

# MOIRA RIVER CONSERVATION AUTHORITY

SCANNED by



# Flood Plain Mapping Master Drainage Plan

# **Bell Creek**



Canada

Environment Environnement Canada



Ministry of Resources

Ministère des Richesses naturelles

CANADA/ONTARIO FLOOD DAMAGE REDUCTION PROGRAM



ECOS GARATECH ASSOCIATES LTD. Consulting Engineers



#### ECOS GARATECH ASSOCIATES LTD.

Consulting Engineers

1625 Steeles Ave. E., Unit 19, Brampton, Ont. L6T 4T7 TEL. (416) 458-4110 FAX (416) 458-1479

File No.: 8551-15-010

November 6, 1989

Moira River Conservation Authority P.O. Box 698 Belleville, Ontario K8N 5B3



Attention: Mr. D. King

General Manager

Reference: Flood Plain Mapping Master Drainage Plan

Bell Creek

Dear Dave:

We are pleased to submit herewith our Report entitled Flood Plain Mapping - Master Drainage Plan - Bell Creek, detailing the hydrologic and hydraulic analyses carried out, as well as the preparation of a Master Drainage Plan, for Bell Creek within the City of Belleville and the Township of Thurlow.

We trust that the results, conclusions and recommendations contained in this Report and the Flood Risk Maps will assist the Authority in establishing a comprehensive Water Management Program and a Master Drainage Plan for the Bell Creek Watershed, and we would be pleased to assist and participate in the implementation and compilation of these programs.

Yours truly,

ECOS GARATECH ASSOCIATES LTD.

M.D. Garraway Project Manager

P.S.H. Lim, P.Eng. Project Engineer

MDG/pl

Encl.



#### MOIRA RIVER CONSERVATION AUTHORITY



Canada Canada

Environment Environnement



Ministry of Ministère des Richesses

CANADA/ONTARIO FLOOD DAMAGE REDUCTION PROGRAM

FLOOD PLAIN MAPPING MASTER DRAINAGE PLAN

BELL CREEK

NOVEMBER 1989

PREPARED BY:

ECOS GARATECH ASSOCIATES LTD. 1625 Steeles Avenue East Unit 19 Brampton, Ontario L6T 4T7

#### PREFACE

Under the Terms of Reference established by the Moira River Conservation Authority, this report documents the findings and conclusions of the hydrologic and hydraulic analyses, and the Master Drainage Planning undertaken for Bell Creek within the City of Belleville and the Township of Thurlow.

#### ACKNOWLEDGEMENTS

Ecos Garatech are grateful to the following organizations for their support and co-operation throughout the course of the study:

Moira River Conservation Authority

Ontario Ministry of Natural Resources (Eastern Region)

City of Belleville

Township of Thurlow

Atmospheric Environment Service, Environment Canada

#### STUDY TEAM MEMBERS

M.D. Garraway, C.E.T. - Project Manager

P.S.H. Lim, P.Eng. - Project Engineer

E. Calwell, P.Eng. - Hydrotechnical Engineer

#### PROJECT TEAM MEMBERS

A. Rungis (Miss) - Chairperson

P. Sandhu, P.Eng. - Federal Member

L.H. Christl, P.Eng. - Provincial Member

#### SUMMARY

In the spring of 1988, the Moira River Conservation Authority retained Ecos Garatech Associates Ltd. to undertake flood and fill line delineation, as well as the preparation of a Master Drainage Plan, for Bell Creek within the City of Belleville and the Township of Thurlow, from the Bay of Quinte to the top of the watershed, north of Highway No. 401.

#### Flood and Fill Line Delineation

Hydraulic systems have been analyzed with the aid of the HEC-2 computer program supplemented by cross sections taken by field surveys. The resulting Regulatory (100 year) flood plain and corresponding fill line have been plotted on the Moira River Conservation Authority's Flood Risk Mapping, Sheet Nos. 1 to 8.

All lands falling within the flood and fill line delineations are considered to be susceptible to flooding, and subject to erosion and potential slope failure. Therefore, it has been recommended that the City, and Thurlow Township, in co-operation with the Authority, prepare Official Plan Policies and Zoning By-Laws covering the regulation of Bell Creek in accordance with Provincial water management objectives. The Master Drainage Plan, Part B of this report, will assist the involved agencies to meet this goal.

#### Bell Creek Master Drainage Plan

In the mid 1900's municipal engineers, in an attempt to improve the level of convenience on roadways, replaced roadside ditches with curb and gutter, paved sidewalks, catchbasins, and storm sewers. If water conveyance on these roadways was undesirable the answer was to install yet another catchbasin. This increase in the number of catchbasins allowed too much water to enter the storm sewer during intense events and the result was sewer surcharging and backups which caused basement flooding. Failure to provide safe and adequate overland flow paths also led to surface ponding on some properties. As a result the further downstream in the urban watershed, the more severe the problem.

The answer to this problem is to prepare Storm Water Master Drainage Plans for a watershed prior to development. This not only provides education for the municipalities, developers, designers, and general public about the severity and necessity for storm water management, but good management planning is more economical than attempting to "fix" an existing problem.

While on-site problems were severe, the problems downstream were inevitably worse. The "efficiency" of the storm sewer system created increases in both the volume and peak magnitude of storm water runoff. In the major system watercourses and lakes, these effects were manifested as increased flood damage, increased erosion damage, and increased pollution. To illustrate the magnitude of some of these effects, consider the following examples.

- (a) In the 1950's, one municipality developed a 100 hectare parcel using the conventional drainage system. It is currently faced with having to spend \$4.2 million on remedial erosion and bank stability works.
- (b) In the last 25 years, Ontario has spent over \$200 million on remedial works through the MNR, the conservation authorities and their member municipalities. And yet a great deal has been left undone.

Storm Water Management is an attempt to resolve both the on-site and downstream problems by:

- (a) establishing a preventative program that will be less expensive to society than a remedial one;
- (b) establishing the same level of protection against flood damage to properties caused by water below or above the ground as we have had on our other watercourses for many years (Conservation Authorities' Act); and
- (c) establishing control of the quality of urban runoff to the degree dictated by downstream conditions.

It is necessary to integrate into one coherent set of policies the concerns that used to be handled separately by various agencies such as the municipality, MNR, MOE, MTO, and the conservation authorities. It requires a higher level of cooperation between departments in a municipality during planning, implementation, operation, and maintenance. It also requires that engineers, planners, biologists, economists, and sociologists work together to produce more viable and exciting urban developments.

That it can be done has already been proven. That it can be done economically has also been proven in Brampton, Burlington, Guelph, Markham, Mississauga, Oakville, and Ottawa-Carleton, to name only a few. The total costs comprise both on-site and offsite (external) works.

A large percentage of the time there is no need to provide offsite works downstream of developments incorporating on-site storm water management practices. This is a marked contrast to experience with conventional drainage systems where large offsite pipes, channels, and outfalls were the norm. Taking both onsite and off-site works together, the total initial capital costs of developments using storm water management are less than those using the conventional approach.

Urbanization of a rural watershed such as Bell Creek can lead to incidence of increased flooding downstream. If left uncontrolled this increased runoff will not only provide nuisance flooding but will also ultimately limit the potential for development within the watershed. The purpose of Part B of this document is to serve as a guideline and set criteria for storm water management within the watershed. Setting guidelines will ultimately enable each property within the watershed to achieve its full potential.

The adopted criteria has set the control of post-development flows to that of the pre-development condition for the 5, 10, 25, 50, and 100 year storm events.

For the area north of the Canadian National Railway (CNR), the future industrial land must provide runoff control on-site. To the south of the CNR the residential areas will be permitted runoff control either on-site or on-line.

To co-ordinate the development of a viable urban area, each developer must submit a Storm Water Management Plan Report for review by the local Municipalities, the City of Belleville and the Township of Thurlow, and the Moira River Conservation Authority. This report shall contain, in addition to the major and minor system and runoff control designs, a plan addressing erosion and bank stability remedial measures and water quality maintenance.

# TABLE OF CONTENTS

REPORT SUMMARY

SECTI	ON		PAGE NO	) .
PART	A - F	FLOOD PLAIN DELINEATION		
1.0	INTRO	DUCTION	1-1	
		Study Objective Background Information 1.2.1 Watershed Description 1.2.2 Study Area 1.2.3 Previous Investigations	1-1 1-1 1-1 1-1 1-1	
	1.3	Study Procedure	1-1	
2.0	HYDRO	DLOGY	2-1	
	2.2	General Procedures Hydrologic Parameters Results	2-1 2-2 2-3 2-8	
3.0	HYDR	AULICS	3-1	
	3.2 3.3 3.4 3.5 3.6	Hydraulic Model Starting Water Surface Elevations Water Surface Profiles Sensitivity Analysis Structures Reservoir Routing Results	3-1 3-2 3-2 3-2 3-3 3-10 3-10	
4.0	FILL	LINE DELINEATION	4-1	
5.0	SUMM	ARY, CONCLUSIONS AND RECOMMENDATIONS	5-1	
		Summary and Conclusions Recommendations	5-1 5-2	
PART	В -	MASTER DRAINAGE PLANNING		
6.0	INTR	ODUCTION	6-1	
	6.3	General Background Study Area Criteria	6-1 6-1 6-2 6-2	

# TABLE OF CONTENTS (Cont'd)

SECTI	ON		PAGE NO.
7.0	HYDRO	DLOGY	7-1
	7.1	Pre-Development	7-1
		7.1.1 Drainage Area and Sub-Basins	7-1
		7.1.2 Watershed Characteristics	7-1 7-1
		7.1.3 Results	7-1 7-5
	7.2	Post-Development	7-5
		7.2.1 General Watershed Development Trends 7.2.2 Watershed Characteristics	7-5
			7-5
	7.3	7.2.3 Results Comparison of Results	7-5
8.0	STORM	WATER CRITERIA AND GUIDELINES	8-1
	0 1	Process	8-1
		Process Major-Minor System	8-3
	0.2	8.2.1 Road Crossings	8-4
		8.2.2 Design of Streets for Convenience	8-4
		and Conveyance	
	8.3	Methods and Degree of Quantity Control	8-5
	8.4	Methods and Degree of Quality Control	8-7
		8.4.1 Erosion and Bank Stability	8-8
9.0	DISCU	JSSION OF STORM WATER MANAGEMENT PROPOSALS	9-1
	9.1	Watershed Area North of the Canadian National Railway	9-1
	0 2	Existing Storm Water Controls	9-1
	9.4	Watershed Area South of the Canadian	9-2
	9.3	National Railway	
		TOWARD TO THE TOWARD TOWARD TO THE TOWARD TO	10 1
10.0	CONC	LUSIONS AND RECOMMENDATIONS	10-1
	10.1	General	10-1
		Bell Creek	10-2
		10.2.1 General	10-2
		10.2.2 Storm Water Drainage Controls	10-3
		10.2.3 Water Quality Measures	10-4
		10.2.4 Erosion Control Measures	10-4

# LIST OF TABLES

TABLE NO.		PAGE NO.
2.1	Proposed Land Use Bell Creek	2-5
2.2	Comparison of CN Values	2-6
2.3	Hydrologic Modelling Parameters Future Conditions	2-7
2.4	Comparison of 100 Year Peak Flows Bell Creek	2-10
2.5	100 Year Peak Flows With Detention Pond Bell Creek	2-11
2.6	Peak Flood Flows at the Mouth of Bell Creek	2-12
3.1	Water Surface Elevations Upper Bell Creek City of Belleville And Thurlow Township	3-4
3.2	Structure Performance Data	3-6
3.3	100 Year Water Surface Elevations Lower Bell Creek City of Belleville And Thurlow Township	3-8
7.1	Hydrologic Modelling Parameters Present Conditions - Bell Creek	7-3
7.2	Bell Creek Storm Water Management Comparison of Peak Flows	7-4
7.3	Hydrologic Modelling Parameters	7-6

# LIST OF FIGURES

FIGURE NO.	<u>.</u>	PAGE NO.
2.1	Proposed Development Areas Bell Creek	2-4
2.2	HYMO Schematic Bell Creek Watershed	2-9
6.1	Future Development Bell Creek Areas	6-4
7.1	Bell Creek Watershed - Sub-Basins	7-2
8.1	Storm Water Management Process	8-2
9.1	Potential Detention Areas	9-4

# APPENDICES

APPENDIX A	References and Abbreviations
APPENDIX B	12-Hour Design Rainfall Depths
APPENDIX C	MacLaren's Figures 3.1 and 3.7
APPENDIX D	Stage-Discharge-Storage Curve CNR at Tributary 2
APPENDIX E	Monthly Mean Water Levels Lake Ontario (Extract from MacLaren's Report)
APPENDIX F	Bridge Data
APPENDIX G	Detailed List of Pre-Development Flows
APPENDIX H	Detailed List of Post-Development Flows
APPENDIX I	Glossary
APPENDIX J	Stormwater Management Study/Assessment Recommended Table of Contents
APPENDIX K	Computer File Listing (All Runs)

# SUPPORT DOCUMENTS

- 1. HYMO Model Input Data and Output Files
- 2. HEC-2 Model Input Data and Output Files

## 1.0 INTRODUCTION

#### 1.1 STUDY OBJECTIVE

In view of development pressures along Bell Creek and potential for flooding, the Moira River Conservation Authority authorized Ecos Garatech Associates Ltd. to undertake a Flood Plain Mapping Study along the upper portion of Bell Creek within the City of Belleville.

The principal objectives of the study was the delineation of the Regulatory flood plain and associated fill line for approximately 8.3 kilometres along Bell Creek from the Canadian National Railway to north of Highway No. 401. In 1984 a Flood Plain and Water Management Study was completed by MacLaren Plansearch Inc. for the lower reaches and tributaries of Bell Creek. Due to the increase in expected development of the watershed these areas were re-evaluated during this study.

#### 1.2 BACKGROUND INFORMATION

#### 1.2.1 Watershed Description

The Bell Creek watershed drains an area of 23.3 km2. The watershed, located in the City of Belleville and the Township of Thurlow extends southerly for some 8.3 km to the Bay of Quinte (an arm of Lake Ontario). The point at which Bell Creek discharges into the Bay of Quinte is located in the south-eastern part of Belleville.

#### 1.2.2 Study Area

The extent of the study included the main channel and tributaries of Bell Creek from its mouth at the Bay of Quinte to just north of the Highway No. 401 culvert crossing (top of the watershed).

#### 1.2.3 Previous Investigations

In 1984 the Moira River Conservation Authority requested a study be completed on the lower Bell Creek area including the "tributary 1". This report entitled, "Flood Plain and Water Management Study, Bell Creek", was completed by MacLaren Plansearch Inc. This study provided the starting water surface elevations at the Bay of Quinte.

#### 1.3 STUDY PROCEDURE

The Flood Plain Mapping Study of Bell Creek in the City of Belleville generally followed the project procedure outlined below.

#### Data Collection and Field Surveys

During the initial stages of the study, pertinent information was obtained from the Moira River Conservation Authority, the City of Belleville, the Township of Thurlow, the Ministry of Natural Resources, and Environment Canada.

In the months of October and November 1988, Ecos Garatech conducted the following field surveys:

- (1) Field surveys to supplement the digital photogrammetric mapping.
- (2) Field surveys to supplement dimensions of all hydraulic structures crossing the watercourse.
- (3) Field surveys to verify the horizontal and vertical accuracy of the digital mapping.

Digital photogrammetric mapping was completed by Marshall, Macklin and Monaghan during 1988. Results of the field surveys to verify the accuracy are described in the Report on Inspection of Horizontal and Vertical Accuracy for Selected 1:2000 Scale Mapping, April 1989, Ecos Garatech Associates Ltd.

#### Flood Plain Mapping

The project Team requested Ecos Garatech to incorporate the Lower Bell Creek area into the Upper Bell Creek Flood Plain Mapping Study.

Information pertaining to cross-sections, channel inverts and gradients, hydraulic roughness, and bridge crossings were obtained from field surveys, construction drawings, surrounding surveys, previous investigations, and the Authority's Flood Risk Maps.

Water surface profiles were generated for the various flood events.

The results of the hydrologic and hydraulic analyses and the methodologies employed were subsequently approved by the Project Team comprising of the Conservation Authority, the Ministry of Natural Resources (Eastern Region) and a representative of the Federal - Provincial Flood Damage Reduction Program.

The flood plain resulting from the Regulatory flood and the corresponding fill lines were plotted on the Moira River Conservation Authority's Flood Risk Mapping, Sheet Nos. 1 to 8.

#### 2.0 HYDROLOGY

#### 2.1 GENERAL

In March of 1984, MacLaren Plansearch Inc. completed a report entitled "Flood Plain and Water Management Study - Bell Creek" (Ref.1), for the Moira River Conservation Authority.

In that report, the following information regarding hydrologic analyses and the determination of peak flows was provided:

- The Regional Flood Frequency Analysis, whereby four streamflow stations (Demorestville Creek, Bloomfield Creek, Wilton Creek, and Shelter Valley Brook) were selected to be used for flood frequency analysis. The statistics from these stations were improved by combining the coefficient of skew of the study watersheds with that of thirty long-term WSC stations.
- 2) The regional analysis using the methodology outlined by Sangal & Kallio.
- 3) The synthetic unit hydrograph method, whereby, the computer program, HYMO, was utilized to generate peak flows from 12 hour duration rainfall events.
- 4) Four railroad embankments (three at the Canadian National Railway and one at the Canadian Pacific Railway) crossing the main channel and tributaries of Bell Creek were reservoir routed, to evaluate their potential in reducing peak flows. As a result of the evaluation, it was determined that these embankments were not significant in attenuating peak flows, and therefore, were not included in the final analysis. Discharge-storage information was obtained from the 1984 report, Table 3.4 (after page 3-9).
- 5) The results of the rainfall analysis (un-attenuated) were subsequently used as the design flows in the hydraulic analysis to determine the flood elevations along Bell Creek.

Based on the preceding, the hydrologic analysis for this study was carried out following this methodology. The methodology described in the above report was used to reflect any potential changes to the watershed parameters (CN, K and Tp) and thus, the peak flows.

Due to the changes in the future land use as a result of the expansion in the City limits, peak flood flows are expected to be higher. Consequently, EGA Consultants was authorized to undertake the following:

- 1) To prepare stage-discharge-storage curves for the railway structures.
- 2) To include reservoir routing in the hydrologic models to account for the available storage at the railway structures.
- 3) To re-run the hydrologic models for the Regulatory and the more frequent flood events, including the selected stormwater management plan.

#### 2.2 PROCEDURES

The synthetic unit hydrograph method was used to determine the peak flood flows along Bell Creek.

Future land use plans from the City of Belleville (Ref. 2) and Thurlow Township (Ref. 3), in conjunction with the hydrologic soil groups, were utilized to determine the curve numbers (CN). Based on the land use, the percent imperviousness of the sub-catchments were estimated, and the times to peak (Tp) and recession constants (K) were adjusted in accordance to Figures 3.5 and 3.6 of Reference 1.

In addition, the stage-discharge-storage curve was determined for the CNR crossing Tributary 2 at the outlet of sub-catchment 308, due to the previous calculated storage curve being exceeded (see Appendix C for the delineation of the sub-catchments and the location of the tributaries).

The stage-discharge-storage curves for the following railway embankments were not exceeded as provided in the previous study, and therefore, the curves need not have to be recalculated:

- 1) The CPR crossing the main channel at the outlet of subcatchment 317.
- 2) The CNR crossing the North Tributary (main channel) at the outlet of sub-catchment 306.
- 3) The CNR crossing the East Tributary at the outlet of sub-catchment 304.

The stage-discharge-storage curve for the CNR crossing Tributary 2 is provided in Appendix D. For the other crossings identified above, refer to MacLaren's report.

Also, MacLaren's report recommended an on-stream detention pond at the outlet of sub-catchment 315 (at the old City limits) as a result of undertaking stormwater management alternatives.

The adjustments to the watershed parameters in conjunction with the stage-discharge-storage data were used as data input into the computer program, HYMO, to simulate the peak flood flows for the 100, 50, 25, 10 and 5 year 12-hour duration storm events.

#### 2.3 HYDROLOGIC PARAMETERS

#### A) Soils and Land Use

The hydrologic soil cover complex numbers (CN), or curve numbers, is a function of the soil types and land use classifications. The soil types were categorized into their respective hydrologic soil groups (Ref. 4, 5, 6 and 7). The proposed land use for the Bell Creek watershed was obtained from zoning by-laws of the Township of Thurlow (Ref. 3) and land use plans in the City of Belleville (Ref. 2). The proposed land use within the Bell Creek watershed is illustrated in Figure 2.1, and provided in Table 2.1.

The soil groups and land use were combined into hydrologic soil cover complex numbers. The resulting curve numbers are given in Table 2.2, which also compares the curve numbers determined by MacLaren.

#### B) Rainfall Depths and Distribution

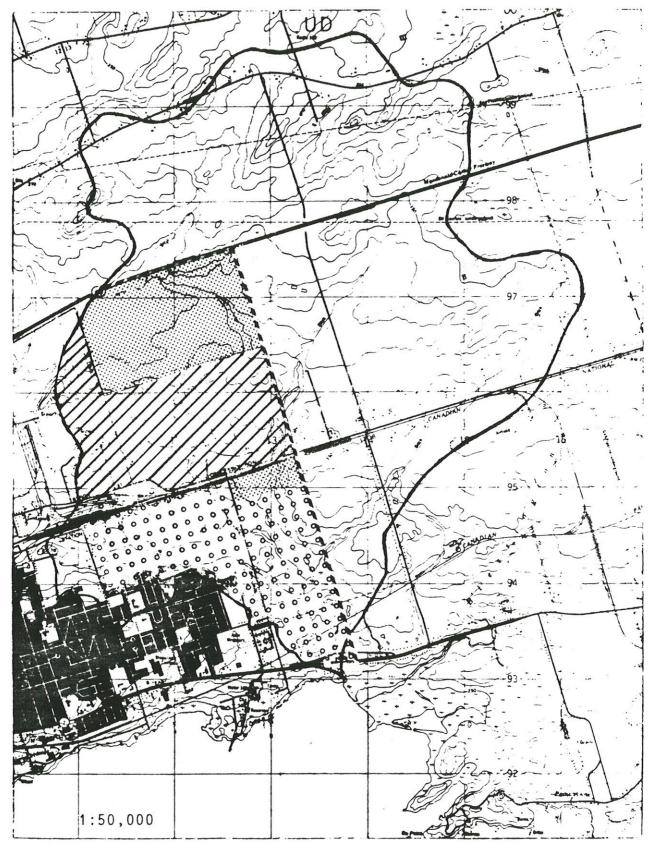
The 12 hour design rainfall depths for the various storm events were obtained from Table 3.1 of MacLaren's report. The design rainfall depths were distributed using the 12 Hour SCS Type II distribution.

The design rainfall depths are appended in Appendix B.

# C) Recession Constants, Times to Peak and Watershed Parameters

The ratio of the recession constant (K) to the time to peak (Tp) of the unit hydrograph is a function of the watershed parameter (B).

The present conditions K and Tp values (Table 3.2 of Ref. 1) were used as the basis in the updating of the values. Based on the proposed land use, the percent imperviousness within each sub-catchment was estimated. The K and Tp values were then updated to reflect the effect of urbanization, in accordance to Figures 3.5 and 3.6 of MacLaren's report. The results of the updated K, Tp and B values are given in Table 2.3.



- Restricted Industrial

- Gen. Industrial - - City Limits

Figure 2.1 Proposed Development Areas - Bell Creek

# TABLE 2.1

# PROPOSED LAND USE

# BELL CREEK

		Tibasa
Sub-catchment	-	Future Change in Land Use
Area	o.	of Sub-catchment Area
I.D.	*	or sub-catchment Area
301	15	from rural to industrial
302	8	from rural to industrial
303	0	(no development)
304	0	(no development)
305	70	from rural to industrial
306	74	from rural to industrial
307	100	from rural to industrial
308	96	from rural to industrial
309	4	from rural to residential
310	95	from rural to industrial
311	99	from rural to residential
312	90	from rural to industrial
313	70	from rural to residential
	30	from rural to industrial
314	90	from rural to residential
315	0	(no change)
316	0	(no change)
317	36	from rural to residential
318	0	(no change)
319	50	from rural to residential
320	90	from rural to industrial

TABLE 2.2

COMPARISON OF CN VALUES

Sub-catchment Area	Drainage Area	CN Valu	Updated
I.D.	(km2)	Future	Values
301	2.95	79	85
302	2.59	83	85
303	2.93	78	86
304	3.29	83	83
305	1.35	79	89
306	1.16	82	90
307	0.62	86	88
308	1.42	73	87
309	1.86	86	86
310	0.41	88	89
311	0.41	90	90
312	0.60	85	91
313	0.78	88	90
314	0.36	87	89
315	0.36	83	89
316	0.167	83	89
317	0.60	86	88
318	0.25	74	80
319	0.10	87	88
320	0.142	82	90

Note: Un

Underlined values were changes due to proposed development at the time of the MacLaren report (1984).

TABLE 2.3
HYDROLOGIC MODELLING PARAMETERS

## FUTURE CONDITIONS

Sub-catchment	Drainage	<b></b>	Futu	re		
Area	Area	CN	%	K	Tp	В
I.D.	(km2)	Values	Impervious			
			_			400
301	2.95	85	9	3.66	1.77	196
302	2.59	85	5	2.52	1.35	202
303	2.93	86	0	2.81	1.59	206
304	3.29	83	0	2.54	1.44	205
305	1.35	89	42	0.32	0.64	580
306	1.16	90	43	0.32	0.64	580
307	0.62	88	57	0.22	0.44	580
308	1.42	87	57	0.27	0.53	580
309	1.86	86	1	3.33	1.50	170
310	0.41	89	57	0.19	0.32	485
311	0.41	90	35	0.50	0.55	350
312	0.60	91	54	0.20	0.39	570
313	0.78	90	43	0.48	0.53	350
314	0.36	89	32	0.50	0.41	280
315	0.36	89	26	2.93	0.92	123
316	0.167	89	28	0.47	0.41	290
317	0.60	88	13	1.08	0.56	192
318	0.25	80	26	0.29	0.29	320
319	0.10	88	45	0.12	0.24	580
320	0.142	90	50	0.13	0.25	580

Note: Future conditions based on the new current Official Plan and Zoning By-Laws.

#### 2.4 RESULTS

The updated hydrologic parameters (K, Tp and CN values) of the Bell Creek watershed were assembled as computer data input and analyzed utilizing the computer program, HYMO, for the 12-hour duration 100, 50, 25, 10 and 5 year storm events. A watershed schematic of the HYMO computer model is illustrated in Figure 2.2.

The results of the simulation, incorporating reservoir routing at the railway structures, for the 100 year storm event are provided in Table 2.4. The future conditions (1984 Official Plan and Zoning By-Laws) peak flows generated by MacLaren, without reservoir routing, are also given in Table 2.4 for comparison. As expected, higher flows were generated from those areas where the proposed land use has changed 1984 study to residential and/or in the from rural industrial in the present study (See Table 2.1). The railway embankment crossing Tributary 2 at the outlet of subcatchment 308 reduces the 100 year peak flow by about 60%. The other structures have less than 10% reduction in the 100 year peak flow.

In addition, an on-stream detention pond was included in the simulations at the outlet of sub-catchment 315 along Tributary 1. Table 2.5 provides the routed peak flows at key locations along Bell Creek. A 100 year inflow of 6.84 cms was reduced to 3.81 cms after going through the proposed detention pond on Tributary 1.

The results of the peak flows for the various storm events at the mouth of Bell Creek are provided in Table 2.6.

The results of the hydrologic analysis and the methodologies employed were approved by the Project Team.

The generated peak flood flows were subsequently utilized in the hydraulic assessment of Bell Creek.

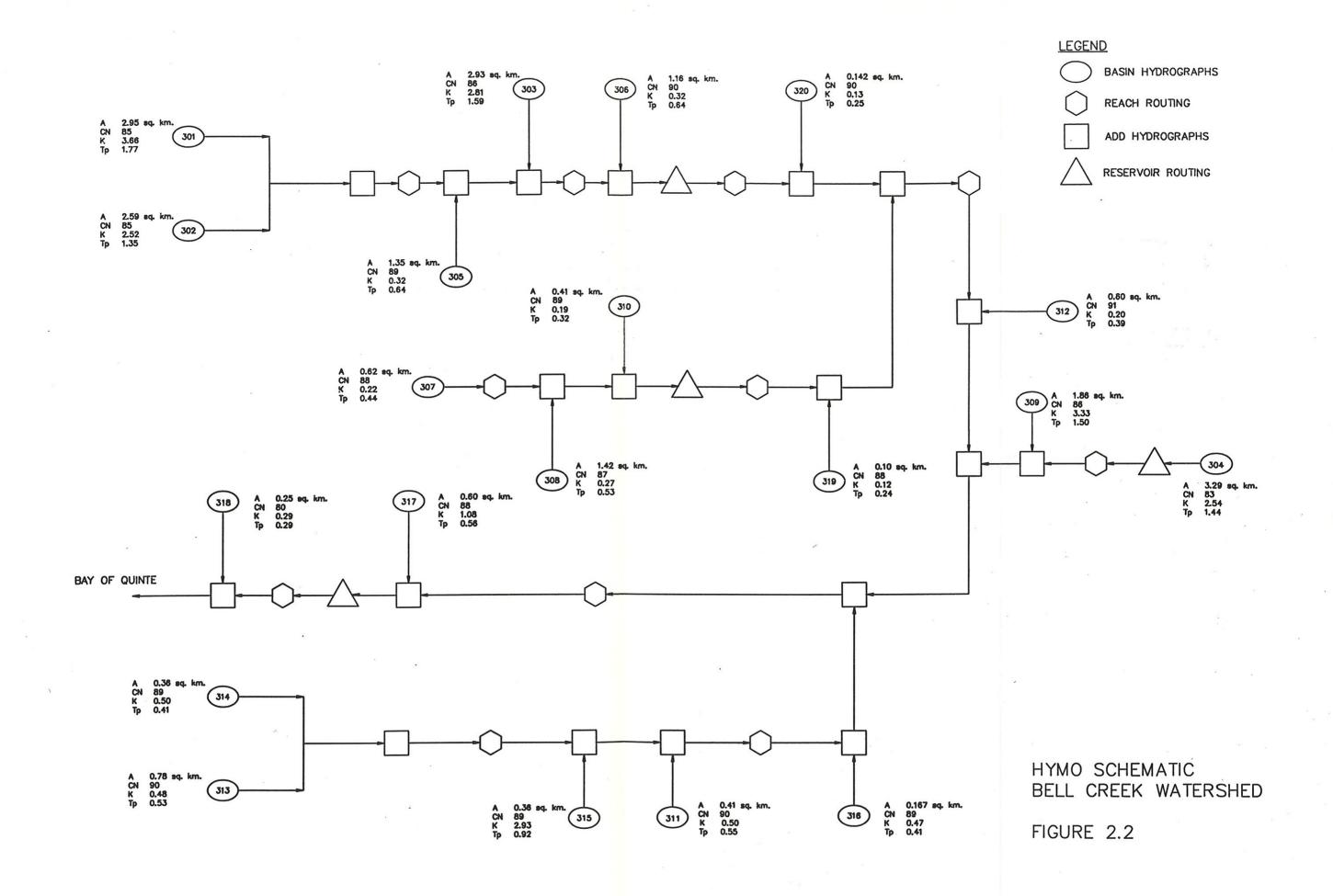


TABLE 2.4

COMPARISON OF 100 YEAR PEAK FLOWS

# FUTURE CONDITIONS

# BELL CREEK

Location	100 Year Peak Flows MacLaren's	(cms) EGA's
Tributary 2 industrial (Outflow 307)	2.58	4.00
Tributary 2 at CNR* (Outflow 308)	N/A	(13.71) 5.56
Tributary 2 at Confluence with Main Branch (Outflow 319)	5.48	5.65
North Tributary at CNR* (Outflow 306)	N/A	(17.81) 16.84
North Tributary below CNR Embankment (Outflow 320)	12.88	16.91
Main Branch above Confluence with Tributary 1 (Outflow 312)	15.76	22.56
Eastern Tributary at CNR* (Outflow 304)	N/A	(5.12) 4.83
Eastern Tributary above Confluence with Main Branch (Outflow 309)	7.66	7.14
Tributary 1 at old City Limits (Inflow 316)	9.17	6.84
Tributary 1 above Confluence with Main Branch (Outflow 316)	10.38	8.28
Main Stream below CPR Crossing* (Outflow 317)	27.03	(34.71) 31.99
Bell Creek at Bay of Quinte (Outflow 318)	27.20	32.13

Notes: \* - Denotes location of reservoirs.
Flows in brackets are inflows into reservoirs.

### TABLE 2.5

# 100 YEAR PEAK FLOWS

# FUTURE CONDITIONS WITH DETENTION POND

#### BELL CREEK

			••	D 1-	777	/ \
Location	Backwater	100	rear	Peak	FIOWS	(Clis)
Tributary 2 industrial (Outflow 307)		4	1.00			
Tributary 2 at CNR* (Outflow 308)			3.71) 5.56			
Tributary 2 at Confluence with Main Branch (Outflow 319	9)	Ę	5.65			
North Tributary at CNR* (Outflow 306)			7.81) 5.84			
North Tributary below CNR Embankment (Outflow 320)		16	5.91			
Main Branch above Confluence with Tributary 1 (Outflow 312)		22	2.56			
Eastern Tributary at CNR* (Outflow 304)			5.12) 4.83			
Eastern Tributary above Confluence with Main Branch (Outflow 309)		,	7.14			
Tributary 1 at old City Limits** (Inflow 316)			6.84) 3.81			
Tributary 1 above Confluence with Main Branch (Outflow 31)	6)	,	4.39			
Main Stream below CPR Crossing* (Outflow 317)			4.45) 1.68			
Bell Creek at Bay of Quinte (Outflow 318)		3	1.78			

Notes: \* - Denotes location of reservoirs.

\*\* - Denotes location of SWM detention pond.
Flows in brackets are inflows into reservoirs.

TABLE 2.6

PEAK FLOOD FLOWS

AT THE MOUTH OF BELL CREEK

Return Period (yrs)	Peak Flood No SWM Pond	Flows (cms) With SWM Pond
5	17.60	17.07
10	21.20	20.68
25	25.53	25.09
50	28.77	28.32
100	32.13	31.78

Note: Refer to Table 2.5 for location of SWM Pond.

#### 3.0 HYDRAULICS

#### 3.1 HYDRAULIC MODEL

The floodline, or water surface elevation, for the Regulatory and the lower return frequency flood events is a function of the design flows and the ability of the channel, flood plain and river crossings to carry or pass these flows. In order to establish the water surface elevations at various locations in the study watershed, a detailed hydraulic analysis must be carried out. The channel and flood plain properties, as well as the characteristics of the various structures along the channel, must be considered in this analysis.

The hydraulic program used by Ecos Garatech to compute the water surface profiles was developed at the Hydrologic Engineering Center (HEC) by the U.S. Army Corps of Engineers and is commonly known as HEC-2.

The program computes and plots (by printer) the water surface profiles of river channels of any cross-section for either subcritical or supercritical flow conditions. It is capable of analyzing the effects of various hydraulic structures such as bridges, culverts, weirs, embankments and dams. Roughness coefficients can be specified by a number of methods to account for the change in roughness with the depth of flow or the actual location of the flow within the flood plain. Input to the program may be in either Imperial or Metric units.

A hydraulic model of the study reach was constructed by inputting specific cross-sections along the length of the flood plain into the model. These were taken from digital elevation models (DEM's), supplemented by field surveys and reconnaissance. The characteristics of the main channel and the flood plain, such as the hydraulic roughness, as obtained from field reconnaissance, were also included in the model. All river crossings and hydraulically significant structures and sections were also entered into the model to produce a physical representation of the study area.

The hydraulic model for the study (Upper Bell Creek) area, so established, may also be used to determine the capacity of various structures and channel reaches and to determine the effects of channel improvements, dykes and floodways on the water surface profiles.

In addition, the 1984 hydraulic model prepared by MacLaren was modified to reflect the updated flows generated in Section 2.

# 3.2 STARTING WATER SURFACE ELEVATIONS

The 1984 hydraulic model, from the Bay of Quinte to the Canadian National Railway crossing, has a starting water surface elevation of 75.03 m. This elevation is the maximum monthly mean water level for Lake Ontario in June (See table in Appendix E).

The hydraulic model for the Upper Bell Creek area starts approximately 200 m downstream of the Canadian National Railway crossing to the upstream side of Highway No. 401. The starting water surface elevation for this model was initiated at critical depth.

# 3.3 WATER SURFACE PROFILES

A detailed hydraulic model was constructed for the Upper Bell Creek area.

Upon completion of the hydrologic component of the study, water surface profiles associated with the Regulatory (100 year) flood and the 50, 25, 10, and 5 year flood events were computed using the developed hydraulic model in conjunction with the HEC-2 computer program.

The water surface profiles associated with the various flood events were also generated for the Lower Bell Creek area, using the modified 1984 hydraulic model.

## 3.4 SENSITIVITY ANALYSIS

A sensitivity analysis of the roughness coefficient, Manning's 'n' values, was undertaken in order to observe the potential change in the water surface profile of the 100 year flood within the Upper Bell Creek hydraulic regime.

The developed hydraulic model was modified to reflect a 10% increase and a 10% decrease in the 'n' values, and water surface profiles were re-generated.

A review of the results indicated that with a 10% variation of Manning's 'n' values, the change in the water surface elevations were less than 0.05 m. This minimal change would not alter the generated 100 year flood plain.

#### 3.5 STRUCTURES

Floodwater unduly confined by structures can cause excessive water pondage. This may result in flooding of upstream properties, over-topping of roadways, excessive scour and erosion and, in severe cases, the loss of a structure. On the other hand, over-design of new structures for the sake of safety can add materially to the initial cost of the structure, and possibly increase downstream damages by increasing flood flows.

Reconnaissance and field surveys within the study limits (Upper Bell Creek) ascertained detailed information required to analyze the performance characteristics of the hydraulic structures. This information was used as computer input data, not only to determine the extent of flooding for the various flood events but also to analyze the performance of the individual structure.

Water surface profiles were generated with structures crossing the watercourse. The results of the hydraulic analysis for Upper Bell Creek, pertaining to water surface elevations, for the various return frequency flood events are presented in Table 3.1.

The resultant stage-discharge rating curves for the individual structure for Upper Bell Creek, are provided in the support document entitled "Bridge Data". The structure performance data are provided in Table 3.2.

The term "structure velocity" given in Table 3.2 is defined as the average velocity of the flow discharging through the structure for an effective flow area.

The resultant 100 year flood elevations for Lower Bell Creek are given in Table 3.3.

TABLE 3.1

WATER SURFACE ELEVATIONS

UPPER BELL CREEK

CITY OF BELLEVILLE AND THURLOW TOWNSHIP

Location and		Water	Surface Elevat	ions (m)	
Cross-section	100 Year Flood	50 Year Flood	25 Year Flood	10 Year Flood	5 Year Flood
Number					
Main Channel					
1	87.01	86.98	86.93	86.88	86.81
161	87.51	87.47	87.42	87.36	87.30
Canadian National					
Railway and					
County Road No. 18	3				
268	88.98	88.83	88.63	<b>8</b> 8.37	88.19
557	89.03	88.90	88.75	88.60	88.52
804	89.87	89.82	89.77	89.69	89.63
Farm Crossing					
<b>86</b> 8	90.18	90.15	90.13	90.08	90.05
889	90.41	90.38	90.34	90.30	90.25
1217	91.91	91.88	91.85	91.79	91.76
1443	93.04	93.01	92.99	92.95	92.92
1532	93.32	93.30	93.28	93.24	93.21
1862	93.92	93.89	93.86	93.80	93.76
2285	94.68	94.65	94.62	94.57	94.54
2545	95.46	95.43	95.41	95.36	95.31
2788	96.22	96.20	<b>96.1</b> 9	96.16	96.14
3060	96.73	96.70	96.68	96.63	96.60
3384	98.21	98.18	98.15	98.11	98.07
Highway No. 401		,			
3555	101.09	100.67	100.48	100.28	100.12
3631	101.38	101.06	100.90	100.76	100.68
3870	102.61	102.59	102.58	102.56	102.54
4134	104.78	104.77	104.75	104.73	104.70
4431	107.18	107.15	107.13	107.10	107.07

TABLE 3.1 (Cont'd)

# WATER SURFACE ELEVATIONS UPPER BELL CREEK CITY OF BELLEVILLE AND THURLOW TOWNSHIP

Location and Cross-section Number	100 Year Flood	<u>Water</u> 50 Year Flood	Surface Elevat 25 Year Flood	ions (m) 10 Year Flood	5 Year Flood
Tributary 3					
				0.4.04	02.00
92	94.11	94.07	94.05	94.01	93.98
Farm Crossing					
			04 447	04.20	04 200
117	<b>94.4</b> 3	94.42	94.41E	94.39	94.29E
286	94.63	94.61	94.58E	94.55	94.53
414	95.03	95.01	94.99	94.96	94.94
628	96.34	96.32	96.29	96.25	96.21
Mitchell Road					
665	96.63	96.62	96.60	96.58	96.55E
	96.75	96.73	96.71	96.68	96.64E
694	97.07	97.04	97.02	96.98	96.95
779		97.75	97.72	97.68	97.65
932	97.77	91.15	. 91.12	37.00	37.00
Farm Crossing					
<b>94</b> 8	98.01	97.99	97.96	97.93	97.89
1169	98.61	98.59	98.57	98.55	98.52
1103	20.01	50.05			

E - Estimated

TABLE 3.2
STRUCTURE PERFORMANCE DATA

Location	Flood Event (yr)	Discharge (cms)	Structure Velocity (m/s)	Class of Flow	% Weir Flow Over Roadway Embankment	Total Head Loss (m)
Main Channel						
Canadian	100	16.8	3.80	LF	-	1.21
National	50	14.8	3.66	LF		1.07
Railway	25	12.7	3.48	LF	-	0.92
wara may	10	10.1	3.22	LF	annum.	0.72
	5	8.21	3.01	LF		0.58
County Road	100	16.8	1.24	PF-WF	88	0.01
No. 18	50	14.8	2.62	PF-WF	27	0.11
NO. 10	25	12.7	2.54	PF	***	0.12
	10	10.1	2.52	LF	majorature.	0.14
	5	8.21	2.57	LF		0.18
	100000000		2.20	777 III	94	0.53
Farm Crossing	100	17.8	2.38	PF-WF	93	0.55
	50	15.6	2.40	PF-WF	93 94	0.57
	25	13.4	2.39	PF-WF	92	0.59
	10	10.5	2.25	PF-WF PF-WF	94	0.61
	5	8.40	2.09	Pr-wr	34	0.01
Highway No. 401	100	4.86	2.74	PF	-	3.16
nighway No. 401	50	4.25	2.82	PF		2.86
	25	3.65	2.73	LF	about	2.73
	10	2.85	2.53	LF	-	2.64
	5	2.26	2.36	LF		2.60

TABLE 3.2 (Cont'd)
STRUCTURE PERFORMANCE DATA

Location	Flood Event	Discharge	Structure Velocity	Class of Flow	% Weir Flow Over Roadway	Total Head Loss
	(yr)	(cms)	(m/s)		Embankment	(m)
Tributary 3						
Farm Crossing	100	4.93	1.24	PF-WF	90	0.20
I di in Ci Obbilig	50	4.32	1.23	PF-WF	90	0.22
	25	3.72	2.77	PF-WF	46	0.24
	10	2.93	1.80	PF-WF	31	0.28
	5	2.34	2.23	PF-WF	15	0.23
Mitchell Road	100	4.93	1.43	PF-WF	89	0.39
in the second	50	4.32	1.32	PF-WF	84	0.40
	25	3.72	1.30	PF-WF	72	0.40
	10	2.93	1.28	PF-WF	66	0.41
	5	2.34	1.19	PF-WF	50	0.46
Farm Crossing	100	4.93	2.04	PF-WF	95	0.15
	50	4.32	2.11	PF-WF	95	0.15
	25	3.72	1.89	PF-WF	96	0.16
	10	2.93	1.62	PF-WF	88	0.19
	5	2.34	1.76	PF-WF	81	0.19

#### Abbreviations:

LF-WF - Low flow and weir flow condition.

The water level is below the low chord of the structure and is flowing over the roadway embankment.

PF-WF - Pressure flow and weir flow condition.

The water level is above the low chord of the structure and is flowing over the roadway embankment.

PF - Pressure flow condition.

The water level is above the low chord of the structure but not over the roadway embankment.

The water level is below the low chord of the structure.

TABLE 3.3

# 100 YEAR WATER SURFACE ELEVATIONS LOWER BELL CREEK CITY OF BELLEVILLE AND THURLOW TOWNSHIP

Location and Cross-section Number	100 Year Water MacLaren's	Surface Elevations (m) EGA's			
Main Channel					
1.0 3.0	75.03 75. <b>4</b> 2	75.03 75.52			
Abandoned Rail Crossing					
6.0 8.0	75.68 76.31*	75.76 76.36*			
Highway No. 2					
11.0 13.0	77.34 77.76	77.29 77.80			
Kingston Road					
16.0 17.0 19.0	78.60 79.35 80.36	79.01 79.41 80.40			
Canadian Pacific Railway					
22.0 24.0 27.0 29.5 202.0 203.6 205.0 207.0 208.5	81.22 81.23 81.65 82.69 83.39 84.59 85.46 85.82 86.59	81.46 81.47 81.68 82.72 83.43 84.64 85.55 85.91 86.63			

<sup>\* -</sup> critical depth

# TABLE 3.3 (Cont'd)

# 100 YEAR WATER SURFACE ELEVATIONS LOWER BELL CREEK CITY OF BELLEVILLE AND THURLOW TOWNSHIP

Location and	100 Year Water	Surface Elevations (m)		
Cross-section Number	MacLaren's	EGA's		
much hart and				
<u>Tributary 1</u>				
30.0	82.38	82.16		
31.0	82.80	82.76		
34.0	84.32	84.24		
301.0	85.23	85.14		
302.8	85.50	85.38		
304.0	86.69	86.48		
304.6	87.24	87.18		
306.0	88.24	88.35		
307.0	88.46	88.66		
321.0	88.85	89.07		
Tributary 2				
220.0	85.87	85.97		
230.0	85.88	85.98		
East Tributary				
2016.0	83.64*	83.62*		
2020.0	84.05*	84.02*		

<sup>\* -</sup> critical depth

#### 3.6 RESERVOIR ROUTING

Four railroad embankments (three at the Canadian National Railway and one at the Canadian Pacific Railway) crossing the main channel and tributaries of Bell Creek were reservoir routed (see also Sections 2.1 and 2.2).

Although the Canadian National Railway structures were reservoir routed, the outflow is governed by the hydraulic capacity of the structures of County Road No. 18, which is located immediately upstream of the railway.

The hydraulic analysis undertaken for the Canadian National Railway and County Road No. 18 produced a water surface elevation of about 89.0 m upstream of the structures.

Reservoir routed results gave an elevation of about 89.03 m for the Canadian National Railway structure crossing the main channel, and an elevation of about 89.13 m for the Canadian National Railway structure crossing Tributary 2.

#### 3.7 RESULTS

The extent of flooding within the study area of Upper Bell Creek, as a result of the Regulatory (100 year) flood was plotted on the Moira River Conservation Authority's Flood Risk Maps, Sheet Nos. 1 to 8.

For the Lower Bell Creek area, the 100 year lake flood elevation of 76.20 m was superimposed on the backwater simulations at the Bay of Quinte. The backwater effect of 76.20 m ends at about 70 m downstream of Highway No. 2.

The results of the hydraulic investigations for Upper Bell Creek are:

- (1) The Manning's 'n' sensitivity analysis demonstrated that a 10% deviation in the values would not significantly alter the simulated Regulatory flood plain.
- (2) The Canadian National Railway and Highway No. 401 structures can discharge the various flood events, without weir flow occurring over the roadway embankment.
- (3) The bridge structure of County Road No. 18 can discharge, without weir flow occurring over the roadway embankment, up to the 25 year flood event.

- (4) Weir flow over the roadway embankment will occur at all the culvert crossings (three Farm Crossings and Mitchell Road).
- (5) For the 100 year flood event, the total head loss through the structures varied from 0.01 m at County Road No. 18 to 3.16 m at the Highway No. 401 crossing.
- (6) In reviewing the flood plain of Upper Bell Creek, it was estimated that 9 buildings are within the 100 year flood plain.

The results of the hydraulic analyses, the 1:2000 scale digital mapping illustrating the Regulatory (100 year) flood plain and the methodologies employed were subsequently approved by the Project Team.

#### 4.0 FILL LINE DELINEATION

Certain areas, outside the Regulatory flood plain itself, may not be suitable for development because of the potential risk of erosion and/or slope failure. In other areas, some regulation is required to ensure that excavated material is not deposited in the Regulatory flood plain.

In consultation with the Conservation Authority and the Project Team, guidelines were adopted in order that Ecos Garatech could delineate the fill line for Upper Bell Creek. Basically, the guidelines are as follows:

- (1) The fill line will be plotted as a dashed line and will be located outside of the Regulatory flood plain and exclude, wherever possible, existing buildings whilst at the same time ensuring a margin of safety for future development.
- (2) The fill line will be plotted as a straight line and, wherever possible, follow existing features such as fence lines, roadways, bush lines, buildings, etc.
- (3) The fill line, in areas where existing features and steep slopes are not prevalent, will have a minimum set back of fifteen (15) metres from the Regulatory floodline.
- (4) The fill line, in areas of steep slopes (greater than fifteen (15) percent), will be set back a reasonable distance from the break in slope.
- (5) The fill line may, in certain areas, be a combination of any of the four (4) thereof.

#### 5.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

#### 5.1 SUMMARY AND CONCLUSIONS

As a result of the hydrologic and hydraulic analyses the following are noted:

- The peak flood flows for the various return frequency events were determined for Bell Creek in the City of Belleville and the Township of Thurlow, as a result of updating the K and Tp values given in the 1984 report.
- (2) The Manning's 'n' sensitivity analysis demonstrated that a 10% deviation in the values would not significantly alter the simulated Regulatory flood plain.
- (3) The Canadian National Railway and Highway No. 401 structures can discharge the various flood events, without weir flow occurring over the roadway embankment.
- (4) For the 100 year storm event, the total head loss through the structures varied from 0.01 m at County Road No. 18 to 3.16 m at the Highway No. 401 crossing.
- (5) In reviewing the flood plain of Upper Bell Creek, it was estimated that 9 buildings are within the 100 year flood plain. The buildings are located immediately upstream of County Road No. 18.

The extent of flooding within the study area of Upper Bell Creek, as a result of the Regulatory (100 year) storm and the corresponding fill line were plotted on the Moira River Conservation Authority's Flood Risk Mapping, Sheet Nos. 1 to 8.

For the Lower Bell Creek area, the 100 year lake flood elevation of 76.20 m was superimposed on the backwater simulations at the Bay of Quinte. The backwater effect of 76.20 m ends at about 70 m downstream of Highway No. 2.

#### 5.2 RECOMMENDATIONS

In order to establish limits of community development and institute land use practices consistent with environmental limitations, the following measures are recommended:

- (1) The Moira River Conservation Authority accept the flood and fill lines as delineated on the Flood Risk Maps, Sheet Nos. 1 to 8, as the extent of hazard lands designation adequate for future zoning. That is, the lands lying within the flood and fill line delineations be considered as being susceptible to flooding and subject to erosion and potential slope failure.
- (2) The City of Belleville and the Township of Thurlow, in cooperation with the Conservation Authority, prepare Official Plan Policies, Zoning By-Laws and Master Drainage Plan covering the regulations of the Bell Creel watershed, in accordance with Provincial objectives of water management.
- (3) The developed hydraulic computer models should be used to assess the effect of any proposed changes to the Bell Creek system. Should any proposed changes be constructed, then the computer models should be updated to reflect current hydraulic conditions.

#### 6.0 INTRODUCTION

#### 6.1 GENERAL

Ecos Garatech Associates Limited (EGA) was retained by the Moira River Conservation Authority to complete a Flood Plain Mapping and Storm Water Management Study for the Bell Creek Watershed. The watershed is comprised of land in the east of the City of Belleville and in the south of the Township of Thurlow. The objective of this study is to ensure that the storm water runoff, produced by increasing urbanization in the watershed, is managed in a manner consistent with the ideals and objectives of the Moira River Conservation Authority, the City of Belleville and the Ministry of Natural Resources.

#### 6.2 BACKGROUND

The majority of the Bell Creek Watershed is currently undeveloped. However, development is projected over much of the basin. This development will translate into a major increase in runoff and if left uncontrolled, will lead to an increased incidence of flooding and erosion control problems.

Attenuating flows will not only maintain pre-development conditions but will also protect the natural channel from erosion or bank instability. Where design of the major system requires utilizing the channel to convey overland flows to a storm water pond, channelization must occur ensuring not only sufficient design capacity but also that erosion control and bank stability be addressed.

At present there are no Storm Water Criteria and Guidelines for either the City of Belleville or the Township of Thurlow, nor are there any Master Drainage Plans for Bell Creek in these Municipalities.

EGA completed the Flood Plain Mapping for the Upper Bell Creek area and at that time flood lines were also regenerated for Lower Bell Creek. It was determined that this would be the time to proceed with the development of Storm Water Management Guidelines due to the recent hydrologic and hydraulic studies (Part A of this Report) completed as well as the current development pressures on the watershed. Therefore the purpose of this document is to encourage well planned development within the watershed while at the same time addressing the following objectives:

- (a) prevent loss of life and minimize property damage
- (b) eliminate or reduce to the minimum, surface ponding and flooding causing inconvenience.
- (c) minimize the effect of development on Bell Creek
- (d) avoid flooding and erosion downstream of developments
- (e) minimize the impact of water quality from urbanized areas
- (f) eliminate adverse effects of construction activities on Bell Creek
- (g) minimize the total cost of the drainage system and related works by using the latest proven design and construction techniques.

#### 6.3 STUDY AREA

The Bell Creek Watershed comprises approximately 23.3 km2 of urban and rural land on the east side of Belleville. The recent annexation by the City has enclosed about 7 km2 within the City boundary and Thurlow comprises the other 15.3 km2. Development trends indicate that the ultimate post development land use for the watershed will be residential and industrial as shown on Figure 6.1.

#### 6.4 CRITERIA

In order that development may proceed uninhibited from neighbouring lands the following criteria were adopted to control post-development runoff:

#### (a) Hydrotechnical

Storm water management will involve the use of the Major - Minor System Concept.

Storm water runoff facilities and controls for the minor drainage system will be of required capacity for the 5 year design event or less frequent event as dictated by the local municipality.

Storm water runoff facilities and controls for the major drainage system will be required to maintain predevelopment runoff for the 5, 10, 25, 50 and 100 year storm events.

#### (b) Residential

Storm water runoff facilities and controls for the major drainage system can be located:

- i) on-site (within the proposed development lands)
- iii) on-line (on watercourse proper or tributary)

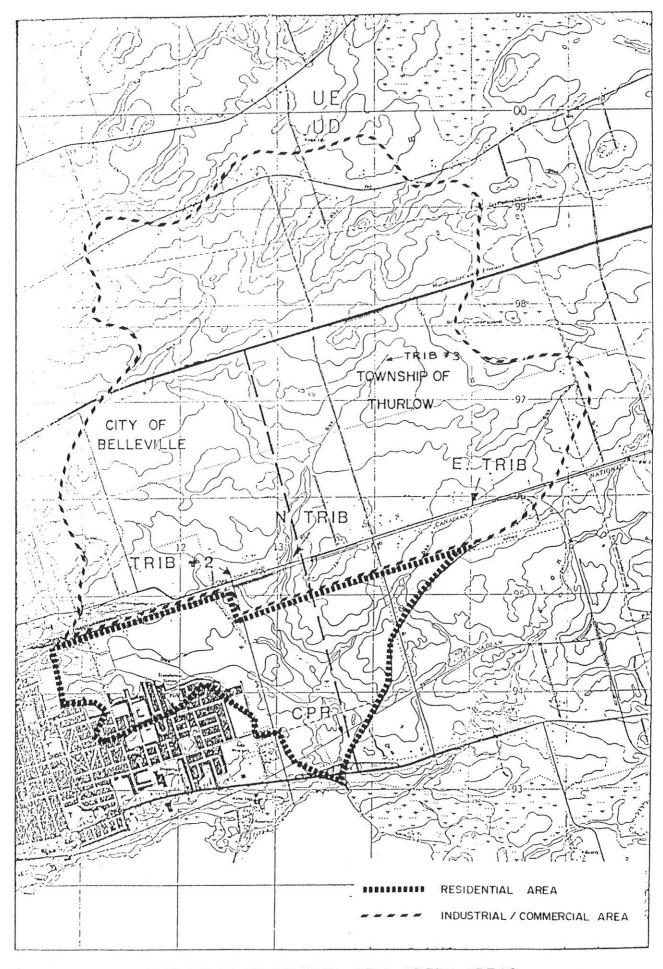
The general desire would be to locate the facility either on-site or off-line. Every proposal for an online facility must address clearly the reasons for not considering the preferred options. Furthermore, any proposed on-line facility must provide additional storage capacity for the control of the increase in volume of runoff from the proposed upstream developments.

Complete hydrotechnical evaluations will be required to support location, size, control structure, erosion and environmental concerns, and operation and maintenance.

#### (c) Industrial and Commercial Development

Storm water facilities and controls for the major drainage system will be required to be located within the proposed site of the development. Pre-development conditions must be maintained at property boundaries.

Complete hydrotechnical evaluations will be required to support type of control facilities whether they be storage facilities in designated landscape areas, parking lots, minor system, or on rooftops.



FUTURE DEVELOPMENT - BELL CREEK AREAS

#### 7.0 HYDROLOGY

#### 7.1 PRE-DEVELOPMENT

#### 7.1.1 Drainage Area and Sub-Basins

The Bell Creek Watershed was divided into 20 sub-basins. These sub-basins along with the corresponding routing reaches are shown in Figure 7.1.

The storm water analysis for this study incorporated the entire Bell Creek Watershed. The areas of the sub-basins and corresponding pre-development watershed data were obtained from the "Flood Plain and Management Study - Bell Creek" submitted by MacLaren Plansearch in 1984.

#### 7.1.2 Watershed Characteristics

The hydrologic soils groups (SCS classification) were also taken from the MacLaren report. Much of the watershed is overlain by soils having a moderate runoff potential (Soils Group C).

The Curve Number (CN), which refers to the runoff index factor that combines the soil group and land use characteristics was calibrated for each sub-basin. The CN, K, and Tp values used for each sub-basin are listed in Table 7.1.

#### 7.1.3 Results

The pre-development flow simulation was accomplished by applying the HYMO computer program.

The results for the 5, 10, 25, 50, and 100 year storm events are represented in Table 7.2 for various points of interest in the watershed. For a more detailed listing see Appendix G.

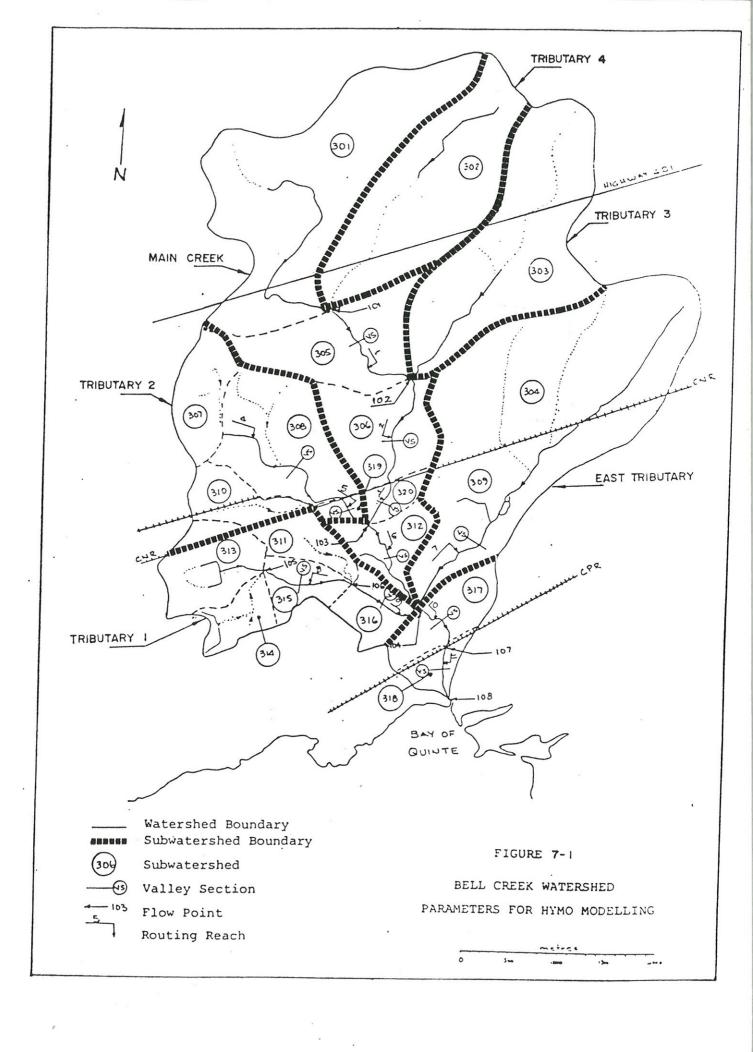


TABLE 7.1

HYDROLOGIC MODELLING PARAMETERS

PRESENT CONDITIONS

BELL CREEK

SUB-BASIN	Drainage Area (km2)	% Imperv.	CN	Present K (hrs)	Conditions Tp (hrs)	B Value
301 302 303 304 305 306 307 308 309 310 311 312 313 314 315 316 317 318 319 320	2.95 2.59 2.93 3.29 1.35 1.16 0.62 1.42 1.86 0.41 0.41 0.60 0.78 0.36 0.36 0.167 0.60 0.25 0.10	22 35 4 20 60 15 25	79 83 78 83 79 82 77 72 86 84 85 84 82 86 83 82 86 74 72 82	3.66 2.52 2.81 2.54 3.60 2.72 1.13 2.44 3.33 0.30 2.28 2.70 1.14 0.18 3.47 0.48 1.49 0.93 0.98 1.13	1.97 1.44 1.59 1.44 1.53 1.20 0.74 1.50 0.45 0.86 1.07 0.75 0.27 1.07 0.42 0.68 0.42 0.68 0.42 0.53	196 206 204 205 162 167 230 182 170 447 146 152 230 447 123 290 170 170 172 175

#### BELL CREEK STORM WATER MANAGEMENT COMPARISON OF PEAK FLOWS

LOCATION	100 yea PRE (cms)	POST (cms)	50 year PRE (cms)	POST (cms)	25 year PRE (cms).	POST (cms)	10 year PRE (cms)	POST (cms)	5 year PRE (cms)	POST (ces)
Trib #2 (Outflow 307)	1.13	4.00	0.95	3.53	0.79	3.07	0.57	2.44	0.42	1.97
Trib #2 at CNR* (Outflow 308)	(3.28) 2.85	(13.71) 5.56	(2.78) 2.53	(12.19) 5.24	(2.27) 2.12	(10.72) 4.83	(1.64) 1.62	(8.72) 4.28	(1.22) 1.18	(7.07) 3.84
Trib #2 at Confluence w/ Main Cr.(Outflow 319)	2.91	5.65	2.57	5.31	2.15	4.89	1.61	4.32	1.17	3.84
N. Trib at CNR* (Dutflow 306)	(12.52) 11.97	(46.10) 42.38	(10.68) 10.31	(40.29) 35.74	(8.92) 8.76	( <b>34.6</b> 3) 30.29	(6.68) 6.58	(27.11) 22.36	(5.07) 5.00	(21.75) 18.28
N. Trib below CNR (Outflow 320)	12.03	41.19	10.36	35.58	8.82	30.10	6.61	22.36	5.04	18.26
Main CR, above Confluence w/ Trib #1 (Outflow 312)	14.69	46.02	12.70	40.67	10.55	34.57	7.76	25.89	5.85	21.35
E. Trib at CNR* (Outflow 304)	(5.12) 4.83	(16.82) 10.05	(4.43) 4.27	(14,65) 9,23	(3.77) 3.75	(12.55) 8.46	(2.90) 2.89	(9.79) 7.21	(2.25) 2.25	(7.82) 5.90
E. Trib above Main Cr. (Outflow 309)	7.14	14.46	6.36	13.13	5.57	11.82	4.31	9.85	3.36	8.20
Trib #1 at old City Limit (Inflow 316)	3.18	6.84	3.28	6.01	3.11	5.20	2.15	4.12	1.62	3.31
Trib #1 above Confluence w/ Main Cr (Outflow 316)	4.83	8.28	4.18	7.37	3,85	6.47	2.70	5.22	2.05	4.23
Main Cr below CPR* (Outflow 317)	(24,47) 23.60	(64.86) 52.23	(21,44) 20,54	(56.99) 45.81	(17.95) 17.49	(49.01) 39.93	(13.25) 13.21	(37.32) 32.22	(10.14) 10.13	(30.81) 27.14
Bell Creek at Bay of Quinte (Outflow 318)	23.70	52.38	20.64	46.23	17.58	40.02	13.28	32.30	10.19	27.19

<sup>\*</sup> denotes location of reservoirs

Note: Post-development flows are uncontrolled (no SWM).

#### 7.2 POST-DEVELOPMENT

#### 7.2.1 General Watershed Development Trends

Present zoning has the lands south of the CNR tracks, within the City of Belleville, classified as residential with the exception of an industrial buffer strip south of the tracks. One parcel of land north of the CNR tracks has recently had its zoning designation changed to industrial. The rest of the watershed is currently designated primary agricultural.

Considering development pressures and local trends it is assumed, for post-development conditions, that the residential area will extend eastward and that the majority of the remaining lands will become industrial/commercial.

#### 7.2.2 Watershed Characteristics

Changes in future development over the watershed are reflected in new watershed parameters. Table 7.3 indicates the changes in CN, K, and Tp due to the increased imperviousness of the watershed.

#### 7.2.3 Results

The post-development flow simulation was accomplished by reapplying the HYMO computer program with the modified watershed parameters.

The results for the 5, 10, 25, 50, and 100 year storm events are represented in Table 7.2 for various points of interest. For a more detailed listing see Appendix H.

#### 7.3 COMPARISON OF RESULTS

There are significant increases in the pre- and post-development (uncontrolled) peak flows ranging from approximately 70% to 370%. All storm events contain a variety of increases in flow depending upon the location in the watershed.

TABLE 7.3

HYDROLOGIC MODELLING PARAMETERS
FUTURE CONDITIONS - FULL DEVELOPMENT
BELL CREEK

SUB-	Drainage	_			onditions	
BASIN	Area	%	CN	K	Tp	В
I.D.	(km2)	Imperv.		(hrs)	(hrs)	Value
301	2.95	46	88	0.50	1.00	580
302	2.59	47	89	0.36	0.72	580
303	2.93	42	89	0.42	0.84	580
304	3.29	47	86	0.36	0.72	580
305	1.35	48	89	0.38	0.75	580
306	1.16	43	90	0.32	0.64	580
307	0.62	57	88	0.22	0.44	580
308	1.42	57	87	0.27	0.53	580
309	1.86	29	89	0.84	0.98	322
310	0.41	57	89	0.19	0.32	485
311	0.41	35	90	0.50	0.55	350
312	0.60	54	91	0.20	0.39	570
313	0.78	43	90	0.48	0.53	350
314	0.36	32	89	0.50	0.41	280
315	0.36	26	89	2.93	0.92	123
316	0.167	28	89	0.47	0.41	290
317	0.60	24	89	0.51	0.48	295
		26	80	0.29	0.29	320
318	0.25		88	0.12	0.24	580
319	0.10	45				
320	0.142	50	90	0.13	0.25	580

#### 8.0 STORM WATER CRITERIA AND GUIDELINES

#### 8.1 PROCESS

The use of storm water management and its proper integration into viable urban developments requires an integrated effort on the part of engineers, planners, developers, and government agencies.

A key feature of all of these plans has been the incorporation of natural waterways, tree stands and valleys, and man-made swales, channels and ponds into continuous park greenways. Since these aesthetic areas are used for water transport, retention, detention or even recharge, they conform to the Blue-Green Concept. Basically the concept requires that the open spaces provided by the Hazard Lands, major drainage systems, valleys and parks be integrated into a continuous Green Belt for the beneficial use of both people and water transport.

As shown in Figure 8.1, the first interface between agencies occurs during the preparation of the Moira River Conservation Authority's Watershed Master Plan. Watershed Urban Drainage Constraints and Targets identified in the Watershed Master Plan should define all the flood plains and flood damage centres, areas of erosion and bank instability and the effects of urbanization and storm water management measures on quantity and quality in general terms.

Using the opportunity provided by development, the municipality should determine the optimum set of storm water measures needed for development of specific areas and indicate approximate sizes and locations of channels and quantity and quality ponds, to satisfy the unique constraints of that drainage area. Ideally, this is done through the preparation of a Master Drainage Plan completed in conjunction with a Secondary Plan for an area when all other services are considered.

When a draft plan of subdivision is being prepared for a portion of a community, the proponent's water resource engineer would then prepare a preliminary Storm Water Management Plan. With street and lot layouts, the engineer will be able to define the extent and directions of the major and minor systems and how the facilities will meet the requirements of the Master Drainage Plan. The requirements for erosion and sediment control should be conceptually investigated. (See Appendix J for a Recommended Table of Contents for Storm Water Management Study/Assessment submission.)

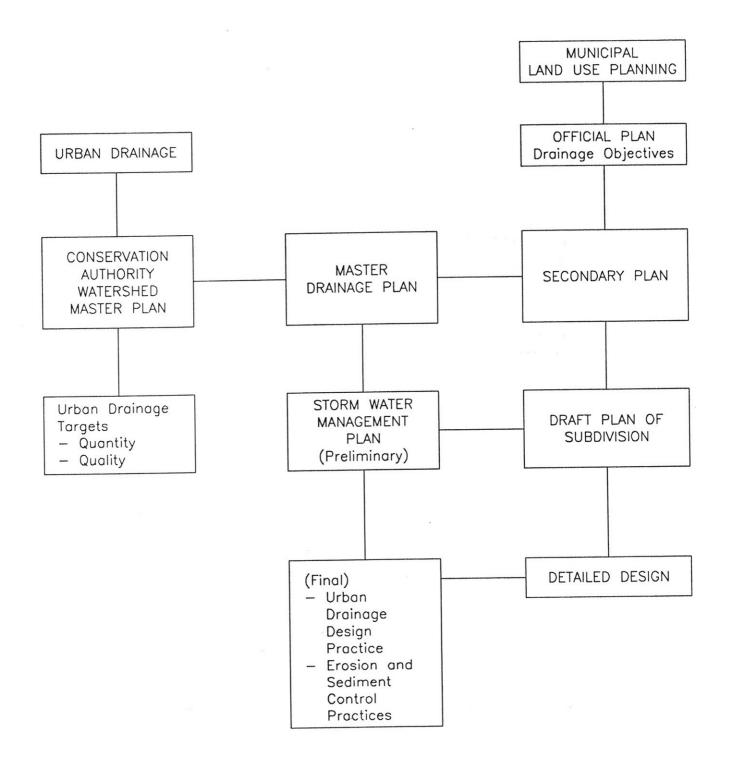


FIGURE 8.1
STORM WATER MANAGEMENT PROCESS

Only when detailed design drawings become available is it possible to prepare the Final Storm Water Management Plan Report. The details for this Report are incorporated into the design drawings. The final Storm Water Management Plan Report should document how the works will meet or exceed the applicable requirements of the Master Drainage Plan and Conservation Authority's Watershed Master Plan and should detail the erosion and sediment control measures.

From the above, it is obvious that the following items be included in every urban drainage project - storm water quality and quantity to protect against surface flooding, protection against basement flooding, erosion and sediment control during construction, streets designed for both convenience and conveyance, and a receiving watercourse that will be a stable habitat for fish and wildlife under the projected flow regime.

#### 8.2 MAJOR-MINOR SYSTEM

The use of the Major - Minor storm water management concept allows for a cost effective management of storm water runoff.

#### (a) Minor System

The minor system is the storm drainage system consisting of roof gutters, rainwater leaders, service connections, swales, street gutters, catchbasins, and storm sewers, and is designed to convey runoff from the more frequent, less intense storms, eliminating or minimizing the inconvenience in the area. For this watershed the design storm for the minor system shall be the 5 year storm.

#### (b) Major System

The route followed by storm runoff when the minor system is inoperative or of inadequate capacity constitutes the major system. This system will function whether or not it has been planned or designed, and whether or not developments are situated wisely with respect to it. As a result it is imperative that as development proceeds the major system be designed to provide protection against flooding and damage, equivalent to that provided by the flood plain criteria recommended by the Ministry of Natural Resources and endorsed by the Moira River Conservation Authority.

Interface between the major and minor system are the swales and catchbasins. Swales and/or catchbasins should be designed to capture all of the flows up to the intensity of the minor system design frequency (5 year design storm).

#### 8.2.1 Road Crossings

Where roads cross the major system the following design storm events should be used:

	Design	Flood	Frequency*
Road	Culverts up	to	Bridges, Culverts
Classification	6 m span		over 6 m span
Arterial, Freeway	,		
Regional	50		100
Collector	25		50
Local	10		25

\*Refer to latest version of Ministry of Transportation of Ontario Directive PRO B-100.

If bridges or culverts are designed for an event less than the 100 year design storm flow, backwater effects must be determined.

#### 8.2.2 Design of Streets for Convenience and Conveyance

Streets, gutters, catchbasins, and storm sewers should be designed to minimize frequent surface ponding for events up to the 5 year design storm.

The Urban Drainage Design Guidelines released by the Ontario Government in 1987, suggest that the following flooding depths be utilized for both the major and minor system.

- (i) Suggested depths of flooding on streets while acting as part of the minor system:
  - (a) no curb overtopping.
  - (b) on local roads, the flow may spread to the crown.
  - (c) on collector roads the flow spread should leave one lane free of water.
  - (d) on arterials the flow spread should leave one lane in each direction free of water.
  - (e) flow across intersections is not permitted.

- (ii) Suggested depths of flooding permitted for streets and at intersections during 100 year events:
  - (a) no building should be inundated at the ground line, unless the building has been floodproofed.
  - (b) for all classes of roads, the product of depth of water at the gutter (m) times the velocity of flow (m/s) should not exceed 0.65 m2/s except in special cases.
  - (c) for arterial roads the depth of water at the crown should not exceed 0.15 metres.

To meet the criteria for major storm runoff, low points along the road are only permitted if adequate provision is made for safe discharge of overland flow at the low points.

The use of reverse grade driveways is discouraged but if use is proposed, proponent must ensure that a suitable degree of flood protection has been provided.

#### 8.3 METHODS AND DEGREE OF QUANTITY CONTROL

Urbanization leads to increased runoff due to increased use of impervious surfaces and faster transport of water in storm sewers and on streets.

Several methods are available to alleviate the increase such as:

#### Rainwater Leaders

Discharging rainwater leaders from buildings onto grassed areas can increase infiltration and hence decrease the volume of runoff as well as decreasing velocity and peak flows.

#### Rooftop Storage

Temporarily detaining rainfall on the flat roofs of high density residential, commercial, and industrial buildings can safely reduce the rate of runoff to 42 l/s/ha of roof.

By using a controlled roof drain, a gravel berm around a beehive pot drain or merely decreasing the size of rainwater leader, a total depth of 50 to 75 mm can readily be retained on a flat roof. Special care must be given to the design and construction of such roofs to prevent cracking and leaking.

#### Parking Lot Storage

Rainfall may be temporarily detained by ponding at central catchbasins or at the edges of asphalt parking lots. Temporary detention may also be achieved within a 300 mm layer of granular pavement (sand and gravel or crushed stone). This works well in the summer but poorly in the winter.

#### Grassed Swales

Where ground slopes are small, grassed swales may be used to collect and transport runoff. With velocities in the range of 0.5 to 2.0 m/s, the peak rate is reduced and groundwater recharge increased.

Streets, Gutters, Catchbasins, and Storm Sewers

Catchbasins should have orifice plates, orifice inserts, or other flow controlling devices installed so that runoff capture is controlled during the less frequent, high intensity storms.

Streets will have to be designed to handle the overland flow during these infrequent storms and lead it safely to the watercourses and channels. Proper street grading is therefore required to ensure a continuous overland flow path and provision of discharge points to limit the depth and velocity of flow on streets to a safe level.

#### Detention and Retention Facilities

Detention facilities are normally "dry" or flow-through and serve only to detain water during significant runoffs.

Retention facilities always have some ponding water in them for quality control, aesthetics, or recreation.

Each facility is unique and pond designers must take into consideration the sociological, environmental, engineering, architectural, recreational, and safety and maintenance aspects.

#### Outlet Control Structures From Ponds

The outlet for a storm water pond must control the outflow to pre-development conditions for the 5 and up to the 100 year design storm. Outlets must not only be designed for this required hydraulic efficiency, but also for ease of operation and maintenance.

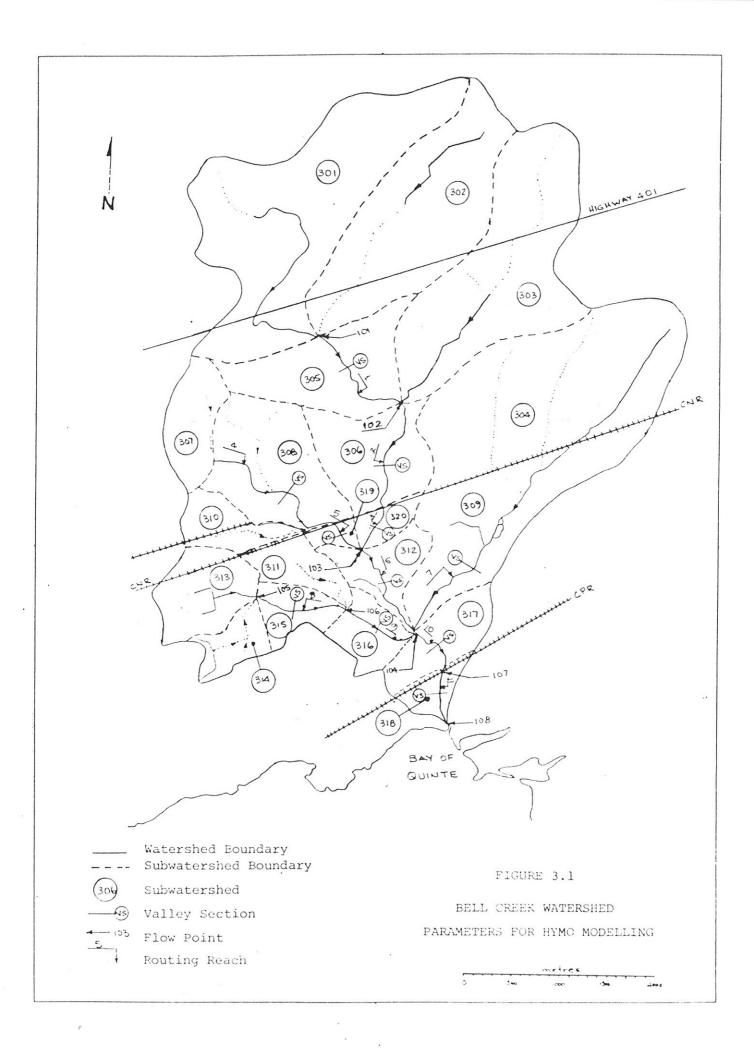
Inlets and outlets must be protected to prevent child or major debris access. The area at the downstream end of the outlet must be protected against erosion by channel lining and/or an energy dissipator. This is necessary for all minor system outlets to the channel as well.

#### 8.4 METHODS AND DEGREE OF QUALITY CONTROL

Urbanization of an agricultural area will lead to an increase in sediment and debris transport during construction. Until recently little attention has been given to water quality control or enhancement following the construction phase.

Recent watershed studies have indicated that water quality following development need not be adversely affected and, in fact may be improved as compared to present conditions. Permanent holding ponds or engineered marshes at major storm sewer outfalls and along watercourses in combination with other measures can provide "treatment" of stormwater sediment and pollutants normally settling out associated with urbanization. Both the Ministry of the of Natural Resources are Ministry Environment and promoting the use of permanent ponding areas at outfall points for water quality improvement. These ponds are required to accommodate only normal low-flow drainage from developments as well as pollutant laden "first-flush" runoff following prolonged dry periods. They are not intended to attenuate peak flows.

Some other measures which encourage the settling out of urban runoff contaminants include draining roof areas to pervious areas, use of soak away pits, use of grassed swales, use of "bottomless" catchbasins and manholes, and the retention of vegetated buffer strips adjacent to watercourses and drainage swales. It is most important that the use of the applied water quality technique be appropriate for the particular development under consideration.



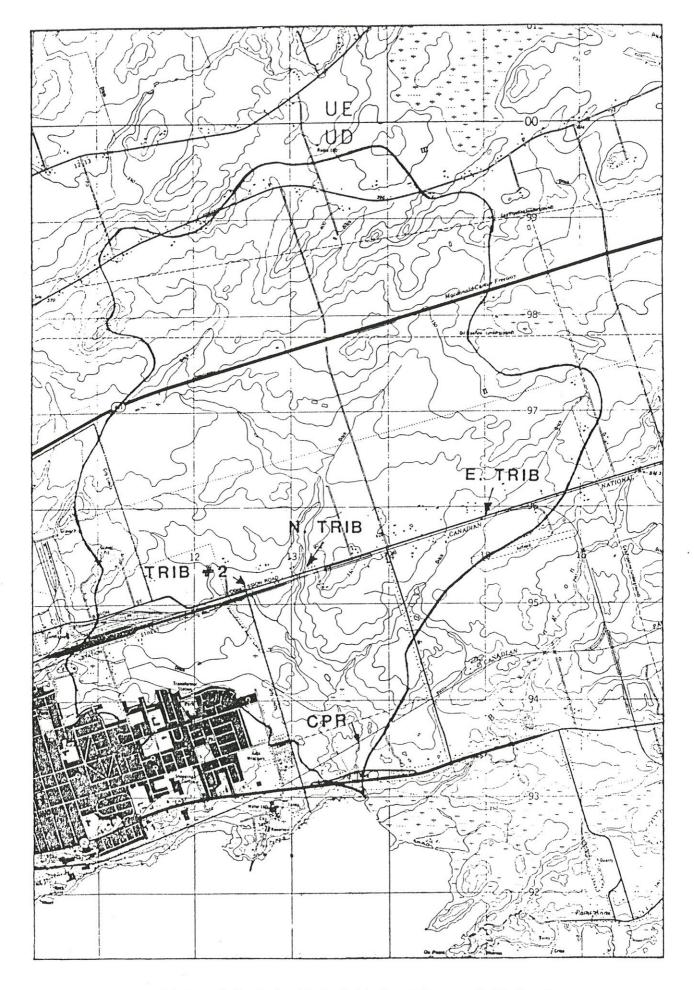
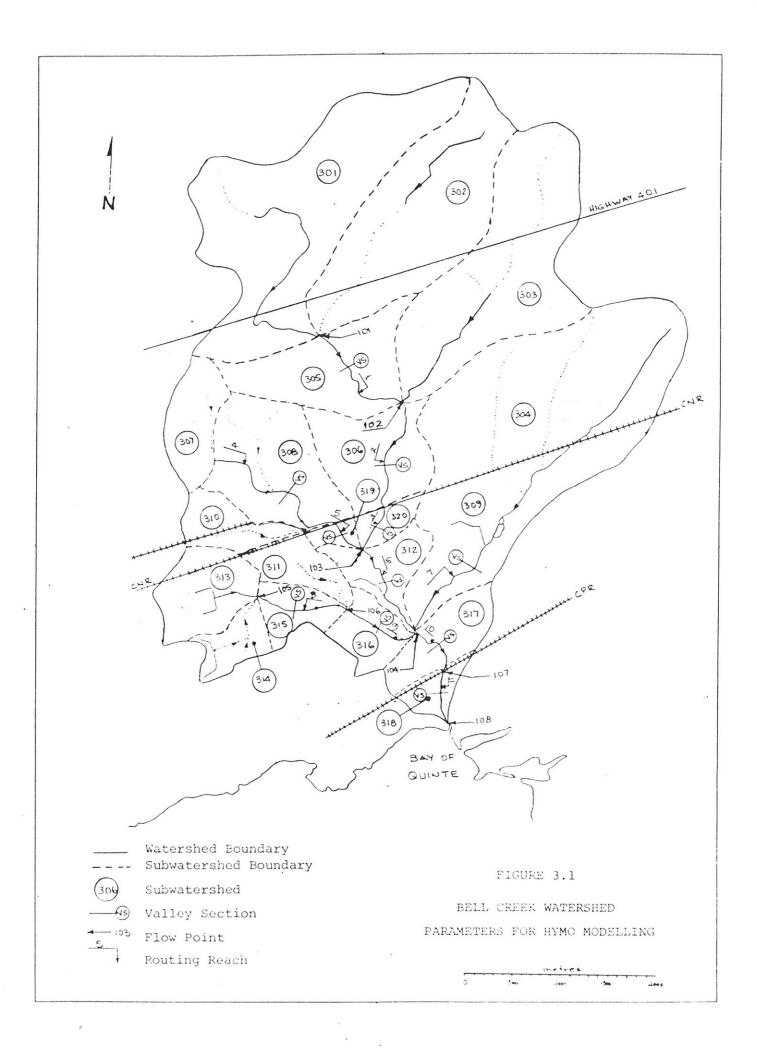


Figure 3.7 Principal Rail Crossings - Bell Creek



#### APPENDIX D

STAGE-DISCHARGE-STORAGE CURVE
CNR AT TRIBUTARY 2

#### STAGE-DISCHARGE-STORAGE CURVE

# CNR AT TRIBUTARY 2

Stage (m)	Discharge (cfs)	Storage (ac-ft)	
87.50	0.0	0.0	
87.53	10.0	0.006	
87.57	21.0	0.042	
87.66	41.0	0.367	
87.77	65.0	0.862	
88.00	94.0	2.85	
88.24	117.0	5.99	
88.50	140.0	11.1	
89.01	182.0	25.5	
89.50	231.0	49.3	

#### APPENDIX E

MONTHLY MEAN WATER LEVELS

LAKE ONTARIO

(Extract from MacLaren's Report)

#### TABLE 4.1

# MONTHLY MEAN WATER LEVELS LAKE ONTARIO - KINGSTON GAUGE 13988

Month	Mean Water Level (m) GSCD
	1
January	74.54
February	74.56
March	74.65
April	74.85
May	74.99
June	<u>75.03</u> *
July	74.99
August	74.89
September	74.75
October	74.63
November	74.55
December	74.53
1:100 Year <sup>2/</sup>	76.5 (flood elevation)
1:100 Year	76.7 (wave uprush level)

<sup>\*</sup> greatest monthly mean water level and starting backwater level for design precipitation storm runoff

Canadian Hydrographic Service, 1983 "Monthly Mean Levels - Present and Past, with a Forecast of Probable Future Levels", Monthly Mean Water Level Bulletin - Great Lakes and Montreal Harbour

<sup>2/</sup> Fisheries and Environment Canada and Ontario Ministry of Natural Resources, 1978. "Great Lakes Flood and Erosion Prone Areas" Mapping Sheet 62 -Bay of Quinte

APPENDIX F

BRIDGE DATA

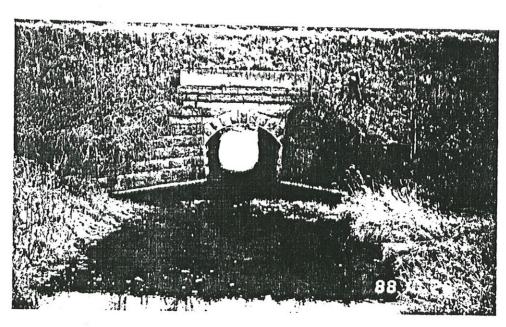
WATERCOURSE BELL CREEK	MAP SHEET No.	8
LOCATION CANADIAN NATIONAL RAILWAY	U.T.M. GRID REFERENCE _	4895268 m N
CROSS-SECTION No. 192		313047 m E

#### A. SPECIFICATIONS B. STAGE DISCHARGE CURVE Span \_\_\_\_\_\_ 3.0 \_\_\_ m 89. Top of Road Elevation 93.14 Top of Road Elevation (min.) 93-00 88 Low Chord (Soffit) Elevation Upstream \_\_\_\_\_\_\_89.34 \_\_\_\_ m Low Chord (Soffit) Elevation Downstream 84.34 ELEVATION (m 87. Upstream Invert Elevation 86.54 m Downstream Invert Elevation 86.36 Manning's 'n' Value \_\_\_\_\_\_ 0.020 Type of Structure STONE ARCH CULVERT DISCHARGE (cms)

# C. PHOTOGRAPHIC PRESENTATION

DATE:

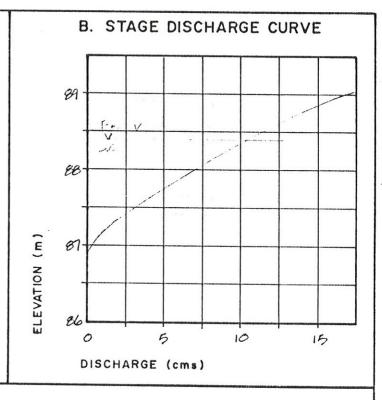
15

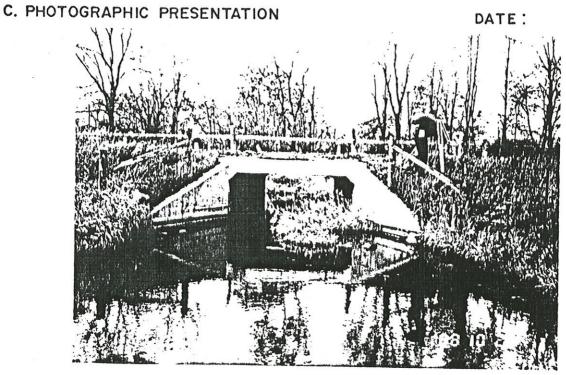


USETKEMI FY'E

WATERCOURSE BELL GREEK	MAP SHEET No	8
LOCATION COUNTY ROAD No. 18	U.T.M. GRID REFERENCE	4895304 m N
CROSS-SECTION No. 231		313036 m E

# A. SPECIFICATIONS Span 3.45 m Length of Structure 13.40 m Top of Road Elevation 89.10 m Top of Road Elevation (min.) 88.40 m Low Chord (Soffit) Elevation Upstream 88.38 m Low Chord (Soffit) Elevation Downstream 88.38 m Upstream Invert Elevation 86.83 m Downstream invert Elevation 86.83 m Effective Flow Area 5.60 m Manning's 'n' Value 0.013 Type of Structure CONCRETE CULVERY

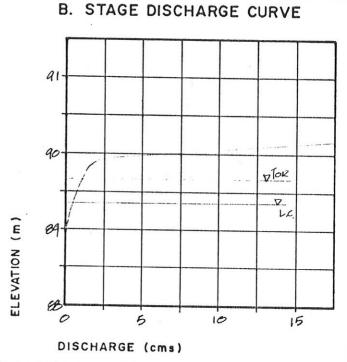




DOTYNETREAT! FACE

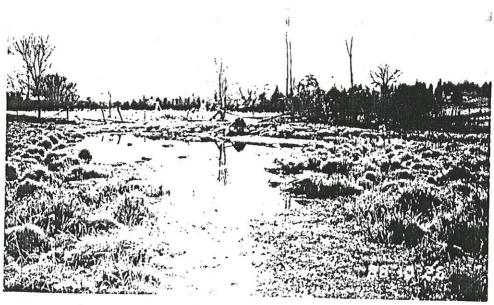
WATERCOURSE BELL CREEK	MAP SHEET No
LOCATION FARM CROSSING	U.T.M. GRID REFERENCE 4895845 m N
CROSS-SECTION No 864	313101 . 5

# A. SPECIFICATIONS Span \_\_\_\_\_\_ | 1.44 \_\_\_ m 91. Length of Structure \_\_\_\_\_\_ m Top of Road Elevation \_\_\_\_\_\_ 89.67 \_\_\_\_ m Top of Road Elevation (min.) 29.67 m Low Chord (Soffit) Elevation Upstream \_\_\_\_\_\_\_89.36 Low Chord (Soffit) Elevation Downstream 69.41 ELEVATION (m 89 Downstream Invert Elevation \_\_\_\_\_\_\_88.93 Effective Flow Area \_\_\_\_\_\_ 0.54 m<sup>2</sup> Type of Structure 121PLE 0.48m CSP



# C. PHOTOGRAPHIC PRESENTATION

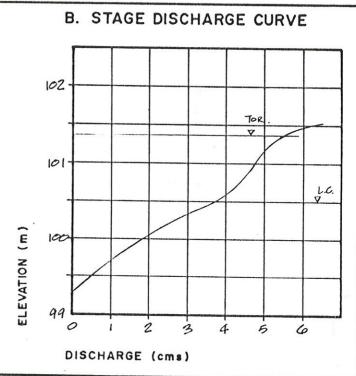
DATE:



UPSTREAM FACE

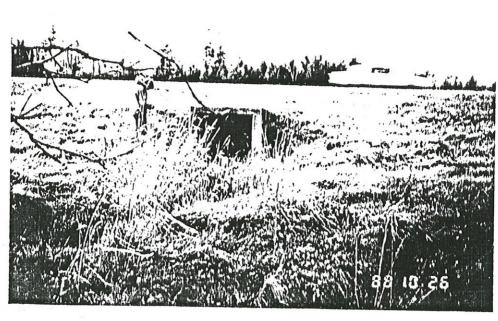
WATERCOURSE BELL CREEK	MAP SHEET No.	1
LOCATION HIGHWAY No. 401	U.T.M. GRID REFERENCE	4897255 m N
CROSS-SECTION No. 3503		311703m F

# A. SPECIFICATIONS 1.25 m Span \_\_\_ Length of Structure \_\_\_\_\_\_ 52.00 m Top of Road Elevation \_\_\_\_\_\_\_ 101.86 m Top of Road Elevation (min.) 10.36 m Low Chord (Soffit) 100.50 m Elevation Upstream \_\_ Low Chord (Soffit) Elevation Downstream 100.32 m Upstream Invert Elevation 99.25 m Downstream Invert Elevation 99.07 m Manning's 'n' Value \_\_\_\_\_\_\_ 0.013 Type of Structure SQUARE CONC. BOX CHUERT



#### C. PHOTOGRAPHIC PRESENTATION

DATE:



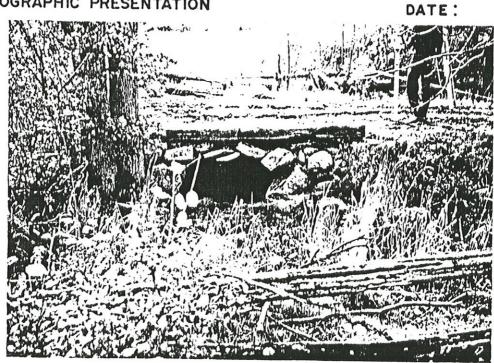
DOWNSTREAM FACE

WATERCOURSE	BELL	CREEK (TRIB.)	MAP SHEET No.	6
LOCATION	FARM	CROSSING	U.T.M. GRID REFERENCE	4896433m N
CROSS-SECTION N	lo	102		313314m E

# 

# B. STAGE DISCHARGE CURVE

# C. PHOTOGRAPHIC PRESENTATION



UPSTREAM FACE

WATERCOURSE	BELL CREEK (TRI	MAP SHEET No.	6
LOCATION	MITCHELL. ROAD	U.T.M. GRID REFERENCE _	4896775 m N
CROSS-SECTION No	656	-	313603 m E

# A. SPECIFICATIONS Span \_\_\_\_\_ m Length of Structure \_\_\_\_\_\_9.4co Top of Road Elevation \_\_\_\_\_\_96.62 Top of Road Elevation (min.) 96:39 Low Chord (Soffit) Elevation Upstream \_\_\_\_\_\_ 96.42 \_\_\_ m Low Chord (Soffit) Elevation Downstream 16.47 Upstream Invert Elevation 95.52 Downstream Invert Elevation 95.57 1.08 Effective Flow Area \_\_\_ m<sup>2</sup> Manning's 'n' Value \_\_\_\_\_ 0.024 Type of Structure DOUBLE CSP (0.9m AND 0.75m)

# B. STAGE DISCHARGE CURVE 96.5 VIC. VIOR 96.0 95.5 ELEVATION DISCHARGE (cms)

#### C. PHOTOGRAPHIC PRESENTATION





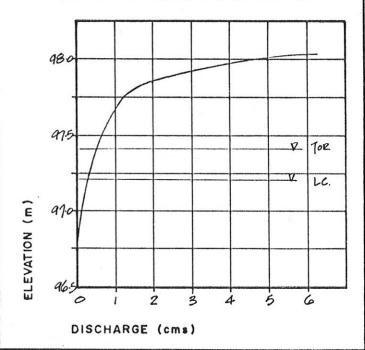
DOIVHSTREAM FACE

WATERCOURSE	BELL	CREEK (TRIB.)	MAP SHEET No.	4	
LOCATION	FARM	CROSSING	U.T.M. GRID REFERENCE	4896993 m N	_
CROSS-SECTION N	0.	938		313741 m F	

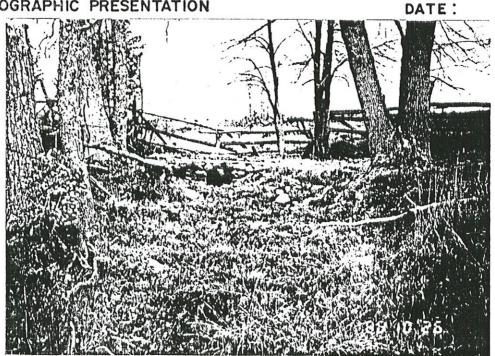
# A. SPECIFICATIONS

Span	0.60	_ m
Length of Structure	3.20	_ m
Top of Road Elevation	97.41	m
Top of Road Elevation (min.)	97.41	m
Low Chord (Soffit) Elevation Upstream	91.21	_ m
Low Chord (Soffit) Elevation Downstream	97.26	m
Upstream Invert Elevation _	96-61	m
Downstream Invert Elevation	96.66	m
Effective Flow Area	0.28	m²
Manning's 'n' Value	0.024	
Type of Structure	0.60m CSP	

### B. STAGE DISCHARGE CURVE



#### C. PHOTOGRAPHIC PRESENTATION



UPSTREAM FACE

# APPENDIX G

DETAILED LIST OF PRE-DEVELOPMENT FLOWS

APPENDIX 6

		PPENDIX		CHCNT	PRE-DEVELO	DMENT				
			MATER MANAG		25 year		10 year		5 year	
	100 yea		50 year				PEAK FLOW	Qρ	PEAK FLOW	Qp
LOCATION	PEAK FLOW	Qр	PEAK FLOW	Qр	PEAK FLOW	Qp	(cfs)	(cms)	(cfs)	(cms)
	(cfs)	(cms)	(cfs)	(cms)	(cfs)	(cms)			49.93	1.41
BASIN 301	124.99	3.54	106.55	3.02	88.88	2.52		1.87		1.78
BASIN 302	143.06	4.05	123.90	3.51	105.30	2.98		2.29	62.89	
FLOW PT #101	246.00	6.97	226.40	6.41	191.00	5.41		4.08	111.00	3.14
REACH #1	247.50	7.01	211.50	5.99	177.60			3.79	102.30	2.90
BASIN 305	47.32	1.34	40.30	1.14	33.59	0.95		0.71	18.83	0.53
PARTIAL FLOW @ PT #10	2 293.20	8.30	251.00	7.11	210.00	5.95		4.47	120.00	3.40
BASIN 303	114.59	3.24	97.16	2.75	80.52	2.28		1.68	44.19	1.25
FLOW PT #102	403.30	11.42		9.74		8.13		6.06	162.00	4.59
REACH #2	393.90	11.15	335.30	9.49		7.94		5.93		4.49
BASIN 306	58.16	1.65	50.11	1.42		1.20		0.91	24.87	0.70
FLOW @ RR TRACK	442.00	12.52	377.00	10.68		8.92		6.68		5.07
RESERVOIR 501	422.60	11.97	364.00	10.31		8.76		6.58		5.00
REACH #3	421.00	11.92	362.80	10.27	308.30	8.73		6.55		4.97
BASIN 320	11.96	0.34	10.26	0.29		0.24		0.19		0.14
FLOW D/S OF RR @ 320	425.00	12.03	366.00	10.36	311.50	8.82	233.60	6.61		5.04
BASIN 307	39.91	1.13	33.71	0.95	27.80	0.79	20.25	0.57		0.42
REACH #4	38,30	1.08	32.10	0.91	26.10	0.74	18.70	0.53	13.40	0.38
BASIN 308	42.76	1.21		1.00	28.07	0.79	19.36	0.55	13.37	0.38
ADD HYD (134)	79.60	2.25		1.88	53.50	1.51	37.40	1.06	26.40	0.75
BASIN310	71.99	2.04		1.76		1.50	41.36	1.17	32.54	0.92
BASIN 308+310	116.00	3.28		2.78		2.27	58.00	1.64	43.00	1.22
RESERVOIR 502	100.70	2.85		2.53		2.12		1.62	41.80	1.18
REACH #5	99.50	2.82		2.47		2.08		1.55		1.13
BASIN 319	5.08	0.14		0.12		0.10		0.07	1.61	0.05
ADD HYD (132)	102.90	2.91		2.57		2.15		1.61		1.17
FLOW PT #103	506.80	14.35		12.32		10.31		7.65		5.78
REACH #6	496.90	14.07		12.13		10.08		7.40		5.58
BASIN 312	33.61	0.95		0.83		0.70		0.54		0.43
ADD HYD (134)	518.80	14.69		12.71		10.55		7.76		5.85
BASIN 304	180.78	5.12		4,43		3.77		2.90		2.25
RESERVOIR #503	170.50	4.83		4.27		3.75		2.89		2.25
	99.22	2.81		2.52		2.12		1.67		1.34
BASIN 309		7.14		6.38		5.57		4.31		3.36
ADD HYD (135)	252.00	21,38		18.69		15.43		11.41		8.69
PARTIAL @ PT #104	755.20			1.60		1.72		1.03		0.80
BASIN 313	65.71	1.86		2.22		1.93		1.53		1.23
BASIN 314	88.90	2.52		3.37		3.28		2.21		1.73
FLOW PT #105	137.60	3.90				2.19		1.43		1.11
REACH #8	91.00	2.58		2.21		0.3		0.28		0.20
BASIN 315	16.31	0.46		0.40		2.5		1.69		1.31
ADD HYD (116)	106.90	3.03		2.61		0.59		0.48		0.31
BASIN 311	27.74	0.79		0.68				2.15		1.62
FLOW PT #106	134.60	3.81		3.28		3.1				1.61
REACH #9	134.30	3.80		3.30		3.1		2.14		0.67
BASIN 316	57.48	1.63		1.39		1.10		0.88		2.05
ADD HYD (116)	170.80	4.83		4.18		3.8		2.70		
FLOW PT #104	846.00	23.96		21.07		17.6		12.97		9.88 9.84
REACH #10	841.80	23.84		20.88		17.4		12.89		0.72
BASIN 317	53.32	1.51		1.32		1.1		0.90		
FLOW PT #107	864.00	24.47		21.4		17.9		13.25		10.14
RESERVOIR #504	833.50	23.60		20.5		17.4		13.21		10.13
REACH #11	832.90	- 23.59		20.5		17.4		13.21		10.13
BASIN 318	14.08	0.40		0.33		0.2		0.19		0.14
FLOW PT #108	837.00	23.70	729.00	20.6	621.00	17.5	8 469.00	13.28	360.00	10.19

When a Storm Water Management Plan is submitted for a proposed development the proponent should submit an outline of his proposed erosion-sediment control plan. Methods of control are such things as sediment traps or temporary retention ponds, seeding of topsoil stock piles, isolated stripping of development lands, and vegetation screens.

# 8.4.1 Erosion and Bank Stability

Urbanization, if uncontrolled will accelerate the natural evolution of a valley. As a result, if erosion or bank instability is already evident, the proponent should participate in stabilizing the situation by appropriate remedial measures or by controlling the quantity and rate of runoff. Attention should also be paid to erosion caused by overbank flow. Erosive velocities should either be avoided or remedial works constructed to handle them.

#### Channelization

Where channelization is required, the works should be designed to the extent possible, to maintain natural vegetation in the floodway and to replicate the good features of the natural channel.

Small weirs should be used to keep velocities low. Side slopes should not be steeper than 3:1 (horizontal:vertical) and parabolic and V-shaped channels are preferred over trapezoidal channels.

## Storm Sewer Outlets

The channel must be protected at local points of entry of the storm sewer system to the major system. Protection can be provided through the design of a channel lining or an energy dissipator.

### Overland Flow Outfalls

In designing overland flow outfalls from streets to other components of the major system aesthetics, erosion control, and water quality are of dominant concern. Protection must be provided to protect the major system from erosion or bank instability.

#### 9.0 DISCUSSION OF STORM WATER MANAGEMENT PROPOSALS

#### 9.1 WATERSHED AREA NORTH OF THE CANADIAN NATIONAL RAILWAY

The watershed area north of the CNR tracks is proposed to industrial/commercial development. Thus all developments must control their post development conditions to pre-development levels on site. Care must also be given during storm water system design to ensure that natural storage is also maintained within the area. This does not mean that the existing floodlines must remain the same, but that the storage capacity of the watershed sub-basins must be equal to or exceed the natural pre-development storage volume. Care must be taken to maintain adequate storage at the Highway 401 culvert and a change in culvert size must not be considered without the approval of the Moira River Conservation Authority, the Ministry of Natural Resources, and the Ministry of Transportation of Ontario.

Should a change occur in the floodline location, approval must be obtained from the Moira River Conservation Authority and the Ministry of Natural Resources prior to development proceeding.

To allow flexibility in design of on-site storm water management systems for this area no potential storm water controls have been examined. Each proponent shall present his storm water management scheme, utilizing approved controls and each scheme must be examined on an individual basis or as a part of a development group.

#### 9.2 EXISTING STORM WATER CONTROLS

The three CNR culverts provide an interface between Upper and Lower Bell Creek drainage areas. In order that flows do not increase downstream, the culverts on the East Tributary, Tributary #2 and the main channel must not be changed in grade, size, or hydraulic capacity. Results of the pre- and post-development modelling indicate that these culverts play a significant role in attenuation flows (see Table 7.2) for all storm events. If changes are proposed the proponent must obtain review and approval of design from the Moira River Conservation Authority, the Ministry of Natural Resources, the City of Belleville, and/or the Township of Thurlow, and the Canadian National Railway. The proponent must also show, through revised hydraulic modelling, the upstream and downstream effects of such change.

The Lower Bell Creek Watershed also has a restrictive crossing. The CPR culvert on the main channel (flow Point 107) also serves to attenuate peak flows. Similar care and approvals must be obtained to substantiate hydraulic changes at this crossing.

# 9.3 WATERSHED AREA SOUTH OF THE CANADIAN NATIONAL RAILWAY

It is most likely that development in the residential areas will incorporate the use of detention or retention facilities. It should be noted that the use of storm water management ponds generally indicates that there will be a need for channelization and erosion control due to the increases in volume resulting from sustained flows. Proposed and/or potential pond locations are shown on Figure 9.1.

### Tributary #1 and East Tributary

Development runoff along the two tributaries in Lower Bell Creek could be accommodated through the use of an on-line detention facility. Maintaining a green-belt, that can act as a detention area during intense storm events, along the floodway is a viable alternative provided that homes are located outside the floodplain. Any changes to the location of the floodlines must meet with the approval of the Moira River Conservation Authority and the Ministry of Natural Resources and the governing municipality.

Care should be taken to ensure that all road crossings meet these storm water criteria under new floodline conditions and that the regenerated floodlines adequately model the effects of the crossing.

Erosion control, bank stability and water quality must also be considered as important design aspects of a storm water pond on the tributaries. It is assumed that runoff must travel some distance either through the storm sewer system, overland, or down the channel to reach the storm water pond. Therefore the proponent must submit an erosion control and bank stability plan outlining remedial measures at storm sewer outlets, overland flow outfalls, and channelization measures required to ensure that erosive velocities and higher peaks upstream of the pond will not inadvertently damage the existing channel. Water quality initiatives must be addressed by the proponent for conditions during and after construction.

### Main Channel

Development along the main channel requires careful design considerations.

Sub-basins 320 and 312 are small and the creek and floodplain meander through the centre of them. It is unlikely that there is sufficient land to accommodate storm water ponds on site.

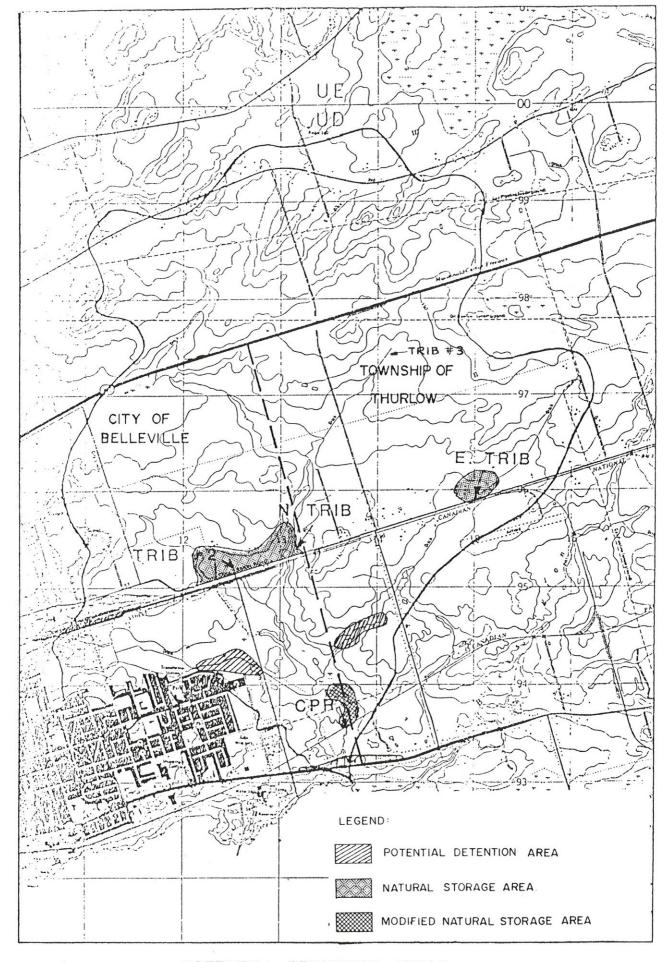
Potential does exist to utilize and enhance the natural storage capacity generated by the CPR culvert. Care must be taken to ensure that this pond has sufficient volume to accommodate the increase in runoff volume for the watershed area upstream of the CPR. Although peak flows are attenuated to pre-development conditions the increase of imperviousness of the watershed has increased the total volume of runoff.

Land adjacent to the railroad tracks could perhaps provide an economical green space. This proposal is valid provided that channelization and sufficient storage be provided to accommodate 100 year flows. The channel could be designed to convey the 25 year or more frequent storms provided that the floodplain is protected from the erosive velocities and higher peaks of the more intense events. Related backwater effects must be considered on the East Tributary and Tributary #1 to determine the requirement for associated remedial measures on the tributaries. Any alterations in the floodline locations are subject to the approval of the Moira River Conservation Authority and the Ministry of Natural Resources.

Erosion control and bank stability measures may be required along the downstream reach below the CPR tracks based on the increased runoff volumes produced by development in the main channel area.

## Below the CPR Tracks

Channelization is perhaps the most cost effective alternative to handle the peak flows through this area. The reach is relatively short and the land base is too small to support on-site detention facilities. The effects of urbanization on the sub-watershed (Sub-Basin 318) increases the peak flow from 0.4 to 1.09 cms, which if left uncontrolled would be approximately 4% of the entire pre-development flow at the Bay of Quinte.



POTENTIAL DETENTION AREAS

## 10.0 CONCLUSIONS AND RECOMMENDATIONS

## 10.1 GENERAL

It is recommended that the Moira River Conservation Authority, City of Belleville, surrounding Municipalities and Local Developers adopt a planning procedure that requires the preparation of Master Drainage Plans.

# Storm Water Management Policies, Criteria and Guidelines

It is recommended that the Moira River Conservation Authority, in conjunction with the City of Belleville and surrounding Municipalities, develop specific policies, criteria and guidelines for the implementation of Storm Water Management practices. Since many of the watersheds overlap municipal boundaries, the policies, criteria and guidelines should be prepared jointly to ensure consistency in their application.

#### Master Drainage Plans

In conjunction with an adopted planning procedure, appropriate storm water management policies, criteria and guidelines, and along with approved Official/Secondary Planning Documents, it is recommended that the Municipalities, in association with developers, prepare Master Drainage Plans for those watersheds experiencing significant development pressures. The preparation of the Master Drainage Plans should be carried out by qualified consultants, in conjunction with the Conservation Authority.

## Storm Water Management Plans

It is recommended that a Storm Water Management Study be required for all proposed developments. The studies should be carried out in accordance with established planning procedures, adopted storm water policies, criteria and guidelines, and if applicable, approved Master Drainage Plans.

The study should address a specific storm water management plan and generally follow the Recommended Table of Contents provided in Appendix J.

The cost of these undertakings, which can be substantial, should be paid by the proponents of the land developments. Several methods of payment have been used by various municipalities and as such, it is sufficient at this time to be aware that the burden of cost for such work is being transferred to the developers of the land.

Once the Master Drainage Plan has been prepared, reviewed and accepted by all parties, then developers should retain a qualified consultant to prepare specific Storm Water Management Plans. The Authorities should again retain a qualified consultant to review individual Storm Water Management Plans. As in the case of the Master Drainage Plan, the cost of any review should be paid by the participating proponents of the land developments.

#### 10.2 BELL CREEK

## 10.2.1 General

The Bell Creek watershed is under extreme development pressure. Several land developments have been proposed and are in various stages of the planning and review process.

Because there are no specific requirements to undertake Master Drainage Plans within the context of the planning process and no Municipality approved Storm Water Management Policies and Criteria have been adopted, land developers do not totally appreciate the complex nature of addressing drainage concerns as well as the value of an overall collective approach for the effective management of runoff within the Bell Creek watershed.

In 1984 the Conservation Authority undertook Flood Plain Mapping for the Lower Bell Creek watershed. The study established Regulatory Floodlines for the main channel to the south of the CNR Railway and along Tributary #1. Since development pressure was being experienced on Tributary #1, the study did prepare a Master Drainage Plan for the tributary. The proposed storm water facility on Tributary #1 has been considered a valid approach to control runoff from the surrounding proposed developments.

This study has resulted in a Master Drainage Plan for the entire Bell Creek Watershed. The Plan identifies sufficient guidelines and criteria to enable the proponents of land developers to address drainage, water quality, and erosion control concerns within the context of the development of the watershed.

## 10.2.2 Storm Water Drainage Controls

It is recommended that:

Storm water runoff be controlled according to the following criteria:

- (a) facilities for the major drainage system be required to maintain pre-development runoff for the 5, 10, 25, 50, and 100 year design storm events.
- (b) residential storm water runoff facilities and controls for the associated major system can be located on-site, off-line, or on-line. Any proposal for an on-line facility should be incorporated into a park like setting, account for any increased volume of runoff from upstream areas, and be justifiable relative to the preferred options of on-site or offline.
- (c) industrial and commercial storm water runoff facilities and controls for the associated major system be located off-line or on-site.

Construction of a storm water pond on Tributary #1 will help abate erosion due to the increase in runoff created by development. A similar pond on the East Tributary could aid in development runoff and associated erosion control on the East Tributary of Bell Creek.

Modification of the natural storage upstream of the CPR culvert crossing could provide storm water management potential for development of the Main Channel residential area located upstream of the confluence with the tributaries (Sub-Basins 312 and 320).

## 10.2.3 Water Quality Measures

The provision for water quality maintenance and enhancement are primarily based upon the installation of water quality holding ponds at major outfall points. The size of the water quality ponds be weighed against potential vegetation and habitat destruction in each outfall area. Wherever possible, these ponds would be located off-line relative to the main watercourse.

In addition to storm water ponds, storm drainage facilities be installed with specific components that encourage the settling out of pollutants and particulate matter. Deepened sumps in manholes, "bottomless" or "pervious" catchbasins or manholes, and draining roof areas to pervious surfaces to promote infiltration aid in storm water quality improvement.

## 10.2.4 Erosion Control Measures

The potential for increased erosion through increased flows should not be a concern due to the storm water controls imposed on the watershed up to the 100 year storm frequency. However, the extended duration of peak flows could be a factor in increasing erosion.

It is important therefore that all erosion sensitive areas and unstable banks be identified prior to development so that remedial measures can be undertaken to impede the creek decay.

Channelization measures be incorporated in all reaches where the flows are in exceedance of the existing predevelopment level.

Protection measures be provided at all major system outfall locations along the main watercourse.

Protection measures be provided for all storm sewer outlets at their entry points into the major system.

# APPENDIX A

REFERENCES AND ABBREVIATIONS

#### REFERENCES

- 1. Moira River Conservation Authority. Flood Plain and Water Management Study, Bell Creek. Report prepared by MacLaren Plansearch Inc. dated March, 1984.
- 2. City of Belleville. Official Plan of the Belleville and Suburban Planning Area Amendment No. 122. Report prepared by Ainley and Associates Ltd. dated November, 1987.
- 3. Township of Thurlow. Comprehensive Zoning By-Law No. 3014. by Township of Thurlow. dated August 1987.
- 4. U.S. Department of Agriculture. Soil Conservation Services,
  Urban Hydrology for Small Watersheds, Technical Release
  No.55. by the Engineering and Watershed Planning Unit. dated
  January 1975.
- 5. Ministry of Transportation of Ontario. <u>Design Flood</u>
  <u>Estimation for Medium and Large Watersheds</u>, <u>Bridge</u>
  Hydraulics Manual <u>Chapter C</u>. Downsview: 1979.
- 6. U.S. Department of Agriculture. <u>Soil Conservation Services</u>, <u>National Engineering Handbook</u>, <u>Section 4</u>, <u>Hydrology</u>. Washington: U.S. Government Printing Office, 1972.
- 7. Bureau of Reclamation, U.S. Department of the Interior.

  <u>Design of Small Dams</u>. Washington: U.S. Government Printing
  Office, 1974.
- 8. Ministries of Natural Resources, Environment, Municipal Affairs, and Transport and Communications; Association of Conservation Authorities of Ontario; Municipal Engineers Association; and Urban Development Institute, Ontario. <u>URBAN DRAINAGE DESIGN GUIDELINES</u>. April 1987.

## **ABBREVIATIONS**

m

metres .

yr, yrs

years

cfs

cubic feet per second

m3/s, cms

cubic metres per second

km

kilometres

sq km, km2

square kilometres

Ref.

reference(s)

no.

number

CN

curve number (used in hydrology)

hr

hours

SWM

Storm Water Management

trib

tributary

CNR

Canadian National Railway

W/

with

CPR

Canadian Pacific Railway

pre

pre-development

post

post-development

m2/s,

square metres per second

## APPENDIX B

12-HOUR DESIGN RAINFALL DEPTHS

# 12-HOUR DESIGN RAINFALL DEPTHS

# BELL CREEK

Return Period (yr)	12-Hour Rainfal (mm)	ll Depths (in)
5	50.1	1.97
10	56.7	2.23
25	65.0	2.56
50	71.1	2.80
100	77.1	3.04

# APPENDIX C

MACLAREN'S FIGURES 3.1 AND 3.7

# APPENDIX H

DETAILED LIST OF POST-DEVELOPMENT FLOWS

APPENDIX H

		PPENDIX		CHENT	DOCT BEUEL	ODMENT				
			MATER MANAG		POST-DEVEL		40		E	
	100 yea		50 year		25 year		10 year	0-	5 year	0-
LOCATION	PEAK FLOW		PEAK FLOW		PEAK FLOW	Qρ	PEAK FLOW		PEAK FLOW	<b>Q</b> p
	(cfs)	(cms)	(cfs)	(cms)	(cfs)	(cms)	(cfs)	(cms)	(cfs)	(cms)
BASIN 301	626.77	17.75		15.59	477.93	13.53		10.83	309.43	8.76
BASIN 302	543.60	15.39	480.50	13.61	418.60	11.85		9.49	271.36	7.68
FLOW PT #101	1141.80	32.33		28.56	878.00	24.86		19.88	567.70	16.08
REACH #1	904.50	25.61	792.30	22.44	682.40			15.19	425.40	12.05
BASIN 305	273.93	7.76	241.85	6.85	210.41	5.96		4.79	138.47	3.92
PARTIAL FLOW @ PT #10	2 1111.80	31.48	969.80	27.46	832.10	23.56		18.40	519.40	14.71
BASIN 303	578.78	16.39	513.15	14.53	448.57	12.70		10.23	294.37	8.34
FLOW PT #102	1615.90	45.76	1416.20	40.10		34.67		27.40	773.80	21.91
REACH #2	1485.40	42.06	1294.50	36.68	1109.10	31.41		24.63	694.90	19.68
BASIN 306	268.92	7.62	239.43	6.78	210.37	5.96		4.84	140.48	3.98
FLOW @ RR TRACK	1628.00	46.10	1422.80	40.29	1223.10	34.63	957.20	27.11		21.75
RESERVOIR 501	1496.60	42.38	1262.10	35.74	1069.60	30.29	789.80	22.36	645.60	18.28
REACH #3	1447.60	40.99		35.40	1057.10	29.93	785.10	22.23	640.80	18.15
BASIN 320	46.64	1.32		1.18		1.05	30.50	0.86	25.40	0.72
FLOW D/S OF RR @ 320	1454.70	41.19		35.58		30.10	789.80	22.36	644.80	18.26
BASIN 307	141.19	4.00		3.53		3.07	86.29	2.44	69.52	1.97
REACH #4	110.70	3.13		2.83		2.52	73.80	2.09	60.10	1.70
BASIN 308	301.33	8.53		7.53		6.55		5.23	148.95	4.22
ADE HYD (134)	407.60	11.54		10.26		9.01		7.32		5.92
BASIN 310	110.77	3.14		2.79		2.45		1.99		1.64
BASIN 308+310	484.10	13.71		12.19		10.72		8.72		7.07
RESERVOIR 502	196.40	5.56		5.24		4.83		4.28		3.84
REACH #5	194.60	5.51		5.18		4.78		4.22		3.78
	32.48	0.92		0.82		0.72		0.58		0.48
BASIN 319	199.60	5.65		5.31		4.89		4.32		3.88
ADD HYD (132)		46.84		40.89		34.99		26.61		21.99
FLOW PT #103	1654.20	45.18		39.91		33.88		25.41		21.02
REACH #6	1595.40			4,10		3,63		2.98		2,48
BASIN 312	161.87	4.58		40.67		34.57		25.89		21.35
ADD HYD (134)	1625.00	46.02				12.55		9.79		7.82
BASIN 304	593.85	16.82		14.65				7.21		5.90
RESERVOIR #503	354.80	10.05		9.23		8.46		4.64		3.77
BASIN 309	263.90	7.47		6.62		5.78		9.85		8.20
ADD HYD (135)	510.70	14.46		13.13		11.82				28.13
PARTIAL @ PT #104	2097.80		1863.10	52.76			1206.60	34.17		2.29
BASIN 313	154.44	4.37		3.89		3.42		2.78		
BASIN 314	69.20	1.96		1.73		1.51		1.21		0.98
FLOW PT #105	218.80	6.20		5.51		4.84		3.93		3.23
REACH #8	149.90	4.24		3.73		3.23		2.56		2.06
BASIN 315	24.84	0.70		0.62		0.5		0.44		0.36
ADD HYD (116)	173.70	4.92		4.33		3.74		2.98		2.41
BASIN 311	81.37	2.30	72.42	2.05		1.80		1.46		1.20
FLOW PT #106	241.40	6.84	212.10	6.01		5.20		4.12		3.31
REACH #9	234.00	6.63	206.70	5.85	180.60	5.1		4.08		3.32
BASIN 316	84.85	2.40	75.00	2.12	65.34	1.85		1.48		1.20
ADD HYD (116)	292.30	8.28	260.20	7.37	7 228.40	6.47	7 184.20	5.22		4.23
FLOW PT #104	2306.00	65.30	2028.60	57.44	1749.40	49.5		37.26		30.83
REACH #10	2254.60	63.84		56.19	9 1705.70	48.3	0 1297.00	36.73		30.31
BASIN 317	109.56	3.10		2.74		2.3	9 68.21	1.93	55.64	1.58
FLOW PT #107	2290.40	64.88			9 1730.80	49.0	1 1317.80	37.32	1088.00	30.81
RESERVOIR #504	1844.60	52.23		45.81		39.9		32.22	958.60	27.14
REACH #11	1844.20		1618.80		1409.00	39.9		32.20		27.12
BASIN 318	38.58	1.09		0.93		0.7		0.58		0.43
FLOW PT #108	1849.60		3 1632.60		3 1413.20		2 1140.60	32.30		27.19
I CON III WIVO	1012100	02100								

APPENDIX I

GLOSSARY

## BELL CREEK STORMWATER MANAGEMENT

### GLOSSARY

#### Drainage Area

- 1. The area contributing to a single drainage basin, expressed in hectares, square kilometres, or other units of area. Also called Catchment Area, Watershed, and River Basin.
- 2. The area served by a drainage system receiving storm and surface water; or by a watercourse.

### Flood Plain

The relatively flat or lowland area adjoining a river, stream, watercourse, lake, or other body of standing water which has been or may be temporarily with flood water. For administration purposes, the flood plain may be defined as the area that would be inundated with the Regulatory Flood.

## Flood Proofing

A combination of structural changes and adjustments to properties subject to flooding primarily for the reduction of flood damages.

### Imperviousness Ratio

The ratio of impervious surfaces to total surface area within a watershed or drainage area.

### Major Drainage System

That storm drainage system which carries the total runoff of the drainage system less the runoff carried by the minor system. The major system will function whether or not it has been planned and designed, and whether or not developments are situated wisely with respect to it. (Generally overland, above ground flow.)

#### Minor Drainage System

That storm drainage system which is frequently used for collecting, transporting, and disposing of snowmelt, miscellaneous minor flows, and storm runoff up to the capacity of the system (for Bell Creek - 5 year design storm). The minor system is sometimes termed the "convenience system", "initial system", or "storm sewer system".

### Storage

## Detention Storage

That water that is detained on a surface and does not become runoff until some time after the storm has ended.

## Offstream (off-line) Storage

The temporary storage of storm water away from the main channel of flow.

### Onstream (on-line) Storage

The temporary storage of storm runoff water behind embankments or dams located on the channel.

### Retention Storage

Water that is more or less permanently retained in an area with a free surface, commonly called a "wet pond" or lake.

### Surcharge

The flow condition occurring in closed conduits when the hydraulic grade line is above the conduit crown; or the transition from open channel to pressure flow.

#### Watercourse

A channel in which a flow of water occurs, either continuously or intermittently, and if the latter, with some degree of regularity. Such flow must be in a definite direction. Watercourses may be either natural or artificial, and flow may occur either on the surface or underground.

## APPENDIX J

STORM WATER MANAGEMENT STUDY/ASSESSMENT RECOMMENDED TABLE OF CONTENTS

# STORM WATER MANAGEMENT STUDY/ASSESSMENT RECOMMENDED TABLE OF CONTENTS

LETTER OF TRANSMITTAL

SUMMARY

#### SECTION NO.

## 1.0 <u>INTRODUCTION</u>

- 1.1 General
- 1.2 Background
- 1.3 Study Area
- 1.4 Criteria

## 2.0 HYDROLOGY

- 2.1 Model Selection
- 2.2 Rainfall Distributions
- 2.3 Soils
- 2.4 Pre-Development
  - 2.4.1 Drainage Area and Sub-Basins
  - 2.4.2 Watershed Characteristics
  - 2.4.3 Results
- 2.5 Post-Development
  - 2.5.1 Development Areas
  - 2.5.2 Drainage Area Modifications (if any)
  - 2.5.3 Watershed Characteristics
  - 2.5.4 Results
- 2.6 Flood Plain Mapping (if applicable)
- 2.7 Comparison of Results

#### 3.0 STORM WATER MANAGEMENT ALTERNATIVES

- 3.1 Storm Water Management Options
- 3.2 Runoff Control Options

  - 3.2.1 Option 1 3.2.2 Option 2
  - 3.2.3 Option n

- 3.3 Uncontrolled Areas
- 3.4 Comparison of Storm Water Management Alternatives
- 3.5 Recommended Storm Water Management Plan
  - 3.5.1 Detention/Retention Pond
  - 3.5.2 Control Structure
  - 3.5.3 Other Storage Areas and Control Devices (rooftops and parking lots)
  - 3.5.4 Sediment and Erosion Control
  - 3.5.5 Outfall Structures

## 4.0 WATER QUALITY MEASURES

- 4.1 Rationale
- 4.2 Analysis of Options
- 4.3 Recommended Plan

## 5.0 EROSION AND SEDIMENTATION CONTROL

- 5.1 Inventory of Existing Conditions
- 5.2 Recommended Erosion Control Plan
- 5.3 Erosion and Sediment Controls

### 6.0 STAGING AND IMPLEMENTATION STRATEGY

### 7.0 CONCLUSIONS AND RECOMMENDATIONS

- 7.1 Storm Water Drainage Control
- 7.2 Water Quality Measures
- 7.3 Erosion and Sedimentation Control

#### LIST OF TABLES

- 1. Rainfall Distributions
- 2. Soils
- 3. Sub-Basin Parameters (CN, Tp, K, etc.)
- Hydrologic Modelling Results (pre- and post-development)
- 5. Summary of Storm Water Management Alternatives
- 6. Stage-Discharge-Storage Data
- 7. Reservoir Modelling Results

### LIST OF FIGURES

- 1. Location of Proponent Watershed
- 2. Pre-Development Model Sub-Basin
- 3. Schematic of Pre-Development Model
- 4. Project Land Use for Proponent Watershed
- 5. Post-Development Model Sub-Basin
- 6. Schematic of Post-Development Model
- Storm Water Management Plan (pond and control structure, outfall structure, sediment and erosion control)
- 8. Flood Plain Mapping (if applicable)

#### APPENDICES

APPENDIX A - Relevant Computer Simulations Output

APPENDIX B - References

APPENDIX C - Relevant Correspondence/Meetings Material

# APPENDIX K

COMPUTER FILE LISTING (ALL RUNS)

## BELL CREEK

# HYMO FILES

FILENAME	DISKETTE No.	FILE CONTENT
BELHY.DO1	HG1	100 YEAR 12 HR RAINFALL EVENT. 4 RESERVOIR STRUCTURES (3 CNR & 1 CPR)
BELHY.001	HG1	OUTPUT FILE FOR BELHY.DO1
BELHY.DO2	HĞ1	50 YEAR 12 HR RAINFALL EVENT. 4 RESERVOIR STRUCTURES (3 CNR & 1 CPR)
BELHY.002	HG1	OUTPUT FILE FOR BELHY.DO2
BELHY.D03	HG1	25 YEAR 12 HR RAINFALL EVENT. 4 RESERVOIR STRUCTURES (3 CNR & 1 CPR)
BELHY.003	HG1	OUTPUT FILE FOR BELHY.DO3
BELHY.DO4	HG1	10 YEAR 12 HR RAINFALL EVENT. 4 RESERVOIR STRUCTURES (3 CNR & 1 CPR)
BELHY.004	HG1	OUTPUT FILE FOR BELHY.DO4
BELHY.D05	HG2	5 YEAR 12 HR RAINFALL EVENT. 4 RESERVOIR STRUCTURES (3 CNR & 1 CPR)
BELHY.005	HG2	OUTPUT FILE FOR BELHY.DOS
BELHY.DO6	HG2	2 YEAR 12 HR RAINFALL EVENT. 4 RESERVOIR STRUCTURES (3 CNR & 1 CPR)
BELHY.006	HG2	OUTPUT FILE FOR BELHY.DO6

## BELL CREEK

# HYMO FILES

FILENAME	DISKETTE No.	FILE CONTENT
BELHY.D11	HG2	100 YEAR 12 HR RAINFALL EVENT. 4 RESERVOIR STRUCTURES (3 CNR & 1 CPR) PLUS DETENTION POND AT OUTLET OF SUB-CATCHMENT 315.
BELHY.011	HG2	OUTPUT FILE FOR BELHY.D11
BELHY.D12	HG2	50 YEAR 12 HR RAINFALL EVENT. 4 RESERVOIR STRUCTURES (3 CNR & 1 CPR) PLUS DETENTION POND.
BELHY.012	HG2	OUTPUT FILE FOR BELHY.D12
BELHY.D13	HG3	25 YEAR 12 HR RAINFALL EVENT. 4 RESERVOIR STRUCTURES (3 CNR & 1 CPR) PLUS DETENTION POND.
BELHY.013	HG3	OUTPUT FILE FOR BELHY.D13
BELHY.D14	HG3	10 YEAR 12 HR RAINFALL EVENT. 4 RESERVOIR STRUCTURES (3 CNR & 1 CPR) PLUS DETENTION POND.
BELHY.014	H63	OUTPUT FILE FOR BELHY.D14
BELHY.D15	H63	5 YEAR 12 HR RAINFALL EVENT. 4 RESERVOIR STRUCTURES (3 CNR & 1 CPR) PLUS DETENTION POND.
BELHY.015	HG3	OUTPUT FILE FOR BELHY.D15
BELHY.D16	HG3	2 YEAR 12 HR RAINFALL EVENT. 4 RESERVOIR STRUCTURES (3 CNR & 1 CPR) PLUS DETENTION POND.
BELHY.016	HG3	OUTPUT FILE FOR BELHY.D16

# LOWER BELL CREEK

# HEC-2 FILES - BAY OF QUINTE TO CNR

FILENAME	DISKETTE No.	FILE CONTENT
LBELH2-1.D01	H1	100 YEAR EVENT. MAIN CHANNEL, TRIBUTARY 2 AND EAST TRIBUTARY.
LBELHE-1.001	H1	EDIT-2 OUTPUT FILE FOR LBELH2-1.D01
LBELH2-1.001	H1	OUTPUT FILE FOR LBELH2-1.D01
LBELH2-1.D02	H1	50 YEAR EVENT. MAIN CHANNEL, TRIBUTARY 2 AND EAST TRIBUTARY.
LBELH2-1.002	H1	OUTPUT FILE FOR LBELH2-1.D02
LBELH2-1.D03	H1	25 YEAR EVENT. MAIN CHANNEL, TRIBUTARY 2 AND EAST TRIBUTARY.
LBELH2-1.003	H1	OUTPUT FILE FOR LBELH2-1.D03
LBELH2-1.DO4	H1	10 YEAR EVENT. MAIN CHANNEL, TRIBUTARY 2 AND EAST TRIBUTARY.
LBELH2-1.004	H1	OUTPUT FILE FOR LBELH2-1.D04
LBELH2-1.D05	H1	5 YEAR EVENT. MAIN CHANNEL, TRIBUTARY 2 AND EAST TRIBUTARY.
LBELH2-1.005	H1	OUTPUT FILE FOR LBELH2-1.D05

# LOWER BELL CREEK

# HEC-2 FILES - BAY OF QUINTE TO CNR

FILENAME	DISKETTE No.	FILE CONTENT
LBELH2-2.D01	Н1	100 YEAR EVENT. TRIBUTARY 1.
LBELHE-2.001	H1	EDIT-2 OUTPUT FILE FOR LBELH2-2.D01
LBELH2-2.001	H1	OUTPUT FILE FOR LBELH2-2.D01
LBELH2-2.D02	H1	50 YEAR EVENT. TRIBUTARY 1.
LBELH2-2.002	H1	OUTPUT FILE FOR LBELH2-2.D02
LBELH2-2.D03	H1	25 YEAR EVENT. TRIBUTARY 1.
LBELH2-2,003	H1	OUTPUT FILE FOR LBELH2-2.D03
LBELH2-2.D04	H1	10 YEAR EVENT. TRIBUTARY 1.
LBELH2-2.004	H1	OUTPUT FILE FOR LBELH2-2.D04
LBELH2-2.D05	H1	5 YEAR EVENT. TRIBUTARY 1.
LBELH2-2.005	H1	OUTPUT FILE FOR LBELH2-2.D05

# UPPER BELL CREEK

# HEC-2 FILES - CNR TO HWY NO. 401

FILENAME	DISKETTE No.	FILE CONTENT
 	now have they have been been talk to the new time and the part they have the	
UBELSD.DO1	S1	STAGE-DISCHARGE RUNS. 3 PROFILES.
UBELSE.001	S1	EDIT-2 OUTPUT FILE FOR UBELSD.D01
UBELSD.001	S1	OUTPUT FILE FOR UBELSD.D01
UBELSD.D02	S1	STAGE-DISCHARGE RUNS. 3 PROFILES.
UBELSE.002	S1	EDIT-2 OUTPUT FILE FOR UBELSD.D02
UBELSD.002	S1	OUTPUT FILE FOR UBELSD.DO2
UBELH2.D01	U1	100 YEAR EVENT. MAIN CHANNEL AND TRIBUTARY.
UBELHE.001	U2	EDIT-2 OUTPUT FILE FOR UBELH2.D01
UBELH2.001	U1	OUTPUT FILE FOR UBELH2.D01
UBELH2.D02	U1	50 AND 25 YEAR EVENTS. MAIN CHANNEL AND TRIBUTARY.
UBELHE.002	U2	EDIT-2 OUTPUT FILE FOR UBELH2.D02
UBELH2.002	U1	OUTPUT FILE FOR UBELH2.DO2
UBELH2.D03	U1	10, 5 AND 2 YEAR EVENTS. MAIN CHANNEL AND TRIBUTARY.
UBELHE.003	U2	EDIT-2 OUTPUT FILE FOR UBELH2.D03
UBELH2.003	U1	OUTPUT FILE FOR UBELH2.D03

# UPPER BELL CREEK

# HEC-2 FILES - CNR TO HWY NO. 401

FILENAME	DISKETTE No.	FILE CONTENT
UBELH2.D05	U1	50 AND 25 YEAR EVENTS. TRIBUTARY ONLY.
UBELHE.005	U2	EDIT-2 OUTPUT FILE FOR UBELH2.D05
UBELH2.005	U1	OUTPUT FILE FOR UBELH2.D05
UBELH2.D06	U1	10, 5 AND 2 YEAR EVENTS. TRIBUTARY ONLY.
UBELHE.006	U2	EDIT-2 OUTPUT FILE FOR UBELH2.D06
UBELH2.006	U1	OUTPUT FILE FOR UBELH2.D06
UBELH2.HD1	U2	100 YEAR EVENT. MANNING'S 'n' VALUES INCREASED BY 10%
UBELHE.H01	U2	EDIT-2 OUTPUT FILE FOR UBELH2.HD1
UBELH2.H01	U2	OUTPUT FILE FOR UBELH2.HD1
UBELH2.LD1	U2	100 YEAR EVENT. MANNING'S 'n' VALUES DECREASED BY 10%
UBELHE.L01	U2	EDIT-2 OUTFUT FILE FOR UBELH2.LD1
UBELH2.LO1	U2	OUTPUT FILE FOR UBELH2.LD1

## BELL CREEK

# HYMO FILES - STORM WATER MANAGEMENT

FILENAME	DISKETTE No.	FILE CONTENT
PRE.DO1	SWM1	100 YEAR 12 HR RAINFALL EVENT. PRE-DEVELOPMENT CONDITIONS 4 NATURAL RESERVOIRS (3 CNR & 1 CPR)
PRE.001	SWM1	OUTPUT FILE FOR PRE.DO1
PRE.DO2	SWM1	50 YEAR 12 HR RAINFALL EVENT. PRE-DEVELOPMENT CONDITIONS 4 NATURAL RESERVOIRS (3 CNR & 1 CPR)
PRE.002	SWM1	OUTPUT FILE FOR PRE.DO2
PRE.DO3	SWM1	25 YEAR 12 HR RAINFALL EVENT. PRE-DEVELOPMENT CONDITIONS 4 NATURAL RESERVOIRS (3 CNR & 1 CPR)
PRE.003	SWM1	OUTPUT FILE FOR PRE.DO3
PRE.DO4	SWM1	10 YEAR 12 HR RAINFALL EVENT. PRE-DEVELOPMENT CONDITIONS 4 NATURAL RESERVOIRS (3 CNR & 1 CPR)
PRE.004	SWM1	OUTPUT FILE FOR PRE.DO4
PRE.DO5	SWM2	5 YEAR 12 HR RAINFALL EVENT. PRE-DEVELOPMENT CONDITIONS 4 NATURAL RESERVOIRS (3 CNR & 1 CPR)
PRE.005	SWM2	OUTPUT FILE FOR PRE.DO5

# BELL CREEK

# HYMO FILES - STORM WATER MANAGEMENT

FILENAME	DISKETTE No.	FILE CONTENT
POST.DO1	SWM2	100 YEAR 12 HR RAINFALL EVENT. POST-DEVELOPMENT CONDITIONS 4 NATURAL RESERVOIRS (3 CNR & 1 CPR)
POST.001	SWM2	OUTPUT FILE FOR POST.DO1
POST.DO2	SWM2	50 YEAR 12 HR RAINFALL EVENT. POST-DEVELOPMENT CONDITIONS 4 NATURAL RESERVOIRS (3 CNR & 1 CPR)
POST.002	SWM2	OUTPUT FILE FOR POST.DO2
POST.DO3	SWM2	25 YEAR 12 HR RAINFALL EVENT. POST-DEVELOPMENT CONDITIONS 4 NATURAL RESERVOIRS (3 CNR & 1 CPR)
POST.003	SWM2	OUTPUT FILE FOR POST.DO3
POST.DO4	SWM3	10 YEAR 12 HR RAINFALL EVENT. POST-DEVELOPMENT CONDITIONS 4 NATURAL RESERVOIRS (3 CNR & 1 CPR)
POST.004	SWM3	OUTPUT FILE FOR POST.DO4
POST.DO5	SWM3	5 YEAR 12 HR RAINFALL EVENT. POST-DEVELOPMENT CONDITIONS 4 NATURAL RESERVOIRS (3 CNR & 1 CPR)
POST.005	SWM3	OUTPUT FILE FOR POST.DO5