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DEPARTMENT OF ECOLOGY

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MEMORANDUM
April 2, 1981

To: Rick Pierce

From: Art Johnson, Darrel Anderson, Shirley Prescott

Subject: Surface Water Quality in Chambers Creek/Clover Creek Drainage Basin, November 1980 - January 1981

Introduction

A water quality survey of creeks and lakes in south Tacoma's Chambers Creek/Clover Creek drainage basin was conducted by the Department of Ecology (DOE) Water and Wastewater Monitoring Section during the period November 1980 through January 1981. Survey objectives were to determine the condition of these waters and compare the findings with available historical data.

The impetus for this work came from concerns voiced by the DOE Southwest Regional Office and the Department of Social and Health Services (DSHS) over deteriorating ground water quality in this expanding urban area. A September 1980 DSHS report concluded that the "high rates of ground water movement possible in the major aquifer unit" coupled with "increased sewage disposal to ground" was causing increasingly rapid deterioration of ground water quality as measured by nitrate, chloride, and bacteria concentrations. Based on these findings, ground and surface water surveys were initiated in November 1980 to gather baseline data and further define the extent of the problem. The ground water work was directed by DSHS and will be described in a separate report. The results of the DOE surface water survey are presented below.

The following report is submitted to meet the above objective. The general format was to follow that used in the DSHS part of the report so that it could be incorporated and published as one report.

AJ:DA:SP:cp

Attachment

SURFACE WATER QUALITY SURVEY

Survey Approach

A water quality survey of creeks and lakes in south Tacoma's Chambers Creek/Clover Creek drainage basin was conducted by the Department of Ecology (DOE) Water and Wastewater Monitoring Section during the period November 1980 through January 1981. Survey objectives were to determine the condition of these waters and compare the findings with available historical data. Again, because of the limited duration of this survey, there has been no attempt to define seasonal variations in water quality.

Study Area Description

The Chambers Creek/Clover Creek system drains approximately 100 square miles of northwest Pierce County ranging from industrialized portions of Tacoma to rural countryside. In the upper basin, Clover Creek and its tributaries, Spanaway and Morey creeks, drain 68 square miles of rural and residential land and flow into the south end of Steilacoom Lake. Spring-fed Ponce de Leon Creek on the lake's east shore is the other major lake inlet.

Steilacoom Lake outlet is the headwaters of 3-1/2 mile-long Chambers Creek which flows to Puget Sound. Flett and Leach creeks join Chambers Creek about 2 miles above its mouth. Flett Creek drains 13.6 square miles including commercial and industrial parts of Tacoma. The Leach Creek drainage consists of 7.1 square miles of lightly developed residential land. Both streams are fed by upstream settling basins which collect and detain urban runoff.

During the period of this survey, flows in upper Clover Creek and in its north fork submerged below their stream beds at points several hundred yards above the confluence of their respective stream channels. Below the confluence, flows gradually resumed, fed primarily by surface runoff from the Brookdale area. This reach of Clover Creek is a diversion of the original channel which followed a more northerly route through Pacific Lutheran University campus.

Sewage disposal throughout the drainage is via septic tank and drainfield with the exception of University Place, Fort Lewis, and McChord Air Force Base which are sewered. No significant point sources are known. Surface waters are classified as state Class A or Lake Class waters in accordance with present and potential uses and in consideration of natural potential water quality.

Survey Methods

Figure 1 shows the location of sites monitored in the drainage. Each of the 21 creek stations was sampled on five occasions between November 1980 and January 1981. The ten lakes included in the survey were sampled once each. All samples were surface grabs.

Temperature, pH, specific conductance, dissolved oxygen, and secchi depth (lakes only) were measured in the field. Creek flows were determined at selected stations from USGS staff gage readings or measurements made with a Marsh-McBirney electromagnetic flow meter. The parameters listed below were determined from samples placed on ice and returned to the DOE Tumwater Laboratory* for analysis according to *Methods for Chemical Analysis of Water and Wastes*, EPA, 1977.

Creeks

1. Turbidity (NTU)
2. Total suspended solids (mg/l)
3. Chemical oxygen demand (mg/l)
4. Total ammonia-nitrogen (mg/l)
5. Nitrite-nitrogen (mg/l)
6. Nitrate-nitrogen (mg/l)
7. Orthophosphate-phosphorus (mg/l)
8. Total phosphate-phosphorus (mg/l)
9. Chloride (mg/l)
10. Fecal coliform (col/100 ml)

Lakes

1. Color (units)
2. Total ammonia-nitrogen (mg/l)
3. Nitrite-nitrogen (mg/l)
4. Nitrate-nitrogen (mg/l)
5. Orthophosphate-phosphorus (mg/l)
6. Total phosphate-phosphorus (mg/l)
7. Chloride (mg/l)
8. Fecal coliform (col/100 ml)

*Most of the fecal coliform analyses were performed by the DSHS Seattle laboratory.

In mid-December an additional series of creek samples was collected at stations 2, 3, 10, 15, 17, 21, and from the South Tacoma Swamp near the Tacoma Airpark and forwarded to the DSHS Seattle laboratory and the Environmental Protection Agency for metal and organic chemical analysis, respectively. The EPA results are not available at this writing.

Results and Discussion

The creek data collected are summarized in Tables 1 and 2. Table 3 shows results for the lake samples.

Creeks: Physical Quality

Creek temperatures remained within state Class A standards as expected this time of year. Most waters were clear when sampled except Clover Creek diversion at station 5 and Flett and Leach creeks. These streams are fed primarily by urban runoff, as described earlier. If the range in turbidity observed in other parts of the drainage is considered background, then the above creeks often exceeded the 5 NTU above background limit allowed for Class A waters (see Appendix A).

These same sites also had the highest suspended solids concentrations. The maximum levels measured in Leach Creek and at Chambers Creek mouth on Puget Sound approached the limits of the 25-80 mg/L range considered only moderately protective of aquatic life[2].

Creeks: Chemical Quality

Dissolved oxygen and pH met Class A criteria with the exception of upper Leach Creek where dissolved oxygen concentrations consistently fell between 6.5 and 7.5 mg/l as compared to the 8 mg/l Class A standard. A violation of the Class A standard at this time of year suggests that dissolved oxygen problems may be severe there during the warmer summer months.

Specific conductance measurements indicated the widest variations in dissolved solids content occurred in Clover Creek diversion and in Flett and Leach creeks.

Ammonia-nitrogen and nitrite-nitrogen concentrations were low except for ammonia-nitrogen in the outlets from Spanaway and Sequalitchew lakes. At each of these outlets the majority of samples collected exceeded a level of 0.2 mg/l indicative of organic pollution. It should be noted that Sequalitchew Lake is used as a rearing pond for trout, and Spanaway Lake's outlet has a permanent duck population. Neither compound approached concentrations toxic to stream life.

Most drainage waters, other than upper Leach Creek, Sequalitchew Lake outlet, and Spanaway Lake inlet, were high in nitrate-nitrogen, exceeding concentrations sufficient to support nuisance growths of algae[3], other growth factors being present in adequate amounts. Spanaway Lake inlet drains undeveloped land on the Fort Lewis military reservation and may represent an approximation of background conditions for the drainage; i.e., 0.2-0.3 mg/l. In general, the higher nitrate-nitrogen levels were observed in Clover Creek with progressively lower levels in Chambers Creek drainage followed by Spanaway drainage. The highest average nitrate-nitrogen concentration for an individual station, 2.2 mg/l, was measured at station 12 on short, spring-fed Ponce de Leon Creek, tributary to Steilacoom Lake.

Low amounts of phosphate were observed in most creeks except in the vicinity of Clover Creek's north fork confluence where the 0.1 mg/l potential algal bloom threshold for total phosphate-phosphorus in running waters was exceeded[4].

Chloride concentrations followed the pattern described above for nitrate in that levels in Clover Creek tended to be slightly greater than in Chambers Creek drainage except for Leach Creek, and considerably above those in Spanaway drainage. The high chloride concentrations in Leach Creek are consistent with previously discussed observations on elevated turbidity and solids, low dissolved oxygen, and relatively low amounts of nitrate-nitrogen in this stream which suggest adverse impacts from urban runoff. The concentrations of dissolved constituents measured in Clover Creek relative to other parts of the drainage are suggestive of input from septic tank leachate.

Based on the limited data collected, trace metal concentrations in most drainage waters may be low. Metal concentrations in most samples analyzed were below minimum detection limits and within recommended levels for protection of aquatic life, as shown in Table 2. Elevated levels of iron, lead, and manganese were detected in the South Tacoma Swamp samples, probably reflecting the urban/industrialized nature of its sources. Flett and Leach creeks and Sequalitchew Lake had elevated iron and/or manganese levels. The detection limits for the mercury and silver analyses were above protection criteria concentrations.

Creeks: Bacterial Quality

Fecal coliform concentrations generally exceeded the Class A standard of 100 colonies per 100 ml (median value) in Clover, Chambers, and Ponce de Leon creeks. Gross contamination; i.e., thousands of colonies per 100 ml was evident in some of the samples collected. Spanaway drainage, Murray Creek, and Sequalitchew Lake outlet were within the standard.

Lake Quality

The south Tacoma lakes included in the survey appear to fall into three groups based on nutrient levels and size, shape, and location. All lakes are phosphate limited as indicated by their total inorganic nitrogen to orthophosphate-phosphorus ratios (greater than 10^5). American, Sequalitchew, and Louise lakes have low nitrate and phosphate concentrations relative to the other lakes and to potential bloom thresholds. These lakes are outside the perimeter of Chambers Creek/Clover drainage basin. Spanaway and Gravelly Lake along the basin's southwest border are a second group comparable in their relatively higher potential for biological productivity as indicated by increased nitrate levels. All the above lakes meet state Lake Class standards (see Appendix A).

Finally, the northern group of small, shallow lakes such as Waughop, Tule, Wapato, and Charlton, and large but relatively shallow Steilacoom Lake have very high production potential at existing nitrate and phosphate concentrations. These lakes also are those where other parameters first begin to indicate reduced water quality. Water clarity was generally low. Wapato and Charlton lakes had depressed dissolved oxygen concentrations and Charlton Lake pH also was low. The highest fecal coliform concentrations were measured in these lakes, with Waughop and Wapato not meeting the state Lake Class standard of 50 colonies/100 ml (median value).

These lake data are in general agreement with results obtained by USGS from samples collected in American, Steilacoom, Spanaway, Gravelly, Louise, and Wapato lakes in the early 1970's (see Appendix B).

Comparison with Historical Data

The historical record of water quality in Chambers Creek/Clover Creek drainage consists primarily of data collected by DOE and USGS at six routine monitoring stations in the early 1960's and mid-1970's. The November-January data from these sites are summarized in Table 4 and compared with results from the same sites sampled during the present survey.

Specific conductance, chloride, and, to a lesser extent, nitrate-nitrogen, show moderate increases with each consecutive sampling period for most stations except lower Flett Creek where these constituents and phosphate decrease in concentration. The removal of the Flett dairy herd in the early 1970's and the closure of a rendering plant adjacent to the dairy may account in part for this decrease. The increase in dissolved constituents in the other parts of the drainage is presumably due to expanding residential development. Phosphate concentrations at the two upper drainage stations on Clover Creek do not appear to have changed with time, while data on lower drainage stations suggest current levels may be less than in past years. Some of this change seems to coincide with a reduced use of phosphate in detergents.

Stronger evidence for a trend toward deteriorating surface water quality comes from station 12A070 on Chambers Creek mouth where monitoring continued during the intervening years between 1964 and 1975. Figure 2 traces data collected at this station on chloride, nitrate-nitrogen, and phosphate. Chloride shows substantial increases between 1964 and the present. The nitrate increase is less pronounced while phosphate remains at about the same level. Also shown in the figure is a consistent winter nitrate peak, apparently a result of the flushing action of winter rains and reduced biological demand. Comparison with rainfall or stream flow data, not available at this writing, would help interpret this historical record.

Summary

The major findings from this survey of surface water quality in Chambers Creek/Clover Creek drainage are summarized below. It should be kept in mind that results of a winter water sampling program may overestimate water quality with respect to temperature, dissolved oxygen, and perhaps other parameters.

1. Creek waters met Class A standards for temperature, turbidity, and dissolved oxygen with the following exceptions: Clover Creek diversion at station 5; Leach and Flett creeks - high turbidity; upper Leach Creek - low dissolved oxygen.

2. Fecal contamination was widespread in the drainage. Clover, Chambers, Flett, Leach, and Ponce de Leon creeks failed to meet Class A fecal coliform standards.

3. Nitrate-nitrogen concentrations were high in all creeks and at or above levels sufficient to support algal blooms except at Sequalitchew Lake outlet. Phosphate concentrations, however, were below bloom potential except in the vicinity of Clover Creek's north fork confluence.

4. In general the highest nitrate-nitrogen and chloride levels were found in Clover Creek with progressively lower amounts in Chambers Creek drainage and in Spanaway drainage.

5. Leach Creek appears to be adversely impacted by urban surface runoff as indicated by its high loads of turbidity, solids, and chloride and its low dissolved oxygen.

6. The relatively increased concentrations of dissolved constituents in Clover Creek in the upper basin are typical of septic tank leachate influences.

7. Based on limited data, trace metal concentrations appear to be low in most of these creeks. Increased levels of iron were noted in Flett Creek and the South Tacoma Swamp. Manganese concentrations were at the protection criteria limit in Leach Creek and Sequalitchew Lake outlet.

8. American, Sequalitchew, Louise, Spanaway, and Gravelly lakes were of good quality. The small, shallow lakes Waughop, Tule, Wapato, and Charlton, and larger Steilacoom Lake have high biological production potential. These lakes have reduced clarity and some show low dissolved oxygen, low pH, and evidence of fecal contamination.

9. Limited historical data indicate that levels of chloride and, to a lesser extent, nitrate-nitrogen, have increased at certain creek sites since the early 1960's. The historical record shows nitrate concentrations are at a maximum in the winter.

Recommendations

1. Conduct a water quality survey similar to that reported here during late summer 1981 to document the condition of Chambers Creek/Clover Creek drainage surface waters during low-flow conditions. Urban runoff impacts to Leach Creek and the influence of septic tank leachate on Clover Creek would be of particular interest.

2. Activate one or more of the historic routine monitoring stations in the drainage in order that, at a future date, a sufficient data base will exist to utilize recently developed trend detection techniques[6]. The suggested stations for activation are, in order of priority, 12A130 Clover Creek at Waller Road, 12A070 Chambers Creek mouth, and 12A110 Clover Creek mouth at Steilacoom Lake.

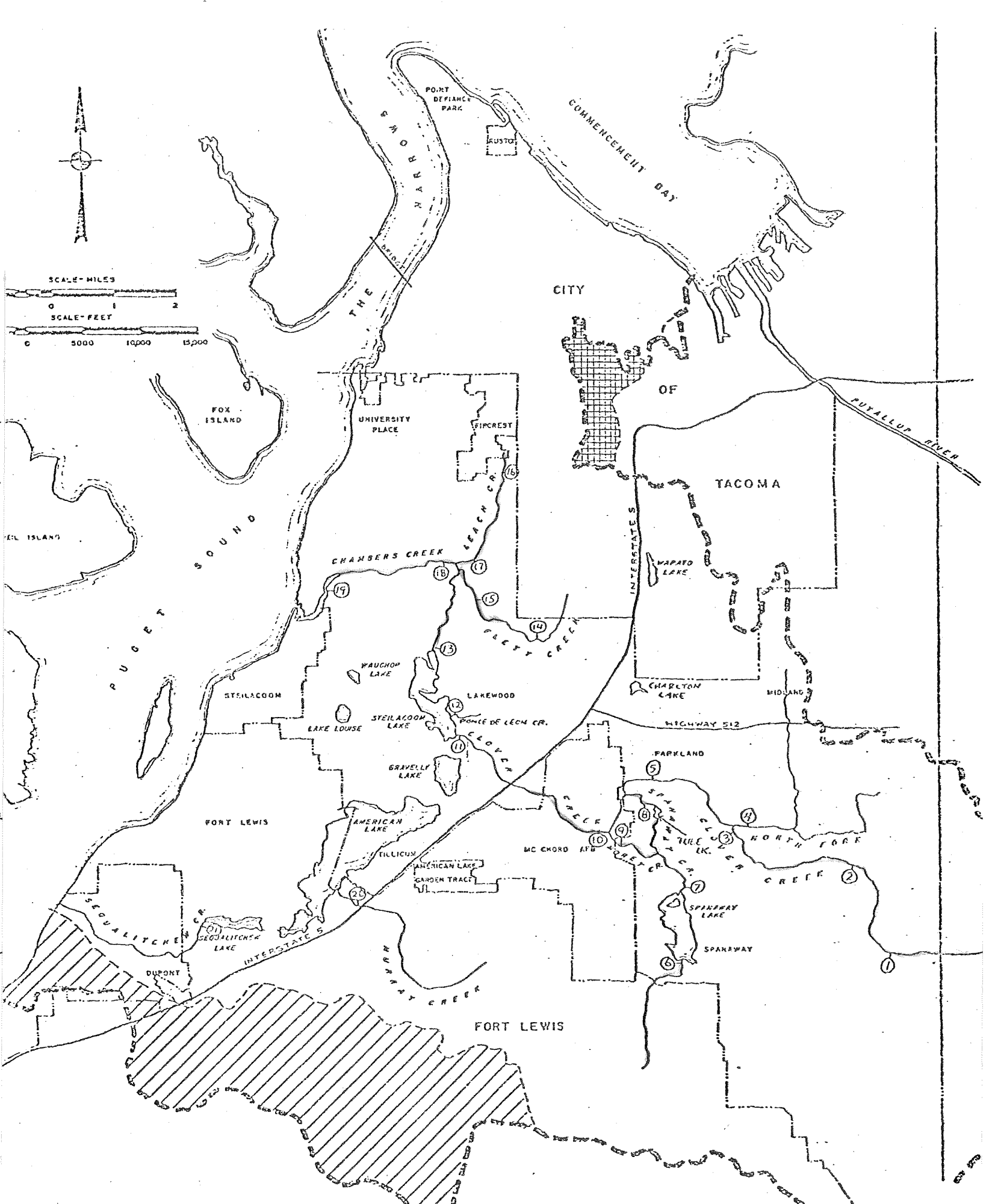

Figure 1. Creek stations and lakes sampled in Chambers Creek/Clover Creek drainage, November 1980 - January 1981.

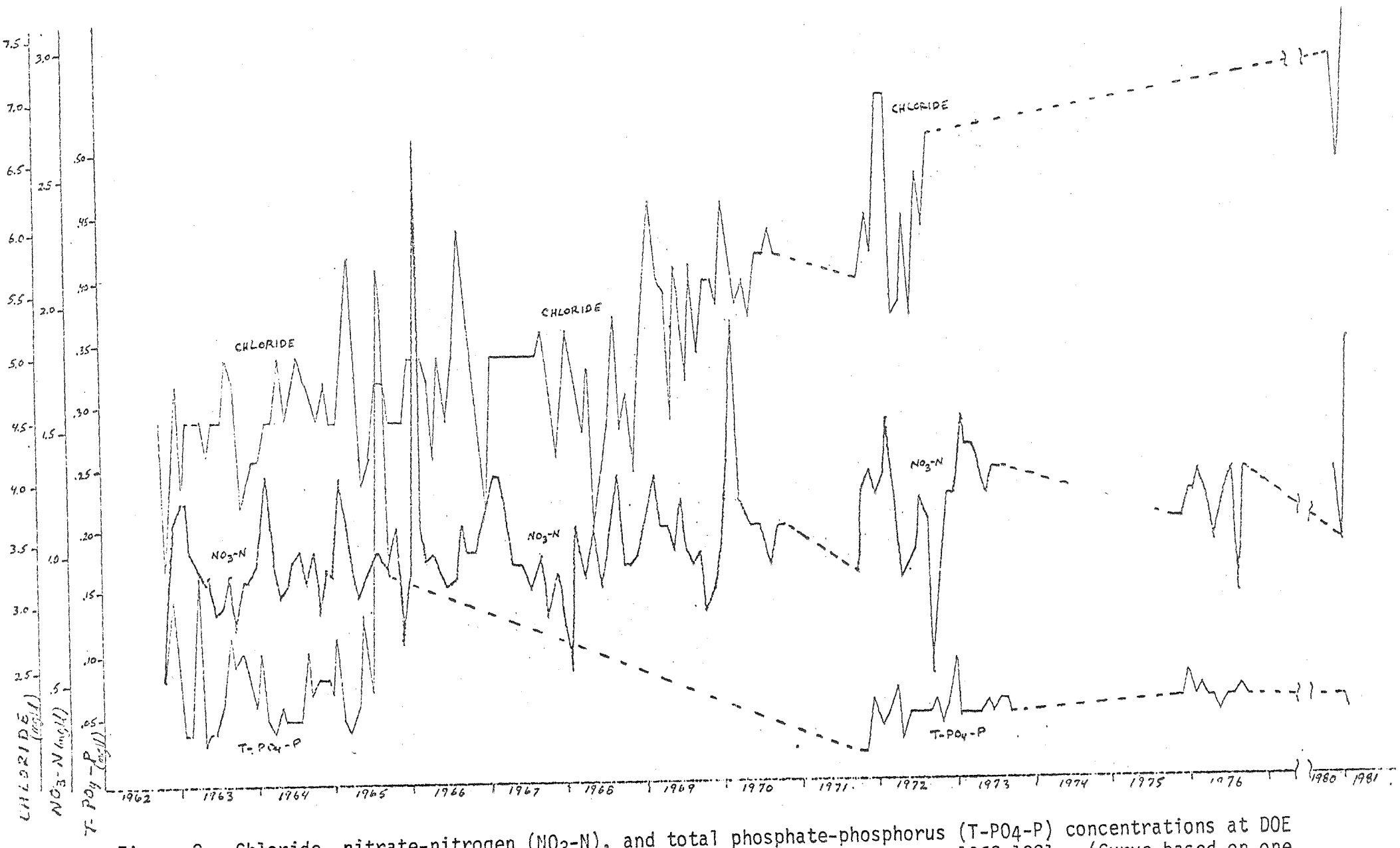

Figure 2. Chloride, nitrate-nitrogen (NO_3-N), and total phosphate-phosphorus (T-PO4-P) concentrations at DOE monitoring station 12A070 on Chambers Creek mouth near Steilacoom, 1962-1981. (Curve based on one sample per month 1962-1970 and two samples per month, averaged, thereafter.)

Table 1. Water Quality of Creeks in the Chambers Creek/Clover Creek Drainage Basin, November 1980 - January 1981

Sampling Site	Flows (cfs)	Temperature (°C)	Turbidity (NTU)	Total Suspended Solids (mg/L)	Dissolved Oxygen (mg/L)	Chemical Oxygen Demand (mg/L)	pH	Specific Conductance (umhos/cm)
Upper Clover Creek								
		a/						
#1 Clover Cr. @ Military Rd.	1.2 - 4.6	9.4(7.3-11.2) b/	2(1-4)	3(<1-7)	9.7(8.6-10.7)	14(8-19)	6.9(6.6-7.2)	151(132-186)
#2 Clover Cr. @ Waller Rd.	4.5 - 9.4	7.8(5.7-10.4)	2(1-3)	7(<1-10)	11.4(10.5-12.2)	14(8-21)	6.9(6.5-7.2)	145(133-153)
#3 Clover Cr. above N. Fork	-	7.7(5.3-10.5)	3(1-8)	4(1-11)	10.3(8.7-11.5)	17(8-21)	7.1(6.7-7.3)	144(127-153)
#4 N. Fork Clover Cr.	-	7.9(5.2-10.9)	7(2-14)	4(1-10)	11.5(10.3-12.3)	31(15-40)	7.2(6.8-7.5)	151(122-191)
#5 Clover Cr. @ Airport Rd.	.4 - 3.7	9.2(6.1-11.6)	10(2-27)	12(1-34)	12.0(10.8-13.0)	31(4-60)	7.0(6.6-7.3)	97(31-143)
Spanaway Creek Drainage								
#6 Inlet to Spanaway Lk.	3.1 - 8.0	7.1(5.6-9.2)	2(1-4)	2(<1-4)	9.5(8.7-10.2)	19(13-26)	6.7(6.4-7.1)	87(80-90)
#7 Outlet from Spanaway Lk.	6.4 - 13	8.5(6.7-12.0)	3(1-4)	1(<1-2)	8.5(7.6-9.7)	13(4-17)	7.0(6.8-7.3)	120(118-124)
#8 Tule Lk. outlet	2.9 - 14	8.8(6.8-11.6)	3(2-5)	6(<1-21)	10.5(9.6-11.2)	12(4-21)	7.1(6.7-7.4)	121(115-124)
#9 Morey Cr.	1.1 - 1.9	7.9(6.1-10.4)	2(1-4)	2(<1-6)	10.2(8.8-11.0)	11(4-17)	7.1(6.7-7.3)	123(119-127)
Lower Clover Creek								
#10 Clover Cr. @ McChord AFB	-	8.8(7.0-10.8)	2(1-5)	3(<1-6)	8.9(8.3-9.7)	7(4-13)	6.8(6.3-7.2)	131(126-134)
#11 Mouth @ Steilacoom Lk.	4.0 - 8.5	8.5(6.2-11.4)	3(2-4)	4(2-6)	11.2(10.4-12.1)	16(4-25)	7.1(6.6-7.4)	127(108-133)
Ponce de Leon Creek								
#12 Mouth @ Steilacoom Lk.	8.7 - 16	10.9(7.4-12.3)	2(1-4)	2(1-4)	10.6(10.5-10.9)	6(4-12)	6.9(6.5-7.3)	150(140-172)
Chambers Creek Drainage								
#13 Outlet from Steilacoom Lk.	-	8.4(6.8-11.9)	4(2-7)	12(8-16)	13.0(11.7-14.0)	21(13-29)	7.9(7.4-9.3)	134(126-140)
#14 Upper Flett Cr. @ Cemetery	-	7.9(5.6-11.4)	11(5-19)	8(1-26)	9.3(7.1-10:4)	16(4-23)	6.8(6.5-7.3)	109(68-148)
#15 Lower Flett Cr. @ Custer Rd.	5.3 - 11	7.7(5.1-11.8)	11(5-14)	10(2-20)	8.3(7.5-9.2)	19(4-29)	6.6(6.2-6.9)	128(83-180)
#16 Upper Leach Cr. @ 40th W.	-	8.3(6.2-12.2)	14(3-39)	23(7-74)	7.1(6.5-7.5)	28(22-36)	7.3(6.9-7.9)	370(147-535)
#17 Lower Leach Cr. @ Bridgeport Rd.	6.4 - 15	8.5(6.8-11.5)	5(2-16)	15(<1-64)	11.2(10.3-12.1)	19(4-32)	7.5(6.9-8.0)	238(111-298)
#18 Chambers Cr. below Leach Cr.	-	9.1(7.5-12.2)	4(2-6)	7(2-10)	11.4(10.5-12.2)	13(4-23)	7.3(7.1-7.7)	162(140-217)
#19 Chambers Cr. Mouth	-	8.8(6.8-11.7)	7(4-13)	20(6-59)	11.0(10.0-11.5)	17(9-32)	7.4(6.9-7.9)	161(141-176)
Murray Creek								
#20 At Camp Murray	.9 - 2.3	7.9(6.1-9.6)	1(1-2)	1(<1-2)	10.7(9.7-11.4)	13(8-17)	7.2(6.8-7.5)	113(108-122)
Sequalitchew Creek								
#21 Sequalitchew Lk. Outlet	-	5.9(5.3-6.7)	3(1-7)	2(<1-4)	9.2(6.8-12.3)	20(13-29)	7.1(6.6-8.0)	134(120-146)

a/ Mean, except coliform data which are medians.

b/ Range (based on one sample each collected 11/13, 11/17, 12/1, 12/15, and 1/12).

c/ Both MPN (most probable number) and MF (membrane filter) methods employed in analyzing bacteria samples.

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Table 1. (Continued)

Sampling Site	Total Ammonia-nitrogen, [NH3+NH4]-N (mg/L)	Nitrite-nitrogen, NO2-N (mg/L)	Nitrate-nitrogen NO3-N, (mg/L)	Orthophosphate-phosphorus, O-PO4-P (mg/L)	Total Phosphate-phosphorus, T-PO4-P (mg/L)	Chloride (mg/L)	Fecal Coliform c/ (col/100 ml)
Upper Clover Creek							
#1 Clover Cr. @ Military Rd.	.02(.01-.03)	<.01(all samples)	1.5(1.4-1.6)	<.01(all samples)	.02(all samples)	14(7.7-21)	43(9-93)
#2 Clover Cr. @ Waller Rd.	.01(<.01-.02)	<.01(all samples)	1.9(1.8-2.2)	<.01(all samples)	.02(all samples)	9.8(8.0-12)	91(15-260)
#3 Clover Cr. above N. Fork	<.01(<.01-.01)	<.01(all samples)	1.9(1.6-2.3)	<.01(all samples)	.03(02-.05)	8.4(4.6-12)	150(23-4,300)
#4 N. Fork Clover Cr.	.07(.02-.15)	.01(<.01-.02)	1.5(.88-2.0)	.09(.04-.23)	.13(.07-.18)	10(8.0-12)	150(23-260)
#5 Clover Cr. @ Airport Rd.	.03(<.01-.06)	.01(<.01-.03)	1.6(.24-2.9)	.08(.04-.15)	.17(.09-.31)	6.5(1.5-10)	580(43-46,000)
Spanaway Creek Drainage							
#6 Inlet to Spanaway Lk.	.01(<.01-.01)	<.01(all samples)	.20(.14-.28)	<.01(all samples)	.02(.02-.03)	5.3(3.8-6.9)	19(9-91)
#7 Outlet from Spanaway Lk.	.01(<.01-.31)	.01(<.01-.02)	.38(.19-.79)	<.01(all samples)	.02(.02-.03)	6.2(5.0-6.9)	73(43-130)
#8 Tule Lk. outlet	.05(.01-.07)	.02(<.01-.03)	.90(.65-1.3)	<.01(all samples)	.02(.01-.03)	6.2(6.1-6.9)	43(21-240)
#9 Morey Cr.	.05(<.01-.08)	.01(<.01-.02)	.85(.48-1.4)	<.01(all samples)	.02(.01-.03)	5.8(5.0-6.9)	43(<30-150)
Lower Clover Creek							
#10 Clover Cr. @ McChord AFB	.03(.01-.04)	<.01(<.01-.01)	1.7(1.5-2.2)	.02(<.01-.03)	.04(.02-.05)	6.5(5.0-7.7)	43(9-93)
#11 Mouth @ Steilacoom Lk.	.02(.01-.02)	<.01(all samples)	1.8(1.2-2.4)	.01(<.01-.02)	.04(.02-.05)	5.9(5.0-6.9)	340(43-2,400)
Ponce de Leon Creek							
#12 Mouth @ Steilacoom Lk.	.01(<.01-.02)	<.01(all samples)	2.2(1.9-2.4)	.05(.014-.06)	.06(.05-.08)	7.4(5.0-9.2)	150(23-430)
Chambers Creek Drainage							
#13 Outlet from Steilacoom Lk.	<.01(<.01-.01)	<.01(all samples)	.50(.10-1.5)	<.01(<.01-.01)	.04(.03-.05)	6.0(6.1-6.9)	42(4-930)
#14 Upper Flett Cr. @ Cemetery	.07(.03-.15)	.01(all samples)	.99(.18-2.1)	.02(.01-.03)	.05(.02-.06)	5.9(4.6-6.9)	40(7-240,000)
#15 Lower Flett Cr. @ Custer Rd.	.09(.03-.16)	<.01(<.01-.01)	1.3(.32-2.5)	.03(all samples)	.07(.04-.09)	5.0(3.0-8.4)	150(93-2,300)
#16 Upper Leach Cr. @ 40th W.	.06(.03-.12)	<.01(<.01-.01)	.19(.13-.28)	.04(.02-.05)	.05(.04-.06)	20(7.7-29)	390(43-2,400)
#17 Lower Leach Cr. @ Bridgeport Rd.	.03(.01-.05)	<.01(<.01-.01)	.98(.42-1.4)	.03(.02-.04)	.04(.04-.05)	10(5.3-13)	430(93-2,400)
#18 Chambers Cr. below Leach Cr.	.04(.02-.06)	<.01(.01-.01)	1.3(1.0-1.7)	.02(.01-.03)	.06(.05-.06)	7.7(6.9-9.2)	150(23-210)
#19 Chambers Cr. Mouth	.04(.02-.07)	<.01(<.01-.01)	1.3(.97-1.8)	.02(.01-.03)	.05(.05-.06)	7.0(6.0-7.7)	110(23-460)
Murray Creek							
#20 At Camp Murray	.02(.01-.03)	<.01(all samples)	1.1(.20-1.3)	<.01(<.01-.01)	.02(.01-.03)	4.4(3.1-7.0)	30(15-66)
Sequalitchew Creek							
#21 Sequalitchew Lk. Outlet	.24(.03-.49)	<.01(all samples)	.09(<.01-.21)	<.01(all samples)	.03(.02-.05)	4.7(3.8-5.4)	3(3-<30)

AV/C1(B4-5

Table 2. Metal concentrations in Chambers Creek/Clover Creek drainage samples[a] collected December 15, 1980.

Sampling Site	Arsenic (µg/l)	Barium (mg/l)	Cadmium (µg/l)	Chromium (µug/l)	Iron (mg/l)	Lead (ug/l)	Manganese (µg/l)	Mercury (µg/l)	Selenium (µg/l)	Silver (µg/l)	Sodium (mg/l)
#2, Clover Creek at Waller Road	<10	<.25	<2	<10	<.05	<10	<10	<.5	<5	<10	<10
#3, Clover Creek above N. Fork	<10	<.25	<2	<10	.10	<10	<10	<.5	<5	<10	<10
#10, Clover Creek at McChord AFB	<10	<.25	<2	<10	.13	<10	<10	<.5	<5	<10	<10
#15, Flett Creek at Custer Road	<10	<.25	<2	<10	.37	<10	22	<.5	<5	<10	<10
#17, Leach Creek at Bridgeport Road	<10	<.25	<2	<10	.15	<10	110	<.5	<5	<10	10
#21, Sequalitchew Lk. Outlet	<10	<.25	<2	<10	.05	<10	90	<.5	<5	<10	10
-- , So. Tacoma Swamp, Tacoma Air Park	<10	<.25	<2	<10	.60	20	34	<.5	<5	<10	10
Protection Criteria for Freshwater Aquatic Life[b]	50	--	0.4	100	1.0	25	100	.05	50	.10	--

[a]Each data point based on a single sample.

[b]Sources: EPA, 1976. Quality Criteria for Water.
American Fisheries Society, 1979. A Review of EPA Redbook: Quality Criteria for Water.
National Academy of Sciences, 1973, Water Quality Criteria 1972.

Table 3. Water Quality of Lakes in the Chambers Creek/Clover Creek Drainage Basin a/

Lake Name	Area (acres)	Mean Depth (feet)	Date Sampled	Temp. (°C)	Secchi Depth (ft)	Color (Platinum-cobalt units)	Dissolved Oxygen (mg/L)	pH	Specific Conductance (umhos/cm)	[illegible]
American	1100	53	12/29/80	8.5	15	17	8.4	7.0	109	
Sequalitchew	91	5	12/29/80	8.8	10	25	8.6	6.9	142	
Louise	39	22	1/5/81	7.9	27	8	10.1	7.2	73	
Spanaway	280	16	12/29/80	7.7	9	38	9.9	6.9	115	
Gravelly	160	38	1/5/81	8.6	24	8	10.3	6.9	140	
Steilacoom	320	11	12/29/80	9.7	5	42	8.6	7.0	125	
Waughop	33	7	1/5/81	8.2	3	63	11.0	7.3	74	
Tule	30	5	1/5/81	7.7	5	-	10.0	7.0	118	
Wapato	28	5	1/5/81	8.4	3	58	7.3	7.0	72	
Charlton	25	5	1/5/81	8.6	-	67	4.2	5.8	111	

a/ Data based on single, midlake, surface samples, except fecal coliform which are median and range of 4 sa taken around lake perimeter.

b/ American, Steilacoom, Spanaway, and Sequalitchew lakes bacteria data based on MF methods, remainder of t data obtained with MPN methods.

Table 3. (Continued)

Lake Name	Nitrite nitrogen, NO2-N (mg/L)	Nitrate nitrogen NO3-N (mg/L)	Orthophosphate-phosphorus, (O-PO4-P) (mg/L)	Total Phosphate-phosphorus (mg/L)	Chloride (mg/L)	Fecal b/ Coliform (col/100 ml
American	<.01	.02	.01	.04	3.8	18(13-128)
Sequalitchew	<.01	.20	<.01	.05	6.1	3(1-8)
Louise	<.01	.07	<.01	.02	4.6	3(<3-4)
Spanaway	<.01	.49	<.01	.02	6.9	21(12-42)
Gravelly	<.01	.58	.01	.03	5.4	6(3-9)
Steilacoom	<.01	1.2	.01	.04	6.1	33(12-49)
Waughop	<.01	.15	.03	.14	4.6	150(43-2,400
Tule	<.01	1.1	<.01	.02	6.9	33(15-43)
Wapato	<.01	.32	.04	.05	4.6	93(43-2,300
Charlton	<.01	1.2	<.01	.02	6.9	11(<2-23)

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Table 4. Historical water quality data from DOE routine monitoring stations in Chambers Creek/Clover Creek drainage for the November through January period in 1962-64 and 1975-76 compared to data collected November 1980 through January 1981.

Parameter	Sampling Period	#2 (12A130) Clover Creek at Waller Road Mean (Range)	No. of Samples	#11 (12A110) Clover Cr. Mouth of Steilacoom Lk. Mean (Range)	No. of Samples	#13 (12A100) Chambers Cr. below Steilacoom Lk. Mean (Range)	No. of Samples	#15 (12C070) Lower Flett Creek Mean (Range)	No. of Samples	#17 (12B070) L Creek Mean (Range)
Specific Conductance (μmhos/cm)	1962-64	94 (84-99)	6	97 (82-106)	6	107 (96-112)	6	164 (131-198)	6	124 (101-148)
	1975-76	-- --	--	113 (80-130)	6	121 (110-130)	6	147 (112-180)	6	195 (100-260)
	1980-81	145 (133-153)	5	127 (108-133)	5	134 (126-140)	5	128 (83-180)	5	238 (111-298)
Chloride (mg/l)	1962-64	3.0 (2.5-3.5)	6	3.7 (3.0-4.5)	6	3.9 (3.8-4.2)	6	6.6 (4.5-9.0)	6	4.4 (2.8-6.5)
	1975-76	-- --	--	-- --	--	-- --	--	-- --	--	-- --
	1980-81	9.8 (8.0-12)	5	5.9 (5.0-6.9)	5	6.0 (6.1-6.9)	5	5.0 (3.0-8.4)	5	10 (5.3-13)
Nitrate-nitrogen NO_3-N (mg/l)	1962-64	.86 (.68-1.2)	6	1.1 (.84-1.6)	6	.71 (.34-1.1)	6	2.5 (1.9-2.9)	6	.78 (.29-1.2)
	1975-76	-- --	--	1.2 (.90-1.4)	5	.80 (.30-1.2)	6	1.4 (1.0-2.1)	6	1.1 (.40-1.2)
	1980-81	1.9 (1.8-2.2)	5	1.8 (1.2-2.4)	5	.50 (.70-1.5)	5	1.3 (.32-2.5)	5	.98 (.42-1.4)
Total Phosphate-phosphorus $T-PO_4$-P (mg/l)	1962-64	.03 (.02-.05)		.03 (.02-.07)		.09 (.03-.22)		.15 (.05-.37)		.05 (.04-.06)
	1975-76	-- --		.04 (.04-.05)	6	.05 (.04-.07)	6	.14 (.11-.25)	6	.10 (.05-.25)
	1980-81	.02 (all samples)	5	.04 (.02-.05)	5	.04 (.03-.05)	5	.07 (.04-.09)	5	.04 (.04-.05)

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1. Littler, J.D. and J.T. Aden, 1980. *An Evaluation of Groundwater Quality for the Chambers Creek/Clover Creek Drainage Basin - Pierce County,* Washington Dept. of Social and Health Services, 39 pp.

2. National Academy of Sciences, 1973. *Water Quality Criteria 1972,* 594 pp.

3. Kline, L., 1959. *River Pollution 1. Chemical Analysis,* Acacemic Press Inc., New York, 206 pp.

4. EPA, 1976. *Quality Criteria for Water,* 256 pp.

5. EPA, 1976. *Water Quality Assessment: A Screening Method for Non-designated 208 Areas,* EPA-600/9-77-023, 649 pp.

6. Yake, W.E., 1979. *Water Quality Trend Analysis -- The Spokane River Basin,* Project Report No. DOE-PR-6, Washington Dept. of Ecology, 39 pp.

APPENDIX A

Washington State Water Quality Standards
for Class A Waters*

(2) CLASS A (EXCELLENT).

(a) General Characteristic. Water quality of this class shall meet or exceed the requirements for all or substantially all uses.

(b) Characteristic Uses. Characteristic uses shall include, but are not limited to, the following:

(i) Water supply (domestic, industrial, agricultural).

(ii) Wildlife habitat, stock watering.

(iii) General recreation and aesthetic enjoyment (picnicking, hiking, fishing, swimming, skiing, and boating).

(iv) Commerce and navigation.

(v) Fish and shellfish reproduction, rearing, and harvesting.

(c) Water Quality Criteri .

(i) Fecal Coliform Organisms

(A) Freshwater - Fecal Coliform Organisms shall not exceed a median value of 100 organisms/100 ml, with not more than 10 percent of samples exceeding 200 organisms/100 ml.

(B) Marine water - Fecal Coliform Organisms shall not exceed a median value of 14 organisms/100 ml, with not more than 10 percent of samples exceeding 43 organisms/100 ml.

(ii) Dissolved Oxygen.

(A) Freshwater - Dissolved oxygen shall exceed 8.0 mg/l.

(B) Marine water - Dissolved oxygen shall exceed 6.0 mg/l, except when the natural phenomenon of upwelling occurs, natural dissolved oxygen levels can be degraded by up to 0.2 mg/l by man-caused activities.

(iii) Total Dissolved Gas - the concentration of total dissolved gas shall not exceed 110 percent of saturation at any point of sample collection.

*From Chapter 173-201 WAC - Water Quality Standards for Waters of the State of Washington (1/17/78) 33 p.

(iv) Temperature - water temperatures shall not exceed 18.0° Celsius (freshwater) or 16.0° Celsius (marine water) due to human activities. Temperature increases shall not, at any time, exceed $t = 28/(T + 7)$ (freshwater) or $t = 12/(T - 2)$ (marine water).

When natural conditions exceed 18.0° Celsius (freshwater) and 16.0° Celsius (marine water), no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3° Celsius.

For purposes hereof, "t" represents the permissive temperature change across the dilution zone; and "T" represents the highest existing temperature in this water classification outside of any dilution zone.

Provided that temperature increase resulting from nonpoint source activities shall not exceed 2.8° Celsius, and the maximum water temperature shall not exceed 18.3° Celsius (freshwater).

(v) pH shall be within the range of 6.5 to 8.5 (freshwater) or 7.0 to 8.5 (marine water) with a man-caused variation within a range of less than 0.5 units.

(vi) Turbidity shall not exceed 5 NTU over background turbidity when the background turbidity is 50 NTU or less, or have more than a 10 percent increase in turbidity when the background turbidity is more than 50 NTU.

(vii) Toxic, radioactive, or deleterious material concentrations shall be below those of public health significance, or which may cause acute or chronic toxic conditions to the aquatic biota, or which may adversely affect any water use.

(viii) Aesthetic values shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch, or taste.

(5) LAKE CLASS.

(a) General Characteristic. Water quality of this class shall meet or exceed the requirements for all or substantially all uses.

(b) Characteristic Uses. Characteristic uses for waters of this class shall include, but are not limited to, the following:

(i) Water supply (domestic, industrial, agricultural).

(ii) Wildlife habitat, stock watering.

(iii) General recreation and aesthetic enjoyment (picnicking, hiking, fishing, swimming, skiing, and boating).

(iv) Fish and shellfish reproduction, rearing, and harvesting.

(c) Water Quality Criteria.

(i) Fecal Coliform Organisms - (lakes and impoundments) shall not exceed a median value of 50 organisms/100 ml, with not more than 10 percent of samples exceeding 100 organisms/100 ml.

(ii) Dissolved oxygen - no measurable decrease from natural conditions.

(iii) Total dissolved gas - the concentration of total dissolved gas shall not exceed 110 percent of saturation at any point of sample collection.

(iv) Temperature - no measurable change from natural conditions.

(v) pH - no measurable change from natural conditions.

(vi) Turbidity shall not exceed 5 NTU over background conditions.

(vii) Toxic, radioactive, or deleterious material concentrations shall be less than those which may affect public health, the natural aquatic environment, or the desirability of the water for any use.

(viii) Aesthetic values shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch, or taste.

Appendix B. Historical data on lakes in Chambers Creek/Clover Creek drainage during the month of February in 1970, 1973, and 1975 (from Water Resources Data for Washington, USGS).

Lake Name	Date Sampled	Sampling Depth (feet)	Specific Conductance (μmhos/cm)	Nitrate-nitrogen, NO_3-N (mg/l)	Total Phosphate-phosphorus T-PO_4-P (mg/l)	Chloride (mg/l)
American	2/19/70	50	105	.04	.01	3.7
Steilacoom	2/19/70	10	114	.90	.00	5.6
Spanaway	2/15/73	3	94	.60	.02	5.4
Gravelly	2/19/70	25	144	.70	.02	4.7
Louise	2/16/73	3	65	.09	.01	4.9
Wapato	2/20/75	3	65	.49	.09	3.9