Urban Storm-Water-Quality Data Portland, Oregon, and Vicinity

U.S. GEOLOGICAL SURVEY
Open-File Report 78-851

Prepared in cooperation with the
U.S. Army Corps of Engineers
Columbia Region Association of Governments

URBAN STORM–WATER–QUALITY DATA, PORTLAND, OREGON, AND VICINITY

By Timothy L. Miller

U.S. GEOLOGICAL SURVEY
Open-File Report 78-851

Prepared in cooperation with the
U.S. ARMY CORPS of ENGINEERS
COLUMBIA REGION ASSOCIATION of GOVERNMENTS

1978

UNITED STATES DEPARTMENT OF THE INTERIOR
CECIL D. ANDRUS, Secretary
GEOLOGICAL SURVEY
H. William Menard, Jr., Director

For additional information write to:

U.S. GEOLOGICAL SURVEY
P.O. Box 3202
Portland, Oregon 97208

CONTENTS

ILLUSTRATION

TABLES

Conversion Factors

[The following factors may be used to convert the units published herein to the International System of Units (SI).]

To convert from	To	Multiply by
	Length	
inch (in)	millimeter (mm)	25.4
foot (ft)	meter (m)	0.3048
mile (mi)	kilometer (km)	1.609
	Area	
square foot (ft^2)	square meter (m^2)	0.09290
square mile (mi^2)	square kilometer (km^2)	2.590
	Volume	
gallon (gal)	liter (L)	3.785
	Specific combinations	
foot per mile (ft/mi)	meter per kilometer (m/km)	0.1894
cubic foot per second (ft^3/s)	cubic meter per second (m^3/s)	0.02832
	Temperature	
degrees Fahrenheit ($^\circ F$)	degrees Celsius ($^\circ C$)	5/9 after subtracting 32 degrees

URBAN STORM-WATER-QUALITY DATA, PORTLAND, OREGON, AND VICINITY

--

By Timothy L. Miller

--

ABSTRACT

Urban storm-water-quality characteristics in the metropolitan area of Portland, Oreg., and Vancouver, Wash., were determined for eight drainage basins with varying drainage areas, basin slopes, impervious areas, and land uses. Automatic water-quality samplers, rain gages, and stream gages were installed in each basin. From September 1, 1975, to June 3, 1977, data were collected to determine rainfall intensities and define discharge hydrographs. Data from almost 650 samples show variation in concentration for about 20 parameters. This report contains data collected between May 1, 1976, and June 3, 1977. Data on the first 500 samples collected before May 1, 1976, are reported by McKenzie and Miller (1976).

INTRODUCTION

The U.S. Geological Survey, in cooperation with the U.S. Army Corps of Engineers and the Columbia Region Association of Governments (CRAG), has collected data to determine urban storm-water quality in the Portland area. Rainfall, stage, and sample-collection equipment were installed in eight drainage basins to obtain water-quality data for a total of 62 events between September 1, 1975, and June 3, 1977. Data for the first 48 events are reported by McKenzie and Miller (1976). In a separate but related study, rainfall and runoff data are being collected for eight additional drainage basins to determine rainfall-runoff relationships. Data from these 16 stations and from combined sewered basins monitored by the city of Portland will be used by the Geological Survey to model urban runoff.

BASIN LOCATIONS AND CHARACTERISTICS

Location

Locations of the eight streamflow and sampling stations are shown in figure 1, and each is identified by an eight-digit station number. The eighth basin, Vancouver, Wash., was added since the first report. The rain gage, where it is not adjacent to the streamflow station, is identified by a different eight-digit station number. Table 1 gives the station number, name, and location as determined from Geological Survey 1:24,000-scale topographic maps.

Definitions of Basin Characteristics

For this report the basin characteristics listed in table 2 are defined as follows:

1. Drainage area.--Area of the basin, in square miles, planimetered from Geological Survey 1:24,000-scale topographic maps. Basin boundaries were determined by first outlining drainage divides on topographic maps and then adjusting for existing storm-sewer diversions on the basis of information from city and county agencies. A field determination was made where sewer infiltration may possibly occur or where drainage divides could not be determined on maps.

2. Basin slope.--The average slope of the basin, in percent, was calculated from Geological Survey topographic maps using the formula described by Wisler and Brater (1959):

$$BASLOPE = \frac{DL}{A} \times 100 \qquad (1)$$

where

D = contour interval, in feet,
L = total length of contours, in feet, and
A = drainage area of the basin, in square feet.

3. Average channel slope.--The average channel slope, in feet per mile, for the basin, as determined from topographic maps. Channel slope was calculated for each of the various stream channels in the basin. Channel slope is defined as the difference in elevation at points 10 percent and 85 percent of the distance between a gaging station and the upstream basin boundary, divided by the distance between the two points.

Because each basin has more than one well-defined channel, the basin channel slope is a length-weighted average computed by:

$$CHNSLOP = \frac{L_1(X_1)+\ldots+L_n(X_n)}{L_1+\ldots+L_n} \qquad (2)$$

where

n = The number of defined channels,
L = the total length, in miles, of each channel, and
X = the channel slope, in feet per mile, for each channel.

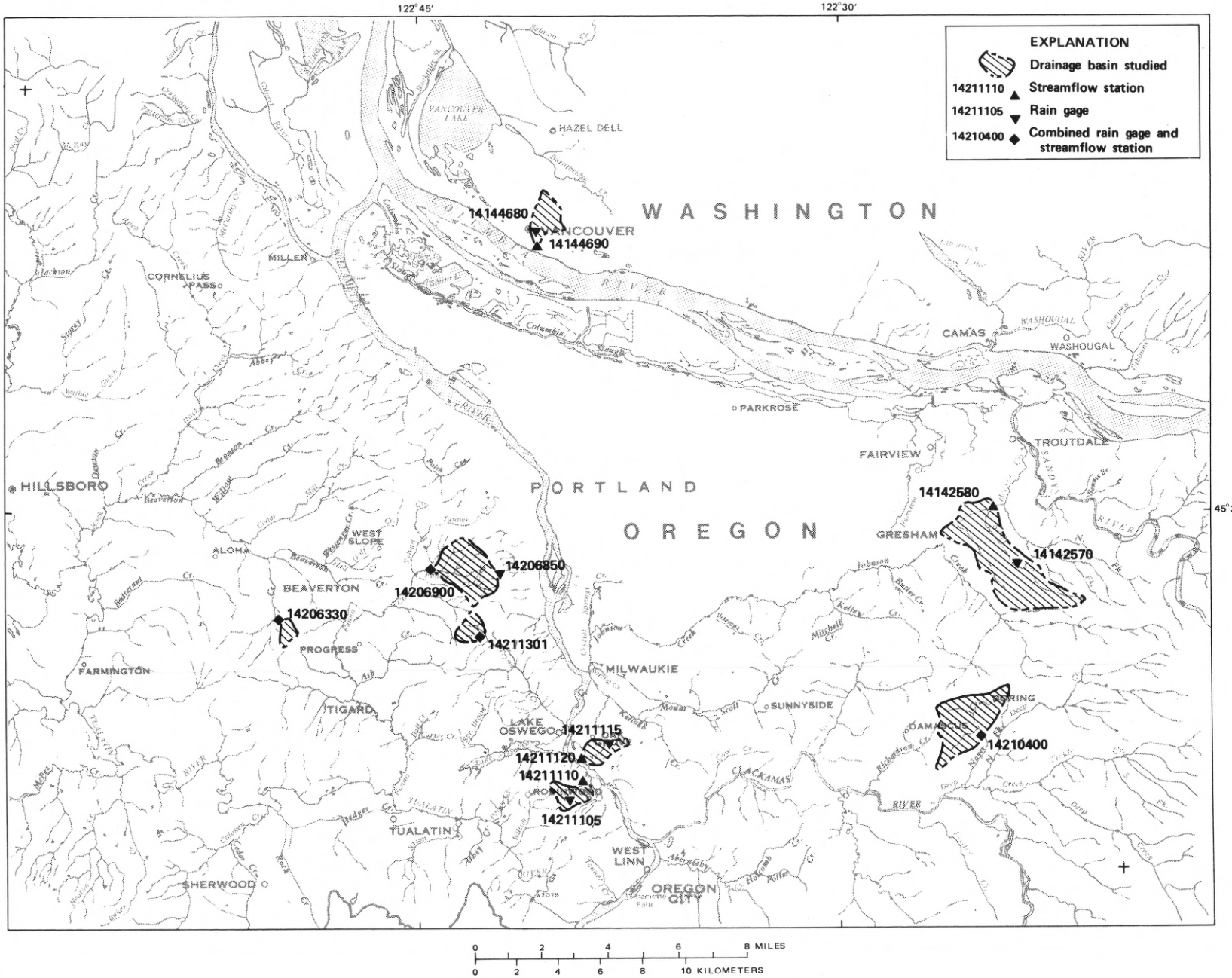

Figure 1.—Locations of streamflow stations and rain gages used for urban storm-water-quality study.

Table 1.--Locations of streamflow stations and rain gages

Station number	Name and location
14142570	Rain gage.--Powell Valley Grade School near Gresham, lat 45°29'26", long 122°22'54", in SW¼ sec.12, T.1 S., R.3 E., Multnomah County, Oreg.
14142580	Streamflow station.--Kelly Creek on Kane Road near Gresham, lat 45°30'44", long 122°23'56", in NE¼ sec.2, T.1 S., R.3 E., Multnomah County, Oreg.
14144680	Rain gage.--Vancouver City Hall, lat 45°37'54", long 122°40'08", in NW¼ sec.27, T.2 N., R.1 E., Clark County, Wash.
14144690	Streamflow station.--Vancouver sewer outfall near Highway I-5 bridge, lat 45°37'21", long 122°40'14", in SE¼ sec.27, T.2 N., R.1 E., Clark County, Wash.
14206315	Rain gage.--Beaverton City Hall, lat 45°29'02", long 122°48'11", in SW¼ sec.15, T.1 S., R.1 W., Washington County, Oreg.
14206330	Rain gage and streamflow station.--Beaverton Creek tributary at SW. Murray Blvd. in Beaverton, lat 45°28'08", long 122°49'28", in SW¼ sec.21, T.1 S., R.1 W., Washington County, Oreg.
14206850	Rain gage.--KPAM-FM radio station on Council Crest in Portland, lat 45°29'21", long 122°41'41", in NW¼ sec.16, T.1 S., R.1 E., Multnomah County, Oreg.
14206900	Rain gage and streamflow station.--Fanno Creek at SW. 56th Ave. in Portland, lat 45°29'17", long 122°44'01", in NW¼ sec.18, T.1 S., R.1 E., Multnomah County, Oreg.
14210400	Rain gage and streamflow station.--Noyer Creek on State Highway 212 near Damascus, lat 45°25'06", long 122°24'31", in SW¼ sec.2, T.2 S., R.3 E., Clackamas County, Oreg.
14211105	Rain gage.--View Drive in Robinwood, lat 45°23'24", long 122°38'53", in SE¼ sec.14, T.2 S., R.1 E., Clackamas County, Oreg.
14211110	Streamflow station.--Willamette River tributary on Old River Road in Robinwood, lat 45°24'01", long 122°38'37", in NE¼ sec.14, T.2 S., R.1 E., Clackamas County, Oreg.
14211115	Rain gage.--Oak Lodge RFPD No. 4 in Oak Grove, lat 45°24'57", long 122°37'53", in NW¼ sec.12, T.2 S., R.1 E., Clackamas County, Oreg.
14211120	Streamflow station.--Willamette River tributary on SE. River Road in Oak Grove, lat 45°24'34", long 122°38'39", in SE¼ sec.11, T.2 S., R.1 E., Clackamas County, Oreg.
14211301	Rain gage and streamflow station.--Tryon Creek tributary at Portland, lat 45°27'43", long 122°42'18", in SE¼ sec.20, T.1 S., R.1 E., Multnomah County, Oreg.
14211450	Rain gage.--Johnson Creek tributary on Roberts Ave. in Gresham, lat 45°29'26", long 122°25'22", in SE¼ sec.10, T.1 S., R.3 E., Multnomah County, Oreg.

4. Impervious area.--Percentage of the basin impervious to the infiltration of rain, such as asphalt roads, paved parking lots, and roofs. The area was determined by CRAG personnel using 1:7,200-scale black-and-white aerial photographs taken in 1974.

5. Land use.--Percentage of the basin, in land use of types I through V, as mapped by CRAG personnel from 1974 aerial photographs.

   I. Rural - Includes all undeveloped land, agricultural land, parks, cemeteries, and unpaved school playgrounds.

   II. Single-family residential - Includes single-family detached dwellings and duplexes.

   III. Multifamily residential - Includes multifamily housing units and trailer parks.

   IV. Commercial - Includes general wholesale and retail buildings, schools, churches, light industry, and airports.

   V. Industry - Includes heavy industry.

6. Area under construction.--Percentage of drainage basin disturbed by construction on a specific arbitrary date.

7. Basin shape.--The ratio of the length to average basin width (Office of Water Data Coordination, chap. 7, 1977), calculated using the formula:

$$\text{BASHAPE} = \frac{(L_c)^2}{A} \tag{3}$$

where

L_c = straight-line distance from the basin outlet to the point on the basin divide used to measure main channel length, in miles, and

A = area of the drainage basin, in square miles.

Characteristics

Since the first data report was written, improvements have been made in the measurement of basin characteristics. This report presents current measured values for basin characteristics and supersedes values cited in the first data report. Basin characteristics of drainage area, basin slope, average channel slope, impervious area, land use by type, area under construction, and basin shape are given in table 2.

Table 2.--Basin characteristics

Station no. and name	Drainage area (mi^2)	Basin slope (percent)	Average channel slope (ft/mi)	Impervious area (percent)	Land use, in percent					Area under construction		Basin shape factor
					I	II	III	IV	V			
					Rural	Single family	Multi-family	Commercial	Industrial	(percent)	Date	
14142580 Kelly Creek	4.16	5	45	9	83	11	4	2	0	0.7	2- 4-76	3.7
14144690 Vancouver	1.00	4	110	49	25	13	36	21	5	Not measured		3.0
14206330 Beaverton Cr. tributary	.21	7	180	19	42	53	5	0	0	.2	2- 5-76	1.4
14206900 Fanno Creek	2.37	16	230	32	12	76	6	6	0	.2	2- 5-76	1.6
14210400 Noyer Creek	2.04	6	130	4	93	6	0	1	0	.05	2- 4-76	.9
14211110 Willamette R. tributary in Robinwood	1.03	17	420	10	69	29	0	2	0	.7	5-26-76	1.9
14211120 Willamette R. tributary in Oak Grove	.74	5	130	36	15	73	4	8	0	.2	2- 5-76	2.8
14211301 Tryon Creek	.36	8	180	32	13	72	10	5	0	.4	5-28-76	1.2

Sampling Equipment and Guidelines

The data report by McKenzie and Miller (1976) includes detailed descriptions of equipment and how it was used to collect rainfall, discharge, and water-quality data. The report also includes a discussion of the frequency of sampling, preparation for storms, and guidelines for sampling during an extended storm.

ANALYSES OF BASE FLOW

A few base-flow samples were collected after May 1, 1976. Samples were collected using a depth-integrating suspended-sediment hand sampler when flows were high enough to permit its use. If flows were too low for the hand sampler, samples were collected by submerging a sediment bottle in the stream. The analyses of base-flow samples are tabulated in table 3.

REFERENCES CITED

McKenzie, S. W., and Miller, T. L., 1976, Basic data on urban storm-water quality, Portland, Oregon: U.S. Geological Survey Open-File Report 76-594, 71 p.

Office of Water Data Coordination, 1977, Physical basin characteristics for hydrologic analyses, chap. 7 in National handbook of recommended methods for water-data acquisitions: Office of Water Data Coordination (in press). Available from U.S. Geological Survey, Reston, Va.

Wisler, C. O., and Brater, E. F., 1959, Hydrology: New York, John Wiley, 408 p.

Table 3.--Base-flow data

[Samples that did not have one or more filters with a colony count in the statistically ideal range (fecal coliform, 20 to 60 colonies/100 mL; fecal streptococci, 20 to 100 colonies/100 mL) are reported with the remark "B"]

Item	Kelly Creek	Vancouver		Murray Blvd.	Fanno Creek	Robin-wood	Oak Grove	Tryon Creek
Date sampled	12-16-76	12-20-76	2-2-77	12-16-76	12-16-76	12-16-76	12-16-76	12-16-76
Stage (ft)	0.67	0.04	--	0.07	0.02	0.24	0.09	0.09
Discharge (ft^3/s)	1.4	.1	0.1	.08	.09	.16	.12	.18
Specific conductance at 25°C (micromhos/cm)	200	980	295	245	240	190	200	198
Turbidity (Jtu)	11	55	65	6	10	6	8	10
Suspended sediment (mg/L)	8	74	--	4	4	2	3	11
Fecal coliform (colonies/100 mL)	14B	6B	140	560	49	100B	3,400	24B
Fecal streptococci (colonies/100 mL)	96	2,900	100B	3,800	280	1,800	6,000	136
Temperature (°C)	7.0	11.0	--	8.5	7.0	7.0	7.0	7.0
Dissolved oxygen (mg/L)	12.0	9.8	--	9.3	10.2	11.0	11.1	7.6
pH (units)	7.3	10.5	7.4	7.1	7.3	7.2	7.3	6.7
Alkalinity (mg/L as $CaCO_3$)	--	410	96	--	--	--	--	--
Dissolved solids (mg/L)	136	576	--	149	148	142	134	121

HYDROLOGIC DATA

Table 4 is a tabulation of miscellaneous data collected during the study period. Data collected during the last 12 storm events are tabulated in table 5, which is organized in sequential station number order. For each station, the data on complete storm events are listed in chronological order, followed by incomplete storm events. Each storm event is given a Roman numeral that is a continuation of the numerals assigned in the first data report.

Table 4.--Miscellaneous data

[ND, not detectable]

	Kelly Creek	Vancouver				Oak Grove
Date	10-24-76	2-20-77	2-20-77	6-3-77	6-3-77	9-14-76
Time	1510	1140	1345	1245	1535	0515
Arsenic (mg/L)	ND	0.030	0.035	0.041	ND	0.062
Cadmium (mg/L)	0.015	.080	.060	.008	0.005	.005
Chromium (mg/L)	.05	.25	.20	.045	ND	.05
Copper (mg/L)	.19	.75	2.0	.18	.10	.05
Mercury (mg/L)	.00005	.0001	.0001	.00028	.0003	.0002
Lead (mg/L)	.080	1.84	.32	.65	.40	.11
Zinc (mg/L)	.29	3.25	10.0	1.10	1.20	.23

	Vancouver	Noyer Creek
Date	12-20-76	4-14-76
Time	Base flow	1915
Chemical oxygen demand (mg/L)	170	--
Total phosphorus (mg/L)	1.04	--
Total organic nitrogen (mg/L)	10.4	--
Ammonia (mg/L)	.02	--
Diss. nitrite + nitrate (mg/L)	3.29	1.0
Dissolved silica (mg/L)	29	11.2
Dissolved chloride (mg/L)	16.5	60
Dissolved sulfate (mg/L)	19	75
Dissolved calcium (mg/L)	29.4	12.0
Dissolved magnesium (mg/L)	5.6	1.2
Dissolved iron (mg/L)	.07	.02
Dissolved sodium (mg/L)	175	4
Dissolved potassium (mg/L)	4.3	15

	Kelly Creek	Vancouver				Oak Grove
Date	2-20-77	2-20-77	2-20-77	2-20-77	6-3-77	6-3-77	9-14-76
Time	1405	1140	1300	1345	1050	1215	0515
Oil and grease (mg/L)	0.70	10.1	0.66	3.54	47.1	26.2	58.2

Table 5.--Hydrologic data collected during storms

[Samples that did not have one or more filters with a colony count in the statistically ideal range (fecal coliform, 20 to 60 colonies/100 mL; fecal streptococci, 20 to 100 colonies/100 mL) are reported with the remark "B"]

Station number and name: 14142580 - Kelly Creek Storm V Date: 2-20-77

Time (2400 hour)	Stage (ft)	Discharge (ft^3/s)	Specific conductance at 25°C (micromhos/cm)	Settleable solids (mL/L)	Turbidity (Jtu)	Suspended sediment (mg/L)	BOD_5 (mg/L)	BOD_u (mg/L)	Rate of BOD satisfaction, k (day^{-1})	Fecal coliform (colonies/100 mL)	Fecal streptococci (colonies/100 mL)
1230	0.71	1.8	200	0	15	(8)	1.4	3.9	0.04	17B	--
1330	.79	2.6	156	.2	15	--	4.7	13	.04	--	--
1345	.88	3.8	168	.2	15	--	--	--	--	--	--
1355	.96	5.3	96	1.2	80	168	--	--	--	--	--
1405	1.09	8.3	106	--	75	(271)	11	21	.06	--	--
1422	1.23	13	124	3.8	100	449	12	24	.06	--	--
1442	1.36	19	138	3.0	110	--	--	--	--	--	--
1502	1.43	22	91	2.7	170	--	--	--	--	--	--
1512	1.44	23	89	--	140	(521)	14	26	.06	300B	45,000
1535	1.39	20	60	1.3	120	--	--	--	--	--	--
1605	1.24	13	53	.8	100	208	6.1	14	.06	--	--
1620	1.19	11	59	1.0	100	--	--	--	--	--	--
1640	1.14	9.8	62	.6	100	(162)	--	--	--	--	--
1655	1.10	8.6	67	.7	95	--	--	--	--	--	--
1710	1.08	8.1	69	.5	90	171	5.2	11	.06	--	--
1725	1.06	7.5	71	.6	95	--	--	--	--	--	--
1740	1.04	7.0	71	.6	100	128	--	--	--	--	--
1750	1.03	6.8	71	.4	95	--	6.0	12	.06	--	--
1820	.99	5.9	65	.3	90	--	--	--	--	--	--
1920	.96	5.3	61	.4	80	--	--	--	--	--	--
2020	.95	5.1	64	--	60	79	6.3	10	.08	--	--
2050	.94	4.9	64	.2	55	--	--	--	--	--	--
2120	.93	4.7	66	.5	55	79	5.4	11	.06	--	--
2150	.92	4.5	69	.2	55	--	--	--	--	--	--
2225	.91	4.3	77	.5	55	59	5.3	11	.06	--	--

Time (2400 hour)	Temp. (°C)	Dissolved oxygen (mg/L)	pH (units)	Alkalinity (mg/L as $CaCO_3$)	COD (mg/L)	Dissolved solids (mg/L)	Total phosphorus as P (mg/L)	Total Kjeldahl nitrogen as N (mg/L)	Ammonia as N (mg/L)	Dissolved nitrite plus nitrate as N (mg/L)	Remarks
1230	9.5	11.5	7.5	89	--	133	--	--	--	1.9	Total coliform (colonies/100 mL) 25,000 at 1512.
1345	--	--	7.4	70	--	--	--	--	--	--	
1405	10.5	--	--	--	62	--	0.33	1.5	0.11	1.8	
1422	--	--	7.0	52	--	--	--	--	--	--	
1442	--	--	--	--	--	95	--	--	--	--	Average settleable solids density (g/mL) 0.13.
1502	--	--	7.1	33	--	--	--	--	--	--	
1512	10.5	10.0	--	--	100	--	.48	1.9	.10	1.8	
1535	--	--	6.9	36	--	--	--	--	--	--	
1605	--	--	6.9	18	--	--	--	--	--	--	
2020	--	--	--	--	--	--	--	--	--	1.3	

Table 5.--Hydrologic data collected during storms--Continued

Station number and name: 14142580 - Kelly Creek Date: 10-24-76

Time (2400 hour)	Stage (ft)	Discharge (ft^3/s)	Specific conductance at 25°C (micromhos/cm)	Settleable solids (mL/L)	Turbidity (Jtu)	Suspended sediment (mg/L)	BOD_5 (mg/L)	BOD_u (mg/L)	Rate of BOD satisfaction, k (day^{-1})	Fecal coliform (colonies/100 mL)	Fecal streptococci (colonies/100 mL)
0910	0.62	0.31	260	--	120	(10)	2.8	14	0.02	16B	220
1510	1.05	3.0	160	--	85	(127)	9.1	18	.06	2,600	5,100

Time (2400 hour)	Temp. (°C)	Dissolved oxygen (mg/L)	pH (units)	Alkalinity (mg/L as $CaCO_3$)	COD (mg/L)	Dissolved solids (mg/L)	Total phosphorus as P (mg/L)	Total Kjeldahl nitrogen as N (mg/L)	Ammonia as N (mg/L)	Dissolved nitrite plus nitrate as N (mg/L)	Remarks
0910	--	--	7.6	120	--	175	--	--	--	7.0	Total coliform (colonies/100 mL) 14,000 at 1510.
1510	--	--	7.7	86	40	133	0.26	1.1	0.03	7.0	

Station number and name: 14206330 - Murray Boulevard Storm V Date: 10-24-76

Time (2400 hour)	Stage (ft)	Discharge (ft^3/s)	Specific conductance at 25°C (micromhos/cm)	Settleable solids (mL/L)	Turbidity (Jtu)	Suspended sediment (mg/L)	BOD_5 (mg/L)	BOD_u (mg/L)	Rate of BOD satisfaction, k (day^{-1})	Fecal coliform (colonies/100 mL)	Fecal streptococci (colonies/100 mL)
1050	0.06	0.08	284	--	6	(17)	1.8	5.2	0.04	7,400B	--
1300	.33	.59	87	--	140	(324)	14	39	.04	7,600B	36,000
1330	.33	.59	85	1.2	140	--	--	--	--	--	--
1400	.25	.40	96	.9	45	110	--	--	--	--	--
1430	.20	.31	102	.9	35	--	--	--	--	--	--
1500	.18	.27	106	.9	35	68	11	30	.04	--	--
1530	.13	.18	116	1.0	25	--	--	--	--	--	--
1600	.10	.13	120	--	45	--	--	--	--	--	--
1700	.51	1.4	38	--	200	610	8.1	22	.04	2,700	29,000

Time (2400 hour)	Temp. (°C)	Dissolved oxygen (mg/L)	pH (units)	Alkalinity (mg/L as $CaCO_3$)	COD (mg/L)	Dissolved solids (mg/L)	Total phosphorus as P (mg/L)	Total Kjeldahl nitrogen as N (mg/L)	Ammonia as N (mg/L)	Dissolved nitrite plus nitrate as N (mg/L)	Remarks
1050	--	--	7.3	100	10	180	0.07	0.37	--	4.4	Total coliform (colonies/100 mL) 10,000 at 1700.
1300	12	--	--	--	20	72	.37	1.4	--	--	
1330	--	--	7.0	24	--	--	--	--	--	--	
1430	--	--	7.0	31	--	--	--	--	--	--	
1530	--	--	7.1	36	--	--	--	--	--	--	Average settleable solids density (g/mL) 0.091.
1600	--	--	--	--	--	94	--	--	--	--	
1700	--	--	6.7	10	--	35	--	--	--	3.5	

Table 5.--Hydrologic data collected during storms--Continued

Station number and name: 14206900 - Fanno Creek Storm V Date: 10-24-76

Time (2400 hour)	Stage (ft)	Discharge (ft^3/s)	Specific conductance at 25°C (micromhos/cm)	Settleable solids (mL/L)	Turbidity (Jtu)	Suspended sediment (mg/L)	BOD_5 (mg/L)	BOD_u (mg/L)	Rate of BOD satisfaction, k (day^{-1})	Fecal coliform (colonies/100 mL)	Fecal streptococci (colonies/100 mL)
1115	-0.01	0.20	200	--	3	(3)	1.1	5.6	0.02	87	61B
1135	-.01	.65	202	2.9	90	496	7.0	20	.04	--	--
1400	.03	.82	190	.8	25	102	--	--	--	--	--
1520	.16	1.4	202	--	60	222	8.4	17	.06	--	--
1550	.53	4.3	202	2.4	95	--	--	--	--	--	--
1650	.58	4.8	161	1.6	50	166	--	--	--	--	--
1715	.56	4.6	131	--	120	441	18	36	.06	--	--
1740	1.15	13	138	--	300	1,330	20	56	.04	27,000B	--
1810	1.09	11	86	2.3	180	315	--	--	--	--	--
1840	.78	7.0	86	--	270	811	18	49	.04	--	--
2040	1.47	19	80	9.2	600	2,160	17	47	.04	26,000B	57,000

Time (2400 hour)	Temp. (°C)	Dissolved oxygen (mg/L)	pH (units)	Alkalinity (mg/L as $CaCO_3$)	COD (mg/L)	Dissolved solids (mg/L)	Total phosphorus as P (mg/L)	Total Kjeldahl nitrogen as N (mg/L)	Ammonia as N (mg/L)	Dissolved nitrite plus nitrate as N (mg/L)	Remarks
1115	--	--	--	--	--	134	0.07	0.47	0.04	5.3	Total coliform
1400	--	--	7.5	78	--	--	--	--	--	--	(colonies/100 mL)
1520	--	--	7.4	84	39	--	--	1.3	.04	--	95,000B at 2040.
1650	--	--	7.4	60	--	--	--	--	--	--	
1715	--	--	7.4	43	--	96	--	--	--	--	Average settleable solids
1740	--	--	--	--	100	104	--	--	--	--	density (g/mL)
1840	--	--	6.8	25	130	--	--	--	--	--	0.154.

Table 5.--Hydrologic data collected during storms--Continued

Station number and name: 14206900 - Fanno Creek Storm VI Date: 2-20-77

Time (2400 hour)	Stage (ft)	Discharge (ft^3/s)	Specific conductance at 25°C (micromhos/cm)	Settleable solids (mL/L)	Turbidity (Jtu)	Suspended sediment (mg/L)	BOD_5 (mg/L)	BOD_u (mg/L)	Rate of BOD satisfaction, k (day^{-1})	Fecal coliform (colonies/100 mL)	Fecal streptococci (colonies/100 mL)
1220	0.06	0.85	232	<0.1	10	(7)	2.6	5.3	0.06	71B	--
1315	.24	1.9	205	.2	20	(33)	6.7	14	.06	--	--
1405	.27	2.1	165	.4	35	(50)	6.3	13	.06	--	--
1505	.78	7.0	200	--	85	(192)	7.0	14	.06	786B	7,400B
1545	.61	5.1	153	3.0	65	(108)	18	24	.10	--	--
1645	.46	3.6	132	.9	55	(70)	9.3	16	.08	--	--
1735	.36	2.8	127	.9	170	(303)	8.7	18	.06	2,600	--

Time (2400 hour)	Temp. (°C)	Dissolved oxygen (mg/L)	pH (units)	Alkalinity (mg/L as $CaCO_3$)	COD (mg/L)	Dissolved solids (mg/L)	Total phosphorus as P (mg/L)	Total Kjeldahl nitrogen as N (mg/L)	Ammonia as N (mg/L)	Dissolved nitrite plus nitrate as N (mg/L)	Remarks
1220	--	--	7.4	92	20	145	0.07	0.50	0.22	1.4	Total coliform
1315	--	--	--	--	--	132	--	--	--	--	colonies/100 mL)
1405	--	--	7.1	58	--	--	--	--	--	--	11,000 at 1505.
1505	--	--	--	--	52	--	.26	1.1	.16	1.6	
1545	9	10	--	--	--	--	--	--	--	--	Average settleable solids
1735	--	--	7.0	38	58	--	.40	--	--	--	density (g/mL) 0.06.

Table 5.--Hydrologic data collected during storms--Continued

Station number and name: 14210400 - Noyer Creek Storm V Date: 2-20-77

Time (2400 hour)	Stage (ft)	Discharge (ft^3/s)	Specific conductance at 25°C (micromhos/cm)	Settleable solids (mL/L)	Turbidity (Jtu)	Suspended sediment (mg/L)	BOD_5 (mg/L)	BOD_u (mg/L)	Rate of BOD satisfaction, k (day^{-1})	Fecal coliform (colonies/100 mL)	Fecal streptococci (colonies/100 mL)
1200	0.49	0.33	69	--	4	(18)	0.8	1.6	0.06	5B	--
1445	.51	.36	51	--	300	629	3.0	8.5	.04	--	--
1520	.48	.31	65	--	20	--	--	--	--	--	--
1555	.75	1.2	44	--	350	--	6.5	13	.06	--	--
1612	.92	2.3	38	0.7	420	661	4.2	8.6	.06	1,600	17,500
1630	.91	2.3	42	.8	460	--	--	--	--	--	--
1645	.87	2.0	50	1.3	600	--	--	--	--	--	--
1715	.86	1.9	54	--	180	(164)	6.2	17	.04	--	--
1730	.87	2.0	54	.2	105	--	--	--	--	--	--
1745	.83	1.7	53	.3	110	--	--	--	--	--	--
1800	.80	1.5	55	.8	110	--	6.9	14	.06	--	--
1830	.76	1.3	62	--	80	--	--	--	--	--	--
1845	.74	1.2	64	.1	80	(56)	5.5	14	.04	--	--
2000	.70	.97	65	.1	65	--	--	--	--	--	--
2030	.70	.97	62	< .1	60	--	4.5	9.4	.06	--	--
2300	.66	.81	64	--	50	18	--	--	--	530	--

Time (2400 hour)	Temp. (°C)	Dissolved oxygen (mg/L)	pH (units)	Alkalinity (mg/L as $CaCO_3$)	COD (mg/L)	Dissolved solids (mg/L)	Total phosphorus as P (mg/L)	Total Kjeldahl nitrogen as N (mg/L)	Ammonia as N (mg/L)	Dissolved nitrite plus nitrate as N (mg/L)	Remarks
1200	8.5	9.0	--	--	12	52	0.06	0.25	0.10	1.4	Total coliform
1445	9.0	--	--	--	34	41	.33	1.0	.12	1.2	(colonies/100 mL)
1520	--	--	--	--	--	53	--	--	--	--	17,000B at 1612.
1555	--	--	--	--	--	47	--	--	--	--	
1612	9.5	10.7	6.4	8	--	--	--	--	--	--	Average settleable solids
1715	--	--	--	--	--	50	--	--	--	--	density (g/mL)
1830	--	--	--	--	64	--	.22	.94	.08	2.5	0.42.
1845	8.5	--	6.7	13	--	--	--	--	--	--	
2300	6	--	--	--	--	63	--	--	--	--	

Table 5.--Hydrologic data collected during storms--Continued

Station number and name: 14211110 - Robinwood Date: 10-24-76

Time (2400 hour)	Stage (ft)	Discharge (ft^3/s)	Specific conductance at 25°C (micromhos/cm)	Settleable solids (mL/L)	Turbidity (Jtu)	Suspended sediment (mg/L)	BOD_5 (mg/L)	BOD_u (mg/L)	Rate of BOD satisfaction, k (day^{-1})	Fecal coliform (colonies/100 mL)	Fecal streptococci (colonies/100 mL)
1355	0.28	0.27	205	--	10	(17)	2.6	7.2	0.04	220	2,800
1430	.29	.30	197	0.5	10	--	--	--	--	--	--
1500	.29	.30	185	1.6	15	--	--	--	--	--	--
1530	.29	.30	175	2.4	10	--	--	--	--	--	--
1600	.29	.30	171	.9	15	--	--	--	--	--	--
1630	.30	.34	168	--	15	46	--	--	--	--	--
1715	.31	.38	182	.8	15	--	--	--	--	--	--

Time (2400 hour)	Temp. (°C)	Dissolved oxygen (mg/L)	pH (units)	Alkalinity (mg/L as $CaCO_3$)	COD (mg/L)	Dissolved solids (mg/L)	Total phosphorus as P (mg/L)	Total Kjeldahl nitrogen as N (mg/L)	Ammonia as N (mg/L)	Dissolved nitrite plus nitrate as N (mg/L)	Remarks
1355	--	--	7.8	84	10	162	0.07	0.47	0.03	7.0	Total coliform (colonies/100 mL) 1500 at 1355.
1630	--	--	7.6	64	--	135	--	--	--	--	Average settleable solids density (g/mL) 0.013.

Table 5.--Hydrologic data collected during storms--Continued

Station number and name: 14211120 - Oak Grove Storm V Date: 9-14-76

Time (2400 hour)	Stage (ft)	Discharge (ft^3/s)	Specific conductance at 25°C (micromhos/cm)	Settleable solids (mL/L)	Turbidity (Jtu)	Suspended sediment (mg/L)	BOD_5 (mg/L)	BOD_u (mg/L)	Rate of BOD satisfaction, k (day^{-1})	Fecal coliform (colonies/100 mL)	Fecal streptococci (colonies/100 mL)
0400	0.30	0.19	134	0.8	40	(136)	4.4	12	0.04	1,800	2,600
0445	.86	5.6	141	2.3	85	(485)	9.5	19	.06	6,000B	--
0515	.96	7.4	93	1.9	95	(428)	10	21	.06	6,000B	68,000
0545	.85	5.4	55	1.0	50	(198)	7.7	15	.06	6,900B	--
0615	.66	2.8	52	.7	25	(95)	5.5	15	.04	3,900	--
0645	.55	1.7	54	.4	20	(84)	5.5	11	.06	5,000	--
0715	.46	.88	57	.2	20	--	4.3	12	.04	6,500	--
0745	.46	.88	59	.2	20	(33)	4.0	11	.04	2,600	15,000

Time (2400 hour)	Temp. (°C)	Dissolved oxygen (mg/L)	pH (units)	Alkalinity (mg/L as $CaCO_3$)	COD (mg/L)	Dissolved solids (mg/L)	Total phosphorus as P (mg/L)	Total Kjeldahl nitrogen as N (mg/L)	Ammonia as N (mg/L)	Dissolved nitrite plus nitrate as N (mg/L)	Remarks
0400	15.5	8.9	--	--	--	--	--	--	--	--	Total coliform
0445	15.5	--	7.3	54	--	--	--	--	--	--	(colonies/100 mL)
0515	15.5	--	7.0	31	50	--	0.6	1.6	0.2	--	2,000B at 0400,
0545	15.5	--	--	--	--	--	--	--	--	--	48,000B at 0515,
0615	15.5	--	6.8	16	--	--	--	--	--	--	4,400B at 0745.
0645	15.5	--	--	--	--	--	--	--	--	--	
0715	15.5	--	--	--	--	--	--	--	--	--	
0745	15.5	--	7.2	20	--	--	--	--	--	--	

Table 5.--Hydrologic data collected during storms--Continued

Station number and name: 14211120 - Oak Grove Storm VI Date: 2-20-77

Time (2400 hour)	Stage (ft)	Discharge (ft^3/s)	Specific conductance at 25°C (micromhos/cm)	Settleable solids (mL/L)	Turbidity (Jtu)	Suspended sediment (mg/L)	BOD_5 (mg/L)	BOD_u (mg/L)	Rate of BOD satisfaction, k (day^{-1})	Fecal coliform (colonies/100 mL)	Fecal streptococci (colonies/100 mL)
1115	0.12	0.08	210	--	7	(14)	1.2	3.3	0.04	370	--
1150	.13	.09	200	<0.1	7	--	--	--	--	--	--
1200	.17	.12	198	.2	15	(36)	--	--	--	--	--
1205	.20	.15	195	.2	15	--	--	--	--	--	--
1215	.24	.21	180	.2	25	(46)	3.7	7.4	.06	--	--
1230	.24	.21	148	.3	25	--	--	--	--	--	--
1255	.18	.13	117	.2	20	--	--	--	--	--	--
1310	.28	.26	119	.6	25	(65)	9.5	16	.08	--	--
1311	.28	.26	124	3.3	80	(430)	14	21	.10	--	--
1313	.58	1.6	124	7.0	130	--	--	--	--	--	--
1315	.58	1.6	125	--	190	(806)	16	34	.06	--	--
1318	.54	1.5	128	4.5	95	--	--	--	--	--	--
1320	.54	1.5	126	4.3	150	--	--	--	--	--	--
1323	.53	1.4	131	--	160	--	--	--	--	--	--
1331	.52	1.3	155	2.5	130	--	--	--	--	--	--
1352	.55	1.5	139	3.5	110	(385)	21	31	.10	--	--
1355	.74	3.0	136	7.0	190	--	--	--	--	--	--
1357	.74	3.0	132	7.0	270	--	--	--	--	--	--
1400	.82	3.9	128	--	330	(1,280)	24	49	.06	--	--
1405	.83	4.1	115	10.0	340	--	--	--	--	1,890	24,200
1430	.74	3.0	102	2.2	120	--	--	--	--	--	--
1500	.65	2.1	88	1.2	60	(168)	10	20	.06	--	--
1555	.50	1.2	71	.8	60	(122)	9.3	19	.06	--	--
1645	.37	.53	75	.6	50	--	--	--	--	--	--
1800	.30	.30	81	.3	37	(52)	6.2	12	.06	3,600	--

Time (2400 hour)	Temp. (°C)	Dissolved oxygen (mg/L)	pH (units)	Alkalinity (mg/L as $CaCO_3$)	COD (mg/L)	Dissolved solids (mg/L)	Total phosphorus as P (mg/L)	Total Kjeldahl nitrogen as N (mg/L)	Ammonia as N (mg/L)	Dissolved nitrite plus nitrate as N (mg/L)	Remarks
1115	8	--	7.4	80	18	142	0.07	0.25	0.18	0.92	Total coliform (colonies/100 mL) 5,900 at 1405.
1205	--	--	--	--	--	142	--	--	--	--	
1255	--	--	7.2	40	--	85	--	--	--	--	
1315	--	--	--	--	120	88	.66	3.2	.04	.32	
1331	--	--	7.2	56	--	--	--	--	--	--	Average settleable solids density (g/mL) 0.11.
1352	--	--	--	--	--	103	--	--	--	--	
1400	--	--	--	--	210	--	.66	5.2	.11	1.3	
1555	--	--	6.8	18	--	--	--	--	--	--	

Table 5.--Hydrologic data collected during storms--Continued

Station number and name: 14211120 - Oak Grove

Date: 10-24-76

Time (2400 hour)	Stage (ft)	Discharge (ft^3/s)	Specific conductance at 25°C (micromhos/cm)	Settleable solids (mL/L)	Turbidity (Jtu)	Suspended sediment (mg/L)	BOD_5 (mg/L)	BOD_u (mg/L)	Rate of BOD satisfaction, k (day^{-1})	Fecal coliform (colonies/100 mL)	Fecal streptococci (colonies/100 mL)
1200	0.18	0.05	245	--	5	(9)	1.8	5.1	0.04	670	2,800
1320	.34	.30	198	1.6	55	(162)	6.4	18	.04	--	--
1345	.54	1.6	220	--	220	830	9.2	25	.04	5,800	24,000
1615	.45	.75	135	1.7	70	(195)	--	--	--	--	--

Time (2400 hour)	Temp. (°C)	Dissolved oxygen (mg/L)	pH (units)	Alkalinity (mg/L as $CaCO_3$)	COD (mg/L)	Dissolved solids (mg/L)	Total phosphorus as P (mg/L)	Total Kjeldahl nitrogen as N (mg/L)	Ammonia as N (mg/L)	Dissolved nitrite plus nitrate as N (mg/L)	Remarks
1200	--	--	7.9	110	--	160	--	--	--	--	Total coliform (colonies/100 mL) 28,000 at 1345.
1320	--	--	7.6	79	--	--	--	--	--	--	
1345	--	--	--	--	82	156	0.62	2.8	0.03	5.3	
1615	11.5	--	7.3	40	--	--	--	--	--	--	Average settleable solids density (g/mL) 0.085.

Table 5.--Hydrologic data collected during storms--Continued

Station number and name: 14211301 - Tryon Creek Date: 10-24-76

Time (2400 hour)	Stage (ft)	Discharge (ft^3/s)	Specific conductance at 25°C (micromhos/cm)	Settleable solids (mL/L)	Turbidity (Jtu)	Suspended sediment (mg/L)	BOD_5 (mg/L)	BOD_u (mg/L)	Rate of BOD satisfaction, k (day^{-1})	Fecal coliform (colonies/100 mL)	Fecal streptococci (colonies/100 mL)
1140	0.09	0.18	187	--	15	(6)	2.5	6.9	0.04	130B	--
1235	.39	.95	205	--	160	(302)	19	96	.02	2,100	7,800
1335	.47	1.3	111	9.5	60	(150)	--	--	--	--	--
1500	.44	1.2	80	--	30	(53)	21	43	.06	--	--
1630	.51	1.5	77	3.0	90	(328)	20	40	.06	--	--
1700	.79	3.5	67	--	300	(1,230)	24	64	.04	6,900	33,000

Time (2400 hour)	Temp. (°C)	Dissolved oxygen (mg/L)	pH (units)	Alkalinity (mg/L as $CaCO_3$)	COD (mg/L)	Dissolved solids (mg/L)	Total phosphorus as P (mg/L)	Total Kjeldahl nitrogen as N (mg/L)	Ammonia as N (mg/L)	Dissolved nitrite plus nitrate as N (mg/L)	Remarks
1140	--	--	--	--	--	122	--	--	--	--	Total coliform
1235	--	--	7.1	62	55	131	0.81	1.8	0.08	6.6	(colonies/100 mL)
1335	--	--	6.7	17	--	--	--	--	--	--	24,000.
1500	--	--	--	--	--	71	--	--	--	--	
1700	--	--	6.6	16	160	--	.34	4.1	.04	4.8	Average settleable solids density (g/mL) 0.028.

Table 5.--Hydrologic data collected during storms--Continued

Station number and name: 14211301 - Tryon Creek Date: 2-20-77

Time (2400 hour)	Stage (ft)	Discharge (ft^3/s)	Specific conductance at 25°C (micromhos/cm)	Settleable solids (mL/L)	Turbidity (Jtu)	Suspended sediment (mg/L)	BOD_5 (mg/L)	BOD_u (mg/L)	Rate of BOD satisfaction, k (day^{-1})	Fecal coliform (colonies/100 mL)	Fecal streptococci (colonies/100 mL)
1250	0.58	1.9	73	--	110	(376)	20	40	0.06	3,900B	43,000
1345	.59	1.9	52	2.1	100	(291)	14	28	.06	--	--
1435	.45	1.2	65	.8	50	(82)	7.3	14	.06	--	--
1525	.29	.64	81	.5	40	(49)	5.7	12	.06	--	--
1615	.24	.52	95	.3	35	(37)	3.9	11	.04	--	--
1710	.23	.50	106	.2	35	(98)	4.3	12	.04	1,200	--

Time (2400 hour)	Temp. (°C)	Dissolved oxygen (mg/L)	pH (units)	Alkalinity (mg/L as $CaCO_3$)	COD (mg/L)	Dissolved solids (mg/L)	Total phosphorus as P (mg/L)	Total Kjeldahl nitrogen as N (mg/L)	Ammonia as N (mg/L)	Dissolved nitrite plus nitrate as N (mg/L)	Remarks
1250	--	--	6.4	13	94	--	0.62	2.3	0.02	1.2	Average settleable solids density (g/mL) 0.10.
1345	10.5	9.2	6.4	11	--	--	--	--	--	--	
1525	--	--	--	--	--	60	--	--	--	--	
1710	--	--	6.5	27	--	--	--	--	--	--	

Table 5.--Hydrologic data collected during storms--Continued

Station number and name: 14144690 - Vancouver, Wash. Storm I Date: 2-20-77

Time (2400 hour)	Stage (ft)	Discharge (ft^3/s)	Specific conductance at 25°C (micromhos/cm)	Settleable solids (mL/L)	Turbidity (Jtu)	Suspended sediment (mg/L)	BOD_5 (mg/L)	BOD_u (mg/L)	Rate of BOD satisfaction, k (day^{-1})	Fecal coliform (colonies/100 mL)	Fecal streptococci (colonies/100 mL)
1120	0.25	0.01	550	--	140	5	--	--	--	130	--
1140	.52	.21	570	--	140	478	25	68	0.04	--	--
1200	1.1	2.2	355	3.6	140	815	55	91	.08	--	--
1230	1.52	5.7	122	2.5	95	525	26	72	.04	--	--
1300	2.3	18	93	1.2	65	369	--	--	--	--	--
1315	2.5	23	67	--	140	805	19	38	.06	500	33,000B
1345	1.42	4.7	87	.8	55	82	--	--	--	--	--
1430	1.23	3.1	56	.6	40	63	13	21	.08	--	--
1500	.98	1.6	66	.4	35	41	--	--	--	--	--
1530	.72	.61	76	.2	30	35	10	20	.06	--	--
1543	.66	.47	81	.1	30	24	--	--	--	--	--
1600	.60	.34	89	<.1	25	22	7.4	20	.04	1,600	--
1615	.97	1.5	95	--	80	237	17	35	.06	--	--
1645	.85	.95	92	.4	50	64	--	--	--	--	--
1715	.67	.49	101	.3	45	47	12	26	.06	--	--

Time (2400 hour)	Temp. (°C)	Dissolved oxygen (mg/L)	pH (units)	Alkalinity (mg/L as $CaCO_3$)	COD (mg/L)	Dissolved solids (mg/L)	Total phosphorus as P (mg/L)	Total Kjeldahl nitrogen as N (mg/L)	Ammonia as N (mg/L)	Dissolved nitrite plus nitrate as N (mg/L)	Remarks
1140	11.0	9.9	7.0	82	190	367	0.62	8.1	2.3	1.9	Average settleable solids density (g/mL) 0.19.
1200	--	--	6.1	15	--	246	--	--	--	--	
1230	11.3	--	6.4	8	--	91	--	--	--	--	
1315	11.2	10.0	--	--	250	49	.53	3.3	.29	1.2	
1430	11.7	--	6.5	7	85	45	.16	.99	.43	1.0	
1530	12.0	--	--	--	--	60	--	--	--	--	
1600	12.0	--	--	--	63	67	.07	.62	.33	1.6	
1615	12.2	--	--	--	160	80	.22	1.5	.27	1.5	
1715	12.0	10.3	6.7	12	--	--	--	--	--	--	

Table 5.--Hydrologic data collected during storms--Continued

Station number and name: 14144690 - Vancouver, Wash. Storm II Date: 6-3-77

Time (2400 hour)	Stage (ft)	Discharge (ft^3/s)	Specific conductance at 25°C (micromhos/cm)	Settleable solids (mL/L)	Turbidity (Jtu)	Suspended sediment (mg/L)	BOD_5 (mg/L)	BOD_u (mg/L)	Rate of BOD satisfaction, k (day^{-1})	Fecal coliform (colonies/100 mL)	Fecal streptococci (colonies/100 mL)
1050	10.43	0.11	350	1.4	40	61	35	--	--	620	--
1145	10.64	.42	210	2.4	65	146	39	--	--	--	--
1215	10.99	1.6	150	17	80	206	--	--	--	--	--
1245	11.53	5.8	56	--	75	204	17	--	--	--	--
1315	11.53	5.8	68	.6	55	128	--	--	--	--	--
1345	11.48	5.3	45	.5	45	95	8.3	22	0.04	--	--
1445	11.39	4.4	37	.6	45	100	8.2	22	.04	--	--
1535	11.90	10.8	128	--	65	217	9.7	26	.04	3,900	19,000
1555	11.76	8.7	34	.8	50	164	8.6	17	.06	--	--
1615	11.80	9.3	25	.7	50	177	--	--	--	--	--
1635	11.96	11.8	22	.8	55	164	7.2	20	.04	--	--
1655	11.68	7.6	23	.6	55	111	--	--	--	--	--
1720	11.45	5.0	26	.6	50	71	5.6	15	.04	--	--
1740	11.57	6.3	25	.6	50	128	--	--	--	--	--
1800	11.74	8.4	22	.6	50	122	5.5	15	.04	--	--
1825	11.26	3.3	24	.5	50	70	--	--	--	--	--
1845	10.99	1.6	26	.2	45	45	5.0	14	.04	--	--
1905	10.86	1.1	29	.2	20	40	--	--	--	5,500	30,000

Time (2400 hour)	Temp. (°C)	Dissolved oxygen (mg/L)	pH (units)	Alkalinity (mg/L as $CaCO_3$)	COD (mg/L)	Dissolved solids (mg/L)	Total phosphorus as P (mg/L)	Total Kjeldahl nitrogen as N (mg/L)	Ammonia as N (mg/L)	Dissolved nitrite plus nitrate as N (mg/L)	Remarks
1050	15	6.6	7.0	70	170	242	0.18	3.2	1.83	3.6	Total coliform (colonies/100 mL) 58,000 at 1535, 34,000 at 1905.
1145	--	--	6.6	19	--	174	--	--	--	--	
1215	--	--	6.4	11	--	106	.36	2.4	.79	1.8	
1245	--	--	--	--	59	--	--	--	--	--	
1315	--	10.6	6.4	10	--	--	--	--	--	--	
1445	--	--	--	--	--	13	--	--	--	--	Average settleable solids density (g/mL) 0.08.
1535	--	--	6.4	6	34	79	.29	1.2	.54	.8	
1800	--	--	6.3	5	--	6	--	--	--	--	