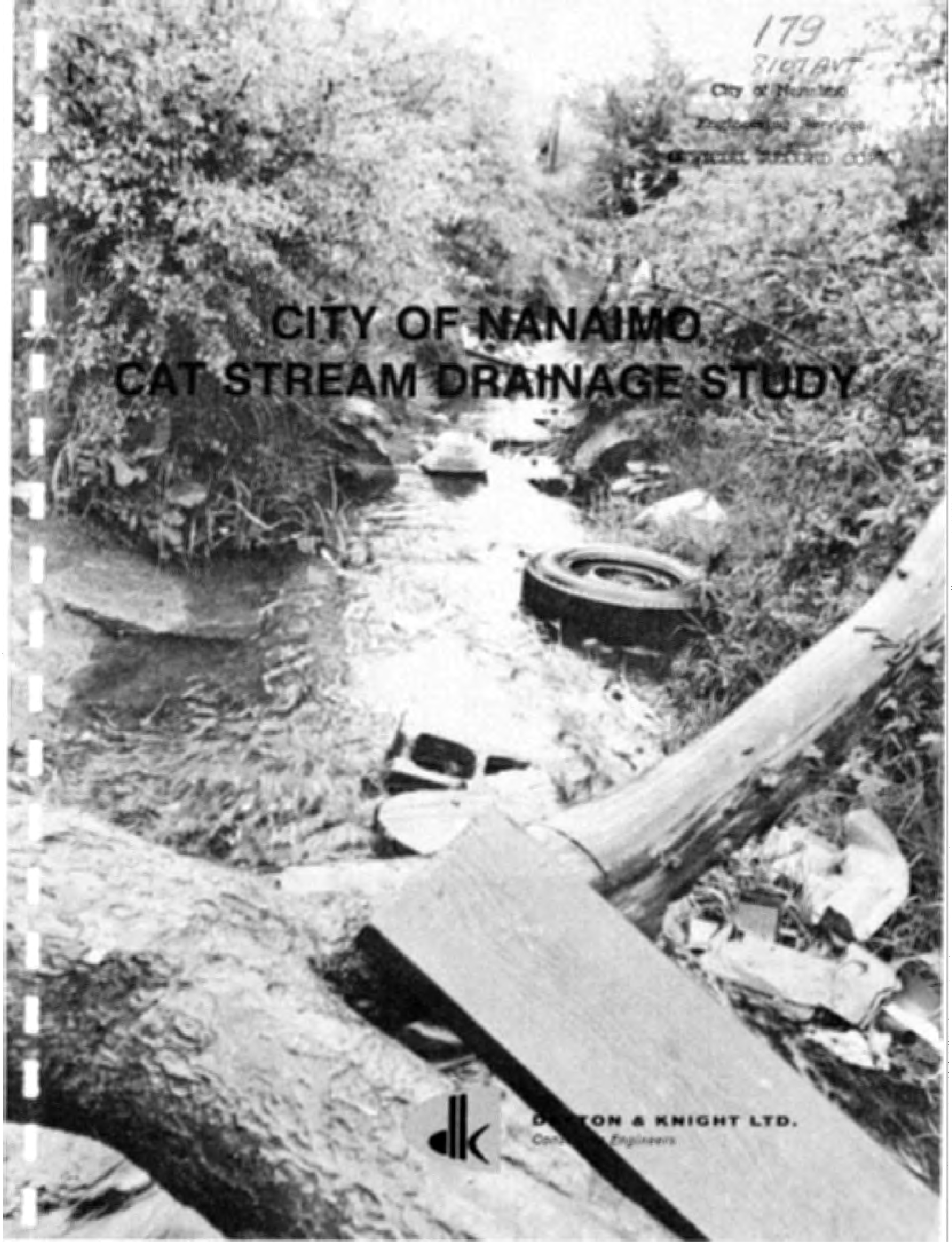
CITY OF NANAIMO
CAT STREAM DRAINAGE STUDY



D[illegible]TON & KNIGHT LTD.
Con[illegible] Engineers

DAYTON & KNIGHT LTD.
Consulting Engineers

1865 MARINE DRIVE, BOX 91247, WEST VANCOUVER, B.C. V7V 3N9 PHONE 922-3255

May 16, 1980

Mr. A. W. MacDonald,
Director of Public Works,
City of Nanaimo,
455 Wallace Street,
Nanaimo, B.C.
V9R 5J6

Dear Mr. MacDonald:

A study of the Cat Stream Drainage Basin, as authorized by your letter of October 17, 1979, has now been completed. Our report is submitted herewith.

Initial sections of the report present data gathered during the survey and the compiled criteria for designs of drainage plans. The ILLUDAS Computer Program is selected for analyzing flows and drainage works.

Four plans for drainage improvements are presented, ranging in capital cost between $309,000 and $431,000. The plan comprising a 25 year rainfall recurrence interval and two retention-detention facilities is recommended for implementation at an estimated capital cost of $353,000.

The report also discusses future stormwater management for the basin, and outlines several programs for the City to consider.

Thank you for the opportunity to work on this study, and we look forward to assisting the City in its application.

Respectfully submitted,

DAYTON & KNIGHT LTD.
per
Martin J. J. Dayton

REPORT

TO

CITY OF NANAIMO

on

PLAN OF IMPROVEMENTS

and

STORMWATER MANAGEMENT CONCEPTS

for

CAT STREAM DRAINAGE BASIN

May 16, 1980

DAYTON & KNIGHT LTD.
Consulting Engineers

CITY OF NANAIMO

CAT STREAM DRAINAGE STUDY

CONTENTS

FIGURES

TABLES

APPENDIX

CITY OF NANAIMO

CAT STREAM DRAINAGE STUDY

SUMMARY

1. Dayton & Knight Ltd. was hired on October 17, 1979 for a study of the Cat Stream Drainage Basin in Nanaimo.

2. The purpose of the study was to recommend a plan of improvements to control flooding problems in the Cat Stream and to ensure that such a plan not only protected the natural amenities of the creek but also recognized the requirements of Federal and Provincial control agencies.

3. The Cat Stream Drainage Basin comprises 267 ha (660 ac.), of which about 141 ha (348 ac.) are an older developed area below Wakesiah Ave., 40 ha (100 ac.) around Malaspina College are institutional and 86 ha (212 ac.) above Wakesiah Ave. are largely undeveloped but developable.

4. The Cat Stream is the natural watercourse draining the basin. It is about 3 km (2 mi.) long, and comprises a series of open channels with culverts at ten road crossings.

The creek joins Chase River near Park Avenue.

5. The creek flows largely through private property without easements or rights-of-way. The City maintains the road crossings, but has not accepted responsibility for maintenance on private property.

6. The creek has a history of drainage problems and flooding damage, which prompted this study to design and estimate improvement plans.

7. The majority of the basin slopes gently from the Chase River westwards towards Wakesiah Avenue and Jingle Pot Road. Some 20 ha (50 ac.) of the basin at the upstream terminus is steep and rocky, but is being developed.

8. The majority of the basin soil mantle is gravel, sand or sandy loam, all of which are permeable. The underlying layers, about .5 to 1.5 m (1.5 to 5 ft.) below, are either clay or glacial till, both of which are impermeable.

9. Future land use in the Drainage Basin is projected for in-filling of the existing residential area, new residential areas and continuation of the existing institutions. An arterial highway is currently proposed to cross the headwaters of the basin, but this route has not been accepted.

10. There are rain gauge records covering nine years at the Biological Station, 33 years at Nanaimo Airport, four years at the GNWD Water Reservoir and less than one year at the City Yard. Either the lack of short duration intensities or the short period of record prevent the derivation of accurate rainfall curves from the gauge records around Nanaimo.

11. A procedure of extrapolation and interpolation with recording stations at Comox, Victoria and Vancouver, for which long term records exist, was employed to develop a family of rainfall curves for Nanaimo. It was found that Nanaimo compared most closely with Vancouver Airport.

12. The family of all year curves so derived vary from both the previous City design curves and the criteria established in the 1977 Trunk Storm Sewer Study, but agree reasonably well with the 1978 City Manual of Engineering Standards which were extrapolated by comparison with other Vancouver Island records.

13. Winter rainfall curves were also derived which for the same duration result in lower rainfall intensities than the all year curves.

14. Measurements of rainfall taken during the December 1979 flooding of the Cat Stream show that the return period was in the order of a one or two year storm for durations less than 2 hours but when consecutive multi-day rainfall extremes were considered the return period increased to a 50 year storm event. The rainfall was of considerable duration so that all holding spots were filled but the intensities were those of a routine winter storm.

15. The present City Manual of standards specifies either the Rational Method for calculation of peak rates of flow, or approved alternative methods.

The ILLUDAS Computer Program was also used in this study, and the results compared with Rational Method calculations.

16. The survey was fortunate to obtain actual on-site measurements of flow and flood levels during the December, 1979, storm. These data served as known points in the computer model, which was judged to improve the accuracy of the computer process in correlating stream flows and rainfall.

17. There are natural ponds in the undeveloped area west of Wakesiah that provided on-line detention storage during the December, 1979 storm. The effects of such storage were accommodated by the ILLUDAS program, which is its primary advantage over the Rational Method.

18. Good results were obtained from the comparison between the ILLUDAS Program and the actual recorded stream flows and rainfalls.

19. When computed flows by the Rational Method utilizing City Standards for runoff coefficients were compared with the ILLUDAS

calculations, the ILLUDAS flows were higher. Higher runoff coefficients had to be used in the Rational Method to get comparable results.

Runoff coefficients calculated for the December storm showed the requirement for higher coefficients to be valid.

20. The hydraulics of culverts is one of the most misunderstood and mis-applied aspects of drainage design. It is often overlooked that the capacity of a culvert is usually governed by its entrance conditions, so that making the culvert larger does not necessarily increase its capacity.

21. Control of debris in natural watercourses is another area of misunderstanding in municipal drainage systems. Most flooding is actually caused by debris in the watercourses obstructing culverts or the channel, and not from natural causes.

22. Every watershed must have a major and minor routing for storm water. In the Cat Stream Drainage Basin, the Creek is both the minor and the major route, because no alternatives exist for flood flows to be diverted or to escape.

23. The problems of debris, encroachment and erosion in natural watercourses such as the Cat Stream influence the design of drainage improvements to correct flooding.

24. This report tabulates a series of design criteria for the Cat Stream Drainage Basin, including rainfall curves, retention-detention storage and hydraulic calculations.

25. From the design criteria and policies, two sets of design flows and storage needs for 25 year and 200 year recurrence intervals were calculated. At Park Avenue, the design flow for the 200 year recurrence is about 30 percent greater than for the 25 year.

26. Four plans were then designed and estimated for cost. Two plans were for a 25-year recurrence - one with storage of Wakesiah and the second with storage at both Wakesiah and Third. Plans 3 and 4 were similar except for 200-year recurrence.

27. Plan 1 - with 25-year recurrence and storage at Wakesiah, comprises new culverts at five road crossings between Third and Albert.

It also includes re-grading some 400 m (1300 ft.) of the creek in the vicinity of Chesterlea.

Total capital cost is $309,000.

28. Plan 2 also has a 25 year recurrence but incorporates two storage ponds - one west of Wakesiah and a second near Third.

The plan then requires new culverts only at Third, and the creek regrading is not needed.

Total estimated capital cost is $353,000, of which $150,000 is allowed for purchase of 2.4 ha (6 ac.) of land for the storage pond at Third.

29. Malaspina College is presently planning a game sanctuary in the natural ponds west of Wakesiah, and has applied for the necessary licence. This report assumes that these ponds would also provide retention storage during flood flows in the creek.

30. Plan 3 has a 200 year recurrence and storage at Wakesiah only, so is similar to Plan 1 except for its ability to pass higher flows. Six new culvert road crossings are needed.

Total estimated capital cost is $431,000.

31. Plan 4, a 200 year recurrence includes the two storage areas and requires only one upgraded road crossing. Total estimated capital cost is $384,000, including $150,000 for land purchase.

32. All costs are 1980 Contractor's prices to an Engineering News Record Construction Cost Index of 3300. They include 25 percent for contingencies and engineering and 12 percent for interim financing.

33. The four plans should not be compared on capital cost alone because they provide different results and have different environmental impacts.

34. Plan 2 is recommended for implementation.

35. Cat Stream Creek is a fisheries resource, and any plan of improvements should be integrated with fishery requirements.

36. Nanaimo's current Community Plan establishes the policy of a buffer strip or green belt along the Cat Stream.

Other bylaws and regulations set standards for setbacks and building elevations near the creek.

37. The question of private or public ownership for the bed of a natural watercourse such as the Cat Stream is not readily resolved. At present it is largely in private hands.

38. In the past few years the legal liability of municipalities for flooding damages has increased dramatically.

39. In order to protect themselves, and to enable needed improvements to be made on private property, some municipalities are considering acquisition of property containing the beds of natural watercourses.

40. Other municipalities retain a position that natural watercourses on private property are not the business of the public body as far as drainage is concerned.

41. This study recommends that the City enact a Watercourses Bylaw, in which no work could be done in or near the creek without a permit.

42. Implementation of a drainage plan such as is recommended in this report is the most difficult aspect of a drainage system in many British Columbia municipalities, particularly with regard to financing and cost apportionment..

43. Ten specific recommendations arising from the study are made in the final chapter of the report.

CHAP. No. 9

CITY OF NANAIMO

CAT STREAM DRAINAGE STUDY

1. INTRODUCTION

The Cat Stream is located in one of the older areas of the City of Nanaimo, beginning near Jingle Pot Road west of Wakesiah Avenue and running to the east and south to discharge into the Chase River near the intersection of Park Avenue and Seventh Street, as shown on Figures 1 & 2. The catchment or drainage area is 267 ha (660 ac.).

The Creek floods adjacent properties periodically, and is considered a potential trouble area for drainage as the tributary area in the City develops.

TERMS OF REFERENCE

Terms of Reference for this study are set out in the City of Nanaimo letter dated August 29, 1979.

The purpose of the study is as follows:

1. To review the drainage catchment area, including existing road culverts.

2. To recommend a plan of improvements to control the flooding problems and maintain the natural amenities of the Creek.

3. To incorporate into the study the requirements of Federal and Provincial Fisheries Agencies and current stormwater management concepts.

Dayton & Knight Ltd. was awarded the survey and report on October 17, 1979.

CONDUCT OF SURVEY

Work commenced in October 1979 with field surveys to establish the drainage area boundaries and collect data on existing culverts and creek conditions. Rainfall data was obtained from the Atmospheric Environment Service.

During the storm in December, 1979, creek levels were monitored and photographs were taken. The City provided the rainfall records for December from the Works Yard gauge.

Meetings were held in January 1980 with the City of Nanaimo Planning Department and with the Fish and Wildlife Branch in Nanaimo. Progress reports were made to City Engineering staff on January 30 and March 21, 1980. The report was reviewed in draft form on May 1, 1980 prior to submission.

Engineering investigations and preparation of the report were carried out by D.J. Palmer, P.Eng., with supervision by B. L. Walker, P.Eng., and under the general direction of A. Berzins, P.Eng. and M.J.J. Dayton, P.Eng.

ACKNOWLEDGEMENTS

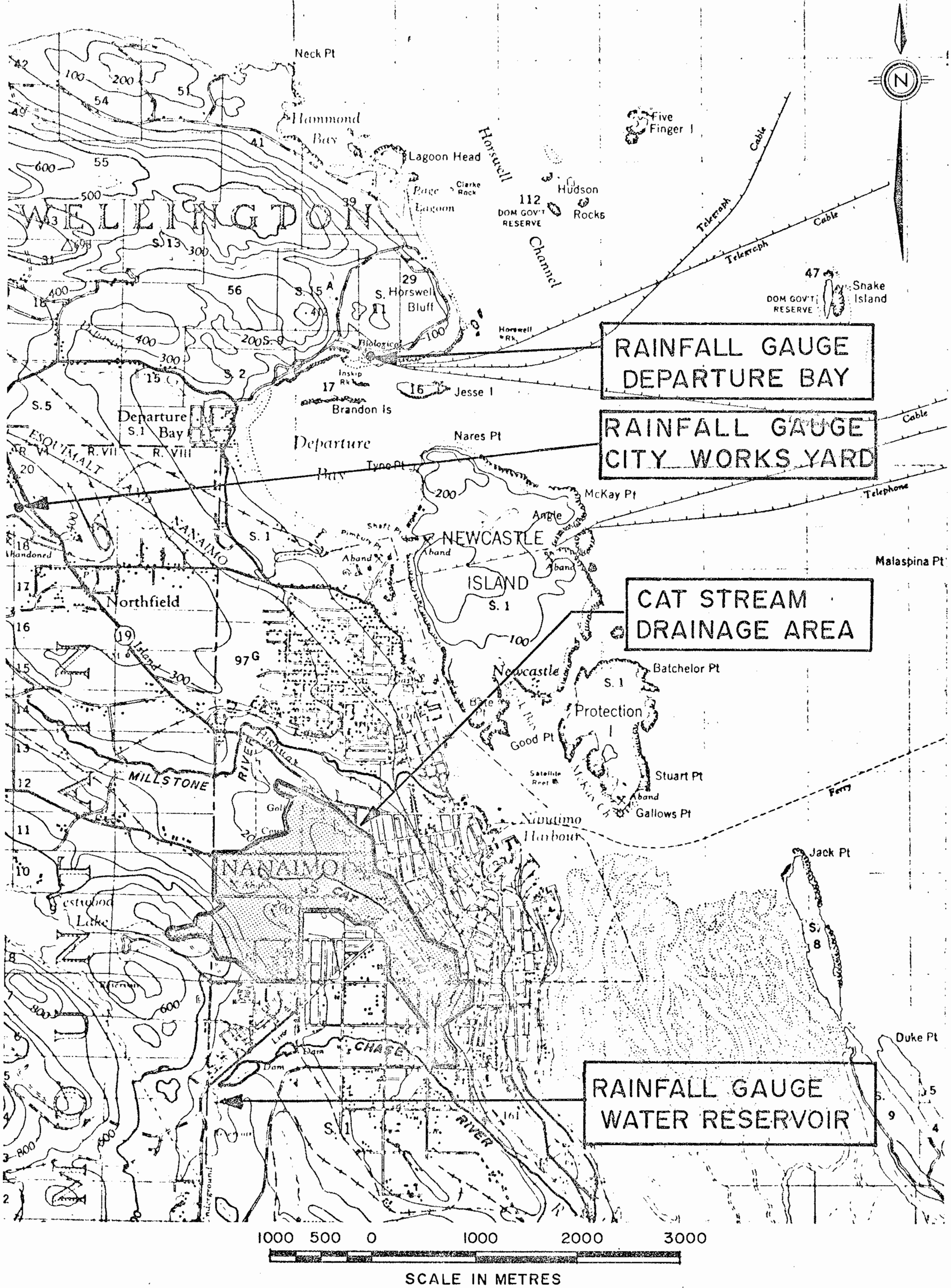
The assistance of the Director of Public Works, Mr. A. W. MacDonald, and his staff, in outlining specific requirements and furnishing plans and information, has been most valuable.

We also thank Mr. W.S. Mackay, Director of Planning and Development for the City of Nanaimo and Mr. G. Schaefer of the Atmospheric Environment Service for the information they provided.

ABBREVIATIONS

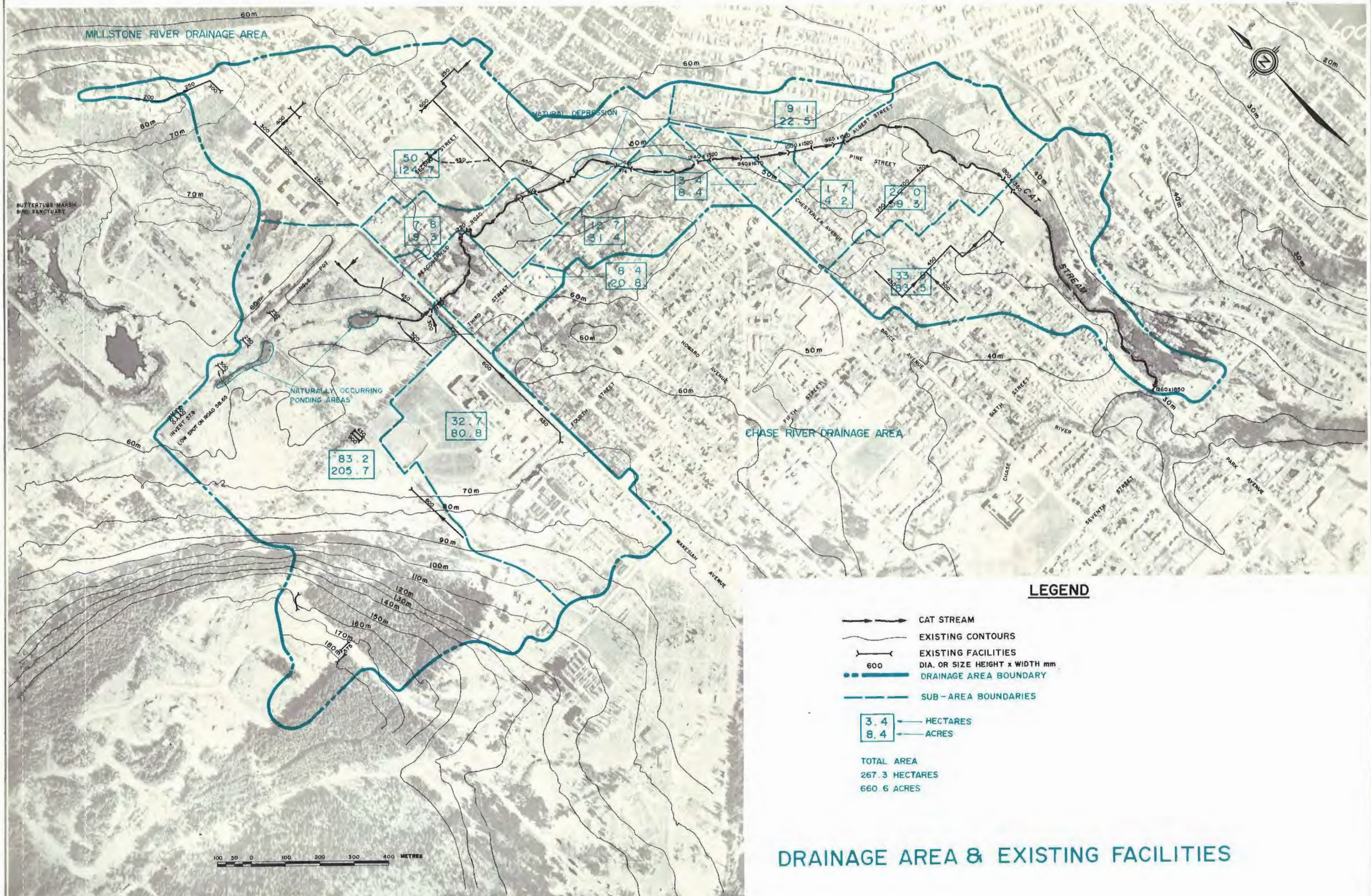
The following abbreviations have been used in this report:

ha	- hectares
m	- metres
mm	- millimetres
ft.	- feet
^{o}C	- degrees Centigrade
^{o}F	- degrees Fahrenheit
hr	- hour
cfs	- cubic feet per second
ILLUDAS	- Illinois Urban Drainage Area Simulator
m^3/s	- cubic metres per second
m^3	- cubic metres
yd^3	- cubic yards
CSP	- corrugated steel pipe
RC	- reinforced concrete



LOCATION PLAN

FIGURE I



DRAINAGE AREA & EXISTING FACILITIES

FIGURE 2

2. EXISTING DRAINAGE FACILITIES

DRAINAGE AREA AND MAJOR FACILITIES

The drainage area is outlined on Figure 2 which also shows contours. The drainage area has been divided into 11 sub-areas, with areas varying from 83.2 ha (205.7 ac.) to 1.7 ha (4.2 ac.), such that the area contributing to each culvert can be calculated.

The highest portion of the drainage area is in the College Park Subdivision which rises to about 200 m (650 ft.). Most of the storm water from the subdivision drains over a cliff to an energy dissipation structure and diversion ditch which carries the water across Jingle Pot Road at Addison Avenue into the Buttertubs Marsh area. The southern part of College Park Subdivision drains to the Cat Stream, finding its way overland to the natural ponding area west of Wakesiah Avenue.

Malaspina College is serviced by a system of stormwater drains which terminate in a 600 mm (24 in.) diameter R.C. pipe behind the High School. A system of ditches and culverts continue to the ponding area.

An extensive drainage system serves the High School, carrying most of the runoff east to Wakesiah Avenue and then north to Third Street terminating in a 600 mm (24 in.) diameter R.C. pipe. A ditch continues to the entrance of the culvert under Wakesiah Avenue.

The Millstone River drainage area to the north is separated from the Cat Stream drainage area by the diversion along Addison Avenue and by Jingle Pot Road. Buttertubs Marsh to the north of Jingle Pot Road has been developed as a wildfowl sanctuary with controlled levels and an inlet from the Millstone River. The water level in the Marsh is generally higher than in the Cat Stream, as evidenced by the figure of 57.0 m (187 ft.) in March 1979 and 56.9 m (186.6 ft.) in April 1980. These compare with a lowest elevation of 58.65 (192 ft.) on Jingle Pot Road and elevations on the natural pond west of Wakesiah Avenue of 54.50 m (178.8 ft.) in March 1979, 54.00 m (177.1 ft.) in October 1979 and 54.77 (179.6 ft.) in April 1980.

There are five culverts crossing Jingle Pot Road between those at Addison Avenue and the intersection with Wakesiah Avenue. The three nearest Wakesiah Avenue are small and are intended to carry local drainage across Jingle Pot Road into the natural pond. The last two are 500 mm (20 in.) diameter CSP with invert elevations of 57.9 m (189.9 in.). One is blocked at the north end.

The drainage area includes some undeveloped residential land north of Jingle Pot Road and west of Wakesiah. East of Wakesiah Avenue the drainage area is mostly developed residential land.

The Cat Stream runs from the natural ponding area at Wakesiah to the east and south until it enters the Chase River near Park Avenue and Seventh Street. The gradients on the creek vary from near zero to 1.5 percent. The upper reaches are overgrown and restricted in some areas with vegetation and debris. Below Albert Street the channel is in better condition although there is some debris and several beaver dams.

Survey has been carried out to establish elevations, sizes, type and condition of the ten existing culverts on the creek. This information is contained in Appendix 1. Location of the culverts is shown on Figure 2 and Figure 3 shows a profile of the creek. The capacity of the culverts shown is the maximum capacity without flooding of adjacent developed ground or buildings.

Culvert Location	Size Diameter or height x width mm	in.	Type	Capacity m^3/s	cfs
Wakesiah Avenue	1130	44	Woodstave	2.4	85
Beaconsfield Road	1220	48	CSP	1.8	65
Howard Avenue	910	36	CSP	2.0	70
Third Street	610x910	24x36	CSP	2.3	80
Bruce Avenue	1240x1520	48x60	R.C. box	1.1	40
Chesterlea Avenue	940x1670	37x66	R.C. box	3.4	120
Pine Street	1000x1520	39x60	R.C. box	3.7	130
Albert Street	965x1520	38x60	R.C. box	3.5	125
Fifth Street(2 sections)	1200x1360 1260x1850	47x54 50x73	R.C. box	4.5	160
Park Avenue	1260x1850	50x73	R.C. box	9.6	340

The following culverts cross Jingle Pot Road east of Addison Avenue:

Size (dia.) mm	in.	Invert Elevations (m) North	South	Distance from Addison Avenue m	ft.
500	20	57.74	blocked	60	200
500	20	57.91	57.85	75	250
300	12	57.37	59.00	265	870
250	10		blocked	400	1300
250 & 300	10 & 12	57.65	57.05	480	1580

OTHER DRAINAGE FACILITIES

The majority of the catchment area, where developed, has street ditches, driveway culverts and road culverts.

In some areas storm sewer systems have been built. Figure 2 illustrates areas served by a storm sewer system and gives an indication of the sizes involved. It is not a complete inventory and not all sizes have been shown. There are nine main areas served as listed below.

1. Malaspina College. The campus area is served by storm sewers which terminate in a 600 mm (24 in.) diameter R.C. pipe west of the High School.

2. Wakesiah Avenue. The system on Wakesiah terminating in a 600 mm (24 in.) diameter R.C. pipe at Third Street. This system carries water from the High School, B.C. Hydro Yard and the lower parts of Malaspina College.

3. Fifth Street between Bruce Avenue and Park Avenue. A residential area is served by this system which terminates in a 450 mm (18 in.) diameter pipe on Park Avenue. A ditch then leads to the Cat Stream south of Robins Park.

4. Albion Street. A small system of 250 mm (10 in.) to 450 mm (18 in.) diameter pipes serving a residential area.

5. College Park Subdivision. A small part of the subdivision is served by a system which discharges water at the edge of the subdivision to find its way over the cliff to the east of the subdivision.

6. Garner Crescent. A system of 200 mm (8 in.) to 300 mm (12 in.) diameter serving a subdivision.

7. Wakesiah Avenue and lane south of First Street. This system services a residential development on Wakesiah Avenue.

8. Howard Avenue and Second Street. This drainage system services a residential area and a school and has a maximum size of 600 mm (24 in.) diameter. Parts of the system are deep with a manhole depth of 3.4 m (11.2 ft.) at Second Street and Howard Avenue. The 450 mm (18 in.) diameter pipe from this intersection to the Cat Stream passes through private property.

9. Subdivision at Wakesiah Avenue and Jingle Pot Road. The storm sewers from the subdivision terminate at the creek between the natural pond and Wakesiah Avenue at three points with two 300 mm (12 in.) diameter and one 450 mm (18 in.) diameter outlets.

DRAINAGE PROBLEMS

As development of the catchment area has progressed, the rate of runoff has increased along with flooding problems.

Below Fifth Street the creek is in a well defined channel. Ponding occurs on Robins Park due to a local area of low gradients. The ponding is increased by several beaver dams on the creek.

The area between Fifth Street and Wakesiah Avenue is the main area of concern. Several houses near the creek have low basement elevations compared with flood levels in the creek. Flooding occurs several times a year in this area. As can be seen from the creek profile (Fig. 3) the creek has a good gradient over most of its length, except for the area between Third Street and Pine Street.

The culverts at Chesterlea and Bruce are too high by about 900 mm (3 ft.), thus causing a backwater upstream. The lower culvert at Third Street is lower than the downstream culvert at Bruce Avenue and is therefore ineffective.

The basement in the house just upstream of the Bruce Avenue culvert floods before the culvert can run full. There was water in the basement on October 26, 1979 during a relatively minor storm.

The storm of mid-December 1979 caused a lot of problems along the creek with a considerable amount of ponding between Bruce Avenue and Third Street and also upstream of Third Street.

The creek is impeded in several areas by blockages and by growth of vegetation, principally blackberries. The section of creek between Wakesiah and Beaconsfield contains debris, and the section between Beaconsfield and Howard is overgrown. The condition of the creek between Bruce Avenue and Fifth Street is better but there is some debris which should be removed and some vegetation which should be cleared.

The woodstave culvert at Wakesiah is partly filled with gravel which reduces its carrying capacity considerably. Other culverts affected by deposition of gravel are those at Beaconsfield Road, Pine Street and Albert Street. The culvert at Chesterlea is partly blocked by debris, vegetation and a fence.

SYSTEM ADEQUACY

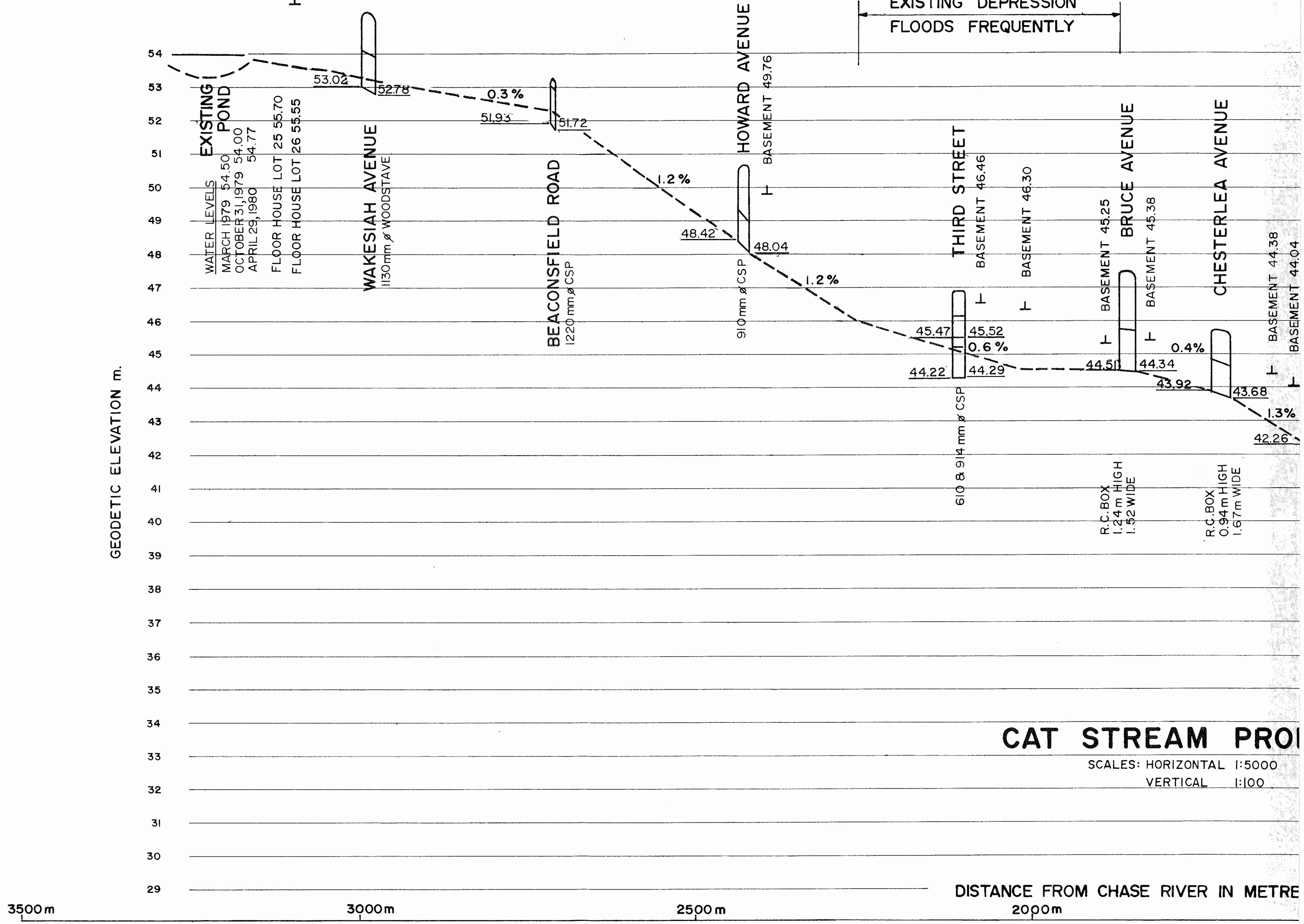
The effect of the gravel deposited in the culvert at Wakesiah has been to limit flows during recent storms to about .85 m^3/s (30 cfs). This has been fortunate for those downstream, especially the apart ments on Wakesiah Avenue which are situated near the creek at a low elevation. Gravel deposited in the culvert at Beaconsfield Road and the flat gradient, however, would contribute to a high water level if a higher rate of flow was realized. The natural ponding occurring during a storm at the area of Third Street has also helped downstream conditions in the past.

The problem of flooded basements has occurred frequently in spite of these factors. It would have been worse, however, if they were absent.

Without a surveyed profile down the length of the creek, it is difficult to choose a proper elevation when installing culverts. The result of this lack of data is one culvert on top of another at Third Street, and a culvert downstream at Bruce Avenue which is higher than the one at Third Street.

Some houses have been built with basement elevations too close to the creek elevation, particularly the house at Bruce Avenue with a basement elevation of 45.25 m (148 ft.).

The rate of runoff has increased over the years with development while the creek has become overgrown and more restricted with debris.



EXISTING DEPRESSION
FLOODS FREQUENTLY
EXISTING POND
WATER LEVELS
MARCH 1979 54.50
OCTOBER 31,1979 54.00
APRIL 29,1980 54.77
FLOOR HOUSE LOT 25 55.70
FLOOR HOUSE LOT 26 55.55
WAKESIAH AVENUE
1130mm ø WOODSTAVE
53.02
52.78
0.3%
51.93
51.72
BEACONSFIELD ROAD
1220 mm ø CSP
1.2%
HOWARD AVENUE
BASEMENT 49.76
48.42
48.04
910 mm ø CSP
1.2%
THIRD STREET
BASEMENT 46.46
BASEMENT 46.30
45.47
45.52
0.6%
44.22
44.29
610 & 914 mm ø CSP
BASEMENT 45.25
BRUCE AVENUE
BASEMENT 45.38
44.51
44.34
R.C. BOX
1.24 m HIGH
1.52 WIDE
0.4%
43.92
CHESTERLEA AVENUE
43.68
R.C. BOX
0.94 m HIGH
1.67m WIDE
BASEMENT 44.38
BASEMENT 44.04
1.3%
42.26
GEODETIC ELEVATION m.
54
53
52
51
50
49
48
47
46
45
44
43
42
41
40
39
38
37
36
35
34
33
32
31
30
29
CAT STREAM PRO
SCALES: HORIZONTAL 1:5000
VERTICAL 1:100
DISTANCE FROM CHASE RIVER IN METRE
3500 m
3000 m
2500 m
2000 m

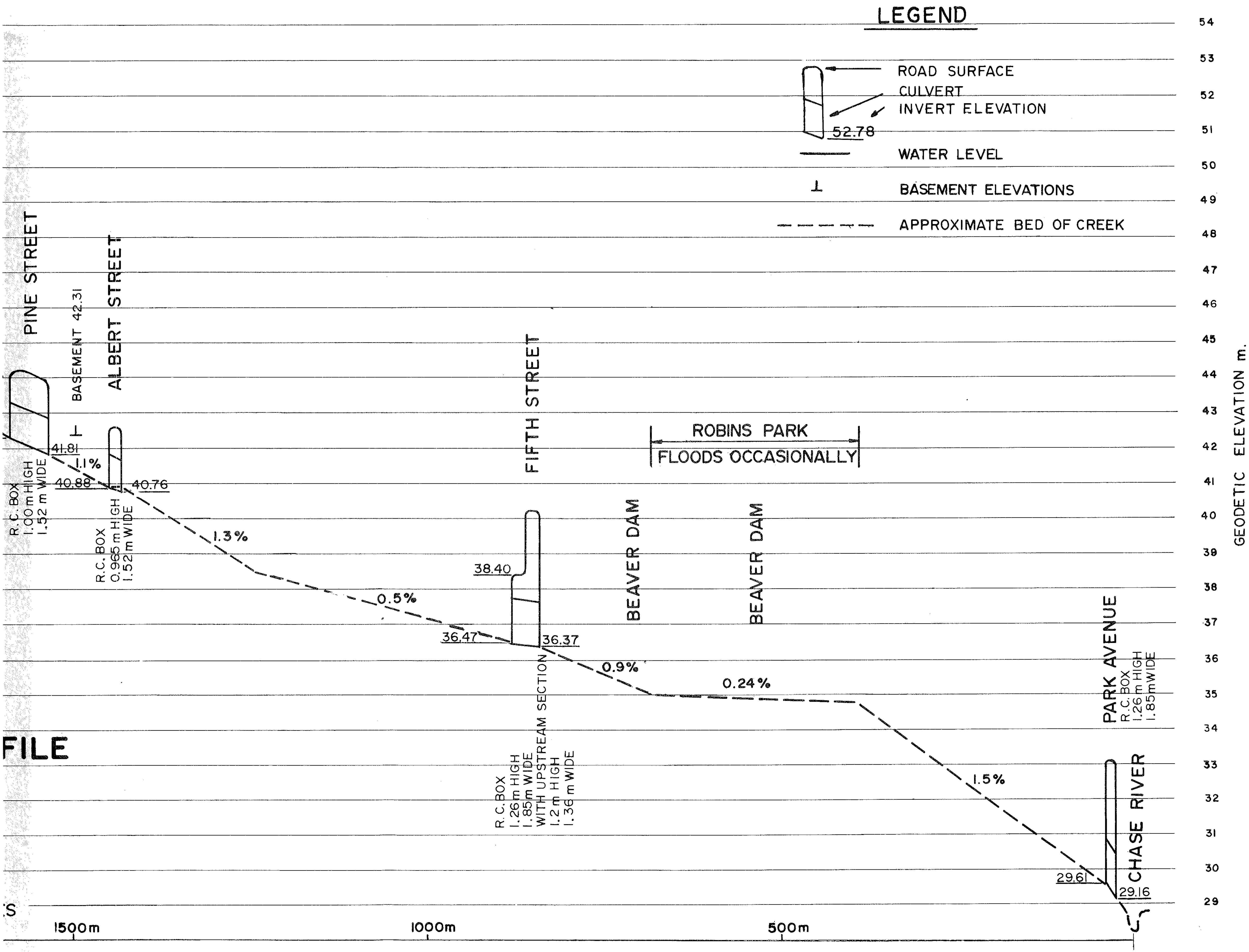

LEGEND
ROAD SURFACE
CULVERT
INVERT ELEVATION
52.78
WATER LEVEL
BASEMENT ELEVATIONS
APPROXIMATE BED OF CREEK
PINE STREET
BASEMENT 42.31
ALBERT STREET
41.81
1.1%
40.88
40.76
R.C. BOX
1.00 m HIGH
1.52 m WIDE
R.C. BOX
0.965 m HIGH
1.52 m WIDE
1.3%
0.5%
FIFTH STREET
38.40
36.47
36.37
R.C. BOX
1.26 m HIGH
1.85 m WIDE
WITH UPSTREAM SECTION
1.2 m HIGH
1.36 m WIDE
ROBINS PARK
FLOODS OCCASIONALLY
BEAVER DAM
BEAVER DAM
0.9%
0.24%
1.5%
PARK AVENUE
R.C. BOX
1.26 m HIGH
1.85 m WIDE
CHASE RIVER
29.61
29.16
FILE
S
1500m
1000m
500m
54
53
52
51
50
49
48
47
46
45
44
43
42
41
40
39
38
37
36
35
34
33
32
31
30
29
GEODETIC ELEVATION m.

FIGURE 3

3. CHARACTERISTICS OF AREA

TOPOGRAPHY

Most of the catchment area is gently sloping, with the lower portion being mainly residential. West of Wakesiah Avenue and south of Jingle Pot Road, there is a large area of undeveloped land. The High School and Malaspina College border on the undeveloped land. West of this area a steep bank leads up to the College Park Subdivision, a small portion of which is included in the Cat Stream drainage area. The major part of the undeveloped area drains into a natural pond west of Wakesiah Avenue. The Cat Stream commences at the pond outlet and continues east and then south to the Chase River. Along the creek there are ten culverts, the first at Wakesiah Avenue and the last at Park Avenue.

Elevations vary from 30 m (100 ft.) geodetic where the creek meets the Chase River to 54 m (177 ft.) at the pond west of Wakesiah. Most of the catchment area is below 73 m (240 ft.) with only a small portion rising to about 200 m (650 ft.) in the west.

Contour plans at 3 m (10 ft.) contour intervals are available from mapping done during the period 1960 to 1963. Recent contour plans are available for part of the catchment area from mapping done in 1979 for the North-South Arterial study. These are 2 m (6.6 ft.) contours at a scale of 1:5,000. Information from both of these plans has been used to produce the 10 m (33 ft.) interval contours, shown on Figure 2.

The baseplan has been prepared from a photograph taken in March 1979.

GEOLOGY AND SOILS

Figure 4 shows the soil types in the catchment area, as reported in "Soil Survey of Southeast Vancouver Island and Gulf Islands, B.C." by J.H. Day, L. Farstad and D.G. Laird. This report was produced by the Canada Department of Agriculture in cooperation with the University of British Columbia and the B.C. Department of Agriculture and is Report No. 6 of the B.C. Soil Survey 1959.

The principal deposits upon which the soils in the Nanaimo area have developed were formed before, during and after the last glaciation of the area. Glacial ice at one time filled the depression between Vancouver Island and the mainland and buried all of Vancouver Island except for the summits of the highest mountains. Glacial till, a compact mixture of clay, silt, sand, gravel and boulders deposited by glacial ice, was deposited over the floors and sides of valleys to a thickness of more than 30 m (100 ft.) in some places.

After the glaciers retreated, the sea covered the greater part of the present lowlands, forming marine deposits. The land surface has since risen relative to the sea so that marine deposits are now found at an elevation of 120 m (400 ft.) at Nanaimo.

In some places the till has been removed by waves along former sea shores and thin marine gravels have combined with inter-glacial sand or gravel to give stony or sandy soils of the Qualicum series which cover a large part of the catchment area. The Fairbridge and Cowichan soils are formed in a similar way but have finer particles and are less permeable.

The south-western portion of the catchment area, in the area of Malaspina College, is reported as having soils of the Shawnigan series. This is a gravelly, sandy loam underlain by compact till.

In general, the soils rest either on till or on clay so that they are not as dry as would be expected from their coarse texture.

The soils are generally described as permeable or very permeable, except for the Cowichan series, which occupy a small part of the catchment area.

The underlying clay or glacial tills, together with the frequent winter rainfall promote a high water table condition as demonstrated by the pond west of Wakesiah. This pond is reported to always contain water. The surface run-off of rainfall can therefore be relatively high, during the winter months when the surface soils approach saturation.

CLIMATE

The climate is referred to as modified maritime. Most precipitation occurs in the winter months as a result of storms moving inland from the Pacific Ocean. Annual precipitation averages 960 mm (38 in.) with an average of only 50 mm (2 in.) occurring in July and August. Mean annual temperature is $10^{o}C$ ($50^{o}F$).

Typically, summer rainfall can be short duration high intensity while during winter months lower intensity longer duration rainfall events occur.

EXISTING DEVELOPMENT

The portion of the catchment area to the east of Wakesiah Avenue is mainly residential with most of the area fully developed. Undeveloped land which is zoned residential comprises 14 percent of the 141 ha (348 ac.) in this portion.

The catchment area to the west of Wakesiah Avenue, is mainly undeveloped. Of the 126 ha (312 ac.) in this portion, 30 ha (74 ac.) are zoned residential. Of this, 3 ha (7 ac.) have been developed with another 10 ha (25 ac.) now under development. The Institutional developments comprise 40 ha (100 ac.) which include the B.C. Hydro, High School and Malaspine College area. The remaining 56 ha (138 ac.) are undeveloped and are zoned rural. Rural and undeveloped residential areas comprise 57 percent of the 126 ha (312 ac.) in this portion of the drainage basin.

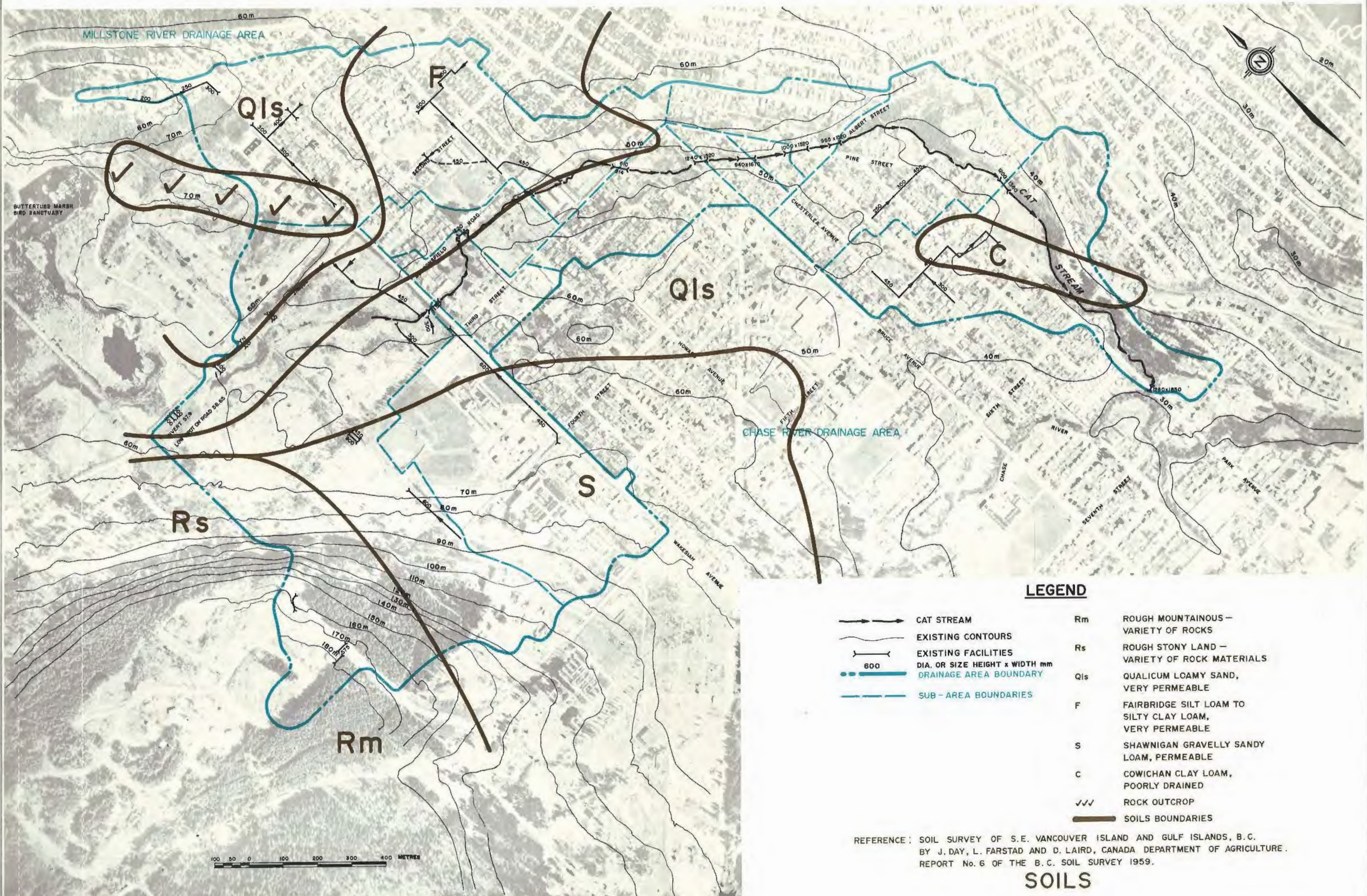
FUTURE DEVELOPMENT

The City Planning Department's predictions for future land use changes in the existing residential areas will not significantly alter drainage. Future development will consist principally of infilling of these residential areas, which will not greatly affect drainage.

Development of the large area of undeveloped land in the area of the existing pond west of Wakesiah, however, will be crucial to future flows in the creek. As shown on Figure 5 this area is zoned Rural 2 now. The Community Plan, however, shows 10 ha (25 ac.) becoming residential and the remainder becoming institutional. So there is a potential for 98 ha (180 ac.) of new residential and institutional development above Wakesiah Avenue.

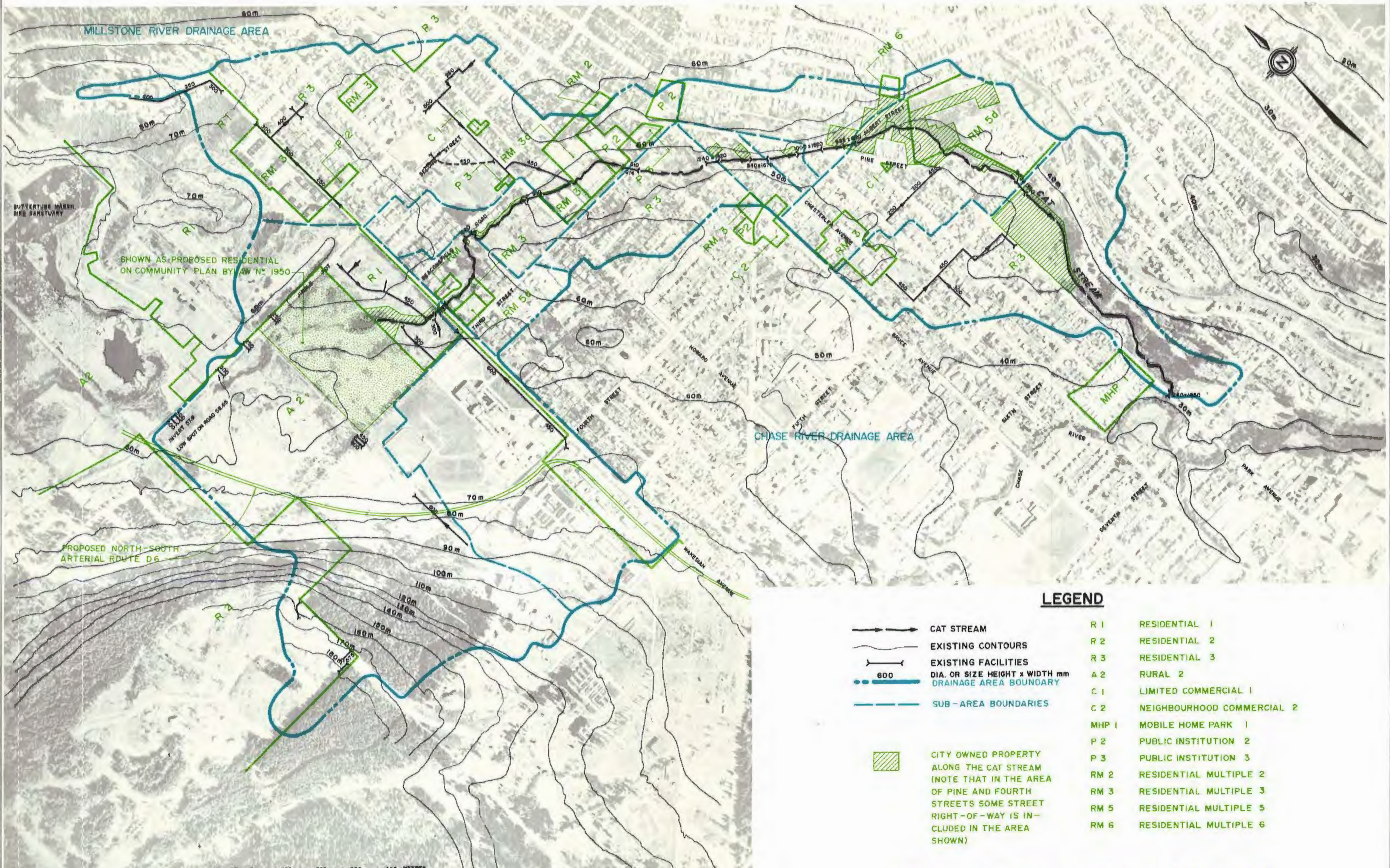
North-South Arterial. The proposed North-South Arterial Routes D1, D2, D5 and D6 cross the headwaters of the catchment area, in the area of Wakesiah Avenue and Malaspina College. The "preferred" route D6 is shown on Figure 5. The rate of runoff would be increased by the paved surfaces.

Malaspina College. Malaspina College is located in the headwaters of the catchment area west of Wakesiah Avenue. The Ten Year Facilities Development Plan of the College, dated November 1979, shows development of a wildfowl sanctuary area and arboretum in the undeveloped area to the north of the College. A series of ponds with four control weirs are shown. If these ponds are designed and operated to provide stormwater storage they could significantly reduce peak flows in the Cat Stream. This concept will be discussed in Chapter 5 of this report. This development is awaiting determination of land ownership.



SOILS

FIGURE 4



ZONING BYLAW, COMMUNITY PLAN AND CITY OWNERSHIP

FIGURE 5

4. RAINFALL ANALYSIS

For economical design of drainage facilities, data on rainfall intensities over durations from five minutes to 24 hours is needed. From long term records of rainfall, intensity-duration-frequency (IDF) curves can be constructed which predict rainfall intensities for specific return periods and durations.

These data are available only from recording rain gauge stations of the tipping bucket type or equivalent.

AVAILABLE RECORDS

The following records are available in the Nanaimo area:

1. Departure Bay. This station, located at the Biological Station, provides data from 1971 to the present. The gauge is a tipping bucket type but the chart is changed weekly and the scale is such that the records are useful only for durations of one hour and longer.

2. Nanaimo Water Reservoir. This station provided data for four years, 1963 to 1966. This is unfortunately too short a period for reliable long term predictions. The gauge was the tipping bucket type and provided data for durations of five minutes and longer. The elevation is 120 m (400 ft.).

3. Nanaimo City Yard. This gauge started operations in the fall of 1979 and does not yet have a full year of records. Data was obtained, however, for the storm in mid-December, 1979. The gauge is a tipping bucket type and the chart is changed daily at 8 a.m. The charts are forwarded to the Atmospheric Environment Service (AES) in Vancouver for processing. The elevation is 114 m (370 ft.).

4. Nanaimo Airport. This station is located at Cassidy Airport, about 14 km (9 miles) south of the City. It commenced operation in 1947 and continues to this day. The gauge is a manual type which is read daily. The elevation is 30 m (100 ft.).

Those records which include short duration data are not of sufficient length for calculation of reliable IDF rainfall curves.

ELEVATION FACTOR

Studies of rainfall intensities in the Greater Vancouver Area have shown that as elevation increases rainfall intensities increase as well as total annual rainfall. For Greater Vancouver an elevation adjustment factor was developed for rainfall intensity curves which showed that for an elevation of 1200 m (4000 ft.) intensities were greater than at sea level by a factor of 1.6 for a 5 minute duration and 2.3 for a 120 minute duration. Some of the elevation factors for two durations are as follows:

	5 min.	120 min.
1200 m (4000 ft.)	1.6	2.3
120 m (400 ft.)	1.1	1.3
50 m (170 ft.)	1.07	1.13

The Nanaimo Water Reservoir gauge was situated at an elevation of about 120 m (400 ft.), while the average elevation in the Catstream basin is 50 m (170 ft.).

The elevation factor for Greater Vancouver may not be completely applicable in Nanaimo but the factor is useful in comparing IDF curves for Vancouver and Nanaimo, which will be done in a subsequent section. The errors introduced by the short term records, however, are probably more significant than the elevation effects.

COMPARISON OF RAINFALL RECORDS

Data from long term recording stations on Vancouver Island and the Greater Vancouver Area was provided by the Atmospheric Environment Service.

Three stations were chosen on the basis of their location with respect to Nanaimo, the availability of records for the four years 1963 to 1966, and availability of analysis for durations down to five minutes. The period 1963 to 1966 was chosen to coincide with the period for which records are available at the Nanaimo Water Reservoir gauge. The stations chosen were:

1. Comox Airport - records are available from 1963 onwards.

2. Victoria Gonzales Heights - records are available from 1925 to 1930, 1937 to 1951, 1953 to the present.

3. Vancouver Airport - records are available from 1953 onwards.

These records are continuing. Analysis of these records has been carried out by the Atmospheric Environment Service to the end of 1977.

The Nanaimo Water Reservoir records for 1963 to 1966 have been analyzed to provide IDF curves for return periods of 2, 5 and 10 years.

The records for the other three stations were analyzed for this study by Dayton & Knight Ltd. for the 1963 to 1966 period to provide two year return period curves. These curves were then compared as shown in Figure 6. It can be seen that the highest intensities were recorded at the Nanaimo Water Reservoir, followed by Comox Airport, Vancouver Airport and then Victoria Gonzales Heights.

The curves derived from short term records over four years were then compared with the curves derived from the long term records for each station as shown in Figures 7, 8 and 9. It can be seen that the Comox Airport short term curve intensities are higher than the intensities for the long term curve, for durations of one hour or less. For Comox then, if the short run record was used for design, the design would be overly conservative. The reverse has occurred for the Vancouver Airport curves, with the long term record providing higher intensities than the short term record.

The short term and long term curves for Victoria Gonzales Heights are similar, and intensities are somewhat less than at Vancouver or Comox Airports. It appears, therefore, that the Comox and Vancouver Airport curves are more applicable to Nanaimo than the Victoria Gonzales Heights curve.

Looking at the intensities for a five minute rainfall, the short term figure for Comox Airport is 39.6 mm/hr, while the long term value is 31.4 mm/hr. The ratio is 39.6/31.4 = 1.26.

If the figure of 48.3 mm/hr for the Water Reservoir is reduced by this ratio it becomes 48.3/1.26 = 38.3 mm/hr. This is similar to the 38.1 mm/hr recorded for the long term record at Vancouver Airport, and appears to be a suitable figure to use.

For longer durations the variations are not so great and the Vancouver Airport figure at 24 hours duration appears to be suitable. Figure 10 shows the Departure Bay and Vancouver Airport two year return period curves. The Vancouver Airport curve is conservative when compared with the Departure Bay curve.

The foregoing analysis has been based on a two year return period because it is dangerous to project a long return period from only four years of records.

The analysis, therefore, should be repeated every two or three years in order to refine the results and confirm their accuracy.

DERIVATION OF IDF CURVES

The Gumbel procedure as used by the Atmospheric Environment Service was adopted. This is based on the extreme event for each calendar year. In order to derive 5 minute intensities from a four year record the extreme events for each year are arranged in order of magnitude and assigned order numbers 1, 2, 3 and 4.

For example, for Comox Airport, the four figures provided by the Atmospheric Environment Service for 5 minute extreme intensities for the years 1963 to 1966 are as follows:

1963	5.1 mm
1964	2.0 mm
1965	4.1 mm
1966	2.5 mm

These are assigned an order number and the return period for each event is calculated as Tr = (n + 1)/m where n is the number of years of record.

Order (m)	Rainfall in 5 minutes mm	$Tr = \frac{n+1}{m} = \frac{5}{m}$ Years
1	5.1	5.0
2	4.1	2.5
3	2.5	1.67
4	2.0	1.25

These values are then plotted on Gumbel paper and a straight line fitted to the four points. A programmable calculator was used to determine a least mean squares fit.

The rainfall over 5 minutes for a return period of 2 years was then calculated. It can also be read off the Gumbel plot. This point is then plotted as one point on the IDF curve after converting the rainfall over 5 minutes to an hourly rainfall. In this case the 2 year rainfall figure was 3.3 mm which is 39.6 mm/hour.

The procedure is then repeated at durations of 10 minutes, 15 minutes, 30 minutes, 1 hour, 2 hours, 6 hours, 12 hours and 24 hours.

Table 1 shows the resulting figures.

SEASONAL RAINFALL

Rainfall records for the winter months October to March can be used to develop a series of IDF curves for the winter season. Similarly, the summer season or all year curves can also be developed.

In the Greater Vancouver Area the winter rainfall intensities at short durations are considerably less than either the summer intensities or the all year intensities, the latter two being similar. This is illustrated on Figure 11 where the winter intensity for a 25 year, 30 minute storm is 18.5 mm/hr (0.73 in/hr) versus 28 mm/hr (1.1 in/hr) from the all year curve. Reductions in intensities occur for durations up to 24 hours, as shown by the reduction factors listed at the bottom of Table 1.

What this means is that during the winter months low intensity long duration storms prevail which frequently cause saturation of the surface soil and an increased runoff coefficient. In summer, the storms can be of much higher intensity but generally they are of short duration such that ground conditions are not normally saturated.

In the Greater Vancouver Area, the winter rainfall intensity combined with the winter runoff coefficients, because of potential saturated ground conditions, generally result in the highest flows for design purposes.

Without more local data to suggest otherwise, the winter rainfall criteria for Vancouver Airport are judged applicable for the Cat Stream basin.

RECOMMENDED DESIGN CURVES

It is recommended that the design curves for return periods of 5, 10, 25 and 200 years be as shown in Figure 11. These are based on the records at Vancouver Airport.

Figure 11 shows both winter curves and all year curves. The all year curves will be slightly higher intensity than the summer curves and given the method of derivation they are also considered suitable for use as summer curves.

The recommended curves should be updated when records of sufficient length are available from the City's Works Yard gauge.

In the meantime the City Yard records will be useful for correlating runoff with rainfall.

COMPARISON WITH PREVIOUS DESIGN CURVES

Figure 12 compares the 5 year and 10 year recommended design curves with the previous City Design Curve, the Water Reservoir Curve used in the 1977 drainage study and the 1978 City Manual of Engineering Standards Design Curves.

The previous City Design Curve 10 year equation was $R = 37/(t + 13)$ where t is the duration in minutes and R is the intensity in inches/hour. The corresponding 50 year equation was $R = 43/(t + 8)$. Converted to intensities in mm/hr these become:

$$10 \text{ year} \qquad R = \frac{940}{t + 13} \qquad\qquad 50 \text{ year} \qquad R = \frac{1092}{t + 8}$$

The 10 and 50 year calculated intensities are shown in Table 1. Also shown are the calculated intensities from the Water Reservoir curves.

The Manual of Engineering Standards Design Curves were derived by comparison of the 10 year return period curves for Courtenay, Comox, Saanich and Victoria with the previous City Rainfall Curve.

It can be seen from Figure 12 that the 1978 Design Curves are similar to the recommended all year curves from this study. The 1978 curves, however, do not extend beyond 300 minutes duration. When analysis of stormwater storage is carried out, longer durations, up to 24 hours, need to be considered. The recommended winter curves are lower intensity than the 1978 Design Curves, especially in the short duration range.

The Water Reservoir Curves show higher intensities at short durations than the curves in this report, while the previous City Design Curve shows lower intensities at durations exceeding two hours.

STORM IN DECEMBER 1979

City Yard Gauge Analysis. The rainfall gauge at the Nanaimo City Yard was in operation in time to record rainfall in the storm of mid-December 1979.

Rain fell on December 12, 13 and 14 and then with no rain for 45 hours over the period December 14, 15 and 16 started again about 10 a.m. on December 16th and continued almost without a break until 9 p.m. on December 17th. During this period intensities were recorded as below:

Duration Hours	Intensity mm/hour	Return Period in Years Based on Vancouver Airport Figures All Year Rainfall	Winter Rainfall
5 minutes	9.6	less than 2	less than 2
10 minutes	8.4	less than 2	less than 2
15 minutes	7.2	less than 2	less than 2
30 minutes	6.4	less than 2	less than 2
1 hour	6.4	less than 2	less than 2
2 hours	6.0	less than 2	2
6 hours	4.2	2	4
12 hours	3.9	5	8
24 hours	3.05	8	8

Return periods for shorter durations were less than 2 years and increased to only 8 years for a 24 hour duration.

The short duration (less than 2 hours) rainfall intensities resulting from the December 1979 storm were, therefore, relatively minor.

AES Analysis. A report, "The Rainstorm of December 13-18, 1979 over Southwestern British Columbia" was published in May 1980 by Mr. Schaefer of the AES. The estimated return period in years for short duration rainfall at various recording stations were as follows:

Location	RETURN PERIOD FOR DURATION SHOWN 15 min	30 min	1 hr	6 hr	12 hr
Vancouver Int'l Airport	<2	<2	2	21	63
Victoria Gonzales Hts.	<2	2	3	14	41
Victoria Int'l Airport	<2	2	2	2	4
Jordan River	-	-	2	12	39
North Vancouver District	<2	2	4	25	25

Estimated return periods for consecutive multi-day rainfall extremes were also calculated as follows:

Location	# Years Records Used	Return Period For Duration Shown 1	2	3	4	5	6	7 days
Vancouver Int'l Airport	33	70	38	29	42	71	70	45
Victoria Gonzales Hts.	70	57	73	33	25	82	62	48
Victoria Int'l Airport	36	7	9	6	18	62	39	25
Nanaimo Airport	29	11	5	7	21	56	42	22
Jordan River	52	60	29	25	31	73	72	60
Port Alberni	26	9	5	6	3	3	3	4
Comox Airport	32	2	2	3	2	2	2	2

From the AES analysis it is apparent that for durations of less than 1 hour the return period was generally 2 years or less. Heavy showers were not a factor. For duration between 2 and 12 hours, return periods increased rapidly at some stations (Vancouver Int'l Airport = 63 years) but remained low a relatively short distance away (Victoria Int'l Airport = 4 years).

At most stations the storm reached its greatest return period after several days of continuous rainfall. For example, at Vancouver International Airport the return period after 5 days of rain was 71 years and at Nanaimo Airport it was 56 years after the same duration. Again the storm was area sensitive in that Comox and Alberni were less than 10 year return periods.

In summary, the December storm did not produce high short duration rainfall intensities, however, multi-day extremes exceeding 60 year return periods occurred.

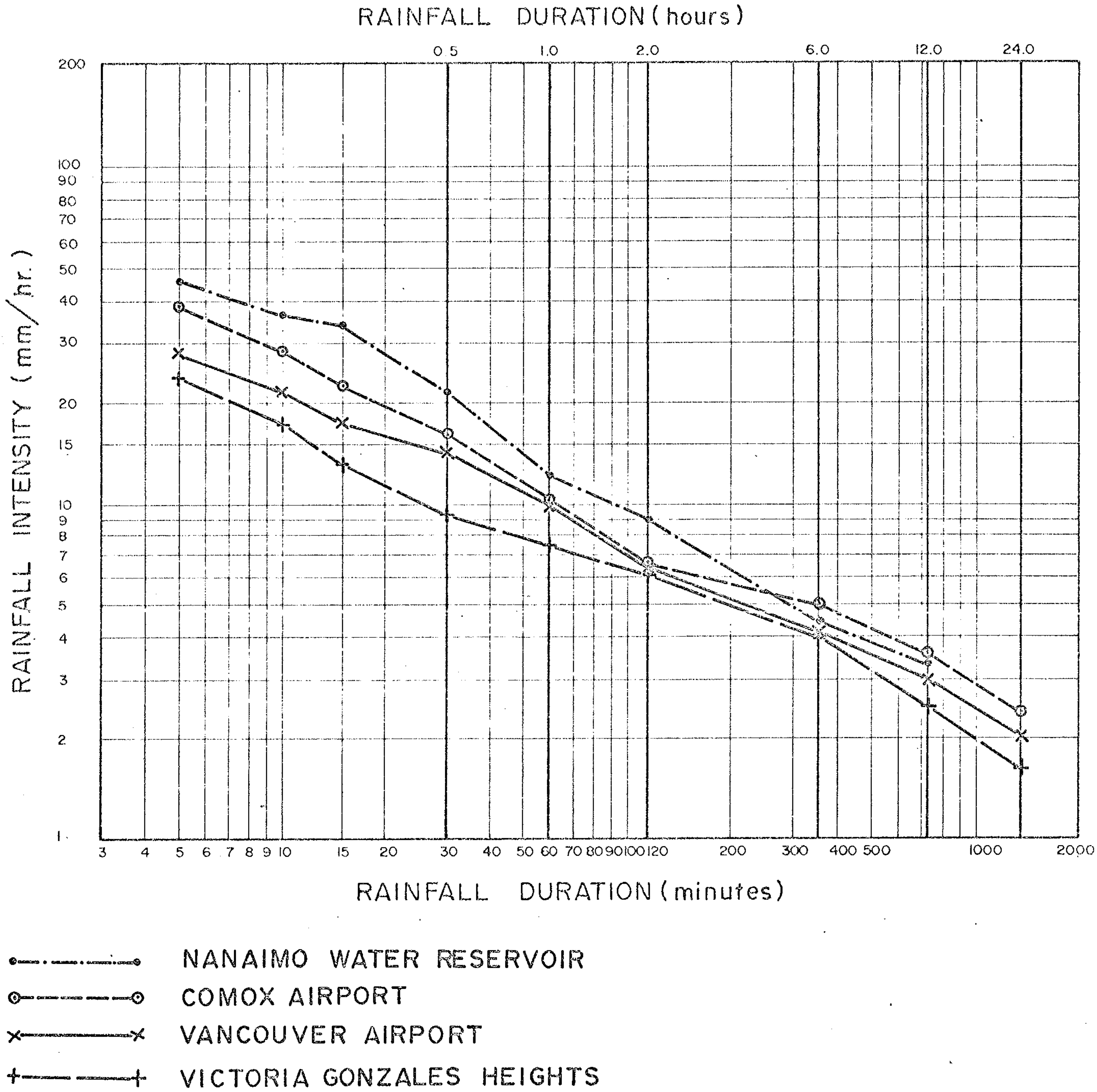
Creek Measurements. During this storm, water levels at critical points along the Cat Stream were recorded so that the runoff could be correlated with rainfall as a check on the assumptions made in design.

Peak levels were reported to have occurred on the morning of December 17th. Chapter 5 of this report deals with correlation of this rainfall to stream flow.

TABLE 1

SUMMARY OF RAINFALL INTENSITIES
(mm/hr)

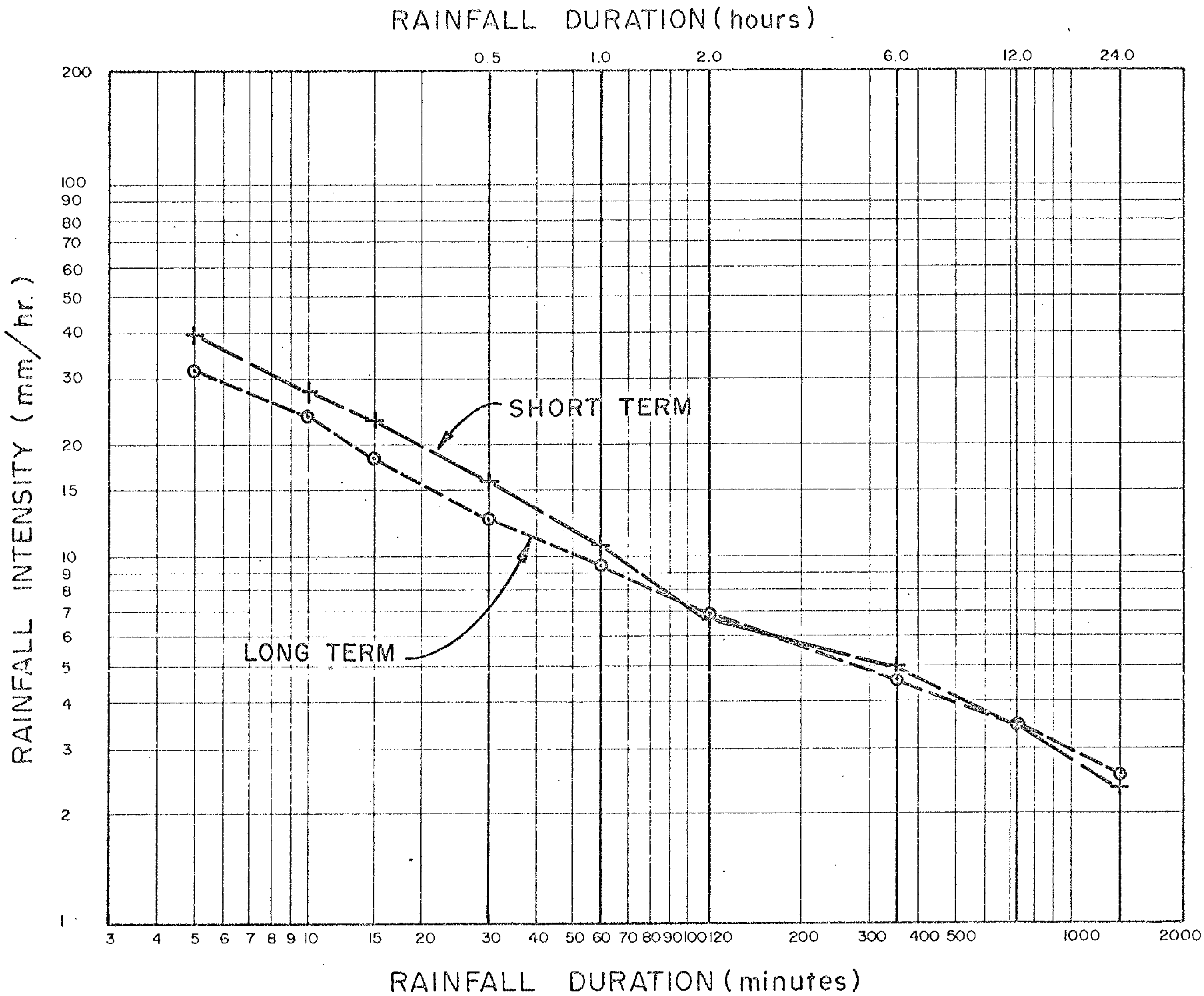
Station	Return Period Yrs.	DURATION 5 min	10 min	15 min	30 min	1 hr.	2 hr.	6 hr.	12 hr.	24 hr.
Nanaimo Water Reservoir 1963-1966	2	48.3	38.1	35.6	21.3	13.0	9.1	4.4	3.3	
Comox Airport 1963-1966	2	39.6	28.8	23.2	16.8	10.6	6.7	5.0	3.5	2.3
Vancouver Airport 1963-1966	2	28.7	21.3	17.8	14.5	10.3	6.6	4.1	3.0	2.0
Victoria Gonzales Heights 1963-1966	2	24.5	17.2	13.2	9.3	7.4	6.2	4.0	2.4	1.6
Comox Airport 1963-1977	2	31.4	23.8	19.1	13.5	9.4	6.8	4.7	3.5	2.4
Vancouver Airport 1953-1977	2	38.1	28.1	23.3	15.3	10.4	6.9	4.3	3.3	2.2
Victoria Gonzales Heights 1925-1977	2	22.8	16.2	13.2	9.4	7.2	5.6	3.7	2.7	1.9
Departure Bay 1971-1977						9.8	6.9	4.0	2.7	1.7
Vancouver Airport 1953-1977	5	53.9	39.8	33.5	21.7	13.5	9.1	5.1	4.0	2.8
	10	64.4	47.6	40.2	25.9	15.5	10.5	5.7	4.5	3.2
	25	77.6	57.4	48.8	31.3	18.1	12.3	6.4	5.2	3.7
	50	87.5	64.7	55.1	35.3	20.0	13.7	6.9	5.6	4.1
	100	97.2	71.9	61.3	39.3	21.9	15.1	7.4	6.1	4.5
Nanaimo Water Reservoir 1963-1966	5	69.9	53.3	53.3	31.8	20.0	12.7	6.1	4.6	
	10	81.3	63.5	62.2	39.4	23.9	15.5	6.9	5.3	
Old City Design Curves										
R= 940/t+13	10	52	41	34	22	13	7.1	2.5	1.3	0.6
R=1092/t+8	50	84	61	47	29	16	8.5	3.0	1.5	0.8
Recommended Design Curves (all year)	2	38.1	26.9	21.9	15.5	10.9	7.7	4.4	3.1	2.2
	5	53.9	37.5	30.4	21.1	14.7	10.3	5.8	4.0	2.8
	10	64.4	44.6	36.0	24.9	17.3	11.9	6.7	4.6	3.2
	25	77.6	53.5	43.0	29.6	20.4	14.1	7.8	5.4	3.7
	50	87.5	60.2	48.3	33.2	22.8	15.7	8.7	6.0	4.1
	100	97.2	66.7	53.5	36.8	25.2	17.3	9.5	6.6	4.5
	200	107.0	73.4	58.8	40.3	27.7	19.0	10.4	7.1	4.9
Winter Curves Reduction Factor		.61	.61	.61	.63	.66	.72	.85	.93	1.00



ALL BASED ON RECORD FOR 1963 – 1966 (4 YEARS)

TWO YEAR RETURN PERIOD RAINFALL
COMPARISON OF STATIONS

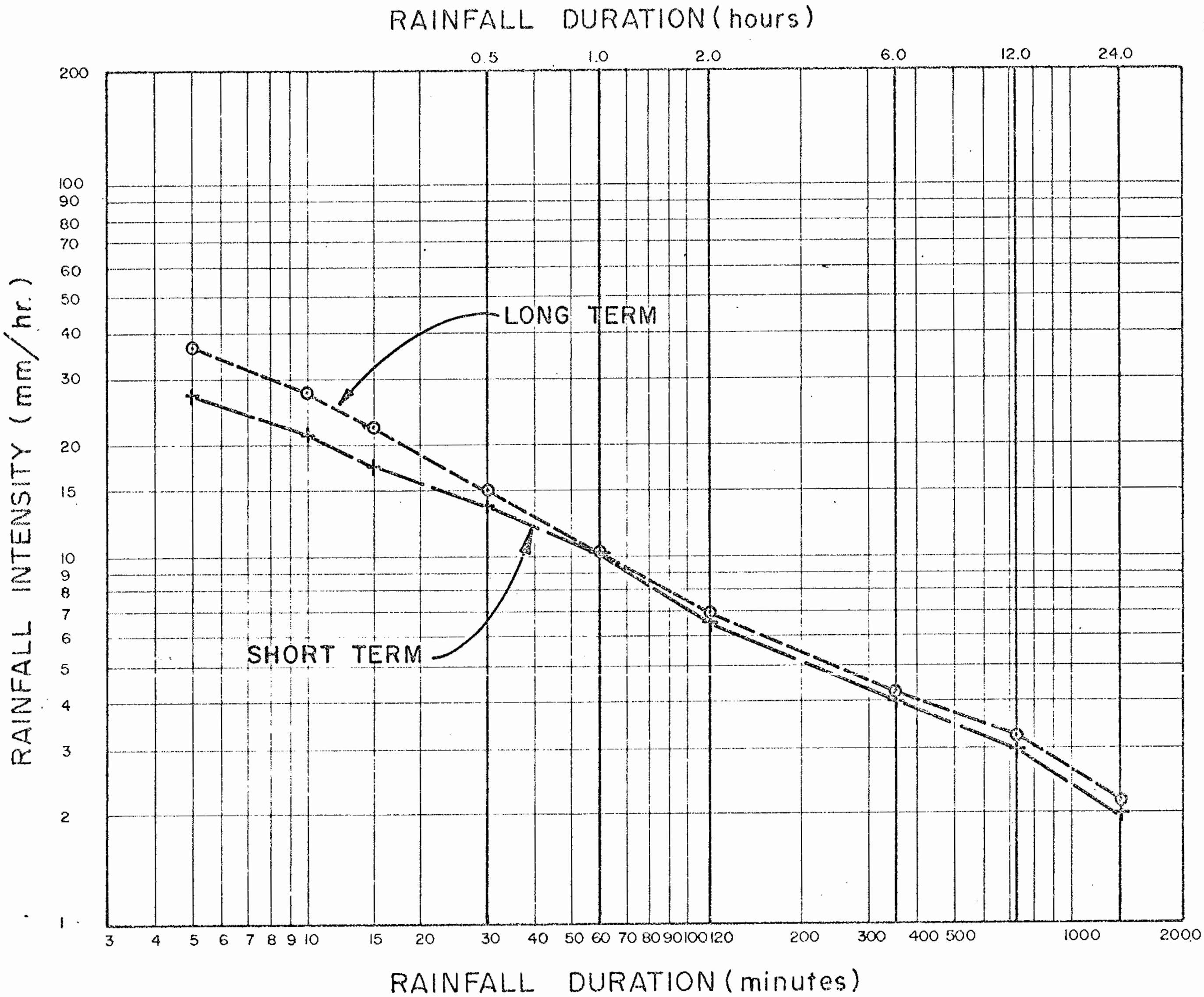
FIGURE 6



+——— ——+ TWO YEAR RETURN PERIOD BASED ON RAINFALL RECORD FOR 1963 – 1966 (4 YEARS)

⊙——— ——⊙ TWO YEAR RETURN PERIOD BASED ON RAINFALL RECORD FOR 1963 – 1977 (15 YEARS)

TWO YEAR RETURN PERIOD RAINFALL
COMOX AIRPORT

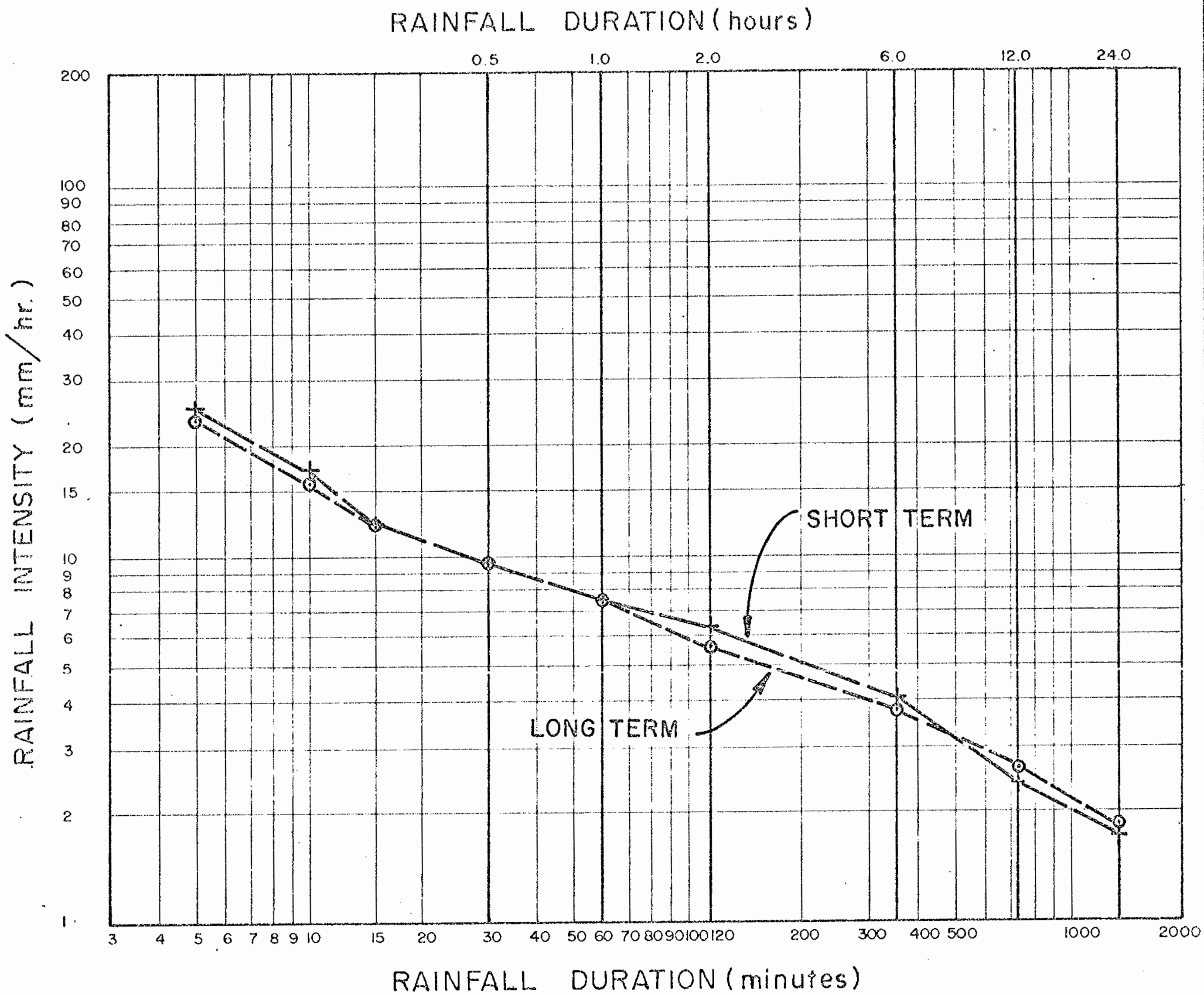


+——— ——+ TWO YEAR RETURN PERIOD BASED ON RAINFALL RECORD FOR 1963 – 1966 (4 YEARS)

⊙————⊙ TWO YEAR RETURN PERIOD BASED ON RAINFALL RECORD FOR 1953 – 1977 (25 YEARS)

TWO YEAR RETURN PERIOD RAINFALL
VANCOUVER AIRPORT

FIGURE 8

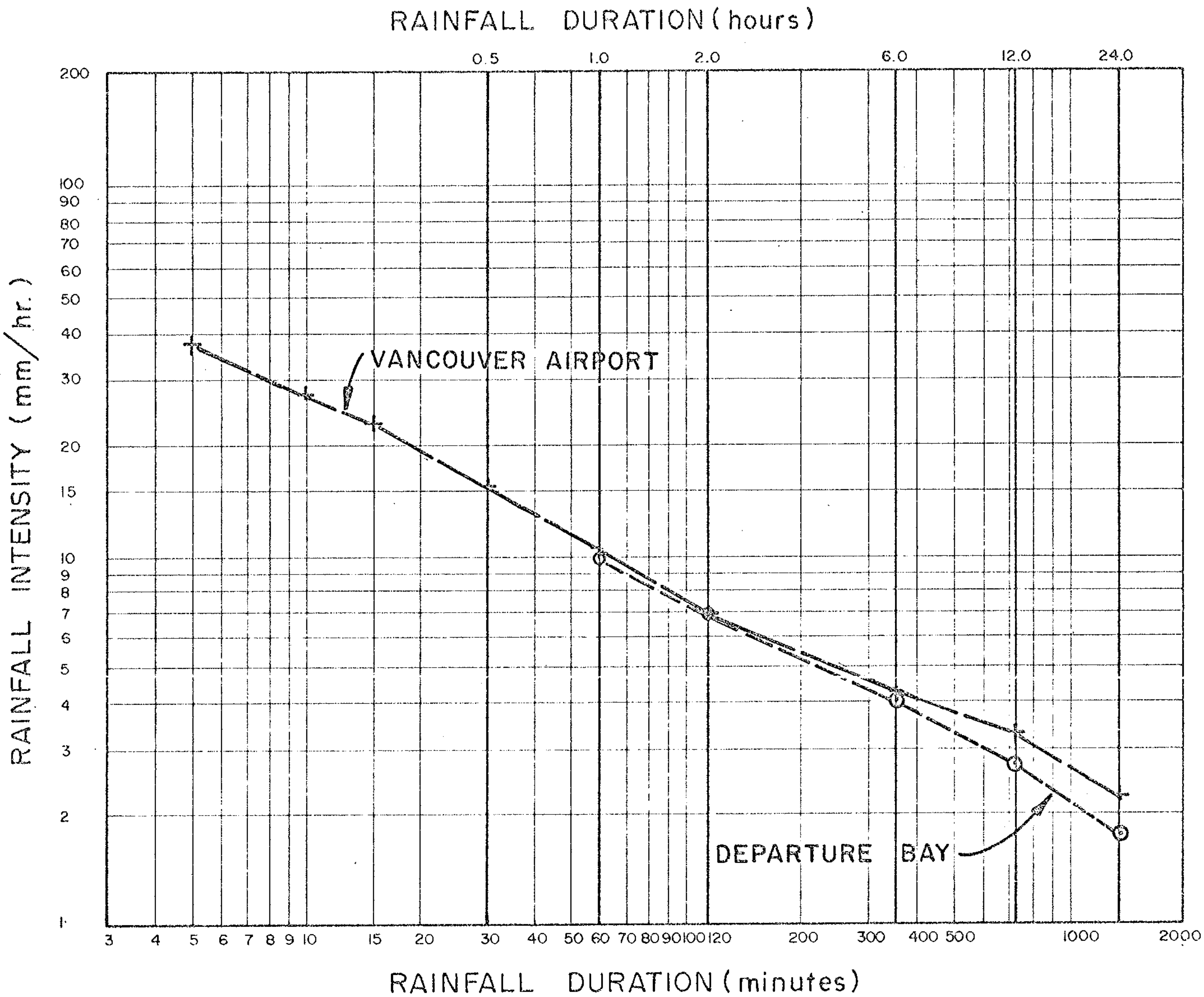


+———+ TWO YEAR RETURN PERIOD BASED ON RAINFALL RECORD FOR 1963 – 1966 (4 YEARS)

⊙———⊙ TWO YEAR RETURN PERIOD BASED ON RAINFALL RECORD FOR 46 YEARS

TWO YEAR RETURN PERIOD RAINFALL
VICTORIA GONZALES HEIGHTS

FIGURE 9

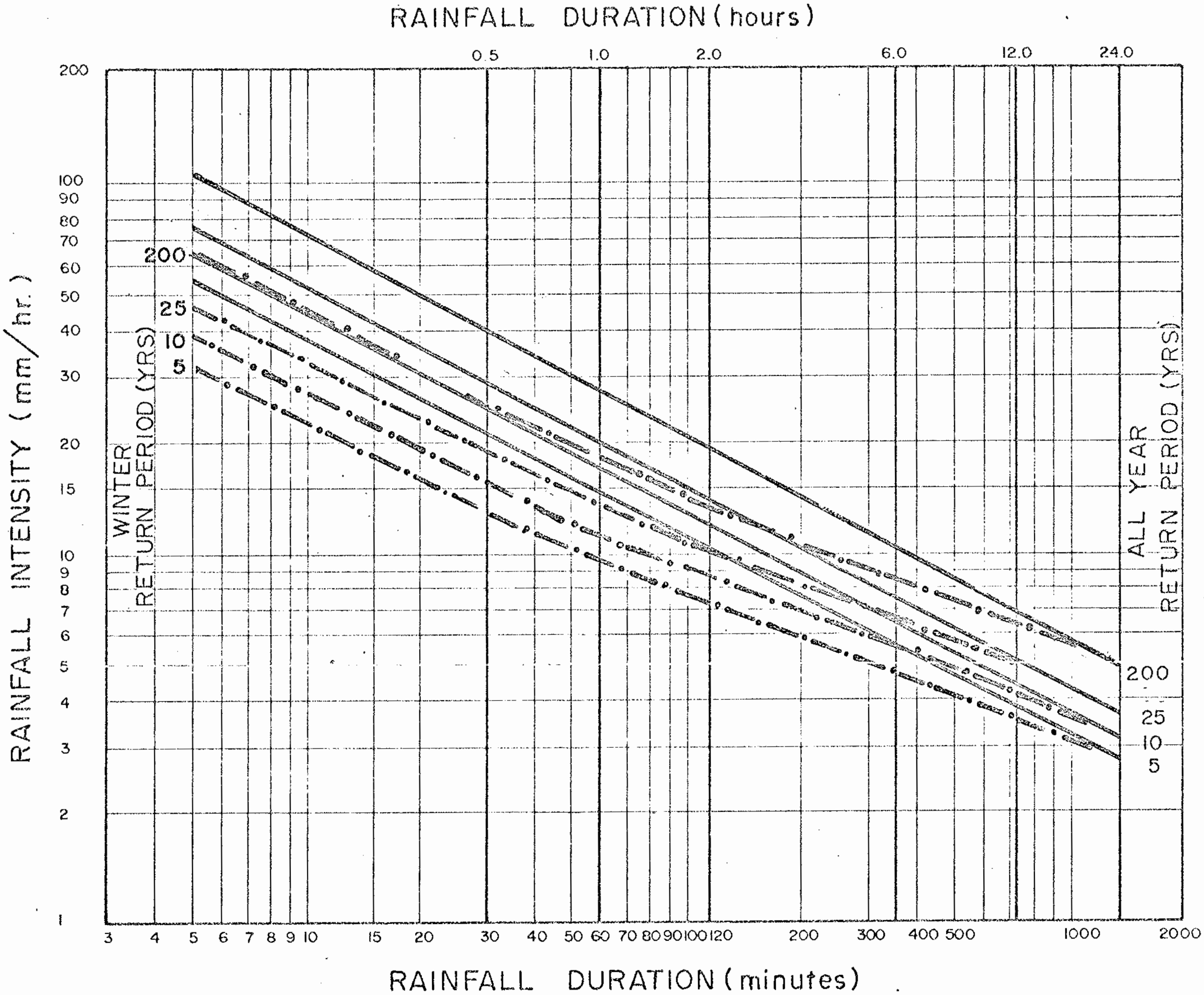


+———— ——+ TWO YEAR RETURN PERIOD FOR VANCOUVER AIRPORT, BASED ON RECORD FOR 1953–1977 (25 YEARS)

⊙—— —— ——⊙ TWO YEAR RETURN PERIOD FOR DEPARTURE BAY, BASED ON RECORD FOR 1971–1977 (7 YEARS)

TWO YEAR RETURN PERIOD RAINFALL CURVES FOR VANCOUVER AIRPORT AND DEPARTURE BAY

FIGURE 10

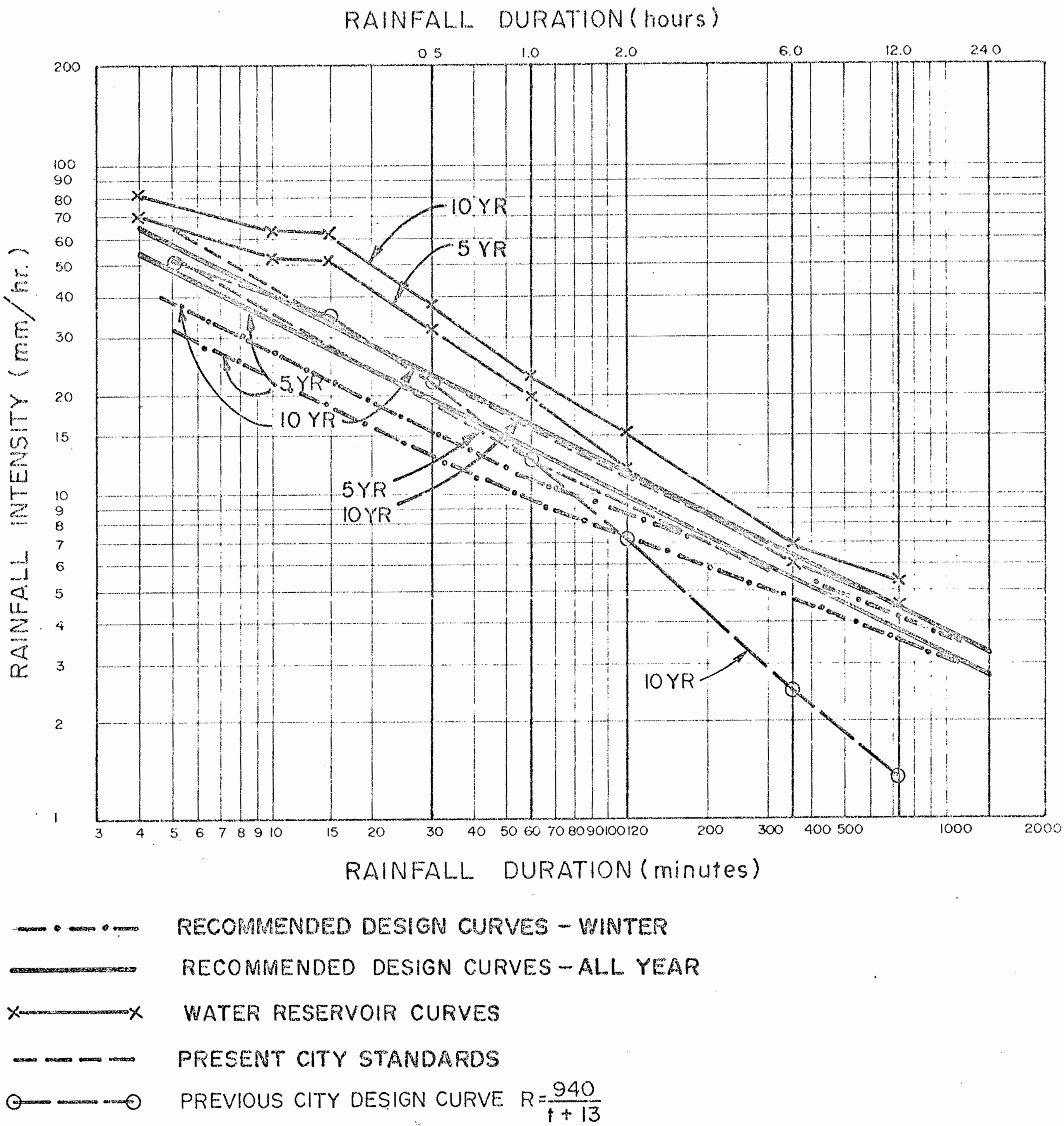


RECOMMENDED DESIGN CURVES – ALL YEAR

RECOMMENDED DESIGN CURVES – WINTER

RECOMMENDED DESIGN RAINFALL CURVES

FIGURE 11



COMPARISON OF DESIGN RAINFALL CURVES

FIGURE 12

5. DESIGN CRITERIA

This Chapter reviews current City design criteria, comments on factors affecting drainage, discusses an alternate method for calculating flows, comments on drainage policies and recommends criteria to be used for preliminary design of improvements for this study.

CURRENT DESIGN CRITERIA

Design criteria for storm sewers in the City "Manual of Engineering Standards and Specifications" dated August, 1978 are based on use of the rational method. Alternative design methods are allowed if approved by the Engineer. In the Rational Method:

$$Q = CIA$$

where Q is storm runoff flow in c.f.s.
I is the rainfall intensity in inches per hour from the IDF curves.
A is the area of the contributing catchment in acres.
C is the runoff coefficient.

Inlet times are not to exceed 10 minutes. Return periods are specified as 5 years for lateral sewers, 10 years for trunk sewers and 25 years for a watercourse or integral culvert within the length of a watercourse.

Runoff coefficients are specified as follows:

Type of Development	Coefficient
City business areas	0.65 to 0.90
City dense residential	0.50 to 0.80
Rural Areas	0.35 to 0.55
Parks, golf courses	0.10 to 0.35

RUNOFF COEFFICIENT

The determination of a runoff coefficient is the most crucial part of design by the rational method. The rainfall intensity and the area are generally well defined but the runoff coefficient is not. Normally the runoff is lower in the summer months when the probability of saturated ground conditions is low and the rainfall is generally of short duration. The runoff coefficient increases with prolonged rainfall. Flow measurements in the City of Vancouver have shown coefficients as high as 0.84 during winter months for residential areas and on one occasion, in which a heavy snowfall was followed by a rise in temperature and rainfall, a runoff coefficient of 1.1 was measured in the Still Creek drainage area.

For this study, an estimate was made for each subarea, of the percentage of impervious area, that is paved roads, driveways and roofs which are directly connected, and for these a coefficient of 1.0 was used. For the remaining mainly grassed area a coefficient of 0.4 was used. This resulted in a average coefficient for residential areas of approximately 0.6, which is within the range of coefficients currently in use by the City. The 0.4 for grassed areas, however, is higher than the range of 0.1 to 0.35 currently specified.

These coefficients were then used to calculate flows. Later the coefficients were modified to higher values when the coefficients were re-estimated from field measurements. This will be discussed in a subsequent section.

STORAGE

Storage occurs naturally both in the channel and in low lying areas along the Cat Stream. The water stored in the ponding areas eventually flows down the creek but the delay while it is retained in the ponds means that the peak rate of streamflow is reduced.

Peak rates of flow in the creek can be decreased by providing additional storage. In order to calculate storage requirements quickly under a number of different conditions, a computer program utilizing a hydrograph design method can be used.

A number of computer models have been developed recently, each with advantages, disadvantages and peculiarities. The ILLUDAS model described hereafter is available locally and enables storage and flow calculations to be carried out readily.

ILLUDAS COMPUTER PROGRAM

The Illinois Urban Drainage Area Simulator, ILLUDAS, was developed by the Illinois State Water Survey. The Water Survey conducted a literature search of urban runoff and found that the design method developed by the British Road Research Laboratory (RRL) and used successfully in Britain was promising. The RRL method was tested in the United States on basins in 10 cities. Runoff from paved areas was accurately predicted but the method could not be used for all urban basins unless a grassed-area component was added. The ILLUDAS program was then developed using the RRL method for paved surfaces and adding a grassed area component. This was done by taking water storage in the soil and soil categories into account.

The program predicts runoff from these two components, paved areas and grassed areas, using a design storm of any chosen length and predicts rates of flow taking pipe or channel storage into account.

Processing for this study was carried out at the University of British Columbia Computing Centre, and some 50 computer runs were made using the ILLUDAS model.

The proper duration for a design storm must be chosen, the critical duration being the one which causes the greatest rate of flow and/or requirement for storage at a particular point. The critical duration varies with size of catchment area, the storage requirements, the rainfall pattern and will be different at different points on the creek. Studies using ILLUDAS have shown that one hour may be used as the critical duration for a wide range of basin sizes when storage is not considered. With storage, critical durations increase and longer durations govern for the Cat Stream.

CORRELATION OF STREAMFLOW AND RAINFALL

As reported in Chapter 4, rainfall was recorded for the storm in mid-December, 1979. Water levels were also recorded at some points along the creek and a number of photographs were taken. This enabled the actual flow through culverts to be calculated.

The ILLUDAS computer program was used to simulate the storm. The catchment area was divided into sub-areas in order to calculate flow at each culvert.

The rainfall used was that recorded at the Nanaimo City Yard, starting at midnight on the 12-13th December and finishing at 1 a.m. on 19th December, a period of 6 days.

Flows calculated by ILLUDAS are shown on Figure 13 along with selected estimated flows from the field measurements. These flows represent the results of several trial runs that culminated in a reasonable correlation between computed and measured flows. It was necessary to assume relatively impervious soil conditions to achieve a good correlation.

It is interesting to note that high flows of almost equal magnitude occurred on Friday, December 14th and on Monday, December 17th.

The effect of storage upstream of Wakesiah in the area of the existing pond was taken into account by asuming that the culvert at Wakesiah could not discharge more than 0.85 m^3/s (30 cfs). This is the estimated maximum flow through the culvert with the water levels measured during the December storm and with the culvert partly filled with gravel.

The rainfall and flows at Wakesiah Avenue, Third Street and Albert Street are shown on Figure 13. Table 2 shows the estimated and computed flows.

TABLE 2

COMPUTED AND MEASURED STREAM FLOWS - DECEMBER 1979 STORM

Culvert	ILLUDAS Computed Flow m^3/s	cfs	Estimated Flow m^3/s	cfs	Comments
Wakesiah Avenue	0.85	30	0.71-0.85	25-30	culvert partially filled with gravel.
Beaconsfield Road	1.0	36	more than 0.7	more than 24	culvert partially filled with gravel, overland flow not included.
Howard Avenue	1.1	40	0.9	33	
Third Street	1.8	63	1.8	62	
Bruce Avenue	2.0	71	1.4	50	Low velocities due to backwater effects.
Chesterlea Avenue	2.1	73			
Pine Street	2.1	74			
Albert Street	2.2	79	2.5	90	
Fifth Street	2.5	88			
Park Avenue	2.9	101			

The flows were estimated from field measurements of maximum water levels during the storm and from photographs. The program calculates that a quantity of storage of 3700 m^3 (4850 yd^3) was needed to limit the streamflow to 0.85 m^3/s (30 cfs) at Wakesiah Avenue. From field survey the actual area covered by water during the storm was about 430 m (1410 ft.) long and 40 m (130 ft.) wide with an average depth of about 0.2 m (8 in.) for a storage volume of 3440 m^3 (4500 yd^3) which compares well with the 3700 m^3 (4850 yd^3) calculated by the computer model. The maximum depth of water at the entrance to the culvert on Wakesiah was about 0.8 m (2.6 ft.).

COMPARISON OF RATIONAL METHOD AND ILLUDAS

Flows were then compared using both ILLUDAS and the Rational Method as shown in Table 3. For the Rational Method, the runoff coefficients discussed previously were used along with the winter rainfall curve for a 25-year storm.

The flows are hypothetical because they are based on no storage on the creek and assume a fully developed condition.

TABLE 3

COMPARISON OF ILLUDAS AND RATIONAL METHOD FLOWS

Design Point	ILLUDAS m^3/sec.	ILLUDAS c.f.s	Rational Method m^3/sec.	Rational Method c.f.s	Ratio
Wakesiah Avenue	3.2	113	2.9	102	1.1
Beaconsfield Road	3.4	120	2.9	102	1.2
Howard Avenue	3.5	124	3.0	106	1.2
Third Street	4.8	169	4.1	145	1.2
Bruce Avenue	5.1	180	4.2	148	1.2
Chesterlea Avenue	5.2	183	4.3	152	1.2
Pine Street	5.3	187	4.3	152	1.2
Albert Street	5.6	198	4.4	155	1.3
Fifth Street	6.2	219	4.7	166	1.3
Park Avenue	7.0	247	5.2	183	1.3

The flows predicted by ILLUDAS are 10 percent to 35 percent higher than those predicted by the Rational Method when City Standards are applied.

If higher runoff coefficients are assumed, a better comparison will result. To match the flows, the following runoff coefficients (compared with City Standards) are needed:

Impervious areas upstream of Wakesiah Avenue	1.0	(0.65 to 0.90)
Grassed areas upstream of Wakesiah Avenue	0.5	(0.1 to 0.35)
Area downstream of Wakesiah Avenue (residential)	0.8	(0.5 to 0.8)

Some runoff coefficients were calculated for the measured flows in the December 1979 storm.

For the culvert at Wakesiah Avenue, with a flow of 0.85 m^3/s (30 cfs) and a contributing area of 116 ha (286 ac.), the coefficient was calculated as 0.42. This is high considering the storage involved and the nature of the catchment area. A higher figure would have resulted if there had been no storage.

For the ILLUDAS calculated flow of 2.2 m^3/s (79 cfs) at Albert Street, the runoff coefficient is 0.6 overall and if the flow at Wakesiah Avenue is deducted, along with the contributary area to calculate the runoff coefficient for the area between Wakesiah Avenue and Albert Street culverts, the resulting coefficient is 0.81. For the field measured flow of 2.5 m^3/s (90 cfs) the coefficient is almost 1.

A good correlation is therefore obtained between the Rational Method and ILLUDAS if the runoff coefficients are increased to the forementioned values, which are higher than the City Standards, and these higher runoff coefficients are supported by field measurements during the December 1979 storm. Saturated ground after a long wet period is the probable cause for the high runoff coefficients.

CULVERT HYDRAULICS

The flow through culverts is affected by culvert slope, size, the culvert entrance, the channel approach velocity, the roughness of the culvert wall and the level of the headwater and tailwater.

The control of flow in a culvert is either at the inlet or at the outlet. In general inlet control is the most common and occurs when the culvert barrel can carry more flow than can enter the culvert.

With inlet control the flow is dependent on the headwater elevation above the culvert invert at the entrance, the approach velocity, the culvert size and the entrance geometry.

Ponding of water at a culvert entrance will increase the discharge significantly. In many cases some ponding is permissable. Care must be taken however to ensure that the embankment or adjacent property is not endangered.

Culvert hydraulic calculations in this study have been based on the Handbook of Concrete Pipe Hydraulics published by the Portland Cement Association.

DRAINAGE BASIN POLICIES

There are several problems associated with natural water-courses in an urban environment that must be recognized in the design stage.

These problems and their effects on design criteria for the Cat Stream Drainage Basin are discussed hereafter.

Flood Flow Routing. Present City requirements are to size creek culverts to pass a 25-year return period storm flow. This means that a storm in excess of a 25-year return period would theoretically exceed the culvert capacity. The routing and rate of discharge of this excess flow must be considered in drainage planning.

The 100 or 200 year return period should be evaluated for flood flows. The natural channel can be used to contain the flow if measures such as creek widening, erosion control, and overflow channels at roadways are judged feasible. Alternatively, a base flow, say 25-year, can be left in the creek and excess flows routed in a pipeline or alternate channel to the point of discharge. This alternative is generally expensive, but may be necessary in built-up urban areas.

Through storage, the rate of runoff from a flood event can be reduced to a lesser rate of flow to equal the capacity of the creek.

The quantity of runoff to be handled remains the same but the rate of discharge can be reduced by extending the time over which water is discharged to the creek. The more storage that is provided, the lower the rate of discharge will be. The storage can be both on stream or off stream.

The Cat Stream below Wakesiah passes through low density development and City owned park land. There is a natural low lying area near Third Street. Upstream of Wakesiah, the drainage basin is largely undeveloped and a larger natural pond is found just above Wakesiah.

The existing natural storage on the creek, accordingly, is available as a means of restricting the peak rates of flow. Furthermore, the relatively undeveloped state of the land immediately adjacent to the creek makes the creek channel a reasonable choice for flood routing.

Erosion. The Cat Stream has an average grade of 0.8 percent between Chase River and Wakesiah Avenue, as indicated on Figure 3. In addition there are ten culverts at major road crossings along the route.

The combination of the relatively flat grade and the fixed structures at road crossings has served to prevent significant erosion in the bed of the creek.

The creek banks, as observed, are largely covered with a mantle of weeds and brush, and are not unstable.

Erosion in the creek, accordingly, is not a problem and will not be a future problem provided creek velocities are restrained and alignments are kept reasonably uniform. For the reported soil conditions velocities should be kept in the 1.2 to 1.8 m/s (4 to 6 fps) range to prevent excessive erosion.

Encroachment. As discussed in Chapter 2 there are several buildings between Fifth and Wakesiah that have or have been threatened by flooding in the past. One house near Bruce Avenue is affected by relatively minor storms.

On the whole, however, compared to natural watercourses in other developed municipalities, the problems of encroachment in the Cat Stream Basin are not severe.

The creek is not built-in to the landscaping of properties as it is in North and West Vancouver, nor are there buildings and patios directly on or along side the creek bed. One foot bridge was noted near Albert Street.

Even though the creek flows on private land for most of its route, therefore, encroachment is not a major problem.

Debris. Natural watercourses in an urban environment inevitably become garbage dumps, whether it be grass clippings, leaves, stumps, branches, tires or simply household trash.

There is no other aspect of natural watercourse preservation that is more difficult to control and more harmful to the drainage function.

The majority of drainage problems are caused by debris, and this is true for every municipality and for every natural watercourse that flows through urban developments.

Nanaimo should ensure that it has the necessary authority to stop disposal of solid wastes into natural watercourses. Grills and protective works at culvert entrances, if properly designed and maintained, can assist in protecting against culvert blockages, but only if debris is prevented from entering the watercourse will adequate capacity in the creek be maintained.

Fisheries Resource. Thirty or forty years ago little attention was paid to the small natural watercourses as an integral part of the total fisheries resource. As a result, many of the natural spawning grounds in small creeks have been lost.

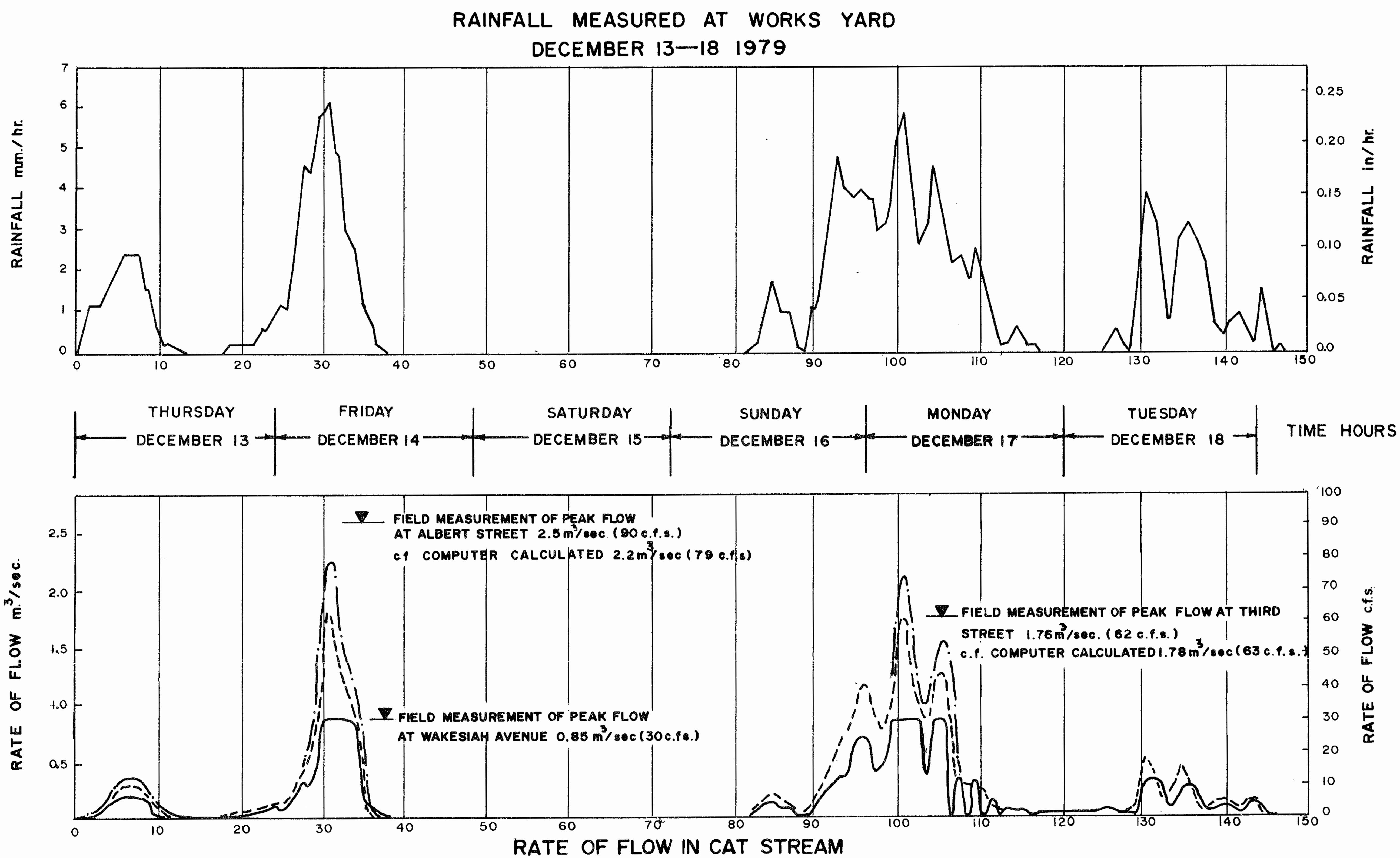
In recent years an effort has started to both return and enhance these small creek spawning grounds.

This requires, firstly, that the creek not be conduited throughout its length, and secondly, that erosion, debris and velocities be controlled to within limits.

The Provincial Fish and Wildlife Branch and the Federal Fisheries and Marine Service have joint jurisdiction over fisheries in spawning creeks. A number of creeks are fish bearing in Nanaimo, including the Cat Stream from the confluence with Chase River to Wakesiah Avenue.

The Fish and Wildlife Branch have advised that there is limited spawning of fish in the Cat Stream but nonetheless it is desirable to protect and increase the resource. Fish hatch in the spring and live in low velocity parts of the creek until the following spring at which time they go to sea.

The Branch would like to see storage provided in the sub-areas before the main creek is reached to decrease the rate of runoff and thereby minimize the need to upgrade and change the main channel.



LEGEND

FLOWS AS CALCULATED BY COMPUTER MODEL

———————— WAKESIAH AVENUE

— — — — — — THIRD STREET

———— · ———— ALBERT STREET

DECEMBER 1979 STORM

CORRELATION OF CALCULATED AND MEASURED FLOWS

NOTE : MAXIMUM FLOW AT WAKESIAH AVENUE OF 0.85 m^3/sec (30 c.f.s.) WAS SELECTED TO SIMULATE STORAGE CONDITION

FIGURE 13

The disposal of roof drain water to ground was also considered desirable as a method serving to increase summer low flows as well as decreasing the rate of winter runoff.

PROPOSED DESIGN CRITERIA

Listed hereafter is a summary of design criteria, including policies, recommended for adoption by the City for the Cat Stream.

1. Rational Method for drainage areas in alternative with no storage.

2. ILLUDAS Program for drainage area in the retention-detention alternative.

3. Rainfall curves from Figure 11 of this report. All year or winter curves to be used and the higher result to be selected for design.

4. For analysis of the creek flows, return period not less than 25 years with provision for routing 200 year flood flows in the creek channel.

5. Return periods per City Standards elsewhere in Drainage Area with consideration for flood routing.

6. A minimum runoff coefficient of 0.8 in residential areas and 0.5 in grassed areas for use with Winter IDF curves and the Rational Method.

7. A soil category of 4 for use with Winter IDF curves and the ILLUDAS Program.

8. Conduits at road crossing designed as culverts with inlet and/or outlet capacity control. Headwalls to be provided.

9. Peak velocities less than 1.5 m/s (5 fps) to prevent erosion, or revetment to be provided.

10. Fisheries resource protected by velocity, debris and deposition controls.

11. No encroachment of structures on level of flood plain for 200 year storm.

CITY OF NANAIMO

CAT STREAM DRAINAGE STUDY

6. DESIGN FLOWS

The design criteria and policies proposed in the previous Chapter can now be used to determine stormwater flows in the creek.

Both the 25-year return and 200-year return period events have been calculated so that alternatives under each each degree of protection can be compared.

25 YEAR RETURN PERIOD STORM

For information and comparison, flows were calculated for the following conditions. Each condition assumes no storage is available and the results are summarized in Table 4.

a) An undeveloped condition - assuming that the whole area was undeveloped.

b) Present development.

c) A fully developed condition - assuming that those areas now zoned for residential were fully developed and that the area west of Wakesiah and south of Jingle Pot Road which is now undeveloped was to develop in accordance with the Malaspina College Ten Year Facilities Development Plan.

TABLE 4

DESIGN FLOWS FOR 25 YEAR STORM
UNDEVELOPED TO FULLY DEVELOPED CONDITIONS - NO STORAGE

Design Point	Existing Culvert Capacity		Undeveloped Condition		Present Development		Full Development	
	m^3/s	cfs	m^3/s	cfs	m^3/s	cfs	m^3/s	cfs
Wakesiah Avenue	2.4	85	2.4	85	3.0	106	3.2	113
Beaconsfield Road	1.8	65	2.6	92	3.2	113	3.4	120
Howard Avenue	2.0	70	2.6	92	3.3	116	3.5	124
Third Street	2.3	80	3.6	127	4.5	159	4.8	169
Bruce Avenue	1.1	40	3.8	134	4.7	166	5.1	180
Chesterlea Avenue	3.4	120	3.9	138	4.8	169	5.2	183
Pine Street	3.7	130	4.0	141	4.9	173	5.3	187
Albert Street	3.5	124	4.2	148	5.2	183	5.6	198
Fifth Street	4.5	159	4.7	166	5.8	205	6.2	219
Park Avenue	9.6	340	5.3	187	6.5	229	7.0	247

With the exception of Park Avenue, it can be seen that under present conditions a 25-year flow exceeds the capacity of the creek culverts and that full development of the catchment area magnifies this condition. Storage or channel upgrading, or both, will be necessary to accommodate the design flows.

A natural storage pond exists upstream of Wakesiah in an area which the College is proposing to develop into a sanctuary. This natural storage area can and should be used to also retain stormwater so that a controlled release rate can be maintained through the culvert at Wakesiah. It is judged a reasonable release rate would be 0.85 m^3/s (30 cfs) which equals the flow through the culvert during the December 1979 storm and compares with the culvert capacity of 2.4 m^3/s (85 cfs).

A second storage area is available at Third Street. This area floods periodically but is usually dry in contrast to the pond above Wakesiah which always contains water. The property is privately owned and therefore it may be difficult to develop this site for storage. The culvert capacity at Bruce is 1.1 m^3/s (40 cfs) if basement flooding of the house on Bruce near the culvert inlet is to be avoided. If the house is protected by dyking the creek, the culvert capacity can be increased to 2.4 m^3/s (85 cfs) and this value has been selected as a release rate for the storage at Third.

Table 5 shows resulting flows for a 25 year return period and the required storage volumes for a future fully developed condition. The flows have been calculated for two conditions of storage, above Wakesiah only and at both Wakesiah and at Third.

TABLE 5

DESIGN FLOWS AND STORAGE REQUIREMENTS

25 YEAR STORM

Design Point	Storage at Wakesiah				Storage at Wakesiah and at Third			
	Flow		Storage Req'd		Flow		Storage Req'd	
	m^3/s	cfs	m^3	yd^3	m^3/s	cfs	m^3	yd^3
Wakesiah	0.85	30	20,000	26,000	0.85	30	20,000	26,000
Beaconsfield	1.3	46			1.3	46		
Howard	1.5	53			1.5	53		
Third	3.3	116			3.3	116		
Bruce	3.6	127			2.4	85	9,000	12,000
Chesterlea	3.7	131			2.6	92		
Pine	3.8	134			2.7	95		
Albert	4.1	145			2.8	99		
Fifth	4.7	166			3.8	134		
Park	5.5	194			4.8	169		

The effect of storage is to reduce the rate of flow downstream from the storage by about 2.35 m^3/s (83 cfs) at Wakesiah and 2.7 m^3/s (95 cfs) below Bruce.

200 YEAR RETURN PERIOD STORM

Information on flood levels for a 200 year return period storm is required for the establishment of permissible building elevations and setbacks under the Zoning Bylaw. The data is also necessary for determining the routing and sizing of flood flow facilities.

On the basis of full development and release rates of 0.85 m^3/s (30 cfs) at Wakesiah Avenue and 2.4 m^3/s (85 cfs) at Bruce Avenue, the 200-year flows and storage requirements are shown in Table 6.

TABLE 6

DESIGN FLOWS AND STORAGE REQUIREMENTS

200 YEAR STORM

Design Point	Storage at Wakesiah				Storage at Wakesiah and at Third			
	Flow		Storage		Flow		Storage	
	m^3/s	cfs	m^3	yd^3	m^3/s	cfs	m^3	yd^3
Wakesiah	.85	30	34,000	44,000	.85	30	34,000	44,000
Beaconsfield	1.3	46			1.3	46		
Howard	1.7	60			1.7	60		
Third	4.3	152			4.3	152		
Bruce	4.6	162			2.4	85	14,000	18,000
Chesterlea	4.7	166			2.6	92		
Pine	4.9	173			2.7	95		
Albert	5.3	187			3.2	113		
Fifth	6.1	215			4.4	155		
Park	7.1	251			5.9	208		

These design flows and storage requirements derived for 25-year and 200-year return periods are used in the next chapter in the design of plans to improve drainage.

7. ALTERNATIVES FOR IMPROVEMENTS

Preceding chapters have outlined the deficiencies and problems in the existing Cat Stream drainage system, analyzed rainfall and runoff data to produce criteria for design, and established policies for improvements to the existing drainage system.

This chapter summarizes the designs and estimates of cost for alternative plans to improve the existing drainage.

DESIGN REQUIREMENTS

Local flooding has been a common occurrence for the areas adjacent to the Cat Stream. It appears that this local flooding has worsened in recent years because there has been little maintenance on the creek and there has been an increase in deposits, weeds and brush. This condition can only deteriorate further with time and upstream development.

Basic to any plan of drainage improvements, therefore, is the requirement for alleviation or elimination of local flooding problems.

A second requirement is that the creek remain a natural watercourse and not be converted into an enclosed stormwater conduit. The latter possibility would be the most expensive solution, but would be permanent, would save future operating and maintenance funds, and would allow other uses of the lands that presently contain the creek and its flood plain.

Since the creek is a fisheries resource, however, and since there is now a growing demand for natural watercourse preservation and control in urban areas, as is witnessed by Nanaimo's Community Plan, conduit enclosures of the Cat Stream are not considered further.

Lastly, future use of the Cat Stream must include the function of flood routing since there is no other route for flood flows to follow. A blocked culvert at Wakesiah, for example, would only temporarily deter stormwater from continuing along the creek.

If future facilities were designed to be reached or exceeded in capacity on an average of once in 10 years, accordingly, the eleven year storm and greater would still have to be accommodated, somehow, in the Cat Stream.

The system, therefore, must be checked for its ability to pass flows exceeding the design criteria, and the extent of possible damage therefrom should be judged.

ALTERNATIVE PLANS.

Four plans have been designed and estimated in subsequent sections.

Two of the plans have been designed for a 25 year recurrence interval and two for a 200 year. For both recurrence intervals, different storage conditions have been investigated. For the 25-year plans, the effect of the 200 year flood flows have been estimated, but only from preliminary calculations.

The various plans are illustrated on Figures 14, 15 and 16.

Estimates of capital cost have been prepared for each plan. Culvert work provides for the installation of reinforced concrete culvert pipe and restoration of the road surfaces. Reinforced concrete headwalls are allowed for each new and existing culvert where road crossings are improved. Trash racks would comprise a grillage above the culvert entrance with provision for overflow and maintenance access. Creek cleaning provides for clearing out of debris and cutting back brush and brambles on banks. Where necessary to accommodate flood flows widening or dyking of the channel banks in critical sections is allowed for. Storage at Third allows for construction of the dyke but only minor excavation to contour the basin with provision for reseeding of the disturbed soils. Storage at Wakesiah allows for only a storm-water diversion from the road ditch and a control structure. The existing pond is adequate.

To construction costs are added a 25% allowance for engineering and contingencies and a 12 percent allowance for financing and administration.

Plan 1 - 25 year winter storm.

- full development.

- storage west of Wakesiah.

Basic to this plan and the three other plans is the use of the natural storage pond west of Wakesiah which is proposed for development by Malaspina College.

Flow from the developed campus and High School area above Wakesiah would be diverted to the pond and released into the existing culvert crossing Wakesiah at a controlled rate not exceeding about 0.85 m^3/s (30 cfs).

In Plan 1, about 20,000 m^3 (26,000 yd^3) of storage are needed in the pond to maintain the release rate at .85 m^3/s (30 cfs). This volume represents about 0.9 m (3 ft.) of water depth over a pond area of 2 ha (5 ac.) which can be accommodated in the natural ponding area without berm construction. Diversion of flow from the Wakesiah west ditch to the pond and a control structure to limit the release rate from the pond are required.

Below Wakesiah, five new culvert road crossings will be required between Third and Albert Avenue to accommodate the 25 year flows.

Between Third and Pine the creek would be regraded to prevent the flooding of the low lying area in this reach of the creek. Minor creek widening is needed between Pine and Albert. A trash rack would be installed at Park Ave.

Otherwise, the creek channel is adequate after clearing out of debris and brush to accommodate the 25-year storm flows without flooding homes.

Assuming full implementation of Plan 1, the water levels created by the 200 year storm would not cause flooding of the road crossings but the creek channel would flood between Pine and Fifth and in Robins Park. Velocities in the creek channel between Albert and Pine would reach 2 m/s (6.5 fps) which is above the upper limit to prevent excessive erosion. The 200-year flood would therefore cause some erosion and flooding.

Estimate of Cost. The total capital cost of Plan 1 is estimated at $309,000, made up as follows:

1.	Control structure and diversion above Wakesiah		Lump Sum	$ 30,000
2.	Third St. Culvert	2x17 m of (57 ft)	1070 mm (42 in)	$ 24,000
3.	Bruce Ave. Culvert	2x25 m of (82 ft)	1070 mm (42 in)	$ 34,000
4.	Chesterlea Ave. Culvert	2x27 m of (87 ft)	1070 mm (42 in)	$ 37,000
5.	Pine St. Culvert	53 m of (174 ft)	760 mm (30 in)	$ 26,000
6.	Albert St.	15 m of (50 ft)	1070 mm (42 in)	$ 11,000
7.	Allowance for headwalls		Lump Sum	$ 16,000
8.	Allowance for trash rack at Park Ave.		Lump Sum	$ 5,000
9.	Allowance for cleaning out of creek		Lump Sum	$ 10,000
10.	Allowance for widening creek		Lump Sum	$ 8,000
11.	Creek Regrading		Lump Sum	$ 20,000
		Sub-Total		$221,000
12.	25% for Contingencies & Engineering			55,000
13.	12% for Interim Financing			33,000
		TOTAL PLAN 1		$309,000

Plan 2 - 25 year winter storm.

- full development.

- storage at Wakesiah and Third.

Firstly it includes diversion of stormwater, presently flowing on Wakesiah Avenue and originating in the institutional complex, westwards into the storage pond above Wakesiah, the same as Plan 1.

Secondly, it includes construction of a second storage retention facility between Bruce and Third as shown on Figure 16. This retention pond would be on-line, and would appear simply as a widening of the creek for other than flood flows. When flow in the creek reached the level of the top of the culverts at Bruce Ave. the water would back up and the pond would start filling. After the storm subsided and flows decreased, the water would release automatically from the pond. The maximum rate released to the creek downstream of the pond would be governed by the capacity of the culvert at Bruce. A release rate of 2.4 m^3/s (85 cfs) has been preliminary selected so as not to exceed the capacity of the existing downstream culverts and creek channel.

As indicated on Figure 16, earthwork is required in order to construct the pond which eliminates the creek regrading required in Plan 1. Some 1.5 ha (3.5 ac.) of private land are required for the pond, however, which may be difficult to acquire. Considering lot sizes, about 2.4 ha (6 ac.) of land would have to be purchased.

New twin culverts would be required at Third, the creek must be cleaned of debris and brush and a dyke is necessary between Bruce and Third to protect the low lying houses. Widening of the creek is not necessary downstream of Bruce.

Because of the storage retention, the 200 year flood flow would cause less impact than Plan 1. Flooding would occur between Pine and Albert and between Bruce and Chesterlea.

Estimate of Cost. The estimated total capital cost of Plan 2 is $353,000, as follows:

1.	Wakesiah Storage Pond		Lum Sum	$ 30,000
2.	Third St. Culvert	2x17 m of (57 ft)	1070 mm (42 in)	$ 24,000
3.	Storage and dyke at Third		Lump Sum	$ 30,000
4.	Purchase Property	2.4 ha (6 ac)	Lump Sum	$150,000
5.	Allowance for headwalls		Lump Sum	$ 3,000
6.	Allowance for trash rack at Park Ave.		Lump Sum	$ 5,000
7.	Allowance for cleaning out creek		Lump Sum	$ 10,000
		Sub-Total		$252,000
8.	25% for Contingencies & Engineering			63,000
9.	12% for Interim Financing			38,000
		TOTAL PLAN 2		$353,000

Plan 3 - 200 year winter storm.

- full development

- storage west of Wakesiah.

Plan 3 is similar to Plan 1 except that the storage requirement increases to 34,000 m^3 (44,000 yd^3) to maintain a .85 m^3/s (30 cfs) release rate and the downstream design flow at Park Ave. is about 30 percent higher. Six new culvert road crossings are required, together with regrading and reconstruction of the creek between Third and Pine. The Creek must be cleared of debris and also widened between Pine and Fifth. A trash rack would be installed at Park Ave.

The City Park at Fifth and Park would flood, but this is judged to be acceptable as no structures would be affected and erosion would be minimal.

Estimate of Cost. The estimated total capital cost of Plan 3 is $431,000, as follows:

1.	Storage at Wakesiah		Lump Sum	$ 35,000
2.	Third St. Culvert	2x17 m of (52 ft)	1070 mm (42 in)	$ 24,000
3.	Bruce Ave.	2x25 m of (82 ft)	1220 mm (48 in)	$ 39,000
4.	Chesterlea Ave.	2x27 m of (87 ft)	1220 mm (48 in)	$ 42,000
5.	Pine St.	53 m of (174 ft)	1220 mm (48 in)	$ 42,000
6.	Albert St.	2x15 m of (50 ft)	1070 mm (42 in)	$ 21,000
7.	Fifth St.	39 m of (128 ft)	910 mm (36 in)	$ 23,000
8.	Allowance for head walls		Lump Sum	$ 20,000
9.	Allowance for trash rack		Lump Sum	$ 5,000
10.	Allowance for cleaning out creek		Lump Sum	$ 10,000
11.	Allowance for creek widening		Lump Sum	$ 22,000
12.	Creek Regrading		Lump Sum	$ 25,000
		Sub-Total		$308,000
13.	25% for Contingencies & Engineering			77,000
14.	12% for Interim Financing			46,000
		TOTAL PLAN 3		$431,000

Plan 4 - 200 year winter storm.

- full development.

- storage at Wakesiah and at Bruce.

Plan 4 is similar to Plan 2 except that the design flows are up to 23 percent higher and storage requirements are about 60 percent higher.

With the addition of storage at Third, the peak flows are reduced downstream so that widening or dyking of the creek channel is needed only between Bruce and Chesterlea and Pine and Albert.

Estimate of Cost. The estimated total capital cost of Plan 4 is $384,000, as follows:

1.	Wakesiah Storage Pond		Lump Sum	$ 35,000
2.	Third St. Culvert	2x17 m of (57 ft)	1070 mm (42 in)	$ 24,000
3.	Storage and dyke at Third		Lump Sum	$ 35,000
4.	Purchase property	2.4 ha (6 ac)	Lump Sum	$150,000
5.	Allowance for headwall		Lump Sum	$ 3,000
6.	Allowance for trash rack		Lump Sum	$ 5,000
7.	Allowance for cleaning out creek		Lump Sum	$ 10,000
8.	Allowance for dyking or widening work		Lump Sum	$ 12,000
		Sub-Total		$274,000
9.	25% for Contingencies & Engineering			69,000
10.	12% for Interim Financing			41,000
		TOTAL PLAN 4		$384,000

COMPARISON OF PLANS

Capital Costs. Estimated capital costs of the four plans are summarized as follows:

Plan 1	-	\$309,000
Plan 2	-	\$353,000
Plan 3	-	\$431,000
Plan 4	-	\$384,000

Plans 1 and 2 are designed for a 25 year storm and Plans 3 and 4 for a 200 year storm.

A storm exceeding a 25 year recurrence interval, assuming either Plan 1 or 2 was implemented, would cause some flooding of property and low lying homes below Bruce Avenue. Channel erosion would also occur.

Natural ponding has always existed above Wakesiah and it is assumed the City's needs for retention can be accommodated with the requirements of Malaspina College.

Without a second storage facility at Third, five new culvert road crossings and minor creek widening are needed in Plan 1 for the 25-year flow, while six new culvert road crossings and additional creek widening are needed in Plan 3 for the 200-year flow. The capital cost of Plan 3 increases by \$122,000 or 40 percent more than Plan 1.

Storage at Third reduces the needed road improvements to only a new culvert crossing at Third for both Plan 2 - 25-year and Plan 4 - 200-year. Widening of the creek is not necessary in Plan 2 but some widening is required in Plan 4 between Bruce and Albert.

Based on the need for 2.4 ha (6 ac.) of land for storage at Third at \$25,000 per acre, Plan 4 costs \$31,000 or 9 percent more than Plan 2. The uncertainty, however, is whether the land can be acquired and if the estimated price is realistic. The decision regarding storage at Third should be made on the basis of several factors, including capital costs.

Two anomolies have appeared in this study.

The first is that design flows calculated by the Rational Method are usually higher than flows calculated by the hydrograph method employed in ILLUDAS. The reverse was true in this study until runoff coefficients were substantially increased in the Rational Method.

The second is that the primary purpose of retention-detention works in a storm drainage system is to save money, but the reverse was the case in this study for the 25 year flood flows. Plan 2, with the additional storage at Third, costs \$44,000 more than Plan 1 for 25 year flows while for 200 year protection, additional storage resulted in only an 11 percent decrease in cost. In order to justify a second storage retention facility on the Cat Stream, therefore, there must be other compensating factors.

Operation and Maintenance. As outlined previously, retention storage on the Cat Stream at Third would be empty most of the year. When the on-line system capacity was exceeded, however, it would be needed.

Experiences in parts of the United States in which such facilities have been in operation for some years is that there are maintenance problems involved in ensuring that the pond will function when needed on an intermittent, unpredictable basis.

Maintenance of the storage works, therefore, must be done by the public corporation on a regular basis and would be a continuing expense against the plan utilizing storage.

Fisheries Resource. Storage on a natural watercourse is beneficial to the fisheries resource because it reduces peak flows, reduces the need to widen the creek channel, lowers peak velocities, and helps with the problems of scour, erosion and depositions.

These are problems, common to all natural watercourses, that have been accentuated by developments within the watershed. Developments do not cause more rainfall, but they lower the percentage of rain that enters the ground and they speed up the rates at which surface water reaches a watercourse.

The result of development, to the fisheries resource, is a more dangerous and difficult environment for fish than existed under natural conditions.

Environmental Impact. A storage retention pond that is empty for most of the time would not be a nuisance or offence provided it was kept neat and tidy and was not allowed to become a breeding ground for mosquitos, weeds and brush.

The upstream pond west of Wakesiah would be a retention-detention pond that would have water in it all the time. During flood flows its level would rise, but this should not adversely affect its principal use as a sanctuary.

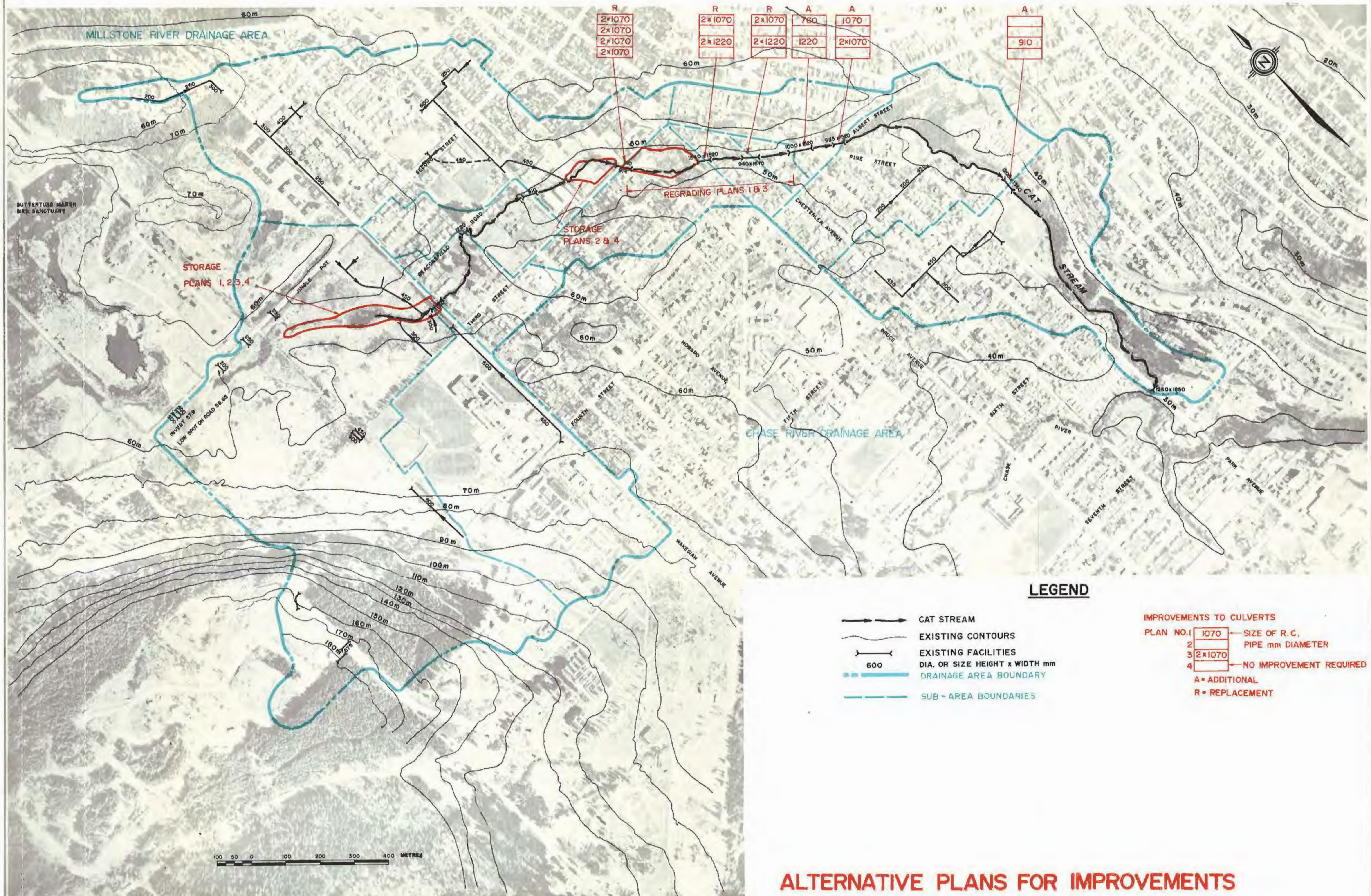
Though not foreseen now, it is possible that some auxiliary use for the storage pond at Third could be devised that would not prevent its use as a flood reservoir when needed. Provided the City cleaned it up after each flood, for example, it could be a passive park with trees and shrubs that could tolerate an occasional flood.

There is danger to the public associated with multiple use of a storage reservoir, however, and this should not be part of the comparison in favour of retention ponds.

In summary, it is judged that the environmental impact of storage ponds in the Cat Stream Basin is negligible.

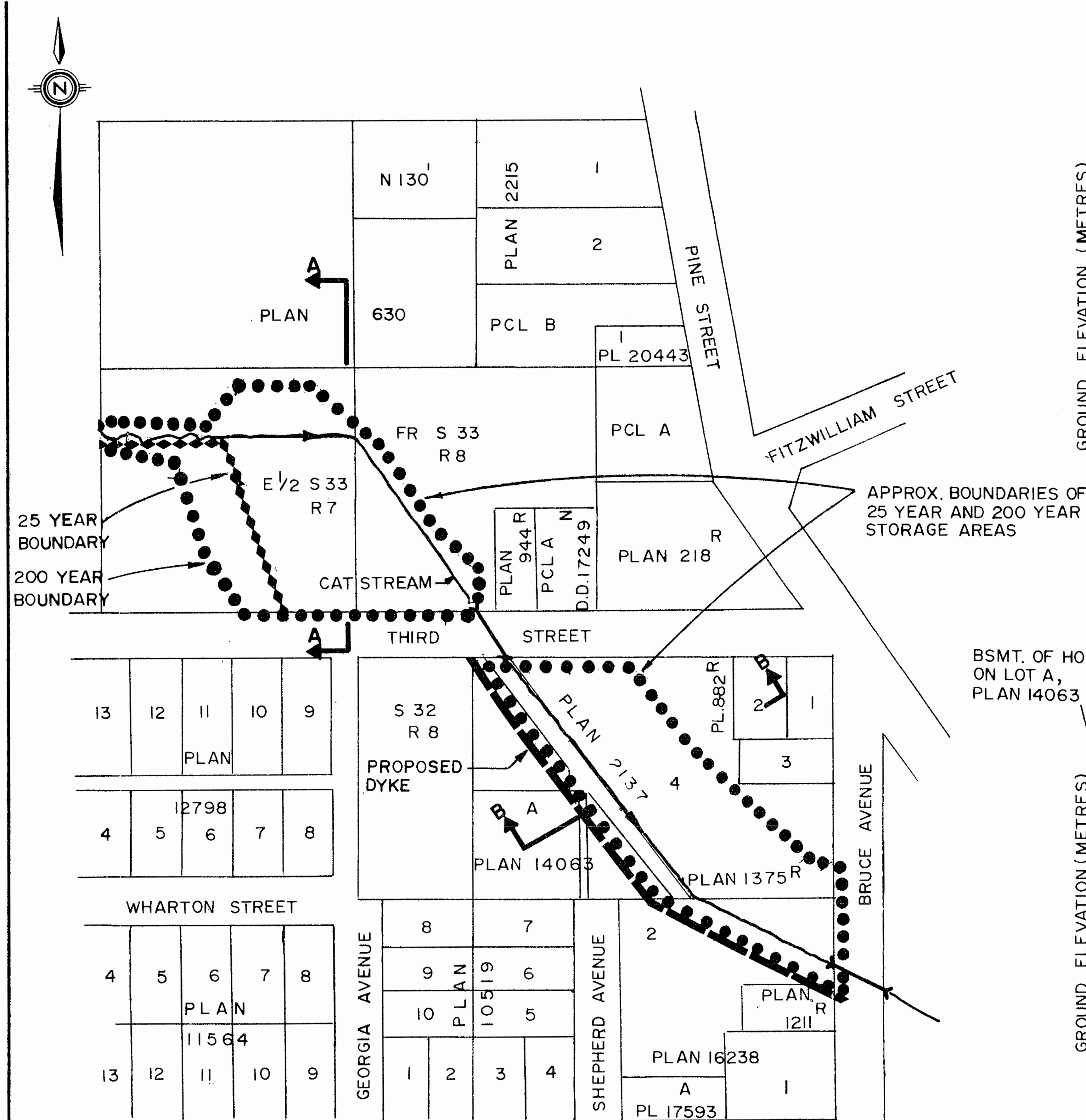
Recapitulation. Protection of the fisheries resource is the single most compelling argument in favour of storage retention ponds for the Cat Stream Drainage Basin.

It is judged that the additional cost of $44,000 for Plan 2 over Plan 1 would be justified because of the added benefits to fisheries, and Plan 2 is recommended for adoption.



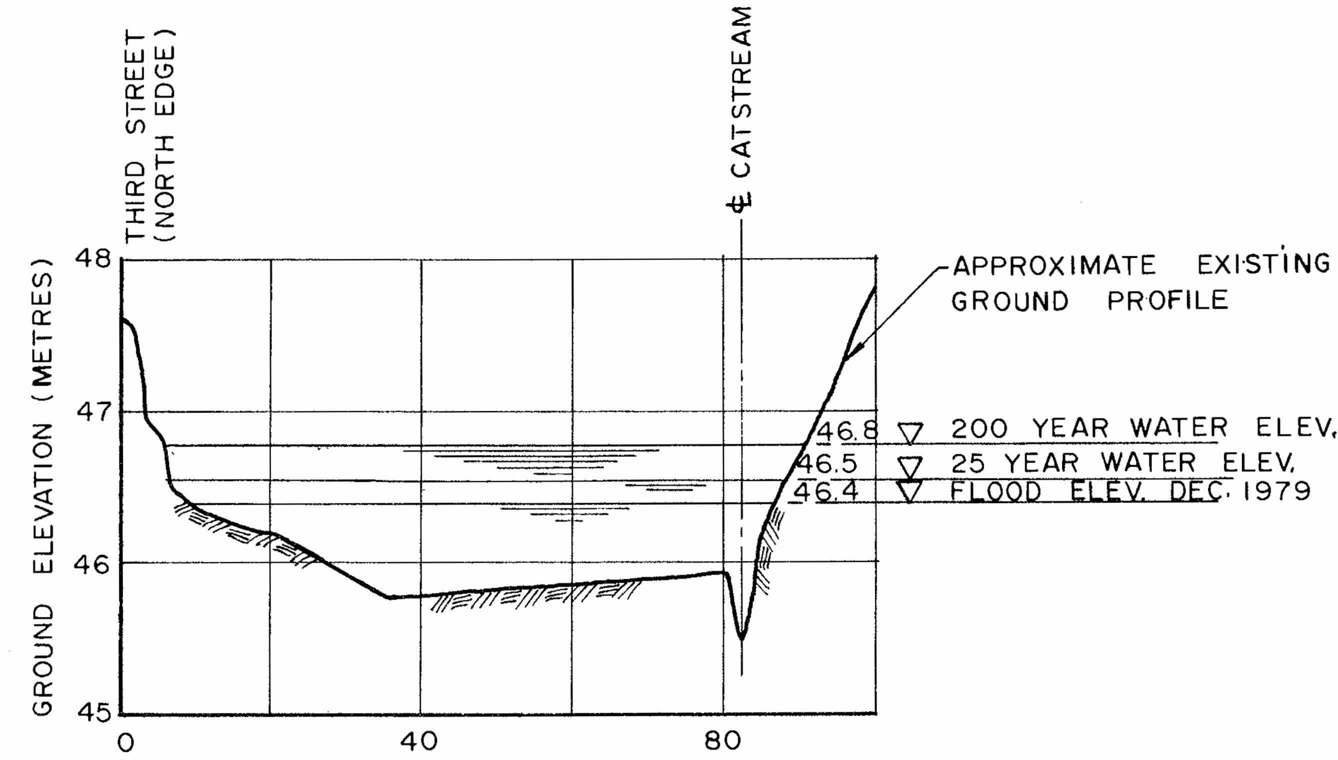
ALTERNATIVE PLANS FOR IMPROVEMENTS

FIGURE 14

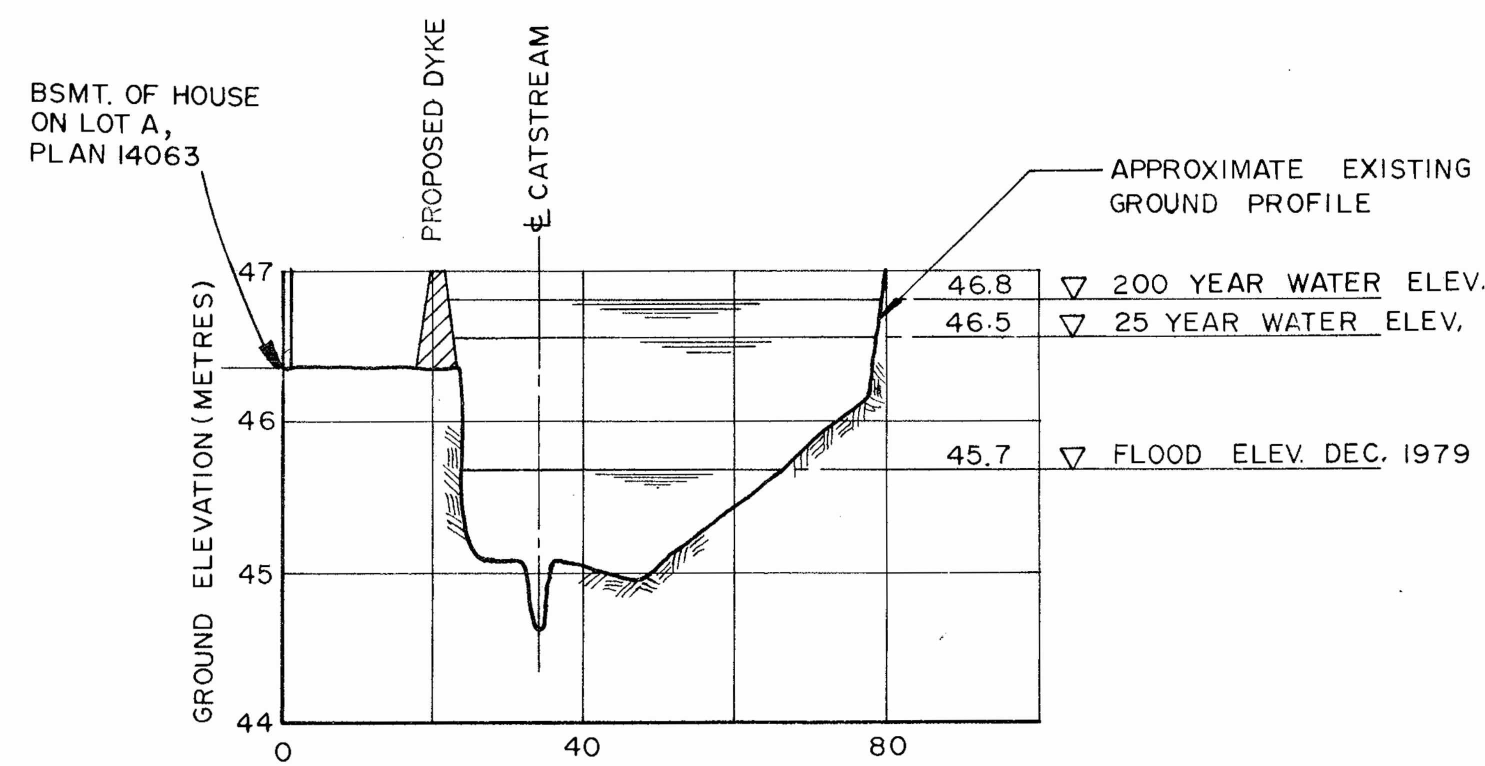


PLAN

SCALE
1 : 2000



SECTION A-A



SECTION B-B

PROFILES

SCALES
HORIZ. 1 : 1000
VERT 1 : 50

STORAGE AREA AT THIRD STREET

FIGURE

8. WATERCOURSE PRESERVATION AND MANAGEMENT

In order to overcome flooding problems and implement improvement programs, long term development policies are needed for major watercourses which pass through urban development.

The works necessary to overcome flooding and erosion problems can be expensive, particularly where urban development has encroached within the natural watercourse.

The preservation of watercourses in their natural state is desirable wherever possible and practical. A "greenbelt" strip along the creek is ideally suited for containment of the watercourse and can also be used for multipurpose recreational activities. In many undeveloped areas this concept can readily form part of the overall planning approach.

For areas which are already developed the problem is more complex and suitable solutions more difficult to find.

MUNICIPAL REGULATIONS

Bylaw 1950, the Community Plan, sets out a policy on land adjacent to lakes and streams as follows: "New subdivision and development will be managed to improve or retain the environmental quality of the shores and banks of fresh water bodies. Techniques including purchasing, zoning, land dedication requirements, development permits and floodplains designation will be used to maintain a buffer area between water bodies and adjacent land uses."

The Cat Stream is included in a list of principal water bodies concerned.

Section 2.3.0 concerning stormwater drainage states: ". . . . The City will give consideration to the adoption of a policy which would provide for the implementation of a storm drainage program in both existing and developing areas of the City. In addition, the City will give consideration to establishing cost sharing formulas for storm drainage."

The Community Plan, then, sets out the City's intentions to maintain drainage systems in their natural state by requiring a buffer strip between a creek and adjacent land uses.

Zoning Bylaw 2000 provides for a building or structure setback of 15 m (50 ft.) from the "natural boundary" of a fish bearing watercourse. The Chase River and tributaries, of which the Cat Stream is one, are included in the list of fish bearing watercourses. The 15 m setback may be reduced to 7.5 m (25 ft.) if approved by the Provincial Ministry of the Environment.

For flood control, the underside of the "floor system" must be a minimum of 1.5 m (5 ft.) above the "natural boundary" or 0.6 m (2 ft.) above the 200 year flood level. The "natural boundary" is defined as "the visible high water mark of any lake, river, stream or other body of water where the presence and action of the water are so common and usual and so long continued in all ordinary years, as to mark upon the soil of the bed of the lake, river, stream, or other body of water, a character distinct from that of the banks thereof, in respect to vegetation, as well as in respect to the nature of the soil itself."

Set backs for buildings and minimum elevations to protect against flooding are established in the Zoning Bylaw.

Both the Zoning Bylaw and Community Plan, however, apply only to new development. Existing development which do not comply with the current regulations are another more difficult matter.

PROVINCIAL REGULATIONS

The Provincial Water Rights Branch has authority over storage, diversion of water and the construction of drainage works in creeks. Water Rights approval must be obtained whether or not the creek is under private or public control. When assessing proposed drainage works, the Water Rights Branch seek input from the Fish and Wildlife Branch.

PRIVATE VERSUS PUBLIC OWNERSHIP

There are two basic approaches for preserving creeks and controlling the effects of stormwater runoff.

a) The City could leave ownership in private hands as far as possible with responsibility for maintenance being left to the individual owners. This is the present situation on the Cat Stream.

b) The City could adopt a policy of acquiring control of the creek bed and a strip of land on each side through rights-of-way. This strip could be used to provide a greenbelt along the stream with public access. Maintenance would be entirely the City's responsibility.

City control has the advantage of permitting effective flood and erosion control measures and maintainance procedures. Control of drainage works would then be similar to control of sewerage, water and road facilities. The disadvantage is the need to acquire the rights-of-way.

Private ownership has the apparent advantage of leaving the responsibility for preservation of the creek in its natural state, and maintainance procedures in the hands of the private property owners.

The obvious disadvantage is that property owners will not maintain or preserve the creek in its natural state. Perhaps more important is that private ownership does not mean that a Municipality is not, at least in part, responsible or liable for damages caused by flooding or stream bed erosion. A municipality's position in law with respect to private ownership of a creek is not entirely clear. If the City requires new development to construct drainage works that discharge to a creek, possibly incorporating storage ponds, erosion control measures and trash racks all of which are designed for an "X" year return period and other City specified criteria, then the City may well be responsible if subsequent damage occurs that is related to the drainage works. The City must seek the advice of its solicitor on the matter of drainage law in British Columbia.

A combination of both public and private control is frequently the case found in Municipalities. For new development, the acquisition of rights-of-way can be arranged with relative ease but in existing development those properties, where negotiations are difficult, may be left as private ownership.

In general, public control through acquisition of rights-of-way on either side of the creek channel is the preferred option to ensure the implementation and continued maintainance of drainage policy, but is often impractical or impossible in presently developed areas.

CREEK PRESERVATION AREA REQUIREMENTS

One alternative arising from this study, accordingly, is for the City to require areas to be preserved along the Cat Stream from all new development, from all existing development where control over the watercourse is judged advisable to mitigate flooding, and from other existing development where property rights can be obtained with relative ease so as to secure a "green belt" for as much of the creek as possible.

This green belt could be called the Creek Preservation Area. It need not be owned by the City, but could be an area in which all future development was under close control.

This would require a Creek Preservation Area bylaw.

Preservation Area requirements would be based on the following criteria:

1. Minimum widths should comply with the City's Zoning Bylaw set back requirements of 15 m (50 ft.) from the edge of the creek.

2. Minimum widths should also be sufficient to contain the 200-year flood flow with minimum .6 m (2 ft.) freeboard.

3. Minimum widths should also be adequate to permit erosion control measures for flood flows, construction of trash racks and sedimentation basins ahead of culverts, and to allow access and maintainance of facilities.

4. In special cases, minimum rights-of-way widths can be reduced if the creek is confined in a revetted channel, or flume or enclosed conduit.

Figure 17 illustrates typical Preservation Area requirements. This illustration is general only and will require detailed hydraulic calculations and field surveys to establish actual requirements for various reaches of the creek.

FLOOD FLOW ROUTING

As discussed in a previous chapter on drainage policies that influence design criteria, each natural watercourse must be studied to see what will happen when the design storm is exceeded.

On steeper hillsides, for example, an overflow at one point in the system may send flood waters on an entirely different route to the main watercourse, usually to the distress of downstream development.

These studies are often termed major and minor flood routing analyses. For the Catstream Basin, the routes coincide.

POLLUTION

All urban drainage is polluted. Studies on the effect of urban runoff on stream pollution have shown that stormwater is sometimes more polluted than raw sewage when specific pollutants are considered. This may be significant at times in the Cat Stream, particularly in the summer after a long dry period when stream flows are low and the first flush of a heavy rainfall carries a significant load of pollutants into the stream.

Stormwater treatment is not likely to achieve a high priority in this area in the near future. The use of ponds to control peak flows, however, will have a beneficial effect on pollution.

RETENTION - DETENTION

Much has been written in recent years about stormwater management and modern methods of drainage design.

Nearly all this writing has taken age-old principles, given them new names, and left the implication that something new has been added to drainage expertise.

The principles involved attempt to utilize the pattern of individual rain storms, in which rainfall often builds up to a peak and then gradually subsides.

In the Rational Method of design, facilities are sized for the peak flows predicted to be reached or exceeded. It can readily be seen that if these peaks could be eliminated the facilities could all be smaller and cheaper.

The tool for eliminating peak flows on the system is storage, exactly the same as balancing reservoirs are built in a waterworks system near the demand in order to supply peak hourly flows while the transmission system carries only peak daily demands.

Storage in drainage systems to reduce peak flows has been used for many years. It can be located on or near the major watercourse, such as Burnaby Lake which regulates flow to Brunette River through a control dam built in 1925.

Storage can also be incorporated into the lateral storm drain system and individual buildings in the area. This philosophy is relatively new in concept. Roof tops could be built with special devices so that water ponds on the roof before running off. Parking lots, playing fields, roads and other facilities could have storage ponding devices. Roof downpipes could be taken to splash pads instead of storm sewers.

All these designs, properly incorporated, could serve as storage to reduce peak flows to the major watercourse. Storage on lateral storm drain systems can be incorporated into new development providing a master plan for stormwater, roads and other utilities are coordinated at the outset to provide for proper routing of minor and major flows. In existing developed areas, the task is often impractical.

For the Cat Stream Drainage Basin, however, with only 14 percent undeveloped area below Wakesiah, it would be virtually impossible to initiate individual on-site storage works that would be effective. Above Wakesiah, a potential 72 ha (180 ac.) are undeveloped but the existing on-stream pond should be utilized to keep the number of storage facilities to a minimum.

It is judged, therefore, that storage retention-detention for the Cat Stream must be in or adjacent to the natural watercourse at the two locations proposed, namely Third and Wakesiah.

IMPLEMENTATION

The plan recommended for adoption in this study to relieve flooding of the Cat Stream is described in Chapter 7 and shown on Figures 14 and 15. It is a straightforward drainage system comprising a balance between open channels, culverts, and retention-detention storage.

The recommended plan, however, also includes policies for future management of the drainage basin. If accepted, they could be applied universally thoughout the City and might have long term effects on the whole future of storm drainage in the area as a whole.

A few of the problems involved in implementing the Cat Stream plan, accordingly, are discussed hereafter.

Financial. In general terms, the City's Community Plan includes provision for the City to provide storm drainage works in both developed and undeveloped areas, and allows for establishment of cost sharing formulas.

The City has already approved one major drainage bylaw under a Council Initiative plan, and a second is currently under consideration for the capital works budget.

For the two million dollar bylaw now being implemented, a general levy across the City has been instituted to cover bond redemption and interest payments.

In the Cat Stream Basin, the major drainage works recommended in this report are estimated at \$353,000, with a budget of \$18,000 per year for operation and maintenance.

Assuming 20 year instalment debentures at 12½ percent, therefore, the total annual cost of the system for 1981 would be about \$68,000.

This represents a charge of \$7.50 per ha (\$3.00 per ac.) across the entire City, or \$258 per ha (\$103 per ac.) for the Cat Stream Basin alone. On a mill rate basis, it would be the equivalent of 0.40 mills over net taxable assessed valuation in the City.

Municipal Act. Drainage has been called the forgotten municipal utility.

Under the Municipal Act, Municipalities have authority to construct and operate drainage works that are required for public development. There are also special sections that deal with ditches and watercourses on farmland.

It is submitted, however, that the Act requires amendments in order to place drainage on the same utility basis as water and sewerage. The Act was changed in the fifties and sixties for water and sewerage, and now drainage should be included.

Along with new legislation to simplify drainage approvals and financing should go Senior Government financial assistance. Waste disposal and water supply did not reach firm footings in British Columbia until the Federal and Provincial assistance plans were instituted. Drainage, which has even larger capital costs associated with it, is beyond the financial powers of most municipalities unless there is an assistance plan. A Provincial grant of 75 percent of bond redemption and interest over the equivalent of 2½ mills, the same as for water and sewerage, would enable municipalities to solve their most pressing drainage problems.

It is recommended that the City petition the Provincial Government for such legislation.

Drainage Area Concept. A City wide levy to finance drainage works over a long period of time is simple and direct.

The City of Vancouver built its first major drains about 1911 and the system was completed by the late nineteen sixties. All this work was financed the same way - from the general revenue mill rate to repay capital borrowing.

The District of West Vancouver, on the other hand, has no bonded indebtedness for drainage and has built its system from the annual budget. Now that it faces multi-million dollar costs with no chance of receiving approvals therefor, it is in a stalemate position. Some work has been done on the major creeks under local improvement, with the District paying most of the cost out of general revenue and assuming responsibility for future operation and maintenance to perpetuity - again from general revenue.

This study submits that the fairest and best way to apportion costs for major drainage works is on the drainage area concept.

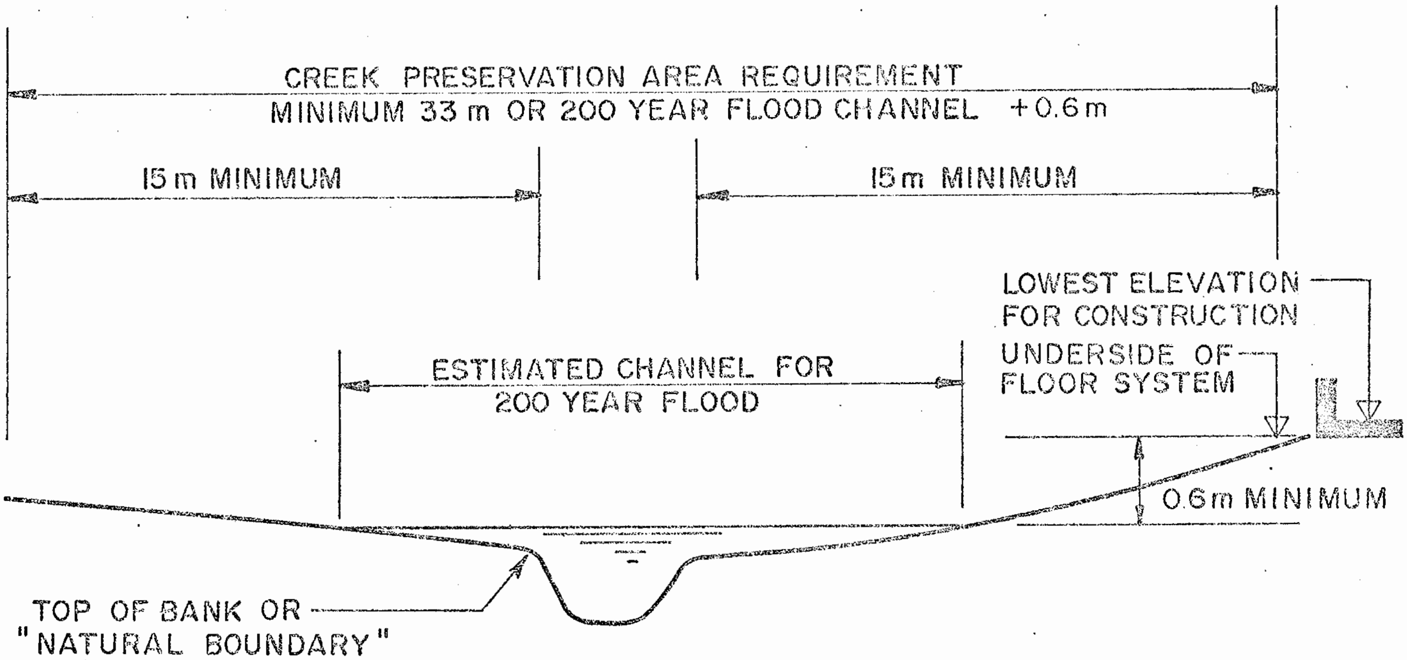
This would mean that the lands within the natural drainage Basin of the Cat Stream would pay all the costs of construction, operation and maintenance of the plan recommended in this study. A basic principle of the cost apportionment system should be that the entire area would share in some percentage of the cost, with the remaining percentage applied uniformly to the areas actually liable to flooding.

Those that flood, or could flood, would benefit the most from the scheme, and accordingly would pay more than the others. Everyone in the Basin, however, would share in the overall cost because everyone contributes water to the flooding.

Development Cost Charge. Lastly, the drainage plan evolving from this study includes capacity for complete development of the Drainage Basin as well as capacity for the existing urban setting.

The area, accordingly, could readily qualify for a Development Cost Charge Bylaw for drainage.

On a simplified basis, since about 65 percent of the area is already developed, 35 percent of the total capital cost could be divided among the vacant land parcels as the first Development Cost Charge.



NOTE :

1. THE 15 m SETBACK IS FROM THE "NATURAL BOUNDARY" AND MAY BE REDUCED TO 7.5 m IF APPROVED BY THE PROVINCIAL MINISTRY OF THE ENVIRONMENT

2. MINIMUM WIDTH OF CREEK PRESERVATION AREA CAN BE REDUCED IN SPECIAL CASES IF THE CREEK IS CONFINED IN A REVETTED CHANNEL, FLUME OR ENCLOSED CONDUIT

TYPICAL CREEK PRESERVATION AREA REQUIREMENTS

FIGURE 17

CITY OF NANAIMO

CAT STREAM DRAINAGE STUDY

9. RECOMMENDATIONS

The following recommendations are based on the foregoing study of the Cat Stream Drainage Basin, the analyses of rainfall and runoff, the requirements for improvements to the existing drainage works, the designs and estimates of cost derived for alternative improvements, and the environmental impact of such improvements on the amenities of both the Drainage Basin and the City as a whole;

It is recommended that:

1. The family of rainfall curves shown on Figure 11 of this report be adopted as the standard for the City of Nanaimo.

2. Use of the Rational Method be continued for storm drainage design, but that preference be given to use of the ILLUDAS Computer Program for basins where retention-detention storage appears possible.

3. The City prepare a bylaw to prohibit the placing of refuse or trash of any kind in its natural watercourses.

4. The design flows and storage requirements for the Catstream Drainage Basin be adopted for a 25-year rainfall recurrence interval, with the creek serving as both the minor and major flood route.

5. That Plan 2 of this report, with a 25-year rainfall recurrence interval and comprising storage at both Wakesiah and Third be adopted in principle.

6. That culverts crossing Jingle Pot Road be blocked off to prevent Millstone River flow from entering the Cat Stream Basin.

7. The City prepare a bylaw to regulate construction of any kind in or near its natural watercourses.

8. The City petition the Provincial Government for legislation to place storm drainage on the same basis as water and sewerage for Senior Government approvals and financial assistance.

9. The City prepare a Development Cost Charge Bylaw for the Cat Stream Drainage Basin, and

10. The City proceed with applications to control authorities for approval to implement Plan 2 of this report.

CULVERT DATA SHEET

LOCATION: Wakesiah Avenue

CULVERT: Type: Woodstave pipe, at outlet horizontal internal diameter 1.18 m, at entrance vertical distance from invert to crown 1.13 m.
Length: 17.5 m

Invert Elevation at Inlet 53.02 m

Invert Elevation at Exit 52.78 m

GENERAL REMARKS: Elevation of road shoulder - 55.250
Culvert is half-filled with gravel
Outlet control assumed
Culvert appears to be in good condition

CAPACITY: For a surcharge of 20%, top water level upstream of 54.36 m, capacity is 2.4 m^3/sec. For 50% surcharge, TWL is 54.7 m, and capacity 3.1 m^3/sec.
For present condition of culvert, for a top water level of 54.7 m, capacity is estimated at 1.7 m^3/sec.
Downstream conditions limit flow to about 2.4m^3/sec. without flooding.

LOCATION: Beaconsfield Road

CULVERT: Type: 1220 mm diameter corrugated steel pipe (CSP)

Length: 6.1 m

Invert Elevation at Inlet 51.93 m

Invert Elevation at Exit 51.72 m

GENERAL REMARKS: Culvert in good condition but cannot flow full without overland flow to the south of the culvert. Culvert is half full of gravel which reduces capacity to about 0.7m^3/sec. without overland flow.

CAPACITY: For a water level at the inlet of 52.87 m, capacity, assuming inlet control, is 1.2 m^3/sec., if gravel is removed. If some filling takes place to allow level to rise to the crown of the culvert without overflow, capacity increases to 1.8 m^3/sec.

CULVERT DATA SHEET

LOCATION: Howard Avenue

CULVERT: Type: 910 mm diameter CSP

Length: 17.5 m

Invert Elevation at Inlet 48.42 m

Invert Elevation at Exit 48.04 m

GENERAL REMARKS: Inlet control assumed.
Elevation of road shoulder is 50.6 m.

CAPACITY: For a surcharge of 450 mm top water level is 49.79 m.
Capacity is 1.40 m^3/sec.
For surcharge to road elevation, capacity is 2.0m^3/sec.

LOCATION: Third Street

		610 mm dia.	914 mm dia.
CULVERT:	Type:	CSP	CSP
	Length:	17.5 m	17.5 m
	Invert Elevation at Inlet	45.47 m	44.22 m
	Invert Elevation at Exit	45.52 m	44.29 m

GENERAL REMARKS: Two culverts, one above the other.
There is believed to be a third culvert at an even greater depth. It is not visible and is probably full of gravel so its contribution has been ignored.
The 914 mm diameter is probably partly blocked also.
Road shoulder elevation is 46.9 m

CAPACITY: Assuming a) Surcharge to 46.8m, just below road level.
b) Inlet control for 610 mm dia. culvert.
c) Outlet control for 914 mm dia. culvert.

Capacities are: 610 mm dia. 0.6 m^3/sec.
914 mm dia. 1.7 m^3/sec.
2.3 m^3/sec.

CULVERT DATA SHEET

LOCATION: Bruce Avenue

CULVERT: Type: Concrete box, angled entrance, inside dimensions 1.24 m high x 1.52 m wide.
Length: 25 m

Invert Elevation at Inlet 44.51 m

Invert Elevation at Exit 44.34 m

GENERAL REMARKS: Basement level of house near upstream end of culvert is 45.24 m. This restricts the water level at the culvert entrance.
The culvert has parallel wing walls extending 1.4 m at both entrance and exit.
Road shoulder elevation is 47.5 m

CAPACITY: Water level upstream of 45.1, capacity = 1.1 m^3/sec.

LOCATION: Chesterlea Avenue

CULVERT: Type: Concrete box, angled entrance with headwalls, inside dimensions 1.67 m wide, 0.94 m high.
Length: 26.5 m

Invert Elevation at Inlet 43.92 m

Invert Elevation at Exit 43.68 m

GENERAL REMARKS: Exit partly blocked by fence, debris and vegetation.
Entrance also partly blocked by vegetation.
Road shoulder elevation is 45.7 m

CAPACITY: For water level to 45.3m, capacity is 3.7m^3/sec.

CULVERT DATA SHEET

LOCATION: Pine Street

CULVERT: Type: Concrete box, 1.52 m wide, 1.00 m high

Length: 52.8 m

Invert Elevation at Inlet 42.26 m

Invert Elevation at Exit 41.81 m

GENERAL REMARKS: Wing walls at entrance extend 1.7 m.
Concrete wall one side of channel at exit 11 m long.
Gravel 150 mm deep at exit.
Elevation on road shoulder is 43.5 m downstream,
44.1 upstream

CAPACITY: For a water level at 44.0m, capacity is 3.7m^3/sec.

LOCATION: Albert Street

CULVERT: Type: Concrete box, 1.52 m wide, 0.965 m high.

Length: 15.3 m

Invert Elevation at Inlet 40.88 m

Invert Elevation at Exit 40.76 m

GENERAL REMARKS: Wing walls at entrance. Entrance needs cleaning
out and should have a concrete apron.
There is about 80 mm of gravel at the exit.
Creek is blocked with debris about 20 m downstream.
Elevation on centre of road is 42.6 m

CAPACITY: For a water level at 42.31, basement elevation upstream,
capacity is 3.5m^3/sec.

CULVERT DATA SHEET

LOCATION: 5th Street

CULVERT: Type: Concrete box, 1.85 m wide x 1.26 m high, with an upstream portion, partly constructed of concrete blocks, 1.36 m wide x 1.2 m high.

Length: 39 m

Invert Elevation at Inlet 36.47 m

Invert Elevation at Exit 36.37 m

GENERAL REMARKS: Some cleaning of vegetation is desirable around entrance. Capacities are calculated for the upstream section of the structure.

CAPACITY: For water level at 38.3m, surface level of properties upstream, capacity is 4.5m^3/sec.

LOCATION: Park Avenue

CULVERT: Type: Concrete Box, 1.85 m wide, 1.26 m high.

Length: 14 m

Invert Elevation at Inlet 29.61 m

Invert Elevation at Exit 29.16 m

GENERAL REMARKS: Surcharging should present no problems. Road shoulder elevation is 33.1m

CAPACITY: For water level upstream at road shoulder elevation 33.1, capacity is 9.6m^3/sec.


CAT STREAM PROFILE
SCALES: HORIZONTAL 1:5000
VERTICAL 1:100
ALTERNATIVE PLANS FOR IMPROVEMENTS
LEGEND
ROAD SURFACE
CULVERT
INVERT ELEVATION
WATER LEVEL
BASEMENT ELEVATIONS
APPROXIMATE BED OF CREEK
IMPROVEMENTS TO CULVERTS
PLAN Nº 1. 760 SIZE OF R.C. PIPE mm DIAMETER
2.
3. 1220
4. NO IMPROVEMENT REQUIRED
A = ADDITIONAL
R = REPLACEMENT
EXISTING DEPRESSION
FLOODS FREQUENTLY
STORAGE PLANS 1,2,3 & 4
STORAGE PLANS 2 & 4
REGRADING PLANS 1 & 3
EXISTING POND
WATER LEVELS
MARCH 1979 54.50
OCTOBER 31, 1979 54.00
APRIL 29, 1980 54.77
FLOOR HOUSE LOT 25 55.70
FLOOR HOUSE LOT 26 55.55
WAKESIAH AVENUE
1130 mm ⌀ WOODSTAVE
BEACONSFIELD ROAD
1220 mm ⌀ CSP
HOWARD AVENUE
BASEMENT 49.76
910 mm ⌀ CSP
THIRD STREET
BASEMENT 46.46
BASEMENT 46.30
610 & 914 mm ⌀ CSP
BRUCE AVENUE
BASEMENT 45.25
BASEMENT 45.38
R.C. BOX 1.24 m HIGH 1.52 WIDE
CHESTERLEA AVENUE
R.C. BOX 0.94 m HIGH 1.67 m WIDE
BASEMENT 44.38
BASEMENT 44.04
PINE STREET
R.C. BOX 1.00 m HIGH 1.52 m WIDE
BASEMENT 42.31
ALBERT STREET
R.C. BOX 0.965 m HIGH 1.52 m WIDE
FIFTH STREET
R.C. BOX 1.26 m HIGH 1.85 m WIDE WITH UPSTREAM SECTION 1.2 m HIGH 1.36 m WIDE
BEAVER DAM
BEAVER DAM
ROBINS PARK
FLOODS OCCASIONALLY
PARK AVENUE
R.C. BOX 1.26 HIGH 1.85 m WIDE
CHASE RIVER
53.02
52.78
51.93
51.72
48.42
48.04
45.47
45.52
44.22
44.29
44.51
44.34
43.92
43.68
42.26
41.81
40.88
40.76
38.40
36.47
36.37
29.61
29.16
0.3%
1.2%
1.2%
0.6%
0.4%
1.3%
1.1%
1.3%
0.5%
0.9%
0.24%
1.5%
2×1070 2×1070 2×1070 2×1070 R
2×1070 2×1220 R
2×1070 2×1220 R
760 1220 A
1070 2×1070 A
A 910
GEODETIC ELEVATION m.
DISTANCE FROM CHASE RIVER IN METRES
3500m
3000m
2500m
2000m
1500m
1000m
500m

FIGURE 15