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.

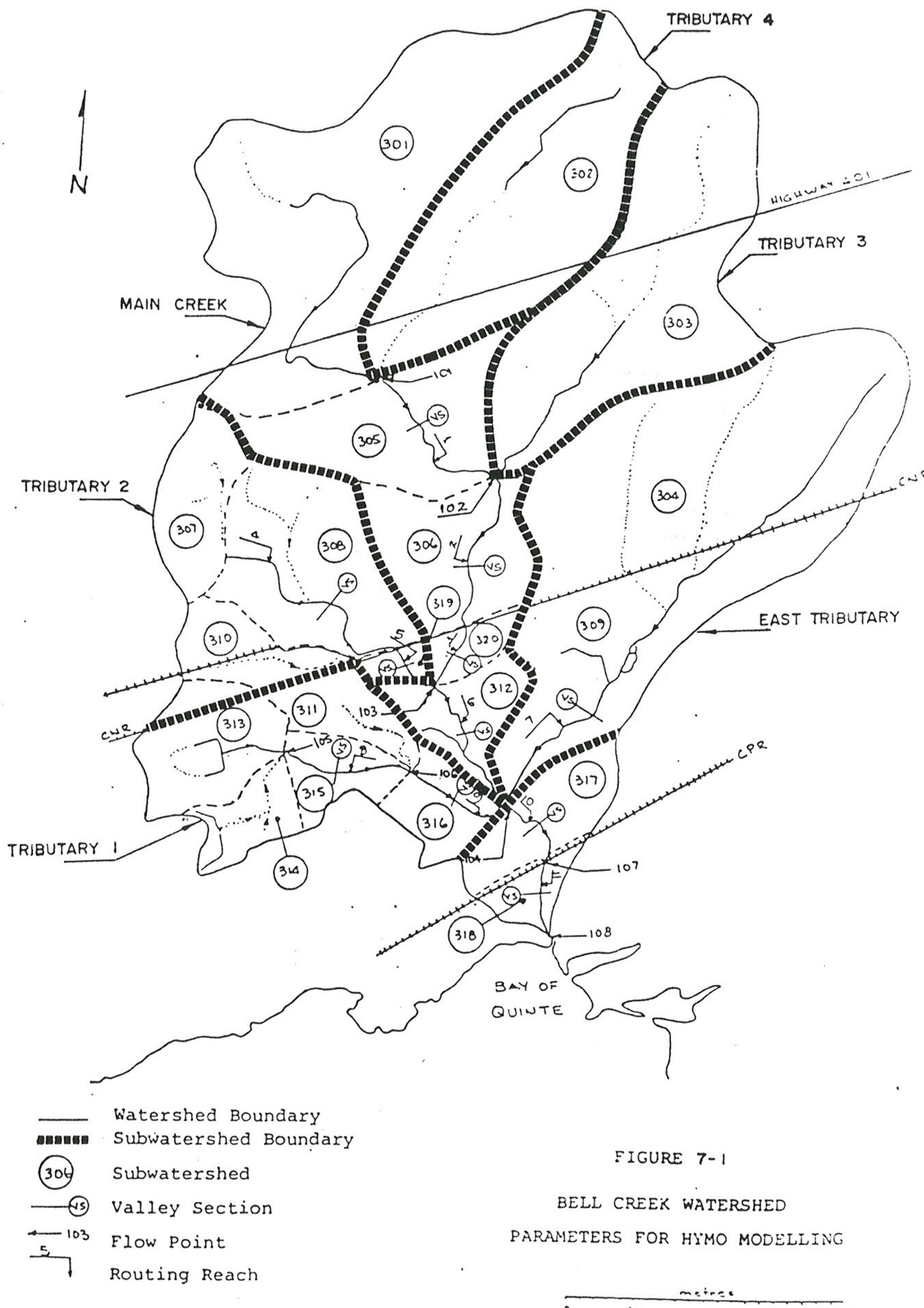


FIGURE 7-1

BELL CREEK WATERSHED

PARAMETERS FOR HYMO MODELLING

TABLE 7.1

HYDROLOGIC MODELLING PARAMETERS
PRESENT CONDITIONS
BELL CREEK

SUB-BASIN I.D.	Drainage Area (km2)	% Imperv.	CN	Present Conditions K (hrs)	Tp (hrs)	B Value
301	2.95		79	3.66	1.97	196
302	2.59		83	2.52	1.44	206
303	2.93		78	2.81	1.59	204
304	3.29		83	2.54	1.44	205
305	1.35		79	3.60	1.53	162
306	1.16		82	2.72	1.20	167
307	0.62	22	77	1.13	0.74	230
308	1.42		72	2.44	1.20	182
309	1.86		86	3.33	1.50	170
310	0.41	35	84	0.30	0.45	447
311	0.41	4	85	2.28	0.86	146
312	0.60		84	2.70	1.07	152
313	0.78	20	82	1.14	0.75	230
314	0.36	60	86	0.18	0.27	447
315	0.36	15	83	3.47	1.07	123
316	0.167	25	82	0.48	0.42	290
317	0.60		86	1.49	0.68	170
318	0.25		74	0.93	0.42	170
319	0.10		72	0.98	0.48	172
320	0.142		82	1.13	0.53	175

TABLE 7.2

BELL CREEK STORM WATER MANAGEMENT
COMPARISON OF PEAK FLOWS

LOCATION	100 year PRE (cms)	100 year POST (cms)	50 year PRE (cms)	50 year POST (cms)	25 year PRE (cms)	25 year POST (cms)	10 year PRE (cms)	10 year POST (cms)	5 year PRE (cms)	5 year POST (cms)
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* (Outflow 306)	(12.52) 11.97	(46.10) 42.38	(10.68) 10.31	(40.29) 35.74	(8.92) 8.76	(34.63) 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

* 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-BASIN I.D.	Drainage Area (km2)	% Imperv.	CN	Future Conditions K (hrs)	Future Conditions Tp (hrs)	B 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
318	0.25	26	80	0.29	0.29	320
319	0.10	45	88	0.12	0.24	580
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.)

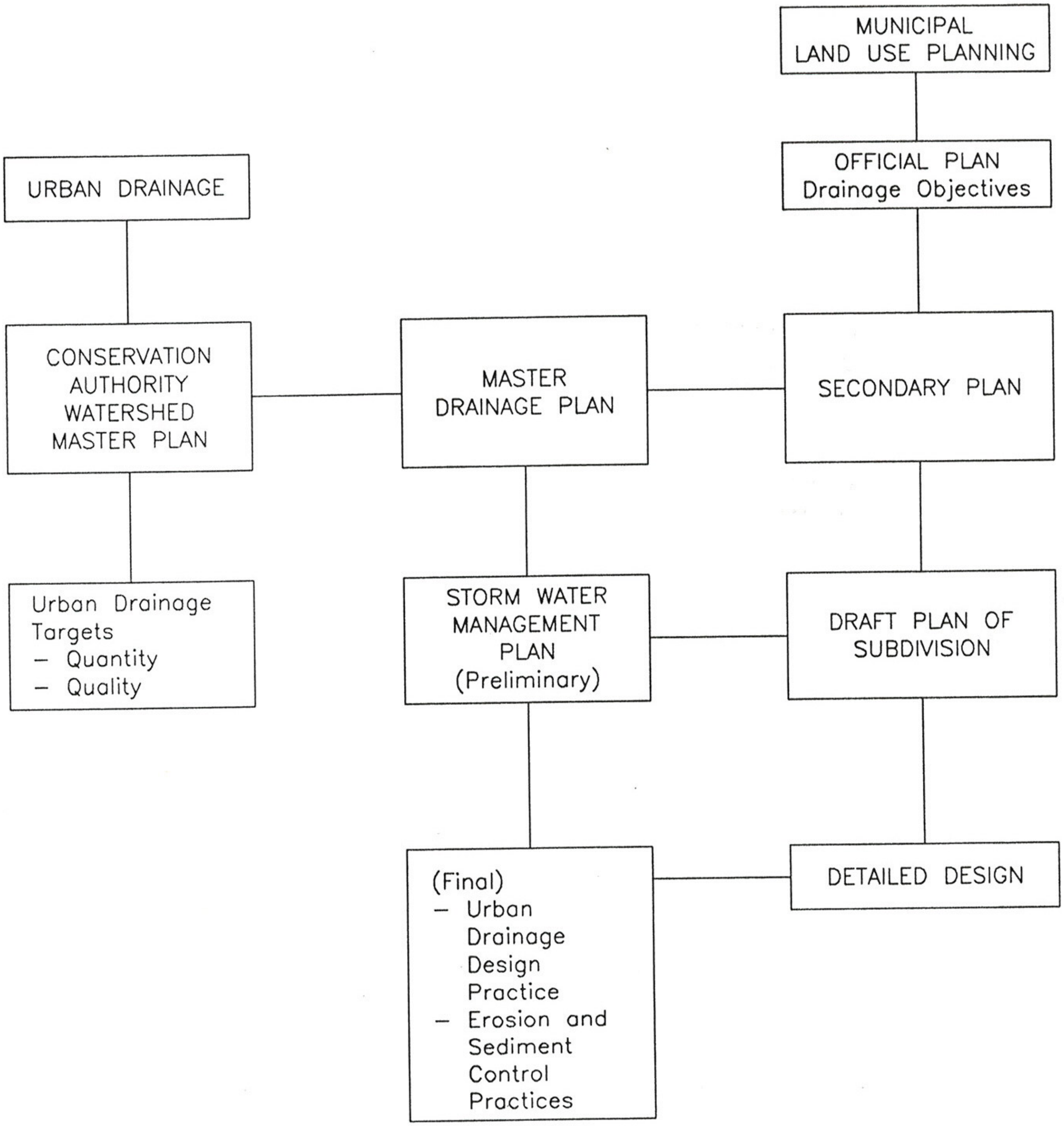


FIGURE 8.1

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:

Road Classification	Design Flood Frequency* Culverts up to 6 m span	Bridges, Culverts 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.

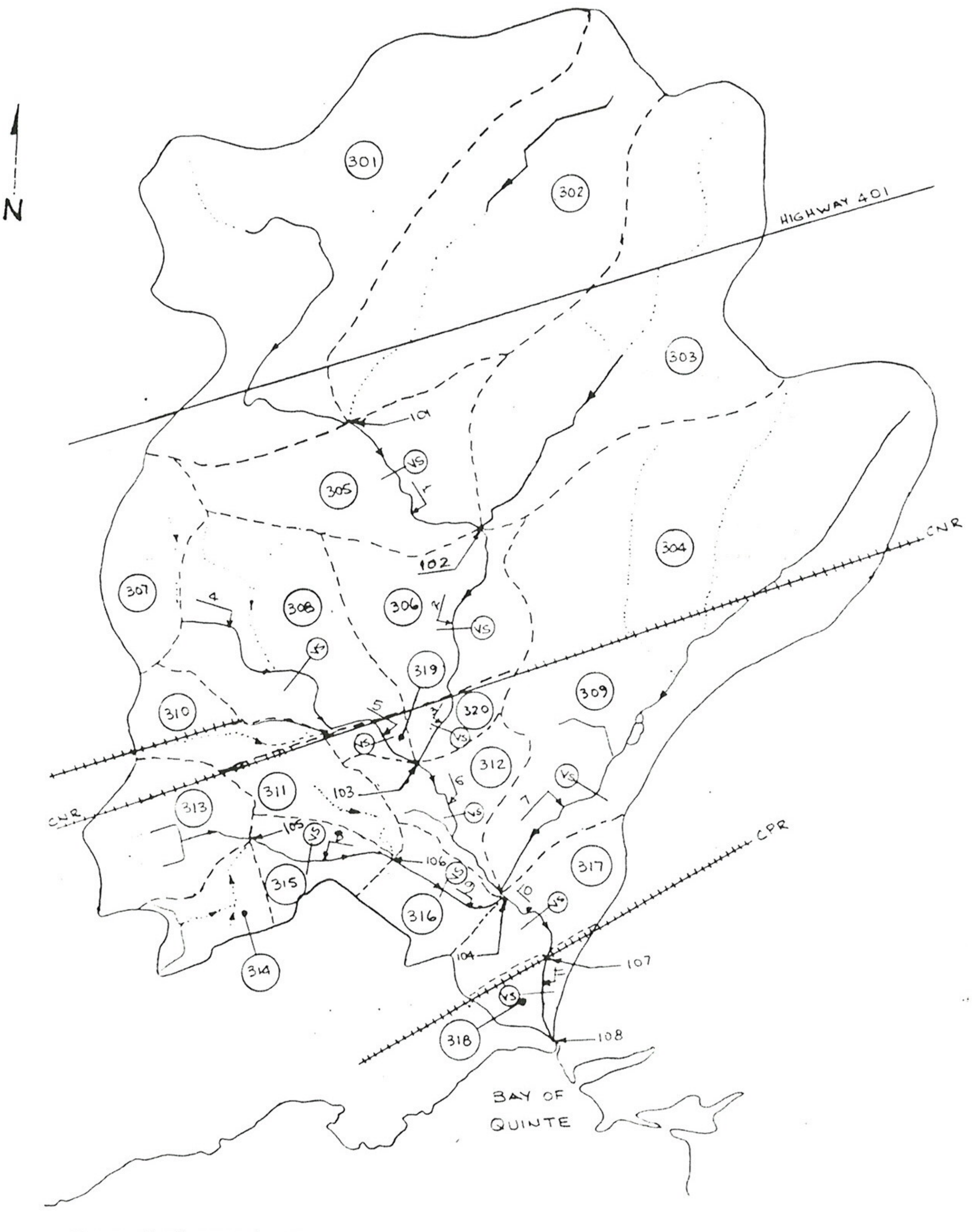
Inlets and outlets must be protected to prevent child or major debris access. The area at the downstream end of the outlet must be protected against erosion by channel lining and/or an energy dissipator. This is necessary for all minor system outlets to the channel as well.

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 by settling out sediment and pollutants normally associated with urbanization. Both the Ministry of the Environment and Ministry of Natural Resources are 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.



Watershed Boundary
Subwatershed Boundary
306 Subwatershed
VS Valley Section
103 Flow Point
5 Routing Reach

FIGURE 3.1

BELL CREEK WATERSHED

PARAMETERS FOR HYMO MODELLING

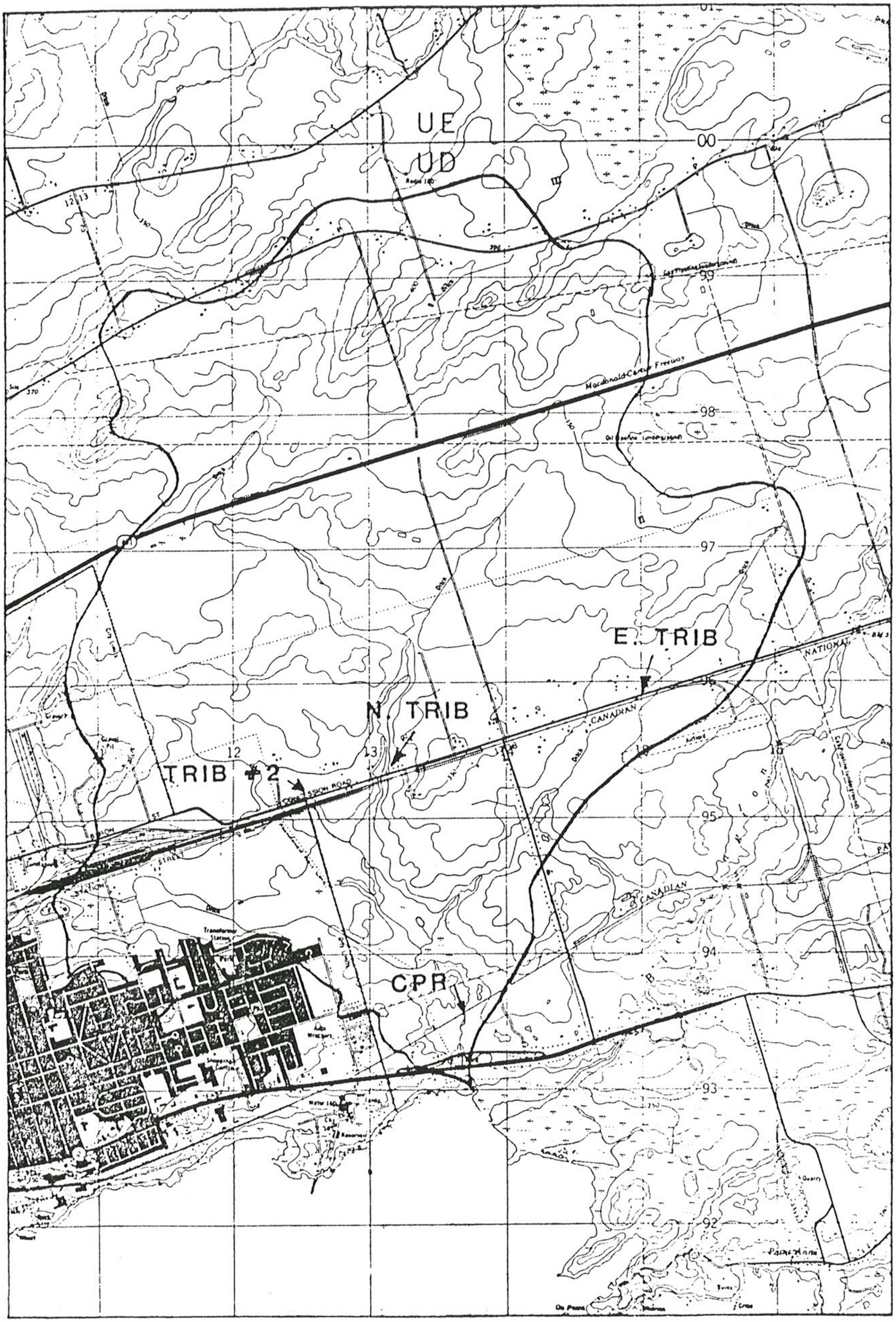
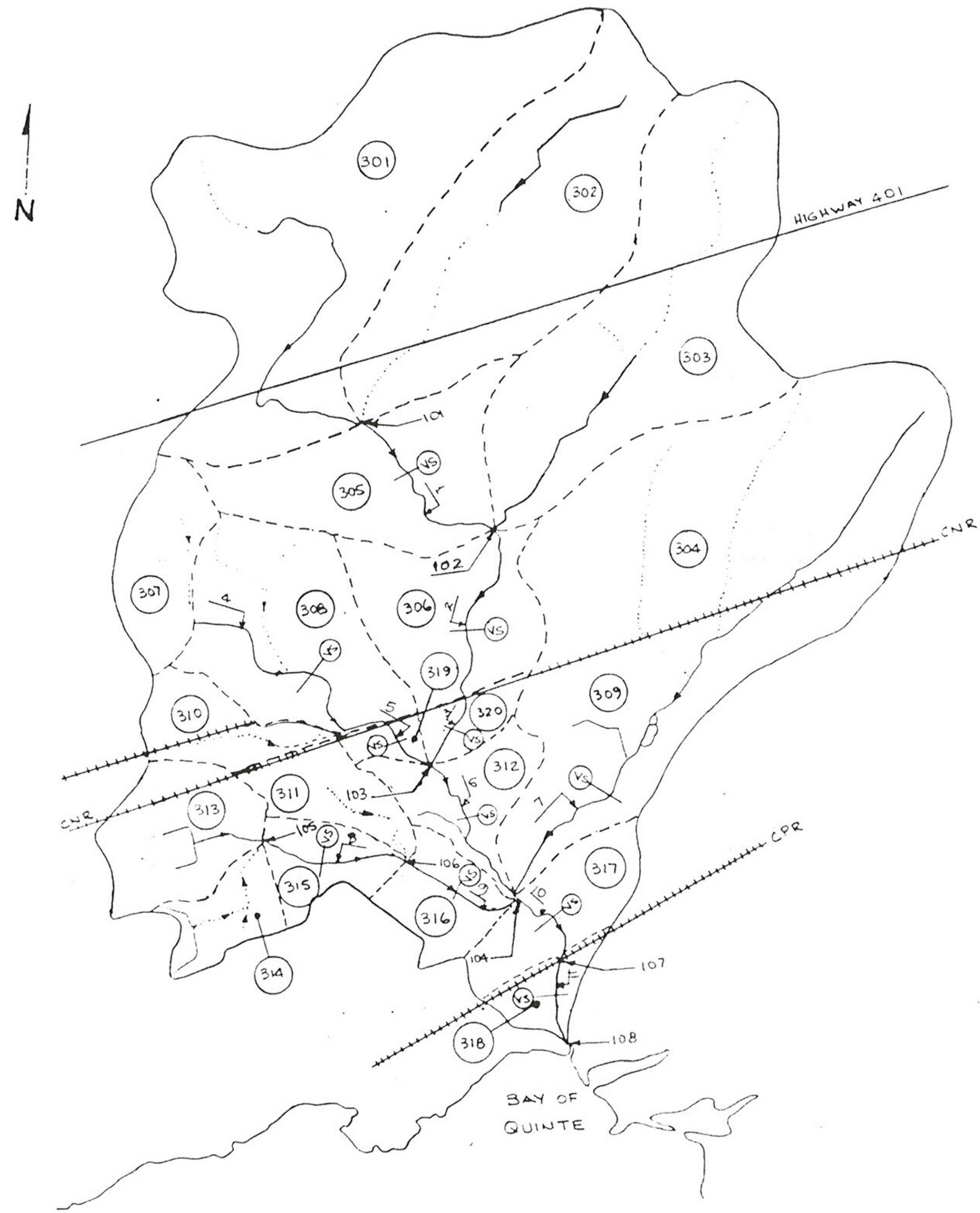


Figure 3.7 Principal Rail Crossings - Bell Creek



Watershed Boundary
Subwatershed Boundary
Subwatershed
Valley Section
Flow Point
Routing Reach

FIGURE 3.1

BELL CREEK WATERSHED

PARAMETERS FOR HYMO MODELLING

metres