Data on Quantity and Quality of Water Flowing in Drainage Systems of Dry Docks at Puget Sound Naval Shipyard, Bremerton, Washington, 1994

U.S. GEOLOGICAL SURVEY
Open-File Report 95-361

Prepared in cooperation with the
DEPARTMENT OF THE NAVY
ENGINEERING FIELD ACTIVITY, NORTHWEST
NAVAL FACILITIES ENGINEERING COMMAND

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1995

U.S. DEPARTMENT OF THE INTERIOR

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CONVERSIONS FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
foot (ft)	0.3048	meter
cubic foot per second (ft^3/s)	0.02832	cubic meter per second

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

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ABSTRACT

Data on the quantity and quality of ground water that drains into dry docks at the Puget Sound Naval Shipyard can be useful for planning environmental remediation work at the shipyard. Ground-water discharges into and total drain-water discharges from individual dry docks were computed from a single set of discharges of individual inflowing drains and outflowing drain-water collection culverts that were measured in June, July and August 1994. Ground-water inflows to dry docks no. 1, 2, 3, 4, 5, and 6 equalled 0.07, 0.30, 0.29, 0.61, 1.18, and 6.2 cubic feet per second, respectively, and total drain-water discharges from the dry docks equalled 0.07, 0.30, 0.33, 0.61, 1.36, and 11.7 cubic feet per second, respectively. The differences between total outflows and ground-water inflows were mostly cofferdam and floodgate leakage and cooling water from a ship in dry dock no. 6. Observed salinities indicate that 18, 92, 28, 44, 55, and 69 percent of the ground-water inflows to dry docks no. 1 through 6 and 18, 92, 37, 44, 63, and 82 percent of the total outflows from the dry docks was saline water from Sinclair Inlet.

Concentrations of total copper in samples from 36 sites varied from less than 1 to 71 micrograms per liter, and concentrations of total lead varied from less than 1 to 44 micrograms per liter. None of 43 semi-volatile organic compounds that were analyzed for in samples from 19 sites were detected at concentrations greater than the laboratory minimum reporting level (5 or 10 micrograms per liter). A total of 13 volatile organic compounds were found at concentrations

greater than laboratory minimum reporting levels (mostly 0.2 microgram per liter) in 8 samples that were analyzed for 63 volatile organic compounds. Trichloroethene and at least three other chlorinated hydrocarbons were found in each sample.

INTRODUCTION

Puget Sound Naval Shipyard, a U.S. Navy installation within the Bremerton Naval Complex in the city of Bremerton, is located on Sinclair Inlet of Puget Sound in the western part of the state of Washington (fig. 1). Major work done at this installation since its founding in the 1890's includes building, modifying, repairing, and dismantling ships. A result of this long history of work is that concentrations of some metals and organic compounds in soil and ground water at the shipyard are elevated and in some places exceed regulatory limits. Specifically, in ground water some concentrations of arsenic, cadmium, chromium, lead, mercury, polynuclear aromatic hydrocarbons, methylene chloride, and trichloroethene exceed Model Toxic Control Act (MTCA) ground-water cleanup levels (URS Consultants, Inc., 1993). To obtain information for use in the selection and planning of necessary remediation work, the Navy and its consultants are conducting investigations to determine the magnitude, extent, fate, and movement of metals, organic compounds, and other constituents by ground water to the marine waters and bottom sediments at and near the shipyard. These investigations, including the one that is the subject of this report, are part of the Comprehensive Long-Term Environmental Action Navy (CLEAN) program.

Most of the work at the shipyard is concentrated in and near the yard's six dry docks, which are commonly referred to as DD-1 through DD-6 (fig. 1). The numbering corresponds to the order in which they were constructed. The dry docks, which are fixed concrete structures, range from about 650 to 1,150 ft in length, from about 108 to 190 ft in width, and have floors that range from about 20 to 49 ft below sea level. All but one of the dry docks (DD-2) were constructed with drains to relieve lateral hydrostatic pressure on their side and head walls and uplift on the floors when the dry docks are dry (not flooded). These drains discharge water to the dry docks, where it is collected and conveyed in a network of open channels before it is pumped into Sinclair Inlet. Although the walls and floor of DD-2 were constructed sufficiently heavy and strong so that pressure-relief drains were not necessary, some ground water does drain to this dry dock also.

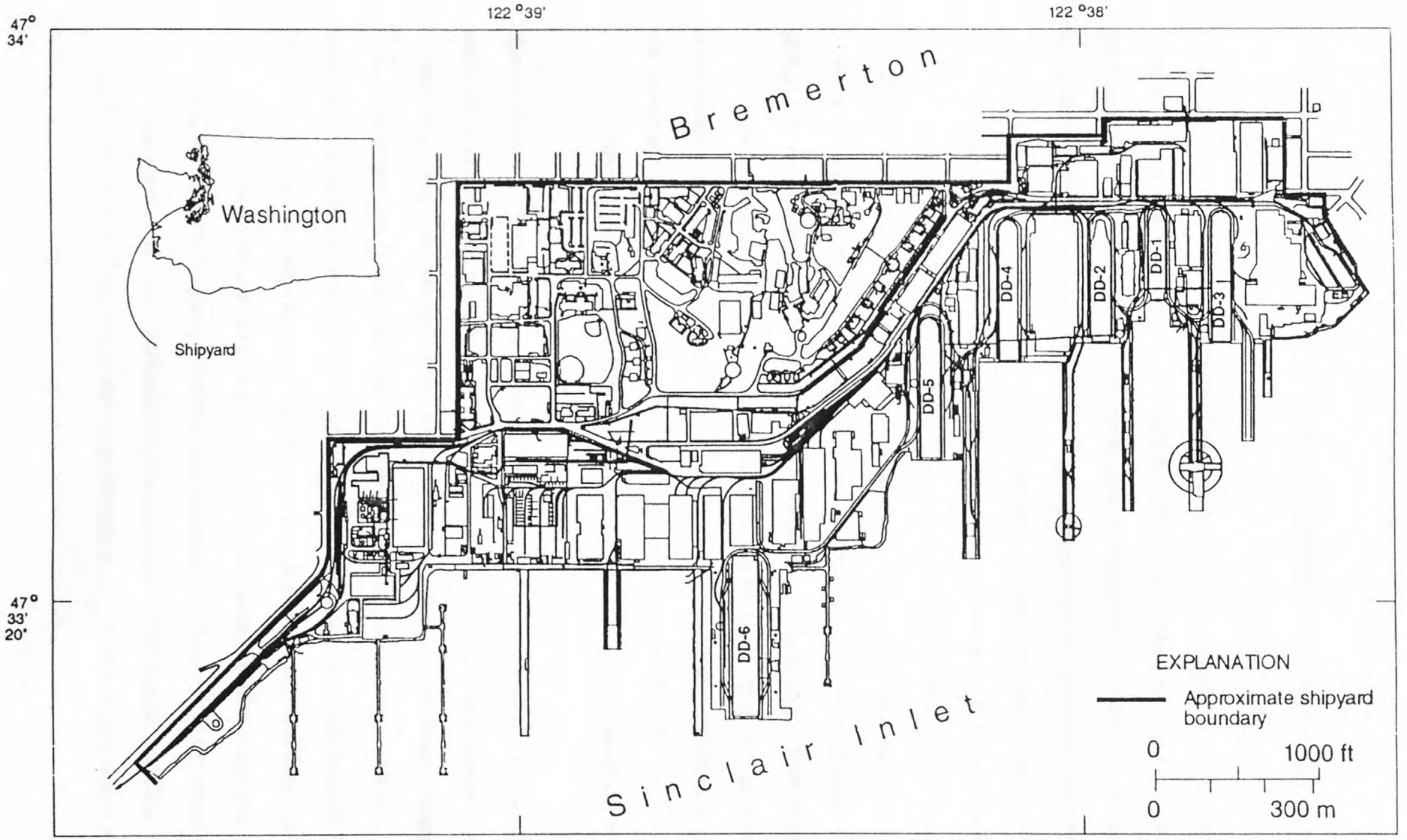

Figure 1. Puget Sound Naval Shipyard and locations of dry docks (DD).

Because the dry docks are dry more than 95 percent of the time, the dry-dock drains act as wells or ground-water sinks and probably have a large effect on ground-water flow at and near the shipyard.

Purpose

To obtain information for use in investigations of the movement of metals, organic compounds, and other constitutents by ground water, data on water-discharge rates and water quality were collected at various locations in the drainage systems of the dry docks. This report presents these data.

Method and Scope

Water-discharge rates were measured at the ends and other locations along culverts that collect drainage water from various sections of individual dry docks. Also, rates at which selected individual drain pipes discharge into the culverts were measured. Discharges were measured only once at most sites, and all the measurements were made during June, July, and August 1994. Discharge rates of water flowing in the culverts were measured using a current-meter gaging technique employed by the U.S. Geological Survey to measure discharges in streams (Rantz and others, 1982). With this technique, water velocity and depth are measured at numerous places across the width of the stream. Because of the relatively shallow depth of water at many of the measuring sites (depths ranged from about 0.05 to 1 ft), a pygmy meter was used. The accuracy (expected error) of most discharge measurements in this study by this technique was estimated to range from about 10 to 30 percent. The estimates of accuracy were subjective and were based on the depth and uniformity of flow, and the number of velocity measurements in a cross section. The least accurate were at some locations in the collector culverts where the depth was less than 0.1 ft, the velocity varied greatly across the width of the flow, or the velocities were only a fraction of a foot per second. A few discharges could only be estimated to within about 50 percent. Discharges

from most individual drains were measured volumetrically by using a stop watch to determine the length of time it took to collect an arbitrary volume of water in a calibrated 5-gallon bucket. The accuracy of most of these measurements ranged from about 5 to 30 percent and depended mostly on the accuracy of the time measurement. The least accurate measurements were at sites where the discharge was so large that the bucket filled in a few seconds.

Specific electrical conductance (for calculating salinity) and water temperature were measured in the field at most of the discharge-measurement sites, or samples were collected for determining conductance in the laboratory. Salinity was computed from conductance and temperature using a computer program given by Fononoff and Millard (1983). Samples for determining concentrations of selected constituents in water also were collected from 36 sites (table 1 and figs. 2 through 7). These sites included most of the major outflows from the dry docks. Concentrations of total copper and lead were determined in samples from all 36 sites, and concentrations of dissolved copper and lead were determined in samples from 2 of them. Lead was selected because it is one of the metals for which a MTCA level was exceeded, and copper was selected because it is one of the metals that may not meet the criteria of a permit for discharging drain water to Sinclair Inlet (John Frech, Puget Sound Naval Shipyard, oral commun., 1994). The turbidity of each of these samples, a measure of suspended-solids content, was also determined. Concentrations of 43 semi-volatile organic compounds, including polynuclear aromatic hydrocarbons, were determined in samples from 19 sites, and concentrations of 63 volatile organic compounds (including methylene chloride and trichloroethene) were determined in samples from 8 of the sites. Six of the organic compounds are in both the semi-volatile and volatile list. (See tables 8 and 9 in the section "Water Quality" for lists of the organic compounds.) Most samples that were analyzed for volatile organic compounds were collected from individual drains or near the upstream ends of collection channels before the water flowed far and had the opportunity to lose material by volatilization to the atmosphere. Also, these samples were mostly from near the heads of the dry docks where the chance of sampling fresh ground water that flowed through the

***Table 1.**--Discharges, salinities and temperatures of water at selected sites in the drainage systems of the six dry docks at Puget Sound Naval Shipyard, Bremerton, Washington, and sites where other water-quality data were collected*

[ft^3/s, cubic feet per second; ppt, part per thousand; °C, degrees Celsius; --, no data; *, data used to compute total dry-dock outflow; e, estimated value; MM, total and dissolved copper and lead; M, total copper and lead; S, semi-volatile organic compounds, V, volatile organic compounds; see figures 2 through 7 for locations of data-collection sites]

Site identifier	Date	Time[1]	Discharge (ft^3/s)	Salinity (ppt)	Temperature (°C)	Water-quality analyses	Description of data-collection site
Dry dock no. 3							
DD3-A	06/28/94	--,1045	--	0.1	--	M,S,V	Drain pipe, base N wall, near E corner
DD3-B	06/28/94	--,1230	--	.5	16.6	M,S,V	Drain pipe, base N wall, near W corner
DD3-E-14C	07/07/94	0850,0845	0.10	.1	16.3	MM,S	E-side culvert, near N end
DD3-E-14C	08/11/94	0840,0850	.074	.1	16.7	--	E-side culvert, near N end
DD3-E	07/07/94	0900,0950	* .065	*5.4	15.9	M	W-side collector basin, culvert from E
DD3-E	08/11/94	0905,0920	.068	6.2	16.9	--	W-side collector basin, culvert from E
DD3-W-PW	08/11/94	0930,0930	.093	.1	17.9	--	Process water discharge, W side, N part
DD3-W-N	07/07/94	0915,0955	* .077	*3.0	16.3	M,S	W-side collector basin, culvert from N
DD3-W-N	08/11/94	0920,0920	.12	2.3	17.4	--	W-side collector basin, culvert from N
DD3-W-S	07/07/94	0930,1000	* .19	*16.2	15.0	M	W-side collector basin, culvert from S
DD3-W-S	08/11/94	0910,0920	.38	16.7	16.0	--	W-side collector basin, culvert from W
DD3-CD-E	07/07/94	1030,1025	.004	29.5	13.0	--	Leakage from coffer dam to E-side culvert
DD3-CD-W	07/07/94	1025,1020	.04	29.5	13.9	M	Leakage from coffer dam to W-side culvert
Computed total dry-dock outflow			.33	11.0			
Dry dock no. 1							
DD1-E-343	07/06/94	1105,1040	.008e	4.4	--	M,S,V	E-side culvert, near N mid point
DD1-E-B	07/06/94	1325,1340	* .05e	*4.6	--	M	E-side culvert, S end
DD1-W-245	07/06/94	1135,1130	.003e	3.1	15.7	M,S	W-side culvert, near mid point
DD1-W-B	07/06/94	1255,1310	* .02e	*7.3	14.6	M	W-side culvert, S end
Computed total dry-dock outflow			.07	5.4			

***Table 1**.--Discharges, salinities and temperatures of water at selected sites in the drainage systems of the six dry docks at Puget Sound Naval Shipyard, Bremerton, Washington, and sites where other water-quality data were collected--Continued*

Site identifier	Date	Time[1]	Discharge (ft^3/s)	Salinity (ppt)	Temperature (^oC)	Water-quality analyses	Description of data-collection site
Dry dock no. 2							
DD2-FC1	07/07/94	--,1155	--	2.9	--	M,S	Crack in floor, near N end at center
DD2-E	07/07/94	--,1310	*0.25e	*27.2	--	M,S	E-side culvert, S end
DD2-W	07/07/94	--,1301	* .05e	*25.8	--	--	W-side culvert, S end
Computed total dry-dock outflow			.30	27.0			
DD2-XC	07/07/94	1245, --	.76	18.6	--	--	E-W tunnel at center of DD2
Sum of computed total dry-dock outflows from DD-3,DD-1 and E part DD-2			.65	16.9			
Dry dock no. 4							
DD4-FD1	07/01/94	1350,1350	.061	9.3	--	M	Floor drain, W side, 150 ft from N end
DD4-FD2	07/01/94	1400,1400	.030	8.2	--	M	Floor drain, W side, 250 ft from N end
DD4-FD3	07/01/94	1415,1416	.017	24.7	--	M,S,V	Floor drain, W side, 700 ft from N end
DD4-EW	07/01/94	1420,1417	.003	.0	--	--	Outflow from eye-wash station
DD4-E-C	07/01/94	--,1630	--	.8	--	MM,S,V	Crack in W wall E culvert, 40 ft N end
DD4-E-NB	07/01/94	1050,1530	*.26	* 4.3	14.1	M,S	E-side culvert, N part, S end
DD4-E-SB	07/01/94	1100, --	*.026	*25. e	12.1	--	Sum of drains to E-side culvert, S part
DD4-W-NB	07/01/94	1325,1535	*.32	*19.3	--	M,S	W-side culvert, N part, W end
Computed total dry-dock outflow			.61	13.1			

***Table 1.**--Discharges, salinities and temperatures of water at selected sites in the drainage systems of the six dry docks at Puget Sound Naval Shipyard, Bremerton, Washington, and sites where other water-quality data were collected--Continued*

Site identifier	Date	Time[1]	Discharge (ft^3/s)	Salinity (ppt)	Temperature (^oC)	Water-quality analyses	Description of data-collection site
Dock no. 5							
DD5-E-1E	08/05/94	1120,1550	0.003	2.8	13.3	MM,S,V	Drain 1, E wall, E-side culvert
DD5-E-FD1	08/05/94	0820,1710	.018	21.2	14.3	M	Floor drain, E side, N part
DD5-E-NB	08/05/94	1130,1535	*.15	*19.3	13.1	M,S	E-side culvert, N part, S end
DD5-E-SB	08/05/94	1145,1530	*.35	*27.4	12.3	M	E-side culvert, S part, N end
DD5-W-1W	08/05/94	0940,1510	.004	2.2	13.6	M	Drain 1, W wall, W-side culvert
DD5-W-NB	08/05/94	0900,1440	*.33	* 5.8	12.8	M,S	W-side culvert, N part, S end
DD5-W-FD2	08/05/94	0830,1720	.27	19.0	12.3	M	Floor drain, to W side, middle
DD5-W-11W	08/05/94	1000,1000	*.093	*18.3	12.3	--	Drain 11, W wall, W-side culvert
DD5-E-FD2	08/05/94	0840, --	.016	--	--	--	Floor drain, to E side, middle
DD5-W-SB	08/05/94	0925,1450	*.44	*20.6	13.4	M	W-side culvert, S part, N end
Computed total dry-dock outflow			1.36	18.5	--		
Pump 4	08/11/94	-- ,1445	--	16.1	--	M,S,V	Pump in pump-well 4 (outflow from DD-1 through DD-5)
Sum of computed total outflows from DD-1 through DD-5			2.7	16.5			
Dry Dock no. 6							
DD6-A	06/28/94	0820,0635	.072	4.9	14.2	M,S,V	Drain in base N wall, 7 ft W of center
DD6-E-D2	06/30/94	1135,1400	.88	15.1	12.3	M,S	E-side culvert, at 2nd door from N
DD6-E-NB	06/30/94	1200,1355	*2.4	*16.1	13.8	M	E -side culvert, N part, S end
DD6-E-NB	08/11/94	1340,1320	3.2	20.6	--	--	E-side culvert, N part, S end
DD6-E-SB	06/30/94	1205,1350	*2.6	*27.6	--	M	E-side culvert, S part, N end
DD6-E-SB	08/11/94	1325,1320	2.2	29.4	--	--	E-side culvert, S part, N end
DD6-W-D2	06/29/94	1440,1420	.80	17.9	13.1	M,S	W-side culvert, at 2nd door from N
DD6-W-NB	06/29/94	1510,1415	*6.3	*25.9	13.8	M	W-side culvert, N part, S end
DD6-W-NB	08/11/94	1300,1030	5.3	25.8	--	--	W-side culvert, N part, S end
DD6-W-SB	08/11/94	1130,1030	* .41	*27.7	15.	M	W-side culvert, S part, N end
Computed total dry-dock outflow			11.7	24.3			

***Table 1**.--Discharges, salinities and temperatures of water at selected sites in the drainage systems of the six dry docks at Puget Sound Naval Shipyard, Bremerton, Washington, and sites where other water-quality data were collected--Continued*

Site identifier	Date	Time[1]	Discharge (ft^3/s)	Salinity (ppt)	Temperature (^oC)	Water-quality analyses	Description of data-collection site
Pump 6	07/01/94	-- ,0900	--	24.1	--	M,S	Pump in pump-well 6

[1] First time is that of discharge measurement, second time is that of collection of water-quality sample.

shipyard was largest. The samples that were analyzed for semi-volatile organic compounds were from the same locations as the samples analyzed for volatile compounds plus some sites near the downstream ends of collection channels.

Nearly all samples were collected directly into sample bottles. Samples of water flowing from drain pipes were caught in the sample bottles in midair. Samples from the culverts were collected by submerging hand-held bottles and moving them slowly across the flow or by pumping the water with a peristaltic pump. Samples of water being pumped from the dry docks to Sinclair Inlet were obtained by opening valves in small-diameter lines on the downstream side of the pump-discharge lines and collecting the samples directly into sample bottles.

Acknowledgments

The author thanks the numerous individuals at Puget Sound Naval Shipyard who took the time to explain the workings of the dry-dock drainage systems and made many of the data-collection sites accessible. Special thanks are due to John Frech of the Environmental Group at the shipyard for being a personal guide and for assisting with data collection. The work described in this report was part of a larger program in which the U.S. Geological Survey is providing technical assistance in the field of hydrology to Engineering Field Activity, Northwest of the Department of the Navy at a number of sites where the Navy is conducting environmental studies. The Survey's work at Puget Sound Naval Shipyard is administered by William Schrock of Engineering Field Activities, Northwest.

All six dry docks are parallel and are oriented in a north-south direction along the north shoreline of Sinclair Inlet (fig. 1). The entrance to each dry dock, except DD-6, is approximately in line with or set back from the present shore line. Most of DD-6 protrudes into Sinclair Inlet. The fill behind the sidewalls and headwall (north wall) and beneath the floor of each dry dock, except DD-2, is coarse-grained material with imbedded drain pipes or crushed-rock drainage courses. Both fresh and saline ground water in the fill flows by gravity into these drains, which discharge into longitudinal concrete collection culverts within the dry docks. The invert elevations of the culverts (lowest points in culvert cross sections) are below the elevations of the dry-dock floors, and consequently help maintain a dry working environment in the dry docks. In addition to ground-water drainage, leakage by the cofferdams at the entrances to the dry docks, leakage from floodgates, cooling water used by ships in the dry docks, and process water is sometimes discharged to the culverts.

Water that is collected by the longitudinal collection culverts of DD-1 through DD-5 discharges into a tunnel that runs east-west beneath the floors of the dry docks. This tunnel, which varies in diameter from about 6 to 9 ft, connects five different pump wells from which the water can be pumped to Sinclair Inlet. Most of the time, water is pumped from only one of the pump wells while the pumps in a second pump well are on standby and pump only occasionally, and the pumps in the other pump wells are idle. During special operations, such as the flooding of a dry dock, selected gates in the tunnel can be closed to isolate individual or groups of dry docks and pump wells. The longitudinal culverts in DD-6 also discharge to an east-west tunnel that in turn discharges to a pump well. However, this tunnel and pump well are not connected to the tunnel and pump system for DD-1 through DD-5.

The following subsections give additional descriptions of the drainage systems of individual dry docks, and describe and give the results of the discharge measurements. The order in which the dry docks are described is from east to west (fig. 1). Information on water quality is given in a latter section titled "Water Quality". However, salinity data also are included with the water-discharge data.

Dry Dock No. 3

DD-3, the easternmost dry dock at the shipyard, is about 930 ft long and 130 ft wide, has vertical walls, and is the shallowest of the six dry docks. The tops of the walls of this and every other dry dock except DD-6 are about 11 ft above sea level. The floor in the south part of DD-3 is 23 ft below sea level, and the floor in the north part is 3 ft higher. This dry dock was constructed in such a way that a temporary barrier can be installed at about its mid point so that the north part could be kept dry when the south part is flooded. The longitudinal drain-water collection culverts in DD-3 run beneath the dry-dock floor near the base of the side walls (fig. 2). These culverts are about 2 ft wide, 2 ft deep, and have inverts about 3 ft below the dry-dock floor. Drain water from the side walls flows directly into the culverts, while water from drains in the headwall of the dry dock flows in gutters and pipes that discharge to the north parts of the longitudinal culverts. Leakage from the cofferdam at the entrance to the dry dock flows in gutters and across the dry-dock floor to the south parts of the culverts.

All water from DD-3 flows into a collection basin near the center of the west-side culvert and then into the east-west tunnel that connects the dry docks to the pump wells (fig. 2). The north and south parts of the west-side culvert both discharge directly into this collection basin. All or part of the water from the east-side culvert flows into a transverse culvert that also discharges directly to the collection basin on the west side. Fay, Spofford, and Thorndike (1979b) mention another transverse culvert that connects the south parts of the east and west culverts; however, this transverse culvert could not be found.

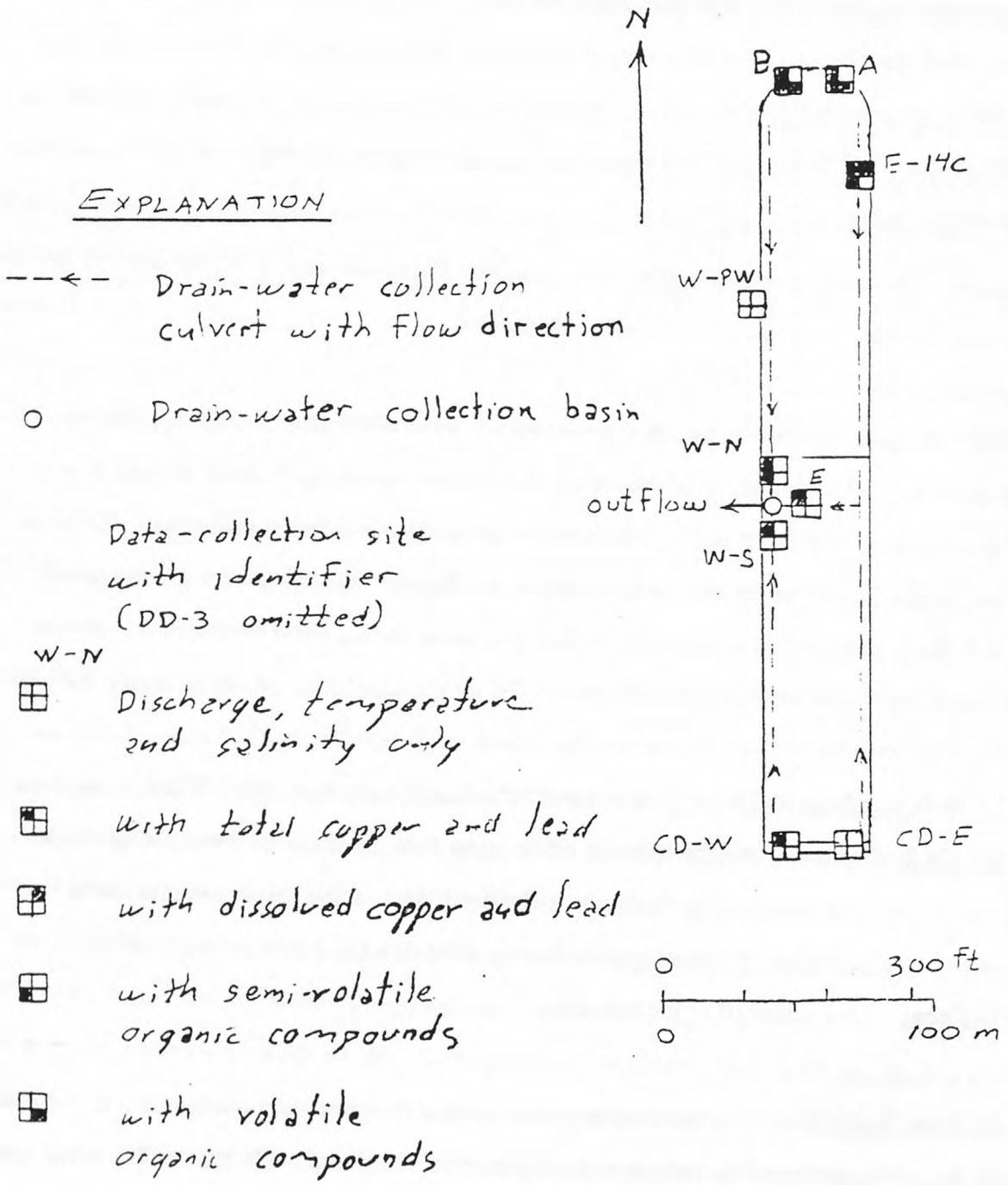

Figure 2.--Drain-water collection culverts and data-collection sites in dry dock no. 3.

For measuring discharge and taking water samples, the culverts were accessed through grate-covered openings spaced about 25 ft apart along the culverts and from the collection basin on the west side. However, most of the grates are rusted in their frames and were not removed during the present study. Discharge measurements were made at one location near the upstream end of the north part of the east-side culvert (site E-14C), at the ends of the three culverts that discharge directly into the collection basin (sites E, W-N and W-S), of the leakage from the cofferdam at the dry dock entrance into the east- and west-side culverts (sites CD-E and CD-W), and of a process-water line that was flowing into the north part of the east-side culvert (W-PW) (see table 1 and fig. 2). Measurements in the north part of the east culvert were made by constricting the flow cross section to less than 1 ft wide and measuring water velocities with a current meter. Discharges at the other locations were measured volumetrically. The estimated accuracy of the discharge measurements in DD-3 ranged from about 10 to 30 percent. Because of potential hazards, project personnel did not enter the culverts in this dry dock to measure discharges of individual drains that flow into the culverts. Discharges of drains in the head wall were not measured because the discharges were too small to be measured with a current meter and the drain lines were too close to the dry-dock floor to be caught in a bucket.

Data collected on July 7, 1994, show that the discharge from the transverse culvert into the west-side collection basin (site E) was less than the discharge in the north part of the east-side culvert (site E-14C). The reverse was expected because the discharge at the end of the transverse culvert should be a sum of the discharge at the upstream measuring site plus additional drainage to the east-side culvert south of the site. As a check, discharges at these two and selected other locations were measured again on August 11, and a similar anomaly was found in the second set of measurements. Two possible reasons are proposed for the anomaly. One is that the accuracy of the measurements was not good enough to determine the true difference between discharges at the two sites. The other, and perhaps more likely, is that there is flow from the east culvert to the west culvert through the transverse culvert that was not found.

The computed total outflow from DD-3 on July 7, 1994, was 0.33 ft^3/s with a salinity of 11.0 ppt (parts per thousand) (table 1). The rate of ground-water discharge into DD-3, which can be computed as the total outflow less cofferdam leakage (sites CD-E and CD-W), was 0.29 ft^3/s, which was 87 percent of the total. The fractions of the ground-water discharge and total outflow that was saline water from Sinclair Inlet can be calculated from the salinities. If the salinity of water in Sinclair Inlet is assumed to be 29.5 ppt (the salinity of the cofferdam leakage and a typical value for Sinclair Inlet) and the salinity of fresh ground water is zero, then the calculated proportions of the ground-water inflow and total outflow from DD-3 that was water from Sinclair Inlet are 28 and 37 percent, respectively. The salinity of water from Sinclair Inlet was assumed to be 29.5 ppt in all calculations in this report, even though the salinity of water in the inlet varies with space and time and was greater than this value at some of the data-collection sites.

The computed total outflow on August 11, 1994, was 0.57 ft^3/s, which was nearly twice that on July 7. The greater outflow on the August date was due partly to a process-water discharge that did not exist on the July measurement date and a larger flow from the south part of the west-side culvert. The reason for the latter is not known.

Dry Dock No. 1

DD-1, the oldest and smallest of the six dry docks, is about 650 ft long. The side walls are stepped, 108 feet apart at the top, and 78 ft apart across the floor. The floor is 28 ft below sea level. As in DD-3, the longitudinal drainage-collection culverts run beneath the dry-dock floor near the base of the side walls. These culverts are about 2 ft wide, 3 ft high, and have inverts about 5 ft below the dry-dock floor. They discharge at their south ends to a transverse channel that flows into to the east-west tunnel. Access to the culverts for measuring discharge and collecting water samples is through grate-covered openings in the dry-dock floor spaced about 25 ft apart, and from the transverse channel that can be entered through a grate-covered opening on the east side of the dry dock.

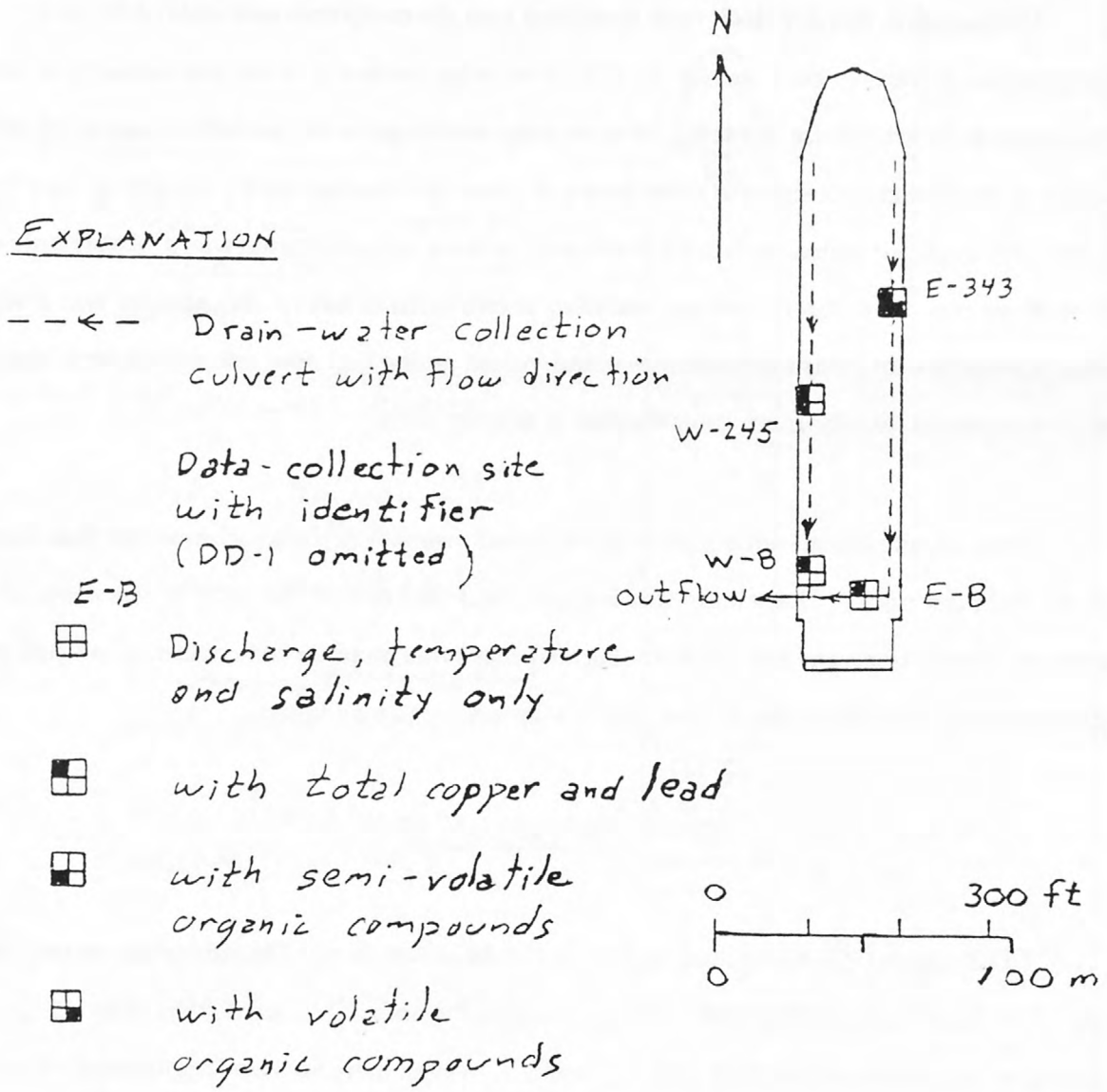

Figure 3.--Drain-water collection culverts and data-collection sites in dry dock no. 1.

Discharges in this dry dock were measured near the midpoints and ends of the two longitudinal culverts (table 1 and fig. 3). (The flow at the south end of the east culvert was actually measured in the transverse channel.) Most of these discharges were made by constricting the width of the flow cross-section to a few tenths of a foot and measuring the velocity at only one point with a current meter. Because the accuracy of these measurements was probably only about 30 to 50 percent, these discharges are identified as estimated in table 1. No attempt was made to enter the culverts to measure discharges of individual drains that flow into the culverts, and there was no apparent leakage from the cofferdam in this dry dock.

The computed total outflow from this dry dock was 0.07 ft^3/s, which was less than from any of the other dry docks. The salinity was 5.4 ppt, which means that the outflow was about 18 percent saline water from Sinclair Inlet. Because there was no observed cofferdam leakage or process water, all of this outflow was probably ground-water discharge.

Dry Dock No. 2

DD-2 is about 900 ft long, and its floor is 35 ft below sea level. The side walls are stepped and are 145 ft apart across the top and 104 ft apart across the floor. This dry dock is without pressure-relief drains in the floor and side walls; however, there are two longitudinal culverts. These culverts, which are about 10 ft either side of the longitudinal axis of the dry dock, discharge directly to the east-west tunnel at the south end of the dry dock. Access to these culverts is practical only from the tunnel, which can be entered through a grate-covered opening near the southwest corner of the dry dock. The discharge at the south end of the east culvert (site E) was estimated by measuring the velocity at one location in the flow cross section. The accuracy of this estimate may be only about 50 percent. The discharge of the west culvert (site W) was much less than that of the east culvert and was estimated without the benefit of a measurement. The total

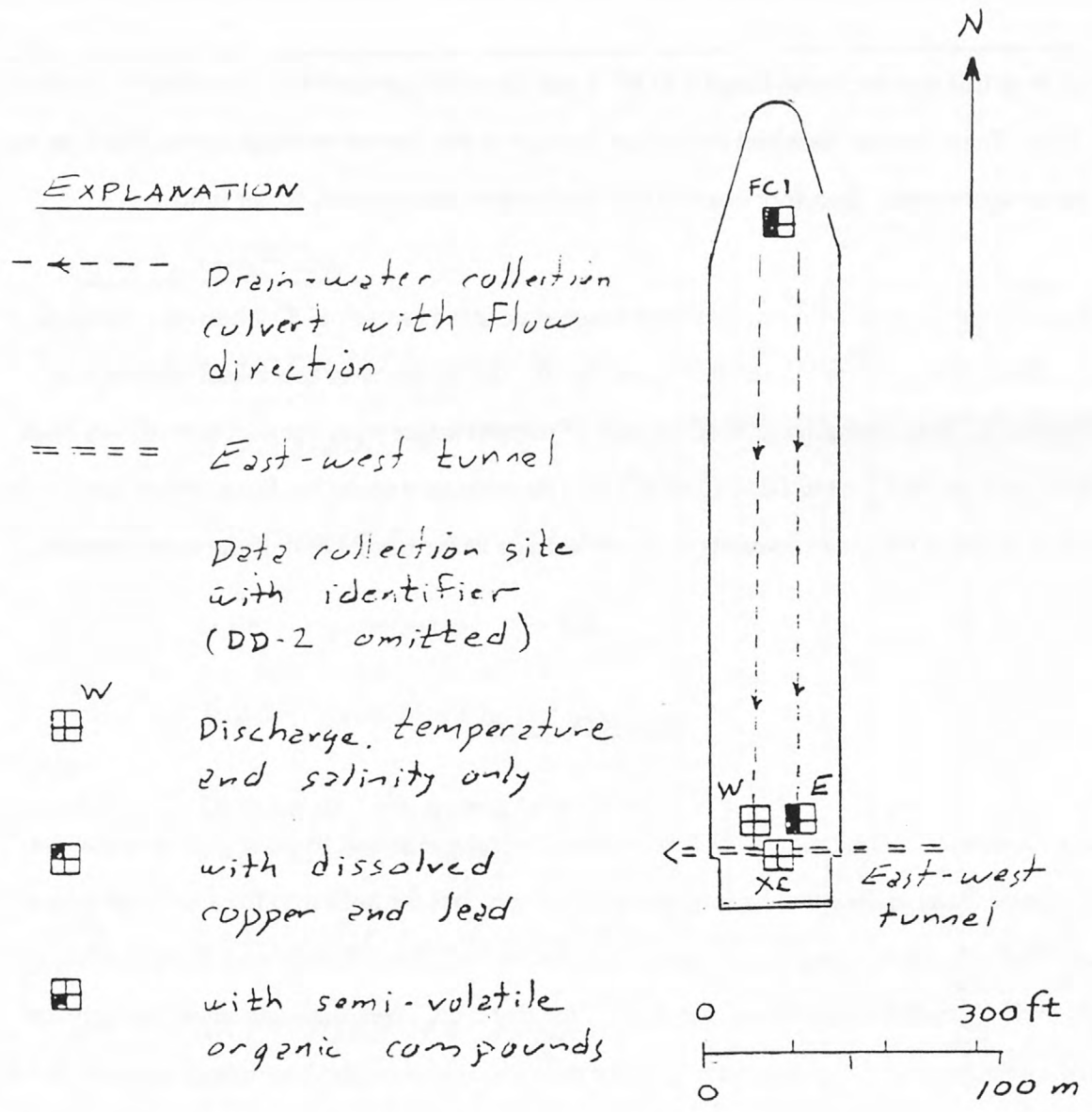

Figure 4.--Drain-water collection culverts and data-collection sites in dry dock no. 2.

discharge from this dry dock was about 0.30 ft^3/s and about 92 percent of it was saline water from Sinclair Inlet. There was no observed cofferdam leakage or process-water discharge to DD-2 on the day of the measurements; therefore nearly all of the outflow was ground-water inflow.

Discharge in the east-west tunnel was measured near the center of DD-2 between the ends of the longitudinal culverts (site XC on table 1 and fig. 4). The accuracy of this measurement was about 10 percent. This discharge (0.76 ft^3/s) was 17 percent larger than the sum of outflows from DD-3, DD-1 and the east part of DD-2 (0.65 ft^3/s). The difference could be due to either low accuracies in some of the measurements or direct leakage to the tunnel east of the measurement site.

Dry Dock No. 4

DD-4 is about 1,000 ft long, is 147 ft wide, has vertical walls, and its floor is 43 ft below sea level. Drainage water is collected by longitudinal culverts that are built into the side walls of the dry dock. The culverts, which are rectangular in cross section, are 5 ft wide and about 5 ft high, and have inverts about 3 ft lower than the floor of the dry dock. Personnel can enter the culverts through doors in the dry dock walls near both the north and south ends. Water from culverts flows into the east-west tunnel where it crosses the dry dock about 150 ft from its south end. Although the east-side culvert extends both north and south of the east-west tunnel, the west-side culvert extends only north of the tunnel. The path by which drainage from the extreme south part of the west side of the dry dock leaves the dry dock is unknown.

Water from drains in the side walls of DD-4 flows into the culverts from pipes spaced about 20 feet apart along the side walls or ceilings of the culverts, and drains in the head wall flow through pipes and gutters into the upstream ends of the culverts. Drainage from beneath the floor of the dry dock flows up through weep holes in the dry-dock floor, laterally in transverse drainage

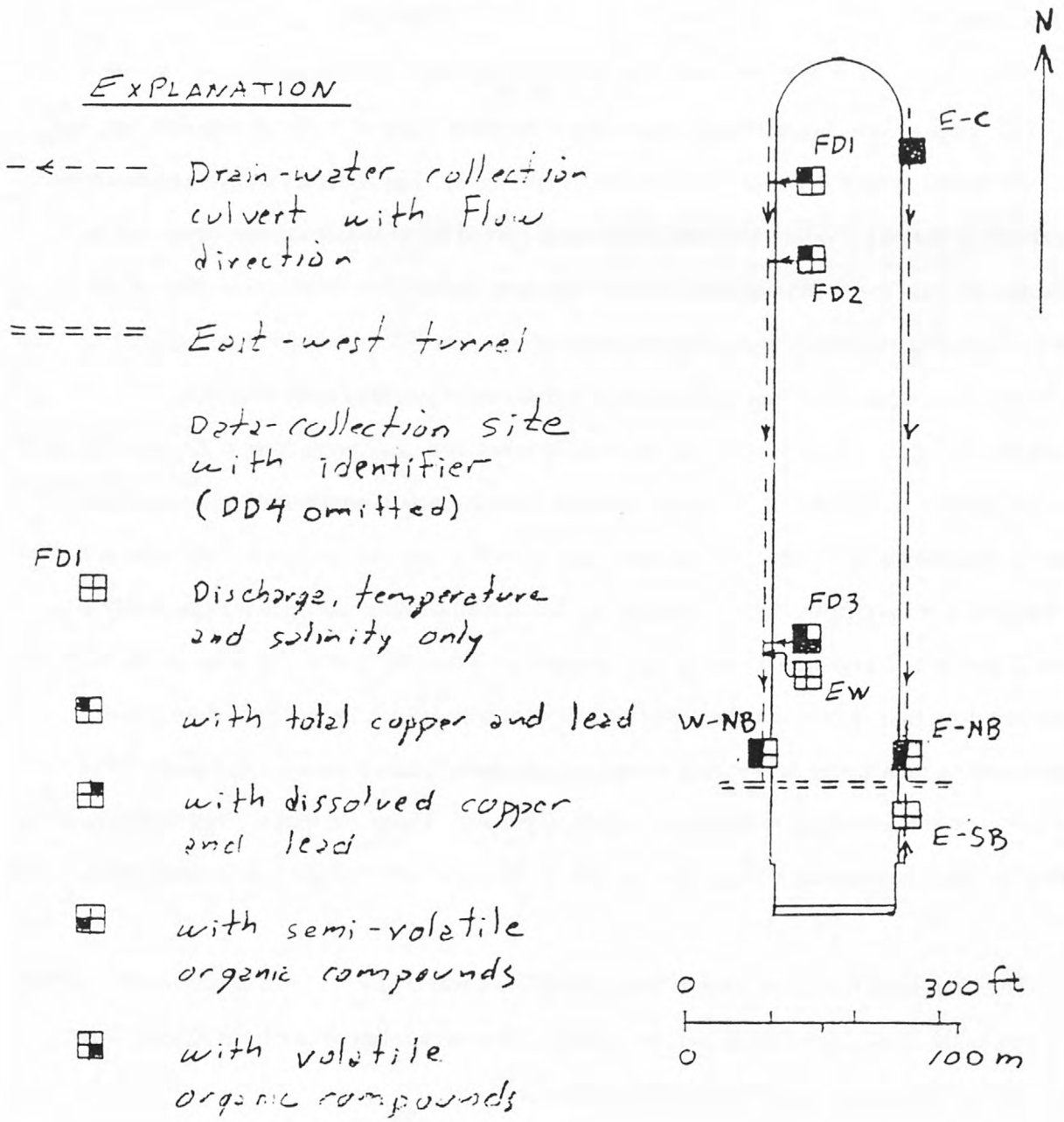

Figure 5.--Drain-water collection culverts and data-collection sites in dry dock no. 4.

slots (about 0.4 ft wide by 0.4 ft deep) in the floor, longitudinally in gutters along the dry-dock side walls, and then through pipes that connect the gutters to the longitudinal culverts at about 24-ft intervals.

Discharges were measured at or near where the north parts of both culverts flow into the east-west tunnel (sites E-NB and W-NB in table 1 and fig. 5). The accuracy of these measurements was about 20 percent. Water velocities in the south part of the east-side culvert could not be measured because the water was too shallow; therefore, the outflow from this section of culvert (site E-SB) was calculated by summing measured discharges from the individual wall drains. The discharges from these and other wall drains into the culvert (table 2) were measured volumetrically. The accuracy of the volumetrically measured discharges from individual drains in DD-4 probably was 10 percent or better; however, because small, unmeasureable quantities of water from drains beneath the dry-dock floor also were flowing into the culvert, the accuracy of the discharge that was computed by summing individual wall-drain discharges was probably also about 20 percent. The discharge in the few transverse 0.4 ft-wide slots in the floor on the west side of the dry dock that appeared to be conveying most of the water from the floor drains was determined by measuring the velocity at one location in each slot with a current meter (table 1). The accuracy of these measurements was about 30 percent. The pipes that convey water from the gutters to the culverts enter the culverts too low for the flow to be caught in a bucket.

The computed total discharge of water from DD-4 was 0.61 ft^3/s, and the computed salinity (13.1 ppt, table 1) indicates that 44 percent of the outflow was saline water from Sinclair Inlet. Nearly all of this water was ground-water discharge.

Table 2.--Discharges, salinities and temperatures of water flowing from individual drains and in collection culverts within dry dock no. 4 of Puget Sound Naval Shipyard, Bremerton, Washington
[ft^3/s, cubic feet per second; °C, degrees Celsius; ppt, parts per thousand; --, no data; e, estimated value]

Site identifier and remark[1]	Measured discharge[2] (ft^3/s)	Temperature[2] (°C)	Salinity[2] (ppt)
	East-side culvert		
1 to 20	0.	--	--
Culvert	.22	14.	2.8
21 to 29	0.	--	--
30	.000	--	--
Un W	.004e	--	--
31 to 39	0.	--	--
40 C	.002	--	22.3
Un W	.004e	--	3.9
41 C	.003	--	16.3
42 C	.004	--	23.7
43 C	0.	--	--
44 C	0.	--	--
45 W	0.	--	--
N-part outflow (E-NB)	.26	14.1	--
S-part outflow (E-SB)	.026	12.1	--
46 C	.000	--	--
47 E	0.	--	--
Un W	0.	--	--
48 E	.011	12.0	--
49 E	.009	11.5	--
Un W	0.	--	--
50 E	.004	11.2	--
Un W	0.	--	--
51 E	.001e	--	--
52 C	.001e	--	--
	West-side culvert		
1 to 6	0.	--	--
Floor drain (FD1)	.061	--	9.3
7 to 10	0.	--	--
Floor drain (FD2)	.030	--	8.2
11 to 29	0.	--	--
Floor drain (FD3)	.017	--	24.7
Eye-wash outflow	.003		0.0
30 to 39	0.	--	--
40	.012	--	24.0
41 C	.003	--	26.4
42	0.	--	--
43	0.	--	--
44	0.	--	--
45	.002	--	27.6

Table 2.--Discharges, salinities and temperatures of water flowing from individual drains and in collection culverts within dry dock no. 4 of Puget Sound Naval Shipyard, Bremerton, Washington--Continued

Site identifier and remark[1]	Measured discharge[2] (ft^3/s)	Temperature[2] (^oC)	Salinity[2] (ppt)
	West-side culvert--continued		
Culvert	0.23	--	15.7
46 W	.095	--	27.9
Outflow (W-NB)	.32c	--	19.3c

[1] Numbers identify drain pipes or channels and were assigned by personnel in Puget Sound Naval Shipyard Environmental Group. "Un" denotes unnumbered drain; numbers increase from north to south. "W", "E" and "C" denote drain pipes discharging into culvert from west and east walls, and from ceiling, respectively; identifier in parenthesis is same as in figure 5 and table 1.

[2] Data are from measurements and samples collected on July 1, 1994; "c" denotes value computed from data for drain 46 and culvert at the site between drains 45 and 46.

The size and geometry of DD-5 and the configuration of its drainage system (fig. 6) are nearly identical to that of DD-4. An exception is that the east-west tunnel crosses DD-5 near its north end, and the both east- and west-side longitudinal culverts extend both north and south of the east-west tunnel. Water discharges were measured in both culverts at the four locations where they flow into the cross tunnel (sites *E-NB, E-SB, W-NB and W-SB* in table 1 and fig. 6). The discharge rates of the nearly 100 individual drains that flow into each of the culverts also were measured (table 3). The accuracy of all these discharge measurements ranged from about 5 to 10 percent. The discharge of water from floor drains in the transverse slots in the dry-dock floor were measured by the same method as in DD-4. There was no obvious leakage from the cofferdam at the time of the measurements. However, there was a small process-water discharge, and there was some discharge over spillways at the south ends of the longitudinal culverts that was leakage from Sinclair Inlet by gates in tunnels used to flood the dry dock (table 3).

The total discharge from DD-5, which was computed as the sum of the discharges at the ends of the culverts plus the discharge from drain 11 in the west-side culvert, which discharges directly into the east-west tunnel, was 1.36 ft^3/s (table 1). The sum of the individual drain discharges (tables 3 and 4) was 1.43 ft^3/s, which differs from 1.36 ft^3/s by only 5 percent. (The value of 1.36 ft^3/s is given in the Abstract and Summary of this report to be consistent with the value in table 1; however, either of the two values could have been used.) The computed salinity of the outflow (18.5 ppt, table 1) implies that 63 percent of the outflow was saline water from Sinclair Inlet. The outflow from DD-5 was about twice the outflow from DD-4 and about equal to the sum of the discharges from DD-1 through DD-4.

Discharge from drains in the east wall of the east-side culvert and the west wall of the west-side culvert is ground water from behind the dry-dock side and head walls, and discharge from drains in the west wall of the east-side culvert and east wall of the west-side culvert is ground

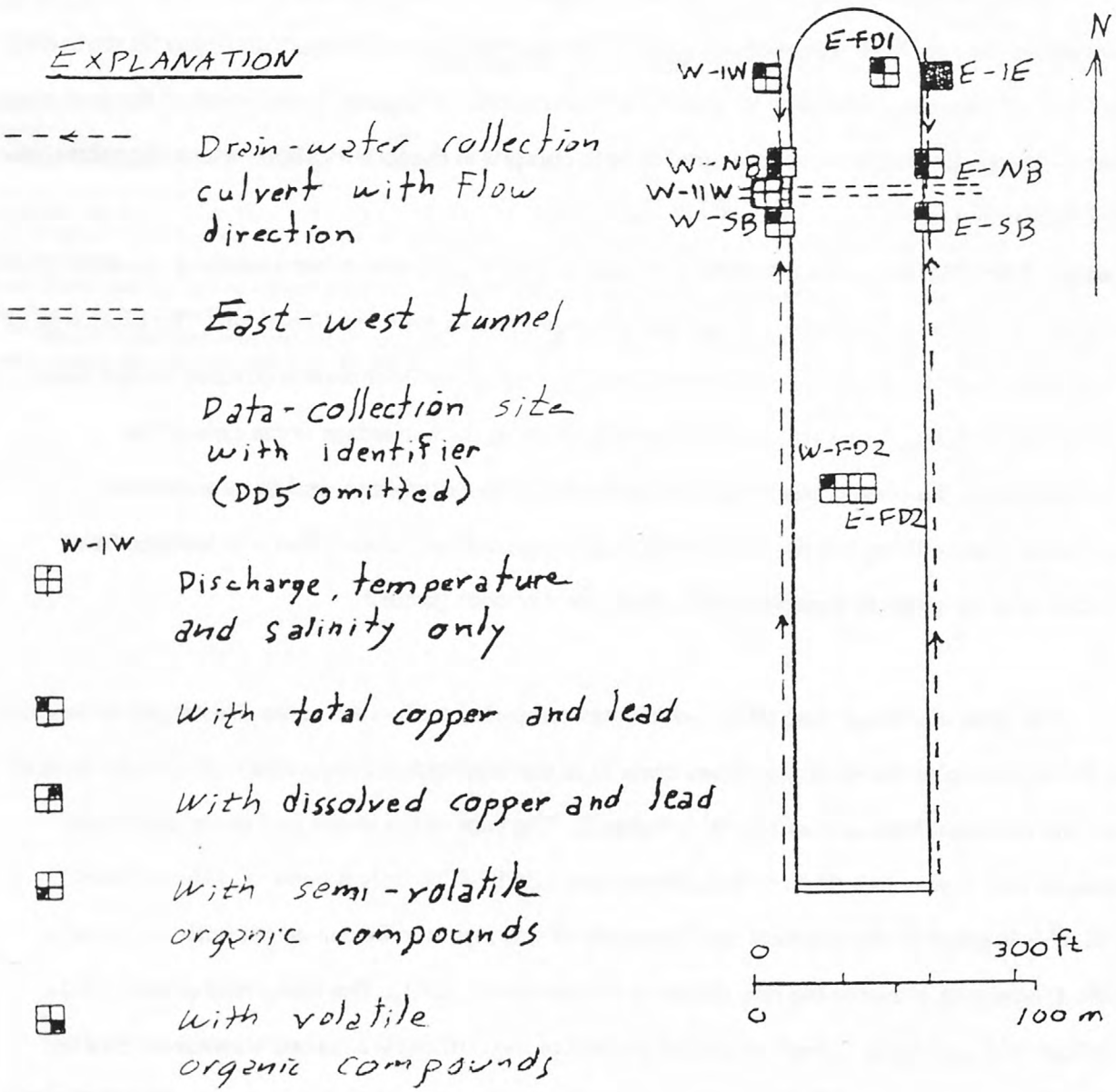

Figure 6.--Drain-water collection culverts and data-collection sites in dry dock no. 5.

Table 3.--Discharges, salinities and temperatures of water flowing from individual drains and in collection culverts within dry dock no. 5 of Puget Sound Naval Shipyard, Bremerton, Washington
[ft, feet; ft^3/s, cubic feet per second; °C, degrees Celsius; ppt, parts per thousand; --, no data; e, estimated value]

Site[1] identifier and remark	Distance[2] (feet)	Measured[3] discharge (ft^3/s)	Cumulative[4] discharge (ft^3/s)	Temperature[3] (°C)	Salinity[3] (ppt)
		East-side culvert, northern part			
1 E	2	0.003	0.003	13.3	2.8
Un W	--	0.	.003	--	--
2 E	21	0.	.003	--	--
3 E	41	.011	.014	12.7	16.9
Un W	--	.016	.030	14.9	21.5
4 E	63	.006	.036	13.0	18.1
5 E	82	.032	.068	13.0	18.8
Un W	--	.016	.084	14.6	21.5
6 E	92	.017	.101	12.5	20.2
Door	103		.101	--	--
Un W	--	0.	.101	--	--
7 E	111	.019	.120	13.0	21.2
8 E	131	0.	.120	--	--
Un W	131	0.	.120	--	--
9 E	148	.002	.122	13.2	18.4
Un W	--	0.	.122	--	--
10 E	171	.015	.137	12.2	25.9
N-part outflow (E-NB)	180	.15	(.14)	13.1	19.3
Un W	180	0.	--	--	--
		East-side culvert, southern part			
S-part outflow (E-SB)	190	.35	(.37)	12.3	27.4
Un W	204	0.	.372	--	--
Un W	228	0.	.372	--	--
Un W	252	0.	.372	--	--
Un W	276	0.	.372	--	--
11 E	291	.016	.372	11.4	21.1
Un W	--	0.	.356	--	--
12 E	309	0.	.356	--	--
Un W	--	0.	.356	--	--
13 E	332	.024	.356	11.4	21.0
Un W	--	0.	.332	--	--
14 E	349	0.	.332	--	--
15 E	372	.034	.332	11.5	21.7
Un W	372	0.	.298	--	--
16 E	389	0.	.298	--	--
Un W	--	0.	.298	--	--
17 E	412	.004	.298	11.8	24.2
Un W	--	0.	.296	--	--
18 E	429	.005	.296	11.8	25.2
Un W	--	0.	.289	--	--
19 E	452	.005	.289	11.7	26.2

Table 3.--Discharges, salinities and temperatures of water flowing from individual drains and in collection culverts within dry dock no. 5 of Puget Sound Naval Shipyard, Bremerton, Washington--Continued

Site[1] identifier and remark	Distance[2] (feet)	Measured[3] discharge (ft^3/s)	Cumulative[4] discharge (ft^3/s)	Temperature[3] (^oC)	Salinity[3] (ppt)
Un W	--	0.	0.284	--	--
20 E	469	0.	.284	--	--
21 E	492	0.	.284	--	--
Un W	492	0.	.284	--	--
22 E	509	0.	.284	--	--
Un W	--	0.	.284	--	--
23 E	532	.001	.284	11.0	30.6
Un W	--	.004	.283	17.8	16.9
24 E	549	0.	.279	--	--
Un W	--	0.	.279	--	--
25 E	572	.000	.279	11.5	28.7
Un W	--	0.	.279	--	--
26 E	590	.005	.279	11.2	29.0
27 E	612	.018	.274	10.8	29.6
Un W	612	0.	.256	--	--
28 E	629	0.	.256	--	--
Un W	--	0.	.256	--	--
29 E	653	.074	.256	10.9	29.5
Un W	--	0.	.182	--	--
30 E	669	0.	.182	--	--
Un W	--	0.	.182	--	--
31 E	693	.014	.182	11.2	30.5
Un W	--	0.	.168	--	--
32 E	710	.005	.168	11.2	31.0
33 E	728	.023	.163	10.8	30.9
Un W	--	0.	.140	--	--
34 E	742	.006	.140	10.7	30.2
Un W	--	0.	.134	--	--
35 E	758	.015	.134	11.1	30.0
36 E	773	.005	.119	11.0	31.0
Un W	--	0.	.114	--	--
37 E	788	.001	.114	12.6	29.0
38 E	802	.010	.113	11.5	30.5
Un W	802	0.	.103	--	--
39 E	818	0.	.103	--	--
Un W	--	0.	.103	--	--
40 E	833	0.	.103	--	--
41 E	848	.007	.103	11.6	30.6
Un W	--	0.	.095	--	--
Door	862	--	.095	--	--
42 E	863	.001	.095	13.0	29.3
43 E	878	0.	.095	--	--
Un W	--	0.	.095	--	--
44 E	893	.040	.095	13.2	27.5
Un W	--	0.	.055	--	--

Table 3.--Discharges, salinities and temperatures of water flowing from individual drains and in collection culverts within dry dock no. 5 of Puget Sound Naval Shipyard, Bremerton, Washington--Continued

Site[1] identifier and remark	Distance[2] (feet)	Measured[3] discharge (ft^3/s)	Cumulative[4] discharge (ft^3/s)	Temperature[3] (°C)	Salinity[3] (ppt)
45 E	908	0.002	0.055	12.2	30.2
46 E	923	.006	.053	11.9	30.1
Un W	--	0.	.047	--	--
47 E	938	0.	.047	--	--
Un W	--	0.	.047	--	--
48 E	953	0.	.047	--	--
49 E	968	.000	.047	13.7	26.9
50 W	973	.045e	.047	15.9	31.2
Spillway	981	.002e	.002	--	--
		West-side culvert, northern part			
Un N	0	0.	0.	--	--
1 W	2	.004	.004	13.6	2.2
Un E	--	0.	.004	--	--
2 W	27	.059	.063	12.7	3.3
3 W	43	.057	.120	12.7	3.7
Un E	--	0.	.120	--	--
4 W	65	.008	.128	13.4	3.6
5 W	81	.016	.144	13.0	4.1
Un E	--	0.	.144	--	--
6 W	104	.018	.162	12.9	4.6
Door	116	--	.162	--	--
7 W	121	.026	.188	12.9	6.2
Un E	121	0.	.188	--	--
8 W	144	.037	.225	12.4	11.3
Un E	144	0.	.225	--	--
9 W	161	0.	.225	--	--
Un E	--	0.	.225	--	--
10 W	184	.016	.241	12.2	14.5
N-part outflow (W-NB)	192	.33	(.24)	12.8	5.8
Un E	192	0.	--	--	--
(11 W)	201	.093	--	12.3	18.3
		West-side culvert, southern part			
S-part outflow (W-SB)	202	.44	(.58)	13.4	20.6
Un E	--	0.	.584	--	--
12 W	223	.029	.584	12.8	20.1
13 W	240	.015	.555	12.6	19.2
Un E	240	0.	.540	--	--
14 W	263	.004	.540	12.2	17.3
Un E	263	0.	.536	--	--
15 W	280	.003	.536	12.2	17.0

Table 3.--Discharges, salinities and temperatures of water flowing from individual drains and in collection culverts within dry dock no. 5 of Puget Sound Naval Shipyard, Bremerton, Washington--Continued

Site[1] identifier and remark	Distance[2] (feet)	Measured[3] discharge (ft^3/s)	Cumulative[4] discharge (ft^3/s)	Temperature[3] (°C)	Salinity[3] (ppt)
Un E	--	0.	0.533	--	--
16 W	303	0.	.533	--	--
Un E	-	0.	.533	--	--
17 W	321	.007	.533	12.3	14.9
Un E	--	0.	.526	--	--
18 W	343	.027	.526	12.2	15.1
Un E	--	0.	.499	--	--
19 W	360	0.	.499	--	--
20 W	383	.014	.499	12.7	16.3
Un E	383	0.	.485	--	--
21 W	400	.005	.485	13.4	18.6
Un E	--	0.	.480	--	--
22 W	423	0.	.480	--	--
Un E	--	0.	.480	--	--
23 W	441	0.	.480	--	--
Un E	--	0.	.480	--	--
24 W	463	0.	.480	--	--
Un E	--	0.	.480	--	--
25 W	481	0.	.480	--	--
Un E	--	0.	.480	--	--
26 W	504	0.	.480	--	--
27 W	520	0.	.480	--	--
Un E	--	0.	.480	--	--
28 W	543	.002	.480	13.7	21.3
Un E	551	.171	.478	12.7	17.5
29 W	560	0.	.307	--	--
Un E	574	.040	.307	13.3	19.2
30 W	583	0.	.267	--	--
31 W	599	0.	.267	--	--
Un E	599	0.	.267	--	--
32 W	623	0.	.267	--	--
Un E	623	0.	.267	--	--
33 W	640	.002	.267	14.1	18.5
Un E	--	0.	.265	--	
34 W	663	.014	.265	13.9	18.6
Un E	--	0.	.251	--	--
35 W	681	.015	.251	13.9	18.9
Un E	--	0.	.236	--	--
36 W	711	0.	.236	--	--
37 W	726	0.	.236	--	--
Un E	--	0.	.236	--	--
38 W	741	.002	.236	14.1	24.9
Un E	--	.001e	.234	--	--
39 W	756	.001	.233	14.3	17.6
40 W	771	.001e	.232	--	--

Table 3.--Discharges, salinities and temperatures of water flowing from individual drains and in collection culverts within dry dock no. 5 of Puget Sound Naval Shipyard, Bremerton, Washington--Continued

Site[1] identifier and remark	Distance[2] (feet)	Measured[3] discharge (ft^3/s)	Cumulative[4] discharge (ft^3/s)	Temperature[3] (°C)	Salinity[3] (ppt)
Un E	--	0.	0.231	--	--
41 W	786	.001e	.231	--	--
42 W	801	.000	.230	--	--
Un E	801	0.	.230	--	--
43 W	816	.010	.230	13.0	22.6
Un E	--	0.	.220	--	--
44 W	831	0.	.220	--	--
45 W	846	.013	.220	12.5	26.5
Un E	--	0.	.207	--	--
46 W	861	0.	.207	--	--
Un E	--	0.	.207	--	--
47 W	876	0.	.207	--	--
Door	883	--	.207	--	--
48 W	891	0.	.207	--	--
Un E	--	0.	.207	--	--
49 W	906	0.	.207	--	--
50 W	922	.005	.207	14.0	26.4
Un E	--	0.	.202	--	--
51 W	937	0.	.202	--	--
Un E	--	0.	.202	--	--
52 W	953	0.	.202	--	--
53 W	967	0.	.202	--	--
Un E	--	0.	.202	--	--
Un E	--	0.	.202	--	--
54 W	997	.002e	.202	--	--
Spillway	--	.2e	.200	--	--

[1] Numbers identify drain pipes or channels and were assigned by personnel in Puget Sound Naval Shipyard Environmental Group. Numbers increase from north to south; "Un" denotes unnumbered drain; "N", "E", "S" and "W" denote drain pipes discharging into culvert from north, east, south and west walls of culvert, respectively; "Door"shows location of access door; spillway discharges water that leaks by flood gates; drains located between north- and south-part outflows not included in these outflows.

[2] Distances are from north end of culvert.

[3] Data are from measurements and samples collected on Aug. 5, 1994.

[4] Cumulative discharges are sums of observed individual drain discharges; cumulations are along the direction of flow in the collecting culvert; in the northern parts of the culverts flow is from north to south; in the southern parts flow is from south to north; parentheses denote cumulative discharge that should equal measured discharge in culvert.

***Table 4.**--Flow rates of water from various sources discharging into dry dock no. 5 of Puget Sound Naval Shipyard, Bremerton, Washington*

[All discharges are in cubic feet per second and were computed from data in table 3; E, east; W, west]

Ground-water discharge		
East sidewall and east half of north wall (sum of E-culvert E-wall drains)	0.43	
West sidewall and west half of north wall (sum of W-culvert W-wall drains)	.51	
Total sidewalls and north-wall discharge	.94	
East-half floor discharge (sum of E-culvert W-wall drains except unnumbered drain between 23 and 24 and drain 50)	.03	
West-half floor drainage (sum of W-culvert E-wall drains)	.21	
Total floor discharge	.24	
Total ground-water discharge	1.18	1.18
Other water		
Process water (E culvert, unnumbered drain between 23 and 24)	.004	
Floodgate and cofferdam leakage (E-culvert drain 50, and spillways in both culverts)	.25	
Total other-water discharge	.25	.25
Total inflow to dry dock		[1]1.43

[1] Difference between this computed inflow (1.43 ft^3/s) and the computed outflow given in table 1 (1.36 ft^3/s) is due to outflow having been computed using measurements of culvert discharge, while the inflow was computed using discharge measurements of individual drains; the difference is consistent with the accuracy of the measurements (5 to 10 percent).

water from beneath the dry-dock floor. (It was not possible to separate ground-water discharges from head and side walls.) Because discharges from individual drains in DD-5 were measured and the sources of the water in these drains are known it was possible to calculate separate ground-water discharges from behind the walls and from beneath the floor for the east and west half of this dry dock (table 4). These calculations show that ground-water discharge from behind the walls was about four times that from beneath the floor. The discharge from behind the walls in the east half of the dry dock was 84 percent of the discharge from behind the walls in the west half, but the discharge from beneath the floor in the east part was only 14 percent of that from the west part. The smaller discharges from the east half were unexpected, considering the proximity of the east wall of the dry dock to Sinclair Inlet (fig. 1). A comparison of the salinities of the outflows from the east- and west-side culverts (table 3) shows that the drain water on the east side was more saline than on the west side. This is consistent with the proximity of the east wall of the dry dock to Sinclair Inlet.

The total ground-water discharge to the dry dock was 1.18 ft^3/s (table 4), which was 83 or 87 percent of the total outflow (depending on which value of outflow is used). Salinities imply that 55 percent of the ground-water discharge to the dry dock was water from Sinclair Inlet.

Dry Dock No. 6

DD-6, the newest and largest of the dry docks at the shipyard, is about 1,100 ft long, 190 ft wide, and its floor is about 49 ft below sea level. The tops of the walls of this dry dock are about 12 ft above sea level. Drain pipes from behind the side walls and beneath the floor flow directly to longitudinal culverts that are built into the base of the side walls, and drains in the head wall flow in gutters or pipes that flow into the north ends of the culverts. Drainage from beneath the floor also can flow upward through weep holes to transverse slots in the floor that discharge to gutters that run longitudinally beneath the floor of the dry dock near the base of the side walls. The gutters are connected to the culverts about every 150 ft by 2-ft wide by 1-ft high rectangular

channels. The culverts are 3 ft wide and about 7 ft high. Their lower halves are rectangular, and their inverts are about 4 ft lower than the dry-dock floor. Personnel can enter the culverts through six doors in each side wall of the dry dock. Water from the culverts flows into an east-west tunnel, and then to the pump well for this dry dock. This tunnel crosses the dry dock about 250 ft from its south end.

Discharge in the culverts was measured at the four locations where they flow into the tunnel to the pump well (sites E-NB, E-SB, W-NB and W-SB in table 1 and fig. 7). Discharge in the curverts also was measured at 10 other locations and discharge from each of the more than 70 individual drains that flow into each culvert also was measured (table 5). Most of the discharge measurements were made on June 29 and 30, 1994; however, measurements in the south part of the west-side culvert were delayed until August 11 while a safety issue was being resolved. On August 11 discharge measurements also were made at some of the same sites where measurements were made on June 29 or 30. The estimated accuracy of most of these measurements was 5 to 10 percent.

During this study a ship that was undergoing maintenance in the dry dock was pumping water for cooling from Sinclair Inlet and discharging the warmed water into a gutter that discharged into the west-side culvert. There was no obvious leakage from the cofferdam at the entrance to this dry dock; however, the source of the approximately 1.9 ft^3/s flowing from a drain at the south end of the east-side culvert (drain 77 S bottom, table 5) was leakage from Sinclair Inlet by a floodgate (Roy Pollard, Puget Sound Naval Shipyard, oral commun., 1994).

The total outflow from DD-6, as computed by summing the discharges at the downstream ends of the culverts was 11.7 ft^3/s (table 1). The sum of discharges of individual drains discharging into the dry dock (tables 5 and 6) was 12.2 ft^3/s, which is only 4 percent greater than

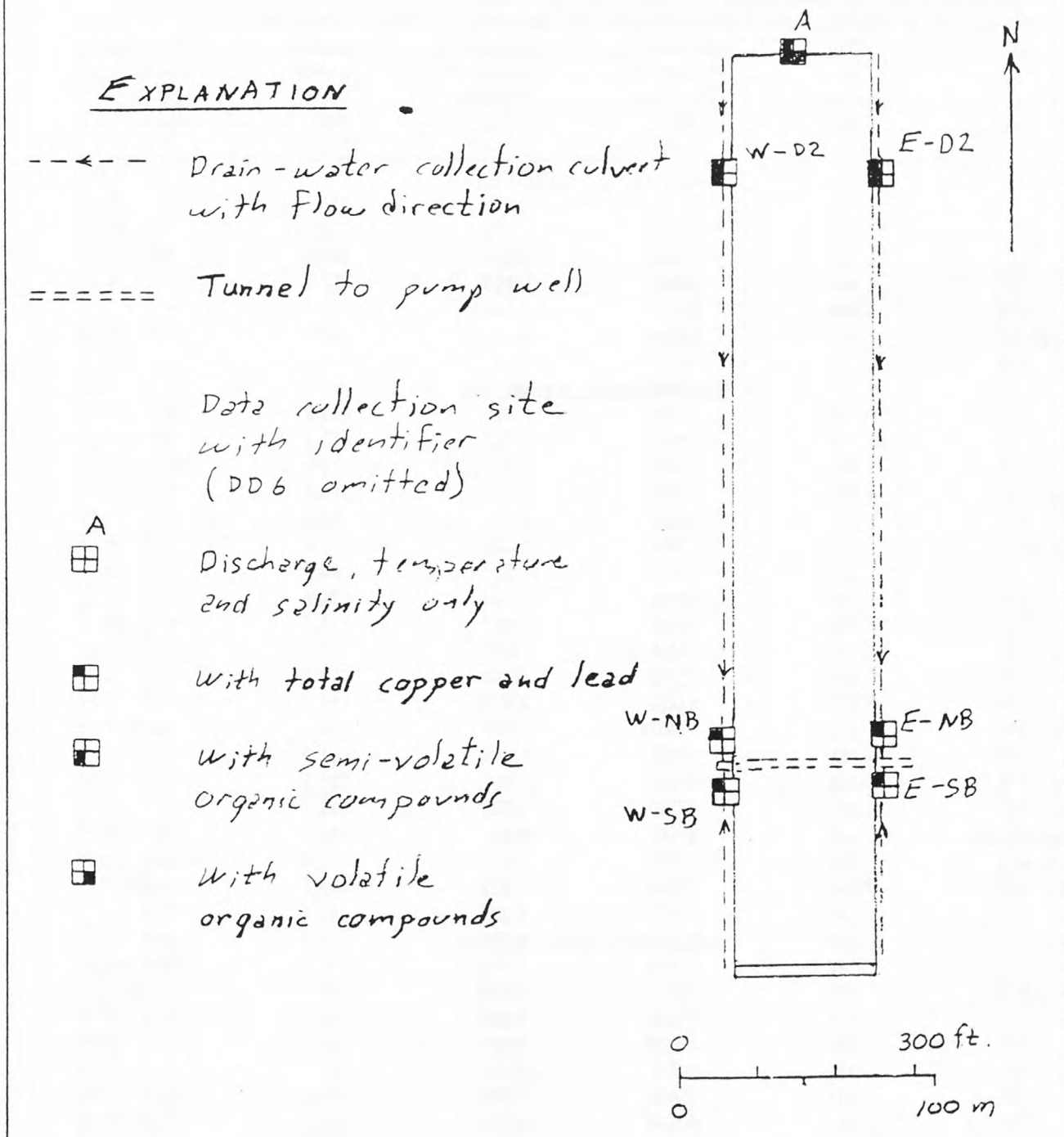

Figure 7.--Drain-water collection culverts and data-collection sites in dry dock no. 6.

Table 5.--Discharges, salinities and temperatures of water flowing from individual drains and in collection culverts within dry dock no. 6 of Puget Sound Naval Shipyard, Bremerton, Washington
[ft^3/s, cubic feet per second; °C, degrees Celsius; ppt, parts per thousand; --, no data; e, estimated value]

Site [1] identifier and remark	Distance [2] (feet)	Measured [3] discharge (ft^3/s)	Cumulative [4] discharge (ft^3/s)	Temperature [5] (°C)	Salinity [5] (ppt)
		East half of north wall of dry dock			
-- N	9	0.	0.	--	--
-- N	15	.099	.099	13.6	5.2
-- N	33	.058	.157	13.4	5.8
-- N	40	.008	.165	13.5	7.3
-- N	46	0.	.165	--	--
4 W-EN 2x1		.156	(.165)	13.5	5.9
		East-side culvert, northern part			
1 E	2	.016	.016	13.5	6.9
2 E	18	.005	.021	13.1	8.8
3 W	28	.177	.198	12.6	15.8
4 W-EN 2x1	32	.156	.354	13.5	5.9
Culvert	35	.24	(.35)	13.2	6.0
5 E door 1	39	.004	.358	13.0	9.0
6 E	62	.007	.365	12.5	12.2
7 W	70	.232	.597	11.9	17.3
8 E	86	.010	.607	12.2	14.6
9 E	110	.016	.623	11.9	14.7
10 W	118	.225	.848	11.2	20.5
11 E	134	.024	.872	11.9	19.6
12 W 2x1	150	.002e	.874	--	--
13 E	158	.002	.876	11.7	19.3
14 W	166	.116	.992	11.3	20.6
15 E	183	.030	1.022	11.7	17.7
Culvert (E-D2)	200	.88	(1.02)	12.3	15.6
16 E door 2	206	.034	1.056	11.6	16.9
17 W	214	.147	1.203	11.1	22.8
18 E	230	.022	1.225	11.1	19.1
19 E	254	.001	1.226	11.1	19.9
20 W	262	.069	1.295	11.1	13.6
21 W 2x1	270	0.	1.295	--	--
22 E	279	.001	1.296	11.1	21.3
23 E	303	.004	1.300	11.1	21.1
24 W	311	0.	1.300	--	--
25 E	327	.002	1.302	11.2	21.7
26 E	351	.004	1.306	11.4	22.8
27 W	359	0.	1.306	--	--
28 E	375	.003	1.309	11.5	24.2
29 W 2x1	391	.004e	1.313	--	--
Culvert	395	1.2	(1.31)	12.1	16.1
30 E door 3	399	.003	1.316	11.8	20.5
31 W	407	0.	1.316	--	--
32 E	423	.003	1.319	11.6	19.0

Table 5.--Discharges, salinities and temperatures of water flowing from individual drains and in collection culverts within dry dock no. 6 of Puget Sound Naval Shipyard, Bremerton, Washington--Continued

Site [1] identifier and remark	Distance [2] (feet)	Measured [3] discharge (ft^3/s)	Cumulative [4] discharge (ft^3/s)	Temperature [5] (°C)	Salinity [5] (ppt)
33 E	447	0.001	1.320	11.4	11.8
34 W	455	0.	1.320	--	--
35 E	471	.002	1.322	11.7	13.7
36 E	495	0.008	1.330	11.4	19.1
37 W	503	0.	1.330	--	--
38 W 2x1	511	.010	1.340	13.0	0.0
39 E	519	.000	1.340	--	--
40 E	543	.002	1.342	11.2	14.2
41 W	551	.000	1.342	--	--
42 E	567	.002	1.344	11.2	13.6
43 E	591	.002e	1.346	--	--
44 W	599	.068	1.414	11.0	21.2
Culvert	610	1.3	(1.41)		
45 E door 4	615	.011	1.425	11.5	16.6
46 W 2x1	631	.013	1.438	14.4	0.1
47 E	639	.004	1.442	12.0	18.5
48 W	647	.035	1.477	11.1	21.2
49 E	663	.001e	1.478	--	--
50 E	687	.001	1.479	12.0	19.2
51 W	695	.487	1.966	10.9	20.8
52 W 2x1	703	.165	2.131	14.8	0.1
53 E	711	.001	2.132	12.7	14.8
54 E	733	.004	2.136	13.4	14.7
55 W door 5	784	.251	2.387	11.0	19.0
Hose	784	.034	2.421	14.1	30.2
56 W	792	.271	2.692	11.0	18.8
57 W	840	.083	2.775	11.1	17.5
58 W 2x1	854	.004	2.779	--	--
N-part outflow (E-NB)	864	2.4, 3.2	(2.78)	13.8	16.1
		East-side culvert, southern part			
S-part outflow (E-SB)	870	2.6, 2.2	(2.53)	--	27.6
59 E	880	.000	2.535	--	--
60 W	888	.157	2.535	11.1	18.0
61 E	904	.008	2.378	11.7	15.8
62 E	928	.002	2.370	12.0	16.7
63 W	936	.136	2.368	11.11	8.0
64 E	952	0.	2.232	--	--
65 E door 6	976	.006	2.232	11.9	21.1
66 W	984	.104	2.226	10.9	25.2
67 W 2x1	992	.004e	2.122	--	--
68 E	1,001	.001	2.118	11.8	25.2
69 E	1,025	.003	2.117	11.3	27.5

Table 5.--Discharges, salinities and temperatures of water flowing from individual drains and in collection culverts within dry dock no. 6 of Puget Sound Naval Shipyard, Bremerton, Washington--Continued

Site [1] identifier and remark	Distance [2] (feet)	Measured [3] discharge (ft^3/s)	Cumulative [4] discharge (ft^3/s)	Temperature [5] (°C)	Salinity [5] (ppt)
70 W	1,033	0.192	2.114	10.8	30.0
71 E	1,049	.004	1.922	11.2	26.2
72 E	1,073	.000	1.918	--	--
73 W	1,074	.018	1.918	10.6	29.7
Culvert	1,080	1.9		--	--
74 E	1,098	.002e	1.900	--	--
75 W	1,100	0.	1.898	--	--
76 S top	1,102	.032	1.898	10.5	30.1
77 S bottom	1,102	1.866	1.866	13.7	29.3
		West half of north wall of dry dock			
-- N	7	0.072	0.072	14.2	4.9
-- N	22	0.	.072	--	--
-- N	27	.009	.081	14.7	6.3
-- N	48	.062	.143	15.3	6.2
-- N	69	.103	.246	15.2	6.1
-- N	74	0.	.246	--	--
-- N	89	0.	.246	--	--
2 E-WN 2x1		.222	(.246)	15.2	5.9
		West-side culvert, northern part			
1 W	3	0.024	0.024	13.1	19.2
2 E-WN 2x1	5	.222	.246	15.2	5.9
3 W	10	.016	.262	13.3	17.6
4 E	14	.110	.372	14.4	14.8
Culvert	25	.36	.372	14.7	9.5
5 W door 1	28	.008	.380	14.11	6.6
6 W	52	0.	.380	--	--
7 E	60	.190	.570	12.3	22.1
8 W	76	0.	.570	--	--
9 W	100	.003	.573	12.0	27.0
10 E	108	0.	.573	--	--
11 W	123	.001	.574	11.9	28.2
UnnE 2x1	139	0.	.574	--	--
12 W	147	.087	.661	11.2	29.2
13 E	155	.194	.855	--	--
14 W	171	.006	.861	11.0	28.3
Culvert (W-D2)	190	.80	.861	13.1	17.9
15 W door 2	196	.008	.869	11.0	30.9
16 W	203	.163	1.032	11.1	27.4
17 W	219	0.	1.032	--	--
18 W	243	.009	1.041	11.2	29.6
19 E	251	.073	1.114	11.3	27.4
20 E 2x1	259	.010	1.124	--	--
21 W	267	.007	1.131	11.4	29.6

Table 5.--Discharges, salinities and temperatures of water flowing from individual drains and in collection culverts within dry dock no. 6 of Puget Sound Naval Shipyard, Bremerton, Washington--Continued

Site [1] identifier and remark	Distance [2] (feet)	Measured [3] discharge (ft^3/s)	Cumulative [4] discharge (ft^3/s)	Temperature [5] (°C)	Salinity [5] (ppt)
22 W	292	0.011	1.142	11.5	29.2
23 E	300	.165	1.307	11.2	28.4
24 W	316	.004	1.311	11.5	29.6
25 W	340	.001	1.312	12.0	29.7
26 E	348	.159	1.471	11.2	29.6
27 W	363	.005	1.476	11.6	29.6
28 E 2x1	380	.142	1.618	16.1	30.0
Culvert	385	1.6	1.618	12.7	21.1
29 W door 3	387	0.	1.618	--	--
30 E	396	.141	1.759	11.2	29.2
31 W	412	.001	1.760	--	--
32 W	436	0.	1.760	--	--
33 E	444	.083	1.843	11.0	28.7
34 W	456	.015	1.858	11.0	28.6
35 W	481	.001	1.859	--	--
36 E	489	0.191	2.050	11.0	27.6
37 E 2x1	497	.049	2.099	14.5	27.7
38 W	505	0.	2.099	--	--
39 E	537	.206	2.305	10.9	25.9
40 W	540	.003	2.308	11.2	27.9
41 W	552	.009	2.317	11.3	28.4
42 W	577	.053	2.370	11.1	28.7
43 E	585	.149	2.519	11.0	24.6
Culvert	595	2.5	2.519	12.4	23.0
44 W door 4	601	.013	2.532	11.2	29.7
45 E 2x1	616	1.8, .98	4.332	15.0	26.8
46 W	625	.009	4.341	11.3	28.7
47 E	632	.080	4.421	11.0	24.1
48 W	649	.010	4.431	10.8	27.7
49 W	673	.017	4.448	11.1	28.3
50 E	681	.214	4.662	11.0	24.7
51 W	697	.014	4.676	11.0	27.1
52 W	721	.013	4.689	11.0	26.4
53 E	729	.089	4.778	11.1	20.6
54 E 2x1	737	1.6, 1.0	6.378	15.1	30.2
55 W	745	.010	6.388	11.1	27.4
Culvert	765	6.6	6.338	--	25.6
56 W door 5	769	.006	6.394	11.0	27.2
57 E	777	.041	6.435	11.1	17.8
58 W	793	.012	6.447	10.7	26.2
59 W	817	.003	6.450	11.0	24.1
60 E	825	0.	6.450	--	--
61 W	841	.003	6.453	10.9	25.7

Table 5.--Discharges, salinities and temperatures of water flowing from individual drains and in collection culverts within dry dock no. 6 of Puget Sound Naval Shipyard, Bremerton, Washington--Continued

Site [1] identifier and remark	Distance [2] (feet)	Measured [3] discharge (ft^3/s)	Cumulative [4] discharge (ft^3/s)	Temperature [5] (°C)	Salinity [5] (ppt)
N-part outflow (W-NB)	850	6.3, 5.3	(6.5)	13.8	25.9
		West-side culvert, southern part			
S-part outflow (W-SB)	856	.41	(.43)	15.0	27.7
62 E 2x1	864	.244	.430	16.4	30.7
63 W	866	.009	.186	11.0	28.2
64 E	874	.080	.177	12.4	25.2
65 W	889	.009	.097	11.0	28.1
66 W	913	.004	.088	11.0	28.0
67 E	922	.031	.084	13.1	28.0
68 W	937	.012	.053	10.8	25.7
69 W door 6	961	.001	.041	11.3	22.2
70 E	969	0.	.040	--	--
71 E 2x1	977	0.	.040	--	--
72 W	986	0.	.040	--	--
73 W	1,010	.008	.040	11.0	24.0
74 E	1,017	0.	.032	--	--
75 W	1,034	.016	.032	11.0	24.6
76 W	1,057	.002	.016	11.0	25.6
77 E	1,060	0.	.014	--	--
78 W	1,082	.008	.014	11.3	26.6
79 E	1,084	0.	.006	--	--
80 S top	1,086	.006	.006	12.8	29.7
81 S bot	1,086	.000e	.000	--	--

[1]Numbers identify drain pipes or channels and were assigned by personnel in Puget Sound Naval Shipyard Environmental Group. Numbers increase from north to south; "N" denotes drain pipe discharging from north wall of dry dock; "E", "S" and "W" denote drain pipes discharging into culvert from east, south and west walls of culvert, respectively; "WN" and "EN" denote channel conveying drainage from west and east halves of north wall, respectively; "2x1" denotes 2-ft wide by1-ft high channel that connects longitudinal gutter to culvert; "door n" shows location of nth access door from north end; "hose" is process-water discharge from a hose into the culvert; identifier in parenthesis is same as on figure 7 and table 1.

[2] Distances for drain pipes in north wall are from center of dry dock; distances for sites in culverts are from north walls of culverts.

[3] Discharges of drains in north wall are from measurements made on June 28,1994; discharges at all sites in the east and the north part of the west culvert are from measurements on June 30, 1994, and June 29, 1994, respectively, except when two discharges are given, the second discharges are from measurements on August 11, 1994; discharges in the south part of the west culvert are from measurements on August 11, 1994; discharge from drains 28, 37, 45, 54 and 62 in the west-side culvert is cooling water from a ship in the dry dock; discharge from drain 77 in east culvert is water leaking by gate in tunnel used to flood dry dock; discharge from this drain obtained by subtracting discharges from drains 74 to 76 from discharge measured in culvert between drains 73 and 74.

Table 5.--Discharges, salinities and temperatures of water flowing from individual drains and in collection culverts within dry dock no. 6 of Puget Sound Naval Shipyard, Bremerton, Washington--Continued

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[4] Cumulative discharges are sums of observed individual drain discharges; cumulations are along the direction of flow in the collecting culvert or channel; along the north wall flow is away from the center of the dry dock; in the north parts of the culverts flow is from north to south; in the south parts flow is from south to north; parentheses denote cumulative discharge that should equal measured discharge in channel or culvert.

[5] Temperatures and salinities of individual drains are from measurements or samples collected on same day as discharge measurements, temperatures and salinities of some culvert flows are from measurements and samples collected on a different day.

***Table 6.**--Flow rates of water from various sources discharging into dry dock no. 6 of Puget Sound Naval Shipyard, Bremerton, Washington*

[All discharges are in cubic feet per second and were computed from data in table 5; E, east; W, west]

Ground-water discharge		
East-half north wall (E culvert, drain 4)	0.16	
West-half north wall (W culvert, drain 2)	.22	
Total north-wall discharge	.38	
East sidewall (E culvert, sum E-wall drains)	.26	
West sidewall (W culvert, sum W-wall drains)	.61	
Total sidewall discharge	.87	
East-half floor drainage (E culvert, sum W-wall drains except 2x1)	2.8	
West-half floor drainage (W culvert, sum E-wall drains except 2x1)	2.2	
Total floor discharge	5.0	
Total ground-water discharge	6.2	6.2
Other water		
Cooling and other process water (hose and all 2x1 channels except N-wall drainage)	4.1	
Floodgate and cofferdam leakage (S-wall drains)	1.9	
Total other-water discharge	6.0	6.0
Total inflow to dry dock		12.2

[1] Difference between this computed inflow (12.2 ft^3/s) and the computedoutflow given in table 1 (11.7ft^3/s) is due to outflow having beencomputed using measurements of culvert discharge, while the inflow wascomputed using mostly discharge measurements of individual drains and channels; the difference is consistent with the accuracy of the measurements (5 to 10 percent).

the sum of the outflows. (The outflow value, 11.7 ft^3/s, is used in both the Abstract and Summary of this report.) The computed outflow salinity of 24.3 implies that 82 percent of the outflow was water from Sinclair Inlet.

The computations of the total inflows and outflows required adding discharges that were measured in the south part of the west-side curvert to discharges that were measured in the other parts of the culverts about 6 weeks earlier. Although one cannot be certain that discharges were the same during both measurement periods, the flow from the south part of the west-side culvert was mostly saline ground water and cooling water from Sinclair Inlet (see table 5), and the saline ground-water inflow was probably nearly the same during both measurement periods. (See the following subsection "Effect of Tide Stage on Discharge".)

Because the sources of water from the individual drains were known, ground-water discharges from various parts of the dry dock could be computed (table 6) as for DD-5. However, for DD-6 it was also possible to calculate separately ground-water discharges from the headwall and sidewalls. About half of the total outflow (6.2 ft^3/s) was ground-water discharge; the remainder was mostly gate leakage (16 percent) and cooling-water discharge (34 percent). Salinities imply that 69 percent of the ground-water discharge was from Sinclair Inlet. Ground-water discharge from beneath the floor of DD-6 accounted for about 80 percent of the total ground-water discharge, with 14 percent from behind the sidewalls, and 6 percent from behind the north wall. Ground-water discharge from behind the east sidewall and the east part of the north wall were greater than from the corresponding parts on the west side, but discharge from the west half of the floor was greater than from the east half.

Effect of Tide Stage on Discharge

Because water-discharge rates at most sites in the dry docks probably vary with tide in Sinclair Inlet and with upland ground-water levels, and because water-discharge rates were measured during this study only once at most sites, the discharges presented in this report may differ from tide-cycle or seasonal averages. The quantitative effects of seasonal variations of upland ground-water levels on ground-water seepage rates are unknown; however, the effects of tide can be approximated. One can probably assume that instantaneous rates of ground-water discharge into the dry docks are approximately proportional to the differences between the water level in Sinclair Inlet and the elevations of dry-dock drains. The latter can be approximated as the elevations of the dry-dock floors. Consequently, the average maximum difference, in percent, between a measured discharge and the average discharge over a tide cycle is approximately equal to 100 percent multiplied by half the tide range divided by the depth of the dry-dock floor below sea level. Tides in Sinclair Inlet are semi-diurnal with a difference of about 12 ft between mean higher high and mean lower low water. Using a tide range of 12 ft and a dry-dock floor elevation of -23 ft (the elevation in the south part of dry dock no. 3), the computed value of the average maximum difference between measured and tide-cycle average discharge is 100x(6 ft/23ft) = 26 percent. In most cases the difference would be less because all other dry docks are deeper than dry dock no. 3, and most of the time the tide is not at the daily maximum or minimum.

Water samples that were collected from the drainage systems of the dry docks were analyzed to determine salinity, temperature, turbidity, concentrations of copper and lead, and concentrations of volatile and semi-volatile organic compounds. However, not all samples were analyzed for all these water-quality characteristics. Samples from all 36 water-quality data-collection sites were analyzed for concentrations of total copper and total lead, and samples from two of these sites also were analyzed for concentrations of dissolved copper and lead. Samples from 19 sites were analyzed for semi-volatile organic compounds, and samples from 8 of these sites also were analyzed for volatile organic compounds (see table 7).

Copper and Lead

Concentrations of total copper and total lead in samples from the dry-dock drainage systems ranged from less than 1 to 71 µg/L (micrograms per liter) and less than 1 to 44 µg/L, respectively (table 7). Concentrations of both metals in two sets of duplicate samples were self-consistent, and concentrations of both metals in the two field blanks that were analyzed for these constituents were less than the laboratory minimum reporting levels (1 µg/L). Concentrations of dissolved copper and lead were relatively small in all three samples for which these determinations were made. The maximum concentrations were 6 µg/L and less than 1 µg/L, respectively.

Concentrations of total copper and lead in samples from DD-5 were fairly uniform and mostly lower than concentrations in samples from the other dry docks. Concentrations of total lead in seven of the eight samples from DD-5 were less than 1 µg/L, and the concentration in the eighth was less than 5 µg/L. The maximum concentration of total copper in samples from DD-5 was only 7 µg/L. Concentrations of total copper and lead in the four samples from DD-1 were also

Table 7.--Chemical and physical characteristics of water at selected sites in the drainage systems of the six dry docks at Puget Sound Naval Shipyard, Bremerton, Washington

[ppt, parts per thousand; °C, degrees Celsius; NTU, nephelometric turbidity unit; µg/L, microgram per liter; dup., field duplicate at preceding site; --, no data; <, less than; S, sample analyzed for semi-volatile organic compounds; V, sample analyzed for volatile organic compounds]

Site identifier	Date	Time	Salinity (ppt)	Temperature (°C)	Turbidity (NTU)	Copper		Lead		Semi-volatile organic compounds[1]	Volatile organic compounds[2]
						dissolved (µg/L)	total (µg/L)	dissolved (µg/L)	total (µg/L)		
Dry dock no. 3											
DD3-A	06/28/94	1045	0.1	--	0.1	--	<1	--	<1	S	V
DD3-B	06/28/94	1230	.5	16.6	2.5	--	17	--	16	S	V
DD3-E-14C	07/07/94	0845	.1	16.3	.2	6	21	<1	3	S	--
dup.	07/07/94	0846	--	--	--	--	16	--	2	--	--
DD3-E	07/07/94	0950	5.4	15.9	.3	--	20	--	10	--	--
DD3-W-N	07/07/94	0955	3.0	16.3	2.4	--	47	--	3	S	--
DD3-W-S	07/07/94	1000	16.2	15.0	.5	--	71	--	28	--	--
DD3-CD-W	07/07/94	1020	29.5	13.9	.5	--	18	--	32	--	--
Dry dock no. 1											
DD1-E-343	07/06/94	1040	4.4	--	.3	--	7	--	7	S	V
DD1-E-B	07/06/94	1340	4.6	--	.6	--	14	--	6	--	--
DD1-W-245	07/06/94	1130	3.1	15.7	.2	--	15	--	6	S	--
DD1-W-B	07/06/94	1310	7.3	14.6	.2	--	17	--	8	--	--
Dry dock no. 2											
DD2-FC1	07/07/94	1155	2.9	--	.4	--	<1	--	<1	S	--
DD2-E	07/07/94	1310	27.2	--	.2	--	6	--	36	S	--
Dry dock no. 4											
DD4-FD1	07/01/94	1350	9.3	--	.1	--	4	--	20	--	--
DD4-FD2	07/01/94	1400	8.2	--	3.0	--	3	--	11	--	--
DD4-FD3	07/01/94	1640	24.7	--	2.6	--	7	--	44	S	V
DD4-E-C	07/01/94	1630	.8	--	.1	2	1	<1	<1	S	V
dup.	07/01/94	1631	--	--	--	--	1	--	<1	S	V
DD4-E-NB	07/01/94	1530	4.3	--	--	--	17	--	10	S	--
DD4-W-NB	07/01/94	1535	15.7	--	--	--	27	--	25	S	--

Table 7.--Chemical and physical characteristics of water at selected sites in the drainage systems of the six dry docks at Puget Sound Naval Shipyard, Bremerton, Washington--Continued

Site identifier	Date	Time	Salinity (ppt)	Temperature (°C)	Turbidity (NTU)	Copper		Lead		Semi-volatile organic compounds[1]	Volatile organic compounds[2]
						dissolved (µg/L)	total (µg/L)	dissolved (µg/L)	total (µg/L)		
Dry dock no. 5											
DD5-E-1E	08/05/94	1550	2.8	13.3	0.1	3	3	<1	<1	S	V
DD5-E-FD1	08/05/94	1710	21.2	14.3	.2	--	7	--	<1	--	--
DD5-E-NB	08/05/94	1535	19.3	13.1	.1	--	4	--	<1	S	--
DD5-E-SB	08/05/94	1530	27.4	12.3	.1	--	3	--	<5	--	--
DD5-W-1W	08/05/94	1510	2.2	13.6	.1	--	1	--	<1	--	--
DD5-W-NB	08/05/94	1440	5.8	12.8	--	--	4	--	<1	S	--
DD5-W-FD2	08/05/94	1720	19.0	12.3	.1	--	1	--	<1	--	--
DD5-W-SB	08/05/94	1450	20.6	13.4	.2	--	3	--	<1	--	--
Pump 4	08/11/94	1445	16.1	--	.5	--	14	--	<1	S	V
Dry Dock no. 6											
DD6-A	06/28/94	0635	4.9	14.2	.2	--	3	--	8	S	V
DD6-E-D2	06/30/94	1400	15.1	12.3	.1	--	<1	--	1	S	--
DD6-E-NB	06/30/94	1355	16.1	13.8	.1	--	9	--	24	--	--
DD6-E-SB	06/30/94	1350	27.6	--	.7	--	2	--	38	--	--
DD6-W-D2	06/29/94	1420	17.9	13.1	.1	--	<1	--	4	S	--
DD6-W-NB	06/29/94	1415	25.9	13.8	.1	--	25	--	26	--	--
DD6-W-SB	08/11/94	1030	27.7	15.	.1	--	<5	--	7	--	--
DD6-pump	07/01/94	0900	24.1	--	.2	--	1	--	4	--	--
Field blanks											
DD2-FD1	07/07/94	1146	--	--	--	--	<1	--	<1	--	--
DD3-B	06/28/94	1242	--	--	--	--	--	--	--	--	V
DD4-E-C	07/01/94	1640	--	--	--	--	--	--	--	S	--
DD5-E-FD1	08/05/94	1711	--	--	--	--	<1	--	<1	--	--
DD5-E-NB	08/05/94	1711	--	--	--	--	--	--	--	S	--

[1] "S" indicates that sample from this site analyzed for 43 semi-volatile organic compounds; none of the compounds analyzed for were detected at concentrations equal to or greater than the analyzing laboratory's minimum reporting level; see table 8 for list of compounds and reporting levels.

[2] "V" indicates that sample from this site analyzed for 63 volatile organic compounds; see table 9 for list of compounds and results of analyses.

fairly uniform; concentrations of total copper ranged from 7 to 17 µg/L, whereas concentrations of total lead ranged only from 6 to 8 µg/L. Variations of concentrations in samples from the other four dry docks were much larger than from DD-2 or DD-5.

In some dry docks there appears to be a tendency for concentrations in samples from individual drains and from the upstream ends of collection culverts to be smaller than in samples from the downstream ends of collection culverts. However, there are many exceptions, so this apparent tendency may be a coincidence rather than a result of some process. For example, concentrations of total copper and lead in DD-6 are smaller in the sample from the north-wall drain (site A) and in the samples from near the upstream ends of the north parts of the two culverts (sites E-D2 and W-D2) than in samples from the downstream ends (sites E-NB and W-NB). Also, concentrations in the sample from the floor drain in DD-2 are smaller than in the sample from the end of the culvert. In DD-4 concentrations of total copper and total lead in the sample from the crack in the wall of the culvert (site E-C), and of total copper in samples from three floor drains (sites FD1, FD2 and FD3) were smaller than concentrations in samples from the downstream ends of the north parts of the culverts (sites W-NB and E-NB); however, concentrations of lead in samples from the floor drains were as large as concentrations in samples from the ends of the culverts. Also, although concentrations in the sample from one drain in the north wall of DD-3 (site A) were much smaller than concentrations in samples from the ends of the three culverts at the collection basin (sites E, W-N and W-S), concentrations in the sample from a similar wall drain (site B) were about the same as in samples from the ends of the culverts.

Although the reason for the variability of total copper and total lead concentrations within and between dry docks is not known, several are possible. They include (1) spatial variability in concentrations of the inflowing water, (2) addition of copper and lead to the water as it flows through the collection system as a result of the work being done in the dry dock, (3) variability in the suspended-solids concentrations in samples, and (4) variability in the salinity of samples. The data collected are not sufficient to evaluate these different possibilities.

Semi-Volatile Organic Compounds

Concentrations of all 43 semi-volatile organic compounds analyzed for (table 8) in samples from all 19 sites (table 7), including 1 duplicate sample and 2 field blanks, were less than the laboratory minimum reporting level. The reason that semi-volatile organic compounds were not detected in samples from the dry dock even though they were found previously in samples of soil and ground water from the shipyard (URS Consultants, Inc., 1992a) may be their relatively low solubility, and hence, low mobility.

Volatile Organic Compounds

Four or more volatile organic compounds were found at concentrations larger than the laboratory minimum reporting level (0.2 µg/L for most compounds) in each sample collected from eight sites (tables 7 and 9). Altogether, 13 of the 63 compounds analyzed for were found in 1 or more samples. Twelve of the 13 compounds that were found were chlorinated hydrocarbons; the other, bromoform, is a related compound. All 13 typically are found in various industrial solvents. In more than half the 41 cases where the concentration of a compound was larger than the laboratory minimum reporting level (not including the duplicate sample), the concentration was less than 1 µg/L. In only five of the cases was the concentration larger than 10 µg/L. The largest observed concentration was 340 µg/L of tetrachloroethene in the sample of the discharge from a drain at the base of the west side of the north wall of DD-3 (site B). The concentration of this compound in the discharge from a similar drain on the east side of this same dry dock (site A) was much smaller, 1.7 µg/L. Concentrations of total copper and lead also were much higher in the sample from the west drain than from the east drain (table 7). Concentrations of all volatile organic compounds in the field blank were less than the laboratory minimum reporting level, and the consistency of concentrations in the duplicate pair was reasonable.

Table 8.--Semi-volatile organic compounds analyzed for in samples from sites in the drainage systems of dry docks at Puget Sound Naval Shipyard, Bremerton, Washington, and laboratory minimum reporting levels
[CAS, Chemical Abstract Service; reporting levels are in micrograms per liter]

Compound	CAS registry number	Laboratory minimum reporting level
1,2,5,6-Dibenz[a,h]anthracene	53703	10
1,2,4-Trichlorobenzene[1]	120821	5
1,2-Dichlorobenzene[1]	95501	5
1,3-Dichlorobenzene[1]	541731	5
1,4-Dichlorobenzene[1]	106467	5
2,4-Dinitrotoluene	121142	5
2,6-Dinitrotoluene	606202	5
2-Chloronaphthalene	91587	5
4-Bromophenylphenyether	101553	5
4-Chlorophenylphenyether	7005723	5
n-Nitrosodimethlyamine	62759	5
n-Nitrosodiphenylamine	86306	5
n-Nitrosodi-n-propylamine	621647	5
Acenaphthene	83329	5
Acenaphthylene	208968	5
Anthracene	120127	5
Benzo[a]anthracene	56553	10
Benzo[b]fluoranthene	205992	10
Benzo[k]fluoranthene	207089	10
Benzo[a]pyrene	50328	10
Benzo[g,h,i]perylene	191242	10
Butyl benzyl phthalate	85687	5
Bis(2-chloroethoxy) methane	111911	5
Bis(2-chlorethy) ether	111444	5
Bis(2-chlorisoptopyl) ether	108601	5
Bis(2-ethlyhexyl)phthalate	117817	5
Chrysene	218019	10
Di-n-butyl phthalate	84742	5
Diethyl phthalate	84662	5
Dimethyl phthalate	131113	5
Di-n-octyl phthalate	117840	10
Fluorene	86737	5
Fluoranthene	206440	5
Hexachlorobenzene	118741	5
Hexachlorobutadiene[1]	87683	5
Hexachlorocyclopentadiene	77474	5
Hexachloroethane	67721	5
Indeno(1,2,3-cd)pyrene	193395	10
Isophorone	78591	5
Naphthalene[1]	91203	5
Nitrobenzene	98953	5
Phenanthrene	85018	5
Pyrene	129000	5

[1] This compound was also analyzed as a volatile organic compound (see table 9); laboratory minimum reporting level for which is 0.2 micrograms per liter.

***Table 9.**--Concentrations of volatile organic compounds and salinities in water samples from selected sites in the drainage systems of dry docks at Puget Sound Naval Shipyard, Bremerton, Washington*

[CAS, Chemical Abstract Service; f.b. field blank; dup., duplicate sample collected in field; concentrations are in micrograms per liter except as indicated; nd, compound not detected at a concentration greater than laboratory minimum reporting level; --, no data]

Compound name	CAS registry number	Laboratory minimum reporting level	Sample-collection site									
			DD1-E-143	DD3-A	DD3-B	DD3-B (f.b.)	DD4-FD3	DD4-E-C	DD4-E-C (dup.)	DD5-E-1E	Pump 4	DD6-A
Sample-collection date, (month/day, 1994)			7/06	6/28	6/28	6/28	7/01	7/01	7/01	8/05	8/11	6/28
Sample-collection time			1040	1045	1230	1242	1640	1630	1631	1550	1445	0635
Salinity, in parts per thousand			4.4	0.1	0.5	--	24.7	0.8	--	2.8	16.1	5.0
1,1,1,2-Tetrachloroethane	6302060	0.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1,1,2,2-Tetrachloroethane	79345	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1,1,1-Trichloroethane	71556	.2	nd	.2	nd	nd	2.7	.3	.3	nd	nd	.8
1,1,2-Trichloro 1,2,2-trifluoroethane	76131	.2	35	5.5	66	nd	nd	nd	.3	6.2	.4	.2
1,1,2-Trichloroethane	79005	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1,2,3-Trichlorobenzene	8761612	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1,2,3-Trichloropropane	96184123	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1,2,4-Trichlorobenzene	120821	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1,2,4-Trimethylbenzene	9563612	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1,3,5-Trimethylbenzene	108678135	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1,1-Dichloroethane	75343	.2	nd	nd	nd	nd	1.8	nd	nd	nd	nd	.4
1,1-Dichloroethene	75354	.2	nd	nd	.3	nd	.6	nd	nd	.3	nd	nd
1,1-Dichloropropene	56358611	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1,2-Dibromo-3-chloropropane	96128	1	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1,2-Dibromoethane (EDB)	106934	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1,2-Dichlorobenzene (ortho)	95501	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1,2-Dichloroethane	107062	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	.2
1,2-Dichloropropane	78875	.2	nd	.2	nd	nd	nd	nd	nd	nd	nd	nd
1,3-Dichlorobenzene (meta)	541731	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1,3-Dichloropropane	14228913	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

***Table 9.**--Concentrations of volatile organic compounds and salinities in water samples from selected sites in the drainage systems of dry docks at Puget Sound Naval Shipyard, Bremerton, Washington--Continued*

Compound name	CAS registry number	Laboratory minimum reporting level	Sample-collection site									
			DD1-E-143	DD3-A	DD3-B	DD3-B (f.b.)	DD4-FD3	DD4-E-C	DD4-E-C (dup.)	DD5-E-1E	Pump 4	DD6-A
1,4-Dichlorobenzene (para)	106467	0.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2,2-Dichloropropane	59420722	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2-Chloroethylvinylether	1107582	1	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2-Chlorotoluene	9549812	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4-Chlorotoluene	10643414	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
cis-1,2-Dichloroethene	156592	.2	nd	0.5	nd	nd	0.2	nd	0.9	nd	nd	0.4
cis-1,3-Dichloropropene	10061015	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
trans-1,2-Dichloroethene	15660512	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
trans-1,3-Dichloropropene	10061026	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
n-Butylbenzene	104518	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
n-Propylbenzene1	03651	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
p-Isopropyltoluene	99876	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
sec-Butylbenzene	135988	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
tert-Butylbenzene	98066	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Acrolein	1070282	0.	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Acrylonitrile	1071312	0.	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Benzene	71432	0.	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Bromobenzene	108861	0.	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Bromochloromethane	74975	0.	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Bromodichloromethane	75274	.2	nd	nd	nd	nd	nd	nd	nd	nd	0.2	nd
Bromoform	75252	.2	nd	nd	nd	nd	nd	nd	nd	nd	.4	nd
Bromomethane	74839	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Chlorobenzene	108907	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Chloroethane	75003	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Chloroform	67663	.2	1.0	.85	.4	nd	nd	.3	nd	nd	2.4	.9
Chloromethane	74873	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Dibromochloromethane	124481	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Dibromomethane	74953	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

***Table 9.**--Concentrations of volatile organic compounds and salinities in water samples from selected sites in the drainage systems of dry docks at Puget Sound Naval Shipyard, Bremerton, Washington--Continued*

Compound name	CAS registry number	Laboratory minimum reporting level	Sample-collection site									
			DD1-E-143	DD3-A	DD3-B	DD3-B (f.b.)	DD4-FD3	DD4-E-C	DD4-E-C (dup.)	DD5-E-1E	Pump 4	DD6-A
Dichlorodifluoromethane	75718	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Ethylbenzene	100414	0.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Hexachlorobutadiene	87683	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Isopropyl benzene	98828	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Methylene chloride	75092	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Methyltertbutylether (MTBE)	1634044	1.	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Naphthalene	91203	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Styrene	100425	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Tetrachloroethene	127184	.2	nd	1.7	340	nd	nd	37	38	nd	0.9	nd
Tetrachloromethane	56235	.2	0.6	nd	nd	nd	nd	nd	nd	nd	nd	nd
Toluene	108883	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Trichloroethene (TCE)	79016	.2	2	1.7	5.8	nd	0.3	2.3	2.3	0.3	1.9	12
Trichlorofluoromethane	75694	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Vinyl chloride	75014	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Xylenes (total)	1330207	.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

Trichloroethene, one of two volatile organic compounds that previously were found in ground water at concentrations exceeding the MTCA ground-water cleanup level (URS Consultants, Inc., 1993), was found in samples from all eight sites. However, concentrations of methyl chloride, the other volatile compound previously found at concentrations that exceeded the MTCA level, were less than the laboratory minimum reporting level in all samples. Concentrations of toluene, benzene and xylene, major components of gasoline, were less than the laboratory minimum reporting levels, 0.2 µg/L, in all samples.

SUMMARY

Previous investigations have shown that one result of more than 90 years of work at the Puget Sound Naval Shipyard is that concentrations of some metals and organic compounds in soil and ground water at the shipyard exceed some regulatory limits. Because some of these metals and organic compounds can be transported by ground water, and because the dry-dock drainage systems probably have a large effect on the ground-water flow system, information on the quantity and quality of ground water that discharges into the drainage systems of dry docks could be useful for planning environmental restoration work.

Computations using a single set of measured discharges of many of the inflows and outflows from the drainage systems indicate that ground-water discharges to dry docks no. 1, 2, 3, 4, 5, and 6 equaled 0.07, 0.30, 0.29, 0.61, 1.18, and 6.2 ft^3/s, respectively, at the time of the measurements in June, July and August 1994. Total drain-water discharges from the dry docks equalled 0.07, 0.30, 0.33, 0.61, 1.36, and 11.7 ft^3/s, respectively. The differences between ground-water inflows and total outflows were mostly the result of leakage by cofferdams and floodgates and, in dry dock no. 6, cooling water from a ship in dry dock. On the basis of salinities of the water at the discharge measuring sites and of the water in Sinclair Inlet, the proportions of the ground-water inflows to dry docks 1 through 6 that were saline water from Sinclair Inlet were calculated to be 18, 92, 28, 44, 55, and 69 percent, and the proportions of the total outflows that were saline water were 18, 92, 37, 44, 63, and 82 percent.

Water-quality samples were collected at a total of 36 sites in the dry-dock drainage systems. Samples from all sites were analyzed for total copper and total lead. Concentrations of total copper ranged from less than 1 to 71 micrograms per liter and concentrations of total lead ranged from less than 1 to 44 micrograms per liter. Concentrations of both metals were smallest in samples from DD-5. Concentrations of all 43 semi-volatile organic compounds that were analyzed for in samples from 19 sites were all less than the analyzing laboratory minimum reporting level (5 or 10

micrograms per liter). Concentrations of 63 volatile organic compounds were determined in samples from 8 sites. A total of 13 different compounds, 12 of them chlorinated hydrocarbons, were detected at concentrations larger than the laboratory minimum reporting levels (mostly 0.2 micrograms per liter) in the 8 samples. At least four volatile organic compounds were detected in every sample, and trichloroethene was found in every sample.

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