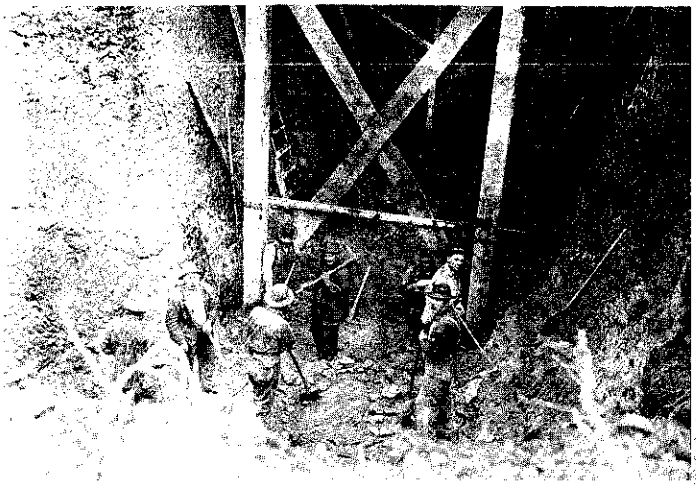
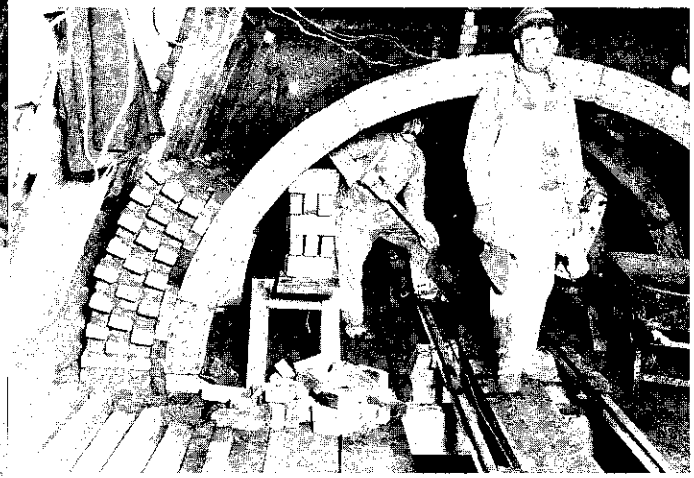
PART III

EXISTING SEWERAGE, SEWAGE DISPOSAL AND DRAINAGE

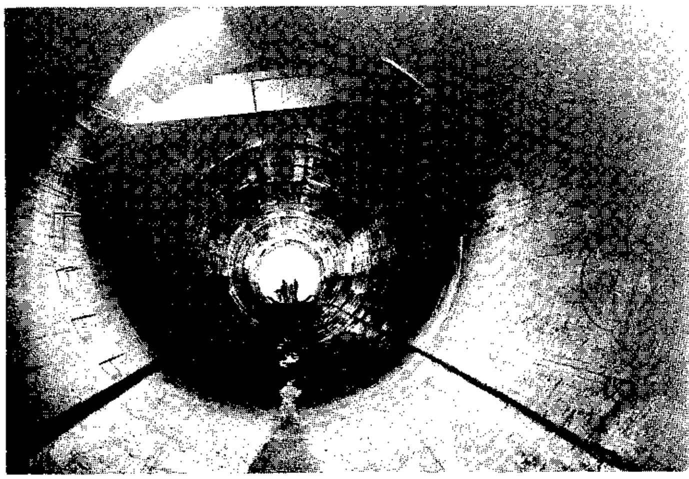
CONSTRUCTION OF NORTH TRUNK SEWER



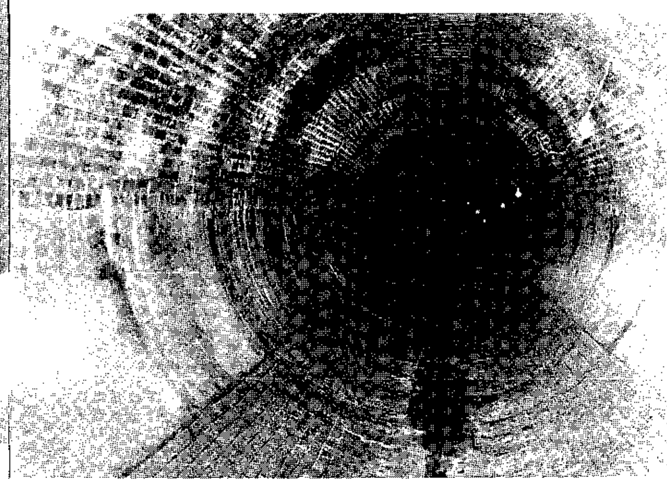
← OPEN CUT TRENCH for 144-inch Interbay section constructed in 1912.



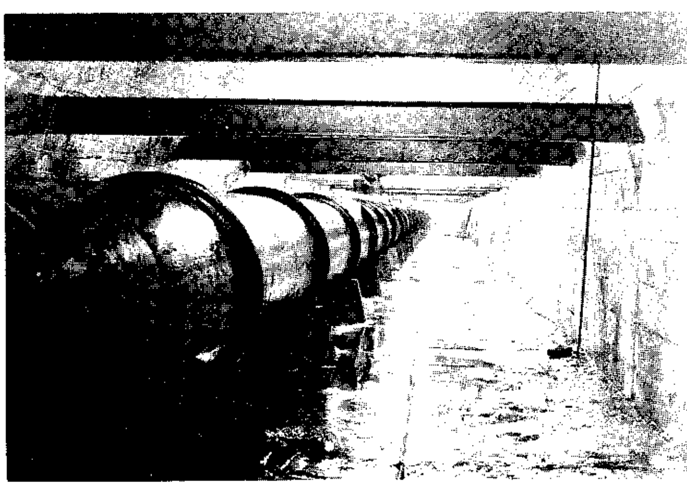
LAYING BRICK ARCH in 144-inch Interbay tunnel section. →



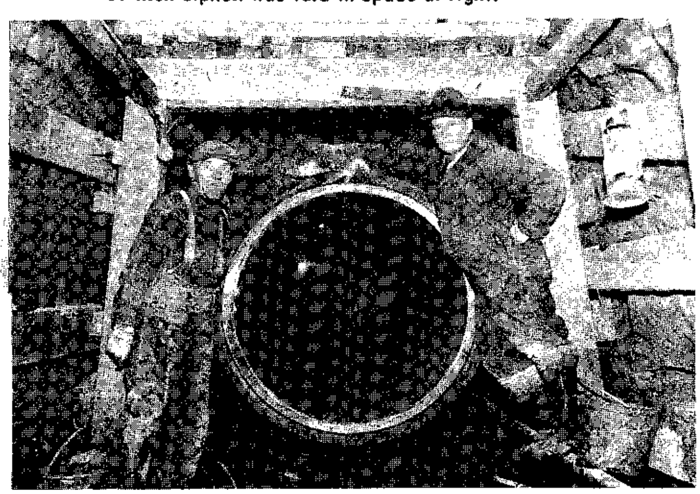
← 144-INCH CONCRETE SECTION constructed in open cut, ready for laying of brick invert and construction of manhole.



COMPLETED 114-INCH TUNNEL SECTION beneath Montlake Boulevard. →



← 40-INCH SIPHON IN TUNNEL under ship canal at 3rd Street West. Subsequently, an additional 60-inch siphon was laid in space at right.



48-INCH CONCRETE PIPE being laid in Laurelhurst tunnel section. →

SEATTLE, 1912

Chapter 6

EXISTING SEWERAGE AND DRAINAGE FACILITIES

One of the basic objectives of the present survey is that of determining the extent to which facilities presently in use can be incorporated in a long-range program of sewerage and drainage improvements. Accordingly, all such facilities were appraised and evaluated in terms of their ability to meet both present and future needs.

Information presented in this chapter was derived from questionnaires answered by various sewerage agencies, from reviews of plans and reports, and from field investigations. Information and data concerning sewage volumes and composition, although obtained as part of the study of existing systems, are set forth in Chapter 7 on sewage characteristics.

Responsibility for providing sewerage service within the metropolitan area is divided among 19 cities and 22 sewerage districts (Fig. 6-1). Of these 41 agencies, 15 are presently engaged in the operation of sewerage facilities (Table 6-1). The remainder (Table 6-2) are either (1) in various stages of planning, financing and constructing facilities (2) annexed to operating agencies, or (3) essentially inactive. In addition to the public systems, there are 8 semi-public and private systems which serve military, airport, and industrial establishments, and multiple housing developments (Fig. 6-1 and Table 6-3).

Between them, the various agencies operate and maintain about 1,550 miles of sewers, 75 pumping stations, and 25 sewage treatment works. Of the total length of sewers, about 510 miles are separate sanitary lines, while 1,040 miles are of the combined type carrying both sanitary sewage and storm drainage. Virtually all of the combined sewers are located in Seattle.

The aggregate design capacity of the 25 treatment plants is 28 mgd, which is sufficient to treat only about one-third of the average daily sewage flow generated during dry weather (average DWF). Consequently, close to 50 mgd of sewage and industrial wastes are being discharged without treatment through about 60 independent outfalls. Despite the multiplicity of facilities, only about 70 per cent of the residents of the area are served by public sewers. The remaining residents provide and maintain individual septic tank systems, which are being constructed at a rate of about 6,000 per year.

Information regarding assessed valuation, tax rate, service and other charges, and bonded indebtedness is given in Table 6-4. This table also lists annual costs of operation and maintenance.

Responsibility for providing drainage facilities rests with the cities and, to a limited extent, with local drainage districts and the counties. In addition to Seattle, only four cities and one local district have storm drainage systems worthy of note. Drainage activities of the counties are limited by law to situations directly associated with street and highway construction and drainage. As a result, such facilities as exist in the unincorporated areas are mainly by-products of street and highway drains and serve localized problem areas only.

In the following sections of this chapter, each existing sewerage and drainage system is analyzed in sufficient detail to permit its evaluation in terms of the future sewerage and drainage requirements of the area.

SEWERAGE FACILITIES OUTSIDE SEATTLE

Of the 35 square miles now occupied by cities and sewer districts situated in the metropolitan area outside Seattle, about 20 square miles were sewered as of July 1, 1957. In this outside area, sewerage service is provided by five cities and nine sewer districts (Table 6-1). Sewage treatment plants are operated by each of the five cities and by seven of the nine districts.

Bellevue Sewer District

The Bellevue Sewer District was organized in 1948 to serve a small section of what is now the city of Bellevue. Today, the district encompasses an area of nine square miles, including most of Bellevue, all of four other cities (Beaux Arts, Clyde Hill, Hunts Point and Medina), and adjacent unincorporated areas. Only 1.1 square miles are now sewered and serve a connected population of 4,100. Construction has begun, however, in Utility Local Improvement District (ULID) No. 7, which will serve the northerly section of the district. Construction has begun also in ULID No. 8, which includes Clyde Hill, Hunts Point and Medina. No service is contemplated in the Beaux Arts area until about 1959.

The Bellevue collection system consists of 21 miles of sewers ranging in size from 6 to 16 inches, and four sewage pumping stations, two of which are utilized for flushing an intercepting sewer submerged in

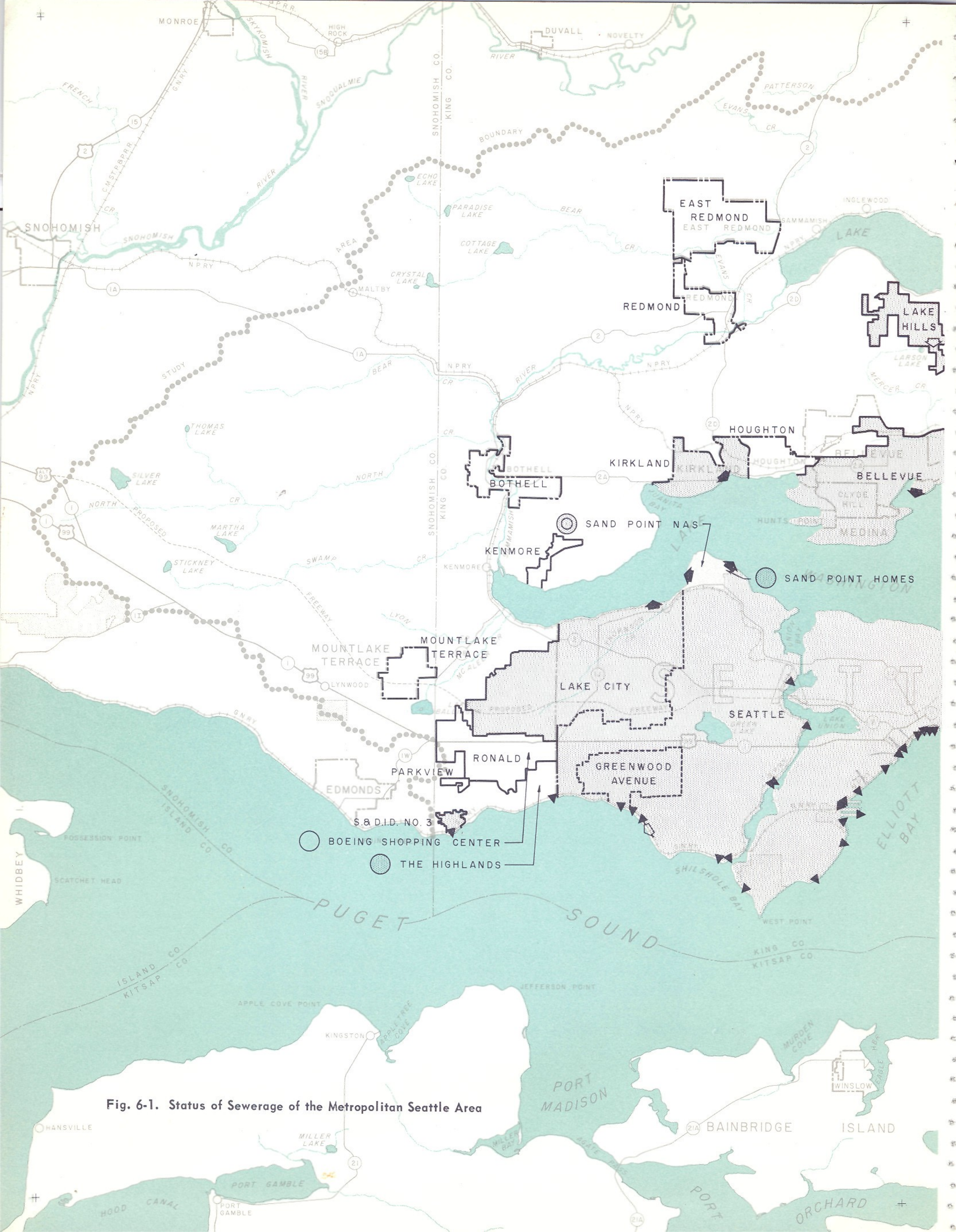
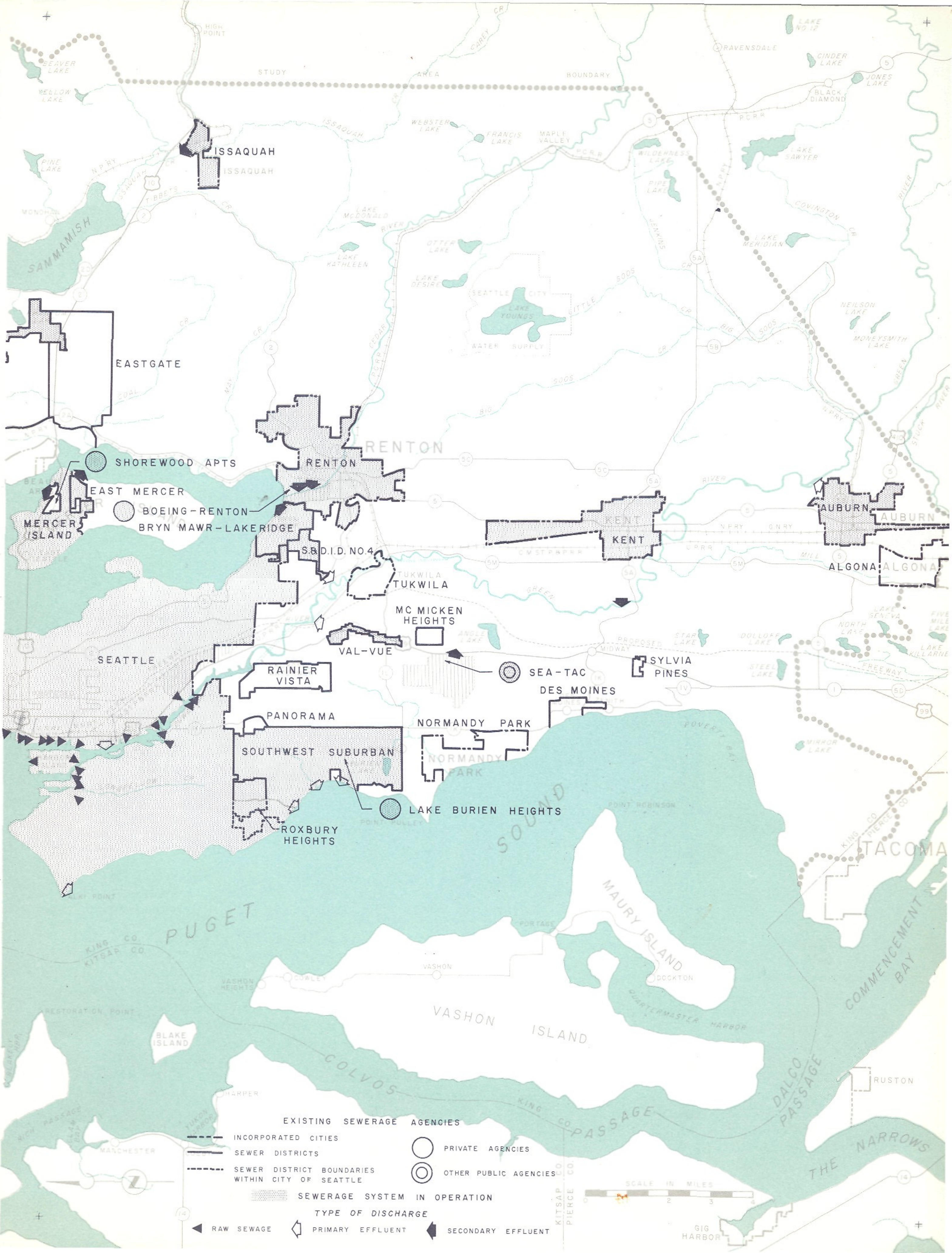


Fig. 6-1. Status of Sewerage of the Metropolitan Seattle Area



ISSAQUAH
EASTGATE
SHOREWOOD APTS
EAST MERCER
BOEING-RENTON
BRYN MAWR-LAKERIDGE
MERCER ISLAND
RENTON
S.B.D.I.D. NO.4
TUKWILA
MC MICKEN HEIGHTS
VAL-VUE
KENT
AUBURN
ALGONA
SEATTLE
RAINIER VISTA
SEA-TAC
SYLVIA PINES
DES MOINES
PANORAMA
NORMANDY PARK
SOUTHWEST SUBURBAN
LAKE BURIEN HEIGHTS
ROXBURY HEIGHTS
TACOMA
PUGET SOUND
MAURY ISLAND
VASHON ISLAND
COLVOS PASSAGE
DALCO PASSAGE
COMMENCEMENT BAY
THE NARROWS
BLAKE ISLAND
RUSTON
GIG HARBOR
SAMMAMISH
STUDY AREA BOUNDARY
RAVENSDALE
BLACK DIAMOND
MAPLE VALLEY
LAKE YOUNGS
SEATTLE CITY WATER SUPPLY
EXISTING SEWERAGE AGENCIES
INCORPORATED CITIES
SEWER DISTRICTS
SEWER DISTRICT BOUNDARIES WITHIN CITY OF SEATTLE
PRIVATE AGENCIES
OTHER PUBLIC AGENCIES
SEWERAGE SYSTEM IN OPERATION
TYPE OF DISCHARGE
RAW SEWAGE
PRIMARY EFFLUENT
SECONDARY EFFLUENT
SCALE IN MILES

Table 6-1. Status of Sewerage in Operating Sewerage Agencies

Agency	Date agency formed	Area, square miles		Population	
		Total	Sewered	Total	Connected
Cities and towns					
Auburn	1891	2.1	2.0	8,000	7,000
Issaquah	1913	0.7	0.3	1,100	1,450
Kent	1890	3.0	1.7[a]	4,150	4,000
Kirkland	1905	2.0	2.0[b]	5,750	5,750
Renton	1901	5.0	3.3	16,500	14,800
Seattle[c]	1865	79.5[d]	69.5[e]	561,000	510,000
Sewer districts					
Bellevue[f]	1948	9.0	1.1	g	4,100
Bryn Mawr - Lake Ridge	1950	1.1	0.8	g	4,500
East Mercer	1952	0.3	0.3	600	500
Lake Hills	1955	1.9	0.3	1,550	1,460
Mercer Island	1953	2.2	0.9	3,000	800
Sewerage and Drainage District No. 3	1939	0.5	0.5[h]	g	1,100
Sewerage and Drainage District No. 4	1943	0.4	0.3	2,300	2,400
Southwest Suburban	1945	6.8	3.5	g	12,600
Val Vue	1945	0.4	0.2	g	1,150
Total		114.9	86.7		571,610

Agency	Sewers			Number of pumping stations	Treatment plants			Discharge to
	Miles	Year first constructed	Diameter range, inches		Type[i]	Year constructed[j]	Capacity, average mgd	
Cities and towns								
Auburn	28	1910	6-30	1	P	1950	1.1	Green River
Issaquah	13	1940	8-15	0	S	1940	0.23	Issaquah Creek
Kent	10	k	6-24	1	S	1954	1.7	Green River
Kirkland	32	1942	6-24	5	S	1943-51	1.6	Lake Washington
Renton	36	1910	6-24	1	S	1943-53	2.2	Cedar River
Seattle[c]	1,233[m]	1883	6-144	39[n]	p		26.5[q]	r
Sewer districts								
Bellevue[f]	21	1953	6-16	4	S	1954-57	0.56	Lake Washington
Bryn Mawr-Lake Ridge	15	1952	6-18	2	S	1952	0.43	Lake Washington
East Mercer	5	1954	8-12	0	S	1955	0.13	Lake Washington
Lake Hills	7	1955	8-18	5	P	1955-57	0.32	Land
Mercer Island	25	1956	6-16	8	s			t
Sewerage and Drainage District No. 3	7[u]	1941	6-18	0	v			Puget Sound
Sewerage and Drainage District No. 4	10	1943	6-18	2	P	1943-44	0.2	Duwamish River
Southwest Suburban	54	1942	8-36	5	P	1956	8.2	Puget Sound
Val Vue	3	1947	6-15	0	P	1955	0.28	Duwamish River
Total	1,526			73			43.45	

[a] *Includes 0.2 square mile outside city limits.*
[b] *1.5 square miles inside city limits; 0.5 square mile outside.*
[c] *Includes the systems of Lake City, Greenwood Avenue, and Roxbury Heights Sewer Districts now operated by Seattle.*
[d] *Exclusive of water areas.*
[e] *Includes 2.5 square miles outside city limits.*
[f] *Includes cities of Beaux Arts, Bellevue, Clyde Hill, Medina and Hunts Point.*
[g] *No reliable estimate available.*
[h] *Also serves "Old Firlands" area.*
[i] *P - primary; S - secondary.*
[j] *Where two years are shown, second indicates major enlargement.*
[k] *Initial construction of modern sewers assumed to be prior to 1930.*
[m] *1,029 miles combined; 204 miles separate sanitary.*
[n] *Does not include several small lift stations serving small areas.*
[p] *Seattle operates five treatment plants and has one under construction; in addition, there are a number of raw sewage outfalls and bypasses; see section on existing Seattle system.*
[q] *Total capacity. Includes Alki Point plant and enlargement of Lake City plant, both under construction.*
[r] *See section on existing Seattle system.*
[s] *Sewage treated at Bellevue plant.*
[t] *See Bellevue.*
[u] *Includes 1.9 miles outside district.*
[v] *Comminuter and chlorination station, inoperative.*

Table 6-2. Status of Sewerage in Non-Operating Sewerage Agencies[a]

Agency	Date formed	Area, square miles	Status
Cities and towns			
Algona	1955	1.4	Inactive.
Beaux Arts	1954	0.1	Annexed to Bellevue Sewer District.
Bellevue	1953	4.0	Served by Bellevue Sewer District.
Bothell	1909	1.6	System financed; plans in preparation.
Clyde Hill	1953	1.0	Annexed to Bellevue Sewer District; sewers under construction.
East Redmond	1956	3.6	Inactive.
Houghton	1947	1.3	Partially served by Kirkland.
Hunts Point	1955	0.3	Annexed to Bellevue Sewer District; sewers under construction.
Medina	1955	1.3	Annexed to Bellevue Sewer District; sewers under construction.
Mountlake Terrace	1954	1.5	Preliminary plans in progress.
Normandy Park	1953	1.6	Inactive.
Redmond	1912	1.3	System financed; construction scheduled 1957-58.
Tukwila	1908	0.7	Inactive.
Sewer districts			
Des Moines	1946	0.5	System financed; plans in progress; construction scheduled spring 1958.
Eastgate	1957	4.0	Preliminary planning scheduled fall 1957.
Greenwood Avenue	1946	2.7	Completely sewered; operated by Seattle.
Kenmore	1955	0.5	Inactive.
Lake City	1946	12.2	Approximately 50 per cent sewered; operated by Seattle.
McMicken Heights	1948	0.3	Inactive.
Panorama	1945	0.2	Inactive.
Parkview	1948	0.1	Inactive.
Rainier Vista	1945	1.2	System financed; plans in preparation, scheduled for construction spring 1958.
Richmond	1949	0.5	System operated by King County Engineer under Sewerage and Drainage District No. 3.
Ronald	1951	1.5	System financed; plans in preparation.
Roxbury Heights	1944	0.8	Approximately 50 per cent sewered; operated by Seattle.
Sylvia Pines	1957	0.1	New district; plans in progress.

[a]*Presently unsewered except as noted.*

the water adjacent to the shoreline of Meydenbauer Bay (Fig. 6-2 and Table 6-5). Complete treatment facilities, with a design capacity of 0.56 mgd, were constructed in 1954 and are now being expanded to a capacity of 2 mgd (Fig. 6-3). The added units are temporary and are to be abandoned when area-wide sewerage service becomes available. Plant effluent is chlorinated and discharged to Lake Washington. Sewage from Mercer Island Sewer District is treated at the Bellevue plant under a contractual arrangement.

Table 6-3. Summary of Private and Semi-Public Sewerage Facilities

System	Facility served	Area served, square miles	Treatment		Discharge to
			Type[a]	Capacity, average mgd	
Boeing-Renton	Aircraft plant	0.25	S	0.5	Cedar River
Boeing Shopping Center	[b]	0.03	P	0.18	Puget Sound
The Highlands	Residential	0.7	None	—	Puget Sound
Lake Burien Heights	Apartments	0.03	P	0.15	Puget Sound
Sand Point Naval Air Station	Military reservation	0.70	S	0.86	Lake Washington
Sand Point Homes	University housing	0.003	S	0.1	Lake Washington
Shorewood	Apartments	0.05	S	0.26	Lake Washington
Seattle-Tacoma International Airport	Airport	[c]	S	0.1	Bow Lake

[a]*P — primary; S — secondary.*

[b]*Constructed to serve proposed shopping center - nonoperating.*

[c]*Serves airport terminal and service buildings.*

Table 6-4. Summary of Financial Information for Sewerage Agencies

Agency	Assessed valuation,[a] $1,000,000	Levy,[b] mills	Service charge,[c] dollars	Connection fee, dollars	Bonds outstanding, $1,000		Annual cost of maintenance and operation, dollars
					General obligation	Revenue	
Sewer districts							
Bellevue	7.8	1.30	3.00	17.00	118.0	1,505.0	29,300
Bryn Mawr - Lake Ridge		None	2.00	17.50	None	295.0	15,230
East Mercer		None	4.00	300.00	None	124.0	5,890
Greenwood	12.2	1.00	2.00[d]	75.00[e]	127.0	1,803.0	f
Lake City	42.8	1.00	3.00[g]	35.00[h]	609.0	5,792.0	f
Lake Hills		None	3.50	None	None	140.0	4,800
Mercer Island	4.8	2.40	5.00	35.00	150.0	912.0	35,380
Roxbury Heights	1.2	2.30	None[i]	None	17.0	None	f
Southwest Suburban	15.2	2.30	3.00	15.00	481.0	3,800.0	84,000[j]
Val Vue		None	4.00	100.00[k]	None	146.0	8,470
Sewerage and Drainage District No. 3		None	0.22[m]	None	None	None	540
Sewerage and Drainage District No. 4		None	22.00[n]	None	None	None	13,240
Cities and towns							
Auburn		None	1.50	None	None	140.0	9,000
Issaquah		None	1.25[p]	0.83[q]	None	None	7,420
Kent		None	0.75	10.00	None	390.0	22,230
Kirkland		None	2.00[r]	50.00	None	283.0[s]	19,000
Renton	18.1	3.05	0.75	10.00	t	62.8	19,030
Seattle	637.4	0.003	1.00[u]	None	1,776.0	None	492,130

Based on data submitted by sewerage agencies; five additional agencies, Des Moines, Rainier Vista, Ronald, Redmond and Bothell have issued bonds for proposed facilities but are, as yet, inoperative.

[a] *Assessed valuation as of January 1, 1956, given only if there is levy for sewerage.*

[b] *Portion of general levy designated for sewerage.*

[c] *Monthly, unless otherwise indicated.*

[d] *Per single residence and duplex; more for others. Residents of the district also pay $1.00 per month City of Seattle charge.*

[e] *Per single residence; others, $150.00.*

[f] *Included in Seattle.*

[g] *Sewer bond charge; portion in Seattle also pays $1.00 city service charge; portion outside pays city pro-rata share of annual maintenance and operation cost – $6.54 per household in 1956.*

[h] *Late charge; applies if connected more than one year after service is available.*

[i] *Portion now within Seattle pays $1.00 service charge.*

[j] *Estimated cost for first year of operation.*

[k] *Included in original assessment.*

[m] *Annual per front foot charge.*

[n] *Flat annual charge.*

[p] *Charge is $1.50; $0.25 discount if paid by 10th of month.*

[q] *Per front foot.*

[r] *$3.00 outside city limits.*

[s] *Estimated sewerage portion of $850,000 outstanding sewer and water bonds.*

[t] *Unspecified portion of $589,000 water and sewerage issue.*

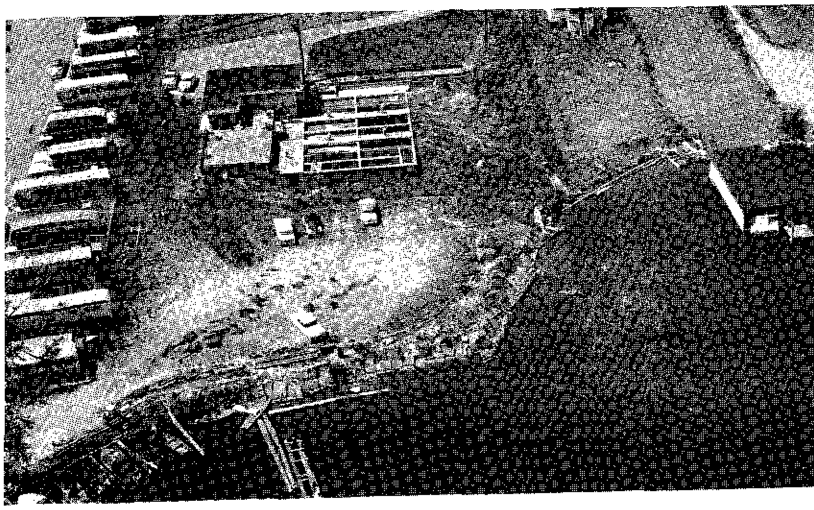
[u] *Minimum charge for 3/4-inch water service, with additional charge of $0.06 per 100 cubic feet for water in excess of 900 cubic feet per month.*

Bryn Mawr-Lake Ridge Sewer District

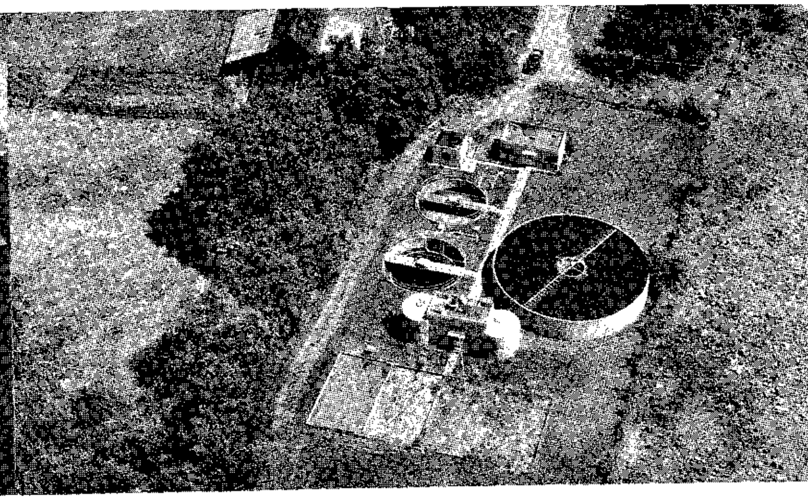
This district, which was formed in 1950 and comprised an area of 1.1 square miles, has boundaries in common with Seattle on the north and with Sewerage and Drainage District No. 4 and the city of Renton on the south. The collection system covers an area of 0.8 of a square mile, and consists of 15 miles of 6-inch to 18-inch sewers and two pumping stations. It serves a connected population of 4,500, as well as part of the Boeing-Renton plant (Fig. 6-4 and Table 6-6). Secondary treatment is provided by a plant which has a design capacity of 0.43 mgd and the effluent, after being disinfected, is discharged to Lake Washington (Fig. 6-5).

East Mercer Sewer District

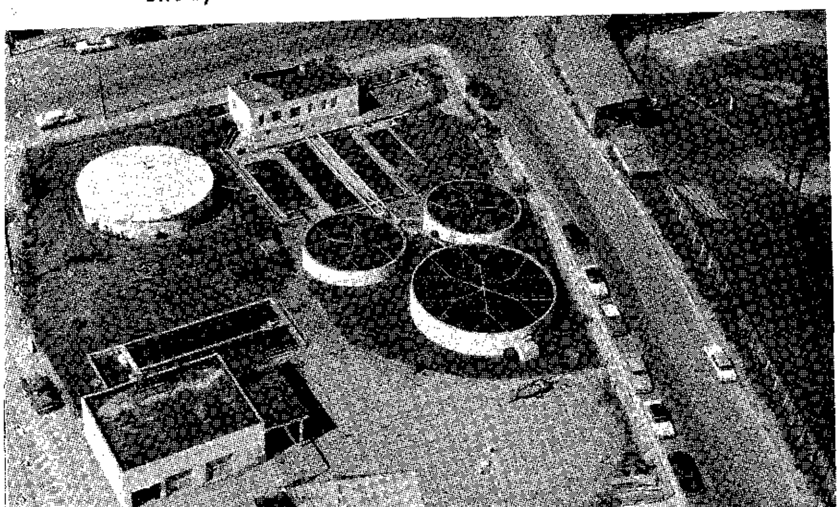
Formed in 1952, the East Mercer Sewer District comprises a 0.3 square mile section of northeasterly Mercer Island. Sewerage facilities were constructed throughout the district in 1954, and now serve a connected population of 500. The system is composed of 5.2 miles of 8-inch to 12-inch sewers (Fig. 6-2 and Table 6-7), and a secondary type sewage treatment plant with a design capacity of 0.13 mgd (Fig. 6-6). Plant effluent is chlorinated and discharged to Lake Washington.



BRYN MAWR SEWAGE TREATMENT PLANT showing digesters and control building at left and aeration and sedimentation tanks at right. Effluent from this activated sludge plant is discharged *into* Lake Washington. Digested sludge is removed from site by tank truck.

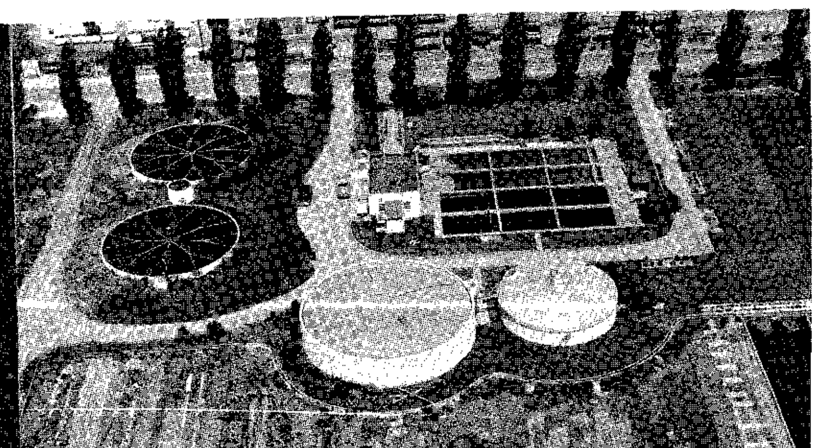


ISSAQUAH SEWAGE TREATMENT PLANT provides secondary treatment for a connected population of 1,100. Picture shows, from front to rear, sludge drying beds, digesters, trickling filter (right), secondary and primary clarifier and control buildings. Effluent is discharged into Issaquah Creek.



KIRKLAND SEWAGE TREATMENT PLANT provides secondary treatment of sewage from a connected population of 5,750, serving, in addition to Kirkland itself, the northerly section of Houghton and unincorporated areas east of the city. Plant effluent is discharged to Lake Washington via a trunk storm drain situated on the street beyond control building, upper right. Final sedimentation tank and sludge conditioning building are at lower left. Primary sedimentation tanks are located between control building and trickling filters with digester at left.

BELLEVUE SEWAGE TREATMENT PLANT showing aeration units in foreground, sedimentation tanks and control building with sludge drying beds at left, and sewer district headquarters in rear. Effluent from this activated sludge plant is discharged to Lake Washington. Plant additions which will quadruple the capacity are now being constructed.



RENTON SEWAGE TREATMENT PLANT showing sludge drying beds in foreground, digesters (center), trickling filters (left rear), two primary and two secondary rectangular sedimentation tanks (right rear), and control building. Note difference in clarity of liquid in primary tanks as compared with that in secondary tanks.

SUBURBAN SEWAGE TREATMENT PLANTS DISCHARGING WITHIN THE LAKE WASHINGTON DRAINAGE BASIN

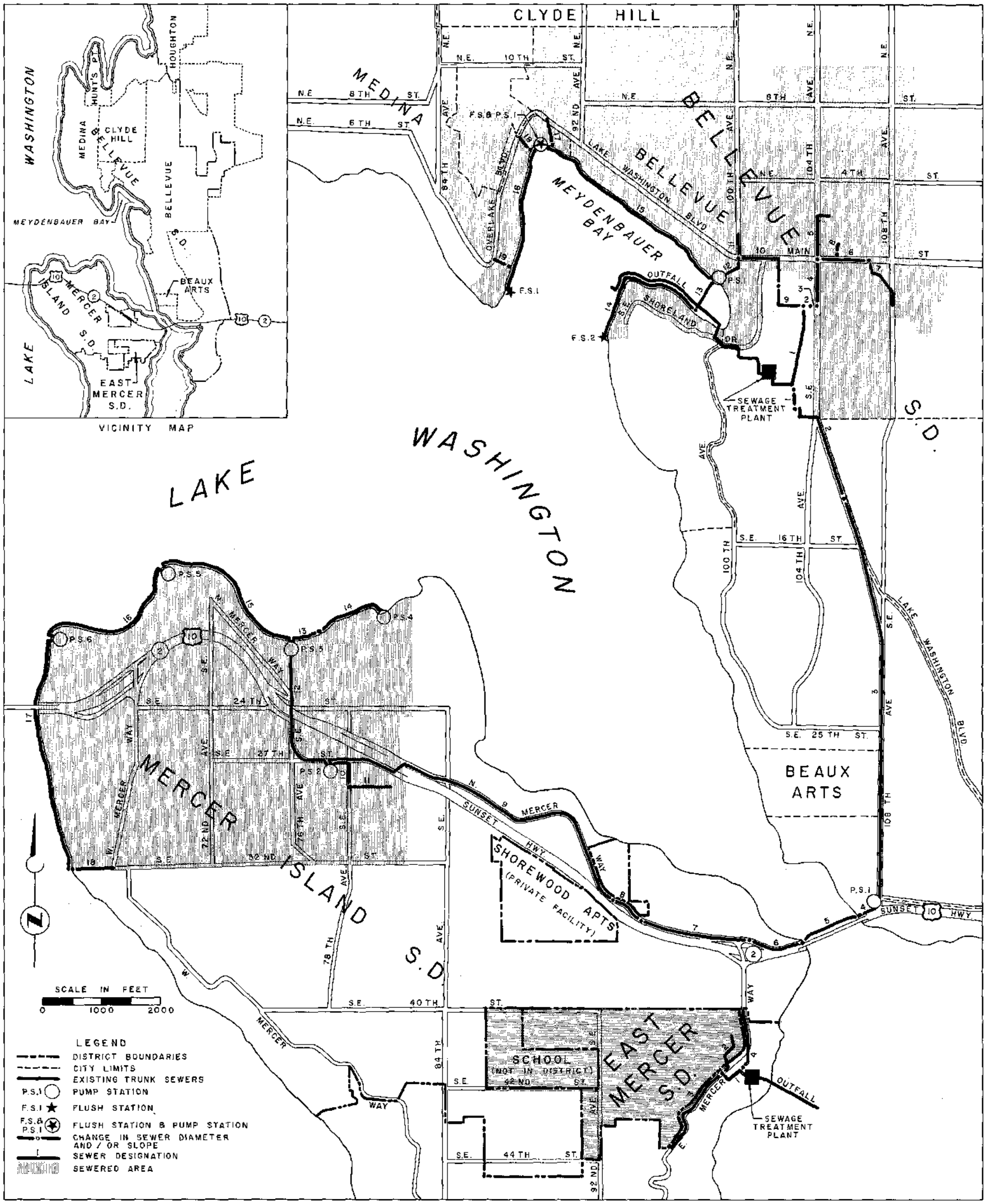


Fig. 6-2. Sewered Areas and Principal Sewerage Facilities Bellevue, East Mercer, and Mercer Island Sewer Districts

Table 6-5. Description of Principal Sewerage Facilities, Bellevue Sewer District

Facility[a]	Description[b]	Capacity,[c] mgd
1	1,880 ft of 14-in. CA pressure section	
2	170 ft of 12-in. CA pressure section	
3	100 ft of 12-in. conc at 6.49%	5.8
4	790 ft of 15-in. conc at 0.20%	1.8
5	890 ft of 10-in. conc at 0.22%	0.7
6	1,180 ft of 10-in. and 12-in. conc and RC at 3.09%	2.5
7	900 ft of 10-in. CI and conc at 0.40%	0.9
8	240 ft of 10-in. conc at 8.00%	1.3
9	410 ft of 12-in. CA at 2.85%	3.9
10	1,480 ft of 12-in. and 15-in. CA and conc at 0.80%	3.7
11	370 ft of 8-in. conc at 6.35%	2.0
12	640 ft of 8-in. CA force main	
13	750 ft of 8-in. CI inverted siphon	
14	2,060 ft of 8-in. CA submerged pressure line	
15	3,780 ft of 10-in. CA submerged pressure line	
16	2,720 ft of 8-in. CA submerged pressure line	
17	360 ft of 8-in. CA and conc at 7.10%	2.1
18	390 ft of 8-in. CA and conc at 1.20%	0.9
19	330 ft of 8-in. CA and conc at 3.0%	1.3
Outfall	3,200 ft of 16-in. CA and CI; discharge to Lake Washington	

[a]See Fig. 6-2 for location.

[b]Where slope varies within section, limiting or average slope is shown. CA signifies cement-asbestos pipe; conc, concrete; RC, reinforced concrete; CI, cast iron.

[c]Capacity calculated using Manning's formula, "n" equals 0.013.

Lake Hills Sewer District

Sewers were first constructed in the Lake Hills area in 1955 as part of a private development. The sewer district was formed the same year and now comprises an area of about 1.9 square miles. The collection system is being rapidly extended, and now consists of about 7 miles of 8-inch to 18-inch sewers and 5 sewage pumping stations (Fig. 6-7 and Table 6-8).

A primary type treatment plant, the design capacity of which was doubled in 1957 to its present level of 0.32 mgd, provides treatment for the flow from a connected population of about 1,460 (Fig. 6-8). Plant effluent is sprayed over a well isolated section of land by means of a sprinkler type irrigation system and is absorbed by the soil. The treatment facilities, however, are temporary in nature and are to be abandoned when the area becomes sufficiently developed to permit a permanent solution to its sewerage problems.

Mercer Island Sewer District

This district, formed in 1953, comprises an area of 2.2 square miles, of which 0.9 square mile is sewered. Constructed in 1956, the sewerage facilities consist of 25.1 miles of 6-inch to 16-inch sewers and 8 pumping stations, and serve a connected population of over 800 (Fig. 6-2 and Table 6-9). The principal intercepting sewer is submerged in Lake Washington and extends along the entire shoreline of the district. Because it was impractical to lay this interceptor to grade, it was constructed as a force main and several flushing stations were provided to purge it with lake water for removal of settled solids.

It was planned originally to construct a sewage treatment plant and outfall at the north end of Mercer Island. This idea was abandoned, however, and a siphon was laid under the east channel of the lake to convey sewage to the mainland for treatment at the Bellevue plant.

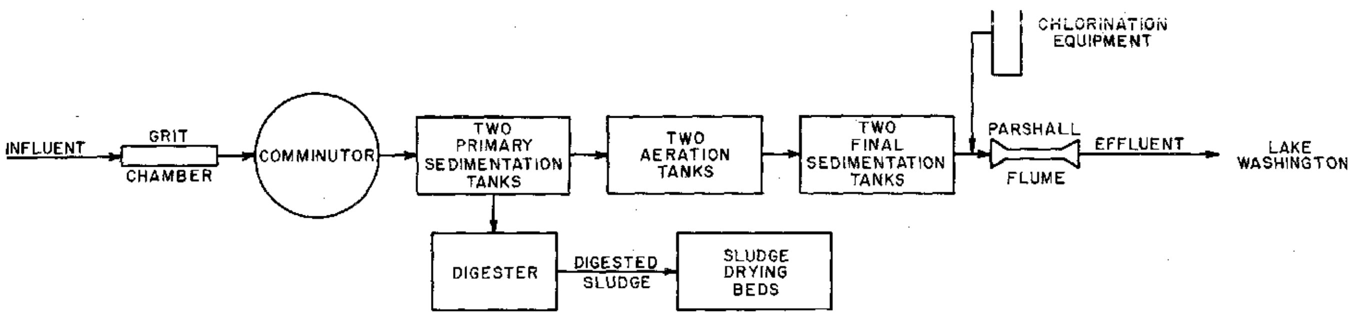


Fig. 6-3. Flow Diagram - Bellevue Sewage Treatment Plant

Complete treatment is provided for sewage from the Bellevue and Mercer Island Sewer districts in this activated sludge plant, the average daily capacity of which is presently being increased from 0.56 mgd to 2.0 mgd by the addition of temporary facilities.

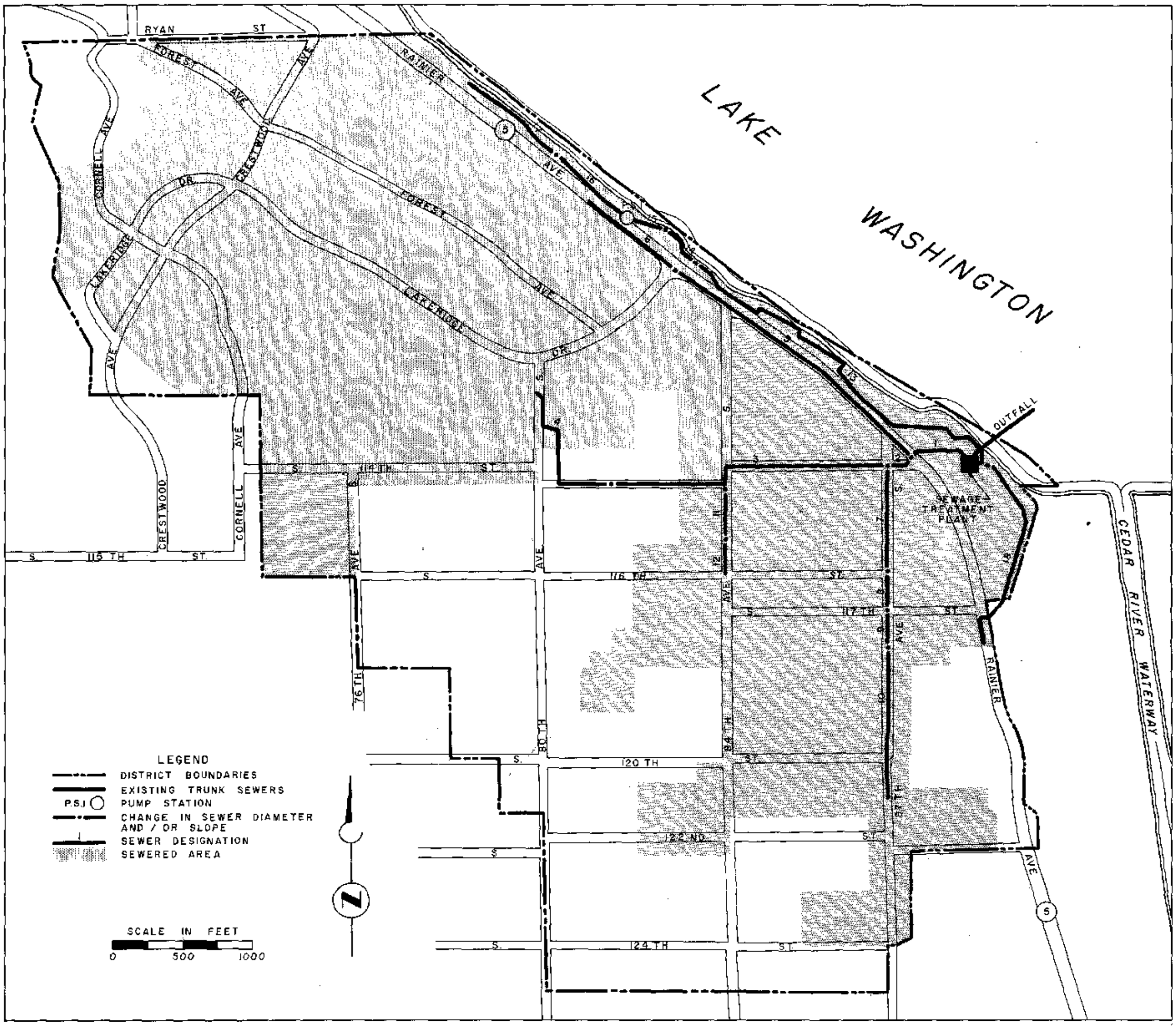


Fig. 6-4. Sewered Area and Principal Sewerage Facilities
Bryn Mawr - Lake Ridge Sewer District

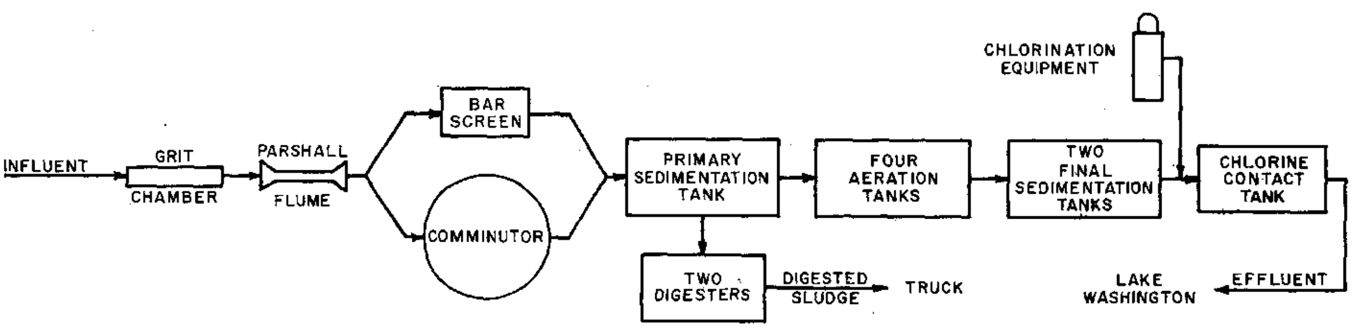


Fig. 6-5. Flow Diagram — Bryn Mawr - Lake Ridge Sewage Treatment Plant

Designed for an average daily capacity of 0.43 mgd, this activated sludge plant provides complete treatment for sewage of the Bryn Mawr - Lake Ridge District and, in addition, serves part of the Boeing plant at Renton.

Table 6-6. Description of Principal Sewerage Facilities, Bryn Mawr - Lake Ridge Sewer District

Facility[a]	Description[b]	Capacity,[c] mgd
1	480 ft of 18-in. PS and conc at 0.31%	3.8
2	190 ft of 10-in. PS at 9.62%	4.4
3	2,060 ft of 8-in. PS at 1.79%	1.1
4	1,140 ft of 8-in. and 10-in. PS at 0.30%	0.8
5	2,190 ft of 12-in. PS at 0.30%	1.3
6	800 ft of 10-in. PS at 0.40%	0.9
7	800 ft of 10-in. PS at 5.93%	3.5
8	260 ft of 10-in. PS at 3.33%	2.6
9	260 ft of 10-in. PS at 0.77%	1.3
10	1,030 ft of 10-in. PS at 0.26%	0.7
11	410 ft of 8-in. PS at 5.13%	1.8
12	220 ft of 8-in. PS at 1.08%	0.8
13	2,760 ft of 12-in. CI and PS at 0.20%	1.0
14	410 ft of 12-in. PS at 0.10%	0.7
15	310 ft of 10-in. CI force main	
16	570 ft of 10-in. CI and conc at 0.23%	0.7
17	810 ft of 10-in. conc at 0.45%	1.0
18	1,560 ft of 8-in. PS at 0.35%	0.5
Outfall	Land section, 50 ft of 12-in. CI; submerged section, 470 ft of 12-in. CI; discharge to Lake Washington	

[a]*See Fig. 6-4 for location.*

[b]*Where size and slope varies within section, limiting or average slope is shown. PS signifies pipe sewer (local designation); CI, cast iron; conc, concrete.*

[c]*Capacity calculated using Manning's formula, "n" equals 0.013.*

Roxbury Heights Sewer District

Roxbury Heights Sewer District, formed in 1944, was the first district created in the state under the existing sewer district law. It occupies an area of 0.75 square miles, of which about 0.4 square miles is sewered (Fig. 6-9 and Table 6-10).

Table 6-7. Description of Principal Sewerage Facilities, East Mercer Sewer District

Facility[a]	Description[b]	Capacity,[c] mgd
1	540 ft of 12-in. PS	
2	750 ft of 10-in. PS	
3	1,620 ft of 8-in. PS	
4	1,090 ft of 8-in. PS	
Outfall	Land section, 330 ft of 12-in. PS; submerged section, 1,020 ft of 12-in. CI; discharge to Lake Washington	

[a]*See Fig. 6-2 for location.*

[b]*Slopes unknown; no plans available. PS signifies pipe sewer (local designation); CI, cast iron.*

[c]*Capacity unknown; see footnote b.*

All of the sewered portion of the district was annexed to the city of Seattle in 1956. Since January 1, 1957, the collection system and treatment plant (Fig. 6-10) have been operated by city forces under an informal agreement. A plan is now being formulated, however, whereby the city would continue to operate the collection system but the treatment plant would be abandoned and the sewage conveyed to the Southwest Suburban plant for treatment.

Southwest Suburban Sewer District

Formerly called the White Center Sewer District, this agency was created in 1945 to serve a federal housing project. Subsequent to the war, a large surrounding area was annexed to the original district and the present name was adopted.

As now constituted, the Southwest Suburban District has an area of 6.8 square miles, about one-half sewered, and a connected population of 12,600. Although the initial system for the housing project was constructed in 1942, most of the district's 54 miles of 8-inch to 36-inch sewers and 5 pumping stations

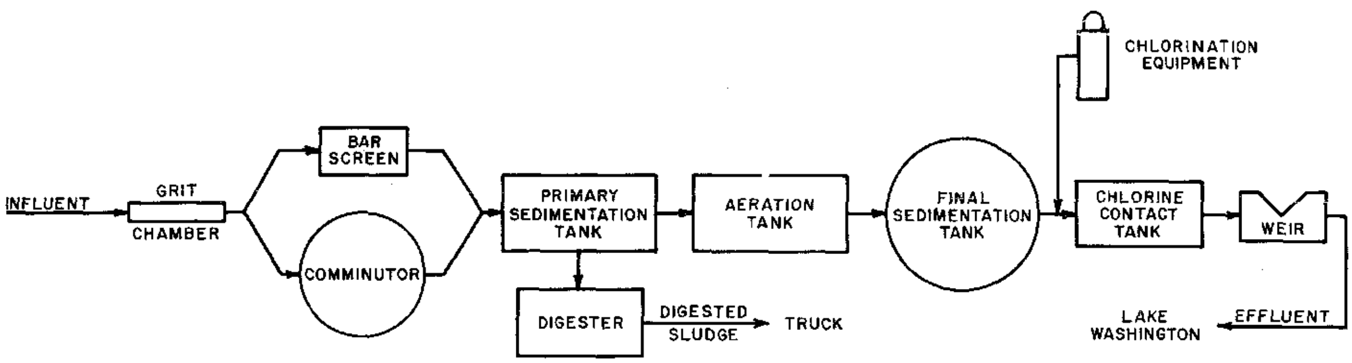


Fig. 6-6. Flow Diagram - East Mercer Sewage Treatment Plant

Activated sludge treatment is provided by the East Mercer Sewer District in this plant which has design capacity for an average daily flow of 0.13 mgd.

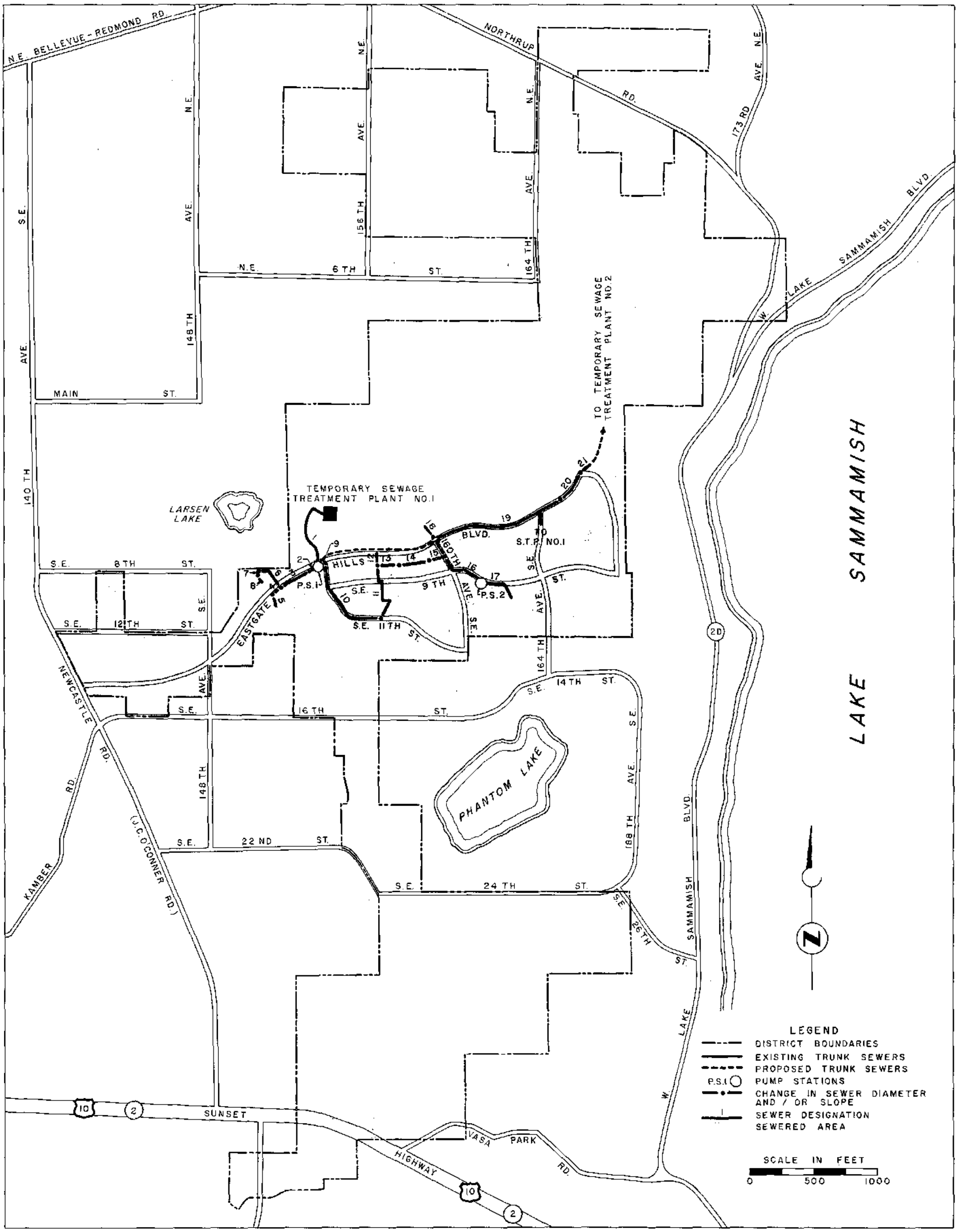


Fig. 6-7. Sewered Area and Principal Sewerage Facilities, Lake Hills Sewer District

Table 6-8. Description of Principal Sewerage Facilities, Lake Hills Sewer District

Facility[a]	Description[b]	Capacity,[c] mgd
1	1,140 ft of 6-in. aluminum pressure line	
2	210 ft of 12-in. conc at 1.17%	2.5
3	510 ft of 12-in. St at 1.17%	2.5
4	170 ft of 12-in. conc at 1.17%	2.5
5	230 ft of 10-in. conc at 0.28	0.8
6	480 ft of 12-in. conc at 0.40%	1.4
7	70 ft of 8-in. conc at 5.22%	1.8
8	170 ft of 8-in. conc at 1.58%	1.0
9	40 ft of 12-in. VC at 1.02%	2.3
10	1,480 ft of 12-in. VC at 0.26%	1.2
11	1,050 ft of 12-in. VC at 0.25%	1.1
12	200 ft of 10-in. VC at 0.42%	0.9
13	320 ft of 8-in. VC at 3.66%	1.5
14	440 ft of 8-in. VC at 5.98%	1.9
15	280 ft of 8-in. VC at 1.36%	0.9
16	830 ft of 6-in. CA force main	
17	600 ft of 10-in VC at 0.28%	0.8
18	230 ft of 15-in. conc at 0.46%	2.8
19	2,120 ft of 18-in. conc at 0.40%	4.3
20	510 ft of 18-in. conc at 0.40%	4.3
21	160 ft of 18-in. conc at 0.50%	4.8

[a]See Fig. 6-7 for location.

[b]Where slope varies within section, limiting or average slope is shown. Conc signifies concrete pipe; St, steel; VC, vitrified clay; CA, cement-asbestos.

[c]Capacity calculated using Manning's formula, "n" equals 0.013.

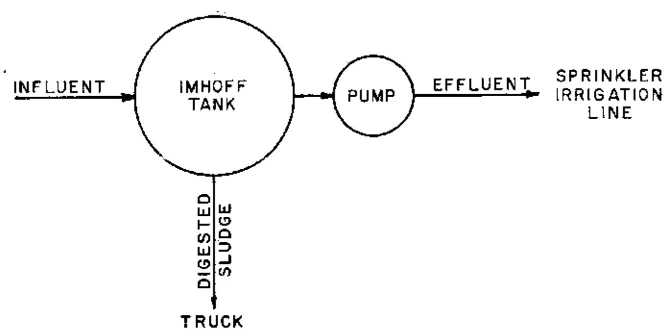


Fig. 6-8. Flow Diagram - Lake Hills Sewage Treatment Plant

Designed to serve temporarily pending full development of the district, an Imhoff tank of wood construction provides primary treatment capacity for an average daily flow of 0.16 mgd. Effluent is sprinkled over the ground surface and absorbed by the soil. An additional Imhoff tank, not shown here, was added during the course of the survey, doubling the plant capacity to 0.32 mgd.

Table 6-9. Description of Principal Sewerage Facilities, Mercer Island Sewer District

Facility[a]	Description[b]	Capacity,[c] mgd
1	410 ft of 12-in. CA at 3.37%	4.2
2	2,020 ft of 10-in. and 15-in. conc gravity and pressure line at 1.16%	4.4
3	7,070 ft of 8-in. and 10-in. CA force main	
4	380 ft of 16-in. CA force main	
5	1,240 ft of 16-in. CI force main	
6	790 ft of 16-in. CA force main	
7	1,980 ft of 18-in. conc at 0.22%	3.2
8	530 ft of 12-in. conc at 0.30%	1.3
9	6,350 ft of 12-in. CA force main	
10	810 ft of 12-in. conc at 0.22%	1.1
11	750 ft of 10-in. conc at 0.30%	0.8
12	2,650 ft of 10-in. CA force main	
13	400 ft of 12-in. CA force main	
14	1,300 ft of 10-in. CA submerged pressure line	
15	2,850 ft of 12-in. CA submerged pressure line	
16	2,730 ft of 12-in. CA submerged pressure line	
17	4,180 ft of 10-in. CA submerged pressure line	
18	340 ft of 10-in. conc at 2.33%	2.4

[a]See Fig. 6-2 for location.

[b]Where slope varies within section, limiting or average slope is shown. CA signifies cement-asbestos pipe; conc, concrete; CI, cast iron.

[c]Capacities calculated using Manning's formula, "n" equals 0.013.

were constructed during the past several years (Fig. 6-9 and Table 6-11). An outstanding feature of the collection system is that all the new sewers, including house connections, are equipped with rubber gasket pipe joints to reduce infiltration of ground water. The original housing project, however, has combined sewers which must be separated to obtain maximum benefits from the new system. A separation program is planned for early construction.

A primary type sewage treatment plant was completed in 1957 (Fig. 6-11). With a design capacity of 8.2 mgd, this plant is the largest now operating in the metropolitan area and is capable of serving the entire Salmon Creek basin as well as adjacent areas along the shore of Puget Sound. Effluent is chlorinated and discharged to Puget Sound.

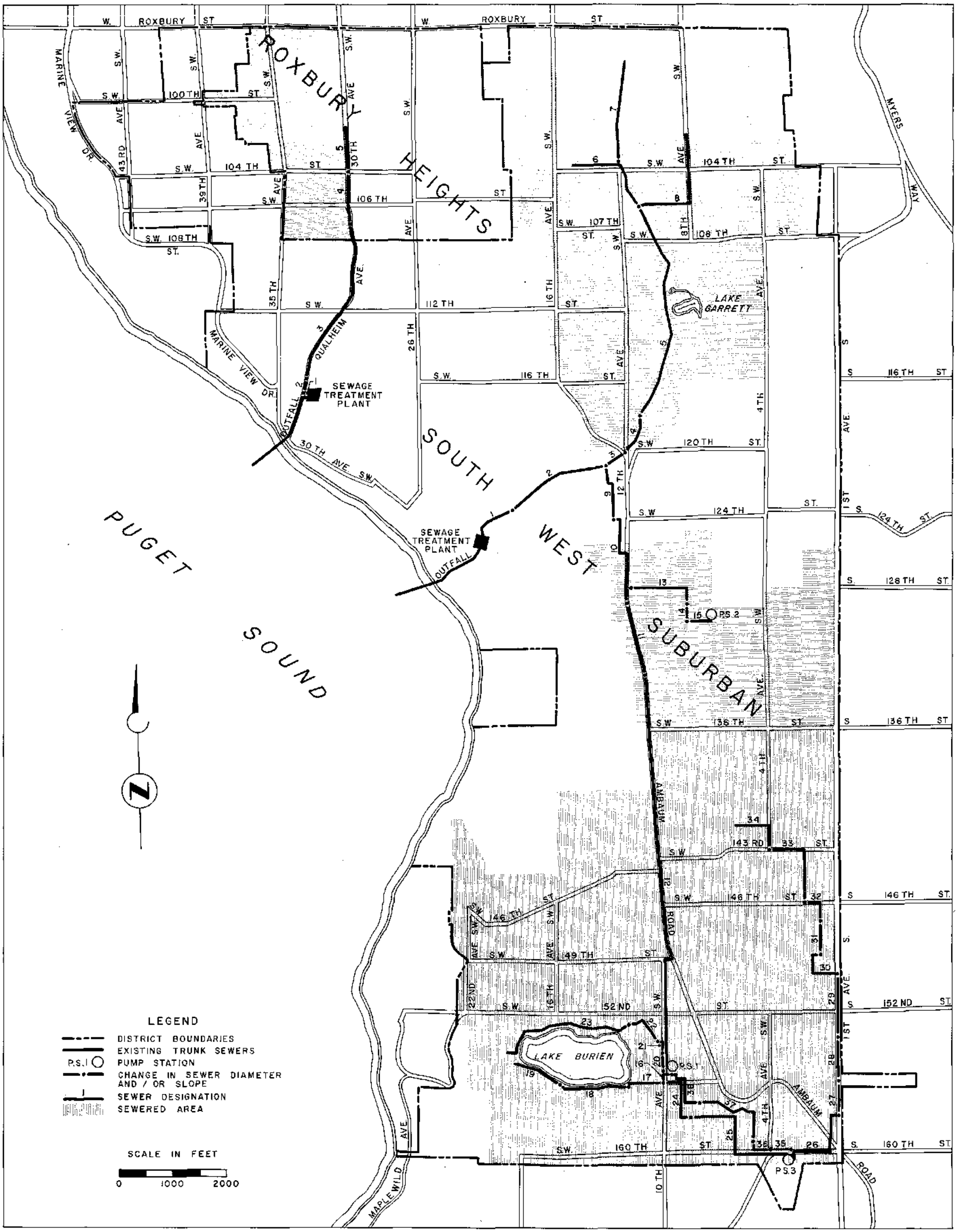


Fig. 6-9. Sewered Areas and Principal Sewerage Facilities, Southwest Suburban and Roxbury Heights Sewer District

Table 6-10. Description of Principal Sewerage Facilities, Roxbury Heights Sewer District

Facility[a]	Description[b]	Capacity,[c] mgd
1	60 ft of 15-in. conc at 0.2%	1.8
2	280 ft of 15-in. conc at 1.7%	5.4
3	3,140 ft of 15-in. conc at 5.75%	9.0
4	1,000 ft of 18-in. conc at 0.5%	4.8
5	830 ft of 15-in. conc at 0.5%	2.9
Outfall	Land section, 900 ft of 15-in. conc; submerged section, 880 ft of 14-in. CI	

[a]*See Fig. 6-9 for location.*

[b]*Where slope varies within section, limiting or average slope is shown. Conc signifies concrete pipe; CI, cast iron.*

[c]*Capacity calculated using Manning's formula, "n" equals 0.013.*

Val-Vue Sewer District

The Val-Vue Sewer District, one of the smallest operating districts, was formed in 1945 and covers an area of only 0.37 square miles. Approximately half of the district is served by 3.2 miles of 6-inch to 15-inch sewers (Fig. 6-12 and Table 6-12), and by a primary type treatment plant with a design capacity of 0.28 mgd (Fig. 6-13). Effluent is chlorinated prior to discharge to the Duwamish River.

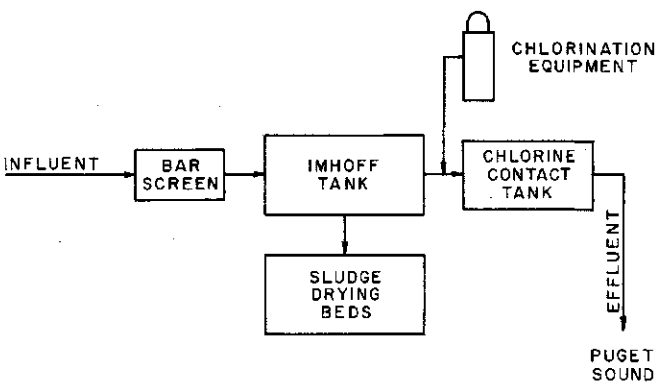


Fig. 6-10. Roxbury Heights Sewage Treatment Plant

Since the annexation of sewered section of the Roxbury Heights Sewer District to the city of Seattle in 1956, this primary treatment plant with a design capacity of 0.15 mgd has been operated by city forces.

Footnotes for Table 6-11 →

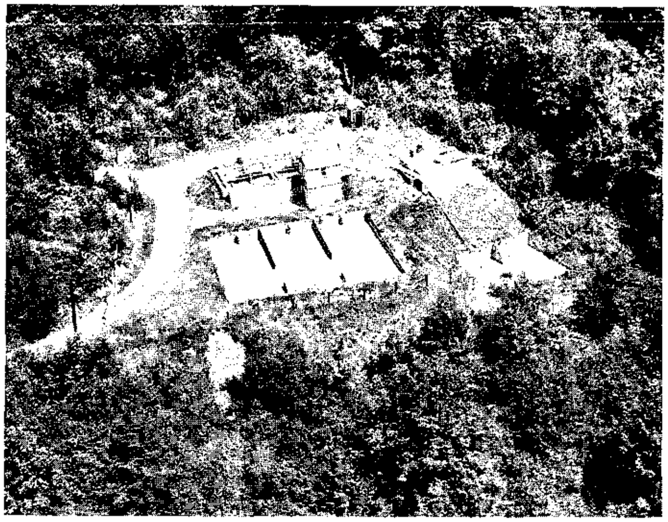
[a]*See Fig. 6-9 for location.*

[b]*Where slope varies within section, limiting or average slope is shown. Conc signifies concrete pipe; CA, cement-asbestos; PS, pipe sewer (local designation); RC, reinforced concrete; St, steel.*

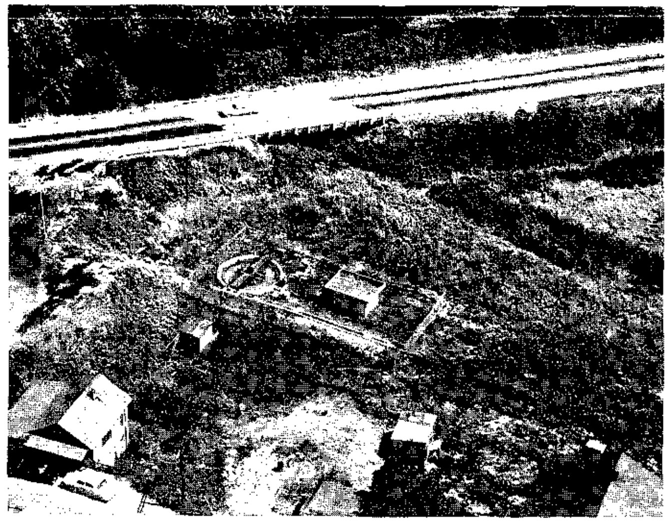
[c]*Capacity calculated using Manning's formula, "n" equals 0.013.*

Table 6-11. Description of Principal Sewerage Facilities, Southwest Suburban Sewer District

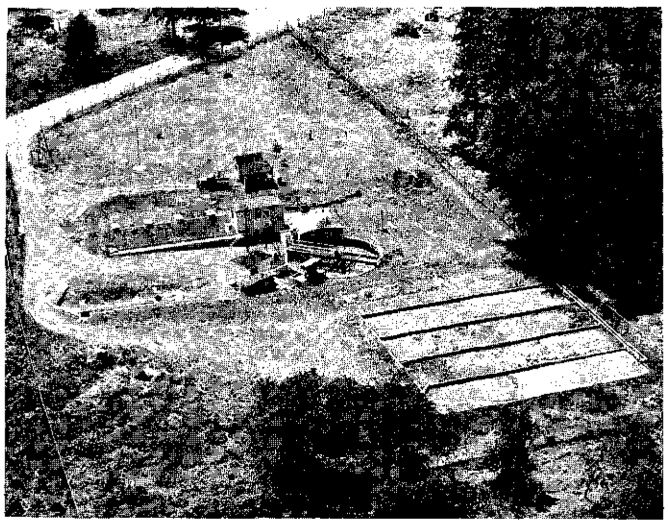
Facility[a]	Description[b]	Capacity,[c] mgd
1	790 ft of 36-in. conc at 1.53%	53
2	1,990 ft of 30-in. conc at 5.20%	60
3	460 ft of 18-in. conc at 6.30%	17
4	900 ft of 21-in. conc at 0.67%	8.3
5	4,240 ft of 24-in. conc at 0.20%	6.5
6	1,780 ft of 18-in. conc at 0.27%	3.5
7	1,920 ft of 12-in. conc at 0.30%	1.3
8	2,270 ft of 12-in. conc at 0.50%	1.6
9	1,080 ft of 24-in. conc at 5.00%	33
10	1,900 ft of 24-in. and 30-in. conc at 0.30%	14
11	1,360 ft of 18-in. conc at 3.68%	13
12	7,800 ft of 16-in. CA force main	
13	1,420 ft of 15-in. and 16-in. conc and CA at 0.33%	2.4
14	350 ft of 15-in. conc at 1.00%	4.2
15	450 ft of 8-in. CA force main	
16	280 ft of 24-in. conc at 0.51%	10
17	680 ft of 15-in. conc at 0.30%	2.3
18	1,320 ft of 14-in. CA at 0.31%	1.9
19	960 ft of 12-in. and 14-in. CA and PS at 0.30%	1.3
20	420 ft of 18-in. conc at 0.55%	5.1
21	320 ft of 18-in. conc at 0.88%	6.4
22	740 ft of 18-in. conc at 0.30%	3.8
23	2,590 ft of 12-in. conc and CA at 0.32%	1.3
24	1,130 ft of 18-in. conc at 0.53%	5.0
25	2,400 ft of 12-in. CA force main	
26	1,820 ft of 18-in. and 24-in. conc at 0.30%	8.0
27	650 ft of 18-in. conc at 1.50%	8.3
28	830 ft of 18-in. conc at 5.71%	16
29	1,150 ft of 18-in. conc at 0.62%	5.4
30	960 ft of 15-in. and 18-in. conc at 1.02%	4.2
31	650 ft of 15-in. conc at 1.95%	5.8
32	670 ft of 15-in. conc at 3.77%	8.0
33	1,680 ft of 15-in. conc at 0.34%	2.4
34	1,100 ft of 15-in. conc at 0.22%	1.9
35	330 ft of 24-in. conc at 0.96%	14
36	470 ft of 24-in. conc at 5.40% (24-in. overflow from this section to Miller Creek)	34
37	1,700 ft of 24-in. conc at 1.00%	15
38	1,030 ft of 24-in. conc at 0.40%	9.2
Outfall	Land section, 1,060 ft of 36-in. RC; submerged section, 640 ft of 36-in St; discharge to Puget Sound	



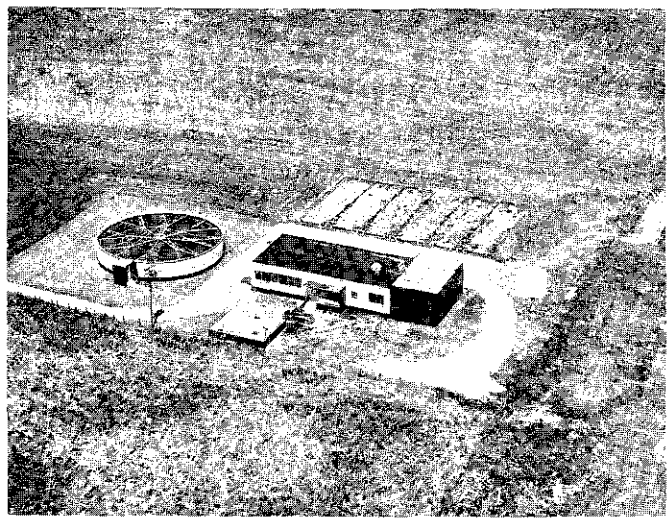
SEELYE SEWAGE TREATMENT PLANT, showing sludge drying beds in foreground, and Imhoff tanks at left and right of pump and chlorinator house.



VAL-VUE SEWAGE TREATMENT PLANT provides primary treatment by means of clarifier-digester unit at left. Steel pressure influent line enters inlet structures from right.



AUBURN SEWAGE TREATMENT PLANT, showing sludge drying beds in right foreground, inlet structures at left, circular primary clarifier and control building. Digesters are underground behind control building.



KENT SEWAGE TREATMENT PLANT provides primary treatment except during canning season. Sedimentation tanks are housed in building adjacent to digesters at right. Trickling filters are shown at left, sludge drying beds in rear.

GREEN-DUWAMISH VALLEY SEWAGE TREATMENT PLANTS

At present, the connected population totals 1,150. This number, however, will be increased substantially with the addition of facilities soon to be constructed for a new ULID.

Sewerage and Drainage Improvement District No. 3

Commonly known as Richmond Beach, this district serves its own half square mile area plus about 40 acres outside its boundaries, including the "Old Firlands" area. Sewerage facilities, originally constructed under a federal grant, have been extended periodically and now comprise about 7.2 miles of sewers ranging in size from 6-inch to 18-inch (Fig. 6-14 and Table 6-13). Parts of the system are utilized as combined sewers, a number of catch basins being connected. Originally, sewage was comminuted and chlorinated but is now discharged into Puget Sound without treatment.

Because the district was formed and continues to operate under drainage law, the King County Commissioners act as district commissioners and operation is supervised by the county engineer. In 1950, the residents of the area formed the Richmond Sewer District, but, to date, the district commissioners have not taken action to acquire and operate the system.

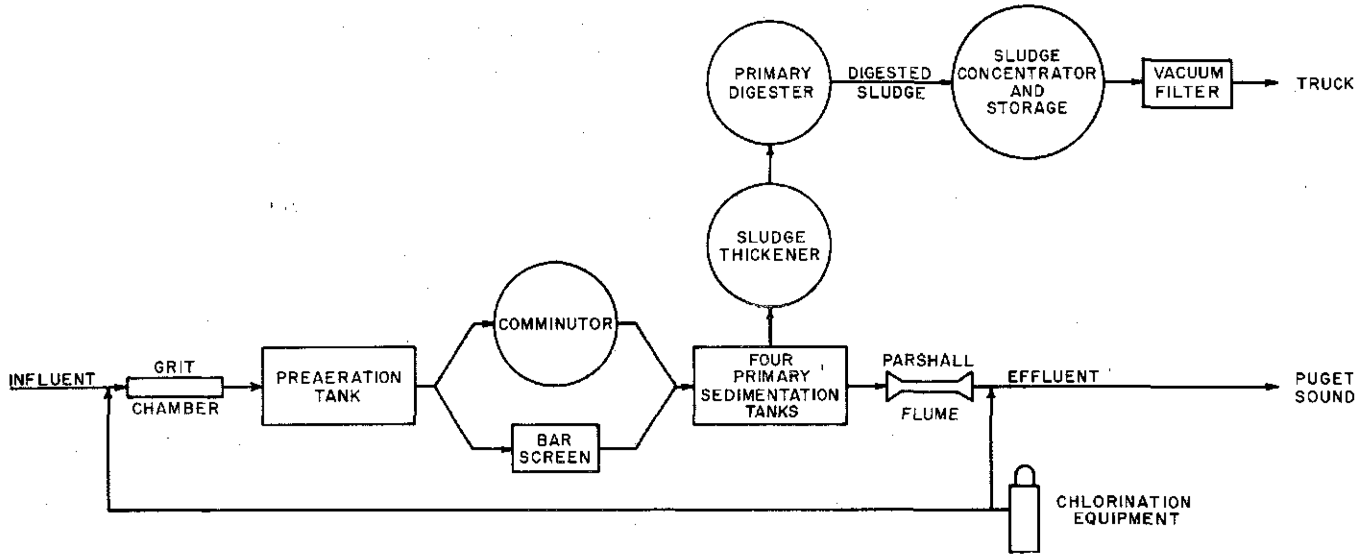


Fig. 6-11. Flow Diagram - Southwest Suburban Sewage Treatment Plant

This primary treatment plant with an average daily capacity of 8.2 mgd was completed in 1957. It is the largest treatment plant in the metropolitan area at the present time and has sufficient capacity to serve its natural tributary area when fully developed.

Sewerage and Drainage District No. 4

This district, usually referred to as Seelye, was formed in 1943 under drainage law and also is administered and operated by King County. It now comprises an area of 0.37 square miles, essentially all of which is sewered.

Initially constructed to serve a private housing development, the collection system has been extended and improved and now consists of 9.5 miles of 6-inch to 18-inch sewers, and 2 pumping stations (Fig. 6-15 and Table 6-14). Treatment is obtained in an Imhoff-tank type of primary treatment plant with a design capacity of 0.20 mgd (Fig. 6-16). Chlorinated effluent is discharged to the Duwamish River.

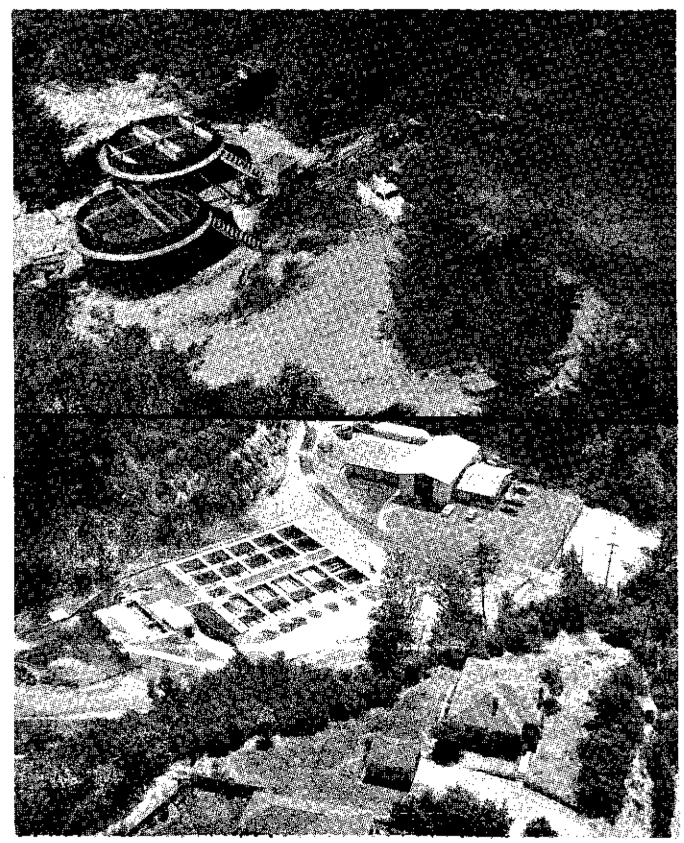
Table 6-12. Description of Principal Sewerage Facilities, Val-Vue Sewer District

Facility[a]	Description[b]	Capacity,[c] mgd
1	370 ft of 12-in. St pressure line	
2	1,030 ft of 15-in. conc at 4.00%	8.3
3	1,410 ft of 12-in. conc at 5.80%	5.6
4	3,070 ft of 12-in. conc at 2.80%	3.8
Outfall	Land section, 470 ft of 24-in. conc; submerged section, 70 ft of 24-in. conc; discharge to Duwamish River	

[a]*See Fig. 6-12 for location.*

[b]*Where slope varies within section, limiting or average slope is shown. St signifies steel pipe; conc, concrete pipe.*

[c]*Capacity calculated using Manning's formula, "n" equals 0.013.*



(Above) LAKE HILLS treatment plant utilizes temporary wooden Imhoff tanks for primary treatment pending full development of the area. Effluent is sprayed over the surrounding wooded area.

(Below) SOUTHWEST SUBURBAN treatment plant provides primary treatment and has capacity to serve the entire Salmon Creek basin. Inlet and grit removal structures and primary sedimentation tanks, foreground; building at rear houses digesters, metering, pumping, sludge conditioning equipment, maintenance shop, office and laboratory. Note proximity of residences on surrounding bluffs.

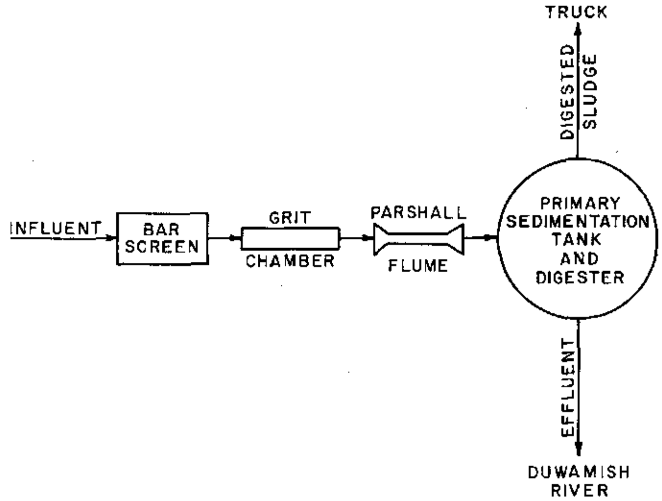


Fig. 6-13. Flow Diagram – Val-Vue Sewage Treatment Plant

The Val-Vue treatment plant, designed for an average flow of 0.28 mgd, provides primary treatment for the Val-Vue Sewer District situated adjacent to Highway 99 a short distance west of Tukwila.

Table 6-13. Description of Principal Sewerage Facilities, Sewerage and Drainage Improvement District No. 3

Facility[a]	Description[b]	Capacity,[c] mgd
1	1,310 ft of 15-in. PS at 1.00%	4.2
2	900 ft of 8-in. PS at 8.54%	2.3
3	570 ft of 15-in. PS at 3.88% (section overflows to 21-in. storm overflow to Puget Sound)	8.1
4	200 ft of 15-in. PS at 6.81%	11
5	460 ft of 12-in. PS at 2.81%	3.8
6	830 ft of 15-in. PS at 8.49%	12
7	30 ft of 18-in. PS at 0.49%	4.8
8	260 ft of 18-in. PS at 0.29%	3.6
9	320 ft of 15-in. PS at 0.71%	3.5
10	340 ft of 12-in. PS at 0.03%	0.4
11	320 ft of 10-in. PS at 0.03%	0.3
12	10,160 ft of 8-in. PS, slope unknown	
Outfall	Length, size and material unknown; discharge to Puget Sound	

All combined sewers except No. 12, which is separate sanitary.

[a]*See Fig. 6-14 for location.*

[b]*Where slope varies within section, limiting or average slope is shown. PS signifies pipe sewer (local designation).*

[c]*Capacity calculated using Manning's formula, "n" equals 0.013.*

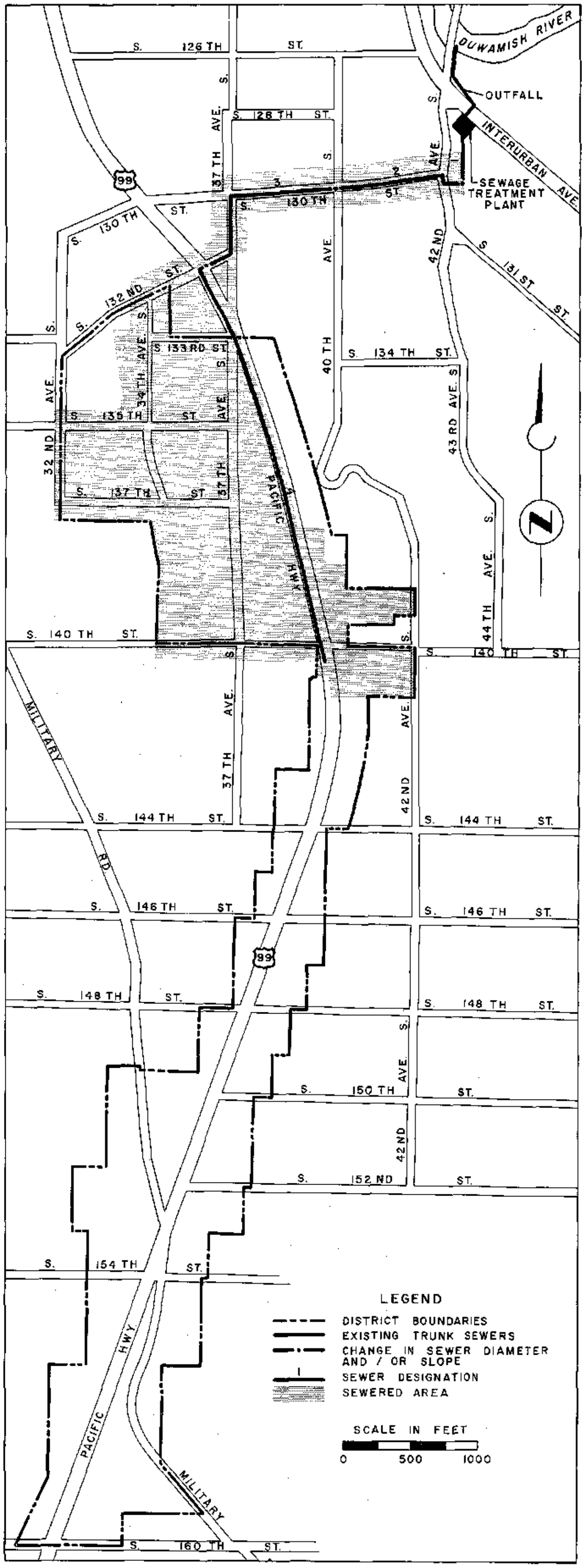


Fig. 6-12. Sewered Area and Principal Sewerage Facilities Val-Vue Sewer District

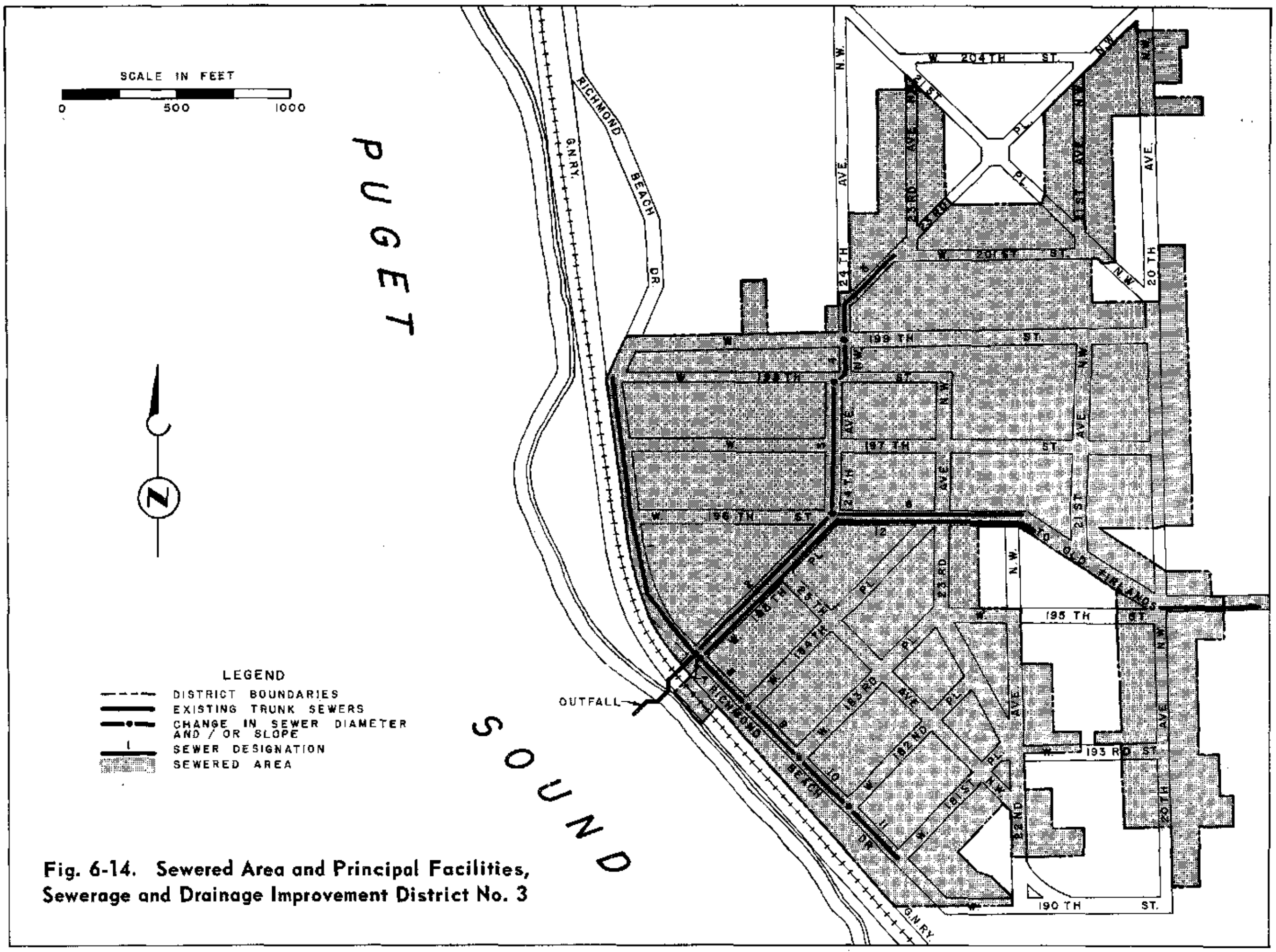


Fig. 6-14. Sewered Area and Principal Facilities, Sewerage and Drainage Improvement District No. 3

Table 6-14. Description of Principal Sewerage Facilities, Sewerage and Drainage District No. 4

Facility[a]	Description[b]	Capacity,[c] mgd	Facility[a]	Description[b]	Capacity,[c] mgd
1	160 ft of 8-in. pipe at 37.60%	4.8	14	370 ft of 8-in. pipe at 3.13%	1.4
2	390 ft of 8-in. pipe at 0.63%	0.6	15	340 ft of 8-in. pipe at 3.23%	1.4
3	150 ft of 8-in. pipe at 4.13%	1.6	16	230 ft of 8-in. pipe at 0.50%	0.6
4	300 ft of 8-in. pipe at 4.64%	1.7	17	530 ft of 8-in. pipe at 0.63%	0.6
5	160 ft of 8-in. pipe at 5.72%	1.9	18	270 ft of 8-in. pipe at 1.33%	0.9
6	190 ft of 8-in. pipe at 10.32%	2.8	19	300 ft of 8-in. pipe at 4.40%	1.6
7	240 ft of 8-in. pipe at 6.92%	2.1	20	190 ft of 8-in. pipe at 5.44%	1.8
8	220 ft of 8-in. pipe at 2.70%	1.3	21	230 ft of 8-in. pipe at 8.90%	2.4
9	360 ft of 8-in. pipe at 0.63%	0.6	22	2,790 ft of 6-in. CA force main	
10	400 ft of 8-in. pipe at 1.90%	1.1	23	140 ft of 15-in. conc at 0.56%	3.1
11	280 ft of 8-in. pipe at 0.81%	0.7	24	500 ft of 12-in. PS at 0.50%	1.6
12	190 ft of 8-in. pipe at 3.12%	1.4	25	840 ft of 8-in. PS at 3.20%	1.4
13	190 ft of 8-in. pipe at 9.00%	2.4	Outfall	Length unknown, 8-in. conc; discharge to Duwamish River	

[a]*See Fig. 6-15 for location.*
[b]*Where slope varies within section, limiting or average slope is shown. Except as indicated, material unknown; conc signifies concrete pipe; PS, pipe sewer (local designation); CA, cement-asbestos.*
[c]*Capacity calculated using Mannings formula, "n" equals 0.013.*

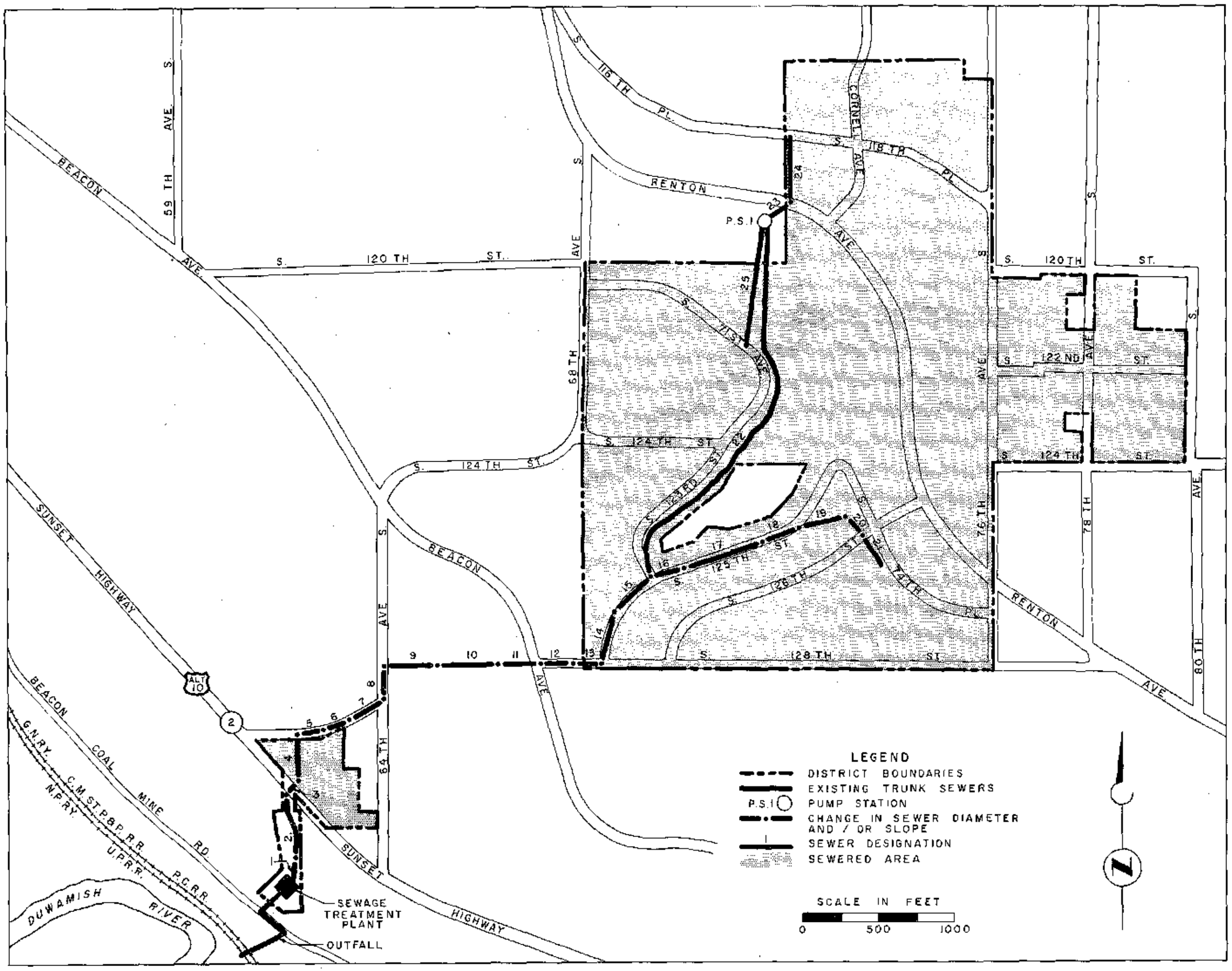


Fig. 6-15. Sewered Area and Principal Sewerage Facilities Sewerage and Drainage District No. 4

City of Auburn

Auburn was incorporated in 1891 and now occupies an area of 2.1 square miles, almost entirely sewered. Of its present population of 8,000, about 7,000 are connected to the sewerage system. The first sewers were constructed in 1910 and were designed to collect sanitary sewage only. Subsequently, however, combined sewers were used in newer sections of the city and served until 1950 when they were replaced by separate sanitary sewers (Fig. 6-17 and Table 6-15).

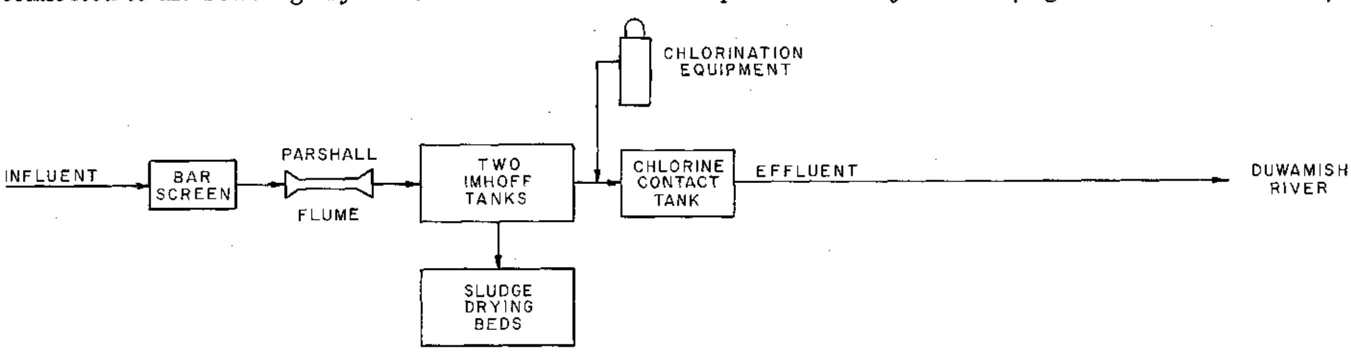


Fig. 6-16. Flow Diagram - Sewerage and Drainage District No. 4 Sewage Treatment Plant

Primary treatment for the small community of Seelye is provided by two Imhoff tanks with a combined average daily capacity of 0.20 mgd. The plant and sewer system are operated by Sewerage and Drainage District No. 4.

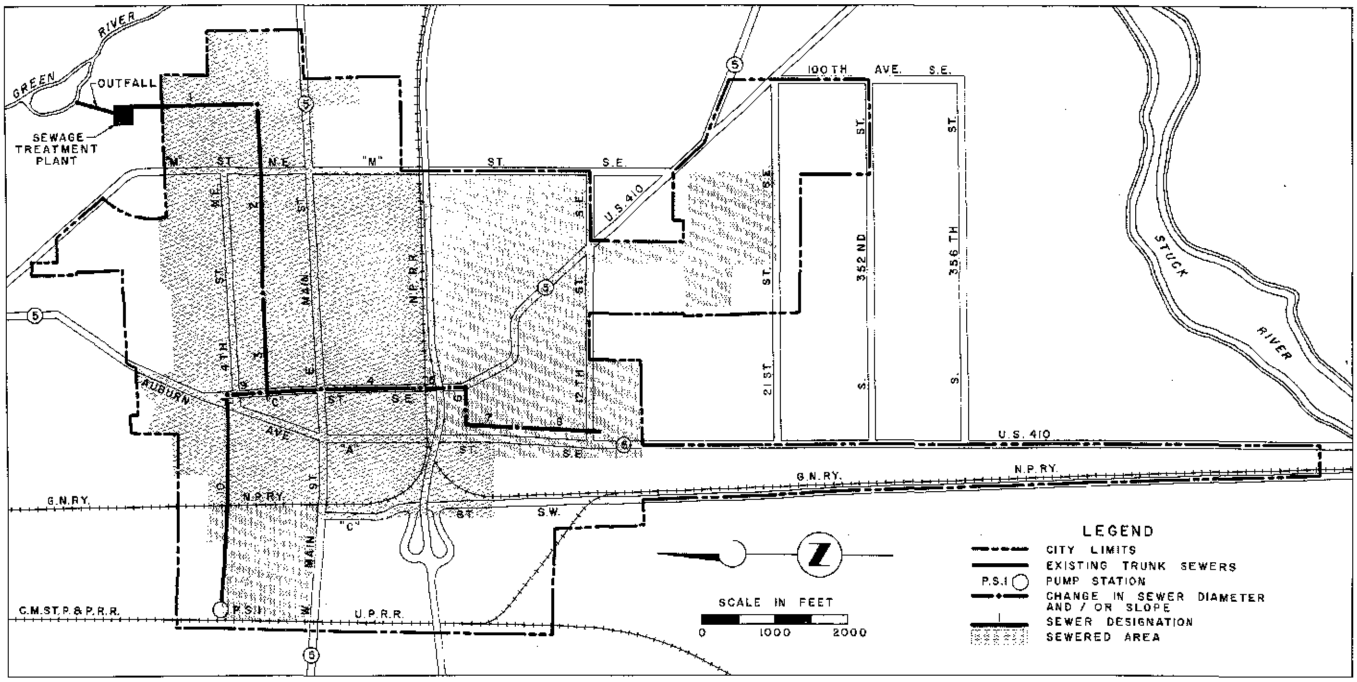


Fig. 6-17. Sewered Area and Principal Sewerage Facilities, City of Auburn

Septic tanks were the sole means of sewage treatment prior to 1950. In that year, a primary sedimentation tank with a design capacity of 1.1 mgd was constructed, and the septic tanks were converted to sludge digestion and sludge storage units (Fig. 6-18). Chlorinated effluent from the treatment plants is discharged to the Green River. Effluent pumping is necessary during high stages of the river.

City of Issaquah

Incorporated in 1913, the city of Issaquah now comprises an area of about 0.7 square miles, one-half of which is sewered. Essentially all of its population, which was 1,196 in 1957, are connected to the sewer system.

Sewerage construction began in 1940. At present, the system consists of 13 miles of sewers ranging in size from 8 inches to 15 inches (Fig. 6-19 and Table 6-16), and a secondary type sewage treatment plant with a design capacity of 0.23 mgd (Fig. 6-20). Plant effluent is chlorinated and discharged to Issaquah Creek.

City of Kent

Incorporated in 1890, Kent is the second oldest city in the metropolitan area. It has a present area of 3 square miles and a population of 4,150,

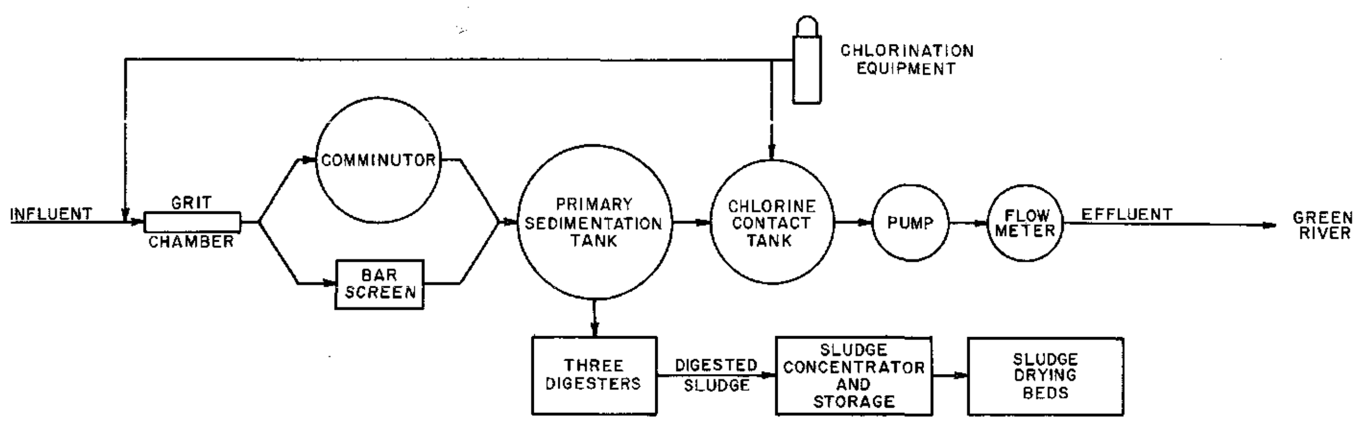


Fig. 6-18. Flow Diagram - Auburn Sewage Treatment Plant

The city of Auburn provides primary treatment in this plant which employs a circular clarifier having capacity for an average daily flow of 1.1 mgd. The sludge digester and storage units were initially designed as septic tanks but were converted when the plant was enlarged in 1950.

Table 6-15. Description of Principal Sewerage Facilities, City of Auburn

Facility[a]	Description[b]	Capacity,[c] mgd
1	1,570 ft of 30-in. pipe at 0.06%	6.5
2	2,570 ft of 24-in. pipe at 0.17%	6.0
3	2,670 ft of 30-in. pipe at 0.13%	9.5
4	2,360 ft of 24-in. pipe at 0.24%	7.2
5	420 ft of 12-in. PS at 0.25%	1.1
6	600 ft of 12-in. PS at 0.50%	1.6
7	690 ft of 18-in. pipe at 0.30%	3.7
8	1,160 ft of 15-in. pipe at 0.30%	2.3
9	560 ft of 18-in. PS at 0.17%	2.8
10	3,000 ft of 12-in. CI force main	
Outfall	Length, size and material unknown; discharge to Green River.	

[a]*See Fig. 6-17 for location.*

[b]*Where slope varies within section, limiting or average slope is shown. Except as indicated, material unknown; PS signifies pipe sewer (local designation); CI, cast iron.*

[c]*Capacity calculated using Manning's formula, "n" equals 0.013.*

Table 6-16. Description of Principal Sewerage Facilities, City of Issaquah

Facility[a]	Description[b]	Capacity,[c] mgd
1	160 ft of 15-in. VC, slope unknown	
2	920 ft of 12-in. VC at 0.40%	1.4
3	1,770 ft of 10-in. VC at 0.40%	0.9
4	840 ft of 12-in. VC at 0.40%	1.4
5	1,010 ft of 12-in. VC at 0.55%	1.7
6	1,000 ft of 10-in. VC at 0.40%	0.9
Outfall	Length unknown, 15-in. VC; discharge to Issaquah Creek.	

[a]*See Fig. 6-19 for location.*

[b]*Where slope varies within section, limiting or average slope is shown. VC signifies vitrified clay pipe.*

[c]*Capacity calculated using Manning's formula, "n" equals 0.013.*

of which about 4,000 are connected to the sewerage system.

Kent has approximately 10 miles of 6-inch to 24-inch sewers (Fig. 6-21 and Table 6-17), one pumping station, and a sewage treatment plant with a design capacity of 1.7 mgd. Treatment normally consists of primary sedimentation and effluent chlorination (Fig. 6-22). In the canning season, however, a trickling filter equipped with a forced draft blower is used after primary sedimentation to accommodate the additional load from two canneries. Effluent containing filter humus is chlorinated and discharged to the Green River.

City of Kirkland

Incorporated in 1905, the city of Kirkland has an area of 2.0 square miles and had a population in 1955 of 5,750. Within the corporate limits, the present sewered area is about 1.5 square miles but the city also serves about 0.5 square miles of surrounding area, including the northerly part of the city of Houghton.

Sewers were first constructed in Kirkland in 1942. Today, the collection system serves a connected popu-

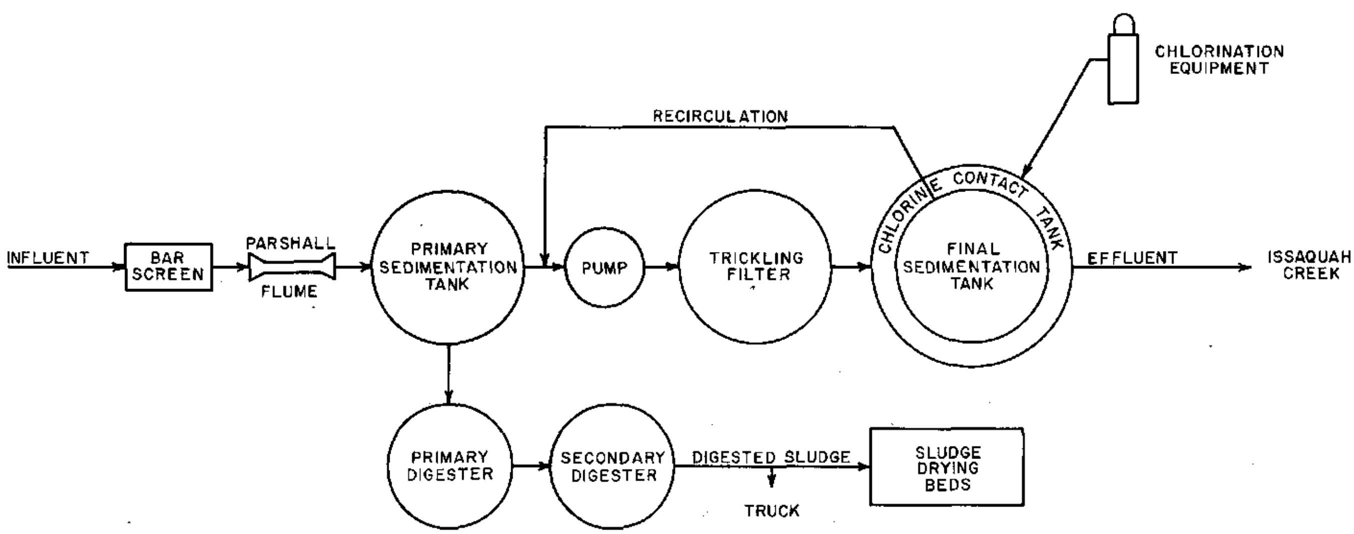


Fig. 6-20. Flow Diagram - Issaquah Sewage Treatment Plant

This sewage treatment plant with design capacity for an average daily flow of 0.23 mgd provides secondary treatment for sewage from the city of Issaquah.

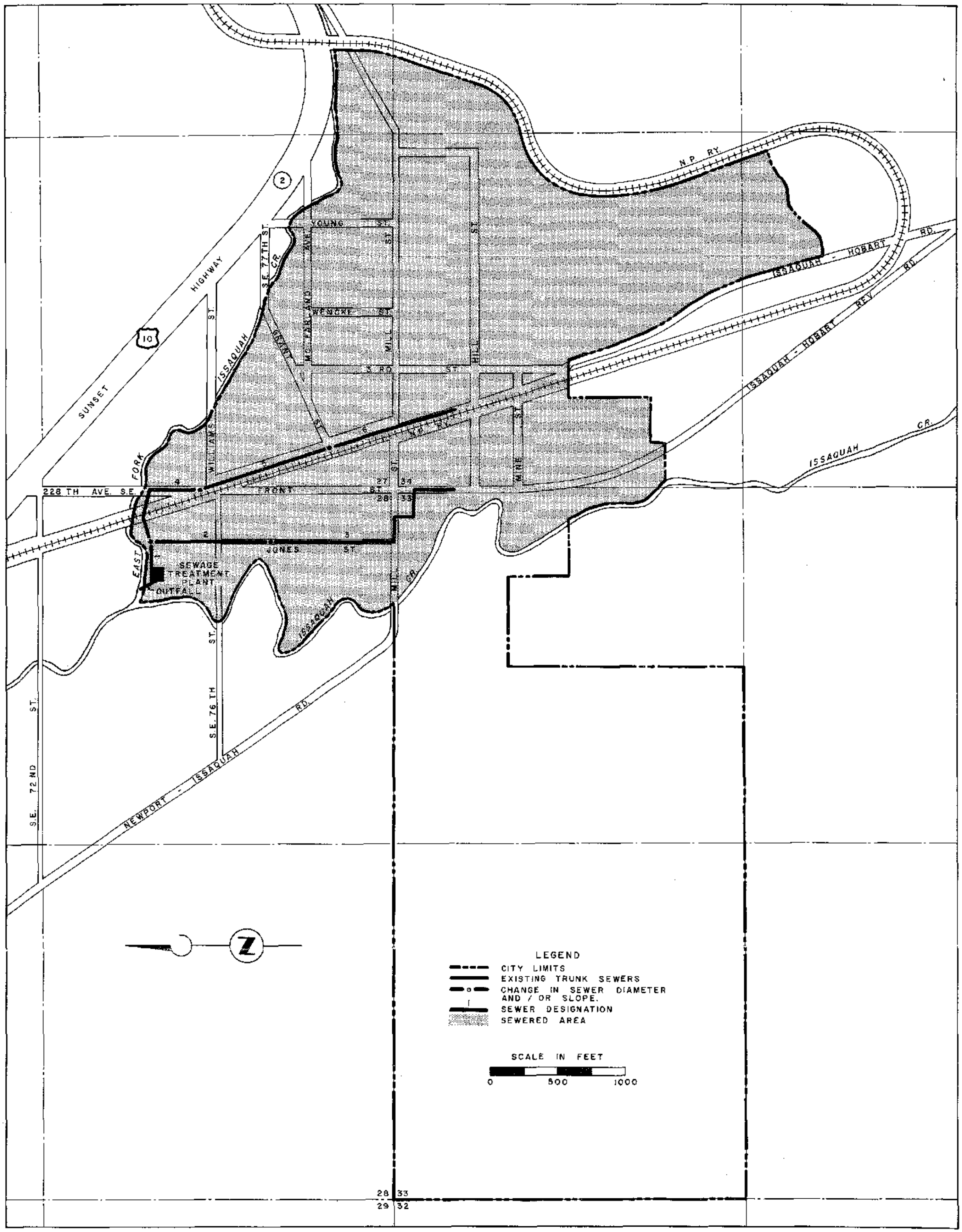


Fig. 6-19. Sewered Area and Principal Sewerage Facilities, City of Issaquah

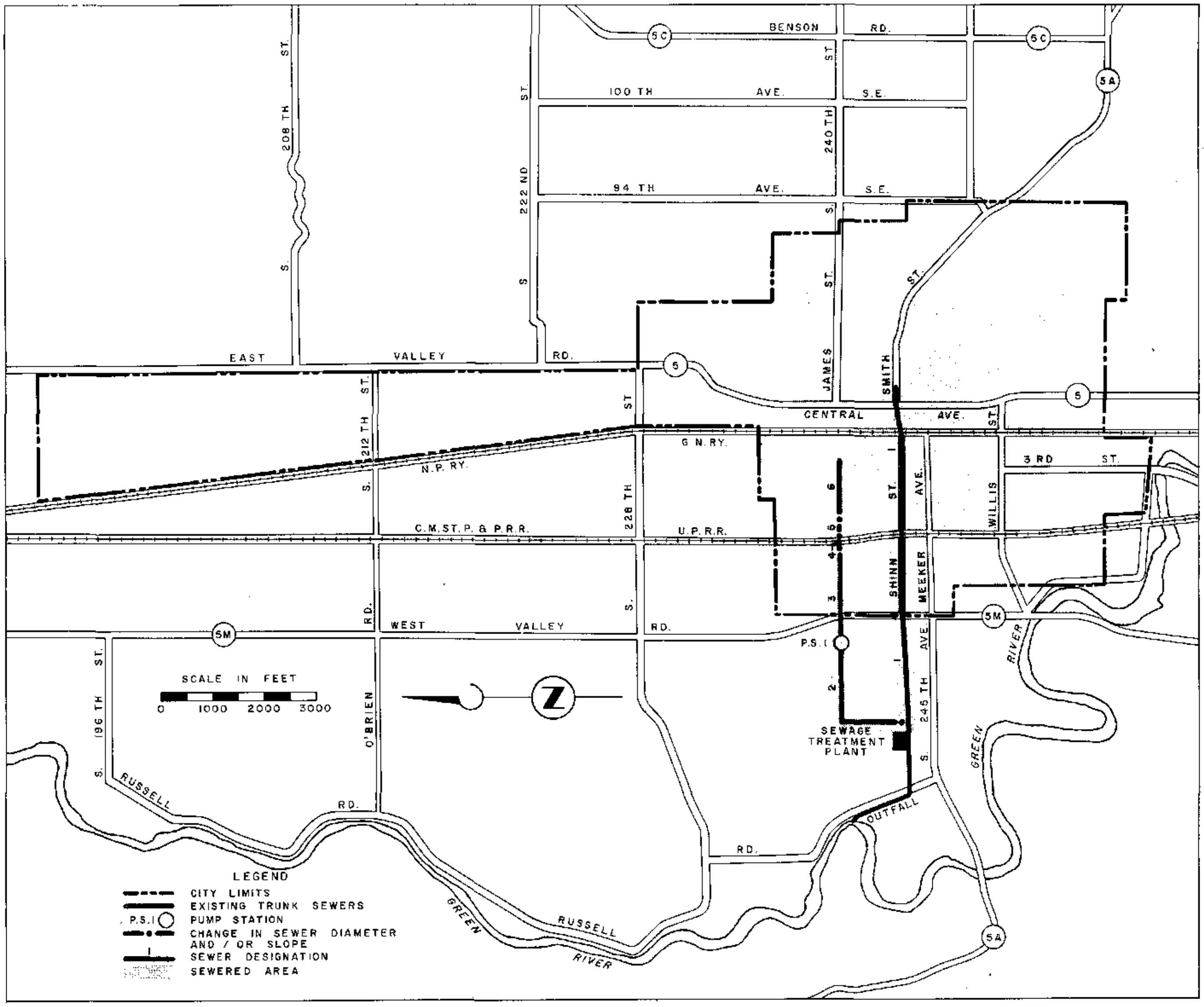


Fig. 6-21. Sewered Area and Principal Sewerage Facilities City of Kent

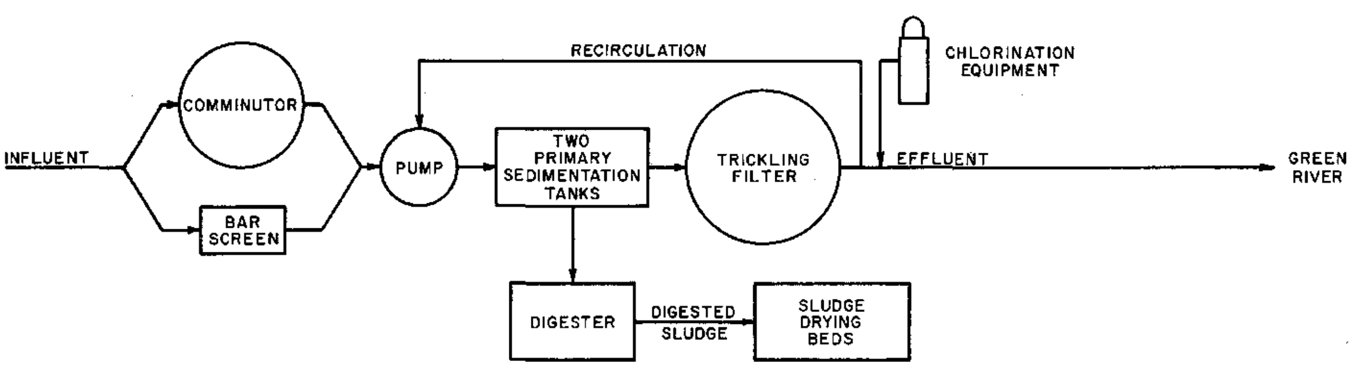


Fig. 6-22. Flow Diagram - Kent Sewage Treatment Plant

Normally operated as a primary treatment plant, the trickling filter is used during the canning season to provide for the extra loading from several canneries. The sedimentation tanks have design capacity for an average daily flow of 1.7 mgd.

Table 6-17. Description of Principal Sewerage Facilities, City of Kent

Facility[a]	Description[b]	Capacity,[c] mgd
1	6,640 ft of 24-in. VC at 0.08%	4.2
2	2,950 ft of 12-in. CA force main	
3	1,830 ft of 18-in. RC at 0.22%	3.2
4	220 ft of 18-in. RC at 0.36%	4.1
5	330 ft of 15-in. RC at 0.30%	2.3
6	1,170 ft of 15-in. RC at 0.20%	1.9
Outfall	Length unknown, 30-in. conc; discharge to Green River.	

[a] *See Fig. 6-21 for location.*

[b] *Where slope varies within section, limiting or average slope is shown. VC signifies vitrified clay pipe; RC, reinforced concrete; CA, cement-asbestos; conc, concrete.*

[c] *Capacity calculated using Manning's formula, "n" equals 0.013.*

lation of about 5,750 and consists of 5 pumping stations and 32 miles of sewers ranging in size from 6 inches to 20 inches (Fig. 6-23 and Table 6-18). Treatment facilities, initially constructed in 1943 and enlarged in 1951, share a downtown site with the City Hall and provide two stage secondary treatment during the summer season. During the wet season it is operated as a conventional trickling filter plant and, when so operated, has capacity for an average flow of 0.35 mgd (Fig. 6-24). Chlorinated effluent is discharged to Lake Washington through a trunk storm sewer adjacent to the plant site.

City of Renton

Renton, with a population of 16,500, is the second largest city in the metropolitan area. It was incorporated in 1901 and constructed its first sewers in 1910. Sewerage service is provided to a connected population of about 14,800 through a collection system which covers two-thirds of the city area of 5 square miles. This system has 1 pumping station and a total of 36 miles of 6-inch to 20-inch sewers (Fig. 6-25 and Table 6-19).

Treatment is obtained by means of a secondary type plant, which was constructed in 1943 and enlarged in 1953 to its present design capacity of 2.2 mgd (Fig. 6-26). Plant effluent, after chlorination, is discharged near the mouth of the Cedar River.

Private and Semi-Public Systems

Five privately owned developments, two publicly

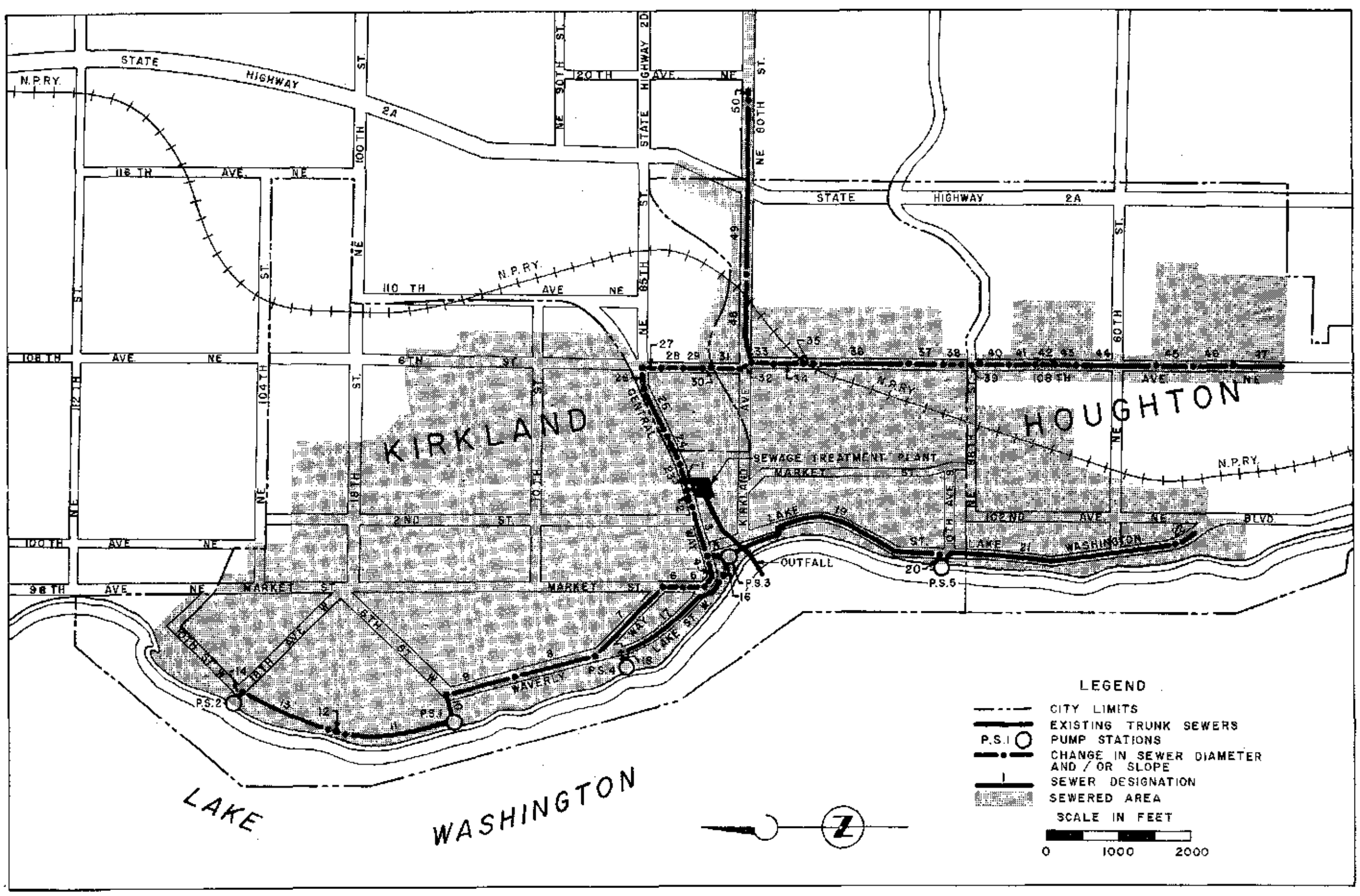


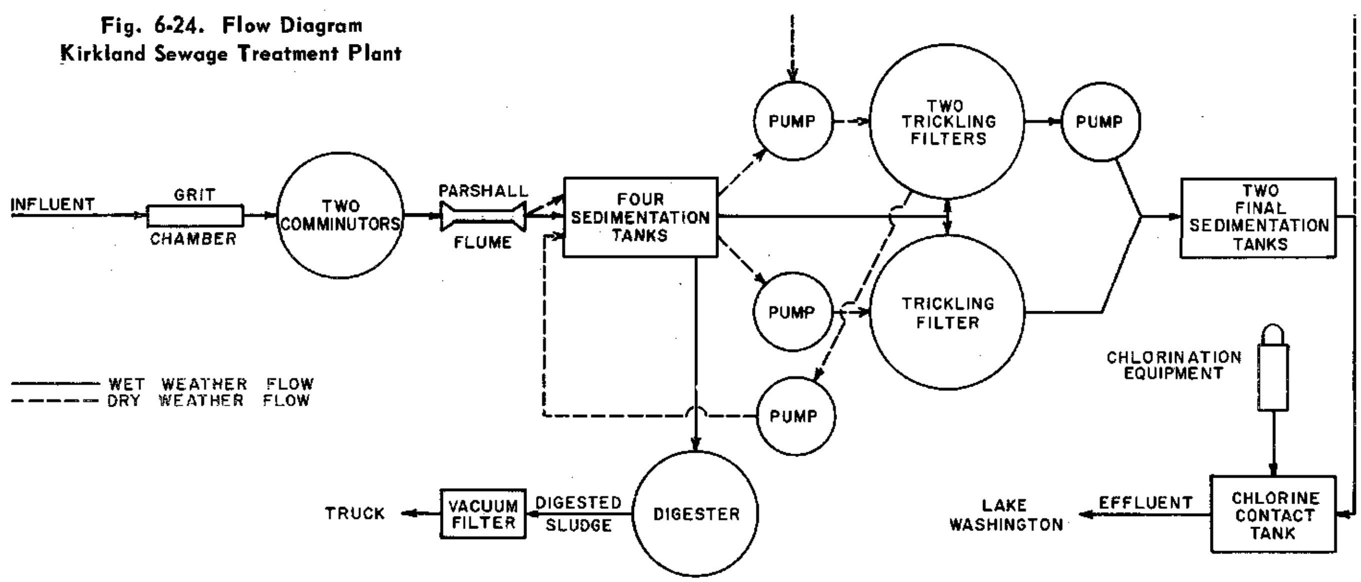
Fig. 6-23. Sewered Area and Principal Sewerage Facilities, City of Kirkland

Table 6-18. Description of Principal Sewerage Facilities, City of Kirkland

Facility[a]	Description[b]	Capacity,[c] mgd	Facility[a]	Description[b]	Capacity,[c] mgd
1	60 ft of 24-in. conc at 0.10%	4.6	27	250 ft of 12-in. conc at 1.00%	2.3
2	260 ft of 18-in. conc at 0.13%	2.4	28	300 ft of 12-in. conc at 2.00%	3.2
3	690 ft of 15-in. conc at 0.18%	1.8	29	280 ft of 12-in. conc at 9.50%	7.1
4	440 ft of 12-in. conc at 0.25%	1.1	30	70 ft of 12-in. conc at 1.00%	2.3
5	320 ft of 8-in. conc at 5.00%	1.8	31	400 ft of 12-in. conc at 6.60%	5.8
6	300 ft of 8-in. conc at 6.20%	2.0	32	140 ft of 12-in. conc at 5.70%	5.4
7	1,340 ft of 10-in. conc at 0.60%	1.1	33	300 ft of 12-in. conc at 5.00%	5.1
8	1,140 ft of 10-in. conc at 0.50%	1.0	34	450 ft of 12-in. conc at 1.00%	2.3
9	1,000 ft of 10-in. conc at 0.30%	0.8	35	170 ft of 12-in. conc at 6.40%	5.8
10	300 ft of 6-in. CI force main		36	1,240 ft of 10-in. conc at 2.00%	2.0
11	1,420 ft of 12-in. CA at 0.22%	1.1	37	440 ft of 10-in. conc at 1.00%	1.4
12	220 ft of 12-in. conc at 0.22%	1.1	38	260 ft of 8-in. conc at 0.60%	0.6
13	1,380 ft of 12-in. CA at 0.22%	1.1	39	250 ft of 8-in. conc at 1.70%	1.0
14	20 ft of 4-in. CI force main		40	400 ft of 8-in. conc at 2.50%	1.2
15	190 ft of 8-in. CA force main		41	380 ft of 8-in. conc at 6.70%	2.0
16	270 ft of 12-in. conc at 0.43%	1.5	42	270 ft of 8-in. conc at 4.30%	1.6
17	1,950 ft of 12-in. conc at 0.25%	1.1	43	260 ft of 8-in. conc at 1.50%	1.0
18	130 ft of 4-in. CI force main		44	1,400 ft of 8-in. VC at 1.20%	0.9
19	3,250 ft of 12-in. conc at 0.25%	1.1	45	530 ft of 8-in. VC at 1.10%	0.8
20	30 ft of 8-in. CI force main		46	540 ft of 8-in. VC at 0.96%	0.8
21	3,690 ft of 12-in. conc at 0.25%	1.1	47	830 ft of 8-in. VC at 0.60%	0.6
22	310 ft of 12-in. conc at 1.90%	3.1	48	1,250 ft of 10-in. conc, slope unknown	
23	350 ft of 18-in. conc at 0.15%	2.6	49	2,470 ft of 8-in. conc, slope unknown	
24	410 ft of 15-in. conc at 0.18%	1.7	50	50 ft of 10-in. conc, slope unknown	
25	730 ft of 12-in. conc at 2.66%	3.7	Outfall	Plant effluent discharges to storm sewer, thence to Lake Washington	
26	330 ft of 12-in. conc at 1.80%	3.0			

[a]See Fig. 6-23 for location. [b]Where slope varies within section, limiting or average slope is shown. Conc signifies concrete pipe; CI, cast iron; CA, cement-asbestos; VC, vitrified clay. [c]Capacity calculated using Manning's formula, "n" equals 0.013.

Fig. 6-24. Flow Diagram Kirkland Sewage Treatment Plant



owned installations, and one industry are still served by independent sewerage systems. Undoubtedly, some of these will be connected to the systems of nearby cities and districts as the metropolitan area continues to develop.

Boeing-Renton. Sanitary sewage from the Boeing Airplane Company operation at Renton is collected and conveyed to a secondary type treatment plant. Chlorinated effluent from this plant, which has a design capacity of 0.5 mgd, is discharged to Cedar River waterway several thousand feet above the point where the waterway enters Lake Washington. Site drainage and some diluted industrial wastes are discharged to Lake Washington through separate outfalls. Concentrated toxic and other processing wastes are hauled

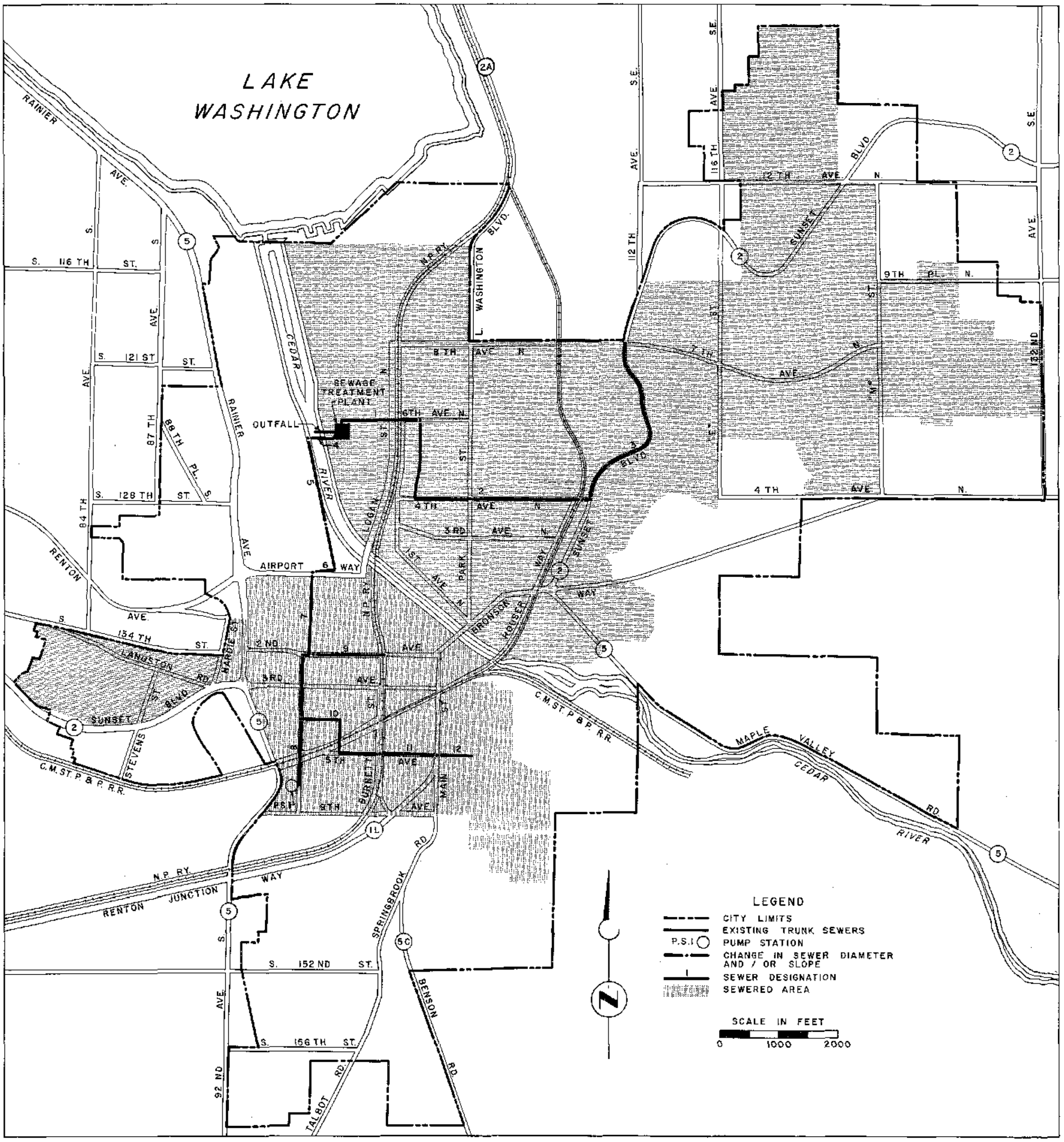


Fig. 6-25. Sewered Area and Principal Sewerage Facilities, City of Renton

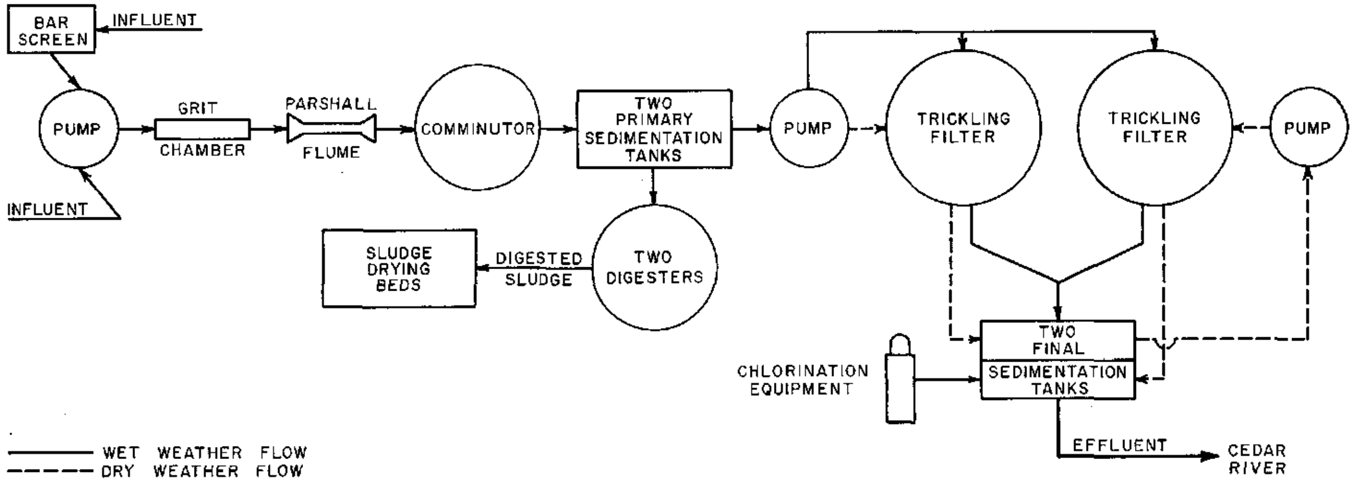


Fig. 6-26. Flow Diagram - Renton Sewage Treatment Plant

Additional treatment is provided for dry season flows by converting one of the final sedimentation tanks and one of the trickling filters to second stage treatment units, as shown. Wet weather flows are given standard trickling filter type secondary treatment. The average daily capacity of the primary sedimentation tanks, based on two hours detention, is 2.2 mgd.

from the site by tank truck for disposal elsewhere.

Boeing Shopping Center. Designed to serve a proposed shopping center in the vicinity of Aurora Avenue and 160th Street, this system consists of a single 12-inch sewer extending to Puget Sound, and of an Imhoff tank type of primary sewage treatment plant with a design capacity of about 0.18 mgd. These facilities are not in use, however, as the shopping center has not yet been developed.

Table 6-19. Description of Principal Sewerage Facilities, City of Renton

Facility[a]	Description[b]	Capacity,[c] mgd
1	1,430 ft of 24-in. conc at 0.20%	6.5
2	4,320 ft of 24-in. conc at 0.23%	7.0
3	3,420 ft of 12-in. conc at 3.88%	4.5
4	520 ft of 24-in. conc at 1.00%; includes siphon under Cedar River; 24-in. overflow ahead of siphon	14.7
5	1,500 ft of 24-in. conc at 0.12%	5.1
6	1,210 ft of 24-in. conc at 0.09%[d]	4.4
7	2,600 ft of 24-in. conc at 0.12%	5.0
8	1,120 ft of 8-in. CI force main	
9	1,130 ft of 18-in. conc at 0.70%	5.7
10	1,930 ft of 18-in. conc at 0.20%	3.1
11	900 ft of 15-in. conc at 0.30%	2.3
12	570 ft of 10-in. conc at 19.00%	13.8
Outfall	Land section, 260 ft of 24-in. conc; submerged section, length unknown, 24-in. conc; discharge to Cedar River	

[a]*See Fig. 6-25 for location.*

[b]*Where slope varies within section, limiting or average slope is shown. Conc signifies concrete pipe; CI, cast iron.*

[c]*Capacity calculated using Manning's formula, "n" equals 0.013.*

[d]*Distance scaled; slope calculated.*

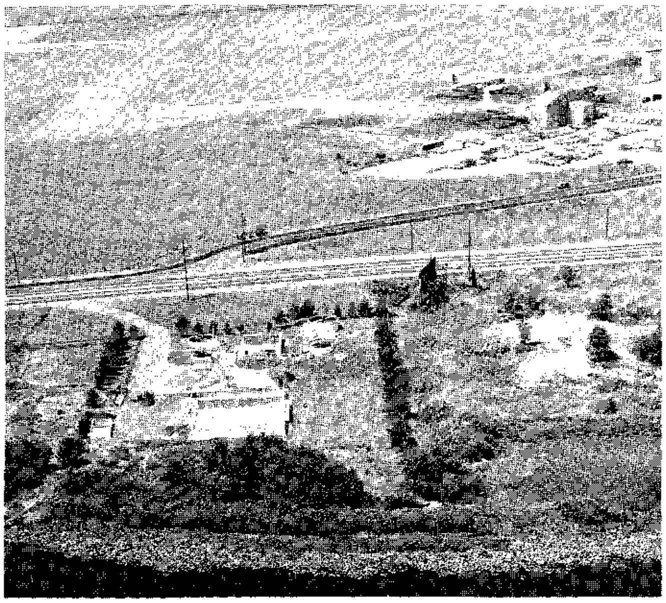
The Highlands. A privately owned sewer system serves this residential development which is situated along Puget Sound in the vicinity of the Seattle Golf and Country Club. No treatment is provided for the sewage which is discharged to Puget Sound at several points.

Lake Burien Heights. Sewerage facilities serving this private housing development, located at SW 136th Street and Ambaum Boulevard SW, consist of local collecting sewers and an Imhoff tank type of primary treatment with a design capacity of 0.15 mgd. Chlorinated plant effluent is discharged into Puget Sound.

Sand Point Naval Air Station. This station operates its own sewerage system, which includes a trickling filter type secondary sewage treatment plant with a design capacity of 0.86 mgd. Chlorinated effluent is discharged to Lake Washington.

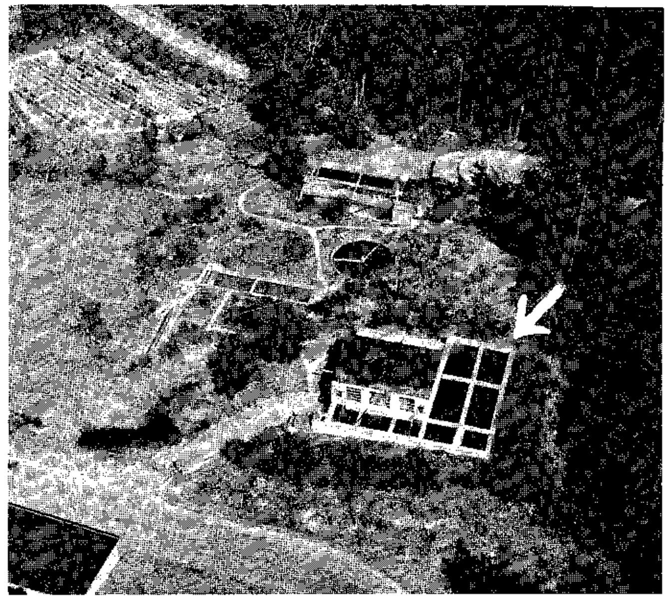
Sand Point Homes. Originally built for war housing, this multiple dwelling development, located in the vicinity of 60th Street NE and 65th Street, is now owned and operated by the University of Washington. Sewerage facilities, also owned and operated by the University, consist of local collecting sewers and an activated sludge type secondary treatment plant with a design capacity of 0.1 mgd. Plant effluent is discharged to Lake Washington after being chlorinated.

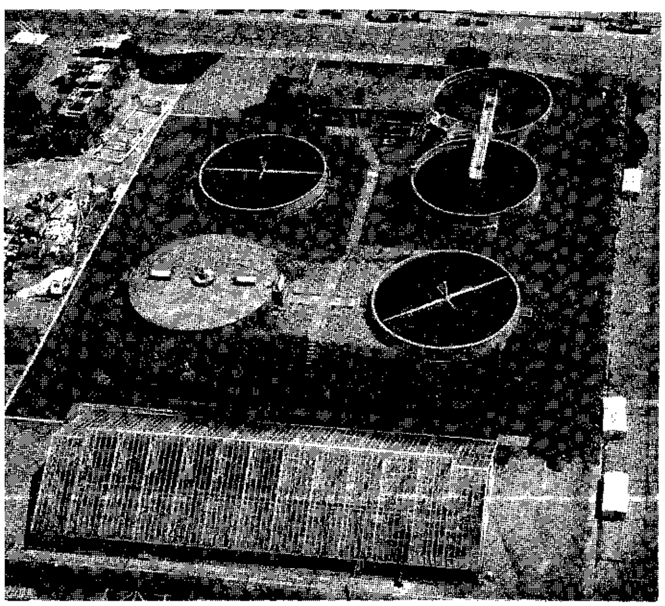
PRIVATE AND SEMI-PUBLIC SEWAGE TREATMENT PLANTS



SEATTLE-TACOMA AIRPORT TREATMENT PLANT with a design capacity of 0.10 mgd serves the Seattle-Tacoma Airport. Bio-filters provide secondary treatment and plant effluent is chlorinated and discharged into Bow Lake. Digested sludge is dried in open air drying beds in foreground.

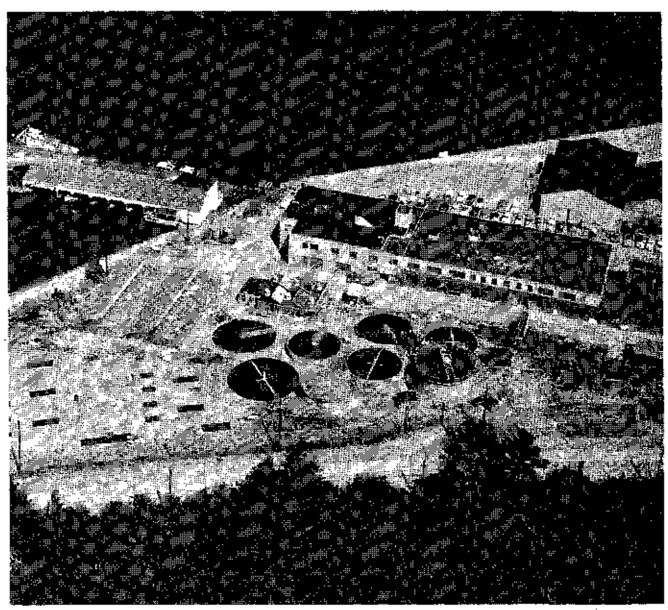
SHOREWOOD APARTMENTS SEWAGE TREATMENT PLANT shares a site with the water filtration plant (arrow) at Shorewood Apartments on Mercer Island. Primary sedimentation (rectangular tank) is followed by roughing filter and activated sludge treatment. Digested sludge is used as a soil conditioner on apartment grounds.





BOEING-RENTON SEWAGE TREATMENT PLANT provides trickling filter type secondary treatment for sanitary wastes generated at the vast Boeing Airplane Company plant at Renton. Note glass covered sludge drying beds in foreground.

SAND POINT NAVAL AIR STATION SEWAGE TREATMENT PLANT employs bio-filters for secondary treatment of sewage from the station. Digested sludge is air dried in the glass covered drying beds at left.



Shorewood Apartments. This private housing development, situated along the northerly shoreline of Mercer Island, has its own sewer system and an activated sludge type secondary sewage treatment plant with a capacity of 0.26 mgd. Plant effluent is chlorinated prior to discharge to Lake Washington. The Shorewood development is bounded on three sides by the Mercer Island Sewer District.

Seattle-Tacoma Airport. Sewerage facilities serving the Seattle-Tacoma Airport are operated by the Port of Seattle. Sewage is treated in a secondary type plant having a design capacity of 0.1 mgd and plant effluent is chlorinated and discharged to Bow Lake.

Operation and Maintenance

With only minor exceptions, operation and maintenance of the various treatment works and pumping stations are excellent. This, of course, is a credit to plant operators and their assistants and reflects a high degree of interest in their assigned duties. Much of the good work can be attributed no doubt to an interchange of ideas at meetings of plant operators, and to attendance at short courses in plant operation and maintenance. The latter are given biennially under the joint sponsorship of the University of Washington, the Pollution Control Commission, the State Department of Public Health, the Association of Washington Cities, and the Pacific Northwest Sewage and Industrial Wastes Association.

On the other hand, sewer maintenance practices vary widely in scope and thoroughness. Many of the agencies have no regularly assigned maintenance personnel, with the result that such work is confined either to emergency needs or, at best, to occasional cleaning and repair jobs during slack periods in other assigned duties. A few agencies, however, conduct cleaning programs on a schedule designed to cover their systems about once each year.

STORM DRAINAGE FACILITIES OUTSIDE SEATTLE

A brief description of existing storm drainage facilities outside Seattle is given in Table 6-20.

Taken as a whole, the facilities there listed are of little or no significance from the standpoint of comprehensive storm drainage planning. Only Auburn, Kent, Kirkland and Renton have constructed drains which locally serve substantial areas. Most of the other cities have done nothing about this problem and only a few have constructed minor drains to relieve critical areas.

Numerous isolated tracts in unincorporated portions of the metropolitan area are served by storm drains.

Table 6-20. Storm Drainage Systems Outside of the City of Seattle

Place	Description of system
Auburn	A separate storm drainage system was constructed in 1950. Some catch basins and numerous roof drains are connected to the sanitary sewers. Trunk storm drains are insufficient in size to serve more than city areas.
Bellevue	Except for several large culverts under streets and other obstructions, there are no significant facilities. Several 24-inch storm drains designed to serve isolated areas are under construction. A comprehensive storm drainage system is being designed.
Bothell	One 12-inch to 36-inch drain intercepts storm drainage from a number of laterals which serve the westerly section of the city. The remainder of the city has no system. The existing system is reported to have some sanitary sewer connections.
Houghton	Several minor storm drains serve part of the business section. Two war housing projects, one of which has been razed, have local systems.
Kent	Two storm drains, a 12-inch and an 18-inch, serve part of the downtown area and other isolated sections of the city. Considerable street drainage and nearly all roof drainage from the downtown area is discharged into sanitary sewers.
Kirkland	Separate storm drains, ranging in size from 12 inches to 60 inches, convey storm runoff from a considerable section of the city to Lake Washington. Effluent from the sewage treatment works discharges to one of the storm drain trunks. Numerous catch basins and roof drains are connected to the sanitary sewers.
Lake Hills	All developed sections are served by a separate storm drainage system. Area has comprehensive storm drainage plan. Trunks range from 12 inches to 42 inches in diameter.
Mountlake Terrace	One 15-inch storm drain serves school grounds. Remainder of city has no storm drainage facilities.
Redmond	Existing drainage facilities consist of a single 12-inch drain. A storm drainage system is scheduled for construction in 1958.
Richmond Beach	Served by partially combined sewer system. See section on existing sewerage.

For the most part, however, these were constructed for the purpose of relieving localized flooding problems, mainly in connection with street and highway drainage.

SEWERAGE AND DRAINAGE FACILITIES OF THE CITY OF SEATTLE

Seattle lies across the natural outlets of the Green-Duwamish and Lake Washington drainage basins, which together comprise about 90 per cent of the metropolitan area. Its sewerage system, besides being by far the largest and most complex of those under consideration, occupies a strategic location with respect to long-term sewerage planning on a metropolitan basis. This situation, coupled with problems brought about by major deficiencies in present facilities, necessitated an extensive study of the Seattle system.

General Features of the Seattle System

A general layout of the Seattle sewerage and drainage systems, together with their service areas and points of disposal, is shown in Fig. 6-27. In all, about 67 square miles of the land area within the city, which totals 79.5 square miles, are presently sewered. An outside area of 2.5 square miles also is served by the city. Within the city, the connected population is roughly 510,000, as compared to an estimated total population of 560,000.

According to available records, the collection system consists of 1,029 miles of combined sewers, 204 miles of separate sanitary sewers, 7 miles of storm drains, and 39 pumping stations. About one-fifth of the estimated total sewage and industrial waste flow of 65 mgd now being generated receives varying degrees of treatment at 5 sewage treatment plants. The balance of 52 mgd is discharged as raw sewage through about 50 outfalls scattered along Puget Sound, Elliott Bay, Duwamish River, Lake Union and the Ship Canal. In addition, a number of industries discharge wastes independently to Duwamish River, Lake Union and the Ship Canal. Enlargements to the existing Lake City plant and construction of a new treatment plant at Alki Point, which are both in progress, will increase the total treatment capacity by about 15 mgd.

As stated in Chapter 2, early collection systems followed natural drainage channels and discharged raw sewage to the nearest watercourses. But as the city developed, its natural topography was altered to some extent by filling of low areas and by major regrading for street construction. Further, as pollution of Lake Union and Lake Washington increased and more adequate points of disposal became a necessity, intercepting sewers and tunnels were constructed across natural drainage boundaries in order to convey the sewage to salt water. Consequently, most of the area which comprises the city up to 1954 is served by four major and numerous minor collection systems. With one exception, all of these discharge raw sewage directly to Puget Sound. Sewage from the Henderson-East Marginal Way system, which is the exception, is delivered to the Diagonal Avenue plant for treatment and disposal.

In 1954, the north side annexation brought in four sewer districts, each of which had previously constructed its own separate sanitary sewer system. Of these, the Blue Ridge, North Beach and Greenwood systems lie in the Puget Sound basin and discharge to the sound, while the Lake City systems drains toward and discharges to Lake Washington. Annexation of the Roxbury Heights area in 1956 brought still another separate sanitary sewer system into the city. Four of these five districts have sewage treatment plants but none of them has storm drainage facilities.

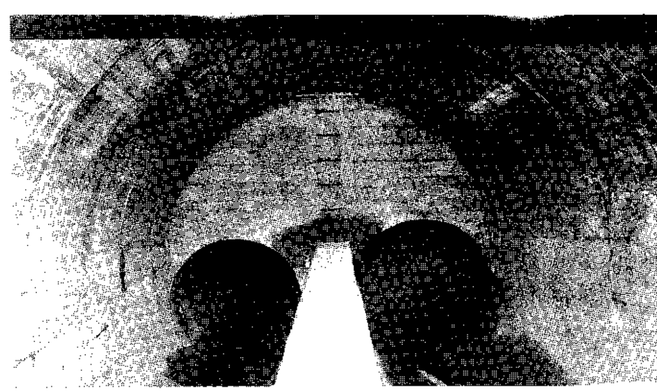
Principal Sewerage Facilities

Principal sewerage facilities are shown and the areas they serve are described in Figs. 6-28 through 6-35. Component sections of the various sewers are designated by numbers and each section is described under its corresponding number in Table 6-21. Flow diagrams for the five sewage treatment plants are shown in Figs. 6-36 through 6-40. For convenience in reference, Table 6-21 and Figs. 6-28 through 6-40 are located at the end of this chapter.

Local Effects of Combined Sewers

At Seattle, local effects stemming from the use of combined sewers are manifested both by frequent overflows from overflow and bypass structures and by flooding of streets and basements. Flooding occurs during even moderate storms and is due to overload conditions in the collection system. In some cases, overloading leads also to direct damage of sewers and related structures.

The frequencies with which overflow and overload conditions develop, as well as their nature and extent, depend on a number of different factors. Of these, the most important is the rainfall intensity used in



SIDE WEIR overflow to Ship Canal

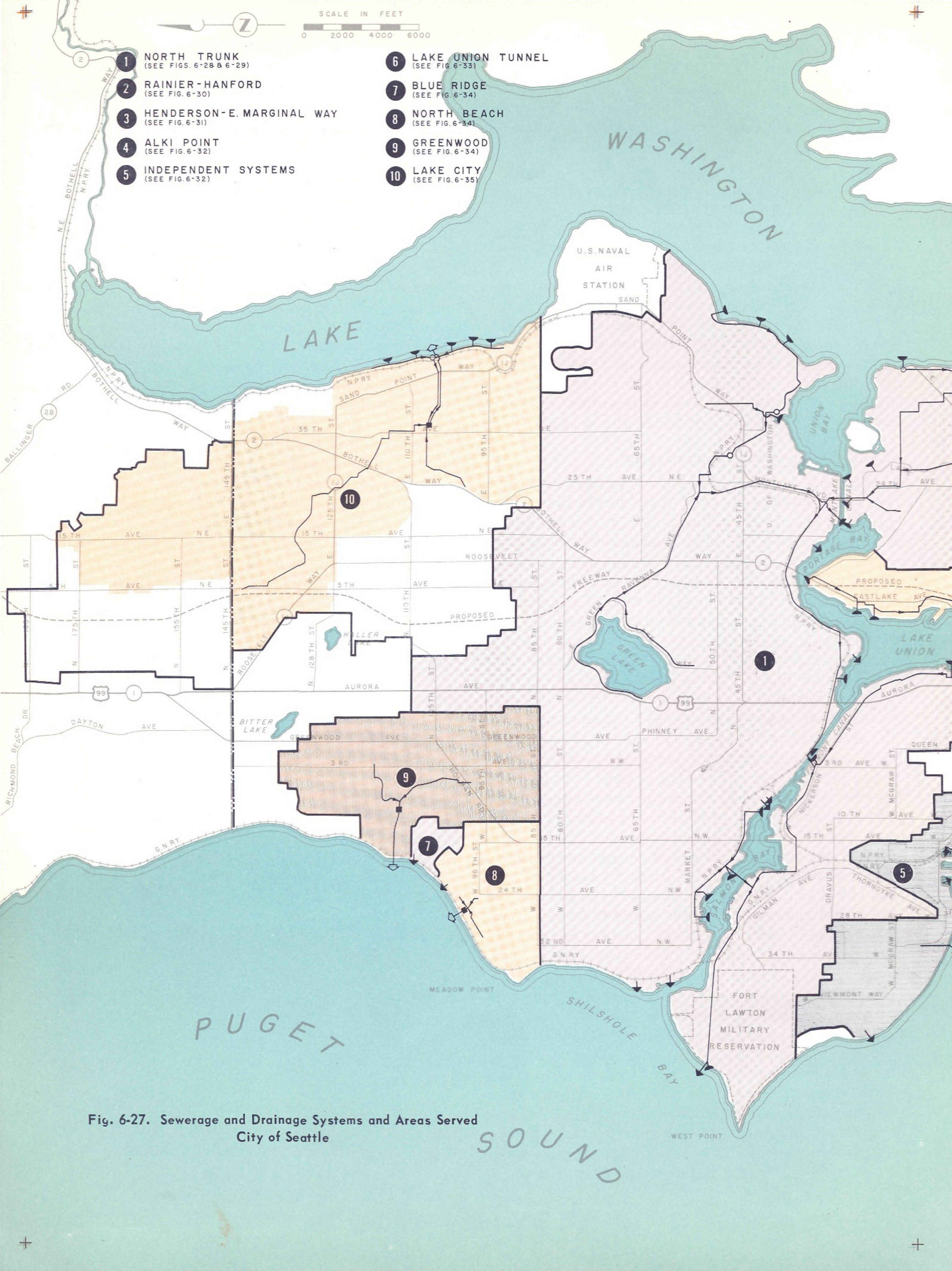
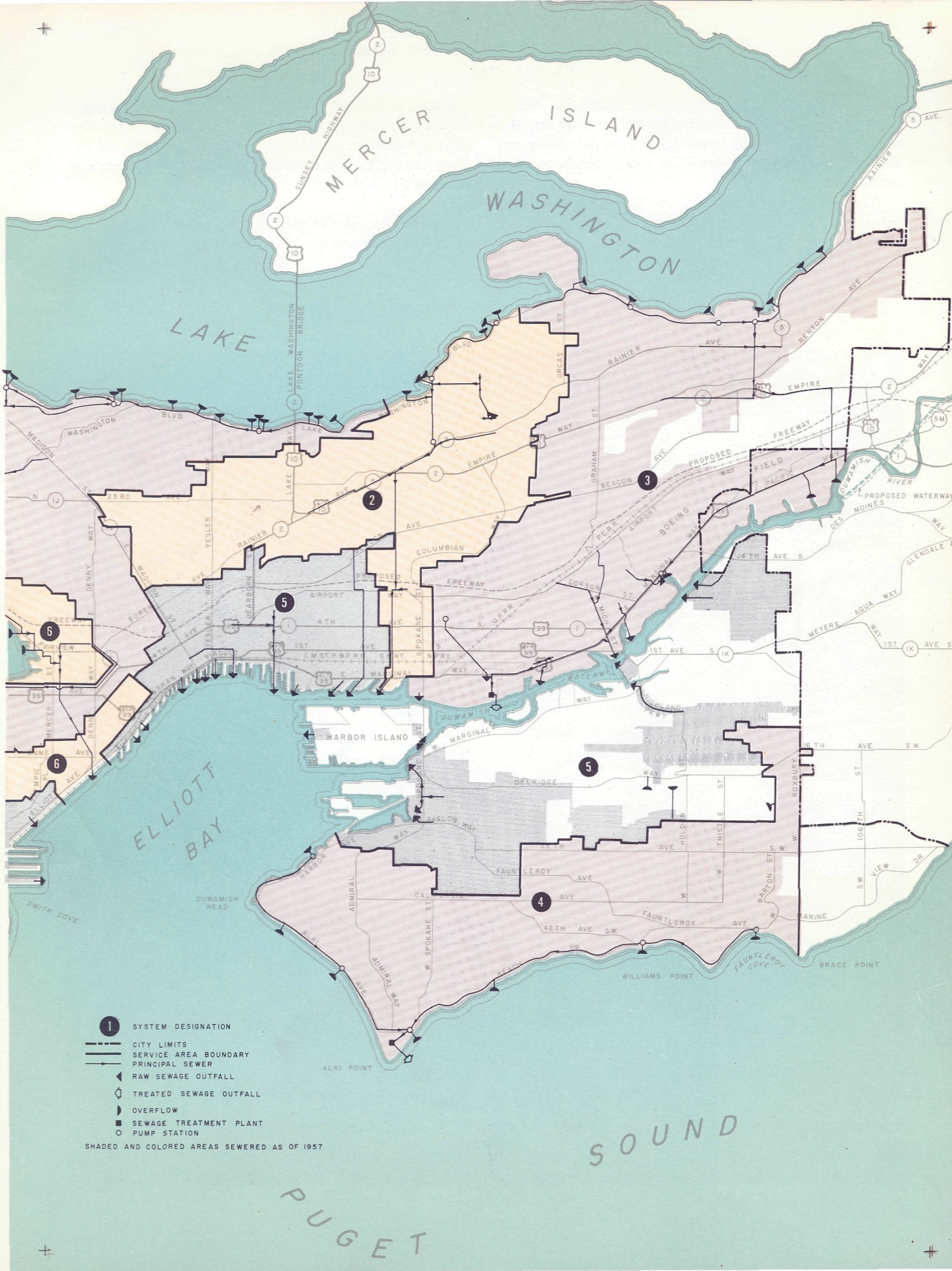


Fig. 6-27. Sewerage and Drainage Systems and Areas Served
City of Seattle

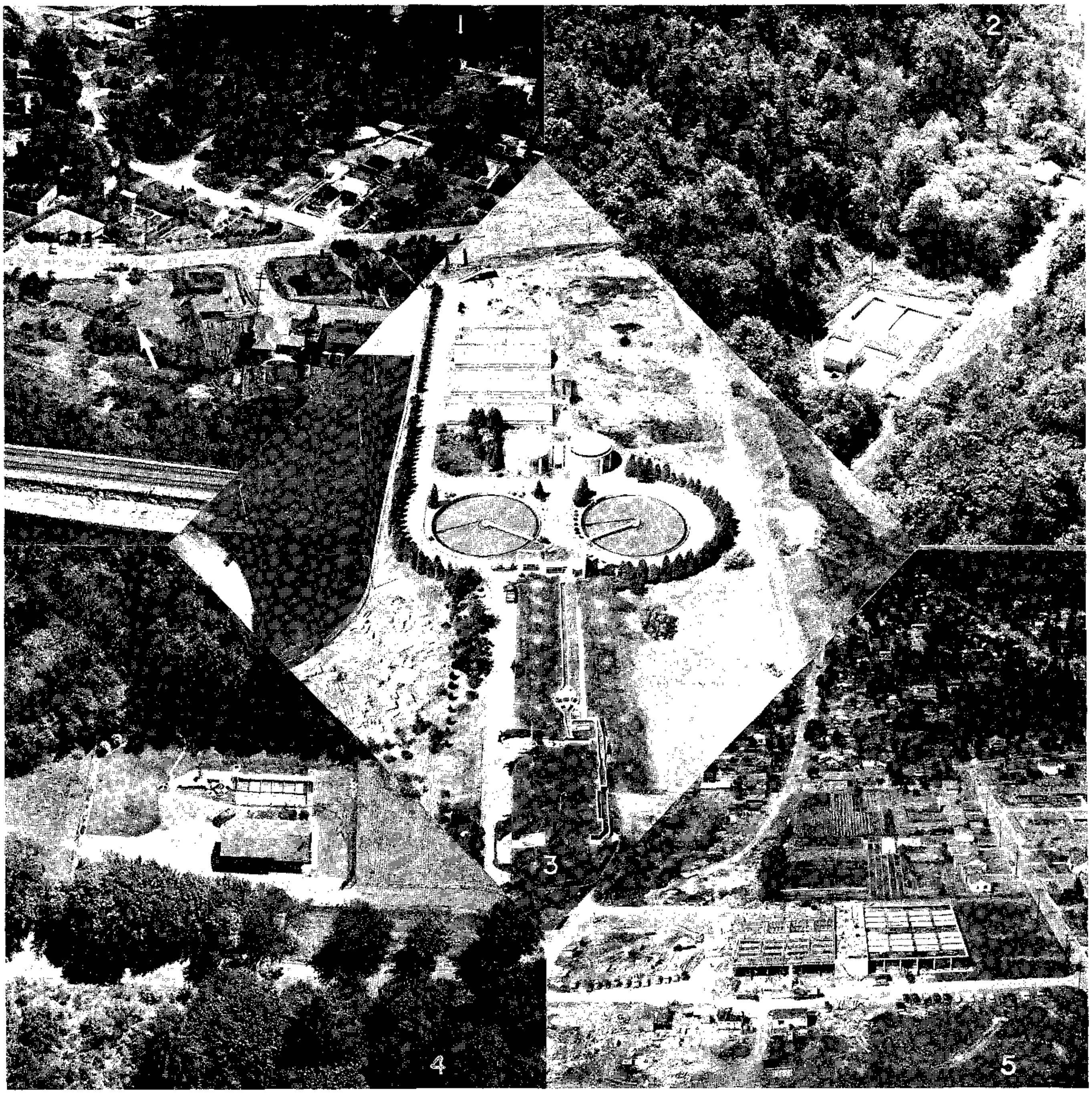

MERCER ISLAND
LAKE WASHINGTON
ELLIOTT BAY
PUGET SOUND
HARBOR ISLAND
DUWAMISH HEAD
SMITH COVE
ALKI POINT
WILLIAMS POINT
FAUNTLEROY COVE
BRACE POINT
DUWAMISH RIVER
PROPOSED WATERWAY
LAKE WASHINGTON PONTOON BRIDGE
SYSTEM DESIGNATION
CITY LIMITS
SERVICE AREA BOUNDARY
PRINCIPAL SEWER
RAW SEWAGE OUTFALL
TREATED SEWAGE OUTFALL
OVERFLOW
SEWAGE TREATMENT PLANT
PUMP STATION
SHADED AND COLORED AREAS SEWERED AS OF 1957

determining the necessary sewer capacity. Other factors involve such matters as topography and the extent of development in the local service areas and the quality both of construction and of operation and maintenance.

Damage to public and private property resulting from the backing-up of water in surcharged sewers has been a matter of continual concern and expense not only to the city but to many individual residents. Aside from property damage, overflows from surcharged sewers results in a situation which, at the very least, is a nuisance and a potential hazard to community health.

Overflows. As is common practice in the design of combined systems, Seattle sewers are provided

SEWAGE TREATMENT PLANTS SERVING SEATTLE



with overflow and bypass structures whereby wet weather flows in excess of intercepting sewer and pumping station capacities are diverted to convenient points of disposal. Although the majority of these structures, which may be either overflow manholes or side weirs, are incorporated in trunk lines leading to intercepting sewers, many are located also along the interceptors themselves.

Theoretically, overflow structures in use at Seattle are designed to function when the flow in the sewer reaches from five to nine times the estimated sanitary flow. Since, however, the overflow weir crests generally are set at a height approximately equal to the quarter depth of the approach sewer, overflowing usually begins when the ratio of storm flow to sanitary flow reaches two to one, or even less.

Overflows are frequent, even during summer months, occurring at most structures on an average of about 40 times during the period from May through September. On the other hand, because flows in excess of trunk or interceptor capacity are generally of short duration, the actual volume of sanitary sewage thus discharged is relatively small.

Further information concerning overflow conditions is presented in subsequent chapters. Chapters 8 and 10 discuss their effects on receiving waters; Chapter 13 presents an analysis of their frequency and volume as related to the size of intercepting sewers; and Chapter 15 discusses the overflow problem as it affects future sewerage planning and design.

Overloaded Sewers. Until recently, the design of combined sewers in Seattle has been based on a uniform runoff of 15 cubic feet per minute per acre. For many of the drainage areas, this amount of runoff can be expected to occur with storms having a recurrence interval of only two years. It follows, therefore, that overloading of the systems in these areas is likely to occur at a similar frequency.

As emergencies have arisen, various steps have been taken to prevent or alleviate conditions resulting from the backing up of excess flows. Systems originally intended to function independently have been interconnected; weirs have been installed in manholes to divert part of the flow from one sewer to another; sewers tributary to overloaded sections have been plugged and the flow diverted; emergency bypasses have been constructed; and relief sewers have been installed to provide additional capacity in the most troublesome areas. As a result of these modifications, some of which have been completed without any record being made of their nature and location, it is difficult to make the hydraulic analyses which are required for the planning of trunk and interceptor improvements. In fact, conditions in some areas are such that an analysis of the present facilities is practically impossible.

Additional information concerning overloaded sewers will be found in two of the later chapters. Chapter 8 includes a detailed discussion of their detrimental effects, while Chapter 18 presents an analysis of the problem as it affects future planning and design.

Operation and Maintenance

Maintenance of the Seattle sewerage system is performed on a variable schedule based both on past experience and on the results of an annual inspection program. As part of the latter, all sewers up to 15 inches in diameter are candled for evidence of obstructions or damage. Inspection of most of the large sewers, however, is limited to sections in the vicinity of points of entry. This is because of the long distances between manholes, the depth of sewage flow, and the inaccessibility of tunnel sections.

←

(1) NORTH BEACH SEWAGE TREATMENT PLANT, a 0.43 mgd primary treatment plant, is hidden beneath this landscaped site (arrow). The only plant structure visible to nearby residents is the small building which houses the access stairway at center of the triangular site. Note the two residences immediately adjacent to the property line at right of site. Effluent is discharged to Puget Sound offshore from the beach shown in foreground.

(2) ROXBURY HEIGHTS SEWAGE TREATMENT PLANT, originally constructed by the Roxbury Heights Sewer District, has been operated by Seattle since annexation of the Roxbury area in 1956. Primary effluent from the Imhoff tanks shown here is discharged to Puget Sound offshore from the beach shown in background.

(3) DIAGONAL AVENUE TREATMENT PLANT is the only plant in the area treating combined sewage. The circular clarifiers, center, provide primary sedimentation for an average daily flow of 8.0 mgd. Wet weather flow to the plant is limited to this rate by an upstream flow regulator, the excess being bypassed. Note the glass covered sludge drying beds behind digesters and the effluent discharge into Duwamish River at top of picture near end of row of trees.

(4) GREENWOOD AVENUE SEWAGE TREATMENT PLANT, located near the mouth of Piper Creek in Carkeek Park, is designed to remove floatable materials from sewage. Effluent is chlorinated and discharged into Puget Sound opposite the public bathing beach. Agitation of sewage by air to promote floatation is noticeable in forward compartment. Floatable materials are removed from the stilling chamber in rear by spray jets. Building in foreground houses blower and other plant equipment.

(5) LAKE CITY SEWAGE TREATMENT PLANT during construction of additions in 1957. Section at right houses the original 2.5 mgd activated sludge plant. Digesters are at center and new units which will bring plant capacity to 10.0 mgd are at left. Effluent is discharged to Lake Washington through a tunnel under a high ridge which prevents natural flow from the site to the lake by gravity.

Certain sewers, especially those with steep grades, have required little or no maintenance, whereas others require flushing, dragging or root removal from one to four times every year. Since troublesome sections are generally known from past experience, regular cleaning programs are scheduled accordingly. Maintenance schedules for other sections are developed annually on the basis of conditions observed during the annual inspection.

Sand traps, which are located ahead of each of the siphons, are inspected frequently and normally require cleaning only twice a year. Material removed at such times is inspected for pieces of broken pipe or brick which might indicate breakage in tributary sewers. Debris is pumped from catch basins on an average of three to four times a year.

A crew of four to eleven men is regularly assigned to sewer maintenance duties in each of five maintenance districts, and is augmented as necessary to cope with seasonal and emergency conditions. In addition, a city-wide crew of twelve men is regularly assigned to maintenance of the storm water catch basins. This crew also is augmented for emergency work during and following storms. Mechanical equipment includes fourteen trucks, five of which are equipped with winches and dragging equipment; four trailer-mounted cleaning and root cutting devices; and seven eductors for catch basin cleaning.

During the annual inspection, and also while performing routine maintenance duties, a special effort is made to detect cracks, breaks, and other signs of deterioration in sewer lines and structures. Failures requiring immediate attention are either replaced or repaired on an emergency basis, whereas other repair and replacement work is scheduled as manpower becomes available. Cracked sewers normally are not replaced until there is evidence of progressive failure. Cracks are estimated to have developed in about 15 per cent of the smaller sewers now in service and, of course, are far more numerous in older systems.

Principal maintenance problems are the sand and grit deposits which accumulate in sewers with flat grades, and the frequent backups which occur in many sections of the city during periods of moderate to heavy rainfall. In sewers which cannot be cleaned by conventional equipment, or which are inaccessible, accumulated deposits of sand and grit may account for some of the backups.

Pumping stations are operated and maintained by two crews of two men, each crew working under a machinist who in turn reports to the foreman of sewage treatment plants. Normally, each station is visited three times weekly for the purpose of washing down wet wells, cleaning floats, changing pumping record charts, recording total pumpage, greasing and oiling equipment, alternating manually operated pumps, checking equipment for signs of failure, and general cleaning. Conditions which cannot be corrected by the maintenance crews are reported to the machinist, who either makes the necessary repairs in the field or calls upon the general machine shop or the department electrician for assistance.

Sewage treatment plants are operated and maintained by a regular crew of twelve operators and laborers under the supervision of a foreman. Each of the five treatment plants is attended eight hours a day and is normally unattended for sixteen hours. At present, operators assigned to the Diagonal Avenue plant also operate and maintain the Roxbury Heights plant on a part-time basis. When required, the services of a machinist and an electrician are available, as is additional help during emergencies. Two painters, regularly assigned to the city shop, do part-time painting and waterproofing at pumping stations and treatment plants.

Table 6-21. Description of Principal Sewerage Facilities, City of Seattle

Facility[a]	Description[b,c]	Capacity,[d] mgd
North Trunk System – Interbay District		
1	1,120 ft of 48-in. CI submarine outfall to water depth of 40 ft	80[e]
2	8,000 ft of 144-in. BR and BI at 0.033%, includes 3,380 ft of tunnel under Fort Lawton	273
3	4,040 ft of 144-in. BR and BI at 0.032%	269
4	1,640 ft of 138-in. BI at 0.035%	290
5	4,550 ft of 138-in. BR and BI at 0.033%	244
North Trunk System – Ballard District		
6	1,290 ft of twin 36-in. wood stave inverted siphon; discharge through 450 ft of 72-in. RC at 0.028% to sewer 3 at 24th Avenue West	29[f]
7	Sandcatcher, overflow and siphon structure, includes 120 ft of 36-in. overflow outfall	....
8	960 ft of 66-in. RC at 0.035%	40
9	2,080 ft of 54-in. RC at 0.04%	26
10	2,130 ft of 42-in. RC at 0.10%	21
11	1,360 ft of 36-in. RC at 0.08%	12
North Trunk System – Central District		
12	50 ft of 60-in. BI at 3.53%, sandcatcher, 30 ft long side weir overflow, and 400 ft of 39-in by 60-in. rectangular overflow outfall. Overflow starts when flow reaches 30 mgd. Weir capacity, 145 mgd; overflow outfall capacity 110 mgd with water surface at weir crest	....
13	2,550 ft of 72-in. BI at 0.19% and 120 ft of 78-in. BI at 0.24%	120
14	2,500 ft of 60-in. BR tunnel at 0.13 - 0.14% and 250 ft of 66-in. BR tunnel at 0.17%	54
15	980 ft of 54-in. BR tunnel at 0.18%	46
16	2,920 ft of 48-in. BR tunnel at 0.20 - 0.26%	38
17	30-ft long side weir overflow and 460 ft of 42-in. and 48-in. overflow outfall. Overflow starts when flow reaches 32 mgd. Weir capacity, greater than 130 mgd	....
18	2,550 ft of 84-in. BI at 0.21%, includes 200 ft of tunnel	162
19	210 ft of parallel 24-in. and 66-in. conc inverted siphons under Broad Street underpass	116
20	3,530 ft of 60-in. BR at 0.61% and 390 ft of 66-in. BR at 0.38%	113
21	360 ft of 48-in. BR at 1.60% and 640 ft of 42-in. BR at 4.21%	100
22	240 ft of 48-in. BR at 1.03%	83
23	330 ft of 42-in. BR at 1.0%	56
North Trunk System – Lake Union District		
24	360 ft of parallel 48-in. and 60-in. CI inverted siphons in concrete tunnel; discharge through 150 ft of 108-in. BI to sewer 5	125
25	460 ft of 108-in. BI at 0.073%	225
26	Sandcatcher and emergency overflow	....
27	4,800 ft of 108-in. BI at 0.074 - 0.077%	221
28	4,760 ft of 108-in. BR and BI at 0.087%	230
29	3,210 ft of 108-in. BR at 0.068%	182
30	1,960 ft of 108-in. BR at 0.065%	178
North Trunk System – Green Lake District		
31	80 ft of 96-in. BI at 0.074%; discharge to sewer 30	160
32	50 ft long side weir overflow and 1,260 ft of 84-in. overflow outfall. Overflow starts when flow reaches 120 mgd. Weir capacity, greater than 375 mgd	....
33	6,880 ft of 138-in. BR and BI at 0.16%	535

Continued on next page

Table 6-21. Continued

Facility[a]	Description[b,c]	Capacity,[d] mgd
34	3,560 ft of 72-in. BR tunnel at 2.563% and 130 ft of 126-in. BR tunnel	375
35	Sandcatcher	....
36	3,420 ft of 90-in. BR and BI at 0.45%	288
37	2,200 ft of 90-in. BI at 0.15%	195
38	1,760 ft of 90-in. BI at 0.11% and 290 ft of 90-in. BI at 0.085%	160
39	320 ft of 72-in. BI at 0.11%	90
40	2,170 ft of 54-in. BI at 0.14 - 0.16%	47
41	590 ft of 48-in. BI at 0.14 - 0.16%	34
42	660 ft of 42-in. BI at 0.16 - 0.26%	26
43	800 ft of 36-in. BR at 0.24 - 0.28%	16
44	2,940 ft of 54-in. BI at 0.22%	59
45	3,000 ft of 42-in. BI at 0.20%	29
46	Overflow weir from Green Lake to sewer 38, includes 170 ft of 24-in. connecting pipe. 3-ft weir with crest at elevation 160.5 mean sea level datum	....
47	Overflow weir from Green Lake to sewer 44, includes 210 ft of 24-in. connecting pipe. 3-ft weir with crest at elevation 160.5 mean sea level datum	....
48	Overflow weir from Green Lake to sewer 44, includes 160 ft of 24-in. connecting pipe. 2-ft weir with crest at elevation 160.5 mean sea level datum	....
49	930 ft of 96-in. BR at 0.10%	160
North Trunk System – Laurelhurst District		
50	1,730 ft of 42-in. RC at 0.08% and 300 ft of 36-in. BR at 0.85%; discharge to sewer 49	18
PS-1	Pumping station, includes 80 ft of 20-in. CI force main. Contains 2 pumps; capacities 5.2 mgd at 39 ft total head and 5.4 mgd at 39 ft total head	....
51	2,410 ft of 42-in. RC at 0.08%	18
52	730 ft of 30-in. conc at 0.4%	17
53	610 ft of 30-in. conc at 0.24%	13
PS-2	Pumping station, includes 40 ft of 20-in. CI force main and 230 ft of 36-in. emergency overflow and bypass line. Contains 2 pumps; capacities 4.2 mgd at 22 ft total head and 4.8 mgd at 21 ft total head	....
54	840 ft of 48-in. RC at 0.07%	24
55	1,200 ft of 48-in. RC at 0.045%	20
56	1,660 ft of 42-in. RC at 0.06 - 0.072%, includes 1,500 ft of tunnel	17
57	740 ft of 42-in. RC at 0.05%	14
58	Stormwater overflow and 430 ft of 24-in. conc and 30-in. wood stave outfall	....
59	1,600 ft of 30-in. conc at 0.09%	7.8
60	2,450 ft of 30-in. conc at 0.07%	7.0
61	60 ft of 18-in. conc at 1.72%, 20-ft long side weir overflow, and 980 ft of 36-in. conc and wood stave overflow outfall. Overflow starts when flow reaches 4 mgd. Weir capacity, 60 mgd	....
62	4,540 ft of 36-in. to 60-in. at 0.25 - 4.5%. Capacity range 70 - 90 mgd	....
North Trunk System – Lake Washington District		
63	1,090 ft of 48-in. BR at 0.15%; discharge to sewer 30	31
64	510 ft of 48-in. BR inverted siphon under Lake Washington Ship Canal	24
65	Sandcatcher, 40-ft long side weir overflow, and 220 ft of 60-in. overflow outfall. Overflow starts when flow reaches 30 mgd. Weir capacity greater than 260 mgd	....
66	770 ft of 114-in. BR at 0.123%	280

Continued on next page

Table 6-21. Continued

Facility[a]	Description[b,c]	Capacity,[d] mgd
67	1,280 ft of 66-in. BI at 0.227%	100
68	2,770 ft of 90-in. BI at 0.173%	200
69	1,540 ft of 72-in. BR at 0.2%	120
70	4,260 ft of 60-in. BR and BI at 0.5%	115
71	1,210 ft of 66-in. BI at 0.16%	85
72	1,760 ft of 60-in. BR and BI at 0.186%	72
73	850 ft of 54-in. BR at 0.18 - 0.22%	46
74	1,940 ft of 54-in. BR at 0.15 - 0.16%	42
75	5,360 ft of 48-in. BR and BI at 0.25%	40
76	1,360 ft of 32-in. by 48-in. BR oviform at 0.54%	28
77	1,190 ft of 24-in. by 36-in. BR oviform at 2.09%	26
PS-3	Pumping station, discharges to sewer 75 through 1,010 ft of twin 12-in. CI force mains. Contains 2 pumps; capacities 1.2 mgd at 46 ft total head and 2.7 mgd at 46 ft total head. Emergency overflow and stormwater bypass from adjacent manhole through 410 ft and 730 ft of parallel 20-in. CI outfalls. The longer outfall also serves as overflow from tributary sewer	....
78	2,930 ft of 15-in. conc at 0.17%	1.7
PS-4	Pumping station, includes 120 ft of 10-in. CI force main. Contains 2 pumps; capacities 1.2 mgd at 13 ft total head and 1.2 mgd at 14 ft total head. Emergency overflow and stormwater bypass from adjacent manhole through 420 ft of 24-in. CI outfall	....
79	4,240 ft of 18-in. conc at 0.13 - 0.14%; discharge to PS-3	2.6
PS-5	Pumping station, discharges to sewer 77 through 300 ft of 12-in. CI force main. Contains 2 pumps; capacities 0.95 mgd at 81 ft total head and 1.7 mgd at 85 ft total head. Emergency overflow and stormwater bypass from adjacent manhole through 300 ft of 24-in. CI outfall	....
80	1,960 ft of 12-in. at 0.22%	1.1
81	370 ft of 24-in. at 0.10%	4.6
82	3,960 ft of 21-in. at 0.12%	3.6
83	3,440 ft of 18-in. at 0.14%	2.6
PS-6	Pumping station, includes 60 ft of 10-in. CI force main. Contains one pump having a capacity of 1.3 mgd at 18 ft total head. Emergency overflow and stormwater bypass from adjacent manhole through 16-in. CI outfall. Overflow from tributary sewer through 230 ft of 20-in. CI outfall	....
84	3,140 ft of 15-in. at 0.17%	1.7
85	1,840 ft of 8-in. at 0.35%	0.5
Rainier - Hanford System		
86	5,390 ft of 100-in. by 150-in. BI at 0.075%. Discharges through 48-in. CI submarine outfall at low flows and over spillway at shore line at high flows	308
87	720 ft of 48-in. BI at 0.10%	29
88	6,070 ft of 108-in. BI at 0.4%, includes 5,600 ft of tunnel	510
89	440 ft of 102-in. BI at0.286 - 0.30%	365
90	2,310 ft of 102-in. BI at 0.21 - 0.26%	315
91	1,400 ft of 75-in. BR at 0.55%, discharges to sewer 90. Formerly discharged to sewer 199, which has been abandoned	195
92	850 ft of 72-in. BR at 0.55%	175
93	2,480 ft of 66-in. BI at 0.28 - 0.32%	102
94	3,740 ft of 60-in. BI at 0.31 - 0.32%	95
PS-7	Pumping station, discharges to sewer 93 through 50 ft of parallel 10-in. and 20-in. force mains. Contains 3 pumps; capacities 1.0 mgd at 30 ft total head, 4.7 mgd at 32 ft total head, and 5.0 mgd at 32 ft total head	....

Continued on next page

Table 6-21. Continued

Facility[a]	Description[b,c]	Capacity,[d] mgd
95	3,520 ft of 42-in. BR at 0.10%, includes 1,800 ft of tunnel	16
96	Sandcatcher	....
97	1,270 ft of 18-in. at 0.14 - 0.69%	2.6
98	1,290 ft of 72-in. BI at 0.074 - 0.084%, includes 200 ft of 72-in. RC and 36-in. CI overflow outfall	74
99	1,290 ft of 72-in. BI at 0.055% - 0.065%	64
100	430 ft of 48-in. BI at 0.12%	32
101	1,650 ft of 48-in. BI at 0.10 - 0.12%	29
102	630 ft of 42-in. BI at 0.13 - 0.14%	24
103	400 ft of 15-in. conc at 0.68 - 1.5%, includes 30-in. overflow to creek on 38th Avenue between Conover Way and Alaska Street	3.5
PS-8	Pumping station, discharges to facility 96 through 100 ft of 10-in. CI force main, includes 430 ft of 16-in. CI emergency overflow and stormwater bypass outfall. Contains 2 pumps; capacities 1.2 mgd at 15-ft total head and 1.5 mgd at 16 ft total head	....
104	1,440 ft of 21-in. conc at 0.10%	3.2
105	320 ft of 15-in. conc at 0.42%	2.7
106	3,260 ft of 15-in. conc at 0.17 - 0.18%	1.7
PS-9	Pumping station, includes 50 ft of 8-in. CI force main. Contains one pump having a capacity of 0.58 mgd at 14 ft total head	....
Henderson - East Marginal Way System		
STP	Sewage treatment plant, primary type. Design capacity 8 mgd at 2 hours detention. Discharges through 30-in. outfall to Duwamish Waterway	....
107	3,300 ft of 60-in. RC with VC liner at 0.055%	39
108	3,700 ft of 60-in. RC with VC liner at 0.05%	37
109	Flow regulator and overflow, designed to divert 6.5 mgd from sewer 147 to sewer 108, includes 30 ft of 24-in. connecting pipe	....
110	4,320 ft of 42-in. RC at 0.12%; discharges to sewer 147	23
PS-10	Pumping station, includes short length of 20-in. force main. Contains 2 pumps; capacities 2.4 mgd at 18 ft total head and 2.6 mgd at 18 ft total head. Emergency overflow and stormwater bypass from adjacent manhole through 350 ft of 36-in. conc outfall	....
111	9,200 ft of 42-in. RC at 0.10%	21
112	20-ft long side weir overflow and 1,490 ft of 42-in. conc overflow outfall at 0.2 - 3.2%. Weir crest set at crown of interceptor	....
113	1,080 ft of 42-in. RC at 0.10%	21
114	Side weir overflow, 20 ft of twin 24-in. CI at 0.178%, 75 ft of 36-in. conc at 0.178%, 60 ft of 42-in. conc at 0.10% and 1,560 ft of 84-in. conc overflow outfall. Overflow starts when flow reaches 19 mgd. Weir capacity, greater than 110 mgd	....
115	680 ft of 84-in. RC at 0.108%	133
116	3,090 ft of 72-in. RC at 0.103%	87
117	650 ft of 60-in. RC at 0.21%	76
118	680 ft of 60-in. RC at 0.15%	64
119	2,250 ft of 60-in. RC at 0.09 - 0.10%	53
120	2,080 ft of 42-in. RC at 0.20 - 0.23% and 48-in. BR at 0.12 - 0.13% and 250 ft of parallel 30-in. VC at 0.35% and 24-in. VC at 0.87%	30
121	Junction chamber receiving overflows from facilities 134 and 136 and 1,300 ft of 84-in. RC overflow outfall	....
122	1,230 ft of 72-in. BI at 0.55 - 0.65% and 60 ft of 48-in. RC at 2.22%, overflow; discharges to facility 121	200

Continued on next page

Table 6-21. Continued

Facility[a]	Description[b,c]	Capacity,[d] mgd
123	860 ft of 66-in. BI at 0.65 - 0.7%, overflow	173
124	490 ft of 60-in. BR at 1.0%, overflow	145
PS-11	Pumping station, discharges to sewer 120 through 1,290 ft of twin 15-in. CI force mains. Contains 2 pumps; capacities 2.4 mgd at 20 ft total head and 2.8 mgd at 21 ft total head. Emergency overflow and stormwater bypass from adjacent manhole with discharge to sewer 121	....
125	1,900 ft of 21-in. conc at 0.16 - 0.2%	4.1
PS-12	Pumping station, includes 10 ft of 10-in. CI force main. Contains 2 pumps; capacities 1.5 mgd at 16 ft total head and 1.6 mgd at 18 ft total head	....
126	3,230 ft of 21-in. conc at 0.14 - 0.15%	3.8
127	1,800 ft of 18-in. conc at 0.14%	2.6
PS-13	Pumping station, includes 10 ft of 8-in. CI force main. Contains 2 pumps; capacities 1.0 mgd at 18 ft total head and 1.1 mgd at 18 ft total head. Emergency overflow and stormwater bypass from adjacent manhole through 350 ft of 16-in. wood stave outfall. Tributary sewer also overflows to outfall	....
128	2,810 ft of 15-in. conc at 0.17%	1.7
129	Overflow manhole and 680 ft of 24-in. conc and wood stave outfall	....
130	2,540 ft of 24-in. conc at 0.1% and 330 ft of 30-in. at 0.64%	4.6
131	4,420 ft of 18-in. conc at 0.19%, discharges to PS-11	3.0
132	Overflow manhole and 90 ft of 15-in. and 16-in. outfall	....
133	1,220 ft of 15-in. VC at 0.45%	2.8
134	20 ft long side weir overflow, discharges to sewer 121. Overflow starts when flow reaches 3 mgd. Weir capacity, greater than 77 mgd	....
135	1,220 ft of 48-in. BI at 0.7%	77
136	30 ft long side weir overflow, discharges to sewer 121. Overflow starts when flow reaches 4 mgd. Weir capacity greater than 93 mgd	....
137	1,570 ft of 78-in. BI at 0.075%	93
138	1,410 ft of 78-in. BI at 0.055 - 0.066%	85
139	760 ft of 72-in. BI at 0.14%	100
140	30 ft long side weir overflow, discharges to sewer 124. Sanitary flow discharges to sewer 119 through 18-in. sewer. Overflow starts when flow reaches 17 mgd. Weir capacity greater than 145 mgd	....
141	2,910 ft of 60-in. BR and BI at 0.9 - 1.62%	155
142	2,040 ft of 60-in. BI at 0.5 - 0.65%	130
143	2,260 ft of 24-in. RC at 0.10 - 0.18%	4.6
144	1,170 ft of 30-in. RC at 0.12 - 0.18%	9.0
145	450 ft of 24-in. RC at 0.07 - 0.36%	5.0
146	1,110 ft of 70-in. by 102-in. BI outfall at 0.075%, from facility 109	110
147	2,110 ft of 65-in. by 96-in. BI at 0.052 - 0.067%	83
148	2,870 ft of 50-in. by 78-in. BI at 0.075 - 0.10%	48
149	740 ft of 50-in. by 78-in. BI at 0.10%	53
150	1,740 ft of 42-in. BI at 0.11%	22
151	860 ft of 50-in. by 78-in. BI outfall at 0.085%, from facility 152	49
152	Flow regulator and overflow, designed to divert 1.5 mgd from sewer 153 to sewer 107	....
153	330 ft of 40-in. by 66-in. BI at 0.11%	31
154	510 ft of 30-in. conc at 0.13%	10
155	230 ft of 48-in. RC culvert, discharges to slough	....

Continued on next page

Table 6-21. Continued

Facility[a]	Description[b,c]	Capacity,[d] mgd
156	1,020 ft of 42-in. steel at 0.04%	13
157	350 ft of roadside ditch	....
158	250 ft of 84-in. RC at 0.033%	74
159	1,900 ft of 60-in. RC at 0.039 - 0.053%	33
160	670 ft of 54-in. RC at 0.058 - 0.089%	31
161	1,150 ft of 48-in. RC at 0.079 - 0.084%	27
PS-14	Pumping station, discharges to sewer 160 through 1,140 ft of 18-in. conc force main and 480 ft of 24-in. conc at 0.15 - 0.23%. Contains 3 pumps; capacities 4.3 mgd at 28 ft total head, 4.8 mgd at 27 ft total head, and 4.8 mgd at 28 ft total head	....
West Seattle Systems		
STP	Sewage treatment plant, primary type. Design capacity of 60 mgd wet weather flow at 30 minutes detention. Discharges to water depth of 85 ft in Puget Sound through 1,400 ft of 42-in. RC outfall	....
PS-15	Pumping station, discharges to STP through 1,200 ft of parallel 24-in. and 42-in. force mains. Emergency overflow and stormwater bypass through 1,100 ft of 66-in. outfall	60
162	1,410 ft of 30-in. RC at 0.45%	18
PS-16	Pumping station, includes 4,440 ft of 24-in. force main and 560 ft of 60-in. overflow outfall	17
163	6,890 ft of 42-in. RC at 0.052%	15
PS-17	Pumping station, includes 2,600 ft of 21-in. force main and 480 ft of 42-in. overflow outfall	9.0
164	4,850 ft of 54-in. RC at 0.11%	42
165	2,000 ft of 54-in. pressure sewer	....
166	4,740 ft of 36-in. pressure sewer	....
PS-18	Pumping station, includes 1,400 ft of twin 27-in. force mains and 800 ft of 72-in. overflow outfall	39
167	840 ft of 42-in. RC at 0.25%	33
PS-19	Pumping station, includes 6,250 ft of 30-in. force main and 620 ft of 60-in. overflow outfall	23
168	1,540 ft of 42-in. conc at 0.11% and 70 ft of 24-in. conc and CI outfall	24
169	1,540 ft of 42-in. conc at 0.11% and 160 ft of 24-in. conc and CI outfall	24
170	2,840 ft of 18-in. conc at 1.8 - 16.1%. Outfall data unavailable	22
171	1,180 ft of 30-in. conc at 0.07% and 17-in. by 20-in. wood box outfall	7.0
172	860 ft of 24-in. at 0.19 - 0.448%	6.5
173	1,080 ft of 30-in. conc at 0.095%	8.0
174	Overflow, 700 ft of 24-in. BR	....
175	700 ft of 24-in. conc at 3.78% and septic tank. Discharge from septic tank to Longfellow Creek through 30-in. and 36-in. culvert	28
176	1,450 ft of 12-in. conc at 5.5 - 22%, stormwater overflow from pumping station at West Webster and 28th SW to Longfellow Creek	8.5
177	650 ft of 30-in. conc at 3.9 - 10.6% and 14-in. wood stave outfall	65
Lake Union Tunnel System		
178	5,600 ft of 72-in. BR at 0.08%, includes 5,300 ft of tunnel. Discharges through 48-in. CI submarine outfall at low flows and through 60-in. RC outfall at shore line at high flows	66
179	330 ft of 32-in. by 48-in. BR oviform at 3.02%	69
180	1,540 ft of 28-in. by 42-in. BR oviform at 2.74 - 8.77%	44
181	830 ft of 28-in. by 42-in. BR oviform at 2.22%. Overflow manhole on sewer 23 diverts up to 10 mgd to sewer 181	40
182	1,580 ft of 24-in. by 36-in. BR oviform at 0.15%	7.0
183	1,830 ft of 21-in. and 24-in. VC at 0.15%	4.0

Continued on next page

Table 6-21. Continued

Facility[a]	Description[b,c]	Capacity,[d] mgd
184	2,490 ft of 24-in. by 36-in. BR and 21-in. VC at 0.15%	4.0
185	1,240 ft of 24-in. by 36-in. BR oviform and 24-in VC at 0.15%	5.7
186	1,370 ft of 21-in VC at 0.15 - 0.18%	4.0
187	1,350 ft of 15-in. and 18-in. VC at 0.18 - 0.4%	2.9
188	1,000 ft of 21-in. and 24-in. VC at 0.33 - 1.47%	8.5
189	790 ft of 18-in. VC at 0.19%	3.0
190	1,150 ft of 15-in. VC at 0.25 - 0.4%	2.1
191	620 ft of 12-in. VC at 0.4%	1.5
Elliott Bay Independent Systems		
192	800 ft of 96-in. BI at 0.12%. Discharges through 180 ft of 20-in. CI submarine outfall at low flow and over spillway at shore line at high flow	200
193	1,640 ft of 90-in. BI at 0.12 - 0.15%	180
194	1,020 ft of 90-in. BI at 0.10 - 0.11%	160
195	760 ft of 84-in. BI at 0.13%	150
196	1,130 ft of 84-in. BI at 0.10%	130
197	500 ft of 72-in. BI at 0.14%	100
198	410 ft of 54-in. BI at 1.0%	125
199	4,450 ft of 48-in. by 72-in. BR oviform abandoned tunnel at 0.286%. Tunnel gated at east portal. Reportedly receives flow from west slope of Beacon Hill through drop manholes	70
200	880 ft of 72-in. BI at 0.175%. Discharges through 54-in. RC submarine outfall at low flow and through 72-in. outfall at shore line at high flow	110
201	490 ft of 66-in. BR at 0.177%	77
202	960 ft of 72-in. BI at 0.15%	105
203	770 ft of 60-in. BI at 0.13%	60
204	2,560 ft of 48-in. BI at 0.13%	33
205	1,430 ft of 48-in. BR and BI at 0.33 - 0.38%. Outfall data unavailable	48
206	610 ft of 32-in. by 48-in. BR oviform at 0.33%	22
207	320 ft of 28-in. by 42-in. BR oviform at 0.32%	15
208	920 ft of 22-in. by 33-in. BR oviform at 0.66%	11
209	1,140 ft of 42-in. RC at 5.0 - 5.2%. Discharges through 760 ft of 16-in submarine outfall at low flow and through 24-in. outfall at shore line at high flow	147
North Beach System		
STP	Sewage treatment plant, primary type. Design capacity 0.43 mgd at 2 hours detention. Discharges through 1,200 ft of outfall, including 1,000 ft submarine section, to Puget Sound	....
210	770 ft of 18-in. conc at 1.65 - 3.26%	8.8
211	1,010 ft of 15-in. conc at 5.53 - 8.6%	13
212	200 ft of 24-in. conc at 1.03%	15
213	1,510 ft of 18-in. conc at 1.71 - 6.63%	9.0
Blue Ridge System		
214	1,050 ft of 10-in. CI outfall	....
Greenwood Avenue System		
STP	Sewage treatment plant, primary type, designed to remove grease and floatable matter only. Discharges through 3,200 ft of outfall, including 1,200 ft submarine section, to Puget Sound	....
215	500 ft of 24-in. conc at 1.59%	18

Continued on next page

Table 6-21. Continued

Facility[a]	Description[b,c]	Capacity,[d] mgd
216	3,000 ft of 12-in. conc at 3.3 - 20.8%	5.0
217	310 ft of 21-in. conc at 2.52%	16
218	2,640 ft of 15-in. and 18-in. conc at 2.04 - 27.6%	9.6
219	1,430 ft of 21-in. conc at 0.28 - 0.37%	5.4
Lake City System		
STP	Sewage treatment plant, secondary type. Discharges to Lake Washington through 2,440 ft of 72-in. RC at 0.3% and 1,410 ft of 90-in. horseshoe tunnel at 0.3%. Discharge through 30-in. submarine outfall at low flow and through 42-in. and 48-in. submarine outfalls at high flow. Diversion structure at treatment plant provides for overflowing Thornton Creek to outfall at high creek levels	10
220	1,650 ft of 36-in. conc at 0.45%, includes 70 ft inverted siphon across Thornton Creek	29
221	2,670 ft of 36-in. conc at 0.90 - 2.66%	25
222	960 ft of 42-in. conc at 0.3%	36
223	1,220 ft of 30-in. conc at 2.12%	38
224	2,610 ft of 30-in. conc at 1.5 - 1.9%	36
225	2,810 ft of 27-in. and 30-in. conc at 1.74 - 13.5%	26
226	1,330 ft of 30-in. conc at 0.8%	24
227	1,940 ft of 27-in. and 30-in. conc at 0.6 - 2.4%	21
228	6,090 ft of 30-in. at 0.5 - 3.6%	19
229	12,000 ft of 8-in. to 12-in. lake front gravity interceptor with intermediate lift stations	....
PS-20	Pumping station, discharges to STP through 4,200 ft of 14-in. force main. Contains 3 pumps; capacities 1.0 mgd at 38 ft total head, 1.1 mgd at 37 ft total head, and 1.1 mgd at 40 ft total head	....

[a]*See Figs. 6-29 to 6-37 for location of facilities.*

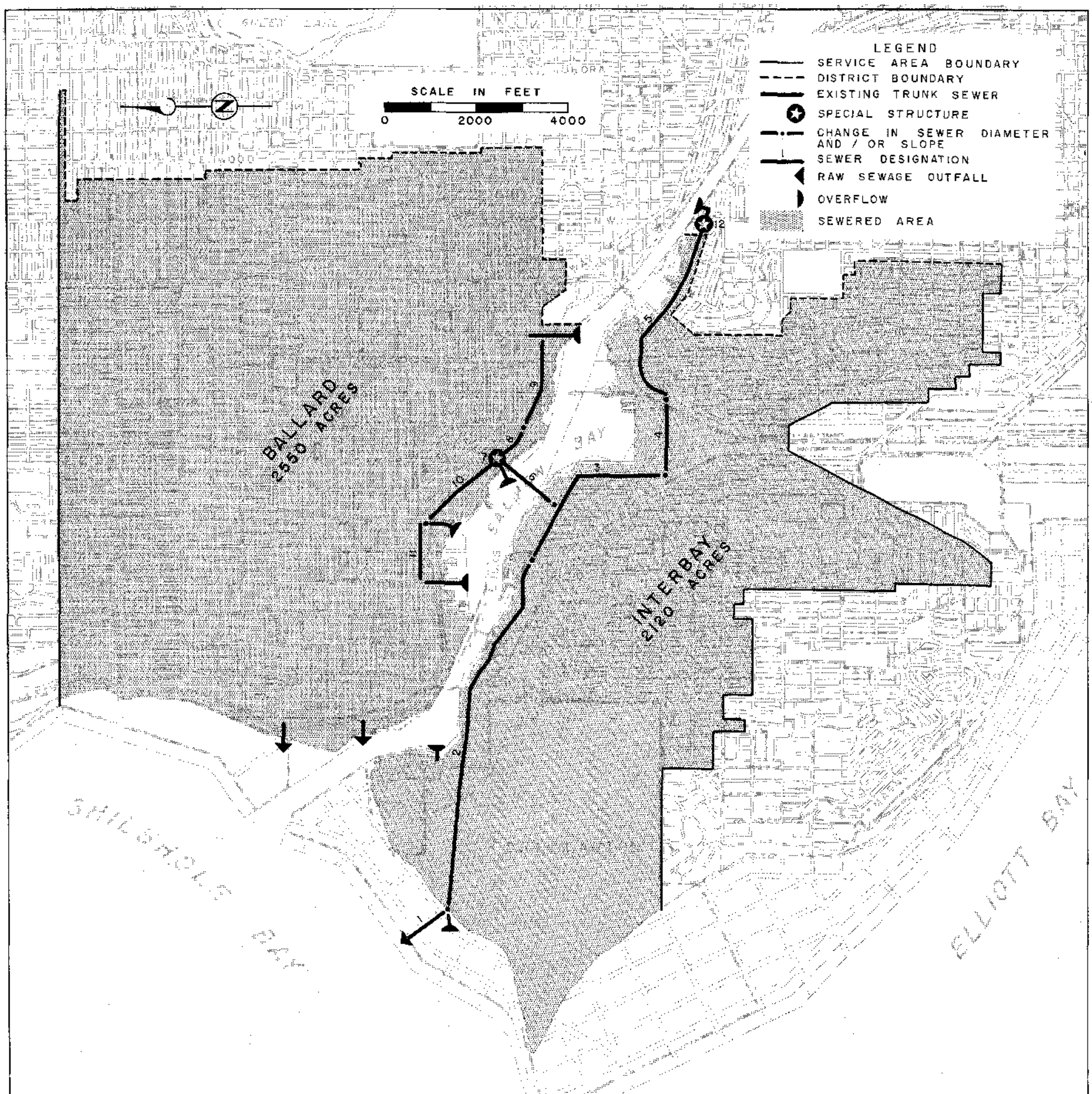
[b]*BR, brick; n equals 0.017 for 42-in. and smaller, n equals 0.015 over 42-in. Conc, concrete; n equals 0.013. BI, concrete with brick invert; n equals 0.013. RC, reinforced concrete; n equals 0.013. VC, vitrified clay; n equals 0.013. CI, cast iron; c equals 100. CMP, corrugated metal pipe; n equals 0.017.*

[c]*All lengths rounded off to nearest 10 feet.*

[d]*Flowing full. Where size, slope or type of material varies within sections, capacity determined either for limiting condition or for minimum surcharging where physical conditions permit. For cross sections other than circular, capacity calculated for equivalent circular section.*

[e]*At mean sea level with approach sewer flowing full.*

[f]*With sewer 3 flowing full.*

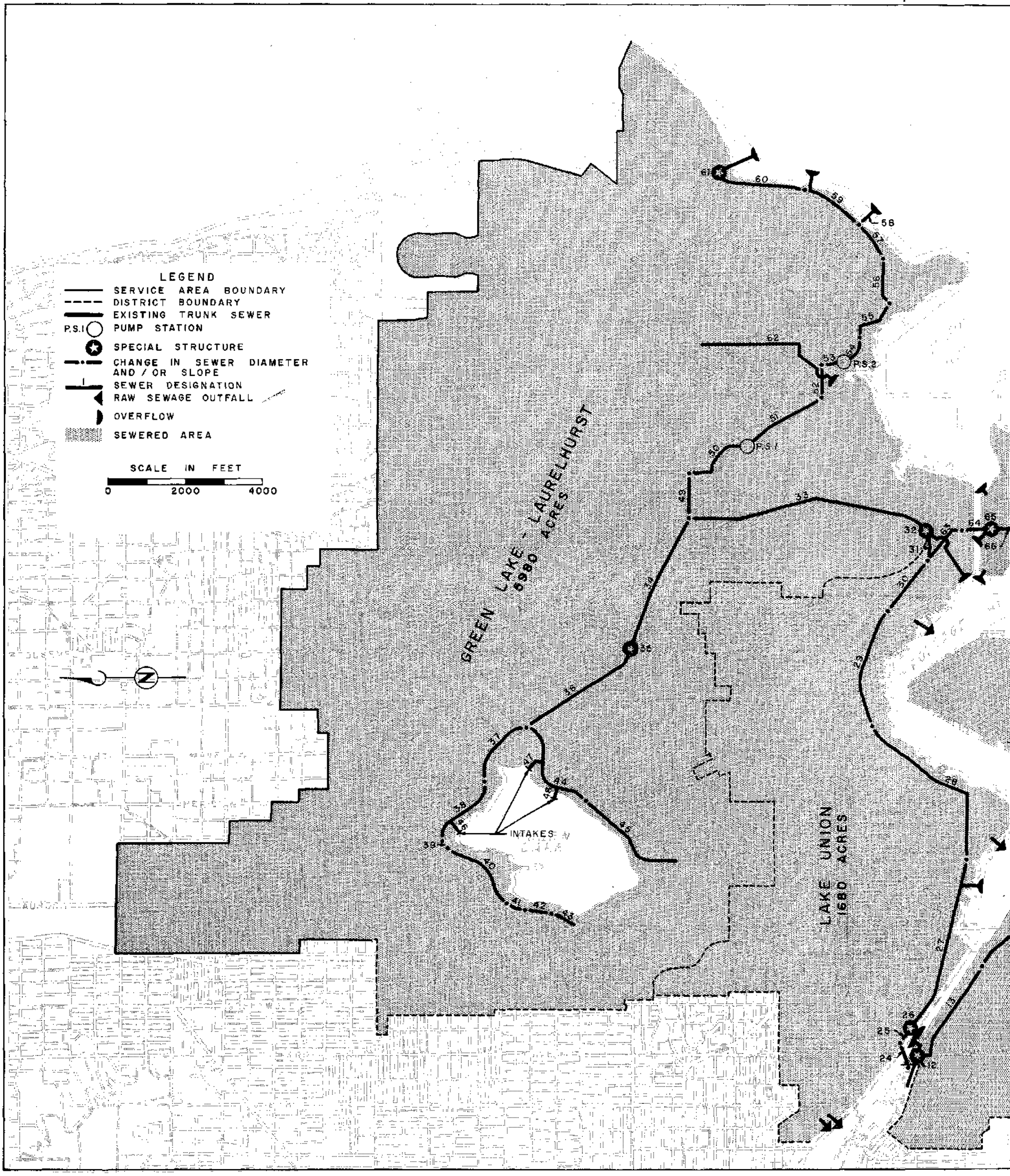


Trunk system terminates with a tunnel 200 feet in depth under Fort Lawton (No. 2) and an outfall extending 1,200 feet into Shilshole Bay to a depth of 40 feet (No. 1). Flows in excess of the outfall capacity are discharged to the beach over a weir in the end of the tunnel. Lateral sewers serving the Interbay district discharge directly to the trunk, while flow from the Ballard district is intercepted along the north side of the waterway and conveyed to the trunk through twin siphons (No. 6).

Flow from a small area along the west side of Ballard is discharged to Puget Sound through independent outfalls. A waterfront interceptor, soon to be constructed, will divert this flow to a point below the Government Locks where a siphon will convey it beneath the waterway to the North Trunk.

The North Trunk system also serves an additional 12,410 acres to the east and south (Fig. 6-29). All numbered sections are described in Table 6-21.

Fig. 6-28. North Trunk System - Interbay and Ballard Districts


LEGEND
SERVICE AREA BOUNDARY
DISTRICT BOUNDARY
EXISTING TRUNK SEWER
P.S.I PUMP STATION
SPECIAL STRUCTURE
CHANGE IN SEWER DIAMETER AND / OR SLOPE
SEWER DESIGNATION
RAW SEWAGE OUTFALL
OVERFLOW
SEWERED AREA
SCALE IN FEET
0 2000 4000
GREEN LAKE - LAURELHURST
6980 ACRES
LAKE UNION
1680 ACRES
INTAKES
P.S.1
P.S.2

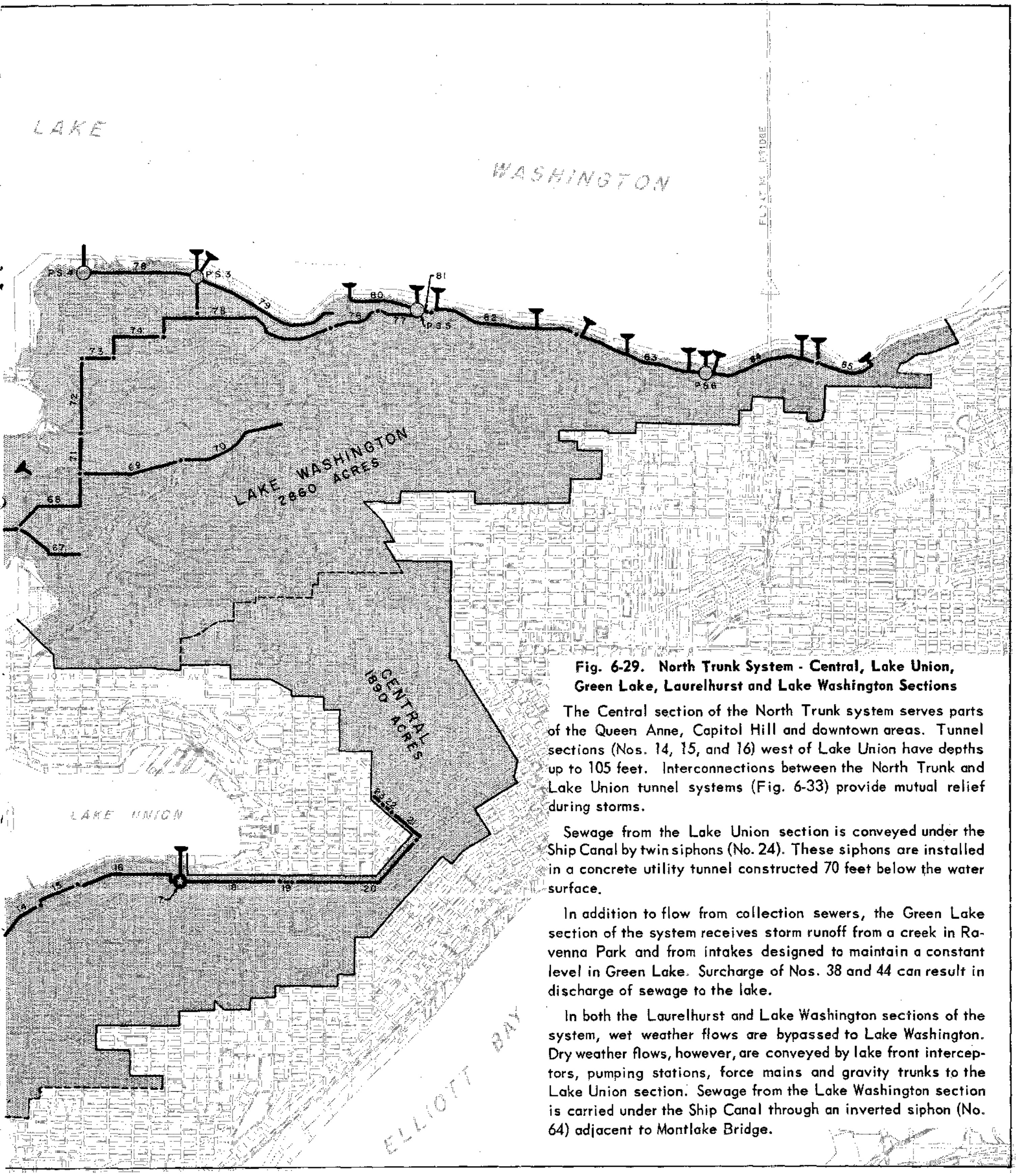


Fig. 6-29. North Trunk System - Central, Lake Union, Green Lake, Laurelhurst and Lake Washington Sections

The Central section of the North Trunk system serves parts of the Queen Anne, Capitol Hill and downtown areas. Tunnel sections (Nos. 14, 15, and 16) west of Lake Union have depths up to 105 feet. Interconnections between the North Trunk and Lake Union tunnel systems (Fig. 6-33) provide mutual relief during storms.

Sewage from the Lake Union section is conveyed under the Ship Canal by twin siphons (No. 24). These siphons are installed in a concrete utility tunnel constructed 70 feet below the water surface.

In addition to flow from collection sewers, the Green Lake section of the system receives storm runoff from a creek in Ravenna Park and from intakes designed to maintain a constant level in Green Lake. Surcharge of Nos. 38 and 44 can result in discharge of sewage to the lake.

In both the Laurelhurst and Lake Washington sections of the system, wet weather flows are bypassed to Lake Washington. Dry weather flows, however, are conveyed by lake front interceptors, pumping stations, force mains and gravity trunks to the Lake Union section. Sewage from the Lake Washington section is carried under the Ship Canal through an inverted siphon (No. 64) adjacent to Montlake Bridge.

This system diverts sewage and storm runoff from the Lake Washington watershed to the East Waterway of Duwamish River. Dry weather flow is intercepted along the lake front and pumped (PS 8) to a tunnel (part of No. 95) under Charlestown Street. From here it is conveyed by gravity to PS 7 which lifts it into the Rainier Avenue trunk.

Flows from the Rainier valley area converge at Hanford Street and are conveyed through a tunnel under Beacon Hill (part of No. 88) and thence to the waterway. Prior to construction of the Lake Washington interceptor and the Hanford tunnel, the flow from Rainier Avenue was diverted through a tunnel under Bayview Street (see arrow). This tunnel was abandoned because of insufficient capacity and concern regarding its possible collapse. Should separation of the Rainier-Hanford system become necessary, the Bayview tunnel could be repaired and utilized as a storm drain.

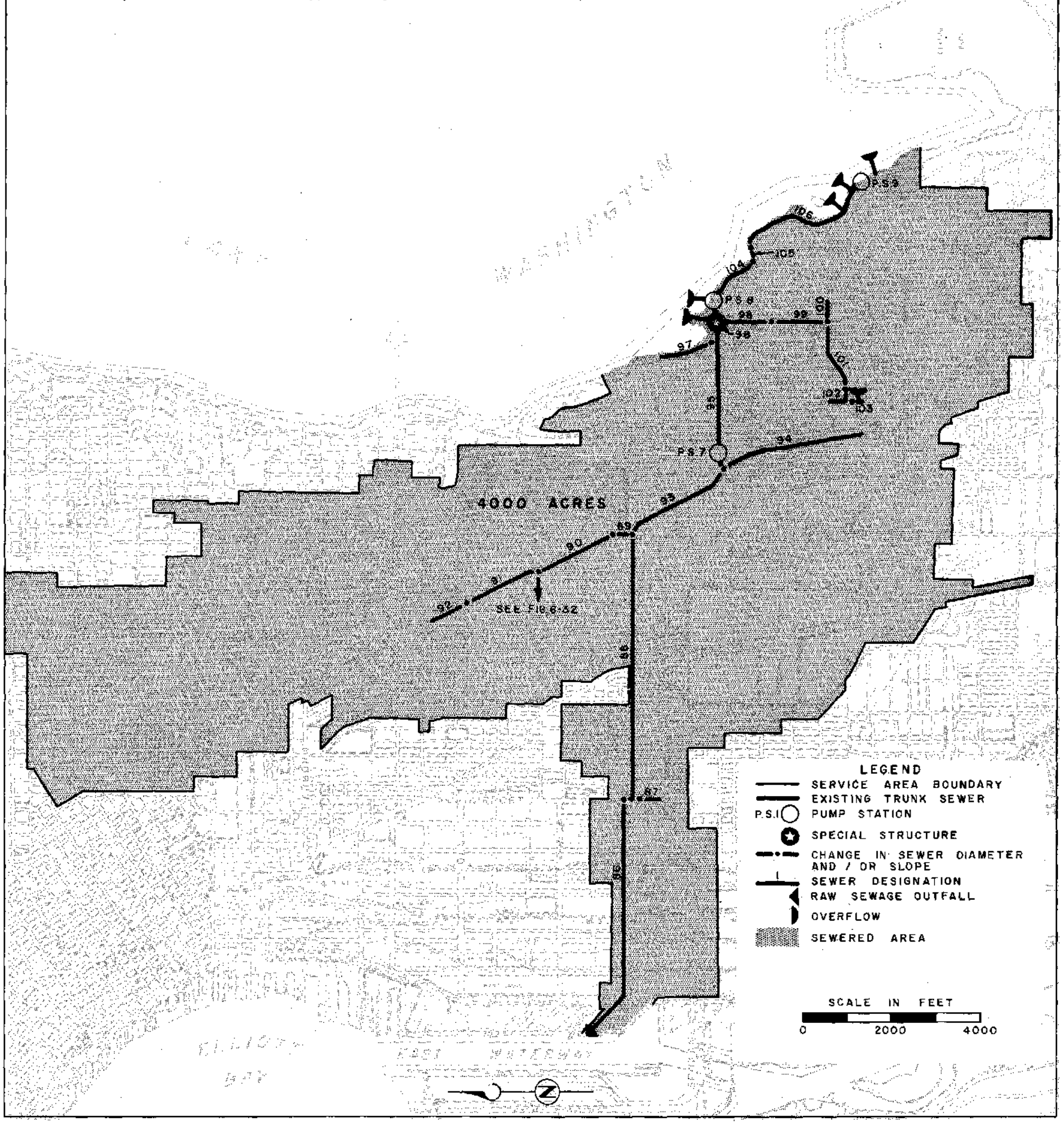


Fig. 6-30. Rainier - Hanford System

Dry weather flows are conveyed from the Lake Washington watershed around the south end of Beacon Hill to East Marginal Way. Flows from parts of the heavily industrialized Duwamish valley, including 470 acres outside the city, are intercepted along East Marginal Way and discharged into the Michigan Street trunk sewer (No. 147). Here a regulating station (No. 109) diverts up to 6.5 mgd through Nos. 108 and 107 to the Diagonal Avenue treatment plant. Since sections of the intercepting sewer have only about 10 per cent of the capacity of tributary trunks, up to 90 per cent of the wet weather flow is bypassed at various locations. Three small systems, as well as a number of industries, discharge directly to the Duwamish.

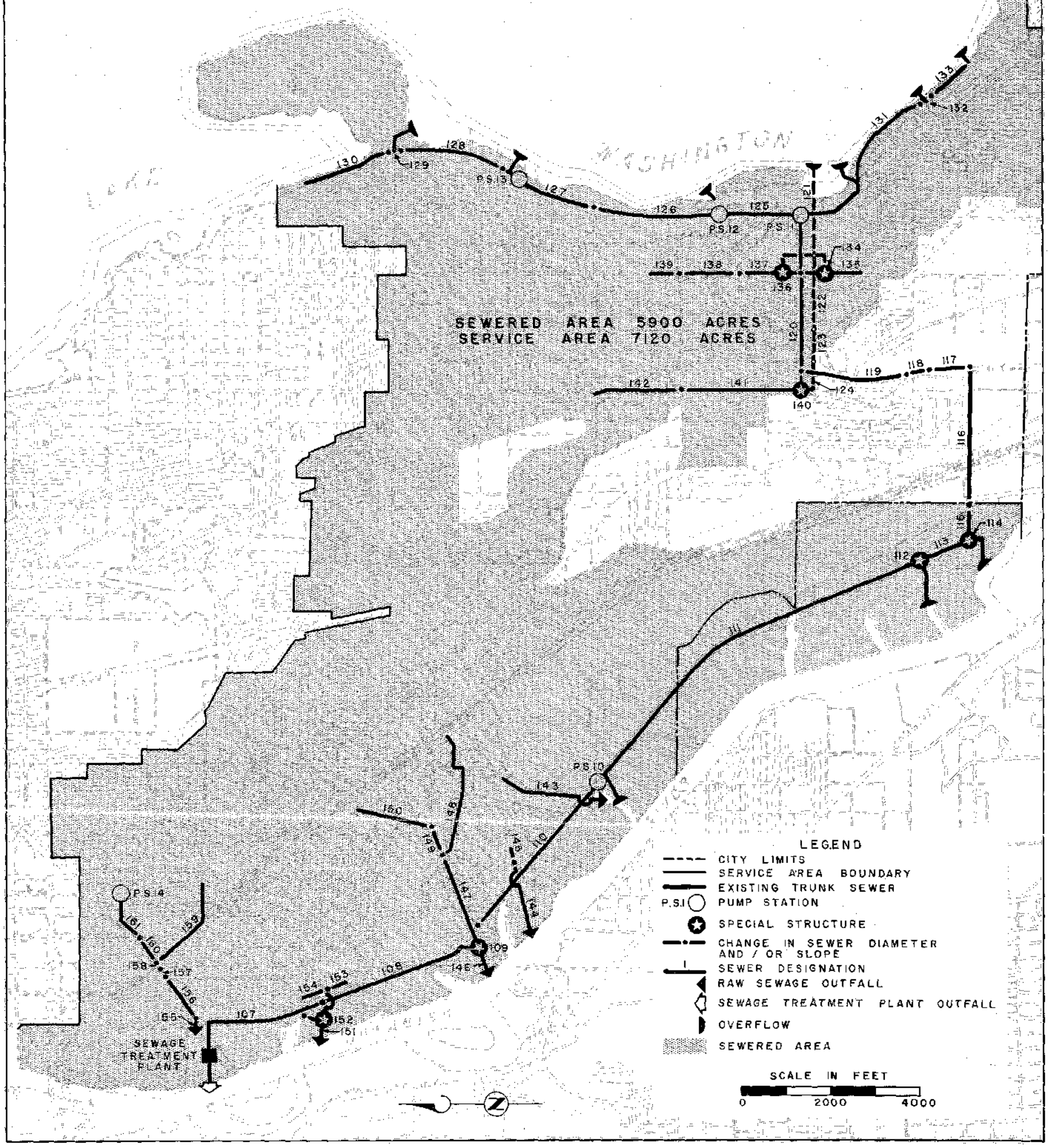


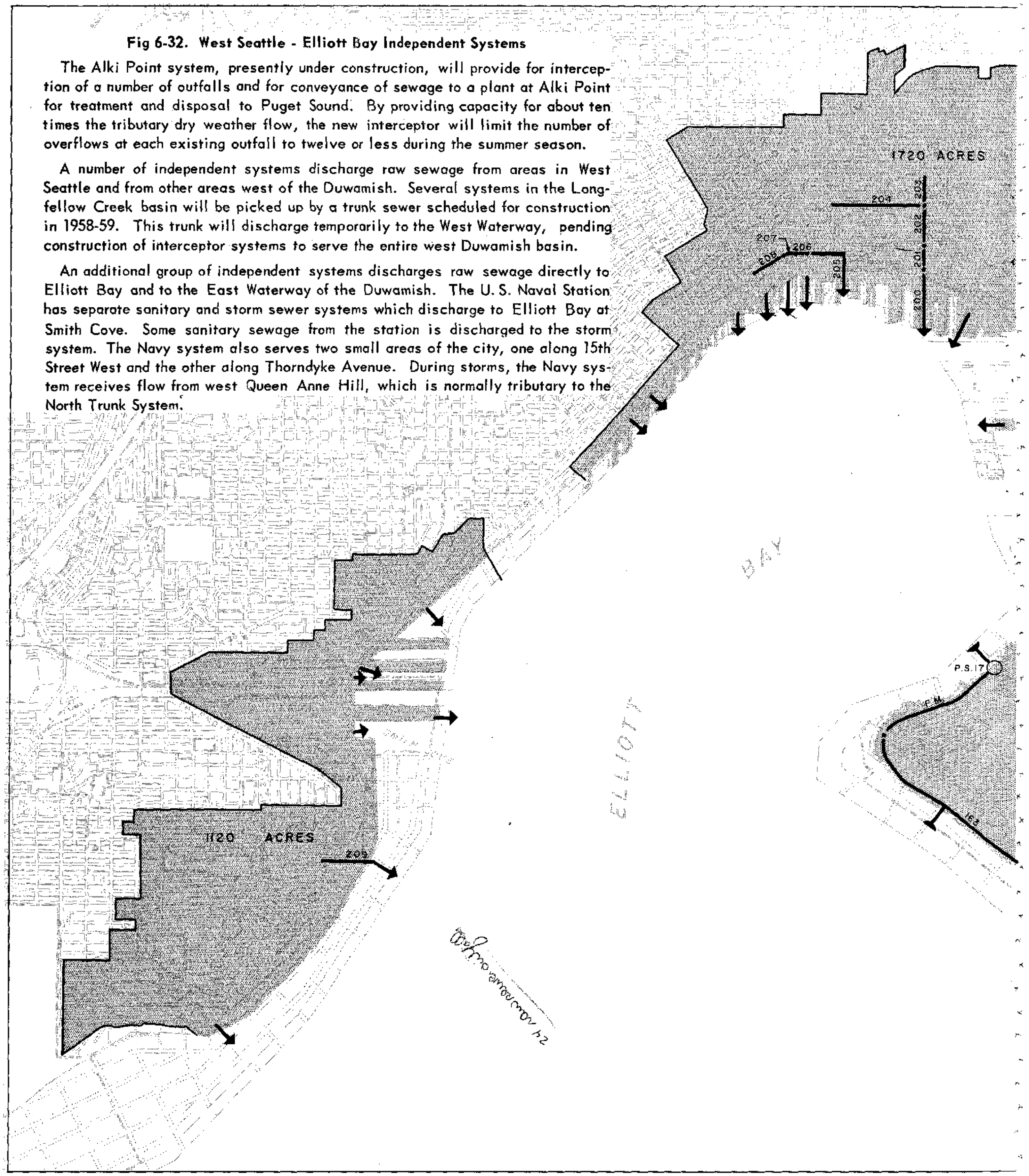
Fig. 6-31. Henderson - East Marginal Way System

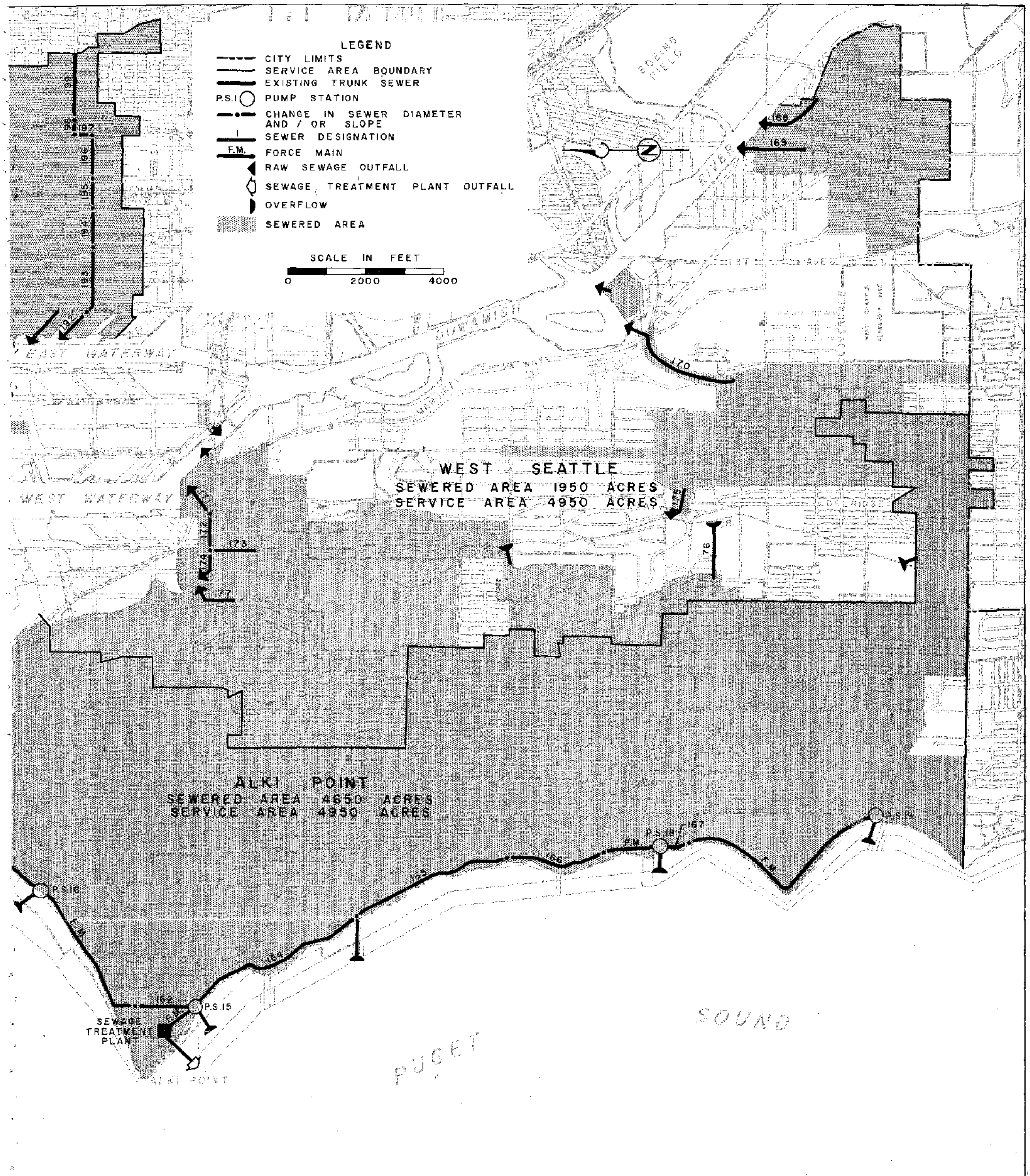
Fig 6-32. West Seattle - Elliott Bay Independent Systems

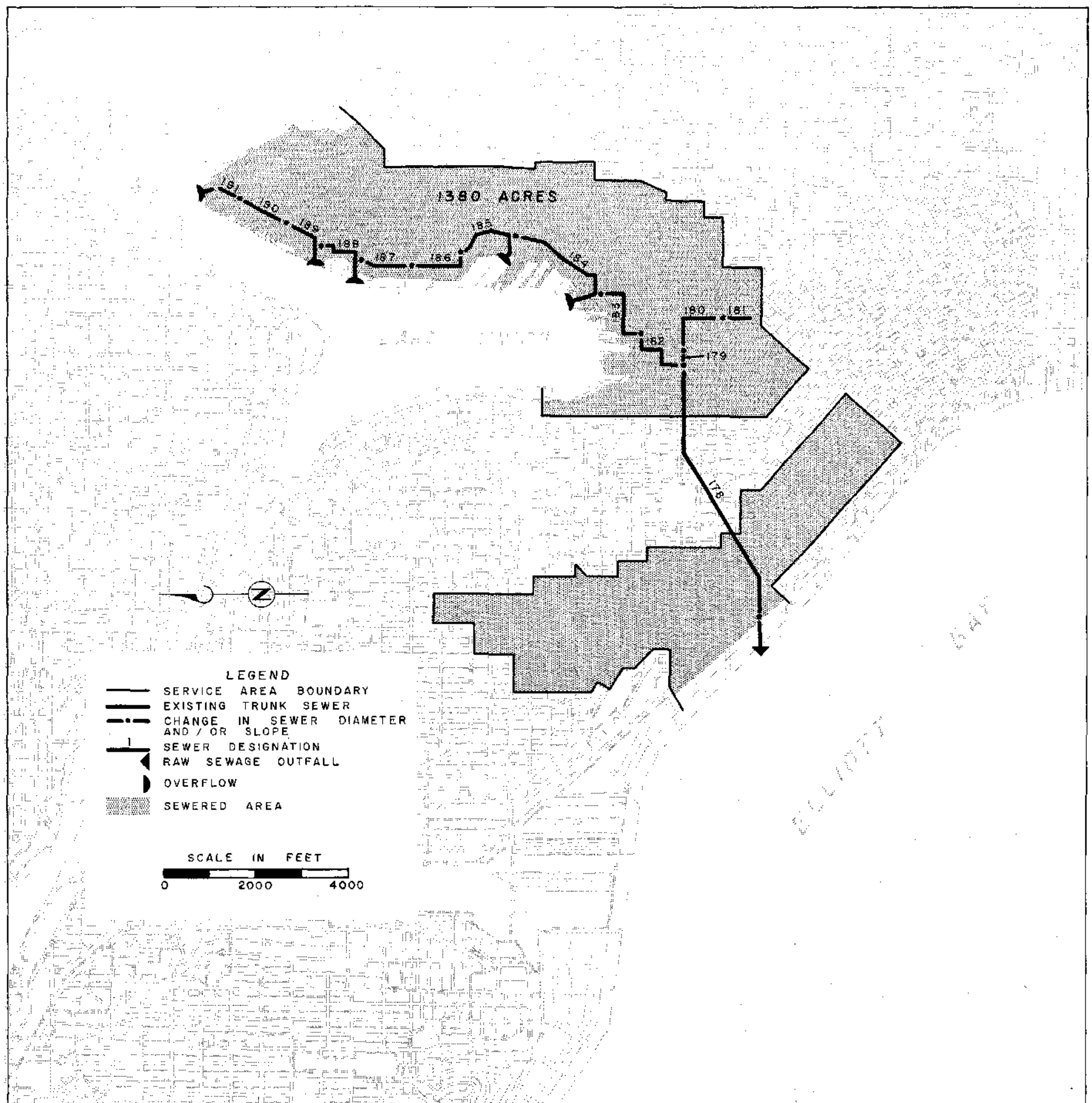
The Alki Point system, presently under construction, will provide for interception of a number of outfalls and for conveyance of sewage to a plant at Alki Point for treatment and disposal to Puget Sound. By providing capacity for about ten times the tributary dry weather flow, the new interceptor will limit the number of overflows at each existing outfall to twelve or less during the summer season.

A number of independent systems discharge raw sewage from areas in West Seattle and from other areas west of the Duwamish. Several systems in the Longfellow Creek basin will be picked up by a trunk sewer scheduled for construction in 1958-59. This trunk will discharge temporarily to the West Waterway, pending construction of interceptor systems to serve the entire west Duwamish basin.

An additional group of independent systems discharges raw sewage directly to Elliott Bay and to the East Waterway of the Duwamish. The U. S. Naval Station has separate sanitary and storm sewer systems which discharge to Elliott Bay at Smith Cove. Some sanitary sewage from the station is discharged to the storm system. The Navy system also serves two small areas of the city, one along 15th Street West and the other along Thorndyke Avenue. During storms, the Navy system receives flow from west Queen Anne Hill, which is normally tributary to the North Trunk System.



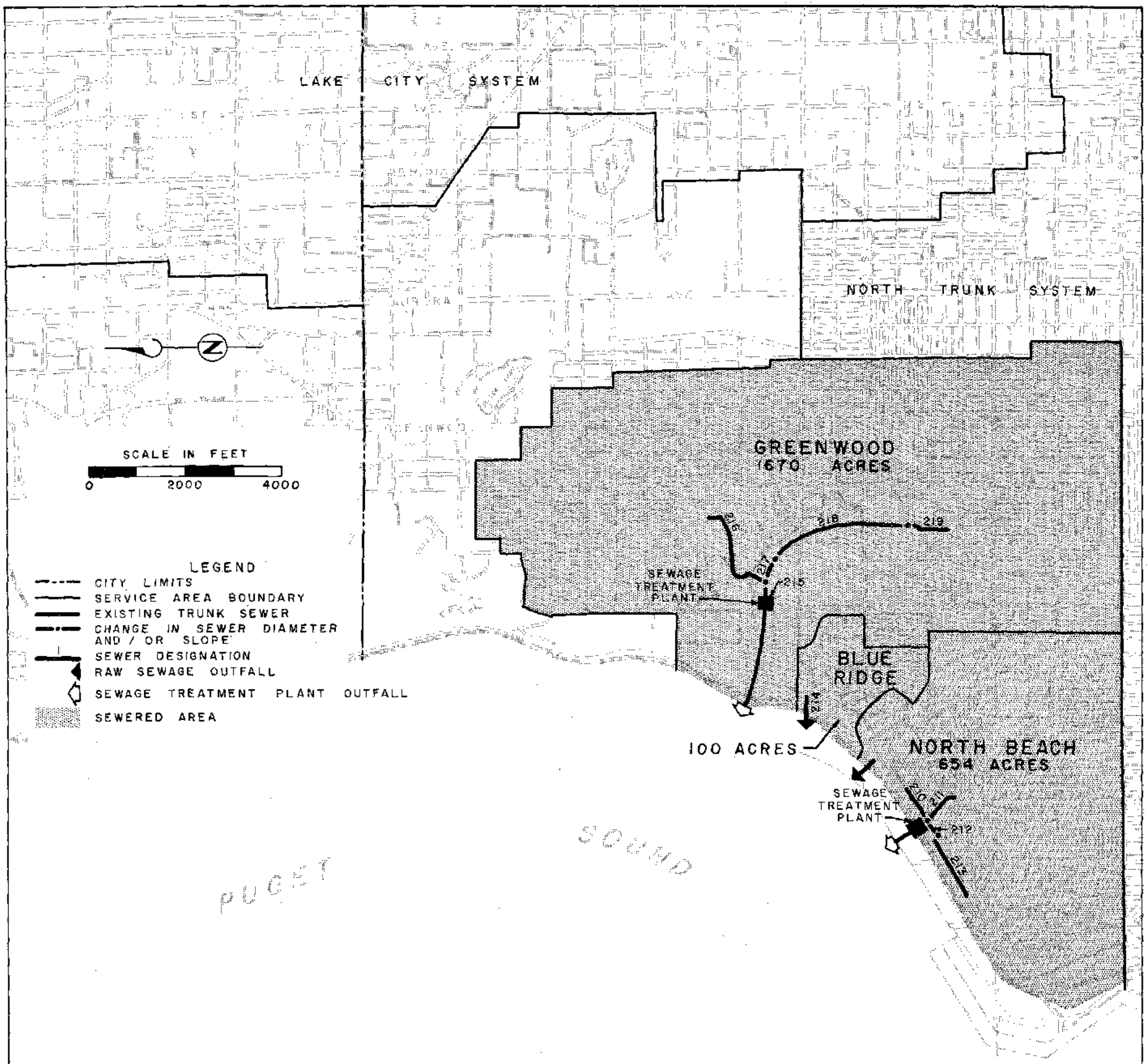

LEGEND
CITY LIMITS
SERVICE AREA BOUNDARY
EXISTING TRUNK SEWER
P.S.1 PUMP STATION
CHANGE IN SEWER DIAMETER AND / OR SLOPE
SEWER DESIGNATION
F.M. FORCE MAIN
RAW SEWAGE OUTFALL
SEWAGE TREATMENT PLANT OUTFALL
OVERFLOW
SEWERED AREA
SCALE IN FEET
0 2000 4000
WEST SEATTLE
SEWERED AREA 1950 ACRES
SERVICE AREA 4950 ACRES
ALKI POINT
SEWERED AREA 4650 ACRES
SERVICE AREA 4950 ACRES
EAST WATERWAY
WEST WATERWAY
DUWAMISH
RIVER
BOEING FIELD
SEWAGE TREATMENT PLANT
P.S.15
P.S.16
P.S.18
PUGET
SOUND



This system was constructed in 1895 to eliminate raw sewage discharges into Lake Union and was the first major sewer project in Seattle. Initially, it served south Queen Anne Hill, Capitol Hill and a large part of the downtown area, but it soon became grossly overloaded and relief was provided by construction of the central section of the North Trunk sewer (Fig. 6-29). At present, the primary function of the Lake Union tunnel system is to divert sewage from the low areas around the lake and from a small downtown section and to convey it to Elliott Bay through the tunnel (No. 178). This system also serves an area lying along the west slope of the divide between Lake Union and Elliott Bay. In the downtown area, there are interconnections with the central section of the North Trunk system (Fig. 6-29).

Frequent backups of sewage are reported to occur at the south end of Lake Union and in the vicinity of the east end of the tunnel.

Fig. 6-33. Lake Union Tunnel System



Developed originally as separate sewer districts, these systems were taken over by Seattle in 1954. All three systems have separate sanitary sewers.

Since their bonds had already been redeemed, the North Beach and Blue Ridge districts were dissolved following annexation to Seattle. The Greenwood Avenue Sewer District continues to operate, but only for the purpose of retiring its bonded indebtedness. District officials estimate this will be accomplished about 1965.

Sewage from the North Beach area is given primary treatment, whereas the Greenwood plant provides only for grease and scum removal. Raw sewage from the Blue Ridge District formerly was discharged through three outfalls. Two of these have been intercepted and the tributary flow, except for that from about 10 homes in low areas, is now conveyed to the North Beach treatment plant. The northeasterly portion of the original district is presently served by the Greenwood Avenue system. These changes have reduced the size of the original Blue Ridge District to about 100 acres, from which sewage is still discharged to Puget Sound without treatment (No. 214).

Each of the three systems is subject to considerable ground water infiltration and to direct inflow from roof drains.

Fig. 6-34. Greenwood Avenue, North Beach and Blue Ridge Systems

The Lake City Sewer District was formed in 1946 to provide sewerage service for a large area northeast of Seattle. In 1954, most of the district area was annexed to Seattle. Since then, the city has operated the sewer system, including the portion outside the present city boundary.

Sewage is conveyed to the treatment plant by two principal gravity trunks, which are intended ultimately to serve the entire Thornton Creek basin, and by an intercepting sewer and a series of pumping stations along the lake front. Treatment plant effluent is conveyed to Lake Washington through a tunnel.

Although the Lake City system is designed for sanitary sewage only, excessive infiltration of ground water has resulted in flows which, even during dry weather, consistently exceed the treatment plant design capacity of 2.5 mgd. Peak rates up to 5 times the average dry weather flow are experienced during storms. Plant enlargements now under construction will provide a design capacity of 10.5 mgd and a hydraulic, or peak rate of flow, capacity of 25 mgd.

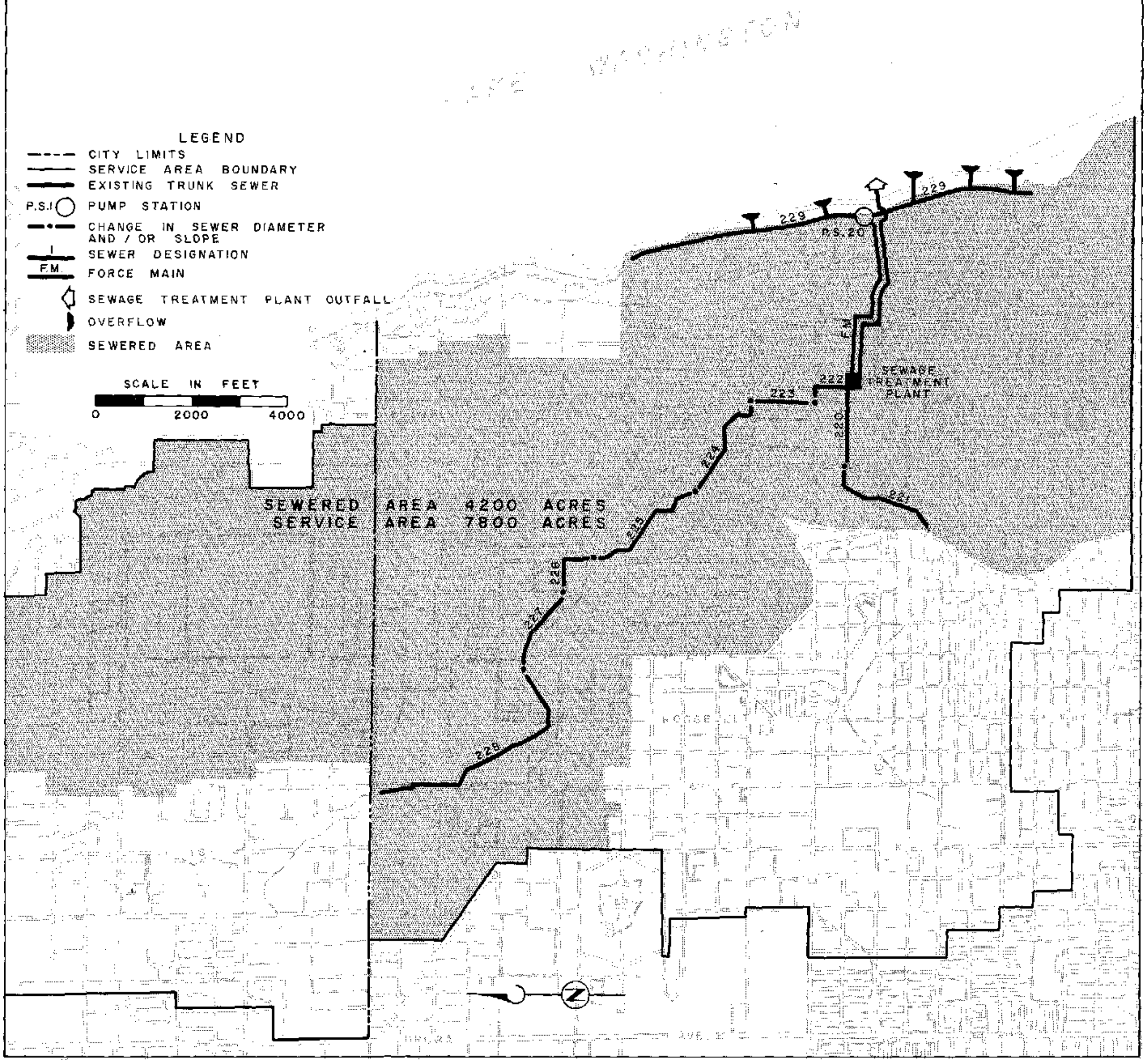


Fig. 6-35. Lake City System

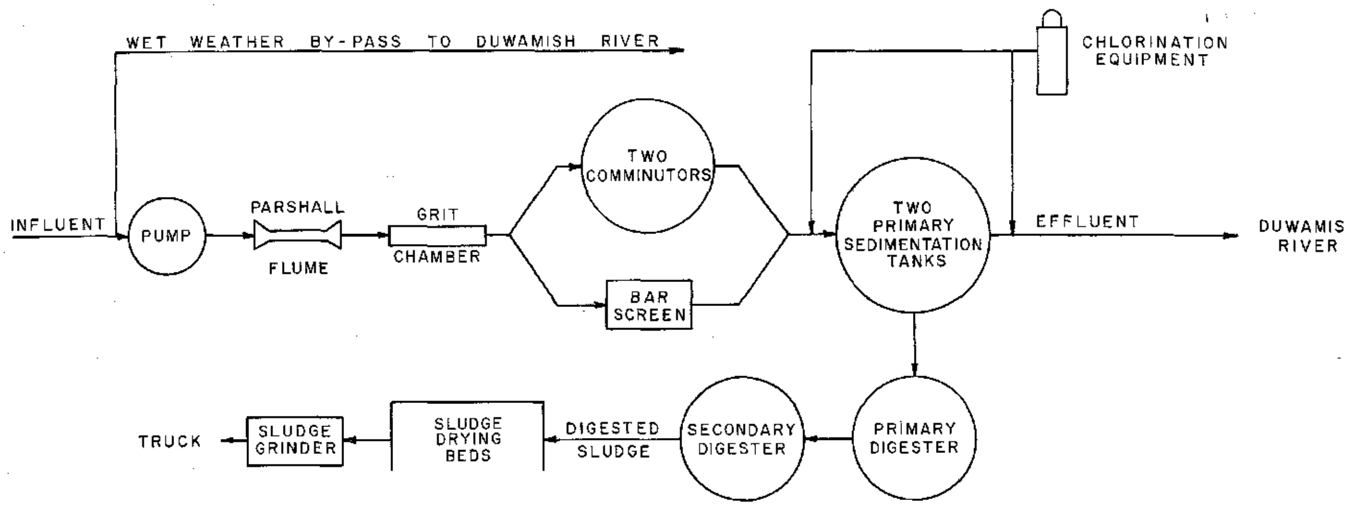


Fig. 6-36. Flow Diagram - Diagonal Avenue Sewage Treatment Plant

The Diagonal Avenue plant provides primary treatment for combined sewage collected by the Henderson - East Marginal Way system of the city of Seattle. The two circular clarifiers have combined capacity for an average flow of 8 mgd. Flow into the plant is limited to the plant capacity by an upstream regulating station which bypasses the excess to Duwamish River during storms. The sludge beds are glass covered in "greenhouse" fashion and dried digested sludge is pulverized and utilized as a soil conditioner at city parks.

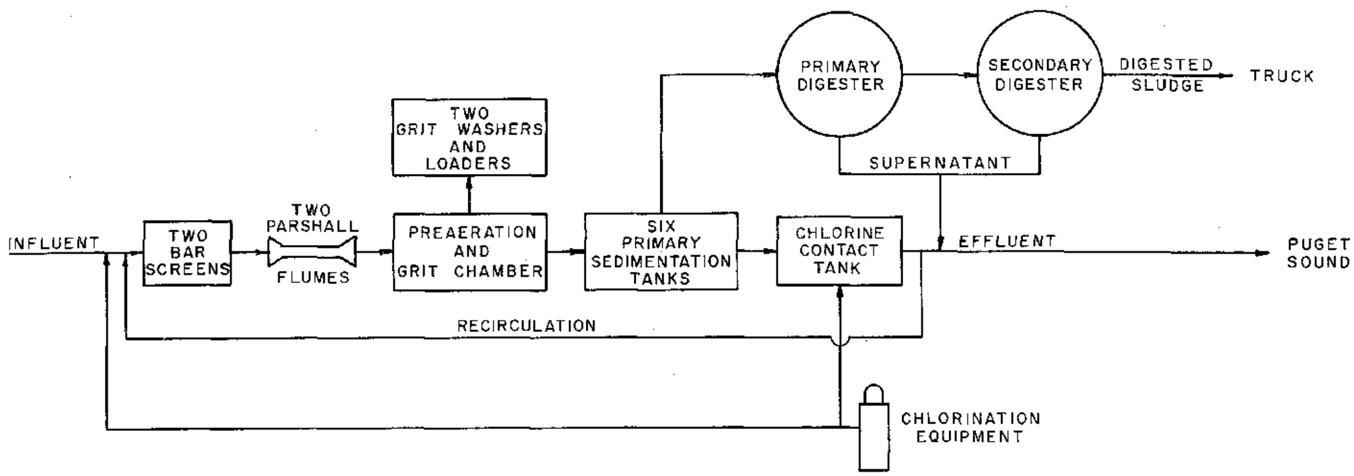


Fig. 6-37. Flow Diagram - Alki Point Sewage Treatment Plant

Presently being constructed, the Alki Point plant will provide primary treatment for West Seattle sewage. The sedimentation tanks are designed to provide 30 minutes detention for storm flows of 60 mgd. During dry weather, the average daily flow is expected to be only 7.5 mgd, and recirculation will be utilized to maintain a detention period of about 5 hours. Because the plant is situated in a residential area, all plant units will be completely housed.

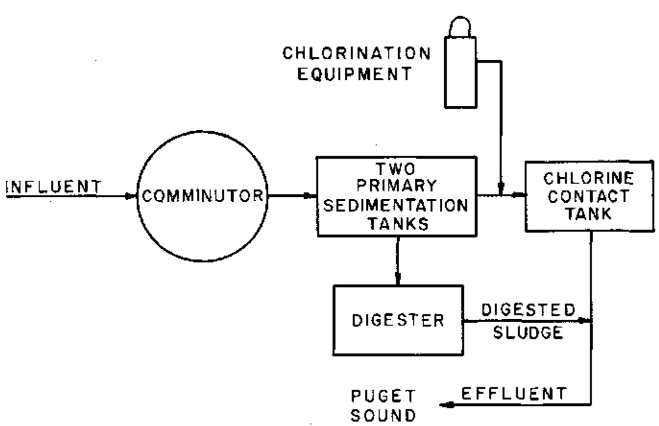


Fig. 6-38. Flow Diagram - North Beach Sewage Treatment Plant

This primary treatment facility is located in a highly developed residential area and for this reason was constructed below the ground surface. A reinforced concrete roof supports a landscaped ground cover. The plant has primary sedimentation capacity for an average daily flow of 0.43 mgd. Digested sludge is discharged to the plant outfall which terminates in 40 feet of water, 1,000 feet offshore.

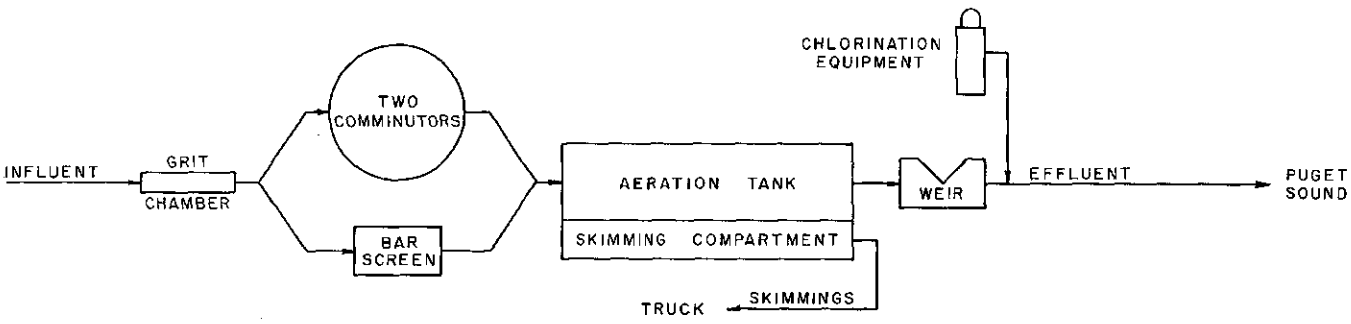


Fig. 6-39. Flow Diagram - Greenwood Avenue Sewage Treatment Plant

Situated in Carkeek Park near the mouth of Piper Creek, this plant serves to remove scum and floatable substances from sewage generated in the Greenwood Avenue Sewer District. The plant was constructed by the district prior to annexation of the area to the city of Seattle in 1954 and, since that time, it has been operated by city forces. Chlorination of the essentially raw sewage effluent does not reduce bacterial densities sufficiently to maintain satisfactory conditions in the public bathing area which extends both north and south of the outfall.

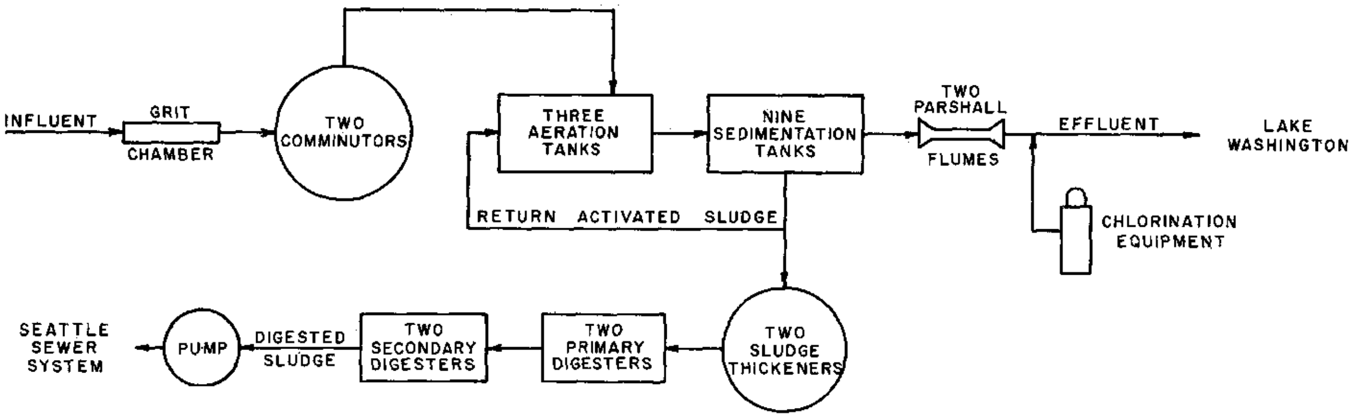


Fig. 6-40. Flow Diagram - Lake City Sewage Treatment Plant

The Lake City sewage treatment plant was constructed by the sewer district prior to annexation of Lake City to Seattle in 1954. City forces have operated the plant since that time. Originally designed for an average daily flow of 2.5 mgd, it soon became grossly overloaded and its capacity is now being increased to 10.0 mgd, which will make it the largest plant in the metropolitan area. As part of this expansion, the standard activated sludge treatment process now being utilized is being modified as shown above.

Chapter 7
SEWAGE CHARACTERISTICS

As a prerequisite to the planning and design of sewerage works, it is necessary to determine the characteristics of the sewage, namely, its volume, its strength, and its composition. Characteristics with respect to volume comprise hourly, daily, and seasonal variations in flow, and are important in that they determine the capacities of collection sewers, pumping stations, treatment units and outfalls. Characteristics with respect to strength and composition, primarily as measured by the suspended solids and biochemical oxygen demand (BOD) determinations, are important in that they exert a controlling influence on the degree of treatment which must be provided in order to produce an effluent of acceptable quality. In other words, a study of the sewage characteristics of a particular community or metropolitan area enables development of the unit quantity and unit load factors which are required for design purposes.

NATURE AND SCOPE OF SEWAGE STUDIES

Field studies undertaken during the present survey included the collection of data pertaining to (1) sewage volume, strength and composition; (2) the location and extent of storm water infiltration; and (3) the type, volume and effect of industrial wastes. Infiltration was studied in detail, with particular reference to the separate sanitary sewers at Lake City where this problem has been a matter of considerable concern. In the course of the field work, all available water supply and sewage treatment plant reports and records were reviewed, and information concerning sewage

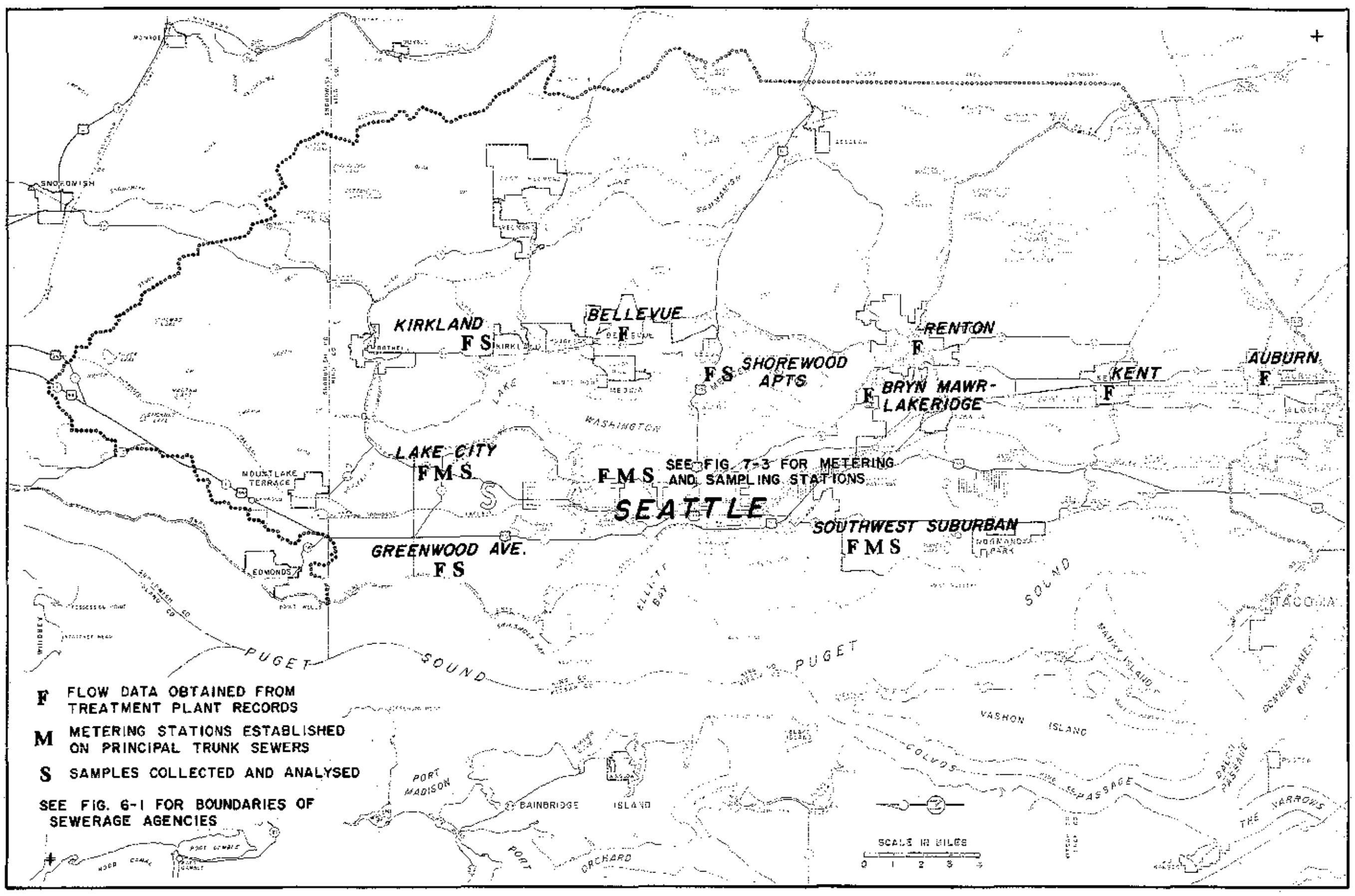
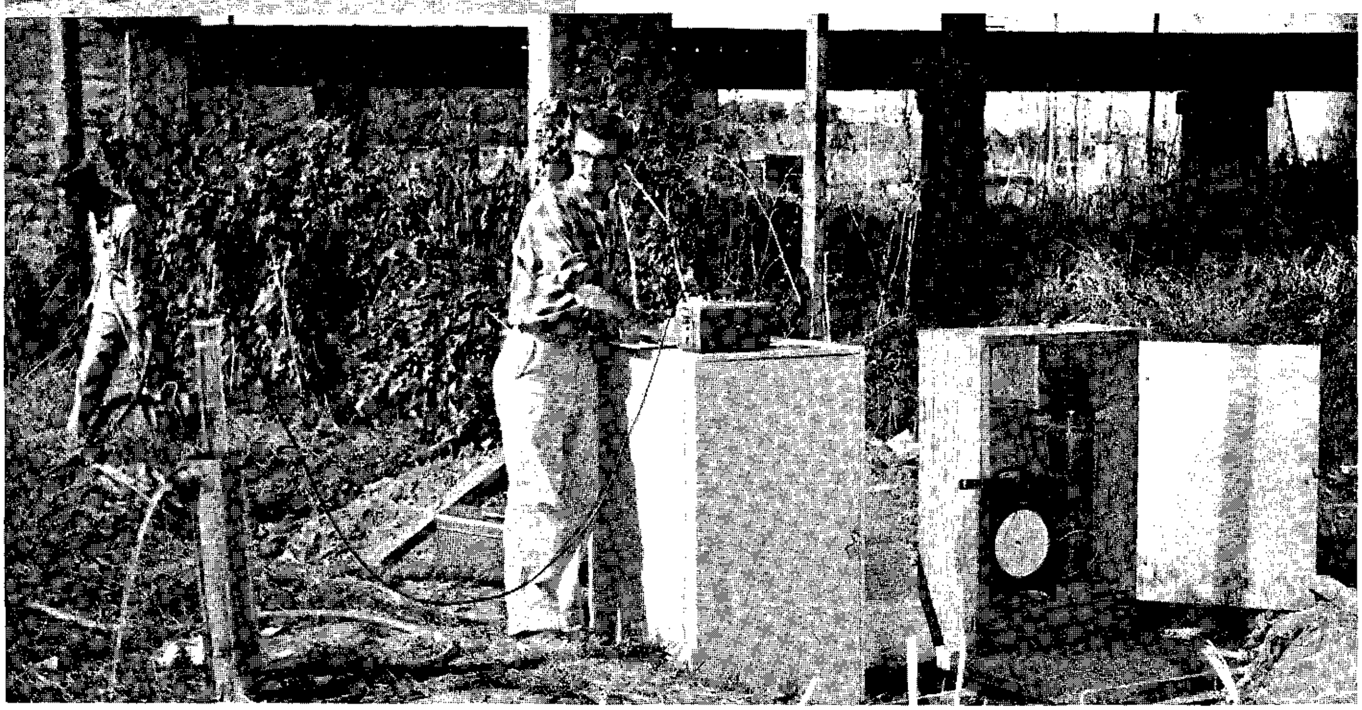


Fig. 7-1. Sources of Data on Sewage Characteristics

Records for existing sewage treatment plants and from metering stations established during the survey provided information on sewage flow rates. Raw sewage samples from a number of the treatment plants and metering stations were collected and analyzed to determine sewage strength and composition.

TOTAL COUNT METHOD, as used for calibration of the metering station on the North Trunk sewer, begins (left photograph) with the pouring of a small quantity of isotope into an upstream manhole. During this operation, the radioactivity level is monitored by means of an ionization rate meter. At the metering manhole downstream (lower photograph) a small quantity of sewage is pumped through a cylinder in which the Geiger-Mueller tubes are suspended. The total number of counts is recorded on a portable scaler shown on top of cabinet in center. On the right is the depth recorder and nitrogen gas cylinder, and in the center is the cabinet housing the vacuum type sewage sampler. See Appendix B for detailed description of total count method.

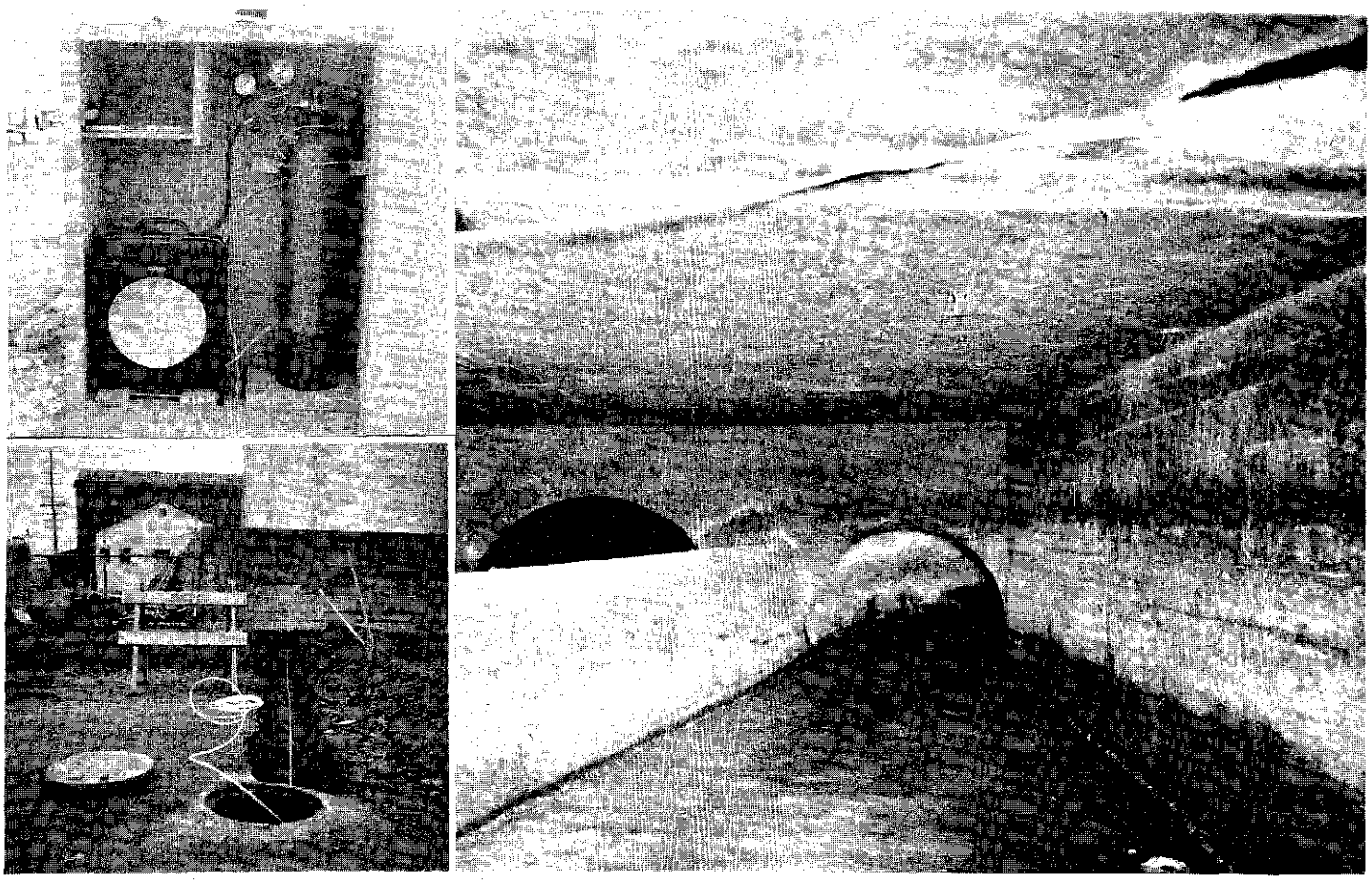


characteristics was developed by flow measurement and by the collection and analysis of representative samples.

Sewage Volume

Volumetrically, sewage can be considered to have two components. Of these, the first consists of sanitary sewage and industrial wastes, while the second consists of underground and surface water which enters sewers through joints and other openings. Depending upon the means and time of access, the latter component is termed either infiltration or storm inflow.

Since storm water inflow is limited generally to



METERING OF SEWAGE FLOW involved installation of a gas bubbler and sensitive pressure recorder to determine the depth of flow. Calibration curves relating depth to rate of flow were developed either by dilution of a radioactive isotope (the total count method herein described) or by calculations based on the physical and hydraulic characteristics of the pipe. On the Ballard trunk, the metering station was in a 116-inch wide by 69-inch high concrete box section with a side overflow weir (right photograph). At this station, the nitrogen gas cylinder and recorder were located off the edge of the roadway (left photographs). Flexible polyethylene tubing, protected by conduit in the roadway, was used between the cylinder and the invert of the sewer.

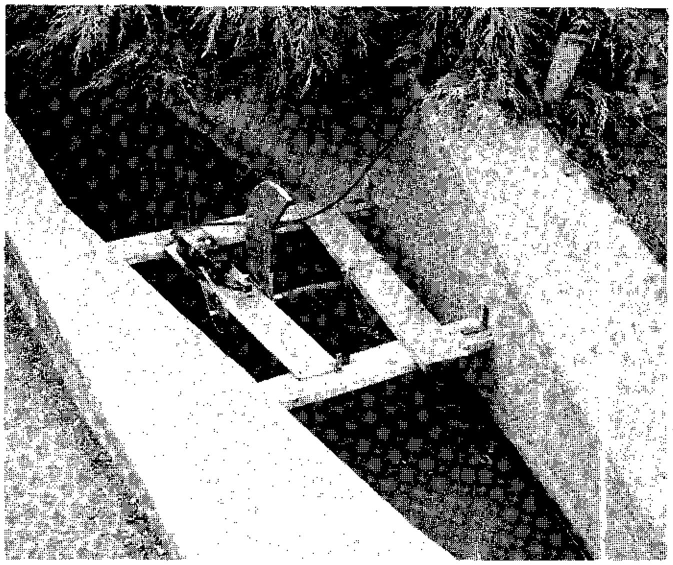
periods of actual rainfall, it is desirable to consider sewage volume in terms of both dry weather and wet weather flow. Dry weather flow (DWF) consists of sanitary sewage, industrial waste contributions, and infiltration from ground water. Wet weather flow (WWF) consists of the same components supplemented by storm water inflow. Dry weather flow determines, for the most part, the normal loading imposed on the major units of a sewage treatment plant, whereas wet weather flow determines the hydraulic capacity required not only for treatment purposes but for collection and conveyance.

Ground water infiltration varies seasonally with ground water level. This condition is significant in that it has a direct bearing on dry weather flows, both winter and summer. For example, if the ground water level is relatively high during the winter or wet season, the dry weather flow, meaning the flow at times when no rain has fallen, is correspondingly high and affects design requirements accordingly.

In the case of systems with separate sewers, records of flow measurements were available at sewage treatment plants serving those systems. In the case of combined sewers, only limited information was obtainable and came from records of flow measurements at the Diagonal Avenue treatment plant.

Of an estimated 75 mgd of sewage generated within the metropolitan area, only 15 mgd is metered regularly at the 25 sewage treatment plants. Additional flow data for the combined systems of Seattle, plus information on upstream infiltration and storm inflow to separate systems, were obtained by establishing metering points at seven locations and by recording the time of pump operation at two pumping stations (Fig. 7-1). In addition, minimum flow rates were estimated at 50 locations by gaging the depth of flow. Insofar as practicable, each of the seven metering points was selected so as to measure flows from the largest tributary area which could be obtained without including any upstream overflow or bypass structure.

Because of the high velocities which prevail in combined trunks during storm conditions, and also because of the wide range of flows, it generally was not practicable to construct a weir or flume within the



DIPPER TYPE SAMPLER was utilized at sampling locations where variation in depth of flow was relatively small. Type of weir or of other control sections immediately downstream determines shape of dipper required to collect quantity of sample proportional to rate of flow. Installation above is in the upstream converging section of the parshall flume at the city of Kirkland sewage treatment plant. Short length of hose discharges sample, which is collected as dipper revolves, to container suspended under board at right.

sewer selected as a measuring point. As a consequence, the sewer itself was utilized as a metering section at all but two of the seven locations. Straight sections having a constant grade were selected and were calibrated over a range of flows by means of the recently developed "total count" method. In this method a small, measured quantity of radioactive isotope is added upstream and the total count of gamma rays emitted by this material in passing the metering point is utilized in determining the rate of flow. A more detailed description of the isotope technique, together with individual calibration curves, is given in Appendix B.

At all metering stations, the depth of flow was measured continuously by means of a gas bubbler and sensitive pressure recorder. In each case, the bubbler tubing was carried in a conduit from the recorder to the invert of the sewer. A cylinder of compressed nitrogen provided the gas supply necessary to operate the bubbler.

Sewage flows, both total daily and instantaneous, are expressed as million gallons per day (mgd). Unit quantities for design purposes are expressed as gallons per capita per day (gpcd) in the case of sanitary sewage, and as gallons per acre per day (gpad) in the case of infiltration, storm inflow and industrial waste.

During those periods when lawn and garden irrigation is at a minimum, water consumption and sanitary sewage flows are approximately equal, and sewage flow in excess of water consumption is a measure of infiltration or storm inflow. Hence, metered records of water consumption serve as a check on sanitary sewage flows and on the variations therein which take place both seasonally and on a long term basis.

Sewage Strength and Composition

Because of the scarcity locally of adequate data on sewage strength and composition, it was necessary to undertake an extensive program of sampling and analysis. As a part of that program, raw sewage was sampled for periods ranging from four to eight days at each of five sewage treatment plants and at two trunk sewer metering stations (Fig. 7-1). Composite samples obtained each day were refrigerated during collection and were analyzed immediately thereafter at the sanitary engineering laboratory of the University of Washington. Laboratory analyses included determinations of hydrogen ion concentration; BOD before and after settling; and of total, suspended, settleable, and volatile solids. Sewage temperatures, and in some cases dissolved oxygen content, were determined in the field. In addition, the relative freshness of the sewage was observed and information was obtained concerning the quantity of grit carried in combined sewers.

In conducting the sampling program, one of the problems was that of collecting composite samples which would be properly representative of the varying conditions which occur in the course of a 24-hour period. An example of the manner in which variations take place in 24 hours is shown in Fig. 7-2. The two curves in this figure are based on flow meas-

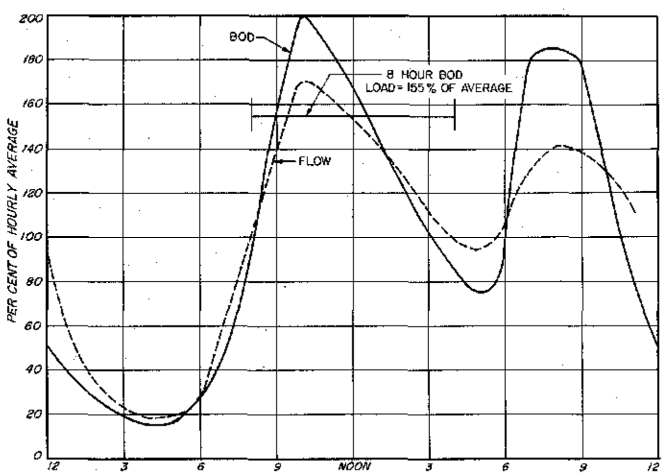
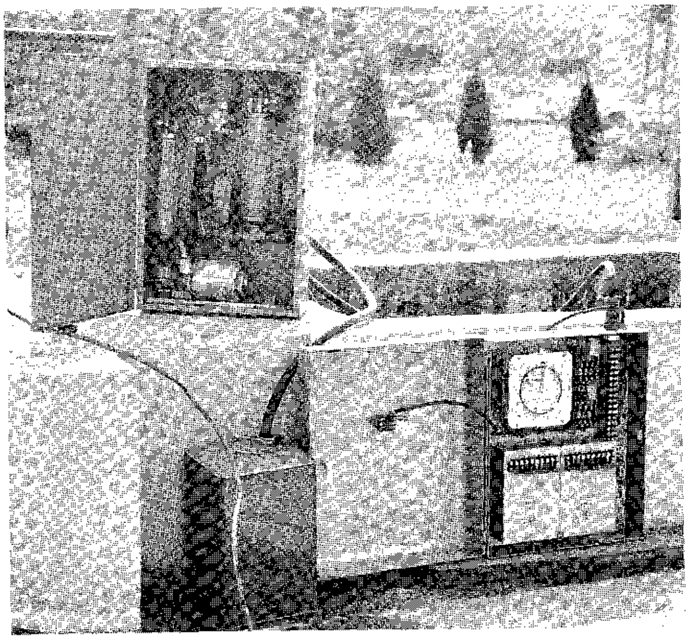
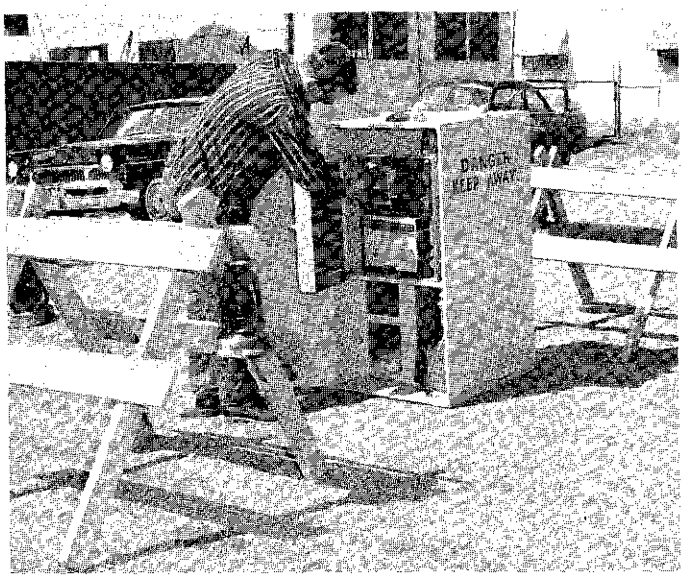
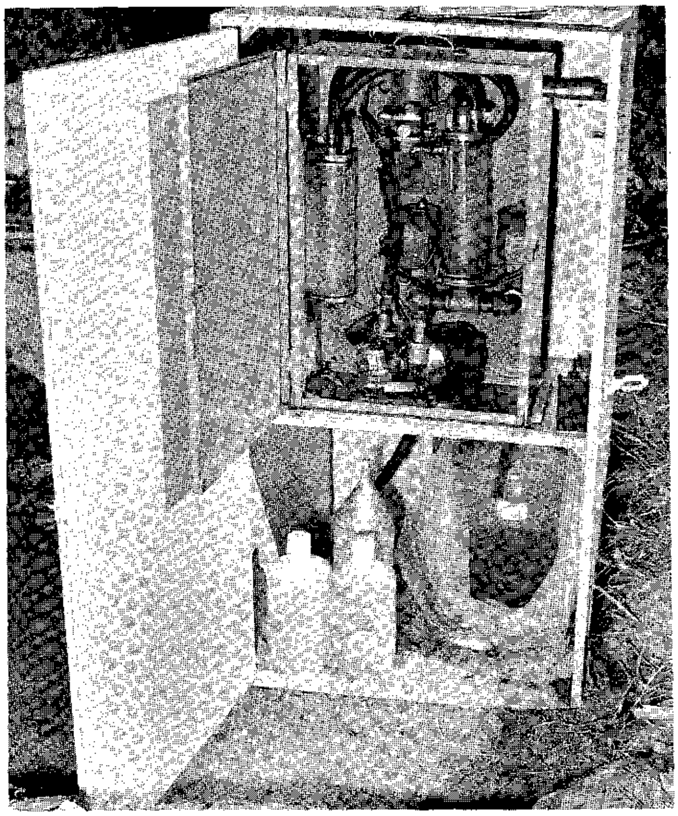


Fig. 7-2. Typical Hourly Variation in Flow and BOD at Greenwood Sewage Treatment Plant

Variations are typical of conditions in separate sanitary sewerage systems serving residential areas. Both the rate of flow and the strength of sewage drop to a minimum during the early morning hours, at which time ground water infiltration is predominant. Based on analyses by Engineering Testing Laboratory of city of Seattle. Samples collected August 12, 1954.







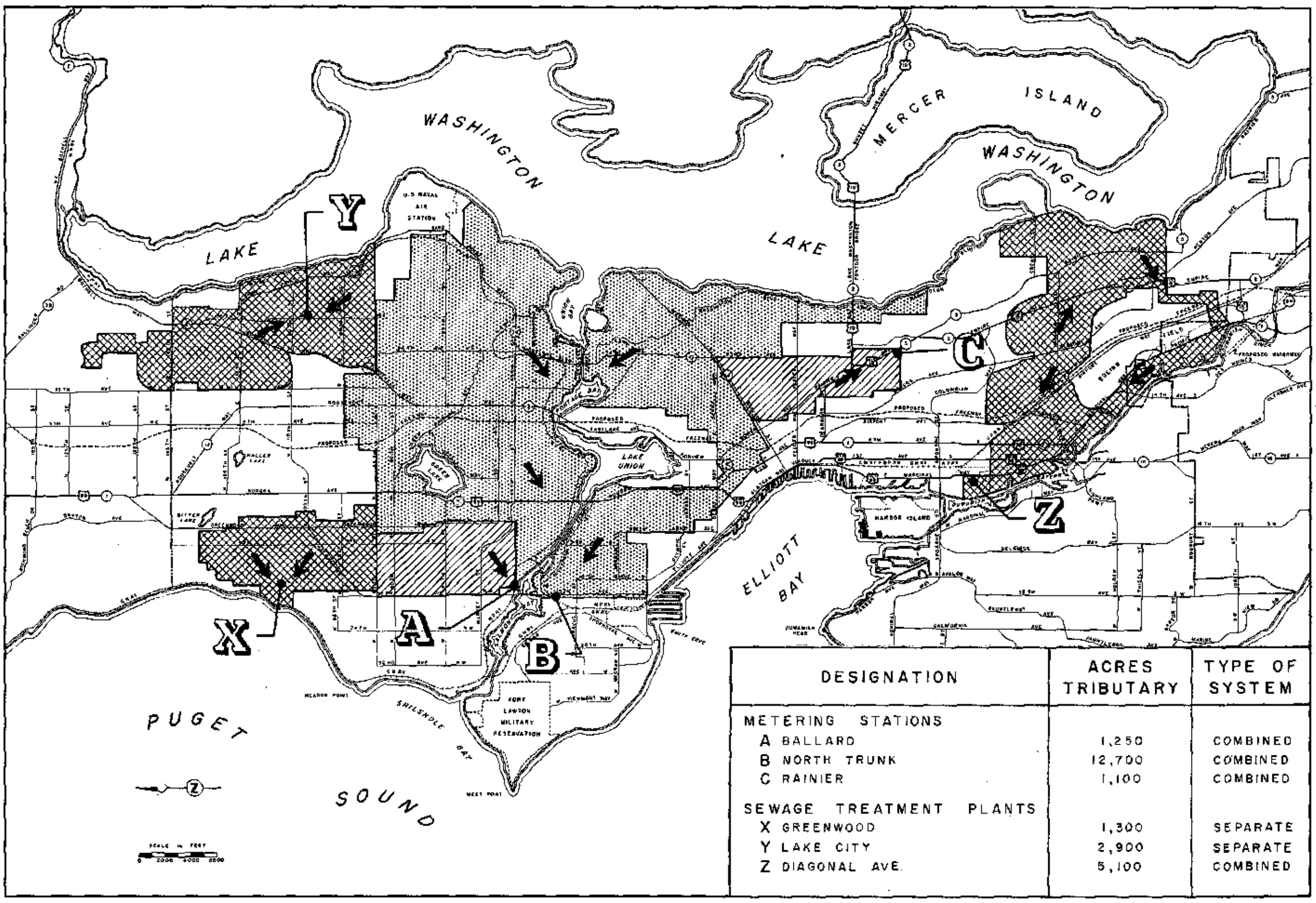
VACUUM PUMP SEWAGE SAMPLER. In above view vacuum pump is seen at the bottom of the metal case under the moisture trap at the left and the sample receiver at the right. In operation, the timer actuates the pump, which in turn draws sewage upward through a vacuum hose extending into the flow being sampled. Short probe control in receiver operates solenoid valves (1) to close line from sewer, (2) to close vacuum line from pump and open to exhaust, and (3) to open drain line to sample storage container. Sewage then drains to container until level falls below the longer probe. At that time, valve on line to container closes and valve on line to sewer opens and allows remainder of sewage in receiver to flow back to the sewer. Sample container in lower right of cabinet is 5-gallon bottle enclosed in plastic bag to eliminate condensation of atmospheric moisture and is refrigerated with dry ice.

urements and analyses of grab samples collected at the Greenwood sewage treatment plant and are typical of dry weather conditions in a small residential area served by separate sanitary sewers. Variations indicated by the curves are naturally more extreme than those which take place in the large trunk lines of the city of Seattle.

Composite samples were collected by means of automatic sampling devices, the function of which is to remove small portions of the flowing sewage at constant intervals ranging from five to twenty minutes. Two types of samplers were used during the survey, one equipped with an automatic dipper and the other with a vacuum pump, and both were operated in conjunction with appropriate devices for flow metering and recording.

Automatic samplers of the dipper type were used only at sewage treatment plants and were installed ahead of metering flumes or weirs in the inlet channels. This sampler is so designed that each dip removes an amount which is directly proportional to the actual flow.

At the metering stations in combined sewers, the dipper machine could not be used because variations in the depth of flow between dry and wet weather quite possibly would exceed the operating range of the dipper. For that reason, a new type of sampler was designed and built which can be mounted over or adjacent to a manhole. Actuated by a timer, this sampler is equipped with a vacuum pump which withdraws a measured portion of sewage at regular intervals through a 1-inch hose and discharges it to a sample bottle. To obtain a reasonably composite sample, the amount collected over periods ranging from eight



DESIGNATION	ACRES TRIBUTARY	TYPE OF SYSTEM
METERING STATIONS		
A BALLARD	1,250	COMBINED
B NORTH TRUNK	12,700	COMBINED
C RAINIER	1,100	COMBINED
SEWAGE TREATMENT PLANTS		
X GREENWOOD	1,300	SEPARATE
Y LAKE CITY	2,900	SEPARATE
Z DIAGONAL AVE.	5,100	COMBINED

Fig. 7-3. Area Tributary to Metering Stations and Major Treatment Plants in Seattle

All metering stations established on Seattle's combined sewers, with the exception of that on the North Trunk, were so located that no overflows occurred upstream from the metering point. Flow in the North Trunk was metered during the late summer months of 1957 when rainfall and overflows were relatively infrequent.

to twelve hours is proportioned manually to the total flow recorded during each such period. While less precise than the dipper machine, the new machine nevertheless enabled the collection of sufficiently representative samples at each of the trunk sewer metering stations.

Measurements of sewage strength and composition are expressed herein in terms both of concentration and of total loading. Concentration is reported as parts per million by weight (ppm), whereas total loading is reported as pounds per day. Unit quantities are expressed as pounds per capita per day (ppcd).

Infiltration

Infiltration and storm inflow require separate consideration because they are the cause of what has become a serious problem to many sewerage systems in the metropolitan area. For example, the Lake City system, which is typical of almost all of them, is subject continuously during winter months to a high rate of infiltration and to a five-fold increase in inflow at the sewage treatment plant during periods of moderate to heavy rainfall.

Industrial Waste

The volume, strength and composition of industrial wastes are not related either to the resident population or to the areal extent of a sewerage service area. They are determined instead by the number, type and magnitude of industrial operations. Insofar as volume is concerned, it is possible for design purposes to use a reasonable allowance per gross acre which is based on experience elsewhere and on local records of water consumption. Strength and composition, on the other hand, are of lesser importance in long range planning and can be reckoned with either by regulating ordinances or by the incremental addition of treatment facilities.

SEWAGE VOLUME AND COMPOSITION

As stated earlier, information regarding sewage characteristics was obtained by flow measurements

Table 7-1. Metering Stations on Combined Sewers in Seattle

Station designation	Location[a]	Sewer size, diameter, inches	Tributary area, acres	Population[b]	Type of area
North Trunk	Thorndyke and Emerson	138	12,700	195,000	Residential, commercial and heavy industrial
Rainier	Rainier and Bayview	102	1,100	22,000	Multiple dwelling and light industrial
Ballard	11 NW and W 45	69 x 116 box	1,250	24,500	Residential, commercial with few industries
Total metered			15,050	241,500	

[a]*See Fig. 7-3.*

[b]*Seattle City Planning Commission estimate, 1955.*

and laboratory analyses and by reviewing operation records and reports. Necessary data were developed both for representative locations in the Seattle system and for other systems requiring separate appraisal.

City of Seattle

Operating records of the Lake City, Greenwood, and Diagonal Avenue sewage treatment plants provided needed information concerning flow conditions in both separate and combined sewer systems. Routine analyses of influent samples, while providing valuable background information, were not considered to be sufficiently representative for the purposes of the survey. This is because single grab samples rather than composite samples were used in making the analyses.

Sewage from the remainder of Seattle, which in dry weather comprises about 90 per cent of all that originating in the metropolitan area, is discharged to Puget Sound without treatment. To study conditions in that area and also to develop essential information concerning sewage characteristics, metering and sampling stations were established at three locations in principal trunk sewers (Fig. 7-3 and Table 7-1).

Lake City System. Situated at East 107th Street and 38th Avenue NE, the Lake City sewage treatment plant serves a tributary area of 2,900 acres with approximately 250 miles of separate sanitary sewers, including house connections. Development of this area, as reflected by the number of permits for new house connections, has been taking place at a rapid rate since 1953 (Fig. 7-4). At the end of 1957, approximately 8,000 permits had been issued, representing a connected population of 25,000.

Wet weather flows during the period from January 1 through January 7, 1956 generally exceeded the maximum capacity of the meter and reached an estimated peak of 14 mgd on January 6 (Fig. 7-5). Dry weather flows, as metered from July 16 through July 22, 1956, averaged close to 3.0 mgd, as compared to a treatment plant design capacity of 2.5 mgd. During this period the per capita rate averaged 120 gpd. The latter value is considerably higher than might be expected in a predominantly residential area such as Lake City where winter water use amounts to 53 gpcd.

A serious situation with regard to storm inflow is evidenced by the excessive wet weather flow. Similarly, excessive ground water infiltration is evidenced by the high per capita flow and the minimum flow rate of 2 mgd.

Samples were taken at the plant for eight days in the period from July 17 through July 31, 1957 (Table 7-2). Average flow during this period was 3.0 mgd. As computed from the analysis results, the per capita BOD contribution averaged 0.14 pounds per day and is considered normal for sewage from a residential area. For suspended solids, the per capita value averaged 0.21 pounds per day. This is somewhat higher than normal and may be attributed partially to the high grit and sand content of trench drainage from sewer construction projects.

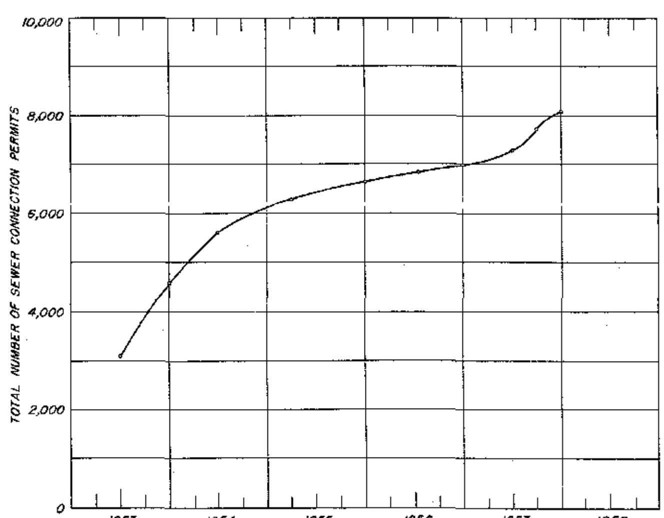


Fig. 7-4. Sewer Connections in Lake City Sewer District

Based on total number of house connection permits issued by the Lake City Sewer District and by Seattle since annexation.

Table 7-2. Sewage Characteristics at Sampling Stations in Seattle

Date	Day	Average flow, mgd	BOD			Solids							
			Raw		Settled[a]	Total		Suspended			Settleable		
			ppm	lb/day	ppm	ppm	Volatile ppm	ppm	lb/day	Volatile ppm	ml/l	ppm	Volatile ppm
Lake City Plant, July 1957													
17	Wed	3.1	128	3,300	79	510	250	258	6,650	162	7.5	162	120
18	Thur	3.1	135	3,480	89	446	222	158	4,070	120	6	92	67
19	Fri	3.1	123	3,180	88	472	354	336	8,650	228	7.5	204	136
24	Wed	3.0	169	4,240	103	446	229	–	–	–	7	–	–
25	Thur	2.9	174	4,200	100	634	372	216	5,220	184	7	172	126
26	Fri	3.1	120	3,100	100	450	278	166	4,300	152	8	136	102
30	Tue	3.0	119	2,980	77	392	206	144	3,600	116	7	76	66
31	Wed	3.0	143	3,580	79	426	250	182	4,550	156	8	116	108
Weighted average				3,500					5,290				
Diagonal Avenue Plant, August 1957													
13	Tue	4.8	151	6,050	60	408	382	186	7,450	156	6.5	140	116
14	Wed	4.7	108	4,220	64	466	–	196	7,660	175	7	62	49
16	Fri	4.8	96	3,840	65	492	–	156	6,250	130	5	94	82
19	Mon	4.5	101	3,780	68	378	–	240	9,000	195	5	170	156
Weighted average				4,470					7,590				
Greenwood Plant[b], July 1954													
8	Thur	1.5	124	1,550	–	–	–	109	1,360	92	–	–	–
9	Fri	1.5	108	1,350	–	–	–	130	1,625	110	–	–	–
14	Wed	1.5	103	1,290	–	–	–	163	2,040	137	–	–	–
15	Thur	1.5	112	1,400	–	–	–	146	1,820	120	–	–	–
16	Fri	1.5	126	1,580	–	–	–	162	2,030	141	–	–	–
19	Mon	1.5	84	1,050	–	–	–	127	1,590	103	–	–	–
20	Tue	1.4	99	1,160	–	–	–	116	1,450	97	–	–	–
21	Wed	1.4	105	1,230	–	–	–	151	1,760	117	–	–	–
Weighted average				1,330					1,710				
North Trunk Sewer, October 1957													
4	Fri	39	100	32,500	63	316	238	106	34,400	104	4	102	102
5	Sat	39	83	27,000	61	224	218	106	34,400	84	3	90	74
7[c]	Mon	48	98	39,200	65	364	234	208	83,000	148	5	148	110
8[c]	Tue	52	85	36,800	65	322	282	116	50,400	100	4	58	40
9	Wed	43	99	35,400	61	344	220	124	44,400	118	4.5	60	60
10	Thur	36	94	28,200	59	316	284	146	43,900	134	5.0	104	92
11	Fri	38	86	27,200	52	292	260	120	38,000	114	4	84	82
Weighted average				32,400					47,000				
Ballard Trunk Sewer, August and September 1957													
22	Thur	1.7[d]	126	1,780	102	390	224	110	1,560	60	5	50	40
23	Fri	1.7	170	2,400	–	376	–	140	1,990	100	5	64	60
26	Mon	1.7	133	1,880	101	466	294	170	2,420	142	5	76	68
28	Wed	1.7	94	1,330	75	312	270	116	1,650	–	5	66	–
29	Thur	1.7	120	1,700	80	506	330	192	2,720	179	7	128	116
30	Fri	1.7	154	2,180	98	378	254	136	1,930	91	6	76	37
3	Tue	1.7	248	3,500	–	524	400	224	3,180	196	8	154	86
4	Wed	1.7	167	2,360	117	406	270	124	1,760	116	7	82	75
Weighted average				2,140					2,150				

All analyses performed on raw sewage samples. See Fig. 7-3 for location of sampling points. Temperature and pH during sampling period: Lake City plant, 15° C, 7.3; Diagonal Avenue plant 19° C, 7.3; Greenwood plant, no temperature, 7.1; North Trunk, 20° C, 7.0; Ballard Trunk, 22° C, 7.3.

[a] *One hour settling period.*

[b] *From analyses performed by Seattle Engineering Department laboratories and converted to 24-hour composite values per Fig. 7-2.*

[c] *Occasional showers on this date.*

[d] *Flow metered on initial day of sampling and similar average assumed for remainder of sampling period.*

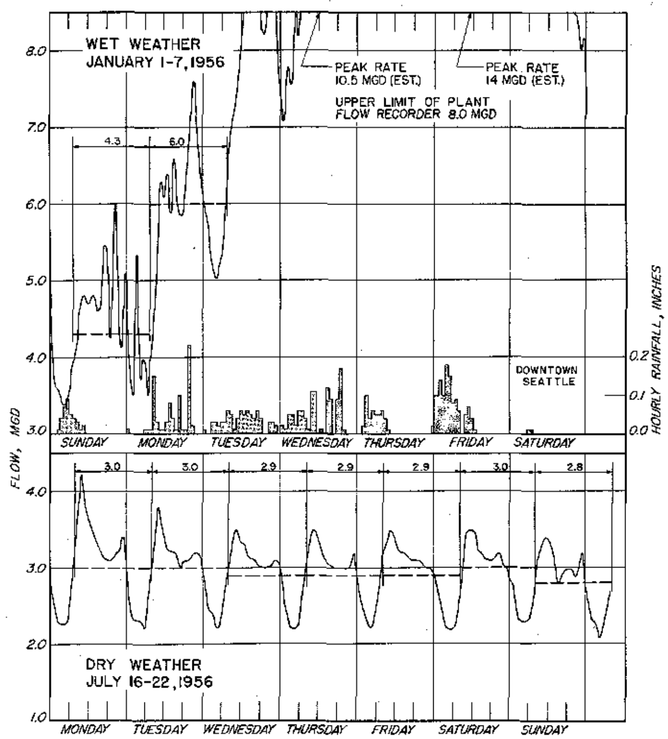


Fig. 7-5. Hourly Variation in Flow at Lake City Sewage Treatment Plant

Estimates by operating personnel provide the only data on flows in excess of 8.0 mgd, the meter chart capacity. It is reasonable to assume that the estimated maximum rate of 14 mgd on January 6, 1956, was exceeded on December 21, 1955 when the treatment plant was flooded. Flows below 8.0 mgd are from plant meter records.

Analyses of 8-hour composite samples, as made by the treatment plant operators during 1955-56, show BOD values ranging from a low of 130 ppm in January to a high of 317 ppm in August. Suspended solids values ranged from 72 ppm in January to 364 ppm in August. Raw sewage temperatures ranged from 35° F in the winter to 61° F in the summer. During the same period, plant effluent temperatures ranged from 40° F in the winter to 63° F in the summer.

Greenwood System. The Greenwood sewage treatment plant is situated at Carkeek Park and serves a tributary area of 1,320 acres. Based on the number of house connections, which at present totals 5,300, the plant serves a connected population of 17,000.

Records of dry and wet weather flow, as obtained from meter readings at the treatment plant, indicate that the Greenwood system is subject to considerable infiltration and storm inflow during wet weather periods (Fig. 7-6). This condition is reflected by an average flow at such times of 3.4 mgd, as compared to a dry weather average of 1.4 mgd. The latter represents a per capita flow of 82 gpd. In contrast, per capita water consumption during the winter averages 62 gpd.

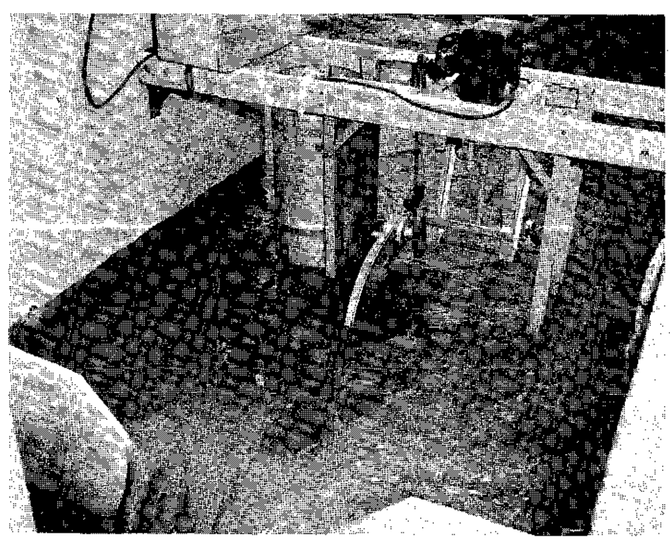
Information regarding BOD and suspended solids loadings was developed from analysis results reported by the engineering department of the city of Seattle[1]. These results, which were for 6-hour composite samples, were adjusted to a 24-hour basis by relating them to the BOD data plotted in Fig. 7-2. As calculated from the 24-hour values (Table 7-2), the per capita contributions are 0.08 pounds per day for BOD and 0.11 pounds per day for suspended solids. The latter is close to normal but the BOD value is low, even for strictly domestic sewage.

Diagonal Avenue System. Situated at Diagonal Avenue and East Marginal Way, the Diagonal Avenue treatment plant is the only one in the metropolitan area which receives sewage from a system of combined sewers. The tributary area, which includes a large industrial district, occupies approximately 5,100 acres (Fig. 6-31) and has an estimated resident population of 30,000.

Average dry weather flow during a two week period (Fig. 7-7) was 4.3 mgd or 143 gpcd. This per capita rate is high and reflects in part the effect of industrial waste contributions. Wet weather input is limited by two upstream regulators which divert all flow above 6.5 mgd to adjacent receiving waters.

Composite samples were collected over a 14-day period from August 6 to August 19, 1957, using for the first time the new sampler described previously in this chapter. Since several complications developed

[1] *Report by Engineering Testing Laboratory of the city of Seattle, September 1, 1954.*



DIPPER TYPE SAMPLER in operation at the influent works of the Lake City treatment plant. In foreground is the V-notch weir which provides necessary upstream flow depth. Sample is discharged to container in pipe cylinder to left of dipper.

in this initial operation, analysis results herein reported are limited to those for samples collected during the second week from August 13 through August 19. Despite the presence of industrial wastes, the analysis result (Table 7-2) show fairly low concentrations for both BOD and suspended solids. In contrast, per capita loadings are somewhat high and reflect the contributions from industrial sources.

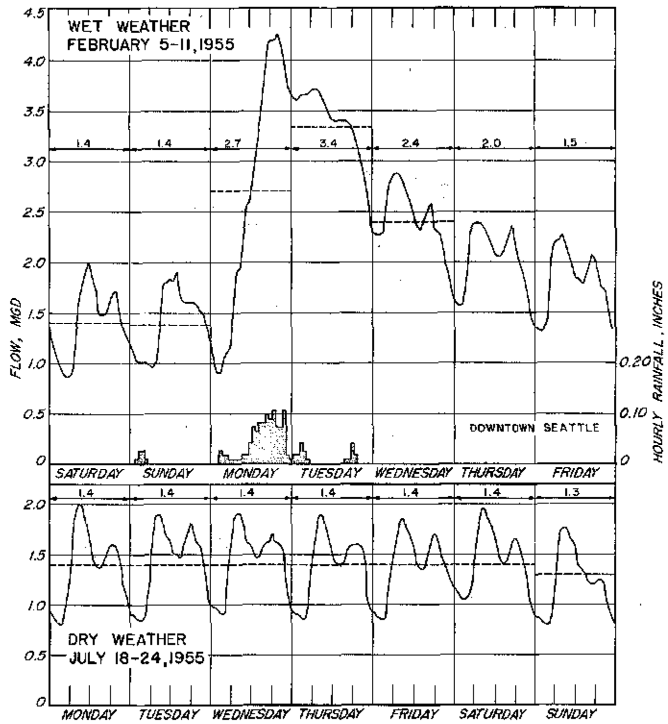


Fig. 7-6. Hourly Variation in Flow at Greenwood Sewage Treatment Plant

The increase in the minimum rate of flow during storm periods and its decline the next few days to dry season levels indicates that roof and foundation drains are the principal sources of wet weather inflow. Based on flow studies made by city of Seattle.

North Trunk System. This is the largest system in Seattle. Flow from a major portion of the system was metered in a manhole at Thorndyke Avenue and Emerson Street during dry weather from September 15 to October 15, 1957 (Fig. 7-8). The tributary area of the metered portion was approximately 12,700 acres (Fig. 7-3) with an estimated contributary population of 195,000. Dry weather flow averaged 35 mgd. This is equivalent to a per capita average of 180 gpd, on which basis it is far in excess of the general average for the metropolitan area.

The high per capita rate is due to a combination of conditions consisting of (1) overflows from Green Lake and from Seattle Water Department reservoirs; (2) direct inflow from surface streams and springs which have been diverted to the sewer system; and (3) ground water infiltration. Quite possibly, some of the infiltration is taking place in the area along Ravenna Boulevard where the recent cave-in occurred.

Sewage was sampled at the metering station manhole for seven days from Ocober 4 through October 11, 1957. All samples were taken by means of the vacuum sampler and were composited manually every eight to twelve hours in proportion to the metered flow. As calculated from the analysis results (Table 7-2), the per capita loadings amount to 0.17 pounds per day for BOD and 0.24 pounds per day for suspended solids. These values are somewhat high,

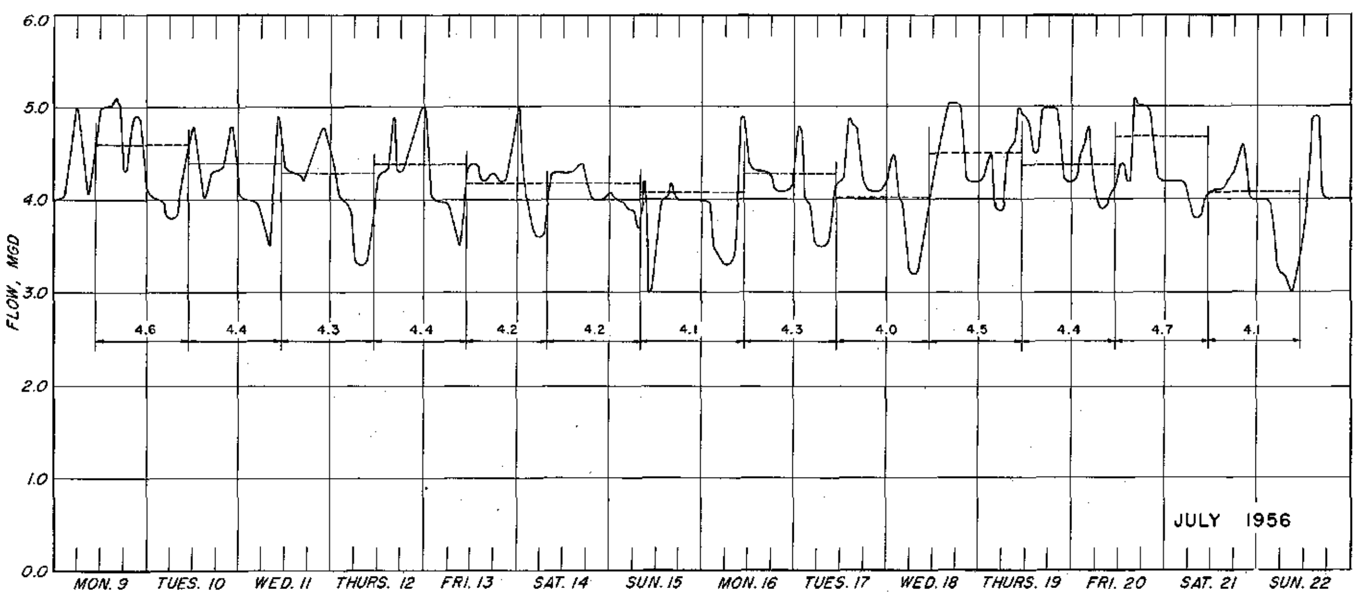


Fig. 7-7. Hourly Variation in Flow at Diagonal Avenue Sewage Treatment Plant

Because of the combined collection system and the predominantly industrial character of the tributary area, sewage flows average considerably higher in dry weather than would be expected from a residential area served by separate sanitary sewers. Based on plant meter records.

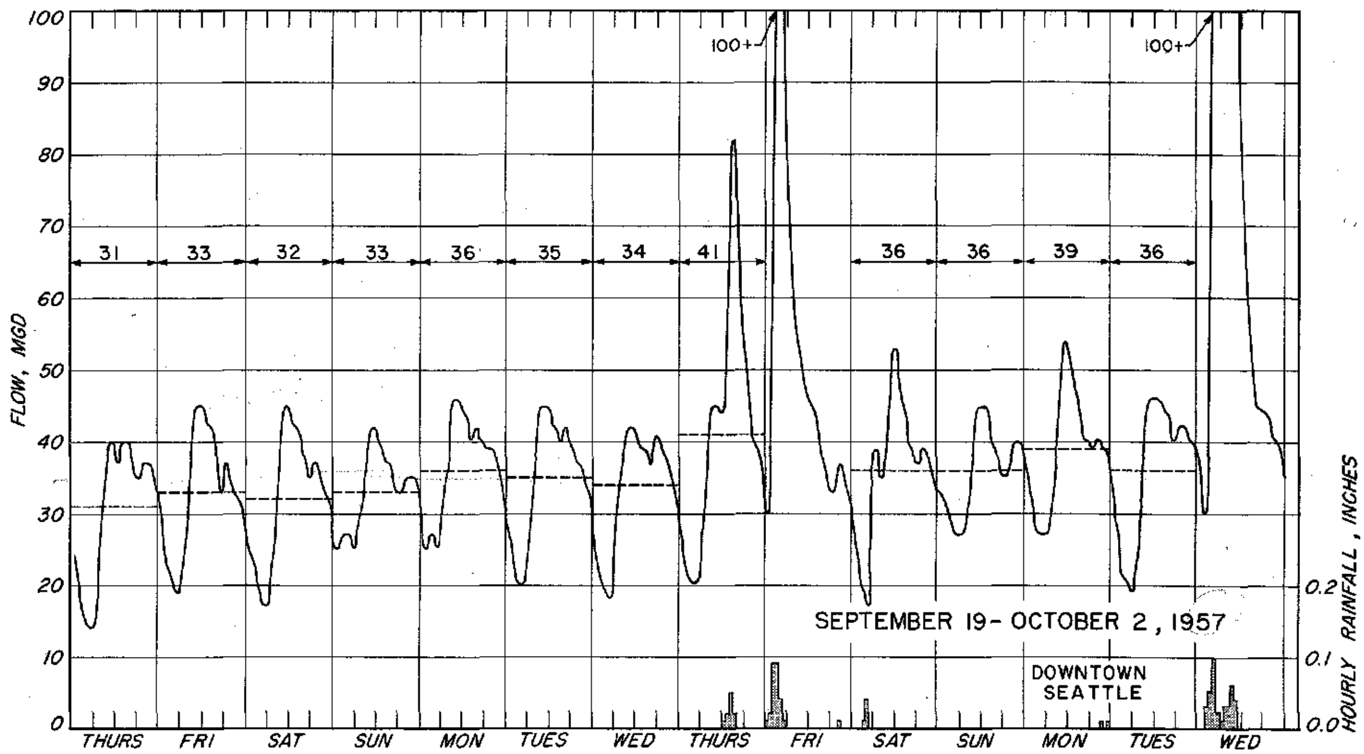


Fig. 7-8. Hourly Variation in Flow at North Trunk Sewer Metering Station

Sewage flow from an estimated population of 195,000 was metered at this station. For dry weather conditions, the average per capita rate of 180 gallons per day is the highest of those observed at all metering locations during the course of the survey.

apparently reflecting the effect of contributions from the industrial area along the Lake Washington Ship Canal. In terms of concentration, however, the North Trunk samples are the weakest of all of those collected in Seattle. In other words, the per capita loadings are high but the strength is low because of the extreme dilution brought about by the above mentioned conditions.

Ballard System. Sewage from approximately 1,300 acres of the Ballard area (Fig. 7-3) was metered near a storm water inflow to Lake Washington Ship Canal. Average dry season flow was 1.7 mgd (Fig. 7-9), while wet season flow averaged almost 5 mgd when rain was not actually falling.

Sewage samples were collected at the metering station on seven days during a period from August 22 to September 4, 1957 (Table 7-2). Average BOD and suspended solids values are each 0.09 ppcd.

Rainier Avenue System. In this system, a metering station was established at Rainier Avenue and Bayview Street. At that point (Fig. 7-3), the tributary area is approximately 1,100 acres, with an estimated population of 22,000.

Wet season flows, as metered from February 16 through February 22, 1957, were slightly lower than

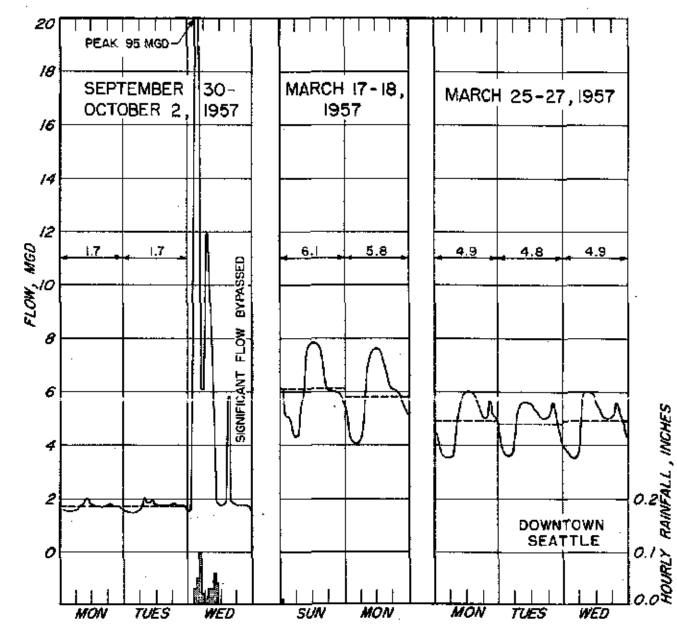


Fig. 7-9. Hourly Variation in Flow at Ballard Trunk Sewer Metering Station

Even in the absence of rainfall, wet season flow in this combined sewer averaged between three and four times the dry season flow. Hourly variations for the first two days shown are of doubtful accuracy because of a shallow depth of flow and the effect of bottom deposits of grit.

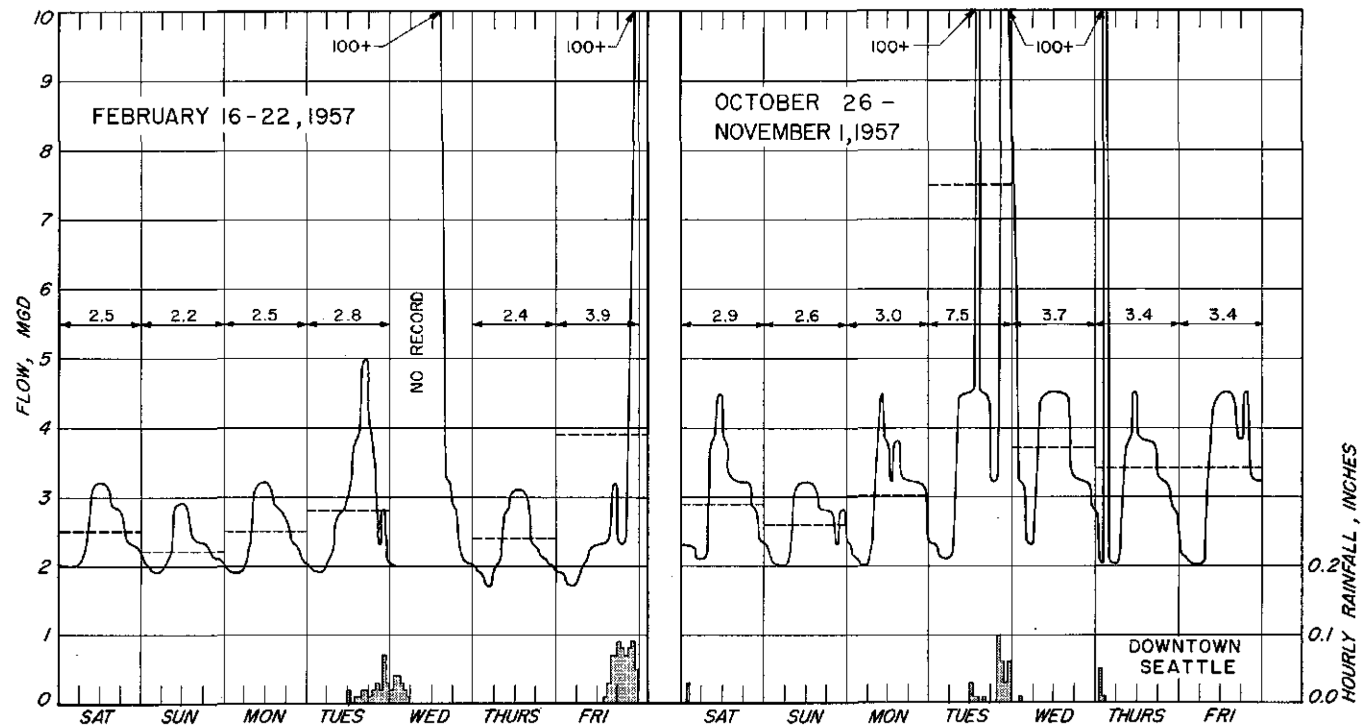


Fig. 7-10. Hourly Variation in Flow at Rainier Avenue Trunk Sewer Metering Station

Peak rates of flow in this combined sewer exceeded 100 mgd even with rainfalls as low as 0.05 inches per hour. The similarity between minimum flows during the two periods indicates a relatively stable ground water level.

those metered near the end of the dry season (Fig. 7-10). Minimum flows during both periods were almost identical, thus indicating a similar ground water level and a similar rate of infiltration. Per capita flow during dry weather averaged 120 gpd.

City of Auburn

Records of sewage flow at the Auburn treatment plant were obtained from meter charts and were plotted (Fig. 7-11) for both a dry season period and wet season period. Dry season flows, as recorded from July 15 to July 21, 1956, averaged 0.6 mgd, or 85 gpcd. Wet weather flow, as recorded from January 1 to January 7, 1956, averaged 1.7 mgd, or 240 gpcd. By comparison, water consumption during the winter amounted to 57 gpcd.

Bellevue Sewer District

Flows at the Bellevue sewage treatment plant also were plotted for typical dry and wet season periods (Fig. 7-12). Dry season flow, as recorded from July 15 through July 21, 1956, averaged 0.14 mgd, representing a per capita flow of 34 gpd. Wet weather flow, as recorded from January 1 through January 7, 1956, averaged 0.8 mgd, and apparently is limited only by the hydraulic capacity either of the plant influent sewer or the inlet works. Winter water consumption in the Bellevue-Medina area averages 57 gpcd.

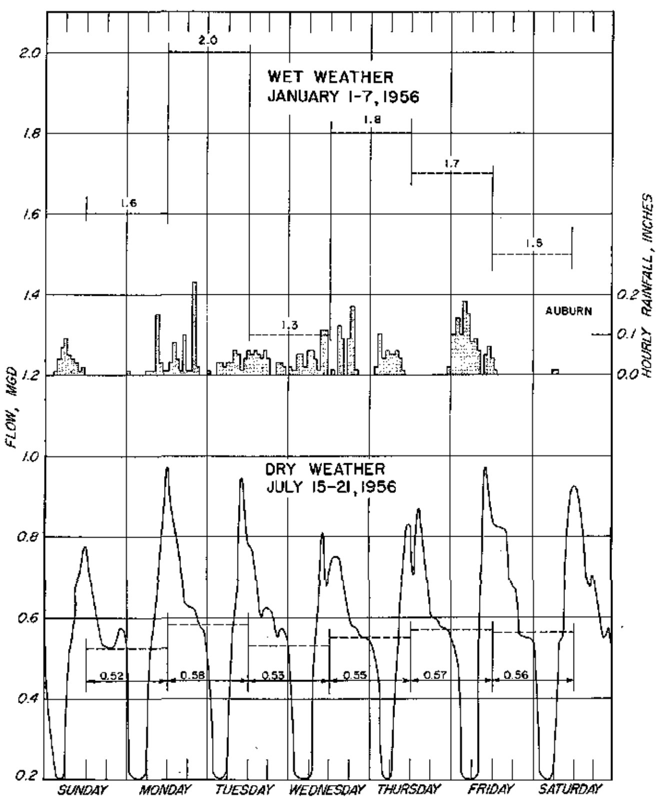


Fig. 7-11. Variation in Flow, Auburn Sewage Treatment Plant

Hourly rates not shown for January as the recorder is inaccurate at high rates of flow. Records of total daily flow during wet weather believed to be reliable. Based on plant meter records.

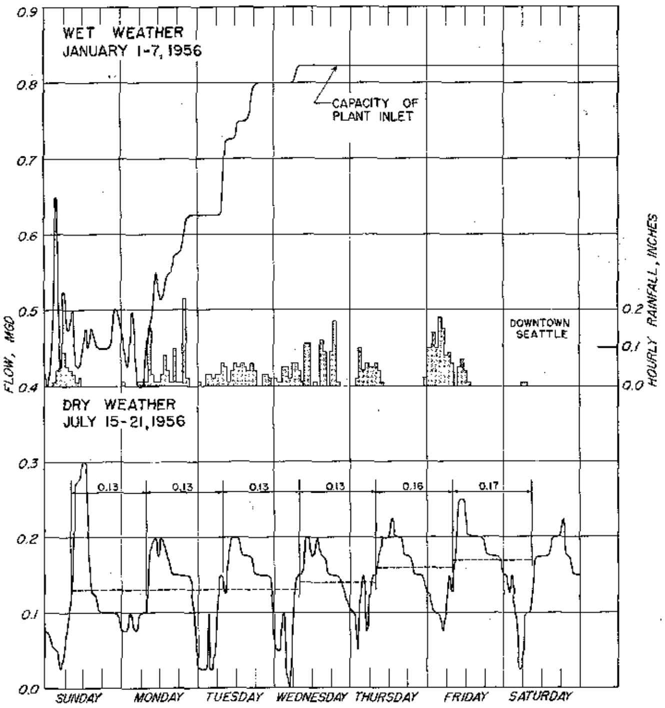


Fig. 7-12. Hourly Variation in Flow at Bellevue Sewage Treatment Plant

Wet weather flows are five or six times average dry weather flows and are apparently limited by the hydraulics of the influent sewer or inlet works. Based on plant meter records.

Bryn Mawr - Lake Ridge Sewer District

Due to a meter outage during the summer of 1956, records of dry weather flow at the Bryn Mawr plant were obtained for the period from November 24 through November 30, 1956 and are plotted in Fig. 7-13. During this period, the average flow was 0.21 mgd, or 47 gpcd. Flow rates during most of the wet weather period from January 1 to January 7, 1956 were in excess of the treatment plant meter capacity of 1.1 mgd. Winter water consumption averages 48 gpcd.

City of Kent

Dry season flows as recorded at the Kent sewage treatment plant from July 15 through July 21, 1956, averaged 0.7 mgd, or 117 gpcd (Fig. 7-14). These flows include an estimated delivery of 0.5 mgd from three cannery operations. By deducting the cannery contribution, the net flow from other sources becomes 0.2 mgd, or 50 gpcd.

City of Kirkland

At the Kirkland sewage treatment plant, dry weather flows during the period from June 30 through July 6, 1957, averaged 0.3 mgd, or 52 gpcd (Fig. 7-15). Wet weather flows, as recorded from January 1 through January 7, 1956, reached a peak of 2.3 mgd. Per capita water consumption during the winter months is estimated by the city to average 55 gpd.

Analyses were made of composite samples collected at the treatment plant for seven days during the period from July 9 through July 22, 1957 (Table 7-3). Average per capita values, as computed from the analysis results, are 0.19 pounds per day for suspended solids and 0.09 pounds per day for BOD. Although the latter is low for a strictly domestic sewage, the suspended solids value is higher than normal.

City of Renton

Records of typical wet and dry season flows at the Renton sewage treatment plant are plotted in Fig. 7-16. Dry weather flow, as metered from July 14 through July 21, 1956, averaged 0.7 mgd, representing a per capita rate of 42 gpd. Wet season flow during the period from January 1 through January 8, 1957, averaged approximately 1 mgd, with a peak rate of 3 mgd recorded on January 7. Analyses made by treatment plant personnel on samples collected during dry weather show a BOD value of 110 to 150 ppm and an average suspended solids value of 150 ppm.

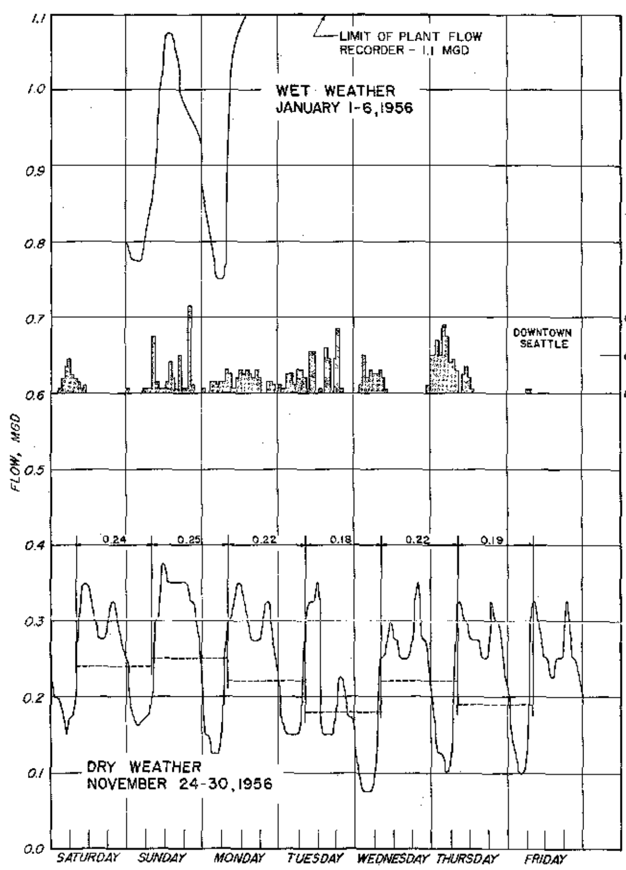


Fig. 7-13. Hourly Variation in Flow at Bryn Mawr - Lake Ridge Sewage Treatment Plant

Wet weather flow rates regularly exceed the capacity of the influent meter and bear no resemblance to the typical hourly flow variations occurring during dry weather. Based on plant meter records.

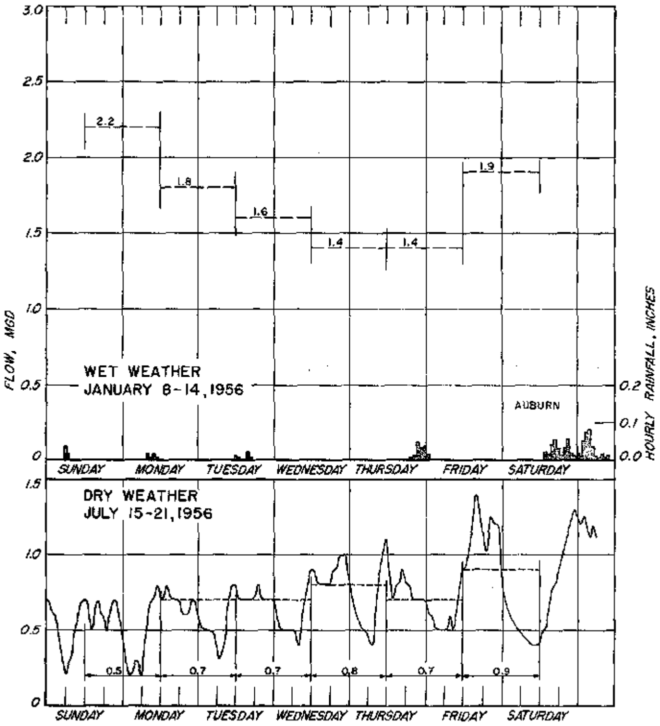


Fig. 7-14. Hourly Variation in Flow at Kent Sewage Treatment Plant

Canneries tributary to the Kent plant account for about 0.5 mgd of the average daily flow during dry weather. Wet weather flows, for which daily averages only are shown, indicate that both infiltration and storm inflow are prevalent. Flow rate indicator is inaccurate at higher flows during wet weather.

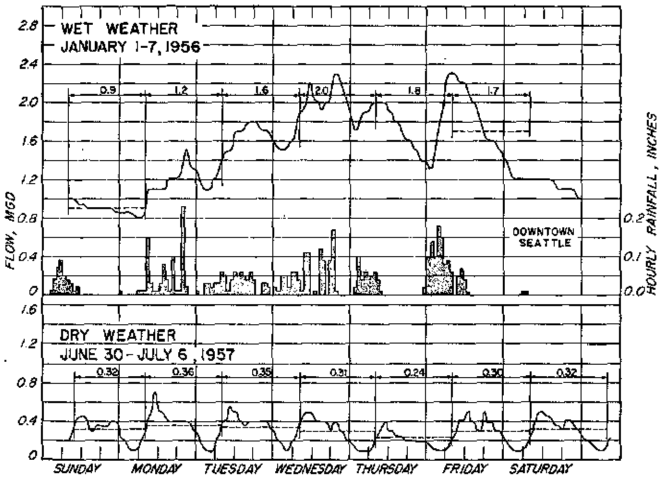


Fig. 7-15. Hourly Variation in Flow at Kirkland Sewage Treatment Plant

Peak wet weather flow of 2.3 mgd is about seven times the average dry weather flow. An even higher peak flow, 3.5 mgd, was recorded December 20, 1955. Based on plant meter records.

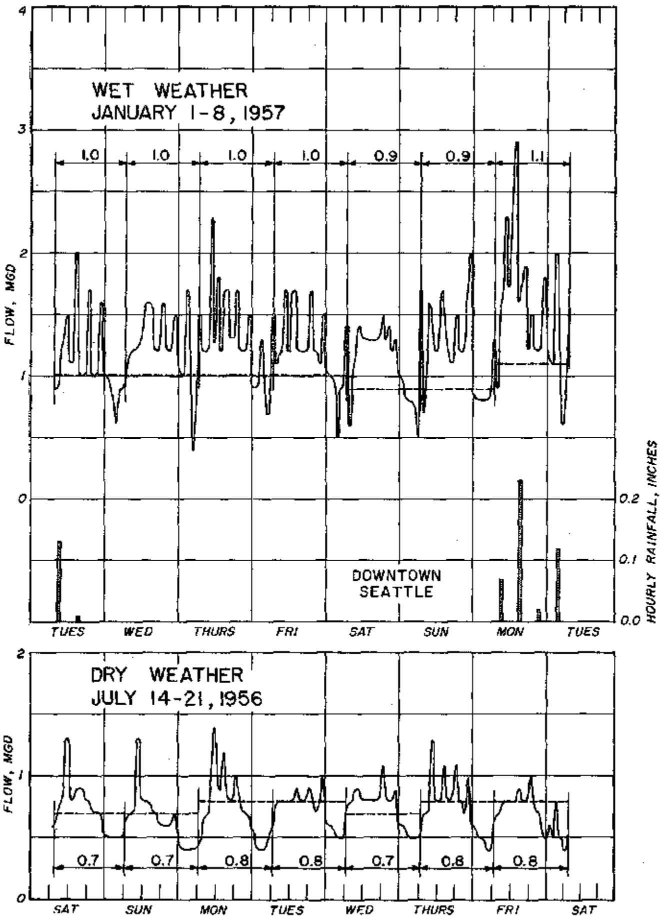


Fig. 7-16. Hourly Variation in Flow at Renton Sewage Treatment Plant

Average dry weather flow increased from 0.7 mgd to 0.9 mgd late in the summer of 1957, and is attributed to increased development resulting from expansion of the Boeing factory at Renton. Based on plant meter records.

Shorewood Apartments

Wet and dry season flows recorded at the Shorewood Apartments sewage treatment plant show that this is one of the few systems in the metropolitan area which is not subject to a sizeable increase in flow during the winter months. Wet season flow (Fig. 7-17) is less than the dry season flow in the same year, apparently because of reduced occupancy during the winter. Based on complete occupancy, the dry season flow of 0.2 mgd represents a per capita rate of 87 gpd. Water consumption during the winter amounts to 70 gpcd.

As indicated in Table 7-3, sewage samples were collected at the Shorewood treatment plant from June 20 through July 1, 1957. Suspended solids and BOD contributions, as computed from the analysis results, average 0.14 and 0.16 ppcd, respectively, for an estimated connected population of 2,300 persons.

Southwest Suburban Sewer District

Construction of the Southwest Suburban sewage treatment plant and of the majority of its tributary system was completed in February of 1957. Dry weather flow, as metered from August 25 through August 31, averaged 1.3 mgd (Fig. 7-18), representing a per capita contribution of 100 gpd for the

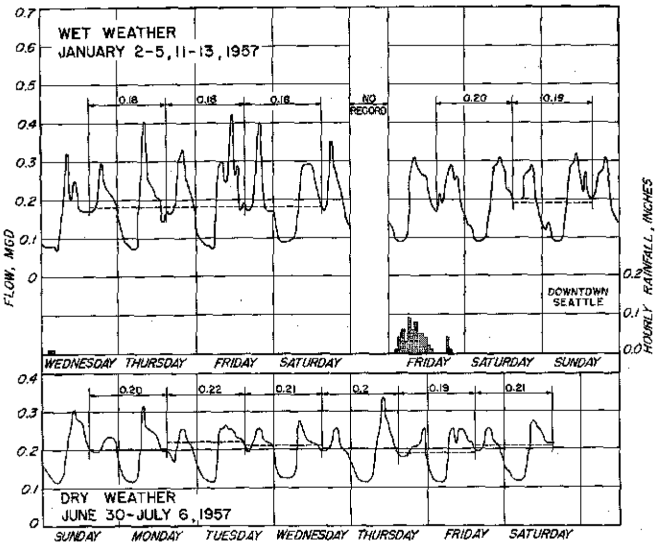


Fig. 7-17. Hourly Variation in Flow at Shorewood Apartments Sewage Treatment Plant

Average dry weather flow during the summer season exceeds wet season flow by as much as 0.3 mgd and is due, in part, to an increase in contributory population during the summer months. Based on plant meter records.

tributary population of 12,600 persons. Water consumption during winter months averaged nearly 60 gpcd.

Wet weather flows during the week beginning November 10 reached a peak rate of 3.0 mgd on November 13. On February 26, shortly after the treatment plant

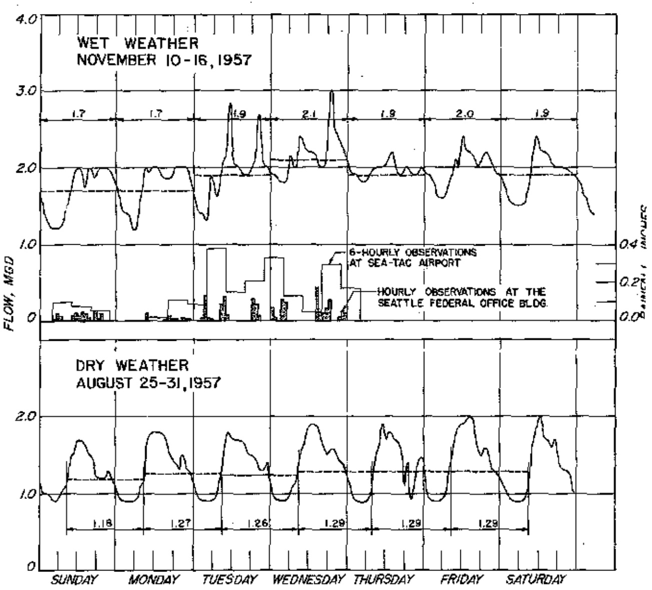


Fig. 7-18. Hourly Variation in Flow at Southwest Suburban Sewage Treatment Plant

Compared to other plants in the metropolitan area, wet weather flows show a much smaller increase in proportion to dry weather flows. This is attributed to the newness of the system as a whole and the use of approved jointing materials. Based on plant meter records.

had been placed in service, a peak of 5.4 mgd was recorded.

Additional flow data were obtained for both wet and dry weather conditions by means of a meter installed temporarily at Pumping Station No. 1 (Fig. 6-9). Sewage reaching this station is generated in a 1,200 acre area near Lake Burien and comes also from an area immediately to the east and south. Dry weather flow from the two areas, which have an estimated total population of 6,750, averaged 0.5 mgd, or 74 gpcd (Fig. 7-19).

Sewage samples were taken at the Southwest Suburban treatment plant from August 12 through September 23, 1957. Values calculated from the analysis results (Table 7-3) reveal per capita contribution of 0.17 pounds per day for BOD and 0.23 pounds per day for suspended solids. These values are higher than those prevailing elsewhere in the metropolitan area and may be due in part to the high proportion of new homes equipped with garbage grinders.

Relative Freshness of Metropolitan Area Sewage

A characteristic common to the sewage from almost all parts of the metropolitan area is its generally fresh condition. This stems mainly from the large amount of ground water which enters the sewers. In addition to its diluting effect, ground water serves also to reduce sewage temperatures and thus to inhibit bacterial decomposition. Sewage freshness is reflected by the results of numerous dissolved oxygen tests which have been made in recent years by the engineering testing

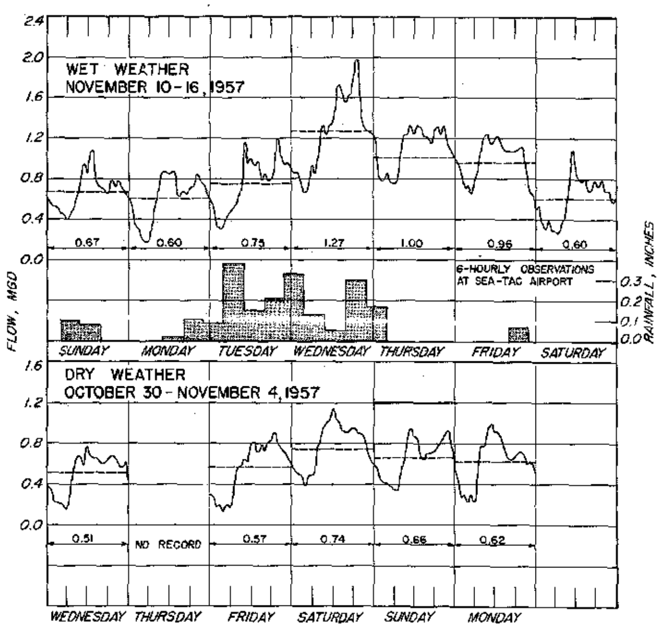
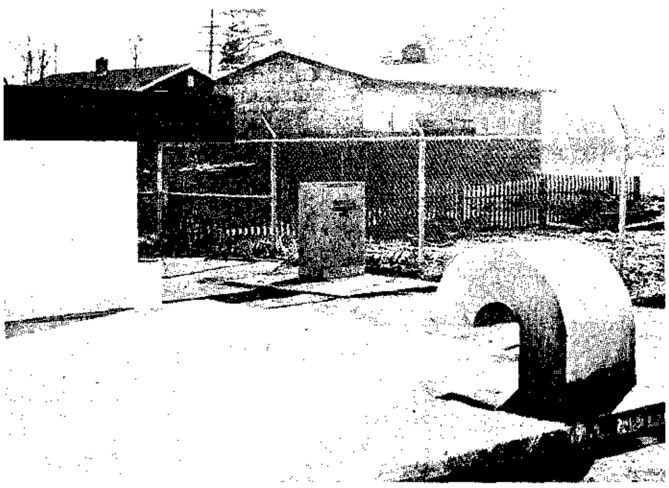


Fig. 7-19. Hourly Variation in Flow at Southwest Suburban Pumping Station No. 1

Sewers tributary to this station were constructed in 1957 and obviously have connections which allow entry of storm water.



FLOW METER installation of the bubbler type on influent sewer at Southwest Suburban Sewer District Pumping Station No. 1. Note proximity of residence beyond fence.

laboratory of the city of Seattle. These tests show concentrations ranging from 4 to 8 ppm in the winter months and of 2 ppm or more in summer months. In the summer, values below 2 ppm are found only near the downstream ends of the larger trunks.

Two benefits normally associated with weak, fresh sewage are the virtual elimination of odor conditions in and about pumping stations and treatment works, and the absence of concrete corrosion by hydrogen sulfide. In the Southwest Suburban Sewer District, however, the treatment plant influent was devoid of oxygen during summer months and had to be chlorinated for odor control. This condition appears to have been brought about by a combination of two factors, the first a low rate of infiltration, and the second a low rate of flow associated with the inception of a new system.

Occasional odor problems can be expected in other suburban areas as the sewerage systems are expanded.

Table 7-3. Sewage Characteristics at Sampling Points Outside Seattle

Date	Day	Average flow, mgd	BOD					Solids					
			Raw		Settled[a]	Total		Suspended			Settleable		
			ppm	lb/day	ppm	ppm	Volatile ppm	ppm	lb/day	Volatile ppm	ml/l	ppm	Volatile ppm
Kirkland Plant, July 1957													
9	Thur	0.32	210	561	122	683	411	564	1,505	490	12	468	379
10	Wed	0.31	225	580	120	778	463	478	1,230	382	15	378	274
11	Thur	0.31	165	424	109	558	334	254	653	231	10	196	148
12	Fri	0.30	164	409	104	686	494	224	558	192	6	196	165
16	Tue	0.30	174	428	80	666	392	478	1,175	376	11.5	400	304
18	Thur	0.33	201	560	118	644	372	330	919	240	10.5	146	106
22	Mon	0.33	295	806	200	788	482	582	1,590	425	15	424	370
Weighted average				540					1,090				
Shorewood Apartments, June and July 1957													
20	Thur	0.21	211	370	130	506	308	238	416	214	10	150	142
21	Fri	0.21	180	314	129	534	342	300	523	280	8	250	242
22	Sat	0.20	150	250	120	498	410	150	250	132	7	102	94
25	Tue	0.23	210	404	165	560	312	170	326	129	7.5	76	35
1	Mon	0.21	163	285	127	458	247	161	282	147	7.5	108	99
Weighted average				325					358				
Southwest Suburban Plant, August and September 1957													
12	Mon	1.3	171	1,850	82	656	403	428	4,640	318	11	344	296
13	Tue	1.3	206	2,230	103	652	408	334	3,610	258	13	254	240
15	Thur	1.3	230	2,490	104	544	294	232	2,520	192	10	196	182
16	Fri	1.3	204	2,210	130	678	428	254	2,750	230	10	208	188
19[b]	Thur	1.3	161	1,750	88	498	214	180	1,950	162	5	80	74
23[b]	Mon	1.3	180	1,950	138	520	338	202	2,190	166	8	96	62
Weighted average				2,080					2,950				

All analyses performed on raw sewage samples. See Fig. 7-1 for location of sampling points.

Temperature and pH during sampling period: Kirkland, 18° C, 7.3; Shorewood Apartments, 22° C; Southwest Suburban, 17° C, 7.1.

[a]*One hour settling period.*

[b]*September.*

They are not likely, however, to be serious nor are they likely to become a matter of general concern. For the most part, sulfide formation will be minimized not only by natural conditions of temperature and water quality but by taking advantage of a topography which makes it possible to maintain adequate velocities in all sewers.

Presence of Grit in Combined Sewage

One of the most difficult problems inherent in combined sewerage systems is that involved in removing grit brought in by storm flows. Street washings, by their nature, contain an appreciable quantity of gritty material. This material, combined with that introduced by the sanding of icy streets in winter months, is picked up in combined sewers and conveyed therein to points of disposal. No problems are encountered, of course, where the sewers terminate in direct discharges to open bodies of water. On the other hand, the delivery of grit laden sewage to a sewage treatment plant requires that adequate facilities be provided for its removal.

While it is desirable for design purposes to develop information concerning the quantity and the particle size of grit carried in a sewer system, it is virtually impossible to obtain such information in advance. For that reason, it is necessary to rely instead on experience at existing plants operating in the same vicinity under similar conditions.

With respect to the combined sewers in Seattle, operating records at the Diagonal Avenue treatment plant show but little grit removal during wet weather periods. Removal during dry weather averages 2 cubic feet per million gallons and reaches a maximum of 5 cubic feet. There are two reasons for the low removals during wet weather. First, velocities through the grit removal unit are such that the detention time therein is not sufficient to permit deposition and settlement. As a consequence, grit accumulates in the digester, thereby reducing its capacity and necessitating periodic removal. Second, two flow regulators at Michigan and Brandon streets upstream from the plant bypass a large portion of the storm flow to nearby receiving waters. These bypassed flows are taken from the lower portion of the sewer and thus carry the heavier particles of grit along with them.

Samples of grit were obtained from the digester at the Diagonal Avenue plant and were analyzed for gradation by the city engineering laboratories. Results of these analyses, together with those for grit found at the bottom of the North Trunk and Ballard interceptors, are presented in Fig. 7-20. This figure also includes a grading analysis of sand similar to that used for sanding city streets.

Grit from the digester consists mainly of material passing a 40-mesh screen, thus indicating that the grit removal device takes out most of the larger and heavier particles.

The high percentage of coarse material in the samples from the trunk sewers results from the classifying action of the storm flows and indicates that most of the fine material is kept in suspension and disposed of through the outfall.

In the North Trunk interceptor, 25 per cent of the deposit is 3 inches and larger in size. By comparison, all of the sand used for street sanding passes a 1/4-inch screen and has a gradation curve lying between those of the digester and sewer samples.

Grit in the bottom of the North Trunk sewer at Thorndyke Avenue and Emerson Street was found to be cemented together by an asphaltic material and have an average depth of two feet. This same cemented material was found off the submarine outfall of the North Trunk.

INFILTRATION AND STORM INFLOW

As used herein, the term "infiltration" denotes the flow or movement of water through the interstices or pores of a soil or other porous medium, and the subsequent access of such water to a sewer through cracks, breaks, and defective joints. On the other hand, the term "storm inflow" denotes the flow which

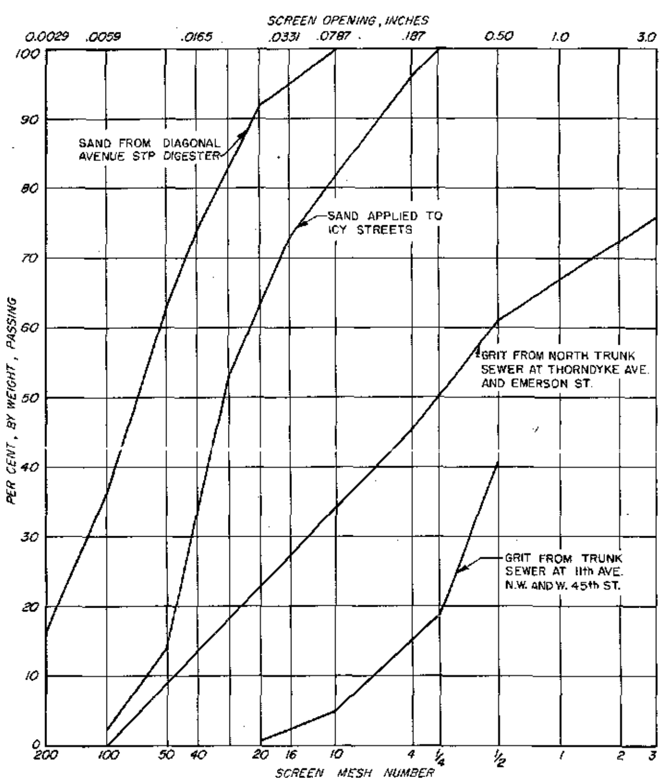


Fig. 7-20. Sieve Analyses of Grit Samples

Based on analyses by Engineering Testing Laboratory of the city of Seattle.

enters a sanitary sewer more or less directly during a rainfall and for a short period thereafter. These definitions overlap to some extent in that rainstorms, if long enough in duration, will cause a rise in ground water level and a resulting increase in the rate of inflow from saturated soils. Both storm inflow and infiltration are expressed herein as gallons per acre per day (gpad).

In general, infiltration and storm inflow are regarded as components of sewage volume. For the purpose of the present study, however, they require special consideration because of the serious problems they have created in most of the sewerage systems serving the metropolitan area. Severe infiltration is occurring, for example, in systems consisting entirely of separate sanitary sewers, most of which are designed to accommodate no more than a nominal amount of infiltration. Similarly, most of the sewage treatment plants are overtaxed with respect to hydraulic capacity and some of them, under storm conditions, either overflow or bypass raw sewage.

Combined systems, by their nature, are designed to accommodate large quantities of storm water. For that reason, the problem of ground water infiltration becomes important only as it relates to interceptor design. Interceptor sewers are designed normally to accommodate dry weather flow plus storm flow from low intensity rains, and to overflow or bypass during storms of moderate or higher intensity. Without an adequate allowance for dry weather infiltration, bypassing may be necessary even in the absence of rainfall.

Lake City System

As agreed upon in undertaking the sewerage survey, a detailed study was made of infiltration in the Lake City sewerage system. Elsewhere in the metropolitan area, studies were limited in scope and were undertaken primarily for corroborative purposes.

As a matter of background information, it should be noted that the entire Lake City system is of recent origin. Sewer construction did not begin until 1949, although it continued at a rapid rate thereafter until December of 1954. At that time, the State Pollution Control Commission issued a directive to the effect that no additions to the collection system would be approved until the sewage treatment plant, completed and placed in operation in late 1953, was enlarged to accommodate the excessive flow already being developed. In 1957, following the start of treatment plant additions, the commission ruling was withdrawn and further sewer construction was undertaken. Between 1955 and 1957, however, the sewered area remained essentially static at 2,900 acres. This system serves an estimated population of 25,000 persons and consists of 90 miles of sewers plus about 160 miles of house connections. Most of the sewers are 8 inches in diameter.

Available data on infiltration, consisting solely of flow records at the sewage treatment plant, indicate that troubles with infiltration and storm inflow have been more or less continuous ever since the plant was first placed in service. In 1954, the firm of Hill and Ingman, consulting engineers to the district, submitted a report on the problem of excessive flows at the treatment plant and the steps to take to correct them. Fig. 7-21, adapted from that report, is a plot of the hourly variation in flow for typical wet and dry weather periods in 1954, the first full year of plant operation. An analysis of the records for that year reveals that over 60 per cent of the total flow of approximately 1,300 million gallons, or 800 million gallons, was attributable to infiltration and storm inflow. On that basis, infiltration and inflow were roughly equivalent to a third of the annual rainfall received by the sewered area of 2,900 acres.

During the wet season, particularly when rain has been falling for several days at a low or moderate rate, a high intensity rainfall is manifested almost immediately by a sudden increase in metered flow at the sewage treatment plant. Flows at such times damp out any normal variation and result in a pattern similar to that of a storm hydrograph. Furthermore, they exceed the maximum rate which can be indicated by the treatment plant meter, which is 8.0 mgd. Readings on a depth gage ahead of the metering flume indicated flows as high as 11 mgd during the first year of operation.

Flows return almost immediately to near normal following the cessation of a heavy rainstorm. At such times, however, the minimum between the hours of 1 a.m. and 6 a.m. is about 1 mgd higher than it is normally. A period of two to three days usually elapses before the minimum returns to its pre-storm level.

In the five years the system was operated by the district, no action was taken toward a solution of the infiltration problem. Recently, however, specifications prepared by the city of Seattle in connection with the construction of sewers to serve a new area in Lake City call for the use of improved jointing materials. It can be expected, therefore, that infiltration in this particular area will be reduced to an acceptable level.

A contract in the amount of $760,000 was awarded on December 26, 1956 for enlargement of the sewage treatment plant. The enlarged plant has a design capacity of 10.5 mgd and a hydraulic capacity of 25 mgd.

Scope of Infiltration Study

Studies of the infiltration problem were directed toward the attainment of several objectives. These were:

1. The development of information concerning the magnitude of infiltration and storm inflow in various sections of the Lake City system. Information thus developed provides possible clues as to where remedial measures might be most effective.

2. The determination, if possible, of the actual sources of infiltration and inflow.

3. The development of measures to reduce infiltration in existing facilities as well as in facilities to be constructed in the future.

4. The development of design criteria both for areas presently sewered and areas to be sewered in the future.

As a first step in achieving the foregoing objectives, a program of continuous metering was established in trunk sewers and pumping stations tributary to the sewage treatment plant (Fig. 7-22). Continuous metering of flows was augmented by depth of flow measurements made in 50 manholes at various locations throughout the district. These measurements were obtained with the assistance of city sewer maintenance personnel and were made in May and again in August during low flow hours from 1 a.m. to 6 a.m.

Results of Infiltration Measurements

Unfortunately, the continuous metering program failed to achieve all of the desired results. Rainfall after April 14, the date when meter installations were completed, was abnormally low. In the following 30 days, rainfall amounted to 0.3 inches as compared to a normal of 2.0 inches. The only storm of sufficient intensity to be of any value to the infiltration study occurred on May 17 and May 18, 1957.

On May 16, typical dry season conditions prevailed at the two trunk sewer metering stations, as well as at the treatment plant (Fig. 7-23). In the early morning hours, 1 a.m. to 6 a.m., the plotted data show little or no variation in flow. Remembering, therefore, that the Lake City system consists entirely of sanitary sewers and that it serves an essentially residential area, it can be assumed that the flow during those hours was due almost wholly to the infiltration of ground water. In other words, the rate of 1.8 mgd then recorded represents a district-wide infiltration rate of 600 gpad.

Flows recorded during the several light rainfalls which occurred on May 17 and 18 are plotted in Fig. 7-24 and reflect the effect of a sudden influx of rain water in the early morning hours of May 18. At that time, the flow rate increased by approximately 1 mgd following a rainfall of nearly 0.20 inches in 4 hours. Based on flows at the two trunk sewer metering sta-

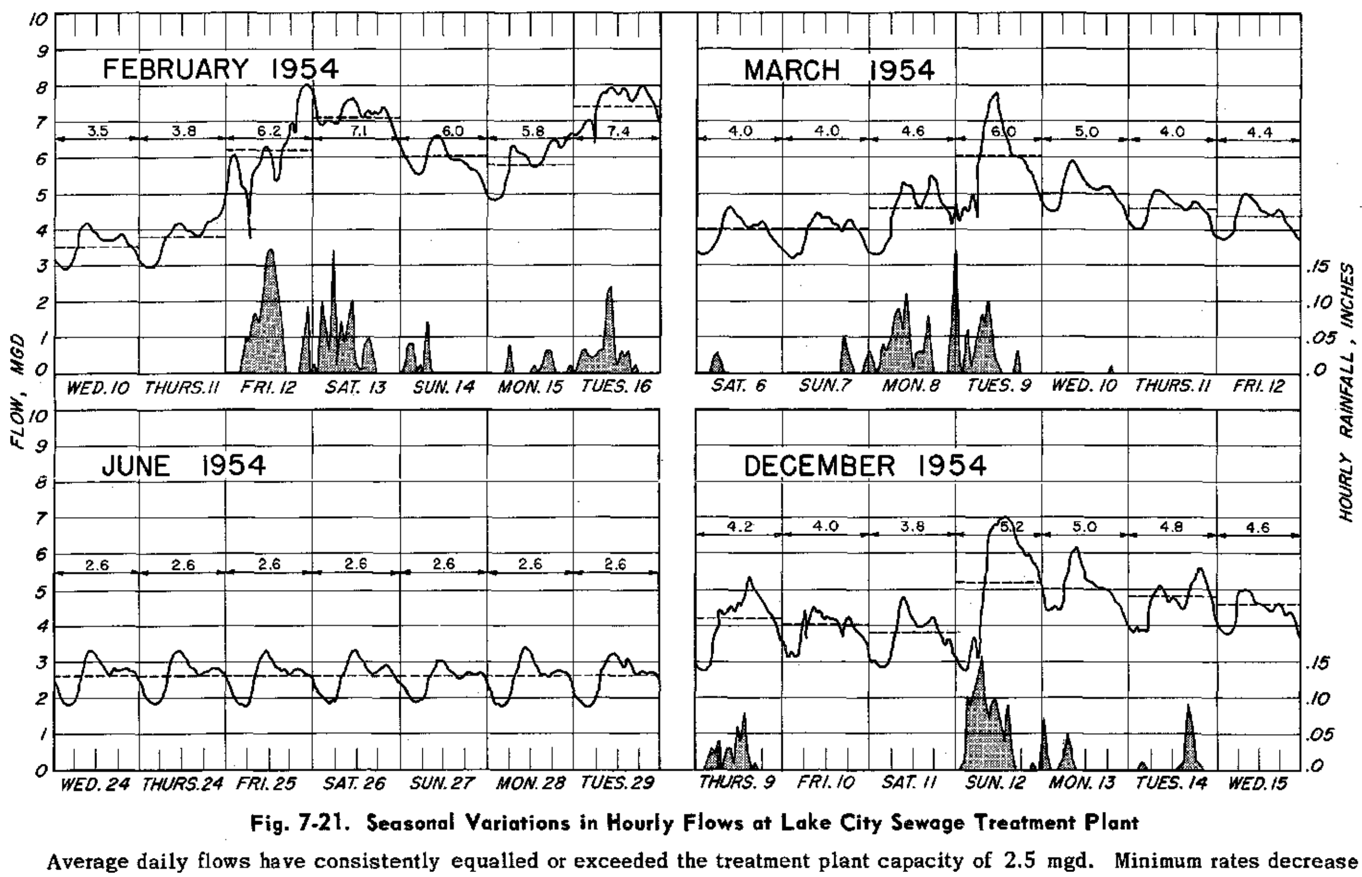


Fig. 7-21. Seasonal Variations in Hourly Flows at Lake City Sewage Treatment Plant

Average daily flows have consistently equalled or exceeded the treatment plant capacity of 2.5 mgd. Minimum rates decrease daily for several days following rainfall, thus indicating that rain water percolating downward through the soil gains access to the sewers. Based on report by Hill and Ingman, consulting engineers to Lake City Sewer District.

tions, the storm inflow contributions on an areal basis were about as follows:

Westerly trunk	0.35 mgd	1050 gpad
Northerly trunk	0.35 mgd	360 gpad
Remainder of district	0.40 mgd	390 gpad

Assuming that all of the early morning flow was infiltration plus storm inflow, the total thereof on May 18 amounted to 1,000 gpad for the entire district and to 2,200 gpad for the area served by the westerly trunk. These figures were confirmed by a rainfall of about equal intensity which occurred later the same day.

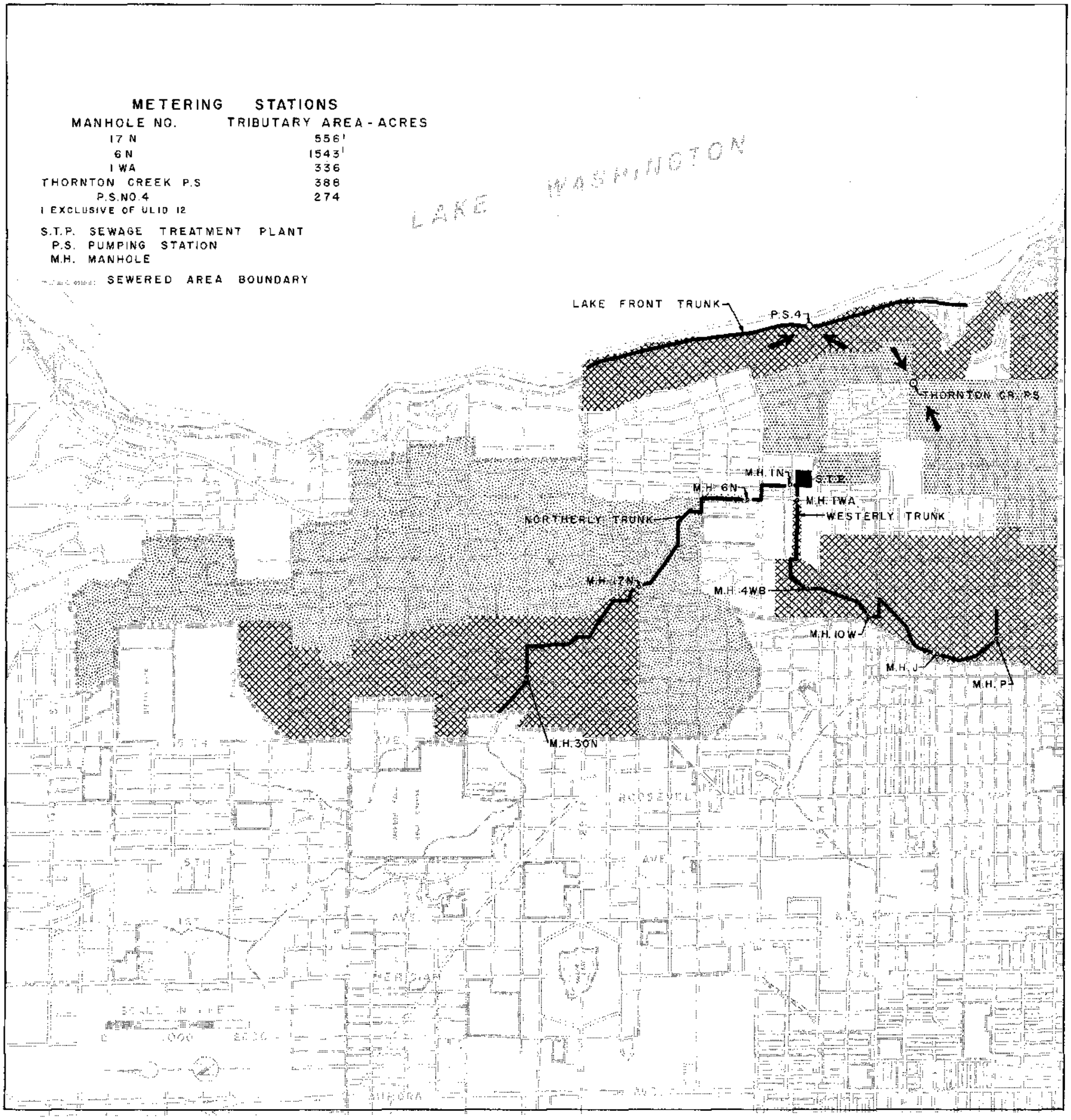


Fig. 7-22. Principal Sewers and Metering Stations in Lake City System

Continuous flow records were obtained from metering points established in manholes 1N, 6N, 17N, and 1WA, and from the two pumping stations. Additionally, manual gagings were made at selected manholes, especially on the westerly trunk, to determine the location of areas subject to excessive rates of infiltration.

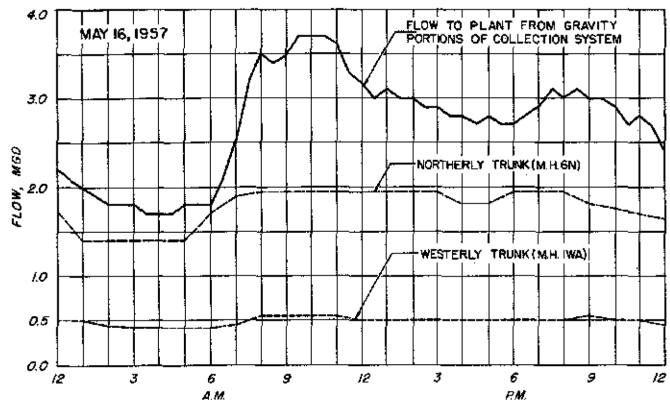


Fig. 7-23. Dry Weather Flow in Gravity Portions of Lake City System

Dry weather flows from the northerly and westerly trunks of the Lake City system account for a large proportion of the flow reaching the treatment plant by gravity.

A second metering station on the northerly trunk, situated upstream from the first, provided additional information on the tributary area (Fig. 7-25). Since flow from the upper station is tributary to that at the lower station, it is evident that the upswing in inflow which occurred at the latter reflects additional pick up between the two points.

As determined from flow measurements recorded at five metering points (Table 7-4), infiltration decreased from 915 gpad in May to 670 gpad by the end of August. Two conclusions are thus indicated. First, sewers in the Lake City system are subject to considerable leakage, and second, the rate of infiltration decreases with the decline in ground water level which occurs gradually during the summer season.

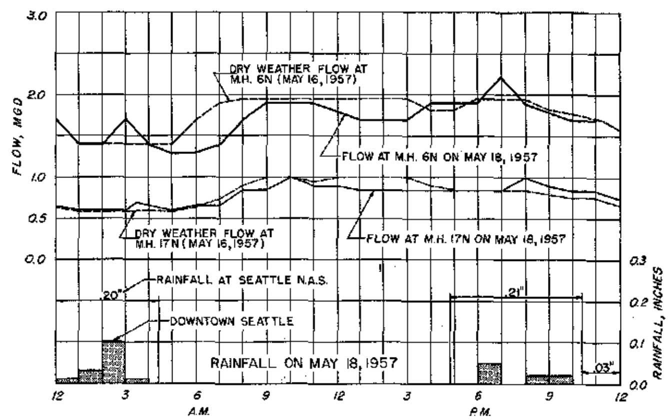


Fig. 7-25. Comparison of Dry and Wet Weather Flows in Northerly Trunk of Lake City System

A significant amount of storm inflow enters the northerly trunk between manhole 6N and manhole 17N.

Seasonal low flow gagings listed in Tables 7-5 and 7-6 serve to identify the major sources of infiltration. On May 15-16, 1957, incremental flows from the upper reaches of the northerly trunk sewer showed rates of 1,700 gpad at manhole 33 and of 1,620 gpad at manhole 28AN. Both rates are relatively high, considering that the gagings in question were preceded by a dry period going back to approximately April 20. Proceeding downstream, as additional areas with little infiltration are added, the cumulated rate diminishes to 960 gpad at manhole 6N.

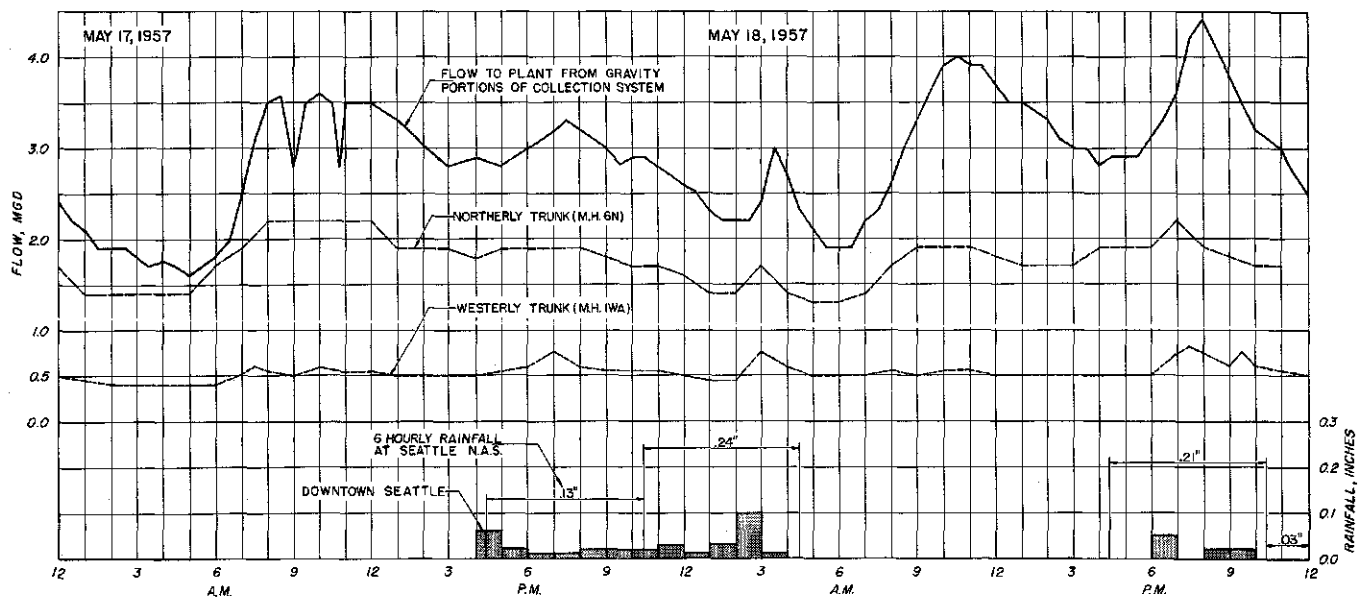


Fig. 7-24. Wet Weather Flow in Gravity Portions of Lake City System

After a slight rainfall on the evening of May 17, the increase in flow at the treatment plant was closely matched by an increased flow in the westerly trunk. Rainfall about 3 a.m. the following morning caused an increase in flow of 1.0 mgd at the plant. About 0.7 mgd of this was attributable to increased flow from the westerly and northerly trunks. Comparable increases occurred early in the evening of May 18.

Table 7-4. Summary of Infiltration Measurements, Lake City, 1957

Tributary area[a]		May 15-16 1957		Aug. 30-31 1957	
Metering point	acres	mgd	gpad	mgd	gpad
MH 6N	1,543	1.4	910	-	-
MH 1N	1,817	-	-	1.0	550
MH 1WA	336	0.42	1,250	0.45	1,340
Pumping Station No. 4	274	0.16	585	0.12	425
Thornton Creek Pumping Station	388	0.35	900	0.31	800
Summary	2,541	2.33	915	-	-
	2,815	-	-	1.88	670

[a]*See Fig. 7-23 for location.*

A comparison of the incremental rates on May 15 with those on August 30 shows a decline in all areas along the northerly trunk, with the exception of that tributary to manhole 28AN. The increase at this point apparently was caused by trench drainage from construction under way in ULID 12.

With respect to the westerly trunk, the early morning record (Table 7-5) reveals a high rate of infiltration, 2,080 gpad, in the tributary area between manholes 130 and 4WB. When these measurements were made, it was observed also that a continuous stream of ground water was entering manhole 4WB through a cracked section.

In order to determine the particular locality responsible for the high rate of infiltration, the August measurements (Table 7-6) included gagings at manhole 10W, which is situated between manholes 130 and 4WB. Readings there obtained demonstrated that most of the leakage was occurring in an 86 acre area tributary to the trunk between manholes 10W and 1WA.

Further information regarding minimum flows was obtained by timing pump operation at two pumping stations, Thornton Creek and Station No. 4. While some areas tributary to the Thornton Creek station (Fig. 7-22) show high infiltration rates (Table 7-5 and Table 7-6), their total contributions are relatively small and thus have no appreciable effect on the total flow. A major portion of the minimum flow at this station is from the area tributary to manhole 657 and from other areas which were not included in the depth gaging program.

Pumping Station No. 4 (Fig. 7-22) receives sewage from the sewered area of Lake City fronting on Lake Washington, including that picked up in a lake front interceptor. Infiltration in this area, as indicated by minimum flow measurements at the pumping sta-

Table 7-5. Minimum Flow Gagings, Lake City System, May 15-16, 1957.

Manhole number	Cumulative			Incremental		
	Tributary area, acres	Flow, gpd	Infiltration, gpad	Tributary area, acres	Flow, gpd	Infiltration, gpad
Northerly Trunk						
33	31	52,000	1,700	31	52,000	1,700
29	284	302,000	1,060	253	250,000	1,000
28AN	391	475,000	1,220	107	173,000	1,620
17N	556	600,000	1,080	165	125,000	760
6N	1,543	1,400,000	910	987	800,000	810
Westerly Trunk						
P	37	19,000	500	37	19,000	500
O	64	45,000	700	27	26,000	960
130	141	61,000	435	77	16,000	207
4WB	312	416,000	1,340	171	355,000	2,080
1WA	336	420,000	1,250	24	4,000	170
Thornton Creek Pumping Station						
499	68	25,000	368	68	25,000	368
467	125	74,000	590	57	49,000	865
571	135	88,000	650	10	14,000	1,400
593	147	121,000	820	12	33,000	2,750
657	234	196,000	840	87	75,000	860
Pumping station	388	350,000	900	154	154,000	1,000
Pumping Station No. 4						
344	6	0	0	6	0	0
390	54	19,000	350	48	19,000	390
429	68	20,000	290	14	900	61
427	94	56,000	590	26	36,000	1,400
Pumping station	274	160,000	585	180	104,000	580

Table 7-6. Minimum Flow Gagings, Lake City System, August 30-31, 1957

Manhole number	Cumulative			Incremental		
	Tributary area, acres	Flow, gpd	Infiltration, gpad	Tributary area, acres	Flow, gpd	Infiltration, gpad
Northerly Trunk						
33	31	17,000	560	31	17,000	560
29	284	238,000	840	253	221,000	875
28AN	391	605,000	1,550	107	367,000	3,400
17N	556	650,000	1,170	165	45,000	270
2-2A	852	810,000	950	296	160,000	540
867	1,298	1,070,000	825	446	259,000	580
1N	1,817	1,000,000	550	519	-	-
Westerly Trunk						
P	37	16,000	425	37	15,800	425
O	64	32,000	500	27	16,000	600
130	141	42,000	300	77	10,000	130
10W	250	117,000	470	109	75,000	690
4WB	312	345,000	1,100	62	228,000	3,700
1WA	336	450,000	1,340	24	105,000	4,400
Thornton Creek Pumping Station						
499	68	13,000	190	68	13,000	190
467	125	29,000	230	57	15,800	280
593	137	64,000	470	12	34,600	2,880
657	224	156,000	700	87	92,000	1,050
Pumping station	388	310,000	800	164	154,000	940
Pumping Station No. 4						
344	6	0	0	6	0	0
390	54	17,000	310	48	17,300	360
429	68	22,000	320	14	4,300	310
Pumping station	274	116,000	425	206	94,000	460

Table 7-7. Infiltration and Storm Inflow, Lake City Plant

Month	Flow, mgd			Storm inflow[c]		Infiltration[d]	
	Minimum[a]	Peak	Normal[b]	mgd	gpad	mgd	gpad
1956							
January	3.0	14.0	4.0	10	3,400	3.0	1,000
1954							
February	3.0	10.0	4.0	6.0	2,100	3.0	1,000
March	3.4	7.8	4.3	3.5	1,200	3.4	1,200
April	2.6	4.8	3.8	1.0	340	2.6	890
May	2.0	3.5	3.5	0	0	2.0	690
June	1.5	3.8	3.8	-	-	1.5	510
July	1.9	4.5	3.4	1.1	380	1.9	650
August	1.6	3.6	3.4	0.2	69	1.6	550
September	1.6	4.3	3.5	0.8	270	1.6	550
October	1.6	3.7	3.7	0	0	1.6	550
November	2.3	5.2	3.3	1.9	650	2.3	790
December	2.7	7.0	3.5	3.5	1,200	2.7	930

Tributary area, 2,920 acres.

[a]*Minimum flow rate for a period of relatively dry days.*

[b]*At same time as peak flow but on a previous dry day.*

[c]*Peak rate minus normal rate.*

[d]*Assuming minimum flow predominantly infiltration.*

tion and at various manholes, is consistently low. Manhole 344, which is in the area tributary to Station No. 4, was the only one of the 50 gaged in the entire Lake City district which showed no early morning flow.

Areas of the Lake City sewer system subject to summer infiltration rates in excess of 1,500 gpad are depicted in Fig. 7-26. Conditions there indicated are based on results of early morning gagings at the 50 manholes.

Because of the lack of storm flows during the metering program, information regarding wet weather conditions had to be obtained from the treatment plant meter charts (Fig. 7-27). Readings for January 6,

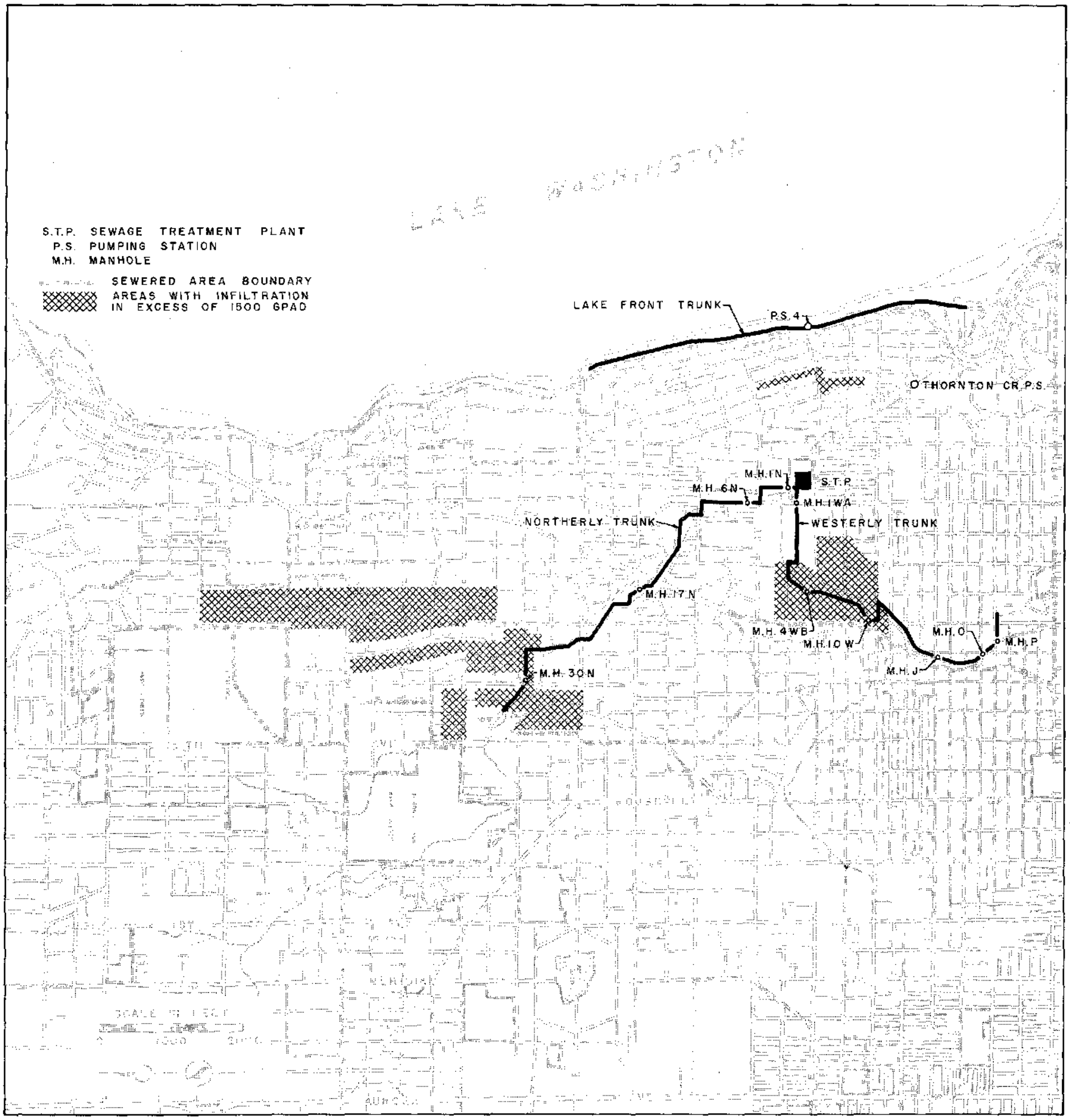


Fig. 7-26. Areas with Excessive Infiltration Rates in Lake City System

Based on results of the metering and minimum flow gaging programs. Remedial measures to reduce the quantities of storm inflow and infiltration to sanitary sewers should be undertaken first in the areas here indicated.

1956 are included because the peak rate of input on that day was the highest ever observed at the treatment plant.

Peak rates of infiltration and storm inflow, as obtained from the curves in Fig. 7-27, are listed in Table 7-7. It will be seen that the peak storm rate amounted to 3,400 gpad and that winter infiltration ranged from 1,000 to 1,200 gpad. During the summer months, storm inflow rates were generally less than 100 gpad, while infiltration ranged from 500 to 650 gpad.

Hourly records of storm flows at the Lake City treatment plant (Fig. 7-21) are indicative of two general conditions.

1. A sudden increase in flow with the advent of a storm. This is due largely to direct connections of catch basins, downspouts, and other illegal sources of storm input.

2. A gradual reduction in minimum flows at the end of a storm. This indicates a continuing but diminishing input of storm water stored in surface soils at an elevation higher than that of the normal ground water. Water thus accumulated may enter the sewer system through faulty joints in house connections or through foundation drains. The latter are installed for the purpose of protecting basement walls and may be directly connected to house sewers. No information is available, however, as to the number of them in use in the Lake City area.

A study in Erie County, New York,[1] showed an average inflow from foundation drains of 3,000 gpd

[1]Spencer, R.C., Standards for Sanitary Sewers and Present Community Needs, *Sewage and Industrial Wastes, 26, September 1954.*

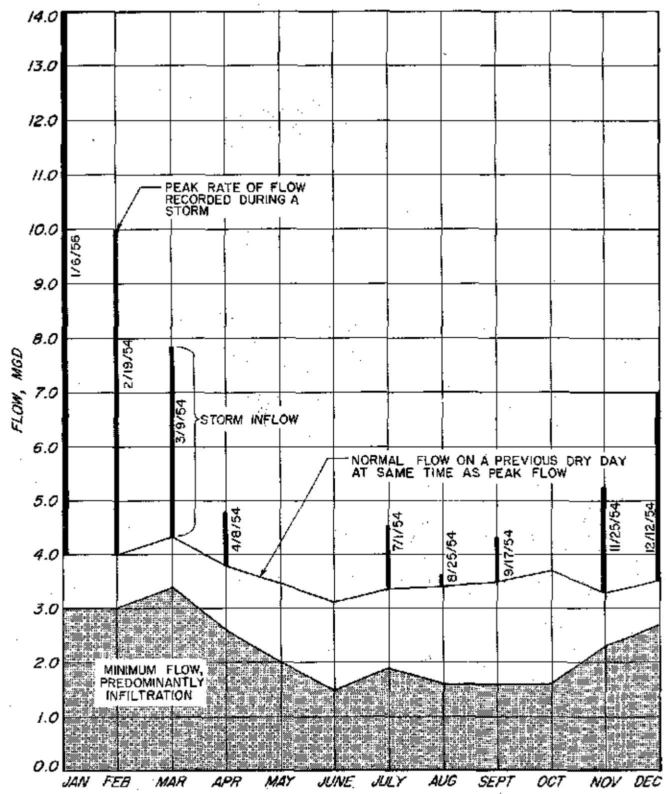


Fig. 7-27. Average Monthly Infiltration and Peak Storm Flows at Lake City Sewage Treatment Plant

The upper limit of the shaded area represents the average, by months, of minimum daily rates of flow. Storm inflow is represented by the difference between the peak rate and the normal dry weather rate at the same time of day or days preceding the storm. Storm inflow values are the maximum recorded each month. Based on plant flow records.

Table 7-8. Infiltration and Storm Inflow, Other Separate Sanitary Systems

Sewage treatment plant	Tributary area, acres	Dry weather infiltration[a]		Wet weather infiltration and storm inflow[a]	
		mgd	gpad	mgd	gpad
City of Seattle — Greenwood plant	1,320	0.4[b]	300	3.6	2,700
Auburn	1,300	0.2	150	–	–
Bellevue	700	0.02	30	0.8[c]	1,140
Bryn Mawr	510	0.08	160	1.1[c]	2,200
Kent	1,100	0.2	180		
Kirkland	1,300	0.15	115	1.9	1,500
Renton	2,100	0.4	190	1.3[d]	600
				0.5[e]	240
Shorewood Apartments	75	0.12	1,600	0.07	900
Southwest Suburban	1,200	0.21	175	1.45[f]	1,200

Hourly variations in flow for typical wet and dry weather weeks shown on Figs. 7-6 and 7-12 through 7-19.

[a]*Flow rate during early morning hours except where noted.*

[b]*Average dry weather flow less winter water consumption for area.*

[c]*Capacity of flow meter, rate shown probably exceeded.*

[d]*Storm inflow occurred during other than early morning hours.*

[e]*Infiltration only.*

[f]*Data for separate system tributary to pumping station No. 1.*

ROOF LEADERS which disappear below ground should be suspected as a possible source of storm inflow in areas served by separate sanitary sewers. By pouring a small quantity of water containing dye into the roof gutter and observing the sewage flow at a downstream manhole, it can readily be determined whether or not a leader is connected to the sewer.

per house in a suburban residential district. At four houses per acre, this flow would amount to a total of 12,000 gpad. Hence, if drains from only one house in twelve were connected to a sanitary sewer, the resulting increase in flow would be 1,000 gpad.

Based on the findings here reported, it is concluded that rates of infiltration and storm inflow vary over a wide range in the Lake City system. Certain local areas have excessive rates and should be examined further under the remedial program described later in this report.

Infiltration and Storm Inflow in Other Separate Systems

Information on infiltration and storm inflow in other metropolitan area systems served by separate sanitary sewers was obtained by examining the meter charts at a number of treatment plants. There is some doubt, however, as to the reliability of the flow rates indicated by certain of these meters under storm flow conditions. This is because most of the plants are heavily overloaded at such times and because there is a possibility also of overflow upstream from the meter.

Peak rates of infiltration and storm inflow, as determined from meter readings recorded early in 1956, are listed in Table 7-8. This table also lists the dry weather rates and is based on data presented previously in the section dealing with sewage flows.

In considering the foregoing data, it should be recognized that leakage and inflow can be expected in the future to receive increasing attention on the part of engineers concerned with sewer system design. This trend is already apparent and is manifested in some areas by the use of concrete pipe with rubber ring joints.

To determine the effect of the rubber rings, a limited metering program was undertaken in several areas served by the Southwest Suburban Sewer District. In so doing, flows from the White Center system of combined sewers, which are tributary to the sewage treatment plant, were excluded by establishing the metering station on the 24-inch influent line at Pumping Station No. 1 (Fig. 6-9). This station, situated near Lake Burien, serves an area of approximately 1,200 acres and receives sewage both by gravity flow and by pumping. Pumped flows originate in Pumping Station No. 3, which discharges into the gravity system a short distance upstream from Station No. 1.

Dry weather flows at Station No. 1, as measured from October 30 to November 4, 1957, averaged 0.60 mgd and dropped to a minimum of 0.10 mgd during the early morning hours (Fig. 7-19). In the next week, however, following the first prolonged rainfall of the season, the average flow jumped to 1.27 mgd on November 13 and the minimum to 0.80 mgd on November 14.

To ascertain the source of storm inflow, separate measurements were made of the gravity flow and of that originating at Station No. 3 (Fig. 7-28). It is evident from the plotted data that a major portion of the inflow originated in the gravity system. For the period of measurement, the flow from Station 3 re-

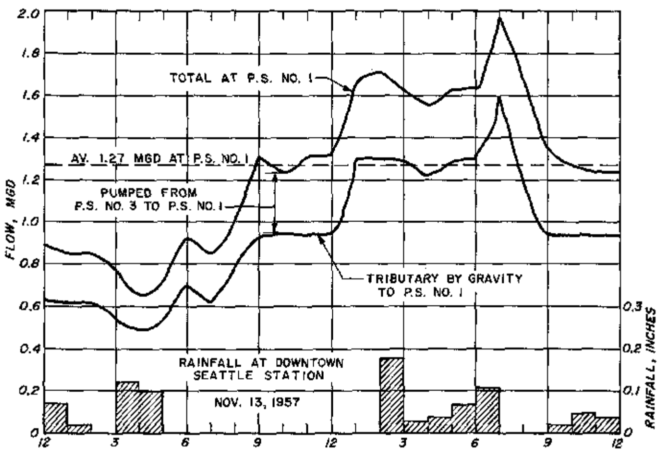


Fig. 7-28. Wet Weather Flow at Southwest Suburban Pumping Station No. 1

Flow measurements during a rain storm on November 13, 1957 reveal that most of the storm inflow originates in the area tributary by gravity rather than in the area served by Pumping Station No. 3.

Table 7-9. Infiltration and Storm Inflow, Southwest Suburban Sewer District

Tributary area		Infiltration				Storm inflow	
		Dry season		Wet season			
Designation	Acres	mgd	gpad	mgd	gpad	mgd	gpad
Pumping Station No. 1[a]	520	0.10[b]	192	0.24[c]	460	1.0[d]	1,920
Pumping Station No. 3	680	0.11[b]	162	0.11[c]	162	0.1[d]	147
Total at Pumping Station No. 1[e]	1,200	0.21[b]	175	0.35[c]	291	1.1[d]	915

See Fig. 6-9 for location of pumping stations.

[a]*For tributary area served by gravity system.*

[b]*Minimum flow - October 30, 1957.*

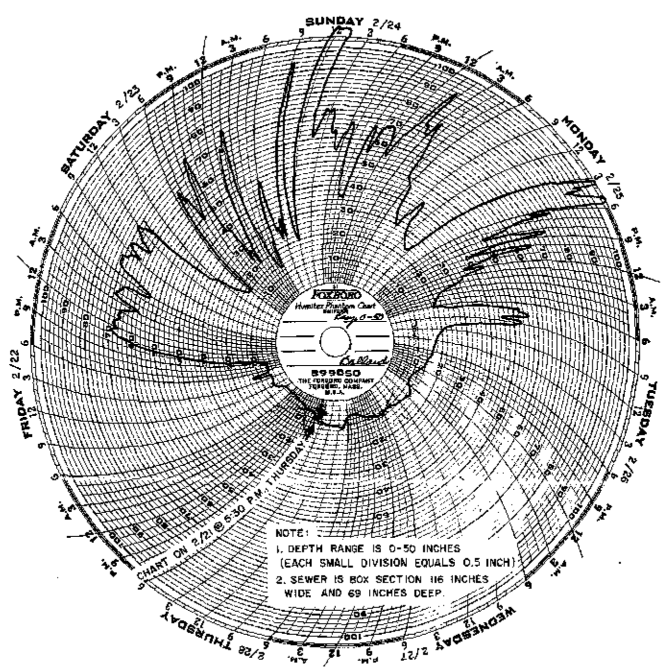
[c]*Minimum flow - December 4, 1957.*

[d]*Peak flow on November 13, 1957, less normal dry weather peak flow.*

[e]*Pumping station No. 3 discharges to system tributary to No. 1.*

mained essentially the same in wet weather despite the fact that the tributary areas are about equal in extent and that Station 3 serves a total of 1,075 connections as compared to 851 in the gravity system.

In the area tributary by gravity to Station No. 1, peak storm inflow amounted to 1,920 gpad (Table 7-9). By comparison, the peak in the area tributary to Station No. 3 was only 145 gpad. If it can be assumed that ground water conditions in the two areas are equivalent, the latter figure seems to indicate that rubber ring joints are effective in minimizing infiltration. On that basis, the high rate of inflow in the gravity area indicates that storm water is reaching the sewers from sources other than faulty joints.



DEPTH OF FLOW CHART from portable meter installed at Ballard trunk metering station shows wet and dry weather conditions during week of February 21-28, 1957. A side weir, located at this point, overflows combined sewage to the Ship Canal when the depth of flow exceeds 31 inches. During a storm shortly before noon on Sunday, February 24, the overflow outlet became clogged and sewage overflowed through the manhole onto the ground surface. This resulted in partial inundation of the immediate area.

Combined Systems

Information concerning infiltration in the combined sewers of the city of Seattle was obtained from meter charts at the Diagonal Avenue plant and from measurements at three metering stations (Fig. 7-3). These sources yielded the data presented in Table 7-10, which shows an average infiltration rate of 950 gpad during the dry season. Wet season infiltration at the Rainier and Ballard stations, neither of which is subject to upstream overflows, averaged 2,100 gpad.

In arriving at the figure for the area tributary to the Rainier and North Trunk metering stations, it was assumed that the minimum flow again was due entirely to infiltration. This assumption, however, is not entirely valid because of the light industrial and commercial operations which are being carried

Table 7-10. Infiltration in Seattle Combined Systems

Sewered area		Infiltration			
		Dry season		Wet season	
Designation	Acres	mgd	gpad	mgd	gpad
North Trunk	12,700	14	1,100	b	b
Diagonal Avenue	5,100	3.0	600	b	b
Rainier	1,100	2.0	1,800	1.7	1,550
Ballard	1,250	0.2	150	3.2[c]	2,500
Total	20,150	19.2	950	4.9	2,100

See Fig. 7-3 for locations.

[a]*In absence of rainfall.*

[b]*No metering during winter; large number of overflows upstream render data meaningless.*

[c]*Average flow less winter water consumption for area.*

on in areas tributary to those stations. Infiltration in the area tributary to the Ballard metering point was computed by deducting average winter water consumption from the average sewage flow.

CHARACTERISTICS OF INDUSTRIAL WASTE

Industrial waste disposal conditions and practices are subject to increasingly critical scrutiny by regulatory agencies and by various groups interested in protecting and preserving surface water resources. As a consequence, more rigid controls and more rigid standards with respect to disposal operations can be anticipated in the future. Liquid wastes presently discharged directly to receiving waters either will have to be treated by the responsible industry or will have to be disposed of in a publicly owned sewage treatment works. Except for very large quantities and for waste requiring special treatment, the latter method is generally the more feasible from the standpoints of economy and convenience.

For planning purposes, the two most important criteria with respect to the handling of industrial wastes are those of volume and composition. As to volume, which is the more critical of the two, sufficient capacity must be provided in trunk and intercepting sewers to avoid costly and unnecessarily paralleling at some later date. Treatment capacity, except for such structures and channels as are designed to meet ultimate requirements, may be provided as it becomes necessary. With sufficient hydraulic capacity in basic units, future increases in BOD and suspended solids loadings can be accommodated satisfactorily by the incremental addition of sedimentation tanks and sludge digestion facilities.

As a final note on the general problem of industrial waste disposal, it should be pointed out that a public sewerage authority is not necessarily obligated to receive such wastes without regard to their volume or composition. Depending on local circumstances, varying degrees of pretreatment may be required of an industry prior to acceptance of its wastes.

Sources and Volume of Industrial Waste

In Washington, every industry producing a waterborne waste, whether it be discharged independently or to a public sewer system, is required to obtain a permit from the State Pollution Control Commission. An abstract of data pertaining to all such permits and permit applications in the metropolitan area was provided by the Commission and is the principal source of information used in this report. This abstract covers a total of 150 industries, of which 58 produce waste flows of 50,000 gpd or more (Table 7-11).

Because of the seasonal nature of some of the industries, it is not likely that the maximum discharge rates occur simultaneously. As a consequence, the totals given in Table 7-11 are higher than those which are actually encountered.

For convenience in sewerage planning, industrial waste contributions from areas which have no significant seasonal operations, can be estimated on a gross acre basis by using records of winter water consumption. To that end an analysis was made of

Table 7-11. Major Industrial Waste Sources, 1957

Industry group	Seattle			Auburn	Kent	Renton	Others	Total in metropolitan area
	Puget Sound	Elliott Bay	Duwamish Waterway					
Number								
Food and beverage	5	7	8	2	3		1	26
Metals	1	2	7		1			11
Metal plating			6			2		8
Chemicals			4					4
Miscellaneous	1	1	3			2	2	9
Total	7	10	28	2	4	4	3	58
Waste quantity, 1,000 gpd[a]								
Food and beverage	806	1,759	2,000	221	970		100	5,856
Metals	285	1,380	21,261		110			23,036
Metal plating			6,769			1,686		8,455
Chemicals			2,764					2,764
Miscellaneous	4,338	84	1,119			530	402	6,473
Total	5,429	3,223	33,913	221	1,080	2,216	502	46,584

Source: "Industrial Waste Sources in the Seattle Metropolitan Area," Pollution Control Commission, State of Washington, 1957.

Data for industries having maximum waste volumes less than 50,000 gpd are not included in this table.

[a]*For maximum day; includes estimated maximums for seasonal industries.*

winter water use in a 975 acre tract situated along Duwamish Waterway from Harbor Island to Boeing Field. At present between 20 and 30 per cent of this area either is vacant or is reserved by existing industries for future expansion.

As reported in Chapter 4, winter use in the 975 acre tract averaged 3.1 mgd, or 3,200 gpad. In the three meter routes for which the data were obtained, the average ranged from 1,840 to 3,700 gpad.

At the risk of being repetitive, it should be pointed out again that higher water consumption in this particular area occurs during summer months when large quantities are used for gravel washing and cold storage operations. In both of these, however, the resulting wastes are suitable for direct discharge to adjacent waterways and thus are not significant with respect to sewerage planning.

Strength and Composition of Industrial Waste

Virtually no information is available concerning the strength and composition of specific industrial wastes in the Seattle area. Based, however, on analyses of samples taken from the influent to the Diagonal Avenue treatment plant and from the North Trunk sewer, it is evident that the industrial waste component of these flows has a strength no greater than that of the sanitary sewage. For the Diagonal Avenue plant, after deducting the BOD contribution of the resident population tributary thereto, it is estimated that the industrial wastes have a population equivalent of only 15,000 persons. The nature of the principal industries tributary to this plant and the approximate volumes of waste they produce are given in Table 7-12.

Table 7-12. Sources of Industrial Wastes Tributary to Diagonal Avenue Sewage Treatment Plant

Nature of operation	Number of industries	Waste volume,[a] 1,000 gpd
Adhesives and related chemicals	2	851
Beverage bottling	1	2.5
Cement handling and distribution	1	0.5
Compressed gasses	1	1,150
Food canning	1	170
Metal plating	2	65.7
Sawmill	1	5
Steel fabrication	1	5
Truck manufacturing	1	225
Other	3	72.5
Total	14	2,547.2

Source: "Industrial Waste Sources in the Seattle Metropolitan Area", Pollution Control Commission, State of Washington, 1957.

[a]*Maximum day.*

The presence in industrial waste of substances toxic to fish and other aquatic life is a matter of great concern in the Puget Sound region, particularly where disposal is to inland waters which provide little dilution. Wastes from metal plating works, of which there are a relatively large number in the Seattle area (Table 7-11), are especially hazardous. Separate pretreatment of these wastes, as well as of certain others which are more than normally hazardous, is now required by the Pollution Control Commission. In some instances, pretreatment may have to be continued unless dilution by sanitary and other flows increases to an extent sufficient to reduce the concentration of toxic materials to tolerable limits. Many of these materials cannot be removed by ordinary sewage treatment processes. Furthermore, some of them are likely to have a deleterious effect on the biological processes involved in sludge digestion and in secondary treatment.

Despite the fact that industrial wastes reaching the Diagonal Avenue plant appear to have caused little or no operational trouble, the same situation will not necessarily prevail when treatment facilities are provided for the remainder of the Seattle area. For example, the bituminous material found in the North Trunk is capable of creating operating difficulties. Other materials which should be excluded from a sewer system include those which are capable either of structural damage by direct attack or of creating an explosive atmosphere. In other words, strong acids and alkalis should be excluded, as should gasoline, kerosene and other petroleum products.

Experience in other cities has shown that industrial waste abuses of a sewer system, while usually unintentional, are often undetected until treatment works are constructed. Prevention of such abuses is best achieved by (1) tracing such materials to their sources, (2) maintaining an educational program for waste producing industries, and (3) enacting a comprehensive ordinance governing the use of the sewerage system. Seattle does not now have such an ordinance.

SUMMARY OF SEWAGE CHARACTERISTICS

Data with respect to sewage volume and composition, as measured in metropolitan Seattle for both residential and combined residential and industrial areas, are summarized in Table 7-13. Figures there listed, coupled with appropriate supporting information, are utilized in developing basic criteria for planning and design purposes.

Volume of Sanitary Sewage

A sanitary sewage contribution of 60 gpcd is considered suitable for design purposes and represents a moderate increase compared to the present contribution. For trunk sewers within a major sewerage area, a peak flow of 175 per cent of average is selected and

Table 7-13. Summary of Sewage Characteristics

Location	Estimated population[a]	Tributary area, acres	Sewage strength and composition: BOD, lb/day	BOD, ppcd	Suspended solids, lb/day	Suspended solids, ppcd	Winter water use, gpcd	Sewage volume: Dry weather, mgd	Sewage volume: Wet weather, mgd	Infiltration: Dry season, gpad	Infiltration: Wet[b] season, gpad
Seattle											
North Trunk	195,000	12,700	32,400	0.17	47,000	0.24		35.0		1,100	
Diagonal Avenue	30,000	5,100	4,470	0.15	7,590	0.25		4.3		600	
Lake City	25,000	2,920	3,500	0.14	5,290	0.21	53	3.0	8.0	550	4,400
Ballard	24,500	1,250	2,140	0.09	2,150	0.09	58	1.7	5.0[c]	150	2,500
Rainier	22,000	1,100						3.0	2.5[c]	1,800	1,550
Greenwood	16,000	1,320	1,330	0.08	1,710	0.11	62	1.4	3.4	300	2,700
Auburn	2,000	1,280					57	0.6		150	
Bellevue	4,100	700					57	0.14	0.8	30	1,140
Bryn Mawr	4,500	512					48	0.2	1.1	160	2,200
Kent	4,000	1,090					66	0.7	2.2	180	2,200
Kirkland	5,750	1,280	540	0.09	1,090	0.19	55	0.3	2.0	115	1,500
Renton	16,500	2,110						0.7	1.0	190	840
Shorewood	2,300	75	325	0.14	358	0.16	62	0.2	0.2	1,600	900
Southwest Suburban	12,600	1,200	2,080	0.17	2,950	0.23	60	1.3	3.8	175[e]	1,206[e]
Total	369,250	32,637	46,785		68,138			52.5	31.7		
Weighted average				0.15		0.22	56				

[a] *Based on estimates from Seattle Planning Commission and on data furnished by individual sewerage agencies.*

[b] *Wet season values include storm inflow except as noted for systems served by combined sewers.*

[c] *Combined system; values are for average flow during wet season exclusive of storm runoff.*

[d] *Based on contributory population of 311,000 included in sampling program.*

[e] *For separate sanitary system tributary to pumping station No. 1 (Table 7-9).*

is believed sufficient to allow properly for momentary peaks. For trunk sewers serving more than one major sewerage area and for sewage treatment plants, a ratio of 150 per cent of the averages is selected and is considered appropriate for the large areas which such facilities normally serve.

Volume of Industrial Waste

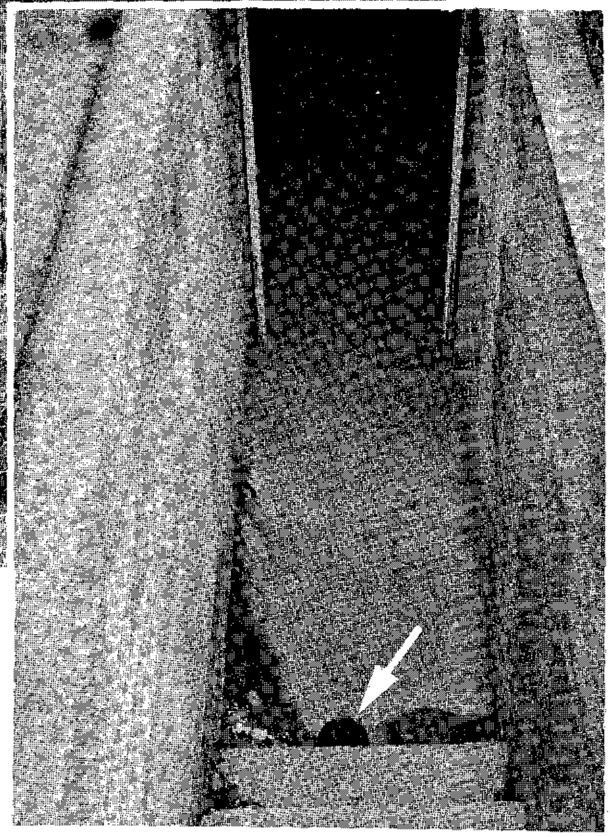
For presently developed industrial zones, an average waste contribution of 4,000 gpad and a peak of 8,000 gpad are in line with present experience. In the case, however, of new industrial zones, the tendency toward less intense land utilization is resulting in a lower unit use of water per acre and thus in a correspondingly lower unit production of liquid wastes. This tendency stems from the provision of adequate parking space for employees, of adequate room for essential transportation facilities, and of landscaping to create a pleasant working environment. For new light industrial zones and for heavy industrial zones occupying an area of 1,000 acres or more, an allowance of 2,000 gpad for average flow is considered sufficient. For heavy industrial zones smaller than 1,000 acres, the possibility that one or two fairly "wet" industries might locate therein calls for application of a higher allowance, namely, an average of 4,000 gpad. With respect to peak rates of flow, values equal to 300 per cent of average for light industrial areas and 200 per cent of average for heavy industrial areas are appropriate.

It is assumed for all new areas that cooling water and other clean waste water will be disposed of separately. In all cases, of course, infiltration and storm flow allowances must be added to the liquid waste allowances.

Infiltration and Storm Inflow

Improvements in construction practices, coupled with new developments in pipe jointing techniques, have demonstrated elsewhere that infiltration rates can be achieved in future construction which will be substantially lower than those observed during the present survey. Likewise, the provision of adequate storm drainage in areas presently lacking such facilities, supplemented by a program to eliminate obvious sources of inflow, can bring about a major reduction in direct storm inflow to sanitary systems.

Infiltration. Minimum flows measured during the metering program naturally included a small amount of sanitary sewage in addition to ground water. For that reason, and because of the reduction of infiltration which could be achieved by the procedures outlined above, the quantities selected as applicable to



ILLEGAL CONNECTIONS, of which these two are typical examples, permit storm inflow to the Lake City system. In the photograph above overflow from the wooden catch basin in foreground is conveyed to manhole in background (arrow). In the photograph at right, the drain (arrow) at the base of an exterior stairwell conveys stairwell drainage, as well as that from an adjacent patio, to a sanitary sewer.

existing construction are 1,200 gpad for the wet season and 300 gpad for the dry season. These apply to both combined and separate sewers. In the design of interceptor sewers, however, consideration will have to be given to infiltration conditions in each specific sewerage area.

For new construction involving separate sanitary sewers, a wet season allowance of 600 gpad will provide a safety factor of about 100 per cent over and above that which could reasonably be attained. This allowance implies the use of suitable jointing materials and the provision of adequate inspection during construction of sewers and house connections. Because of reduced ground water levels, a design allowance of 300 gpad will suffice for dry season conditions.

Storm Inflow to Sanitary Sewers. Storm inflow to existing sanitary sewers can be reduced materially by means of the corrective measures described in Chapter 16. An allowance of 2,000 gpad, which rate is seldom exceeded in the Lake City system, is therefore suitable for design purposes. In other words, the combined infiltration and inflow allowance amount to a total of 3,200 gpad. Records for all other separate systems indicate that the wet weather rates therein do not exceed this total.

In the case of new construction, assuming availability of adequate storm drainage facilities and appropriate regulations to prevent direct connection of catch basins, downspouts and foundation drains, no allowance need be made for summer storms. For winter storms, an allowance of 500 gpad is advisable in order to accommodate minor inflow from undetected sources.

Composition

In recent years, a general increase in the strength of sanitary sewage has been noted in many cities and is believed to reflect the effect of several factors, notably the increased use of home garbage grinders. Design criteria must allow for a continuation of this trend. In the case, therefore, of treatment plants serving areas of primarily residential and commercial development, unit values appropriate for planning purposes are 0.20 ppcd for BOD and 0.25 ppcd for suspended solids.

For the Diagonal Avenue treatment plant, which serves a diversified industrial area, available analysis results (Table 7-13) indicate that the strength of the wastes now being received is similar on the whole to that of sanitary sewage. As far as the future is concerned, it is possible that the strength of the industrial wastes may increase substantially as a result of changes in the industrial pattern. This, however, will pose no particular problem, providing trunk sewers and treatment plant structures are designed with a capacity sufficient to accommodate the increased flow. On that basis, any increase in strength could be accommodated by constructing additional digestion and sludge handling facilities.

Assuming, therefore, that sewage and industrial waste strengths will remain equal, equivalent population values can be assigned to industrial areas on the basis of average daily waste volume. For the contributions referred to above, the equivalent populations are 33 persons per acre at 2,000 gpad, and 67 persons per acre at 4,000 gpad. As applied to the metropolitan area as a whole, this method of calculation results in a BOD and suspended solids allowance for industrial waste in an amount equal to 40 per cent of that for sanitary sewage.

With reference to the grit transported in sewage from a combined system, design should be based on removal of the large amounts carried by storm flows. As pointed out earlier, existing facilities at the Diagonal Avenue sewage treatment plant remove an average of about 5 cubic feet of grit per million gallons under dry weather conditions. This value is in line with average dry weather removals recorded at treatment plants in San Francisco which serve combined systems.

In wet weather, as much as 50 cubic feet per million gallons is removed at the San Francisco plant. At Seattle, where it is necessary to use from 600 to 1,000 yards of sand per day for sanding icy streets, much larger amounts of grit can be expected. Under storm flow conditions, therefore, an allowance of 80 cubic feet of grit per million gallons is appropriate.

Sewage from systems which are entirely separate normally carries only 0.2 to 0.4 cubic feet of grit per million gallons. Deposits which accumulate during dry weather, however, are flushed out by peak wet weather flows and may, at such times, result in a grit load as high as 5 cubic feet per million gallons.

Chapter 8

ENVIRONMENTAL AND ECONOMIC EFFECTS OF SEWERAGE AND DRAINAGE DEFICIENCIES

Environmental effects stemming from sewerage and drainage deficiencies in the metropolitan Seattle area range from minor nuisances to conditions involving a significant hazard to community health and well being. Economic effects, in addition to those involving damage to property, include losses due to impairment of fisheries resources and of areas devoted largely to recreational activity. For convenience in presentation, sewerage deficiencies will be considered under each of two categories, namely, those associated with community disposal systems and those associated with individual disposal systems. Additionally, consideration will be given briefly to the effects of these systems, both community and individual, on the waters of Lake Washington and Puget Sound. And finally, effects attributable to inadequate drainage will be outlined and some of the problems relating to conditions in suburban areas will be discussed.

COMMUNITY SEWERAGE SYSTEMS

In community sewerage systems, the deficiencies which lead to nuisance conditions and other objectionable effects consist generally of insufficient sewer capacity, leaking sewers, illicit drain connections, and either inadequate treatment or no treatment. Many of the facilities presently in use not only are incapable of meeting future needs but are already overloaded or otherwise inadequate.

Overloaded collection sewers, whether due to an inherent lack of capacity or to excessive infiltration and storm inflow are manifested by overflowing manholes, localized flooding, and backing up of sewage into basements. These conditions result, in turn, in local nuisance and inconvenience, in property damage, and in situations hazardous to public health.

Overloading of Seattle Sewers

Many of the combined sewers now serving the city of Seattle were designed and constructed around the turn of the century. In view, therefore, of their age and of the heavy burden which has been imposed on them as a result of the unprecedented population growths in recent years, it is not surprising that various shortcomings are becoming increasingly apparent. What is surprising, perhaps, is the fact that most of these old sewers are still in reasonably good condition and are deficient only to the extent that they lack the capacity to carry the combined flows of sewage and storm drainage.

On the basis of design criteria employed until recently, overloading of the combined sewers can be

DURING PERIODS OF RAINFALL, combined sewers in Seattle frequently become overloaded. In this view, combined sewage and storm water is surging from two manholes.

Fig. 8-1. Sources of Sewage Backup Complaints in Seattle, 1952 - 57

MERCER ISLAND
LAKE WASHINGTON
ELLIOTT BAY
PUGET SOUND
HARBOR ISLAND
DUWAMISH HEAD
SMITH COVE
ALKI POINT
WILLIAMS POINT
FAUNTLEROY COVE
BRACE POINT
DUWAMISH RIVER
PROPOSED WATERWAY
BOEING FIELD
LAKE WASHINGTON PONTOON BRIDGE
SUNSET HIGHWAY

expected to occur on an average of once every two years (Chapter 6). Furthermore, most of these sewers are serving systems which have been extended far beyond the limit anticipated at the time of design. As a consequence, many of them become overloaded during periods of even light rainfall and are thus responsible for relatively frequent trouble with backed-up sewage and overflowing manholes.

In 1951, the city engineering department made an extensive study of sewer capacities. Initial results of that study, as reported by the department in 1952,[1] indicated that, even on the original basis of design, over 50 per cent of the sewers serving the city were overloaded. These studies have since been continued and have served to substantiate the initial findings.

Since 1951, the city engineering department has been keeping a record of complaints about sewage backup. This record is plotted in Fig. 8-1, which shows the number and sources of complaints for a 6-year period ending in the spring of 1957. In all, 692 complaints were received during the six years, representing an average of about 115 per year. In reviewing this record, it should be noted that the recorded complaints cover only those which were accompanied by a claim for alleged damage. Numerous complaints are received following almost every storm but are not officially recorded unless they involve a claim for damage.

Table 8-1 lists the number of claims associated with the six heaviest storms during the six-year period. As there indicated, these storms resulted in a total of 314 claims, ranging from 36 for the storm of June 4, 1956 to 68 for the storm of December 19, 1953. Since heavy storms account for less than one-half of the total number of complaints, it appears that the sewers in some areas become overloaded during storms of lesser severity.

According to sewer maintenance personnel, flooding of streets and washouts in the vicinity of overflowing manholes occur at frequent intervals. One such incident took place during the storm of February 24, 1957 at a survey metering station situated at 11th Avenue and West 45th Street. In this case, an overflow from the manhole caused a street washout 25 feet in diameter and 30 inches deep.

Although the total expense incurred by the city in the payment of claims and in the repair of damages due to sewage backups reportedly falls far short of the capital outlay which would be required for corrective purposes, no one is inclined to contend that such incidents should be condoned or allowed to continue.

[1]Planning and Progress, Seattle City-Wide Sewage Disposal Problem, *Seattle Engineering Department, 1952.*

Table 8-1. Complaints of Sewage Backups Received by the City of Seattle following the Heaviest Storms of Recent Years

Date of Storm	Complaints Received[a]
June 29, 1952	56
September 30, 1953	54
December 19, 1953	68
June 4, 1956	36
February 24 and 25, 1957	54
April 18 and 19, 1957	46
Total for six storms	314

Source: Seattle Engineering Department.

[a]*Only complaints involving alleged damage are recorded.*

Basements flooded with backed-up sewage, if not an actual hazard to health, are certainly a source of severe discomfort and annoyance. As such, they represent a dereliction in sewerage service which should be minimized or eliminated.

From an economic standpoint, heavy surcharging can lead to severe damage of sewers and their appurtenant structures and thus to a possible outlay for necessary repair and replacements. This condition is especially true in the older brick sewers.

In considering the present overload problem, it is important to bear in mind the fact that substantial portions of the areas tributary to already inadequate sewers are not as yet fully developed. Obviously, therefore, flooding and overflow conditions are bound to become increasingly serious unless measures are taken in the meanwhile to provide necessary relief.

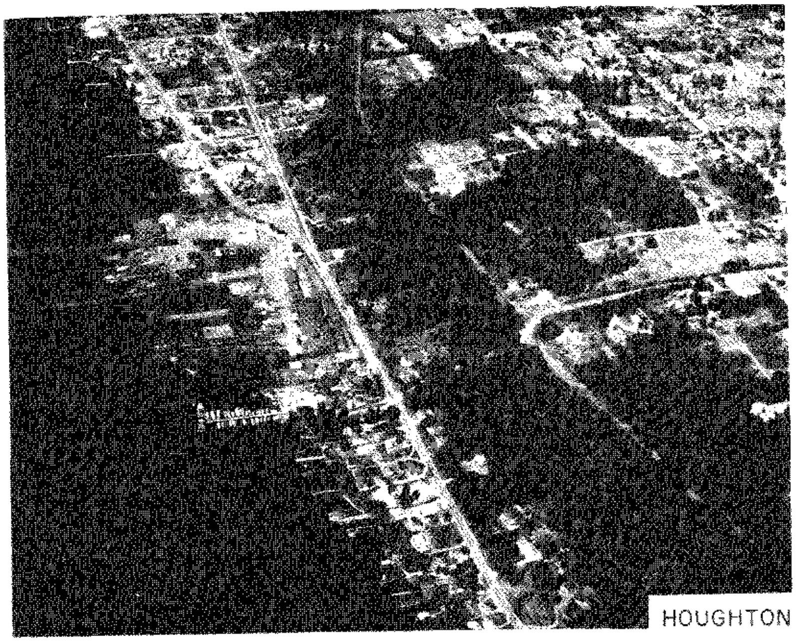
Deficiencies in Other Systems

Serious overload conditions prevail also in many public sewerage systems outside Seattle (Chapter 7). Although many of these systems have been constructed since World War II, infiltration and storm inflow quantities already overtax both sewer and treatment plant capacities. In some cases, there is little or no capacity left either for increased sanitary sewage flows which will result from future increases in population, or for the additional infiltration and storm inflow which will result from collection system extensions.

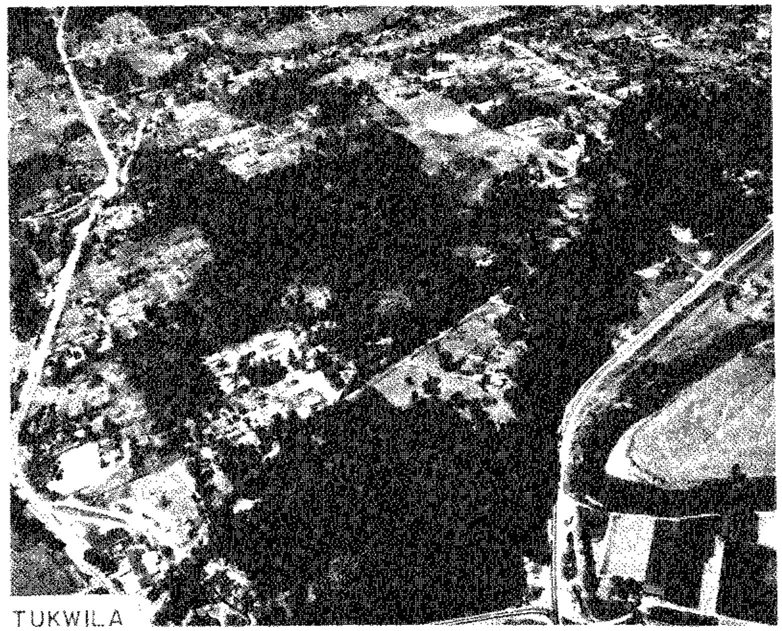
INDIVIDUAL SEWAGE DISPOSAL SYSTEMS

Approximately 30 per cent of the metropolitan area population still lacks public sewerage service. Of this group, about one-sixth lives on farms and other sparsely settled areas, and the balance lives in sub-

DEVELOPMENT IN UNSEWERED AREAS. Within the metropolitan area, a total of approximately 100 square miles is now in urgent need of public sewerage. In addition to suburban developments north and south of Seattle and east of Lake Washington, the unsewered area includes eleven incorporated cities. These aerial views illustrate the extent of development dependent on individual sewage disposal systems. →

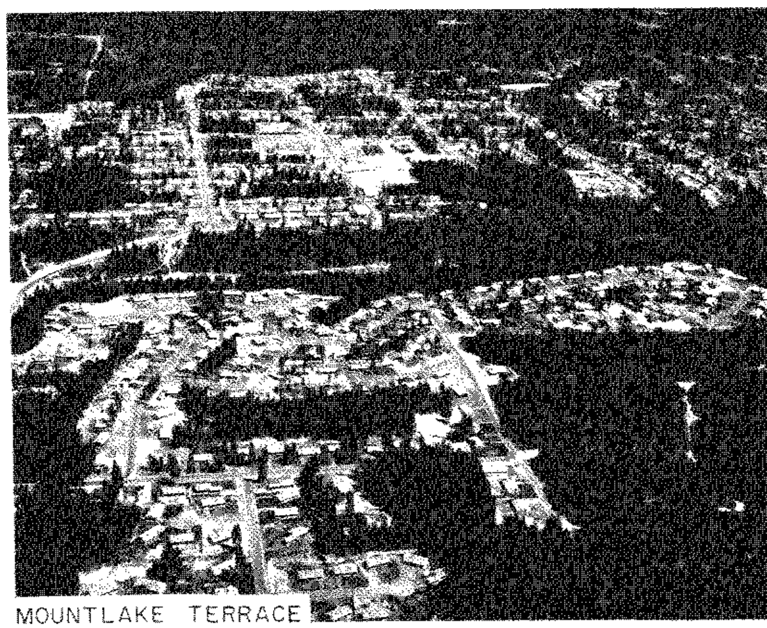


HOUGHTON

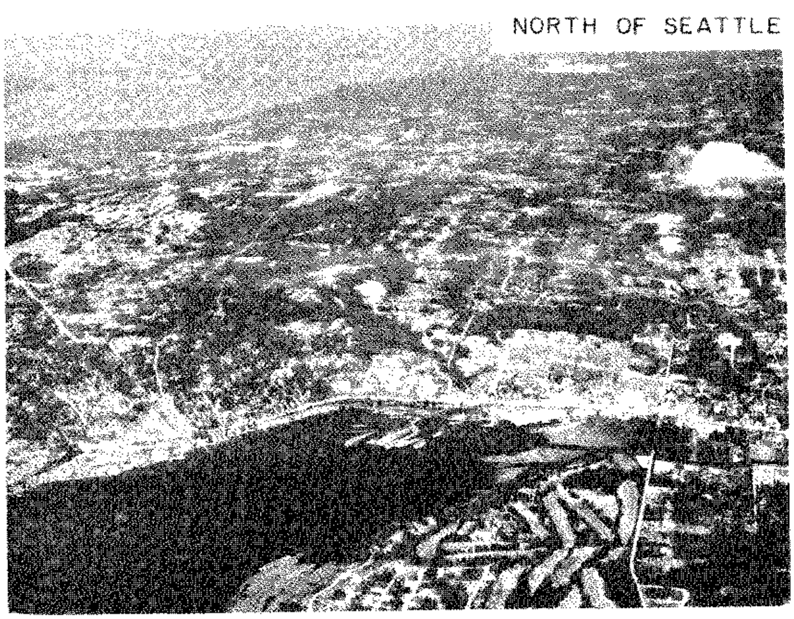


TUKWILA

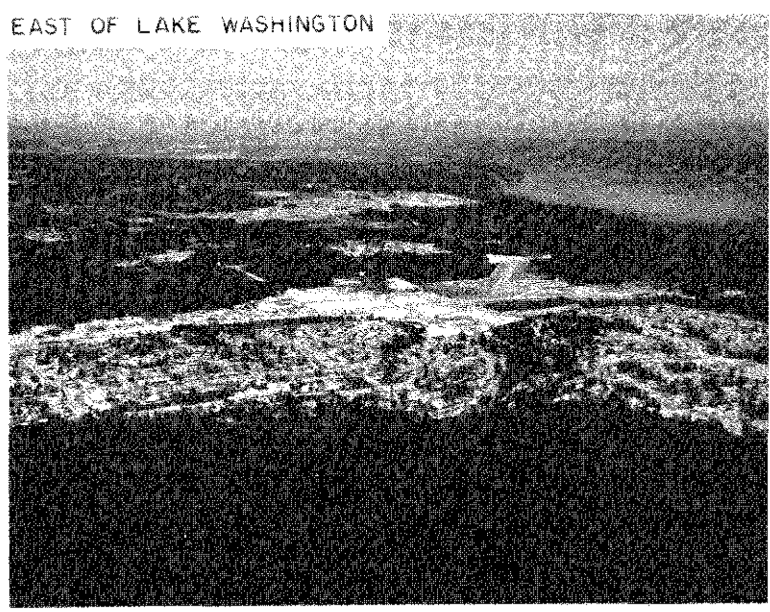
BOTHELL



MOUNTLAKE TERRACE



NORTH OF SEATTLE



EAST OF LAKE WASHINGTON

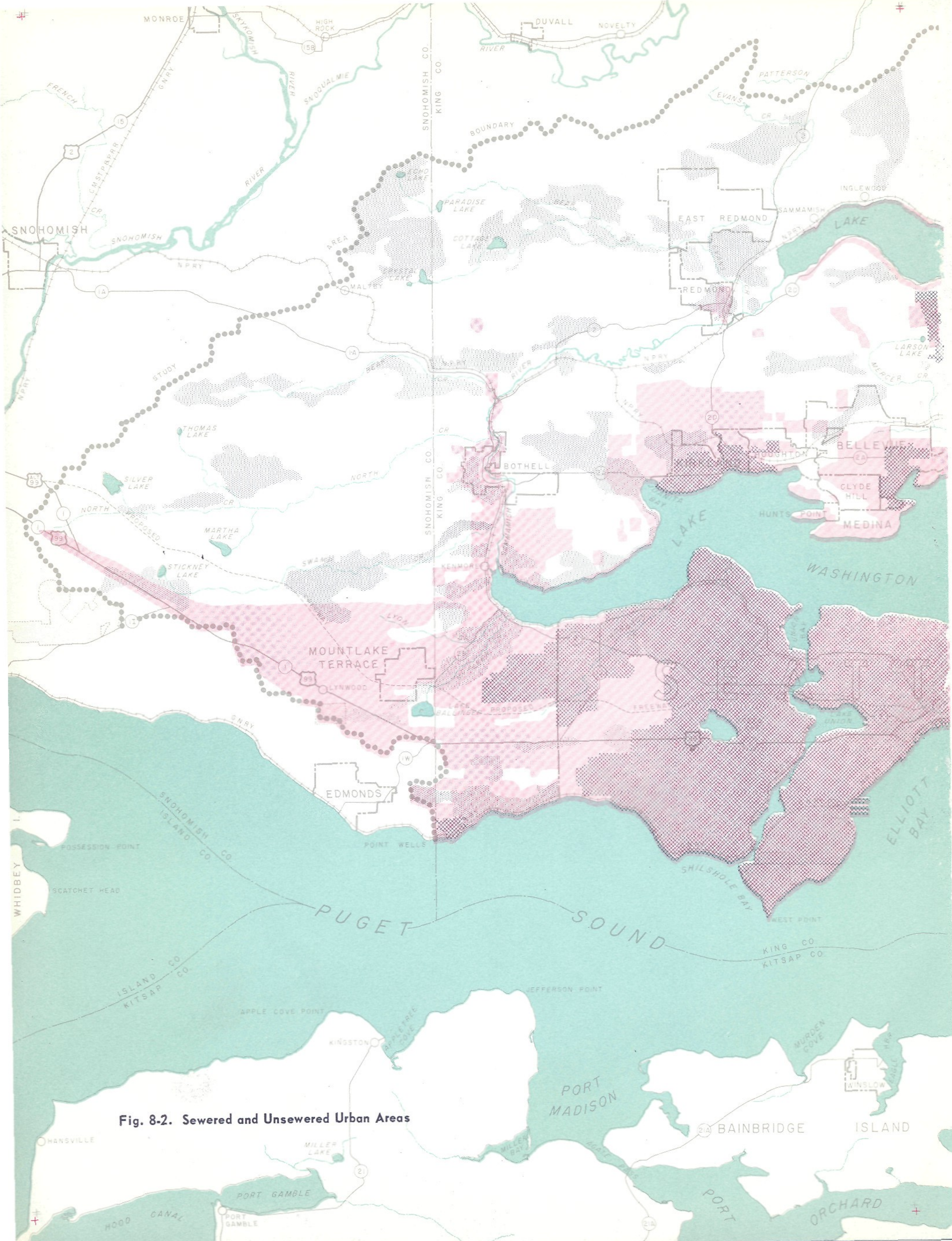
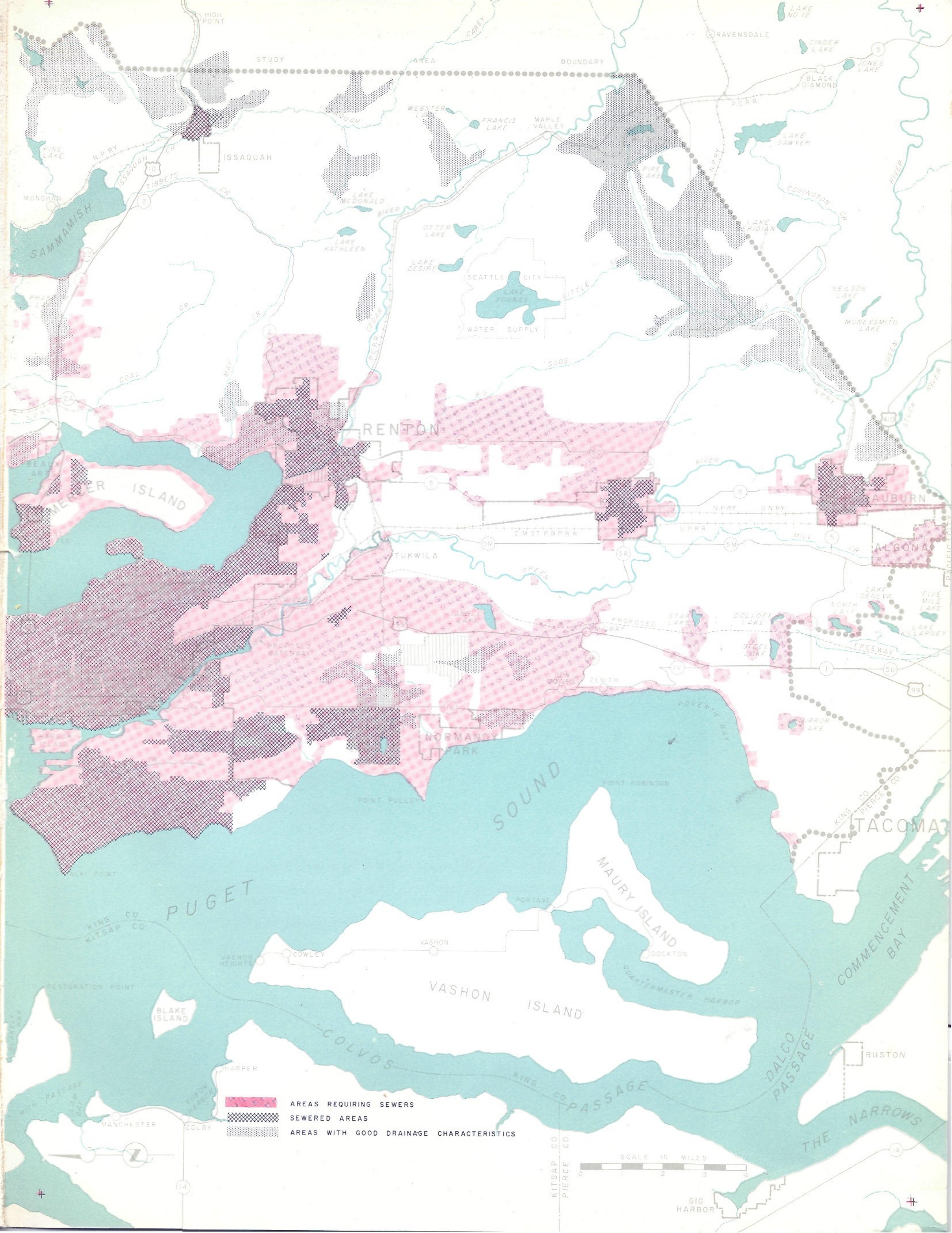


Fig. 8-2. Sewered and Unsewered Urban Areas


AREAS REQUIRING SEWERS
SEWERED AREAS
AREAS WITH GOOD DRAINAGE CHARACTERISTICS
STUDY AREA BOUNDARY
SCALE IN MILES
0 1 2 3 4
ISSAQUAH
RENTON
TUKWILA
AUBURN
ALGONA
TACOMA
RUSTON
MERCER ISLAND
NORMANDY PARK
DES MOINES
ZENITH
MIDWAY
MAPLE VALLEY
BLACK DIAMOND
RAVENSDALE
HIGH POINT
MONOHAN
SAMMAMISH
PINE LAKE
LAKE YOUNGS
SEATTLE CITY WATER SUPPLY
PUGET SOUND
VASHON ISLAND
MAURY ISLAND
BLAKE ISLAND
COLVOS PASSAGE
DALCO PASSAGE
THE NARROWS
COMMENCEMENT BAY
QUARTERMASTER HARBOR
POINT PULLEY
POINT ROBINSON
ALKI POINT
RESTORATION POINT
PORTAGE
VASHON
VASHON HEIGHTS
COWLEY
DOCKTON
HARPER
MANCHESTER
COLBY
GIG HARBOR
KING CO
KITSAP CO
PIERCE CO

urban areas and cities. In the latter case, insanitary conditions and economic problems brought on by the lack of public sewerage have been a matter of increasing concern not only to the residents directly affected but to local officials and health and pollution control authorities.

Although previous reports on sewerage problems have mentioned those of the unsewered areas, no attempt has been made either to determine the geographical extent of such areas or to assess their importance in terms of economic and other factors. As a part of the present survey, therefore, the location and extent of these areas has been determined and information has been obtained concerning their current problems.

Basis for Need of Public Sewerage

Experience in the metropolitan area indicates that it usually becomes advantageous to construct public sewers when the population density reaches about 4 persons per acre. At this stage of development, individual systems are subject to relatively frequent failure and thus are likely to be more costly than public sewerage. Failures occur when the surrounding surface soils become saturated with sewage effluent and drainage is either impeded or stopped altogether

Extent of Area in Need of Public Sewerage

In determining the extent to which public sewerage is presently required, it is necessary first to ascertain which portions of the metropolitan area fall within the density requirement. To that end, preliminary information was obtained from census tract data, from existing land use maps, and from aerial survey maps and photographs. This procedure, augmented by direct areal inspection, resulted in the delineation of about 200 square miles having a population density of 4 or more per acre (Fig. 8-2). Subtracting from this figure the 87 square-mile area which is already sewered (Table 6-1) leaves a gross unsewered area of 113 square miles. After deducting allowances for minor uninhabitable areas and for small vacant tracts which lie within developed areas and were unavoidable included in the gross total, the net area in need of sewers amounts to 100 square miles.

For the study area as a whole, the population of the portion without public sewers amounts at present to a total of 260,000. This represents the study area population (Table 5-9) less (1) the population of the sewered area (Table 6-1) and (2) an estimated 40,000 persons residing in rural portions. In terms of density, a total of 260,000 in an area of 100 square miles amounts to a little over 4 persons per acre.

Sewage Disposal in Unsewered Areas

Approximately 85,000 individual household sewage disposal systems are now in use in the unsewered area depicted in Fig. 8-2. Almost all of these installations depend on soil leaching systems for the disposal of septic tank effluent. Leaching is accomplished usually by means of tile drains laid several feet beneath the ground surface. Some private systems, however, employ dry wells and others discharge directly to roadside ditches and to streams and lakes.

Effect of Unfavorable Soil Conditions

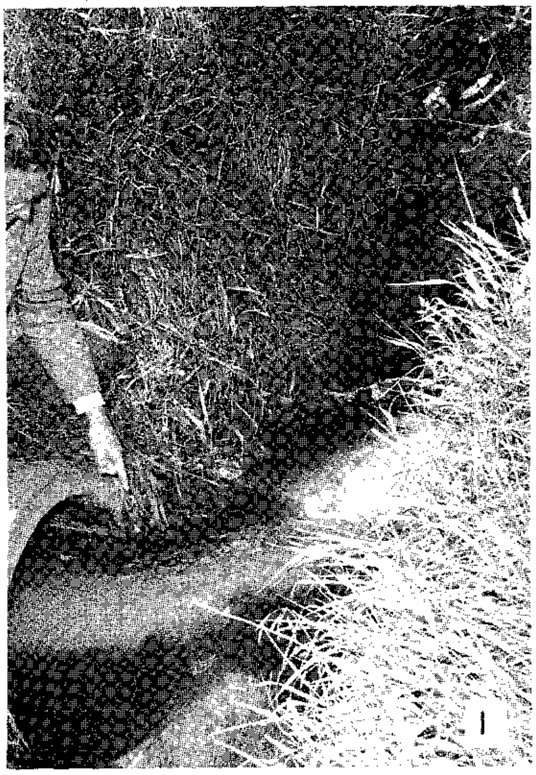
Optimum soil drainage conditions prevail in only a small percentage of the metropolitan area (Fig. 8-2). In the remainder of the area, drainage is either poor or variable. It is poor, of course, where surface soils are impervious, and is variable either where surface formations are underlain by an impervious stratum or where the area is subject to a high ground water table or flooding (Fig. 3-5).

Under optimum conditions of soil drainage, and providing the septic tank is adequately maintained, a leaching system may function satisfactorily for many years. On the other hand, in soils with poor drainage characteristics or in areas where ground water is too near the surface, leaching failures may develop after only a short period of use. In such an event, the tank effluent pools on the ground surface or seeps into roadside ditches. In hilly areas where the surface soils are underlain by an impervious stratum, the effluent may be transported laterally for a considerable distance, ultimately seeping out of hillsides, accumulating in low areas, or finding its way into surface waters.

Leaching system failures are usually more or less isolated during the early stages of a subdivision development. As the number of septic tanks increases, however, the effluent effects tend to become cumulative and result eventually in saturation of the surface soils. When that happens, leaching line failures are frequent and conditions develop which not only are a nuisance but a serious menace to community health.

Effects of Crowded Installations

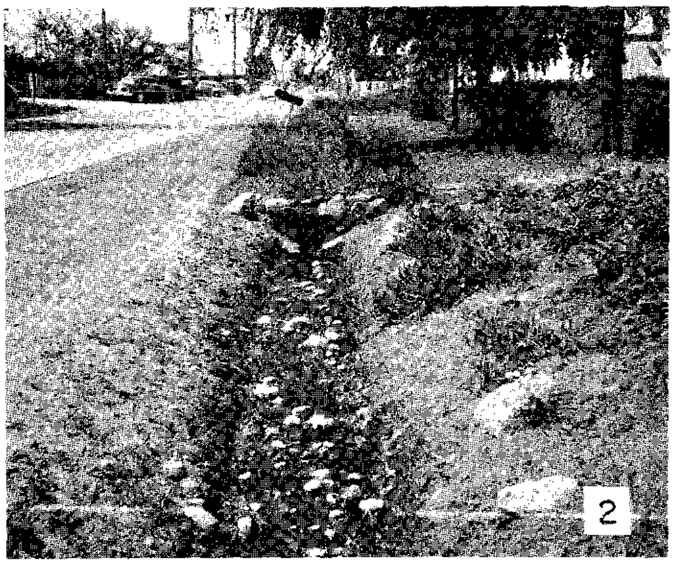
The consequences of too many private disposal systems in localities where drainage is inadequate are revealed in records of the Seattle-King County Health Department. These records show that the department is called upon during an average year to make approximately 6,000 inspections of private system failures. Many other failures are known to occur but are corrected without being referred to the department. Based on the reported cases alone, at least one out of every fourteen units fails each year. These failures are common in the heavily developed sections north and south of Seattle, in southwesterly Snohomish

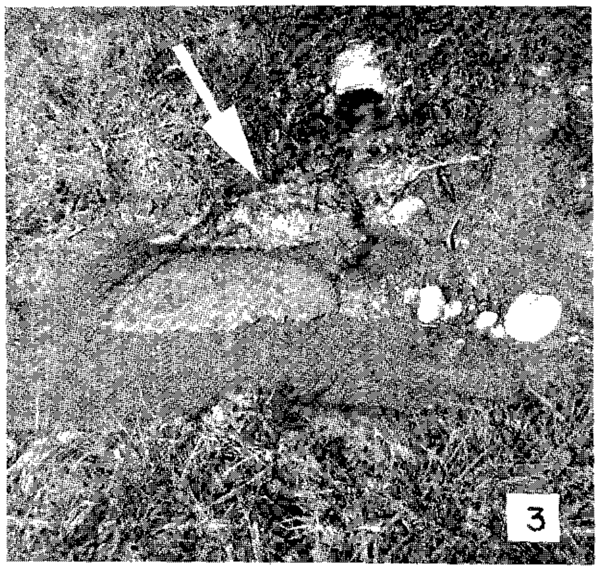


(1) CLOUDY SEPTIC TANK EFFLUENT is visible in the discharge from this storm drain.

(2) THIS IS ONE OF MANY ROADSIDE DITCHES carrying a continuous flow of septic tank effluent.

(3) DIRECT DISCHARGE TO OPEN DITCH. Note sludge deposit.





County, and along the eastern shoreline of Lake Washington.

During the course of the survey, septic tank overflows were observed at numerous locations. In some parts of the study area, conditions have become so intolerable that the issuance of building permits has been greatly curtailed. In others, the permits require leaching lines of such an extent as to make the installation cost prohibitive. Faced with these prospects, subdividers and builders frequently are unable to proceed with proposed developments.

Cost of Sewage Disposal in Unsewered Areas

Health Department records for the past six years indicate that private disposal systems have been constructed at the rate of about 6,000 per year. At an estimated average cost of $375 per installation, this means that the annual investment in such systems is about $2,250,000.

Reasonable maintenance practice requires that the accumulated solids be removed from septic tanks at least once every five years. On that basis, approximately 17,000 of the 85,000 units now in use require cleaning every year. At the prevailing rate of $30

IMPERVIOUS SOIL CONDITIONS (photo 1), indicated here by local flooding, retard downward drainage of septic tank effluent.

SEEPAGE OF SEPTIC TANK EFFLUENT (photo 2, arrow) toward roadside ditch results from leaching line failure brought about by impervious soil condition.

PERIODIC RENOVATION of leaching lines (photo 3) is required in areas where downward drainage is inadequate.

per cleaning, this represents an annual expenditure of about $510,000.

Costs of repairing leaching line failures vary over a wide range. While minor repairs may suffice in some cases, replacement of part or all of the drain lines is often required. At the present rate of about $2.00 per lineal foot, the cost of total replacement may run well over $300 per system.

Based on discussions with Health Department inspectors, the average expenditure for inspection and repairs is estimated to be not less than $75 per failure. For the 6,000 reported each year, the total annual cost thus amounts to at least $450,000. Since many failures are not reported, the actual total is unquestionably much higher.

It is evident from the foregoing figures that the total annual expenditure for new construction and for the maintenance and repair of private disposal systems aggregates over $3,200,000. In comparison, an annual outlay of that magnitude would finance nearly $50 million worth of capital improvements and would provide local sewers for essentially all of the unsewered areas shown in Fig. 8-2. This comparison is based on an average cost for sewerage facilities of $800 per acre, a 5 per cent interest rate on invested capital, and a 30-year bond life. While additional expenditures for trunk sewers and treatment and disposal works would also be entailed, local sewers so provided would be capable of serving about one-half million persons, or about twice the number served by all the private systems now in use.

REMOVAL OF SEWAGE FROM INLAND AREAS

Coincident with the construction of local sewers, facilities must be provided for conveyance of the sewage to points of treatment and disposal. In some communities, particularly those situated adjacent to bodies of water capable of receiving sewage, the distance involved in conveyance to treatment and disposal points is relatively short and causes no problem from the standpoint of cost. In others, where suitable disposal sites are not close at hand, long and costly sewers are required and may impose a financial hardship of almost insurmountable magnitude.

Many inland communities within the study area have found themselves in the latter predicament. Despite their desire to construct urgently needed local sewers, and their financial capability to do so, they have been utterly unable to finance the sewers which are required to convey the sewage to treatment and disposal sites outside their immediate areas. This situation prevails in most of the densely populated inland sections of the metropolitan area and is particularly acute in the Lake Washington drainage basin.

Recent studies have indicated that nutrient substances contained in sewage effluents being discharged into Lake Washington are causing an excessive algal growth which threatens both its natural beauty and its value for recreational purposes. To prevent further degradation, both the Pollution Control Commission and the State Department of Public Health have enacted regulations designed to bring about the elimination of sewage discharges.

Compliance with these regulations will, of course, necessitate the construction of sewers wherein all sewage will be picked up and carried out of the drainage basin for treatment and disposal elsewhere. Except for a relatively small portion of the basin which is now served by the city of Seattle, no such facilities are presently available and, because of the distances involved, no way has yet been found to finance their construction.

Certain problems are developing in the absence of necessary conveyance sewers and can be expected to continue until such a time as corrective action is undertaken. These problems include:

1. A delay in the construction of vitally needed local sewerage facilities.
2. The continued installation of private sewage disposal systems, many of which are doomed to failure.
3. An exhaustion of financial resources through the construction of temporary treatment works.
4. A curtailment of desirable land developments.
5. A further degradation of Lake Washington and other inland lakes.

CONDITIONS IN ENVIRONMENTAL WATERS

It would be superfluous at this point to stress the importance of environmental waters as a major asset of the metropolitan Seattle area. Until recently, however, their value has been taken for granted and little has been done to minimize or prevent their fouling by discharges of sanitary sewage and industrial waste. With recognition fully established, the problem now is one of determining the extent to which such waters are being degraded and the steps that must be taken in the future to assure effective maintenance of acceptable conditions.

The first extensive study to ascertain the effect of sewage and waste disposal operations on the waters of the area was made by the State Pollution Control Commission in 1942 and 1943. Within the past ten years, several additional studies have been made and between them have covered all of the waters presently subject to sewage and waste discharges. In scope, these studies were concerned with such factors as bacterial contamination, nuisance conditions, chemical and biological effects, and nutrient enrichment of Lake Washington.

Bacterial Contamination

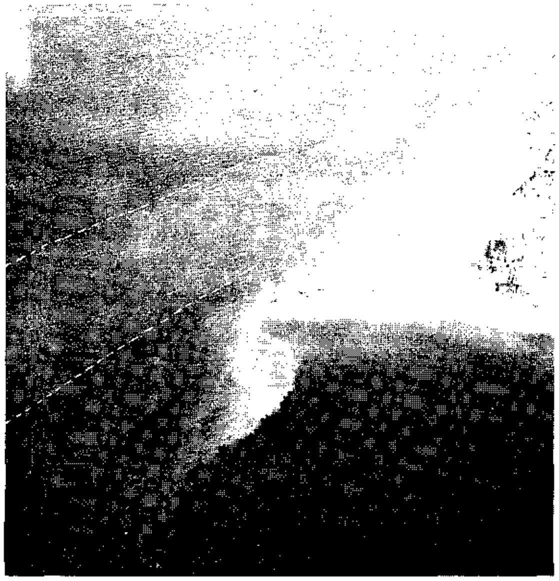
In accordance with standard public health practice, bacterial contamination of water affected by sewage disposal practices is expressed in terms of the MPN (most probable number) of organisms of the coliform group. Members of this group, though not pathogenic or disease producing, are present in immense numbers in fecal discharges of all warm blooded animals, including man. Since the group as a whole is readily cultured and identified, these organisms are a useful indicator of the possible presence of pathogenic bacteria of sewage origin. Certain members of the coliform group, however, propagate in surface soils and, as a result, are normally present to some extent in all natural surface waters. Additionally, drainage from fields fertilized with animal manures frequently is a source of high counts in surface waters.

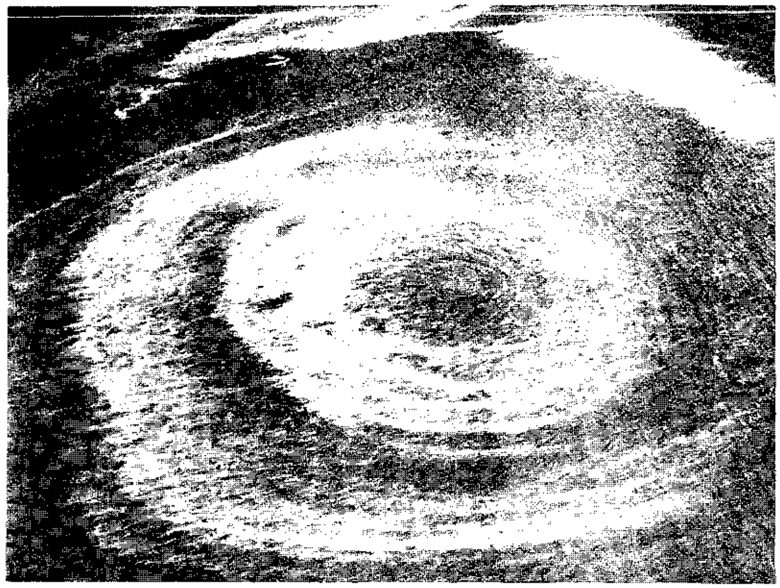
In the case of waters used for recreational purposes, very little evidence is available which relates the degree of coliform contamination to the incidence of water-borne disease. As a result, bathing water standards of governmental health agencies are far from consistent, ranging in upper limits from 240 to 2,400 MPN per 100 ml. Further, these are variously expressed as the arithmetic mean, median, or geometric mean of a series of samples or, in some cases, the maximum for a single sample.[2] It is evident, therefore, that a specific coliform limit does not necessarily define a line between safe and hazardous water but rather is intended as a desirable and, presumably, a reasonably attainable goal.

Over the past fifteen years, several standards of bacteriological quality for bathing purposes have been administratively applied by public health and pollution control agencies in the state of Washington. More recently, however, the Washington Pollution Control Commission has adopted water quality objectives promulgated by the Pollution Control Council, Pacific Northwest Area. For bathing areas, these objectives prescribe that the average MPN in a representative group of samples should not exceed 240 per 100 ml and that this number should not be exceeded in more than 20 per cent of the individual samples examined. This standard is referred to hereinafter as the Washington standard.

Because the Washington standard is believed to be somewhat stringent, the studies reported below made use also of a more lenient standard under which it is stipulated that not more than 20 per cent of a representative number of samples should have a coliform

[2] *Garber, W. F.*, Bacterial Standards for Bathing Waters, *Sewage and Industrial Wastes, 28-6-795 (June 1956).*





SEWAGE "BUBBLE" at terminus of North Trunk sewer outfall (right photo). About 40 mgd of untreated sewage is discharged at this point. Path of sewage field from North Trunk outfall during flood tide (left photo) is distinguishable from normal turbidity along shoreline of West Point. On ebb tides, sewage field was traced to Golden Gardens, two miles north of outfall.

count in excess of 1,000 per 100 ml. Actually, however, it makes little difference which standard is applied, as the coliform count in most of the samples was found to exceed the higher limit.

Summary of Bacteriological Studies, 1942-1951. A sanitary survey of Lake Washington conducted by the State Pollution Commission in 1942 and 1943 included the bacteriological examination of 536 samples taken at 36 sampling stations along the shoreline. A summary of the findings presented in the report on this survey[3] shows that conditions at 27 of the 36 sampling stations failed to meet the Washington standard. On that basis, the commission concluded that substantial sections of the shoreline were unsatisfactory for bathing purposes at the time of the survey.

As a part of his study in 1947 and 1948 of the Seattle sewerage problem,[4] Dr. Abel Wolman arranged for the collection and bacteriological examination of samples of the shore waters of Puget Sound. Under this program, which covered seven major public bathing areas on the sound within Seattle and involved six different sampling periods, the total number of samples amounted to 866, or approximately 125 from each beach. A summary of the results then obtained, as given in the report by Dr. Wolman, showed that not a single beach met the Washington standard during any of the six sampling periods.

In 1949, the State Pollution Control Commission undertook an investigation of pollution problems in Puget Sound. This work was under the direction of Professor R. O. Sylvester of the Department of Civil Engineering, University of Washington, and included an extensive study of bacterial conditions in the shore waters of Puget Sound and in the lower reaches of Green River. A total of 281 samples was taken at 24 sampling stations, 3 of which were in Green River and 21 were situated along the sound between Richmond Beach and the mouth of Salmon Creek. Here again it was found that the Washington standard was exceeded at every station and that few of the stations met the less stringent standards based on an MPN value of 1,000. The report on this work [5] recommended that essentially all of Seattle's Puget Sound beaches be closed to bathing.

In November 1950, the Seattle Engineering Department reinstituted the sampling program carried on during the Wolman survey. For a period of about 13 months, samples were collected on the average of at least once a week at 44 sampling stations situated at bathing areas in the sound and in Lake Washington. In all, 3,150 samples were analyzed, including 1,475 from Lake Washington and 1,675 from Puget Sound. A summary of these analyses, as set forth in a report issued by the city engineer in 1952, indicates that both of the two standards of bacteriological quality were exceeded at all of the Puget Sound stations. At Lake Washington, the Washington standard was exceeded at all stations and 60 per cent of the stations failed to meet the standard based on an MPN of 1,000.

[3] Sources and Extent of Lake Washington Pollution, *Bulletin No. 29, June 1943, State Pollution Commission.*

[4] City of Seattle, Report of Sewage Disposal, 1948, *by Abel Wolman.*

[5] Puget Sound Pollution, Seattle Metropolitan Area, 1949, *R. O. Sylvester and Associates.*

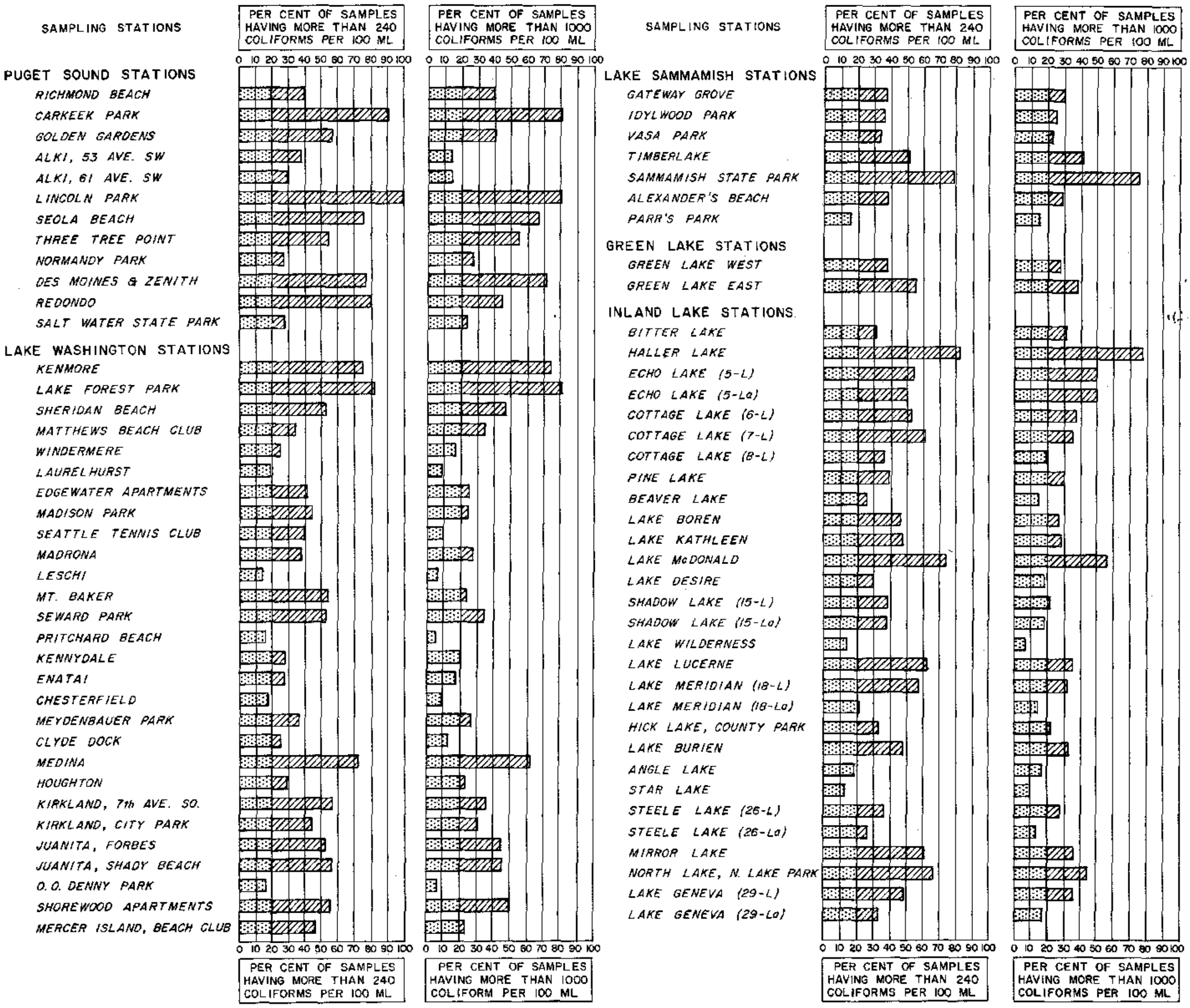


Fig. 8-3. Bacteriological Quality of Bathing Waters in King County

Based on results of sampling program conducted by Seattle-King County Health Department, 1952 to 1956 inclusive (see Table 8-2). Shaded area shows per cent in excess of the indicated standards.

Seattle-King County Health Department Bacteriological Study, 1952-56. The most recent and by far the most comprehensive study of the bacterial quality of the surface waters of the metropolitan area was conducted by the Seattle-King County Health Department during the years 1952 through 1956. This study covered essentially all of the public and semipublic bathing beaches of the area, including beaches at the smaller lakes. In all, conditions were checked at 78 beaches and 3,250 samples were collected and analyzed. From 5 to as many as 138 samples were taken at each station, the total depending generally on the extent of bathing activity.

Results of the health department survey (Table 8-2 and Figure 8-3) show that 69 of the 78 beaches failed to meet the Washington standard and that 55 failed also to meet the standard based on an MPN value of 1,000. None of the 12 Puget Sound stations and only 25 of the Lake Washington stations met the Washington standard, while only 2 stations on the sound and 10 on Lake Washington met the less stringent standard. These findings substantiate those of the previous studies.

Lake Washington beaches adjacent to unsewered residential areas, such as Kenmore, Lake Forest Park and Sheridan Beach, are among the most heavily contaminated. Two factors probably account for this condition. First, because of the poor drainage char-

Table 8-2. Bacteriological Quality of Bathing Waters in King County

Sampling station designation	Location of sampling station[a]	Number of samples analyzed	Years sampling conducted	Coliform organisms, MPN[b] per 100 ml		Per cent of samples	
				Lowest value found	Highest value found	MPN[b] greater than 240	MPN[b] greater than 1,000
1	Richmond Beach	5	53,55	23	24,000	40	40
2	Carkeek Park	22	54,55,56	62	240,000	91	82
3	Golden Gardens	27	55,56	23	7,000	57	41
4	Alki, 53 Avenue SW	21	55,56	23	2,400	38	14
5	Alki, 61 Avenue SW	21	55,56	62	7,000	29	14
6	Lincoln Park	31	55,56	700	24,000	100	81
7	Seola Beach	24	52,53,55,56	240	24,000	75	67
8	Three Tree Point	45	52,53,55,56	0	240,000	55	55
9	Normandy Park	30	52,53,55	0	24,000	27	27
10	Des Moines and Zenith	53	52,53,55,56	15	240,000	77	72
11	Redondo	40	52,53,55,56	23	24,000	80	45
12	Salt Water State Park	39	52,53,55,56	0	240,000	28	23
W-1	Kenmore	24	53,54,55	0	240,000	75	75
W-2	Lake Forest Park	122	53,54,55,56	38	240,000	83	82
W-3	Sheridan Beach	112	53,54,55,56	15	240,000	53	47
W-4	Matthews Beach Club	18	53,55,56	38	24,000	34	34
W-5	Windermere	36	55,56	0	24,000	25	17
W-6	Laurelhurst	32	55,56	0	7,000	19	9
W-6a	Edgewater Apartments	12	56	46	24,000	42	25
W-7	Madison Park	34	55,56	23	7,000	44	24
W-8	Seattle Tennis Club	10	55,56	23	24,000	40	10
W-9	Madrona	37	55,56	46	24,000	38	27
W-10	Leschi	14	55,56	0	24,000	14	7
W-11	Mt. Baker	26	55,56	13	7,000	54	23
W-12	Seward Park	38	55,56	0	24,000	53	34
W-14	Pritchard Beach	37	55,56	6	24,000	16	5
W-15	Kennydale	85	52,53,54,55,56	13	240,000	28	20
W-16	Enatai	104	53,54,55,56	13	240,000	28	18
W-17	Chesterfield	22	53,55,56	15	24,000	18	9
W-18	Meydenbauer Park	48	54,55,56	22	24,000	37	27
W-19	Clyde Dock	16	54,55,56	23	2,400	25	13
W-20	Medina	57	52,53,54,55	0	24,000	72	63
W-21	Houghton	62	53,54,55,56	0	24,000	29	23
W-22	Kirkland, 7th Avenue So.	33	53,54,55,56	38	2,400	57	36
W-23	Kirkland, City Park	54	53,54,55,56	6	24,000	44	31
W-24	Juanita, Forbes	91	52,53,54,55,56	0	240,000	53	45
W-25	Juanita, Shady Beach	68	52,53,54,55,56	23	24,000	57	46
W-26	O. O. Denny Park	42	52,53,54,55,56	46	24,000	17	7
W-28	Shorewood Apartments	138	52,53,54,55,56	0	240,000	56	50
W-32	Mercer Island, Beach Club	30	53,54,55,56	6	7,000	47	23
S-1	Gateway Grove	37	52,53,54,55,56	46	24,000	38	30
S-2	Idylwood Park	41	52,53,54,55,56	0	24,000	37	25
S-4	Vasa Park	44	52,53,54,55,56	22	240,000	34	23
S-5	Timberlake	31	53,54,55,56	0	240,000	52	42
S-6	Sammamish State Park	113	52,53,54,55,56	15	240,000	79	75
S-7	Alexander's Beach	24	52,53,55,56	88	2,400	38	29
S-8	Parr's Park	20	52,53,55,56	0	2,400	15	15
1-L	Green Lake West	39	55,56	0	24,000	38	28
2-L	Green Lake East	42	55,56	6	24,000	55	38
3-L	Bitter Lake	45	52,53,54	12	2,400	31	31
4-L	Haller Lake	113	52,53,54,55,56	5	240,000	82	77
5-L	Echo Lake	52	52,53,55,56	21	240,000	54	50
5-La	Echo Lake	32	52,56	21	24,000	50	50

Continued on next page

Table 8-2. Continued

Sampling station designation	Location of sampling station[a]	Number of samples analyzed	Years sampling conducted	Coliform organisms, MPN[b] per 100 ml		Per cent of samples	
				Lowest value found	Highest value found	MPN[b] greater than 240	MPN[b] greater than 1,000
6-L	Cottage Lake	30	52,53,54,55,56	0	24,000	53	37
7-L	Cottage Lake	23	52,53,54,55,56	0	2,400	61	35
8-L	Cottage Lake	25	52,53,55,56	38	7,000	36	20
9-L	Pine Lake	23	52,53,54,55,56	21	70,000	39	30
10-L	Beaver Lake	27	52,53,54,55,56	0	24,000	26	15
11-L	Lake Boren	11	55,56	23	24,000	46	27
12-L	Lake Kathleen	32	55,56	13	7,000	47	28
13-L	Lake McDonald	23	55,56	23	24,000	74	57
14-L	Lake Desire	27	55,56	13	24,000	30	19
15-L	Shadow Lake	58	53,54,55,56	6	7,000	38	21
15-La	Shadow Lake	29	53,56	46	24,000	38	19
16-L	Lake Wilderness	58	.53,54,55,56	46	2,400	14	7
17-L	Lake Lucerne	66	55,56	21	24,000	62	35
18-L	Lake Meridian	64	53,54,55,56	6	24,000	58	33
18-La	Lake Meridian	14	53,56	21	2,400	21	14
22-L	Hick Lake, County Park	76	52,53,54,55,56	0	24,000	33	22
23-L	Lake Burien	36	53,54,55,56	23	24,000	47	33
24-L	Angle Lake	48	52,53,54,55,56	0	240,000	19	17
25-L	Star Lake	39	52,55,56	22	7,000	13	10
26-L	Steele Lake	25	52,53,55,56	21	24,000	36	28
26-La	Steele Lake	23	52,53,54,55,56	15	2,400	26	13
27-L	Mirror Lake	31	52,55,56	23	7,000	61	35
28-L	North Lake, North Lake Park	18	53,55,56	62	24,000	67	44
29-L	Lake Geneva	29	53,55,56	6	24,000	48	35
29-La	Lake Geneva	18	53,54,55,56	0	24,000	33	17

Data from bacteriological surveys conducted by the Seattle - King County Department of Public Health during the years 1952 to 1956 inclusive.

[a]*See Fig. 8-4.*

[b]*MPN - Most probable number.*

acteristics of the soils in these localities, septic tank effluents are entering the lake. And second, heavily contaminated runoff is entering the lake in streams which meander through densely populated unsewered areas.

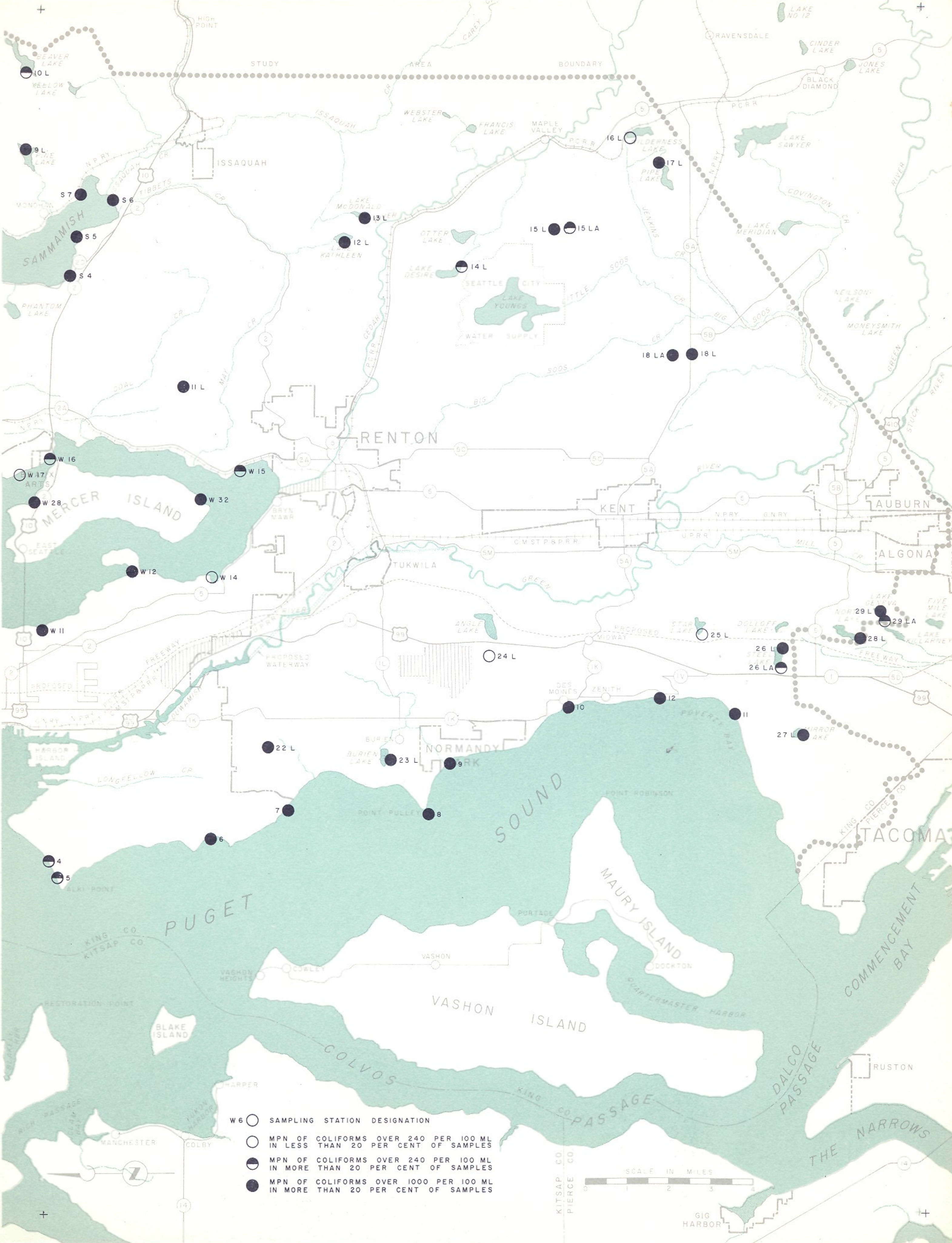
A similar situation apparently prevails at smaller lakes where residential developments along shorelines rely on private disposal systems. Only 3 of a total of 36 sampling stations at these lakes were found to comply with the Washington standard and only 11 complied with the MPN limit of 1,000 per 100 ml.

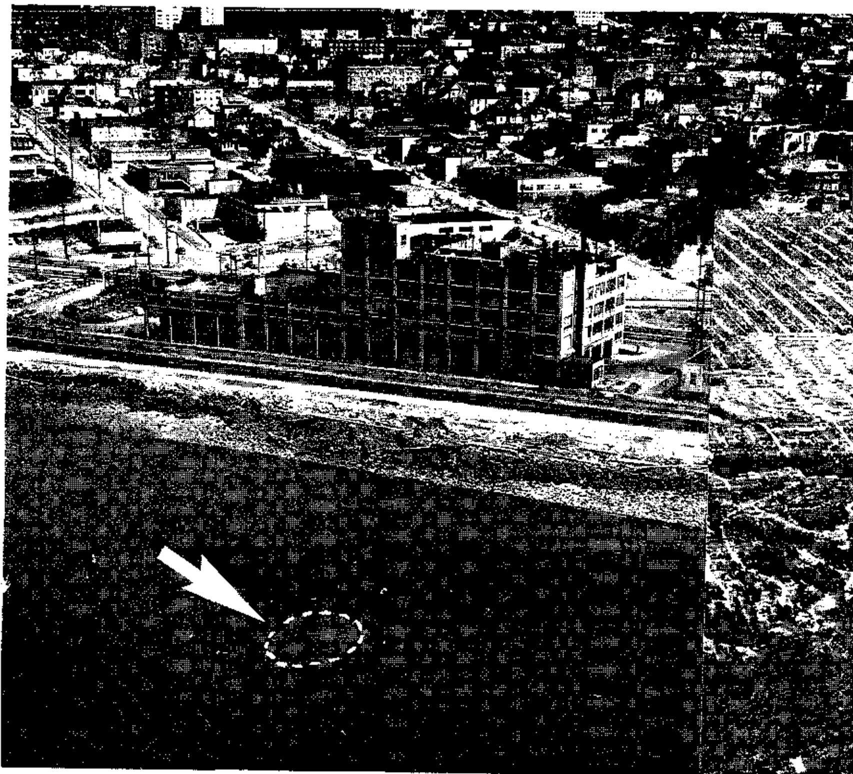
Except in several minor instances, no improvements have been made since the foregoing study was completed which would alter measurably the conditions existing at the time the samples were taken. Locations of the sampling stations, together with conditions in terms of compliance with the standards of quality, are shown in Fig. 8-4.

Surface drainage accounts, of course, for a certain portion of the bacterial densities found at all stations. At most stations, however, the maximum densities were far too high and violations of the standards were far too frequent to attribute the results to natural causes alone. In this regard, the 1949 report of the Pollution Control Commission states: "The natural coliform median for the salt water area, as determined from sampling data over a number of years, is 23 (or less) MPN per 100 ml. This is the value which can be said is due to normal land runoff and waterfowl. . . . Any count in excess of this may be attributed to the presence of sewage. This is particularly true in areas of known sewage discharge in which cases there can be little doubt as to the origin of the coliform organisms."

While it has been argued that there is little epidemiological evidence linking use of contaminated beaches with an actual outbreak of disease, conditions at these beaches are at least a potential hazard and have long been a source of concern to public health authorities. In any case, since coliform organisms are a known constituent of sewage, they should be held to a minimum in recreational waters for esthetic reasons if for no other.

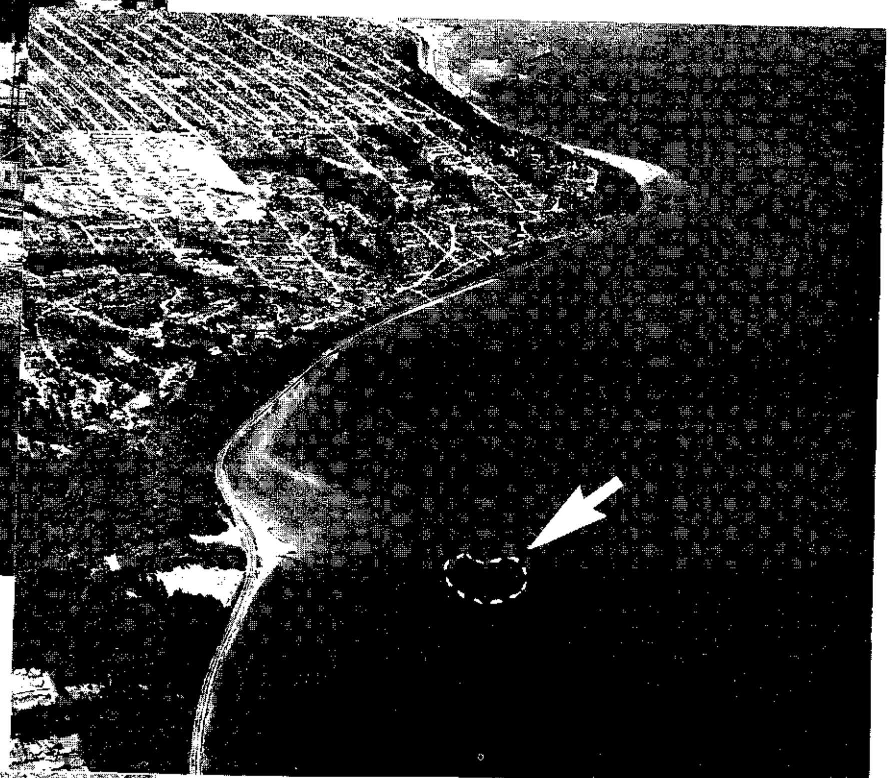
Fig. 8-4. Location of and Conditions at Bacteriological Sampling Stations


STUDY AREA BOUNDARY
RENTON
KENT
AUBURN
ALGONA
TUKWILA
ISSAQUAH
MERCER ISLAND
NORMANDY PARK
TACOMA
RUSTON
PUGET SOUND
VASHON ISLAND
MAURY ISLAND
COLVOS PASSAGE
DALCO PASSAGE
THE NARROWS
COMMENCEMENT BAY
LAKE SAMMAMISH
LAKE YOUNGS
SEATTLE CITY WATER SUPPLY
W6 SAMPLING STATION DESIGNATION
MPN OF COLIFORMS OVER 240 PER 100 ML IN LESS THAN 20 PER CENT OF SAMPLES
MPN OF COLIFORMS OVER 240 PER 100 ML IN MORE THAN 20 PER CENT OF SAMPLES
MPN OF COLIFORMS OVER 1000 PER 100 ML IN MORE THAN 20 PER CENT OF SAMPLES
SCALE IN MILES
0 1 2 3 4



RAW SEWAGE OUTFALL near foot of Denny Way is one of 22 such discharges along the Elliott Bay waterfront.

←



SEWAGE IS DISCHARGED offshore from Carkeek Park public bathing beach at mouth of Piper Creek.

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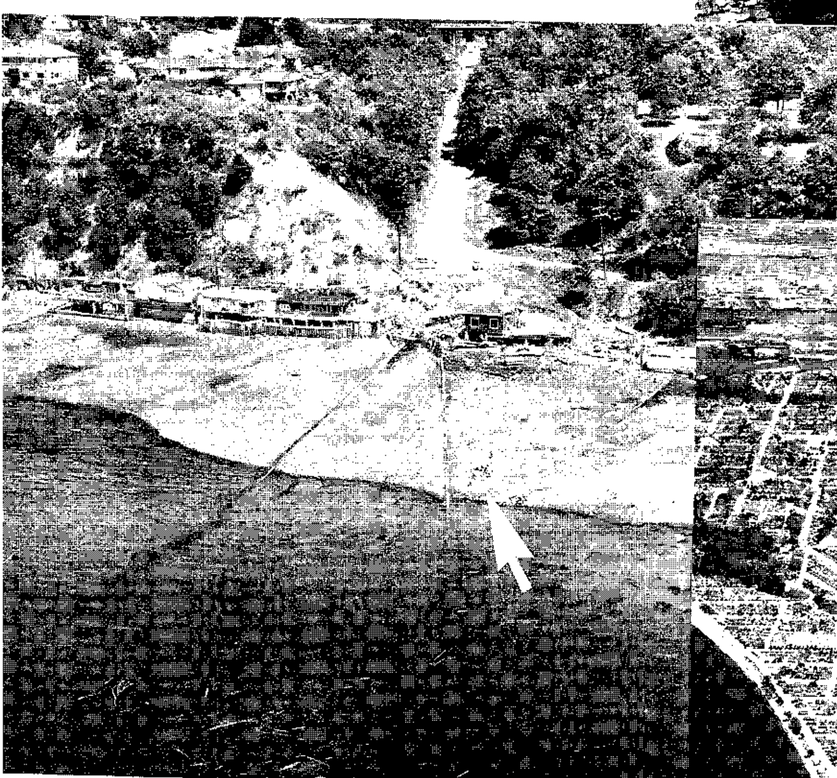
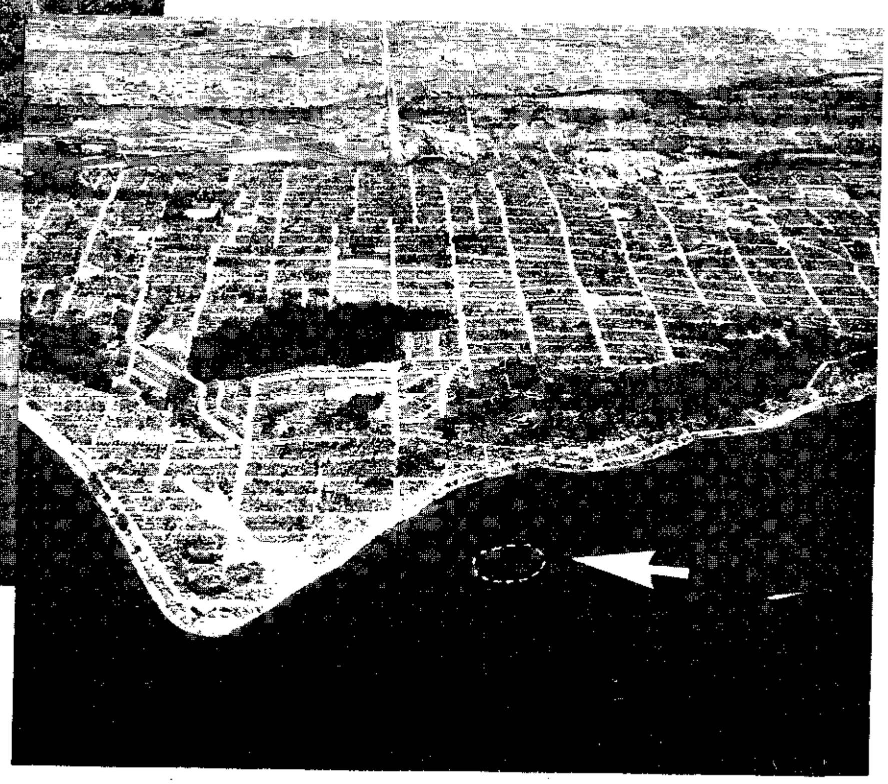


TWIN RAW SEWAGE OUTFALLS at foot of 32nd Avenue West. Note floating debris and children at play at water's edge (arrow).

←



RAW SEWAGE "BUBBLE" off Alki Point (right arrow). This
ischarge will be eliminated when the new treatment plant, now
nder construction, (left arrow) is completed.

→

As a final note, it should be pointed out (1) that many of the salt water bathing areas are at beaches which are utilized also for clamming, and (2) that Lake Washington is utilized at some locations as a source of domestic water supply. Both of these uses call for far more stringent standards than those applicable to bathing waters.

Nuisance Conditions

Raw sewage, in addition to being heavily infested with bacteria, contains both coarse and finely divided suspended and floatable substances, a large proportion of which is putrescible. When discharged into a body of water, the heavy components of sewage usually settle at the bottom, whereas the lighter components either are dispersed through the water or float at the surface. Depending on wind conditions and on current and other water movements, these substances may be transported for considerable distances, ending eventually as shore deposits, as accumulations in quiet areas, or as attachments to physical obstructions such as piers, boathouses and sea walls. Wherever found, they are unsightly and are productive usually of disagreeable odors, bottom deposits, and slime and fungal growths.

Nuisance conditions of the type just described prevail in and adjacent to many local water areas and are inevitable in view of the large number of raw sewage discharges and combined sewer overflows. Previous reports refer to them frequently. In 1948, Dr. Wolman pointed out that physical conditions were poor in inner Elliott Bay, in Lake Union, in parts of the West Seattle shoreline, and in the vicinity of the North Trunk outfall. In 1949, the Pollution Control Commission report on pollution in Puget Sound made repeated reference to the presence of sewage solids on beaches and to grease slicks of sewage origin in the offshore waters.

Various studies conducted as part of the present survey, such as the current studies reported in Chapter 11, afforded ample opportunity for direct observation of nuisance conditions in receiving water areas. Such conditions were most noticeable in the general vicinity of raw sewage outfalls and, to a lesser extent, in the vicinity of combined sewer overflows. At times, however, unsightly conditions and disagreeable odors were found to prevail over relatively large areas.

Sewage debris of every description was found regularly on many of the beaches opposite points of outfall. Debris was frequently found also in the vicinity of points of overflow along the west Lake Washington shoreline. At times, unsightly sewage solids, grease slicks and clouds of turbidity were traced for considerable distances offshore and were observed at other times to travel directly onshore. Odor conditions, which invariably were present near many of the points of raw sewage discharge, at times were noticeable several miles inland from the North Trunk outfall and over considerable areas along Elliott Bay and Duwamish River.

Nuisance effects at any given point can be expected to vary considerably, depending on current, tide and wind conditions. Nevertheless, it can be concluded (1) that nuisances in one form or another prevail continuously in some areas; (2) that there is probably no section of shoreline along Puget Sound, Elliott Bay or Duwamish River which is not at times affected to some degree; and (3) that local nuisances frequently prevail along the Lake Washington shoreline. Visible evidence of sewage from raw sewage outfalls, from combined sewer overflows, and from individual houseboat and pleasure craft discharges was seen more or less continuously in Lake Washington and the Ship Canal. Bypassing and overloading at some of the sewage treatment plants, which occur at rather frequent intervals during the wet season, produce noticeable though less pronounced effects in Puget Sound, Green River and Lake Washington.

Chemical and Biological Effects

Fortunately, Puget Sound has a tremendous capacity to dilute, disperse and assimilate the large quantities of oxygen consuming materials contained in the sewage and industrial waste discharges which it presently receives. Results of previous studies, coupled with those obtained from a limited number of analyses made during the survey, indicate that such discharges, except in the immediate vicinity of the largest outfalls, have essentially no effect on either the dissolved oxygen content or the chemical quality of the waters of the sound.

An examination of a series of 40 bottom samples taken in the vicinity of the North Trunk outfall indicated that such deposits are generally concentrated within a radius of 1,000 feet of the point of discharge. It indicated also that their effect on biological conditions, even within the area of concentration, is limited and that they produce no measurable effects beyond 1,000 feet from the point of discharge (Appendix C). Minor sludge deposits undoubtedly exist in the vicinity of all raw sewage outfalls but their effects are probably even more localized than those observed at the North Trunk outfall.

Recent studies (Chapter 12) have shown that dissolved oxygen concentrations in the lower reaches of Duwamish River have approached and, at times, have been reduced below the generally recognized limit of 5.0 ppm which is required to maintain favorable conditions for fish and other forms of aquatic life. Concentrations as low as 4.8 ppm have been found rather consistently in the vicinity of the Spokane Street bridge during critical periods of the year. In this connection it should be noted that there are times when the oxygen content of the salt water entering the river with the tide approaches the critical limit. It is apparent, nonetheless, that the low oxygen condition in the river is due to the discharge therein of large quantities both of raw and primary treated sewage and of industrial waste. This condition, together with what it means in relation to the valuable fisheries resources of the river, is discussed in detail in Chapter 12.

In terms of general public interest, the one problem which has caused the greatest concern in recent years is the degradation of Lake Washington due to nutrient enrichment brought about by the discharge of sewage effluents. Numerous reports indicate that algal "blooms", with related odors, bottom sediment accumulations, and oxygen depletion, have been greatly accelerated in recent years. At the same time, there have been repeated warnings that the lake is approaching a state of eutrophication, meaning permanent impairment. Because of the importance of this problem, all of Chapter 10 is devoted to a discussion of the biology of Lake Washington and to a detailed analysis of the various factors which contribute to its degradation.

EFFECTS OF INADEQUATE DRAINAGE

Effects of inadequate drainage within Seattle were discussed earlier in this chapter in the section dealing with the overloading of combined sewers. Outside Seattle, drainage problems result largely from the lack of suitable facilities. As noted in Table 6-20, Lake Hills is the only community which has a properly planned system of storm drains.

Very little information is available or could be obtained in regard to drainage conditions in areas which either have no storm drains or are served by drains of inadequate capacity. As a consequence, it has not been possible either to determine the extent to which serious flooding has occurred in these areas or to assess the resulting damage in terms of its economic impact. In the course of the survey, however, it was observed that localized flooding occurs in suburban areas during periods of moderate to heavy rainfall.

From the standpoint of environmental effects, periodic flooding of suburban areas creates a multitude of hazards. In addition to the usual discomfort and inconvenience, public health and safety are endangered, especially in the case of children and their frequent urge to explore storm water accumulations. Likewise, traffic movement is impeded, water supply wells may become contaminated, and normal activity is curtailed.

Economic effects attributable to poor drainage are manifested most obviously by property damage which, depending on rainfall and local conditions, may range from minor to severe. Less apparent is the effect brought about by the practice in many areas of connecting roof, foundation, yard and even street drains to the sanitary sewers. This practice necessitates the oversizing of intercepting sewers and provision of greater pumping and hydraulic capacity at treatment plants than would otherwise be required. As stated earlier in Chapter 7, wet weather flows up to six times the average dry weather flow are being experienced at some locations.

Problems associated with inadequate drainage can be expected to become increasingly severe. Development of suburban communities, with a consequent increase in the areal extent of pavement, roofs, and other impervious surfaces, leads to an increase in storm water runoff and thus to a furtherance of the flood hazard where drainage facilities are inadequate. This situation will continue until such a time as a remedial program is initiated and construction of adequate facilities is undertaken on a systematic and properly integrated basis.

It is not intended to imply that the need for drainage improvements has been ignored. On the contrary, comprehensive studies have been made in some areas and plans for relief have been developed. Apparently, however, no way has been found as yet to finance construction of the recommended facilities.

Drainage problems in suburban areas have received considerable attention on the part of E. L. Evans, county road engineer of King County. As long ago as 1950, Mr. Evans advocated the enactment of legislation under which funds would be made available for the control of flood conditions. In a letter dated December 28, 1950, which was addressed to Charles O. Carroll, prosecuting attorney of King County, Mr. Evans suggested "that an effort be made to have legislation passed which would provide means by which the county could take care of drainage of many depressed areas or pot holes which cannot be drained naturally but are subject to flooding during the winter months, similar to the conditions encountered in the Oak Lake District which we took care of last year.

"We are constantly encountering flood conditions in low areas which have been developed in permitting faster runs than when the territory was in its natural state. We felt that the people living in these areas were entitled to relief the same as those living along a river bank.

"The Board of County Commissioners some time ago requested me to confer with your office, Planning Commission, Health Department, and other interested agencies in an effort to have a bill drawn revising the present flood control laws to take care of these conditions mentioned."

Approximately five years later, Mr. Evans wrote to the Board of County Commissioners, again stressing the flood problem and requesting legislative action.

The following comments from his letter of January 9, 1956 are of particular interest:

"The recent period of heavy rainfall has again emphasized the serious need for proper and adequate drainage disposal facilities for the densely populated suburban areas.

"This office has been literally besieged by demands for relief from this so-called 'outlawed water'. Our expression of sympathy and explanation that the county has no legal means of helping is of little consolation to those people whose homes are being flooded. Many contend the county does have responsibility since they control development of the area through platting and building regulations. Comprehensive studies have been made and feasible plans developed which would, if permitted, control these flash floods. The problem, however, is to obtain funds and legal authority to do the work. County roads, too, would be much easier to construct and maintain without this excessive moisture.

"A number of years ago we recognized the problem and by using improvement funds, supplemented by an appropriation from the state, corrected a flooding situation in the Oak Lake area. Subsequently an opinion obtained from the Prosecuting Attorney ended our program. River funds could not be used for this purpose. Flood damage from rivers could be alleviated but similar damage from drainage could not.

"Our attempt to amend the state law in 1951 was unsuccessful and since then the problem has become increasingly acute. I believe laws are needed now to permit the handling of storm drainage on a metropolitan basis."

It is apparent from the foregoing comments that county authorities are fully familiar with the drainage problems of suburban areas. It is apparent also that local flooding and resultant damage will become increasingly severe until a means is found both to attack the problem on an area-wide basis and to finance construction of the necessary facilities.