SEWERAGE AND DRAINAGE OF THE GREATER VANCOUVER AREA BRITISH COLUMBIA

A REPORT TO THE CHAIRMAN AND MEMBERS
VANCOUVER AND DISTRICTS JOINT SEWERAGE AND DRAINAGE BOARD

BOARD OF ENGINEERS
CHARLES GILMAN HYDE
JOHN OLIVER
A M RAWN, CHAIRMAN

SEPTEMBER, 1953

VANCOUVER AND DISTRICTS
JOINT SEWERAGE AND DRAINAGE BOARD

September 16, 1953

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GREATER VANCOUVER SEWERAGE AND DRAINAGE SURVEY

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September 16, 1953

Chairman and Members
Vancouver and Districts Joint
Sewerage and Drainage Board
1303 Sun Building
Vancouver 3, British Columbia

Gentlemen:

Pursuant to resolutions of the Vancouver and Districts Joint Sewerage and Drainage Board, dated April 20, 1950 and March 20, 1952, the Board of Engineers has completed and submits herewith its report upon sewerage and storm drainage of the Greater Vancouver Area.

Full information concerning the investigation is presented in the accompanying report. An analysis has been made of all sewerage projects considered feasible and each such project has been evaluated in terms of both general suitability and total annual cost. Methods of storm water drainage have been studied and costs approximated for providing the minimum degree of service commensurate with protection from flooding due to storm waters.

For purposes of the survey, the Greater Vancouver Area was divided into three sections delineated by topographic, geographic and economic considerations. These sections are designated as Burrard Peninsula, North Shore, and Richmond. Throughout the report each section has been treated as an independent entity.

The sewerage projects found to be the most economical and satisfactory involve the conveyance of sewage for final disposal to eight locations. Of these, five are tributary to Fraser River, two to Burrard Inlet, and one to Strait of Georgia. At all but two of these locations, conditions are such that sewage can be discharged to the receiving waters without treatment. At these two locations, treatment of the sewage will be required. A treatment plant would be constructed on Iona Island to treat the sewage of the western portion of Burrard Peninsula and of Sea Island prior to discharge to Strait of Georgia and a treatment plant would be constructed adjacent to First Narrows to treat the major portion of the sewage produced in the North Shore Section before discharge to Burrard Inlet.

A joint agency similar to the Vancouver and Districts Joint Sewerage and Drainage Board should be formed within the Greater Vancouver Area to finance, construct and operate the facilities recommended in this report. The fairest and most equitable distribution of costs will be achieved if each of the political entities within the area assumes a proportion of the total annual cost of each project.

A summary of the report is given in Chapter 20. Chapter 21 lists the recommendations.

Respectfully submitted,

BOARD OF ENGINEERS

Charles Gilman Hyde
Charles Gilman Hyde

John Oliver
John Oliver

A M Rawn
A M Rawn, Chairman

Contents

SEWERAGE AND DRAINAGE OF THE GREATER VANCOUVER AREA

Chapter 1
Introduction

The Proposed Service Area

The following report proposes to present the facts, conclusions and recommendations developed and based upon a survey of the sewerage and drainage conditions and problems of the Greater Vancouver Area. This area is a rapidly growing metropolitan region and embraces the following cities, municipalities and unorganized communities:

Cities
- New Westminster
- North Vancouver
- Port Coquitlam
- Port Moody
- Vancouver

Municipalities
- Burnaby
- Coquitlam
- Fraser Mills
- North Vancouver
- Richmond
- West Vancouver

Unorganized
- District Lot 172
- University Endowment Lands
- University of British Columbia

Objectives of the Survey

Every community, especially if it be growing and not static, should plan as wisely and comprehensively as possible for the future. Such long-range planning should encompass, among other things, the basic services of sewerage and drainage. It is the purpose of this survey and report to develop a long-range program for provision of these services for the Greater Vancouver Area.

Briefly, the principal objectives of the present survey may be stated to be a provision of sewerage and drainage facilities for the entire Greater Vancouver Area with the accompanying high standard of environmental sanitation, all at the lowest cost commensurate with adequate accomplishment.

The objectives of the survey may be stated more explicitly as follows:

1. The development of an orderly, comprehensive master plan of sewerage for the entire area embraced within the communities and social units named above. Such a plan includes major sewers, appurtenant facilities such as pumping stations, treatment works, and outfalls or other methods of final disposal required to provide for a predictable future development of population and industry.

2. The investigation and evaluation of possible methods of providing storm water drainage for the entire area. Such study includes the determination of the most appropriate type of drainage works for each drainage basin. Anticipated future development within each such basin will in large measure determine the nature of such drainage facilities.

3. The inclusion in such master plan, to the extent determined to be logical and expedient, of existing serviceable sewerage and drainage facilities. Currently active rights and equities should be recognized and satisfied, both legally and financially.

4. The protection of shores and shore waters, and of inland waters, both surface and underground, from pollution

or contamination by sewage, sewage treatment plant effluents and industrial wastes. In these respects the requirements of legally constituted control agencies should be recognized and fulfilled.

5. The placement and layout of facilities in such manner as shall avoid nuisances due to odours, unsightliness or other causes, and as shall serve effectively through a sufficient period.

6. An estimate of the cost of required sewerage and drainage works and a determination and recommendation of practicable schemes of financing and of governmental organization.

Uses of Environmental Waters and Shores

The salt and fresh waters in the bays, estuaries, lakes and rivers of the Greater Vancouver Area are of inestimable value from the standpoints of healthful living conditions, recreational use, and many utilitarian purposes. These values have been of immediate concern to the Board of Engineers and its staff, and have been controlling factors in planning and conducting the survey and in defining the conclusions and recommendations at which these studies have arrived. These matters are of such vital importance that Chapter 6 of this report is devoted to their consideration.

Pollution of Shores and Shore Waters

To date, no treatment of any kind has been given to the sewage of the Greater Vancouver Area, and crude sewage has been discharged at an increasingly large number of outfalls into the environmental waters, both salt and fresh. The result has been that some of these waters and their shores have become polluted to an extent that is definitely disagreeable, if not actually dangerous to health. Such pollution must be eliminated where it now obtains, and prevented where it might occur in the future, if the best interests of the region are to be preserved and promoted.

Areal Comprehensiveness

Equal conditions of sewerage and drainage for all portions of the area under discussion should be provided by any competent master plan. This should be accomplished both for the sections presently developed and for those which will be developed in the future. The cost to each community should be appropriate to its location, topography, and needs. It should be proportional, also, to its operational requirements. Moreover, all planning and construction of sewerage works must provide for the future connection of sewers from an outlying naturally tributary area whose development and consequent need of sewerage facilities can be anticipated for a reasonable period in the future.

Population Development

This survey has been deemed advisable partly because of the serious pollution of certain shores and shore waters and the possibility of greater and more widespread pollution due to the assured increase in population numbers and densities. The whole area under discussion is growing rapidly, the expansion taking place to the north, east and south of the City of Vancouver, the population of which city in 1931 represented 76 percent of the population of the entire area, and in 1951 but 67 percent.

It is of vital consequence that every possible effort be made to determine the probable rates of population growth, the total numbers, and their distribution throughout the area for as long a period in the future as is reasonably predictable. The importance of a population forecast stems from the fact that the volumes of sewage and industrial wastes bear a quite definite relationship to the contributory population.

The need for provision of storm drainage facilities is also closely related to the population increase. Furthermore, the use of beach areas and other recreational features is closely associated with population numbers and their locale. The importance of population to sewerage and drainage is so significant that Chapter 9 of the report is devoted to its discussion.

Cooperation Between Political Entities

Any program of long-term regional planning, whatever its objective, demands some measure of cooperation between the political and social entities involved. In the present case the proposed sewerage and drainage program will demand cooperation with respect to the design, construction and operation of works and the manner of financing.

Legal Sanctions

The existing legislation governing the operations of the Vancouver and Districts Joint Sewerage and Drainage Board is patently inadequate and in some respects inappropriate for continued functioning over a greatly increased area. The Board at present has jurisdiction over all of the area within the Municipality of Burnaby and the City of Vancouver and within that portion of the City of New Westminster known as the Glenbrook Drainage Area. The proposed service area is much more extensive. The present method of cooperative financing requires that certain adjustments and changes be inaugurated. Furthermore, the extent of the provision of trunk and intercepting sewers and of storm drainage facilities to be furnished by the central authority, presently named the Vancouver and Districts Joint Sewerage and Drainage Board, demands clarification and modification to provide greater flexibility. Looking toward a reasonably distant future it will be a mistake to enact such rigid measures that adaptation to changed conditions becomes difficult or impossible. These matters are discussed in Chapters 18 and 19 of the report.

General Quality and Adequacy of Existing Facilities

Existing sewerage and drainage facilities fall within two categories: (1) those provided by and under the jurisdiction of the Vancouver and Districts Joint Sewerage and Drainage Board; and (2) those constructed by local authorities. The latter either are tributary to the Board's sewers and drains or are completely independent thereof. Descriptions of the existing facilities are presented in Chapter 10 of the report.

In general the existing sewers, particularly those of more recent construction, have been well built and are of adequate capacity. Extensive work in terms of new intercepting sewers, pumping stations, and other accessories is now demanded if the existing sources of serious pollution of shores and shore waters in English Bay and Vancouver Harbour and of the waters of the North Arm of Fraser River are to be eliminated. One of the main objectives of the survey has been the determination of the best method to redeem or preserve the quality of those waters.

General Necessity for Local Sewerage and Drainage

Large portions of the Greater Vancouver Area are covered with relatively impermeable surface materials. Individual septic tanks and cesspools to serve the homes and businesses in such districts sooner or later become unsatisfactory, unhygienic and sources of public nuisance. For that reason public sewerage becomes imperative and must be provided as soon as the population density becomes sufficient to warrant the expense of general sewerage. With the rapid increase in population throughout the area, sewers will become necessary and must be provided. The development should be systematic with appropriate points of concentration and outfall into some adequate receiving body of water with such degree of sewage treatment as may be necessary at the time or in the future. Lands which may ultimately be needed for sewage treatment plants should be secured in ample time. In similar fashion, provision of adequate storm drainage facilities must be made as they become necessary to ensure unrestricted development of the area.

Historical Review of District and Local Sewerage and Drainage

The earliest sewers constructed by a community in the area were laid in the City of Vancouver in 1890. The first sewers constructed by the Vancouver and Districts Joint Sewerage and Drainage

Board were laid in conformity with the recommendations of the Lea Report in 1914. Since that date the Board has continued to construct many trunk and intercepting sewers, with numerous outfalls into English Bay, Vancouver Harbour and the North Arm of Fraser River. Almost all of these facilities have been constructed as combined sewers for carrying both sanitary sewage and surface water.

The Lea Report

Rapid population growth in the Vancouver area during the years 1909-1910 forced on the municipalities of the area the problems of disposal of both sanitary sewage and surface water. Consequently, in the face of insistent public demand, The Burrard Peninsula Joint Sewerage Committee was formed and in June, 1911, engaged the services of R.S. Lea to report on a suitable scheme for sewerage and drainage on Burrard Peninsula. The final report and recommendations of Mr. Lea were submitted to the committee in February, 1913. The Lea Report is reproduced in Appendix I of this report. The recommendations were substantially as follows:

1. That the principle of the separate system of sewers be adopted in the areas draining to English Bay, False Creek, and Burnaby Lake.

2. That the most suitable points of outfall are: (a) into English Bay on the line of Imperial Street; (b) into Burrard Inlet at Clark Drive and other points; (c) into Fraser River.

3. That the interception of floating matter is essential for sewage discharged into English Bay and Burrard Inlet, and that there is a possibility of some form of treatment being required in the future for sewage discharged into Fraser River or its North Arm.

4. That the following works be constructed:

(a) An intercepting sewer along the south shore of English Bay from Imperial Street to Cambie Street, with the necessary outfall works and trunks.

(b) An intercepting sewer along Clark Drive from Seventh Avenue to the Inlet, with the necessary outfall works and trunks.

(c) An intercepting sewer south of Still Creek and Burnaby Lake, discharging to Fraser River.

(d) Various trunks on the south slope of the peninsula, discharging to the North Arm of Fraser River.

(e) A West End intercepting sewer and outfall discharging to Burrard Inlet near Brockton Point, and a trunk and outfall in Hastings Townsite.

(f) Improvement of the Brunette River and Still Creek watercourses.

5. That the estimated cost of construction during the next five years, 1913-1918, to cover the above works be $5,500,000 and the estimated additional cost of completing the scheme to cover the whole peninsula be $5,500,000 during the following 25 years.

6. That a Joint Sewerage Board be formed to control and carry out the work.

All of these recommendations were adopted with one exception. In actual practice, the entire area under the jurisdiction of the Joint Sewerage and Drainage Board has been served by combined sewers except for that portion which drains naturally to Burnaby Lake.

Based on these recommendations, the Burrard Peninsula Joint Sewerage Board was formed on August 1, 1913, by Proclamation of the Provincial Executive. On March 4, 1914, an Act entitled "An Act providing for a Joint Sewerage and Drainage System for the City of Vancouver and Adjoining Districts" was passed by the provincial legislature. The Act provided for the construction, financing, and maintenance of all trunk and intercepting sewers and watercourses in the area recommended in the Lea Report. Administration of the Act became the responsibility of a newly constituted board called the Vancouver and Districts Joint Sewerage and Drainage Board.

Vancouver and Districts Joint Sewerage and Drainage Board

Incorporation. The Vancouver and Districts Joint Sewerage and Drainage Board was incorporated by the Vancouver and

Districts Joint Sewerage and Drainage Act, Chapter 79 of the Statutes of British Columbia, 1914. The Act is reproduced in full in Appendix II.

Area Served. The sewerage district originally created included the City of Vancouver, the Municipalities of Burnaby, Point Grey and South Vancouver. In 1928 that portion of the City of New Westminster known as the Glenbrook Drainage Area was included under the jurisdiction of the sewerage district. Following the amalgamation of the Municipalities of Point Grey and South Vancouver with the City of Vancouver in 1929, the sewerage district assumed its present status of three participating members.

Board Membership. The Board comprises a Chairman, the Mayors of the Cities of Vancouver and New Westminster, the Reeve of the Municipality of Burnaby, and two additional members appointed annually by, and from, the Council of the City of Vancouver. The Chairman, who shall not be a member of the council of any community within the sewerage district, is appointed by the Lieutenant-Governor in Council of the Province of British Columbia. He is the chief executive officer of the Board and is responsible for the general supervision and management of the affairs of the Board.

General Powers. The Board has the power to acquire and hold real and personal property for the purpose for which it is incorporated. It is empowered to construct, operate and maintain main sewers, sewers, drains and other works within the sewerage district in substantial accordance with the Lea Report of 1913.

Borrowing Powers. The Board is empowered to borrow for the purpose of carrying out its objectives an amount not exceeding $10,500,000. The amount borrowed by the Board to December 31, 1952 was $9,272,833. The Province of British Columbia guarantees the payment of both interest and principal of all securities issued by the Board pursuant to this Act. Sinking fund instalments are paid annually by the Board to the Minister of Finance of the Province of British Columbia in trust to extinguish that portion of the Board's debt which is to be retired by a sinking fund plan.

Annual Estimates. On or before the 21st day of March in each year the Board is required to prepare an estimate of the sums required to meet the operating expenses for the current year and to meet fixed charges on bonded indebtedness.

Apportionment of Costs. The annual estimate so prepared is apportioned by the Board among the communities within the sewerage district in accordance with their several liabilities therefor pursuant to the Act. Such amounts thus determined by the Board are payable on or before August 15th of each year.

Liability of Member Communities. All money borrowed by the Board is upon its credit at large and does not limit the amount of indebtedness that may be incurred by any member. Repayment of the Board's indebtedness is made through levies against each member in the proportion and in the manner prescribed by the Act.

Purpose and Scope of This Report

This report discusses in generally non-technical language and in appropriate detail the diverse physical, social and economic circumstances and conditions which govern all important phases of the sewerage and drainage problems of the area. It sets forth the conclusions which have been determined from study of the basic facts and the governing conditions. Furthermore, it presents the recommendations which, if carried out in proper sequence and at the appointed times, should guarantee satisfactory solutions of the sewerage and drainage problems of the area in their various phases.

The report is primarily concerned with the collection, treatment and disposal of the sewage of the various communities comprising the Greater Vancouver Area. It deals with trunk and intercepting sewers, with main pumping stations, and with treatment and disposal works, rather than with local sewers which are not directly related to the proposed master plan for the area. Local sewerage is deemed to be an independent function of each political entity in the area.

The report also deals with surface and storm water drainage in general terms. Preliminary layout of drainage facilities cannot be done in a manner similar to that by which preliminary layout of sanitary sewerage facilities is accomplished.

It has been attempted to make this report so comprehensive and complete that the reader, if he is so inclined, may determine or verify for himself the validity of any of the recommended projects. Specifically, the following more significant matters have been investigated and are discussed in the report:

1. The geography, topography, geology, climatology and water resources of the area.

2. The existing conditions of the receiving waters of the area.

3. The principles and functions of sewerage and sewage treatment with particular emphasis on specific processes and methods which may be utilized in the Greater Vancouver Area.

4. The physical, social and economic conditions and the extent of the areas presently being served and those to be served at some future time with sewerage and drainage.

5. Past, present and possible future population developments in each of the several communities and other political and social entities included within the Greater Vancouver Area.

6. The existing sewerage and drainage facilities in the area and their involved problems.

7. The quantity and composition of the sewages and industrial wastes now being collected within the area and the estimated characteristics of those which may be collected in the future from all parts of the area.

8. The loadings, in terms of volume, suspended solids, and biochemical oxygen demand, which now or will in the future obtain at proposed points of outfall in the area, including such treatment works as are presently required.

9. The ability of the ocean, tidal and river waters bordering the Greater Vancouver Area to receive wastes as determined by currents, density and oxidizing capacity.

10. The determination of unit costs for construction, maintenance and operation of sewerage and drainage works and the basis for design of these facilities.

11. The physical, social and economic feasibility of each of the several sewerage plans which have been set up, studied and subjected to analysis, including the matters of their location, boundaries, area, population, sewage flow and loadings, and their collection, pumping, treatment and outfall works.

12. The estimated capital or construction cost of each of the several sewerage plans.

13. The estimated annual costs, including both fixed and maintenance and operation charges, through a considerable term of years, of each of the several sewerage plans.

14. The comparison of possible alternate sewerage plans for providing comparable services and results in a given collection area, and the determination of the most desirable plan for that area.

15. The determination of the most probable types of drainage works which will be required in each of the political and topographic entities within the Greater Vancouver Area in the foreseeable future along with estimates of construction, maintenance and operation costs of these works.

16. The organization, government and financing of the several recommended sewerage and drainage projects as related both to their construction and to their operation.

Field and Laboratory Studies

In connection with this survey and report, work has been conducted in the field to acquire the facts and to define the conditions controlling certain aspects of providing sewerage and drainage for the entire Greater Vancouver Area. In large measure this work has been done by outside organizations, such as the Pacific Oceanographic Group, the National Research Council, and the University of British Columbia. The staff of the Vancouver and Districts Joint Sewerage and Drainage Board has made many current measurements by the use of floats in English Bay and the North Arm of Fraser River, has gauged the sewage flow in certain of the Board's trunk sewers, has collected many bacteriological samples of sewage receiving waters which have been analysed in the Board's laboratory, has collected sewage samples which were analysed in part in the Board's laboratory and in part in the chemical laboratories of the British Columbia Research Council, has made studies of routes of trunk and intercepting sewers and of locations of outfalls. The survey staff has collected and analysed sewage samples from one of the Board's trunk sewers and has performed reconnaissance work in the field. All of this work is described and the results presented in the report.

Office Studies

The office studies conducted by the staff of the Vancouver and Districts Joint Sewerage and Drainage Board, by the survey staff, and by the Board of Engineers have comprised the collection, examination, evaluation and final assembly of information and data as secured in the field and laboratory, as furnished by contributing agencies, and as derived from other sources. The outline of the scope of the report suggests the nature of the office studies. It will be observed that they have been concerned, for example, with population, its development and distribution, with water use, sewage flows, rainfall and runoff, area determinations, the computation of construction quantities, the determination of unit costs, the preliminary layout of sewerage projects, the determination of the types of surface and storm water drainage facilities indicated for portions of the area under consideration, and the estimation of the capital or construction cost and of the annual costs of those projects which are proposed to serve the entire Greater Vancouver Area.

Information and Data Available to the Survey

A large amount of information and factual material has been made available to the survey in existing public documents including reports, statistical bulletins and other publications, maps and charts, of Federal, Provincial and local governmental agencies. Full use of this valuable material has been made in the preparation of this report.

The Pacific Oceanographic Group and the Hydrographic Service of Canada have conducted comprehensive studies in behalf of the survey and have furnished invaluable detailed information concerning the tides and currents in the Strait of Georgia, English Bay, Burrard Inlet, and Fraser River. The National Research Council, through its Fraser River Model and otherwise, has supplied information of great worth concerning the behaviour of currents and tides in the North Arm of Fraser River, and has greatly assisted the work of the survey by permitting the use of certain facilities.

Authorization of Survey and Report

The Greater Vancouver Sewerage and Drainage Survey resulted from a proposal to have a Board of Engineers review the Lea Report of 1913 and recommend a revised comprehensive plan for sewerage and drainage of a considerable part of the Lower Mainland of British Columbia, including the present sewerage and drainage district. A Board of Engineers was appointed for such purpose by the Vancouver and Districts Joint Sewerage and Drainage Board on April 20, 1950. A Resolution adopted by the Sewerage and Drainage Board on that date is quoted as follows:

VANCOUVER AND DISTRICTS JOINT SEWERAGE AND DRAINAGE BOARD

RESOLUTION

THAT WHEREAS the Board at its meeting on August 18th, 1949, agreed that a comprehensive re-examination of the general problem of sewage disposal and surface water drainage in the Sewerage District be undertaken:

AND THAT in the opinion of the Board it is desirable that a Board of three Engineering Consultants be set up to make further special studies and investigations and to prepare a plan to provide for the sewage disposal facilities for the District when fully populated and developed.

AND WHEREAS Mr. A M Rawn, Chief Engineer and

General Manager of the County Sanitation Districts of Los Angeles County was retained as a Consultant:

BE IT NOW RESOLVED that a Board of Engineering Consultants be appointed to consist of Messrs. A M Rawn, Chas. Gilman Hyde and E. A. Cleveland to carry out such investigations and studies as may to them seem necessary and to prepare and submit by the end of this year, if possible, a plan and report, with recommendations and advice. The submission shall set out the steps that should be taken and their probable sequence to provide completely for the collection and disposal of the surface waters and sewage and the type of sewage treatment processes that may be necessary to ensure the protection of bathing beaches and sanitarily acceptable conditions in the Sewerage District and in the surrounding river and sea waters. It is required that the plan shall comprehend the complete occupation and development of the peninsula.

Vancouver, B. C.
April 20, 1950.

An extract from the Minutes of the Meeting of the Sewerage and Drainage Board on August 18, 1949, follows:

The Chairman then read the following statement:

"The Vancouver and Districts Joint Sewerage and Drainage Board was created in the year 1914 by the Legislature of the Province with power to construct, maintain and operate such main sewers and drains and other works as might be required for a system of sewerage and sewage disposal and surface water drainage in substantial accordance with the report of R. S. Lea, Esq., Consulting Engineer of Montreal. A copy of the report was filed with the Provincial Secretary.

The Plan contemplated a sewerage system expanding as the requirements developed for a population of upwards of a million. This population it was then estimated might be reached by about 1950.

The method of sewage disposal proposed by Mr. Lea after extensive surveys and investigations was by diffusion and dilution in the waters adjacent to the Burrard Peninsula.

The actual distribution of population, the intensive use of bathing beaches, and filling and development of the head of False Creek and Industrial Island, and location of industrial areas elsewhere on the Peninsula, the increase in shipping in the Harbour, the effect on the tidal currents off Point Grey by the extension of the jetty at the mouth of the North Arm of Fraser River, the developments in methods of sewage disposal, and other aspects of the general plan suggested the desirability of a comprehensive re-examination of the whole problem.

A very considerable amount of investigation by the Board's Engineers has been done in the interval since the Lea Report. Some further investigations were put in hand a few months ago and others are now in progress and a large amount of data accumulated.

It is the view of the Board that following such further surveys and investigations as seem desirable a complete review of the existing system should be made by a Board of perhaps three Sanitary Engineering Consultants and a plan be prepared for such additional works as may be necessary to provide for the satisfactory collection and disposal of the storm water and sewage of the whole area within the Board's jurisdiction.

This course of action has been put before Premier Johnson and the Minister of Finance, to the latter of whom the Sewerage Board reports monthly. . . . "

The following statement was prepared by Dr. Cleveland, Chairman of the Sewerage and Drainage Board, as of date April 20, 1950:

The Vancouver and Districts Joint Sewerage and Drainage Board at its meeting this morning completed the appointment of a Board of Engineering Consultants to review the system of trunk sewers, interceptors, and sewage disposal in and around Burrard Peninsula carried out in general conformity with the Lea Report.

The Consulting Board will consist of A M Rawn, Charles Gilman Hyde and E. A. Cleveland. . . .

The Consultants have been instructed by the Sewerage Board to carry out such further investigations as may to them seem necessary in addition to the large amount of material already accumulated by the Board's engineering staff and to prepare and submit by the end of the year if possible a plan and report with recommendations and advice. The submission shall set out the steps that should be taken and their probable sequence to provide completely for the collection and disposal of the surface waters and sewage and the type of sewage treatment processes that may be necessary to ensure the protection of bathing beaches and sanitarily acceptable conditions in the Sewerage District and in the surrounding river and sea waters.

It is required that the plan shall comprehend the complete occupation and development of the peninsula.

The authority of the Vancouver and Districts Joint Sewerage and Drainage Board extends only to the City of Vancouver, the Municipality of Burnaby and a part of the City of New Westminster.

The members of the Board expressed the hope that as a result of the Board's action all of the Municipalities adjacent to the waters both north and south of the peninsula from Pitt River to the Strait of Georgia will become interested to the end that sewerage facilities for the whole area may be logically planned in advance of its growing requirements.

Appointment and Personnel of Consulting Board

As an initial step in the selection of the Board of Engineers, Mr. A M Rawn, Chief Engineer and General Manager of the County Sanitation Districts of Los Angeles County, California, was engaged in July, 1949. During that month he "... spent several days in looking over the Burrard Peninsula and adjacent waters, in examination of data and in discussion of many aspects of the problem. He has indicated his views on the further special studies and investigations that should be made. These are in hand." -- Minutes of Meeting of Sewerage and Drainage Board held August 18, 1949.

The first formal meeting of the full Board of Engineers was held in Vancouver at the offices of the Vancouver and Districts Joint Sewerage and Drainage Board from August 15 to 18, 1950. Since that date meetings of the Board have been held as required by the progress of the survey.

Dr. Ernest A. Cleveland served as Chairman of the Consulting Board until his untimely death on January 8, 1952. He was succeeded by Mr. Gordon M. Gilbert, who served only until February 20, 1952, when he also passed away. At this time, Mr. A M Rawn was appointed Chairman of the Board of Engineers. At a meeting of the Sewerage and Drainage Board on March 20, 1952, Mr. John Oliver, City Engineer of Vancouver, was appointed as the third member of the Consulting Board.

Survey Quarters, Organization and Personnel

Until September, 1952, no special quarters and no organized staff were assigned to the work of the survey and the preparation of the report. Up to that time, the field and office studies had been carried on by members of the engineering and other staffs of the Sewerage and Drainage Board under the immediate direction of the Chief Engineer, with advice from the Consulting Board.

In September, 1952, office space in the quarters of the Sewerage and Drainage Board was assigned to the survey, and full-time personnel were engaged to assemble the material which had been accumulated as a basis for the formulation of sewerage and drainage facilities to serve the entire Greater Vancouver Area. Mr. Donald A. Reinsch was engaged as Principal Assistant Engineer, Greater Vancouver Sewerage and Drainage Survey. Mr. Martin J.J. Dayton, a member of the Sewerage and Drainage Board's engineering staff, was assigned to assist Mr. Reinsch in the assembly of material and the preparation of the report. Mr. Victor E. Weldie, also of the Sewerage and Drainage Board's staff, was assigned in October, 1952, as draftsman. Stenographic service was performed by the Sewerage and Drainage Board's staff, notably by Miss Kathleen Galbraith. Mr. Frank J. Kersnar has given part-time service of extraordinary value in the preparation of the report.

Acknowledgements

In the conduct of the survey and the production of this report, the Board of Consulting Engineers and its staff have enjoyed the invaluable assistance and support of the members of the Vancouver and Districts Joint Sewerage and Drainage Board. The Board's staff has gathered and furnished most of the information and statistical data upon which this report is based.

The Board of Consulting Engineers is deeply appreciative of the investigations made in its behalf by the Pacific Oceanographic Group of the Fisheries Research Board of Canada, the Hydrographic Service of Canada and the National Research Council with respect to the behaviour of tides and currents in the environmental waters of the area.

The cooperation of the several administrative boards of the communities embraced within the Greater Vancouver Area and that of their engineers and other officials is acknowledged with gratitude. These communities include the Cities of New Westminster, North Vancouver, Port Coquitlam, Port Moody and Vancouver, the Municipalities of Burnaby, Coquitlam, Fraser Mills, North Vancouver, Richmond and West Vancouver, and the unorganized communities administered by the Provincial Government.

The Board of Consulting Engineers has received valuable assistance and information from the following departments of the Government of Canada: the Department of Trade and Commerce, the Department of Transport, the Department of Resources and Development, the Department of Public Works, the Department of Health and Welfare, and the Department of Fisheries; and from the following departments of the government of the Province of British Columbia: the Department of Municipal Affairs, the Department of Lands and Forests, the Department of Health and Welfare, and the Department of Fisheries; and from the Dominion-Provincial Fraser River Basin Board, the University of British Columbia, the British Columbia Research Council, and the Lower Mainland Regional Planning Board of British Columbia.

The Board of Consulting Engineers

is deeply aware of and grateful for the faithful labours of the engineering staffs of the Sewerage and Drainage Board and of its own staff. All of these men and women have worked earnestly to develop the facts, assemble and analyse the information and prepare much of the text of the report.

Chapter 2
Geography

Importance of Geography to the Sewerage Problem

Geography is the science of the earth and the life upon it; it describes the land, sea and air, and the distribution of plant and animal life. It deals with the earth's form, movements, and its natural subdivisions. It is concerned with man's activities of all sorts: political, social, physical. In its broad aspects it

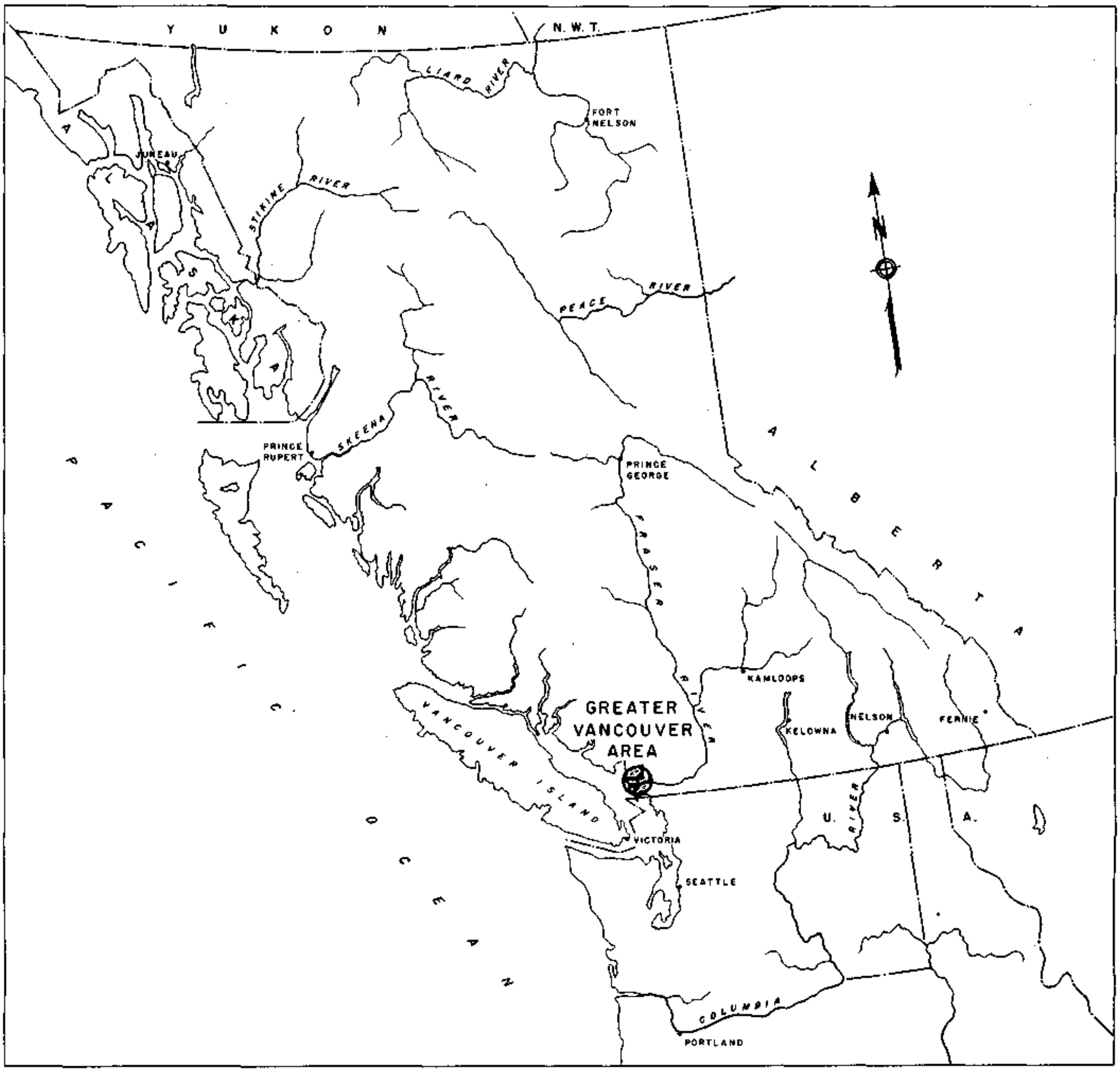


Figure 1. Location of Greater Vancouver Area
The Greater Vancouver Area is on the Lower Mainland of British Columbia in the southwestern corner of the province.

embraces a consideration of the topographic features of the ground surface, of climate, and of population numbers and their distribution. These last three matters bear so directly upon sewerage and drainage problems that they will be discussed separately in subsequent chapters of this report.

To the extent that geography is concerned with the growth and distribution of population and with industrial and agricultural developments, it affects the characteristics of the wastes produced in an area. Local geography as it relates to existence and utilization of recreational areas bordering bodies of water, both salt and fresh, may dictate the type and degree of sewage treatment required and the location of the treatment and disposal works. Sewage characteristics coupled with local geography may impose such rigid requirements for collection and disposal of wastes as to result in heavy expenditures in sewerage works.

Long range planning of sewerage and drainage facilities for any extensive area demands that due consideration be given to the geographic environment of that area. Attention must be paid to the present uses of an area and to those which may obtain in the predictable future. It is possible to plan properly the improvements to serve effectively for a considered period of time only through a detailed knowledge of the character of an area.

The Land Areas and Their Boundaries

Greater Vancouver lies on what is known as the Lower Mainland of British Columbia in the southwestern corner of the province. It is bounded on the south by the main channel of Fraser River, on the east by Pitt River, on the north by the Coast Range, and on the west by the Strait of Georgia. The Strait of Georgia is connected with Pacific Ocean through Queen Charlotte Strait on the north and Juan de Fuca Strait on the south. The International Boundary between Canada and the United States runs through Juan de Fuca Strait. Vancouver Island, on which Victoria, the capital of British Columbia, is situated, forms the western shore of the Strait of Georgia. Figure 1 shows the Province of British Columbia and portions of adjacent areas, certain cities and rivers, and the location of the Greater Vancouver Area.

The Greater Vancouver Area, as shown on Figure 2, comprises a land area of some 293 square miles, has a general length of 25 miles in an east-west direction and an average north-south width of 15 miles. Burrard Inlet, extending inland some 18 miles from the Strait of Georgia, and the North Arm and the main channel of Fraser River divide the area into three geographic sections: (a) North Shore, the northernmost section, lies along the southerly sloping Coast Range foothills on the north shore of Burrard Inlet west of the inlet's North Arm; (b) Burrard Peninsula lies between the North Arm of Fraser River and Burrard Inlet and extends easterly to Pitt River; (c) Richmond, the southernmost section, lies in the Fraser River delta between the main channel and North Arm of Fraser River. The land areas within the three sections are 99, 148, and 46 square miles, respectively.

Burrard Inlet and Fraser River

Burrard Inlet, a tidal body of water, connects with the Strait of Georgia at the western extremity of the Greater Vancouver Area. English Bay, the seaward portion of the Inlet, is a wide mouthed bay on the shores of which are beach areas offering excellent recreational facilities. Six miles east of its inlet, English Bay narrows to Lions Gate, or First Narrows, a narrow deep channel about one mile long and 1,200 feet wide. The channel opens into the main portion of Burrard Inlet which contains Vancouver Harbour, one of the world's best. Vancouver Harbour is about five miles long and one and one-half miles wide. Dock and harbour facilities are available on both the north and south shores. About five miles east of First Narrows, Burrard Inlet again contracts to form Second Narrows, which is about one mile long and 2,500 feet wide. From Second Narrows the inlet extends eastward about seven miles.

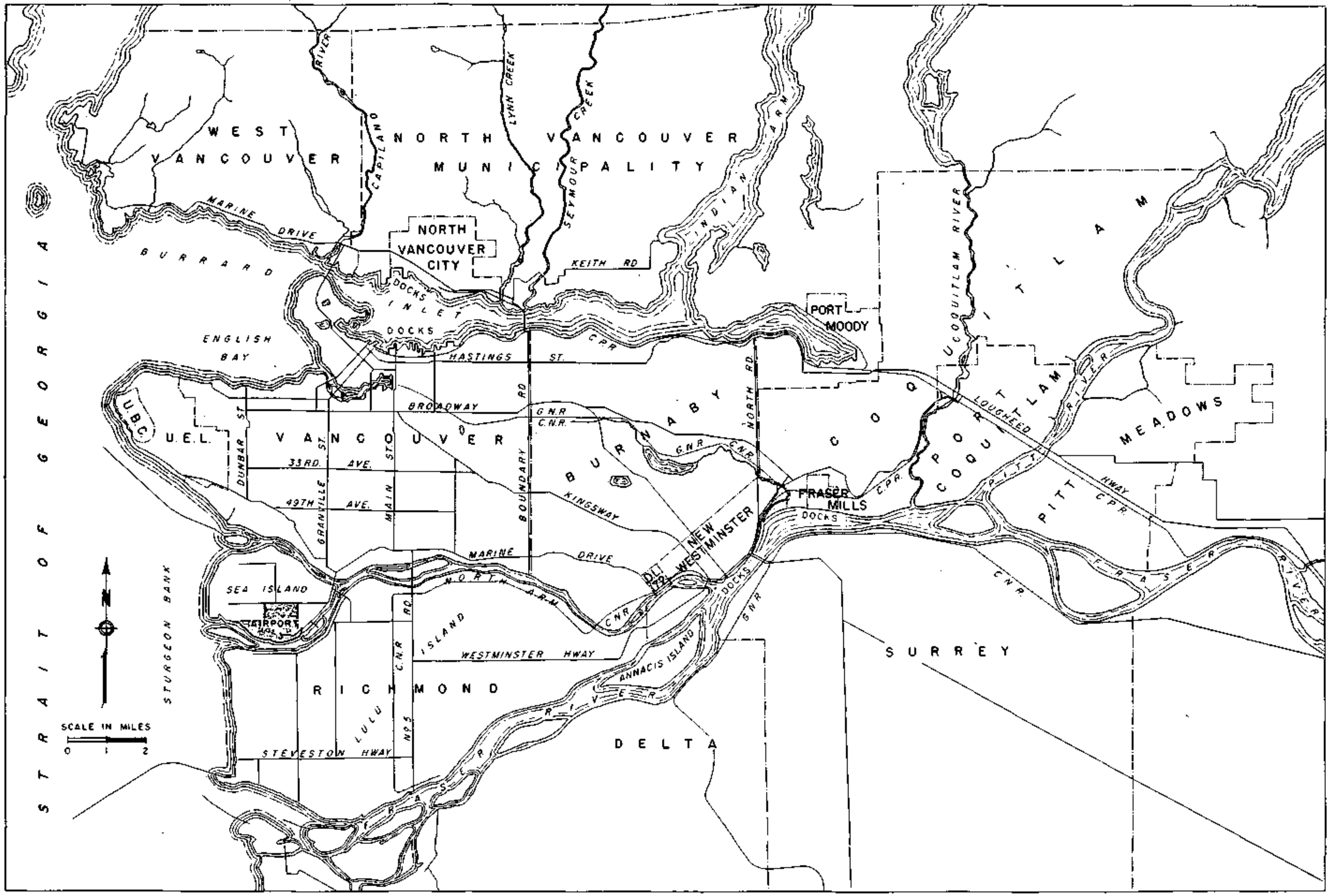


Figure 2. Greater Vancouver Area

The Greater Vancouver Area has a land area of some 293 square miles, a length of 25 miles in an east-west direction, and an average north-south width of 15 miles. Fourteen political entities, administered by city, municipal or provincial government, are in the area.

Indian or North Arm takes off about three miles east of Second Narrows and extends northeastward some twelve miles.

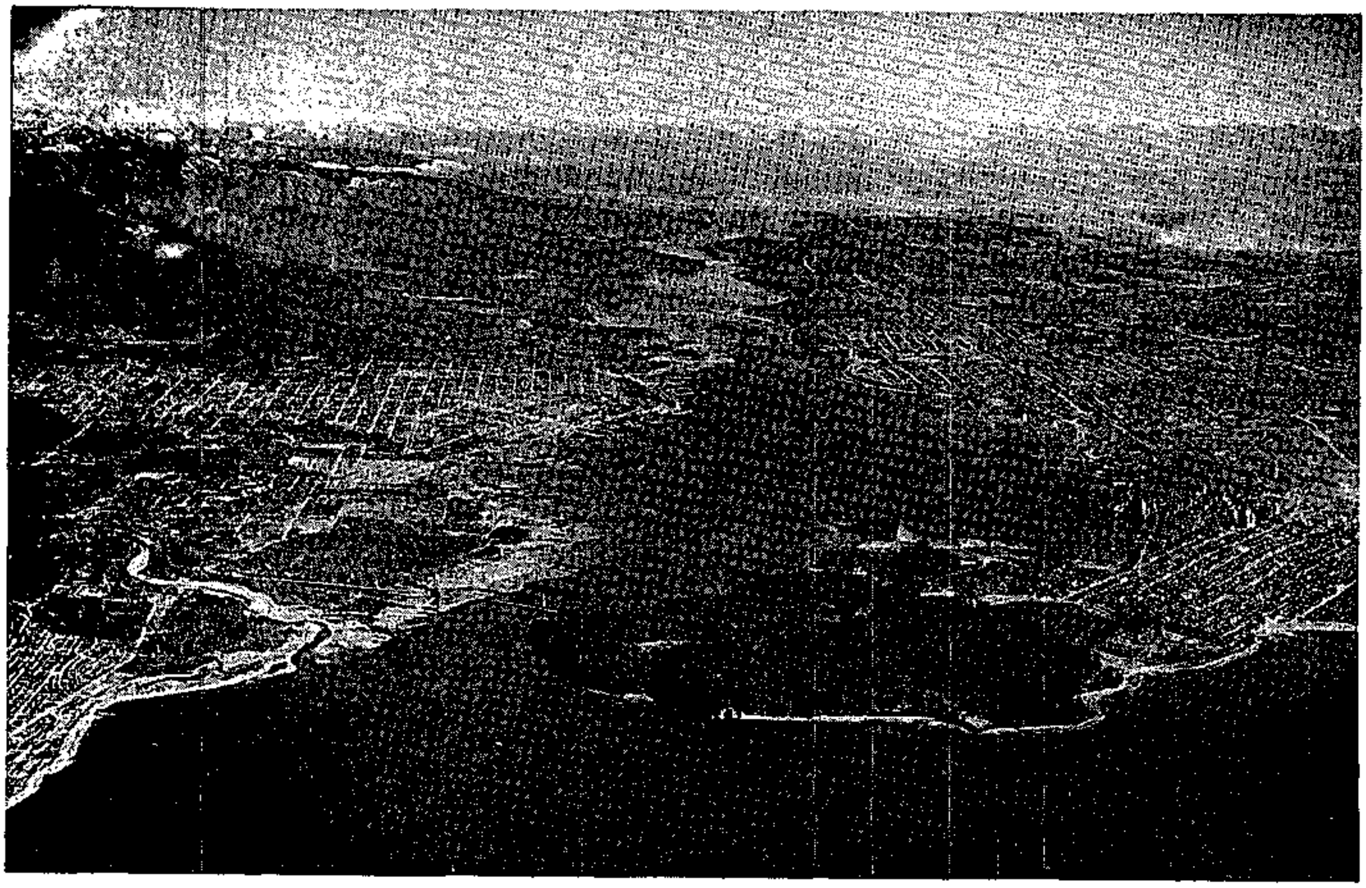
Fraser River, the southern boundary of the Greater Vancouver Area, is one of the principal rivers tributary to Pacific Ocean on the North American continent. Minimum flow in the river is 30,000 cubic feet per second while flood flows reach a peak of over 500,000. Thirteen miles upstream of its mouth, Fraser River divides into two channels, the North Arm and the main channel. The delta lands formed between the two arms constitute the Richmond section of the Greater Vancouver Area.

Areal Development

Present development of the Greater Vancouver Area is largely on the western end of Burrard Peninsula. Most of the residential development as well as a major part of commerce and industry of the area is now centred in the City of Vancouver. The eastern portion of the peninsula is rapidly expanding, both industrially and residentially. Although North Shore is predominantly residential at present, active industrial development is occurring along the shore of Burrard Inlet east of First Narrows. The Richmond section is now largely agricultural but industrial and residential development is increasing.

Figure 2 shows the major geographic features of the Greater Vancouver Area.

Figure 4 shows a land use map prepared by the Lower Mainland Regional Planning Board of British Columbia indicating the actual uses of the



Courtesy Aero Surveys Limited

Figure 3. Burrard Inlet

Burrard Inlet extends inland some 18 miles from the Strait of Georgia. The Municipalities of West and North Vancouver and the City of North Vancouver are on the north of the inlet and the City of Vancouver and Municipality of Burnaby are on the south. In the foreground are Lions Gate Bridge, the longest vehicular suspension bridge in the British Empire, and Stanley Park.

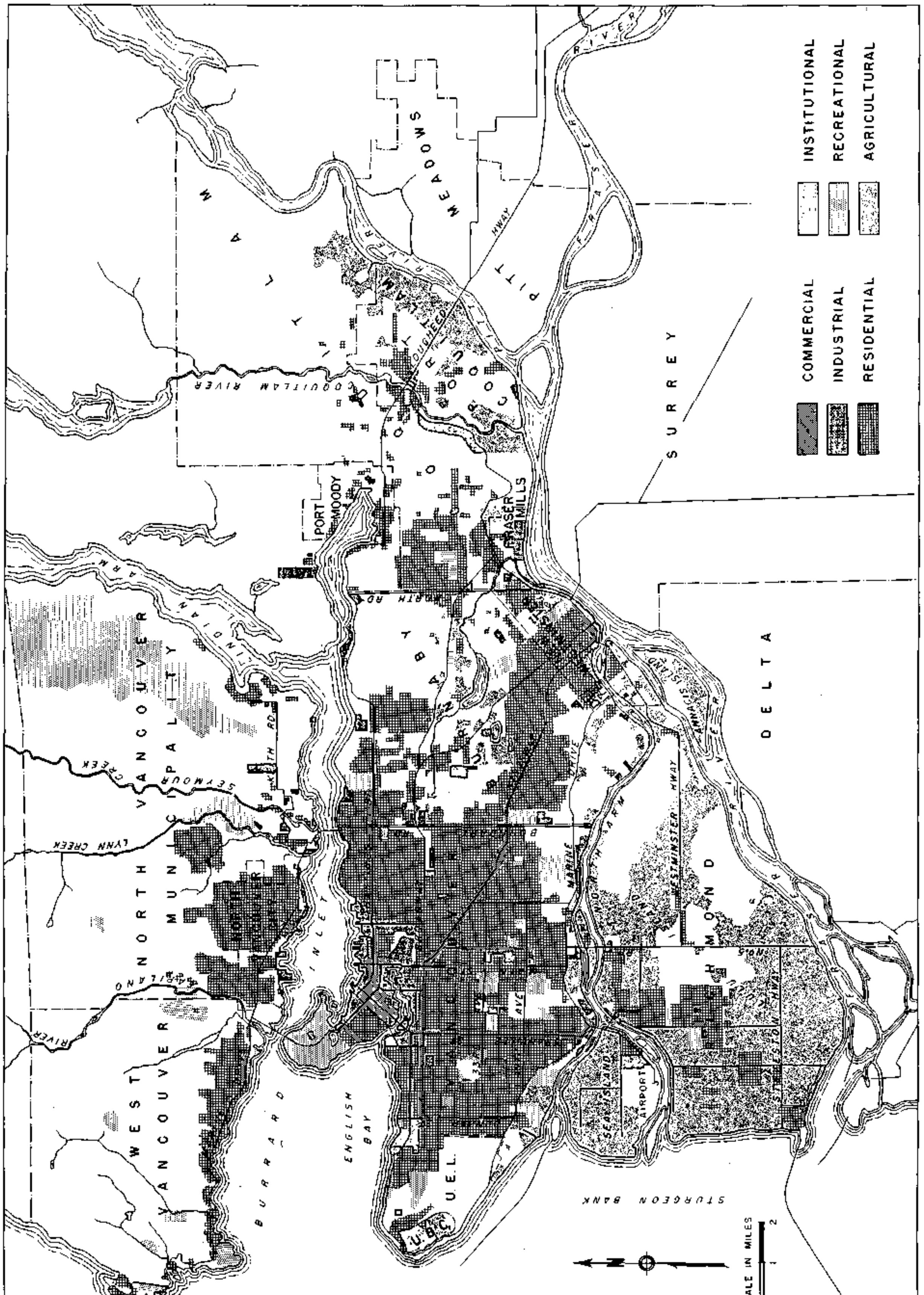


Figure 4. Land Use Map of Greater Vancouver Area

This map, prepared in 1949 by the Lower Mainland Regional Planning Board, shows land use in the Greater Vancouver Area. Areas not classified are unused land.

land areas in 1949. Table 1 gives the estimated area encompassed by each of the six categories.

Table 1
Land Use Areas in 1949

Use	Area, acres
Residential	40,000
Commercial[a]	3,000
Industrial	4,000
Institutional[b]	3,000
Recreational[c]	11,000
Agricultural[d]	22,000

Areas estimated from Figure 4.

[a] Includes store and office buildings.
[b] Includes hospitals, schools, military and other governmental establishments.
[c] Includes major parks and golf courses.
[d] Includes all farmed areas.

Communities

Within the Greater Vancouver Area are five incorporated cities, six incorporated municipalities, three unorganized communities administered by the Provincial Government of British Columbia, and several areas such as Indian Reserves and Military Reserves administered by the Government of Canada. Table 2 gives the areas, 1951 populations and 1952 assessed valuations for each of the cities, municipalities and unorganized communities. Figure 2 shows their locations and boundaries.

City of New Westminster. New Westminster was incorporated as a city in 1860. Its governing body comprises a mayor and seven aldermen.

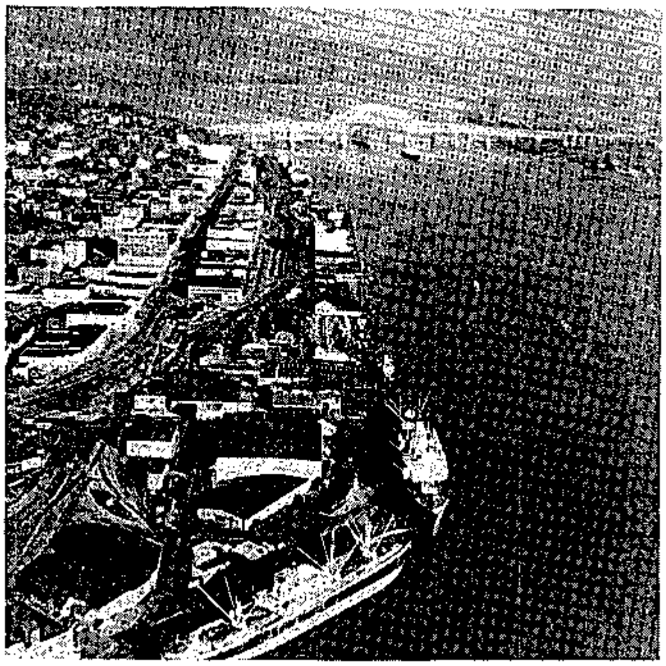
From 1859 to 1868 the city was the seat of government of the colony of British Columbia. The economic development of the city has been based on

Table 2
Areas, Populations and Assessed Valuations of Communities

Community	Total Area,[a] acres	Population[b]	Assessed Valuation,[c] dollars		
			Land	Improvements	Total
Cities:					
New Westminster	4,394	28,639	15,184,600	44,166,783	59,351,383
North Vancouver	3,131	15,687	7,011,170	13,759,720	20,770,890
Port Coquitlam	6,200	3,232	1,392,848	1,965,480	3,358,328
Port Moody	2,980	2,246	986,447	1,772,290	2,758,737
Vancouver	27,965	344,833	183,638,900	424,665,466	608,304,366
Municipalities:					
Burnaby	21,704	58,376	14,906,420	50,624,725	65,531,145
Coquitlam	37,204	15,697	2,068,504	12,638,858	14,707,362
Fraser Mills	390	369	174,835	1,670,967	1,845,802
North Vancouver	40,818	14,469	7,630,188	14,990,047	22,620,235
Richmond	35,000	19,186	6,586,904	17,207,226	23,794,130
West Vancouver	20,515	13,990	8,605,865	20,727,680	29,333,545
Unorganized:					
District Lot 172	160	1,469	264,680	1,015,600	1,280,280
University of British Columbia	548	[d]	[e]	[f]	
University Endowment Lands	2,692	2,120	1,295,662[g]	3,942,450[g]	5,238,112[g]
Total	203,701	520,313	249,747,023	609,147,292	858,894,315

[a] Areas stated are land and water areas within municipal limits and were obtained from "Regional Industrial Index of British Columbia", Regional Development Division of Province of British Columbia Department of Trade and Industry, 1952 edition.
[b] 1951 census populations furnished by Bureau of Statistics of the Government of Canada.
[c] Assessed valuations include both taxable and exempt valuations determined in January, 1952. Values given were obtained from preliminary assessment rolls of each community and may be subject to slight revision.
[d] Daytime population estimated at 6,000.
[e] No assessed valuation for land.
[f] Insurance valuation of improvements excluding contents is $15,201,000.
[g] Does not include undeveloped and exempt valuations.

lumbering and fishing. Lumber was first exported by deep sea vessels in 1864 and the first salmon cannery was built on the bank of Fraser River in 1871. Development of these two basic industries was followed by the establishment of such important secondary industries as wood products, machinery manufacturing, and meat, fruit and vegetable packing. At present, New Westminster is a distributing and marketing centre for products of the Fraser Valley. As a deep sea port, its shipping volume ranks second to that of Vancouver. Some 400 deep sea vessels call annually at New Westminster. The city is ideally located as an industrial centre since it is a converging point of the transcontinental and international railways and highways.



Courtesy Photographic Surveys (Western) Limited

Figure 5. Waterfront of the City of New Westminster

New Westminster, situated on the north bank of Fraser River, ranks second to the City of Vancouver as a deep sea shipping port. Some 400 deep sea vessels call annually at the port. The Pattullo Bridge crosses the Fraser at New Westminster and, as the only vehicilar bridge across the Fraser River in the Greater Vancouver Area, carries the bulk of traffic into or out of the area.

City of North Vancouver. North Vancouver was incorporated as a city in 1907. Its governing body comprises a mayor and six aldermen.

The economy of the city is supported by shipping, shipyards, lumber mills, and numerous manufacturing establishments. The 17,000 feet of deep sea waterfront offers great opportunities for development of harbour and industrial facilities. The largest steel shipyard in Canada is in North Vancouver. With completion of the proposed extension of the Pacific Great Eastern Railway into the area, this deep sea port could become a shipping and distributing point for products of central and north central British Columbia.

City of Port Coquitlam. Port Coquitlam was incorporated as a city in 1913. Its governing body comprises a mayor and five aldermen.

The economy of the city is based primarily on logging, manufacturing of rubber products and small fruit farming. It is the western freight terminus of the Canadian Pacific Railway and is connected with the port of New Westminster by a branch line. Stage lines provide connections with Vancouver, New Westminster and all points in the Fraser Valley.

City of Port Moody. Port Moody was incorporated as a city in 1913. Its governing body comprises a mayor and five aldermen.

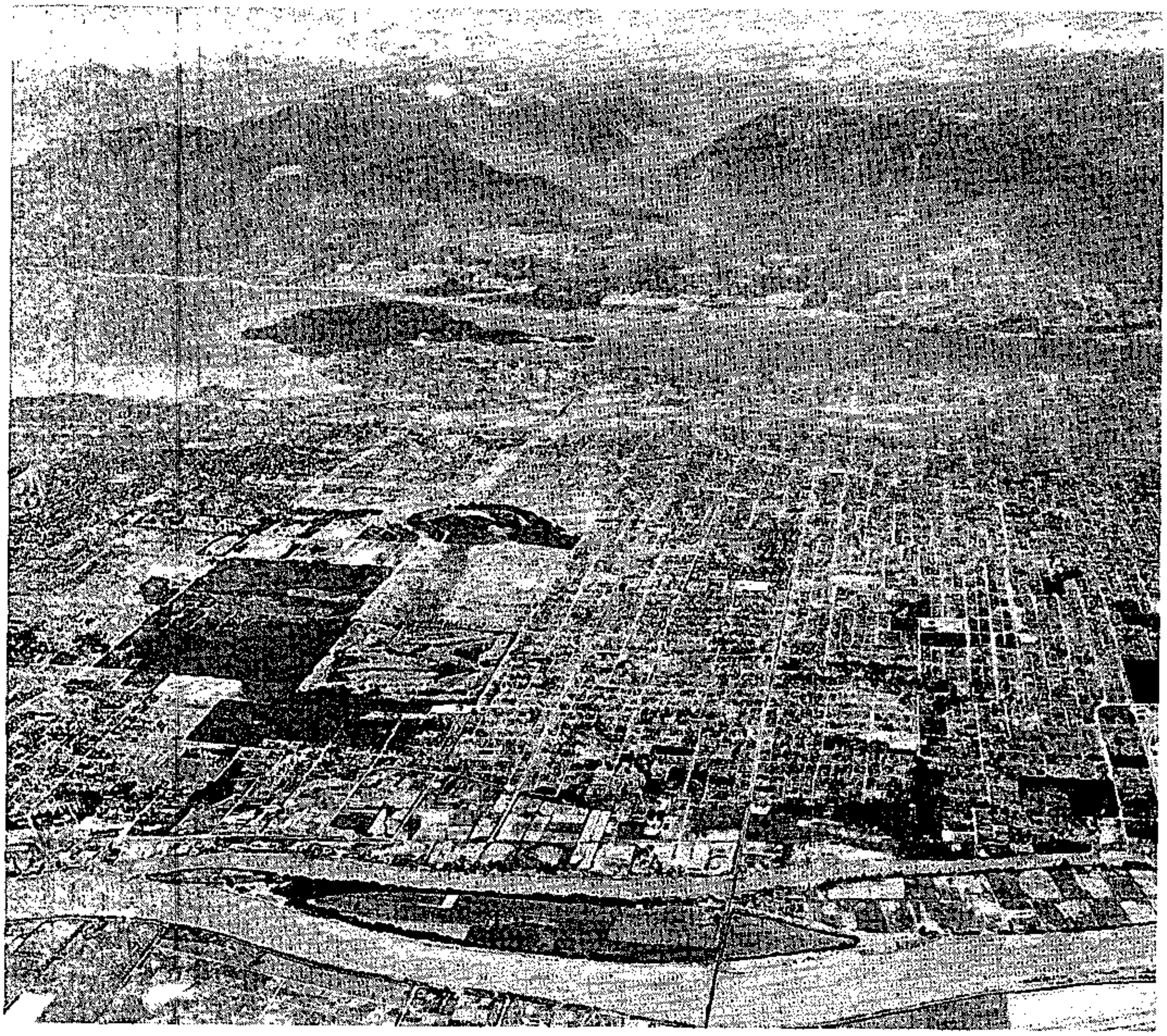
The city is ideally situated for future industrial expansion since it is accessible to deep sea shipping and offers excellent highway and rail transportation. Present industrial development includes lumber and wood products industries.

City of Vancouver. Vancouver was incorporated as a city in 1886 and in 1929 amalgamated with the Municipalities of Point Grey and South Vancouver to form its present boundaries. Its governing body comprises a mayor and eight aldermen.

The four basic industries of the Province of British Columbia, forestry, agriculture, mining and fishing, are all of major importance to the economy of the City of Vancouver. The city is one of the most important manufacturing areas in Canada because of its geographic location and the existence of large supplies of raw materials close at hand. It is the largest distribution centre in western Canada and is the Pacific terminus of the Canadian Pacific and the Canadian National Railways and the Canadian terminus of the Great Northern Railway. Dock and moorage facilities are located in Vancouver Harbour, False Creek and on the North Arm of Fraser River. Many diversified industries exist adjacent to the waterfront of the city.

Municipality of Burnaby. Burnaby was incorporated as a district municipality in 1892. Its governing body comprises a reeve and seven councillors.

Burnaby has grown rapidly in recent years from a small farming and residential community into a large residential district with highly industrialized



Courtesy Photographic Surveys (Western) Limited

Figure 6. City of Vancouver and Communities on the North Shore

The City of Vancouver lies on the western portion of Burrard Peninsula between the North Arm of Fraser River, shown in the foreground, and Burrard Inlet. The Municipalities of West Vancouver and North Vancouver are on the north shore of the inlet. Stanley Park, on the shore of Burrard Inlet in the City of Vancouver, has an area of 1,000 acres.

sections. Manufacturing operations include sawmilling, shingle milling, furniture and box making, oil refining, brick making and peat processing. The municipality is served by three railroads and is crossed by highways from the eastern provinces and the United States. Harbour facilities are in a rapid state of development, as are industrial areas, along the North Arm of Fraser River, the shores of Burrard Inlet and in the central valley adjacent to the railroads. Burnaby is the proposed terminus of the trans-mountain pipe line from the Alberta oil fields.

Municipality of Coquitlam. Coquitlam was incorporated as a district municipality in 1891. Its governing body comprises a reeve and six councillors.

The municipality is primarily agricultural and residential. There is some industrial development along Fraser River where dock facilities are available.

Municipality of Fraser Mills. Fraser Mills was incorporated as a district municipality in 1913. Its governing body comprises a reeve and four councillors.

The municipality is supported by the large timber industry of the Fraser Mills Company. It has good harbour facilities and is served by a branch line of the Canadian Pacific Railroad.

Municipality of North Vancouver. North Vancouver was incorporated as a district municipality in 1891. Its governing body comprises a reeve and six councillors.

The municipality has good harbour facilities and its waterfront is undergoing gradual industrial expansion. Excellent residential areas exist on its mountain slopes.

Municipality of Richmond. Richmond was incorporated as a district municipality in 1879. Its governing body comprises a reeve and five councillors.

The municipality contains some of the most fertile land in the entire Lower Mainland Area. The principal activities include agriculture, dairying, peat processing, poultry raising, fish, fruit and vegetable canning, and flour and rice milling. The foreshores of several of the islands have adequate harbour and railroad facilities which make them suitable for some future industrial expansion. Vancouver International Airport on Sea Island is contained within the municipality.

Municipality of West Vancouver. West Vancouver was incorporated as a district municipality in 1912. Its governing body comprises a reeve and six councillors.

Development thus far has been entirely residential and this will probably continue. Ideal residential sites, providing excellent views of English Bay and Burrard Inlet, are to be found on the sloping hills of the Coast Range. Although no railroads pass through the municipality at present, it is probable that the Pacific Great Eastern Railway will, in the future, make use of its presently owned right of way along the waterfront. Consideration is also being given to the construction of a highway to Squamish, on the shore of Howe Sound, 25 miles north of West Vancouver.

Unorganized Communities. The three unorganized communities which are administered by the Provincial Government of British Columbia are the University of British Columbia, the University Endowment Lands, and District Lot 172.

The University and University Endowment Lands are on the seaward end of Burrard Peninsula. Excellent residential sites are available within the Endowment Lands and development thereon is progressing rapidly. District Lot 172 lying on the north bank of North Arm of Fraser River adjacent to the City of New Westminster is primarily residential although some industrial development may occur along the foreshore.

Lands administered by the Government of Canada are contained within the limits of incorporated communities, and include a number of Indian Reserves and several shore installations of the Department of National Defence. Indian Reserves are found on the shores of Burrard Inlet, on the North Arm of Fraser River and on Coquitlam River. These reserves have a total area of about 1,000 acres and are exempt from taxation. Military shore installations are, for the most part, along the south shore of English Bay. These installations also are exempt from taxation.

Recreational Areas

Excellent recreational resources, including beaches, yachting basins, parks, golf courses, playgrounds, and winter sports areas, are available in the Greater Vancouver Area. Bathing beach areas exist on both sides of Burrard Inlet. The most highly utilized beaches are on the shores of English Bay in Burrard Inlet. Yacht harbours and basins are provided on both shores of English Bay, in Coal Harbour above the First Narrows, and at various places on Fraser River and its distributaries. The aggregate length of utilizable beaches is about 12 miles.

The largest park in Greater Vancouver, Stanley Park, comprises 1,000 acres. This park has been preserved in its primitive state throughout most of its area. Eleven miles of roads, five miles of bridle trails and 22 miles of foot trails traverse the park. A small zoo is located therein. There are over 100 smaller parks scattered throughout the Greater Vancouver Area encompassing in excess of 2,500 acres. In addition, the area contains ten public and private golf courses, most of which are located on Burrard Peninsula. Winter sports facilities are provided on the mountains north of Burrard Inlet where two major ski lifts operate.

Agriculture

Most of the areas surrounding the highly populated and industrialized Burrard Peninsula are presently or potentially agricultural. The present estimated total cultivated area, as shown on Figure 4, is 22,000 acres.

Because of the fertility of the soil, particularly in the Richmond section and in the eastern portion of the Greater Vancouver Area, it is probable that the area developed for agricultural purposes will increase with increased urban populations.

Industry

The industrial development of the Greater Vancouver Area is now centred on the shores of Burrard Inlet and the North Arm of Fraser River. Figure 7

Table 3
Presently Developed and Available Industrial Areas

Community	Presently developed,[a] acres			Available,[b] acres		
	Heavy	Light	Total	Heavy	Light	Total
Cities:						
New Westminster	313	33	346	588	36	624
North Vancouver	28	5	33	205	60	265
Port Coquitlam	110	3	113	1,110	43	1,153
Port Moody	25	0	25	550	50	600
Vancouver	1,950	367	2,317	2,288	838	3,126
Municipalities:						
Burnaby	1,355	632	1,987	3,808	730	4,538
Coquitlam	400	100	500	1,400	300	1,700
Fraser Mills	350	0	350	350	0	350
North Vancouver	180	32	212	293	139	432
Richmond	700	20	720	4,000	500	4,500
Unorganized:						
District Lot 172	0	0	0	20	0	20
Total	5,411	1,192	6,603	14,612	2,696	17,308

Source: "Regional Industrial Index of British Columbia", 1952 Edition, Regional Development Division of Province of British Columbia Department of Trade and Industry.

Only communities having present or potential industrial areas are listed in this table.

[a] Does not include vacant property in areas zoned for industry.
[b] Includes all areas zoned for industry and other areas which are suitable for industrial development.

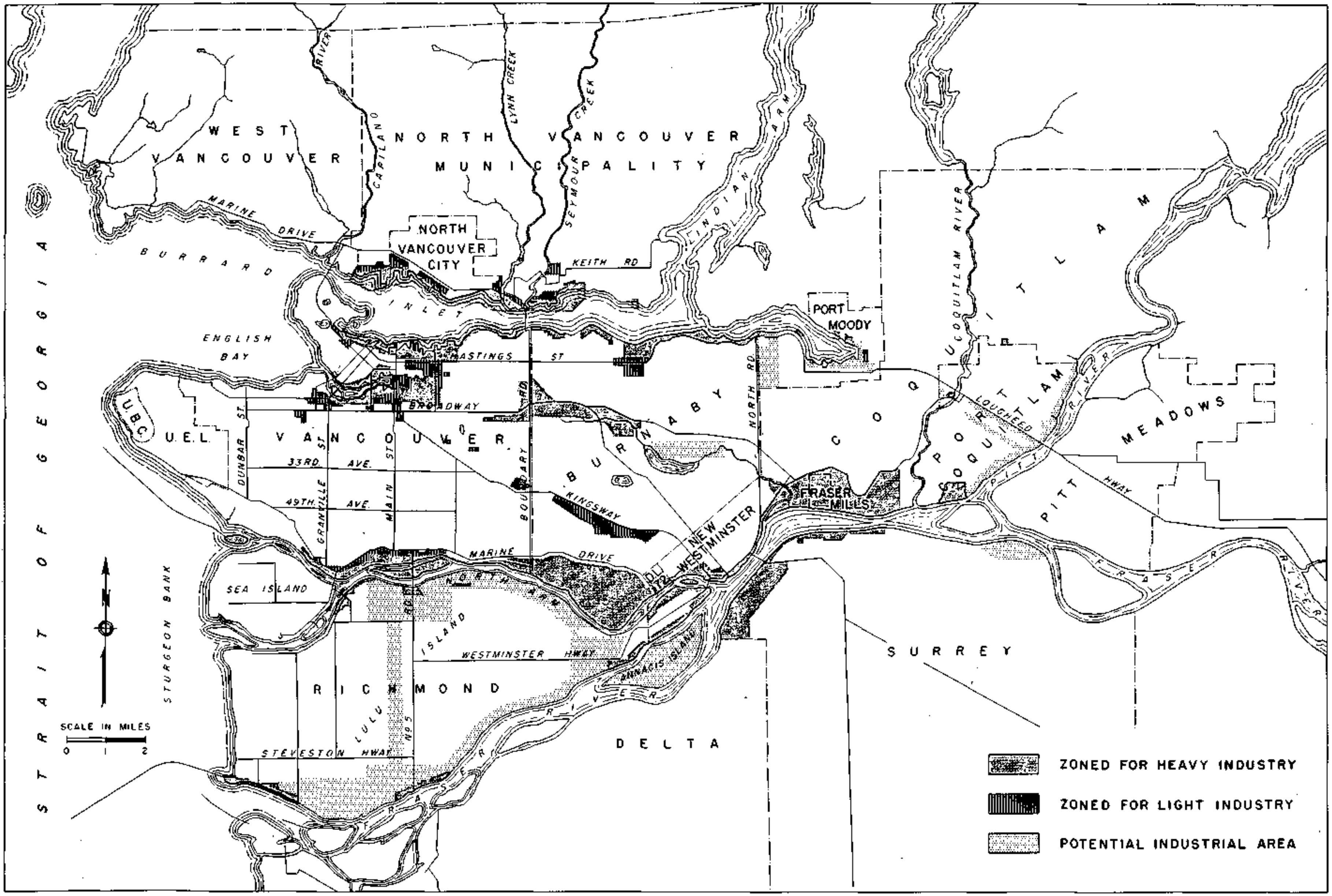


Figure 7. Present and Future Industrial Areas

This map, prepared by the Provincial Department of Trade and Industry, shows the areas which were zoned for industrial purposes in 1951 and those areas which may be utilized for industrial purposes in the future. In 1951, the area actually occupied by industry was 6,600 acres or 38 percent of the total of 17,300 acres deemed suitable for industrial development.

shows industrial areas in 1951 and the areas which can be industrialized in the future as determined by the Provincial Department of Trade and Industry. In 1951 the area occupied by industry was 6,600 acres, or 38 percent of the total area of 17,300 acres suitable for industrial development. Table 3 shows for each community the area that is presently developed for industrial purposes, as well as that which can be developed in the future.

For the City of Vancouver only, the total worth of industrial production during 1949 is reported to have been 358 million dollars. Lumber and wood products accounted for 62 million dollars for that year, or 17 percent of the total. Other important industries include meat slaughtering and packing, petroleum refining and products, and fish processing and canning.

Shipping, which centres in Vancouver Harbour, is an important industry at present and will probably increase in importance in future years. Because it contains the major seaport on the Pacific coast of Canada, the Greater Vancouver Area will benefit directly from increased trade with the Far East as well as other parts of the world. As time goes on additional shipping facilities can and doubtless will be developed along the north shore of Burrard Inlet and along the banks of Fraser River.

Transportation

Passenger and freight transportation into and out of the area is possible by air, land and sea. The air traffic facilities are centred at Vancouver International Airport on Sea Island. The heavy land traffic through the area is carried primarily by rail, but increasing quantities of goods are being transported by highway freight companies. Sea traffic enters the area at either Vancouver Harbour or New Westminster. Figure 2 shows the locations of the major harbour and dock facilities, rail and highway arteries, and the airport.

Vancouver International Airport, owned and operated by the City of Vancouver, is the port of entry for flights originating outside of Canada. It is served by United Air Lines, which maintains service to the United States, Trans-Canada Air Lines, which connects with other Canadian cities, Canadian Pacific Air Lines which operates flights to the Far East, British Commonwealth Pacific Air Lines which operates flights to Australia and other southwest Pacific points, and Queen Charlotte Air Lines, which connects with Alaskan points. The airport is fairly convenient to the metropolitan area and has ample room for expansion. Fog is frequent and flights are often diverted to a former military airport at Abbotsford, some 45 miles to the east. The Vancouver airport is supplemented by an adjacent seaplane channel and anchorage.

Courtesy Photographic Surveys (Western) Limited

Figure 8. Vancouver International Airport

The airport, located on Sea Island in the Municipality of Richmond, is the port of entry for flights originating outside of Canada as well as the terminus for Canadian air lines. It is convenient to the metropolitan area and has ample room for expansion.

Rail traffic is carried by three major systems: the Canadian Pacific and the Canadian National Railroads connecting with the east, and the Great Northern Railroad connecting the area with the south. All three systems provide both freight and passenger service. Rail service to the area may be augmented by extending the Pacific Great Eastern Railroad southward to Greater Vancouver from Squamish, 25 miles to the north. This road would provide service between Greater Vancouver and central and northern British Columbia.

The principal highways of the area are the Trans-Canada Highway, the main east-west artery, and the King George V Pacific Highway connecting with United States Highway 99. Both of these highways are undergoing and will continue to undergo relocation and improvement to furnish adequate high speed access routes. Within the Burrard Peninsula, Hastings-Barnet, Kingsway, Lougheed and Grandview Highways radiate south and east from the City of Vancouver. Traffic across Burrard Inlet is carried by bridges over Lions Gate, or First Narrows, and over Second Narrows. Lions Gate Bridge is the longest vehicular suspension bridge in the British Empire. North Arm of Fraser River is crossed by one railroad and three vehicular bridges, while the main channel of Fraser River is crossed at New Westminster by one bridge which must presently carry all highway traffic destined to the east or south. The major public transit systems in the area are operated by the British Columbia Electric Company and Pacific Stage Lines.

Ocean going vessels enter the area through Burrard Inlet or Fraser River. The former, in which trade facilities are fairly well concentrated between Lions Gate and Second Narrows, affords a salt water port protected from storms and river flood flows. A large number of steamship lines and shipping companies have terminals in the harbour. In 1950 the cargo entering and leaving Vancouver Harbour totalled 10 million tons, of which 60 percent were imports and 40 percent exports. Ferry service to Vancouver Island points operates from Vancouver Harbour. Both Burrard Inlet and Fraser River afford room for expansion of water transportation facilities. In the former area this expansion can take place most easily on the north shore of the inlet, while in the latter, expansion seaward from New Westminster could occur on both banks of the river.

Chapter 3
Topography and Geology

Importance of Topography and Geology

In planning of sewerage and drainage facilities, topography and geology of an area are basic factors influencing the design and construction of the works. The slope of the ground normally determines the sewer or storm conduit gradient and thereby the size of the conduit, the velocity of flow, and the time of travel to an intercepting sewer or place of disposal. Velocity of flow and time of travel have some effect on the characteristics of sewage, while the sewer size affects cost. Natural drainage features generally compel subdivision of an extensive area if the greatest economy is to be attained.

The major portion of the factual material in this chapter is taken from a report entitled "Geology of Vancouver and Vicinity" by Victor Dolmage, Consulting Geologist, submitted to the Vancouver and Districts Joint Sewerage and Drainage Board in 1950.

Topography

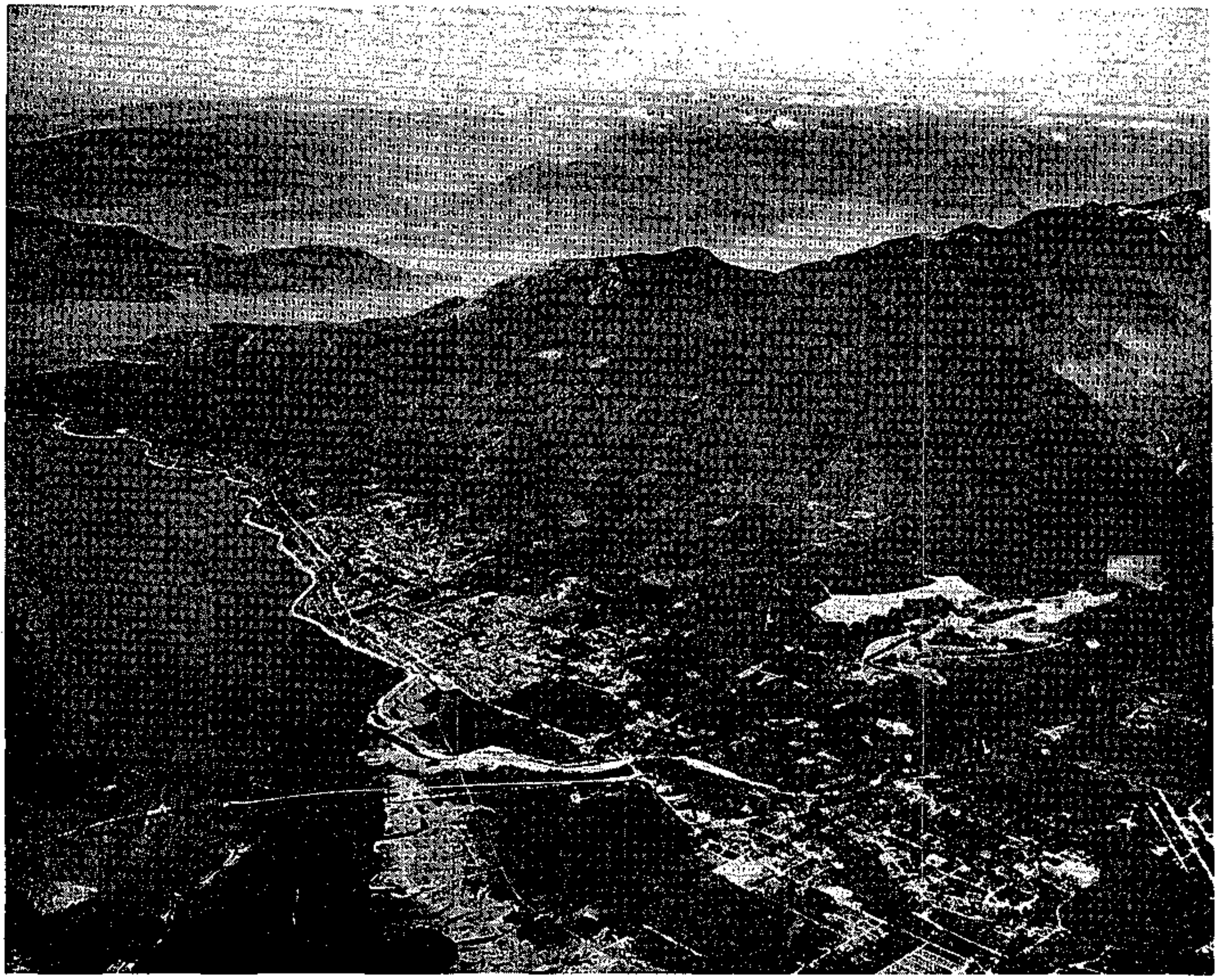
The Greater Vancouver Area, with the exception of the Fraser River delta islands, is largely overspread with rolling hills and mountains. It is deeply indented by Burrard Inlet, a major salt water seaway, and is bounded on the south by Fraser River. Ample grades for drainage to the nearest waterway exist in all parts except in the river delta. The presence of ridges normal to the waterways increases the difficulty of constructing intercepting sewers along the foreshores.

The Greater Vancouver Area is naturally divided into three distinct topographic sections, each having the same boundaries as the three geographic sections described in Chapter 2. Similarly each topographic-geographic area is, with fair accuracy, of different geological construction. The northernmost, or North Shore, section lies north of Burrard Inlet; the central section, Burrard Peninsula, lies between Burrard Inlet and the North Arm of Fraser River; and the southern section, comprising the Fraser River delta islands, lies south of the North Arm of Fraser River and north of its main channel.

Burrard Glacier issued from the valley of Fraser River and cut out the great trench known today as Burrard Inlet. Indian River Glacier from the north gouged a deep fiord called the North or Indian Arm. Both were eroded to depths of hundreds of feet below sea level. At the close of the glacial period the land surface stood 600 or 700 feet lower, referred to sea level, than it does at the present time. During the glacial period the river valleys were widened and straightened and formed into the "U" shaped trenches characteristic of such glaciation.

North Shore. The area north of Burrard Inlet occupies a portion of the south slope of the Coast Range. This slope descends from the summits of the range at elevations around 5,000 feet to the shores of Burrard Inlet and the delta of the Fraser River. This descent is made in a distance of five to six miles and has a general gradient of ten to thirteen percent. The slope is deeply scored by torrential rivers, the largest of which are the Capilano, Lynn, Seymour and Coquitlam. The slope has been greatly modified by glaciation and by the great pile of deltaic gravel and sand built upon it by the streams just mentioned. The combined deltas of the three first named rivers extend from the sea shore to an elevation of 600 feet above sea level.

Subsequent to the final retreat of the glaciers the land rose slowly. During several pauses in which the level of the ocean remained substantially stationary,



Courtesy Aero Surveys Limited

Figure 9. North Shore Section

The south slope of the Coast Range descends from elevations of 5,000 feet to the shore of Burrard Inlet in a distance of five to six miles. Major development on the North Shore has taken place below an elevation of about 1,500 feet. The Municipalities of West Vancouver and North Vancouver and the City of North Vancouver comprise the entire North Shore Section.

the deltas were advanced horizontally, forming well defined terraces still clearly visible. The average slope in this large delta area is less than the ten to thirteen percent mountain slope upon which the deltas were built. Earlier delta deposits were cut through by the rivers which formed them. Capilano and Seymour Rivers have cut narrow canyons deep into the underlying bedrock.

West of Capilano River the six hundred foot elevation is reached less than one mile north from the shore. It is reached about six miles up the Capilano River valley; about ten miles up the Seymour River valley and some fourteen miles up Coquitlam River valley from the edge of the Fraser estuary.

Burrard Peninsula. Burrard Peninsula lies between Burrard Inlet, a deep waterway formed by the Burrard Glacier, and the North Arm of Fraser River.

The peninsula is divided into two nearly equal segments by a pronounced east-west valley. At the valley's western end lie English Bay and False Creek and at its eastern end Burnaby Lake and Brunette River.

The northern segment of the peninsula is a long narrow ridge marked by a succession of peaks. These, named in order from east to west with their respective elevations above sea level, are: Welcome Lake plateau, 500 feet; Burnaby Mountain, 1000 feet; Berry Point hill, 600 feet; Second Narrows hill, 300 feet; Hastings Park hill, 200 feet; West End, Vancouver, 120 feet; and Stanley Park, 200 feet. These peaks are separated from one another by saddles and have gentle slopes to the south and steep ones to the north.

The southern segment is a uniform narrow ridge extending from New Westminster to Point Grey with gentle slopes both to south and north. There are only two prominent irregularities on the surface of this segment. One is Little Mountain, which rises to 400 feet above sea level, and the other is a deep wide valley running northwest to English Bay at Jericho Beach. Less prominent features of the south segment of Burrard Peninsula are two wave cut terraces on the north and south slopes, 120 and 180 feet above sea level, respectively. These elevations correspond to those of two terraces on the deltas of Capilano and Seymour Rivers and mark two pauses in the general rise of the land at the close of the glacial period.

Fraser River Delta Islands. The islands lie south of the North Arm of Fraser River and north of the main channel. They constitute a part of a very flat plain whose elevation is approximately sea level. The delta of Fraser River is in continuous process of formation and is being extended westward by the heavy load of sediments deposited annually by this great stream.

Geology

Tertiary sediments make up the principal superficial geologic formation in the Greater Vancouver Area. These sediments comprise layers of sandstones, shales, and conglomerates in various thickness dipping gently to the south. They lie on the old eroded surface of the granitic rocks of the Coast Range batholith, a great mass of intruded igneous rock whose rise was stopped considerably below the ground surface existing at the time of upheaval. The tertiary sediments are themselves overlain by a thick complex of glacial and inter-glacial deposits, thin in the north and east and thickening to 200 feet or more to the west and south. These, again, are overlain by delta deposits of the Capilano, Seymour, Coquitlam and Fraser Rivers. Figure 10 shows the distribution of various geologic formations found in the Greater Vancouver Area.

North Shore. The granitic rocks of the Coast Range batholith include granite, granodiorite and diorite, as well as numerous included blocks of old prebatholithic rocks. They are all unweathered and are equally hard and strong. In order to be excavated they require drilling and heavy blasting. Except in the western and higher parts of West Vancouver and in the vicinity of the North or Indian Arm of Burrard Inlet, they are too deeply buried to be encountered in sewer excavations. Even where they are covered only by glacial deposits, they are often deep enough to render excavation into the granitic rocks unnecessary. Tertiary sediments in the North Shore Section are usually buried below later glacial, inter-glacial and delta deposits. In only a few small areas are these sediments exposed.

Along the western portion of the North Shore, glacial and inter-glacial deposits are found on the surface, while along the eastern portion these deposits are covered by the recent deposits of gravels and sands formed by the Capilano, Seymour and Lynn Rivers.

Burrard Peninsula. Glacial deposits laid down on top of tertiary sediments cover the entire section with the exception of a few steep slopes where the underlying tertiary sediments are exposed. The glacial deposits vary in thickness and in places have depths approaching several hundred feet.

The glacial sediments are made up of at least two, and probably more, sheets of boulder clay separated by deposits of sand, gravel, silt and clay. Each sheet of boulder clay represents a single advance of the glacial ice. The intervening sediments were deposited during a period between two glacial

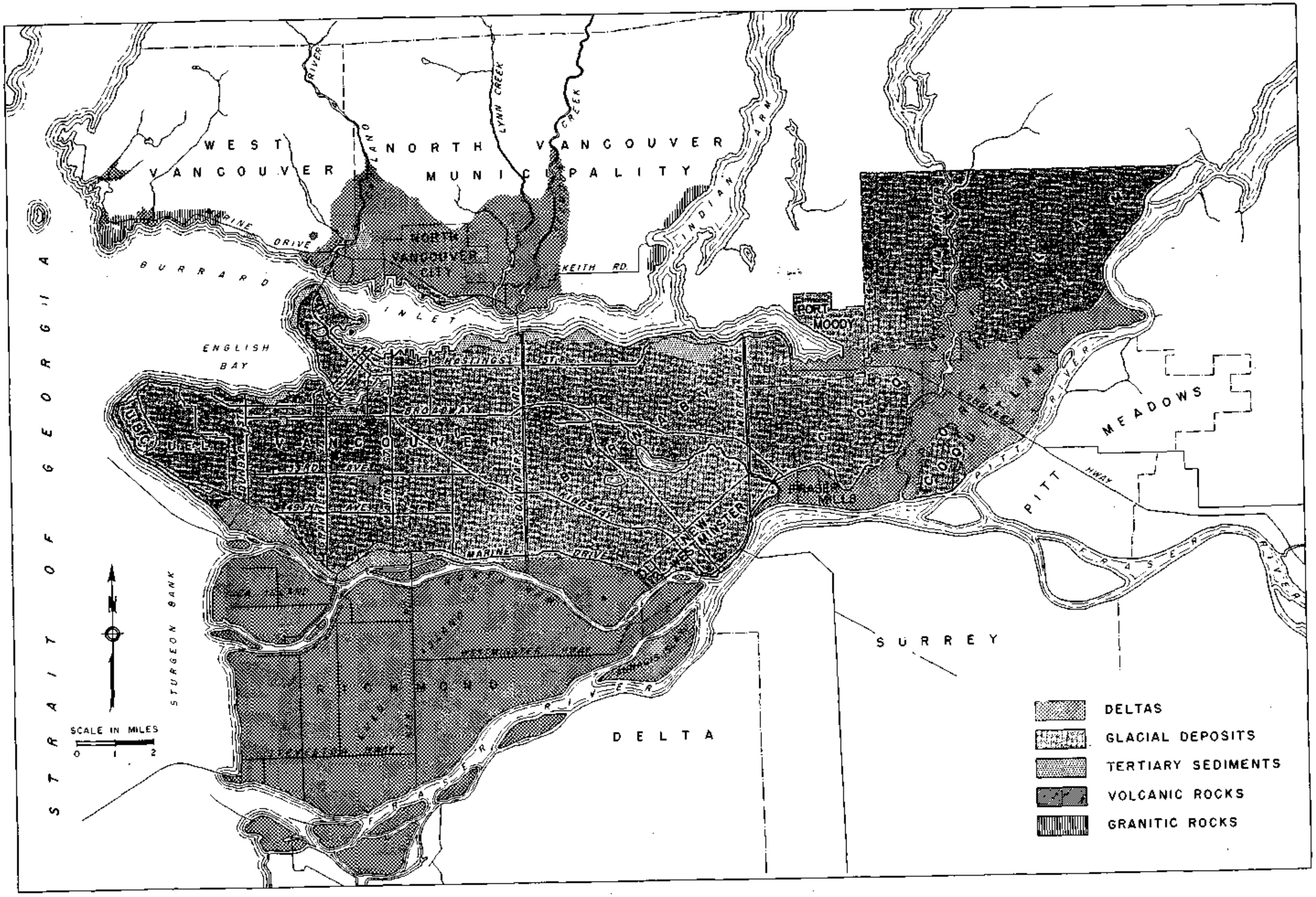


Figure 10. Geological Formations in the Greater Vancouver Area

Principal superficial geologic formations in the Greater Vancouver Area are shown by this map, prepared by Victor O. Dolmage, Consulting Geologist. Tertiary sediments, comprising layers of sandstones, shales and conglomerates, make up the principal formations.

advances and therefore are termed inter-glacial sediments. The upper, or younger, sheet of boulder clay forms a continuous mantle over the entire region, except for a few small areas where the underlying formations are exposed. Its thickness ranges from 10 feet to more than 100 feet. The sheet usually consists of a tough blue clay with varying amounts of sand, gravel and boulders and exhibits corresponding variations in physical properties. Layers with little or no sand or boulders are hard and brittle, while the sandy boulder clay is strong and resistant to weathering processes. The boulder clay is generally sufficiently tough to stand up well in excavations, except in places where it is broken and water has entered the fractures.

The lower, or older, sheet of boulder clay has been observed in a few restricted areas and is probably present under the thick inter-glacial deposits of the entire region. This hypothesis is based on the established fact that there were at least two advances and retreats of the Pleistocene glaciers and also that if such a boulder clay were deposited it would have been preserved from erosion by the thick inter-glacial deposits.

The inter-glacial sediments are well exposed in the sea cliffs surrounding Point Grey. In places thicknesses of 200 feet are exposed between the overlying boulder clay and sea level. The sediments are well stratified and the strata are nearly horizontal. The formation consists of an upper layer of sands and fine gravels which grade downwards into a central zone consisting of thick beds of fine silts and clays. While the individual strata of the inter-glacial sediments are lenticular and are not continuous throughout the area, this central zone of clays and silts is continuous. Below these are other sands and fine gravels. A few thin strata of peat are exposed in the sea cliffs and these and the adjoining clays yield plant fossils such as leaves, twigs, seeds and pollen. These have been identified as belonging to a flora adapted to a temperate rather than a frigid climate. The sands and gravels have the high porosity characteristic of such deposits while the underlying silts and clays are relatively tight.

On the northern slope of the western portion of Burrard Peninsula, tertiary sediments are found relatively close to the surface. The formation consists mainly of sandstone with one thick deposit of conglomerate, several thick strata or lenses of shale, and one or two thin streaks of lignite. The strata are almost entirely undisturbed and have a uniform flat dip to the south of about ten degrees. Only one or two minor faults have been seen in this formation. Because of the uniformity, state of hardness and undisturbed stratification, these tertiary sediments are ideal tunnelling rocks.

Fraser River Delta Islands. The islands in the mouth of Fraser River have been formed by the sand and silt transported by the stream and deposited when its velocity was slackened upon discharge into the Strait of Georgia. Several large and deep deposits of peat are found in this section, particularly on Lulu Island. Since the area is nearly at sea level, ground water is often found within two feet of the ground surface.

Chapter 4
Climate

Effect of Climate Upon Sewerage and Sewage Treatment

Climate is the average state of the atmosphere over a particular place or region of the earth's surface, related to a particular epoch and taking into consideration the average and extreme variations to which the atmospheric state is subject. The principal factors which determine climate are air temperature, rainfall, daylight and darkness, sunshine and clouds, wind direction and velocity, and such attendant effects as evaporation from land and water surfaces, and fog. The factors affect problems and conditions of sewerage, sewage treatment and disposal in a variety of ways.

Nearly all of the sewers in the Greater Vancouver Area are of the combined type carrying both sanitary sewage and storm water as opposed to the separate type carrying only sanitary sewage. Obviously the adequate design of combined sewers demands complete knowledge of the quantities and distribution of rainfall over the tributary surface area. During rainstorms of considerable intensity, storm water flows many times greater than the flow of sanitary sewage must be transported in combined sewers.

The amount and seasonal distribution of rainfall may also cause variation in the volume of flow in separate sewers. Among the most common reasons for this are: (a) infiltration of ground water into sewers through poorly constructed joints at times when the ground water table has risen above the sewer grade; (b) illicit connections of foundation and roof drainage; and (c) surface water entering through leaking manhole covers. The amount of storm and ground water which collects in a separate sewerage system, while it may not be great, does have an effect upon the design of intercepting sewers, pumping stations, and treatment works. Its influence, therefore, upon the components of a sewerage system must be accurately evaluated.

Diversion of combined sewage flow from one point to another some distance away presents problems not inherent in diversion of a separate flow. Although the same amount of sanitary sewage may be involved in each case, it flows undiluted in a separate sewer. In a combined sewer, the sanitary sewage may be diluted to many times its volume with storm runoff during periods of rain. A major problem in the Greater Vancouver Area is to determine what rainfall intensity and frequency will be used in the design of diversion sewers required to divert sewage from places where it is undesirable to those where it will do no harm.

The Greater Vancouver Area has many valuable recreational facilities. In particular the bathing beaches of English Bay attract tens of thousands of people annually. Climatological conditions, particularly temperature, wind, sunshine, and rainfall, are the determinative factors in the utilization of these beaches at the present time and indicate the season of use. Both the climatological data and public response indicate that May 1 to September 30 of each year limit the popular beach season.

General Climatic Conditions

General climatic conditions are best evaluated by study of long term meteorological data. The Meteorological Division of the Department of Transport of Canada has collected data in downtown Vancouver since 1905 and at Vancouver Airport on Sea Island since 1938. In addition to these two locations, there are numerous others within the Greater

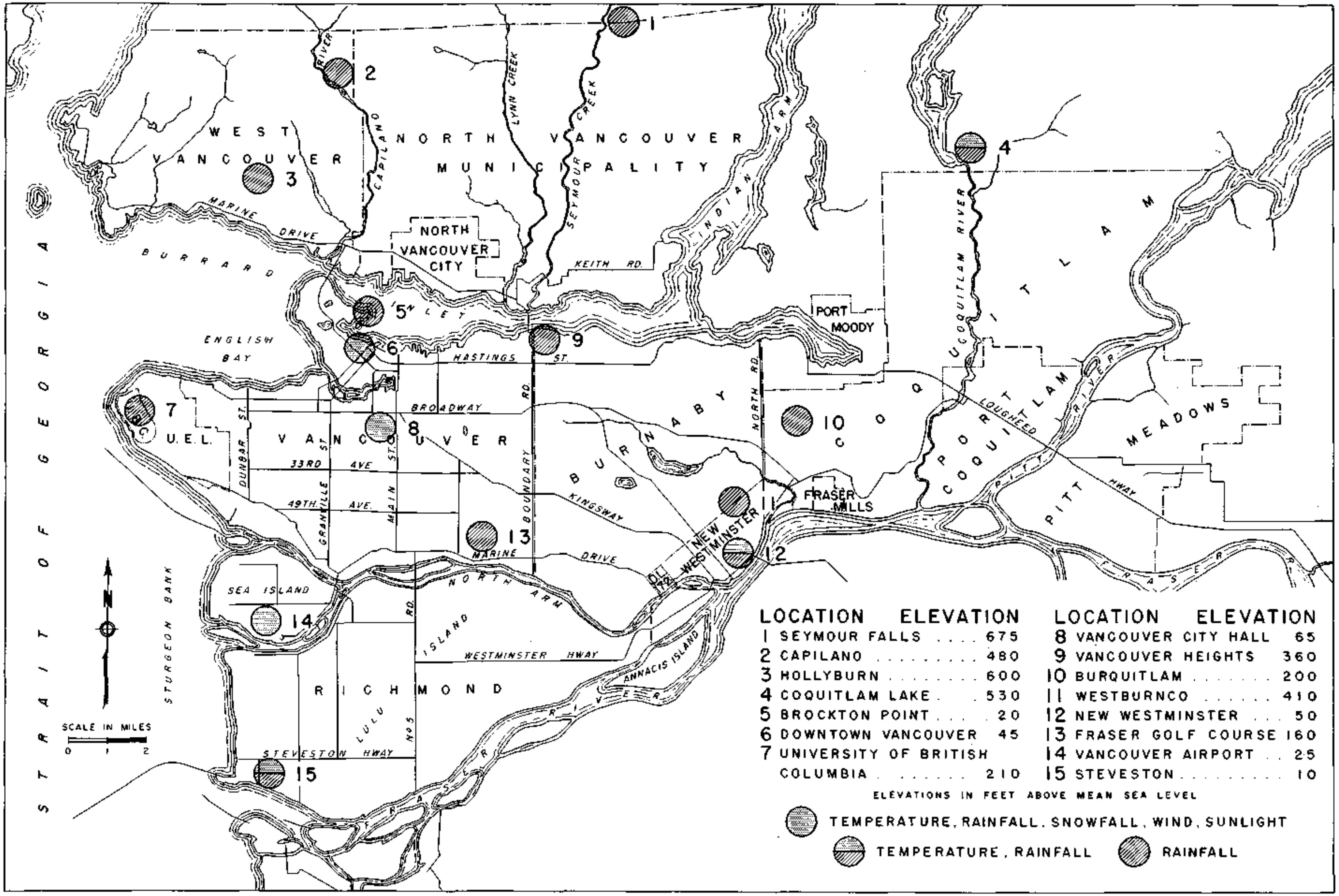


Figure 11. Climatological Stations in the Greater Vancouver Area

In addition to the two official stations of the Meteorological Division of the Department of Transport of Canada at Vancouver and Vancouver Airport, climatological data are collected at thirteen other locations in the Greater Vancouver Area.

Table 4
Mean Monthly and Extreme Recorded Temperatures

Month	Vancouver Airport[a]					Downtown Vancouver[b]				
	Mean,[c] °F			Extreme,[d] °F		Mean,[c] °F			Extreme,[d] °F	
	Monthly	Maximum	Minimum	Maximum	Minimum	Monthly	Maximum	Minimum	Maximum	Minimum
January	35.9	41.6	20.6	58.7	0.0	36.3	43.1	26.1	59.4	2.3
February	39.4	43.3	34.0	61.0	3.4	39.2	44.5	31.2	61.1	8.0
March	43.1	47.2	41.3	66.3	23.0	43.4	49.3	39.0	68.3	15.3
April	48.6	51.2	46.0	76.2	30.0	48.8	54.8	44.9	78.8	27.0
May	54.5	56.7	51.6	83.0	36.3	54.9	58.0	51.2	83.0	32.9
June	59.3	61.5	56.9	83.0	40.2	59.8	62.7	56.7	92.4	39.8
July	63.4	65.6	61.7	87.0	44.4	63.8	67.0	60.5	91.3	43.6
August	62.6	65.3	60.6	87.0	44.6	63.2	66.7	59.6	92.2	38.7
September	57.8	60.5	55.4	83.7	32.5	57.7	62.1	54.1	85.5	29.9
October	50.5	53.3	46.9	70.7	26.7	50.5	54.4	44.2	77.0	21.0
November	42.8	48.0	38.9	62.0	20.1	43.4	48.8	39.5	62.7	9.6
December	39.1	44.5	34.1	57.0	9.4	38.8	46.0	32.9	59.7	8.0

Source: Meteorological Division of Department of Transport of Canada. See Figure 11 for location of stations.

[a] Period of record 1938-1950, inclusive.
[b] Period of record 1905-1946, inclusive.
[c] Mean of stated daily temperatures during month.
[d] Individual temperature reading.

Vancouver Area where precipitation and temperature records are maintained. Figure 11 shows the locations of the meteorological stations.

Air Temperature. Temperatures in the Greater Vancouver Area are moderate in comparison with most of the remainder of the west coast of Canada. There are appreciable variations over the area because of wide difference in elevation and because slopes with a southern exposure receive considerably more sun-

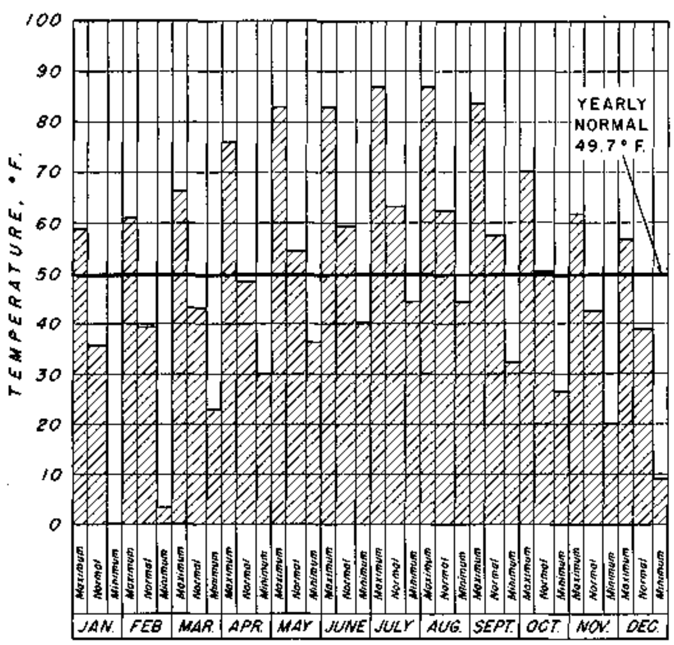


Figure 12. Normal and Extreme Temperatures at Vancouver Airport

The figure shows normal temperatures for each month as well as the individual extreme readings which have been recorded during the period 1938-1950. The maximum variation of monthly temperatures from the yearly normal of 49.7°F is about 14°F. Extreme temperatures of 0°F and 87°F have been recorded.

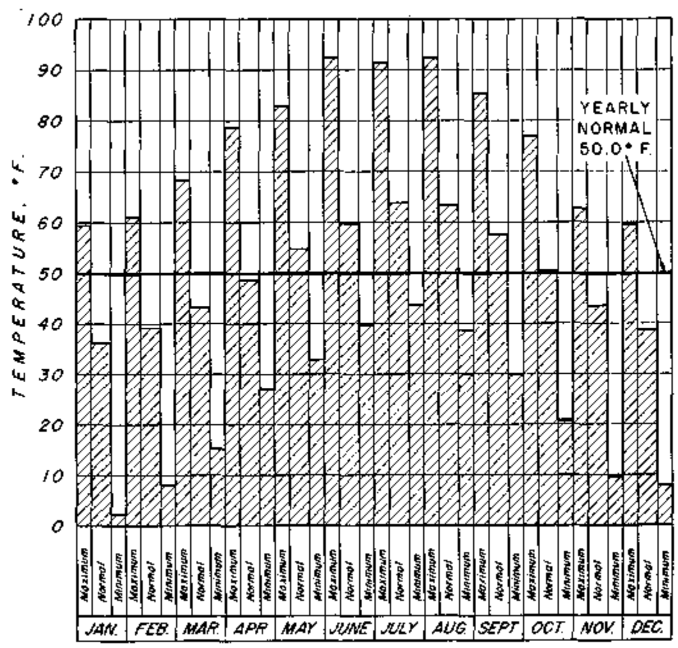


Figure 13. Normal and Extreme Temperatures in Downtown Vancouver

During the period 1905-1946, the maximum variation of monthly temperatures from the yearly normal of 50.0°F has been slightly less than 14°F. Extreme temperatures of 2.3°F and 92.4°F have been recorded. Monthly normal temperatures are slightly higher than at Vancouver Airport.

light than those with a northern exposure. In general, however, the area enjoys a mild climate with moderate winter and summer temperatures. The Strait of Georgia and contiguous waters, plus the protective wall of the Coast Range mountains to the north, are largely responsible for the mild yearly mean temperature. The Strait of Georgia moderates the temperatures in summer as well as winter, while the mountains form an effective barrier against almost all of the polar outbreaks which produce sub-zero winter temperatures in the valleys of the southern interior regions of the province.

Table 4 and Figure 12 give the temperatures at the weather station at Vancouver Airport for the period 1938-1950. The mean annual temperature is 49.7°F, with a mean monthly variation from a minimum of 20.6°F in January, 1950, to a maximum of 65.6°F in July, 1941. The minimum recorded temperature is 0.0°F and the maximum 87.0°F. Temperatures at the weather station in downtown Vancouver for the period 1905-1946 are presented in Table 4 and Figure 13. The mean annual temperature is 50.0°F with a mean monthly variation from a minimum of 26.1°F in January, 1916, to a maximum of 67.0°F in July, 1942. The minimum recorded temperature is 2.3°F and the maximum 92.2°F.

Wind. The directions, prevalence, and general ranges in velocity of winds as recorded at the Vancouver Airport for the thirteen year period, 1938-1950, are shown in Table 5 and Figure 14. Similar records at the weather station in downtown Vancouver are shown in Table 6 and Figure 15 for the twenty-one year period, 1922-1942. The prevailing winds are east to southeast, The strongest winds are from the northwest, as indicated in Figures 14 and 15. Calm, defined as existing whenever the rate of air movement is less than one mile per hour, prevails 1.5 percent of the time at Vancouver Airport and 3.3 percent of the time in downtown Vancouver. In general, periods of calm occur most fre-

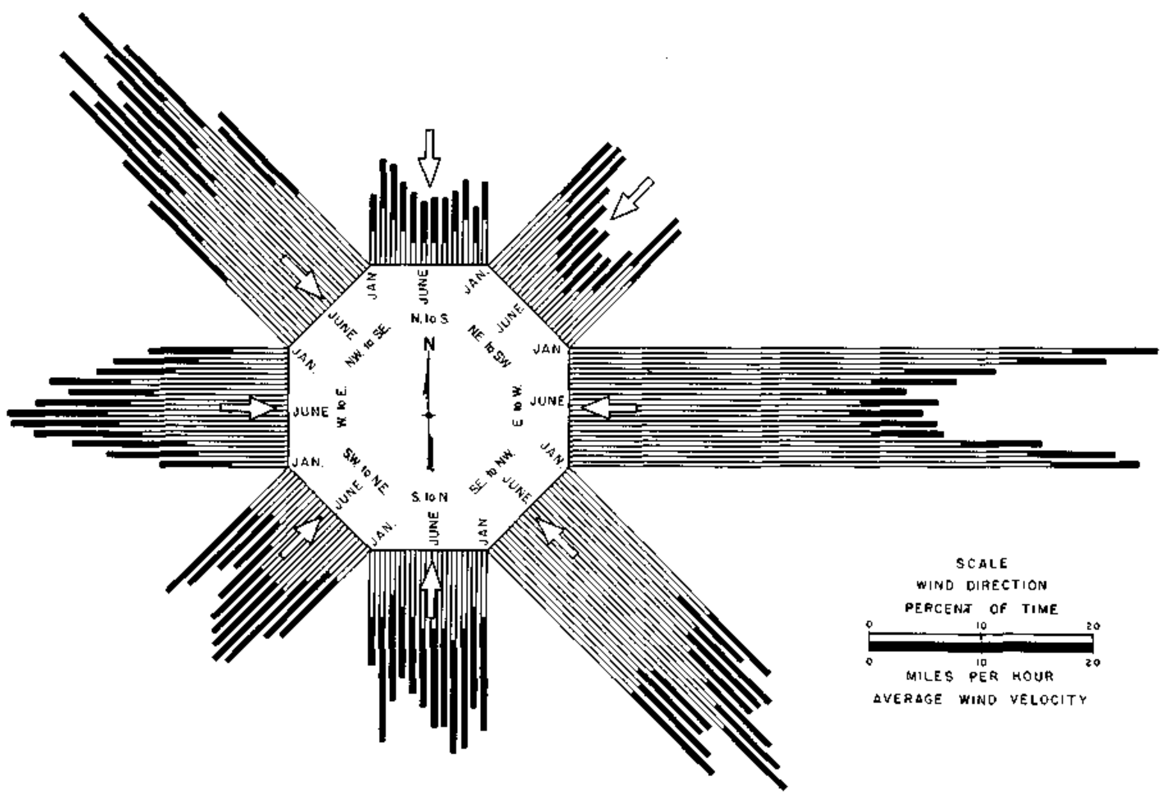


Figure 14. Wind Directions and Velocities at Vancouver Airport

Prevailing winds are east to southeast and the strongest winds are from the northwest.

Table 5
Direction, Velocity and Frequency of Winds at Vancouver Airport

Direction	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
	Velocity, mph											
N	3.1	4.2	4.7	4.1	4.3	3.5	3.9	3.8	3.4	3.4	3.1	3.2
NE	6.1	6.4	7.2	6.2	5.9	5.0	5.5	4.8	4.0	4.7	5.7	6.1
E	7.4	7.8	7.9	7.5	7.0	6.8	6.4	6.7	6.3	7.1	7.7	7.9
SE	7.5	7.9	9.3	8.8	7.7	8.0	7.8	7.7	7.1	7.8	8.8	10.1
S	9.8	8.8	10.3	9.8	8.5	8.6	6.8	6.6	6.1	9.2	10.9	4.1
SW	6.9	7.9	9.9	8.6	7.7	6.9	6.1	6.3	5.6	6.6	8.5	10.3
W	6.3	8.1	10.1	9.4	9.5	8.8	8.3	7.3	7.0	6.9	7.4	7.3
NW	9.6	9.7	12.3	11.1	12.2	11.2	12.0	11.4	10.5	9.7	6.8	9.7
	Frequency, percent											
N	3	5	4	3	2	2	2	2	3	4	2	4
NE	9	9	8	6	5	4	4	3	4	5	9	8
E	45	40	30	27	23	26	25	26	27	35	41	43
SE	18	15	18	18	19	22	24	26	18	17	18	18
S	6	5	7	8	7	7	7	6	5	4	6	6
SW	4	4	6	8	8	8	8	6	4	4	5	5
W	5	8	9	13	15	16	14	12	14	10	8	5
NW	8	12	17	16	20	14	15	18	23	19	9	9
Calm	2	2	1	1	1	1	1	1	2	2	2	2

Source: Meteorological Division of Department of Transport of Canada. Period of record 1938-1950, inclusive. Direction shown is that from which wind was blowing. See Figure 11 for location of stations.

quently during the winter months.

Precipitation. The maximum, mean, and minimum monthly precipitation at Vancouver Airport for 13 years, 1938 to 1950, is shown graphically in Figure 16 and given in Table 7. Similar data for the downtown Vancouver station with 46 years of records, 1905 to 1950, are

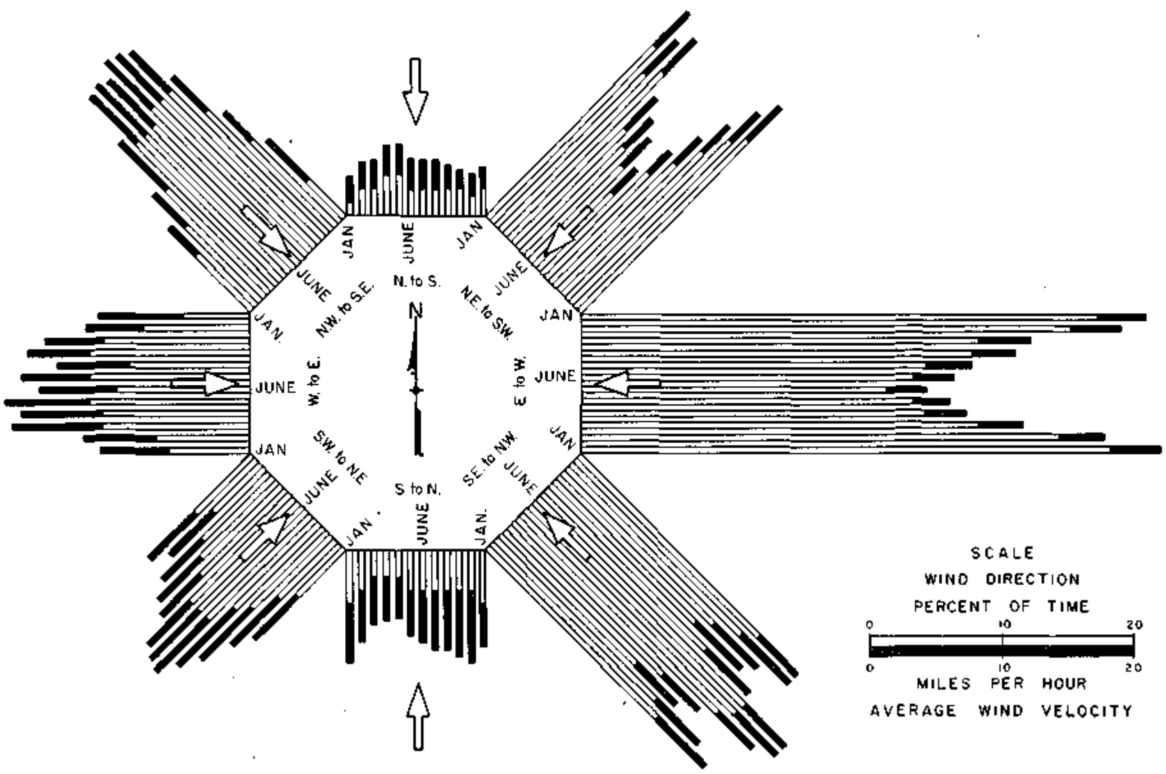


Figure 15. Wind Directions and Velocities in Downtown Vancouver

Prevailing winds are east to southeast as at Vancouver Airport. Average velocities are lower than at the airport.

Table 6
Direction, Velocity and Frequency of Winds in Downtown Vancouver

Direction	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
	Velocity, mph											
N	1.9	2.0	2.1	2.2	2.3	2.3	2.2	2.2	1.8	1.5	1.7	1.7
NE	3.5	3.4	3.4	3.2	2.9	2.7	2.5	2.2	2.5	2.7	2.9	3.5
E	3.6	3.7	3.8	3.7	3.4	3.1	3.0	2.7	3.0	3.3	3.4	3.7
SE	4.1	5.1	4.7	4.9	4.6	4.2	4.3	3.7	3.8	4.3	4.5	5.1
S	3.2	5.4	5.0	4.5	4.5	3.9	3.4	3.1	3.2	3.6	3.9	4.4
SW	4.6	5.1	5.5	6.0	5.5	5.1	4.5	4.3	4.6	4.3	4.6	4.9
W	5.2	5.4	6.8	6.1	6.3	5.8	5.1	5.4	4.7	4.3	4.3	6.4
NW	2.8	3.4	4.9	4.9	5.1	4.7	4.9	4.6	4.0	3.5	2.9	4.2
	Frequency, percent											
N	1	2	2	3	3	2	2	2	2	2	1	2
NE	18	16	17	13	11	10	8	11	13	15	17	18
E	39	37	30	29	26	25	23	25	26	30	36	40
SE	19	18	16	15	17	22	22	21	16	14	17	18
S	4	3	3	3	3	3	3	2	2	2	3	4
SW	5	6	8	9	11	11	11	9	8	7	5	6
W	6	7	11	11	12	10	12	9	12	11	8	5
NW	6	8	11	15	15	15	16	16	16	13	9	4
Calm	2	3	2	2	2	2	3	5	5	6	4	3

Source: Meteorological Division of Department of Transport of Canada. Period of record 1922-1942, inclusive. Direction shown is that from which wind was blowing. See Figure 11 for location of stations.

shown in Figure 17 and given in Table 7. In determining total precipitation, ten inches of snow are considered equivalent to one inch of rain.

Average annual precipitation at Vancouver Airport is 40 inches. The average monthly precipitation ranges from a maximum of six and one-half

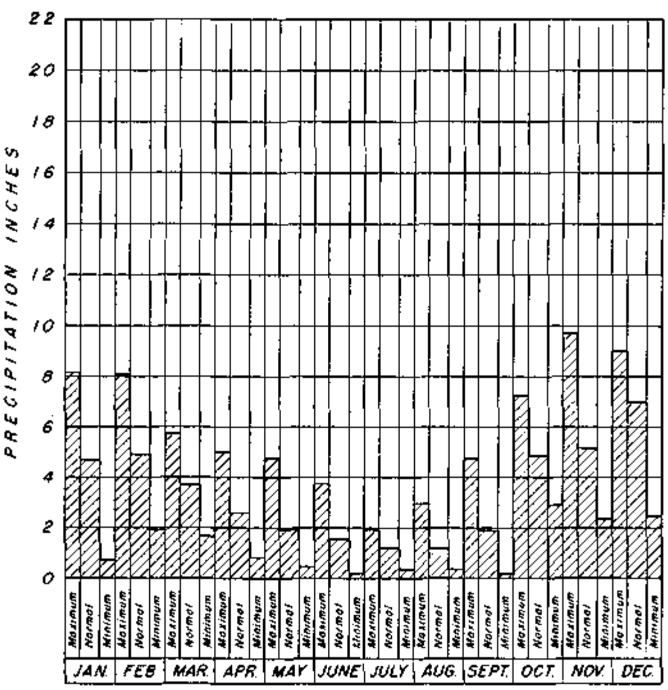


Figure 16. Precipitation at Vancouver Airport

Average annual precipitation during the period 1938-1950 is 40 inches. Average monthly precipitation ranges from about one inch in July to about six and one half inches in December. The maximum monthly precipitation of record was 9 64 inches in November, 1948.

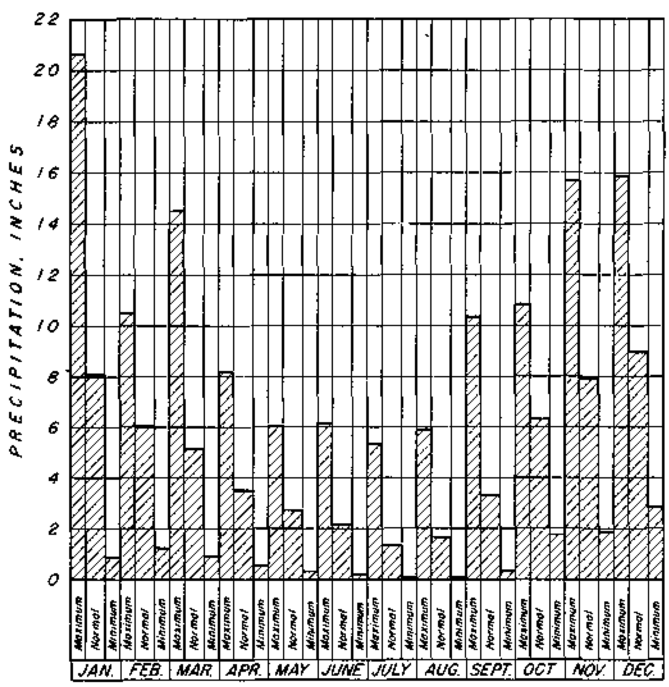


Figure 17. Precipitation in Downtown Vancouver

Average annual precipitation during the period 1905-1950 is 57 inches. Average monthly precipitation ranges from about one inch in July to about nine inches in December. The maximum monthly precipitation of record was 20.65 inches in January, 1935.

Table 7
Maximum, Mean and Minimum Inches of Precipitation

Month	Vancouver Airport[a]			Downtown Vancouver[b]		
	Maximum, in.	Mean, in.	Minimum, in.	Maximum, in.	Mean, in.	Minimum, in.
January	8.17	4.69	0.72	20.65	8.14	0.84
February	8.07	4.92	1.94	10.50	6.02	1.21
March	6.79	3.69	1.66	14.55	5.17	0.89
April	5.00	2.59	0.95	8.20	3.50	0.53
May	4.76	1.95	0.33	6.05	2.77	0.31
June	3.78	1.53	0.21	6.14	2.19	0.17
July	1.94	1.19	0.33	5.32	1.37	0.02
August	2.97	1.18	0.29	5.86	1.65	0.07
September	4.75	1.90	0.16	10.37	3.32	0.30
October	7.25	4.86	2.91	10.85	6.28	1.76
November	9.64	5.17	2.36	15.66	7.86	1.84
December	9.00	6.50	2.44	15.88	8.97	2.84
Year	49.95	40.17	31.34	67.55	57.25	37.83

Source: Division of Meteorology of Department of Transport of Canada. See Figure 11 for location of stations. 10 inches of snow considered equivalent to one inch of precipitation.

[a] Period of record 1938-1950, inclusive.
[b] Period of record 1905-1950, inclusive.

inches in December to a minimum of one inch in July and August.

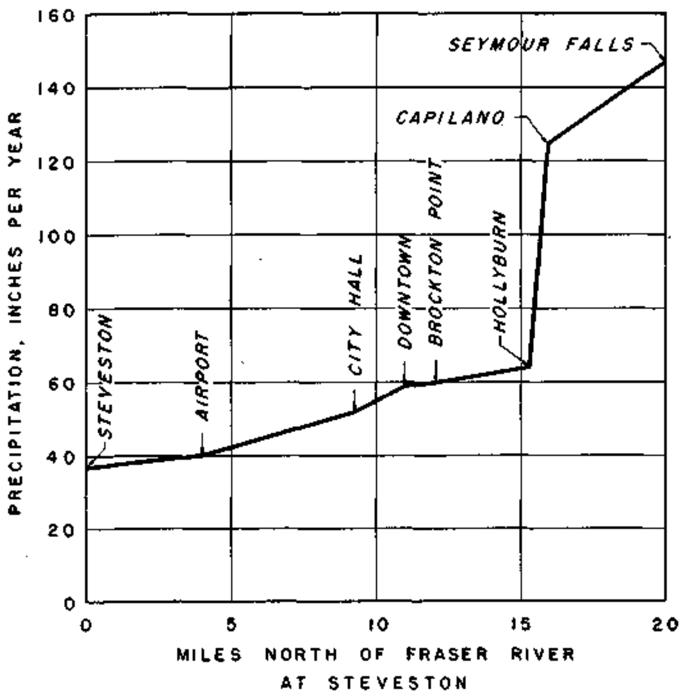


Figure 18. Variation of Precipitation in Greater Vancouver Area

Most of the rain bearing winds in the Greater Vancouver Area come from the southwest. As the winds approach the mountains, the moisture laden air is forced upward with subsequent cooling to the dewpoint. Average precipitation at Steveston, located on Fraser River at an elevation of 10 feet above sea level, is 37 inches per year while the average precipitation at Seymour Falls, on the south slope of the Coast Range, at an elevation of 675 feet above sea level, is 147 inches per year.

Average annual precipitation at the downtown Vancouver station is 57.25 inches with a total of 11.30 inches or 19.8 percent falling during the five months period, May to September, inclusive. The greatest annual precipitation occurred in 1900 prior to establishment of the Department of Transport station and was recorded as 72.29 inches. The lowest annual precipitation occurred in 1929 and was 37.83 inches. The average monthly precipitation ranges from a maximum of about nine inches in December to a minimum of about one inch in July.

It is noted from Figures 16 and 17 and Table 7 mentioned above that there is considerable difference in amount of precipitation between Vancouver Airport and downtown Vancouver. This may be attributed to the fact that most of the rain bearing winds come from the southwest and are forced upward as they approach the mountains with consequent cooling to the dew point followed by rain or snow. The variation in average precipitation from the community of Steveston on the north bank of the main channel of Fraser River to Seymour Falls situated in the Coast Range north of Burrard Inlet is shown in Figure 18. The average precipitation ranges from 37 inches per year at Steveston to 147 inches per year at Seymour Falls. The elevations of these places range from

Table 8
Mean, Maximum and Minimum Hours of Sunshine

Month	Vancouver Airport[a]			Downtown Vancouver[b]		
	Mean	Maximum	Minimum	Mean	Maximum	Minimum
January	83.9	120.0	58.4	48.4	100.7	14.4
February	88.3	109.2	54.5	80.2	148.4	42.0
March	128.0	160.5	76.2	125.5	233.8	63.0
April	167.5	198.1	145.5	168.0	257.5	79.0
May	247.4	299.1	173.6	226.0	313.1	140.0
June	253.8	279.6	226.3	223.0	329.2	135.7
July	283.4	324.2	240.2	280.0	381.2	145.0
August	233.8	306.8	153.8	253.8	348.2	130.6
September	201.9	223.2	161.3	177.9	236.2	79.4
October	117.0	145.4	65.0	110.1	150.9	55.0
November	71.5	84.2	56.6	52.9	96.8	28.8
December	40.5	51.1	31.7	37.8	73.5	10.7
Year	1917.0	2018.3	1802.3	1784.7	2023.8	1604.7

Source: Meteorological Division of Department of Transport of Canada. See Figure 11 for location of stations.

[a] Period of record 1947-1950, inclusive.
[b] Period of record 1909-1950, inclusive.

10 feet above sea level at the former to 674 feet at the latter.

Rainfall intensities and their effect upon storm and combined sewer design will be discussed in Chapter 13.

Sunlight. Maximum, mean, and minimum numbers of hours of sunshine monthly at Vancouver Airport for the four year period, 1947-1950 and for downtown Vancouver for the 42 year period, 1909-1950, are presented in Table 8. The percentages of the total annual hours of sunshine occurring during the five month period May - September, are as follows: maximum, 73.5 percent, in 1950; minimum 60.2 percent, in 1941; average, 64.0 percent. This period has been taken as the recreational season insofar as use of local beaches is concerned. The number of hours of sunlight per month reached a peak of 381.2, or an average of 12.3 hours per day, in July, 1931. In December, 1917, there were only 10.7 hours of sunshine, or an average of but 21 minutes per day.

Snow and Freezing Conditions. Monthly mean, maximum, and maximum 24 hour depths of snowfall at Vancouver Airport

Table 9
Mean, Maximum and Maximum 24 Hour Inches of Snowfall

Month	Vancouver Airport[a]			Downtown Vancouver[b]		
	Mean	Maximum	Maximum 24 hours	Mean	Maximum	Maximum 24 hours
January	5.9	37.0	10.1	10.3	33.7	17.5
February	4.8	23.9	6.4	7.1	36.5	14.5
March	0.1	0.8	0.8	2.1	16.2	7.1
April	0.0	0.1	0.1	0.3	9.5	5.5
May	0.0	0.0	0.0	0.0	0.0	0.0
June	0.0	0.0	0.0	0.0	0.0	0.0
July	0.0	0.0	0.0	0.0	0.0	0.0
August	0.0	0.0	0.0	0.0	0.0	0.0
September	0.0	0.0	0.0	0.0	0.0	0.0
October	0.0	0.0	0.0	0.0	3.8	[c]
November	1.1	3.8	3.1	1.7	27.0	15.0
December	3.3	16.6	8.1	5.3	27.0	11.0
Year	15.2	42.1	-	26.8	80.6	-

Source: Meteorological Division of Department of Transport of Canada. See Figure 11 for location of stations. Minimum monthly snowfalls of 0.0 inches have been recorded at both stations.

[a] Period of record 1938-1950, inclusive.
[b] Period of record 1906-1950, inclusive
[c] Data missing.

are shown in Table 9. A total annual depth of 15.2 inches of snowfall represents an average at that station. The annual average in downtown Vancouver is 26.8 inches as shown in Table 9.

Sharp frosts lasting for several days at a time may occur in the Greater Vancouver Area during the period November to April.

Fog. Fog occurs frequently during the night and early morning hours of the fall months. Fog, which may linger for several days in the low lying areas, is seldom found above an elevation of about 250 feet.

Chapter 5
Water Resources

Importance of Water Resources

Sewage may be regarded as the spent water supply of a community. The quantity of domestic and industrial sewage which originates in an area is therefore usually related to the water use in that area. To determine that relationship, a study of the water resources of the area is required.

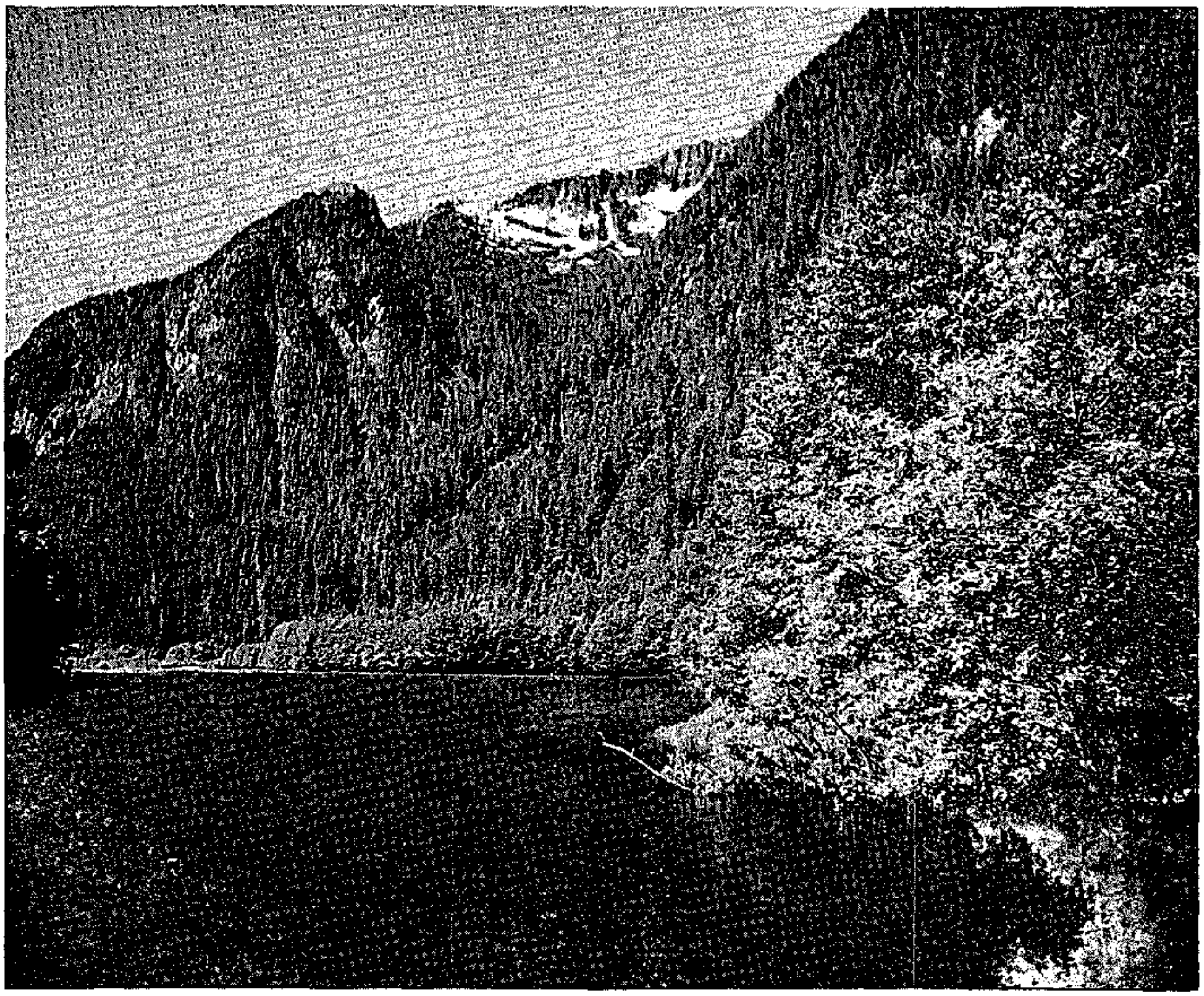
The water supply is used for domestic, industrial and public purposes. Its use, in terms both of total volume and rate, is influenced by availability, pressure, quality, climate and cost. The amount of used water that finds its way into sewers is dependent on many conditions. The type of sewage collection system affects the volume of public water supplies which reach the sewers. Under the separate or sanitary sewerage system only domestic or industrial wastes are admitted into the sewers, while under the combined system surface waters from street and household drains are also accepted in the same sewer which carries domestic and industrial wastes. Under certain conditions the volume of sewage in a separate or sanitary sewer may actually exceed the draft upon the public water supply because of ground water infiltration or the extensive use of private sources. Under other conditions, as much as 50 percent or more of the water used may be for lawn sprinkling, irrigation, street flushing and fire fighting, and thus may never reach the sewers.

The availability and cost of water may well be a major factor in the industrial and residential development of an area. In some localities, the scarcity of water may be the limiting influence in such development. In others, in which an adequate and inexpensive supply is available, water constitutes no barrier to development.

Water Supply

All of the domestic water supplies of the Greater Vancouver Area are derived from the mountain lakes and streams in the Coast Range north and east of Burrard Inlet. With but two exceptions, all domestic water is supplied by the Greater Vancouver Water District, a corporate body created by Act of Legislature in 1924. The District supplies water in bulk to member communities and has authority to sell water outside its legally constituted boundaries. The City of North Vancouver and the small settlement of Caulfield in the Municipality of West Vancouver have independent water sources. North Vancouver obtains its water from Lynn Creek and Caulfield from Nelson and Cypress Creeks. There are no municipal well supplies presently in use in the Greater Vancouver Area. At present it is believed that no industrial well supplies are in use in the area. There are, however, a few private wells supplying a small quantity of water for domestic and agricultural purposes in rural areas.

The Greater Vancouver Water District supplies water by gravity from three sources: Capilano River, Seymour River and Coquitlam Lake. The catchment basins have a total area of about 226 square miles, of which 68 square miles are in the Capilano, 47 square miles in the Seymour and 111 square miles in the Coquitlam Lake watershed. The watersheds are either owned outright by the Water District or are leased from the Crown for a period of 999 years. They are in mountainous regions covered with luxuriant forest growth. No residential development exists in them and constant patrolling prevents trespassing. For storage and regulating purposes, the Water District maintains four impounding reservoirs



Photograph by Kenneth E. Patrick

Figure 19. Seymour River

The Seymour River, together with Capilano River and Coquitlam Lake, are the sources of water for the Greater Vancouver Water District. The watersheds are in mountainous regions covered with luxuriant forest growth and are closed to the public. The total watershed area is 226 square miles, of which 47 square miles are in the Seymour watershed.

and ten regulating and balancing tanks. The four impounding reservoirs have a combined capacity of 9,500 million gallons. A fifth impounding reservoir will be incorporated into the system upon completion in 1954 of Cleveland Dam. This dam, on the Capilano River about three and one-half miles north of its mouth, will be 325 feet high and have an available storage of 12,200 million gallons. It will increase the developed area of the Capilano watershed to 76 square miles.

Water Quality

Water from the system of the Greater Vancouver Water District is of excellent quality and is suitable for normal domestic and industrial purposes. Because of the lack of any human habitation on the watersheds, the bacteriological quality is excellent. Chlorination is resorted to during portions of the year solely to fulfill the most rigorous bacteriological standards. The water is soft and usually free of turbidity or color. Mineral analyses show it to have a pH of

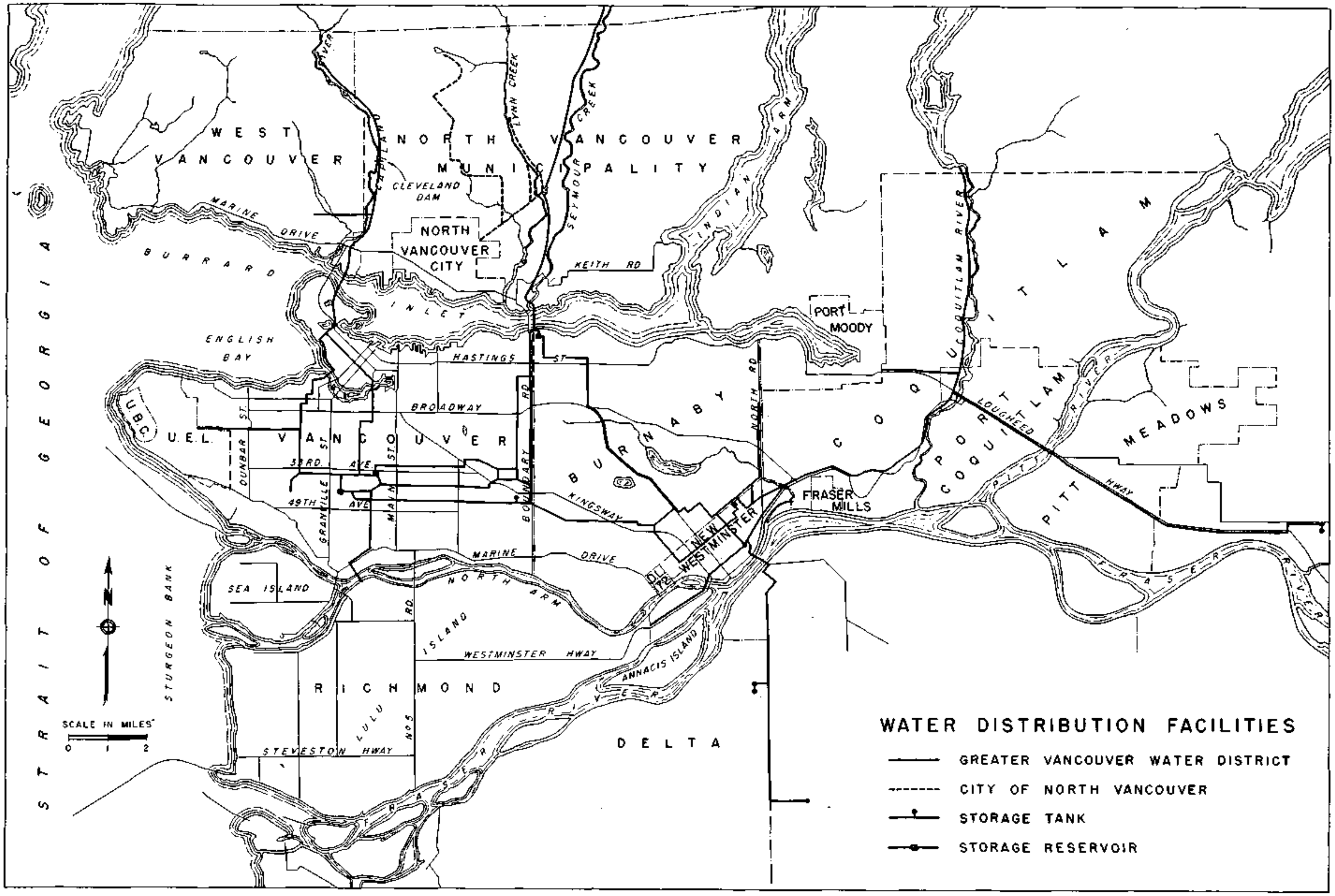


Figure 20. Water Distribution Facilities

The distribution system of the Greater Vancouver Water District includes over 125 miles of supply mains. The average daily water demand in the District for 1951 was 72.7 million gallons.

Table 10

Typical Mineral Analysis of Domestic Water Supply of Greater Vancouver Area

Constituent	Concentration
Calcium	1.9
Magnesium	1.4
Sodium[a]	2.1
Iron	0.1
Chloride	1.0
Sulfate	4.6
Nitrate	0.4
Bicarbonate	4.2
Total Hardness	9.7
Alkalinity	3.4
Silica	4.0
Total Dissolved Solids	22.5
pH	7.0

All analyses reported in this Table were conducted by personnel of British Columbia Research Council on sample collected October 25, 1946 from Seymour River supply. Analyses except pH are reported as parts per million, ppm, of stated constituent with exception of total hardness and alkalinity, which are reported as calcium carbonate.

[a] Includes other alkalies expressed as sodium.

7.0, a total hardness not exceeding ten parts per million expressed as calcium carbonate, and total dissolved solids of less than 23 parts per million. Table 10 presents results of a typical mineral analysis of a water sample from the Seymour River supply. Analyses of the other supplies are virtually the same in all respects, and very little variation in mineral composition has been observed over a period of many years.

Water Distribution

Figure 20 presents the major distribution facilities of the water supply systems serving the area. Over 125 miles of supply mains are included in the system of the Greater Vancouver Water District. No pumping is required in the major distribution system. The Water District supplies water to member communities, each of which is independently responsible for local distribution.

Water is conveyed to the City of North Vancouver through a line six miles long and the local distribution system comprises a total of 59 miles. The settlement of Lynn Valley within the Municipality of North Vancouver is served by the City of North Vancouver supply. An additional source is available to the city to meet peak demands during the summer through a connection to the Greater Vancouver Water District's supply mains.

No data were available regarding the distribution system of the settlement of Caulfield in the Municipality of West Vancouver.

Water Consumption

Table 11 presents the total and per capita average daily demand during 1951 by each of the communities within the Greater Vancouver Water District, as well as the number of service connections in each. The average daily use in the area was 70.2 million gallons, of which 48.5 million gallons were supplied to the City of Vancouver. These figures are equivalent to 139 and 140 gallons per capita per day, respectively. The peak daily summer demand of 111.6 million gallons was 159 percent of the average daily demand for the district as a whole. In the City of Vancouver the peak daily demand of 79.2 million gallons represented 164 percent of the average daily consumption in 1951.

The average daily demand during the year 1952 on the City of North Vancouver system was reported to be 4 million gallons of which 0.7 million gallons were supplied to the settlement of Lynn Valley. The peak daily summer demand was reported to be 5.5 million gallons.

Cost of Water

Since no pumping of water is required in the system of the Greater Vancouver Water District, the unit charge for water to each member community served by the District is the same. The charge is estimated and set at the beginning of each year, and adjustments may be made during the ensuing year to maintain the balance between income and expenditures as closely as possible. The unit charge set for the year 1952 was 6.6 cents per thousand gallons delivered to the local authority.

Table 11
Communities Served by the Greater Vancouver Water District

Community	Number of Service Connections	Average Daily Demand Total, 1,000 gpd	Average Daily Demand Per Capita,[a] gpcd
Member Cities:			
New Westminster	7,835	5,152	180
Port Coquitlam	867	534	165
Port Moody	678	269	120
Vancouver	86,605	48,536	140
Member Municipalities:			
Burnaby	16,900	7,906	135
Coquitlam	3,000	623	40
Fraser Mills	130	415	1,125[b]
North Vancouver	5,020	1,192	82
Richmond	5,760	3,283	171
West Vancouver	4,450	1,368	98
Non-members:			
District Lot 172	450	93	63
University Endowment Lands and University of British Columbia	400	823	238
Total	123,195	70,194[c]	139[d]

Data on number of services and on total daily consumption furnished by Greater Vancouver Water District for year 1951. City of North Vancouver not listed on this table since it uses municipal source of supply exclusively except during summer months.

[a] Estimated using 1951 census figures given in Table 2, Chapter 2.
[b] Water use dominated by demands of large lumber mill.
[c] Deliveries to other communities outside area covered in this report total 2.5 million gallons per day. Total average demand on Greater Vancouver Water District supply equals 72.7 million gallons per day.
[d] Total population served estimated to be 504,600.

Chapter 6
Use and Condition of Shores and Shore Waters

Influence on Development

The influence of the ocean and of the navigable waters upon the growth and development of the Greater Vancouver Area cannot be appraised too highly. The location of the City of Vancouver, with its excellent deep sea harbour and miles of shore, has played an important part in the city's rapid and substantial growth. The cities and districts surrounding Vancouver all have boundaries on at least one stretch of navigable water. Large industries, lured by the opportunity of economical ocean transportation, have been quick to capitalize on the industrial potential of the area. The result has been a phenomenal expansion in population, industry and commerce.

The recreational opportunities afforded by the many miles of good beaches have definitely increased the residential popularity of the entire area. The beaches are frequented by visitors from all of the neighbouring communities and by tourists from far and wide. There is every indication that the public use of these beaches and associated areas will increase as the metropolitan population grows. The limit to that patronage will be the capacity of the available shoreline areas to acceptably handle the visiting crowds.

Unfortunately, with the growth in the population resident in the area, contamination of the shores and shore waters has increased dangerously. Crude sewage always has been discharged at some point or other into the adjacent waters. This practice has produced unpleasant and unhygienic conditions at many places. A primary objective of the sewerage projects considered by the survey and recommended in this report has been the production and maintenance of shores and shore waters free from unsightliness and unsanitary conditions. Only so can the contemplated development and use of the beaches and the growth of adjacent residential and industrial areas proceed without protest or restriction.

Use by Industry

As shown in Figure 7, Chapter 2, the majority of industrial sites in the Greater Vancouver Area are on low-lying, flat ground immediately adjacent to some waterway or railroad. The waterfront industrial sites, both existing and proposed, are shown diagrammatically in Figure 22. It is always difficult and often impossible to design gravity trunk sewers or interceptors to pick up the sewage and trade wastes from these low places. As a result, nearly all of the industrial sites within the area face the possibility of eventually having their liquid wastes pumped to an intercepting sewer.

The False Creek area is an excellent example of this situation. It is only in recent years that the expense of constructing and operating pumping stations there has been deemed to be justifiable. This area, in the heart of the City of Vancouver, contains a heavy concentration of industry. Sewage was discharged directly into False Creek until several pumping stations were constructed by the city to pump the sewage into intercepting sewers on the north and south banks. This has relieved the pollution in False Creek to a material extent. It should be recognized as essential that wastes of all industries situated on ground too low to be drained economically by gravity shall be pumped to the most convenient trunk or intercepting sewer.

The major industry in the Greater Vancouver Area is lumber and its associated products. To this industry can be traced most of the debris that litters the beaches and shore lines. The Vancouver Park Board makes a determined effort to clear the beaches under its jurisdiction of this debris, but every high tide deposits its load of logs, cuttings, and mill waste. The huge booming grounds connected with this industry are highly essential.

Bathing Beaches

The location and extent of the bathing beaches are shown in Figure 22. The largest and most popular beaches are in the City of Vancouver but numerous smaller beaches along the North Shore and Fraser River are growing in popularity. The aggregate lengths of public beaches suitable for recreational purposes is estimated to be 12 miles. In addition, it has been suggested that the Burnaby Lake area be developed as a large park for boating, swimming, picnicking and riding, and for all sorts of sports meetings, especially aquatic events. This would provide another three or four miles of fresh water bathing shores and relieve the ultimate con-

Courtesy Vancouver Sun

Figure 21. English Bay Beach in the City of Vancouver

Summer attendance at patrolled beaches in the City of Vancouver increased from 1,000,000 people in 1941 to 1,500,000 in 1952, according to estimates of the Vancouver Park Board.

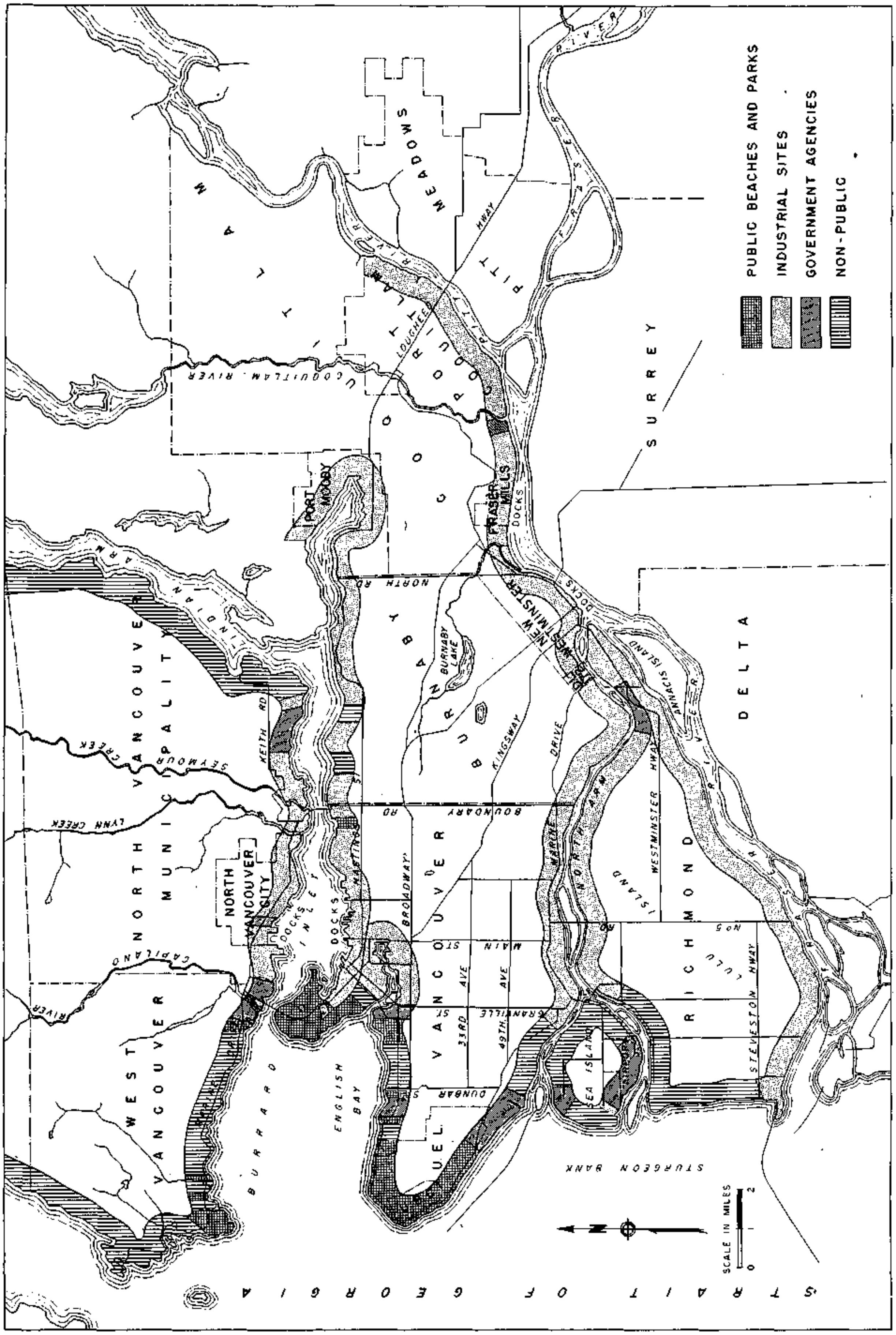


Figure 22. Uses of Shores and Shore Waters in the Greater Vancouver Area

Major swimming beaches and other water recreation areas are on the shores of English Bay. Docks and industrial sites are found on both shores of Burrard Inlet and on the banks of Fraser River.

gestion of the existing beaches. This project is still under consideration and is far from realization.

The present attendance at the City of Vancouver beaches, the only beaches in the area, that are supervised and patrolled, can only be approximated. The period during which the beaches are used to any extent for swimming normally extends from about May 1 to September 30. According to estimates made by the Vancouver Park Board, the summer attendance at Vancouver beaches during 1952 totalled 1,500,000 people. Of these, 70 percent were Vancouver residents; 20 percent from other places in the Greater Vancouver Area; and 10 percent from the provinces and states outside the Area. This total was made up of an average daily attendance through July and August of 15,000 on weekdays and 70,000 on Sundays. In 1941 the estimated total summer attendance at Vancouver beaches was 1,000,000 people. Beach use during the period 1941-1952 increased by 50 percent, while population growth estimates for the same period show an increase of 40 percent in the Greater Vancouver Area. It is reasonable to conclude that future beach attendance can be expected to increase roughly in proportion to the population growth of the area.

Boating

Yachting enthusiasts have ample opportunity for sailing and boating under good conditions in the water of English Bay. Large numbers of motor craft and

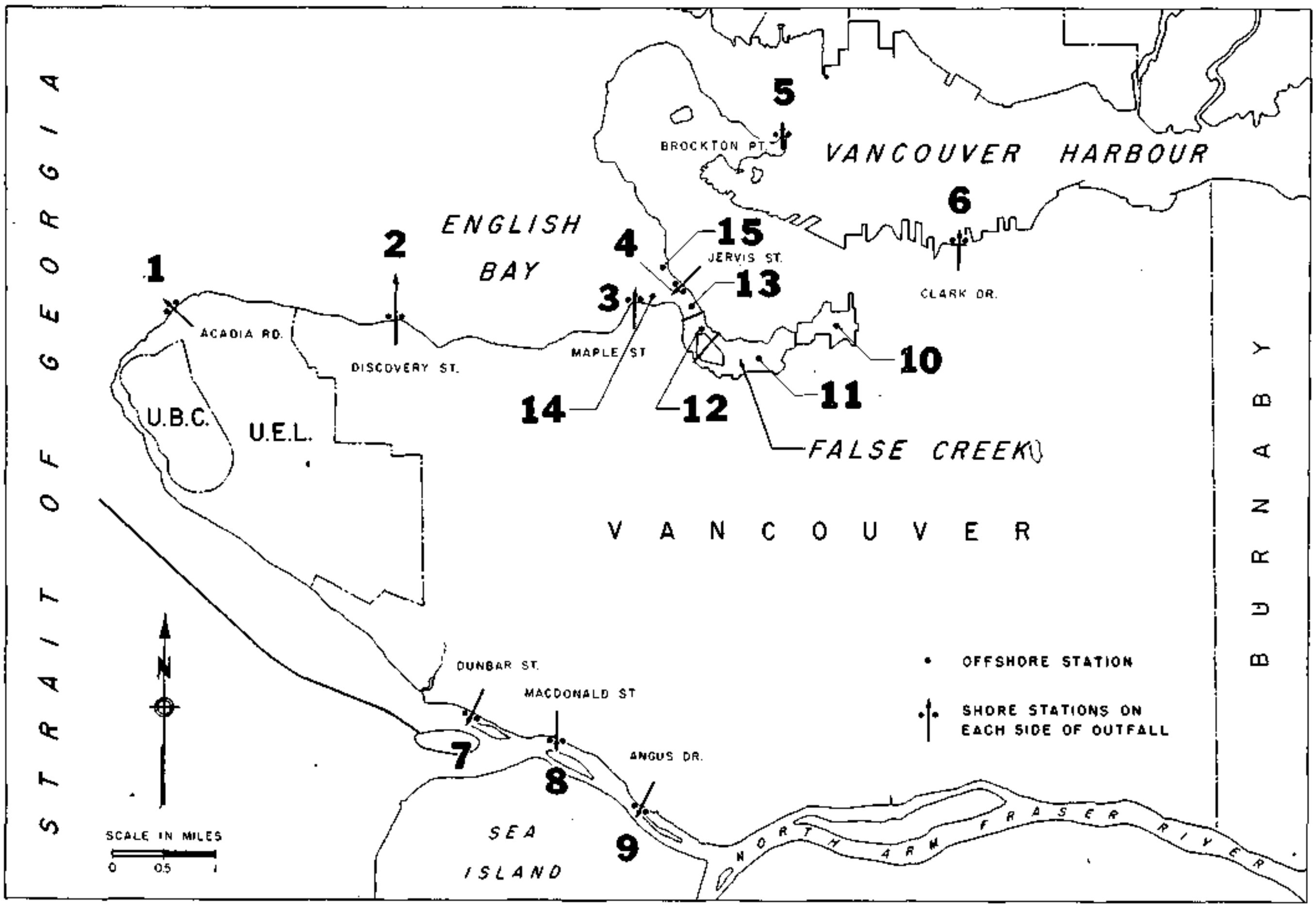


Figure 23. Existing Sewage Outfalls and Bacteriological Sampling Stations

Crude sewage has always been discharged into the waters surrounding the Greater Vancouver Area. Because of increased populations, contamination of the shore waters has increased and has produced unpleasant and unhygienic conditions at many places. Bacterial samples were collected at nine shore and six offshore stations in 1950 and analyses indicate that all stations were contaminated by organisms of intestinal origin.

row boats also are used in the bay for recreational purposes, including fishing. Additionally, commercial fishing is a major industry along the entire western coast, and the Vancouver area is the home port for many fishing vessels large and small. Anchorage and dock areas are shown in Figure 22. Waste discharges from vessels using the harbour and adjacent waters contribute to the pollution of the shores and shore waters.

Other Uses

Figure 22 shows the waterfront areas utilized by various governmental agencies for such purposes as military establishments and Indian Reserves. Non-public areas indicated on Figure 22 are either used for residential purposes or are presently unused. Private residences along the shore usually are well kept and in no way add to the pollution

Table 12

Most Probable Numbers of Coliform Organisms per cc in Burrard Inlet, English Bay, False Creek and North Arm of Fraser River

Date	Tide[a]	Station[b]																			
		1		2		3		4		5		6		7		8		9	
		R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
1949																					
Oct. 25	[c]												50						
Oct. 31	E	6	5	2	21	2	24												
Nov. 1	F												21						
1950																			
Jan. 4	[d]	70	13	5	1	70	70			70									
Jan. 5	E												70						
Jan. 6	[c]													70	70	70	70	70	70
Jan. 25	E	70	24	70	6	24	13												
Jan. 26	[e]									70			70						
Jan. 30	E													70	70	70	70	70	70
Mar. 27	E			6	13	70	13												
Mar. 28	F									6									
Mar. 29	F	2	24												70		70		70
Mar. 30	F											70	70						
June 12	[f]	2	70	2	6	6	13	6	70	70									
June 21	E	70+	70	13	5	6	70	70	70	70	70								
June 29	[g]	6	70	2	13	21	24	70+	70+	6	70								
July 5	[h]	24	70	1	1	1	2	2	2	6	6								
July 13	[i]	70	70+	2	6	70	70	70	21	70	70								
July 18	E	2	24	13	1	10	70	4	21	24	24								
July 27	[j]			70+	5	70+	24	70	24	70	24								
Aug. 3	[k]	70	70	21	2	70	2	5	5	70+	6								
Aug. 9	[l]	70	70	24	70+	1	2	6	24	6	70								
Aug. 21	F	6	2	3	13	70	24	4	70	24	21								
Aug. 30	E	13	24	13	13	1	2	24	24	70	13								
Sept. 6	F	70	21	24	70	2	2	2	5	70	70								

Analyses are reported as most probable number (MPN) per cubic centimeter.
Samples were collected to right (R) and left (L) of stations directly onshore from outfall.

[a] Stage of tide indicated by: F-flood and E-ebb.
[b] Location of stations shown on Figure 23.
[c] Time of sampling not recorded.
[d] Ebb at stations 1 and 2; slack at station 3; flood at station 5.
[e] Flood at station 5; ebb at station 8.
[f] Ebb at stations 1 and 2; flood at stations 3 and 4.
[g] Ebb at stations 1, 2 and 3; flood at stations 4 and 5.
[h] Flood at station 1; slack at station 2; ebb at stations 3, 4, and 5.
[i] Ebb at stations 1, 2, and 3; flood at stations 4 and 5.
[j] Flood at stations 2, 3 and 4; ebb at station 5.
[k] Flood at station 1; ebb at stations 2, 3, 4, and 5.
[l] Ebb at station 1; flood at stations 2, 3, 4, and 5.

Table 13
Most Probable Numbers of Coliform Organisms per cc in False Creek

Date	Tide[a]	Station[b]					
		10	11	12	13	14	15
1950							
June 14	c	70	24	70	70	13	6
June 22	E	70+	70+	70+	6	70+	24
June 28	E	70+	70+	70+	70	70	70
July 6	d	70	70+	70+	13	2	0
July 11	E	70+	70+	70+	70+	13	1
July 17	E	70+	70+	70+	70+	13	70
July 22	e	70+	70+	70+	70	70+	70+
Aug. 2	f	70+	70	2	6	5	24
Aug. 8	F	70+	13	-	1	1	2
Aug. 17	E	70+	70+	70+	70+	24	70+
Aug. 24	g	70+	70+	70	6	6	6
Sept. 5	F	70+	70+	1	0	0	2

Results of analyses are reported as most probable number (MPN) per cubic centimeter.

[a] State of tide indicated by: F–flood and E–ebb.
[b] Locations of stations shown on Figure 23.
[c] Ebb at stations 10, 11, and 12; slack at station 13; flood at stations 14 and 15.
[d] Flood at station 10; slack at stations 11 and 12; ebb at stations 13 and 14 and 15.
[e] Ebb at stations 10, 11, and 12; flood at stations 13, 14, and 15.
[f] Slack at station 10; ebb at stations 11, 12, 13, 14, and 15.
[g] Ebb at station 10; slack at station 11; flood at stations 12, 13, 14, and 15.

of the adjoining waters. Float houses and shanties, of which the exact reverse is true, exist in several scattered locations along the shores.

Present Pollution of Shores and Shore Waters

At present crude sewage is discharged without treatment into ocean and river waters of the Greater Vancouver Area at nearly sixty known locations. These locations are presented and discussed in detail in Chapter 10. Figure 23 has been prepared, however, to show the general locations of certain sewage outfalls with respect to beach and recreational areas.

The extent of bacterial contamination of the shores and shore waters was examined by the Vancouver and Districts Joint Sewerage and Drainage Board in 1949 and 1950. Samples for bacteriological testing were collected at each of nine shore stations and six offshore stations as shown on Figure 23. Shore samples were collected onshore from outfalls discharging crude sewage into the waters of Burrard Inlet, English Bay, False Creek and North Arm of Fraser River. At each station samples were obtained at knee depth in sterile bottles a short distance on either side of a point directly onshore from the outfall to evaluate the effect of near-shore currents on spread of sewage from the outfalls. Offshore samples were collected from stations located on the waters of False Creek and were obtained in sterile bottles from beneath the water surface.

The samples were tested for numbers of coliform group organisms present. Laboratory testing was carried out in the bacteriological laboratory of the Greater Vancouver Water District. Presumptive and confirmed tests for coliform group organisms were performed in duplicate in accordance with "Standard Methods for the Examination of Water and Sewage" published by the American Public Health Association. Tables 12 and 13 present the results of these tests in terms of the most probable number (MPN) of coliform organisms per cubic centimeter. The stage of the tide obtaining at collection of each sample is also shown.

At present no official standards or limits defining bacterial contamination of bathing waters are in force within the Province of British Columbia. A study of standards in force in many of the states of the United States shows that they vary between wide limits in defining bacterial contamination. A comparison of the results obtained during the above-mentioned sampling program with several standards or limits in force elsewhere coupled with the fact that many of the existing crude sewage outfalls are located in or adjacent to important beach and recreational areas leads to the conclusion that the problem of pollution is a serious one, not only in English Bay, but also in Vancouver Harbour and the North Arm of Fraser River. It is probable that, unless corrective measures are taken to ensure the proper disposal of the sewage, the degree of pollution will increase as the volume of sewage flow increases until large areas of the beaches will no longer be safe for use. Such a condition would be intolerable.

Chapter 7
Principles and Functions of Sewerage and Sewage Treatment

Sewerage

Personal and public health and private and public comfort require that community wastes, both liquid and solid, be promptly removed from all premises and disposed of in some innocuous manner. Because of its intrinsic character, sanitary or domestic sewage requires substantially instant removal from the sources of its production with concurrent transportation to some suitable and acceptable place of disposal. There it may or may not be treated, depending upon local conditions. Storm waters from streets, roofs and land surfaces must be taken away practically as fast as produced, for the obvious reason that street surface storage in the modern city is extremely limited. In congested urban areas, therefore, public comfort and convenience demand adequate storm water inlets and storm drains, often called storm sewers.

In the past it has been customary to convey the sanitary or domestic sewage and the storm waters of an area in a single system of conduits called combined sewers. The custom arose before the possible necessity for treatment of the sanitary or domestic sewage became manifest. Such combined sewers were commonly taken to the nearest points of outfall in some body of receiving water, regardless of the extent of pollution which might thereby be engendered. Modern hygienic standards will no longer tolerate the fact or the extent of pollution frequently caused by such promiscuous discharges. Some form and degree of treatment frequently has become necessary to prevent possible danger to public health and to avoid nuisances due to odour and unsightliness.

The public demand for clean, unpolluted environmental waters, especially those used for recreational purposes, argues strongly for the construction of separate systems of conduits, one for the collection and transportation of domestic sewage, including industrial wastes, and the other for the collection and transportation of storm waters. This separation of sanitary sewage from the relatively unpolluted storm waters allows for the effective and economical treatment of the sewage.

Sewage Treatment Methods

Sewage treatment is undertaken for the sole purpose of making disposal practicable and sanitary. Two general types or degrees of treatment, namely, primary and secondary treatment, are currently being utilized. Very frequently, with adequate volumes of diluting or receiving water and under other favourable conditions, either no treatment is required or else primary treatment alone is sufficient. Secondary treatment methods seldom are used alone. They are almost invariably preceded by some form of primary treatment. Figure 24 shows diagrammatically the types of sewage treatment generally indicated for various methods or locations of disposal.

The dilution of sewage in an adequate volume of water containing a normal amount of dissolved oxygen actually may be regarded as a secondary process of sewage treatment in itself although it will not be discussed as such. As a practical matter, and as later stated in greater detail, the receiving body of water must have adequate depth, a sufficient velocity, and such isolation as the particular conditions may require.

Primary treatment, fundamentally a mechanical procedure, is aimed at the removal of floating material, suspended solids, grease or fats, and such amounts of organic matter as are incidental to

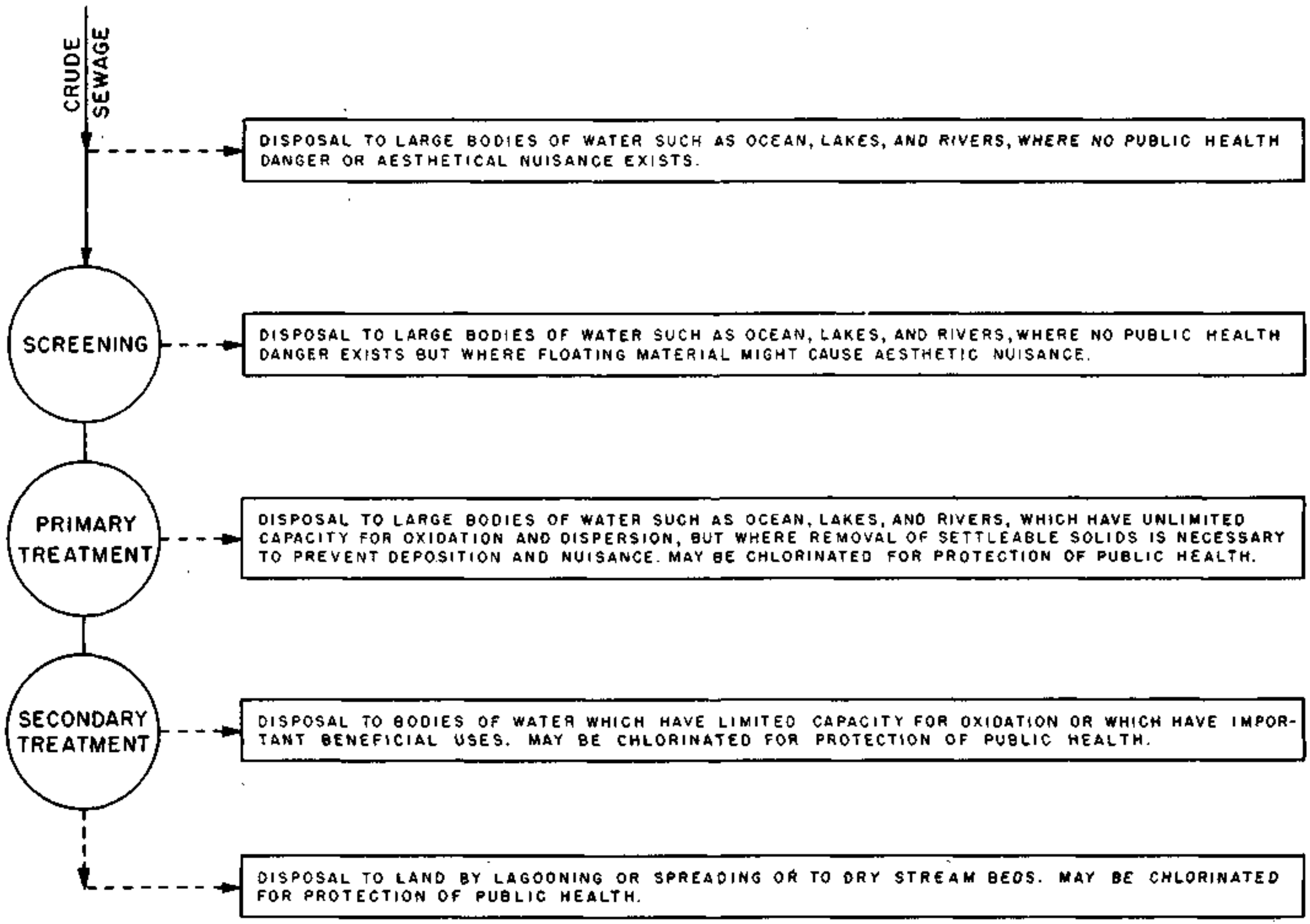


Figure 24. Sewage Treatment Processes

Classification of sewage treatment processes is made on the basis of the degree of treatment. Minimum treatment is provided in primary plants, while increasing degrees of treatment are afforded in secondary plants. Primary treatment is used preliminary to secondary treatment or where disposal of the effluent is to be to receiving waters of capacity sufficient to ensure no danger to beneficial uses of the waters. Secondary treatment is used where disposal of the effluent is to be to receiving waters of limited capacity or onto land.

the process. Secondary or final treatment, fundamentally biological in its nature, attempts to oxidize the organic residue of primary treatment.

As a safeguard to the public health and to obviate nuisances due to odours, chlorination of sewage effluents may be practised prior to ultimate disposal. Chlorination, properly accomplished under controlled conditions, is capable of destroying most of the pathogenic organisms contained in sewage. Disinfection may be employed alone in some cases, but more commonly and rationally as a supplement to primary or secondary treatments.

Primary Treatment

Primary treatment processes are used to prepare an effluent suitable to undergo secondary treatment or to be disposed of by dilution. If secondary treatment is to be employed, the design as a whole should recognize the proper function and capacity of both primary and secondary features of the plant. If the primary effluent is to be disposed of by dilution, the capacity of the diluting water to receive the effluent controls the design of the plant.

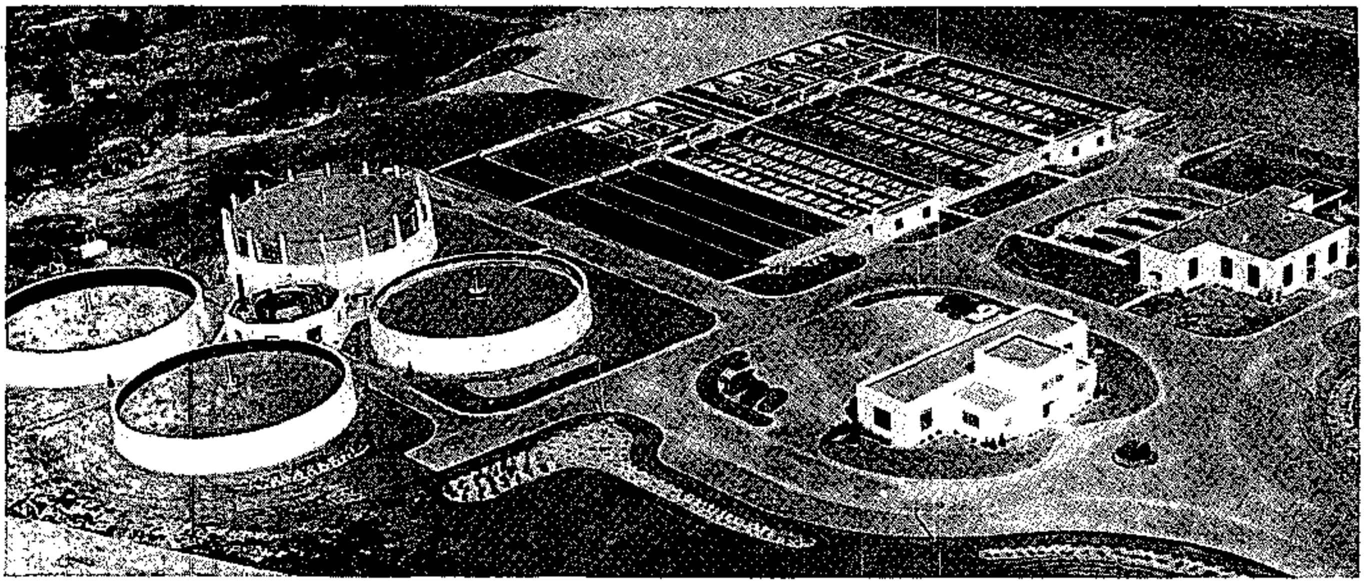
Primary treatment usually provides the following functions:

(1) Removal of grit or sandy material.
(2) Removal or maceration of large floating material.
(3) Removal of part of the solids by sedimentation or quiescent subsidence.

Primary treatment plants may be classified according to the length of time provided for settling. High-rate primary plants usually provide one hour or less of sedimentation, depending on the final disposal of the effluent. Removal of practically all floating material and about 50 percent of the suspended solids is usually accomplished.

Standard-rate primary plants usually provide two hours of sedimentation. In addition to the floating material, they remove practically all of the settleable solids and up to 70 percent of the suspended solids. This treatment normally reduces both the total oxidizable material and the fats about 35 percent. Frequently, prior to sedimentation, the sewage is aerated to restore its oxygen, to remove inorganic grit, and to coagulate the finely divided suspended solids. Aeration also increases the extent of grease or fat removal.

An incomplete but simple primary treatment process of low cost consists of passing the sewage through screens or bar racks with relatively small openings. This procedure is aimed at the removal of the larger solids which would float if the sewage were discharged directly into a receiving body of water. This treatment process has as its principal objective the prevention of visual evidence of sewage in the receiving body of water.



Courtesy City of Portland, Oregon

Figure 25. Primary Type Sewage Treatment Plant

This plant provides for primary treatment of sewage prior to disposal by dilution. Plant units include: (1) grit chambers at right centre; (2) sedimentation tanks at upper right; (3) separate sludge digestion tanks at lower left; (4) control and administration buildings at right foreground.

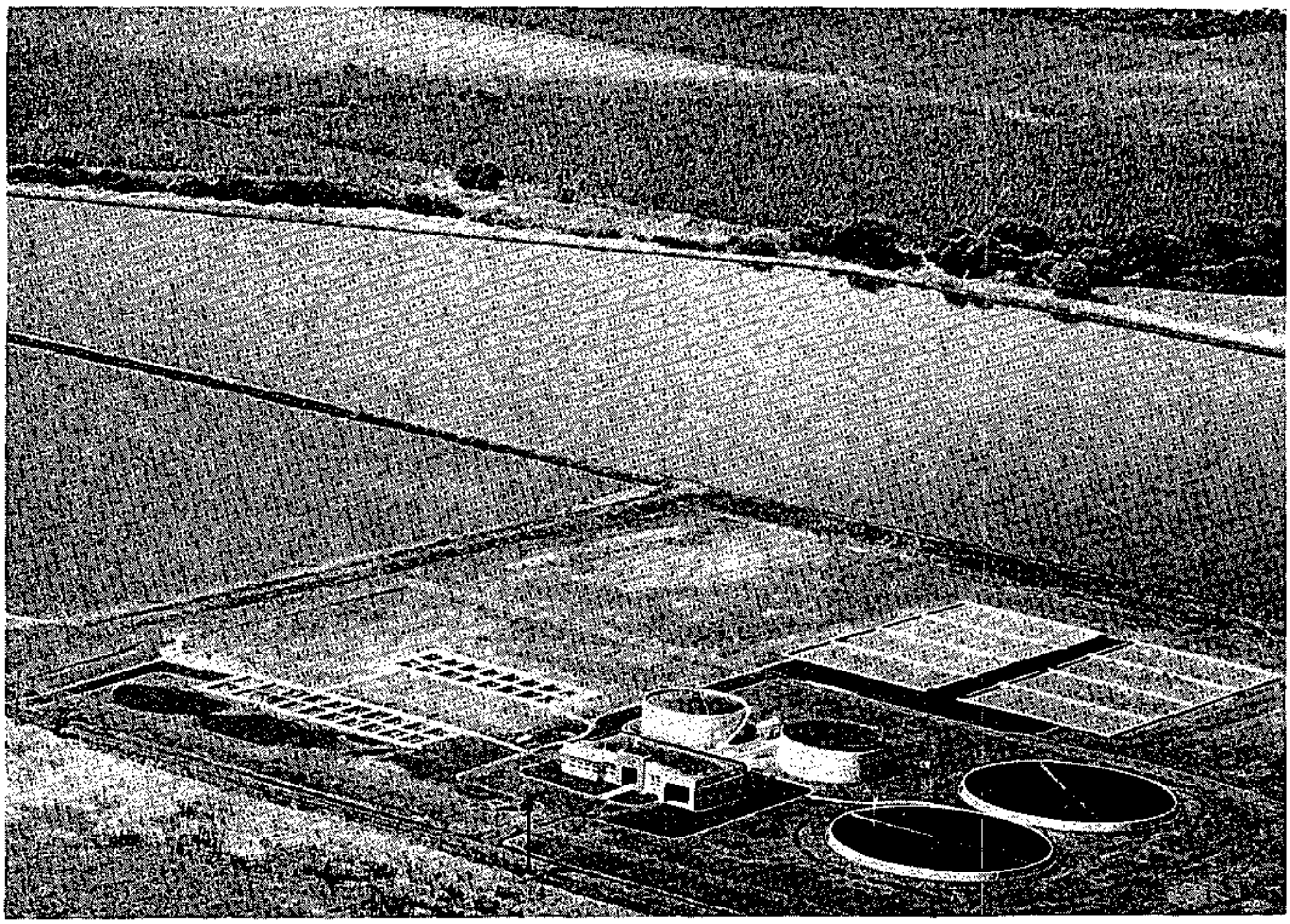
Secondary Treatment

Secondary treatment processes provide for the biologic oxidation of organic material not removed by primary treatment. Such treatment generally is required for land disposal or for disposal to bodies of water of otherwise inadequate receiving capacity. After primary treatment to remove floating and settleable solids, the organic material remaining in the sewage is in a dissolved, colloidal or finely suspended state. Through an appropriate type of secondary treatment, this organic matter is oxidized partially or completely prior to discharge. The combination of primary and secondary treatment to produce a stable, relatively clear effluent is termed "complete" treatment.

Secondary treatment is usually accomplished by one of the three following methods:

(1) Trickling filtration.
(2) Activated sludge process.
(3) Oxidation ponds.

Trickling filtration involves spreading the sewage, after it has undergone primary treatment, over a bed of coarse rock. It then trickles slowly through the rock bed. Oxidation is achieved by numerous plant and animal organisms which form a film on the surfaces of the rocks. The organic matter in the sewage is utilized as a food material by these organisms. The effluent from a properly working trickling filter contains considerable suspended material in a well nitrified and flocculated condition. This material usually is removed from the sewage in a secondary sedimentation tank which commonly provides a two-hour settling period. Trickling filters



Courtesy City of Santa Rosa, California

Figure 26. Complete Type Sewage Treatment Plant

This plant provides for complete treatment of sewage by sedimentation, high-rate trickling filters and oxidation ponds prior to disposal to a creek of limited receiving capacity. Plant units include: (1) primary sedimentation tanks at lower left; (2) trickling filters at lower right; (3) secondary sedimentation tanks at left centre; (4) oxidation ponds at left and top; (5) separate sludge digestion tanks at centre; (6) sludge drying beds at right centre; and (7) control building at bottom centre.

are generally classified either as high-rate or as standard-rate units, depending upon the rate per unit of filter media at which sewage is applied to them. High-rate trickling filters remove 70-80 percent of the oxidizable material contained in the sewage, while standard-rate units may remove 75-90 percent.

The activated sludge process provides for the oxidation of organic matter in sewage by bringing the sewage in contact with oxygen and with biologically active sludge which has been produced by the process. Effluent from primary sedimentation units is introduced into aeration tanks, together with so-called "activated" sludge returned from final settling tanks. Oxygen is supplied by air blown through diffusers commonly placed along one side of the aeration tank. The activated sludge contains great numbers of biologic organisms which consume or otherwise destroy the organic matter in the sewage as the mixture is being agitated by the air. For sewage of normal strength, detention time in the aeration tanks ranging from six to eight hours is commonly required for reasonably complete oxidation of the organics. A secondary settling period of about two hours is required to remove the sludge from the aerated mixed sewage and sludge. A portion of the sludge so removed is returned to the effluent from the primary tanks at the inlet of the aeration tank. Effluent from the final settling process is normally clear and of fair bacteriological quality. Ninety percent or more of the total oxidizable organic material originally contained in the sewage is removed by this process.

The third method of accomplishing secondary treatment is by means of oxidation ponds. This method is the least expensive secondary treatment process known. It is, however, strictly subject to the limitations of available land, temperatures, and sunlight. In accordance with the best practice, after undergoing primary treatment, the sewage is introduced into large open ponds with a detention time of about 20 days. During this time the oxidizable organic material is utilized by algae and other biologic forms which exist and thrive in the ponds. The normal effluent from oxidation ponds is of greenish hue due to chlorophyll-bearing organisms, but is otherwise fairly clear. It has a lower content of coliform bacteria than does the unchlorinated effluent from any other known method of sewage treatment.

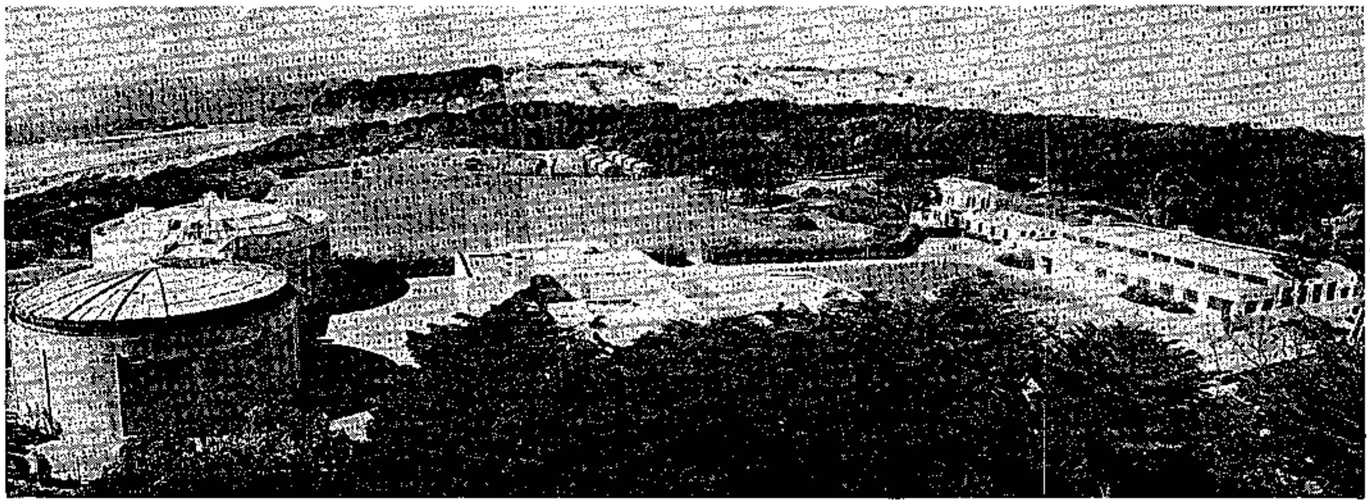
Sludge Handling and Disposal

The solids, both floatable and settleable, which are separated from sewage during treatment processes are known as sludge. Sludge is commonly collected by mechanical scrapers from the sedimentation tank bottom and by skimmers from the surface and is generally transferred to holding tanks. These structures, known as sludge digestion tanks or digesters, are part of the facilities of nearly all modern sewage treatment plants. They are reasonably gas tight tanks from which air is excluded. In these tanks complex changes occur in the putrescible elements of the sludge due to biologic action. This results in production of combustible gas and a stable non-putrescible residue termed "digested sludge", which, when dry, is humus-like and resembles peat. The process of digestion is greatly accelerated by heat and the optimum biological activity occurs at a temperature of about 95°F. Digested sludge may be used as a fertilizer base, as land fill, or, in cases where satisfactory disposal conditions exist, it can be returned in liquid form to the plant effluent for discharge therewith into the receiving body of water.

Separate sludge digestion is the most common method for handling sludge, although under certain special conditions other means may be practical.

Sewage Disposal by Dilution

Satisfactory disposal of sewage by dilution requires complete knowledge of the receiving capacity of the body of water. Proper disposal to the ocean or tidal waters demands a knowledge of currents, tides, mass water movements, temperature structure, and other factors which are known to affect the dilution and dispersion of sewage. Taken together



Courtesy City of San Francisco, California

Figure 27. Sewage Treatment Plant in a Famous Park

This plant is located in Golden Gate Park in San Francisco, California. The plant units are completely enclosed to prevent possible nuisances from odour or unsightliness. The landscaping and architecture are such that the plant blends into the surrounding park and most park visitors are unaware of the plant's existence.

these factors define the receiving capacity of the waters at any given point. They can fix the proper location of an outfall site and the distance and depth to which sewage must be conveyed into such waters before final discharge. In some locations, it is often feasible to discharge sewage without treatment because currents and dispersion are such as to preclude the return of sewage to shore in any detectable form. In most cases, however, it is necessary to provide some type of treatment which will at least remove readily settleable and floating material such as large solids, oil and grease which would either form objectionable deposits or float on the surface and possibly return to shore. Only under unfavourable circumstances is it necessary to provide for a more comprehensive type of treatment prior to discharge into ocean or tidal waters.

Satisfactory disposal in bodies of water such as streams, rivers and lakes requires that a detailed study be made of their available oxygen resources. If the amount of dilution water and of utilizable dissolved oxygen are insufficient, treatment may be required not only to reduce the suspended solids but also to reduce the organic load imposed by the sewage. The degree of treatment will be determined by the receiving capacity of the body of water as above defined. The necessity to protect the body of water against degradation which would affect its other uses must be recognized. These uses may include water supply, shipping, fishing, boating, swimming, and other forms of recreation. The use to which downstream portions of a river are put must always be considered, since waste discharged from a given point may constitute a source of pollution or contamination to some downstream community. Under exceptionally favourable conditions, public health and aesthetic requirements may be satisfied with no treatment of the sewage prior to discharge.

Sewage Disposal on Land

Sewage may be discharged onto the ground as in irrigation, intermittent sand filtration, or spreading on porous areas where it may ultimately find its way to ground water, into stream beds, or evaporate. Such methods of disposal commonly require a higher degree of treatment to remove organic, putrescible material prior to discharge than is required where disposal by dilution may properly be employed.

Benefits Accruing from Sewerage and Sewage Disposal

Public Health. A moment's thought will give convincing evidence of the incalculable value of modern sewerage and the sanitary disposal of the collected sewage and industrial wastes. A lack of sewerage has contributed to the unsanitary conditions of the past in nearly every urban community. Those conditions denoted filthy surroundings, noisome odours, and diseases such as bubonic plague, cholera, typhoid fever and dysentery.

Good sewerage and sanitary sewage disposal signify the very reverse of the conditions just referred to. They help make possible the modern, clean, healthful city. Their benefits are expressed not only in terms of pleasant living and a high standard of public health, but also in terms of an otherwise impossible economic status of the citizens of a community so served. The history of civilization attests to the supreme significance of the sanitary collection and disposal of the wastes of a community.

It is obvious, therefore, that the most important single benefit which may be attributed to proper and adequate sewage treatment is the abatement of the disease potential. By appropriate treatment and disposal methods, tidal waters and their shores, and bodies of fresh water, such as rivers and lakes and their shores, can be made safe for public use. This may be accomplished by suitable treatment of the sewage prior to its discharge, or by removing existing discharges to locations where favourable currents and volumes of dilution water are available.

Aesthetic. Improper disposal of sewage may be offensive, both to eye and nose. It is sometimes considered by the public to be an aesthetic nuisance in degree much greater than is warranted by its actual menace to health. The importance of the problems created by sewage and its disposal is now so generally well recognized by the public that the need for proper treatment and disposal is almost universally conceded. The aesthetic value of clean shores and shore waters cannot be directly assessed on a dollars and cents basis but is of immeasurable value to any community.

Economic. Sewage can be regarded as an economic liability to the community producing it. While it is true that there are recoverable constituents of some value in sewage, the process of recovery is generally more costly than the value of the recoverable substances. When sewage must be treated, however, some of the cost may be defrayed by recovery and sale of certain utilizable by-products. These include: water for irrigation, for cooling in steam power generating plants, and for other industrial uses; sludge to be used as a fertilizer and soil conditioner or burned for its fuel value; and combustible gas resulting from sludge digestion, used as a source of heat or of power in internal combustion engines. Because, in the Greater Vancouver Area, there is a great amount of public interest and some prevalent misconceptions as to the value of substances which might be reclaimed from sewage, each of the above-mentioned economic benefits will be discussed in detail as it relates to the area under consideration in this report.

Salvage of Values from Sewage in the Greater Vancouver Area

Sewage in General. From the very beginning of modern sewerage it has been a dream of many to find some way to utilize the imagined values in the sewage in some fashion which would pay large dividends. Such a possibility does not yet exist. Sewage is extremely dilute, and whatever mineral or other substances are dissolved or conveyed therein are extremely tenuous. About the best that can be done is to treat the sewage to the extent that the liquid portion may be safely and satisfactorily used in irrigation or industry, if needed, or for supplementing ground water resources through spreading and infiltration. By-products of sewage treatment such as sewage sludge and combustible gas from sludge digestion may help to reduce the cost of operation.

Water. Water reclaimed from sewage is accepted and used in many places to augment natural supplies for irrigation and to furnish a supply for various industrial uses. These uses obviously can logically obtain only in areas where natural water supplies are either insufficient to meet the demand or are costly in comparison with water reclaimed from sewage. The cost of reclaiming water from sewage depends upon the degree of additional treatment required to produce usable water from a sewage effluent suited to the conditions of disposal locally prevailing. Thus, if only primary treatment prior to disposal by dilution were required under local conditions, the cost of reclaiming water would be relatively high, since considerable additional treatment would be required to make the water suitable for most uses.

Abundant natural water supplies suitable for all purposes are available in the Greater Vancouver Area. The quantity and frequency of yearly rainfall is sufficient for most agricultural purposes and may be readily supplemented by river waters. The abundance of the natural water resources of the area makes it perfectly obvious that water reclaimed from sewage would have no value commensurate with its cost of production. Little if any water is employed for irrigation on crops, and the requirements of local industry are readily met from other less expensive sources. Industry certainly does not require water reclaimed from sewage. Therefore, reclamation of water from sewage is not considered to be economically feasible or justifiable in the Greater Vancouver Area.

Combustible Gas. Gas produced in the process of digestion may be put to beneficial use in any of the ways that other natural or artificial gaseous hydrocarbon fuels are utilized. Substantially all modern sewage treatment plants can make excellent use of such gas for maintaining temperatures for optimum biological activity in sludge digestion tanks, for developing power to operate plant equipment, for incinerating heavy bulky materials separated from the sewage entering the plant, or for drying sewage sludge.

Sludge gas is produced in the anaerobic decomposition of organic material by bacteria and other organisms during the sludge digestion process. Approximately 18.5 cubic feet of gas with a caloric value of 650 BTU per cubic foot are produced from one pound of organic material. From the known character of sewage in the Greater Vancouver Area it may be anticipated that the daily sludge contribution from 17 persons will produce 17 cubic feet of gas which will equal the heat and power value of one horsepower-hour. Gas not utilized in the operation of a sewage treatment plant generally is burned in a waste gas burner as a matter of safety and to eliminate any possible odour nuisance.

It is well recognized that, in sewage treatment plants processing the sewage flow from a combined sewerage system, there are times when the sewage is so diluted with storm water as to yield little of the organic matter which is required by the organisms accomplishing digestion. Therefore, during periods of prolonged flow of sanitary sewage diluted with storm water, the gas production will drop off. To provide for such occurrences it is necessary to have gas storage capacity or a stand-by supply. A portion of the gas produced during normal plant operation may be stored for use at the times of low gas production.

A consideration of all of the factors involved in the use of sludge gas indicates that it should be utilized to the greatest extent possible in the Greater Vancouver Area to obtain power for use in sewage treatment plants. Such utilization would effect, in most instances, a considerable saving in plant operation costs.

Sludge. Many factors affect the economic utilization of digested sewage sludge and may make its use for beneficial purposes so expensive as to fail to justify its preparation in a usable form. In such a case, the least expensive means of safe, final disposal of the innocuous digested sludge may be the most appropriate.

Perfectly dry sludge may contain 50 percent of organic matter, of which from one to two percent is organic nitrogen, and very small percentages are potash and phosphoric acid. These chemical constituents and the remaining organic solid material make digested sludge an excellent soil builder. The addition of various chemicals in appropriate amounts may bring the concentration of the nitrogen and other constituents up to those furnished in commercial fertilizers. When the digested sludge is removed from digestion tanks, it is in suspension in water and commonly represents about six percent of the total liquid volume on a dry basis. In liquid form the sludge is of quite limited usefulness. Until the liquid content is so reduced as to permit easy application of the sludge to the soil in much the same manner as manure, the difficulties of transportation and handling are usually so great as to render its use uneconomical and impracticable.

In a few locations liquid sludge is hauled by tank trucks directly from digestion tanks and applied to the soil. If the efficiency of such an operation is measured in terms of revenue or economy, it will be found of little value. In fact, it may become a liability to the sewerage authority because the sludge as taken from the digestion tanks commonly contains, as noted above, but six percent of dry solids. Thus it would be necessary to haul some 8,000 pounds of wet sludge in order to make use of 500 pounds of dry solids.

One of the most commonly accepted and efficient, and certainly the least expensive, methods of separating the digested sludge solids from the liquid is to spread the mixture upon permeable sand beds. A portion of the liquid will drain through the sand and will be carried away, while the remainder will evaporate. The dry or damp sludge solids become spadable and can then be removed for use. Such a method is not readily applicable to conditions in the Greater Vancouver Area because the frequency of rainfall and low temperatures obtaining during the winter months would make drying in the open practically impossible. Therefore, if complete or fairly complete drying is to be achieved, it must be done by means involving mechanical filtration and heat drying or on glass covered beds similar to greenhouses in construction. These requirements have been found to render the reclamation of solids so expensive as to make the whole operation uneconomical.

As the urbanization of the Greater Vancouver Area increases, the locations where large scale use can be made of digested sewage sludge will become fewer and more distant. Depending upon distance, nature of the separation method, type of soil, and quantity of sludge applied to the soil, it is estimated that under the most favourable conditions the cost would amount to between $25 and $40 per acre per year to transport and apply sludge to land. It is quite doubtful that agricultural land in the area under consideration, particularly that which presently has little soil depth and relatively low fertility and water retaining characteristics, can afford this cost.

The present outlook for the utilization of digested sewage sludge as a fertilizer or soil conditioner in the Greater Vancouver Area is not favourable. It must be noted, however, that three factors not presently assessable may in the future make such utilization desirable. These are: (1) advances in the methods now used for sludge drying; (2) the decision by a public authority that soil building with sewage sludge is eligible for public subsidy; and (3) development of new uses for digested sludge or partially digested sludge, for example, in the composting of organic material contained in garbage and other city refuse.

Chapter 8
Division into Sewerage Areas

Necessity for Creating Sewerage Areas

In planning for the sewerage and drainage of a large area, one of the basic requirements is the division of that area into a number of more or less independent areas. This division is dictated by certain controlling conditions, among which are: geography; topography; economy; past, present and future populations; political boundaries; present and future land use; and specific sewerage requirements. Because sewerage planning is more logically based on economic rather than upon political considerations, the subdivision should be based largely on topographic or geographic rather than on political boundaries.

As discussed in Chapters 2 and 3, there are three naturally distinct geographic and topographic sections in the Greater Vancouver Area, namely: the North Shore Section, the Burrard Peninsula Section, and the Richmond Section. To study the present and predicted future development of the sections and to permit the layout of sewage collection, treatment and disposal facilities, each of the three sections has been further subdivided into a number of smaller areas designated "sewerage areas". Figure 28 shows the locations and boundaries of the three sections and of the several sewerage areas.

In general, planning for storm drainage facilities requires a further subdivision into individual drainage areas, each of which is tributary to a body of water suitable for disposal of storm waters. Each of the sewerage areas described hereinafter contains one or more natural watercourses or drainage ways which may be utilized for storm drainage purposes. The boundaries of the areas established for sanitary sewerage purposes are not necessarily coincident with drainage area boundaries. For example, storm water of a portion of the City of Vancouver drains eastward through Still Creek and Burnaby Lake while the sanitary sewage collection system drains westward to the existing Clark Drive trunk sewer.

North Shore Section

The North Shore Section includes the City of North Vancouver and the Municipalities of North Vancouver and West Vancouver. The section had a census population of 44,200 in 1951 and its total land area is 63,080 acres.

Figure 28 shows the locations and boundaries of the three sewerage areas into which the North Shore Section is divided. Table 14 gives the areas and 1951 populations of each community contained within the three sewerage areas of the North Shore Section.

Point Atkinson Sewerage Area - North Shore Section. The Point Atkinson Sewerage Area has a land area of 9,350 acres and an estimated 1951 population of 2,400.

A portion of the Municipality of West Vancouver comprises the entire area of the Point Atkinson Sewerage Area. Major development in the area to date has largely been confined to the settlements of Horseshoe Bay, Whytecliff and Caulfield along the shore line and the lower slopes of the Coast Range. There are as yet no public sewerage facilities in the area.

The area contains numerous small creeks, including Nelson and Cypress, discharging directly into the waters of Burrard Inlet. These small drainage ways can be utilized effectively in the construction of gravity collection sewers to convey the sewage of the respective areas toward shore and, properly maintained, can be used as major storm drainage channels.

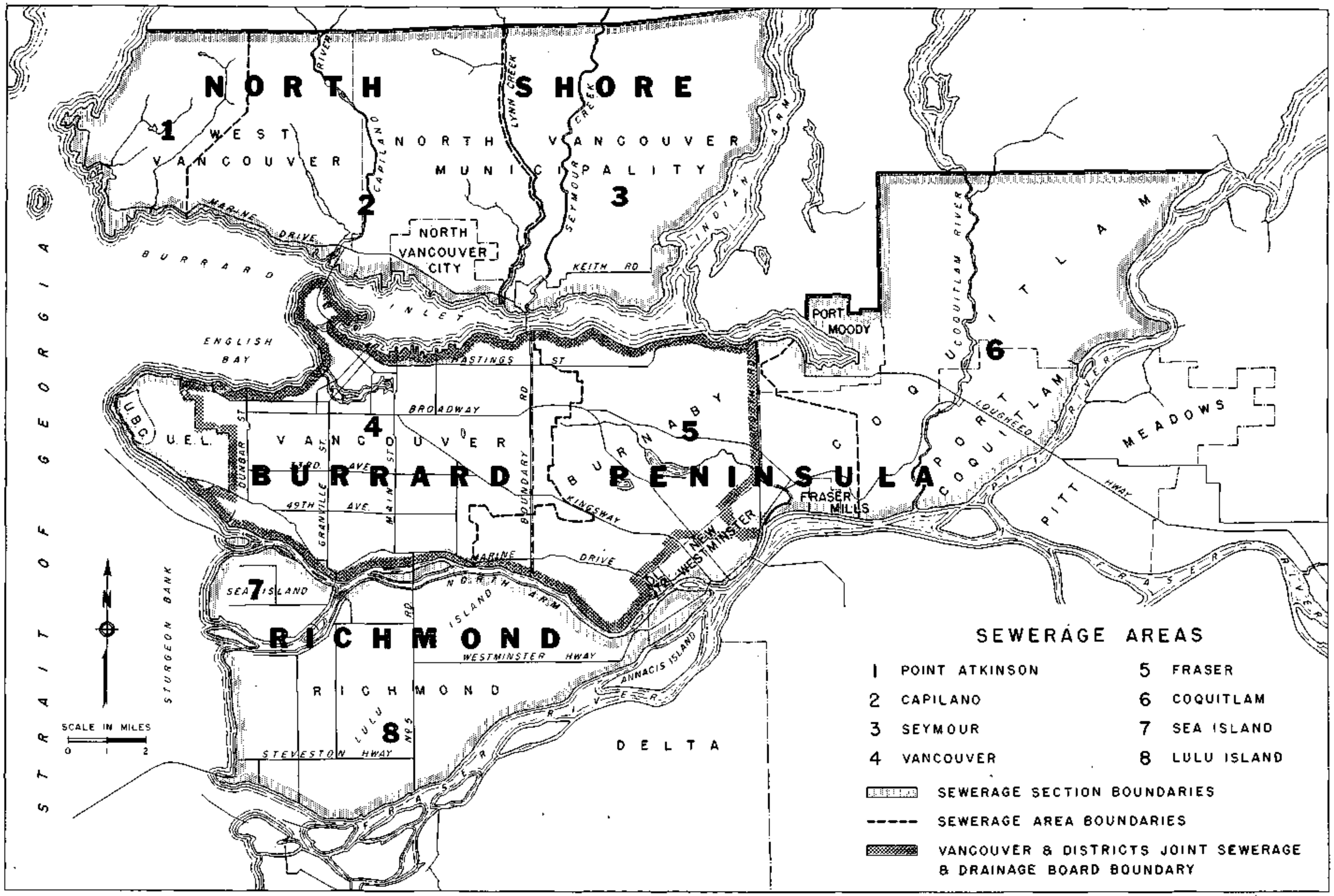


Figure 28. Sewerage Sections and Areas

The three major topographic sections of the Greater Vancouver Area, namely, North Shore, Burrard Peninsula and Richmond have been divided for study purposes into eight sewerage areas. The boundary of the existing Vancouver and Districts Joint Sewerage and Drainage Board is shown in red.

Table 14
Estimated Areas and 1951 Populations of Communities in Sewerage Areas of North Shore Section

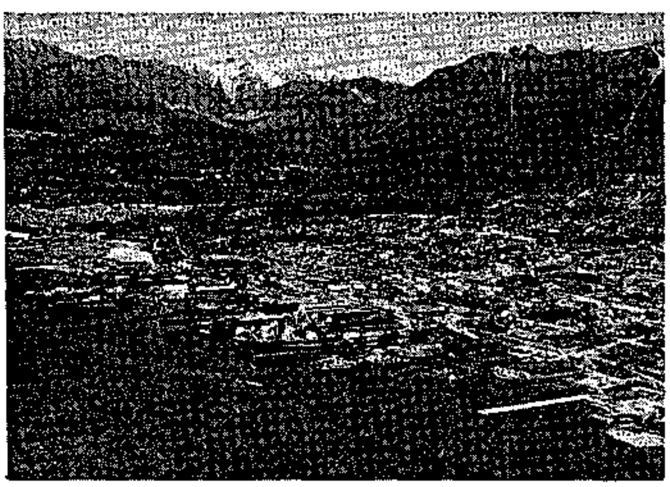
Community	Point Atkinson		Capilano		Seymour	
	Area, acres	Population[a] 1951	Area, acres	Population[a] 1951	Area, acres	Population[a] 1951
Cities:						
North Vancouver	-	-	2,710	15,700	-	-
Municipalities:						
North Vancouver	-	-	14,290	11,500	24,550	3,000
West Vancouver	9,350	2,400	12,180	11,600	-	-
Total	9,350	2,400	29,180	38,800	24,550	3,000

Location of sewerage areas shown on Figure 28.

[a] Populations determined from 1951 census enumeration district data.

Capilano Sewerage Area - North Shore Section. The Capilano Sewerage Area has a land area of 29,180 acres and an estimated 1951 population of 38,800.

Portions of the Municipalities of West and North Vancouver and all of the City of North Vancouver are in the sewerage area. Present development is along the shore and on the lower slopes of the mountains. The existing sewerage facilities within the area include four sanitary sewage outfalls in the City of North Vancouver, owned and maintained by the city. Numerous industries located along the waterfront discharge wastes into the waters of Burrard Inlet east of Capilano River.



Courtesy Photographic Surveys (Western) Limited

Figure 29. Portion of North Shore Section

The North Shore Section has an area of 63,080 acres and in 1951 had a population of 44,200. Present development is in the Capilano Sewerage Area shown in the photograph.

In addition to the lower reaches of the Capilano River Valley, the area contains a number of small drainage basins which are tributary to Burrard Inlet. Construction of gravity collection sewers may be accomplished by following these natural lines of drainage toward shore. Improvement and maintenance of these watercourses will enable them to be used for storm water drainage channels.

Seymour Sewerage Area - North Shore Section. The Seymour Sewerage Area has a land area of 24,550 acres and an estimated 1951 population of 3,000.

The area is occupied entirely by a portion of the Municipality of North Vancouver. Residential and industrial development is confined to the shores of Burrard Inlet and the lower slopes of the Coast Range and includes the settlements of Dollarton and Deep Cove. There are as yet no public sewerage facilities in the area.

The western portion of the area is drained by Lynn and Seymour Rivers while the remainder is drained by a number of small creeks discharging into Burrard Inlet and Indian Arm of Burrard Inlet. The construction of gravity collection sewers may be accomplished by following these natural lines of drainage toward shore. These rivers and creeks also may be utilized as storm drainage channels.

Burrard Peninsula Section

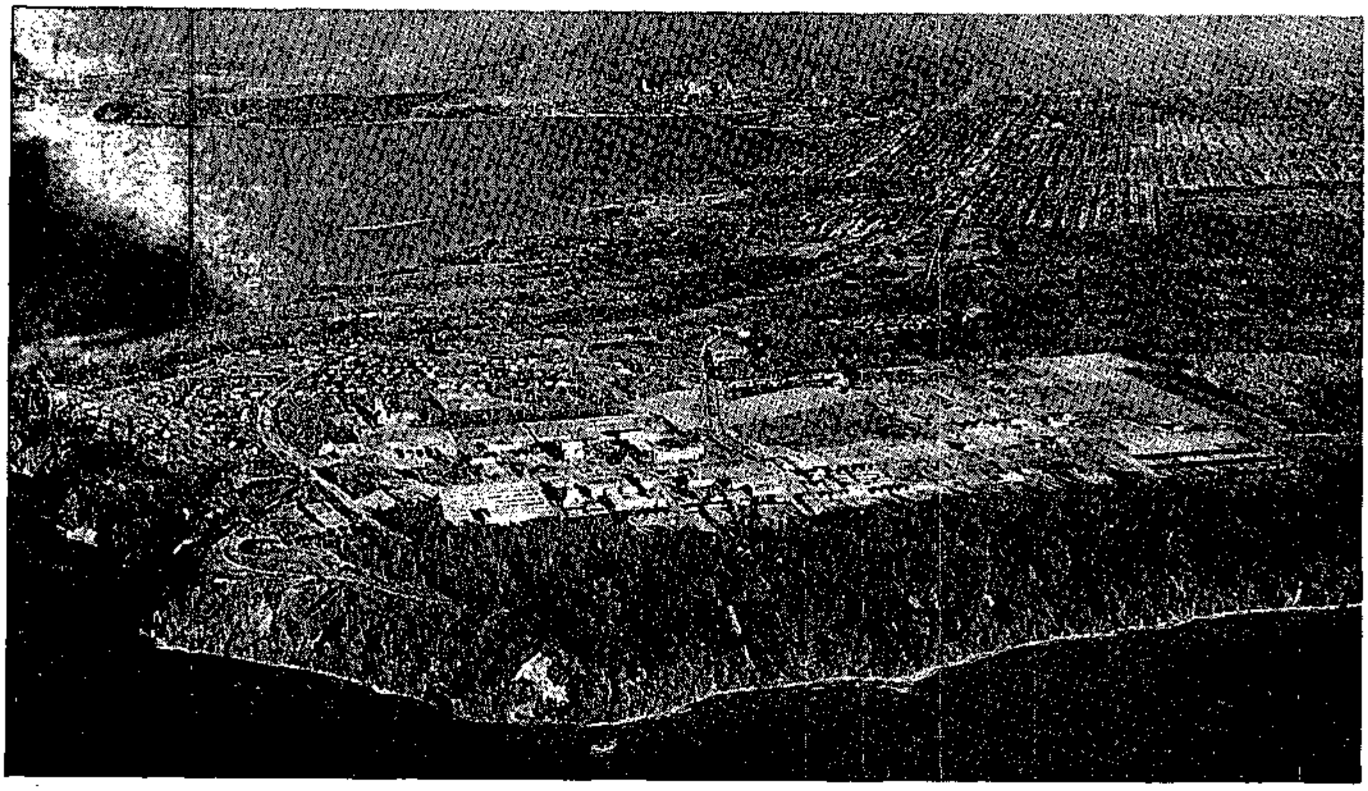
The Burrard Peninsula Section includes all of the Cities of Vancouver, Port Moody and Port Coquitlam, the Municipalities of Burnaby, Coquitlam and Fraser Mills, the unorganized communities of District Lot 172, the University Endowment Lands and the University of British Columbia, and the major portion of the City of New Westminster. The section had an estimated population of 454,900 in 1951 and its total land area is 94,810 acres.

Figure 28 shows the locations and boundaries of the three sewerage areas into which the section is divided. Table 15 gives the areas and estimated 1951 populations of each community contained within the three sewerage areas of the Burrard Peninsula Section.

Vancouver Sewerage Area - Burrard Peninsula Section. The Vancouver Sewerage Area, constituting the western portion of Burrard Peninsula Section, has a land area of 31,760 acres and an estimated 1951 population of 357,800. The City of Vancouver comprises the major part of the area. Also in the area are the University Endowment Lands, the University of British Columbia and a small portion of the Municipality of Burnaby.

The Vancouver Sewerage Area is almost completely sewered. Sewerage facilities are provided by the Vancouver and Districts Joint Sewerage and Drainage Board and by each of the communities. Combined sewage, containing both sanitary sewage and storm water, and storm water alone are discharged through approximately 40 outfalls and storm water overflows into the shore waters bordering the area.

The area is divided into a northern and a southern section by a ridge running laterally along the approximate centre of Burrard Peninsula. The natural slope is towards the north on one side of the



Courtesy Aero Surveys Limited

Figure 30. Portion of Vancouver Sewerage Area - Burrard Peninsula Section

The Vancouver Sewerage Area has an area of 31,760 acres and in 1951 had a population of 357,800. Included in the area are the University of British Columbia and University Endowment Lands shown in the foreground, as well as the major portion of the City of Vancouver shown in the background.

Table 15

Estimated Areas and 1951 Populations of Communities in Sewerage Areas of Burrard Peninsula Section

Community	Vancouver		Fraser		Coquitlam	
	Area, acres	Population[a] 1951	Area, acres	Population[a] 1951	Area, acres	Population[a] 1951
Cities:						
New Westminster	-	-	2,650	26,600	-	-
Port Coquitlam	-	-	-	-	6,700	3,200
Port Moody	-	-	580	200	2,400	2,000
Vancouver	26,510	342,100	1,450	2,700	-	-
Municipalities:						
Burnaby	2,010	13,600	19,690	44,800	-	-
Coquitlam	-	-	3,790	9,300	25,240	6,400
Fraser Mills	-	-	390	400	-	-
Unorganized:						
District Lot 172	-	-	160	1,500	-	-
University of British Columbia	550	b	-	-	-	-
University Endowment Lands	2,690	2,100	-	-	-	-
Total	31,760	357,800	28,710	85,500	34,340	11,600

Location of sewerage areas shown on Figure 28.

[a] Populations determined from 1951 census enumeration district data.
[b] Non-resident daytime population estimated to be 6,000 in 1951.

peninsula and the south on the other. This characteristic has been utilized in the construction of the present collection systems, which convey sewage and storm water northward and southward toward the shores and to final disposal by dilution without treatment.

Fraser Sewerage Area - Burrard Peninsula Section. The Fraser Sewerage Area has a land area of 28,710 acres and an estimated 1951 population of 85,500.

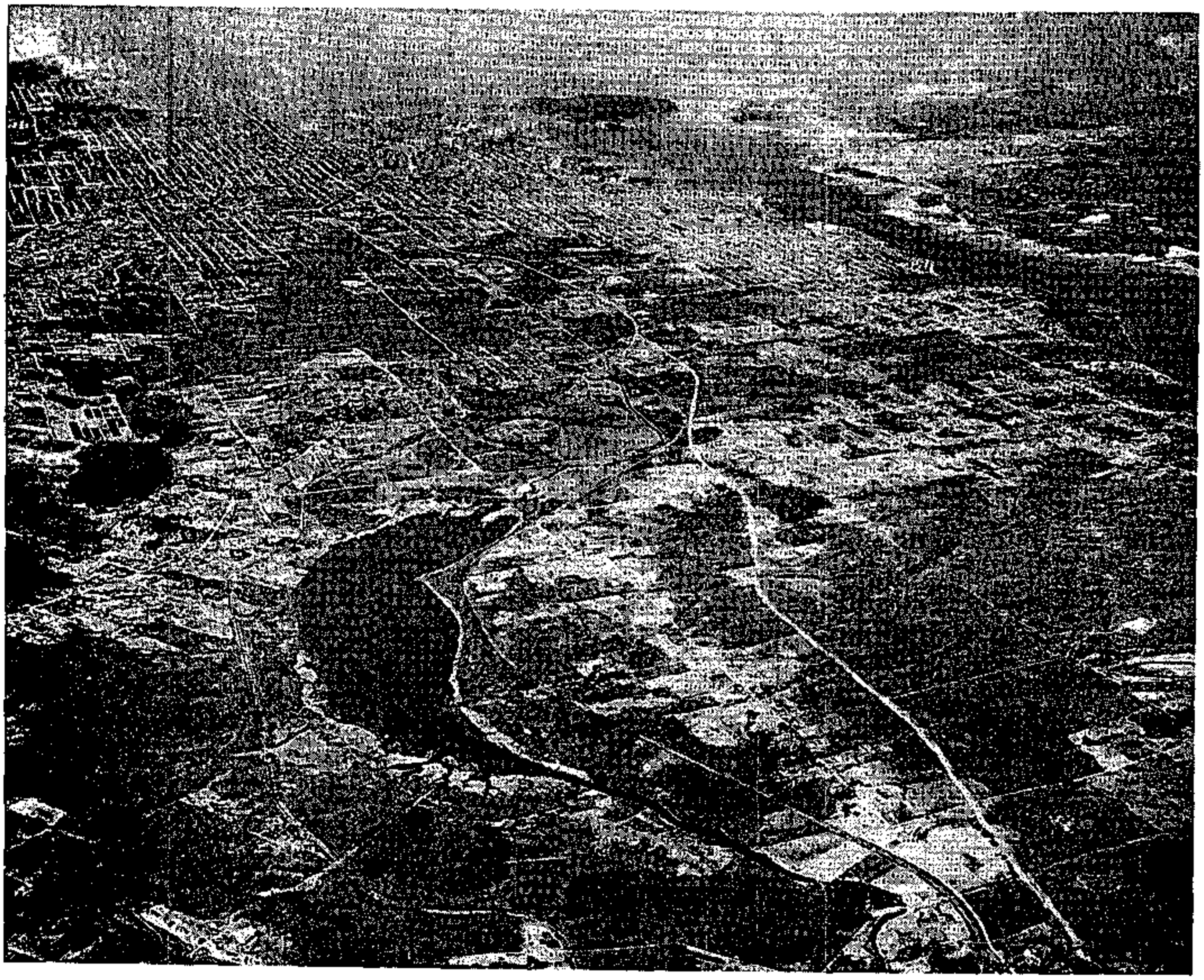
The Municipality of Fraser Mills, the unorganized community of District Lot 172, the major portion of the Municipality of Burnaby, a portion of the Municipality of Coquitlam, the major portion of the City of New Westminster, and a small portion of the southeast corner of the City of Vancouver are included within the area. Sewerage facilities, where they exist in the area, are provided by the City of New Westminster, the Municipality of Burnaby, the Municipality of Fraser Mills, and the Vancouver and Districts Joint Sewerage and Drainage Board. Sewage and storm water are presently discharged to the Fraser River through about thirteen outfalls in New Westminster and one in Fraser Mills and to Burrard Inlet through three outfalls in the northern portion of Burnaby. A considerable portion of the area is presently relying upon individual septic tanks for sewage disposal.

The northern portion of the area drains into Burrard Inlet, the central portion drains into the main channel of Fraser River through Still Creek, Burnaby Lake and Brunette River, and the southern portion drains into the North Arm of Fraser River. Construction of collection facilities for sewage and storm water may continue to make use of these lines of natural drainage.

Coquitlam Sewerage Area - Burrard Peninsula Section. The Coquitlam Sewerage Area has a land area of 34,340 acres and an estimated 1951 population of 11,600.

The City of Port Coquitlam and the major portions of the City of Port Moody and the Municipality of Coquitlam are in the sewerage area. There are as yet no public sewerage facilities in the area.

The area is traversed by a number of creeks and by Coquitlam River. The



Courtesy Aero Surveys Limited

Figure 31. Portion of Fraser Sewerage Area – Burrard Peninsula Section

In the foreground are Burnaby Lake and Brunette River in the Fraser Sewerage Area The area contains 28,710 acres and in 1951 had a population of 85,500. Industrial and residential expansion is taking place in the area.

courses of these waterways offer possible routes for sewers to convey the sewage of the area to a suitable point final disposal. The watercourses themselves may be utilized as storm drainage channels.

Richmond Section

The Richmond Section is located between the North Arm and the main channel of Fraser River and contains Lulu and Sea Islands on which are the Municipality of Richmond and a portion of the City of New Westminster. The section had an estimated population of 21,200 in 1951 and its total land area is 29,730 acres.

Figure 28 shows the locations and boundaries of the two sewerage areas into which the Richmond Section is divided. Table 16 gives the areas and estimated 1951 populations of each community contained within the two sewerage areas of the Richmond Section.

Lulu Island Sewerage Area - Richmond Section. The Lulu Island Sewerage Area has a land area of 26,230 acres and an estimated 1951 population of 19,000.

The area contains a portion of the Municipality of Richmond and, on the eastern end, the settlement of Queens-

Table 16

Estimated Areas and 1951 Populations of Communities in Sewerage Areas of Richmond Section

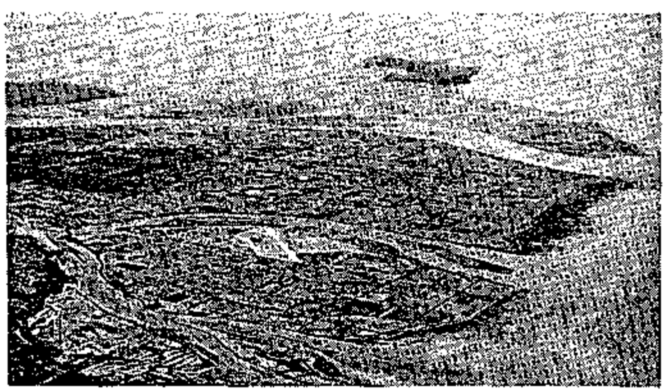
Community	Lulu Island		Sea Island	
	Area, acres	Population[a] 1951	Area, acres	Population[a] 1951
Cities:				
New Westminster	730	2,000	-	-
Municipalities:				
Richmond	25,500	17,000	3,500	2,200
Total	26,230	19,000	3,500	2,200

Location of sewerage areas shown on Figure 28.

[a] Populations determined from 1951 census enumeration district data.

borough, a portion of the City of New Westminster. There are no public sewerage facilities in the area.

Lulu Island is completely surrounded by dykes to prevent flooding. Numerous drainage ditches convey storm and ground water and diluted septic tank effluent to the borders of the island where, in most cases, pumps lift the water into Fraser River and its North and Middle Arms. Soil and ground water conditions, combined with extreme flatness, render the provision of sewerage and drainage facilities in the area both difficult and expensive.



Courtesy Photographic Surveys (Western) Limited

Figure 32. Portion of Richmond Section

Lulu and Sea Islands in the Fraser River delta comprise the Richmond Section. The section has an area of 29,730 acres and in 1951 had a population of 21,200. Although the section is predominately agricultural at present, industrial and residential developments are taking place at an increasing rate. Vancouver International Airport is situated on Sea Island.

Sea Island Sewerage Area - Richmond Section. The Sea Island Sewerage Area has a total land area of 3,500 acres and an estimated 1951 population of 2,200.

The area contains Iona, Mitchell and Sea Islands, all of which are in the Municipality of Richmond. The existing sewerage facilities in the area include three sanitary sewer outfalls serving the Vancouver International Airport and nearby residential developments on Sea Island. The outfalls discharge into the Middle Arm of Fraser River.

The area is flat and is dyked to prevent flooding. Numerous drainage ditches traverse it. Soil conditions and lack of appreciable natural slope combine to make sewerage and drainage expensive.

Comparison with Existing Sewerage and Drainage Board Area

The area now served by the Vancouver and Districts Joint Sewerage and Drainage Board, as prescribed by legislative enactments, falls entirely within the Burrard Peninsula Section and includes the City of Vancouver, the Municipality of Burnaby and a portion of the City of New Westminster. The area within the jurisdiction of this body is 50,200 acres. The facilities owned and operated by the Vancouver and Districts Joint Sewerage and Drainage Board are discussed in detail in Chapter 10. Briefly, they include trunk and intercepting sewers and outfalls into Burrard Inlet and Fraser River.

Figure 28 also shows the presently prescribed boundaries of the Vancouver and Districts Joint Sewerage and Drainage Board in addition to the boundaries of the three major sewerage sections and those of the various sewerage areas.

Chapter 9
Population

Importance of Population Studies

Proper and competent planning for the comprehensive sewerage of any area, great or small, must include a thorough study of the past and probable future population development. The reason for this lies in the fact that the quantity of sanitary sewage is directly related to the population distribution and extent. The rate of flow and total volume of sewage determine the required capacities and sizes of sewers, pumping plants and treatment works. The dates and places when and where such facilities shall need to be provided can only be determined by a forecast of population growth and distribution. The ultimate success of any local or general program of sewerage is therefore dependent upon the accuracy of the population prediction. To make such predictions, an inventory of all controlling factors must be made and these factors properly evaluated.

Indices of Growth

The factors involved in the prediction of the future population of the Greater Vancouver Area are many and varied. Among the most significant are:

1. General population trends and movements.
2. Average population age and excess of births over deaths.
3. Climatic conditions.
4. Transportation facilities: ships, railroads, highways, air.
5. Availability and cost of water.
6. Industrial and/or commercial opportunities.
7. Extent and degree of environmental sanitation.
8. Educational, recreational, and social facilities.
9. Housing conditions.
10. Area suitable for increased residential and industrial expansion.

Each of these factors must be evaluated with a knowledge of past and present conditions. Their future influence can only be appraised through past experience. Some factors can well cause unpredictable future changes. For these and other reasons, the best of population predictions must be regarded as tentative and suggestive rather than exact.

The great movement of population from east to west which has been noted during the development of western North America is illustrated by comparison of the populations of British Columbia and Canada as a whole:

	1871	1911	1951
British Columbia	36,000	392,000	1,153,000
Canada	3,689,000	7,207,000	13,893,000

In 1871 less than one percent of the population of Canada resided in British Columbia while by 1951 this proportion had increased to over eight percent. Also to be noted from these census figures is the fact that while the total population of Canada increased almost four times, the population of British Columbia increased over 32 times during the period 1871-1951. The rate of growth of the Greater Vancouver Area has been greater than that of other areas in British Columbia. In 1911 the population of this area represented 75 percent of the total urban population and 39 percent of the total provincial population, while in 1941 these figures were 85 percent and 46 percent, respectively. Between 1941 and 1951 the rates of growth of the province and of the Greater Vancouver Area were approximately the same, the 1951 population of the latter area being 45 percent of the former.

The nature of population development within the province has undergone a complete change from one predominantly rural in 1871, when 90 percent of the population lived in farming areas, to one of urban character in 1941, when 54 percent of the population lived in cities.

A marked increase in the proportion of births to deaths has been noted in Canada for many years, as shown by the following tabulation:

	1926	1950
Births	233,000	371,000
Deaths	107,000	124,000
Excess, Births over Deaths	126,000	247,000
Percent Excess, Births over Deaths	54	66

In 1926 the ratio of births to deaths was about 2.2 to 1, while in 1950 this ratio was about 3.0 to 1. Similar statistics for British Columbia for 1950 indicate 27,000 births and 12,000 deaths or a ratio of 2.3 to 1. To some extent this lower ratio for British Columbia may be attributed to the fact that many elderly retired people have settled in the province, particularly in its southwest portion.

The general climatic conditions of the Greater Vancouver Area are discussed in Chapter 4 of this report. The equable climate of the area is an important factor tending to increase population development.

As discussed in Chapter 2 of this report, the Greater Vancouver Area is the land, air, and sea transportation centre of western Canada. Trade with other countries to the south, west and north originates in the area. As increased industrial and commercial activity occurs, there is every reason to believe that transportation facilities will be expanded and augmented.

The development of the Greater Vancouver Area will not be restricted by shortage of water supply since almost unlimited quantities can be made available from the Coast Range to the north.

As the interior of British Columbia and western Canada become more highly developed, industry and commerce within the Greater Vancouver Area will expand correspondingly and new industries utilizing new sources of raw materials will come into existence. An example of this is presently being exhibited as the Trans - Mountain pipeline from Alberta nears completion. Oil refinery and storage facilities are being constructed and enlarged on both sides of Burrard Inlet. As shown in Chapter 2, a considerable area of land suitable for future industrial development exists in the area.

Land suitable for future residential purposes is abundant within the Greater Vancouver Area. Current building trends indicate rapid development on the North Shore and on Burrard Peninsula eastward from the City of Vancouver. It is also anticipated that significant future residential and industrial development will occur in Richmond in spite of the generally unfavourable soil, drainage, and foundation conditions.

Methods of Predicting Population

All methods for predicting population are inevitably subject to error. The influence of several of the factors listed above cannot be definitely evaluated. Their effects may be such that a prediction of population growth may be far from correct.

In engineering practice one or more of eight standard methods are used for predicting population growth. These are:

1. Arithmetical progression, in which a constant increment of growth is added periodically.
2. Geometrical progression, in which a constant percentage of increase is assumed for equal periods of time.
3. Decreasing rate of increase, which gives results between the arithmetical and geometrical progressions.
4. Graphical extension of the population-time curve into the future by inspection guided by judgment.
5. Graphical comparison with similar areas having greater populations and commonly of greater age.
6. Logarithmic trend, in which a future population is computed from a formula based upon the rate of population development in the past.
7. Comparison of rate of change of the ratio of the community or area population to the population in the next larger political subdivision; for example, city to province or province to country.
8. Logistic curve, in which it is assumed that the future population will be limited to some saturation value by the level of economic opportunity and that the growth of an area will approach

saturation at a decreasing rate.

Past, Present and Predicted Future Populations

It is the opinion of the Board of Engineers that the logistic curve method represents the most competent means presently available for predicting future populations. Several of the other methods, commonly employed, are based on the assumption that population will increase at some assumed or estimated rate. Such an assumption may lead to illogical and erratic conclusions. The logistic curve method is based upon the hypothesis that population will increase at a decreasing rate until a so-called saturation population is reached.

The saturation population of an area may be estimated in a number of ways. If the area under consideration is well developed and approaching maturity, the percentage rate of increase of population between census periods is usually a decreasing one. When this percentage is plotted against total population, it is possible to draw and extend the curve to an intersection with the population axis and thus fix the population at the saturation limit. Studies of the population statistics of the communities in the Greater Vancouver Area indicate that this method is not applicable since the rate of increase of population is not presently decreasing but, on the contrary, is increasing. A second method of estimating saturation population is by use of the anticipated ultimate population density or number of persons per habitable acre of land. This method was deemed feasible for use in the Greater Vancouver Area.

A study of each community was made to estimate the probable average saturation density in terms of numbers of persons per habitable acre. The stu-

Table 17

Total and Habitable Land Areas and Predicted Densities and Saturation Populations of Communities in the Greater Vancouver Area

Communities	Land Area		Ultimate Development	
	Total,[a] acres	Habitable,[b] acres	Density,[c] persons/acre	Predicted Population
Cities:				
New Westminster	3,380	3,300	18	59,000
North Vancouver	2,710	2,500	18	45,000
Port Coquitlam	6,700	5,000	15	75,000
Port Moody	2,980	1,800	10	18,000
Vancouver	27,960	24,000	27	650,000
Municipalities:				
Burnaby	21,700	20,000	15	300,000
Coquitlam	29,030	15,000	8	120,000
Fraser Mills[d]	390	390		500
North Vancouver	38,840	12,000	8	96,000
Richmond	29,000	19,000	10	190,000
West Vancouver	21,530	8,000	8	64,000
Unorganized:				
District Lot 172	160	160	18	3,000
University of British Columbia[e]	550	550	-	10,000
University Endowment Lands	2,690	2,500	12	30,000
Total	187,620	114,200		1,650,000[f]

[a]Determined by planimeter from Dominion Department of Mines and Resources topographic maps.
[b]Land area, including streets, which may be developed in forseeable future. Does not include parks, steep cliffs or land to which water cannot readily be supplied.
[c]Average population density over entire habitable area.
[d]Municipality comprises lumber mill and workers residences; population is estimated to remain constant at 1951 level.
[e]Predicted maximum transient population.
[f]Does not include University of British Columbia.

Table 18

Past Populations and Percentages of Predicted Saturation Populations of Communities in the Greater Vancouver Area

Communities	Predicted Saturation Population	Census Year 1911 Population	1911 Percent Saturation	1921 Population	1921 Percent Saturation	1931 Population	1931 Percent Saturation	1941 Population	1941 Percent Saturation	1951 Population	1951 Percent Saturation
Cities:											
New Westminster	59,000	13,200	22.4	14,500	24.6	17,500	29.7	22,000	37.3	28,600	48.2
North Vancouver	45,000	7,800	17.3	7,700	17.1	8,500	18.9	8,900	19.8	15,700	34.7
Port Coquitlam	75,000	a	a	1,200	1.6	1,300	1.7	1,500	2.0	3,200	4.3
Port Moody	18,000	a	a	1,000	5.6	1,300	7.2	1,500	8.3	2,200	12.2
Vancouver	650,000	120,800	18.6	163,200	25.1	246,600	37.9	275,400	42.3	344,800	53.1
Municipalities:											
Burnaby	300,000	a	a	10,600	3.5	25,600	8.6	30,300	10.1	58,400	19.2
Coquitlam	120,000	a	a	2,400	2.0	4,900	4.1	7,900	6.7	15,700	13.0
Fraser Mills	500	a	a	a	a	600	120.0	600	120.0	400	80.0
North Vancouver	96,000	400	0.4	3,000	3.1	4,800	5.0	5,900	6.1	14,500	14.8
Richmond	190,000	a	a	4,800	2.5	8,200	4.3	10,400	5.5	19,200	10.0
West Vancouver	64,000	a	a	2,400	3.8	4,800	7.5	7,700	12.0	14,000	21.7
Unorganized:											
District Lot 172	3,000	a	a	a	a	a	a	800	26.7	1,500	50.0
University Endowment Lands	30,000	a	a	a	a	500	1.7	800	2.7	2,100	7.0
Total	1,650,000	152,200		208,900		324,600		373,700		520,300	

Census data obtained from "Census of Canada" 1931 and 1941 editions by Dominion Department of Statistics.
[a] No census data.

dies included consideration of economic opportunity, present population distribution, land use and habitable land, accessibility and transportation facilities, proximity of business and industrial areas both present and probable future, and probable types of residential construction. Table 17 presents the total and habitable land areas contained within each community and the anticipated density per acre and total population at the time of maximum or ultimate development.

Using these saturation populations and past census data, Table 18 was prepared to show the percentages of the saturation population at each past census period for each municipality. The percentages of saturation were then plotted on a logistic grid and curves projected into the future as shown on Figure 33. From the future percentages of saturation, the predicted population of each municipality in the Greater Vancouver Area was computed at ten year intervals from 1960 to the year 2000 and is given in Table 19. Figure 34 is a graphical representation of these predicted populations.

To be of value in the planning of sewerage facilities for any area, the predicted future populations must be distributed over that area as logically as can be accomplished utilizing all of the available information. On the basis of the population data just described together with the land use map shown in Figure 4, Chapter 2, as well as the census enumeration area figures for 1951, topographic maps, aerial photographs, and the results of field reconnaissance, Figure 35 was prepared. It shows the estimated average population densities which may be expected in the Greater Vancouver Area at ultimate development.

A maximum population density of

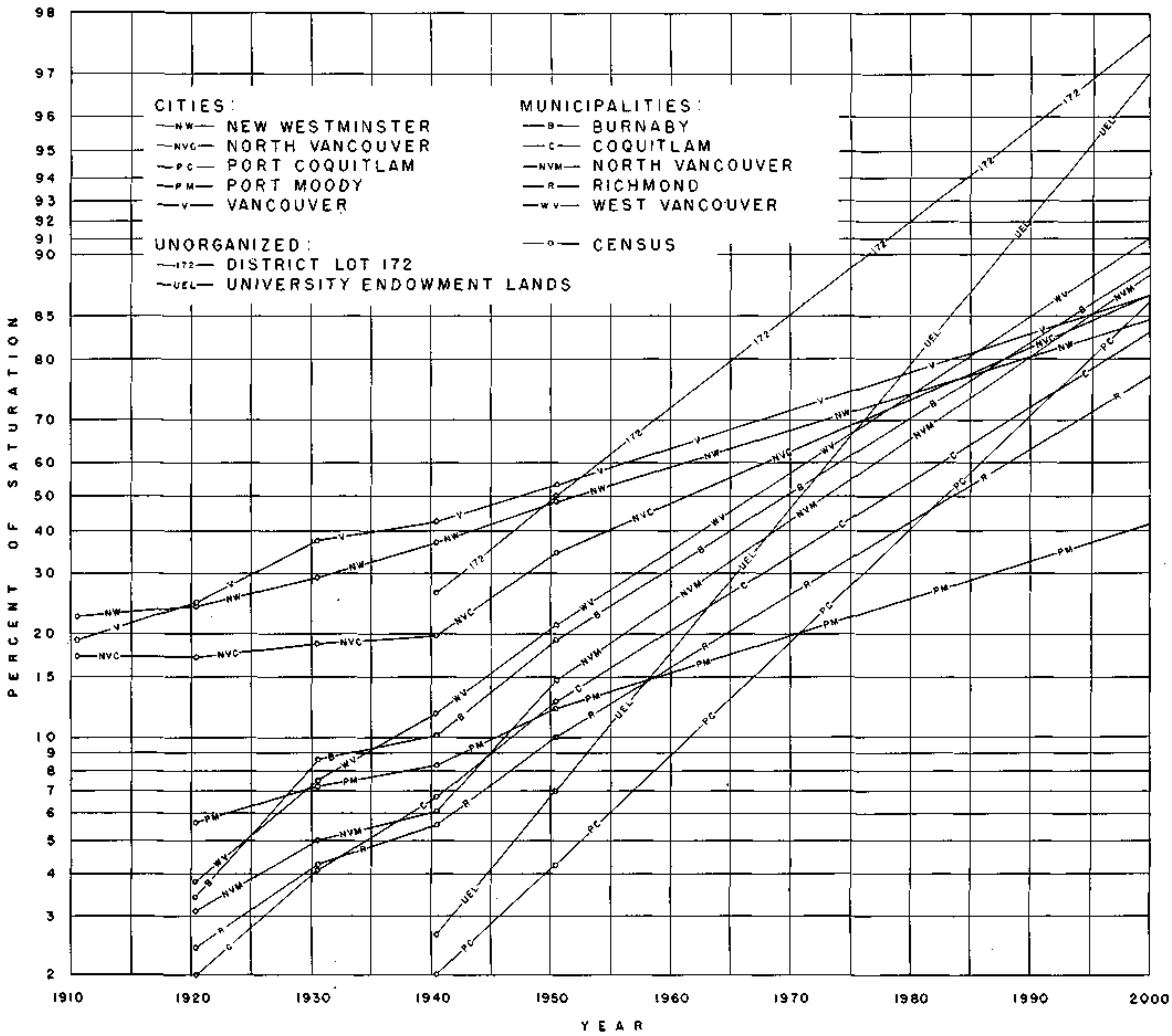


Figure 33. Past and Predicted Future Populations Expressed as Percentages of Estimated Saturation Populations of Communities in the Greater Vancouver Area, 1911-2000

This method of predicting future populations is described by C. J. Velz in Civil Engineering Volume 10, Page 619, October 1940. The plotted points represent the percentage which each census population is of the estimated saturation population. Estimation of saturation populations for the various communities was accomplished by considerations of economic opportunity, present population distribution, land use and habitable land accessibility and transportation facilities, proximity of business and industrial areas, both present and probable future, and probable types of residential construction.

75 persons per acre has been taken to represent areal development comprising multiple-storey apartment buildings concentrated in a relatively small area. A minimum density of 0.5 persons per acre has been taken to represent a population scattered over a relatively large area. Actually, such population will doubtless be concentrated in isolated units but, averaged over the large area, would be equivalent to the figure of 0.5 persons per acre. This value has been assumed to be the minimum average population density which could possibly require or support public sewerage facilities.

Between these two extremes of

Table 19

Predicted Future Populations of Communities in the Greater Vancouver Area, 1960-2000

Communities	Predicted Saturation Population	1960		1970		1980		1990		2000	
		Percent Saturation	Population	Percent Saturation	Population	Percent Saturation	Population	Percent Saturation	Population	Percent Saturation	Population
Cities:											
New Westminster	59,000	59.0	35,000	67.5	40,000	74.2	44,000	80.2	47,000	84.5	50,000
North Vancouver	45,000	47.4	21,000	62.0	28,000	73.0	33,000	81.5	37,000	86.5	39,000
Port Coquitlam	75,000	8.9	6,700	19.0	14,000	40.0	30,000	71.0	53,000	86.0	65,000
Port Moody	18,000	15.5	3,000	19.7	4,000	26.0	5,000	32.6	6,000	41.3	7,500
Vancouver	650,000	63.6	413,000	71.7	466,000	78.0	507,000	83.0	540,000	86.6	563,000
Municipalities:											
Burnaby	300,000	31.0	93,000	50.5	152,000	70.2	210,000	82.0	246,000	89.0	267,000
Coquitlam	120,000	20.5	25,000	34.0	41,000	54.0	65,000	72.0	86,000	83.0	100,000
North Vancouver	96,000	25.4	24,000	43.0	41,000	65.3	63,000	80.5	77,000	88.2	85,000
Richmond	190,000	15.9	30,000	26.4	50,000	42.4	81,000	63.0	120,000	77.0	146,000
West Vancouver	64,000	35.0	22,000	56.6	36,000	74.0	47,000	85.0	54,000	91.0	58,000
Unorganized:											
District Lot 172	3,000	71.9	2,200	85.1	2,500	92.0	2,800	95.6	2,900	97.6	2,900
University Endowment Lands	30,000	17.6	5,300	46.0	14,000	79.0	24,000	92.1	28,000	97.0	29,000
Total[a]	1,650,000		680,700		889,000		1,112,300		1,297,400		1,412,900

Percentages of saturation determined from Figure 33. Municipality of Fraser Mills not shown in this table since population of 500 in 1951 is considered to be saturation. University of British Columbia estimated to have ultimate maximum transient population of 10,000.

[a] Includes Municipality of Fraser Mills population of 500, but does not include University of British Columbia transient population.

population densities described above, Figure 35 shows six other average densities which have been taken to represent average levels of population densities. These are:

(1) 50 persons per acre - representing a highly developed commercial and industrial district containing some multiple-storey apartment buildings.

(2) 30 persons per acre - representing a less highly developed commercial district interspersed with single family and multiple family residential zones.

(3) 20 persons per acre - representing a completely developed residential district with a normal complement of commercial and business establishments.

(4) 15 persons per acre - representing a completely developed single family residential district.

(5) 10 persons per acre - representing a residential district in which relatively large lots are predominant.

(6) 5 persons per acre - representing either a residential area in which large lots are predominant or a small area of a higher population concentrated within and averaged over a larger area.

It should be recognized that there can be no distinct line of demarcation between the various levels of population density described above since the densities actually shade off gradually. The figures used are for planning purposes only and are not intended to indicate any definite boundary between the various levels. It must also be mentioned that for purposes of estimating the requirements for sewerage facilities the population densities are so-called equivalent densities, including not only the actual population but also the anticipated population equivalent of business and industry. Furthermore, the distribution of densities as indicated on Figure 35 is one for gross areas.

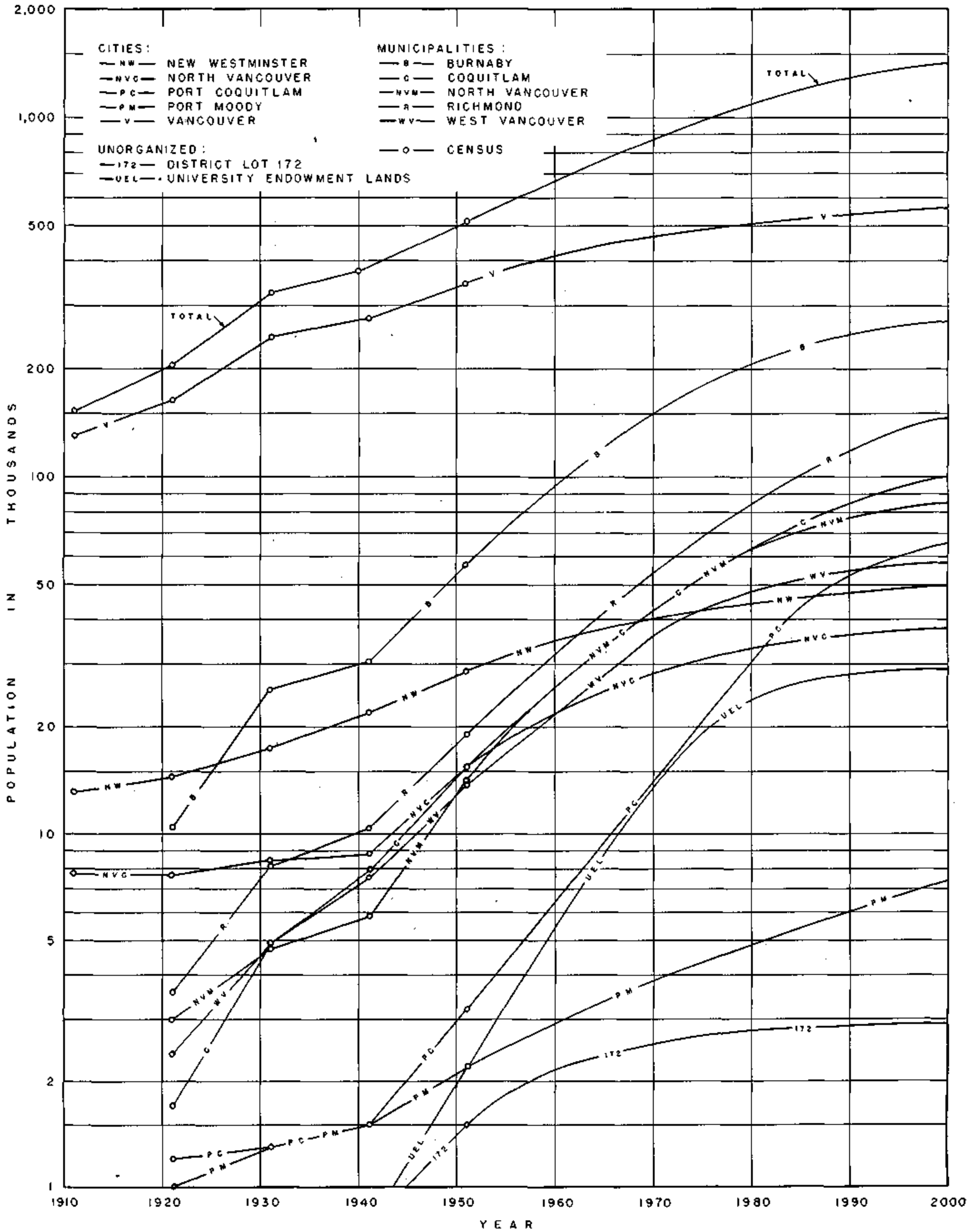


Figure 34. Past and Predicted Future Populations of Communities in the Greater Vancouver Area, 1911 to 2000

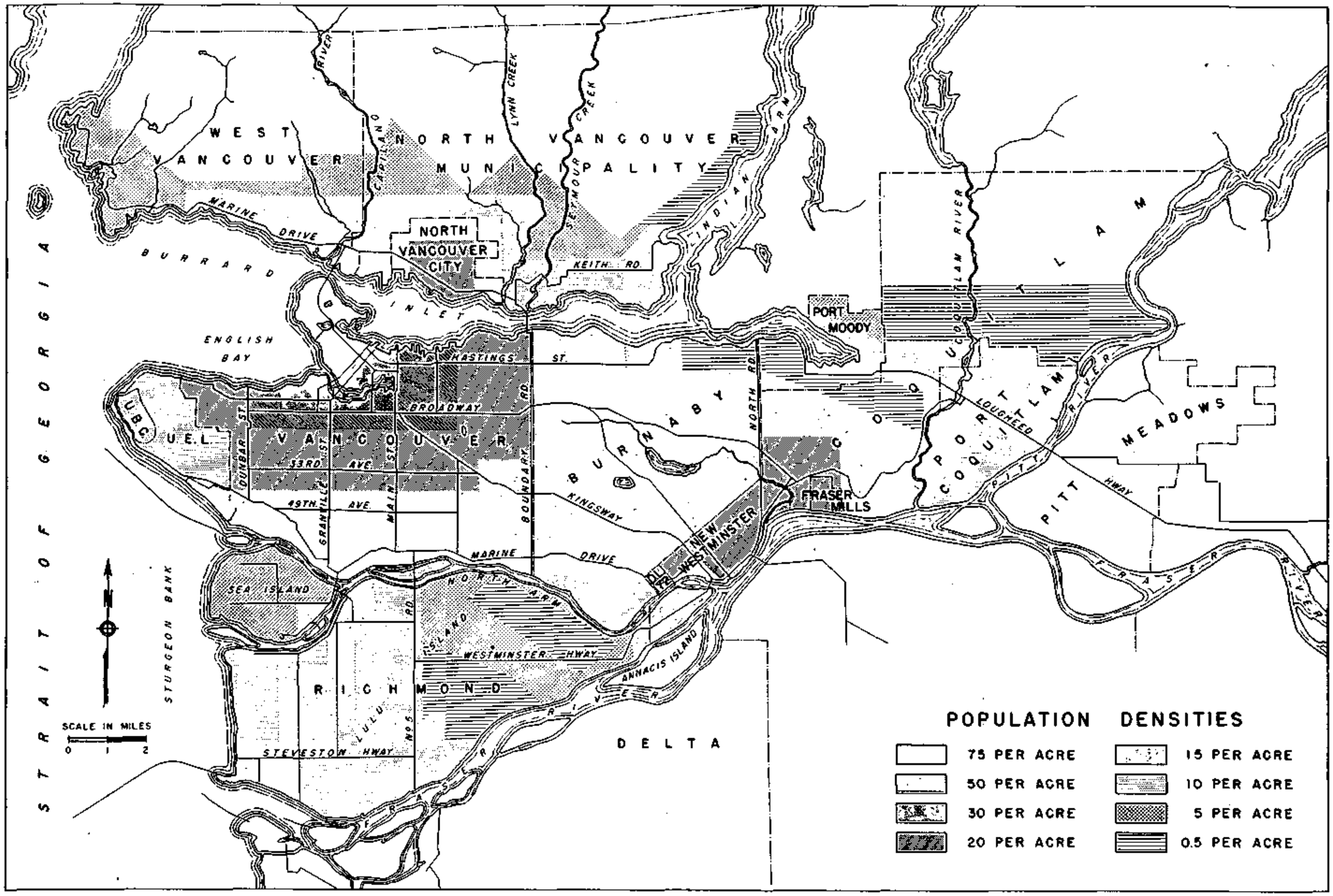


Figure 35. Predicted Population Densities in the Greater Vancouver Area at Ultimate Development

To be of value in the planning of sewerage facilities for any area, predicted future populations must be distributed over that area as logically as can be accomplished utilizing all of the available information. The average population densities which may be expected in the Greater Vancouver Area at the time of ultimate development have been used to estimate sewage flows.

Chapter 10
Existing Sewerage and Drainage Facilities

Significance of Existing Facilities in Planning for the Future

In the development of a master plan or program of sewerage and drainage for a large area, it is important that the plan include and recognize all existing serviceable utilities. To accomplish this end, all existing sewerage and drainage facilities of each agency within the area are studied with a view to their eventual incorporation into an overall master plan.

The area presently being administered under the Vancouver and Districts Joint Sewerage and Drainage Act, consisting of the City of Vancouver, the Municipality of Burnaby and a portion of the City of New Westminster, has been provided with sewerage and drainage in general accordance with a comprehensive master plan prepared in 1913 by R.S.Lea. The portions of these municipalities that are sewered have, in the most part, been provided with trunk sewers and lateral systems of adequate design for the conveyance of domestic and industrial wastes, as well as storm water runoff. Lea, in 1913, recognized the possibility that at some future date some means of disposal other than by dilution in receiving bodies of water might be required. For this reason, he recommended that the systems of sewers for collecting sanitary sewage and industrial wastes be separate from the systems collecting storm water, so that domestic and industrial wastes could be collected and treated without regard to the vast quantities of storm water which are invariably associated with a combined system. His recommendations were not followed in this respect, however, and most of the sewers in the existing district are combined. This complicates the problem of interception and disposal within most of the area and renders its accomplishment more difficult.

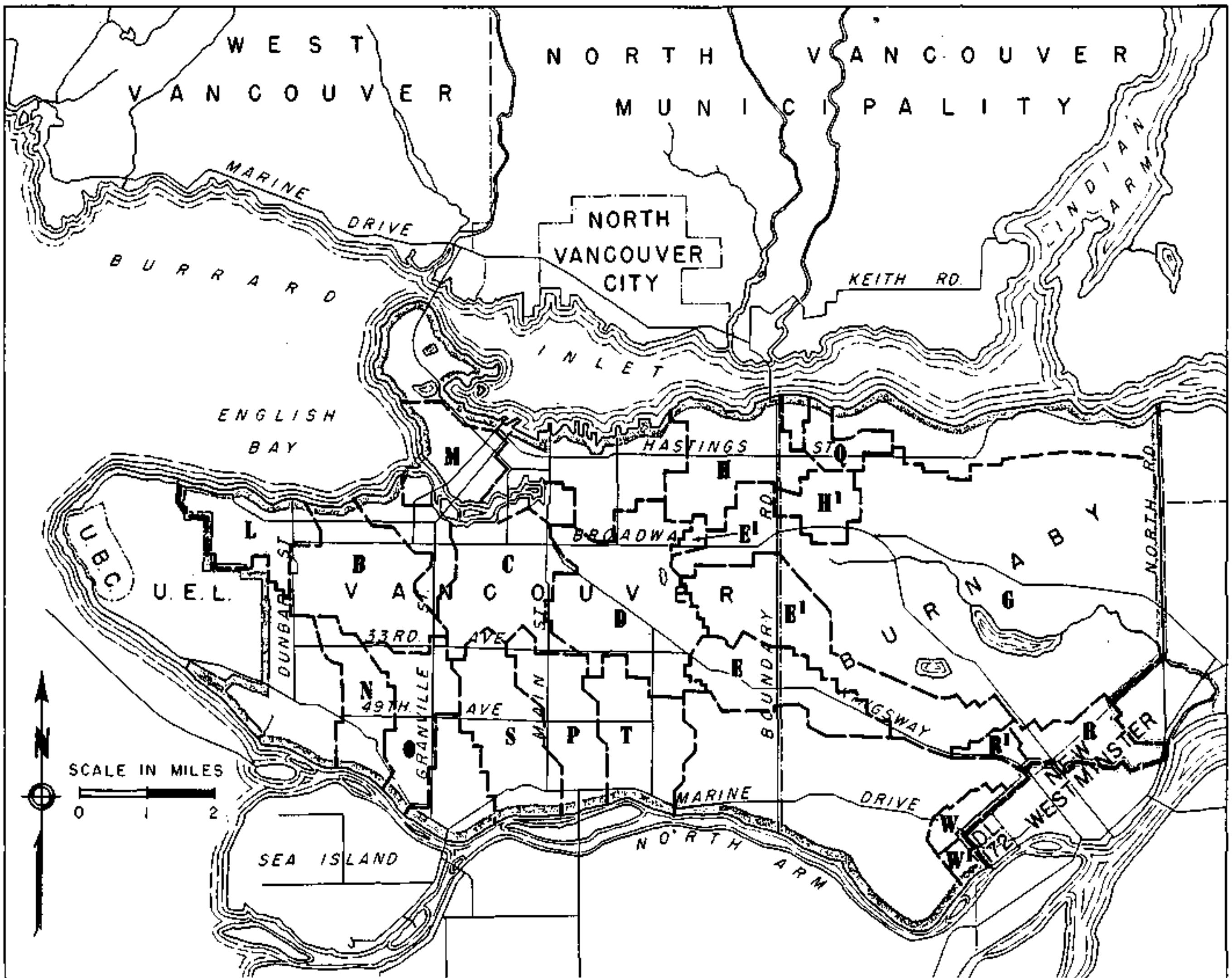
Information regarding the history, financial status and construction, and the maintenance and operation of sewerage and drainage facilities was gathered for every existing sewerage and drainage agency in the Greater Vancouver Area. In the following sections of this chapter, the existing services of each agency are described in sufficient detail to indicate the basis of appraisal for incorporation into the various plans studied.

Vancouver and Districts Joint Sewerage and Drainage Board

History. The Vancouver and Districts Joint Sewerage and Drainage Board is responsible for administering the Vancouver and Districts Joint Sewerage and Drainage Act of 1914 with subsequent amendments. The Act provides, in general, for the construction, financing and maintenance of all trunk sewers and watercourses within the district in substantial accordance with the Lea Report. Operations in general conformity with the Lea Report have been carried out since 1914. The Lea Report and the Act are reproduced in Appendices I and II, respectively.

The first sewers to be placed under the Board's jurisdiction were portions of the Balaclava, Cambie, China Creek, and Macdonald trunks purchased in 1914. The first sewer constructed by the Board in 1914 was an extension of the China Creek trunk. Since that time, the sewerage system of the Board has expanded until today most of the major trunk sewers presently serving the Burrard Peninsula are owned and maintained by the Board.

Description. The Board owns and maintains trunk sewers and drains in the City of Vancouver, the Municipality of Burnaby, and a portion of the City of New Westminster. The drainage areas presently served are shown in Figure 36 and



DRAINAGE AREAS					
SYMBOL	NAME	SYMBOL	NAME	SYMBOL	NAME
B	BALACLAVA STREET	H	HASTINGS PARK	R	GLENBROOK
C	CAMBIE STREET	L	ALMA IMPERIAL	R'	GLENBROOK
D	CHINA CREEK	M	WEST END INTERCEPTOR	S	MANITOBA STREET
E'	COPLEY	N	MACDONALD STREET	T	BORDEN STREET
E	COLLINGWOOD	O	ANGUS STREET	W	WILLARD STREET
G	BURNABY LAKE	P	SOUTH HILL	W'	WILLARD STREET
H'	HASTINGS PARK	Q	WILLINGDON AVENUE		

Figure 36. Drainage Areas of the Vancouver and Districts Joint Sewerage and Drainage Board

The Board owns and maintains trunk sewers and drains in most drainage areas comprising 400 or more acres within the City of Vancouver, the Municipality of Burnaby and a portion of the City of New Westminster. Drainage areas are delineated not only for design purposes but also for the apportionment of costs of construction and maintenance and operation.

listed in Table 20. The location of each of the Board's sewers, drains, and outfalls is shown in Figure 37.

Table 21 summarizes the sewerage and drainage facilities owned and operated by the Vancouver and Districts Joint Sewerage and Drainage Board and shows their capacities and costs. Appendix III gives a complete listing of the units comprising each facility. Unless otherwise noted, the stated construction costs are the actual costs at the time of construc-

Table 20

Existing Drainage Areas of the Vancouver and Districts Joint Sewerage and Drainage Board

Name	Symbol[a]	Type of System	Area in Acres
Balaclava Street	B	Combined	2,470
Cambie Street	C	Combined	2,075
China Creek	D	Combined	2,910
Copley	E'	Sanitary	2,380
Collingwood	E	Sanitary	1,660
Clark Drive Interceptor[b]	F	Combined	6,950
Burnaby Lake	G	Sanitary	6,400
Hastings Park	H'	Sanitary	610
Hastings Park[c]	H	Combined	2,166
English Bay Interceptor[d]	J	Combined	6,495
Burnaby Lake[e]	K	Storm	11,180
Alma Imperial	L	Combined	1,250
West End Interceptor	M	Combined	814
Macdonald Street	N	Combined	473
Angus Street	O	Combined	1,200
South Hill	P	Combined	1,040
Willingdon Avenue	Q	Combined	510
Glenbrook	R'	Sanitary	283
Glenbrook[f]	R	Combined	1,200
Manitoba Street	S	Combined	1,400
Borden Street	T	Combined	2,226
Willard Street	W'	Storm	230
Willard Street	W	Storm	350

Drainage areas were established for apportionment of costs of construction, maintenance and operation of the type of system shown.

[a] Symbols refer to Figure 36.
[b] Provides capacity for combined flow from area D and sanitary flow from areas E and E'; costs are apportioned over area D only.
[c] Provides capacity for sanitary flow from area H'; costs are apportioned over area H only.
[d] Contains areas B, C, L, and City of Vancouver Maple Street area.
[e] Contains areas H, E, E' and G for storm drainage purposes.
[f] Provides capacity for sanitary flow from area R'; costs are apportioned over area R only.

Table 21

Facilities of Vancouver and Districts Joint Sewerage and Drainage Board

Area Served[a]	Description of Facilities[b]	Capacity cfs	Period Constructed	Cost dollars
Sewerage Works:				
Balaclava Street	20,985 ft. of 30 to 96-in. RC, BHS and SLHS	95 to 2210	1912-1920	709,000
Cambie Street	17,340 ft. of 33 to 96-in. RC, BHS and SLHS	50 to 1370	1912-1947	366,300
Clark Drive Interceptor	62,815 ft. of 15 to 96-in. RC, BHS, SLHS and SS	7 to 2086	1911-1950	1,325,300
Hastings Park	18,685 ft. of 12 to 78-in. RC, BHS, and ESS	4 to 500	1915-1948	426,000
English Bay Interceptor	27,930 ft. of 54 to 96-in. RC and BHS	83 to 191	1929-1933	1,520,100
Alma-Imperial	8,640 ft. of 24 to 96-in. RC and BHS	16 to 310	1924-1932	253,800
West End Interceptor	9,685 ft. of 33 to 54-in. RC, BHS and SS	c	1914-1940	197,300
Macdonald Street	4,400 ft. of 28 to 60-in. RC	110 to 115	1912	40,300
Angus Street	5,125 ft. of 42 to 66-in. RC	115 to 360	1912-1925	78,000
South Hill	10,635 ft. of 32 to 96-in. BHS and RS	190 to 460	1931-1946	300,632
Willingdon Avenue	2,670 ft. of 30 to 60-in. RC	177 to 275	1931-1932	83,400
Glenbrook	19,265 ft. of 12 to 102-in. RC, BHS and SS	5 to 355	1914-1952	396,400
Manitoba Street	9,140 ft. of 42 to 91-in. RC and BHS	159 to 418	1952	600,000
Borden Street	8,355 ft. of 30 to 84-in. RC	76 to 408	1948-1950	495,400
Drainage Works:				
Willard Street	5,470 ft. of open channel incl. culverts		1950	22,400
Still Creek - Burnaby Lake - Brunette River	10,030 ft. of 60 to 78-in. RC and BHS; 53,400 ft. of open channel		1914-1952	853,500

See Appendix III for complete listing of facilities.

[a] See Figure 36 and Table 20 for description of areas served.
[b] RC indicates reinforced concrete pipe; BHS, Boston horseshoe section; SLHS, St. Louis horseshoe section; SS, special section; ESS, egg shape section; RS, riveted steel pipe. See Figure 37 for location of facilities.
[c] Pressure conduit.

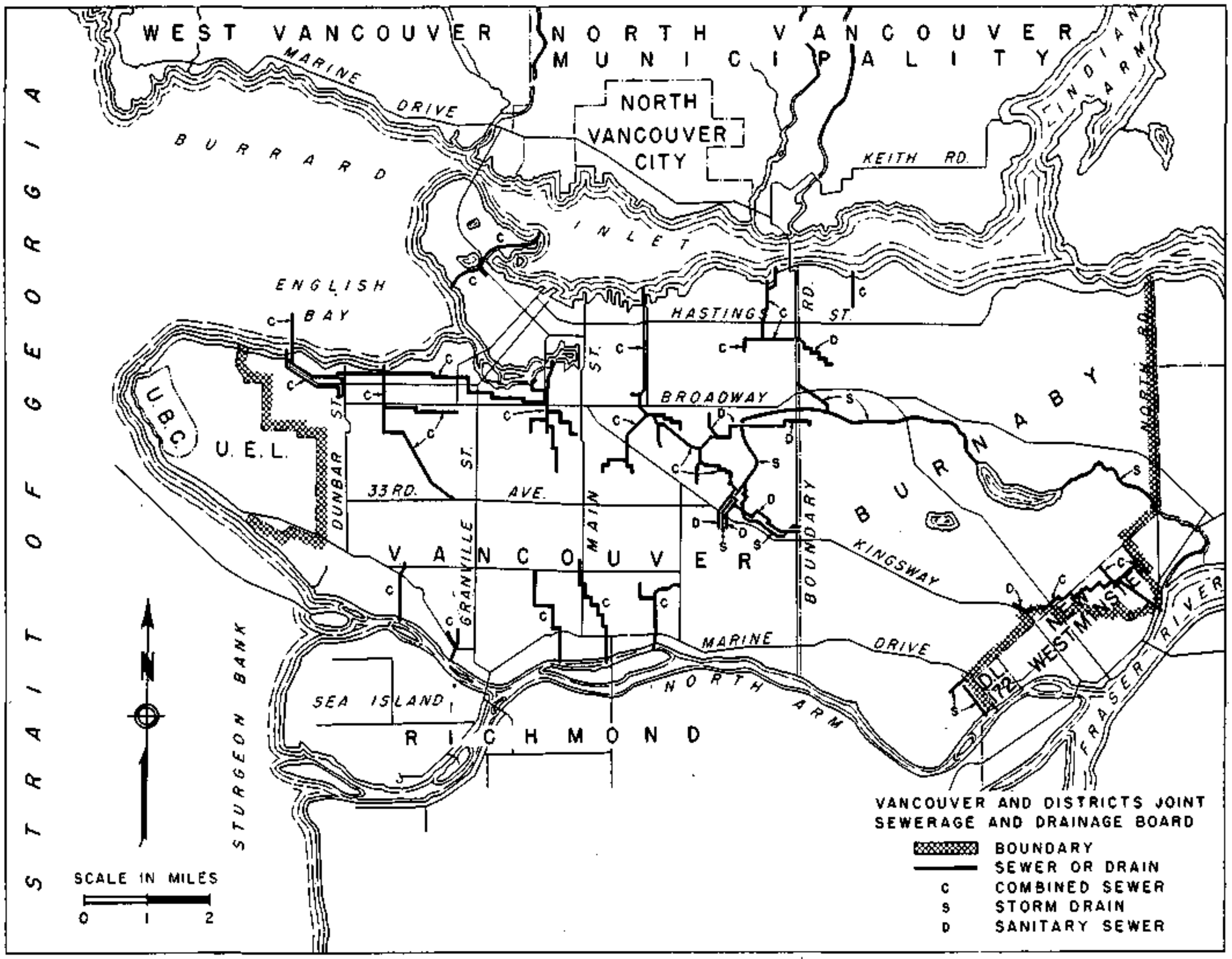


Figure 37. Sewerage and Drainage Facilities of the Vancouver and Districts Joint Sewerage and Drainage Board

The Board's facilities comprise conduits and open channels for conveying sewage and storm water from the area under its jurisdiction to points of disposal. Combined sewers convey domestic or sanitary sewage and storm water; sanitary sewers convey only domestic or sanitary sewage; storm drains convey only storm water. Combined and sanitary sewers are enclosed conduits while storm drains are enclosed conduits or open channels. A complete listing of all of the Board's facilities is given in Appendix III. Flow in the system is entirely by gravity and conduits range in diameter from 12 to 114 inches. The system includes eleven trunk sewers and extensions, three intercepting sewers, and three open channels for storm water conveyance. All sewage collected in the Board's sewers is disposed of by dilution.

tion. The sewers are all of gravity type and range in diameter from 12 to 114 inches. The system includes eleven trunk sewers and extensions, three intercepting sewers, and three open channels for storm water disposal. No sewage treatment plants have been constructed by the Vancouver and Districts Joint Sewerage and Drainage Board and all sewage from the area is disposed of by dilution.

Maintenance and Operation. The collection and disposal system of the Sewerage Board is maintained and operated by a permanent staff of 15 men. The staff is under the direction of a maintenance superintendent and is provided with equipment, office, and storage facilities apart from the main offices of the Board. During the winter months, when long periods of rain often create troublesome conditions, an additional group of 10 to 15 men may be employed on maintenance. With the exception of the submarine outfalls, the crew makes a regular check and inspection of every facility at least once a month. The submarine outfalls are in-

Table 22

Bonded Indebtedness of Vancouver and Districts Joint Sewerage and Drainage Board, December 31, 1952

	Year of Issue	Year of Maturity	Rate of Interest Percent	Original Issue	Refunded in 1941[a]	Cancelled in 1941[a]	Retired by Dec. 31, 1952	Outstanding Dec. 31, 1952
Sinking Fund:								
1	1914	1954	4.5	$ 2,433,333				$2,433,333
2	1920	1959	5.0	800,000	$ 522,000	$ 22,000		256,000
3	1922	1962	5.5	300,000	76,000	54,000		170,000
4	1922	1962	5.0	300,000	97,500	46,500		156,000
5	1927	1965	4.5	400,000	73,000	10,000		317,000
6	1929	1968	4.5	300,000	34,000	14,000		252,000
7	1929	1969	5.0	600,000	27,000	21,500		551,500
8	1931	1970	4.5	600,000	247,000	12,000		341,000
Instalment Debentures:								
9B	1938	1938-62	4.0	250,000			120,000	130,000
10A	1938	1939-63	4.0	500,000			215,000	285,000
11	1939	1940-64	4.0	361,000			142,000	219,000
12	1940	1941-70	3.5	166,000			499,000	701,000
			4.0	1,034,000				
13	1947	1948-52	2.0	35,000			35,000	
14	1948	1949-73	3.0	204,000			73,000	577,000
			3.25	446,000				
15	1952	1954-77	3.0	210,000				1,800,000
			3.25	371,000				
			3.50	1,219,000				
Total				$10,529,333[c]	$1,076,500	$180,000	$1,084,000	$8,188,833[b]

[a] In 1941 a portion of issue 12 was used to refund portions of issues 2 to 8. The sinking fund reserve accumulated from 1920 to 1941 for the refunded portions was used to cancel further portions of issues 2-8.
[b] Sinking fund reserve as of December 31, 1952 was $3,257,920. The net outstanding indebtedness therefore was $4,930,913.
[c] The total amount borrowed by the Board as defined in the Act was $9,272,833. This represents the difference between the total of the original issues and the total refunded and cancelled.

spected by divers twice a year.

The Sewerage Board facilities are, for the most part, well constructed and kept in excellent condition and there is rarely any trouble in their operation and maintenance.

Financial. Bonded indebtedness against the sewerage and drainage facilities at the end of the 1952 fiscal year was $8,188,833. This represents the remaining amount unpaid on several general bond issues aggregating $9,272,833, required to finance the construction of the trunk system. Table 22 presents the history of each of these bond issues, including the year of issue and maturity, the rate of interest, the portions refunded, cancelled and retired, and the amount outstanding at the end of the 1952 fiscal year, December 31, 1952.

The total borrowing power of the Sewerage and Drainage Board is limited under the Act to $10,500,000. The estimates in the Lea Report were made under the headings of "Immediate Construction" and "Deferred Construction". Facilities listed under "Immediate Construction" were estimated to cost $5,500,000 while those under "Deferred Construction" were estimated to cost $5,500,000. These estimates were made in 1913, however, when the Engineering News-Record Construction Cost Index was 100. Since that time the Index has risen to nearly 600, and it is not possible to complete the work covered under "Deferred Construction" with the funds originally allotted.

The Board has no revenue through sales or agreements with neighbouring municipalities. It operates entirely on yearly assessments paid by the members of the Board. The levy is apportioned among the members of the Board in the manner prescribed in the Act. Table 23

Table 23

Vancouver and Districts Joint Sewerage and Drainage Board
Apportionment of Levies

Year	Total Levy in Dollars	Apportionment in Dollars		
		Vancouver	Burnaby	New Westminster
1932	370,645.49	333,528.73	31,457.72	5,659.04
1933	382,677.34	344,223.86	32,509.91	5,943.57
1934	420,115.86	377,652.99	35,912.77	6,550.10
1935	418,387.47	375,206.68	36,489.24	6,691.55
1936	432,836.44	388,248.38	37,798.21	6,789.85
1937	448,240.45	397,989.93	43,224.45	7,026.07
1938	451,142.71	398,139.91	45,824.50	7,178.30
1939	462,520.56	407,223.73	48,318.96	6,977.87
1940	479,039.93	421,496.14	50,371.88	7,171.91
1941	485,195.04	427,048.27	50,852.35	7,294.42
1942	482,935.34	424,579.46	51,026.14	7,329.74
1943	488,705.94	428,581.64	52,814.94	7,309.36
1944	484,454.96	431,408.90	48,813.19	4,232.87
1945	487,424.53	434,404.99	48,715.16	4,304.38
1946	499,664.77	446,056.06	49,331.25	4,277.46
1947	494,609.68	442,971.15	47,535.25	4,103.28
1948	506,299.05	452,846.89	48,687.15	4,765.01
1949	576,302.87	514,380.27	56,975.21	4,947.39
1950	570,672.42	512,120.82	54,006.92	4,544.74
1951	591,916.79	519,105.94	66,389.69	6,421.16
1952	615,111.32	539,979.49	64,213.23	10,918.60

gives the yearly payments by members from 1932 to 1952. For 1952, the total levy was $615,000. The expenditures for 1952 totalled $596,000, of which $491,000 represented bond redemption and interest, $30,000 represented administration and general costs, and $75,000 represented the cost of maintenance and operation of the entire works. When the amount expended during a given year is greater than the levy for that year, the deficit is included in the levy for the following year; alternatively, when the amount expended is less than the levy, the surplus is deducted from the levy for the following year.

City of Vancouver Facilities

History. The first sewers in the City of Vancouver were constructed in about 1890. Portions of the China Creek, Cambie, Balaclava and Macdonald trunks were built about 1911. In 1914, these trunk sewers were purchased by the Sewerage Board. Construction of sewers within the city has proceeded regularly since then with the result that about 80 percent of the area of the city is now sewered. The sewers are nearly all combined as shown in Figure 38.

Description. The city owns, maintains and operates all sewers and drains within its boundaries with the exception of those owned and operated by the Sewerage and Drainage Board. Figure 38 shows the city boundaries, certain streets, and the location of the principal existing sewerage and drainage facilities. Trunk sewers range in diameter from 15 to 72 inches. The system drains generally to Burrard Inlet on the north and the North Arm of Fraser River on the south. There are nine pumping stations within the system.

Roof drains and foundation drain tiles from most buildings in Vancouver discharge into underground sumps connected to sewers in the streets. In a separate system, this necessitates construction of storm sewers at depths sufficient to drain basements. The prevailing high ground water table in the area, however, combined with the large percentage of buildings with floors below natural ground level, make such construction desirable.

In areas where separate sewers prevail, the storm and sanitary conduits commonly are laid simultaneously as twin sewers in one trench. Storm and sanitary sewers are carried to each

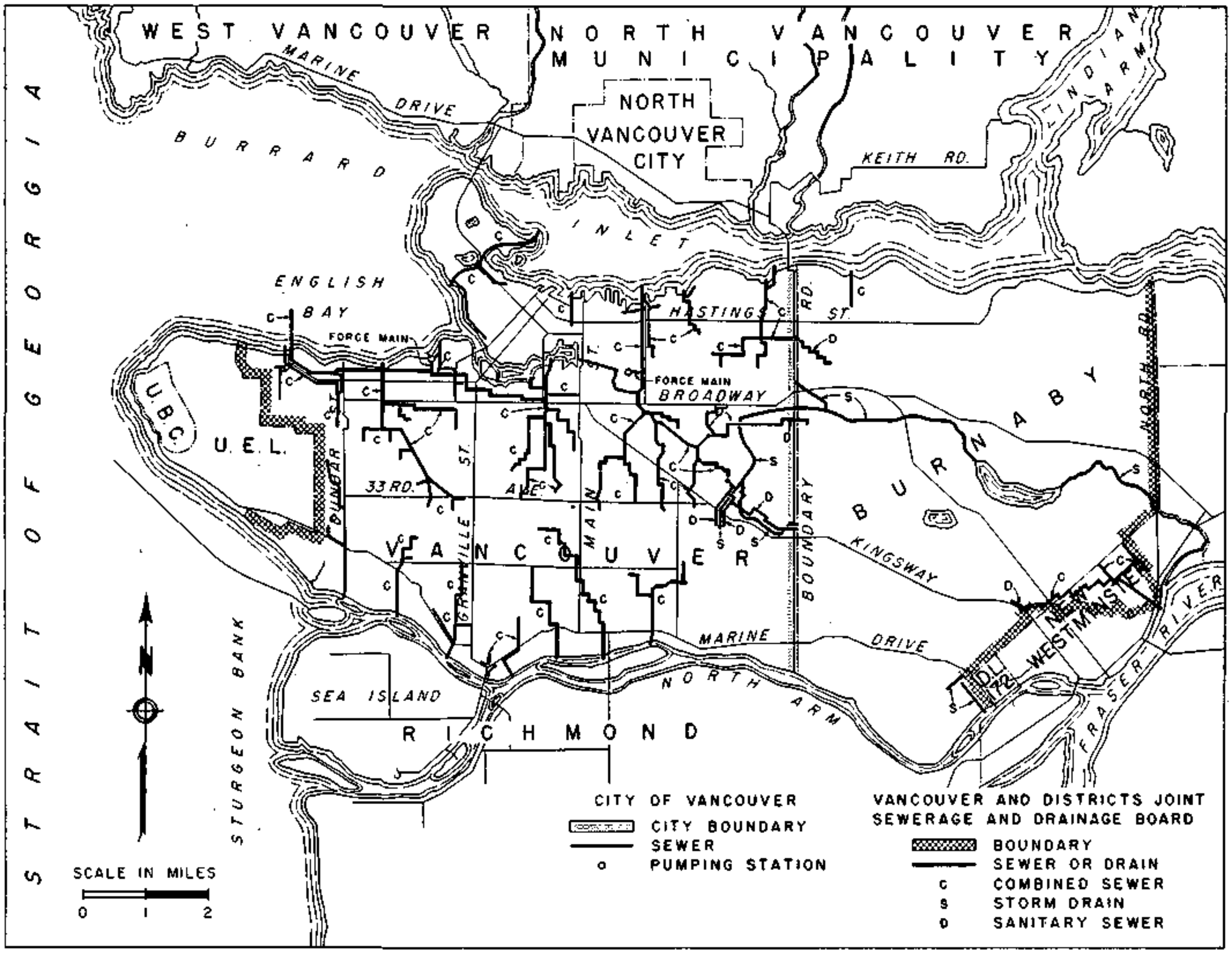


Figure 38. Principal Sewerage and Drainage Facilities City of Vancouver

Most of the units comprising the collection system of the City of Vancouver drain to trunk or intercepting sewers of the Vancouver and Districts Joint Sewerage and Drainage Board. Trunk sewers of the city range in diameter from 15 to 72 inches. Several pumping stations are located adjacent to False Creek.

house in a drainage area.

Maintenance and Operation. Maintenance and operation of the sewerage system is carried out by city crews consisting of a staff of about 42 men together with the necessary equipment and yard facilities. The collection system, on the whole, is well maintained and in good condition, though some of the older small sewers are reported to be deteriorating and considerable ground water infiltration occurs in a number of the sanitary sewers.

Financial. Bonded indebtedness against the sewerage and drainage facilities at the end of the 1952 fiscal year ending December 31, 1952, was $14,604,000. This represents the remaining amount unpaid on general bond issues required to finance the construction of the collection system. By December 31, 1952, the city had used all of its allocation of $5,270,000 from the 10-year financing plan approved by the voters in 1945. A new by-law, which was voted on in December, 1952, provides $750,000 for sewer construction.

Information obtained from the city indicates that $2,924,000 was expended for sewerage and drainage facilities during 1952. Of this sum, $1,200,000 represented capital outlay, $540,000 was paid to the Vancouver and Districts Joint Sewerage and Drainage Board as a yearly assessment, $997,000 was used for the retirement of bonds, and $187,000 represented the cost of operation and maintenance of the entire works.

Individual building connections to sewers are constructed to the property line by city crews and a connection fee is charged for each. Taxpayers in the city are not required to pay sewerage service or rental charges either as a lump sum fee or on a metered basis. The entire cost of all sewerage facilities is included in the general taxation rate.

Municipality of Burnaby Facilities

History. Burnaby has been a member of the Vancouver and Districts Joint Sewerage and Drainage Board since the formation of the Board in 1914 and the sewers that have been built within its boundaries have been constructed in general accordance with the recommendations of the Lea Report. The first sewers were built in 1926 and the existing system has been installed in increments from that date. A small local system was built in 1908 as part of a land development scheme on the north slope of Burnaby but did not become part of the municipal system until many years later.

Description. The sewerage and drainage facilities of Burnaby comprise a collection system of trunks and laterals draining to trunk sewers and drains owned

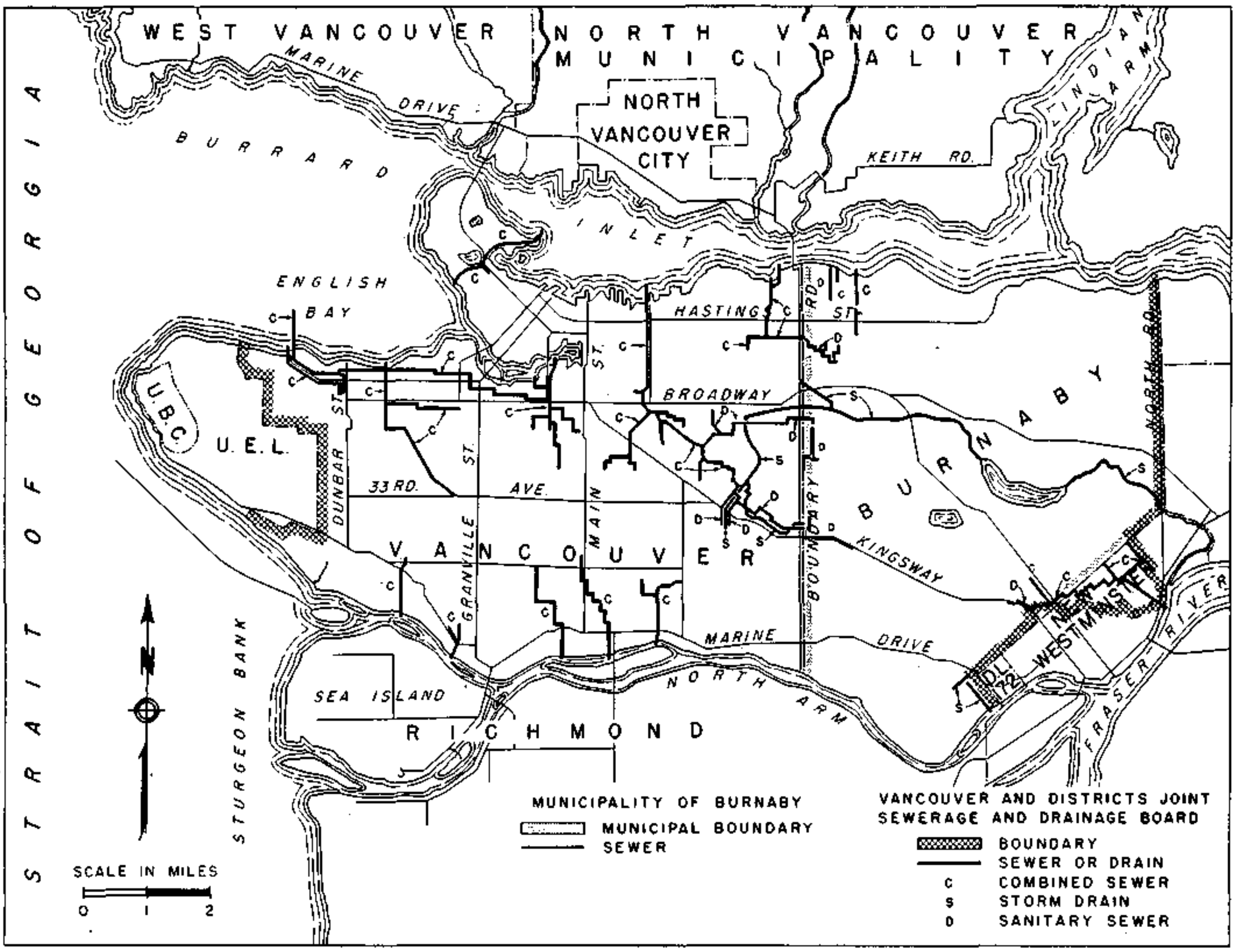


Figure 39. Principal Sewerage and Drainage Facilities Municipality of Burnaby

Most of the units comprising the collection system of the Municipality of Burnaby drain to trunk sewers of the Vancouver and Districts Joint Sewerage and Drainage Board. Main sewers in Burnaby range in diameter from 15 to 48 inches. Flow in the system is entirely by gravity.

by the Sewerage and Drainage Board. Figure 39 shows the boundaries of the municipality, certain streets, and the location of the principal existing sewerage and drainage facilities. Main sewers range in size from 15 to 48 inches. Flow in the system is entirely by gravity and the crude sewage is disposed of by dilution. Approximately 20 percent of the developed area in Burnaby is sewered and this represents an estimated connected population of 22,000 persons.

Maintenance and Operation. During an average year, a staff of 2 men is employed on maintenance and operation of the sewerage and drainage system. The major portion of the maintenance budget is used to facilitate disposal of the surface storm water by road ditches, culverts and natural watercourses. A continual program of construction and repair of these services is carried on throughout the municipality. The large area of Burnaby, combined with the limited budget available, make this a difficult task. The sewerage system is reported to be in good condition and to function satisfactorily in most places. Ground water infiltration and illicit storm water connections to sanitary sewers are reported to be major problems in some localities.

Financial. Bonded indebtedness against the sewerage and drainage facilities at the end of the 1952 fiscal year ending December 31, 1952, was $476,000. This represents the remaining amount unpaid on general bond issues required to finance the construction of the collection system. Burnaby has operated under the Municipal Refunding Act since 1932, and it is only in recent years that financial conditions within the municipality have improved to the extent that active construction of sewerage and drainage facilities could be resumed.

Information obtained from the municipality indicates that during 1952 $259,000 was expended on sewerage and drainage facilities. This includes $154,000 for capital outlay, $64,000 for the Vancouver and Districts Joint Sewerage and Drainage Board assessment, $35,000 for bond redemption and interest, and $6,000 for maintenance and operation of the entire works.

Burnaby obtains no revenue from its sewerage system other than connection charges for buildings. There are no service or rental charges and the cost of sewerage facilities is assessed on a local improvement basis.

City of New Westminster Facilities

History. The first sewerage works in New Westminster were installed in 1911 and consisted of a small collection system and trunk sewer serving a portion of the Glenbrook drainage area. Sewage was discharged to the Fraser River east of the Pattullo Bridge. The trunk was constructed under a joint agreement between Burnaby and New Westminster since a large portion of the drainage area is in Burnaby. The trunk was purchased outright from its original owners by the Vancouver and Districts Joint Sewerage and Drainage Board in 1928. The outfall, however, is still owned by the City of New Westminster.

The remainder of the sewerage facilities in the city have been constructed in increments since 1911. The Glenbrook drainage area is the only portion of the city within the boundaries of the area served by the Sewerage and Drainage Board.

Description. Figure 40 shows the city boundaries, certain streets, and the location of the principal existing sewerage and drainage works. Main sewers range in size from 12 to 30 inches. The lines all slope rapidly to the south and discharge into Fraser River. The system is a mixture of combined and separate sewers and is entirely gravity. Approximately 75 percent of the total city area is sewered. There are now thirteen outfalls into Fraser River. No treatment of the sewage is provided.

Queensborough, a portion of the City of New Westminster situated on Lulu Island, has no public sanitary sewerage facilities. The habitable area lies below the high water level of Fraser River and is protected by dykes. Storm water runoff from the area is carried in open channels to the river. Pumps assist in draining the area during high water stages of the river.

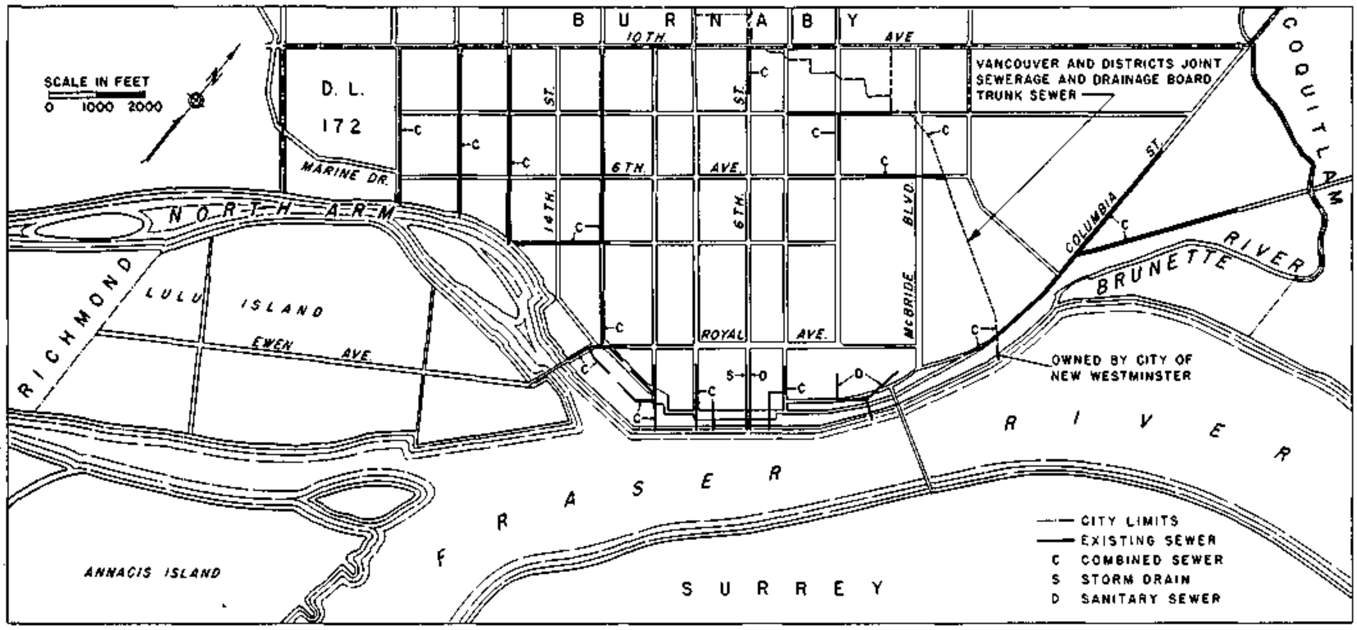


Figure 40. Principal Sewerage and Drainage Facilities City of New Westminster

Main sewers in the City of New Westminster system range in diameter from 12 to 30 inches. The system is a mixture of combined and separate sewers and is entirely gravity. Sewage is discharged without treatment into Fraser River. A portion of the City of New Westminster lies in the Vancouver and Districts Joint Sewerage and Drainage Board's area and is tributary to a trunk sewer owned by the Board.

Maintenance and Operation. The sewerage and drainage system is maintained and operated by city crews. There is no permanent staff for maintenance and operation but about 18 men are on call at all times. The facilities are reported to be in good condition. As above stated, there are 13 outfalls discharging into Fraser River from New Westminster and generally unsanitary conditions are reported to prevail along the industrial waterfront near these outfalls.

The steep slopes of the city and relatively high intensity storms of short duration combine to produce a runoff that often surcharges the sewers. Fortunately, damage from such occurrences is slight due mainly to the short duration of these storms.

Financial. There is no bonded indebtedness against the sewerage and drainage works at present. Funds used for construction of the works are all obtained on a local improvement assessment basis.

Information obtained from the city indicates that during 1952 $81,000 was expended for sewerage and drainage facilities. Of this sum, $54,000 represented capital outlay, $11,000 represented the Vancouver and Districts Joint Sewerage and Drainage Board yearly assessment, and $16,000 the cost of maintenance and operation of the entire works.

New Westminster has no service or rental charges for its sewer system and derives no revenue from it other than connection fees for individual buildings at the time of connection.

City of North Vancouver Facilities

History. The first sewerage facilities in the City of North Vancouver were installed in 1911 and consisted of a small collection system and outfall into Burrard Inlet at Mahon Avenue. The system has been extended gradually since that time so that approximately 30 percent of the population is now served. The construction and financing of the facilities is entirely a local concern and the city has never entered into joint agreements with its neighbouring municipalities.

Description. Figure 41 shows the city boundaries, certain streets, and the location of the principal existing sewerage and drainage works. The present facilities comprise a collection system, two trunk sewers, four outfalls which discharge into Burrard Inlet, and one pumping station. There is no treatment plant and the sewage is disposed of entirely by dilution. Main sewers range in size from 6 to 24 inches. The sewers slope generally to the south.

The present system was designed for sanitary sewage only, but high infiltration rates in portions of the system create a surcharge during heavy rains.

The northerly developed area of the city is partially served with sanitary sewers which are of sufficient capacity to allow extensions to the limits of the drainage areas within the city. No provision has been made for the sewage from the naturally tributary area of the Municipality of North Vancouver.

Developments in the city and municipality have increased storm water runoff to dangerous proportions and various creeks and waterways are becoming inadequate. The storm water drainage areas extend far into the Municipality of North Vancouver and runoff can be expected to continue to increase steadily.

Maintenance and Operation. Sewerage and drainage facilities within the city are

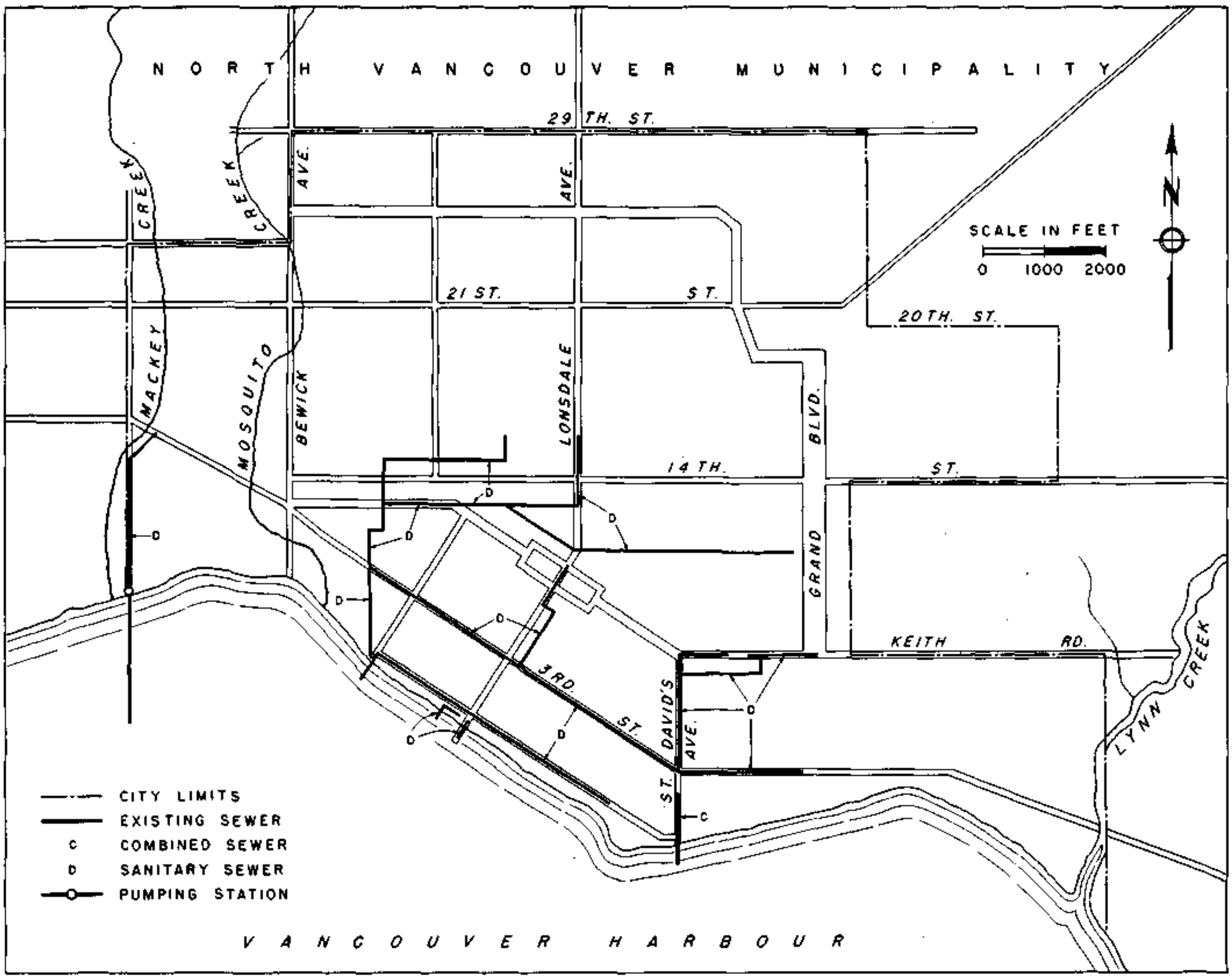


Figure 41. Principal Sewerage and Drainage Facilities City of North Vancouver

Main sewers in the City of North Vancouver range in diameter from 6 to 24 inches. Flow in the system is entirely by gravity except for one small pumping station. Sewage is discharged without treatment into Burrard Inlet. Storm water is conveyed to Burrard Inlet by several creeks.

constructed, maintained, and operated by a staff of 6 men. Difficulty is being experienced in preventing erosion in the natural watercourses. The sewers are reported to be in fair condition.

Financial. In 1931 the City of North Vancouver was placed under the direction of a commissioner appointed by the Provincial Government. Since 1943, however, the city has operated under the Municipal Refunding Act. All of the outstanding debts of the city have been consolidated into one account and it is virtually impossible to separate the bonded indebtedness chargeable to sewerage and drainage. The first call on city revenue is to maintain payments on this overall indebtedness which will not be completely discharged until 1977.

Information obtained from the city indicates that during 1952 $27,000 was expended for sewerage and drainage facilities. Of this sum, $15,000 represented capital outlay, and $12,000 represented the cost of maintenance and operation of the entire sewerage and drainage system.

The City of North Vancouver has no service or rental charges for its sewers. A fee is charged for connection to the sewer which covers the cost of the connection. Money for sewerage works is obtained on a local improvement assessment basis.

City of Port Coquitlam Facilities

There are no public sanitary sewerage facilities in Port Coquitlam and all sanitary sewage is disposed of by septic tanks. In the more densely populated sections of the city septic tanks are not functioning satisfactorily because of small lots and poor soil conditions.

Storm waters are drained in culverts and channels to the Coquitlam, Pitt or Fraser Rivers. There has been some flooding of parts of the area during spring freshet seasons.

City of Port Moody Facilities

Port Moody has no public sanitary or storm sewers. The entire city is serviced with septic tanks, the majority of which operate satisfactorily. In certain sections, however, they are reported to be causing considerable nuisance.

Storm water runoff is carried by culverts and drainage channels to Burrard Inlet. This system is in good order and adequate for the present conditions.

Municipality of Coquitlam Facilities

At present, there are no central collection facilities in the municipality. Sewage disposal in the area is entirely by septic tanks. In the southwesterly corner of the municipality, the settlement of Maillardville has a high density of population and is subdivided into small, narrow lots. The nuisance from inefficient septic tanks in this area is pronounced.

Storm water runoff is carried by culverts and drainage channels to the Coquitlam, Pitt or Fraser Rivers.

The provincial government owns and operates a mental hospital, an industrial home, a rest home, and an asylum colony farm comprising some 1,000 acres within the municipality. Domestic sewage from the hospitals and buildings in this area is collected in large septic tanks that discharge to Coquitlam River. It is reported that these tanks are completely inadequate. A sanitary sewerage scheme, with treatment, for the main buildings is under consideration at present.

Municipality of Fraser Mills Facilities

History. The Canadian Western Lumber Company at Fraser Mills operates and maintains a large mill and townsite within the municipality. A small local sanitary sewerage system, constructed in 1948, serves the area.

Description. The sanitary sewerage facilities in Fraser Mills comprise a collection system and outfall to Fraser River. The collection system consists of 3,630 feet of 8-inch sewer.

Storm water is disposed of through culverts and ditches into Fraser River. Recurrent flooding of the townsite is common during high water in the river. During these floods, the sanitary sewerage system becomes inoperative and the mill is forced to shut down.

The sewerage facilities operate by gravity and sanitary sewage is discharged without treatment into Fraser River.

Maintenance and Operation. The sewerage and drainage works are maintained and operated by a part-time local crew. The system is reported to be in good condition and to operate successfully other than at freshet seasons of the river.

Financial. Indebtedness charged against the sewerage and drainage works at the end of 1952 was $2,400. This represents the amount unpaid on a general loan used to finance construction of the works.

Information obtained from Fraser Mills indicates that during 1952 $8,300 was expended for sewerage and drainage facilities. Of this sum, $6,900 represented loan interest and redemption payments, and $1,400 represented the cost of maintenance and operation of the entire system. There were no capital expenditures during 1952. Money for this operation is obtained from the general revenue fund of the municipality.

Municipality of North Vancouver Facilities

There are no public sanitary sewerage facilities within the Municipality of North Vancouver. Storm water is disposed of through natural watercourses draining to Burrard Inlet. Increasing imperviousness of the ground surface due to rapid development in the municipality may soon overtax the present capacity of these natural creeks.

All industrial, residential, and commercial buildings are served with septic tanks. These function satisfactorily in certain areas but present a nuisance problem in others.

The principal function of the maintenance and operation crew in the Municipality of North Vancouver is the maintenance of the ditches and watercourses used for storm water disposal. There is no bonded indebtedness charged to drainage. The municipality has operated under the Municipal Refunding Act since 1932.

Municipality of Richmond Facilities

History. Sewerage facilities in Richmond comprise a small collection system and outfall for sanitary sewage from a residential subdivision on Sea Island. The airport and the Royal Canadian Air Force development adjacent to the airport on Sea Island also have small collection systems and outfalls for sanitary sewage but are not under the control of Richmond. No public sanitary sewerage facilities are provided on Lulu Island. The Sea Island system was constructed in 1943 as part of a Wartime Housing subdivision and turned over to Richmond in 1950.

Both Sea Island and Lulu Island are traversed by a network of open channels, dykes and pumps for storm water disposal. This system has developed in increments since 1870, at which time nine separate drainage districts were organized within Richmond. In 1937, six of these districts amalgamated to form the Lulu Island Amalgamated Dykes and Drainage District. This district includes all of Lulu Island except Steveston and operates under the Richmond Dyking and Drainage Development Act. The Steveston Local Improvement Maintenance District, the Sea Island Drainage District and the Sea Island Dyking District are responsible for the remainder of Richmond. These districts operate under by-laws of the Richmond council. The executive and engineering responsibilities of all districts are in the hands of the Richmond municipal council and engineer.

Description. The Sea Island sanitary system serves an area of 140 acres. Sewage is pumped directly into the Middle Arm of Fraser River without treatment. The sewers, although recently constructed, are overloaded due to infiltration of ground water. Sanitary sewage from the airport and the R.C.A.F. development is also pumped directly into the Middle Arm of Fraser River. The remainder of both Lulu Island and Sea Island is serviced with septic tanks, which, in general, are unsatisfactory. Several areas, particularly Steveston, are greatly in need of sanitary sewerage.

The major difficulties in the construction of sewers in Richmond are the extreme flatness of the country, the poor foundation conditions, and a high ground water table. The ground, apart from the peat bogs, is fairly soft clay eighteen inches to nine feet deep overlying saturated sand to a depth of 400 feet or more. The clay blanket is not uniform and has been known to have depths changing from more than seven feet to less than two in a distance of 30 feet. These factors combine to make septic tanks an extremely unsatisfactory method of sewage disposal.

Richmond has approximately 400 miles of ditches of which 65 miles are considered main canals. There are 55 drainage outlets to the river, some with pumps.

Maintenance and Operation. The sewerage and drainage facilities in Richmond are maintained and operated by municipal crews. The number of men employed may vary from five to 500 depending on the season and flood conditions in Fraser River. Difficulties have been encountered in the Sea Island system due to uneven displacement of the sewers in bad ground. A section of the trunk leading to the outfall was replaced in 1951 after several pipes had collapsed.

Complete effective maintenance and operation of the drainage system is a large undertaking that is years away from reality at this time. More effective channels, conduits, pumps, and outfalls are needed in most parts of the district. Cleaning the network of ditches and channels is a continuous, difficult, and expensive operation.

Financial. The bonded indebtedness against the sewerage and drainage works at the end of 1952 was $63,400. This represents the amount remaining unpaid on general bonds used to finance existing sewerage and drainage facilities. These bonds will be retired by 1954. In addition, the Lulu Island Amalgamated Dykes and Drainage District has an overdrawn account with the Richmond Council of $49,000. Richmond has never operated under the Municipal Refunding Act.

Information obtained from the municipality indicates that during 1952 $77,000 was expended on the sewerage and drainage facilities. Of this sum, $4,000 represented bond redemption and interest payments, and $73,400 represented the cost of operation and maintenance of the entire works. The drainage districts obtain their revenue from a special assessment on land apart from the general tax rate of Richmond. Work done on the Sea Island sanitary system is paid for by local improvement assessments.

Municipality of West Vancouver Facilities

There are no sanitary sewers in the Municipality of West Vancouver. Storm drainage is carried to Burrard Inlet in well defined but irregular watercourses. Some of these gullies have been improved by paving and rocking. Numerous culverts and bridges have been installed. The flow in the gullies is extremely turbulent and irregular, due to the steep and rocky terrain in the watersheds and the high precipitation rate on the North Shore. As West Vancouver expands northward and the stands of timber immediately north of the habitable area are logged and burned, the storm water runoff rate will increase greatly with consequent greater danger of property damage.

The immediate problem in West Vancouver is, however, the collection and disposal of sanitary sewage. Individual lots are relatively large throughout the municipality and it might appear as though individual disposal would be possible and satisfactory. In most areas, however, the ground is unsuitable for septic tanks, with the result that tank effluent is discharged into open ditches. Odour nuisance along some of the lower streets of the municipality is reported to be increasing.

Construction of a sewage collection system in West Vancouver will be difficult due mainly to large differences in elevation between houses on the north and south sides of many streets and in part to rock that will be encountered in excavation. It may prove advisable to provide lateral sewers in each lane and street designed to service only the houses on the high side.

At present, West Vancouver employs a small maintenance and operation crew whose most important concern is storm water disposal. There is no bonded indebtedness that can be charged to the storm water system and all maintenance and operation costs are obtained from the general revenue funds.

District Lot 172 Facilities

District Lot 172 has no sanitary sewerage system. Residences operate on septic tanks which are currently satisfactory.

A storm water system of drains and a drainage channel to the North Arm of Fraser River have been installed in a portion of the district. No trouble is experienced with its operation.

Affairs of this community are administered by the Provincial Government. It has no bonded indebtedness chargeable to its drainage facilities. The works are maintained by the Provincial Department of Public Works.

University of British Columbia Facilities

History. The lands and buildings of the University of British Columbia are owned by the Provincial Government. The first sewerage facilities were installed in 1923. The sanitary sewerage works comprise a collection system and outfall into English Bay, the outfall being shared jointly with University Endowment Lands. The sewerage system has been extended gradually since 1923 as the need has arisen. The University of British Columbia is not a member of the Vancouver and Districts Joint Sewerage and Drainage Board but portions of the system have been designed and constructed by the Board on a contract basis.

Description. The sewerage and drainage facilities within the university area provide for separate collection of sanitary sewage and storm water. Figure 42 shows the boundaries of the University of British Columbia and the University Endowment Lands, certain streets, and the location of the principal existing sewerage and drainage works. These sewers range in diameter from 12 to 18 inches and the lines slope generally to the west and north.

The sanitary sewerage system comprises two main sewers and an outfall sewer discharging to English Bay. This outfall is used jointly by the University of British Columbia and adjacent portions of the University Endowment Lands. The sewerage system is entirely gravity. No treatment is provided and disposal is by dilution in the waters of English Bay.

Storm water runoff is conveyed by storm drains and open channels to the disposal site off Point Grey.

Maintenance and Operation. The sewerage and drainage facilities of the University of British Columbia are reported to be in fair condition although there is considerable infiltration into portions of the sanitary system. Root growths in the sewers have also caused trouble in places and have made expensive cleaning operations necessary. The outfall used jointly by the University of British Columbia and the University Endowment Lands is a makeshift affair and was not intended to be a permanent installation. Sewerage and drainage maintenance is performed for the University of British Columbia by the Vancouver and Districts Joint Sewerage and Drainage Board on a contract basis.

Financial. There is no bonded indebtedness charged against the sewerage and drainage works. The costs are paid at the time of installation by government grants.

Information obtained from the University of British Columbia offices indicates that during 1952 $700 was expended for sewerage and drainage facilities. This amount represented the cost of maintenance and operation of the entire system.

University Endowment Lands Facilities

History. The University Endowment Lands is owned and operated by the Provincial Government of British Columbia. The area is as yet only partially subdivided. It offers choice residential properties. Sewerage facilities are installed in each subdivision before lots are sold. These facilities have been expanded gradually since the first installation in 1924. The University Endowment Lands is not a member of the Vancouver and Districts Joint Sewerage and Drainage Board, but the Board has frequently been engaged to design and construct their sewerage and drainage facilities.

Description. Figure 42 shows the boundaries, certain streets, and the location of the principal existing sewerage and drainage works within this area. These sewers range in diameter from 12 to 18 inches and slope generally to the north.

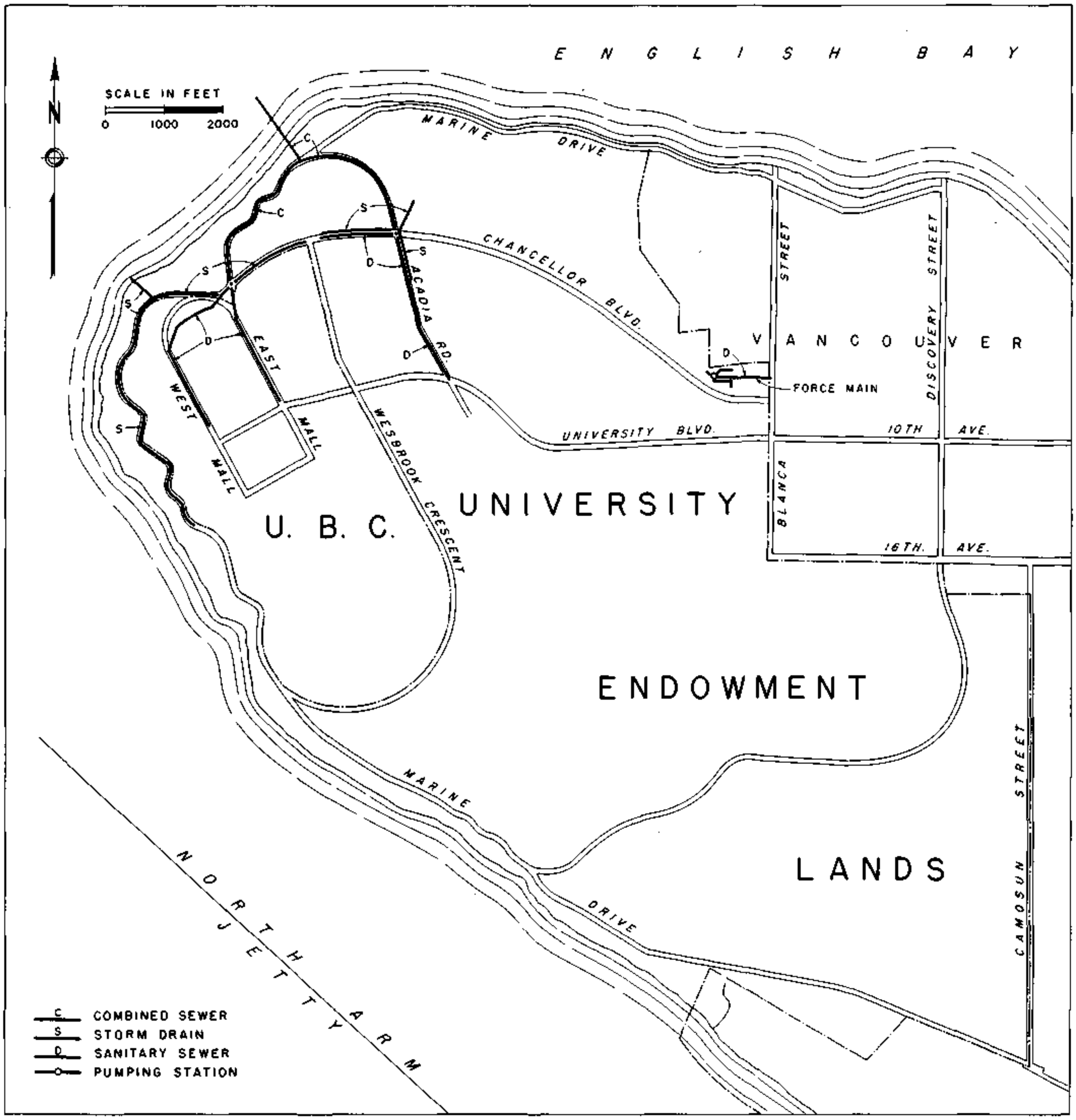


Figure 42. Principal Sewerage and Drainage Facilities of the University of British Columbia and the University Endowment Lands

Main sewers in the University of British Columbia range in diameter from 12 to 18 inches and provide for separate collection of sanitary sewage and storm water. Flow is entirely by gravity. Main sewers in the Endowment Lands comprise both separate and combined sewers ranging in diameter from 12 to 18 inches. Sewage from the University is discharged without treatment into English Bay as is a portion of the flow from the Endowment Lands. The remainder of the flow from the latter area is pumped into a sewer of the City of Vancouver and is also discharged without treatment into English Bay.

The system includes both separate and combined sewers. No treatment is provided for the sanitary sewage.

In the areas sewered on the separate system, storm water is carried to English Bay through outfalls or deep gullies while sanitary sewage is either taken to the Acadia Road outfall shared jointly with the University of British Columbia or pumped to a sewer of the City of Vancouver. The combined sewers also drain to the Acadia outfall. In the unsubdivided portions of the area, storm water is carried by culverts and natural watercourses to the nearest body of receiving water.

Maintenance and Operation. There is no regular staff for sewerage and drainage maintenance and the work is done as required by a general foreman and maintenance staff. Portions of the system are in good condition but there are some older lines that will need replacement shortly. Illicit connections for storm water disposal are reported to exist in most of the sanitary systems. Root growth in many of the sewers has also been a major problem.

Financial. There is no bonded indebtedness charged against the sewerage and drainage works. The work is financed through an endowment fund which is then charged to the property served either by general tax or on a local improvement basis.

Information obtained from the University Endowment Lands offices indicates that during 1952 $1,300 was expended for sewerage and drainage facilities. Of this sum, $800 represented capital outlay and $500 represented the cost of maintenance and operation of the entire system.

Chapter 11
Characteristics of Sanitary Sewage

Effect of Sewage Characteristics on Design

Proper and competent planning and design of sewerage facilities is based upon a knowledge of the quantity and strength of the particular sewage involved. The quantity of sewage determines the volumetric capacities of collection sewers, pumping plants, sewage treatment works and outfalls. The strength of the sewage, primarily as measured by the biochemical oxygen demand and suspended solids tests, has a controlling influence upon the type and size of various units of a treatment plant. It largely determines, also, the degree of treatment necessary to produce the quality of effluent required for specific conditions of disposal.

As discussed in Chapter 10, many of the existing sewers within the Greater Vancouver Area are of the combined type. During dry periods these sewers convey sanitary sewage only, while during and shortly following periods of rain they convey sanitary sewage mixed with storm water. Under the local controlling conditions, therefore, planning of sewerage facilities must not only recognize the characteristics of the sanitary sewage but also the contribution of storm water in those areas presently served by combined sewers. The methods employed by the survey for the estimation of storm water runoff are described in Chapter 13.

Gauging and Sampling of Sewage Flows

No reliable information relating to the volume and composition of the sanitary sewage of the Greater Vancouver Area was available to the survey. It was necessary, therefore, for the survey staff to conduct certain field work and laboratory studies to evaluate those characteristics of sanitary sewage which are most significant in the design of collection, treatment and disposal facilities.

Field work embraced the measurement of sewage flows and the collection of samples for laboratory analysis. Sewage flows were measured in two large sewers serving developed areas comprised of residential, business and industrial districts. These were the English Bay intercepting sewer at the intersection of First Avenue and Point Grey Road and the Clark Drive trunk sewer at a manhole just south of Hastings Street, both in the City of Vancouver and owned by the Vancouver and Districts Joint Sewerage and Drainage Board. Samples for laboratory analysis were collected from the English Bay intercepting sewer. These sewers serve areas whose present character most nearly resembles that predicted to represent ultimate development in all other areas of the Greater Vancouver Area.

Data concerning sewage flows at the Kitsilano pumping station of the sewerage system of the City of Vancouver were also available to the survey.

Figure 43 shows the location of the gauging and sampling stations above described.

Because the Fraser River and the Strait of Georgia have virtually unlimited capacities for the ultimate disposal of sewage, it was believed that analyses of a relatively few samples would be sufficient to provide information as to the probable composition of the sewage. Therefore, only three sets of samples from one sewer were analyzed and the results thus obtained were used to predict the probable future unit or per capita contribution. Allowances were made in the predicted future characteristics to allow for increased contributions from industry and other sources such as increased use of household garbage grinders.

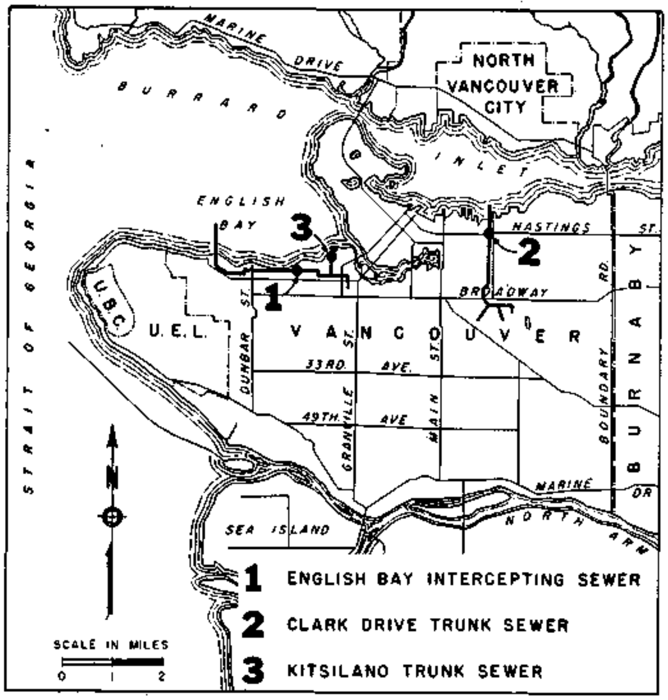


Figure 43.
Location of Gauging and Sampling Stations

To determine the characteristics of the sewage from areas whose present development resembles the type of metropolitan development anticipated in the Greater Vancouver Area, flow gauging and sampling programs were carried out. Dry weather sewage flows were measured in two of the combined sewers of the Vancouver and Districts Joint Sewerage and Drainage Board and in a trunk sewer of the City of Vancouver. Samples for laboratory analysis were collected from the English Bay intercepting sewer of the Sewerage and Drainage Board.

Two 24-hour and one 7-hour composite samples were obtained from the English Bay intercepting sewer at the gauging station located at the intersection of First Avenue and Point Grey Road within the City of Vancouver. The samples were collected downstream from a Palmer-Bowlus flume so that the sewage was thoroughly mixed. The samples were made up of grab portions taken at 15-minute intervals. The quantity of each grab sample was proportional to the rate of flow at the time of collection. The composites were thus representative of the total periods which each covered.

A different method of measuring sewage flow was employed at each of the three stations located as shown in Figure 43 . A Palmer-Bowlus flume installed in the English Bay intercepting sewer determines the rate of flow of the sewage from the depth of flow through the flume as indicated by a float and a continuously operating water level recorder. The rate of sewage flow into the Kitsilano pumping station is measured in a similar manner with the exception that a Parshall flume is employed as the primary metering element. The rate of flow in the Clark Drive trunk sewer was obtained by manually measuring the depth of flow at ten minute intervals and calculating the rate of flow from the assumed hydraulic characteristics of the pipe.

In this report rates of sewage flow are expressed as cubic feet per second (cfs) and unit or per capita flows are expressed as Imperial gallons per capita per day (gpcd). A rate of flow of one cubic foot per second is equal to 539,000 Imperial gallons per day.

Laboratory Analysis

Laboratory studies on the samples collected as above described were confined to the determination of biochemical oxygen demand and suspended solids, both total and volatile. All analytical work was performed in laboratory space generously made available by the British Columbia Research Council.

The biochemical oxygen demand test measures the quantity of oxygen utilized within a specified time and at a specified temperature in the biochemical oxidation of organic matter contained in the sewage. It is not related to the oxygen requirements of chemical combustion but is entirely determined by the availability of organic material as a biological food and by the amount of oxygen utilized by micro-organisms during oxidation. The test was performed as prescribed in the latest edition of "Standard Methods for the Analysis of Water and Sewage" with the exception that normal tap water, buffered and aerated, was used for dilution purposes instead of distilled water.

The total suspended solids were determined by filtering a measured quantity of sample through a prepared What-man No. 40 filter paper. The filter paper was prepared by drying in a 103°C oven for thirty minutes and allowing to cool and stabilize in the air for thirty minutes. It was then weighed. The sewage samples were filtered through the paper using a Buchner funnel and suction. The filter papers containing the suspended solids were dried, cooled and weighed as described above. The differences in weight between the initial and final weighings were taken as the weights of suspended solids contained in the volumes of the samples filtered. The test was performed in duplicate on each sample.

Volatile suspended solids were determined by igniting the filter papers containing the suspended solids in previously weighed crucibles in an electric furnace at a temperature of 600°C for fifteen minutes. The weight of ash remaining after ignition was taken to represent the fixed suspended solids, while the difference between the weight of fixed suspended solids and the total suspended solids represented the volatile suspended solids.

The results of these analyses are

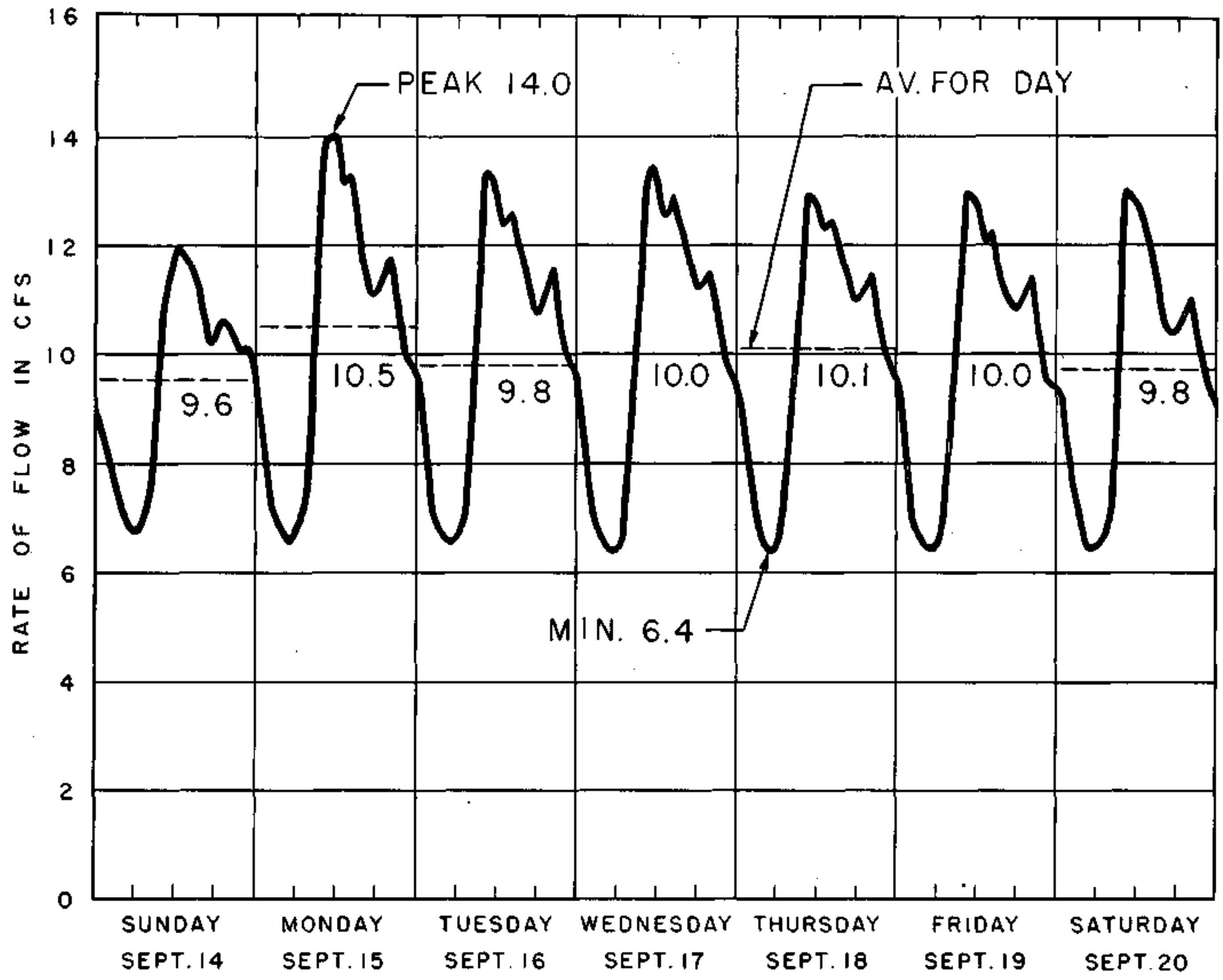


Figure 44. Hourly Variation in Flow in the English Bay Intercepting Sewer of the Vancouver and Districts Joint Sewerage and Drainage Board, September 14-20, 1952

Sewage flows during the week of September 14-20, 1952 are considered to represent normal dry weather flow conditions in this combined sewer. Flows are measured by a Palmer-Bowlus flume and continuously operating water level recorder. The average rate of flow during the week was 10.0 cfs. The peak rate of flow occurred at 11 am on Monday, September 15, and was 14.0 cfs, or 133 percent of the average for that day.

expressed in this report as parts per million by weight (ppm). Total loadings of biochemical oxygen demand (bod) and suspended solids are expressed as pounds per day (ppd); the unit or per capita contributions are expressed as pounds per capita per day (ppcd).

Present Characteristics

Sewage Quantities. Figure 44 shows the hourly variation in the rate of sewage flow in the English Bay intercepting sewer as measured during the week of September 14-20, 1952. This week may be assumed to represent typical dry weather flow conditions. The average rate of flow for the week was 10.0 cfs. The peak rate of flow occurred at 11 am on Monday, September 15, and was 14.0 cfs, or 133 percent of the average for that day. Minimum rates of flow normally occurred about 6 am and were approximately 6.4 cfs for each day, or 64 percent of the average rate.

In determining the amount of sam-

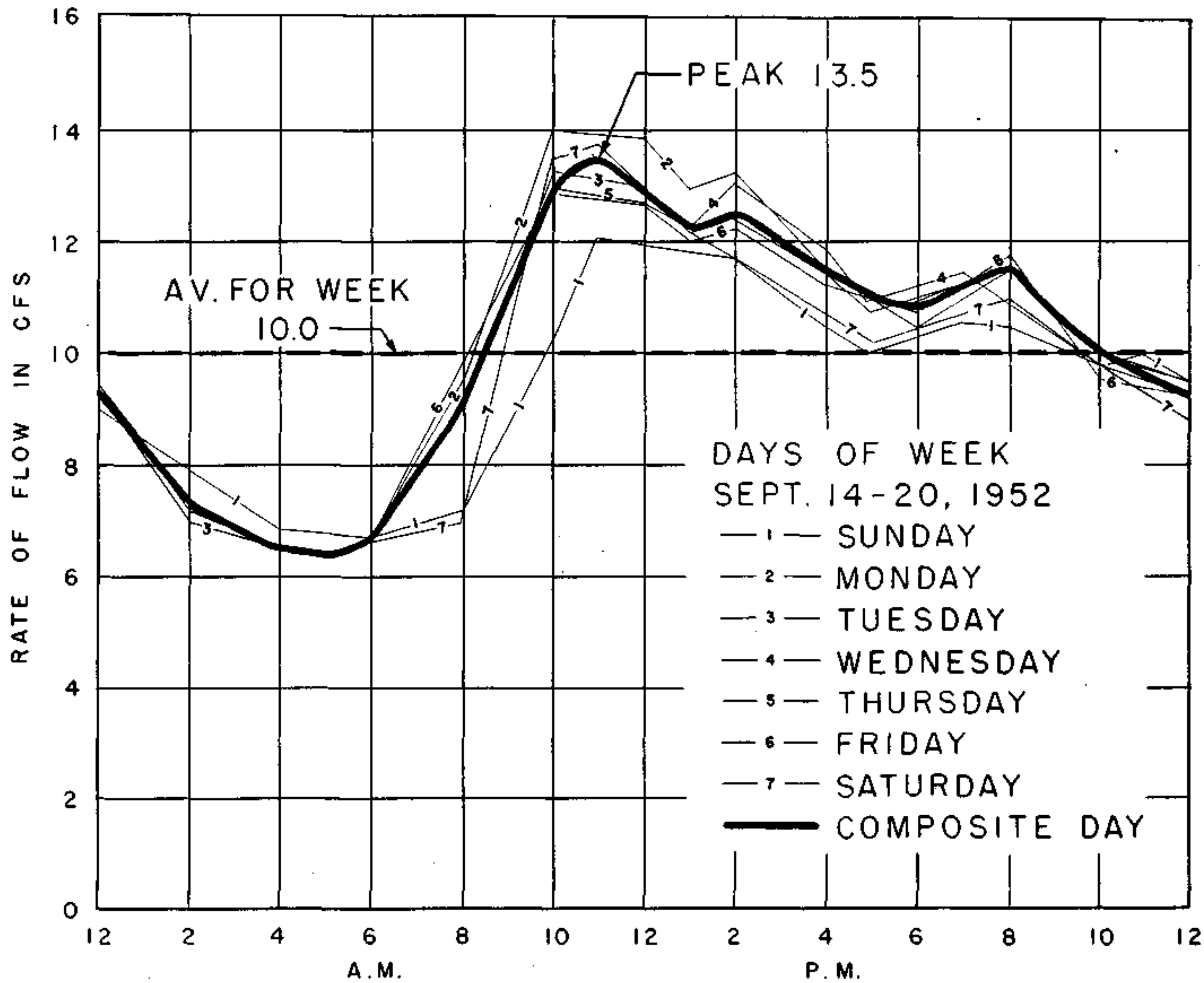


Figure 45. Composite Hourly Variation in Flow During a Typical Dry Weather Week, September 14-20, 1952 in the English Bay Intercepting Sewer of the Vancouver and Districts Joint Sewerage and Drainage Board

Since a study of flow records for this intercepting sewer indicated that the variation in rate of flow is closely similar for all dry weather conditions, this composite curve was used for proportioning samples collected at fifteen minute intervals into daily composite samples for laboratory analysis.

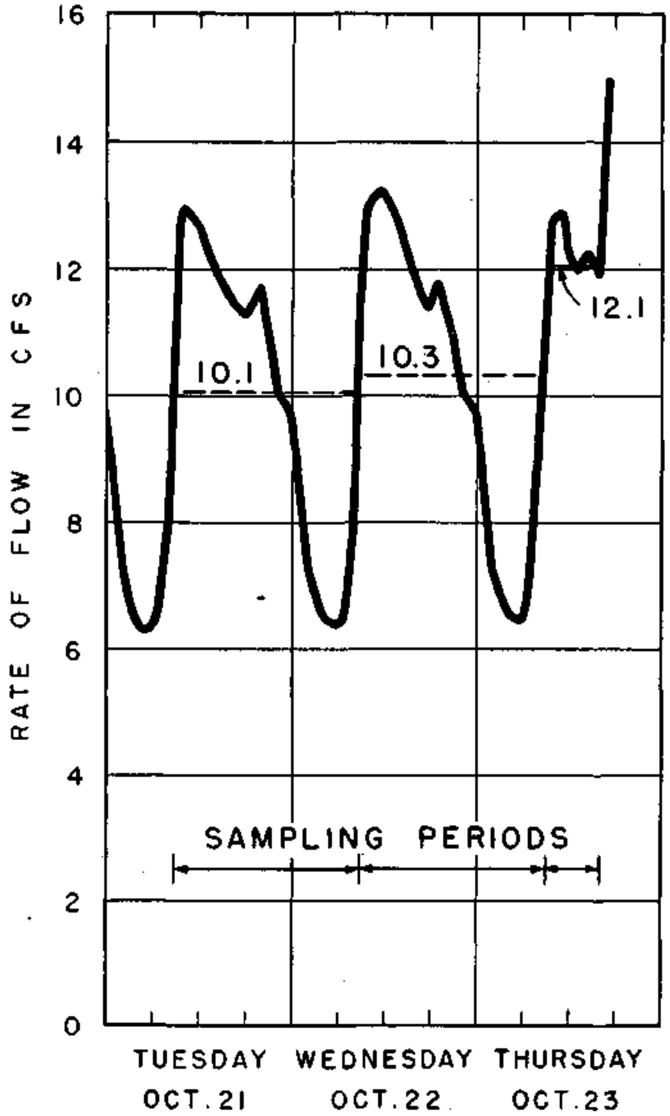


Figure 46. Hourly Variation in Flow in the English Bay Intercepting Sewer of the Vancouver and Districts Joint Sewerage and Drainage Board During the Sampling Period, October 21-23, 1952

Since both the average rate of flow and the hourly variation in flow rate shown on this figure are comparable to those shown on Figure 44, the method used for proportioning grab samples into daily composite samples was justified.

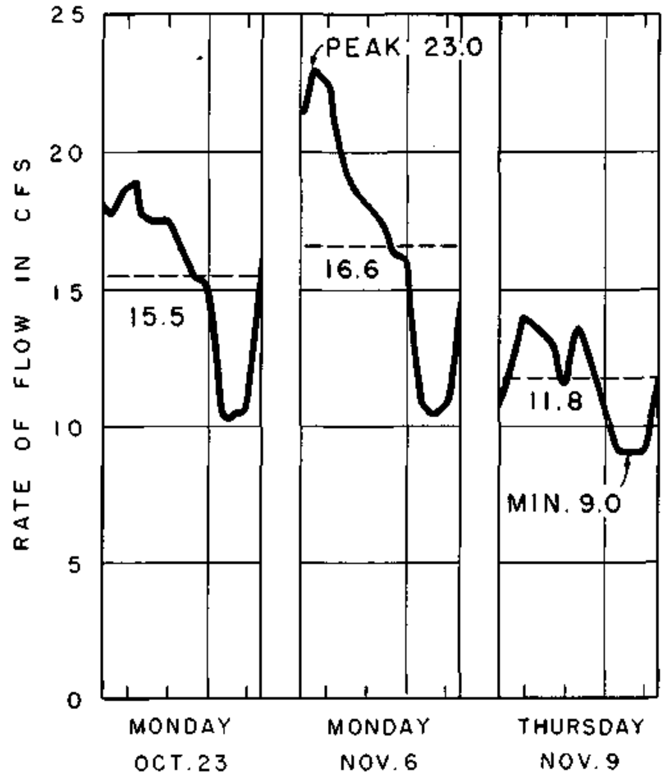


Figure 47. Hourly Variation in Flow in the Clark Drive Trunk Sewer of the Vancouver and Districts Joint Sewerage and Drainage Board During Dry Weather Flow, October and November, 1950

Flows were gauged by manually measuring the depth of flow at ten minute intervals and calculating the rate of flow from the assumed hydraulic characteristics of the pipe. The average rate of flow recorded was 14.6 cfs. The peak rate of flow occurred on Monday, November 6, 1950, at 11 am and was 23.0 cfs, or 139 percent of the average for that day.

ple to collect from the English Bay intercepting sewer at each fifteen minute sampling interval, as previously described, use was made of a composite curve of hourly variation in rate of sewage flow prepared for the week of September 14-20, 1952. This curve, as well as curves showing the hourly variation in flow for each day of that week, is shown in Figure 45. Use of this composite curve as a basis for collecting sewage samples was considered to be justified, since a study of flow records for the intercepting sewer indicated that the variation in rate of flow is closely similar for all dry weather conditions.

Figure 46 shows the hourly variation in flow in this intercepting sewer as measured during the period of sampling. Both the average rate of flow and the hourly variations in flow rate are comparable to those obtaining during the typical dry weather week of September 14-20, 1952.

Figure 47 shows the hourly variation in the rate of sewage flow in the Clark Drive trunk sewer during three days of measurement in October and November,

1950. The days shown were without rainfall, but a significant amount of rainfall had occurred over a period of days prior to the gaugings. The average rate of flow for the days of measurement was 14.6 cfs. The peak rate of flow occurred on Monday, November 6, 1950, at 11 am and was 23.0 cfs, or 139 percent of the average for that day. The minimum rate of flow occurred at 4 am on November 9, 1950, and was 9.0 cfs, or 76 percent of the average for that day.

Figure 48 shows the hourly variation in the rate of sewage flow into the wet well of the Kitsilano pumping station for the week of September 14-20, 1952. As stated above, the flows obtaining during this week may be assumed to represent typical dry weather conditions. The average rate of flow for the week was 0.93 cfs. The peak rate of flow occurred on Monday, September 15, at 9 am and was 1.95 cfs, or 189 percent of the average for that day. Minimum rates at this station commonly occur at about 4 am and are about 0.35 cfs, or 38 percent of the average flow.

The dry weather flow in the three sewers discussed above is made up of three elements: (1) sanitary wastes from residences and connected industries; (2) water introduced through drainage tiles commonly installed adjacent to building foundations to carry off ground water which is relatively high in the area; and (3) ground water infiltration entering the sewers at joints and other points throughout the lengths of the sewers. The latter two items presumably account for the fact that the minimum flows in the English Bay intercepting sewer and the Clark Drive trunk sewer

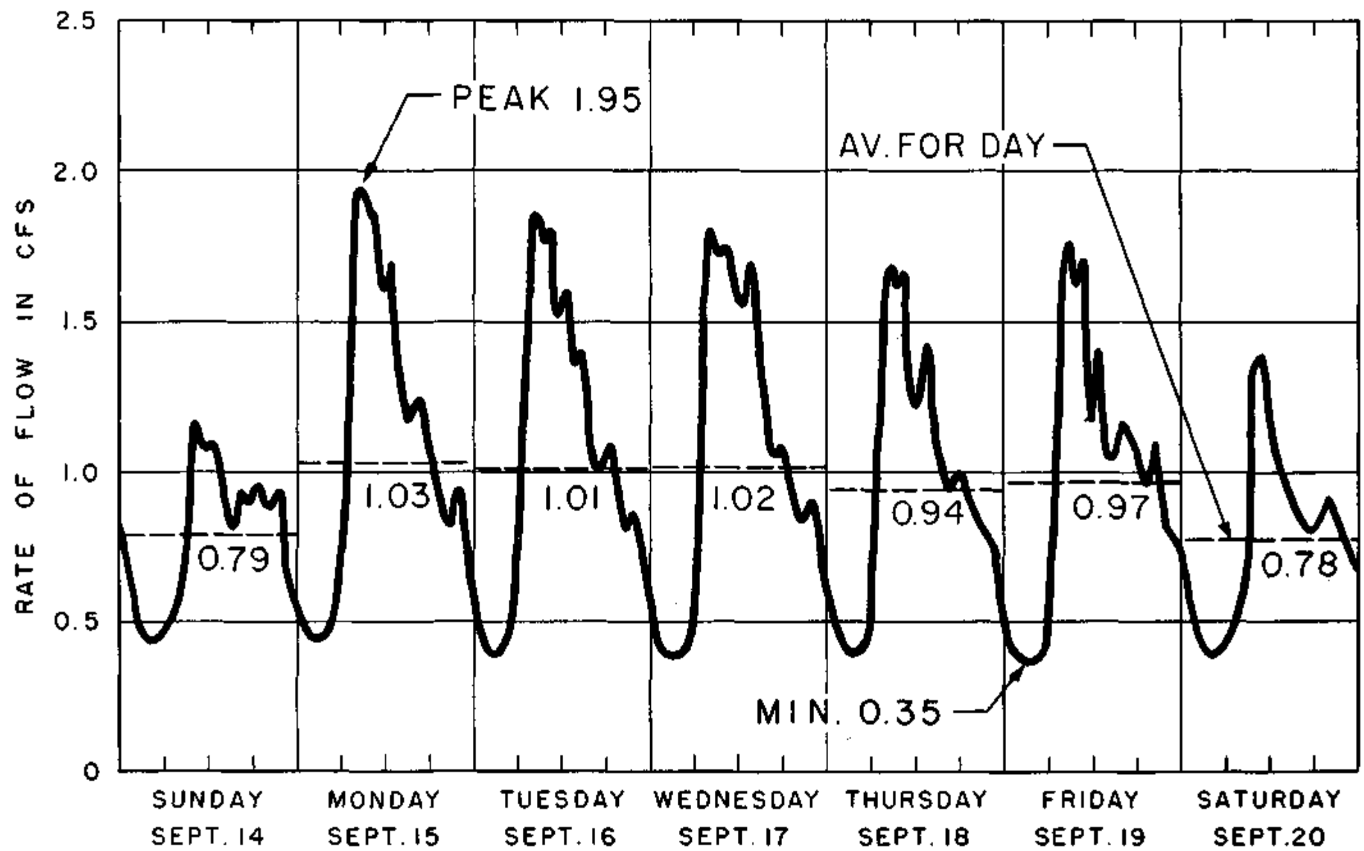


Figure 48. Hourly Variation in Flow at the Kitsilano Pumping Station of the City of Vancouver, September 14-20, 1952

The flows obtaining during this week have been assumed to be representative of dry weather conditions. Flows are measured by a Parshall flume and a continuously operating water level recorder installed at the entrance to the wet well of the pumping station. The average rate of flow during the week was 0.93 cfs. The peak rate of flow occurred on Monday, September 15, at 9 am and was 1.95 cfs or 189 percent of the average for that day.

are higher than those generally obtaining in similar large sewers into which but little or no ground water enters. The minimum rate of flow into the Kitsilano pumping station does not indicate ground water effects of the same extent as those prevailing in the two other sewers.

Measurement of wet weather, or storm flows, in the area covered by the survey was not undertaken for various reasons. The sewer of greatest interest in this connection, namely the English Bay intercepting sewer, is provided with several by-passes or overflows which make total runoff determination extremely difficult, if not impossible. Other main sewers have storm water overflows into English Bay, False Creek, and Burrard Inlet. Several combined sewers of the Vancouver and Districts Joint Sewerage and Drainage Board with outfalls in the North Arm of Fraser River do not have such by-passes or overflows. In no case, however, are they equipped with rate of flow measuring devices, and as yet none serve territory of the type and extent of development typical of predicted future conditions elsewhere in the Greater Vancouver Area.

Sewage Strength. Table 25 presents the results of analyses performed on the samples collected from the English Bay intercepting sewer. The results indicate a rather weak sewage with respect to the concentration of bod and suspended solids. The average concentration of these constituents was 126 and 153 ppm, respectively. These relatively low values may probably be attributed to the dilution of the sanitary sewage by ground water entering the sewer through drain tile connections or through leaky joints in the sewer.

Table 25

Analysis of Sewage
English Bay Intercepting Sewer

Sampling Period[a] 1952	Average Sewage Flow[a] cfs	BOD[b] ppm	Suspended Solids Total ppm	Suspended Solids Volatile ppm
Oct. 21-22	10.1	124	152	121
Oct. 22-23	10.3	128	154	128
Oct. 23	12.1	177	254	206
Weighted Average[c]	10.2	126	153	124

Samples collected and flows measured at intersection of 1st Avenue and Point Grey Road in City of Vancouver.
[a]9 am to 9 am except October 23rd which was 9 am to 4 pm.
[b]5 day 20°C.
[c]Weighted according to flow for the two 24-hour samples only.

Total and Per Capita Loadings. Table 26 gives the calculated loadings in the English Bay intercepting sewer as presently effective. Average daily contributions of sewage flow, bod, and suspended solids are calculated to be 98 gpcd, 0.13 ppcd, and 0.15 ppcd, respectively. The loadings of bod and suspended solids contained in the 7-hour sample collected on October 23 represented 48 and 57 percent, respectively, of the average total daily loadings of the preceding two days. Similar values, namely 46 and 54 percent, are presented in the "Report Upon the Collection, Treatment and Disposal of Sewage and Industrial Wastes of the East Bay Cities, California", June 30, 1941, by Hyde, Rawn and Gray.

Table 26

Present Loadings
English Bay Intercepting Sewer

Population[a]	55,000
Volume[b]	
Average daily flow, cfs	10.0
Average daily flow, gpcd	98
Peak rate, cfs	14.0
Percent peak of average[c]	133
Minimum rate, cfs	6.4
Percent minimum of average[c]	64
BOD[d]	
Average, pounds per day	6,900
Average, ppcd	0.13
Suspended Solids[d]	
Average, pounds per day	8,400
Average, ppcd	0.15
Percent volatile solids	80

[a]Estimated from information furnished by office of City Engineer of Vancouver, based upon 1951 preliminary census figures for enumeration districts tributary to point of measurement.
[b]Based on typical dry weather week of September 14-20, 1952. See Figure 44.
[c]Average for day on which stated rate occurred.
[d]Based on analyses reported in Table 25.

It is of interest to note that the average per capita flow of 98 gallons per day is approximately 70 percent of the average per capita water consumption of 140 gallons per day as reported in Chapter 5. This percentage figure is comparable with figures for other areas of more or less similar character. For example, in the sewerage report for the East Bay Cities of California, a study of the results of comprehensive sewage flow gaugings and of equally comprehensive water consumption data lead to the conclusion that 65 percent of the domestic water supply and 90 percent of the industrial water supply would normally reach the sewers. In this connection it should be stated that the long, practically rainless summer period in that section of California produces a heavy, long-term demand for water for the irrigation of private lawns and gardens, of public parks, and other similar areas.

Calculated Design Factors

To estimate future flow quantities of sanitary sewage and future loadings, it is necessary to take cognizance of and to make allowances for: (1) contributions from industries which, although presently existent, are not as yet connected with sewers; (2) contributions from new industries which may develop in the future; (3) contributions due to increased use of household appliances such as garbage grinders; and (4) seepage from foundation tile drains which will contribute to the flow in all combined sewers. Design factors have been developed with these conditions in mind.

Table 27

Calculated Design Factors
Sanitary Sewage

Volume	
Sanitary system,[a] gpcd	95
Combined system,[b] gpcd	110
Percent peak of average	150
Percent minimum of average	65
BOD, ppcd	0.17
Suspended Solids	
Total, ppcd	0.20

[a]Carrying wastes from residences and industries only.
[b]Carrying ground water from foundation tile drains in addition to wastes from residences and industries.

Table 27 presents the calculated design factors applying to sanitary sewage in the Greater Vancouver Area. Per capita flows are given for two types of sewerage systems, namely, those which will carry only sanitary sewage and those which will convey combined storm water and sanitary sewage. In estimating dry weather flows in combined sewerage systems, allowances have been made for ground water contributions from building drain tiles. The ratio of peak to average rate of flow, 150 percent, is considered to be applicable only to large systems with extended lateral or collection sewers. For smaller systems this ratio would be considerably greater. The loadings of bod and suspended solids, 0.17 and 0.20 ppcd, respectively, represent an increase of approximately 30 percent over the present loadings set forth in Table 26.

Chapter 12
Requirements for the Disposal of Sewage

Methods of Disposal

Disposal of sewage and storm water of the Greater Vancouver Area may be to the tidal waters of the Strait of Georgia and Burrard Inlet or to Fraser River. The controlling factors which dictate the location of disposal works and the necessity of treatment before discharge differ greatly between sewage and storm water.

Storm Water. The primary objective in the disposal of storm water is its discharge into the nearest adequate waterway in such a manner as to minimize property damage and to obtain the greatest possible drainage benefits. Because discharge of surface runoff into a body of water does not endanger beneficial use of that water, the selection of disposal points is dependent completely on economy, and no analysis other than the carrying capacity need be made of a stream or other body of water in determining appropriate disposal points. This chapter is, therefore, devoted exclusively to the requirements for disposal of sewage. The collection and disposal of storm waters from the three topographic sections of the Greater Vancouver Area are discussed in Chapter 17.

Sewage. Sewage disposal practice has in large measure been established by developments in science and by public sentiment. Proper disposal of sewage is determined primarily by considerations of public health and aesthetics. Public health has always been of paramount importance, but more recently public enjoyment and satisfaction have begun to influence both the type and location of disposal works. It is obvious that the public health should be protected by all possible means, both direct and indirect. It is therefore imperative that all recreational beaches and inhabited shores, all tidal waters and all river waters be kept free of dangerous contamination or pollution by sewage.

Currents in the waters of the Greater Vancouver Area are such that sewage or sewage effluent discharged at one place in the area may be transported to another in a concentration such as to constitute a potential source of contamination or nuisance. Because of this, the provision of sanitary sewage disposal is properly the concern of all citizens in the area.

Objectives for Sewage Disposal

Sewage disposal in British Columbia is not controlled by any one governmental agency. Several federal and provincial departments are concerned with certain phases which fall within their jurisdictions. Among them are the following:

1. Provincial Department of Health and Welfare
2. Provincial Department of Fisheries
3. Provincial Department of Lands and Forests - Water Rights Branch
4. Federal Department of Health and Welfare
5. Federal Department of Fisheries
6. Federal Department of Public Works

Each of these agencies is responsible for certain aspects of water quality control and each will require that the maintenance of receiving waters shall conform to its regulations.

Because of this varied control and interest in sewage disposal, the Board of Engineers believes that specific requirements for sewage disposal should not be determined until such time as the detailed design of a particular plan or sewerage project is undertaken. In determining such requirements, each individual disposal plan must be considered separately and all of the pertinent factors evaluated. Such a procedure involves a careful case - by - case determination and cannot be accomplished by the establishment of arbitrary standards.

The basic objectives of sewage disposal are applicable generally to any region. The following are believed necessary in the Greater Vancouver Area:

1. Disposal of sewage and trade wastes should not cause the appearance of grease, oil or oily sleeks, or of visible solids of sewage origin in waters used for bathing or other forms of recreation, nor should the disposal cause deposit of such materials on beaches or shores to an extent such as to constitute a nuisance.

2. Unavoidable discolouration of waters in the vicinity of sewer outfalls should be permitted. The permissible extent, degree and nature of discolouration should be determined by the location of specific waste discharges.

3. Sewage should be so discharged into a body of receiving water as to avoid bacterial contamination of recreational waters. The determination of bacterial contamination should be based upon logical, proper evaluation of the uses of the waters in question.

4. Discharged wastes should not contain toxic materials in concentrations detrimental to fish, bird or other wildlife, nor should they reduce the quantity of dissolved oxygen in the receiving waters below the level necessary to the survival of such life.

5. Waste disposal should cause no obnoxious odours along the beaches or shores of the area or in the vicinity of any sewage treatment works.

These objectives have been applied throughout the survey in laying out projects for study and comparison. The following portions of this chapter deal with the investigations and the conclusions reached regarding disposal of sewage in the Greater Vancouver Area.

DISPOSAL TO TIDAL WATERS

Controlling Factors

The capacity of tidal waters to receive sewage and render it harmless is directly related to the ability to dilute the sewage, destroy the pathogenic organisms, and oxidize the organic matter contained therein. This ability, in turn, is related to the quantity and composition of the sewage involved, the oxygen content of the water, and to conditions of current, depth and density at and adjacent to the disposal site.

When sewage or sewage effluent is discharged below the surface of sea water, it tends to rise immediately because of its lesser density. In rising, the sewage mixes with sea water and spreads over an increasingly larger area as it nears the surface. The extent of dilution which will have been accomplished when the sewage - sea water mixture reaches the surface is dependent upon the depth of the outlet, temperature differences between sewage and sea water, and upon current velocity.

The initial energy imparted to the sewage because of its lesser density is not usually dissipated, even with the admixture of large quantities of sea water, until the mixed liquid reaches the surface. At that point, one of two general phenomena will occur. Either the sewage - sea water mixture will plunge beneath the surface and disappear completely or it will float and spread as a part of the surface layer of less dense water. The first phenomenon, where the mixture plunges under the surface, results from the discharge of sewage into sea water which is considerably colder than the surface water. In rising, the sewage mixes with this colder water. By the time the mixture reaches the surface, its temperature is lower than that of the surrounding top waters and its density is greater. Because of this density difference, an unstable condition exists and the denser sewage - sea water mixture will tend to submerge. The second phenomenon, where the sewage-sea water mixture spreads laterally over the surface, occurs when the density of the sewage-sea water mixture is less than that of the surface water. By the time the sewage reaches the surface, although it has been mixed with denser sea water in rising, the density of the mixture has not been lowered below that of the surrounding surface waters. The mixture, therefore, will float and will move with the surface layer, at the same time continuing to mix and diffuse with greater quantities of sea water. After a period of time, varying from less than one to as many as three hours, depending on the initial dilution achieved, all traces of sewage will have been dissipated.

The concentration of suspended solids originally contained in sewage effluent is decreased not only by dilution but also through utilization as food material by certain microscopic and macroscopic organisms normally present in sea water. The decrease in coliform density, a measure of bacterial contamination, is not attributable to dilution alone but also to the fact that normal sea water contains substances which seem to have an antibiotic effect on coliform organisms. Studies showing this effect are reported by Vaccaro, Briggs, Carey, and Ketchum in an article entitled, "Viability of Escherichia coli in Sea Water", American Journal of Public Health, October, 1950.

The movement of surface water in the Greater Vancouver Area is controlled by the concurrent action of the tide and by the discharge of fresh water from Fraser River into the Strait of Georgia.

Tides. The tidal pattern of the area is one of diurnal inequality. The amplitude of the tide varies through a two-week cycle. During spring tides, the tide falls very low on one ebb and rises high on the following flood. Throughout the next cycle the tide remains relatively high with only a minor fall and rise. During neap tides there are two fairly similar tides of small amplitude each day. Figure 49 shows graphically the spring and neap tidal ranges which are common at Point Atkinson. Tidal ranges in excess of fifteen feet are not unusual during spring tides.

In the Strait of Georgia, the flooding tide moves northward and the ebbing tide moves southward. Along the eastern shore of the strait bordering the Greater Vancouver Area, the movement associated with the flood tide is considerably greater than that with the ebb tide. The tidal drift, therefore, is predominantly in a northerly direction.

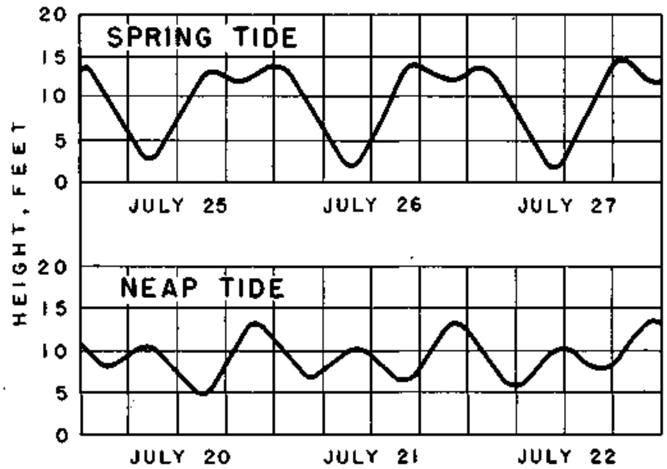


Figure 49. Typical Spring and Neap Tidal Ranges at Point Atkinson, British Columbia

The tidal pattern of the area is one of diurnal inequality in which the amplitude of the tide varies through a two week's cycle. Tidal ranges in excess of fifteen feet are not unusual during spring tides.

Fraser River Discharge. Fresh water is released into the Strait of Georgia by Fraser River at a variable rate during the year. The peak discharge during the freshet season is more than ten times the average winter discharge. The freshet usually begins during the early part of May and the river flow rises to a maximum in mid-June. Winter flows are relatively constant from October through April. Figure 50 shows the variation in flow in the Fraser River at Hope, British Columbia, during the period October 1949 to September 1950, as measured by the Department of Resources and Development of Canada. At Hope, which is 90 miles upstream from the mouth of the river, the drainage area is approximately 96 percent of that at the mouth. Flows in the lower reaches of Fraser River may be estimated by the application of factors developed by the Department of Resources and Development. These factors take into account the contributions of rivers and other watercourses downstream from Hope. The peak discharge of Fraser River to the Strait of Georgia is estimated to exceed 500,000 cfs, while the average

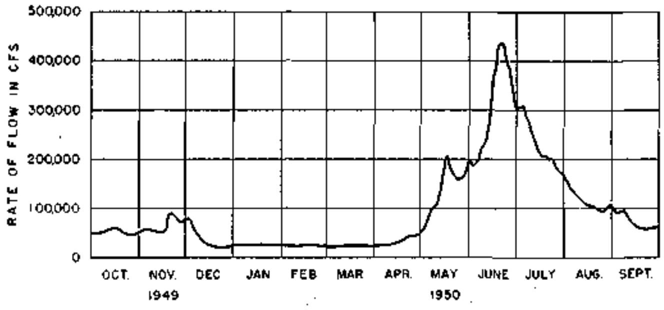


Figure 50. Fraser River Flow at Hope, British Columbia, October 1949 to September 1950

The discharge of Fraser River to Strait of Georgia is at a variable rate during the year. Winter flows are relatively constant and low. Freshets normally begin in May and maximum flows usually occur in June. Contributions from watercourses downstream from Hope, the location of measurements shown above, increase the average winter discharge to 30,000 cfs and the peak discharge to over 500,000 cfs.

winter discharge is estimated to be 30,000 cfs.

Studies Conducted for the Survey

Several investigations to obtain information relating to the controlling factors discussed above have been conducted by the Vancouver and Districts Joint Sewerage and Drainage Board alone and in cooperation with other governmental organizations. A brief description of each of these investigations is given below.

Fraser River Estuary Project. This cooperative project was undertaken to gather oceanographic data necessary to describe the circulation and rate of exchange in the Fraser River estuary and contiguous waters of English Bay. The following organizations or agencies contributed personnel, equipment or funds for the conduct of the project: (1) Vancouver and Districts Joint Sewerage and Drainage Board; (2) National Research Council; (3) Institute of Oceanography, University of British Columbia; (4) British Columbia Lands and Forests Department, Air Surveys Branch; (5) Tidal Branch, Hydrographic Service, Department of Mines and Technical Surveys of Canada; and (6) the Pacific Oceanographic Group of the Fisheries Research Board of Canada. The latter agency provided the general direction and supervision of the project.

Between November 1949 and April 1950, work was carried on by the Vancouver and Districts Joint Sewerage and Drainage Board with the advice of the Pacific Oceanographic Group. In May 1950, the project was increased in scope and embraced all of the above mentioned agencies. This work involved the collection of samples and analyses for dissolved oxygen and salinity and included a determination of the temperature structure. During the period November 1949 to April 1950, 52 stations in Vancouver Harbour and English Bay were occupied once each month and samples were taken at each position twice on opposite phases of the tide. In May 1950, the area under investigation was extended to include the Fraser estuary as far south as the main channel of the river. During the period May 1950 to February 1951, the area between Vancouver Harbour and the main channel of Fraser River was covered by a network of 42 stations. These stations were occupied at frequent intervals until October 1950, and an additional series of samples was collected in February 1951 to evaluate winter conditions.

By correlation of the data collected from each station with reference to the tide, a synoptic representation of the water structure over the entire area under consideration was obtained.

The methods employed and all data collected have been compiled and published by the Pacific Oceanographic Group under the title "Pacific Coast Data Record, Fraser River Estuary Project, 1950." An analysis of these data with respect to the movement of surface water was made for the Vancouver and Districts Joint Sewerage and Drainage Board by the Pacific Oceanographic Group and was published under the title "The Oceanographic Phase of the Vancouver Sewage Problem", by R. L. I. Fjarlie, a report which has been used by the Board of Engineers as the basis for evaluating possible sites for disposal of sewage into the tidal waters of the Greater Vancouver Area.

Tidal Current Surveys. Studies of tidal currents in English Bay and Vancouver Harbour were conducted in 1950 by the

Hydrographic Service of the Department of Mines and Technical Surveys of Canada in cooperation with the Vancouver and Districts Joint Sewerage and Drainage Board. Data were collected from 26 current observation stations extending from Point Grey to Second Narrows. Each station was occupied throughout a complete tidal cycle of 25 hours on two occasions during the period June to August, 1950. Current velocities were measured at several depths using a current meter. Directions were determined by compass.

A report entitled "Current Investigations, Burrard Inlet - 1950", describing in detail the nature of the currents in Vancouver Harbour and English Bay, was submitted to the Vancouver and Districts Joint Sewerage and Drainage Board by the Hydrographic Service. The data were used by the Hydrographic Service in preparing Tidal Publication No. 22, entitled "Tidal Current Charts, Vancouver Harbour, British Columbia."

Other Investigations. In addition to the studies enumerated above, intermittent studies of currents in the waters of English Bay, Vancouver Harbour, and the Fraser River estuary have been conducted by the Sewerage and Drainage Board since 1927.

Movements of Water Masses

As discussed previously in this chapter, knowledge of the movement of surface waters is necessary to determine the proper location of sewage outfalls and the degree of treatment necessary prior to discharge. As a result of the Fraser River Estuary Project and the Tidal Currents Surveys, the movement of various masses of water bordering the Greater Vancouver Area can be described.

Movements of water masses from the main channel of Fraser River, Sturgeon Bank and the North Arm, as well as the circulation in English Bay, are described in detail in the "Oceanographic Phase of the Vancouver Sewage Problem" referred to above, and the descriptions presented herein have largely been taken from that source. Movements of water masses were determined from results of the synoptic surveys of July 18 to 28, 1950, when the Fraser River discharge was about 200,000 cubic feet per second. These movements have been taken as representative of conditions in midsummer. The movements were checked against aerial survey data and are consistent with data from previous and subsequent synoptic surveys and with actual current measurements made with floats.

Determination of current velocities and directions at various stages of the tide in Vancouver Harbour was made and reported upon by the Tidal Branch of the Hydrographic Service. The results are shown in the current charts for the harbour. These observations are in agreement with the results obtained from free float studies. The description presented herein relative to circulation in Vancouver Harbour has largely been taken from the Hydrographic Service report to the Sewerage and Drainage Board.

Main Fraser River. When fresh water from Fraser River reaches the Strait of Georgia, it flows out over the denser sea water forming a distinct upper layer. This layer is freshest near the mouth of the river, and increases in salinity with time and distance as it gradually mixes with the underlying sea water. It is distinguished visually by the large amount of suspended silt carried by the river.

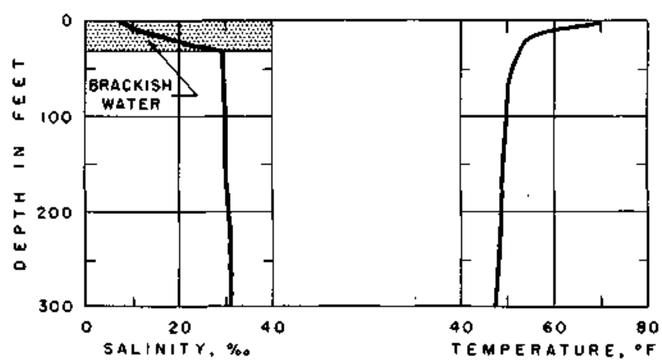


Figure 51. Typical Salinity-Depth and Temperature-Depth Curves for Strait of Georgia in Fraser River Area

Measurements of salinity and temperature confirm visual evidences of the presence of a distinct upper layer of fresh water from Fraser River in the Strait of Georgia. The layer of brackish river water is characterized by relatively low salinity which increases with depth until at about 20 feet the salinity of normal sea water is reached.

In addition to visual evidences of its presence, the layer may be detected by analyses of samples of the water taken at varying depths. Measurements of salinity and temperature structure indicate the density structure. Figure 51 shows typical salinity-depth and temperature-depth curves. The layer of brackish river water is characterized by relatively low salinity. The salinity of the upper layer increases with depth and at a depth of about 20 feet equals that of normal sea water.

The amount of Fraser River water discharged to the Strait of Georgia is a function of the river flow and of the tides. Upstream from any tidal effect, the river has a constant seaward velocity under any condition of river flow or tide. In the region affected by the tide, two phenomena occur dependent on the rate of discharge of the river and the tidal phase.

During the period of midsummer flow and spring tide, sea water intrudes under the fresh water and moves upstream or downstream depending on the tidal phase as shown on Figure 52. As the tide rises, sea water flows into the river mouth lifting the river water and carrying it upstream until the energy of the mass of water moving upstream is equalled by the energy of the mass of water moving downstream. The river runoff accumulates behind this barrier of equal energy and the water level in the river rises. It continues to rise for a short period after high tide in the Strait of Georgia. At the start of ebb tide, the velocity of the water moving upstream becomes zero and the upper layer of fresh water moves seaward at a rapid rate. The accumulated runoff is released as a cloud of brackish water, which is carried clear of the river mouth by its momentum and becomes subject to movement by the tidal currents. Because of the intermittent discharge of river water to the strait, the layer of fresh water entering the strait on any given ebb tide is separated from preceding or subsequent layers by the distance moved during the time between tidal cycles. The clouds may remain distinct for several cycles, but eventually mix with the underlying sea water and lose their identity.

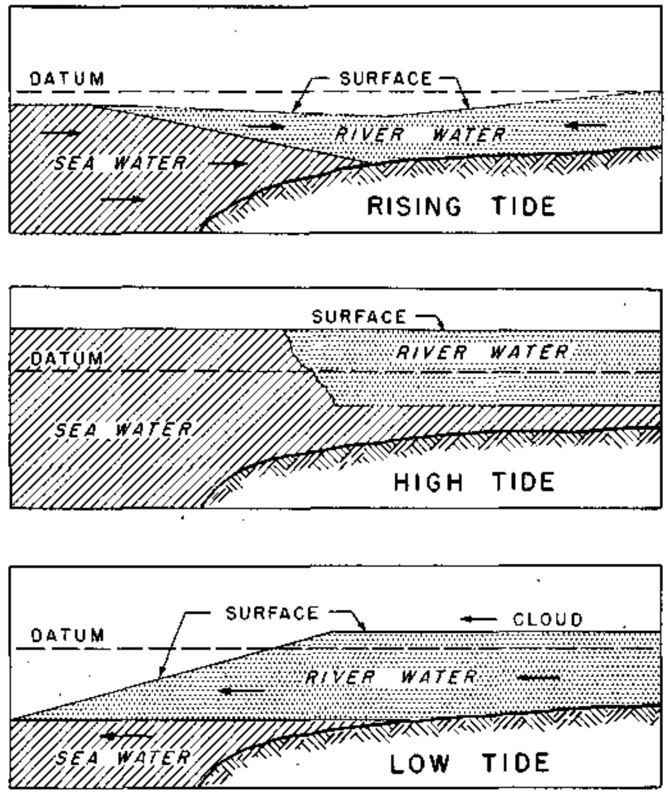


Figure 52. Cross Section of Fraser River Estuary Movements at Tide Stages

The stage of the tide has a direct effect on the rate of discharge of Fraser River to Strait of Georgia. During spring tides, sea water flows upstream, under the fresh river water on rising tides, and, by raising the level of the river, causes an accumulation of fresh water upstream. As the tide falls, the accumulated runoff is released to Strait of Georgia.

Figure 53 shows diagrammatically the water mass movements from the main Fraser River during periods of midsummer flows and spring tides. A surface cloud of relatively fresh water, shown as "A" on Figure 53, forms during a falling tide at the river mouth. As the tide continues to fall, the cloud grows in size and at low tide occupies a large area offshore from the river mouth. The rising tide in the Strait of Georgia moves northward as well as shoreward and, as the tide rises, the cloud is separated from the river mouth and is moved rapidly northward. At high tide, a portion of the cloud lies on Sturgeon Bank as shown by "A" on the figure. The remainder of the cloud, "A-1", extending northwestward, mixes with the waters of the Strait

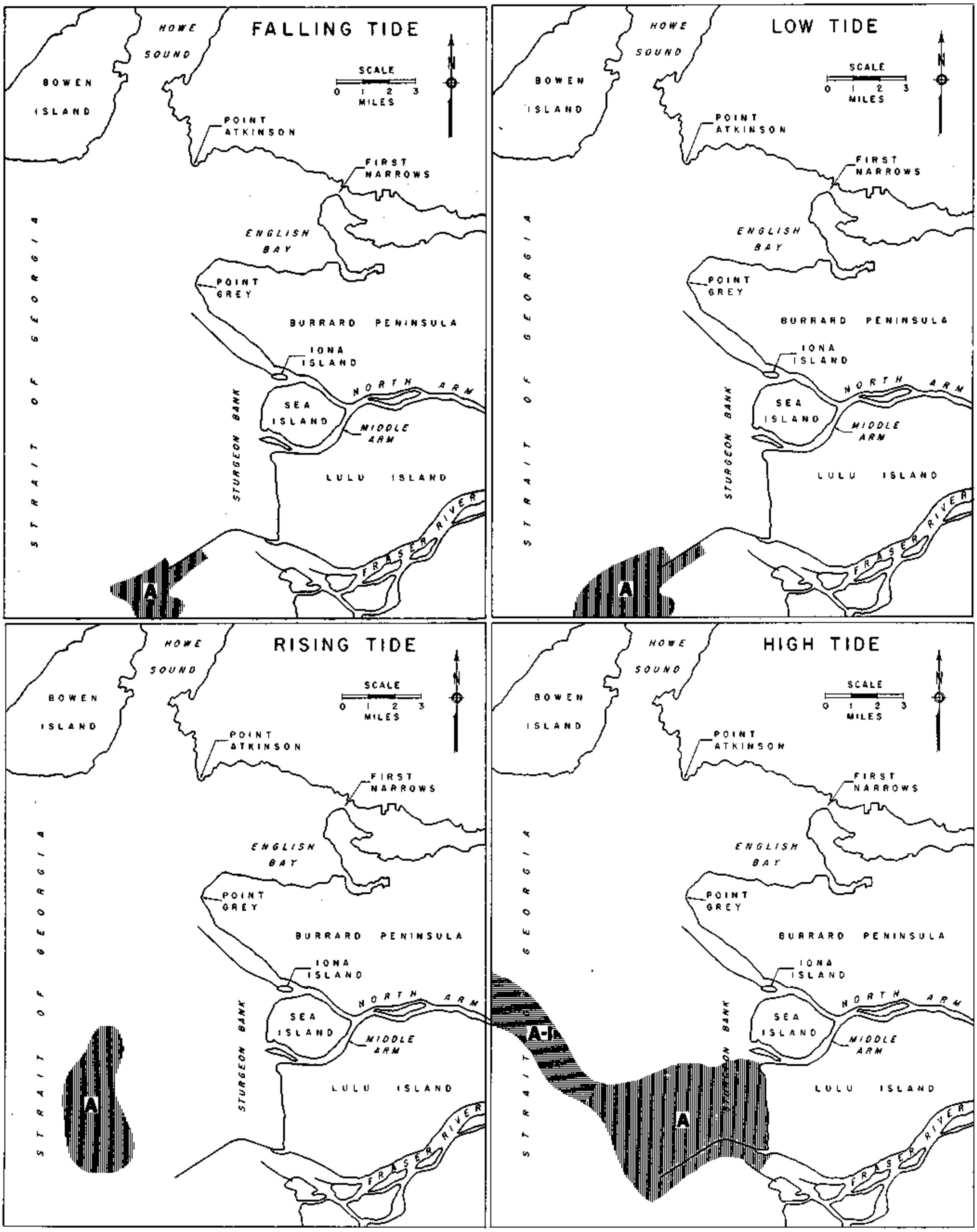


Figure 53. Water Mass Movements in the Fraser River Estuary During Successive Tidal Stages

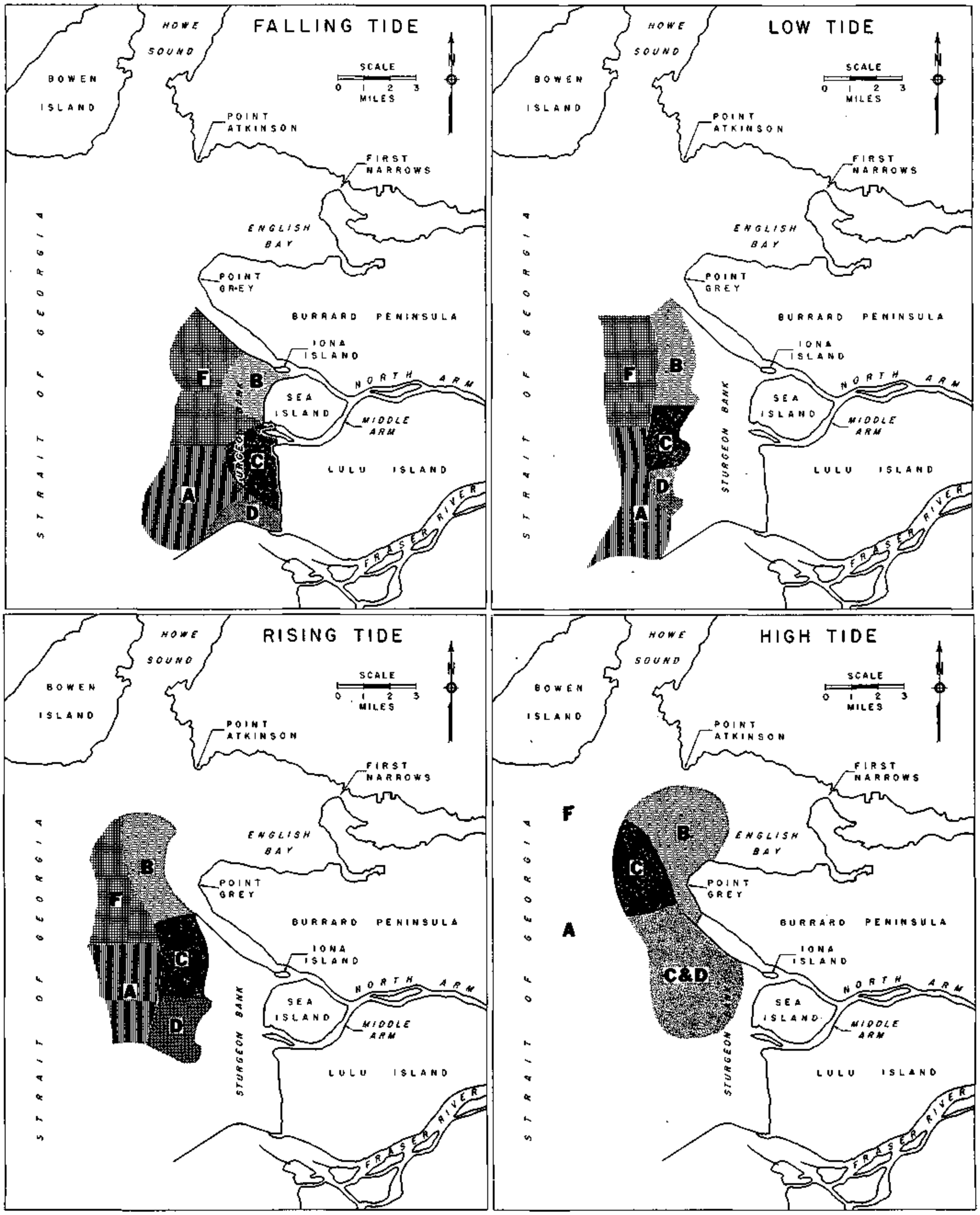
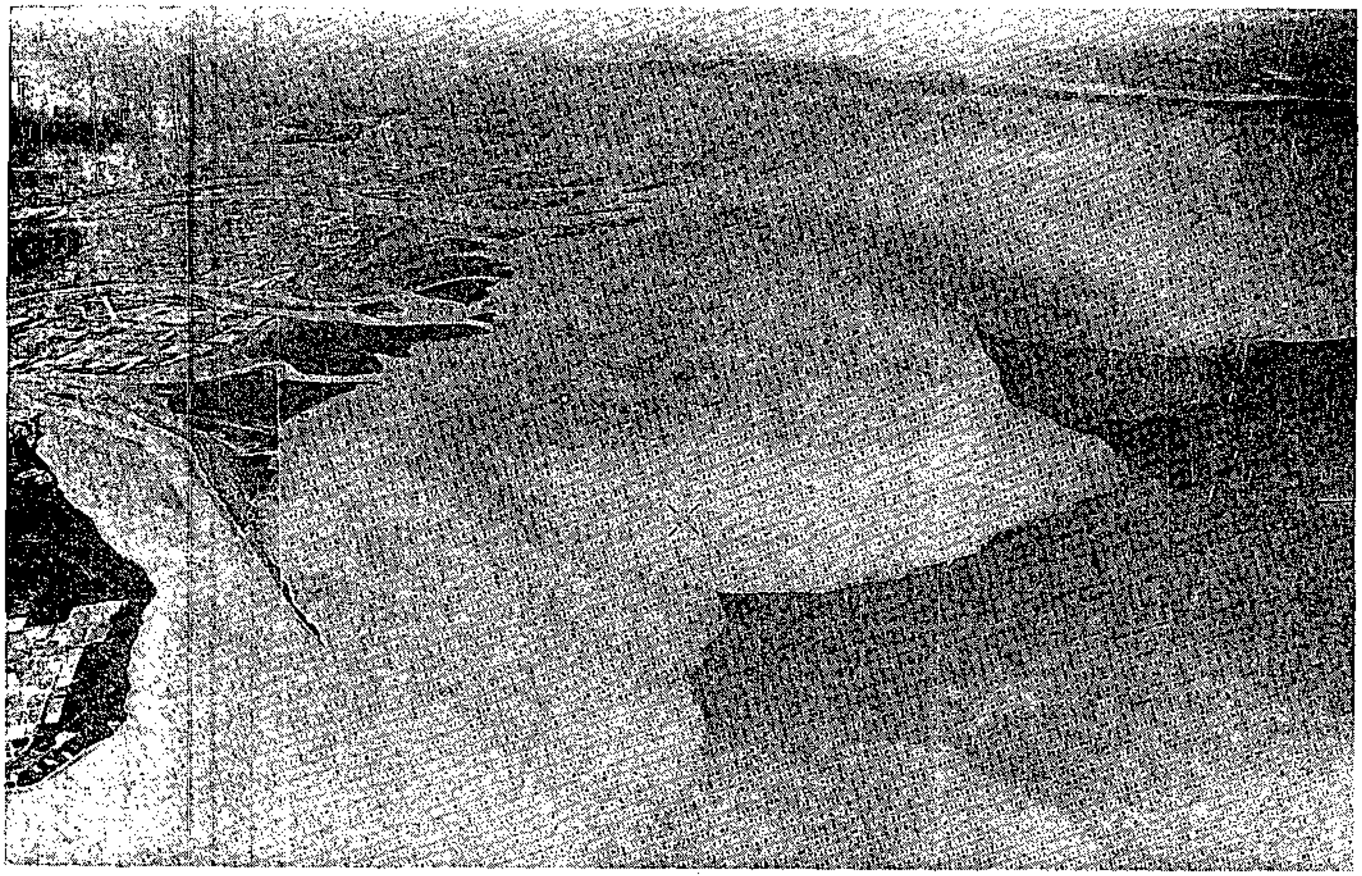


Figure 54. Water Mass Movements on Sturgeon Bank During Successive Tidal Stages

of Georgia and moves out of the area of consideration on the next ebb tide. During the tidal cycle, the river water, "A", has mixed with underlying sea water and the salinity of the cloud has increased.

During periods of maximum runoff in Fraser River, a second phenomenon occurs in the flow of river water into the Strait of Georgia. At these times, the elevation of the water surface in the river is always higher than the elevation of the water surface in the Strait of Georgia. Consequently, the flow of river water into the strait continues throughout the tidal cycle. At these times, the upper layer of turbid river water is a continuous chain of connected clouds passing out from the river mouth to be moved by the tidal currents. Although the discharge of river water to the strait is continuous under these conditions, the rate of discharge varies with the tide, being greatest during ebb tides and least during flood tides.

Sturgeon Bank. As shown on Figure 54, there are five water masses on Sturgeon Bank as the tide starts falling. These are: brackish water, "A", which has moved onto the bank on the previous rising tide from the main channel discharge of Fraser River; fresh water, "B", from Macdonald Slough; fresh water, "C", from the Middle Arm of Fraser River; fresh water, "D", spilled over the jetty from Fraser River on the last of the previous high tide; and brackish water, "F", which originated at "C" and "D" on the previous tidal cycle. These water masses all move seaward as the tide falls and are accelerated by the outflow of the river and its distributaries. At low tide, Sturgeon Bank is drained and the three masses, "B", "C" and "D", lie off their respective channels in the deep water at



Photograph by B. C. Lands and Forests Dept.

Figure 55. Water Masses on Sturgeon Bank

Clouds of fresh river water from Fraser River and its distributaries are discharged to Strait of Georgia on falling tides. Figure 54 shows these water masses diagrammatically.

the edge of the bank. The brackish water masses, "A" and "F", are farther seaward and have become more saline by mixing with the underlying sea water. With the rising tide, all the masses move rapidly northward and undergo mixing and dilution with underlying sea water. The movement is directed toward Howe Sound and is held away from Point Grey and English Bay by the water mass from the North Arm. At high tide, part of the Macdonald Slough water, "B", is in the entrance to English Bay and part has been carried up the North Arm as the reversal of flow occurred. Water from the Middle Arm, "C", and main Fraser, "D", has returned to Sturgeon Bank. Brackish water, "A", lies well offshore and now, two tidal cycles after having been discharged from Fraser River, has almost lost its identity. The brackish water, "F", which originated at "C" and "D" two tidal cycles previously is now west of the entrance to English Bay and is well mixed with sea water.

North Arm. As shown on Figure 56, fresh water, "G", emerges from the North Arm as the tide starts falling and spreads northward and eastward around Point Grey to overlie the southern foreshore. Included in this mass is a portion of Sturgeon Bank water which intruded the North Arm through Macdonald Slough on the previous flood tide. At low tide the water mass, which had accumulated upstream in the North Arm during the previous high tide, extends almost as far northward as Howe Sound. This serves to keep water from Sturgeon Bank seaward of the shore and English Bay. As the tide rises, the first portion of the North Arm discharge, "G-1", is separated from the main mass by the intrusion of water flowing southwestward from Point Atkinson. This portion, "G-1", moves out of the area of consideration, but the main portion of the North Arm discharge moves into English Bay. At high tide, the water mass, "G", has almost entirely entered Vancouver Harbour. That portion which has not entered the harbour leaves English Bay on the following ebb and together with the mass, "G-1", are the only portions of the North Arm discharge to move out of the area of consideration in one tidal cycle.

English Bay. The circulation of surface water within English Bay as determined from results of aerial surveys and direct current measurements is shown on Figure 57. These methods permit a more detailed determination of position of various water masses than is obtainable from the synoptic surveys. During falling tide, the cloud of water from the North Arm, "G", moves northward and eastward around Point Grey and occupies all of the southern foreshore. At the same time, tidal water ebbing from False Creek flows along Kitsilano and Second Beaches towards Stanley Park, while water from Vancouver Harbour, "H", flows outward through First Narrows. The velocity of flow through First Narrows is high, at times approaching 5 knots, or nearly 6 miles per hour, along the north shore. Towards the last of the ebb, flow along the southern shore slackens, becomes weak and variable, and tends to reverse so as to cause a seaward flow along the south shore. This water moves underneath the fresher water from the North Arm because of its greater salinity and density. New North Arm water continues to advance as a surface layer around Point Grey into English Bay. At low tide, the westward movement along the south shore ceases. The volume of False Creek water in the bay is a maximum and now lies along Kitsilano and Second Beaches. The ebb stream from Vancouver Harbour continues to move seaward along the north shore although it loses some water to an anti-clockwise eddy in the middle of the bay.

During rising tide, conditions change rapidly. The North Arm cloud moves toward First Narrows, spreading over Spanish Bank and Locarno Beach. A part of the water which was along Jericho and Kitsilano Beaches enters False Creek following that portion of the False Creek water which had moved into the corner of English Bay toward the end of the previous ebb tide. The portion of False Creek water which had moved northward on the ebb now enters Vancouver Harbour in front of the North Arm cloud and behind the last of the ebb discharge from

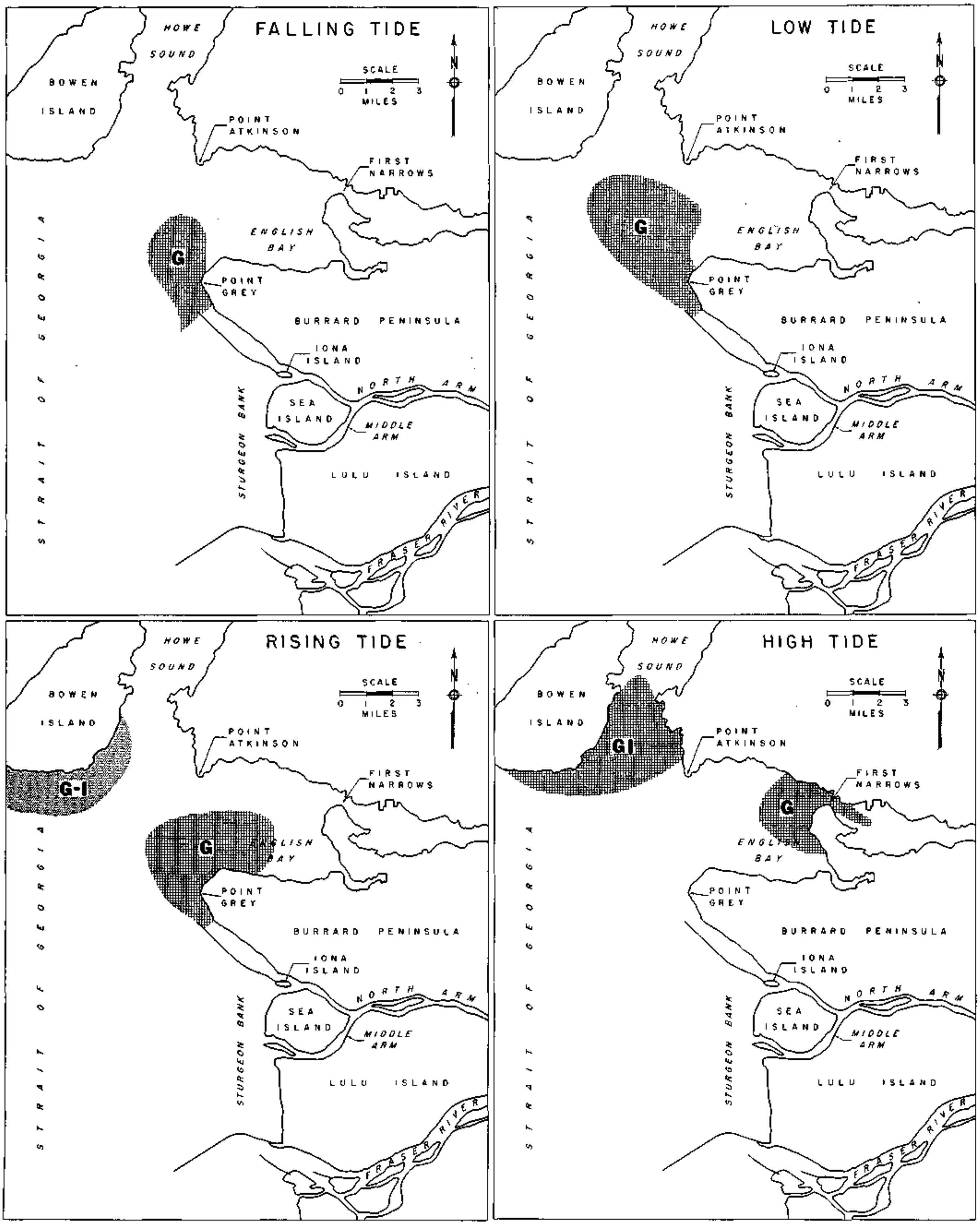


Figure 56. Water Mass Movements from North Arm of Fraser River During Successive Tidal Stages

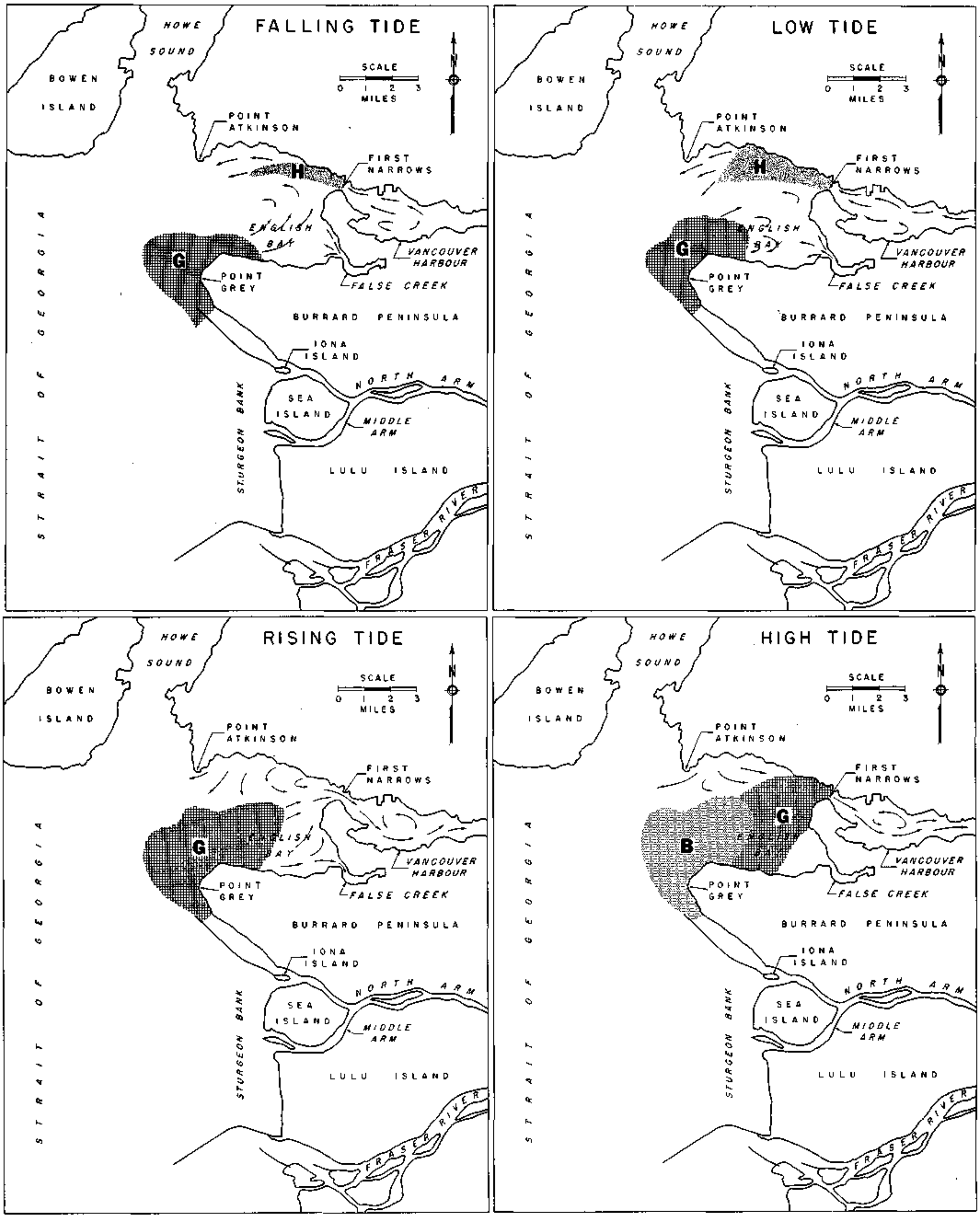


Figure 57. Water Mass Movements in English Bay, False Creek and Vancouver Harbour During Successive Tidal Stages

First Narrows. The main stream of Vancouver Harbour water, discharged through First Narrows on the ebb tide, continues to flow westward along the north shore of English Bay. A portion of this water mass moves into the anti-clockwise eddy in the middle of the bay which persists until the last of the tidal rise.

At high tide, the North Arm water lies along the south and east shores of English Bay enclosing residual water in the southeast corner of the bay along the beaches near False Creek. Water from Vancouver Harbour lies along the north shore and water discharged from Sturgeon Bank during the previous ebb is now in the entrance to English Bay.

The Sturgeon Bank water, which is in the entrance of English Bay at high tide, recedes seaward on the falling tide and moves out of the area of consideration. The net movement during the tidal cycle has been a slight anti-clockwise progress around English Bay. With the exception of the Sturgeon Bank water, the only water which has moved out of the area has been that portion of the water discharged from Vancouver Harbour on the ebb tide which has moved seaward of Point Atkinson.

Vancouver Harbour. Figure 57 shows diagrammatically the general nature of the circulation in Vancouver Harbour. It is clearly established that, in the area between Brockton Point and Terminal Dock, the currents tend to circulate anti-clockwise on both rising and falling tides, On falling tides, the main water mass movement in the harbour is westward in the central and northern parts. A weak eddy forms along the southern shore. On a rising tide, the main water mass movement is from Brockton Point toward the Canadian National dock. The current along the north shore, after a period of varying velocity and direction, forms an eddy and continues to set westward until it rejoins the main stream in the region opposite Brockton Point.

Within the harbour, the strongest currents occur from one to two hours after maximum flood. The current may reach two knots setting eastward offshore from the Canadian National dock and one knot setting westward along the north shore.

Variations in Water Mass Movements

During tides of small amplitude, the main difference in the movements above described for various water masses would be in the distance of transport per tidal cycle. The anti-clockwise movement in English Bay would be less rapid. It is doubtful if Sturgeon Bank water ever intrudes English Bay on the lower velocities associated with tides of small range.

When Fraser River is in freshet, the seaward flow in the North Arm does not reverse during flood tide and the discharge velocity is high. The main discharge is directed towards Bowen Island rather than around Point Grey. The direction and quantity of the North Arm discharge effectively prevents the intrusion of water from Sturgeon Bank to English Bay. The larger quantities of fresh water released to the system increase the displacement per tidal cycle and the net transport throughout the entire system. Because of increased lateral dispersion of the North Arm discharge, however, a larger quantity enters English Bay at freshet time than during lower river flows.

When the Fraser River discharge is low in late summer, the North Arm discharge is affected by the tide to a greater extent than has been described. Its waters move into English Bay and do not provide any barrier against the intrusion of water from Sturgeon Bank. The net transport over a tidal cycle during this time is considerably less than during the higher river flows and a longer period of time is required for Sturgeon Bank water to reach English Bay.

Direct Current Measurements

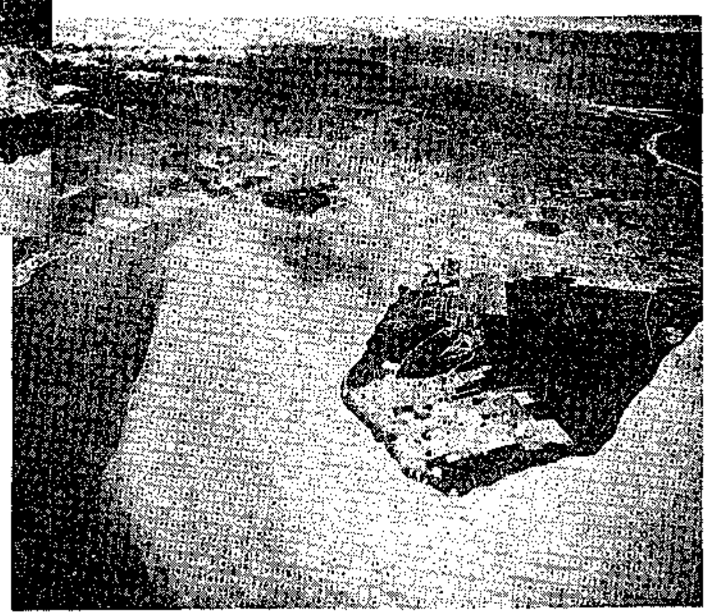
Observation of current velocities and directions by means of floats was conducted by the Vancouver and Districts Joint Sewerage and Drainage Board intermittently over a number of years. The results of these float surveys were studied in detail as a part of the preparation of the report on "The Oceanographic

As shown at left, the surface cloud of North Arm water forms off Point Grey on a falling tide and a portion overlies the southern foreshore of English Bay.

As shown below, the cloud has moved northward at low tide and covers almost the entire entrance to English Bay and has penetrated eastward along the south shore.

As shown above the cloud moves eastward on a rising tide and occupies all of the south portion of the bay.

As shown at right, the cloud starts to pass through First Narrows into Vancouver Harbour with high tide. This series of photographs was taken in June 1950 as a part of the Fraser River Estuary Project.



Photographs by B. C. Lands and Forests Dept.

Figure 58. Water Masses in English Bay

Phase of the Vancouver Sewage Problem."

Table 28 shows the number of days of float observations which were made by the Vancouver and Districts Joint Sewerage and Drainage Board from 1927 to 1950 at various locations in the area. As shown in the table, there have been 166 individual days of observations. A complete tabulation of all the float surveys has been made as a part of the Fraser River Estuary Project and is included in the data record of that project.

Because the float study results are recorded elsewhere and because the results indicate that the currents vary from season to season depending primarily on the seasonal variation in Fraser River flow, it has been deemed appropriate to present in this report only typical or representative float paths observed during 1950.

Figure 59 shows the type of float used for measuring surface and subsurface currents. The floats were released and allowed to drift with the current as long as they remained within the area under observation. Floats were approached periodically and their positions determined by taking double sextant angles on shore control points and plotting on specially prepared boat sheets. For the most part, positions were determined at approximately hourly intervals, although at times, when a large number of floats was being maintained in the water or when the floats became widely dispersed, the time interval was considerably greater.

Figures 60 through 66 show representative float paths observed each month from March through September, 1950. In addition, each figure includes the tidal curve for each day for which float movements are shown and the variation in Fraser River discharge for the month.

Table 28

Direct Current Measurements
Vancouver and Districts
Joint Sewerage and Drainage Board

	Days of Observations						
Month	1927	1929	1941	1945	1949	1950	Total
March						5	5
April						4	4
May						12	12
June				8	3	15	26
July		2		17	8	13	40
August	2		9	3	9	10	33
September	14		5	3	4	2	28
October	10	1					11
November					2		2
December					5		5
Total	26	3	14	31	31	61	166

Observations made in English Bay in all years listed.

Observations made in North Arm of Fraser River in 1929, 1941, and 1950.

Observations made in Vancouver Harbour in 1945, 1949, and 1950.

Observations made in Fraser River estuary in 1950.

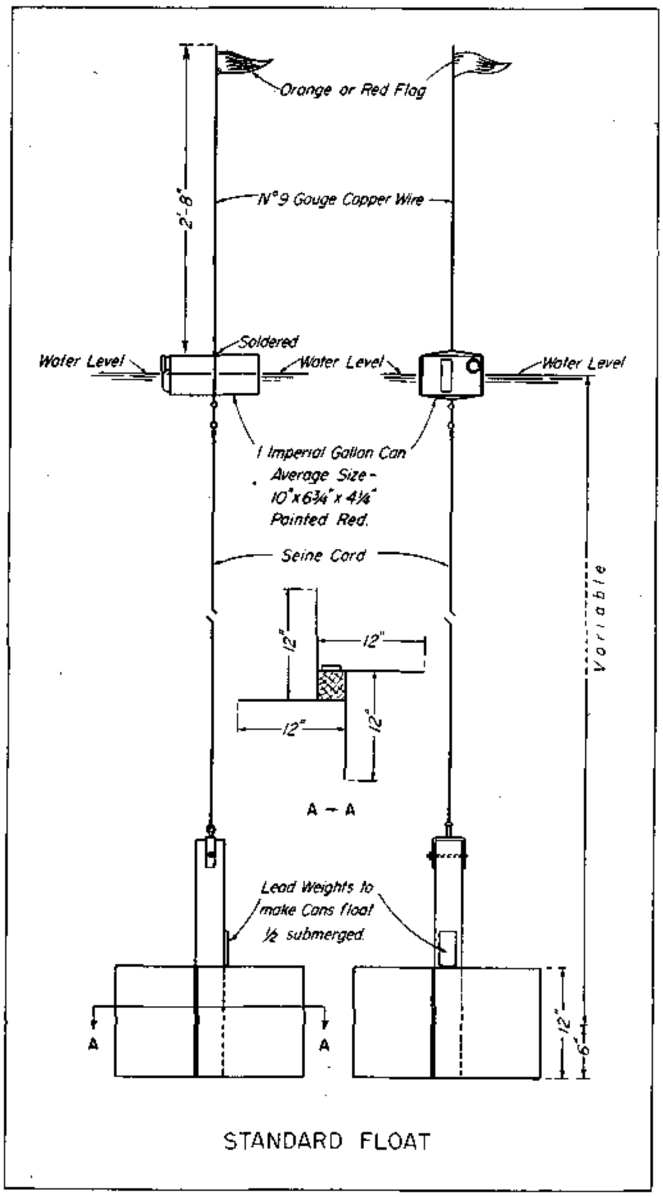
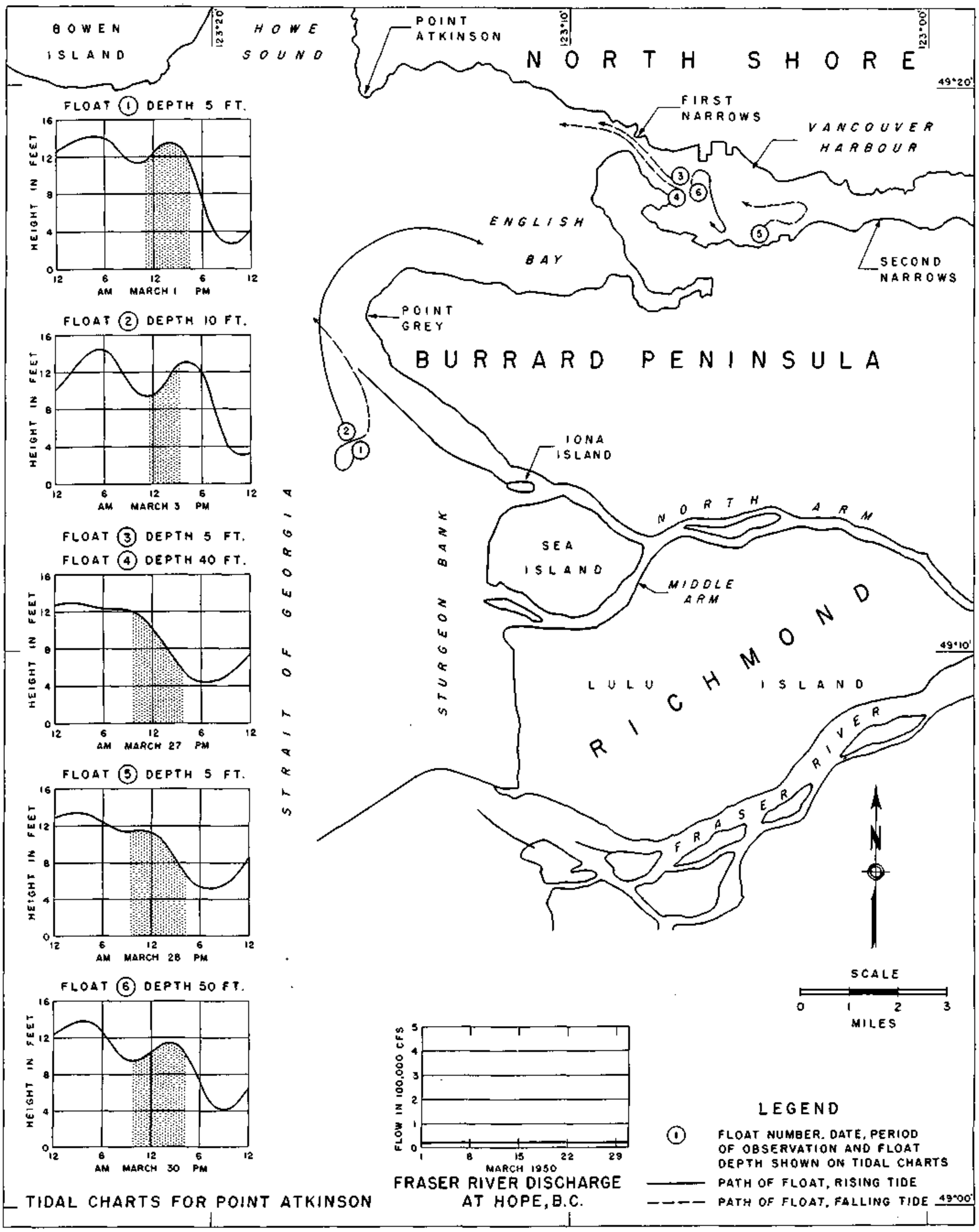


Figure 59. Floats Used in Current Studies

The study of surface and sub-surface currents in the Greater Vancouver Area was accomplished by using floats which were allowed to drift with the current.



Figure, 60. Currents in Vancouver Harbour, English Bay, and North Arm of Fraser River March 1950

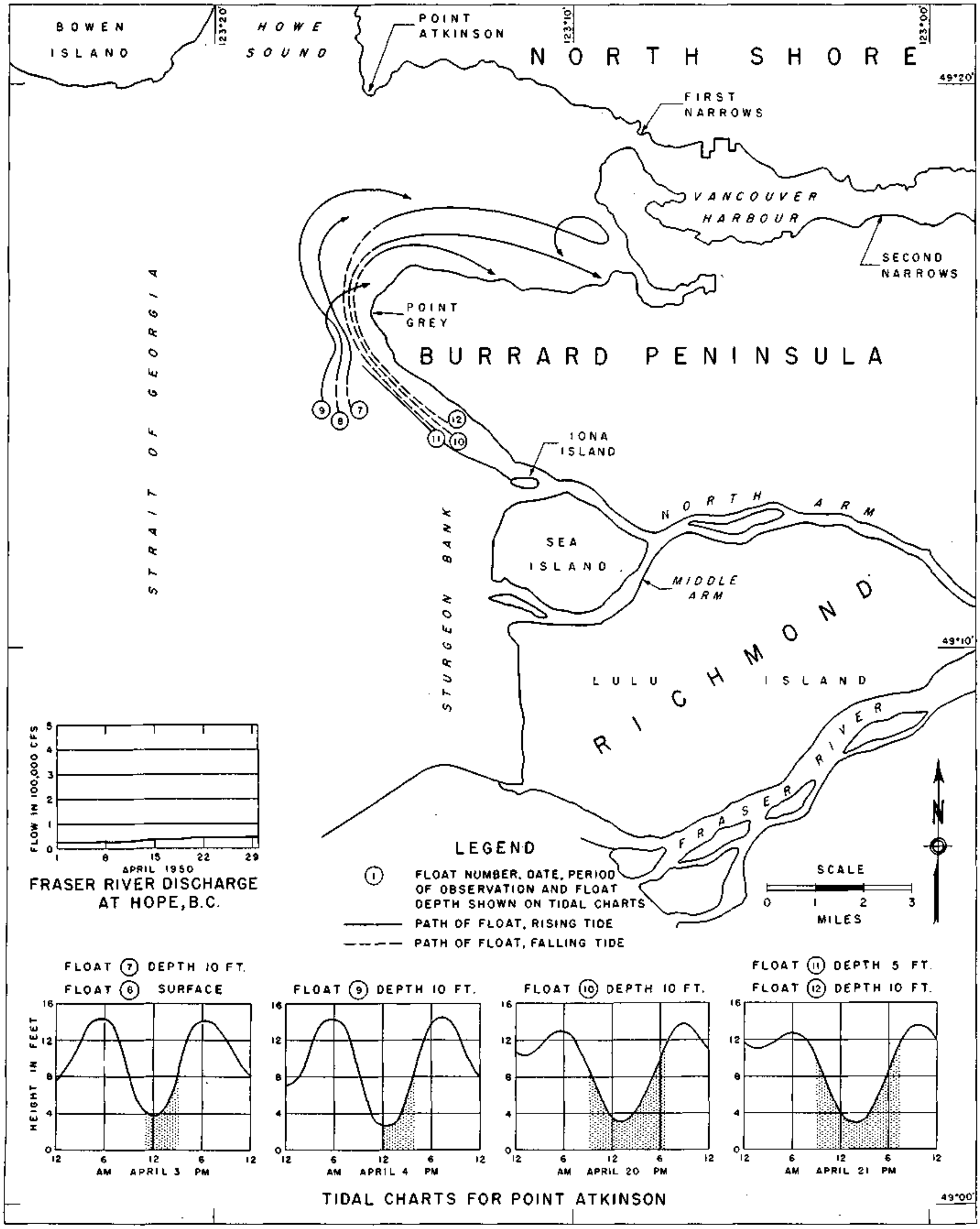


Figure 61. Currents in English Bay and North Arm of Fraser River April 1950

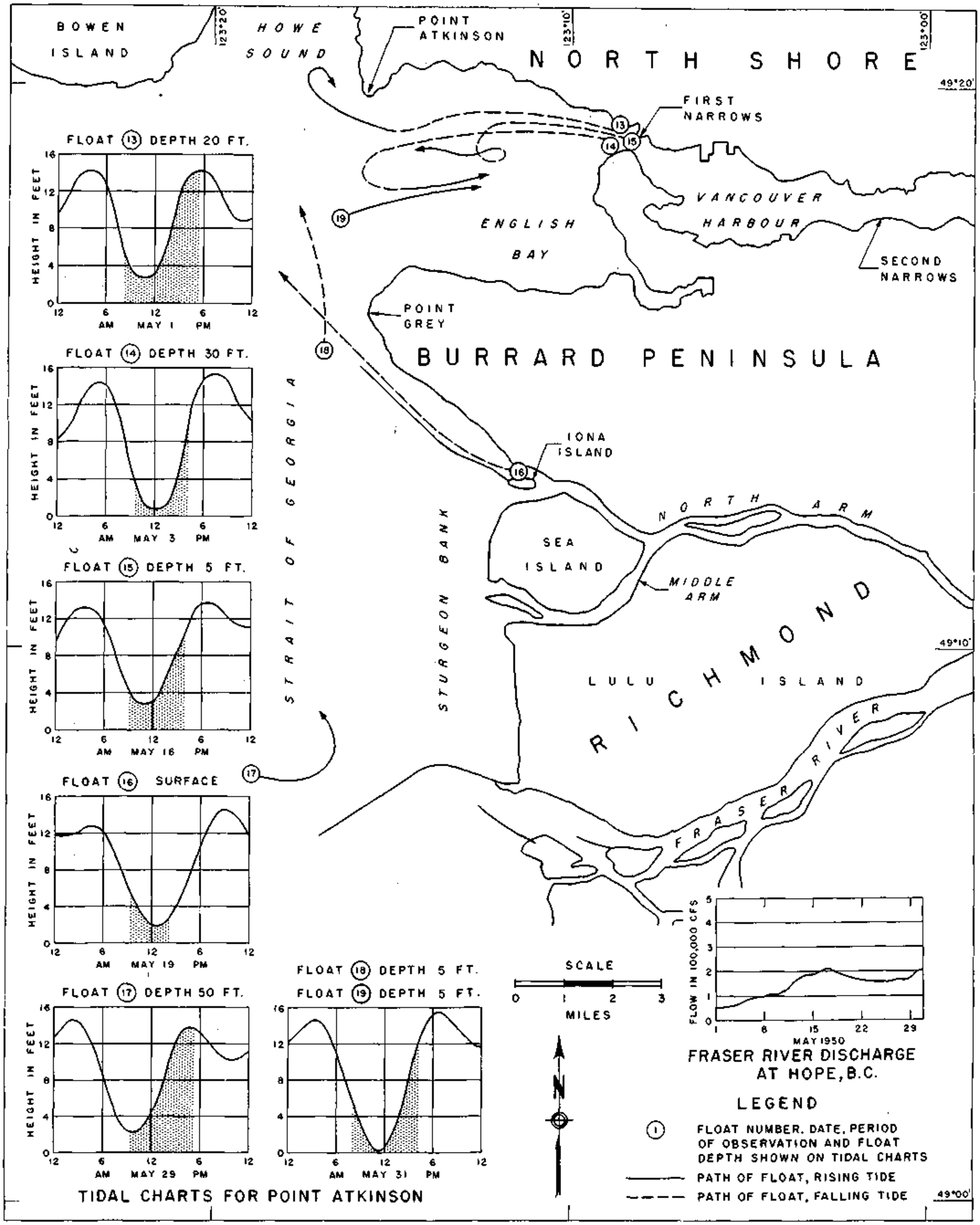


Figure 62. Currents in English Bay, North Arm of Fraser River and Fraser River Estuary May 1950

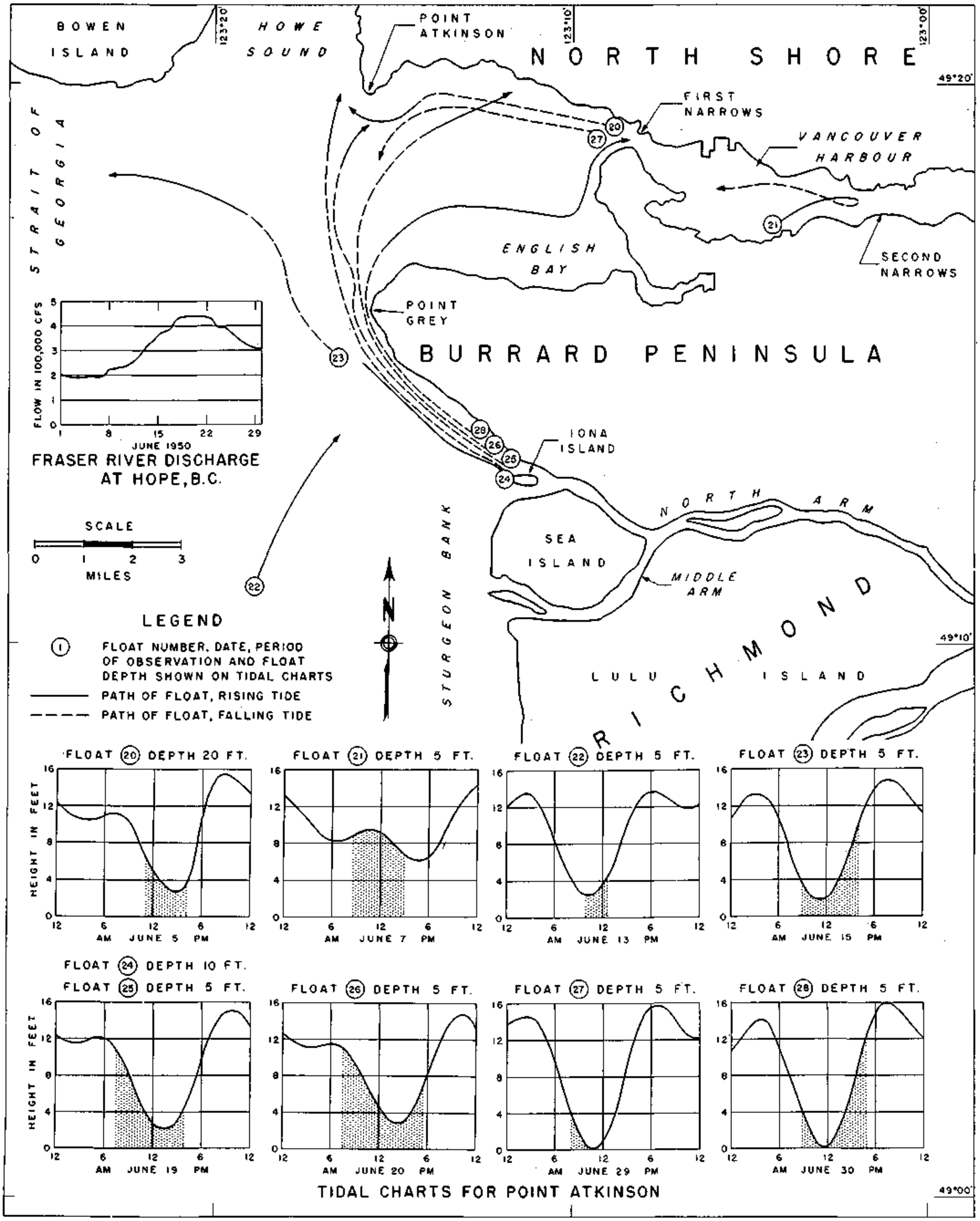


Figure 63. Currents in Vancouver Harbour, English Bay, North Arm of Fraser River and Fraser River Estuary, June 1950

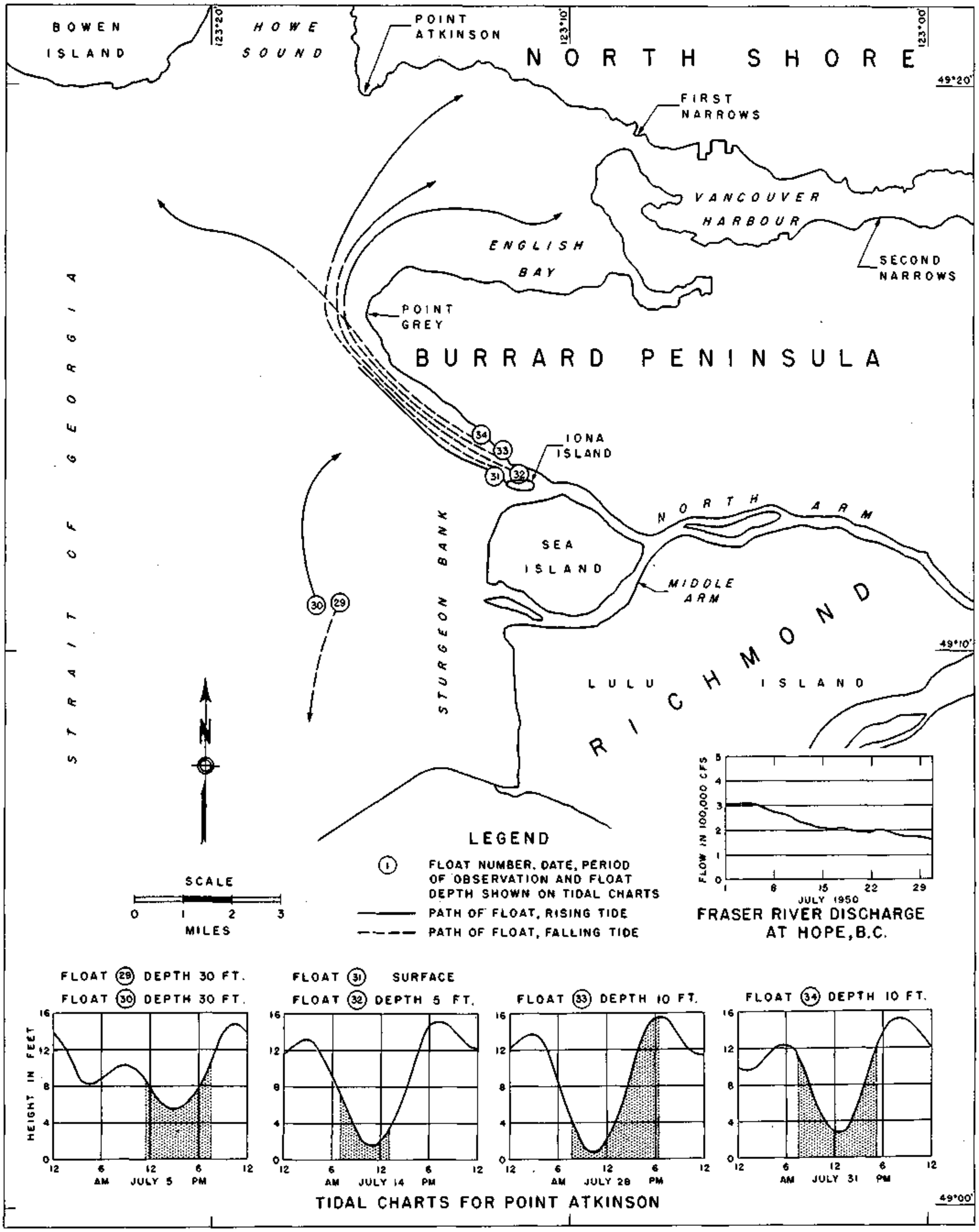


Figure 64. Currents in English Bay. North Arm of Fraser River and Fraser River Estuary July 1950

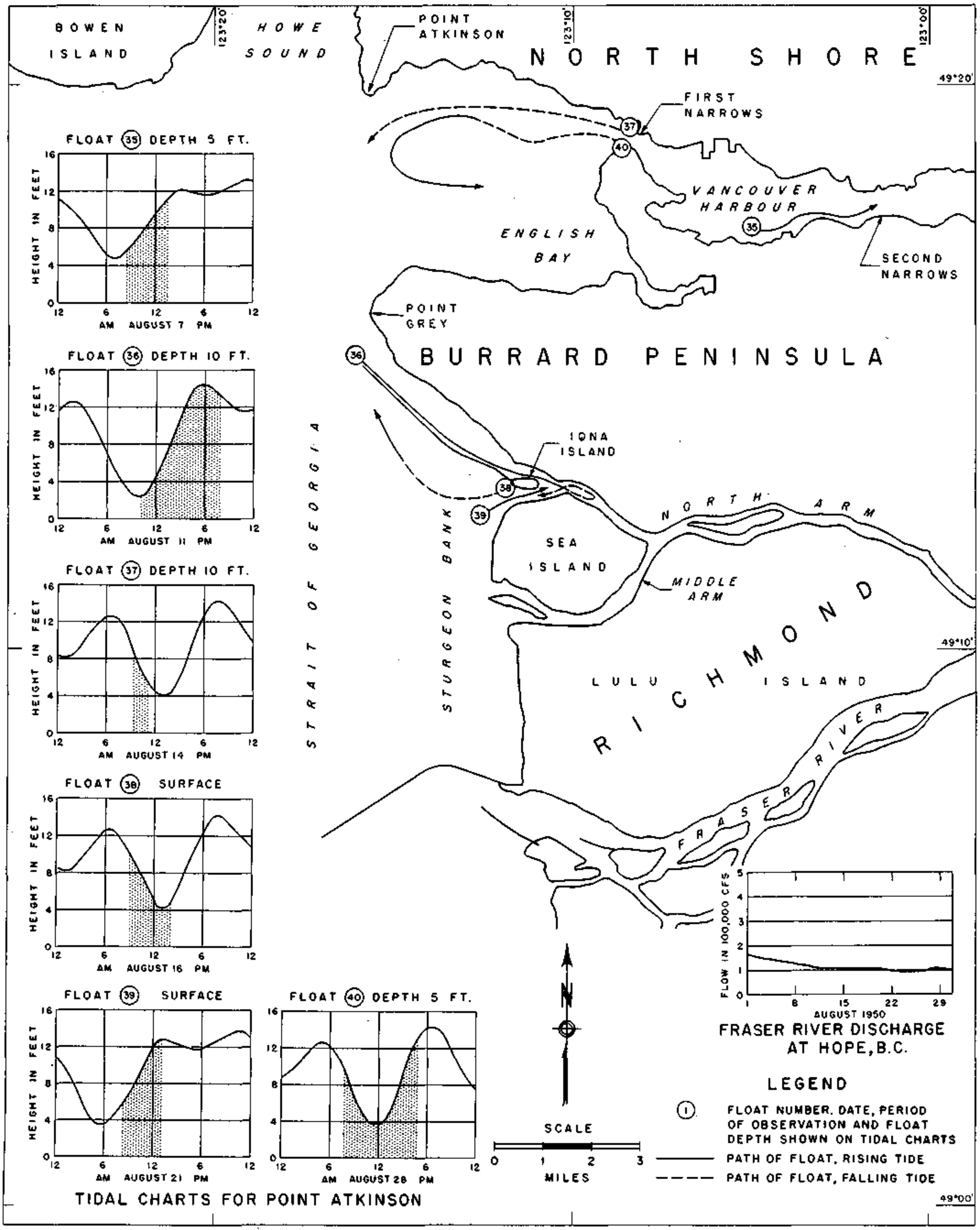


Figure 65. Currents in Vancouver Harbour, English Bay, and North Arm of Fraser River August 1950

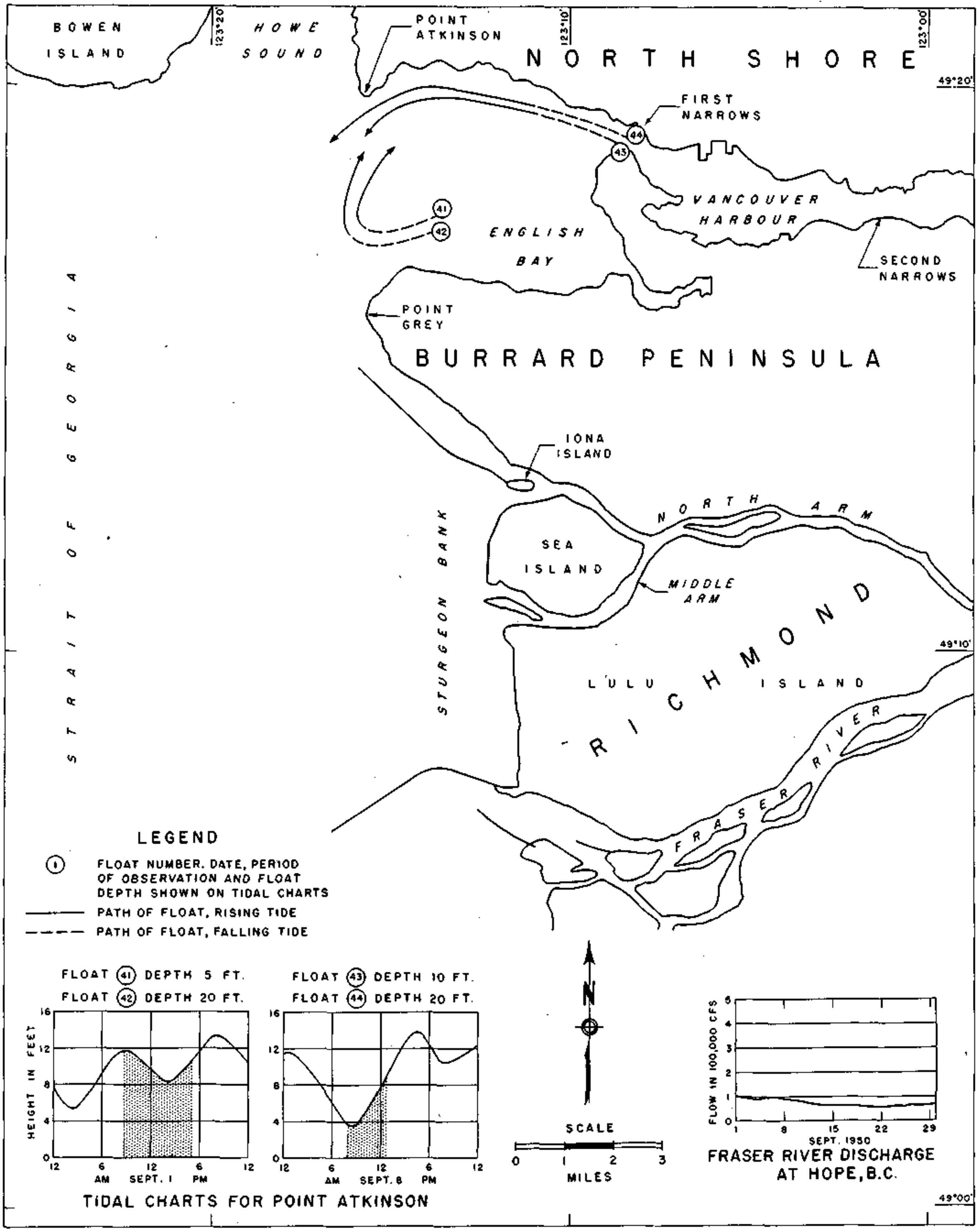


Figure 66. Currents in English Bay
September 1950

The directions of observed currents as indicated on these figures generally confirm the water mass movements described earlier in this chapter for the waters of the main channel of Fraser River, Sturgeon Bank, the North Arm and English Bay.

Selection of Outfall Sites

The extent of the area occupied by sewage or sewage effluent discharged to tidal waters is determined not only by the initial dilution which obtains when the sewage-sea water mixture reaches the surface but also by the surface currents. The possibility of contamination of beaches or recreational waters by sewage must be examined in the light of all available oceanographic information. The previous section of this chapter has set forth a description of the movements of surface water masses as determined by synoptic surveys, aerial photographs and direct current measurements with free floats and current meters. The movements have been discussed for what may be called the midsummer period and the effects due to changes in river discharge and tidal amplitude have been stated.

The selection of possible sites for outfalls must recognize and be governed not only by the conditions existing in the receiving waters but also by the topography of the land areas, the distribution of population at present and in the predicted future, and the relative economies between various locations at which the sewage of a given tributary area may be collected for ultimate disposal. It is necessary, therefore, to determine the degree of treatment which would be required prior to discharge to various bodies of receiving waters in order that the relative economies of the sewerage plans may be determined.

Degree of Treatment Required

The quantity of sewage discharged has a direct bearing on the extent of the area which will be occupied by the sewage-sea water mixture in concentrations which might represent potential contamination. The quantities of sewage which might be discharged to tidal waters of the area are presented in Chapters 14, 15 and 16. Table 29 presents a summary of these average sewage flows which are predicted for the time when the tributary areas have reached maximum development. The flows are grouped according to possible location of outfall.

Table 29

Possible Sewage Discharges to Tidal Waters

Location of Outfall[a]	Average Sewage Flow[b] cfs
Sturgeon Bank	130
English Bay North Shore	8
First Narrows	26
Vancouver Harbour North Shore	18
Burrard Inlet East portion	4

a See Chapters 14, 15 and 16.
b Predicted ultimate sanitary flow.

Main Fraser River. As discussed previously and as shown in Figures 53 and 54, a portion of the water discharged from the main channel of Fraser River requires two tidal cycles to reach the entrance of English Bay. The remainder of the discharge from the Fraser is carried into the Strait of Georgia.

It will be possible to discharge sewage in the main channel of the Fraser River without any treatment. A proper outfall should extend far enough from shore to reach the deep channel where satisfactory velocities occur. It should include a number of outlets to provide the greatest possible initial surface dilution. By the time the sewage-sea water mixture reaches any recreational area, the dilution would be so great that no contamination or nuisance would result.

Sturgeon Bank. As shown on Figure 54, a portion of the water on Sturgeon Bank is carried by a rising tide into the North Arm through Macdonald Slough between Iona and Sea Islands. On a falling tide, this water moves down the North Arm, around Point Grey, and into English Bay. The remainder of the water which covers Sturgeon Bank on a rising tide moves offshore and northward as the tide falls. During most of the summer months, the flow from the North Arm is sufficient to prevent this water from entering English Bay. When river flow is low in late summer, some Sturgeon Bank water may intrude into English Bay. Because of the lower net transport at these times, however, the elapsed time of movement from Sturgeon Bank to English Bay is much greater than during periods of high flow in the North Arm.

It would be possible to discharge effluent from a high-rate primary treatment plant to Sturgeon Bank if a dam were constructed across Macdonald Slough to prevent any back flow to the North Arm. To provide for periods of low tide when large portions of Sturgeon Bank are exposed, it would be necessary to construct a channel across the bank to deep water.

North Arm. As shown on Figures 56 and 57, water discharged from the North Arm sweeps around Point Grey and into English Bay on falling tides. A portion of this water overlies the beaches along the southern shore and the remainder is carried into Vancouver Harbour. Because of the short time during which the effluent could mix with sea water, sewage discharged into the North Arm near its mouth would require secondary treatment such as would be provided by a high-rate trickling filter treatment plant. This plant would have to treat all sewage delivered to it, including the combined flow of domestic sewage and storm water during specified periods of rainfall. In addition, it would probably be necessary to chlorinate the plant effluent during such critical periods as might obtain when the waters of English Bay are used for recreational purposes.

English Bay. As shown on Figure 57, the movement of water in English Bay is anti-clockwise. The movement is generally eastward along the southern shore and westward along the northern shore. During rising tides, water from the south shore moves into Vancouver Harbour before reaching the north shore, while water along the north shore leaves the system seaward of Point Atkinson. Sewage discharged into the southern portion of the bay would require secondary treatment, such as that provided by the activated sludge process, and effluent chlorination would be necessary during critical periods. In addition, this plant would have to treat all sewage delivered to it, including the combined flow of domestic sewage and storm water during specified periods of rainfall. Because of the net movement seaward and consequent quicker removal of the sewage - sea water mixture, sewage discharged into the northern portion of the bay would not require as high a degree of treatment as that required for the southern portion. Effluent from a standard-rate primary treatment plant, chlorinated during critical periods, would be suitable for discharge into these waters. The depths at which it is possible to discharge sewage effluent along the north shore, the rapid currents which exist, and the fact that water from this zone leaves the system on each tidal cycle combine to make this degree of treatment sufficient. At certain locations along the western portion of the north shore of English Bay, it would be possible, without offense or unsanitary results, to discharge relatively small quantities of crude sewage through outfalls extending into deep water.

Vancouver Harbour. As shown on Figure 57, the movement of water within Vancouver Harbour is similar to that in English Bay and is anti-clockwise. Water enters the harbour from the southern part of English Bay and is discharged into the northern part after having made a circuit of the harbour. Sewage would require at least standard-rate primary treatment prior to discharge into the harbour. Effluent chlorination would be necessary during critical periods.

East Portion - Burrard Inlet. No studies of water mass movements were conducted in conjunction with this survey in the waters of Burrard Inlet east of the Second Narrows. Because of the relatively small quantities of sewage which will be produced in areas tributary to these waters and because it is possible to reach deep water with relatively short outfalls, it is anticipated that crude sewage may be discharged to the waters east of the Second Narrows.

DISPOSAL TO RIVER WATERS

Controlling Factors

Fraser River, one of the largest on the Pacific slope of the North American continent, passes through the Greater Vancouver Area and discharges into the Strait of Georgia. Numerous smaller rivers, namely, Capilano, Seymour, Coquitlam, Pitt and Brunette, also traverse the area. The topography of the land, the extent and distribution of population, and the general feasibility of various sewage collection systems indicate that sewage or sewage effluent might be discharged to Fraser River, its North Arm, or to Burnaby Lake which is tributary to Brunette River. It is necessary to evaluate and study the various conditions which control the degree of treatment required for proper disposal to these waters.

The ability of the rivers within the Greater Vancouver Area to receive sewage without unsanitary and obnoxious results is directly related to the rate of flow and to the concentration of dissolved oxygen present, as well as to the quantity and composition of sewage involved and to the upstream and downstream uses of the river.

The factors which control the ability of a river to receive sewage are:

1. Sufficient volume to dilute materials of sewage origin.
2. Sufficient velocity to prevent deposition and formation of sludge banks.
3. Sufficient dissolved oxygen to satisfy the organic demand of the sewage and sustain fish and other aquatic life.

The solubility of oxygen in water varies inversely with its temperature; thus, greater amounts may be dissolved in cold water than in warm. The concentration of dissolved oxygen is also affected by the oxygen demand of organic material contained in the water. Upstream uses may limit or reduce the amount of oxygen available for oxidizing sewage. Downstream uses for such purposes as water supply, recreation, irrigation, or industry could well determine the degree of treatment necessary prior to discharge. Obviously, sewage discharged to a river with insufficient oxygen resources or with important downstream uses would require a higher degree of treatment than would sewage discharged to a river with an excess of available dissolved oxygen and with downstream uses which would be unaffected by sewage discharges.

Data Available to Survey

To evaluate the capacity of river waters to receive sewage within the Greater Vancouver Area, use was made of all available sources of information relative to river flows, dissolved oxygen concentrations, and water temperatures. These data are contained in published reports of various agencies. In addition, special studies were conducted for purposes of this survey on the Fraser River Model of the National Research Council.

The studies conducted by the survey have attempted to define the most critical conditions of receiving capacity. Such conditions determine the degree of sewage treatment necessary to meet the objectives of sewage disposal presented earlier in this chapter.

River Flow

Fraser River flows are measured at Hope, British Columbia, about 90 miles upstream from the mouth of the river, by the Department of Resources and Development of Canada. Table 30 gives the mean monthly flows and the minimum average daily flow at Hope for each month of the 5 year period beginning October 1947 and ending September 1952. The lowest mean monthly flow of 18,400 cubic feet per second (cfs) occurred in March 1952, and the greatest mean monthly flow of 379,000 cfs occurred in June 1948. During this 5 year period the minimum daily flow was 17,500 cfs, the maximum daily flow was 536,000 cfs and the mean for the period 95,300 cfs. Figure 67 shows the variation of mean monthly flow.

For the purpose of estimating flows at various downstream locations, the Department of Resources and Development has determined factors to be applied to the recorded flows at Hope. These factors take into account the inflow to

Table 30

Mean Monthly and Minimum Daily Flows of Fraser River at Hope, B. C., 1947-1952

Month	Flow, cubic feet per second									
	1947-1948		1948-1949		1949-1950		1950-1951		1951-1952	
	Mean	Minimum	Mean	Minimum	Mean	Minimum	Mean	Minimum	Mean	Minimum
October	73,300	63,300	88,000	70,700	52,600	43,400	55,900	47,300	43,500	35,400
November	54,200	42,600	56,700	43,800	64,000	52,800	54,600	32,100	38,200	24,700
December	37,200	31,700	29,300	21,500	42,400	22,700	46,400	37,400	26,400	21,800
January	33,700	28,700	23,700	21,800	25,700	24,100	32,000	26,200	23,800	20,600
February	24,500	18,700	22,900	21,300	24,700	23,800	29,100	24,200	21,600	18,300
March	22,300	21,100	24,400	22,200	23,600	21,300	23,300	20,100	18,400	17,500
April	34,200	22,700	76,100	25,700	33,600	23,300	58,400	26,600	57,300	19,800
May	231,000	67,700	225,000	126,000	147,000	53,800	213,000	87,800	195,000	98,200
June	379,000	248,000	217,000	164,000	314,000	193,000	212,000	194,000	233,000	199,000
July	181,000	149,000	144,000	126,000	235,000	170,000	178,000	132,000	198,000	142,000
August	163,000	141,000	121,000	102,000	118,000	97,100	97,600	67,600	109,000	73,600
September	122,000	91,300	74,200	53,300	75,000	60,400	54,700	44,900	66,000	53,100
Year	113,000	18,700	92,300	21,300	96,500	21,300	88,400	20,100	86,100	17,500

Source: Water Resources Division of Department of Resources and Development of Canada.
Data for 1948-1952 are unpublished and subject to revision.

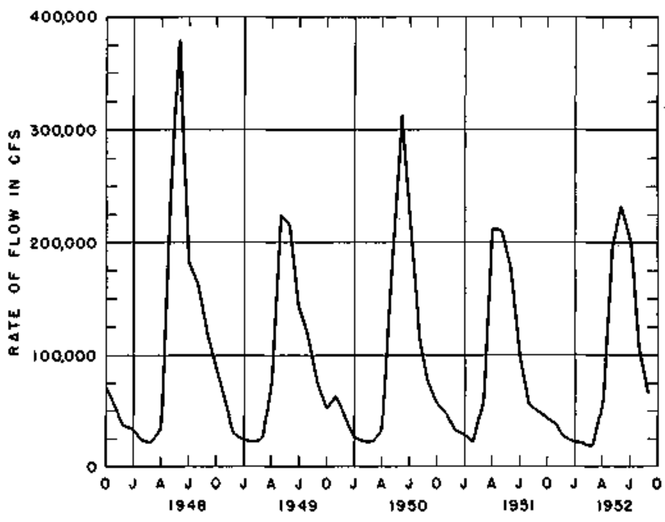


Figure 67. Mean Monthly Fraser River Flows at Hope, British Columbia, October 1946 to September 1952

Fraser River flows are measured at Hope, B. C., by the Department of Resources and Development of Canada. During the five year period October 1946 to September 1952, the minimum mean monthly flow occured during March 1952 and was 18,400 cfs, while the maximum occurred during June 1948 and was 379,000 cfs. Application of factors developed by the Department of Resources and Development to allow for inflow to the Fraser River downstream from Hope indicates that the minimum discharge to Strait of Georgia was 27,400 cfs and the maximum 470,000 cfs.

the Fraser between Hope and the point under consideration. Direct measurement of river flows within the Greater Vancouver Area is complicated by the fact that the river is subject to tidal effects. Table 31 gives the factors which may be applied to the recorded Fraser River flows at Hope for the estimation of flows at New Westminster. The minimum daily and greatest mean monthly river flows at New Westminster during the above-mentioned period are estimated to have been 26,000 cfs and 470,000 cfs, respectively.

At New Westminster, Fraser River is divided into the main channel and the North Arm. Approximately 15 percent of the total flow goes to the North Arm and the remainder follows the main channel. Further downstream, the Middle Arm branches from the North Arm and is estimated by the Department of Resources and Development to receive approximately six percent of the total Fraser River flow.

Tidal effects in the North Arm were the subject of a report published by the British Columbia Research Council in 1951. Results of free float and dye observations over a 24 hour period are described. During this study the tide had a range of about 12 feet and the river flow at Hope was 69,000 cfs. For conditions existing at the time of this study, it was concluded that at least 24 hours may be required for a complete change or flushing of the water of the North Arm to occur. Under conditions of lower river flows and higher tidal ranges, the time would be greater while with higher river flows and lower tidal ranges, the time would be less.

Table 31

Percentage Increase in Fraser River Flow Between Hope and New Westminster, British Columbia

Month	Increase, percent
January	39
February	48
March	49
April	40
May	28
June	24
July	26
August	26
September	27
October	34
November	46
December	50

Source: Water Resources Division of Department of Resources and Development of Canada.

At the request of the Vancouver and Districts Joint Sewerage and Drainage Board, several studies were made on the Fraser River Model to determine the velocity of flow in the North Arm of the river. The model was built by the National Research Council in cooperation with the University of British Columbia for the Department of Public Works of Canada. The primary purpose of this model, known technically as an hydraulic erodible-bed tidal river model, is to study problems connected with the maintenance of navigable channels in the Fraser River estuary. The horizontal scale is 1:600 and the vertical scale is 1:70. The discharge scale is 1:360,000, which means that a flow of one cubic foot per second in the model is equivalent to a flow of 360,000 cubic feet per second in the prototype. The time scale is 1:70, which implies that a one year period in nature may be reproduced in about five and one quarter days. Tidal variations in the Strait of Georgia are reproduced, but the north-south movements are not. Hence, the model cannot be used to determine conditions beyond the river's mouth.

In the tests performed on the model, a large freshet was imposed with a Hope discharge of about 400,000 cubic feet per second. The tide of June 30, 1950, was used since it is a good example of a large amplitude tide which may occur annually. Series of tests were performed under two different sets of conditions: (1) as they presently exist in the prototype and (2) with the Middle Arm of Fraser River and Macdonald Slough, between Iona and Sea Islands, blocked.

Under the first set of conditions, a float moved down the North Arm from the vicinity of Boundary Road to Wreck Beach in a time corresponding to five hours in nature. Under the second set of conditions, due to increased velocity in the North Arm, the time was decreased to about three hours.

During winter months the flow in Brunette River, which drains Burnaby Lake, is measured by the Department of Resources and Development. During periods of low flows in the summer, no measurements are made, although the flow at these times is reported to be practically zero. From the sewage disposal standpoint this latter period is the more critical.

Dissolved Oxygen

Data on water quality in Fraser River are contained in a report entitled "Water Quality in the Fraser-Thompson River System of British Columbia" prepared for the Dominion-Provincial Fraser River Basin Board by the British Columbia Research Council in 1952.

Measurements of dissolved oxygen and temperature as well as of other characteristics were made at various stations on Fraser River at intervals over the period of a year. Table 32 gives the results of tests for dissolved oxygen and temperature in Fraser River adjacent to New Westminster. The averages of several samples collected during the stated period and the estimated river flow at New Westminster are presented in the table. From the estimated flow and the determined concentration of dissolved oxygen, the average daily quantity of dissolved oxygen transported by the river has been calculated. As given in Table 32, this quantity varies from about 3,000,000 pounds per day in January to over 18,000,000 pounds per day in May.

No determinations of dissolved oxygen in Brunette River have been made since, during critical periods, the quantity of flow is negligible, and therefore little or no oxygen is available for the oxidation of organic matter.

The bod value presented in Chapter 11 is the standard bod which is exerted in five days at a temperature of 20°C or 68°F. Data presented in Table 32 indicates that Fraser River temperatures are always considerably below this value. It is also highly unlikely that the entire five day bod of a unit quantity of sewage discharged into Fraser River will be exerted before the sewage has entered and become dispersed in the Strait of Georgia. The bod of sewage is known to vary with time and temperature and these variations are predictable for normal domestic sewage. It is possible, therefore, to calculate the portion of the five day, 20°C bod which will be exerted under other time and temperature conditions.

Table 32

Oxygen Resources of Fraser River at New Westminster

Date	Estimated Flow cfs	Water Temperature °C	Dissolved Oxygen	
			ppm	lbs. per day
1950				
August 23 - 25	122,000	17.8	8.9	5,800,000
September 21 - 25	75,000	16.3	9.5	3,800,000
November 29 - 30	74,000	4.9	12.4	4,900,000
1951				
January 31 - February 5	38,000	0.3	14.0	2,900,000
April 4 - 6	49,000	6.4	12.4	3,300,000
May 18 - 22	350,000	10.2	9.6	18,100,000
June 26 - 29	244,000	14.7	10.8	14,200,000
July 26 - 31	179,000	17.2	10.2	9,800,000

Flows estimated using factors shown in Table 31 and average flows for days shown measured at Hope, B. C., by Department of Resources and Development of Canada.

Data on water temperature and concentration of dissolved oxygen from "Water Quality in the Fraser - Thompson River System", British Columbia Research Council for the Dominion-Provincial Fraser River Basin Board, April, 1952, and are averages of conditions during indicated period.

Capacity to Receive Sewage

Fraser River. A measure of the oxygen demand of sewage or of any waste is its biochemical oxygen demand (bod). The bod of sewage in the Greater Vancouver Area is evaluated in Chapter 11 of this report and estimated future per capita loadings or contributions are given. Based on the quantity of sewage which may be made tributary to various locations on Fraser River and North Arm, it is possible to calculate the daily bod loading which might be imposed upon these waters.

Figure 68 shows the general locations at which the various collection systems described in Chapters 14 and 16 would be tributary to Fraser River. Table 33 presents the estimated ultimate flows and loadings of five day 20°C bod.

As a means of assessing the effect of the estimated ultimate bod loading upon the oxygen resources of Fraser River, it has been assumed that sewage discharged from all of the indicated locations will be in the river for a mean time of one day and that the variation of

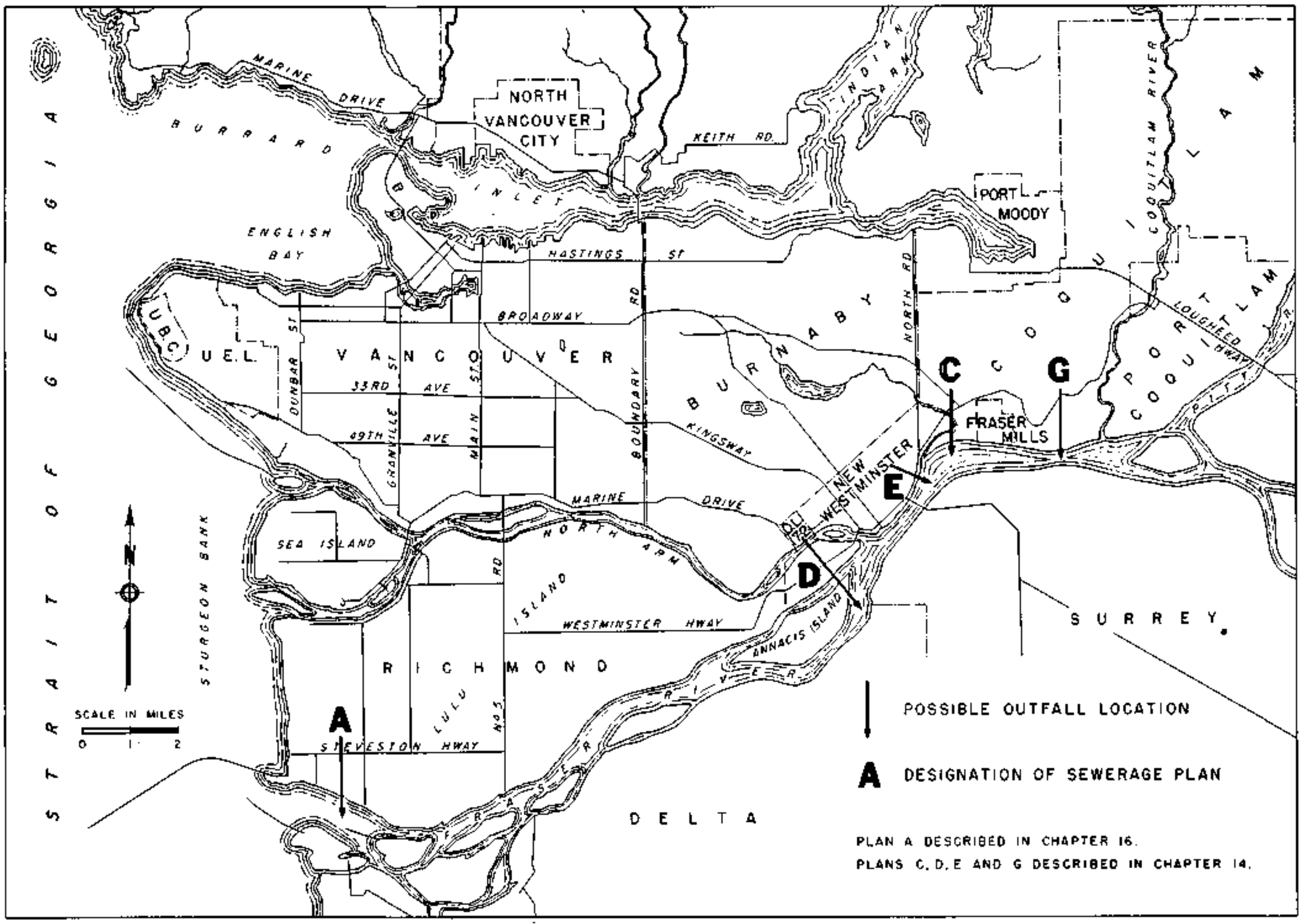


Figure 68. Proposed Locations of Outfalls to Fraser River

The most appropriate sewerage plans for the Greater Vancouver Area include conveyance of sewage from areas naturally tributary to Fraser River to five separate locations on the river for ultimate disposal.

Table 33
Estimated Ultimate Sewage Flow and Biochemical Oxygen Demand Loading to Fraser River

Location	Flow, cfs	BOD[a] lbs. per day
A	23.9	23,000
C	44.5	43,000
D	20.4	19,000
E	7.9	7,000
G	16.6	16,000
b	9.6	9,000
c	3.7	4,000
Total	126.6	121,000

See Figure 68 for location of possible outfalls.
Letters indicate sewerage plans described in Chapters 14 and 16.
See Chapter 11 for per capita contributions of flow and bod.
[a] 5 day 20°C.
[b] Ultimate contribution from central portion of Lulu Island; location dependent upon development of population.
[c] Ultimate contribution from portions of Coquitlam and Port Coquitlam tributary to Pitt River; location dependent upon development of population.

bod with time and temperature will be normal. Table 34 presents a comparison of this oxygen demand with the quantities of dissolved oxygen contained in the river during the sampling and analysis program described above. The observed river temperatures shown in Table 32 have been used in calculating the effective bod of the sewage. It is shown that, under the most critical conditions indicated in the comparison, the oxygen demand is less than one percent of the oxygen carried by the river.

The great amount of dilution water which is available in Fraser River may be effectively utilized to disperse finely divided suspended solids contained in sewage if outfalls are located so as to discharge at points where high current velocities and adequate depths exist.

Table 34

Comparison of Observed Oxygen Resources of Fraser River with Estimated Ultimate Biochemical Oxygen Demand

Observed Oxygen Resources[a]		Effective BOD[b]
Date	lbs. per day	lbs. per day
1950		
Aug. 23 - 25	5,800,000	31,000
Sept. 21 - 25	3,800,000	29,000
Nov. 29 - 30	4,900,000	13,000
1951		
Jan. 31 - Feb. 5	2,900,000	12,000
April 4 - 6	3,300,000	15,000
May 18 - 22	18,000,000	19,000
June 26 - 29	14,200,000	25,000
July 26 - 31	9,800,000	30,000

[a] From Table 32.
[b] Based on estimated total ultimate 5 day 20°C. bod given in Table 33. Assumptions: (1) Water temperatures given in Table 32; (2) Mean time of 24 hours required for sewage from all outfalls to leave system; normal variation of bod with time and temperature.

North Arm. The observed velocities and currents in the tidal waters of the Strait of Georgia have a significant effect upon the capacity of the North Arm to receive sewage. It has been shown by current studies and model tests that water may move down the North Arm, around Point Grey, and into English Bay within a few hours on certain stages of the tide. This fact definitely precludes the direct discharge of crude sewage into the North Arm.

Brunette River and Burnaby Lake. Because of extremely low flows in Brunette River, the quantity of dissolved oxygen available to oxidize organic material is limited. At certain times little or no dilution water is available to disperse and transport suspended material. Moreover, because of the low rates of inflow and outflow of Burnaby Lake during critical periods, wastes discharged thereto would tend to accumulate. Therefore, the capacities of these waters to receive sewage or other wastes are strictly limited.

Degree of Treatment Required

Fraser River. An analysis of the present and anticipated future uses of Fraser River and of the amount of dissolved oxygen available for oxidizing organic wastes indicates that sewage may be discharged to the river without treatment. It must be recognized that changes in the use of the river, which cannot presently be foreseen, may require some type of treatment in the future. Wastes containing materials in concentrations sufficient to be deleterious to fish or other aquatic life when discharged to the river, would necessarily require pretreatment prior to acceptance to the sewage collection system.

North Arm. Crude sewage discharged directly into the North Arm would be a source of contamination of recreational beaches. To afford proper protection to these recreational areas, any sewage discharged to the North Arm must be treated. Because of the large amounts of dissolved oxygen present in the North Arm, the effluent from a standard-rate primary treatment plant, chlorinated during critical periods, would be suitable for discharge thereinto, provided that such a plant were located several miles upstream from its mouth. A treatment plant located near the mouth of the North Arm, as previously discussed, would have to provide secondary treatment such as high-rate trickling filtration.

Brunette River and Burnaby Lake. Because of the limited receiving capacity of Brunette River and Burnaby Lake, sewage discharged to either of these waters would require secondary treatment, such as that provided by a high-rate trickling filter treatment plant. Chlorination of the effluent would be required at all times. Such treatment would afford adequate protection to the waters of Burnaby Lake from public health and aesthetic standpoints.

Chapter 13
Design Criteria and Basis of Cost Estimates

Limitations of Present Study

In the preliminary layout of a sanitary sewerage system detailed designs of the facilities are not essential. The layouts must, however, be in sufficient detail to permit making reasonably accurate cost estimates and competent comparison between such various plans as may be investigated. All plans so compared must achieve acceptable results with respect to the ultimate disposal of sewage. The final determination of the most appropriate plan will rest in large measure upon economic considerations. Other considerations, however, as discussed elsewhere, may influence the final decision.

In the layout of sanitary sewerage projects to serve the Greater Vancouver Area sufficient attention was given to the location and size of each facility to ensure that the estimation of cost of the units making up each separate plan was on a comparable basis. These locations and sizes, however, must be regarded as somewhat tentative and suggestive. Detailed engineering study performed at a later date may alter the location and size of some of the units in the interest of economy or perfection.

As stated in Chapter 1 the present survey of sanitary sewerage facilities has been concerned only with the planning of: (1) trunk and intercepting sewers and their appurtenant pumping stations, (2) treatment plants, (3) disposal works. It has not included lateral sewers because such are considered to be of local responsibility. The survey has been concerned in detail with the storm water facilities which exist in areas presently sewered on the combined basis. The reason for this is that interceptors, pumping plants, and treatment and disposal works in such areas would of necessity have to be designed with storm water drainage in view and consequently would be many times larger than if sanitary sewage flow alone were considered.

The layout of storm drainage facilities for the Greater Vancouver Area, other than those portions served by combined sewers, has been accomplished on a much more general basis than have sanitary sewerage projects. In the areas not sewered at present, where separate systems of storm and sanitary sewers are recommended, the kind, location, and cost of storm drainage facilities have been generalized. It was considered that storm water conveyance and disposal did not require the degree of immediate and detailed attention as do sanitary and combined sewerage facilities since location and the wishes of the public will largely determine the extent and type of improvement to be provided in each storm water drainage unit.

General Methods of Design

The general factors used in the tentative design of facilities for all plans considered are presented in this chapter. In subsequent chapters the specific design methods, which may differ as between the major sewerage areas, are described in connection with the discussion of each particular project.

Storm water quantities were calculated by the Rational Method which is expressed in terms of the equation: $Q=CiA$, in which "Q" is the runoff in cubic feet per second, "C" is the coefficient of runoff of the area, "i" is the rainfall intensity rate in inches per hour of a storm of selected frequency and determined duration, and "A" is the tributary area in acres.

Loadings used in the layout of proposed sanitary sewerage facilities were determined by multiplying the per capita quantities or contents of the sewage by the predicted contributory population at a specified time in the future.

All design and layout work done within the Greater Vancouver Area in connection with this survey has made use of the existing datum plane of the Vancouver and Districts Joint Sewerage and Drainage Board. Figure 69 illustrates the relationship between the datum plane utilized by the Board and those of other communities, agencies and organizations.

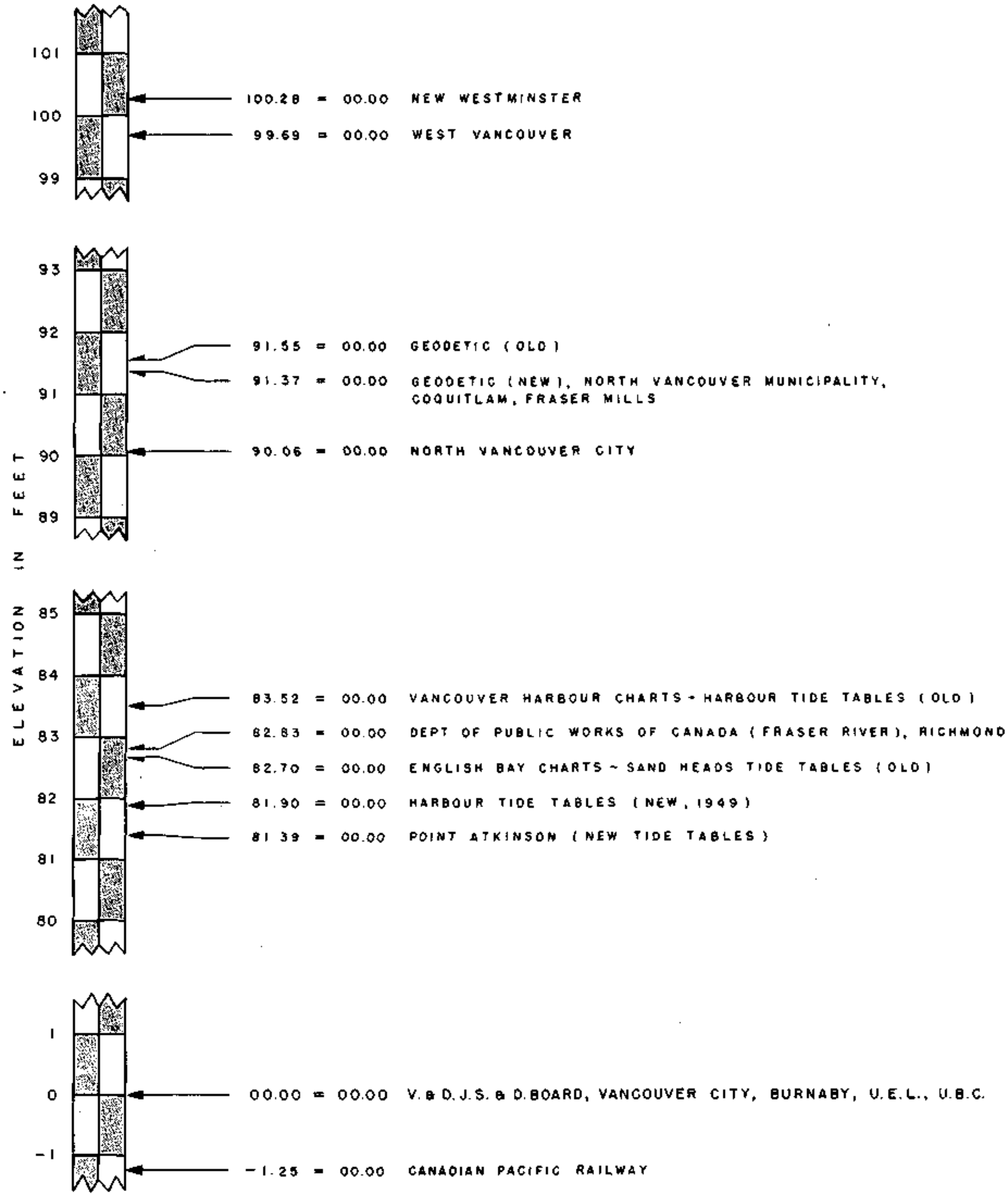


Figure 69. Datum Planes in Use in the Greater Vancouver Area

All design and layout work in connection with the survey has made use of the existing datum plane of the Vancouver and Districts Joint Sewerage and Drainage Board.

Design Factors

Loadings. The per capita quantities or unit contributions of flow, suspended solids, and biochemical oxygen demand used for design in each of the sewerage areas are presented in Table 35. The derivation of these quantities is discussed in Chapter 11.

Table 35
Calculated Design Factors
Sanitary Sewage

Volume	
Sanitary system[a], gpcd	95
Combined system[b], gpcd	110
Percent peak of average	150
Percent minimum of average	65
BOD, ppcd	0.17
Suspended Solids	
Total, ppcd	0.20
Percent volatile	70

[a] Carrying wastes from residences and industries only.
[b] Carrying ground water from foundation tile drains in addition to wastes from residences and industries.

Wastes from all industries presently located in the Greater Vancouver Area should be discharged into the public sewers. Since some of these wastes may contain large contributions of suspended solids, biochemical oxygen demand, and grease, pretreatment prior to discharge to the public sewers in such cases may be necessary.

To this end, a controlling by-law defining the characteristics of wastes acceptable for discharge into the sewerage systems of the area might be in order. A resolution, tantamount to a by-law in its effect, defining the general limitations placed on industrial wastes, is in force in the Sanitation Districts of Los Angeles County, California. This resolution, entitled 'Policy Governing Use of District Trunk Sewers', February 1952, is quoted in part as follows:

a. Material which will settle out in the sewers, such as sand or metal filings, will not be discharged to the sewers. Waste waters containing such materials must be passed through sand traps or other suitable structures, properly designed and maintained, before discharge to the sewers.

b. Moderate amounts of dispersed grease and oil can usually be tolerated, but sewer stoppages occur from grease accumulations, and excessive amounts of oil have caused difficulties at the treatment plant. Industries therefore may not use the sewers as a means for disposal of oil and grease, and steps must be taken to remove these substances from waste waters insofar as practicable. In the case of industries with large volumes of waste waters containing oils of a hydrocarbon nature, the floatable oil content will be limited to 10 parts per million. Industries with wastes containing animal or vegetable oils or fats, mixed with other suspended matter rendering separation difficult, may in some cases be allowed higher concentrations of floatable oil or grease, up to 25 parts per million. Dispersed oil and grease will in general be allowed in concentrations up to 600 p. p. m. provided that dilution of the waste in sewage does not cause the oil or grease to separate on the surface or collect on the walls of the sewer.

c. Unreasonable or unnecessarily large amounts of suspended and settleable solids will not be discharged to the sewer.

d. High B. O. D. wastes may in some cases cause excessive putrefaction or sulfide formation. In such cases suitable restrictions will be imposed, or the industry will be charged the cost of corrective treatment.

e. Wastes of strong odors, such as mercaptans, will not be discharged to the sewer.

f. Dissolved sulfides in wastes discharged to the sewer must not exceed a concentration of 0.1 p. p. m.

g. Acids will not be discharged to the sewer. Generally, acid wastes must be neutralized to a pH value of 6 or above. Highly alkaline wastes are not generally harmful, except in rare instances where they may cause incrustation of sewers.

h. Compounds which may give off toxic or flammable gases in amounts considered dangerous by the Sanitation Districts will not be permitted in the sewers. The concentration of cyanide in any waste, (including HCN and CN^-) must not exceed 10 p. p. m. Wastes containing radioactive materials will require special consideration.

i. Blow-down or bleed from cooling towers or other evaporative coolers, equalling not more than half of the evaporation loss (one third of the make-up), are acceptable in the sewer. Where cooling is done by using only heat exchange without utilizing evaporative cooling, the waste water must not be discharged to the sewer.

j. The sanitary sewers in the Sanitation Districts are not designed to carry storm waters. Industries must therefore segregate sewage and industrial wastes from roof and yard run-off, with the roof and yard run-off going to suitable storm water channels.

k. As it is important to keep the temperatures of the sewage as low as possible, temperatures of discharges will generally be limited to 120°F. Where the quantity of discharge represents a significant portion of the flow in a particular sewer, it may be necessary to lower the limit to reduce sulfide generation in the sewer.

It is believed that such a by-law, with necessary modifications to suit the particular conditions existing in the Greater Vancouver Area, will be helpful. Consequently, all of the planning of sewerage facilities in connection with this survey has recognized such regulative control.

Roughness Coefficients. Manning's pipe friction formula has been used for the determination of the diameters of all sewers planned in connection with this report. A coefficient of roughness, "n", of

0.013 has been assumed for all gravity trunk sewers and sanitary sewage intercepting sewers. Gravity intercepting sewers of the combined type, in which flows are relatively undisturbed by connections and changes of direction and which are of large diameter, have been proportioned using an "n" of 0.012. Force mains, inverted siphons and outfalls have been designed using an "n" of 0.015.

The Palmer-Bowlus flume installed in the English Bay Interceptor at First Avenue and Point Grey Road accurately records the quantities of flow carried by the interceptor. The average value of "n" for partial depths, calculated from these measurements of quantity and simultaneous measurements of depth is 0.012. The conduit immediately upstream from the flume consists of 3,800 feet of 66-inch Boston horseshoe tunnel section at a physical grade of 0.10%. There are no connections or changes in direction within this section. It has been in service for 22 years as a combined sewer and there is no evidence of corrosion or deposition on its crown or sidewalls. If the "n" value for the interceptor is 0.012 for partial flows, it should be in the neighbourhood of 0.011 for full flow. The assumed design "n" of 0.012 for large combined intercepting sewers thus appears to be conservative.

Runoff Coefficients. The storm water runoff coefficient of an area is largely dependent upon the degree of imperviousness and the general slope of the area from which the runoff is derived. The coefficient must adequately recognize the extent of percolation into exposed soil and other porous surfaces, the loss by evaporation, and the retention in puddles and depressions of both pervious and impervious surfaces. Runoff coefficients expressed as a proportion of the rainfall are to be found for various surfaces in technical literature.

For the Greater Vancouver Area, a typical residential block was studied with regard to the various percentages of different kinds of surfaces and an average coefficient of imperviousness was calculated for the block. This is shown in Table 36. The coefficient of 0.36 has been used for residential areas during the summer months, May through September, when the probability of saturated ground conditions is low and the rainfall storms are generally of short duration. The runoff coefficient increases with prolonged rainfall. During the winter months, when long rainstorms and saturated ground conditions are frequent, the runoff coefficient becomes much greater. Flow measurements made by the Vancouver and Districts Joint Sewerage and Drainage Board indicate that runoff coefficients as high as 0.84 have obtained during winter months. On one occasion, in which a heavy snowfall was followed immediately by an abrupt rise in temperature and a warm rain, a runoff coefficient slightly greater than 1.1 was recorded.

Rainfall Intensities. A series of rainfall intensity curves has recently been developed by the Vancouver and Districts Joint Sewerage and Drainage Board for use in the rational method of combined sewer and storm drain design. These curves were derived from rainfall re-

Table 36
Runoff Coefficient for Average Residential Block in the Greater Vancouver Area

Surface	Square Feet Per Block	Runoff Coefficient	Sq. Ft. Per Block x Runoff Coeff.	Adjusted Runoff Coefficient
Roofs	28,000	0.90	25,200	0.13
Roads	25,000	0.85	21,250	0.11
Sidewalks	11,000	0.85	9,350	0.05
Gardens, Lawns, etc.	116,000	0.10	11,600	0.01
Lanes	10,000	0.15	1,500	0.01
Total	190,000	-	68,900	0.36

Average residential block assumed to include: 20 lots, each 50 by 125 feet; lane allowance of 20 feet; and road allowances of 33 feet on all four sides.

cords covering 37 years, obtained with a Friez automatic gauge on the roof of the Vancouver City Hall located in the vicinity of Hastings and Main Streets from 1913 to 1936 and at 12th Avenue and Cambie Street from 1936 to date.

In this analysis, each day of the 37 years of records was examined and tables prepared listing the maximum 15, 30, 60, and 120 minute rainfall intensities that occurred during each 24 hour period. Bar graphs and mass curves for each of these four durations were plotted as shown in Figure 70. The mass curves show the number of days in 37 years that a rainfall intensity of a stated duration was equalled or exceeded. To allow for possible omissions and errors in the day by day analysis of the records, the curves were drawn slightly above the peaks indicated by the bar graphs.

For convenience in design, the interpretation of the rainfall intensity records was divided into three sections. Summer intensities were assumed to occur during the five month period, May 1 to September 30. The remaining seven months were considered to represent winter conditions. The all-year intensity curves are a combination of those of

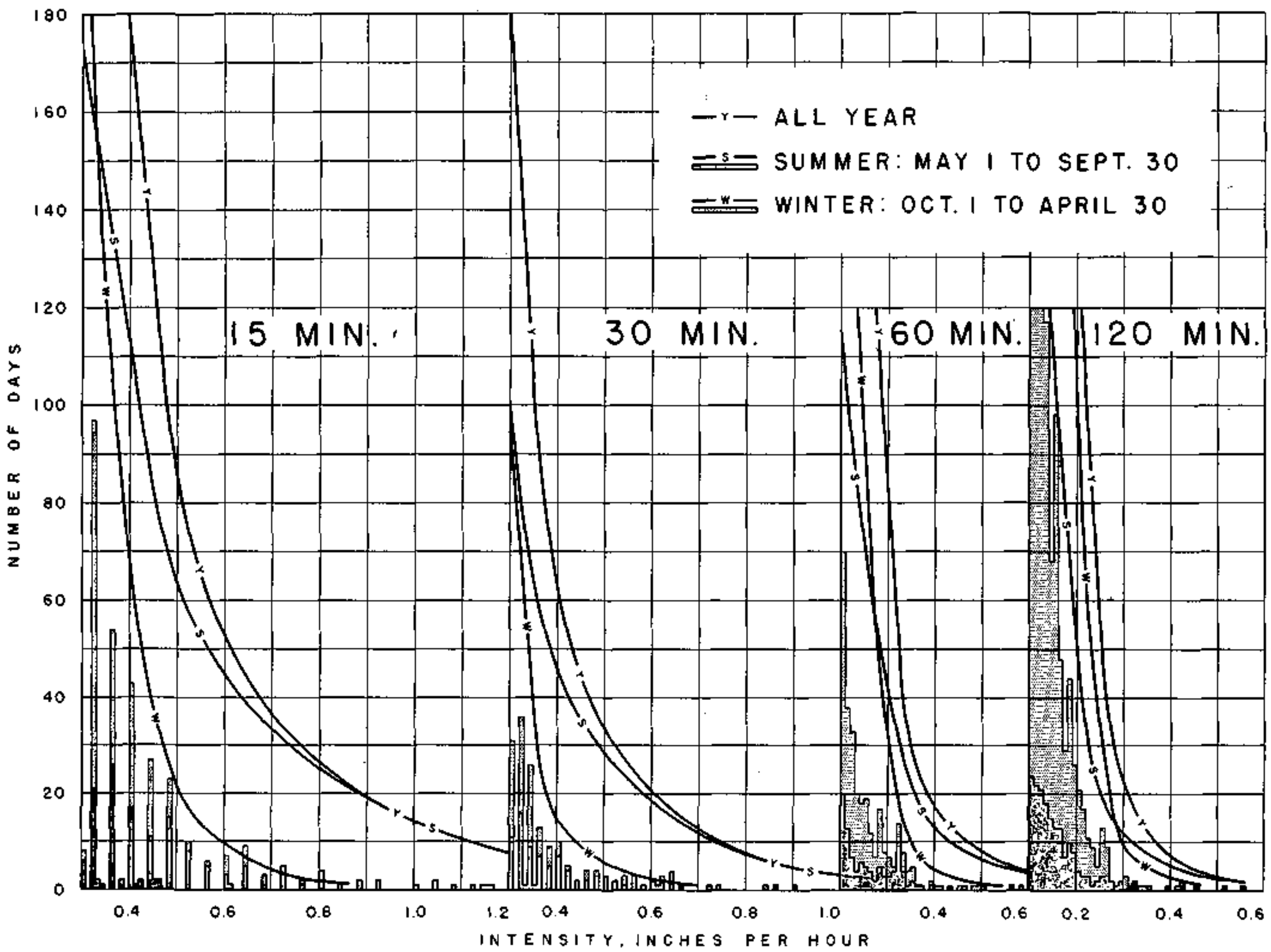


Figure 70. Bar Graphs and Mass Curves of Rainfall Intensities

The bar graphs were derived from rainfall records obtained with a Friez automatic gauge located on the roof of the Vancouver City Hall. The rainfall records cover a 37 year period. The bar graphs show the number of days during the 37 years that rainfall intensities of 15, 30, 60 and 120 minutes duration were equalled or exceeded. The mass curves were drawn slightly above the peaks indicated by the bar graphs to allow for possible omissions and errors in the day by day analysis of the records. From the mass curves shown in this figure, curves showing various frequencies of rainfall intensity were developed as shown on Figures 71, 72 and 73.

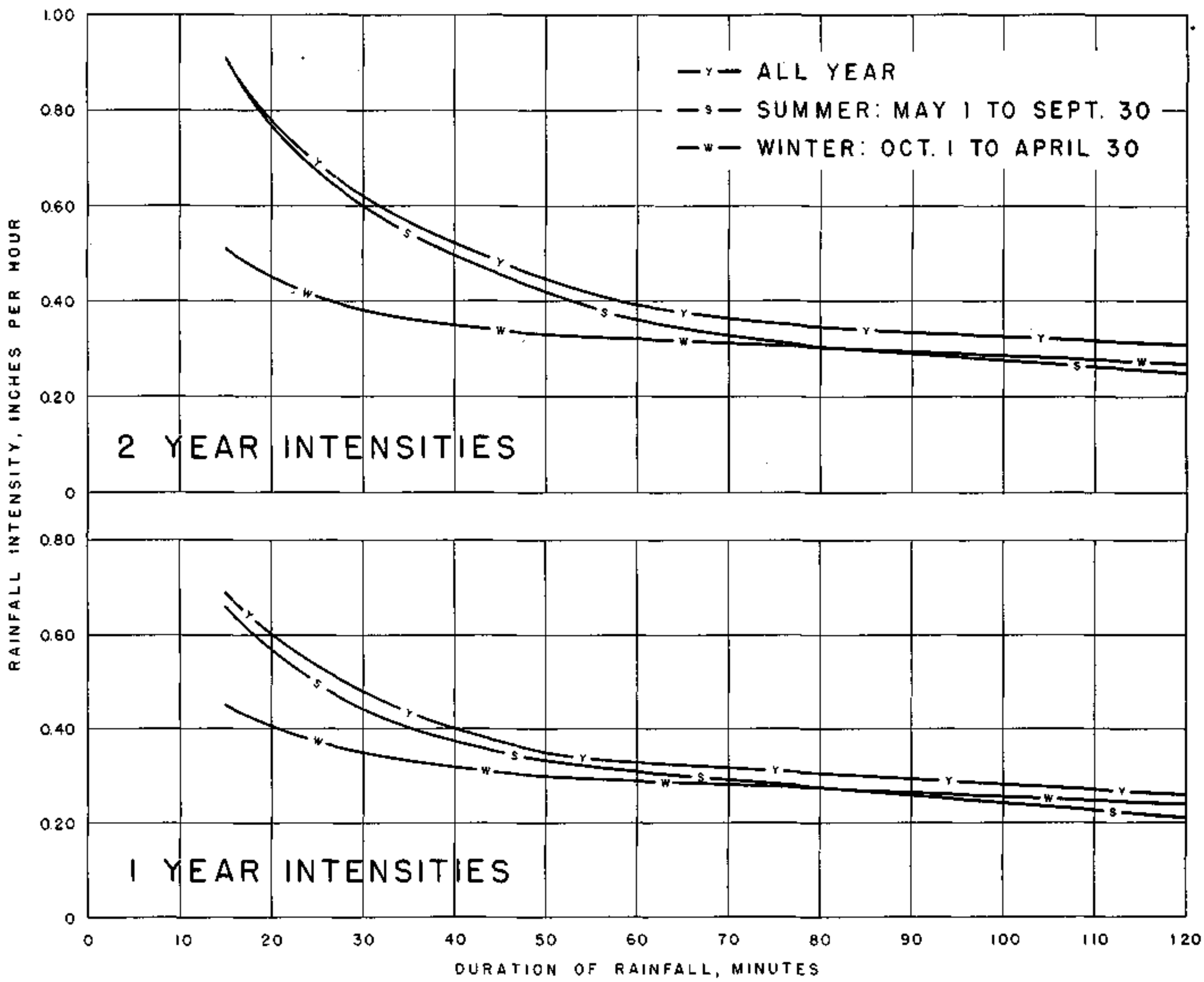


Figure 71. Rainfall Intensities Equalled or Exceeded Once in 1 Year and Once in 2 Years

summer and winter.

Curves have been prepared to exhibit four frequencies of rainfall intensity, namely, those equalled or exceeded once in 1, 2, 5, and 10 years. With 37 years of records, the one year curve was composed of intensities that were equalled or exceeded 37 times in 37 years; the two year curve, 18.5 times in 37 years; the five year curve, 7.4 times in 37 years; and the ten year curve, 3.7 times in 37 years. For each frequency of occurrence, intensities for summer, winter and all-year conditions were determined from the 15, 30, 60 and 120 minute duration mass curves of each respective season and plotted as duration-intensity curves for each frequency as shown in Figures 71 and 72.

For the design of combined intercepting and trunk sewers in connection with this survey and report, it was found necessary to prepare rainfall curves for the five summer months of intensities equalled or exceeded more than once per summer. These were derived in a similar manner from the mass curves of summer intensities and are shown in Figure 73.

Because of the method of deriving the duration-intensity curves, they are actually probability curves based on 37

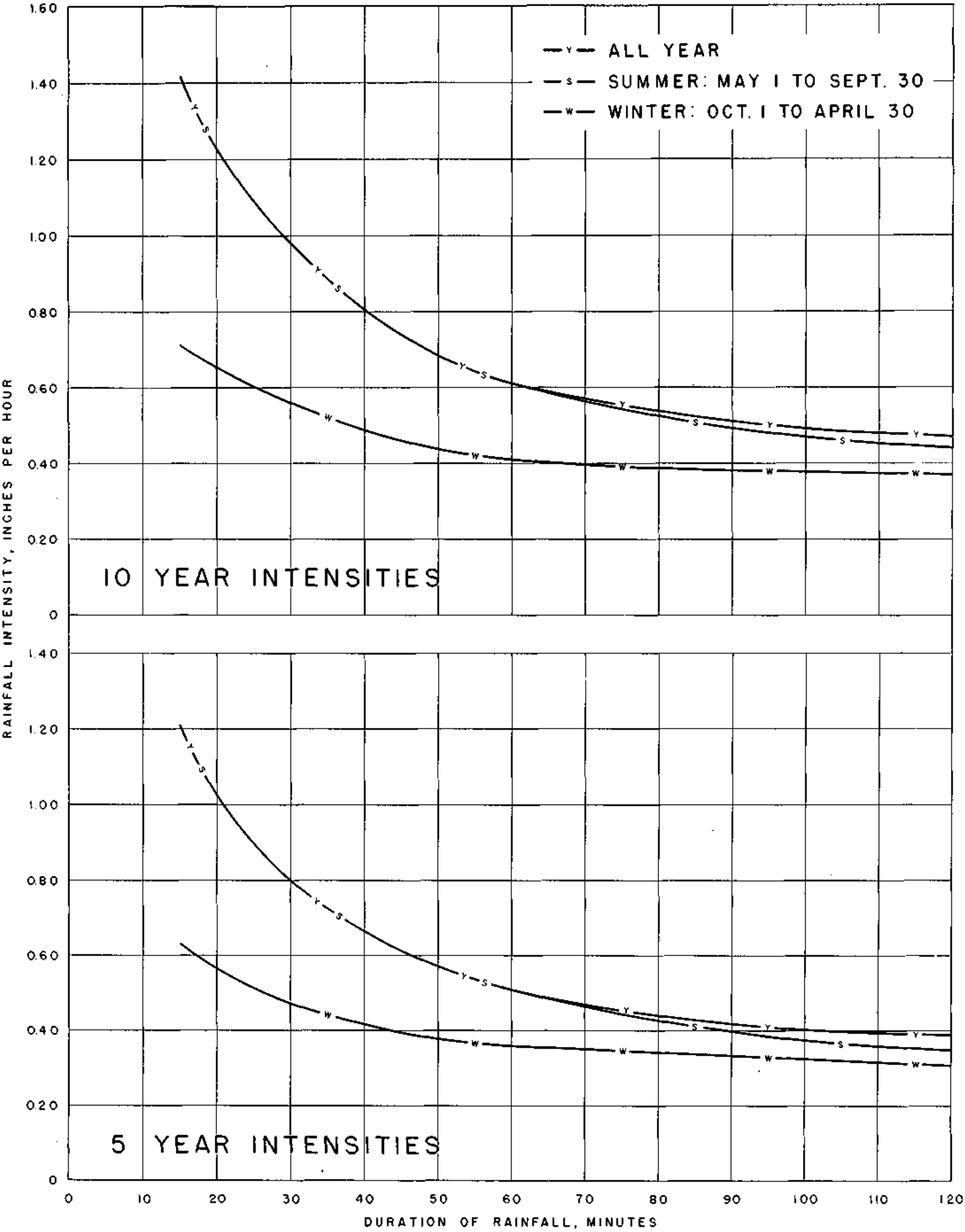


Figure 72. Rainfall Intensities Equalled or Exceeded Once in 5 Years and Once in 10 Years

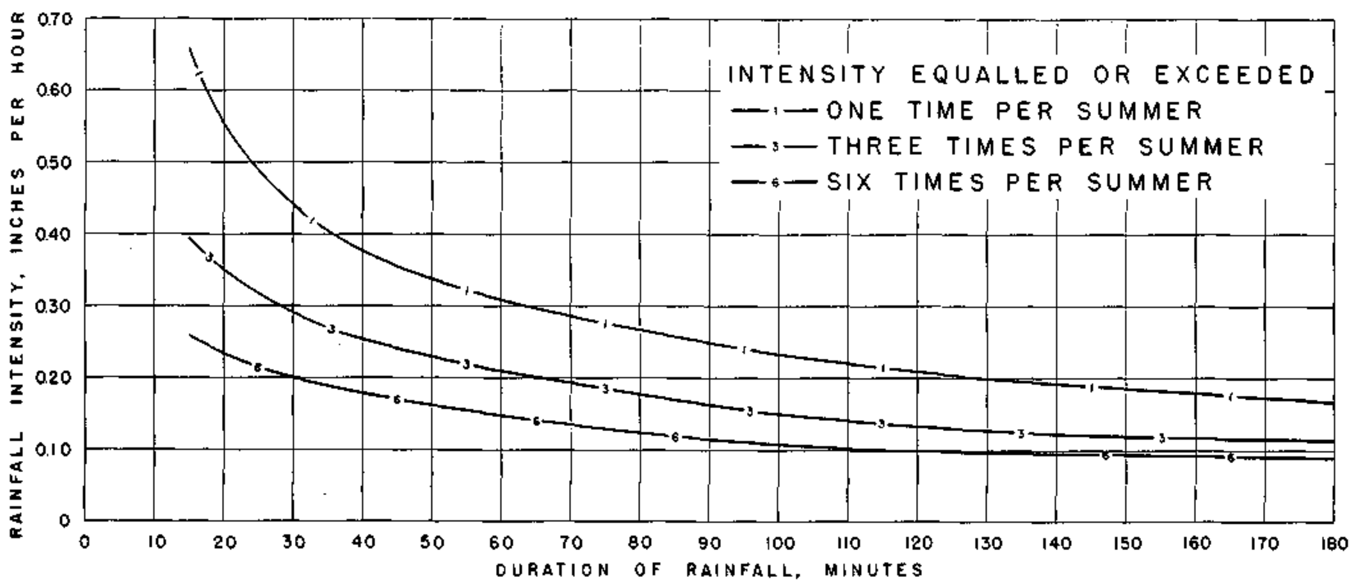


Figure 73. Rainfall Intensities Equalled or Exceeded One, Three and Six Times per Summer

years of rainfall records and do not necessarily represent the pattern of a typical rainstorm. Although it may be possible for any one storm to follow a large portion or all of the appropriate time-intensity-frequency curve, such an occurrence is highly unlikely.

Intercepting and Trunk Sewers

Intercepting and trunk sewers are designed to transport to the final point or points of disposal the maximum rates of flow expected during the selected design period and to transport suspended solids at such velocities that the deposit and stranding of these solids will be negligible.

In sanitary trunk and intercepting sewers the maximum rate of flow may occur by reason of some combination of the following component elements of the total sewage flow: the peak rate of sewage flow from domestic sources; the rate of contribution of industrial wastes; and the infiltration of ground water into the sewers.

Rates of flow of domestic sewage will fluctuate widely during the day as shown by the flow charts presented in Chapter 11. This is especially true of flows from small areas where the peak rate of flow may be 250 percent of the average. As the tributary area becomes larger, the ratio of peak to average flow decreases.

The design flow rates for sanitary sewers in systems considered for the Greater Vancouver Area have been based on the estimated average rates of flow in the sewers multiplied by a factor dependent upon the population contributory thereto. This factor was obtained from the curve shown in Figure 74.

As previously discussed in Chapter 11, the quantities of industrial wastes that may be expected in the Greater Vancouver Area are small in comparison with domestic flows. The design unit flows, as adopted for the various systems, however, contain allowances for industrial wastes in accordance with the types of areas to be served.

The flow charts presented in Chapter 11 represent observed variations in dry weather flow from a combined system. These flows contain an increment of ground water from building foundation drain tiles that are connected directly to the sewers. The per capita contributions derived from those charts, therefore, already contain some allowance for infiltration, as well as a ground water allowance associated with a combined system.

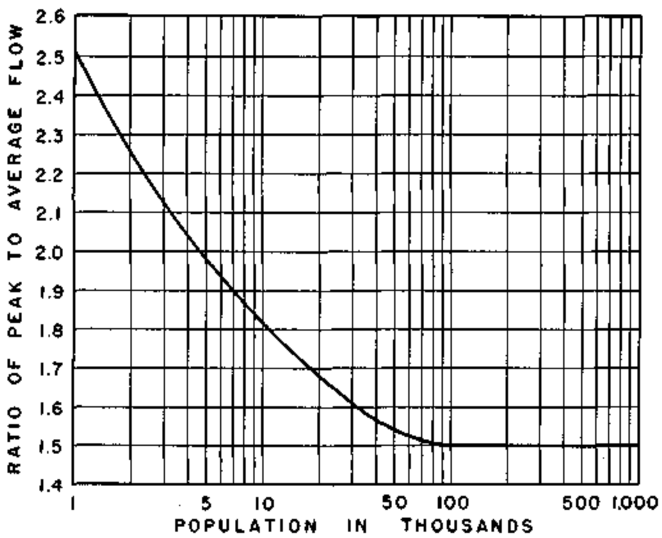


Figure 74. Relationship of Contributory Population to the Ratio of Peak to Average Sewage Flow

The design rate of sanitary sewage flow in each of the conduits considered for the Greater Vancouver Area has been based on the estimated average rate of flow multiplied by a factor dependent upon the contributory population.

These contributions are suitable for use in the design of trunk and intercepting sewers and treatment plants for combined systems. Where new sanitary trunk and intercepting sewers are proposed, however, the per capita flow allowances have been reduced because the discharge into sanitary sewers of ground water from house foundations should not be permitted. Unfortunately, the high ground water table generally prevailing throughout the Greater Vancouver Area makes it virtually impossible to exclude all infiltration from a sanitary sewer. For this reason, the sanitary sewerage systems have been proportioned to include a reasonable allowance for infiltration.

In combined trunk and intercepting sewers, the maximum rate of flow may occur by reason of some combination of the following component elements of the total flow: the peak rate of sewage flow from domestic sources; the rate of contribution of industrial wastes; and the rate of storm water runoff. Domestic sewage and industrial wastes have already been described as a function of the population of an area, and storm water runoff as a function of the coefficient of imperviousness and of the rainfall intensity for an area. The size of each combined sewer has been based upon an intensity curve for a specific rainfall frequency, the selection of which is discussed in subsequent chapters. In the tentative designs made in connection with this survey and this report, the worst condition of peak sanitary flow coinciding with the determined storm water flow has been assumed. When rainfall occurs at other than peak hours of sanitary flow, the resulting slightly smaller flows will tend to reduce somewhat the frequency of discharge from the storm water overflows in the system.

The ability of a sewer, either combined or separate, to transport the suspended solids contained in sewage depends upon the velocity of flow. For present purposes, a minimum velocity of two feet per second has been adopted for sanitary sewers flowing full and a minimum velocity of three feet per second for combined or storm sewers flowing full. These velocities are considered to be the minima, respectively, which will keep the conduits clean. The higher minimum velocity adopted for combined or storm sewers is required because of the heavy particles of grit and gravel inevitably associated with storm flows. Wherever possible, sewers have been planned to have flowing-full velocities considerably higher than the stated minimum, so that the required minimum velocity may be exceeded at low flows.

In sewers up to and including 72 inches in diameter, circular pipe conduits have been assumed. For conduit sizes greater than 72 inches, a monolithic Boston horseshoe section has been assumed, since its construction is considered less expensive than a comparable circular pipe section. Figure 75 presents the hydraulic characteristics of the Boston horseshoe section.

Pumping Stations.

Pumping stations on sanitary sewers are generally found to be economically justified when the depth of sewer approaches 30 feet. In some instances, local

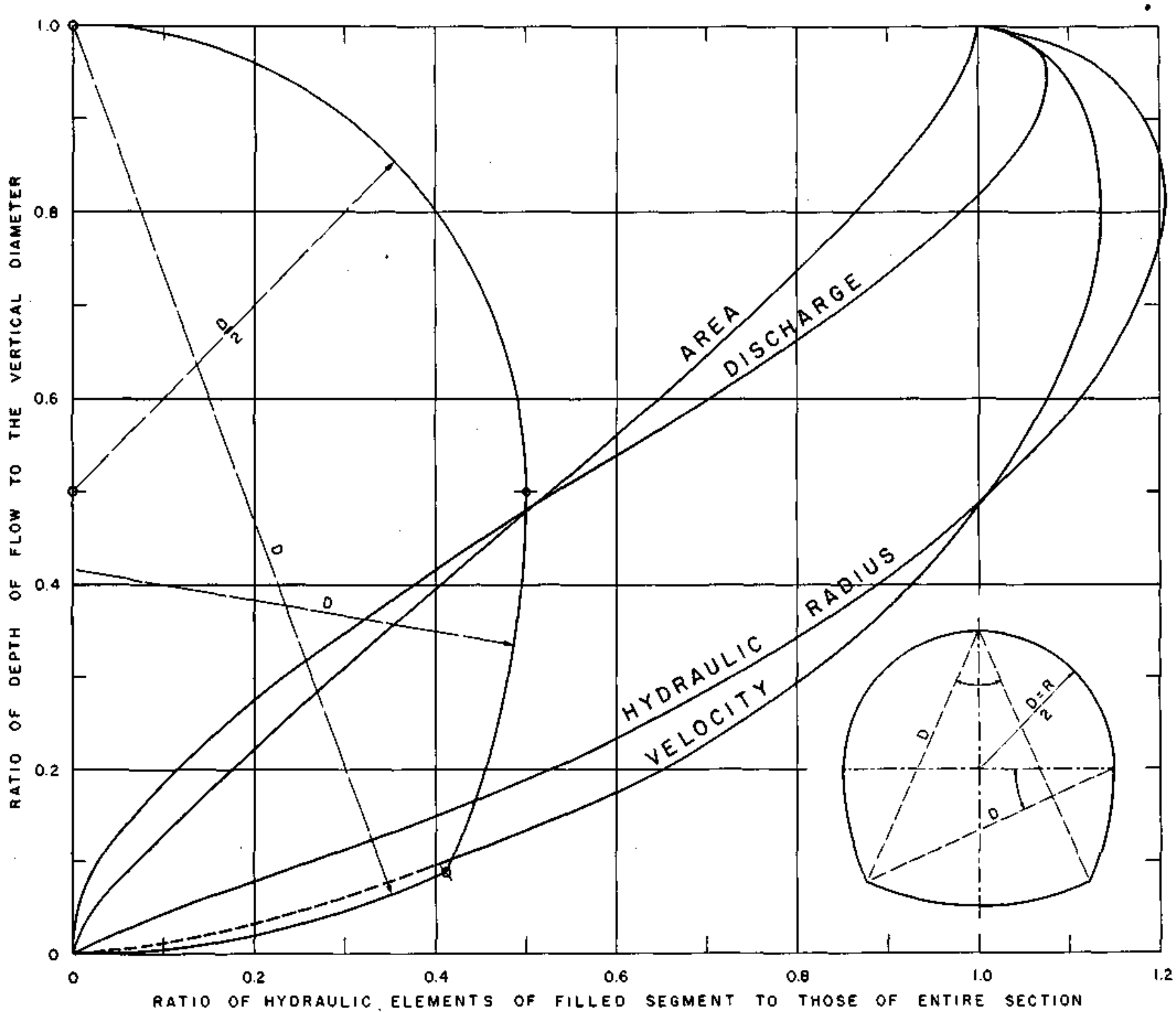


Figure 75. Hydraulic Elements of the Boston Horseshoe Section

For conduits greater than 72 inches in diameter, use of a monolithic Boston horseshoe section has been assumed since its construction cost is considered less expensive than that of a comparable circular pipe conduit.

ground conditions or topography may vary this depth considerably. Every effort has been made to locate pumping stations so that long force mains would not be required.

All pumping stations have been planned to handle the peak flow estimated to occur at some definite time. The station structures have been proportioned to accommodate all of the pumping units which may be required to pump the anticipated ultimate future flow. These structures would be of the simplest possible design with minimum practical sump sizes. Wherever possible, superstructures would be eliminated, the entire station being placed below ground level. Where superstructures are necessary, they would be of a size suited to the proper housing of the equipment ultimately required. Their architectural treatment has been assumed to be appropriate to their surroundings.

To meet the expected variations in flow, pumps would be: (1) of the magnetic-coupled type; or (2) equipped with variable speed motors; or (3) sized so that a simple programming of the pumping schedule would meet all flow variations. Adequate standby capacity has been provided in all pumping station layouts and estimates.

Sewage Treatment Plants.

In the various design studies conducted by the survey, the following four processes of sewage treatment were considered:

1. High-rate primary type.
2. Standard-rate primary type.
3. High-rate trickling filter type.
4. Activated sludge type.

These processes of sewage treatment are discussed in Chapter 7.

Treatment plants have been laid out on the basis of the average flows estimated to occur at some definite future time. In all cases, the plants were considered to be so designed and constructed that expansion thereof to meet additional flow requirements can easily and economically be accomplished. All plants have been considered to be designed to provide maximum flexibility and ease of operation.

In the provisional layout of sewage treatment plants for the Greater Vancouver Area in connection with this survey and report it was assumed that the sewage would be typically domestic, as demonstrated in Chapter 11; that plants serving a combined area would not be required to handle storm water flows in excess of the design peak sanitary flow; and that the variation in flow through the plants would be normal. Treatment plants having a capacity of 10 cfs or greater were assumed to utilize sludge gas either for the generation of power or as fuel for internal combustion engines, driving pumps or other equipment.

Drainage Facilities.

As mentioned previously, preliminary designs and layouts of specific drainage facilities other than those associated with combined systems have not been included in this survey. However, many of the design data, pertinent to the combined systems located in the City of Vancouver and gathered in connection with the survey, may be applied, with certain reservations, to other locations. The precise applicability of the rainfall intensity values derived from recordings made in Vancouver to other cities and municipalities in the area is not known. This can be established, however, if several years of rainfall intensity records are obtained for these communities. This would involve the installation of new rain gauges at strategic points throughout the area. Suitable rainfall rate curves for all drainage areas should be prepared before detailed designs of storm drains within such areas are attempted.

In the study of drainage facilities conducted by the survey the following matters were considered:

1. The relative desirability of conveying storm water runoff from a drainage area to a point of disposal in improved open channels versus enclosed conduits.
2. The sequence of construction involved in the development of a drainage facility to its ultimate capacity.
3. The relative merits of the relocation of drainage facilities on dedicated streets versus the utilization of the natural drainage courses by obtaining easements and rights-of-way.
4. The natural rights and legal liabilities of the communities and residents of the communities affected by the drainage facility.
5. The limit and extent of the responsibilities of a joint agency with respect to storm drainage as apart from sanitary sewerage facilities.
6. The degree and extent of storm drainage facilities to be provided by each community for developments within its boundaries as apart from the facilities supplied by a joint agency.

With these considerations in mind, the drainage works anticipated to be required within the Greater Vancouver Area within the foreseeable future were divided into several broad classifications for purposes of selecting the type of works required for a given drainage area and of estimating its cost. The classifications are as follows:

Type A. The drainage facilities are assumed to consist of improved open channels with culverts and bridges at street intersections. Pumping stations or dykes within the drainage area would not be required. The classification is further subdivided with respect to the average slope of the ground within the drainage area. Type A1 applies to areas with an average ground slope of 0 to 2 percent; Type A2, 2 to 8 percent; and Type A3, greater than 8 percent.

Type B. The drainage facilities are assumed to consist of completely enclosed conduits with pumping stations or dykes not being required within the drainage area. The classification is further subdivided with respect to the average slope of the ground within the drainage area into Types B1, B2 and B3 with the same ground slopes as Types A1, A2 and A3.

Type C. The drainage facilities are assumed to consist of improved open channels with culverts and bridges at street intersections. Pumping stations and dykes would be required within the drainage area. It is further assumed that the average ground slope within a drainage area requiring these facilities would be less than 2 percent.

Type D. The drainage facilities are assumed to consist of completely enclosed conduits. Pumping stations and dykes would be required within the drainage area. As in Type C, it is further assumed that the average ground slope would be less than 2 percent.

Methods of Estimating Costs

Estimating the probable costs of sewerage facilities for a survey of this nature is a difficult task at best. Some of the reasons why any such cost estimates must be considered as tentative are as follows: (1) the layouts and designs are necessarily of a preliminary nature; (2) detailed construction drawings are not available; and (3) the estimates must be made relatively far in advance of actual construction. However, estimates of construction and of operating costs of the various sewerage facilities involved have been prepared using all current sources of knowledge to ensure that the relative costs of all projects studied will be as realistic as possible. Therefore, general changes, either in the designs or in cost indices, should have little effect upon the relative economy of the various projects outlined and compared herein.

Estimating the costs of drainage facilities in the degree of precision required by this survey is an even more difficult task since preliminary layouts and designs of the various works have not been attempted. It was decided, however, that a reasonably close approximation to the costs of the general possibilities outlined herein for future storm water drainage could be obtained by applying known costs for specific storm water facilities in a drainage area already provided with such facilities to other areas with similar topographic and climatic conditions in which similar storm water facilities are proposed. The costs per acre of drainage area for various types of storm water facilities have been evolved.

The cost data of all sorts presented herein have been gathered from many sources. Particular emphasis has been placed on the known costs of sewerage and drainage facilities already constructed in the Greater Vancouver Area. All cost data obtained were adjusted to an

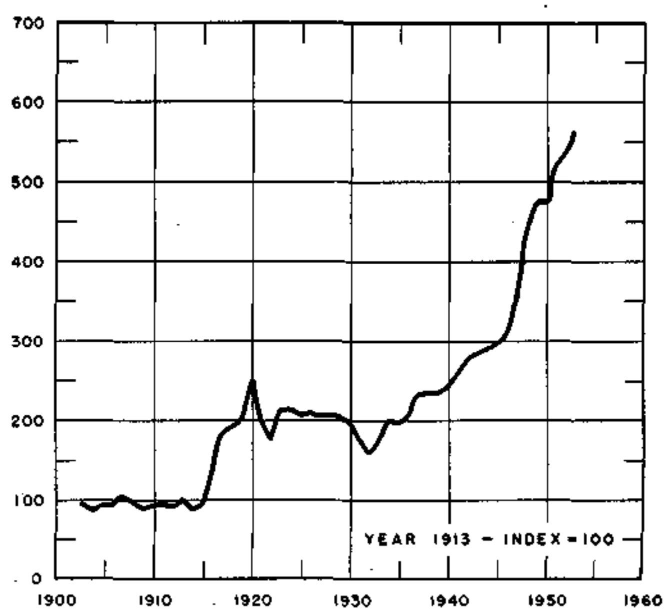


Figure 76. Engineering News-Record Construction Cost Index

All cost data obtained and used for estimating purposes in this report were adjusted to an Engineering News-Record Construction Cost Index of 700 to provide in some measure for possible future increases in costs.

Engineering News-Record Construction Cost Index of 700. An index of 700, which is higher than the October 1, 1952 index of 585, was selected to provide in some measure for possible future increases in costs. Figure 76 shows the variation in the index between 1913 and 1952.

The unit costs of sewerage and drainage facilities developed for use in this survey do not include engineering, contingencies, administration, labour benefits, lands, rights-of-way, repaving of street surfaces, and special foundations such as piling. To cover all items except special foundations, the total estimated costs of sewerage and drainage facilities include an allowance of 25 percent. Costs are further increased by a varying percentage dependent upon local conditions where special foundations are deemed necessary.

Construction Costs

Trunk and Intercepting Sewers. Unit costs of trunk and intercepting sewers are presented in Table 37. The costs given have been derived from actual construction costs of sewers of the Vancouver and Districts Joint Sewerage and Drainage Board and of the City of Vancouver.

Force Mains. Unit costs of force mains are presented in Table 38. The costs given are the costs of the pipe in place, including all excavation and backfill but excluding repaving of street surfaces.

Tunnels. Unit costs of tunnels are shown in Figure 77. Costs were derived from the actual construction costs of tunnels in the Greater Vancouver Area. The tunnels are considered to be concrete lined and reinforced.

Submarine Outfalls. Unit costs of submarine outfalls are shown in Figure 78. Costs were derived from actual construction costs of submarine outfalls of the Vancouver and Districts Joint Sewerage and Drainage Board.

Pumping Stations Two curves used for estimating the costs of pumping stations are shown in Figure 79. The upper curve represents the costs of independent stations located on trunk or intercepting sewers remote from sewage treatment works. The lower curve represents the cost of pumping stations located at and constructed in conjunction with a sewage treatment plant. In such cases, the cost of the pumping works is not included in the treatment plant cost as given hereinafter.

Sewage Treatment Plants The curves used for estimating the costs of sewage treatment plants are shown in Figure 79. To determine the curves, studies were made of the costs of sewage treatment plants of each type actually constructed in the State of California, and the costs adjusted for local climatic and construction conditions.

As a further check on the cost estimates, use was made of a yardstick of sewage treatment plant construction costs prepared by C. J. Velz, Engineering News-Record, October 14, 1948, based upon the contract costs of 185 plants in 16 states north and east of the Missouri and Ohio Rivers. These cost data, after adjustment to agree with the Engineering News-Record Construction Cost Index at the time of construction and to recognize the degree of treatment, were plotted by Velz to show the most probable cost and the best and worst quarters in the range in costs for plants of any design capacity. Because of the influence of a less favourable climate, both as respects design requirements and construction, costs of plants in the Greater Vancouver Area have been assumed to fall in the range between the curves for the most probable and the worst quarter costs. The curves shown in Figure 79 representing estimated costs of sewage treatment plants in the Greater Vancouver Area are similar to the Velz curves in the relationship between plant capacity and unit cost.

The estimated costs of treatment plants presented herein include sludge digestion and disposal facilities but do not include influent or effluent pumping stations. The costs of pumping stations at the plants were not included in the plant costs since in some cases no pumping may be required. Where pumping stations will be required, their costs have been estimated in accordance with the curves given in Figure 79.

Drainage Facilities Estimated unit costs of various types of drainage facilities are

Table 37
Estimated Unit Costs of Sewers

Size Inches	Material	Type of Excavation	Cost per Lineal Foot, Dollars					
			5-Foot Excavation	10-Foot Excavation	15-Foot Excavation	20-Foot Excavation	25-Foot Excavation	30-Foot Excavation
12	RC	Wet	7.80	11.20	16.20	23.30	29.60	36.60
		Dry	5.50	7.10	9.90	14.40	18.70	26.00
15	RC	Wet	8.70	12.20	17.50	24.90	31.50	38.70
		Dry	6.30	8.00	11.00	15.40	20.20	27.80
18	RC	Wet	9.80	13.70	19.70	27.90	35.10	43.30
		Dry	7.30	9.20	12.50	17.50	22.70	31.20
20	RC	Wet	10.70	14.90	21.20	30.00	38.00	46.50
		Dry	8.20	10.20	13.80	19.10	24.70	33.70
22	RC	Wet	11.50	15.80	22.60	31.90	40.00	48.40
		Dry	8.80	11.00	14.90	20.20	26.30	35.80
24	RC	Wet	12.60	17.40	24.60	34.70	43.50	53.10
		Dry	9.90	12.20	16.30	22.20	28.70	38.90
27	RC	Wet	14.20	19.00	27.00	38.00	47.50	58.30
		Dry	10.90	13.30	18.10	24.30	31.40	41.80
30	RC	Wet	15.90	21.40	30.10	41.60	52.00	63.50
		Dry	12.30	15.00	20.00	25.00	32.60	44.60
33	RC	Wet	17.30	22.70	32.40	45.10	56.20	68.40
		Dry	13.60	16.40	22.00	29.30	37.50	49.60
36	RC	Wet	18.50	24.90	35.00	48.50	60.00	73.30
		Dry	14.60	17.70	23.70	31.70	40.00	54.00
39	RC	Wet	-	26.50	37.60	52.50	64.50	78.00
		Dry	-	19.70	26.30	34.50	43.80	57.50
42	RC	Wet	-	28.30	40.00	55.00	68.10	83.00
		Dry	-	20.50	27.40	36.40	46.10	61.50
45	RC	Wet	-	30.80	43.00	59.40	72.50	87.30
		Dry	-	23.00	30.50	40.00	50.00	65.50
48	RC	Wet	-	32.30	45.50	62.40	77.00	91.00
		Dry	-	24.50	32.70	42.50	52.50	70.20
51	RC	Wet	-	35.20	48.80	66.00	80.70	97.50
		Dry	-	26.50	35.00	45.50	56.90	74.00
54	RC	Wet	-	37.80	52.50	71.00	87.00	105.00
		Dry	-	28.60	37.70	48.70	60.40	78.50
57	RC	Wet	-	40.00	55.30	73.50	90.00	108.00
		Dry	-	30.10	39.90	51.30	63.50	82.10
60	RC	Wet	-	42.00	58.40	78.00	95.80	115.50
		Dry	-	32.00	42.00	54.00	66.80	87.30
63	RC	Wet	-	45.00	61.70	82.00	100.00	120.00
		Dry	-	34.00	44.70	57.20	70.50	90.50
68	RC	Wet	-	48.50	66.50	88.00	107.00	128.50
		Dry	-	36.90	48.20	61.00	75.00	98.00
72	RC	Wet	-	52.80	72.50	95.40	115.50	138.50
		Dry	-	40.50	52.60	66.50	81.50	105.00
78	BHS	Wet	-	67.10	75.00	99.70	120.50	146.50
		Dry	-	47.00	53.60	68.60	84.80	110.50
84	BHS	Wet	-	69.50	85.40	111.00	136.00	162.50
		Dry	-	55.30	62.60	78.60	96.30	124.00
90	BHS	Wet	-	78.80	95.50	124.50	150.00	178.00
		Dry	-	64.00	71.60	89.00	107.50	136.50
96	BHS	Wet	-	88.60	106.50	137.00	164.00	194.00
		Dry	-	72.70	81.10	99.30	119.00	151.00
102	BHS	Wet	-	-	116.00	148.50	178.00	210.00
		Dry	-	-	88.30	108.70	130.00	163.00
108	BHS	Wet	-	-	127.00	161.50	192.00	226.00
		Dry	-	-	98.10	119.00	141.00	177.00
114	BHS	Wet	-	-	139.00	175.50	207.00	244.00
		Dry	-	-	108.50	131.00	154.00	192.00
120	BHS	Wet	-	-	152.50	190.00	225.00	263.00
		Dry	-	-	121.50	144.00	169.00	208.00

RC signifies reinforced concrete pipe; BHS, Boston horseshoe section.
Costs do not include the 25 percent allowance for engineering, administration, contingencies, repaving of streets, rights-of-way or special appurtenances, or an allowance for special foundations.
Costs include conduit, laying, excavation, timber, backfill, manholes, cleanup and foundations.
In wet and dry excavation, hand excavation is considered necessary at depths below 15 feet.

Table 37 - Continued

In wet excavation, cost per cubic yard for excavation, timber and backfill varied from $3.75 at 5-foot depths to $9.25 at 30-foot depths. A 6-inch subdrain at $1.25 per lineal foot and gravel bedding 6-inches to 18-inches in depth at $5.00 per cubic yard were considered necessary in wet excavation.

In dry excavation, cost per cubic yard for excavation, timber and backfill varied from $2.55 at 5-foot depths to $6.50 at 30-foot depths.

In wet and dry excavation, trench sides were considered vertical and supported by timbers. The trench width was considered to be 12 inches wider than the exterior diameter of the conduit.

In wet and dry excavation, concrete cradle at $13.00 per cubic yard in place was considered necessary for pipe sewers at depths below 15 feet.

Table 38
Estimated Unit Costs
of Reinforced Concrete Force Mains

Size in Inches	Cost per Lineal Foot Dollars
12	6.00
16	7.70
18	8.90
24	12.70
30	17.50
36	23.00
42	30.50
48	37.70
54	45.10
60	52.50
68	61.50
72	67.50

Cost is for pipe with 100-foot maximum operating head and includes reinforced concrete collars.

Unit costs include pipe, laying, excavation, timber, backfill and cleanup. Excavation, timber and backfill are based on an average cover of 4 feet and a trench 12 inches wider than the exterior diameter of the pipe.

Costs do not include engineering, administration, contingencies, repaving of streets, or rights-of-way.

presented in Table 39 for each of the classifications and ground slope conditions described above. The costs given have been derived from actual recent construction costs of drainage works of the Vancouver and Districts Joint Sewerage and Drainage Board and of the City of Vancouver. The costs also recognize the natural differences which exist between the topographic sections of the Greater Vancouver Area. The costs do not include dyking systems where such are necessary for the protection or reclamation of the affected territory.

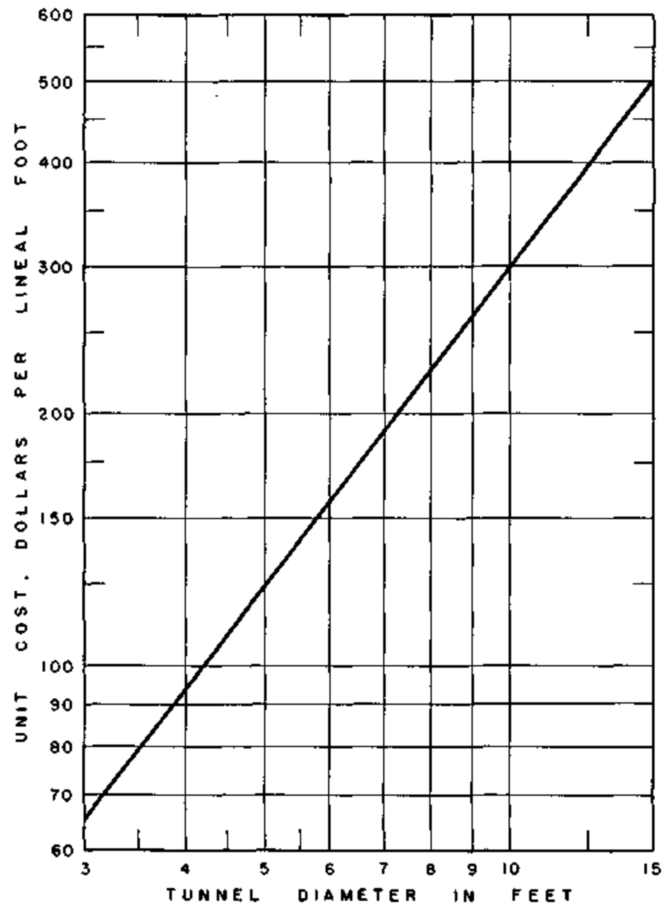


Figure 77. Estimated Unit Costs of Tunnels

The curve was derived from actual construction costs of tunnels in the Greater Vancouver Area; costs were adjusted to an Engineering News - Record Construction Cost Index of 700. The tunnels are considered to be concrete lined and reinforced. The costs do not include allowances for engineering and contingencies.

Annual Costs

Bond Redemption and Interest. In lieu of depreciation of the sewerage and drainage facilities, the retirement of 25 year instalment debentures has been assumed to represent a reasonable depreciation allowance. An interest rate on the bonds of four percent was selected as representing the rate at which bonds for the projects herein proposed could be sold. The annual payment covering bond redemption and interest for any given year

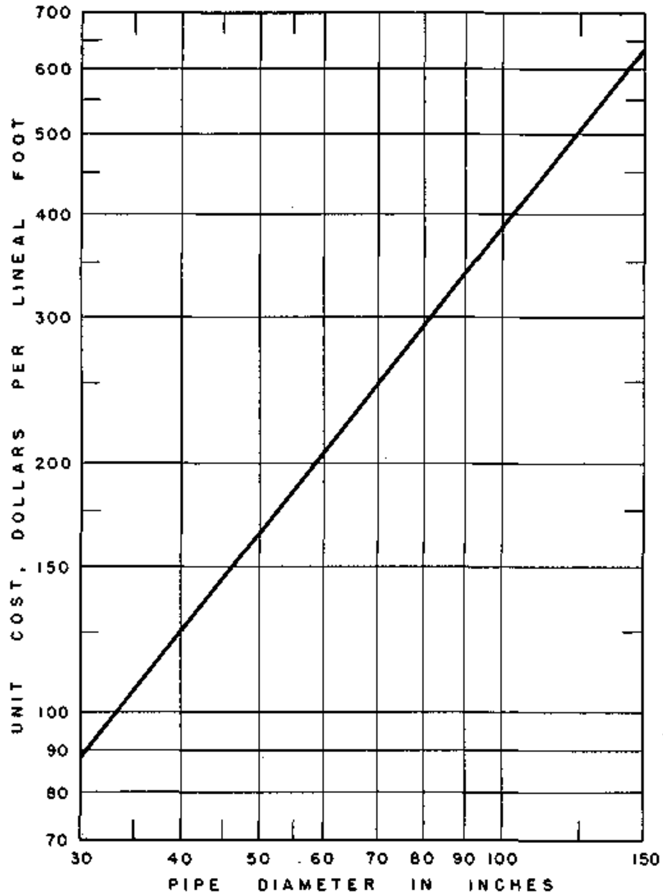


Figure 78. Estimated Unit Costs of Submarine Outfalls

The curve was derived from the actual construction costs of submarine outfalls of the Vancouver and Districts Joint Sewerage and Drainage Board; costs were adjusted to an Engineering News-Record Construction Cost Index of 700. The costs do not include allowances for engineering and contingencies.

would therefore constitute the total fixed charges for that year on the facilities involved. Under this method, equal annual payments are made over the life of the debentures. For 25 equal annual payments of bond redemption and interest on debentures bearing four percent interest, the annual cost represents 6.4 percent of the initial expenditure.

Maintenance and Operation. The annual cost of maintaining and operating the conduits or open channels required to convey the sewage or storm water to the final points of disposal has been assumed to be one quarter of one percent of the total construction cost of these facilities. This figure checks reasonably well with the average annual maintenance and operation cost for the extensive system of sewers and drains of the Vancouver and Districts Joint Sewerage and Drainage Board.

The curves used for estimating the operation and maintenance costs of sewage pumping stations and treatment plants are presented in Figure 80. These are based on a study of operating costs of plants throughout California and have been adjusted to the British Columbia wage and price differential. They include all costs of administration incident to the operation of the various facilities. Administration costs are intended to include those of supervision, engineering and office overhead, as well as legal

Table 39
Estimated Unit Costs of Major Drainage Facilities

Facility		Cost per Acre, Dollars		
Type	Average Ground Slope in Percent	North Shore Section	Burrard Peninsula Section	Richmond Section
Open Channel				
A1	0 to 2	60	80	80
A2	2 to 8	50	65	
A3	> 8	40	50	
Conduit				
B1	0 to 2	260	340	340
B2	2 to 8	230	300	
B3	> 8	200	270	
Open Channel with Pump				
C	0 to 2	120	140	140
Conduit with Pump				
D	0 to 2	320	400	400

Costs do not include engineering, administration, contingencies, or rights-of-way.

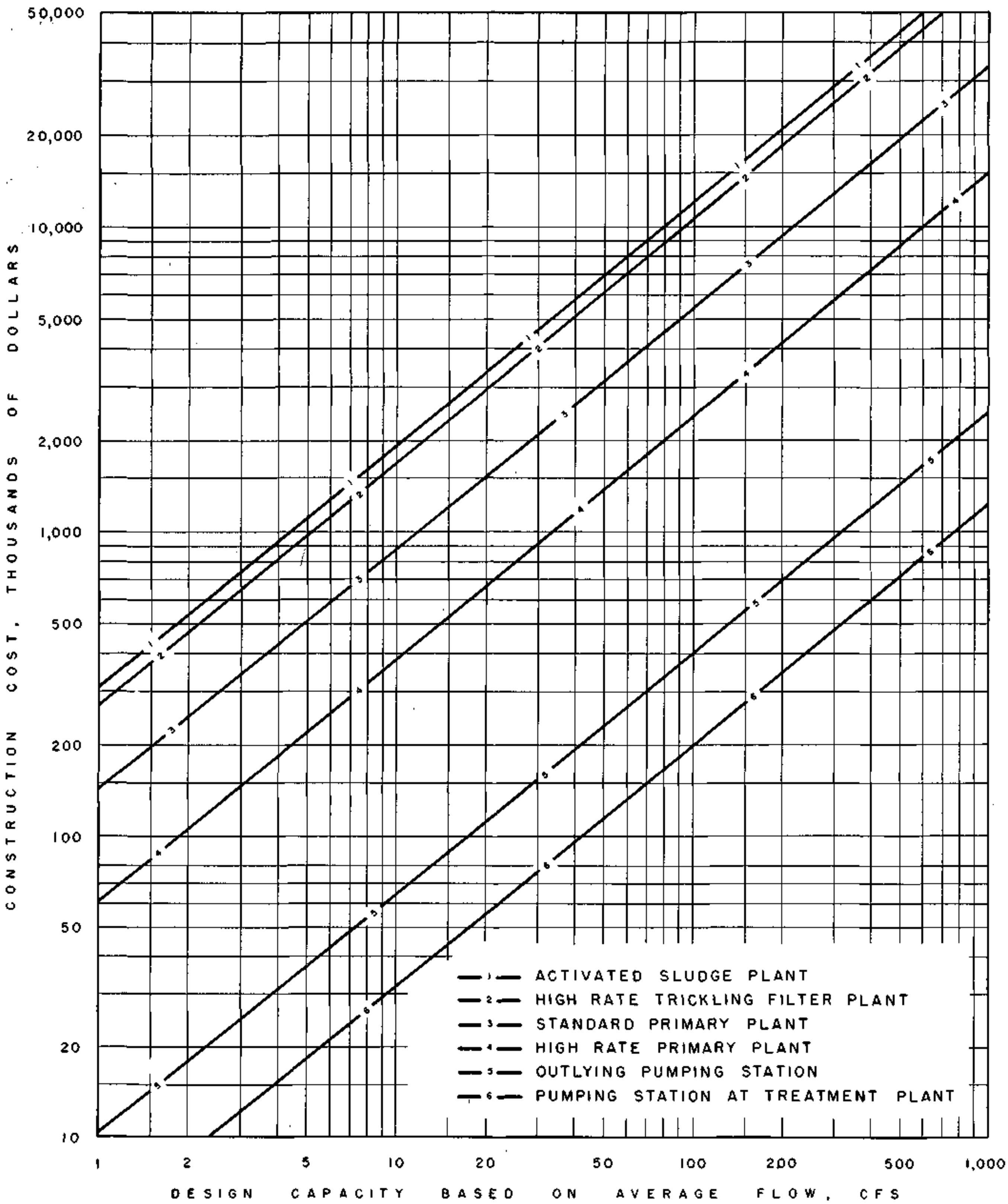


Figure 79. Estimated Construction Costs of Sewage Treatment Plants and Pumping Stations

The costs are based on an Engineering News-Record Construction Cost Index of 700. They do not include allowances for engineering, contingencies, administration, land, rights-of-way, or special foundations such as piling. All costs imply first class construction and a design allowing maximum flexibility and ease of operation. The treatment plant costs include sludge digestion and disposal facilities but do not include influent or effluent pumping stations.

fees, special consultant's fees, accident and liability insurance, and miscellaneous items.

The operating costs for each type of treatment plant were computed in detail and include all necessary costs of plant

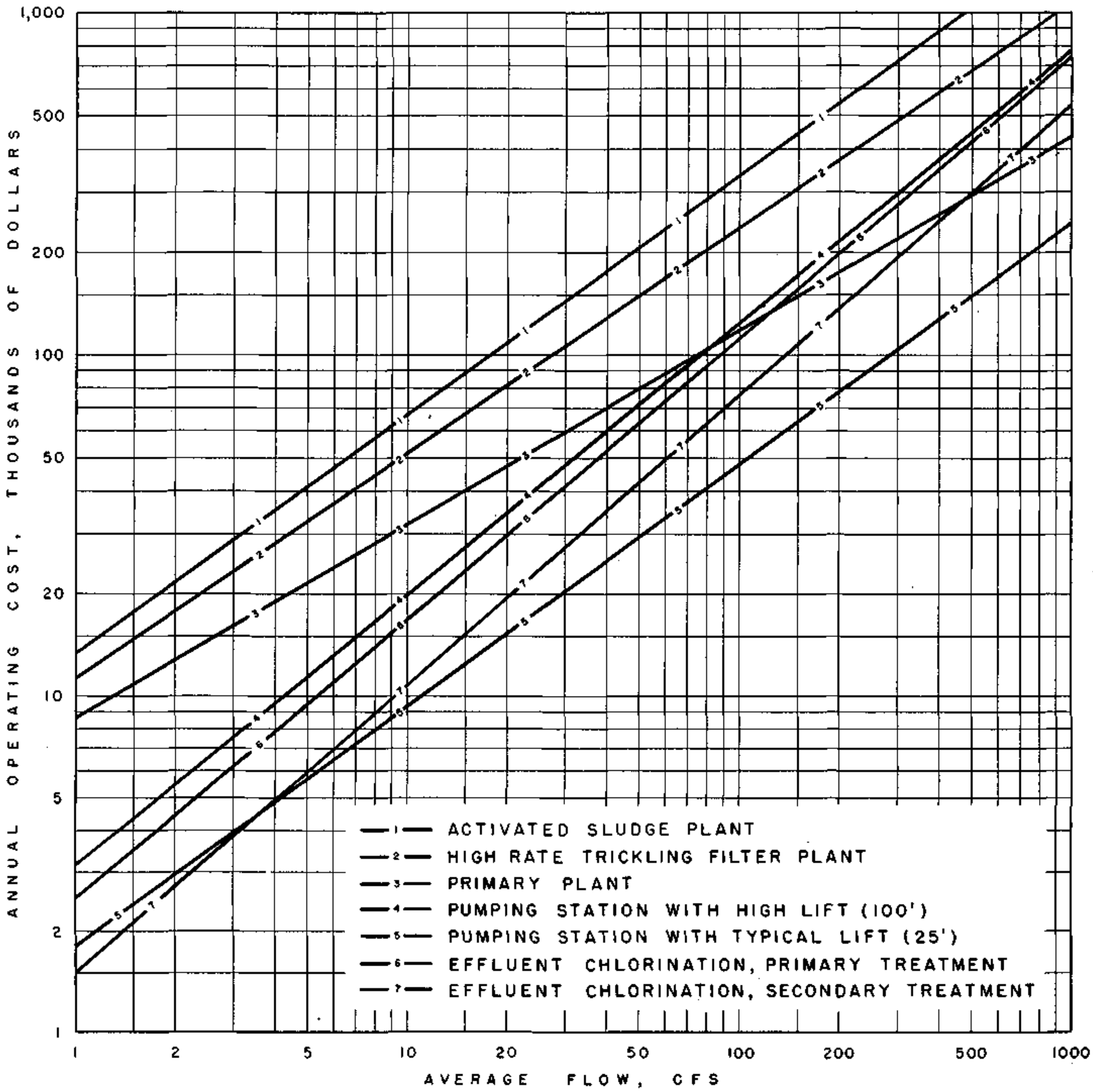


Figure 80. Estimated Annual Maintenance and Operation Costs of Sewage Treatment Plants and Pumping Stations

The costs given are for the average sanitary sewage flow and include all costs of administration as well as all necessary costs of plant supervision and operational services and costs of all supplies, replacement parts and miscellaneous equipment necessary for maintenance and operation. The costs for sewage treatment plants include the cost of operating pumping stations with typical lifts when these stations are located adjacent to the plant but do not include chlorination. All treatment plants having a capacity of 10 cfs or greater are assumed to utilize sludge gas either for the generation of power or as fuel for engines driving pumps or other equipment.

supervision and operational services. The costs for sewage treatment plants include the cost of operating pumping stations with typical or normal lifts when these stations are located adjacent to the plant.

Pumping station operating costs include all maintenance and operation costs including power. Power charges currently in effect in the area were used in determining costs of operation.

Chlorination costs were derived by using a chlorine demand of 8 ppm for primary effluents and 5 ppm for secondary effluents, and include the cost of the chlorine gas plus the cost of its application.

Total Annual Costs

The total annual costs of any sewerage or drainage facility comprise the fixed costs, which include bond redemption and interest, and the operating and maintenance costs, which include operational services, administration, supplies, replacement parts and miscellaneous items. Throughout this report, except as otherwise specifically stated, the annual costs are presented as the average annual costs over five year periods. The method of computing the average annual costs can best be illustrated by the following hypothetical example. The construction cost of a system includes $2,000,000 for conduits, $100,000 for pumping stations and $1,000,000 for a standard-rate primary sewage treatment plant with effluent chlorination, making a total construction cost of $3,100,000. The average sewage flow during the five year period is 2 cfs. The entire flow passes through one outlying pumping station with a lift of 25 feet. The average annual cost for the five year period, calculated as outlined above, would be as follows:

Cost Item	Average Annual Cost, dollars
Bond redemption and interest (25 year instalment debentures at 4 percent)	198,000
Maintenance and Operation	
Conduits (1/4 of one percent of construction cost)	5,000
Pumping Station (from Figure 80)	3,000
Sewage Treatment Plant (from Figure 80)	13,000
Chlorination (from Figure 80)	3,000
Subtotal - M & O	24,000
Total Annual Cost	222,000

Chapter 14

Sewerage Plans for the Burrard Peninsula Section

Selection of Sewerage Plans for Study

To determine the most satisfactory solution of the sewerage problem of an area, all possible plans are analyzed for general suitability. The plan which is demonstrated to have the lowest annual cost will generally be found to be the best suited to the needs of the area, all other considerations being equal.

The Burrard Peninsula Section is divided by natural topographic features into three sewerage areas, namely, the Vancouver, Fraser, and Coquitlam Sewerage Areas. Each of these is discussed separately and all apparently feasible plans for the sewerage of each area have been investigated. Each plan suggested for detailed analysis and comparison satisfies certain fundamental controlling conditions and requirements. As set forth and discussed in the preceding chapters of this report, the major controlling factors are: geography, topography, geology and climate; use of shores and shore waters; population numbers and distribution; value of existing sewerage facilities; characteristics of the sewage; and, finally, the requirements for ultimate disposal of the sewage.

The degree or extent of sewage treatment required is largely dependent upon conditions at the selected place of discharge and the quantity of sewage involved. As will be shown by several of the comparisons presented in this chapter, it is commonly more economical to convey the sewage to a place where disposal may be accomplished with a relatively low degree of treatment than to dispose of the sewage at a location adjacent to the tributary area producing the sewage if disposal there demands a high degree of treatment.

Brief Description of Recommended Plans

Sewerage of the Burrard Peninsula Section can best be accomplished by conveying the sewage to six separate points of ultimate disposal. Conditions for sewage disposal are so favourable in the section that at only one location has it been deemed necessary to provide for sewage treatment. Because of the anticipated volume of sewage and the fundamental necessity of protecting the beaches of English Bay against contamination, sewage from the Vancouver Sewerage Area should be treated. To provide this treatment, it is proposed to construct a high-rate primary treatment plant on Iona Island in the North Arm of Fraser River with effluent discharge into the tidal waters of the Strait of Georgia. The volume of diluting water available at the five other outfall locations, coupled with the present and anticipated future use of adjacent waters, obviates the necessity for treatment at these points in the foreseeable future.

Figure 81 shows the general layout of the major intercepting and trunk sewers required, The letter designation indicated for each plan is the one under which that plan is described.

Use of Existing Facilities

In the development of plans to serve the Burrard Peninsula Section, every effort was made to incorporate the existing sewerage facilities into the overall program.

Most of the existing sewerage facilities in the section are in the Vancouver Sewerage Area. These facilities comprise trunk sewers which, for the most part, discharge combined sewage and storm water into Burrard Inlet, the main channel of Fraser River, or the North Arm of Fraser River. The facilities proposed under the overall program provide for the interception of these discharges and the conveying of the sewage to a more suitable point of disposal.

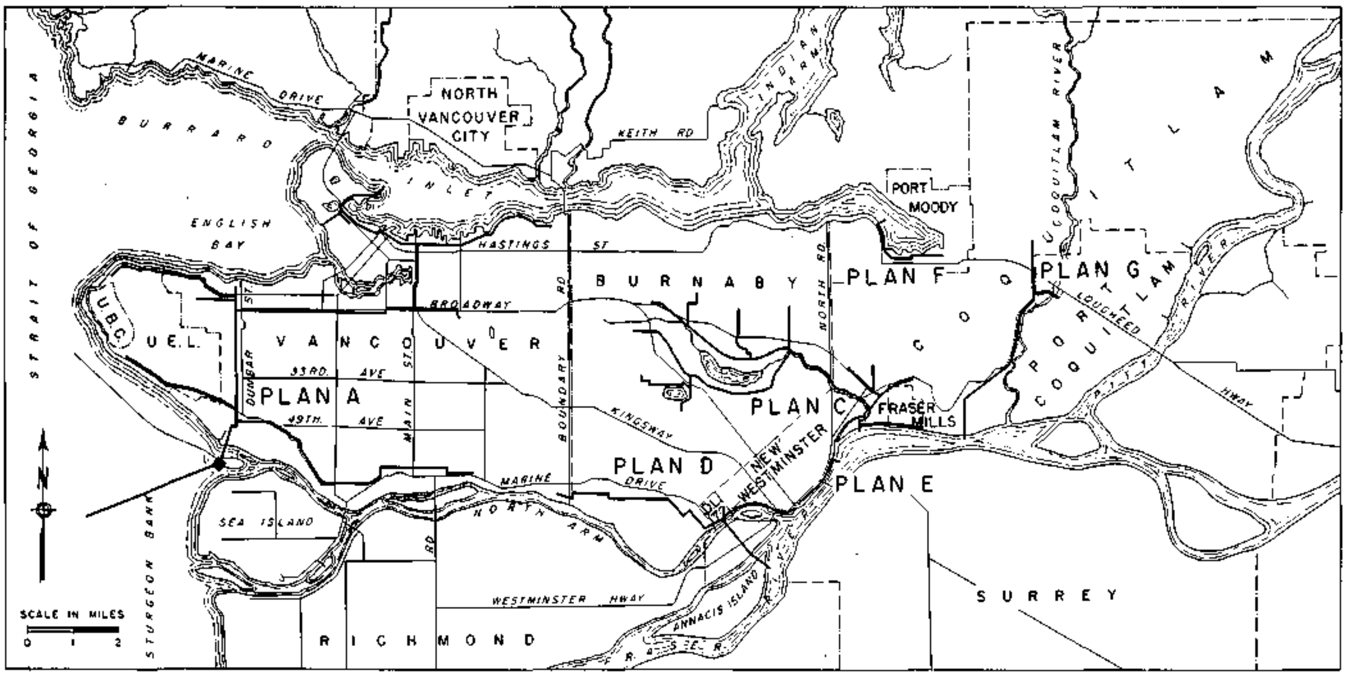


Figure 81. General Layout of Recommended Plans for Burrard Peninsula Section

Sewerage of the Burrard Peninsula Section can best be accomplished by conveying the sewage to six separate points of ultimate disposal. Conditions for sewage disposal are so favourable in the section that at only one location has it been necessary to provide for sewage treatment prior to discharge.

Preliminary Design of Facilities

All sewers, tunnels, force mains and outfalls have been planned with sufficient capacity to accommodate the estimated ultimate peak rates of sanitary sewage flow. Some of the facilities, as described in the following pages, also provide capacity for conveying storm water. Provision of capacity for the ultimate rate of sewage flow was considered necessary because in most instances the locations and conditions are or will be such that future duplication or paralleling of conduits would be difficult and expensive.

Facilities such as pumping stations and sewage treatment plants have been so laid out that future additions may be made in steps or stages according to need. In these cases, it is expected that the initial design and construction will be such as to permit easy and economical enlargement.

The sequence or time of construction of the units of various plans was determined by consideration of the sewerage requirements of the tributary area, of the uses of shore waters presently utilized for disposal, and of the proper order of development necessary to ensure adequate protection of the shores and shore waters of the Greater Vancouver Area. Briefly summarized, the suggested sequence of construction assumes a time schedule as follows:

by 1955: Elimination of continuous crude sewage discharges into English Bay.

by 1960: (1) Elimination of combined sanitary and storm flow discharges into English Bay except at specified frequencies. (2) Elimination of the major portion of continuous crude sewage discharges into Vancouver Harbour.

by 1965: Elimination of all continuous crude sewage discharges into Vancouver Harbour.

by 1970: Elimination of combined sanitary and storm flow discharges into the North Arm of Fraser River except at certain specific frequencies.

It will be observed that the sequence of construction has been broken down into five year periods. Actual construction of the proposed facilities will probably constitute a continuing program, however, with the completion of each stage by the specified date. For purposes of calculating the annual costs presented in this report, it has been necessary to group the proposed facilities within stated construction periods and to assume that the cost of facilities indicated for construction in a given year would have no effect upon the annual costs computed for earlier years.

At the outset of the survey, it was obvious that the sewage of the various sewerage areas would have to be transported through considerable distances to reach suitable disposal sites. On the other hand, because of the topography of the section, storm water can properly be disposed of in nearby bodies of water. For this reason, the facilities proposed in those portions of the section not presently sewered on a combined basis have been laid out as separate systems. The design criteria for sewers intercepting existing combined trunk sewers will be discussed under each sewerage area.

The unit or per capita sewage flows and the per capita contributions of biochemical oxygen demand and suspended solids are given in Table 35, Chapter 13. For those portions of the section which are sewered on the combined basis, a per capita flow of 110 gallons per day has been used. For the remainder of the section, which is to be sewered by separate systems, a per capita flow of 95 gallons per day has been used. As discussed in Chapter 11, the design factors include suitable allowances for contributions from tributary industry. The ultimate population contributory to each facility was estimated by multiplying the tributary area by the predicted ultimate population density distribution shown on Figure 35, Chapter 9.

This chapter deals with the plans considered for each sewerage area of the Burrard Peninsula Section. The various plans are outlined and described and their estimated construction and annual costs are presented. Where two separate plans for sewering the same area were studied, a comparison of their construction and annual costs was made to determine the more economical plan. Other possibilities, which were not deemed worthy of further study, are briefly described and the reasons for no further consideration are given.

VANCOUVER SEWERAGE AREA

Basic Considerations

The most pressing sewerage requirement in the Vancouver Sewerage Area is the elimination of the continuous discharge of crude sewage into the recreational waters of English Bay. Intermittent discharges or overflows of diluted sanitary sewage during periods of storm water runoff through existing combined sewer outfalls can be tolerated providing the volume and frequency of such overflows do not endanger the public uses of the receiving waters. Since the normal recreational use of the waters of the area is limited to the five months, May through September, consideration of the permissible frequency of overflows has been confined to those months.

All existing outfalls into English Bay and False Creek discharge combined sanitary sewage and storm water. As discussed in Chapter 10 and as shown on Figure 37, only one of these outfalls, namely that at Discovery Street, extends any considerable distance offshore. The remainder terminate close to shore. To provide protection of the recreational waters in this area, all of the outfall conduits must be intercepted and the sewage conveyed to a more suitable place of disposal. It has therefore been necessary to determine the most economical design of an intercepting system commensurate with the values received from the protection afforded. Studies of rainfall frequency and intensity during the five month period under consideration, and of the design of facilities to accommodate the runoff from storms of various intensities have been made. These indicate that the necessary protection will be provided at the greatest overall economy if an intercepting system is constructed which will remove all sewage from English Bay except for an average of one overflow of dilute sewage per recreational season from the short outfalls and for an average of three overflows per season from the Discovery Street outfall. Elimination, insofar as possible, of the discharge of any sewage upon the beaches along the Spanish Banks and in the vicinity of Park Lane in the West End of Vancouver is considered to be necessary to secure the objectives sought for the area.

The uses to which the waters of Vancouver Harbour are put do not require the same degree of protection as that proposed to be afforded in English Bay. The only requirement that may reasonably be imposed is the elimination of the continuous discharge of sanitary sewage into the harbour. During periods of storm, all of the combined sewage could quite properly be discharged into the harbour with no adverse effect on the beneficial uses of its waters. Intercepting sewers along the harbour foreshore are herein proposed to carry only the peak flows of sanitary sewage. Existing outfalls to the harbour would discharge all of the combined flows during storms.

As discussed in Chapter 12, waters of the North Arm of Fraser River flow around Point Grey onto the beaches of English Bay. It is necessary to eliminate continuous discharges of crude sewage into the North Arm if the beaches of English Bay are to be protected. Again, however, the design of an intercepting system along the North Arm of Fraser River must be as economical as possible commensurate with the benefits to be derived. Because of the considerable degree of dilution and dispersion afforded any sewage overflowing into the North Arm, it is believed that a higher frequency of overflow can properly be allowed there than is permissible if the overflow were made directly into English Bay. The frequency of overflows providing the most economical intercepting sewer design and yet affording reasonable protection to the uses of English Bay and of the North Arm itself, has been determined to be an average of six during the five month recreational season in the upper reaches and three per season in the lower reaches.

Two sewerage plans, designated Plan A and Plan B, have been laid out in conformity with the above criteria. Plan A provides for the conveyance of all the sewage of the Vancouver Sewerage Area to a treatment plant on Iona Island with effluent discharge to the tidal waters of the Strait of Georgia. Plan B provides for the conveyance of the sewage of the area to two treatment plants, one on Iona Island and one at the foot of Clark Drive, serving the western and eastern portions of the area, respectively.

Although it is possible to locate a sewage treatment plant on the shores of English Bay, detailed studies of such a possibility were not made for the following reasons:

1. The plant would necessarily be located in the immediate vicinity of important recreational and residential areas. Construction there of a plant to provide for the proper control of possible nuisances would be expensive when compared to plants more suitably located.

2. Effluent discharge would be into recreational waters in which adequate dilution and dispersion could not be achieved. Because of this fact, disinfection of the effluent would be required during certain periods of the year.

3. The plant would have to treat the combined flow of sanitary sewage and storm water at the design frequency to provide the same degree of protection as afforded by the plant on Iona Island.

Plan A

Plan A provides for the collection and conveyance of the sewage of the Vancouver Sewerage Area to a high-rate primary sewage treatment plant on Iona Island with effluent discharge to the tidal waters of the Strait of Georgia.

Figure 82 shows the locations of the facilities embraced by Plan A. Table 40 presents the lengths, sizes and slopes of the conduits and the design flows and estimated construction costs of the facilities required for the completion of Plan A. This table also indicates the suggested sequence of construction. The initial construction cost of this plan is estimated to be $11,489,000 and the total ultimate construction cost $28,813,000

The intercepting sewers contained

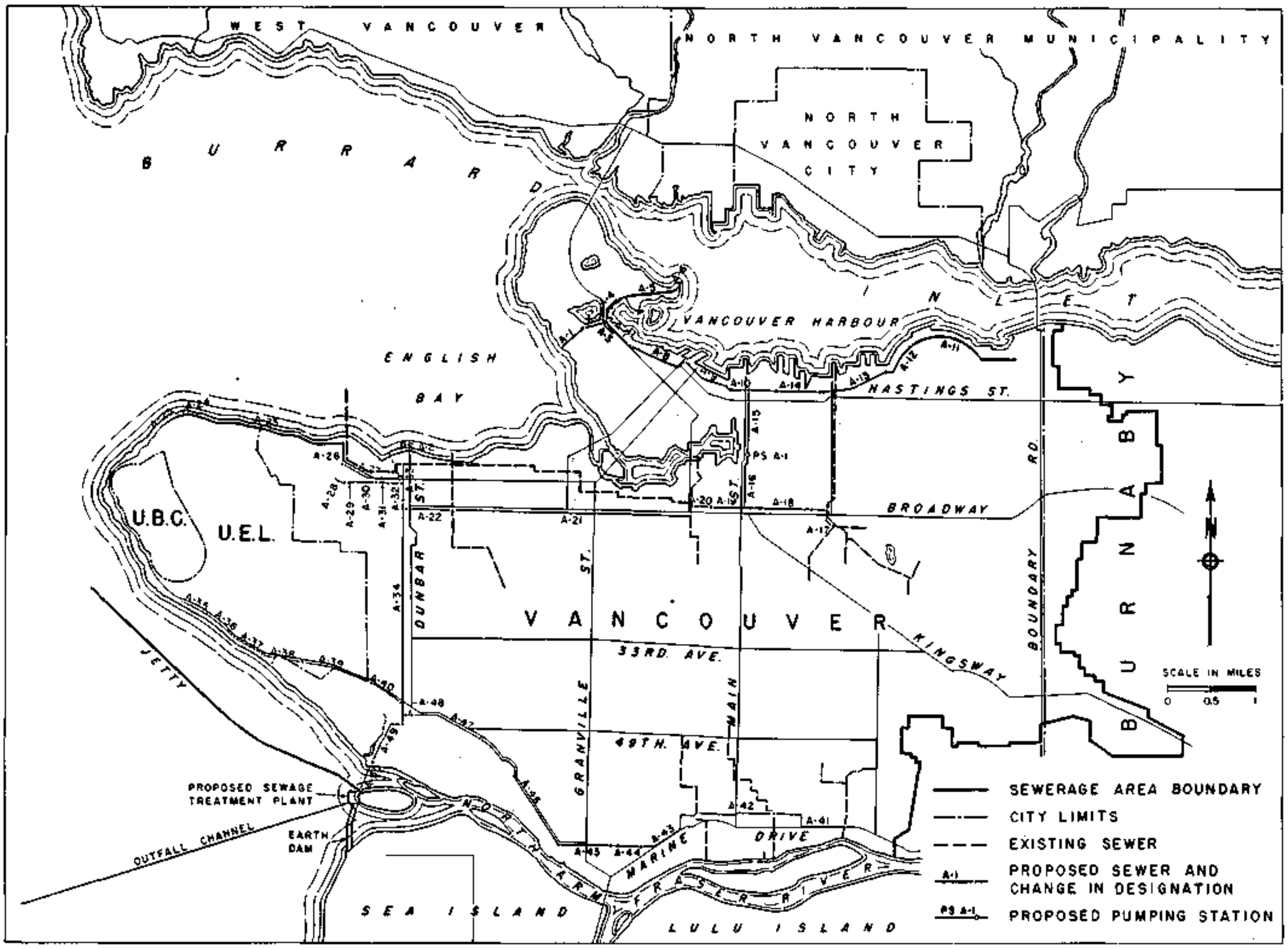


Figure 82. Proposed Layout of Plan A - Vancouver Sewerage Area

Plan A proposes the collection of the sanitary sewage of the entire Vancouver Sewerage Area to a high-rate primary treatment plant located on Iona Island. Effluent would be discharged to tidal water of Sturgeon Bank. Storm water would be conveyed to this location but would bypass the treatment plant.

in Plan A have been laid out on the basis of the criteria discussed above. The functions of the facilities, certain controlling conditions and the dates suggested for construction are as follows:

1. A-1 through A-6: together with the existing West End intercepting sewer, to eliminate all discharges of sewage to English Bay Beach and to provide capacity for the ten year winter storm; to be constructed by 1955.

2. A-7 through A-10: to eliminate continuous discharge of sanitary sewage into Vancouver Harbour except during periods of storm runoff, when all sewage will be bypassed to the harbour; to be constructed by 1965.

3. A-11 through A-14: to eliminate continuous discharge of sanitary sewage into Vancouver Harbour except during periods of storm runoff, when all sewage will be bypassed to the harbour; to be constructed by 1965.

4. A-15, A-16, and PS A-1: to convey sanitary sewage flow from sewers A-7 through A-14 to sewer A-19 except during periods of storm runoff, when combined sewage will be discharged to Vancouver Harbour through existing outfalls; to be constructed by 1965.

5. A-17 through A-20: to eliminate continuous discharge of sanitary sewage into Vancouver Harbour except during periods of storm runoff, when all sewage will be bypassed to the harbour through the existing Clark Drive intercepting sew-

Table 40
Estimated Design Flows and Construction Costs of Plan A Facilities
Vancouver Sewerage Area

Facility[a]	Design Flow cfs	Construction Cost[b], Dollars 1955	1960	1965	1970	1975
Sewers:						
A-2: 1,485 ft. of 72-in. RC[c]	148	99,000				
A-3: 1,000 ft. of 42-in. RC[c]	57	38,000				
A-4: 1,830 ft. of 78-in. BHS[c]	226	146,000				
A-7: 2,200 ft. of 39-in. RC at 0.045%	17.6			129,000		
A-11: 6,950 ft. of 36-in. RC at 0.05%	14.6			388,000		
A-12: 2,400 ft. of 36-in. RC at 1.10%	14.6			59,000		
A-13: 2,850 ft. of 36-in. RC at 0.27%	17.8			120,000		
A-17: 1,950 ft. of 48-in. RC at 0.08%	35.9		60,000			
A-20: 1,350 ft. of 63-in. RC at 1.05%	93.6		100,000			
A-23: 1,190 ft. of 22-in. RC at 5.18%	36.9	17,000				
A-24: 540 ft. of 24-in. RC at 2.70%	36.9	8,000				
A-26: 1,200 ft. of 36-in. RC at 0.15%	25.9	29,000				
A-27: 3,800 ft. of 42-in. RC at 0.15%	37.5	135,000				
A-28: 650 ft. of 20-in. RC at 8.0%	38.7	7,000				
A-29: 500 ft. of 22-in. RC at 4.5%	38.7	6,000				
A-30: 1,340 ft. of 24-in. RC at 3.15%	38.7	18,000				
A-31: 830 ft. of 30-in. RC at 2.26%	39.2	15,000				
A-32: 1,030 ft. of 30-in. RC at 0.19%	39.2	18,000				
A-33: 1,900 ft. of 114-in. BHS at 0.059%	400	348,000				
A-35: 1,400 ft. of 12-in. RC at 1.30%	2.7				10,000	
A-36: 1,800 ft. of 12-in. RC at 0.61%	2.7				12,000	
A-37: 1,800 ft. of 12-in. RC at 3.30%	3.2				12,000	
A-38: 2,400 ft. of 15-in. RC at 0.54%	3.2				22,000	
A-39: 3,250 ft. of 18-in. RC at 0.13%	3.6				51,000	
A-40: 2,940 ft. of 18-in. RC at 2.10%	5.0				30,000	
A-48: 900 ft. of 96-in. BHS at 0.070%	258				120,000	
Tunnels: concrete lined						
A-1: 1,400 ft. of 72-in.[c]	148	272,000				
A-5: 3,600 ft. of 78-in.[c]	226	800,000				
A-8: 3,880 ft. of 39-in. at 0.060%	17.6			344,000		
A-9: 3,900 ft. of 42-in. at 0.065%	21.6			380,000		
A-10: 700 ft. of 48-in. at 0.040%	24.6			81,000		
A-14: 5,300 ft. of 51-in. at 0.045%	28.8			663,000		
A-15: 3,800 ft. of 66-in. at 0.035%	53.1			655,000		
A-18: 4,220 ft. of 48-in. at 0.10%	37.4		446,000			
A-19: 2,050 ft. of 63-in. at 0.135%	93.6		334,000			
A-21: 14,170 ft. of 72-in. at 0.26%	235		2,750,000			
A-22: 3,300 ft. of 72-in. at 0.42%	300		640,000			
A-34: 12,800 ft. of 114-in. at 0.059%	400	4,440,000				
A-41: 5,320 ft. of 60-in. at 0.085%	73				825,000	
A-42: 4,740 ft. of 66-in. at 0.12%	112				830,000	
A-43: 5,000 ft. of 66-in. at 0.19%	142				875,000	
A-44: 1,740 ft. of 66-in. at 0.28%	147				305,000	
A-45: 4,040 ft. of 75-in. at 0.09%	155				808,000	
A-46: 7,760 ft. of 93-in. at 0.055%	208				2,090,000	
A-47: 4,600 ft. of 96-in. at 0.048%	216				1,260,000	
Force mains:						
A-16: 3,350 ft. of 54-in. RC	56.3			189,000		
A-26: 10,030 ft. of 36-in. RC	53.1	287,000				
Outfalls:						
A-6: 125 ft. of 72-in. RC	226	41,000				
A-49: 3,300 ft. of 114-in. BHS land section	608	605,000				
A-50: 2,800 ft. of 114-in. BHS	608	1,590,000				
Total, conduits		8,919,000	4,330,000	3,008,000	7,250,000	
Pumping stations:						
A-1:	37.5[d]			230,000[d]		
A-2:	35.9[d]	219,000[d]				
Influent at plant	45.0[e]	131,000[e]		107,000[f]		69,000[g]

Table 40 - Continued

Facility[a]	Design Flow cfs	Construction Cost[b], Dollars				
		1955	1960	1965	1970	1975
Sewage treatment plant	45.0[e]	1,720,000[e,h]		1,440,000[f,h]		890,000[g,h]
Outfall channel and appurtenances	608	500,000				
Total construction cost		11,489,000	4,330,000	4,785,000	7,250,000	959,000

[a] See Figure 82 for location of facilities.
[b] From Tables 37 and 38 and Figures 77, 78, and 79; plus 25 percent for engineering, administration and contingencies.
[c] Designed as pressure conduit.
[d] Ultimate capacity.
[e] Initial construction.
[f] Enlargement from 45.0 cfs to 95.0 cfs.
[g] Enlargement from 95.0 cfs to ultimate capacity of 130 cfs.
[h] Includes an allowance for special foundations.

er and outfall; overflows of mixed sewage and storm water from the Clark Drive sewer through the China Creek overflow to False Creek will occur on an average of once per season; to be constructed by 1960.

6. A-21 through A-22: together with the existing English Bay intercepting sewer, to eliminate continuous discharge of sewage into English Bay; to provide capacity sufficient to allow an average of one overflow of combined sewage per recreational season into English Bay; to be constructed by 1960.

7. A-23 through A-25: to eliminate all discharges of sewage onto the beaches along Spanish Banks; to provide capacity for the ten year winter storm; these units to be constructed by the Provincial Government in 1953 and purchased from the government at a later date.

8. A-26, A-27, and PS A-2: to eliminate continuous discharge of sewage into English Bay; to provide capacity sufficient to allow an average of three overflows of combined sewage per recreational season into English Bay through the Discovery Street outfall; to be constructed by 1955.

9. A-28 through A-32: to eliminate continuous discharge of sewage to English Bay; to provide capacity sufficient to allow an average of three overflows of combined sewage per recreational season into English Bay through the Discovery Street outfall; to be constructed by 1955.

10. A-33 and A-34: to eliminate continuous discharge of sewage to English Bay; to provide capacity sufficient to allow an average of three overflows of combined sewage per season into English Bay through the Discovery Street outfall; to be constructed by 1955.

11. A-35 through A-40: to provide capacity for sanitary sewage from the south slope of the University Endowment Lands; to be constructed by 1970.

12. A-41 through A-43: to eliminate continuous discharge of sewage into the North Arm of Fraser River; to provide capacity sufficient to allow an average of six overflows of combined sewage per season to the North Arm; to be constructed by 1970.

13. A-44 through A-48: to eliminate continuous discharge of sewage to the North Arm of Fraser River; to provide capacity sufficient to allow an average of three overflows of combined sewage per season into the North Arm; to be constructed by 1970.

14. A-49 and A-50: to convey sewage across the North Arm of Fraser River to a treatment plant on Iona Island; to be constructed by 1955.

The treatment plant on Iona Island would be of the high-rate primary type with a design capacity equal to the sanitary sewage flow. Influent pumping would be required. Treated sewage would be discharged approximately 15,000 feet offshore to deep water of the Strait of Georgia through an effluent channel dredged across Sturgeon Bank. During periods of storm water runoff, flow in excess of plant capacity would be bypassed to the effluent channel. The effluent channel would be designed to confine all flow during periods of low tide when little or no dilution is available on Sturgeon Bank. During periods of higher water the channel would be submerged and mixing and dispersion would take place in the waters covering Sturgeon Bank. An earth dam would be constructed across Macdonald Slough, between Iona and Sea Islands, to prevent the movement of sewage effluent upstream into the North Arm of Fraser River on a rising tide. This will preclude the possibility of material of sewage origin entering the North Arm on a rising tide and being carried around Point Grey and into the recreational waters of English Bay on a falling tide.

As shown on Table 40, it is proposed to construct the sewage treatment plant in stages. Enlargement of the plant will be required as intercepting sewers are constructed, which will make new portions of the Vancouver Sewerage Area tributary to the plant. Enlargements required subsequent to the completion of the intercepting sewer system will be due to population increases in the sewerage area. Initial construction of the plant is suggested for 1955 to correspond with construction of the first stages of the intercepting sewer system.

Plan B

Plan B provides for the treatment of the sewage of the Vancouver Sewerage Area in two separate plants. Sewage from the western portion would be treated in a high-rate primary plant on Iona Island as described under Plan A. Sewage from the eastern portion would be treated in a standard-rate primary plant at the foot of Clark Drive on the foreshore of Vancouver Harbour.

Figure 83 shows the tentative location of the facilities embraced by Plan B. Table 41 presents the lengths, sizes and slopes of the conduits and the design flows and estimated construction costs of the facilities required for the completion of Plan B. This table also gives the suggested sequence of construction. The initial construction cost of this plan is estimated to be $11,003,000 and the total ultimate construction cost $30,318,000.

Intercepting sewers proposed under Plan B provide for sewerage of the Vancouver Sewerage Area equivalent to that proposed to be accomplished by the intercepting sewers under Plan A.

The standard-rate primary plant at the foot of Clark Drive would be constructed on ground filled for the purpose. Influent pumping would be required. Effluent chlorination would probably be necessary during critical periods. By locating the plant at Clark Drive, the existing collection system of the tributary area would be fully utilized. Plant effluent would be discharged through the existing outfall which terminates at a minimum depth of 45 feet.

Comparison of Plan A and Plan B

Table 42 summarizes the figures presented in Tables 40 and 41 giving the estimated costs of construction of the facilities proposed under Plan A and Plan B. The estimated initial construction cost of Plan B, $11,003,000, is shown to be $486,000 lower than that of Plan A. The estimated total ultimate construction cost of $28,813,000 for Plan A, however, is shown to be $1,505,000 lower than that of Plan B.

The true economy of a project or plan is best reflected by its annual cost rather than by its construction cost. As a practical matter, assuming that the involved capital cost can be financed and that all other requirements are fulfilled, the annual costs may well determine the merit of one plan over another. Annual costs are comprised of the following elements: (1) bond redemption and interest payments, and (2) costs of administration, operation and maintenance. The methods of computation of each of these elements of annual cost are discussed in Chapter 13 of this report. These methods have been used in the determination of annual costs.

Table 43 presents the calculated average annual costs of Plan A and Plan B for five year periods from 1955 to 2000

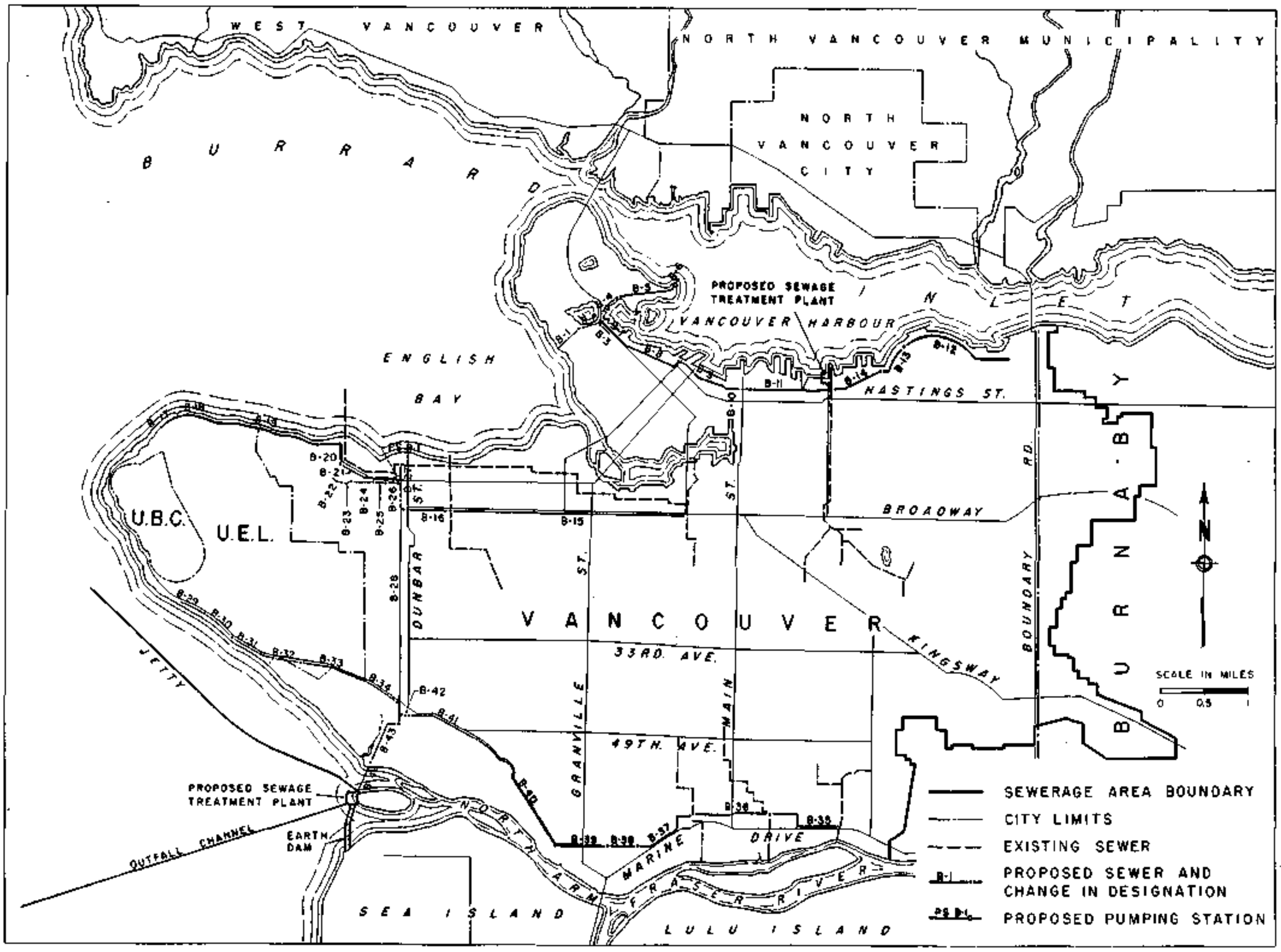


Figure 83. Proposed Layout of Plan B - Vancouver Sewerage Area

Plan B proposes the collection of the sanitary sewage of the entire Vancouver Sewerage Area to two plants. The sewage of the western portion would be conveyed to a high-rate primary treatment plant located on Iona Island. Effluent would be discharged to tidal water of Sturgeon Bank. The sewage of the eastern portion would be conveyed to a standard-rate primary treatment plant located at the foot of Clark Drive. Effluent would be discharged to Vancouver Harbour and would be chlorinated during critical periods. Storm water carried to these locations would bypass the treatment works.

and also the average annual cost over this 45 year period. Average annual costs of Plan A range from a high of $2,087,000 during the five year period 1975 to 1980 to a low of $314,000 during the five year period 1995 to 2000. Average annual costs of Plan B range from a high of $2,196,000 during the five year period 1975 to 1980 to a low of $271,000 during the five year period 1995 to 2000. Because of the lower initial construction cost of Plan B, the average annual costs of Plan B are shown to be less than those of Plan A during the first few years. As the system of intercepting sewers is completed, however, the average annual costs of Plan A become lower than those of Plan B. As the bonds issued in the early years of the projects are retired, the annual costs will decline until, as shown for Plan B, the bond redemption and interest payments will end. The estimated average annual cost over the 45 year period 1955 to 2000, for which comparisons have been made, is shown to be $1,235,000 for Plan A and $1,299,000 for Plan B. Over this period, Plan A would cost an average of $64,000 per year less than would Plan B. The average annual savings over the 45 year period would thus amount to a total of $2,880,000.

As an alternative to Plan A, as above described, it would be possible to locate sewage treatment facilities on the north

Table 41

Estimated Design Flows and Construction Costs of Plan B Facilities Vancouver Sewerage Area

Facility[a]	Design Flow, cfs	Construction Cost[b], Dollars 1955	1960	1965	1970
Sewers					
Clark Drive system					
B-2: 1,485 ft. of 72-in. RC[c]	148	99,000			
B-3: 1,000 ft. of 42-in. RC[c]	57	38,000			
B-4: 1,830 ft. of 78-in. BHS[c]	226	146,000			
B-7: 2,200 ft. of 39-in. RC at 0.045%	17.6			129,000	
B-12: 6,950 ft. of 36-in. RC at 0.05%	14.6			388,000	
B-13: 2,400 ft. of 36-in. RC at 1.10%	14.6			59,000	
B-14: 2,850 ft. of 36-in. RC at 0.27%	17.8			120,000	
Iona Island system					
B-17: 1,190 ft. of 22-in. RC at 5.18%	36.9	17,000			
B-18: 540 ft. of 24-in. RC at 2.70%	36.9	8,000			
B-20: 1,200 ft. of 36-in. RC at 0.15%	25.9	29,000			
B-21: 3,800 ft. of 42-in. RC at 0.15%	37.5	135,000			
B-22: 650 ft. of 20-in. RC at 8.0%	38.7	7,000			
B-23: 500 ft. of 22-in. RC at 4.5%	38.7	6,000			
B-24: 1,340 ft. of 24-in. RC at 3.15%	38.7	18,000			
B-25: 830 ft. of 30-in. RC at 2.26%	39.2	15,000			
B-26: 1,030 ft. of 30-in. RC at 0.19%	39.2	18,000			
B-27: 1,900 ft. of 114-in. BHS at 0.059%	400	348,000			
B-29: 1,400 ft. of 12-in. RC at 1.30%	2.7				10,000
B-30: 1,800 ft. of 12-in. RC at 0.61%	2.7				12,000
B-31: 1,800 ft. of 12-in. RC at 3.30%	3.2				12,000
B-32: 2,400 ft. of 15-in. RC at 0.54%	3.2				22,000
B-33: 3,250 ft. of 18-in. RC at 0.13%	3.6				51,000
B-34: 2,940 ft. of 18-in. RC at 2.10%	5.0				30,000
B-42: 900 ft. of 96-in. BHS at 0.070%	258				120,000
Tunnels: concrete lined					
Clark Drive system					
B-1: 1,400 ft. of 72-in.[c]	148	272,000			
B-5: 3,600 ft. of 78-in.[c]	226	800,000			
B-8: 3,880 ft. of 39-in. at 0.060%	17.6			344,000	
B-9: 3,900 ft. of 42-in. at 0.065%	21.6			380,000	
B-10: 700 ft. of 48-in. at 0.040%	24.6			81,000	
B-11: 5,700 ft. of 48-in. at 0.050%	27.5			662,000	
Iona Island system					
B-15: 14,170 ft. of 72-in. at 0.26%	235		2,750,000		
B-16: 3,300 ft. of 72-in. at 0.42%	300		640,000		
B-28: 12,800 ft. of 114-in. at 0.059%	400	4,440,000			
B-35: 5,320 ft. of 60-in. at 0.085%	73				825,000
B-36: 4,740 ft. of 66-in. at 0.12%	112				830,000
B-37: 5,000 ft. of 66-in. at 0.19%	142				875,000
B-38: 1,740 ft. of 66-in. at 0.28%	147				305,000
B-39: 4,040 ft. of 75-in. at 0.09%	155				808,000
B-40: 7,760 ft. of 93-in. at 0.055%	208				2,090,000
B-41: 4,600 ft. of 96-in. at 0.048%	216				1,260,000
Force main:					
B-19: 10,030 ft. of 36-in. RC	53.1	287,000			
Outfalls:					
B-6: 125 ft. of 72-in. RC	226	41,000			
B-43: 3,300 ft. of 114-in. BHS land section	608	605,000			
B-44: 2,800 ft. of 114-in. BHS	608	1,590,000			
Total, conduits		8,919,000	3,390,000	2,163,000	7,250,000

Table 41 - Continued

Facility[a]	Design Flow cfs	Construction Cost[b], Dollars 1955	1960	1965	1970
Pumping stations:					
Clark Drive system					
Influent at plant	63.0[d]			186,000[d]	
Iona Island system					
Influent at plant	30.0[e]	95,000[e]			80,000[f]
B-1:	35.9	219,000			
Sewage treatment plants:					
Clark Drive	63.0[d]			5,176,000[dg]	
Iona Island	30.0[e]	1,270,000[eg]			1,070,000[fg]
Outfall channel and appurtenances:					
Iona Island	608	500,000			
Total construction cost		11,003,000	3,390,000	7,525,000	8,400,000

[a] See Figure 83 for location of facilities.
[b] From Tables 37 and 38 and Figures 77, 78, and 79; plus 25 percent for engineering, administration and contingencies.
[c] Designed as pressure conduit.
[d] Ultimate capacity.
[e] Initial construction.
[f] Enlargement from 30.0 cfs to ultimate capacity of 67.0 cfs.
[g] Includes an allowance for special foundations.

bank of the North Arm of Fraser River opposite Iona Island, with an outfall directly into the North Arm. Because of the adverse location of both the treatment works and the place of outfall, such a plant would be required to provide, in

Table 42

Comparison of Estimated Construction Costs of Plan A and Plan B
Vancouver Sewerage Area

Plan	Construction Cost, Dollars 1955	1960	1965	1970	1975	Total
Plan A[a]						
Conduits[b]	8,919,000	4,330,000	3,008,000	7,250,000		23,507,000
Pumping stations	350,000		337,000		69,000	756,000
Sewage treatment plant	1,720,000		1,440,000		890,000	4,050,000
Outfall channel	500,000					500,000
Total	11,489,000	4,330,000	4,785,000	7,250,000	958,000	28,813,000
Plan B[c]						
Conduits[b]	8,919,000	3,390,000	2,163,000	7,250,000		21,722,000
Pumping stations	314,000		186,000	80,000		580,000
Sewage treatment plants						
Iona Island	1,270,000			1,070,000		2,340,000
Clark Drive			5,176,000			5,176,000
Outfall channel	500,000					500,000
Total	11,003,000	3,390,000	7,525,000	8,400,000		30,318,000

Plan A proposes the collection of the sanitary sewage of the entire area to a high-rate primary treatment plant located on Iona Island. Effluent would be discharged to tidal water of Sturgeon Bank. Storm water would be conveyed to this location but would bypass the treatment works.

Plan B proposes the collection of the sewage of the entire area to two plants. The sewage of the western portion would be conveyed to a high-rate primary treatment plant located on Iona Island. Effluent would be discharged to tidal water of Sturgeon Bank. The sewage of the eastern portion would be conveyed to a standard-rate primary treatment plant located at the foot of Clark Drive. Effluent would be discharged to Vancouver Harbour at a depth of 45 feet and would be chlorinated during critical periods. Storm water carried to these locations would bypass the treatment works.

[a] From Table 40.
[b] Includes sewers, tunnels, force mains and outfalls.
[c] From Table 41.

Table 43

Computed Average Annual Costs During Five Year Periods, 1955-2000, of Plan A and Plan B - Vancouver Sewerage Area

Cost Item	Average Annual Costs in Thousands of Dollars									
	1955 to 1960	1960 to 1965	1965 to 1970	1970 to 1975	1975 to 1980	1980 to 1985	1985 to 1990	1990 to 1995	1995 to 2000	45 Year Average
Plan A										
Bond redemption and interest[a]	736	1,013	1,319	1,784	1,845	1,109	832	526	61	
Maintenance and operation										
Conduits[b]	22	33	40	58	58	58	58	58	58	
Pumping stations[c]	23	23	65	68	69	70	71	72	73	
Sewage treatment plant[c]	54	71	98	112	115	118	120	121	122	
	99	107	203	238	242	246	249	251	253	
Total annual cost, Plan A	835	1,120	1,522	2,022	2,087	1,355	1,081	777	314	1,235
Average sanitary flow, cfs	25.0	43.0	72.0	92.0	97.0	100.0	103.0	105.5	108.0	82.8
Plan B										
Bond redemption and interest[a]	704	921	1,403	1,939	1,939	1,235	1,018	536	0	
Maintenance and operation										
Conduits[b]	22	30	35	53	53	53	53	53	53	
Pumping stations[c]	23	23	23	23	23	23	23	23	23	
Sewage treatment plants[c]										
Iona Island	54	56	58	76	79	80	81	83	85	
Clark Drive			71	75	76	79	80	81	81	
Chlorination[c]			23	25	26	27	28	29	29	
	99	109	210	252	257	262	266	269	271	
Total annual cost, Plan B	803	1,030	1,613	2,191	2,196	1,497	1,284	805	271	1,299
Average sanitary flow, cfs	25.0	27.0	72.0	92.0	97.0	100.0	103.0	105.5	108.0	82.8

Plan A proposes the collection of the sanitary sewage of the entire area to a high-rate primary treatment plant located on Iona Island. Effluent would be discharged to tidal water of Sturgeon Bank. Storm water would be conveyed to this location but would bypass the treatment works.

Plan B proposes the collection of the sewage of the entire area to two plants. The sewage of the western portion would be conveyed to a high-rate primary treatment plant located on Iona Island. Effluent would be discharged to tidal water of Sturgeon Bank. The sewage of the eastern portion would be conveyed to a standard-rate primary treatment plant located at the foot of Clark Drive. Effluent would be discharged to Vancouver Harbour at a depth of 45 feet and would be chlorinated during critical periods. Storm water carried to these locations would bypass the treatment works.

[a] Payments on 25 year instalment debentures at 4 percent interest.
[b] 1/4 of one percent of construction cost.
[c] From Figure 80.

addition to primary treatment, secondary treatment such as could be obtained by a high-rate trickling filter. It would be necessary to treat the entire flow of the combined sewage since, when discharged into the waters of the North Arm, the flow at certain times would be carried around Point Grey and onto the beaches of English Bay within one tidal cycle. It would also be necessary to provide for effluent chlorination during the recreational season to prevent possible contamination of the foreshores and recreational waters of English Bay.

An indication of the greater cost of such an alternative may be obtained by comparing the estimated cost of the Iona Island sewage treatment plant, including the necessary conduits to convey the combined sewage flow across the North Arm, with the cost of a high-rate trickling filter plant. Under Plan A, the total cost of these facilities is estimated to be $6,140,000. The total construction cost of a high-rate trickling filter plant, as shown on Figure 79, Chapter 13, is estimated to be $56,000,000. Operating costs, as shown on Figure 80, Chapter 13, for a trickling filter plant with effluent chlorination are greatly in excess of the operating costs of a primary plant. It is obvious, therefore, that the location proposed under Plan A is by far the more satisfactory.

Another possible alternative to Plan A might be the construction of two sewage plants, one to serve the northern and one the southern portion of the area. The north plant would be located adjacent to Spanish Banks near the existing Discovery Street outfall, with effluent discharge into English Bay. The south plant would be located on Iona Island as under Plan A. Treatment at the north plant would probably have to be by the activated sludge process or by standard-rate trickling filtration. It would be necessary to treat the entire flow of combined sewage to provide the same degree of protection as afforded by the facilities proposed under Plan A. The construction cost of the north plant alone is estimated to be $45,000,000, a sum which is considerably greater than the total construction cost of Plan A. In addition, the adverse location and the higher operating costs of a north plant make this alternative scheme still less desirable than Plan A.

Considering the total annual costs of Plan A and Plan B, and the relative suitability of the two alternative proposals, it is evident that the facilities proposed under Plan A are best suited to the present and anticipated future needs of the Vancouver Sewerage Area.

FRASER SEWERAGE AREA

Basic Considerations

Sewerage requirements in the Fraser Sewerage Area differ from those in the Vancouver Sewerage Area. In the latter area, which is almost completely sewered, the primary requirement is the interception of crude sewage being discharged to the recreational waters of the area. In the Fraser Sewerage Area, which as yet is largely unsewered, the primary requirement is the provision of sewerage for all portions of the area. To permit the construction of the required sewerage works, a suitable system of trunk and intercepting sewers must be provided.

The topography of most of the area, coupled with requirements for sewage disposal as discussed in Chapter 12, indicates that separate rather than combined collection systems are best suited to the area. Sewerage facilities proposed to serve all presently unsewered portions of the Fraser Sewerage Area have, therefore, been laid out with capacity for sanitary sewage only.

The sequence of construction proposed under the various plans considered provides for the construction of facilities first in those locations where the greatest need exists. The remaining required facilities would be constructed at later dates in conformance with the objectives previously stated for the protection of the shores and shore waters of the Greater Vancouver Area.

The Fraser Sewerage Area is divided topographically into four parts. Plans have been laid out and studied in detail for three of these. Sewerage plans for the fourth, on the north slope of Burrard Peninsula, have not been laid out since relatively small individual collection systems may be provided as the need arises. Short outfalls discharging crude sewage to the deep waters of Burrard Inlet will operate here satisfactorily. It would therefore appear to be appropriate that, as sewerage is required, this portion of the area be provided with combined rather than separate sewers.

Plan C

Plan C proposes the construction of trunk and intercepting sewers within that portion of the Fraser Sewerage Area which is tributary to Still Creek, Burnaby Lake and Brunette River. An outfall would discharge untreated sewage into Fraser River at a minimum depth of 25 feet. The proposed sewage collection system comprises sewers, an outfall and a pumping station. The facilities have been laid out with capacity for the flow of sanitary sewage only.

Figure 84 shows the tentative locations of the facilities embraced by Plan C. Table 44 presents the lengths, sizes and slopes of the conduits and the design flows and estimated construction costs of the facilities required for the completion of the plan. The table also gives the

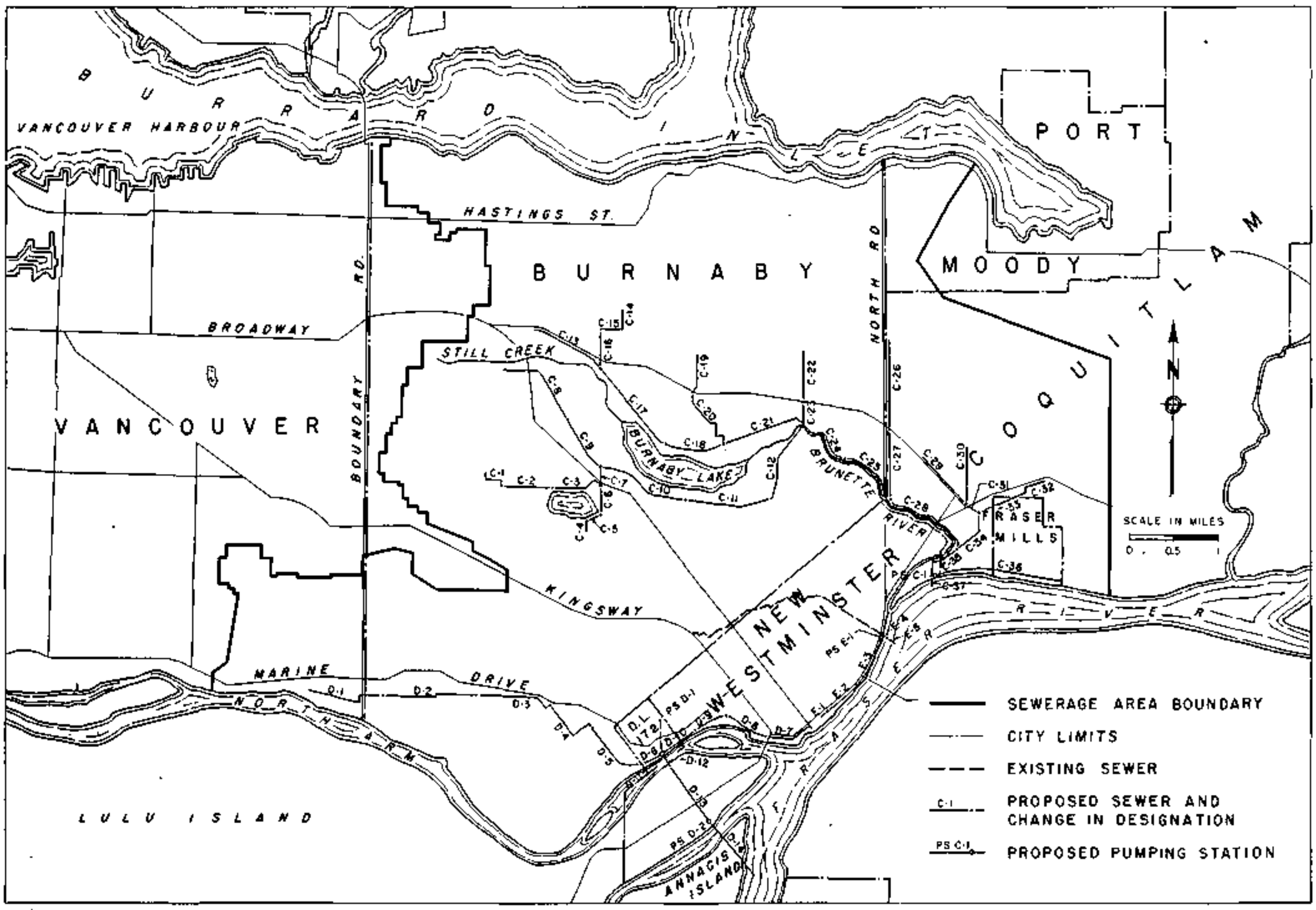


Figure 84. Proposed Layouts of Plan C, Plan D and Plan E - Fraser Sewerage Area

Plan C proposes the collection of the sanitary sewage of that portion of the Fraser Sewerage Area tributary to Burnaby Central Valley and Brunette River to an outfall discharging to the main Fraser River east of the mouth of Brunette River. Plan D proposes the collection of the sanitary sewage of that portion of the Fraser Sewerage Area tributary to North Arm of Fraser River to an outfall discharging to the main Fraser River off the easterly end of Annacis Island. Plan E proposes the collection of the sanitary sewage of that portion of the Fraser Sewerage Area readily tributary to the existing Glenbrook Drainage Area combined outfall. The existing outfall to Fraser River would be extended.

suggested sequence of construction. The initial construction cost of this plan is estimated to be $2,767,000 and the total ultimate construction cost $4,217,000.

The intercepting sewers shown on Figure 84, tentatively located on both sides of Burnaby Lake, would be subject to revision if the lake were to be filled and the land reclaimed. Under such a condition, only one of the intercepting sewers might be required and its location would necessarily be modified to suit the altered topography.

The size of the outfall has been proportioned to carry the design flow at peak river stages. The pumping station indicated as PS C-1 on Figure 84 is required to lift the sewage from intercepting sewer C-36 into the outfall.

As discussed in Chapter 12, it is possible to discharge crude sewage into the main channel of Fraser River with no adverse effects upon the quality of the river water or the uses to which the stream is put. To achieve an initial maximum degree of dilution and dispersion the outfall should be provided with multiple or branching outlets.

Plan C1

Plan C1, as an alternative to Plan C, proposes the construction of a high-rate trickling filter plant near the upper end of Burnaby Lake to serve the upper portion of the Burnaby Central Valley and the discharge of a chlorinated effluent to

Table 44

Estimated Design Flows and Construction Costs of Plan C Facilities
Fraser Sewerage Area

Facility[a]	Design Flow, cfs	Construction Cost[b], Dollars 1955	1960	1970
Sewers				
C-1: 2,300 ft. of 14-in. RC at 0.32%	3.0	18,000		
C-2: 3,100 ft. of 20-in. RC at 0.16%	5.4	56,000		
C-3: 2,900 ft. of 15-in. RC at 0.40%	5.7	51,000		
C-4: 950 ft. of 8-in. RC at 15.5%	2.9		5,000	
C-5: 850 ft. of 14-in. RC at 0.30%	2.9		8,000	
C-6: 1,800 ft. of 14-in. RC at 0.70%	4.4		17,000	
C-7: 1,000 ft. of 18-in. RC at 0.85%	9.4	18,000		
C-8: 5,300 ft. of 20-in. RC at 0.10%	4.4		106,000	
C-9: 3,500 ft. of 18-in. RC at 0.46%	7.0		61,000	
C-10: 5,400 ft. of 36-in. RC at 0.062%	16.7	432,000		
C-11: 4,600 ft. of 42-in. RC at 0.037%	19.5	460,000		
C-12: 5,000 ft. of 42-in. RC at 0.047%	21.8	445,000		
C-13: 4,600 ft. of 20-in. RC at 0.17%	5.6		63,000	
C-14: 1,300 ft. of 8-in. RC at 3.85%	2.2		9,000	
C-15: 1,300 ft. of 10-in. RC at 1.55%	2.2		10,000	
C-16: 2,200 ft. of 8-in. RC at 7.0%	3.1		16,000	
C-17: 5,800 ft. of 27-in. RC at 0.088%	9.2		197,000	
C-18: 3,200 ft. of 30-9n. RC at 0.060%	10.0		168,000	
C-19: 2,000 ft. of 10-in. RC at 5.0%	4.0		23,000	
C-20: 4,700 ft. of 20-in. RC at 0.13%	5.0		94,000	
C-21: 5,750 ft. of 39-in. RC at 0.048%	18.1		430,000	
C-22: 2,400 ft. of 10-in. RC at 2.9%	2.5		19,000	
C-23: 2,150 ft. of 8-in. RC at 4.5%	2.5		15,000	
C-24: 3,600 ft. of 42-in. RC at 0.23%	47.0	225,000		
C-25: 3,600 ft. of 42-in. RC at 0.23%	47.0	135,000		
C-26: 4,700 ft. of 12-in. RC at 4.35%	6.2	41,000		
C-27: 2,900 ft. of 14-in. RC at 3.0%	6.7	28,000		
C-28: 5,600 ft. of 60-in. RC at 0.17%	52.0	330,000		
C-29: 4,000 ft. of 8-in. RC at 1.60%	1.4	32,000		
C-30: 3,000 ft. of 8-in. RC at 8.5%	2.4	22,000		
C-31: 1,100 ft. of 10-in. RC at 5.9%	3.5	10,000		
C-32: 1,550 ft. of 16-in. RC at 0.65%	5.9	19,000		
C-33: 2,800 ft. of 16-in. RC at 0.80%	6.7	35,000		
C-34: 3,300 ft. of 27-in. RC at 0.15%	9.6	73,000		
C-35: 1,900 ft. of 60-in. RC at 0.17%	61.0	112,000		
C-36: 7,600 ft. of 20-in. RC at 0.23%	5.6			171,000
Outfall:				
C-37: 1,000 ft. of 54-in. RC	66.7	225,000		
Total, conduits		2,767,000	1,241,000	171,000
Pumping station				
C-1:	3.9[c]			38,000[c]
Total construction cost		2,767,000	1,241,000	209,000

[a] See Figure 84 for location of facilities.
[b] From Table 37, and Figures 78 and 79; plus 25 percent for engineering, administration and contingencies.
[c] Ultimate capacity.

the lake. Sewage from the remainder of the area tributary to Brunette River would be conveyed to Fraser River and discharged without treatment at a minimum depth of 25 feet, as provided under Plan C.

Figure 85 shows the tentative locations of the facilities embraced by Plan C1. Table 45 presents the lengths, sizes and slopes of the conduits and the design flows and estimated construction costs of the facilities required for the completion of the plan. This table also gives the suggested sequence of construction. The initial construction cost of this plan is estimated to be $3,874,000 and the total ultimate construction cost $6,460,000. The sequence of construction suggested for Plan C1 corresponds with that suggested for Plan C.

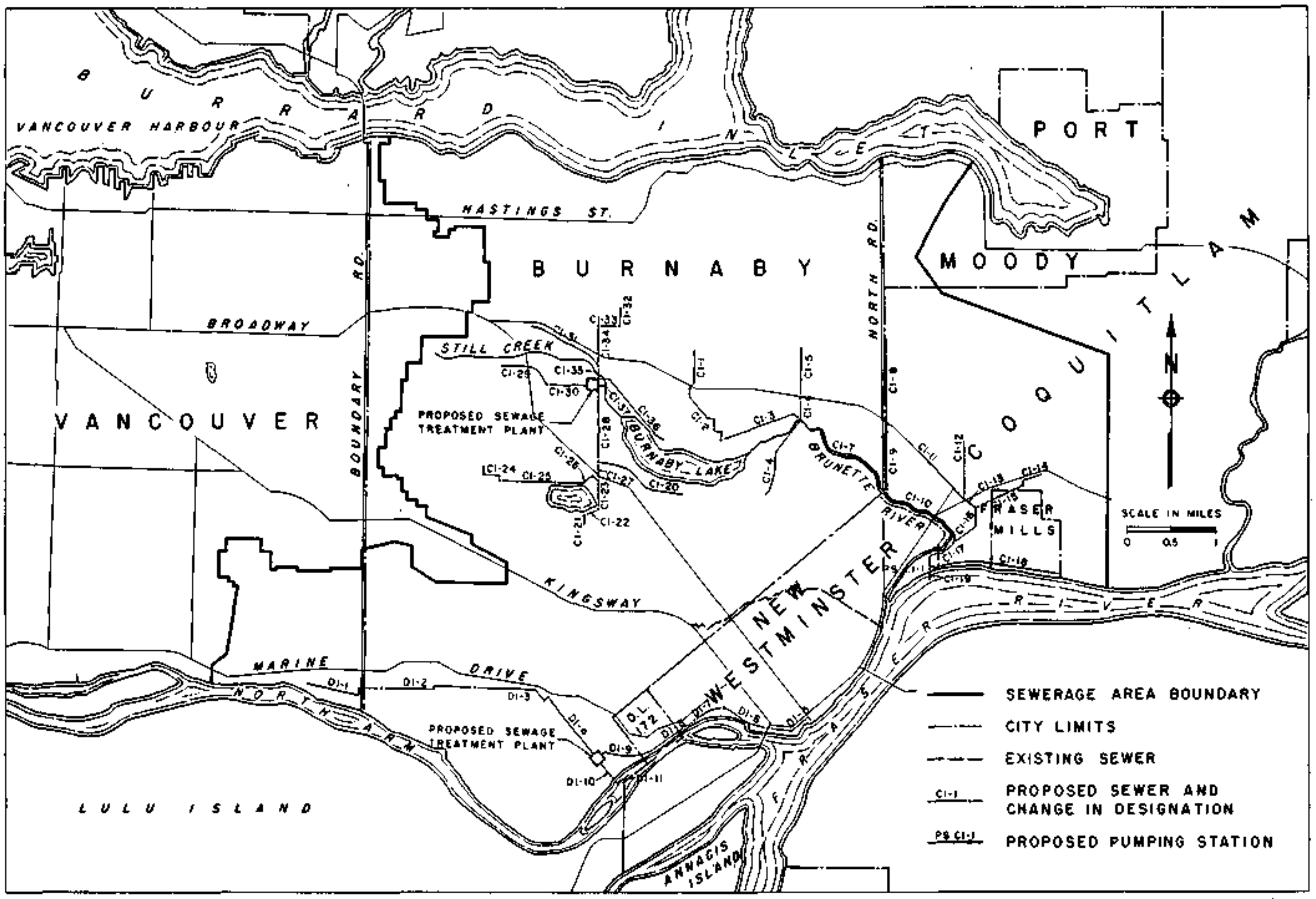


Figure 85. Proposed Layouts of Plan C1 and Plan D1 - Fraser Sewerage Area

Plan C1 proposes the collection of the sanitary sewage of that portion of the Fraser Sewerage Area tributary to Burnaby Central Valley and Brunette River to two locations. Sewage from the western portion would be conveyed to a high-rate trickling filter treatment plant located adjacent to Still Creek near the upper end of Burnaby Lake and chlorinated effluent would be discharged to the lake. Sewage from the eastern portion would be discharged to the main Fraser River east of the mouth of Brunette River. Plan D1 proposes the collection of the sanitary sewage of that portion of the Fraser Sewerage Area tributary to North Arm of Fraser River to a standard-rate primary treatment plant located adjacent to the North Arm. Effluent would be discharged to the North Arm and would be chlorinated during critical periods.

Comparison of Plan C and Plan C1

Table 46 summarizes the figures presented in Tables 44 and 45 which present the estimated costs of construction of the facilities embraced by Plan C and Plan C1. The initial construction cost of Plan C, $2,767,000, is estimated to be $893,000 lower than that of Plan C1. The total ultimate construction cost of Plan C, $4,217,000, is estimated to be $2,243,000 less than that of Plan C1.

Table 47 presents the calculated average annual costs of Plan C and Plan C1 for five year periods from 1955 to 2000, and also the average annual costs over this 45 year period. Average annual costs of Plan C range from a high of $284,000 during the five year period 1975 to 1980 to a low of $15,000 during the five year period 1995 to 2000. Average annual costs of Plan C1 range from a high of $490,000 during the five year period 1975 to 1980 to a low of $97,000 during the five year period 1995 to 2000. Throughout the period for which comparisons have been made the annual costs of Plan C are lower than those of Plan C1. The average annual cost over the 45 year period, 1955 to 2000, is shown to be $162,000 for Plan C and $301,000 for Plan C1. Over this period, Plan C would cost an average of $139,000 per year less than Plan C1. The average annual savings over the 45 year period would thus amount to a total of $6,255,000.

Consideration of the economies evidenced by the above comparison of Plan

Table 45

Estimated Design Flows and Construction Costs of Plan C1 Facilities Fraser Sewerage Area

Facility[a]	Design Flow, cfs	Construction Cost[b], Dollars 1955	1960	1970
Sewers:				
C1-1: 2,000 ft. of 10-in. RC at 5.0%	4.0		23,000	
C1-2: 4,700 ft. of 20-in. RC at 0.13%	5.0		94,000	
C1-3: 5,750 ft. of 27-in. RC at 0.090%	9.3		194,000	
C1-4: 5,000 ft. of 18-in. RC at 0.17%	4.2	172,000		
C1-5: 2,400 ft. of 10-in. RC at 2.9%	2.5		19,000	
C1-6: 2,150 ft. of 8-in. RC at 4.5%	2.5		15,000	
C1-7: 7,200 ft. of 30-in. RC at 0.24%	20.1	269,000		
C1-8: 4,700 ft. of 12-in. RC at 4.35%	6.2	41,000		
C1-9: 2,900 ft. of 14-in. RC at 3.0%	6.7	28,000		
C1-10: 5,600 ft. of 48-in. RC at 0.17%	24.9	250,000		
C1-11: 4,000 ft. of 8-in. RC at 1.60%	1.4	32,000		
C1-12: 3,000 ft. of 8-in. RC at 8.5%	2.4	22,000		
C1-13: 1,100 ft. of 10-in. RC at 5.9%	3.5	10,000		
C1-14: 1,550 ft. of 16-in. RC at 0.65%	5.9	19,000		
C1-15: 2,800 ft. of 16-in. RC at 0.80%	6.7	35,000		
C1-16: 3,300 ft. of 27-in. RC at 0.15%	9.6	73,000		
C1-17: 1,900 ft. of 48-in. RC at 0.17%	33.8	85,000		
C1-18: 7,600 ft. of 20-in. RC at 0.23%	5.6			171,000
C1-20: 5,400 ft. of 18-in. RC at 0.12%	3.5		102,000	
C1-21: 950 ft. of 8-in. RC at 15.5%	2.9		5,000	
C1-22: 850 ft. of 14-in. RC at 0.30%	2.9		8,000	
C1-23: 1,800 ft. of 14-in. RC at 0.70%	4.4		17,000	
C1-24: 2,300 ft. of 14-in. RC at 0.32%	3.0	18,000		
C1-25: 3,100 ft. of 20-in. RC at 0.16%	5.4	56,000		
C1-26: 2,900 ft. of 15-in. RC at 0.40%	5.7	51,000		
C1-27: 1,000 ft. of 18-in. RC at 0.85%	9.4	18,000		
C1-28: 4,800 ft. of 30-in. RC at 0.125%	14.4	139,000		
C1-29: 4,100 ft. of 16-in. RC at 0.17%	3.1		103,000	
C1-30: 2,400 ft. of 18-in. RC at 0.22%	4.9		66,000	
C1-31: 4,600 ft. of 18-in. RC at 0.29%	5.6		112,000	
C1-32: 1,300 ft. of 8-in. RC at 3.85%	2.2		9,000	
C1-33: 1,300 ft. of 10-in. RC at 1.55%	2.2		10,000	
C1-34: 2,200 ft. of 8-in. RC at 7.0%	3.1		16,000	
C1-35: 900 ft. of 24-in. RC at 0.13%	8.1		30,000	
C1-36: 5,800 ft. of 12-in. RC at 0.32%	2.0		87,000	
Outfalls:				
C1-19: 1,000 ft. of 42-in. RC	39.8	166,000		
C1-37: 500 ft. of 30-in. RC	27.2	10,000		
Total, conduits		1,494,000	910,000	171,000
Pumping stations:				
C1-1:	3.9[f]			38,000[f]
Influent at plant	10.0[c]	40,000[c]		23,000[d]
Sewage treatment plant:	10.0[c]	2,340,000[c e]		1,444,000[d e]
Total construction cost		3,874,000	910,000	1,676,000

[a] See Figure 85 for location of facilities.
[b] From Table 37 and Figures 78 and 79; plus 25 percent for engineering, administration and contingencies.
[c] Initial construction.
[d] Enlargement from 10 cfs to 18 cfs ultimate capacity.
[e] Includes an allowance for special foundations.
[f] Ultimate capacity.

Table 46

Comparison of Estimated Construction Costs of Plan C and Plan C1 Fraser Sewerage Area

Plan	Construction Cost, Dollars 1955	1960	1970	Total
Plan C[a]				
Conduits[b]	2,767,000	1,241,000	171,000	4,179,000
Pumping station			38,000	38,000
Total	2,767,000	1,241,000	209,000	4,217,000
Plan C1[c]				
Conduits[b]	1,494,000	910,000	171,000	2,575,000
Pumping stations	40,000		61,000	101,000
Sewage treatment plant	2,340,000		1,444,000	3,784,000
Total	3,874,000	910,000	1,676,000	6,460,000

Plan C proposes the collection of the sanitary sewage of that portion of the area tributary to Burnaby Central Valley and Brunette River to an outfall discharging to the main Fraser River east of the mouth of Brunette River at a depth of 25 feet.

Plan C1 proposes the collection of the sanitary sewage of that portion of the area tributary to Burnaby Central Valley and Brunette River to two locations. Sewage from the western portion would be conveyed to a high-rate trickling filter treatment plant located adjacent to Still Creek near the upper end of Burnaby Lake and chlorinated effluent would be discharged to the lake. Sewage from the eastern portion would be discharged to the main Fraser River east of the mouth of Brunette River at a depth of 25 feet.

[a] From Table 44.
[b] Includes sewers and outfalls.
[c] From Table 45.

Table 47

Computed Average Annual Costs During Five Year Periods, 1955-2000, of Plan C and Plan C1 - Fraser Sewerage Area

Cost Item	Average Annual Costs in Thousands of Dollars 1955 to 1960	1960 to 1965	1965 to 1970	1970 to 1975	1975 to 1980	1980 to 1985	1985 to 1990	1990 to 1995	1995 to 2000	45 Year Average
Plan C										
Bond redemption and interest[a]	177	256	256	269	269	92	13	13	0	
Maintenance and operation										
Conduits[b]	7	10	10	11	11	11	11	11	11	
Pumping station[c]				3	4	4	4	4	4	
	7	10	10	14	15	15	15	15	15	
Total annual cost, Plan C	184	266	266	283	284	107	28	28	15	162
Average flow, cfs	6.3	13.1	16.5	22.5	26.8	30.0	32.2	34.2	36.0	24.2
Plan C1										
Bond redemption and interest[a]	248	306	306	410	410	162	104	104	0	
Maintenance and operation										
Conduits[b]	4	6	6	7	7	7	7	7	7	
Pumping station[c]				3	4	4	4	4	4	
Sewage treatment plant[c]	20	38	46	53	57	61	64	67	70	
Chlorination[c]	3	7	9	11	12	13	14	15	16	
	27	51	61	74	80	85	89	93	97	
Total annual cost, Plan C1	275	357	367	484	490	247	193	197	97	301
Average flow, cfs	6.3	13.1	16.5	22.5	26.8	30.0	32.2	34.2	36.0	24.2

Plan C proposes the collection of the sanitary sewage of that portion of the area tributary to Burnaby Central Valley and Brunette River to an outfall discharging to the main Fraser River east of the mouth of Brunette River at a depth of 25 feet.

Plan C1 proposes the collection of the sanitary sewage of that portion of the area tributary to Burnaby Central Valley and Brunette River to two locations. Sewage from the western portion would be conveyed to a high-rate trickling filter treatment plant located adjacent to Still Creek near the upper end of Burnaby Lake and chlorinated effluent would be discharged to the lake. Sewage from the eastern portion would be discharged to the main Fraser River east of the mouth of Brunette River at a depth of 25 feet.

[a] Payments on 25 year instalment debentures at 4 percent interest.
[b] 1/4 of one percent of construction cost.
[c] From Figure 80.

C and Plan C1 leads to the conclusion that the best interests of the area tributary to Still Creek, Burnaby Lake and Brunette River within the Fraser Sewerage Area will be served by the construction of Plan C.

Plan D

Plan D proposes the construction of intercepting sewers within that portion of the Fraser Sewerage Area which is tributary to the North Arm of Fraser River. An outfall would extend across the eastern end of Lulu Island and Annacis Island and would discharge untreated sewage into the main channel of Fraser River at a minimum depth of 30 feet. The proposed sewage collection system comprises sewers, a force main, an outfall and two pumping stations. The facilities have been laid out with capacity sufficient for the flow of sanitary sewage only.

Figure 84 shows the tentative locations of the facilities embraced by Plan D. Table 48 presents the lengths, sizes and slopes of the conduits and the design flows and estimated construction costs of the facilities required for the completion of the plan. The table also gives the suggested sequence of construction. The initial construction cost of this plan is estimated to be $1,608,000 and the total construction cost $2,588,000.

The sequence of construction shown in Table 48 suggests that the sanitary sewage of the tributary area served by facilities indicated as D-1 through D-6 on Figure 84 be discharged into the North Arm of Fraser River until 1970. This date corresponds to the suggested time of completion of the proposed intercepting sewer along the North Arm within the Vancouver Sewerage Area. Under Plan D, facilities to convey the sewage across the North Arm would be constructed by 1970. Sewage would thereafter be discharged into the main channel of Fraser

Table 48

Estimated Design Flows and Construction Costs of Plan D Facilities
Fraser Sewerage Area

Facility[a]	Design Flow, cfs	Construction Cost[b], Dollars 1960	1970	1980
Sewers:				
D-1: 4,800 ft. of 22-in. RC at 0.125%	6.2	96,000		
D-2: 5,900 ft. of 30-in. RC at 0.070%	10.8	280,000		
D-3: 4,200 ft. of 33-in. RC at 0.065%	13.5	294,000		
D-4: 4,100 ft. of 36-in. RC at 0.066%	17.2	360,000		
D-5: 3,700 ft. of 42-in. RC at 0.040%	20.0	360,000		
D-6: 1,350 ft. of 42-in. RC at 0.052%	22.8	132,000		
D-7: 2,350 ft. of 14-in. RC at 0.22%	2.5		35,000	
D-8: 2,700 ft. of 18-in. RC at 0.11%	3.6		62,000	
D-9: 2,150 ft. of 18-in. RC at 0.19%	4.5		81,000	
D-10: 2,450 ft. of 20-in. RC at 0.17%	5.6		126,000	
D-13: 4,500 ft. of 30-in. RC at 0.49%	28.7		225,000	
Force mains:				
D-11: 100 ft. of 36-in. RC	22.8	14,000		
D-12: 700 ft. of 36-in. RC	27.6		96,000	
Outfall:				
D-14: 4,000 ft. of 36-in. RC	30.7		138,000	
Total, conduits		1,536,000	763,000	
Pumping stations:				
D-1:	8.7[c]	72,000[c]	59,000[d]	
D-2:	15.0[c]		124,000[c]	34,000[e]
Total construction cost		1,608,000	946,000	34,000

[a] See Figure 84 for location of facilities.
[b] From Tables 37 and 38 and Figures 78 and 79; plus 25 percent for engineering, administration and contingencies.
[c] Initial construction.
[d] Enlargement from 8.7 cfs to 18.4 cfs ultimate capacity.
[e] Enlargement from 15.0 cfs to 20.4 cfs ultimate capacity.

River offshore from the easterly end of Annacis Island.

Plan D1

Plan D1, as an alternative to Plan D, proposes the construction of a standard-rate primary treatment plant on the north side of the North Arm of Fraser River to serve that portion of the Fraser Sewerage Area which is tributary to the North Arm of Fraser River. Effluent, chlorinated during critical periods, would be discharged into the North Arm.

Figure 85 shows the tentative locations of the facilities embraced by Plan D1. Table 49 presents the lengths, sizes and slopes of the conduits and the design flows and estimated construction costs of the facilities required for completion of the plan. This table also gives the suggested sequence of construction. The initial construction cost is estimated to be $1,188,000 and the total ultimate construction cost $3,856,000.

The sewage collection system proposed under Plan D1 differs but slightly from that proposed under Plan D. Construction of facilities across the North Arm and Lulu and Annacis Islands is not required under Plan D1. The suggested sequence of construction of Plan D1 corresponds with that suggested for Plan D. Construction of the proposed sewage treatment plant would be completed by 1970, at which time discharge of crude sewage into the North Arm would cease by reason of the construction of intercepting sewers in both the Vancouver and Fraser Sewerage Areas. Prior to that time, sewage would be discharged into the North Arm as under Plan D.

Comparison of Plan D and Plan D1

Table 50 summarizes the figures presented in Tables 48 and 49 giving the estimated costs of construction of the facilities required under Plans D and D1. The estimated initial construction cost

Table 49

Estimated Design Flows and Construction Costs of Plan D1 Facilities Fraser Sewerage Area

Facility[a]	Design Flow cfs	Construction Cost,[b] Dollars 1960	Construction Cost,[b] Dollars 1970
Sewers:			
D1-1: 4,800 ft. of 22-in. RC at 0.125%	6.2	96,000	
D1-2: 5,900 ft. of 30-in. RC at 0.070%	10.8	280,000	
D1-3: 4,200 ft. of 33-in. RC at 0.065%	13.5	294,000	
D1-4: 5,000 ft. of 36-in. RC at 0.066%	17.2	375,000	
D1-5: 2,350 ft. of 14-in. RC at 0.22%	2.5		35,000
D1-6: 2,700 ft. of 18-in. RC at 0.11%	3.6		62,000
D1-7: 2,150 ft. of 18-in. RC at 0.19%	4.5		81,000
D1-8: 2,450 ft. of 20-in. RC at 0.17%	5.6		126,000
D1-9: 4,800 ft. of 27-in. RC at 0.087%	9.1		348,000
Outfall:			
D1-10: 1,400 ft. of 36-in. RC - land section	27.6	44,000	
D1-11: 300 ft. of 36-in. RC	27.6	41,000	
Total, conduits		1,130,000	652,000
Pumping station:			
Influent at plant	6.5[c]	58,000[c]	46,000[d]
Sewage treatment plant:	18.4[e]		1,970,000[ef]
Total construction cost		1,188,000	2,668,000

[a] See Figure 85 for location of facilities.
[b] From Table 37 and Figures 78 and 79; plus 25 percent for engineering, administration and contingencies.
[c] Initial construction.
[d] Enlargement from 6.5 cfs to ultimate capacity of 18.4 cfs.
[e] Ultimate capacity.
[f] Includes an allowance for special foundations.

Table 50

Comparison of Estimated Construction Costs of Plan D and Plan D1
Fraser Sewerage Area

Plan	Construction Cost, Dollars			
	1960	1970	1980	Total
Plan D[a]				
Conduits[b]	1,536,000	763,000		
Pumping stations	72,000	183,000	34,000	
Total	1,608,000	946,000	34,000	2,588,000
Plan D1[c]				
Conduits[b]	1,130,000	652,000		
Pumping stations	58,000	46,000		
Sewage treatment plant		1,970,000		
Total	1,188,000	2,668,000		3,856,000

Plan D proposes the collection of the sanitary sewage of that portion of the area tributary to North Arm of Fraser River to an outfall discharging to the main Fraser River off the easterly end of Annacis Island at a depth of 30 feet.

Plan D1 proposes the collection of the sanitary sewage of that portion of the area tributary to North Arm of Fraser River to a standard-rate primary treatment plant located adjacent to the North Arm. Effluent would be discharged to the North Arm and would be chlorinated during critical periods.

[a] From Table 48
[b] Includes sewers, force mains and outfalls.
[c] From Table 49.

Table 51

Computed Average Annual Costs During Five Year Periods, 1960-2000, of Plan D and Plan D1 - Fraser Sewerage Area

Cost Item	Average Annual Costs in Thousands of Dollars								
	1960 to 1965	1965 to 1970	1970 to 1975	1975 to 1980	1980 to 1985	1985 to 1990	1990 to 1995	1995 to 2000	40 Year Average
Plan D									
Bond redemption and interest[a]	103	103	164	164	166	63	63	2	
Maintenance and operation									
Conduits[b]	4	4	6	6	6	6	6	6	
Pumping stations[c]	7	8	21	22	23	25	26	27	
	11	12	27	28	29	31	32	33	
Total annual cost, Plan D	114	115	191	192	195	94	95	35	129
Average flow, cfs	6.8	8.0	12.7	14.0	15.2	16.2	16.9	17.5	13.4
Plan D1									
Bond redemption and interest[a]	76	76	247	247	247	171	171	0	
Maintenance and operation									
Conduits[b]	3	3	5	5	5	5	5	5	
Pumping station[c]	6	6							
Sewage treatment plant[c]			34	37	38	40	41	42	
Chlorination[c]			8	9	10	10	10	11	
	9	9	47	51	53	55	56	58	
Total annual cost, Plan D1	85	85	294	298	300	226	227	58	197
Average flow, cfs	5.2	6.1	11.4	12.7	13.8	14.7	15.3	15.8	11.9

Plan D proposes the collection of the sanitary sewage of that portion of the area tributary to North Arm of Fraser River to an outfall discharging to the main Fraser River off the easterly end of Annacis Island at a depth of 30 feet.

Plan D1 proposes the collection of the sanitary sewage of that portion of the area tributary to North Arm of Fraser River to a standard-rate primary treatment plant located adjacent to the North Arm. Effluent would be discharged to the North Arm and would be chlorinated during critical periods.

[a] Payments on 25 year instalment debentures at 4 percent interest.
[b] 1/4 of one percent of construction cost.
[c] From Figure 80.

of Plan D, $1,608,000, is shown to be $420,000 greater than that of Plan D1. The estimated total ultimate construction cost of Plan D, $2,588,000, is shown to be $1,268,000 less than that of Plan D1.

Table 51 presents the calculated average annual costs of Plan D and Plan D1 for five year periods from 1960 to 2000 and also the average annual cost over this 40 year period. Average annual costs of Plan D range from a high of $195,000 during the five year period 1980 to 1985 to a low of $35,000 during the five year period 1995 to 2000. Average annual costs of Plan D1 range from a high of $300,000 during the five year period 1980 to 1985 to a low of $58,000 during the period 1995 to 2000. The average annual cost over the 40 year period, 1960 to 2000, is shown to be $129,000 for Plan D and $197,000 for Plan D1. Over that period the estimated average annual savings of Plan D over Plan D1 are $68,000. The aggregate of these savings over the 40 year period would be $2,720,000.

Consideration of the economies evidenced by the above comparison of Plan D and Plan D1 leads to the conclusion that the best interests of the area tributary to the North Arm of Fraser River within the Fraser Sewerage Area will be served by the construction of Plan D.

Plan E

Plan E proposes the construction of an intercepting sewer to serve that portion of the Fraser Sewerage Area which can readily be made tributary to the existing outfall from the Glenbrook Drainage Area of the Vancouver and Districts Joint Sewerage and Drainage Board. The sewage collection system comprises sewers, an outfall and a pumping station.

Figure 84 shows the tentative locations of the facilities embraced by Plan E. Table 52 presents the lengths, sizes and slopes of the conduits and the design flows and estimated construction costs of the facilities required for the completion of Plan E. The table also gives the suggested time of construction as 1970, which is comparable with other plans for areas tributary to Fraser River or its North Arm. The total construction cost of this plan is estimated to be $398,000.

The area tributary to the facilities proposed under Plan E is presently sewered, in part, by a combined collection system. Facilities indicated on Figure 84 as E-1 through E-3 and PS E-1 have been laid out with capacity for the flow of sanitary sewage only. During periods of storm runoff, flow in excess of the design capacity would be discharged through existing outfalls into Fraser River. Facility E-4, the existing outfall from the Glenbrook Drainage Area, is owned by the City of New Westminster. It is proposed that this facility be purchased from the city and that the outfall be ex-

Table 52

Estimated Design Flows and Construction Costs of Plan E Facilities
Fraser Sewerage Area

Facility[a]	Design Flow cfs	Construction Cost[b], Dollars 1970
Sewers:		
E-1: 450 ft. of 8-in. RC at 0.60%	0.9	7,000
E-2: 2,100 ft. of 12-in. RC at 0.30%	1.9	55,000
E-3: 3,000 ft. of 15-in. RC at 0.17%	2.6	137,000
Outfall:		
E-4: 220 ft. of 102-in. SS		13,000[c]
E-5: 500 ft. of 90-in. BHS		170,000
Total, conduits		382,000
Pumping station:		
E-1:	1.4	16,000
Total construction cost		398,000

[a] See Figure 84 for location of facilities.
[b] From Table 37 and Figures 78 and 79 ; plus 25 percent for engineering, administration and contingencies.
[c] Estimated construction cost of existing outfall built in 1913 to be purchased from the City of New Westminster.

Table 53

Computed Average Annual Costs During Five Year Periods, 1970-2000, of Plan E - Fraser Sewerage Area

Cost Item	Average Annual Costs in Thousands of Dollars 1970 to 1975	1975 to 1980	1980 to 1985	1985 to 1990	1990 to 1995	1995 to 2000	30 Year Average
Plan E							
Bond redemption and interest[a]	25	25	25	25	25	0	
Maintenance and operation							
Conduits[b]	1	1	1	1	1	1	
Pumping station[c]	2	2	2	2	2	2	
	3	3	3	3	3	3	
Total annual cost, Plan E	28	28	28	28	28	3	24
Average sanitary flow, cfs	0.94	1.00	1.04	1.07	1.10	1.12	1.04

Plan E proposes the collection of the sanitary sewage of that portion of the area readily tributary to the existing Glenbrook Drainage Area combined outfall. The existing outfall would be extended to discharge to the main Fraser River at a depth of 40 feet.

[a] Payments on 25 year instalment debentures at 4 percent interest.
[b] 1/4 of one percent of construction cost.
[c] From Figure 80.

tended into the river channel to discharge at a minimum depth of 40 feet.

No alternative plan has been considered for Plan E because of the relatively small area involved and the absence of any other feasible method or point of disposal. Unforeseen changes may occur in the uses of Fraser River so that treatment of the sewage tributary to this portion of the Fraser Sewerage Area may conceivably become necessary. In that event, it is probable that treatment prior to discharge would also be required at the outfall proposed under Plan C. The sanitary sewage flow tributary to Plan E may readily be conveyed by pumping to that location.

Table 53 presents the calculated average annual costs of Plan E for five year periods from 1970 to 2000. Average annual costs range from $28,000 during the 25 year period 1970 to 1995, while 25 year bonds issued for construction in 1970 are being retired, to $3,000 per year during the five year period 1995 to 2000. The average annual cost over the 30 year period, 1970 to 2000, for which costs have been computed, is shown to be $24,000.

COQUITLAM SEWERAGE AREA

Basic Considerations

The sewerage requirements of the Coquitlam Sewerage Area are comparable in general to those of the Fraser Sewerage Area. The primary requirement throughout is the provision of collection systems. This necessitates the prior construction of a suitable system of trunk and intercepting sewers.

Topography and sewage disposal requirements in the Coquitlam Sewerage Area are such that it is necessary to convey sewage a considerable distance to reach appropriate locations for ultimate disposal. Storm water, on the other hand, may readily and economically be disposed of in the nearest watercourse or tidal water. Separate, rather than combined, collection systems are therefore deemed most suitable for the area. The sequence of construction proposed under the various plans provides for facilities as the need for sewerage shall arise.

The Coquitlam Sewerage Area is divided topographically into four portions. Plans have been laid out and studied in detail for the sewerage of two of these. That portion of the sewerage area which drains eastward to Pitt River was not studied in detail since the nature and location of development therein cannot be anticipated with any reasonable degree of accuracy at this time. That portion of the sewerage area which lies north of Burrard Inlet was not included in the proposed sewerage plans, since it may with propriety be sewered by a local collection system discharging crude sewage into the deep, near-shore water of Burrard Inlet.

Plan F

Plan F has been laid out to serve that portion of the Coquitlam Sewerage Area which is situated on the south shore of Burrard Inlet. It proposes the construction of an intercepting sewer along the south shore of the eastern arm of Burrard Inlet. An outfall, 200 feet in length, would be constructed and sewage would be discharged without treatment into Burrard Inlet at a minimum depth of 30 feet. The facilities have been laid out with capacity sufficient for the flow of sanitary sewage only.

Figure 86 shows the tentative locations of the facilities embraced by Plan F. Table 54 presents the lengths, sizes, slopes, and the design flows and estimated construction costs of the facilities required for the completion of Plan F. The suggested time of completion of this plan, 1960, is comparable with the suggested sequence of construction for other areas tirubtary to the eastern part of Burrard Inlet which is not used for recreation. The total construction cost of this plan is estimated to be $260,000.

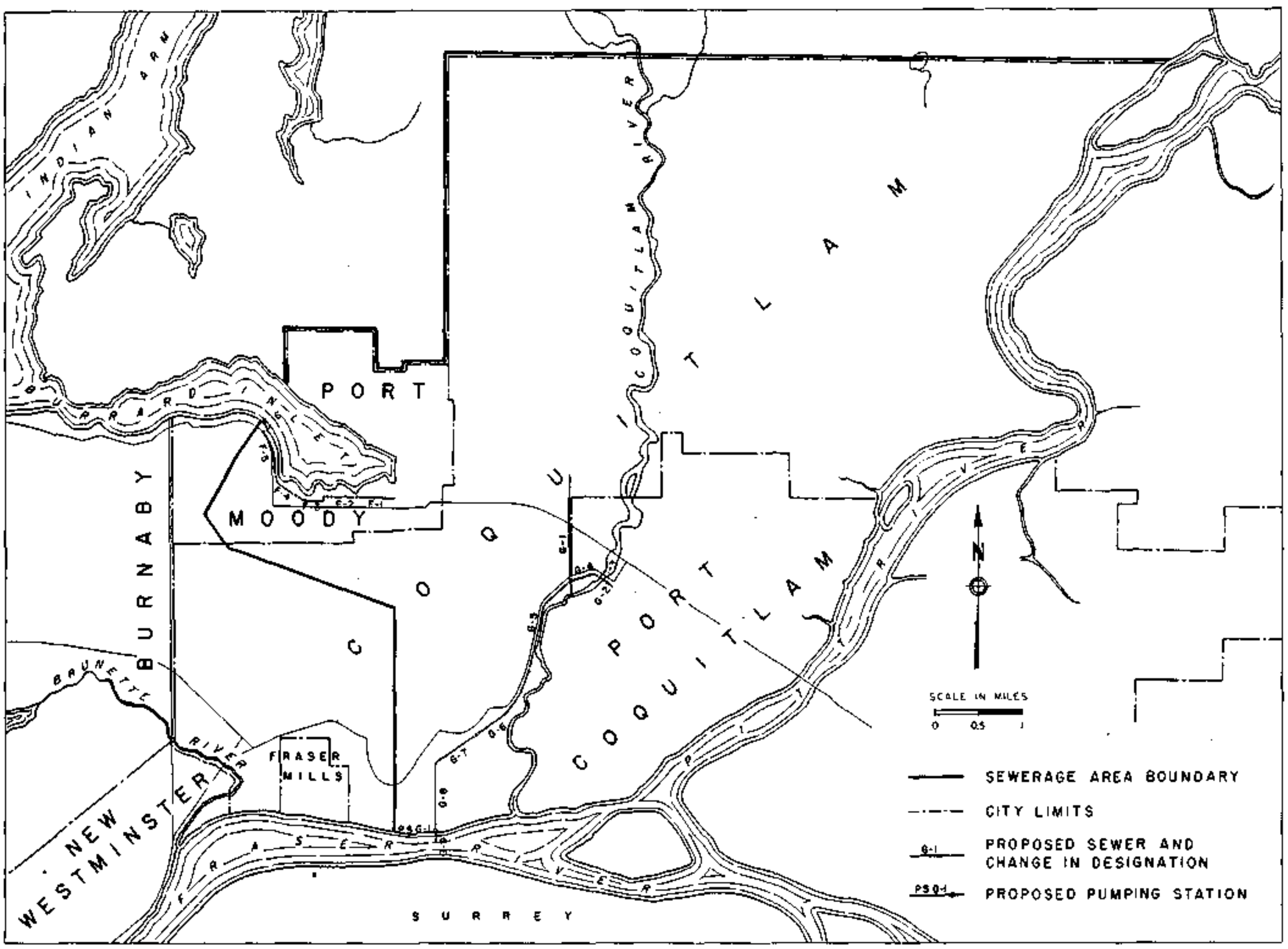


Figure 86. Proposed Layouts of Plan F and Plan G - Coquitlam Sewerage Area

Plan F proposes the collection of the sanitary sewage of that portion of the Coquitlam Sewerage Area tributary to the south shore of Burrard Inlet to an outfall discharging to Burrard Inlet westerly of the present development of the City of Port Moody. Plan G proposes the collection of the sanitary sewage of that portion of the Coquitlam Sewerage Area tributary to Coquitlam River to an outfall discharging to the main Fraser River west of the mouth of Coquitlam River.

Table 54

Estimated Design Flows and Construction Costs of Plan F Facilities
Coquitlam Sewerage Area

Facility[a]	Design Flow cfs	Construction Cost[b], Dollars 1960
Sewers:		
F-1: 2,500 ft. of 14-in. RC at 0.17%	2.2	53,000
F-2: 1,650 ft. of 16-in. RC at 0.14%	2.7	38,000
F-3: 2,600 ft. of 16-in. RC at 0.18%	3.2	60,000
F-4: 1,900 ft. of 18-in. RC at 0.16%	4.1	47,000
F-5: 2,000 ft. of 18-in. RC at 0.16%	4.1	50,000
Outfall:		
F-6: 200 ft. of 18-in. RC	4.1	12,000
Total construction cost		260,000

[a] See Figure 86 for location of facilities.
[b] From Table 37 and Figure 78, plus 25 percent for engineering, administration and contingencies.

Plan F1

Plan F1 proposes the construction of intercepting sewers along the south shore of the eastern arm of Burrard Inlet to serve the same area as Plan F.

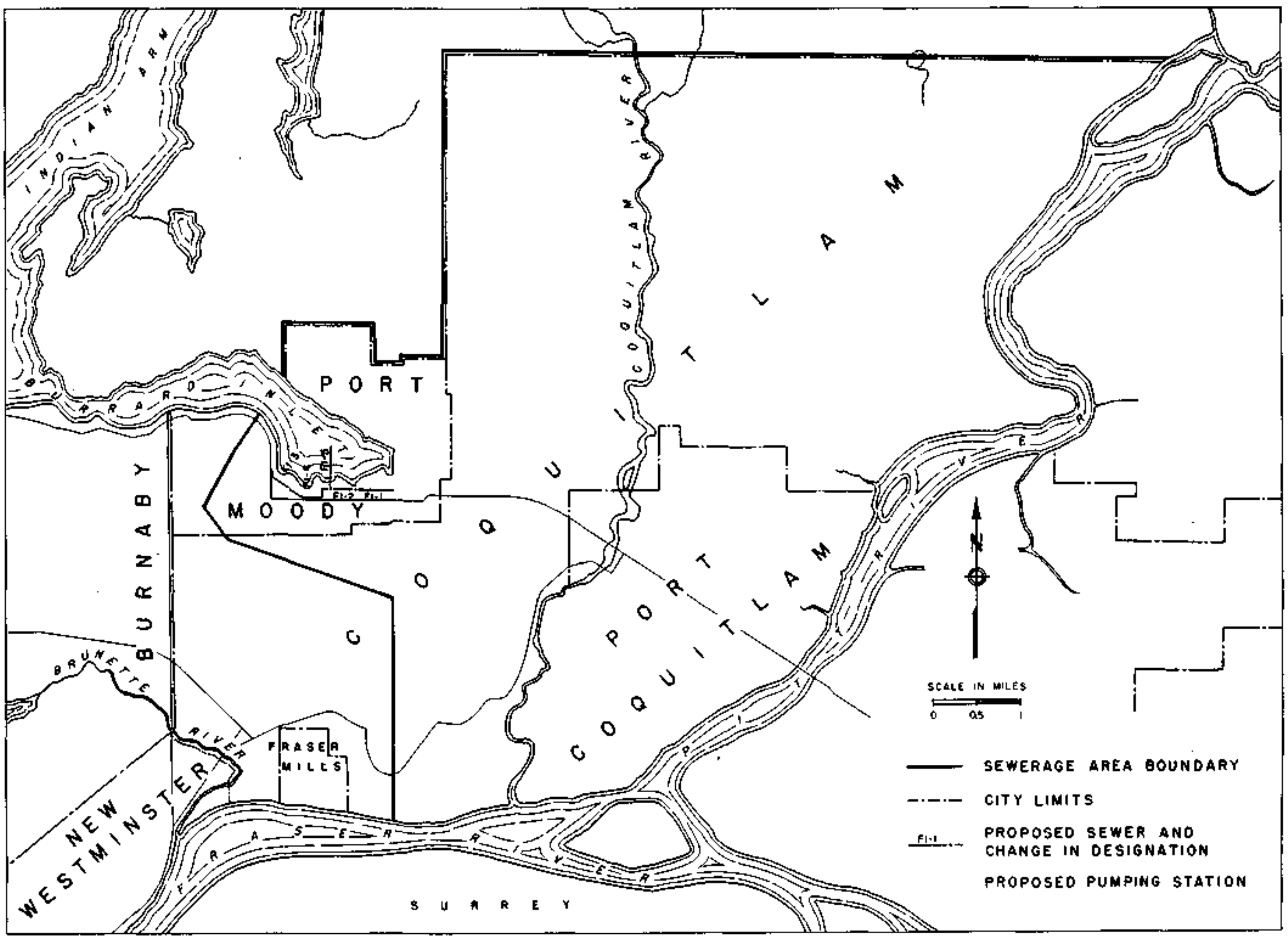


Figure 87. Proposed Layout of Plan F1 - Coquitlam Sewerage Area

Plan F1 proposes the collection of the sanitary sewage of that portion of the Coquitlam Sewerage Area tributary to the south shore of Burrard Inlet to an outfall discharging to Burrard Inlet offshore of the present development of the City of Port Moody.

Table 55

Estimated Design Flows and Construction Costs of Plan F1 Facilities

Coquitlam Sewerage Area

Facility[a]	Design Flow cfs	Construction Cost[b], Dollars 1960
Sewers:		
F1-1: 2,500 ft. of 14-in. RC at 0.17%	2.2	53,000
F1-2: 1,650 ft. of 16-in. RC at 0.14%	2.7	38,000
F1-3: 1,900 ft. of 10-in. RC at 0.27%	1.1	38,000
F1-4: 2,600 ft. of 12-in. RC at 0.23%	1.7	34,000
Outfall:		
F1-5: 2,600 ft. of 18-in. RC	4.1	150,000
Total construction cost		313,000

[a] See Figure 87 for location of facilities.
[b] From Table 37 and Figure 78; plus 25 percent for engineering, administration and contingencies.

An outfall, 2,600 feet in length, would discharge crude sewage into Burrard Inlet at a minimum depth of 18 feet. Plan F1 differs from Plan F in the location and length of the outfall and consequent changes in the design flows in the intercepting sewers.

Figure 87 shows the tentative locations of the facilities embraced by Plan F1. Table 55 presents the lengths, sizes, slopes, and the design flows and estimated construction costs of the facilities required for the completion of Plan F1. The suggested time of completion of this plan is 1960. The total construction cost of Plan F1 is estimated to be $313,000.

Comparison of Plan F and Plan F1

Comparison of figures presented in Tables 54 and 55 shows that the estimated construction cost of Plan F is $53,000 less than that of Plan F1. Table 56 pre-

Table 56

Computed Average Annual Costs During Five Year Periods, 1960-2000, of Plan F and Plan F1 - Coquitlam Sewerage Area

Cost Item	Average Annual Costs in Thousands of Dollars								
	1960 to 1965	1965 to 1970	1970 to 1975	1975 to 1980	1980 to 1985	1985 to 1990	1990 to 1995	1995 to 2000	40 Year Average
Plan F									
Bond redemption and interest[a]	17	17	17	17	17	0	0	0	
Maintenance and operation Conduits[b]	1	1	1	1	1	1	1	1	
Total annual cost, Plan F	18	18	18	18	18	1	1	1	11
Average flow, cfs	0.83	1.00	1.17	1.35	1.53	1.70	1.85	1.98	1.43
Plan F1									
Bond redemption and interest[a]	20	20	20	20	20	0	0	0	
Maintenance and operation Conduits[b]	1	1	1	1	1	1	1	1	
Total annual cost, Plan F1	21	21	21	21	21	1	1	1	14
Average flow, cfs	0.83	1.00	1.17	1.35	1.53	1.70	1.85	1.98	1.43

Plan F proposes the collection of the sanitary sewage of that portion of the area tributary to the south shore of Burrard Inlet to an outfall located westerly of the present development of the City of Port Moody. The outfall would discharge to Burrard Inlet at a depth of 30 feet.

Plan F1 proposes the collection of the sanitary sewage of that portion of the area tributary to the south shore of Burrard Inlet to an outfall located offshore of the present development of the City of Port Moody. The outfall would discharge to Burrard Inlet at a depth of 18 feet.

[a] Payments on 25 year instalment debentures at 4 percent interest.
[b] 1/4 of one percent of construction cost.

sents the calculated average annual costs of these two plans for five year periods from 1960 to 2000. During the period 1960 to 1985, the average annual cost of Plan F is shown to be $18,000 and that of Plan F1 to be $21,000. The average annual cost over the 40 year period for which comparisons have been made is $11,000 for Plan F and $14,000 for Plan F1. Thus, the cost of Plan F is shown to be $3,000 per year lower than Plan F1 for the 40 year period. The average annual savings over this period would thus amount to a total of $120,000. The consistent annual savings represented by Plan F indicate that this plan will best serve the interests of this portion of the Coquitlam Sewerage Area.

Plan G

Plan G proposes the construction of trunk and intercepting sewers within that portion of the Coquitlam Sewerage Area which is tributary to Coquitlam River. Sewage would be conveyed by a system of conduits to Fraser River into which the sewage would be discharged without treatment. The facilities have been laid out with capacity sufficient for the flow of sanitary sewage only. Pumping facilities will be required to discharge the sewage into Fraser River.

Figure 86 shows the tentative locations of the facilities embraced by Plan G. Table 57 presents the lengths, sizes and slopes of the conduits and the design flows and estimated construction costs of the facilities required for completion of Plan G. This table also gives the suggested sequence of construction. The initial construction cost of this plan is estimated to be $1,305,000 and the total ultimate construction cost $1,442,000.

No alternatives were considered for this portion of the Coquitlam Sewerage Area, since the most economic solution of the sewerage problem is obviously one whereunder the sewage of the tributary area will be conveyed to a location where disposal may be accomplished without treatment. Such a project is proposed under Plan G.

Table 58 presents the calculated average annual costs of Plan G for five year periods from 1965 to 2000. Average annual costs range from a high of $106,000 during the period 1985 to 1990 to a low of $19,000 during the period 1995 to 2000. The average annual cost over the 35 year

Table 57

Estimated Design Flows and Construction Costs of Plan G Facilities
Coquitlam Sewerage Area

Facility[a]	Design Flow cfs	Construction Cost[b], Dollars 1965	1970	1980
Sewers:				
G-1: 6,200 ft. of 14-in. RC at 1.50%	4.8		93,000	
G-2: 500 ft. of 27-in. RC at 0.085%	9.0	18,000		
G-4: 2,200 ft. of 27-in. RC at 0.090%	9.3	74,000		
G-5: 6,200 ft. of 36-in. RC at 0.060%	16.3	380,000		
G-6: 4,600 ft. of 36-in. RC at 0.072%	18.0	300,000		
G-7: 3,500 ft. of 42-in. RC at 0.040%	20.3	153,000		
G-8: 4,100 ft. of 42-in. RC at 0.045%	21.4	164,000		
Inverted siphon:				
G-3: 300 ft. of two 15-in. RC	9.0	24,000		
Outfall:				
G-9: 1,000 ft. of 30-in. RC	24.9	104,000		
Total, conduits		1,217,000	93,000	
Pumping station:				
G-1:	10.0[c]	88,000[c]		44,000[d]
Total construction cost		1,305,000	93,000	44,000

[a] See Figure 86 for location of facilities.
[b] From Table 37 and Figures 78 and 79; plus 25 percent for engineering, administration and contingencies.
[c] Initial construction.
[d] Enlargement from 10.0 cfs to ultimate capacity of 16.6 cfs.

Table 58

Computed Average Annual Costs During Five Year Periods, 1965-2000, of Plan G - Coquitlam Sewerage Area

Cost Item	Average Annual Costs in Thousands of Dollars							
	1965 to 1970	1970 to 1975	1975 to 1980	1980 to 1985	1985 to 1990	1990 to 1995	1995 to 2000	35 Year Average
Plan G								
Bond redemption and interest[a]	83	89	89	92	92	9	3	
Maintenance and operation								
Conduits[b]	3	4	4	4	4	4	4	
Pumping station[c]	5	7	8	9	10	11	12	
	8	11	12	13	14	15	16	
Total annual cost, Plan G	91	100	101	105	106	24	19	78
Average flow, cfs	4.0	6.4	8.5	10.5	12.4	13.8	14.5	7.0

Plan G proposes the collection of the sanitary sewage of that portion of the area tributary to Coquitlam River to an outfall discharging to the main Fraser River west of the mouth of Coquitlam River at a depth of 50 feet.

[a] Payments on 25 year instalment debentures at 4 percent interest.
[b] 1/4 of one percent of construction cost.
[c] From Figure 80.

period, 1965 to 2000, for which costs have been computed, is shown to be $78,000.

CONCLUSIONS

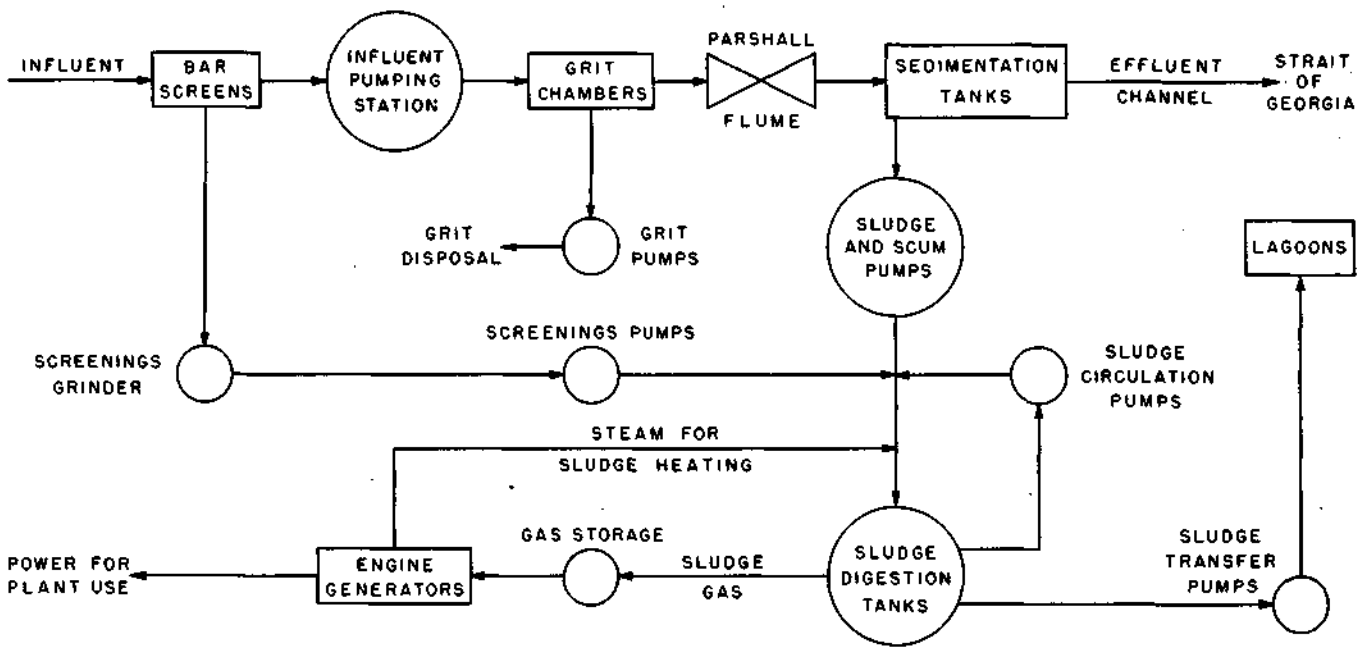
Vancouver Sewerage Area

Considering the analyses and comparisons presented of the plans considered for the Vancouver Sewerage Area, the Board of Engineers concludes that the best, most effective and most economical solution of the sewerage problems of this area will be achieved by adoption of Plan A. Under this plan, sanitary sewage from the entire sewerage area would be conveyed to a high-rate primary treatment plant located on Iona Island in the North Arm of Fraser River. After treatment, the sewage would be discharged into an effluent channel, which, during periods of low tide, would convey the sewage effluent 15,000 feet across Sturgeon Bank to deep water in the Strait of Georgia. During periods of high water this channel would be submerged and mixing and dilution would occur with the tidal waters covering Sturgeon Bank. The effluent channel would be constructed with a rock and pile jetty on its northerly side to deter a northward movement of the sewage effluent. Macdonald Slough, which lies between Iona and Sea Islands, would be dammed to prevent sewage effluent from being carried upstream on a rising tide through the slough to the North Arm. This will preclude the possibility of sewage effluent being transported by the waters of the North Arm around Point Grey and into English Bay on a falling tide.

A tentative layout of the proposed sewage treatment plant to serve the Vancouver Sewerage Area is shown in Figure 88. As planned, the plant would include mechanically cleaned bar screens, an influent pumping station, grit chambers, sedimentation tanks with facilities for skimming, and separate sludge digestion. The initial capacity of the plant would be 45 cfs with provisions for enlargement in the future to a maximum capacity of 130 cfs. The proposed treatment works would include an administration building housing offices and laboratory; a pump and engine building housing engine generators for production of power from sludge gas, influent pumps, a garage, shops and storage space; a digester and gas control building; and a gas holder. Digested sludge would be discharged to lagoons.

At the proposed site of the treatment works on Iona Island, the existing surface elevation is such that it would be necessary to raise the level of the ground

FLOW DIAGRAM



DESIGN FACTORS

LOADING

AVERAGE FLOW, CFS	45.0
MINIMUM FLOW, CFS	29.2
PEAK FLOW, CFS	67.5
BOD, 1,000 LB/DAY	37.6
SUSPENDED SOLIDS, 1,000 LB/DAY	44.2

BAR SCREENS

TO HANDLE PEAK FLOW
1-INCH CLEAR OPENING BETWEEN BARS

INFLUENT PUMPS

TO HANDLE PEAK FLOW WITH STANDBY CAPACITY

GRIT CHAMBERS

NUMBER	2
MAXIMUM CAPACITY PER CHAMBER, CFS	65

SEDIMENTATION TANKS

NUMBER	4
DETENTION TIME, HOURS	1
LENGTH, FEET	150
WIDTH, FEET	27
AVERAGE WATER DEPTH, FEET	10
MAXIMUM HYDRAULIC CAPACITY PER TANK, CFS	22.5

SLUDGE DIGESTION TANKS

(BASED ON DESIGN FOR ULTIMATE OF 4 TANKS)

NUMBER	2
DIAMETER, FEET	70
SIDE WATER DEPTH, FEET	25
LOADING, 1,000 LB DRY SOLIDS/DAY	18
(ASSUMED 40% REMOVAL BY SEDIMENTATION)	
UNIT LOADING, LB DRY SOLIDS/CU.FT./DAY	0.15

Figure 88. Flow Diagram and Design Factors for Initial Stage of Construction of Sewage Treatment Plant, Plan A - Vancouver Sewerage Area

about five feet to ensure that the plant be above high tides. This can readily be accomplished by hydraulic dredging of material from Macdonald Slough.

The geological formations along the proposed route of facility A-34 on Figure 82, a tunnel through Burrard Peninsula, were the subject of study by the Vancouver and Districts Joint Sewerage and Drainage Board in 1950 and 1951. A report, submitted to the Board by Dr. Victor Dolmage, Consulting Geologist, discusses in detail the results and conclusions determined from the field drilling program. This report is included herein as Appendix IV. Stated briefly, the investigations indicate that the tunnel will pass through tertiary sediments and through an intermediate boulder clay.

Fraser Sewerage Area

The analyses and comparisons of plans for the sewerage of the Fraser Sewerage Area compel the conclusion that the interests of this area will best be served by adoption of Plans C, D and E. Under these plans, sanitary sewage from the several tributary portions of the sewerage area would be conveyed for ultimate disposal in the waters of the main channel of Fraser River. Because of the high degree of dilution and the rapid dispersion available in the relatively deep and swift channel, treatment facilities will not be required at this time or in the foreseeable future. As a protection to the agency charged with the construction, maintenance and operation of the proposed facilities and to ensure that changes in uses in the waters of Fraser River shall not make the continuing use of these facilities impracticable, it is recommended that land be secured adjacent to the outfalls proposed under Plans C and D upon which treatment plants could be constructed if required at some later time.

Coquitlam Sewerage Area

The analyses and comparisons of the plans studied for the Coquitlam Sewerage Area have led the Board of Engineers to conclude that the adoption of Plans F and G will best serve the interests of the sewerage area. Under these plans, sanitary sewage from the tributary area under Plan F would be discharged without treatment into the deep water of Burrard Inlet and sewage from the area tributary under Plan G would be discharged without treatment into the main channel of Fraser River. As recommended for the Fraser Sewerage Area, land should be secured adjacent to the two proposed outfall sites so that treatment facilities may be constructed if they become necessary in later years.

Chapter 15
Sewerage Plans for the North Shore Section

Selection of Sewerage Plans for Study

The North Shore Section has developed to the extent that portions of it may be considered metropolitan in nature. In a metropolitan area the most satisfactory and economic solution of the sewerage problem is generally achieved when sewage from the entire area is brought to a single point for disposal. The studies conducted by the survey, therefore, were concerned only with plans proposing the concentration of sewage from relatively large areas at one point for disposal.

The North Shore Section is divided into three sewerage areas, namely, the Capilano, the Point Atkinson, and the Seymour. From the standpoint of their sewerage each of these areas has been considered as an independent unit. Every plan studied was required to satisfy certain fundamental controlling conditions and requirements as set forth and discussed in the preceding chapters of this report. Some of the controlling factors are: geography, topography, geology and climate; use of beaches and shore waters; population numbers and distribution; value of existing sewerage facilities; characteristics of the sewage; and finally, methods and requirements for disposal of sewage.

Disposal of the sewage of the North Shore Section may be accomplished by discharge into the waters of Burrard Inlet, Queen Charlotte Channel, and the Indian Arm of Burrard Inlet. The selection of a disposal site is usually based on economic considerations, although aesthetic demands may exert a strong influence. Disposal directly into popular recreational shore waters, even though all public health and engineering requirements may be met, could very well depreciate, if not actually destroy, the aesthetic value of the waters.

Brief Description of Recommended Plans

The following sections of this chapter present the various sewerage plans studied for the North Shore Section. As a result of these studies, it has been found that the most feasible method of sewerage in the Capilano Sewerage Area is represented by a project designated Plan A which proposes delivery of the sewage of the entire area to a standard-rate primary treatment plant located on the foreshore east of Capilano River. Effluent would be discharged to the First Narrows through a submarine outfall extending 700 feet offshore from the low water line and terminating at a minimum depth of 50 feet. It is not anticipated that the Point Atkinson Sewerage Area will ever develop to an extent requiring long-range planning for sewerage facilities. Local systems may be constructed to collect septic tank effluent from individual residences and other installations with discharge at locations suitable for disposal of this type of sewage effluent. The character and location of future development in the Seymour Sewerage Area is presently quite indeterminate. It is possible that sewage collection facilities not now needed may be required in this area at some future time. The sewerage needs of the existing rather isolated settlements may be satisfied in the manner outlined above for the Point Atkinson Sewerage Area.

Use of Existing Facilities

The only existing sewerage facilities in the North Shore Section are in the City of North Vancouver. Its system of sanitary sewers is reported to be overloaded due to infiltration. The intercepting sewers proposed under the plans presented herein provide for the interception of sanitary sewage only, with the excess flow occurring during periods of rainfall being discharged into Vancouver Harbour through local outfalls. In this manner, the proposed plans will utilize the local sewerage facilities as they now exist.

Preliminary Design of Facilities

All conduits considered for the North Shore Section have been laid out with capacity sufficient for the estimated ultimate peak sanitary sewage flow. This was considered necessary because future duplication or enlargement of most of the conduits would be difficult and expensive. In addition, future population trends and densities can be predicted with fair accuracy in the portions of the North Shore Section for which detailed plans have been studied.

Pumping stations and sewage treatment plants have been planned for stage construction with provision for future expansion to ultimate capacity. The initial design and construction of these facilities should present an arrangement which will permit the future installation of additional units at minimum expense.

The sequence or time of construction of the sewerage facilities for the North Shore Section has been determined by the predicted need for such facilities and by the overall objectives for the protection of the shores and shore waters of the Greater Vancouver Area. These objectives indicate that by 1965 all crude sewage discharges into Vancouver Harbour should be eliminated. For purposes of calculating annual costs presented in this report, it has been assumed that the costs of facilities indicated for construction by a given year will have no effect upon the estimated annual costs for earlier years.

The per capita sewage flow and the contributions of biochemical oxygen demand and suspended solids used for the North Shore Section are shown in Table 35, Chapter 13. The design flow for each facility is based on the ratio of peak to average flow as shown in Figure 74, Chapter 13. The ultimate population contributory to each facility was estimated by multiplying the tributary area by the predicted ultimate population density distribution shown on Figure 35, Chapter 9.

CAPILANO SEWERAGE AREA

Basic Considerations

In the Capilano Sewerage Area, the most urgent sewerage requirement is the provision of trunk sewers and sewage disposal facilities so that communities in the area may proceed with the construction and operation of needed local collection systems. It is proposed that all areas to be served in this sewerage area be provided with separate collection facilities for sanitary sewage and storm water. Storm water may be disposed of into the natural watercourses and creeks, while sanitary sewage must be conveyed over relatively long distances to reach suitable locations for treatment and disposal.

The Capilano Sewerage Area is divided topographically by Capilano River into two portions. Under Plan A it is proposed to concentrate all of the sewage from both portions of the area in one treatment plant, while under Plan B it is proposed to construct two separate treatment plants. Both plans have been laid out to achieve comparable results from engineering and sanitary standpoints.

Plan A

Plan A proposes the delivery of the sanitary sewage from the entire Capilano Sewerage Area to a standard-rate primary treatment plant to be located adjacent to the foreshore east of Capilano River. It is proposed to discharge the effluent through a submarine outfall 700 feet beyond the low water line into First Narrows at a minimum depth of 50 feet. During critical periods of the year, chlorination of the plant effluent may be required to afford additional protection for the shores and shore waters of the area.

The western branch of the collection system consists of a series of trunk and intercepting sewers with an inverted siphon under Capilano River. The eastern branch also consists of a series of trunk and intercepting sewers conveying sewage to the plant. At the plant pumps would lift the sewage to an elevation which would allow gravity flow through the plant and outfall. The size of the outfall was calculated to carry the design flow at maximum high tide. The elevation of the plant was fixed to eliminate all possibility of flooding due to high tides and river floods. The exact location of the plant will determine the extent of the filling operations necessary to accomplish this end.

Figure 89 shows the layout of Plan A as tentatively proposed. It shows the locations and designations of all facilities contained in the plan. Table 59 gives the lengths, sizes and slopes of the conduits and the design flows and estimated construction costs of the proposed facilities as well as the suggested sequence of construction. The initial construction cost of this plan is estimated to be $1,606,000 and the total ultimate construction cost $4,960,000.

Plan B

Plan B proposes the construction of separate sewage treatment plants for the western and the eastern portions of the Capilano Sewerage Area. The western plant would be a standard-rate primary treatment plant with effluent chlorination during critical periods of the year. A submarine outfall, 1,000 feet long would discharge into English Bay at a minimum depth of 60 feet. The plant would be located on reclaimed land adjacent to the shore in the Municipality of West Vancouver. Extensive filling operations would be necessary to raise the level of the plant site above the elevation of maximum high tide. The eastern plant would also be a standard-rate primary treatment plant with effluent chlorination during critical periods of the year. A submarine outfall 2,000 feet long would discharge into Vancouver Harbour at a minimum depth of 60 feet. The plant would be lo-

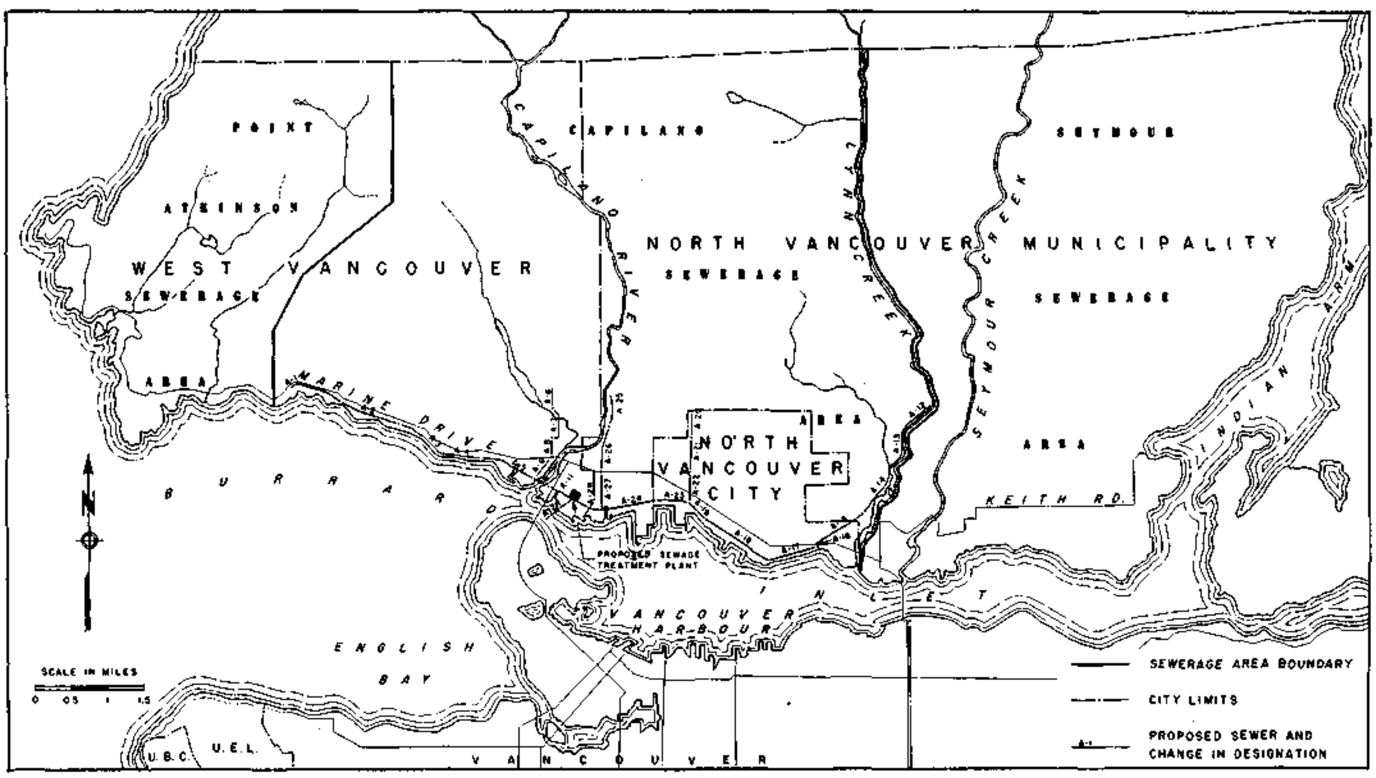


Figure 89. Proposed Layout of Plan A - Capilano Sewerage Area

Plan A proposes the treatment of the sewage of the entire Capilano Sewerage Area in a standard-rate primary treatment plant located in the Indian Reservation adjacent to the First Narrows. Effluent, chlorinated during critical periods, would be discharged to First Narrows.

Table 59
Estimated Design Flows and Construction Costs of Plan A Facilities
Capilano Sewerage Area

Facility[a]	Design Flow cfs	Construction Cost[b], Dollars 1960	1965	1985
Sewers:				
A-1: 3,600 ft. of 12-in. RC at 0.22%	1.6	90,000		
A-2: 4,400 ft. of 14-in. RC at 0.70%	3.6	99,000		
A-3: 4,200 ft. of 22-in. RC at 0.10%	5.5	84,000		
A-4: 2,600 ft. of 24-in. RC at 0.12%	7.7	57,000		
A-5: 4,900 ft. of 30-in. RC at 0.06%	9.8	128,000		
A-6: 1,300 ft. of 8-in. RC at 7.7%	2.4	10,000		
A-7: 3,100 ft. of 10-in. RC at 2.6%	2.7	24,000		
A-8: 1,350 ft. of 8-in. RC at 7.6%	2.9	17,000		
A-9: 2,250 ft. of 14-in. RC at 0.38%	2.9	17,000		
A-11: 1,900 ft. of 30-in. RC at 0.10%	12.8	64,000		
A-12: 2,100 ft. of 10-in. RC at 4.75%	4.7		17,000	
A-13: 3,400 ft. of 12-in. RC at 2.95%	6.0		31,000	
A-14: 4,200 ft. of 20-in. RC at 0.24%	6.7		57,000	
A-15: 3,700 ft. of 18-in. RC at 0.52%	7.5		44,000	
A-16: 250 ft. of 12-in. RC at 20.0%	7.5		2,000	
A-17: 3,800 ft. of 24-in. RC at 0.125%	7.9		88,000	
A-18: 5,600 ft. of 36-in. RC at 0.059%	16.1		420,000	
A-19: 2,200 ft. of 36-in. RC at 0.10%	20.1		170,000	
A-20: 1,850 ft. of 8-in. RC at 6.4%	3.0		14,000	
A-21: 2,200 ft. of 12-in. RC at 2.0%	4.0		20,000	
A-22: 2,300 ft. of 10-in. RC at 5.6%	4.7		18,000	
A-23: 2,600 ft. of 36-in. RC at 0.10%	21.4		202,000	
A-24: 4,000 ft. of 42-in. RC at 0.07%	24.0		200,000	
A-25: 2,400 ft. of 10-in. RC at 4.15%	3.0		19,000	
A-26: 3,600 ft. of 10-in. RC at 3.90%	4.3		28,000	
A-27: 3,000 ft. of 15-in. RC at 0.50%	4.6		54,000	
A-28: 2,500 ft. of 42-in. RC at 0.07%	26.8		125,000	
Inverted siphon:				
A-10: 600 ft. of 2-18-in. RC	12.8	65,000		
Outfall:				
A-29: 2,000 ft. of 42-in. RC	39.6	330,000		
Total, conduits		985,000	1,509,000	
Pumping station:				
Influent at plant	4.6[c]	21,000[c]	48,000[d]	17,000[e]
Sewage treatment plant	4.6[c]	600,000[c]	1,280,000[d]	500,000[e]
Total construction cost		1,606,000	2,837,000	517,000

[a] See Figure 89 for location of facilities.
[b] From Table 37 and Figures 78 and 79; plus 25 percent for administration, engineering and contingencies.
[c] Initial construction.
[d] Enlargement from 4.6 cfs to 20.0 cfs.
[e] Enlargement from 20 cfs to ultimate capacity of 26.4 cfs.

cated in the Capilano Indian Reserve within the City of North Vancouver.

Figure 90 shows the tentative locations of all facilities embraced by Plan B. Table 60 presents the lengths, sizes and slopes of conduits and the design flows and estimated construction costs of the facilities required for the completion of Plan B. This table also gives the suggested sequence of construction which is comparable to the sequence suggested for Plan A. The initial construction cost of this plan is estimated to be $1,444,000 and the total ultimate construction cost $4,994,000.

Comparison of Plan A and Plan B

Table 61 presents a summary of the information contained in Tables 59 and 60, and shows the estimated construction costs of the facilities required under Plans A and B. The initial construction cost of Plan B is shown to be $162,000 lower than that of Plan A, but the total ultimate construction cost of Plan A is

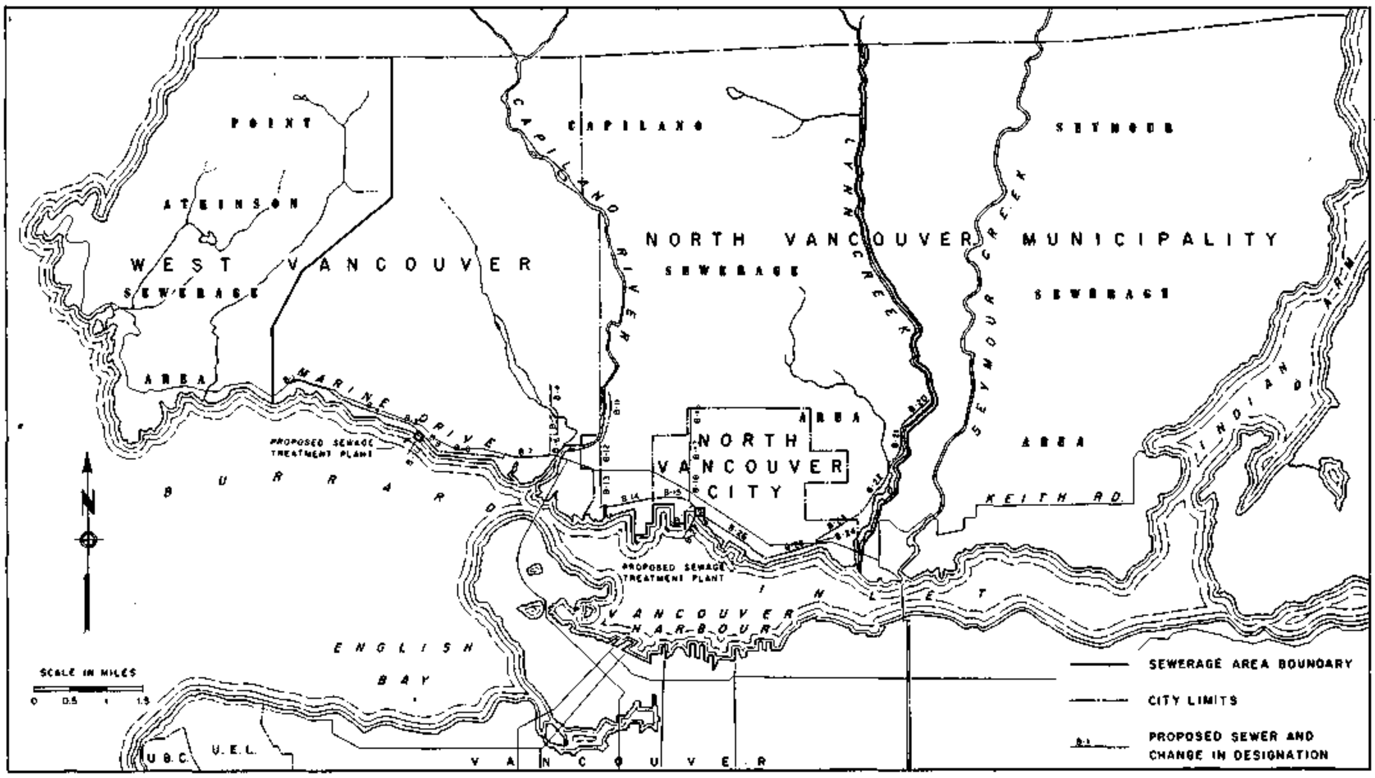


Figure 90. Proposed Layout of Plan B - Capilano Sewerage Area

Plan B proposes: (1) treatment of the sewage of West Vancouver in the Capilano Sewerage Area in a standard-rate primary treatment plant located in West Vancouver adjacent to the ocean shore and discharge of chlorinated effluent to English Bay; and (2) treatment of the sewage of the Municipality of North Vancouver and the City of North Vancouver in the Capilano Sewerage Area in a standard-rate primary treatment plant located in an Indian Reservation in the City of North Vancouver and discharge of chlorinated effluent to Vancouver Harbour.

shown to be $34,000 lower than that of Plan B.

The true economy of a project is best reflected by its annual cost. This cost consists of bond redemption and interest payments and maintenance and operation charges. The methods of computation of these items are discussed in Chapter 13 of this report and have been used in the determination of annual costs of the plans considered for the North Shore Section.

Table 62 presents the calculated average annual costs of Plans A and B for five year periods from 1960 to 2000 also the average annual cost over this 40 year period. Average annual costs of Plan A range from a high of $350,000 during the five year period 1980 to 1985 to a low of $103,000 during the period 1990 to 1995. Average annual costs of Plan B range from a high of $368,000 during the five year period 1980 to 1985 to a low of $114,000 during the period 1960 to 1965. Throughout most of the period for which comparisons have been made, the annual cost of Plan A is lower than that of Plan B. By the year 2000, the majority of the 25-year instalment debentures required for the construction of the proposed facilities will have been redeemed and it is to be noted that the maintenance and operation charges for Plan A become $18,000 per year lower during the period 1995 to 2000 than are the charges for Plan B. This fact indicates an even greater disparity of costs between Plan A and Plan B if a longer period were considered. The calculated average annual cost over the 40-year period, 1960 to 2000, is shown to be $248,000 for Plan A and $262,000 for Plan B. Over the period in question, Plan A would cost an average of $14,000

Table 60
Estimated Design Flows and Construction Costs of Plan B Facilities
Capilano Sewerage Area

Facility[a]	Design Flow, cfs	Construction Cost[b], Dollars 1960	1965	1970	1985
Sewers:					
West Vancouver system					
B-1: 3,600 ft. of 12-in. RC at 0.22%	1.6	90,000			
B-2: 4,400 ft. of 14-in. RC at 0.70%	3.6	99,000			
B-3: 1,600 ft. of 14-in. RC at 1.00%	4.3	30,000			
B-4: 1,300 ft. of 8-in. RC at 7.70%	2.4	10,000			
B-5: 3,100 ft. of 10-in. RC at 2.60%	2.7	24,000			
B-6: 1,350 ft. of 8-in. RC at 7.60%	2.9	17,000			
B-7: 5,300 ft. of 22-in. RC at 0.12%	5.9	113,000			
B-8: 2,600 ft. of 24-in. RC at 0.13%	8.0	61,000			
B-9: 2,600 ft. of 24-in. RC at 0.165%	9.2	72,000			
North Vancouver system					
B-11: 2,400 ft. of 10-in. RC at 4.15%	3.0		19,000		
B-12: 3,600 ft. of 10-in. RC at 3.90%	4.3		28,000		
B-13: 3,000 ft. of 15-in. RC at 0.50%	4.6		54,000		
B-14: 3,900 ft. of 22-in. RC at 0.12%	6.1		117,000		
B-15: 2,600 ft. of 30-in. RC at 0.08%	8.5		195,000		
B-16: 1,850 ft. of 8-in. RC at 6.40%	3.0		14,000		
B-17: 2,200 ft. of 12-in. RC at 2.00%	4.0		20,000		
B-18: 2,300 ft. of 10-in. RC at 5.60%	4.7		18,000		
B-19: 2,200 ft. of 30-in. RC at 0.08%	11.5		165,000		
B-20: 2,100 ft. of 10-in. RC at 4.75%	4.7		17,000		
B-21: 3,400 ft. of 12-in. RC at 2.95%	6.0		31,000		
B-22: 4,200 ft. of 20-in. RC at 0.24%	6.7		57,000		
B-23: 3,700 ft. of 18-in. RC at 0.52%	7.5		44,000		
B-24: 250 ft. of 12-in. RC at 20.0%	7.5		2,000		
B-25: 3,800 ft. of 24-in. RC at 0.12%	7.9		88,000		
B-26: 5,600 ft. of 30-in. RC at 0.16%	16.1		364,000		
Outfalls:					
B-10: 1,000 ft. of 24-in. RC	13.4	165,000			
B-27: 2,000 ft. of 33-in. RC	27.0		250,000		
Total, conduits					
West Vancouver system		681,000			
North Vancouver system			1,483,000		
Pumping stations:					
West Vancouver system					
Influent at plant	4.6[c]	21,000[c]		13,000[d]	
North Vancouver system					
Influent at plant	12.4[c]		47,000[c]		19,000[e]
Sewage treatment plants:					
West Vancouver	4.6[c]	742,000[cf]		208,000[df]	
North Vancouver	12.4[c]		1,310,000[c]		470,000[e]
Total construction cost					
West Vancouver system		1,444,000		221,000	
North Vancouver system			2,840,000		489,000

[a] See Figure 90 for location of facilities.
[b] From Table 37 and Figures 78 and 79; plus 25 percent for engineering, administration and contingencies.
[c] Initial construction.
[d] Enlargement from 4.6 cfs to ultimate capacity of 8.4 cfs.
[e] Enlargement from 12.4 cfs to ultimate capacity of 18.0 cfs.
[f] Includes an allowance for special foundations.

per year less than Plan B. Over the 40-year period the estimated savings would aggregate $560,000.

When the difference between the estimated annual costs of two or more projects is not great, it becomes necessary to evaluate other factors than those directly related to cost. In the case of

Table 61
Comparison of Estimated Construction Costs of Plan A and Plan B
Capilano Sewerage Area

Plan	Construction Cost, Dollars				
	1960	1965	1970	1985	Total
Plan A[a]					
Conduits[b]	985,000	1,509,000			2,494,000
Pumping station	21,000	48,000		17,000	86,000
Sewage treatment plant	600,000	1,280,000		500,000	2,380,000
Total	1,606,000	2,837,000		517,000	4,960,000
Plan B[c]					
West Vancouver system					
Conduits[b]	681,000				681,000
Pumping station	21,000		13,000		34,000
Sewage treatment plant	742,000		208,000		950,000
North Vancouver system					
Conduits[b]		1,483,000			1,483,000
Pumping station		47,000		19,000	66,000
Sewage treatment plant		1,310,000		470,000	1,780,000
Total	1,444,000	2,840,000	221,000	489,000	4,994,000

Plan A proposes the treatment of all of the sewage of the Capilano Sewerage Area in a standard-rate primary plant to be located in the Indian Reservation adjacent to the First Narrows and discharge of chlorinated effluent to the First Narrows.

Plan B proposes: (1) treatment of the sewage of West Vancouver in the Capilano Sewerage Area in a standard-rate primary plant to be located in West Vancouver adjacent to the ocean shore and discharge of chlorinated effluent to English Bay; (2) treatment of the sewage of North Vancouver District and North Vancouver City in the Capilano Sewerage Area in a standard-rate primary plant to be located in an Indian Reservation in North Vancouver City and discharge of chlorinated effluent to Vancouver Harbour.

[a] From Table 59.
[b] Includes sewers, inverted siphons and outfalls.
[c] From Table 60.

Plan B, there is no available location which is completely isolated or removed from recreational waters in the western portion of the Capilano Sewerage Area. Even though the type of treatment proposed would satisfy engineering and public health criteria, it is possible that such a plant would endanger the aesthetic value of adjacent shores and shore waters. The treatment plant proposed for the eastern portion of the area would necessarily be located near fairly well developed sections and for this reason might be considered an aesthetic handicap. On the other hand, the treatment plant location proposed under Plan A would be removed from presently built up sections and sufficient land could be acquired to provide a buffer strip of trees and other plantings around the works. The discharge of effluent into First Narrows as proposed under Plan A would result in much more rapid dispersion and mixing with the receiving waters than could be obtained at either of the treatment plant locations proposed under Plan B.

Consideration of the aesthetic and economic advantages of Plan A over Plan B leads to the conclusion that the best interests of the Capilano Sewerage Area will be served by the construction of Plan A.

POINT ATKINSON SEWERAGE AREA

Basic Considerations

Development of a metropolitan nature is not anticipated within the Point Atkinson Sewerage Area. Future development will probably centre in and around existing settlements such as Horseshoe Bay and Caulfield. Conditions for the disposal of sewage in the waters bordering the area are such that crude sewage may be discharged through outfalls extending to deep water where large dilutions would occur and currents would rapidly disperse the sewage. There are a number of locations along the shores of the area where such outfalls can operate satisfactorily if developments should make construction of sewerage facilities for the area necessary.

It is proposed that the entire sewerage area be provided, as required, with separate collection facilities for sanitary sewage and storm water. As in the other parts of the North Shore, the topography of the ground and the availability of natural watercourses for the removal of storm water combine to make separate collection facilities practical. In addition, the possibility that treatment of the sanitary sewage may be required sometime in the future makes a separate system of sewers desirable.

The present sewerage requirements in the Point Atkinson Sewerage Area are of a local rather than a general character. Although it is beyond the scope of this report to develop preliminary plans for local sewerage, it is pertinent to suggest possibilities which are worthy of consideration in dealing with such problems.

Horseshoe Bay

Horseshoe Bay is the only settlement in the Point Atkinson Sewerage Area for which sewerage requirements may be predicted at present. Its geographical and topographical location limit to a comparatively small area the ultimate development that may be expected. The settlement consists of nearly 1,000 permanent residents and is a popular fishing and recreational resort, and is the mainland terminus for ferry services to island points.

Disposal of the sewage of residences and other establishments in the vicinity of Horseshoe Bay is presently being accomplished by individual septic tank sys-

Table 62

Computed Average Annual Costs During Five Year Periods, 1960-2000, of Plan A and Plan B - Capilano Sewerage Area

Cost Item	Average Annual Costs in Thousands of Dollars 1960 to 1965	1965 to 1970	1970 to 1975	1975 to 1980	1980 to 1985	1985 to 1990	1990 to 1995	1995 to 2000	40 Year Average
Plan A									
Bond redemption and interest[a]	103	284	284	284	284	214	33	33	
Maintenance and operation									
Conduits[b]	2	6	6	6	6	6	6	6	
Chlorination[c]	3	9	10	12	13	13	14	14	
Sewage treatment plant[c]	17	36	40	44	47	48	50	51	
	22	51	56	62	66	67	70	71	
Total annual cost, Plan A	125	335	340	346	350	281	103	104	248
Average flow, cfs	3.3	12.5	15.0	17.3	19.5	20.8	22.0	22.8	16.6
Plan B									
Bond redemption and interest[a]	92	273	287	287	287	226	45	31	
Maintenance and operation									
Conduits[b]	2	5	5	5	5	5	5	5	
Chlorination[c]	3	9	11	13	14	15	15	16	
Sewage treatment plants[c]	17	48	54	58	62	64	66	68	
	22	62	70	76	81	84	86	89	
Total annual cost, Plan B	114	335	357	363	368	310	131	120	262
Average flow, cfs	3.3	12.5	15.0	17.3	19.5	20.8	22.0	22.8	16.6

Plan A proposes the treatment of all of the sewage of the Capilano Sewerage Area in a standard-rate primary plant to be located in the Indian Reservation adjacent to the First Narrows and discharge of chlorinated effluent to the First Narrows.

Plan B proposes: (1) treatment of the sewage of West Vancouver in the Capilano Sewerage Area in a standard-rate primary plant to be located in West Vancouver adjacent to the ocean shore and discharge of chlorinated effluent to English Bay; (2) treatment of the sewage of North Vancouver District and North Vancouver City in the Capilano Sewerage Area in a standard-rate primary plant to be located in an Indian Reservation in North Vancouver City and discharge of chlorinated effluent to Vancouver Harbour.

[a] Payments on 25 year instalment debentures at 4 percent interest.
[b] 1/4 of one percent of construction cost.
[c] From Figure 80.

tems and cesspools which, in general, are considered unsatisfactory because of unsuitable soil conditions. A local collection system with suitable disposal works is indicated.

Disposal of sewage from the settlement of Horseshoe Bay may be satisfactorily accomplished by one of the three following methods:

1. Discharge of crude sewage into Queen Charlotte Channel on either side of the bay.
2. Discharge into deep water of Horseshoe Bay of chlorinated effluent from a primary sewage treatment plant.
3. Discharge into deep water of the bay of effluent collected by an intercepting sewer from individual septic tanks.

The third method would probably represent the cheapest solution and, if the individual tanks were constructed and maintained properly, would provide adequate treatment and disposal. Final determination, however, will depend on the relative economies of the several possibilities based on detailed studies.

SEYMOUR SEWERAGE AREA

Basic Considerations

The extent and location of future development in the Seymour Sewerage Area cannot be determined with sufficient accuracy at present to warrant even a tentative layout of comprehensive sewerage facilities. If industry should develop along the waterfront, corresponding residential and business development will undoubtedly follow in portions of the area. If such events occur, proper planning of facilities may be accomplished for the localities as they develop.

Under present conditions, crude sewage may be discharged into the deep waters of Burrard Inlet bordering the area without endangering public health or creating a nuisance. The location of such discharges will depend on the area and population served and the uses of the shores. Future changes, which cannot now be evaluated, may require treatment of the sewage prior to discharge.

When and if any locality in the area requires sewerage, a separate sewerage collection system should be provided. Storm water may be economically disposed of in the natural watercourses of the area.

Present sewerage requirements of the Seymour Sewerage Area are similar to those of the Point Atkinson Sewerage Area already described. Suggested methods of sewage collection and disposal for the latter area would apply equally well to the Seymour Sewerage Area.

CONCLUSIONS

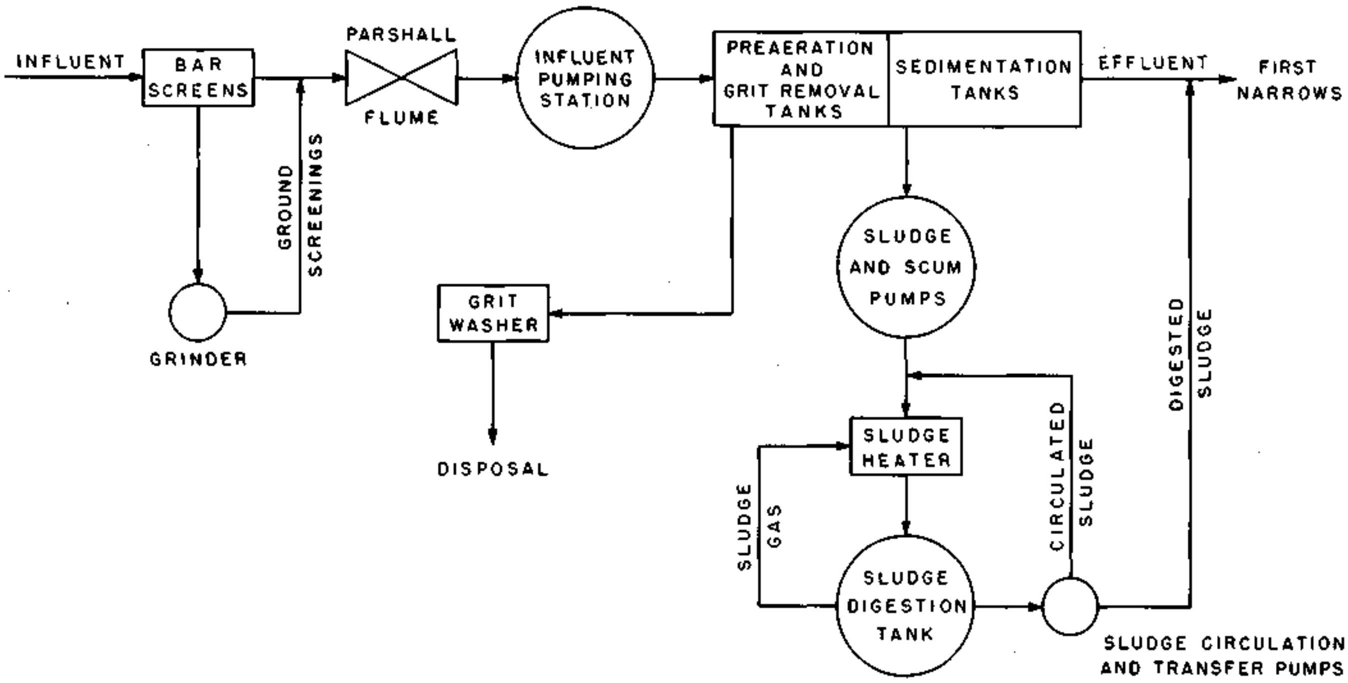
Capilano Sewerage Area

A review of all controlling conditions, including relative economy, demands of public health, aesthetics and urgency of sewerage needs, demonstrates the general superiority of Plan A, as above described. The Board of Engineers, therefore, concludes that Plan A should be adopted for the sewerage of the Capilano Sewerage Area.

Under this plan, sanitary sewage from the entire area would be delivered to a standard-rate primary treatment plant located east of Capilano River adjacent to Burrard Inlet, and the effluent, chlorinated during critical periods, would be discharged into deep water of First Narrows.

The treatment proposed would involve 30 minutes of preaeration and 60 minutes of sedimentation at the design flow. The units required in the proposed plant would include a mechanically cleaned bar screen, an influent pumping station, combination preaeration and grit removal units, sedimentation tanks with facilities for skimming, and separate sludge digestion tanks. Digested sludge would be discharged through the outfall. Figure 91 shows a schematic flow diagram of the proposed plant and the basic design factors for the initial construction of the works. The essential structures in the proposed treatment plant would include a control building housing the influent pumps, all sludge handling equipment, necessary work shop and storage space, an office, and a laboratory.

FLOW DIAGRAM



DESIGN FACTORS

LOADING

AVERAGE FLOW, CFS	4.6
MINIMUM FLOW, CFS	3.0
PEAK FLOW, CFS	7.6
BOD, 1,000 LB/DAY	4.4
SUSPENDED SOLIDS, 1,000 LB/DAY	5.2

BAR SCREENS

TO HANDLE PEAK FLOW
¾-INCH CLEAR OPENING BETWEEN BARS

INFLUENT PUMPS

TO HANDLE PEAK FLOW
TO INCLUDE STANDBY CAPACITY

PREAERATION AND GRIT REMOVAL TANKS

(BASED ON DESIGN FOR ULTIMATE OF 6 TANKS)

NUMBER	2
DETENTION TIME, HOURS	0.5
LENGTH, FEET	46
WIDTH, FEET	18
AVERAGE WATER DEPTH, FEET	10
MAXIMUM HYDRAULIC CAPACITY PER TANK, CFS	8.0

SEDIMENTATION TANKS

(BASED ON DESIGN FOR ULTIMATE OF 6 TANKS)

NUMBER	2
DETENTION TIME, HOURS	1
LENGTH, FEET	92
WIDTH, FEET	18
AVERAGE WATER DEPTH, FEET	10
MAXIMUM HYDRAULIC CAPACITY PER TANK, CFS	8.0

SLUDGE DIGESTION TANKS

(BASED ON DESIGN FOR ULTIMATE OF 3 TANKS)

NUMBER	1
DIAMETER, FEET	50
SIDE WATER DEPTH, FEET	25
LOADING, 1,000 LB DRY SOLIDS/DAY (ASSUMED 70% REMOVAL BY SEDIMENTATION)	3.6
UNIT LOADING, LB DRY SOLIDS/CU. FT./DAY	0.15

Figure 91. Flow Diagram and Design Factors for Initial Stage of Construction of Sewage Treatment Plant, Plan A - Capilano Sewerage Area

Point Atkinson and Seymour Sewerage Areas

The present extent of development of these areas does not justify preliminary or tentative layouts of comprehensive sewerage facilities. The Board of Engineers concludes, however, that as future developments occur and the nature, extent and type of the required facilities can be determined, collection systems be constructed to serve developed portions of the areas. Such facilities should be laid out in conformance with the engineering, public health and aesthetic principles which have guided the development of the plans presented in this report.

Chapter 16

Sewerage Plans for the Richmond Section

Selection of Sewerage Plans for Study

The Richmond Section is naturally divided into two sewerage areas, namely, Lulu Island and Sea Island. In addition, several smaller islands lying in the North Arm of Fraser River are considered a part of this section.

The present character of development in the Richmond Section indicates that it may be completely developed for residential and industrial purposes in future years. Certain factors are not assessable at present, however, making it difficult to plan for the sewerage of some parts of the area with any degree of certainty. For example, the ultimate use of Sea Island may be for the airport and associated activities, or it may even include greatly increased residential development. Again, the demand for or desirability of maintaining the major portion of Lulu Island for agricultural purposes may be great enough to forestall residential and industrial developments much beyond those now existing. The plans studied for the Richmond Section recognize these factors.

The most feasible sewerage plans for the Richmond Section must not only be the most economical, but must also satisfy all public health and aesthetic requirements. Chapter 12 describes the degree of sewage treatment required prior to disposal in the waters surrounding the Richmond Section.

Brief Description of Recommended Plans

The most appropriate plans for the sewerage of the Richmond Section involve the construction of separate collection facilities on Lulu Island and on Sea Island. Figure 92 shows the general layout of the facilities required for completion of the recommended plans. On Lulu Island, a trunk sewer discharging crude sewage into Fraser River is required to serve the western portion. When sewerage is required in the eastern portion of the island, similar facilities should be provided. The sewage of Sea Island is proposed to be conveyed to the northwest corner of the island whence it would be pumped to the Iona Island sewage treatment plant proposed under Plan A for the Burrard Peninsula Section in Chapter 14.

Use of Existing Facilities

The settlement of Burkeville and the Vancouver International Airport on the southeast side of Sea Island constitute the only portion of the Richmond Section which is sewered at present. Sewage from this portion is now being discharged into the Middle Arm of Fraser River. The plans considered for the Sea Island Sewerage Area make full use of the existing collection systems.

Preliminary Design of Facilities

All conduits have been laid out with capacity sufficient to accommodate the ultimate peak sanitary sewage flow predicted for the tributary areas. Provision of capacity for the ultimate flow is considered necessary because of the difficult construction conditions which exist in the Richmond Section. Because of these conditions, the additional cost of providing sewers of a size sufficient to serve the predicted ultimate population will not be great in comparison with the cost of providing sewers proportioned to meet the needs of a less distant future since the cost of the pipe itself would be but a relatively small part of the total cost of any completed sewer.

Pumping stations have been laid out to permit future enlargement in stages or steps according to need. It is expected that the initial construction will in all cases be such that additions can readily be made.

The suggested sequence of construction was determined by considerations of the sewerage requirements of the tributary area, the probable future conditions and uses of waters presently used for sewage disposal, and the proper order of development necessary to ensure protection of the shores and shore waters of the Greater Vancouver Area. The sequence of construction has been broken down into five year periods. It is expected, however, that the actual construction of the proposed facilities will be a continuous one. For the purposes of calculating annual costs as used in this report, it has been necessary to group the facilities by construction periods and to assume that the facilities indicated for construction in a given year have no effect upon annual costs of earlier years. When applied to actual construction, however, the stated time indicates the year by which the given facilities would be completed.

Greatest economy in both sewerage and drainage will be obtained in the Richmond Section by the construction of separate collection and disposal facilities for sanitary sewage and storm water. Disposal of the sewage of the Richmond Section may be either to the main channel of Fraser River or to the Strait of Georgia. Disposal of storm water may be to any of the waters surrounding the section.

A unit or per capita sewage flow of 95 gallons per day, as given in Table 35, Chapter 13, has been used in the layout of sewerage facilities in the Richmond Section. The table also presents the anticipated per capita contributions of biochemical oxygen demand and suspended solids. The ultimate population contributory to each facility was determined by multiplying the tributary area by the predicted ultimate population density distribution shown on Figure 35, Chapter 9.

The plans presented in this chapter provide for the sewerage of the Sea Island Sewerage Area and for the western portion of Lulu Island. It is proposed that the settlement of Queensborough on the eastern end of Lulu Island be served by the facilities provided under Plan D for the Burrard Peninsula Section in Chapter 14. Sewerage facilities for the central portion of Lulu Island cannot be laid out at present because the location and extent of future developments cannot now be predicted with any assurance. If or when the development in this region becomes such as to require public sewerage, a system similar to that laid out for the western portion of Lulu Island could be provided. Provision of facilities to serve the several smaller islands lying within the Richmond Section is considered to be a local problem which may best be dealt with by the local agency involved. Such facilities should be planned to provide the same measure of protection to the shores and shore waters of the area as that afforded by the plans presented in this report.

LULU ISLAND SEWERAGE AREA

Basic Considerations

Since no public sewerage facilities presently exist in the Lulu Island Sewerage Area, the most pressing need is for trunk sewerage facilities to serve the presently developed portions of the area. Such trunk sewers can be utilized by the local sewerage agency as a basis for the establishment of a comprehensive local collection system.

As discussed in Chapter 12, it would be necessary to provide for sewage treatment prior to discharge into the North Arm of Fraser River, since this water tends to move around Point Grey and into the recreational waters of English Bay. Sewage may be discharged without treatment into the main channel of Fraser River with no deleterious effect upon the present or foreseeable future uses of the river. In the layout of plans to serve the Lulu Island Sewerage Area, therefore, the main channel of Fraser River was considered to be the only proper place of ultimate disposal.

Two sewerage plans, designated Plan A and Plan B, have been studied for the Lulu Island Sewerage Area. The two plans differ in that under Plan A capacity is provided to serve the western portion of Lulu Island only, while under Plan B additional capacity has been provided for the sewage of the Sea Island Sewerage Area.

Plan A

Plan A proposes the delivery of the sewage of the western portion of Lulu Island to an outfall discharging at a minimum depth of 20 feet in the main channel of Fraser River about one mile east of its mouth. The sewerage system comprises sewers, pumping stations and an outfall. The system has been proportioned to provide capacity for the estimated ultimate peak sanitary sewage flow from the tributary area.

The sewers of Plan A are proposed to have a maximum depth of cut of about 12 feet. Detailed investigations and design may necessitate relocation of some of the facilities because of poor foundation conditions which obtain over the greater part of the area.

Figure 92 shows the tentative locations of all facilities embraced by Plan A. Table 63 presents the lengths, sizes and slopes of the conduits and the design flows and estimated construction costs of the facilities required for the completion of Plan A. This table also gives the suggested sequence of construction. The initial construction cost of this plan is

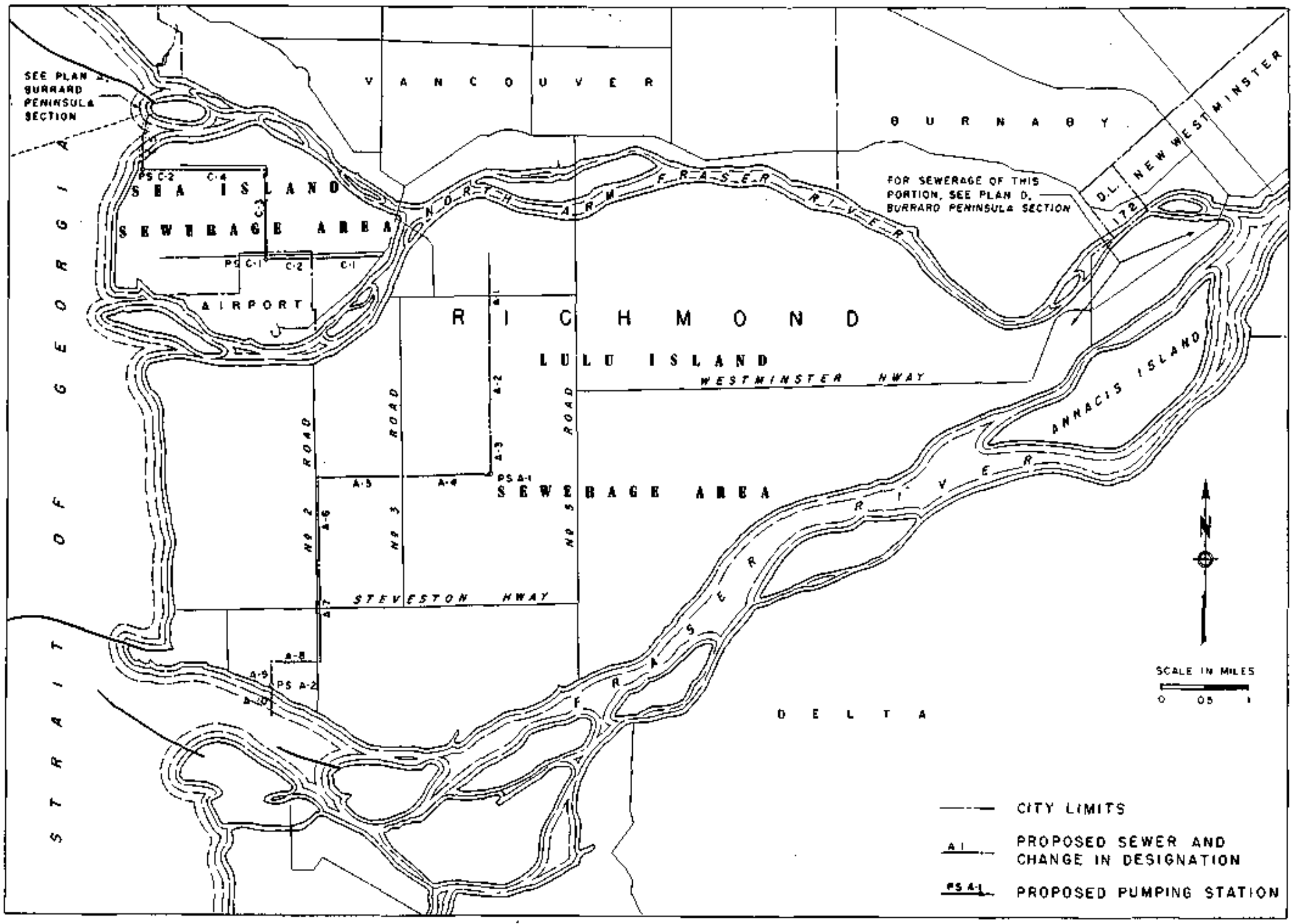


Figure 92. Proposed Layouts of Plan A and Plan C, Richmond Section

Plan A proposes the collection of the sanitary sewage of the western portion of Lulu Island to an outfall discharging to the main Fraser River. Plan C proposes the collection of the sanitary sewage of Sea Island to the northwest corner of the island from where it would be pumped to the sewage treatment plant proposed under Plan A for the Burrard Peninsula Section.

Table 63

Estimated Design Flows and Construction Costs of Plan A Facilities
Lulu Island Sewerage Area

Facility[a]	Design Flow cfs	Construction Cost[b], Dollars				
		1955	1960	1965	1975	2000
Sewers:						
A-1: 5,280 ft. of 22-in. RC at 0.09%	5.1			82,000		
A-2: 5,280 ft. of 30-in. RC at 0.06%	10.0			139,000		
A-3: 2,640 ft. of 33-in. RC at 0.066%	12.6			92,000		
A-4: 5,280 ft. of 36-in. RC at 0.055%	15.6		129,000			
A-5: 5,280 ft. of 42-in. RC at 0.038%	19.2		164,000			
A-6: 5,280 ft. of 48-in. RC at 0.034%	26.2		218,000			
A-7: 5,640 ft. of 51-in. RC at 0.034%	30.8		268,000			
A-8: 2,640 ft. of 54-in. RC at 0.030%	32.8		153,000			
A-9: 1,400 ft. of 54-in. RC at 0.034%	35.8	83,000				
Outfall:						
A-10: 2,100 ft. of 45-in. RC	35.8	380,000				
Total, conduits		463,000	932,000	313,000		
Pumping stations:						
A-1:	1.0[c]		13,000	26,000	30,000	24,000
A-2:	0.7[d]	13,000	38,000	29,000	57,000	42,000
Total construction cost		476,000	983,000	368,000	87,000	66,000

[a] See Figure 92 for location of facilities.
[b] From Table 37 and Figures 78 and 79 plus 25 percent for engineering, administration and contingencies. Pumping station costs include an allowance for special foundations.
[c] Initial construction. Subsequent enlargement to 3.6, 7.8, and 10.2 cfs capacity.
[d] Initial construction. Subsequent enlargement to 5.0, 8.8, 18.0, and 23.9 cfs capacity.

estimated to be $476,000 and the total ultimate construction cost $1,980,000.

Plan B

Plan B differs from Plan A only in the design capacities of several of the facilities. Under Plan B, it is proposed to convey the sewage flow from the Sea Island Sewerage Area to the trunk sewer system on Lulu Island and to discharge the sewage from the entire tributary portion of the Richmond Section into the main channel of Fraser River.

Figure 93 shows the tentative locations of the facilities embraced by Plan B. Table 64 presents the lengths, sizes and slopes of the conduits and the design flows and estimated construction costs of the facilities required for the completion of Plan B within the Lulu Island Sewerage Area. This table also gives the suggested sequence of construction. The initial construction cost of this plan in the Lulu Island Sewerage Area is estimated to be $505,000, and the total ultimate construction cost $2,108,000.

SEA ISLAND SEWERAGE AREA

Basic Considerations

Two sewerage plans, designated Plan B and Plan C, have been studied for the Sea Island Sewerage Area. Under Plan B, the sewage of the area would be conveyed southward across the Middle Arm of Fraser River to a connection with facilities proposed for the Lulu Island Sewerage Area. Under Plan C, the sewage would be conveyed northward across Macdonald Slough with discharge to the sewerage facilities on Iona Island as proposed under Plan A for the Burrard Peninsula Section.

Plan B

Plan B provides for the conveyance of the sewage of Sea Island and the western portion of Lulu Island to an outfall discharging into the main channel of Fraser River. Sewage from Sea Island would be pumped through a force main across the Middle Arm of Fraser River to Lulu Island, where it would be combined with sewage from the Lulu Island Sewerage Area. The sewage would flow through a series of sewers and pumping stations to the point of ultimate disposal.

Figure 93 shows the locations of all facilities embraced by Plan B. Table 65 presents the lengths, sizes and slopes of the conduits and the design flows and estimated construction costs of the facilities required for the completion of Plan B within the Sea Island Sewerage Area. The total construction cost of this plan in the Sea Island Sewerage Area is estimated to be $565,000. It is proposed to construct all of these facilities by the same date.

Plan C

Plan C proposes the conveyance of the sewage of Sea Island to the northwest corner of the island whence it would be pumped to the proposed Iona Island sewage treatment plant.

Figure 92 shows the tentative locations of all facilities embraced by Plan C. Table 66 presents the lengths, sizes and slopes of the conduits and the design flows and estimated construction costs of the facilities required for the completion of Plan C. The total construction cost is estimated to be $595,000. It is proposed that all of these facilities be constructed by the same date.

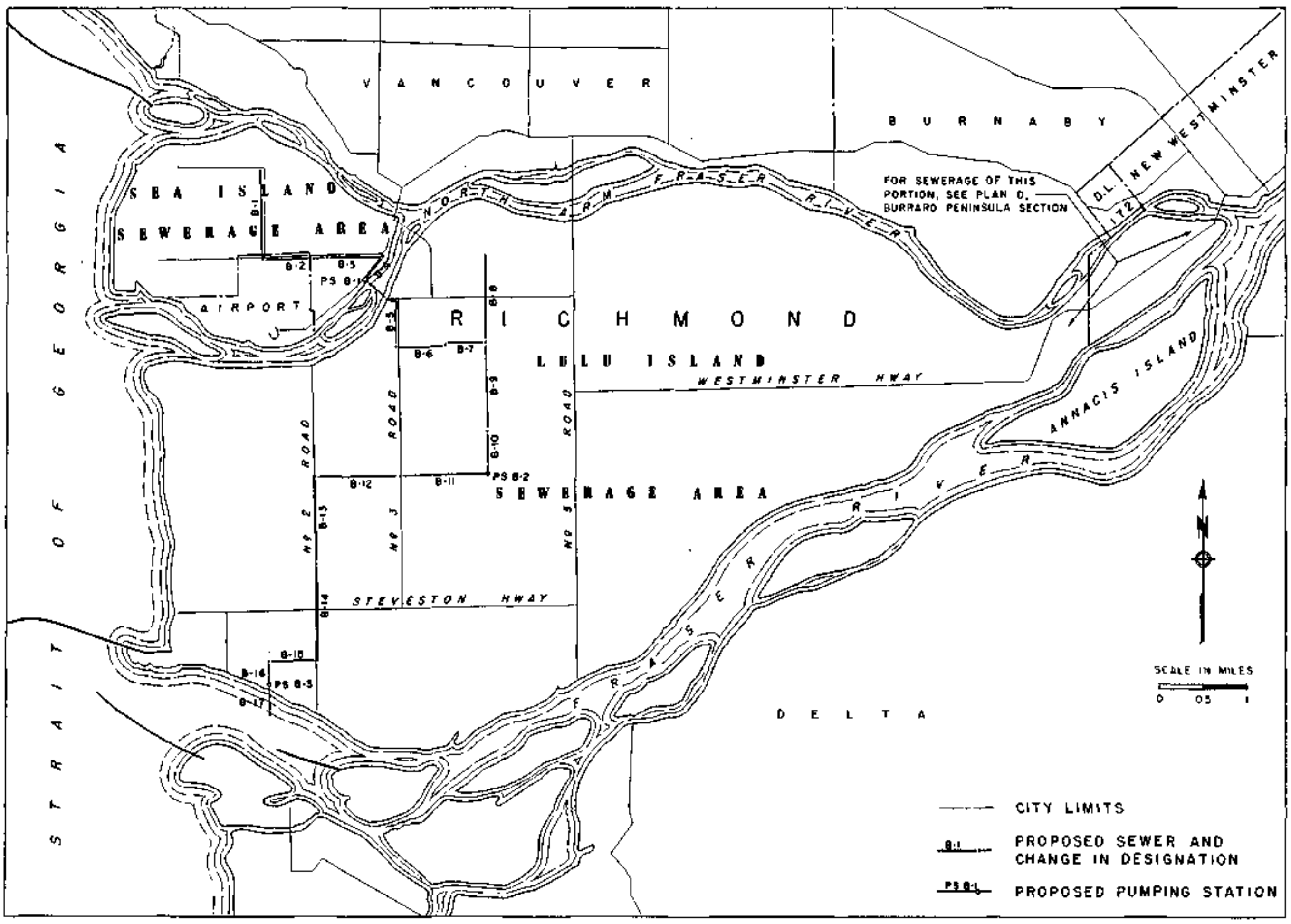


Figure 93. Proposed Layout of Plan B, Richmond Section

Plan B proposes the collection of the sanitary sewage of Sea Island and the western portion of Lulu Island to an outfall to the main Fraser River as proposed under Plan A for the Richmond Section.

Table 64

Estimated Design Flows and Construction Costs of Plan B Facilities
Lulu Island Sewerage Area

Facility[a]	Design Flow cfs	Construction Cost[b], Dollars 1955	1960	1965	1975	2000
Sewers:						
B-8: 5,280 ft. of 22-in. RC at 0.09%	5.2			82,000		
B-9: 5,280 ft. of 36-in. RC at 0.055%	15.6			163,000		
B-10: 2,640 ft. of 39-in. RC at 0.050%	18.2			94,000		
B-11: 5,280 ft. of 42-in. RC at 0.045%	21.2		132,000			
B-12: 5,280 ft. of 45-in. RC at 0.035%	24.7		164,000			
B-13: 5,280 ft. of 51-in. RC at 0.038%	32.9		217,000			
B-14: 5,640 ft. of 57-in. RC at 0.027%	36.5		296,000			
B-15: 2,640 ft. of 57-in. RC at 0.030%	38.6		148,000			
B-16: 1,400 ft. of 57-in. RC at 0.035%	41.6	83,000				
Outfall:						
B-17: 2,100 ft. of 48-in. RC	41.6	409,000				
Total, conduits		492,000	957,000	339,000		
Pumping stations:						
B-2:	1.0[c]		13,000	38,000	38,000	31,000
B-3:	0.7[d]	13,000	38,000	37,000	70,000	42,000
Total construction cost		505,000	1,008,000	414,000	108,000	73,000

[a] See Figure 93 for location of facilities.
[b] From Table 37 and Figures 78 and 79 plus 25 percent for engineering, administration and contingencies. Pumping station costs include an allowance for special foundations.
[c] Initial construction. Subsequent enlargement to 4.9, 10.2 and 14.1 cfs capacity.
[d] Initial construction. Subsequent enlargement to 4.9, 10.1, 20.6 and 27.8 cfs capacity.

COMPARISON OF PLANS

Sewerage of the Richmond Section may be accomplished by a combination of Plan A and Plan C as described above or by the adoption of Plan B which would serve the entire section. To determine the most economical solution, therefore, a comparison must be made of the combined cost of Plans A and C with the cost of Plan B.

Table 67 summarizes the figures given in Tables 63 and 66 for Plans A and C, respectively, and in Tables 64

Table 65

Estimated Design Flows and Construction Costs of Plan B Facilities
Sea Island Sewerage Area

Facility[a]	Design Flow cfs	Construction Cost[b], Dollars 1965
Sewers:		
B-1: 5,280 ft. of 18-in. RC at 0.11%	3.4	82,000
B-2: 3,880 ft. of 20-in. RC at 0.14%	5.0	95,000
B-3: 2,940 ft. of 22-in. RC at 0.10%	5.8	103,000
B-4: 1,650 ft. of 24-in. RC at 0.08%	6.4	73,000
B-6: 2,940 ft. of 27-in. RC at 0.07%	8.1	55,000
B-7: 2,640 ft. of 27-in. RC at 0.095%	9.3	58,000
Force main:		
B-5: 4,940 ft. of 18-in. RC	6.4	55,000
Total, conduits		521,000
Pumping station:		
B-1:	3.9[c]	44,000[c]
Total construction cost		565,000

[a] See Figure 93 for location of facilities.
[b] From Tables 37 and 38, and Figure 79; plus 25 percent for engineering, administration and contingencies.
[c] Ultimate capacity.

Table 66

**Estimated Design Flows and Construction Costs of Plan C Facilities
Sea Island Sewerage Area**

Facility[a]	Design Flow cfs	Construction Cost[b], Dollars 1965
Sewers:		
C-1: 4,180 ft. of 15-in. RC at 0.15%	2.1	68,000
C-2: 2,640 ft. of 18-in. RC at 0.12%	3.5	69,000
C-3: 5,280 ft. of 20-in. RC at 0.11%	4.4	198,000
C-4: 7,520 ft. of 24-in. RC at 0.08%	6.4	146,000
Force main:		
C-5: 3,500 ft. of 18-in. RC	6.4	39,000
Total, conduits		520,000
Pumping stations:		
C-1:	2.6[c]	31,000[c]
C-2:	3.9[c]	44,000[c]
Total construction cost		595,000

[a] See Figure 92 for location of facilities.
[b] From Table 37 and 38, and Figure 79; plus 25 percent for engineering, administration and contingencies.
[c] Ultimate capacity.

and 65 for Plan B. The estimated total combined construction cost of Plans A and C is $2,575,000, which is $98,000 less than the construction cost of Plan B.

Other factors being equal, annual costs generally indicate the suitability of one plan or combination of plans when compared with another plan. Annual costs are comprised of the following

Table 67

**Comparison of Estimated Construction Costs
of Plans Considered for Richmond Section**

Plan	Construction Cost, Dollars 1955	1960	1965	1975	2000	Total
Plan A[a]						
Conduits[b]	463,000	932,000	313,000			1,708,000
Pumping stations	13,000	51,000	55,000	87,000	66,000	272,000
Plan C[c]						
Conduits[b]			520,000			520,000
Pumping stations			75,000			75,000
Total Plans A and C	476,000	983,000	963,000	87,000	66,000	2,575,000
Plan B						
Lulu Island[d]						
Conduits[b]	492,000	957,000	339,000			1,788,000
Pumping stations	13,000	51,000	75,000	108,000	73,000	320,000
Sea Island[e]						
Conduits[b]			521,000			521,000
Pumping stations			44,000			44,000
Total Plan B	505,000	1,008,000	979,000	108,000	73,000	2,673,000

Plan A proposes the collection of the sanitary sewage of the western portion of the Lulu Island Sewerage Area to an outfall extending 2,100 feet into the main Fraser River and Discharging crude sewage at a depth of about 20 feet.

Plan B proposes the collection of the sanitary sewage of the Sea Island Sewerage Area and of the western portion of the Lulu Island Sewerage Area to an outfall to the main Fraser River as proposed under Plan A.

Plan C proposes the collection of the sanitary sewage of the Sea Island Sewerage Area to the northwest corner of Sea Island, whence it would be pumped to the sewage treatment plant proposed under Plan A for the Burrard Peninsula Section in Chapter 14.

[a] From Table 63.
[b] Includes sewers, force mains and outfalls.
[c] From Table 66.
[d] From Table 64.
[e] From Table 65.

elements: (1) bond redemption and interest, and (2) costs of administration, operation and maintenance. The methods of computation of each of these elements are discussed in Chapter 13 of this report.

Table 68 presents the calculated average annual costs of the combined Plans A and C and of Plan B for five year periods from 1955 to 2000 and the average annual cost over this 45 year period. Average annual costs of Plans A and C range from a high of $186,000 during the five year period 1975 to 1980 to a low of $33,000 during the five year period 1955 to 1960. Average annual

Table 68

Computed Average Annual Costs During Five Year Periods, 1955-2000, of Plans A and C and Plan B - Richmond Section

Cost Item	Total Annual Costs in Thousands of Dollars									
	1955 to 1960	1960 to 1965	1965 to 1970	1970 to 1975	1975 to 1980	1980 to 1985	1985 to 1990	1990 to 1995	1995 to 2000	45 Year Average
Plan A										
Bond redemption and interest[a]	31	94	118	118	124	93	30	6	6	
Maintenance and operation										
Conduits[b]	1	3	4	4	4	4	4	4	4	
Pumping stations[c]	1	4	10	12	14	16	18	20	22	
	2	7	14	16	18	20	22	24	26	
	33	101	132	134	142	113	52	30	32	
Plan C										
Bond redemption and interest[a]			38	38	38	38	38	0	0	
Maintenance and operation										
Conduits[b]			1	1	1	1	1	1	1	
Pumping stations[c]			3	4	5	5	6	7	7	
			4	5	6	6	7	8	8	
			42	43	44	44	45	8	8	
Total annual cost, Plans A and C	33	101	174	177	186	157	97	38	40	111
Average flow, cfs	0.5	2.8	6.6	8.4	10.6	13.2	16.2	18.6	19.9	10.8
Plan B										
Lulu Island portion										
Bond redemption and interest[a]	32	96	122	122	129	97	33	7	7	
Maintenance and operation										
Conduits[b]	1	3	4	4	4	4	4	4	4	
Pumping stations[c]	1	4	12	14	16	18	20	22	24	
	2	7	16	18	20	22	24	26	28	
	34	103	138	140	149	119	57	33	35	
Sea Island portion										
Bond redemption and interest[a]			36	36	36	36	36	0	0	
Maintenance and operation										
Conduits[b]			1	1	1	1	1	1	1	
Pumping station[c]			2	2	3	3	3	4	4	
			3	3	4	4	4	5	5	
			39	39	40	40	40	5	5	
Total annual cost, Plan B	34	103	177	179	189	159	97	38	40	113
Average flow, cfs	0.5	2.8	6.6	8.4	10.6	13.2	16.2	18.6	19.9	10.8

Plan A proposes the collection of the sanitary sewage of the western portion of the Lulu Island Sewerage Area to an outfall extending 2,100 feet into the main Fraser River and discharging crude sewage at a depth of about 20 feet.

Plan B proposes the collection of the sanitary sewage of the Sea Island Sewerage Area and of the western portion of the Lulu Island Sewerage Area to an outfall to the main Fraser River as proposed under Plan A.

Plan C proposes the collection of the sanitary sewage of the Sea Island Sewerage Area to the northwest corner of Sea Island, whence it would be pumped to the sewage treatment plant proposed under Plan A for the Burrard Peninsula Section in Chapter 14.

[a] Payments on 25 year instalment debentures at 4 percent interest.
[b] 1/4 of one percent of construction cost.
[c] From Figure 80.

costs of Plan B range from a high of $189,000 during the five year period 1975 to 1980 to a low of $34,000 during the five year period 1955 to 1960. The calculated average annual cost over the 45 year period, 1955 to 2000, is shown to be $111,000 for the combined Plans A and C and $113,000 for Plan B.

In the layout of sewerage plans for Sea Island, it has been assumed that residential developments thereon will continue. Under Plan B, capacity for sewage from Sea Island has been provided in the facilities proposed to be constructed on Lulu Island. It is possible that future residential developments on Sea Island may be curtailed and the entire island utilized by the airport and associated activities. This would result in the production of a much smaller quantity of sewage flow than if residential developments should continue. If this should happen, the facilities proposed for Lulu Island under Plan B would have excess capacity, thus resulting in unnecessary expenditures. The suggested sequence of construction is such that facilities in the southwestern part of Lulu Island would be constructed before the future use of Sea Island is evident. Under Plan B, these facilities would include capacity for Sea Island sewage, while under Plan A they would not. The independent construction of Plan A and Plan C would represent greater flexibility than would Plan B.

CONCLUSIONS

The Board of Engineers concludes that Plans A and C as described above should be adopted for the sewerage of the Richmond Section because of the economies evidenced by the cost comparisons given in Tables 67 and 68 and because of their greater flexibility in various respects. Under Plan A capacity is proposed to be provided for the ultimate sewage flow from the western portion of Lulu Island in a system which will discharge crude sewage into the main channel of Fraser River 2,100 feet offshore at a minimum depth of 20 feet. Under Plan C, the sewage of Sea Island would be conveyed to the Iona Island sewage treatment plant proposed in Chapter 14 for the Vancouver Sewerage Area of the Burrard Peninsula Section. Land should be obtained adjacent to the proposed outfall location under Plan A so that treatment facilities may be constructed if they should become necessary in later years.

Sewerage of the eastern portion of Lulu Island may properly be accomplished as described under Plan D for the Fraser Sewerage Area of the Burrard Peninsula Section in Chapter 14. The remainder of Lulu Island may be provided with a sewerage system similar to that proposed under Plan A if required by future developments.

Chapter 17
Drainage Facilities for the Greater Vancouver Area

Advantages of Regional Drainage Facilities

The fulfilment of a properly co-ordinated plan for the protection of land and improvements in the Greater Vancouver Area from damage due to storm waters, is a major undertaking in financing and construction.

With few exceptions the cost of financing the construction of major storm drainage facilities will be less if carried out by a joint agency than by the individual communities concerned. In addition some of the natural drainage areas lie within two or more communities. For these reasons the financing, construction and maintenance of the major storm drainage facilities by a joint agency is advisable. In addition to direct advantages, indirect and intangible benefits will accrue to all residents and property owners of the Greater Vancouver Area because of reduced interruption to travel and communication. The general prosperity of the area is inherent in, and inseparable from, the general welfare of all portions of the area.

The development and improvement of major storm drainage facilities in the City of Vancouver, the Municipality of Burnaby and a portion of the City of New Westminster is now the responsibility of the Vancouver and Districts Joint Sewerage and Drainage Board. In the remainder of the Greater Vancouver Area, the provision and maintenance of drainage works are the responsibility of the individual communities. Rapid development and growth of these communities, together with the consequent denuding of the forested drainage areas in some of them, has already rendered the capacity of certain of the natural drainage courses completely inadequate.

Division into Drainage Areas

The three natural geographic and topographic sections comprising the Greater Vancouver Area, namely, the Burrard Peninsula, North Shore, and Richmond Sections, constitute a logical division for drainage, as well as sewerage, planning. Division of the sections into smaller areas for these purposes, because of differing requirements for the disposal of sewage and storm water, must of necessity be different. The sewerage areas have been delineated and described in earlier chapters of this report. Sewerage plans for each of these areas have also been outlined. A division of the sections into drainage areas has not been attempted at this time because the boundaries of each drainage area may more properly be determined when the detailed design of facilities is undertaken. General drainage plans for each of the three natural geographic and topographic sections are presented in the following sections of this chapter.

Burrard Peninsula Section. The Burrard Peninsula Section is divided topographically into numerous natural drainage areas. Those lying within the City of Vancouver, the Municipality of Burnaby, and a portion of the City of New Westminster are administered by the Vancouver and Districts Joint Sewerage and Drainage Board.

The section is bounded on the south by Fraser River. Flood control measures for this river are the responsibility of the Federal and Provincial Governments and, therefore, are not considered to be within the scope of this report. The uses of the Coquitlam and Pitt Rivers are such that responsibility for their maintenance is not logically vested in any local governmental agency concerned with storm water drainage. They, also, are deemed to be outside the scope of this survey and report.

North Shore Section. Drainage areas in the North Shore Section are defined by the natural topography of the ground and are of relatively small size. Each has a natural outlet to a river or to tidal waters. The Lynn, Capilano and Seymour Rivers are used as sources of water supply for most of the Greater Vancouver Area and the control of these rivers in their upper reaches is the responsibility of two water supply agencies, the Greater Vancouver Water District and the City of North Vancouver. The improvement and maintenance of the lower reaches is the responsibility of agencies of the Provincial Government. Some of the smaller creeks discharging to the rivers, however, fall under the responsibility of local government and the improvement of these creeks as storm water drains is necessarily considered in this report.

Richmond Section. The division of this section into independent or separate drainage areas is not related to any significant extent to topography since variations in ground surface elevations are negligible over the entire section. Existing facilities, rights-of-way, and economic considerations, rather than topography, determine the boundaries and sizes of the drainage areas. Independent drainage facilities must obviously be provided for Sea Island and Lulu Island.

Selection of Drainage Plans for Study

For purposes of estimating costs of major drainage facilities, a study was made of existing drainage structures within the Vancouver and Districts Joint Sewerage and Drainage Board. This study, discussed in Chapter 13, resulted in the division of drainage structures into several classifications. This was accomplished primarily on the basis of topography and land use. Each section of the Greater Vancouver Area has been divided into zones, each of which falls into one of these classifications. The total cost of providing drainage for each such section has been estimated on the basis of the areas within the section falling into the various classifications. In the study of drainage requirements, natural rights and legal liabilities of the several communities and their inhabitants were considered to be of importance in the selection of the types of drainage facilities required.

Cost comparisons between possible alternate drainage projects were not made, since economic considerations will not necessarily govern the degree of storm water drainage which should be provided. In the future, public preference may demand a greater degree of drainage than would be requisite for the protection of the area from flooding only. For the purposes of this report the relative suitability of closed conduits versus open channels for storm water conveyance was decided on the basis of existing or predicted future improvements in any given area.

The facilities proposed herein would provide for the minimum degree of drainage required in any area commensurate with the adequate protection of that area. In many cases, furthermore, it has been considered practicable to provide an open channel initially and, at some later time, to provide a closed conduit for the conveyance of the storm waters.

Use of Existing Facilities

In planning for the disposal of storm water from the Greater Vancouver Area, the existing drainage facilities must form the basis of any comprehensive master plan of drainage. In planning sewerage facilities, on the other hand, distinct economies may often be realized by combining, through artificial means, two or more natural drainage areas and conveying sanitary sewage some distance for final treatment and disposal.

Most of the existing drainage facilities in the Greater Vancouver Area are adequate for present needs and may be incorporated into an overall scheme of drainage with a minimum of difficulty. In some instances, however, natural watercourses are privately owned and difficulty may be encountered in improving these watercourses to serve as major drainage facilities. Easements or rights-of-way along all natural watercourses should be obtained promptly by the communities in the area so that future improvements may be undertaken as they become necessary.

The systems of drainage facilities proposed in this report have been planned to utilize all existing drainage facilities to the fullest extent possible. The program of works tentatively proposed consists of gradual reconstruction and improvement of natural watercourses to their predicted ultimate development.

Preliminary Design of Facilities

In the layout of drainage facilities, precise information regarding local topography and locations of individual drainage areas is required before even preliminary plans of drainage structures can be evolved. Little information of sufficient precision is readily available at this time for any of the areas outside the present jurisdiction of the Vancouver and Districts Joint Sewerage and Drainage Board. This information cannot be obtained without prolonged and expensive surveys. Such surveys are made more properly at the time when detailed designs of the necessary facilities are undertaken. For this reason an actual layout of the drainage facilities required was not attempted in connection with this survey and report.

Description of Major Drainage Facilities

Figure 94 shows the drainage classifications which have been assumed for various portions of the Greater Vancouver Area. Table 69 presents, for each of the three sections, the area contained in each classification.

The areas stated in Table 69 comprise the entire acreage of the drainage areas. The major storm drainage facilities to be constructed in these areas will comprise improvements and reconstructions from the points of discharge to predetermined locations in the drainage areas above which major construction is not justified or required. This is consistent with the manner in which the costs per acre for drainage works were derived in Chapter 13.

In those low lying portions of any area where seasonal flooding due to freshets or tidal action occurs, the financing, construction and maintenance of dyking systems necessary for the protection or reclamation of the affected

Table 69

Estimated Areas to be Served by Major Drainage Facilities in the Greater Vancouver Area

Classification[a]	Area in Acres[b]		
	Burrard Peninsula Section	North Shore Section	Richmond Section
Open channel:			
A1	7,500	-	-
A2	2,250	3,650	-
A3	2,500	47,850	-
Conduit:			
B1	1,950	-	-
B2	9,150	-	-
B3	10,800	-	-
Open channel with pump:			
C	1,700	-	-
Conduit with pump:			
D	2,550	-	16,150
Total	38,400	51,500	16,150

[a] See Chapter 13 for description of classification.
[b] See Figure 94 for locations of zones of classification.

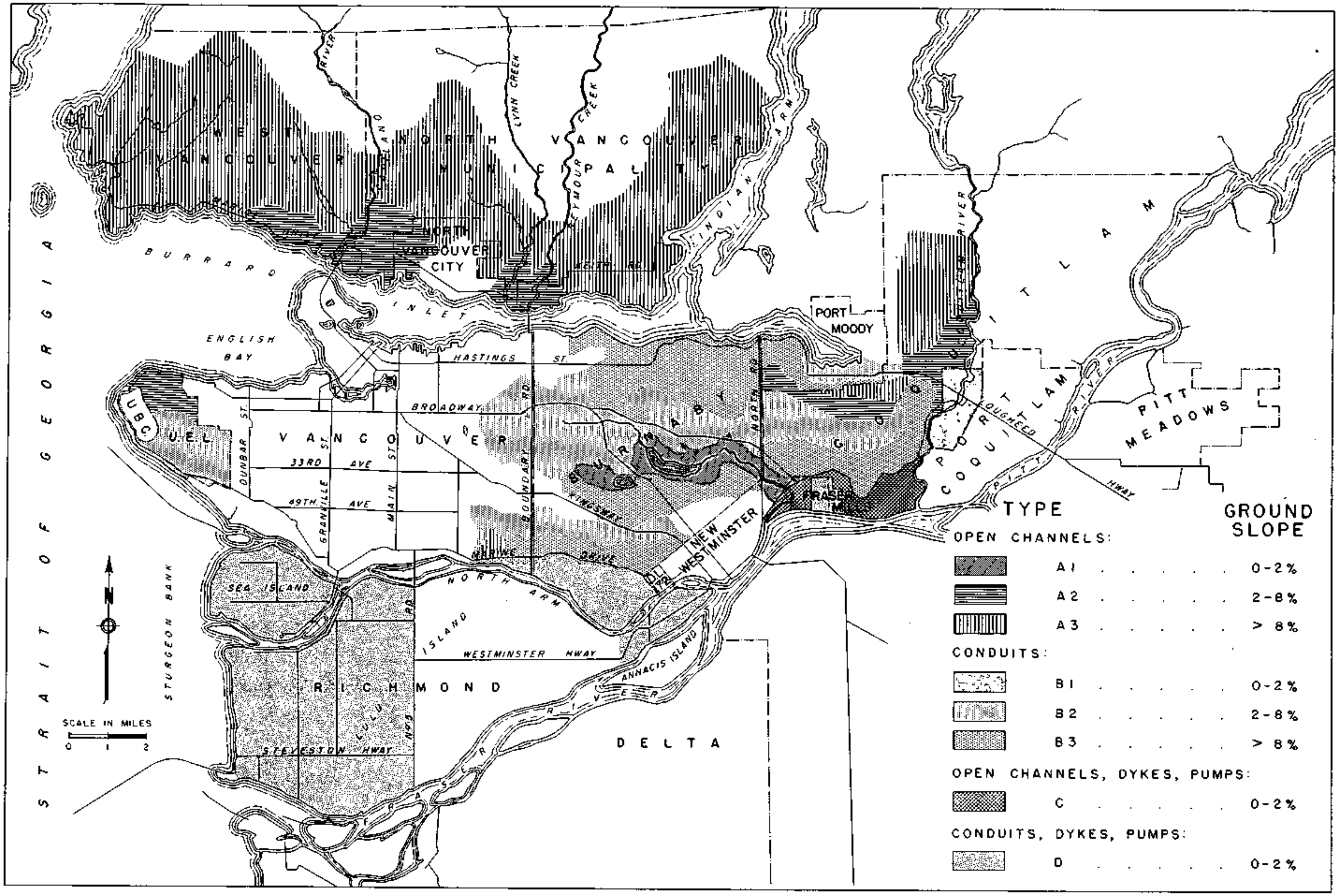


Figure 94. Proposed Drainage Classifications for the Greater Vancouver Area

Provision of storm drainage in the Greater Vancouver Area requires that eight different types of facilities be provided. Areas requiring the various types are delineated above. No drainage type is shown on the figure for those portions of the area in which adequate drainage facilities are already provided or in which the type of facility required is indeterminate at present.

territory are not considered to be the responsibility of any joint drainage agency. The drainage facilities proposed herein, therefore, do not include dyking systems.

Burrard Peninsula Section The major portion of the City of Vancouver is served by combined sewers in which storm water and sanitary sewage are carried in a single conduit to a point or points of disposal. Portions of the City of New Westminster, the University Endowment Lands, and the Municipality of Burnaby are also served by combined sewers. The problem of storm water collection and disposal in these areas is discussed in Chapter 14. With the exception of these areas and the north slope of Burnaby, which drains to Burrard Inlet, separate collection systems for sanitary sewage and storm water are herein proposed for all presently unsewered areas in the Burrard Peninsula Section.

The Still Creek-Burnaby Lake-Brunette River drainage area, with the exception of the portion east of North Road, has been administered by the existing Sewerage and Drainage Board since its formation in 1914. Improvements have been made in the area since that time, but a large amount of work remains to be done before the ultimate drainage requirements of the area will be satisfied. It is proposed that Still Creek be eventually enclosed in suitable conduits from the vicinity of Renfrew Street in Vancouver to the vicinity of the upper end of Burnaby Lake. A dredged channel would be maintained through the lake and an open channel of suitable proportions would be retained for Brunette River from the outlet or eastern end of Burnaby Lake to Fraser River. The portion of Brunette River from North Road to Fraser River would be realigned and improved.

The drainage areas tributary to the Still Creek-Burnaby Lake-Brunette River system may be served for many years by open channels, although the enclosure of most of these channels may be necessary at some time in the future.

It has been assumed that Burnaby Lake will continue to be utilized in its present form for drainage purposes. The development of the lake for other than drainage purposes is not properly a function of a drainage agency. Whatever the ultimate character of the development of Burnaby Lake may be, however, drainage facilities coordinated to that use would naturally be provided.

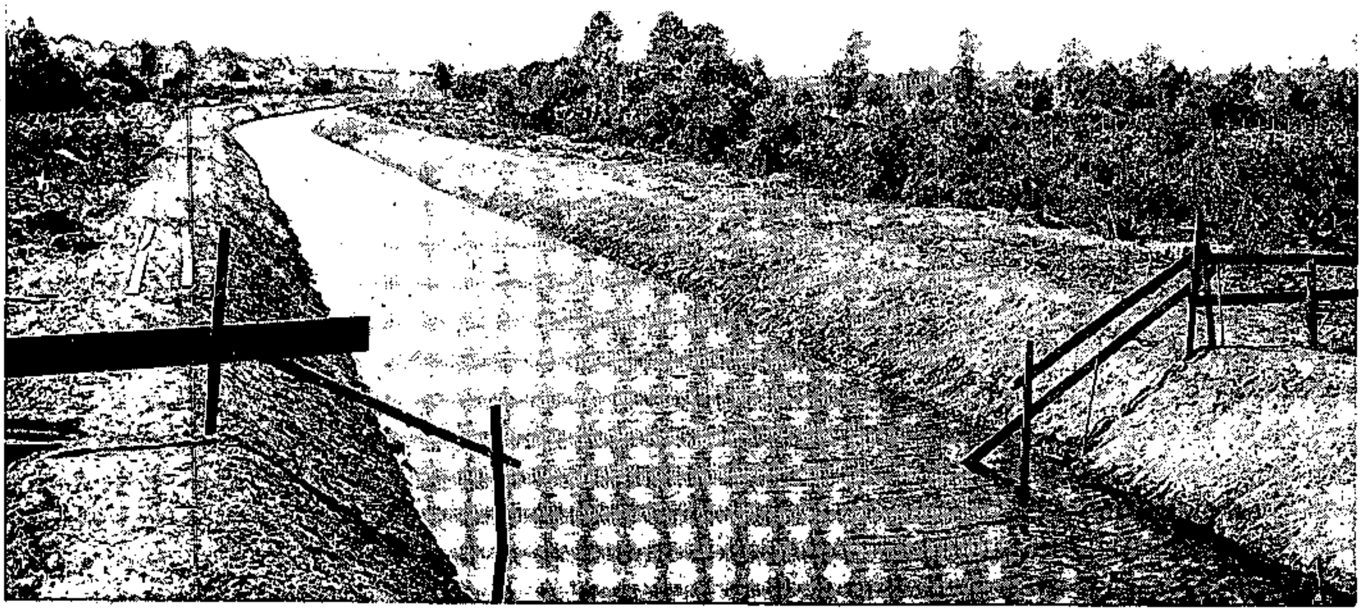
The north slope of Burnaby draining to Burrard Inlet can be served with combined sewers. The major drainage facilities for this area will thus, of necessity, be closed conduits. The south slope of Burnaby and the southeast corner of Vancouver from Marine Drive to the North Arm of Fraser River should ultimately be drained with closed conduits and pumping stations for storm water disposal. The area within the south slope north of Marine Drive will probably also require closed conduits.

The major drainage facilities in that portion of the City of Port Moody proposed to be served with sanitary sewerage works are assumed to consist of closed conduits through the main residential and industrial portions of the city. Open channels are considered to be a satisfactory means of storm water collection for the remainder of the city.

In the City of Port Coquitlam, it is proposed that storm water runoff be conveyed to either the Fraser, Pitt or Coquitlam Rivers in closed conduits in the developed portions of the city and in open channels in the remainder. The drainage of the Municipality of Coquitlam can be accomplished in a similar manner, although natural watercourses can be utilized for storm water disposal for many years to come. Only those portions of Port Coquitlam and Coquitlam for which sanitary sewerage plans are herein proposed are included in the drainage studies since the nature of the development in the remaining portions cannot be predicted with any degree of accuracy at present.

In the University Endowment Lands, the natural watercourses presently used for the disposal of storm water from the northern watershed would be preserved for this purpose. The southern slope of the University Endowment Lands would be provided with closed conduits for surface water disposal.

The University of British Columbia



Courtesy Vancouver and Districts Joint Sewerage and Drainage Board

Figure 95. Still Creek Before and After Improvement as a Major Drainage Channel

The photographs, taken from almost the same location, show what can be done to a natural watercourse to improve its ability to serve as a major drainage facility. The upper photograph, taken in 1927, shows a portion of Still Creek west of Burnaby Lake in its natural condition, while the lower shows the creek after improvements were completed in 1935. Such improvements increase the carrying capacity of a natural watercourse manyfold.

is now served with major drainage facilities which are considered satisfactory for the ultimate development of that institution.

In the Municipality of Fraser Mills, it is proposed that the major drainage works shall be of the closed conduit type.

North Shore Section. Storm water from most of the North Shore Section is now disposed of in the numerous natural watercourses in the area. Many of these traverse privately owned property and are considered an asset to them.

The continued use of these natural watercourses seems to be the most appropriate means of transportation and disposal of storm water in the North Shore Section. It is proposed, therefore, that the main drainage works should include the improvement and reconstruction of these existing open channels together with the enclosure of such channels under street crossings and through highly developed commercial or industrial property. In all cases, gravity flow in the channels to ultimate points of disposal is possible.

Richmond Section. The satisfactory collection and disposal of storm water in the Richmond Section is a complex problem. The existing drainage facilities include a network of open channels and ditches whose capacity and type are not such as will provide satisfactory drainage for the predicted future development. Increased population and industrial growth in the Richmond Section will require the construction of a more satisfactory drainage system. The elimination of the large open channels through highly developed residential and industrial districts, both as drainage and safety measures, will be required. It is proposed, therefore, as the ultimate solution of the storm drainage problems of Lulu Island and Sea Island, to enclose the existing open channels in conduits. The conduits should also be designed to lower the ground water table to a satisfactory elevation.

Future developments on Sea Island may be such that the entire island may be devoted to the airport and associated activities. In such an event, the provision of major drainage facilities might properly be undertaken by the authority responsible for the development of the island.

In those portions of the Richmond Section which may continue to be used solely for agricultural purposes, open channels will continue to be a reasonably satisfactory means of storm water collection. Such areas have not been included in the cost estimate for drainage facilities. Pumping will be required throughout the section to lift storm waters to Fraser River during periods of high water or high tide.

Cost of Major Drainage Facilities

Table 70 gives the estimated construction costs of the major drainage facilities considered for the Greater Vancouver Area from 1955 to 2000. The estimated sequence of construction, as presented in the table, was arrived at by consideration of the predicted development of the area. In most cases, it is believed that sanitary sewerage facilities

Table 70

Estimated Construction Costs of Major Drainage Facilities for the Greater Vancouver Area

Section	Construction Cost[a], Dollars						
	1955	1960	1965	1970	1975	1980	Total
Burrard Peninsula	1,632,000	2,629,000	2,340,000	2,130,000	660,000	473,000	9,864,000
North Shore	-	672,000	672,000	637,000	637,000	-	2,618,000
Richmond	2,025,000	2,025,000	2,025,000	2,025,000	-	-	8,100,000

[a] From Table 39; plus 25 percent for engineering, contingencies and administration.

Table 71

Computed Average Annual Costs of Major Drainage Facilities for the Greater Vancouver Area During Five Year Periods, 1955-2000

Section	Average Annual Cost, Thousand Dollars									
	1955 to 1960	1960 to 1965	1965 to 1970	1970 to 1975	1975 to 1980	1980 to 1985	1985 to 1990	1990 to 1995	1995 to 2000	45 Year Average
Burrard Peninsula:										
Bond redemption and interest[a]	104	272	422	558	600	526	358	208	72	
Maintenance and operation[b]	4	11	17	22	24	24	24	24	24	
Total annual cost	108	283	439	580	624	550	382	232	96	366
North Shore:										
Bond redemption and interest[a]	-	43	86	127	168	168	125	82	41	
Maintenance and operation[b]	-	2	3	5	7	7	7	7	7	
Total annual cost	-	45	89	132	175	175	132	89	48	110[c]
Richmond:										
Bond redemption and interest[a]	129	258	387	516	516	387	258	129		
Maintenance and operation[b]	5	10	15	20	20	20	20	20	20	
Total annual cost	134	268	402	536	536	407	278	149	20	303

[a] Payments on 25 year instalment debentures at 4 percent interest.
[b] 1/4 of one percent of construction cost. Does not include allowance for operation of pumping stations in Type C and D areas.
[c] Average for 40 years.

will be required earlier than will any major storm drainage facilities. Table 71 gives the calculated average annual costs for the proposed drainage facilities for the Greater Vancouver Area by five year periods from 1955 to 2000. Since the numbers, locations, and capacities of pumping stations cannot be determined until detailed design is undertaken, the annual costs for areas defined by Types C and D do not include maintenance and operation charges for pumping stations.

Chapter 18
Apportionment of Costs

Need for Equitable Apportionment Method

Preceding chapters in this report have presented the recommended projects for the sewerage and drainage of the Greater Vancouver Area which the Board of Engineers believes will most nearly fulfill the requirements of all portions of the area. In this chapter will be presented the methods of apportioning the construction, maintenance and operation costs of the proposed facilities which in the opinion of the Board of Engineers will be most equitable to all communities and citizens in the area.

The Greater Vancouver Area as dealt with in this report contains five cities, six municipalities and three unorganized communities. Because of geographic and topographic factors, the area has been divided into three sections, namely, the North Shore Section, the Burrard Peninsula Section and the Richmond Section. Each of the three sections was further subdivided into sewerage areas, the boundaries of which were determined primarily by economic considerations. The sewerage areas are not necessarily coextensive with political subdivisions and, in most cases, a single area contains more than one political entity. In addition, since the condition of the waters surrounding the Greater Vancouver Area is of concern to each of the communities in the area, satisfactory disposal of sanitary sewage is necessarily of importance to them all. Because of this interrelation of interest among the communities, the desirability of the formation of a single agency to be responsible for the provision and operation of sewerage works to serve the entire area is evident. Similarly, cooperative action among the communities in providing adequate drainage facilities will be of value by reason of the economies which will obtain through such action and because of the benefits which will accrue to the entire area through adequate drainage. For these reasons, formation of a single agency to be responsible for the construction and operation of the major sewerage and drainage works recommended in this report appears to be the most logical means available to the communities in the area. The principal recommended sewerage works are shown on Figure 96, which also shows the boundaries of the communities in the Greater Vancouver Area. Since their exact location and extent were not determined, proposed drainage facilities are not shown.

Once the establishment of a joint agency is assumed, the problem immediately arises as to how the costs of construction and operation of the works should be apportioned among the communities of the area. Any method of apportionment should be such that each community would be charged on the basis of benefit received. Any other method would obviously be unfair and would in all probability be unsuccessful. In addition, to obtain maximum value from the formation of a single joint agency, the apportionment should be so arranged that general obligation bonds could be issued by the agency.

Present Methods of Apportionment

The Vancouver and Districts Joint Sewerage and Drainage Board is presently administered under the Vancouver and Districts Joint Sewerage and Drainage Act. This Act is reproduced in Appendix II. The drainage areas under the jurisdiction of the present Board are shown in Figure 36, Chapter 10.

Distribution of the costs of the sewerage and drainage facilities constructed by the Board, together with all operation, maintenance and administration charges, is covered in Section 35 of the Act and is hereinafter briefly described.

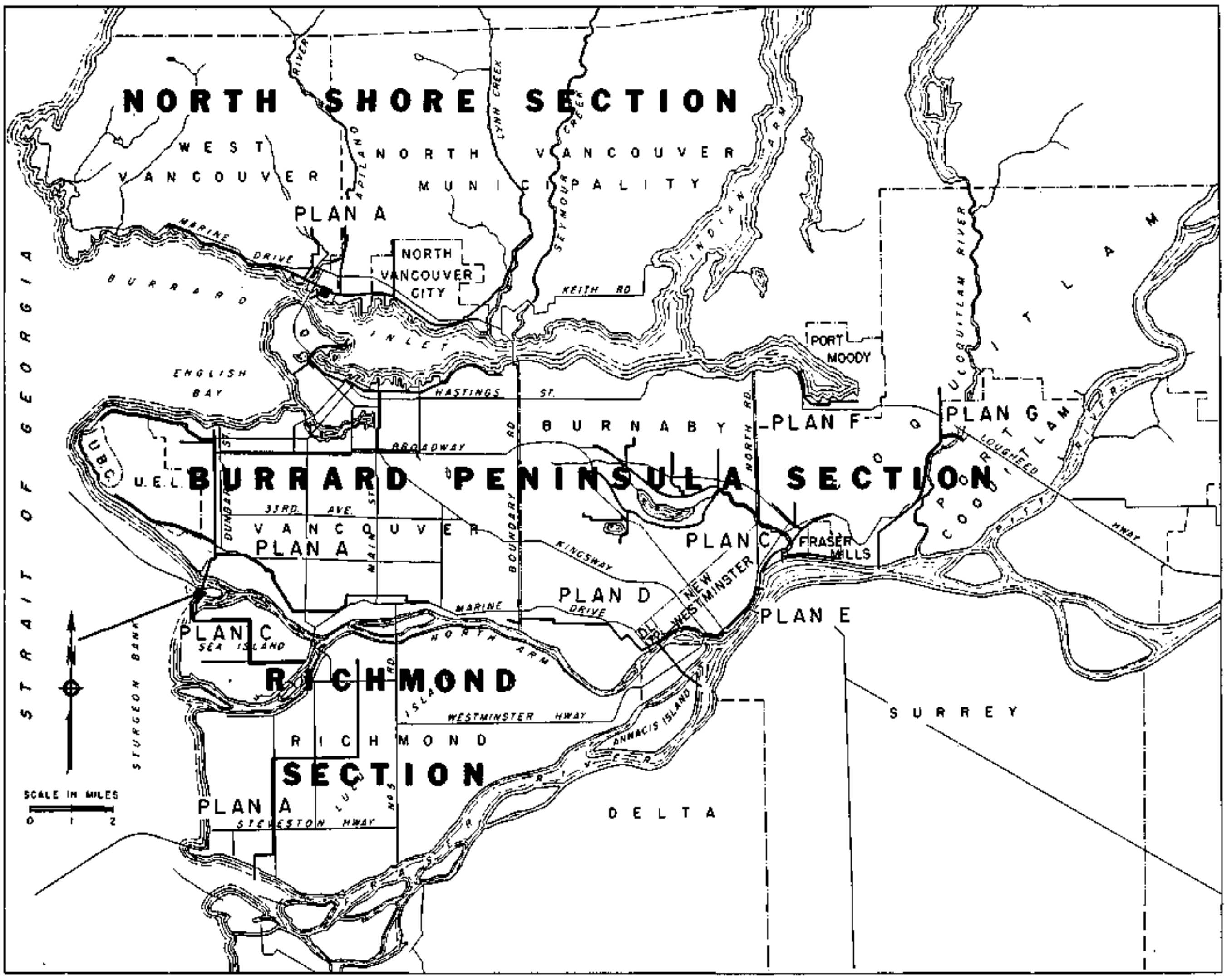


Figure 96. General Layout of Recommended Sewerage Plans for Greater Vancouver Area

The sewerage projects found to be the most economical and satisfactory for the Greater Vancouver Area involve the conveyance of sewage for final disposal to eight locations. Of these, five are tributary to Fraser River, two to Burrard Inlet, and one to Strait of Georgia. At all but two of these locations, conditions are such that sewage may be discharged to the receiving waters without treatment. Plans shown above for the Burrard Peninsula, North Shore and Richmond Sections, are described in Chapters 14, 15 and 16, respectively.

Administration Charges. The administration charges of the Board are distributed among all members in proportion to the total assessed valuation of the land of each member. The assessed valuation totals include exempt land but do not include either taxable or exempt improvements.

Operation and Maintenance Charges. The operation and maintenance charges for facilities in each drainage area are apportioned among the members in that drainage area in proportion to the total assessed valuation of the land of each member in the drainage area. The assessed valuation totals include exempt land but do not include either taxable or exempt improvements. If a drainage area lies wholly within one community, the entire operation and maintenance charges for that drainage area are borne by the community concerned.

Fixed Charges. Fixed charges for bond redemption and interest are divided into two portions. Thirty percent of the fixed charges is distributed among all the members in proportion to the total assessed valuation of the land of each member. Seventy percent of the fixed charges for each drainage area is apportioned among the members in that drainage area in proportion to the total assessed valuation of the land of each member in that drainage area. If a drainage area lies wholly within one community, the entire 70 percent of the fixed charges for bond redemption and interest for that drainage area is borne by the community concerned. As in the other apportionments, assessed valuation totals include exempt land but do not include either taxable or exempt improvements.

Recommended Revisions to Present Methods of Apportionment

The Board of Engineers believes that the most equitable method of apportioning the costs of the sewerage and drainage facilities proposed in this report is by the establishment of a new system apart from the existing operations of the Vancouver and Districts Joint Sewerage and Drainage Board. Since the regional agency proposed to administer the recommendations of this report will include the members of the present Board, it will be necessary to maintain separate accounts and methods of apportionment until such time as the bonded indebtedness of the present agency is completely retired.

At the time of formation of a new agency, administration, operation, maintenance and capital construction would cease to be performed by the existing agency. However, the boundaries, statutory limitations, and legal rights and obligations of the existing Board would be preserved until such time as its bonded indebtedness is completely extinguished. The Vancouver and Districts Joint Sewerage and Drainage Act could then be repealed and the assets transferred to the new agency.

As has been discussed in Chapter 14, the Vancouver Sewerage Area in the Burrard Peninsula Section does not include that portion of the Municipality of Burnaby that is presently included in the Copley Drainage Area of the existing Sewerage and Drainage Board. Rather, in the interests of ultimate economy, this portion has been included in the Fraser Sewerage Area and would not be tributary to the Copley trunk sewer. Because of this, payments made by the Municipality of Burnaby after the formation of the new joint agency toward retirement of bonds used to finance the Copley sewer should be calculated on the basis of the amended area, rather than on the present basis.

With the exception of the Copley Area, present methods of apportionment of the costs of the Vancouver and Districts Joint Sewerage and Drainage Board should be continued until such time as its bonded indebtedness is retired.

Possible Methods of Future Apportionment

The Board of Engineers believes that the fairest available method of financing the construction of the various works proposed in this report is by the issuance of general obligation bonds. These bonds have been assumed to be of the 25 year instalment debenture type bearing a four percent interest rate. The fixed charges of bond redemption and interest for the retirement of these bonds will be assessed in some manner against the various communities in the area. Each community will further assess these charges against its taxpayers in any appropriate manner.

The proportioning of costs among the communities in the Greater Vancouver Area may be accomplished in numerous ways. It is the opinion of the Board of Engineers, however, that the basic concept of the present method of apportionment is logical and desirable. Under this method, a small portion of the total cost of each particular project is paid by all members of the agency and by other serviced areas, while the remainder, and greater portion, is paid by those receiving direct benefits.

The total assessed valuation of both land and improvements is a better indication of the worth and development of an area than the total assessed valuation of land alone. All calculations, therefore, have been made on the basis of total assessed valuation of land and improvements within a sewerage area or community except as noted below.

The Municipality of Coquitlam contains large government institutions that accounted for over fifty percent of its total assessed valuation of land and improvements in the 1952 fiscal year. These institutions, which consist of a mental hospital, industrial home, and a home for the aged, do not contribute directly to the tax revenues of the municipality. They are supported entirely by provincial government grants, but certain of their services and utilities are supplied by Coquitlam. It was considered that the inclusion of the assessed valuation of the land and improvements of these institutions as part of the assessed valuation of the municipality would place an unfair burden upon Coquitlam. The institutions, therefore, have been omitted in the calculations of cost of apportionment.

In addition, it is proposed that the University of British Columbia be excluded from the calculations on apportionment of costs. The university is a provincial government institution contained entirely within its own political boundaries. The organization is supported by provincial grants, endowments and fees.

The Board of Engineers recommends that the regional agency in the Greater Vancouver Area enter into agreements with the federal or provincial government responsible for administration of non-taxable institutions for the payment of charges arising out of any institution's participation in any sewerage or drainage facility. Such charges should be computed in general conformity with the cost apportionment principles outlined in this report.

In the previous discussion on present methods of apportionment, it has been noted that, under the Vancouver and Districts Joint Sewerage and Drainage Act, separate methods are used to apportion administration costs, operation and maintenance costs, and bond redemption and interest costs among its members. The Board of Engineers proposes that in the apportionment of costs for facilities recommended in this report, costs, regardless of their nature, be distributed by one method only.

Past and Present Assessed Valuations. A study of the financial statements of the City of Vancouver for the period 1881-1951 indicates that the average per capita total assessed valuation of land and improvements in the city has been remarkably uniform and is about $1,300. The period of available records of other communities is much shorter than that of the City of Vancouver, but the per capita assessed valuations of the surrounding communities agree fairly well with that of the city.

Predicted Assessed Valuations. In view of the remarkably uniform average per capita assessed valuation, a sum of $1,300 per capita has been used to estimate future assessed valuations. This figure, when multiplied by the predicted population, will give the predicted assessed valuation for any community in any given year. While future changes may increase or decrease the per capita value, it is probable that the relative distribution of assessed valuation in the communities of the Greater Vancouver Area will remain the same as herein predicted.

Table 72 presents the predicted future average total assessed valuations of land and improvements for the communities in the Greater Vancouver Area for five year intervals between 1955 and 2000. Table 73 gives the relative percent of the predicted future total assessed valuation of each community. Predicted populations are contained in Chapter 9 of the report.

Distribution of Costs. The general method of apportionment of administration costs, operation and maintenance costs, and bond redemption and interest costs believed to be the most equitable for all communities concerned is as follows:

1. A percentage of the total cost to be divided among all communities in the same proportion as their respective assessed valuation bears to the total assessed valuation of all communities.

2. The remaining percentage of the total cost of work serving each sewerage or drainage area to be divided among the communities within that sewerage or drainage area. In the event that there are two or more communities within the sewerage or drainage area the cost would

Table 72

Predicted Assessed Valuations of Communities in the Greater Vancouver Area

Community	Assessed Valuations in Millions of Dollars								
	1955 to 1960	1960 to 1965	1965 to 1970	1970 to 1975	1975 to 1980	1980 to 1985	1985 to 1990	1990 to 1995	1995 to 2000
Cities:									
New Westminster	46.0	48.5	51.0	53.3	55.5	57.5	60.0	62.0	64.0
North Vancouver	22.0	28.0	33.0	38.0	42.0	45.0	47.0	49.0	50.0
Port Coquitlam	6.5	10.0	15.0	22.7	32.5	45.5	62.0	73.0	81.0
Port Moody	2.7	3.5	4.3	5.2	6.1	6.9	7.8	8.6	9.4
Vancouver	550.0	580.0	605.0	630.0	650.0	670.0	690.0	705.0	720.0
Municipalities:									
Burnaby	88.0	117.0	150.0	193.0	235.0	272.0	300.0	320.0	335.0
Coquitlam	15.5	28.0	44.0	61.5	77.0	90.0	102.5	115.0	125.0
Fraser Mills	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
North Vancouver	26.0	35.0	47.0	61.0	75.0	86.0	96.0	105.0	112.0
Richmond	30.0	42.0	56.2	74.0	95.0	117.5	142.0	165.0	182.0
West Vancouver	32.0	40.0	49.0	58.0	67.0	74.0	79.0	83.0	85.0
Unorganized:									
District Lot 172	2.1	2.5	2.9	3.2	3.4	3.6	3.7	3.8	3.8
University Endowment Lands	7.9	11.8	17.5	25.0	32.0	36.5	39.6	41.7	42.7
Total	830.5	948.1	1,076.7	1,226.7	1,372.3	1,506.3	1,631.4	1,732.9	1,811.7

be apportioned in the same proportion as the assessed valuation of each community within the sewerage or drainage area bears to the total assessed valuation of the entire sewerage or drainage area.

Costs to each community for the works proposed in this report were investigated using three different percentage distributions. The first provides that 30 percent be distributed among all members and that 70 percent be distributed among the members directly benefiting. The second provides that the distribution be 20-80, and the third for a

Table 73

Relative Assessed Valuations of Communities in the Greater Vancouver Area

Community	Percentage of Total Assessed Valuation of the Greater Vancouver Area								
	1955 to 1960	1960 to 1965	1965 to 1970	1970 to 1975	1975 to 1980	1980 to 1985	1985 to 1990	1990 to 1995	1995 to 2000
Cities:									
New Westminster	5.52	5.11	4.74	4.35	4.05	3.82	3.68	3.58	3.53
North Vancouver	2.65	2.96	3.06	3.10	3.06	2.99	2.88	2.83	2.76
Port Coquitlam	0.78	1.05	1.40	1.85	2.37	3.02	3.80	4.21	4.47
Port Moody	0.32	0.37	0.40	0.42	0.44	0.45	0.48	0.50	0.52
Vancouver	66.25	61.26	56.19	51.33	47.35	44.50	42.27	40.67	39.73
Municipalities:									
Burnaby	10.60	12.35	13.95	15.75	17.15	18.04	18.40	18.50	18.50
Coquitlam	1.87	2.96	4.08	5.01	5.61	5.97	6.28	6.64	6.90
Fraser Mills	0.22	0.19	0.17	0.15	0.13	0.12	0.11	0.10	0.10
North Vancouver	3.13	3.59	4.36	4.97	5.47	5.71	5.88	6.05	6.18
Richmond	3.61	4.43	5.21	6.04	6.91	7.80	8.71	9.51	10.05
West Vancouver	3.85	4.22	4.55	4.73	4.88	4.91	4.85	4.79	4.69
Unorganized:									
District Lot 172	0.25	0.26	0.27	0.26	0.25	0.24	0.23	0.22	0.21
University Endowment Lands	0.95	1.25	1.62	2.04	2.33	2.42	2.43	2.40	2.36
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table 74

Bond Redemption and Interest Payments for Sewerage Facilities, 1955-2000, 30-70 Method of Apportionment

Community	Bond Redemption and Interest Payments in Thousands of Dollars									
	1955 to 1960	1960 to 1965	1965 to 1970	1970 to 1975	1975 to 1980	1980 to 1985	1985 to 1990	1990 to 1995	1995 to 2000	45 Year Average
Cities:										
New Westminster	21	51	56	80	76	59	34	26	1	45
North Vancouver	7	40	90	92	89	77	55	12	7	52
Port Coquitlam	2	5	30	39	46	45	44	11	2	25
Port Moody	1	9	10	10	10	9	2	1	1	6
Vancouver	688	997	1,270	1,631	1,630	997	711	433	50	930
Municipalities:										
Burnaby	138	244	286	369	393	245	126	86	8	210
Coquitlam	18	41	96	117	123	87	61	18	3	63
Fraser Mills	4	5	4	4	3	1	1	1	1	3
North Vancouver	9	36	86	102	111	100	76	20	11	61
Richmond	32	87	144	160	173	137	82	23	7	94
West Vancouver	11	47	104	112	114	100	72	18	10	65
Unorganized:										
District Lot 172	1	4	5	7	6	5	2	1	1	4
University Endowment Lands	12	20	37	65	81	54	41	25	3	38
Total	944	1,586	2,218	2,788	2,855	1,916	1,307	675	105	1,600

10-90 division. Table 74 shows the apportionment of costs on a 30-70 basis of bond redemption and interest charges for sewerage facilities between 1955 and 2000 for each of the communities. Each member's share of the 30 percent was calculated by consideration of the assessed valuation figures in Table 73. The division of the 70 percent was accomplished by considering separately each project shown on Figure 96, determining the relative total assessed valuations of the portions of each community contributing directly to that project, and applying these proportions to the cost of the project.

In a similar manner, calculations were made of the apportionment of sewerage costs on a 20-80 and 10-90 percent basis of division. Table 75 shows a comparison of the total bond redemption and interest payments which would be made by each community between 1955 and 2000 on a 30-70, 30-80 and 10-90 basis.

Recommended Method of Future Apportionment

As shown in Table 75, total bond redemption and interest payments by any one community are approximately the same regardless of the basis of division of the costs. Consideration of the assumptions on which the cost analyses are based, including predictions of future population, economy and development,

Table 75

Total Bond Redemption and Interest Payments for Sewerage Facilities, 1955-2000, 30-70, 20-80, and 10-90 Methods of Apportionment

Community	Total Bond Redemption and Interest Payments in Thousands of Dollars		
	30-70	20-80	10-90
Cities:			
New Westminster	2,020	1,870	1,725
North Vancouver	2,345	2,375	2,410
Port Coquitlam	1,120	1,050	980
Port Moody	265	260	255
Vancouver	42,035	42,760	43,470
Municipalities:			
Burnaby	9,475	9,200	8,925
Coquitlam	2,820	2,730	2,640
Fraser Mills	120	120	120
North Vancouver	2,755	2,645	2,540
Richmond	4,225	4,175	4,125
West Vancouver	2,940	2,900	2,860
Unorganized:			
District Lot 172	160	155	150
University Endowment Lands	1,690	1,730	1,770
Total	71,970	71,970	71,970

leads the Board of Engineers to believe that factors other than relative costs to each community should govern the selection of the basis to be used for cost apportionments.

After a review of all controlling conditions, including the success of the present method of apportionment and the desirability of arranging the financing to strengthen the partisanship of the regional board, the Board of Engineers concludes that the adoption of a 30-70 basis of division is the fairest and best method of cost apportionment. The adoption of this principle in future apportionment is therefore recommended.

The average annual cost to each community during five year periods between 1955 and 2000 for sewerage facilities is presented in Table 76. Costs for drainage facilities would be apportioned in a similar manner. Because individual drainage areas were not delineated in detail as a part of this survey, the assessed valuation of the portion of each community which will lie within each drainage area could not be determined. However, to obtain an approximation of the cost of drainage facilities to each community, the total cost has been apportioned in the following manner: 30 percent of the total annual cost was divided among the communities within the Greater Vancouver Area in proportion to their relative assessed valuations and the remaining 70 percent divided in proportion to the estimated cost of drainage facilities within each community. The values thus obtained are given in Table 77.

Costs to Each Community

Table 78 presents a summary of the total annual costs for sewerage and drainage by five year periods from 1955 to 2000 for each of the communities. The costs include bond redemption, bond interest, and all operation and maintenance charges, and have been calculated on a 30-70 basis of division. Table 78 also gives the predicted populations, assessed valuations, and tax rates in mills per dollar of assessed valuation for the Greater Vancouver Area as a whole and for each of the 13 communities in the area. The average tax rate required to finance construction, maintenance and operation of the recommended sewerage and drainage facilities for the entire area is estimated to vary from 1.6 mills for the first five year period, 1955-1960, to 3.6 mills for the five year period 1970-1975, to 0.4 mills for the five year period 1955-2000. The average tax rate for this 45 year period, 1955-2000, is calculated to be 2.0 mills.

Tax rates presented in this report have been obtained by dividing the calculated annual costs for each community by its estimated total assessed valuation of land and improvements and are given in mills per dollar. This has provided a uniform basis for the comparison of tax rates between communities. Unfortunately, however, the existing basis of assessment in individual communities is not uniform throughout the Greater Vancouver Area. The tax rates to be paid by property owners in each community, therefore, will require adjustments to conform to the basis of assessment at present employed by individual communities. It is not considered to be within the scope of this report, or of the agency proposed to administer the recommendations of this report, to attempt to establish a common basis of assessment for the communities.

In the discussion of cost apportionment of the proposed facilities, the unorganized communities of University Endowment Lands and District Lot 172 have been treated as if they were to be members of the regional agency. As a practical matter, these communities may not become members of the regional agency, but any agreement between the agency and the responsible governmental body should provide for charges to the communities as if they were members of the agency.

City of New Westminster. Figure 97 is a graphical representation of the predicted figures of population, assessed valuation, and the calculated annual costs and tax rates in mills presented in Table 78 for the City of New Westminster during the period 1955-2000. As therein shown, the tax rate required to finance the City of

Table 76

Computed Average Annual Payments for Sewerage Facilities During Five Year Periods, 1955-2000

Community	Average Annual Payments in Thousands of Dollars									
	1955 to 1960	1960 to 1965	1965 to 1970	1970 to 1975	1975 to 1980	1980 to 1985	1985 to 1990	1990 to 1995	1995 to 2000	45 Year Average
CITIES:										
New Westminster										
Bond redemption and interest	21	51	56	80	76	59	34	26	1	
Maintenance and operation	2	5	7	11	11	10	10	10	10	
	23	56	63	91	87	69	44	36	11	53
North Vancouver										
Bond redemption and interest	7	40	90	92	89	77	55	12	7	
Maintenance and operation	1	7	15	16	17	17	17	17	17	
	8	47	105	108	106	94	72	29	24	65
Port Coquitlam										
Bond redemption and interest	2	5	30	39	46	45	44	11	2	
Maintenance and operation	1	1	3	5	6	8	9	10	10	
	3	6	33	44	52	53	53	21	12	26
Port Moody										
Bond redemption and interest	1	9	10	10	10	9	2	1	1	
Maintenance and operation	1	1	1	1	1	1	1	1	1	
	2	10	11	11	11	10	3	2	2	7
Vancouver										
Bond redemption and interest	688	997	1,270	1,631	1,630	997	711	433	50	
Maintenance and operation	87	103	188	218	216	215	216	217	218	
	775	1,100	1,458	1,849	1,846	1,212	927	650	268	1,121
MUNICIPALITIES:										
Burnaby										
Bond redemption and interest	138	244	286	369	393	245	126	86	8	
Maintenance and operation	8	15	24	39	43	46	49	51	51	
	146	259	310	408	436	291	175	137	59	247
Coquitlam										
Bond redemption and interest	18	41	96	117	123	87	61	18	3	
Maintenance and operation	1	3	9	12	14	14	15	16	18	
	19	44	105	129	137	101	76	34	21	74
Fraser Mills										
Bond redemption and interest	4	5	4	4	3	1	1	1	1	
Maintenance and operation	1	1	1	1	1	1	1	1	1	
	5	6	5	5	4	2	2	2	2	4
North Vancouver										
Bond redemption and interest	9	36	86	102	111	100	76	20	11	
Maintenance and operation	1	6	14	17	20	23	24	25	26	
	10	42	100	119	131	123	100	45	37	79
Richmond										
Bond redemption and interest	32	87	144	160	173	137	82	23	7	
Maintenance and operation	2	7	17	21	25	28	31	34	37	
	34	94	161	181	198	165	113	57	44	116
West Vancouver										
Bond redemption and interest	11	47	104	112	114	100	72	18	10	
Maintenance and operation	1	8	17	20	21	23	23	23	23	
	12	55	121	132	135	123	95	41	33	83
UNORGANIZED:										
District Lot 172										
Bond redemption and interest	1	4	5	7	6	5	2	1	1	
Maintenance and operation	1	1	1	1	1	1	1	1	1	
	2	5	6	8	7	6	3	2	2	5
University Endowment Lands										
Bond redemption and interest	12	20	37	65	81	54	41	25	3	
Maintenance and operation	1	2	6	9	11	12	12	13	13	
	13	22	43	74	92	66	53	38	16	46

Table 77

Computed Average Annual Payments for Drainage Facilities During Five Year Periods, 1955-2000

Community	Average Annual Payments in Thousands of Dollars									
	1955 to 1960	1960 to 1965	1965 to 1970	1970 to 1975	1975 to 1980	1980 to 1985	1985 to 1990	1990 to 1995	1995 to 2000	45 Year Average
CITIES:										
New Westminster										
Bond redemption and interest	9	16	23	29	27	21	14	7	1	
Maintenance and operation	1	1	1	1	1	1	1	1	1	
	10	17	24	30	28	22	15	8	2	18
North Vancouver										
Bond redemption and interest	2	6	11	14	15	13	8	4	3	
Maintenance and operation	1	1	1	1	1	1	1	1	1	
	3	7	12	15	16	14	9	5	4	9
Port Coquitlam										
Bond redemption and interest	1	10	19	30	32	33	24	13	2	
Maintenance and operation	1	1	1	1	1	1	1	1	1	
	2	11	20	31	33	34	25	14	3	19
Port Moody										
Bond redemption and interest	1	10	19	20	20	20	10	1	1	
Maintenance and operation	1	1	1	1	1	1	1	1	1	
	2	11	20	21	21	21	11	2	2	12
Vancouver										
Bond redemption and interest	64	140	186	220	217	162	94	51	13	
Maintenance and operation	2	6	7	9	9	8	8	8	7	
	66	146	193	229	226	170	102	59	20	135
MUNICIPALITIES:										
Burnaby										
Bond redemption and interest	61	129	199	272	282	220	149	77	6	
Maintenance and operation	2	5	8	11	11	11	11	11	11	
	63	134	207	283	293	231	160	88	17	164
Coquitlam										
Bond redemption and interest	1	26	53	81	106	124	98	71	44	
Maintenance and operation	1	1	2	3	4	4	4	5	5	
	2	27	55	84	110	128	102	76	49	70
Fraser Mills										
Bond redemption and interest	1	1	5	9	9	9	9	9	1	
Maintenance and operation	1	1	1	1	1	1	1	1	1	
	2	2	6	10	10	10	10	10	2	7
North Vancouver										
Bond redemption and interest	2	24	47	70	91	89	66	43	20	
Maintenance and operation	1	1	1	2	3	4	4	4	4	
	3	25	48	72	94	93	70	47	24	53
Richmond										
Bond redemption and interest	90	183	276	372	377	288	194	99	4	
Maintenance and operation	4	7	11	13	14	15	15	15	15	
	94	190	287	385	391	303	209	114	19	221
West Vancouver										
Bond redemption and interest	3	18	35	51	64	61	44	28	13	
Maintenance and operation	1	1	2	3	3	3	3	3	3	
	4	19	37	54	67	64	47	31	16	38
UNORGANIZED:										
District Lot 172										
Bond redemption and interest	1	1	1	1	1	1	1	1	1	
Maintenance and operation	1	1	1	1	1	1	1	1	1	
	2	2	2	2	2	2	2	2	2	2
University Endowment Lands										
Bond redemption and interest	1	10	21	33	43	41	31	20	9	
Maintenance and operation	1	1	1	1	1	1	1	2	2	
	2	11	22	34	44	42	32	22	11	25

Table 78

Predicted Population, Assessed Valuation, and Estimated Annual Cost and Tax Rate for Communities in the Greater Vancouver Area During Five Year Periods, 1955-2000

Community	1955 to 1960	1960 to 1965	1965 to 1970	1970 to 1975	1975 to 1980	1980 to 1985	1985 to 1990	1990 to 1995	1995 to 2000	45 Year Average
CITIES:										
New Westminster										
Total population in thousands	33	36	39	41	43	45	46	48	49	42
Assessed valuation, millions of dollars	46	48	51	53	56	58	60	62	64	55
Annual cost, thousands of dollars	33	73	87	121	115	91	59	44	13	71
Tax rate, mills	0.7	1.5	1.7	2.3	2.1	1.6	1.0	0.7	0.2	1.3
North Vancouver										
Total population in thousands	20	23	26	29	32	34	36	38	38	31
Assessed valuation, millions of dollars	22	28	33	38	42	45	47	49	50	39
Annual cost, thousands of dollars	11	54	117	123	122	108	81	34	28	75
Tax rate, mills	0.5	1.9	3.5	3.2	2.9	2.4	1.7	0.7	0.6	1.9
Port Coquitlam										
Total population in thousands	6	8	12	17	25	37	48	56	62	30
Assessed valuation, millions of dollars	6	10	15	23	32	46	62	73	81	39
Annual cost, thousands of dollars	5	17	53	75	85	87	78	35	15	50
Tax rate, mills	0.8	1.7	3.5	3.2	2.6	1.9	1.3	0.5	0.2	1.3
Port Moody										
Total population in thousands	3	3	4	4	5	5	6	6	7	5
Assessed valuation, millions of dollars	3	4	4	5	6	7	8	9	9	6
Annual cost, thousands of dollars	4	21	31	32	32	31	14	4	4	19
Tax rate, mills	1.3	5.2	7.8	6.4	5.3	4.4	1.8	0.4	0.4	3.2
Vancouver										
Total population in thousands	400	430	455	480	500	518	533	545	556	491
Assessed valuation, millions of dollars	550	580	605	630	650	670	690	705	720	644
Annual cost, thousands of dollars	841	1246	1651	2078	2072	1382	1029	709	288	1255
Tax rate, mills	1.5	2.1	2.7	3.3	3.2	2.1	1.5	1.0	0.4	2.0
MUNICIPALITIES:										
Burnaby										
Total population in thousands	85	110	135	165	190	215	240	255	263	184
Assessed valuation, millions of dollars	88	117	150	193	235	272	300	320	335	223
Annual cost, thousands of dollars	209	393	517	691	729	522	335	225	76	411
Tax rate, mills	2.4	3.4	3.5	3.6	3.1	1.9	1.1	0.7	0.2	1.8
Coquitlam										
Total population in thousands	23	30	38	48	58	70	80	90	98	59
Assessed valuation, millions of dollars	16	28	44	62	77	90	102	115	125	73
Annual cost, thousands of dollars	21	71	160	213	247	229	178	110	70	144
Tax rate, mills	1.3	2.5	3.6	3.4	3.2	2.5	1.7	1.0	0.6	2.0
Fraser Mills										
Total population in thousands	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Assessed valuation, millions of dollars	2	2	2	2	2	2	2	2	2	2
Annual cost, thousands of dollars	7	8	11	15	14	12	12	12	4	9
Tax rate, mills	3.5	4.0	5.5	7.5	7.0	6.0	6.0	6.0	2.0	4.5
North Vancouver										
Total population in thousands	23	30	38	48	58	68	75	80	84	56
Assessed valuation, millions of dollars	26	35	47	61	75	86	96	105	112	71
Annual cost, thousands of dollars	13	67	148	191	225	216	170	92	61	131
Tax rate, mills	0.5	1.9	3.1	3.1	3.0	2.5	1.8	0.9	0.5	1.8
Richmond										
Total population in thousands	28	37	48	61	76	93	110	130	140	80
Assessed valuation, millions of dollars	30	42	56	74	95	118	142	165	182	100
Annual cost, thousands of dollars	128	284	448	566	589	468	322	171	63	338
Tax rate, mills	4.3	6.8	8.0	7.7	6.2	4.0	2.3	1.0	0.3	3.4

Table 78 - Continued

Community	1955 to 1960	1960 to 1965	1965 to 1970	1970 to 1975	1975 to 1980	1980 to 1985	1985 to 1990	1990 to 1995	1995 to 2000	45 Year Average
West Vancouver										
Total population in thousands	19	25	32	40	46	50	53	55	57	42
Assessed valuation, millions of dollars	32	40	49	58	67	74	79	83	85	63
Annual cost, thousands of dollars	16	74	158	186	202	187	142	72	49	120
Tax rate, mills	0.5	1.8	3.2	3.2	3.0	2.5	1.8	0.9	0.6	1.9
UNORGANIZED:										
District Lot 172										
Total population in thousands	2	2	2	3	3	3	3	3	3	3
Assessed valuation, millions of dollars	2	2	3	3	3	4	4	4	4	3
Annual cost, thousands of dollars	4	7	8	10	9	8	5	4	4	6
Tax rate, mills	2.0	3.5	2.7	3.3	3.0	2.0	1.2	1.0	1.0	2.0
University Endowment Lands										
Total population in thousands	4	7	11	17	21	24	27	28	29	19
Assessed valuation, millions of dollars	8	12	18	25	32	36	40	42	43	28
Annual cost, thousands of dollars	15	33	65	108	136	108	85	60	27	71
Tax rate, mills	1.9	2.7	3.6	4.3	4.2	3.0	2.1	1.4	0.6	2.5
GREATER VANCOUVER AREA										
Total population in thousands	646	741	840	953	1057	1162	1257	1334	1386	1044
Assessed valuation, millions of dollars	831	948	1077	1227	1372	1508	1632	1732	1812	1349
Annual cost, thousands of dollars	1307	2348	3454	4409	4577	3449	2510	1572	702	2703
Tax rate, mills	1.6	2.5	3.2	3.6	3.3	2.3	1.5	0.9	0.4	2.0

New Westminster's share of the construction, maintenance and operation of the recommended sewerage and drainage facilities is estimated to vary from 2.3 mills for the five year period 1970-1975, to 0.2 mills for the five year period 1995-2000. The average tax rate for the period 1955-2000 is estimated to be 1.3 mills.

City of North Vancouver. Figure 98 is a graphical representation of the predicted figures of population, assessed valuation, and the calculated annual costs and tax rates in mills presented in Table 78 for the City of North Vancouver during the period 1955-2000. As therein shown, the tax rate required to finance the City of North Vancouver's share of the construction, maintenance and operation of the recommended sewerage and drainage facilities is estimated to vary from 3.5 mills for the five year period 1965-1970, to 0.6 mills for the five year period 1995-2000. The average tax rate for the period 1955-2000 is estimated to be 1.9 mills.

City of Port Coquitlam. Figure 99 is a graphical representation of the predicted figures of population, assessed valuation, and the calculated annual costs and tax rates in mills presented in Table 78 for the City of Port Coquitlam during the period 1955-2000. As therein shown, the tax rate required to finance the City of Port Coquitlam's share of the construction, maintenance and operation of the recommended sewerage and drainage facilities is estimated to vary from 3.5 mills for the five year period 1965-1970, to 0.2 mills for the five year period 1995-2000. The average tax rate for the period 1955-2000 is estimated to be 1.3 mills.

City of Port Moody. Figure 100 is a graphical representation of the predicted figures of population, assessed valuation, and the calculated annual costs and tax rates in mills presented in Table 78 for the City of Port Moody during the period 1955-2000. As therein shown, the tax rate required to finance the City of Port Moody's share of the construction, maintenance and operation of the recommended sewerage and drainage facilities is estimated to vary from 7.8 mills for the five year period 1965-1970, to 0.4 mills for the five year period 1995-2000. The average tax rate for the period 1955-2000 is estimated to be 3.2 mills.

City of Vancouver. Figure 101 is a graphical representation of the predicted

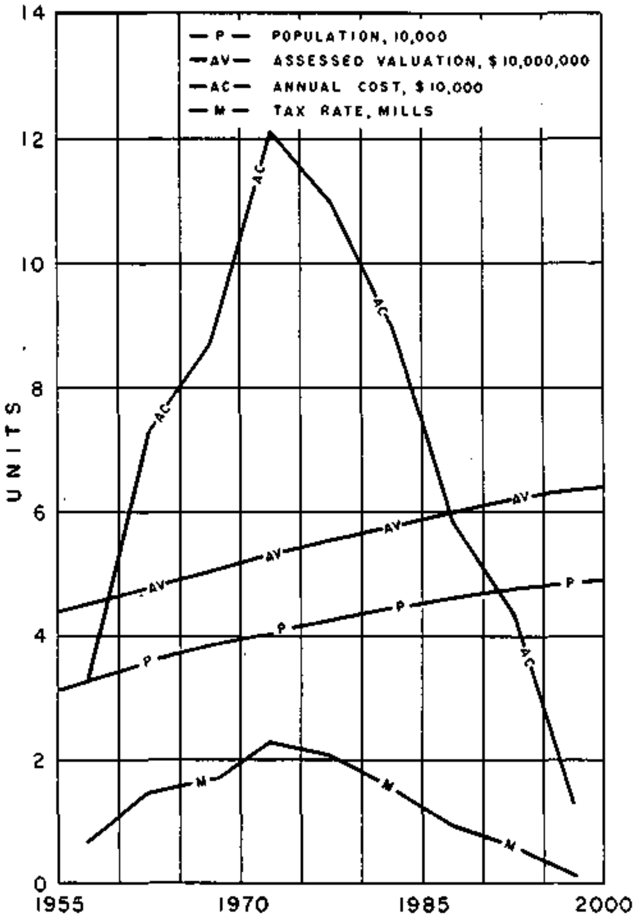


Figure 97. City of New Westminster

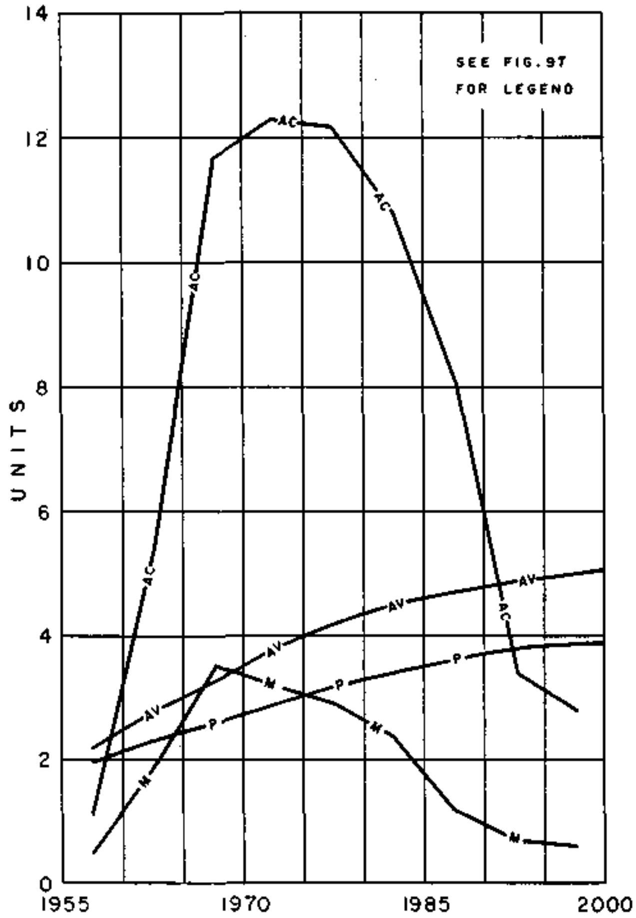


Figure 98. City of North Vancouver

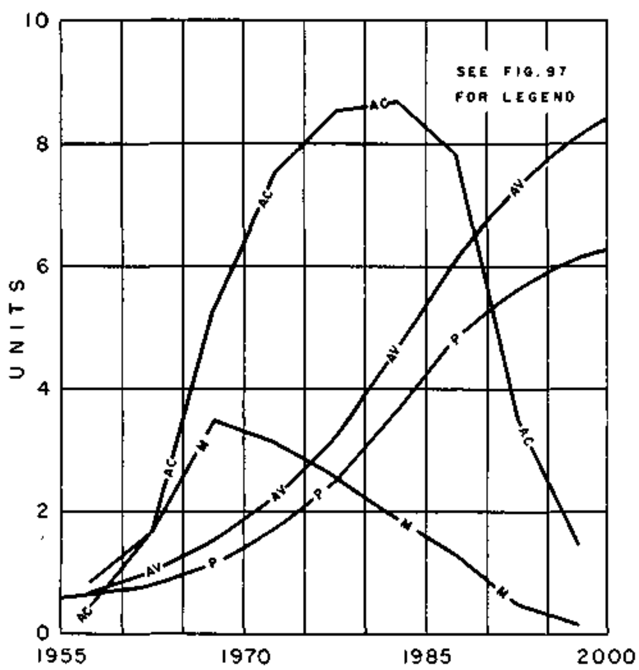


Figure 99. City of Port Coquitlam

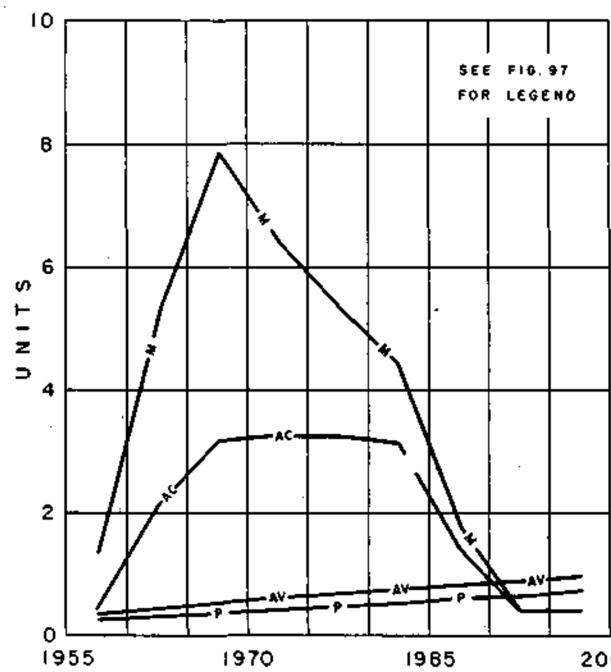


Figure 100. City of Port Moody

The above graphs illustrate the predicted populations and assessed valuations and estimated average annual costs and tax rates for sewerage and drainage facilities during the 45 year period 1955-2000.

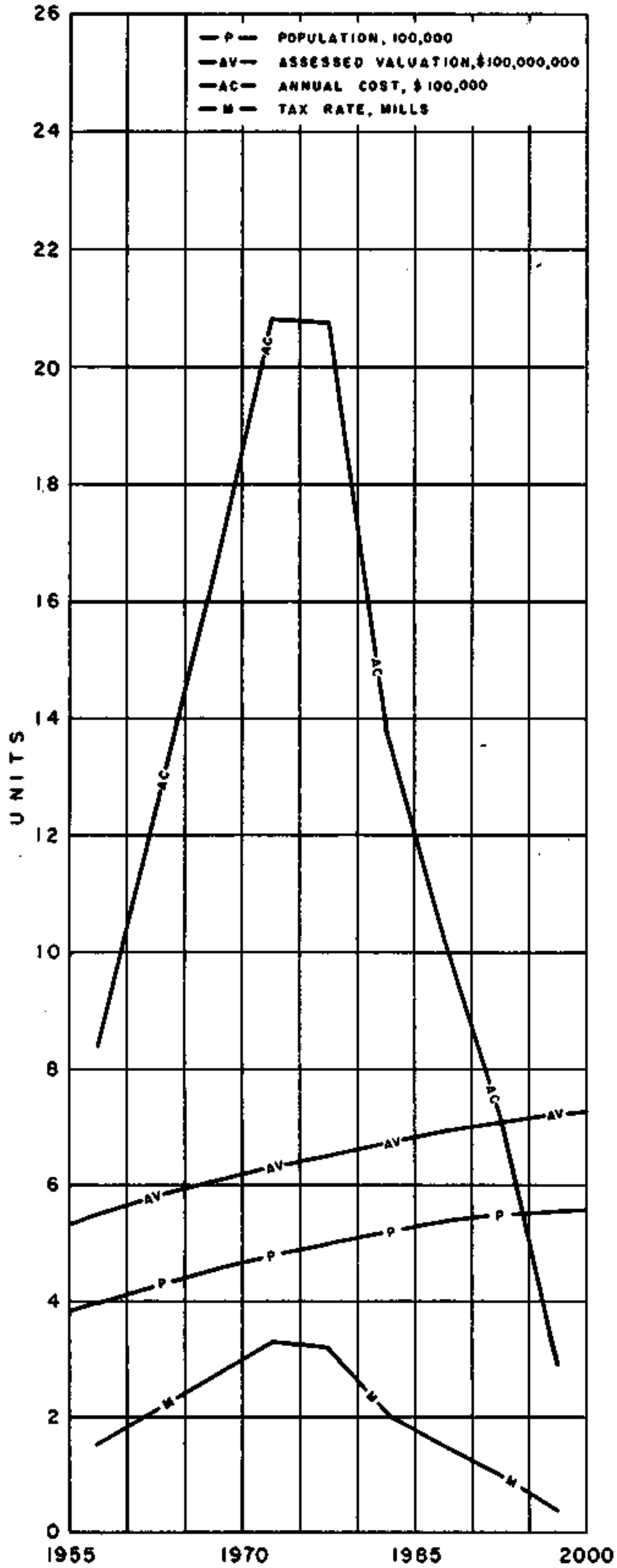


Figure 101. City of Vancouver

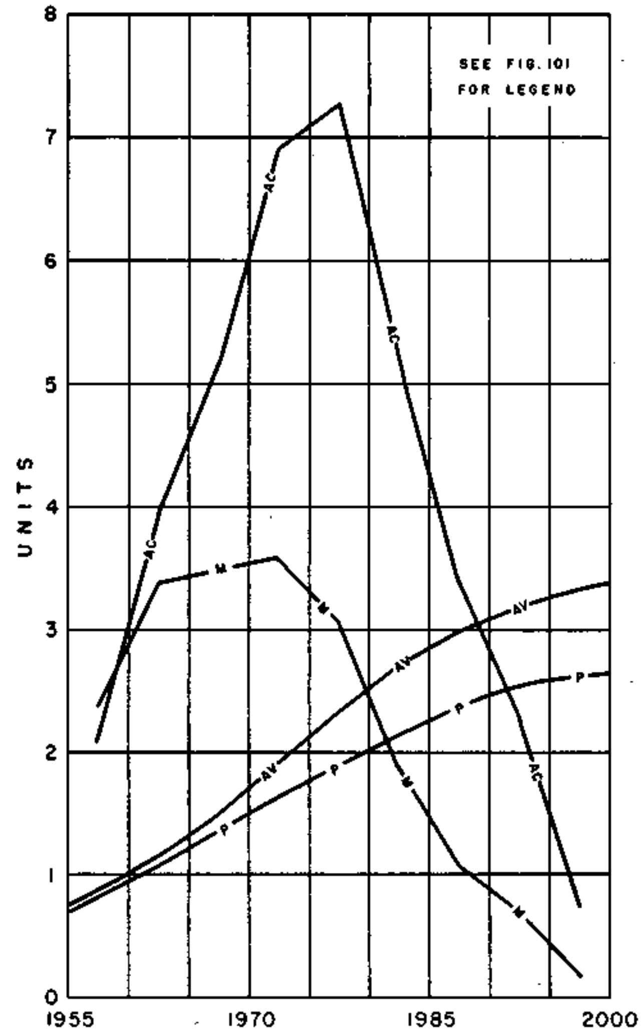


Figure 102. Municipality of Burnaby

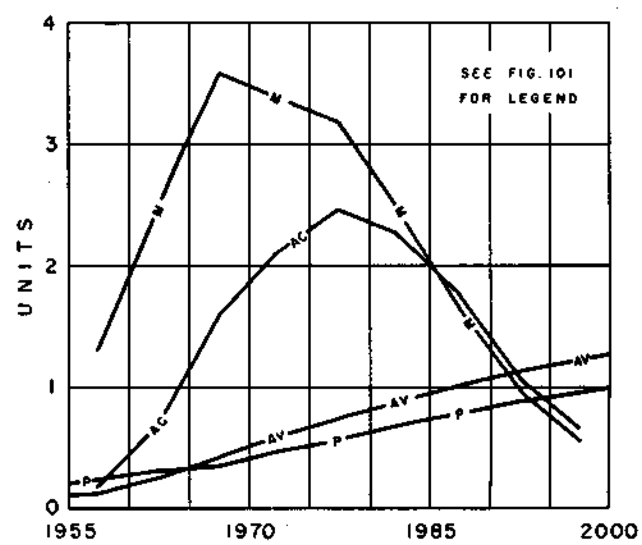


Figure 103. Municipality of Coquitlam

The above graphs illustrate the predicted populations and assessed valuations and estimated average annual costs and tax rates for sewerage and drainage facilities during the 45 year period 1955-2000.

figures of population, assessed valuation, and the calculated annual costs and tax rates in mills presented in Table 78 for the City of Vancouver during the period 1955-2000. As therein shown, the tax rate required to finance the City of Vancouver's share of the construction, maintenance and operation of the recommended sewerage and drainage facilities is estimated to vary from 3.3 mills for the five year period 1970-1975, to 0.4 mills for the five year period 1995-2000. The average tax rate for the period 1955-2000 is estimated to be 2.0 mills.

Municipality of Burnaby. Figure 102 is a graphical representation of the predicted figures of population, assessed valuation, and the calculated annual costs and tax rates in mills presented in Table 78 for the Municipality of Burnaby during the period 1955-2000. As therein shown, the tax rate required to finance the Municipality of Burnaby's share of the construction, maintenance and operation of the recommended sewerage and drainage facilities is estimated to vary from 3.6 mills for the five year period 1970-1975, to 0.2 mills for the five year period 1995-2000. The average tax rate for the period 1955-2000 is estimated to be 1.8 mills.

Municipality of Coquitlam. Figure 103 is a graphical representation of the predicted figures of population, assessed valuation, and the calculated annual costs and tax rates in mills presented in Table 78 for the Municipality of Coquitlam during the period 1955-2000. As therein shown, the tax rate required to finance the Municipality of Coquitlam's share of the construction, maintenance and operation of the recommended sewerage and drainage facilities is estimated to vary from 3.6 mills for the five year period 1965-1970, to 0.6 mills for the five year period 1995-2000. The average tax rate for the period 1955-2000 is estimated to be 2.0 mills.

Municipality of Fraser Mills. Figure 104 is a graphical representation of the predicted figures of population, assessed valuation, and the calculated annual costs and tax rates in mills presented in Table 78 for the Municipality of Fraser Mills during the period 1955-2000. As therein shown, the tax rate required to finance the Municipality of Fraser Mills' share of the construction, maintenance and operation of the recommended sewerage and drainage facilities is estimated to vary from 7.5 mills for the five year period 1970-1975, to 2.0 mills for the five year period 1995-2000. The average tax rate for the period 1955-2000 is estimated to be 4.5 mills.

Municipality of North Vancouver. Figure 105 is a graphical representation of the predicted figures of population, assessed valuation, and the calculated annual costs and tax rates in mills presented in Table 78 for the Municipality of North Vancouver during the period 1955-2000. As therein shown, the tax rate required to finance the Municipality of North Vancouver's share of the construction, maintenance and operation of the recommended sewerage and drainage facilities is estimated to vary from 3.1 mills for the five year period 1965-1970, to 0.5 mills for the five year period 1995-2000. The average tax rate for the period 1955-2000 is estimated to be 1.8 mills.

Municipality of Richmond. Figure 106 is a graphical representation of the predicted figures of population, assessed valuation, and the calculated annual costs and tax rates in mills presented in Table 78 for the Municipality of Richmond during the period 1955-2000. As therein shown, the tax rate required to finance the Municipality of Richmond's share of the construction, maintenance and operation of the recommended sewerage and drainage facilities is estimated to vary from 8.0 mills for the five year period 1965-1970, to 0.3 mills for the five year period 1995-2000. The average tax rate for the period 1995-2000 is estimated to be 3.4 mills.

Municipality of West Vancouver. Figure 107 is a graphical representation of the predicted figures of population, assessed valuation, and the calculated annual costs and tax rates in mills presented in Table 78 for the Municipality of West Vancouver during the period 1955-2000. As therein shown, the tax rate required to finance the Municipality of West Vancouver's share of the construction, maintenance and operation of the recommended sew-

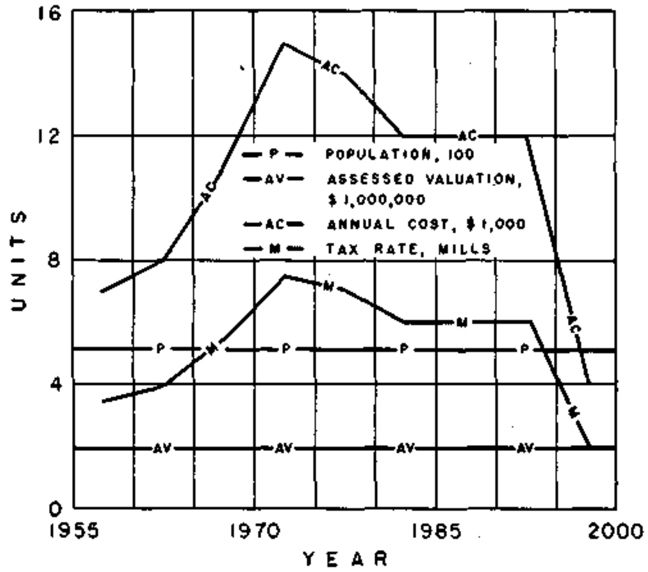


Figure 104. Municipality of Fraser Mills

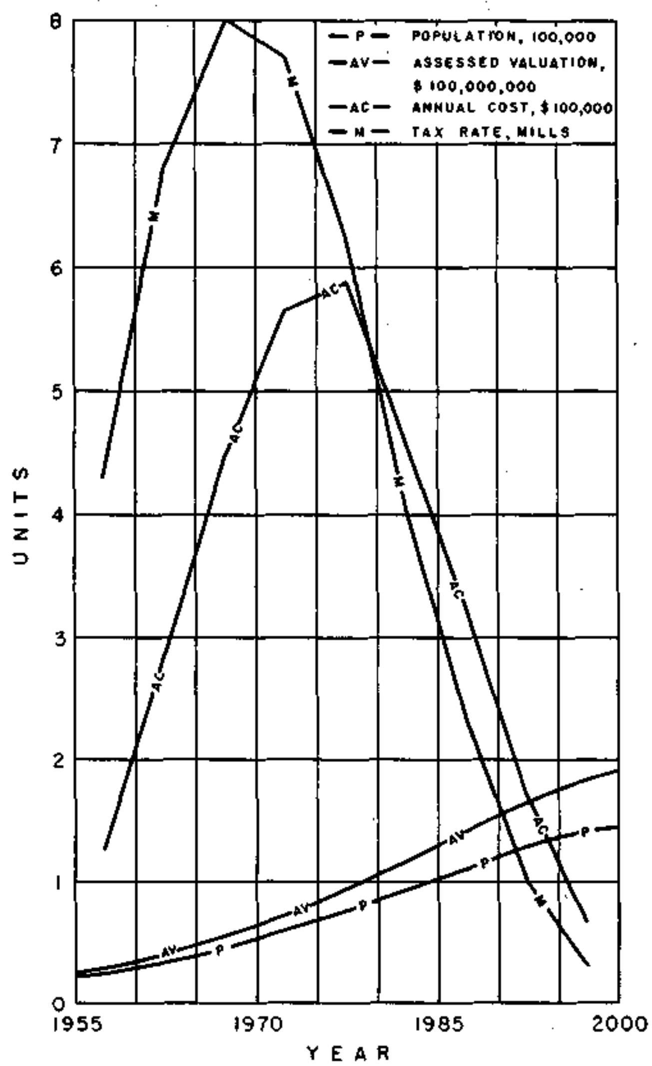


Figure 106. Municipality of Richmond

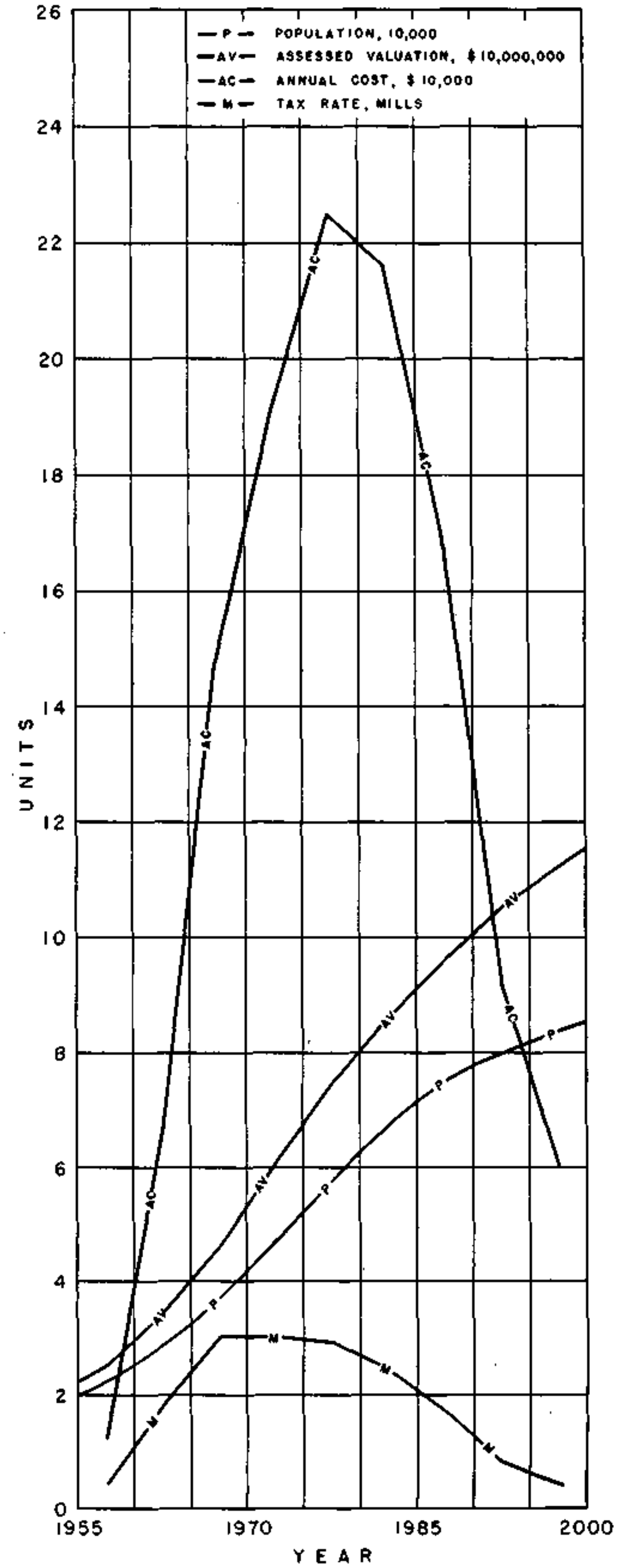


Figure 105. Municipality of North Vancouver

The above graphs illustrate the predicted populations and assessed valuations and estimated average annual costs and tax rates for sewerage and drainage facilities during the 45 year period 1955-2000.

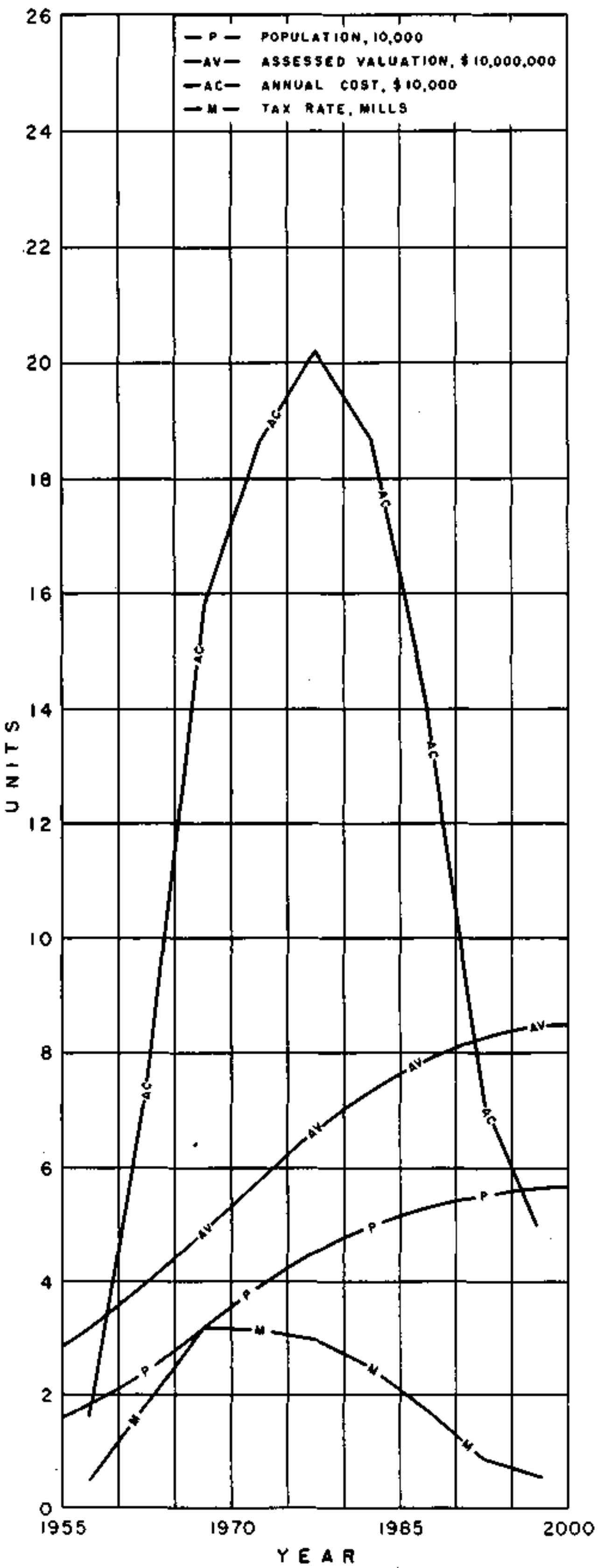


Figure 107. Municipality of West Vancouver

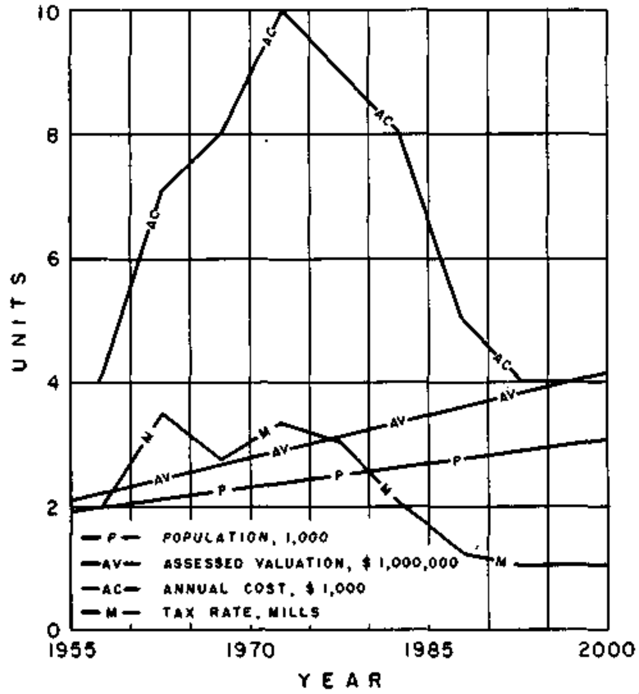


Figure 108. District Lot 172

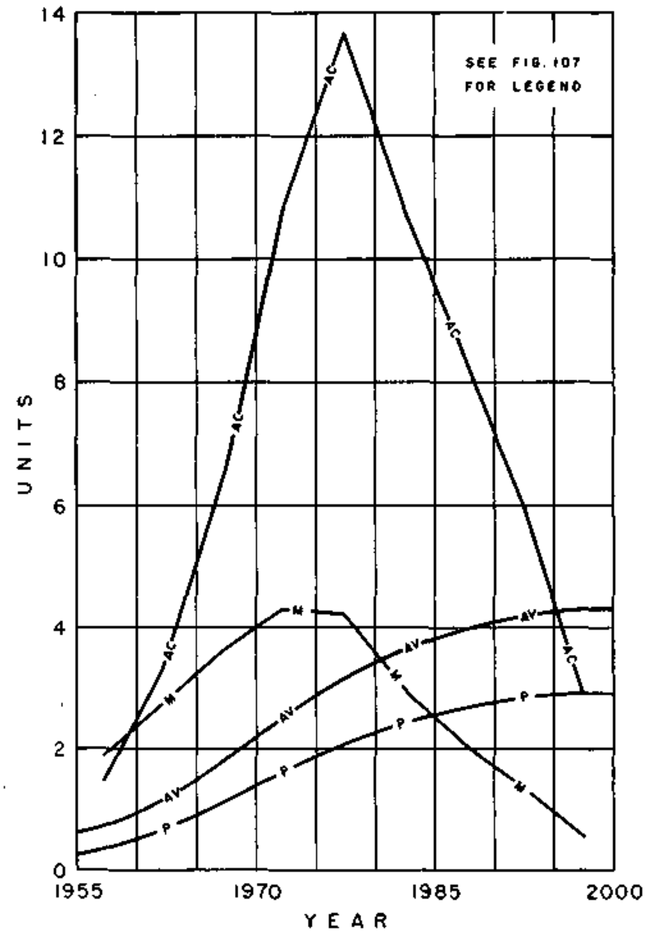


Figure 109. University Endowment Lands

The above graphs illustrate the predicted populations and assessed valuations and estimated average annual costs and tax rates for sewerage and drainage facilities during the 45 year period 1955-2000.

erage and drainage facilities is estimated to vary from 3.2 mills for the five year period 1965-1970, to 0.6 mills for the five year period 1995-2000. The average tax rate for the period 1995-2000 is estimated to be 1.9 mills.

District Lot 172. Figure 108 is a graphical representation of the predicted figures of population, assessed valuation, and the calculated annual costs and tax rates in mills presented in Table 78 for District Lot 172 during the period 1955-2000. As therein shown, the tax rate required to finance District Lot 172's share of the construction, maintenance and operation of the recommended sewerage and drainage facilities is estimated to vary from 3.5 mills for the five year period 1960-1965, to 1.0 mills for the five year period 1995-2000. The average tax rate for the period 1955-2000 is estimated to be 2.0 mills.

University Endowment Lands. Figure 109 is a graphical representation of the predicted figures of population, assessed valuation, and the calculated annual costs and tax rates in mills presented in Table 78 for the University Endowment Lands during the period 1955-2000. As therein shown, the tax rate required to finance the University Endowment Lands' share of the construction, maintenance and operation of the recommended sewerage and drainage facilities is estimated to vary from 4.3 mills for the five year period 1970-1975, to 0.6 mills for the five year period 1995-2000. The average tax rate for the period 1955-2000 is estimated to be 2.5 mills.

Chapter 19
Structure of Government

Present Legislation

The Vancouver and Districts Joint Sewerage and Drainage Board is the only agency in the Greater Vancouver Area which presently constructs, maintains and operates regional sewerage and drainage facilities. The Board's activities are governed by the Vancouver and Districts Joint Sewerage and Drainage Act. The Act is reproduced in Appendix II.

The territory under the jurisdiction of this body includes the City of Vancouver and the Municipality of Burnaby in their entirety and that portion of the City of New Westminster known as the Glenbrook Drainage Area.

Because much of the area to be served by facilities proposed in this report lies beyond the prescribed boundaries of the existing Board, the Board, as presently constituted, cannot provide these facilities. Therefore, new legislation is required to establish a regional agency with authority to finance, construct, maintain and operate, and administer the major sewerage and drainage facilities, both sanitary and storm, proposed for the Greater Vancouver Area.

Proposed Sewerage and Drainage Agency

The following sections of this chapter present in general terms the conclusions reached by the Board of Engineers relative to the organization, administration, general powers, and cost apportionment methods of the agency to be charged with the provision of the major sewerage and drainage facilities in the Greater Vancouver Area. The name of such an agency might well be the Greater Vancouver Sewerage and Drainage Board.

Organization. Each of the cities and municipalities within the Greater Vancouver Area, as described in this report, should be represented on the Board by one of its elected public officials. The Board would elect its Chairman from among its members.

Administration. Subject to the authority of the Board, the actual undertakings of the Board should be directed by a Commissioner appointed by the Board. The Commissioner should be a registered professional engineer who is not a member of the Board.

General Powers. The Board should be empowered to finance, construct, maintain and operate all necessary major sewerage and drainage facilities within or without its boundaries. The location and extent of the facilities to be provided by the Board should be in general accordance with the recommendations contained in this report. The facilities should be constructed according to the time schedule suggested herein, unless construction of a given project is requested at an earlier date by the Board member or members of the community or communities within which the project is to be constructed.

The Board should have the right to perform work requisite to its function but not included in this report upon a two-thirds vote of its membership and by this same majority to amend any of the projects herein recommended in a manner which is not inconsistent with the objectives of this report. The Board should be able to finance, design and construct facilities, in addition to those requisite to its function, for any member, at the sole and exclusive cost to that member, if so requested by the member in question.

The Board should have the power to establish the uses to which its facilities could be put and to prevent any person or agency using them for any purpose except that intended.

To provide the facilities recommended in this report, the Board should be empowered to borrow such sums of money as may from time to time be required to finance its undertakings. The total amount of bonds issued to finance the construction of all recommended projects should not exceed 65 million dollars or 6 percent of the total assessed valuation of land and improvements within the boundaries of the Board, whichever is greater.

Cost Apportionment. As presented in Chapter 18, it is recommended that costs for construction and maintenance and operation of facilities provided by a joint agency be apportioned in the following manner:

1. 70 percent to the member or members comprising the sewerage or drainage area which the facility serves. In the event that there are two or more members within the sewerage or drainage area, the cost would be apportioned in the same proportion as the assessed valuation of land and improvements of each member within the sewerage or drainage area bears to the total assessed valuation of land and improvements within the sewerage or drainage area.

2. 30 percent to all members of the Board, apportioned in the same proportions as the assessed valuation of land and improvements of a member bears to the total assessed valuation of land and improvements of all members.

Boundaries of sewerage and drainage areas should be delineated by the Board. The entire area tributary to one point of outfall or disposal proposed herein for sewage should be defined as a sewerage area. In a similar manner, each storm drainage area would comprise the entire area naturally tributary to one point of outfall. Boundaries of sewerage and drainage areas will not necessarily coincide.

Provision for New Members. It may be found advantageous to extend operation of the Board to include areas in communities not included in the membership of the Board proposed in this report. In each such event, a new member should immediately assume its share of the 30 percent cost apportionment as calculated by the method described above and also its proportion of 70 percent of the total cost of facilities provided to serve a newly delineated sewerage or storm drainage area.

Future Status of Vancouver and Districts Joint Sewerage and Drainage Board

Until the last of the outstanding debts of the Vancouver and Districts Joint Sewerage and Drainage Board have been retired, it is recommended that the charges on these obligations be apportioned among the present members of the Board in the manner prescribed in the Vancouver and Districts Joint Sewerage and Drainage Act. In cases where presently delineated drainage area boundaries of the Vancouver and Districts Joint Sewerage and Drainage Board differ from sewerage drainage area boundaries which will be delineated to carry out the projects recommended in this report, the existing boundaries should be changed to conform to the new conditions.

The maintenance and operation of all the existing facilities of the Vancouver and Districts Joint Sewerage and Drainage Board should be assumed by the Greater Vancouver Sewerage and Drainage Board. The costs for maintenance and operation of the Vancouver and Districts Joint Sewerage and Drainage Board facilities should be apportioned in the same manner as recommended for facilities constructed by the Greater Vancouver Sewerage and Drainage Board.

Chapter 20
Summary

The Board of Engineers submits the following summary of the information contained in the foregoing report. This presentation attempts to give in clear and concise terms the outstanding facts, observations and conclusions set forth in detail in the report.

Chapter 1 - Introduction

1. The Greater Vancouver Area embraces the five cities of New Westminster, North Vancouver, Port Coquitlam, Port Moody and Vancouver, the six municipalities of Burnaby, Coquitlam, Fraser Mills, North Vancouver, Richmond and West Vancouver, and three unorganized areas, District Lot 172, University Endowment Lands and the University of British Columbia.

2. Any adequate and proper solution of the sewerage and drainage problems of the Greater Vancouver Area must recognize and accomplish six basic requirements and objectives, namely:

(1) The development of an orderly, comprehensive long-range master plan of sewerage, sewage treatment and disposal for the entire area and each of its units.

(2) The investigation and evaluation of possible methods of providing storm water drainage for the entire area and each of its units.

(3) The inclusion in such master plan of all existing serviceable sewerage and drainage facilities.

(4) The protection of shores and shore waters, and of inland waters from pollution or contamination by sewage, sewage effluent and industrial wastes.

(5) The placement and layout of facilities in such manner as shall avoid nuisances due to odours, unsightliness or other causes, and as shall serve effectively through a sufficient period.

(6) An estimate of the cost of required sewerage and drainage works and a determination and recommendation of practicable schemes of financing and of governmental organization.

3. The salt and fresh waters contiguous to and within the Greater Vancouver Area are of inestimable value. Their worth has controlled the planning and conduct of the survey and to a large extent has determined its findings and recommendations.

4. Some of these waters have already become polluted to a dangerous and obnoxious extent by reason of the promiscuous discharge of crude sewage and industrial wastes into them.

5. Extensive undertakings in terms of sewerage and sewage treatment and disposal works are now demanded if existing sources of serious pollution or contamination of shores and shore waters of the area are to be eliminated.

6. Since many controlling phases of the sewerage and storm drainage problems of the area are intimately associated with population, it is of vital consequence that every possible effort be made to determine the probable rates of population growth, the total numbers, and their distribution in each community and throughout the area for as long a period in the future as is reasonably predictable.

7. In 1911, in response to insistent public demand, the Burrard Peninsula Joint Sewerage Committee was formed and engaged R. S. Lea of Montreal to report on a suitable scheme for the sewerage and drainage of Burrard Peninsula. The final report and recommendations of Mr. Lea were submitted to the com-

mittee in February 1913, and are reproduced in Appendix I of this report.

8. Based on the recommendations of the Lea Report, the Vancouver and Districts Joint Sewerage and Drainage Board, hereinafter sometimes referred to as the Board, was incorporated in 1914. The various functions and powers of the Board are discussed in this report and the legislative act is reproduced in Appendix II.

9. Existing sewerage and drainage facilities fall within two categories: (1) those provided by and under the jurisdiction of the Board, and (2) those constructed by local authorities. In general the existing facilities, particularly those of more recent construction, have been well built and are of adequate capacity.

10. The first public sewers constructed in the area were laid in the City of Vancouver in 1890. The first sewers constructed by the Board were laid in 1914 in conformity with the recommendations of the Lea Report.

11. The Greater Vancouver Sewerage and Drainage Survey herein reported upon resulted from a proposal to have a Board of Engineers review the Lea Report of 1913 and recommend a comprehensive plan for the sewerage and drainage of a considerable part of the Lower Mainland of British Columbia, including the present sewerage and drainage district. A Board of Engineers was appointed for that purpose by the Vancouver and Districts Joint Sewerage and Drainage Board on April 20, 1950.

12. This survey and report have been concerned with every phase of the sewerage problem of the Greater Vancouver Area, including all physical, social and economic conditions which affect or control its proper solution. Particular consideration has been given to such sewerage features as trunk sewers, main pumping stations, treatment plants, effluent disposal, and outfalls, rather than to strictly local sewerage which is not of general significance. The report also deals in general terms with surface and storm water drainage.

13. The report has been made sufficiently comprehensive to permit verification of the relative and absolute validity of the many statements, conclusions and recommendations advanced therein.

14. In connection with this survey and report, work has been conducted in the field to acquire the facts and to define the conditions controlling certain aspects of providing sewerage and drainage for the entire Greater Vancouver Area. This work has been done by several organizations, including the Pacific Oceanographic Group, the National Research Council, the Hydrographic Service of Canada, the University of British Columbia, the staff of the Vancouver and Districts Joint Sewerage and Drainage Board, and the staff of the survey.

15. The office studies conducted by the staff of the Vancouver and Districts Joint Sewerage and Drainage Board, by the survey staff, and by the Board of Engineers have comprised the collection, examination, evaluation and final assembly of information and data as secured in the field and laboratory, as furnished by contributing agencies, and as derived from other sources.

16. The Board of Engineers and its staff desire to acknowledge and to express their deep gratitude for the invaluable assistance received throughout the conduct of the survey and the preparation of this report from many persons, organizations and public agencies.

Chapter 2 - Geography

17. The geography of an area, as related to sewerage and drainage problems, is of controlling significance by reason of its influence upon population growth and directional trends, upon industrial and agricultural development, upon the existence and use of recreational areas, and even upon the location, type and required efficiency of sewerage and drainage works.

18. The Greater Vancouver Area, located in the southwesterly corner of the Lower Mainland of British Columbia, has a total land area of almost 300 square miles, and has a general east-west length of 25 miles and a north-south width of 15 miles.

19. The area is bordered on the south by the main channel of Fraser River, on the east by Pitt River, on the north by the Coast Range and on the west by the Strait of Georgia.

20. Fraser River, one of the principal rivers tributary to Pacific Ocean on the North American continent, has peak flows of over 500,000 cubic feet per second and minimum flows of 30,000 cubic feet per second. Thirteen miles upstream from its mouth in Strait of Georgia, Fraser River divides into two channels, the North Arm and the main channel.

21. Burrard Inlet is a large tidal body of water extending some 18 miles eastward from the Strait of Georgia and includes English Bay, Vancouver Harbour and Indian Arm.

22. Burrard Inlet and the North Arm of Fraser River divide the area into three geographic sections, namely, the North Shore, Burrard Peninsula and Richmond.

23. Present development in the Greater Vancouver Area is largely on the western end of Burrard Peninsula which lies between Burrard Inlet and the North Arm of Fraser River. The eastern portion of the peninsula is developing rapidly, both industrially and residentially.

24. The North Shore, occupying the lower slopes of the Coast Range north of Burrard Inlet, is predominantly residential at present. However, active industrial developments are taking place along the north shore of Vancouver Harbour.

25. Richmond, comprising Sea and Lulu Islands and several smaller islands, occupies delta lands between the North Arm and the main channel of Fraser River.

26. Within the Greater Vancouver Area are five incorporated cities, six incorporated municipalities, three unorganized communities administered by the Provincial Government of British Columbia, and several areas such as Indian and Military Reserves administered by the Government of Canada.

27. The total population of the Greater Vancouver Area was 520,313 in 1951. Of this total population, 66 percent resided in the City of Vancouver.

28. Recreational beaches are found on both sides of Burrard Inlet and around Point Grey on the western end of Burrard Peninsula. The most highly utilized beaches are on the southern and eastern shores of English Bay. Other excellent recreational resources, including parks, golf courses, playgrounds, yachting basins and winter sports areas, exist in the Greater Vancouver Area.

29. In 1949, the estimated area used for farming was 22,000 acres, or slightly less than 11 percent of the total land area of the Greater Vancouver Area. These areas lie generally to the east and south of the more highly developed portion of Burrard Peninsula.

30. Present industrial development centres on the shores of Burrard Inlet, including False Creek, and the North Arm of Fraser River. In 1951, 38 percent of the 17,300 acres estimated to be suitable for industrial purposes was already developed.

31. The total worth of industrial production within the City of Vancouver is reported to have been 358 million dollars in 1949. Lumber and wood products are the most important of the many varied industries which include meat processing, petroleum refining and products, and fish processing and canning.

32. Because it contains Vancouver

Harbour, the major seaport on the Pacific Coast of Canada, the Greater Vancouver Area will benefit directly from increased trade with the Far East as well as other parts of the world. Although shipping now centres in the harbour, additional facilities are in use along the banks of Fraser River which is navigable throughout the area.

33. Passenger and freight transportation is available by air, land and sea. The airport on Sea Island is convenient to the metropolitan area and is served by local, national and international flights. Rail systems provide service to the East and South and a connecting line is under consideration which will provide service between Greater Vancouver and central and northern British Columbia. Local and express highways exist and are being developed as the need for them arises. A large number of steamship lines and shipping companies have terminals and attendant facilities on the navigable waters of the area.

Chapter 3 - Topography and Geology

34. Topographic and geologic conditions have a determinative influence upon practically every phase of sewerage and drainage. Specifically, this influence is exercised on the routes and sizes of collection facilities, the need for and location of pumping stations, the selection of construction methods, the design of heavy structures, the location of treatment works, and the location of outfalls for both sewage and storm water.

35. The Greater Vancouver Area is naturally divided into three distinct topographic sections, each of which may be said with fair accuracy to be different in its geological formation and structure. The northernmost, or North Shore section, lies north of Burrard Inlet; the central section, Burrard Peninsula, lies between Burrard Inlet and the North Arm of Fraser River; and the southernmost, comprising the Fraser River delta islands, lies south of the North Arm and north of the main channel of Fraser River.

36. North Shore is deeply scored by torrential rivers, the largest of which are the Capilano, Lynn and Seymour. The slope, which descends from 5,000 feet above sea level southward to Burrard Inlet in five or six miles, has been greatly modified by glaciation and by the deposition of deltaic gravel and sand built up by the streams just mentioned.

37. Burrard Peninsula is divided into two nearly equal segments by an east-west valley. At the valley's western end lie False Creek and English Bay and at its eastern end Burnaby Lake and Brunette River. The northern segment is a long narrow ridge marked by a succession of minor peaks while the southern segment is a uniform narrow ridge extending from New Westminster to Point Grey with gentle slopes both to north and south.

38. The islands of the Fraser River delta constitute a part of a very flat plain whose elevation is approximately sea level. The delta of Fraser River is in continuous process of formation and is being extended westward by the heavy load of sediments deposited annually.

39. Tertiary sediments, comprising layers of sandstones, shales and conglomerates in various thickness dipping gently to the south, make up the principal superficial geologic formation in the Greater Vancouver Area. These sediments overlie the granitic rocks of the Coast Range batholith and are themselves overlain by a thick complex of glacial and inter-glacial deposits and by delta deposits of the Capilano, Lynn, Seymour, Coquitlam and Fraser Rivers.

40. Along the western portion of the North Shore, glacial and inter-glacial deposits are found on the surface while along the eastern portion these deposits are covered by the deltas of the Capilano, Lynn and Seymour Rivers. Tertiary sediments are exposed in a few small areas only, and granitic rocks are generally too deeply buried to be uncovered in excavations for sewers and drains except in the higher levels of the western por-

tion and along the shore of the Indian Arm of Burrard Inlet.

41. Burrard Peninsula is almost completely covered by glacial sediments. Only on a few steep slopes are underlying tertiary sediments exposed. A sheet of boulder clay, varying in depth from 10 to more than 100 feet, covers most of the peninsula. The sheet usually consists of a tough blue clay with varying amounts of sand, gravel and boulders and exhibits corresponding variations in physical properties.

42. The islands of the Fraser River delta have been formed by the sand and silt transported by the river and deposited when the river velocity slackened prior to discharge into Strait of Georgia. Several large and deep deposits of peat are found in this section. Ground water is also found close to the surface.

Chapter 4 - Climate

43. The principal factors which define climate are air temperature, rainfall, daylight and darkness, sunshine and clouds, wind direction and velocity, and such attendant effects as evaporation from water surfaces and fog.

44. A complete knowledge of the quantities and distribution of rainfall over the area is fundamental to the proper design of all types of sewers, both separate and combined, and of storm drains, both closed conduits and open channels.

45. Climatological conditions are determinative in the utilization of the beach and other recreational facilities of the Greater Vancouver Area. Both the climatological data and public response indicate that May 1 to September 30 of each year limit the popular beach season.

46. Long-term meteorological data have been assembled and evaluated. These are statistically set forth in tables and graphs in the foregoing report.

47. The climate of the area is mild with generally moderate winter and summer temperatures.

48. The mean annual temperature in the area is about 50°F. Extreme temperatures of 0.0°F and 92.2°F have been recorded.

49. Prevailing winds are from the east and southeast, while the strongest winds are from the northwest.

50. The amount of precipitation over the area increases rapidly with increasing distance north of Fraser River and with elevation above sea level. The average annual precipitation at Vancouver Airport is 40 inches, in downtown Vancouver, 57 inches, and at Seymour Falls in the Coast Range, 147 inches.

51. Average monthly precipitation in downtown Vancouver ranges from nine inches in December to less than one and one-half inches in July. Only 20 percent of the total yearly rainfall occurs during the five month period May to September.

52. Sixty-five percent of the total annual sunlight hours occur in the May to September beach recreational season.

Chapter 5 - Water Resources

53. The water supply of a community is used for domestic, industrial and public purposes. The extent and rate of use is influenced by availability, pressure, quality, cost and climatic conditions.

54. Both the total quantity of water consumed and its rate of use are reflected in the flow of sewage. Under certain conditions, the flow of sewage in a separate or sanitary system may exceed the draft upon the public water supply because of ground water infiltration or the extensive use of private sources.

55. In some areas, a scarcity of water may be a factor limiting development. An adequate and inexpensive supply removes this barrier. The Greater Vancouver Area is fortunate in the possession of abundant water supplies which may be conveyed from nearby catchment areas in the Coast Range to the use areas

by gravity and with no treatment other than chlorination.

56. Water supplies in the Greater Vancouver Area are of excellent quality and suitable for all normal domestic and industrial purposes. The total hardness does not exceed 7 parts per million and the total dissolved solids are less than 23 parts per million.

57. Over 125 miles of supply mains are included within the system of the Greater Vancouver Water District. The independent supply of the City of North Vancouver is carried to the city through a main six miles long.

58. The average daily water use in the communities served by the Greater Vancouver Water District was 70.2 million gallons, or 139 gallons per capita, in 1951.

Chapter 6 - Use and Condition of Shores and Shore Waters

59. All of the communities in the Greater Vancouver Area have boundaries on at least one stretch of navigable water.

60. Important industries, particularly lumber, are located on the shores of these waterways.

61. The residential popularity of the area has been definitely enhanced by the recreational advantages inherent in the many miles of good beaches with which the area is fortunately endowed.

62. Crude sewage has always been discharged into the waters of the area and has produced unpleasant and unhygienic conditions in many places.

63. As of this date, crude sewage is being discharged without treatment of any kind at nearly 60 known locations, not including contributions from ocean-going vessels, pleasure craft or float houses.

64. A primary objective of the sewerage facilities recommended in this report has been the production and maintenance of shores and shore waters free from unsightliness and unsanitary conditions.

65. The major beach areas are located on the shores of English Bay and on the seaward end of Burrard Peninsula. Public beaches have an aggregate length of about 12 miles.

66. The total attendance at the patrolled beaches of the City of Vancouver during the 1952 summer season was estimated by the Vancouver Park Board to be 1,500,000 persons. This represents an increase of 50 percent over the estimate of 1,000,000 persons for the summer of 1941. In the 11 years, 1941 to 1952, the population of the Greater Vancouver Area increased 40 percent.

67. During July and August, 1952, the average weekday beach attendance was estimated to be 15,000 and on Sundays, 70,000.

68. The bays, harbours and other waters of the area are extensively used by commercial fishing boats, pleasure craft of all sorts and float houses, all of which, together with ocean-going vessels, contribute to the pollution of these waters.

69. Samples for bacteriological testing to determine the extent of shore water contamination were collected by the Vancouver and Districts Joint Sewerage and Drainage Board during 1949 and 1950. These were collected at nine shore stations and six offshore stations.

70. Results of presumptive and confirmed tests for coliform group organisms are tabulated for each station and are shown in this report.

71. At present, no official standards defining permissible limits of bacterial contamination of bathing waters are in force in the Province of British Columbia. A comparison of the results of bacteriological sampling with standards in force elsewhere, coupled with the fact that many of the existing crude sewage

outfalls are located in or adjacent to important beach areas, leads to the conclusion that the contamination of shores and shore waters is a serious problem.

72. Unless corrective measures are taken to bring about more proper disposal of sewage, the conclusion is inescapable that the degree of contamination will increase as the volume of sewage flow increases until large areas of the beaches will no longer be safe or even decent to use.

Chapter 7 - Principles and Functions of Sewerage and Sewage Treatment

73. Personal and public health and private and public comfort require that community wastes, both liquid and solid, be promptly removed from all premises and disposed of in some innocuous manner.

74. In the past, both the domestic sewage and the storm waters of an area have commonly been collected and conveyed in a single system of conduits called combined sewers and discharged without treatment. These promiscuous discharges have all too frequently caused obnoxious and unsanitary conditions, no longer regarded as tolerable.

75. The public demand for clean, unpolluted environmental waters argues strongly for the construction of separate systems of conduits for domestic sewage and storm waters, since this separation allows for the effective and economical treatment of the sewage.

76. Sewage treatment is undertaken for the sole purpose of making disposal practicable and sanitary.

77. There are two general types or degrees of sewage treatment currently being utilized, namely, primary and secondary treatment.

78. Primary treatment processes, through the removal of grit, floating material, suspended solids, grease or fats, and incidental amounts of organic matter, are used to prepare an effluent suitable to undergo secondary treatment or to be disposed of by dilution.

79. Secondary treatment processes provide for the biologic oxidation and stabilization of the organic material contained in sewage which has not been removed by primary treatment.

80. The solids, other than grit, separated from sewage by treatment processes are known as sludge and are generally transferred to sludge digestion tanks for further treatment before ultimate disposal. During the process of digestion, complex biologic changes occur which produce a combustible gas and a stable, humus-like residue termed "digested sludge".

81. Sewage may be disposed of satisfactorily by dilution in bodies of salt or fresh water provided the receiving capacity of such water mass is sufficient to preclude the possibility of contamination or pollution. The receiving capacity of any water mass is related directly to its volume and to its content of available oxygen.

82. Receiving capacity coupled with the beneficial uses of a water mass govern the degree of sewage treatment necessary prior to discharge.

83. Public health and aesthetic benefits always accrue to a community from good sewerage and sewage disposal facilities. Direct economic benefits, on the other hand, are rarely achieved.

84. There are three possible products of sewage treatment which, under favourable circumstances, may help to defray its cost. These are: (1) reclaimed water for use in industry or for irrigation; (2) combustible gas for use as a source of heat or power; (3) digested sludge for use as a soil conditioner or fertilizer.

85. Since abundant natural water supplies are available in the Greater Vancouver Area, reclamation of water

from sewage is not economically feasible or justifiable.

86. Sludge gas produced in the anaerobic decomposition of organic material during the sludge digestion process should be utilized in the Greater Vancouver Area to obtain heat and power for use in sewage treatment plants.

87. In the Greater Vancouver Area, the preparation of digested sewage sludge for utilization as a fertilizer or soil conditioner is not presently economically feasible or justifiable.

Chapter 8 - Division into Sewerage Areas

88. One of the basic requirements in planning comprehensive sewerage and drainage facilities for an extended area is the division of that area into more or less independent units as determined by topographic, economic and various developmental factors. Among the latter are political boundaries, population and land use.

89. The three natural sections of the Greater Vancouver Area are: North Shore, Burrard Peninsula and Richmond. Each of these has been further subdivided into a number of smaller areas designated as "sewerage areas".

90. Planning for storm drainage facilities requires a further subdivision into individual drainage areas. Present purposes did not require that these be delineated. Boundaries of the areas established for sanitary sewerage purposes are not necessarily coincident with drainage area boundaries.

91. The North Shore Section, lying north of Burrard Inlet, includes the City of North Vancouver and the Municipalities of North Vancouver and West Vancouver. The section had a census population of 44,200 in 1951 and its total land area is 63,080 acres.

92. The North Shore Section was divided into three sewerage areas: Point Atkinson, Capilano and Seymour. Major residential and industrial development at present is centred in the Capilano Sewerage Area.

93. The Burrard Peninsula Section, lying between Burrard Inlet and Fraser River, includes all of the Cities of Port Coquitlam, Port Moody and Vancouver, the Municipalities of Burnaby, Coquitlam and Fraser Mills, the unorganized communities of District Lot 172, the University Endowment Lands and the University of British Columbia, and the major portion of the City of New Westminster. The section had an estimated population of 454,900 persons in 1951 and its total land area is 94,810 acres.

94. The Burrard Peninsula Section was divided into three sewerage areas: Vancouver, Fraser and Coquitlam. Major development at present is in the Vancouver and Fraser Sewerage Areas.

95. The Richmond Section, lying between Fraser River and its North Arm, includes the Municipality of Richmond and a portion of the City of New Westminster. The section had a census population of 21,200 persons in 1951 and its total land area is 29,730 acres.

96. The Richmond Section was divided into two sewerage areas: Sea Island and Lulu Island. All air transport facilities of the Greater Vancouver Area are located on Sea Island. Lulu Island is predominantly agricultural at present; however, future increases in industrial and residential uses will occur.

97. The area presently served by the Vancouver and Districts Joint Sewerage and Drainage Board falls entirely within portions of the Vancouver and Fraser Sewerage Areas of the Burrard Peninsula Section and includes the City of Vancouver, the Municipality of Burnaby and a portion of the City of New Westminster. The area under the jurisdiction of the Board totals 50,200 acres.

Chapter 9 - Population

98. Competent and comprehensive planning for the sewerage of any area demands that the probable future growth and distribution of population in that area be determined with the utmost care and skill.

99. The quantity of sanitary sewage is directly related to the population of an area; the rate and volume of sewage flow fix the sizes and capacities of sewers, pumping plants, treatment works and outfalls.

100. The prediction of future population requires that an inventory be made of all controlling conditions. Ten such conditional factors have been listed and evaluated for the purposes of this report.

101. Some factors can cause unpredictable future changes and for this and other reasons the most carefully prepared population forecasts must be regarded as tentative and suggestive rather than exact.

102. A consideration of all factors, past, present and anticipated future, indicates that the population growth and ultimate development of the Greater Vancouver Area will not be restricted in any foreseeable material way.

103. More particularly, the definite movement westward of population, commerce and industry, a well established and pronounced urban tendency, an increasing longevity and ratio of births over deaths, together with many favourable local factors including a salubrious climate, land availability and transport opportunities, indicate a continuous population growth in the Greater Vancouver Area.

104. Of eight more or less standard methods of population prediction enumerated in the report, the Board of Engineers considers that the logistic curve method represents the most competent means presently available for predicting future populations. That method is based upon the hypothesis that the rate of population increase will at length become a decreasing one and will so continue until a saturation limit is reached.

105. The saturation population of the Greater Vancouver Area was estimated on the basis of the anticipated ultimate population density or number of persons per habitable acre of land.

106. A study of each community was made for the purpose of estimating the probable average saturation density in terms of numbers of persons per habitable acre. The studies included the consideration of such factors as economic opportunity, present population distribution, land use and habitable land area, accessibility and transportation facilities, proximity of business and industrial areas both present and probable future, and probable types of residential construction.

107. The past percentages of the estimated ultimate saturation population of each community were plotted on a logistic grid and the curves projected to obtain the future percentages of saturation. The predicted population of each community in the Greater Vancouver Area was then computed at 10 year intervals from 1960 to 2000.

108. The predicted future populations in the Greater Vancouver Area are:

1960	680,700
1970	889,000
1980	1,112,300
1990	1,297,400
2000	1,412,900
Saturation	1,650,000

109. To be of value in the planning of sewerage facilities for any area, the predicted future populations must be distributed over that area as logically as can be accomplished using all of the available information. On the basis of population and land use data, topographic maps, aerial photographs, and the results of field reconnaissance, the distribution of the average population densities

which may be expected in the Greater Vancouver Area at ultimate development was established. These densities ranged from a maximum of 75 persons per acre to a minimum of 0.5.

Chapter 10 - Existing Sewerage and Drainage Facilities

110. In the development of a master plan or program of sewerage and drainage for a large area, it is important that the plan include and recognize all existing serviceable utilities. This has been done in the present case.

111. The sewerage and drainage works of the Vancouver and Districts Joint Sewerage and Drainage Board and of each of the communities making up the Greater Vancouver Area, as herein considered, are described in the report. The discussion also includes the history, the financial situation, and the maintenance and operation of the existing facilities.

112. The Board was formed in 1914 pursuant to a recommendation contained in the report by R. S. Lea.

113. The Board owns and maintains trunk sewers and drains in the City of Vancouver, the Municipality of Burnaby, and a portion of the City of New Westminster.

114. The Board operates entirely on yearly assessments received from its members.

115. The City of Vancouver owns, maintains and operates all the sewers and drains within its boundaries except for those controlled by the Board. Approximately 80 percent of the area of Vancouver is presently served with sewers, mostly of the combined type.

116. Sewerage and drainage facilities in the Municipality of Burnaby comprise local collection systems draining to trunk sewers and drains owned by the Board. The systems are a mixture of combined and separate sewers. About 20 percent of the developed area of Burnaby is sewered.

117. Sewerage and drainage facilities in the City of New Westminster comprise local collection systems of separate and combined sewers draining either to the Glenbrook trunk sewer owned by the Board or to individual outfalls in the Fraser River. Approximately 75 percent of the total city area is sewered.

118. The City of North Vancouver has a local sanitary sewer system comprising collection systems and outfalls into Burrard Inlet. Storm water, for the most part, is disposed of in natural watercourses.

119. The Municipality of Fraser Mills has a small local sanitary sewer system and outfall. Drainage facilities comprise a system of culverts and ditches discharging to the Fraser River.

120. Sanitary sewerage facilities in Richmond comprise small collection systems and outfalls for sanitary sewage from a residential subdivision, an airport, and an R.C.A.F. development, all on Sea Island. The remainder of Richmond has no public sanitary sewerage facilities. Drainage facilities in Richmond, both on Lulu and Sea Islands, consist of a network of open channels, with dykes and pumps.

121. The sanitary sewerage works in the University of British Columbia comprise a collection system and outfall into English Bay, while storm water is conveyed by storm drains and open channels to the disposal site off Point Grey.

122. The presently subdivided portions of the University Endowment Lands are served with sewerage and drainage facilities. The system includes both separate and combined sewers.

123. There are no public sanitary sewerage facilities in the Cities of Port Coquitlam and Port Moody, or in the Municipalities of Coquitlam, North Vancouver and West Vancouver, or in District

Lot 172. Storm water is conveyed, for the most part, in natural watercourses.

124. Sewage disposal in areas not provided with public collection and disposal facilities is accomplished by means of individual septic tanks. These are unsatisfactory in many locations because of ground conditions not suitable for disposal of the tank effluent.

Chapter 11 - Characteristics of Sanitary Sewage

125. The term sanitary sewage characteristics, as employed in the report, is both quantitative and qualitative. The quantity and strength of sanitary sewage are determinative factors controlling the planning and design of sewerage works.

126. To determine the typical characteristics of the sanitary sewage, measurements of flow were obtained by the survey at three locations and samples for laboratory analyses were collected at one of these measuring stations.

127. Laboratory studies on the samples collected were confined to the determination of biochemical oxygen demand and suspended solids, both total and volatile.

128. Flow measurements in and analyses of sanitary sewage samples collected from the English Bay intercepting sewer in the City of Vancouver indicate that the average daily per capita contributions of flow, biochemical oxygen demand and suspended solids are 98 Imperial gallons, 0.13 pound and 0.15 pound, respectively.

129. The calculated design factors, applying to sanitary sewage in the Greater Vancouver Area, include allowances for increased industrial and domestic contributions, and are as follows:

Flow,	
Imperial gallons per capita per day	
Sanitary system	95
Combined system	110
Percent peak of average flow	150
Percent minimum of average flow	65
Biochemical oxygen demand,	
pounds per capita per day	0.17
Suspended solids,	
pounds per capita per day	0.20

Chapter 12 - Requirements for the Disposal of Sewage

130. Disposal of the sewage of the Greater Vancouver Area may be to tidal waters of the Strait of Georgia and Burrard Inlet or to Fraser River and its distributaries.

131. The controlling factors which dictate the location of sewage disposal works and the necessity of prior treatment before discharge to these waters are different from those applying to the disposal of storm water.

132. Disposal of storm water is primarily controlled by economic considerations and has as its objective the safe, efficient discharge of surface water runoff into the nearest adequate waterway.

133. The development of science, the protection of the public health, and the demands of public comfort and convenience have all influenced the development of sewage disposal practice.

134. Sewage disposal in British Columbia is under the jurisdiction of several federal and provincial departments of government.

135. It is the opinion of the Board of Engineers that specific requirements for sewage disposal cannot be determined until such time as the detailed design of a particular plan or sewerage project is undertaken.

136. In connection with this report, several long-range objectives are considered to be essential to the proper disposal of sewage in the Greater Vancouver Area. Foremost among these are the requirements that beach areas shall not be contaminated with sewage and that disposal shall not cause nuisances due to

odours or unsightliness.

Disposal to Tidal Waters

137. The capacity of sea water to receive sewage and render it harmless is directly related to its ability to dilute the sewage, destroy the pathogenic organisms, and oxidize the organic matter contained therein.

138. When sewage or sewage effluent is discharged below the surface of sea water, it tends to rise immediately, mixing with large quantities of sea water as it does so.

139. When sewage or sewage effluent, diluted with sea water, reaches the surface, one of two general phenomena will occur. Either the sewage-sea water mixture will sink under the surface, or it will float and spread over the surface. In the latter case, after a period of time varying from less than one to as many as three hours, all traces of the sewage will normally disappear.

140. The tidal pattern of the Greater Vancouver Area is one of diurnal inequality in which the amplitude of the tide varies through a two-week cycle.

141. Fresh water is released into the Strait of Georgia by Fraser River at a variable rate during the year. The peak discharge during freshet flows is estimated to exceed 500,000 cfs and the average winter discharge 30,000 cfs.

142. Several investigations to obtain information about controlling factors affecting sanitary sewage disposal have been carried out by the Vancouver and Districts Joint Sewerage and Drainage Board alone and in cooperation with other governmental agencies.

143. One such cooperative project, undertaken to gather oceanographic data descriptive of the circulation and rate of exchange in Fraser River estuary and contiguous waters of English Bay, was the Fraser River Estuary Project.

144. This project involved the collection and analyses of samples for dissolved oxygen and salinity and included determination of temperature structure.

145. During the period November 1949 to April 1950, 52 stations in Vancouver Harbour and English Bay were occupied once each month. Between May 1950 and February 1951, 42 stations in the area between Vancouver Harbour and the main channel of Fraser River were occupied at frequent intervals.

146. All data collected have been compiled and published by the Pacific Oceanographic Group under the title "Pacific Coast Data Record, Fraser River Estuary Project, 1950". An analysis of these data with respect to the movement of surface water was made by the Pacific Oceanographic Group and published under the title "The Oceanographic Phase of the Vancouver Sewage Problem" by R. L. I. Fjarlie.

147. Study and evaluation of hourly tidal currents in English Bay and Vancouver Harbour were conducted in 1950 by the Hydrographic Service of the Department of Mines and Technical Surveys of Canada in cooperation with the Vancouver and Districts Joint Sewerage and Drainage Board.

148. Data were collected from 26 separate current observation stations from Point Grey to Second Narrows.

149. The data were analysed by the Hydrographic Service in a report entitled "Current Investigations, Burrard Inlet - 1950", and were used in preparing Tidal Publication No. 22, entitled "Tidal Current Charts, Vancouver Harbour, British Columbia".

150. Knowledge of movement of surface waters is necessary for the proper location of sewage outfalls and in determining the degree of treatment necessary prior to discharge.

151. Movements of water masses from the main channel of Fraser River, Sturgeon Bank and North Arm, as well as

the circulation in English Bay and Vancouver Harbour have been examined with respect to the fulfilment of the objectives considered to be essential to the proper disposal of sewage in the Greater Vancouver Area.

152. Observations of current velocities and directions by means of floats were conducted by the Vancouver and Districts Joint Sewerage and Drainage Board over a number of years.

153. These float surveys have been studied and the results are described in the report.

154. Before selecting possible sites for sanitary sewage outfalls, it is necessary to determine the degree of treatment which would be required prior to discharge to various bodies of receiving waters.

155. Sanitary sewage can be discharged into the lower reaches of Fraser River without any treatment provided the outfall extends to the deep channel of the river and is equipped with multiple outlets.

156. Construction of a dam across Macdonald Slough to prevent back flow into the North Arm would permit discharge of effluent from a high-rate primary treatment plant to a channel across Sturgeon Bank extending to the deep water of the Strait of Georgia.

157. Sanitary sewage discharged into the North Arm near its mouth would require secondary treatment, such as would be provided by a high-rate trickling filter treatment plant with effluent chlorination during critical periods.

158. Sewage discharged into the southern zone of English Bay would require secondary treatment such as would be provided by the activated sludge process. Sewage discharged into the northern zone of the bay would require a lower degree of treatment such as would be provided by a standard-rate primary treatment plant. Effluent chlorination during critical periods would be required in both zones of the bay.

159. Sewage would require standard-rate primary treatment with effluent chlorination during critical periods prior to discharge to Vancouver Harbour.

160. It is considered that the local conditions are and will be such that crude sewage may properly be discharged to Burrard Inlet east of Second Narrows.

Disposal to River Waters

161. The ability of a river to receive sewage without unsanitary and obnoxious results is directly related to the rate of flow, the concentration of dissolved oxygen present, the quantity and composition of sewage involved, and to the upstream and downstream uses of the river.

162. To evaluate the capacity of river waters within the Greater Vancouver Area to receive sewage, use was made of all available sources of information relative to river flows, dissolved oxygen concentrations, and water temperatures.

163. Fraser River flows are measured at Hope, British Columbia, by the Department of Resources and Development of Canada. The department has determined factors by which to estimate flows at various downstream locations when applied to recorded flows at Hope.

164. At New Westminster, Fraser River divides into the main channel and the North Arm. Approximately 15 percent of the total flow goes to the North Arm.

165. A model of the lower Fraser River has been built by the National Research Council in cooperation with the University of British Columbia for the Department of Public Works of Canada. This model was utilized to determine the velocity of flow in the North Arm under certain imposed flow and tidal conditions.

166. Under conditions of freshet flow and large amplitude tide, a float moved down the North Arm from Boundary Road to the vicinity of Wreck Beach in a time corresponding to five hours in nature. With the Middle Arm of Fraser River and Macdonald Slough blocked, the time was decreased to three hours.

167. Data on water quality in Fraser River are contained in the report entitled "Water-Quality in the Fraser-Thompson River System of British Columbia" prepared for the Dominion-Provincial Fraser River Basin Board by the British Columbia Research Council in 1952.

168. The average daily quantity of dissolved oxygen transported by the river varies from nearly 3,000,000 pounds per day in January to over 18,000,000 pounds per day in May.

169. A measure of the oxygen demand of sewage or any waste is its biochemical oxygen demand. Based on the quantity of sewage which may be made tributary to various locations on Fraser River and North Arm, the daily biochemical oxygen demand loading which might be imposed upon these waters has been calculated.

170. Under the most critical conditions and when the tributary areas have reached ultimate development, the oxygen demand of the sewage will be less than one percent of the oxygen carried by Fraser River.

171. Recognition of the velocities and currents affecting the discharge of water from the North Arm definitely precludes the direct discharge of untreated sewage thereinto.

172. The present and anticipated future uses of Fraser River coupled with the great excess of dissolved oxygen available for oxidizing the organic matter in sewage indicate that sewage may be discharged to the river without treatment.

173. Sewage discharged into the upper reaches of the North Arm would require standard-rate primary treatment with effluent chlorination during critical periods.

174. During the summer, flows in Brunette River are low.

175. Sewage discharged to Brunette River or to Burnaby Lake would require secondary treatment such as would be provided by a high-rate trickling filter with effluent chlorination.

Chapter 13 - Design Criteria and Basis of Cost Estimates

176. The detailed design of the facilities is not essential in a preliminary report on sewerage and drainage, but each project studied must be laid out in sufficient detail to permit a comparison with other possible schemes proposed to serve the same purpose and yield equivalent results.

177. Assuming comparable performance, the final determination of the most appropriate sewerage project will rest largely upon economic considerations.

178. Although the layouts of sewerage projects to serve the Greater Vancouver Area, as proposed for the purposes of the survey and report, must be regarded as somewhat tentative, planning has been accomplished in sufficient completeness to permit the necessary comparisons between projects with respect to merit and economy.

179. The present survey of sanitary sewerage facilities has been concerned with the planning of trunk and intercepting sewers and their appurtenant pumping stations, with treatment plants, and with disposal works.

180. The layout of storm drainage facilities, with the exception of those which exist in the areas presently sewered on the combined system, has been accomplished on a much more general

basis than the layout of sanitary sewerage projects.

181. Storm water quantities were calculated by the rational method which is expressed in terms of the equation: $Q = CiA$.

182. The loadings used in the layout of proposed sanitary sewerage facilities were determined by multiplying the per capita quantities or contents of the sewage by the predicted contributory population.

183. Wastes from industries should be discharged into the public sewers; however, pretreatment of some of these wastes may be necessary prior to discharge to the sewers if the crude waste would have any deleterious effects upon the functioning of the sewerage system.

184. Manning's pipe friction formula has been used for the determination of the diameters of all sewers planned in connection with this report.

185. A coefficient of roughness, "n", of 0.013 has been assumed for all gravity trunk sewers and sanitary sewage intercepting sewers, 0.012 for combined sewage intercepting sewers, and 0.015 for force mains, inverted siphons, and outfalls.

186. A storm water runoff coefficient of 0.36 has been assumed to obtain during the summer months in the Greater Vancouver Area, and a coefficient of 0.84 during winter months.

187. A series of rainfall intensity curves has been developed by the Vancouver and Districts Joint Sewerage and Drainage Board for use in the rational method of combined sewer or storm drain design.

188. All trunk and other sewers and conduits were planned to have self-scouring velocities and to have capacities sufficient to convey the predicted peak rates of flow.

189. Pumping stations on sanitary sewers were generally found to be economically justified where the depth of the sewer approached 30 feet.

190. Pumping station structures were planned to accommodate the equipment ultimately required but the equipment itself is proposed to be installed in steps or stages as found to be necessary or desirable in the future.

191. Four types of sewage treatment, capable of meeting various sorts of controlling conditions, were considered. The four types are: (1) high-rate primary; (2) standard - rate primary; (3) high - rate trickling filter; (4) activated sludge.

192. All proposed sewage treatment plants were assumed to treat typically domestic sewage; to have capacities equal to the average rates of sanitary sewage flow predicted to occur at definite future dates; to be so arranged that future expansion could be easily and economically accomplished to meet additional flow requirements; to provide maximum flexibility and ease of operation; and, if the capacity is 10 cfs or over, to utilize sludge gas for the generation of power.

193. Suitable rainfall rate curves for all drainage areas outside the boundaries of the Board are required. This will involve installation of rain gauges at strategic points throughout the Greater Vancouver Area.

194. The drainage works required in the Greater Vancouver Area within the foreseeable future were divided into several broad classifications for purposes of selecting the type of works required for a given drainage area and of estimating its cost. The classifications are: Type A, improved open channels; Type B, closed conduits; Type C, improved open channels with pumping stations and dykes; Type D, closed conduits with pumping stations and dykes.

195. The cost estimates presented

must be regarded as somewhat tentative. All cost data are, however, comparable. They have been gathered from many sources and adjusted to a common Engineering News-Record Construction Cost Index of 700. Unit costs employed for all principal types of structures involved under the various projects are stated in the report.

196. In lieu of a direct allowance for depreciation of sewerage and drainage facilities, the retirement of 25 year instalment debentures has been assumed to represent adequate provision therefor.

197. An interest rate on the bonds of four percent was selected as representing the rate at which bonds for the projects herein proposed could probably be sold.

198. Annual bond redemption and interest payments would constitute the total fixed charges for any given year.

199. The annual cost of maintaining and operating conduits or open channels has been assumed to be one quarter of one percent of the total construction cost of these facilities.

200. Maintenance and operation costs of pumping stations and sewage treatment plants have been based on a study of costs throughout California and have been adjusted to compensate for the British Columbia wage and price differential.

201. The calculated total annual costs of all sewerage and drainage facilities include the fixed charges of bond redemption and interest and the maintenance and operation costs which are comprised of all types of services and supplies.

202. Unless otherwise specifically noted, all annual costs presented in the report are the calculated averages of five year periods and of stated total periods.

Chapter 14 - Sewerage Plans for the Burrard Peninsula Section

203. The Burrard Peninsula Section is divided into three sewerage areas, namely, the Vancouver, Fraser and Coquitlam Sewerage Areas. Each was considered separately for sewerage purposes.

204. Every effort was made to incorporate the existing facilities into the overall program.

Vancouver Sewerage Area

205. The sequence of construction of the units of the various plans studied was determined by considerations of the controlling requirements. Briefly summarized, the suggested sequence is as follows:

1955 - Elimination of continuous crude sewage discharges into English Bay.

1960 - Elimination of combined sanitary and storm flow discharges into English Bay except at specified frequencies. Elimination of major portion of continuous crude sewage discharges into Vancouver Harbour

1965 - Elimination of all continuous crude sewage discharges in Vancouver Harbour.

1970 - Elimination except at certain specified frequencies of combined sanitary and storm flow discharges into the North Arm of Fraser River.

206. For the purpose of determining the best plan of sewerage it was possible to develop only two rational projects. These were studied with respect to all controlling conditions, including construction and annual costs.

207. Plan A proposes the collection of the sanitary sewage of the entire area to a high-rate primary treatment plant located on Iona Island. Effluent would be discharged to the tidal waters of Sturgeon Bank. Quantities of storm water would be conveyed to this location but would bypass the treatment works. These storm water quantities have been determined by the frequency of overflows to be per-

mitted at the existing combined sewer outfalls into English Bay and the North Arm of Fraser River. Plan A is demonstrated to be the more economical plan for the Vancouver Sewerage Area.

208. As detailed in the report, Plan A would effect an estimated savings of $2,880,000 during the 45 year period 1955-2000, over the most acceptable alternate plan.

Fraser Sewerage Area

209. In the Fraser Sewerage Area, it is proposed that in all presently unsewered areas there be provided separate collection facilities for sanitary sewage and storm water, except as noted.

210. The Fraser Sewerage Area is divided topographically into four portions. Plans have been laid out and studied in detail for three of these.

211. Sewerage of the fourth portion, the north slope of the area, has not been included in the overall planning since it is anticipated that individual collection systems, possible of the combined type, may be provided as the need arises.

212. Plan C proposes the collection of the sanitary sewage of that portion of the area tributary to Burnaby Central Valley and Brunette River to an outfall discharging into the main channel of Fraser River east of the mouth of Brunette River, and is demonstrated to be the more economical plan for that portion of the Fraser Sewerage Area draining to Still Creek, Burnaby Lake and Brunette River.

213. As detailed in the report, Plan C would effect an estimated savings of $6,255,000 during the 45 year period 1955-2000, over the most acceptable alternate plan.

214. Plan D proposes the delivery of the sanitary sewage of that portion of the area tributary to the North Arm of Fraser River to an outfall discharging into the main channel of Fraser River off the easterly end of Annacis Island, and is demonstrated to be the more economical plan.

215. As detailed in the report, Plan D would effect an estimated savings of $2,720,000 during the 40 year period 1960 - 2000, over the other most acceptable plan.

216. Plan E proposes the collection of the sanitary sewage of that portion of the area readily tributary to the existing combined sewer outfall of the Glenbrook Drainage Area. The existing outfall to the main channel of Fraser River would be extended.

217. No alternative has been considered for Plan E because of the relatively small area served and the absence of any other feasible method or point of disposal.

Coquitlam Sewerage Area

218. In the Coquitlam Sewerage Area, it is proposed that separate collection facilities be provided for sanitary sewage and storm water.

219. The Coquitlam Sewerage Area is divided topographically into four portions. Plans have been laid out and studied in detail for two of these portions.

220. The portion of the sewerage area draining eastward to Pitt River and the portion lying north of Burrard Inlet were not included in the comprehensive sewerage plans, since the nature and location of developments in these portions cannot be anticipated with accuracy at this time.

221. Plan F proposes the delivery of the sanitary sewage of that portion of the area tributary to the south shore of Burrard Inlet to an outfall located westerly of the present development of the City of Port Moody. The outfall would discharge into Burrard Inlet. This plan is demonstrated to be the more economical.

222. As detailed in the report, Plan F would effect an estimated savings of

$120,000 during the 40 year period 1960-2000, over the alternate plan.

223. Plan G proposes the delivery of the sanitary sewage of that portion of the Coquitlam Sewerage Area which is tributary to Coquitlam River to an outfall discharging into the main channel of Fraser River west of the mouth of Coquitlam River.

224. No alternative has been considered for Plan G since it is apparent that the most economic solution to the sewerage problem is to convey the sewage of the tributary area to a location where disposal may be accomplished by dilution without treatment.

Chapter 15 - Sewerage Plans for the North Shore Section

225. The North Shore Section has developed to the extent that portions of it may be regarded as metropolitan in nature.

226. Extensive experience has demonstrated the economy of cooperative sewerage undertakings. For that reason, only plans proposing the concentration of sewage from relatively large areas at one disposal point were studied in connection with this report.

227. The North Shore Section is divided into three sewerage areas, namely, Capilano, Point Atkinson and Seymour. Each was considered separately for sewerage purposes.

228. In the schemes contemplated to serve the North Shore Section, every effort was made to incorporate such sewerage facilities as are in existence into the overall program.

Capilano Sewerage Area

229. In the Capilano Sewerage Area, it is proposed that all areas be provided with separate collection facilities for sanitary sewage and storm water.

230. Two general schemes were developed; these were compared as to costs, both capital and annual, and as to other influencing factors.

231. Plan A proposes the treatment of all of the sanitary sewage of the Capilano Sewerage Area in a standard-rate primary plant to be located in the Indian Reservation adjacent to the First Narrows and the discharge of the effluent into First Narrows. Effluent would be chlorinated during critical periods. This plan is demonstrated to be the more economical.

232. As detailed in the report, Plan A would effect an estimated savings of $560,000 during the 40 year period 1960-2000, over the alternate plan.

Point Atkinson Sewerage Area

233. Development of a metropolitan nature is not anticipated within the area.

234. Conditions for the disposal of sewage in bordering waters are such that crude sewage may safely be discharged therein.

235. Sewerage requirements at present are of a local rather than general character and are deemed to be outside the scope of this report.

Seymour Sewerage Area

236. The extent and location of future development cannot now be determined with sufficient assurance to warrant even a preliminary layout of comprehensive sewerage facilities.

237. The present sewerage requirements of the Seymour Sewerage Area are similar to those of the Point Atkinson Sewerage Area.

Chapter 16 - Sewerage Plans for the Richmond Section

238. The Richmond Section is divided into two sewerage areas, namely, Lulu Island and Sea Island. Each was considered separately for sewerage purposes.

239. In this section, it is proposed that all areas be provided with separate collection facilities for sanitary sewage and storm water.

240. Plans presented in this chapter provide for sewerage of Sea Island and the western portion of Lulu Island. The settlement of Queensborough on the eastern end of Lulu Island would be served by the facilities proposed under Plan D for the Burrard Peninsula Section as described in Chapter 14 of this report.

241. Plans for sewerage of the central portion of Lulu Island were not laid out since the location and extent of future developments cannot be predicted with any assurance. If or when public sewerage is required, a system similar to that laid out for the western portion of Lulu Island could be provided.

242. Two general schemes involving three possible projects were developed for the solution of the sewerage problems of the western portion of Lulu Island and of Sea Island. These schemes were laid out and studied in detail.

243. The combination of Plan A and Plan C is demonstrated to be the more economical for the sewerage of the two areas in question.

244. Plan A proposes the collection of the sanitary sewage of the western portion of Lulu Island and its disposal without treatment through an outfall into the main channel of Fraser River.

245. Plan C proposes the conveyance of the sanitary sewage of the Sea Island Sewerage Area to the northwest corner of Sea Island from where it would be pumped to the sewage treatment plant recommended under Plan A for the Burrard Peninsula Section in Chapter 14 of this report.

246. Plans A and C will effect estimated savings of $90,000 during the 45 year period 1955-2000, over the alternate plan.

Chapter 17 - Drainage Facilities for the Greater Vancouver Area

247. The fulfilment of a properly coordinated plan for the protection of land and improvements against damage due to storm water will constitute a major undertaking in financing and construction.

248. The rapid development and growth of some of the communities in the Greater Vancouver Area has rendered certain of the natural drainage courses in the area completely inadequate.

249. Both direct and indirect benefits will accrue to all residents of the area through the correction of adverse storm drainage conditions.

250. The three natural geographic and topographic sections in the Greater Vancouver Area, namely, the Burrard Peninsula, North Shore, and Richmond Sections, constitute a logical division for storm drainage, as well as sewerage, planning

251. The delineation of drainage areas was deemed to be unnecessary for the purpose of this report. Their boundaries more properly may be determined when detailed design of facilities is undertaken.

252. The Burrard Peninsula Section is divided topographically into numerous natural drainage areas. Those lying within the City of Vancouver, the Municipality of Burnaby, and a portion of the City of New Westminster are administered by the Vancouver and Districts Joint Sewerage and Drainage Board. The Fraser, Pitt and Coquitlam Rivers have been excluded from the studies.

253. The drainage areas within the North Shore Section will be determined by the natural topography of the ground and will consist of a number of relatively small areas each with a natural outlet to a river or to tidal waters. The Lynn, Capilano and Seymour Rivers have been

excluded from the studies.

254. Existing facilities, rights-of-way and economic factors, rather than topography, determine the boundaries and sizes of the drainage areas in the Richmond Section.

255. The actual layout of storm drainage facilities has not been attempted and is deemed to be beyond the required or proper scope of this report. Information essential to the design of such works is not readily available for most of the area.

256. In connection with this survey and report, the classifications of major drainage works and their costs, as presented in Chapter 13, have been applied to the portions of the Greater Vancouver Area in which improved drainage facilities will be required.

257. The three topographic sections in the Greater Vancouver Area have been studied with respect to their general drainage requirements and the results are presented in the report.

258. The type of facilities proposed represents the minimum type which will ultimately be required for adequate drainage.

259. The estimated construction and annual costs of the major drainage facilities considered for the Greater Vancouver Area during the 45 year period 1955 - 2000, are also presented in the report.

Chapter 18 - Apportionment of Costs

260. Various factors indicate that provision of the sewerage and drainage facilities proposed in this report for the Greater Vancouver Area be through a single joint agency.

261. The apportionment of costs of the proposed sewerage and drainage facilities among the various communities in the Greater Vancouver Area should be such that each member in the joint agency is charged on the basis of benefit received.

262. Distribution of costs among the member municipalities of the existing Vancouver and Districts Joint Sewerage and Drainage Board is outlined in Section 35 of the Vancouver and Districts Joint Sewerage and Drainage Act, which is reproduced in Appendix II of this report.

263. The existing bonded indebtedness of the Board should be retired under the present methods of apportionment. A new system of apportionment apart from the operations of the existing Board should be initiated to finance the facilities proposed in this report.

264. General obligation bonds are believed to be the fairest available method of financing the construction of the various proposed works.

265. The Board of Engineers believes that the basic concept of distributing a portion of the cost for providing sewerage and drainage facilities among all members of the joint agency and the remainder among the member or members receiving direct benefits is logical and desirable.

266. It is considered that the total assessed valuation of both land and improvements is a better indication of the worth and development of an area than land alone and calculations of apportionments in connection with this report have been made on that basis.

267. For reasons given in the report, it is proposed to exclude the exempt assessed valuations of the large Provincial Government institutions in Coquitlam from the total assessed valuation of land and improvements of the municipality.

268. The University of British Columbia has been similarly excluded from the calculations on apportionment of costs.

269. Agreements should be reached with the responsible governmental agency for the payment of charges arising out of any exempt institution's participation in any sewerage or drainage facility provided by the joint agency.

270. A study of information obtained from the financial statements of the City of Vancouver and other communities in the Greater Vancouver Area indicates that the average per capita assessed valuation of land and improvements in the Greater Vancouver Area is about $1,300. This value was used in the prediction of future assessed valuations employed in this report.

271. The predicted future average assessed valuations of land and improvements for the communities within the Greater Vancouver Area during five year intervals between 1955 and 2000 are presented in the report.

272. The general method of apportionment of costs of administration, operation and maintenance, and fixed charges for bond redemption and interest as proposed by the Board of Engineers is as follows:

(1) A percentage of the total cost to be divided among all communities in the same proportion as their respective assessed valuation bears to the total assessed valuation of all communities.

(2) The remaining percentage of the total cost of work serving each sewerage or drainage area to be divided among the communities within that sewerage or drainage area. In the event that there are two or more communities within the sewerage or drainage area the cost would be apportioned in the same proportion as the assessed valuation of each community within the sewerage or drainage area bears to the total assessed valuation of the entire sewerage or drainage area.

273. The costs to each community for the works proposed in this report were investigated on a 30-70, 20-80, and 10-90 percent basis of division and are presented in the report.

274. The 30-70 basis of division is demonstrated to be the most equitable for the conditions predicted to obtain in the Greater Vancouver Area.

275. The average annual payments for each community during five year periods between 1955 and 2000 for the proposed sewerage and drainage facilities were calculated and are presented in appropriate tables.

276. The computed tax rates incident upon the construction and operation of the recommended projects for the communities in the Greater Vancouver Area are discussed and presented in Table 78 and Figures 97 to 109, inclusive.

Chapter 19 - Structure of Government

277. The Vancouver and Districts Joint Sewerage and Drainage Board is the only agency in the Greater Vancouver Area which presently constructs, maintains and operates regional sewerage and drainage facilities. The Board operates pursuant to the Vancouver and Districts Joint Sewerage and Drainage Act.

278. Existing legislation is inadequate and inappropriate for sewerage and drainage operations in the area considered in this report.

279. New legislation is required to establish a regional agency with authority to finance, construct, maintain and operate, and administer the major sewerage and drainage facilities proposed for the Greater Vancouver Area. Such an agency might well be named the Greater Vancouver Sewerage and Drainage Board.

280. Conclusions relative to the proper organization, administration and general powers, and to the cost apportionment procedure of the agency to be charged with the duty of providing major sewerage and drainage facilities in the Greater Vancouver Area are set forth in the report.

Chapter 21
Recommendations

Based on findings and conclusions developed in studying the sewerage and drainage problems of the Greater Vancouver Area, and in view of the menace to public health inherent in the recreational use of sewage contaminated waters both salt and fresh, the presence of septic tank effluent in open drains, natural and otherwise, the consequent need for adequate sewerage in many unsewered areas as well as the public welfare implications in lack of appropriate storm drainage, the Board of Engineers recommends:

For the Burrard Peninsula Sewerage Section

1. That Sewerage Plans A, C, D, E, F and G for the Burrard Peninsula Section be adopted and implemented.

Under Plan A, sanitary sewage from the University of British Columbia, the University Endowment Lands, a major portion of the City of Vancouver, and a small portion of the Municipality of Burnaby would be conveyed to a high-rate primary treatment plant on Iona Island in the North Arm of Fraser River.

Under Plans C, D, E, F and G, crude sanitary sewage from Port Coquitlam, Port Moody, New Westminster, a portion of Vancouver, the major part of Burnaby, Coquitlam, Fraser Mills and District Lot 172 would be discharged at various selected points in Burrard Inlet and the main Fraser River.

2. That land immediately be secured adjacent to outfalls proposed under Sewerage Plans C, D, F and G upon which sewage treatment plants may be constructed at some later date if changes occur in the uses of the waters of Fraser River or Burrard Inlet that make the proposed discharge of crude sewage undesirable.

3. That the areas for which no preliminary plans of sewerage are herein presented be provided with collection and disposal facilities for sanitary sewage at such times as local conditions and developments warrant, in substantial accordance with the general principles of this report.

4. That, except as noted in the report, separate collection systems for sanitary sewage and storm water be provided in all new areas sewered in the Burrard Peninsula Section.

For the North Shore Sewerage Section

5. That Sewerage Plan A for the North Shore Section be adopted and implemented.

Under Plan A, sanitary sewage from the City of North Vancouver and portions of the Municipalities of North Vancouver and West Vancouver would be conveyed to a standard-rate primary treatment plant in the Indian Reservation adjacent to the First Narrows, and dispersed after treatment into the First Narrows.

6. That, except as otherwise noted in the report, separate collection systems for sanitary sewage and storm water be provided in all new areas sewered in the North Shore Section.

7. That, although present development of the western portion of the Municipality of West Vancouver and the eastern portion of the Municipality of North Vancouver does not justify preliminary layouts of comprehensive sewerage facilities at this time, sewerage facilities be constructed to serve such portions of the areas as shall develop provided such facilities conform with the engineering, public health and aesthetic principles of this report.

For the Richmond Sewerage Section

8. That Sewerage Plans A and C for the Richmond Section be adopted and

implemented.

Under Plan A, crude sanitary sewage from the western portion of Lulu Island would be discharged to the main channel of Fraser River. Under Plan C, the sanitary sewage of Sea Island would be conveyed to the Iona Island sewage treatment plant proposed under Plan A for the Burrard Peninsula Section.

9. That separate collection systems for sanitary sewage and storm water be provided in all new areas sewered in the Richmond Section.

10. That land immediately be obtained adjacent to the outfall proposed under Plan A so that sewage treatment facilities may be constructed if treatment should become necessary in later years.

11. That the portions of Lulu Island not included in Plan A be provided with collection and disposal facilities similar to those proposed under Plan A as required.

For Drainage of the Greater Vancouver Area

12. That development and improvement of major drainage facilities be undertaken at such time as requested by the community or communities concerned.

For Apportionment of Costs

13. That, until such time as outstanding bonds are retired, the present methods of apportionment of bond redemption and interest charges of the existing Vancouver and Districts Joint Sewerage and Drainage Board be continued.

14. That the total cost of the works proposed in the report, together with the future operation and maintenance charges of the existing works of the Vancouver and Districts Joint Sewerage and Drainage Board, be apportioned among the various communities in the following manner:

(a) 70 percent to the members included in whole or in part in the sewerage or drainage area which the facility serves.

(b) 30 percent to all members.

15. That each member's share of the 70 percent shall be in the same proportion that the total assessed valuation of land and improvements of the member within a sewerage or drainage area bears to the total assessed valuation of land and improvements of the entire sewerage or drainage area for which the facility is provided.

16. That each member's share of the 30 percent shall be in the same proportion that its total assessed valuation of land and improvements bears to the total assessed valuation of land and improvements of all members.

17. That, in the case of the University Endowment Lands and District Lot 172, the regional sewerage and drainage agency enter into agreements with the Provincial Government for the payment of annual assessments as if these communities were individual members of the proposed board.

18. That the regional sewerage and drainage agency enter into agreements with the Federal or Provincial Government responsible for administration of non-taxable institutions for the payment of charges arising out of the institution's participation in any sewerage or drainage facility.

19. That the Government of the Province of British Columbia enact the necessary legislation to create the Greater Vancouver Sewerage and Drainage Board with the objects, powers, and mode of management to carry out the recommendations of this report.

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Appendix I

THE LEA REPORT OF 1913

LETTER OF TRANSMITTAL

820 New Birks Building,
Montreal.

To the Chairman and Members,
Burrard Peninsula Joint Sewerage Committee.

GENTLEMEN:—

I have the honour to submit herewith my final report on the Burrard Peninsula Joint Sewerage Scheme.

I was engaged by this Committee in June, 1911, to investigate and report on a suitable scheme. Early the following July, I visited the City to familiarize myself with local conditions and advise in preliminary moneys and the collection of data.

This work was carried on under the supervision of the City Engineer previous to the appointment in January, 1912, of a Resident Engineer, who took charge of the work and reported to me direct.

Preliminary reports were submitted on January 4th and May 31st, 1912, and two interim reports embodying the main features of the one now submitted, were presented to the Committee on December 12, 1912, and January 31, 1913.

May I, in transmitting this report, remark on the wisdom and foresight shown by those who took the initiative in promoting this scheme.

The participating Municipalities are to be congratulated upon being, I believe, the first to voluntarily attempt united action in an undertaking of such magnitude in advance of pressing necessity.

I wish further to acknowledge the hearty co-operation of the Members of the Joint Committee, and the Municipal officials, who have always shown a live interest in and an appreciation of the importance of the problems under investigation. I feel the Committee were fortunate in securing a Resident Engineer fittingly qualified for the position by his previous training and experience on the staff of an engineering firm of international reputation.

Respectfully,
(Signed) R. S. LEA.

820 New Birks Building,
Montreal, Que., Feb. 1st, 1913.

To the Chairman and Members,
Burrard Peninsula Joint Sewerage Committee.

GENTLEMEN,—

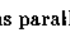
Before proceeding to a detail discussion of the various headings under which this report is written, it will, I think, be well to put before you a brief summary of the subject matter.

1. The area of the Peninsula, including New Westminster, is 55,600 acres.
1. The annual rainfall, averaged over the last seven years, is 56 inches, and the average number of wet days 174.
3. The present population (1912) is estimated at 182,000. The estimated population, 1950, is 1,400,000.
4. At the present time about 6,000 acres is more or less efficiently sewered. There is no standard basis for design or construction.
5. The investigations by the State Board of Health, New York, and the British Royal Commission, have thrown much light on the disposal of sewage in tidal waters.
6. The most suitable points of outfall are: (a) into English Bay on the line of Imperial Street; (b) into Burrard Inlet at Clark Drive and other points; (c) into Fraser River. The interception of floating matter is essential in(a) and desirable in (b). There is a possibility of some form of treatment being required in the future at (c).

It is essential that the English Bay foreshore should be preserved from pollution. The principle of the separate system is advocated on the areas draining to English Bay and False Creek. Burnaby Lake is incapable of digesting sewage, and the separate system is advocated on that area.

7. It is proposed to construct:
   (a) An interceptor along the South shore of English Bay from Imperial Street to Bridge Street, with the necessary outfall works and trunks.
   (b) An interceptor along Clark Drive from Seventh Avenue to the Inlet, with the necessary outfall works and trunks.
   (c) An interceptor South of Still Creek and Burnaby Lake, discharging to the Fraser.
   (d) Various trunks on the South slope of the Peninsula, discharging to the North Arm.
   (e) A West End interceptor and outfall, discharging beyond Brockton Point, and a trunk and outfall in Hastings Townsite.
   (f) Improvement works, Brunette River and Still Creek.
8. The estimated cost of construction during the next five years is 5 1-2 million and covers the above works. The estimated additional cost of completing the scheme to cover the whole Peninsula is 5 1-2 million during the following 25 years.
9. A Joint Sewerage Board should control and carry out the work. If the Government guarantee the bond issue it should consist of one representative appointed by the Government and one by each of the Municipalities interested.

TOPOGRAPHICAL

Plan No. 1 shows the natural features and Municipal Boundaries of the two Peninsulas. They are split up into defined drainage areas by three main ridges—two running from East to West and one from North to South, the height of land taking the form of a letter H on its side, thus: 

The first ridge runs roughly parallel to the shore of the Inlet from one-quarter (¼) to two (2) miles inland, from Port Moody to Stanley Park.

The second ridge runs parallel to the first and also to the Fraser River from the junction of the Brunette and Fraser Rivers to the extreme end of Point Grey.

The third ridge, forming the cross-bar of the H, runs in a Southerly direction from Hastings Park.

I have named the five natural drainage areas formed by these ridges by their places of discharge, and their respective acreages are set out hereunder, together with the areas in each Municipality.

Acreage of Natural Drainage Areas.

	Vancouver.	South Vancouver.	Burnaby.	Point Grey.	Total
Burrard Inlet	2,200	....	2,600	....	4,800
False Creek	3,600	2,900	....	900	7,400
English Bay	1,750	....	....	4,200	5,950
Fraser River	....	4,800	5,500	7,300	17,600
Burnaby Lake	1,700	1,200	14,100	....	17,000
	9,250	8,900	22,200	12,400	52,750

Burrard Inlet Drainage Area.

This area comprises a strip of land along the South shore of Burrard Inlet; the distance inland of the divide varying from one-quarter of a mile to two miles, and the height of land ranging from ten feet above sea level, at the narrow neck between False Creek and the Inlet, to some twelve hundred feet in the neighbourhood of Barnet.

False Creek Drainage Area

The limits of this area extend from one-quarter mile back from the creek on the North, to three and a half (3½) miles on the South-east. As a general rule the contours run parallel to the shore line of the Creek, and, with the exception of some few flat places, the slope is good. The natural drainage is by numerous small creeks.

English Bay Drainage Area.

This area lies to the South of English Bay and to the West of the False Creek area. The Easterly half of this area is high with a steep fall to the water. The natural drainage of the Westerly half of this area is through a flat valley running in a South-easterly direction to the Bay. There is a small low level area near Kitsilano Beach.

Fraser River Drainage Area.

This area includes the whole of the Southern portion of the Peninsula. Starting from the Brunette River on the East, the ridge runs rapidly to an elevation of four hundred feet above high water, continuing almost due West at an elevation varying between three and four hundred feet to Point Grey, where the ground falls abruptly to sea level. Generally speaking, the contours run parallel to the river and the ridge, although their regularity is somewhat broken by deep ravines and creeks, especially in South Vancouver. There are two low lying tracts, one lying within the bend of the river in the South of Burnaby, and the other in Point Grey in the Indian Reserve. Towards Point Grey the ground rises almost precipitously from the river flats.

Burnaby Lake Drainage Area.

This area comes next to the Fraser River area in size, and from a drainage point of view presents the most difficulties. In shape it resembles a large dish. Its boundaries vary in elevation from some 1200 feet above sea level, near Barnet on the North to just over a hundred near Trout Lake. The Northern slope rises gradually to the ridge. This has not been contoured. It is mostly uncleared. The height of the divide from the Inlet area varies from 300 feet to the 1200 feet elevation near Barnet. The Southern slope is more broken than the Northern, and there are several small drainage areas. The Westerly portion of the area is drained by a long flat creek, known as Still Creek, which divides into two branches near the Municipal Boundary and discharges into Burnaby Lake, to which most of the Easterly portion drains. The outlet from the Lake is by the Brunette River, which discharges into the Fraser just above New Westminster.

Meteorological.

The annual rainfall and number of wet days for the past seven years are set out hereunder. The records have been supplied by Mr. Shearman, the Government Meteorologist. The rain gauge is located at 2273 Sixth Avenue.

Summary of Wet and Dry Days from January, 1906, to December, 1912.

Month	1906		1907		1908		1909		1910		1911		1912	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
January ..	22	9	13	18	23	8	21	10	22	9	25	6	22	9
February	15	13	15	13	20	9	24	4	16	12	16	12	17	12
March	11	20	18	13	18	13	14	17	18	13	11	20	5	26
April	13	17	11	19	14	16	11	19	15	15	8	22	13	17
May	15	16	7	24	15	16	17	14	10	21	13	18	11	20
June	17	13	10	20	7	23	7	23	11	19	6	24	9	21
July	2	29	4	27	6	25	15	16	3	28	5	26	10	21
August ..	4	27	11	20	7	24	7	24	8	23	7	24	11	20
Sept.	14	16	10	20	11	19	11	19	9	21	15	15	8	22
October ..	22	9	14	17	19	12	18	13	18	13	12	19	20	11
Novem. ..	19	11	23	7	20	10	23	7	23	7	23	7	23	7
Decem. ..	24	7	20	11	20	11	17	14	25	6	27	4	26	5
Totals	178	187	156	209	180	186	185	180	178	187	168	197	175	191
Total Rainfall	58.55		57.59		62.69		58.53		58.36		52.26			

NOTE.—When rainfall is 0.01 inch or over, the day is considered to be wet.

It is interesting to note that although Vancouver has an annual rainfall of more than twice that of London, England, Vancouver has fewer wet days in the year. The actual figures for London, England, are:—

	Total Rainfall.	Wet Days	Dry Days
1909	26.75	190	175
1910	25.08	186	179

The gauges are old-fashioned, readings being taken only twice a day, consequently there is no record of the short rain storms of high intensity of the thunder storm type, the chief controlling factor in sewer design. Fortunately, this type rarely occurs. The meteorological peculiarity of the district is a continuous rate of moderate intensity—a peculiarity common to other parts of the Pacific Coast.

Very complete records have been kept in the past at San Francisco and Seattle, and I am indebted to the City Engineer of New Westminster for the records of the automatic gauge established there at the end of 1911.

From the foregoing data and a close study of local conditions, I have been able to formulate what should be a reliable estimate of the maximum probable rate of rainfall for any period from five to sixty minutes.

More information should be obtained on this question, and I advise the establishment of ten automatic recording rain gauges in different parts of the Peninsula.

Plate 2 shows:—

(1) Estimated maximum rate of rainfall over periods from five to sixty minutes. The circles show the intensity of the heaviest storms recorded during the year 1912 at New Westminster.

(2) An analysis of the intensity of rainfall falling in one hour, computed from the New Westminster records. It is a noticeable fact that on only three days did over one-quarter inch of rain fall in one hour. This point will be referred to later.

(3) The direction of winds in English Bay averaged over the years 1910 and 1911. The horizontal lines represent weeks. Off shore winds, i.e., Easterly, are the prevailing winds.

Population.

One of the chief problems an Engineer has to deal with in the layout and design of a large sewerage scheme is of an economic nature. To construct a sewer that becomes too small for the needs of a district and has to be rebuilt before the loan under which it was constructed, is repaid, is bad economics, and it is equally bad to burden the ratepayers of to-day with a large capital outlay on a sewer that will not be called upon to do its full duty till many years after the completion of the payment of the loan.

The usual life of sewer construction bonds is forty years, but there is no reason why the works should not be in as good a condition and as capable of doing the work they were designed for far beyond this period, provided the proper skilled supervision is given in their design and construction, and proper control is exercised over the expansion of the scheme to deal with the growth in development of the outside areas. The high and low level interceptors in the Toronto Main Drainage Scheme, the largest in this country, were designed for thirty-eight years, and I propose to apply this figure to Greater Vancouver and design for the year 1950—or, to be more correct—for the population which I estimate will be resident on the Peninsula by that time.

In the case of Burrard Peninsula, Nature has fixed the limits and areas of the different watersheds, so the problem is somewhat simplified.

The forecasting of the growth of population in a well-developed and settled country is not an easy matter. In a fast developing new country such as this it becomes increasingly difficult, and really the only logical basis on which one can found an estimate is the actual growth of other cities in the past, in conjunction with such other conditions as are likely to affect the City's growth.

Plate No. 3 shows the actual rate of growth of different cities on this continent applied to Vancouver. Thus, if Greater Vancouver grows at the same rate as Boston, the population in 1950 will be 500,000; while if it grows at the same rate as Chicago, it will be 2,000,000. There is a wide difference between these figures, and somewhere between the two lies the true value of the unknown quantity. Taking into consideration the awakening of the great nations of the West, China and Japan, the construction of the Panama Canal, the railway developments in British Columbia, together with the natural harbour facilities in and around Burrard Peninsula, I do not think that I am taking an exaggerated view when I estimate the population in the year 1950 at 1,400,000, including New Westminster. This rate of growth is between that of New York and Chicago, and is shown on the diagram. The population may not follow the curve shown; it may increase more rapidly at first and drop off later.

It is really unimportant whether the population reaches that actual figure by 1950 or not. The scheme which I will submit to you will be designed to deal with the sewage of a population of 1,217,000 persons within the present Municipal Boundaries of the City of Vancouver, South Vancouver, Burnaby, and Point Grey, together with the rainfall from the areas as then developed.

The distribution of the population is another very important point in the problem. The table below shows the present distribution and density of population on the City of Vancouver by wards.

These figures apply to residential population only. There is an additional "day" population which, in the down-town business section, may increase the above figures by several hundred per cent. For example, the actual density per acre in the case of the new B. C. Electric Building amounts to 1,000, while in the Rogers Building it is estimated at 1,400.

Where the combined system of sewerage is in operation, however, once the population reaches 100 per acre the size of the trunk sewer is not affected by any further increase, as the controlling factor is not the actual sewage flow, but the run-off from the rain falling on the impervious area. In other words, up to a population of 100 per acre the surface is partly porous and a portion of the rainfall soaks away into the ground. Above a population of 100 per acre, provision must be made for dealing with practically the whole of the rainfall. These figures are, of course, used in a general sense applying to large areas.

Area and Population of City of Vancouver by Wards.

Ward	Population	Area	Population per Acre
1	21,386	670	31.4
2	15,120	400	38.0
3	13,342	440	33.0
4	25,439	1,100	23.0
5	17,923	1,260	14.0
6	20,155	2,040	10.0
7	4,711	2,980	1.6
8	4,024	360	11.0
Total	122,100	9,250	13.2 average

Plan No. 4 shows my estimate of the population density in 1950. The figures given must be looked on as averages for the particular area they apply to. They give an average over the whole Peninsula of 25.2 persons per acre. The population per acre of other large cities on this continent are:—

New York	26	per acre
Chicago	18.6	" "
Pittsburgh	20.5	" "
Philadelphia	18.6	" "
Boston	26	" "
Baltimore	28.6	" "

Existing Sewer Areas.

The areas already sewered, or provided for by trunk sewers, are shown on Plan No. 10, hatched green. The sewers have been designed on varying data and on different systems and forms of construction. Many of them will have to be enlarged, or supplementary sewers constructed. The City of Vancouver has already constructed portions of the main trunk sewers, which form a part of the scheme, at Balaclava Street, Bridge Street and China Creek; and Point Grey has recently constructed a trunk sewer outlet at Kaye Road. Burnaby has under consideration a joint scheme with New Westminster for a small portion of the Municipality draining naturally through that city.

The Disposal and Collection of Sewage.

The subject of predominating importance in this investigation is the location of outfalls in the tidal bays and estuaries adjacent to the Peninsula. I believe, therefore, that it will assist in the desired appreciation of the studies leading to the conclusions, if their consideration is preceded by a discussion of the principles underlying the theory and practice of sewage disposal, with particular regard to dilution in natural waters.

No attempt will be made to qualify the general statements herein employed, by enumerating exceptions to which they may be subject, but which are of rare, rather than of fundamental importance.

The dry weather sewage of a community has been defined as its water supply after it has been used; that is to say, it is composed of clean water, carrying away with it in solution and suspension, a relatively small proportion of discarded wastes—scarcely as much as one part by weight in a thousand—under prevailing and anticipated conditions on the Peninsula. These discarded wastes are present in the sewage, in about equal quantities of mineral and organic matter. The one-half part of unstable organic matter is the potentially offensive constituent in the one thousand parts of sewage; which, as a whole, is dangerous to the public health, chiefly because there may be some disease-producing bacteria amongst the multitude of useful organisms it contains.

The organic content of sewage, in common with all dead, unstable matter, is eventually converted into the inoffensive mineral form by oxidation. Bacteria are the most important natural agents at work in the accomplishment of this result, by virtue of their activity and efficiency in converting organic matter to a readily oxidizable form.

When this bacterial action takes place in the presence of air, or other available sources of oxygen, the resulting products are not offensive; but after the supply of oxygen is exhausted, the process is accompanied by the evolution of foul-smelling odors, noxious gases, and other disagreeable manifestations of what has been termed putrefaction.

About one-half of the organic content of sewage above referred to, is present in solution, and the remainder as solid matter, which must, however, be liquefied preliminary to its final oxidation.

In a properly constructed sewerage system, the dissolved oxygen available in, or taken up by, the sewage, is sufficient to meet the demands of the readily oxidizable matter, and the sewage reaches the point of disposal in a fresh, and only mildly disagreeable condition. When discharged into a body of water, the soluble matter mixes with, and is diluted by the water to a varying degree; the lighter solids float, some very finely divided and semi-solid matter, differing but little in specific gravity from the water itself, is carried in suspension, while the heavier solids tend to sink to the bottom, obviously to an extent depending on the transporting power of the prevailing currents.

The floating solids are gradually broken up by mechanical forces, become waterlogged, or lose their buoyancy by the escape of entrained gases, and in a large measure sink to the bottom along with some of the particles originally in suspension.

These settled or precipitated sewage solids are commonly known as sludge; and when accumulated to any considerable depth on the bottom, the activities of the bacteria and other organisms deplete the available oxygen within the mass. Consequently, the process of decomposition, which follows, is accompanied by the production of foul-smelling gases. As a result of this decomposition, some of the organic sludge is liquefied, while the major portion is changed from its originally offensive to a stable inoffensive condition. The intensity of this action is promoted by a circulation set up in the mass of the sludge, incidental to the release of the gases therefrom; which, in their ascent through the water, carry along with them, and disperse, particles and masses of decaying sludge; and, in their subsequent escape to the atmosphere, cause the bubbling that commonly occurs at the surface of waters overlying foul bottoms.

The liquid products of the original solids diffuse through the water, and together with the organic matter originally in solution, are ultimately oxidized to inoffensive mineral forms, either directly or after conversion by the bacteria to a readily oxidizable condition.

The oxygen required for these purifying processes, though obtained to some extent by the reduction of its compounds, is derived for the most part from the dissolved oxygen stored in the water, which is replenished by absorption from the atmosphere. There is a limit to which this dissolved oxygen can be reduced without objectionable results. A higher percentage of residual oxygen is needed during the warm summer weather. Should the supply prove insufficient to maintain this safe margin of residual oxygen, the offensive conditions peculiar to putrefaction may here again prevail in time, and, in extreme cases, the diluting water will become dark colored, foul-smelling, and exhale offensive odors.

The surface water discharged from storm water drains carries large quantities of silt in suspension, which settle readily to form deposits. Washings from streets at the beginning of storms may be charged with considerable organic filth, also, but not to such an extent nor of such frequent occurrence, as to give rise to the offensive conditions resulting from the organic deposits of domestic sewage. It is possible, however, that the silt discharged from combined sewers, may, under some circumstances, be so impregnated with organic filth as to become appreciably offensive when accumulated in deposits. Deposits of both organic and inorganic matter, it is to be noted, are often responsible for the obstruction of navigable channels.

The offensive conditions previously referred to must inevitably result, to some extent, wherever the bacterial decomposition of organic matter in sewage is obliged to take place in the absence of an adequate supply of oxygen. On the other hand, when sewage is discharged into a current of sufficient strength to prevent the deposition of the heavier organic solids, or to so break up and disperse them, that any escaping complete oxidation while in suspension finally subside without concentration over a large area, the digestion of these solids takes place without any noticeable offence.

In like manner, under favourable circumstances, no offence is created in the further bacterial decomposition and final oxidation of the unstable liquid products of sludge digestion, or of the organic matter originally in solution. The essential condition to this end is: that the demand for oxygen necessary for the destruction of the organic content of sewage, shall not overtax the capacity of the diluting water to furnish it. To maintain this condition, it will not alone suffice to discharge the sewage into a body of water capable of its assimilation. Obviously, in order that the fullest advantage may be taken of the purifying agencies and properties inherent in the diluting water, the sewage must be brought under the influence of these agencies. That is to say, it must be discharged where it will be subject to such action of the currents, winds and other allied factors, as will effect its adequate dilution in the surrounding water.

So far reference has been made only to the grosser and more disagreeable pollution that may result from the disposal of sewage by dilution. There are other features of importance in this connection. Apart from the presence of floating solids of sewage origin, the discharge of a large volume of sewage into a relative clean body of water, is usually attended by an appreciable turbidity and discolouration, in the immediate vicinity of (and to a diminishing extent remote from) the outlet. Another characteristic indication of a sewer outlet is the existence of a thin film of grease or oily sleek overlying the water.

Occasionally, where large quantities of industrial wastes are discharged into the sewers, this discolouration may be intense and extensive in its effects; grease and oily wastes may also accumulate to cause very unsightly and nauseating conditions at the surface, besides interfering with the freshening of the water by aeration.

Generally speaking, however, when the discharge is into a current of sufficient strength to prevent local deposits of organic matter, the conditions, peculiar to the vicinity of a sewer outlet, are not offensive to any considerable degree, and are objectionable chiefly because of what they imply. Floating particles of garbage, pieces of paper and fecal matter, together with the oily sleek on the surface, are of course unsightly, and, though gradually broken up and dispersed by the action of winds, waves and currents, may create a nuisance when washed ashore, or to localities devoted to bathing, boating or other forms of recreation.

So far as definite information on the subject goes, it appears that a large majority of the pathogenic bacteria, originally present in sewage, die within a week or ten days in natural waters. Some of the more resistant forms may, however, survive and retain their virulence for a much longer time. The presence of disease-producing germs in the diluting water, constitutes a menace to the public health to a degree depending on the uses to which the water is put. The chief danger arises from the possible infection of water and ice supplies and shell fish. Opportunities for the transmission of disease are also afforded to some extent in connection with bathing, boating, handling driftwood and logs, and in other pursuits common to a waterfront.

There is another feature of great importance in connection with the subject of disposal of sewage by dilution. The presence of sewage in inland or tidal waters may result in the reduction and destruction of the fish life naturally abounding therein. This may be partly due to the fish leaving a neighbourhood where the environment is, in a general way, unfavourable to them. Moreover, certain constituents of sewage, particularly that of industrial origin, may exert a direct toxic action on fish, or so affect their respiratory organs that they die of suffocation. Usually, however, the presence of sewage in natural waters is prejudical to fish, chiefly because it may be the means of depleting the supply of oxygen, below the saturation value, favourable to, or even essential for, their preservation.

On the other hand, it is to be noted that sewage may serve as the source of part of their food supply. This important service in the economy of nature is made possible by various micro-organisms, the lower assimilating the constituents of food value in the sewage and serving as a food themselves for more advanced types of aquatic life, finally developing to a form on which young fish can feed. It has been found also that under some circumstances the discharge of sewage into tidal waters is responsible for the growth of certain green seaweeds, which may become stranded on the foreshores, and constitute a nuisance by their subsequent offensive decomposition.

The whole question of the disposal of sewage by dilution in natural waters calls for the consideration, in the first place, of the objectionable conditions that may be created therein, and, in the second place, of the possibility of these conditions proving a nuisance. These objectionable features have already been discussed in detail, and may be summarized as follows:—

(1) The infection of water by pathogenic bacteria.

(2) The turbidity, discolouration and unsightly surface conditions in the vicinity of, and remote from the outlet; usually only mildly disagreeable, but occasionally decidedly so.

(3) The evolution of foul odors, and the unsightly appearance of the water resulting from the putrefaction of sludge deposits, or from the putrefaction of the organic matter in solution in the water, following the exhaustion of the oxygen therefrom.

(4) Pollution of the foreshores by the offensive decomposition of stranded sewage solids, and aquatic plants which thrive because of the presence of sewage.

(5) The introduction into the water of substances which are either toxic to fish or deprive them of the oxygen necessary for their preservation.

(6) The obstruction of otherwise navigable channels by deposits of organic solids and silt.

Consequences of this nature can always be minimized, and very often avoided altogether, by the exercise of care and judgment in locating the outfall, and in providing facilities for the proper discharge of the sewage.

It is essentially important to take the best advantage of such factors as will insure the prompt and adequate dilution of the sewage by inter-mixture with the diluting water. In so far as aesthetic nuisances are concerned, the organic solids are the hardest to deal with.

Experience and research have gone far towards establishing what degree of dilution may be safely regarded as adequate for the prevention of offensive conditions. In so far as this experience relates to the widely practiced custom of disposal in rivers, it points to the general conclusion that a flow of six or seven cubic feet per second of well aerated water, per 1000 people contributing sewage to the stream, is sufficient for its satisfactory assimilation.

Assuming that a river water is, at any point in its course, free from the elements of pollution, the quantity of sewage that can be safely discharged at this point without creating offensive conditions, obviously depends not only on the population already tributary to the river below, but on the time available for the purification of the up-stream sewage, before it enters a zone subject to pollution from the down-stream population.

Similarly, it is evident that a very low dilution may suffice for sewage discharged into a river, which in a short time empties into and merges with a relatively large body of well aerated water.

Variations in the composition of the sewage, or of the diluting water itself, may, however, introduce mischievous complications that are neither expected nor always clearly understood. It is still more difficult to predetermine the efficiency of the dilution effected by the factors favourable thereto. This is particularly true of tidal waters since the flow past the outlet is not continuous, but is periodically checked or reversed. Other modifying factors that call for attention in connection with the disposal of sewage by dilution in salt or brackish waters, are:—

(1) There is a stronger tendency for the sewage to rise and form a surface stratum in salt than in fresh water, on account of the higher specific gravity of the salt water. This retards the diffusion and dilution of the sewage, and aggravates the disagreeable surface conditions in the vicinity of the outlet.

(2) Salt water also appears to precipitate more of the finely divided colloidal matter in sewage, to add to troublesome sludge deposits.

(3) The decomposition of sludge deposits seems to be more complete and offensive in salt water, and the resulting products either directly or indirectly make a heavier demand on the dissolved oxygen stored in the water.

(4) Normally, salt water contains less dissolved oxygen than fresh water, but is capable of absorbing it at a higher rate from the atmosphere, under similar conditions affecting saturation and aeration.

The dilution required for the inoffensive assimilation of sewage by salt water has not been so closely approximated as in the case of fresh water. It is a matter much more difficult of determination from observations and studies of the results of practice. It is known that the oxidation of the sewage entering the upper reaches of some long rivers is practically completed before it reaches other points of pollution or finally enters the ocean. On the other hand, a portion of the sewage discharged into tidal harbors and estuaries is carried out by the tides in only a partially fermented condition; moreover, the re-aeration of the waters remaining at low tide by the more highly saturated waters of the rising tide, and the inflow of varying quantities of land water add to the complexity of the circumstances as a basis for determining either the degree of the dilution or a measure of the purification thereby effected. It would appear, however, that fresh water has a greater capacity than salt water for the inoffensive assimilation of sewage.

Another subject with regard to which conflicting opinions are held by those most familiar with it, is the safe margin of residual dissolved oxygen that must be maintained for the preservation of fish life in either fresh or salt water. All are agreed that a higher saturation percentage is required for the more active species, but differ widely in an estimate of this percentage.

I do not propose to advance definite statements with respect to a disputed subject, or to question the reliability of conclusions deduced from special investigations of the principles involved. However, considering the capacity of fresh water for the digestion of sewage, and making due allowances for the effects of the dissimilar properties of salt water, it would seem that a dilution of from one in seventy to one in a hundred should be sufficient to prevent offensive results following the discharge of sewage of ordinary strength into well aerated sea water; and that a dilution of from one in a hundred to one in one hundred and twenty-five should be adequate for the protection of major fish life in fresh and salt water.

It will be understood that the previous remarks are of a general character and do not apply to offensive conditions arising from the putrefaction of subsided organic solids, or to those conditions which are objectionable in appearance only.

Assuming that any or all of the objectionable features already referred to, do prevail, the degree to which they can be said to constitute a nuisance depends on the uses to which the waters and shores are put, and on the density of, and proximity thereto, of human habitations. For instance, to cite an extreme case: a river might be intensely polluted by the sewage from a community without causing a nuisance, provided it flowed away to the sea through an uninhabited country, was not navigable, nor suitable for purposes of recreation, and was not, in its natural state, frequented by fish.

Usually, however, the existence of pollution establishes a nuisance, either in: (1) the hygienic sense, such as the infection by pathogenic bacteria of water supplies, ice supplies, shell fish, bathing waters, and, of less importance in this sense, the nuisances due to the foul odors of putrefaction; or in the (2) aesthetic sense, that is, arising from conditions that are offensive to the senses, such as floating solids of evident sewage origin, grease, scum, discoloured waters, and putrefactive odors; and, finally, in what may be called the (3) economic sense, the most important of which are the destruction of fish life and the obstruction of navigable channels.

Some idea of the quantity of suspended solids discharged from sewers can be formed from an estimate submitted by the New York Sewerage Commission with respect to the sewage of that city. These Commissioners estimate that for each thousand persons tributary to the sewers, forty-five tons of suspended solids are discharged annually. Moreover, the forty-five tons of solids, when mixed with the harbor waters, form over 2,200 tons of wet sludge, having a bulk of approximately 2,500 cubic yards.

When it becomes impossible, or economically impracticable, to dispose of sewage by dilution, without creating a nuisance of some kind, recourse must be had to such artifical treatment of the sewage as will eliminate the particular features and constituents responsible for the nuisance.

Where the nuisances are caused by floating matters, screens and grease interceptors are provided for their separation. When silt is the objectionable feature, blocking the outfall pipe or channels in the vicinity of the outlet, it can be removed by passing the sewage through a grit chamber with reduced velocity to allow the silt to subside. When, as frequently does happen, the trouble is due to sludge deposits, the sewage is passed very slowly through sedimentation basins to effect the removal of all but the very finest of the suspended organic matter; occasionally chemical precipitants are used to assist in the sedimentation.

The necessity of keeping the sewage in a fresh state limits the duration of the sedimentation period, and about one-third of the organic matter, together with about the same proportion of bacteria can be removed by plain sedimentation. The removal of the heavier organic solids simplifies the problem of disposal with respect to the formation of troublesome sludge deposits, and also to a less extent with respect to the degree of dilution required for the satisfactory assimilation of the sewage. When the available quantity of diluting water is incapable of effecting this latter purpose, the load on the water must be lightened by the oxidation of the organic matter in the subsided sewage, preliminary to its final discharge. That is to say, the sewage must be submitted to a process of so-called purification.

Broad Irrigation, or sewage farming, was one of the earliest methods adopted for this purpose. It originated and has had its most extensive application in England. Later, an allied method, known as "Intermittent Filtration," came into practice in the New England States. The natural sandy formation there permits satisfactory treatment at a higher rate than is favourable for the cultivation of most crops.

Both of these methods have been continued where large areas of suitable land are available. Still later, Contact Beds, and more recently, Sprinkling Filters, were developed in England and have come into general recognition. The filtering medium in both types consists of some such easily procurable material as broken stone. Their method of operation, however, is entirely different.

With Contact Beds, the sewage is admitted to the tanks containing the filtering medium, and is retained there for sufficient time to permit the desired sedimentation, bacterial action and oxidation; the sewage is then drained off, and further opportunity is afforded for the digestion of the retained solids, by allowing the tank to remain empty for a time, before re-charging. Where the degree of purification requires it, the whole process is repeated on secondary beds. The effluent is acceptably clear, and, more important still, is oxidized to a stable condition. The bacteria also are largely reduced.

In Sprinkling Filters, the sewage is sprayed over a coarser medium, through which it freely percolates. The effluent from these filters is oxidized to a condition of stability, and the bacteria largely reduced. The effluent is not clear, but the solids still in suspension are relatively stable and readily subside with a few hours' sedimentation. Preliminary clarification is favourable to the successful and economical operation of Contact Beds, Sprinkling Filters, and to a less extent Intermittent Sand Filters.

Sprinkling Filters and Contact Beds have largely superceded the earlier land treatment methods, chiefly because the comparatively small area required has made their general adoption possible. Sprinkling Filters are a marked improvement over Contact Beds in this respect.

The very great disparity in the areas—it is usually found necessary to provide for the various methods of purification—can be fairly represented by stating that the sewage which would require 200 acres for its disposal by Broad Irrigation, can be treated on 25 acres by Intermittent Filtration, on two to three acres in Contact Beds, and on one acre of Sprinkling Filters.

With respect to the character of the effluent produced, the modern methods do not compare with the earlier land treatments. The effluent from a well conducted sewage farm approximates the quality of a good drinking water. The effluent from Intermittent Filters is not quite so good, although all but one or two per cent. of the bacteria are removed, and in appearance it is all that can be desired.

Contact Beds and Sprinkling Filters, in conjunction with proper facilities for screening and subsidence, can nevertheless produce a stable effluent of satisfactory appearance, that is to say, there is little likelihood of it becoming offensive to the senses, and it can be safely discharged into a harbour or stream, without danger of creating a nuisance in either the aesthetic or commercial sense.

Very often, however, bacterial contamination is the chief objection, and at times the sole objection to the discharge of crude sewage into natural waters. It has already been pointed out that sedimentation and the different processes of purification are effective to a varying degree in removing the bacteria. Moreover, subsided sewage may be sterilized by treatment with some such disinfectant as "Hypochlorite of Lime." This treatment may be applied, either in conjunction with, or without, any of the processes of purification, according as it may be necessary or expedient from economical reasons to do so. Where the sewage is charged with trade wastes, more elaborate clarification plants or special processes may be required for its treatment.

In short, it is possible, by artifical treatment of sewage, to effect almost any desired degree of purification. It is largely a question of expense.

Apart from the initial cost of the works, their successful operation requires more intelligent attention, and entails a greater expense, the further the purification is carried. Moreover, the operation of a disposal plant in the vicinity of human habitations is subject, usually to sentimental, and occasionally to real objections.

Where inland and tidal waters are available for the convenient disposal of sewage by dilution, obviously the logical method of procedure is to utilize the natural purifying agencies and properties inherent to these waters in so far as it can be safely and satisfactorily done; resorting to artificial treatment for the removal of only such pollution as may interfere with the accomplishment of this result.

The tidal bays and estuaries surrounding the Burrard Peninsula are destined to become by necessity and adaptability the scene of extensive harbor developments and commercial activity. The extent to which it can be safely planned to make use of them for the disposal therein of sewage on the Peninsula, is limited in part by the standard of cleanliness that should be maintained around a busy water front.

The Metropolitan Sewerage Commission of New York has during the past six years conducted a most exhaustive investigation, partly for the purpose of establishing such a standard for New York harbor. The New York Bay Pollution Commission had previously made a study of the situation on somewhat similar lines from 1903 to 1906. At the instance of the Board of Apportionment, an independent enquiry was undertaken in 1909 and completed two years later.

The Metropolitan Commission had the staff, means and facilities at their disposal, to carry out on a large scale many experiments and tests, having an important bearing on the effects produced by the discharge of sewage into tidal waters. The five members of the Commission were men of wide experience and of recognized ability, and they had the benefit of the independent opinions of eight experts, selected from the best in the profession, including a leading authority on harbor pollution from the Old Country.

Considering the scope and nature of the enquiry, the views of the New York Commission as expressed in their recommendations, submitted a few months ago to that corporation, are worthy of the highest consideration and will be quoted here in so far as they apply to conditions covered by this investigation.

General Recommendations of the New York Sewerage Commission as to the Degree of Cleanliness That Should Be Maintained in the Harbour Waters. August 12, 1912.

1. Garbage, offal or solid matter recognizable as of sewage origin, shall not be visible in any of the harbor waters.

2. Marked discoloration or turbidity due to sewage or trade wastes, effervescence, or oily sleek, odor or deposits, shall not occur, except in the immediate vicinity of sewer outfalls, and then only to such an extent and in such places as may be permitted by the authority having jurisdiction over the sanitary conditions of the harbor.

3. The discharge of sewage shall not materially contribute to the formation of deposits injurious to navigation.

4. Except in the immediate vicinity of docks and piers and sewer outfalls, the dissolved oxygen in the water shall not fall below 3.0 cubic centimeters per litre of water. Near docks and piers there should always be sufficient oxygen in the water to prevent nuisance from odors.

5. The quality of water at points suitable for bathing or oyster culture should conform substantially as to bacterial purity to a drinking water standard.

There are two recognized systems for collecting and conveying to the point of disposal the domestic and industrial wastes of a community, and the surface water from its drainage area.

(1) The separate system, where the domestic and industrial waste are kept entirely separate from the surface water flow, separate channels being provided for each.

(2) The combined system, where the domestic and industrial wastes and the surface water flow into one common sewer.

In a report to the Joint Committee on May 31, 1912, I referred to the question with special reference to English Bay and False Creek areas, and I expressed myself as being in favor of the principle of the separate system for these areas, inasmuch as it permits of fuller advantage being taken of the Main Drainage Scheme in keeping False Creek and the foreshore of English Bay unpolluted.

In the design of a large sewerage system such as this, the Engineer is confronted by two distinct problems:—

(a) The collection and disposal of the domestic and trade liquid refuse of the community, defined as sewage.

(b) The collection and disposal of the rainfall running off the paved and impervious surfaces, defined as surface water.

In the first case, the **collection** is a comparatively simple matter, as the quantity of sewage from any given area can be accurately ascertained and estimated, while the disposal of the collected sewage without nuisance or injury to public health is often a matter of considerable difficulty; in the second case, the conditions are reversed, the **collection** of the surface water is the principal problem, its **disposal**, as it is practically unpolluted, being a comparatively simple matter.

The relative amounts of surface waters and sewage vary, of course, with local conditions. On Burrard Peninsula, taking an average area of, say, one thousand acres and a population of forty per acre, it would be necessary to provide a channel with a capacity of fifteen cubic feet per second to deal with the maximum sewage flow; but to take off the maximum flow of surface water from the same area, a channel capacity of five hundred cubic feet would be required.

Now as to the disposal of these two liquids. The sewage, which is of small volume and constant flow but highly polluted, and the surface water, which is of large volume, occasional flow and comparatively innocuous.

It is obvious that surface water can be discharged into many natural channels and under conditions where the discharge of crude sewage would be highly objectionable.

Take for example, False Creek, Burnaby Lake and the many creeks draining to English Bay and the Fraser River; all these can be utilized for the disposal of surface water. Of course, as a district develops, land becomes valuable and the creeks have to be culverted and filled in. But, provided the culverts are properly designed, there is no reason why these creeks should not continue to carry out the functions that Nature constructed them for, that is, the removal of surface water from their natural drainage area.

The disposal of the sewage is a very different problem, and in the case of English Bay and False Creek areas, it is necessary to intercept it by an expensive sewer and outfall to carry it to a point off Imperial Street, where it can be disposed of by dilution and dispersion without nuisance or injury to public health. The North Arm of the Fraser River can digest the small quantity of sewage which now discharges there, but as the contributary population increases, the sewage flow will increase, and a time will undoubtedly come when either an interceptor will have to be constructed or some form of treatment adopted.

As I stated in my previous report—modern practice where sewage has to be treated or carried long distances by interceptors, favours the separate system.

The chief argument against the adoption of the separate system is on the ground of the alleged greater expense it involves; and, as a general proposition, it is true that, with a common outlet it does cost more to construct a system of separate sewers and storm water drains than to construct a combined system. What this extra expense may amount to in any particular case, however, depends on the extent to which local conditions may introduce modifying factors that tend to equalize the costs. In this connection it is to be noted that:—

(1) A system of surface water drains may be less extensive than a system that has to provide for the removal of sanitary sewage, depending on the gutter grades and the intensity of rainfall.

(2) Inasmuch as the minimum depth to which surface water drains must be laid, is governed by considerations of depth of cover rather than provisions for house drainage, the excavations for these conduits may be much less where the separate system is adopted.

(3) Moreover, since the consequences that may follow overcharging during excessive storms are not likely to be so disastrous and objectionable in the case of a surface water drain as from a combined sewer, it may not be necessary in some instances to provide the same capacity for surface water, where the separate system is adopted, as might seem desirable with the combined system.

(4) A somewhat cheaper construction may be permissible in a surface water drain than in a combined sewer, considering that the drain is not subject to the same scouring action, that the objection to worn surfaces and leakage are not usually so serious in a drain as in a sewer, and, finally, that better opportunities are afforded for the repair of a conduit in which the flow is only periodical.

It must be remembered that the previous discussion does not take into consideration special provisions for the disposal of sanitary sewage.

Whilst nearly every modern Sanitarian admits that the separate is the better system, it is looked on as somewhat of a luxury. It must not be forgotten, however, that the luxury of to-day becomes the necessity of to-morrow, and in considering a scheme of this magnitude, the trend of modern practice must be taken into account rather than the actual methods in use at the present time.

In Germany, one of the pioneer countries in sewage disposal work, it has been largely adopted. In Boston, in 1903, an Act was passed forcing estate owners to construct a surface water drain and a sanitary sewer, and giving the Municipalities power to expend one-twentieth of one per cent. of their taxable valuation, outside the statutory debt limit, in the construction of the separate sewers. In the new Federal Capital of Australia, the separate system has been adopted. On the other hand, the British Royal Commission on Sewage Disposal expresses the opinion that the system is impracticable for large towns. Conditions in England, however, are very different to conditions here, and even there the trend of opinion is shown very markedly in a recent discussion on the Glasgow Main Drainage Works, where Maurice Fitzmaurice stated in effect that they had nearly trebled their original allowance per acre for storm water during the last ten years.

It would be difficult at this time in advance of complete subdivisions and street profiles, to submit a reliable comparison of the initial costs of the separate and combined systems over the whole Peninsula, or even on those areas where the separate system is recommended. It can be said, however, that the conditions tend to equalize the first costs of the two systems, particularly in so far as good grades and moderate intensity of rainfall are conducive to this end.

There is another way in which the separate system will prove more economical, and that is in deferring capital expenditure. The conditions on the Peninsula are such that in many localities the removal of surface water is not of such a pressing necessity as the removal of the sewage, and in many cases the construction of the surface water trunks could be deferred.

The particular advantage of the separate system in the case of English Bay and False Creek areas is that it will prevent the pollution of the foreshore by domestic sewage. A reference to the meteorological sheet will show that, roughly speaking, rain falls every other day, and although the proposed interceptor is designed to take all but the heaviest storms (occurring, say, three times a year) from the area at present drained on the combined system, the adoption of the combined system as a whole would mean a gradual increase in the number of occasions in which the interceptor would not take the flow from the combined trunks, until eventually the trunks would be discharging dilute domestic sewage on three days out of seven.

Reference has already been made to the standards of purity laid down by the New York experts who state the standard required for bathing places should approximate that required for drinking water.

Studies of Waters in and Around the Peninsula.

I will now put before you in detail the observations made and the conclusions to which I have come in studying the bodies of water in and around the Peninsula. Particulars of their areas and depth are given in Plans Nos. 8 and 9. It will be convenient to discuss each in detail with reference to:—

(1) Their capacity for the digestion of sewage;
(2) The standard of purity desirable;
(3) The most suitable position of point of outfall.

English Bay.

Capacity. East of a line between Point Atkinson and Point Grey, English Bay has a high water area of 21 square miles, with a maximum depth of over 300 feet.

It is hardly fair to assume that the whole of this bay is available for Greater Vancouver. The North shore districts have an equal interest, and for the purposes of my calculations I shall take that part of the bay inside a line drawn from Point Grey to Siwash Rock—within these limits there is an area of six square miles, with an average depth of 40 feet, and a tidal volume on a 10-foot tide of over 10,000 million gallons. Now, ignore altogether the permanent low water volume and take into consideration only the above tidal volume on this one-third part of English Bay which is brought in twice a day. It will digest on the basis of a 1/100 dilution the sewage from 2,000,000 people without nuisance or injury to fish life. It will be seen, further on in this report, that the estimated 1950 population discharging sewage to the bay is but 270,000. With the immense quantity of water available for dilution, the only nuisances likely to occur would be those of an aesthetic nature, and proper provision will be made for intercepting all floating matter.

The Fraser River has a very important and beneficial effect on English Bay from a sewage disposal point of view. Plan 6a shows the pencentages of land water present in the bay at low and high water of the Fraser River on the rising and falling tide and on the surface and at a depth of 10 feet. It will be seen that during the time of high water of the Fraser (i.e., the summer months) there is a layer containing a high percentage of land water over the bay. Experiments at New York shewed that when sewage was discharged into a mixture of 85% land water, it was in equilibrium, that is to say, it neither rose nor fell. I believe that this top layer of land water will check the rise of sewage to the surface, if it does not altogether prevent it.

There is one more point to note, and that is the possibility of future harbour developments involving the construction of a breakwater out from the Point Grey foreshore.

Standard of Purity. The standard of purity demanded for the foreshore of English Bay is high, owing to the presence of bathing beaches, and the fact that it is the only shore on the Peninsula really suitable for purposes of recreation. As before mentioned, the standard fixed by the New York experts for waters of this class is that it should approach the purity of drinking water.

Point of Outfall. Numerous float experiments have been made with a view to determining the point of outfall where the best diffusion could be obtained. It was found that the principal factors giving rise to the currents in English Bay were the Fraser River and the wind—the tides having comparatively little effect.

The Fraser River, during its high season, causes a definite current across from Point Grey to the First Narrows at all stages of the tide. The effect is less marked during the low season.

Between this line and the shore—there is at all times a circular clockwise movement of the water—the general run of the surface currents during the high season of the Fraser is shewn on Plan No. 5. The First Narrows is, of course, from a dispersion point of view, the ideal point for discharge. Estimates of cost were carefully gone into, and although the actual cost of carrying an outfall there is not prohibitive, it was considered that equally good results could be obtained by discharging at a more accessible point.

On the line of Imperial Street, some 5,000 feet out, was eventually fixed as the most suitable point of discharge. A large number of floats were started from this point; their limits of travel, after various periods, are shewn on Plan 6, which also shews the limits of travel of floats set out from Point Grey during the high stage of the Fraser. The possibility of the construction of a breakwater running out from the Spanish Bank has not been lost sight of, and the interceptor is at such a level as to permit of extension to Point Grey.

False Creek.

Capacity. False Creek has an area at high water of nearly 1½ square miles, while the area at low water is just under one-half square mile. The amount of water entering on a 10-foot tide is about 1600 million gallons.

At the present time False Creek is in a very undeveloped condition. It is probable that eventually the upper end will be filled in and the remainder dredged and deepened, the large expanse of mud flats visible at low water being removed. Whatever may be done in the future, False Creek will always remain a small, comparatively shallow body of water in the midst of a thickly populated district—diffusion will be poor, owing to the lack of through currents. Moreover, right out at the mouth of the creek, on either side, are the Kitsilano and English Bay bathing beaches, and this fact alone is sufficient to condemn it as a suitable place for the disposal of crude sewage. False Creek can, however, play a very useful part as a relief outlet in times of occasional heavy storms to those areas where the combined system is in operation. This will be referred to later.

Standard of Purity. The standard of purity desirable for False Creek is governed by the presence at the entrance of the bathing beaches mentioned above, and should, as in the case of English Bay, approach to that of drinking water. It is, of course, a physical impossibility to attain to this standard, but all reasonable means should be taken to keep the creek unpolluted, both as regards the discharge of sewage and the throwing overboard of garbage and offal from vessels lying in the creek, and from the premises abutting on it.

Burrard Inlet.

Capacity. The areas and tidal volumes of Burrard Inlet are:—

	Area H. W. Square Miles	Tidal Volume 10-foot rise
Between First and Second Narrows	7.6	12,000 million gallons
Above Second Narrows	16.0	27,000 " "

In considering the capacity of Burrard Inlet for receiving sewage, the possibility of the construction of a dam at the Second Narrows must be taken into account. Consequently, I prefer to take the tidal volume between First and Second Narrows as the amount of water available for dilution. This 12,000 million gallons will, on a dilution of 1 to 100, effectively oxidize, without nuisance or injury to fish life, the sewage flow from a population of 2,400,000 people. The North shore has a half interest in Burrard Inlet, so I will divide this figure by two, and say that the tidal volume of Burrard Inlet, between the First and Second Narrows, can digest with proper dispersion the sewage of 1,200,000 people on the Greater Vancouver Sewerage area.

As in the English Bay calculations, the permanent low water volume is ignored, as is the 27,000 million gallons above the Second Narrows which would be available unless the Second Narrows dam was constructed.

The estimated 1950 population discharging to the Inlet is 565,000.

No sewage should be discharged into Coal Harbor on the shore line between Brockton Point and the C. P. R. wharf, as there is little through current in this locality, and a tendency for the water to become stagnant. I am making provisions for intercepting the sewer outfalls at present discharging between these points, and carrying them across to the North-east shore of Stanley Park.

Standard of Purity. The standard of purity demanded for Burrard Inlet is, in the absence of bathing beaches, not so high as in English Bay, and the calculations of dilution prove that there is an ample margin of safety. The interception of floating matter is, of course, desirable, but is not a necessity.

Point of Outfall. There are many localities along the water front suitable for points of outfall—the line of Clark Drive is the most convenient for the principal outfall. There are numerous other points where the smaller areas could discharge—the outfall pipes should be carried beyond the pier line into deep water.

Fraser River.

Capacity. The minimum discharge of the Fraser River is in the month of March and amounts, at Hope, to about 20,000 c.f.s. The maximum discharge, which occurs in June, is about 400,000 c. f. s. The discharge at New Westminster will be considerably above these figures, but in the absence of reliable records, I prefer to take 20,000 c. f. s., or about 10,000 million gallons per day.

Just below New Westminster, the North Arm strikes off the main river. The rise and fall of the tide makes the determination of the proportion of flow down each of these channels a difficult matter. I estimate that the North Arm flow will, under present conditions, never be less than 1,000 million gallons per day, which amount, on a 1 in 100 dilution basis, will deal with the sewage flow from 100,000 persons.

The minimum flow of the main river would, on the same basis, oxidize the sewage flow of 900,000 people. The construction of harbour and dock works might necessitate the reduction of flow down the North Arm, and I do not at the present time feel in a position to make any more definite statement than that the Fraser River and the North Arm will be capable of dealing with any sewage that can be discharged there during the next five years.

Standard of Purity. The standard of purity should be such that no ill-effects are produced on fish life, and as far as present knowledge goes, a 1 to 100 dilution is perfectly safe.

Points of Discharge. The outfalls should be carried well out into the stream to obtain effective dispersion. For the Brunette River outfall, the best point available is near the Municipal Boundary, and for the North Arm area there should be some eight or ten outfalls along the bank between New Westminster and Eburne.

Burnaby Lake.

Burnaby Lake has a mean water area of about 430 acres, about two-thirds square mile, with a minimum depth of seven feet. I should place its capacity at about 70 million cubic feet, or, say, 500 million gallons. After a spell of dry weather it is practically stagnant, and is quite incapable of digesting any considerable amount of raw sewage.

Description of Proposed Works

It will be convenient to describe the proposed works area by area, under the following headings:—

(a) English Bay and False Creek area.
(b) Burrard Inlet area.
(c) Burnaby Lake area.
(d) Fraser River area.

English Bay and False Creek Area.

This area is shown in Plan No. 10 in brown. It comprises an area of 8,650 acres with a combined population of 270,000, distributed among the different Municipalities as follows:—

	Area in acres	Estimated Population in 1950
City of Vancouver	2,750	127,000
Point Grey	5,100	119,000
South Vancouver	800	24,000
Total	8,650	270,000

This area is one of those for which, in my previous reports, I have expressed a preference for the principle of the separate system of sewerage. The advantages of this system have already been fully discussed.

Certain areas have already been sewered on the combined system, and, while I do not propose to interfere with these areas at present, the combined system should be rigorously confined to its present limits and all extensions put in on the separate system. The English Bay and False Creek interceptor is designed so that, notwithstanding these combined areas, the system will, in practice, approximate, as far as its effect on False Creek or English Bay is concerned, to the separate system, in as much as it will only be in times of rare heavy rainfall of over a quarter of an inch per hour that the storm water overflows will come into action.

A reference to the Meteorological diagram shows that in 1912 this would have been only three times in the course of the year.

As already pointed out, the most suitable point of discharge for this area is some five thousand feet out from the shore on the line of Imperial Street.

The outfall pipe (60 inches in diameter) would be carried out at first to a distance of three thousand feet. As the population on the area increases, extensions of this pipe would be necessary to obtain proper diffusion of the sewage, arrangements would be made for the interception of all the floating matter which might be liable to be carried back to the foreshore by certain winds. The record of winds during 1910 and 1911, given on Plate No. 2, shows that the prevailing winds are offshore.

Several different routes have been examined for the line of the interceptor, and one following the foreshore, called the "Foreshore Line," and another in tunnel through Kitsilano Hill, called the "Tunnel Line," have been selected as the best two. The Foreshore Route is the cheaper and has much to recommend it. There are certain obstacles in the way of foreshore rights; these could be easily overcome, as the sewer will be in such a position and of such construction that it will form a protection to the property without, in any way, interfering with its future development, either as a residential or commercial district. The sewer would be utilized as a retaining wall, and the Marine Drive continued from Imperial Street along the foreshore to Kitsilano Beach. The sewer would be nine feet internal diameter, with an invert elevation 93 feet above City datum, and the grade would be 1 in 2700. Commencing from Imperial Street, the foreshore line would follow high water mark, being carried around the small bay in front of the Jericho Club. At Balaclava Street the size and grade would change to eight feet and 1 in 2400, respectively. Continuing along the foreshore to Balsam Street it would then strike across the park to the corner of Yew and Cornwall Streets, then up Yew to First Avenue, and along First Avenue to the C. P. R. tracks, following the tracks under the Granville Street bridge, and swinging round into Sixth Avenue. This portion of the route is subject to the agreement of the C. P. R. There is an alternative line in tunnel. The sewer would continue down Sixth Avenue to Heather Street, and at this point the Bridge Street area would be picked up.

I will now describe the alternative route on the Tunnel Line. Starting from Imperial Street, the sewer would follow the shore line and strike across the Government Reserve into Point Grey Road The size would be 7′ 6″, one in 1,000 grade. At Balaclava Street the size would change to 6′ 6″. The line would continue along First Avenue to Yew Street, where it would swing across under private property to the corner of Arbutus Street and Second Avenue. It would continue along Second Avenue to Fir Street, where it would swing round in a South-easterly direction, crossing Granville Street and running to the junction of Sixth Avenue back lane and Birch Street. It would then follow the back lane to Bridge Street, where the Bridge Street area would be picked up.

Almost the whole of this line is in deep tunnel. There are certain shallow places where shafts would be sunk, from which the tunnels could be economically driven.

This interceptor is designed to take the sewerage flow from the estimated population in 1950, together with the surface water of the ordinary storms from the areas at present sewered on the combined system. There are several trunks draining to this interceptor, and it may be well to state here that I define a trunk as any sanitary or surface water sewer which deals with the sewage or surface water flow from an area of 400 acres or over.

The main trunk sewers in this area are:—

(a) Imperial.
(b) Alma.
(c) Balaclava.
(d) Maple.
(e) Bridge.

In addition to the above, there are two low level areas, the sewage from which will have to be pumped up to the interceptor. They are:—

(f) Kitsilano Beach area, and the
(g) Low level area, Bridge and Main Streets, South of Lansdowne Street.

Imperial Street Area.

All of the 720 acres of this area lie to the West of Imperial Street in Point Grey. The estimated population for 1950 is 14,400. Commencing at the interceptor, this trunk will run South along Imperial Street to Sixth Avenue. The area should be sewered on the separate system.

Alma Street Area.

Six hundred and eighty acres between Imperial Street and North of the natural divide in Point Grey, and 130 acres in the City, are included in this area. The trunk starts from the interceptor at the East boundary of the present Jericho Club property and runs in a South-westerly direction to the junction of Alma Street and Fourth Avenue. The exact location to this point depends on the method of sub-division in the Government Reserve, which is now being cleared for sub-dividing. This area also should be sewered on the separate system.

The Balaclava Area.

This area comprises some two thousand five hundred acres, with an estimated population in 1950 of 93,000. Commencing from the interceptor, the sewer will run South on Balaclava Street to Sixteenth Avenue (a portion of this has already been constructed by the City of Vancouver), East on Sixteenth to MacDonald, North on MacDonald to Eighteenth, East on Eighteenth to Trafalgar, North on Trafalgar to Chaldecott, East on Chaldecott to Yew, and North on Yew almost to the Bodwell Road, where the contributing area reaches the limit of 400 acres.

The principal branches from the main trunk would run on Broadway to Balsam Street, thence South to Tenth Avenue.

Maple Street Area.

This area is already sewered on the combined system, discharging through a four-foot sewer down Maple Street. This sewer will be connected to the interceptor, which will take all but the heaviest storms.

Bridge Street Area.

The Bridge Street area comprises some 2500 acres, of which 2340 acres are drained by gravitation to the interceptor. The remaining 160 acres is a low level area.

Parts of this Bridge Street area, both in the City and in Point Grey, have already been sewered on the combined system, but, as I have already pointed out, these combined areas should be confined within their present limits.

Commencing from the interceptor at Sixth Avenue and Heather one line of the sewer would follow the creek in a South-westerly direction to Broadway, and then South up Laurel to King Edward

Avenue. The other branch would start from the interceptor at Bridge and Sixth Avenue, run South on Bridge to Fourteenth Avenue, East on Fourteenth to Yukon, South on Yukon to Nineteenth Avenue, East on Nineteenth to Columbia, and South on Columbia to McMullen Avenue. The best site for the pumping station, to deal with the low level area, would probably be in the neighbourhood of the Garbage Destructor.

Burrard Inlet Area.

The areas discharging to Burrard Inlet are shown on the plan in pink and blue. The greater part of these areas drain naturally to False Creek and Burnaby Lake.

The principal outlet will be at Clark Drive. There will be smaller outlets at Stanley Park and Hastings Park and other points along the water front. In the event of False Creek being filled in, I think it may be possible to drain this area also to Burrard Inlet, together with that portion of the City lying between Pender Street and the Creek, shown uncoloured on the plan.

Clark Drive Outfall.

The area discharging at the Clark Drive outfall is shown in blue, and the distribution and the estimated population of the different Municipalities is set out hereunder:

	Area in acres	Estimated Population in 1950
City of Vancouver	2,500	90,000 + 63,000
South Vancouver	3,300	99,000
Burnaby	2,450	49,000

As will be seen from the plan, part of this area drains naturally to False Creek and part to Burnaby Lake. The treatment of the former area depends entirely on what is done with that portion on the Creek lying East of Main Street bridge. Apart from any question of sewerage, if it is filled up it will be necessary to make provision for dealing with the surface water, or, in other words, China Creek will have to be continued from its present outlet, through the fill to the open water.

In any case, it will be necessary to carry a sewer to deal with the sewage flow across to Burrard Inlet, and it will, I think, be better to make this sewer of such a size as will take not only the sewage but the ordinary surface water. To put it another way, if China Creek is to be extended, it will be better to extend it to the Inlet rather than to Main Street bridge. Questions of economy, however, demand that this extension should be designed to take only ordinary storm flow, and in filling in the Creek suitable provision should be made for a relief outlet which would only come into use should the Clark Drive outfall become gorged by a heavy rainfall.

The cost of this Clark Drive outfall, or a proportion of it, should be charged against the False Creek improvement, as it will relieve that improvement of a long length of expensive culvert.

The outfall pipe would be carried well out into deep water at the end of Clark Drive, and arrangements would be made for intercepting all floating matter.

It would run South down Clark Drive to Fifth Avenue, where it would cross under the Great Northern tracks. The area lying to the East of the head of False Creek is already mostly sewered and discharging into False Creek. These sewers would be cut off by the interceptor. From Fifth Avenue the main line would swing across into Keith Drive, running South to just past Ninth Avenue, where it would turn into the Creek and run in a South-easterly direction to Clark Drive and Eleventh Avenue. From this point it would follow the Creek to Twelfth Avenue and along Twelfth to Victoria Drive. The line would then run round the South side of Trout Lake into Twenty-second Avenue, crossing the natural divide just West of Renfrew Street. From this point onward only sewage would be taken.

The main sewer would run South on Renfrew to the Municipal Boundary, where it would cross under the B. C. Electric tracks, following the Creek in a South-easterly direction to the junction of Boundary Road and Vanness Avenue, taking at this point the population on some 450 acres in Burnaby.

There would be several important branch trunks off this line. The first would start from the Great Northern crossing at Clark Drive, following the cut to Slocan Street and running East to Boundary Road and Thirteenth Avenue. From this point it would follow the contour of the ground in a South-easterly direction, terminating at the Pole Line Road, just North of Walker Avenue, where the contributing area would be about 400 acres. The whole of the area dealt with by this trunk sewer drains naturally to Burnaby Lake, and, in accordance with the principles laid down, it would be a sanitary sewer, taking sewage only.

Stanley Park Outfall.

This outfall would discharge into the rapid current on the North-east shore of Stanley Park. It would run across the low area in the Park to the North shore of Coal Harbor, crossing the harbor in the proposed causeway to the foot of Georgia Street; here it would divide into two branches, one running up Georgia, intercepting the sewage, at present discharging to Coal Harbor, at Dunsmuir Street and Gifford Street; and the other striking across on the line of the Park limits to Beach Avenue, where the sewer at present discharging on the East shore of Stanley Park would be picked up.

The Georgia Street branch should be eventually extended to Burrard Street and the dry weather flow of the existing sewer picked up. An overflow from the present combined sewer is permissible at this point at the present time.

West of Burrard Street, as already mentioned, no sewage should be discharged, and sanitary sewers should be laid and connected to the Stanley Park outfall. The same remarks apply to the area lying to the North of False Creek, and an interceptor should be laid along Beach Avenue and sanitary sewers connected to it. The sewers above discussed are relatively small and do not come within the scope of this report (except for that part of the interceptor shown on the plan), but the prevention of pollution of the bathing beaches at English Bay and the foreshore of Coal Harbor is of such importance that I thought it well to refer to it.

Hastings Park Outfall, Etc.

This outfall and trunk drain an area of 800 acres. There will be various similar areas along Burrard Inlet water front, but they will fall below the limit of 400 acres, and are outside the scope of this report. The outfall pipe should in each case be carried out to deep water and floating matter intercepted.

Burnaby Lake Area.

The total area draining naturally to Burnaby Lake amounts to some 17,000 acres, or nearly 26 square miles.

As I have already pointed out, this area resembles a large dish, with a single outlet—the Brunette River. At the present time the sides and bottom of the dish are covered with vegetation and soil of an absorbent nature, which retains the rain and retards a large percentage of the run-off. By the year 1950 the assumed population on this area is some 200,000 people, and a considerable change will have taken place in the nature of this covering—streets and roofs will have taken the place of trees and undergrowth. I estimate that with the heaviest storms the run-off from this watershed will then be at least 4,000 cubic feet per second, that is to say, assuming a velocity of flow of five feet per second and a depth of ten feet, a channel 80 feet wide would have to be provided. It is of the utmost importance that the natural drainage channels of this district should be conserved and some sound policy of developing them to meet the demands of the future adopted. I have included in the estimates for "Immediate Construction" a sum of $200,000 for improving Still Creek and the Brunette River, and providing for such drainage as may be necessary during the next five years.

To meet the needs of the district during the next five years for sewerage facilities, two interceptors have been provided, one discharging to Clark Drive, which has already been described, and the other to the Fraser River, near the Brunette mouth, designed, like the previous one, to take sewage only. Commencing at the City Boundary, it would run as shown on the plan and intercept all sewage from Still Creek, Burnaby Lake and Brunette River.

As to the ultimate disposal of the sewage, quite recently the public health authorities have given permission to New Westminster to discharge their raw sewage into the Fraser, provided no nuisance is caused. I see no reason why permission should not be given to discharge the sewage from this interceptor—with the same proviso: But there may come a time when some form of treatment will be necessary.

Fraser River Area.

The acreage and estimated distribution of population of the area draining the North Arm of the Fraser River is shown by the following table:—

Point Grey	7,300 acres	137,000 population
South Vancouver	4,800 acres	48,000 population
Burnaby	5,500 acres	65,000 population.

At the present time the question of whether the combined or separate system will be the better for this area, is an indeterminable one. Under existing conditions, as previously stated, I estimate that the North Arm of the Fraser River can digest the sewage of 100,000 persons without nuisance or injury to fish life—provided proper dispersion is obtained. The time will undoubtedly come when either some form of local treatment will have to be adopted or an interceptor constructed. I have made provisions for the latter in the "Deferred Construction" estimates, and it is shown in a broken red line on Plan No. 10—although it is quite possible that future developments may make the former method more suitable. To meet the needs of the district during the next five years, I propose the construction of trunks on the lines shown on plans.

Estimates.

The following estimates of cost are set out under two heads, "Immediate Construction" and "Deferred Construction." The first covers all the work shown in firm red lines on the plan, and the cost of the trunk sewers constructed by the City of Vancouver (excepting the Maple Street sewer) and Point Grey, shown in green.

The sum of $200,000 is also included for the straightening and improving Still Creek and the Brunette River. It is proposed that these works should be constructed during the next five years. The expenditure being five and a half million dollars.

The "Deferred Construction" estimates give the cost of the construction that will be necessary to place the remaining area of the Peninsula on the same footing as the area covered by the "Immediate Construction" estimates, i.e., the provision of sanitary and surface water trunks for every area of 400 acres, together with such interceptors and outfalls as will be necessary.

These "Deferred Construction" estimates are of necessity of an approximate nature, and the amount of expenditure and the rate of construction required depends, of course, on the rate of growth and development of the Peninsula.

Estimates—Immediate Construction, Area Draining to Imperial Street Outfall, English Bay.

(Coloured brown on Plan No. 10.)

Estimate of cost of construction of outfall, interceptor and sanitary and surface water trunks, as shown in firm red lines:—

Outfall				$175,000
Interceptor				662,000
TRUNKS (Sanitary and Surface):—				
	Vancouver	Point Grey	South Vancouver	
Imperial Street area		$ 58,000		
Alma Road area	$ 18,000	101,000		
Balaclava Street area	372,000	398,000		
Bridge Street area	188,000	80,000	$74,000	
Totals	$578,000	$637,000	$74,000	$1,289,000
				$2,126,000
Outfalls to Trunks				45,000
				$2,171,000

NOTE.—The cost of the portion of Balaclava and Bridge Street trunks already constructed by the City of Vancouver is included in above estimates.

Area Draining to Clark Drive Outfall, Burrard Inlet.

(Coloured blue on Plan No. 10.)

Estimate of cost of construction of outfall, interceptor and combined trunks on natural area, and sanitary trunks on area draining naturally to Burnaby Lake, as shown in firm red lines:—

Outfall				$ 50,000
Interceptor				240,000
	Vancouver	South Vancouver	Burnaby	
Trunks (Combined)	$518,000	$137,000		
Trunks (Sanitary only)	95,000	56,000	$154,000	
Totals	$613,000	$193,000	$154,000	$960,000
Great Northern Cut Outfall				30,000
				$1,280,000

Area Draining to Burrard Inlet.

(Coloured pink on Plan No. 10.)

	Vancouver
Stanley Park Outfall:	
Outfall and Interceptor	$ 80,000
Hastings Park Outfall:	
Outfall and Trunk	40,000
Total	$120,000

Area Draining to Brunette River Outfall.

(Coloured yellow on Plan No. 10.)

Estimate of cost of construction of outfall and interceptor, as shown in firm red lines:—

	Burnaby
Outfall and Interceptor	$383,000
Still Creek, Burnaby Lake and Brunette River improvement	200,000
Total	$583,000

Area Draining to Fraser River.

(Coloured green on Plan No. 10.)

	Point Grey	South Vancouver	Burnaby	
Trunks and Outfalls	$96,000	$282,000	$420,000	
				$798,000

NOTE.—The cost of the Kaye Road trunk, already constructed by Point Grey, is included in the above estimates.

ABSTRACT OF ESTIMATES.

IMMEDIATE CONSTRUCTION (DURING NEXT FIVE YEARS).

English Bay Area	$2,171,000
Clark Drive Area	1,280,000
Burrard Inlet Area	120,000
Brunette River Area	583,000
Fraser River Area	810,000
Total	$4,964,000
Add Engineering, Contingencies, etc.	536,000
	$5,500,000

DEFERRED CONSTRUCTION (DURING FOLLOWING 25 YEARS).

Estimates of cost of providing trunks for the sewerage and surface water drainage of the areas shown part coloured on Plan No. 10, the surface water drainage of portion of Clark Drive area draining naturally to Burnaby Lake and the Fraser River interceptor:—

Burnaby Lake Area	$3,400,000
Point Grey Area	1,000,000
Fraser River Area	1,100,000
Total	$5,500,000

CONSTRUCTION AND CONTROL OF WORKS.

It is unusual for the construction of works covering such a large area as these, and lying in several Municipalities, to be carried out under the immediate supervision of the Municipal Councils concerned. In cases where this has been attempted the results have not been satisfactory. Moreover, a work of this description should really be constructed without regard to Municipal boundaries. It should be looked upon as a scheme devised and carried out with a view to placing on a sure foundation the sanitary interests of the great city which will one day cover this Peninsula. Before putting before you proposals for the constitution and powers of a Joint Board, it will be well to outline for your information the constitution and powers of similar bodies which are doing excellent work in other parts of the Empire and the United States.

MELBOURNE.

The Melbourne and Metropolitan Board of Works received its constitution by Act of Parliament in December, 1890. The main object of the Board's creation was to provide Melbourne and suburbs with an efficient system of sewerage. The Board consists of a chairman and 39 members, who are nominated by 22 Municipalities and who hold office for three years, the representation being on a basis of assessment valuation. The salaried chairman, who must devote his whole time to the duties of the office, is appointed by the Board.

The Board has complete control of all sewer work within the Metropolitan area, and has, since its formation, spent over $30,000,000 on construction, which includes trunk sewers, branch sewers and house connections as far as the street line.

It has power to make and collect taxes on all property within its jurisdiction. The taxes are based on "net annual value," the maximum levy being one shilling and twopence in the pound on sewered property, and two pence in the pound on unsewered property. This corresponds, approximately, to a tax rate of seven and one mills to the dollar.

It is interesting to note that the Board is at the present time seeking further powers to control the Metropolitan rivers, streams and watercourses and sub-divisions of land.

BIRMINGHAM AND DISTRICT, ENGLAND.

The Birmingham Tame & Rea Main Drainage Board was formed by provisional order of the Local Government Board in 1877, for the purpose of:—

"(a) Purchasing such lands and erecting, making and maintaining such buildings, machinery and plant as may "be required for the treatment at outfall works of the "sewage of the several urban sanitary districts.

"(b) Constructing or providing such intercepting sewerage "works as may be necessary to convey the sewage of "the several districts and contributory places to the "said outfall works."

The constitution of the Board is similar to that of Melbourne, the members being elected by the constituent Municipal Councils from among the members of their own body for a term of three years. Neither the chairman nor members receive any salary.

The Board controls an area of over 90 square miles, with a population of nearly one million people.

The works and expenses incurred by the Joint Board and various Municipalities are divided into two classes:—

(a) "Outfall Works" include treatment works and all works necessary for conveying the sewage of any Municipality from that Municipality to its point of disposal, and all expenses of management. The cost of these works is defrayed out of a common fund contributed to by the various Municipalities in proportion to their respective populations.

(b) "Intercepting Works" include such works as may be necessary to convey the sewage of any district to the Outfall Works. These works, when serving one Municipality, may be constructed either by that Municipality or by the Joint Board, but where two Municipalities are concerned, the work must be done by the Joint Board.

The cost of any intercepting work is charged to such of the constituent authorities and in such proportion as the Board thinks fit.

BOSTON, MASS.

The Board of Metropolitan Sewerage Commissioners was established by Act of the Massachusetts Legislature in 1889. Its object was to provide for the building, maintenance and operation of a system of sewage disposal for the Myrtle and Charles River Valleys.

It is composed of three "able and discreet men, inhabitants of the Commonwealth," who are appointed trienially by the Governor with the advice and consent of the Council. Each member receives a salary of $3,000.00 a year. The Board has powers to construct and maintain certain defined works. The expenditure on sewerage works since the Board's formation amounts to about $15,000,000. The area controlled is now 199 square miles, lying in 24 Municipalities, and the population close on one million. To meet the expenses of the Board, the Commonwealth issues 40-year 4% bonds. The interest and sinking fund requirements are apportioned among the contributing Municipalities on a valuation basis, while the maintenance charges are on a population basis.

There are many other Joint Boards in operation; in England alone there are over 40, all working along similar lines to one of the three above mentioned.

Two very divergent views can be taken of the policy in which this scheme is entered upon; one, that it is a joint scheme in the sense that it is of common interest to every individual on the Peninsula, and the other, that the scheme is a joint scheme from the point of view of the Municipality rather than of the individual. To put it another way: the Peninsula can be considered as one large Municipality with common interest, or a group of Municipalities each with its individual interests.

Personally, I incline to the broader view; but I quite recognize that such a view is open to objection at the present time, as each Municipality has its own responsibilities and bond issues, and the interests of one may perhaps seem to clash with the interests of another.

I will now outline my views of what the constitution and powers of the Board should be, on the assumption that the Provincial Government will guarantee the bonds.

Representation.

A Board composed of representatives from the Councils of different Municipalities, with a chairman appointed by the Lieutenant-Governor in Council and holding office during his pleasure. The basis of representation would be roughly on population or valuation, and would give Vancouver two representatives and the outside Municipalities one each.

Assessment, Interest and Sinking Fund Charges.

to be assessed on one of the following principles:—

(a) The work to be divided into two classes: (1) that of common interest, which includes interceptors, purification works, and all works designed for the prevention of pollution of natural bodies of water; (2) that of local interest, which includes trunk sewers draining 400 acres or over. The charges for (1) to be assessed over the whole district. The charges for (2) to be borne by the Municipalities in proportion to the assessment valuation of the area actually drained.

(b) The natural rights and liabilities of each Municipality to be taken into account. The charges for all works to be apportioned on a basis of the provision made for and the benefits derived by each Municipality. The apportionment to be fixed by the Board, with right of appeal to the courts from its decisions.

Duties.

The duties of the Board would be primarily to carry out and maintain the sewerage scheme as outlined in this report. They would also exercise a general supervision over all the sewer construction, and would take such steps as might be necessary to preserve the natural bodies of water from pollution.

They would have similar powers to a Municipality in the way of expropriating land, and would engage their own officers, and enter into contracts.

In concluding this report, I should like to remind the Committee that, although eighteen months have elapsed since this investigation was commenced, the time has barely sufficed for the collection of indispensable data. At the inception of the undertaking the plans of the district were incomplete and unreliable, and there was no information available as to the elevation of the greater part of the area. On my visit, a year ago, a considerable portion of my time was taken up in reluctantly designing and laying out in advance of the main scheme, portions of the Balaclava, Bridge and China Creek trunks. The success of a scheme of this description depends very largely on the selection of the points of outfall—a problem which involves extended and tedious float observations through the various different conditions of the tides, the wind, and the Fraser River.

Respectfully submitted,

R. S. LEA.

Per A. D. Creer.

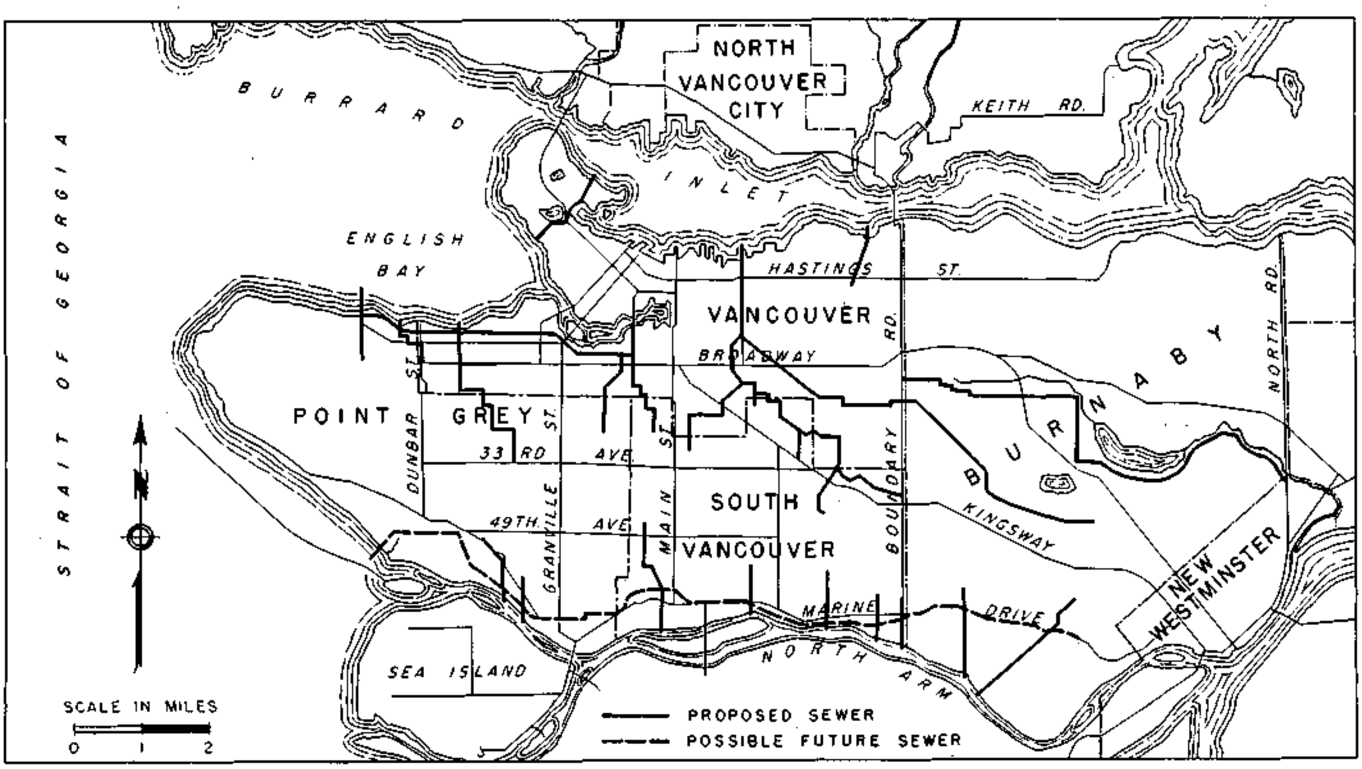


Figure 110. Facilities Recommended in R. S. Lea Report

This figure was adapted from Plate 10 of the report of R. S. Lea to the Burrard Peninsula Joint Sewerage Committee in 1913. Plates 1-9 and 11 have not been adapted for inclusion herein.

Appendix II

VANCOUVER AND DISTRICTS JOINT SEWERAGE AND DRAINAGE ACT

1914, c. 79; 1915, c. 64; 1917, c. 70; 1918, c. 95; 1920, c. 97; 1921 (2nd Sess.), c. 51; 1926-27, c. 70; 1928, c. 53; 1929, c. 66; 1934, c. 66.

An Act providing for a Joint Sewerage and Drainage System for the City of Vancouver and Adjoining Districts.

[*Consolidated for convenience only, June 21st, 1937.*]

HIS MAJESTY, by and with the advice and consent of the Legislative Assembly of the Province of British Columbia, enacts as follows:—

Short Title.

Short title. **1.** This Act may be cited as the "Vancouver and Districts Joint Sewerage and Drainage Act."

Interpretation.

Interpretation. **2.** (1.) Where the following expressions or words occur in this Act, or in any rules, regulations, or by-laws to be made under this Act, they shall be construed in the manner following, unless the context otherwise requires:—

"Municipality." "Municipality" shall include any and every municipality now incorporated or that may hereafter become incorporated, whether city or district, and whether incorporated by special Act of the Legislature or under the provisions of the "Municipalities Incorporation Act":

"Sewerage district." "Sewerage district" shall mean that part of the Province bounded on the north by Burrard Inlet, on the west by English Bay and the Gulf of Georgia, on the south by the North Arm of the Fraser River and the present boundary between the Municipality of Burnaby and the City of New Westminster, and on the east by the present boundary between the Municipalities of Burnaby and Coquitlam, together with that part of the City of New Westminster lying within the proposed Glenbrook drainage area as shown outlined in green on the plan of the said proposed drainage area on file in the Land Registry Office at the City of New Westminster numbered 14919:

"Street." "Street" shall include any highway, and any public bridge, and any boulevard, square, mews, court, road, lane, alley, or passage, whether a thoroughfare or not:

"Watercourse." "Watercourse" shall include any river, stream, creek, or lake, whether ordinarily carrying or containing water or not:

"Drain." "Drain" shall mean any artificial channel constructed for the conveyance of surface water, and shall include any part of a drain and any right of making or of user or other right in or respecting a drain:

"Sewer." "Sewer" shall include sewers and drains of every description, except drains to which the word "drain" interpreted as aforesaid applies, and shall include any conduit, pipe, or channel, together with its appurtenances, used for the conveyance of domestic sewage, factory refuse, or any other polluting liquid; and shall include any part of a sewer and any rights of making or of user or other right in or respecting a sewer:

"Main sewer." "Main sewer" shall include any sewer which shall be constructed, purchased, or otherwise acquired as such under the provisions of this Act, and any existing sewer referred to in the report referred to in section 14 hereof:

"Land." "Land" shall include all real estate, messuages, tenements, and hereditaments, houses and buildings of any tenure, and foreshore, lands covered with water, frontage rights, rights-of-way, and easements, and any right, title, or interest in land of any kind or nature whatsoever:

"Drainage area." "Drainage area" shall mean any area of lands within the sewerage district which is established by the Board as a drainage area under the provisions of this Act:

"Land valuation." "Land valuation" shall mean the valuation of any area of lands within the sewerage district which is determined by the Board as a land valuation under the provisions of this Act.

(2.) For the purposes of this Act, the City of New Westminster shall be included in the words "municipality within the sewerage district" used in this Act. 1914, c. 79, s. 2; 1915, c. 64, s. 2; 1918, c. 95, s. 2; 1929, c. 66, s. 2.

Board.

Board. **3.** (1.) For the purposes of carrying into execution the provisions of this Act, a Board, to be called the "Vancouver and Districts Joint Sewerage and Drainage Board," is hereby established, and the same is hereinafter referred to as "the Board."

Constitution of Board. (2.) The Board shall be composed of a Chairman and the Mayors, for the time being, of the Cities of Vancouver and New Westminster, and the Reeve, for the time being, of each other municipality within the sewerage district, and two additional members who shall be appointed annually by the Council of the City of Vancouver. 1914, c. 79, s. 3; 1918, c. 95, s. 3; 1928, c. 53, s. 2; 1929, c. 66, s. 3.

Chairman appointed by Lieut.-Governor in Council. **4.** The Chairman, who shall not be a member of the Council of any municipality in the sewerage district, shall be appointed by the Lieutenant-Governor in Council, and shall hold office during the pleasure of the Lieutenant-Governor in Council, and shall be paid such salary as shall be fixed by the Lieutenant-Governor in Council, and shall devote such of his time as may be necessary to the proper carrying-out of the objects of this Act. *Salary.*

Powers of Chairman; veto. **5.** The Chairman shall be the chief executive officer of the Board. He shall have the general supervision and management of the affairs of the Board, preside at all meetings of the Board, and shall have the right at any time after the passage thereof to intervene and return for reconsideration or to veto any by-law, resolution, or proceeding of the Board, subject to an appeal to the Lieutenant-Governor in Council, whose decision shall be final and binding. 1918, c. 95, s. 4.

No member to hold office of profit in gift of Board. **6.** No member of the Board shall hold any office or place of profit in the gift of the Board, or, except as to his salary or remuneration, be concerned or interested in any manner, whether directly or indirectly, in any contract with the Board, or any profit thereof, or in the profit of any work to be done under the authority of this Act, or in any expenditure under this Act. 1918, c. 95, s. 5.

7. [*Repealed.* 1918, c. 95, s. 6.]

8. [*Repealed.* 1918, c. 95, s. 7.]

9. [*Repealed.* 1918, c. 95, s. 8.]

Offices. **10.** The Board shall from time to time provide and maintain fit and convenient offices for holding the meetings of the Board and transacting its business, and for the use of its offices, and for transacting all business connected with the Board; and for such purpose may acquire by purchase or otherwise any land which by the Board may be considered necessary for such purposes, and may erect buildings thereon.

Clerk. **11.** (1.) The Chairman may appoint a Clerk or Secretary and Treasurer, who shall hold office during the pleasure of the Chairman, and shall be paid such salary as may be fixed by the Board. He shall not be a member of the Board or of the Council of any municipality in the sewerage district.

Officers. (2.) The Board shall from time to time engage such solicitors, counsel, engineers, agents, officers, and servants as it may deem necessary for the purposes of this Act.

Meetings. (3.) The Board shall meet once a month, or oftener if required by the Chairman, and the members, other than the Chairman, shall each receive fifteen dollars for each meeting attended by them. 1918, c. 95, s. 9.

By-laws. **12.** The Board shall have power to pass all necessary rules, regulations, and by-laws for the purpose of carrying into effect the provisions of this Act; and to enable the Board to construct, maintain, and operate the main sewers, sewers, drains, and other works referred to in section 14; and generally with regard to the management and transaction of the business of the Board, including the fixing of the necessary quorum for the transaction of business, the mode of executing and authenticating the securities mentioned herein, or any contract or instrument in writing as to which no express provision is made by this Act, the persons by whom the seal of the Board may be affixed to any deed or instrument under seal, and the duties, discipline, and regulation of all officers and servants of the board. 1914, c. 79, s. 12; 1934, c. 68, s. 2.

Corporate body.

13. The Board shall be a corporation under the name "Vancouver and Districts Joint Sewerage and Drainage Board," and shall have power to acquire and hold real and personal property for the purposes for which it is incorporated, and to alienate the same when no longer required for such purposes, by sale, exchange, or otherwise; and no member of the Board shall be liable for its debts, obligations, or acts.

Powers of Board.

Powers of Board.

14. (1.) The Board shall have power within the sewerage district, and without such district, with the consent of the Lieutenant-Governor in Council, at any time to enter upon any lands, without the consent of the owner thereof, and to make all necessary surveys, and to construct, maintain, and operate such main sewers, sewers, and drains, and other works in connection therewith as shall, in the opinion of the Board, be required for a system of sewerage and sewage disposal and surface-water drainage within the sewerage district, in substantial accordance with the report bearing date the first day of February, 1913, made by R. S. Lea, Esquire, consulting engineer, and submitted by the Burrard Peninsula Joint Sewerage Committee to the Provincial Board of Health, and filed in the office of the Provincial Secretary, or in accordance with any changes in such system that may be made by the Board with the approval of the Lieutenant-Governor in Council; and for the above purposes the Board may enter into contracts with any person for the construction, maintenance, and operation of the works aforesaid or any part thereof, or may execute such works or any part thereof without contract, and for such purpose may purchase materials and employ labour as may be required.

(2.) The Board shall have and may exercise all the powers vested in it by subsection (1) in respect of any lands which are from time to time within the sewerage district, whether or not the said lands are included in the system comprised in the said report made by R. S. Lea, Esquire. 1914, c. 79, s. 14; 1929, c. 66, s. 4.

Altering or closing up sewers.

15. The Board may from time to time enlarge, lessen, alter the course of, cover in, or otherwise improve any main sewer, sewer, or drain of the Board, and may discontinue, close up, or destroy any such main sewer, sewer, or drain that has, in the opinion of the Board, become unnecessary; but in such case compensation, or a main sewer, sewer, or drain as effectual, shall be provided for any municipality having a sewer or drain connected with the main sewer, sewer, or drain so discontinued, closed up, or destroyed.

Purchase or expropriation of land.

16. (1.) The Board may, as required for carrying out the provisions of this Act, take, or enter upon and use, by purchase or agreement, or without the consent of the owner, any land, watercourse, sewer, or drain, including all rights required for the exercise of the powers contained in sections 14, 15, 17, and 19.

Procedure to expropriate.

(2.) When the Board determines to expropriate any land, watercourse, sewer, or drain, including as aforesaid, the Board shall, within thirty days thereafter, cause to be recorded in the Land Registry Office of the district in which such land, watercourse, sewer, or drain is situated a description thereof sufficiently accurate for identification, with a statement of the estate or interest therein required by the Board, if such estate or interest is less than an estate in fee-simple; and such description and statement shall be signed by the Chairman, or, in the absence of such officer, by any person acting in his place under the authority of the Board, and an estate in fee-simple in such land, watercourse, sewer, or drain, or such lesser estate or interest therein as is set forth in such statement, shall thereupon vest in the Board; and notice of such expropriation shall forthwith be given to the owner as shown by the books of said Land Registry Office of such land, watercourse, sewer, or drain. The Board may enter upon and use any land, watercourse, sewer, or drain, including as aforesaid, and may lay and keep and continue main sewers, or sewers and drains, therein without the consent of the owner and without expropriation; and may also without the consent of the owner and without expropriation take from any land, watercourse, sewer, or drain all wood, timber, stone, gravel, sand, clay, water, or other material which may be required for the purposes of the Board.

Compensation.

(3.) The Board shall pay any purchase price or compensation agreed upon, and in case of expropriation or of entering upon and using without purchase, agreement, or expropriation, or of taking wood, timber, stone, gravel, sand, clay, water, or other material as aforesaid, shall pay all damages that shall be sustained by any person by reason thereof beyond any advantage which the claimant may derive from the contemplated work; and such damages, in default of an agreement being arrived at, shall be decided by arbitration pursuant to the provisions of the "Arbitration Act," by three arbitrators, one of the arbitrators to be appointed by each party, and the third by the two arbitrators so appointed, and the purchase price, compensation, or damages paid hereunder shall be regarded as a portion of the cost of the works authorized by this Act.

Provisions in "Municipal Act" relating to expropriation to apply.

(4.) Sections 369 to 376 of the "Municipal Act" of the Statutes of 1914 shall apply to all cases of the exercise by the Board of any of the powers conferred by section 16; and for the purposes of the application of said sections of the "Municipal Act" to this Act, the word "Board" shall be substituted for the words "municipality," "municipal corporation," and "Council" where they occur in said sections of the "Municipal Act."

Restoration the only compensation in case of highway.

Notwithstanding anything contained in this section, the only compensation which shall be made in respect of the exercise of the powers contained in sections 14, 15, 17, and 19 in respect of any road, street, or other way of public travel shall be the restoration provided for in section 18. 1914, c. 79, s. 16; 1918, c. 95, s. 10.

Right to use highway.

17. The Board may carry any main sewer, sewer, or drain through, across, or under any street, road, railway, highway, or other way, either public or private, in such manner as not unnecessarily to obstruct or impede travel thereon; and may carry same into, through, across, under, or over any watercourse, and into, through, across, or under any lands whatsoever, and may enter upon and dig up any such street, road, railway, highway, or other way, watercourse, or lands for the purpose of laying main sewers, sewers, or drains, and of maintaining and repairing the same; and in general may do any other acts or things necessary or convenient and proper for the purposes of this Act. In entering upon and digging up any street, road, railway, highway, or other way of public travel, the Board shall be subject to such reasonable regulations as may be made by the Council of the municipality wherein such work shall be performed. Before entering upon any such street, road, railway, highway, or other way of public travel for the purpose of laying a main sewer, sewer, or drain, the Board shall give at least ninety days' notice of such contemplated action to such municipality; but it shall be lawful for such municipality to waive the giving of such notice or to shorten the period thereof.

Right to use watercourse.

Subject to municipal regulations.

Notice.

Road to be put in good order.

18. Whenever the Board shall dig up any road, street, or way of public travel as aforesaid, it shall, so far as practicable, restore the same to as good a condition as the same was in before such digging began; and the Board shall at all times indemnify and save harmless the several municipalities within which such roads, streets, or ways are situated against all damages which may be recovered against them respectively by reason of anything done or omitted by the Board, and shall reimburse them for all expenses which they may incur by reason of any defect or want of repair of any road, street, or way caused by the construction of any of the said main sewers, sewers, or drains, or by the maintaining or repairing of the same.

Municipalities indemnified.

Change of watercourse or highway.

19. The Board may close or may change the width, depth, grade, or direction of any watercourse, and may, with the consent of the Council of the municipality within which same is situated, widen or change the location or grade of any road, street, or way of public travel crossed by any main sewer, sewer, or drain of the Board or in which same may be located. 1914, c. 79, s. 19; 1929, c. 66, s. 5.

Plans of new municipal sewers to be furnished to Board.

20. Before any new sewer is constructed by any of the municipalities in the sewerage district, or any alteration, connection, or extension is made by any such municipality to any then existing main sewer or sewer, plans and particulars shall be submitted to the Board on forms supplied by the Board; and such new sewer shall not be constructed or any alteration, connection, or extension made to any then existing main sewer or sewer until the Board has approved of the plans and particulars submitted. Each municipality in the sewerage district shall connect its sewers now constructed or hereafter to be constructed with a main sewer, subject to the direction, control, and regulation from time to time of the Board.

Board may require restoration to original condition.

21. If any new sewer is constructed or alteration, connection, or extension is made by any such municipality to any then existing main sewer or sewer without the consent of the Board, the Board may, within three months after such construction, alteration, connection, or extension has been reported to them by its engineer, cause notice in writing to be given to the municipality by whom such construction, alteration, connection, or extension is made, requiring such municipality to carry out such works as the Board may deem necessary as a consequence of such construc-

Or may restore at expense of defaulting person.

tion, alteration, connection, or extension, or the Board may require such municipality to restore such main sewer or sewer to its original condition; and if such notice is not compiled with, the Board may do said works at the expense of the municipality in default, and may recover from such municipality the expense thereof in any Court of competent jurisdiction.

Limitation of application of ss. 20 and 21.

21A. The provisions of sections 20 and 21 shall not apply in respect of that part of the City of New Westminster which is situate without the sewerage district. 1929, c. 66, s. 6.

Malicious injury to property of Board.

22. Any person who shall wantonly or maliciously destroy or injure any main sewer, sewer, or drain of the Board, or any property owned or used by the Board for the purposes of this Act, shall pay to the Board three times the amount of the damage done, to be recovered at the suit of the Board in any Court of competent jurisdiction.

Penalty.

Sale of property no longer required.

23. (1.) The Board may from time to time sell, lease, or dispose of any property, real or personal, no longer needed for the construction, maintenance, or operation of the main sewers or sewers and drains of the Board.

Conveyance may be given.

(2.) Real estate so sold may be conveyed by the Board subject to such easements, reservations, and restrictions as the Board may deem necessary.

Claims for damages barred in one year.

24. All claims for damages by reason of the expropriation or taking, or entering upon and using, without the consent of the owner and without expropriation, of lands, watercourses, sewers, or drains, including the rights referred to in section 16, or by reason of the taking of any wood, timber, stone, gravel, sand, clay, water, or other material, shall be presented within one year from the date of such expropriation or taking or entering upon and using without expropriation, or from the date when the alleged damages were sustained or became known to the claimant; or in case of a continuance of damage, then within one year from the time when the cause of action arose or became known to the claimant.

Establishment of drainage area.

24A. (1.) In case of any main sewer, sewer, or drain purchased or constructed or proposed to be constructed under this Act, the Board may establish for the purposes of this Act a drainage area comprising all or any of the lands within the sewerage district which by reason of their situation with respect to the main sewer, sewer, or drain are served or drained or capable of being served or drained by means of the main sewer, sewer, or drain, or by any extension or use thereof contemplated in the plan or system under which the same is purchased or constructed or proposed to be constructed. The Board shall have power to determine and fix the boundaries of each drainage area, and may from time to time alter the boundaries of any drainage area established under this section. Every decision of the Board under this section shall, subject to the appeal provided by this Act, be final and conclusive.

(2.) Pending the completion of the entire system of works authorized by this Act, the Board may, for the purpose of temporarily providing for the disposal of sewage from any area of land, connect the main sewers and sewers of that area with the main sewers of any drainage area established by the Board, and may for that purpose maintain such connection without including the first-mentioned area within the boundaries of the drainage area. 1915, c. 64, s. 3; 1929, c. 66, s. 7.

Plan to be filed.

24B. The Board on establishing a drainage area shall file in the Land Registry Office of the district in which the lands are situate a plan showing such drainage area outlined in green, and on altering the boundaries of a drainage area shall in like manner file an amended plan showing the drainage area as altered. 1915, c. 64, s. 3.

Determination of land valuation.

24C. (1.) For the purposes of this Act, the Board shall have power annually to determine the land valuation of any area of lands within the sewerage district, whether comprising the whole or part of any municipality, by taking as a basis therefor the assessed valuation of the lands within the area as ascertained from the revised municipal assessment roll of the municipality for the last preceding year, except that if it appears to the Board as the result of investigation or from evidence produced that the relation of assesesd valuation to the actual reasonable value of the lands differs in different municipalities, the Board may for the purpose of uniformity of valuation refer the matter to the Provincial Assessor and Collector of Vancouver Assessment District, who shall thereupon determine the land valuation of the area upon such basis as he may deem proper and report his determination to the Board in writing. The decision of the Board determining any land valuation in accordance with the report so obtained shall, for the purpose of constituting the basis of any apportionment to be made by the Board under this Act, be final and conclusive.

(2.) [*Repealed.* 1934, c. 68, s. 3.]

Interpretation of "lands."

(3.) For the purposes of this section "lands" shall mean the ground or soil and everything annexed to it by nature, or that is under the soil, except mines and minerals, precious or base, belonging to the Crown. 1915, c. 64, s. 3.

Contracts.

Mode of contracting.

25. (1.) Any contract which, if made between private persons, would be by law required to be in writing and under seal may be made on behalf of the Board in writing under the common seal of the Board, and may in the same manner be varied or discharged.

(2.) Any contract which, if made between private persons, would be by law required to be in writing signed by the parties to be charged therewith may be made on behalf of the Board in writing signed by the Chairman, or, in the absence of the Chairman, by any person acting in his place under the authority of the Board, and may in the same manner be varied or discharged. 1914, c. 79, s. 25; 1918, c. 95, s. 11; 1929, c. 66, s. 9.

Tenders to be advertised for.

26. Except in cases of emergency, before any contract to the amount of one thousand dollars or upwards is entered into by the Board, three days' notice at the least shall be given in two of the daily newspapers circulating in the sewerage district, expressing the nature and purposes of such contract and inviting tenders for the execution of same. The Board shall not be bound to accept the lowest or any tender, and if it accepts any tender may accept the tender which, in view of all the circumstances, appears to it to be most advantageous, and shall take security for the due and faithful performance of every such contract.

Proceedings against Board.

Notice.

Limitation.

27. No action shall be commenced against the Board or any member thereof, or any person acting under its authority or under the authority of this Act, unless one month's previous notice in writing thereof has been given to the person against whom such action is intended to be brought; and any such action shall be commenced within one year after the cause of action arose, and not afterwards.

Compounding.

28. The Board may compound for such sum of money or other recompense, as to the Board may seem proper, with any person who has entered into any contract with the Board, or any bond or agreement for the faithful performance thereof, or has made deposit for the performance of any tender in respect of any penalty or forfeiture incurred by reason of the non-performance of such contract or agreement, or breach of the condition of such bond, or otherwise, or by reason of failure to carry out the terms of such tender or to enter into contract in accordance therewith.

Borrowing Money.

Borrowing-powers.

29. (1.) It shall be lawful for the Board, and it is hereby empowered, after receiving the consent of the Lieutenant-Governor in Council, to borrow for the purpose of carrying out its objects an amount not exceeding ten million five hundred thousand dollars for a term not exceeding forty years. The sum of five million dollars may be borrowed at such time as to the Board may seem proper, and the further sum of five million five hundred thousand dollars not sooner than three years after the passing of the Act repealed by this Act, or such earlier time as the Lieutenant-Governor in Council may determine.

(2.) Except in cases otherwise specially provided by this Act, money borrowed by the Board shall be by the issue and sale of bonds, debentures, temporary debentures, debenture stock, or inscribed or registered stock or other form of security approved by the Lieutenant-Governor in Council, all of which are hereinafter referred to as "securities."

(3.) Securities of the Board may be issued subject to such conditions as to call, recall, or redemption, and shall bear such rate of interest, and shall be payable at such date or dates, and in such currency or currencies, and at such place or places, and in such manner as the Board by by-law or resolution may determine.

(4.) Securities of the Board may be sold for such sum, whether the sum is the par value or less or more than the par value thereof, and in such manner, and upon such terms and conditions as the Board, subject to the approval of the Lieutenant-Governor in Council, shall determine.

(5.) All proceeds realized from the sale of securities by the Board when borrowing moneys pursuant to the authority vested in it by subsection (1) shall be paid into a chartered bank or banks to the credit of a special account in the name of the Minister of Finance, to be held by him in trust for the Board, and shall be paid out by him to the Board or its nominees as may from time to time be required for the discharge of the liabilities incurred in carrying out the undertakings authorized by this Act. 1915, c. 64, s. 4; 1934, c. 68, s. 4.

30. (1.) The Board shall have power from time to time—

Convertible debentures.

(*a.*) To declare all or any of the bonds, debentures, or other securities issued or authorized to be issued by the Board to be convertible into stock:

Equivalent amount of stock.

(*b.*) To authorize the issue of an equivalent amount of such stock in exchange for such bonds, debentures, or other securities:

Redemption of debentures by issue of stock.

(*c.*) To authorize the creation and issue of any stock on such conditions as it may determine for the purpose of redeeming any outstanding bonds, debentures, or other securities, and of paying the expenses in connection with such redemption.

How conversion effected.

Any such conversion of bonds, debentures, or other securities into stock may be effected either by arrangement with the holders of such bonds, debentures, or other securities, or by the purchase thereof out of the moneys received by the sale of stock, or partly in one way and partly in another.

Agreement as to stock.

(2.) The Board may from time to time enter into an agreement with any bank, person, firm, or corporation to provide for all or any of the following matters:—

(*a.*) For the issue, inscription, or registration of stock on register to be kept at such bank or with such person, firm, or corporation or elsewhere, and for the appointment and remuneration of a registrar thereof:

(*b.*) For effecting the conversion of bonds, debentures, or other securities into stock and regulating the transfer of stock:

(*c.*) For the issue of stock certificates and the signature of the same, and for issuing stock free from stamp duty:

(*d.*) For paying interest on stock or the capital sums represented thereby:

(*e.*) For issuing stock certificates to bearer, and as often as occasion shall arise reregistering or reinscribing the stock represented by such certificates:

(*f.*) For receiving from time to time all moneys raised under this Act, and for paying such moneys from time to time into the account of the Board with any bank or financial agents duly appointed in that behalf:

(*g.*) For the issue of allotment letters and provisional scrip certificates to represent money paid up on account of any stock, pending the issue of the final stock certificates:

(*h.*) For the transfer of stock from one place of registry to another:

(*i.*) Generally for conducting all business connected with the issue and service of the stock and the inscription, registration, and transfer thereof.

Securities valid and binding.

(3.) Securities purporting to be issued pursuant to the power contained in this Act shall be valid and binding in the hands of a bona-fide purchaser for value, notwithstanding that any of the requirements of this Act in connection with the issue thereof have not been complied with. *1914, c. 79, s. 30; 1929, c. 66, s. 11;* 1934, c. 68, s. 5.

By-laws for borrowing money.

30A. (1.) The Board may, subject to the approval of the Lieutenant-Governor in Council, pass by-laws from time to time for any of the following purposes:—

(*a.*) To borrow such sum or sums of money as may be required to repay, renew, or refund any of its temporary debentures or loans secured by the hypothecation or pledging of its securities, and for such purposes to authorize the issue and sale of new securities. When the said temporary debentures or loans are repaid out of the proceeds of the sale of a new issue of securities as aforesaid, the said temporary debentures or the securities hypothecated or pledged as security for the said loans, as the case may be, shall forthwith be cancelled and shall not be reissued:

(*b.*) To borrow such sum or sums of money as may be required to repay, renew, or refund any of its securities issued subject to conditions as to call, recall, or redemption by the Board, and for such purpose to authorize the issue and sale of new securities in such amounts as will realize net the sum or sums of money required for the purpose aforesaid: Provided, however, that the entire principal amount of such new securities shall be payable not more than forty years from the date of the day upon which the indebtedness of the Board being so repaid, renewed, or refunded was incurred, and that the securities so repaid, renewed, or refunded shall forthwith be cancelled and shall not be reissued.

(2.) The cancellation of all securities pursuant to this section shall be attested by the Chairman or such other person as the Board may direct, and the Deputy Minister of Finance or such other person as the Lieutenant-Governor in Council may direct, by a joint certificate in duplicate signed by them setting out the facts for purposes of record.

(3.) A recital or declaration in a by-law authorizing the issue and sale of securities for any purpose mentioned in this section to the effect that the amount of the securities so authorized is required to be borrowed shall be conclusive evidence of that fact.

(4.) The power of the Board to borrow any sum or sums of money in pursuance of the authority vested in it by this section shall be in addition to and over and above its power to borrow from time to time for the purpose of carrying out its objects an amount not exceeding ten million five hundred thousand dollars, and in determining or arriving at the said amount no sum or sums of money borrowed by the Board pursuant to this section shall be taken into account. 1934, c. 68, s. 6.

Hypothecation of securities.

30B. (1.) Pending the sale of any of its securities (including temporary debentures) or in lieu of the sale thereof, the Board may hypothecate or pledge such securities for the purpose of borrowing moneys on the credit of the Board, provided such hypothecation or pledging is duly authorized by by-law of the Board. The Board may make such agreement for the repayment of any such loan and interest thereon as it may deem expedient. The proceeds of every such loan shall be applied to the purposes for which the securities were authorized to be issued, but the lender shall not be bound to see to the application of such proceeds, and if the said securities are subsequently sold the proceeds from such sale shall be applied in the first instance in repaying the loan.

Approval of Lieut.-Governor in Council required.

(2.) The power of the Board to borrow any sum or sums of money in pursuance of the authority vested in it by this section shall be subject to the approval of the Lieutenant-Governor in Council, and shall be in addition to and over and above its power to borrow from time to time for the purpose of carrying out its objects an amount not exceeding ten million five hundred thousand dollars, and in determining or arriving at the said amount no sum or sums of money borrowed by the Board pursuant to this section shall be taken into account. *1934, c. 68, s. 7.*

Provisions of by-law.

31. (1.) The Board, when issuing securities other than temporary debentures, shall, in the by-law authorizing the issuance thereof, provide:—

(*a.*) For the apportionment thereto annually of a sum sufficient, with the estimated accumulation of interest on the investment thereof, to discharge the debt created by such securities at maturity, and such apportionment shall, in the case of securities payable at the expiration of forty years from the issuance thereof, be at the rate of one-sixtieth part of the whole amount in each of the first ten years, one-fiftieth part of the whole amount in each of the second ten years, one-thirtieth part of the whole amount in each of the third ten years, and the remainder of such apportionment shall be equally divided among the next ten years; and in the case of securities payable at a time other than forty years from the issuance thereof, such apportionment shall be in like proportions; or

(*b.*) For the raising annually of a certain specific sum to be such as will be sufficient, with the estimated accumulation of interest on the investment thereof, to discharge the debt created by such securities at maturity; or

(*c.*) In the case of securities the principal and interest of which are combined into one sum and made payable in equal annual payments during the currency of the securities, for the raising annually during the currency of the securities of a certain specific sum so as to provide for each payment as it becomes due; or

(*d.*) In the case of securities the interest on which is to be paid annually or semi-annually and the principal of which is to be met by the payment of a certain specific sum in each year during the currency of the securities, for the raising annually during the currency of the securities of a certain specific sum for the payment of each instalment of the principal as it becomes due:

Provided that the Board shall, in determining any annual sum to be apportioned or raised for the purposes mentioned in clauses (*a*) and (*b*) of this subsection, estimate the rate of interest on the investment thereof at not more than four per centum per annum, capitalized yearly.

(2.) The amounts so provided for the purposes mentioned in clauses (*a*) and (*b*) of subsection (1) shall be paid by the Board to the Minister of Finance, to be held by him in trust to invest for the purpose of extinguishing at maturity the debts created by said securities, and such investment may be in said securities if they are obtainable below par, otherwise in such manner as he shall determine, subject to the approval of the Lieutenant-Governor in Council. 1934, c. 68, s. 8.

Temporary debentures, time of payment.

31A. (1.) The Board, when issuing temporary debentures, shall provide that the entire principal amount thereof shall be payable not more than five years from the issuance thereof, and in the case of temporary debentures issued pursuant to the authority vested in it by subsection (1) of section 30A shall provide that the entire principal amount thereof shall be payable not more than five years from the date of the day upon which the indebtedness of the Board being repaid, renewed, or refunded from out of the proceeds of the sale thereof was incurred.

(2.) No sinking fund shall be required to be set up in respect of temporary debentures. 1934, c. 68, s. 9.

Power to borrow in anticipation of revenue.

32. (1.) The Board may, by resolution or by-law, borrow in the course of any year, in anticipation of the collection of its revenue for such year, such sum or sums of money as it may require to meet its lawful current expenditures by the issue of promissory notes under the seal of the Board and signed by the Chairman and countersigned by the Treasurer of the Board, or signed or countersigned by some other person or persons authorized by the Board to sign or countersign the same; and each of such promissory notes shall be valid and binding upon the Board according to its tenor.

(2.) Any promissory note so issued may be in such form as the Board may from time to time adopt.

(3.) Money so borrowed by the Board may be by way of a loan from the Province of British Columbia or any person, bank, or corporation willing to make the same, and the Province may make any such loan in the manner that may be prescribed from time to time by the Lieutenant-Governor in Council.

(4.) The power of the Board to borrow any sum or sums of money in pursuance of the authority vested in it by this section shall be in addition to and over and above its power to borrow from time to time for the purpose of carrying out its objects an amount not exceeding ten million five hundred thousand dollars, and in determining or arriving at the said amount no sum or sums of money borrowed by the Board pursuant to this section shall be taken into account. 1934, c. 68, s. 10.

Government Guarantee.

Provincial guarantee.

33. The Province of British Columbia may guarantee, in the manner that may from time to time be prescribed by the Lieutenant-Governor in Council, the payment of both interest and principal of all securities issued by the Board pursuant to this Act. 1934, c. 68, s. 11.

34. [*Repealed.* 1934, c. 68, s. 12.]

Indebtedness of money borrowed.

34A. All money borrowed by the Board shall be upon its credit at large, and shall also constitute an indebtedness of the several municipalities within the sewerage district, repayable by each municipality in the proportion and manner prescribed herein, notwithstanding the provisions of any Act limiting the amount of indebtedness that may be incurred by any such municipality; and in calculating or arriving at the amount of such last-mentioned indebtedness no money borrowed by the Board shall be included or calculated therein. 1934, c. 68, s. 13.

Annual Estimates.

Annual estimates.

35. On or before the twenty-first day of March in each year the Board shall cause a detailed estimate to be prepared of the sums required to meet:—

(*a.*) Its operating and maintenance expenses for the then current year:

(*b.*) The amount required during the then current year to pay the interest on money borrowed, to provide for its sinking fund requirements, for the payment of serial securities and instalments of principal on account of securities issued, and to pay all instalments of principal and interest on account of the purchase price of any property, real or movable, acquired by the Board; and

(*c.*) Any deficit consequent upon the Board's estimate in any former year having been less than the amount of the expenditure required for the purposes of the Board during such year. 1934, c. 68, s. 14.

Apportionment.

35A. When its annual estimate is prepared, the Board shall forthwith apportion the sums required among the several municipalities within the sewerage district in accordance with their respective liabilities therefor as determined by the Board pursuant to this Act, and issue and deliver to each municipality a precept under its seal and signed by the Chairman or other person acting in his place for such purpose under the authority of the Board, setting forth the amount determined to be paid by such municipality to the Board. 1934, c. 68, s. 15.

Determination of liabilities of municipalities.

35B. (1.) The respective liabilities of the municipalities within the sewerage district for the sums required for the purposes of the annual estimate of the Board shall be determined by the Board as follows:—

(*a.*) For the purposes mentioned in clause (*a*) of section 35, the liability of each municipality with respect to each drainage area shall be in the same proportion to the total amount to be raised therefor as the land valuation of the part of the municipality situate within the drainage area bears to the total land valuation of the drainage area:

(*b.*) For the purposes mentioned in clause (*b*) of section 35, the liability of each municipality with respect to thirty per centum of the amount required therefor shall be in the proportion that the total land valuation of each municipality bears to the total land valuation of the sewerage district; and with respect to the remaining seventy per centum of the amount required therefor, regard shall be had to the respective portions thereof relating to each drainage area; that is to say, each portion of the seventy per centum relating to a drainage area which lies wholly within one municipality shall be apportioned wholly to that municipality, and each portion of the seventy per centum relating to a drainage area which includes parts of two or more municipalities shall be apportioned in the respective proportions that the land valuation of the part of each municipality included within the drainage area bears to the total land valuation of the drainage area:

(*c.*) For the purposes mentioned in clause (*c*) of section 35, the liability of the municipalities for the amount required therefor shall be in the proportions to be determined pursuant to clause (*a*) or (*b*) of this subsection, according to the nature of the deficit.

(2.) For the purposes of this section, the total land valuation of the City of New Westminster shall be the total land valuation of that part of the city which is situate within the sewerage district. 1934, c. 68, s. 15.

Levy and collection of moneys.

35C. The sums of money to be paid by the several municipalities within the sewerage district to the Board in any year pursuant to this Act shall be levied and collected by each municipality in the same way as sums of money required for other lawful purposes of the municipality for such year may be levied and collected, and shall be due and payable on the fifteenth day of August in such year, and, if not paid on the due date, shall bear interest therefrom until the date of payment at the rate of six per centum per annum. 1934, c. 68, s. 15.

Payment and enforcement of money.

35D. (1.) All money due and payable by a municipality to the Board pursuant to this Act shall, if not paid when due, be recoverable at the suit of the Board against the municipality in any Court of competent jurisdiction, and the Board may also enforce payment thereof by the appointment of a receiver of the rates, taxes, levies, and other revenues of the defaulting municipality. The powers conferred upon the Board by this section for the recovery and enforcement of payment of money due and payable to it by a municipality may be exercised separately or concurrently or cumulatively.

Receiver.

(2.) Any such receiver may be appointed by a Judge of the Supreme Court of British Columbia upon the application of the Board made in a summary manner. 1934, c. 68, s. 15.

Power of receiver to strike rate.

35E. Any receiver appointed pursuant to section 35D may, with the consent of the Lieutenant-Governor in Council, examine the assessment rolls of the defaulting municipality, and may, in like manner as rates are struck for general municipal purposes, but without limiting the amount of the rate, strike a rate in the dollar sufficient to cover the amount of money due and payable by the municipality to the Board, with such addition to same as the receiver deems sufficient to cover interest, his own fees and costs, and the collector's percentage up to the time when such rate will probably be available. 1934, c. 68, s. 15.

Levy of rate.

35F. Such receiver shall thereupon issue a precept under his hand directed to the collector of the defaulting municipality, and shall annex to the precept the roll of such rate, and shall by such precept, after reciting his appointment and that the municipality has neglected to satisfy its indebtedness to the Board, and referring to the roll annexed to the precept, command said collector to levy such rate forthwith. 1934, c. 68, s. 15.

Dealing with general rate roll.

35G. In case at the time of levying such rate the said collector has a general rate roll delivered to him, he shall add a column thereto headed "Vancouver and Districts Joint Sewerage and Drainage Board Arrears Rate," and shall insert therein the amount in such precept required to be levied on each person respectively, and shall levy the amount of such rate struck by the said receiver as aforesaid, and shall, with all reasonable expedition, return to the said receiver the precept with the amount levied thereon, after deducting his percentage. 1934, c. 68, s. 15.

Surplus to municipality.

35H. The receiver shall, after satisfying all indebtedness of the defaulting municipality to the Board and all his own fees and costs, pay any surplus within ten days after receiving same to the municipality for its general purposes. 1934, c. 68, s. 15.

Rates when delinquent.

35I. Any such rate struck and levied in pursuance of this Act shall be deemed to be delinquent at such time as it would become so if it were a tax levied by the defaulting municipality, and each person against whom such rate is levied shall be liable to pay the same in like manner as if the said rate were a tax levied by the municipality against such person, and the municipality shall enforce the collection of the said rate in the same manner as it may enforce the collection of its taxes, and for such purpose the said rate shall be deemed to be a tax levied by the municipality. 1934, c. 68, s. 15.

Clerks to be officers of Court.

35J. The clerks, assessors, collectors, and other officers of the defaulting municipality shall for all purposes connected with the carrying into effect or permitting or assisting the receiver to carry into effect the provisions of this Act with respect to the striking, levying, and collecting of the said rate be deemed to be officers of the Court appointing the receiver, and as such shall be amenable to the Court, and may be proceeded against by attachment, or otherwise, to compel them to perform their duties hereby imposed upon them. 1934, c. 68, s. 15.

Appeal.

Appeal.

36. (1.) If at any time any municipality within the sewerage district is dissatisfied with any decision of the Board regarding the carrying-out of the general scheme of this Act, or any decision establishing a drainage area pursuant to section 24A, or (except as otherwise provided in section 24C) any decision determining any land valuation pursuant to section 24C, or with any estimate, determination, or apportionment of the Board pursuant to sections 35, 35A, and 35B, an appeal shall lie to the Lieutenant-Governor in Council, whose decision thereon shall be final and binding.

Notice of appeal.

(2.) Except as otherwise ordered by the Lieutenant-Governor in Council, no such appeal shall be heard unless notice of the appeal stating the grounds on which the appeal is based is served upon the Board within one month after the date of the decision, estimate, determination, or apportionment appealed from.

Costs.

(3.) In case of an appeal, the Lieutenant-Governor in Council may order any special investigation to be made, and may employ therein engineers and other persons, and obtain expert advice with reference to the subject-matter of the appeal. The Lieutenant-Governor in Council shall have the power to fix and award costs on the appeal, including therein all expenses incurred in connection with any investigation made or advice obtained, and may order the costs or any part thereof to be paid by the Board or by any municipality within the sewerage district as may be deemed just. 1915, c. 64, s. 6; 1934, c. 68, s. 16.

Accounts.

Accounts to be kept.

Annual report.

37. (1.) The Board shall at all times keep accurate and complete accounts of its receipts, expenditures, assets, and liabilities, and shall include an abstract of the same in an annual report to be made by the Board to the Minister of Finance and municipalities within the sewerage district.

Inspection of books.

(2.) The accounts and books of the Board shall be at all reasonable times open to inspection by any of the municipalities in the sewerage district, by the Auditor-General, or by any person appointed by the Lieutenant-Governor in Council. 1914, c. 79, s. 37; 1918, c. 95, s. 15.

Salaries and other expenses declared part of cost of construction.

38. All salaries or remuneration paid to the Chairman and other members of the Board, and to its Clerk, or Secretary and Treasurer, engineers, or any of its officials, agents, or servants, and all costs, charges, and expenses which shall be in any way incurred in the carrying-out of the provisions of this Act, and of the preliminary expenses incurred by the municipalities in the sewerage district in relation to the system referred to in section 14, shall be paid out of the moneys of the Board in the same way as if the same were being paid in the actual construction of works authorized by this Act. 1914, c. 79, s. 38; 1918, c. 95, s. 16.

Superannuation of employees.

38A. It shall be lawful for the Board, from its funds:—

(a.) To aid and assist by annual money grant or otherwise, as the Board may deem expedient, the establishment and maintenance of superannuation or official benefit funds for employees of the Board, for providing pensions, gratuities, or retiring allowances to such employees; and for that purpose, if the Board thinks fit, to deduct from the salaries of the employees such amounts as the Board may deem necessary or expedient:

Insurance against sickness.

(b.) To contribute or pay the full amount or any portion of any premium in respect of any benefit, accident, or sickness or life insurance policy, or scheme of group insurance for the purpose of insuring all or any employees of the Board against sickness, accident, or death, as the case may be. 1926–27, c. 76, s. 2.

Repeal and Substitution.

Repeal and substitution.

39. The "Burrard Peninsula Joint Sewerage Act," being chapter 7 of the Statutes of 1913, is hereby repealed, and the provisions of this Act are hereby substituted therefor; and the Burrard Peninsula Joint Sewerage Board, as constituted under the provisions of said Act, upon the passing of this Act, shall be and become the Board established by this Act; and the property, members, officers, and servants of the Board constituted under the provisions of said Act shall, upon the passing of this Act, be and become the property, members, officers, and servants of the Board established by this Act, upon the same terms as to remuneration and otherwise as heretofore, and all rights, liabilities, claims, and demands by and against the Board constituted under said Act shall continue by and against the Board established by this Act.

Ratification.

Ratification.

40. The resolution of the Burrard Peninsula Joint Sewerage Board passed on the fifth day of September, 1913, authorizing the obtaining of loans, and the obtaining of loans thereunder, is hereby ratified and confirmed and declared to be valid and binding upon the Board.

1914, c. 79; 1915, c. 64; 1917, c. 70; 1918, c. 95; 1919, c. 87; 1921 (2nd Sess.), c. 51; 1926-27, c. 76; 1928, c. 53; 1929, c. 66; 1934, c. 68.

An Act to amend the "Vancouver and Districts Joint Sewerage and Drainage Act."

[Assented to 30th November, 1939.]

HIS MAJESTY, by and with the advice and consent of the Legislative Assembly of the Province of British Columbia, enacts as follows:—

Short title.

1. This Act may be cited as the "Vancouver and Districts Joint Sewerage and Drainage Act Amendment Act, 1939."

Power to waive payment of certain interest by the Corporation of the District of Burnaby.

2. Notwithstanding anything contained in the "Vancouver and Districts Joint Sewerage and Drainage Act" and amending Acts, it shall be lawful for Vancouver and Districts Joint Sewerage and Drainage Board to waive and forego payment by the Corporation of the District of Burnaby of all interest owing by the said Corporation of the District of Burnaby on the sum of money determined by the said Board to be paid on the first day of November, 1932, by the said Corporation as its apportionment of the annual estimate of the said Board prepared in the year 1932, and the said Board is hereby empowered to waive and forego payment of the said interest by the said Corporation.

1914, c. 79; 1915, c. 64; 1917, c. 70; 1918, c. 95; 1919, c. 87; 1921 (2nd Sess.), c. 51; 1926-27, c. 76; 1928, c. 53; 1929, c. 66; 1934, c. 68; 1939, c. 49.

An Act to amend the "Vancouver and Districts Joint Sewerage and Drainage Act."

[Assented to 6th December, 1940.]

HIS MAJESTY, by and with the advice and consent of the Legislative Assembly of the Province of British Columbia, enacts as follows:—

Short title.

1. This Act may be cited as the "Vancouver and Districts Joint Sewerage and Drainage Act Amendment Act, 1940."

Amends s. 2.

2. Section 2 of the "Vancouver and Districts Joint Sewerage and Drainage Act," being chapter 79 of the Statutes of 1914, is amended by adding thereto the following definition:—

"'Chairman' means the Chairman of the Vancouver and Districts Joint Sewerage and Drainage Board appointed under this Act."

Amends s. 4.

3. Section 4 of said chapter 79 is amended by inserting after the word "Council," in the fourth line, the words "notwithstanding anything to the contrary contained in the 'Municipal Superannuation Act' or any other Act."

Amends s. 30.

4. Section 30 of said chapter 79, as amended by section 5 of the "Vancouver and Districts Joint Sewerage and Drainage Act Amendment Act, 1934," is amended by striking out the last three words of clause (i) of subsection (2), and substituting therefor the words "transfer and cancellation thereof."

Amends s. 30A.

5. Section 30A of said chapter 79, as enacted by section 6 of the "Vancouver and Districts Joint Sewerage and Drainage Act Amendment Act, 1934," is amended by adding to subsection (1) the following clause:—

"(c.) To borrow such sum or sums of money as may be required to purchase all or any of its outstanding securities, and for such purpose to authorize the issue and sale of new securities in such amounts as will realize the sum or sums of money required for the purpose aforesaid, but the entire principal amount of such new securities shall be payable not later than the date of maturity of the securities being purchased, and the securities so purchased shall forthwith be cancelled and shall not be reissued."

Amends s. 31.

6. (1.) Section 31 of said chapter 79, as re-enacted by section 8 of the "Vancouver and Districts Joint Sewerage and Drainage Act Amendment Act, 1934," is amended by inserting in subsection (1), after clause (*d*), the following clause:—

"(*e*.) In the case of an issue of instalment or serial debentures, for the raising in each year of a sum for the payment of interest and a sum to provide for the payment of the debentures as the same severally become due."

(2.) Said section 31 is further amended by striking out subsection (2), and substituting therefor the following:—

"(2.) The amounts so provided for the purposes mentioned in clauses (*a*) and (*b*) of subsection (1) shall be paid by the Board to the Minister of Finance, to be held by him in trust to invest and reinvest from time to time for the purpose of extinguishing at maturity the debts created by said securities, and such investment or reinvestment may be in said securities, or in such other securities as the Minister shall, subject to the approval of the Lieutenant-Governor in Council, determine. Securities issued by the Board and purchased by the said Minister shall be cancelled by him when they are no longer required for the purposes of this section and shall not be reissued."

1914, c. 79; 1915, c. 44; 1917, c. 70; 1918, c. 95; 1919, c. 97; 1921 (2nd Sess.), c. 51; 1926-27, c. 74; 1928, c. 49; 1929, c. 46; 1934, c. 68; 1939, c. 50; 1940, c. 66.

An Act to amend the "Vancouver and Districts Joint Sewerage and Drainage Act."

[*Assented to 28th March, 1945.*]

HIS MAJESTY, by and with the advice and consent of the Legislative Assembly of the Province of British Columbia, enacts as follows:—

Short title.

1. This Act may be cited as the "Vancouver and Districts Joint Sewerage and Drainage Act Amendment Act, 1945."

Amends s. 31A.

2. Section 31A of the "Vancouver and Districts Joint Sewerage and Drainage Act," being chapter 79 of the Statutes of 1914, which section was enacted in said chapter 79 by section 9 of chapter 68 of the Statutes of 1934, is amended by striking out subsection (1), and substituting therefor the following:—

"(1.) The Board, when issuing temporary debentures, shall provide that the entire principal amount thereof shall be payable not more than five years from the issuance thereof."

Appendix III

EXISTING FACILITIES OF THE VANCOUVER AND DISTRICTS JOINT SEWERAGE AND DRAINAGE BOARD

Facility[a]		Capacity	Year(s)	
Name	Description[d]	cfs[b]	Constructed	Cost[c]
BALACLAVA STREET TRUNK SEWER				
	575 ft. of 30-in. RC at 5.40%	95		
	905 ft. of 42-in. RC at 2.20%	150	1919	
	1,105 ft. of 54-in. BHS at 0.94%	200	to	408,600
Strathcona Extension	1,285 ft. of 66-in. BHS at 1.0%	355	1920	
	1,515 ft. of 72-in. BHS at 0.68%	365		
	2,900 ft. of 96-in. BHS at 0.30%	530		
	500 ft. of 48-in. BHS at 0.57%	113		
	1,150 ft. of 54-in. BHS at 0.57%	156		
Broadway Extension	1,200 ft. of 42-in. BHS at 1.50%	128		
	550 ft. of 48-in. BHS at 1.25%	170		
	2,800 ft. of 54-in. BHS at 0.90%	195		
	900 ft. of 72-in. RC at 0.33%	248	1915	205,600
Balaclava Extension	1,300 ft. of 57-in. SLHS at 0.231%	526		
	1,000 ft. of 51-in. SLHS at 0.559%	610		
Trunk[e]	2,300 ft. of 62-in. SLHS at 0.714%	1,175		
	300 ft. of 96-in. BHS at 5.15%	2,210	1912	94,800
Outfall	700 ft. of 60-in. RC			
CAMBIE STREET TRUNK SEWER				
Willow Street Extension[f]	1,700 ft. of 60-in. RC at 0.50%	186	1912	45,600
	1,200 ft. of 66-in. RC at 0.60%	265		
	500 ft. of 42-in. RC at 0.25%	50		
Manitoba Street Extension[g]	1,500 ft. of 48-in. RC at 0.25%	72	1912	33,500
	2,400 ft. of 54-in. RC at 0.17%	82		
	1,800 ft. of 66-in. BHS at 2.50%	550		
Columbia Street Extension	2,000 ft. of 60-in. BHS at 0.60%	210	1918	116,700
	1,600 ft. of 48-in. BHS at 2.20%	225	1919	
Cambie Street Extension	350 ft. of 42-in. BHS at 1.33%	117	1927	20,200
	400 ft. of 33-in. BHS at 5.00%	119		
	650 ft. of 66-in. BHS at 6.00%	875		
	800 ft. of 72-in. BHS at 5.69%	1,090		
Trunk and Outfall[h]	300 ft. of 78-in. BHS at 3.00%	970	1912	125,000
	900 ft. of 48-in. BHS at 0.17%	62		
	900 ft. of 54-in. SLHS at 0.97%	940		
Heather Street Overflow	340 ft. of 96-in. BHS at 2.00%	1,370	1947	25,300
CLARK DRIVE INTERCEPTOR				
	300 ft. of 15-in. RC at 1.77%	7		
	800 ft. of 18-in. RC at 1.77%	14		
Collingwood Sanitary Trunk	750 ft. of 24-in. RC at 0.35%	13		
	5,600 ft. of 27-in. RC at 0.38%	19	1915	95,500
	1,450 ft. of 24-in. RC at 0.25%	11		
	890 ft. of 30-in. RC at 0.57%	31		
	700 ft. of 34-in. x 51-in. ESS at 0.20%	31		
	810 ft. of 42-in. RC at 0.10%	32	1950	52,600[i]
Rhodes Street Sanitary Trunk	900 ft. of 15-in. RC at 0.288%	3	1950	25,200
	1,200 ft. of 18-in. RC at 0.26%	5		
	400 ft. of 15-in. RC at 0.595%	5		
	300 ft. of 18-in. RC at 0.20%	5	1927	
Copley Sanitary Trunk	2,200 ft. of 30-in. RC at 0.34%	24	to	232,000
	2,000 ft. of 33-in. RC at 0.30%	29	1928	
	1,500 ft. of 36-in. RC at 0.22%	31		
	2,550 ft. of 42-in. RC at 0.25%	50		
	1,050 ft. of 30-in. RC at 0.25%	21	1950	34,700

Facility[a]		Capacity cfs[b]	Year(s) Constructed	Cost[c]
Name	Description[d]			
	700 ft. of 48-in. RC at 0.187%	62		
	400 ft. of 54-in. RC at 0.147%	76		
	400 ft. of 60-in. RC at 0.140%	98		
	1,050 ft. of 36-in. RC at 0.51%	48		
	600 ft. of 27-in. RC at 4.00%	62		
	700 ft. of 30-in. RC at 2.77%	68		
	700 ft. of 36-in. RC at 3.22%	120		
	240 ft. of 42-in. RC at 1.01%	101	1914	
	200 ft. of 33-in. RC at 4.01%	106	to	300,700
China Creek Extensions	200 ft. of 30-in. RC at 13.93%	155	1917	
	680 ft. of 42-in. RC at 3.60%	192		
	900 ft. of 42-in. RC at 4.80%	223		
	1,100 ft. of 48-in. RC at 4.10%	295		
	4,600 ft. of 78-in. BHS at 0.565%	420		
	1,500 ft. of 51-in. SLHS at 0.90%	690		
	1,400 ft. of 54-in. RC at 2.22%	296		
	400 ft. of 66-in. RC at 1.01%	342		
	1,400 ft. of 24-in. RC at 1.30%	26		
	2,300 ft. of 42-in. RC at 0.68%	83		
	500 ft. of 48-in. BHS at 1.67%	200		
	1,100 ft. of 54-in. BHS at 1.11%	222		
Canoe Creek Trunk	900 ft. of 60-in. BHS at 0.58%	210	1914	179,200
	850 ft. of 66-in. BHS at 1.30%	410		
	3,500 ft. of 78-in. BHS at 0.75%	480		
Canoe Creek Trunk[j]	2,600 ft. of 72-in. x 79-in. SS at 0.75%	480	1911	15,000
China Creek Trunk[k]	1,400 ft. of 68-in. SLHS at 1.50%	2,086	1911	83,000
China Creek Overflow	575 ft. of 51-in. SLHS		1916	235,500
Interceptor	7,500 ft. of 96-in. BHS			
Outfall	1,020 ft. of 72-in. BHS		1916	71,600
HASTINGS PARK TRUNK SEWER				
	675 ft. of 12-in. RC at 1.52%	4		
	3,510 ft. of 18-in. RC at 0.20%	5		
Hastings Extension (Sanitary)	1,800 ft. of 20-in. RC at 0.48%	10	1948	121,700
	700 ft. of 22-in. RC at 0.36%	11		
	630 ft. of 18-in. RC at 0.41%	7		
	400 ft. of 48-in. BHS at 0.75%	132		
	2,000 ft. of 60-in. SS at 0.437%	180		
	450 ft. of 60-in. BHS at 0.12%	94		
	1,720 ft. of 48-in. RC at 0.88%	141		
Trunk	600 ft. of 42-in. x 54-in. ESS at 0.87%	135	1915	262,700
	1,400 ft. of 72-in. BHS at 0.20%	200		
	1,300 ft. of 78-in. SS at 0.415%	360		
	660 ft. of 72-in. BHS at 1.24%	500		
	640 ft. of 54-in. BHS at 4.00%	420		
	1,200 ft. of 78-in. BHS at 0.70%	460		
Outfall	500 ft. of 30-in. BHS			
Overflow	500 ft. of 78-in. BHS at 0.70%	460	1928	41,600
ENGLISH BAY INTERCEPTOR				
	9,040 ft. of 54-in. BHS at 0.141%	83	1929	
	7,110 ft. of 66-in. BHS at 0.10%	118	to	
Interceptor	3,540 ft. of 84-in. BHS at 0.075%	191	1933	1,276,900
	5,200 ft. of 96-in. BHS			
Outfall	3,040 ft. of 66-in. RC		1930-1931	243,200
ALMA IMPERIAL TRUNK SEWER				
	600 ft. of 24-in. RC at 0.50%	16		
Sanitary Trunk to EBI	960 ft. of 30-in. RC at 0.23%	20	1924	
	400 ft. of 30-in. RC at 0.65%	33	to	253,800
	400 ft. of 42-in. RC at 0.60%	78		
	900 ft. of 54-in. BHS at 0.82%	187	1927	
Storm Trunk	600 ft. of 72-in. BHS at 0.30%	245		
	4,400 ft. of 96-in. BHS at 0.10%	310		
Outfall	360 ft. of 60-in. RC		1932	
	20 ft. of 66-in. RC			

Facility[a]		Capacity	Year(s)	
Name	Description[d]	cfs[b]	Constructed	Cost[c]
WEST END INTERCEPTOR				
	1,000 ft. of 42-in. RC			
	1,510 ft. of 42-in. x 54-in. SS			
Trunk	1,370 ft. of 42-in. RC		1914	
	1,790 ft. of 53-in. BHS		to	182,700
	3,650 ft. of 48-in. x 60-in. SS		1918	
Overflow	240 ft. of 33-in. RC			
Outfall	125 ft. of 54-in. RC		1940	14,600
MACDONALD STREET TRUNK SEWER[l]				
	700 ft. of 28-in. RC at 10.97%	110		
Trunk	400 ft. of 30-in. RC at 7.87%	115	1912	40,300
	3,300 ft. of 60-in. RC			
ANGUS DRIVE TRUNK SEWER				
Marine Drive Extension	1,230 ft. of 42-in. RC at 1.30%	115	1925	29,900
	1,400 ft. of 48-in. RC at 0.72%	122		
	320 ft. of 48-in. RC at 4.33%	300		
	320 ft. of 54-in. RC at 1.39%	235		
Trunk[m]	750 ft. of 60-in. RC at 1.88%	360	1912	48,100
	480 ft. of 48-in. RC at 5.00%	325		
	625 ft. of 66-in. RC at 1.00%	340		
SOUTH HILL TRUNK SEWER[n]				
	630 ft. of 48-in. BHS at 1.52%	190		
	1,020 ft. of 54-in. BHS at 1.48%	245		
	800 ft. of 60-in. BHS at 1.27%	310		
	640 ft. of 54-in. BHS at 2.11%	305		
	620 ft. of 60-in. BHS at 1.47%	335	1931	
Trunk	900 ft. of 66-in. BHS at 0.89%	335	to	296,700
	1,750 ft. of 60-in. BHS at 1.84%	370	1936	
	600 ft. of 66-in. BHS at 0.99%	355		
	400 ft. of 60-in. BHS at 1.42%	330		
	755 ft. of 54-in. BHS at 4.97%	460		
	350 ft. of 60-in. BHS at 1.29%	315		
	2,070 ft. of 96-in. BHS			
Outfall	100 ft. of 32-in. RSP		1946	3,900
WILLINGDON AVENUE TRUNK SEWER				
	650 ft. of 48-in. RC at 1.50%	177		
	1,100 ft. of 54-in. RC at 1.30%	227	1931	
Trunk	470 ft. of 42-in. RC at 11.50%	345	to	83,400
	60 ft. of 60-in. RC at 1.00%	265	1932	
	140 ft. of 54-in. x 60-in. SS at 1.00%	275		
Outfall	250 ft. of 30-in. RC			
GLENBROOK TRUNK SEWER				
	275 ft. of 20-in. RC at 8.94%	41		
McBride Extension	550 ft. of 22-in. RC at 5.80%	42	1952	25,000
	240 ft. of 24-in. RC at 3.75%	43		
	650 ft. of 24-in. RC at 2.10%	33		
	350 ft. of 22-in. RC at 4.50%	38		
Cumberland Extension	400 ft. of 20-in. RC at 8.95%	41	1951	62,300
	500 ft. of 24-in. RC at 9.22%	68		
	580 ft. of 36-in. RC at 1.56%	84		
	225 ft. of 30-in. RC at 4.10%	83		
	1,290 ft. of 12-in. RC at 2.21%	5		
Kingsway Extension	810 ft. of 15-in. RC at 0.58%	5	1951	98,200
	1,100 ft. of 30-in. RC at 0.25%	21		
Burnaby Extension[o]	1,320 ft. of 48-in. RC at 0.70%	121	1933	
	625 ft. of 41-in. RC at 1.70%	121		
	2,700 ft. of 54-in. BHS at 1.10%	220	1930	
Trunk	1,350 ft. of 60-in. BHS at 0.90%	260	to	114,300
	700 ft. of 66-in. BHS at 1.00%	355	1932	
Trunk[p]	5,250 ft. of 78-in. SS		1914	96,600
Outfall[q]	350 ft. of 102-in. SS		1914	

Facility[a]		Capacity cfs[b]	Year(s) Constructed	Cost[c]
Name	Description[d]			
MANITOBA STREET TRUNK SEWER				
North of Marine Drive	350 ft. of 42-in. RC at 2.45% 3,000 ft. of 48-in. RC at 3.40% 1,500 ft. of 54-in. RC at 3.83% 1,075 ft. of 48-in. RC at 5.50% 410 ft. of 60-in. RC at 1.70% 225 ft. of 48-in. RC at 5.60% 80 ft. of 60-in. RC at 2.07%	159 267 387 341 343 343 378	1952	208,000
South of Marine Drive	2,300 ft. of 91-in. BHS	418	1952	352,000
Outfall	200 ft. of 72-in. RC	418	1952	40,000
BORDEN STREET TRUNK SEWER				
East Extension	770 ft. of 30-in. RC at 3.50% *710 ft. of 36-in. RC at 2.76%* 1,150 ft. of 42-in. RC at 3.40%	76 111 187	1949 to 1950	84,000
West Extension	490 ft. of 48-in. RC at 1.20% 350 ft. of 54-in. RC at 0.65% 1,075 ft. of 60-in. RC at 0.45%	158 160 176	1950	132,300
Trunk	1,600 ft. of 54-in. RC at 3.50% 325 ft. of 60-in. RC at 2.50% 550 ft. of 68-in. RC 675 ft. of 60-in. RC	370 408	1948 to 1949	181,700
Outfall	340 ft. of 84-in. RC		1949	84,100
Lateral	320 ft. of 30-in. RC at 1.00%	41	1950	13,300
WILLARD STREET				
Willard Street Trunk	3,070 ft. of Open Channel 400 ft. of 36-in. Steel Culverts		1950	22,400
12th Avenue Trunk	2,000 ft. of Open Channel			
STILL CREEK - BURNABY LAKE - BRUNETTE RIVER				
Collingwood Storm Trunk	2,100 ft. of 72-in. BHS at 0.37% 1,700 ft. of 66-in. BHS at 0.37% 2,600 ft. of 78-in. BHS at 0.37%	275 215 340	1922 to 1924	158,200
Rhodes Street Storm Trunk	2,100 ft. of 72-in. RC at 0.324% 1,030 ft. of 68-in. RC at 0.585%	245 275	1950	178,300
Still Creek	30,000 ft. of Open Channel, Culverts and Bridges		1914 to 1935	253,000
Permanent Culverts Still Creek	300 ft. of 2-72-in. RC Culverts		1951	76,700
North Branch of Still Creek	3,400 ft. of Open Channel 200 ft. of 60-in. RC Culverts		1951	41,700
Burnaby Lake	10,000 ft. of Dredged Channel		1950-1952	30,800
and Brunette River	Original 10,000 ft. of Dredged Channel in Lake, Caribou Road Dam, and 10,000 ft. of Drainage Channel (Brunette River)		1914 to 1935	114,800

[a] See Figure 37 for location of facilities.
[b] Sewer capacity calculated flowing full using 'n' of 0.013 in Manning's formula.
[c] Figures rounded to nearest hundred dollars.
[d] Lengths given to nearest 25 feet. RC indicates reinforced concrete pipe; BHS, Boston horseshoe section; ESS, egg shaped section; SS, special section; SLHS, St. Louis horseshoe section; RSP, riveted steel pipe.
[e] Constructed by Vancouver and purchased by the Sewerage Board for $94,800 in 1915.
[f] Constructed by Vancouver and purchased by the Sewerage Board for $45,600 in 1915.
[g] Constructed by Vancouver and purchased by the Sewerage Board for $33,500 in 1915.
[h] Constructed by Vancouver and purchased by the Sewerage Board for $125,000 in 1914.
[i] Cost of reconstruction and lowering in 1950.
[j] Constructed by Vancouver and purchased by the Sewerage Board for $15,000 in 1914.
[k] Constructed by Vancouver and purchased by the Sewerage Board for $83,000 in 1914.
[l] Constructed by Point Grey and purchased by the Sewerage Board for $40,300 in 1914.
[m] Constructed by Point Grey and purchased by the Sewerage Board for $48,100 in 1925.
[n] Does not include the South Hill Sanitary Trunk Sewer built in 1926 for $58,700 and leased to the City of Vancouver in 1930.
[o] Constructed by Burnaby and purchased by the Sewerage Board for $1 in 1951.
[p] Constructed by New Westminster and purchased by the Sewerage Board for $96,600 in 1928.
[q] Constructed and owned by New Westminster.

Appendix IV

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Vancouver, B. C.

June 14, 1951.

SUPPLEMENT TO REPORT ON GEOLOGY OF VANCOUVER & VICINITY JULY, 1950.

In a report entitled "The Geology of Vancouver and Vicinity", prepared in July 1950, for the Vancouver and Districts Joint Sewerage and Drainage Board, the writer made some predictions based on surface geology, as to the conditions which might be encountered in a proposed tunnel through Point Grey peninsula, along the line of Highbury Street, at an elevation close to sea level. The prognostications were tentative and to be tested by drilling. Seven holes drilled along the line of the proposed tunnel from the surface down to the tunnel level have now been completed, and the present supplementary report is an interpretation of the drilling information and a correlation of this information with the conclusions drawn from the surface geology and stated in the earlier reports.

On pages 14 and 15 of that report it was predicted that the tunnel would start in the tertiary sandstones and shales and, excepting a short probable interval near 1st Avenue, it would continue in these tertiary sediments for a considerable distance, depending on the elevation to which this formation was found to extend in the central part of the peninsula. It was further stated that after passing through the tertiary sandstones the tunnel would probably encounter a lower boulder clay and then enter the unconsolidated sediments of the inter-glacial period. As these strata lie horizontally, it was thought that the tunnel would continue in similar strata to near the south portal, where it would encounter and pass through the upper boulder clay, which mantles the entire peninsula. It was inferred that certain beds of fine silt and clay of the inter-glacial sediments, seen at numerous places in the cliffs surrounding the peninsula, would probably be found by the drilling to overlie the tunnel through most of its length and so protect it from serious water troubles during its construction. It was, however, also pointed out that these sediments are lenticular in habit and that individual strata might not be continuous throughout the length of the tunnel and that lenses of sand saturated with water might be encountered.

The drilling showed that the above sequence of formations would be followed as far as some point in the vicinity of 30th Avenue and that the tunnel would pass out of the sandstones somewhere in the vicinity of 24th Avenue and out of the lower boulder clay into the inter-glacial sediments a little further on. It would then continue in these formations to some point near 30th Avenue. From this point on, instead of continuing in the inter-glacial sediments as was expected, a thick bed of boulder clay appeared in holes 6, 5, 7, and probably 4 at Marine Drive, and the tunnel from 30th Avenue to 41st Avenue would be either in or immediately under this boulder clay. From 41st Avenue south to Marine Drive and beyond, the tunnel would again be in the inter-glacial sediments.

This boulder clay decreases from a thickness of over 100 feet in hole 6 at Memorial Park to less than 10 feet at hole 7 at 41st Avenue.

Between 41st Avenue and Marine Drive, there is a little doubt as to what happens to it but the evidence is fairly strong that it rises slightly and is intersected by the upper boulder clay near Marine Drive. The evidence for this is (1) the double thickness of boulder clay in hole 4, and (2) the fact that the sands in hole 7 produced large quantities of water, while those in hole 4 were nearly dry.

Therefore, the original expectations

were fulfilled, excepting for the interruption of this boulder clay between 30th and 41st Avenues.

The boulder clay will be more difficult to tunnel than the unconsolidated sediments, but there is less danger of

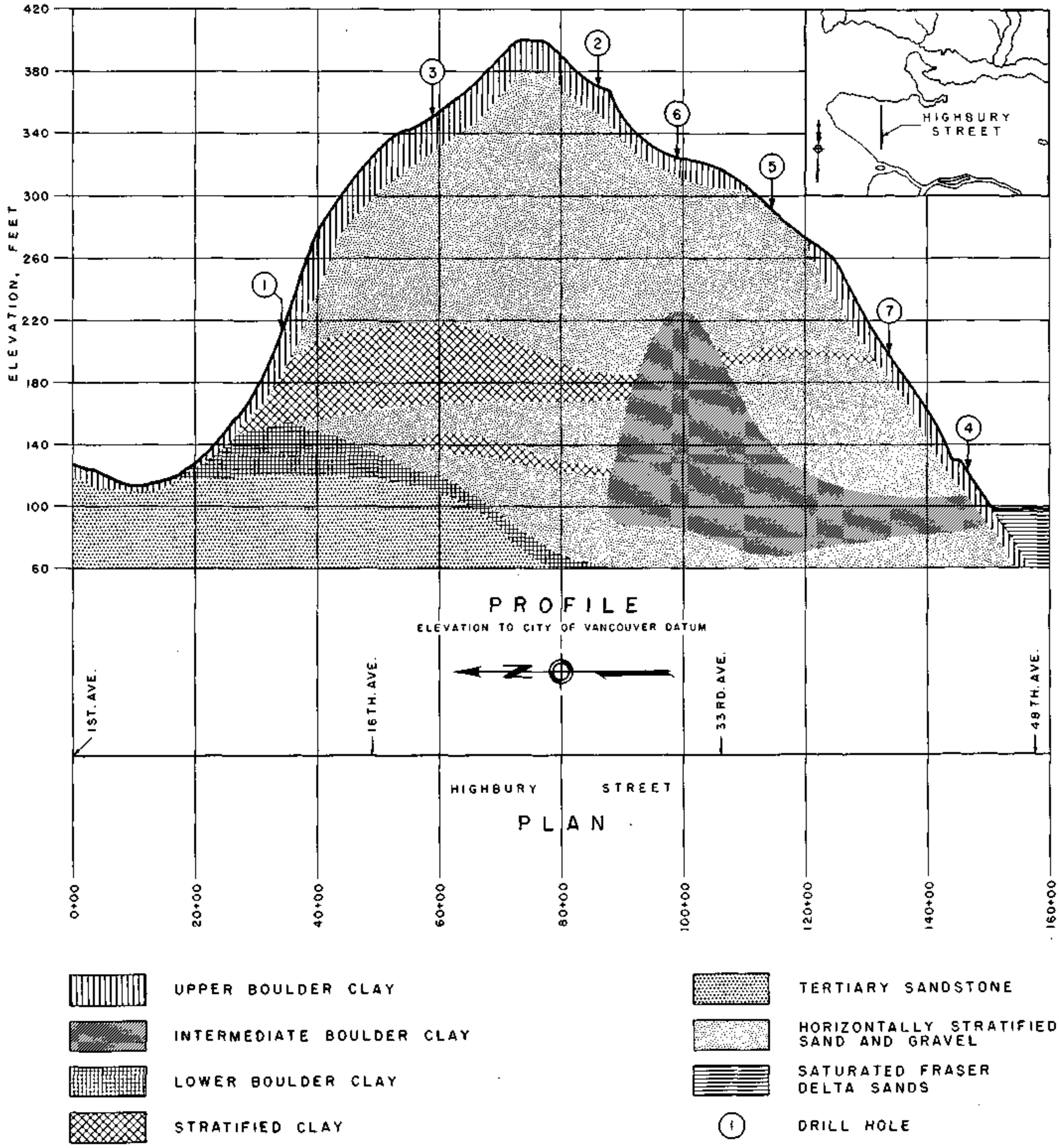

Figure 111. Geological Formations of Burrard Peninsula along Highbury Street

This figure was adapted from a report of Dr. Victor Dolmage on the geological structure along the route of Highbury Street in the City of Vancouver. The report was submitted to the Vancouver and Districts Joint Sewerage and Drainage Board in 1950. As described in Chapter 14, it is proposed to convey sewage from the north slope of Burrard Peninsula through a tunnel to the south slope of the peninsula. The tentative location of this tunnel is along the route of Highbury Street.

encountering saturated sand lenses.

The water hazard as visualized earlier has not been greatly changed by the presence of the middle boulder clay since it would probably be as effective a shield against water as the stratified clays. No water pressure was encountered beneath the boulder clay, nor beneath the lowest stratified clay.

The artesian water encountered in hole 1 came from the sands and gravels above the upper clay in the inter-glacial formation and it probably entered this formation through a break or gap in the upper boulder clay at some higher elevation.

A small amount of artesian water was encountered in hole 2 at a point just above the lower one of two beds of stratified clay in the inter-glacial sediments. It is very probable that this water entered through a break between the upper stratified clay and the thick boulder clay found in hole 6.

The large flow of water in hole 7 probably entered the formation through a similar break on the south slope of this boulder clay. However, it is clear from the drilling that the inter-glacial clays are not so well developed south of hole 2, as north of it. This is remarkable in view of the fact that these clays are well exposed along the cliffs bordering the Fraser River, a short distance to the southwest.

The two principal flows of artesian water were below elevation 200 and while the flow was considerable, the pressure was low. At hole 7 a pressure of only 5 pounds per square inch was measured, which gives an artesian head of 11.5 feet above the hole or elevation 210.75. It is certain, however, that the ground water level rises considerably higher than this in the higher parts of the peninsula. The water which rose to the surface in hole 2 at elevation 375.2, came from a thin seam of sands between two beds of clay. It is possible that the water used in drilling caused this to happen.

Respectfully submitted,
(Signed) V. Dolmage