GREATER VANCOUVER
SEWERAGE AND DRAINAGE DISTRICT

STUDY OF

COQUITLAM / PORT MOODY DRAINAGE AREA

DAYTON & KNIGHT LTD.
Consulting Engineers

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May 24, 1988

Mr. K. Taylor, P.Eng.
Administrator, Sewers
Greater Vancouver Sewerage & Drainage District
4330 Kingsway
Burnaby, B.C.
V5H 4G8

Dear Mr. Taylor:

In conformity with the terms of reference we are pleased to submit our report on the Coquitlam / Port Moody Drainage Area.

In summary, the report identifies, concludes and recommends the following:

1) The existing GVS&DD structures for the area are slightly inadequate for the 10 year storm event of the terms of reference. Of 52 structures, 5 are inadequate; for the 100 year storm event, a total of 10 are inadequate. We believe upgrading plans should be for the 100 year event. The costs to upgrade the 10 structures to pass the 100 year storm total $925,000. The capitalized potential damage losses total $971,000.

2) Streamway corridors (major overland flood paths) downstream of the intakes are not essential with the proposed program (100 year design, a storm sewer system in the Williams Street Drainage Area and debris basins).

3) The physical condition of the existing structures is generally good except for the Kyle Street system. The cost of renovating is $200,000.

4) The headscarps appear stable but require regular inspections and extension of outfalls.

Although the headscarps are presently recognized as generally being stable, a debris flow or debris flood occurring in the gullies has potential to do extreme damage and cause loss of life. For this reason, the majority of high priority work recommends construction of debris basins and flood diversion structures at the intakes. These costs amount to $815,000 and are balanced against a total damage cost of $13,935,000 (which does not include loss of life). Other costs include improvements to outfalls in the gullies of about $112,000 for protection against escarpment erosion.

5) Detailed recommendations are provided for monitoring, contingency plans and development policies.

In particular, GVS&DD responsibilities should include all major interjurisdictional drainage in the area and particularly Axford and Ottley basins. Not including inspections, a yearly operating and maintenance budget of $60,000 to $70,000 is suggested for the early years.

We have enjoyed this assignment and are grateful for the help and cooperation provided by all participants.

Yours truly

DAYTON & KNIGHT LTD.

Agris Berzins, P.Eng.

HGK/mjd
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SUMMARY

The Greater Vancouver Sewerage & Drainage District (GVS&DD) and the member municipalities of Port Moody and Coquitlam have taken an important step in the drainage management for the Coquitlam, Chines Heights and Port Moody drainage areas. The study provides a systematic approach to development of improvements for the protection of the study area drainage resources.

The drainage study was undertaken in two parts in 1987 and 1988. The first part included two interim reports to identify immediate remedial measures and to establish an inspections program for the drainage area basins. The second part provides the master plan and is the subject of this report.

Section 1 - Introduction

1. The study was authorized on September 1, 1987 and was required to identify drainage character of the Coquitlam / Port Moody drainage areas, in particular to:

    a) analyze condition of existing GVS&DD structures,

    b) determine the drainage area character from a standpoint of headscarp stability to the ability of existing drainage to handle 10 and 100 year design flows,

    c) determine solutions and drainage improvements,

    d) provide management guidelines.

2. The report was undertaken with the cooperation of the municipalities of Port Moody and Coquitlam, and under the guidance of the Greater Vancouver Regional District.

Section 2 - Drainage Area Characteristics

1. The overall study area includes four major drainage basins totalling 7.3 km^2 of which about half lies in either municipality.

2. The four major drainage diversions are:

a)	Schoolhouse Creek	- 2 basins
b)	Ottley Creek	- 1 basin
c)	Kyle Street	- 5 basins
d)	William Street	- 4 basins

3. Twelve creeks drain the basins all starting from headscarp and upland drainage in Coquitlam and discharging through open and closed drainage courses in Port Moody to Burrard Inlet.

4. The creek systems show varying degrees of stability with respect to debris flow and debris flood hazard. Relative probability is assigned by examination of creek storage ability and headscarp stability.

5. Operations observations indicate a high maintenance effort and costs of $60,000 to $90,000 per year.

6. Some existing drainage structures are in need of repair or improvements.

Section 3 - Criteria

1. The Master Drainage Plan requires runoff criteria for the hydrologic process and the hydraulic process. The hydrologic process determines the volume of runoff and its time distribution for a design storm condition. The hydraulic process routes the predicted runoff through storm drains, channels, floodplains or storage reservoirs. Together they describe the runoff process.

2. In urban drainage, development can cause the rate of runoff to increase by factors of 2 to 4 times depending on the rainfall. Provisions to contain these flows are required to convey flow through Port Moody (major closed or open drainage systems).

3. A design storm concept for rainfall intensity, duration is used with frequency curves (to 24 hour durations) prepared for the Port Moody Gulf Oil Refinery. Storm patterns for hyetographs are developed from AES west coast storm patterns for 1 and 12 hour durations. Winter storm conditions are proposed for the runoff predictions.

4. City of Port Moody and Coquitlam policy of basin protection and non-development are assumed to continue.

5. Hydrologic and hydraulic modelling is undertaken using a single event deterministic planning model developed by the IMPSWM group at the University of Ottawa, OTTHYMO.

6. Environmental criteria considers public protection and stream protection.

7. Cost criteria considered 1988 costs and included costs for ditching, culverting and inlet facilities. An allowance is added for engineering and contingencies. Flood damage criteria are also given. Damage is 100% for debris flow in hazard zone 1, 50% in hazard zone 2, and variable in flood zones.

Section 4 - Storm Drainage Analysis

1. Debris flow, debris flood and major flood hazard zones are identified for each of the basins and drainage facilities. Capacity limitations in culverts and storm drains are shown on Tables 4-1, 4-2, 4-3 and 4-4. Hazard zones are identified on Figures 4-1 and 4-2.

2. Flood damage costs are described on Table 4-5 for the drainage areas. Highest costs are shown for William Street Drainage Area.

3. Debris hazard costs are shown as a one time damage estimate on Table 4-6.

4. Environmental concerns of Fisheries are primarily directed towards the William Street and Schoolhouse Creek systems, especially below St. John's Street culverts.

Section 5 - Drainage Area Master Plan

1. The Master Plan includes policy on development, participant responsibility, planning, coordinating, operations, inspections, liaison and emergency guidelines as well as a schedule of improvements.

2. Drainage improvements identified for the Master Plan are developed in Table 5-1 which is referenced to Figure 5-1. Each improvement is identified and described in the table. Priority, cost and benefit / cost ratio are shown.

Section 6 - Conclusions and Recommendations

1. The Master Plan requires agreement on several categories of policy, watershed management and watershed improvement scheduling. Both municipalities and the GVS&DD have initiated responsible positions in this regard. The study provides guidelines to assist the drainage authorities.

2. Since the 1970's headscarp instabilities and failures have been associated with fills and concentrated drainage discharges down the steep slopes. Remedial work is not specified in detail. However, existing outfalls on the escarpments should be extended to stable creek beds on a scheduled basis or as a result of inspection recommendations.

3. Drainage improvements to contain debris flows and debris floods rank high in priority and benefit / cost ratios.

4. Drainage improvements to major inlets and storm collectors range in priority from high to low. William Street Drainage Area shows a high need for improvement from the Dallas Creek basin to St. John's Street.

5. Recommendations include:

   a) The Master Drainage Plan be changed to incorporate the Ottley Drainage Area.

   b) The three drainage authorities continue to advance the Master Drainage Plan through planning for the undertaking of the identified improvements.

   c) Scheduled inspections of the basins be undertaken by the GVRD.

   d) An emergency plan be developed.

As a further consideration, the GVS&DD should evaluate the inclusion of Ottley and Axford Creeks as part of their drainage responsibility.

GREATER VANCOUVER SEWERAGE & DRAINAGE DISTRICT
STUDY OF COQUITLAM / PORT MOODY
DRAINAGE AREA

1. INTRODUCTION

The following reports on hydrologic and geologic site and drainage investigations of a watershed in the Coquitlam / Port Moody municipalities of British Columbia, Canada. The watershed includes 12 major named creeks draining from Coquitlam to Port Moody. The headscarp of the creeks/gullies primarily lies in Coquitlam and is often referred to as the Chines. The lower receiving floodplains lie in Port Moody, along the west shoreline of Burrard Inlet. Combinations of upland drainage, rejuvenated creek discharges, gullying, slope instabilities and a floodplain receiving environment create special management requirements for the drainage study.

The purpose is the preparation of a master drainage plan to help safeguard lives, public and personal property, and natural resources of the study area. The report is developed in five additional sections including a section of conclusions and recommendations. Included are appendices of geotechnical assessments, and reports on interim recommendations. The interim studies were provided on October 26, 1987 and November 10, 1987 to guide in drainage improvements for areas of high priority which could be accessed easily for immediate attention.

This section presents the study objectives, scope of work, report organization and conduct of survey. Acknowledgements are given to those who actively contributed to the study.

1.1 Objectives and Purpose

The objectives of the drainage area study are detailed in the June 11, 1987 terms of reference contained in Appendix 1. In summary, the terms of reference require:

1. Analysis of existing GVS&DD structures for a 10 year storm.

2. Investigation of streamway corridors downstream of intakes for extreme event.

3. Investigation of the physical condition of structures.

4. Recommendations for new structures.

5. Investigation of headscarp stability.

6. Recommendations for above intake conveyance, monitoring, emergencies and development.

The main detailed activities of this study are summarized as follows:

1. Delineate the watershed and its drainage areas.

2. Determine existing and potential hydrologic and geologic problems and alternative solutions.

3. Evaluate watershed management and responsibilities.

4. Determine downstream channel and major drainage facility capacities for 10 and 100 year design runoff.

5. Determine upstream and downstream hazard zones, and mitigative measures for flood and debris events.

6. Determine encroachment limits in and around the creek basins.

7. Provide management guidelines.

The overall purpose of the study is to develop recommendations for drainage improvements in the major drainage systems and to the Chines area which will adequately safeguard the residents of both communities and assist in preserving the drainage resources of the watershed.

1.2 Report Organization

The report is divided into six sections, including the introduction and conclusions.

Section 1 - includes introduction, a synopsis of the objectives and scope of work, study methods, data sources and acknowledgements.

Section 2 - describes physiography, relevant background information, surface runoff factors, watershed drainage, land use and drainage concerns.

Section 3 - provides the criteria for preparation of the drainage planning including descriptions of the runoff process, management options, hydrological data, environmental needs and cost data.

Section 4 - presents the hydrological analysis of the main drainage areas and its significance.

Section 5 - presents a master drainage plan including proposed improvements, priorities and costs.

Section 6 - concludes the report with study findings and recommendations.

Appendix 1 contains the GVS&DD terms of reference. Appendix 2 is a detailed assessment of the geotechnical constraints and solutions compiled by Thurber Consultants Ltd. Appendices 3 and 4 contain the interim reports for urgent drainage work and an inspection program.

1.3 Authorization and Scope

Authorization to proceed with the study was received on September 1, 1987. Dayton & Knight Ltd. and Thurber Consultants Ltd. as subconsultant, were to undertake the study in two parts. Part 1 was to be completed in October and would address urgent drainage improvements. Part 2 would be completed in 1988 as the overall study report.

To meet the terms of reference and timing, the scope of work required a six phase program as follows:

1. Assembly of detailed drainage plans was undertaken immediately to delineate drainage boundaries, storm drainage inventory, creek gradients and recorded major flow and slide events.

2. Interviews with GVS&DD drainage staff, Coquitlam personnel and Port Moody personnel were initiated and field inspections were undertaken during several weeks at the start of the study. (This included inspection of all ravines from headscarp to drainage inlet, evaluation of each inlet, internal inspections of drainage pipes, open and closed channel investigations through Port Moody, and examination of closed discharge pipes to the ravines from Coquitlam drainage.)

3. Assembly of drainage inventory of streams and existing open and closed channels describing conditions, capacities and deficiencies.

4. Assembly of hydrological criteria and use of hydrologic modelling to determine drainage area flows for 10 and 100 year return design storms.

5. Preparation of flood loss costs for hazard areas and development of benefit/cost ratios for examination of food related alternatives.

6. Development of stormwater management guidelines for the ravines and preparation of a drainage improvement schedule.

Conclusion of Phases 1 through 3 allowed completion of the interim reports.

1.4 Conduct of Survey

The survey was undertaken with the cooperation of the City of Port Moody and the District of Coquitlam. The GVS&DD provided the central coordination and study guidance. Meetings were held with all authorities to determine their engineering requirements, current level of basin management, and known problem areas.

Topographic plans for the drainage area designations were derived from GVS&DD drawings.

The Water Management Branch through Mr. P. Woods was consulted on their knowledge of previous debris flow events and area evaluations.

The Fish and Wildlife Branch and Federal Fisheries and Oceans were consulted on environmental aspects of the creeks.

Thurber Consultants provided geotechnical advice related to scarp stability, ravine stratigraphy, groundwater regimes, erosion process and hazard zoning for debris flows.

Dayton & Knight Ltd. provided the project management, the hydrologic evaluations of the streams and closed storm drains, and the master plan for the drainage areas. The hydrologic computer model "OTTHYMO" was used to evaluate drainage area runoff and stream capacity. A limitation to the hydrologic evaluations is the inclusion of the undefined Burnaby Mountain tributary drainage to the Schoolhouse Creek drainage area.

1.5 Information Sources

The detailed investigations made extensive use of the following information sources:

1) Greater Vancouver Sewerage & Drainage District

   a) GVS&DD Administration Board, Item 6, Port Moody - Coquitlam Drainage, January 21, 1960.

   b) GVS&DD Administration Board, Item 5, Schoolhouse Creek Drainage Area and Drawing SL67, 1960.
   c) GVS&DD, Drawing SF1816, Port Moody - Coquitlam Drainage, April 1987.
      - Sheet 1 - Schoolhouse Creek Location Plan.
      - Sheet 2 - Kyle Street and William Street Drains Location Plan.

   d) GVS&DD, Drawing SR-368, Port Moody - Coquitlam Drainage, Schoolhouse Creek Drainage Areas, October 1962.

   e) GVS&DD, Drawing SL-107, Kyle Street and William Street Drainage Areas, May 1960.

   f) GVS&DD Drawing SF-528, Kyle Street and William Street Trunk Drain, General Plan, Nov. 1960.

   g) GVS&DD Drawing SF-772, Schoolhouse Creek Drainage Area, Agnes Street Diversion, Tributary Areas, Feb. 1964 (Ingersol Street).

   h) GVS&DD, Drawing SK1/SG-819, Schoolhouse Creek, Ingersol Avenue Connection, P&P, Sept. 1978.

   i) GVS&DD, Drawing SF-791, Schoolhouse Creek, Plan of Creek between CPR Tracks and St. Johns Street, Aug. 1964.

   j) GVS&DD, Drawing SF-571, Sheet 1, Kyle Street Drain, General Plan, Nov. 1960.
      - Sheet 2, Kyle Street Trunk Drain, P&P, Outfall - Queens Street - Spring Street, May 1961.

- Sheet 3, Kyle Street Trunk Drain, P&P, Queens Street and Spring Street, May 1961.
- Sheet 4, Kyle Street Trunk Drain, P&P, Mary Street and George Street, May 1961.
- Sheet 5, Kyle Street Trunk Drain, P&P, Grant Street and Henry Street, May 1961.
- Sheet 6, Kyle Street Trunk Drain, P&P, Henry Street and Hugh Street, May 1961.
- Sheet 7, Kyle Street Trunk Drain, P&P, Branches on Moody, Grant and Jane Street, May 1961.
- Sheet 8, Kyle Street Trunk Drain, P&P, St. George Street to St. John's Street, August 1963.
- Sheet 9, Kyle Street Trunk Drain, Details of Inlets 1,2,3, May 1961.

k) GVS&DD Drawing SF-1554, August 1976.
   - Sheet 1, William Street Trunk Drain from Burrard Inlet to St. John's Street, P&P.

l) GVS&DD, Drawing SF-1592, September 1977.
   - Sheet 1, William Street Trunk Drain between Murray Street and CPR r/w, P&P, Details.

m) GVS&DD Drawing SF-558.
   - Sheet 1, William Street Trunk Drain, St. John's Street Crossing, P&P, March 1961.
   - Sheet 2, William Street Trunk Drain between St. John's Street and Henry Street, September 1968.
   - Sheet 3, Between St. John's Street and Buller Street, September 1968 (not constructed).
   - Sheet 4, William Street Trunk Drain Manhole and Inlet Structure Details for Hope Street and Henry Street, January 1975.

n) GVS&DD Drawing SF-772, Schoolhouse Creek Drainage Area, Detail Plan of Washouts at Agnes Street, January 1964 (Ingersol).

o) GVS&DD Drawing SF-1176, City of Port Moody, Schoolhouse Creek, September 1971.
   - Sheet 1, Culvert at Albert and St. George Street.
   - Sheet 2, Culvert at Albert and St. George Street.
   - Sheet 3, 24" Drain on Albert Street.

2. District of Coquitlam

   a) Bylaw No. 1199, 1982, A bylaw to conserve certain natural areas and sensitive land and Schedule A.

   b) District of Coquitlam, File 05 03 02 (letter to residents describing fill restrictions at headscarp), May 1984.

   c) District of Coquitlam, Official Creek Names, May 1987.

d) District of Coquitlam, Escarpment Inspection Checklist, Appendix 'C'.

e) District of Coquitlam, Topographic Maps, Metric Series, Scale 1:4000.

f) District of Coquitlam, Storm Maps, Metric Series, Scale 1:4000.

g) District of Coquitlam, Boundaries of Sensitive Area, Provincial Index 10-508-5455, 1:2000.

h) District of Coquitlam, Moody Coquitlam Escarpment Evaluation (Dwg.) (Location of existing and proposed outfalls, fill sites), and Figures 1,2,3 and 4).

3. City of Port Moody

a) South Shore Drainage Study, 1983 (Willis Cunliffe Tait Delcan).

b) Correspondence - Golder Associates / Port Moody, April 1984, March 1986, Ottley Creek Drainage.

c) Hazard Zone - Improvement Assessment, Sheets 1, 15, including drawings 92G-026 (077, 078, 079).

4. Ministry of Environment

a) Water Management Branch, Port Moody / Coquitlam Debris Flow Landslide Identification Study, P.J. Woods, October 1981 (File P79-28).

5. Environment Canada

a) Atmospheric Environment Services, Vancouver. Intensity, Duration, Frequency Values for:
   - Coquitlam Como Lake, Port Coquitlam City Yard, Port Moody Gulf Oil Refinery (1 to 10 day duration).
   - Coquitlam Lake, Port Moody Gulf Oil Refinery, Buntzen Lake (60 min to 24 hr durations).

6. Reference Publications

a) Climatic Normals, Canada, Department of Transport - Meteorological Branch, Volumes 1,2,3,4,5, Toronto, 1968.

b) Temperature and Precipitation 1941-1970, Atmospheric Environment Service, Department of the Environment, Downsville, Ontario, 1970.

1.6 Acknowledgements

The assistance of Mr. K. Payn, P.Eng. and Mr. K. Taylor, P.Eng., of the Greater Vancouver Sewerage & Drainage District is greatly appreciated. Others who assisted in guiding the study are Mr. N. Nyberg, P.Eng. of Coquitlam and Mr. T. Hunt, A.Sc.T. of Port Moody. Our sincere thanks is conveyed as well to Mr. D. Hope and his G.V.R.D. crew for their assistance in surveying the ravines and providing details on their level of operations. Mr. V. Fraser of the District of Coquitlam as well as Mr. R. Hogue of Port Moody kindly gave their time to describe maintenance and operations activities of either community as well as details of past concerns in the drainage areas.

We also acknowledge:

Ms. S. Latimer, Habitat Protection Technician, Fish and Wildlife Branch, Ministry of Environment, Surrey, B.C.

Mr. B. Dane, Fisheries and Oceans, Pacific Region, Environmental Protection Services, New Westminster, B.C.

Mr. P. Woods, P.Eng., Water Management Branch, Ministry of Environment, Victoria, B.C.

Mr. E. Coatta, Atmospheric Environmental Services, Environmental Protection Service, Vancouver, B.C.

2. DRAINAGE AREA CHARACTER

This section establishes the physical components of the basin, land use, effects of man's activities on drainage and recorded drainage concerns within the creeks and their subbasins. The purpose of this section is to establish the drainage constraints within the drainage areas for examination of the response to rainfall. Response evaluations are used to determine improvement needs, cost and a drainage plan.

2.1 Study Area Description

Figure 2-1 identifies the watershed and drainage area locations. The watershed or study area encompases about 7.3 km^2, is situated on the south shore of Burrard Inlet at its eastern edge, and includes 3.55 km^2 of Port Moody and 3.75 km^2 of Coquitlam. The focal points of the study area are three distinct physical features: a) the Coquitlam uplands, b) the creek drainage gullies, and c) the fan and shoreline areas in Port Moody. Drainage flows start in Coquitlam from closed or open drainage facilities, pass through open creeks in the gullies and are conveyed by open and closed drainage facilities through the fan, floodplain and shoreline deposits in Port Moody out to Burrard Inlet.

Drainage responsibility for the creeks is shared by Coquitlam, Port Moody and the Greater Vancouver Sewerage & Drainage District (GVS&DD).

2.1.1 Drainage Responsibility

Municipal boundaries divide the road and drainage responsibility between the City of Port Moody on the receiving end and the Municipality of Coquitlam at the upper source. In 1960, to allay concerns over the interjurisdictional impacts of major drainage flow within the study area, both communities requested that the Greater Vancouver Sewerage and Drainage District take responsibility for design and operation of major storm collection facilities in the Kyle Street and William Street drainage areas. Later, at the request of the City of Port Moody in 1962, the Schoolhouse Creek drainage area was included.

With the acceptance of the GVS&DD Administrative Board agreements, the GVS&DD became responsible in the drainage areas for:

a) designing facilities for containing ultimate development storm flows,

b) developing a construction program to construct storm drain facilities,

c) obtaining rights-of-way,

d) apportioning costs to each municipality as provided in the Greater Vancouver Sewerage and Drainage Act,

e) maintaining the designated waterways.

2.1.2 Cost Sharing

The District of Coquitlam and Port Moody share in capital and operations costs according to the following percentage distributions.

Basin	Port Moody %	Coquitlam %
Williams Street	63	37
Kyle Street	63	37
Schoolhouse Creek	56	44

2.1.3 Background Studies

Studies on the hydrological apsects of the watersheds were undertaken by the GVS&DD in the 1960's to comply with their drainage responsibility. The GVS&DD drawings SL67, William Street and Moody Street (Kyle Street) Drainage Areas (1960), and SR368, Schoolhouse Creek Drainage Area (1962) serve to describe the natural drainage patterns and outlets for the Coquitlam / Port Moody runoff. At that time, other than major street crossing culverting (with the exception of Kyle Creek below St. Georges), none of the creeks in Port Moody were enclosed or had intakes. Two creeks, Ottley Creek and Axford Creek, were not identified, and their tributary areas were included in the Schoolhouse Creek drainage area. The GVS&DD in their hydrologic studies calculated runoff using very conservative parameters for a 10 year winter design storm. The Kyle Street, William Street and Schoolhouse Creek drainage facilities were designed and built by the GVS&DD using these criteria.

In 1983, the City of Port Moody had the South Shore drainage study completed which included the three drainage areas and City and GVS&DD owned facilities. Open and closed channel reaches were numerically identified, described, and a few rated for 10 and 100 year flow capacity. Ottley Creek was shown to be a drainage area separate from Schoolhouse Creek. Axford Creek was shown to be part of the William Street drainage areas by virtue of a City of Port Moody storm sewer connection. The study showed most of the closed drainage to be adequately sized for the 100 year design storm except for the upper drainage in the William Street drainage area, which has retained a collection of randomly sized, inadequate, pre-development storm drains and open channels, despite many attempts to have it improved.

No studies are available for the Coquitlam drainage facilities although municipal drainage maps and 1982 sensitive lands bylaw studies provide considerable detail with respect to discharge outfall, fill sites, past stability problems, drainage area definition and future works proposals. The Municipality conceptualized a closed collection of surface drainage in five of the major creeks.

Other related studies include geotechnical evaluations and recommended improvements for slides, and the 1981 Water Management Branch (MOE) study of the Chines Heights landslide problems. The Ministry's study followed the 1979 Porter Street (Ottley Creek) slide, and initiated a focus on the stability problems associated with the Chines headscarps. The District of Coquitlam sensitive land bylaw 1192 and current approach to Chines Heights development evolved from the recommendations of the study. Port Moody's Official Community Plan of 1982 similarly addresses the need for the Chines Heights protection.

2.2 Watershed Physiography

The basin structure including topography, geology, soils, bioclimatic and climatic factors and land use are briefly described as supporting background for selection of rainfall-runoff criteria.

2.2.1 Climate

The study area lies within the coastal trough and enjoys a climate best described as modified maritime. The Coast Range Mountains form a barrier against most polar outbreaks which produce sub-zero winter temperatures in interim southern regions of the province, while the Strait of Georgia moderates temperatures in summer and winter. Sharp frosts however, occur from time to time through the winter months.

Maximum precipitation occurs in the winter months as a result of frontal storms moving inland from the Pacific Ocean. The frontal storms are continuous and cover wide areas ranging from 250 km^2 to 2500 km^2. Because of the high precipitation in winter months, maximum wetting and maximum runoff occurs during this season.

In summer, convective storms resulting from thermal stratifications causing instability in the atmosphere cause intense cores of rainfall over limited areas.

The two storm types are in sharp contrast. Extreme rainfalls with durations exceeding 1 to 12 hours or more occur almost exclusively in winter, while extreme intensities lasting for minutes occur in summer.

Table 2-1 describes climatic norms, highs and lows for the Port Moody Gulf Oil Refinery.

At the Atmospheric Environment Services Gulf Oil Refinery climate record station, the average total yearly precipitation amount is 1889 mm (74.4 in.) with 1819.6 mm (71.6 in.) or 96 percent of the total in the form of rainfall.

For the period October to March, 1383 mm (54.5 in.) or 73 percent of the total precipitation occurs. The peak precipitation periods are November, December and January when the average total precipitation is 806 mm (31.7 in.) or 43 percent of average total yearly precipitation. Table 2-1 provides a summary.

2.2.2 Geology

The watershed recent geologic history and stratigraphic descriptions are examined in the Geotechnical Study, Appendix 2.

The Geological Survey of Canada, Map 1484A, New Westminster, describes the surficial geology. Generally, the Coquitlam higher ground is shown comprised of a cap of glacio-marine and marine deposits 3 to 10 m thick overlying glacial drift tills, sands and gravels of 8 to 25 m thick. The highlands drop down to the Burrard Inlet shoreline and Port Moody in gullies where these stratified glacio-marine and marine deposits are shown exposed on steep escarpments. Groundwater and upland drainage collect in the gullies to form creeks which discharge across the marine shore and fluvial sand deposits found along the edge of the Burrard Inlet shoreline. The shoreline deposits of up to 8 m thick overlie a fan of older debris-flow and alluvial deposits. These older materials were washed down from the heights to form the present character bowl-like shapes of many of the landscape's features.

TABLE 2-1

Climatic Normals

PORT MOODY GULF OIL RFY 49° 17'N 122° 53'W 130 m	J	F	M	A	M	J	Ju	A	S	O	N	D	J
Daily Maximum Temperature	4.4	7.3	8.8	12.9	16.0	18.3	22.1	21.9	18.5	13.6	8.2	5.7	13.1
Daily Minimum Temperature	–0.4	1.6	2.4	4.9	7.7	10.4	12.8	12.9	10.7	7.2	3.0	1.1	6.2
Daily Temperature	**2.1**	**4.5**	**5.6**	**8.9**	**11.9**	**14.4**	**17.4**	**17.4**	**14.7**	**10.4**	**5.7**	**3.4**	**9.7**
Standard Deviation, Daily Temperature	1.4	1.5	1.4	1.2	1.0	1.2	1.0	1.5	1.6	0.9	1.1	1.9	0.4
Extreme Maximum Temperature	12.8	18.1	17.5	25.6	30.0	30.6	32.8	33.0	31.7	27.0	17.0	15.0	33.0
Years of Record	10	10	10	10	10	10	10	10	10	10	10	11	
Extreme Minimum Temperature	–14.0	–7.2	–7.8	–0.6	1.7	4.4	8.1	7.2	2.8	–2.2	–6.7	–14.5	–14.5
Years of Record	10	10	10	10	10	10	10	10	10	10	10	11	
Rainfall	228.1	197.0	167.1	127.9	86.2	76.9	54.8	61.6	99.0	199.9	238.3	282.8	1819.6
Snowfall	29.2	6.8	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.2	18.7	59.5
Total Precipitation	**263.5**	**206.9**	**171.4**	**126.7**	**86.4**	**76.9**	**54.8**	**61.6**	**99.0**	**200.1**	**240.1**	**301.9**	**1889.3**
Standard Deviation, Total Precipitation	109.7	60.2	76.8	47.7	56.4	38.6	56.8	43.9	48.9	130.6	119.7	110.5	343.1
Greatest Rainfall in 24 hours	70.6	82.3	64.8	37.6	44.7	37.6	96.8	45.8	55.4	87.9	80.4	112.3	112.3
Years of Record	10	10	10	10	10	10	10	10	9	10	10	11	
Greatest Snowfall in 24 hours	25.4	15.7	6.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.6	32.5	32.5
Years of Record	10	10	10	10	10	10	10	10	10	9	11	11	
Greatest Precipitation in 24 hours	70.6	82.3	64.8	37.6	44.7	37.6	96.8	45.8	55.4	87.9	80.4	112.3	112.3
Years of Record	10	10	10	10	10	10	10	10	9	10	10	11	
Days with Rain	19	17	17	14	12	12	7	10	11	18	19	20	176
Days with Snow	4	1	1	0	0	0	0	0	0	0	1	3	10
Days with Precipitation	20	17	17	14	13	11	7	9	11	16	20	21	176

2.2.3 Groundwater

The Geotechnical Study in Appendix 2 describes the groundwater regime, its recharge and its effects on the headscarp.

Groundwater releases in the upper surficial layers at the top of the watershed are in part at least collected by Coquitlam storm drainage. Base flow resulting from a release from winter ground storage is observed from most of the large enclosed storm drains which discharge to the headscarp. Summer release is small and observed on the larger deeper facilities only (East Sundial - Pourier Street, etc.).

The deeper groundwater releases are much larger and are the major contributors to creek base flows. Dry weather base flow is observed to be less than 1 to 5 percent of creek bankfull flow capacity.

2.2.4 Drainage

Watershed drainage is effected in the Coquitlam uplands by a network of open and closed drains largely paralleling roads. The drainage is collected into larger trunks and is discharged as discrete outfalls to the headscarps of the watershed basins. Larger collectors are brought down to the creek and in some instances, energy dissipators are provided. Smaller drains are often left to discharge down the face of the gulley.

Drainage in the gullies occurs through open channel natural stream flows. The creeks are low order streams no higher than 3 but normally 2 or 1. The drainage density in the gullies is high at about 4-6 km/km^2 (6.5-8.5 mi/mi^2) and confirms the high observed efficiency of the creeks in disposing of water and sediment.

In Port Moody, open ditching along roads predominates except for the GVS&DD major collectors and the City's collection for Ottley and Axford Creeks. Continued protection of the ravines and further effort to construct drainage improvements will increase in importance as risk to life and property loss continues to rise.

For Coquitlam, as drainage improvements continue in the uplands, and open drains are replaced with more efficient pipes, increasing pressures on the creeks and lower drainage collectors could occur. Port Moody's and Coquitlam's responsible attitudes to protection of the headscarps and protection from further drainage impacts will increase in importance.

2.2.5 Land Use

In Coquitlam, the watershed zoning is residential on the uplands and except for a few parcels in Schoolhouse, Axford and Dallas Creek basins, the District of Coquitlam owns and controls gully development. The residential area is at least 90 percent infilled and little developable area remains to accord the 1979 community map.

In Port Moody, the Official Community Plan of November 1982 stipulates that the Chines is to remain in an undeveloped state and the headscarps are to be left undisturbed unless flood protection or stabilization work is needed. Otherwise, the land use on the Port Moody south shore of Burrard Inlet lying within the watershed will remain a mix of residential, commercial and industrial as its exists today. Redevelopment and higher density housing in the residential areas will likely occur with time as will changes in the commercial and industrial areas, but increases in runoff should not become a significant factor for major flow design.

2.3 Drainage Area Description

With the inclusion of the Ottley Creek drainage area, the study area is described in four major drainage divisions:

Area, (ha)	Coquitlam	Port Moody	Total
1. Schoolhouse Creek	170	178*	348
2. Ottley Creek	8.8	26.9	35.7
3. Kyle Street	91	88.5	179.5
4. William Street	107	59.8	166.8
Total (ha)	376.8	353.2	730.0

*Part on Burnaby Mountain.

The major creeks which drain the drainage areas are described by a modification of the Coquitlam nomenclature. Figures 2-2 and 2-3 delineate the four drainage areas, their basin boundaries and major creeks. As well, existing drainage channels are identified.

2.3.1 Schoolhouse Creek Drainage Area

Figure 2-2 describes the drainage for the Schoolhouse Creek basins within the study area.

The Schoolhouse Drainage Area of the 1962 GVS&DD agreement identifies two drainage basins only in an area of 468 ha. From Figure 2-2, Schoolhouse Creek is seen to drain 185 ha of Coquitlam and Port Moody to the Albert Street culvert, and Noble Creek (to the east) to drain about 12.7 ha to the same point. Below the Albert Street culvert, Schoolhouse Creek Basin contains an urban area of 15 ha. Although included in the 1962 GVS&DD plan neither Ottley Creek (46.2 ha), nor Axford Creek (18.2 ha), are a part of the Schoolhouse Creek Drainage Area. Ottley Creek has its own outlet to Burrard Inlet and Axford Creek is presently connected to the Kyle Street Drainage Area. These will be dealt with in their respective sections.

Schoolhouse Creek Drainage Area also includes 135 ha of tributary area from the west slope of Burnaby Mountain which is not directly included in the study area. Runoff from this area is, however, assessed to evaluate capacity of the Schoolhouse Creek channels and culverts below St. John's Street. The Schoolhouse Creek Drainage Area including the west slope runoff area of Burnaby Mountain but excluding Ottley and Axford Creek basins is 348 ha.

In summary, for Schoolhouse Creek basin, about 149 ha or 74.5% of the basin lies above elevation 36 m in the Coquitlam and Port Moody highlands. The gullies occupy about 36 ha or 18%. Below elevation 15 m in Port Moody along Burrard Inlet shoreline, about 15 ha or 7.5% of the basin lies adjacent to the creek. Total basin area is 200 ha. The majority of the basin is upland drainage.

Noble Creek basin occupies 6.8 ha above elevation 36 m, or 53.5% of its basin, and the channel gully occupies about 15.9 ha or 46.5% to total 12.7 ha.

Total area excluding Burnaby Mountain is distributed as follows:

Basin	Total ha	Upland Above 35 m ha	% Total	Gully Area, ha	% Total	Port Moody	% Total
Schoolhouse	200	149	74.5	36	18	15	7.5
Noble	12.7	6.8	53.5	5.9	46.5		
Total	212.7	155.8	73	41.9	20	15	7

The two basins when combined with the Burnaby Mountain drainage of 150 ha, yields a drainage area total of 348 ha. (The 135 ha of Burnaby Mountain drainage area was estimated from GVS&DD Drawing SR-368.)

Coquitlam drainage to Schoolhouse Creek basin including the GVS&DD Ingersol drain occurs through six identified collectors. Although not draining the largest area, the Ingersol collector has had the most concerns due to slide activity. Other major collectors discharge to the top of Schoolhouse Creek where, unlike the other creeks, the channel downgrades in a gradual slope, and storm water discharges are not conveyed to an abrupt steep gully face.

Noble Creek basin has an upland discharge point at the foot of MacIntosh Street which drains the upland area. The drainage occurs over an abrupt gully face. A deep drainage scar was noted on the west bank downstream from the discharge point.

2.3.2 Ottley Creek Drainage Area

Ottley Creek Drainage Area of 35.7 ha lies immediately east of Schoolhouse Creek Drainage Area, and consists of only one basin which is drained by Ottley Creek. The Drainage Area is managed by the two municipalities within their respective borders.

Approximately 5.5 ha or 15.5% of the basin of Coquitlam residential area drains above elevation 36 m drain to the creek through a 1980 constructed storm drain discharging to the creek from the foot of Porter Street. The new drain replaced a storm drain to the east which was destroyed in the 1979 Porter Street slide. The slide resulted in a debris flow, the loss of one home in Port Moody and structural losses to homes in both communities.

The creek occupies 20.5 ha of gully or 51.5% of the basin and stretches from the headscarp in Coquitlam to the Port Moody lowland. In Port Moody, below elevation 15 m, the drainage basin is 9.6 ha of occupied land or 27% of the basin.

Total area for the Ottley Creek Drainage Area is 35.7. ha.

2.3.3 Kyle Street Drainage Area

The Kyle Street Drainage Area includes 179.5 ha and has the largest number of creek basins at five. Axford Creek basin is included but is not shown on the 1960 GVS&DD drainage area. The GVS&DD area totalled 160 ha only (called Moody Street Drainage). Including the Axford basin, the total comes close to the present drainage area size.

The Drainage Area basins from west to east are described in the following table:

Basin	Total Area, ha	Coquitlam Above 36 m elev. (ha)	% Total	Gully Area (ha)	% Total	Port Moody Below 15 m elev. (ha)	% Total
Axford	18.2	3.0	16.5	7.2	39.5	8.0	44
Kyle	27.4	8.0	29	11.9	44	7.5	27
Hachley	34	8.0	23.5	13.3	39	12.7	37.5
Sundial West	21.8	7.4	34	11.0	50	3.4	16
Sundial Centre	8.0	7.0	88	1.0	12	-	-
Sundial East	29.5	17.6	60	11.9	40	3.4	-
Total Sundial	59.3	32	54	23.9	40	3.4	6
Goulet	40.6	18.2	45	19.7	48.5	2.7	6.5
Total	179.5	69.2	39	76	42	34.3	19

Comparison of the percentage of area within the three divisions of each basin shows that the upland impact on the lower drainage areas in Port Moody increases from west to east.

Axford Creek basin is managed by the two municipalities within their jurisdictional boundaries, and major flows from the basin are presently conveyed in Port Moody sewers to the Kyle Street storm drain at Clarke Street.

Drainage flows accumulate at discrete connectors along the length of the enclosed channel which is constructed through Port Moody to Burrard Inlet.

2.3.4 William Street Drainage Area

The William Street Drainage Area is 166.8 ha and includes three creek basins. By comparison, the GVS&DD plan totalled 240 ha of which 133 ha were considered tributary from Coquitlam and the creek gullies.

The area is similar to the Schoolhouse Creek Drainage Area in that one basin dominates the drainage area and combined discharge is concentrated in one open channel through Port Moody. Unlike Schoolhouse Creek the open channel is not well defined, is shallow and crosses through residential lots to St. Johns Street. Schoolhouse Creek Drainage Area also has a larger urban area percentage.

The drainage area basins from west to east are described in the following table:

Basin	Total Area, ha	Coquitlam Above 30 m elev. (ha)	% Total	Gully Area (ha)	% Total	Port Moody (below 15 m elev.) (ha)	% Total
Williams Creek	6.7	0.5	7	6.2	93	-	-
Elgin House Creek	11.1	3.4	30	7.7	70	-	-
Correl Brook	5.3	-	-	5.3	100	-	-
Dallas Creek	88.3	35.5	40	52.8	60	-	-
Above St. Johns	11.7	-	-	-	-	11.7	100
Below St. Johns	43.7	-	-	-	-	43.7	100
Total	166.8	39.4	24	72.0	43	55.4	33

2.4 Creek Systems

The 12 named creeks drain their respective basins as shown on Figures 2-2 and 2-3. This section describes the creek channel gradients, observed condition and reported channel maintenance.

2.4.1 Channel and Valley Character

Figures 2-4, 2-5 and 2-6 show the creek gradients for main and tributary channels of the creeks for each of the four drainage areas. The weighted average creek gradients in their lower two thirds are compared in Table 2-2.

The figures also provide a description of the channel condition and its activity. The Geotechnical Study in Appendix 2 makes reference to these figures in discussion of hazard zones and the evaluation of the headscarp or upper 1/3 of the fall line.

Table 2-2 describes the creek and valley gradients, valley shape and growth. Much of the hardwood stands show evidence of surficial movement as described in Appendix 2. Conifer and fern predominate stable areas. Stumps, when present, from late 1800's logging also show evidence of valley stability. By comparing gradients, valley length, width and shape, the basin stability and potential for debris flow or slide storage can be assessed by a rating product which shows the creeks least capable of containing a slide, debris flow or flood.

TABLE 2-2

Creek and Valley Character at Lower 2/3 of Fall

Drainage Area	Creek - Basin	Channel and Valley Slope		2/3 Channel Length m	Middle Valley Depth m	Middle Valley Width m	Valley* Shape	Predominant Overstory	Predominant Understory	Storage or Carrying Capacity Rating**
Schoolhouse	Schoolhouse Creek	4°	(6.9%)	1000	40-50	200	2-3	Conifer, Hardwood	Salmonberry and Fern	22
	Noble Creek	6.5°	(11.4%)	550	15-25	140	2	Conifer	Fern	2
Ottley	Ottley Creek	6.9°	(12%)	430	30	150	1-2	Conifer, Hardwood	Fern	3
Kyle	Axford Creek	5.3°	(9.2%)	480	25	130	2	Hardwood and Conifer	Fern	3
	Kyle Creek	7.3°	(12.8%)	480	25	150	2	Hardwood and Conifer	Salmonberry	2.5
	Hachley Creek	7.9°	(13.8%)	420	30.35	180	2-3	Hardwood and Conifer	Salmonberry Fern - dense	3
	Sundial Creek	5.3°	(9.3%)	420	25-30	180	2	Conifer	Fern	4
	Sundial East and Centre Creek	7.1°	(12.5%)	470	30-35	140	2-3	Hardwood and Conifer	Fern, Salmonberry	3
	Goulet Creek	5.4°	(9.5%)	560	30-40	200	2	Hardwood and Conifer	Salmonberry, Fern	7
Williams	Williams Creek	8°	(14%)	310	25-30	130	1-2	Conifer	Fern	1.5
	Elgin House Creek	8°	(14%)	470	20-30	150	2	Conifer	Fern	2
	Correl Brook	6.1°	(10.7%)	300	10-20	100	1-2	Conifer	Fern	7
	Dallas Creek (to confluence)	4.0°	(7%)	900	30-40	200	2	Hardwood and Conifer	Salmonberry, Fern	15

* See Figure 2-7.
** Rating (width x length / valley slope)
22 - low carry, high storage
1 - high carry, low storage

Valley Shape 1 = 2 = 3 = 4 =

2.4.2 Basin Hazard Potential

The geotechnical evaluations of Appendix 2 in Table 3 address the relative probability of a debris flow or flood occurrence combined with the channel carrying ability as described in Table 2-2. The relative overall order of debris flow or flood occurrence at the mouth of the gully (or inlet) is described as follows:

Drainage	Basin	Relative Probability Debris Flood	Relative Probability Debris Flow
Schoolhouse Creek	Schoolhouse	2	3
	Noble	2	2
Ottley Creek	Ottley	1	1
Kyle Street	Axford	2	1½
	Kyle	2	2
	Hachley	2	2
	Sundial	2	2½
	Sundial Centre and East	1	1
	Goulet	2	2
William Street	William	2	2
	Elgin House	2	2½
	Correl	3	3
	Dallas	2	3

(Taken from Appendix 2, Table 3)

1 = High
2 = Medium
3 = Low

The above table reflects the geotechnical considerations of the headscarp stability, existing known fill areas, seepage and observed surficial movements, and the hydraulic considerations of channel carrying and storage capacity.

2.4.3 Operations

Observations of channel maintenance by Port Moody and Coquitlam operations, and GVS&DD drainage crews are described for each creek in Table 2-3. The observations deal mainly with the trash racks and grilles at the intakes. Some comment is included regarding recorded slides in the creek.

GVS&DD maintenance costs in 1987 were about $60,000. Most of the cost is apportioned between five creek systems, Kyle, Hachley, Sundial, Goulet and Elgin House-Correl where cleaning is needed every 3 months during winter.

TABLE 2-3

Inlet Operations Observations (1987)

Drainage Area	Basin	Responsibility	Observations
Schoolhouse	Schoolhouse	GVS&DD	1. Ingersol outfall lost once due to one of several slides, pipe (CMP) is rusted out, grit chamber at top of scarp cleaned out biannually, 2-3 m^3 per cleaning (Plate SH-1 outfall). 2. Considerable fill along scarp and evidence of slumping in fill areas at Ingersol, Miller, Wyvern, Oakview, Sirmac in Coquitlam. 3. Flooding in low homes upstream of St. Johns Street culvert crossing. Debris plugs culverts and backs water up (plate SH-4).
	Noble	GVS&DD	1. Since trash guard extended and flume constructed few problems have been experienced (see photograph plate SH-3).
Ottley	Ottley (Hope)	Port Moody	1. Large debris flow moved house in December 1979 (photograph plate OC-3 shows intake). 2. Operations staff maintain sediment basins and clean intake grill at mouth of gully. Cleaning is needed every 2 months during winter. 3. Logged in 1940's. 4. Point discharge from Coquitlam (see photograph plates OC-1, OC-2). 5. Inlet in Port Moody (see photograph plate OC-3 and conveyance (OC-4 and OC-5).
Kyle	Axford (Elgin)	Port Moody	1. Recent sediment movement has been observed. 2. Sediment ponds fill and are cleaned by City of Port Moody every two months during winter. 3. Inlet connected to Port Moody storm sewers (see photograph plate KS-1).
	Kyle	GVS&DD	1. Failed December 1986 and flooded streets, parking lot and City Hall. 2. Little sediment storage capacity at grill (see photograph plates KS-2).
	Hachley (Grant)	GVS&DD	1. No problems in 20 years of record. 2. Advised not to clear trees from creek. 3. Grill is shown in photograph plate KS-3.
	Sundial (Moody)	GVS&DD	1. Removed 110 tandems of material from sediment ponds. 2. Sediment supply has been higher in last 5 years, over 20 years of record. 3. Sediment ponds are not cleaned until the last pond is being filled. 4. Slides in east branch produce much sediment (1983). 5. Grill is shown in photograph plate KS-4.
	Goulet (Hugh)	GVS&DD	1. Sabo structure (Renta weir) constructed has helped keep grill clean. 2. Sediments are clayey silts in ponds; considerable stockpiled materials now removed (in last couple of years). (This basin yields the most material of all GVS&DD channel basins.) 3. Pourier slide of 1983 in Coquitlam produced much sediment. 4. Grill is shown in photograph plate KS-5. 5. Parks at one time maintained trails in this gully.
Williams	Williams (Henry)	GVS&DD	1. Slump in December 1979 of Baron Place in Coquitlam caused concern for apartment residents in Port Moody; has been stabilized with rock fill. 2. Grill cleaned by hand; cleaning is difficult (photograph plate WS-8). 3. Large variations in flows (quick runoff).
	Elgin House Correll Brook	GVS&DD	1. Two drainage sources combined through sediment pond (see photograph plates WS-2 and WS-3). 2. Pond fills in 3-4 months with sand. (By December of 1986 GVS&DD reported that the sediment basin had been cleaned 4 times this fall yielding 30 m^3 of sand.) 3. Slide at bottom of Fresno.
	Dallas	GVS&DD	1. No sediment basin now (once was one). 2. Park trails once used for access. 3. No grill. 4. Creek bends sharply at large apartment complex; no freeboard (see photograph plate WS-1). 5. Open channel below Hope Street floods annually. (Residential access washes out and constricts flow which creates flood in downstream resident.)

2.5 Major Drainage, Port Moody

This section describes the major drainage facilities presently owned and maintained by the GVS&DD and Port Moody. With the exception of Ottley and Axford Creek intakes, all intakes and collectors are GVS&DD operated. The only truly closed system is in the Kyle Street Drainage area. A short section of storm drain collects Noble Creek to an open channel in the Schoolhouse Creek Drainage Area. An inventory and comment is given in Table 2-4.

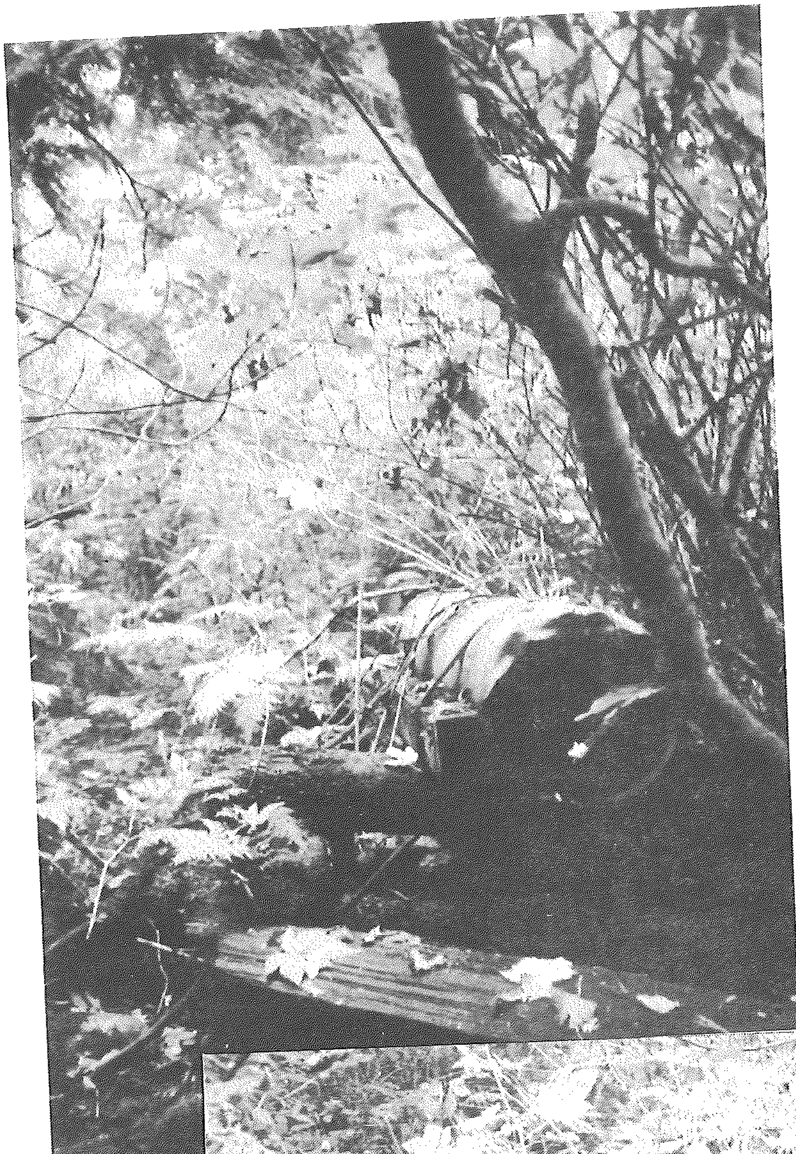
Estimates of capacity are given in a later section.

The table summarizes culvert and storm drain conditions and comments on flood concerns as well as operations and maintenance. City of Port Moody maintenance costs are about $7500 per year for each of the two creeks, (Ottley and Axford).

TABLE 2-4

Inventory of Major Drainage

Drainage Area	Basin	Location and Structure	Description
Schoolhouse Creek	Schoolhouse	1. Albert Street; 1400 x 1700 box culvert 1972 GVS&DD SF1176. 2. CPR crossings to St. John's Street GVS&DD SF 791, 1964; a) St. Johns Street twin 1350 conc. pipe b) Clark Street one 1500 W.S. pipe one 1050 CSP pipe c) Riechhold Chem. 1400 x 1700 W.S. pipe d) CPR 2400 x 1500 Box	- Good inlet wing wall construction - no trash rack. - Abrupt inlet - trash accumulation causes flooding. - Projecting inlet. - Concrete inlet wing walls above large pipe invert. - Projecting inlet. -
	Noble	1. Albert Street; 600 conc. pipe, 2.3x1.8 grill GVS&DD SF1176	- Revised to include flume grating change and picket barrier.
Ottley Creek	Ottley	1. Hope Street inlet 450 pipe and concrete inlet 2. Six alternating sections of 600 ϕ crossing paved areas, and open channel through residential and open areas (Includes 600 ϕ crossing CPR)	- 450 crosses Hope Street and flows in small channel and flume to a 600 pipe crossing at George Street. - Channel floods at high flows in upper reaches.
Kyle Street	Axford	1. Elgin Street inlet crossing Hope Street to open channel 2. Inlet crossing George Street 450 ϕ 525 ϕ 600 ϕ	- Open channel is very small but with good freeboard to homes (see photograph. - Storm drain connects to Kyle system at Clark and Queens.
	Kyle	1. Kyle Street and Hope Street GVS&DD SF571, Sh 8 900 conc. pipe inlet, 1960 2. Main Sewer GVS&DD SF571, Sheets 1-5	- Tapered inlet and grate. - Main storm drain eroded: . joints create discontinuity . two completely worn through . bottom eroded throughout 50 mm (2 mm/yr). - Outfall of main sewer self scours.
	Hachley	1. Grant Street GVS&DD SF571, Sh 7 900-600 conc. pipe inlet, 1962	- Tapered inlet and grate.
	Sundial	1. Moody Street GVS&DD SF571, Sh 7 1050-900 conc. pipe inlet, 1962	- Tapered inlet and grate.
	Goulet	1. Hugh Street GVS&DD SF571, Sh 6 900, 750, 1050, 1200 inlet, 1962	- Tapered inlet and grate. - At intersection of Hugh Street and Henry Street 1050 (0.9%) from 750 (5.3%) shows energy and creates much sedimentation. Fine silts are difficult to clean (energy drop 5-2X).
William Street	William	1. Henry Street GVS&DD SF558 600 pipe, under apartments to 900 pipe from Hope Street to St. George St. - inlet, 1968	- Inlet approach is straight but ditches drain to inlet from either side and need frequent cleaning.
	Dallas (Slaughterhouse)	1. Storm extensions recommended on Hope St. on six occasions from 1962-1980 2. Hope Street Culvert 900 x 1200 CSP 3. St. Georges Street 900 WSP culvert 4. St. Johns Street (1961) to open channel along CPR (warehouse) 1500 conc. (1977) 5. CPR crossing 900 CSP (in 1050 pipe) 6. CPR to outfall (Murray St.) GVS&DD SF1592, 1978, 1500 conc. to Murray and 1200 W.S. outfall	- Floods frequently in area between Hope St. and St. George St. - Projecting entrance. - No grating. - Channel entrance rock wall. - No grating. - Abrupt headwall deep. - No trash rack. - Recommended replacement to CPR 1980 and 1986. - 1978 replacement of failed W.S. pipe.



Ingersol Avenue Outfall

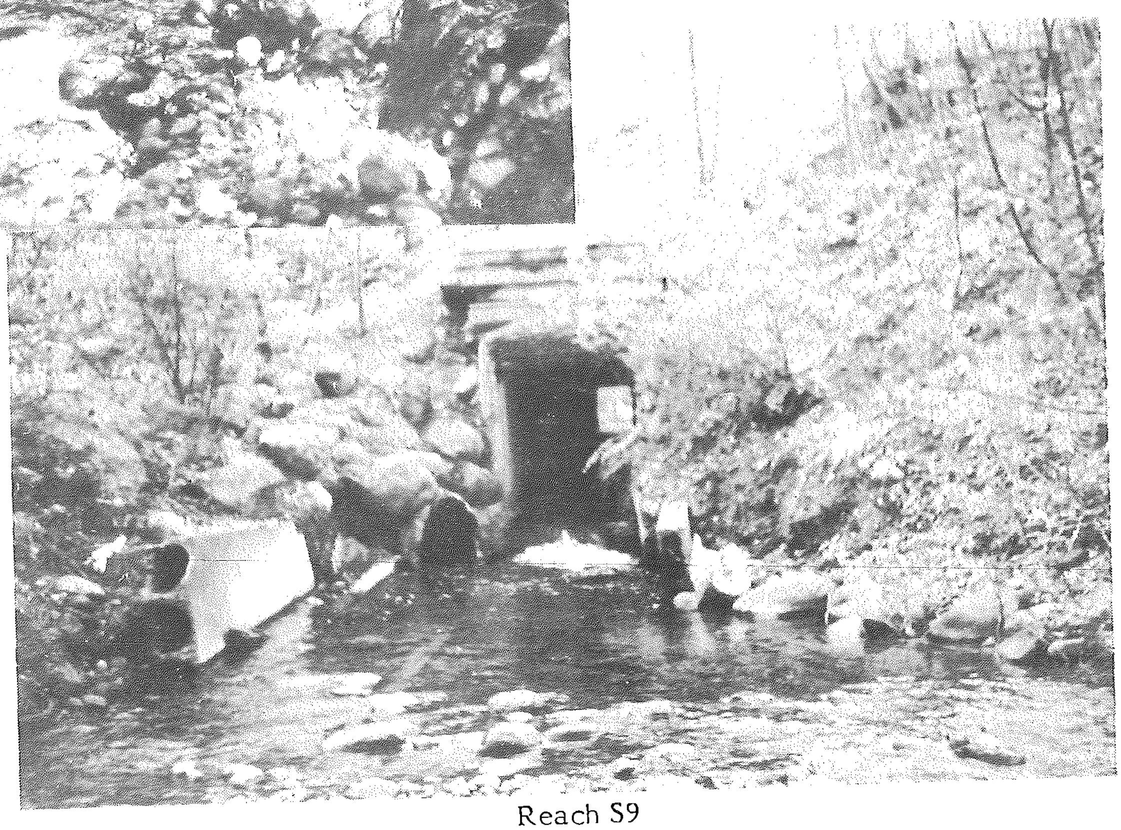
Reach S4.

September 17, 1987.

Reach S6

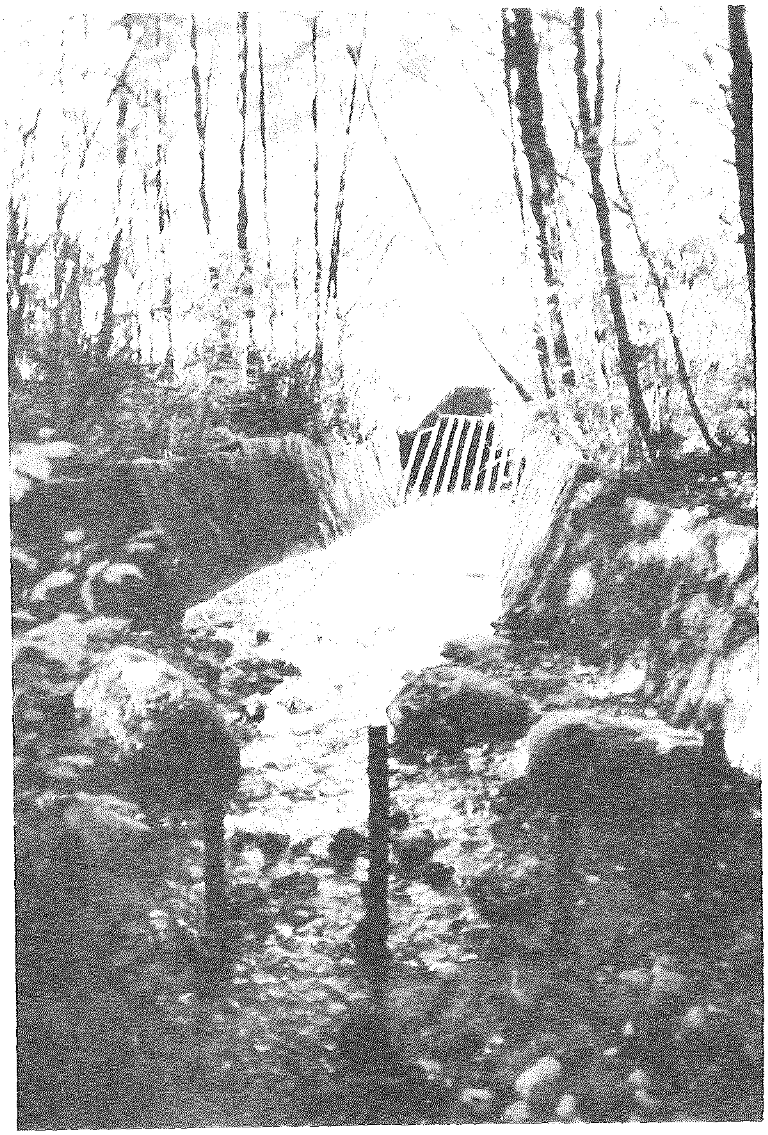
Schoolhouse Creek downstream of School Creek crossing Albert Creek at headwall.

September 9, 1987.



Reach S9
Looking upstream across Albert Street,
shows Noble Creek discharge to Schoolhouse Creek at left.

Schoolhouse Creek Drainage Area



Reach S7/S8

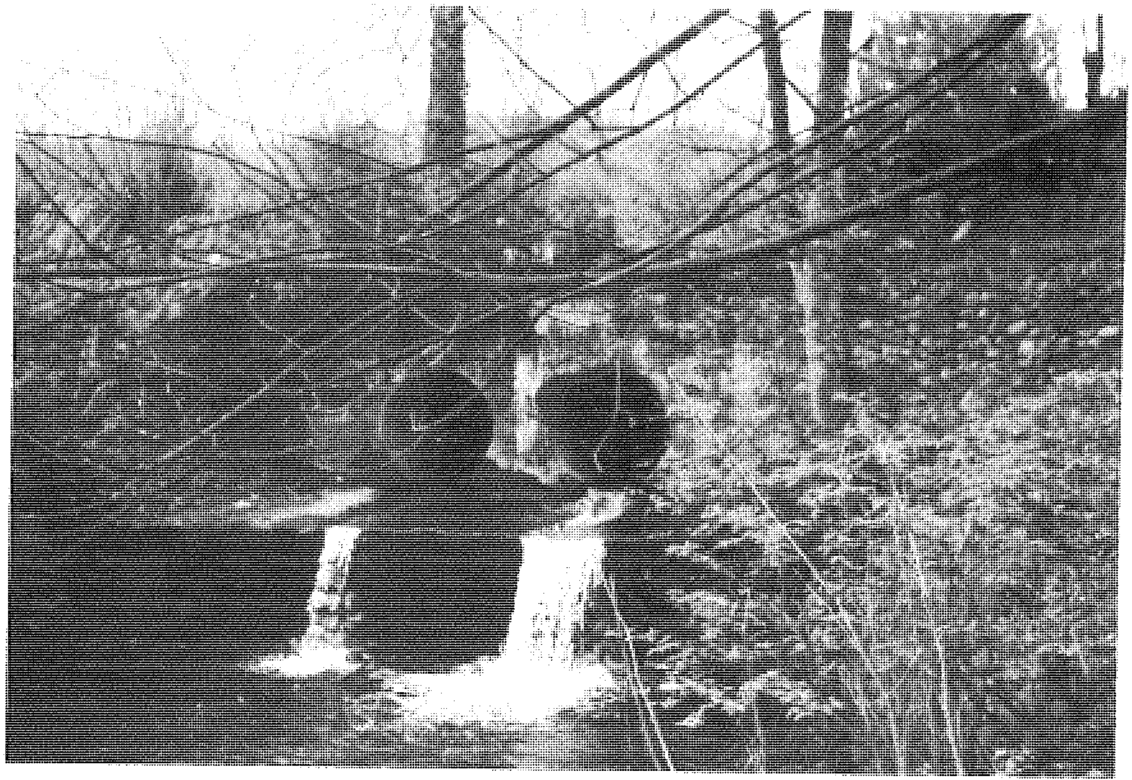
Nobel Creek Intake

September 9, 1987.

Reach S9
Looking downstream from Albert Street down to St. Johns.

Reach S10
Schoolhouse Creek crossing of St. Johns, looking downstream.
September 9, 1987.

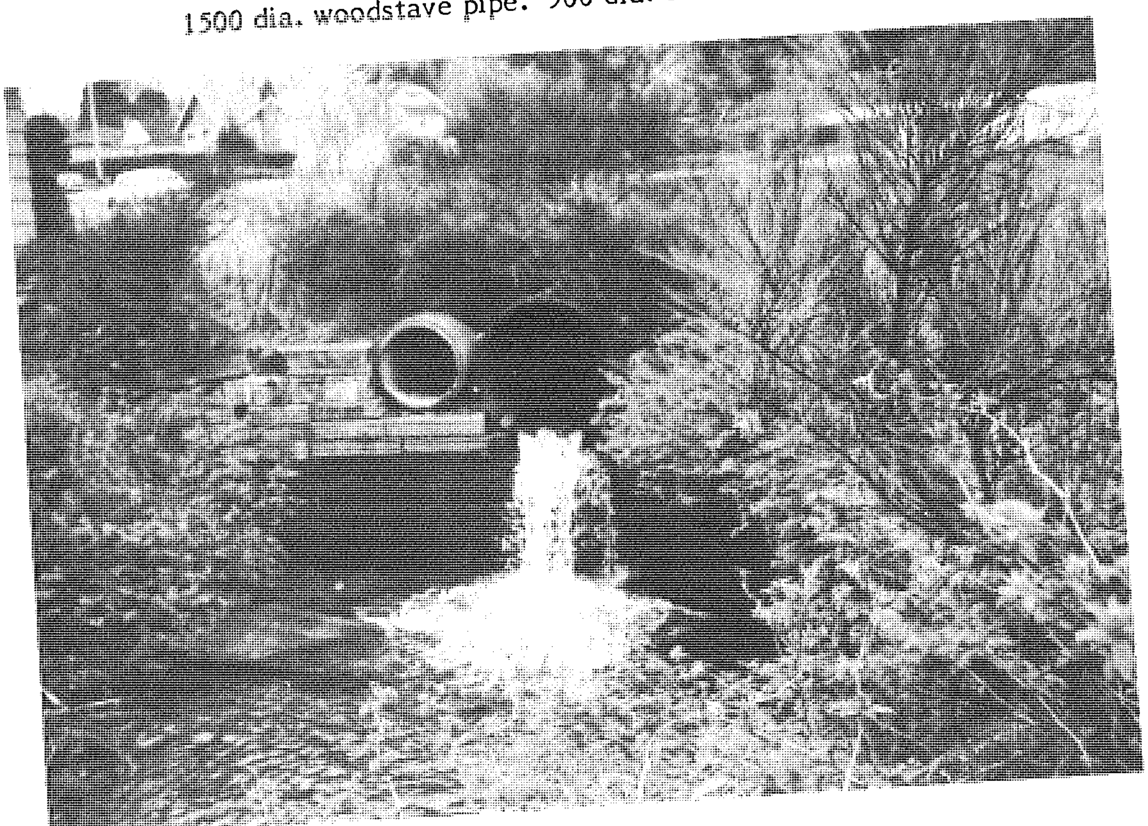
Schoolhouse Creek Drainage Area



Reach S10/S11
Drainage area outlet structure at St. Johns Street.

Reach S11
Check dam downstream of St. Johns at pipe crossing.

Reach S12
Inlet structures at Clarke Street crossing
1500 dia. woodstave pipe. 900 dia. concrete overflow.



Reach S12
Outlet structures at Clarke Street crossing.

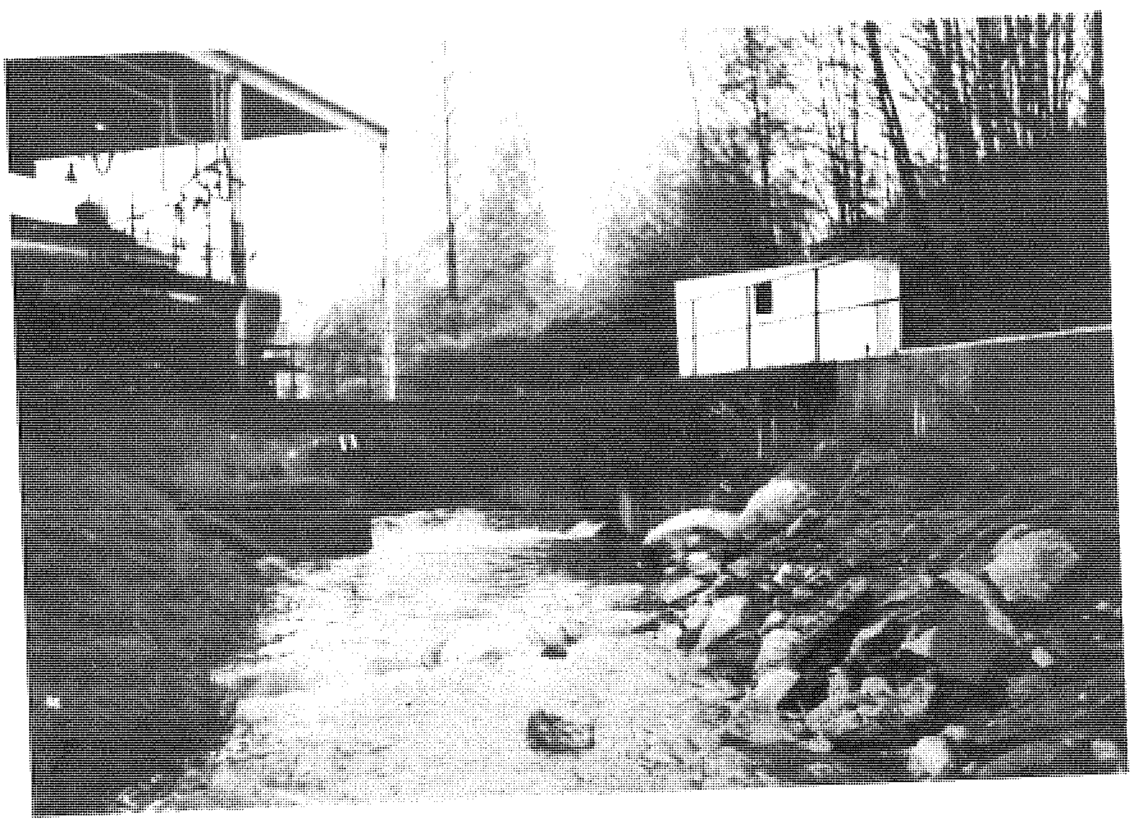
Schoolhouse Creek Drainage Area

Reach S30/S35
Through Riechhold Chemicals looking downstream.

Reach S30
Looking upstream to Andres Wines.

Schoolhouse Creek Drainage Area

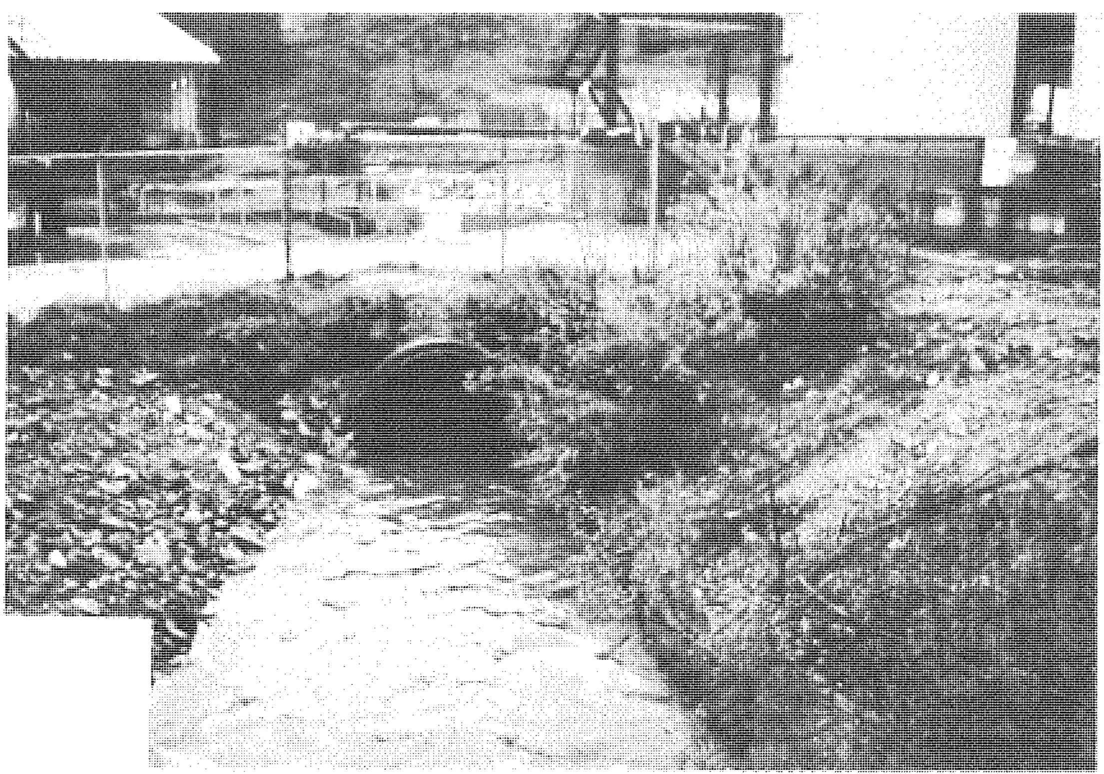
Reach S34/S35
Major tributary 900ϕ



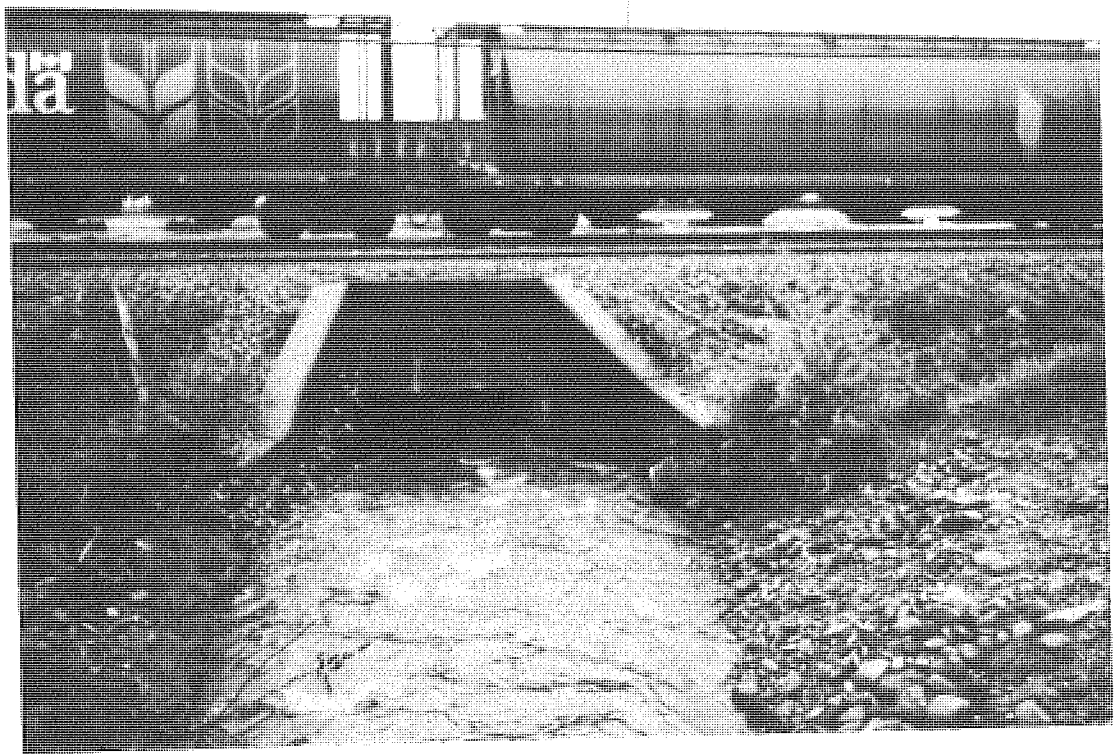
Reach S35
Looking upstream to tributary confluence.

Schoolhouse Creek Drainage Area

Reach S35
Through Riechhold Chemicals looking downstream.
CP Rail in background.



Reach S35
Looking upstream to above plant site.



Reach S36
CP Rail crossing looking downstream.

Reach S36
CP Rail crossing looking upstream.

Ottley Creek Drainage Area

Ottley Creek ditch inlet on Porter Street, Coquitlam.

Ottley Creek Drainage Area

Ottley Creek drainage culvert chained down in flume which has undermined (in Schoolhouse Creek Drainage Area).

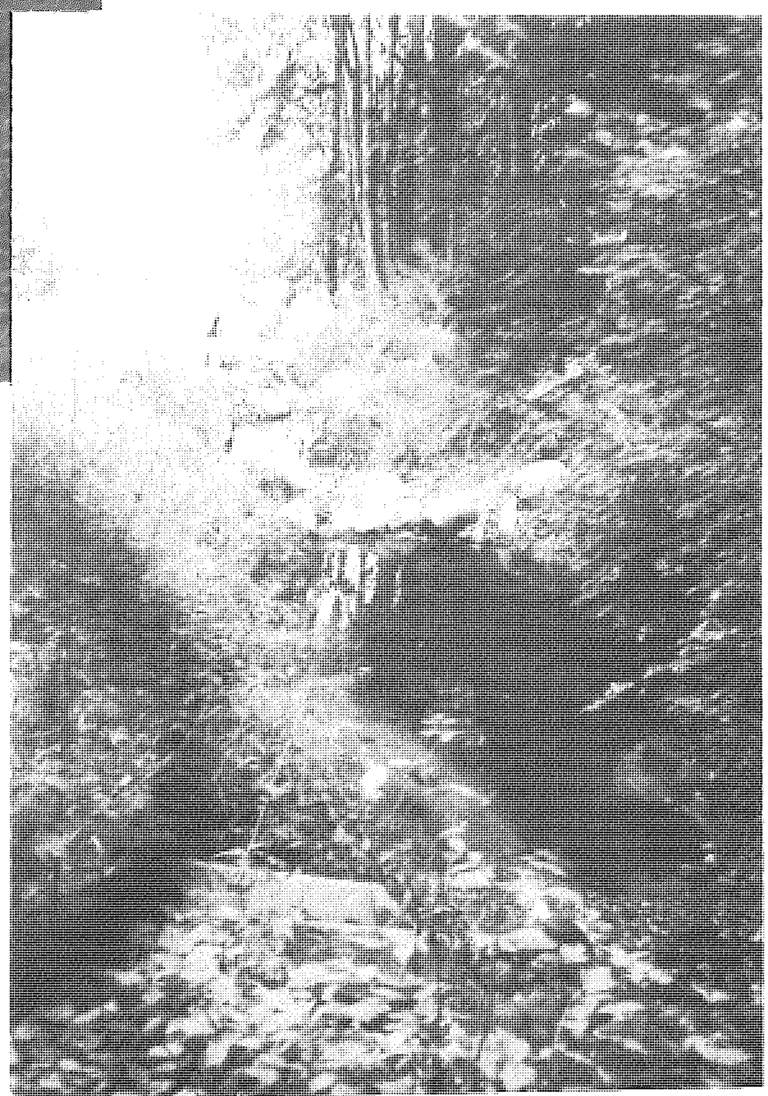
September 3, 1987.

PLATE OC- 2

Step weirs.

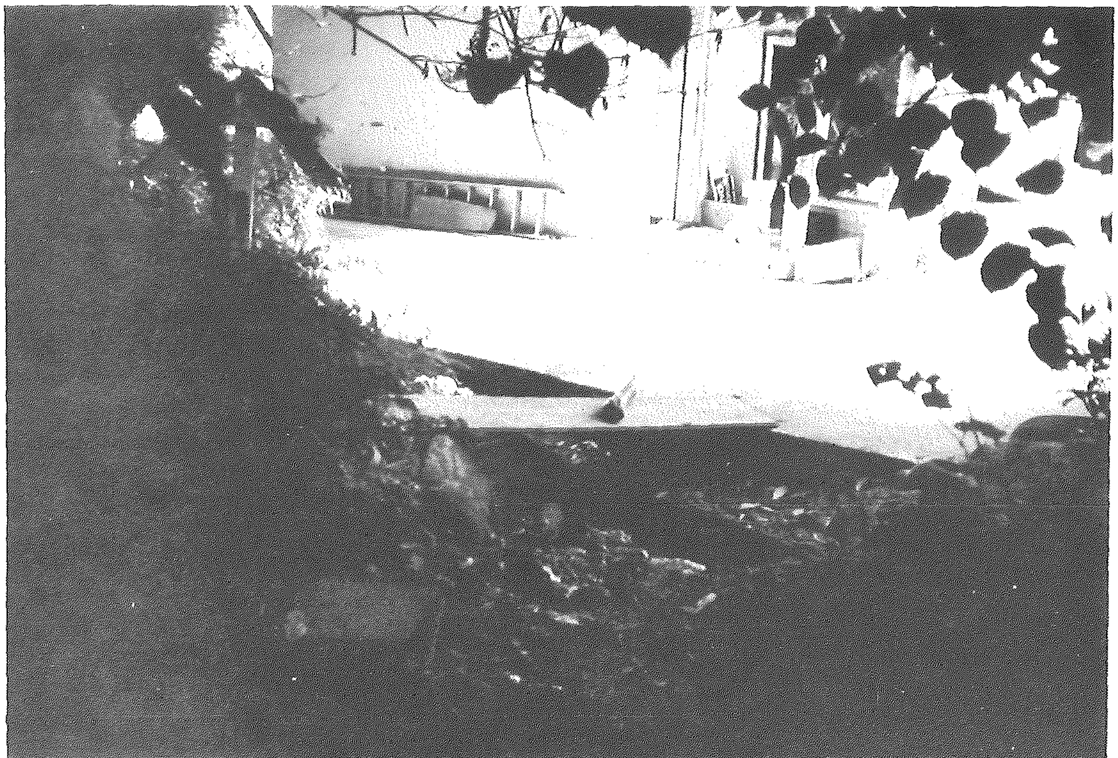
Ottley Creek Drainage Area

Ottley Creek inlet and settling ponds (2) in Schoolhouse Creek Drainage Area.

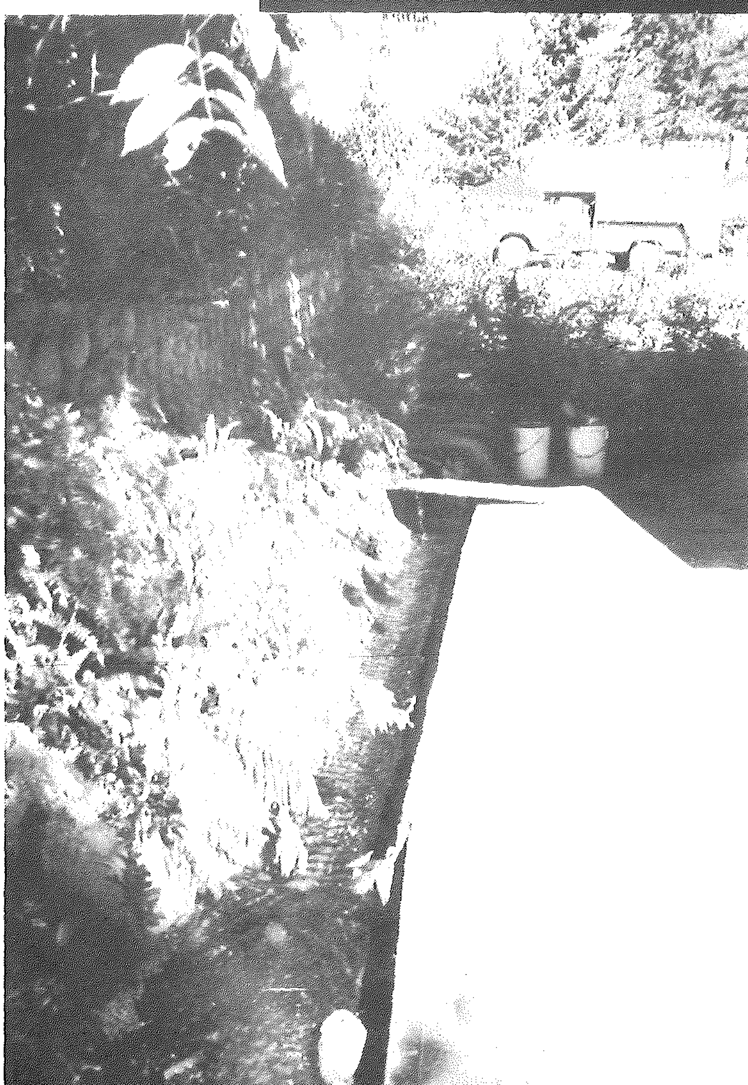


September 3, 1987.

PLATE OC- 3



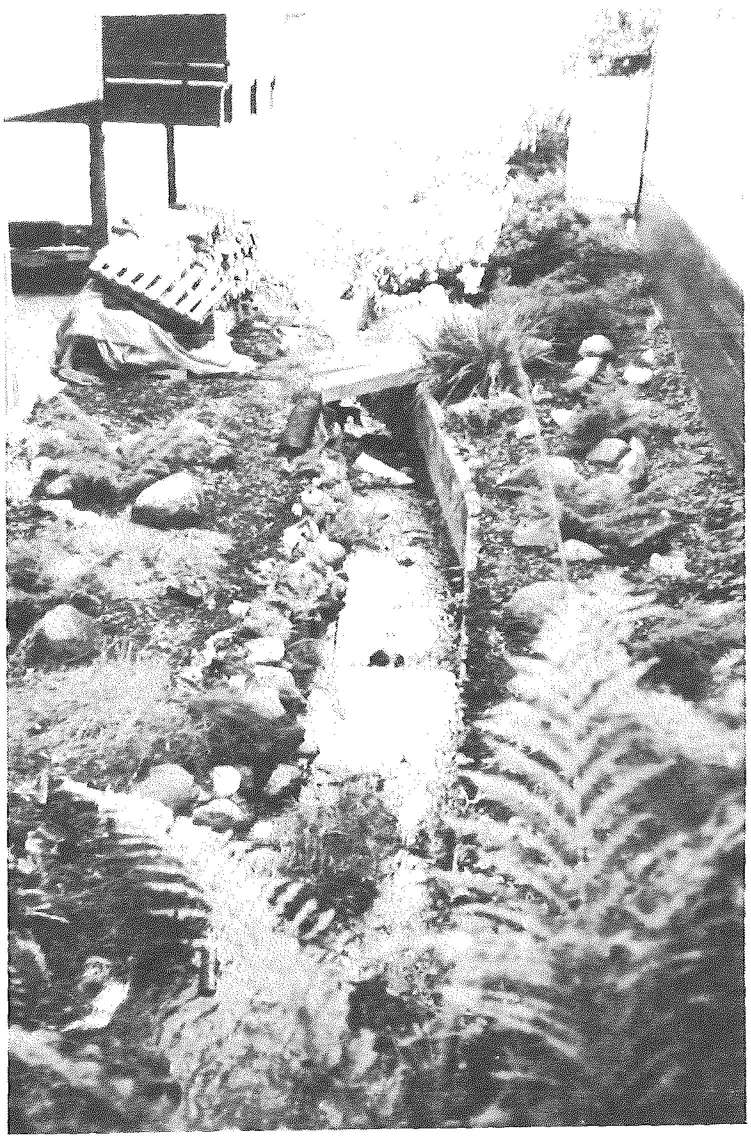
Ottley Creek ditching through private property looking downstream.



Reach 04

Ottley Creek looking downstream through above private property. Channel flume turns 90° right then crosses St. Georges Street to ditch.

Ottley Creek Drainage Area



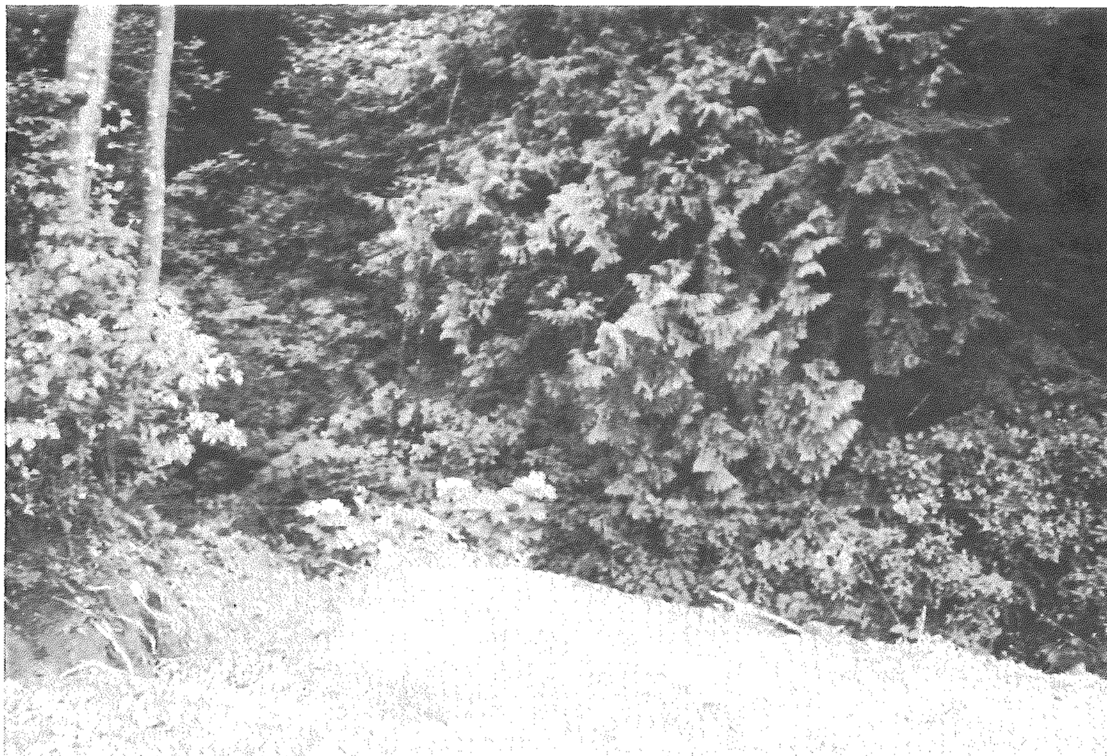
Reach 05

Ottley Creek downstream of St. Georges Street. Discharges below garage (in background).

Ottley Creek Drainage Area

Ottley Creek head scarp showing old slide to right and new point discharge of urban drainage to left.

Kyle Street Drainage Area



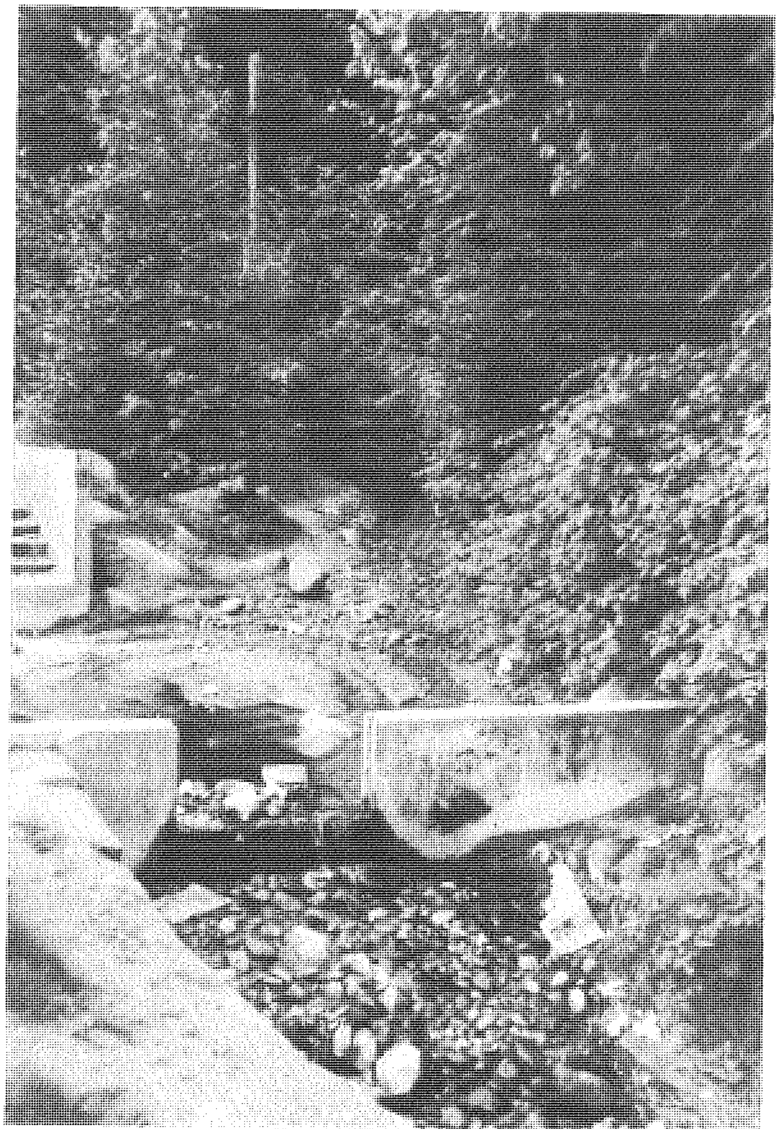
Axford channel looking over road shoulder at Henry Street and Elgin Street.

Reach K2

Axford Creek channel and intake at top of Henry Street and Elgin Street, in Schoolhouse Creek Drainage Aarea. September 3, 1987.

Reach K3
Axford channel looking upstream from St. George Street.

Kyle Street Drainage Area



Reach K10

Kyle Creek channel, sediment trap and intake at George Street and Kyle Street, in Kyle Street Drainage Area.

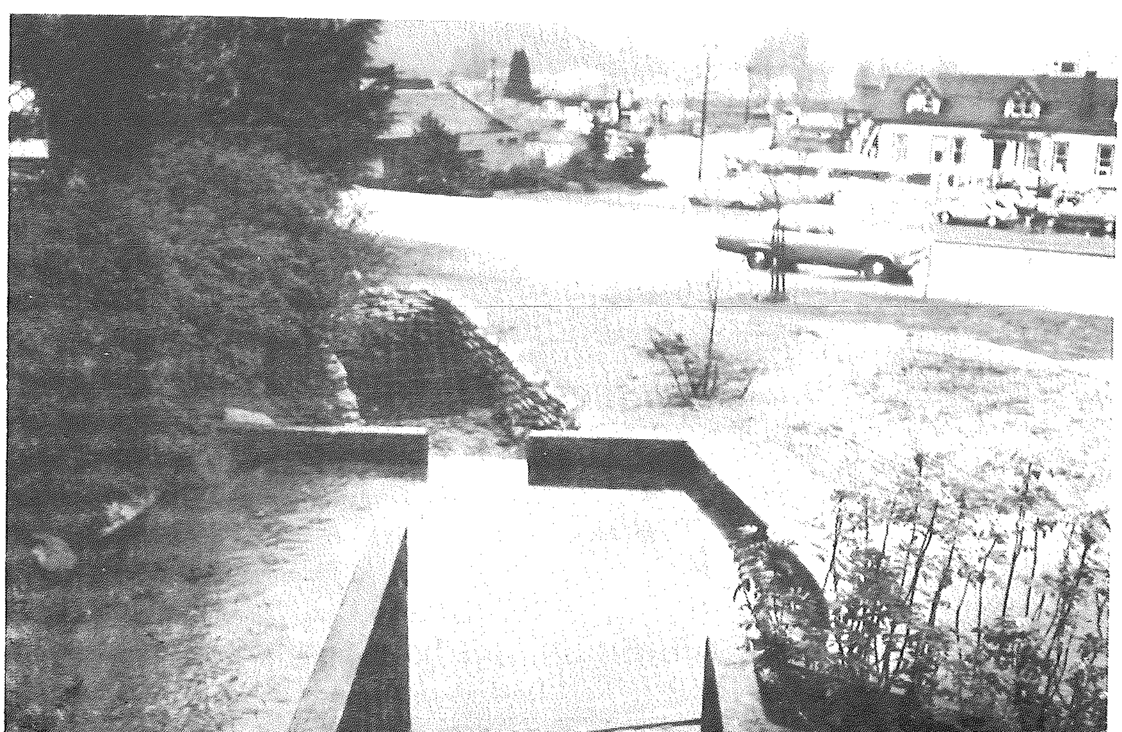


PLATE KS- 2

Kyle Street Drainage Area

Hachley Creek

Reach K16

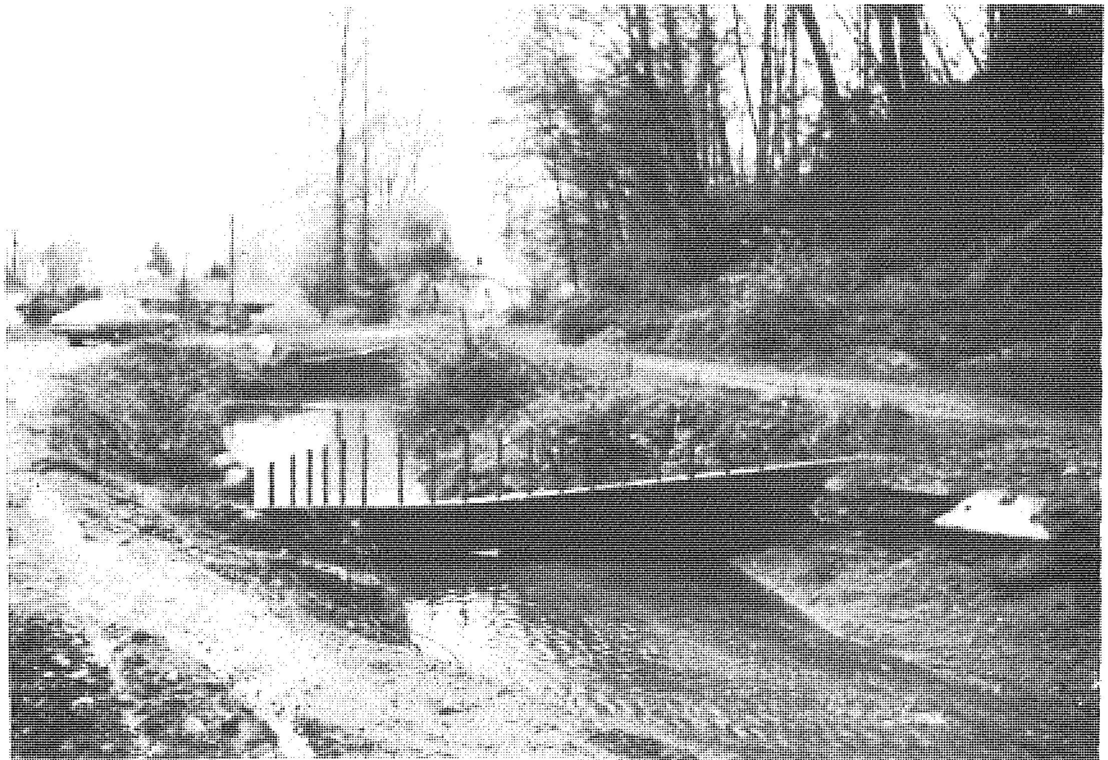
Hachley Creek channel and inlet at Jane Street east of Grant Street. (Note trash guard pickets) in Kyle Creek Drainage area.

September 3, 1987.

Sundial Creek channel, sediment traps, trash guard pickets and intake in Kyle Creek Drainage Area.

September 3, 1987.

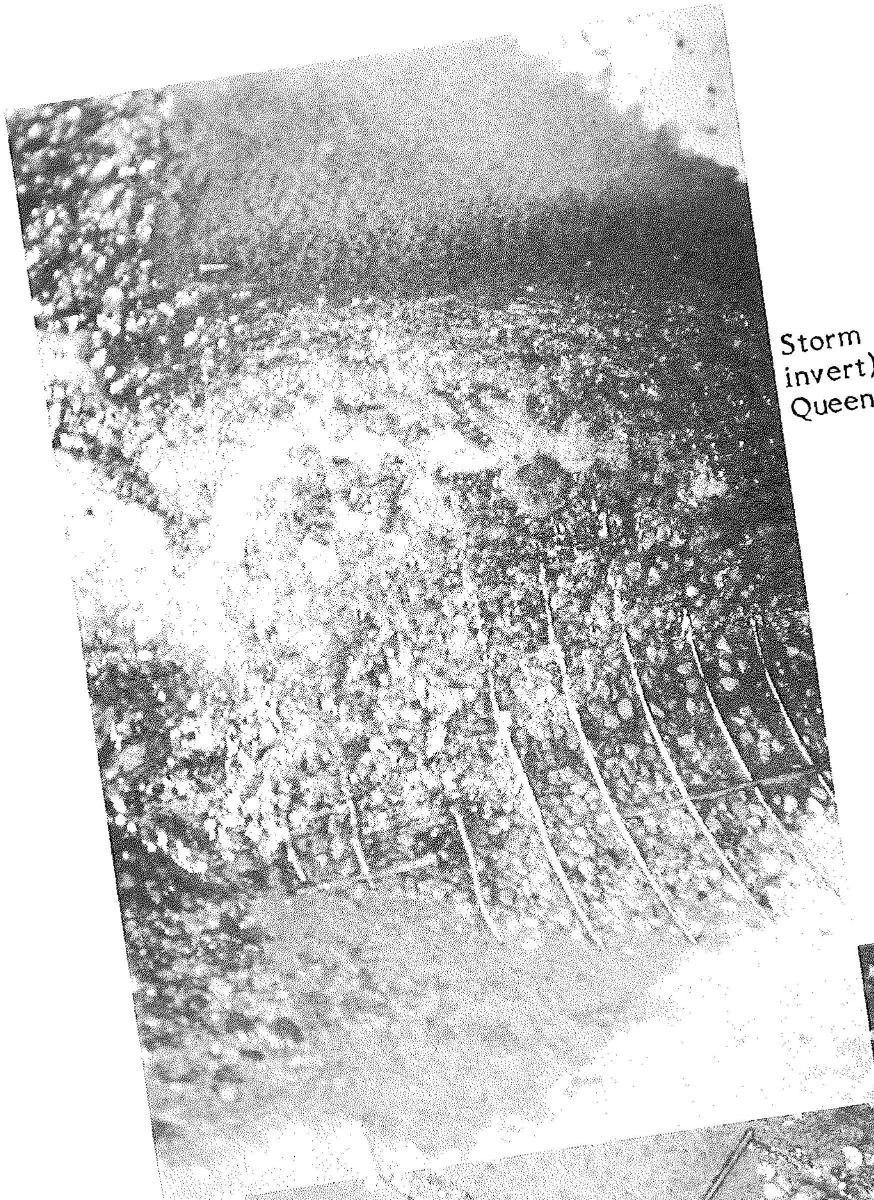
Kyle Street Drainage Area



Goulet Creek sediment basins cleaned.

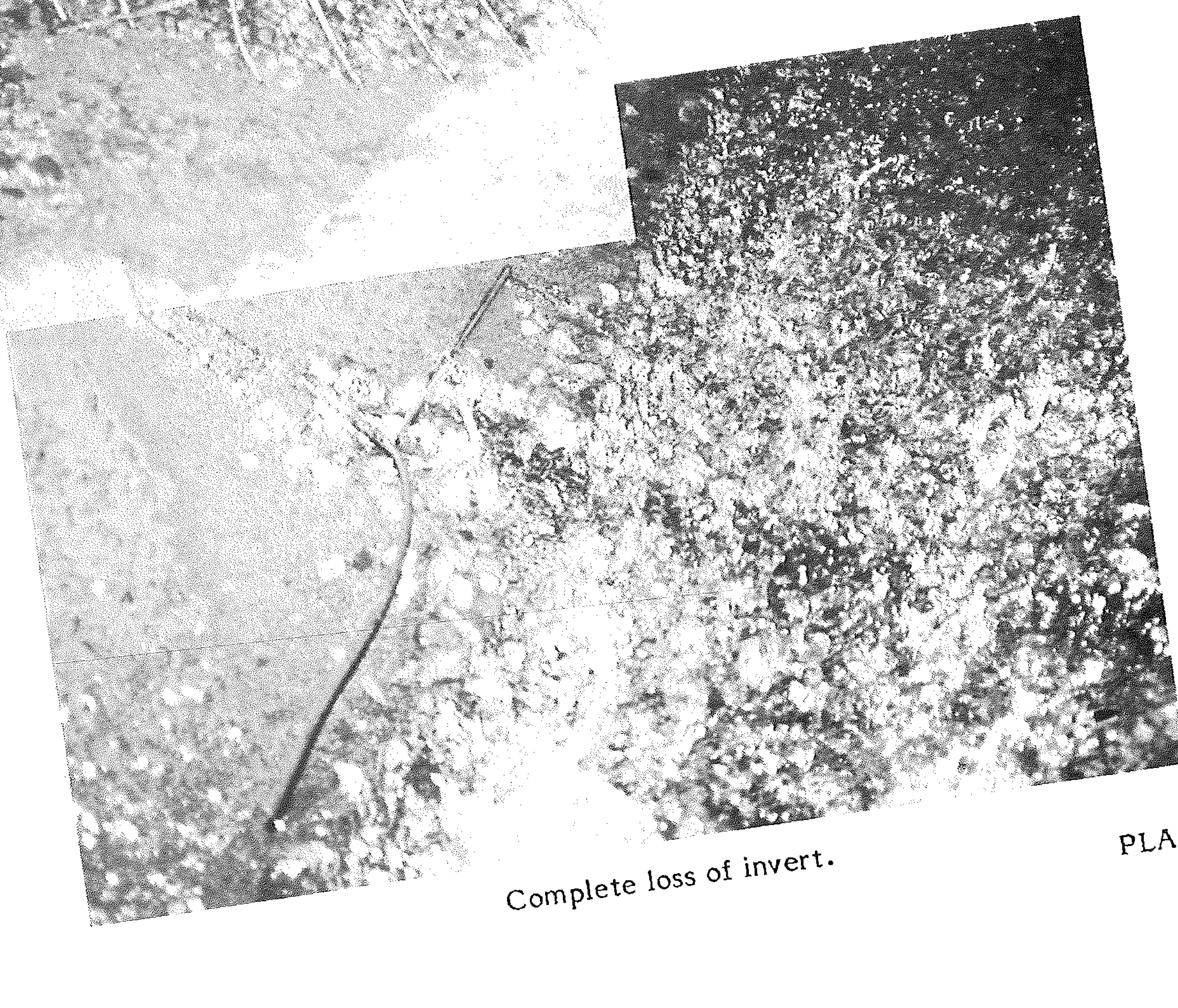
Goulet Creek inlet cleaned.

Kyle Street Drainage Area



Storm drain (built 1962, 50% loss of invert) from Hugh to the bottom of Queens.

September 18, 1987.



Complete loss of invert.

PLATE KS-

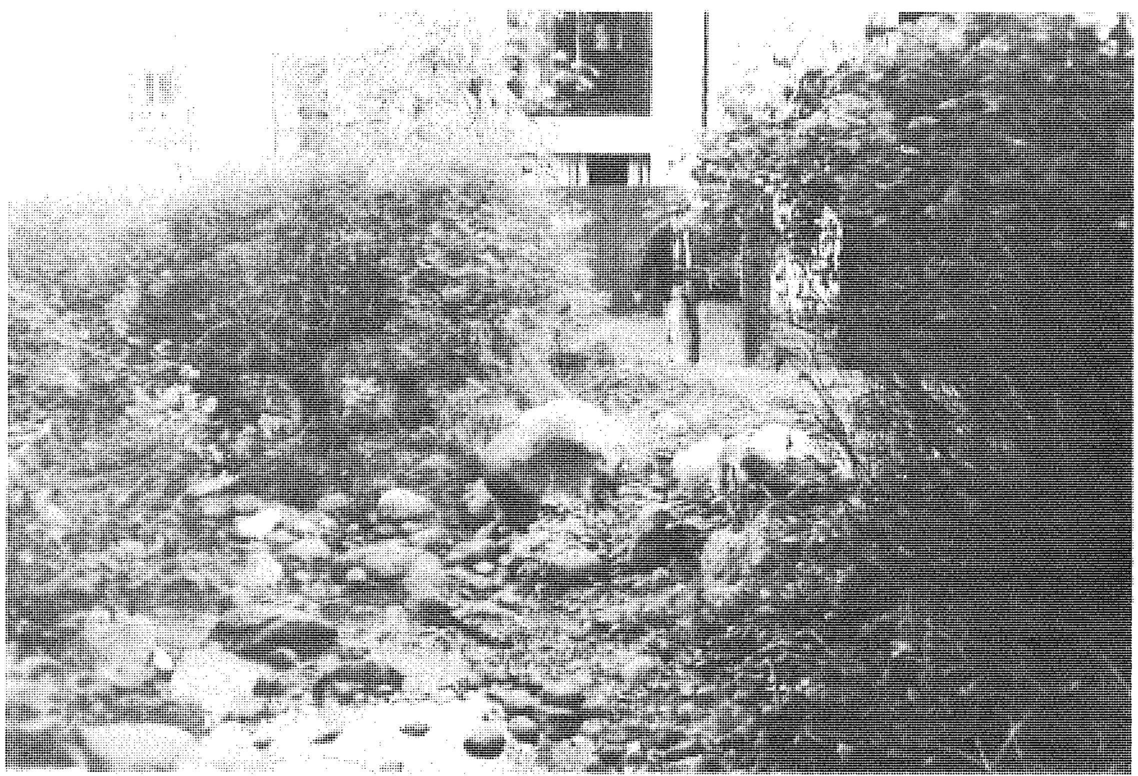
Kyle Street Drainage Area

Kyle Creek - 1,800ϕ (60 inches) outfall.
September 9, 1987.

Gravel bar at discharge.

Williams Street Drainage Area

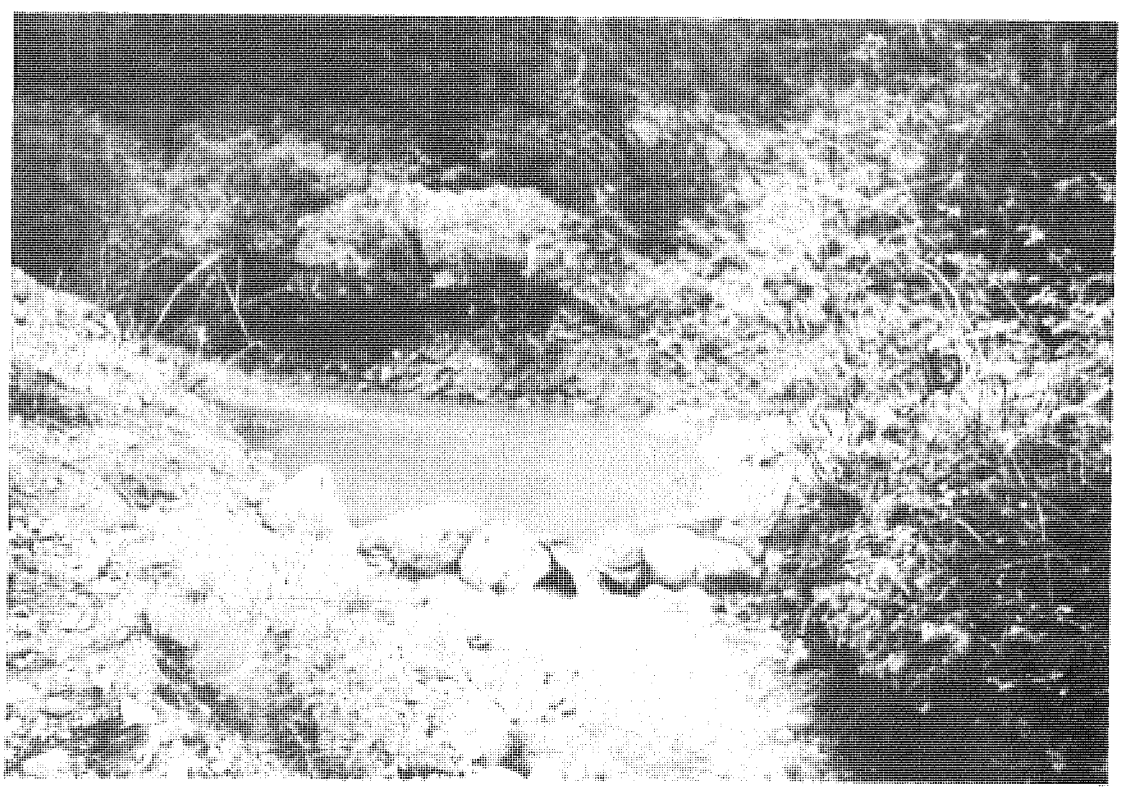
Windfall in Elgin House Drainage Basin caused by undermining of headscarp.



Reach W12
Dallas Creek at apartments above Elgin House Creek confluence.
Note low bankfill flow capacity.

Williams Street Drainage Area

Elgin House Creek confluence at Dallas Creek

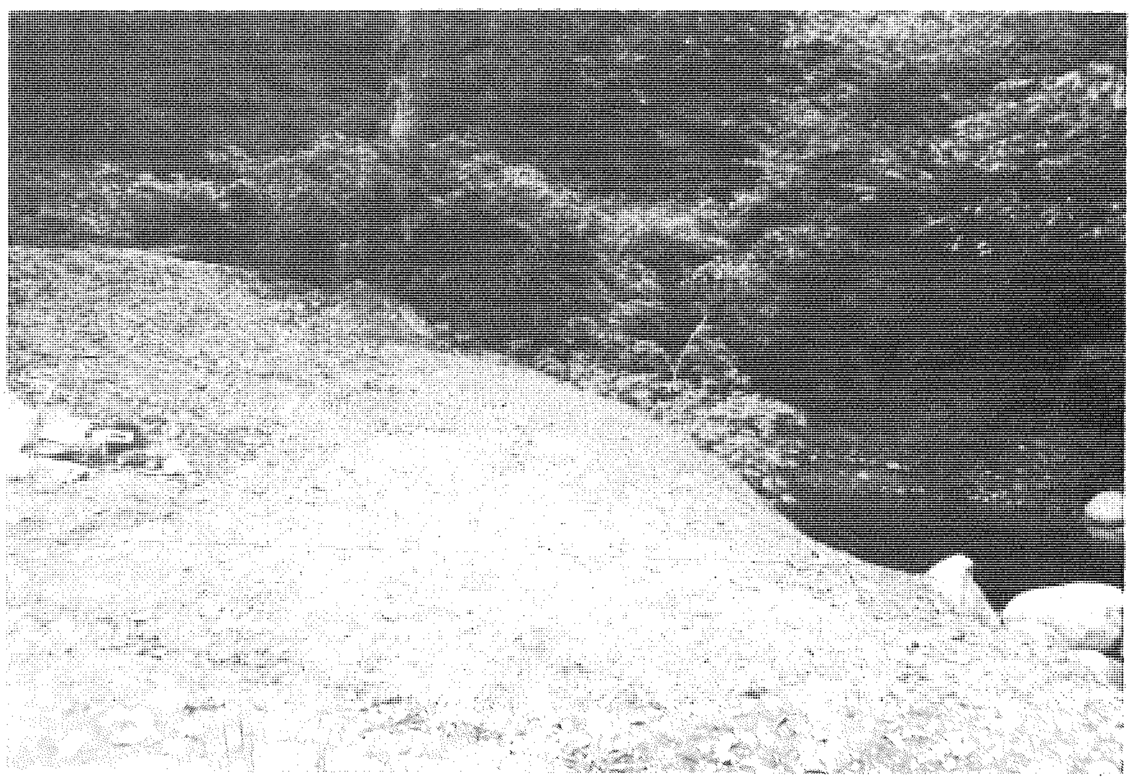


Gravel basin

PLATE WS- 2

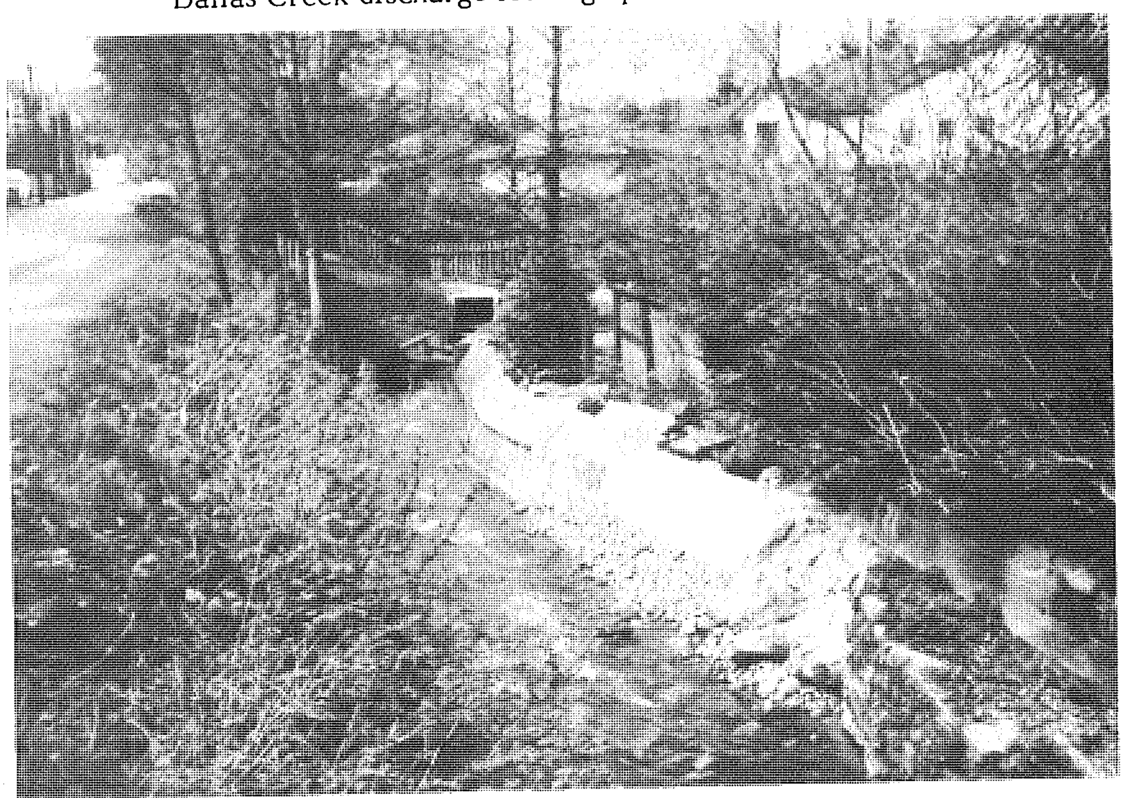
Williams Street Drainage Area

Reach W13
Elgin House Creek, Correl Brook and Dallas Creek (Slaughterhouse Creek)
downstream of confluence, Hope Street alignment crossing in Williams Creek Drainage Area



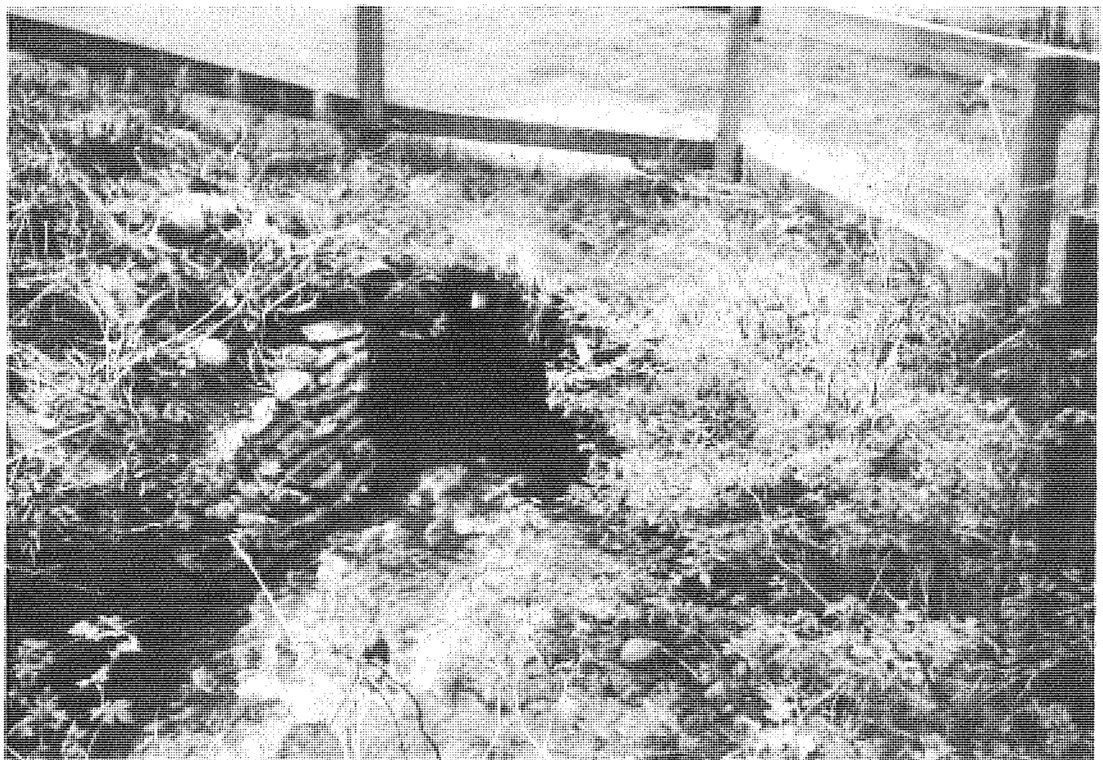
Sediment Pond at Elgin House Creek confluence - September 3, 1987

Reach W14
Dallas Creek discharge looking upstream at Hope Street



Reach W15
Looking downstream at Hope Street

Williams Street Drainage Area



Reach W16
Dallas Creek at St. George Street inlet looking
downstream across St. George Street

Williams Street Drainage Area

Reach W15

Dallas Creek looking upstream from St. Georges Street.

Gabion structures on right bank.

September 9, 1987.

Looking upstream across St. Georges Street

Williams Street Drainage Area

Dallas Creek looking downstream from St. Georges Street flood plain to right. Floods in high flows (confluence of Williams Creek and Dallas Creek in background not visible).

September 9, 1987.

Reach W7

Williams Creek intake and channel at Henry Street above apartments in Williams Creek Drainage Area.

September 3, 1987

Reach W9

Hand placed rock lined channel from Williams Creek looking upstream across St. George Street. Storm drain is sediment filled in upstream reaches and lower section is tapered,

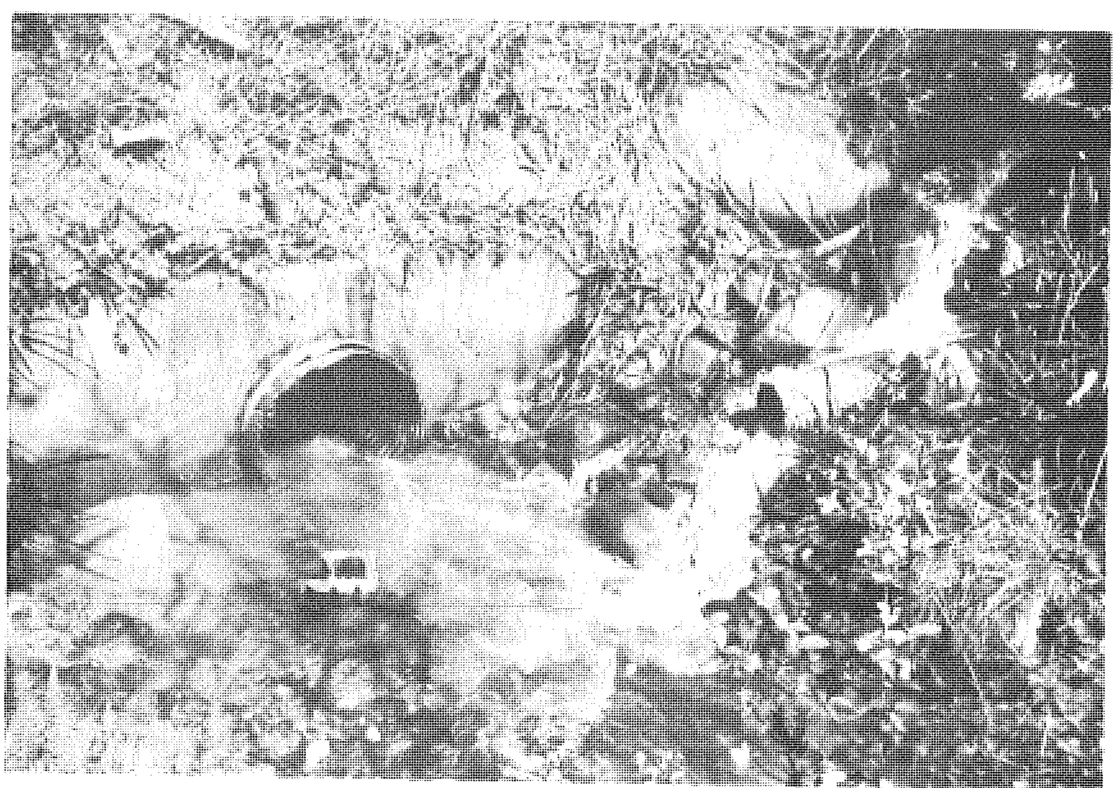
September 9, 1987

Reach W19

St. John Street Crossing below Williams Creek and Dallas Creek confluence.

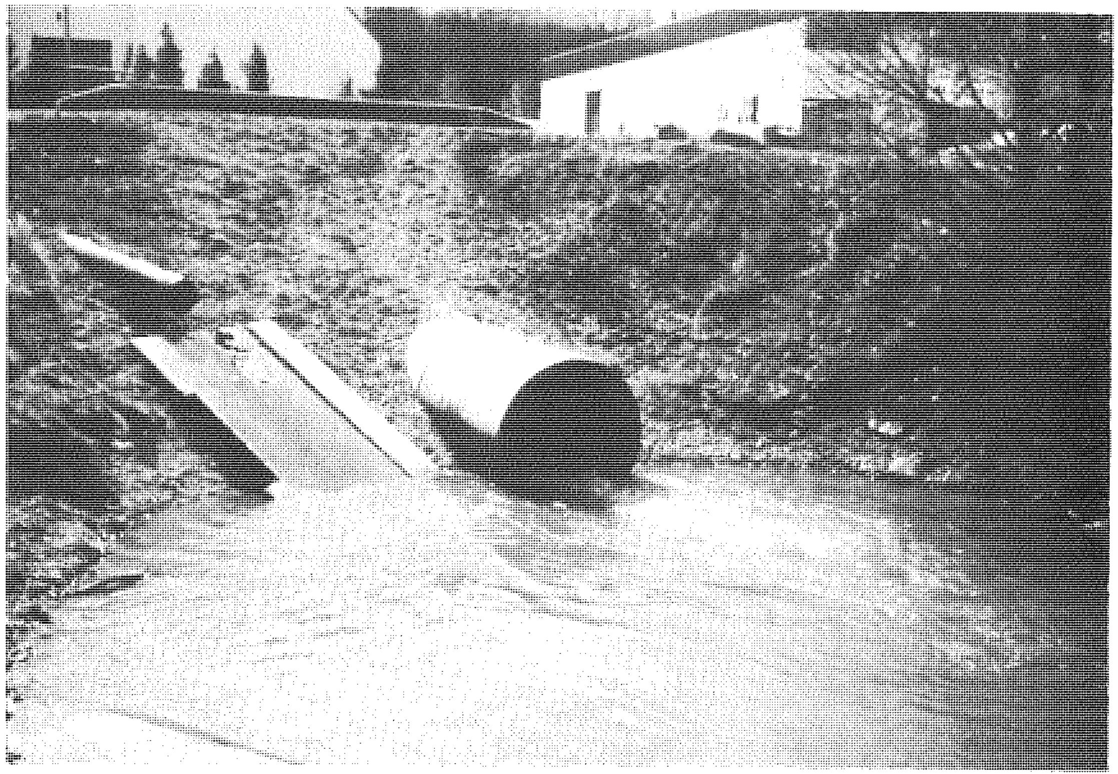
Williams Street Drainage Area

Reach W20
Under warehouse just above C.P. Rail

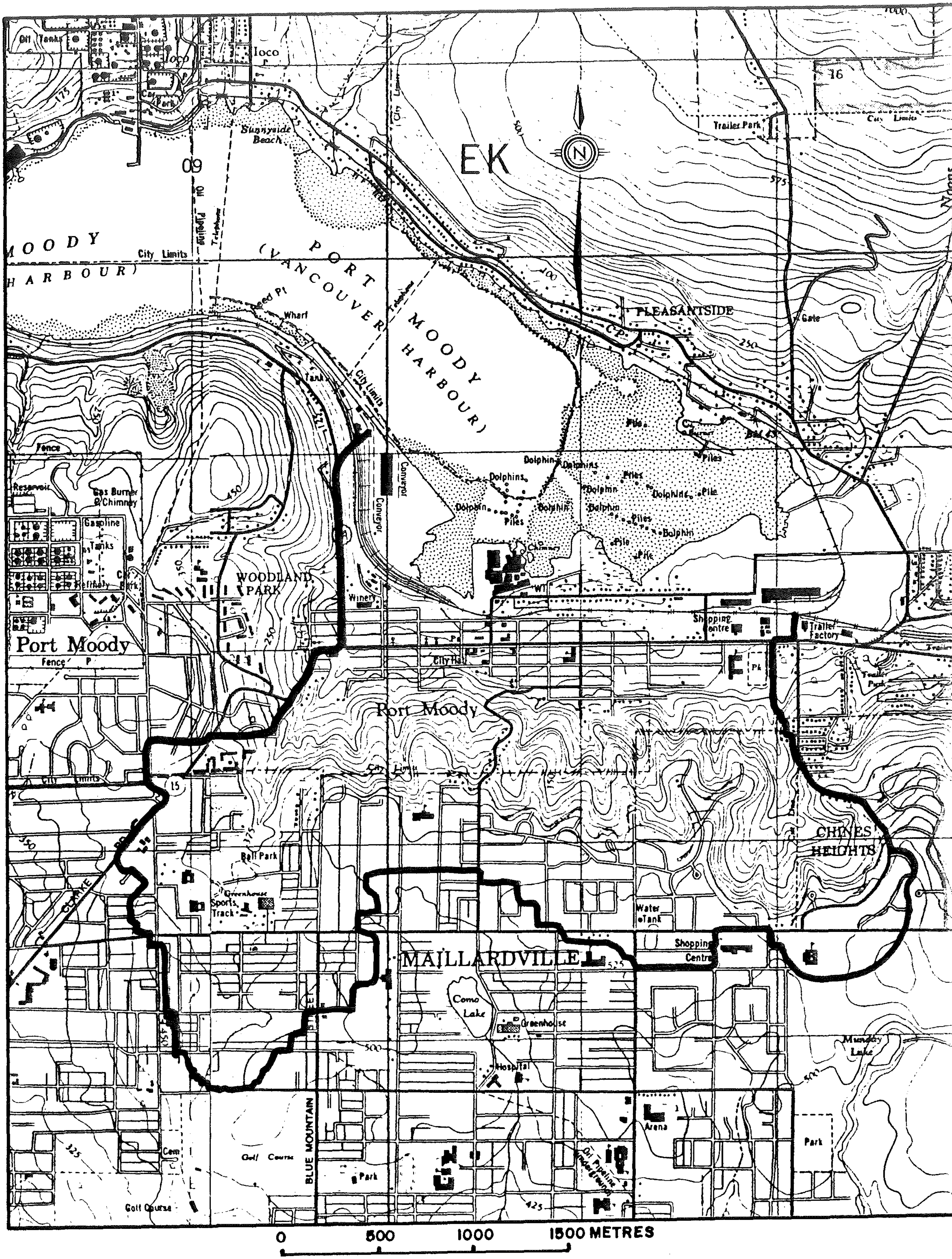


Reach W22
C.P. Rail crossing looking downstream

Williams Street Drainage Area

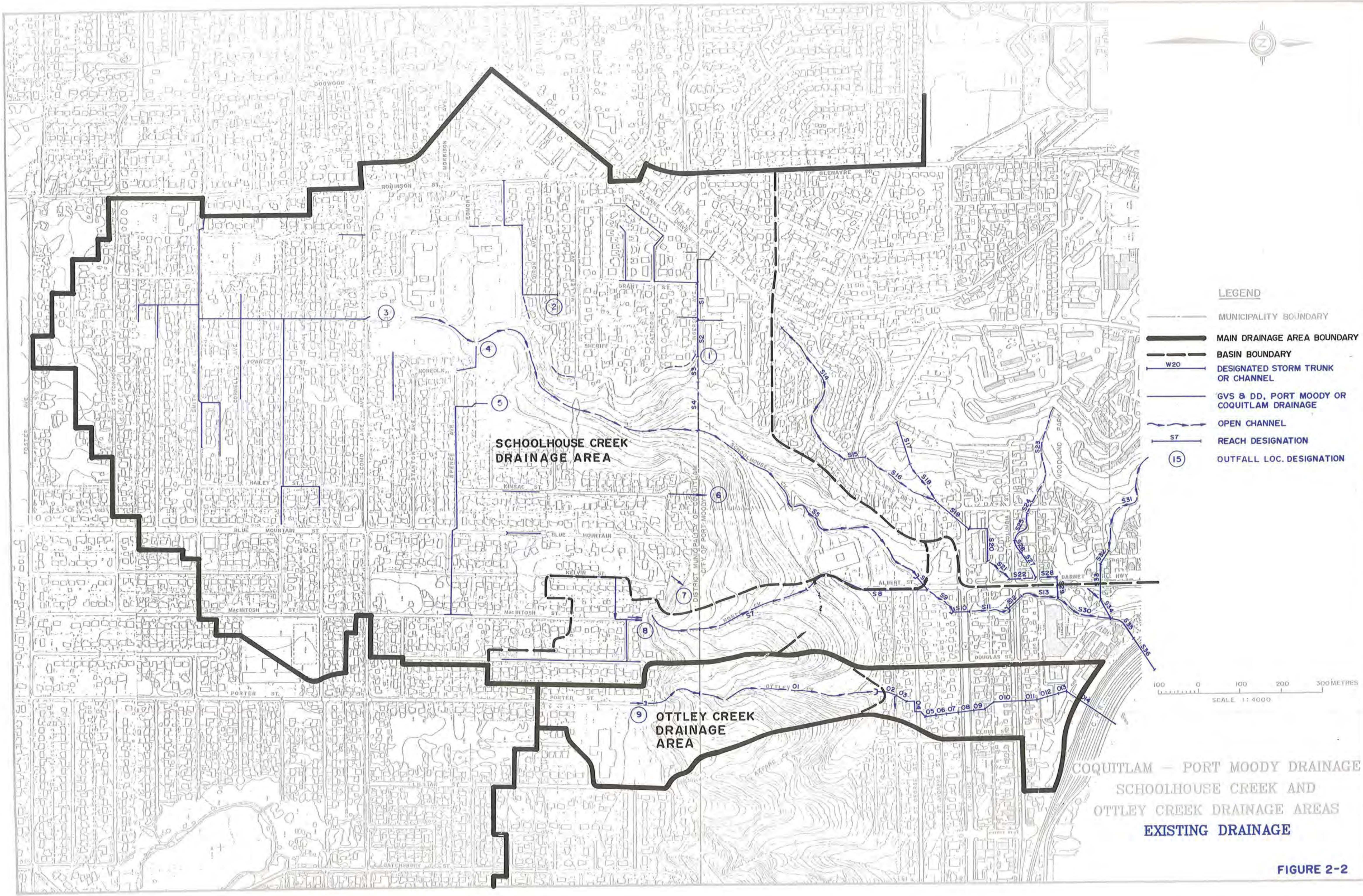


Williams Creek Outfall



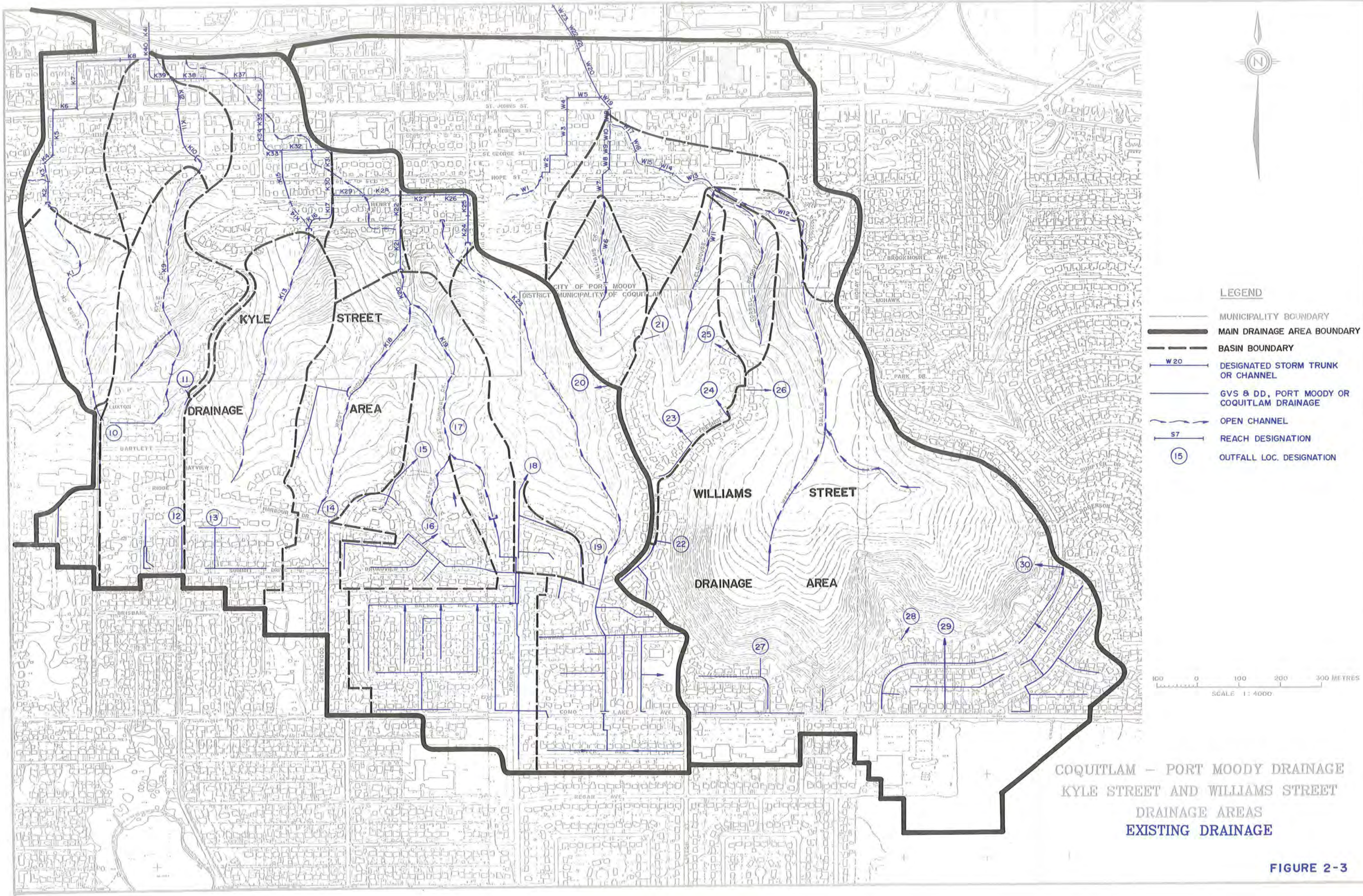
COQUITLAM - PORT MOODY DRAINAGE STUDY AREA

FIGURE 2-1



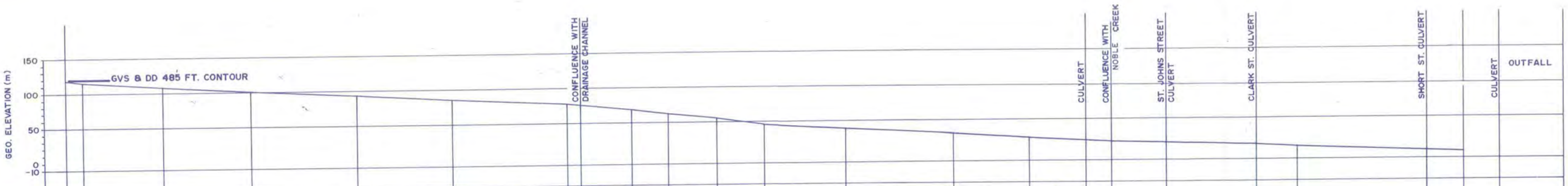
COQUITLAM – PORT MOODY DRAINAGE
SCHOOLHOUSE CREEK AND
OTTLEY CREEK DRAINAGE AREAS
EXISTING DRAINAGE

FIGURE 2-2



COQUITLAM – PORT MOODY DRAINAGE
KYLE STREET AND WILLIAMS STREET
DRAINAGE AREAS
EXISTING DRAINAGE

FIGURE 2-3

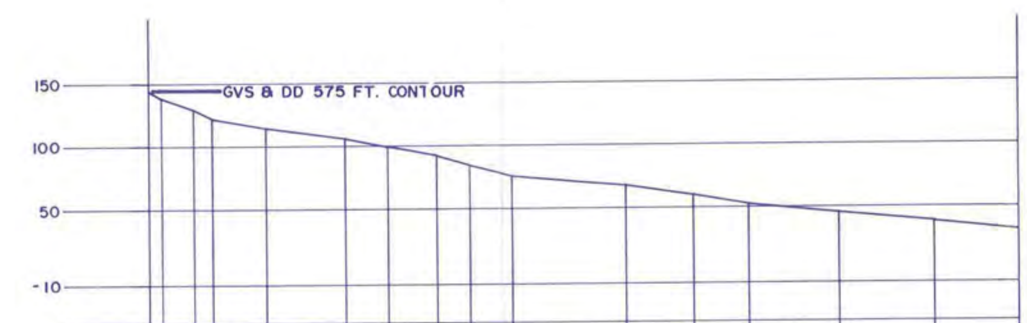


CHANNEL TYPE	A	A	A	B	B	D	D	B	D	B	B	B	B	D	D	–							
HORIZONTAL DISTANCE (m)	24	116	125	152	137	165	18	73	52	70	67	119	155	110	82	37	79	137	58	189	52	52	91
CHANNEL SLOPE (deg.)	7·2	3·8	3·5	2·9	3·2	2·6	4·8	4·8	8·3	6·2	6·5	3·2	2·8	4·0	3·2	2·4	1·1	1·7	3·6	1·8	1·7		

SCHOOLHOUSE CREEK PROFILE

CHANNEL TYPE	A	A	A	A	A	A	A	D	D	B	B	B	E-1	E-1				
HORIZONTAL DISTANCE (m)	12	15	24	24	43	27	37	21	46	58	64	79	64	55	52	104	43	67
CHANNEL SLOPE (deg.)	14·3	26·9	17·6	17·6	10·0	15·8	11·6	19·9	9·4	7·5	6·8	5·5	6·8	7·9	8·3	4·2	10·0	5·2

NOBLE CREEK PROFILE



	A	A	A	D	D	D	E-2	E-2	D	D	D	D		
9	24	15	43	61	34	40	27	34	91	55	43	73	76	70
40·3	17·6	26·9	10·0	7·1	12·6	10·8	15·8	12·6	4·8	7·9	10·0	6·0	5·7	5·0

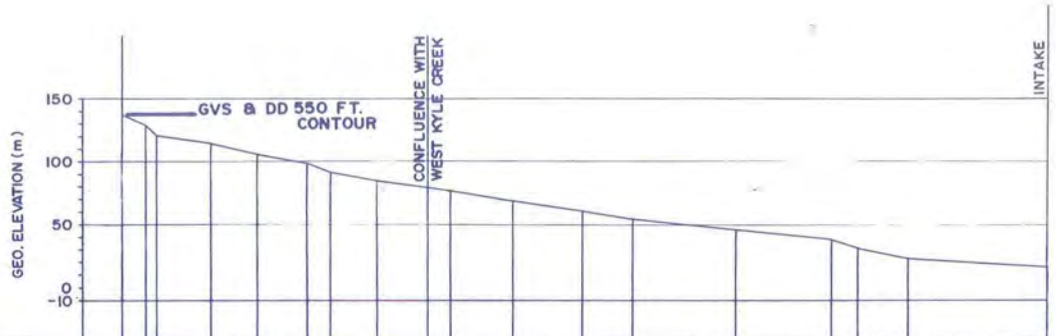
OTTLEY CREEK BASIN PROFILE

CHANNEL TYPE	DESCRIPTION
A	Indistinct channel covered by vegetation, swamp land, no erosion potential.
B	Shallow, ill defined channel, meandering in a wide floodplain.
C	As in B, with occasional points of erosion where channel bends contact the floodplain margin.
D	Relatively straight, well defined channel, little active erosion.
E-1	Relatively straight incised channel, active bank erosion on one side.
E-2	As in E-1, erosion on both sides.
F	Active downcutting.
G-1	Man made channel, vertical walls.
G-2	Man made channel, V-shaped.

COQUITLAM – PORT MOODY DRAINAGE
SCHOOLHOUSE CREEK AND OTTLEY CREEK BASIN PROFILES

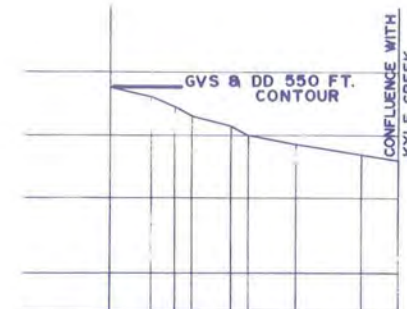
SCALE 1 : 3000

FIGURE 2-4



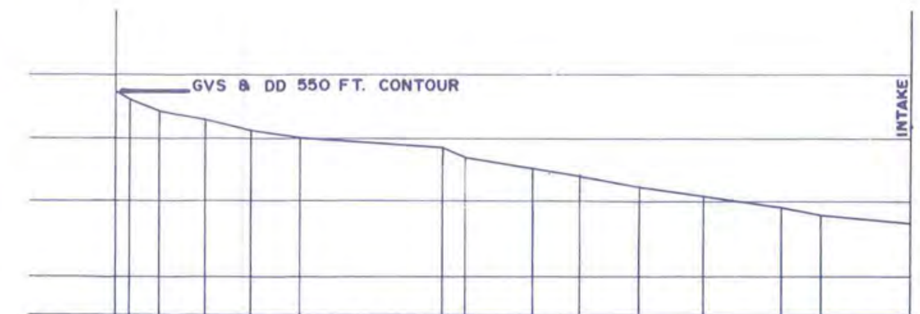
CHANNEL TYPE	A	A	A	A	A	D	D	D	D	D	C	C	C	C	C	C	C
HORIZONTAL DISTANCE (m)	18	9	43	37	40	18	37	40	18	49	55	40	82	76	21	40	110
CHANNEL SLOPE (deg.)	22·9	32·4	10·0	11·6	10·8	22·9	11·6	7·4	7·7	8·8	7·9	10·8	5·3	5·7	19·9	8·8	4·0

KYLE CREEK PROFILE



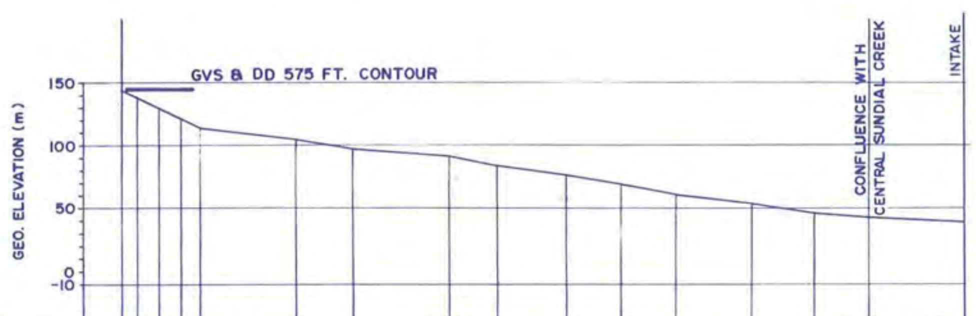
CHANNEL TYPE	A	A	A	A	A	D	D	D
HORIZONTAL DISTANCE (m)	34	18	15	30	15	37	52	30
CHANNEL SLOPE (deg.)	12·6	22·9	26·9	14·3	26·9	11·6	8·3	8·7

WEST KYLE CREEK PROFILE



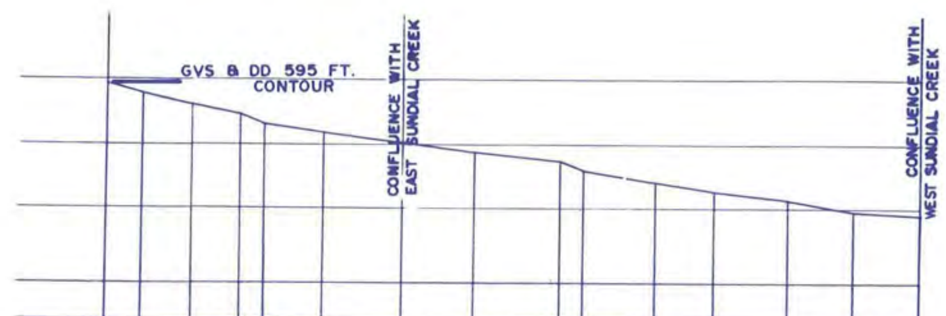
CHANNEL TYPE		A	A	A	A	A	E-1	E-1	E-1	D	D	D	D	D
HORIZONTAL DISTANCE (m)	12	24	37	37	40	113	18	55	37	46	52	61	30	73
CHANNEL SLOPE (deg.)	32·4	17·6	11·6	11·6	10·8	3·9	22·9	7·9	11·6	9·4	8·3	7·1	14·3	6·0

AXFORD CREEK PROFILE



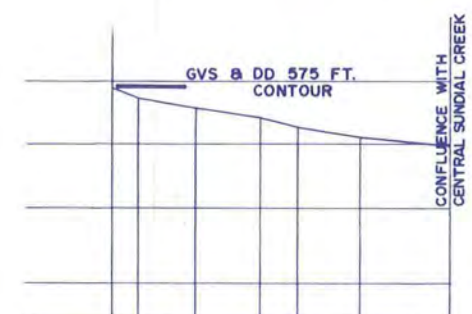
CHANNEL TYPE	A	A	A	A	B	B	B	B	B	B	B	B	B	B	
HORIZONTAL DISTANCE (m)	12	18	18	15	76	46	76	37	52	43	43	58	49	43	76
CHANNEL SLOPE (deg.)	32·4	22·9	22·9	26·9	5·7	9·4	5·7	11·6	8·3	10·0	10·0	7·5	8·8	4·9	3·0

WEST SUNDIAL CREEK PROFILE



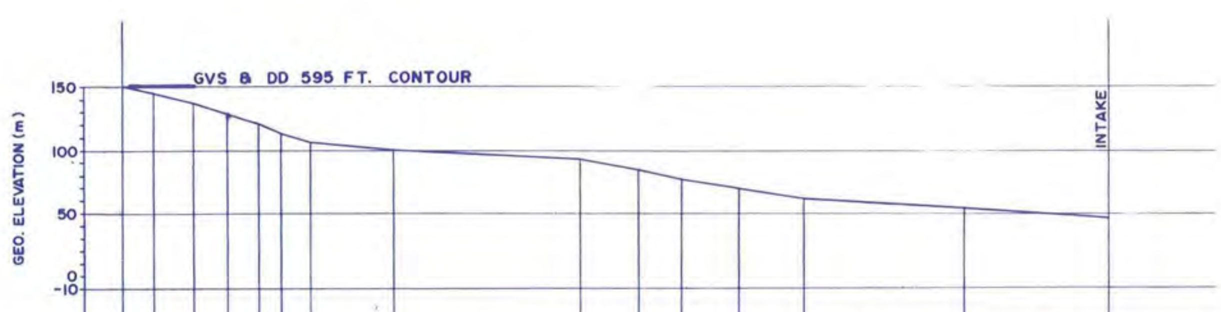
CHANNEL TYPE	A	A	B	B	B	B	C	C	E-1	C	C	C	C	B
HORIZONTAL DISTANCE (m)	27	40	38	18	46	64	55	67	18	55	46	58	52	52
CHANNEL SLOPE (deg.)	15·8	10·8	11·3	22·9	9·4	6·8	7·9	6·5	22·9	7·9	9·4	7·5	8·3	6·2

CENTRAL SUNDIAL CREEK PROFILE



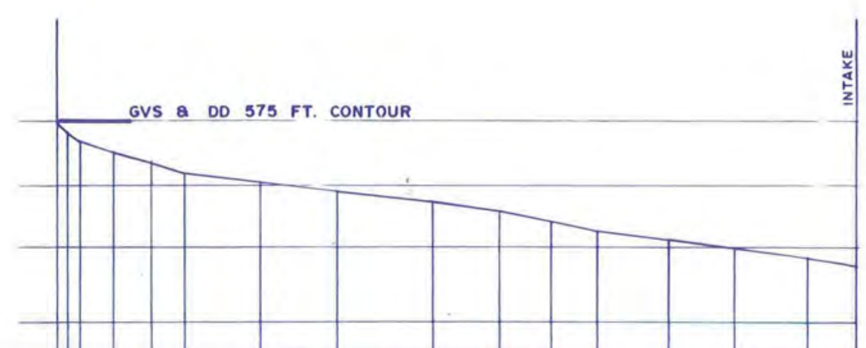
CHANNEL TYPE	A	A	F	F	F	F
HORIZONTAL DISTANCE (m)	21	46	52	30	49	70
CHANNEL SLOPE (deg.)	19·9	9·4	8·3	14·3	8·8	6·2

EAST SUNDIAL CREEK PROFILE



CHANNEL TYPE	A	A	A	A	B	B	B	B	B	B	B	B	B	B
HORIZONTAL DISTANCE (m)	24	31	27	24	18	24	67	149	46	34	46	52	128	116
CHANNEL SLOPE (deg.)	14·3	13·8	15·8	17·6	22·9	17·6	6·5	2·9	9·4	12·6	9·4	8·3	3·4	3·8

GOULET CREEK PROFILE



CHANNEL TYPE	A	A	A	A	A	B	B	B	B	B	B	B	D	D	D
HORIZONTAL DISTANCE (m)	9	11	27	30	27	61	61	76	52	40	37	57	52	58	40
CHANNEL SLOPE (deg.)	40.3	35.5	15.5	14.0	15.5	7.1	7.1	5.7	8.4	10.9	11.8	7.5	8.4	7.5	6.6

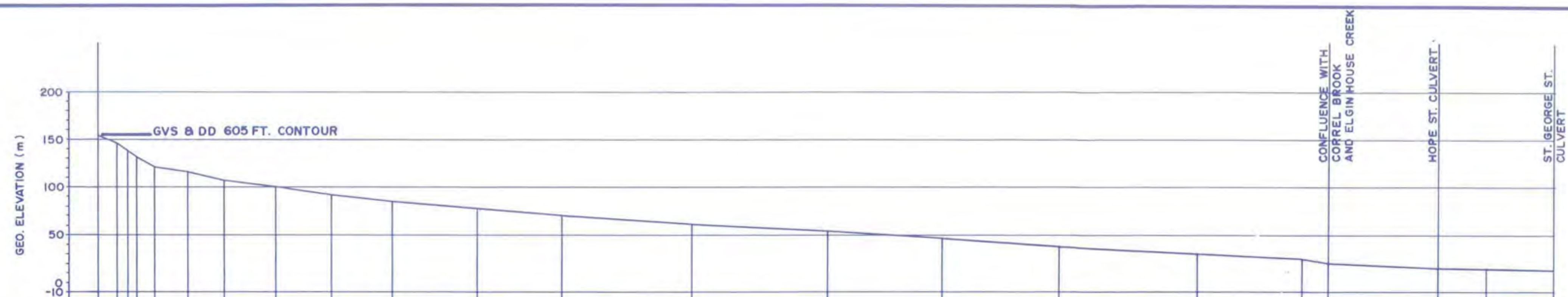
HACHLEY CREEK PROFILE

CHANNEL TYPE	DESCRIPTION
A	Indistinct channel covered by vegetation, swamp land, no erosion potential.
B	Shallow, ill defined channel, meandering in a wide floodplain.
C	As in B, with occasional points of erosion where channel bends contact the floodplain margin.
D	Relatively straight, well defined channel, little active erosion.
E-1	Relatively straight incised channel, active bank erosion on one side.
E-2	As in E-1, erosion on both sides.
F	Active downcutting.
G-1	Man made channel, vertical walls.
G-2	Man made channel, V-shaped.

COQUITLAM – PORT MOODY DRAINAGE
KYLE STREET
BASIN PROFILES

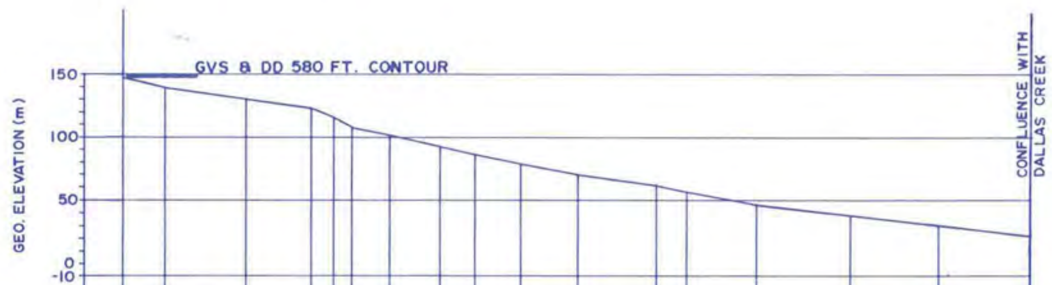
SCALE 1 : 3000

FIGURE 2-5



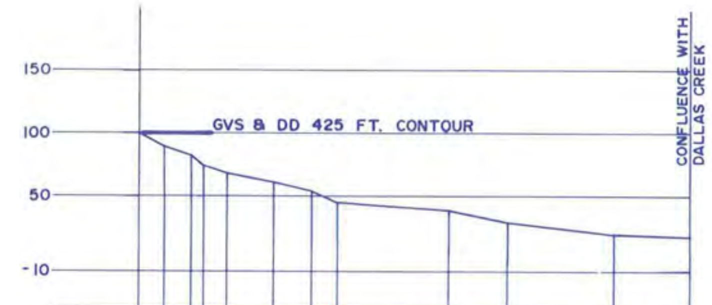
CHANNEL TYPE	A	A	A	A	A	A	B	B	B	B	B	B	B	B	B	B	B	B	G-1	G-1	G-1
HORIZONTAL DISTANCE (m)	21	12	9	18	34	37	55	58	64	88	89	136	143	120	122	147	110	27	117	50	71
CHANNEL SLOPE (deg.)	19·9	32·4	40·3	22·9	12·6	11·6	7·9	7·5	6·8	4·9	4·9	3·2	3·1	3·6	3·6	3·0	4·0	4·5	1·6	2·4	2·2

DALLAS CREEK PROFILE



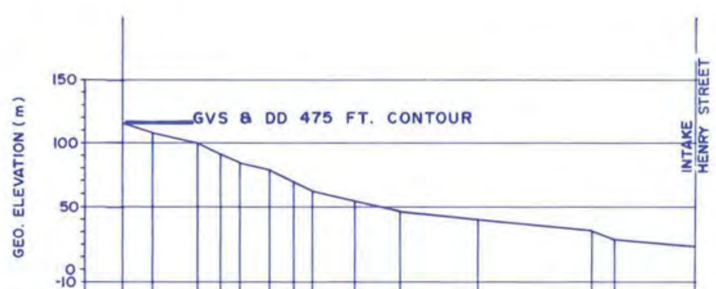
CHANNEL TYPE	A	A	A	C	C	B	B	B	B	B	B	B	B	B	B	B
HORIZONTAL DISTANCE (m)	34	64	52	18	15	30	40	27	37	46	61	24	55	73	79	73
CHANNEL SLOPE (deg.)	12·6	19·5	15·8	22·9	26·9	14·3	10·8	15·8	11·6	9·4	7·1	12·6	7·9	6·0	5·5	6·0

ELGINHOUSE CREEK PROFILE



A	A	A	A	A	A	B	B	B	B	B
21	21	9	18	37	31	21	88	46	86	60
19·9	19·9	40·3	22·9	11·6	13·8	19·9	4·9	9·4	5·1	2·0

CORREL BROOK PROFILE



CHANNEL TYPE	A	A	A	D	D	D	D	B	B	B	B	B	B
CHANNEL DISTANCE (m)	24	37	18	15	24	18	15	34	34	61	91	18	.68
CHANNEL SLOPE (deg.)	17·6	11·6	22·9	26·9	17·6	22·9	26·9	12·6	12·6	7·1	4·8	22·9	4·9

WILLIAMS CREEK PROFILE

CHANNEL TYPE	DESCRIPTION
A	Indistinct channel covered by vegetation, swamp land, no erosion potential.
B	Shallow, ill defined channel, meandering in a wide floodplain.
C	As in B, with occasional points of erosion where channel bends contact the floodplain margin.
D	Relatively straight, well defined channel, little active erosion.
E-1	Relatively straight incised channel, active bank erosion on one side.
E-2	As in E-1, erosion on both sides.
F	Active downcutting.
G-1	Man made channel, vertical walls.
G-2	Man made channel, V-shaped.

COQUITLAM – PORT MOODY DRAINAGE
WILLIAMS STREET
BASIN PROFILES

SCALE 1:3000

FIGURE 2-6

3. CRITERIA

This section establishes the basis for the drainage study through brief description of the runoff processes, selection of the preferred improvements, description of the rainfall-runoff criteria, description of the environmental criteria and presentation of costing criteria. The purpose of this section is to introduce the parameters reasoned appropriate for the analyses described in Section 4. Debris flow criteria are described in Appendix 2 in the geotechnical report.

3.1 Runoff Process

The runoff process is a combination of both hydrologic and hydraulic processes.

3.1.1 Hydrologic Process

The principal aim of urban hydrology is to predict the hydrologic loads, both stormwater volume and peak runoff rates, under existing and future land development conditions.

The runoff process starts with rainfall. Rainfall type, aerial distribution, intensity and pattern affect the runoff process. Only after the rainwater has sufficiently wetted the surface, filled depressions and soaked into pervious ground materials will additional rainfall become runoff. These processes are not well defined nor are they well understood. They are termed initial abstractions and in the cases that were just mentioned are interception, depression storage and infiltration. Antecedent rainfall and ground moisture conditions, soil and cover type, and percentage of pervious or impervious areas which contribute to drainage collectors affect the amount and rate of runoff. The change of surface from pervious to impervious speeds the runoff rate and increases the runoff volume because of a reduction in rainfall losses from surface wetting, depression storage and soil infiltration.

These conditions form the hydrologic components to the runoff process.

3.1.2 Hydraulic Process

Once the overland runoff collects into channels or drainage pipes, it increases to a peak or to several peaks over the duration of and following the end of a storm. The water is stored and released from numerous sections of natural or man-made channels and structures which affect the time-distribution of the runoff hydrograph. Improved or increased hydraulic capacity in the urban drainage system can significantly alter the runoff process. When natural channels are deepened, lined and straightened and when storm sewers are installed, the result reduces watershed storage time and increases the peak rate of runoff. Collected runoff discharging to the gullys from Coquitlam drainage is therefore concentrated and increases erosion potential. Stream channels are rejuvinated and downcutting or toe erosion becomes more evident in the creek. Increased intake, channel and drain capacities through Port Moody are needed as the flows increase.

3.1.3 Runoff Management and Design Method

Rantz (1971) shows that the change from rural to urban, and the construction of storm sewers, without storage detention, have increased drainage peaks from 1 to 4 times for 2-year recurrence rainfalls, to 3 times for 10-year recurrence intervals, to 2.75 times for 25-year, and 2.50 times for 100-year recurrence intervals. Cook (1986) has shown similar effects for a small controlled drainage basin in Ontario. Because of these changes which are brought about by urban development, an attempt must be made to adopt criteria for handling or reducing these potentially dangerous and increased flows.

Drainage design should incorporate a minor and major system. The minor system is normally designed to handle storm flows from 2 to 10-year rainfall recurrence intervals and the major system is designed to handle excess flows up to 25 to 100-year recurrence intervals. The minor system normally handles local drainage from developed areas and remains separate from the major system. The major system provides the higher flood protection level, along streets, in major channels, in special floodways and through large storm sewers. Sometimes an overland route is not feasible for the major system and it must be combined with the minor system in a pipeline, particularly in areas of existing development which were not laid out with the two system concept in mind.

Erosion protection, provisions for sediment transport or reduction and stream pollution also become important.

The minor-major system, erosion-sediment control and pollution are management responsibilities as well as design responsibilities, because management objectives and criteria must be set out for protecting major flood routes, for erosion-sediment reduction and for minimizing the pollution of watercourses.

The natural major drainage in the gullys is in place in the form of the creeks; however the creeks flow more frequently at higher flows as a result of concentrated runoff. In Port Moody, where open channels remain, the major floodways have been encroached upon by development.

3.2 Flood and Debris Flow Management Options

If flood and debris flow control by construction of drainage works is the desired solution, management options include the following:

1. Improved channel hydraulics.
2. Diversion of portions or all of the flow.
3. Delay of peaks through detention facilities.
4. Purchase of floodplain and use restrictions.
5. Combinations of the above.

Option 3, delay by storage is not appropriate unless the gullies can be used.

This is not considered in the analysis. Options 1 and 2 become appropriate, although for protection from loss of life, Option 4 is considered.

3.2.1 Management Plan

Briefly, the stormwater management plan analysis for Port Moody / Coquitlam is to include major channel definition for 100-year flow recurrence, 10-year flow recurrence, and for the catastrophic event which includes boundaries for debris and mud flows as well as flooding.

Following sections deal with the rainfall-runoff process and modelling criteria.

3.3 Rainfall

Rainfall drives the runoff process. The considerations given to rainfall in calculating runoff and their subsequent peak flows include effects of area, intensities, rainfall duration, return frequencies, and the distribution of the rainfall over a given duration. Present limitations in data necessitated simplification from the use of actual storms by selection of a design storm which reflects intensity, rainfall patterns and probability for a particular duration. The design storm is developed from rainfalls recorded over a period of years in the basin.

Long-term rainfall and short-term rainfall requirements are a reflection on basin size and study needs. For this study short-term rainfall is considered only.

3.3.1 Area Effects

For drainage watersheds of 26 km^2 or greater, percentage reduction in average rainfall intensities which have recurrence intervals of 2 to 100 years and durations of ½ to 24 hours are proportional to the size of the basin. Because the largest basin modelled in the Port Moody / Coquitlam study is approximately 3 km^2, this study did not include a reduction factor.

3.3.2 Design Intensity, Duration Frequency Curves

The short-term (less than 24 hours) rainfall intensity, duration, frequency (IDF) data for Port Coquitlam is presented on Figure 3-1.

Further, for the Port Moody - Coquitlam watersheds and upper Fraser Valley, isohyetals or lines of equal rainfall for durations of 30 minutes, 60 minutes, 6 hours and 24 hours and for 5, 10 and 100-year return period events are presented on Figures 3-2, 3-3 and 3-4. The rainfall duration and rainfall return periods are from the intensity-duration-frequency (IDF) curves at 16 Atmospheric Environment Service monitoring stations as identified on the figures.

For Port Moody / Coquitlam analysis, the IDF curve for Port Moody Gulf Oil Refinery as presented in Figure 3-1 was used. A limitation is that the IDF curve is for years of record 1971-1983, and as a consequence, the 50 and 100 year return period curves are estimates. However, the curve does fit well with the isohyetals and is considered useable for the Port Moody / Coquitlam study.

3.3.3 Design Rainfall Pattern

Atmospheric Environmental Service (Hogg) has produced probability curves for short (1 hr) and long (12 hrs) storm patterns which can be used in conjunction with the IDF curves, Figure 3-1 to produce isohyets for chosen durations. The patterns are shown in Figures 3-5 and 3-6.

3.3.4 Design Hyetograph

This study chose the median value from Figures 3-5 and 3-6 for preparation of design storm isohyets for 1 hr, 6 hr and 12 h durations. Discretization was 5 minute intervals for 1 to 12 hr storms.

3.4 Runoff Modelling

Topographic relief, soil conditions, imperviousness, antecedent moisture condition, drainage density, and basin shape determine the amount of runoff from a given rainfall. Hydrologic modelling using mathematic representations of these parameters is used to calculate the runoff hydrographs for the reaches in the study area.

3.4.1 Planning Model Criteria

The OTTHYMO hydrologic model (Wisner, 1984) was used as the hydrologic planning model for the Coquitlam / Port Moody study. The physical parameters used to determine the runoff are given in Table 3-1 as the basin criteria.

3.5 Environmental Criteria

Environmental requirements are divided into two areas: 1. public protection, and 2. stream habitat protection.

Public protection for debris flow is assumed to require safeguards against loss of life. For floodloss, property improvements are assumed to be damaged as a percent of level affected by flood.

All work proposed within the floodplain should first be referred to the Ministry of Environment, Water Management Branch, for approval. It is unlawful to fill in floodplain areas.

Designated fish-bearing creeks are shown on Figures 2-2 and 2-3. Protection against indiscriminate discharges of harmful materials into the channels and storm drain should be made.

3.6 Costing

The following 1988 construction costing criteria were used in developing alternatives:

TABLE 3-1

Port Moody / Coquitlam Drainage Area
Design Criteria for OTTHYMO Drainage Model

Drainage Area	Bain	Subbasin Developed - U Not Developed - R		Area (ha)	Impervious Direct % DI	Impervious Total % TI	Soil Type	Infiltration Rate - U Init. mm/hr	Final mm/hr	Decay L/hr	Initial Moisture mm	tp* hrs	Weighted SCS Curve No.	Depression Storage* Imper-vious %	Per-vious mm	Overland Flow - Kinematic Wave Routing: Impervious SLI %	LGI m	N	Pervious SLP %	LGD m	N
Schoolhouse Creek	Schoolhouse	1U	(C)	70	33	36	C	3.8	2.5	0.14	25	-	-	1.5	4.0	2.3	1050	.015	5.0	30	.035
		2U	(C)	42	31	33	C	3.8	2.5	0.14	25	-	-	1.5	4.0	5.4	500	.015	2.0	200	.035
		3U	(C)	37	33	36	C	3.8	2.5	0.14	25	-	-	1.5	4.0	1.0	480	.015	5.0	50	.035
		4R	Gully	28	0	0	C	-	-	-	-	.15	85	-	-	-	-	-	-	-	-
		5R	Fan	8	0	0	C	-	-	-	-	.07	85	-	-	-	-	-	-	-	-
		6U	(PM)	6.8	33	36	C	3.8	2.5	0.14	25	-	-	1.5	4.0	2.0	200	.015	2.0	30	.035
	Noble	7R	Noble Ck.	5.9	0	0	C	-	-	-	-	.067	85	-	-	-	-	-	-	-	-
	Schoolhouse West Br.	8U	West Br.	50	20	22	C	3.8	2.5	0.14	25	-	-	1.5	4.0	6.6	800	.015	13.3	300	.035
	Schoolhouse North Br.	9U	North Br.	48	25	27	C	3.8	2.5	0.14	25	-	-	1.5	4.0	10.6	170	.015	15.2	500	.035
	Schoolhouse Main Br.	10U	Main Br.	15.8	33	36	C	3.8	2.5	0.14	25	-	-	1.5	4.0	3.6	450	.015	8.0	30	.035
Ottley Creek	Ottley	1U	(C)	5.5	10	13	C	3.8	2.5	0.14	25	-	-	1.5	4.0	2.0	300	.015	2.0	50	.035
		2R	Gully	12	0	0	C	-	-	-	-	.063	8	-	-	-	-	-	-	-	-
		3U	(PM)	9.6	33	36	C	3.8	2.5	0.14	25	-	-	1.5	4.0	8.0	200	.015	25.0	30	.035
Kyle Street	Goulet	1&2U	(C)	18.2	33	36	C	3.8	2.5	0.14	25	-	-	1.5	4.0	2.0	300	.015	2.0	30	.035
	Goulet	3R	Gully	19.7	-	-	C	-	-	-	-	.109	85	-	-	-	-	-	-	-	-
	Sundial E	4U	(C)	17.6	33	36	C	3.8	2.5	0.14	25	-	-	1.5	4.0	2.0	350	.015	2.0	30	.035
	Sundial C	5U	(C)	7.0	33	36	C	3.8	2.5	0.14	25	-	-	1.5	4.0	2.0	350	.015	2.0	30	.035
	Sundial E	6R	Gully	9.6	-	-	C	-	-	-	-	.083	85	-	-	-	-	-	-	-	-
	Sundial W	7U	(PC)	7.4	33	36	C	3.8	2.5	0.14	25	-	-	1.5	4.0	4.0	150	.015	5.0	100	.035
	Sundial	8U	Gully	14.3	-	-	-	-	-	-	-	.077	85	-	-	-	-	-	-	-	-
	Intakes	9U	(PM)	2.7	33	36	C	3.8	2.5	0.14	25	-	-	1.5	4.0	12.0	120	.015	13.0	30	.035
	Intakes	10U	(PM)	3.4	33	36	C	3.8	2.5	0.14	25	-	-	1.5	4.0	11.0	90	.015	13.0	30	.035
	Hachley	11U	(C)	8	33	36	C	3.8	2.5	0.14	25	-	-	1.5	4.0	3.6	250	.015	4.0	30	.035
	Hachley	12R	Gully	13.3	-	-	C	-	-	-	-	.088	85	-	-	-	-	-	-	-	-
	Intake	13U	(PM)	12.7	33	36	C	3.8	2.5	0.14	25	-	-	1.5	4.0	8.1	700	.015	20.0	30	.035
	Kyle	14U	(C)	8.0	33	36	C	3.8	2.5	0.14	25	-	-	1.5	4.0	4.5	400	0.015	5.3	30	.035
	Kyle	15R	Gully	11.9	-	-	C	-	-	-	-	.076	85	-	-	-	-	-	-	-	-
	Intake	16U	(PM)	7.5	33	36	C	3.8	2.5	0.14	25	-	-	1.5	4.0	5.4	300	.015	6.3	30	.035
	Axford	17U	(C)	3.0	33	36	C	3.8	2.5	0.14	25	-	-	1.5	4.0	4.5	400	.015	5.3	30	.035
	Axford	18R	Gully	7.2	-	-	C	-	-	-	-	.058	85	-	-	-	-	-	-	-	-
	Intake	19U	(PM)	8.0	33	36	C	3.8	2.5	0.14	25	-	-	1.5	4.0	5.8	350	.015	12.5	30	.035
William Street	Dallas	1U	(C)	35.5	33	36	C	3.8	2.5	0.14	25	-	-	1.5	4.0	2.7	600	.015	17.5	460	.035
	Dallas	2R	Gully	52.8	-	-	C	-	-	-	-	.153	85	-	-	-	-	-	-	-	-
	Correl	3R	Gully	5.3	-	-	C	-	-	-	-	.048	85	-	-	-	-	-	-	-	-
	Elgin House	4U	(C)	3.4	33	36	C	3.8	2.5	0.14	25	-	-	1.5	4.0	10.0	30	.015	23.6	220	.035
	Elgin House	5R	Gully	7.7	-	-	C	-	-	-	-	.053	85	-	-	-	-	-	-	-	-
	Intake	6U	(PM)	11.7	17	19	C	3.8	2.5	0.14	25	-	-	1.5	4.0	2.8	400	.015	23.3	300	.035
	William	7R	Gully	7.2	-	-	C	-	-	-	-	.05	85	-	-	-	-	-	-	-	-
	Intake	8U	(PM)	43.7	33	36	C	3.8	2.5	0.14	25	-	-	1.5	4.0	1.7	700	.015	6.4	50	.035

* tp = $6.54\, A^{0.39} S^{0.5}$ S = H ft, A = mi^2
** d = $0.77\,(\text{slope})^{-0.49}$
C = Coquitlam
PM = Port Moody

1. Diversion Construction (Part 1, Appendix 6)

a) Easy construction

- 1,500 mm dia concrete pipe	$ 900	/m
- 1,200 mm dia concrete pipe	$ 720	/m
- 1,050 mm dia concrete pipe	$ 560	/m

b) Easy ditching

- side casting and restoration	$ 10	$/m^3$
- trucked from site	$ 20	$/m^3$

2. Culverting

Box culverting - 2,400 x 1,500 sections	$ 1,700	/m
Headwall construction, each	$ 6,000	each
(For pipe see 1 above)		

3. Debris Basin Facilities

Control structure, concrete block	$15,000	each
Excavation, easy	$25,000	/ha-m
Fencing	$ 30	/m
Paving	$ 50	/m
Topsoil and seeding	$ 8,000	/ha
Rip-rap, hand placed	$ 7.50	$/m^2$

4. Channel Improvements

a) Earthwork

- sidecast and restoration	$ 6	$/m^3$
- trucked from site	$ 12	$/m^3$
- rock lining 9-10 m^2/lin metre	$ 80	$/m^3$

b) Levee construction (without ditching)

- 1 m wide, 6:1 and 2:1 slopes		
- local material	$ 6	$/m^3$
- hauled in	$ 16	$/m^3$

c) Planting and Restoration	$ 30	/m
d) Cleaning ($70/hr, crew and truck)	$3-5.00	/m

5. Engineering and Contingencies

Cost increase over basic construction cost	25%

6. Land Purchase

a) Non-urban	$50,000	/ha
b) Urban	125% of assessed value	

7. Flood Losses - Damages to Structures and Contents
Adapted from US Army Corps of Engineers (1978)

a)	Direct debris flow	100% structural 100% to contents
b)	Indirect debris (mud) flow	50% structural 50% to contents
c)	Flooding of single family units to average depth of 1 foot (assuming all houses are 1 storey, 70% of houses have basements, and contents are worth 40% of structural value)	10% structural 14% to contents
d)	Flooding of multi-family units and commercial-industrial complex to average depth of 1 foot (assuming contents are worth 65% of structural value)	7% structural 11% to contents

8. Operating Costs
   - Erosion reinstatement and general inspection maintenance

debris basin	$3,000-$7,500 / yr-basin
channel	$ 1,000 /yr-km

3.7 References

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Wisner (1984) Paul and Choon-Eng P'ng, "OTTHYMO a Model for Master Drainage Plans", Part III IMPSWM Procedures, Level II, Method. University of Ottawa, Ottawa, Ontario.

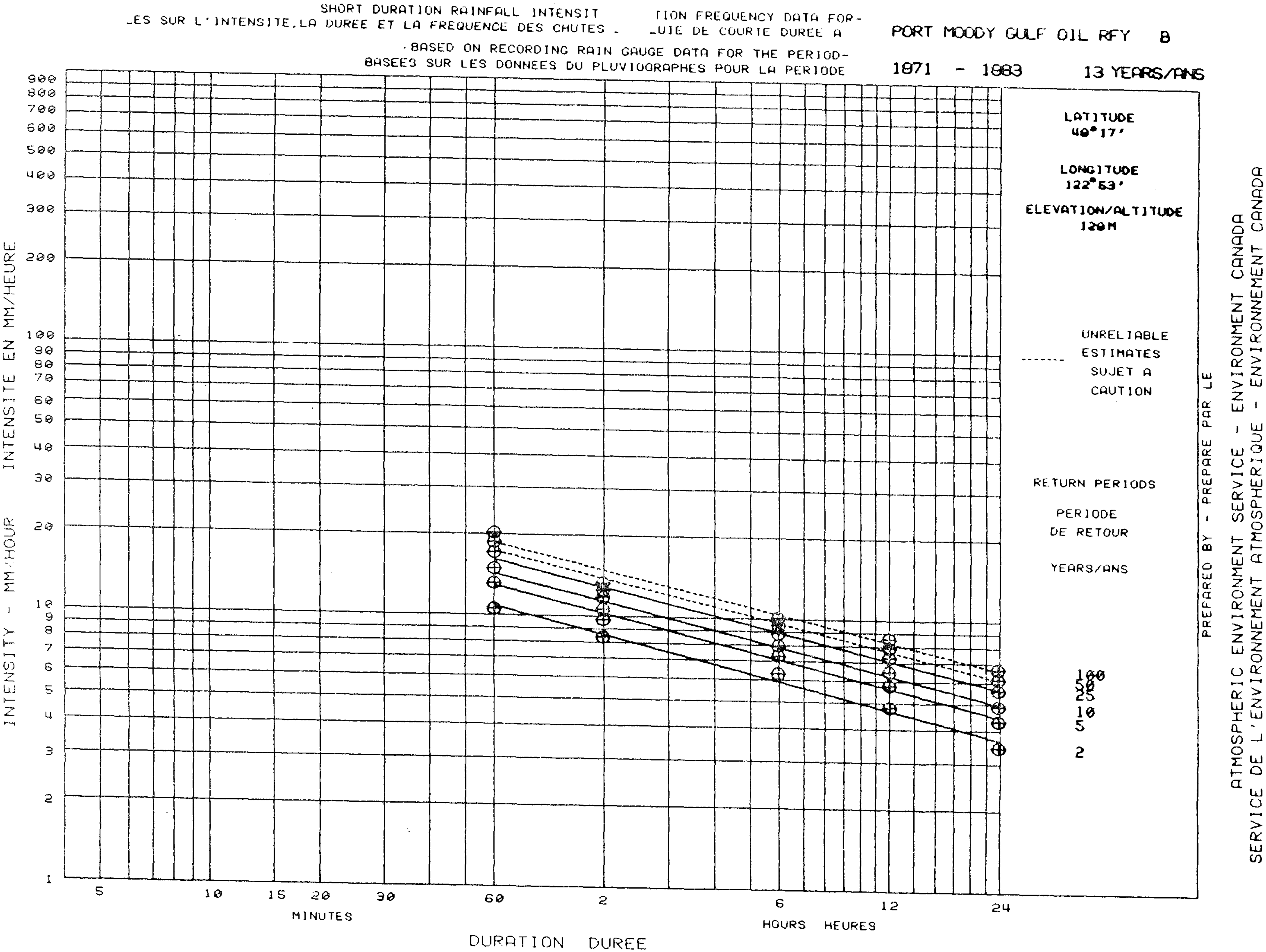
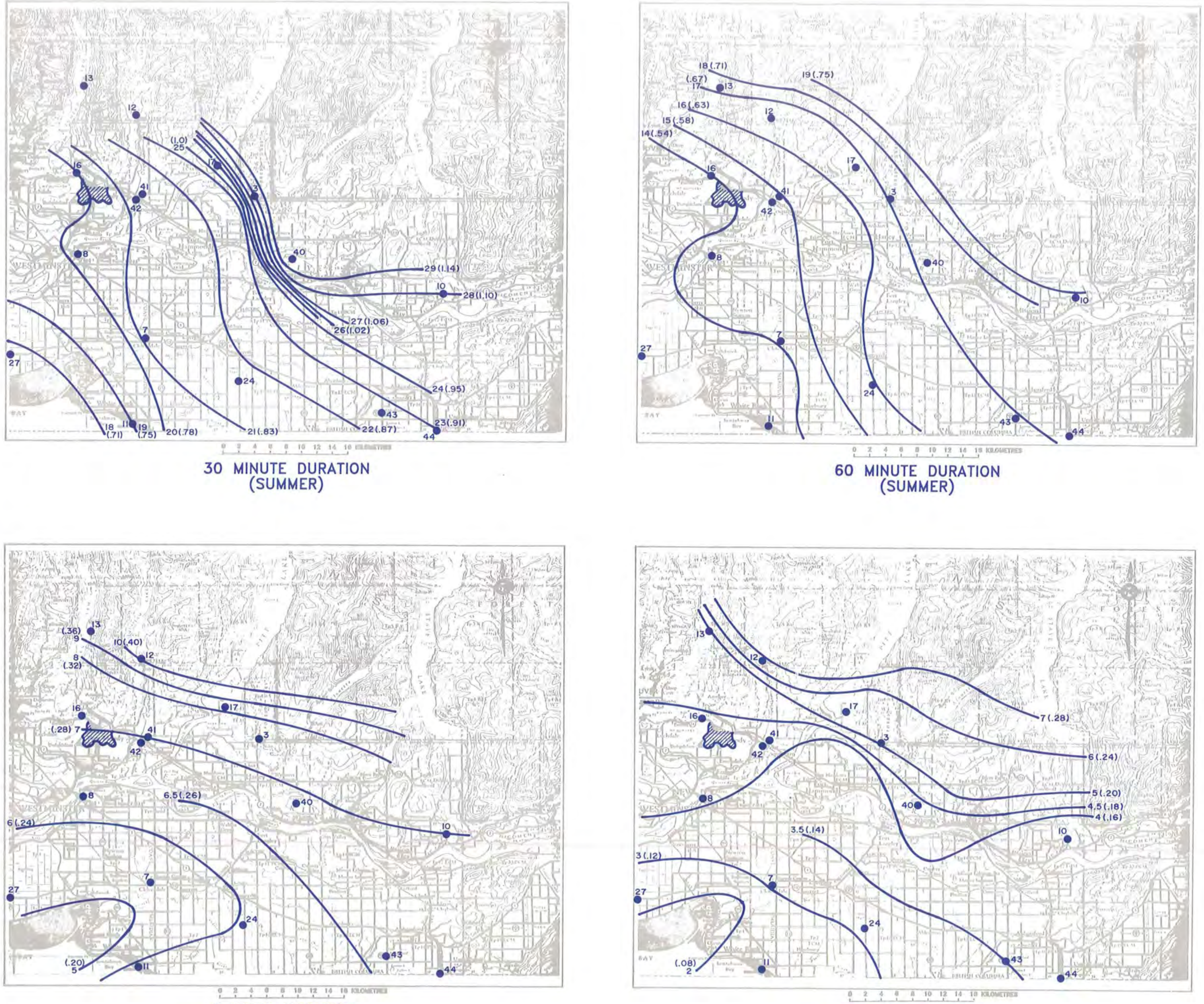


FIGURE 3-1 INTENSITY, DURATION, FREQUENCY CURVES



30 MINUTE DURATION (SUMMER)

60 MINUTE DURATION (SUMMER)

6 HOUR DURATION (WINTER)

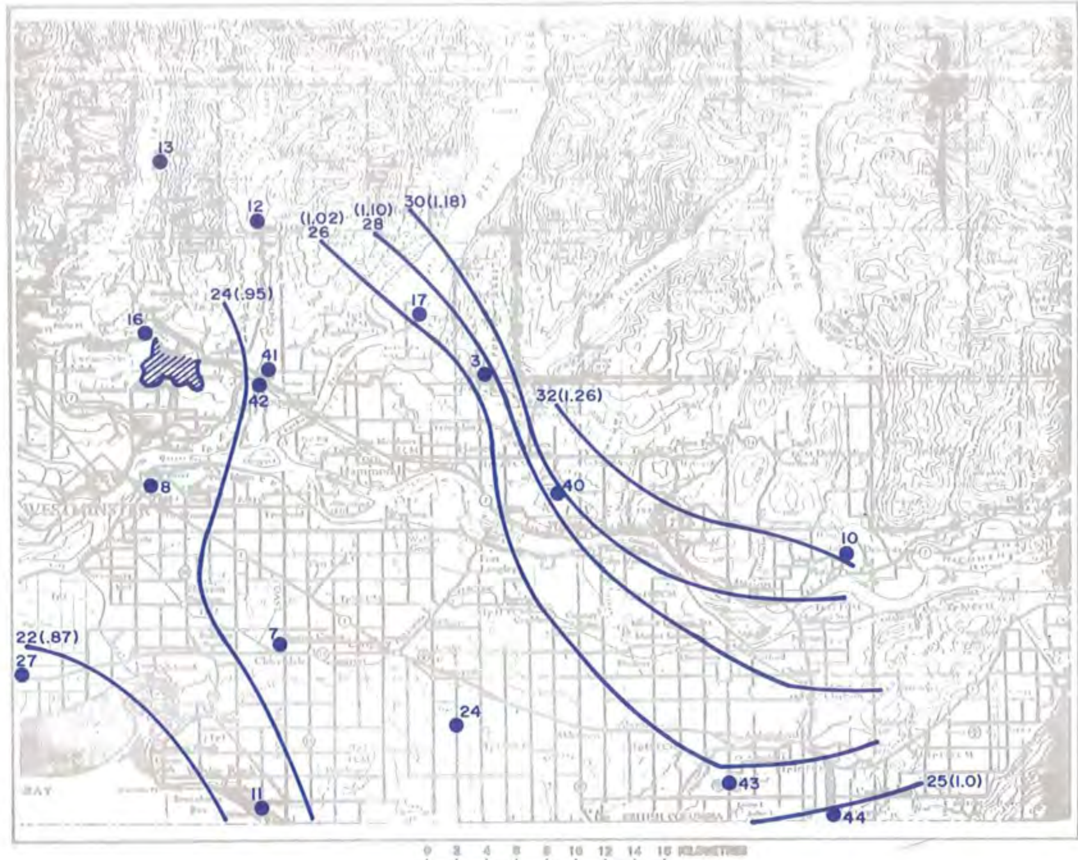
24 HOUR DURATION (WINTER)

LEGEND

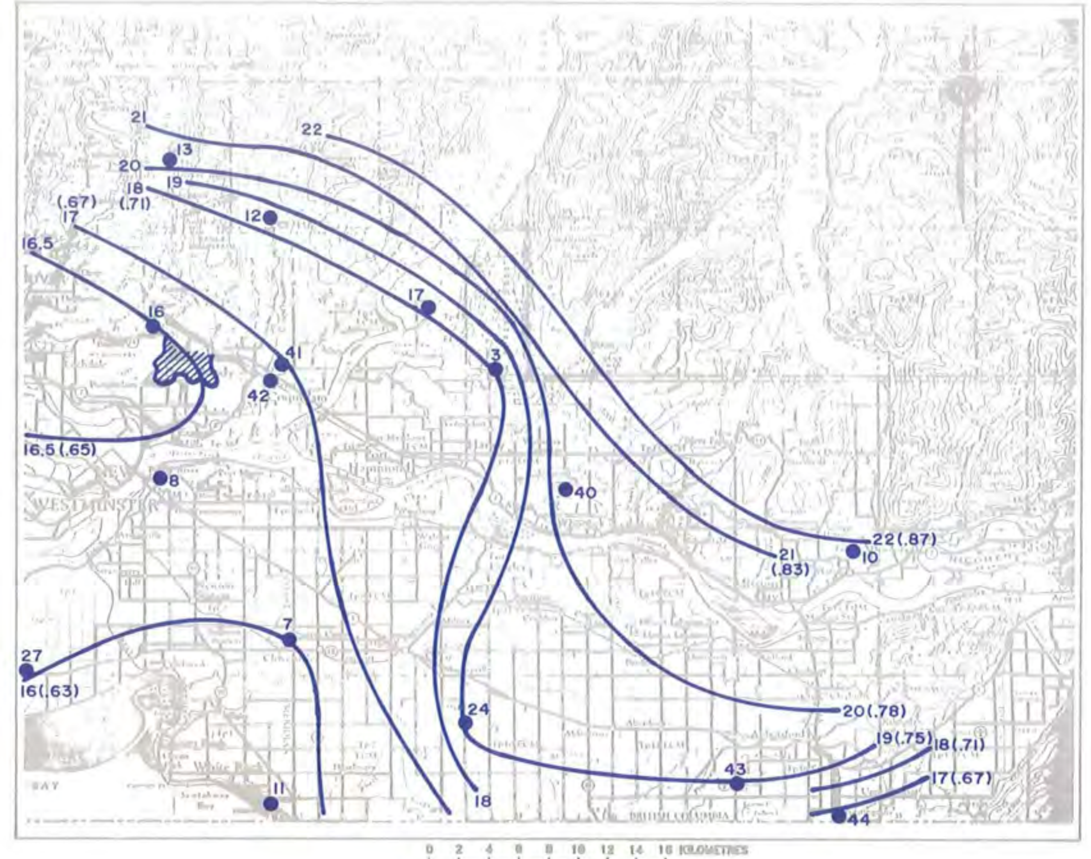
(hatched)	STUDY AREA BOUNDARY
●	RAINFALL STATION (DENOTES RAINFALL STATION LOCATION)
— 7 (2.8)	ISOHEYETS AND RAINFALL INTENSITY mm/hr. (In./hr.)
	NOTE : ISOHEYETS INFORMATION FROM INTENSITY -DURATION – FREQUENCY CURVES FOR STATIONS LISTED BELOW
3	UBCRF ADMIN.
7	SURREY MUNICIPAL HALL
8	SURREY KWANTLEN PARK
10	MISSION WEST ABBEY
11	WHITE ROCK STP
12	COQUITLAM LAKE
13	BUNTZEN LAKE
16	PORT MOODY GULF OIL
17	PITT POLDER
24	LANGLEY LOCHIEL
27	LADNER
40	HANEY MICROWAVE
41	PORT COQUITLAM CITY YARD
42	PORT COQUITLAM MUNICIPAL HALL
43	ABBOTSFORD AIRPORT
44	HUNTINGDON METER STATION

5 YEAR RECURRENCE AVERAGE RAINFALL INTENSITY (mm/hr.)

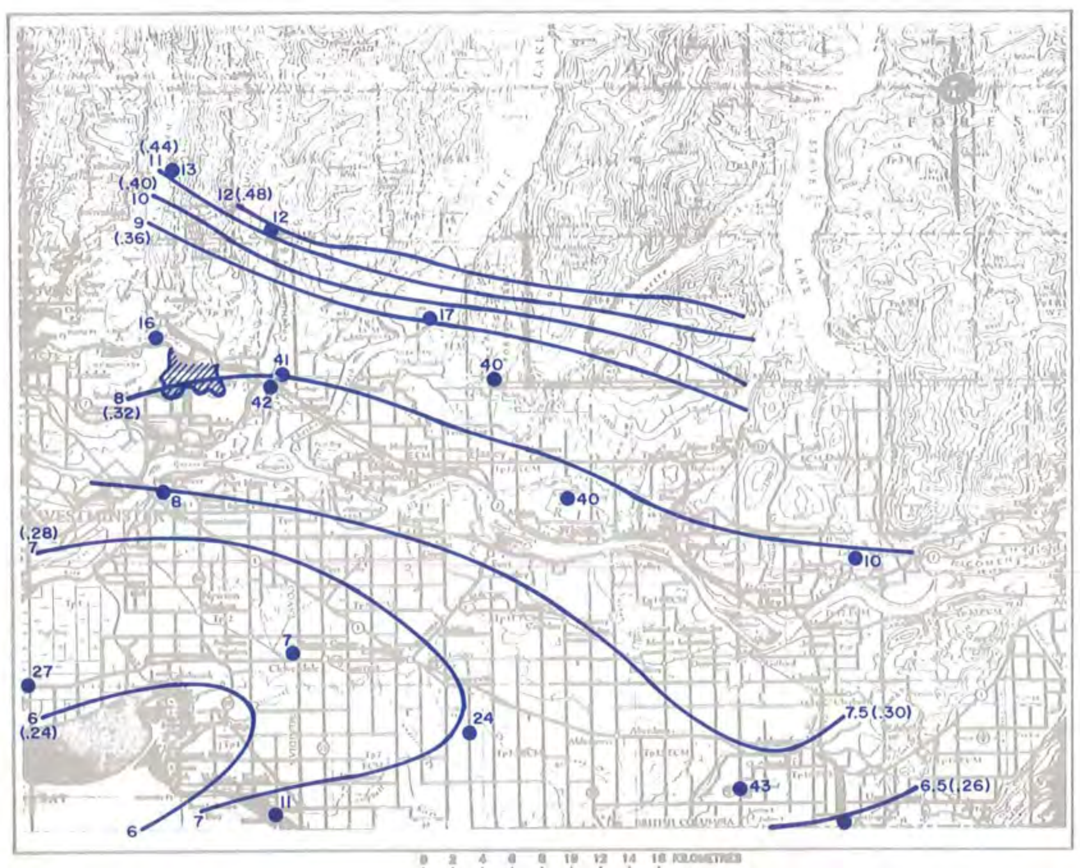
FIGURE 3-2



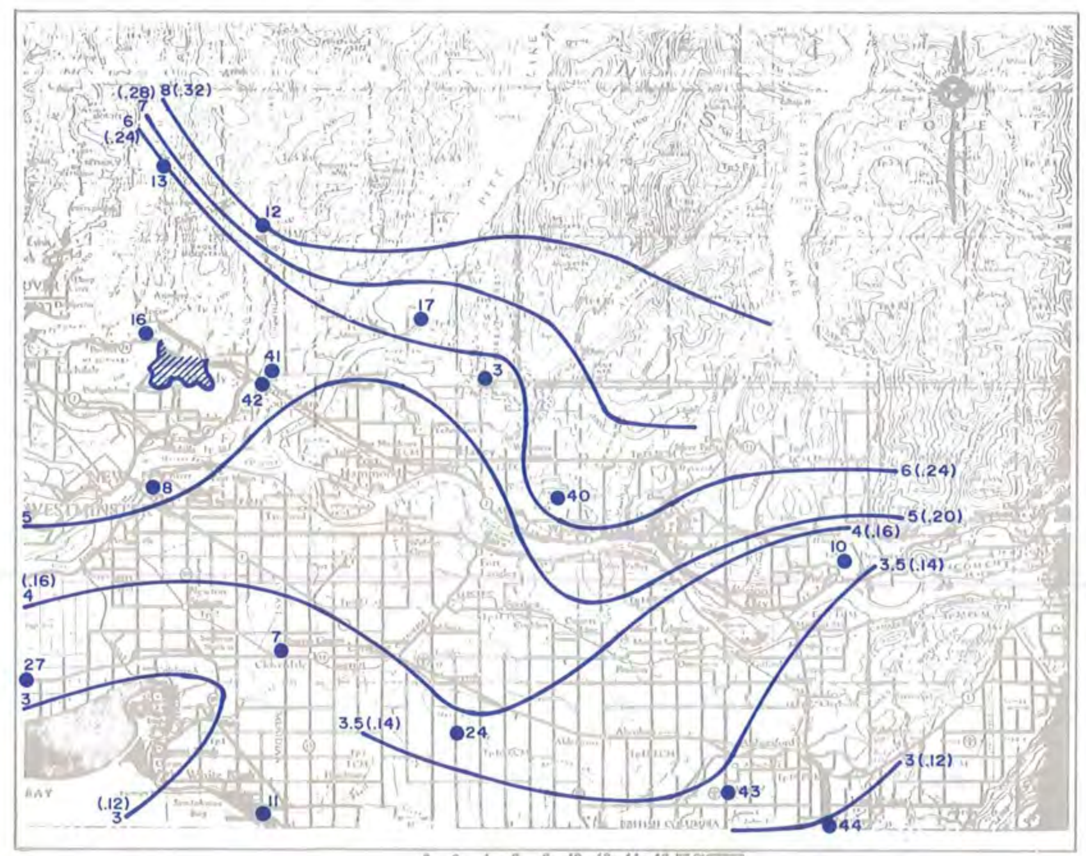
30 MINUTE DURATION
(SUMMER)



60 MINUTE DURATION
(SUMMER)



6 HOUR DURATION
(WINTER)



24 HOUR DURATION
(WINTER)

LEGEND

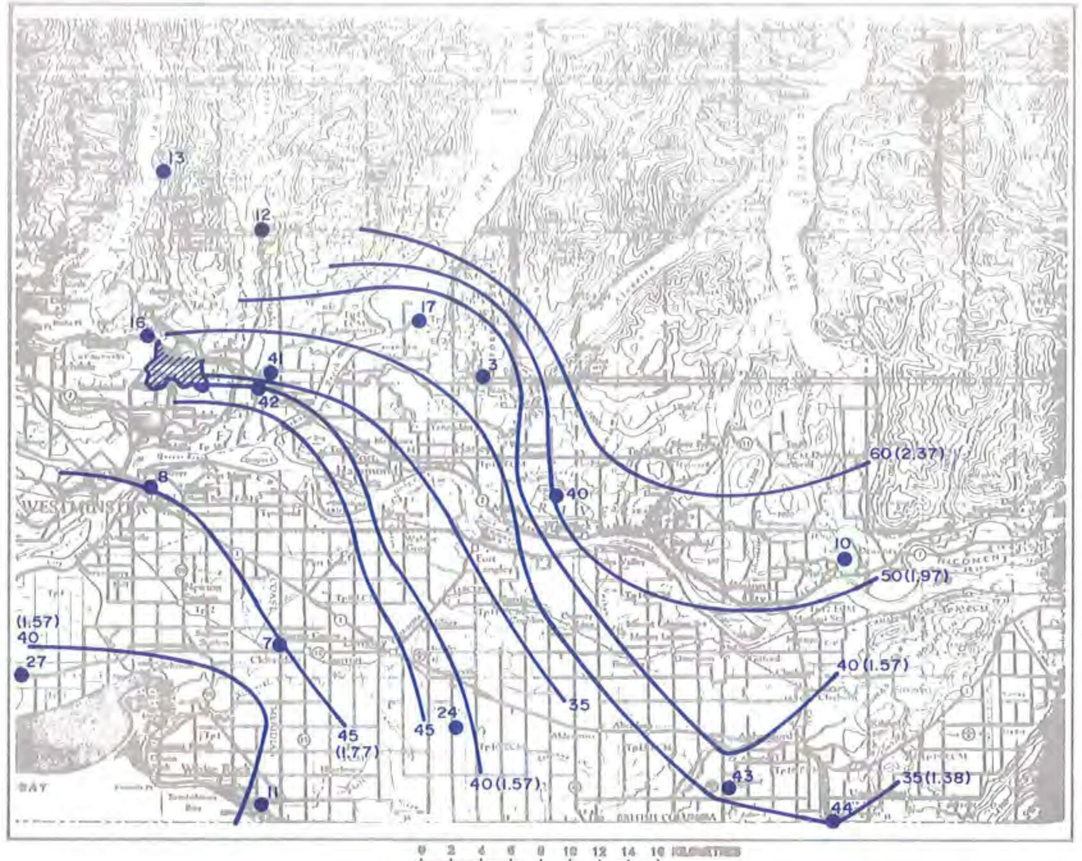
- STUDY AREA BOUNDARY
- ● RAINFALL STATION (DENOTES RAINFALL STATION LOCATION)
- —— 7 (2.8) ISOHEYETS AND RAINFALL INTENSITY mm/hr. (In./hr.)

NOTE : ISOHEYETS INFORMATION FROM INTENSITY –DURATION – FREQUENCY CURVES FOR STATIONS LISTED BELOW

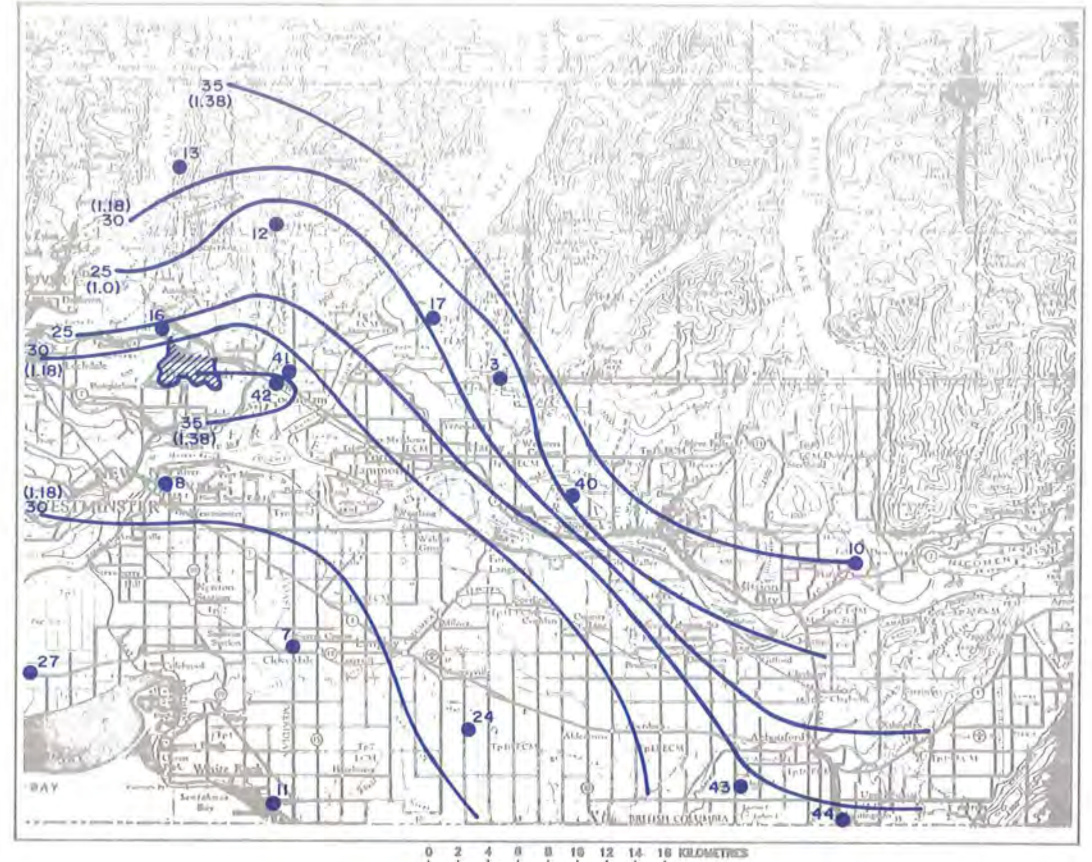
3	UBCRF ADMIN.
7	SURREY MUNICIPAL HALL
8	SURREY KWANTLEN PARK
10	MISSION WEST ABBEY
11	WHITE ROCK STP
12	COQUITLAM LAKE
13	BUNTZEN LAKE
16	PORT MOODY GULF OIL
17	PITT POLDER
24	LANGLEY LOCHIEL
27	LADNER
40	HANEY MICROWAVE
41	PORT COQUITLAM CITY YARD
42	PORT COQUITLAM MUNICIPAL HALL
43	ABBOTSFORD AIRPORT
44	HUNTINGDON METER STATION

10 YEAR RECURRENCE AVERAGE RAINFALL INTENSITY (mm/hr.)

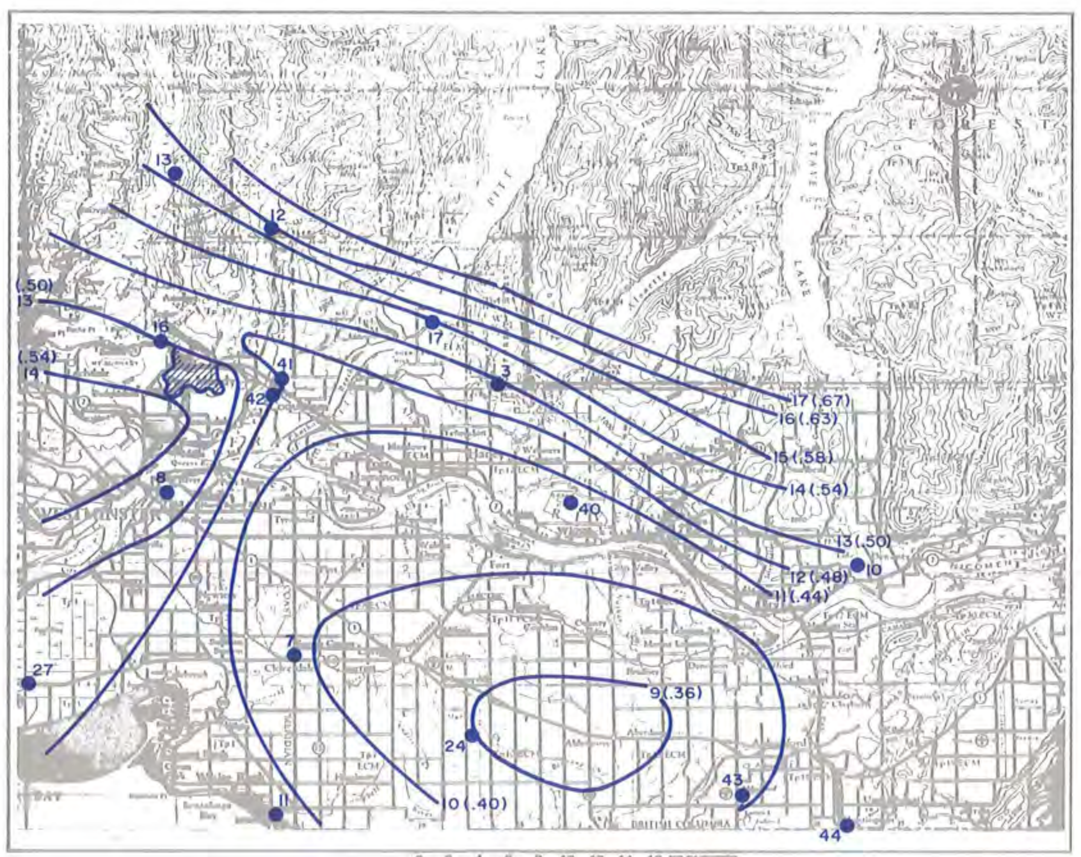
FIGURE 3-3



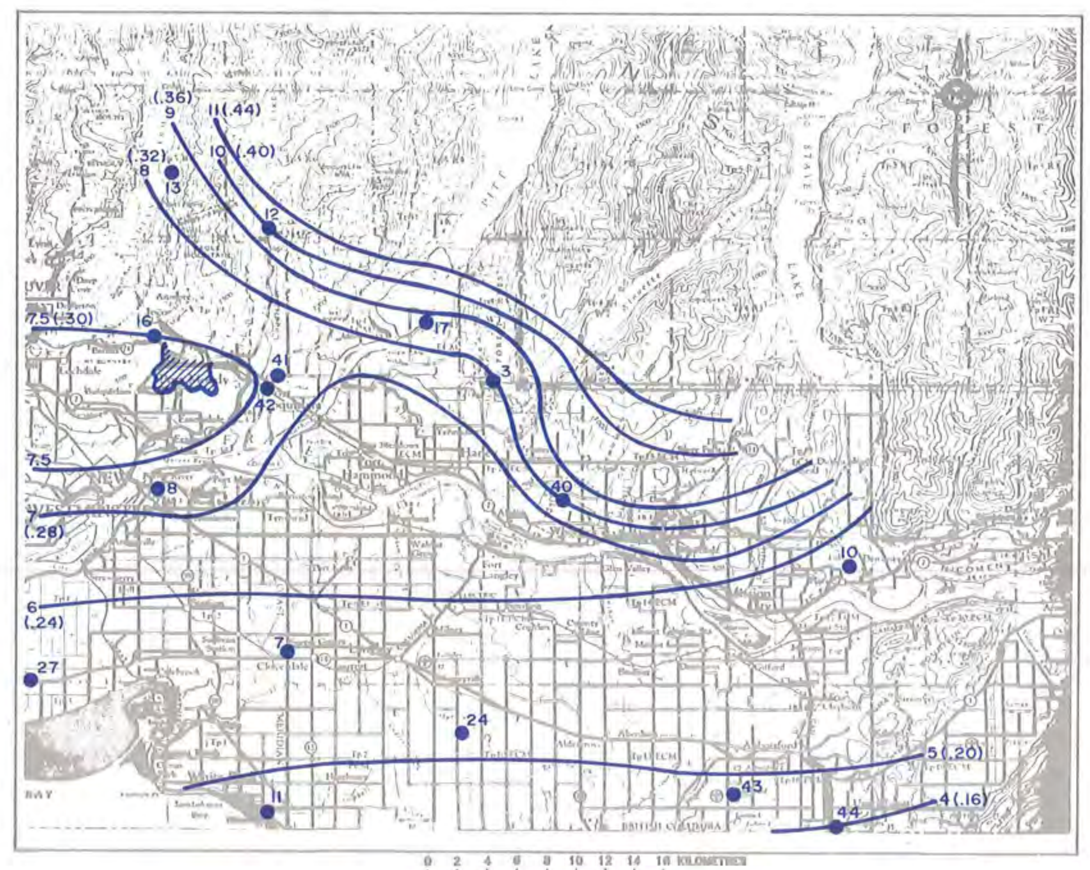
30 MINUTE DURATION
(SUMMER)



60 MINUTE DURATION
(SUMMER)



6 HOUR DURATION
(WINTER)



24 HOUR DURATION
(WINTER)

LEGEND

STUDY AREA BOUNDARY

● RAINFALL STATION (DENOTES RAINFALL STATION LOCATION)

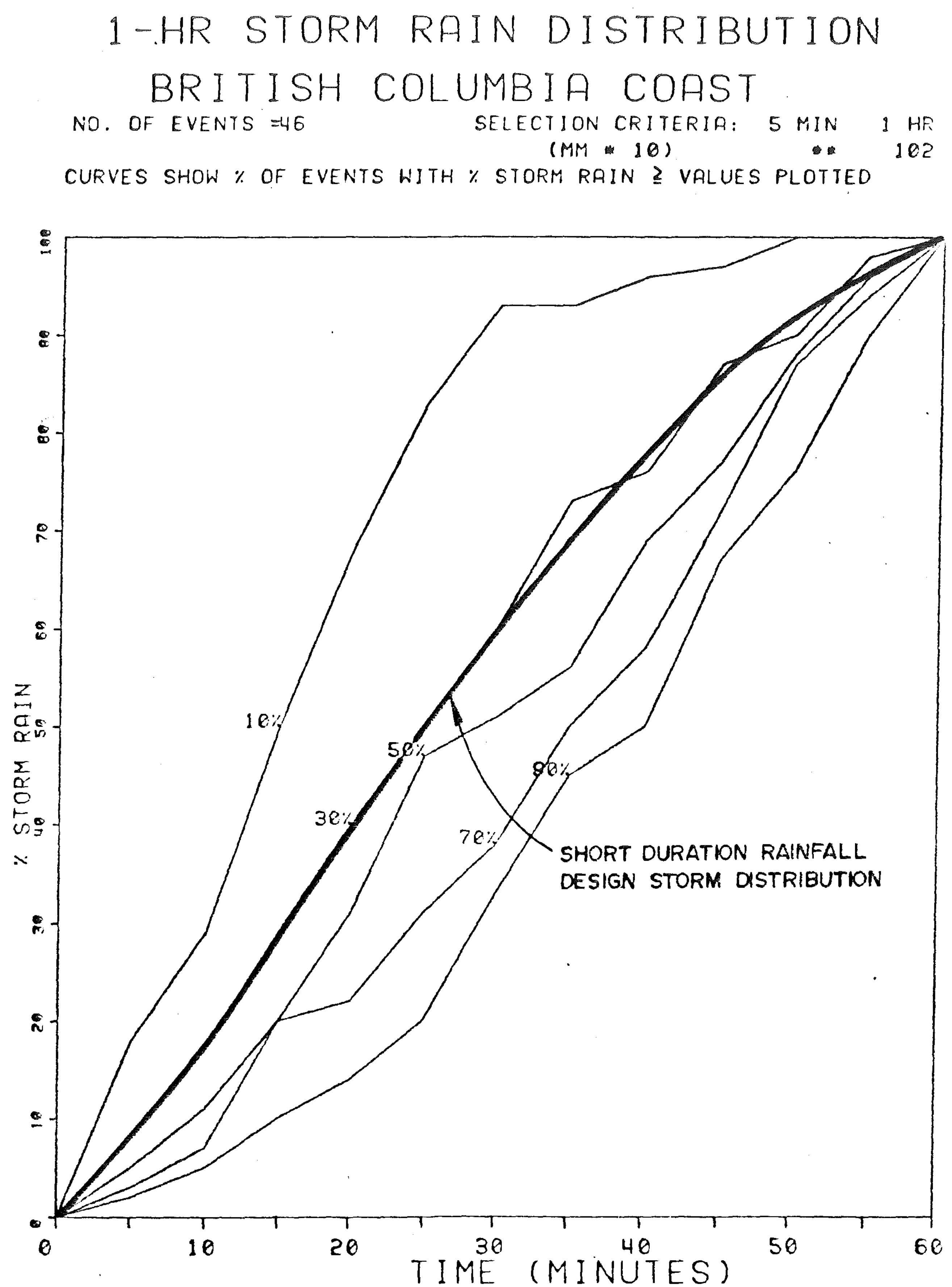
7 (2.8) ISOHEYETS AND RAINFALL INTENSITY mm/hr. (in./hr.)

NOTE : ISOHEYETS INFORMATION FROM INTENSITY –DURATION – FREQUENCY CURVES FOR STATIONS LISTED BELOW

3	UBCRF ADMIN.
7	SURREY MUNICIPAL HALL
8	SURREY KWANTLEN PARK
10	MISSION WEST ABBEY
11	WHITE ROCK STP
12	COQUITLAM LAKE
13	BUNTZEN LAKE
16	PORT MOODY GULF OIL
17	PITT POLDER
24	LANGLEY LOCHIEL
27	LADNER
40	HANEY MICROWAVE
41	PORT COQUITLAM CITY YARD
42	PORT COQUITLAM MUNICIPAL HALL
43	ABBOTSFORD AIRPORT
44	HUNTINGDON METER STATION

100 YEAR RECURRENCE AVERAGE RAINFALL INTENSITY (mm/hr.)

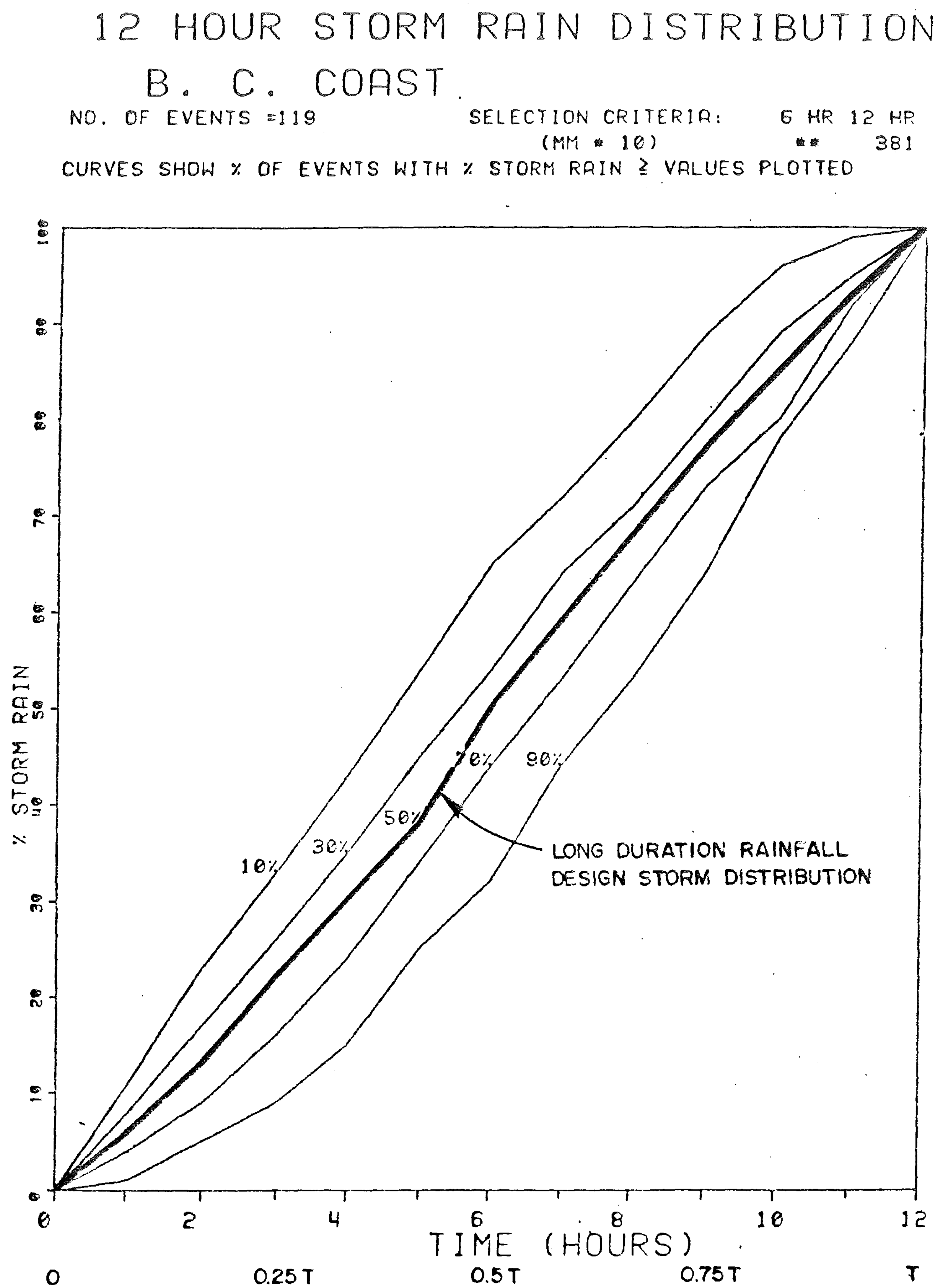
FIGURE 3-4



SHORT DURATION STORM PATTERN
(FOR HYETOGRAPH DEVELOPMENT)

ATMOSPHERIC ENVIRONMENTAL SERVICES
ENVIRONMENTAL PROTECTION SERVICES

FIGURE 3-5



LONG DURATION STORM PATTERN
(FOR HYETOGRAPH DEVELOPMENT)

ATMOSPHERIC ENVIRONMENTAL SERVICES
ENVIRONMENTAL PROTECTION SERVICES

FIGURE 3-6

GREATER VANCOUVER SEWERAGE & DRAINAGE DISTRICT
STUDY OF COQUITLAM / PORT MOODY
DRAINAGE AREA

4. STORM DRAINAGE ANALYSIS

This section on drainage analysis describes the results of the hydrological analyses, presents flood damage costs and debris harzard-damage costs, and describes environmental concerns. The purpose of this section is to establish need for drainage capacity improvements and the damage costs associated with the existing limited drainage works.

The following section presents the plan for the drainage improvements necessary to minimize the damage costs.

4.1 Hydrologic and Debris Flow Assessment

Figures 4-1 and 4-2 describe the existing drainage for the drainage areas, anticipated flood zones and projected hazard areas for debris flow events. A debris flow event is described in three zones; a) direct debris (Zone 1), b) indirect debris or mud (Zone 2), and c) flood (Zone 3). The flood caused by debris flow (Zone 3) is different than the flood caused by inadequate drainage (Zone 4). The debris flow flood results from a blocked drainage inlet in the major collectors. The two flood types are differentiated on the figures.

The hydraulic analysis for the 10 and 100 year flood flows (derived from criteria presented in the previous section) is presented in Tables 4-1, 4-2, 4-3 and 4-4. The tables identify channel reach by an alpha-numeric for cross-reference to the figures, and except for open channels, provide a rating for each culvert or enclosed drain section. The 10 and 100 year flows in column 1 under Peak Storm Flow in Tables 4-1 to 4-4 describe the most up-to-date planning information and replace the 1983 Port Moody study flows.

Study of Tables 4-1 to 4-4 and Figures 4-1 and 4-2 indicate several capacity limitations in the culverting along the major channels in Port Moody in each of the four drainage areas.

4.2 Flood Cost

Annual flood cost is the sum of event probability increments and associated mean event flood cost products associated with the damage criteria developed in Section 3. For example, for the Schoolhouse Creek basin, flood damage is confined to two homes above St. John's Street near Albert Street. The annual flood loss cost is calculated to be $4000. Capitalized over a 50 year period at 10% interest, the total flood loss cost is about $40,000. The annualized values are reported in Table 4-5 for flood associated costs to a 100 year event.

TABLE 4-1

Drainage Inventory and Rating - Schoolhouse Creek Drainage Area

Reach Designation	Size (mm)	Governing Grade (%)	Length (M)	Capacity (cms)	Peak Storm Flow - 1 Hour Storm: 10 Year Return Conc. (1)	10 Year Return Conc. (2)	100 Year Return Conc. (1)	100 Year Return Conc. (2)	Flow** Deficiency (cms)	Pipe or Channel Rating Return Period (yr)	Inlet Control (cms)	Comments
S1	600 ϕ	-	-	0.53	-	0.37	-	0.49	-	-	-	Ingersol storm sewer.
S2	750 ϕ	-	-	0.82	-	0.39	-	0.52	-	-	N/A	-
S3	300 ϕ	-	-	0.61	-	0.40	-	0.53	-	-	N/A	Steel pipe on pile bents.
S4	300 ϕ CSP	6.79	288	-	-	0.42	-	0.56	-	-	N/A	CSP. No outfall structure. Pipe corroded.
S5	Open Ch.	-	-	-	6.00	-	9.21	-	-	100	N/A	Schoolhouse Creek.
S6	1400 x 1750 H	3.63	37.7	12.78	5.82	-	9.12	-	-	-	-	Flared headwall - no grating.
S7	Open Ch.	-	-	-	0.31	-	0.47	-	-	-	N/A	Noble Creek Channel.
S8	600 ϕ	6.79	288	1.70	0.34	-	0.55	-	0.21	10	0.34	Flumed Noble Creek Intake - grilled.
S9	Open Ch.	-	-	-	6.10	-	9.63	-	-	-	N/A	Frequent overbank floods in homes.
S10	2-1350 ϕ conc.	-	-	11.3	6.10	-	9.63	-	4.25	2-3	2x2.69	Headwall - grade control at St. John's creates overbank v/s flooding.
S11	Open Ch.	-	-	-	6.10	-	9.63	-	-	-	N/A	Entrench channel - control weir.
S12	1-1500 ϕ WS	-	-	7.0*	6.10	-	-	-	-	1-2	3.40	Crosses Clark Street
	1050 CSP	-	-	2.2	6.10	-	9.63	-	5.21	1-2	1.02	- overflow.
S13	Open Ch.	-	-	-	6.10	-	9.63	-	-	-	N/A	-
S29	900 ϕ	-	-	2.69	2.04	-	3.12	-	0.43	25	-	-
S30	Open Ch.	-	-	-	7.76	-	12.26	-	-	-	-	-
S34	Open Ch. - 900 ϕ	-	-	-	2.46	-	2.74	-	-	-	N/A	Riechhold Chemicals.
S35	Open Ch.	-	-	-	10.27	-	15.69	-	-	-	N/A	-
S36	1520 x 2440	-	-	-	10.27	-	15.69	-	-	-	-	CPR crossing.

* Improvements recommended 1983.
** Based on Column (1) 100 year flows.

Note: Column (1) are OTTHYMO, 1987.
Column (2) numbers are from Port Moody Study, 1983.

TABLE 4-2

Drainage Inventory and Rating - Ottley Creek Drainage Area

Reach Designation	Size (mm)	Governing Grade (%)	Length (m)	Capacity (cms)	Peak Storm Flow - 1 Hour Storm: 10 Year Return (cms) (1)	Peak Storm Flow - 1 Hour Storm: 100 Year Return (cms) (1)	Flow** Deficiency (cms)	Pipe or Channel Rating Return Period (yr)	Inlet Control (m^3/s)	Comments
01	Open Channel	-	-	-	0.33	0.56	-	-	N/A	-
02	450 ϕ	-	-	0.45*	0.33	0.56	0.23	10	0.33	Overflow goes to Axford Creek (column 2 only)
03	Open Channel	-	-	-	0.33	0.56	-	-	N/A	-
04	600 ϕ	-	-	0.83	0.33	0.56	-	100	-	-
05	Open Channel	-	-	-	0.33	0.56	-	-	N/A	-
06	600 ϕ	-	-	0.68	0.33	0.56	-	100	-	-
07	Open Channel	-	-	-	0.33	0.55	-	-	N/A	-
08	600 ϕ	-	-	0.70	0.33	0.55	-	100	-	-
09	Open Channel	-	-	-	0.33	0.55	-	-	N/A	-
010	600 ϕ	-	-	0.95	0.33	0.55	-	100	-	-
011	Open Channel	-	-	-	0.72	1.14	-	-	N/A	-
012	600 ϕ	-	-	0.36*	0.72	1.14	0.78	1-2	-	-
013	Open Channel	-	-	-	0.72	1.14	-	-	N/A	-
014	600 ϕ	-	-	0.70	0.72	1.14	0.44	10	-	-

* Improvements recommended 1983.
** Based on Column (1) 100 year flows.
N/A Not applicable.

Note: Column (1) OTTHYMO, 1987.

TABLE 4-3

Drainage Inventory and Rating - Kyle Street Drainage Area

Reach Designation	Size (mm)	Governing Grade (%)	Length (m)	Capacity (m^3/s)	Peak Storm Flow - 1 Hour Storm: 10 Year Return (cms) (1)	100 Year Return (cms) (1)	Flow** Deficiency (cms)	Pipe or Channel Rating Return Period (yr)	Inlet Control (m^3/s)
K1	Open Channel	-	-	-	0.19	0.32	-	-	N/A
K2	675 ϕ	-	-	-	0.19	0.32	-	-	-
K3	Open Channel	-	-	-	0.19	0.32	-	-	N/A
K4	450 ϕ	-	-	0.70*	0.19	0.32	-	-	-
K5	525 ϕ	-	-	1.05	0.19	0.32	-	-	N/A
K6	600 ϕ	-	-	1.07	0.19	0.32	-	-	N/A
K7	600 ϕ	-	-	1.13	0.19	0.32	-	-	N/A
K8	600 ϕ	-	-	1.02	0.29	0.32	-	-	N/A
K9	Open Channel	-	-	-	0.46	0.73	-	-	N/A
K10	1200 ϕ	5.65	34	8.50	0.46	0.73	-	100	1.98
K11	900 ϕ	6.43	91	4.96	0.46	0.73	-	100	N/A
K12	1200 ϕ	3.36	65	3.97	0.45	0.73	-	100	N/A
K13	Open Channel	-	-	-	0.47	0.77	-	-	N/A
K14	Open Channel	-	-	-	-	-	-	-	N/A
K15	450 ϕ	-	-	0.45	-	-	-	-	-
K16	900 ϕ	1.38	53	2.27	0.47	0.77	-	100	1.02
K17	600 ϕ	8.15	56	1.84	0.47	0.77	-	100	N/A
K18	Open Channel	-	-	-	0.46	0.75	-	-	N/A
K19	Open Channel	-	-	-	1.11	1.70	-	-	N/A
K20	Open Channel	-	-	-	1.57	2.45	-	-	N/A
K21	1050 ϕ	2.66	105	4.53	1.57	2.45	-	100	HW/D=1.5
K22	900 ϕ	8.86	61	5.95	1.56	2.45	-	100	N/A
K23	Open Channel	-	-	-	0.91	1.48	-	-	N/A
K24	750 ϕ	10.28	66	3.68	0.91	1.48	0.48	25	HW/D=1.5
K25	750 ϕ	5.30	67	2.66	0.91	1.48	-	100	N/A
K26	1050 ϕ	0.90	69	2.69	0.91	1.48	-	100	N/A
K27	1200 ϕ	0.51	88	2.97	0.91	1.48	-	100	N/A
K28	1200 ϕ	2.50	85	7.08	2.57	4.04	-	100	N/A
K29	1200 ϕ	2.55	67	7.08	2.57	4.04	-	100	N/A
K30	1200 ϕ	6.45	43	10.20	3.17	5.00	-	100	N/A
K31	1200 ϕ	3.82	76	7.93	3.17	5.00	-	100	N/A
K32	1350 ϕ	2.30	107	8.78	3.17	5.00	-	100	N/A
K33	1350 ϕ	3.03	52	8.78	3.17	5.00	-	100	N/A
K34	1200 ϕ	3.72	30	7.79	3.17	4.99	-	100	N/A
K35	1200 ϕ	6.18	49	10.76	3.17	4.99	-	100	N/A
K36	1350 ϕ	3.23	72	8.78	3.17	4.99	-	100	N/A
K37	1700 ϕ	0.82	128	9.06	3.17	4.99	-	100	N/A
K38	1500 ϕ	1.85	73	10.20	3.17	4.99	-	100	N/A
K39	1500 ϕ	1.58	95	9.35	4.43	6.93	-	100	N/A
K40	1500 ϕ	1.69	50	9.63	4.77	7.43	-	100	N/A
K41	1500 ϕ	-	-	11.05	4.77	7.43	-	100	N/A

* Improvements recommended 1983.
** Based on Column (1) 100 year flows.

Note: Column (1) numbers are from OTTHYMO, 1987.

TABLE 4-4

Drainage Inventory and Rating - Williams Street Drainage Area

Reach Designation	Size (mm)	Governing Grade (%)	Length (m)	Capacity (cms)	Peak Storm Flow - 1 Hour Storm: 10 Year Return (cms) (1)	10 Year Return (cms) (2)	100 Year Return (cms) (1)	100 Year Return (cms) (2)	Flow Deficiency (cms)	Pipe or Channel** Rating Return Period (yr)	Inlet Control (m^3/s)	Comments
W1	Open Channel			-	-	-	-	-	-	-	-	-
W2	600-450 ϕ			0.36	-	0.34	-	0.44	0.08	10	-	-
W3	900 ϕ			1.70	-	0.36	-	0.47	-	100	N/A	-
W4	900 ϕ			1.84	-	0.47	-	0.65	-	100	N/A	-
W5	600 ϕ			0.76	-	0.48	-	0.66	-	100	N/A	-
W6	Open Channel			-	0.06	-	0.13	-	-	-	N/A	-
W7	600 ϕ			1.58	0.06	-	0.13	-	-	100	0.37	-
W8	900 ϕ			3.25	0.06	-	0.13	-	-	100	N/A	See (*) below
W9	450 ϕ			0.39*	0.06	-	0.12	-	-	100	N/A	-
W10	Open Channel			-*	0.06	-	0.12	-	-	-	N/A	-
W11	Open Channel			-	0.21	-	0.35	-	-	-	N/A	-
W12	Open Channel			-	1.71	-	2.97	-	-	-	N/A	-
W13	Open Channel			-	1.96	-	3.38	-	-	-	N/A	-
W14	900 x 1200			2.20*	1.96	-	3.38	-	1.96	1	1.42	See (*) below
W15	Open Channel			-*	1.96	-	3.38	-	-	-	N/A	-
W16	900 ϕ			1.05*	1.65	-	3.05	-	2.03	1	1.02	-
W17	Open Channel			-*	1.65	-	3.05	-	-	-	N/A	-
W18	Open Channel			-*	2.01	-	3.67	-	-	-	N/A	-
W19	1500 ϕ RC			10.48	2.01	-	3.67	-	-	100	-	-
W20	1500 ϕ RC			10.20	3.78	-	6.14	-	-	100	N/A	-
W21	Open Channel			-*	3.78	-	6.14	-	-	-	N/A	-
W22	900 ϕ CSP (inside 1050 ϕ CSP)			2.83*	3.78	-	6.14	-	4.87	1	1.27	-
W23	1500 ϕ			10.70	3.78	-	6.14	-	-	100	N/A	-

* Improvements recommended 1983.
** Based on Column (1) 100 year flows (except W2).

Note: Column (1) OTTHYMO, 1987.
Column (2) Port Moody Study, 1983.

TABLE 4-5

Drainage Area Flood Damage

Drainage Area	Basin	Reach	Annual Flood Loss $/yr	Capitalized Flood Loss $
Schoolhouse Creek	Schoolhouse	S10	8,800	88,000
		S12	13,500	135,000
	Noble	S8	450	4,500
Ottley Creek	Ottley	O2	1,000	10,000
		012/014	1,000	10,000
Kyle Street	Axford	K3/K4	1,000	10,00
	Goulet	K24	200	2,000
William Street	Dallas	W13/W16	26,400	264,000
	Dallas/William	W22	38,900	389,000

4.3 Debris Hazard Cost

The catastrophic event costs associated with a debris flow, unlike the flood cost, cannot be annualized, and for the purposes of this study, is considered as a one time cost. Included also should be the human cost of loss of life, which cannot be represented in a dollar value. The property loss cost associated with the debris hazard is shown in Table 4-6.

TABLE 4-6

Debris Flow Damage

Drainage Area	Basin	Intake	Maximum Damage Estimate, $1000's
Schoolhouse Creek	Schoolhouse	S6	$ 0
	Noble	S7	$1,835
Ottley Creek	Ottley	O2	$1,425
Kyle Street	Axford	K2	$1,425*
	Kyle	K10	$1,180
	Hachley	K16	$ 975*
	Sundial	K21	$ 590
	Goulet	K24	$1,295
William Street	Dallas/Correl	W13	$ 150
	Ellenhouse		
	William	W7	$5,060*

*Risk of loss of life highest.

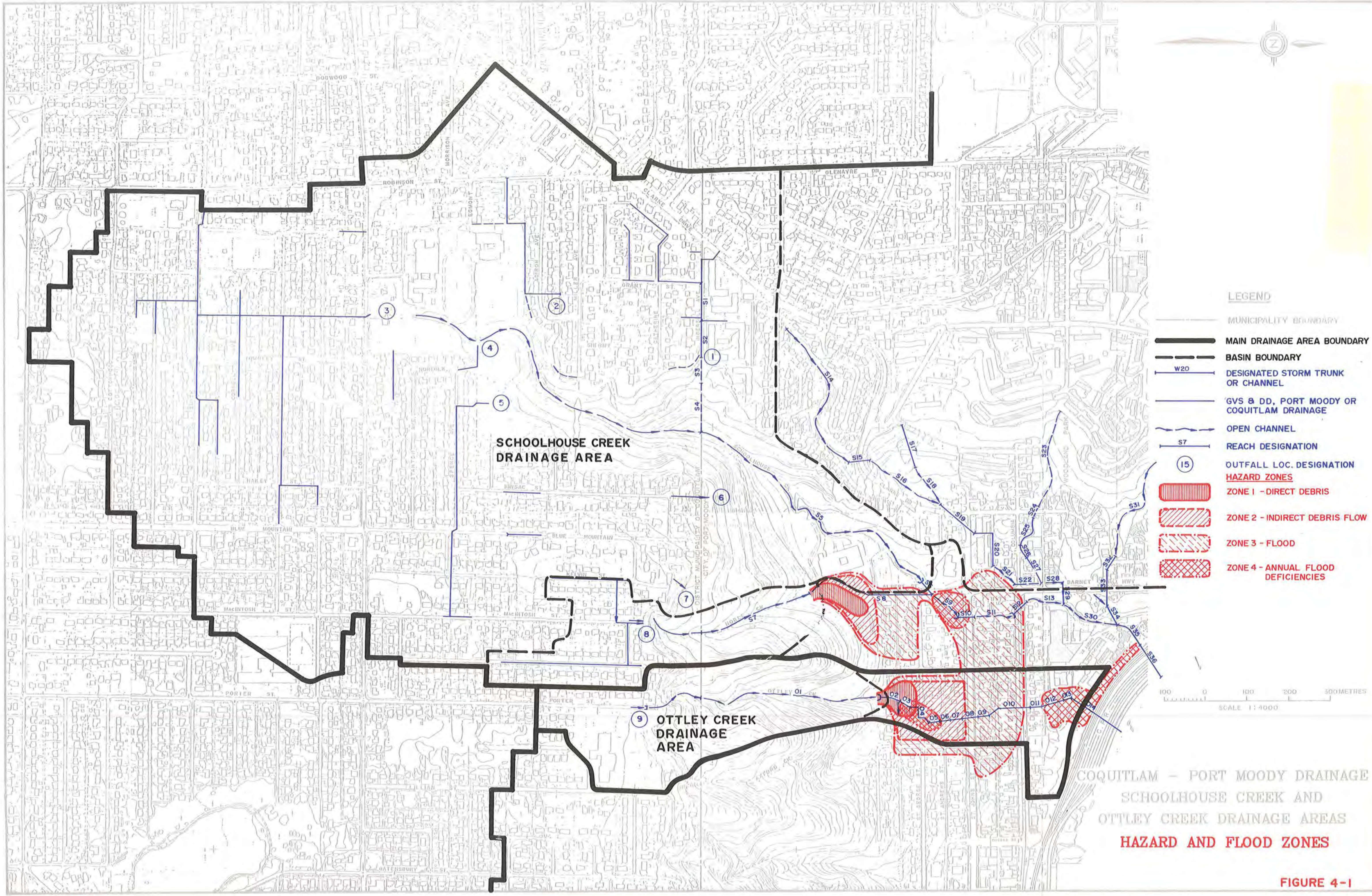
4.4 Environmental Concerns

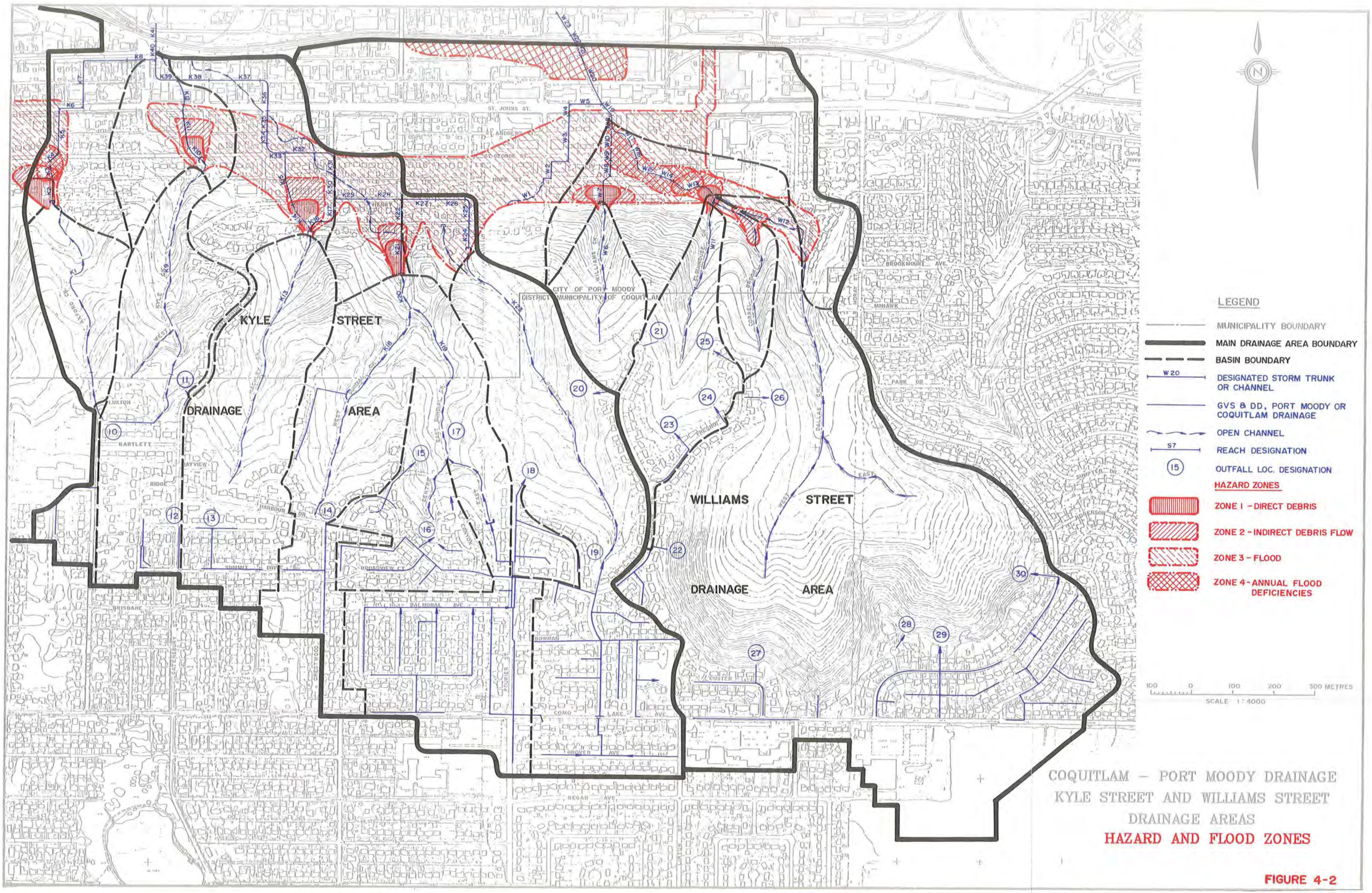
The creeks considered most important to the Fisheries services are the Williams Street and Schoolhouse Creek systems.

Williams Street system supports cutthroat trout to the St. John's Street culvert only; however, the creek contains many reaches of excellent habitat and Fisheries & Wildlife considers maintenance of this system important for future headwater stocking options.

Schoolhouse Creek supports resident and sea-run cutthroat trout as well as Coho salmon. Because the creek supports anadromous species, it is considered most important. The St. John's Street culvert is a major restriction to increased anadromous use.

The Fisheries service considers all the small systems important, because no large river systems exist within the Port Moody Inlet, and the only large system within Indian Arm is the Indian River.


SCHOOLHOUSE CREEK DRAINAGE AREA
OTTLEY CREEK DRAINAGE AREA
LEGEND
MUNICIPALITY BOUNDARY
MAIN DRAINAGE AREA BOUNDARY
BASIN BOUNDARY
W20
DESIGNATED STORM TRUNK OR CHANNEL
GVS & DD, PORT MOODY OR COQUITLAM DRAINAGE
OPEN CHANNEL
S7
REACH DESIGNATION
15
OUTFALL LOC. DESIGNATION
HAZARD ZONES
ZONE 1 - DIRECT DEBRIS
ZONE 2 - INDIRECT DEBRIS FLOW
ZONE 3 - FLOOD
ZONE 4 - ANNUAL FLOOD DEFICIENCIES
100 0 100 200 300METRES
SCALE 1:4000
COQUITLAM - PORT MOODY DRAINAGE
SCHOOLHOUSE CREEK AND
OTTLEY CREEK DRAINAGE AREAS
HAZARD AND FLOOD ZONES
FIGURE 4-1



COQUITLAM - PORT MOODY DRAINAGE
KYLE STREET AND WILLIAMS STREET
DRAINAGE AREAS
HAZARD AND FLOOD ZONES

FIGURE 4-2

5. DRAINAGE AREA MASTER PLAN

The following section describes the structural improvements, priority and costs for the four drainage areas' Master Drainage Plan. The plan is developed from the assessments of existing drainage deficiencies described in Section 2, from the criteria of Section 3 and from the need as determined in Section 4. The plan, although conceptual, provides sufficient guidelines to initiate structural and nonstructural improvements to the watershed for protection of the creek resources and property in the two municipalities.

5.1 Master Plan

Development of a master plan for the drainage areas includes an agreement on policy and watershed management, and the establishment of a construction schedule for the needed drainage improvements. The master plan for the drainage areas encorporates these two categories of management. The first is nonstructural and requires good cooperation and agreement between the three drainage authorities. The second is a program of structural measures necessary for protection of the private and public investment as well as the environment.

5.2 Policy and Management

Because the watershed is interjurisdictional, agreement on drainage policy by both municipalities becomes essential. Both municipalities have taken responsible positions on protection of the natural creek basins to date, and consistency in application and policy in this regard should be continued.

5.2.1 Development

Generally, development within the gullies and the natural floodplains of the drainage area basins should not be permitted, and a continuation of the present policy is therefore supported. Similarly, fills within the basins must not be permitted, as is presently the case. Included also must be assurance that tree clearing will not take place and that any disturbance to the basins which could bring about instability in the escarpments will not be permitted.

5.2.2 Responsibility

Responsibility has been logically separated into two main divisions. The Greater Vancouver Sewerage and Drainage District is responsible for major flows in the ravines and through Port Moody to the inlet. Both municipalities maintain responsibility for minor flows and development within their jurisdictions. The GVS&DD could logically be extended to include all basins such as Ottley and Axford Creeks.

The GVS&DD should continue as a control coordinator to assist in application of drainage policy for the major drainage facilities.

Their responsibilities must include:

1. Planning of major drainage works.
2. Coordinating construction and funding.
3. Operations and maintenance.
4. Inspections of creek and headscarps.
5. Liaison and approvals.
6. Emergency plans.

The first three levels are presently the GVS&DD's responsibility and were described in Section 2. The latter three should be expanded.

Inspection. Inspection requirements are paramount and are the subject of Appendix 4. Each ravine requires access trails from inlet to headscarp. One regular scheduled inspection is to be undertaken in October and February or March of each year. Special inspections should be undertaken following infrequent intense storms. Inspection criteria are detailed in the Appendix which was the subject of November 10, 1987 recommendations to the GVS&DD.

Liaison and Approval. Liaison requires that the Region act as a central coordinator and consolidate policy with respect to the creek protection and major drainage provisions. Specific guidelines for the handling of drainage matters should be established between the GVS&DD and municipalities, and an approval process for work within the ravines should be agreed upon between these three regulatory bodies.

Emergency Planning. As part of the liaison process a committee should be organized to deal with emergency situations which arise in the basins. Emergency measures should at least include:

1. Standing orders at all police and fire departments to contact committee representatives or a 24 hour call number.

2. Organized plan for attendance of operations personnel and others.

3. Immediate lines of communication between operations personnel from each drainage authority.

4. Guidelines for responsibility for each authority (GVS&DD, Port Moody, Coquitlam).

5. Press representative.

5.3 Drainage Improvements

Table 5-1 describes the structural major flow drainage improvements considered appropriate for flood and debris related drainage. The table differentiates between the two flood costs and an estimate of benefit:cost for flood loss and improvements is shown. Priority is given as 1 for high and 4 for low. Figures 5-1 and 5-2 show location of the improvements and reference each

TABLE 5-1

Master Drainage Plan Improvement Schedule

Drainage Area	Basin	Reach	Item	Improvement Description	Benefits	Capitalized Flood Damage Cost $1000's (50 yr) (a)	Debris Flow Damage Cost $1000's (b)	Property Acquisition (c)	Priority (d)	Proposed Cost of Improvem'ts $1000's (1,6) (e)	Proposed Est. Annual Cost $/yr (f)	Benefit/ Cost (6) (g)
Schoolhouse	Schoolhouse	S4-S3	1	Reconstruction of Ingersol outfall approx. 100 m of 300 mm pipe, coal tar coated steel, and impact structure.	Erosion control in creek.	-	-	-	3	50	1000	(2)
	Schoolhouse	S6	2	Debris trash rack upstream of Albert Street culvert.	Collection of trash upstream of St. John's St. culverts to minimize flood problems in reach S9.	Included in Item 3.	-	1	2	20	3000	See Item 4.
	Noble	Outfall	7	Outfall improvements in Coquitlam.	Erosion control.	-	-	-	3	10	1000	(2)
	Noble	S7	3	Inlet freeboard increase, grating with side overflow structure and retaining wall to deflect debris from school.	Flood control & debris flow containment (assumes debris caught in parking lots).	4.5	1835	-	3	25	1000	61:1
	Schoolhouse	S10	4	Inlet construction at St. John's Street culvert.	Improved hydraulics to min. upstream flooding & meet major flood flow capacity.	88	-	-	2	15	500	1.1:1
	Schoolhouse	S12	5	Inlet construction at Clark Street culverts and ditch cleaning including WS culvert replacement with 50 m, 1800 ϕ conc.	Improved hydraulics to meet major flow capacity.	135	-	-	3	70	500	1.8:1
	Schoolhouse	S29	6	Parallel 900 ϕ, 50 m with 600 ϕ conc.	Flood control for major flow.	-	-	-	4	40	-	(2)
Ottley Creek	Ottley	01	1	Outlet impact structure Coquitlam.	Erosion control.	-	-	-	2	15	1000	(2)
		02	2	Storage, inlet and grating construction, see Fig. 5-3.	Debris flow containment.	-	1425	-	1	50	7500	11.5:1
		02, 03, 04, 05	3	Channel enclosures & storm sewer reconstruction 150 m, 600 mm conc.	Flood control for major flow.	10	-	-	2	75	-	0.13
		012, 013	4	Upgrade 100 m of 900-1050 ϕ conc.	Flood control for major flow.	10	-	-	4	75	-	0.06
		014	5	Track crossing (or connect to S36) parallel 130 m, 600 m conc.	Flood control for major flow.	Included in Item 4.	-	-	3	90	-	See Item 4.

cont'd ...

TABLE 5-1 - continued

Kyle Street	Axford	K1/K2	1	Storage, inlet & grating constr., see Fig. 5-3.	Debris flow and flood control.	-	1425 (3)	-	1	60	7500	10.5:1
		K4	2	See Port Moody 1983 study for improvements K4 40 m, 600 ϕ replacing 450 ϕ.	Flood control for major flow.	10	-	-	4	25	-	0.4
	Kyle	Outfall	3	Gatensburg storm discharge relocation.	Erosion and bank stability proection.	-	-	-	1	2	-	(2)
	Kyle	K10	4	Inlet freeboard increase, grating and side overflow structure.	Debris flow and flood control.	-	1180	-	2	45	5000	14:1
	Hachley	K16	5	Storage, inlet and grating construction.	Debris flow and flood control.	-	975 (3)	3 private lots(2613, 2617,2621)	2	300 (5)	5000	2.8:1
	Sundial	K19 East	6	40 m channel diversion and bank protection.	Bank erosion & bank stability protect.	-	-	-	2	15	1000	(2)
	Sundial	K21	7	Inlet modifications.	Flood control and debris flood contain.	-	590	-	3	35	5000	6.9:1
	Goulet	Outfall	8	Improve Baron Dr. outfall by extension & construction of flow control structure, 100 m, 200 ϕ.	Erosion control.	-	-	-	4	20	500	(2)
	Goulet	K24	9	Expansion of storage, improvements to intake.	Debris flow and flood control.	2	1295	-	3	50	5000	13:1
	Collector	K25-K40	10	1300 m storm sewer invert reconstruction steel plate liner on invert and grout.	Protection of $900,000 assessed value of sewer (1988) (more to replace).	900	-	-	2-3	200	5000	3:1 (4)
Williams Street	Williams	W7	1	Storage, inlet and grating construction see Fig. 5-3.	Debris flow and flood control.	-	5060 (3)	-	1	50	5000	50:1
	Dallas, Correl and Elginhouse	W12	2	80 m of diversion ditch.	Flood control (protection for apartments).	30-50	-	-	1	15	1000	1.2-2:1
		W13	3	Inlet and grating improvements.	Flood control.	Included in Item 4.	150	-	2	15	5000	See Item 4.
		W13-W16	4	180 m, 1800 mm ϕ and 80 m, 1200 mm ϕ storm drain plus inlet and grating.	Flood control.	264	-	-	2	325	1000	1.04
		W22/W21	5	50 m, 1800 mm ϕ track crossing and closure.	Flood control.	389	-	-	2	175	1000	2.1:1

(1) Costs include 25% for engineering contingencies.
(2) Not applicable or not measurable - environmental damage.
(3) Highest loss of life risk.
(4) Measured by ratio of estimated sewer value to estimated repair costs.
(5) Including lot purchase $250,000 (3).
(6) 50 year life assumed for major structures. Column (g) = (Columns (a) + (b)) / (Column (e) + 10 x Column (f)).

numerically for tabular cross-reference. Section 2 describes risk for debris flood and debris flow. These ratings are taken into account when assigning priority.

5.3.1 Schoolhouse Creek Drainage Area

A total improvement cost of $230,000 is shown for the drainage area, of which about $85,000 is considered a medium high priority (Items 1, 2 and 4). Concern for Noble Creek debris flow protection (Item 3) is ranked as a medium priority only, but has a high potential benefit:cost ratio of 61:1 for a $25,000 estimate to improve the intake and construct a diversion wall for school protection. Items 5 and 6 are medium to very low priority. Item 5 should be corrected as the area further develops. Item 7 is a medium priority. The Noble Creek outfall should be lengthened to protect the headscarp.

5.3.2 Ottley Creek Drainage Area

A total improvement cost of $305,000 is shown for the drainage area; however, Item 2, of $50,000 for construction of the debris basin work shown on Figure 5-3 only is of immediate need. Sections of open channel below the inlet should be straightened and enclosed as well. Item 3 identifies correction of very poor drainage. Items 4 and 5 are medium priority. They represent upgrading to meet the major flow condition only. Because the track crossing is restrictive it has a higher priority (Item 5). Improvements to the outfall should be undertaken at the headscarp (Item 1) as a medium high priority.

5.3.3 Kyle Street Drainage Area

Total improvement cost of $752,000 is estimated for Kyle Street Drainage Area of which $62,000 is a high priority and $50,000 to $350,000 is a medium high priority. The high priority work is proposed for Axford, Item 1 debris basin as shown in Figure 5-3. Item 3, also high priority, has been initiated by Coquitlam (as identified in Appendix 3).

Item 4 is of medium high priority and is designed to improve inlet conditions at Kyle Creek for protection of the Port Moody City Hall. Storage is not included but a new intake structure and headworks are required. Item 5 is a medium high to medium priority. The cost of Item 5 (Hachley Creek) is high because of the three property purchases. Item 6 is also medium high and requires realignment of channel in the east Sundial Creek tributary. Coquitlam has partially completed this work, but it should be monitored yearly.

Inlet and debris diversion improvements for Sundial, Item 7 and Goulet, Item 9 are medium priority and improvements resemble requirements of other high priority work as shown in Figure 5-3.

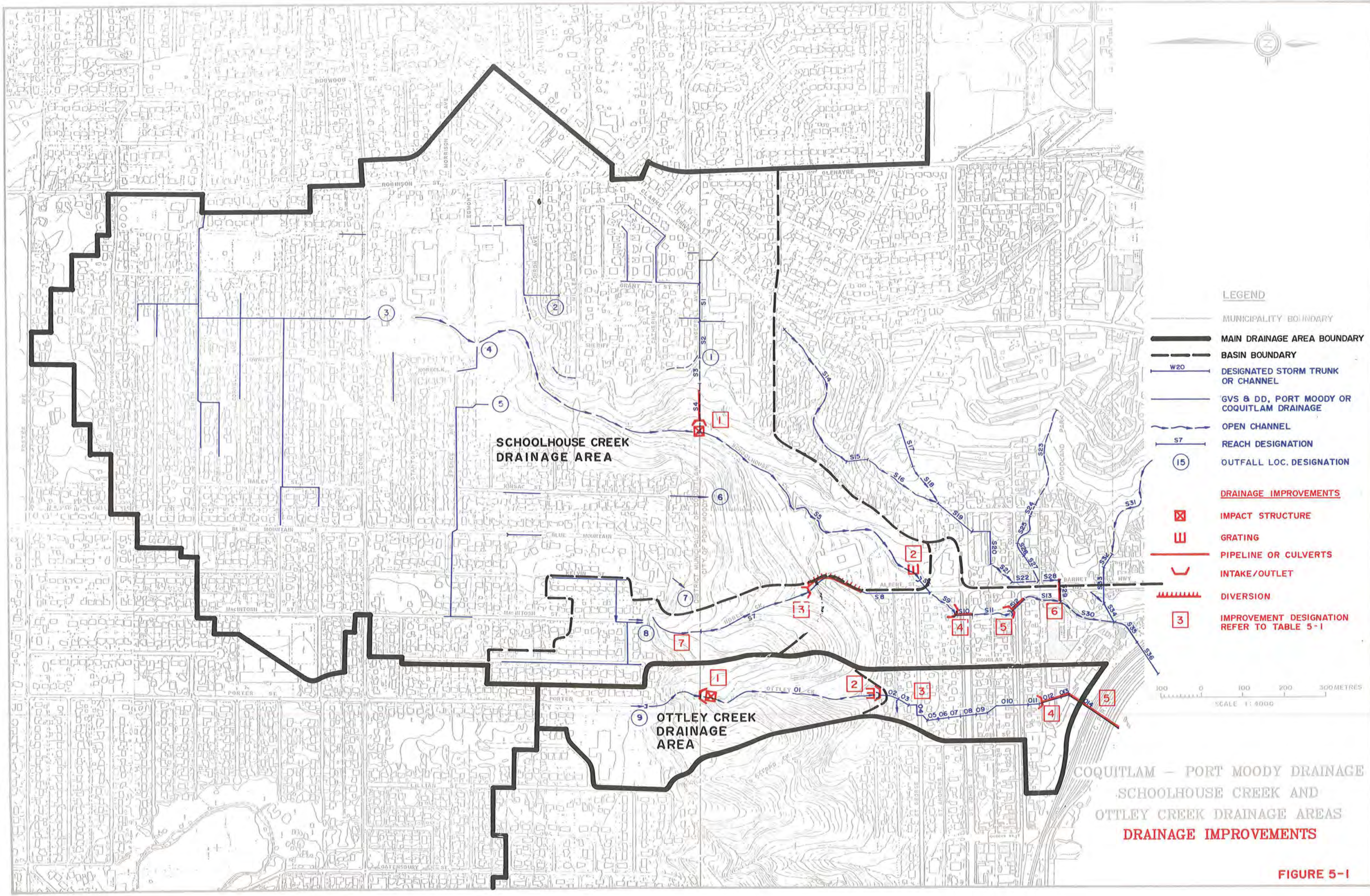
Item 10, the Kyle Street storm drain repairs is a medium high priority. It requires near immediate attention to repair the Kyle Street sewer invert. New lining or a welded metal plate invert should be constructed in stages from the upper to lower reaches over the next 5 years at about $20,000 to $40,000 per year. The sewer invert has been eroded to 50% of its original wall thickness.

Items 2 and 8 are low priority. Item 8, Baron Drive outfall should be monitored yearly as should all outfall discharges of this type. Item 2 is a capacity increase for Port Moody sewers to accommodate major flow only. Use of the street as a floodway is a less costly alternative.

5.3.4 Williams Street Drainage Area

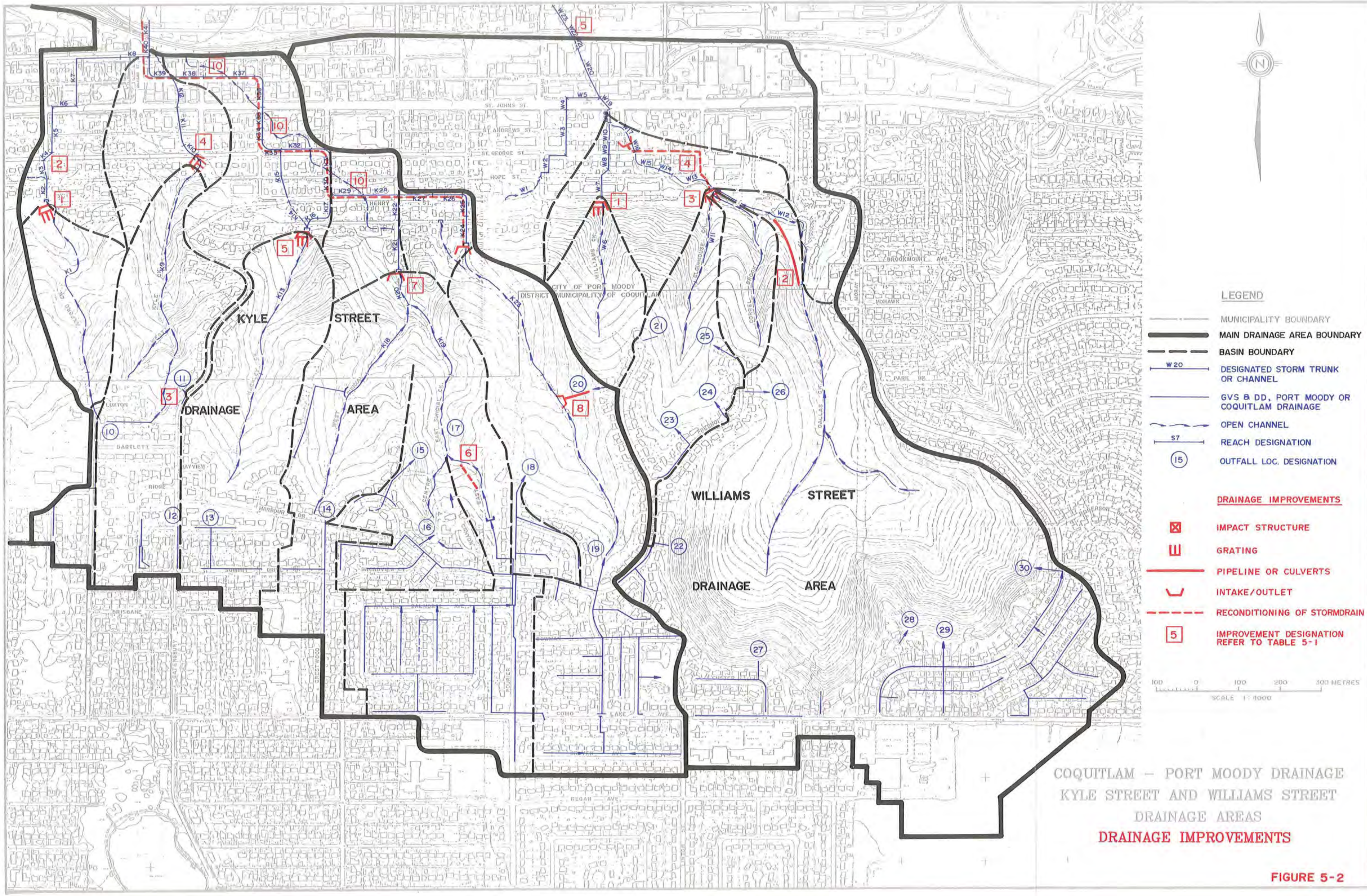
Total improvement costs of $580,000 are estimated for Williams Street. This cost is considered to include all high priority items and all show a benefit/cost ratio greater than 1.

Highest priority is construction of a debris flow containment structure above the Williams Creek intake. It is identified as Item 1 and is shown on Figure 5-3. Also a high priority is the diversion ditch construction on Dallas Creek described in Appendix 3 and identified in Table 5-1 as Item 2. The other high priority items comprise the collection and conveyance of Dallas, Correl and Elginhouse flows from a Buller Street intake, to St. George Street and to the Williams Creek confluence above St. John's Street. These improvements are identified as Items 3, 4 and 5.



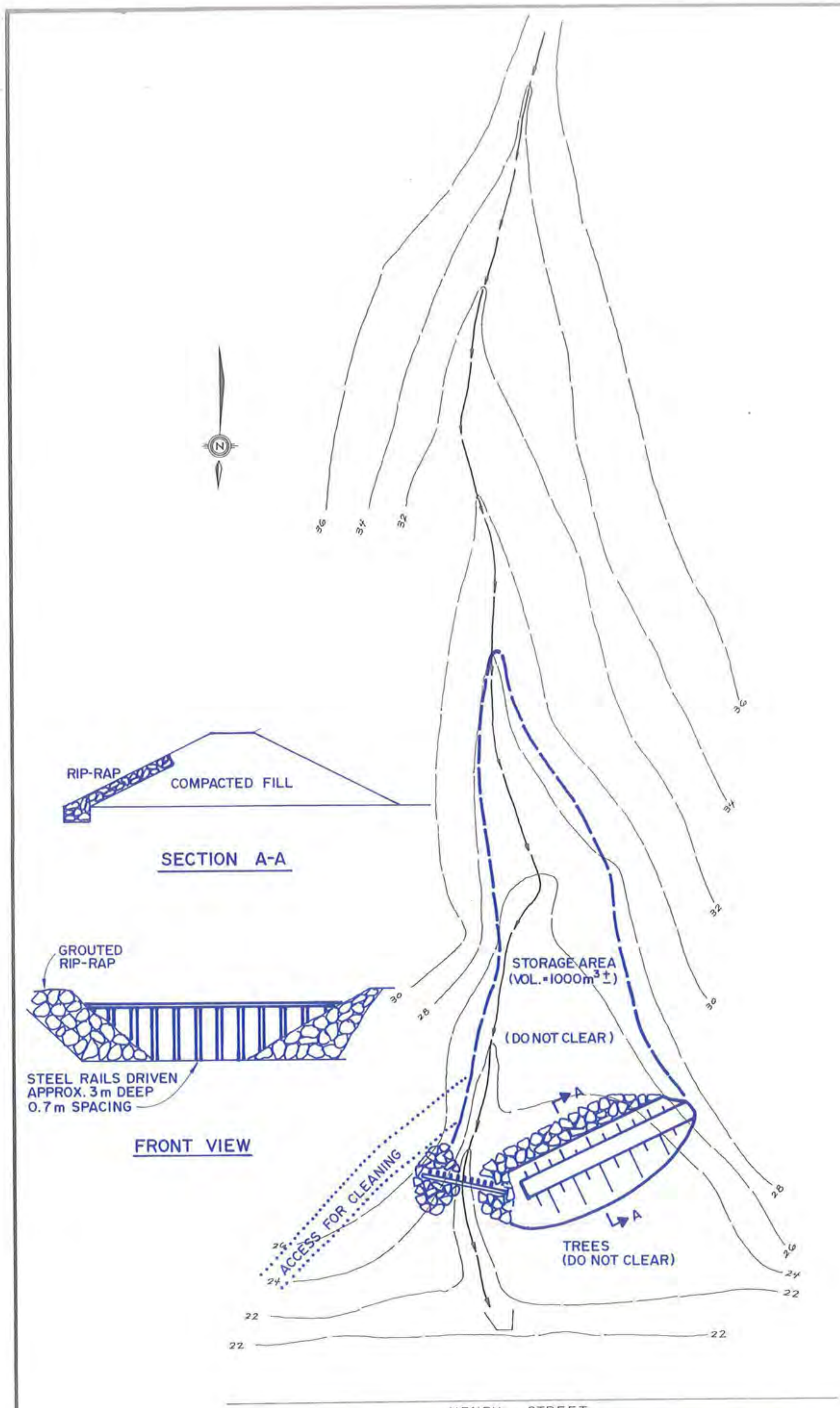
COQUITLAM – PORT MOODY DRAINAGE
SCHOOLHOUSE CREEK AND
OTTLEY CREEK DRAINAGE AREAS
DRAINAGE IMPROVEMENTS

FIGURE 5-1

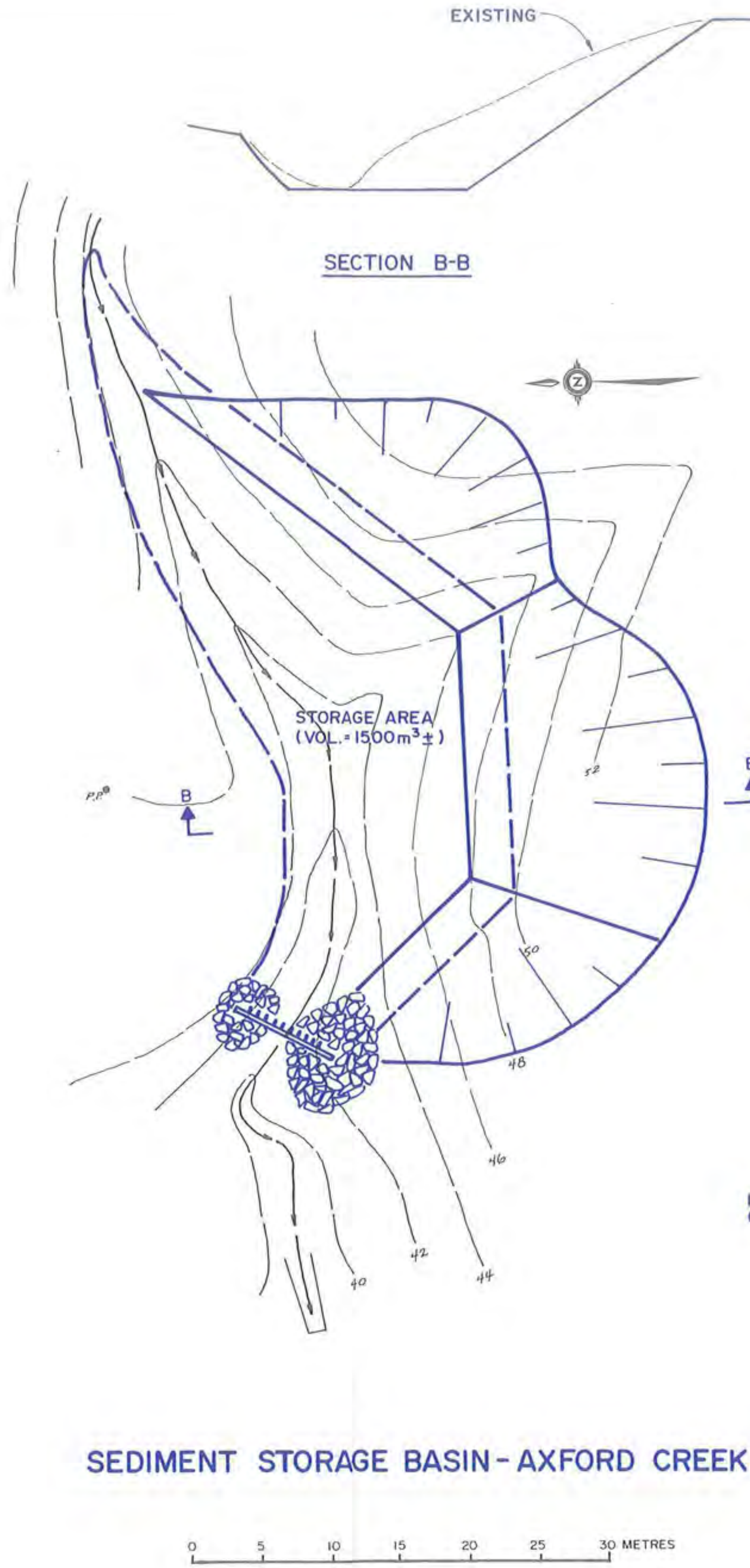


COQUITLAM – PORT MOODY DRAINAGE
KYLE STREET AND WILLIAMS STREET
DRAINAGE AREAS
DRAINAGE IMPROVEMENTS

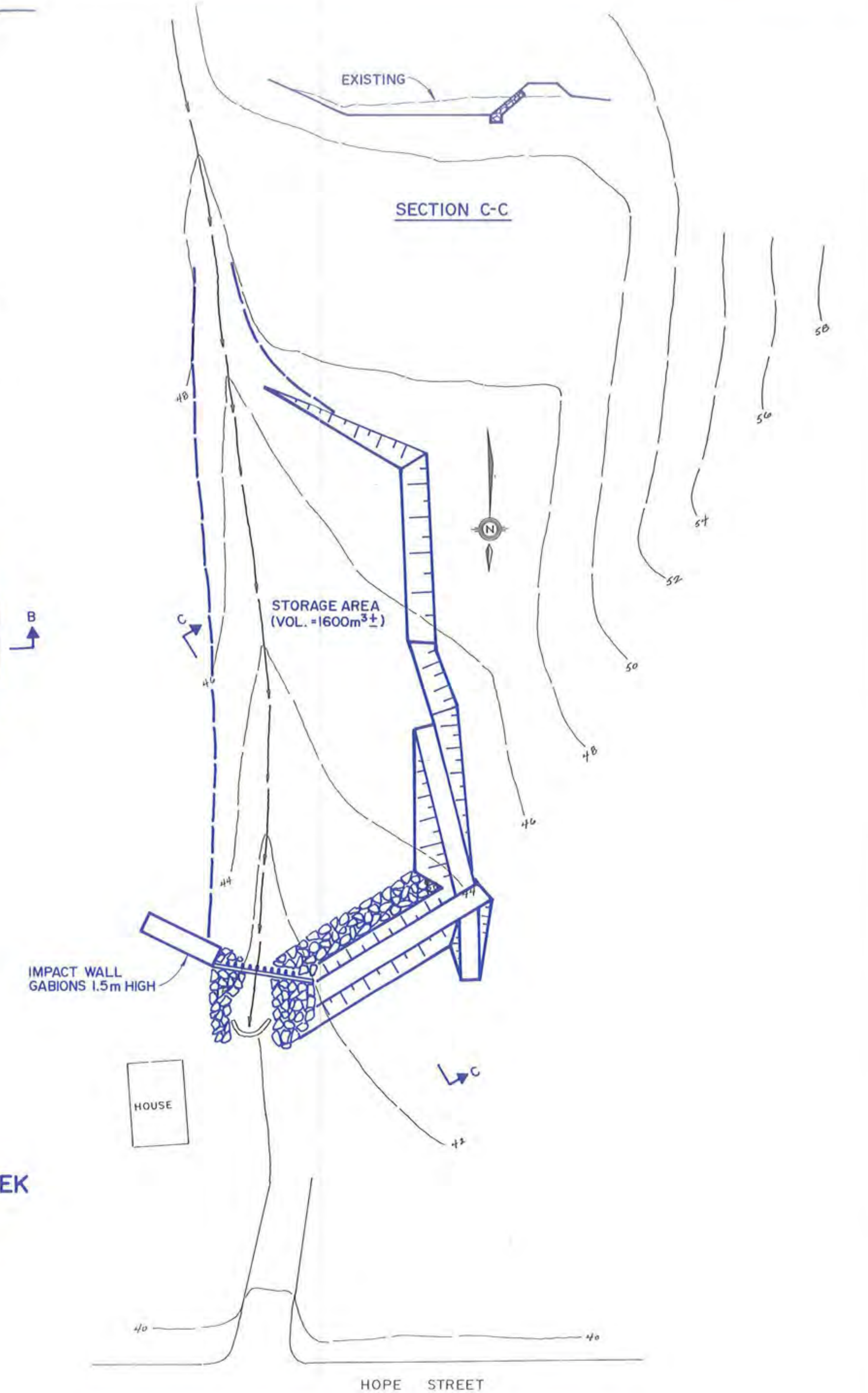
FIGURE 5-2



SEDIMENT STORAGE BASIN - WILLIAMS CREEK



SEDIMENT STORAGE BASIN - AXFORD CREEK



SEDIMENT STORAGE BASIN - OTTLEY CREEK

WILLIAMS, AXFORD AND OTTLEY CREEK INLET IMPROVEMENTS

FIGURE 5-3

6. CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations of this section apply to the geological and hydrological conditions within the creek systems both above and below the Port Moody intakes. Specific recommendations on an inspection program are given in Appendix 4.

6.1 Conclusions

The Master Drainage Plan for the study area should combine nonstructural guidelines with a schedule of structural improvements to produce a drainage management plan for the watershed. Assurance that the plan will serve to protect the communities and their natural resources requires that the drainage authorities responsible for the plan share a common commitment in its undertaking.

To this end, Port Moody, Coquitlam and the Greater Vancouver Sewerage & Drainage District already have made great strides in establishing drainage responsiblities and in undertaking responsible actions for the protection of the creek systems. The Master Drainage Plan can assist in attaining these and other goals by providing an overview of the watershed character, and by focusing on the specific drainage improvements needed for protection of the communities and environment. The task of the drainage managers is to agree on priority, and develop workable solutions and schedules for undertaking the identified work. The following conclusions relate to the identifed drainage improvements of the Master Drainage Plan and should form part of their deliberations.

1. Of the 7.3 km^2 of study area, four major drainage divisions drain from Coquitlam through Port Moody to independent outfalls on Burrard Inlet. These are from west to east and are identified as:

a)	Schoolhouse Creek	348 ha
b)	Ottley Crek	35.7 ha
c)	Kyle Street	179.5 ha
d)	Williams Street	166.8 ha

2. The four drainage areas in the study area comprise one or more drainage basins. Schoolhouse has two, Ottley has one, Kyle has five and Williams has four drainage basins. The basins are drained by a total of 12 major creek systems:

Schoolhouse	Schoolhouse Creek Noble Creek
Ottley	Ottley Creek (Hope Street)

Kyle	Axford Creek (Elgin Street) Kyle Creek Hachley Creek (Grant Street) Sundial Creek (as below) Sundial Centre and East Creek (Moody Street) Goulet Creek (Hugh Street)
Williams	Elginhouse Creek Correl Brook Dallas Creek (Slaughterhouse)

3. Above the intakes, headscarp instabilities and failures are presently associated with manmade fills, and concentrated runoff at the escarpment face (from surface drainage outfalls). The latter, when added to the layered geological formations and the high groundwater seepage can create deep incisions which threaten to undermine the steep escarpment faces. When combined with old fills, the danger of slope failure rises considerably, and is evidenced by the slides recorded since 1970.

4. Slope instabilities were determined highest for Schoolhouse, Ottley, Kyle, Sundial East and Williams basins. Instabilities were relatively average for Noble, Axford, Kyle, Sundial (West), and Elginhouse basins. All others were low.

5. Considering the geological and hydrological basin character, the basins of highest to lowest concern for debris flood and debris flow are, however;

Highest	Medium	Low
Ottley	Noble	Schoolhouse
	Axford	
Sundial East	Kyle Hachley Sundial (West) Williams Elginhouse	 Goulet Correl/Dallas

6. Existing slide scars in all basins appear stable and although they should continue to be monitored, no remedial work is proposed. Remedial work should, however, concentrate on extending existing outfalls to stable channels, and although the priority for this work is lowest, it is subject to yearly inspections and immediate corrections may be required should downcutting reveal large instabilities in the headscarps.

7. Drainage improvements to the intakes, with the exception of Schoolhouse and Dallas basins, all require structures to contain debris as well as hydraulic improvements to the intakes to assure safe flood conveyance in the event of a blockage. These improvements form highest priority.

8. Drainage improvements to the major collector facilities through Port Moody vary in priority from very high to very low. Where streets can convey major flows (100 year) and the drains still can contain minor events (10 year), and where surface flooding or damage to property is not suspected, improvement priorities rank as low. Where limitations due to channel restrictions, pipe inadequacies, inlet construction deficiencies and limited capacities which are demonstrated to have potential for large scale flood loss occur, highest priority is assigned. This is exemplified in the Williams Street Drainage Area where drainage inadequacies extend from well above the Dallas Creek intake all the way to the Williams Street CP Rail track crossing. Others include the Axford intake and Schoolhouse Creek intake.

9. A special case for drainage improvement with a high priority is the refurbishment of the Kyle Street storm drain which has eroded to 50% of its invert wall since construction in 1961. This repair is of immediate concern but could be undertaken in a staged construction program. The cost is estimated at $200,000.

10. Total costs for the improvements are high at $1,867,000, but costs in order of highest to lowest priority may be determined from Table 5-1 as follows:

Priority	Total Cost	Port Moody Cost*	Coquitlam Cost
1	$ 177,000	$152,000	$ 25,000
2	$1,100,000	$714,000	$ 386,000
3	$ 430,000	$293,000	$ 137,000
4	$ 160,000	$145,000	$ 15,000

*Costs are apportioned according to the existing agreement. All costs for Axford and Ottley are presently assumed by Port Moody.

11. To maintain continuity in the watershed, the Greater Vancouver Regional District should assume control over the two major basins Axford and Ottley. These are already part of the study area under their jurisdiction and both have their headwaters in Coquitlam, thus qualifying as interjurisdictional basins.

6.2 Recommendations

We recommend that the Greater Vancouver Sewerage & Drainage District and the two municipalities Coquitlam and Port Moody include the drainage study's findings into a Master Drainage Plan for the Coquitlam / Port Moody study area. In particular, we recommend that:

1. The Master Drainage Plan be changed to include the drainage area boundaries identified in this study.

2. The three drainage authorities continue to examine planning, liaison and approval functions for coordinating the development and funding necessary for the Master Drainage Plan.

3. The Greater Vancouver Sewerage & Drainage District include in their operations scheduled inspections of the ravines as outlined in this study, and expand their operations staff and budget to meet the needs of this study's findings.

4. The drainage authorities develop an emergency plan in the event of a slide or flood related disaster, using as a basis the suggestions proposed in this study.

As a further recommendation the Greater Vancouver Sewerage & Drainage District should consider assuming responsibility for all the major drainage which is interjurisdictional in the study area; in particular include the Axford and Ottley basins.

APPENDIX 1

Terms of Reference

Greater Vancouver Regional District
4330 Kingsway, Burnaby, British Columbia, Canada V5H 4G8
Engineering & Operations Department

Engineering: 432-6450 • Forestry: 432-6410 • Operations & Maintenance: 432-6405 • Pollution Control: 432-6420

File: SD 91.0701

August 13, 1987

Dayton and Knight Ltd.
626 Clyde Avenue
Box 91247
West Vancouver, B.C.
V7V 3N9

...T LTD.

Attention: A. Berzins, P. Eng.

Dear Sirs:

Re: Proposed Study of Port Moody/Coquitlam Drainage Area

As discussed today with Mr. Berzins, we would appreciate receiving a presentation from you for the preparation of a report on the above drainage system. It involves geotechnical investigation of the upland area as well as a study of the drainage system through Port Moody.

The following information is enclosed:

An outline of the proposed study, dated June 11, 1987.
SB 828 Location Plan of the Drainage Areas.
SF 1816 SH1 Schoolhouse Creek, Location Plan.
SF 1816 SH2 Kyle St. and William St. Drains - Location Plan.
SF 1816 SK3 Tributary Creeks.

We would like to reiterate that the purpose of this study would be to determine the adequacy of the District's existing drainage structures, to recommend new construction where necessary and to establish methods to reduce the risk of flooding due to landslides on the escarpment south of Port Moody.

Technical expertise and advice is required from a consultant who is familiar not only with drainage matters, but who can also anticipate the potential for landslides in this area and recommend measures to limit or prevent them. A cost/benefit analysis of proposed solutions is a requirement. Any proposed new construction would be taken to the preliminary design stage and final design would be done by District staff. Completion date for the study can be discussed, but a date much later than September 30, 1987 will make implementation of recommendations before the winter rainy season difficult.

We would be pleased to receive a presentation describing the experience of your firm and the staff who would be assigned together with details of any outside expertise you would employ. Kindly include a brief recommendation or outline of your approach to the project including any site work which you consider necessary to establish design data.

It would be advisable to indicate at this stage any possible conflict of interest with other clients in the area.

Yours truly,

Keith Payn

K. Payn, P. Eng.
Administrator, Sewers

KT/cb/ah
3.21

Enclosures

cc: Min. of Environment
Water Management Branch
10334-152A Street
Surrey, B.C.
V3R 7P8

Attention: Neil Peters

June 11, 1987

Proposed Study of Port Moody/Coquitlam Drainage Area Including Schoolhouse Creek, Kyle St. Drain and William Street Drain

The Purpose of the Report

The purpose of the report is to consolidate available information, determine the adequacy and condition of the existing drainage structures, recommend new construction where necessary and establish methods to reduce the risk of flooding due to landslides. The costs of recommended new construction will be measured against expected cost benefits.

More particularly, the work will involve the following:

Downstream of Intakes

1. Analyse the existing drainage structures to determine adequacy for a 10 year storm.

2. Investigate the provision of a streamway corridor and possible flood proofing of buildings in the extreme event of a greater than 10 year storm or unexpected blockage at any one of the intakes.

3. Investigate the condition of existing structures and recommend repairs where necessary.

4. Recommend new structures where appropriate to reduce the danger of flooding.

Upstream of Intakes

1. Investigate stability of the headscarps by visual inspection and append risk factors to each one.

2. Make recommendations regarding conveyance of storm water from upland areas into ravines to minimise erosion.

3. Recommend procedures to monitor condition of scarps during rainy season.

4. Recommend a contingency plan to be followed in the event of a landslide.

5. Delineate boundaries for permissible development above and below the headscarps.

KT:bm:pah
U3/442

APPENDIX 2

Thurber Consultants Ltd.

Geotechnical Study of Port Moody / Coquitlam

Drainage Area

GEOTECHNICAL STUDY OF
PORT MOODY-COQUITLAM
DRAINAGE AREA

Report
to
Dayton & Knight Ltd.
Consulting Engineers

Thurber Consultants Ltd.
Vancouver, B.C.

File: 17-560-2
March 15, 1988

D. Smith, P.Eng.
Project Principal

O. Hungr, P.Eng.
Project Engineer

Abstract

A geotechnical study has been undertaken of 13 drainages on the Chines Heights Escarpment between Port Moody and Coquitlam, B.C. The study is a part of a wider investigation of drainage and slope movement hazards in this area carried out by Dayton & Knight Ltd. for the Greater Vancouver Regional District. The purpose of the geotechnical component of the study is to assess the probability and nature of slope instability, debris flow and related hazards on the undeveloped portion of the study area and to provide conceptual recommendations for remedial measures.

TABLE OF CONTENTS

1. INTRODUCTION

The purpose of this study is to assess the potential for landsliding and erosion along the Chines Heights escarpment, separating the municipalities of Coquitlam and Port Moody, and to recommend measures which could be used to reduce the occurrence of such processes or to minimize their potential for damage.

The work was authorized by Mr. A. Berzins, P.Eng., based on Thurber Consultants Ltd.'s (TCL) proposal dated August 28, 1987. TCL's work forms part of a wider study of drainage and erosion carried out for the Greater Vancouver Regional District (GVRD)by Dayton & Knight Ltd., Consulting Engineers.

2. STUDY PROCEDURE

Background information in the form of professional and inspection reports was obtained from GVRD, from the two municipalities and from TCL's files.

The study area was examined on aerial photographs prepared between 1952 and 1984. A list of the photographs examined is given in Table 1. A helicopter inspection of the ravine headwalls was carried out on December 16, 1987. Each of the 13 streams forming the upper portions of the drainages was traversed on the ground in September and October 1987 in order to observe the condition of the stream channels and slopes. Field inspection of the sites of specific past problems was also carried out in the presence of the District of Coquitlam and the City of Port Moody personnel.

Preliminary recommendations for interim protection measures and inspection procedures were issued November 1987.

3. SITE DESCRIPTION

3.1 General

The study area encompasses 3 separate watersheds draining north into the Burrard Inlet.

Each watershed contains one or several smaller drainages, descending the north-facing Chines Heights escarpment. There are altogether 13 drainages within the study area, ranging from 0.04 to 1.5 km^2 in area. The upper portions of the drainages, on the Burrard Upland, are enclosed in the District of Coquitlam storm sewer system. The main portions of the drainages comprise steep gullies eroded in the escarpment and descending a vertical elevation difference of approximately 140 m, generally over a length of less than 1 km. Several of the gully heads are widened into a form of semi-circular coulloirs.

The characteristic profiles of the gullies include steep headwalls (typically 30 to 38°) and middle reaches sloping 10 to 20°. The entire escarpment is covered by native second growth mixed forest.

The gully outlets exit onto a series of coalescing fans, sloping north at angles of 6° or less. The fan surfaces are covered by residential neighbourhoods including two schools and other developments.

3.2 Geology

The lowest levels of the escarpment expose overconsolidated silt and clay units pre-dating the last period of glaciation in the Lower Mainland. These beds are located below el. 75 m aproximately (Armstrong, 1984) and are generally covered by slope erosion products. The middle levels of the escarpment consist of a complex interbedded sequence of dense sands, silts and tills of glacial and glacio-fluvial origin known as Quadra Sand. The upper 20 m of the escarpment consist of very dense tills forming a part of Vachon Drift.

The entire escarpment area, with the exception of exposures near the creek channels and in other areas of active erosion, is covered by a thin veneer of soil loosened by root action, frost penetration and other agents of soil creep. This, together with a dense root mat of the forest and subgrowth, is referred to as the colluvial veneer.

3.3 Groundwater Regime

The layered nature of the glacio-fluvial deposits forming Quadra Sand gives rise to a complex groundwater regime. This is illustrated in Figure 1, reproduced from Rulon and Freeze (1985), showing equipotential lines for three hypothetical slope configurations, containing different numbers of low permeability layers interbedded with pervious strata. The resulting groundwater flow patterns involve multiple seepage faces at different levels in the slope, separated by unsaturated wedges.

The groundwater system is recharged by slow vertical percolation through the till capping of the Burrard Upland, which has relatively poor surface drainage.

3.4 Erosion and Landsliding Processes

Based on the present investigations and TCL's previous experience with the Lower Mainland escarpment areas, we recognize the following types of mass wasting processes as being active within the study area:

Channel and Bank Erosion: Under normal circumstances, the stream channels on the escarpment become stabilized by means of self-lining with cobble and gravel lag deposits and the reinforcing effects of vegetation. Periodically, however, bank erosion occurs where the stream flow impacts against the side slope of the ravine due to narrowness of the channel, or an obstruction such as a fallen tree. The sand units are highly erodible and erosion may occur very rapidly. Channel erosion has been observed in only a few of the stream channels and its occurrence can be associated with specific recent changes. These include an increase in the stream flow due to the introduction of added storm water discharge by a new drain, or the recent occurrence of a debris flow which disrupted the natural "lining" of the channel (Ottley Creek).

It is conceivable that a channel erosion or downcutting episode may develop naturally as a result of a change in the character of layers exposed in the head scarp, which form the source of seepage. There is no evidence, however, that such a change can occur suddenly.

Gullying and Seepage Erosion: Gullying is initiated on the steep surfaces of head scarps by concentrated surface water discharge, usually below a drain outlet. Because the escarpment soils are highly erodible, a steep sided "bowl" or "canyon" up to 10 m deep may form in a short period, sometimes during a single storm. Sudden removal and liquefaction of large quantities of sediment follows, with resulting increase in the sediment load of the stream.

Seepage erosion or caving is an unusual and relatively rare process which may develop from some instances of gullying. It is the result of sudden exposure of confined water bearing sand layers at the foot of an erosional bowl. Occasionally, a self-sustaining chain reaction of seepage, erosion and caving of the steep crest of the scarp occurs and may result in the sudden removal of large quantities of previously dense material. Similar events occurred in the past at Westwood Plateau in Coquitlam, in the Maryhill gravel pits and in the Tower Cliffs at Point Grey and are usually described as "washouts". Several hundreds of thousands of cubic metres of materials have been known to be eroded in a matter of hours (Armstrong; 1984, Hungr and Smith, 1985). We are not aware of large scale washout events having occurred on the Chines Heights escarpment in historical time although the stratigraphic configuration of the escarpment creates a potential for them.

Extensive ancient landslide deposits have been identified in excavations in Port Moody (Armstrong, 1984). They may be evidence of large pre-historic washouts on the escarpment.

Debris Avalanching: The dense and generally granular soil units forming the escarpment are not susceptible to deep seated landsliding. As a result, instability is confined to the sliding of the colluvial veneer of loose soil and vegetation over the surface of the dense natural soil. Typical dimensions of the resulting debris slides or debris avalanches are 5 to 20 m in width and 10 to 50 m in length. Thickness of the unstable zone is generally in the order of 1 m.

Judging by the small number of recent scars on the headwall, debris avalanching has been a relatively rare phenomenon on the Chines Heights escarpment. Nearly all known recent occurrences have been associated with failures of fills placed near the crest of the escarpment slopes.

Debris Flow: The debris produced by debris avalanching or erosion occasionally forms a flow discharge of sufficient intensity, to allow it to travel the full length of the gully to the colluvial fan in the form of a surge of liquefied soil. Only one occurrence of this is documented in the study area, in December 1979 (Eisbacher and Clague, 1981). The known circumstances of this event are described in Appendix A. It appears that the flow was triggered by the failure of a fill placed on steep slope and undermined by erosion at a storm sewer outlet. The debris flow destroyed one house in Port Moody and damaged several others (Woods, 1981).

4. HAZARD ASSESSMENT

4.1 Hazards Affecting Areas North of the Escarpment

Of the geological processes described in Section 3.4, only a debris flow has the potential to directly cause damage or injury in Port Moody. However, floods heavily charged with eroded debris (debris floods) can overflow the intake structures at the foot of the slopes and cause water damage to houses located on the fans.

The discussion in Sections 4.2 through 4.5 pertains to the hazards posed by debris flow and debris floods.

4.2 Probability of Occurrence

Potential flood discharges can be related to return periods by statistical means. However, in the present case the probability of flooding damage is not merely a function of discharge but is strongly dependent on the quantity and character of sediment carried by the flood. The sediment quantity is in turn controlled by landsliding and erosional activity upstream of the fan. Another factor influencing the probability of flood damage is the condition of the intake structure which determines the possibility of overflowing .

As a result of the above arguments, and due to a lack of detailed long term measurement of sediment production and stream behaviour, the probability of flooding damage can only be assessed in a qualitative manner. The same is true with regard to the probability of debris flow.

Our estimates of absolute probability, based on known past occurrences and our general experience in the Lower Mainland region, are given below. These estimates pertain to design events, defined in Sections 4.3 and 4.4.

The estimated return period of the design debris flood on a stream of average rating within the study area is 50 years. The estimated return period of the design debris flow event on a stream of average rating is 200 years.

Relative probability of occurrence of the design events is determined by the rating scale presented in Table 3. The ratings are based on observations of head scarp instability features, summarized on Dwg. 17-560-2-1, including landslide scars, areas of slope creep, seepage and erosion.

Another criterion used in deriving the ratings given in Table 3 is the condition of the various reaches of the stream channel on the undeveloped part of the escarpment. The channels were clsssified with respect to current erosional activity, confinement and capacity to store debris, using the classification scheme defined in Table 2 (see Dayton & Knight Ltd. Figures 2-4 to 2-6).

The absolute probability of ocurrence of a design event on each of the streams can be derived from a combination of the average probability estimate given earlier in this section and the relative probability rating given in Table 3. For example, the estimated return period of a debris flow with a medium (average) rating is of the order of 200 years. The coresponding event on a stream with a high rating has a shorter return period of about 50 years. In a stream with a low rating, the return period is about 500 years.

4.3 Design Debris Flood

Apart from design flood discharge, the second most important parameter describing a debris flood event is the quantity of sediment delivered to the fan area. We recommend, for design purposes, that this sediment comprising soil and timber debris) be taken as 1,000 m^3 on those streams considered to have no capacity for storage within the channel upstream (Ottley and Axford Creeks). For all other creeks, the design sediment quantity is estimated to be 500 m^3.

4.4 Design Debris Flow

As mentioned in Section 3.4, there has only been one debris flow ocurrence in the study area within recorded history. The estimated magnitude of this event was 5,000 m^3 (Woods, 1981). This event occurred in connection with several unfavourable circumstances:

- A storm with a 24 hour rainfall intensity corresponding to a 20 year recurrence interval.
- Undermining of fill placed on an extremely steep area of the headscarp by storm sewer outlet erosion.
- The steepness and high degree of confinement of the Ottley Creek basin.

Of these three factors, the second is probably crucial, since no comparable landslides have been reported in the Chines Heights area during greater storms (e.g. December 25, 1972 or January 20, 1968). At present, drainage of the Burrard Upland is heavily controlled due to urbanization. Also, in recent years, the District of Coquitlam's Sensitive Lands Bylaw limits uncontrolled placement of fills on the escarpment.

As a result of the above changes it appears reasonable to assume that future debris flow events within the study area will not exceed the magnitude of the 1979 flow. The design debris flow magnitude is consequently estimated as 5,000 m^3 on those creeks containing no natural debris storage potential and 2,500 m^3 on those that do. Schoolhouse and Dallas Creeks are considered to have no potential to carry debris flow surges as far as their fans due to their low channel slope. They can, however, transport large quantities of sediment by means of debris flood.

4.5 Hazard Zoning

Four types of hazard zones have been defined in this study. They are defined Table 4 and discussed below.

The steep slope hazard zone, Zone S, includes all of the sloping, presently undeveloped surface of the escarpment uphill of the fan areas. The zone has not been specifically mapped. Slopes steeper than approximately 30° must be regarded as having the potential for debris sliding/avalanching which may pose serious risks to persons or developments. The hazard is, however, variable and highly site specific. Therefore, safe or developable areas may be defined in this zone based on detailed investigation.

The direct impact zone of debris flow, Zone D, is the only hazard zone on the fan area containing a risk of serious damage to structures and serious personal injury or death. This is an area where rapidly moving, high discharge surges of liquefied soils and timber debris may enter and deposit with proportionate consequences.

The indirect debris flow impact zone or debris flood zone, Zone DF, is considered susceptible to receiving large discharges of water heavily charged with suspended, bedload and floating sediment, but without the destructive scale and solids content of Zone D. Damage to structures in this zone is expected to be selective and partial and the risk of personal injury relatively low.

The flood zone, Zone F, is susceptible to uncontrolled water flow, resulting in the possibility of water damage to unprotected buildings (especially basements), erosion and silting damage.

The zone boundaries have been outlined on Dayton & Knight Figures 4.1 and 4.2, based on the estimated design event magnitudes, combined with our best estimate of the probable distribution and thickness of deposits.

5. REMEDIAL MEASURES

5.1 Need for Remedial Measures

The following discussion presents the available alternatives for remedial measures. The decision to cary out any of the possible actions must be based on a cost-benefit analysis considering the value of the land involved, estimated damage costs and probabilities, and the cost of implementation.

5.2 Preventative Inspection and Maintenance

The principle of a preventative approach is to identify instability and erosion within the ravine drainages in the early stages of their development, when it may be possible to arrest further progress of sliding or erosion by relatively simple actions such as local diversion of a channel or a pipe outlet. It must be understood that certain occurrences of sliding or erosion connected with major storms may be quite sudden, with little advance warning. Inspection can, however, identify some of the more obviously dangerous situations, such as that believed to have existed prior to the December 1979 debris flow event. The inspection program will, therefore, reduce the probability of occurrence. An outline of a suggested inspection program is given in Appendix 4.

5.3 Intake Upgrading and Protection

Each of the 13 stream channels in the study area enters the Port Moody drainage system at an intake. The safety against flooding damage in Port Moody is highly dependent on the ability of the intakes to function properly when inundated by high water and sediment discharges.

In our estimate, Schoolhouse, Elginhouse, Correl and Dallas Creek intakes are situated and designed so as to be reasonably safe against plugging and overflowing during major floods, although each may overflow during the design debris flood.

Goulet Creek has a sediment storage basin capable of holding approximately 500 m^3 of material and is thus secure against all but the major debris flow events.

Noble and Kyle Creeks have intakes with low freeboard which could overflow during debris floods. The consequences of overflow would, however, be relatively small, because insensitive areas (parking lots) presently cover the indirect impact hazard zones. Flood damage downstream could be reduced by increasing the available freeboard of the intakes and providing overflow protection pipes.

Ottley, Axford, Williams and Hachey Creeks have intakes which could overflow during debris floods. Furthermore, the debris flow impact areas cover existing residential lots and there is therefore a risk of debris flow damage (see Dayton & Knight Figures 4.1 and 4.2).

Conceptual plans for upgrading the first three intakes are shown on Dayton & Knight Figure 5.3 and 4. Debris flow protection of the Hachey Creek outlet would require acquisition of at least one private lot. The concepts have been designed on the premise of obtaining a reasonable degree of protection of the safety of the inhabitants without requiring major structures. The designs consequently retain some degree of residual risk, but are intended to reduce the danger of serious damage and injury to what we consider a reasonable degree.

5.4 Remedial Work in Upper Drainages

During this study, only one area has been identified as requiring early remedial work. This is in the headwaters of East Sundial Creek, where active downcutting and bank erosion has occurred as a result of increased discharges following the installation of a trunk drain discharge. We recommend that the stream channel be protected by check dams, riprap or similar means for 50 m downstream of the existing drain outlet.

A channel diversion to the left is required some 100 m further downstream to prevent continuing erosion at the foot of a large bare scarp. We understand that a temporary diversion was carried out at this location last fall. Further action should be considered after a period of observation.

Gutter drainage on Gatensbury Street should be reviewed in order to guarantee that storm flows collected on the pavement cannot overflow into the Kyle Creek drainage.

5.5 Development Restrictions

Undeveloped areas of the Chines Heights Escarpment should continue being protected by bylaws controlling placement of fill, forest clearing and drainage, similar to the existing District of Coquitlam Sensitive Lands bylaw (Bylaw No. 1199, 1982).

It is further recommended that any proposed development of the natural undeveloped areas of the escarpment should be made conditional upon detailed site specific investigation by a geotechnical specialist. This restriction should also apply to any public or private lots containing portions of the natural areas and those located adjacent to or across the street from the natural areas.

6. SUMMARY

Thirteen drainages in the Chines Heights area have been described and classified in terms of debris flood and debris flow hazards.

The probability of damage due to geotechnical/ hydrologic hazards has been estimated and is given in Section 4.2 and Table 3. The hazard zone areas are defined on Dayton & Knight Figures 4.1 and 4.2. Recommendation for a preventive program of inspection are given in Appendix B.

A discussion of the condition of the existing stream intakes in Port Moody is given in Section 5.3. Recommendations for possible remedial construction are summarized on Dayton & Knight Figure 5.3. Implementation of the remedial measures will require further engineering input, especially to determine the cost-benefit ratio and provide detailed design documents.

Recommendations related to development restrictions on and near the escarpment are given in Section 5.5.

Table 1

AERIAL PHOTOGRAPHS EXAMINED

Roll No.	Approximate Scale	Year
BC 1632	1:60,000	1952
BC 1676	1:20,000	1954
BC 5061	1:20,000	1963
BC 5323	1:20,000	1969
BC 5574	1:40,000	1974
BC 79046	1:20,000	1979
BC 84013	1:40,000	1984

Table 2

CHANNEL CLASSIFICATION

Channel	Type
A	Indistinct channel covered by vegetation, swamp land, no erosion potential.
B	Shallow, ill defined channel, meandering in a wide floodplain.
C	As in B, with occasional points of erosion where channel bends contact the floodplain margin.
D	Relatively straight, well defined channel, little active erosion.
E-1	Relatively straight incised channel, active bank erosion on one side.
E-2	As in E-1, erosion on both sides.
F	Active downcutting.

Table 3

RELATIVE HAZARD PROBABILITY RATING FOR STREAMS IN THE STUDY AREA

Creek	HISTORY Debris Flow	HISTORY Flood	Overall[1] Slope Angle degrees	Instability of Headwall	Presence of Fills and Debris Slide Scars in Headwall	Erosion[2]	Channel[3] Confinement	Debris[3] Storage Areas	RELATIVE OCCURRENCE PROBABILITY RATING Debris Flood	RELATIVE OCCURRENCE PROBABILITY RATING Debris Flow
Schoolhouse	No	No	4	H	H	M	H	Yes	M	L
Noble	No	No	14	M	M	M	MH	Yes	M	MH
Ottley	Yes	No	13	H	H	H	H	No	H	H
Axford	No	No	9	M	L	M	H	No	M	MH
Kyle	No	Yes	10	M	H	L	H	Yes	M	M
Hackley	No	No	10	H	M	L	L	Yes	M	M
Sundial W.	No	No	10	M	M	L	L	Yes	M	LM
Sundial E.	No	Yes	10	H	H	H	M	Yes	H	H
Goulet	No	Yes	8	L	H	L	L	Yes	M	L
Williams	Yes	No	12	H	M	L	MH	Yes	M	MH
Elginhouse	No	Yes	11	M	M	L	L	Yes	M	LM
Correl	No	No	10	L	L	L	L	Yes	L	L
Dallas	No	No	6	L	M	L	L	Yes	M	L

Rating Scale: L=low, LM=low to medium, M=Medium (average), MH=Medium to High, H=High

Notes: [1] From headwall crest to intake.
[2] In upper and middle reaches of the escarpment slope.
[3] In lower one-third of escarpment slope.

Table 4

HAZARD ZONE DEFINITION

Zone S - Steep slopes

Area of natural slope steeper than 30° which must be considered as having the potential to generate debris slides or avalanches. Site-specific investigation is required.

Zone D - Debris flow direct impact zone

Area in the vicinity of fan apex, where large scale rapid movement of liquefied debris can be expected. Velocities may exceed 3 m and discharges several tens of m^3, producing a risk of serious damage or destruction to buildings and injury to persons. Deposit thickness can reach several metres.

Zone DF - Debris flow indirect impact zone (debris flood zone)

Area on the fan downstream of Zone D where large uncontrolled discharges of heavily sediment-laden water can travel, creating deposits generally less than 1 m thick and relatively light damage to buildings.

Zone F - Flooding zone

Lower area of fan, where uncontrolled but relatively diffuse and sediment-free water flows can occur. Damage is generally limited to water damage.

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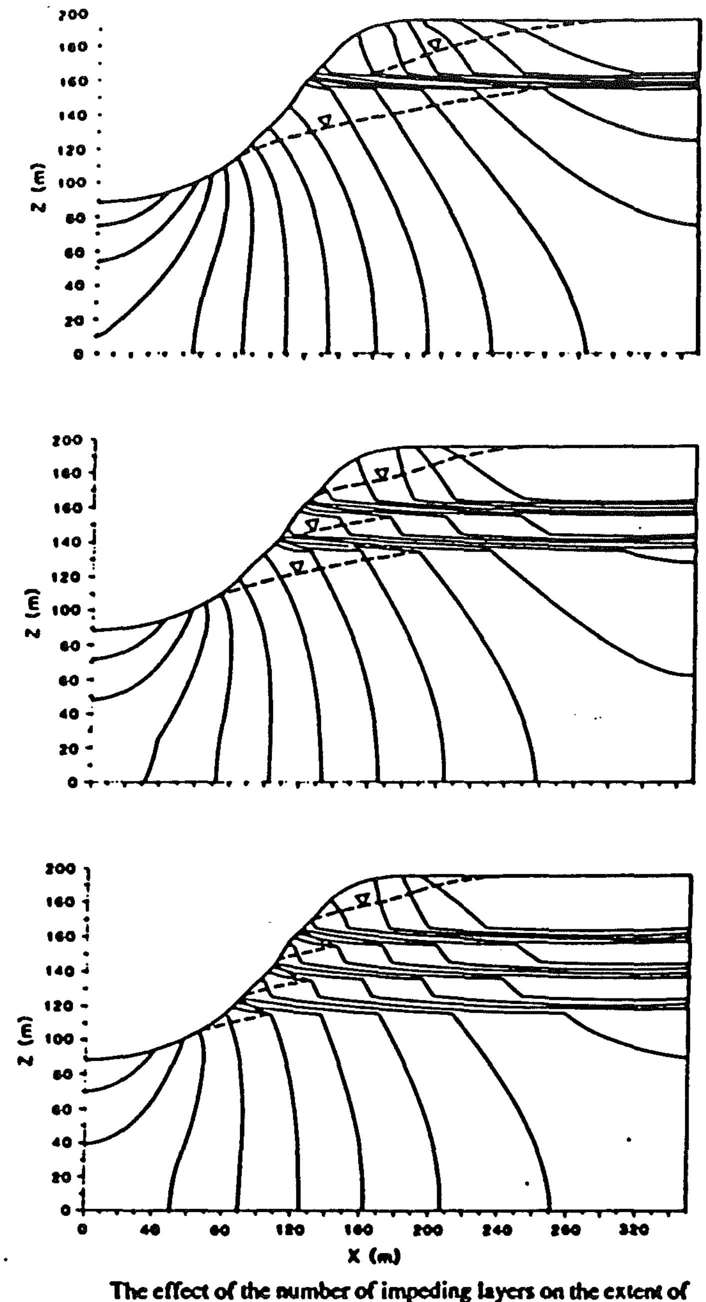
Woods, P. 1981. Port Moody/Coquitlam debris flow landslide identification study. B.C. Ministry of Environment, Water Management Branch, File P79-28.



The effect of the number of impeding layers on the extent of the unsaturated wedges. Rainfall rate = 2.1 × 10^{-8} m/s; K_1 = 10^{-7} m/s; K_1/K_2 = 20.

GROUNDWATER REGIME IN A LAYERED FORMATION (Rulon and Freeze, 1984)

FIG. 1

Appendix A

DESCRIPTION OF THE DECEMBER 14, 1979 DEBRIS FLOW EVENT ON OTTLEY CRREK

(Extract from Woods, 1981)

APPENDIX A

THE 1979 DEBRIS FLOW LANDSLIDE

The damaging landslide initiated as a slump in landfill located at the head of a gully in the yard of 986 Porter Street, Coquitlam (Reference No. 10). Neighbours later recalled hearing a crashing and snapping noise (of breaking trees) some time around 1700 hours December 14, 1979, but were unable to locate its source in the early darkness. More noises were reportedly heard about half an hour later.

At the gully outlet (some 100 metres vertically and 600 metres horizontally away) at 2208 Hope Street in Port Moody, Mrs. Roland first observed logs, mud and debris entering the carport at about 1650 hours. Very alarmed by this sight, Mrs. Roland quickly put outdoor clothing on herself and two children, and ran into the street. Her cries alerted neighbours who moved immediately to evacuate the apartment building across the street. She then ran to a neighbour's house and, after telephoning her husband, returned to find the residence had been completely shifted off its foundation. She estimated that five to seven minutes had elapsed.

The scant warning time permitted the successful evacuation of an elderly lady from her lower level apartment, though it is understood that little time was available for salvaging of household effects. The Roland house apparently shifted farther during the night; flooding occurred through residences and city streets with subsequent resorting of slide debris by water.

The headscarp on Porter Street was found to be some 35 metres high and 20 metres wide with a reported 10 to 12 metres of land lost. On this basis it was estimated that about 4000 cubic metres of material was involved in the initial failure. The headscarp cuts through a substantial thickness of random landfill and buried stumps and organic debris (photo 1-8 and photo 2-2).

On the east side of the fill a culvert discharged drainage over the headscarp. It could later be seen that this was causing erosion of in situ fine sands near the former toe of the failed fill. Also evidence could be seen of seepage emerging from these same pervious layers.

The gully was observed to be substantially scoured for most of its 600 metre length though some debris from the initial failure was deposited at the toe of the headscarp (photo 1-7).

The material deposited in Port Moody was estimated to total some 8000 cubic metres. It ranged from a mixture of large trees and stumps in a matrix of gravel, mud, occasionally pieces of concrete, etc. on Hope Street to mainly mud and occasional floating smaller wood debris below St. George Street, and predominantly silt and water washed sands below St. Andrews Street.

The damage consisted of complete destruction and inundation of the at grade basement of the Roland house above with the main level shifted completely off its foundation and its frame twisted. (The owners were able to salvage considerable goods from the main floor as the structure remained intact, tending to float somewhat above the debris.) On Hope Street, cars were crushed and across the street a garage was battered and wrecked (photos 1-11, 1-12, 2-5 and 2-7).

The lower apartments in the St. George Apartments were inundated to a depth of well over one metre by mud and water which poured in through windows (photo 2-8). Much debris and mud simply flowed around the apartment block and did not cause structural damage. Houses on the lower side of St. George were surrounded by a shallow depth of mud and smaller debris which trapped cars and plugged drains, though damage was essentially limited to basement flooding and landscaping (photos 2-14 and 2-17). A garage door just above St. Andres Street was caved in by the weight of sediment against it.

City crews reported stream flows of several times magnitude above those normally experienced in this gully. (Other gullies apparently also produce considerable flow, though proportionally not near those experienced at Hope Street.) Flooding and handling of storm waters was a major consideration, though damage was minimized by competent action by city crews and volunteers.

In total, about a dozen properties were affected by the landslide and/or subsequent flooding (drawing #4918-R79-15-3). The Provincial Emergency Program paid out well in excess of a quarter of a million dollars in damage relief to private individuals for lost or damaged necessities (this program excluded aid to industry and business and did not provide allowances for land loss, landscaping, etc.).

The same storm system produced numerous other incidents of flooding, land instability and ground settlement in the Port Moody/Coquitlam area and indeed over a widespread area of southwestern British Columbia. Nearby stream related problems included threatened blockages of lower Schoolhouse Creek, and road and railway washouts on Noons Creek.

In the Chines area, cracking was reported in a parking lot fill off Ingersoll and a minor slide occurred behind 1035 Gatensbury. Of more importance was a fill failure off the end of Harbour Drive which developed flow characteristics but came to rest within 125 metres of the headscarp. Also a major fill failure ocurred behind Custer Place causing a blockage of the creek and its displacement around its toe. This landslide, however, did not develop into a flow.

HYDROMETEOROLOGY OF THE DECEMBER 1979 STORM

The landsliding, flooding and associated problems in the Coquitlam/Port Moody area occurred during a period of successive rainstorms affecting a broad portion of Vancouver Island and the Lower Mainland. While many factors had some effect on slope stability, it is apparent that the storm and the effects of infiltration and runoff constituted the triggering mechanism. The storm has been accordingly analyzed to attempt to determine its significant aspects (Reference Nos. 2 and 8).

In general terms, the southwestern coast of British Columbia was subject to successive frontal waves preceded by periods of continuous heavy rainfall.

The rain generally started late on the evening of December 12, 1979, and continued for about 36 hours to December 14, only to recommence for another 30 hours starting December 16. The Porter Street slide occurred near the end of the first storm period while the Harbour Drive landslide occurred near the end of the second storm period.

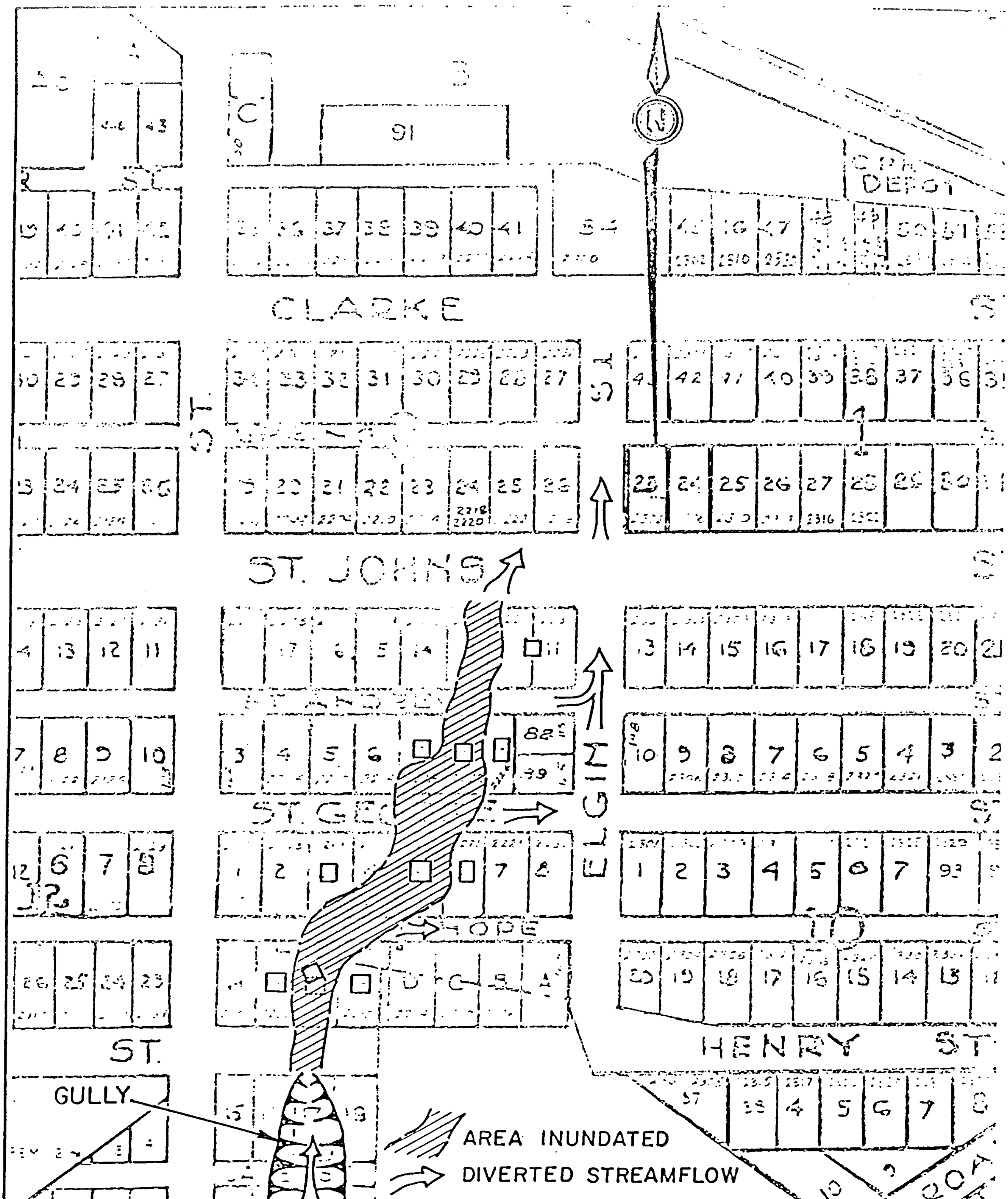
Atmospheric Environment Service records from the continuous recording gauge at Port Coquitlam City Yard (i.e. the closest gauge giving short duration intensities) were analyzed to determine if the runoff near the times of slides was unusual. The times of concentration for the Porter Street and Harbour Drive drainage basins were estimated to be respectively less than 10 minutes and 5 minutes. Analysis of the gauge records revealed that at no time during either of the storm events did the short-term precipitation intensity for periods comparable to the times of concentration exceed about a 1:2 year event. The relative insignificance of short duration rainfall intensity is also apparent from an overview of other precipitation gauges in the Greater Vancouver area (Table Nos. 1 and 2).

Of much more importance than the short-term intensities was the recurrence interval of the longer duration events. At most locations, the storm reached its greatest return periods in the range of durations of one to seven days. At Vancouver International 'A', for instance, the maximum 24 hour intensity during the storm period had a return period of 1:70 years as did the 5 and 6 day events. (It should be noted that considerable variation in frequency of event was noted between various precipitation gauges in the Lower Mainland, with the Vancouver International 'A' recording the rarest event.)

The precipitation at IOCO Refinery reached a near record peak daily total of 126.2 mm from 0800 hours December 13 to 0800 hours December 14, 1979, corresponding to an estimated 1:20 year recurrence interval. The maximum recorded 24 hour rainfall since 1941 at this station is 133.6 mm. The longer term (6 and 7 day) precipitation totals were also in the order of a 1:20 year recurrence interval.

The long duration total precipitation would have a significant affect on saturation of overburden and on groundwater tables, and also on erosion potential as a function of total flow during the storm period.

A recent study (Reference No. 3) examined the historical record of similar storms which contributed to instability problems in the Greater Vancouver area. It was found that such storms causing newsworthy landslide damage in this broad area have occurred on an average once every three years since 1900. (Interestingly the searches of the major Vancouver daily newspapers conducted for that survey did not uncover any record of previous "newsworthy" landslides in the Chines area.)



Province of British Columbia
Ministry of the Environment
WATER MANAGEMENT BRANCH

TO ACCOMPANY REPORT ON
PORT MOODY
1979 – PORTER ST. DEBRIS-FLOW LANDSLIDE
SITE PLAN

SCALE: HOR. 1" = 200'	DATE JAN. 1980	P J Woods ENGINEER
THURBER		FILE No. R79-15 DWG. No 4918-R79-15-3

Appendix B

OUTLINE OF SUGGESTED DRAINAGE INSPECTION PROGRAM FOR UNDEVELOPED AREAS OF THE ESCARPMENT

1. OBJECTIVES

The objectives of the proposed inspection program are to:

a) Provide an early warning of potentially hazardous situations which could lead to landslides, debris flows or floods on the creeks.

b) Monitor problem spots on the creeks in order to note changes and to establish priorities for maintenance and remedial work.

2. ACCESS

In order to have reasonably easy access to the creek ravines, a network of inspection trails should be cleared. We recommend that trails be established following the main channels of Schoolhouse, Noble, Ottley, Axford, Kyle (east branch), Hachley, West Sundial, East Sundial (east branch), Goulet, Williams, Elginhouse and Dallas (west branch) Creeks. Each trail should start at the Port Moody inlet and continue to within sighting distance of the ravine head scarp.

The new trails will, of course, receive use from the general public. The management aspects of this should be assessed by GVRD authorities, in consultation with the affected municipal governments.

3. SCHEDULE

It is recommended that inspections be carried out in February or March and October of each year. Apart from these, special inspections should be conducted soon after each storm exceeding the 5 year return period, based on precipitation records at Coquitlam Lake.

Continued....

4. METHOD

The inspections should identify situations most likely to become triggering events for debris flows, landslides or sudden concentrated water or sediment discharges. The following are descriptions of typical occurrences:

1. Bank erosion. The creek channel is diverted to one side of the floodplain due to deadfall, slide siltation or natural meandering. The bank slope becomes undermined and a near-vertical or overhanging bare scarp of exposed soil is created and gradually enlarged. This undermining removes support from the loose surficial soil layer covering the slope above the scarp and this could eventually slide suddenly into the creek.

2. Channel downcutting. The creek discharges increase due to some factor, possibly a new drainage outlet upstream. The channel bed becomes gradually deepened, producing sediment. This will normally not lead to catastrophic slide events, but the continuing high sediment yield rate may be undesirable.

3. Gully erosion. This type of erosion may occur on a tributary or headscarp gully, often just downstream of a drain outlet. The erosion creates a steep-sided bowl or "canyon" up to 10 m deep. The gradual enlargement and deepening of the erosion scar produces sediment. The hazard of this situation lies in the fact that the growth rate of such a feature can be highly variable. The scar could therefore grow gradually over a long period of time and then suddenly enlarge itself dramatically during a major storm and produce a large sudden discharge of sediment in the creek. This sudden erosion may be due to less cohesive, sandy and possibly water-bearing layers being exposed at the base of the scar.

Continued....

4. Major deadfall. When large trees become uprooted near the creek bank, there is a high probability of the trunk and root system blocking the stream and causing erosion. The uprooting itself may expose a large enough area of bare soil to increase siltation in the creek. It is desirable to identify unstable trees and cut them before they fall.

5. Natural slide. The natural slides in this area involve a layer of soil and roots about 1 m thick, on slopes ranging from 30° to 40° to the horizontal. Unstable slopes will usually be identified by the following symptoms:

   - Rough, hummocky or ridged surface.
   - Freshly tilted or uprooted trees.
   - Series of ridges and depressions at mid-slope.
   - Bulges near the toe of the slope.
   - Wetness and seepage.
   - Undercut toe of the slope.
   - Cracks or bare scarps near the crest of the slope, sometimes with roots stretched across them.

   Not all of the above will necessarily be observable on a potentially unstable slope. On the other hand, all of the above symptoms except the last 2 may be the result of gradual creep processes which will never lead to catastrophic instability. In fact, surface deformations, bent trees and seepage are widespread on the escarpments and usually do not identify a dangerous situation. The inspections should concentrate on fresh changes in the above symptoms, especially recent occurrence of toe undermining and cracks.

6. Fill slide. One of the most frequent slide triggers is instability of fill placed near the crest of steep slopes. The potential instability is identified by the symptoms listed in the previous paragraph occurring on the slopes surrounding the fill. In addition, the fill

Continued....

crest may exhibit sagging features, cracks or bulges, or gully erosion or seepage. One of the most dangerous situations arises when bank or gully erosion undermines the toe of a fill deposit. This was the trigger of the December 1979 slide at Porter Street.

7. Channel obstruction. The following types of channel obstruction may be found:

- Deadfall, single large tree or root system.
- Deadfall, several trees.
- Timber jam.
- Slide debris.
- Fan of silt from gully erosion.
- Fill or foreign material (garbage).

Two types of hazard are associated with obstructions. Most commonly, the obstruction may cause channel overflow to one side, leading to bank erosion. Another possible hazard is water ponding behind an obstruction. The obstruction may be sufficiently pervious to cause no ponding during relatively dry weather. Ponding may then occur during major storms, when seepage through the obstruction cannot handle the increased discharge. The pond could then overflow suddenly and wash out the obstruction.

5. RECORDS

We suggest that the attached form be used to gather routine records of the inspections. The form is intended to record only the main features of the above-described hazards. Apart from this, individual written memos should be prepared with regard to locations of particular concern. The District of Coquitlam standard form should be used to describe the condition of drain outlet structures.

APPENDIX 3

October 26, 1987

Interim Report

Port Moody / Coquitlam Drainage Area

DAYTON & KNIGHT LTD.
Consulting Engineers

626 CLYDE AVENUE, WEST VANCOUVER, BRITISH COLUMBIA, CANADA TELEPHONE: (604) 922-3255
MAILING ADDRESS: P.O. BOX 91247, WEST VANCOUVER, BRITISH COLUMBIA, CANADA V7V 3N9

October 26, 1987

Mr. K. Payn, P.Eng.
Sewers Administrator
Greater Vancouver Sewerage
and Drainage District
4330 Kingsway
Burnaby, B.C.
V5H 4G8

Dear Mr. Payn:

Re: Study of Port Moody / Coquitlam
Drainage Area; Your File SD91.0701

Thank you for our meeting held on October 2, 1987 regarding interim measures for this year's protection within the ravines and our subsequent inspection of the sites held on October 9, 1897.

In preparation for the interim meeting, we interviewed both Port Moody and Coquitlam Engineering staff, visited their perspective drainage works, reconnoitered the ravines with the GVS&DD works staff and internally inspected the Kyle Street storm drain. Unfortunately, we did not finish a complete reconnoiter of the Williams Street Drainage Area system (Dallas Creek, Correl Brook and Elgin House Creek) but did examine the scarp and ravine outlet and storm inlet works. Our site visit of October 9, 1987 provided details necessary for recommending interim measures needed for Dallas (Slaughterhouse) Creek. We also discussed interim work for the Sundial (East) Creek ravine headscarp protection with Coquitlam at a site meeting with Mr. Sever Rondesvedt on October 19, 1987.

The interim measures proposed do not in every case reflect improvements to upgrade the worst conditions, but reflect our relative evaluation of the practicality in making the improvements this year. The improvements proposed are at the ravine storm inlets and within the ravine. As discussed in our meetings, efforts should be made to redirect all surface runoff away from point discharges within the ravines, unless other precautions are made to direct the flows down to stable channel beds.

Our immediate recommendations are to provide inspection access in every ravine from each ravine's outlet to its headscarp. This will allow ease of inspection and an increase in inspection frequency. Thurber Consultants are to provide further advice on inspection requirements. We recommend that GVS&DD formally accept authority for the two drainage basins, Ottley Creek and Axford Creek which are presently maintained by Port Moody. Both have their headscarps in Coquitlam and should be recognised as being both interjurisdictional and major drainage courses. Axford Creek is part of the Kyle Street Drainage Area but Ottley Creek is an independent basin which flows through Port Moody to Port Moody Bay (although major flow could overflow to Axford storm facilities). The 1960 GVS&DD drainage areas should be revised to show the different boundaries. Other ravines such as Sundial Creek East, now not inspected by the District, should be included in an inspection schedule.

The following summarizes the relative concerns and associated interim and long-term upgrading goals. The long-term requirements are tentative only and will be further evaluated. (A marked plan of the drainage basins was left with the District and basins were numbered according to the following numbers.)

	Priority	Immediate	Long-term
1. Schoolhouse	low	- - Access and inspection.	- On Albert Street Inlet - add grating and enclose channel between Albert and St. Johns. - Monitor fill settlements. - Rebuild Ingersol Outfall.
2. Noble Creek	low - moderate	- - Access and inspection.	- Overflow bypass. - Control develop in d/s fan (parking areas).
3. Ottley Creek	high	- Access and inspection. - Survey at inlet.* - Improve storage by excavation to 900 m^3, provide berm and rock, est. $7500.	- Overflow bypass. - Storage add 400 m^3 of basin. - Deflection wall. - Rebuild inlet. - Rebuild storm drain.
4. Axford Creek	high (debris)	- Access and inspection. - Survey at inlet.*	- Overflow bypass. - Excavated basin and rock plus headwall at intake. - Purchase homes. - Rebuilt storm drain.
5. Kyle	moderate to high	- Revise Coquitlam's Gatensbury road drainage (possibly retain along road swale to Pt. Moody). Asphalt swale - 50 m, est. $2000. - Access and inspection.	Inlet - Build large gravel collection basin. - Remove old basin. - Reconstruct headwall. - Bypass? - Zoning restriction? - 1200 m + of invert reconstruction, $40,000.

		Priority	Immediate	Long-term
6.	Hackley	moderate	- Access and inspection. - Could construct berm (interim), est. $1500	- Berm and gravel removal basin. - Bypass?
7.	Sundial (W)	low	- Access and inspection.	
8.	Sundial (E)	moderate to high (slide)	- Access and inspection. - Survey cut scarp.* - Remove spurs in upper reach (10-15 mandays). - Gain access to undermined slope.	- Construct check dams (?) - Extend outfall (?) - Need berm and retaining wall plus bypass structure.
9.	Goulet Creek	-	- Access and inspection.	- Berm off old channel (using fan materials). - Bypass.
10.	Williams	very high	- Access and inspection. - Survey of inlet.*	- Debris (earthen) basin (including rock). - Bypass. - Complete and reconstruct storm drain to confluence.
11.	Elgin House Creek	low	- Access and inspection.	
12.	Correl Brook	low	- Access and inspection.	
13.	Dallas Creek (slaughter house)	low to high (flood)	- Access and inspection. - Provide cutoff or construct diversion channel, $10,000.	- Reconstruct storm drain from Hope Street (or Elgin House Creek confluence to St. Johns Street).

* (We are undertaking the four surveys needed to better determine the improvements needed for Ottley Creek, Axford Creek, Sundial East, and Williams Creek for the agreed upset price of $3,000.00.)

Let us know if the above does not meet your needs for the present.

Yours truly

DAYTON & KNIGHT LTD.

Harlan G. Kelly, P.Eng.

HGK/mjd
113.7
cc Mr. N. Nyberg, P.Eng., Coquitlam
Mr. T. Hunt, A.Sc.T., Port Moody
Mr. U. Hungr, P.Eng., Thurber Consultants

APPENDIX 4

November 10, 1987

Interim Report

Chines Heights Creek Inspections

Port Moody / Coquitlam Drainage

THURBER CONSULTANTS LTD.

M E M O R A N D U M

To: H. G. Kelly, P.Eng.
Dayton and Knight, Ltd.

Date: November 10, 1987

From: O. Hungr,
Thurber Consultants Ltd.

File: 17-560-2

CHINES HEIGHTS CREEK INSPECTIONS,
PORT MOODY - COQUITLAM

1. OBJECTIVES

The objectives of the proposed inspection program are to:

a) Provide an early warning of potentially hazardous situations which could lead to landslides, debris flows or floods on the creeks.

b) Monitor problem spots on the creeks in order to note changes and to establish priorities for maintenance and remedial work.

2. ACCESS

In order to have reasonably easy access to the creek ravines, a network of inspection trails should be cleared. We recommend that a trail be established following the main channel of Schoolhouse, Noble, Ottley, Axford, Kyle (east branch), Hachley, West Sundial, East Sundial (east branch), Goulet, Williams, Elginhouse and Dallas (west branch). Each trail should start at the Port Moody inlet and continue to within sighting distance of the ravine head scarp.

The new trails will, of course, receive use from the general public. The management aspects of this should be assessed by GVRD authorities, in consultation with the affected municipal governments.

3. SCHEDULE

It is recommended that one scheduled regular inspection be carried out during October and one during February or March of each year. Apart from these, special inspections should be conducted soon after each storm exceeding the 5 year return period, based on precipitation records at Coquitlam Lake.

Continued....

4. METHOD

The inspections should identify situations most likely to become triggering events for debris flows, landslides or sudden concentrated water or sediment discharges. The following are descriptions of typical occurrences:

1. Bank erosion. The creek channel is diverted to one side of the floodplain due to deadfall, slide siltation or natural meandering. The bank slope becomes undermined and a near-vertical or overhanging bare scarp of exposed soil is created and gradually enlarged. This undermining removes support from the loose surficial soil layer covering the slope above the scarp and this could eventually slide suddenly into the creek.

2. Channel downcutting. The creek discharges increase due to some factor, possibly a new drainage outlet upstream. The channel bed becomes gradually deepened, producing sediment. This will normally not lead to catastrophic slide events, but the continuing high sediment yield rate may be undesirable.

3. Gully erosion. This type of erosion may occur on a tributary or headscarp gully, often just downstream of a drain outlet. The erosion creates a steep-sided bowl or "canyon" up to 10 m deep. The gradual enlargement and deepening of the erosion scar produces sediment. The hazard of this situation lies in the fact that the growth rate of such a feature can be highly variable. The scar could therefore grow gradually over a long period of time and then suddenly enlarge itself dramatically during a major storm and produce a large sudden discharge of sediment in the creek. This sudden erosion may be due to less cohesive, sandy and possibly water-bearing layers being exposed at the base of the scar.

4. Major deadfall. When large trees become uprooted near the creek bank, there is a high probability of the trunk and root system blocking the stream and causing erosion. The uprooting itself may expose large enough area of bare soil to increase siltation in the creek. It is desirable to identify unstable trees in time where possible and cut them.

Continued....

5. <u>Natural slide</u>. The natural slides in this area involve a layer of soil and roots about 1 m thick, on slopes ranging from 30° to 40° to the horizontal. Unstable slopes will usually be identified by the following symptoms:

   a) Rough, hummocky or ridged surface.
   b) Freshly tilted or uprooted trees.
   c) Cracks or bare scarps near the crest of the slope, sometimes with roots stretched across them.
   d) Series of ridges and depressions at mid-slope.
   e) Bulges near the toe of the slope.
   f) Wetness and seepage.
   g) Undercut toe of the slope.

   Not all of the above will necessarily be observable on a potentially unstable slope. On the other hand, all of the above symptoms except c) and g) may be the result of gradual creep processes which will never lead to catastrophic instability. In fact, surface deformations, bent trees and seepage are widespread on the escarpments and usually do not identify a dangerous situation. The inspections should concentrate on fresh changes in the above symptoms, especially recent occurrence of toe undermining and cracks.

6. <u>Fill slide</u>. One of the most frequent slide triggers is instability of fill placed near the crest of steep slopes. The potential instability is identified by the symptoms listed in the previous paragraph occurring on the slopes surrounding the fill. In addition, the fill crest may exhibit sagging features, cracks or bulges, or gully erosion or seepage. One of the most dangerous situations arises when bank or gully erosion undermines the toe of a fill deposit. This was the trigger of the December 1979 slide at Porter Street.

7. <u>Channel obstruction</u>. The following types of channel obstruction may be found:

   a) Deadfall, single large tree or root system.
   b) Deadfall, several trees.
   c) Timber jam.
   d) Slide debris.
   e) Fan of silt from gully erosion.
   f) Fill or foreign material (garbage).

Continued....

Two types of hazard are associated with obstructions. Most commonly, the obstruction may cause channel overflow to one side, leading to bank erosion. Another possible hazard is water ponding behind an obstruction. The obstruction may be sufficiently pervious to cause no ponding during relatively dry weather. Ponding may then occur during major storms, when seepage through the obstruction cannot handle the increased discharge. The pond could then overflow suddenly and wash out the obstruction.

5. RECORDS

We suggest that the appended form be used to gather routine records of the inspections. The form is intended to record only the main features of the above-described hazards. Apart from this, individual written memos should be prepared with regard to locations of particular concern. The District of Coquitlam standard form should be used to describe the condition of drain outlet structures.

OH:aa

Enclosure

GREATER VANCOUVER SEWERAGE AND DRAINAGE DISTRICT
CREEK DRAINAGE INSPECTION REPORT

REPORT NO. Page ____ of ____

CREEK: ____________ INSPECTOR: ____________

CHAINAGE STARTED AT: ____________ MEASURED Upstream/Downstream DATE: ____________ TIME: ________ WEATHER: ____________

	BANK		EROSION				SLIDING				CHANNEL OBSTRUCTION					URGENCY[4]	COMMENTS:
CHAIN. (m)	L	R	H (m)	L (m)	FRESH.[1]	CAUSE[2]	W (m)	L (m)	DIS-[3] PLACEMENT	FRESH.[1]	H (m)	L (m)	MATERIAL	FRESH.[1]	OVERFLOW (Y/N)		and photo reference (Roll No., Frame)

NOTES:

1. FRESHNESS OF AN EROSION/SLIDING/OBSTRUCTION FEATURE

   FRESH - Occurring at present, or has occurred during the past month. Fresh tree and plant damage, silt in channel. Feature has not been observed before.

   RECENT - Occurred within the past year. Recent tree damage, little new growth.

   OLD - Older than one year, some new growth.

2. EROSION CAUSES

   BANK - Main creek, bank erosion.

   CHANN. - Main creek, channel erosion.

   GULLY - Tributary gully, downward erosion.

   OUT. - Erosion at pipe outlet.

3. LANDSLIDE DISPLACEMENT

   MINOR - Slightly tilted trees, uneven ground surface, no cracks.

   MODERATE - Tilted trees, uneven ground surface, possible cracks.

   LARGE - Fallen trees, cracks and/or bare scarps, very uneven surface.

4. URGENCY CLASS

   LOW - No present concern, noted for record only.

   MODERATE - Potential near future concern, should be specifically checked during next sheduled trip.

   HIGH - Present concern, should be reported to a geotechnical engineer and examined by him.

   V. HIGH - Immediate concern, should be reported and examined ASAP.

5. DIMENSIONS

   H - Height or depth
   L - Length along creek channel
   W - Width, perpendicular to creek.

ESCARPMENT INSPECTION CHECKLIST

APPENDIX 'C'

Location:
Date:
Inspected By:

Weather Conditions:
Regular Inspection:
Special Inspection:

	Yes	No	Remarks
A. Drainage Outfall Condition			
1) Free flow from outlet (no obstruction)?			
2) Pipe free from leaks, cracks, displacement?			
3) Dissipator or splashpad functional?			
4) Erosion or debris buildup?			
5) Cracks, fissures, settling in adjacent embankment?			
6) Headwall in good condition?			
7) Debris accumulating in channel below outfall?			
B. Drainage Pipe, Conduit, Flume Condition			
1) Noticeable changes in grade or settlement?			
2) Free from leaks, cracks, damage?			
3) Inlet screen obstructed?			
4) Trash rack or screen in good condition?			
5) Drainage flows bypassing inlet?			
6) Catch basin requires cleaning?			
C. Excavation or Embankment Construction			
1) Evidence of cracks, fissure, settling?			
2) Evidence of recent construction?			
3) Location on public/private property?			
4) Location within 15 m of crest/toe of slope?			
5) Evidence of flow slides or failure?			
6) Evidence of surface erosion?			
7) Vegetation cover disturbed?			
8) Evidence of tree removal or brush cutting?			
D. Access to Sensitive Lands			
1) Paths or trails enter scarp area?			
2) Fencing, signs, barricades need repair?			
3) Garden debris or rubbish dumped in area?			
4) Evidence of recent occupancy (party or picnic)?			
E. Notification			
1) Inoperation requested by local resident?			
2) Reason given for inspection?			
3) Inspection scheduled from predetermined plan?			

REVIEWED: ______________________

APPROVED: ______________________


LEGEND
MUNICIPALITY BOUNDARY
MAIN DRAINAGE AREA BOUNDARY
BASIN BOUNDARY
W20
DESIGNATED STORM TRUNK OR CHANNEL
GVS & DD, PORT MOODY OR COQUITLAM DRAINAGE
OPEN CHANNEL
S7
REACH DESIGNATION
1000 0 1000 2000 3000 METRES
SCALE 1:4000
GEOTECHNICAL LEGEND
Drain outlet
Slide scar
Signs of creep
Wet area
Slope steeper than 30°
Washout scar
Bank erosion
F
Fill area
F
Past movement of fill
DOGWOOD ST.
ROBINSON ST.
MORRISON AVE
EDMONT
TOWNLEY ST
NORFOLK
SHERIFF
HAILEY ST
KINSAC
BLUE MOUNTAIN ST
BLUE MOUNTAIN
MACINTOSH ST
MACINTOSH ST
PORTER ST
PORTER ST
ALBERT ST
DOUGLAS ST
BARNET HWY
WOODLAND PARK
DISTRICT MUNICIPALITY OF COQUITLAM
CITY OF PORT MOODY
Sheet 1 of 2
Dayton & Knight Ltd.
INSTABILITY & EROSION MAP
Port Moody-Coquitlam Drainage Study
THURBER CONSULTANTS LTD., Geotechnical Engineers
DRAWN O.H
DATE Jan 19/88
APPROVED
SCALE AS SHOWN
DRAWING No 17-560-2-1

ST JOHNS ST
ST ANDREWS ST
ST GEORGE ST
HOPE ST
CITY OF PORT MOODY
DISTRICT MUNICIPALITY OF COQUITLAM
BROOKMOUNT AVE
MOHAWK
PARK DR
LUXTON
BARTLETT
BAYVIEW
RIDGE
HARBOUR DR
SUMMIT
DRIVE
BROADVIEW CT
BALMORAL AVE
BRISBANE
BOWMAN
CUSTER
COMO
LAKE
AVE
GROVER
AVE
REGAN
AVE
LEGEND
MUNICIPALITY BOUNDARY
MAIN DRAINAGE AREA BOUNDARY
BASIN BOUNDARY
W 20
DESIGNATED STORM TRUNK OR CHANNEL
GVS & DD, PORT MOODY OR COQUITLAM DRAINAGE
OPEN CHANNEL
S7
REACH DESIGNATION
1000 0 1000 2000 3000 METRES
SCALE 1:4000
for geotechnical legend see sheet 1
Sheet 2 of 2
Dayton & Knight Ltd.
INSTABILITY & EROSION MAP
Port Moody - Coquitlam Drainage Study
THURBER CONSULTANTS LTD., Geotechnical Engineers
DRAWN OH
TRACED JV
DATE Jan 19/88
APPROVED
SCALE As shown
DRAWING NO 17-560-2-1

to Make Work Program to Go Program

APPENDIX A

PROPOSED 1989 DRAINAGE IMPROVEMENT WORKS (1)

FOR COQUITLAM/PORT MOODY DRAINAGE AREA

			Estimated Cost of Improvements		
Drainage Area	Basin	Improvement Description	Total Cost $	Coquitlam Portion $(2)	Pt. Moody Portion $(2)
Schoolhouse Creek	Schoolhouse Noble	Inspection trail	10,000	4,800	5,200
Kyle Street	Kyle, Hackley, Sundial (E&W), Goulet	Inspection trails	27,000	12,400	14,600
Williams Street	Williams	Sediment storage basin, inlet structure & grating	50,000	20,300	29,700
	Dallas	80 m of diversion ditch	15,000	6,100	8,900
	Williams, Elginhouse, Correl, Dallas	Inspection trails	23,000	9,400	13,600
		TOTAL	125,000	53,000	72,000

(1) Improvement works ranked highest priority in Dayton & Knight Report.

(2) Cost apportionment based on 1987 Assessment. Actual cost apportionment for 1989 works will be based on 1988 Assessment which is not yet available.

GR - Oct 18/88

APPENDIX B

PROPOSED 1989 DRAINAGE IMPROVEMENT WORKS (1)

FOR OTTLEY & AXFORD CREEKS (2)

Drainage Area	Basin	Improvement Description	Estimated Cost of Improvements: Total Cost $	Coquitlam Portion $(2)	Pt. Moody Portion $(2)
Schoolhouse	Ottley	Sediment storage basin, inlet structure and grating	50,000	20,300	29,700
		Inspection trail	4,800	2,300	2,500
		Right-of-way acquisition	30,000	14,400	15,600
Kyle Street	Axford	Sediment storage basin, inlet structure & grating	60,000	25,000	35,000
		Inspection trail	4,000	1,800	2,200
		Right-of-way acquisition	10,000	4,600	5,400
		TOTAL	158,800	68,400	90,400

(1) Improvement works ranked highest priority in Dayton & Knight Report.

(2) Currently outside of the jurisdiction of GVS&DD.

(3) Cost apportionment based on 1987 Assessment.
Actual cost apportionment for 1989 works will be based on 1988 Assessment which is not yet available.

APPENDIX C

DESCRIPTION OF PROPOSED 1989 DRAINAGE IMPROVEMENT WORKS

LISTED UNDER APPENDIX A & B

DRAINAGE BASIN	DESCRIPTION OF IMPROVEMENT WORKS
All	Inspection Trail Provision of an inspection access trail in every ravine from each ravine's outlet to its headscarp. This would allow ease of inspection and increase in inspection frequency. The objective of the inspection program is to detect signs and early warning of potentially hazardous situations which may lead to landslides, debris flows or floods; and to monitor problem areas in the creeks in order to note changes and establish priorities for maintenance and remedial work accordingly.
Williams	Sediment Storage Basin, Inlet Structure & Grating Construction of sediment storage basin with grating for containment in the event of a debris flow. Reconstruction of existing inlet structure to improve the inlet capacity and construction of overflow channel to contain storm flow in the event of a major blockage at the inlet.
Dallas	80 m of Diversion Ditch Construction of 80 m of a storm flow diversion ditch to protect the townhouse complex on James Road from possible flooding during major flows.
Ottley	Sediment Storage Basin, Inlet Structure & Grating Construction of sediment storage basin with grating for containment in the event of a debris flow. Reconstruction of existing inlet structure to improve the inlet capacity and construction of overflow channel to contain storm flow in the event of a major blockage at the inlet. Right-of-Way Acquisition Ottley Creek basin consists of alternating sections of storm sewers and open channel through 12 private properties without any statutory right-of-ways. For the purpose of operation and maintenance by GVS&DD, right-of-way acquisition would be necessary.

Axford

Sediment Storage Basin, Inlet Structure & Grating

Construction of sediment storage basin with grating for containment in the event of a debris flow. Reconstruction of existing inlet structure to improve the inlet capacity and construction of overflow channel to contain storm flow in the event of a major blockage at the inlet.

Right-of-Way Acquisition

Axford Creek basin consists of alternating sections of storm sewers and open channel through 4 private properties without any statutory right-of-ways. For the purpose of operation and maintenance by GVS&DD, right-of-way acquisition would be necessary.

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