	D
E9	30	1130	0.07	30	1830	0.10	7.0	0.23	0.20	4.63	0.3	D
E10	Feb 3	0400	0.07	Feb 3	1840	0.26	14.7	0.78	0.46	24.9	1.4	R+M
E11	4	0930	0.13	Feb 5	0400	0.13	18.5	0.29	0.26	16.6	0.9	M
E12	5	1000	0.13	5	1730	0.13	6.5	0.26	0.26	6.56	0.4	D
E13	10	1130	0.07	10	1900	0.10	7.5	0.33	0.26	6.20	0.3	D
E14	11	0240	0.07	11	1900	0.26	16.3	0.65	0.39	21.3	1.2	R+M
E15	12	1150	0.29	12	2000	0.29	8.2	1.24	0.85	24.5	0.6	M
E16	13	0930	0.33	Feb 14	1940	0.33	23.8	7.94	4.10	348	8.7	R
E17	15	1000	0.10	15	2130	0.10	11.5	0.29	0.20	7.96	0.2	B
E18	16	1200	0.07	16	2130	0.07	9.5	0.20	0.13	5.19	0.1	B
E19	19	1630	0.07	19	2000	0.07	3.5	0.39	0.20	2.56	0.1	R
E20	25	0930	0.03	25	1630	0.07	7.5	0.23	0.08	4.51	0.2	M
E21	26	1130	0.07	26	1540	0.07	3.8	0.26	0.20	2.73	0.1	D
E22	March 14	1100	0.03	March 14	1830	0.03	7.5	0.39	0.20	4.65	0.2	D
E23	15	1110	0.05	15	1800	0.26	6.8	6.18	4.16	103	4.5	R+M
E24	16	1210	0.07	16	1630	0.03	4.3	0.23	0.20	2.86	0.1	R+M
E25	17	1200	0.07	17	1800	0.03	6.0	0.23	0.13	2.89	0.1	D
E26	21	0330	0.13	22	0100	0.13	21.5	6.90	1.82	140	6.1	R
E27	22	0800	0.03	22	1840	0.20	10.7	0.91	0.59	21.6	1.0	M

(1) m3/ha ÷ 10 = mm runoff

(2) M = snowmelt event
B = baseflow
D = diurnal snowmelt (afternoon warming)

Table D.10 Emery Snowmelt Hydrology and Airport Meteorological Data Summary (Cont.)

Airport Temperatures (°C)

event #	start temp (°C)	end temp (°C)	# of hours during event >0°C	# of hours during event >-4°C	% of event with temp. >0°C	% of event with temp. >-4°C	# of hrs preceding event * >0°C	# of hrs preceding event * >-4°C
E1	0.1	0.8	15.5	15.5	100%	100%	1	>24
E2	0.8	-1.5	15.5	15.5	100	100	19	>24
E3	0.8	-6.4	19	21	79	88	>24	>24
E4	-6.0	-4.3	0	0	0	0	0	0
E5	-9.3	-5.4	0	0	0	0	0	0
E6	1.2	0.1	18.5	18.5	100	100	3	17
E7	1.0	-3.1	5.5	10.5	52	100	>24	>24
E8	1.5	-8.3	2.0	6.0	20	59	4	11
E9	-2.7	-4.9	0	6.0	0	86	0	>24
E10	5.4	1.1	14.7	14.7	100	100	15	19
E11	0.1	-0.4	17.5	18	95	97	>24	>24
E12	-0.3	-1.1	4	6.5	62	100	0	>24
E13	-0.3	-0.5	5	6.5	67	87	0	10
E14	0.6	2.4	16.3	16.3	100	100	5	24
E15	2.5	2.7	8.2	8.2	100	100	>24	>24
E16	5.0	3.1	23.8	23.8	100	100	>24	>24
E17	0.8	-1.3	10	11.5	87	100	0	>24
E18	4.0	2.9	9.5	9.5	100	100	2	>24
E19	10.6	4.6	3.5	3.5	100	100	>24	>24
E20	-2.4	-4.6	0	7.5	0	100	>24	>24
E21	-4.4	-2.4	0	3.8	0	100	0	0
E22	-4.6	0.3	3.5	5.5	47	73	0	0
E23	-7.0	1.6	6.0	6.8	88	100	0	0
E24	1.6	-3.9	1.0	4.3	23	100	23	>24
E25	-7.3	-3.5	0	4.0	0	67	0	0
E26	3.7	1.4	21.5	21.5	100	100	16	>24
E27	0.6	1.6	10.7	10.7	100	100	>24	>24

Table D.10 Emery Snowmelt Hydrology and Airport Meteorological Data Summary (Contd.)

event #	Airport precip: precip during event Y/N	Airport precip: possible rain? (mm)	Airport precip: snow depth on 0800 of event (cm)	Airport winds: wind speed (km/h) at start	Airport winds: wind speed (km/h) at end	Airport winds: mean speed for previous day	Airport Relative Humidity (%) max.	Airport Relative Humidity (%) min.
E1	Y	TR	7	15	8	24	100	80
E2	Y	TR	3	7	17	15	100	80
E3	Y	TR	3	20	28	15	100	75
E4	Y	–	10	20	17	15	96	73
E5	Y	—	12	14	19	5.6	90	69
E6	Y	3.6	12	12	26	7.1	100	67
E7	Y	TR	10	35	15	13.9	87	67
E8	Y	TR	18	1	9	8.0	94	69
E9	Y	—	19	7	18	10.2	93	68
E10	Y	3.0	11	19	9	10.7	94	77
E11	Y	—	7	6	6	18.3	100	78
E12	Y	—	8	0	12	10.8	99	78
E13	Y	TR	6	0	0	11.3	97	77
E14	Y	1.4	4	0	7	3.7	100	91
E15	N	—	1	7	0	6.7	100	80
E16	Y	34.0	1	11	7	5.8	100	80
E17	N	—	TR	7	16	8.4	100	85
E18	N	—	TR	22	18	9.7	100	57
E19	Y	0.8	TR	12	13	5.9	97	74
E20	Y	—	3	5	17	11.0	100	76
E21	Y	—	5	18	19	26.2	95	62
E22	N	—	18	15	0	18.2	93	67
E23	Y	3.0	15	24	15	9.3	99	72
E24	Y	17.4	8	35	56	9.7	100	75
E25	N	—	6	20	22	27.5	75	58
E26	Y	13.6	2	21	22	19.0	100	77
E27	Y	—	2	20	26	28.0	100	80

Table D.11 Thistledowns Snowmelt Hydrology and Airport Meteorology Data Summary

	Runoff Period						Runoff characteristics					
event #	start date	time	flow rate (l/sec/ha)	end date	time	flow rate (l/sec/ha)	duration (hrs)	peak flow (l/sec/ha)	ave. flow	total volume (m³/ha)	equiv. snow pack melted depth (cm)	general runoff type (?)
TD1	Feb 2	1300	0.08	Feb 2	1800	0.08	5.0	0.15	0.13	2.27	0.1	B+D
TD2	3	0550	0.10	3	2030	0.23	14.7	1.5	0.93	48.9	2.7	R
TD3	4	1040	0.10	4	1940	0.18	9.0	0.62	0.41	13.3	0.7	M
TD4	5	1100	0.10	5	1850	0.13	7.8	0.72	0.36	10.1	0.6	D
TD5	10	1300	0.13	10	1750	0.13	4.8	0.36	0.26	4.47	0.3	D
TD6	11	0230	0.05	11	2250	0.51	20.3	2.0	0.77	56.1	3.1	R+M
TD7	12	0910	0.28	12	2020	0.51	11.2	2.8	1.5	59.2	1.5	M
TD8	13	0810	0.36	14	1850	0.33	34.6	12.6	0.41	512	12.8	R
TD9	15	1200	0.18	15	1840	0.18	6.7	0.51	0.28	6.71	0.2	B
TD10	16	1210	0.13	16	1650	0.23	4.7	0.36	0.31	5.17	0.1	B
TD11	17	1200	0.15	17	1640	0.23	4.7	0.33	0.28	4.70	0.1	B
TD12	19	1650	0.18	19	1940	0.18	2.8	1.0	0.36	3.73	0.1	R
TD13	21	0950	0.13	21	1350	0.13	4.0	0.26	0.21	2.91	0.1	D
TD14	25	1030	0.08	25	1850	0.10	8.3	0.36	0.23	6.76	0.4	D
TD15	March 3	1200	0.05	March 3	1700	0.08	5.0	0.13	0.10	2.03	0.1	B
TD16	4	1200	0.05	4	1700	0.13	5.0	0.23	0.18	3.16	0.2	D
TD17	6	1030	0.08	6	1800	0.13	7.5	0.54	0.33	8.69	0.4	D
TD18	14	1100	0.10	14	1800	0.10	7.0	0.33	0.26	6.43	0.3	D
TD19	15	1100	0.08	15	2000	0.15	9.0	0.95	0.31	9.77	0.4	R+M
TD20	16	0100	0.13	17	0100	0.57	24.0	8.2	2.0	176	7.7	R+M
TD21	17	1020	0.57	17	2300	0.57	12.7	0.93	0.75	33.7	1.5	M
TD22	19	0000	0.51	19	2330	0.18	23.5	0.51	0.33	28.4	1.2	M
TD23+24	20	1100	0.13	21	2240	0.39	35.6	9.8	3.4	430	18.7	R+M
TD25	22	0840	0.21	22	2140	0.39	12.7	2.5	2.3	103	4.5	M
TD26	24	1000	0.33	24	2130	0.44	11.5	1.0	0.67	27.7	1.2	D
TD27	25	1100	0.46	25	2130	0.44	10.5	0.80	0.62	22.9	1.0	D

Table D.11 Thistledowns Snowmelt Hydrology and Airport Meteorology Data Summary (Cond.)

event #	Airport Temperatures (°C) start temp. (°C)	end temp. (°C)	# of hours during event >0°C	# of hours during event >-4°C	% of event with temp. >0°C	% of event with temp. >-4°C	# of hrs preceding event with temp.: >0°C	# of hrs preceding event with temp.: >-4°C	Airport Prec. precipitation during event Y/N	possible rain? (mm)	snow depth 0800 of event (cm)	Airport Winds wind speed (km/hr) at start	at end	mean speed for previous day	Airport Relative Humidity (%) max	min
TD1	-7.7	-8.0	Ø	Ø	Ø	Ø	Ø	Ø	N	—	15	19	15	4.4	95	71
TD2	5.5	0.7	14.7	14.7	100	100	17	22	Y	3.0	11	33	8	10.7	94	77
TD3	0.8	0.2	9.0	9.0	100	100	>24	>24	Y	—	7	7	19	18.3	100	78
TD4	-0.1	-1.3	4.0	7.8	57	100	Ø	>24	Y	—	8	4	13	10.8	99	78
TD5	1.3	-0.4	4.0	4.8	83	100	1	11	Y	TR	6	Ø	6	11.3	97	77
TD6	0.5	1.9	20.3	20.3	100	100	5	23	Y	1.4	4	Ø	6	3.7	100	91
TD7	0.6	2.7	11.2	11.2	100	100	>24	>24	N	—	1	4	6	6.7	100	80
TD8	2.7	3.5	34.6	34.6	100	100	>24	>24	Y	34.0	1	13	6	5.8	100	80
TD9	3.9	0.2	6.7	6.7	100	100	2	>24	N	—	TR	7	6	8.4	100	85
TD10	4.0	4.4	4.7	4.7	100	100	2	>24	N	—	TR	22	20	9.7	100	57
TD11	6.2	5.5	4.7	4.7	100	100	>24	>24	N	—	TR	11	6	14.4	94	69
TD12	10.5	4.6	2.8	2.8	100	100	>24	>24	Y	0.8	TR	15	18	5.9	97	74
TD13	-0.9	-0.4	Ø	4.0	Ø	100	Ø	>24	Y	—	1	30	20	19.2	98	72
TD14	-3.1	-6.1	Ø	6.0	Ø	72	Ø	>24	Y	—	3	39	33	11.0	100	76
TD15	-5.9	-4.8	Ø	Ø	Ø	Ø	Ø	Ø	N	—	16	30	24	17.8	86	52
TD16	-2.8	-2.4	Ø	5.0	Ø	100	Ø	Ø	N	—	12	Ø	9	13.9	87	47
TD17	-2.1	-7.2	Ø	6.0	Ø	80	Ø	>24	Y	—	16	27	19	19.2	92	62
TD18	-4.8	1.0	3.0	6.0	43	86	Ø	Ø	N	—	18	15	Ø	18.2	93	67
TD19	-1.4	1.5	8.0	9.0	89	100	Ø	6	Y	3.0	15	24	11	9.3	99	72
TD20	1.2	-9.5	12.0	16.0	50	67	12	21	Y	17.4	8	Ø	24	9.7	100	58
TD21	-9.2	-5.2	Ø	7.0	Ø	55	Ø	Ø	N	—	6	17	19	27.5	75	58
TD22	-3.8	-0.7	4.0	23.5	17	100	Ø	10	Y	TR	6	15	4	16.5	94	72
TD23+24	-0.2	0.6	35.6	35.6	100	100	Ø	>24	Y	13.6	5	22	19	8.0	100	77
TD25	0.9	1.5	12.7	12.7	100	100	>24	>24	Y	—	2	19	30	28.0	100	80
TD26	-0.4	-0.5	10	11.5	87	100	Ø	3	N	—	1	7	2	25.3	85	63
TD27	2.2	-1.6	9.0	10.5	86	100	1	>24	N	—	TR	9	15	7.6	91	62

Table D.12 Emery Inter-Event Flows (Baseflows)

prev event	next event	date	time	flow (l/sec/ha)	date	time	flow (l/sec/ha)
		end of previous event (beginning of period)			start of next event (ending of period)		
beginning of Jan	E1	Jan 1	0000	—	Jan 4	1000	0.03
E1	E2	5	0130	0.20	5	0400	0.20
E2	E3	5	1930	0.13	5	2200	0.13
E3	E4	6	2200	0.07	13	0940	0.07
E4	E5	13	1330	0.07	17	0930	0.07
E5	E6	17	1400	0.10	24	0930	0.07
E6	E7	25	0400	0.16	25	0830	0.16
E7	E8	25	2000	0.13	27	0750	0.07
E8	E9	27	1800	0.07	30	1130	0.07
E9	end of Jan.	30	1830	0.10	31	2400	—
beginning of Feb	E10	Feb 1	0000	—	Feb 3	0400	0.07
E10	E11	3	1840	0.26	4	0930	0.13
E11	E12	5	0400	0.13	5	1000	0.13
E12	E13	5	1730	0.013	10	1130	0.07
E13	E14	10	1900	0.10	11	0240	0.07
E14	E15	11	1900	0.26	13	1150	0.29
E15	E16	12	2000	0.29	13	0930	0.33
E16	E19 *	14	1940	0.33	19	1630	0.07
E19	E20	19	2000	0.07	25	0930	0.03
E20	E21	25	1630	0.07	26	1130	0.07
E21	end of Feb.	26	1540	0.07	29	2400	—
beginning of March	E22	Mar 1	0000	—	Mar 14	1100	0.03
E22	E23	14	1830	0.03	15	0110	0.05
E23	E24	15	1800	0.26	16	1210	0.07
E24	E25	16	1630	0.03	17	1200	0.07
E25	E26	17	1800	0.03	21	0330	0.13
E26	E27	22	0100	0.13	22	0800	0.03
E27	end of March	22	1840	0.20	31	2400	—

* E17 and E18 are baseflows

Table D.12 Emery Inter-Event Flows (Cont.)

prev event	next event	duration of period: duration (hrs)	ave. flow (l/sec/ha)	total volume (m³/ha)	"depth" (mm)	depth/day (mm/day)
beginning of Jan	E1	82.0	0.03	8.9	0.9	0.3
E1	E2	2.5	0.20	1.8	0.2	1.7
E2	E3	2.5	0.13	1.2	0.1	1.1
E3	E4	155.7	0.07	39.2	3.9	0.6
E4	E5	91.8	0.07	23.1	2.3	0.6
E5	E6	163.8	0.08	47.2	4.7	0.7
E6	E7	4.5	0.16	2.6	0.3	1.4
E7	E8	35.8	0.10	12.9	1.3	0.9
E8	E9	65.5	0.07	16.5	1.7	0.6
E9	end of Jan.	29.5	0.08	8.5	0.9	0.7
beginning of Feb	E10	28.0	0.09	9.1	0.9	0.8
E10	E11	14.8	0.20	10.7	1.1	1.7
E11	E12	16.0	0.13	2.8	0.3	1.1
E12	E13	14.0	0.10	51.8	5.2	0.9
E13	E14	17.7	0.08	2.2	0.2	0.7
E14	E15	16.8	0.28	16.9	1.7	2.4
E15	E16	13.5	0.31	15.1	1.5	2.7
E16	E19*	117.8	0.20	84.8	8.5	1.7
E19	E20	133.5	0.05	24.0	2.4	0.4
E20	E21	19.0	0.07	4.8	0.5	0.6
E21	end of Feb.	80.3	0.05	14.5	1.5	0.4
beginning of March	E22	323	0.05	58.1	5.8	0.4
E22	E23	6.7	0.04	1.0	0.1	0.3
E23	E24	18.2	0.17	11.1	1.1	1.5
E24	E25	19.5	0.05	3.5	0.4	0.4
E25	E26	81.5	0.08	23.5	2.4	0.7
E26	E27	7.0	0.08	2.0	0.2	0.7
E27	end of March	221.3	0.20	159.3	15.9	1.7

* E17 and E18 are baseflows

Table D.13 Cold Weather Thistledowns Inter-Event Flows (Baseflows)

prev event	next event	date (beginning of period; end of previous event)	time	flow (l/sec/ha)	date (ending of period; start of next event)	time	flow (l/sec/ha)	duration of period (hrs)	ave flow (l/sec/ha)	total volume (m³/ha)	"depth" (mm)	depth/day (mm/day)
beginning of Feb	TD1	Feb 1	0000	—	Feb 2	1300	0.08	37	0.08	10.7	1.1	0.7
TD1	TD2	2	1800	0.08	3	0550	0.10	11.8	0.09	3.8	0.4	0.8
TD2	3	3	2030	0.23	4	1040	0.10	14.7	0.17	9.0	0.9	1.5
TD3	4	4	1940	0.18	5	1100	0.10	15.3	0.14	7.7	0.8	1.2
TD4	5	5	1850	0.13	10	1300	0.13	114	0.13	53.4	5.3	1.1
TD5	6	10	1750	0.13	11	0230	0.05	8.8	0.09	2.9	0.3	0.8
TD6	7	11	2250	0.51	12	0910	0.28	10.4	0.40	15.0	1.5	3.5
7	8	12	2020	0.51	13	0810	0.36	11.8	0.44	18.7	1.9	3.8
8*	12	14	1850	0.33	19	1650	0.18	118	0.26	110.5	11.1	2.3
12	13	19	1940	0.18	21	0950	0.13	14.5	0.16	8.4	0.8	1.4
13	14	21	1350	0.13	25	1030	0.08	84.7	0.11	33.5	3.4	1.0
14	15	25	1850	0.10	Mar 3	1200	0.05	161.2	0.07	40.6 – 25.5/15.1	4.1 – 2.6/1.5	0.6
15	16	Mar 3	1700	0.08	4	1200	0.05	19	0.06	4.1	0.4	0.5
16	17	4	1700	0.13	6	1030	0.08	41.5	0.10	14.9	1.5	0.9
17	18	6	1800	0.13	14	1100	0.10	209	0.11	82.8	8.3	1.0
18	19	14	1800	0.10	15	1100	0.08	17	0.09	5.5	0.6	0.8
19	20	15	2000	0.15	16	0100	0.13	5.0	0.14	2.5	0.3	1.2
20	21	17	0100	0.57	17	1020	0.57	9.3	0.57	19.1	1.9	4.9
21*	23	17	2300	0.57	20	1100	0.13	60	0.35	75.6	7.6	3.0
24*	25	21	2240	0.39	22	0840	0.21	9.7	0.30	10.5	1.1	2.6
25	26	22	2140	0.39	24	1000	0.33	36.3	0.36	47.0	4.7	3.1
26	27	24	2130	0.44	25	1100	0.46	13.5	0.45	21.9	2.2	3.9
27	end of March	25	2130	0.44	31	2400	—	144	0.44	228.1 (?)	22.8	3.8

* TD 9, 10, 11 & 22 are baseflows and TD 23 & 24 are "adjacent" with no baseflow

Table D.14. Example Parts of Factor Analysis (Principal Components)

Correlation Matrix

	RAINTOT	AVEINT	PEAKINT	DRYPER	RUNTOT	AVEDIS	PEAKDIS
RAINTOT	1.000						
AVEINT	0.138	1.000					
PEAKINT	0.512	0.675	1.000				
DRYPER	0.172	-0.096	-0.132	1.000			
RUNTOT	0.909	0.007	0.405	0.091	1.000		
AVEDIS	0.711	0.480	0.654	-0.083	0.678	1.000	
PEAKDIS	0.729	0.372	0.748	0.037	0.704	0.854	1.000

LATENT ROOTS (VARIANCE EXPLAINED)

Factor Components:(1)

	1	2	3	4	5	6	7
	3.964	1.436	0.903	0.283	0.270	0.083	0.061
%	56.6%	20.5	12.9	4.0	3.9	1.2	0.9%
Σ%	56.6%	77.1	90.0	94.0	97.9	99.1	100.0%

(1) first 3 accounts for 90% of variance (first 4 accounts for 94%)

LOADINGS

Factor Components:(2)

	1	2	3	4	5	6	7
RAINTOT	0.857	0.413	-0.067	0.036	0.237	0.138	-0.123
AVEINT	0.489	-0.719	0.392	0.232	0.165	-0.083	-0.047
PEAKINT	0.805	-0.429	0.125	-0.359	0.102	0.064	0.095
DRYPER	0.009	0.568	0.820	-0.012	-0.050	0.006	0.034
RUNTOT	0.803	0.485	-0.225	0.058	0.165	-0.169	0.099
AVEDIS	0.913	-0.076	-0.074	0.267	-0.248	0.115	0.093
PEAKDIS	0.929	0.021	0.006	-0.157	-0.292	-0.106	-0.121

(2) #1 component is very complex and can not be used to simplify the structure defined in this example. Therefor models using individual independent variables are preferred here.

Table D.15. Example Sequence for Step-Wise Multiple Regression Analysis to Predict Runoff Total Volume.

Identification of model predictors

ONE OR MORE CASES DELETED DUE TO MISSING DATA.

NUMBER OF CASES PROCESSED: 59

STEPWISE REGRESSION WITH ALPHA-TO-ENTER= .150 AND ALPHA-TO-REMOVE= .150

STEP= 1	ENTER	RAINTOT	R= .909	RSQUARE= .826
STEP= 2	ENTER	AVEINT	R= .917	RSQUARE= .840
STEP= 3	ENTER	DRYPER	R= .920	RSQUARE= .847

THE SUBSET MODEL INCLUDES THE FOLLOWING PREDICTORS:

CONSTANT
AVEINT
DRYPER
RAINTOT

USE THESE PREDICTORS IN A NEW MODEL SENTENCE TO ESTIMATE THE COEFFICIENTS.

ONE OR MORE CASES DELETED DUE TO MISSING DATA.

NUMBER OF CASES PROCESSED: 59

:PENDENT VARIABLE MEAN: 1.766

Table. D.16

Multiple Regression Analysis based on Step-Wise Model predictors for Runo88 Total Volume

EIGENVALUES OF UNIT SCALED X'X

1	2	3	4
2.794	0.636	0.359	0.211

CONDITION INDICES

1	2	3	4
1.000	2.095	2.788	3.641

VARIANCE PROPORTIONS

	1	2	3	4
CONSTANT	0.032	0.001	0.001	0.966
RAINTOT	0.040	0.003	0.674	0.283
AVEINT	0.042	0.593	0.202	0.163
DRYPER	0.041	0.288	0.414	0.257

MULTIPLE CORRELATION: .920

SQUARED MULTIPLE CORRELATION: .847

ADJUSTED $R^2 = 1-(1-R^2)*(N-1)/DF$, WHERE N= 59, AND DF= 55: .839

$R^2 = 0.84$

VARIABLE	COEFFICIENT	STD. ERROR	STD. COEF.	TOLERANCE	T	P(2 TAIL)
CONSTANT	0.106	0.183	0.	.	.58	.566
RAINTOT	0.289	0.017	0.941	0.94649	17.36	.000
AVEINT	-0.047	0.019	-0.131	0.96634	-2.44	.018
DRYPER	-0.043	0.028	-0.083	0.95600	-1.54	.130

Model: RUNTOT = 0.106 + 0.289 RAINTOT − 0.047 AVEINT − 0.043 DRYPER

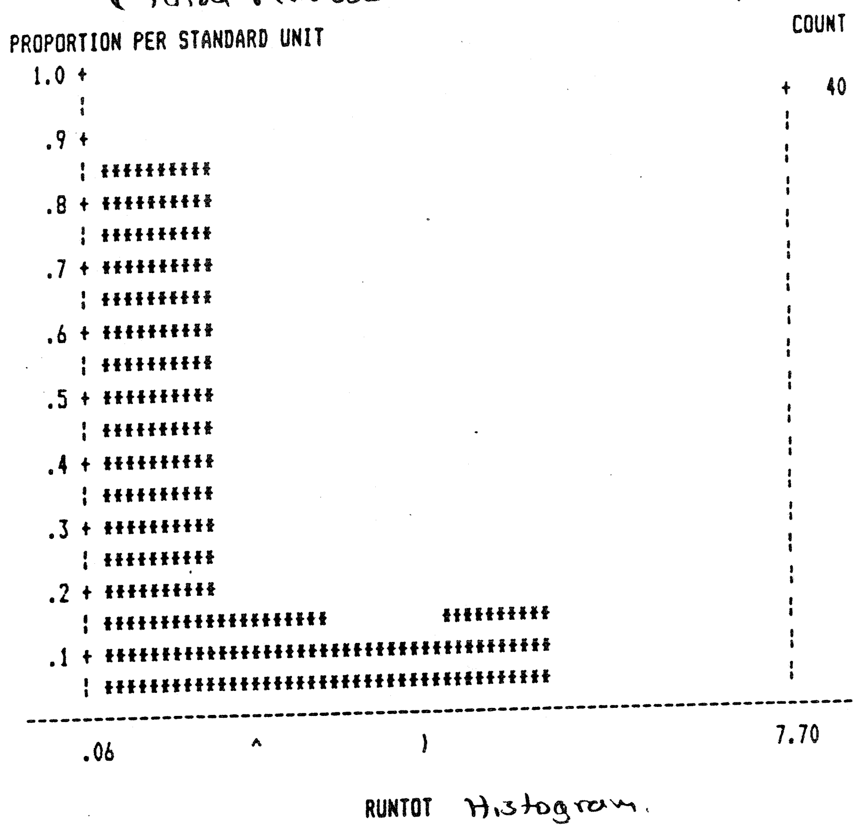
CORRELATION MATRIX OF REGRESSION COEFFICIENTS

	CONSTANT	RAINTOT	AVEINT	DRYPER
CONSTANT	1.000			
RAINTOT	-0.462	1.000		
AVEINT	-0.395	-0.157	1.000	
DRYPER	-0.464	-0.188	0.122	1.000

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	177.794	3	59.265	101.497	.000
RESIDUAL	32.115	55	0.584		

Figure D.1 Example Descriptive Statistics for the Dependent Variable "RUNTOT" (Total Runoff Volume) for Every



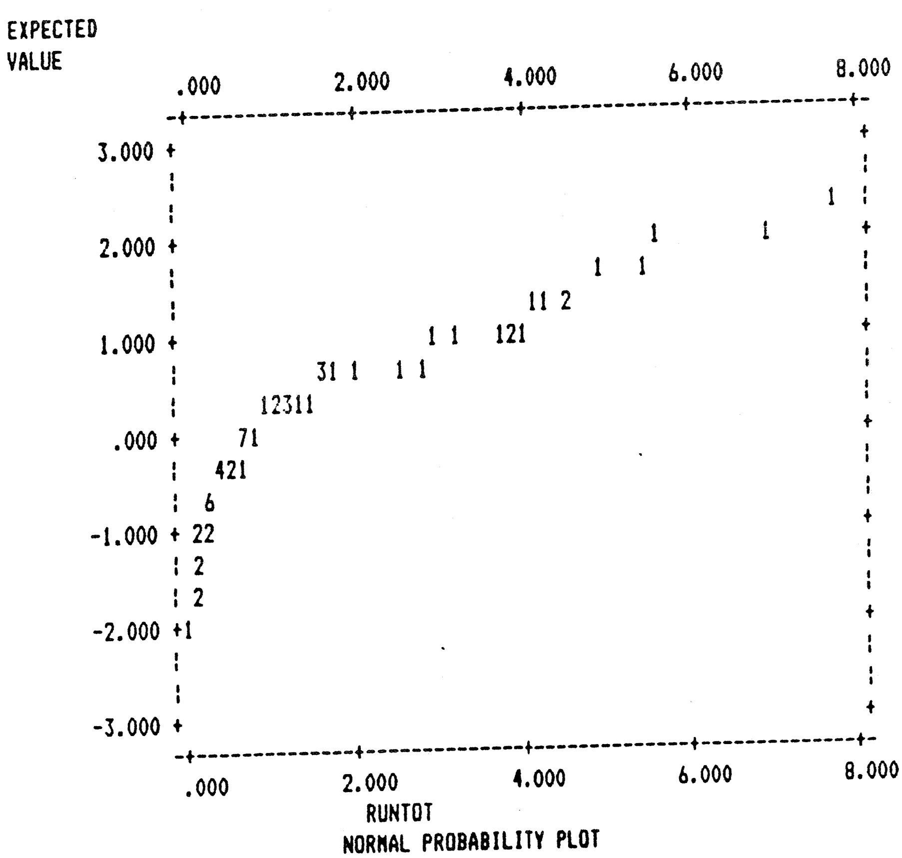


Figure D.2 Sequence Plot of Runoff Volume Observations

NUMBER OF CASES = 60
MEAN OF SERIES = 1.747
STANDARD DEVIATION OF SERIES = 1.876

SEQUENCE PLOT OF SERIES

CASE	VALUE
1	3.200
2	1.140
3	0.680
4	2.000
5	0.600
6	0.890
7	1.630
8	4.270
9	1.380
10	3.920
11	0.130
12	0.510
13	0.730
14	0.170
15	2.990
16	0.630
17	0.260
18	1.030
19	1.110
20	0.160
21	0.170
22	0.640
23	0.220
24	0.640
25	0.250
26	0.390
27	0.810
28	1.240
29	2.520
30	1.260
31	2.750
32	4.480
33	0.100
34	0.150
35	4.950
36	5.420
37	0.730
38	0.064
39	0.250
40	0.410
41	0.360
42	1.500
43	4.000
44	7.700
45	1.700
46	3.700
47	0.270
48	0.300
49	0.220
50	0.510
51	3.870
52	0.730
53	1.580
54	6.930
55	4.140
56	0.330
57	5.640
58	0.400
59	4.530

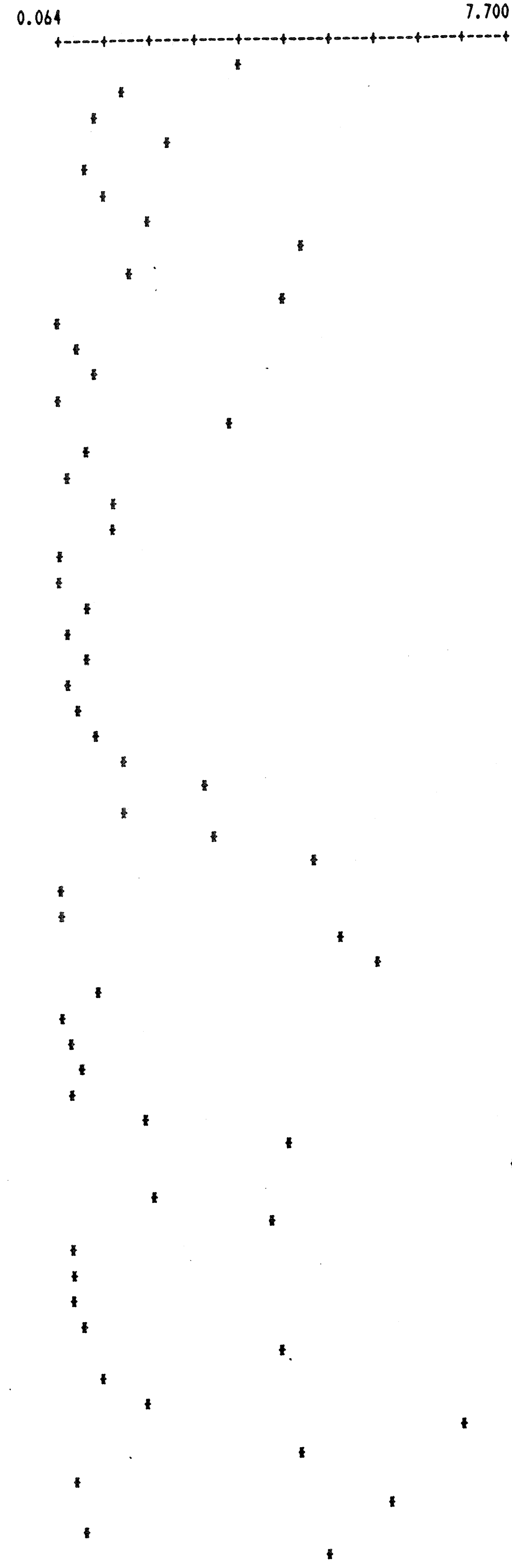


Figure D.3 Box and Stem and Leaf Example Plots

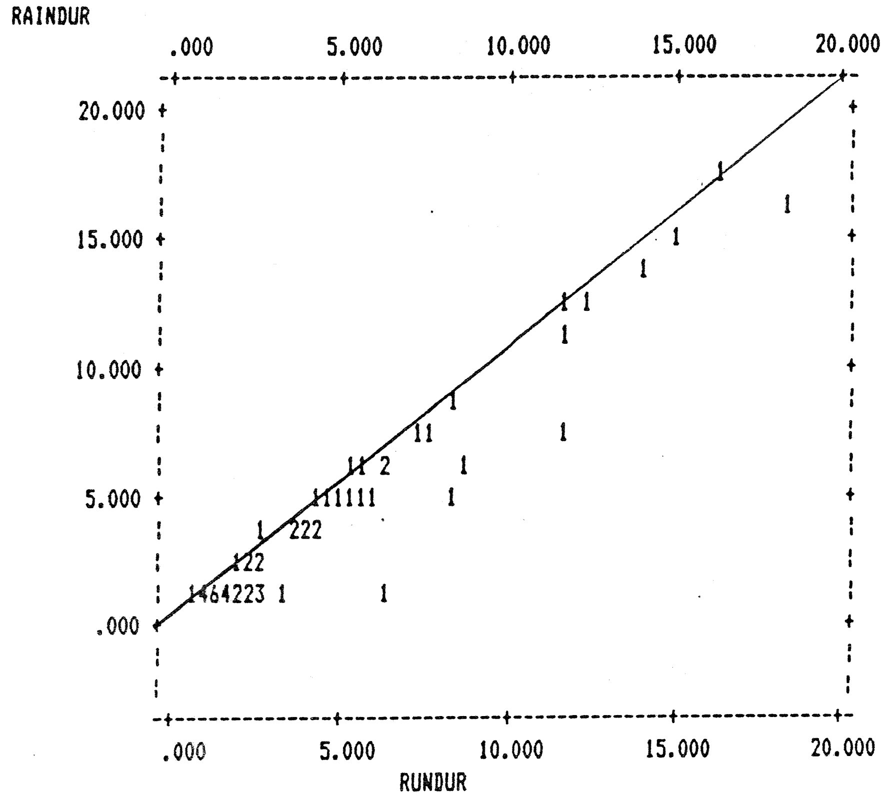
```
          BOX PLOT OF VARIABLE:   RUNTOT
      .06                                              7.70
MINIMUM                                              MAXIMUM

     ----+----------------
I   -I   +               I---------------------        *      *
     ----+----------------
```

```
           STEM AND LEAF PLOT OF VARIABLE:   RUNTOT

SMALLEST VALUE AT TOP OF PLOT IS:   .6400000E-01

              0 M 000000000000000000000000000000001111111111
              0 H 22223333
              0   44444455
          ***OUTSIDE VALUES***
              0   67
```

Figure D.4 Cluster Analysis (Dendogram "Tree")

```
                              DISTANCES
         .000                                                 2.000
PEAKINT  ---------
                 I--
PEAKDIS  -----   I I
             I---- I
AVEDIS   -----     I
                   I---------
AVEINT   -----------        I
                            I---------------------
RUNTOT   ----               I                    I
            I-----------    I                    I
RAINTOT  ----          I    I                    I
                       I-----                    I
RUNDUR   --            I                         I
          I-------------                         I
RAINDUR  --                                      I
                                                 I-------------------------
LAG      --------------------------------        I
                                        I---------
DRYPER   --------------------------------
```

Figure D.5 Example Two-Variable Scatterplots for Simple and Complicated Relationships



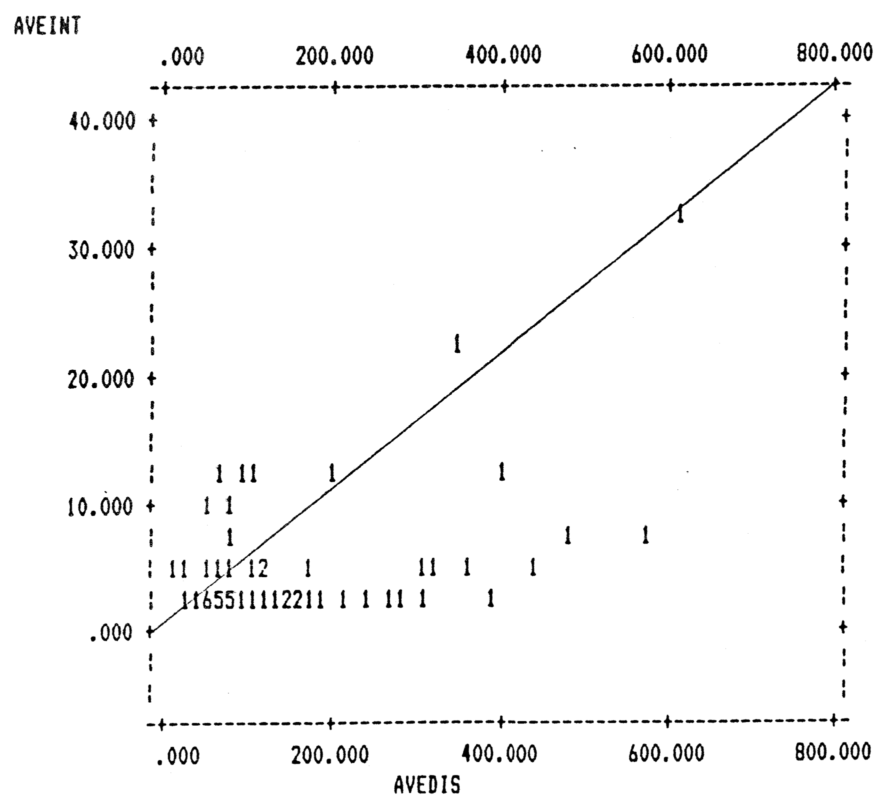


Figure D.6. Scatterplot of Model Estimate verses Observed Data (Should follow the diagonal line).

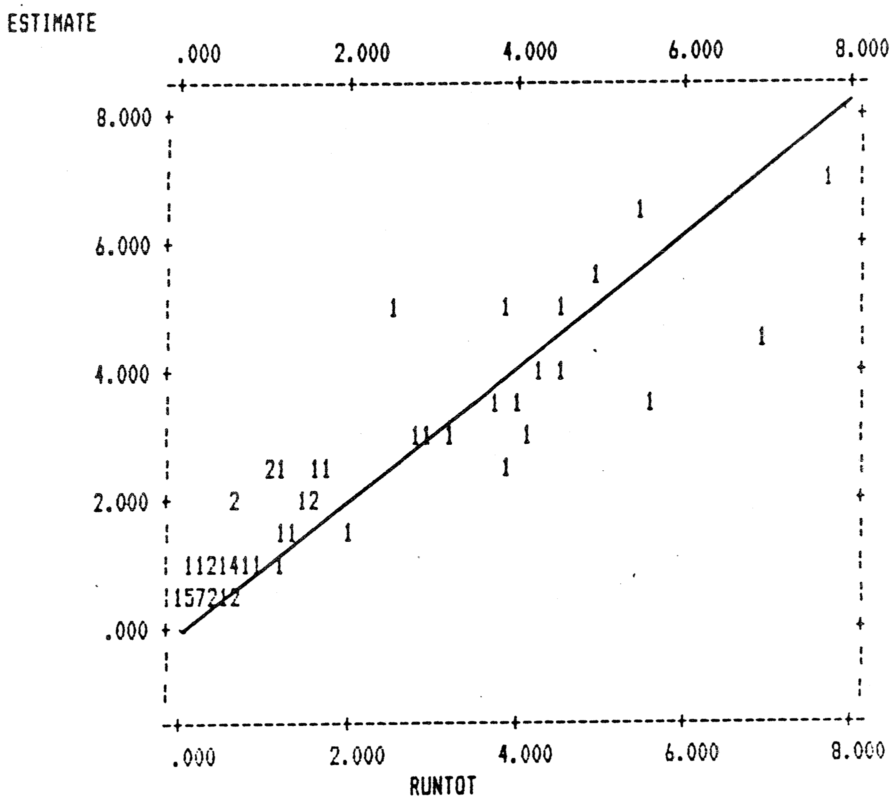
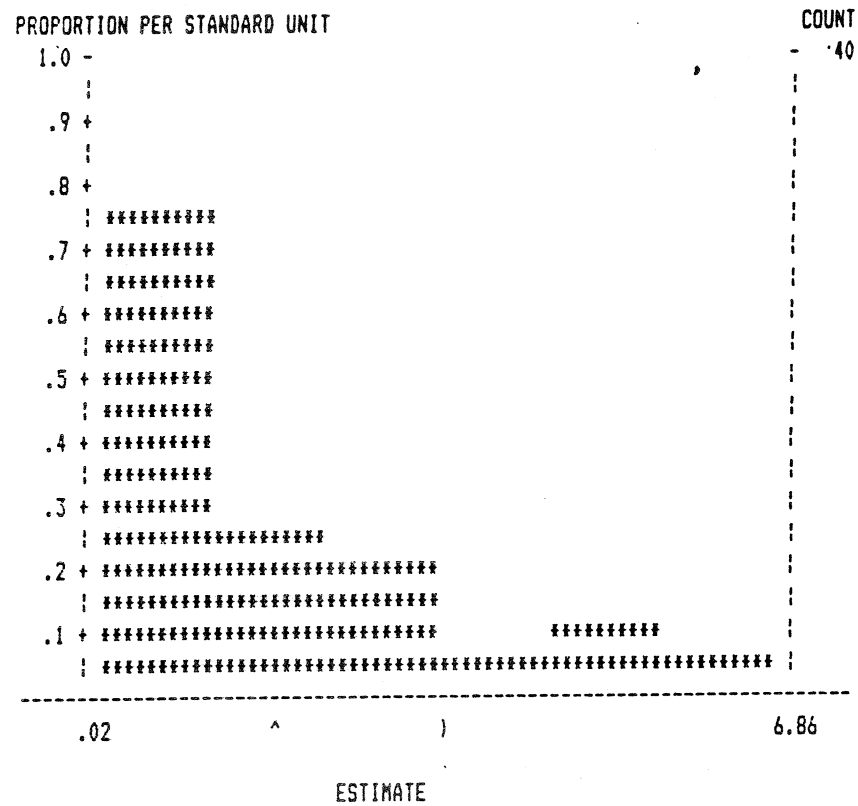
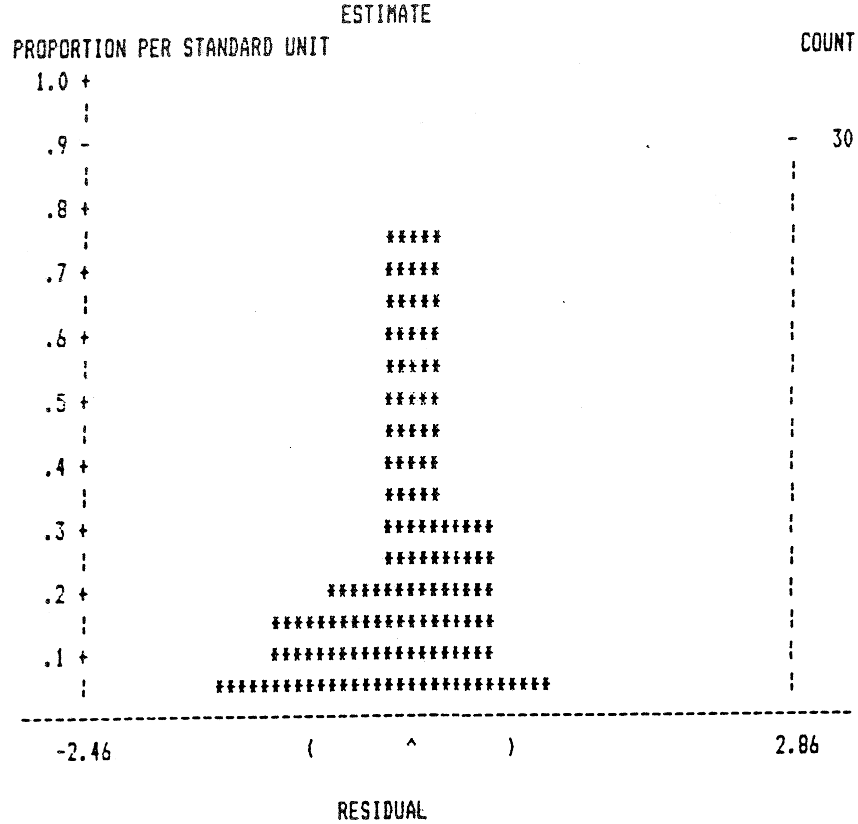


Figure D.7. Analyses of Model Estimates and Residuals (for Step Wise Multiple Regression Model Example for RUNTOT)

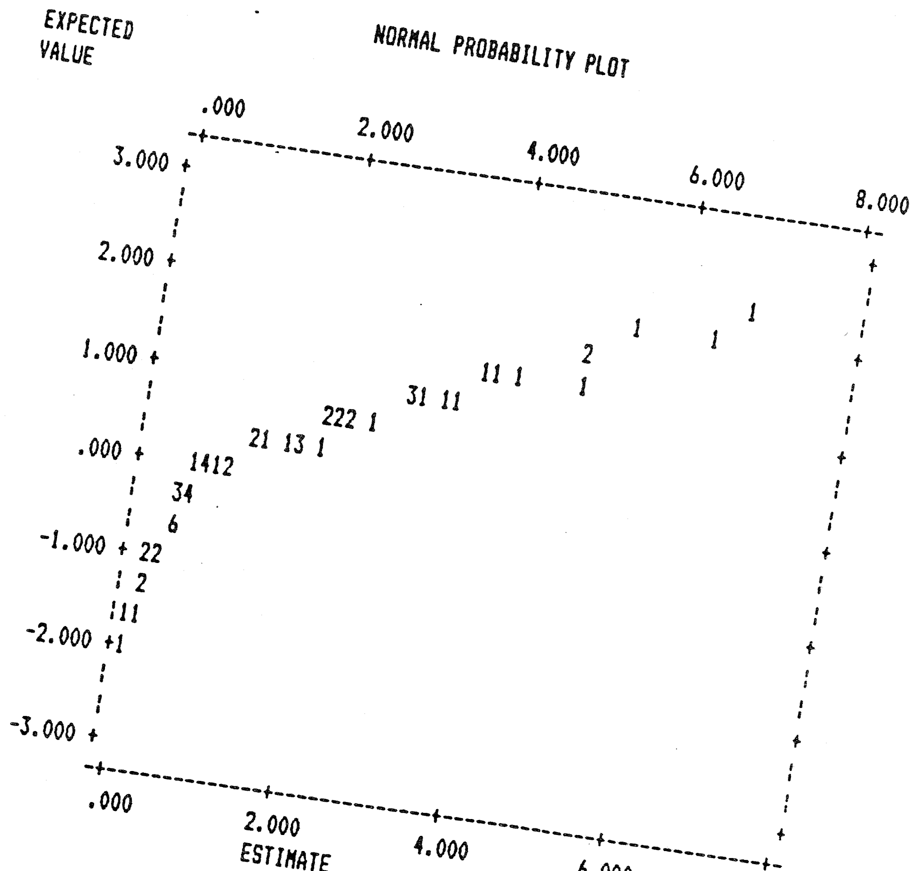
Histograms:

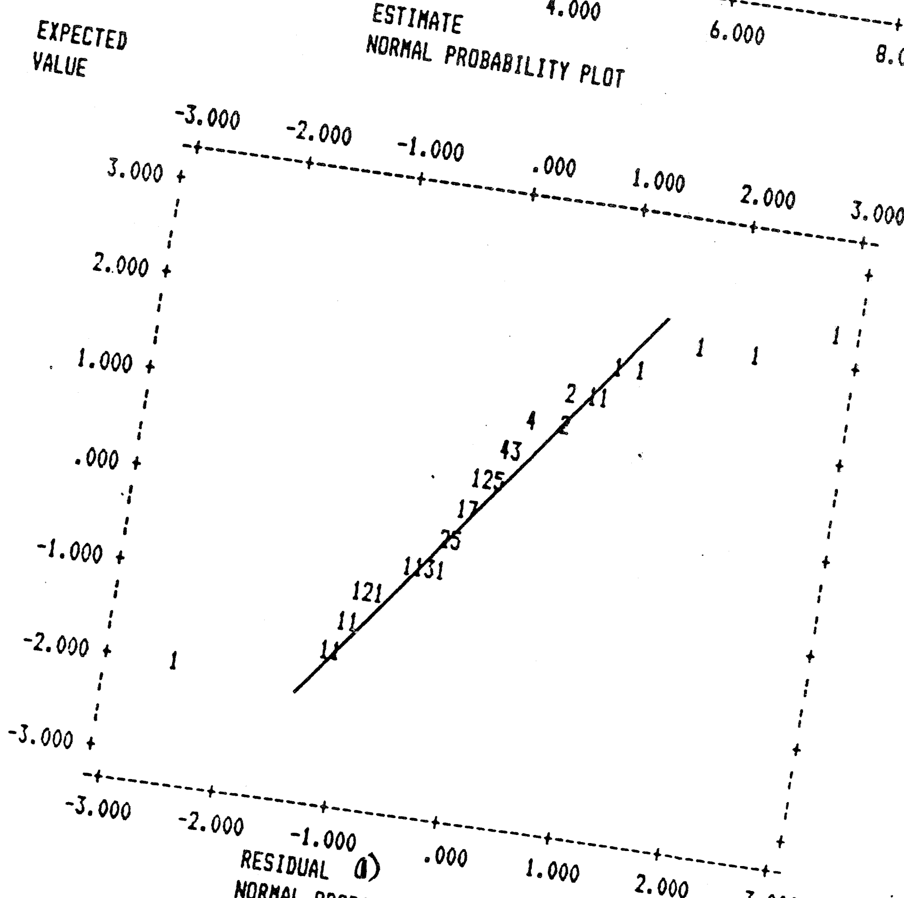




PROPORTION PER STANDARD UNIT COUNT

Figure D.8. Normal Probability Plots of Model Estimates and Residuals for RUNTOT Example.

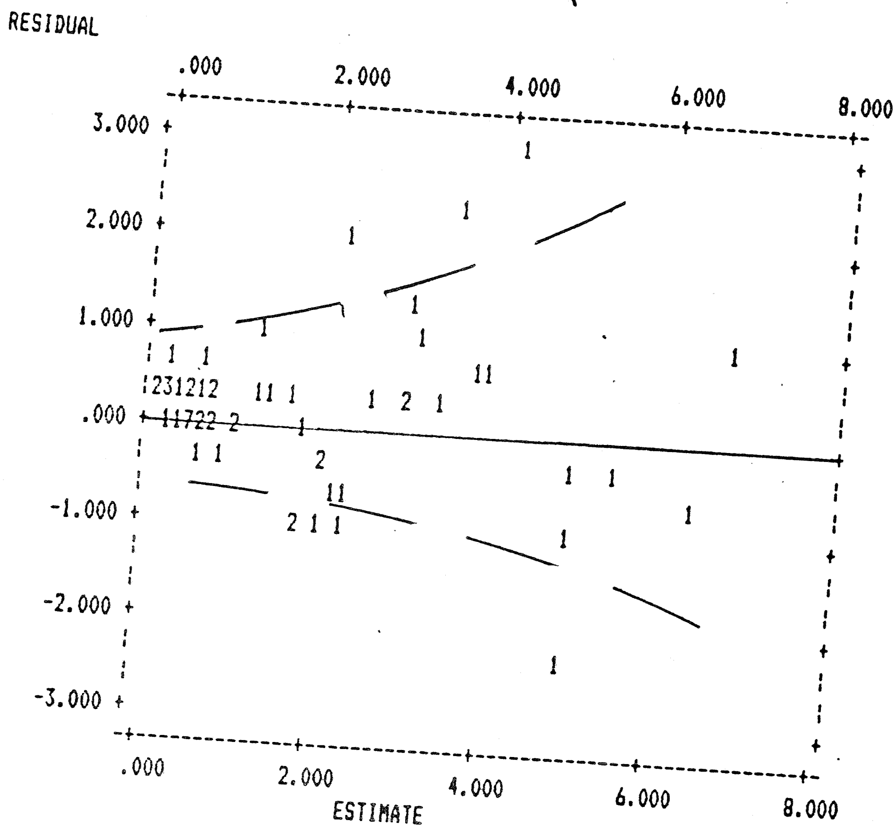


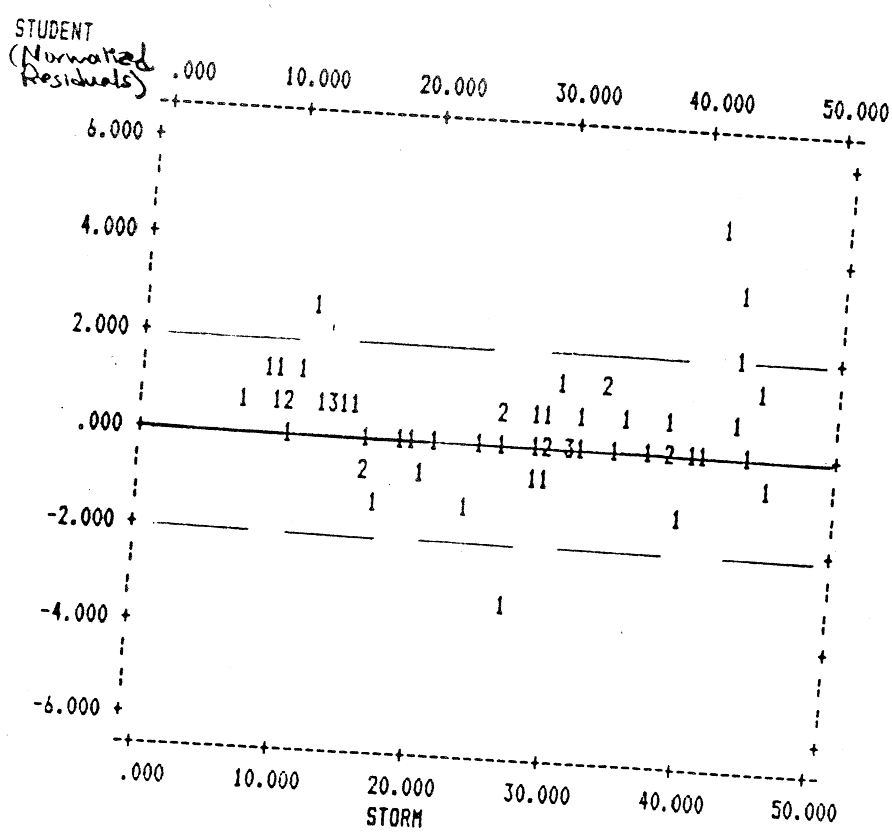


NORMAL PROBABILITY PLOT

(1) require ...

Figure D.9. Scatterplots of Residuals vs. Estimates and Storm Sequence (both should demonstrate "narrow", parallel band centered about "0") for RUNTOT Model Example





APPENDIX E RUNOFF WATER QUALITY DATA

LIST OF TABLES

TABLE	TITLE
E.1	EMERY DESCRIPTIONS OF BASEFLOW GRAB SAMPLES
E.2	WARM WEATHER EMERY BASEFLOW COMPOSITE (24hr) ANALYSES
E.3	WARM WEATHER EMERY BASEFLOW GRAB SAMPLE ANALYSES
E.4	WARM WEATHER THISTLEDOWN BASEFLOW COMPOSITE (24hr) ANALYSES
E.5	COLD WEATHER BASEFLOW ANALYSES
E.6	WARM WEATHER EMERY STORMWATER RUNOFF ANALYSES
E.7	WARM WEATHER THISTLEDOWN STORMWATER RUNOFF ANALYSES
E.8	THISTLEDOWN OUTFALL SAMPLES FOR MELTING PERIODS
E.9	EMERY OUTFALL SAMPLES FOR MELTING PERIODS
E.10	EMERY FIELD SPECIFIC CONDUCTANCE AND pH MEASUREMENTS (WARM WEATHER)
E.11	THISTLEDOWN FIELD SPECIFIC CONDUCTANCE AND pH MEASUREMENTS (WARM WEATHER)
E.12	MAJOR IONS
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(continued)

Table E.1

Baseflow
Emery Descriptions of Grab Samples

May 16, 1983	"very dirty"
June 8	oily film on rocks, milky-green color
June 14	—
June 17	a) —
	b) "really grungy"
June 22	—
July 22	—
July 26	yellow-green color
Aug 30	"dump" during catchbasin cleaning
Aug 31	very dark (sludge)
Sept 12	muddy appearance
Sept 19	yellow-green
Oct 7	no entry in log book
Oct 9	no entry in log book
Nov 2	milky

Table E.2 Warm Weather Emery Baseflow Composite (24-hr) Analyses (mg/l, unless otherwise noted). 1/2

sampling date	total residue	filtrate residue	partic. residue	P	PO_4 filt. react.	TKN	NH_4	phenolics µg/l	COD	FC (#/100 ml)	FS (#/100 ml)	PA (#/100 ml)
May 11, 1983	818	794	24.4	0.27	<0.02	1.7	<0.1	2.8	108	840	5100	—
May 12	734	718	16.3	0.63	0.12	1.9	<0.1	2.2	130	640	9300	—
May 13	—	—	41.2	0.44	0.12	2.4	<0.1	2.4	126	1620	23,000	—
May 16	1066	461	605	0.77	0.12	1.6	<0.1	3.2	80	11,300	10,000	—
June 8	513	500	125	0.23	<0.06	2.0	<0.1	8.0	64	2700	2900	480
June 9	622	607	14.9	—	<0.02	—	—	2.8	10	4200	2800	—
June 22	566	560	6.4	0.30	0.18	0.5	<0.2	1.6	34	—	—	—
July 7	453	443	10.3	—	<0.04	—	—	<0.2	82	—	—	—
Aug 3	492	485	6.7	0.40	<0.04	2.7	<0.1	1.0	44	—	—	—
Aug 10	445	425	19.8	0.42	0.18	1.2	<0.1	<0.4	108	24,000	~100	770
Aug 17	450	421	29.0	0.63	<0.02	1.3	<0.1	3.8	168	300,000	1,080,000	3400
Aug 24	446	426	20.1	0.34	0.06	1.0	<0.1	<0.2	32	650,000	14,000	9500
Sept 8	388	369	18.7	—	0.24	—	—	0.8	52	—	—	—
Sept 29	448	434	14.4	—	<0.1	—	—	0.2	—	6700	4500	—

Table E.2 Warm Weather Every Baseflow Composite (24-hr) Analyses (cont.) 2/2

Sampling date	Al	As	Cd	Co	Cr	Cu	Mo	Ni	Pb	Se	Zn	Spec cond µmhos/cm
May 11, 1983	3.8	<0.03	<0.01	<0.04	0.26	0.03	<0.04	<0.04	<0.04	<0.03	0.07	—
May 12	0.2	<0.03	0.001(?)	<0.01	0.26	0.02	<0.01	0.01	<0.01	0.09	0.12	—
May 13	0.41	<0.03	<0.01	<0.01	0.27	0.02	<0.01	<0.01	<0.01	<0.03	0.11	—
May 16	14.0	<0.03	0.01	<0.04	0.49	0.08	<0.04	0.03	<0.06	<0.03	0.45	—
June 8	<0.2	<0.03	<0.01	<0.04	0.43	0.03	<0.04	0.04	<0.04	<0.03	0.12	—
June 9	—	—	—	—	0.39	0.04	—	—	<0.04	—	0.19	—
June 22	<0.2	<0.03	<0.01	<0.04	0.62	0.03	<0.04	<0.02	<0.06	<0.03	0.20	—
July 7	—	—	—	—	0.42	0.04	—	—	<0.04	—	0.15	—
Aug 3	<0.2	<0.03	<0.006	<0.04	0.47	<0.02	<0.04	<0.04	<0.04	<0.03	0.19	—
Aug 10	0.54	<0.03	<0.005	<0.04	1.20	0.03	<0.06	<0.03	<0.04	<0.03	0.05	700
Aug 17	0.23	<0.03	0.004	<0.04	0.73	0.06	<0.06	<0.02	<0.04	<0.03	0.08	—
Aug 24	<0.2	<0.03	<0.004	<0.04	0.49	0.03	<0.06	<0.02	<0.04	<0.03	0.06	—
Sept 8	—	—	—	—	0.44	0.04	—	—	<0.04	—	0.05	580
Sept 29		—	—	—	1.50	0.10	—	—	0.02	—	0.12	—

Table E.3 Warm Weather Emery Baseflow Grab Sample Analyses (mg/l, unless otherwise noted). 1/2

sampling date	total residue	filtrate residue	part. residue	P	PO4 filt. react.	TKN	NH4	phenolics mg/l	COD	FC #/100 ml	FS #/100 ml	PA #/100 ml
May 16, 83	1066	461	605	0.77	0.12	1.6	<0.1	3.2	80	11,300	10,000	—
June 8	649	565	83.5	1.25	0.24	4.0	<0.1	<0.2	636	21,000	8,300	1,080
June 14	466	354	112	4.70	0.48	26.8	0.3	2.8	188	1200	9,800	1,960
June 17	584	486	97.8	2.93	1.67	3.8	<0.1	1.2	248	2700	21,000	13,500
June 17	844	454	390	3.7	0.60	7.3	<0.1	1.4	432	3300	38,000	16,600
June 22	554	428	126	1.63	0.22	2.8	<0.1	2.0	28	19,000	1400	8,300
July 22	392	327	64.6	0.16	<0.02	1.1	<0.1	<0.4	74	7,200	6,800	2,380
July 26	658	658	<1.7	0.31	0.08	0.6	0.2	0.8	10	1900	<100	1760
Aug 30	1544	324	1220	4.4	0.32	11.5	<0.1	24.2	450	270,000	110,000	20,000
Aug 30	1052	289	763	2.45	0.84	4.5	<0.1	—	374	—	—	—
Aug 31	5547	777	4770	5.7	<0.06	19.0	2.0	32.0	1880	~80,000	40,000	10,000
Sept 12	401	350	51.1	1.0	<0.02	2.5	0.2	<0.2	66	17,000	1000	—
Sept 19	482	438	44.4	0.10	—	—	—	2.4	62	1500	2300	—
Sept 19	—	—	—	—	—	—	—	—	—	—	—	—
Oct 7	308	297	10.7	0.22	0.16	1.5	<0.1	9.2	90	—	—	—
Oct 9	951	645	306	8.0	0.4	7.5	0.1	9.8	2540	1100	~300	~600
Nov 2	507	395	112	0.70	<0.02	3.8	<0.1	1.0	232	440,000	56,000	1600

Table E.3 Warm Weather Emery Baseflow Grab Sample Analyses (mg/l, unless otherwise noted). (Cont.) 2/2

sampling date	al	as	cd	Co	Cr	Cu	Mo	Ni	Pb	Se	Zn	spec. cond. mmhos/cm
May 16, '83	14.0	<0.03	0.01	<0.04	0.49	0.08	<0.04	0.03	<0.06	<0.03	0.45	—
June 8	0.35	<0.03	<0.01	<0.04	0.38	0.08	<0.04	<0.04	<0.04	<0.03	0.45	—
June 14	1.70	<0.03	<0.01	<0.04	0.41	0.09	<0.04	<0.02	0.12	<0.03	0.95	—
June 17	0.60	<0.03	<0.01	<0.04	0.29	0.08	<0.04	<0.03	<0.04	<0.03	0.63	—
June 17	12.0	<0.03	0.01	<0.04	0.47	0.84	<0.04	<0.03	0.79	<0.03	3.50	—
June 22	0.40	<0.03	<0.01	<0.04	0.20	0.08	<0.04	<0.02	0.08	<0.03	1.10	—
July 22	0.51	<0.03	<0.005	<0.04	0.10	0.01	<0.06	<0.03	<0.04	<0.03	0.13	—
July 26	<0.2	<0.03	0.13	<0.04	4.5	2.3	<0.04	2.0	<0.04	<0.03	1.8	—
Aug 30	12.0	<0.03	0.008	<0.04	0.58	0.33	<0.06	0.13	0.81	<0.03	1.3	—
Aug 30	—	—	—	—	—	—	—	—	—	—	—	—
Aug 31	120.0	0.04	0.019	0.07	0.56	0.96	<0.06	0.22	5.60	<0.03	4.70	—
Sept 12	0.8	<0.03	<0.004	<0.04	0.29	0.04	<0.06	<0.04	<0.04	<0.03	0.04	—
Sept 19	<0.2	<0.03	3.4	<0.04	45	7.1	<0.04	<0.04	<0.06	<0.03	0.67	—
Sept 19	<0.2	<0.03	2.5	<0.04	42	2.6	<0.04	<0.04	<0.06	<0.03	0.31	—
Oct 7	—	—	—	—	0.26	<0.02	—	—	<0.04	—	0.05	485
Oct 9	—	—	—	—	0.22	0.03	—	—	<0.04	—	0.17	940
Nov 2	0.4	<0.03	0.009	<0.01	0.05	0.05	<0.01	0.01	0.03	<0.03	0.10	600

Table E.4 Warm Weather Thistledowns Baseflow Composite (24-hr) Analyses (mg/l, unless otherwise noted) 1/2

sampling date	total residue	filtrate residue	part. residue	P	PO_4 filt. react.	TKN	NH_4	phenolics µg/l	COD	FC (#/100 ml)	FS (#/100 ml)	PA (#/100 ml)
July 27	1120	1120	<3.6	0.28	0.18	0.9	0.3	<1.4	26	35,000	28,000	1,300
July 28	1020	1020	<4.6	0.10	—	—	—	—	30	—	—	—
Aug 3	990	979	10.5	0.08	—	1.2	<0.1	—	16	—	—	—
Aug 8	967	967	<1.8	0.18	<0.06	1.9	<0.1	<0.8	16	—	—	—
Aug 15	805	—	—	<0.06	<0.02	0.6	0.1	—	18	—	—	—
Aug 24	951	951	<5.5	<0.04	<0.04	0.6	<0.1	<1.6	8	28,000	1180	4400
Sept 8	1040	—	—	—	0.12	—	—	—	28	—	—	—
Sept 29	631	624	6.9	—	<0.06	—	—	3.2	1490	33,000	2300	—

Table E.4 Warm Weather Thistledowns Baseflow Composite (24-hr) Analyses (mg/l, unless otherwise noted) (cond.) 2/2

sampling date	al	as	cd	Co	Cr	Cu	Mo	Ni	Pb	Se	Zn	spec. cond. (umhos/cm)
July 27	<0.04	<0.03	<0.001	<0.01	<0.01	0.02	<0.04	<0.01	<0.01	<0.03	0.04	—
July 28	—	—	—	—	<0.06	<0.02	—	—	0.09	—	0.11	—
Aug 3	<0.20	<0.03	<0.006	<0.04	<0.06	<0.02	<0.04	<0.04	<0.04	<0.03	<0.02	—
Aug 8	0.04	<0.03	<0.001	<0.01	<0.01	0.02	0.01	<0.01	<0.01	<0.03	0.02	—
Aug 15	—	—	—	—	—	—	—	—	—	—	—	—
Aug 24	<0.20	<0.03	<0.004	<0.04	<0.06	0.02	<0.06	<0.02	<0.04	<0.03	0.05	—
Sept 8	—	—	—	—	<0.06	0.03	—	—	<0.04	—	0.05	1380
Sept 29	—	—	—	—	<0.01	<0.02	—	—	0.03	—	0.02	—

Table E.5 Cold Weather Baseflow Analyses
(mg/l, unless otherwise noted)

	sample number	sample date	sample type	total residue (TS)	filtrable residue (TDS)	partic. residue (SS)	phosphorus as P	phosphate as P	TKN as N	NH_3 as N
Emery (Industrial)	24-hour Composite Analyses:									
	WR 6356 (1)	Jan. 31, 1984	24-hr comp.	1031	1020	11	0.38	0.26	0.7	<0.1
	WR 6362 (1)	Feb. 15, 1984	24-hr. comp.	1076	1050	26	0.16	<0.02	2.0	0.7
	WR 6366 (1)	Feb. 17, 1984	24-hr. comp.	1171	1140	31	0.25	<0.02	2.0	<0.1
	WR 6370	March 7, 1984	24-hr comp.	2563	2220	343	0.7	0.12	3.5	1.0
	WR6375	March 17, 1984	24-hr comp.	532	428	104	0.3	<0.02	1.6	<0.1
	WR 6379 (2)	March 23, 1984	24-hr. comp.	876	819	58	6.0	<0.02	4.8	<0.1
	WR 6381 (E2R)	March 29, 1984	24-hr comp.	914	890	25	0.60	<0.02	2.0	0.4
Emery composite median values:				1031	1020	31	0.38	<0.02	2.0	<0.1
	Grab Sample Analyses:									
	WR6350 (1)	Jan. 9, 1984	grab	1702	1650	52	0.15	<0.06	5.0	3.0
	WR6375	March 19, 1984	grab	628	612	16	0.25	<0.02	1.8	<0.1
	WR 6381 (E1R)	March 26, 1984	grab	1080	1020	60	0.95	—	3.5	<0.1
	WR 6381 (E3R)	March 29, 1984	grab	1260	1070	189	—	—	—	—
Emery overall median values:				1076	1020	52	0.34	<0.02	2.0	<0.1
overall minimum values:				532	428	11	0.15	<0.02	0.7	<0.1
overall maximum values:				2563	2220	343	6.0	0.26	5.0	3.0
number of analyses:				11	11	11	10	9	10	10
Thistledown (Residential)	24-hour Composite Analyses:									
	WR 6350 (2)	Jan. 9, 1984	24-hr comp.	1810	1790	20	0.16	<0.02	1.3	<0.1
	WR 6355 (2)	Jan. 30, 1984	24-hr comp.	2640	2620	19	0.16	0.08	1.3	<0.1
	WR 6356 (2)	Jan. 31, 1984	24-hr comp.	4152	4130	22	0.20	<0.06	1.4	<0.1
	WR 6366 (2)	Feb. 17, 1984	24-hr. comp.	693	666	27	0.35	0.10	1.8	<0.1
thistledown median values:				2230	2210	21	0.18	<0.05	1.4	<0.1
minimum values:				693	666	19	0.16	<0.02	1.3	<0.1
maximum values:				4152	4130	27	0.35	0.10	1.8	<0.1
number of analyses:				4	4	4	4	4	4	4
ratio of Emery median / Thistledown median				0.48	0.46	2.5	1.9	—	1.4	—

Table E.5 Cold Weather Baseflow Analyses
(mg/l, unless otherwise noted) (Contd.)

sample number	sample date	sample type	phenolics (µg/l)	COD	Fecal colif. (#/100 ml)	Fecal Strep. (#/100 ml)	Pseudo. aerug. (#/100 ml)	Cd	Cr
Emery (Industrial) 24-hour Composite Analyses									
WR 6356 (1)	Jan. 31, 1984	24-hr comp.	4.2	34	540	1720	<10	0.002	0.13
WR 6362 (1)	Feb. 15, 1984	24-hr. comp.	6.2	46	500	1200	60	<0.005	0.35
WR 6366 (1)	Feb. 17, 1984	24-hr. comp.	5.0	66	200	2000	50	0.021	0.26
WR 6370	March 7, 1984	24-hr comp.	—	264	—	—	—	0.008	0.65
WR 6375	March 17, 1984	24-hr comp.	—	162	—	—	—	<0.005	0.41
WR 6379 (2)	March 23, 1984	24-hr. comp.	8.4	74	300	3,800	~~80~~ 40	<0.005	0.30
WR 6381 (E2R)	March 29, 1984	24-hr comp.	9.8	50	780	300	1600	<0.005	0.14
Emery composite median values:			6.2	66	500	1720	~~80~~ 50	<0.005	0.35
Grab Sample Analyses:									
WR6350 (1)	Jan. 9, 1984	grab	16	—	6700	5100	460	—	0.21
WR6375	March 19, 1984	grab	3.0	68	—	—	—	0.005	0.03
WR 6381 (E1R)	March 26, 1984	grab	11	320	160	8400	20	<0.005	0.03
WR6381 (E3R)	March 29, 1984	grab	—	—	200	2800	140	—	—
Emery overall median values:			7.3	68	400	2400	~~70~~ 55	<0.005	0.24
overall minimum values:			3.0	34	160	300	<10	<0.005	0.03
overall maximum values:			16	320	6700	8400	1600	0.021	0.65
number of analyses:			8	9	8	8	8	9	10
Thistledown (Residential) 24-hour Composite Analyses									
WR 6350 (2)	Jan. 9, 1984	24-hr comp.	2.8	48	10,500	1,000	>3,000	—	<0.01
WR 6355 (2)	Jan. 30, 1984	24-hr comp.	1.2	40	11,300	1,720	~~1300~~ 60	<0.005	<0.01
WR 6356 (2)	Jan. 31, 1984	24-hr comp.	3.6	48	9,000	15,000	~~210,000~~ 110	0.001	<0.01
WR 6366 (2)	Feb. 17, 1984	24-hr. comp.	1.0	50	360	440	~~280~~ 30	<0.005	<0.01
thistledown median values:			2.0	48	9,750	1,360	85	<0.005	<0.01
minimum values:			1.0	40	360	440	30	<0.005	<0.01
maximum values:			3.6	50	11,300	15,000	>3000	0.001	<0.01
number of analyses:			4	4	4	4	4	3	4
ratio of Emery median / Thistledown median			3.7	1.4	0.04	1.8	<0.05	—	>24

Table E.5 Cold Weather Baseflow Analyses (mg/l, unless otherwise noted) (Cont.)

	sample number	sample date	sample type	Cu	Pb	Zn	Mn	total roadside chloride	cond. (umho/cm)
Emery (Industrial)	24-hour Composite Analyses								
	WR 6356 (1)	Jan. 31, 1984	24-hr comp.	0.02	0.01	0.06	<0.04	480	1870
	WR 6362 (1)	Feb. 15, 1984	24-hr. comp.	0.12	0.06	0.16	0.15	468	1900
	WR 6366 (1)	Feb. 17, 1984	24-hr. comp.	0.04	<0.02	0.19	0.15	496	2025
	WR 6370	March 7, 1984	24-hr comp.	0.18	0.28	0.48	11.5	1228	4100
	WR 6375	March 17, 1984	24-hr comp.	0.03	0.06	0.22	—	—	—
	WR 6379 (2)	March 23, 1984	24-hr. comp.	0.03	<0.04	0.10	0.13	342	—
	WR 6381 (E2R)	March 29, 1984	24-hr comp.	0.04	<0.02	0.11	0.08	374	—
Emery composite median values:				0.04	0.01	0.16	0.14	474	1960
	Grab Sample Analyses:								
	WR6350 (1)	Jan. 9, 1984	grab	0.02	0.05	0.28	0.15	948	—
	WR6375	March 19, 1984	grab	0.06	<0.04	0.14	—	—	—
	WR 6381 (E1R)	March 26, 1984	grab	0.03	<0.02	0.13	0.17	370	—
	WR 6381 (E3R)	March 29, 1984	grab	—	—	—	—	—	—
Emery overall median values:				0.04	<0.04	0.15	0.15	474	1960
overall minimum values:				0.02	<0.02	0.06	<0.04	342	1870
overall maximum values:				0.18	0.28	0.48	11.5	1228	4100
number of analyses:				10	10	10	8	8	4
Thistledown (Residential)	24-hour Composite Analyses								
	WR 6350 (2)	Jan. 9, 1984	24-hr comp.	0.01	<0.02	0.07	0.18	905	—
	WR 6355 (2)	Jan. 30, 1984	24-hr comp.	0.08	0.10	0.10	0.14	1254	—
	WR 6356 (2)	Jan. 31, 1984	24-hr comp.	0.01	0.02	0.06	0.18	2190	7400
	WR 6366 (2)	Feb. 17, 1984	24-hr. comp.	0.02	<0.02	0.06	0.07	251	1205
thistledown median values:				0.015	<0.06	0.065	0.16	1080	4,300
minimum values:				0.01	<0.02	0.06	0.07	251	1205
maximum values:				0.08	0.010	0.10	0.18	2190	7400
number of analyses:				4	4	4	4	4	2
ratio of Emery median / Thistledown median				2.7	—	2.3	0.94	0.44	0.46

Table E.6 Warm Weather Emery Stormwater Runoff Analyses (mg/l, unless otherwise noted)

1/6

storm and date	storm #	total flow (m³/ha)	total residue	filtrate residue	part. residue	P	PO4 filt. react.	TKN	NH4	NO3	phenolics (µg/l)
	2	3	4	5	6	7	8	9	10	18	
May 2	3	80.3E	661	183	478	0.95	0.24	2.6	0.4	—	5.8
May 3	4	19.5E	420	233	187	0.53	0.14	1.7	<0.1	—	27.6
May 8 A	6A (150 samples)		402	332	69.8	—	0.16	—	—	—	4.0
May 8 B	?	37.2E	—	-	—	—	—	—	-	—	—
May 9	6B (102 samples)		363	319	44.2	—	0.48	—	—	—	3.8
May 15	7	32.9	—	—	443	3.86	3.10	2.7	<0.1	—	7.0
May 23	8+9	18.7	410	293	117	—	0.13	—	—	—	7.6
May 26	10	16.7	491	297	194	1.06	0.08	8.6	0.2	—	7.8
May 30	11	43.9	254	147	107	0.45	<0.06	1.3	<0.1	—	5.6
June 1	12	40.2	684	333	351	0.70	<0.06	2.7	0.3	—	9.8
June 4	13	7.5	421	376	44.9	—	0.16	—	—	—	6.2
June 7	15	30.8	276	208	68.1	0.37	0.08	1.2	<0.1	—	4.2
June 29	17	12.7	299	268	30.8	—	0.32	—	—	—	7.0
July 3	19	1.7	463	196	267	—	0.46	—	—	—	2.6
July 7	20	6.6	—	—	—	—	0.46	—	—	—	2.6
July 31	23	6.6	709	270	439	2.15	0.34	5.3	0.3	—	6.4
July 31	24	2.6	371	319	52.4	0.82	0.32	—	—	—	—
Aug 1	25	46.0E	1487	177	1310	—	0.06	5.0	<0.1	—	3.0
Aug 4	26	12.8	378	241	137	—	1.24	1.8	0.2	—	5.4
Aug 8	27	26.0	3502	212	3290	0.84	0.12	2.3	<0.1	—	3.6

Table E.6 Warm Weather Emery Stormwater Runoff Analyses (mg/l, unless otherwise noted) (cont.)

storm avg. date	storm #	total flow (m³/ha)	COD	FC	FS	PA	10 Al	17 As	12 Cd	12 Co
				← #/100 ml		→				
May 2	3	80.3E	124	2600	52,000	—	12.0	<0.03	0.01	<0.04
May 3	4	19.5E	176	1020	11,500	—	4.0	<0.03	<0.01	<0.04
May 8 A	6A (150 samples)	37.2E	76	1080	5500	—	—	—	—	—
May 8 B	?		—	1400	2200	—	—	—	—	—
May 9	6B (102 samples)		56	1020	2800	—	—	—	—	—
May 15	7	32.9	116	540	6700	—	6.1	<0.03	<0.01	<0.04
May 23	8+9	18.7	66	1520	9700	—	—	—	—	—
May 26	10	16.7	98	1860	24,000	—	2.3	<0.03	<0.01	<0.04
May 30	11	43.9	50	3400	10,400	480	2.3	<0.03	<0.01	<0.04
June 1	12	40.2	132	5100	13,100	540	5.8	<0.03	<0.01	<0.04
June 4	13	7.5	104	2000	6600	—	—	—	—	—
June 7	15	30.8	64	8800	38,000	1000	1.4	<0.03	<0.01	<0.04
June 29	17	12.7	128	79,000	85,000	—	—	—	—	<0.02
July 3	19	1.7	190	—	—	—	6.3	<0.03	<0.005	<0.04
July 7	20	6.6	124	—	—	—	2.7	<0.03	0.007	<0.02
July 31	23	6.6	262	520,000	75,000	13,800	7.6	<0.03	0.01	<0.04
July 31	24	2.6	98	—	—	—	—	—	—	—
Aug 1	25	46.0E	228	350,000	142,000	>32,000	13.0	0.23	0.008	<0.04
Aug 4	26	12.8	110	~60,000	29,000	~35,000	1.70	<0.03	<0.004	<0.04
Aug 8	27	26.0	140	53,000	39,000	51,000	5.2	0.05	0.006	<0.04

Table E.6 Warm Weather Emery Stormwater Runoff Analyses (mg/l, unless otherwise noted) (cont.)

storm arr. date	storm #	total flow (m^3/ha)	Cr	Cu	Mo	Ni	Pb	Se	Zn	spec. cond. (umhos/cm)
May 2	3	80.3 E	0.22	0.19	<0.04	0.03	0.43	<0.03	0.92	—
May 3	4	19.5 E	0.32	0.06	<0.04	0.36	0.14	<0.03	0.26	—
May 8 A	6A (150 samples)	37.2 E	0.13	0.04	—	—	0.05	—	0.13	—
May 8 B	?		—	—	—	—	—	—	—	—
May 9	6B (10 samples)		0.30	0.04	—	—	<0.04	—	0.10	—
May 15	7	32.9	0.19	0.16	<0.04	0.05	0.24	<0.03	0.65	—
May 23	8+9	18.7	0.30	0.04	—	—	<0.06	—	0.18	—
May 26	10	16.7	0.22	0.05	<0.04	<0.02	0.09	<0.03	0.25	—
May 30	11	43.9	0.37	0.04	<0.04	<0.04	0.07	<0.03	0.16	—
June 1	12	40.2	0.27	0.10	<0.04	<0.04	0.19	<0.03	0.42	—
June 4	13	7.5	0.25	0.05	—	—	<0.04	—	0.17	—
June 7	15	30.8	0.14	0.03	<0.04	<0.04	0.04	<0.03	0.15	—
June 29	17	12.7	0.01	—	—	—	<0.04	—	0.03	—
July 3	19	1.7	4.00	0.18	<0.04	<0.03	0.30	<0.03	0.89	—
July 7	20	6.6	0.28	0.18	<0.06	<0.04	0.12	<0.03	0.48	—
July 31	23	6.6	1.80	0.43	<0.04	0.07	0.32	<0.03	1.20	—
July 31	24	2.6	1.40	0.05	—	—	—	—	0.17	—
Aug 1	25	46.0 E	2.20	0.28	<0.04	0.04	0.49	0.05	1.10	—
Aug 4	26	12.8	0.18	0.30	<0.04	0.02	0.07	<0.03	0.27	—
Aug 8	27	26.0	0.65	0.12	<0.06	0.21	0.13	0.05	0.41	—

Table E.6 Warm Weather Emery Stormwater Runoff Analyses (mg/l, unless otherwise noted) (Cont.)

storm avg. date	storm #	total flow (m³/ha)	total residue	filtrate residue	part. residue	P	PO4 filt. react.	TKN	NH4	NO3	phenolics (mg/l)
Aug 11 (combine)	(4+ samples) 28A	0.09x 41.3 3.72	259	163	95.9	—	0.12	—	<0.1	—	5.8
Aug 12	(15 samples) 28B	0.91x 37.6	245	188 186	56.9 60	5.1	<0.06 <0.06	—	<0.1	—	5.0
Aug 22	29	55.8	278	159	119	0.75	0.30	2.0	0.02	—	3.6
Aug 31	31	15.5	336	229	107	1.0	0.36	2.1	<0.1	—	4.2
Sept 16	33A		370	140	230	0.52					
Sept 16	33B		341	234	107	0.51					
Sept 16	Σ33	Σ33=79.5E	359	186	143	0.55	0.18	3.0	0.3	1.0	7.4
Sept 19	34	17.5	338	193	145	0.20	0.10	1.5	<0.1	—	1.0
Sept 21	35	37.9	272	159	113	—	0.10	—	—	0.2	5.2
Sept 26	37	2.7	283	244	38.8	1.30	0.78	2.0	0.4	—	—
Oct 4	39	39.9	386	240	146	—	1.18	—	—	—	—
Oct 5 (combine)	(202 samples) 40A	0.80x 7.5 6.0	524	135	389(?)	0.65	<0.04 <0.07	2.5	0.3	0.6	2.8
Oct 6	(49 samples) 40B	0.20x 1.5	—	207	—	—	0.2	—	—	<0.1	—
Oct 9	41	16.4	272	145	76.8	0.44	0.16	2.0	0.4	0.4	3.8
Oct 13	42	71.9	212	115	96.9	—	0.12	1.5	0.3	0.2	4.2
Oct 14	43	58.1	392	169	223	0.44	<0.04	3.6	<0.1	0.2	3.8
Oct 24	45	46.6	168	122	45.8	0.38	0.06	1.3	<0.1	0.4	3.0
Nov 3	+46A Σ46	Σ46=16.0	416	198	218	2.6	0.24	7.5	0.1	<0.1	10.0
Nov 4 (Grab)	46B		1529	1190	339	1.9	0.5	5.0	0.5	<0.1	10.6
Nov 16 snow	49		387	189	198	0.60	<0.06	2.3	<0.1	0.3	12.2

Table E.6 Warm Weather Emery Stormwater Runoff Analyses (mg/l, unless otherwise noted) (Cont.)

storm avg. date	storm #	total flow (m³/ha)	COD	FC (#/100 ml)	FS (#/100 ml)	PA (#/100 ml)	al	as	cd	co
Aug 11	28 A (4 samples)	41.3 (0.09x)	106	55,000	43,000	22,000	2.2	<0.03	<0.004	<0.04
Aug 12	28 B (15 samples)	41.3 (0.91x)	64 (68)	~49,000 (50,000)	44,000	36,000	1.6 (1.67)	<0.03	<0.005	<0.04
Aug 22	29	55.8	110	29,000	17,000	35,000	3.5	<0.03	<0.004	<0.04
Aug 31	31	15.5	136	380,000	59,000	11,000	1.7	<0.03	<0.004	<0.04
Sept 16	33A		98							
Sept 16	33A		96							
Sept 16	33 B	Σ33=79.5E	78	72,000	23,000	3500	—	—	—	—
Sept 19	34	17.5	62	70,000	55,000	9400	1.6	<0.03	<0.006	<0.04
Sept 21	35	37.9	58	31,000	106,000	8700	—	—	—	—
Sept 26	37	2.7	108	—	—	—	—	—	—	—
Oct 4	39	39.9	166	4,100	29,000	3,700	—	—	—	—
Oct 5	40 A (20 samples)	7.5 (0.80x)	58	35,000	51,000	8,900	6.7	<0.03	<0.006	<0.04
Oct 6	40 B (4 samples)	7.5 (0.20x)	100 (66)	19,000 (32,000)	230,000	5,800	—	—	—	—
Oct 9	41	16.4	80	—	—	—	—	—	—	—
Oct 13	42	71.9	196	9800	38,000	2160	—	—	—	—
Oct 14	43	58.1	76	13,400	121,000	—	—	—	—	—
Oct 24	45	46.6	148	77,000	33,000	1100	0.72	<0.03	0.002	<0.01
Nov 3	+ 46A	Σ46=16.0	384	59,000	170,000	~800	4.7	<0.03	0.011	<0.02
Nov 4	46B		[illegible]	32,000	31,000	—	5.7	<0.03	0.006	<0.01
Nov 16 snow	49		200	940	20,000	~300	<0.02	<0.03	<0.005	<0.02

Table E.6 Warm Weather Emery Stormwater Runoff Analyses (mg/l, unless otherwise noted) (Cont.)

Storm event date	Storm #	total flow (m³/ha)	Cr	Cu	Mo	Ni	Pb	Se	Zn	spec. cond. (µmhos/cm)
Aug 11	28A (64 samples)	41.3 (0.09X)	0.19	0.05	<0.06	<0.02	0.08	<0.03	0.18	—
Aug 12	28B (153 samples)	(0.91X)	0.84	0.02 (0.02)	<0.06	<0.03	<0.02 (<0.02)	<0.03	0.12 (0.13)	—
Aug 22	29	55.8	<0.06	0.07	<0.06	<0.02	0.08	<0.03	0.23	250
Aug 31	31	15.5	0.27	0.06	<0.06	<0.04	0.07	<0.03	0.21	—
Sept 16	33A									
Sept 16	33A									
Sept 16	33B	Σ33=79.5E	0.68	0.10	—	—	0.12	—	0.26	265
Sept 19	34	17.5	0.52	0.05	<0.04	<0.04	0.09	<0.03	0.18	—
Sept 21	35	37.9	0.41	0.05	—	—	0.08	—	0.19	—
Sept 26	37	2.7	—	—	—	—	—	—	—	—
Oct 4	39	39.9	0.95	0.37	—	—	0.17	—	0.58	—
Oct 5	40A (202 samples)	7.5 (0.80X)	0.50	0.10	<0.04	0.07	0.13	<0.03	0.36	225
Oct 6	40B (49 samples)	(0.20X)	0.72	0.05 (0.09)	—	—	0.11 (0.13)	—	0.21 (0.33)	340
Oct 9	41	16.4	0.49	0.06	—	—	0.05	—	0.14	240
Oct 13	42	71.9	0.37	0.04	—	—	0.09	—	0.22	225
Oct 14	43	58.1	—	—	—	—	—	—	—	300
Oct 24	45	46.6	0.06	0.03	<0.01	0.01	0.03	<0.03	0.08	215
Nov 3	+46A	Σ46=16.0	0.46	0.16	<0.01	<0.03	0.25	<0.03	0.44	305
Nov 4 (Gravel)	46B		0.16	0.11	<0.01	0.04	0.32	<0.03	0.49	2150
Nov 16 snow	49		<0.01	<0.01	<0.01	<0.01	<0.02	<0.03	<0.01	340

Table E.7 Warm Weather Thistledown Stormwater Runoff Analyses (mg/L, unless otherwise noted)

storm anal. date	storm #	unit area total flow (m³/ha)	total resid.	filterable resid.	part. resid.	P	PO4 filt. react.	TKN	NH4
July 29	24	2.4 E	823	—	—	0.53	<0.06	1.8	<0.1
Aug 2	25	2503 E	686	423	263	0.58	—	3.0	<0.1
Aug 4	—	—	—	—	—	—	—	—	—
Aug 8	27	73.6	112	84	28	0.22	0.12	1.0	0.2
combine { Aug 11	(20 samples) 28A (?)	73.4 0.23× 31.9	229	152 177	77 35	—	0.06 <0.03	—	—
Aug 12	(66 samples) 28B	24.6 ×0.77×	207	185	21.9	—	<0.02	—	<0.1
Aug 31	31	13.3	385	362	22.6	0.20	<0.04	1.9	<0.1
Sept 6	32	2.1	790	779	11	0.28	0.14	6.0	—
Sept 17	33(B)	58.8	219	202	17	—	0.02	—	—
Sept 19	34	18.8	141	130	10.8	—	<0.02	—	—
Sept 21	35	29.5	134	98.4	35.2	—	<0.04	—	—
Sept 26	37	2.4	642	636	6.4	0.13	0.10	1.3	<0.1
Oct 4	39	17.2	283	258	25.0	—	0.16	—	—
combine { Oct 5	(49 samples) 40A	3.9 0.65× 6.0	288	119	169	0.55	0.08	3.3	<0.1
Oct 6	(26 samples) 40B	2.1 0.35×	—	163	—	—	—	—	—
Oct 9	41	15.1	529	518	10.8	—	0.24	5.2	0.1
combine { Oct 12 A	42A (100 samples)	41.6 0.83× 50.1	226	207 227	18.6 16	—	<0.04 <0.04	—	—
Oct 13 B	42B (21 samples)	8.5 0.17×	327	327	<5.2	—	<0.04	—	—
Oct 14	43	32.7	377	347	29.9	0.90	0.08	20.3	<0.1
Oct 24	45	37.8	184	167	17.4	0.28	<0.04	1.4	<0.1
Nov 3	46	15.8	211	186	25.2	0.28	<0.02	1.8	<0.1
(snowmelt) Nov 7	47	—	428	421	6.8	0.16	0.14	1.2	<0.1
	(Urey) 48	31.9	188	164	24	0.38	<0.04	4.0	<0.1
Nov 14	49		286	269	17.2	—	0.06	—	—
Nov 16	49 1st half (100 samples) (?)	86.7	187	161	26.1	0.30	<0.04	1.5	<0.1
Nov 17	49 2nd half (100 samples) (?)		545	538	70.3	0.12	<0.06	0.8	<0.1

Table E.7 Warm Weather Thistledowns Stormwater Runoff Analyses (mg/l, unless otherwise noted) (Cont'd.)

storm anal. date	storm #	unit area total flow (m³/ha)	NO_3	phenolics (µg/l)	COD	FC (#/100 ml)	FS (#/100 ml)	PA (#/100 ml)
July 29	24	2.4 E	—	—	152		—	—
Aug 2	25	2503 E	—	<0.2	184	—	—	—
Aug 4	—	—	—	—	—	—	—	—
Aug 8	27	73.6	—	0.6	20	39,000	7,200	15,500
Aug 11	28A (?) (20 samples)	31.9 0.23X	—	—	74	—	—	—
Aug 12	28B (66 samples)	0.77X	—	1.2	40 48	14,000	18,000	5900
Aug 31	31	13.3	←	1.0	86	490,000	21,000	2500
Sept 6	32	2.1	—	<0.6	32	—	—	—
Sept 17	33(B)	58.8	0.3	3.4	54	131,000	79,000	—
Sept 19	34	18.8	1.0	1.2	18	1500	820	—
Sept 21	35	29.5	0.5	0.8	14	41,000	36,000	4400
Sept 26	37	2.4	—	—	36	123,000	5600	—
Oct 4	39	17.2	—	3.2	60	319,000	41,000	2900
Oct 5	40A (49 samples)	6.0 0.65X	1.8	2.0	58 48	59,000 46,000	67,000	7300 7,000
Oct 6	40B (26 samples)	0.35X	1.1	<0.4	30	23,000	95,000	6700
Oct 9	41	15.1	1.6	1.2	70	—	—	—
Oct 12 A	42A (100 samples)	50.1 0.83X	0.9	1.6	76 69	41,000 36,200	11,200	1240 1150
Oct 13 B	42B (21 samples)	0.17X	1.2	<0.2	34	12,900	5100	1060
Oct 14	43	32.7	1.3	1.2	56	8900	8900	—
Oct 24	45	37.8	0.8	1.2	54	11,700	10,900	1200
Nov 3	46	15.8	0.6	4.0	68	38,000	99,000	~160
Nov 7 (snowmelt)	47	—	1.7	<0.6	42	1500	~500	—
	48 (urban)	31.9	—	2.2	26	—	—	—
Nov 14	49		0.7	0.8	40	3100	1400	~60
Nov 16	49 1st half (100 samples) (?)	86.7	0.7	6.6	42	4600	13,000	~160
Nov 17	49 2nd half (?) (100 samples)		2.1	1.2	18	3300	2700	~180

Table E.7 Warm Weather Thistledowns Stormwater Runoff Analyses (mg/l, unless otherwise noted) (Cont.)

storm end date	storm #	unit area total flow (m³/ha)	Al	As	Cd	Co	Cr	Cu
July 29	24	2.4 E	—	—	—	—	<0.06	0.09
Aug 2	25	2503 E	7.1	<0.03	<0.006	<0.04	<0.06	0.14
Aug 4	—	—	—	—	—	—	0.04	0.04
Aug 8	27	73.6	0.93	0.03	0.004	0.04	0.06	0.02
Aug 11	28A (?) (20 samples)	31.9 (0.23x)	—	—	—	—	0.06	0.14
Aug 12	28B (66 samples)	(0.77x)	0.47	<0.03	<0.005	<0.04	<0.1	0.1 (0.11)
Aug 31	31	13.3	0.23	<0.03	<0.004	<0.04	<0.06	0.03
Sept 6	32	2.1	<0.2	<0.03	<0.004	<0.04	<0.06	0.04
Sept 17	33(B)	58.8	—	—	—	—	0.06	0.03
Sept 19	34	18.8	—	—	—	—	<0.06	<0.02
Sept 21	35	29.5	—	—	—	—	<0.06	<0.02
Sept 26	37	2.4	—	—	—	—	<0.06	0.03
Oct 4	39	17.2	—	—	—	—	<0.04	0.05
Oct 5	40A (49 samples)	6.0 (0.65x)	2.4	<0.03	<0.006	<0.04	<0.04	0.03
Oct 6	40B (26 samples)	(0.35x)	—	—	—	—	<0.04	<0.02 (<0.03)
Oct 9	41	15.1	—	—	—	—	<0.04	0.02
Oct 12 A	42A (100 samples)	50.1 (0.83x)	—	—	—	—	<0.01	0.02
Oct 13 B	42B (21 samples)	(0.17x)	—	—	—	—	0.01	0.09 (0.03)
Oct 14	43	32.7	—	—	—	—	—	—
Oct 24	45	37.8	0.2	<0.03	<0.001	<0.01	<0.01	0.02
Nov 3	46	15.8	<0.2	<0.03	<0.005	<0.02	<0.01	<0.01
(snowmelt) ~~Nov 7~~	47	—	0.15	<0.03	<0.001	<0.01	<0.01	0.02
	48 (rain)	31.9	0.08	<0.03	<0.001	<0.01	<0.01	0.01
Nov 14	49		—	—	—	—	<0.01	0.02
Nov 16	49 1st half (?) (100 samples)	86.7	0.59	<0.03	<0.005	<0.02	<0.01	0.02
Nov 17	49 2nd half (?) (100 samples)		0.25	<0.03	<0.005	<0.02	<0.01	0.01

Table E.7 Warm Weather Thistledowns Stormwater Runoff Analyses (mg/L, unless otherwise noted) (Cont.)

storm and. date	storm #	unit area total flow (m³/ha)	Mo	Ni	Pb	Se	Zn	spec. cond. (μmhos/cm)
July 29	24	2.4 E	—	—	0.14	—	0.18	
Aug 2	25	2503 E	<0.04	<0.04	0.57	<0.03	0.59	—
Aug 4	—	—	—	—	<0.04	—	0.06	—
Aug 8	[illegible]	73.6	0.06	0.02	0.04	0.03	0.04	—
Aug 11	28A (?) (20 samples)	31.9 (0.23x)	—	—	0.20	—	0.61	—
Aug 12	28B (66 samples)	(0.77x)	<0.06	<0.03	<0.02 (0.05)	<0.03	0.07 (0.19)	—
Aug 31	31	13.3	<0.06	<0.04	<0.04	<0.03	0.07	—
Sept 6	32	2.1	<0.06	<0.04	<0.04	<0.03	0.06	1200
Sept 17	33(B)	58.8	—	—	0.06	—	0.07	—
Sept 19	34	18.8	—	—	<0.06	—	0.04	—
Sept 21	35	29.5	—	—	<0.06	—	<0.06	—
Sept 26	37	2.4	—	—	<0.04	—	0.04	—
Oct 4	39	17.2	—	—	<0.04	—	0.10	—
Oct 5	40A (49 samples)	6.0 (0.65x)	<0.04	<0.02	0.15	<0.03	0.16	215
Oct 6	40B (26 samples)	(0.35x)	—	—	0.07 (0.12)	—	0.03 (0.11)	280
Oct 9	41	15.1	—	—	<0.04	—	0.04	850
Oct 12 A	42A (100 samples)	50.1 (0.83x)	—	—	0.05 (0.04)	—	0.06 (0.06)	340
Oct 13 B	42B (21 samples)	(0.17x)	—	—	0.02	—	0.08	530
Oct 14	43	32.7	—	—	—	—	—	570
Oct 24	45	37.8	<0.01	<0.01	0.02	<0.03	0.04	290
Nov 3	46	15.8	<0.01	<0.03	0.08	<0.03	0.05	300
(snowmelt) Nov 7	47	—	<0.01	<0.01	<0.02	<0.03	0.03	710
	48 (?)	31.9	<0.01	<0.01	0.03	<0.03	0.04	290
Nov 14	49	86.7	—	—	0.03	—	0.04	465
Nov 16	49 1st half (?) (100 samples)		<0.01	<0.01	0.05	<0.03	0.07	290
Nov 17	49 2nd half (?) (100 samples)		<0.01	<0.01	0.02	<0.03	0.03	880

Table E-8

Thistledowns Outfall Samples for Melting Periods

sample #	sample date	major type	event volume (m³/ha)	percent of total vol. as base (est.)	approx. snowpack age (days)
6349(2)	Jan. 6, 1984	major melt	?	0%	7
6351(1)	25	rain & daily	?	~20	16
6353(2)	26	base & daily	?	~65	17
6354(1)	27	base & daily	?	~70	18
6357(3)	Feb. 3, 1984	rain & major	38	8	25
6358(2)	6	daily & rain	59	33	26
6360(2)	13	melts & rain	150	21	33
6361(2)	14	rain & major	480	0	36
6362(2)	15	rain & major	37	23	36
6368(2)	20	rain & base	6.0	38	0
6369(2)	22	base & daily	6.5	55	<1
6376(T1R)	March 15, 1984	rain & major	69	12	18
6376(T2R)	16	rain & major	150	12	20
6376(T3R)	19	base & daily	97	65	21
6378(T25R)	21	rain & major	120	16	23
6380(1)	23	grab in baseflow	grab	grab in baseflow	27
		median values:	69	21	20
		minimum values:	6.0	0	0
		maximum values:	480	70	36
		number of analyses:	11	15	16

ratio Emery median / Thistledown median: 0.30 | 1.2 | 1.0

ratio Thistledown "base" / Thistledown "melt": — | — | —

Table E-8

Thistledowns Outfall Samples for Melting Periods (Cont.)

sample #	sample date	major type	total residue (TS)	filtrate residue (TDS)	part. residue (SS)	phosphorus as P	phosphates as P	TKN as N	NH_3 as N
6349(2)	Jan. 6, 1984	major melt	3190	3180	13	0.10	<0.06	1.7	1.2
6351(1)	25	rain & daily	4220	4170	46	0.25	<0.04	2.3	0.5
6353(2)	26	base & daily	2160	2030	126	0.18	<0.04	1.8	<0.1
6354(1)	27	base & daily	1860	1840	21	0.30	<0.06	1.5	0.4
6357(3)	Feb. 3, 1984	rain & major	5160	4770	394	1.5	<0.06	7.3	1.3
6358(2)	6	daily & rain	2270	2140	128	0.35	0.02	5.3	1.2
6360(2)	13	melts & rain	1140	1080	63	0.30	0.04	3.5	1.1
6361(2)	14	rain & major	320	198	119	0.50	<0.02	2.0	<0.1
6362(2)	15	rain & major	1480	1450	26	0.18	<0.04	1.0	0.2
6368(2)	20	rain & base	940	919	21	0.20	<0.06	1.0	<0.1
6369(2)	22	base & daily	1580	1540	35	0.19	0.02	1.7	0.1
6376(T1R)	March 15, 1984	rain & major	1580	1570	68	0.33	<0.02	3.0	0.3
6376(T2R)	16	rain & major	615	603	12	0.20	0.08	1.5	0.2
6376(T3R)	19	base & daily	1040	1040	<6	0.16	0.08	1.0	<0.1
6378(T25R)	21	rain & major	758	741	16	0.29	0.12	1.8	<0.1
6380(1)	23	grab in baseflo	1250	1230	12	0.15	<0.06	0.8	0.2
		median values:	1580	1530	30	0.23	<0.06	1.7	0.2
		minimum values:	320	198	<6	0.10	<0.02	0.8	<0.1
		maximum values:	5160	4770	394	1.5	0.12	7.3	1.3
		number of analyses:	16	16	16	16	16	16	16
		ratio Emery median : Thistledown median	0.85	0.81	3.2	2.2	>2.3	1.5	2.0
		ratio Thistledown "base" : Thistledown "melt"	1.41	1.4	0.70	0.78	—	0.82	<0.5

Table E-8

Thistledowns Outfall Samples for Melting Periods (Cont.)

sample #	sample date	major type	phenolics (µg/l)	COD	Fecal coli.	Fecal Strep.	Pseudo. aerug.	Cd	Cr
					(#/100 ml)				
6349(2)	Jan. 6, 1984	major melt	6.8	38	7,700	4,400	4,120	—	<0.01
6351(1)	25	rain & daily	10.2	46	4,300	2,300	60	—	<0.01
6353(2)	26	base & daily	2.8	28	6,500	1,900	20	—	<0.01
6354(1)	27	base & daily	1.2	26	5,500	1,900	30	—	<0.01
6357(3)	Feb. 3, 1984	rain & major	—	436	—	—	—	0.005	0.03
6358(2)	6	daily & rain	142	186	2,320	5,300	40	<0.005	0.02
6360(2)	13	melts & rain	—	106	8,300	4,700	<20	<0.005	0.01
6361(2)	14	rain & major	12.0	72	3,800	9,900	100	<0.005	0.01
6362(2)	15	rain & major	<0.4	28	400	2,300	40	<0.005	0.30
6368(2)	20	rain & base	—	26	2,040	440	20	0.008	0.05
6369(2)	22	base & daily	4.0	42	860	1,040	70	<0.005	<0.01
6376(T1R)	March 15, 1984	rain & major	202	64	2,080	940	30	<0.005	0.01
6376(T2R)	16	rain & major	1.4	34	1,180	360	10	<0.005	<0.01
6376(T3R)	19	base & daily	<0.4	34	4,300	460	<10	<0.005	<0.01
6378(T25R)	21	rain & major	—	52	1,980	720	10	<0.005	<0.01
6380(1)	23	grab in baseflo	1.2	30	300	<20	<10	<0.005	<0.01
		median values:	2.5	40	2,320	1,900	20	<0.005	<0.01
		minimum values:	<0.4	26	300	<20	<10	<0.005	<0.01
		maximum values:	142	436	8,300	9,900	4120	0.008	0.30
		number of analyses:	12	16	15	15	15	12	16
		ratio Euclid median : Thistledown median	6.0	2.4	0.13	1.3	1.5	>1.2	>35
		ratio Thistledown "base" : Thistledown "melt"	0.80	1.2	4.2	0.72	4.3	—	—

Table E.8

Thistledowns Outfall Samples for Melting Periods (Cont.)

sample #	sample date	major type	Cu	Pb	Zn	Mn	reactive chloride	cond. (umhos/cm)
6349(2)	Jan. 6, 1984	major melt	0.01	0.04	0.09	0.09	1671	—
6351(1)	25	rain & daily	0.08	0.07	0.24	0.25	2233	—
6353(2)	26	base & daily	0.05	0.09	0.11	0.20	913	—
6354(1)	27	base & daily	0.10	0.08	0.06	0.12	752	—
6357(3)	Feb. 3, 1984	rain & major	0.03	0.61	0.68	2.4	2706	8605
6358(2)	6	daily & rain	<0.01	0.34	0.38	0.45	1192	3997
6360(2)	13	melts & rain	0.06	0.17	0.24	0.13	512	2000
6361(2)	14	rain & major	0.07	0.18	0.19	0.24	73	379
6362(2)	15	rain & major	0.03	0.03	0.10	0.12	651	2560
6368(2)	20	rain & base	0.08	0.17	0.43	0.068	341	1650
6369(2)	22	base & daily	0.04	0.08	0.11	0.11	661	2710
6376(T1R)	March 15, 1984	rain & major	0.05	0.14	0.22	0.23	742	—
6376(T2R)	16	rain & major	0.03	<0.06	0.11	0.05	208	—
6376(T3R)	19	base & daily	0.02	<0.06	0.04	0.07	275	—
6378(T25R)	21	rain & major	0.02	<0.04	0.04	0.05	249	—
6380(1)	23	grab in baseflo	<0.02	<0.04	0.13	0.06	476	—
		median values:	0.04	0.09	0.12	0.12	656	2560
		minimum values:	<0.01	0.03	0.04	0.05	73	379
		maximum values:	0.10	0.61	0.68	2.4	2706	8605
		number of analyses:	16	16	16	16	16	7
		ratio Emery median / Thistledown median:	1.8	0.89	2.6	1.2	0.95	0.56
		ratio Thistledown "base" / Thistledown "melt":	0.38	<0.67	0.54	1.33	1.65	1.68

Table E.9
Emery Outfall Samples for
Melting Periods (mg/l, except as noted)

sample #	sample date	major type	event volume (m³/ha)	percent of total vol. as base (est.)	approx. snowpack age (days)
5324	Jan. 4, 1984	daily melt	18	13%	6
6348	5	major & daily	22	5	7
6349(1)	6	major melt	7.4	0	7
6351(3)	25	rain + daily	33	19	16
6353(1)	26	base + daily	7.3	66	17
6354 (3)	27	base + daily	21	72	18
6355 (1)	30	base + daily	13	65	22
6357 (6)	Feb. 4, 1984	base + rain	38	71	26
6358 (1)	6	daily + base	19	14	27
6359(1)	11	rain & major	17	12	33
6359 (2)	12	rain & major	29	54	34
6360 (1)	13	major & rain	46	29	35
6361 (1)	14	rain & major	340	0	36
6368 (1)	20	base + rain	7.3	67	0
6372 (1)	March 15, 1984	rain & major	47	2	18
6374 (E27R)	19	base & daily	1.2	70	20
6379 (1)	22	major & base	22	25	26
median values:			21	25	20
minimum values:			1.2	0	0
maximum values:			340	72	36
number of analyses:			17	17	17

ratio Emery "base" / Emery "melt" : — — —

Table E.9

Emery Outfall Samples for Melting Periods (mg/l, except as noted) (Contd.)

sample #	sample date	major type	total residue (TS)	filtrable residue (TDS)	part. residue (SS)	phosphorus as P	phosphates as P	TKN as N	NH3 as N
5324	Jan. 4, 1984	daily melt	2130	2120	13	0.32	0.22	0.8	<0.1
6348	5	major & daily	1540	1500	35	0.25	0.14	2.2	<0.1
6349(1)	6	major melt	3770	3730	38	0.30	<0.06	3.4	0.6
6351(3)	25	rain + daily	2970	2870	96	0.60	0.14	2.8	0.9
6353(1)	26	base + daily	730	722	11	0.30	0.24	1.3	<0.1
6354 (3)	27	base + daily	2690	2650	42	1.1	0.60	1.8	<0.1
6355 (1)	30	base + daily	1260	1220	38	0.45	0.24	1.8	<0.1
6357 (6)	Feb. 4, 1984	base + rain	1340	1240	95	0.25	<0.02	2.1	<0.9
6358 (1)	6	daily + base	2080	2030	46	4.90	0.08	22.8	1.0
6359(1)	11	rain & major	1570	1360	208	0.65	0.10	3.6	1.5
6359(2)	12	rain & major	760	698	66	0.50	0.34	3.1	0.9
6360(1)	13	major & rain	810	699	108	0.45	0.12	2.8	1.0
6361(1)	14	rain & major	610	344	267	0.50	0.08	2.0	0.3
6368 (1)	20	base + rain	1170	1040	131	0.55	0.16	2.5	0.4
6372 (1)	March 15, 1984	rain & major	6720	6140	581	0.78	0.22	5.8	1.8
6374 (E27R)	19	base & daily	870	365	503	0.65	0.06	2.3	<0.1
6379 (1)	22	major & base	835	691	144	0.69	<0.02	9.0	<0.1
median values:			1340	1240	95	0.50	0.14	2.5	0.4
minimum values:			610	344	11	0.25	<0.02	0.8	<0.1
maximum values:			6720	6140	581	4.90	0.60	22.8	1.8
number of analyses:			17	17	17	17	17	17	17
ratio Emery "base" / Emery "melt":			0.80	0.82	0.55	0.68	<0.14	0.80	<0.25

Table E.9

Emery Outfall Samples for Melting Periods (mg/l, except as noted) (Cont.)

sample #	sample date	major type	phenolics (µg/l)	COD	Fecal colif. (#/100 ml)	Fecal strep. (#/100 ml)	Pseudo. aerug. (#/100 ml)	Cd	Cr
5324	Jan. 4, 1984	daily melt	10.2	128	11,800	5,100	30	(0.006)	1.1
6348	5	major + daily	12.4	54	3100	5,800	20		0.35
6349(1)	6	major melt	16.0	92	1,200	7,600	120		0.49
6351(3)	25	rain + daily	18.0	96	220	2,500	20		1.80
6353(1)	26	base + daily	5.0	48	80	2,260	<20		0.50
6354 (3)	27	base + daily	16.0	126	1,400	2,520	<20		1.20
6355 (1)	30	base + daily	6.2	134	360	860	20	0.006	0.40
6357 (6)	Feb. 4, 1984	base + rain	14.0	90	80	1,060	40	0.007	0.18
6358 (1)	6	daily + base	20.0	60	80	1,400	20	0.007	0.31
6359(1)	11	rain & major	25.0	186	120	1,700	140	0.010	0.07
6359(2)	12	rain & major	16.0	78	40	1,100	60	<0.005	0.03
6360(1)	13	major & rain	14.0	82	780	1,560	20	0.006	0.04
6361(1)	14	rain & major	16.0	134	340	9,700	180	<0.005	0.24
6368 (1)	20	base + rain	(15)	92	60	1,080	10	<0.005	0.01
6372 (1)	March 15, 1984	rain & major	18.6	(94)	1,000	3,100	40	0.009	0.50
6374 (E27R)	19	base & daily	8.2	122	300	13,600	40	<0.005	0.58
6379 (1)	22	major & base	13.0	138	120	3,900	60	<0.005	0.06
median values:			15.0	94	300	2,500	30	0.006	0.35
minimum values:			5.0	48	40	860	<20	<0.005	0.01
maximum values:			25.0	186	11,800	13,600	180	0.010	1.8
number of analyses:			16	16	17	17	17	11	17
ratio Emery "base" / Emery "melt":			0.49	0.72	1.33	0.96	1.8	<0.83	0.69

Table E.9

Emery Outfall Samples for Melting Periods (mg/l, except as noted) (Cont.)

sample #	sample date	major type	Cu	Pb	Zn	Mn	reactive chloride	cond. (umhos/cm)
5324	Jan. 4, 1984	daily melt	0.07	<0.04	0.22	0.055	1121	—
6348	5	major & daily	0.03	0.03	0.53	0.10	812	—
6349(1)	6	major melt	0.04	0.07	0.79	0.10	2128	—
6351(3)	25	rain + daily	0.15	0.18	0.39	0.14	1631	—
6353(1)	26	base + daily	0.11	0.02	0.12	0.04	300	—
6354 (3)	27	base + daily	0.06	0.08	0.14	0.1	1472	—
6355 (1)	30	base + daily	0.11	0.06	0.16	0.08	621	—
6357 (6)	Feb. 4, 1984	base + rain	0.19	0.05	0.37	0.16	612	2275
6358 (1)	6	daily + base	<0.01	<0.04	0.30	0.14	1068	3690
6359(1)	11	rain & major	0.10	0.21	0.47	0.33	680	1400
6359(2)	12	rain & major	0.06	0.08	0.31	0.14	320	1300
6360(1)	13	major & rain	0.05	0.10	0.30	0.18	319	1300
6361(1)	14	rain & major	0.06	0.15	0.37	0.28	125	610
6368 (1)	20	base + rain	0.02	0.10	0.10	0.27	456	1485
6372 (1)	March 15, 1984	rain & major	0.25	0.54	0.85	0.82	3,468	10,900
6374 (E27R)	19	base & daily	0.16	0.34	0.65	0.56	134	—
6379 (1)	22	major & base	0.08	0.10	0.25	0.24	267	—
		median values:	0.07	0.08	0.31	0.14	621	1440
		minimum values:	<0.01	<0.04	0.10	0.04	125	610
		maximum values:	0.25	0.54	0.85	0.82	3,468	10,900
		number of analyses:	17	17	17	17	17	8
		ratio Emery "base" / Emery "melt"	0.57	<0.50	0.48	1.07	0.76	1.36

Emery Field Spec. Cond. and pH Measurements
(warm weather)

date of measurement	type of sample	spec. cond.	pH
May 25, 1983	storm	300	6.0
May 30	storm	150	6.2
June 1	storm	260	7.2
June 4	storm	350	6.5
June 7	storm	230	6.2
June 8	baseflow	675	7.5
June 8	baseflow	650	7.6
June 9	baseflow	750	7.4
June 14	grab	460	7.8
June 17	grab	560	7.4
June 17	grab	460	7.0
June 21	grab	540	6.7
June 28	storm	290	6.3
July 3	minor storm	300	7.3
July 5	storm	225	6.2
July 26	grab (yellow/green)	700	—
July 27	baseflow	550	6.5
July 31 am	storm	200	6.8
July 31 pm	swale storm	300	6.5
Aug 1	storm	110	6.3
Aug 3	baseflow	630	6.8
Aug 4	storm	240	6.8
Aug 9	storm	180	6.8
Aug 10	baseflow	—	6.7
Aug 11	storm	180	6.2
Aug 22	storm	260	6.6
Aug 28	storm	105	6.2
Aug 30	grab (minor storm)	300	6.8
Aug 31	storm	300	6.8
Aug 31	grab	1300	6.9
Sept 12	grab (muddy)	400	7.0
Sept 17	storm	150	6.5
Sept 19	storm	200	6.5
Sept 19	grab (yellow/grey)	550	6.6
Sept 21	storm	100	6.5
Sept 29	baseflow	500	6.7

pH
$n = 35$
$\bar{x} = 6.7$
$\sigma = 0.45$
COV = 0.07

Table E.11

Thistledown Field spec. cond. and pH analyses

date of analyses	type of sample	spec. cond.	pH
Aug 2	storm 30831	425	6.5
Aug 3	baseflow	1100	7.7
Aug 4	storm	640	6.3
Aug 8	storm ?	1225	7.2
Aug 12	storm	220	6.0
Aug 15	dry weather	1040	6.2
Aug 31	storm	455	6.9
Sept 16	storm	200	6.5
Sept 19	storm	150	6.7
Sept 21	storm	75	6.5
Sept 29	baseflow	300	7.2

$n = 11$

$\bar{x} = 6.7$

$\sigma = 0.51$

COV = 0.08

Major Ions Table E.[illegible]12

Every Baseflows	analysis date	2	spec cond	total hardness	Ca	Mg	Na	K	total alkal. as $CaCO_3$	pH	Cl	SO_4	13
10/17 Dump (1)	Sept 9		—	208.4	62.0	(1) 13.05	(2) 27.5	(2) 3.50	(1) 134.2	—	(1) 60.4	(1) 43.0	
11/17 Comp (1)	Sept 29		—	209.8	(3) 60.0	14.6	56.0	(4) 4.30	(1) 131.2	—	86.0	50.0	
12/8 Grab	Oct 7		485	—	(1) 57.0	(1) 11.3	(1) 23.3	(1) 2.00	(1) 114.4	7.30	(1) 50.6	(1) 43.0	
12/23 Dump (1)	Oct 11		940	—	(1) 59.0	(1) 11.3	146.0	4.5	345.2	8.05	(1) 77.2	57.5	
12/23 Grab Moss spills	Nov 2 Snowmelt		600	—	65.0	16.1	(3) 41.0	(3) 4.0	141.0	6.44	78.0	53.5	
11/29 Comp (1)	Nov 4		2150	—	91.0	13.3	335.0	8.1	174.4	6.86	547.0	(2) 47.0	
										7.16			
Thistledown													
11/17 Comp (2)	Sept 29		—	331.5	104.0	17.5	77.0	3.35	181.2	—	122.2	110.0	
11/29 Comp (1)	Snowmelt Nov 7		710	—	86.0	11.6	49.0	3.90	166.2	7.81	439.6	72.5	
Every Storm Runoff													
11/18 (5)	Sept 17		265	100.9	(5) 35.0	(4) 3.3	(4) 1.5	(5) 2.5	(4) 72.0	(1) 7.10	(4) 13.0	(1) 27.0	
12/6 (3)	Sept 19		—	191.1	70.0	14.0	14.7	(1) 1.75	306.4	—	19.0	33.0	
10/17 (1)	Sept 21		—	—	(4) 31.7	(3) 3.2	(1) 9.8	(4) 1.80	(1) 56.0	—	(3) 13.6	(3) 24.0	
12/6 (1)	Oct 5		225	—	(4) 37.5	(1) 2.9	(1) 8.0	(3) 1.80	* 86.6	7.40	(1) 9.0	(4) 24.5	
11/12 (1)	Oct 6		340	—	46.5	5.1	21.0	2.90	104.8	(1) 7.11	25.2	33.0	
12/23 (1)	Oct 9		240	—	(1) 31.0	(5) 3.4	(5) 12.0	* 2.55	(1) 60.8	(5) 7.37	* 17.0	(5) 26.0	
12/12 (1)	Oct 13		225	—	(2) 28.0	(3) 3.1	* 13.3	2.60	(5) 56.2	7.42	(3) 12.8	(2) 24.0	
12/12 (1)	Oct 14		300	—	38.6	4.5	16.0	3.45	93.0	7.57	25.0	27.5	
12/18 (1)	Oct 24		215	—	(1) 25.0	* 4.0	(1) 10.0	(1) 1.70	(3) 73.6	(4) 7.26	(1) 11.6	(1) 22.0	
12/23 (1)	Nov 3		305	—	39.8	5.1	143.0	15.0	89.8	7.37	21.6	29.0	
12/22 Grab (1)	Nov 16		390	—	42.5	6.2	17.3	4.4	113.8	(3) 7.25	29.0	28.0	
										(7.32)			
										(7.31)			

FOLD TO HERE

EFFICIENCY LINE

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Major Ions Table E.12 (Cont.)

	analysis date	2	spec. cond.	total hardness	Ca	Mg	Na	K	total alk.	pH	Cl	SO4	13
Thistletown Storm Runoff													
12/6 (5)	Sept 19A		—	—	154.0	(7) 4.50	(6) 16.8	(7) 2.65	(9) 90.4	—	(7) 26.2	34.0	
12/6 (6)	Sept 19B		—	—	(3) 25.5	(3) 2.60	(3) 10.0	(5) 1.30	91.2	—	(1) 14.8	(5) 27.5	
10/17 (2)	Sept 21		—	—	(1) 17.5	(1) 1.65	(1) 7.4	(1) 1.00	(1) 34.2	—	(1) 10.8	(2) 14.0	
12/16 (2)	Oct 5		(1) 215	—	(4) 29.5	(2) 2.50	(2) 8.0	(5) 2.20	(1) 52.8	(3) 7.04	(2) 11.0	(4) 22.0	
11/2 (1)	Oct 6		(2) 280	—	(7) 37.5	(3) 4.80	(3) 14.0	(1) 2.00	(3) 69.6	(4) 7.33	(4) 18.6	(1) 30.0	
12/23 (2)	Oct 9		850	—	80.0	9.80	90.0	4.70	115.0	7.84	143.6	(1) 3.5	
12/12 (1)	Oct 12A		(1) 340	—	(6) 36.0	(5) 4.30	34.5	(6) 2.50	(8) 57.8	(3) 7.20	46.8	(7) 30.0	
12/17 (3)	Oct 12B		530	—	73.5	8.80	37.0	3.35	128.8	7.98	(8) 42.6	64.5	
12/12 (2)	Oct 14		570	—	51.5	6.40	85.0	3.15	(8) 87.6	(1) 7.45	105.6	40.5	
12/8 (1)	Oct 24		(4) 290	—	(5) 34.0	4.90	(5) 16.0	(2) 1.05	90.8	(3) 7.34	(2) 21.0	31.0	
12/23 (2)	Nov 3		(5) 300	—	(7) 40.4	(6) 4.40	105.0	11.50	(6) 73.0	(3) 7.50	(9) 23.4	(5) 30.5	
11/29	Nov 14		465	—	57.5	8.00	(7) 32.0	3.50	117.4	7.59	(9) 43.8	49.5	
12/22 (1)	Nov 16		(3) 290	—	(2) 24.0	(6) 2.80	(8) 31.5	(7) 3.05	(5) 57.2	(1) 6.90	49.8	(3) 17.5	
12/22 (3)	Nov 17		880	—	108.0	17.70	71.0	4.05	220.2	7.59	98.2	100.0	
										7.43			
Receiving Waters													
Humber River (1) Mimico Park (1)	Nov 11		410	154.8	45.5	10.0	25.0	2.85	105.4	7.52	38.6	39.0	

Overall 7.37

Ions ~~Constituents~~ Table 2-1?

Major Ions for Outfall Snowmelt and Baseflow Samples (Jan. 31 to March 15, 1984)

(mg/l)

Sample	Site	Date	Ca	Mg	Na	K	Cl	SO_4	NO_3	total alkalinity (as $CaCO_3$)	pH (-)	spec. cond. (µmhos/cm)
Baseflow samples												
..56-1	Ewery	Jan. 31, 1984	56	9.4	305	2.1	480	44	0.8	105	7.3	1870
..062-1		Feb. 15	88	16	285	4.5	468	54	0.2	142	7.0	1900
..66-1		Feb. 17	104	18.8	275	4.0	496	66	<0.01	159	6.9	2025
6.70-1		Mar. 7	65	6.7	750	3.4	1228	54	0.2	177	7.1	4100
..56-2	Thistledowns	Jan. 31	168	22	1410	4.1	2190	168	4.0	281	7.7	7400
..66-2		Feb. 17	73	10.4	163	4.5	251	58	1.8	132	7.2	1205
Snowmelts (some with rain)												
..7-6	Ewery	Feb. 4	66	7.9	375	4.3	612	50	1.5	97	7.2	2275
358-1		Feb. 6	73	9.2	1360	4.4	1068	64	1.6	96	7.1	3690
..59-1		Feb. 11	68	8.5	208	6.8	680	40	0.1	75	6.8	1400
-2		Feb. 12	48	6.4	203	6.8	320	40	1.0	126	6.6	1300
..0-1		Feb. 13	54	7.3	200	3.9	319	36	1.1	89	6.9	1300
..8-1		Feb. 20	98	17.1	270	4.8	456	76	0.8	158	7.1	1485
6369-1		Feb. 22	107	23.0	325	4.6	573	79	0.4	197	7.1	2255
..372-1		Mar. 15	120	12.2	2175	6.4	3468	106	0.2	218	7.1	10,900
..57-3	Thistledowns	Feb. 3	110	8.5	3500	4.2	2706	140	0.2	156	7.4	8605
..58-2		Feb. 6	46	2.5	1510	4.0	1192	61	1.1	65	7.1	3997
..360-2		Feb. 13	60	5.6	375	3.8	512	68	2.5	90	7.0	2000
..362-2		Feb. 15	119	18.8	395	4.8	651	98	3.4	174	7.8	2560
..368-2		Feb. 20	114	16.2	206	4.0	341	90	2.8	195	7.5	1650
..369-2		Feb. 22	131	18.3	390	4.1	661	115	3.5	204	7.8	2710
6372-2		Mar. 15	96	9.5	1460	3.4	2422	106	2.5	136	7.5	7900

Table E.14 Warm Weather Dissolved Metal Observations (mg/l)

1	2	total 3 Al	filtered 4 Al	total 5 As	filtered 6 As	total 7 Cd	filtered 8 Cd	total 9 Co	filtered 10 Co
Baseflows:									
Emery	Sept 8	1.20	0.40	<0.03		<0.004		<0.04	
Emery	Sept 8								
Thistletown	Sept 8								
Stormwater Runoff:									
Emery	Sept 17								
Emery	Sept 21								
Thistletown	Sept 19								
Thistletown	Sept 21								
Receiving Waters:									
Emery Outfall Grab	Oct 31	0.30	<0.02	<0.03		<0.005		<0.02	
Emery Pond Outlet	Oct 31	<0.2		<0.03		<0.005		<0.02	
Emery 100yds from Pond	Oct 31	<0.2		<0.03		<0.005		<0.02	
Thistletown Outfall Grab	Oct 31	<0.2		<0.03		<0.005		<0.02	
Thistletown Pond Outlet	Oct 31	<0.2		<0.03		<0.005		<0.02	
Humber R @ Thistletown	Oct 31	<0.2		<0.03		<0.005		<0.02	
Humber R @ Bloor St	Oct 31	<0.2		<0.03		<0.005		<0.02	
Humber R @ QEW	Oct 31	<0.2		<0.03		<0.005		<0.02	
Humber R @ Hiwico Pt	Nov 1	<0.04		<0.03		0.001	<0.001	<0.01	

Table E.14 Warm Weather Dissolved Metal Observations (mg/l) (Cont.)

		total Cr	filtered Cr	total Cu	filtered Cu	total Mo	filtered Mo	total Ni	filtered Ni
Base flows:									
Emery	Sept 8	0.26	0.31	0.04	0.03	<0.06		<0.04	
Emery	Sept 8	0.46	0.41	0.04	0.03				
Thistletown	Sept 8	<0.06		0.02	0.03				
Stormwater Runoff:									
Emery	Sept 17	0.68	0.51	0.10	0.05				
Emery	Sept 21	0.41	0.35	0.05	<0.02				
Thistleton	Sept 19	<0.06		<0.02					
Thistleton	Sept 21	<0.06		<0.02	0.17				
Receiving Waters:									
Emery Outfall Grab	Oct 31	0.35	0.22	0.06	0.02	<0.01		<0.03	
Emery Pond Outlet	Oct 31	0.05	0.03	0.02	<0.01	<0.01		<0.03	
Emery 100 yds from Pond	Oct 31	0.02	<0.01	<0.01		<0.01		<0.03	
Thistleton Outfall Grab	Oct 31	<0.01		<0.01		<0.01	0.01	<0.03	
Thistletown Pond Outlet	Oct 31	<0.01		<0.01		<0.01		<0.03	
Humber R @ Thistleton	Oct 31	<0.01		0.01	<0.01	<0.01		<0.03	
Humber R @ Bloor St	Oct 31	<0.01		<0.01		<0.01		<0.03	
Humber R @ QEW	Oct 31	<0.01		<0.01		<0.01	0.01	<0.03	
Humber R @ Mimico Pt	Nov 1	<0.01		<0.01	0.01	<0.01		0.01	

Table E.14 Warm Weather Dissolved Metal Observations (mg/L) (Cont.)

		total Pb	filtered Pb	total Se	filtered Se	total Zn	filtered Zn
Baseflows:							
Emery	Sept 8	<0.04		<0.03		0.04	<0.04
Emery	Sept 8	<0.04				0.05	
Thistletown	Sept 8	<0.04				<0.04	0.05
Stormwater Runoff:							
Emery	Sept 17	0.12	<0.04			0.26	0.09
Emery	Sept 21	0.08	<0.06			0.19	0.07
Thistletown	Sept 19	<0.06				0.04	0.03
Thistletown	Sept 21	<0.06	0.86			0.06	0.11
Receiving Waters:							
Emery Outfall Grab	Oct 31	0.05	<0.02	<0.03		0.04	0.09
Emery Pond Outlet	Oct 31	0.02	<0.02	<0.03		0.03	0.10
Emery 100yds from Pond	Oct 31	<0.02		<0.03		0.01	0.12
Thistletown Outfall Grab	Oct 31	0.02	<0.02	<0.03		<0.01	0.01
Thistletown Pond Outlet	Oct 31	<0.02		<0.03		<0.01	0.01
Humber R @ Thistletown	Oct 31	<0.02	0.05	<0.03		<0.01	
Humber R @ Bloor St	Oct 31	<0.02	0.07	<0.03		<0.01	
Humber R @ QEW	Oct 31	<0.02	0.04	<0.03		<0.01	
Humber R @ Hwy 401	Nov 1	<0.01		<0.03		0.01	0.04

Table E-15 Cold Weather Dissolved Metal Concentrations (Outfall) (mg/l)

			Cadmium			Chromium			Copper			Lead		
		end date	total	diss.	% diss.	total	diss.	% diss.	total	diss.	% diss.	total	diss.	% diss.
Baseflow Samples:														
Emery	6362 (1)(1a)	Feb. 15, 1984	<0.005	<0.005	—	0.35	0.30	86%	0.12	0.03	25%	0.06	0.03	50%
	6366 (1)(1a)	Feb. 17	0.021	0.014	67%	0.26	0.23	88%	0.04	0.03	75%	<0.02	<0.02	—
	6375 grab	Mar 17	<0.005	0.005	—	0.41	0.37	90%	0.03	<0.02	<67%	0.06	<0.04	<67%
Thistledown	6366 (2)(2a)	Feb. 17, 1984	<0.005	<0.005	—	<0.01	<0.01	—	0.02	0.02	100%	<0.02	<0.02	—
	6380 (Grab)(1a)	Mar. 23	<0.005	<0.005	—	<0.01	<0.01	—	<0.02	0.03	?	<0.04	<0.04	—
Snowmelts (some with rain)														
Emery	6359 (2)(2a)	Feb 12, 1984	<0.005	0.002	?	0.03	0.01	33%	0.06	0.02	33%	0.08	0.01	13%
	6360 (1)(1a)	Feb 13	0.006	<0.005	<83%	0.04	0.02	50%	0.05	0.03	60%	0.10	0.05	50%
	6361 (1)(1a)	Feb 14	<0.005	<0.005	—	0.24	0.20	83%	0.06	0.03	50%	0.15	0.07	47%
	6369 (1)(1a)	Feb 22	<0.005	<0.005	—	0.02	0.01	50%	0.02	0.03	?	0.06	<0.02	<33%
	6372 (1)(1a)	Mar. 15	0.009	<0.005	<56%	0.50	0.36	72%	0.25	0.10	40%	0.54	<0.04	<7%
	6374 (E27A)(E27AR)	Mar. 19	<0.005	<0.005	—	0.58	0.45	78%	0.16	0.03	19%	0.34	<0.06	<18%
	6380 (2)	Mar 22	—	<0.005	—	—	0.04	—	—	0.04	—	—	<0.04	—
	6380 (3)	Mar 23	—	<0.005	—	—	0.28	—	—	0.04	—	—	<0.04	—
Thistledown	6360 (2)(2a)	Feb 13, 1984	<0.005	<0.005	—	0.01	<0.01	0%	0.06	0.03	50%	0.17	0.05	29%
	6361 (2)(2a)	Feb 14	<0.005	<0.005	—	0.01	<0.01	0%	0.07	0.04	57%	0.18	0.04	22%
	6362 (2)(2a)	Feb 15	<0.005	<0.005	—	0.01	<0.01	0%	0.02	0.01	50%	0.05	0.05	100%
	6369 (2)(2a)	Feb 22	<0.005	0.005	—	<0.01	0.01	?	0.04	0.05	100%	0.08	0.09	100%
	6376 (T1A)(T1AR)	Mar 15	<0.005	<0.05	—	0.01	<0.01	0%	0.05	0.03	60%	0.14	<0.06	<43%
	6376 (T2A)(T2AR)	Mar 16	<0.005	<0.05	—	<0.01	<0.01	—	0.03	0.03	100%	<0.06	<0.06	—
	6376 (T3A)(T3AR)	Mar 19	<0.005	<0.05	—	<0.01	<0.01	—	0.02	0.02	100%	<0.06	<0.06	—
	6378 (T25A)(T25AR)	Mar 21	<0.005	<0.005	—	<0.01	<0.01	—	0.02	0.03	?	<0.04	<0.04	—

Table E-15 Cold Weather Dissolved Metal Concentrations (Outfalls) (mg/l)
(Cont.)

			Zinc			Manganese			Misc. Dissolved Metals					
			total	diss.	% diss.	total	diss.	% diss.	Al	As	Co	Mo	Ni	Se
Base flow Samples:		end date												
Emery	6362 (1)(1a)	Feb. 15, 1984	0.16	0.10	63%	—	0.12	—	—	—	—	—	—	—
	6366 (1)(1a)	Feb. 17	0.19	0.14	74%	—	0.13	—	—	—	—	—	—	—
	6375 grab	Mar 17	0.22	0.06	27%	0.24	—	—	0.11	<0.03	<0.02	<0.01	<0.03	<0.03
Thistledown	6366 (2) (2a)	Feb. 17, 1984	0.06	0.02	33%	—	0.03	—	—	—	—	—	—	—
	6380 (grab) (1a)	Mar. 23	0.13	0.21	?	—	0.05	—	0.15	<0.03	<0.02	<0.01	<0.03	<0.03
Snowmelts (some with rain)														
Emery	6359 (2)(2a)	Feb 13, 1984	0.31	0.22	71%	—	0.08	—	—	—	—	—	—	—
	6360 (1)(1a)	Feb 13	0.30	0.17	57%	—	0.10	—	—	—	—	—	—	—
	6361 (1)(1a)	Feb 14	0.37	0.14	38%	—	0.10	—	—	—	—	—	—	—
	6369 (1)(1a)	Feb 22	0.15	0.16	100%	—	0.10	—	—	—	—	—	—	—
	6372 (1)(1a)	Mar. 15	0.85	0.11	13%	—	0.16	—	0.12	<0.03	<0.02	0.01	<0.03	<0.03
	6374 (E27A)(E27AR)	Mar. 19	0.65	0.04	6%	0.56	0.07	13%	0.66	<0.03	<0.02	0.01	<0.03	<0.03
	6380 (2)	Mar 22	—	0.08	—	—	0.12	—	0.08	<0.03	<0.02	<0.01	<0.03	<0.03
	6380 (3)	Mar 23	—	0.04	—	—	0.07	—	0.15	<0.03	<0.02	<0.01	<0.03	<0.03
Thistledown	6360 (2)(2a)	Feb 13, 1984	0.24	0.09	38%	—	0.09	—	—	—	—	—	—	—
	6361 (2)(2a)	Feb 14	0.19	0.07	37%	—	0.03	—	—	—	—	—	—	—
	6362 (2)(2a)	Feb 15	0.04	0.01	<25%	—	0.05	—	—	—	—	—	—	—
	6369 (2)(2a)	Feb 22	0.11	0.12	100%	—	0.09	—	—	—	—	—	—	—
	6376 (T1A)(T1AR)	Mar 15	0.22	0.07	32%	—	0.10	—	0.30	<0.03	0.02	<0.01	<0.03	<0.03
	6376 (T2A)(T2AR)	Mar 16	0.11	0.06	55%	—	0.07	—	0.92	<0.03	<0.02	0.01	<0.03	<0.03
	6376 (T3A)(T3AR)	Mar 19	0.04	0.03	75%	—	0.09	—	0.36	0.08	<0.02	<0.01	<0.03	0.15
	6378 (T25A)(T25AR)	Mar 21	0.04	0.03	75%	0.12	0.05	42%	0.09	<0.03	<0.02	<0.01	<0.03	<0.03

Table E.16 Warm Weather Phenols and Pesticides observed (ng/l) (blanks are less than detection limit)

	aldrin	A-BHC hexachlorocyclohex	B-BHC	G-BHC	A-Chlordane	G-Chlordane	Dieldrin	DMDT Methoxychlor	Endrin
Emery Sheetflow:									
Aug 22 (1)	<1	<1	<1	<1	<2	<2	<2	<5	<4
Aug 30 (2)									
Aug 30 (3)									
Aug 30 (4)		8		2					
Aug 30 (5)		10		10					
Thistledowns Baseflow:									
Aug 8		17		5	2	2	4		
Emery Baseflows:									
June 14	all ND								
June 17 A									
June 17 P									
July 26	all ND								
Aug 3									
Aug 30									
Oct 10									
Oct 11		23			NA	NA		NA	
Nov 2	all ND								

(1) Marta sheetflow #20
(2) No. Telecon Drain #SF111
(3) No. Telecon Drain #SF112
(4) No. Telecon Drain #SF 134
(5) Marta sheetflow #SF135

Table E.16 Warm Weather Phenols and Pesticides observed (ng/L) (blanks are less than detection limit) (Cont.)

	Endosulfan Sulfate	Heptachlor	PCB total (type)	PP-DDD	PP-DDE	PP-DDT	Hexa-chloro-benzene	2356 tetra-chlorophenol	penta-chlorophenol
Emery Sheetflows:									
Aug 22 (1)	<4	<1	80 (1254)	<5	5	<5	<1	90	400
Aug 30 (2)			<20					<50	500
Aug 30 (3)									450
Aug 30 (4)									500
Aug 30 (5)			190 (1254)				1		<50
Thistledowns Baseflow:									
Aug 8									280
Emery Baseflows:									
June 14									
June 17 A									80
June 17 B									50
July 26									
Aug 3									130
Aug 30			630 (1254)						500
Oct 10									100
Oct 11	NA			NA		NA			
Nov 2									

(1) Marta sheetflow #20
(2) No. Telecon Drain #SF111
(3) No. Telecon Drain #SF112
(4) No. Telecon Drain #SF134
(5) Marta sheetflow #SF135

Table E.16 Warm Weather Phenols and Pesticides observed (ng/l) (blanks are less than detection limit) (Cond.)

	aldrin	A-BHC hexachlorocyclohex	B-BHC	G-BHC	A-Chlordane	G-Chlordane	Dieldrin	DMDT Methoxychlor	Endrin
Thistledowns Stormwater Runoff:									
Aug 2	all ND								
Aug 8		9							
Aug 31		8			15	17			
Sept 17A		13		2	7	7	6	20	44
Oct 4							2		
Oct 5		1							
Oct 24				1					
Emery Stormwater Runoff:									
May 5		5		1					
June 7									
July 31									
Aug 8									
Aug 12		6							
Aug 22		5							
Sept 17		2	2	1					
Oct 5									
Oct 13		6							
Oct 14		4							
Oct 24		3							
Nov 3		10							

Table E.16 Warm Weather Phenols and Pesticides observed (ng/l) (blanks are less than detection limit) (Cont.)

	Endosulfan Sulfate	Heptachlor	PCB, total (type)	PP-DDD	PP-DDE	PP-DDT	Hexa-chloro-benzene	2356 tetra-chlorophenol	penta-chlorophenol
Thistledown Stormwater Runoff:									
Aug 2									
Aug 8									60
Aug 31		3			22				70
Sept 17A	10								50
Oct 4									120
Oct 5				5					110
Oct 24									80
Emery Stormwater Runoff:									
May 5			40 (1254)						1500
June 7									950
July 31			55 (1260)						
Aug 8			25 (1260)						630
Aug 12									530
Aug 22								60	560
Sept 17			65 (1254)						730
Oct 5									815
Oct 13			50 (1260)						900
Oct 14			75 (1260)			5			860
Oct 24					1				680
Nov 3			440 (1260)		1	5			600

Freq = 6/7 = 86%
n = 6
$\bar{x}$ = 82
σ = 28
COV = 0.34

Freq = 11/12 = 92%
n = 11
$\bar{x}$ = 796
σ = 273
COV = 0.34

Table E.16 Warm Weather Phenols and Pesticides observed (ng/L) (Cont.)

Phenols and Pesticides Analysed, But Below Detection Limits for All Samples:

Constituent	Detection limit (ng/L)
Endosulfan I	2
Endosulfan II	4
Heptachloroporite	1
Mirex	5
Oxy-Chlorodane	2
OP-DDT	5
234 Tri-Chlorophenol	100
2345 Tetra-Chlorophenol	50
245 Tri-Chlorophenol	50
246 Tri-Chlorophenol	50

Table E.17

Pesticides and Phenols Detected in Snowmelt Outfall Samples (ng/L) (all samples obtained from February 11 → 15, 1984).

Compound	detection limit (ng/L)	Baseflow (Emery) Feb. 15, 1984	Major Melts with Rain (Emery) Feb. 11, 1984	Feb. 14, 1984	(Thistledown) Feb. 13, 1984	Feb. 14, 1984
α - BHC	1	3	4	6	4	4
γ - BHC	1	—(1)	4	3	2	1
α - Chlordane	2	—	2	—	3	4
γ - Chlordane	2	—	2	—	3	10
Dieldrin	2	—	—	—	4	—
total PCBs	20	—	—	80 (2)	—	—
		6362-1	6359-1	6361-1	6360-2	6361-2

(1) not detected; see table ___ for detection limits of other compounds not detected

(2) resembled a mixture of Arcolor 1254 and 1260

October [illegible]

(Observable only)

Warm Weather

	Industrial Parking / Storage Lot Particulates (by size) <125µ	125–500	500–2000	>2000µ	Industrial Area Sheet Flow Samples WHI	Metals	Telecom	Outfall Samples Indus.	Resid.	Approx. Detection Limits Part.	Water
Volatiles:	(nanograms/gram)				(micrograms/liter)						
Benzene	15	10	7	5	6	6	5	5	5	2	1
Chlorobenzene					<2					2	1
Chloroform	18	<5	10	5	<2			5		2	1
(A)→ 1,1-Dichloroethene	<5									2	1
Trans-1,2-Dichloroethene	<5							6		2	1
1,2-Dichloropropane	<5									2	1
Trans-1,3-Dichloropropene	<5									2	1
Ethylbenzene	8	20	<5	<5					<2	2	1
Methylene Chloride	884	78	687	217	2	<2	<2	5	<2	2	1
Tetrachloroethene	60	6	<5	<5		<2	<2			2	1
1,1,2-Trichloroethane	<5									2	1
Trichloroethene	<5							2		2	1
Toluene	20	14	<5	6	<2			5	<2	2	1

	<125µ	125–500	500–2000	>2000µ	WHI	Metals	Telecom	Indus.	Resid.	Part.	Water
Base Neutrals:	(micrograms/gram)										
Acenaphthene	0.1	0.2						<2		0.01	1
Anthracene	0.3	0.3								0.01	1
Benzo (a) Anthracene	4.6	3.4								0.01	1
(B)→ Benzidine								<2		0.01	1
Bis-(2-Ethylhexyl) Phthalate	24.0	15.2	9.9	14.6	380	27	8	18	8	0.01	1
Butylbenzylphthalate	0.9	1.0	0.1		9	8	43	58	5	0.01	1
Di-N-Butylphthalate	7.7	6.0	3.4	4.0	5	4	3	4	3	0.01	1
1,3-Dichlorobenzene		0.2								0.01	1
Diethylphthalate			0.2	0.2	<2	<2	<2	20	<2	0.01	1
Dimethylphthalate					<2	<2		<2		0.01	1
2,4-Dinitrotoluene								<2		0.01	1
Dioctylphthalate	4.8	3.5	2.0	1.5	25	<2	<2	<2	<2	0.01	1
1,2-Diphenylhydrazine	0.1	0.2						<2		0.01	1
Fluoranthene	3.4	3.1	1.3	0.4				<2	<2	0.01	1
Fluorene	0.2	0.2						<2		0.01	1
Isophorone					2				2	0.01	1
N-Nitrosodiphenylamine	1.7	2.0	1.0	0.7				3		0.01	1
Phenanthrene	2.8	2.8	0.9	0.4				<2		0.01	1
Pyrene	2.4	2.0	1.1	0.5				<2		0.01	1

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Table E[illegible]

Organic Priority Pollutants (Cont.)

Acids:									
2-Nitrophenol		<2						0.01	1
4-Nitrophenol		<2						0.02	2
Pentachlorophenol			4		<2			0.01	1
Phenol		<2	<2	<2	<2	<2		0.01	1

Insert above:

(A) 1,2-Dichloroethane	<5							2	1
(B) Bis-(2-Chloroethoxy) Methane				<2				0.01	1

Notes:
- Values shown as < were less than the repeatable detection limits, but were present in the samples.
- blanks indicate not observed

19.

Table E.8

...e Priority Pollutants, Analysed, But Not Observed

	Approx. Detection Limits Parts Under (ug/g)	(ug/L)
Volatiles		
Acrolein	NA*	10
Acrylonitrile	NA	10
Bromomethane	NA	2
Bromodichloromethane	2	1
Bromoform	2	1
Carbon Tetrachloride	2	1
Chloroethane	NA	2
2-Chloroethylvinylether	2	1
Chloromethane	NA	2
Dibromochloromethane	2	1
Dichlorodifluoromethane	NA	2
1,1-Dichloroethene	2	1
Cis-1,3-Dichloropropene	2	1
1,1,2,2-Tetrachloroethane	2	1
1,1,1-Trichloroethane	2	1
Trichlorofluoromethane	NA	1
Vinyl Chloride	NA	2
Base Neutrals	(ug/g)	(ug/L)
Acenaphthene	0.01	1
Benzofluoranthene (B)(K)	0.01	1
Benzo (A) Pyrene	0.01	1
Benzo (G, H, I) Perylene	0.03	3
Bis-(2-Chloroethyl) Ether	0.01	1
Bis-(2-Chloroisopropyl) Ether	0.01	1
4-Bromophenylether	0.01	1
2-Chloronaphthalene	0.01	1
4-Chlorophenylphenylether	0.01	1
Chrysene	0.01	1
Dibenzo(A,H)Anthracene	0.03	3
1,2-Dichlorobenzene	0.01	1
1,4-Dichlorobenzene	0.01	1
3,3-Dichlorobenzidine	0.01	1
2,6-Dinitrotoluene	0.01	1
Hexachlorobenzene	0.01	1
Hexachlorobutadiene	0.01	1
Hexachloroethane	0.01	1

Hexachlorocyclopentadiene	0.01	1
Indeno(1,2,3-C,D) Pyrene	0.03	3
Naphthalene	0.01	1
Nitrobenzene	0.01	1
N-Nitrosodimethylamine	0.01	1
N-Nitrosodi-N-Propylamine	0.01	1
1,2,4-Trichlorobenzene	0.01	1
Acids	(ug/g)	(ug/L)
4-Chloro-3-Methylphenol	0.01	1
2-Chlorophenol	0.01	1
2,4-Dichlorophenol	0.01	1
2,4-Dimethylphenol	0.05	5
2,4-Dinitrophenol	0.05	5
2-Methyl-4,6-Dinitrophenol	0.05	5
2,4,6-Trichlorophenol	0.01	1
Pesticides	(ug/g)	(ug/L)
Aldrin	0.01	1
Alpha-BHC	0.01	1
Beta-BHC	0.01	1
Delta-BHC	0.01	1
Gamma-BHC	0.01	1
Chlordane	0.06	6
4,4'-DDD	0.06	6
4,4'-DDE	0.02	2
4,4'-DDT	0.06	6
Dieldrin	0.02	2
Endosulfan I	0.06	6
Endosulfan II	0.06	6
Endosulfan Sulphate	0.06	6
Endrin	0.02	2
Endrin Aldehyde	0.06	6
Heptachlor	0.01	1
Heptachlor Epoxide	0.01	1
Toxaphene	0.06	6
PCB-1016	0.06	6
PCB-1221	0.06	6

PCB-1232	0.06	6
PCB-1242	0.06	6
PCB-1248	0.06	6
PCB-1254	0.06	6
PCB-1260	0.06	6

NA* = not analysed for particulate samples

Table E.20 Mass Discharges for Every Snowmelt Runoff Events

event type:	event number:	start date	"applic" water quality sample	total volume (m^3/ha)	total residue (TS) Kg/ha	filtrate residue (TDS) kg/ha	part. residue (SS) kg/ha	phosphorus as P g/ha	phosphate as P g/ha	TKN as N g/ha	NH3 as N g/ha
D	E1	Jan. 4	WR5324	11.6	24.7	24.6	0.15	3.7	2.6	9.3	<1.2
D	E2	5	6348	15.1	23.3	22.7	0.53	3.8	2.1	33.2	<1.5
M	E3	5	6348/49	21.9	58.1	57.3	0.80	6.0	1.5	61.3	6.6
D	E4	13	6349	1.78	6.7	6.6	0.07	0.53	<0.1	6.1	1.1
D	E5	17	6349	2.00	7.5	7.5	0.08	0.60	<0.01	6.8	1.2
rain/M	E6	24	6351	16.6	49.3	47.6	1.59	10.0	2.3	46.5	14.9
D	E7	25	6351	10.2	30.3	29.3	0.98	6.1	1.4	28.6	9.2
D	E8	27	6353/54	8.24	14.1	13.9	0.22	5.8	3.5	12.8	<0.8
D	E9	30	6355	4.63	5.8	5.6	0.18	2.1	1.1	8.3	<0.5
	total January:			92.1	220	215	4.6	39	15	210	32
rain/M	E10	Feb. 3	6357	24.9	33.4	30.9	2.4	6.2	<0.5	52.3	<22
D	E11	4	6358	16.6	34.5	33.7	0.76	81	1.3	380	17
D	E12	5	6358	6.56	13.6	13.3	0.30	32	0.5	150	6.6
M	E13	10	6359(1)	6.20	9.7	8.4	1.3	4.0	0.62	22	9.3
rain/M	E14	11	6359(2)	21.3	16.2	14.9	1.4	10.7	7.2	66	19
M	E15	12	6360	24.5	19.8	17.1	2.6	11.0	2.9	69	25
rain/M	E16	13	6361	348	212	120	93	174	27.8	696	104
rain	E19*	19	6368	2.56	3.0	2.7	0.34	1.4	0.41	6.4	1.0
D	E20	25	6368	4.51	5.3	4.7	0.59	2.5	0.72	11.3	1.8
D	E21	26	6368	2.73	3.2	2.8	0.36	1.5	0.44	6.8	1.1
	total February:			458	351	249	103	324	42	1460	185
D	E22	March 14	6372	4.65	31	29	2.7	3.6	1.0	27	8.4
rain/M	E23	15	6372	103	692	632	60	80	23	600	190
D	E24	16	6374	2.86	2.5	1.0	1.4	1.9	0.17	6.6	<0.3
D	E25	17	6374	2.89	2.5	1.1	1.5	1.9	0.17	6.7	<0.3
rain/M.	E26	21	median	140	187	174	13.3	70	20	350	56
M	E27	22	6379	21.6	18	15	3.1	15	<0.4	190	<2
	total March:			275	933	852	82	171	44	1180	254

E17 & E18 are baseflows

D = daily afternoon melt

M = major melt period

rain = rain with usually no snowpack

rain and major melt period

Table E.20 Mass Discharges for Every Snowmelt Runoff Events (Cont.)

event type:	event number:	start date	"applic" water quality sample	total volume (m^3/ha)	phenols (μg/L) g/ha	COD kg/ha	Fecal colif. (#/100 ml) $\times 10^6$/ha	Fecal strep.	Pseudo. aerug.	Cd g/ha	Cr g/ha
D	E1	Jan. 4	WR5324	11.6	0.12	1.5	1,400	590	3.5	0.07	12.8
D	E2	5	6348	15.1	0.19	0.82	470	876	4.5	0.09	5.3
M	E3	5	6348/49	21.9	0.31	1.6	470	1,500	6.6	0.13	9.2
D	E4	13	6349	1.78	0.03	0.16	21	135	0.5	0.01	0.87
D	E5	17	6349	2.00	0.03	0.18	24	152	0.6	0.01	0.98
rain/M	E6	24	6351	16.6	0.30	1.59	36	415	5.0	0.10	29.9
D	E7	25	6351	10.2	0.18	0.98	22	255	3.1	0.06	18.4
D	E8	27	6353/54	8.24	0.09	0.72	61	197	2.5	0.05	7.0
D	E9	30	6355	4.63	0.03	0.62	17	40	1.4	0.03	1.9
total January:				92.1	1.3	8.2	2,500	4,200	27.7	0.55	86
rain/M	E10	Feb. 3	6357	24.9	0.35	2.2	20	264	7.5	0.17	4.5
D	E11	4	6358	16.6	0.33	1.0	13	232	5.0	0.12	5.2
D	E12	5	6358	6.56	0.13	0.39	5.2	92	2.0	0.05	2.0
M	E13	10	6359(1)	6.20	0.16	1.2	7.4	105	1.9	0.06	0.4
rain/M	E14	11	6359(2)	21.3	0.34	1.7	8.5	234	6.4	<0.1	0.6
M	E15	12	6360	24.5	0.34	2.0	191	382	7.4	0.15	1.0
rain/M	E16	13	6361	348	5.6	46.6	1180	33,800	104	<17	84
rain	E19*	19	6368	2.56	0.04	0.24	1.5	28	0.8	<0.01	0.03
D	E20	25	6368	4.51	0.07	0.41	2.7	49	1.4	<0.02	0.05
D	E21	26	6368	2.73	0.04	0.25	1.6	29	0.8	<0.01	0.03
total February:				458	7.4	55.9	1430	[illegible]	137	0.55	98
D	E22	March 14	6372	4.65	0.08	0.44	47	144	1.4	0.04	2.3
rain/M	E23	15	6372	103	1.9	9.7	1,030	3,190	30.9	0.93	52
D	E24	16	6374	2.86	0.02	0.35	8.6	390	0.9	<0.01	1.7
D	E25	17	6374	2.89	0.02	0.35	8.7	390	0.9	<0.01	1.7
rain/M	E26	21	median	140	2.1	13.2	420	350	42.0	0.84	49
M	E27	22	6379	21.6	0.28	3.0	26	842	6.5	<0.1	1.3
total March:				275	4.4	27.0	1540	5310	83	1.8	108

Table E.20 Mass Discharges for Every Snowmelt Runoff Events (Contd.)

event type:	event number:	start date	"applic" water quality sample	total volume (m³/ha)	Cu g/ha	Pb g/ha	Zn g/ha	Mn g/ha	reactive chlorides kg/ha
D	E1	Jan. 4	WR5324	11.6	0.81	<0.46	2.6	0.64	13.0
D	E2	5	6348	15.1	0.45	0.45	8.0	1.5	12.3
M	E3	5	6348/49	21.9	0.77	1.1	14	2.2	32.2
D	E4	13	6349	1.78	0.07	0.12	1.4	0.18	3.8
D	E5	17	6349	2.00	0.08	0.14	1.6	0.20	4.3
rain/M	E6	24	6351	16.6	2.5	3.0	6.5	2.3	27.1
D	E7	25	6351	10.2	1.5	1.8	4.0	1.4	16.6
D	E8	27	6353/54	8.24	0.70	0.41	1.1	0.58	7.3
D	E9	30	6355	4.63	0.51	0.28	0.74	0.37	2.9
total January:				92.1	7.4	7.5	40	9.4	120
rain/M	E10	Feb. 3	6357	24.9	4.7	1.3	9.2	4.0	15.2
D	E11	4	6358	16.6	<0.2	<0.7	5.0	2.3	17.7
D	E12	5	6358	6.56	<0.1	<0.3	2.0	0.92	7.0
M	E13	10	6359(1)	6.20	0.6	1.3	2.9	2.1	4.2
rain/M	E14	11	6359(2)	21.3	1.3	1.7	6.6	3.0	6.8
M	E15	12	6360	24.5	1.2	2.5	7.4	4.4	7.8
rain/M	E16	13	6361	348	21	52	129	97.4	43.5
rain	E19*	19	6368	2.56	0.05	0.26	0.26	0.69	1.2
D	E20	25	6368	4.51	0.09	0.45	0.45	1.2	2.1
D	E21	26	6368	2.73	0.05	0.27	0.27	0.74	1.2
total February:				458	29.0	59.8	163	117	107
D	E22	March 14	6372	4.65	1.2	2.5	4.0	3.8	16
rain/M	E23	15	6372	103	26	56	88	84	357
D	E24	16	6374	2.86	0.46	1.0	1.9	1.6	0.38
D	E25	17	6374	2.89	0.46	1.0	1.9	1.6	0.39
rain/M.	E26	21	median	140	9.8	11.2	43	20	87
M	E27	22	6379	21.6	1.7	2.2	5.4	5.2	5.8
total March:				275	39.6	73.9	144	116	467

Table E-21 Mass Discharges for Thistledowns Snowmelt Runoff Events

event type:	event number:	start date	"applic." water quality sample	total volume (m³/ha)	total residue (TS) kg/ha	filtrate residue (TDS) kg/ha	part residue (SS) kg/ha	phosphorus as P g/ha	phosphate as P g/ha	TKN as N g/ha	NH3 as N g/ha
D	TD1	Feb. 2, 1984	6357	2.3	11.9	11.0	0.91	3.5	<0.1	16.8	3.0
rain/M	TD2	3	6357/58	48.9	182	169	13	45	0.5	310	61
D	TD3	4	6358	13.3	30.2	28.5	1.7	4.7	0.3	70.5	16.0
D	TD4	5	6358	10.1	22.9	21.6	1.3	3.5	0.2	53.5	12.1
D	TD5	10	6360	4.5	5.1	4.9	0.3	1.4	0.2	15.8	5.0
rain/M	TD6	11	6360	56.1	63.9	60.6	3.5	16.8	2.2	196	61.7
M	TD7	12	6360	59.2	67.5	63.9	3.7	17.8	2.4	207	65.1
rain/M	TD8	13	6361	512	163.8	101.4	60.9	256	<10.2	1024	<51
rain	TD12*	19	6368	3.7	3.5	3.4	0.1	0.74	<0.2	3.7	<0.4
D	TD13	21	6369	2.9	4.6	4.5	0.1	0.55	0.1	4.9	0.3
D	TD14	25	median	6.8	10.7	10.4	0.2	1.6	<0.4	11.6	1.4
total February:				720	566	479	86	352	5.9	1910	224
D	TD15	March 3, 1984	median	2.0	3.2	3.1	0.1	0.5	<0.1	3.4	0.4
D	TD16	4	median	3.2	5.1	4.9	0.1	0.7	<0.2	5.4	0.6
D	TD17	6	median	8.7	13.7	13.3	0.3	2.0	<0.5	14.8	1.7
D	TD18	14	6376(T1R)	6.4	10.1	9.7	0.4	2.1	<0.1	19.2	1.9
rain/M	TD19	15	6376(T1R)	9.8	15.5	14.8	0.7	3.2	<0.2	29.4	2.9
rain/M	TD20	16	6376(T2R)	176	108	106	2.1	35.2	14.1	264	35.2
D	TD21	17	6376(T3R)	33.7	35	35	<0.2	5.4	2.7	33.7	<3.4
M	TD23*	20	6378	24.6	19	18	0.4	7.1	3.0	44.3	<2.5
rain/M	TD24	21	6378	405	307	300	6.5	117	49	729	<41
M	TD25	22	6378	103	78	76	1.6	30	12	185	<10
D	TD26	24	median	27.7	44	42	0.8	6.4	<2	47	5.5
D	TD27	25	median	22.9	36	35	0.7	5.3	<1	39	4.6
total March:				822	675	658	13.7	215	81	1410	52

* TD 9, 10, 22 are baseflow events

D = daily afternoon melts

M = major melt period

rain = rain, with no snowpack to melt

rain/M = rain and major melt period

Table E-21 Mass Discharges for Thistledowns Snowmelt Runoff Events (Cont.)

event type:	event number:	start date	"applic." water quality sample	total volume (m³/ha)	phenols (g/ha)	COD (kg/ha)	Fecal coliforms (← 10^6/ha)	Fecal Strep.	Pseudo aerug (→)	Cd (g/ha)	Cr (g/ha)
D	TD1	Feb. 2, 1984	6357	2.3	0.01	1.0	53	44	0.5	0.01	0.07
rain/M	TD2	3	6357/58	48.9	6.9	15.2	1130	2590	9.8	0.12	1.2
D	TD3	4	6358	13.3	1.9	2.5	309	705	2.7	<0.07	0.27
D	TD4	5	6358	10.1	1.4	1.9	234	535	2.0	<0.05	0.20
D	TD5	10	6360	4.5	0.01	0.48	374	212	0.9	<0.02	0.05
rain/M	TD6	11	6360	56.1	0.14	5.9	4660	2640	11.2	<0.3	0.56
M	TD7	12	6360	59.2	0.15	6.3	4910	2780	11.8	<0.3	0.59
rain/M	TD8	13	6361	512	6.1	36.9	19,500	50,700	102	<2.6	5.1
rain	TD12*	19	6368	3.7	0.01	0.1	75	16	0.7	0.03	0.2
D	TD13	21	6369	2.9	0.01	0.1	25	30	0.6	<0.01	<0.03
D	TD14	25	median	6.8	0.02	0.3	158	129	1.4	<0.03	<0.07
total February:				720	16.7	71	31,400	60,400	144	0.2	8.2
D	TD15	March 3, 1984	median	2.0	0.01	0.08	46	38	0.4	<0.01	<0.02
D	TD16	4	median	3.2	0.01	0.13	74	61	0.6	<0.02	<0.03
D	TD17	6	median	8.7	0.02	0.35	202	165	1.7	<0.04	<0.09
D	TD18	14	6376(T1R)	6.4	0.01	0.41	133	60	1.3	<0.03	0.06
rain/M	TD19	15	6376(T1R)	9.8	0.02	0.63	204	92	2.0	<0.05	0.10
rain/M	TD20	16	6376(T2R)	176	0.25	6.0	2080	630	35.2	<0.9	<1.8
D	TD21	17	6376(T3R)	33.7	<0.01	1.1	1450	155	6.7	<0.2	<0.3
M	TD23*	20	6378	24.6	0.06	1.3	487	177	4.9	<0.1	<0.3
rain/M	TD24	21	6378	405	1.0	21.1	8010	2920	81	<2.0	<4.1
M	TD25	22	6378	103	0.26	5.4	2040	742	20.6	<0.5	<1.0
D	TD26	24	median	27.7	0.07	1.1	643	526	5.5	<0.1	<0.3
D	TD27	25	median	22.9	0.06	0.9	531	435	4.6	<0.1	0.2
total March:				822	1.8	39	15,900	6000	165	—	0.4

Table E.21 Mass Discharges for Thistledowns Snowmelt Runoff Events (Cont.)

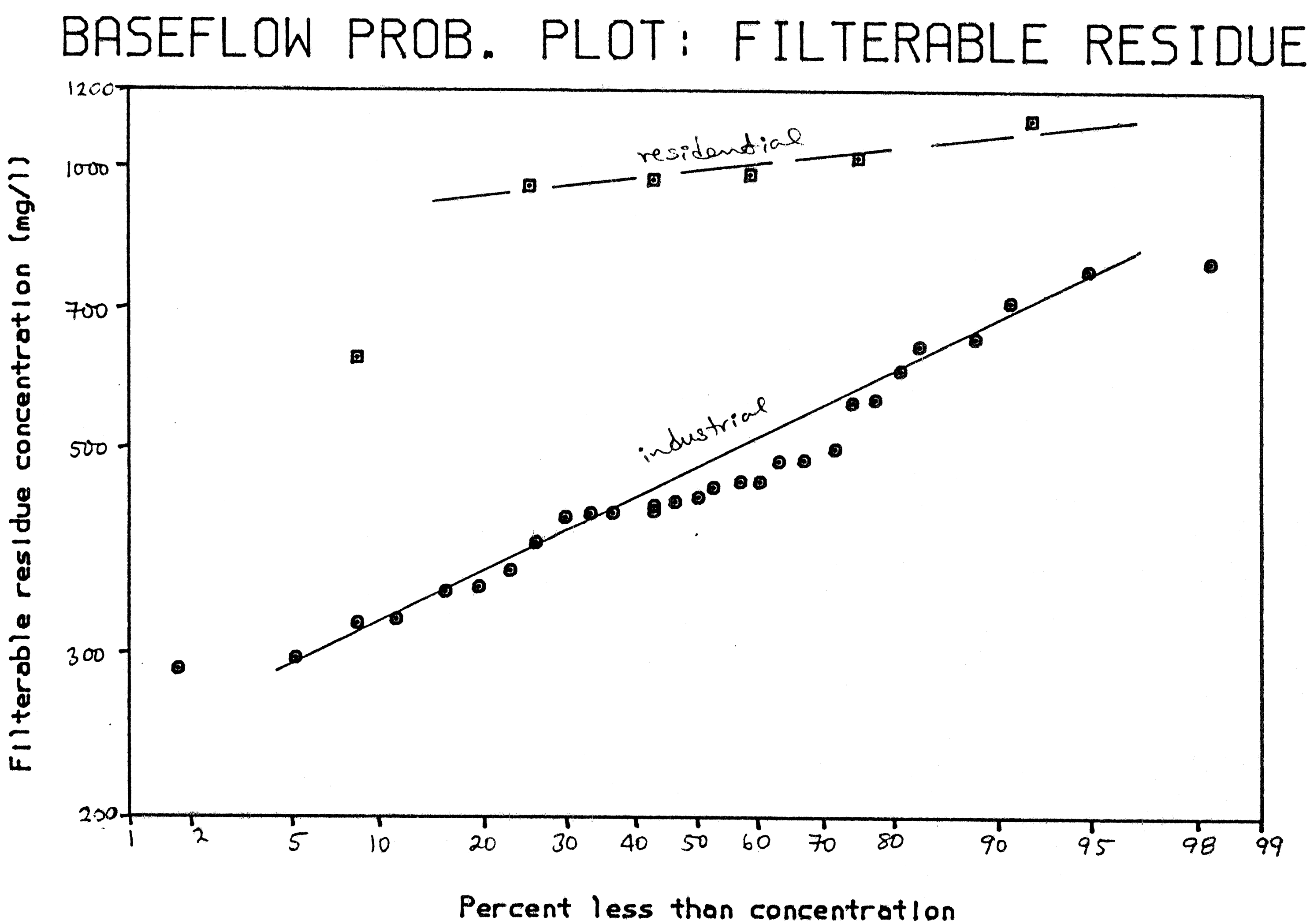
event type:	event number:	start date	"applic." water quality sample	total volume (m³/ha)	Cu g/ha	Pb g/ha	Zn g/ha	Mn g/ha	reactive chloride kg/ha
D	TD1	Feb. 2, 1984	6357	2.3	0.07	1.4	1.6	5.5	6.2
rain/M	TD2	3	6357/58	48.9	0.73	23.2	25.9	69.7	95.3
D	TD3	4	6358	13.3	<0.13	4.5	5.1	6.0	15.9
D	TD4	5	6358	10.1	<0.1	3.4	3.8	4.6	12.0
D	TD5	10	6360	4.5	0.27	0.77	1.1	0.59	2.3
rain/M	TD6	11	6360	56.1	3.4	9.5	13.5	7.3	28.7
M	TD7	12	6360	59.2	3.6	10.1	14.2	7.7	30.3
rain/M	TD8	13	6361	512	35.8	92.2	97.3	122.9	37.4
rain	TD12*	19	6368	3.7	0.3	0.6	1.6	0.3	1.3
D	TD13	21	6369	2.9	0.1	0.2	0.3	0.3	1.9
D	TD14	25	median	6.8	0.3	0.6	0.82	0.82	4.5
total February:				720	45	146	165	230	236
D	TD15	March 3, 1984	median	2.0	0.08	0.18	0.24	0.24	1.3
D	TD16	4	median	3.2	0.13	0.3	0.38	0.38	2.1
D	TD17	6	median	8.7	0.35	0.78	1.0	1.0	5.7
D	TD18	14	6376(T1R)	6.4	0.32	0.90	1.4	1.5	4.7
rain/M	TD19	15	6376(T1R)	9.8	0.49	1.4	2.7	2.3	7.3
rain/M	TD20	16	6376(T2R)	176	5.3	<10.6	19.4	8.8	36.6
D	TD21	17	6376(T3R)	33.7	0.67	<2.0	1.4	2.4	9.3
M	TD23*	20	6378	24.6	0.49	<1.0	1.0	1.2	6.1
rain/M	TD24	21	6378	405	8.1	<16	16	20.3	100
M	TD25	22	6378	103	2.1	<4	4.1	5.2	26
D	TD26	24	median	27.7	1.1	2.5	3.3	3.3	18
D	TD27	25	median	22.9	0.9	2.1	2.8	2.8	15
total March:				822	20	8.2	53	49	232

Table E.22 Winter Baseflow Discharges by Month

	total volume (m³/ha)	total residue (TS) kg/ha	filterable residue (TDS) kg/ha	particulate residue (SS) kg/ha	phosphorus as P g/ha	phosphates as P g/ha	TKN as N g/ha	NH3 as N g/ha	phenols g/ha	COD kg/ha
Thistledown										
February	299	667	661	6.3	53.8	<15	419	<30	0.6	14.4
March	527	1180	1160	11	94.9	<26	738	<53	1.1	25.3
Emery										
January	162	174	165	8.4	55	<3	320	<16	1.2	11.0
February	237	255	242	12.3	81	<5	474	<24	1.7	16.1
March	259	279	264	13.5	88	<5	520	<26	1.9	17.6

	FC	FS	PA	Cd	Cr	Cu	Pb	Zn	Mn	reactive chlorides
	← 10^6/ha		→	←		g/ha			→	kg/ha
Thistledowns										
February	29,200	4070	254	<1.5	<3	4.5	<18	19	48	320
March	51,400	7,170	447	<2.6	<5	7.9	<32	34	84	570
Emory										
January	650	3900	89	<0.8	39	6.5	<6.5	24	24	76.8
February	950	5700	130	<1.2	57	9.5	<9.5	36	36	112
March	1040	6220	142	<1.3	62	10.4	<10	39	39	123

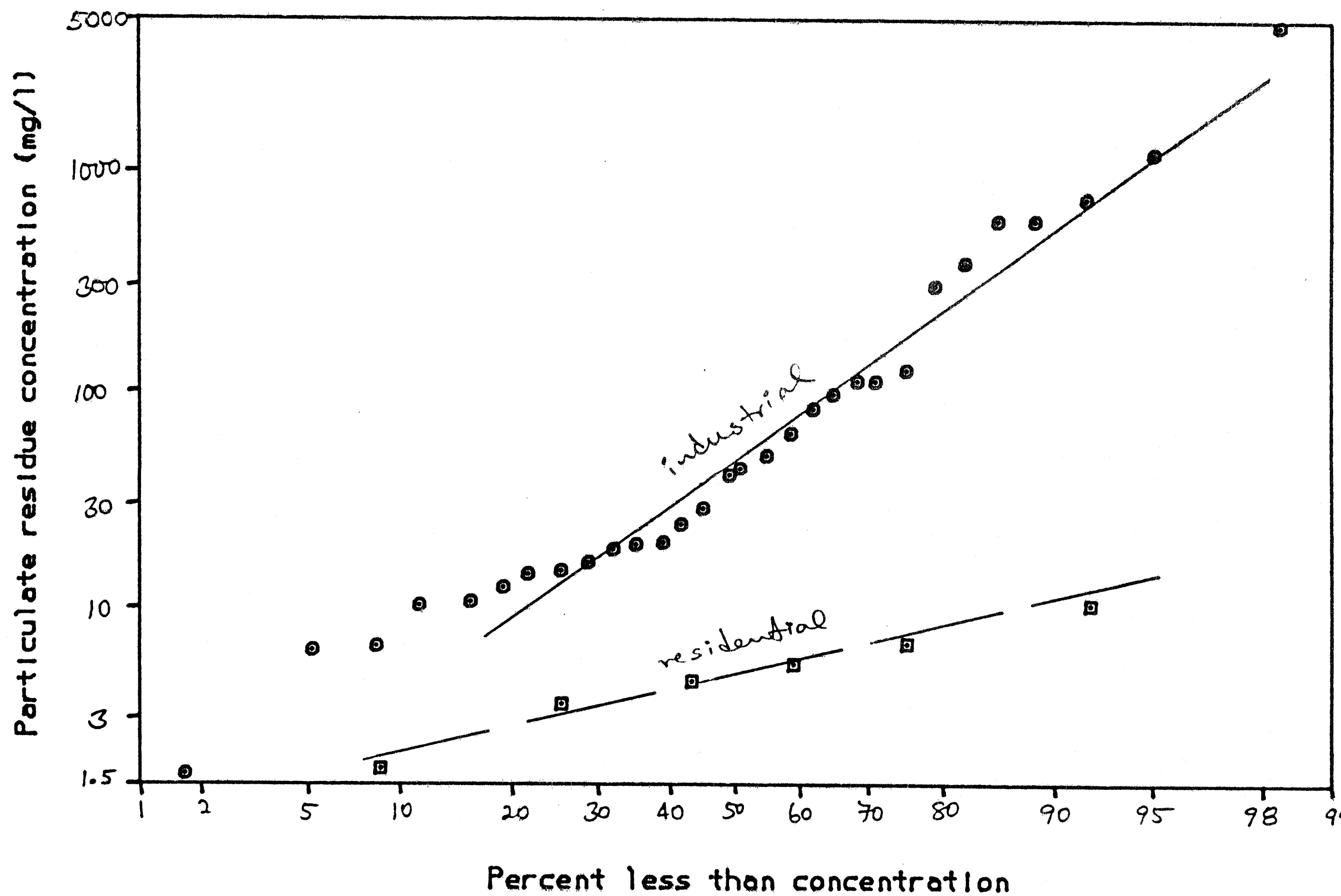
Figure E-1



10/27/84
BTDST/LOG
BTDSE/LOG

Figure E.2

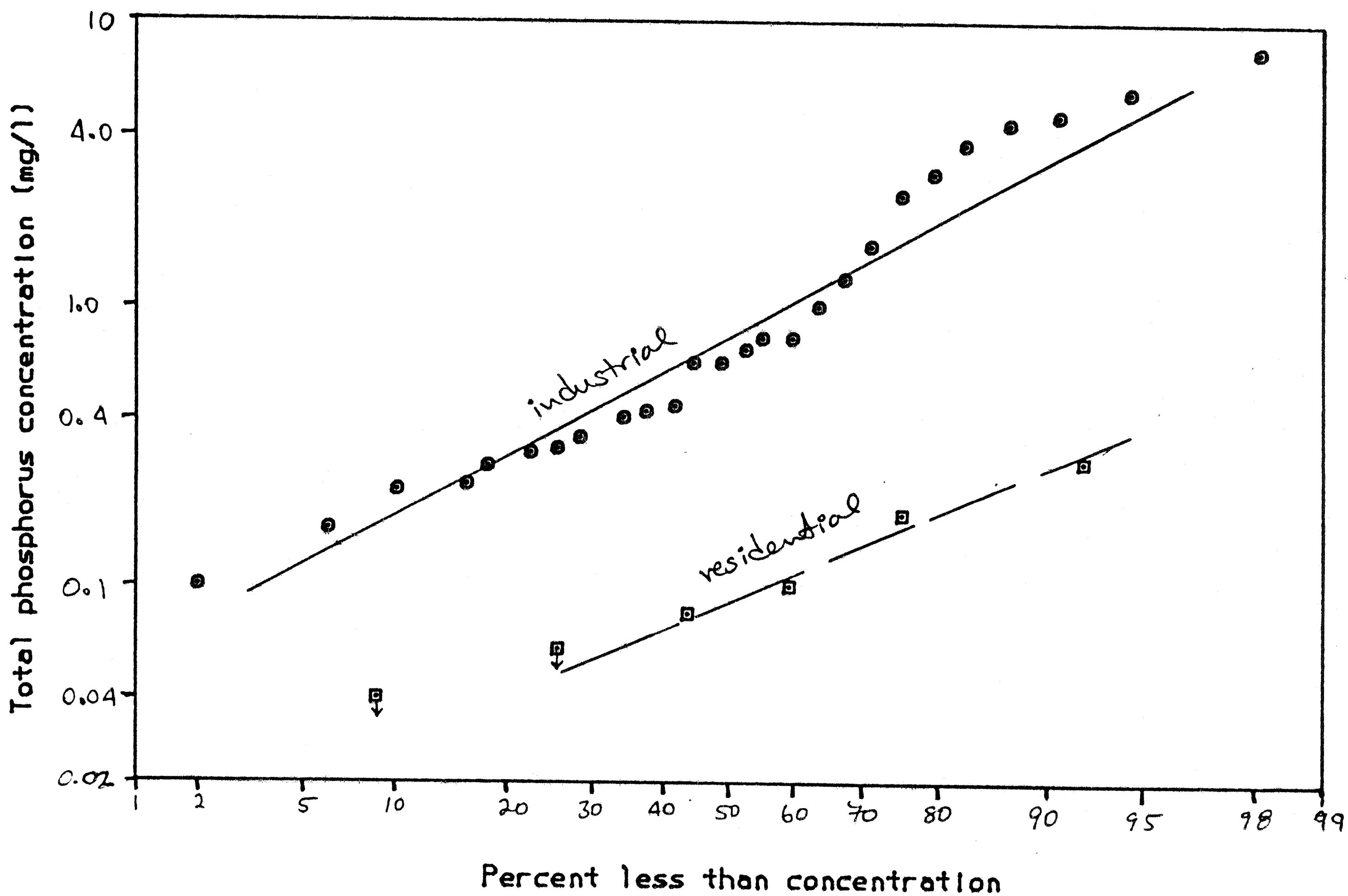
BASEFLOW PROB. PLOT: PARTICULATE RESIDUE



10/27/84
BSST/LOG
BSSE/LOG

Figure E-3

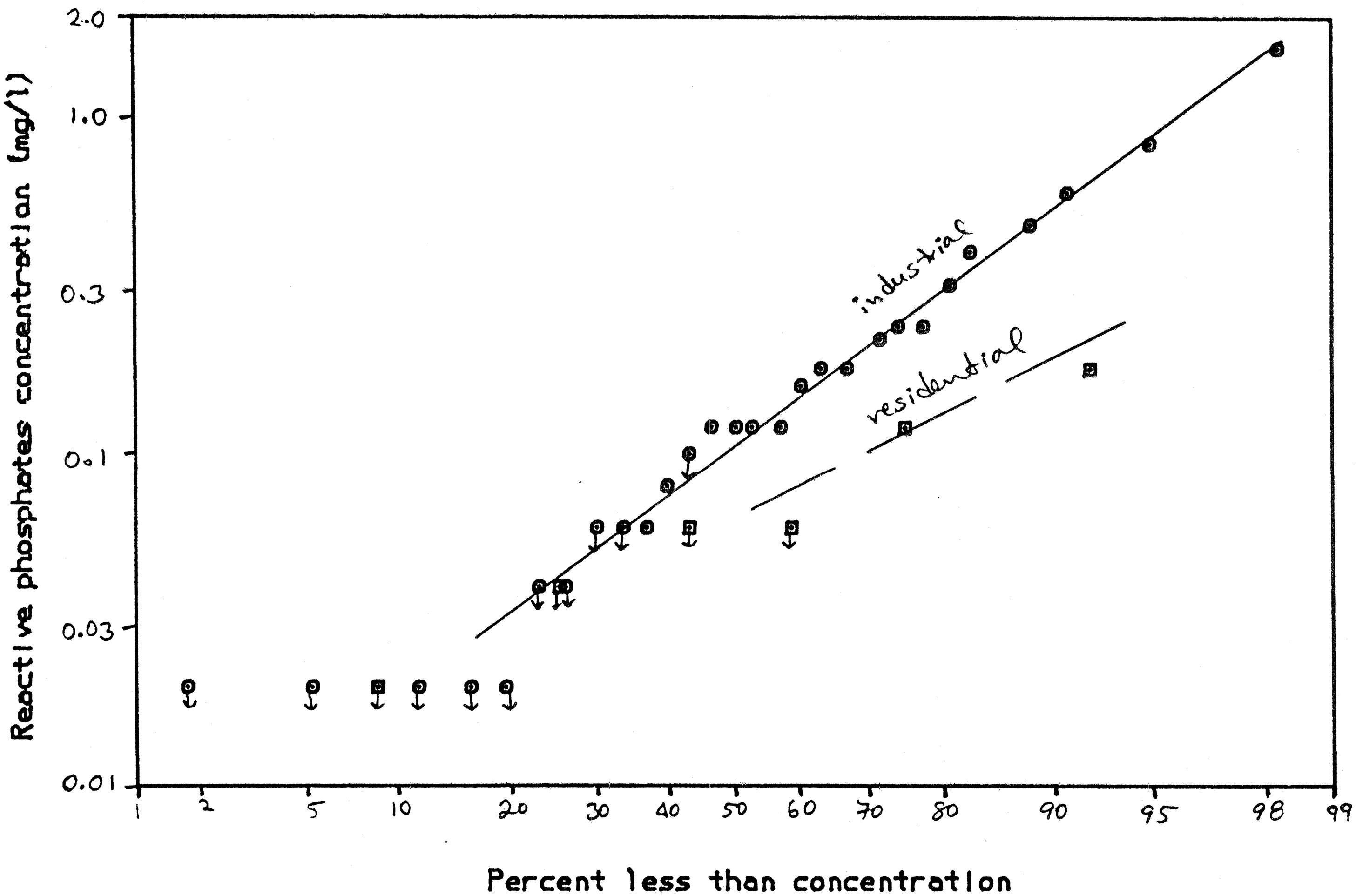
BASEFLOW PROB. PLOT: TOTAL PHOSPHORUS



10/27/84
BPT/LOG
BPE/LOG

Figure E.4

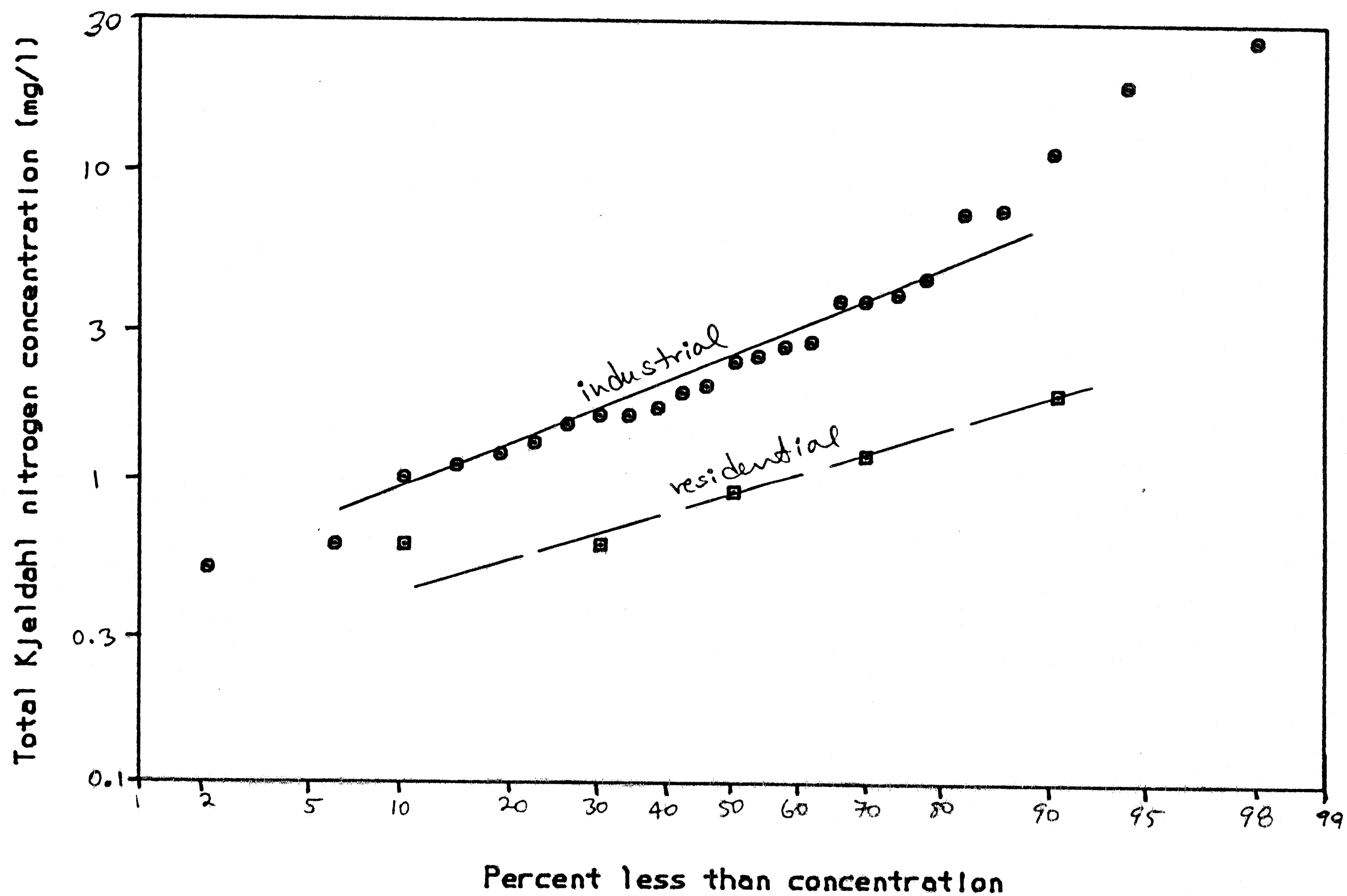
BASEFLOW PROB. PLOT: REACT. PHOSPHATES



10/27/84
BPO4E/LOG
BPO4T/LOG

Figure E.5

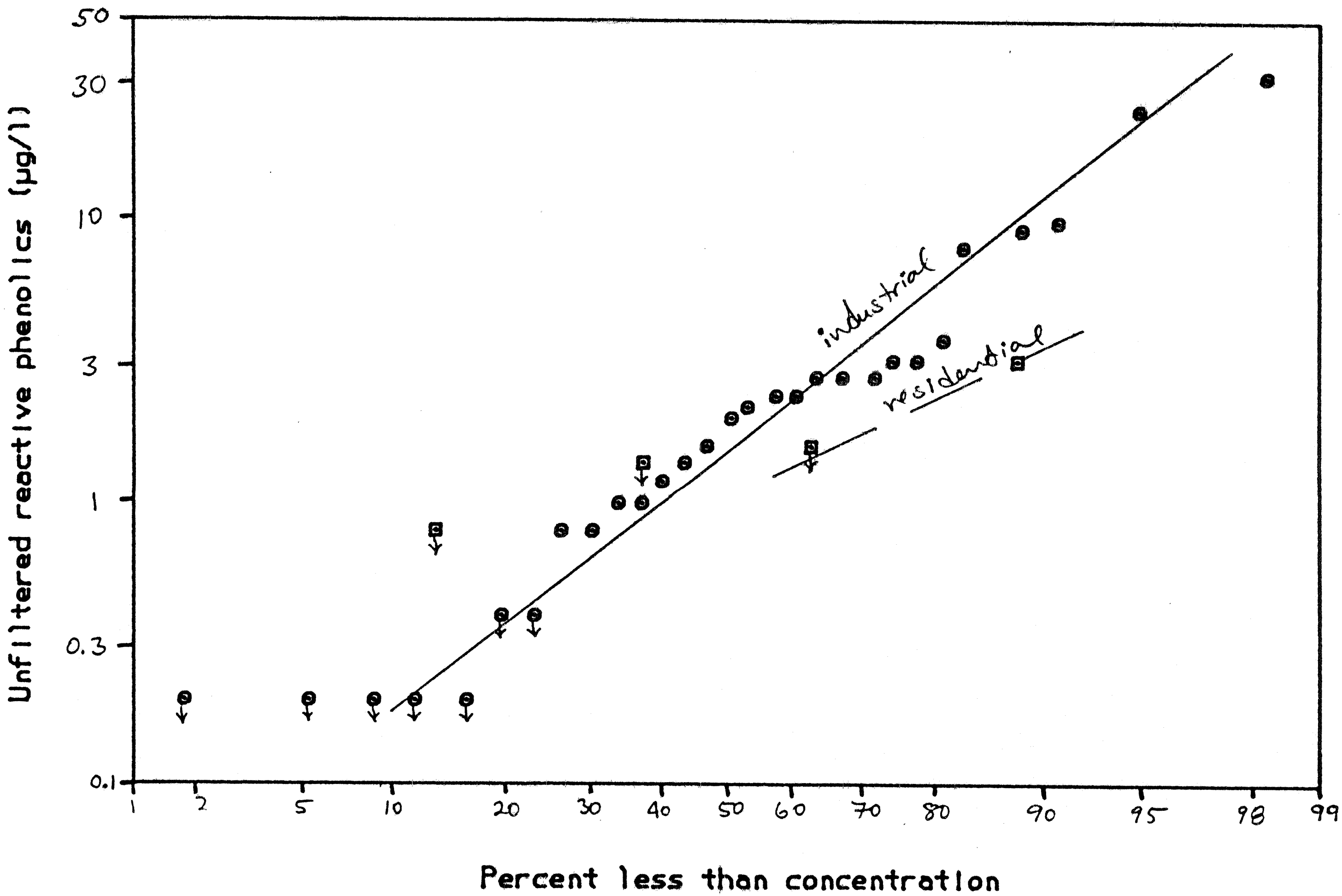
BASEFLOW PROB. PLOT: TOTAL KJELDAHL N



10/27/84
BTKNT/LOG
BTKNE/LOG

Figure E-6

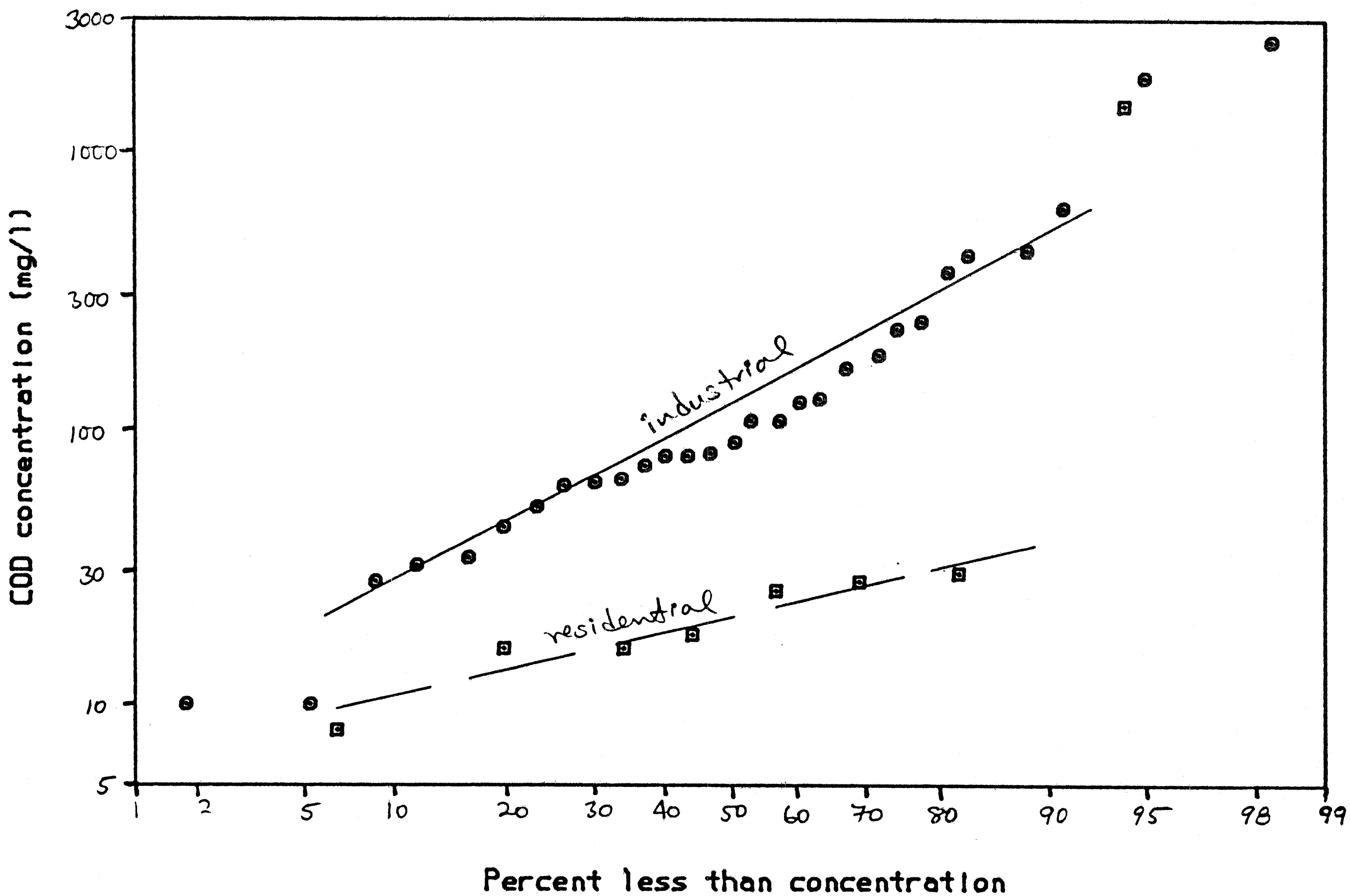
BASEFLOW PROB. PLOT: PHENOLICS



10/27/84
BPHENT/LOG
BPHENE/LOG

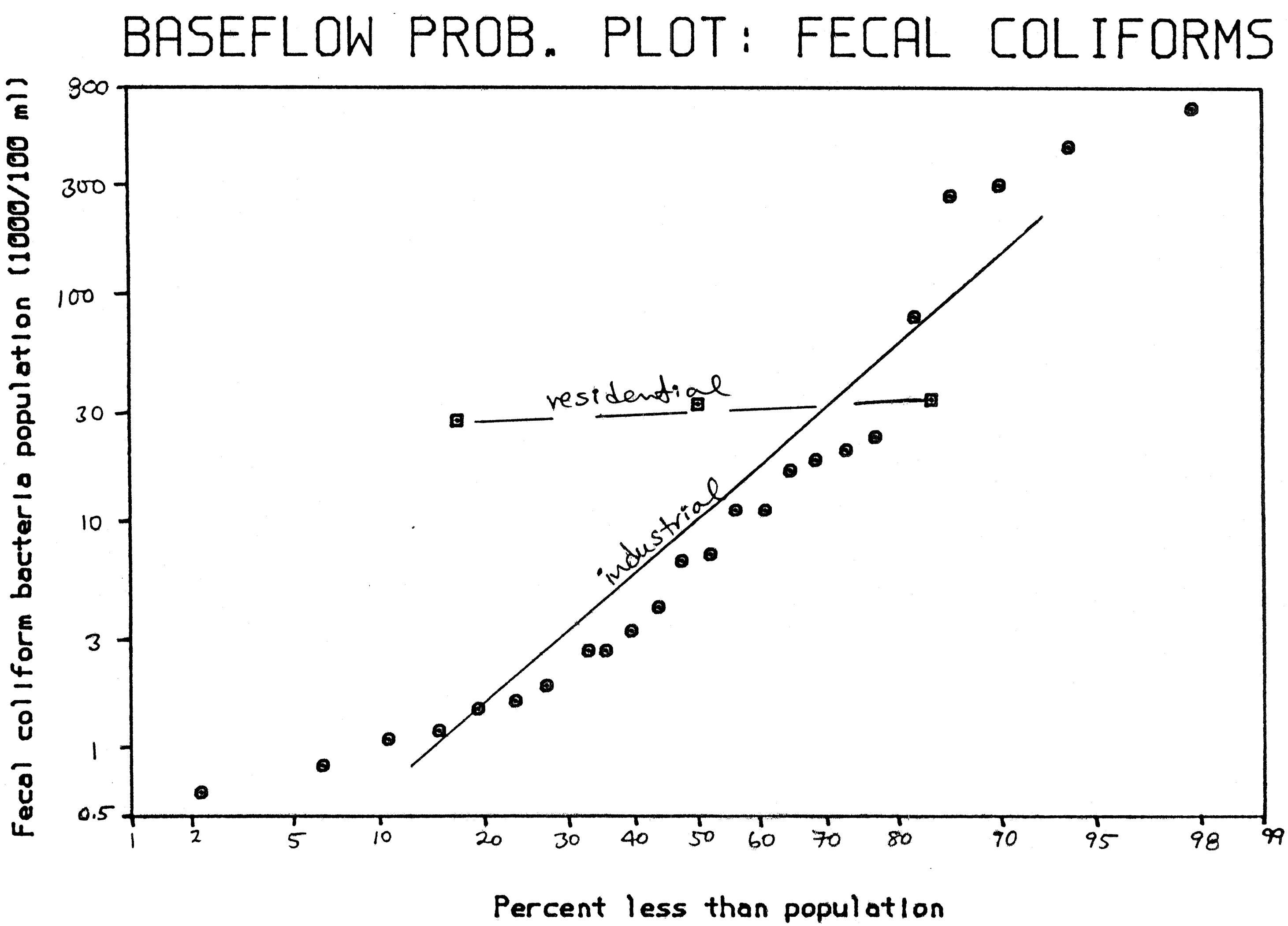
Figure E-7

BASEFLOW PROB. PLOT: COD



10/27/84
B CODE/LOG
B CODT/LOG

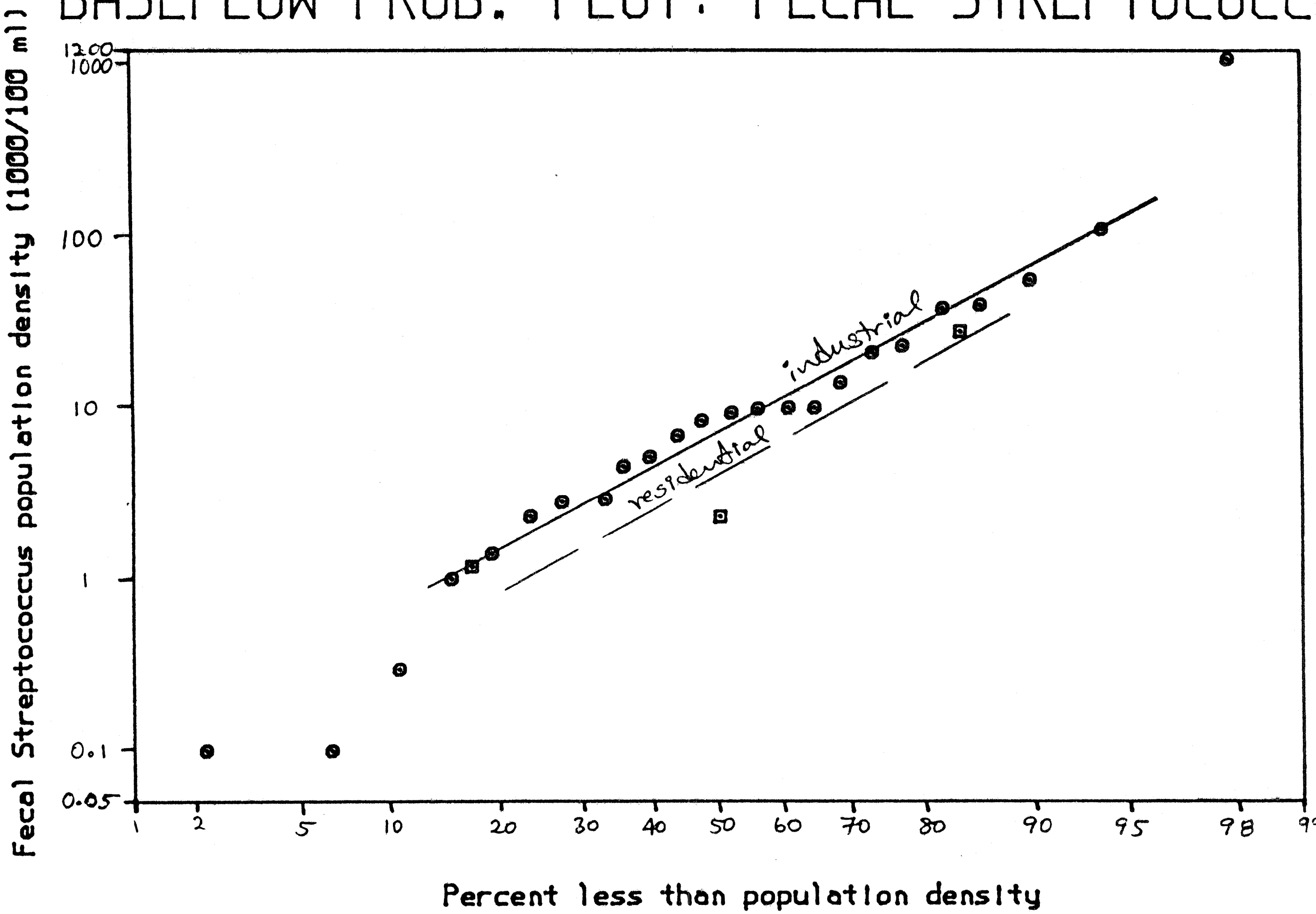
Figure E.8



10/27/84
BFCE/LOG
BFCT/LOG

Figure E09

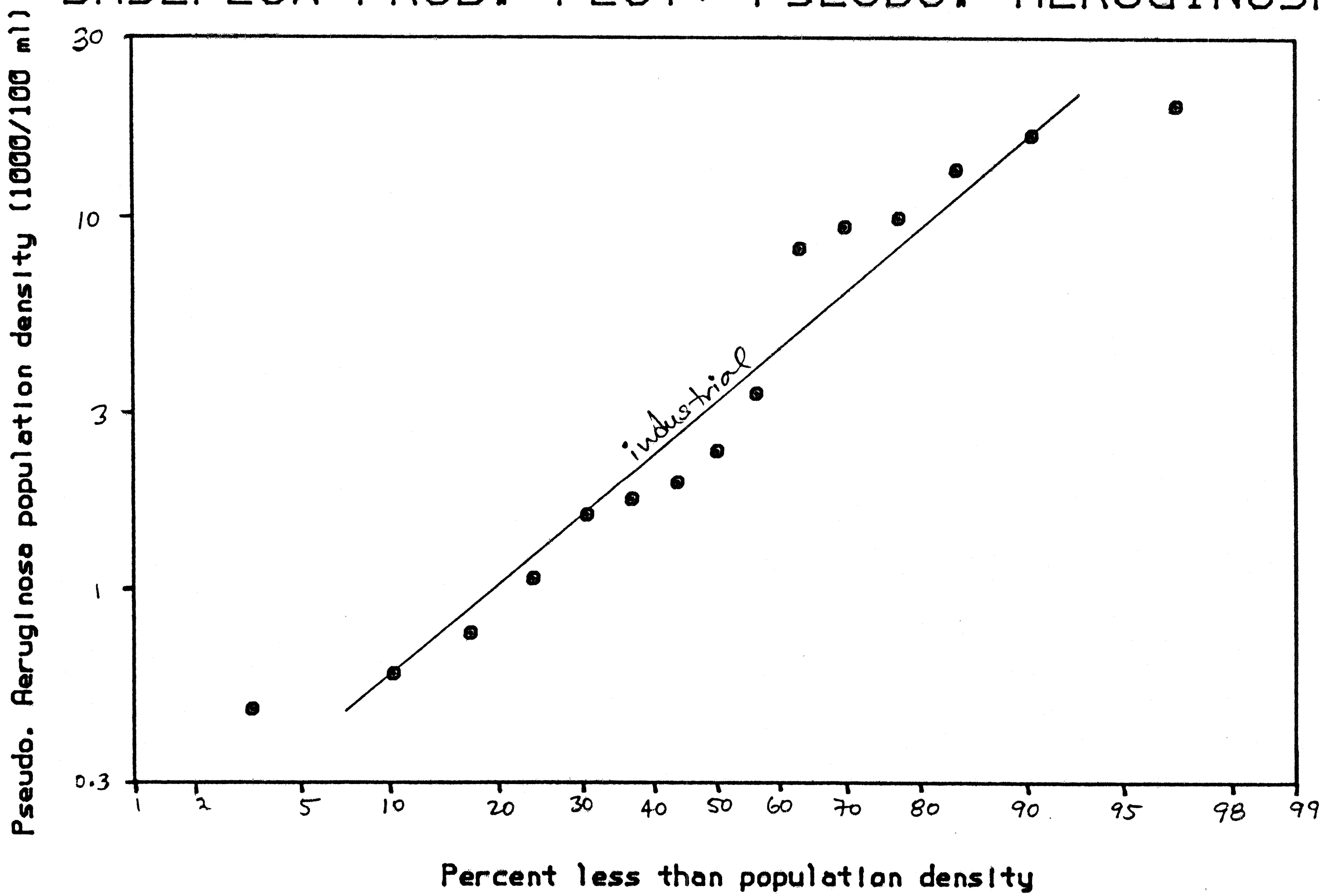
BASEFLOW PROB. PLOT: FECAL STREPTOCOCCUS



10/27/84
B FST/LOG
B FSE/LOG

Figure E.10

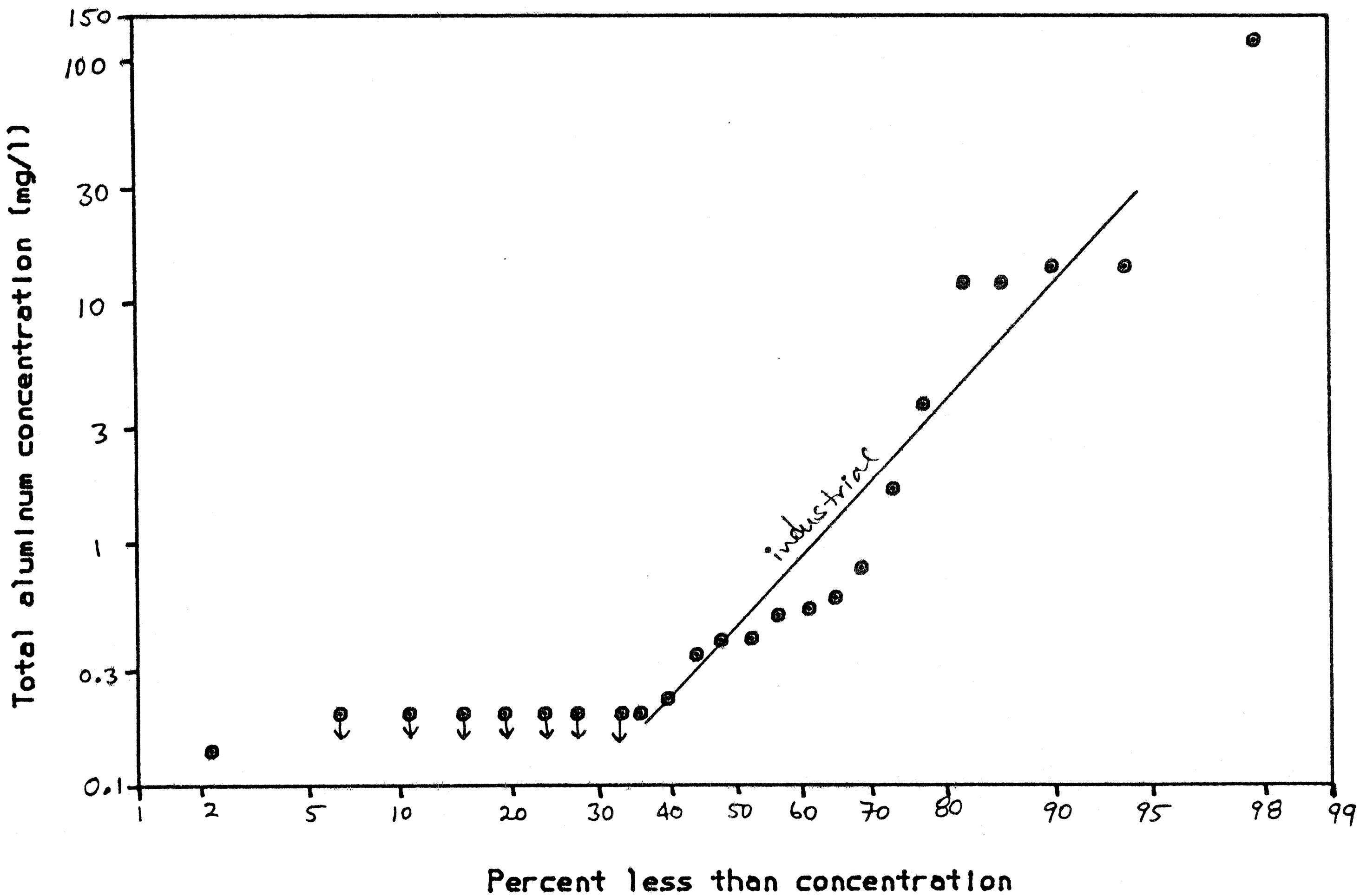
BASEFLOW PROB. PLOT: PSEUDO. AERUGINOSA



10/27/84
BPAE/LOG

Figure E-11

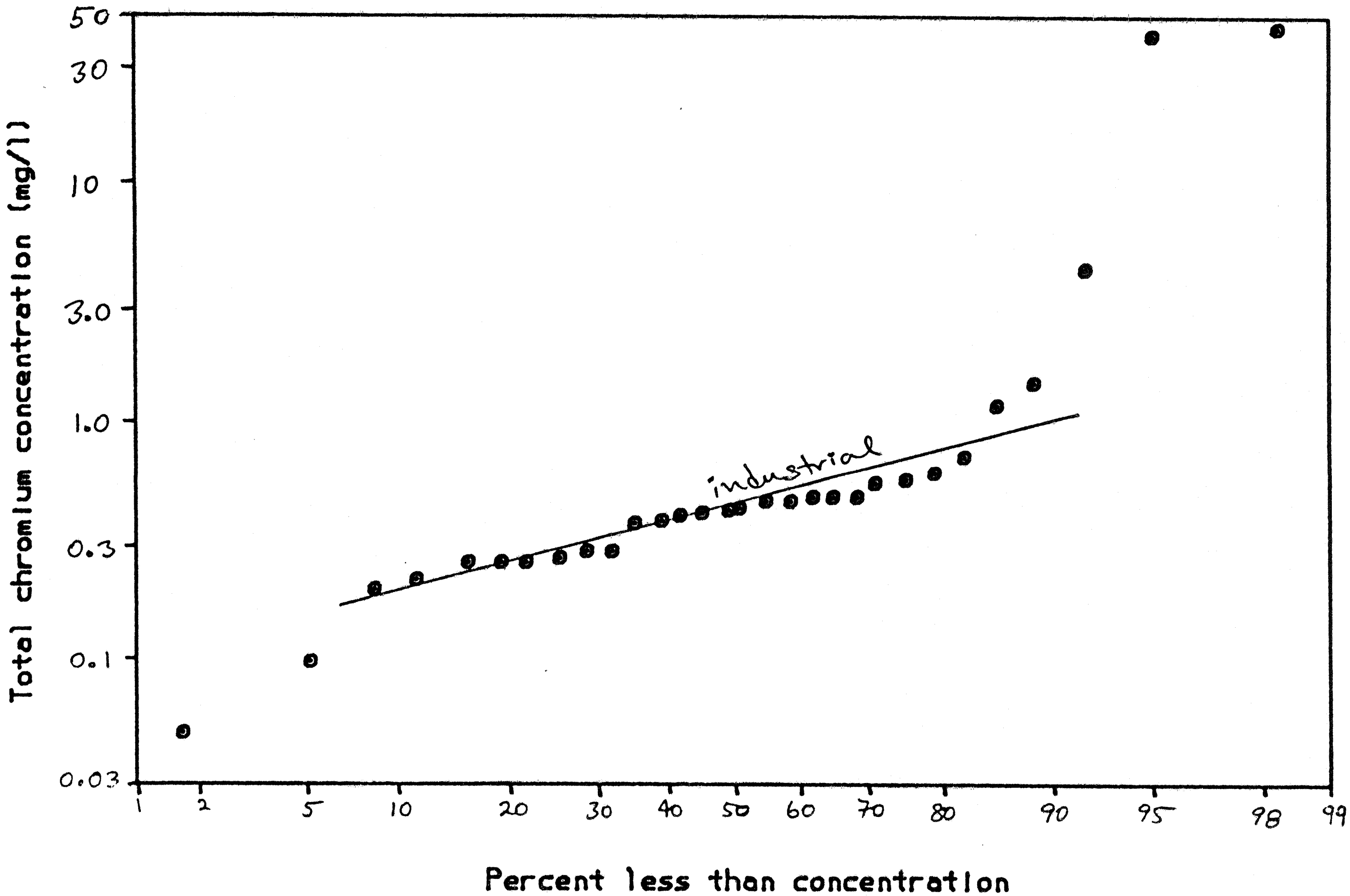
BASEFLOW PROB. PLOT: ALUMINUM



10/27/84
BALE/LOG

Figure E012

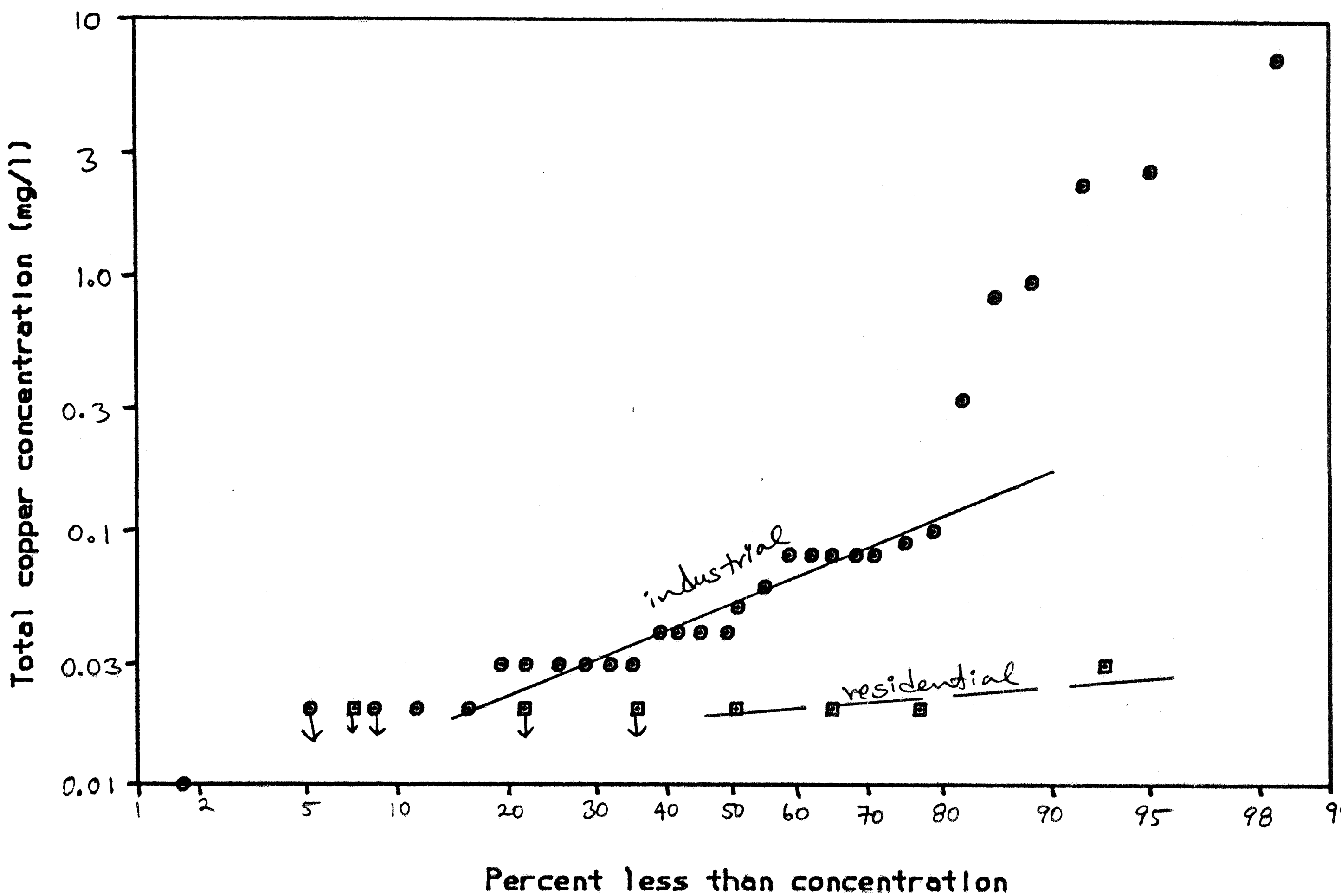
BASEFLOW PROB. PLOT: CHROMIUM



1012718d
BC RE/LOG

Figure E.13

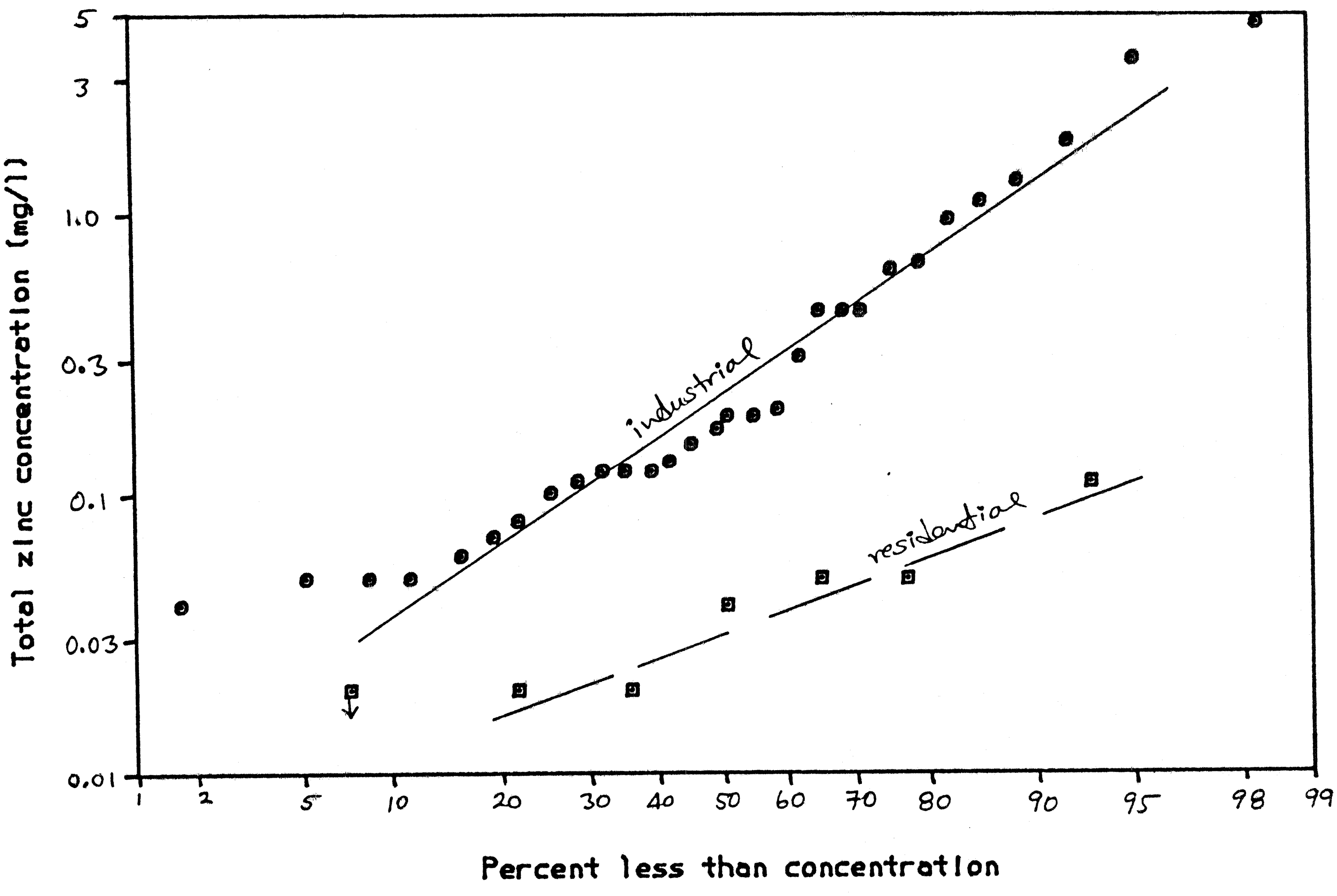
BASEFLOW PROB. PLOT: COPPER



10/27/84
BCUE/LOG
BCUT/LOG

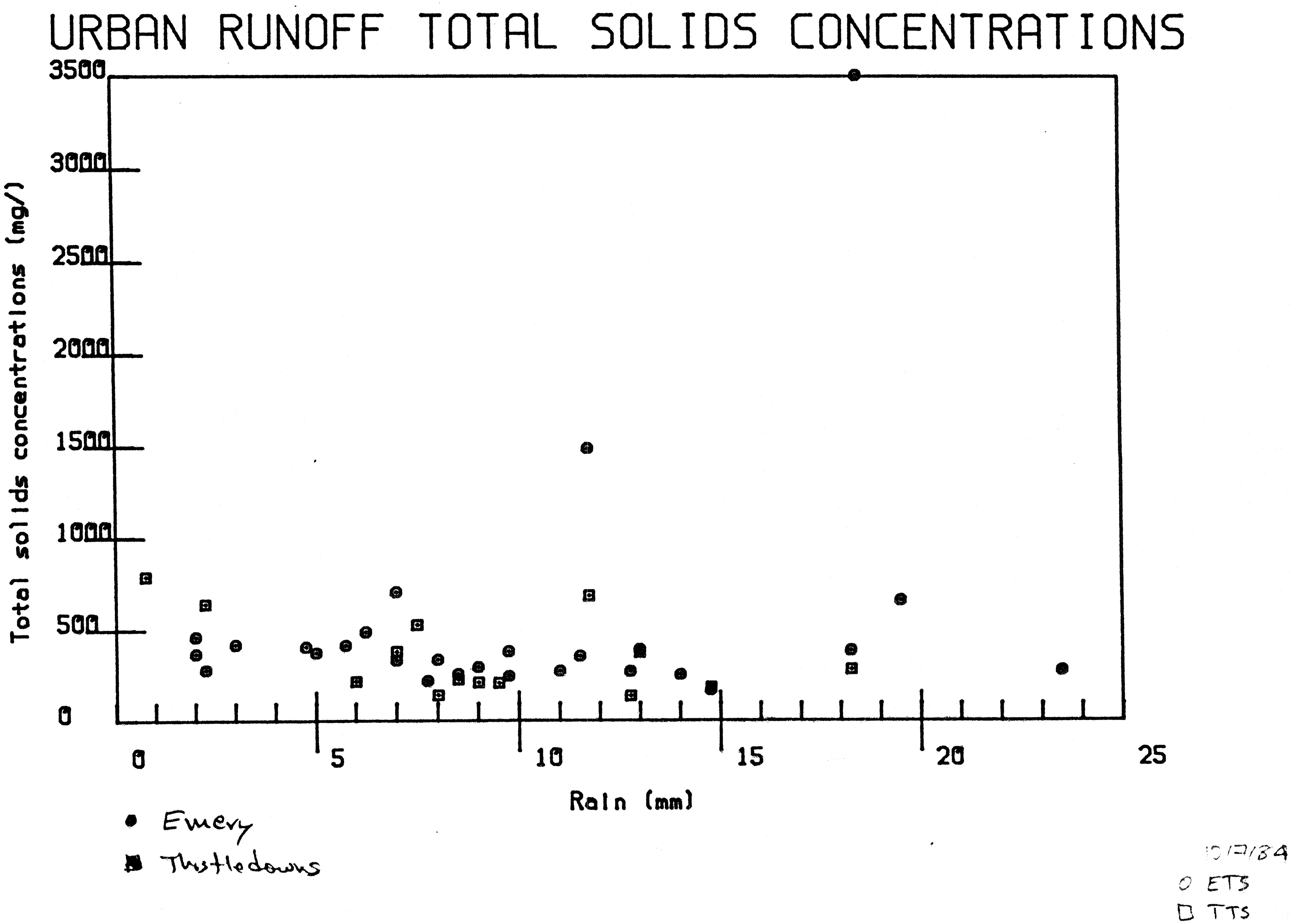
Figure E.14

BASEFLOW PROB. PLOT: ZINC



10/27/84
BZNT/LOG
BZNE/LOG

Figure E.15



URBAN RUNOFF TOTAL SOLIDS CONCENTRATIONS
Total solids concentrations (mg/)
3500
3000
2500
2000
1500
1000
500
0
0
5
10
15
20
25
Rain (mm)
Emery
Thistledowns
10/17/84
O ETS
□ TTS

Figure E.16

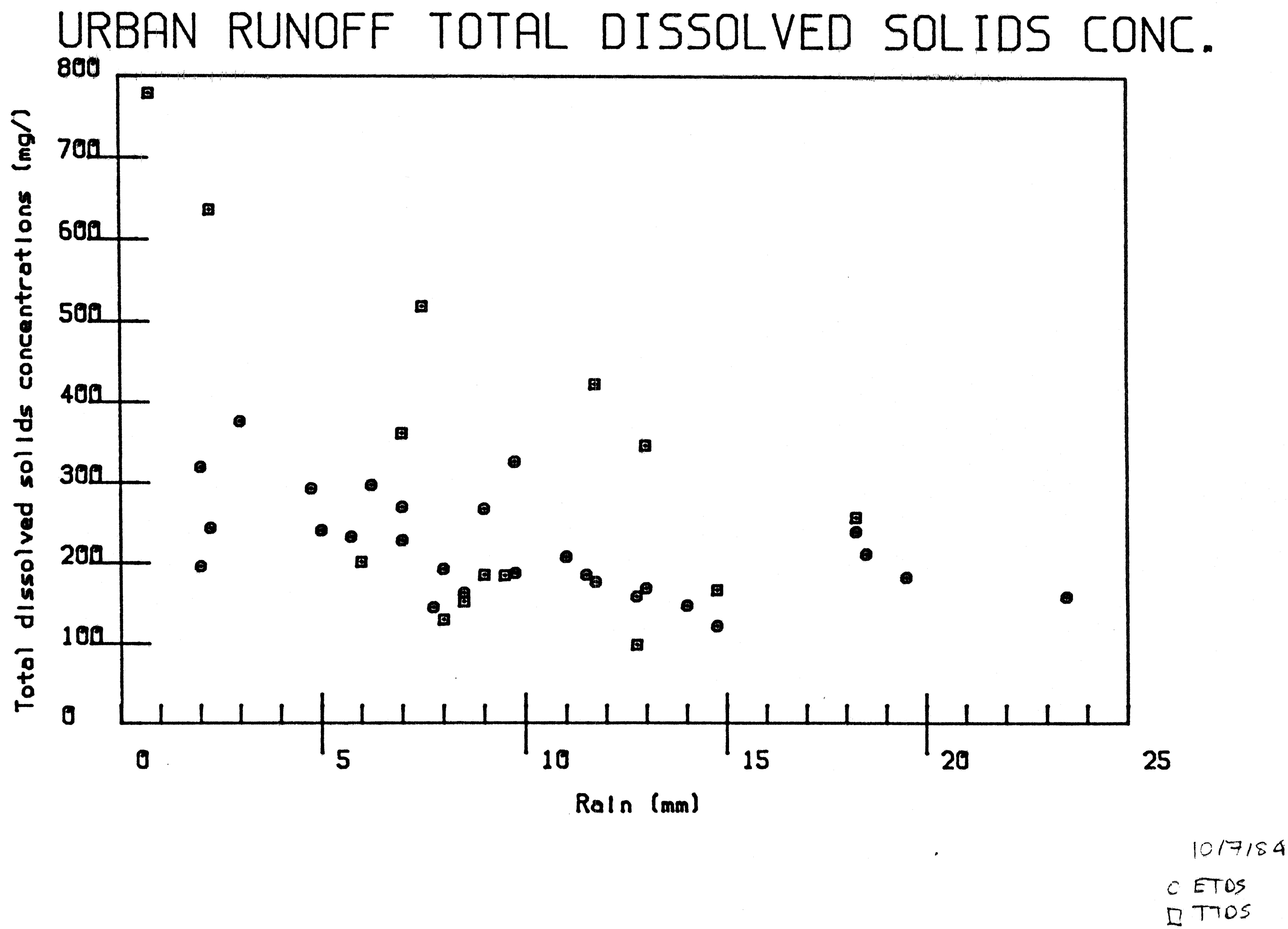
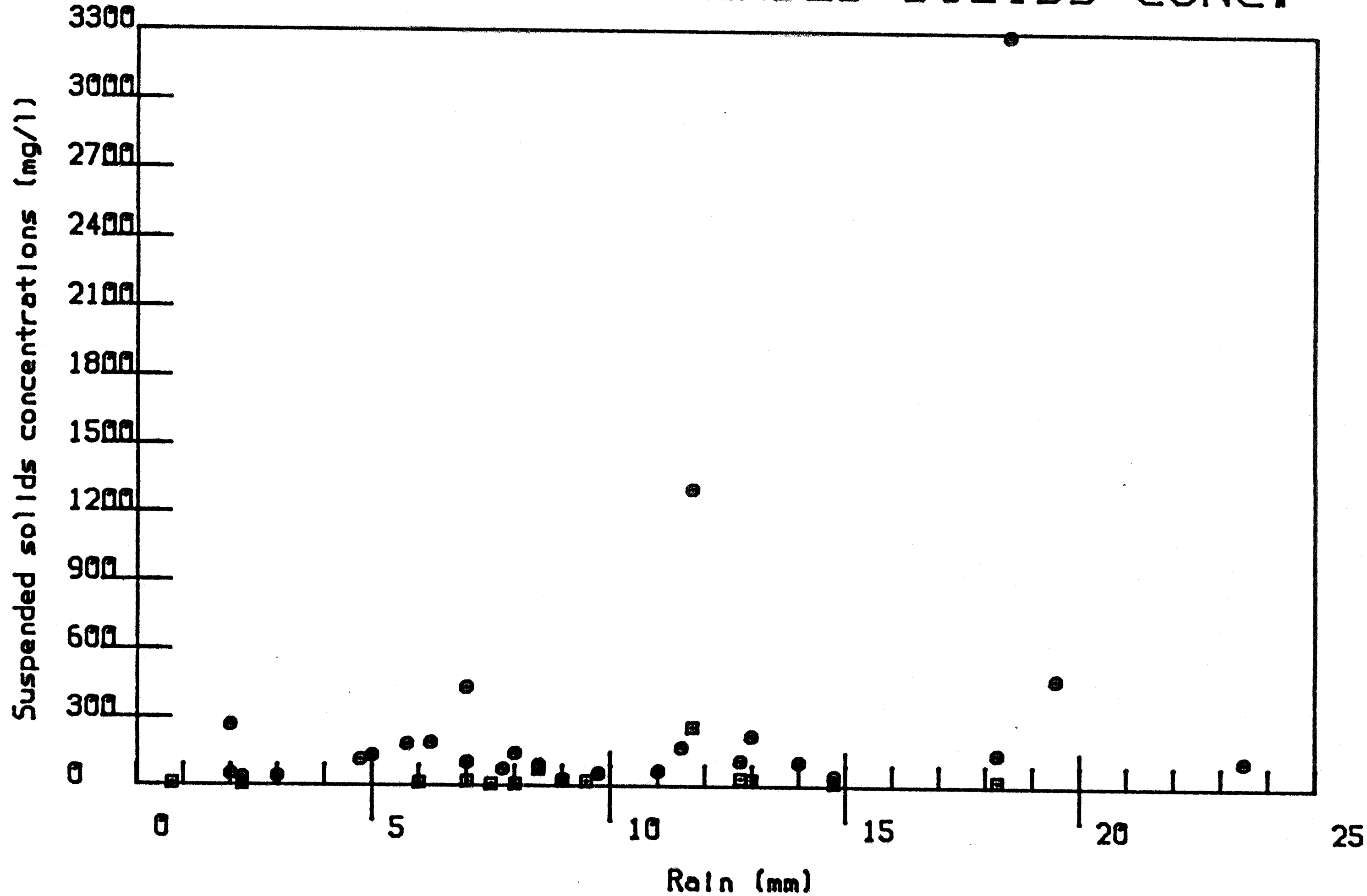

URBAN RUNOFF TOTAL DISSOLVED SOLIDS CONC.
Total dissolved solids concentrations (mg/)
800
700
600
500
400
300
200
100
0
0
5
10
15
20
25
Rain (mm)
10/7/84
c ETDS
□ TTDS

Figure E.17

URBAN RUNOFF SUSPENDED SOLIDS CONC.



10/7/84
○ ESS
□ TSS

Figure E.18

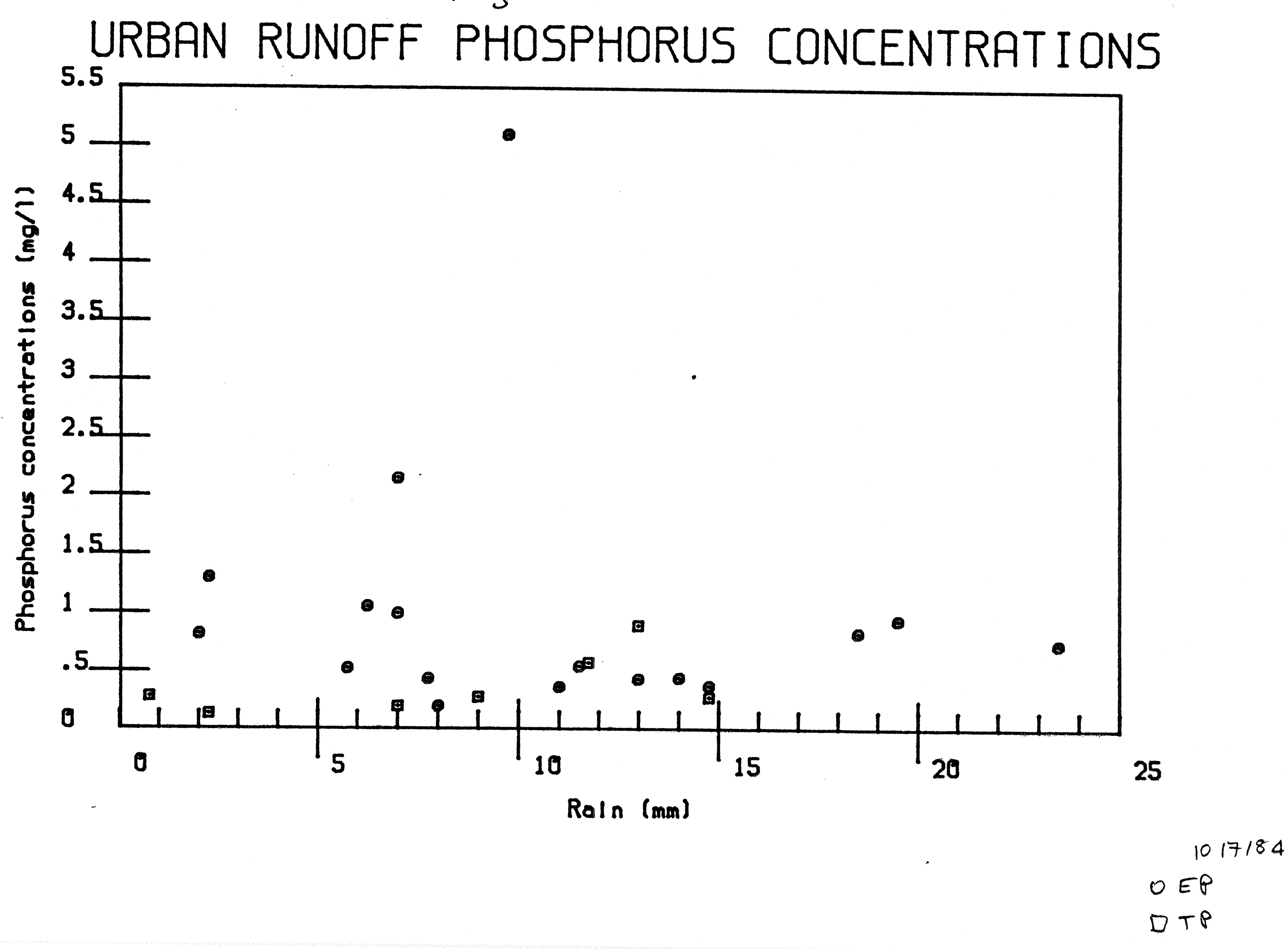
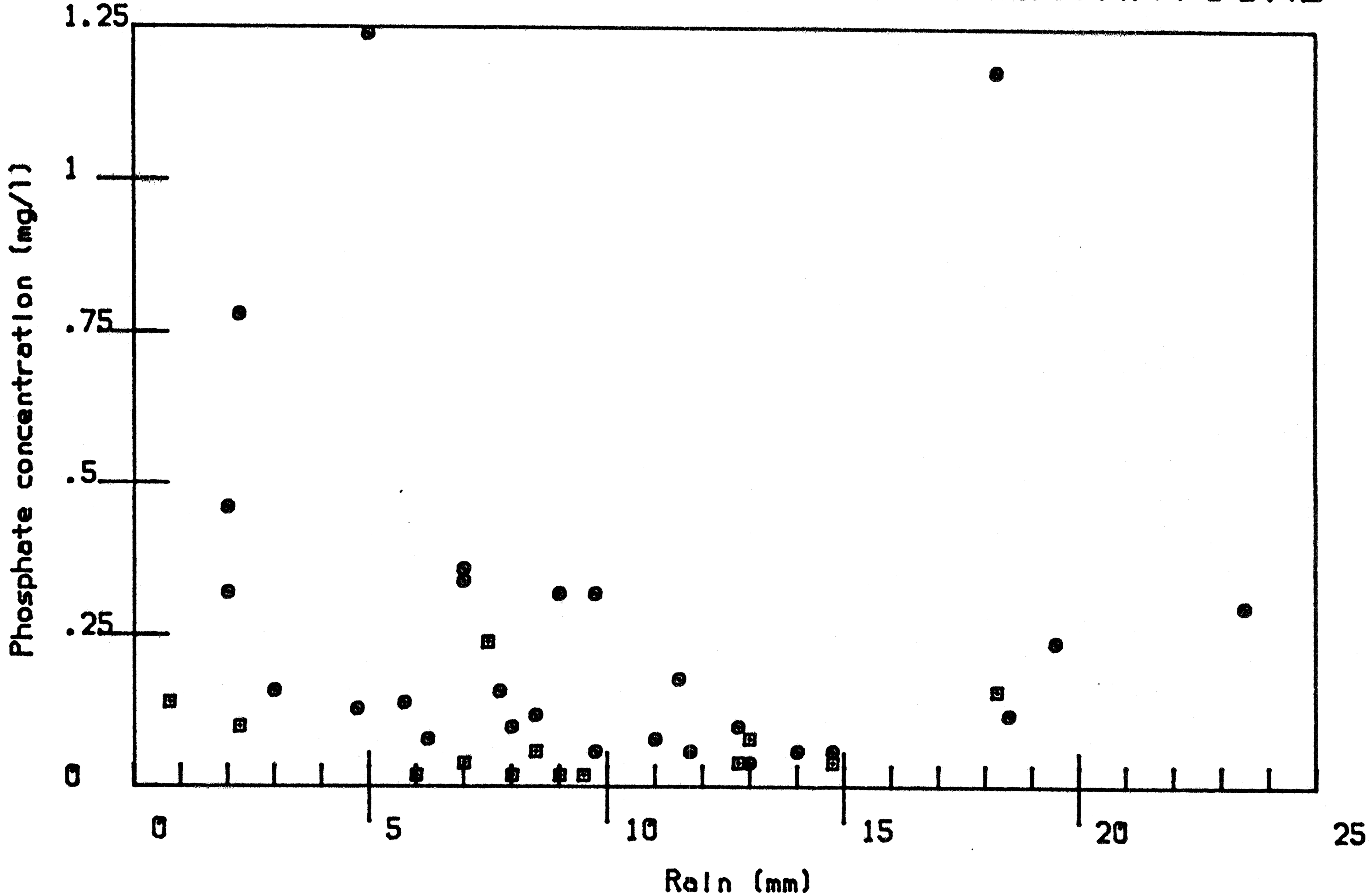

URBAN RUNOFF PHOSPHORUS CONCENTRATIONS
Phosphorus concentrations (mg/l)
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
.5
0
0
5
10
15
20
25
Rain (mm)
10/7/84
○ EP
□ TP

Figure E.19

URBAN RUNOFF PHOSPHATE CONCENTRATIONS



10/7/84
O EPO4
□ TPO4

Figure E.20

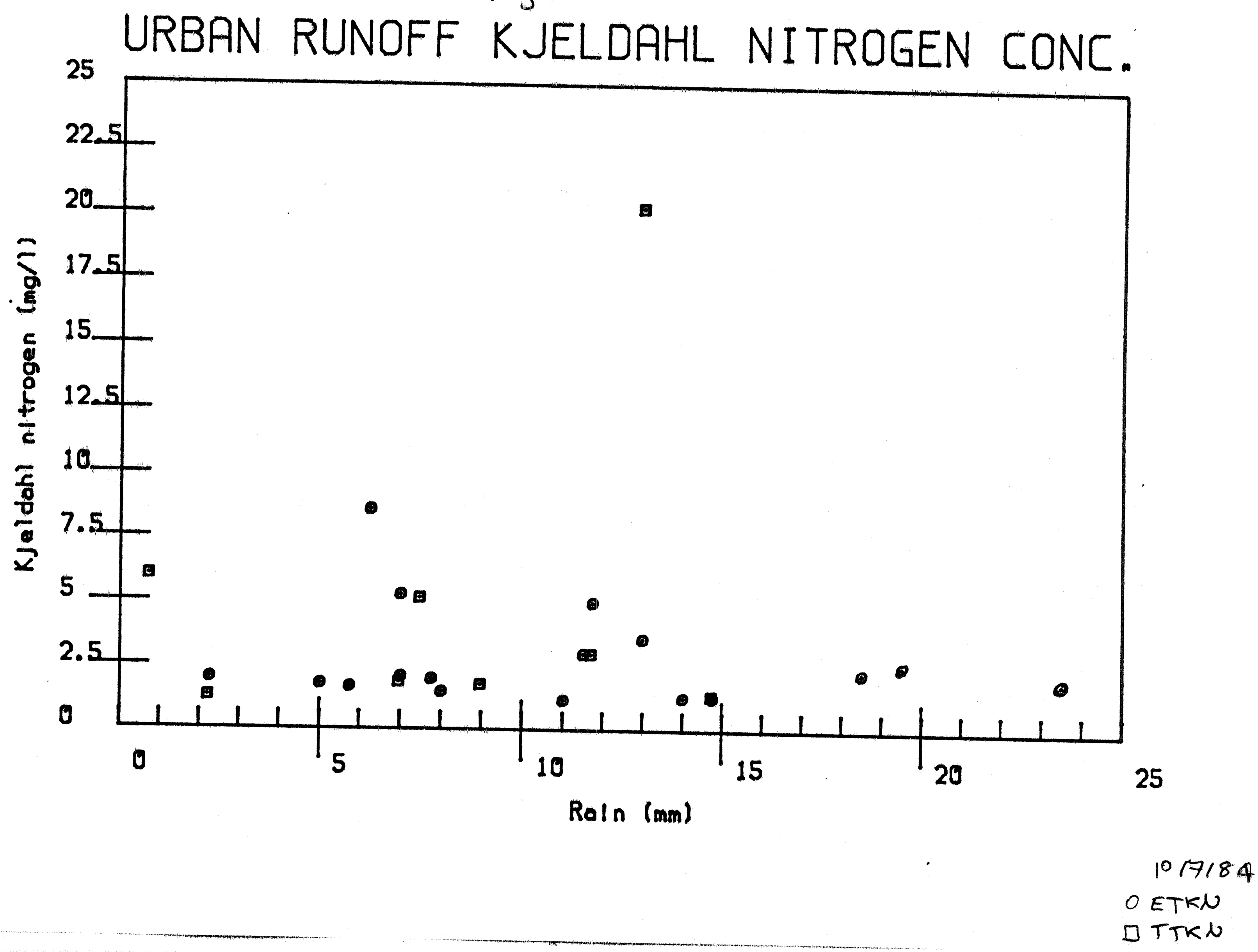
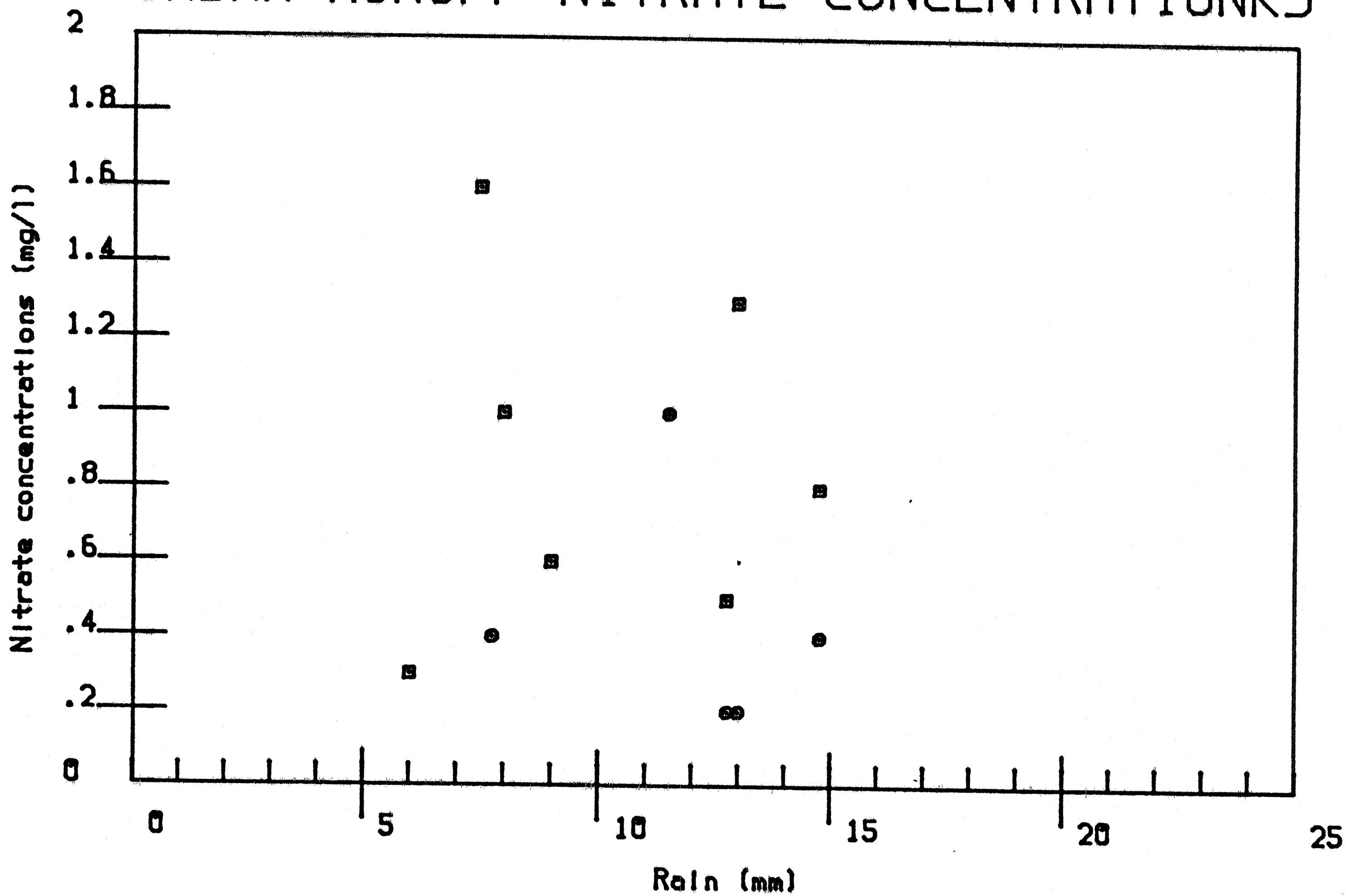

URBAN RUNOFF KJELDAHL NITROGEN CONC.
Kjeldahl nitrogen (mg/l)
25
22.5
20
17.5
15
12.5
10
7.5
5
2.5
0
0
5
10
15
20
25
Rain (mm)
10/7/84
O ETKN
□ TTKN

Figure E021

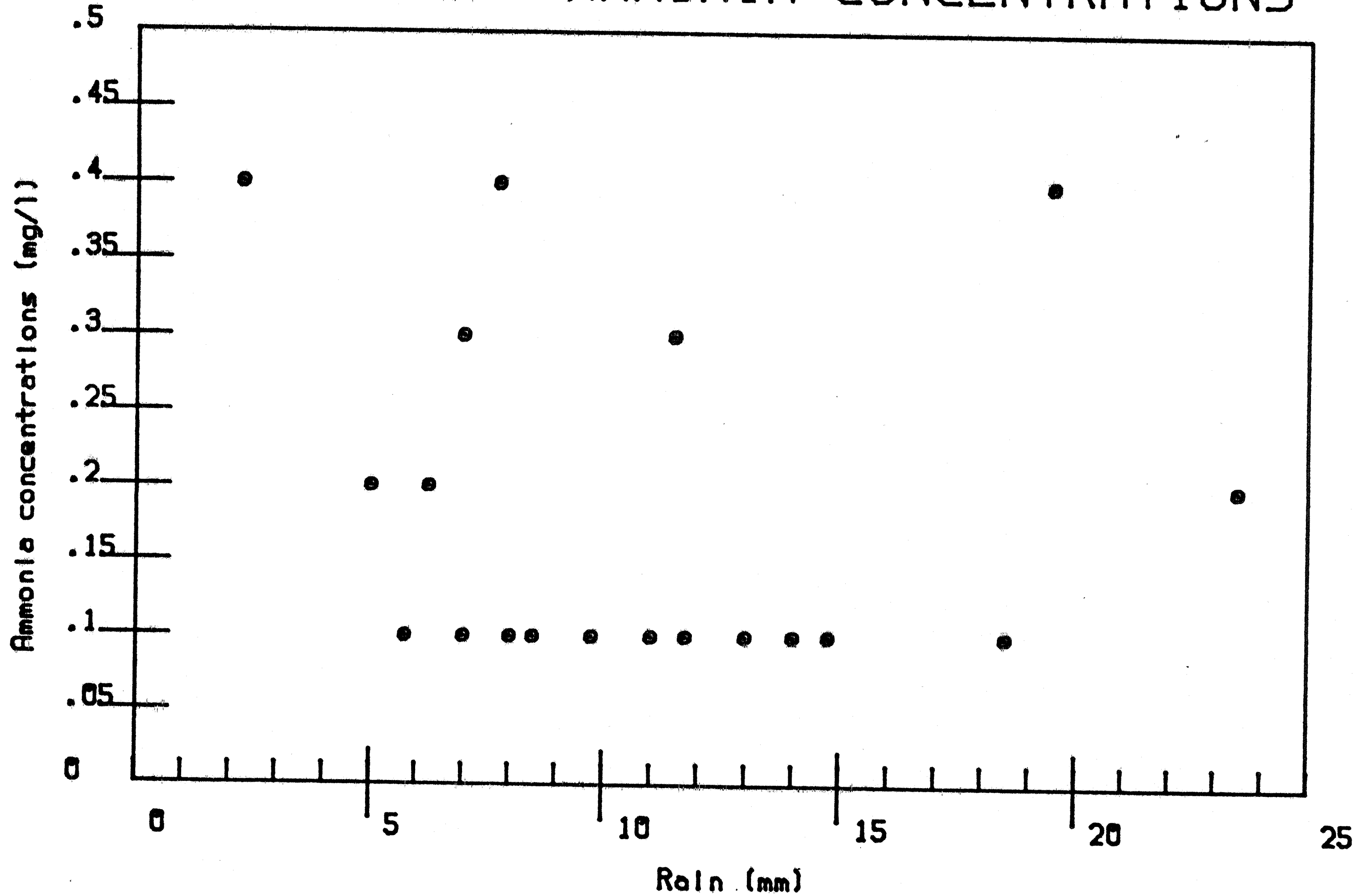
URBAN RUNOFF NITRATE CONCENTRATIONKS



IC 7/84
o EN03
□ TN03

Figure E-22

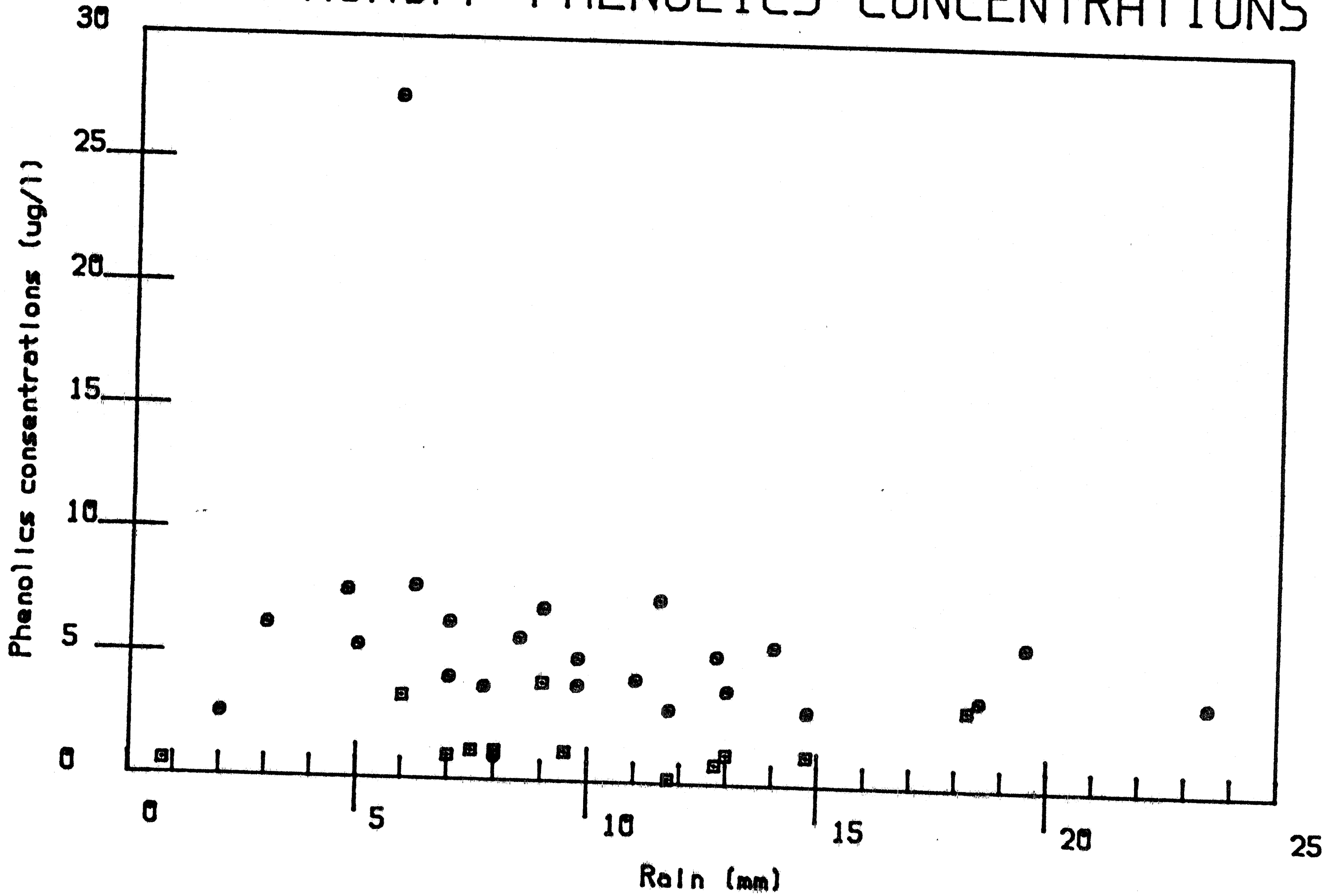
URBAN RUNOFF AMMONIA CONCENTRATIONS



10/7/84
C ENH4

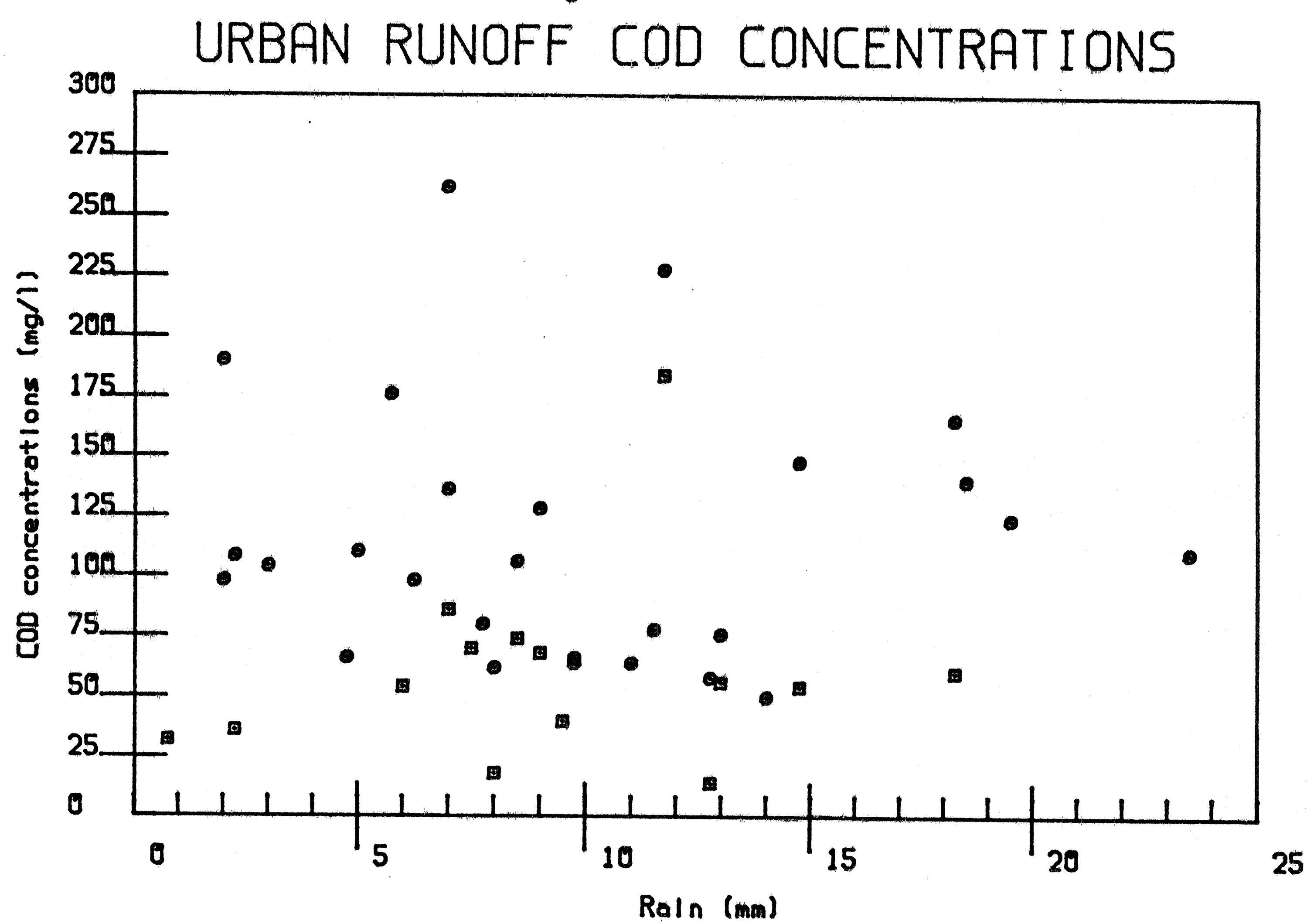
Figure E-23

URBAN RUNOFF PHENOLICS CONCENTRATIONS



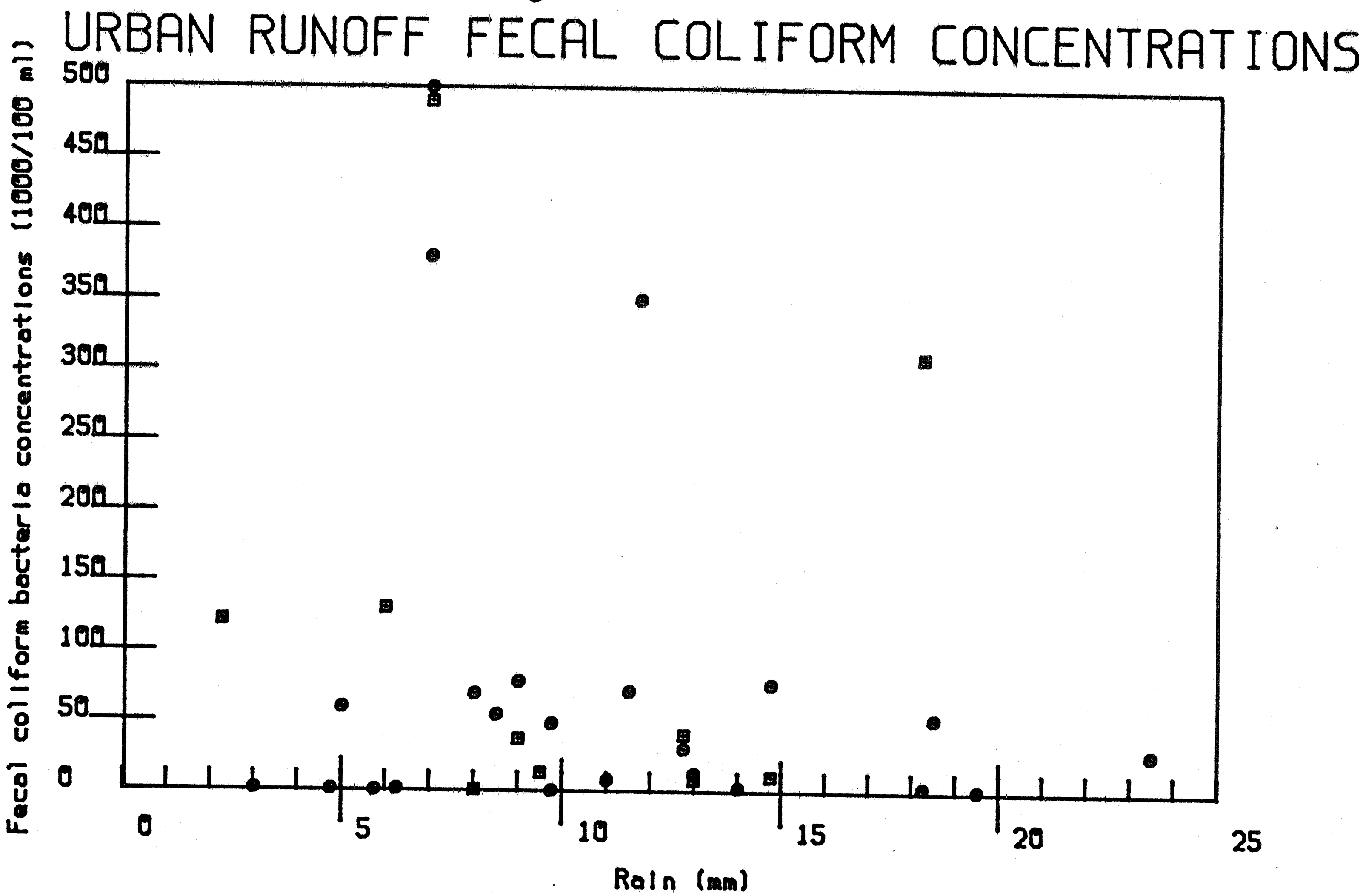
1017/84
o EPHEN
□ TPHEN

Figure E.24



10/7/84
O ECOD
□ TCOD

Figure E-25



10/7/84
○ EFC
□ TFC

Figure E-26

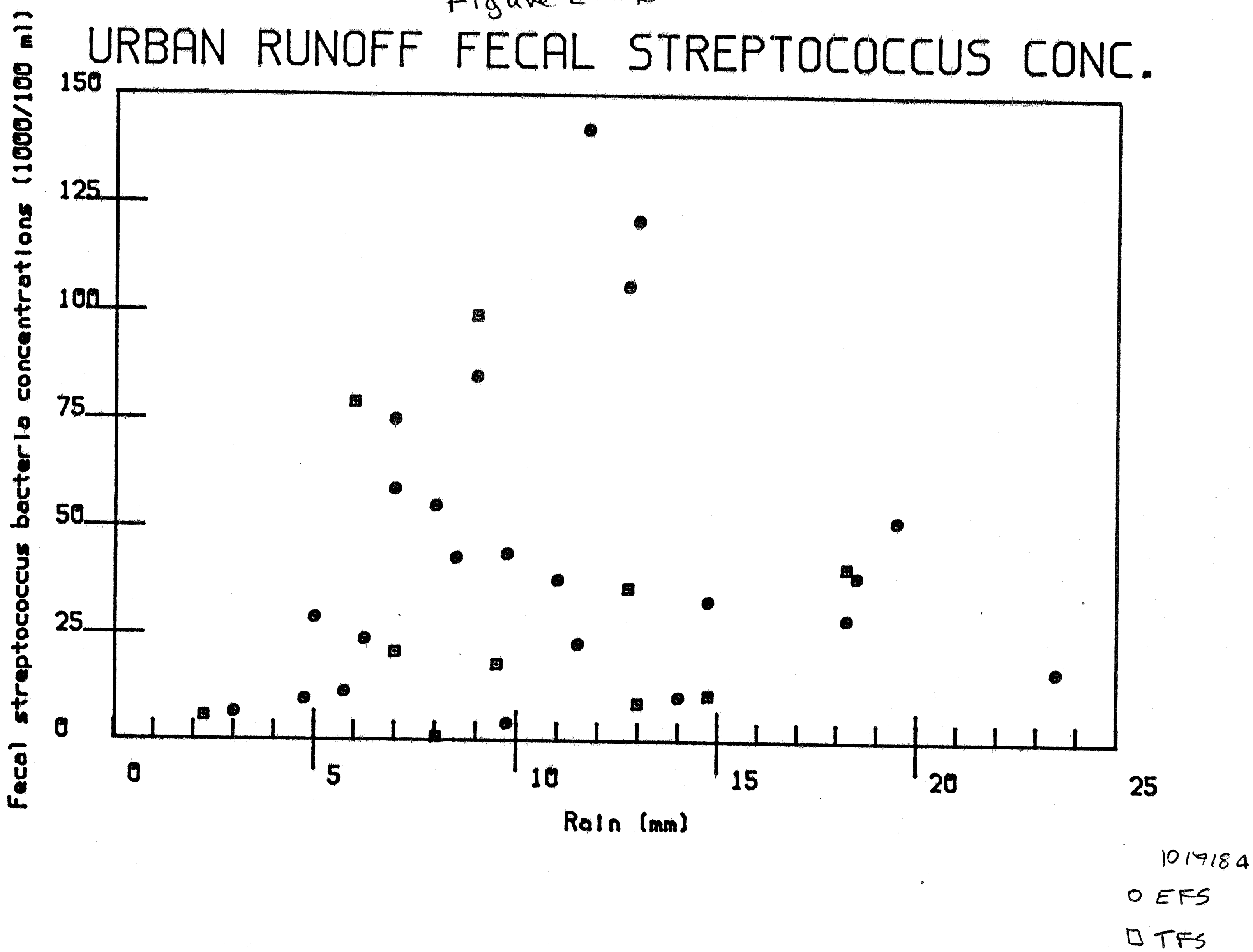

URBAN RUNOFF FECAL STREPTOCOCCUS CONC.
Fecal streptococcus bacteria concentrations (1000/100 ml)
150
125
100
75
50
25
0
0
5
10
15
20
25
Rain (mm)
101984
○ EFS
□ TFS

Figure E027

URBAN RUNOFF PSEUD. AERUGINOSA CONC.

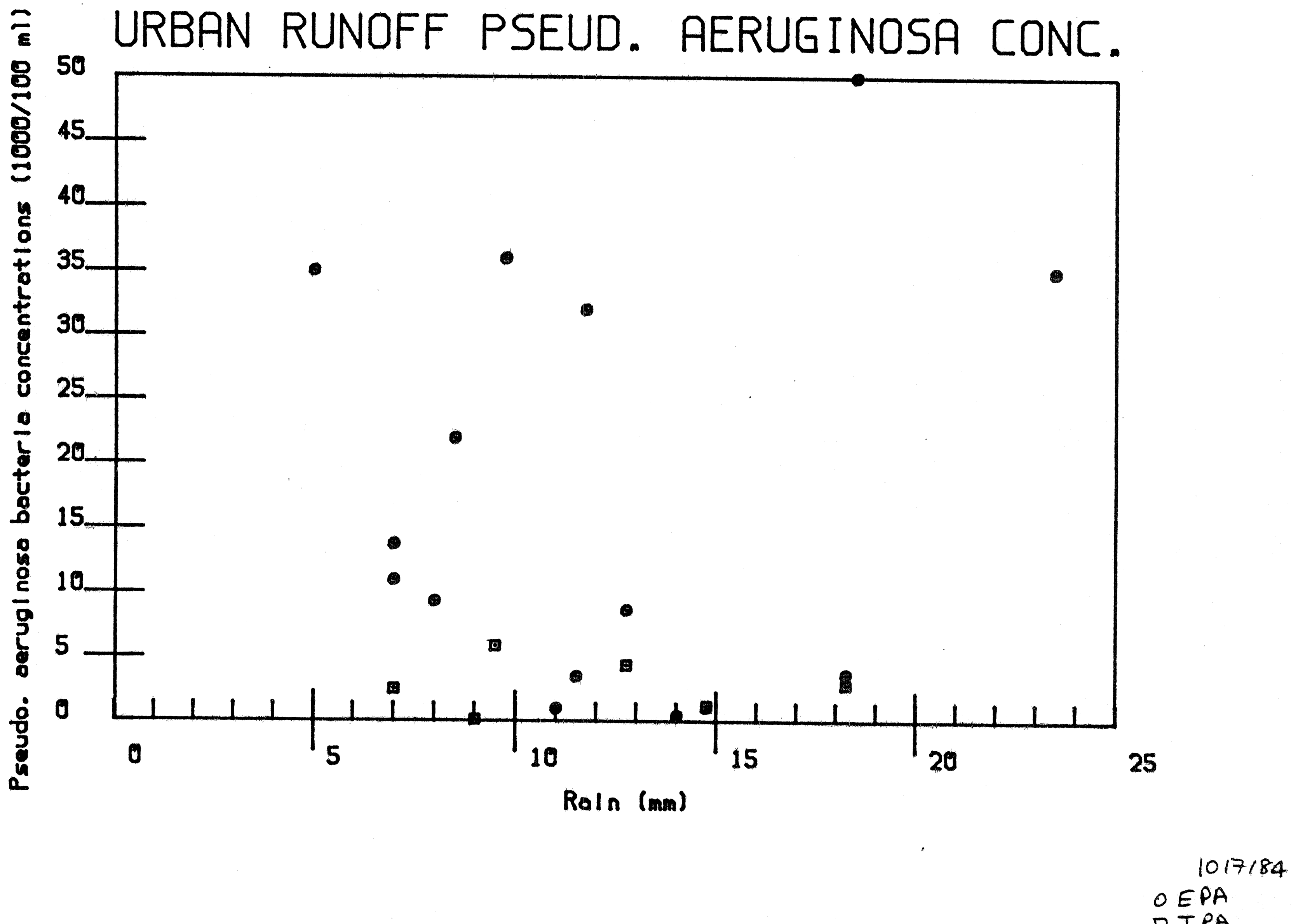


Figure E.28

URBAN RUNOFF ALUMINUM CONCENTRATIONS

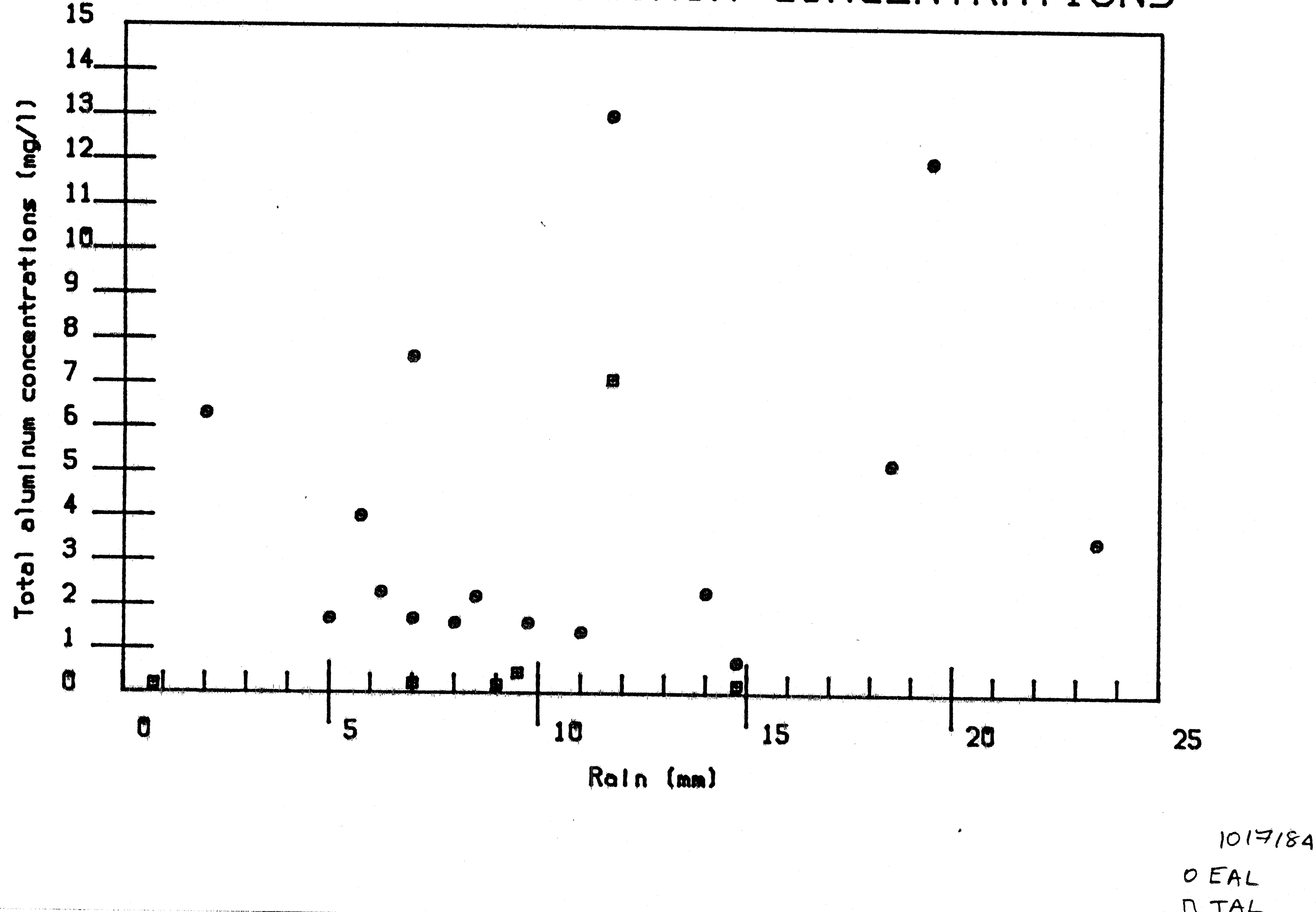
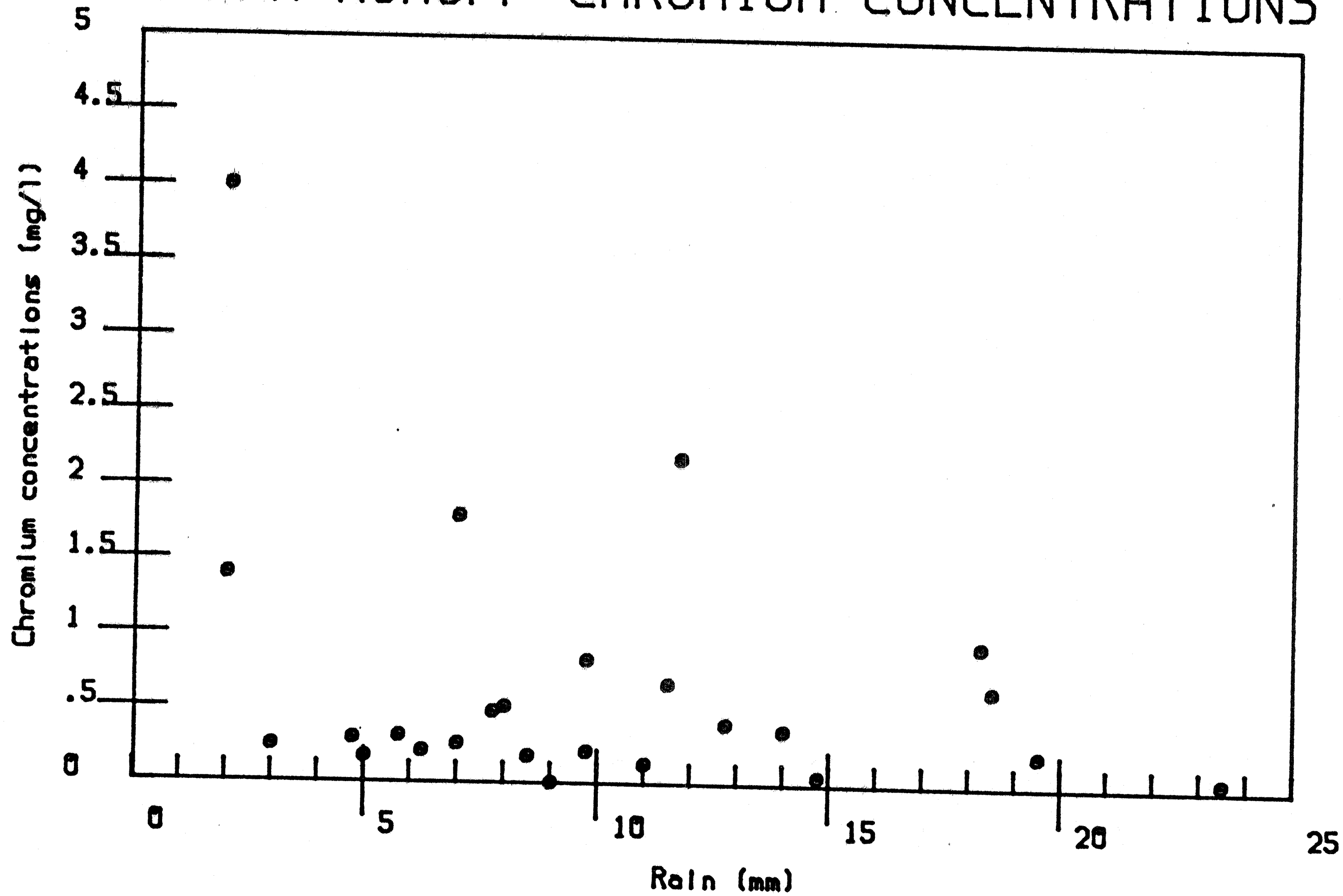


Figure E.29

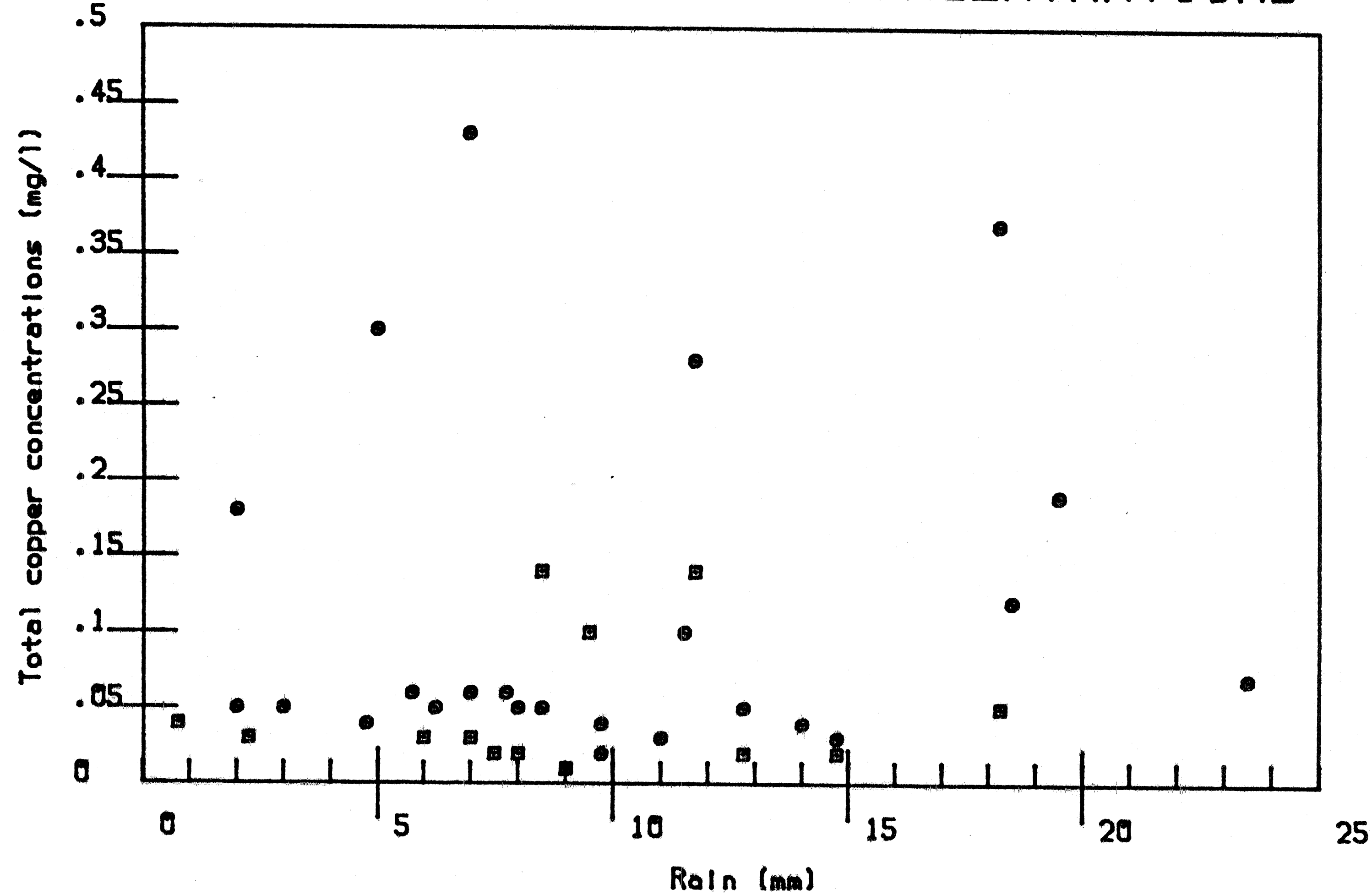
URBAN RUNOFF CHROMIUM CONCENTRATIONS



10/7/84
O E CR

Figure E. 30

URBAN RUNOFF COPPER CONCENTRATIONS



1017184

o ECu
▢ TCu

Figure E.31

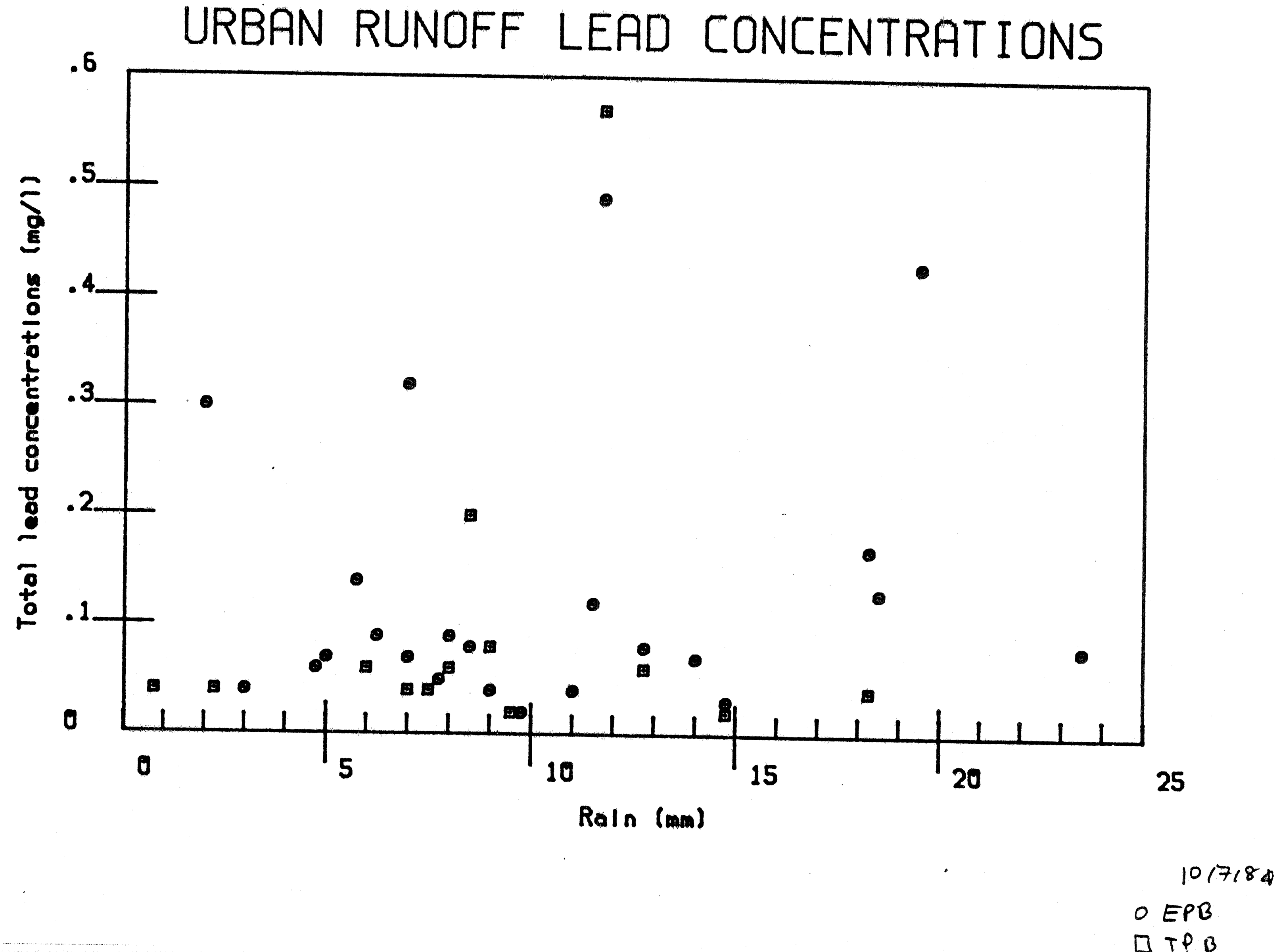
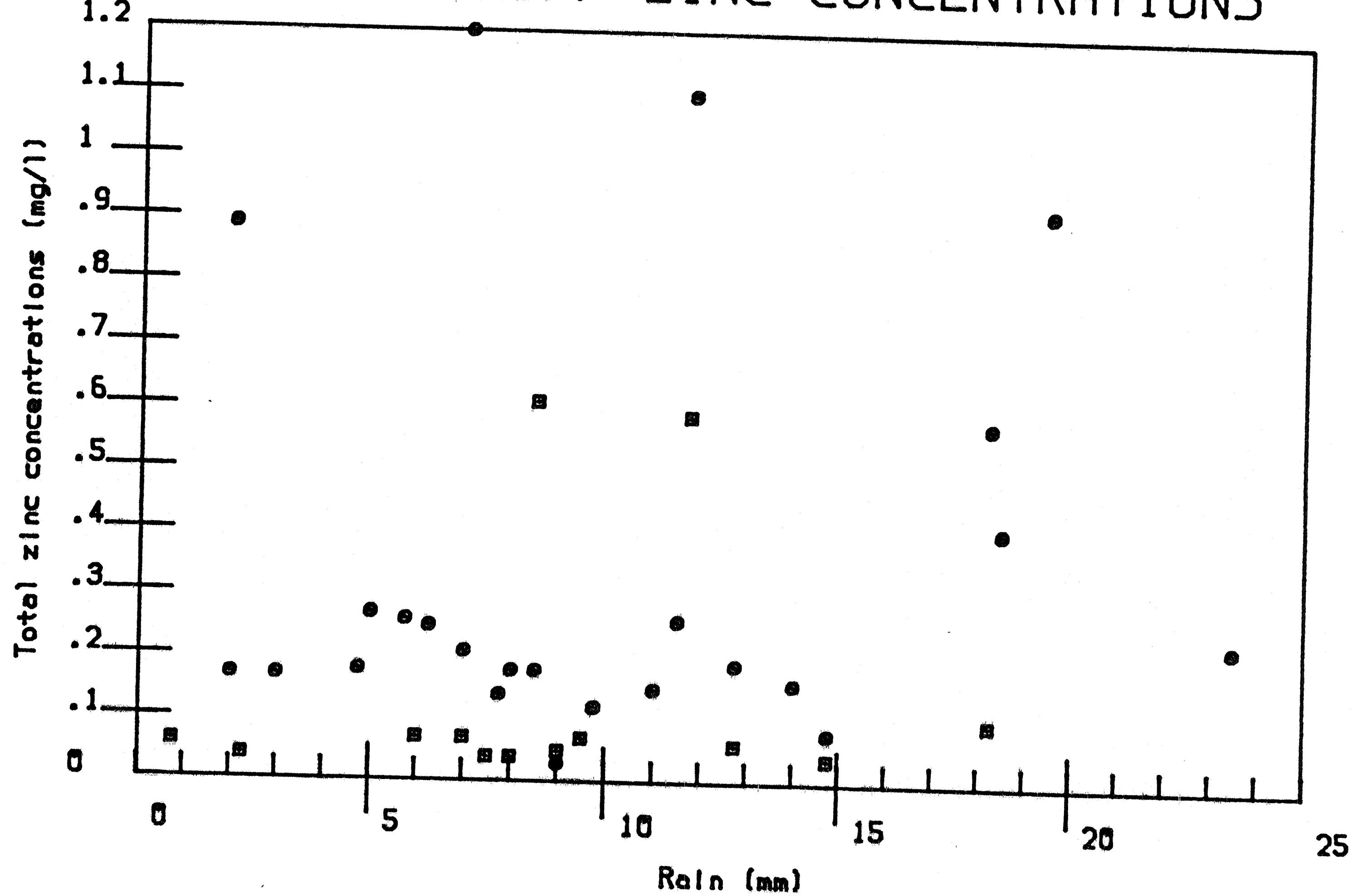

URBAN RUNOFF LEAD CONCENTRATIONS
Total lead concentrations (mg/l)
0
.1
.2
.3
.4
.5
.6
Rain (mm)
0
5
10
15
20
25
10/7/84
o EPB
□ TPB

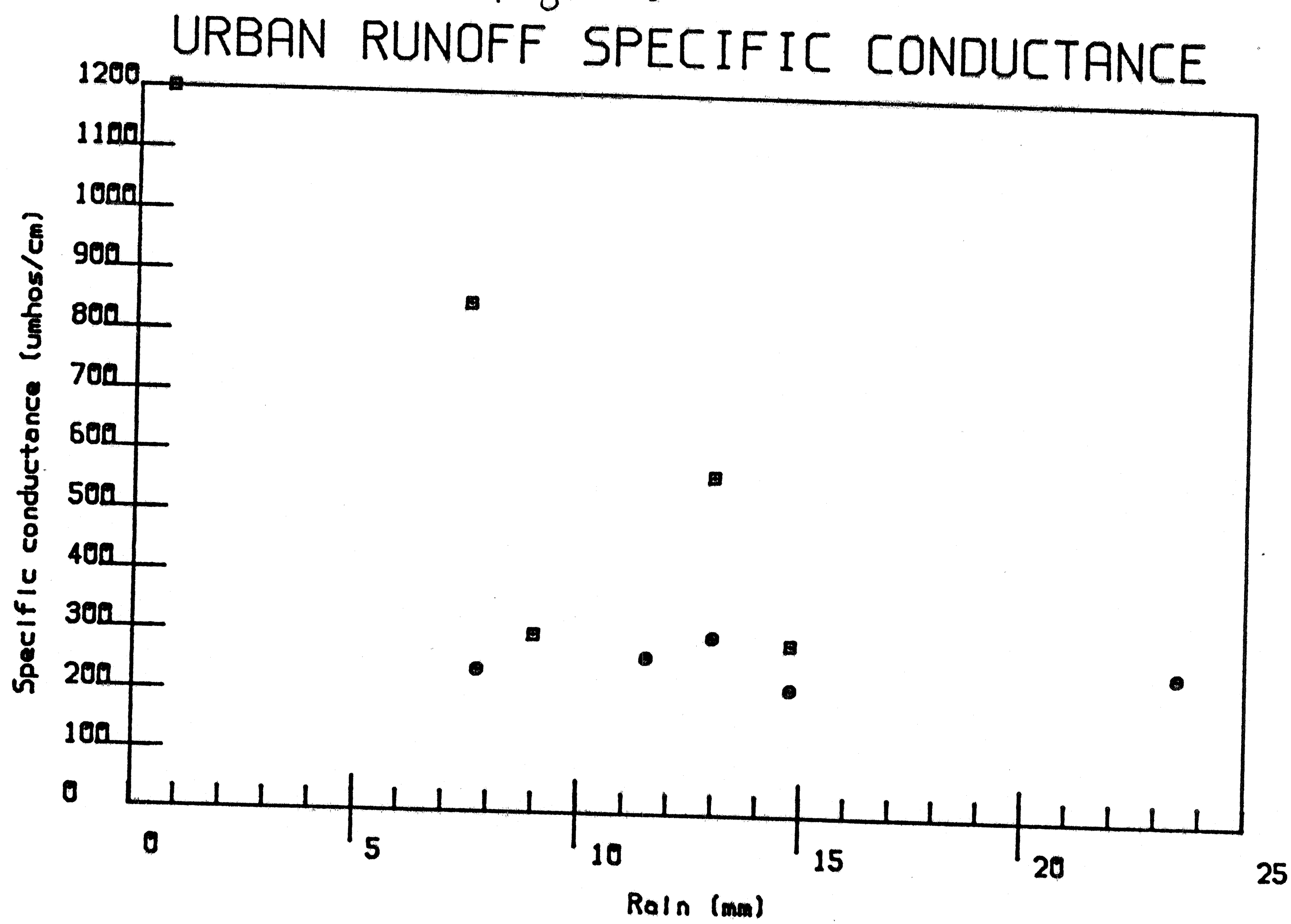
Figure E.32

URBAN RUNOFF ZINC CONCENTRATIONS



10/7/84
○ EZN
□ TZN

Figure E033



10/7/84
o ESC
□ TSC

Figure E.34

STORMWATER PROB. PLOT: FILTERABLE RESIDUE

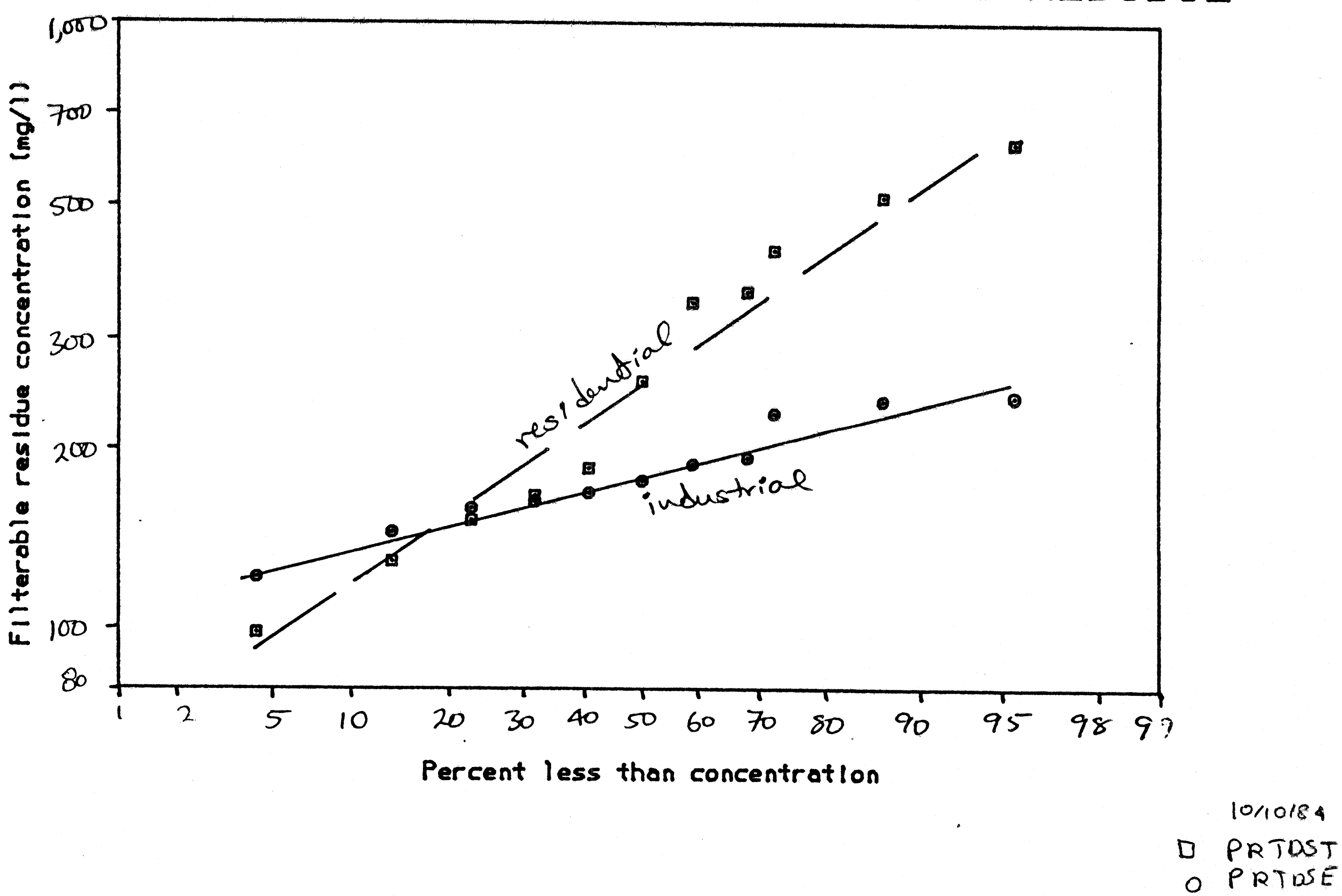


Figure E-35

STORMWATER PROB. PLOT: PARTICULATE RESIDUE

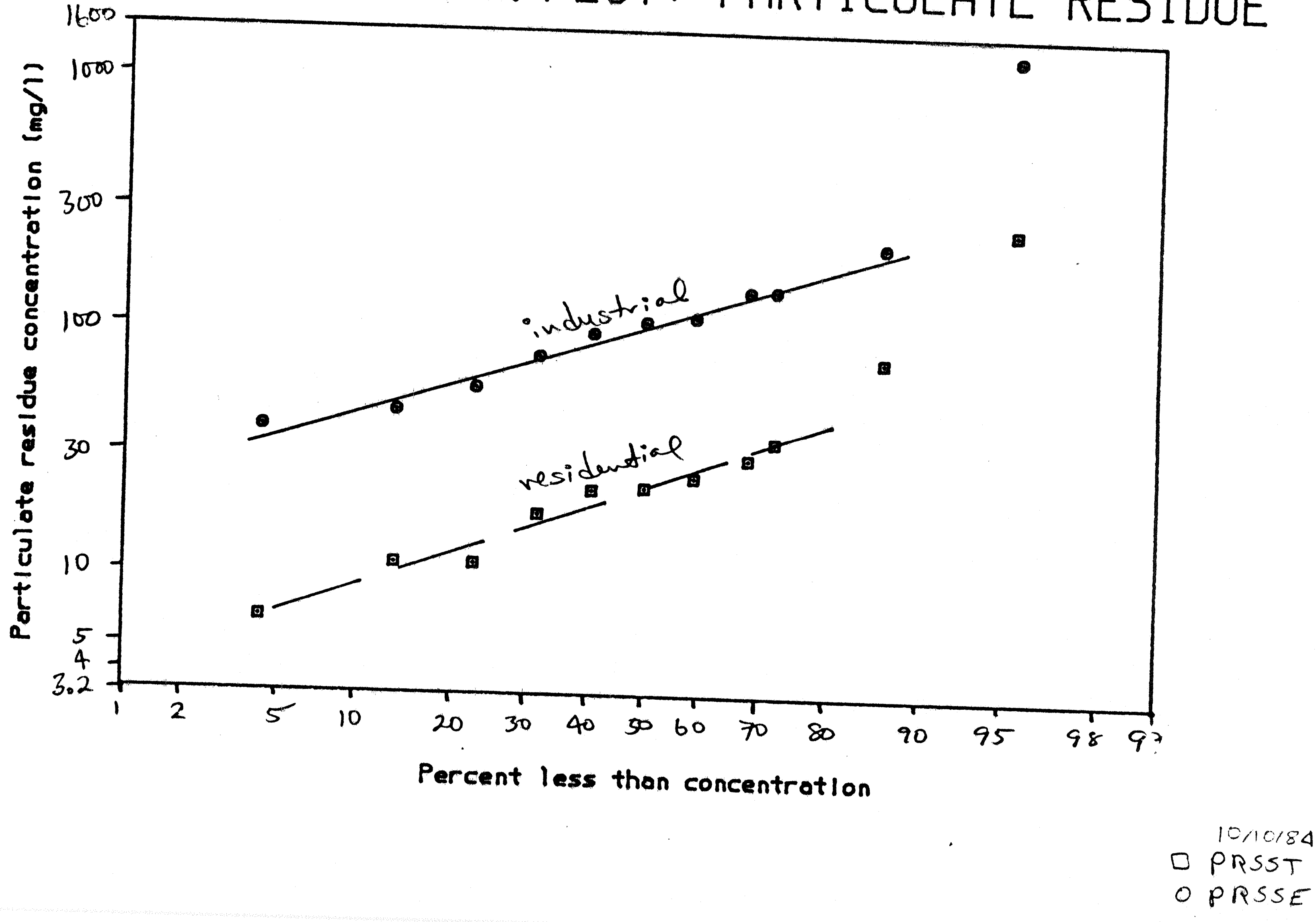
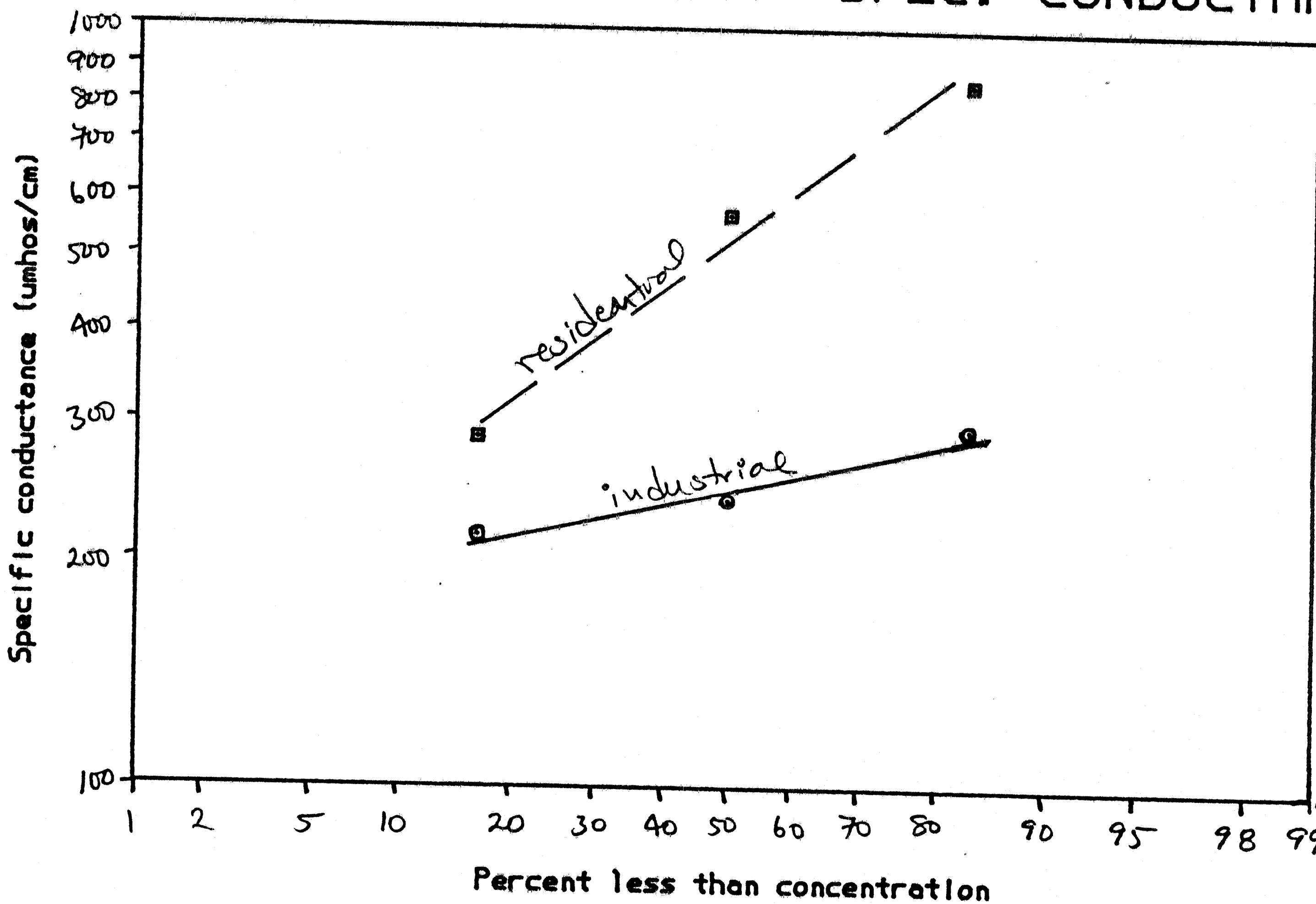


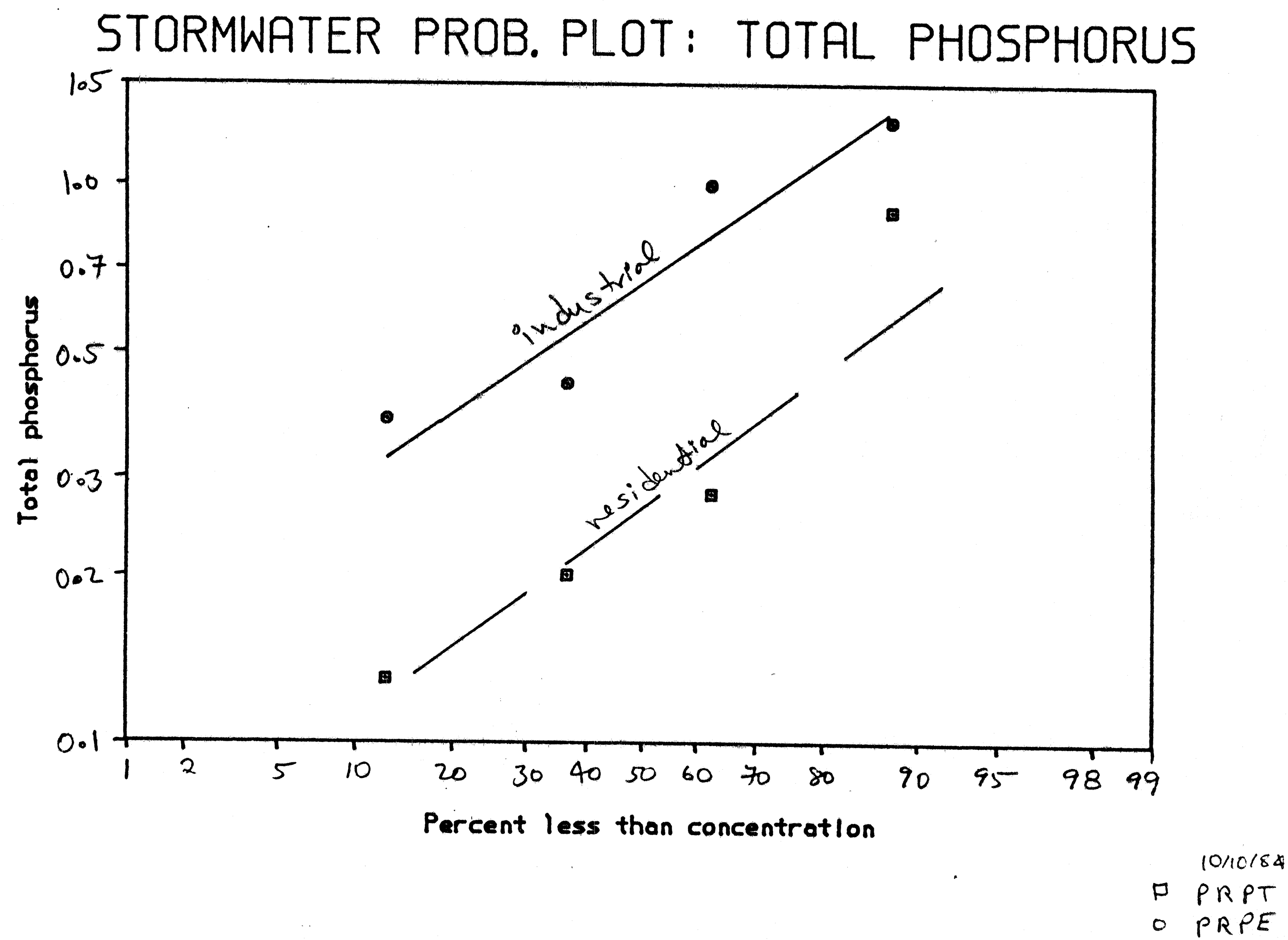
Figure E-36

STORMWATER PROB. PLOT: SPEC. CONDUCTANCE



10/10/84
□ PRSCT
○ PRSCE

Figure E.37



STORMWATER PROB. PLOT: TOTAL PHOSPHORUS
Total phosphorus
1.5
1.0
0.7
0.5
0.3
0.2
0.1
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
Percent less than concentration
industrial
residential
10/10/84
□ PRPT
○ PRPE

Figure E.38

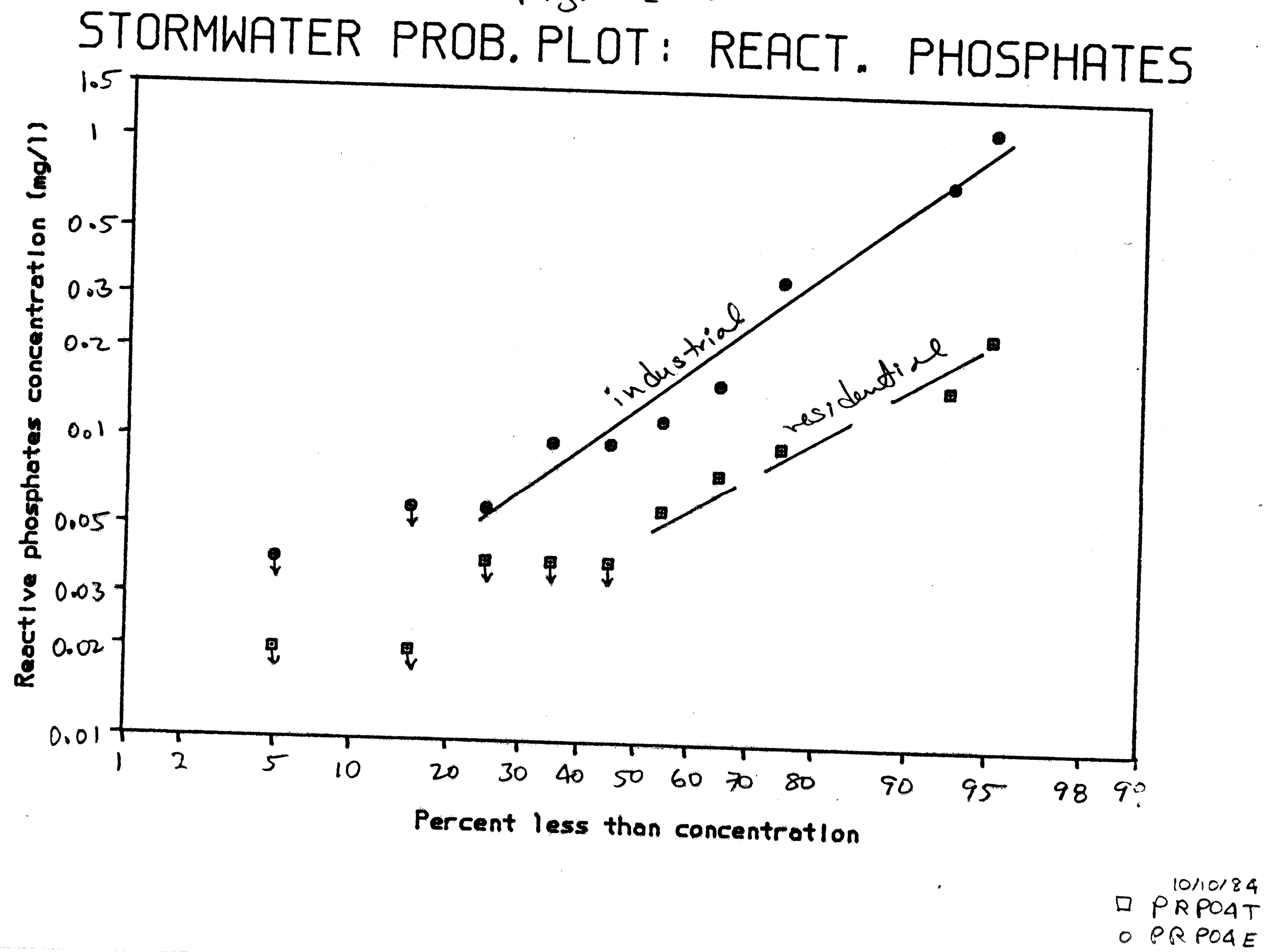

STORMWATER PROB. PLOT: REACT. PHOSPHATES
Reactive phosphates concentration (mg/l)
1.5
1
0.5
0.3
0.2
0.1
0.05
0.03
0.02
0.01
1
2
5
10
20
30
40
50
60
70
80
90
95
98
industrial
residential
Percent less than concentration
10/10/84
□ PRPO4T
○ PRPO4E

Figure E.39

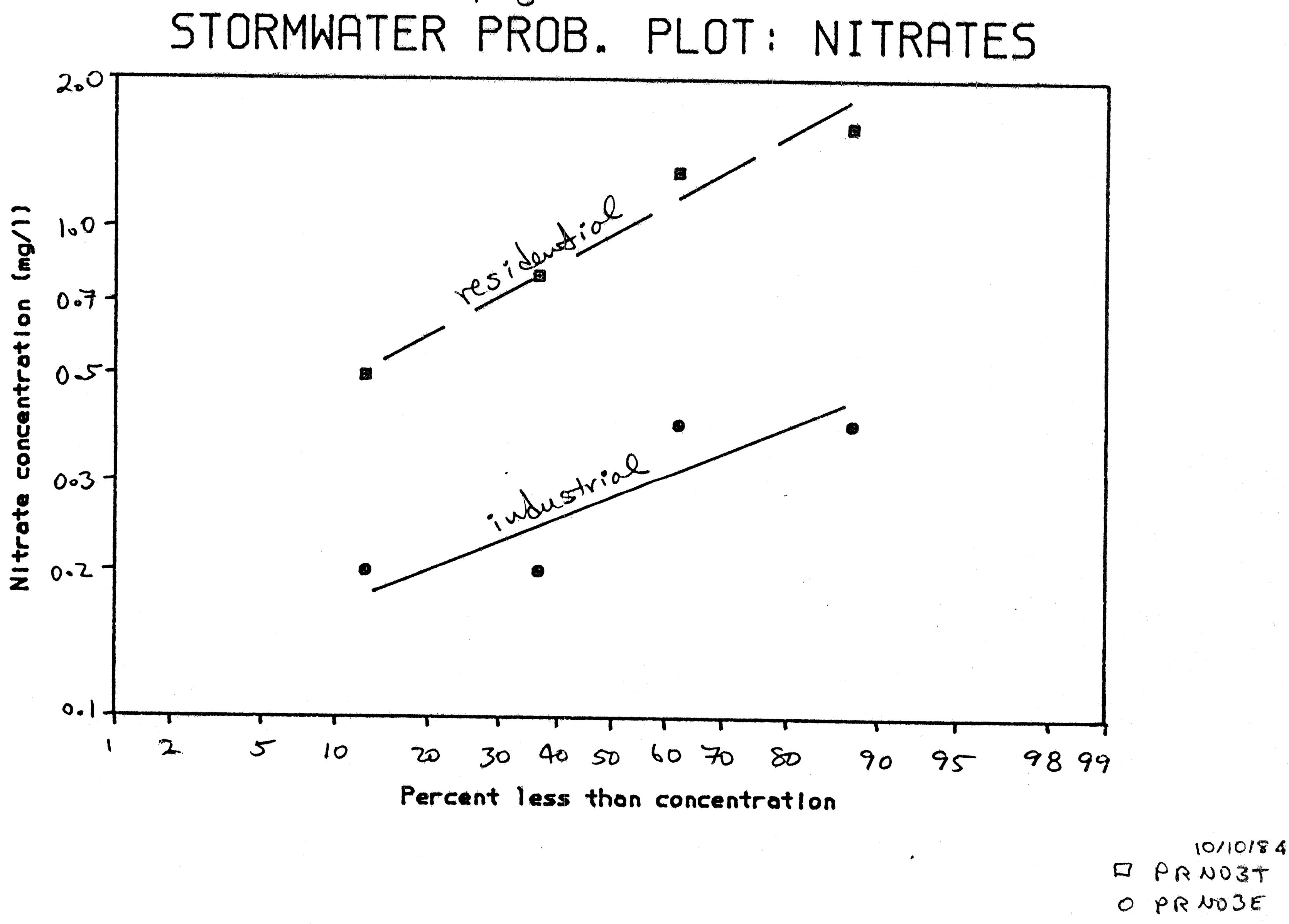

STORMWATER PROB. PLOT: NITRATES
2.0
1.0
0.7
0.5
0.3
0.2
0.1
Nitrate concentration (mg/l)
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
Percent less than concentration
residential
industrial
10/10/84
□ PRNO3T
○ PRNO3E

Figure E.40

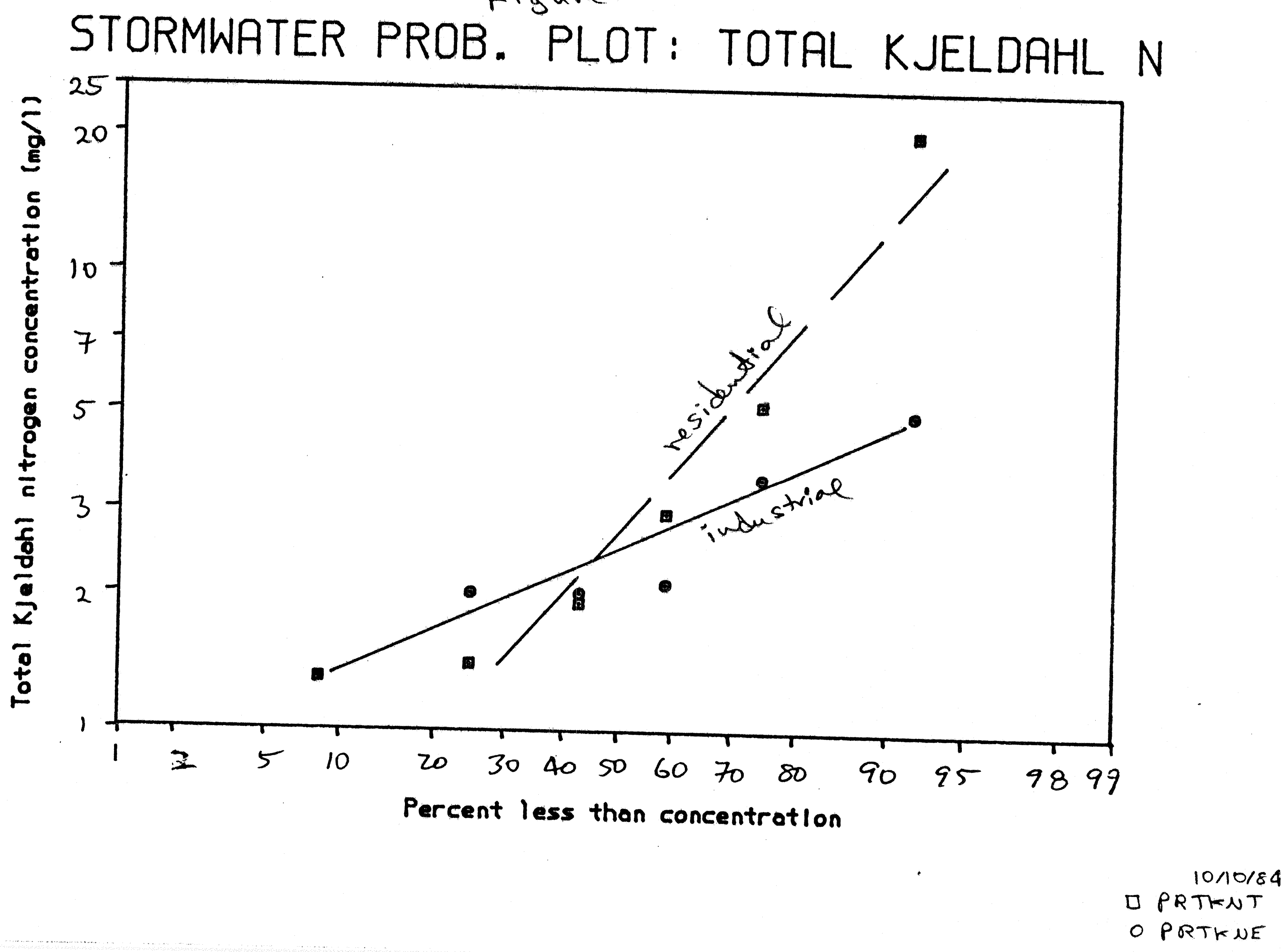

STORMWATER PROB. PLOT: TOTAL KJELDAHL N
Total Kjeldahl nitrogen concentration (mg/l)
25
20
10
7
5
3
2
1
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
Percent less than concentration
residential
industrial
10/10/84
□ PRTKNT
○ PRTKNE

Figure E.41

STORMWATER PROB. PLOT: PHENOLICS

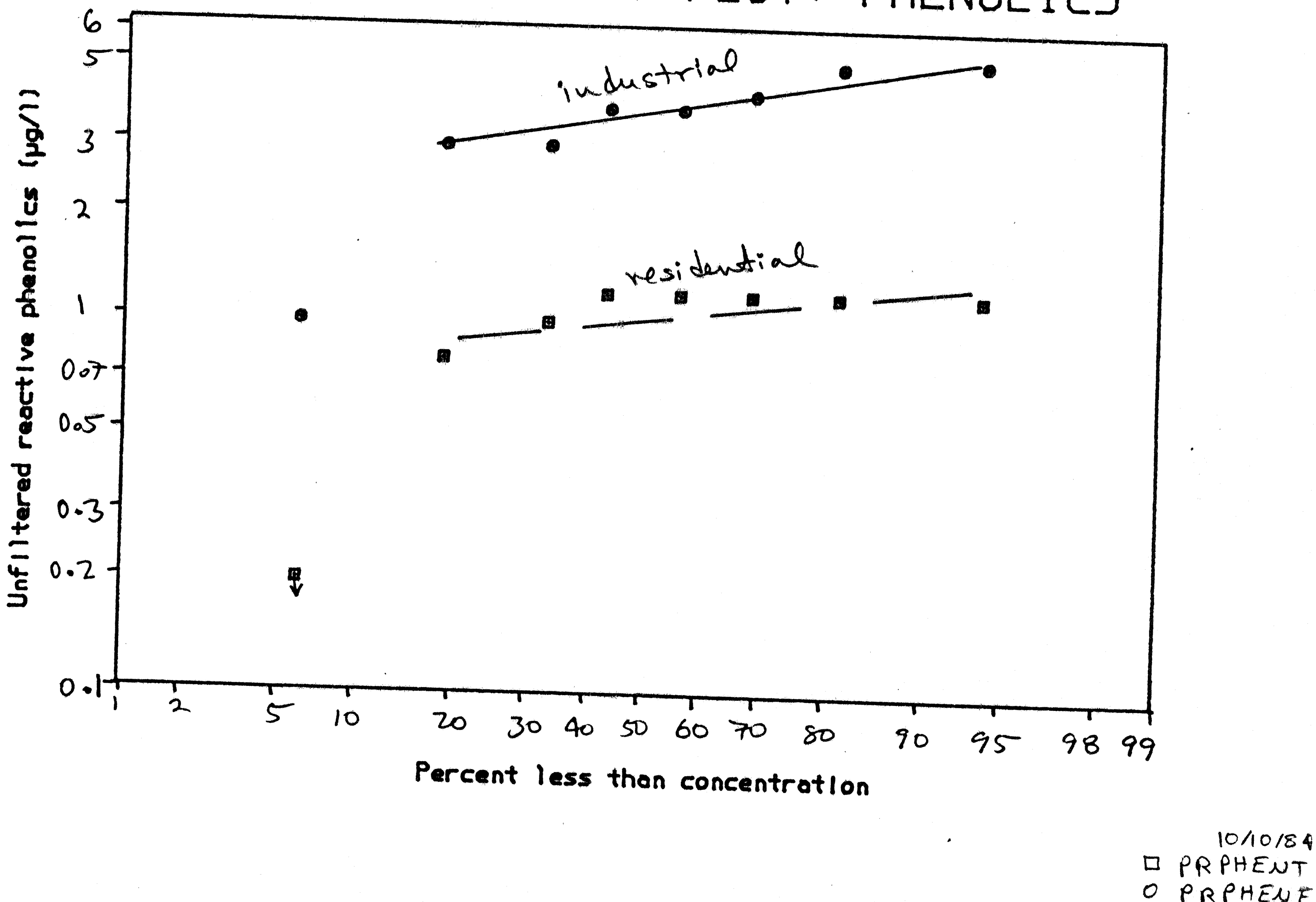


Figure E.4.2

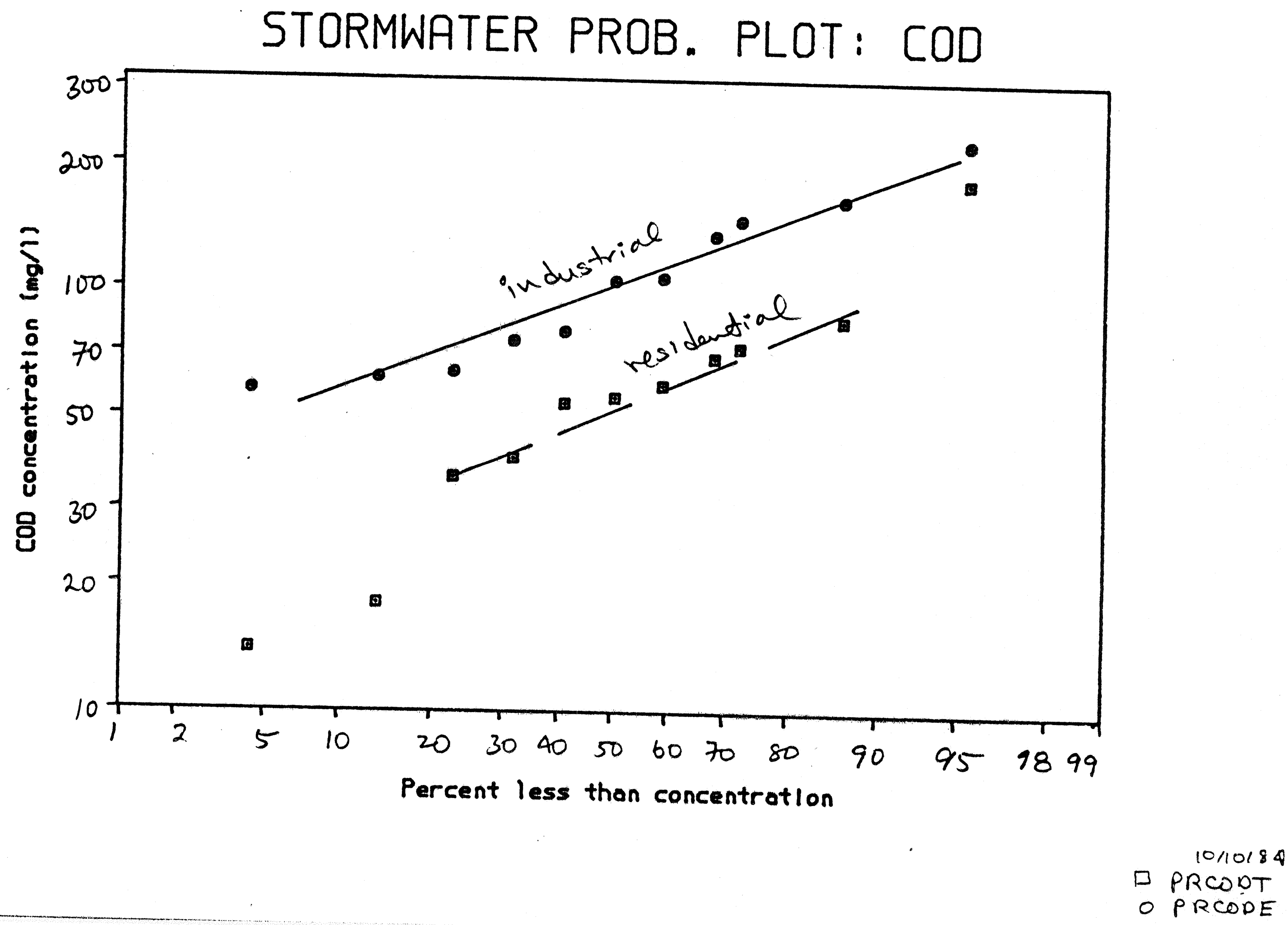
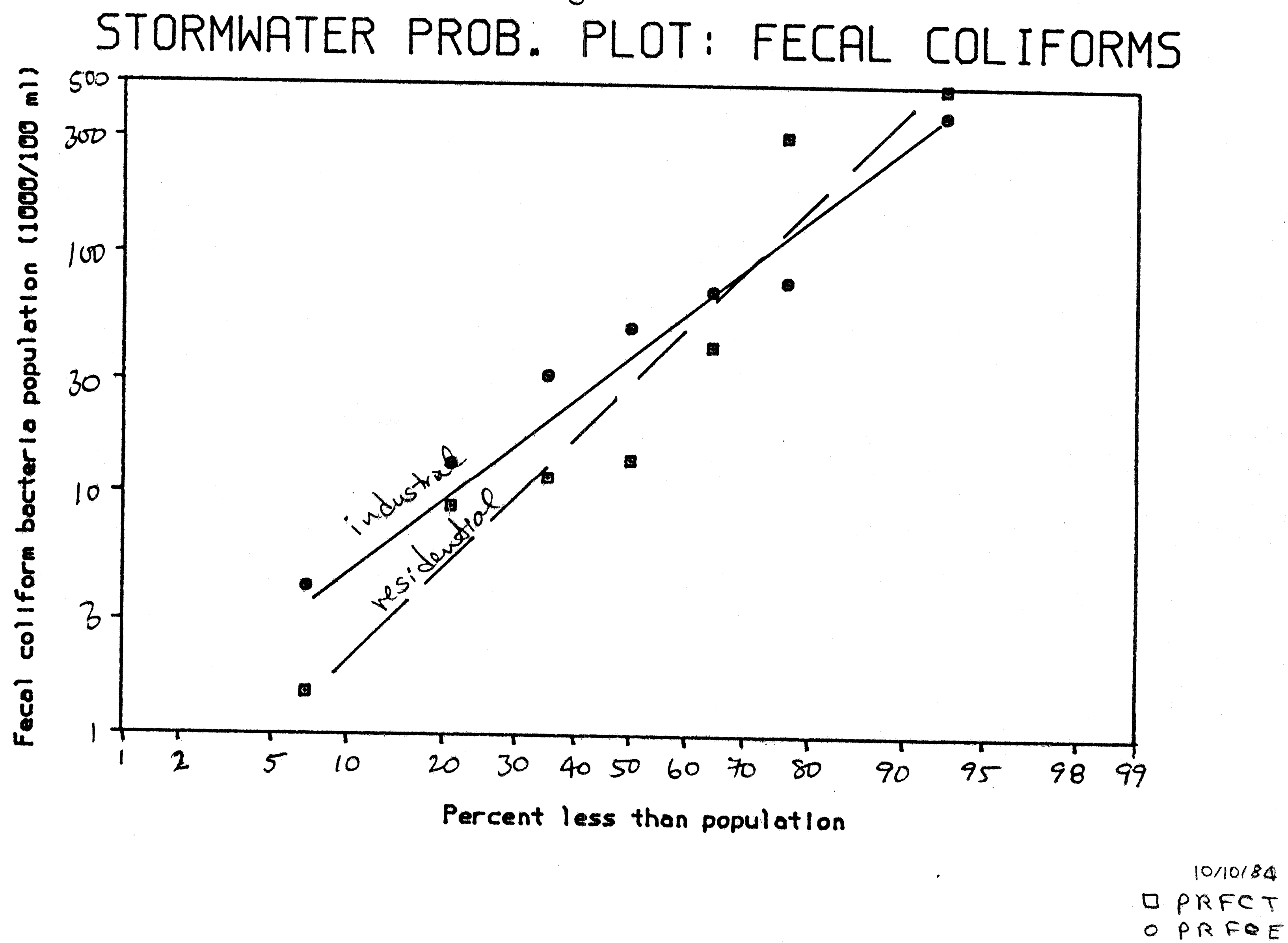
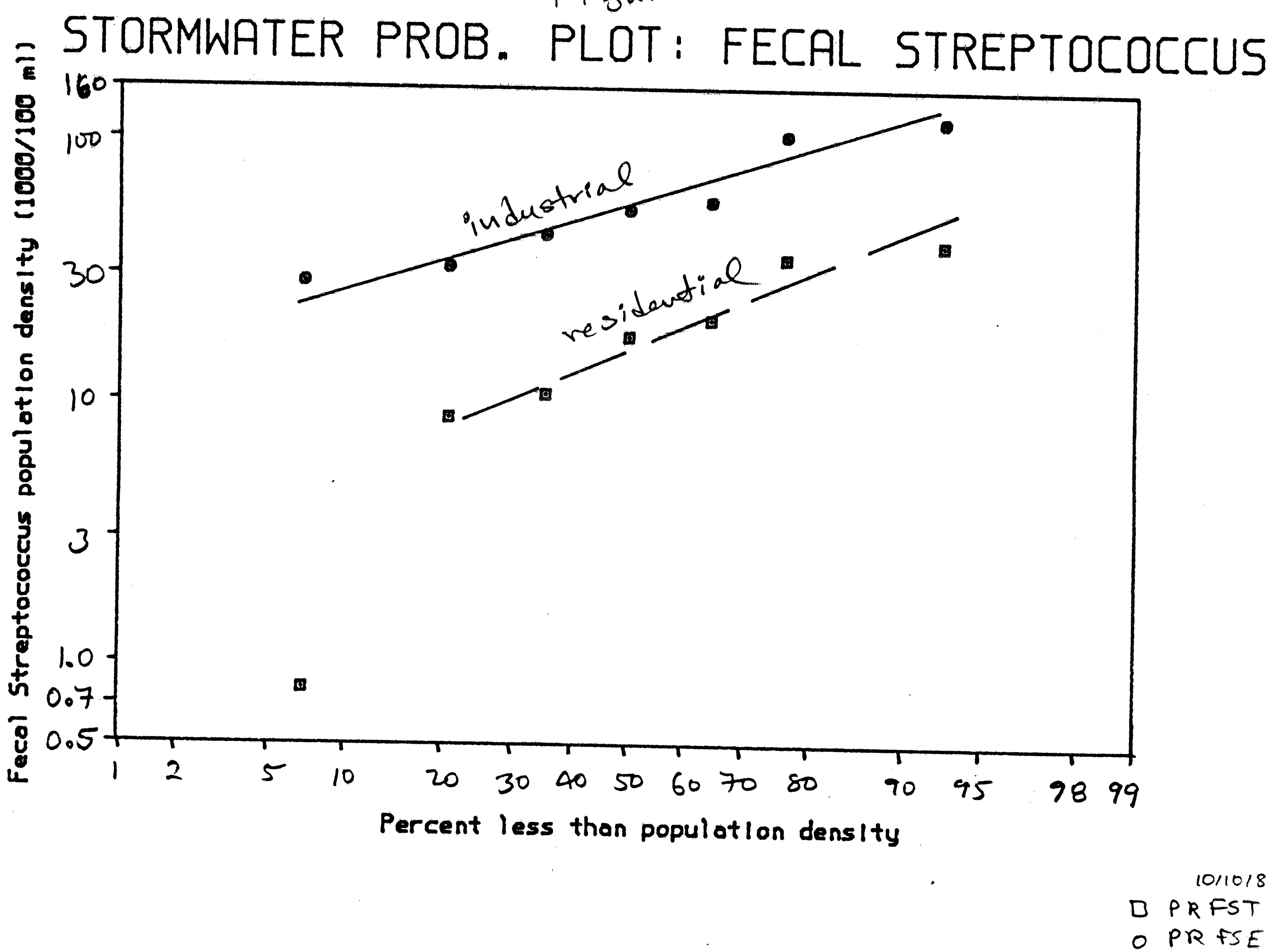

STORMWATER PROB. PLOT: COD
COD concentration (mg/l)
300
200
100
70
50
30
20
10
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
Percent less than concentration
industrial
residential
10/10/84
□ PRCODT
○ PRCODE

Figure E.43



STORMWATER PROB. PLOT: FECAL COLIFORMS
Fecal coliform bacteria population (1000/100 ml)
500
300
100
30
10
3
1
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
Percent less than population
industrial
residential
10/10/84
□ PRFCT
○ PRFCE

Figure E.44



STORMWATER PROB. PLOT: FECAL STREPTOCOCCUS
Fecal Streptococcus population density (1000/100 ml)
160
100
30
10
3
1.0
0.7
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
Percent less than population density
industrial
residential
10/10/84
□ PRFST
o PRFSE

Figure E.45

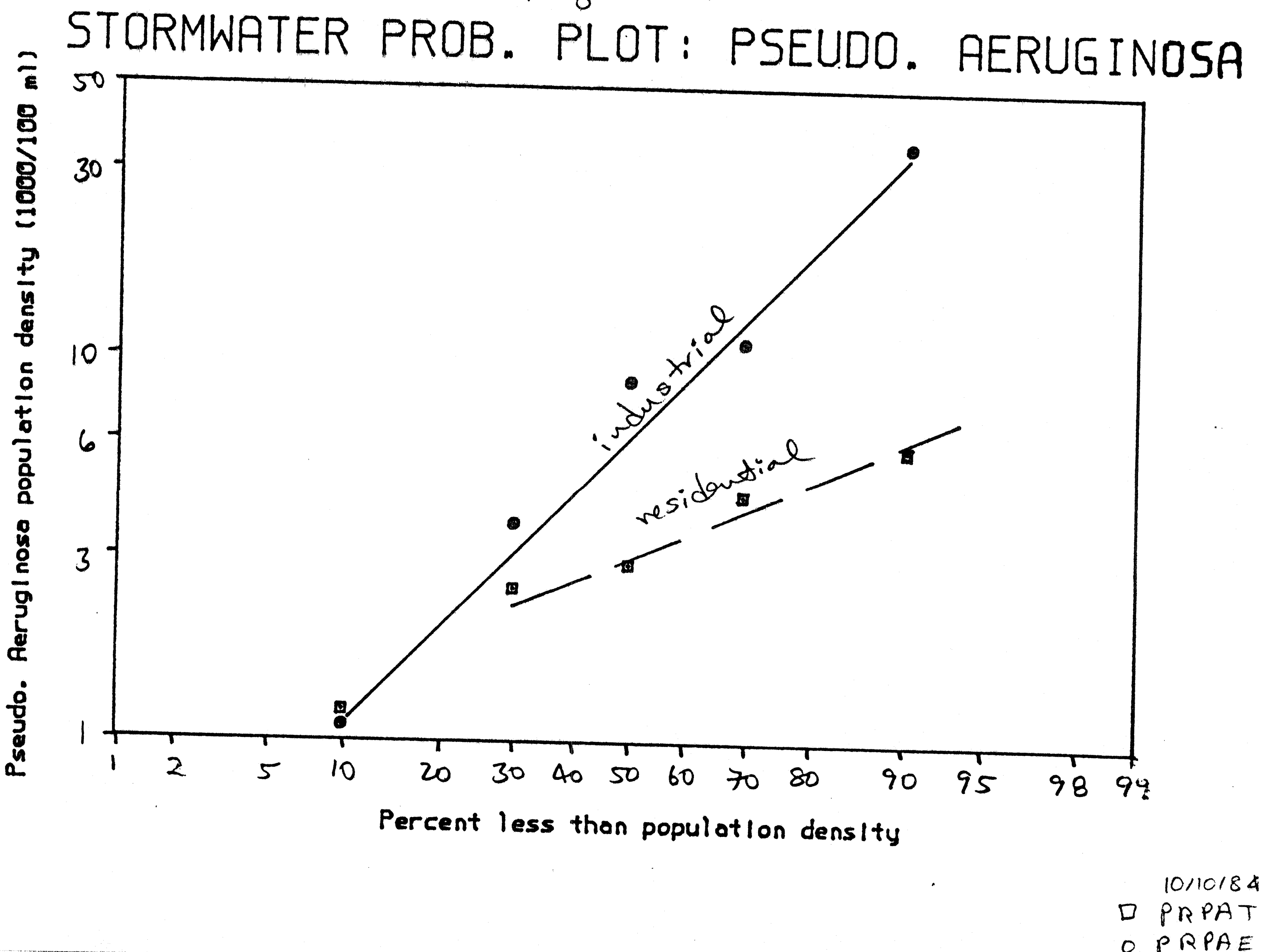
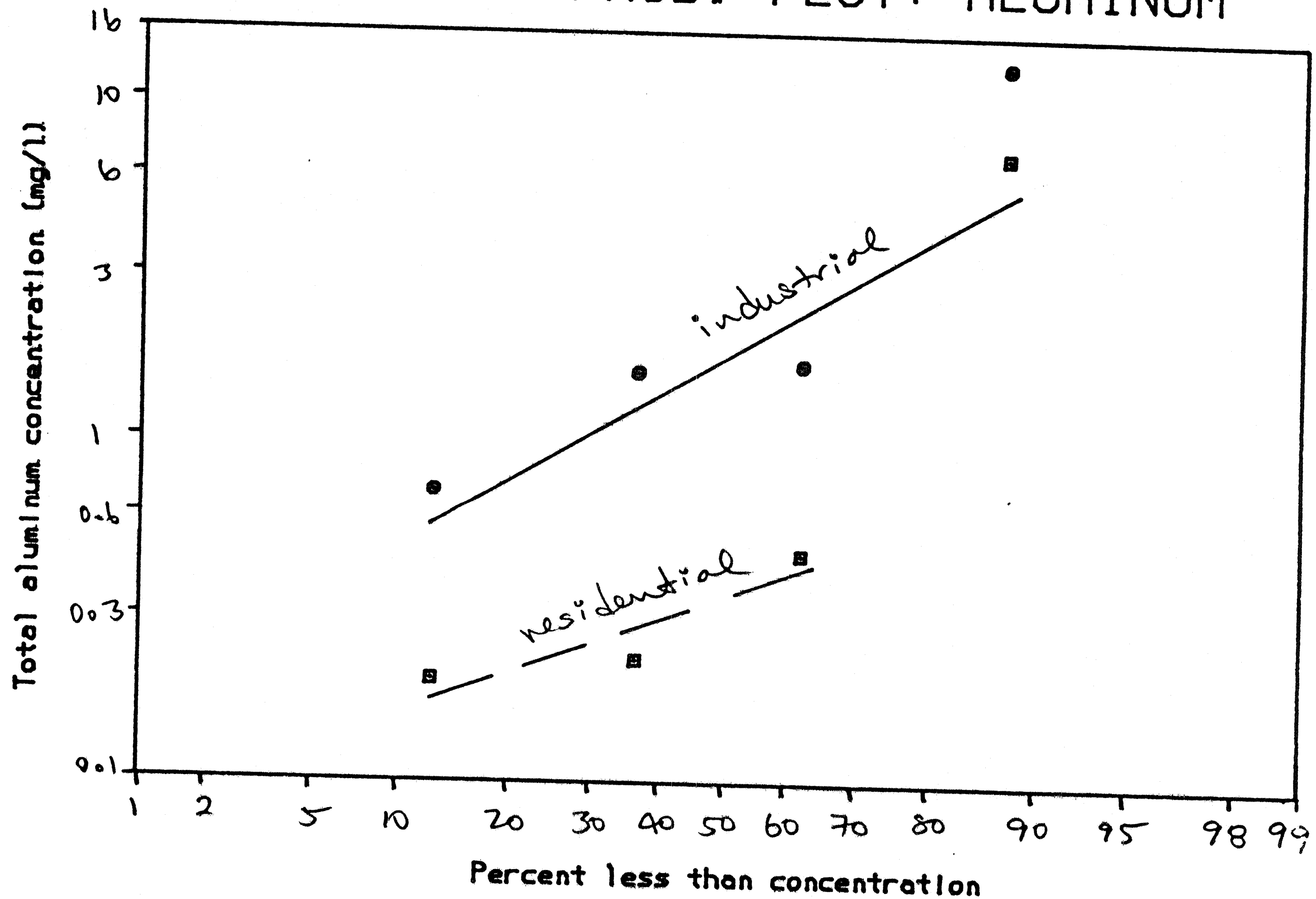

STORMWATER PROB. PLOT: PSEUDO. AERUGINOSA
Pseudo. Aeruginosa population density (1000/100 ml)
50
30
10
6
3
1
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
Percent less than population density
industrial
residential
10/10/84
□ PRPAT
o PRPAE

Figure E.46

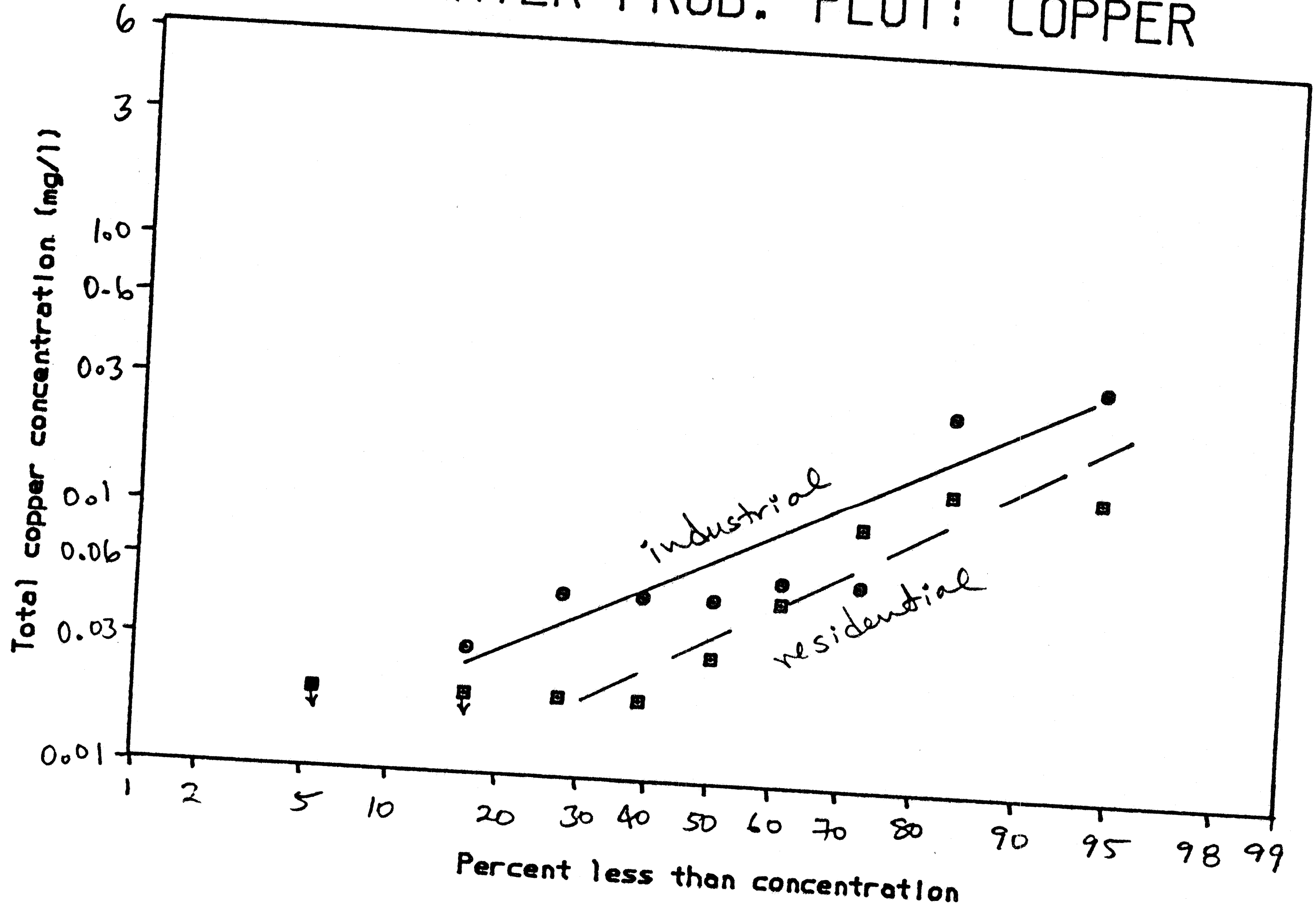
STORMWATER PROB. PLOT: ALUMINUM



10/10/84
□ PRALT
o PRALE

Figure E.47

STORMWATER PROB. PLOT: COPPER



10/10/84
□ PRCUT
○ PRCUE

Figure E.48

STORMWATER PROB. PLOT: LEAD

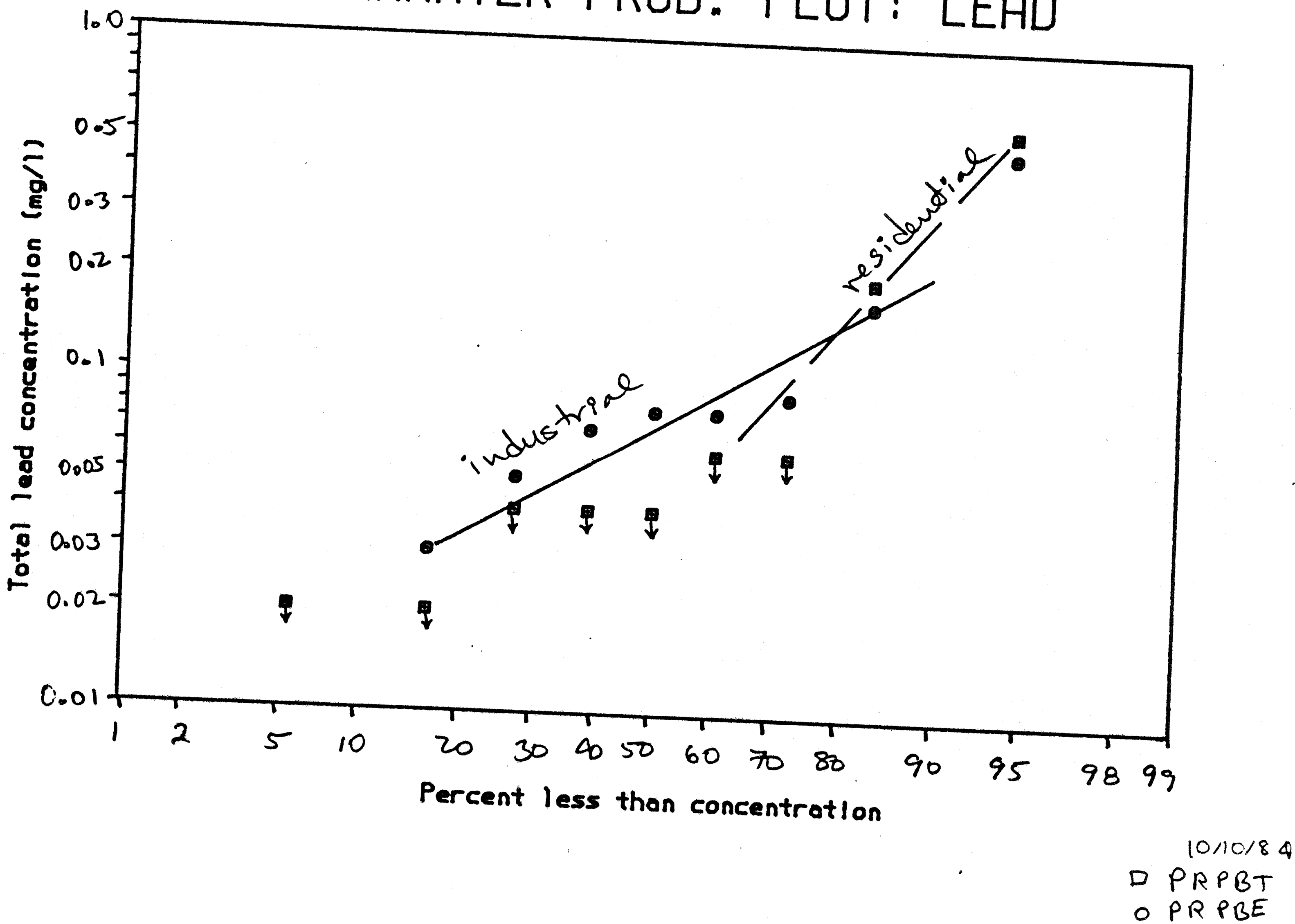
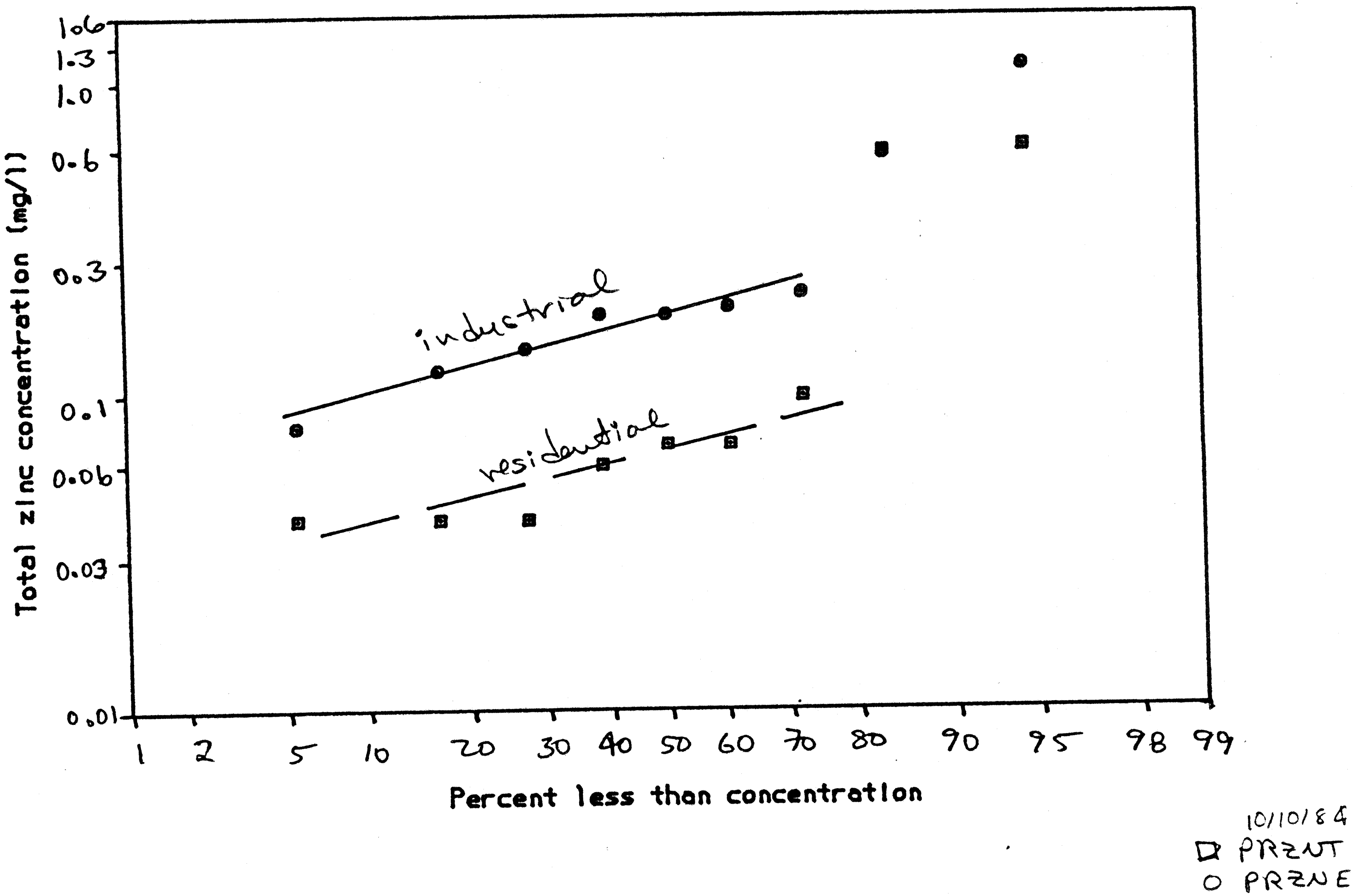


Figure E.49

STORMWATER PROB. PLOT: ZINC



APPENDIX F SOURCE AREA AND PARTICULATE QUALITY DATA

LIST OF TABLES

LIST OF FIGURES

(continued)

FIGURE	TITLE

(continued)

Table F.1 Warm Weather Source Area Sheetflow Quality (mg/l)

Pervious areas

sample #	storm #	Emery (E) or Thistle-downs (T)		total residue (TS)
Group 1: Bareground				
19	#29	E	Emery works yard	588
Group 2: Grass				
SF 139	#39	E	Emery works grass area	388
Group 3: Dirt foot path				
102	#48	T	H.R. park footpath	1240
Group 4: Unpaved driveway				
SF 128	#31	E	unpaved driveway	5620
Group 5: Unpaved parking area / storage area				
4	#27	E	WMI parking/storage area	805
6	#28	E	loose surface carpark	751
20	#29	E	MARTA const. equip. storage	1490
21	#29	E	loose surface carpark	670
SF 102	#30	E	WMI carpark	2520

Table F.1 Warm Weather Source Area Sheetflow Quality (mg/l) (Cont.)

Pervious areas:

			filtrable residue (TDS)	particulate residue 10 (SS)	P 11	PO4, filt. react.	TKN 13	NH4 14	phenolics 15 mg/l
Group 1: Bareground									
E	19	#29	196	392	0.68	0.26	1.8	<0.1	—
Group 2: Grass:									
E	SF 139	#39	285	103	0.56	0.14	3.6	0.4	0.8
Group 3: Dirt footpath:									
T	102	#48	436	807	0.20	0.66	1.3	0.5	<0.4
Group 4: Unpaved driveways:									
E	SF 128	#31	954	4670	3.0	0.10	7.5	<0.1	7.4
Group 5: Unpaved parking/storage areas:									
	4	#27	360	445	0.68	0.08	2.1	<0.1	1.8
E	6	#28	442	309	0.60	0.14	2.0	<0.1	9.2
	20	#29	393	1100	1.03	<0.02	2.8	<0.1	14.8
	21	#29	161	509	1.65	0.42	—	—	—
	SF 102	#30	1220	1290	1.15	<0.04	4.0	<0.1	9.0

Table F.1 Warm Weather Source Area Sheetflow Quality (mg/l) (Cont.)

Pervious areas:

			COD	FC #/100ml	FS #/100ml	PA #/100ml	Al mg/l	Cu	Cd
Group 1: Bareground:									
E	19	#29	54	—	—	—	11	<0.03	<0.004
Group 2: Grass:									
E	SF 139	#39	26	~3300	43,000	2100	1.50	<0.03	<0.03
Group 3: Dirt footpath:									
T	102	#48	66	—	—	—	1.70	<0.03	<0.001
Group 4: Unpaved driveway:									
E	SF 128	#31	418	~300,000	21,000	~100	41.0	<0.03	<0.004
Group 5: Unpaved parking / storage areas:									
	4	#27	140	~4500	6200	5700	7.5	<0.03	<0.004
	6	#28	16.0	40,000	~4,000	~500	10.0	<0.03	<0.005
E	20	#29	222	26000	22,000	51,000	2.8	<0.03	<0.004
	21	#29	272	—	—	—	19.0	<0.03	<0.004
	SF 102	#30	440	20	180	20	6.6	<0.03	0.004

Table F.1 Warm Weather Source Area Sheetflow Quality (mg/l) (cont.)

Pervious areas:

			Co	Cr	Cu	Mo	Ni	Pb
Group 1: Bareground								
E	19	#29	<0.04	<0.06	<0.02	<0.06	0.02	<0.04
Group 2: Grass:								
E	SF 139	#39	<0.10	<0.30	<0.20	<0.30	<0.10	<0.30
Group 3: Dirt footpath:								
T	102	#48	<0.01	<0.01	0.02	<0.01	<0.01	0.03
Group 4: Unpaved driveway:								
E	SF 128	#31	<0.04	0.07	0.14	<0.06	0.07	0.34
Group 5: Unpaved parking/storage areas:								
E	4	#27	<0.04	<0.06	0.25	<0.06	0.04	0.37
E	6	#28	<0.04	0.04	0.02	<0.06	<0.03	<0.02
E	20	#29	<0.04	<0.06	0.11	<0.06	0.03	0.23
E	21	#29	<0.04	<0.06	0.05	<0.06	0.03	0.16
E	SF 102	#30	<0.04	<0.06	0.15	<0.06	0.40	0.27

Table F.1 Warm Weather Source Area Sheetflow Quality (mg/l) (Cont).

Pervious areas:

				Zn	Spec. cond.	pH
Group 1: Bareground site						
E	19	#29	<0.03	0.10	—	—
Group 2: Grass:						
E	SF 139	#39	<0.03	<0.10	400	7.35
Group 3: Dirt footpath:						
T	102	#48	<0.03	0.04	250	7.78
Group 4: Unpaved driveway:						
E	SF 128	#31	<0.03	0.69	1160	7.44
Group 5: Unpaved parking/storage areas:						
E	4	#27	<0.03	0.55	—	—
	6	#28	<0.03	0.26	—	—
	20	#29	<0.03	0.26	—	—
	21	#29	<0.03	0.45	—	—
	SF 102	#30	<0.03	0.55	—	—

Table F.1 Warm Weather Source Area Sheetflow Quality (mg/l) (Contd.)

Impervious areas:

Sample #	Storm #						total residue
Group 6: Roof runoff							
SF 113	#31		T	residential asphalt shingle roof			40.8
SF 119	#31		T	resid. asphalt shingle roof			47.0
SF 122	#31		T	flat roof & asphalt shingle roof			112.0
104	#48		T	composition shingle roof			31.0
1	#27		E	wood manuf. roof			150.8
SF105	#30		E	sausage manuf. roof			74.4
Group 7: Paved parking areas							
8	#28		T	church car park – infrequent use			947.6
15	#28		T	supermarket car park			956.2
SF115	#31		T	A&P Supermarket (near loading docks)			1230.0
SF116	#31		T	A&P supermarket parking lot			1100.0
SF138	#39		T	church carpark – infrequent use			84.8
100	#48		T	supermarket carpark			7930.0
101	#48		T	supermarket (near loading docks)			304.0
2	#27		E	carpark @ MARX			64.4
7	#28		E	hard surface carpark			1637.0
18	#29		E	hard surface – cracked			421.0
SF100	#30		E	Cont. Can – loading docks			255.0
SF103	#30		E	asphalt carpark – loading dock			73.4
SF110	#30		E	light indus. mall			656.0
SF132	#31		E	asphalt carpark – oil stained cracked			315.0
Group 8: Storage areas							
14	#28		T	gas station service court			73.3
SF108	#30		E	carpark / equip. storage			266.0
SF135	#31		E	very cracked asphalt MARTA – vehicle yard			—

Table F.1 Warm Weather Source Area Sheetflow Quality (mg/l) (Contd.)

			S. volatile residue	part. resid	P	PO4 filt. resid.	TKN	NH4	phenols µg/l
Impervious Areas:									
Group 6: Roofs:									
T	SF 113	#31	37.8	<2.9	<0.04	<0.02	0.7	0.2	3.0
	SF 119	#31	41.0	<6.0	<0.04	<0.02	0.9	0.2	2.8
	SF 122	#31	72.4	39.7	0.13	<0.04	2.2	<0.1	2.8
	104	#48	296	<1.3	<0.04	<0.02	0.5	<0.1	0.8
E	1	#27	142.0	8.8	<0.04	<0.02	2.0	0.3	0.8
	SF105	#30	70.8	<3.6	<0.06	<0.02	1.3	0.4	1.6
Group 7: Paved parking areas:									
T	8	#28	60.6	887.0	—	<0.02	—	<0.1	—
	15	#28	75.2	881.0	0.73	<0.02	2.3	<0.1	33.8
	SF115	#31	321.0	910.0	1.75	0.14	12.0	0.5	11.8
	SF116	#31	345.0	757.0	0.90	0.10	5.0	<0.1	12.8
	SF138	#39	29.2	55.6	0.10	<0.02	1.4	0.5	3.6
	100	#48	56.0	7880.0	0.75	<0.02	1.3	<0.1	7.4
	101	#48	81.2	223.0	0.15	<0.02	0.8	<0.1	3.8
E	2	#27	70.6	13.8	<0.04	<0.02	1.1	<0.1	11.0
	7	#28	427.0	1210.0	1.55	0.06	7.0	<0.1	12.2
	18	#29	112.0	309.0	0.70	<0.04	—	—	—
	SF 100	#30	92.2	163.0	1.30	0.20	3.0	0.4	4.4
	SF 103	#30	57.6	150.7	1.76	1.24	3.1	0.3	3.2
	SF110	#30	329.0	327.0	10.3	2.80	6.0	1.0	17.0
	SF 132	#31	213.0	102.0	0.17	<0.02	1.0	<0.1	8.6
Group 8: Storage areas									
T	14	#28	132.2	41.1	—	<0.02	—	0.3	30.0
E	SF101	#30	64.2	202.0	0.66	0.06	2.9	0.3	2.6
	SF 135	#31	—	—	—	—	—	—	—

Table F.1 Warm Weather Source Area Sheetflow Quality (mg/L) (Contd.)

Impervious areas:

	Group 6: Roofs:		COD	FC #/100 mL	FS	PA	Al	As	Cd
T	SF 113	#31	32	~500	540	90,000	<0.20	<0.03	<0.004
T	SF 119	#31	40	3700	5700	~100	<0.20	<0.03	<0.004
T	SF 122	#31	96	~120	940	~20	0.15	<0.03	<0.001
T	104	#48	14	—	—	—	<0.04	<0.03	<0.001
E	1	#27	76	2600	1000	<20	<0.20	<0.03	<0.004
E	SF 105	#30	34	560	380	~100	<0.20	<0.03	<0.004
	Group 7: Paved parking areas:								
T	8	#28	56	—	—	—	—	—	—
T	15	#28	108	~500	<100	440	<0.08	<0.03	<0.005
T	SF115	#31	478	980,000	690,000	~2,000	9.20	<0.03	<0.004
T	SF116	#31	462	19,000	67,000	~5,000	9.00	<0.03	0.009
T	SF138	#39	12	3300	1000	~80	0.35	<0.03	<0.006
T	100	#48	36	—	—	—	0.41	<0.03	0.001
T	101	#48	62	—	—	—	0.39	<0.03	<0.001
E	2	#27	54	~100	<100	466	0.53	<0.03	<0.004
E	7	#28	298	23,000	39,000	15,000	9.50	<0.03	<0.005
E	18	#29	152	—	—	—	4.90	<0.03	<0.004
E	SF 100	#30	132	~30	380	110	0.67	<0.03	<0.004
E	SF 103	#30	64	2800	<100	~100	0.62	<0.03	<0.004
E	SF 110	#30	496	1000	~900	~700	5.70	<0.03	0.015
E	SF 132	#31	52	25,000	3500	~18,300	2.30	<0.03	<0.004
	Group 8: Storage areas:								
T	14	#28	22	~100	<100	~100	0.38	<0.03	<0.005
E	SF 101	#30	82	380	~140	~20	1.30	<0.03	<0.004
E	SF 135	#31	—	18,000	~4,000	5900	4.90	<0.03	<0.004

Table F.1 Warm Weather Source Area Sheet Flow Quality (mg/l) (Cont.)

Impervious areas:

			3 Co	4 Cr	5 Cu	6 Mo	7 Ni	8 Pb	9 Se
	Group 6: Roofs								
	SF 113	#31	<0.04	<0.06	0.03	<0.06	0.12	<0.04	<0.03
T	SF 119	#31	<0.04	<0.06	<0.02	<0.06	<0.04	<0.04	<0.03
	SF 122	#31	<0.01	<0.01	0.01	0.02	<0.01	<0.01	0.03
	104	#48	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.03
	1	#27	<0.04	<0.06	0.03	<0.06	<0.02	<0.04	<0.03
E	SF105	#30	<0.04	<0.06	<0.02	<0.06	<0.02	<0.04	<0.03
	Group 7: Paved parking areas:								
	8	#28	—	—	—	—	—	—	—
	15	#28	<0.04	<0.01	<0.01	<0.06	<0.03	<0.02	<0.03
	SF115	#31	<0.04	<0.06	0.12	<0.06	<0.04	0.43	<0.03
T	SF116	#31	<0.04	0.10	0.36	<0.06	0.08	0.57	<0.03
	SF138	#39	<0.04	<0.04	<0.02	<0.04	<0.02	<0.04	<0.03
	100	#48	<0.01	<0.01	0.06	<0.01	0.01	0.27	<0.03
	101	#48	<0.01	<0.01	0.04	<0.01	<0.01	0.27	<0.03
	2	#27	<0.04	<0.06	0.28	<0.06	0.02	0.08	<0.03
	7	#28	<0.04	0.05	0.02	<0.06	<0.03	0.17	<0.03
	18	#29	<0.04	<0.06	0.04	<0.06	<0.02	0.20	<0.03
	SF100	#30	<0.04	<0.06	0.06	<0.06	<0.02	0.10	<0.03
E	SF103	#30	<0.04	<0.06	0.04	<0.06	0.14	<0.04	<0.03
	SF110	#30	0.09	0.21	2.90	0.08	0.09	0.97	<0.03
	SF132	#31	<0.04	<0.06	0.03	<0.06	<0.04	0.06	<0.03
	Group 8: Storage areas:								
T	14	#28	<0.04	<0.01	0.02	<0.06	<0.03	0.76	<0.03
	SF101	#30	<0.04	<0.06	0.44	<0.06	<0.02	0.24	<0.03
E	SF135	#31	<0.04	<0.06	0.08	<0.06	<0.04	0.32	<0.03

Table F.1 Warm Weather Source Area Sheet Elow Quality (mg/l) (Contd.)

Impervious areas:

Group 6: Roofs:			Zn	spec. cond.	pH
	SF 113	#31	0.66	29	6.48
T	SF 119	#31	0.61	—	—
	SF 122	#31	0.01	86	8.16
	104	#48	0.01	56	8.01
E	1	#27	0.08	—	—
	SF105	#30	0.06	—	—

Group 7: Paved parking areas:					
	8	#28	—	—	—
	15	#28	0.13	—	—
T	SF115	#31	1.00	—	—
	SF116	#31	1.10	—	—
	SF138	#39	0.02	76	6.86
	100	#48	0.37	92	7.70
	101	#48	0.50	112	7.46
E	2	#27	0.51	—	—
	7	#28	0.33	—	—
	18	#29	0.34	—	—
	SF 100	#30	0.34	—	—
	SF103	#30	0.09	—	—
	SF110	#30	2.80	—	—
	SF 132	#31	0.08	290	7.87

Group 8: Storage areas:					
T	14	#28	0.39	—	—
E	SF101	#30	0.28	—	—
	SF135	#31	0.34	—	—

Table F.1 Warm Weather Source Area Sheetflow Quality (mg/l) (Cont.) 11/20

sample #	storm #			total residue
Group 9: Paved driveways:				
11	#28	T	new asphalt driveway	665.0
SF120	#31	T	good condition driveway	350.0
SF133	#31	E	cracked asphalt driveway	506.0
Group 10: Sidewalks:				
SF121	#31	T	concrete	48.8
3	#27	E	WHI footpath	890
SF131	#31	E	concrete	269.0
Group 11: Paved Roads:				
5	#28	T	asphalt road	
10	#28	T	asphalt road	260.0
SF117	#31	T	asphalt (multi-resid.)	1120.0
SF124	#31	T	smooth/cracked asphalt	97.2
105	#48	T	rough/cracked asphalt	114.6
106	#48	T	smooth/cracked asphalt	255.0
107	#48	T	very good asphalt	106.2
16	#29	E	Coca Cola roadway	992.0
17	#29	E	Mary-Abel-Globe roadway	2351.0
SF118	#31	E	light indus	1130.0
SF123	#31	E	asphalt (wood manuf.)	299.0
SF126	#31	E	smooth asphalt, busy	307.0
SF127	#31	E	coarse road, near unpaved driveways	6870
SF130	#31	E	rough asphalt road	637

Table F.1 Warm Weather Source Area Sheetflow Quality (mg/l) (Cont.) 12/20

			filtrate residue	part. resid.	P	PO_4 filt. react.	TKN	NH_4	phenolics ug/L
Group 9: Paved driveways:									
T	11	#28	49.0	616.0	0.22	<0.02	2.1	<0.1	13.6
	SF120	#31	91.6	258.0	0.50	<0.02	4.0	<0.1	5.8
E	SF133	#31	133.0	373.0	0.90	<0.02	5.7	<0.1	7.0
Group 10: Sidewalks:									
T	SF121	#31	28.4	20.3	0.80	0.64	1.1	0.3	8.6
E	3	#27	107.0	783.0	1.30	0.06	5.8	<0.1	9.2
	SF131	#31	183.0	85.7	0.34	<0.04	3.5	<0.1	8.2
Group 11: Paved Roads:									
T	5	#28							
	10	#28	61.0	199.0	0.18	<0.02	0.9	<0.1	5.8
	SF117	#31	248.0	870.0	1.50	0.30	7.5	<0.1	7.4
	SF124	#31	54.2	43.0	0.83	<0.06	1.4	<0.1	4.6
	105	#48	41.0	73.6	0.20	0.06	1.0	<0.1	3.0
	106	#48	48.4	206.6	0.60	0.06	1.8	<0.1	9.6
	107	#48	46.8	59.4	0.38	<0.04	1.8	<0.1	6.8
E	16	#29	121.0	871.0	2.53	<0.06	15.6	<0.1	—
	17	#29	271.0	2080.0	5.10	0.78	12.0	<0.1	74
	SF114	#31	188.0	943.0	0.90	<0.06	3.5	<0.1	11.2
	SF123	#31	129.0	170.0	0.20	0.08	1.1	<0.1	9.8
	SF126	#31	96.6	210.0	0.40	0.10	1.3	<0.1	18.4
	SF127	#31	2440	4430	1.70	<0.02	4.3	<0.1	10.4
	SF130	#31	213	424	0.58	0.06	2.5	<0.1	18.2

Table F.1 Warm Weather Source Area Sheetflow Quality (mg/l) (Cont.) 13/20

			COD	FC (#/100 ml)	FS (#/100 ml)	PA	Al	As	Cd
Group 9: Paved driveways:									
T	11	#28	72	—	—	—	—	—	—
T	SF120	#31	284	~600	1900	~600	5.3	<0.03	0.005
E	SF133	#31	138	66,000	36,000	14,300	3.4	<0.03	<0.004
Group 10: Sidewalks:									
T	SF121	#31	62	11,000	1800	~600	0.48	<0.03	<0.004
E	3	#27	138	90,000	3300	~100	—	—	—
E	SF131	#31	58	19,000	3900	7100	1.20	<0.03	<0.004
Group 11: Paved Roads:									
T	5	#28							
T	10	#28	62	~800	1100	~20	<0.08	<0.03	<0.005
T	SF117	#31	696	~15,000	7900	<100	5.40	<0.03	<0.004
T	SF124	#31	50	4800	13,000	1700	0.63	<0.03	<0.004
T	105	#48	66	—	—	—	<0.04	<0.03	<0.001
T	106	#48	102	—	—	—	2.00	<0.03	<0.005
T	107	#48	66	—	—	—	0.67	<0.03	<0.005
E	16	#29	116	—	—	—	6.2	<0.03	<0.004
E	17	#29	560	140,000	240,000	8300	7.3	<0.03	<0.004
E	SF114	#31	360	10,000	11,000	~2,000	13.0	<0.03	0.007
E	SF123	#31	96	28,000	14,000	15,000	5.6	<0.03	<0.004
E	SF126	#31	140	~3000	~2000	~2000	6.1	<0.03	<0.004
E	SF127	#31	338	~1800	~600	1000	51.0	<0.03	0.007
E	SF130	#31	326	430,000	~6000	~9000	8.90	<0.03	<0.004

Table F.1 Warm Weather Source Area Sheetflow Quality (mg/l) (Cont.)

			Co	Cr	Cu	Mo	Ni	Pb	Se
Group 9: Paved driveways:									
T	11	#28	—	—	—	—	—	—	—
	SF120	#31	<0.04	<0.06	0.21	<0.06	0.09	1.40	<0.03
E	SF133	#31	<0.04	<0.06	0.04	<0.06	<0.04	0.26	<0.03
Group 10: Sidewalks:									
T	SF121	#31	<0.04	<0.06	0.02	<0.06	<0.04	0.08	0.12
E	3	#27	—	—	—	—	—	—	—
	SF131	#31	<0.04	<0.06	0.03	<0.06	<0.04	<0.04	<0.03
Group 11: Paved Roads:									
T	5	#28							
	10	#28	<0.04	<0.01	<0.01	<0.06	<0.03	<0.02	<0.03
	SF117	#31	<0.04	<0.06	0.14	<0.06	0.04	0.36	<0.03
	SF124	#31	<0.04	<0.06	<0.02	<0.06	<0.04	0.09	<0.03
	105	#48	<0.01	<0.01	0.01	<0.01	<0.01	0.03	<0.03
	106	#48	<0.02	<0.01	0.03	<0.01	<0.01	0.45	<0.03
	107	#48	<0.02	<0.01	0.03	<0.01	<0.01	0.16	<0.03
E	16	#29	<0.04	<0.06	0.17	<0.06	0.04	0.81	<0.03
	17	#29	<0.04	<0.06	0.09	<0.06	<0.02	0.48	<0.03
	SF114	#31	<0.04	0.06	0.78	<0.06	0.04	1.00	<0.03
	SF123	#31	<0.04	<0.06	0.07	<0.06	<0.04	0.15	<0.03
	SF126	#31	<0.04	<0.06	0.07	<0.06	0.03	0.42	<0.03
	SF127	#31	<0.04	0.10	0.24	<0.06	0.08	0.55	<0.03
	SF130	#31	<0.04	<0.06	0.13	<0.06	<0.04	0.51	<0.03

Table F.1 Warm Weather Source Area Sheetflow Quality (mg/l) (Cont.) 15/20

			Zn	Spec. Cond.	pH
Group 9: Paved driveways:					
T	11	#28	—	—	—
	SF120	#31	1.00	—	—
E	SF133	#31	0.31	185	7.67
Group 10: Sidewalks:					
T	SF121	#31	0.06	63	7.00
E	3	#27	—	—	—
	SF131	#31	0.06	257	7.77
Group 11: Paved Roads:					
T	5	#28			
	10	#28	0.16	—	—
	SF117	#31	0.47	—	—
	SF124	#31	0.07	82	7.70
	105	#48	0.03	54	6.82
	106	#48	0.19	80	6.87
	107	#48	0.15	78	6.70
E	16	#29	0.83	—	—
	17	#29	0.44	—	—
	SF114	#31	2.10	220	7.62
	SF123	#31	0.26	170	7.86
	SF126	#31	0.59	115	7.79
	SF127	#31	1.60	2250	7.67
	SF130	#31	0.55	220	7.37

Table F.1 Warm Weather Source Area Sheetflow Quality (mg/l) (Cont.)

Drainage System

sample #	storm #			total residue
Group 12: Sealed Drainage Ditches				
12	#28	T	sealed swale	292
SF 118	#31	T	sealed w/ tar & chip	431
SF 125	#31	T	recently sealed w/ tar & chip	654
108	#48	T	sealed w/ tar & chip	193
Group 13: Grass Swales				
9	#28	T	grass swale	47.2
Group 14: Road Gutters				
SF104	#30	E	road gutter	482
SF 108	#30	E	concrete gutters	674
SF 109	#30	E	concrete gutter	1970
SF 129	#31	E	gutter	439
SF 136	#39	E	paved gutter (mod. traffic)	145
SF 137	#39	E	gutter (heavy traffic)	691
SF 140	#39	E	gutter	899
Group 15: Catchbasins				
13	#28	T	catchbasin from grass swale	85.8
Group 16: Northern Telecom area Drain				
SF106	#30	E		232
SF107	#30	E		219
SF111	#31	E		220
SF112	#31	E		220
SF134	#31	E		—

Table F.1 Warm Weather Source Area Sheetflow Quality (mg/L) (Cond.)

Drainage System:

	sample #	storm #	filtrate residue	part. resid.	P	PO4 & H. react.	TKN	NH4	phenolics mg/L
Group 12: Sealed Drainage Ditches:									
	12	#28	286	<6	—	0.12	—	<0.1	2.6
T	SF 118	#31	216	215	0.65	0.18	4.3	0.3	15.6
	SF 125	#31	149	505	0.16	<0.06	1.3	<0.1	4.6
	108	#48	154	37.4	0.55	0.40	1.0	0.2	4.8
Group 13: Grass Swale:									
T	9	#28	36.6	10.6	—	0.12	0.5	<0.1	—
Group 14: Road Gutters:									
	SF104	#30	97.2	385	0.40	0.06	2.3	0.3	9.8
	SF108	#30	150	520	3.60	2.32	6.5	2.4	15.0
	SF109	#30	193	1780	6.00	0.26	12.5	0.5	22.0
E	SF129	#31	123	316	0.33	0.12	1.3	<0.1	18.6
	SF136	#39	47	98	0.17	<0.06	1.0	0.3	4.0
	SF137	#39	181	510	1.60	0.12	3.5	<0.1	32.8
	SF140	#39	307	592	0.70	0.10	2.0	<0.1	1.8
Group 15: Catchbasin:									
T	13	#28	43	42.8	—	0.02	—	<0.1	31.0
Group 16: Northern Telecom Drain:									
	SF106	#30	163	69.2	0.22	<0.04	1.1	0.3	2.0
	SF107	#30	154	64.8	0.23	0.06	1.1	0.2	2.0
E	SF111	#31	160	60	0.15	<0.02	2.0	0.3	6.0
	SF112	#31	156	63.7	0.13	<0.02	2.0	<0.1	5.4
	SF13A	#31	—	—	—	—	—	—	—

Table F.1 Warm Weather Source Area Sheetflow Quality (mg/L) (Cont.)

Drainage System:

	Sample #	Storm #	COD	FC (#/100 mL)	FS	PA	Al	As	Cd
Group 12: Sealed Drainage Ditches:									
	12	#28	46	19,000	7200	2440	<0.08	<0.03	<0.005
T	SF 118	#31	196	390,000	270,000	31,000	1.40	<0.03	<0.004
	SF 125	#31	68	25,000	1,000	6,300	0.88	<0.03	<0.004
	108	#48	50	—	—	—	0.26	<0.03	<0.005
Group 13: Grass Swale:									
T	9	#28	0.20	—	—	—	—	—	—
Group 14: Road Gutters:									
	SF104	#30	82	~700	~80	~120	7.6	<0.1	<0.02
	SF108	#30	192	~8000	11,000	3900	4.2	<0.03	<0.004
	SF109	#30	398	34,000	10,000	3700	11.0	<0.03	0.007
E	SF129	#31	112	10,000	~7,000	~500	7.6	<0.03	<0.004
	SF136	#39	42	1120	740	2700	1.80	<0.03	<0.006
	SF137	#39	392	2700	3500	~500	8.80	<0.03	<0.03
	SF140	#39	214	18,000	45,000	1700	12.00	<0.03	<0.03
Group 15: Catchbasin:									
T	13	#28	14	~600	1300	~160	<0.08	<0.03	<0.005
Group 16: Northern Telecom Drain:									
	SF106	#30	46	15,000	48,000	1400	1.50	<0.03	<0.004
	SF107	#30	42	29,000	55,000	1600	1.40	<0.03	<0.004
E	SF111	#31	124	11,000	19,000	35,000	2.10	<0.03	<0.004
	SF112	#31	128	12,000	~9,000	3600	2.00	<0.03	<0.004
	SF13A	#31	—	24,000	15,000	18,000	3.40	<0.03	<0.004

Table F.1 Warm Weather Source Area Sheetflow Quality (mg/L) (Cont.)

Drainage System:

	sample #	Storm #	3 Co	4 Cr	5 Cu	6 Mo	7 Ni	8 Pb	9 Se
Group 12: Sealed Drainage Ditches:									
	12	#28	<0.04	<0.01	0.01	<0.06	<0.03	<0.02	<0.03
T	SF 118	#31	<0.04	<0.06	0.05	<0.06	<0.04	0.22	<0.03
	SF 125	#31	<0.04	<0.06	0.03	<0.06	<0.04	<0.04	<0.03
	108	#48	<0.02	<0.01	0.01	<0.01	<0.01	0.05	<0.03
Group 13: Grass Swale:									
T	9	#28	—	—	—	—	—	—	—
Group 14: Road Gutters:									
	SF104	#30	<0.1	<0.2	0.40	<0.2	0.20	0.72	<0.1
	SF 108	#30	<0.04	<0.06	0.09	<0.06	0.09	0.31	<0.03
	SF 109	#30	<0.04	0.11	0.22	<0.06	0.03	0.52	<0.03
E	SF 129	#31	<0.04	<0.06	0.03	<0.06	<0.04	0.17	<0.03
	SF 136	#39	<0.04	<0.04	0.03	<0.04	<0.02	0.14	<0.03
	SF 137	#39	<0.10	<0.30	0.23	<0.30	<0.10	0.78	<0.03
	SF140	#39	<0.10	<0.30	<0.20	<0.30	<0.10	0.35	<0.03
Group 15: Catchbasin:									
T	13	#28	<0.04	<0.01	<0.01	<0.06	<0.03	<0.02	<0.03
Group 16: Northern Telecom Drain:									
	SF106	#30	<0.04	<0.06	<0.02	<0.06	<0.02	<0.04	<0.03
	SF107	#30	<0.04	<0.06	<0.02	<0.06	<0.02	<0.04	<0.03
E	SF111	#31	<0.04	<0.06	0.03	<0.06	<0.02	<0.04	<0.03
	SF112	#31	<0.04	<0.06	0.07	<0.06	0.12	<0.04	<0.03
	SF134	#31	<0.04	<0.06	0.04	<0.06	<0.04	0.26	<0.03

Table F.1 Warm Weather Source Area Sheetflow Quality (mg/L) (Cont.) 20/20

Drainage System:

	sample #	Storm #	Zn	Spec Cond	pH
Group 12: Sealed Drains:					
T	12	#28	0.05	—	—
T	SF 118	#31	0.24	—	—
T	SF 125	#31	0.06	200	7.55
T	108	#48	0.06	180	6.92
Group 13: Grass Swale:					
T	9	#28	—	—	—
Group 14: Road Gutters:					
E	SF104	#30	1.16	—	—
E	SF108	#30	0.26	—	—
E	SF109	#30	0.58	—	—
E	SF129	#31	0.20	117	8.27
E	SF136	#39	0.13	89	7.50
E	SF137	#39	0.80	245	7.60
E	SF140	#39	0.30	410	7.71
Group 15: Catchbasin:					
T	13	#28	0.04	—	—
Group 16: Northern Telecom Drain:					
E	SF106	#30	0.10	—	—
E	SF107	#30	0.09	—	—
E	SF111	#31	0.25	—	—
E	SF112	#31	0.33	—	—
E	SF134	#31	0.31	—	—

Table F.2 Snowmelt Sheetflow Sample Concentrations
(mg/l, unless otherwise noted)
"a" samples collected on February 15 and 16
"b" samples collected on March 16 (Emery) and 21 (Thistletown)

		total residue	filtrate residue	particulate residue	phosphorus	phosphates
Grass/Open						
E1a	North York Works Yard (westside)	556	512	44.3	0.40	0.14
E1b		1377	1060	317	0.43	0.06
E10a	5 Kenhar (near transformer)	820	261	559	0.60	—
E10b		358	109	249	0.25	0.12
E17a	20 Norelco (near sidewalk)	—	—	—	—	—
E17b		1160	389	772	0.65	0.34
E18a	20 Norelco (centre of lawn)	—	—	—	—	—
E18b		112	76.6	35.5	0.44	0.32
E21a	10 ac. open field (near Scotia Bank)	92	63.4	28.6	0.95	—
E21b		236	164	72	0.15	0.08
E23a	21 Fenmar (near parking lot)	819	806	13.1	0.10	—
E23b		385	358	26.7	0.10	0.02
E25a	Signet (near Hydro. substation)	396	303	93.3	0.10	—
E25b		147	64.8	82.2	0.25	0.08
T13a	Calstock/Buckhorn (school playground)	337	74.8	262	1.10	0.82
T13b		39.4	31.6	7.8	0.14	0.08
T21a	46 Alhart (lawn)	232	148	83.6	0.12	—
T22a	14 Buckhorn	79	39.4	39.9	0.30	—
T22b		93.6	77.6	20.9	0.29	0.20
Unpaved Storage Yards						
E3a	North York Works Yard (near dirt storage)	16,590	5690	10,900	6.6	—
E3b		1140	787	358	0.70	0.48
E4a	Waste Management Inc. (near debris boxes)	1752	1020	732	1.40	<0.02
E4b		311	143	168	0.60	<0.02
E19a	North York Hydro. (near transformers)	1071	697	374	0.08	<0.02
E19b		306	178	128	0.28	0.06
E20a	Lumberking (lumber storage)	402	317	85.2	0.14	<0.02
E20b		347	76.8	270	0.23	<0.02

Table F-2 Snowmelt Sheetflow Sample Concentrations
(mg/l, unless otherwise noted)
"a" samples collected on February 15 and 16
"b" samples collected on March 16 (Emery) and 21 (Thistletown)
(Cont'd)

		TKN	NH_3	Phenols (µg/l)	COD	Fecal Coliforms (#/100 ml)
Grass/Open						
E1a	North York Works Yard (westside)	3.0	0.2	0.8	62	<10
E1b		1.5	<0.1	8.0	62	<100
E10a	5 Kenhar (near transformer)	3.5	—	—	122	<10
E10b		1.0	<0.1	5.0	38	<100
E17a	20 Norelco (near sidewalk)	—	—	—	—	10
E17b		4.8	0.4	1.2	168	20
E18a	20 Norelco (centre of lawn)	—	—	—	—	<10
E18b		0.8	<0.1	<0.2	16	<20
E21a	10 ac. open field (near Scotia Bank)	4.3	—	3.8	56	<10
E21b		0.8	<0.1	6.2	20	<100
E23a	21 Fenmar (near parking lot)	0.9	—	<0.2	36	<10
E23b		1.3	0.41	3.4	—	<20
E25a	Signet (near Hydro. substation)	1.7	—	3.0	38	<10
E25b		1.0	<0.1	2.2	72	<20
T13a	Calstock/Buckhorn (school playground)	5.6	3.0	0.8	112	<10
T13b		1.0	0.2	1.4	16	<20
T21a	46 Alhart (lawn)	1.2	—	1.0	34	90
T22a	14 Buckhorn	1.2	—	8	26	<20
T22b		1.3	0.4	1.8	20	100
Unpaved Storage Yards						
E3a	North York Works Yard (near dirt storage)	11.5	—	—	34	<20
E3b		2.0	<0.1	7.0	182	<100
E4a	Waste Management Inc. (near debris boxes)	6.0	<0.1	33.0	208	1900
E4b		2.8	<0.1	86	178	100
E19a	North York Hydro. (near transformers)	0.8	0.1	1.2	20	<20
E19b		2.5	0.3	10.0	144	<100
E20a	Lumberking (lumber storage)	24	<0.1	4.0	64	<20
E20b		1.0	<0.1	3.6	90	<100

Table F-2 Snowmelt Sheetflow Sample Concentrations (mg/l, unless otherwise noted)
"a" samples collected on February 15 and 16
"b" samples collected on March 16 (Finch) and 21 (Thistledown)
(Cont.)

		Fecal Strep. (#/100 ml)	Pseudo. aeruginosa	Cd	Cr	Cu
Grass/Open						
E1a	North York Works Yard (westside)	130	<20	<0.005	0.02	<0.01
E1b		100	—	<0.005	0.06	0.03
E10a	5 Kenhar (near transformer)	100	—	—	0.01	<0.01
E10b		<100	<20	<0.005	0.01	0.04
E17a	20 Norelco (near sidewalk)	580	—	—	—	—
E17b		<20	<20	<0.005	<0.01	0.01
E18a	20 Norelco (centre of lawn)	<10	—	—	—	—
E18b		<20	<20	<0.005	0.01	0.03
E21a	10 ac. open field (near Scotia Bank)	40	—	—	<0.01	<0.01
E21b		<100	<20	<0.005	0.02	0.14
E23a	21 Fenmar (near parking lot)	<10	—	—	0.05	<0.02
E23b		180	20	<0.005	<0.01	0.01
E25a	Signet (near Hydro. substation)	<10	—	—	<0.01	<0.02
E25b		<20	<20	<0.005	<0.01	0.01
T13a	Calstock/Buckhorn (school playground)	350	—	<0.005	<0.01	<0.01
T13b		520	<10	<0.005	0.61	0.07
T21a	46 Alhart (lawn)	3,000	—	—	<0.01	0.01
T22a	14 Buckhorn	30	—	—	<0.01	<0.01
T22b		320	<10	<0.005	<0.01	<0.01
Unpaved Storage Yards						
E3a	North York Works Yard (near dirt storage)	420	—	—	0.09	0.14
E3b		<100	—	<0.005	0.05	0.04
E4a	Waste Management Inc. (near debris boxes)	1800	80	0.011	0.13	0.31
E4b		<100	<20	<0.005	0.07	0.17
E19a	North York Hydro. (near transformers)	100	<10	<0.005	<0.01	0.01
E19b		<100	<20	<0.005	0.03	0.07
E20a	Lumberking (lumber storage)	<20	—	<0.005	0.03	0.10
E20b		100	<20	<0.005	0.05	0.06

Table F-2 Snowmelt Sheetflow Sample Concentrations
(mg/l, unless otherwise noted)
"a" samples collected on February 15 and 16
"b" samples collected on March 16 (Emery) and 21 (Thistletown)
(Cont.)

		Pb	Zn	total manganese	reactive chloride
Grass/Open					
E1a	North York Works Yard (westside)	0.04	0.03	—	146
E1b		0.19	0.39	0.30	537
E10a	5 Kenhar (near transformer)	0.07	0.05	—	—
E10b		<0.06	0.10	0.15	3.6
E17a	20 Norelco (near sidewalk)	—	—	—	—
E17b		0.08	0.06	0.14	156
E18a	20 Norelco (centre of lawn)	—	—	—	—
E18b		0.01	0.06	—	—
E21a	10 ac. open field (near Scotia Bank)	<0.02	0.01	0.3	4.0
E21b		<0.06	0.09	0.14	16.8
E23a	21 Fenmar (near parking lot)	<0.02	0.03	—	310
E23b		<0.06	0.12	0.05	167
E25a	Signet (near Hydro. substation)	<0.02	0.02	—	54.8
E25b		0.08	0.06	0.042	7.0
T13a	Calstock/Buckhorn (school playground)	<0.02	0.04	(4.7)	4.0
T13b		<0.04	<0.04	0.016	1.4
T21a	46 Albart (lawn)	0.08	0.07	—	21.2
T22a	14 Buckhorn	0.04	0.02	—	2.6
T22b		<0.02	0.02	0.13	7.0
Unpaved Storage Yards					
E3a	North York Works Yard (near dirt storage)	0.54	0.58	—	—
E3b		0.15	0.42	0.65	283
E4a	Waste Management Inc. (near debris boxes)	0.98	0.94	—	276
E4b		0.61	0.44	1.10	113
E19a	North York Hydro. (near transformers)	0.06	0.05	2.6	232
E19b		0.12	0.33	0.11	34.4
E20a	Lumberking (lumber storage)	0.04	0.09	1.5	31.8
E20b		0.09	0.21	0.19	3.6

Table F.2 Snowmelt Sheetflow Sample Concentrations (mg/l, unless otherwise noted) (Cont.)

		TS	TDS	SS	P	PO4
Unpaved Parking						
E6a	84 Fenmar	2470	1200	1270	17.5	—
E6b		3380	435	2940	1.6	1.8
E11a	7 Kenhar (near gas pump)	16,910	1510	15,400	5.9	—
E11b		6530	799	5730	2.8	0.46
Paved Loading Docks (Storage Areas)						
E24a	Globe Meats (rear) [poor cond, inter. text.]	1529	1180	349	0.50	—
E24b		1860	826	1040	1.30	0.36
T2a	Albion Mall	4690	1330	3360	0.65	<0.02
T2b		240	193	46.8	0.49	0.10
Paved Parking						
E2a	North York Works Yard (near catchbasin)	9118	8420	698	0.60	—
E2b	(poor cond., inter. texture)	2790	2530	260	0.80	0.12
E14a	46 Norelco (Dayco-south side)	—	—	—	—	—
E14b	(poor cond., inter. texture)	826	391	435	0.50	0.12
E15a	46 Norelco (Dayco - front)	—	—	—	—	—
E15b	(poor/ind. cond., inter. texture)	222	125	96.6	0.40	0.24
T1a	Albion Mall (Textile Town)	2880	1450	1430	0.80	—
T1b	(inter. cond., rough-inter. texture)	308	254	53.4	0.12	<0.02
T4a	Thistledown Church	955	460	495	0.60	—
T4b	(poor cond., inter.-smooth texture)	168	83.8	83.7	0.15	<0.02
[Northern Telecom Storm Drain]						
E13a	Signet / Kenhar (No. Telecom drain)	1293	1270	23.2	0.13	<0.02
E13b		368	248	120	0.20	<0.02

Table F.2 Snowmelt Sheetflow Sample Concentrations (mg/l, unless otherwise noted) (Cont.)

Sample	Location	TKN	NH_3	Phen	COD	FC
Unpaved Parking						
E6a	84 Fenmar	32.5	—	—	—	1100
E6b		4.5	0.3	8	302	<100
E11a	7 Kenhar (near gas pump)	29.0	—	100	—	20
E11b		7.3	<0.1	77	4450	<100
Paved Loading Docks (Storage Areas)						
E24a	Globe Meats (rear) [poor cond, inter. text.]	5.0	—	4.0	42	<20
E24b		11.0	0.2	14	80	<100
T2a	Albion Mall	3.5	0.1	3.0	402	21,000
T2b		2.5	<0.1	2.6	156	380
Paved Parking						
E2a	North York Works Yard (near catchbasin)	4.0	—	27	434	310
E2b	(poor cond., inter. texture)	3.5	<0.1	19	292	<100
E14a	46 Norelco (Dayco-south side)	—	—	—	—	20
E14b	(poor cond., inter. texture)	1.5	<0.1	3.2	190	<100
E15a	46 Norelco (Dayco - front)	—	—	—	—	10
E15b	(poor/int. cond., inter. texture)	0.8	<0.1	1.0	46	<100
T1a	Albion Mall (Textile Town)	3.6	—	50	966	20
T1b	(inter. cond., rough-inter. texture)	0.8	<0.1	19.2	58	<20
T4a	Thistledown Church	3.5	—	3.0	194	1600
T4b	(poor cond., inter.-smooth texture)	1.0	<0.1	2.8	44	<20
[Northern Telecom Storm Drain]						
E13a	Signet / Kenhar (No. Telecom drain)	0.8	<0.1	<0.4	48	<10
E13b		1.0	<0.1	2.8	50	<100

Table F.2 Snowmelt Sheetflow Sample Concentrations (mg/l, unless otherwise noted) (cont.)

Sample	Location	TS	TDS	SS	P	PO_4
Sidewalks						
E8a	129 Fenmar	1319	219	1100	0.40	—
E8b	(good cond., smooth texture)	773	180	593	0.50	0.20
T8a	Alhart / Bankfield	689	239	420	1.0	—
T8b	(good cond., smooth texture)	266	83.6	182	0.59	0.38
T12a	9 Calstock	136	69	66.7	0.36	—
T12b	(good cond., smooth texture)	446	125	321	0.93	0.68
T16a	125 Thistledown	340	99	241	0.14	—
T16b	(inter. cond., smooth texture)	523	65.2	458	0.66	0.08
Driveways						
E9a	3 Kenhar	408	249	159	0.20	—
E9b	(poor cond., inter. texture)	302	211	90.4	0.20	0.06
E22a	164 Fenmar (Thomas Equip.)	5600	84	4760	4.6	—
E22b	(poor cond., rough texture)	3410	306	3100	2.0	0.28
T14b	(poor cond., rough texture)	1100	274	822	0.64	0.08
T19a	4 Alhart	918	538	380	0.65	—
T19b	(poor cond., rough texture)	2590	267	2320	2.79	0.30
T24a	17 Bankfield	348	259	89.4	0.55	—
T24b	(very poor cond., inter-rough texture)	798	526	273	0.64	0.12
Roads						
T3a	1-63A Thistledown (townhouses)	1091	212	879	0.90	—
T3b	(good cond., inter. texture)	1030	87.4	947	—	0.40
T5a	Bankfield / Thistledown (inter. cond., rough texture)	1427	1240	187	1.0	—
T15a	3 Alhart	756	523	233	0.30	—
T15b	(inter. cond., smooth texture)	147	119	28.8	0.15	<0.02
T23b	23 Bankfield (cracked)	620	85.6	535	0.20	0.06

Table F.2 Snowmelt Sheetflow Sample Concentrations (mg/L, unless otherwise noted) (cont.)

Sample	Location / Description	TKN	NH_3	Phen	COD	FC
Sidewalks						
E8a	129 Fenmar	1.3	—	3.4	36	<10
E8b	(good cond., smooth texture)	1.8	<0.01	4	90	<100
T8a	Alhart / Bankfield	10	—	2.4	116	490
T8b	(good cond., smooth texture)	2.3	0.8	1.6	122	<20
T12a	9 Calstock	1.9	—	<0.6	34	150
T12b	(good cond., smooth texture)	2.8	0.8	1.2	112	3400
T16a	125 Thistledown	1.4	—	1.0	54	<10
T16b	(inter. cond., smooth texture)	3.8	<0.1	1.6	84	<20
Driveways						
E9a	3 Kenhar	0.8	—	5.8	58	<10
E9b	(poor cond., inter. texture)	1.0	<0.1	3.0	34	<100
E22a	164 Fenmar (Thomas Equip.)	9.5	—	24.0	1700	5100
E22b	(poor cond., rough texture)	4.0	<0.1	2.2	1250	500
T14b	(poor cond., rough texture)	2.5	0.2	1.8	106	<20
T19a	4 Alhart	2.8	—	1.0	184	<20
T19b	(poor cond., rough texture)	9.0	<0.1	1.8	626	100
T24a	17 Bankfield	2.3	—	0.8	98	<10
T24b	(very poor cond., inter-rough texture)	2.0	<0.1	1.8	78	<20
Roads						
T3a	1-63A Thistledown (townhouses)	3.0	—	1.6	246	1500
T3b	(good cond., inter. texture)	1.0	<0.1	2.4	36	<20
T5a	Bankfield / Thistledown (inter cond., rough texture)	5.5	—	19	178	100
T15a	3 Alhart	2.5	—	13.6	196	<20
T15b	(inter. cond., smooth texture)	0.8	<0.1	3.0	30	120
T23b	23 Bankfield (cracked)	1.0	<0.1	3.4	106	<20

Table F.2 Snowmelt Sheetflow Sample Concentrations (mg/L, unless otherwise noted) (cont.)

		FS	pH	Cd	Cr	Cu
Sidewalks						
E8a	129 Fenmar	<10	—	—	<0.01	0.06
E8b	(good cond., smooth texture)	<100	<20	<0.005	0.03	0.16
T8a	Alhart / Banksfield	700	—	—	<0.01	0.05
T8b	(good cond., smooth texture)	500	<10	<0.005	0.06	0.03
T12a	9 Calstock	260	—	—	<0.01	0.01
T12b	(good cond., smooth texture)	1120	<20	0.012	0.01	0.06
T16a	125 Thistledown	110	—	—	<0.01	0.02
T16b	(inter. cond., smooth texture)	960	<20	<0.005	<0.01	0.02
Driveways						
E9a	3 Kenhar	<10	—	—	<0.01	<0.01
E9b	(poor cond., inter. texture)	<100	<20	<0.005	0.02	0.02
E22a	164 Fenmar (Thomas Equip.)	26,000	—	—	0.22	0.64
E22b	(poor cond., rough texture)	13,400	—	0.015	0.19	0.16
T14b	(poor cond., rough texture)	180	<10	<0.005	0.04	0.07
T19a	4 Alhart	<20	—	—	<0.01	0.02
T19b	(poor cond., rough texture)	1800	<20	0.012	0.14	0.28
T24a	17 Banksfield	200	—	—	0.02	0.02
T24b	(very poor cond., inter-rough texture)	20	200	<0.005	<0.01	0.02
Roads						
T3a	1-63A Thistledown (townhouses)	100	—	—	0.06	0.17
T3b	(good cond., inter. texture)	100	<10	<0.005	<0.01	0.02
T5a	Banksfield/Thistledown (inter cond., rough texture)	1440	—	—	0.08	0.09
T15a	3 Alhart	200	—	—	0.02	0.08
T15b	(inter. cond., smooth texture)	180	<10	<0.005	<0.01	0.01
T23b	23 Banksfield (cracked)	740	<10	<0.005	<0.01	0.02

Table F.2 Snowmelt Sheetflow Sample Concentrations (mg/L, unless otherwise noted) (cont.)

Sample	Location / Condition	Pb	Zn	Manganese	residue Chloride
Sidewalks					
E8a	129 Fenmar	0.10	0.15	—	—
E8b	(good cond., smooth texture)	0.28	0.78	0.62	48
T8a	Alhart / Bankfield	0.16	0.22	—	47.6
T8b	(good cond., smooth texture)	0.08	0.11	0.16	4.0
T12a	9 Calstock	0.02	0.07	—	6.8
T12b	(good cond., smooth texture)	0.29	2.70	0.075	6.0
T16a	125 Thistledown	0.13	0.12	—	13.8
T16b	(inter. cond., smooth texture)	0.17	0.20	0.36	2.4
Driveways					
E9a	3 Kenhar	0.07	0.04	—	—
E9b	(poor cond., inter. texture)	<0.06	0.10	0.07	65.6
E22a	164 Fenmar (Thomas Equip.)	1.90	3.40	—	310
E22b	(poor cond., rough texture)	1.00	1.20	1.25	55.8
T14b	(poor cond., rough texture)	0.42	0.21	0.73	87.0
T19a	4 Alhart	0.15	0.08	—	240
T19b	(poor cond., rough texture)	2.80	2.20	0.83	57.4
T24a	17 Bankfield	0.10	0.08	—	68.6
T24b	(very poor cond., inter-rough texture)	<0.04	0.04	0.04	215
Roads					
T3a	1-63A Thistledown (townhouses)	1.50	0.99	—	56.0
T3b	(good cond., inter. texture)	0.15	0.14	0.074	4.2
T5a	Bankfield / Thistledown (inter cond. rough texture)	0.37	0.38	—	585
T15a	3 Alhart	0.47	0.38	—	176
T15b	(inter. cond., smooth texture)	0.07	0.06	0.036	30.4
T23b	23 Bankfield (cracked)	0.07	0.07		

Table F.2 Snowmelt Sheetflow Sample Concentrations (mg/L, unless otherwise noted) (cont.)

Sample	Location	TS	TDS	SS	P	PO_4
Grass Swales						
T11a	Calstock/Buckhorn	447	158	289	0.83	—
T11b		208	166	42	0.15	<0.04
T17a	125 Thistledown	264	239	24.9	0.80	0.66
T17b		126	106	20.1	0.25	0.12
T20a	4,6 Alhart	174	152	21.8	1.10	—
T20b		131	74.4	57	0.29	0.08
T21b	Alhart/Buckhorn	357	93.4	264	0.74	0.34
T5b	Bankfield/Thistledown	382	183	199	0.44	0.22
50/50 Swale						
T18a	Thistledown Rd. School	134	101	32.9	1.90	—
T18b		152	68.6	83.5	0.25	<0.06
Gutter						
E5a	Fenmar (100m from Weston Rd)	2031	1130	901	1.2	—
E5b	(good condition, inter. interface cond.)	1320	694	625	0.45	0.18
E7a	Kenhar/Fenmar	1579	1050	529	0.80	—
E7b	(good cond., paved to curb)	1500	591	912	0.60	0.16
E12a	4 Kenhar	1244	291	953	0.90	—
E12b	(poor cond., poor interface cond.)	694	241	454	0.60	0.08
E16a	30 Norelco (near N. Telecom)	—	—	—	—	—
E16b	(inter. cond., inter. interface cond.)	1010	575	432	0.48	0.12
T6a	2,4 Humberland Ct.	6960	240	6720	5.5	—
T6b	(good cond., inter. interface cond.)	249	97.6	152	0.56	0.22
T7a	62 Bankfield (road shoulder)	433	409	34.1	0.90	0.66
T7b	(poor cond.)	243	113	130	0.54	0.28
T9b	(inter. cond., paved to curb)	1420	190	1230	0.22	<0.06
T10a	Calstock/Allcroft	625	215	410	0.50	—
T10b	(good cond., paved to curb)	232	181	51.1	0.39	0.32

Table F.2 Snowmelt Sheetflow Sample Concentrations (mg/l, unless otherwise noted) (cond.)

Sample	Location	TKN	NH_3	Phen	COD	Fe
Grass Swales						
T11a	Calstock/Buckhorn	2.8	—	1.6	48	40
T11b		1.0	0.2	2.0	26	1020
T17a	125 Thistledown	2.3	0.5	<0.6	64	<10
T17b		1.3	<0.1	2.6	30	<20
T20a	4,6 Alhart	4.1	—	1.0	6.2	<20
T20b		1.0	<0.1	1.6	20	<20
T21b	Alhart/Buckhorn	4.3	1.4	3.0	110	100
T5b	Bankfield/Thistledown	1.3	<0.1	1.4	68	2700
50/50 Swale						
T18a	Thistledown Rd. School	8.8	—	1.2	54	160
T18b		1.0	<0.1	2.8	32	80
Gutter						
E5a	Fenmar (100m from Weston Rd)	3.0	—	—	356	20
E5b	(good condition, inter. interface cond.)	1.5	<0.1	18	178	<100
E7a	Kenhar/Fenmar	2.0	—	—	200	1500
E7b	(good cond., paved to curb)	1.8	<0.1	9.0	302	<100
E12a	4 Kenhar	2.5	—	4.0	234	<10
E12b	(poor cond., poor interface cond.)	1.5	<0.1	9.4	352	<100
E16a	30 Norelco (near N. Telecom)	—	—	—	—	10
E16b	(inter. cond., inter. interface cond.)	1.5	<0.1	6.0	182	<100
T6a	2,4 Humberland Ct.	8.5	—	2.2	76	<20
T6b	(good cond., inter. interface cond.)	1.5	<0.1	1.8	60	20
T7a	62 Bankfield (road shoulder)	6.0	3.2	4.0	114	60
T7b	(poor cond.)	2.3	<0.1	1.4	142	4600
T9b	(inter. cond., paved to curb)	1.3	0.3	2.8	66	120
T10a	Calstock/Allcroft	2.5	—	1.4	106	<10
T10b	(good cond., paved to curb)	1.5	<0.1	1.2	28	300

Table F.2 Snowmelt Sheetflow Sample Concentrations (mg/l, unless otherwise noted) (cond.)

Sample	Location	FS	pH	Cd	Cr	Cu
Grass Swales						
T11a	Calstock/Buckhorn	7300	—	—	<0.01	0.01
T11b		>15,000	<10	<0.005	<0.01	<0.01
T17a	125 Thistledown	200	—	<0.005	<0.01	0.02
T17b		2440	<10	<0.005	<0.01	0.01
T20a	4,6 Alhart	60	—	—	<0.01	<0.01
T20b		200	<20	<0.005	<0.01	<0.01
T21b	Alhart/Buckhorn	1900	<10	<0.005	0.01	0.02
T5b	Bankfield/Thistledown	11,100	<10	<0.005	<0.01	0.02
50/50 Swale						
T18a	Thistledown Rd. School	2200	—	—	<0.01	0.01
T18b		500	<10	<0.005	<0.01	0.03
Gutter						
E5a	Fenmar (100m from Weston Rd)	640	—	—	0.10	0.34
E5b	(good condition, inter.-interface cond.)	800	—	<0.005	0.05	0.12
E7a	Kenhar/Fenmar	500	—	—	0.06	0.85
E7b	(good cond., paved to curb)	100	—	0.005	0.03	0.31
E12a	4 Kenhar	50	—	—	0.05	0.12
E12b	(poor cond., poor interface cond.)	<100	<20	<0.005	0.02	0.05
E16a	30 Norelco (near N. Telecom)	100	—	—	—	—
E16b	(inter. cond., inter. interface cond.)	<100	—	<0.005	0.03	0.07
T6a	2,4 Humberland Ct.	160	—	—	0.06	0.25
T6b	(good cond., inter. interface cond.)	4200	<10	<0.005	0.02	0.02
T7a	62 Bankfield (road shoulder)	4600	—	<0.005	<0.01	0.02
T7b	(poor cond.)	8000	<10	<0.005	0.01	0.01
T9b	(inter. cond., paved to curb)	3500	<20	0.006	0.04	0.20
T10a	Calstock/Allcroft	3900	—	—	<0.01	0.03
T10b	(good cond., paved to curb)	>15,000	10	<0.005	<0.01	0.01

Table F.2 Snowmelt Sheetflow Sample Concentrations (mg/l, unless otherwise noted) (cond.)

		As	Zn	Manganese	reactive chloride
Grass Swales		0.04	0.03	—	50.2
T11a	Calstock/Buckhorn	<0.02	0.04	0.048	71.6
T11b		0.03	0.07	1.15	63.2
T17a	125 Thistledown	0.04	0.10	0.04	24.0
T17b		0.05	0.01	—	36.6
T20a	4,6 Alhart	<0.02	0.03	0.05	12.0
T20b		0.23	0.15	0.13	11.2
T21b	Alhart/Buckhorn	0.14	0.10	0.075	36.6
T5b	Bankfield/Thistledown				
50/50 Swale		0.10	0.09	—	18.4
T18a	Thistledown Rd. School	0.21	0.12	0.056	8.0
T18b					
Gutter		1.10	1.10	—	—
E5a	Fenmar (100m from Weston Rd)	0.45	0.66	0.60	330
E5b	(good condition, inter. interface cond.)	0.91	1.70	—	—
E7a	Kenhar/Fenmar	0.34	1.00	1.5	264
E7b	(good cond., paved to curb)	0.51	0.45	—	—
E12a	4 Kenhar	0.22	0.25	0.38	71.4
E12b	(poor cond., poor interface cond.)	—	—	—	—
E16a	30 Norelco (near N. Telecom)	0.34	0.48	0.34	203
E16b	(inter. cond., inter. interface cond.)	1.50	1.10	—	56.4
T6a	2,4 Humberland Ct.	0.12	0.09	0.12	14.0
T6b	(good cond., inter. interface cond.)	0.06	0.05	0.80	216
T7a	62 Bankfield (road shoulder)	0.03	0.05	0.11	25.2
T7b	(poor cond.)	1.20	1.60	0.082	70.4
T9b	(inter. cond., paved to curb)	0.17	0.09	—	22.2
T10a	Calstock/Allcroft	0.04	0.04	0.037	22.0
T10b	(good cond., paved to curb)				

Table F.2 Snowmelt Sheetflow Sample Concentrations (mg/l, unless otherwise noted) (Cont.)

		Pb	Zn	Manganese	reactive Chloride
Unpaved Parking					
E6a	84 Fenmar	0.08	1.70	—	—
E6b		0.37	1.20	2.5	39.6
E11a	7 Kenhar (near gas pump)	1.60	2.80	—	—
E11b		0.69	1.20	0.75	243
Paved Loading Docks (Storage Areas)					
E24a	Globe Meats (rear) [poor cond., inter. text.]	0.13	0.48	—	255
E24b		0.26	2.70	0.48	417
T2a	Albion Mall	0.23	0.27	(54.0)	54.4
T2b		2.60	0.23	0.07	49.8
Paved Parking					
E2a	North York Works Yard (near catchbasin)	0.35	0.32	—	4742
E2b	(poor cond., inter. texture)	0.32	0.55	1.12	1510
E14a	46 Norelco (Dayco - south side)	—	—	—	—
E14b	(poor cond., inter. texture)	0.11	0.18	0.26	149
E15a	46 Norelco (Dayco - front)	—	—	—	—
E15b	(poor/int. cond., inter. texture)	0.08	0.11	0.07	23.6
T1a	Albion Mall (Textile Town)	0.91	0.79	—	721
T1b	(inter. cond., rough-inter. texture)	0.09	0.25	0.084	81.4
T4a	Thistledown Church	0.97	0.73	—	168
T4b	(poor cond., inter.-smooth texture)	0.05	0.06	0.14	12.0
[Northern Telecom Storm Drain]					
E13a	Signet / Kenhar (No. Telecom drain)	0.05	0.15	—	523
E13b		<0.06	0.10	0.10	80.2

Table F.2 Snowmelt Sheetflow Sample Concentrations
(mg/l, unless otherwise noted) (Cont.)

		FS	PA	Cd	Cr	Cu
Unpaved Parking						
E6a	84 Fenmar	2600	—	—	0.01	0.05
E6b		<100	—	0.007	0.12	0.16
E11a	7 Kenhar (near gas pump)	480	—	—	0.38	0.86
E11b		<100	—	0.013	0.15	0.25
Paved Loading Docks (Storage Areas)						
E24a	Globe Meats (rear) [poor cond, int. text.]	2700	—	—	0.01	0.04
E24b		4300	<20	0.011	0.02	0.10
T2a	Albion Mall	6700	—	<0.005	0.02	0.04
T2b		220	<10	0.006	0.04	0.04
Paved Parking						
E2a	North York Works Yard (near catchbasin)	1270	—	—	0.05	0.05
E2b	(poor cond., inter. texture)	500	—	<0.005	0.07	0.07
E14a	46 Norelco (Dayco - south side)	410	—	—	—	—
E14b	(poor cond., inter. texture)	<100	<20	<0.005	0.01	0.03
E15a	46 Norelco (Dayco - front)	30	—	—	—	—
E15b	(poor/int. cond., inter. texture)	<100	<20	<0.005	<0.01	0.02
T1a	Albion Mall (Textile Town)	100	—	—	0.04	0.12
T1b	(inter. cond., rough-inter. texture)	280	10	<0.005	<0.01	0.02
T4a	Thistledown Church	<100	—	—	0.04	0.10
T4b	(poor cond., inter.-smooth texture)	180	<10	<0.005	<0.01	0.01
[Northern Telecom Storm Drain]						
E13a	Signpost / Kenhar (No. Telecom drain)	120	<20	<0.005	<0.01	<0.01
E13b		200	20	<0.005	<0.01	<0.01

Table F.3 Snowmelt Source Area Sheetflow Major ~~Constituents~~ Ions (mg/L)

	reactive Calcium	reactive Magnesium	reactive Sodium	reactive Potassium	reactive Chloride	reactive Sulphate	total Alkalinity	total soluble nitrates	pH
Grass/Open									
E1a	67	7.1	102	7.9	146	78	123	1.9	7.3
E1b	40	3.0	348	4.2	537	34	117	0.8	8.2
E21a	—	—	—	—	4.0	—	—	0.3	—
T13a	11	3.0	1.8	7.5	4.0	4.0	44	<0.1	6.6
Unpaved Storage Yards									
E3b	52	9.2	210	16	283	43	155	—	8.1
E4a	111	28	196	15	276	235	255	<0.1	7.0
E19a	14	12	22	1.9	232	32	50	2.7	7.2
E20a	67	15	46	1.9	32	115	64	—	7.3
Paved Loading Docks									
T2a	26	0.9	44	1.2	54	23	52	<0.1	6.9
Paved Parking									
E2b	56	6.3	890	6.7	1510	84	117	—	8.1
Northern Telecom Storm Drain									
E13a	133	27	265	3.4	523	97	163	0.3	7.6
Grass Swales									
T17a	12	0.8	78	2.8	63	23	82	<0.1	6.9
Gutters									
T7a	25	3.1	120	7.8	216	28	66	0.6	7.0

Table F.4 Dissolved Metal Sheetflow (Snowmelt) Concentrations (mg/l)

	Cadmium			Chromium			Copper		
	total	dissolved	[3] % diss.	[4] total	[5] dissolved	% diss.	total	dissolved	% diss.
Grass[1]/Open									
E1b[2]	<0.005	<0.005	—	0.06	<0.01	< 17%	0.03	0.02	67%
T13a[3]	<0.005	<0.005	—	<0.01	<0.01	—	<0.01	<0.02	—
T13b	<0.005	<0.005	—	0.61	<0.01	2%	0.07	0.01	14%
Unpaved[5] Storage Yards									
E4b[6]	<0.005	<0.005	—	0.07	0.02	< 29%	0.17	0.27	—
E19a[7]	<0.005	<0.005	—	<0.01	<0.01	—	0.01	<0.02	—
E19b[8]	<0.005	<0.005	—	0.07	0.19	—	—	0.03	—
E20a[9]	<0.005	<0.005	—	0.03	0.01	33%	0.10	0.05	50%
E20b[10]	<0.005	<0.005	—	0.05	<0.01	< 20%	0.06	0.02	33%
Paved[11] Loading Dock									
T2a[12]	<0.005	<0.005	—	0.02	<0.01	< 50%	0.04	0.03	75%
T2b[13]	0.006	0.007	—	0.04	0.03	75%	0.04	0.04	100%
Grass[14] Swale									
T17a[15]	<0.005	<0.005	—	<0.01	0.02	—	0.02	0.02	100%
T17b[16]	<0.005	<0.005	—	<0.01	<0.01	—	0.01	<0.02	—
Gutter[17]									
T7a[18]	<0.005	<0.005	—	<0.01	<0.01	—	0.02	0.03	—
T7b[19]	<0.005	<0.005	—	0.01	0.04	—	0.01	0.03	—
Northern[20] Telecom Area Outfall									
E13B[21]	<0.005	<0.005	—	<0.01	<0.01	—	<0.01	0.03	—
Emery[22] Outfall Grab Sample									
E26b[23]	0.01	<0.005	< 50%	0.22	0.12	55%	0.26	0.06	23%

Table F.4 Dissolved Metal Sheetflow (Snowmelt) Concentrations (mg/l) (Cont.)

	Lead			Zinc			Manganese		
	total	dissolved	%diss	total	dissolved	%diss.	total	dissolved	%diss.
Grass/									
E16	0.19	<0.04	<21%	0.39	0.03	8%	0.30	0.60	—
T13a	<0.02	<0.02	—	0.04	0.01	25%	4.7	0.02	<1%
T13b	<0.04	<0.02	—	<0.04	0.01	—	0.016	0.01	63%
Unpaved									
E4b	0.61	<0.04	<7%	0.44	0.10	23%	1.10	0.29	26%
E19a	0.06	<0.02	<33%	0.05	0.01	20%	2.55	0.06	2%
E18b	0.12	<0.06	<50%	0.33	0.14	42%	0.11	0.07	64%
E20a	0.04	<0.02	<50%	0.09	0.06	67%	1.45	0.07	5%
E20b	0.09	<0.06	<67%	0.21	0.02	10%	0.19	0.02	11%
Paved Lo									
T2a	0.23	<0.02	<9%	0.27	0.09	33%	54.0	0.07	<1%
T2b	2.60	0.14	5%	0.23	0.05	22%	0.07	0.04	57%
Grass									
T17a	0.03	<0.02	<67%	0.07	0.04	57%	1.15	0.03	3%
T17b	0.04	<0.02	<50%	0.10	0.05	50%	0.04	0.01	25%
Gutter									
T7a	0.06	<0.02	<33%	0.05	0.03	60%	0.80	0.06	8%
T7b	0.03	<0.02	<67%	0.05	0.02	40%	0.11	0.02	18%
Northam T									
E13b	<0.06	<0.06	—	0.10	0.03	30%	0.10	0.02	20%
Emery O									
E26b	0.60	<0.06	<10%	1.10	0.10	9%	1.0	—	—

Table F.4

Misc. Dissolved Metal Snowmelt Sheetflow Conc. (mg/l)

	Aluminum	Arsenic	Cobalt	Moly.	Nickel	Selenium
Grass/Open						
E1b	0.73	<0.03	0.03	<0.01	<0.03	<0.03
T13b	<0.08	<0.03	<0.02	<0.01	<0.03	<0.03
Unpaved Storage Yards						
E4b	6.0	<0.03	0.04	0.01	<0.03	<0.03
E19b	91	<0.03	<0.02	<0.01	<0.03	<0.03
E20b	0.26	<0.03	—	0.01	<0.03	<0.03
Paved Loading Dock						
T2b	0.09	<0.03	<0.02	0.01	<0.03	<0.03
Grass Swale						
T17b	0.18	<0.03	<0.02	<0.01	<0.03	<0.03
Gutter						
T7b	0.22	<0.03	<0.02	0.01	<0.03	<0.03
Northern Telecom Area Outfall						
E13b	0.36	<0.03	<0.02	0.01	<0.03	<0.03
Emery Outfall Grab Sample						
E26b	0.22	<0.03	<0.02	<0.01	<0.03	<0.03

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Table F.5

Pesticides and Phenols Detected in Snowmelt Sheetflow Samples (ng/l)

Compound	detection limit (ng/l)	All Samples Analyzed: Grass		Unpaved Storage Yards			paved loading dock	Roadside Drainage (3)		
		E1	T13	E4	E19	E20	T2	E13	T7	T17
α BHC	1	—(1)	6	7	5	3	7	—	4	—
γ BHC	1	—	—	16	1	—	3	—	1	—
α Chlordane	2	—	—	8	—	—	—	—	—	—
γ Chlordane	2	—	—	8	—	—	—	—	—	—
Dieldrin	2	—	—	—	—	—	4	—	—	—
total PCBs	20	—	—	3750(2)	—	—	—	—	—	—
pp-DDD	5	—	—	15	—	—	—	—	—	—
pp-DDE	1	—	—	11	—	—	—	—	—	—
pp-DDT	5	—	—	15	—	—	—	—	—	—
Hexachlorobenzene	1	—	—	2	—	—	—	—	—	—

(1) — : not detected (2) PCB resembled Aroclor 1260

(3) a Thistledown roadside (Alhardt) snowsample (Lab#16359) only had 10 ng/l γ-Chlordane detected

Constituents not detected in all 9 samples analyzed (detection limit, ng/l):

- Aldrin (1)
- β BHC (1)
- DMDT Methoxychlor (5)
- Endosulfan I (2)
- Endosulfan II (4)
- Endrin (4)
- Endosulfan sulfate (4)
- Heptachlorepoxide (1)
- Heptachlor (1)
- Mirex (5)
- Oxychlordane (2)
- op-DDT (5)
- 234 Trichlorophenol (100)
- 2345 Tetrachlorophenol (50)
- 2356 Tetrachlorophenol (50)
- 245 Trichlorophenol (50)
- 246 Trichlorophenol (50)

Table F-6 Snow Transect Quality at Colstock Blvd. (March 14, 1984)
(conc. of melted snow, mg/l, unless otherwise noted)

	distance from edge of snow pack (cm)	distance from edge of snow pack (m)	approx. snow depth (mm)	total residue	filtrate residue	particulate residue	total phosphorus	soluble phosphate	TKN	NH_3	phenols (μg/l)
	0→10	0→0.1	60	2650	2390	258	0.22	0.02	1.5	<0.1	—
	25	0.25	60	6340	6060	282	0.2	<0.02	1.0	<0.1	5.0
	30	0.3	?	112	46	66.3	0.05	0.02	0.7	<0.1	26
	50	0.5	?	2200	1990	205	0.6	0.5	1.0	<0.1	2.4
road edge	75	0.75	400	613	511	103	0.15	<0.04	0.5	<0.1	1.0
	100	1.0	650	572	495	77.8	0.2	<0.04	0.5	<0.1	1.0
edge of surface seal	150	1.5	850	1140	873	266	0.3	<0.02	1.5	<0.1	0.8
	200	2.0	800	720	632	88.5	0.1	<0.02	0.5	<0.1	0.8
	250	2.5	?	117	98.6	18.3	0.04	<0.02	<0.3	<0.1	1.4
	300	3.0	?	100	47.8	52.1	0.1	<0.04	0.5	<0.1	0.8
footpath {	400	4.0	420	187	50.6	137	0.1	<0.02	0.5	<0.1	1.0
	630	6.3	30	475	97.2	378	0.75	0.06	4.0	<0.1	0.8
	800	8.0	250	298	47.6	250	0.1	<0.06	0.8	<0.1	1.0
	1000	10	190	71.6	27.8	43.7	0.05	<0.02	0.5	<0.1	1.0
	1500	15	220	198	30.4	167	0.1	0.06	1.0	0.2	1.2
	2000	20	220	114	37.4	76.5	0.13	<0.02	1.0	<0.1	0.8
	2500	25	210	87	29.4	57.6	0.15	<0.02	0.9	0.2	1.0

Table F-6 Snow Transect Quality at Colstock Blvd. (March 14, 1984) (Cont.)

(conc. of melted snow, mg/l ...

	distance from edge of snow pack (cm)	distance from edge of snow pack (m)	approx. snow depth (mm)	COD	Cd	Cr	Cu	Pb	Zn	Mn	Cl^-
	0→10	0→0.1	60	—	0.005	0.06	0.07	0.38	0.43	0.20	1420
	25	0.25	60	142	—	—	—	0.38	0.24	—	3500
	30	0.3	?	—	0.007	0.05	0.04	0.07	0.23	0.08	13.4
	50	0.5	?	68	—	—	—	0.39	0.17	—	1130
road edge	75	0.75	400	34	—	—	—	0.22	0.11	—	277
	100	1.0	650	32	—	—	—	0.12	0.08	—	285
edge of swale seal	150	1.5	850	62	—	—	—	0.30	0.19	—	284
	200	2.0	800	26	—	—	—	<0.06	0.05	—	504
	250	2.5	?	<6	—	—	—	<0.06	0.02	—	352
	300	3.0	?	12	—	—	—	<0.06	0.03	—	46
footpath	400	4.0	420	18	—	—	—	0.05	0.07	—	12
footpath	630	6.3	30	134	—	—	—	0.12	0.18	—	—
	800	8.0	250	54	—	—	—	<0.02	0.06	—	—
	1000	10	190	12	—	—	—	<0.02	0.04	—	6.2
	1500	15	220	44	—	—	—	0.03	0.02	—	—
	2000	20	220	14	—	—	—	0.06	0.05	—	—
	2500	25	210	22	—	—	—	0.05	0.05	—	—

Table F.7 Snow Transect Quality at Signet Rd. (March 12, 1984)

(conc. of snowmelt water, mg/l, unless otherwise noted)

	distance from edge of snowpack (cm)	(m)	approx. snow depth (mm)	total residue	filtrate residue	particulate residue	total phosphorus	soluble phosphate	TKN	NH3	phenols (μg/l)
	0→10	0→0.1	0→?	27,340	26,200	1140	8.6	<0.4	3.5	0.2	—
	10→20	0.1→0.2	?	22,600	21,800	732	0.56	0.08	2.9	<0.1	15.2
	30	0.3	?	498	127	371	0.48	<0.02	1.5	<0.1	—
curb face	40→50	0.4→0.5	460	17,100	7180	9930	5.7	0.4	15.0	0.1	4.0
	70→80	0.7→0.8	390	26,300	803	25,500	13.7	0.14	33.5	<0.1	—
	100	1.0	380	4350	731	3620	1.32	0.20	3.4	<0.1	2.4
	150	1.5	260	4360	2840	1530	1.03	0.18	3.4	<0.1	3.0
	200	2.0	160	1400	368	1040	0.54	0.08	2.4	<0.1	1.0
	250	2.5	100	598	213	385	0.22	<0.02	1.7	<0.1	2.8
	300	3.0	100	566	196	370	0.31	<0.02	1.5	<0.1	2.0
	400	4.0	120	686	206	480	0.14	<0.02	1.5	<0.1	—
footpath	500	5.0	190	560	154	406	0.39	<0.02	1.5	<0.1	2.6
footpath	750	7.5	130	251	129	122	0.07	<0.02	0.8	<0.1	<0.6
fence	1000	10	50	187	106	81	0.05	<0.02	0.8	<0.1	<0.6
	1500	15	80	882	162	720	0.32	0.02	1.7	<0.1	1.6
	2000	20	40	363	134	229	0.14	<0.02	1.7	<0.1	0.8
	2500	25	80	312	109	203	0.14	<0.04	1.7	0.4	2.0

Table F.7 Snow Transect Quality at Signet Rd. (March 12, 1984)
(conc. of snowmelt water, mg/L, unless otherwise noted)
(Cont.)

	distance from edge of snowpack (cm)	(m)	approx. snow depth (mm)	COD	Cd	Cr	Cu	Pb	Zn	Mn	Cl^-
	0→10	0→0.1	0→?	—	0.009	0.10	0.24	1.0	0.05	1.08	15,730
	10→20	0.1→0.2	?	1930	—	—	—	0.63	0.65	—	13,280
	30	0.3	?	—	<0.005	0.04	0.07	0.22	0.27	0.15	28
Curb face	40→50	0.4→0.5	460	—	—	—	—	5.1	4.1	—	4164
	70→80	0.7→0.8	390	3580	—	—	—	—	—	—	113
	100	1.0	380	—	—	0.18	—	2.3	1.7	—	359
	150	1.5	260	—	—	0.1	—	1.3	1.3	—	1630
	200	2.0	160	182	—	0.08	—	1.1	1.2	—	147
	250	2.5	100	—	—	0.06	—	0.45	0.38	—	70
	300	3.0	100	58	—	0.04	—	0.34	0.29	—	66
	400	4.0	120	—	—	—	—	0.35	0.30	—	70
footpath	500	5.0	190	78	—	0.05	—	0.51	0.77	—	38
footpath	750	7.5	130	30	—	—	—	0.15	0.16	—	46
	1000	10	50	10	—	—	—	0.10	0.15	—	40
Fence	1500	15	80	—	—	—	—	0.65	0.70	—	14
	2000	20	40	82	—	—	—	0.16	0.16	—	31
	2500	25	80	40	—	—	—	0.19	0.24	—	28

Table F.8

Snow Transect Bacteria Data (#/100 ml snowmelt water)

Signed Rd (Industrial) (March 14, 1984)

Distance from edge of snowpack (cm)	(m)	Fecal Coliforms	Fecal Strep.	Pseudo. aerugin.
0→10	0→0.1	<20	60	<20
10→20	0.1→0.2	— (6)	—	—
30	0.3	<20	<20	<20
40→50 (1)	0.4→0.5	—	—	—
70→80	0.7→0.8	—	—	—
100	1.0	—	—	—
150	1.5	—	—	—
200	2.0	—	—	—
250	2.5	—	—	—
300	3.0	—	—	—
400	4.0	<20	<20	<20
500 (2)	5.0	—	—	—
750 (2)	7.5	<20	<20	<20
1000 (3)	10	<20	<20	<20
1500	15	—	—	—
2000	20	<20	20	<20
2500	25	<20	<20	<20

Calstock Rd (Residential) (March 21, 1984)

Distance from edge of snowpack (cm)	(m)	Fecal Coliforms	Fecal Strep.	Pseudo. aerugi.
0→10	0→0.1	320	260	<10
25	0.25	40	20	<10
30	0.3	<20	80	<10
50	0.5	<20	1160	<10
75 (4)	0.75	20	20	<10
100	1.0	20	60	20
150 (5)	1.5	<20	20	<10
200	2.0	<20	100	<10
250	2.5	<20	80	<10
300	3.0	<20	480	<10
400 (2)	4.0	20	40	<20
630 (2)	6.3	<20	240	<10
800	8.0	<20	280	<10
1000	10	40	340	<10
1500	15	<20	420	<10
2000	20	<20	300	<10
250	25	<20	240	<10
300	30	<20	<20	<20

(1) curb-face
(2) foot path
(3) fence
(4) road edge
(5) edge of sealed ditch
(6) not analysed

Table F.9

Snow Transect Major Ions (@ Signet) (mg/l)

1	2	3 reactive Ca	4 reactive Mg	5 reactive Na	6 reactive K	7 reactive Cl^-	8 reactive SO_4	9 total alkalinity	10 soluble NO_3
100 cm		4.5	3.0	220	1.9	359	320.5	297	<0.1
150 cm		57	3.3	1000	1.8	1634	65.5	175	<0.1
200 cm		28	2.0	104	1.4	147	26	88	<0.1
250 cm		21.5	0.7	51	0.2	70	16	25	1.3
300 cm		19	1.0	49	0.2	66	14	26	1.0
500 cm		15	0.6	26	0.7	38	8	24	0.2

Table F.10 Snow Transect Dissolved Metal Concentrations at Signet Rd. (mg/l)

location	Cadmium total	Cadmium diss.	Cadmium % diss.	Chromium total	Chromium diss.	Chromium % diss	Copper total	Copper diss.	Copper % diss
0→10 cm	0.009	0.005	56%	0.10	<0.01	<10%	0.24	0.03	13%
30 cm	<0.005	<0.005	—	0.04	<0.01	<25%	0.07	0.01	14%

	Lead total	Lead diss.	Lead % diss.	Zinc total	Zinc diss.	Zinc % diss.	Manganese		
0→10 cm	1.0	<0.04	<4%	0.05	0.05	100%	1.08	0.17	16%
30 cm	0.22	<0.04	<18%	0.27	<0.02	<7%	0.15	0.03	20%

all dissolved:

	Al	As	Co	Mo	Ni	Se
0→10 cm	<0.08	<0.03	<0.02	<0.01	<0.03	<0.03
30 cm	0.15	<0.03	<0.02	0.01	<0.03	<0.03

Table F.11

Pesticides and Phenyls detected in the two snow Transect Samples Analysed (1)

Constituent (ng/l)	roadside windrow at Signet 0 to 10cm	30cm
G-BHC Hexachlorocyclohex	5.0	4.0
A-Chlordane	11.0	8.0
G-Chlordane	5.0	4.0
Dieldrin	12.0	12.0
PCBs, total	65 (2)	110 (2)
Hexachlorobenzene	1.0	1.0

(1) 234 and 245 Trichlorophenols and 2345 and 2356 Tetrachlorophenols not analysed

(2) resembled mixture of Aroclor 1248 and 1260

note: see Table ___ for detection limits of other pesticides and phenols analysed.

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Table F.8 Dry Particulate Size Distribution 6/19/84 1/3

Source Area Particulates — Pervious Areas	Location/Description	Total Load g/m²	Fraction of Solids in each Particle Size: <37	37→64	64→125	125→250	250→500	500→1000	1000→2000	2000→6450	>6450	Median Size
Bare ground												
T16	60 Banksfield – clay bank	38	0.7	3.1	11.9	24.1	21.0	11.2	6.6	21.3	<0.1	371
E60	Toyork – hard ground vacant area	58,000	3.0	6.7	9.9	16.1	15.5	8.2	5.2	9.8	25.7	481
Grass												
T17	60+61 Banksfield – well maintained lawn, from sod	29	NSS*									
Garden Soil												
T18	16 Banksfield – well maintained flower garden	2560	3.6	5.4	11.1	21.4	16.8	10.0	7.9	8.9	14.9	376
T21	61 Banksfield – well maintained unplanted garden	1538	3.7	10.7	15.3	21.6	23.7	13.6	6.6	3.6	1.2	242
T22	60 Banksfield – garden next to house	5550	8.2	15.6	17.4	23.3	22.0	8.4	3.2	1.4	0.5	172
T24	61 Banksfield – veg. garden	4060	2.1	4.8	12.9	28.7	26.3	9.8	4.9	5.6	4.9	264
T41	51 Alhart – few weeds, no cultivation	3900	1.6	3.8	7.0	10.0	14.8	15.5	19.1	17.9	10.3	918
Footpath												
T63	@ sampling station	1870	1.8	3.8	7.7	10.4	8.8	6.7	7.2	25.3	28.3	2633
Dirt near preserved wood												
E3	Ontario Hydro – storage lot for poles	1800	1.2	0.8	9.2	7.7	10.4	10.4	17.3	33.2	9.8	1595
T27	83 Thistledown – creosote pre wall (from cracks on wood)	40	0.8	3.7	8.1	14.9	22.8	19.3	7.5	22.6	0.4	497
Unpaved driveways												
T20	60+61 Banksfield	921	0.9	2.8	5.0	7.2	11.4	10.8	16.2	41.4	4.2	1735
T64	51 Alhart – crushed limestone	38,000	0.3	0.5	0.4	0.4	0.6	1.2	2.6	11.0	82.9	>6450
Road shoulder												
T25	23 Calstock – not maintained	10,160	3.9	6.2	19.0	20.2	13.2	8.3	7.3	18.8	3.2	263
Unpaved parking lot / storage area												
E2	B+E Furniture – poor	1670	2.2	3.3	6.0	9.9	14.2	13.9	14.1	25.9	10.5	1035
E7	Waste Management Inc – poor	3380	1.2	1.8	8.3	9.7	14.3	13.4	12.7	18.5	20.1	1102
E10	Marx Metals – dirt from scrap metal storage	635	1.8	2.0	7.5	8.4	9.2	10.9	13.0	22.5	24.8	1785
E13	Marta Equip. – poor	2440	1.6	2.3	9.5	11.8	15.1	14.4	16.9	25.6	2.8	837
E14	Thomas Equip – poor	1360	0.8	4.7	3.7	15.9	13.0	11.1	15.5	31.2	4.1	1052
E15	Monarch Propane – poor	5899	<0.1	<0.1	<0.1	2.8	9.8	8.5	17.5	47.4	14.1	3070
E29	Composite for GC/MS (E7, E10, E13, E14, E15)	2740	0.4	1.0	3.3	17.0	13.4	13.3	15.4	25.5	10.7	1104
E54	concrete formwork yard	2720	2.0	3.1	3.1	3.8	5.3	7.0	11.0	36.0	28.7	3817
Rail Road right-of-way												
E30	@ Ontario Hydro – over 6 ft of rails + 1 ft	1.5 g/m rail length	NSS									

* NSS = not sufficient sample for analysis

Table F12 Dry Particulate Size Distribution (Cont)

		<37	37-64	64-125	125-250	250-500	500-1000	1000-2000	2000-6450	>6450	median size
Impervious Areas											
Rooftops											
T43 51 Alhart - flat tar & gravel	7840	0.2	0.3	1.0	1.1	1.3	2.2	3.1	26.1	64.7	>6450
Roof troughs - good	g/m										
T42 51 Alhart - Al trough on compos. shingle	160	2.2	3.7	3.0	2.0	2.8	34.2	49.6	1.5	1.1	1042
T62 60 Thistledown - galv. iron trough on compos. shingle (4 yrs old)	82	10.5	7.9	3.1	1.2	2.3	28.6	44.6	0.3	1.5	937
Footpath											
E4 BoE Furniture - cracked concrete	28	3.3	5.4	14.1	21.4	23.4	13.9	7.8	6.5	4.2	312
Paved parking lot											
E1 North York Yard	162	10.9	10.8	16.5	18.9	19.4	11.8	5.4	3.3	3.1	203
E5 BoE Furniture - good asphalt	13	4.7	5.8	10.7	13.8	18.4	18.5	12.3	5.8	10.0	454
E6 Lumber King - poor loose pts hard	340	3.1	2.9	6.0	7.6	10.0	10.5	14.6	35.5	9.9	1678
E8 Food processing composite - good	61	1.7	3.7	6.8	11.8	24.8	18.2	14.5	14.2	4.4	533
E9 Continental Can - fair	67	0.1	5.4	8.2	12.3	23.5	17.7	10.5	11.7	10.6	514
T19 Shoppers Cart - asphalt - heavy parts	24	3.1	5.7	11.1	20.5	24.6	13.8	12.1	6.8	2.1	348
T45 Church - old asphalt	13	0.8	1.2	2.6	4.8	9.7	16.6	28.9	28.8	6.5	1495
E56 General manuf (403 Signet) - poor	6	0.9	2.6	6.1	13.1	21.9	21.5	20.5	12.4	1.1	626
E57 Avenet (Signet) @ drain	17,600	1.9	5.6	11.4	10.0	16.8	19.3	19.6	13.6	1.8	611
E61 Comercial - fairly good	12	2.6	6.1	7.3	11.1	19.3	17.7	14.9	15.7	5.2	602
Driveway											
T28 Thistledown composite - asphalt good	3	0.5	1.1	2.2	9.9	34.5	20.3	8.0	9.9	13.7	544
Sidewalk											
T46 258 Thistledown - concrete good	13	1.8	4.0	9.2	14.8	19.9	15.5	8.6	17.5	8.6	510
Road	g/curb-meter										
E11 Toryork - old	107	0.8	1.3	3.7	9.4	23.8	24.3	16.9	13.1	6.7	726
E12 Emery composite	40	1.6	2.9	11.7	20.0	21.4	14.9	11.1	10.7	5.7	411
T47 Thistledown Blvd - poor/cracked	2190	0.5	1.1	2.9	6.5	13.3	15.0	15.9	37.2	7.6	1673
T48 82 Alhart - smooth/good	67	2.7	5.8	11.7	20.0	26.1	18.1	7.4	5.8	2.5	344
T49 Humberland Ct - rough/good	100	3.9	7.0	13.4	21.2	25.0	15.1	8.1	5.2	1.1	295
T50 Edgebrook - old asphalt/very poor	103	1.0	1.9	4.2	6.9	8.6	8.1	12.1	41.9	15.1	2765
T51 Bondhead Ct - new seal very good	99	0.8	1.1	1.5	2.9	7.6	17.3	18.4	41.3	9.1	2043
T52 Bondhead - new seal and road shoulder	329	<0.1	0.2	0.1	0.1	0.3	1.0	2.9	70.2	25.3	4878
T53 Church @ Thistledown Blvd - same as 47 into shoulder	156	0.9	1.8	4.0	7.7	13.6	20.5	23.0	25.8	2.6	1065
E55 20 Noreko - asphalt - cracked	140	2.5	4.7	9.7	17.2	24.1	19.7	13.6	7.7	0.9	415
E58 @ Marta - poor/well cracked	485	1.7	3.6	8.3	15.5	23.8	21.5	13.9	8.7	3.0	470
E59 composite - very good ("clean")	43	1.6	3.3	6.7	10.8	17.7	18.7	17.1	19.4	4.7	765
T40. Alhart @ Thistledown - medium tex. road cond.	37(?)	2.0	3.4	7.0	10.8	12.3	9.6	8.7	30.0	16.3	1563

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Table F.B Dry Particulate Size Distribution (Cont) 6/9/84

		<37	37→64	64→125	125→250	250→500	500→1000	1000→2000	2000→6450	>6450	median size
Drainage system											
Sealed drainage ditch											
T26 60 Thistledown - newly sealed	1523	0.2	0.3	0.6	2.1	2.1	9.9	17.3	57.7	9.9	1303
Grass swale											
T23 23 Calstock	7150	0.5	2.3	14.0	41.7	27.4	6.0	3.6	4.5	<0.1	225
44 42 Alhart - good	2150	3.1	5.0	11.1	20.7	23.0	16.0	13.4	3.6	4.1	360
Catchbasin	Eg										
E31 Lumberking 29 Fenmar concrete curb	950	2.7	4.3	9.6	12.8	16.0	15.0	11.4	11.8	16.6	653
E32 Coca Cola - concrete curb	560	2.5	2.9	7.0	14.8	22.1	19.7	12.3	9.3	9.2	520
T33 42 Alhart - grass swale	195	1.7	3.4	7.7	15.0	18.0	17.2	18.0	18.9	<0.1	622
T34 60 Thistledown - newly sealed swale	577	<0.1	0.1	0.1	0.1	0.1	0.1	0.1	57.6	41.8	1858
T35 47 Alhart - grass swale	336	4.7	5.4	10.9	19.1	21.1	12.2	7.5	8.3	10.9	367
T36 Alhart & Ashford 58 - grass swale	313	1.4	2.4	6.4	15.6	21.7	13.8	6.8	21.4	10.5	591
T37 16 Alhart - grass swale (clean)	715	0.8	1.0	2.3	5.1	8.8	8.0	8.5	40.0	25.6	3724
T38 44 Brookwood - concrete gutter	390	1.8	3.5	5.6	11.7	24.2	25.9	11.6	8.2	7.5	562
T39 Calstock - concrete gutter	335	0.1	0.2	1.6	16.2	19.9	19.5	14.0	12.9	15.5	808
Humber River Sediment											
HR70 @ mouth	—	1.0	1.4	4.8	21.8	18.4	3.9	2.1	5.5	40.7	833
HR71 @ Thistledown Outfall	—	0.9	1.6	9.6	38.2	39.7	8.8	0.7	0.2	<0.1	249
HR72 (Thistledown pool @ outfall)	—	1.7	2.1	3.4	25.1	40.3	13.7	5.2	4.9	2.7	360
HR73 (Emery Outfall pool)	—	2.0	18.9	23.8	13.7	8.3	6.4	8.4	15.0	2.7	173
HR74 @ Kleinburg	—	1.2	1.5	2.6	6.9	14.6	11.2	5.3	16.8	43.9	3775
HR75 @ Humber Glen Bridge	—	2.6	5.7	17.6	12.8	4.7	25.4	11.6	3.4	15.1	630

Table F.13 Dry Particulate Quality

Source Area Particulates

Pervious Areas	Location/ Description	Total Load g/m²	Total Solids: Percentage in Size Range <125μ	125-500	500-2000	>2000	Total P mg/g <125μ	125-500	500-2000	>2000	Total Carbon, mg/g <125μ	125-500	500-2000	>2000
Bareground														
T16	60 Banksfield - clay back yard ground	38	15.7	45.1	17.8	21.3	—*	—	—	610	—	—	—	—
E60	Toyork - vacant area	58,000	19.6	31.6	13.4	35.5	900	470	500	310	57	48	75	85
Grass														
T17	60&61 Banksfield - well watered lawn from roof	29	NSS*				NSS				NSS			
Garden Soil														
T18	16 Banksfield - well watered flower garden	2560	20.1	38.2	17.9	23.8	1600	1000	2000	1900	38	33	95	79
T21	61 Banksfield - well watered expanded garden	1538	29.7	45.3	20.2	4.8	1300	1100	—	1600	22	24	—	57
T22	60 Banksfield - garden next to house	5550	41.2	45.3	11.6	1.9	1000	600	940	990	26	26	72	139
T24	61 Banksfield - veg. garden	4060	19.8	55.0	14.7	10.5	1200	590	1300	1400	26	15	48	79
T41	51 Albert - few weeds no cultivation	3900	12.4	24.8	34.6	28.2	1300	780	810	1100	41	51	133	143
Footpath														
T63	@ sampling station	1870	13.3	19.2	13.9	53.6	360	360	430	390	26	26	56	68
Dirt near preserved wood														
E3	Ontario Hydro - storage lot for poles	1800	11.2	18.1	27.7	43.0	490	320	220	120	93	72	117	123
T27	83 Thistledown - creosote fence wall (from fragments on wood)	40	12.6	37.7	26.8	23.0	—	—	—	320	—	—	—	161
Unpaved driveways														
T20	60&61 Banksfield	921	8.7	18.6	27.0	45.6	580	230	240	150	82	48	100	114
T64	51 Albert - crushed limestone	38,000	1.2	1.0	3.8	93.9	220	230	120	96	122	131	152	122
Road shoulder														
T25	23 Calstock - not maintained	10,160	29.1	33.4	15.6	22.0	870	330	420	300	30	28	72	108
Unpaved parking lot / storage areas														
E2	B&E Furniture - poor	1670	11.5	24.1	28.0	36.4	530	240	220	160	65	68	104	112
E7	Waste Management Inc - poor	3380	11.3	24.0	26.1	38.6	840	400	460	380	105	55	61	73
E10	Mary Metals - dirt from scrap metal storage	635	11.3	17.6	23.9	47.3	560	590	610	220	122	96	120	150
E13	Marta Equip. - poor	2440	13.4	26.9	31.3	28.4	690	380	350	340	110	60	102	106
E14	Thomas Equip - poor	1360	9.2	28.9	26.6	35.3	620	400	240	160	103	83	112	122
E15	Monarch Propane - poor	5899	<0.1	12.6	26.0	61.5	—	540	280	260	—	115	120	118
E29	Composite for GC/MS	2740	4.7	30.4	28.7	36.2	composite of above 5 samples							
E54	concrete formwork yard	2720	8.2	9.1	18.0	64.7	460	290	300	250	59	61	82	86
Rail Road right-of-way														
E30	@ Ontario Hydro - on 6 ft 6 rails of site	1.5 g/m rail length	NSS				NSS				NSS			

*NSS = not sufficient sample for analysis
— = " " " " "

Table F.13 Dry Particulate Quality (Cont.)

Source Area Particulates

Pervious Areas	Location/Description	Total Load g/m²	Total Solids: Percentage in Size Range <125µ	125–500	500–2000	>2000	TKN, mg/g <125µ	125–500	500–2000	>2000	COD, mg/g <125µ	125–500	500–2000	>2000
Bareground														
T16	60 Banksfield – clay bank hard ground	38	15.7	45.1	17.8	21.3	—	—	—	487	—	—	—	20.1
E60	Toyork – [illegible] area	52,000	19.6	31.6	13.4	35.5	2990	1940	1660	684	92	69	92	31
Grass														
T17	60&61 Banksfield – well watered [illegible]	29	NSS*				NSS				NSS			
Garden Soil														
T18	16 Banksfield – well watered flower garden	2560	20.1	38.2	17.9	23.8	2350	2110	5860	2490	83	72	165	140
T21	61 Banksfield – well watered [illegible] garden	1538	29.7	45.3	20.2	4.8	1580	1590	—	2070	42	44	—	95
T22	60 Banksfield – garden next to house	5550	41.2	45.3	11.6	1.9	1630	1270	2250	3140	55	49	108	31
T24	61 Banksfield – veg. garden	4060	19.8	55.0	14.7	10.5	1890	973	2650	2690	54	32	100	171
T41	51 Albert – few weeds no cultivation	3900	12.4	24.8	34.6	28.2	2290	2470	5760	4390	100	121	318	305
Footpath														
T63	@ sampling station	1870	13.3	19.2	13.9	53.6	763	424	570	163	23	17	22	6.5
Dirt near preserved wood														
E3	Ontario Hydro – storage lot for poles	1800	11.2	18.1	27.7	43.0	412	405	233	62	48	38	25	12
T27	83 Thistledown – creosote [illegible] wall ([illegible] on wood)	40	12.6	37.7	26.8	23.0	—	2430	—	2820	—	231	—	344
Unpaved driveways														
T20	60&61 Banksfield	921	8.7	18.6	27.0	45.6	1070	440	160	57	61	39	25	15
T64	51 Albert – crushed limestone	38,000	1.2	1.0	3.8	93.9	633	1290	898	24	40	33	104	1.6
Road shoulder														
T25	23 Calstock – not maintained	10,160	29.1	33.4	15.6	22.0	718	450	672	169	34	23	50	35
Unpaved parking lot / storage areas														
E2	B&E Furniture – poor	1670	11.5	24.1	28.0	36.4	630	1000	667	85	33	63	45	65
E7	Waste Management Inc – poor	3380	11.3	24.0	26.1	38.6	1460	625	427	778	153	223	74	68
E10	Harr Metals – dirt from scrap [illegible]	635	11.3	17.6	23.9	47.3	612	441	334	856	141	173	221	178
E13	Marta Equip. – poor	2440	13.4	26.9	31.3	28.4	611	256	232	198	162	83	78	77
E14	Thomas Equip – poor	1360	9.2	28.9	26.6	35.3	540	327	143	77	134	93	52	33
E15	Monarch Propane – poor	5819	<0.1	12.6	26.0	61.5	—	226	70	53	—	129	57	40
E29	Composite for GC/MS	2740	4.7	30.4	28.7	36.2	for GC/MS analysis							
E57	concrete formwork yard	2720	8.2	9.1	18.0	64.7	322	223	177	84	53	44	46	26
Rail Road right-of-way														
E30	@ Ontario Hydro [illegible]	1.5 g/m rail length	NSS				NSS				NSS			

*NSS = not sufficient sample for analysis

— = " " " " "

Table F.13 Dry Particulate Quality (Cont'd)

Source Area Particulates — Pervious Areas	Location/Description	Total Load g/m²	Percentage in Size Range <125	125–500	500–2000	>2000	Cr, ug/g <125	125–500	500–2000	>2000	Mn, ug/g <125	125–500	500–2000	>2000
Bareground														
T16	60 Banksfield – clay back hard ground	38	15.7	45.1	17.8	21.3	—*	–	–	20	—	–	–	730
E6C	Toryork – vacant area	58,000	19.6	31.6	13.4	35.5	39	23	27	22	530	350	450	505
Grass														
T17	60&61 Banksfield – well watered lawn, from rood	29	NSS *				NSS				NSS			
Garden Soil														
T18	16 Banksfield – well watered flower garden	2560	20.1	38.2	17.9	23.8	44	23	33	20	690	410	770	1700
T21	61 Banksfield – well watered expanded garden	1538	29.7	45.3	20.2	4.8	22	20	—	30	500	570	—	980
T22	60 Banksfield – garden next to house	5550	41.2	45.3	11.6	1.9	19	13	23	29	410	330	930	1300
T24	61 Banksfield – veg. garden	4060	19.8	55.0	14.7	10.5	46	26	45	33	590	360	1300	1300
T41	51 Alhart – few weeds no cultivation	3900	12.4	24.8	34.6	28.2	42	26	28	24	780	470	760	1400
Footpath														
T63	@ sampling station	1870	13.3	19.2	13.9	53.6	25	20	17	18	480	340	640	920
Dirt near preserved wood														
E3	Ontario Hydro – storage lot for poles	1800	11.2	18.1	27.7	43.0	37	20	13	13	580	460	620	620
T27	83 Thistledown – creosote fence wall (from flakes on wood)	40	12.6	37.7	26.8	23.0	—	27	—	25	—	440	—	410
Unpaved driveways														
T20	60&61 Banksfield	921	8.7	18.6	27.0	45.6	25	14	12	13	560	330	470	580
T64	51 Alhart – crushed limestone	38,000	1.2	1.0	3.8	93.9	18	14	12	8	850	660	630	670
Road shoulder														
T25	23 Calstock – not maintained	10,160	29.1	33.4	15.6	22.0	25	17	36	16	470	310	560	460
Unpaved parking lot / storage areas														
E2	B&E Furniture – poor	1670	11.5	24.1	28.0	36.4	18	12	13	11	490	310	420	450
E7	Waste Management Inc – poor	3380	11.3	24.0	26.1	38.6	24	230	142	310	2970	2400	4900	4700
E10	Mary Metals – dirt from scrap metal storage	635	11.3	17.6	23.9	47.3	167	550	323	110	1200	1170	1170	650
E13	Marta Equip. – poor	2440	13.4	26.9	31.3	28.4	54	36	31	18	560	390	530	530
E14	Thomas Equip – poor	1360	9.2	28.9	26.6	35.3	51	48	20	22	680	530	550	710
E15	Monarch Propane – poor	5899	<0.1	12.6	26.0	61.5	—	22	33	12	—	540	550	590
E29	Composite for GC/MS (of E7, E10, E13, E14, E15)	2740	4.7	30.4	28.7	36.2	composite of 5 above samples for GC/MS analyses							
E54	concrete formwork yard	2720	8.2	9.1	18.0	64.7	57	39	31	23	510	420	460	510
Rail Road right-of-way														
E30	@ Ontario Hydro – on 6 ft & rails of the	1.5 g/m rail length	NSS				NSS				NSS			

*NSS = not sufficient samples for analysis

Table F.13 Dry Particulate Quality (Cont.)

Source Area Particulates: Pervious Areas — Location/Description	Total Load g/m²	Percentage in Size Range <125	125–500	500–2000	>2000	Cu, ug/g <125	125–500	500–2000	>2000	Zn, ug/g <125	125–500	500–2000	>2000	Pb, ug/g <125	125–500	500–2000	>2000
Bare ground																	
T16 60 Banksfield – clay back, hard ground	38	15.7	45.1	17.8	21.3	–	–	–	20	–	–	–	68	–	–	–	48
E6C Toyork – vacant area	58,000	19.6	31.6	13.4	35.5	72	52	22	12	160	87	83	45	110	65	65	52
Grass																	
T17 60061 Banksfield – well maintained lawn from rows	29	NSS *				NSS				NSS				NSS			
Garden Soil																	
T18 16 Banksfield – well maintained flower garden	2560	20.1	38.2	17.9	23.8	54	16	30	15,000	150	99	180	150	70	34	62	48
T21 61 Banksfield – well weeded, (unweeded?) garden	1538	29.7	45.3	20.2	4.8	21	16	—	24	120	120	—	240	44	38	—	5.
T22 60 Banksfield – garden next to house	5550	41.2	45.3	11.6	1.9	19	13	28	32	150	81	300	130	54	36	64	62
T24 61 Banksfield – veg. garden	4060	19.8	55.0	14.7	10.5	19	11	22	25	78	44	130	120	34	16	32	40
T41 51 Alhart – few weeds, no cultivation	3900	12.4	24.8	34.6	28.2	23	15	28	23	110	68	100	81	56	34	48	37
Footpath																	
T63 @ sampling station	1870	13.3	19.2	13.9	53.6	14	9	17	29	49	35	36	37	38	120	1700	52
Dirt near preserved wood																	
E3 Ontario Hydro – storage lot for poles	1800	11.2	18.1	27.7	43.0	110	110	16	17	370	280	92	56	160	120	67	64
T27 83 Thistledown – creosote pre wall (from fragments on wood)	40	12.6	37.7	26.8	23.0	—	62	—	32	—	500	—	570	—	370	—	3.[illegible]
Unpaved driveways																	
T20 60061 Banksfield	921	8.7	18.6	27.0	45.6	40	36	12	9	180	110	54	29	170	98	58	68
T64 51 Alhart – crushed limestone	38,000	1.2	1.0	3.8	43.9	48	23	13	6	160	120	58	35	140	130	80	62
Road shoulder																	
T25 23 Calstock – not maintained	10,160	29.1	33.4	15.6	22.0	35	39	36	24	120	110	130	53	230	230	240	92
Unpaved parking lot / storage areas																	
E2 B&E Furniture – poor	1670	11.5	24.1	28.0	36.4	22	15	16	4.5	110	82	64	36	90	110	57	54
E7 Waste Management Inc – poor	3380	11.3	24.0	26.1	38.6	430	310	263	80	1040	460	490	700	1400	680	650	680
E10 Mary Metals – dirt & gravel, scrap metal storage	635	11.3	17.6	23.9	47.3	5910	27,200	30,900	16,000	4830	31,000	27,700	2,800	9700	13,600	9700	2800
E13 Marta Equip. – poor	2440	13.4	26.9	31.3	28.4	130	33	28	14	210	96	70	47	500	270	180	87
E14 Thomas Equip – poor	1360	9.2	28.9	26.6	35.3	240	150	65	13	380	290	100	75	460	360	150	98
E15 Monarch Propane – poor	5899	<0.1	12.6	26.0	61.5	–	31	17	9.5	—	270	130	81	—	350	180	110
E29 Composite for GC/MS	2740	4.7	30.4	28.7	36.2												
E54 concrete formwork yard	2720	8.2	9.1	18.0	64.7	25	30	11	12	127	86	49	30	130	119	80	55
Railroad right-of-way																	
E30 @ Ontario Hydro – over 6 ft. 6 in. material site	1.5 g/m rail length	NSS				NSS				NSS				NSS			

(Brackets at the left margin link E7, E10, E13, E14 and E15 to E29.)

Table F.13 Dry Particulate Quality (contd)

		Total solids: Percentage in Size Range				Total P, mg/g by size				Total Carbon, mg/g by size			
		<125µ	125→500	500→2000	>2000	<125µ	125→500	500→2000	>2000	<125µ	125→500	500→2000	>2000
Impervious Areas:													
Rooftops													
T43 51 Alhart - flat tar & gravel	7840	1.5	2.4	5.3	90.8	2100	1130	380	250	187	177	120	100
Roof troughs	g/m												
T42 51 Alhart - good Al trough on compos. shingle	160	8.9	4.8	83.8	2.6	1600	1600	790	850	93	105	17	303
T62 60 Thistledown - galv. iron trough on compos. shingle (4 yrs old)	82	21.5	3.5	73.2	1.8	830	960	1000	1200	71	56	5	446
Footpath													
E4 B & E Furniture - cracked concrete	28	22.8	44.8	21.7	10.7	890	560	640	780	80	85	167	217
Paved parking lot													
E1 North York Yard	162	38.2	38.3	17.2	6.4	800	330	330	190	47	41	82	113
E5 B & E Furniture - good asphalt	13	21.2	32.2	30.8	15.8	620	280	200	220	80	64	105	117
E6 Lumber King - poor loading area	340	12.0	17.6	25.1	45.4	470	330	220	220	105	104	122	121
E8 Food processing composite - good	61	12.2	36.6	32.7	18.6	1700	880	520	2200	132	57	89	144
E9 Continental Can - fair	67	13.7	35.8	28.2	22.3	900	440	570	470	124	47	70	90
T19 Shopping Cent - asphalt - heavy parts	24	19.9	45.1	25.9	8.9	800	320	300	230	62	39	63	81
T45 Church - old asphalt	13	4.6	14.5	45.5	35.3	400	300	220	120	94	62	110	110
E56 General manuf (403 Signet) - poor	6	9.6	35.0	42.0	13.5	570	320	290	240	63	40	63	86
E57 Avenet (Signet) @ drain	17,600	18.9	26.8	38.9	15.4	580	360	360	200	104	69	78	96
E61 Commercial - fairly good	12	16.0	30.4	32.6	20.9	490	330	260	210	86	54	91	102
Driveway													
T28 Thistledown composite - asphalt - good	3	3.8	44.4	28.3	23.6	550	270	410	200	118	46	79	155
Sidewalk													
T46 258 Thistledown - concrete good	13	15.0	34.7	24.1	26.1	1100	700	1100	150	84	115	223	120
Road	kg/curb km												
E11 Toryork - old rough	107	5.8	33.2	41.2	19.8	710	260	260	240	57	44	73	96
E12 Emery composite	40	16.2	41.4	26.0	16.4	840	410	410	350	63	43	76	98
T47 Thistledown Blvd - poor/cracked	2190	4.5	19.8	30.9	44.8	320	220	150	130	81	58	105	126
T48 82 Alhart - smooth/good	67	20.2	46.1	25.5	8.3	330	300	420	730	80	49	80	221
T49 Hinderland Ct - rough/good	100	24.3	46.5	23.2	6.3	1000	420	400	310	69	45	74	94
T50 Edgebrook - old asphalt very poor	103	7.1	15.5	20.2	57.0	490	290	250	210	80	57	116	131
T51 Bankhead Ct - new seal very good	99	3.4	10.5	35.7	50.4	600	260	140	160	149	116	128	140
T52 Bankhead - very good good road shoulder	329	0.3	0.4	3.9	95.5	—	530	260	92	—	192	162	127
T53 Thistledown Blvd - same as 47 into shoulder	152	6.7	21.3	43.5	28.4	650	250	210	200	76	49	92	118
E55 20 Noreko - asphalt cracked	140	16.9	41.3	33.3	8.6	650	290	180	190	56	39	71	103
E58 @ Hadn - poor/well cracked	485	13.6	39.3	35.4	11.7	490	260	26	310	63	49	85	202
E57 composite - very good (clean)	43	11.6	28.5	35.8	24.1	650	300	380	210	68	43	70	90
T40 Alhart @ Thistledown - medium traffic road area	37(?)	12.4	23.1	18.3	46.3	960	320	240	97	64	49	102	122

Table F.13 Dry Particulate Quality (cont.)

	Total solids	Percentage in Size Range <125 µ	125→500	500→2000	>2000	TKN, mg/g <125 µ	125→500	500→2000	>2000	COD, mg/g <125 µ	125→500	500→2000	>2000
Impervious Areas													
Rooftops													
T43 51 Alhart - slat tar & gravel	7840	1.5	2.4	5.3	90.8	11,400	8910	2070	196	412	343	219	48
	g/m												
Roof troughs													
T42 51 Alhart - good Al trough on compos. shingle	160	8.9	4.8	83.8	2.6	3340	4510	432	2990	180	272	49	371
T62 60 Thistledown - galv. iron trough on compos. shingle (4 yrs old)	82	21.5	3.5	73.2	1.8	2290	1400	61	13,900	130	139	18	1100
Footpath													
E4 B & E Furniture - cracked concrete	28	22.8	44.8	21.7	10.7	1910	1990	3190	4420	116	146	287	376
Paved parking lot													
E1 North York Yard	162	38.2	38.3	17.2	6.4	601	169	192	179	44	25	34	47
E5 B & E Furniture - good asphalt	13	21.2	32.2	30.8	15.8	911	1250	611	71	49	58	33	[illegible]
E6 Lumber King - poor loading area hard	340	12.0	17.6	25.1	45.4	516	317	178	80	100	141	82	80
E8 Food processing composite - good	61	12.2	36.6	32.7	18.6	2880	1050	588	1200	253	87	83	163
E9 Continental Can - fair	67	13.7	35.8	28.2	22.3	1130	273	253	296	228	64	48	45
T19 Shoppers Cart - asphalt - heavy parking	24	19.9	45.1	25.9	8.9	403	113	82	104	54	20	21	26
T45 Church - old asphalt	13	4.6	14.5	45.5	35.3	1170	892	650	130	101	50	45	30
E56 General manuf (403 Signet) - poor	6	9.6	35.0	42.0	13.5	581	171	155	108	94	37	39	32
E57 Avenet (Signet) @ drain	17,600	18.9	26.8	38.9	15.4	1120	777	451	275	153	92	70	64
E61 Commercial - fairly good	12	16.0	30.4	32.6	20.9	735	227	163	130	124	59	66	43
Driveway													
T28 Thistledown composite - asphalt - good	3	3.8	44.4	28.3	23.6	2750	511	807	1560	249	82	98	160
Sidewalk													
T46 258 Thistledown - concrete good	13	15.0	34.7	24.1	26.1	3620	7120	12,100	966	146	207	437	93
Road	[illegible]												
E11 Toryork - old trough	107	5.8	33.2	41.2	19.8	348	111	105	75	47	21	19	22
E12 Emery composite	40	16.2	41.4	26.0	16.4	684	289	458	343	74	37	46	64
T47 Thistledown Blvd - poor/cracked	2190	4.5	19.8	30.9	44.8	758	328	219	146	79	39	35	24
T48 82 Alhart - smooth/good	67	20.2	46.1	25.5	8.3	1020	564	1370	4710	94	37	80	448
T49 Humberland Ct - rough/good	100	24.3	46.5	23.2	6.3	942	351	367	271	74	30	36	32
T50 Edgebrook - old asphalt/very poor	103	7.1	15.5	20.2	57.0	655	438	529	481	67	48	73	73
T51 Bondhead Ct - new seal very good	99	3.4	10.5	35.7	50.4	1580	561	254	483	228	110	64	59
T52 Bondhead - very good road shoulder	329	0.3	0.4	3.9	95.5	—	440	1790	118	—	314	144	214
T53 Thistledown Blvd - same as 47 into shoulder	156	6.7	21.3	43.5	28.4	538	170	126	156	62	25	25	32
E55 20 Noreko - asphalt - cracked	140	16.9	41.3	33.3	8.6	631	239	220	230	50	22	25	26
E58 @ Hadn - poor/wavy cracked	485	13.6	39.3	35.4	11.7	394	153	105	168	60	31	23	22
E57 composite - very good (@ Steam.)	43	11.6	28.5	35.8	24.1	721	334	368	285	96	42	44	18
T40 Alhart @ Thistledown - medium type road cond.	377(?)	12.4	23.1	18.3	46.3	1730	862	751	177	87	49	61	41

Table F.13 Dry Particulate Quality (Cont.)

		Total solids: Percentage in Size Range				Cr, ug/g				Mn, ug/g			
		<125	125-500	500-2000	>2000	<125	125-500	500-2000	>2000	<125	125-500	500-2000	>2000
Impervious Areas													
Rooftops													
T43 51 Alhart - slat tar & gravel	7840	1.5	2.4	5.3	90.8	66	45	27	14	870	800	820	370
Roof troughs	g/m												
T42 51 Alhart - good Al trough on compos. shingle	160	8.9	4.8	83.8	2.6	79	94	36	35	580	620	470	340
T62 60 Thistledown - galv. iron trough on compos. shingle (4 yrs old)	82	21.5	3.5	73.2	1.8	87	170	75	13	610	790	760	150
Footpath													
E4 B&E Furniture - cracked concrete	28	22.8	44.8	21.7	10.7	63	66	66	41	690	450	640	1200
Paved parking lot													
E1 North York Yard	162	38.2	38.3	17.2	6.4	31	18	27	27	540	330	540	460
E5 B&E Furniture - good asphalt	13	21.2	32.2	30.8	15.8	69	23	25	25	640	330	480	590
E6 Lumber King - poor loose gravel hard	340	12.0	17.6	25.1	45.4	55	34	18	15	620	360	480	490
E8 Food processing composite - good	61	12.2	36.6	32.7	18.6	65	36	36	28	687	410	570	610
E9 Continental Can - fair	67	13.7	35.8	28.2	22.3	73	90	263	124	733	527	817	1000
T19 Shoppers Cart - asphalt - heavy parts	24	19.9	45.1	25.9	8.9	55	38	61	14	580	410	690	470
T45 Church - old asphalt	13	4.6	14.5	45.5	35.3	39	22	24	11	740	390	470	440
E56 General manuf (403 Signet) - poor	6	9.6	35.0	42.0	13.5	190	190	400	426	673	628	1017	924
E57 Avenet (Signet) @ drain	17,600	18.9	26.8	38.9	15.4	73	88	100	66	520	350	450	495
E61 Commercial - fairly good	12	16.0	30.4	32.6	20.9	237	193	440	61	883	660	1130	1200
Driveway													
T28 Thistledown composite - asphalt - good	3	3.8	44.4	28.3	23.6	70	18	35	40	570	250	570	490
Sidewalk													
T46 258 Thistledown - concrete good	13	15.0	34.7	24.1	26.1	32	17	15	9	670	390	520	610
Road	g/curb-metre												
E11 Toryork - old trough	107	5.8	33.2	41.2	19.8	32	18	33	17	570	310	530	480
E12 Emery composite	40	16.2	41.4	26.0	16.4	83	67	100	140	860	740	1200	1500
T47 Thistledown Blvd - poor/cracked	2190	4.5	19.8	30.9	44.8	44	27	18	16	670	390	520	610
T48 82 Alhart - smooth/good	67	20.2	46.1	25.5	8.3	47	24	45	22	620	360	410	540
T49 Humberland Ct - rough/good	100	24.3	46.5	23.2	6.3	47	34	45	63	710	500	610	810
T50 Edgebrook - old asphalt very poor	103	7.1	15.5	20.2	57.0	37	28	28	17	750	420	600	580
T51 Bondhead Ct - new seal very good	99	3.4	10.5	35.7	50.4	43	31	34	14	710	570	680	410
T52 Bondhead - new seal and road shoulder	329	0.3	0.4	3.9	95.5	—	40	18	12	—	410	498	410
T53 Church @ Thistledown Blvd - same as 47 w/o shoulder	156	6.7	21.3	43.5	28.4	48	37	33	13	570	400	530	570
E55 20 Noreko - asphalt - cracked	140	16.9	41.3	33.3	8.6	60	41	54	190	540	430	720	790
E58 @ Harta - poor/wash cracked	485	13.6	39.3	35.4	11.7	50	39	69	19	620	570	730	620
E57 composite - very good (v. clean)	43	11.6	28.5	35.8	24.1	120	100	270	230	950	800	2100	2500
T40 Alhart @ Thistledown - between road [illegible]	37(?)	12.4	23.1	18.3	46.3	29	19	17	11	600	400	690	730

Table F13 Dry Partic. Quality (contd.)

Impervious Areas	Total solids	% <125	% 125-500	% 500-2000	% >2000	Cu <125	Cu 125-500	Cu 500-2000	Cu >2000	Zn <125	Zn 125-500	Zn 500-2000	Zn >2000	Pb <125	Pb 125-500	Pb 500-2000	Pb >2000
		Percentage in Size Range				Cu, μg/g				Zn, μg/g				Pb, μg/g			
Rooftops																	
T43 51 Alhart - slab tar & gravel	7840	1.5	2.4	5.3	90.8	130	78	30	6	1100	760	290	53	1200	780	210	62
Roof troughs	g/m																
T42 51 Alhart - good - Al trough on compos. shingle	160	8.9	4.8	83.8	2.6	120	94	26	20	510	370	99	110	730	400	48	82
T62 60 Thistledown - galv. iron trough on compos. shingle (4 yrs old)	82	21.5	3.5	73.2	1.8	150	170	120	24	4100	3400	370	490	1000	650	52	110
Footpath																	
E4 B&E Furniture - cracked concrete	28	22.8	44.8	21.7	10.7	280	69	110	38	1300	1000	520	330	460	400	230	110
Paved parking lot																	
E1 North York Yard	162	38.2	38.3	17.2	6.4	44	21	18	10	200	77	170	29	160	130	120	57
E5 B&E Furniture - good asphalt	13	21.2	32.2	30.8	15.8	240	24	74	11	770	190	94	63	450	190	76	60
E6 Lumberking - poor long-pile hard	340	12.0	17.6	25.1	45.4	120	36	20	9	360	160	88	130	190	94	60	66
E8 Food processing composite - good	61	12.2	36.6	32.7	18.6	270	69	951	42	1300	420	297	101	730	380	190	62
E9 Continental Can - fair	67	13.7	35.8	28.2	22.3	390	967	2560	1110	1530	600	1370	450	1130	660	1370	158
T19 Shoppers Cart - asphalt - heavy parts	24	19.9	45.1	25.9	8.9	170	72	230	16	470	380	240	50	850	520	170	66
T45 Church - old asphalt	13	4.6	14.5	45.5	35.3	120	33	23	6	360	210	67	37	410	240	84	68
E56 General manuf (403 Signet) - poor	6	9.6	35.0	42.0	13.5	2600	8860	14,300	11,700	1030	2200	1900	4940	1000	1030	1080	90
E57 Avenet (Signet) @ drain	17,600	18.9	26.8	38.9	15.4	2530	2130	625	94	755	637	533	125	750	523	538	113
E61 Commercial - fairly good	12	16.0	30.4	32.6	20.9	2600	1830	3680	75	1500	798	1032	125	783	628	473	72
Driveway																	
T28 Thistledown composite - asphalt good	3	3.8	44.4	28.3	23.6	170	37	27	14	790	150	150	44	900	240	400	54
Sidewalk																	
T46 258 Thistledown - concrete good	13	15.0	34.7	24.1	26.1	44	27	18	16	430	290	110	78	1200	640	190	120
Road	g/curb-m																
E11 Toryork - old rough	107	5.8	33.2	41.2	19.8	160	190	120	580	310	230	250	300	410	230	290	95
E12 Emery composite	40	16.2	41.4	26.0	16.4	570	640	1700	82	700	960	1400	110	1500	1400	940	70
T47 Thistledown Blvd - poor/cracked	2190	4.5	19.8	30.9	44.8	110	61	40	6.5	430	290	110	78	1200	640	190	120
T48 82 Alhart - smooth/good	67	20.2	46.1	25.5	8.3	240	89	40	19	490	240	250	91	1300	850	280	76
T49 Humberland Ct - rough/good	100	24.3	46.5	23.2	6.3	190	56	49	32	540	400	270	52	1200	940	480	82
T50 Edgebrook - old asphalt very poor	103	7.1	15.5	20.2	57.0	110	40	32	11	330	240	140	82	790	800	400	78
T51 Bandhead Ct - new seal very good	99	3.4	10.5	35.7	50.4	260	93	52	10	690	660	500	26	730	390	160	51
T52 Bondhead - new seal and road shoulder	329	0.3	0.4	3.9	95.5	—	96	22	5	—	260	66	23	—	200	63	47
T53 Thistledown Blvd - same as 47 into shoulder	156	6.7	21.3	43.5	28.4	170	58	56	7	390	320	190	190	1300	1200	330	70
E55 20 Noreko - asphalt - cracked	140	16.9	41.3	33.3	8.6	160	130	260	30	360	270	430	60	730	650	760	100
E58 Haste - poor/well cracked	485	13.6	39.3	35.4	11.7	460	450	460	25	390	270	270	60	570	490	320	50
E57 composite - very good (Bremner)	43	11.6	28.5	35.8	24.1	520	870	1700	35	730	570	530	110	1300	1300	860	110
T40 Alhart @ Thistledown - undermixed road	37(?)	12.4	23.1	18.3	46.3	56	32	25	10	380	200	180	96	530	370	220	110

Table F.13 Dry Particulate Quality (Cont.)

Drainage System	g	Total Solids: Percentage in Size Range <125 μ	125→500	500→2000	>2000	Total P, ug/g <125 μ	125→500	500→2000	>2000	Total Carbon, mg/g <125	125→500	500→2000	>2000
Sealed drainage ditch													
T26 60 Thistledown – newly sealed	1523	1.1	4.2	27.2	67.6	—	310	140	110	—	57	107	121
Grass swale													
T23 23 Calstock	7150	16.8	69.1	9.6	4.5	1100	370	450	460	20	23	57	92
T44 42 Alhart – good	2150	19.2	43.7	29.4	7.7	1200	760	1000	1200	50	44	93	200
Catchbasin	Eg												
E31 Lumberking & 29 Fenmar – concrete curb	950	16.6	28.8	26.4	28.4	430	240	190	170	77	59	99	116
E32 Coca Cola – concrete curb	560	12.4	36.9	32.0	18.5	1100	330	400	390	87	51	80	121
T33 42 Alhart – grass swale	145	12.8	33.0	35.2	18.9	—	—	—	610	—	—	—	60
T34 60 Thistledown – newly sealed swale	577	0.2	0.2	0.2	99.4	—	—	—	33	—	—	95	120
T35 47 Alhart – grass swale	336	21.0	40.2	19.7	19.2	970	340	700	290	49	33	65	117
T36 Alhart & Afford 58 – grass swale	313	10.2	37.3	20.6	31.9	1300	570	740	230	49	35	71	132
T37 16 Alhart – grass swale (clean)	715	4.1	13.9	16.5	65.6	1600	620	640	160	63	42	88	125
T38 44 Buckwath – concrete gutter	390	10.9	35.9	37.5	15.7	790	570	460	730	92	65	92	159
T39 Calstock – concrete gutter	335	1.9	35.2	33.5	28.4	920	410	330	310	92	73	88	112
Humber River Sediment													
HR70 @ mouth	—	7.2	40.2	6.0	46.2	920	440	870	780	27	24	165	150
HR71 @ Thistledown Outfall	—	12.1	77.9	9.5	0.2	960	390	440	—	22	23	47	—
HR72 (Thistledown pool @ outfall)	—	7.2	65.4	18.9	7.6	1000	310	520	700	36	25	53	67
HR73 (Emery Outfall pool)	—	44.7	22.0	14.8	17.7	920	480	650	570	41	32	49	61
HR74 @ Kleinburg	—	5.3	21.5	16.5	60.7	920	390	440	780	31	21	49	59
HR75 @ Humber Glen Bridge	—	25.9	17.5	37.0	18.5	830	350	440	440	22	22	45	99

Table F.13 Dry Particulate Quality (Cont.)

10/12

	Total Solids	Percentage in Size Range				TKN, mg/g				COD, mg/g			
		<125μ	125→500	500→2000	>2000	<125μ	125→500	500→2000	>2000	<125μ	125→500	500→2000	>2000
Drainage System													
Sealed drainage ditch													
T26 60 Thistledown - newly sealed	1523	1.1	4.2	27.2	67.6	1900	781	203	35	115	59	24	5
Grass swale													
T23 23 Calstock	7150	16.8	69.1	9.6	4.5	252	105	328	233	15	6	23	32
T44 42 Alhart - good	2150	19.2	43.7	29.4	7.7	3490	2430	4910	10,300	115	83	206	473
Catchbasin	Kg												
E31 Lumberking @ 29 Fenmar - concrete curb	950	16.6	28.8	26.4	28.4	628	345	257	124	54	23	35	28
E32 Coca Cola - concrete curb	560	12.4	36.9	32.0	18.5	1880	590	444	767	113	59	65	104
T33 42 Alhart - grass swale	195	12.8	33.0	35.2	18.9	—	—	—	1420	—	—	—	36
T34 60 Thistledown - newly sealed swale	577	0.2	0.2	0.2	99.4	—	—	720	71	—	—	93	20
T35 47 Alhart - grass swale	336	21.0	40.2	19.7	19.2	2310	863	949	311	90	42	61	67
T36 Alhart & Ashford 58 - grass swale	313	10.2	37.3	20.6	31.9	2350	983	1390	423	92	45	83	71
T37 16 Alhart - grass swale (clean)	715	4.1	13.9	16.5	65.6	2922	1220	837	197	123	56	66	54
T38 44 Buckthorn - concrete gutter	390	10.9	35.9	37.5	15.7	2600	1311	1120	1250	166	79	92	237
T39 Calstock - concrete gutter	335	1.9	35.2	33.5	28.4	1060	785	449	244	101	91	76	61
Humber River Sediment													
HR70 @ mouth	—	7.2	40.2	6.0	46.2	674	212	1280	498	34	22	221	106
HR71 @ Thistledown Outfall	—	12.1	77.9	9.5	0.2	343	103	221	—	13	5	14	—
HR72 (Thistledown pool @ outfall)	—	7.2	65.4	18.9	7.6	1040	132	315	410	38	7	18	23
HR73 (Emery Outfall pool)	—	44.7	22.0	14.8	17.7	553	319	294	234	36	23	21	20
HR74 @ Kleinburg	—	5.3	21.5	16.5	60.7	771	166	163	104	25	6	6	4
HR75 @ Humber Glen Bridge	—	25.9	17.5	37.0	18.5	681	478	228	208	23	20	7	5

Table F.13 Dry Particulate Quality (Cont.)

		Total Solids – Percentage in Size Range				Cr, ug/g				Hg, ng/g			
		<125	125→500	500→2000	>2000	<125	125→500	500→2000	>2000	<125	125→500	500→2000	>2000
Drainage System													
Sealed drainage ditch													
T26 60 Thatledown - newly sealed	1523	1.1	4.2	27.2	67.6	51	25	15	10	690	440	480	570
Grass swale													
T23 23 Calstock	7150	16.8	69.1	9.6	4.5	42	11	23	21	750	220	600	740
44 42 Alhart - good	2150	19.2	43.7	29.4	7.7	29	17	23	19	640	450	620	480
Catchbasin	Eg												
E31 Lumberking @29 Fenmar - concrete curb	950	16.6	28.8	26.4	28.4	32	22	60	14	610	440	620	570
E32 Coca Cola - concrete curb	560	12.4	36.9	32.0	18.5	89	72	530	33	760	710	1500	780
T33 42 Alhart - grass swale	195	12.8	33.0	35.2	18.9	—	—	—	33	–	—	—	460
T34 60 Thatledown - newly sealed swale	577	0.2	0.2	0.2	99.4	—	—	37	9	—	—	550	500
T35 47 Alhart - grass swale	336	21.0	40.2	19.7	19.2	29	15	20	15	490	270	430	530
T36 Alhart & Abbotsford 58 - grass swale	313	10.2	37.3	20.6	31.9	32	25	20	13	510	300	460	420
T37 16 Alhart - grass swale (clean)	715	4.1	13.9	16.5	65.6	36	18	18	13	750	460	670	490
T38 44 Buckleworth - concrete gutter	390	10.9	35.9	37.5	15.7	43	24	25	14	520	300	380	370
T39 Calstock - concrete gutter	335	1.9	35.2	33.5	28.4	39	23	32	23	560	320	550	590
Humber River Sediment													
HR70 @ mouth	—	7.2	40.2	6.0	46.2	52	32	98	30	480	250	540	680
HR71 @ Thistletown Outfall	—	12.1	77.9	9.5	0.2	41	14	20	—	570	300	570	—
HR72 (Thistletown pool @ outfall)	—	7.2	65.4	18.9	7.6	36	11	19	21	790	210	570	740
HR73 (Emery Outfall pool)	—	44.7	22.0	14.8	17.7	160	73	100	62	620	410	710	590
HR74 @ Kleinburg	—	5.3	21.5	16.5	60.7	38	23	22	18	820	590	620	1200
HR75 @ Humber Glen Bridge	—	25.9	17.5	37.0	18.5	22	11	15	19	440	280	520	550

Table F.13 Dry Particulate Quality (Cont.)

		Total Solids Percentage in Size Range <125	125→500	500→2000	>2000	Cu, ug/g <125	125→500	500→2000	>2000	Zn, ug/g <125	125→500	500→2000	>2000	Pb, ug/g <125	125→500	500→2000	>2000
Drainage System																	
Sealed drainage ditch																	
T26 60 Thistledown - newly sealed	1523	1.1	4.2	27.2	67.6	120	55	23	8	1200	970	780	220	1500	870	210	60
Grass swale																	
T23 23 Calstock	7150	16.8	69.1	9.6	4.5	13	7	32	13	71	45	240	52	110	80	190	70
44 42 Alhart - good	2150	19.2	43.7	29.4	7.7	28	18	29	26	230	160	230	220	120	86	140	100
Catchbasin	Eg																
E31 Lumberking o29 Fenmar - concrete curb	950	16.6	28.8	26.4	28.4	140	160	240	22	340	200	220	83	320	280	160	70
E32 Coca Cola - concrete curb	560	12.4	36.9	32.0	18.5	180	120	360	33	680	330	490	130	780	500	340	150
T33 42 Alhart - grass swale	195	12.8	33.0	35.2	18.9	—	—	—	18	—	—	—	77	—	—	—	84
T34 60 Thistledown - newly sealed swale	577	0.2	0.2	0.2	99.4	—	—	85	6.5	—	—	910	71	—	—	380	64
T35 47 Alhart - grass swale	336	21.0	40.2	19.7	19.2	48	21	25	13	350	170	170	75	[illegible]	120	120	100
T36 Alhart o Afderd 58 - grass swale	313	10.2	37.3	20.6	31.9	57	26	65	13	230	110	150	51	260	130	180	86
T37 16 Alhart - grass swale (clean)	715	4.1	13.9	16.5	65.6	49	21	26	7	450	210	650	120	340	180	210	72
T38 44 Buckwheat - concrete gutter	390	10.9	35.9	37.5	15.7	190	53	31	28	730	280	180	140	200	550	260	16
T39 Calstock - concrete gutter	335	1.9	35.2	33.5	28.4	77	37	27	16	410	270	160	61	1000	570	270	140
Humber River Sediment																	
HR70 @ mouth	—	7.2	40.2	6.0	46.2	83	32	610	66	240	140	620	130	260	240	2100	130
HR71 @ Thistledown Outfall	—	12.1	77.9	9.5	0.2	17	7	15	—	57	23	41	—	44	27	46	—
HR72 (Thistledown pool @ outfall)	—	7.2	65.4	18.9	7.6	53	8	20	32	120	26	110	58	86	44	70	56
HR73 (Emery Outfall pool)	—	44.7	22.0	14.8	17.7	71	92	29	21	230	130	120	81	110	98	98	62
HR74 @ Kleinburg	—	5.3	21.5	16.5	60.7	15	5.5	9	19	49	24	30	36	33	26	42	46
HR75 @ Humber Golan Bridge	—	25.9	17.5	37.0	18.5	8.5	7	10	6.5	30	19	24	13	22	18	38	63

Table F.1A

Potency Factors (Cont)

	Total Carbon (mg/g)				Total Kjeldahl Nitrogen (mg/g)				Chemical Oxygen Demand (mg/g)			
	<125	125→500	500→2000	>2000	<125	125→500	500→2000	>2000	<125	125→500	500→2000	>2000
Pervious Areas												
Bareground	60	50	80	90	3000	2000	1700	590	90	70	90	25
Garden soil	30	30	90	100	1900	1700	4100	3000	70	60	170	150
Footpath	25	25	55	70	760	420	570	160	20	20	20	7
Dirt near preserved wood	90	70	120	140	410	1420	230	1400	50	130	25	180
Unpaved driveways	100	90	130	120	850	870	530	40	50	60	65	8
Road shoulder	30	30	70	110	720	450	670	170	30	20	50	35
Unpaved parking/storage	90	80	100	110	700	440	290	300	110	120	80	60
Impervious Areas												
Rooftops	190	180	120	100	11,400	8900	2100	200	410	340	220	50
Roof drain troughs	80	80	10	370	2800	3000	250	8500	160	210	35	740
Footpath	80	85	170	220	1900	2000	3200	4400	120	150	290	380
Paved parking/storage	90	60	90	110	1000	530	330	260	120	60	50	50
Driveway	120	50	80	160	2800	570	810	1600	250	80	100	160
Sidewalk	85	120	220	120	3600	7100	12,000	970	150	210	440	90
Industrial road	60	45	75	120	560	230	250	220	65	30	30	30
Residential road	85	80	110	135	1000	960	680	820	100	80	65	120
Drainage System												
Sealed drainage	—	60	110	120	1900	780	200	35	120	60	20	5
Grass swale	35	35	75	150	1900	1300	2600	5300	65	45	115	250
Catchbasins	70	50	85	120	2000	870	770	530	100	55	70	75
Humber River Sediments (and outfall pond sediment)	30	25	70	90	670	240	420	290	30	15	50	25

Table F-1A
Potency Factors (Cont.)

	# of samples	total solids loading range (g/m², unless otherwise noted)	Chromium (ug/g) <125u	125→500	500→2000	>2000	Manganese (ug/g) <125	125→500	500→2000	>2000
Pervious Areas										
Bareground	2	38→58,000	40	20	30	20	530	350	450	620
Garden soil	5	190→5560	35	20	30	30	600	430	940	1400
Footpath	1	1900	25	20	20	20	480	340	640	920
Dirt near preserved wood	2	40→1800	40	25	10	20	580	450	680	520
Unpaved driveways	2	920→38,000	20	15	10	10	710	500	550	630
Road shoulder	1	10,000	25	20	35	20	470	310	560	460
Unpaved parking/storage	~~8~~ 7	640→5900	62	130	85	70	1100	820	1200	1200
Impervious Areas										
Rooftops	1	7800	65	45	30	15	870	800	820	370
Roof drain troughs	2	80→160g/m	85	130	55	25	600	710	620	250
Footpath	1	28	65	65	65	40	690	450	640	1200
Paved parking/storage	10	6→18,000	90	75	140	80	660	440	660	670
Driveway	1	3	70	20	35	40	570	250	570	490
Sidewalk	1	13	30	20	15	10	45	30	20	20
Industrial road	5	40→490g/curb-m	70	50	110	120	710	560	1060	1200
Residential road	8	37→2190g/curb-m	50	30	30	20	660	430	560	560
Drainage System										
Sealed drainage	1	1500	50	25	15	10	690	440	480	510
Grass swale	2	2100→7200	35	15	25	20	700	340	610	610
Catchbasins	9	200→1000g	45	30	110	20	600	400	650	520
Humber River Sediments (and outfall pond sediment)	6	not applicable	60	30	45	30	620	340	580	750

Table F.14

Potency Factors (Concluded)

	Copper (µg/g)				Zinc (µg/g)				Lead (µg/g)			
	<125	125→500	500→2000	>2000	<125	125→500	500→2000	>2000	<125	125→500	500→2000	>2000
Pervious Areas												
Bareground	70	30	20	15	160	90	80	60	110	65	65	50
Garden soil	30	15	30	25	120	80	180	140	50	30	50	50
Footpath	15	10	20	30	50	35	35	40	40	120	1700	50
Dirt near preserved wood	110	90	20	20	370	390	90	280	160	260	70	190
Unpaved driveways	45	30	10	10	170	120	55	30	160	110	70	65
Road shoulder	35	40	35	20	120	110	130	50	230	230	240	90
Unpaved parking/storage	1100	4000	4500	2300	1100	4700	4100	540	2000	2100	1600	550
Impervious Areas												
Rooftops	130	80	30	5	1100	760	290	50	1200	780	210	60
Roof drain troughs	140	130	75	20	2300	1900	230	300	870	530	50	100
Footpath	280	70	110	40	1300	1000	520	330	460	400	230	110
Paved parking/storage	910	1400	2200	1300	830	570	580	610	650	440	410	80
Driveway	170	40	30	15	790	150	150	40	900	240	400	50
Sidewalk	670	390	520	610	430	290	110	80	1200	640	190	120
Industrial road	360	460	850	150	500	460	580	130	900	810	630	85
Residential road	160	65	40	10	460	330	210	80	1000	670	270	80
Drainage System												
Sealed drainage	120	55	25	10	1200	970	780	220	1500	870	210	60
Grass swale	15	15	30	20	150	100	240	140	120	85	170	85
Catchbasins	110	60	110	20	460	210	370	90	590	330	240	120
Humber River Sediments (and outfall pond sediment)	40	25	120	30	120	60	160	65	90	75	60	70

Figure F-1

TOTAL SOLIDS VERSUS RAIN - ROUGH RESID ST

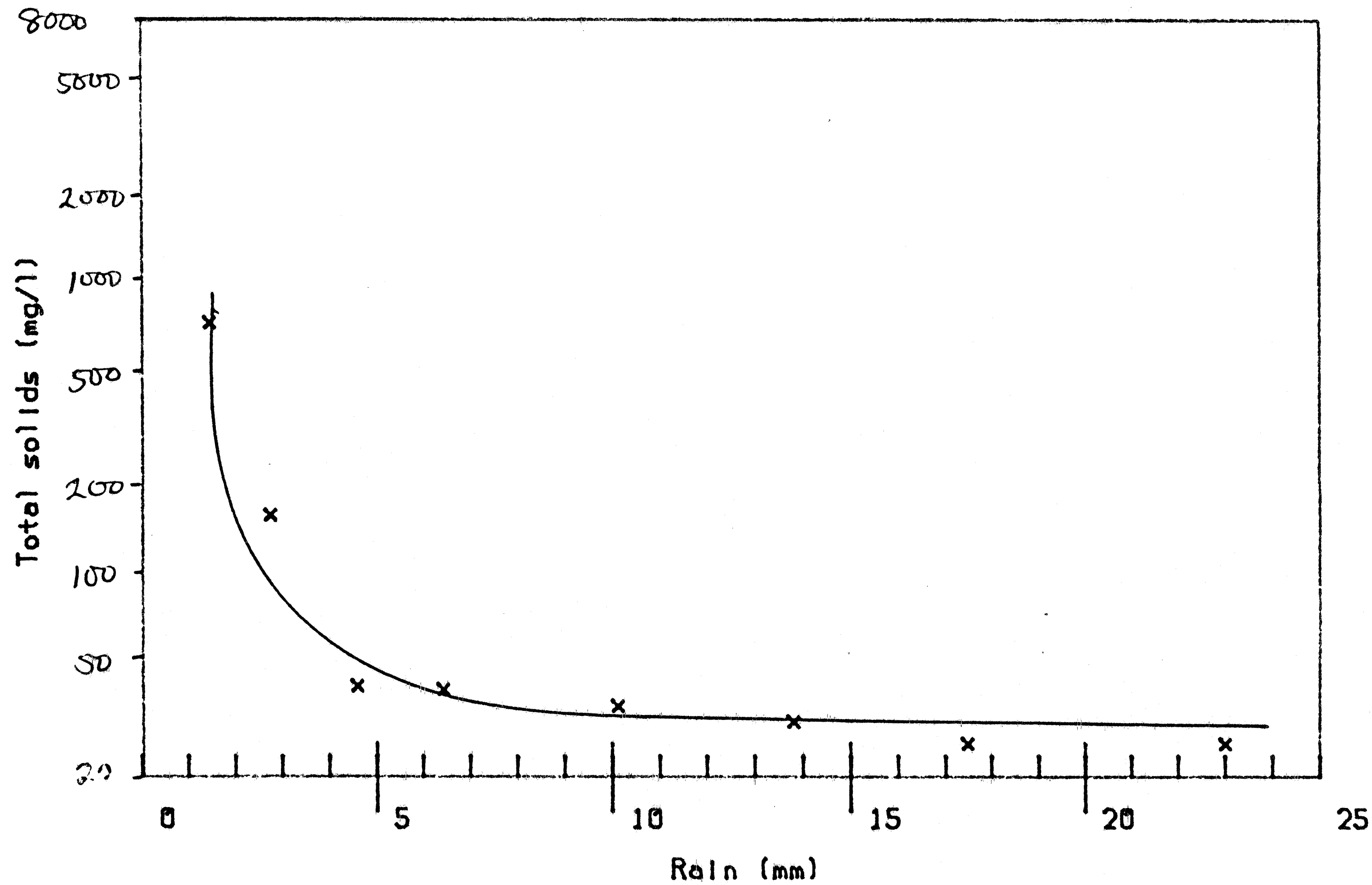
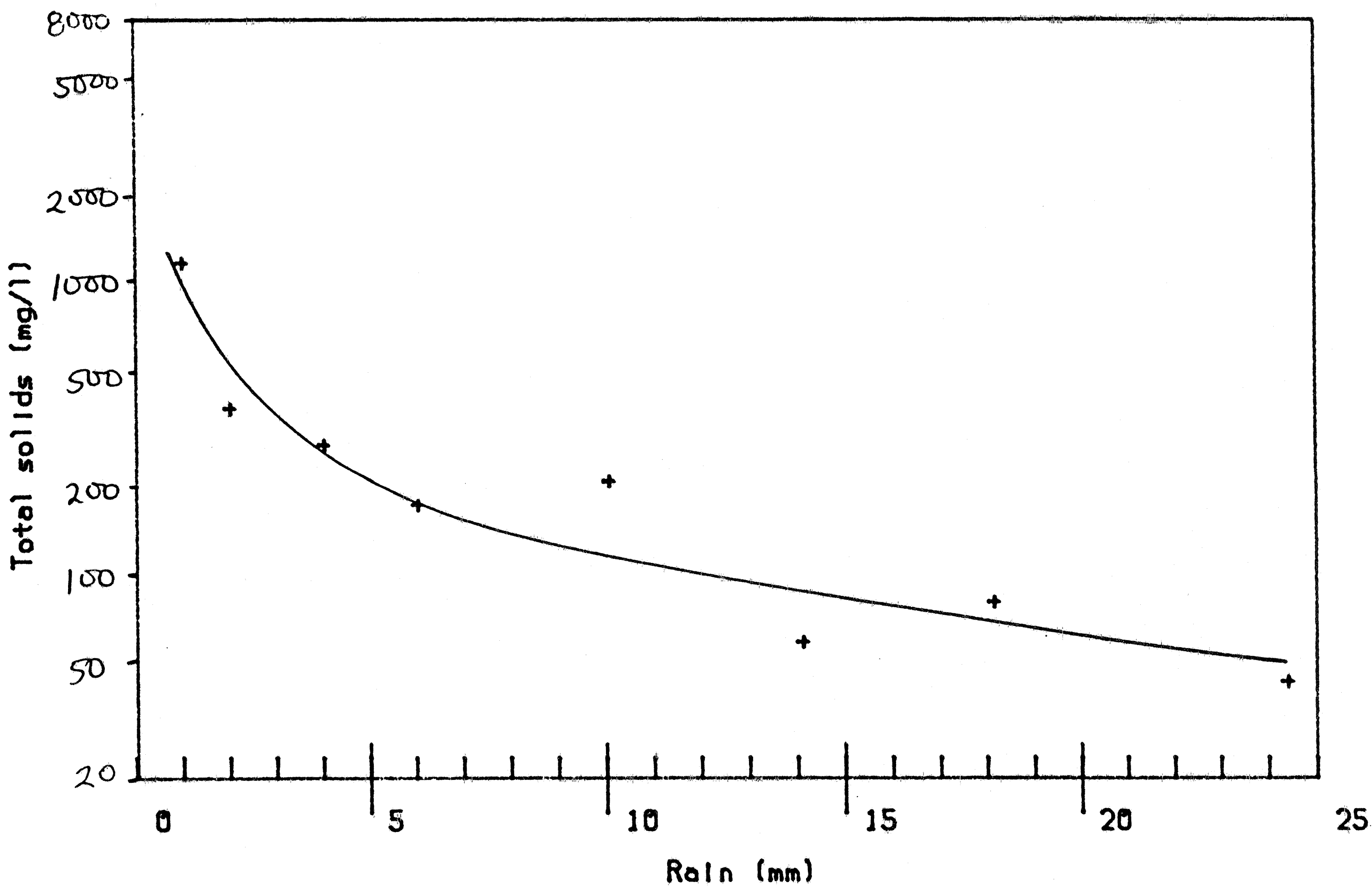


Figure F.2

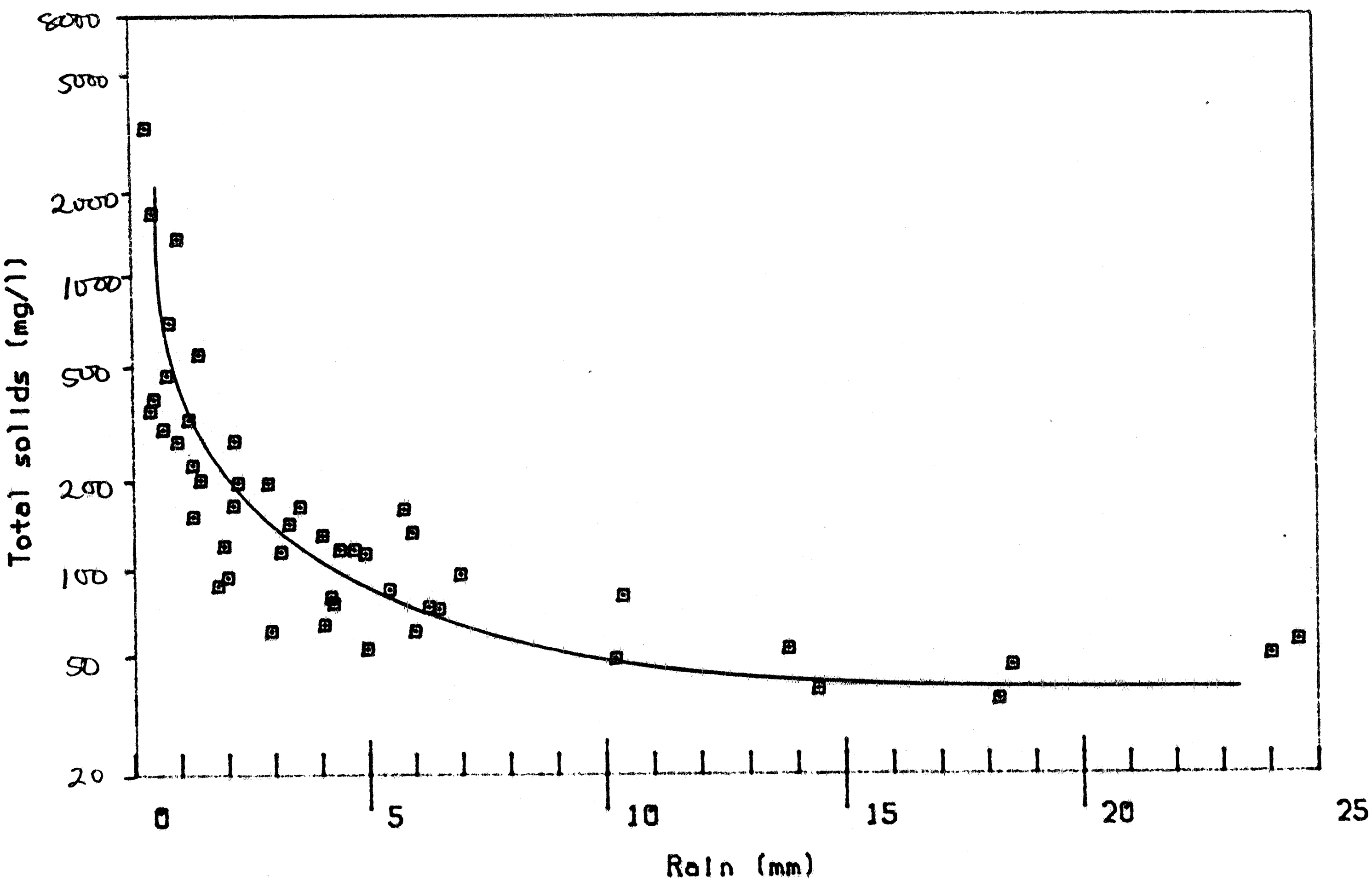
TOTAL SOLIDS VERSUS RAIN - SMOOTH INDUS ST



9/1/84
HD&G

Figure F.3

TOTAL SOLIDS VERSUS RAIN - OTHER STREETS



9/1/84
streets

Figure F.4

TOTAL SOLIDS VERSUS RAIN - OTHER PAVED

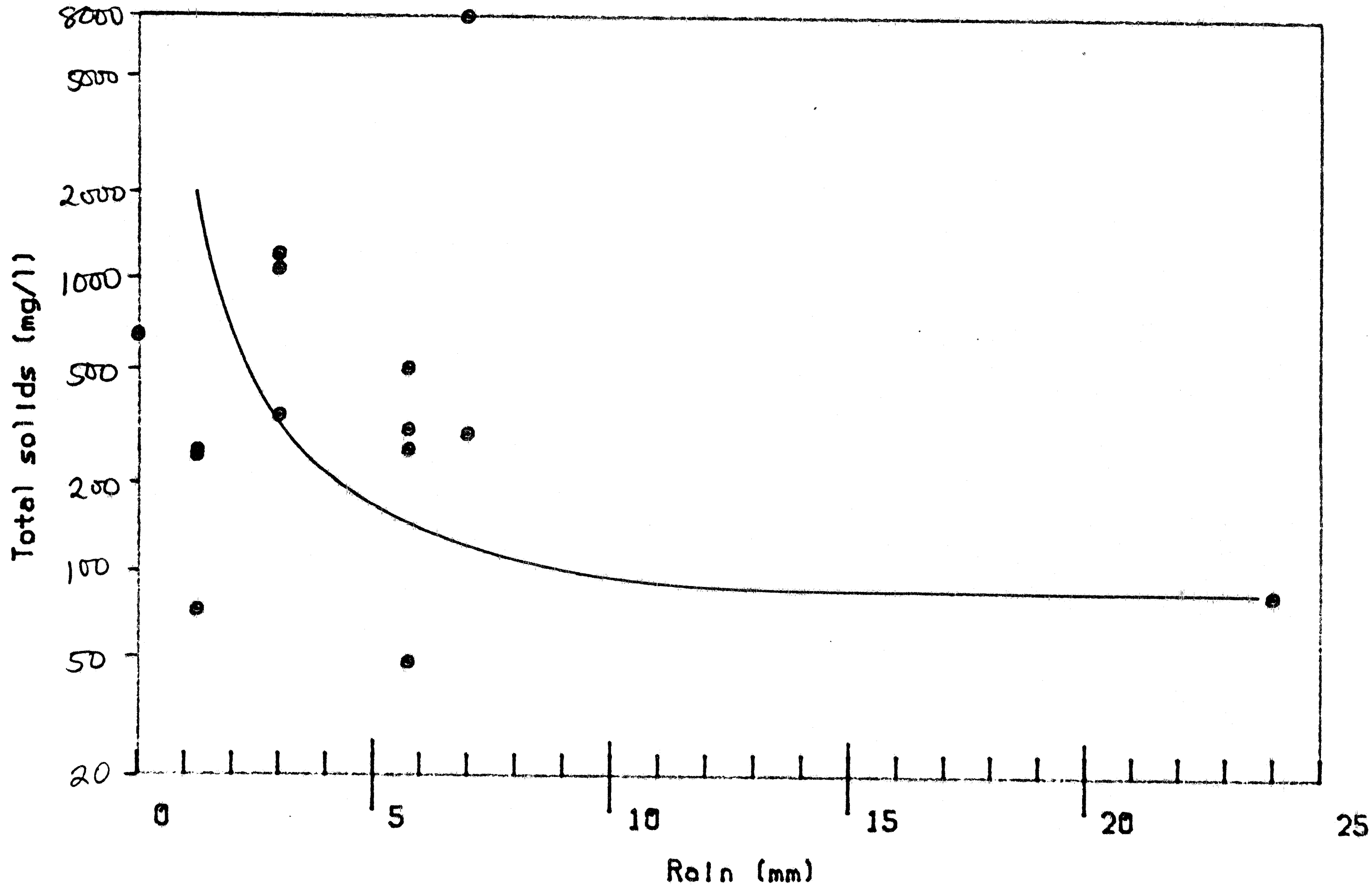


Figure F.5

TOTAL SOLIDS VERSUS RAIN - ROOF RUNOFF

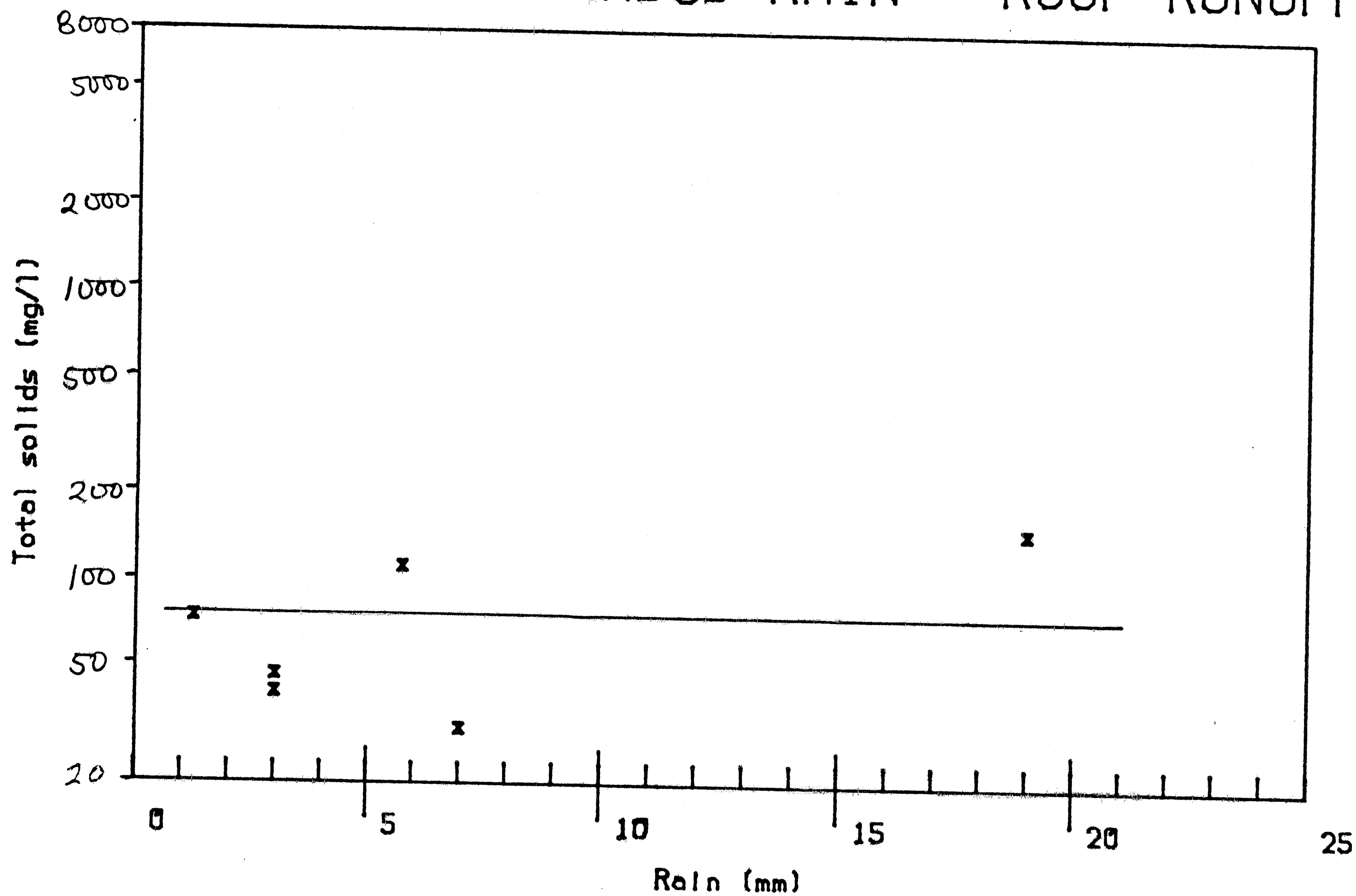
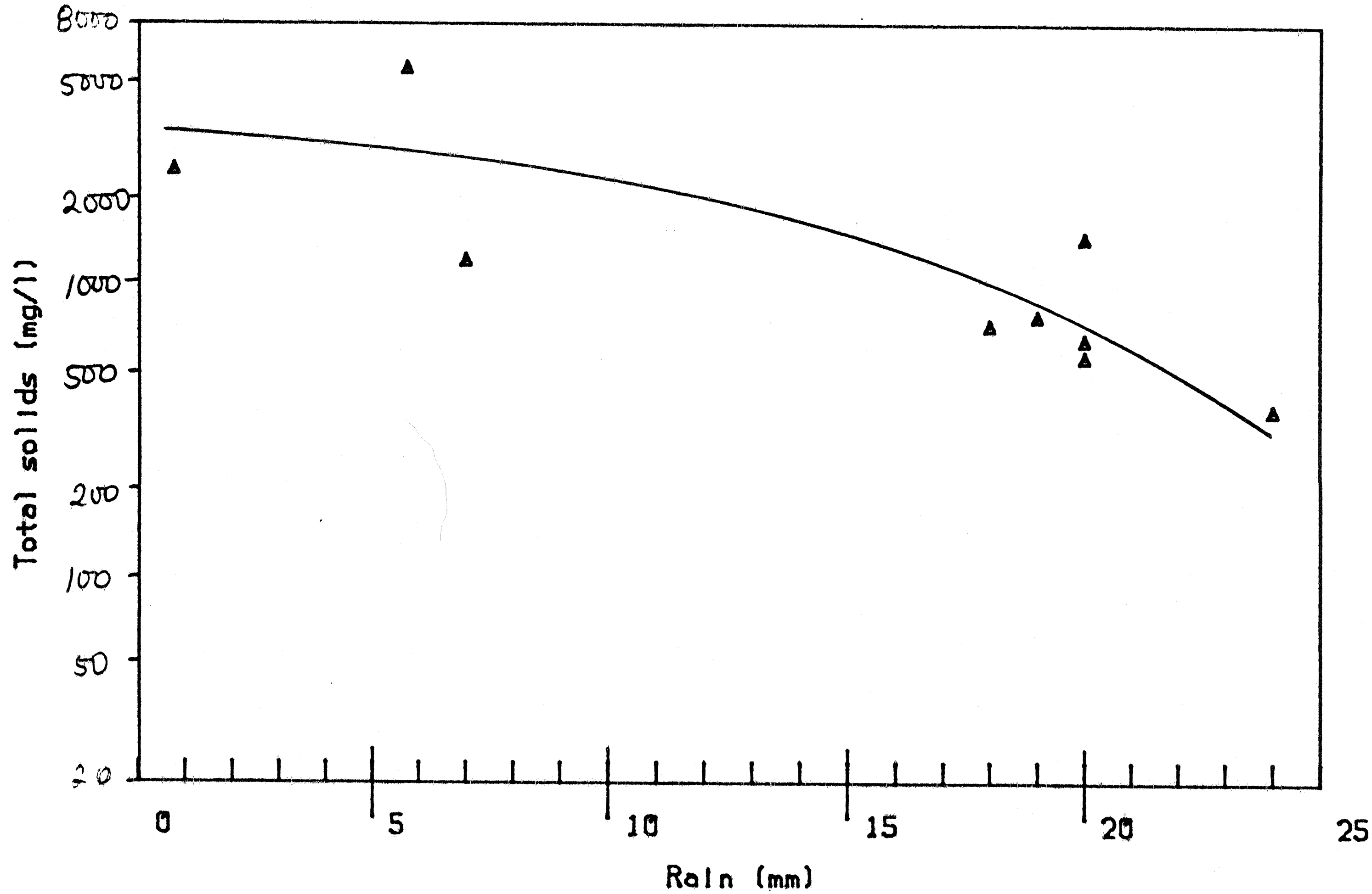


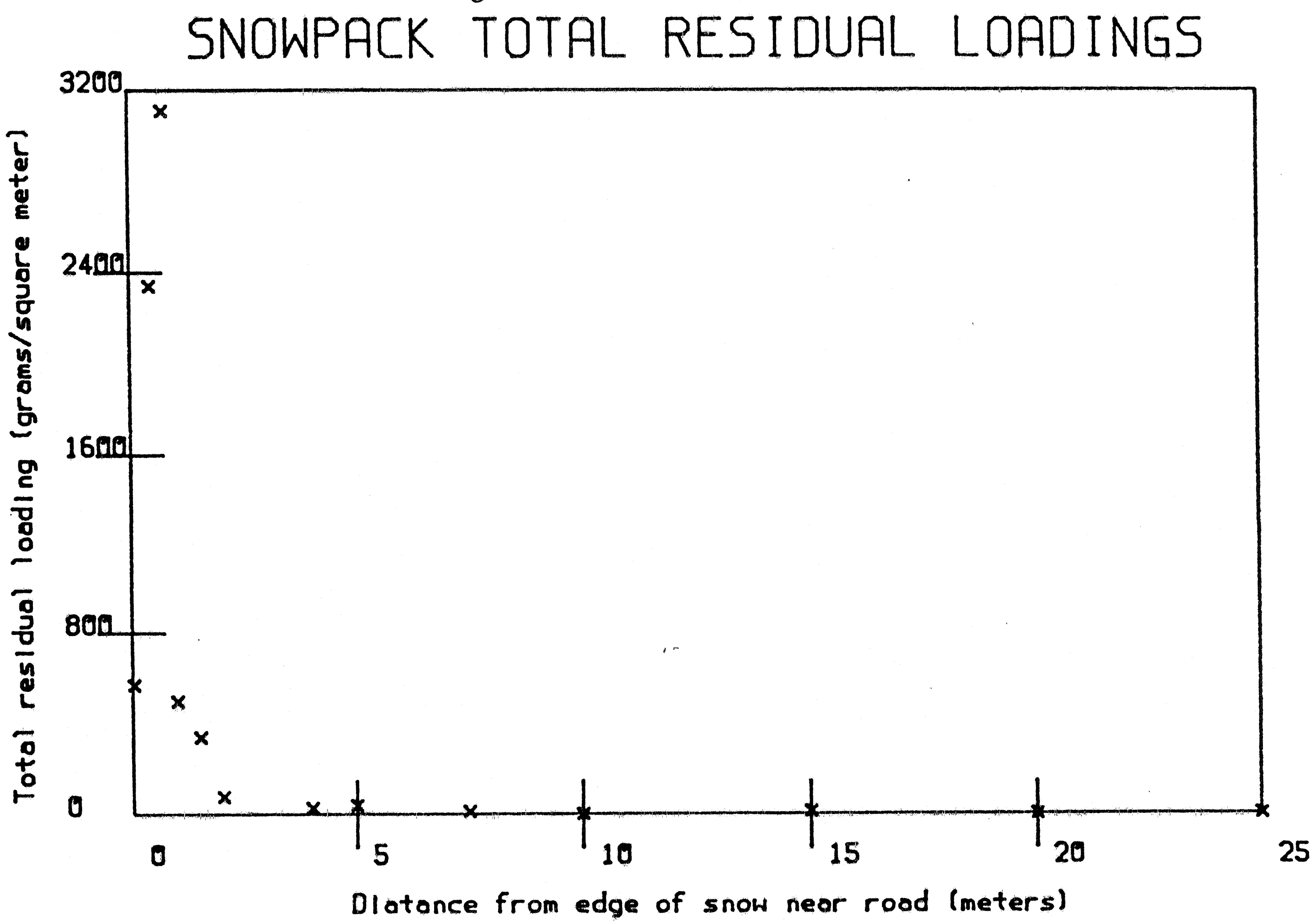
Figure F.6

TOTAL SOLIDS VERSUS RAIN - PERVIOUS AREAS



9/1/84
Pervlg

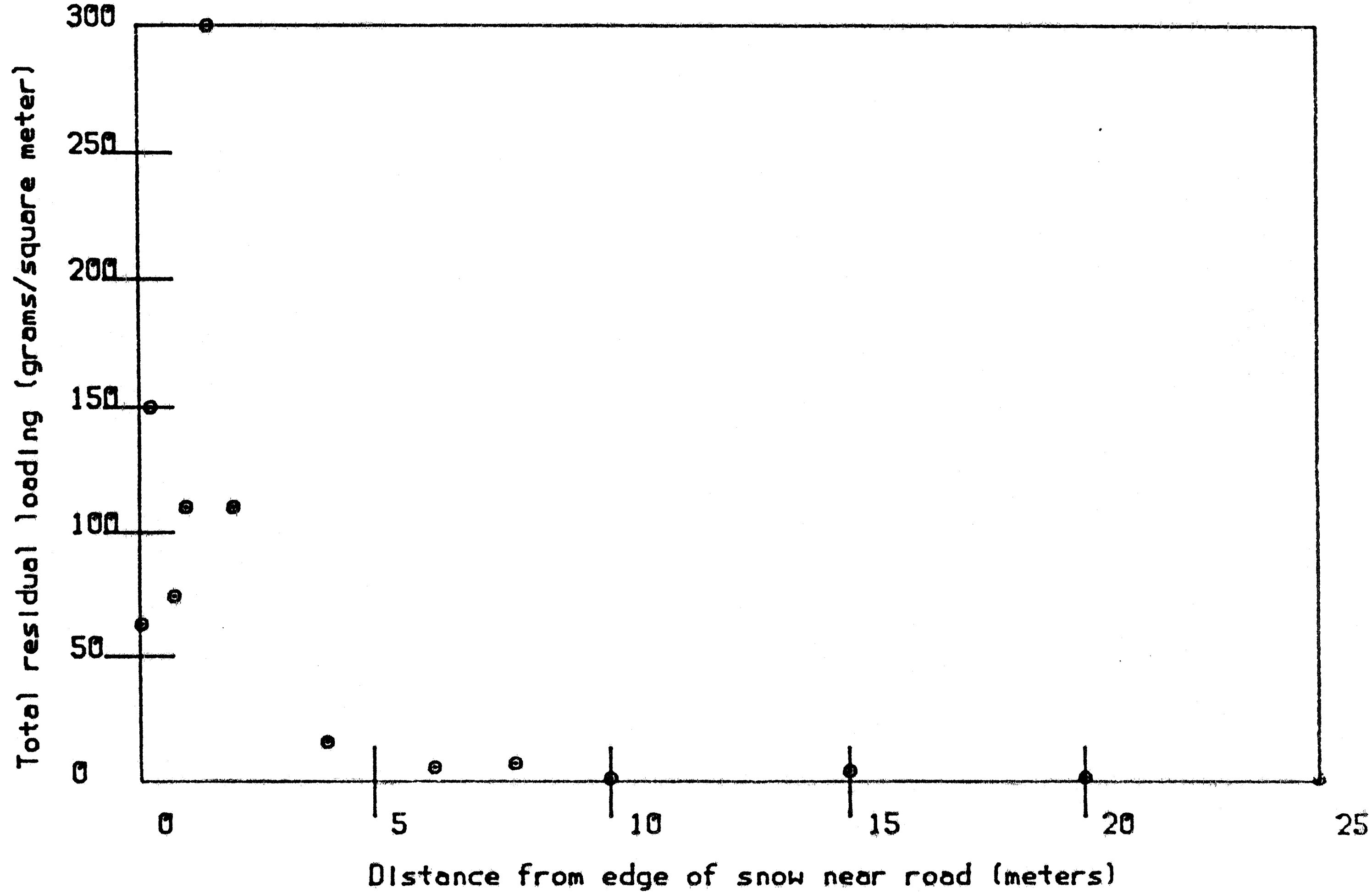
Figure F.7 – Signet Rd.



B5IGLD
Signet Rd.

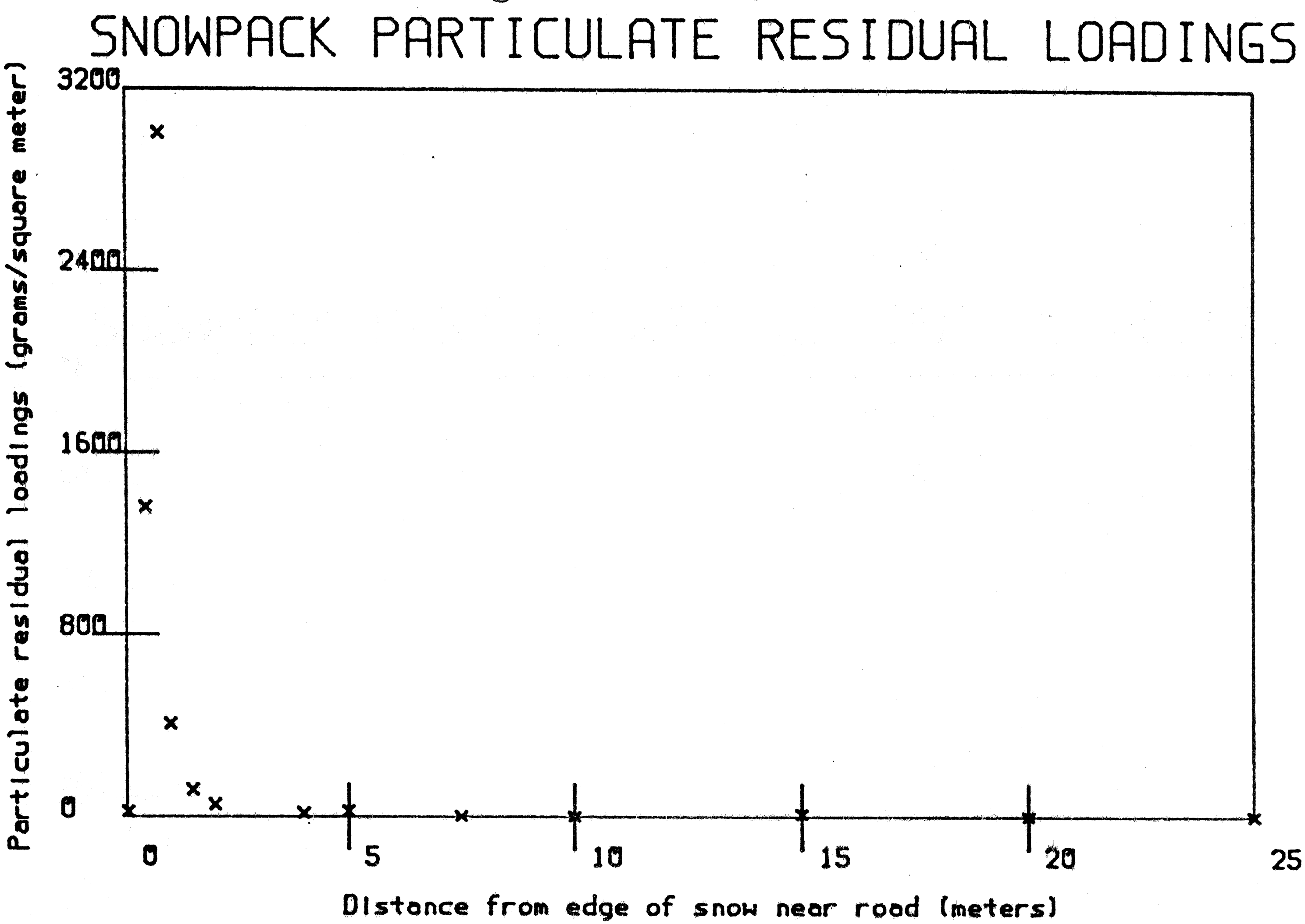
Figure F.8 - Calstock Blvd.

SNOWPACK TOTAL RESIDUAL LOADINGS



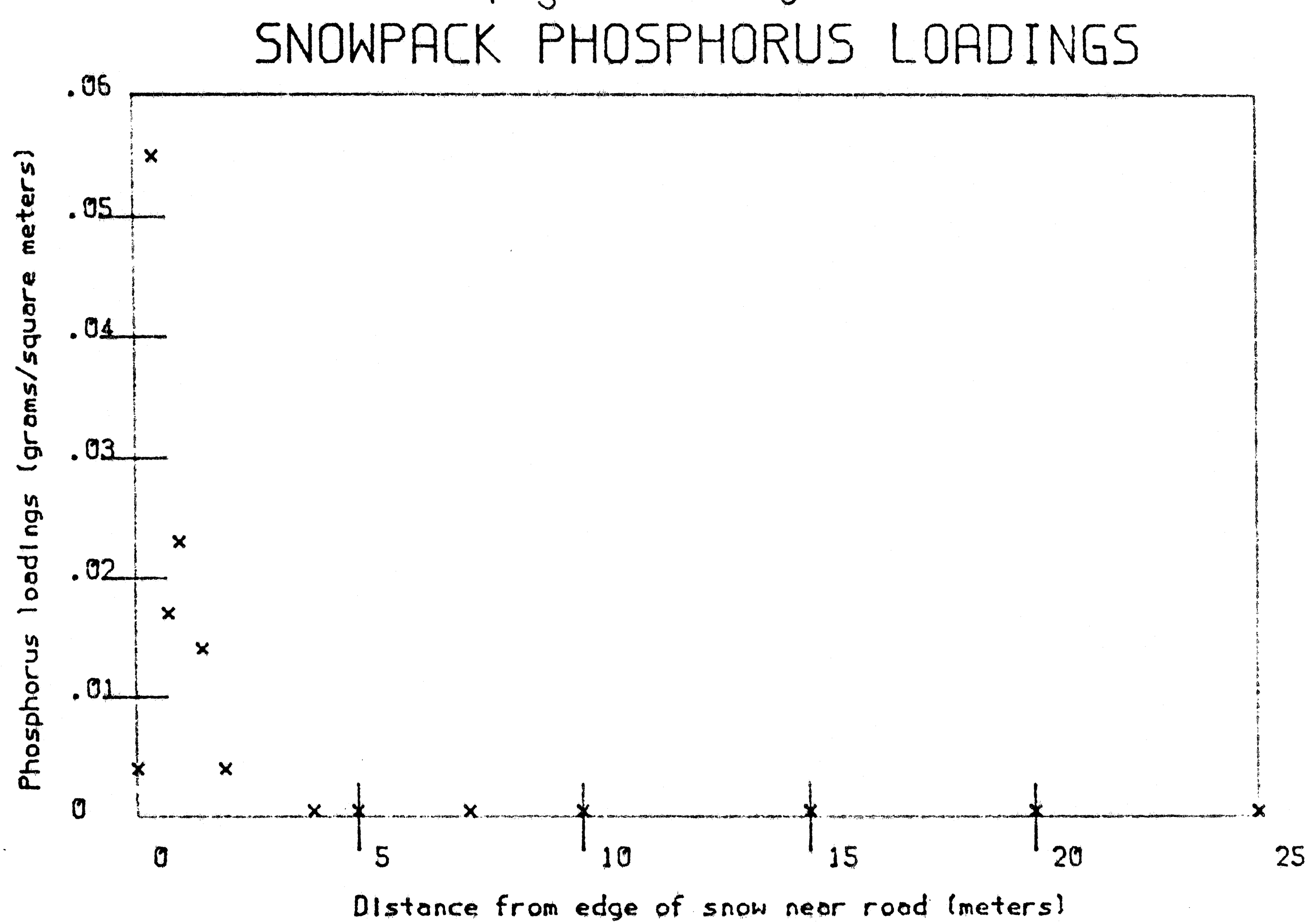
TBCALLD
Calstock Blvd.

Figure F.9 - Signet Rd



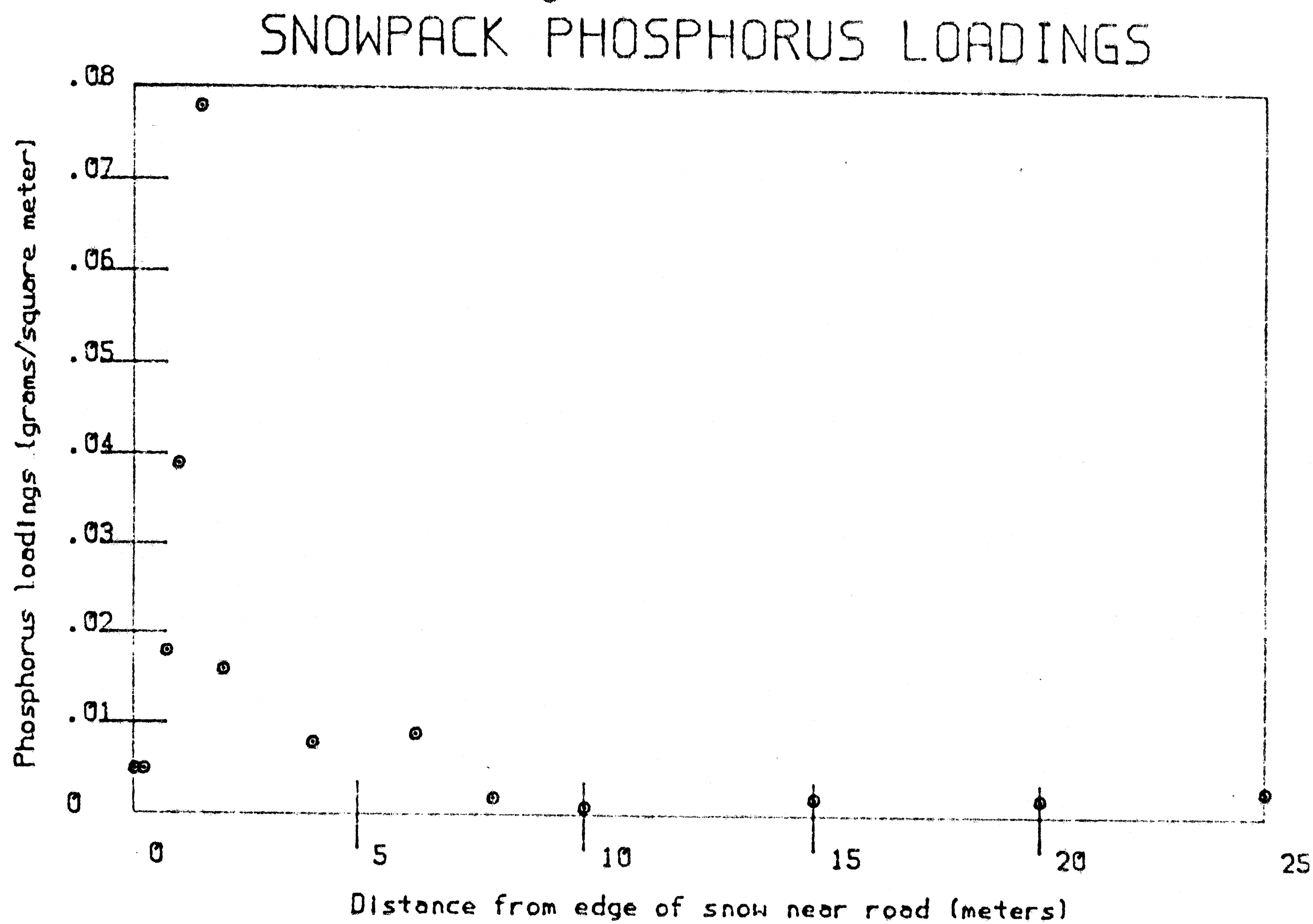
SSSIGLD
Signet Rd

Figure F.11 - Signet Rd.



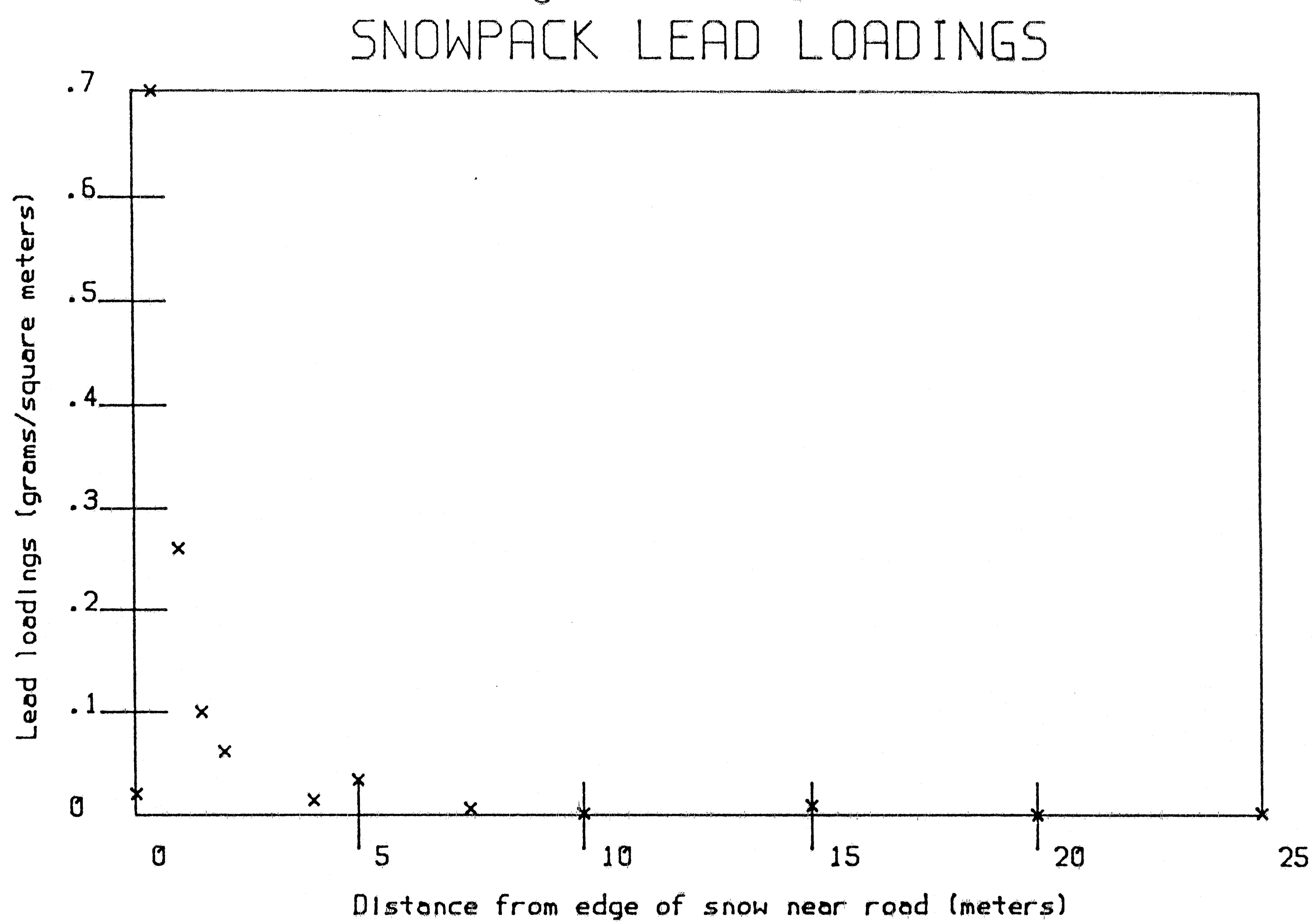
PHSIGLD
Signet Rd.

Figure F.12 - Colstock Blvd.



PHCHLLW
Colstock Blvd

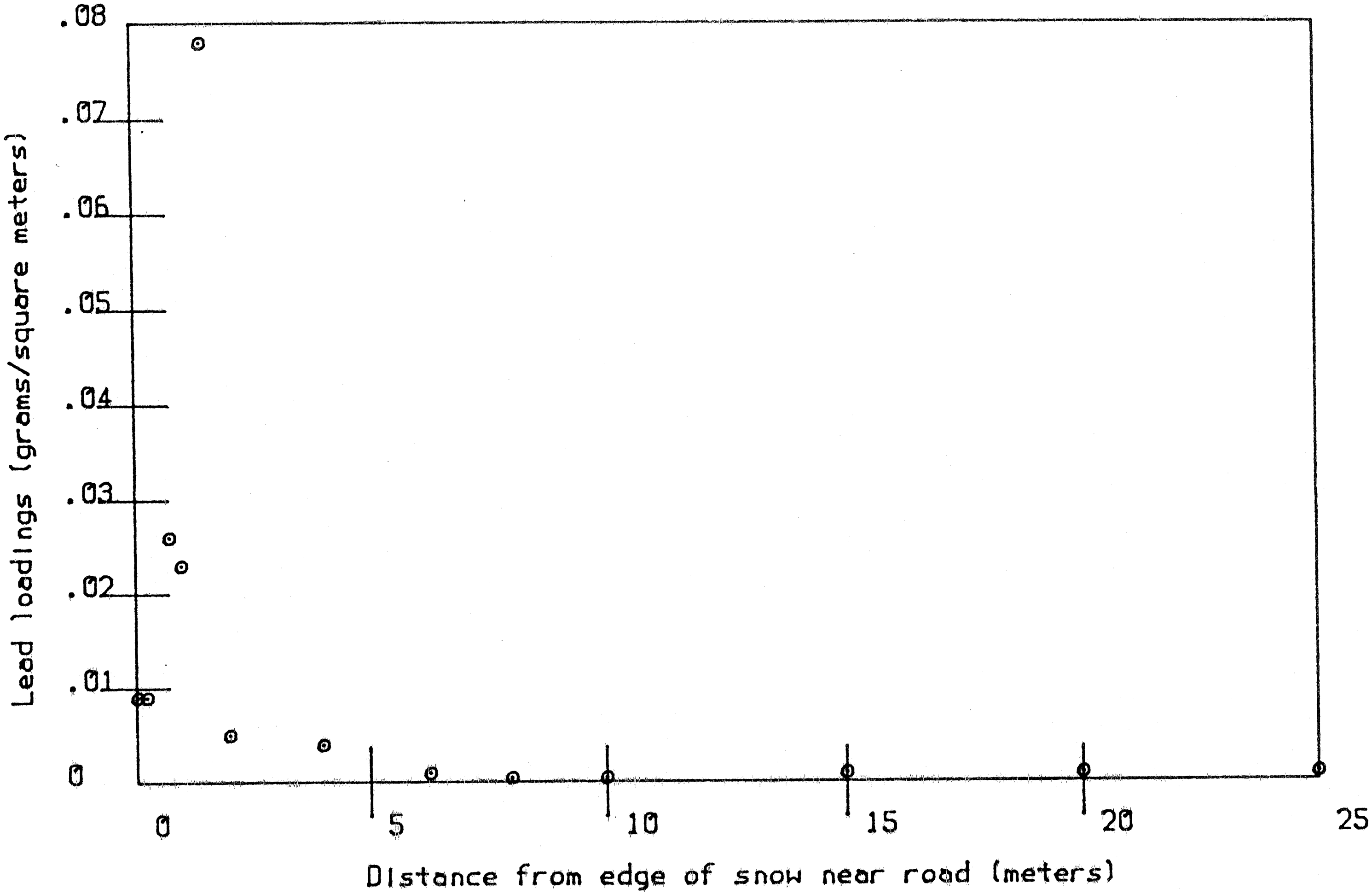
Figure F.13 - Signet Rd



PBSIGLD
Signed Rd

Figure F.14 - Calstock Blvd.

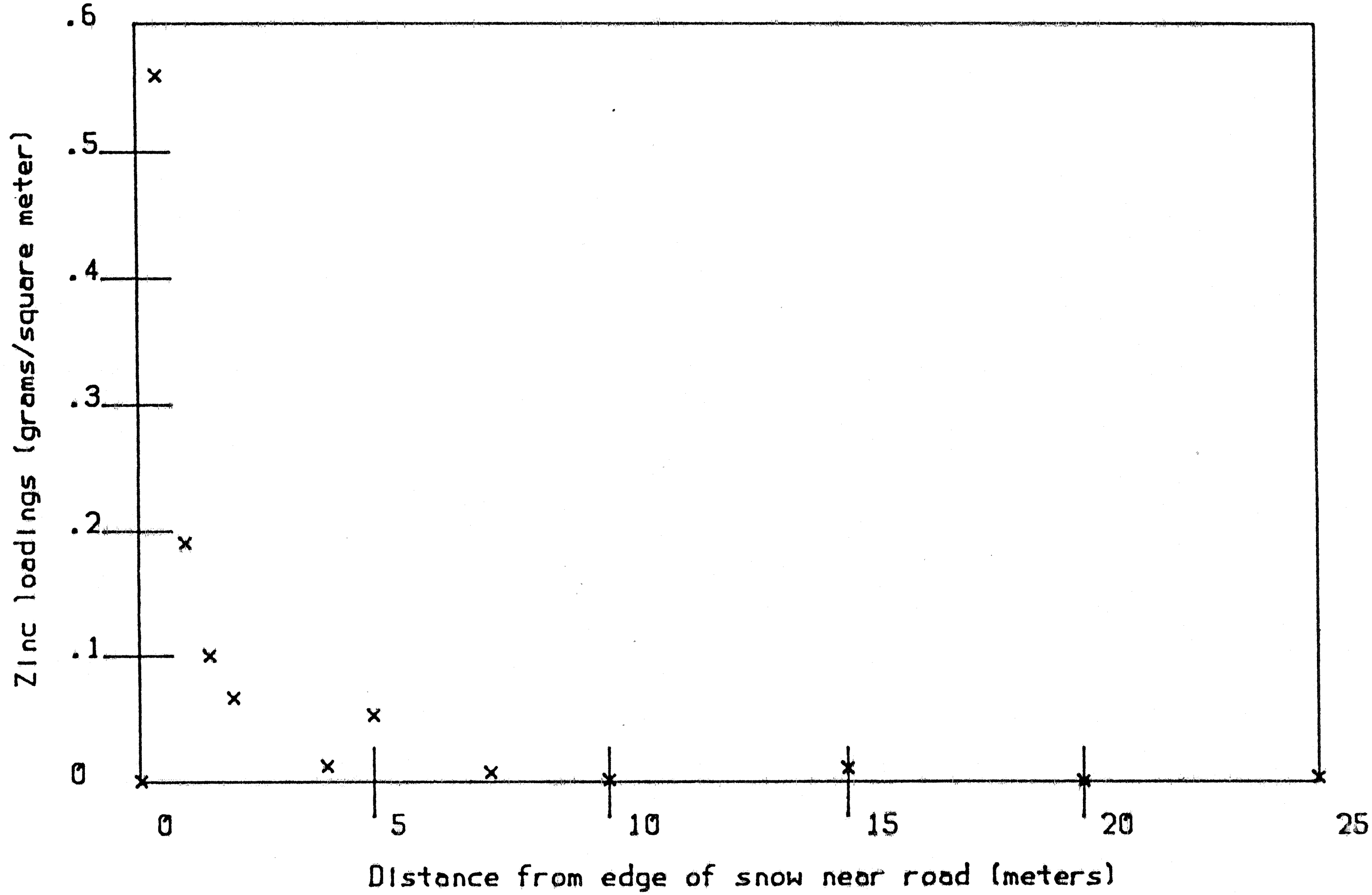
SNOWPACK LEAD LOADINGS



PBCALLD
Calstock Blvd

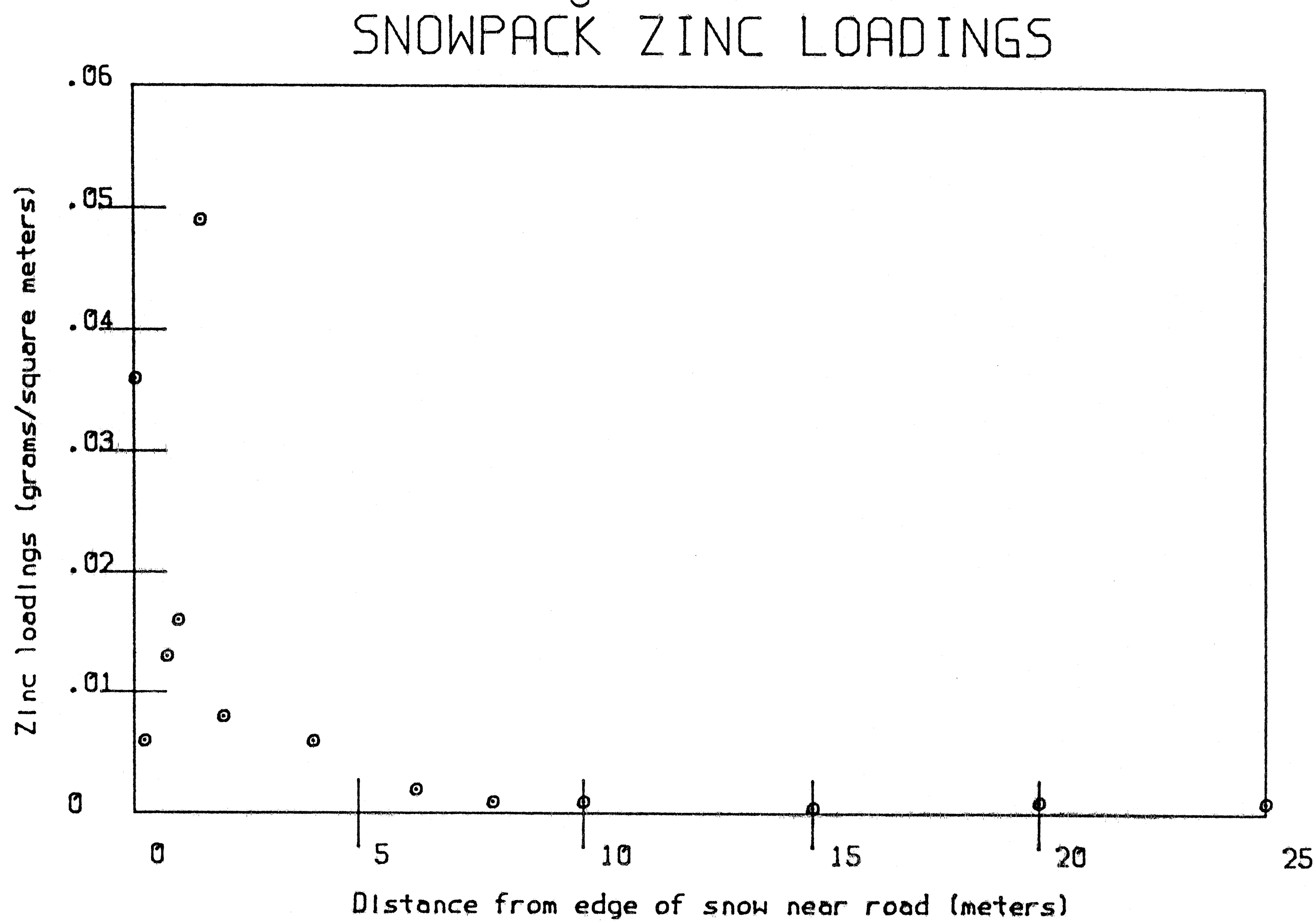
Figure F.15 - Signet Rd.

SNOWPACK ZINC LOADINGS



ZNSIG-LD
Signet Rd

Figure F.16 - Calstock Blvd.



ZNCALLD
Calstock Blvd

Figure F.17

THISTLEDOWNS FILTERABLE RESIDUE SOURCES

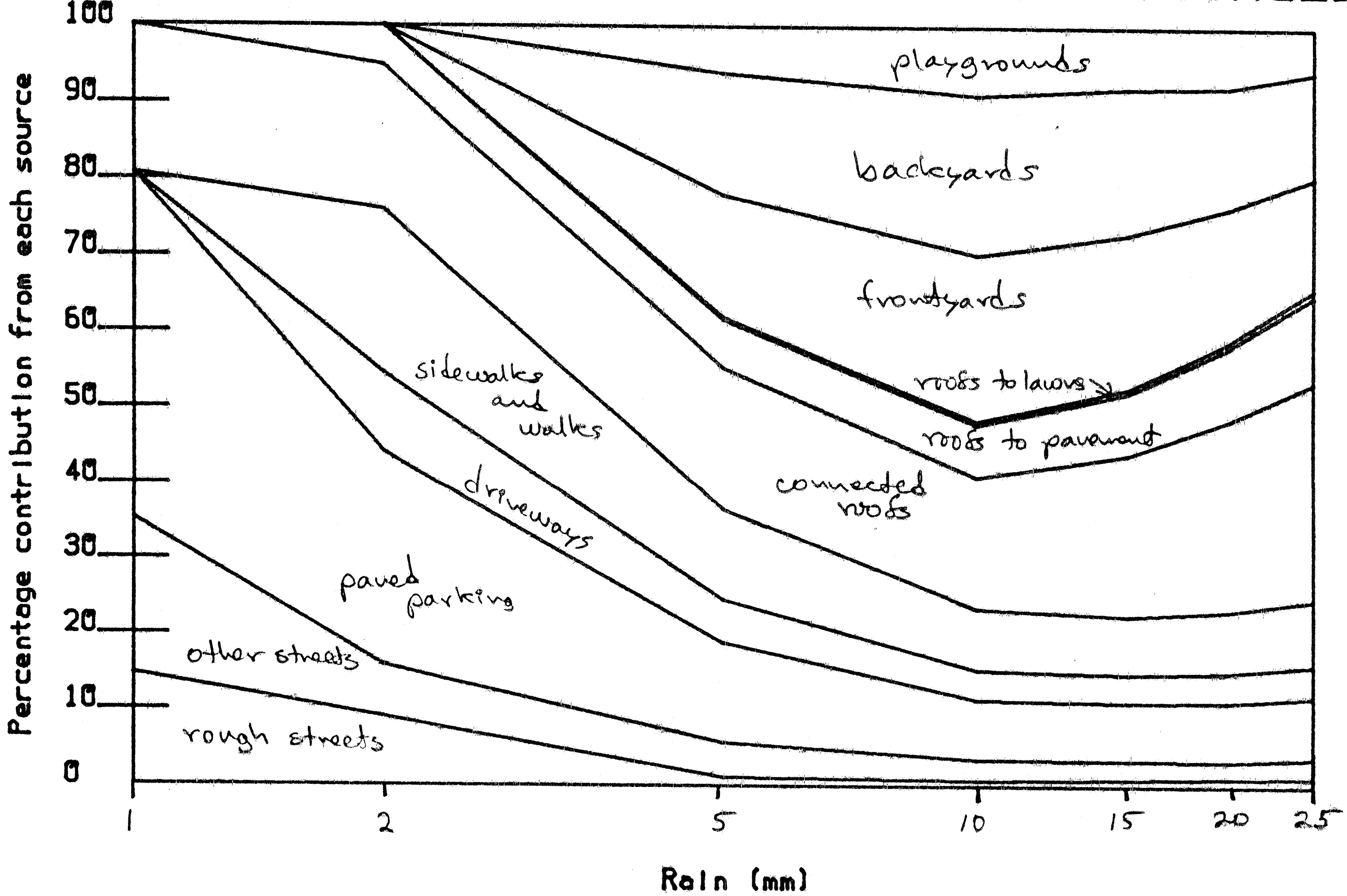


Figure F-18

EMERY FILTERABLE RESIDUE SOURCES

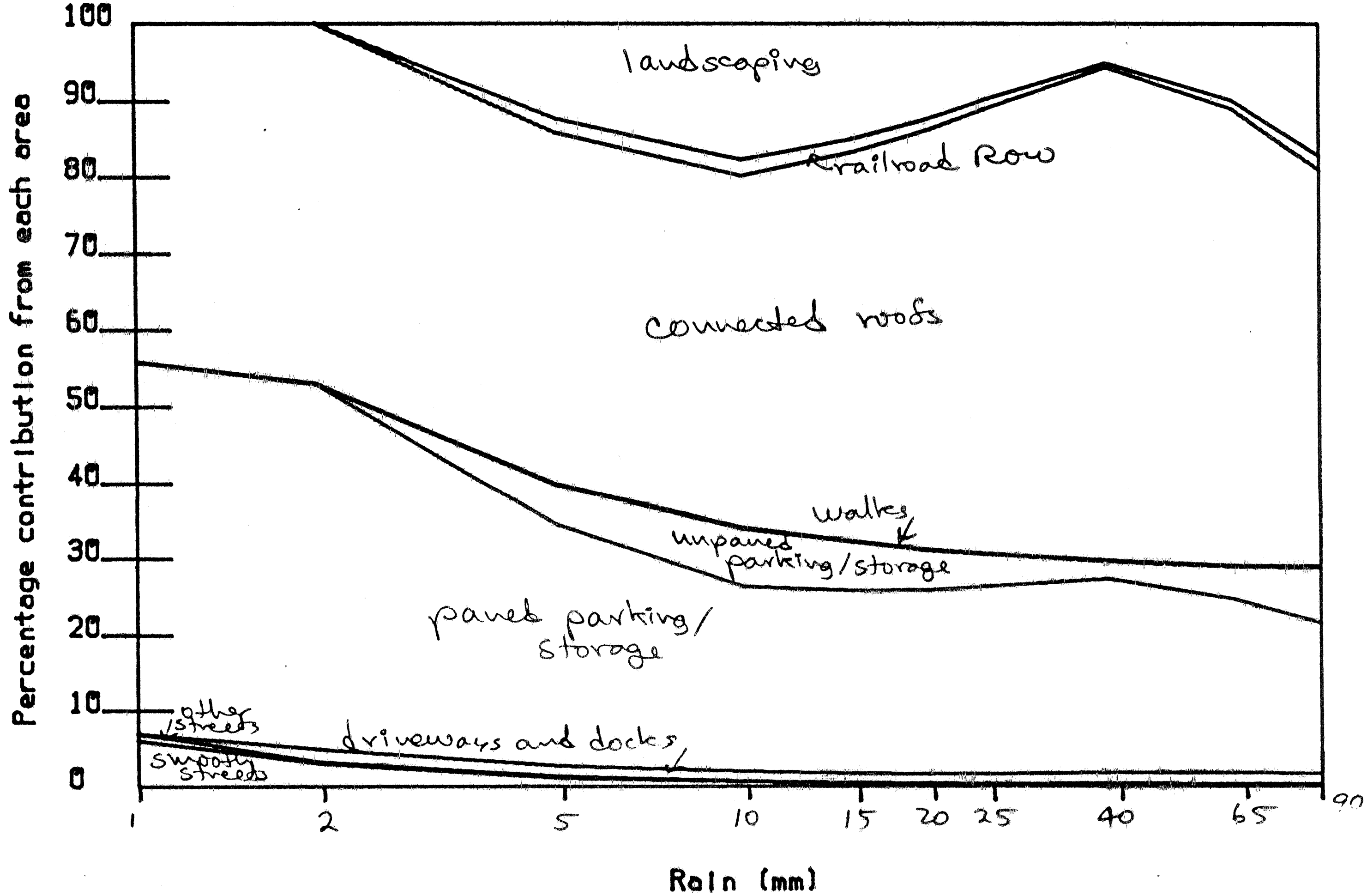


Figure F.19

THISTLEDOWNS PARTICULATE RESIDUE SOURCES

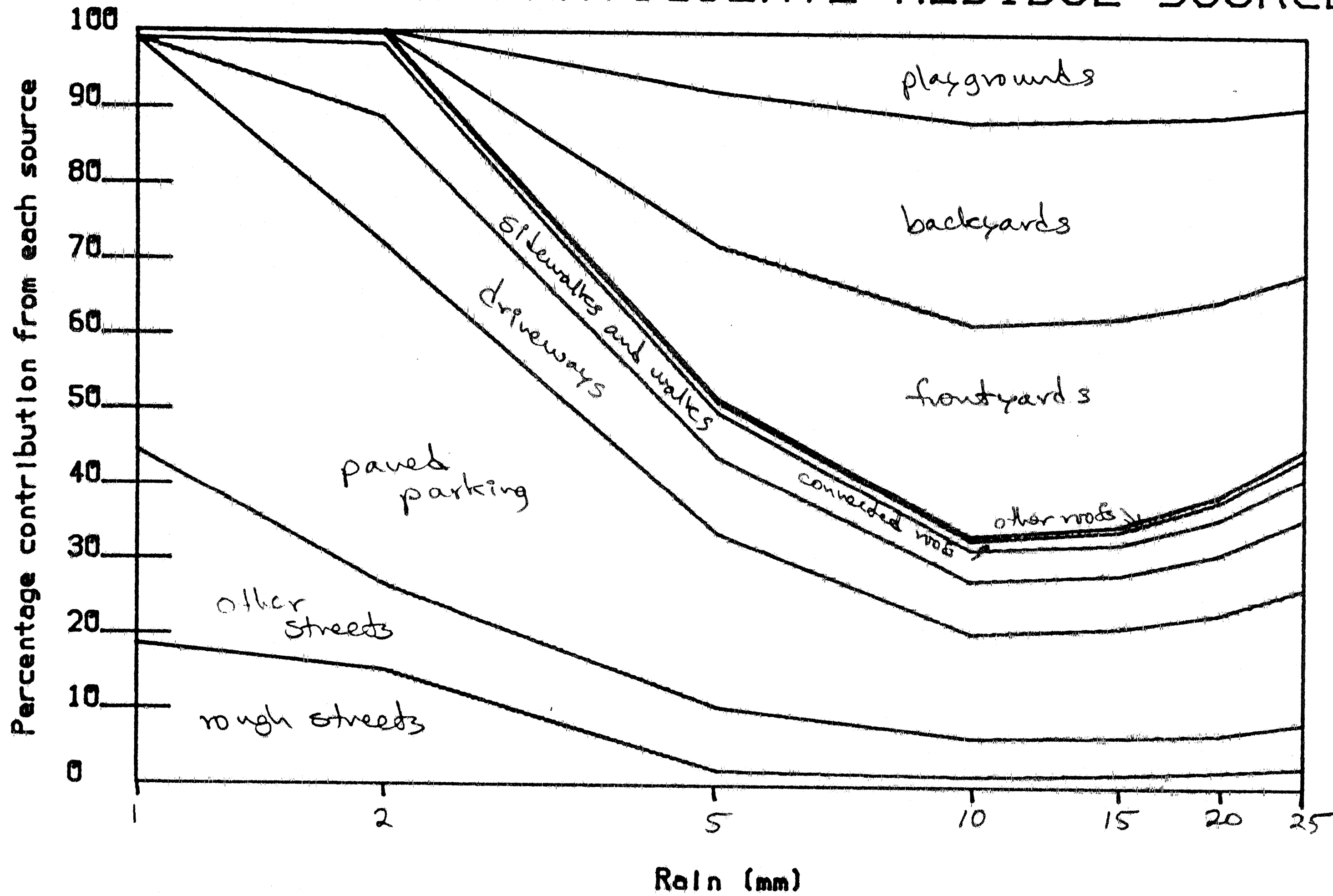


Figure F.20

EMERY PARTICULATE RESIDUE SOURCES

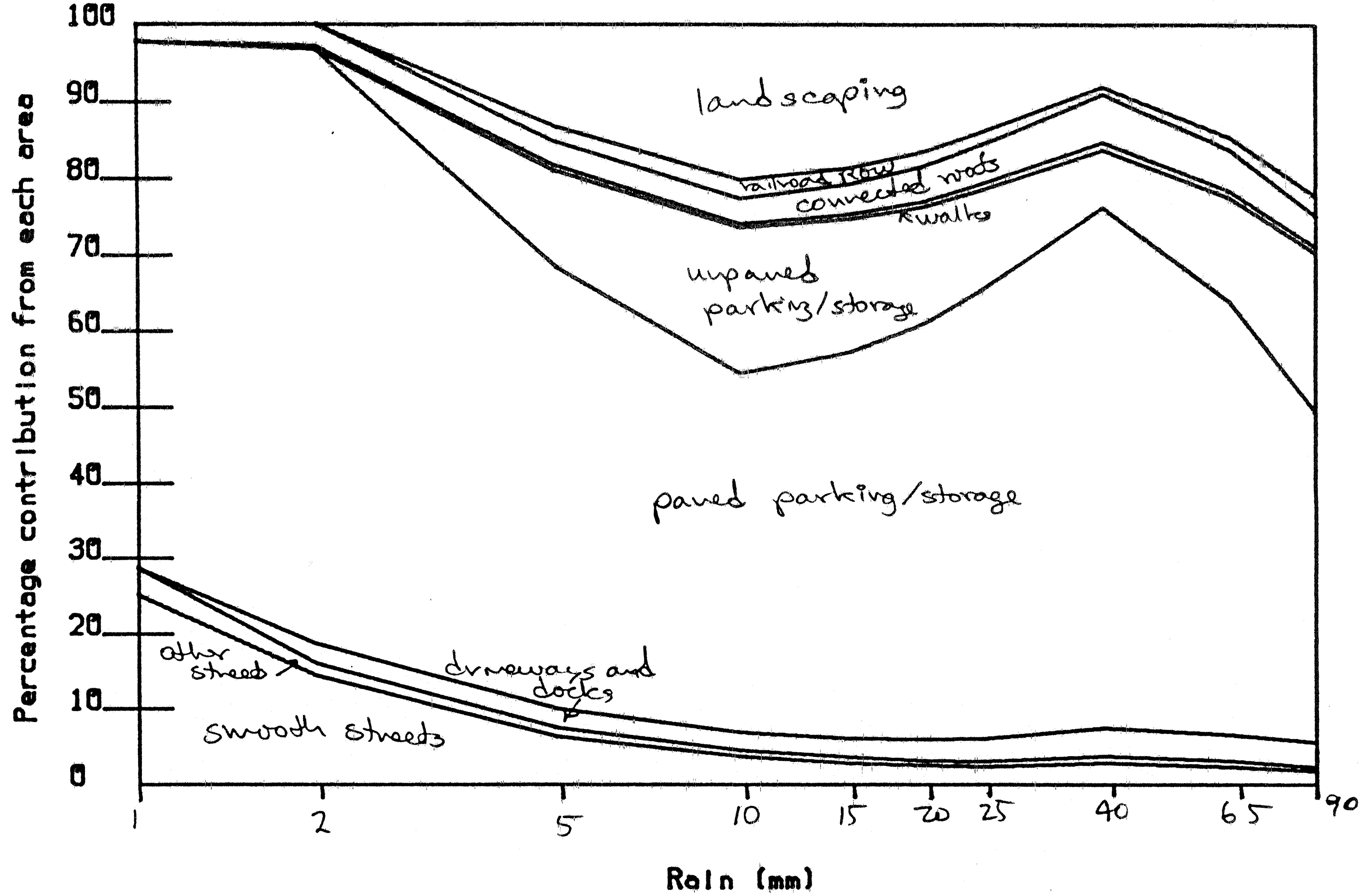


Figure F-21

THISTLEDOWNS PHOSPHORUS SOURCES

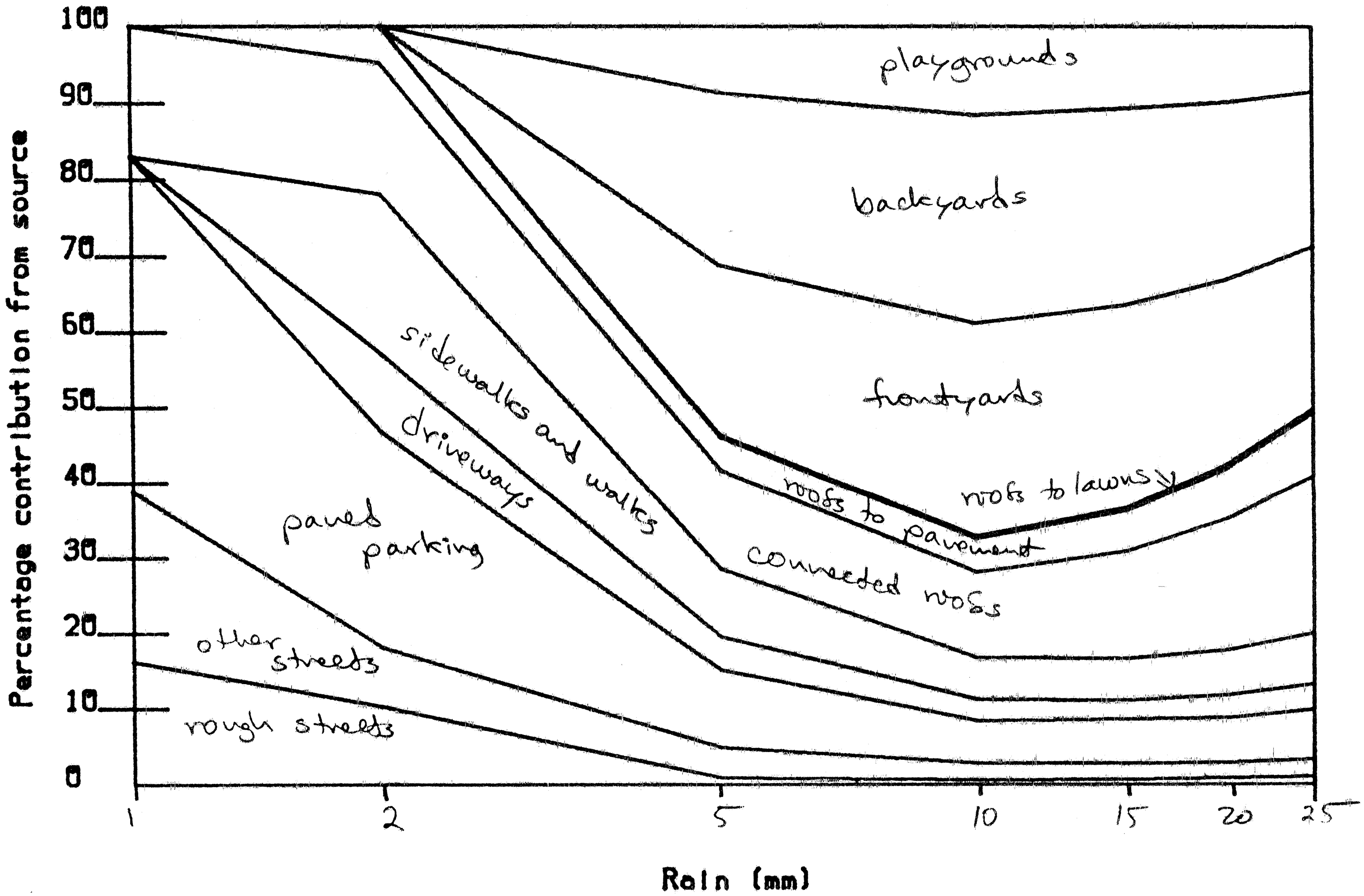
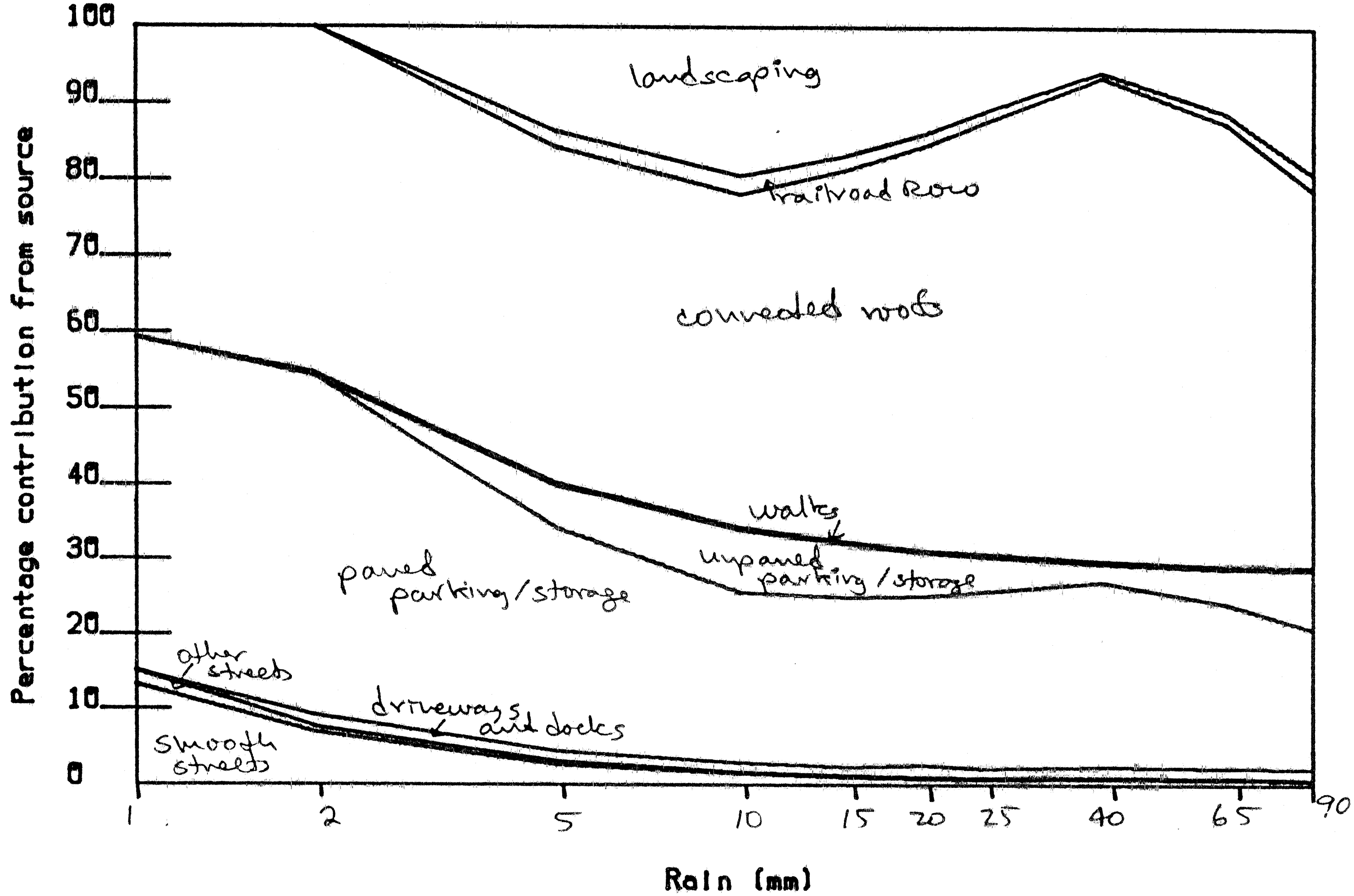


Figure F.22

EMERY PHOSPHORUS SOURCES



alternate

Figure F.23

THISTLEDOWNS REACTIVE PHOSPHATES SOURCES

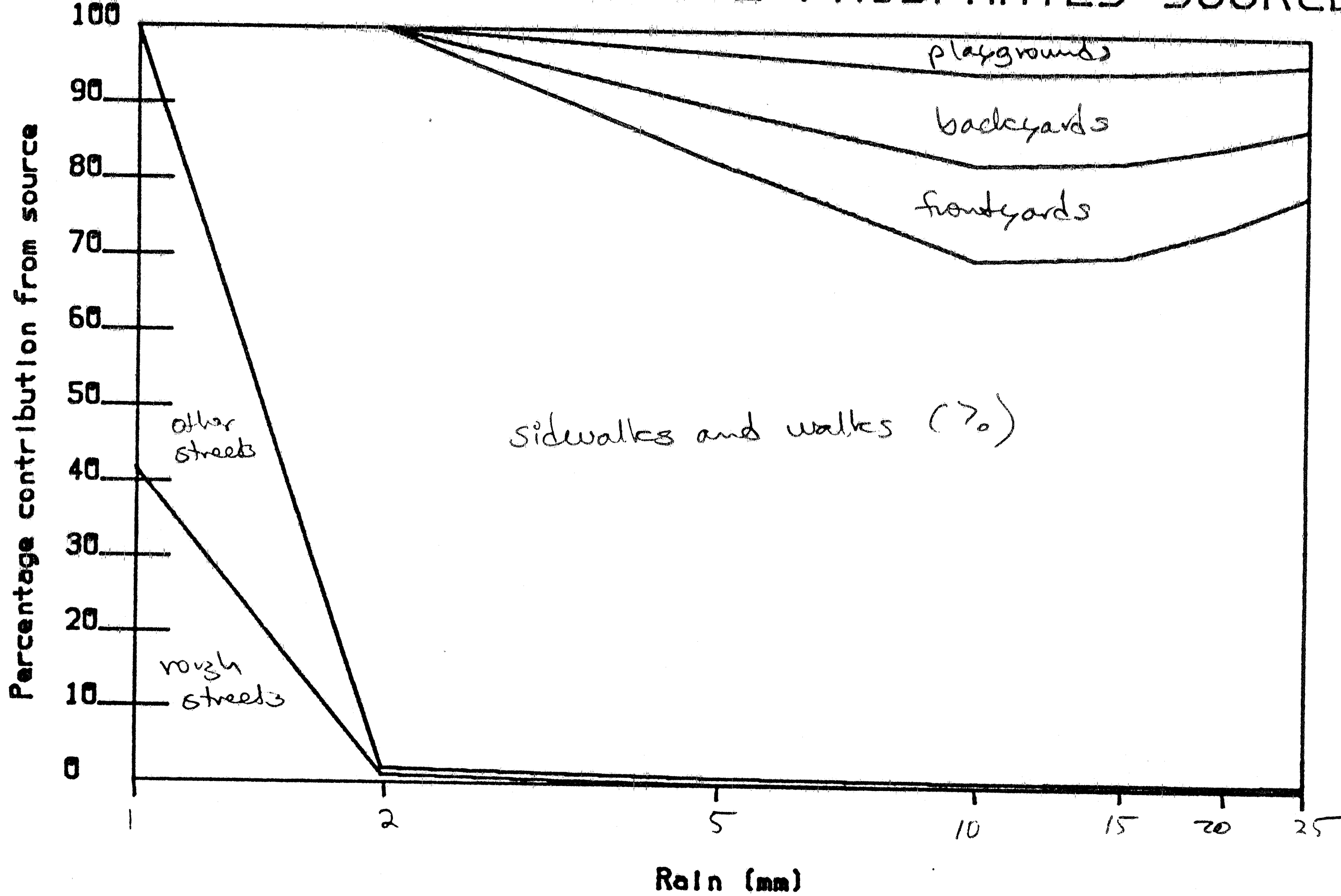


Figure F-24

EMERY REACTIVE PHOSPHATES SOURCES

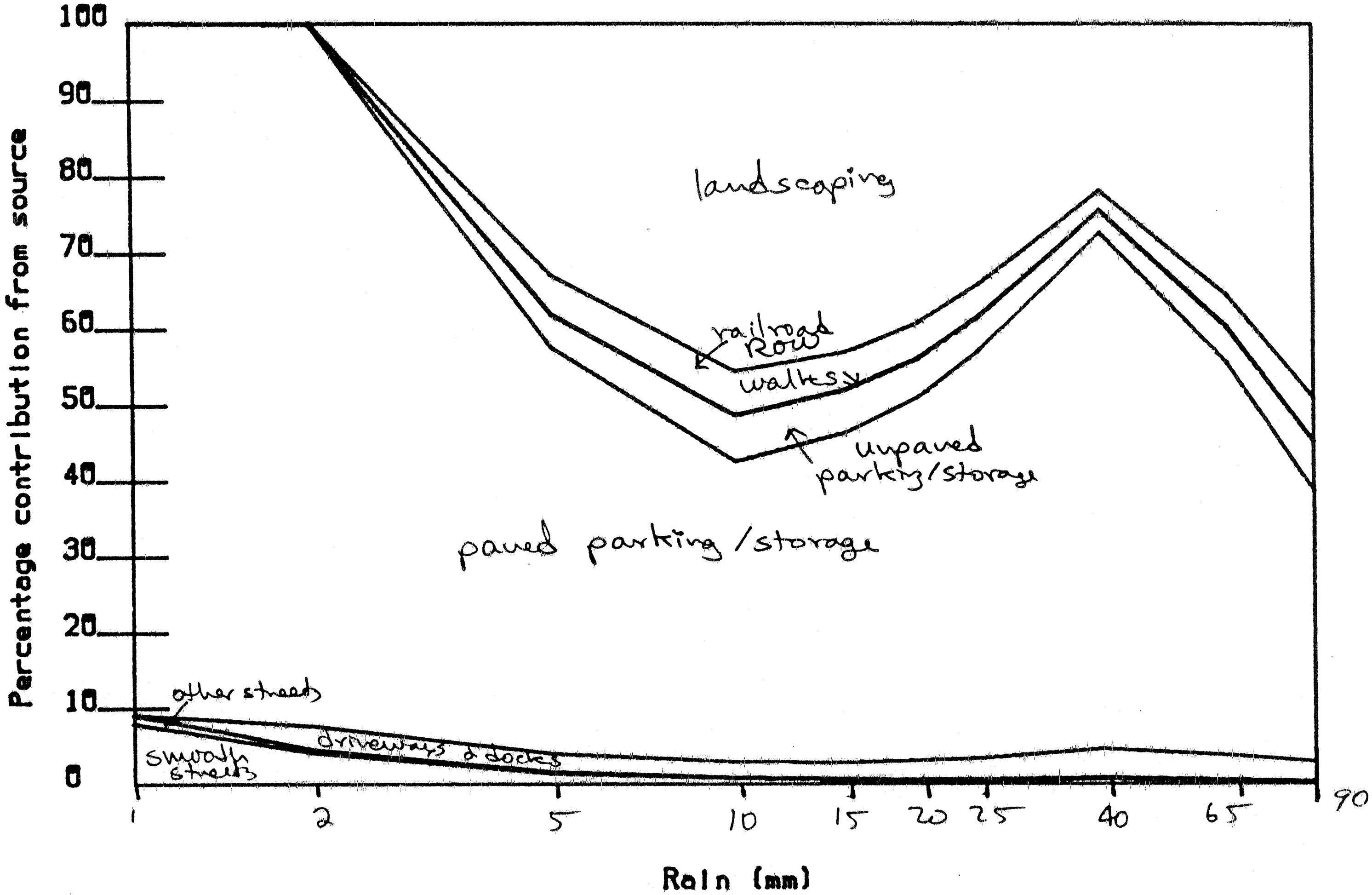


Figure F.25

THISTLEDOWNS TOTAL KJELDAHL N SOURCES

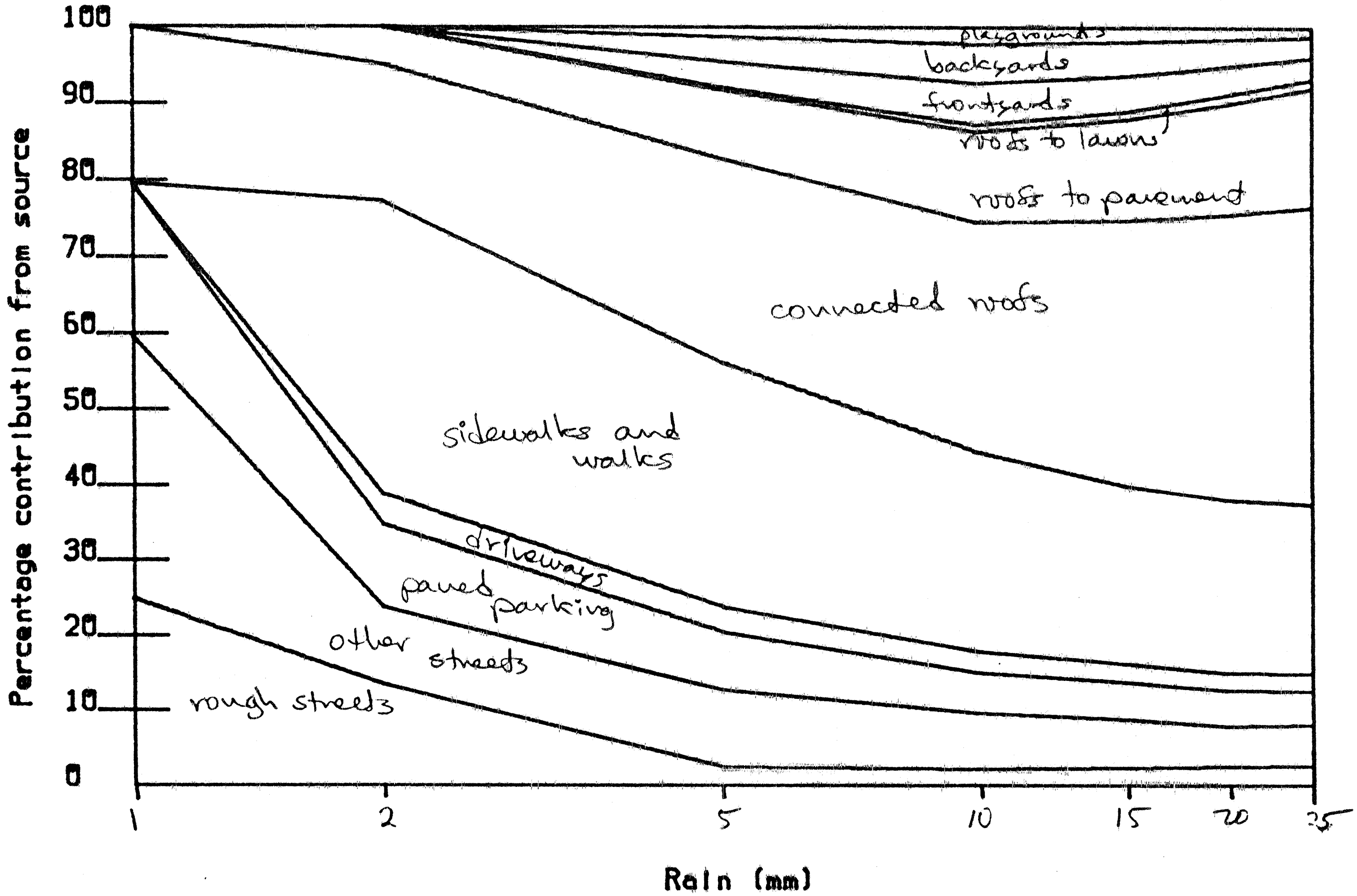


Figure F.26

EMERY TOTAL KJELDAHL NITROGEN SOURCES

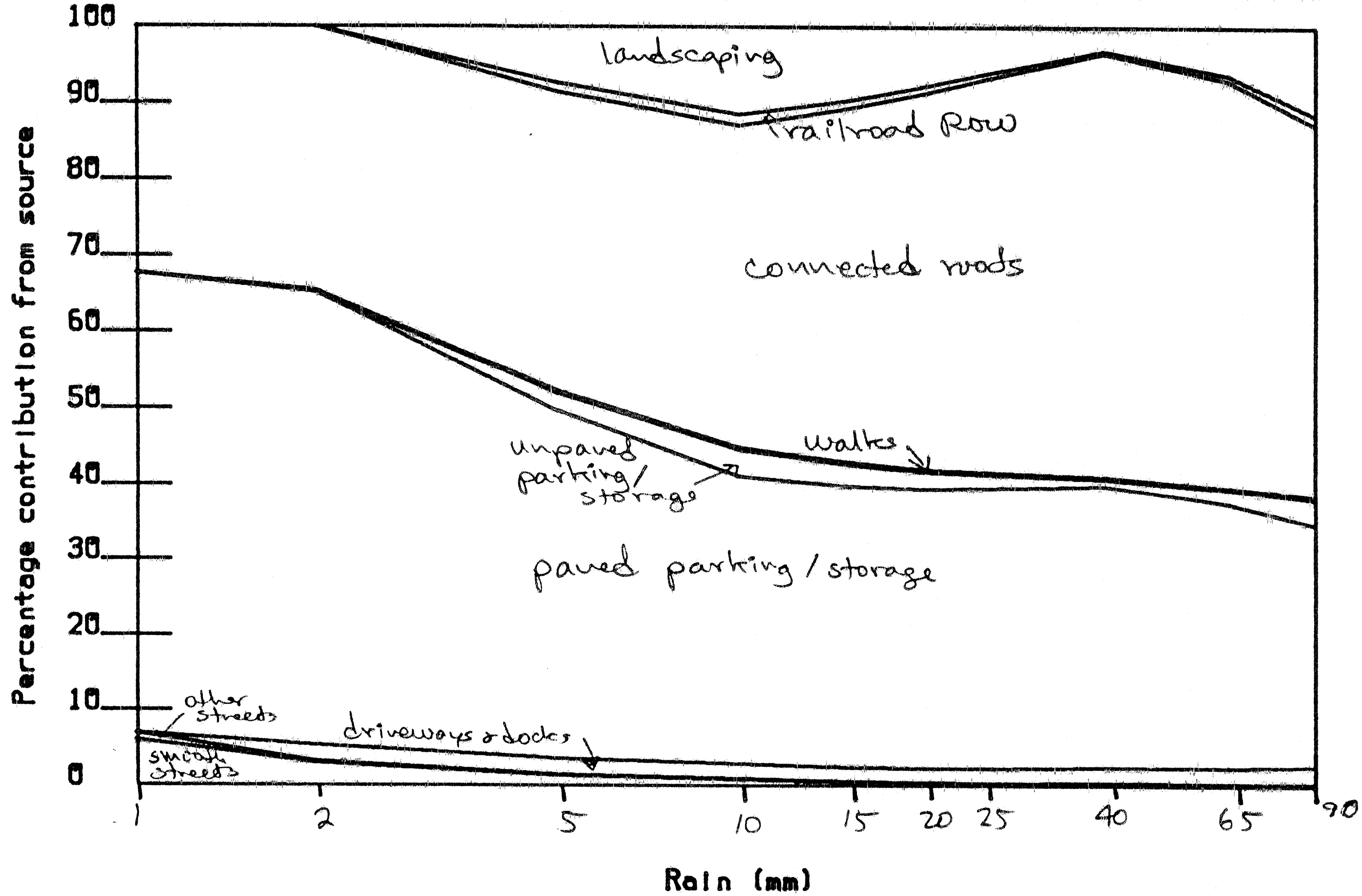


Figure F.27

THISTLEDOWNS PHENOLICS SOURCES

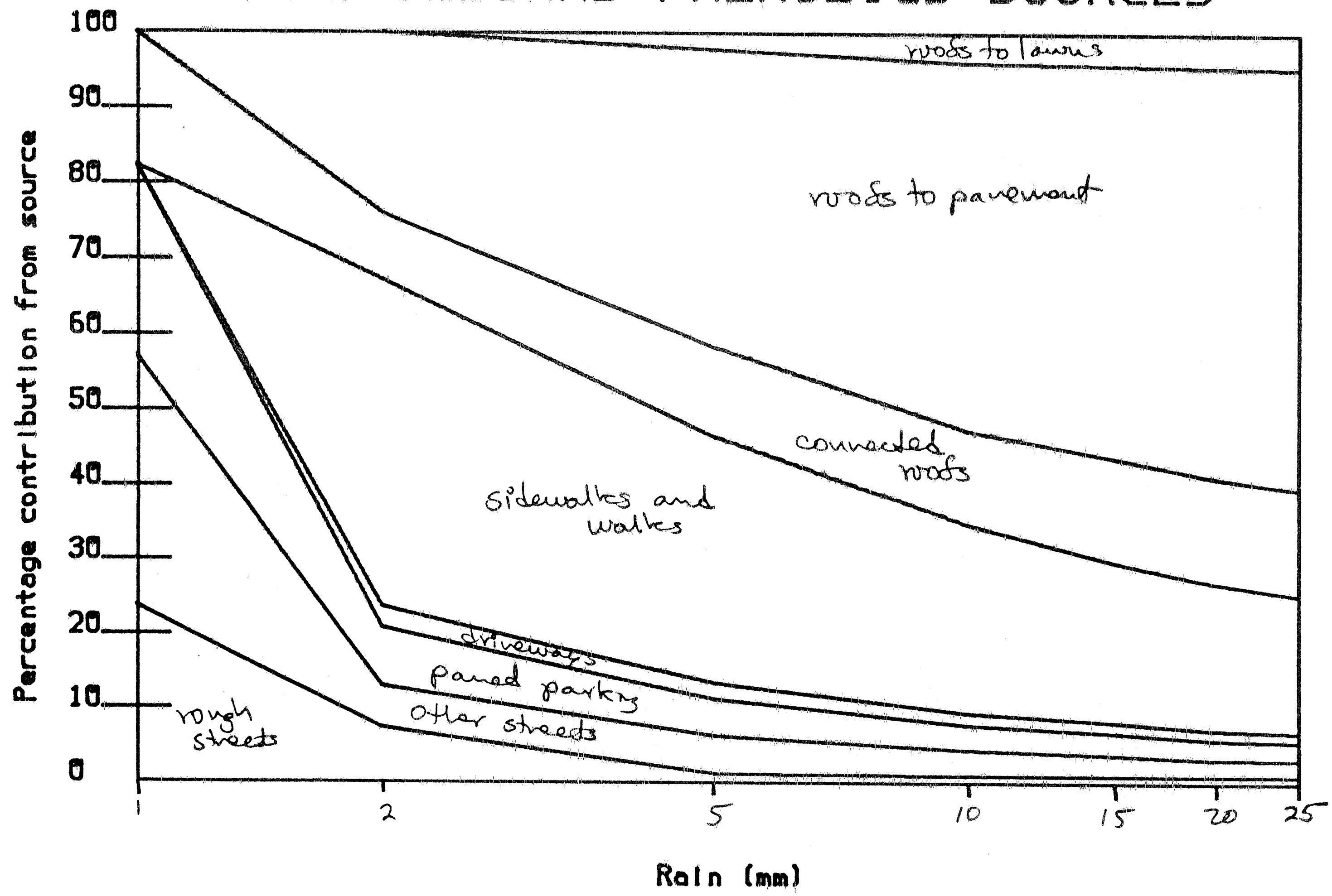


Figure F.28

EMERY PHENOLICS SOURCES

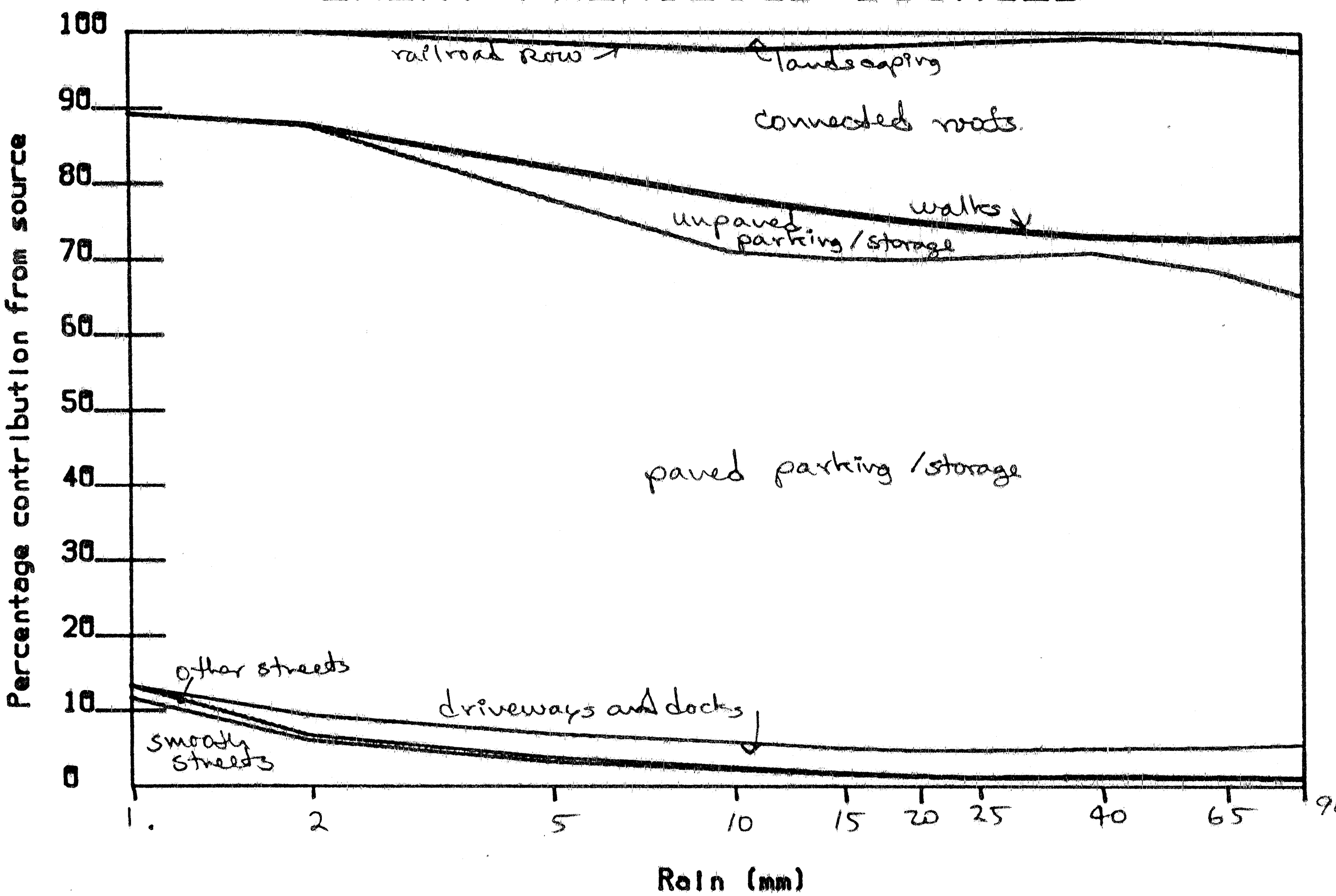


Figure F.29

THISTLEDOWNS COD SOURCES

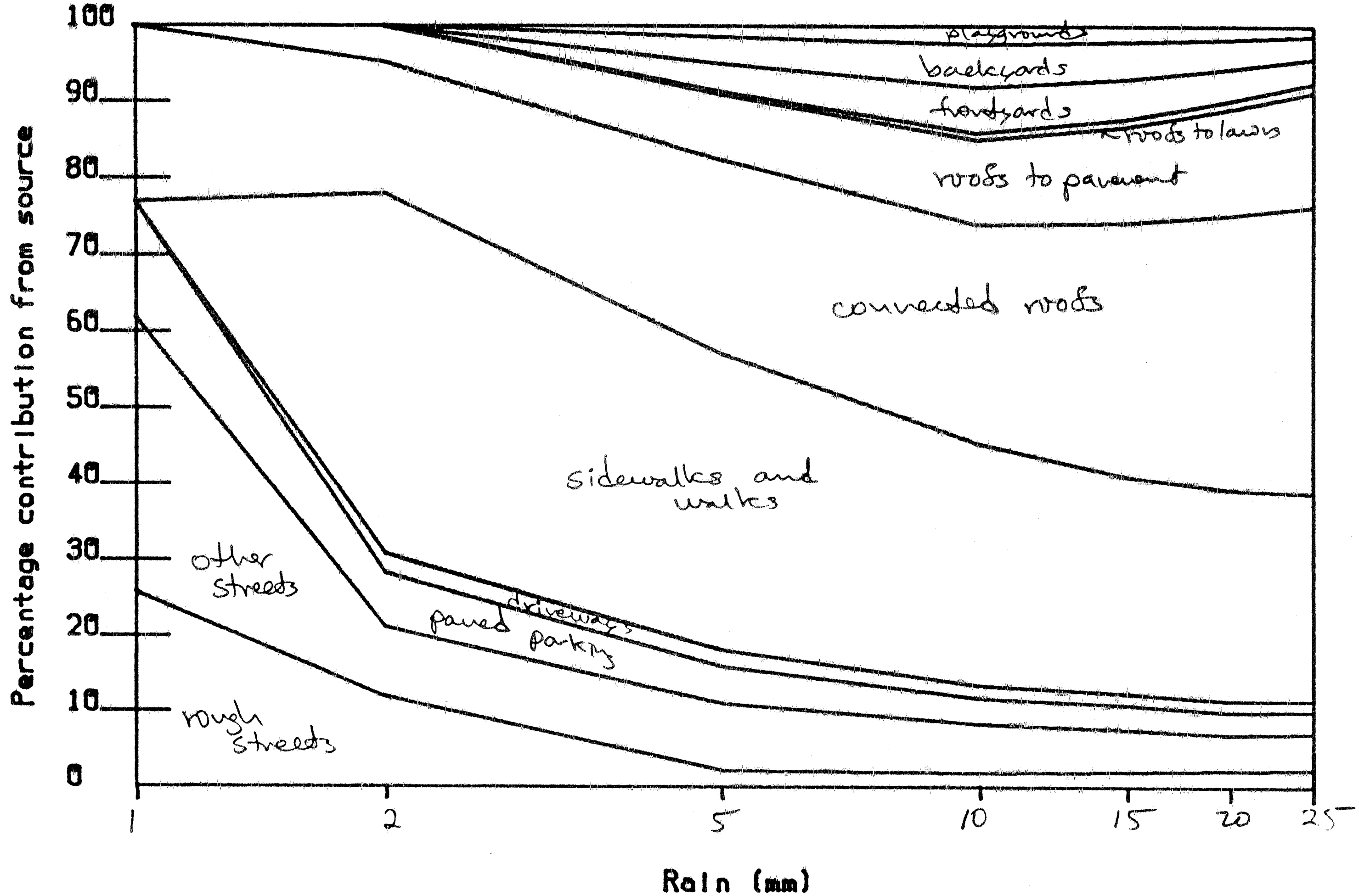


Figure F.30

EMERY COD SOURCES

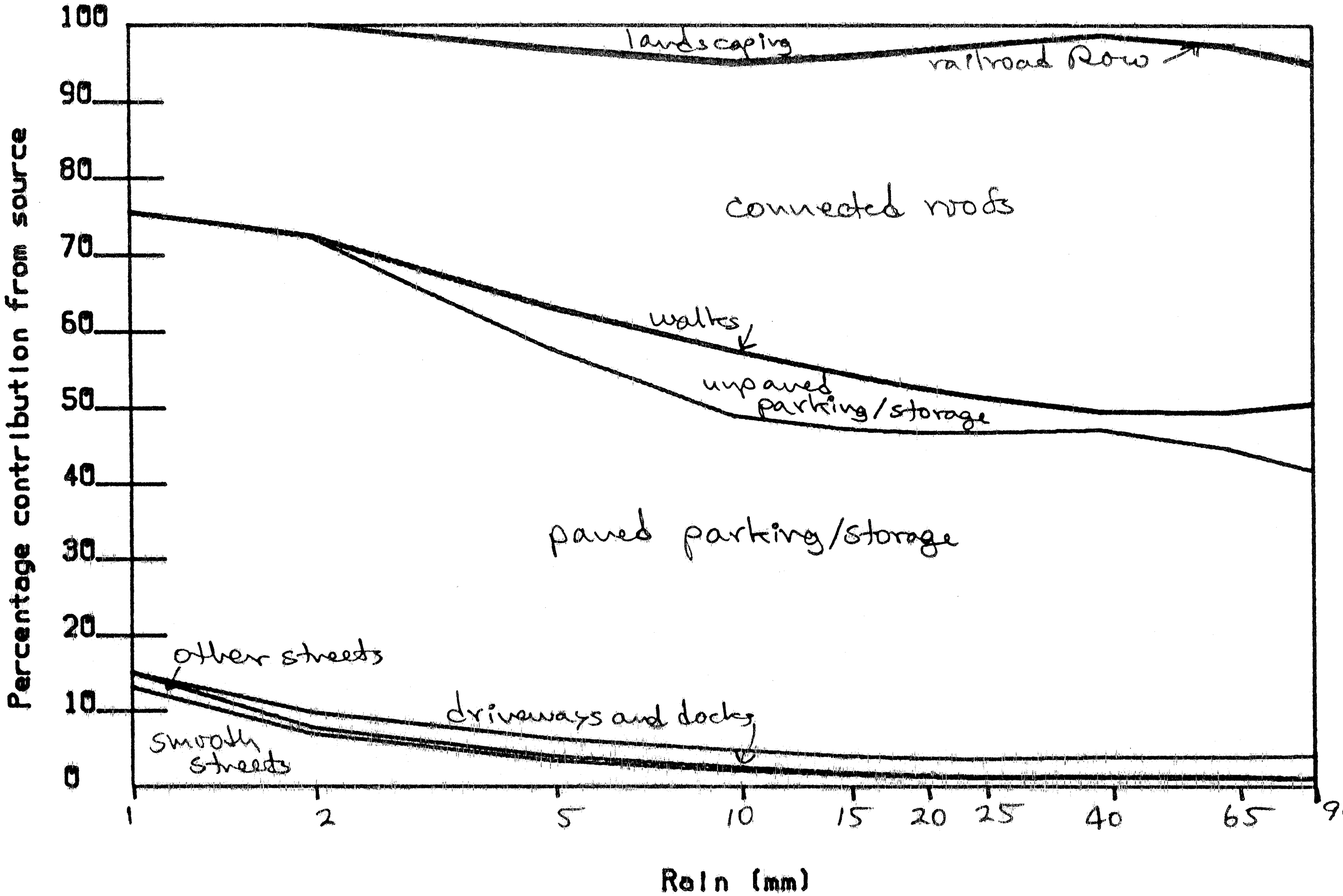


Figure F.31

THISTLEDOWNS FECAL COLIFORM SOURCES

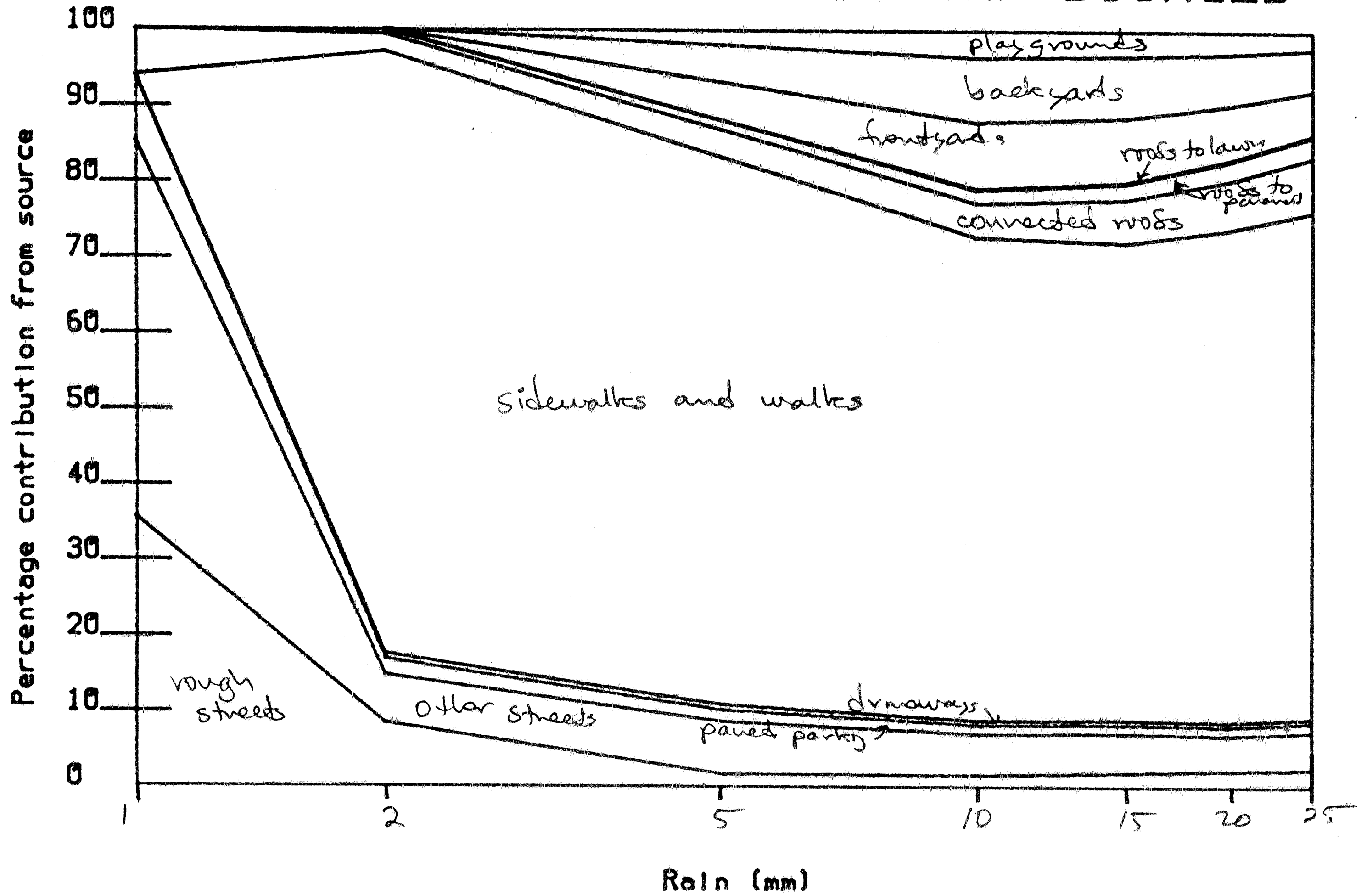


Figure F.32

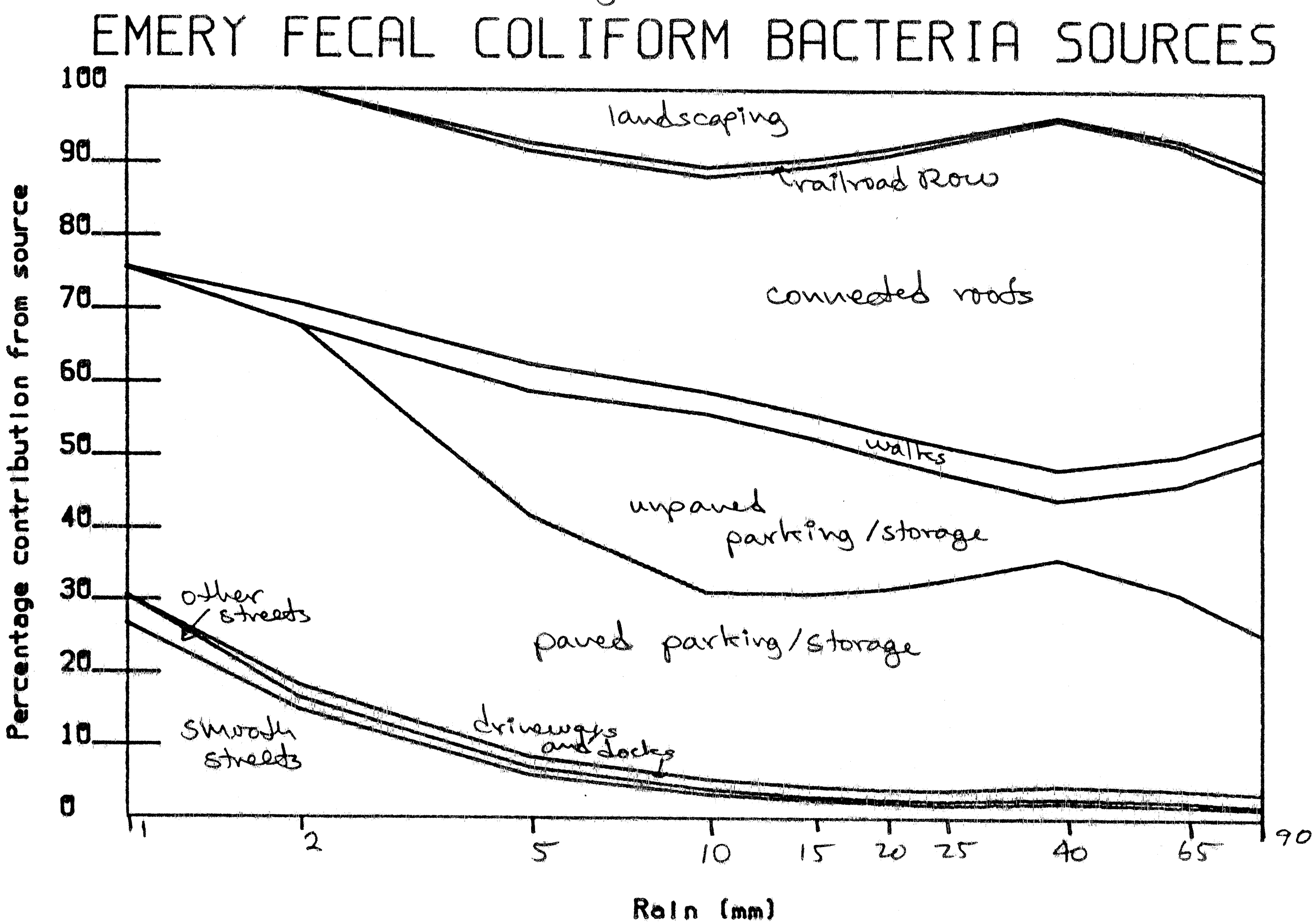

EMERY FECAL COLIFORM BACTERIA SOURCES
100
90
80
70
60
50
40
30
20
10
0
Percentage contribution from source
landscaping
railroad Row
connected roofs
walks
unpaved parking/storage
paved parking/storage
other streets
smooth streets
driveways and docks
1
2
5
10
15
20
25
40
65
90
Rain (mm)

Figure F.33

THISTLEDOWNS FECAL STREP. BACTERIA SOURCES

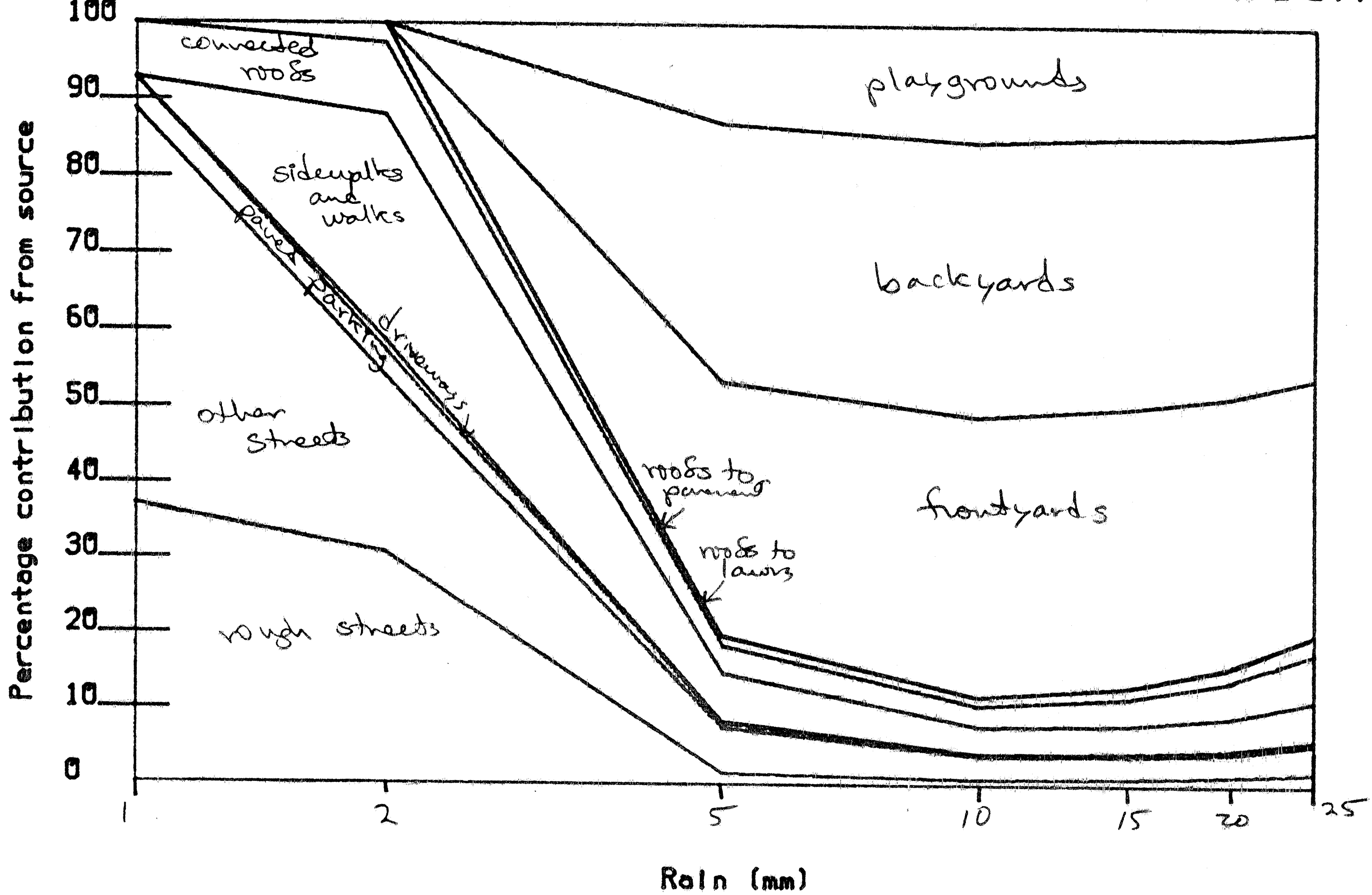


Figure F.34

EMERY FECAL STREP. BACTERIA SOURCES

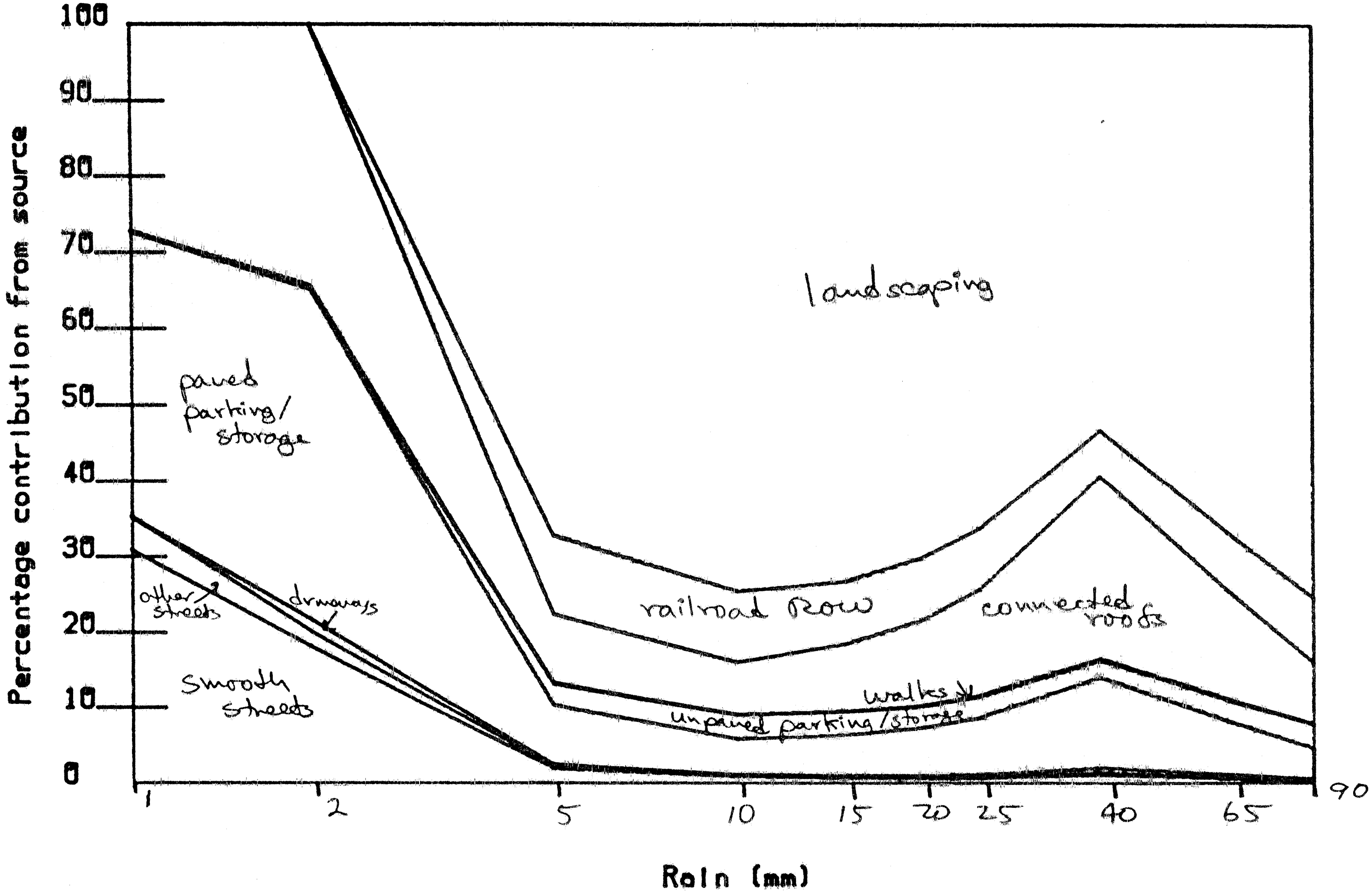


Figure F.35

THISTLEDOWNS PSEUDO. AERUGINOSA SOURCES

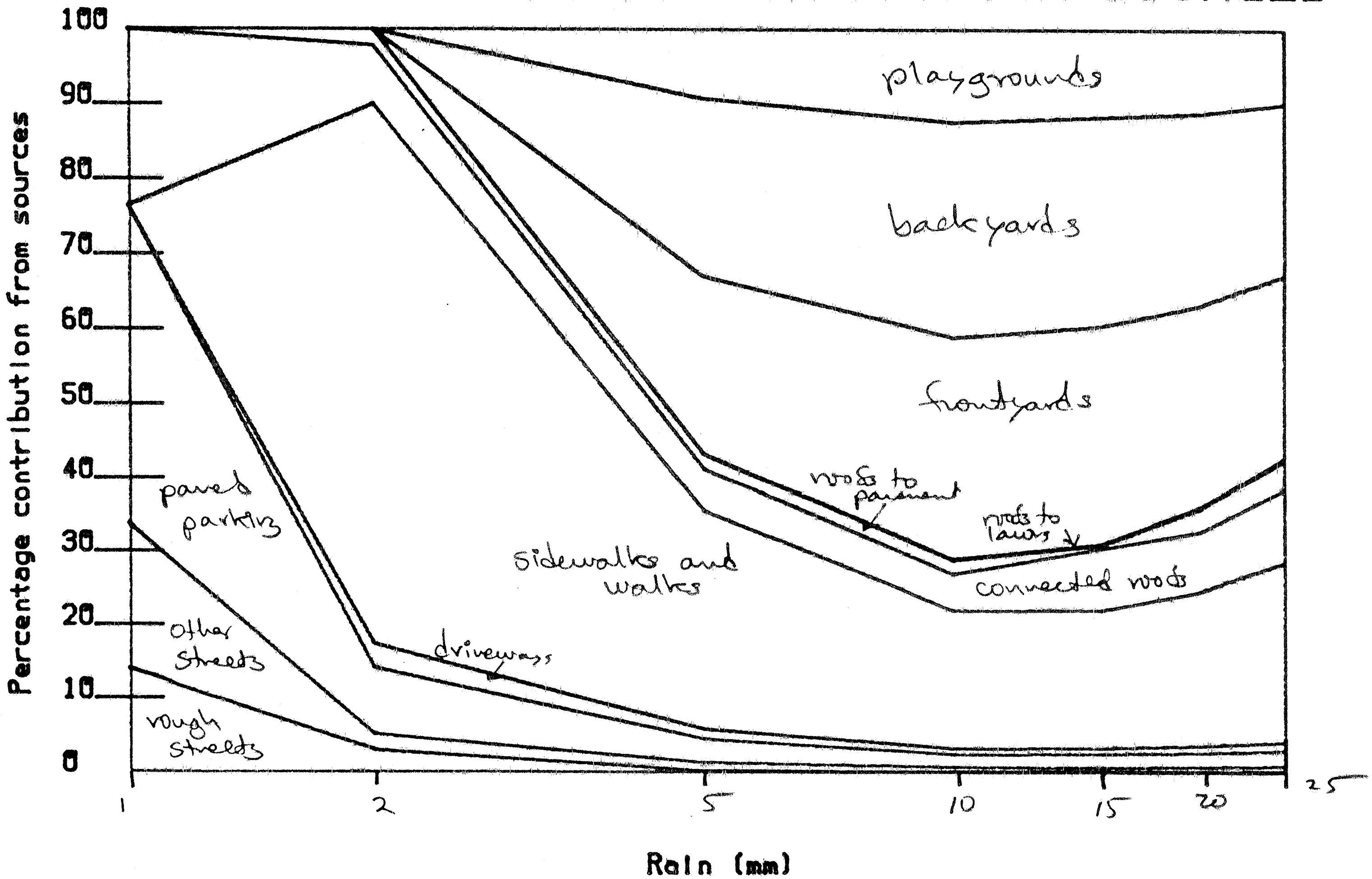


Figure F.36

EMERY PSEUDO. AERUGINOSA BACTERIA SOURCES

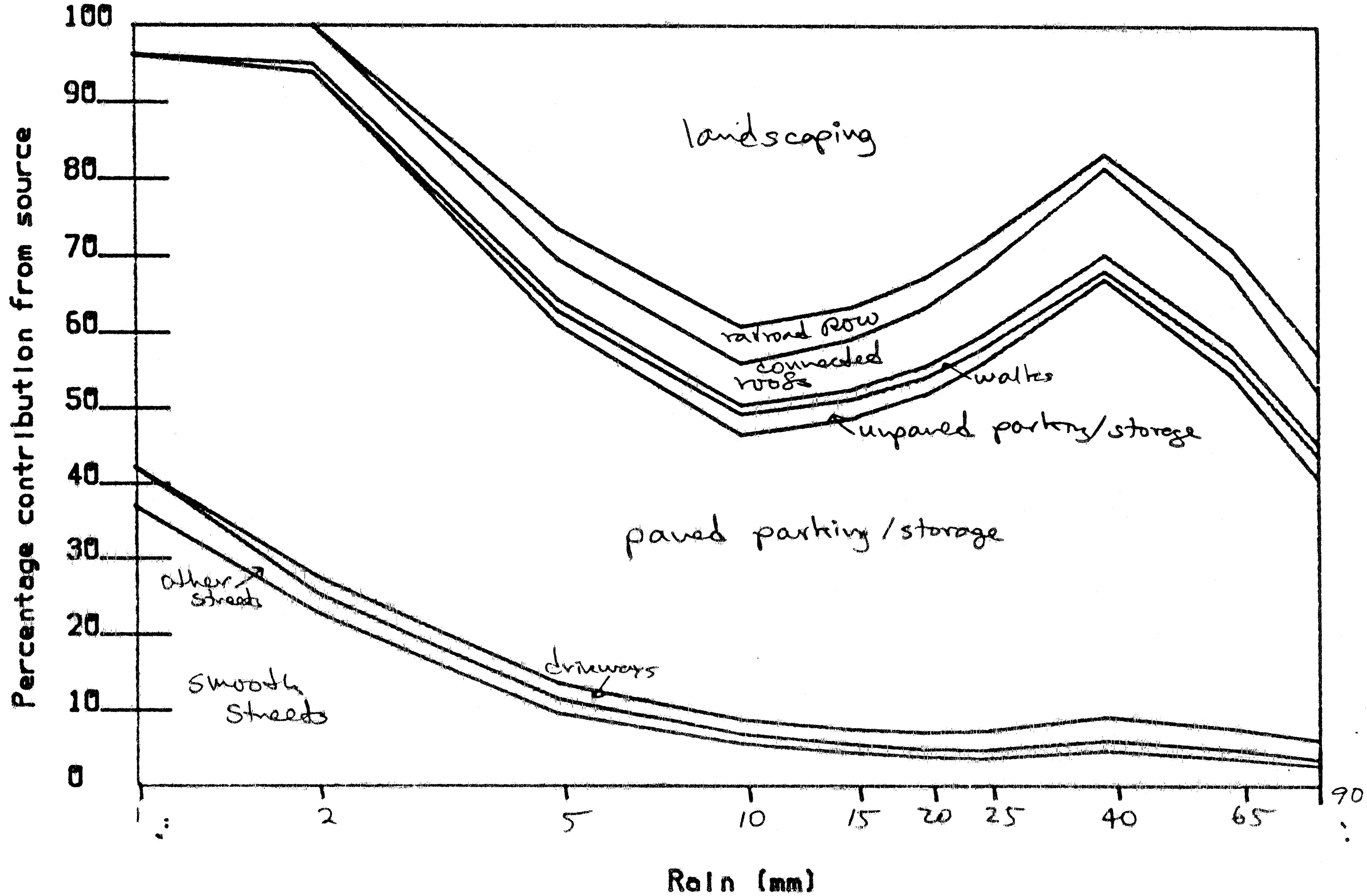


Figure F.37

THISTLEDOWNS ALUMINUM SOURCES

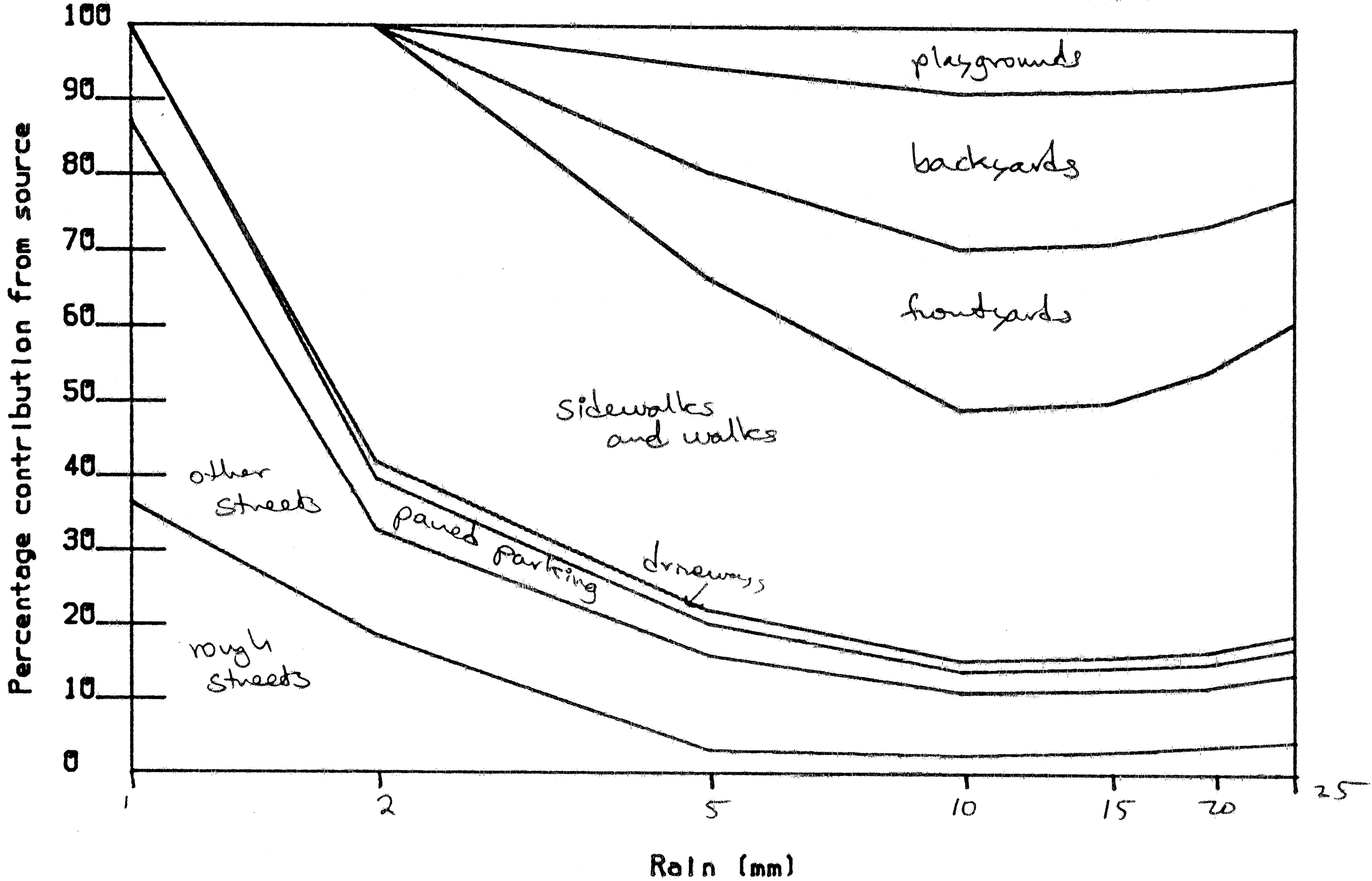


Figure F.38

EMERY ALUMINUM SOURCES

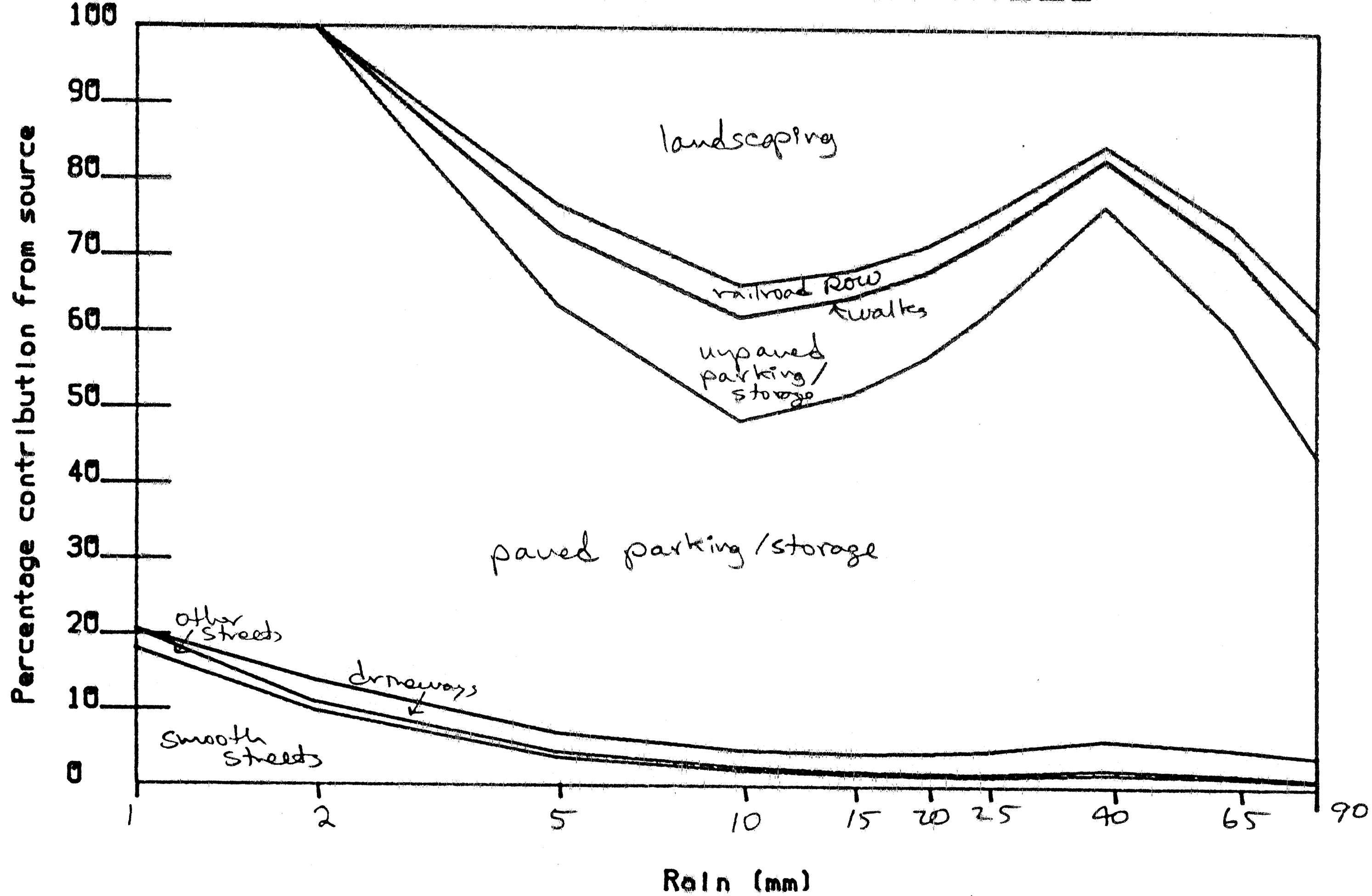


Figure F.39

THISTLEDOWNS COPPER SOURCES

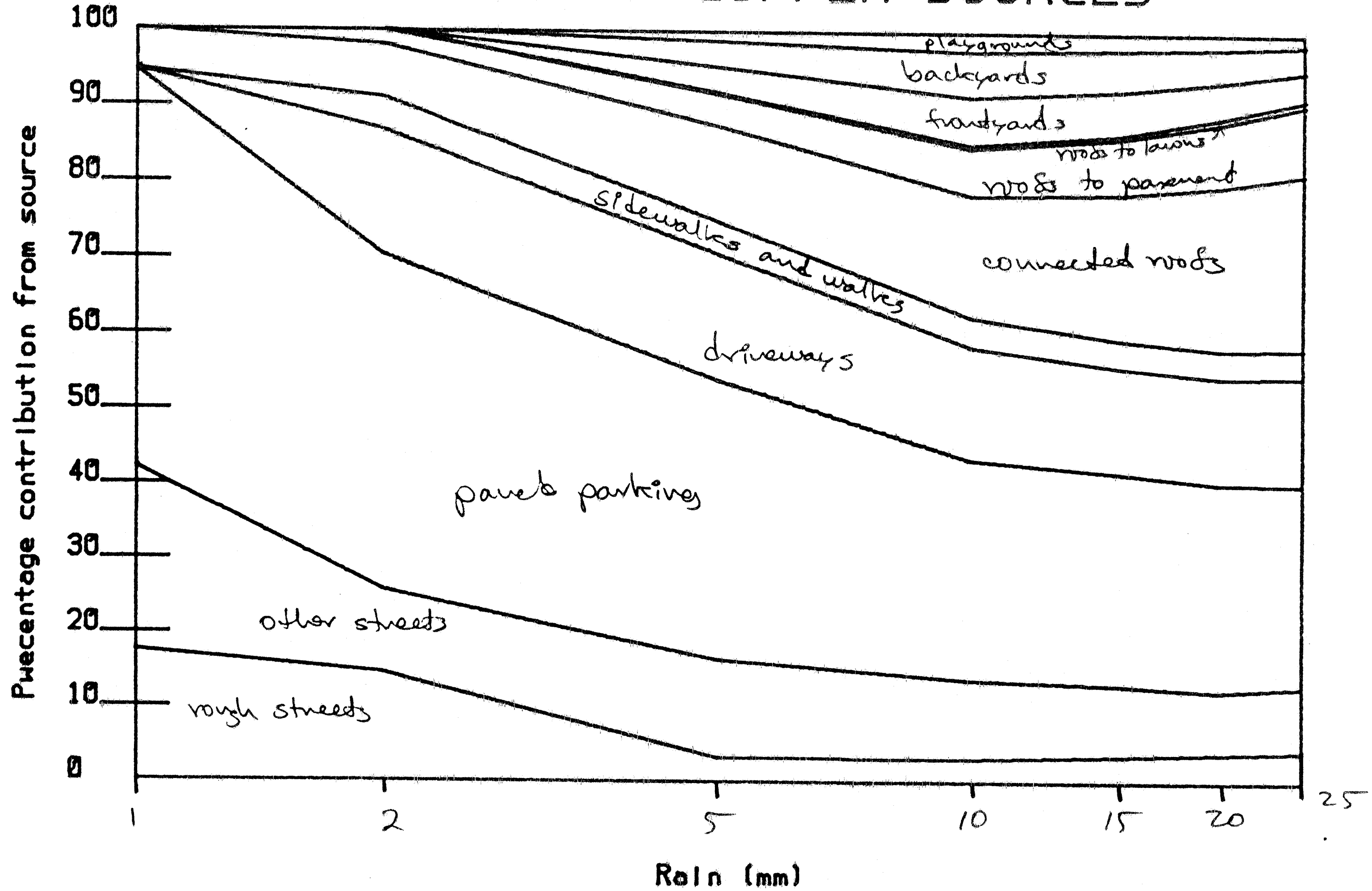


Figure F.40

EMERY COPPER SOURCES

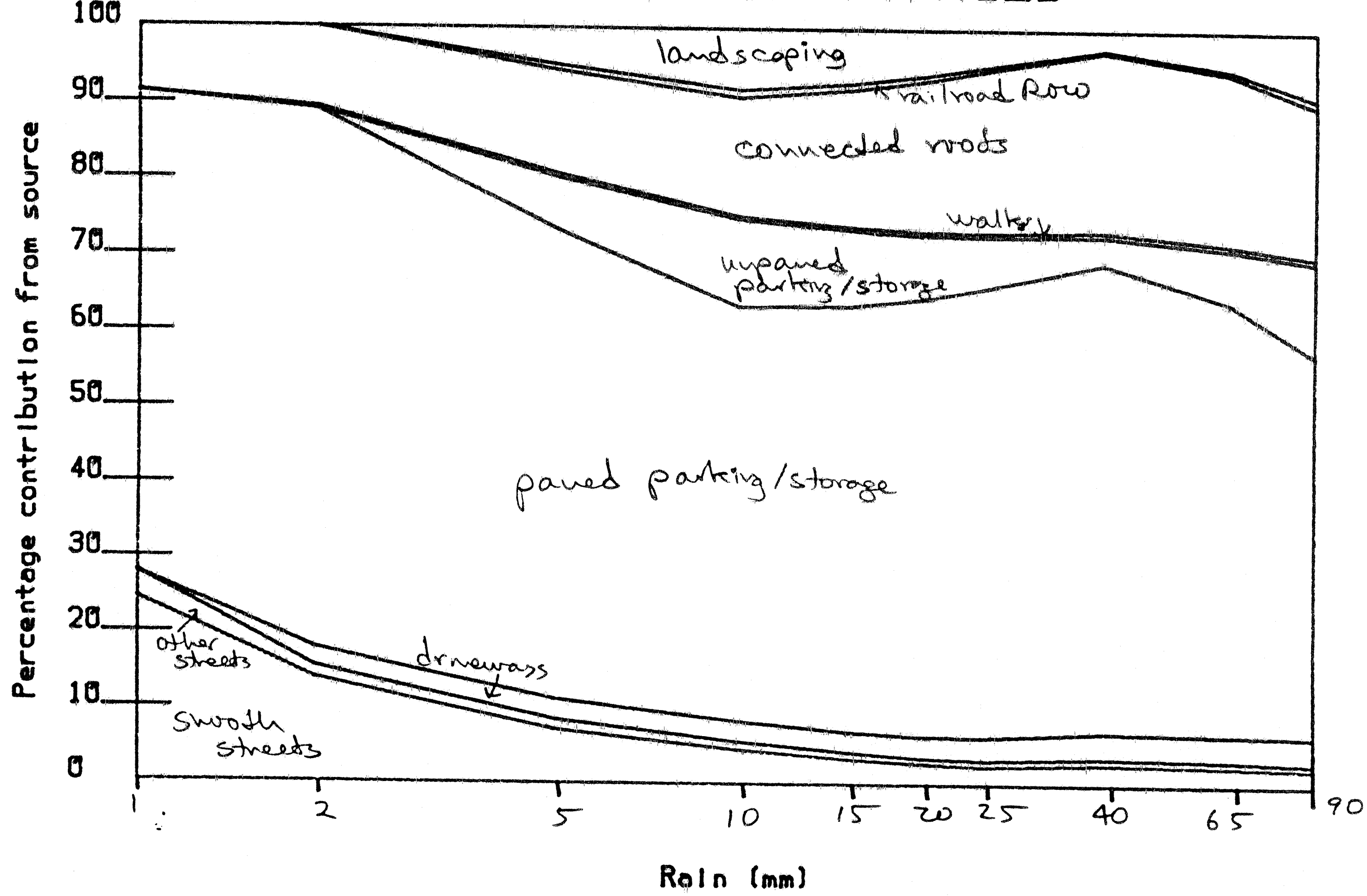
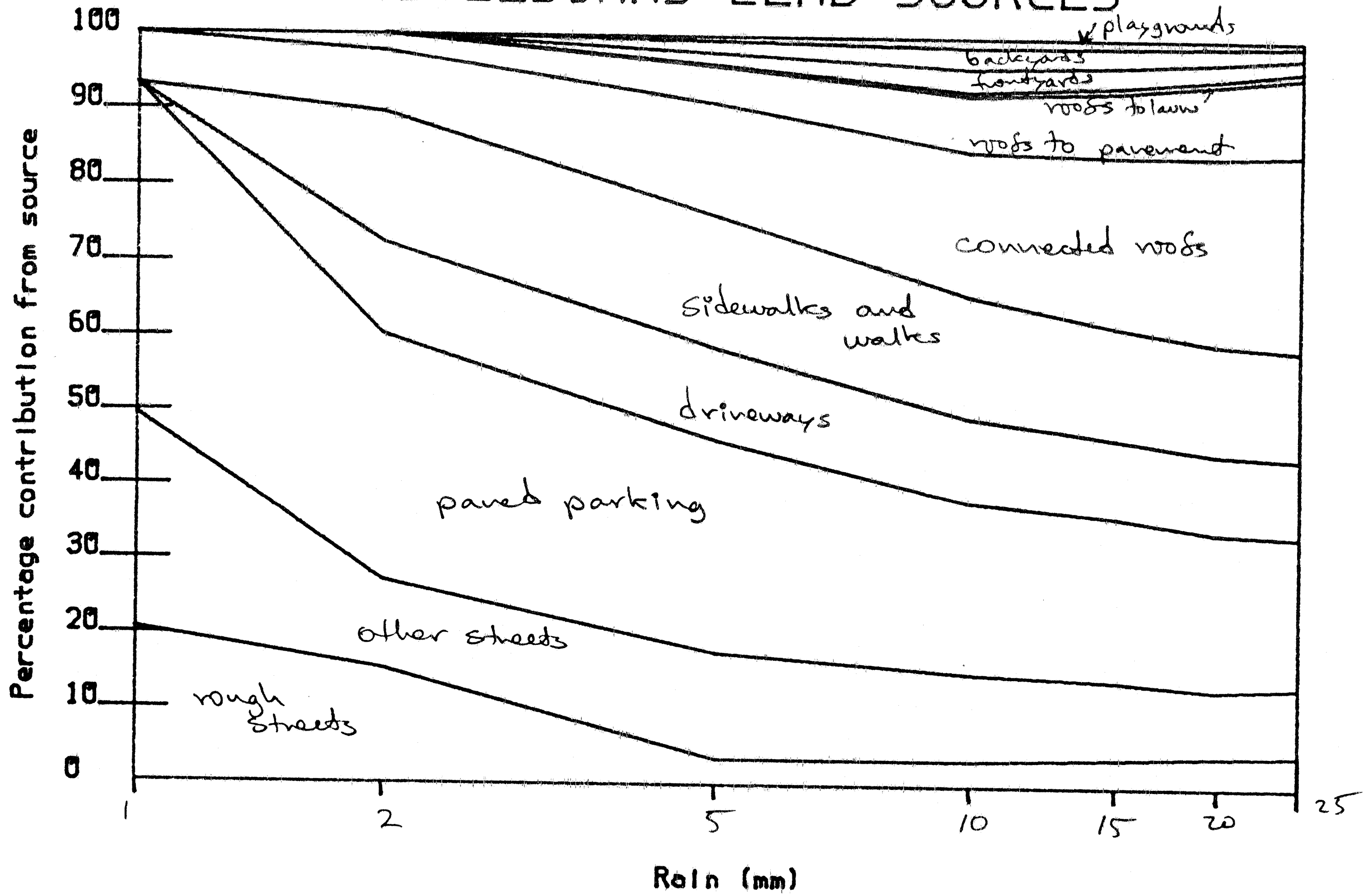


Figure F.41

THISTLEDOWNS LEAD SOURCES



alternatives

Figure F.42

EMERY LEAD SOURCES

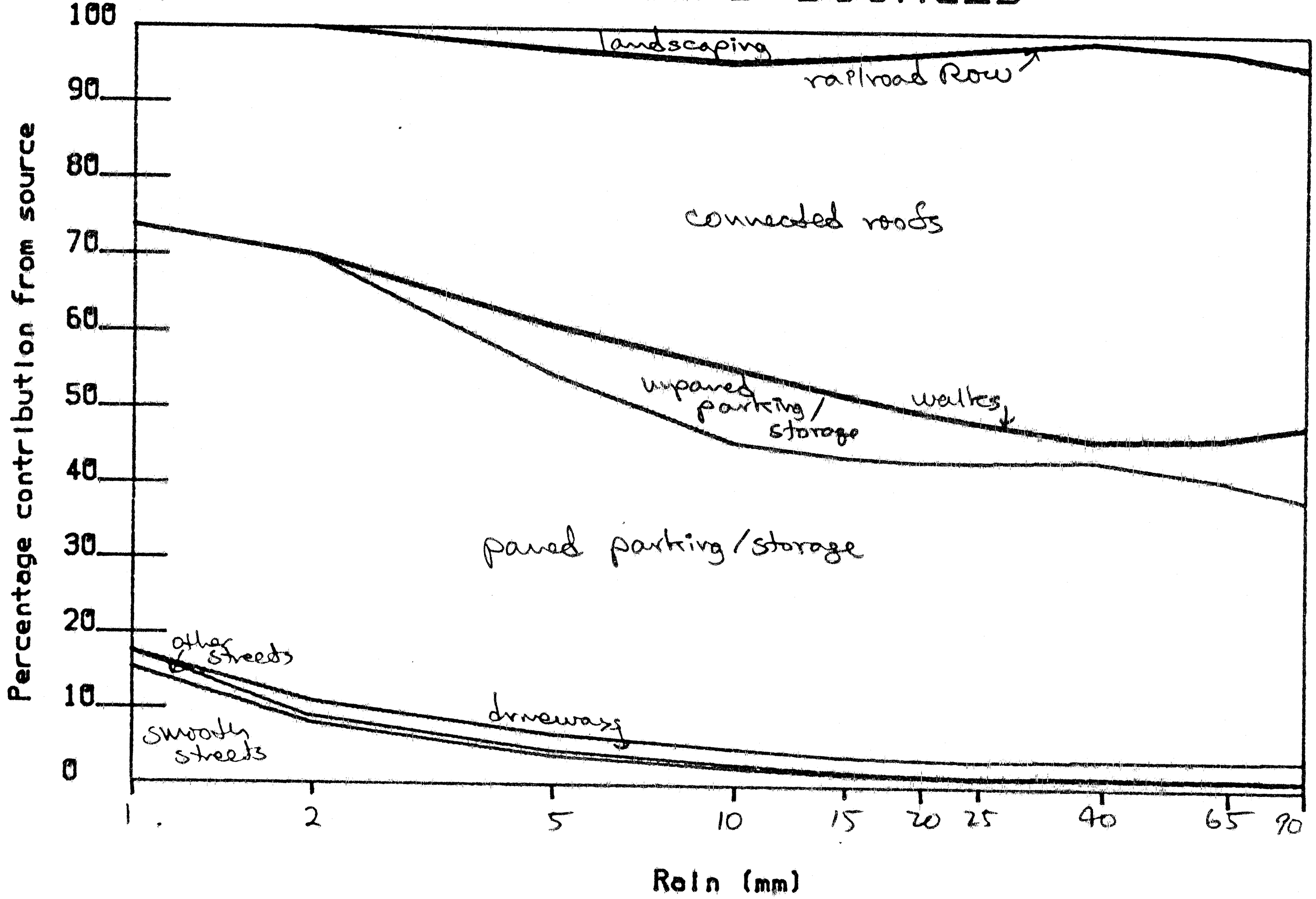


Figure F.43

THISTLEDOWNS ZINC SOURCES

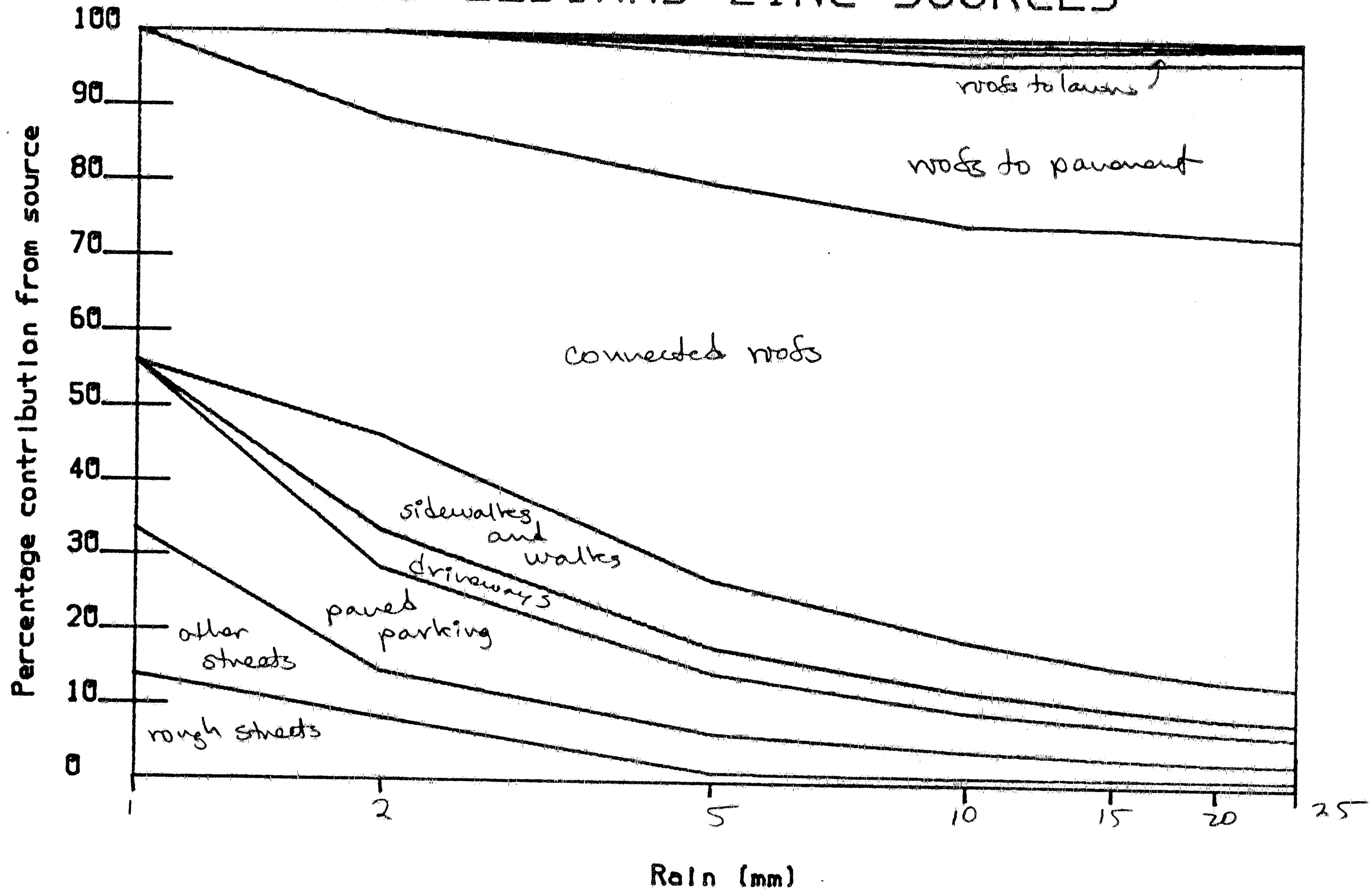


Figure F.44

EMERY ZINC SOURCES

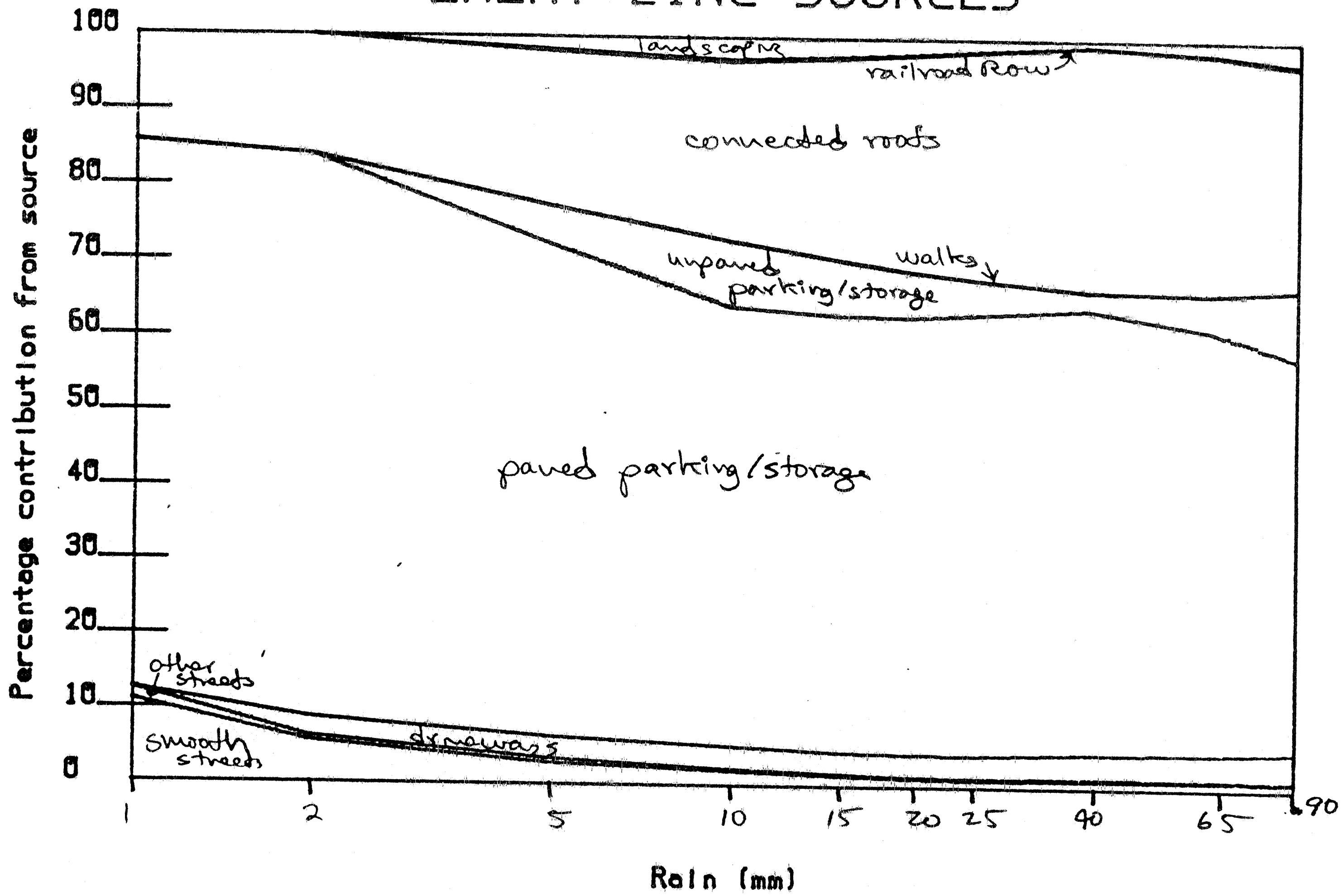
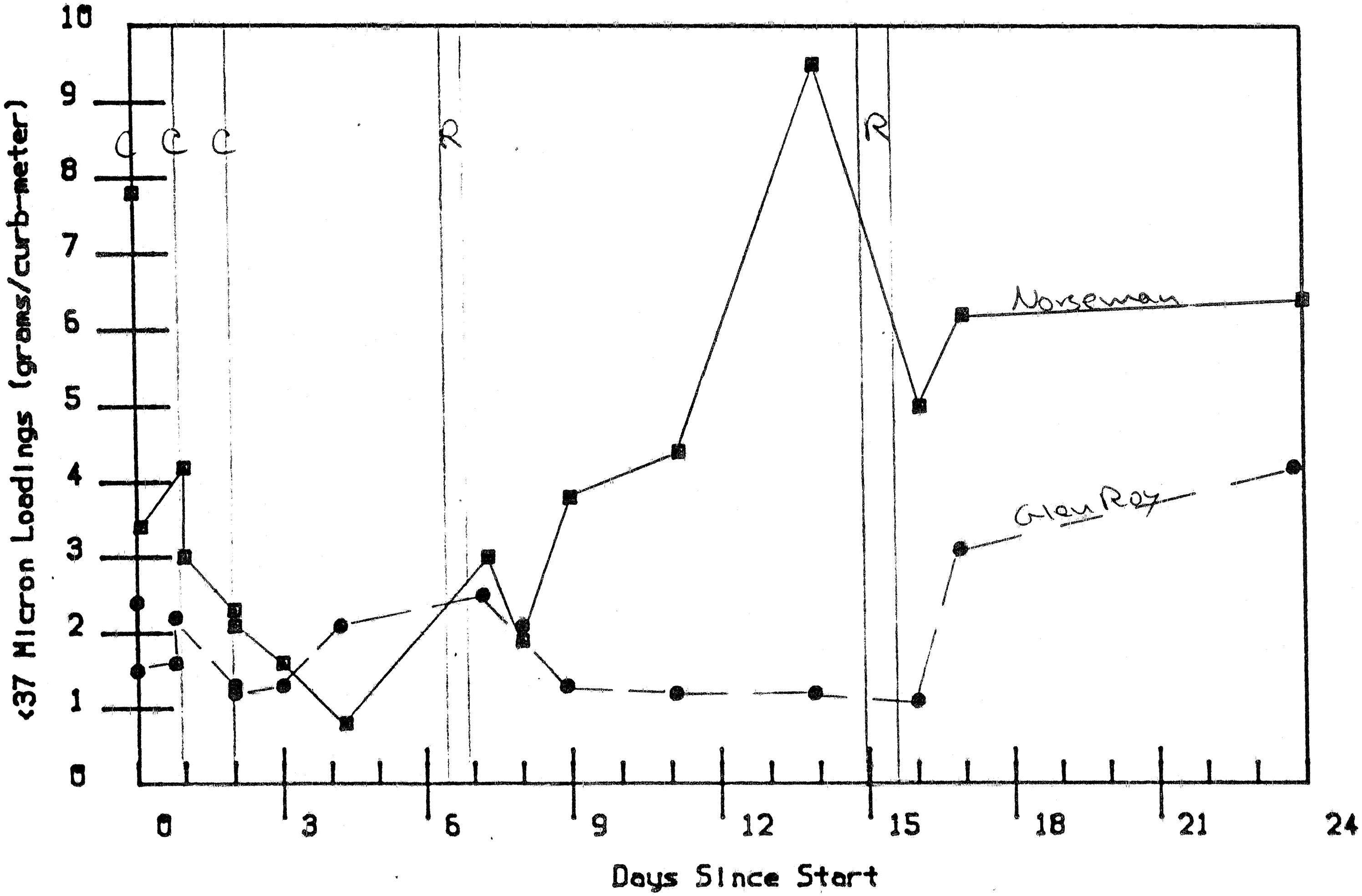


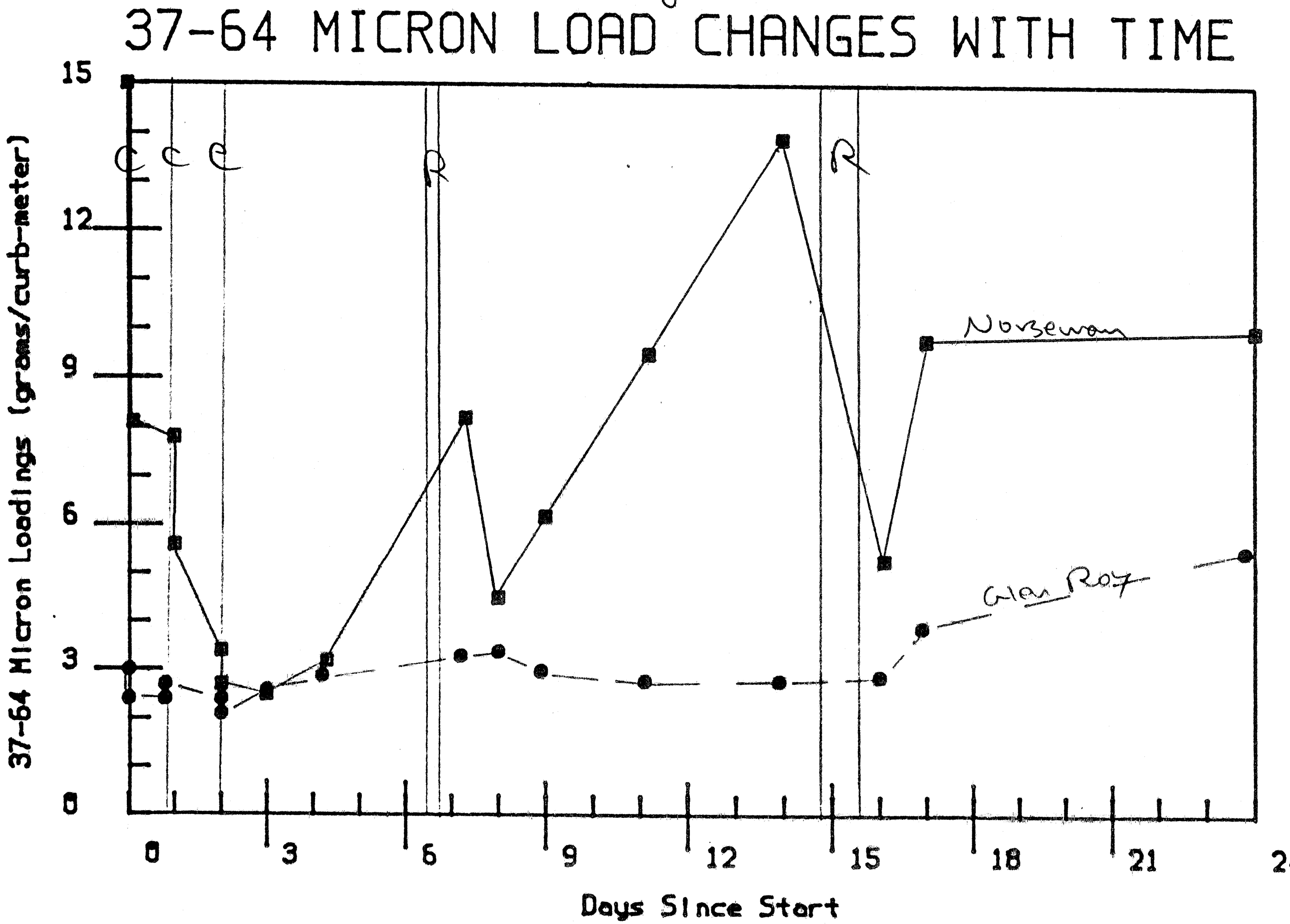
Figure F.45

<37 MICRON PARTICLE LOAD CHANGES WITH TIME



512-184
LT37
C-LT37A
NLT37A

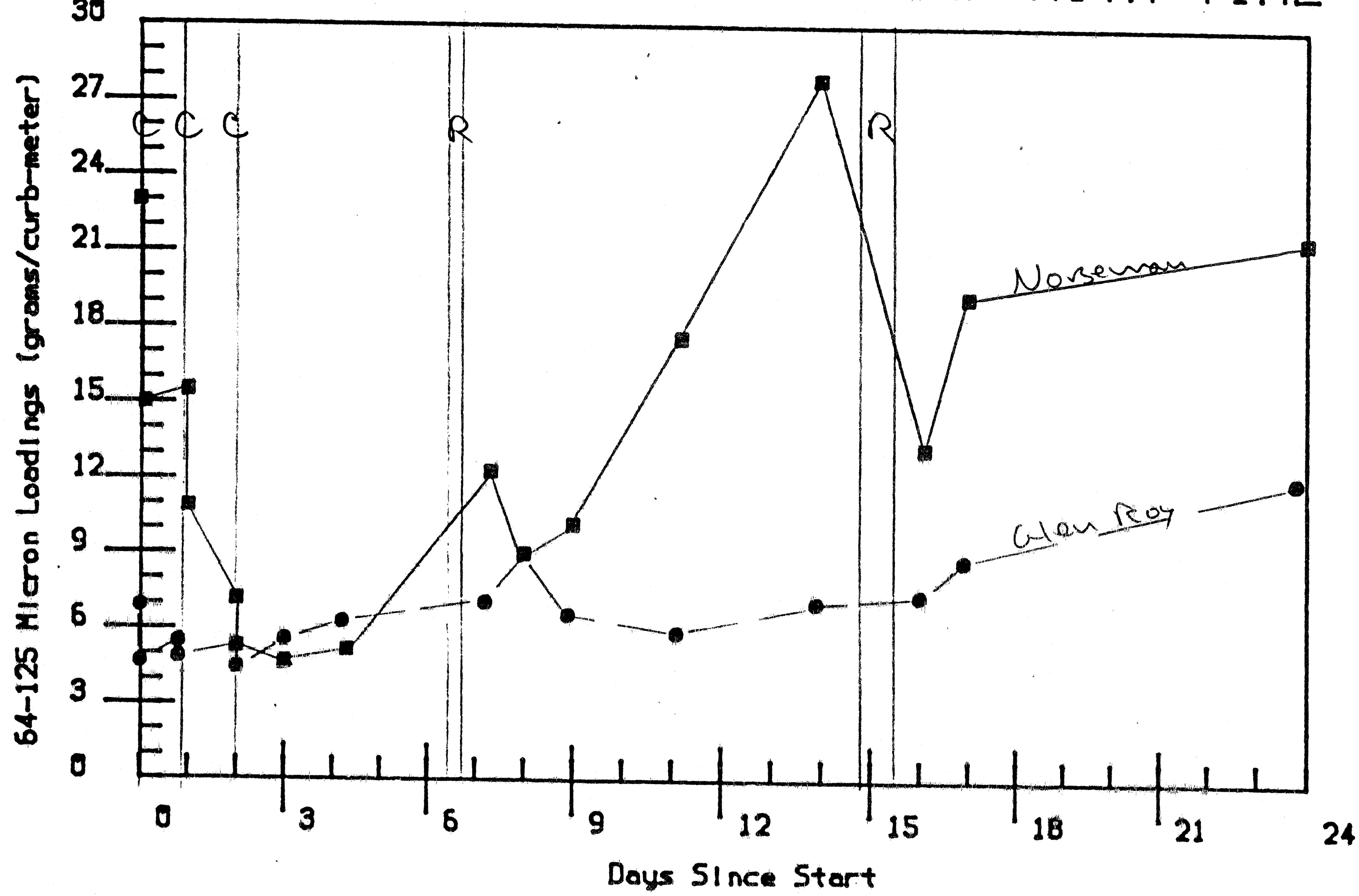
Figure F.4's



5/27/84
A 3764
G 3764A
N 3764A

Figure F.47

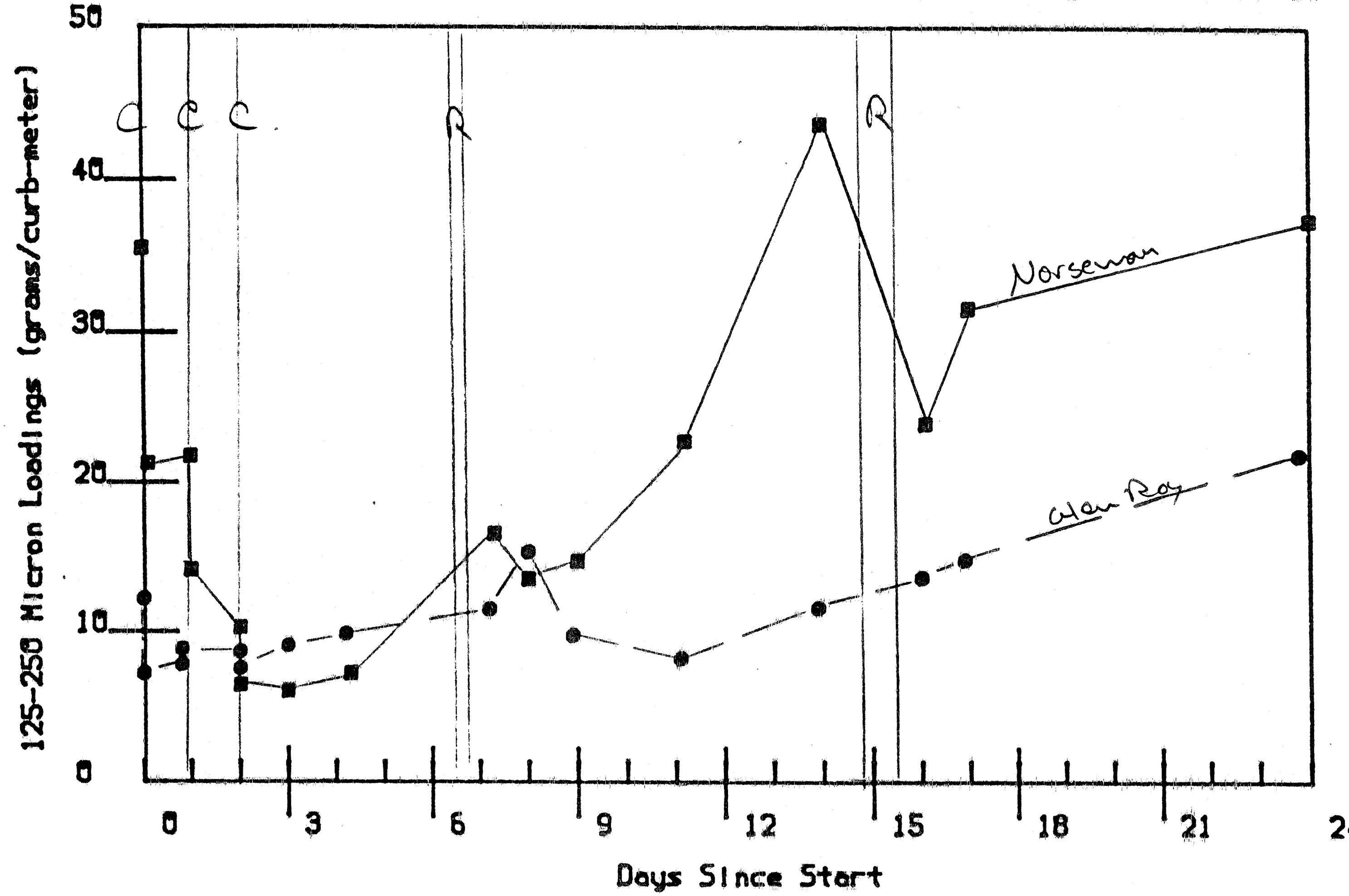
64-125 MICRON LOAD CHANGES WITH TIME



5727184
A64125
G64125A
N64125A

Figure F.48

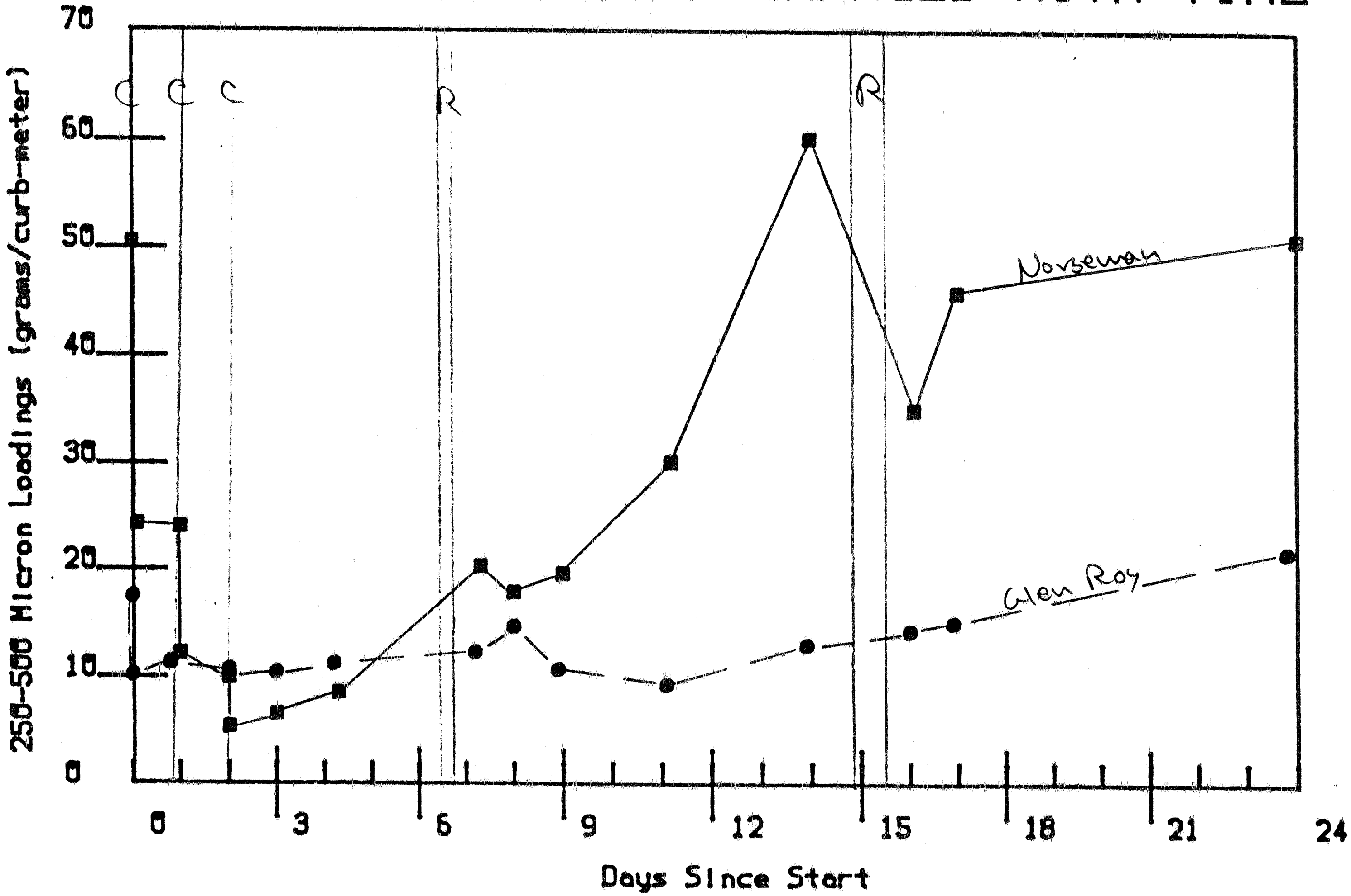
125-250 MICRON LOAD CHANGES WITH TIME



572784
A125250
G-125250A
N125250A

Figure F. 49

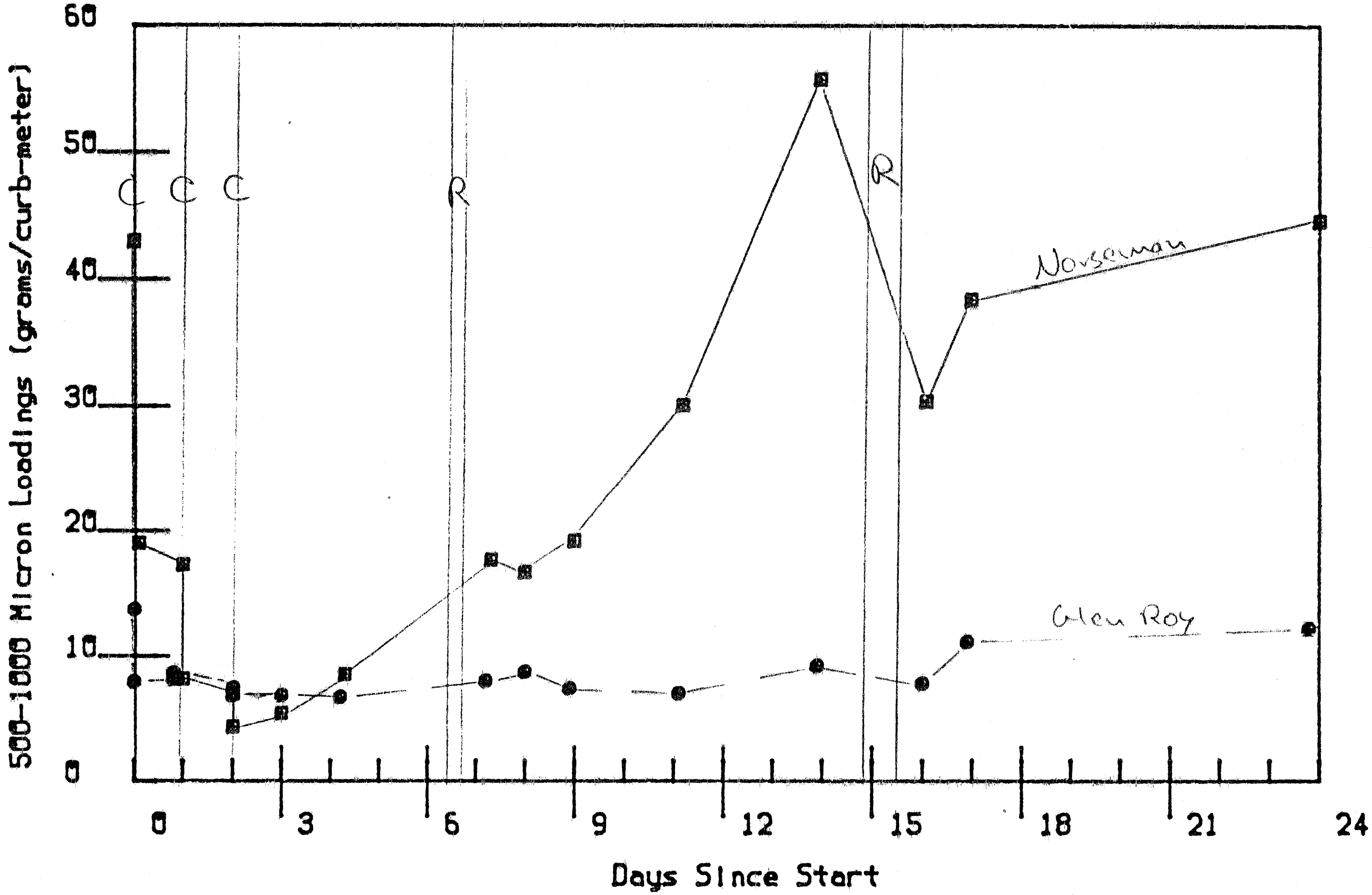
250-500 MICRON LOAD CHANGES WITH TIME



5/27/84
A 250500
G-250500A
N 250500A

Figure F.50

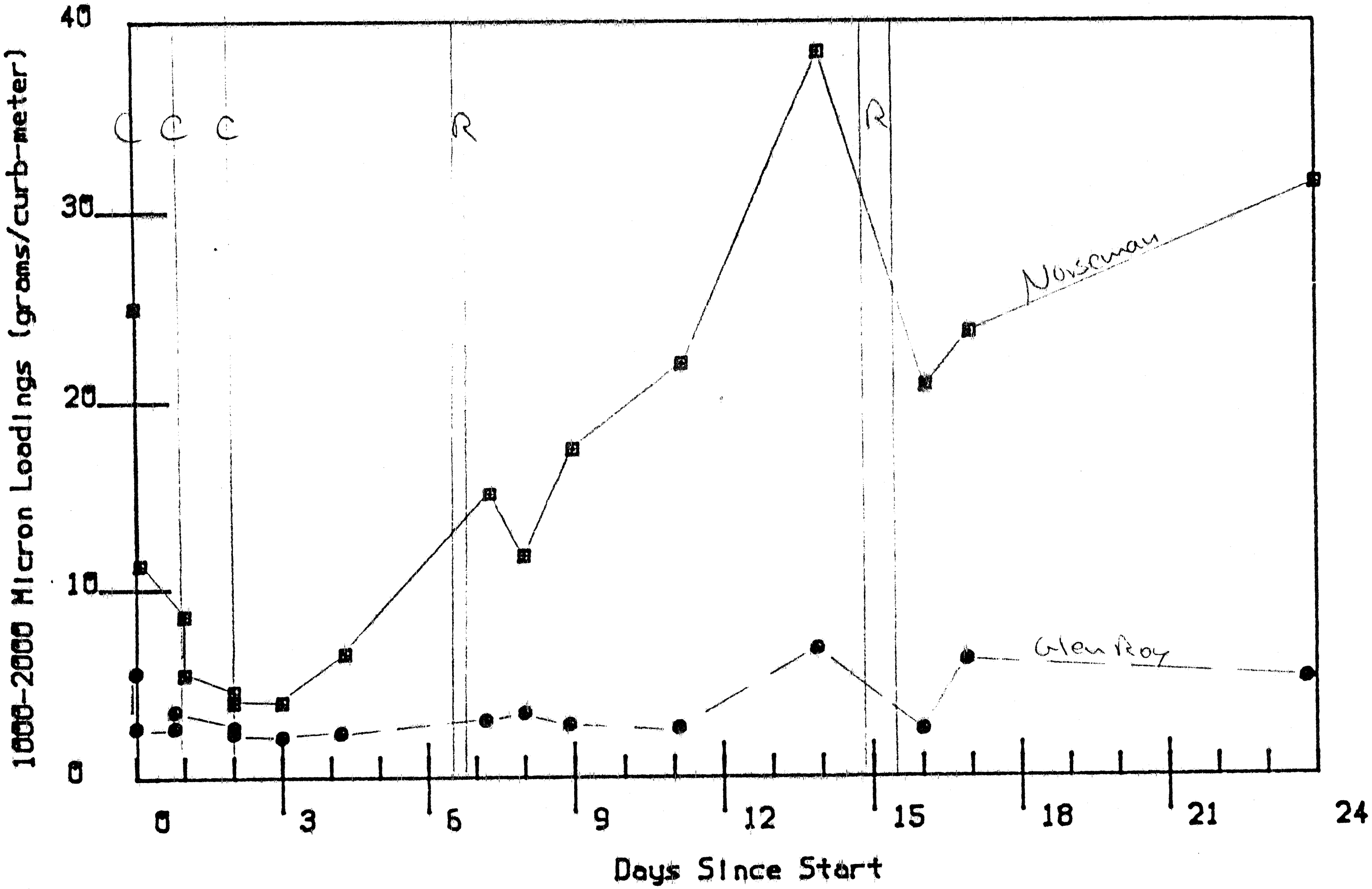
500-1000 MICRON LOAD CHANGES WITH TIME



5/27/84
A 500100 0
G 500100A
N 500100A

Figure F.51

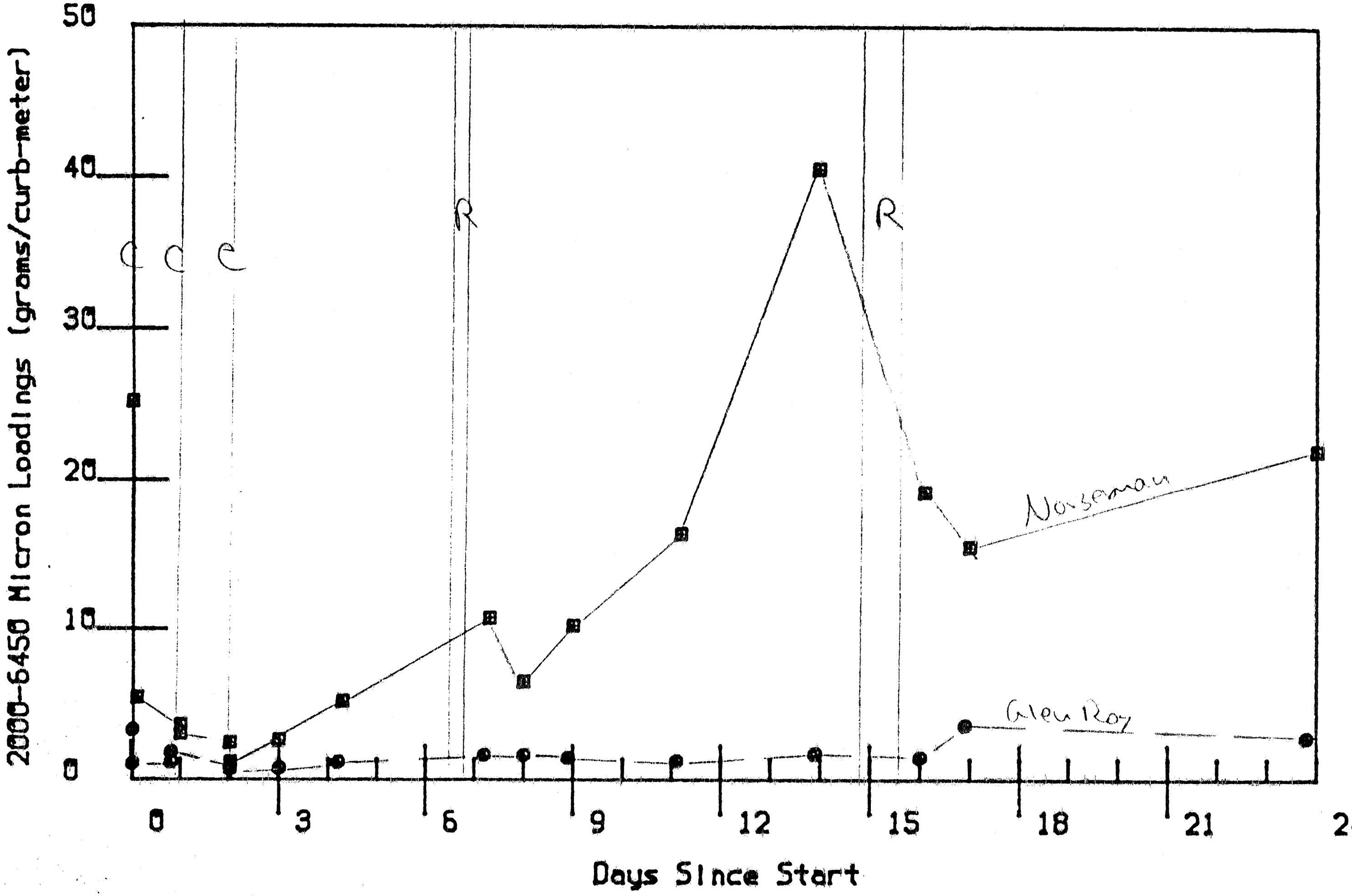
1000-2000 MICRON LOAD CHANGES WITH TIME



5/27/84
A 1000200
G 1020CA
N 1120COA

Figure F.52

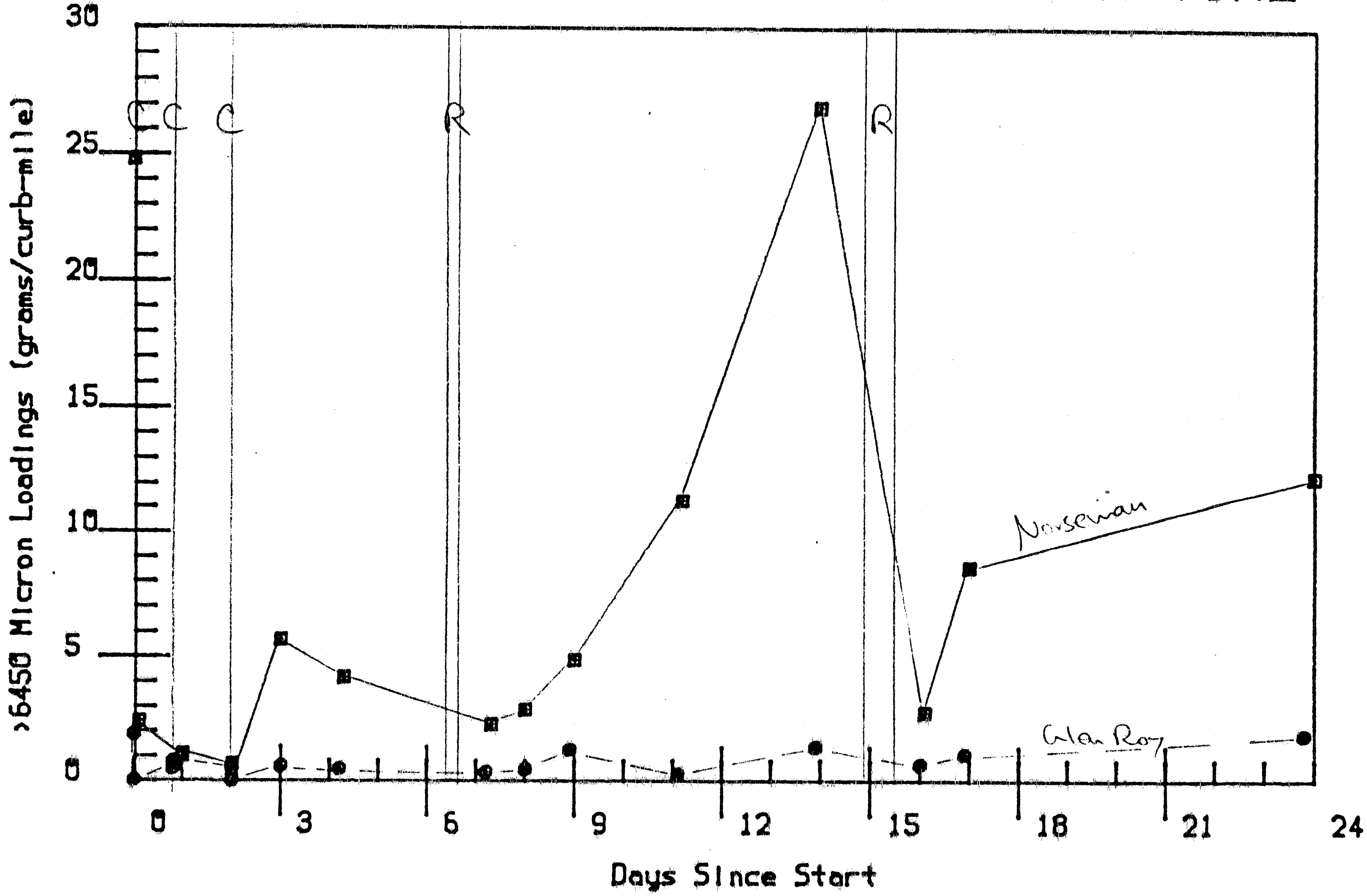
2000-6450 MICRON LOAD CHANGES WITH TIME



5127184
N2006a5A
G2006a5A
A2006a5

Figure F.53

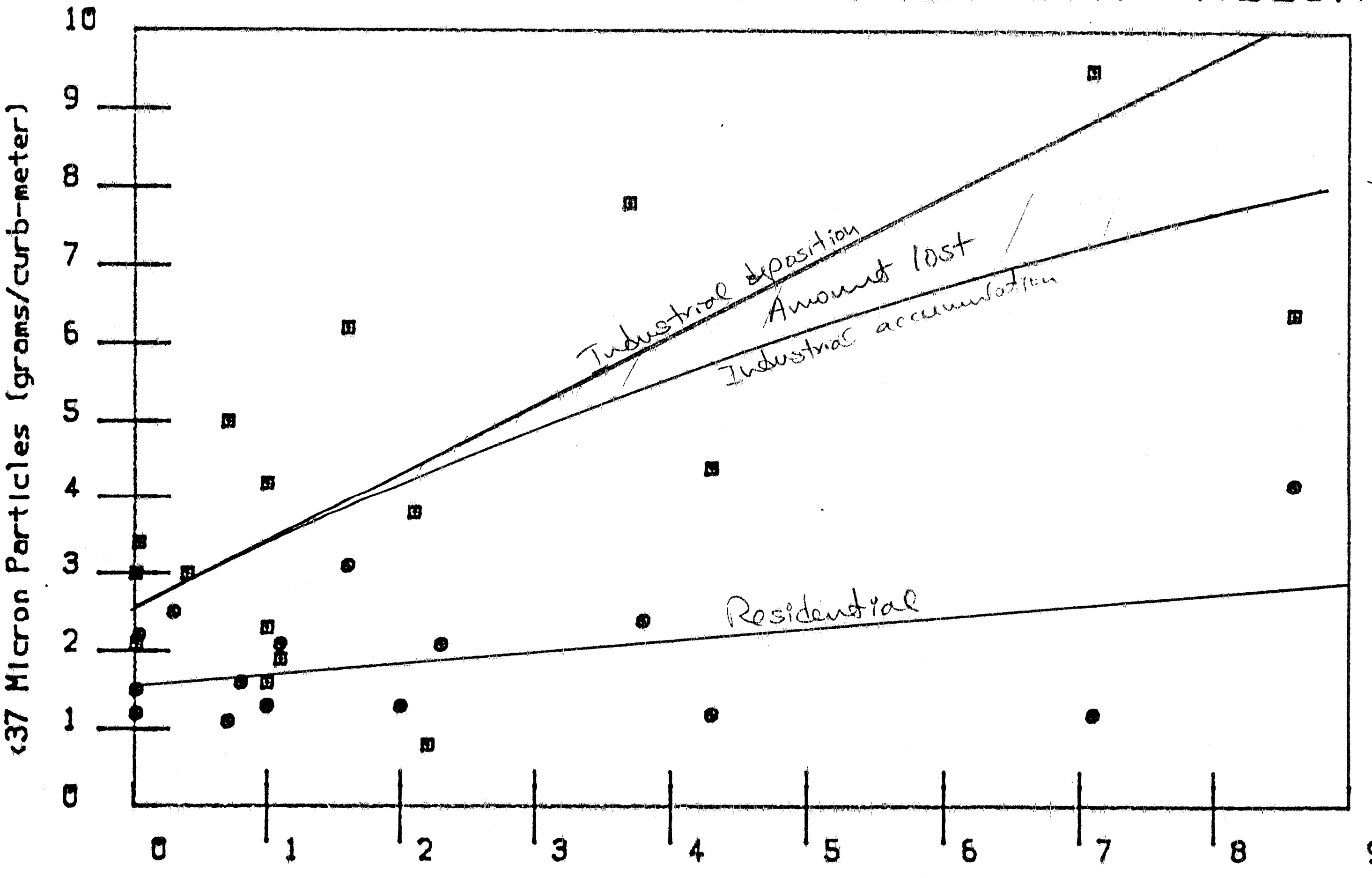
>6450 MICRON LOAD CHANGES WITH TIME



5127184
ACT6450
C-CT64A
NCT64A

Figure F.54

<37 MICRON PARTICLE STREET DIRT ACCUM.



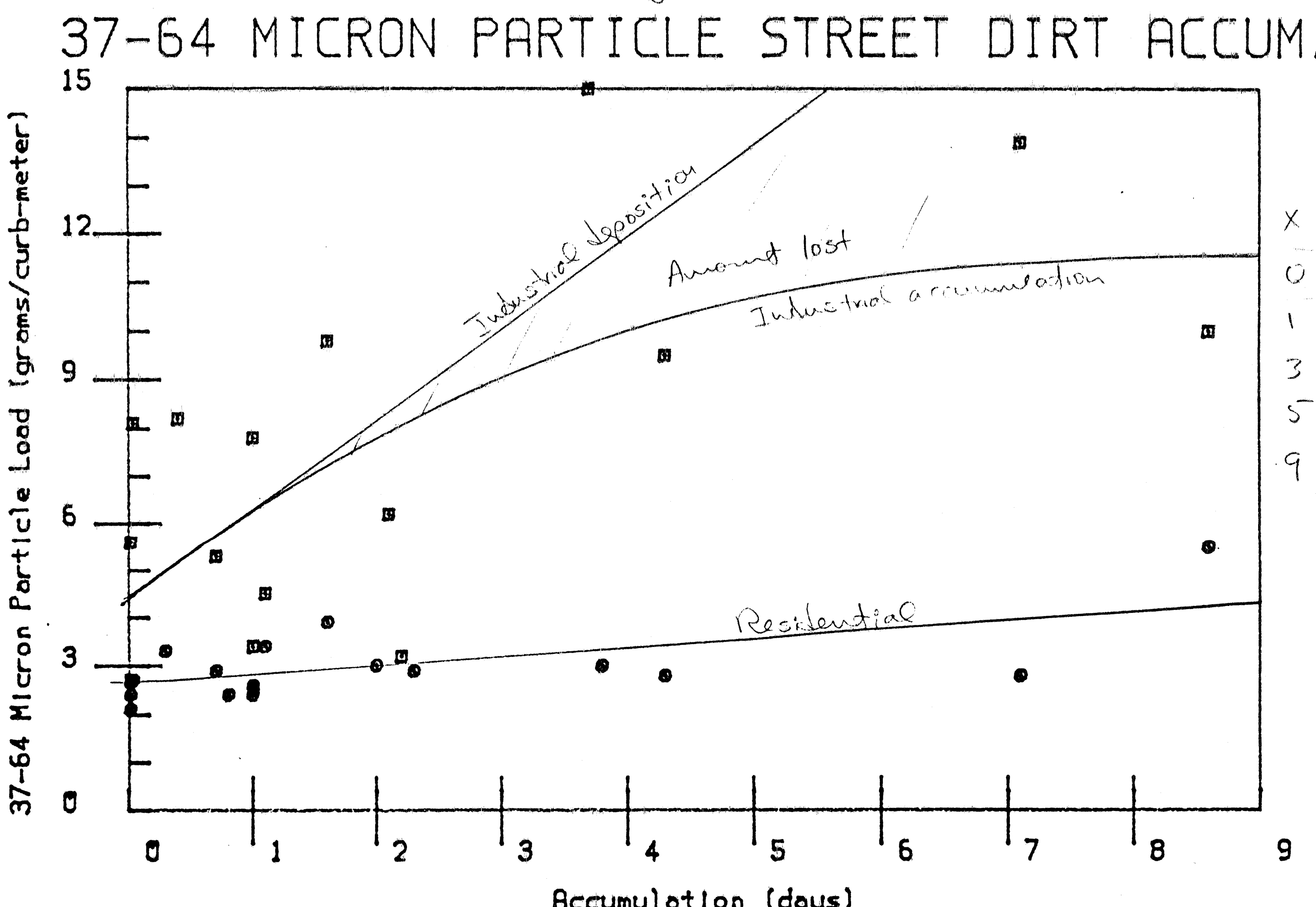
X	$\hat{Y}_I$	$\hat{Y}_R$
0	2.5	1.6
1	3.4	1.7
3	4.9	2.0
5	6.2	2.3
9	8.1	2.9

□ Industrial: $\hat{Y} = 2.49 + 0.89X - 0.03X^2$; $R^2 = 0.47$

○ Residential: $\hat{Y} = 1.60 + 0.14X$; $R^2 = 0.17$

5730184
AC-LT37
ANLT37

Figure F.55



X	$\hat{Y}_I$	$\hat{Y}_R$
0	4.4	2.6
1	6.2	2.8
3	9.0	3.2
5	10.8	3.5
9	11.6	4.3

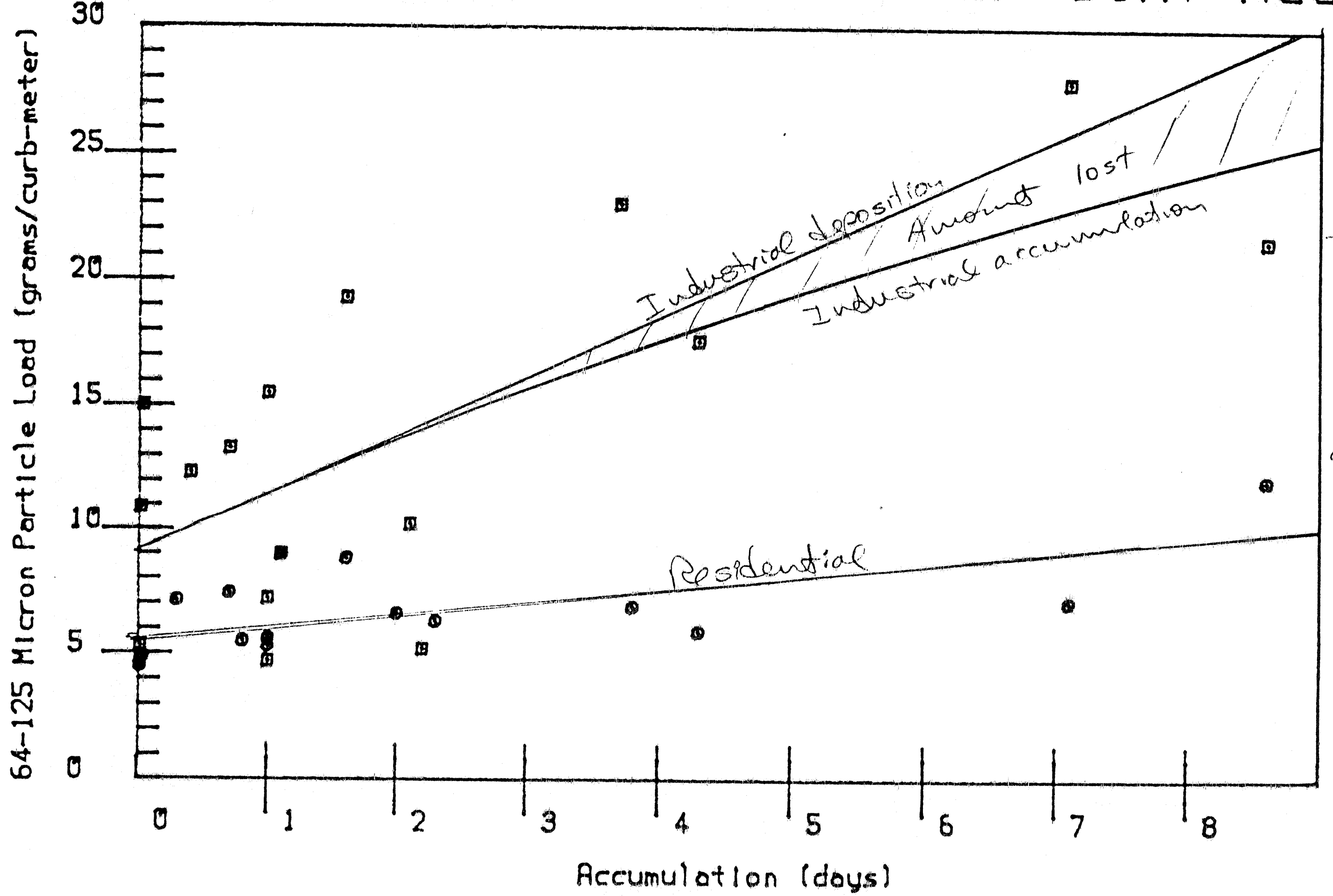
□ Industrial: $\hat{Y}_I = 4.42 + 1.88X - 0.12X^2$; $R^2 = 0.43$

○ Residential: $\hat{Y}_R = 2.58 + 0.19X$; $R^2 = 0.39$

5/30/86
HG-3764
AN 3764

Figure F.56

64-125 MICRON PARTICLE STREET DIRT ACCUM.



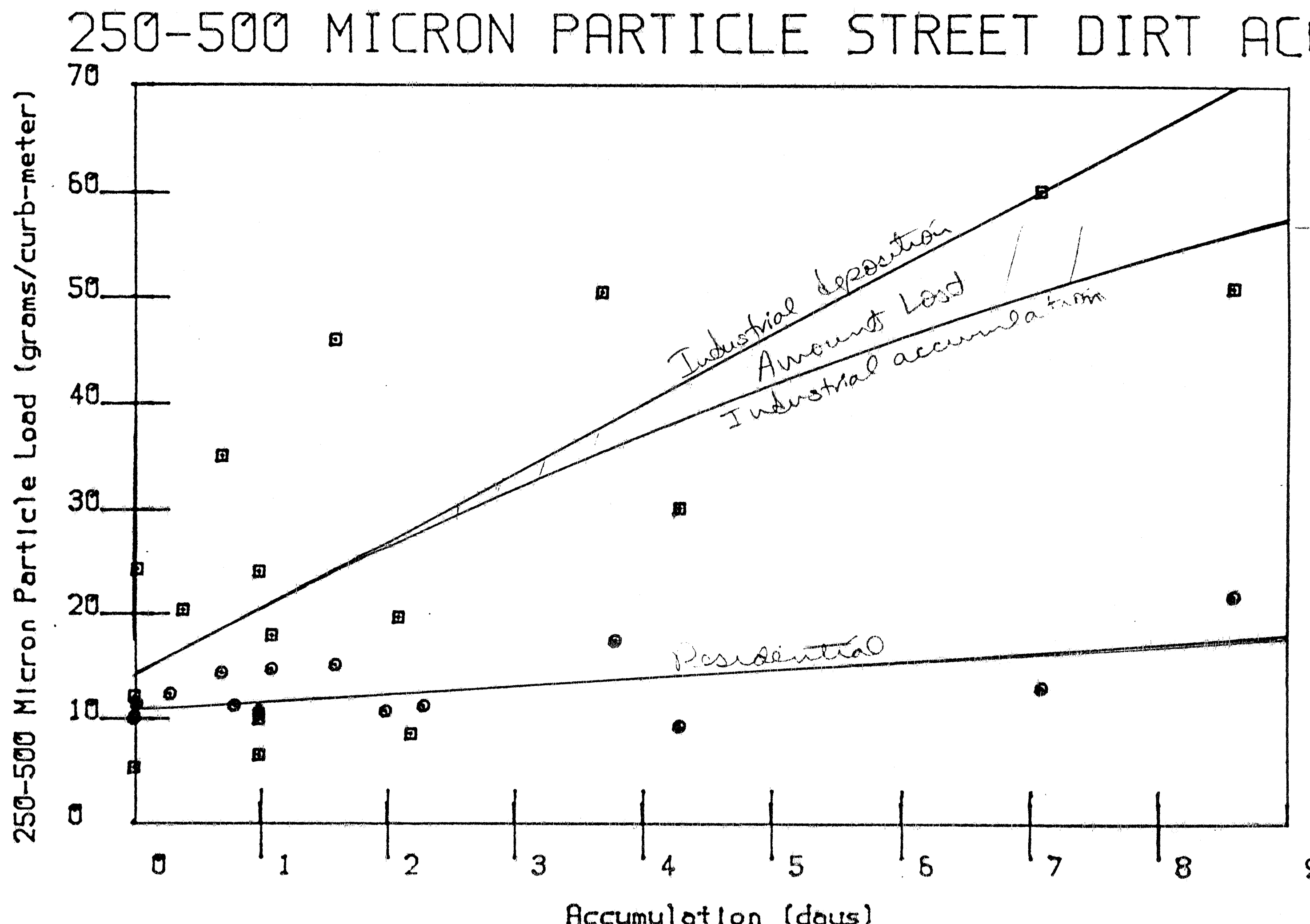
x	$\hat{Y}_I$	$\hat{Y}_R$
0	9.1	5.7
1	11.4	6.2
3	15.6	7.1
5	19.4	8.1
9	25.5	10.0
	30.3	

□ Industrial; $\hat{Y}_I = 9.09 + 2.36x - 0.06x^2$; $R^2 = 0.50$

○ Residential; $\hat{Y}_R = 5.69 + 0.48x$; $R^2 = 0.40$

5130184
AG64125
AN64125

Figure F.58



X	$\hat{Y}_I$	$\hat{Y}_R$
0	14.2	11.1
1	20.5	11.9
3	32.0	13.4
5	42.0	15.0
9	57.3	18.1
	(72.7)	

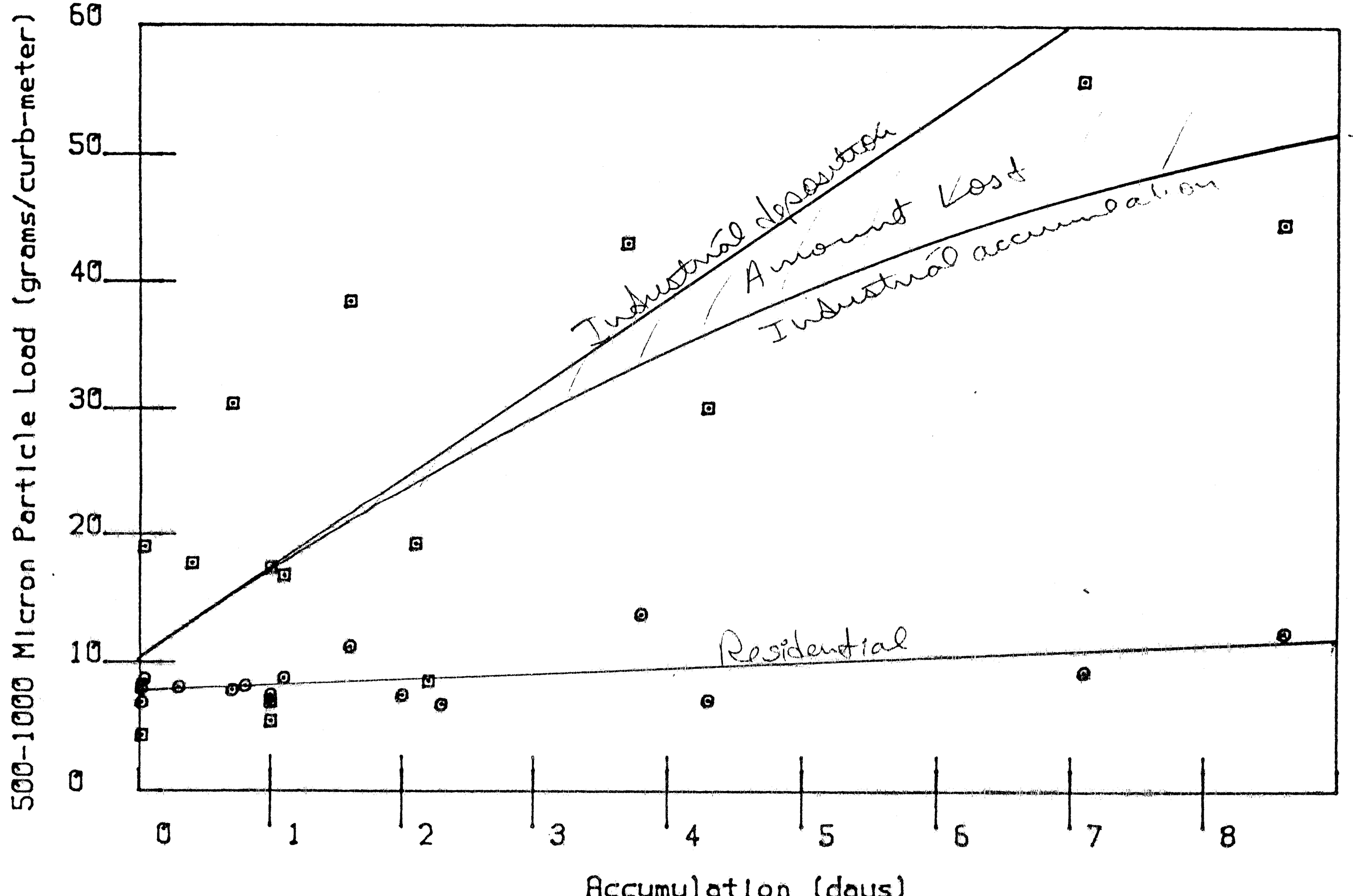
□ Industrial, $\hat{Y}_I = 14.2 + 6.5X - 0.19X^2$; $R^2 = 0.54$

○ Residential, $\hat{Y}_R = 11.1 + 0.78X$; $R^2 = 0.37$

5130184
AC-250500
AN250500

Figure F.59

500-1000 MICRON PARTICLE STREET DIRT ACCUM



X	$\hat{Y}_I$	$\hat{Y}_R$
0	10.5	7.8
1	17.3	8.2
3	29.3	9.1
5	39.0	9.9
9	51.7	11.6
	(74.4)	

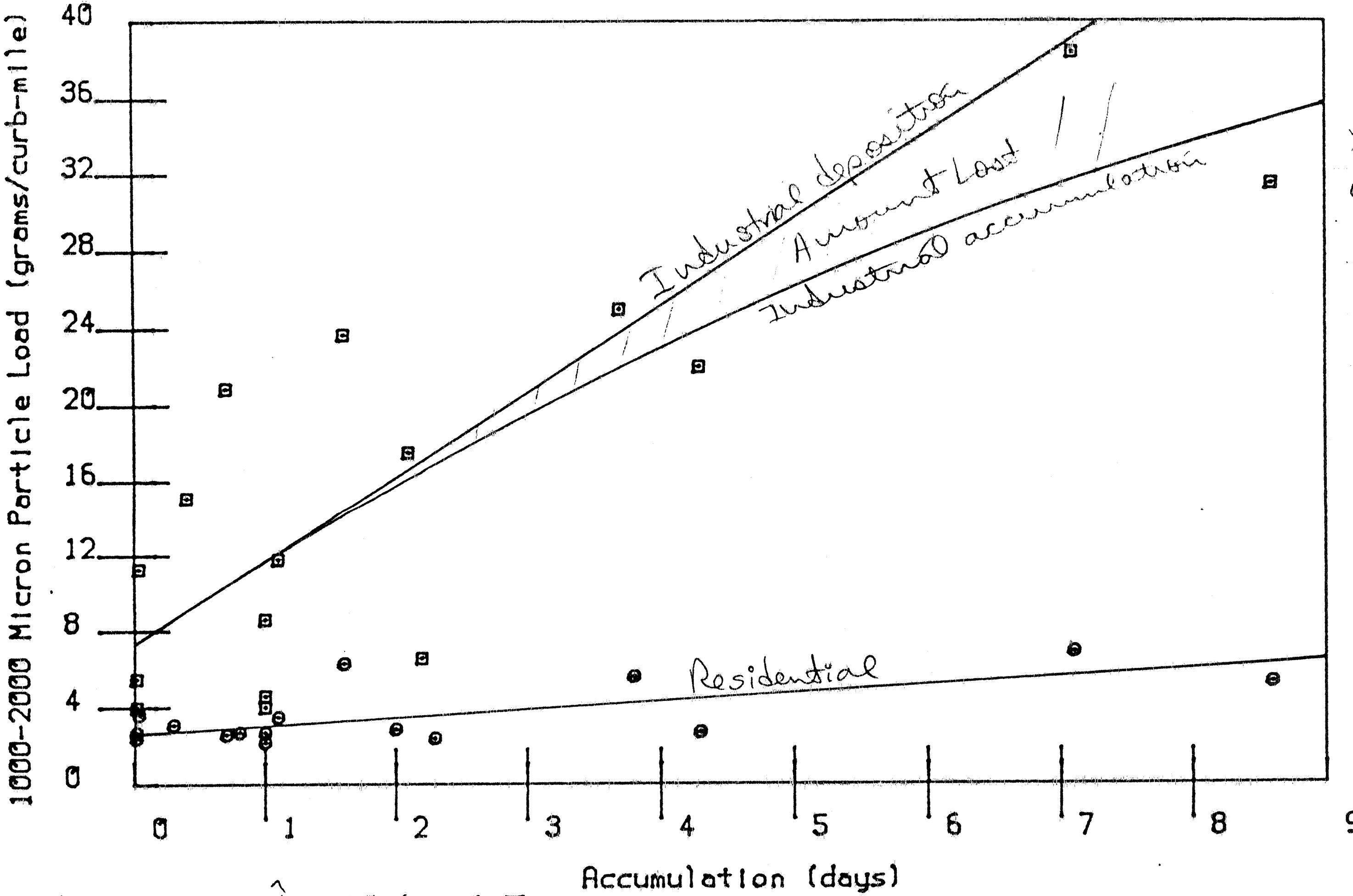
□ Industrial; $\hat{Y}_I = 10.5 + 7.1X - 0.28X^2$; $R^2 = 0.61$

○ Residential; $\hat{Y}_R = 7.8 + 0.42X$; $R^2 = 0.28$

5130184
AG500100
NG500100

Figure F.60

1000-2000 MICRON STREET DIRT ACCUMULATION



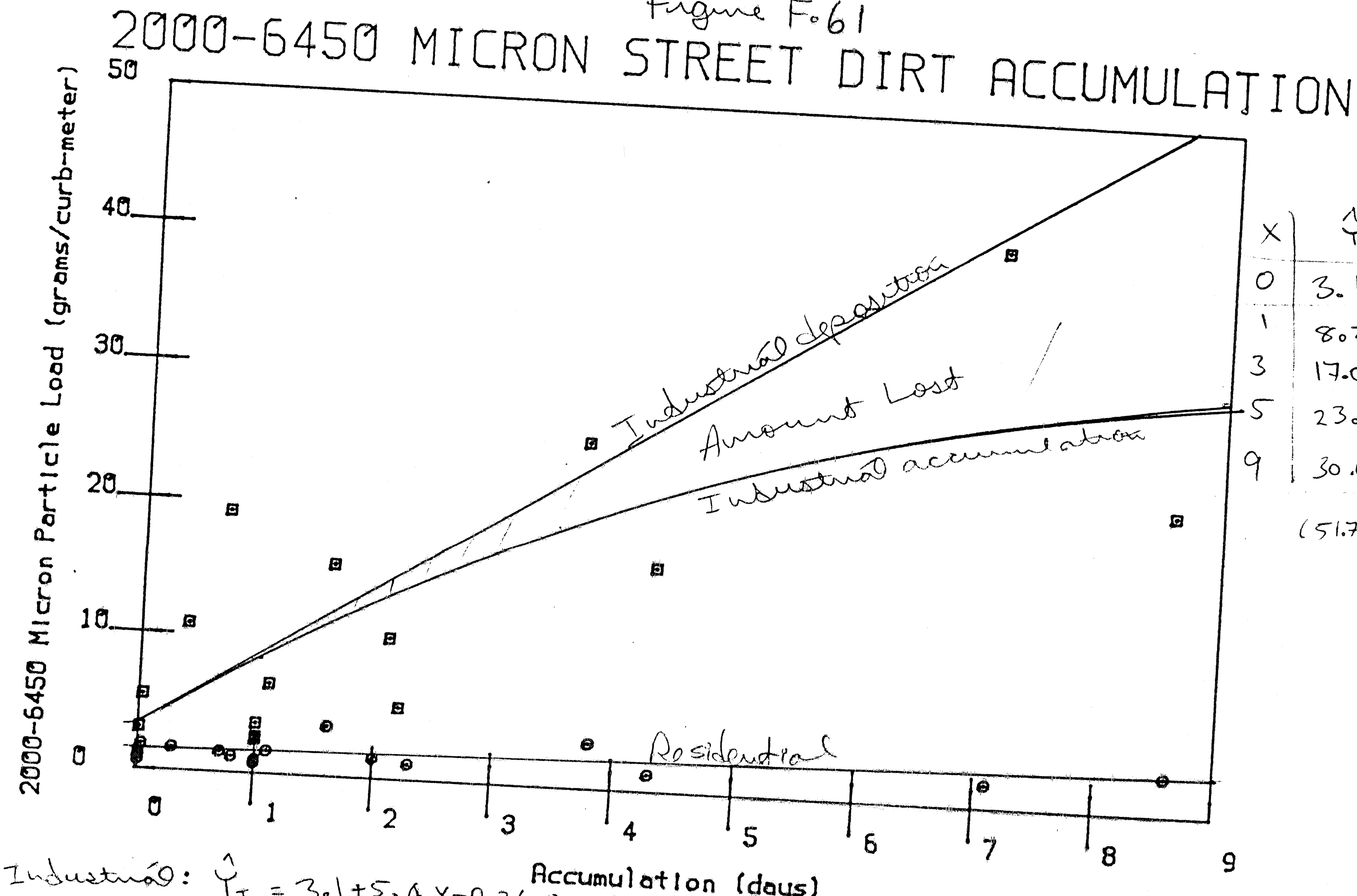
X	$\hat{Y}_I$	$\hat{Y}_R$
0	7.4	2.7
1	11.8	3.1
3	19.6	3.9
5	26.2	4.7
9	35.8 (47.9)	6.2

□ Industrial ; $\hat{Y}_I = 7.4 + 4.5X - 0.15X^2$; $R^2 = 0.66$

○ Residential ; $\hat{Y}_R = 2.7 + 0.39X$; $R^2 = 0.42$

5730134
AG-100020
NG-100020

Figure F.61



X	$\hat{Y}_I$	$\hat{Y}_R$
0	3.1	1.4
1	8.2	1.6
3	17.0	1.9
5	23.6	2.2
9	30.6	2.8

(51.7)

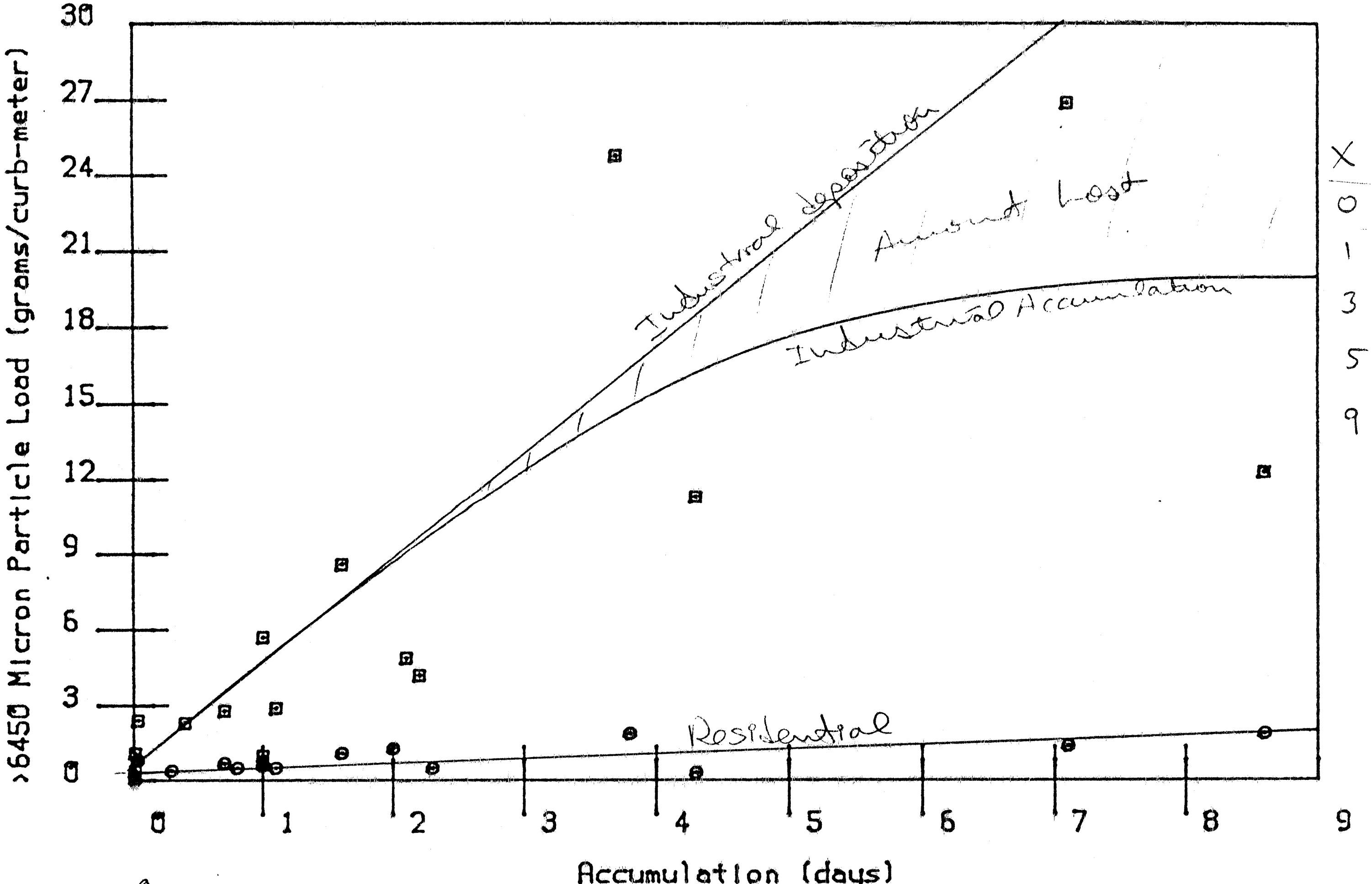
□ Industrial: $\hat{Y}_I = 3.1 + 5.4X - 0.26X^2$; $R^2 = 0.62$

○ Residential: $\hat{Y}_R = 1.4 + 0.15X$; $R^2 = 0.19$

5730/84
AG200064
NG200064

Figure F-62

>6450 MICRON PARTICLE STREET DIRT ACCUM.

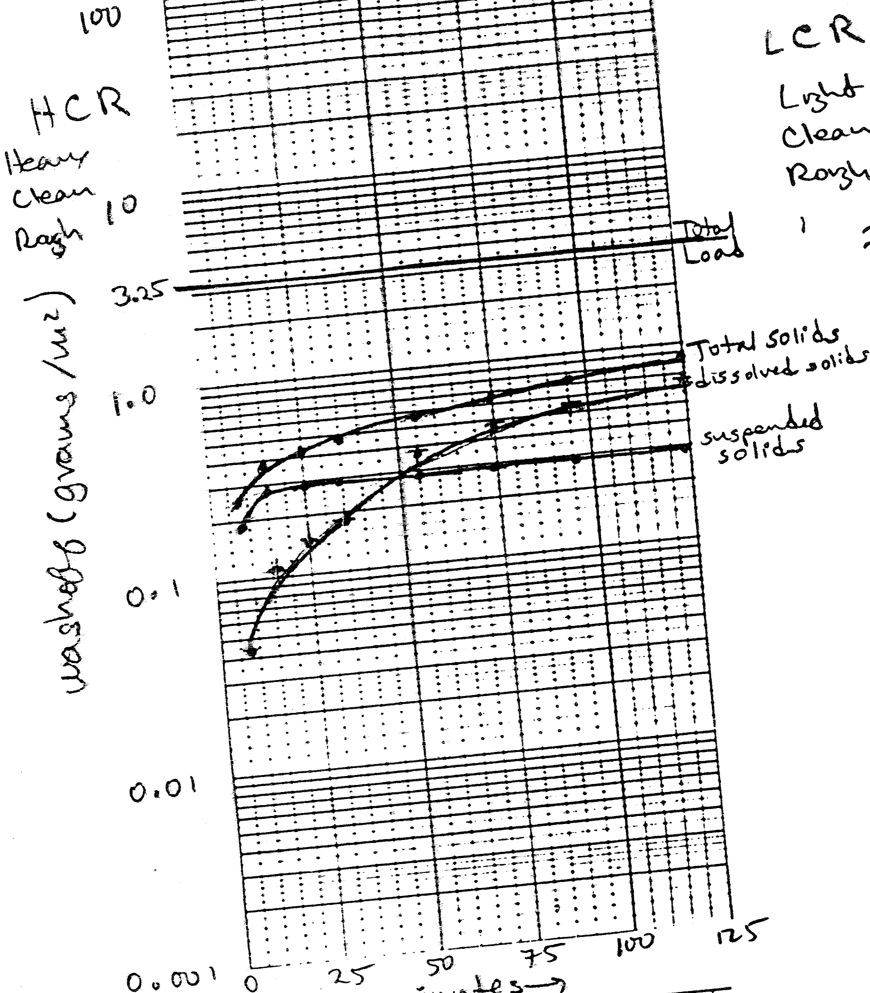


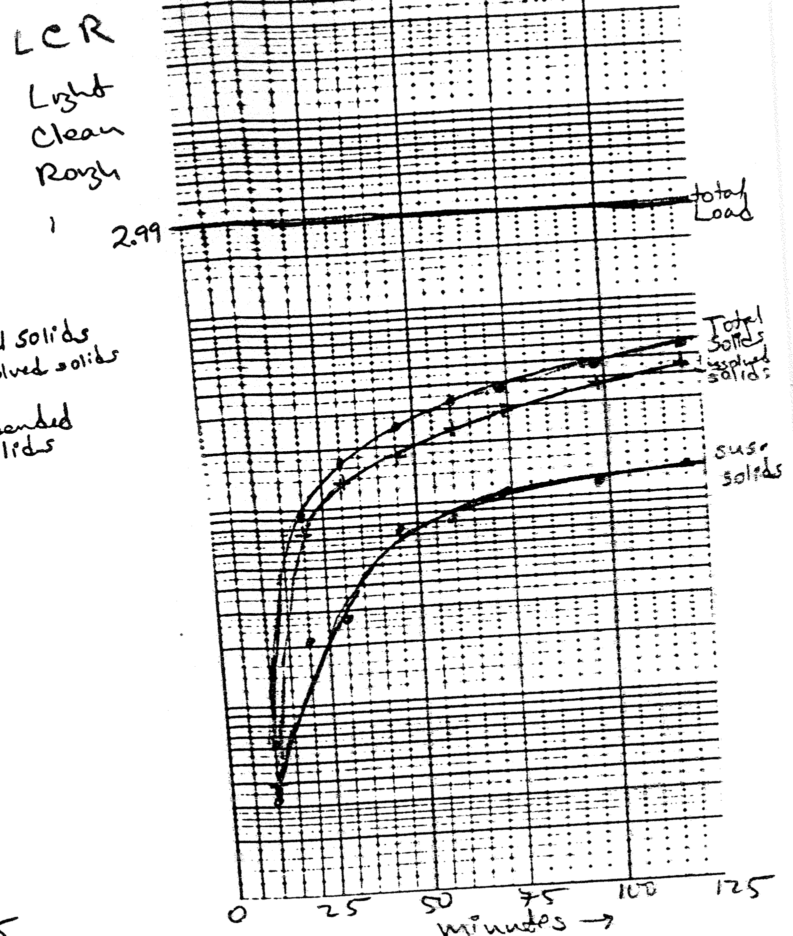
X	$\hat{Y}_I$	$\hat{Y}_R$
0	"1"	0.4
1	"5"	0.6
3	12.5	0.9
5	"20"	1.2
9	"20"	1.9
	(51.9)	

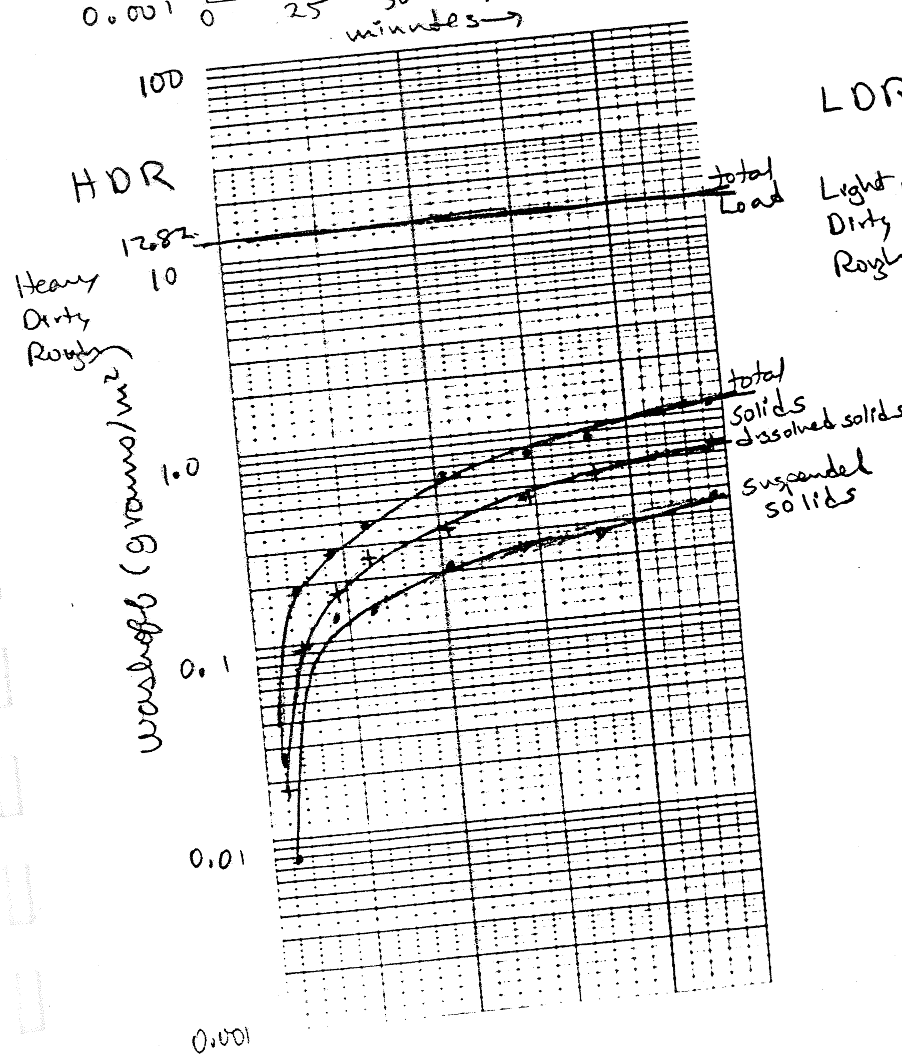
□ Industrial: $\hat{Y}_I \doteq -1.2 + 5.9x - 0.44x^2$; $R^2 = 0.68$

○ Residential: $\hat{Y}_R = 0.44 + 0.16x$; $R^2 = 0.50$

5/30/84
ACGT6450
ANGT64


HCR
Heavy Clean Rough
100
10
3.25
1.0
0.1
0.01
0.001
Total Load
Total solids
dissolved solids
suspended solids
washoff (grams/m²)
0
25
50
75
100
125
minutes→


LCR
Light Clean Rough
2.99
total Load
Total Solids
dissolved solids
sus. solids
0
25
50
75
100
125
minutes →


HDR
Heavy Dirty Rough
100
12.82
10
1.0
0.1
0.01
0.001
total Load
total solids
dissolved solids
suspended solids
washoff (grams/m²)

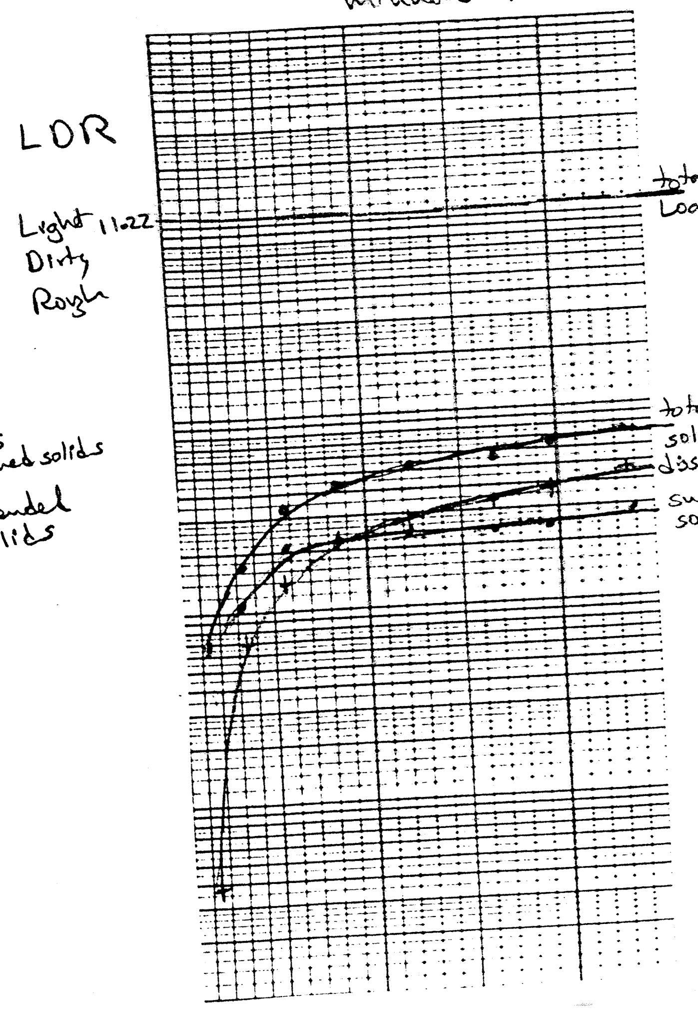
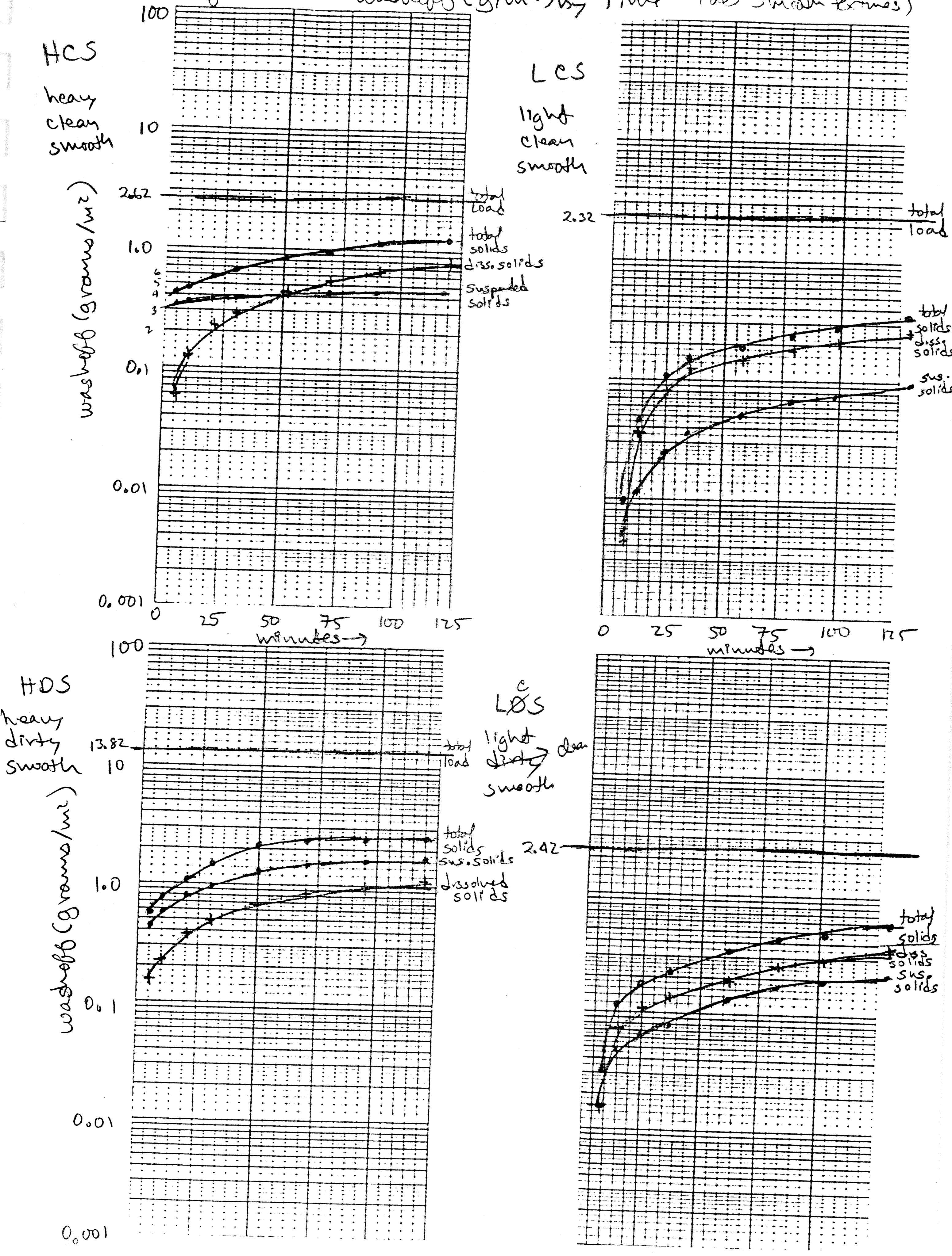

LDR
Light Dirty Rough
11.22
total Load

Figure F.6? washoff (g/m²) by Time (all smooth textures)



Parameter: Avail. Load as a % of Total Load

Constituent: Total Solids

codes:
I: H+ L-
C: D+ C-
T: R+ S-

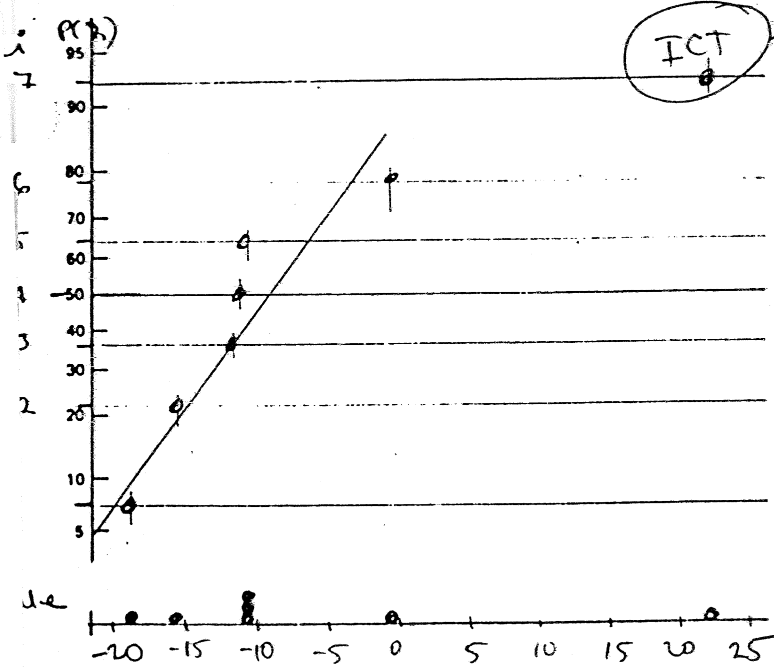
2×3 Factorial Analyses

(divide by 4) Table of Contrast Coefficients:

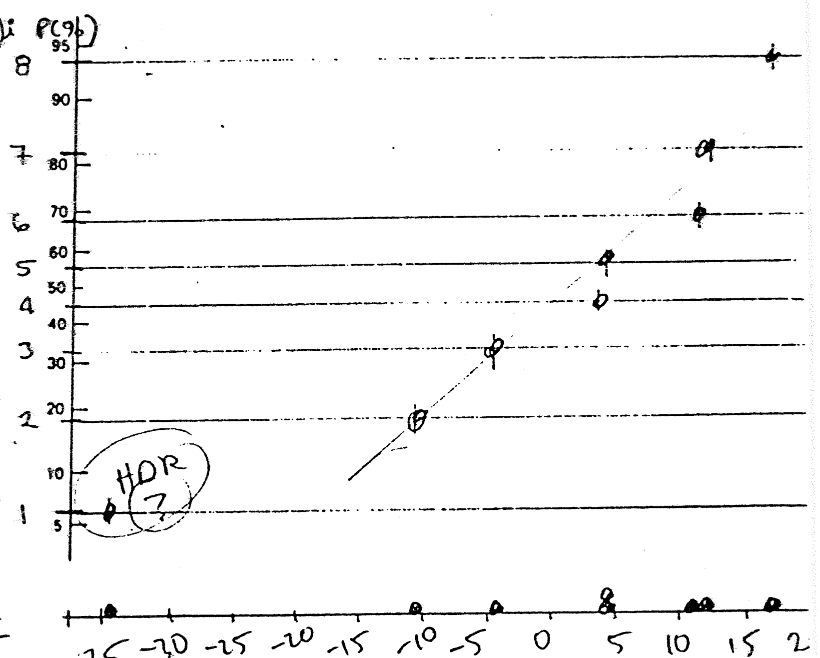
run#	I	C	T	IC	IT	CT	ICT	value	code	model value	residual
1	+	−	+	−	+	−	−	28	HCR	24	4
2	−	−	+	+	−	−	+	50	LCR	46	4
3	+	+	+	+	+	+	+	12	HDR	46	−34
4	−	+	+	−	−	+	−	13	LDR	24	−11
5	+	−	−	−	−	+	+	58	HCS	46	12
6	−	−	−	+	+	+	−	35	LCS	24	11
7	+	+	−	+	−	−	−	20	HDS	24	−4
8	−	+	−	−	+	−	+	63	LDS	46	17
effect =	−11	−16	−18	−11	−0.8	−11	22	$\bar{X}=35$			
rank of effects (w/o mean)	3	2	1	4	6	5	7				

−18 → 22   −34 → 17

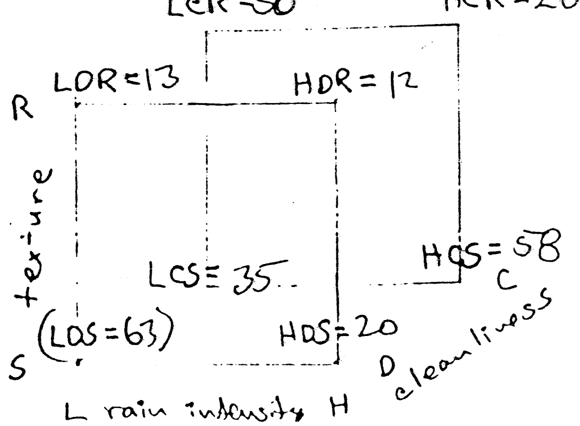
Normal Plot of Factorial Effects:



Normal Plot of Residuals:



2^3 factorial design:



Factorial Model:

(cleanliness)

$\hat{Y} = 35 + \left(\frac{22}{2}\right) ICT$

$\hat{Y} = 35 \pm 11\ ICT$

$\hat{Y} = 24; 46$

Washoff Experiment as a Series of 2^2 Runs (to eliminate LDS)

Available Load as a % of Total Load

I: H+ L−
C: D+ C−
T: R+ S−

replicate codes	I	C	IC	values	s^2	df	ave value
LCR, LCS	−	−	+	50, 35	112.5	1	43
HCR, HCS	+	−	−	28, 58	450	1	43
LDR	−	+	−	13	—	0	13
HDR HDS	+	+	+	12, 20	32	1	16
	1.5	−29	1.5	31	594.5	3	

N=6 for replicates

pooled $s^2 = \frac{594.5}{3} = 198.17$

$V(\text{effect}) = \frac{4}{N}\sigma^2 = \frac{4}{6}(198.17) = 132.11$

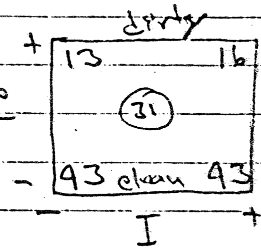
$SE = \sqrt{V} = 11.49$

Average = 31 ± 5.75

I = 1.5 ± 11.5

C = −29 ± 11.5

IC = 1.5 ± 11.5



$\hat{Y} = 31 - 15(C)$

$\hat{Y}$ = 16%; 46%
dirty clean

	I	T	IT	values	s^2	df	ave value
LCR, LDR	−	−	+	50, 13	992	1	32
HCS, HDS	+	−	−	58, 20	722	1	39
LCS	−	+	−	35	—	0	35
HCR, HDR	+	+	+	28, 12	128	1	20
	−4	−8	−11	31	1842	3	

$s^2 = \frac{1842}{3} = 614$

$V = \frac{4}{N}\sigma^2 = \frac{4}{6}(614) = 921$

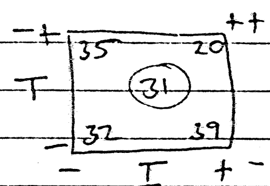
$SE = \sqrt{V} = 30$

Average = 31 ± 15

I = −4 ± 30

T = −8 ± 30

IT = −11 ± 30



$\hat{Y}$ = 31%

	C	T	CT	values	s^2	df	ave value
CS, LCS	−	−	+	58, 35	265	1	47
HDS	+	−	−	20	—	0	20
CR, LCR	−	+	−	28, 50	242	1	39
HDR, LDR	+	+	+	12, 13	0.5	1	13
	−26.5	−7.5	0.5	31	507.5	3	

$s^2 = \frac{507.5}{3} = 169$

$V = \frac{4}{N}\sigma^2 = \frac{4}{6}(169) = 254$

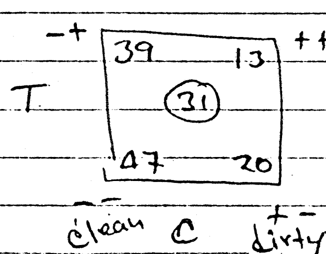
$SE = \sqrt{V} = 16$

Average = 31 ± 8

C = −26.5 ± 16

T = −7.5 ± 16

CT = 0.5 ± 16



$\hat{Y} = 31 - 13(C)$

$\hat{Y}$ = 18; 44
dirty clean

10% if very dirty

$\hat{Y}$ = 17% if dirty (12.6 g/m²) 126 kg/ha $\hat{Y}$ = 45% if clean (2.72 g/m²) 27 kg/ha

Parameter: % washoff @ ~120 min.

Constituent: Total Solids

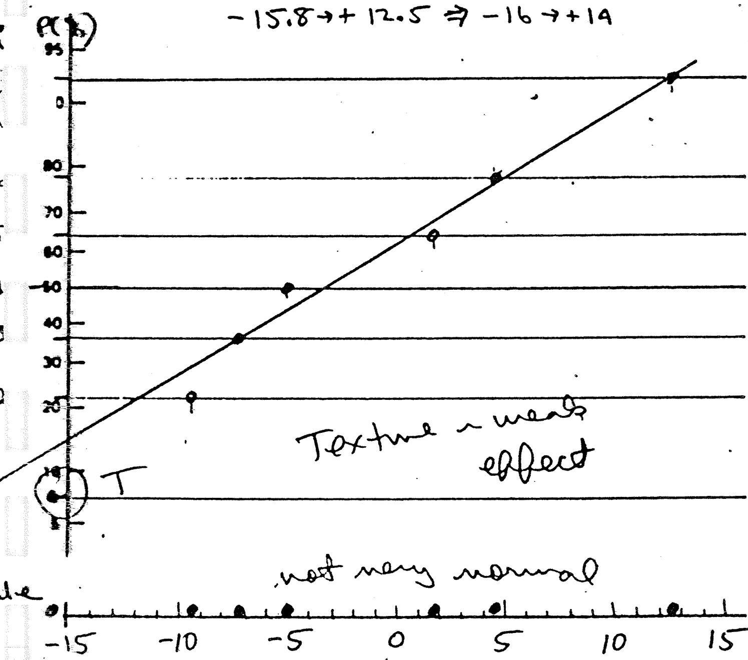
codes:
I: H+ L−
C: D+ C−
T: R+ S−

2x3 Factorial Analyses

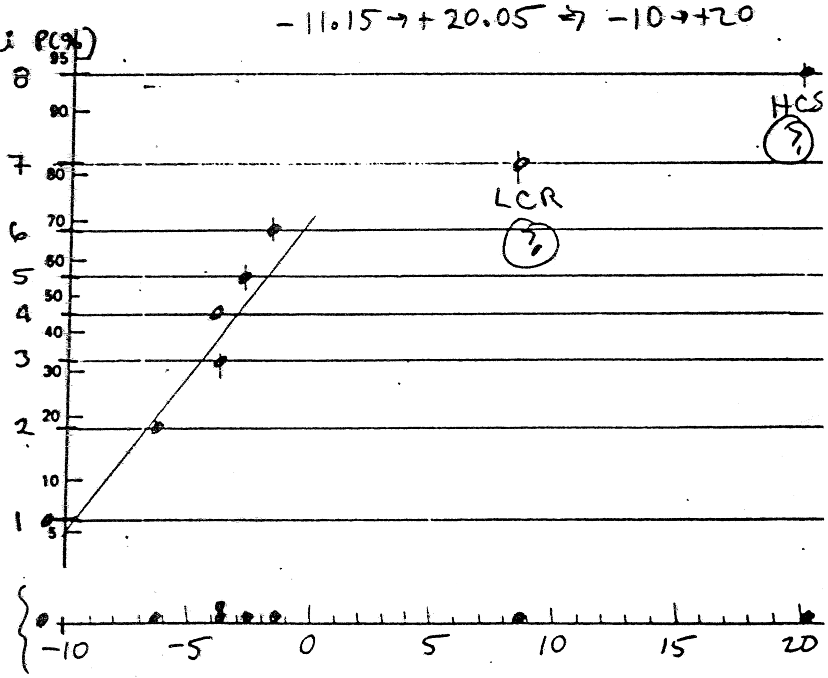
(divide by 4) Table of Contrast Coefficients:

run#	I	C	T	IC	IT	CT	ICT	value (Y)	code	model value ($\hat{Y}$)	resid-ual ($Y-\hat{Y}$)	res rank
1	+	−	+	−	+	−	−	6.6	HCR	10.35	-3.75	4
2	−	−	+	+	−	−	+	19.3	LCR	10.35	8.95	7
3	+	+	+	+	+	+	+	8.9	HDR	10.35	-1.45	6
4	−	+	+	−	−	+	−	6.6	LDR	10.35	-3.75	3
5	+	−	−	−	−	+	+	46.2	HCS	26.15	20.05	8
6	−	−	−	+	+	+	−	15.0	LCS	26.15	-11.15	1
7	+	+	−	+	−	−	−	19.8	HDS	26.15	-6.35	2
8	−	+	−	−	+	−	+	23.6	LDS	26.15	-2.55	5
effect:	4.25	-7.05	-15.80	-5.00	-9.45	1.85	12.50	$\bar{X}$ = 18.25				
rank of effects w/o mean	6	3	1	4	2	5	7					

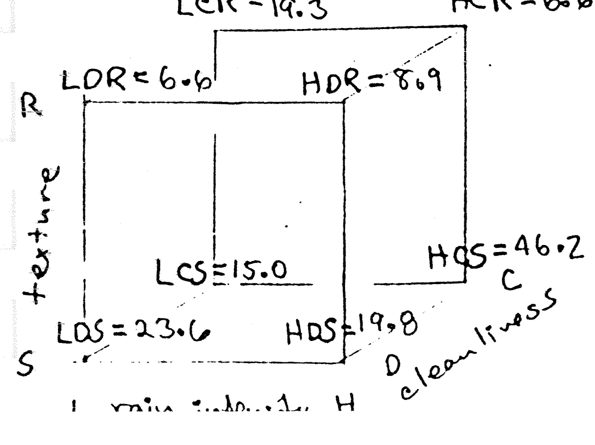
Normal Plot of Factorial Effects:
−15.8 → + 12.5 ⇒ −16 → +14



Normal Plot of Residuals:
−11.15 → + 20.05 ⇒ −10 → +20



2³ factorial design:



Factorial Model:

$$\hat{Y} = 18.25 - \left(\frac{15.80}{2}\right) T$$

$$\boxed{\hat{Y} = 18.25 - 7.9T}$$

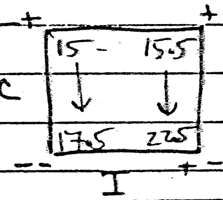
Washoff 2^2 Factorial Runs (eliminate LDS)

Test: Rain (mm) for 90% washoff of available total solids loading

Intensity: High + Low −
Cleanliness: Dirty + Clean −
Texture: Rough + Smooth −

replicate codes:	I	C	IC	values:	s^2	df	ave. values	
LCR, LCS	−	−	+	15, 20	12.5	1	17.5	N=6 for replicates
HCR, HCS	+	−	−	20, 25	12.5	1	22.5	pooled $s^2 = \frac{205.5}{3} = 68.5$
LDR	−	+	−	15	—	0	15	~~v(effect) = $\frac{4}{N}\sigma^2$~~
HDR, HDS	+	+	+	25, 6	180.5	1	15.5	$= \frac{4}{6}(68.5) = 102.75$
effect:	2.75	−4.75	−2.25	ave = 18	Σ=205.5	3		~~SE = $\sqrt{V}$ = 10.1~~

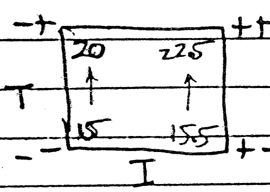
Average = 18 ± 5.1
I = 2.75 ± 10.1
C = −4.75 ± 10.1
IC = −2.25 ± 10.1



model:
$\hat{y} = 18$ (se = 10.1)

	I	T	IT	values:	s^2	df	ave. values	
LCR, LDR	−	−	+	15, 15	0	1	15	$s^2 = \frac{193}{3} = 64.3$
HCS, HDS	+	−	−	25, 6	180.5	1	15.5	$V = \frac{4}{6}(64.3) = 96.5$
LCS	−	+	−	20	—	0	20	
HCR, HDR	+	+	+	20, 25	12.5	1	22.5	SE = $\sqrt{V}$ = 9.8
effect:	1.5	6.25	1.0	ave = 18	Σ=193	3		

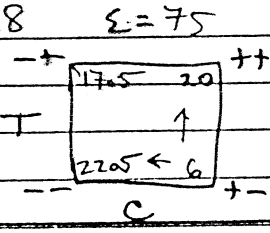
Average = 18 ± 4.9
I = 1.5 ± 9.8
T = 6.3 ± 9.8
IT = 1.0 ± 9.8



model:
$\hat{y} = 18$ (se = 9.8)

	C	T	CT	values:	s^2	df	ave. values	
HCS, LCS	−	−	+	25, 20	12.5	1	22.5	$s^2 = \frac{75}{3} = 25$
HDS	+	−	−	6	—	0	6	$V = \frac{4}{6}(25) = 37.5$
HCR, LCR	−	+	−	20, 15	12.5	1	17.5	~~SE = $\sqrt{V}$ = 6.1~~
HDR, LDR	+	+	+	25, 15	50.0	1	20	
effect:	−7	4.5	9.5	ave = 18	Σ=75	3		

Average = 18 ± 3.1
C = −7 ± 6.1
T = 4.5 ± 6.1
CT = 9.5 ± 6.1



model:
$\hat{y} = 18 + 4.75(CT)$
$\hat{y} = 13.3$; 22.8
CT− CT+

Overall Model:

$\hat{y}$ = 13 mm for clean & rough or dirty & smooth
$\hat{y}$ = 23 mm for clean & smooth or dirty & rough
(rain intensity not a significant factor)
(cleanliness most important 14.5 ; 21.5)
(126 g/m²) dirty clean (2072 g/m²)

APPENDIX G CONTROL EFFECTIVENESS ESTIMATES FOR DIFFERENT LAND USES

LIST OF TABLES

Table G.1

Control Effectivenesses for Low Density Residential Land Use Areas

Low density residential	Runoff Flow	Total Solids	TDS	Suspended Solids	Phos.	TKN	Phenols	COD	Fecal Colif.	Pseudo. aerug.	Copper	Lead	Zinc
Smooth street cleaning													
one or more passes/week	0	0	0	0	.43	0	0	0	.59	0	0	.27	0
one pass/two weeks	0	0	0	0	.38	0	0	0	.53	0	0	.24	0
one pass/month	0	0	0	0	.33	0	0	0	.46	0	0	.21	0
one pass/two months	0	0	0	0	.26	0	0	0	.37	0	0	.17	0
one pass/three months	0	0	0	0	.23	0	0	0	.31	0	0	.14	0
Sidewalks													
porous pavement	0	0	0	0	.11	0	0	0	.33	.11	0	0	0
Driveways													
porous pavement	.13	.18	.18	.24	.21	0	0	0	0	0	.1	.29	0
Connected roofs													
infiltration	.53	.31	.33	0	.29	.76	.76	.79	.29	.25	.74	.5	.92

Table 5-2

Control Effectivenesses for Medium Density Residential Land Use Areas

	Runoff Flow	Total Solids	TDS	Suspended Solids	Phos.	TKN	Phenols	COD	Fecal Colif.	Pseudo. aerug.	Copper	Lead	Zinc
Smooth street cleaning													
one or more passes/week	0	0	0	0	.34	0	0	0	0	0	0	.25	0
one pass/two weeks	0	0	0	0	.31	0	0	0	0	0	0	.23	0
one pass/month	0	0	0	0	.27	0	0	0	0	0	0	.2	0
one pass/two months	0	0	0	0	.21	0	0	0	0	0	0	.16	0
one pass/three months	0	0	0	0	.18	0	0	0	0	0	0	.13	0
Rough street cleaning													
one or more passes/week	0	0	0	0	.19	0	0	0	0	0	0	.15	0
one pass/two weeks	0	0	0	0	.16	0	0	0	0	0	0	.12	0
one pass/month	0	0	0	0	.12	0	0	0	0	0	0	.1	0
one pass/two months	0	0	0	0	.09	0	0	0	0	0	0	.07	0
one pass/three months	0	0	0	0	.07	0	0	0	0	0	0	.06	0
Sidewalks													
porous pavement	0	0	0	0	.1	0	.1	0	.31	.12	0	0	0
Driveways													
porous pavement	.16	.23	.23	.28	.23	0	.12	0	0	0	.16	.35	0
Walkways													
porous pavement	0	0	0	0	0	0	0	0	.15	0	0	0	0
Connected roofs													
infiltration	.18	.11	.12	0	0	.32	.32	.35	0	0	.31	.17	.46
redirect to pervious (1)	.14	0	.1	0	0	.26	.26	.28	0	0	.26	.14	.37

(1) redirect of roofs draining to pavement to lawns

Table G-3

Control Effectivenesses for Pre-1930 High Density Residential Land Use Areas

	Runoff Flow	Total Solids	TDS	Suspended Solids	Phos.	TKN	Phenols	COD	Fecal Colif.	Pseudo. aerug.	Copper	Lead	Zinc
Smooth street cleaning													
one or more passes/week	0	.41	.41	.34	.64	.6	.64	.64	.3	0	.64	.64	.64
one pass/two weeks	0	.24	.24	.31	.58	.55	.58	.58	.27	0	.58	.58	.58
one pass/month	0	.21	.21	.27	.5	.47	.5	.5	.24	0	.5	.5	.5
one pass/two months	0	.17	.17	.21	.4	.38	.4	.4	.19	0	.4	.4	.4
one pass/three months	0	.14	.14	.18	.34	.32	.34	.34	.16	0	.34	.34	.34
Sidewalks													
porous pavement	0	0	0	0	0	.1	.15	0	.19	0	0	0	0
Driveways													
porous pavement	0	0	0	0	0	0	0	0	0	0	0	.11	0
Walkways													
porous pavement	0	0	0	.1	.17	.2	.3	0	.38	.15	.1	0	0

Table G.4

Control Effectivenesses for Recent High Density Residential Land Use Areas

	Runoff Flow	Total Solids	TDS	Suspended Solids	Phos.	TKN	Phenols	COD	Fecal Colif.	Pseudo. aerug.	Copper	Lead	Zinc
Smooth street cleaning													
one or more passes/week	0	0	0	.21	.43	0	0	0	.18	0	0	.25	0
one pass/two weeks	0	0	0	.19	.38	0	0	0	.16	0	0	.23	0
one pass/month	0	0	0	.17	.33	0	0	0	.14	0	0	.2	0
one pass/two months	0	0	0	.13	.26	0	0	0	.11	0	0	.16	0
one pass/three months	0	0	0	.11	.23	0	0	0	.1	0	0	.13	0
Sidewalks													
porous pavement	0	0	0	.14	0	0	0	0	.4	.17	0	0	0
Driveways													
porous pavement	0	.15	.15	.28	.15	0	0	0	0	0	0	.19	0
Connected roofs													
infiltration	.64	.54	.56	0	.41	.84	.84	.87	.4	.48	.84	.64	.95

Table G.5

Control Effectivenesses for Duplex Residential Land Use Areas

	Runoff Flow	Total Solids	TDS	Suspended Solids	Phos.	TKN	Phenols	COD	Fecal Colif.	Pseudo. aerug.	Copper	Lead	Zinc
Smooth street cleaning													
one or more passes/week	0	0	0	0	.3	0	0	0	0	0	0	.18	0
one pass/two weeks	0	0	0	0	.27	0	0	0	0	0	0	.16	0
one pass/month	0	0	0	0	.23	0	0	0	0	0	0	.14	0
one pass/two months	0	0	0	0	.19	0	0	0	0	0	0	.11	0
one pass/three months	0	0	0	0	.16	0	0	0	0	0	0	.1	0
Rough street cleaning													
one or more passes/week	0	0	0	0	.15	0	0	0	0	0	0	0	0
one pass/two weeks	0	0	0	0	.12	0	0	0	0	0	0	0	0
one pass/month	0	0	0	0	.1	0	0	0	0	0	0	0	0
one pass/two months	0	0	0	0	.07	0	0	0	0	0	0	0	0
one pass/three months	0	0	0	0	.06	0	0	0	0	0	0	0	0
Sidewalks													
porous pavement	0	0	0	0	0	0	0	0	.27	.1	0	0	0
Driveways													
porous pavement	0	.17	.17	.28	.17	0	0	0	0	0	0	.22	0
Connected roofs													
infiltration	.61	.46	.46	0	.36	.81	.81	.85	.41	.41	.81	.57	.94

Table G-6

Control Effectivenesses for High Rise Apartment Land Use Areas

	Runoff Flow	Total Solids	TDS	Suspended Solids	Phos.	TKN	Phenols	COD	Fecal Colif.	Pseudo. aerug.	Copper	Lead	Zinc
Sidewalks													
porous pavement	0	0	0	0	0	0	0	0	.23	0	0	0	0
Driveways													
porous pavement	.1	.1	.1	.12	.1	0	0	0	0	0	0	.14	0
Paved parking													
infiltration	.5	.52	.52	.57	.55	.31	.39	.26	.11	.17	.43	.68	0
small detention	0	0	0	.37	.22	0		.1			.26	.44	0
large detention	0	0	0	.51	.3	.11		.14			.34	.54	0
Walkways													
porous pavement	0	0	0	0	0	0	0	0	.11	0	0	0	0
Paved playgrounds													
infiltration	0	0	0	0	0	0	0	0	.23	0	0	0	0
Connected roofs													
infiltration	.18	0	.1	0	.29	.41	.37	.49	.29	.1	.34	.1	.64

Table G.7

Control Effectivenesses for Schools

	Runoff Flow	Total Solids	TDS	Suspended Solids	Phos.	TKN	Phenols	COD	Fecal Colif.	Pseudo. aerug.	Copper	Lead	Zinc
Smooth street cleaning													
one or more passes/week	0	0	0	0	.18	0	0	0	0	0	0	.18	0
one pass/two weeks	0	0	0	0	.16	0	0	0	0	0	0	.16	0
one pass/month	0	0	0	0	.14	0	0	0	0	0	0	.14	0
one pass/two months	0	0	0	0	.11	0	0	0	0	0	0	.11	0
one pass/three months	0	0	0	0	.1	0	0	0	0	0	0	.1	0
Paved parking													
infiltration	.2	.2	.2	.22	.22	0	.16	0	0	0	.16	.42	0
small detention	0	0	0	.13	.09	0		0	0	0	.1	.25	0
large detention	0	0	0	.2	.12	0		0	0	0	.13	.34	0
Paved playgrounds													
infiltration	.14	.14	.14	.18	.32	.21	0	.12	.6	.25	.12	0	0
Connected roofs													
infiltration	.36	.16	.17	0	.13	.52	.68	.61	0	.1	.54	.33	.86

Table G.8

Control Effectivenesses for Hospitals

	Runoff Flow	Total Solids	TDS	Suspended Solids	Phos.	TKN	Phenols	COD	Fecal Colif.	Pseudo. aerug.	Copper	Lead	Zinc
Smooth street cleaning													
one or more passes/week	0	0	0	0	.23	0	0	0	.21	0	0	0	0
one pass/two weeks	0	0	0	0	.21	0	0	0	.19	0	0	0	0
one pass/month	0	0	0	0	.18	0	0	0	.17	0	0	0	0
one pass/two months	0	0	0	0	.14	0	0	0	.13	0	0	0	0
one pass/three months	0	0	0	0	.12	0	0	0	.11	0	0	0	0
Paved parking													
infiltration	.38	.38	.38	.46	.51	.21	.28	.16	.14	.11	.28	.58	.16
small detention	0	0	0	.3	.2	.05		.06	0	0	.17	.35	.06
large detention	0	0	0	.41	.28	.08		.09	0	0	.22	.46	.09
Connected roofs													
infiltration	.35	.16	.16	0	.16	.63	.63	.67	.3	.16	.63	.24	.8

Table G.9

Control Effectivenesses for Strip Commercial Land Use Areas

	Runoff Flow	Total Solids	TDS	Suspended Solids	Phos.	TKN	Phenols	COD	Fecal Colif.	Pseudo. aerug.	Copper	Lead	Zinc
Smooth street cleaning													
one or more passes/week	0	0	0	0	.18	0	0	0	0	0	0	0	0
one pass/two weeks	0	0	0	0	.16	0	0	0	0	0	0	0	0
one pass/month	0	0	0	0	.14	0	0	0	0	0	0	0	0
one pass/two months	0	0	0	0	.11	0	0	0	0	0	0	0	0
one pass/three months	0	0	0	0	.1	0	0	0	0	0	0	0	0
Rough street cleaning													
one or more passes/week	0	0	0	0	.12	0	0	0	0	0	0	0	0
one pass/two weeks	0	0	0	0	.1	0	0	0	0	0	0	0	0
one pass/month	0	0	0	0	.08	0	0	0	0	0	0	0	0
one pass/two months	0	0	0	0	.06	0	0	0	0	0	0	0	0
one pass/three months	0	0	0	0	.05	0	0	0	0	0	0	0	0
Sidewalks													
porous pavement	0	0	0	0	0	0	0	0	.29	.13	0	0	0
Paved parking													
infiltration	.33	.55	.55	.76	.5	.18	.22	.13	.13	.22	.26	.55	.13
small detention	0	0	0	.49	.2	.05		.05	0	0	.16	.33	.05
large detention	0	0	0	.68	.27	.06		.07	0	0	.21	.44	.07
Connected roofs													
infiltration	.42	.33	.35	0	.21	.71	.66	.77	.39	.53	.66	.33	.85
small detention	0	0	0	0	.08	.18		.31			.4	.2	.34
large detention	0	0	0	0	.11	.26		.42			.53	.26	.46

Table G-10

Control Effectivenesses for Shopping Centers

	Runoff Flow	Total Solids	TDS	Suspended Solids	Phos.	TKN	Phenols	COD	Fecal Colif.	Pseudo. aerug.	Copper	Lead	Zinc
Sidewalks													
porous pavement	0	0	0	0	0	0	0	0	.25	0	0	0	0
Paved parking													
infiltration	.59	.75	.75	.89	.75	.35	.42	.28	.28	.42	.47	.78	.24
small detention	0	0	0	.58	.3	.09	0	.11	0	0	.28	.47	.1
large detention	0	0	0	.8	.48	.13	0	.15	0	0	.38	.62	.13
Connected roofs													
infiltration	.59	.18	.18	0	.13	.59	.52	.67	.35	.39	.48	.18	.74
small detention	0	0	0	0	.05	.15		.27			.29	.11	.3
large detention	0	0	0	0	.07	.21		.36			.38	.14	.4

Table G.11

Control Effectivenesses for Office Land Use Areas

	Runoff Flow	Total Solids	TDS	Suspended Solids	Phos.	TKN	Phenols	COD	Fecal Colif.	Pseudo. aerug.	Copper	Lead	Zinc
Smooth street cleaning													
one or more passes/week	0	0	0	0	.39	0	0	0	.37	0	0	.21	0
one pass/two weeks	0	0	0	0	.35	0	0	0	.34	0	0	.19	0
one pass/month	0	0	0	0	.3	0	0	0	.29	0	0	.17	0
one pass/two months	0	0	0	0	.24	0	0	0	.23	0	0	.13	0
one pass/three months	0	0	0	0	.21	0	0	0	.2	0	0	.11	0
Sidewalks													
porous pavement	0	0	0	0	0	0	0	0	.16	0	0	0	0
Driveways													
porous pavement	.13	.18	.18	.24	.21	0	0	0	0	0	.1	.29	0
Paved parking													
infiltration	.39	.58	.58	.71	.58	.24	.3	.18	.18	.24	.35	.64	.18
small detention	0	0	0	.46	.23	.06	0	.07	0	0	.21	.38	.07
large detention	0	0	0	.64	.31	.09	0	.1	0	0	.28	.51	.1
Connected roofs													
infiltration	.29	.21	.21	0	.15	.62	.57	.68	.33	.32	.54	.21	.78
small detention	0	0	0	0	.06	.16		.27			.32	.13	.31
large detention	0	0	0	0	.08	.22		.37			.43	.17	.42

Table 9.12

Control Effectivenesses for Light Industrial Areas

	Runoff Flow	Total Solids	TDS	Suspended Solids	Phos.	TKN	Phenols	COD	Fecal Colif.	Pseudo. aerug.	Copper	Lead	Zinc
Driveways													
porous pavement	0	0	0	0	.1	0	0	0	0	0	0	0	0
Paved parking													
infiltration	.29	.43	.28	.62	.74	.4	.62	.43	.34	.5	.46	.7	.59
small detention	0	0	0	.4	.3	.1	0	.17	0	0	.28	.42	.24
large detention	0	0	0	.56	.4	.14	0	.23	0	0	.37	.56	.32
Connected roofs													
infiltration	.54	.33	.54	0	0	.46	.2	.4	0	0	.33	0	.26
small detention	0	0	0	0	0	.12		.16			.2	0	.1
large detention	0	0	0	0	0	.17		.22			.26	0	.14

Table G-14

Control Effectivenesses for Heavy Industrial Areas

	Runoff Flow	Total Solids	TDS	Suspended Solids	Phos.	TKN	Phenols	COD	Fecal Colif.	Pseudo. aerug.	Copper	Lead	Zinc
Smooth street cleaning													
one or more passes/week	0	0	0	0	0	0	0	0	0	.46	0	0	0
one pass/two weeks	0	0	0	0	0	0	0	0	0	.43	0	0	0
one pass/month	0	0	0	0	0	0	0	0	0	.37	0	0	0
one pass/two months	0	0	0	0	0	0	0	0	0	.29	0	0	0
one pass/three months	0	0	0	0	0	0	0	0	0	.24	0	0	0
Paved parking													
infiltration	.48	.6	.46	.72	.85	.6	.8	.64	.48	.64	.64	.83	.76
small detention	0	0	0	.47	.34	.15	0	.26	0	0	.38	.5	.3
large detention	0	0	0	.65	.46	.22	0	.35	0	0	.51	.66	.41
Connected roofs													
infiltration	.37	.2	.39	0	0	.3	.11	.25	.25	0	.2	0	.14
small detention	0	0	0	0	0	.08		.1			.12	0	.06
large detention	0	0	0	0	0	.11		.14			.16	0	.08

Table G.15

Control Effectivenesses for Cemeterys

	Runoff Flow	Total Solids	TDS	Suspended Solids	Phos.	TKN	Phenols	COD	Fecal Colif.	Pseudo. aerug.	Copper	Lead	Zinc
Smooth street cleaning													
one or more passes/week	0	0	0	0	.39	0	0	0	0	0	0	.37	.36
one pass/two weeks	0	0	0	0	.35	0	0	0	0	0	0	.34	.32
one pass/month	0	0	0	0	.3	0	0	0	0	0	0	.29	.28
one pass/two months	0	0	0	0	.24	0	0	0	0	0	0	.23	.22
one pass/three months	0	0	0	0	.21	0	0	0	0	0	0	.2	.19
Rough street cleaning													
one or more passes/week	0	0	0	0	.23	0	0	.14	0	0	.14	.34	.34
one pass/two weeks	0	0	0	0	.19	0	0	.11	0	0	.11	.28	.28
one pass/month	0	0	0	0	.15	0	0	.09	0	0	.09	.22	.22
one pass/two months	0	0	0	0	.11	0	0	.06	0	0	.06	.16	.16
one pass/three months	0	0	0	0	.09	0	0	.05	0	0	.05	.13	.13
Walkways													
porous pavement	0	0	0	0	.14	0	0	0	.28	0	0	0	0

Table G-17

Control Effectivenesses for Freeways

	Runoff Flow	Total Solids	TDS	Suspended Solids	Phos.	TKN	Phenols	COD	Fecal Colif.	Pseudo. aerug.	Copper	Lead	Zinc
Smooth street cleaning													
one or more passes/week	0	.64	.64	.64	.64	0	0	.64	.64	0	.64	.64	.64
one pass/two weeks	0	.58	.58	.58	.58	0	0	.58	.58	0	.58	.58	.58
one pass/month	0	.5	.5	.5	.5	0	0	.5	.5	0	.5	.5	.5
one pass/two months	0	.4	.4	.4	.4	0	0	.4	.4	0	.4	.4	.4
one pass/three months	0	.34	.34	.34	.34	0	0	.34	.34	0	.34	.34	.34
Rough street cleaning													
one or more passes/week	0	.14	.14	.14	.2	0	0	.19	.18	0	.2	.21	.21
one pass/two weeks	0	.11	.11	.11	.16	0	0	.16	.15	0	.16	.17	.17
one pass/month	0	.09	.09	.09	.13	0	0	.12	.12	0	.13	.14	.14
one pass/two months	0	.06	.06	.06	.09	0	0	.09	.08	0	.09	.1	.1
one pass/three months	0	.05	.05	.05	.08	0	0	.07	.07	0	.08	.08	.08