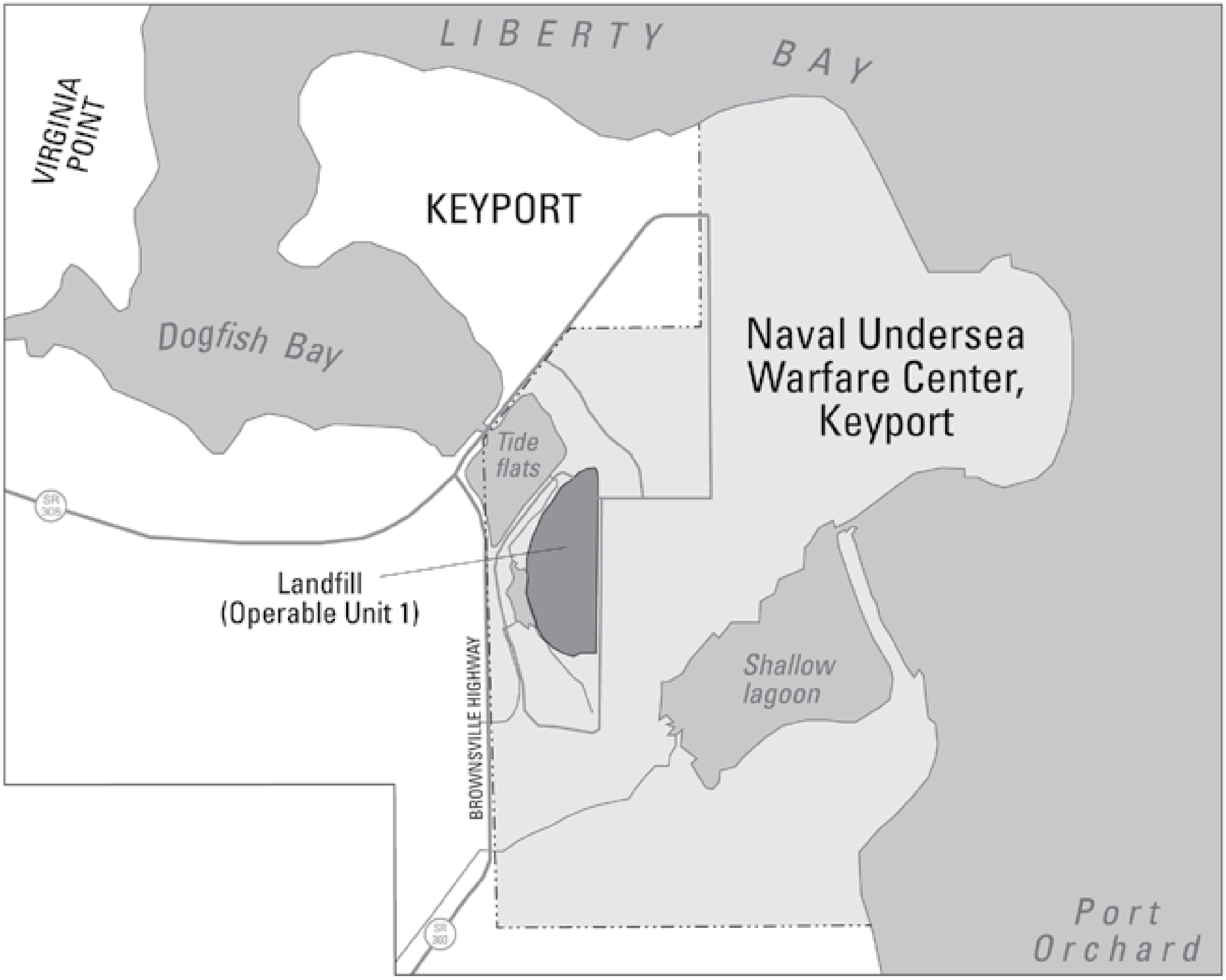
Prepared in cooperation with Department of the Navy,
Naval Facilities Engineering Command, Northwest

Groundwater Geochemical and Selected Volatile Organic Compound Data, Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, June and October 2012



Data Series 766

U.S. Department of the Interior
U.S. Geological Survey

Groundwater Geochemical and Selected Volatile Organic Compound Data, Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, June and October 2012

By R.L. Huffman

Prepared in cooperation with the Department of the Navy,
Naval Facilities Engineering Command, Northwest

Data Series 766

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
SALLY JEWELL, Secretary

U.S. Geological Survey
Suzette M. Kimball, Acting Director

U.S. Geological Survey, Reston, Virginia: 2013

For more information on the USGS—the Federal source for science about the Earth, its natural and living resources, natural hazards, and the environment, visit http://www.usgs.gov or call 1–888–ASK–USGS.

For an overview of USGS information products, including maps, imagery, and publications, visit http://www.usgs.gov/pubprod

To order this and other USGS information products, visit http://store.usgs.gov

Suggested citation:
Huffman, R.L., 2013, Groundwater geochemical and selected volatile organic compound data, Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, June and October 2012: U.S. Geological Survey Data Series 766, 44 p.

Contents

Figures

Tables

Conversion Factors and Datums

Conversion Factors

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
	Area	
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
acre	0.4047	square hectometer (hm^2)
acre	0.004047	square kilometer (km^2)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=(1.8\times°C)+32.$$

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Datums

Vertical coordinate information is referenced to North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to North American Datum of 1927 (NAD 27).

Altitude, as used in this report, refers to distance above the vertical datum.

Groundwater Geochemical and Selected Volatile Organic Compound Data, Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, June and October 2012

By R.L. Huffman

Abstract

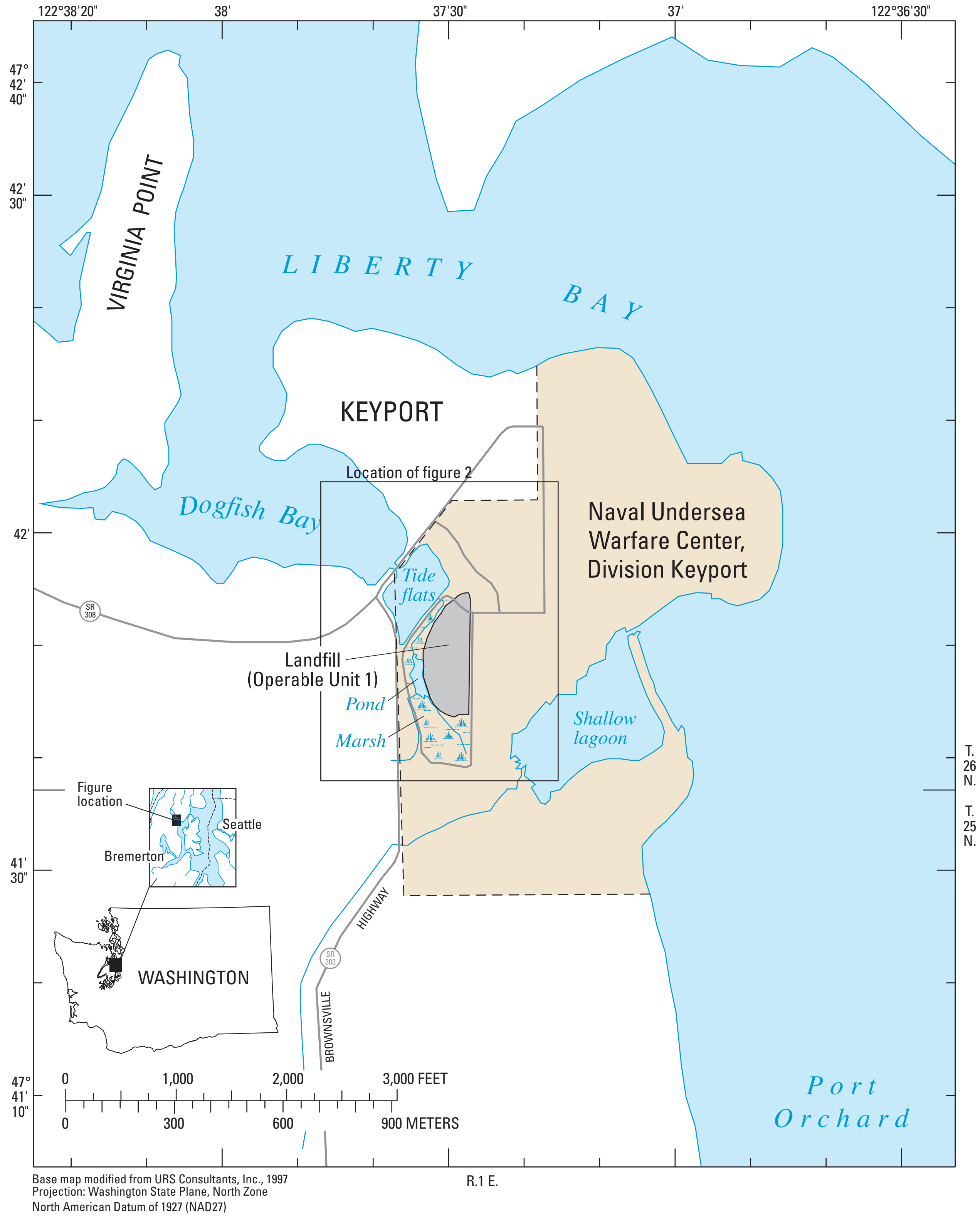
Previous investigations indicate that concentrations of chlorinated volatile organic compounds are substantial in groundwater beneath the 9-acre former landfill at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington. The U.S. Geological Survey has continued to monitor groundwater geochemistry to ensure that conditions remain favorable for contaminant biodegradation as specified in the Record of Decision for the site.

This report presents groundwater geochemical and selected chlorinated volatile organic compound data collected at Operable Unit 1 by the U.S. Geological Survey during June and October 2012, in support of long-term monitoring for natural attenuation. Groundwater samples were collected from 13 wells and 9 piezometers, as well as from 10 shallow groundwater passive-diffusion sampling sites in the nearby marsh. Samples from all wells and piezometers were analyzed for oxidation-reduction (redox) sensitive constituents and dissolved gases. Samples from all piezometers also were analyzed for chlorinated volatile organic compounds, as were all samples from the passive-diffusion sampling sites.

In 2012, concentrations of redox-sensitive constituents measured at all wells and piezometers were consistent with those measured in previous years, with dissolved oxygen concentrations all at 0.4 milligram per liter or less; little to no detectable nitrate; abundant dissolved manganese, iron, and methane; and commonly detected sulfide. In the upper aquifer of the northern plantation in 2012, chlorinated volatile organic compound (CVOC) concentrations at all piezometers were similar to those measured in previous years, and concentrations of the reductive dechlorination byproducts ethane and ethene were slightly higher or the same as concentrations measured in 2011. In the upper aquifer of the southern plantation, CVOC concentrations measured in piezometers during 2012 continued to be extremely variable as in previous years, and often very high, and reductive dechlorination byproducts were detected in two of the four wells and in all piezometers. Beneath the marsh adjacent to the southern plantation, chloroethene concentrations measured in 2012 continued to vary spatially and temporarily, and also were very high. Additionally, CVOC concentrations measured in samplers deployed in access tubes were about two to four times less than those measured in the two samplers buried nearby, beneath the marsh stream. Total CVOC concentration, at what has been historically the most contaminated passive-diffusion sampler site (S-4), continued an increasing trend. For the intermediate aquifer in 2012, concentrations of reductive dechlorination byproducts ethane and ethene were consistent with those measured in previous years.

Introduction

Chlorinated volatile organic compounds (CVOCs) have migrated to groundwater beneath a former 9-acre landfill at Operable Unit 1 (OU 1) of the Naval Undersea Warfare Center (NUWC), Division Keyport, Washington. The NUWC is on a small peninsula in Kitsap County, Washington, in an extension of Puget Sound called Liberty Bay (fig. 1). The former landfill is on the narrow strip of land connecting the peninsula to the mainland and is adjacent to tidal flats that are an extension of Liberty and Dogfish Bays. The OU 1 landfill was constructed in a former marshland and was the primary disposal area for domestic and industrial waste generated by NUWC Division Keyport from the 1930s through 1973.



Base map modified from URS Consultants, Inc., 1997
Projection: Washington State Plane, North Zone
North American Datum of 1927 (NAD27)

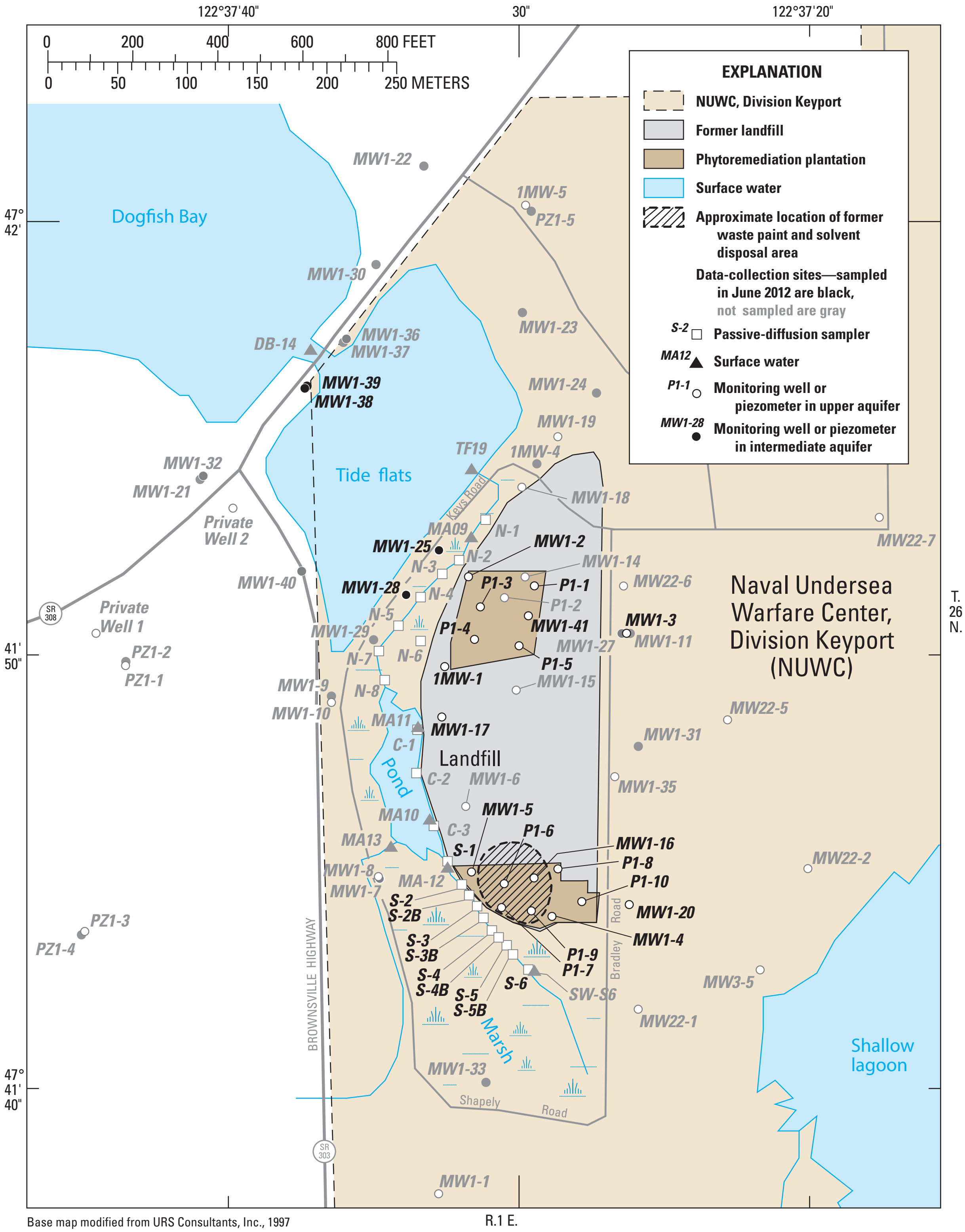
Figure 1. Location of the study area near Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington.

Groundwater beneath OU 1 is within a series of aquifers that are composed of permeable sand, gravel, or fill materials separated by finer grained silt or clay layers. Volatile organic compound (VOC) contamination at OU 1 is only in about the top 60 ft of the unconsolidated deposits in the four hydrogeologic units—the unsaturated zone, the upper aquifer, the middle confining unit, and the intermediate aquifer. Groundwater in the unconfined upper aquifer generally flows from the east to the west toward Dogfish Bay. Groundwater in the predominantly confined intermediate aquifer flows toward the landfill from the south and from the west, and then flows northwest beneath the landfill toward Dogfish Bay (Dinicola and others, 2002). Two perennial freshwater creeks drain the marsh adjacent to the landfill and discharge into the tide flats of Dogfish Bay

CVOCs are in the upper and intermediate aquifers and in surface water at OU 1. The predominant contaminants in groundwater beneath OU 1 are the chloroethene compounds—trichloroethene (TCE), *cis*-1,2-dichloroethene (*cis*-DCE), and vinyl chloride (VC). Less common contaminants include tetrachloroethene (PCE), *trans*-1,2-dichloroethene (*trans*-DCE), 1,1-dichloroethene (1,1-DCE); and the chloroethane compounds—1,1,1-trichloroethane (TCA), 1,1-dichloroethane (1,1-DCA), and 1,2-dichloroethane (1,2-DCA). A need for remedial action was identified because some of the contaminants present a potential risk to humans, primarily through drinking contaminated groundwater or through ingesting seafood harvested from contaminated surface water (URS Consultants, Inc., 1998). The U.S. Navy planted two hybrid poplar plantations on the landfill (fig. 2) in spring 1999 to remove and control the migration of CVOCs in shallow groundwater. The landfill between the plantations is covered with pavement, although the area north of the northern plantation is permeable.

The U.S. Navy began a cooperative effort with the U.S. Geological Survey (USGS) in 1995 to evaluate the effectiveness of natural attenuation processes for removing and controlling the migration of CVOCs in groundwater at OU 1. Field and laboratory studies from 1996 through 2000 demonstrated that biodegradation of CVOCs in shallow groundwater at OU 1 was substantial (URS Consultants, Inc., 1997; Bradley and others, 1998; Dinicola and others, 2002). In 1998, a remedy was developed for contaminated groundwater at OU 1 that included phytoremediation and on-going natural attenuation processes to remove and control the migration of CVOCs in shallow groundwater (URS Consultants, Inc., 1998). In 1999, the U.S. Navy planted two hybrid poplar plantations in two areas on the landfill where contaminant concentrations in groundwater were exceptionally high (fig. 2) (URS Greiner, Inc., 1999). The U.S. Navy regularly monitored contaminant concentrations in groundwater and surface water, along with tree health and water levels, to determine the effectiveness of phytoremediation (CH2M Hill Constructors, Inc., 2002, 2003, 2004, 2005). The USGS has monitored geochemistry and contaminant concentrations in groundwater and surface water annually from 2001 through 2012 to evaluate reduction-oxidation (redox) conditions and CVOC biodegradation.

This report presents groundwater geochemical and selected CVOC data collected by the USGS at OU 1 during June 4–6, 2012, and October 19, 2012, in support of the long-term monitoring for natural attenuation. The USGS collected groundwater samples from 13 wells and 9 piezometers during 2012 (table 1 and fig. 2), and concentrations of various geochemical constituents used to determine redox conditions were determined in all samples. Concentrations of VOCs also were determined by the USGS in samples collected from the 9 piezometers, as well in samples from 10 passive diffusion sampling sites in the nearby marsh bordering the southern landfill. During previous years, passive-diffusion samplers were buried directly in sediment beneath the marsh stream. During 2012, passive-diffusion samplers were deployed at 10 sites in newly installed access tubes immediately adjacent to the landfill side of the marsh creek. For comparison to existing data, passive-diffusion samplers also were buried directly in sediment beneath the marsh at three of the sites during 2012.



Base map modified from URS Consultants, Inc., 1997
Projection: Washington State Plane, North Zone
North American Datum of 1927 (NAD27)

Figure 2. Locations of data-collection sites used to monitor the natural attenuation of chlorinated volatile organic compounds in groundwater beneath the 9-acre former landfill at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington.

Table 1. Wells and piezometers sampled and groundwater levels measured at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 2012.

[**Well or piezometer site No.:** MW, monitoring well; P, piezometer. **USGS site No.:** Unique number for each site based on latitude and longitude of the site. First six digits are latitude, next seven digits are longitude, and final two digits are a sequence number to uniquely identify each site. **Altitudes of groundwater levels and measuring points** are given in feet above or below (-) North American Vertical Datum of 1988. **Water level** is in feet below measuring point (bmp). **Depth of well and screened interval** are in feet below land surface. **Altitude of measuring point:** Water levels in wells are usually reported as depths below land surface, although the measuring point can be any convenient fixed place near the top of the well. For these wells and piezometers, the measuring points are marked points on the tops of well casings—they vary from being near the land surface to a few feet above land surface. The altitude of the measuring point is commonly recorded so that static water levels also can be reported as altitudes. **Abbreviations:** USGS, U.S. Geological Survey; VOC, volatile organic compound; ft, foot; in., inch; –, not measured]

Well or piezometer site No.	USGS site No.	Date and time measured		Groundwater level altitude (ft)	Groundwater level (ft bmp)	Altitude of measuring point (ft)	Depth of well (ft)	Casing diameter (in.)	Screened interval (ft)	VOCs sampled by USGS
1MW-1	474151122373201	06-04-12	1130	3.81	6.25	10.06	16.5	2	5.5–15.5	No
MW1-2	474153122373101	06-04-12	1215	2.44	9.45	11.89	18.5	4	12.5–17.5	No
MW1-3	474152122372501	06-04-12	1200	10.52	3.03	13.55	11.5	4	5.5–10.5	No
MW1-4	474145122372801	06-05-12	1210	5.69	6.51	12.20	13.0	4	7–12	No
MW1-5	474146122373201	06-05-12	1330	4.45	8.63	13.08	12.0	4	6–11	No
MW1-16	474146122372801	06-06-12	1045	4.48	8.6	12.83	12.0	2	6–11	No
MW1-17	474150122373201	06-04-12	1700	6.33	5.61	11.94	16.5	2	7.5–12.5	No
MW1-20	474145122372501	06-05-12	0930	7.08	3.36	10.44	16.0	2	10–15	No
MW1-25	474154122373201	06-06-12	1405	1.96	9.95	11.91	49.0	2	38–48	No
MW1-28	474153122373301	06-06-12	1330	-0.9	11.13	10.23	45.0	2	39–44	No
MW1-38	474156122373701	06-06-12	1415	-0.55	10.38	9.83	59.0	2	44–49	No
MW1-39	474157122373701	06-06-12	1310	-0.73	10.58	9.85	33.7	2	27.7–32.7	No
MW1-41	474152122372901	06-04-12	1415	7.33	7.88	15.21	15.0	2	5–15	No
P1-1	474153122372801	06-04-12	1600	6.17	8.19	14.36	15.0	1	10–15	Yes
P1-3	474153122373102	06-04-12	1515	3.47	9.32	12.79	15.0	1	10–15	Yes
P1-4	474152122373101	06-04-12	1330	5.62	6.93	12.55	15.0	1	10–15	Yes
P1-5	474152122372801	06-04-12	1220	6.75	8.31	15.06	15.0	1	10–15	Yes
P1-6	474146122373001	06-06-12	0940	5.34	7.42	12.76	15.0	1	10–15	Yes
P1-7	474145122373101	06-05-12	1240	5.25	6.87	12.12	15.0	1	10–15	Yes
P1-8	474147122372801	06-06-12	1000	6.26	5.8	12.06	15.0	1	10–15	Yes
P1-9	474145122372901	06-05-12	1130	5.53	6.38	11.91	15.0	1	10–15	Yes
P1-10	474145122372601	06-05-12	1040	6.64	5.22	11.86	15.0	1	10–15	Yes

Sample Collection and Analysis

Water-level measurements and sample collection, processing, and field analyses during 2012 were in accordance with applicable USGS procedures as described in the National Field Manual (U.S. Geological Survey, variously dated). Redox-sensitive analyte measurements and concentrations that were determined for samples from 13 wells and 9 piezometers included dissolved hydrogen (H_2), dissolved oxygen (DO), filtered organic carbon (referred to as dissolved organic carbon, DOC), filtered nitrate plus nitrite, filtered manganese, filtered ferrous iron (iron (II)), filtered sulfate, unfiltered sulfide, dissolved methane, dissolved carbon dioxide, pH, specific conductance, and filtered chloride. Concentrations of CVOCs and other VOCs were determined for samples from all 9 piezometers in the northern and southern landfills, and from all 10 passive-diffusion sampling sites in the marsh. Complete VOC analytical results (including data qualifiers) are available from the USGS National Water Information System (U.S. Geological Survey, 2013). Concentrations of dissolved gases ethane, ethene, and methane also were determined for samples from all wells and piezometers.

After measuring depth to water, all well and piezometer samples were collected with a peristaltic pump and single-use polyethylene tubing. Samples were collected after about three casing-volumes of water were purged from the wells and after allowing field measurements of pH, specific conductance, and DO to stabilize to within 0.1 unit, 3 percent, and 0.3 mg/L, respectively. Field measurements were monitored using a flow-through chamber and a Yellow Springs Instruments (YSI®) 600XLM or 6920 V2 data sonde. The sonde was calibrated prior to use as described in the National Field Manual (U.S. Geological Survey, variously dated, chaps. A6 and A8). The specific conductance sensor was calibrated daily with standard reference solutions (1,000 µS/cm and checked with solutions ranging from 250 to 750 µS/cm); the pH sensor was calibrated daily with two pH standards (7 and 10 and checked against pH 4 buffer solution); and the DO sensor was calibrated daily using the air-saturated water method and occasionally verified with zero-DO solution. Dissolved-oxygen analyses were confirmed for most samples using 0–1 mg/L CHEMets Rhodazine- D® colorimetric vacuum ampoules (manufactured by CHEMetrics®, Inc., Calverton, Virginia).

Concentrations of iron (II) were measured in field samples filtered through a 0.45-µm membrane filter using a colorimetric 1,10-phenanthroline indicator method and a Hach Model 2010 spectrophotometer following Hach Method 8146 (Hach Company, 1998; adapted from American Public Health Association, 1980). Sulfide concentrations were measured in the field with a colorimetric methylene-blue indicator method using a spectrophotometer immediately after collection, according to Hach Method 8131 [Hach Company, 1998; procedure is equivalent to U.S. Environmental Protection Agency method 376.2 (U.S. Environmental Protection Agency, 1983)]. Dissolved carbon dioxide (CO_2) concentrations were measured in the field using Titret®-Sodium hydroxide titrant with a pH indicator (manufactured by CHEMetrics®, Inc., Calverton, Virginia).

Samples for analysis of dissolved H_2 in groundwater were collected after at least 30 minutes of stripping using the bubble-strip method of Chapelle and others (1997), and concentrations were measured in the field using a reduction gas analyzer (Trace Analytical model E-001) (Dinicola and Huffman, 2012). Subsequent samples were collected and analyzed at about 5-minute intervals until consecutive H_2 concentrations stabilized to within 10 percent.

Samples for analysis of nitrate plus nitrite, sulfate, and chloride concentrations were filtered through a 0.45-µm membrane filter into polyethylene bottles, chilled, and sent to the USGS National Water Quality Laboratory (NWQL) in Lakewood, Colorado. Chloride and sulfate were analyzed using ion chromatography as described by Fishman and Friedman (1989). Nitrate plus nitrite were analyzed colorimetrically by cadmium reduction and diazotization as described by Fishman (1993). The results for the nitrate plus nitrite analyses are referred to simply as “nitrate” in this report because nitrite was not detected at the site (Dinicola and others, 2002). Samples for analysis of manganese were filtered into an acid-rinsed bottle, acidified in the field with nitric acid to a pH of less than 2 and then shipped to the NWQL for analysis by inductively coupled plasma as described by Fishman (1993).

Samples for DOC analysis were filtered through a 0.45-µm filter into amber glass bottles, acidified in the field with sulfuric acid to a pH of less than 2, chilled to less than 4°C, and shipped to the NWQL. Organic carbon concentrations were determined using persulfate oxidation as described by Brenton and Arnett (1993).

Samples for VOC analysis were collected in pre-acidified 40-mL glass vials, placed on ice, and shipped to the NWQL for subsequent analysis using purge and trap capillary-column gas chromatography/mass spectrometry as described by Connor and others (1998). Samples for analysis of ethane, ethene, and methane were collected in pre-acidified 40-mL glass vials, placed on ice, and shipped to TestAmerica Laboratories in Denver, Colorado, for subsequent analysis using gas chromatography with a flame-ionization detector according to USEPA Method RSK SOP-175 (U.S. Environmental Protection Agency, 1994; Kampbell and Vandegrift, 1998).

In September 2012, ten 5-ft long by 2-in. diameter polyvinyl chloride (PVC) access tubes were installed vertically, immediately adjacent to the marsh stream between the stream and the southern landfill. The access tubes were placed within 1–3 ft of previously sampled passive-diffusion sites in the stream bed (fig. 2). The lowermost 1 ft of the access tubes were slotted screens, and the bottoms of these screens were driven about 1 ft below the elevation of the adjacent streambed. After installation, passive-diffusion samplers were placed in the access tubes to collect shallow groundwater samples for VOC analyses. The samplers consisted of 6-in. long by 2-in. diameter polyethylene lay-flat tubing filled with de-ionized water and heat sealed at both ends. The samplers were built by USGS personnel at the Washington Water Science Center (WAWSC), Tacoma, Washington. Filled bags were inserted into plastic mesh sleeves to protect the bags from damage. A single sampler was placed in each access tube, and a cap was installed on the tube top to prevent air exchange with the atmosphere. At two sites, an additional sampler was buried in the sediment beneath the marsh creek, as was done during previous years, to evaluate the consistency of data between the access tube and the direct burial sampling results. All passive-diffusion samplers were allowed to equilibrate with the surrounding water for more than 2 weeks, after which they were retrieved by hand, placed on ice, and processed at the WAWSC laboratory within 2 hours of retrieval. A corner of each bag was cut and three pre-acidified 40-mL glass VOC vials were filled, sealed, and kept on ice for shipment to the NWQL for VOC analysis.

Quality assurance and control of geochemical and contaminant sampling included collecting two duplicate samples for selected redox-sensitive analytes and VOCs, and analyzing a field blank sample for VOCs and redox-sensitive analytes. No substantial quality issues were identified in those samples (appendix A).

Selected Monitoring Data

The groundwater chemistry data are grouped with regard to aquifer and location of the well or piezometer. Upgradient sites are the two upper aquifer wells (MW1-3 and MW1-20) located east of the former landfill. The former upgradient intermediate aquifer well (MW1-33) located south of the landfill was decommissioned and can no longer be sampled. Northern plantation sites are all in the upper aquifer and include four wells (1MW-1, MW1-2, MW117, and MW1-41) and four piezometers (P1-1, P1-3, P1-4, and P1-5) in or near the northern phytoremediation plantation; piezometer P1-2 generally is dry during June and has never been sampled. Southern plantation sites also are all in the upper aquifer and include three wells (MW1-4, MW1–5, and MW1-16) and five piezometers (P1-6, P1-7, P1-8, P1-9, and P1-10) in or near the southern phytoremediation plantation. Intermediate aquifer sites include four wells (MW1-25, MW1-28, MW1-38, and MW1-39) that are downgradient of the landfill; no intermediate aquifer wells are in the footprint of the former landfill. Marsh sampling sites refer to the 10 passive-diffusion sampling sites (S-1, S-2, S-2B, S-3, S-3B, S-4, S-4B, S-5, S-5B, S-6) near the southern plantation (fig. 2).

Geochemical Data

Geochemical data collected by the USGS from piezometers and selected wells at OU 1 from 1996 to 2012 are shown in table 2 (at back of report). Historical geochemical data for wells not sampled in 2012 are not included in table 2, but are available in Dinicola (2003, 2004, 2006) and Dinicola and Huffman (2004, 2006, 2007, 2009, 2012). Overall, concentrations of redox-sensitive constituents measured in 2012 were consistent with previous years, with dissolved-oxygen concentrations all at 0.4 mg/L or less; little to no detectable nitrate; abundant dissolved manganese, iron, and methane; and commonly detected sulfide.

Volatile Organic Compounds

VOCs and dissolved ethane and ethene data collected from piezometers and selected intermediate aquifer wells at OU 1 from June 1999 to June 2012 are shown in table 3 (at back of report). Chemical concentrations are reported as less than the reporting level for samples in which the analyte was neither identified nor detected at concentrations equal to or greater than the reporting level. Historical VOC data for wells not sampled in 2012 and for dates before 1999 are not included in table 3. Complete analytical results for the USGS data for 2012 and previous years are available from the USGS National Water Information System web site (U.S. Geological Survey, 2013; or Dinicola and others (2002), Dinicola (2003, 2004, 2006), Dinicola and Huffman (2004, 2006, 2007, 2009, 2012), and Huffman and Dinicola (2011). Complete analytical results for the complimentary U.S. Navy VOC data from 1995 through 2011 are available in U.S. Navy (2012). The total CVOC concentrations calculated for each sample is the sum of concentrations of CVOCs that were positively detected; concentrations reported as “less than” values were not included in the total.

Volatile Organic Compound Concentrations beneath the Phytoremediation Plantations

In the upper aquifer of the northern plantation in 2012, CVOC concentrations at all piezometers were similar to those measured in previous years. In 2012, trace concentrations of CVOCs were detected in samples from piezometers P1-3 and P1-5 and much higher concentrations were measured at piezometer P1-4. Total CVOC concentrations at piezometer P1-4 were similar to concentrations measured in 2011. In all wells and piezometers sampled, the concentrations of the reductive dechlorination byproducts ethane and ethene in 2012 were slightly higher or the same as concentrations measured in 2011.

In the upper aquifer of the southern plantation, CVOC concentrations measured in all piezometers continued to be extremely variable from year to year, and often were high. Compared to 2011, total CVOC concentrations measured in 2012 increased substantially in one piezometer (P1-10), decreased substantially in three piezometers (P1-6, P1-8, and P1-9), and were about the same at one piezometer (P1-7). In 2012, one or both of the reductive dechlorination byproducts ethane and ethene were detected in two of the four wells, and in all piezometers in the southern plantation.

In 2012, CVOC concentrations continued to vary spatially and temporarily beneath the marsh near the southern plantation, and concentrations measured in samplers installed in access tubes (S-2 T and S-4 T in table 3) were about two to four times less than those measured in the two samplers buried nearby beneath the marsh stream (S-2 and S-4 in table 3). Total CVOC concentration, at what has been historically the most contaminated passive diffusion sampler site (S-4), continued a generally consistent increasing trend. The total CVOC concentration from the sampler in the corresponding access tube (S-4 T in table 3) was about four times lower than concentrations from the buried sampler (S-4). The total CVOC concentration from the sampler placed in the S-2 access tube (S-2 T in table 3) was about two times lower than the concentration from buried sampler (S-2).

Volatile Organic Compound Concentrations in the Intermediate Aquifer

For the intermediate aquifer, concentrations of reductive dechlorination byproducts ethane and ethene in 2012 were consistent with those measured in previous years. No other VOCs were measured at these sites in 2012 by USGS.

Summary

The U.S. Geological Survey (USGS) has continued to monitor groundwater geochemistry to ensure that conditions remain favorable for contaminant biodegradation as specified in the Record of Decision. This report presents groundwater geochemical and selected VOC data collected at OU 1 by the USGS during June and October 2012, in support of long-term monitoring for natural attenuation.

Overall, concentrations of redox-sensitive constituents measured in 2012 were consistent with previous years, with dissolved-oxygen concentrations all at 0.4 mg/L or less; little to no detectable nitrate; abundant dissolved manganese, iron, and methane; and commonly detected sulfide.

In the upper aquifer of the northern plantation in 2012, CVOC concentrations at all piezometers were similar to those measured in previous years. The concentrations of the reductive dechlorination byproducts ethane and ethene were slightly higher or the same as concentrations measured in 2011. In the upper aquifer of the southern plantation, CVOC concentrations measured in all piezometers continued to be extremely variable from year to year and one or both of the reductive dechlorination byproducts ethane and ethene were detected in two of the four wells, and in all piezometers in the southern plantation.

In 2012, CVOC concentrations continued to vary spatially and temporarily beneath the marsh near the southern plantation, and concentrations measured in samplers installed in access tubes were about two to four times less than those measured in the two samplers buried nearby beneath the marsh stream.

For the intermediate aquifer, concentrations of reductive dechlorination byproducts ethane and ethene in 2012 were consistent with those measured in previous years. No other VOCs were measured at these sites in 2012 by USGS.

References Cited

American Public Health Association, 1980, Standard methods for the examination of water and wastewater (15th ed.): Washington, D.C., American Public Health Association.

Bradley, P.M., Landmeyer, J.E., and Dinicola, R.S., 1998, Anaerobic oxidation of [1,2-^{14}C] dichloroethene under Mn(IV)-reducing conditions: Applied and Environmental Microbiology, v. 64, no. 4, p. 1560–1562.

Brenton, R.W., and Arnett, T.L., 1993, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of dissolved organic carbon by UV-promoted persulfate oxidation and infrared spectrometry: U.S. Geological Survey Open-File Report 92–480, 12 p. (Also available at http://pubs.er.usgs.gov/publication/ofr92480.)

Chapelle, F.H., Vroblesky, D.A., Woodward, J.C., and Lovely, D.R., 1997, Practical considerations for measuring hydrogen concentrations in groundwater: Environmental Science and Technology, v. 31, no. 10, p. 2873–2877.

CH2M Hill Constructors, Inc., 2002, 2001 annual report—Operable Unit 1, Area 1, former base landfill, Naval Undersea Warfare Center Division, Keyport, Washington: Prepared under Contract Task Order 0062 for Engineering Field Activity, Northwest, Naval Facilities Engineering Command, Poulsbo, Wash.

CH2M Hill Constructors, Inc., 2003, 2002 annual report—Operable Unit 1, Area 1, former base landfill, Naval Undersea Warfare Center Division, Keyport, Washington: Prepared under Contract Task Order 0062 for Engineering Field Activity, Northwest, Naval Facilities Engineering Command, Poulsbo, Wash.

CH2M Hill Constructors, Inc., 2004, 2003 annual report—Operable Unit 1, Area 1, former base landfill, Naval Undersea Warfare Center Division, Keyport, Washington: Prepared under Contract Task Order 0062 for Engineering Field Activity, Northwest, Naval Facilities Engineering Command, Poulsbo, Wash.

CH2M Hill Constructors, Inc., 2005, Draft 2004 annual report—Operable Unit 1, Area 1, former base landfill, Naval Undersea Warfare Center Division, Keyport, Washington: Prepared under Contract Task Order 0062 for Engineering Field Activity, Northwest, Naval Facilities Engineering Command, Poulsbo, Wash.

Connor, B.F., Rose, D.L, Noriega, L.M., and Abney, S.R., 1998, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of 86 volatile organic compounds in water by gas chromatography-mass spectrometry, including detections less than reporting limits: U.S. Geological Survey Open-File Report 97–829, 78 p. (Also available at http://pubs.er.usgs.gov/publication/ofr97829.)

Dinicola, R.S., 2003, Selected natural attenuation monitoring data, Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, June 2001: U.S. Geological Survey Open-File Report 2003–344, 17 p. (Also available at http://pubs.er.usgs.gov/publication/ofr03344.)

Dinicola, R.S., 2004, Selected natural attenuation monitoring data, Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, June 2002: U.S. Geological Survey Open-File Report 2004–1203, 19 p. (Also available at http://pubs.er.usgs.gov/publication/ofr20041203.)

Dinicola, R.S., 2006, Continued biodegradation of chlorethene compounds in ground water at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington: U.S. Geological Survey Scientific Investigations Report 2006–5056, 42 p. (Also available at http://pubs.er.usgs.gov/publication/sir20065056.)

Dinicola, R.S., Cox, S.E., Landmeyer, J.E., and Bradley, P.M., 2002, Natural attenuation of chlorinated volatile organic compounds in ground water at Operable Unit 1, Naval Undersea Weapons Center, Division Keyport, Washington: U.S. Geological Survey Water-Resources Investigations Report 2002–4119, 116 p. (Also available at http://pubs.er.usgs.gov/publication/wri024119.)

Dinicola, R.S., and Huffman, R.L., 2004, Selected natural attenuation monitoring data, Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, June 2003: U.S. Geological Survey Open-File Report 2004–1330, 19 p. (Also available at http://pubs.er.usgs.gov/publication/ofr20041330.)

Dinicola, R.S., and Huffman, R.L., 2006, Selected natural attenuation monitoring data, Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, June 2005: U.S. Geological Survey Open-File Report 2006–1374, 28 p. (Also available at http://pubs.er.usgs.gov/publication/ofr20061374.)

Dinicola, R.S., and Huffman, R.L., 2007, Selected natural attenuation monitoring data, Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, June 2006: U.S. Geological Survey Open-File Report 2007–1430, 30 p. (Also available at http://pubs.er.usgs.gov/publication/ofr20071430.)

Dinicola, R.S., and Huffman, R.L., 2009, Selected natural attenuation monitoring data, Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 2007 and 2008: U.S. Geological Survey Open-File Report 2009–1141, 42 p. (Also available at http://pubs.er.usgs.gov/publication/ofr20091141.)

Dinicola, R.S., and Huffman, R.L., 2012, Biodegradation of cholorethene compounds in groundwater at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1999–2010: U.S. Geological Survey Scientific Investigations Report 2012–5013, 56 p. (Also available at http://pubs.er.usgs.gov/publication/sir20125013.)

Fishman, M.J., ed., 1993, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of inorganic and organic constituents in water and fluvial sediments: U.S. Geological Survey Open-File Report 93–125, 217 p. (Also available at http://pubs.er.usgs.gov/publication/ofr93125.)

Fishman, M.J., and Friedman, L.C., eds., 1989, Methods for determination of inorganic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. A1, 545 p. (Also available at http://pubs.er.usgs.gov/publication/twri05A1.)

Hach Company, 1998, DR/2010 Spectrophotometer Procedures Manual: Loveland, Colo., Hach Company,

Huffman, R.L., and Dinicola, R.S., 2011, Groundwater geochemical and selected volatile organic compound data, Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, June 2009: U.S. Geological Survey Data Series Report 644, 38 p. (Also available at http://pubs.er.usgs.gov/publication/ds644.)

Kampbell, D.H., and Vandergrift, S.A., 1998, Analysis of dissolved methane, ethane, ethenes, and propanes: Environmental Science and Technology, v. 23. no. 8, p. 965–969.

URS Consultants, Inc.,1997, Final summary data assessment report for Operable Unit 1 Naval Undersea Warfare Center Division Keyport, Washington: Prepared by URS Consultants, Seattle, Wash., under Contract Task Order 0189 for Engineering Field Activity, Northwest, Naval Facilities Engineering Command, Poulsbo, Wash., 3 volumes.

URS Consultants, Inc., 1998, Final record of decision for Operable Unit 1 Naval Undersea Warfare Center, Division Keyport, Washington: Prepared by URS Consultants, Seattle, Wash., for Engineering Field Activity, Northwest, Naval Facilities Engineering Command, Poulsbo, Wash., 111 p.

URS Greiner, Inc., 1999, Phytoremediation closure report for Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington: Prepared by URS Greiner, Inc., Seattle, Wash., under Contract Task Order 0189 for Engineering Field Activity, Northwest, Naval Facilities Engineering Command, Poulsbo, Wash.

U.S. Environmental Protection Agency, 1983, Methods for chemical analysis of water and wastes—Office of Research chemical analysis of water and wastes: Washington, D.C., Office of Research and Development Report EPA 600/4-79-020, 552 p.

U.S. Environmental Protection Agency, 1994, RSKSOP 175 rev. no. 2, Sample preparations and calculations for dissolved gas analysis in water samples using a GC headspace equilibration technique: U.S. Environmental Protection Agency Test Methods, Region 1, 14 p., accessed April 9, 2013, at http://www.epa.gov/region1/info/testmethods/pdfs/RSKsop175v2.pdf.

U.S. Geological Survey, 2013, Water quality samples for Washington: National Water Information System web interface, accessed April 9, 2013, at http://nwis.waterdata.usgs.gov/wa/nwis/qwdat.

U.S. Geological Survey, variously dated, National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chaps. A1–A9, accessed September 10, 2012, at http://pubs.er.usgs.gov/publication/twri09.

U.S. Navy, 2012, Final spring 2011 long-term monitoring report, Area 1 Operable Unit 1, Naval Base Kitsap Keyport, Washington: Contract No. N44255-09-D-4005, LTM/O/Task Order 30.

Table 2. Groundwater geochemical data collected at wells and piezometers at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1996–2012.

[All other data were published in Dinicola and others (2002), Dinicola (2003, 2004, 2006), Dinicola and Huffman (2004, 2006, 2007, 2009, 2012), and Huffman and Dinicola (2011); prior to 2000, bicarbonate was calculated from an unfiltered sample. Reported concentrations less than the detection limit usually are estimated. A range of dissolved hydrogen concentrations is shown when equilibration at a single value was never achieved. **Well or piezometer No.:** MW, monitoring well; P, piezometer. **Abbreviations:** nM, nanomolar; mg/L, milligram per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius. **Symbols**: E, estimated value; R, data rejected (selected 1996 dissolved-oxygen data were rejected because of inadequate well purging; selected 2002 dissolved-hydrogen data were rejected because of interference from downhole instruments, 2011, dissolved-hydrogen data were rejected pending further investigation between U.S. Geological Survey field analysis and analyzing laboratory; *, concentration is microgram per liter (µg/L); <, actual value is less than value shown; >, actual value is greater than value shown; –, not analyzed]

Well or piezometer No.	Date sampled	Dissolved hydrogen (nM)	Dissolved oxygen (mg/L)	Filtered (dissolved) organic carbon (mg/L)	Filtered nitrate + nitrite (mg/L as N)	Filtered manganese (mg/L)	Filtered iron (II) (mg/L)	Filtered sulfate (mg/L)
				Upgradient				
MW1-3	06-09-99	0.8	0.4	–	–	0.07	<0.01	–
	06-20-00	.2	.3	–	0.99	.08	<.01	13
	06-12-01	–	4.0	1.1	1.1	.04	.02	14
	06-10-02	2.7	.4	1.4	1.6	.10	.01	11
	06-17-03	–	4.3	1.7	1.8	.09	.05	12
	06-15-04	.2	.2	1.6	–	.09	<.01	12
	06-20-05	<.1	.1	1.4	1.6	.10	.01	15
	06-12-06	<.1	.1	1.4	1.6	.11	<.01	14
	06-18-07	–	.6	1.8	1.1	.09	<.01	16
	06-16-08	–	.6	2.0	1.1	.10	<.01	18
	06-15-09	<.1	.2	1.6	1.0	.12	.01	19
	06-14-10	.2	.5	1.5	.92	.14	.01	17
	06-20-11	1.4R	.1	2.5	.64	.18	.01	17
	06-04-12	<.01	<.2	1.6	.99	.16	.01	17
MW1-20	06-08-99	.9	.3	–	–	.35	.03	–
	06-21-00	.4	<.1	–	<.05	.24	.11	16
	06-13-01	2.1	.2	1.4	<.05	.28	.01	20
	06-12-02	>100R	.1	1.4	<.05	.16	.01	17
	06-17-03	.5	.2	1.7	<.06	.24	.05	18
	06-15-04	.1	.9	1.6	–	.23	.03	18
	06-20-05	.1	.4	1.5	<.06	.25	.21	16
	06-13-06	.1	.1	1.7	<.06	.21	.08	16
	06-18-07	–	.2	1.8	<.06	.21	.34	14
	06-18-08	–	3.4	1.5	<.04	.19	.06	19
	06-15-09	.1	.3	1.6	<.04	.19	.16	13
	06-14-10	.3	.5	1.3	E.02	.06	.05	18
	06-20-11	1.6R	.3	1.6	<.02	.13	.01	13
	06-05-12	.1	.2	1.5	<.02	.12	<.01	13

Table 2. Groundwater geochemical data collected at wells and piezometers at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1996–2012.—Continued

[All other data were published in Dinicola and others (2002), Dinicola (2003, 2004, 2006), Dinicola and Huffman (2004, 2006, 2007, 2009, 2012), and Huffman and Dinicola (2011); prior to 2000, bicarbonate was calculated from an unfiltered sample. Reported concentrations less than the detection limit usually are estimated. A range of dissolved hydrogen concentrations is shown when equilibration at a single value was never achieved. **Well or piezometer No.:** MW, monitoring well; P, piezometer. **Abbreviations:** nM, nanomolar; mg/L, milligram per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius. **Symbols**: E, estimated value; R, data rejected (selected 1996 dissolved-oxygen data were rejected because of inadequate well purging; selected 2002 dissolved-hydrogen data were rejected because of interference from downhole instruments, 2011, dissolved-hydrogen data were rejected pending further investigation between U.S. Geological Survey field analysis and analyzing laboratory; *, concentration is microgram per liter (µg/L); <, actual value is less than value shown; >, actual value is greater than value shown; –, not analyzed]

Well or piezometer No.	Date sampled	Unfiltered sulfide (mg/L)	Dissolved methane (mg/L)	Dissolved carbon dioxide (mg/L)	pH (units)	Specific conductance (µS/cm)	Filtered chloride (mg/L)
			Upgradient				
MW1-3	06-09-99	<0.01	–	–	6.0	202	–
	06-20-00	<.01	0.02	–	5.9	205	8.4
	06-12-01	<.01	.12	–	6.1	203	10
	06-10-02	<.01	.06	140	5.8	182	9.7
	06-17-03	–	.02	80	6.0	199	10
	06-15-04	<.01	.01	–	5.7	205	9.1
	06-20-05	<.01	–	<50	6.0	192	7.5
	06-12-06	<.01	.004	40	5.5	243	7.0
	06-18-07	.01	–	41	5.9	209	5.9
	06-16-08	<.01	–	80	6.0	198	5.1
	06-15-09	.01	.01	80	6.0	208	7.3
	06-14-10	<.01	E.004	70	5.9	200	5.6
	06-20-11	<.01	E.003	80	5.8	238	16
	06-04-12	<.01	<.2*	45	5.9	219	12
MW1-20	06-08-99	<.01	–	–	6.7	546	–
	06-21-00	<.01	.01	–	6.8	530	14
	06-13-01	<.01	.27	–	6.4	544	33
	06-12-02	<.01	.06	97	7.0	701	29
	06-17-03	–	.09	90	6.3	491	32
	06-15-04	<.01	.03	–	6.4	552	35
	06-20-05	<.01	–	80	6.3	520	28
	06-13-06	<.01	.03	60	6.3	574	31
	06-18-07	<.01	–	40	6.8	508	25
	06-18-08	–	–	70	6.6	517	38
	06-15-09	<.01	.05	45	6.5	481	24
	06-14-10	<.01	.03	35	6.9	580	43
	06-20-11	<.01	.02	60	6.5	426	27
	06-05-12	<.01	.03	18	6.7	493	34

Table 2. Groundwater geochemical data collected at wells and piezometers at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1996–2012.—Continued

[All other data were published in Dinicola and others (2002), Dinicola (2003, 2004, 2006), Dinicola and Huffman (2004, 2006, 2007, 2009, 2012), and Huffman and Dinicola (2011); prior to 2000, bicarbonate was calculated from an unfiltered sample. Reported concentrations less than the detection limit usually are estimated. A range of dissolved hydrogen concentrations is shown when equilibration at a single value was never achieved. **Well or piezometer No.:** MW, monitoring well; P, piezometer. **Abbreviations:** nM, nanomolar; mg/L, milligram per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius. **Symbols**: E, estimated value; R, data rejected (selected 1996 dissolved-oxygen data were rejected because of inadequate well purging; selected 2002 dissolved-hydrogen data were rejected because of interference from downhole instruments, 2011, dissolved-hydrogen data were rejected pending further investigation between U.S. Geological Survey field analysis and analyzing laboratory; *, concentration is microgram per liter (µg/L); <, actual value is less than value shown; >, actual value is greater than value shown; –, not analyzed]

Well or piezometer No.	Date sampled	Dissolved hydrogen (nM)	Dissolved oxygen (mg/L)	Filtered (dissolved) organic carbon (mg/L)	Filtered nitrate + nitrite (mg/L as N)	Filtered manganese (mg/L)	Filtered iron (II) (mg/L)	Filtered sulfate (mg/L)
Upper aquifer northern plantation								
1MW-1	09-17-96	0.4	2.8R	–	<0.02	0.18	0.24	7.5
	04-16-97	.8	.4	–	.11	–	8.0	1.4
	03-05-98	.2	.1	–	–	.39	12	–
	10-09-98	.2	.5	–	–	.08	.39	–
	06-21-00	.1	.5	–	<.05	.96	13	.9
	06-11-01	.6	.7	12	<.05	.24	2.9	2.2
	06-10-02	.4	.2	14	<.05	.37	7.3	1.7
	06-17-03	.1	.1	10	<.06	.17	1.2	2.2
	06-16-04	.2	.1	7.7	–	.09	.38	2.0
	06-21-05	.1	.1	9.5	<.06	.12	1.8	1.7
	06-12-06	<.1	.2	8.5	<.06	.12	.8	1.9
	06-19-07	.3	.1	6.8	E.05	1.3	.72	6.4
	06-17-08	.2	.2	9.6	<.04	.13	1.4	1.3
	06-15-09	<.1	.3	7.1	<.04	.10	.55	1.4
	06-14-10	.2	.9	7.5	<.04	.10	.71	.70
	06-20-11	1.1R	.3	7.7	<.02	.08	.06	.79
	06-04-12	.2	.2	7.0	<.02	.07	.3	.51
MW1-2	09-17-96	.5	2.4R	–	<.02	.05	.23	4.6
	04-16-97	.7	.2	–	<.02	–	.13	4.6
	03-02-98	.3	–	–	–	–	.16	–
	10-07-98	.1	.1	–	–	.05	.14	–
	06-09-99	.9	.2	–	–	.08	.09	–
	06-21-00	.3	.1	–	<.05	.06	.10	4.3
	06-12-01	3.5	.3	5.0	<.05	.08	.29	5.4
	06-11-02	>20R	.1	45	<.05	.09	.27	4.2
	06-18-03	.2	.1	6.0	<.06	.10	.29	4.3
	06-17-04	.2	.2	6.7	–	.10	1.0	4.3
	06-22-05	<.1	<.1	20	<.06	.10	.44	4.4
	06-12-06	.1	.1	5.9	<.06	.10	.76	3.7
	06-19-07	.2	<.1	6.0	<.06	.11	.84	3.8
	06-17-08	<.1	.1	6.3	<.04	.11	.64	3.4
	06-15-09	<.1	.3	6.3	<.04	.12	1.2	3.6
	06-14-10	.1	<.1	5.9	<.04	.11	–	3.5
	06-20-11	2R	.1	6.5	<.02	.12	.82	3.2
	06-04-12	.2	.1	5.7	<.02	.13	1.1	3.7

Table 2. Groundwater geochemical data collected at wells and piezometers at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1996–2012.—Continued

[All other data were published in Dinicola and others (2002), Dinicola (2003, 2004, 2006), Dinicola and Huffman (2004, 2006, 2007, 2009, 2012), and Huffman and Dinicola (2011); prior to 2000, bicarbonate was calculated from an unfiltered sample. Reported concentrations less than the detection limit usually are estimated. A range of dissolved hydrogen concentrations is shown when equilibration at a single value was never achieved. **Well or piezometer No.:** MW, monitoring well; P, piezometer. **Abbreviations:** nM, nanomolar; mg/L, milligram per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius. **Symbols**: E, estimated value; R, data rejected (selected 1996 dissolved-oxygen data were rejected because of inadequate well purging; selected 2002 dissolved-hydrogen data were rejected because of interference from downhole instruments, 2011, dissolved-hydrogen data were rejected pending further investigation between U.S. Geological Survey field analysis and analyzing laboratory; *, concentration is microgram per liter (µg/L); <, actual value is less than value shown; >, actual value is greater than value shown; –, not analyzed]

Well or piezometer No.	Date sampled	Unfiltered sulfide (mg/L)	Dissolved methane (mg/L)	Dissolved carbon dioxide (mg/L)	pH (units)	Specific conductance (µS/cm)	Filtered chloride (mg/L)
			Upper aquifer northern plantation				
1MW-1	09-17-96	<0.01	10	–	7.9	–	43
	04-16-97	.01	29	–	7.2	–	–
	03-05-98	.06	–	–	–	–	–
	10-09-98	.01	–	–	7.7	1,080	–
	06-21-00	<.01	.39	–	7.0	1,070	44
	06-11-01	<.01	5.6	–	7.1	974	50
	06-10-02	<.01	14	77	7.7	835	54
	06-17-03	<.01	7.1	50	7.3	847	54
	06-16-04	.03	1.8	18	7.0	843	57
	06-21-05	.02	–	20	7.1	827	48
	06-12-06	.01	3.4	10	7.4	787	48
	06-19-07	.04	1.7	18	7.3	753	7.7
	06-17-08	.01	5.4	11	7.4	737	40
	06-15-09	.02	7.2	10	7.4	676	44
	06-14-10	.02	7.2	30	7.0	590	28
	06-20-11	.02	5.3	22	7.3	569	34
	06-04-12	.02	6.4	20	7.4	578	28
MW1-2	09-17-96	<.01	1.2	–	6.9	–	50
	04-16-97	<.01	2.5	–	6.7	–	–
	03-02-98	–	–	–	–	–	–
	10-07-98	<.01	–	–	6.7	868	–
	06-09-99	<.01	–	–	6.8	901	–
	06-21-00	<.01	.04	–	6.8	870	36
	06-12-01	<.01	.78	–	6.5	853	48
	06-11-02	<.01	.92	200	6.6	829	37
	06-18-03	<.01	.98	160	6.4	870	41
	06-17-04	–	.33	50	6.6	858	40
	06-22-05	<.01	–	75	6.3	720	35
	06-12-06	<.01	.50	115	6.5	815	34
	06-19-07	<.01	.26	45	6.4	820	30
	06-17-08	<.01	.43	40	6.6	797	26
	06-15-09	.01	.77	45	6.6	814	30
	06-14-10	<.01	.73	70	6.5	805	27
	06-20-11	<.01	.58	100	6.4	742	25
	06-04-12	<.01	.59	120	6.4	802	26

Table 2. Groundwater geochemical data collected at wells and piezometers at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1996–2012.—Continued

[All other data were published in Dinicola and others (2002), Dinicola (2003, 2004, 2006), Dinicola and Huffman (2004, 2006, 2007, 2009, 2012), and Huffman and Dinicola (2011); prior to 2000, bicarbonate was calculated from an unfiltered sample. Reported concentrations less than the detection limit usually are estimated. A range of dissolved hydrogen concentrations is shown when equilibration at a single value was never achieved. **Well or piezometer No.:** MW, monitoring well; P, piezometer. **Abbreviations:** nM, nanomolar; mg/L, milligram per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius. **Symbols**: E, estimated value; R, data rejected (selected 1996 dissolved-oxygen data were rejected because of inadequate well purging; selected 2002 dissolved-hydrogen data were rejected because of interference from downhole instruments, 2011, dissolved-hydrogen data were rejected pending further investigation between U.S. Geological Survey field analysis and analyzing laboratory; *, concentration is microgram per liter (µg/L); <, actual value is less than value shown; >, actual value is greater than value shown; –, not analyzed]

Well or piezometer No.	Date sampled	Dissolved hydrogen (nM)	Dissolved oxygen (mg/L)	Filtered (dissolved) organic carbon (mg/L)	Filtered nitrate + nitrite (mg/L as N)	Filtered manganese (mg/L)	Filtered iron (II) (mg/L)	Filtered sulfate (mg/L)
Upper aquifer northern plantation—Continued								
MW1-17	09-17-96	0.7	<0.1	–	<0.02	1.3	62	4.3
	04-16-97	.6	<.1	–	<.02	–	37	68
	10-09-98	–	<.1	–	–	.80	56	–
	06-22-00	1.2	<.1	–	–	1.2	68	–
	06-12-01	2.0–2.7	.4	8.0	<.05	1.2	48	12
	06-17-04	2.5	<.1	7.5	–	.68	>10	18
	06-20-05	1.5	<.1	6.1	<.06	.43	27	7.8
	06-20-07	1.0	<.1	8.1	<.06	.40	22	11
	06-18-08	1.1	<.1	6.1	<.04	.33	17	7.3
	06-15-09	.9	<.1	6.0	<.04	.49	8.5	8.1
	06-14-10	.9	–	5.4	<.04	.49	20	6.9
	06-20-11	2.1R	.3	7.7	<.02	.73	23	3.1
	06-04-12	.5	<.1	9.8	<.02	.57	31	6.8
MW1-41	06-09-99	1.0	.3	–	–	2.2	60	–
	06-21-00	1.2	.1	–	<.05	3.5	55	<.3
	06-11-01	2.0	.3	14	<.05	3.7	66	30
	06-10-02	2.2	.8	20	<.05	3.6	52	.4
	06-18-03	1.9	<.1	19	<.06	3.9	50	<.2
	06-17-04	2.2	.1	19	–	4.0	57	<.2
	06-20-05	.8	.1	17	<.06	3.9	73	<.2
	06-12-06	.7	<.1	18	<.06	3.8	28	<.2
	06-19-07	.4	<.1	20	<.06	3.8	66	<.18
	06-16-08	.4	<.1	20	<.04	3.4	41	<.18
	06-15-09	.3	.1	19	<.04	4.2	29	<.2
	06-14-10	.3	<.1	17	<.04	3.4	43	.3
	06-20-11	1.2R	.1	19	<.02	3.7	63	<.09
	06-04-12	.5	.1	17	<.02	3.7	47	.14
P1-1	06-09-99	.7	.4	–	–	4.0	59	–
	06-11-02	1.4	<.1	17	<.05	2.7	40	<.1
	06-18-03	1.5	<.1	18	<.06	3.4	32	<.2
	06-17-04	1.9	.1	16	–	3.1	39	<.2
	06-22-05	.6	<.1	15	<.06	3.1	68	<.2
	06-12-06	.3	<.1	16	<.06	2.9	54	<.2
	06-19-07	.3	<.1	15	<.06	2.0	49	<.18
	06-16-08	.6	.1	14	<.04	2.1	32	<.18
	06-15-09	.5	<.1	11	<.04	2.3	38	<.2
	06-14-10	.6	<.1	12	<.04	2.3	20	E.1
	06-20-11	1.6R	<.1	13	<.02	2.3	41	<.09
	06-04-12	.7	.05	12	<.02	2.4	31	.09

Table 2. Groundwater geochemical data collected at wells and piezometers at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1996–2012.—Continued

[All other data were published in Dinicola and others (2002), Dinicola (2003, 2004, 2006), Dinicola and Huffman (2004, 2006, 2007, 2009, 2012), and Huffman and Dinicola (2011); prior to 2000, bicarbonate was calculated from an unfiltered sample. Reported concentrations less than the detection limit usually are estimated. A range of dissolved hydrogen concentrations is shown when equilibration at a single value was never achieved. **Well or piezometer No.:** MW, monitoring well; P, piezometer. **Abbreviations:** nM, nanomolar; mg/L, milligram per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius. **Symbols**: E, estimated value; R, data rejected (selected 1996 dissolved-oxygen data were rejected because of inadequate well purging; selected 2002 dissolved-hydrogen data were rejected because of interference from downhole instruments, 2011, dissolved-hydrogen data were rejected pending further investigation between U.S. Geological Survey field analysis and analyzing laboratory; *, concentration is microgram per liter (µg/L); <, actual value is less than value shown; >, actual value is greater than value shown; –, not analyzed]

Well or piezometer No.	Date sampled	Unfiltered sulfide (mg/L)	Dissolved methane (mg/L)	Dissolved carbon dioxide (mg/L)	pH (units)	Specific conductance (µS/cm)	Filtered chloride (mg/L)
			Upper aquifer northern plantation—Continued				
MW1-17	09-17-96	<0.01	8.9	–	6.5	–	61
	04-16-97	.02	23	–	6.6	–	–
	10-09-98	.02	–	–	6.4	1,740	–
	06-22-00	.02	2.8	–	6.5	1,260	160
	06-12-01	.01	9.4	–	6.5	1,200	120
	06-17-04	–	.37	70	6.5	318	150
	06-20-05	.04	–	80	6.3	563	74
	06-20-07	.03	2.9	55	6.5	635	96
	06-18-08	.04	5.5	26	6.6	551	59
	06-15-09	.03	8.3	40	6.3	523	68
	06-14-10	.03	10	120	6.2	271	46
	06-20-11	.08	6.2	140	6.2	715	28
	06-04-12	.03	8.6	80	6.5	751	59
MW1-41	06-09-99	.01	–	–	6.6	1,260	–
	06-21-00	<.01	1.9	–	6.5	1,500	8.3
	06-11-01	.02	25	–	6.3	1,330	9.9
	06-10-02	.04	21	540	6.3	1,190	7.9
	06-18-03	.03	14	500	6.3	1,280	9.5
	06-17-04	.02	7.4	450	6.1	1,300	11
	06-20-05	.01	–	500	6.4	1,300	8.7
	06-12-06	.02	8.5	310	6.3	1,240	8.4
	06-19-07	.01	6.3	350	6.7	1,280	8.7
	06-16-08	.01	9.9	300	6.4	1,240	11
	06-15-09	<.01	18	400	6.2	1,200	16
	06-14-10	.02	24	<10	6.4	1,200	15
	06-20-11	.01	11	250	6.0	1,040	13
	06-04-12	<.01	19	260	6.3	1,150	10
P1-1	06-09-99	<.01	–	–	6.4	1,350	–
	06-11-02	<.01	29	400	6.3	987	9.3
	06-18-03	.02	–	450	6.2	1,030	11
	06-17-04	.02	3.7	430	6.0	987	9.2
	06-22-05	<.01	10	370	6.3	847	7.1
	06-12-06	.01	7.8	225	6.2	979	7.2
	06-19-07	.02	8.1	160	6.1	920	5.7
	06-16-08	.02	12	350	6.5	914	4.4
	06-15-09	.02	24	325	6.3	830	3.7
	06-14-10	.02	27	180	6.4	798	3.4
	06-20-11	.01	12	160	6.4	763	3.0
	06-04-12	.02	27	275	6.2	731	2.9

Table 2. Groundwater geochemical data collected at wells and piezometers at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1996–2012.—Continued

[All other data were published in Dinicola and others (2002), Dinicola (2003, 2004, 2006), Dinicola and Huffman (2004, 2006, 2007, 2009, 2012), and Huffman and Dinicola (2011); prior to 2000, bicarbonate was calculated from an unfiltered sample. Reported concentrations less than the detection limit usually are estimated. A range of dissolved hydrogen concentrations is shown when equilibration at a single value was never achieved. **Well or piezometer No.:** MW, monitoring well; P, piezometer. **Abbreviations:** nM, nanomolar; mg/L, milligram per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius. **Symbols**: E, estimated value; R, data rejected (selected 1996 dissolved-oxygen data were rejected because of inadequate well purging; selected 2002 dissolved-hydrogen data were rejected because of interference from downhole instruments, 2011, dissolved-hydrogen data were rejected pending further investigation between U.S. Geological Survey field analysis and analyzing laboratory; *, concentration is microgram per liter (µg/L); <, actual value is less than value shown; >, actual value is greater than value shown; –, not analyzed]

Well or piezometer No.	Date sampled	Dissolved hydrogen (nM)	Dissolved oxygen (mg/L)	Filtered (dissolved) organic carbon (mg/L)	Filtered nitrate + nitrite (mg/L as N)	Filtered manganese (mg/L)	Filtered iron (II) (mg/L)	Filtered sulfate (mg/L)
Upper aquifer northern plantation—Continued								
P1-3	06-09-99	0.4	0.2	–	–	1.0	19	–
	06-11-02	.3	<.1	17	<0.05	2.6	39	1.0
	06-18-03	.3	.1	18	<.06	2.0	29	1.8
	06-17-04	.7	<.1	16	–	2.8	>10	.55
	06-22-05	.2	<.1	15	<.06	2.8	60	.38
	06-12-06	.2	<.1	16	<.06	2.5	39	.2
	06-19-07	.3	<.1	15	<.06	2.5	40	.24
	06-17-08	.9	<.1	14	<.04	2.9	32	<.18
	06-15-09	.5	.2	11	<.04	3.0	–	E.1
	06-14-10	.4	.2	12	<.04	2.8	21	.2
	06-20-11	1.8R	.3	13	<.02	2.9	47	<.09
	06-04-12	.9	.4	19	.02	3.0	36	.15
P1-4	06-09-99	.7	.3	–	–	.34	2.6	–
	06-13-01	.1	.5	8.7	<.05	.38	3.4	3.8
	06-11-02	.2	.1	8.0	<.05	2.6	3.7	3.5
	06-18-03	.2	.1	7.0	<.06	.43	4.1	4.0
	06-17-04	.1	.1	7.6	–	.42	3.0	4.0
	06-21-05	.1	.1	6.7	<.06	.38	2.3	4.6
	06-12-06	.1	<.1	6.8	<.06	.35	1.8	4.3
	06-19-07	.3	<.1	7.1	<.06	.35	3.2	4.7
	06-16-08	<.1	<.1	7.7	<.04	.35	3.5	4.4
	06-15-09	<.1	.6	7.5	<.04	.39	2.4	4.1
	06-14-10	.2	.7	7.5	<.04	.38	.12	4.4
	06-20-11	2.2R	<.1	8.5	<.02	.41	2.2	5.1
	06-04-12	.1	.1	7.3	<.02	.41	1.4	4.9
P1-5	06-08-99	3.0	.3	–	–	3.1	72	–
	06-10-02	1.7	.1	25	<.05	2.6	62	<.6
	06-18-03	2.2	.1	24	<.06	3.1	54	<.2
	06-17-04	2.1	<.1	23	–	3.1	>10	<.2
	06-21-05	.8	.1	22	<.06	3.5	74	E.1
	06-12-06	.8	<.1	21	<.06	3.6	66	E.1
	06-19-07	.3	<.1	22	<.06	3.2	48	<.2
	06-16-08	1.0	<.1	21	<.04	3.6	44	<.2
	06-15-09	.4	<.1	19	<.04	4.3	33	E.2
	06-14-10	1.2	<.1	18	<.04	3.3	59	E.1
	06-20-11	1.7R	.4	18	<.02	3.4	38	<.09
	06-04-12	1.2	<.1	18	<.02	3.6	21	<.09

Table 2. Groundwater geochemical data collected at wells and piezometers at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1996–2012.—Continued

[All other data were published in Dinicola and others (2002), Dinicola (2003, 2004, 2006), Dinicola and Huffman (2004, 2006, 2007, 2009, 2012), and Huffman and Dinicola (2011); prior to 2000, bicarbonate was calculated from an unfiltered sample. Reported concentrations less than the detection limit usually are estimated. A range of dissolved hydrogen concentrations is shown when equilibration at a single value was never achieved. **Well or piezometer No.:** MW, monitoring well; P, piezometer. **Abbreviations:** nM, nanomolar; mg/L, milligram per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius. **Symbols**: E, estimated value; R, data rejected (selected 1996 dissolved-oxygen data were rejected because of inadequate well purging; selected 2002 dissolved-hydrogen data were rejected because of interference from downhole instruments, 2011, dissolved-hydrogen data were rejected pending further investigation between U.S. Geological Survey field analysis and analyzing laboratory; *, concentration is microgram per liter (µg/L); <, actual value is less than value shown; >, actual value is greater than value shown; –, not analyzed]

Well or piezometer No.	Date sampled	Unfiltered sulfide (mg/L)	Dissolved methane (mg/L)	Dissolved carbon dioxide (mg/L)	pH (units)	Specific conductance (µS/cm)	Filtered chloride (mg/L)
Upper aquifer northern plantation—Continued							
P1-3	06-09-99	0.04	–	–	6.8	1,470	–
	06-11-02	.03	24	400	6.4	1,340	61
	06-18-03	.03	–	350	6.4	1,400	90
	06-17-04	<.01	5.7	330	6.5	1,350	57
	06-22-05	.03	8.4	320	6.4	1,200	68
	06-12-06	.03	7.1	330	6	1,440	51
	06-19-07	.03	7.1	260	6.5	1,420	55
	06-17-08	.03	14	200	6.4	1,230	31
	06-15-09	.03	18	180	6.2	1,220	45
	06-14-10	.03	22	350	6.5	1,050	30
	06-20-11	.06	11	275	6.3	1,040	21
	06-04-12	.04	18	–	6.4	1,000	15
P1-4	06-09-99	.02	–	–	6.9	867	–
	06-13-01	<.01	.93	–	6.6	761	53
	06-11-02	<.01	5.9	90	6.7	734	56
	06-18-03	.01	4.2	70	6.6	778	59
	06-17-04	.02	1.8	60	6.4	782	48
	06-21-05	<.01	1.8	42	6.6	750	47
	06-12-06	<.01	1.7	32	6.4	823	44
	06-19-07	<.01	2.5	26	6.7	745	44
	06-16-08	.01	3.1	20	6.9	749	40
	06-15-09	.01	6.4	25	6.8	724	39
	06-14-10	.01	6.2	30	6.8	795	42
	06-20-11	<.01	3.1	65	6.8	809	46
	06-04-12	<.01	3.5	25	6.9	821	52
P1-5	06-08-99	.01	–	–	6.2	1,320	–
	06-10-02	.02	23	400	6.2	1,200	17
	06-18-03	.02	18	650	6.2	1,150	16
	06-17-04	–	5.8	450	6.4	1,160	14
	06-21-05	.04	9.4	400	6.3	1,150	13
	06-12-06	.05	6.8	370	5.8	1,100	9.9
	06-19-07	.04	8.5	350	6.3	1,030	9.3
	06-16-08	.04	14	275	6.3	1,080	10
	06-15-09	.12	22	500	6.3	1,050	13
	06-14-10	.02	24	400	6.3	990	9.6
	06-20-11	.03	9.7	250	6.3	935	9.3
	06-04-12	.02	18	–	6.4	935	8.5

Table 2. Groundwater geochemical data collected at wells and piezometers at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1996–2012.—Continued

[All other data were published in Dinicola and others (2002), Dinicola (2003, 2004, 2006), Dinicola and Huffman (2004, 2006, 2007, 2009, 2012), and Huffman and Dinicola (2011); prior to 2000, bicarbonate was calculated from an unfiltered sample. Reported concentrations less than the detection limit usually are estimated. A range of dissolved hydrogen concentrations is shown when equilibration at a single value was never achieved. **Well or piezometer No.:** MW, monitoring well; P, piezometer. **Abbreviations:** nM, nanomolar; mg/L, milligram per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius. **Symbols**: E, estimated value; R, data rejected (selected 1996 dissolved-oxygen data were rejected because of inadequate well purging; selected 2002 dissolved-hydrogen data were rejected because of interference from downhole instruments, 2011, dissolved-hydrogen data were rejected pending further investigation between U.S. Geological Survey field analysis and analyzing laboratory; *, concentration is microgram per liter (µg/L); <, actual value is less than value shown; >, actual value is greater than value shown; –, not analyzed]

Well or piezometer No.	Date sampled	Dissolved hydrogen (nM)	Dissolved oxygen (mg/L)	Filtered (dissolved) organic carbon (mg/L)	Filtered nitrate + nitrite (mg/L as N)	Filtered manganese (mg/L)	Filtered iron (II) (mg/L)	Filtered sulfate (mg/L)
Upper aquifer southern plantation								
MW1-4	09-17-96	0.5	2.8R	–	<0.02	0.28	1.8	7.1
	04-16-97	.6	.4	–	.24	–	<.01	8.6
	03-03-98	1.7	.2	–	–	.10	.01	–
	10-08-98	.2	.5	–	–	–	.28	–
	06-07-99	.9	.1	–	–	.20	1.2	–
	06-22-00	.2	.1	–	–	.70	–	5.5
	06-14-01	0.9–3.2	.5	2.5	.08	.54	1.6	5.4
	06-13-02	2.4	.1	3.8	.08	.47	1.2	5.5
	06-20-03	.8	.1	2.5	<.06	.53	.22	5.7
	06-18-04	.2	.1	2.7	–	.61	.12	5.9
	06-23-05	.3	.1	.7	<.06	.14	.03	8.8
	06-13-06	<.1	.1	3.9	<.06	.79	.19	5.7
	06-20-07	.1	<.1	1.4	<.06	.29	.23	7.5
	06-18-08	<.1	.1	2.6	E.03	.42	.19	7.1
	06-16-09	<.1	.4	.8	<.04	.19	<.01	8.7
	06-15-10	<.1	.8	4.5	<.04	1.1	.3	6.4
	06-21-11	1.3R	<.1	4.6	<.02	1.3	.39	6.2
	06-05-12	.1	.1	2.3	<.02	.88	.36	6.3
MW1-5	09-17-96	1.2	<.1	–	<.02	1.6	19	6.4
	04-16–97	.5	<.1	–	.08	–	3.1	2.8
	03-04-98	.7	<.1	–	–	1.3	4.5	–
	10-08-98	2.4	<.1	–	–	1.5	11	–
	06-08-99	.6	.3	–	–	1.2	31	–
	06-22-00	–	<.1	–	–	1.5	39	6.4
	06-13-01	.8	.3	9.6	.12	1.5	25	6.0
	06-13-02	3.4	.5	11	.14	1.5	20	6.3
	06-20-03	.1	.1	11	<.06	1.5	30	6.8
	06-18-04	.1	.4	7.2	–	1.8	>10	5.6
	06-22-05	<.1	<.1	8.2	.16	1.2	27	6.7
	06-13-06	<.1	.1	7.8	.08	1.3	14	6.0
	06-20-07	.1	<.1	8.0	<.06	.10	21	1.7
	06-18-08	<.1	.3	5.9	.15	1.0	16	7.3
	06-16-09	<.1	.2	8.3	.09	1.8	14	5.7
	06-15-10	<.1	.2	7.7	.13	1.4	23	5.8
	06-21-11	1.1R	.1	7.9	.1	1.7	22	5.2
	06-05-12	.1	.1	6.8	.1	1.5	26	5.1

Table 2. Groundwater geochemical data collected at wells and piezometers at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1996–2012.—Continued

[All other data were published in Dinicola and others (2002), Dinicola (2003, 2004, 2006), Dinicola and Huffman (2004, 2006, 2007, 2009, 2012), and Huffman and Dinicola (2011); prior to 2000, bicarbonate was calculated from an unfiltered sample. Reported concentrations less than the detection limit usually are estimated. A range of dissolved hydrogen concentrations is shown when equilibration at a single value was never achieved. **Well or piezometer No.:** MW, monitoring well; P, piezometer. **Abbreviations:** nM, nanomolar; mg/L, milligram per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius. **Symbols**: E, estimated value; R, data rejected (selected 1996 dissolved-oxygen data were rejected because of inadequate well purging; selected 2002 dissolved-hydrogen data were rejected because of interference from downhole instruments, 2011, dissolved-hydrogen data were rejected pending further investigation between U.S. Geological Survey field analysis and analyzing laboratory; *, concentration is microgram per liter (µg/L); <, actual value is less than value shown; >, actual value is greater than value shown; –, not analyzed]

Well or piezometer No.	Date sampled	Unfiltered sulfide (mg/L)	Dissolved methane (mg/L)	Dissolved carbon dioxide (mg/L)	pH (units)	Specific conductance (µS/cm)	Filtered chloride (mg/L)
			Upper aquifer southern plantation				
MW1-4	09-17-96	<0.01	1.2	–	6.9	–	15
	04-16-97	<.01	.70	–	7.3	–	–
	03-03-98	<.01	–	–	–	–	–
	10-08-98	<.01	–	–	6.7	368	–
	06-07-99	<.01	–	–	6.6	350	–
	06-22-00	<.01	.56	–	6.8	412	19
	06-14-01	<.01	3.7	–	6.5	360	22
	06-13-02	<.01	5.2	60	6.6	442	20
	06-20-03	<.01	3.7	40	6.7	324	17
	06-18-04	<.01	1.1	50	6.0	320	23
	06-23-05	<.01	–	<10	7.9	203	7.3
	06-13-06	.01	2.1	30	6.6	362	20
	06-20-07	<.01	.53	14	7.0	252	11
	06-18-08	<.01	1.7	12	7.2	279	15
	06-16-09	<.01	.73	<10	7.7	250	9.0
	06-15-10	<.01	4.1	16	6.9	360	16
	06-21-11	<.01	2.9	–	6.9	325	17
	06-05-12	<.01	2.8	20	6.8	311	13
MW1-5	09-17-96	<.01	2.4	–	6.7	–	21
	04-16–97	.03	18	–	6.6	–	–
	03-04-98	<.01	–	–	–	–	–
	10-08-98	<.01	–	–	6.4	1,740	–
	06-08-99	.01	–	–	6.5	855	–
	06-22-00	<.01	1.1	–	6.6	790	19
	06-13-01	.01	2.4	–	6.4	766	12
	06-13-02	.02	7.4	180	6.5	608	9.6
	06-20-03	.03	4.9	180	6.4	711	10
	06-18-04	–	2.4	200	6.5	795	9.8
	06-22-05	.02	–	70	6.3	520	9.5
	06-13-06	.02	1.9	50	6.5	603	8.5
	06-20-07	.03	1.1	100	6.5	603	44
	06-18-08	.01	1.8	100	6.6	562	8.4
	06-16-90	.02	3.5	500	6.4	684	11
	06-15-10	.01	4.4	80	6.6	647	13
	06-21-11	<.01	3.2	180	6.3	741	15
	06-05-12	.01	3.4	130	6.4	647	12

Table 2. Groundwater geochemical data collected at wells and piezometers at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1996–2012.—Continued

[All other data were published in Dinicola and others (2002), Dinicola (2003, 2004, 2006), Dinicola and Huffman (2004, 2006, 2007, 2009, 2012), and Huffman and Dinicola (2011); prior to 2000, bicarbonate was calculated from an unfiltered sample. Reported concentrations less than the detection limit usually are estimated. A range of dissolved hydrogen concentrations is shown when equilibration at a single value was never achieved. **Well or piezometer No.:** MW, monitoring well; P, piezometer. **Abbreviations:** nM, nanomolar; mg/L, milligram per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius. **Symbols**: E, estimated value; R, data rejected (selected 1996 dissolved-oxygen data were rejected because of inadequate well purging; selected 2002 dissolved-hydrogen data were rejected because of interference from downhole instruments, 2011, dissolved-hydrogen data were rejected pending further investigation between U.S. Geological Survey field analysis and analyzing laboratory; *, concentration is microgram per liter (µg/L); <, actual value is less than value shown; >, actual value is greater than value shown; –, not analyzed]

Well or piezometer No.	Date sampled	Dissolved hydrogen (nM)	Dissolved oxygen (mg/L)	Filtered (dissolved) organic carbon (mg/L)	Filtered nitrate + nitrite (mg/L as N)	Filtered manganese (mg/L)	Filtered iron (II) (mg/L)	Filtered sulfate (mg/L)
Upper aquifer southern plantation—Continued								
MW1-16	09-17-96	2.1	<0.1	–	<0.02	3.9	130	0.2
	04-16-97	.8	<.1	–	<.02	–	120	2.2
	03-04-98	.7	.3	–	–	18	100	–
	10-08-98	9.6	<.1	–	–	5.4	180	–
	06-07-99	6.8	.6	–	–	>5	140	–
	06-22-00	–	.1	–	–	1.9	60	1.2
	06-14-01	1.7	.2	66	.33	2.4	56	1.1
	06-13-02	4.6–7.6	.9	71	<.05	3.2	38	.4
	06-20-03	2.2	.2	29	<.6	2.1	37	.6
	06-22-04	–	.1	36	–	2.1	>10	.1
	06-23-05	.5	.1	20	<.06	2.0	66	.4
	06-13-06	–	.1	17	<.06	1.7	14	20
	06-20-07	–	<.1	18	<.06	1.8	44	9.7
	06-18-08	.1	.1	17	<.04	2.2	28	10
	06-16-09	–	.2	B	<.04	2.6	43.7	88
	06-15-10	<.1	.5	14	<.04	1.7	22	8.6
	06-21-11	1.6R	.2	16	<.02	2.1	17	5.2
	06-06-12	1.3	.3	16	<.02	1.9	18	8.0
P1-6	06-08-99	1.8	.1	–	–	.12	.02	–
	06-14-01	1.8	.2	34	.23	.45	.95	4.9
	06-13-02	1.6	<.1	26	<.05	.88	1.0	4.3
	06-20-03	.3	.2	4.1	<.06	.08	.13	7.5
	06-18-04	1.5	.1	10	–	.11	1.0	7.2
	06-23-05	.3	.1	5.8	<.06	.17	.15	6.3
	06-13-06	1.1	.1	26	<.06	.91	1.4	3.4
	06-20-07	.2	<.1	3.9	<.06	.08	.08	7.1
	06-18-08	.2	.1	10	<.04	.15	.10	5.5
	06-16-09	.1	.1	3.2	<.04	.08	.07	6.1
	06-15-10	.2	.1	2.0	<.04	.06	.05	6.0
	06-21-11	1.2R	.1	2.2	<.02	.07	.06	6.4
	06-06-12	.2	.2	0.88	<.02	.04	.01	7.1
P1-7	06-08-99	1.2	.1	–	–	.61	2.1	–
	06-22-00	–	.1	–	–	2.6	3.2	24
	06-14-01	.2	.2	11	<.05	2.3	2.0	18
	06-14-02	.2	1.3	8.9	<.05	2.2	1.9	12
	06-20-03	.1	.1	5.6	<.06	1.9	1.3	7.5
	06-18-04	.1	<.1	6.9	–	2.4	2.0	9.8
	06-22-05	<.1	.1	8.8	<.06	2.1	1.9	26
	06-13-06	<.1	.5	7.6	<.06	2.0	1.8	20
	06-20-07	.2	.1	5.7	<.06	2.1	1.18	6.0
	06-18-08	<.1	<.1	6.7	<.04	2.1	1.34	6.9
	06-16-09	<.1	.2	6.4	<.04	2.2	1.3	6.5
	06-15-10	<.1	<.1	6.4	<.04	1.9	1.2	17
	06-21-11	1.9R	.3	6.3	<.02	2.2	1.3	17
	06-05-12	.1	.3	5.2	<.02	1.5	.9	10

Table 2. Groundwater geochemical data collected at wells and piezometers at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1996–2012.—Continued

[All other data were published in Dinicola and others (2002), Dinicola (2003, 2004, 2006), Dinicola and Huffman (2004, 2006, 2007, 2009, 2012), and Huffman and Dinicola (2011); prior to 2000, bicarbonate was calculated from an unfiltered sample. Reported concentrations less than the detection limit usually are estimated. A range of dissolved hydrogen concentrations is shown when equilibration at a single value was never achieved. **Well or piezometer No.:** MW, monitoring well; P, piezometer. **Abbreviations:** nM, nanomolar; mg/L, milligram per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius. **Symbols**: E, estimated value; R, data rejected (selected 1996 dissolved-oxygen data were rejected because of inadequate well purging; selected 2002 dissolved-hydrogen data were rejected because of interference from downhole instruments, 2011, dissolved-hydrogen data were rejected pending further investigation between U.S. Geological Survey field analysis and analyzing laboratory; *, concentration is microgram per liter (µg/L); <, actual value is less than value shown; >, actual value is greater than value shown; –, not analyzed]

Well or piezometer No.	Date sampled	Unfiltered sulfide (mg/L)	Dissolved methane (mg/L)	Dissolved carbon dioxide (mg/L)	pH (units)	Specific conductance (µS/cm)	Filtered chloride (mg/L)
			Upper aquifer southern plantation—Continued				
MW1-16	09-17-96	<0.01	4.3	–	6.5	–	150
	04-16-97	.06	29	–	6.5	–	–
	03-04-98	.01	–	–	–	–	–
	10-08-98	<.01	–	–	6.3	3,370	–
	06-07-99	.01	–	–	6.7	1,820	–
	06-22-00	.02	1.2	–	6.7	902	43
	06-14-01	.08	10	–	6.4	953	40
	06-13-02	.04	24	270	6.5	1,400	17
	06-20-03	.06	9.7	240	6.5	835	6.8
	06-22-04	.50	4.3	230	6.3	817	6.9
	06-23-05	.12	–	225	6.6	767	3.8
	06-13-06	.06	3.0	70	6.7	737	3.5
	06-20-07	.13	2.1	190	6.4	763	6.5
	06-18-08	.08	3.3	40	6.4	770	16
	06-16-09	.45	8.8	80	6.4	880	21
	06-15-10	.11	5.9	60	6.3	611	9.4
	06-21-11	.45	3.5	100	6.3	541	8.2
	06-06-12	.45	1.4	70	6.7	706	7.8
P1-6	06-08-99	.04	–	–	6.8	574	–
	06-14-01	.12	6.3	–	6.4	657	47
	06-13-02	.11	11	170	6.4	604	37
	06-20-03	.07	4.8	40	8.1	278	13
	06-18-04	.10	.37	<10	8.6	268	18
	06-23-05	.12	1.4	24	7.1	332	24
	06-13-06	.14	2.6	30	6.6	757	35
	06-20-07	.07	.38	16	8.3	249	10
	06-18-08	.07	2.2	<10	8.3	291	22
	06-16-09	.06	2.2	<10	8.2	318	16
	06-15-10	.05	2.8	20	8.6	272	14
	06-21-11	.05	1	16	8.2	233	11
	06-06-12	.12	.47	50	8.4	247	6.5
P1-7	06-08-99	<.01	–	–	6.7	627	–
	06-22-00	<.01	1.5	–	6.8	851	55
	06-14-01	<.01	4.0	–	6.5	666	41
	06-14-02	<.01	6.0	87	6.6	601	60
	06-20-03	<.01	4.8	50	6.6	498	42
	06-18-04	<.01	1.7	40	6.7	613	56
	06-22-05	<.01	2.3	37	6.5	637	55
	06-13-06	<.01	2.1	–	6.6	639	49
	06-20-07	<.01	2.4	12	6.6	494	43
	06-18-08	<.01	3.8	14	6.7	556	49
	06-16-09	.01	6.6	16	6.7	566	53
	06-15-10	.01	5.5	40	6.8	577	35
	06-21-11	<.01	2.7	23	6.7	557	31
	06-05-12	<.01	4.6	18	7.1	487	26

Table 2. Groundwater geochemical data collected at wells and piezometers at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1996–2012.—Continued

[All other data were published in Dinicola and others (2002), Dinicola (2003, 2004, 2006), Dinicola and Huffman (2004, 2006, 2007, 2009, 2012), and Huffman and Dinicola (2011); prior to 2000, bicarbonate was calculated from an unfiltered sample. Reported concentrations less than the detection limit usually are estimated. A range of dissolved hydrogen concentrations is shown when equilibration at a single value was never achieved. **Well or piezometer No.:** MW, monitoring well; P, piezometer. **Abbreviations:** nM, nanomolar; mg/L, milligram per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius. **Symbols**: E, estimated value; R, data rejected (selected 1996 dissolved-oxygen data were rejected because of inadequate well purging; selected 2002 dissolved-hydrogen data were rejected because of interference from downhole instruments, 2011, dissolved-hydrogen data were rejected pending further investigation between U.S. Geological Survey field analysis and analyzing laboratory; *, concentration is microgram per liter (µg/L); <, actual value is less than value shown; >, actual value is greater than value shown; –, not analyzed]

Well or piezometer No.	Date sampled	Dissolved hydrogen (nM)	Dissolved oxygen (mg/L)	Filtered (dissolved) organic carbon (mg/L)	Filtered nitrate + nitrite (mg/L as N)	Filtered manganese (mg/L)	Filtered iron (II) (mg/L)	Filtered sulfate (mg/L)
				Upper aquifer southern plantation—Continued				
P1-8	06-07-99	1.8	<0.1	–	–	0.20	0.08	–
	06-14-01	.7	.1	4.7	0.06	.16	.22	0.1
	06-13-02	.6	.3	8.8	<.05	.21	.38	.3
	06-20-03	.6	.1	2.3	<.06	.09	.12	.4
	06-18-04	.3	.4	3.0	–	.13	.01	.4
	06-23-05	.2	.2	14	<.06	.12	.12	<.2
	06-13-06	.3	<.1	3.2	<.06	.14	.02	.4
	06-20-07	.3	.1	3.9	<.06	.15	.14	<.18
	06-18-08	.1	<.1	4.1	<.04	.15	.16	.38
	06-15-09	.2	<.1	3.5	<.04	.17	.02	.34
	06-15-10	.3	<.1	3.5	<.04	.16	.1	.4
	06-21-11	1.1R	.2	5.1	<.02	.21	.11	<.09
	06-06-12	.3	.1	3.6	<.02	.16	.07	.11
P1-9	06-08-99	19	.3	–	–	.90	.03	–
	06-22-00	–	.1	–	–	.69	.20	6.6
	06-14-01	6.7	.1	1.7	<.05	.19	.05	7.6
	06-13-02	–	.6	9.8	<.05	1.2	.42	5.6
	06-20-03	.2	.1	3.7	<.06	.24	<.01	7.0
	06-18-04	.2	.1	4.0	–	.26	.14	7.3
	06-23-05	<.1	.1	1.4	<.06	.11	.01	8.7
	06-13-06	4.4	.2	9.6	<.06	1.4	.33	5.3
	06-20-07	.2	.1	4.5	<.06	.28	.13	7.04
	06-18-08	E.2.5	<.1	10	<.04	.17	.07	7.89
	06-16-09	<.1	.2	6.0	<.04	.60	.15	5.4
	06-14-10	.2	<.1	1.2	<.04	.16	<.01	8.6
	06-21-11	1R	.2	2.0	<.02	.20	.04	7.2
	06-05-12	.2	.2	.47	<.02	.11	.01	8.9
P1-10	06-07-99	.7	.3	–	–	.10	.11	–
	06-22-00	–	<.1	–	–	.07	.25	<0.3
	06-13-01	2.0	.2	4.2	<0.05	.07	.20	.06
	06-12-02	.3	.1	3.5	<.05	.05	.41	<.1
	06-19-03	.2	.1	3.5	<.06	.42	.34	2.6
	06-18-04	.1	.1	3.5	–	.58	.35	<.2
	06-22-05	.1	.1	3.3	<.06	.74	.24	<.2
	06-13-06	<.1	.1	3.4	<.06	.92	.15	<.2
	06-20-07	E.1	<.1	4.2	<.06	.10	.31	<.18
	06-18-08	<.1	<.1	4.2	<.04	.12	.23	<.18
	06-15-09	.1	.1	4.0	<.04	.24	.28	<.2
	06-14-10	.2	.1	5	<.04	.28	.19	<.2
	06-21-11	2.2R	.1	5.5	<.02	.43	.25	<.09
	06-05-12	.2	.1	5.4	<.02	.56	.28	.13

Table 2. Groundwater geochemical data collected at wells and piezometers at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1996–2012.—Continued

[All other data were published in Dinicola and others (2002), Dinicola (2003, 2004, 2006), Dinicola and Huffman (2004, 2006, 2007, 2009, 2012), and Huffman and Dinicola (2011); prior to 2000, bicarbonate was calculated from an unfiltered sample. Reported concentrations less than the detection limit usually are estimated. A range of dissolved hydrogen concentrations is shown when equilibration at a single value was never achieved. **Well or piezometer No.:** MW, monitoring well; P, piezometer. **Abbreviations:** nM, nanomolar; mg/L, milligram per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius. **Symbols**: E, estimated value; R, data rejected (selected 1996 dissolved-oxygen data were rejected because of inadequate well purging; selected 2002 dissolved-hydrogen data were rejected because of interference from downhole instruments, 2011, dissolved-hydrogen data were rejected pending further investigation between U.S. Geological Survey field analysis and analyzing laboratory; *, concentration is microgram per liter (µg/L); <, actual value is less than value shown; >, actual value is greater than value shown; –, not analyzed]

Well or piezometer No.	Date sampled	Unfiltered sulfide (mg/L)	Dissolved methane (mg/L)	Dissolved carbon dioxide (mg/L)	pH (units)	Specific conductance (µS/cm)	Filtered chloride (mg/L)
Upper aquifer southern plantation—Continued							
P1-8	06-07-99	0.01	–	–	7.6	381	–
	06-14-01	.02	6.9	–	7.0	363	18
	06-13-02	.02	11	40	6.9	482	35
	06-20-03	<.01	9.6	<10	7.2	285	3.3
	06-18-04	.01	1.7	<10	7.4	336	5.9
	06-23-05	<.01	3.4	<10	7.5	308	4.2
	06-13-06	<.01	4.5	<10	7.5	332	8.0
	06-20-07	<.01	6.6	9	7.5	348	5.9
	06-18-08	<.01	7.9	<10	8.0	358	8.7
	06-15-08	<.01	10	<10	7.9	356	6.7
	06-15-10	<.01	13	15	7.6	353	6.0
	06-21-11	.01	6.4	<10	7.6	361	15
	06-06-12	<.01	9.6	<10	7.8	364	5.9
P1-9	06-08-99	<.01	–	–	6.6	680	–
	06-22-00	<.01	1.7	–	6.8	548	59
	06-14-01	<.01	1.4	–	7.8	289	14
	06-13-02	<.01	7.5	91	6.5	601	71
	06-20-03	.01	2.5	27	7.0	353	23
	06-18-04	<.01	.71	35	6.7	330	26
	06-23-05	<.01	.02	<10	8.3	202	12
	06-13-06	.01	3.2	37	6.6	728	112
	06-20-07	<.01	1.4	10	7.4	325	31
	06-18-08	<.01	.74	<10	7.6	235	28
	06-16-09	<.01	6.7	14	6.8	507	72
	06-14-10	<.01	.6	12	8.3	233	19
	06-21-11	<.01	1.2	<10	7.5	326	28
	06-05-12	<.01	.30	70	8.2	234	7.7
P1-10	06-07-99	<.01	–	–	6.7	560	–
	06-22-00	<.01	1.3	–	7.1	500	15
	06-13-01	<.01	4.9	–	7.2	476	15
	06-12-02	<.01	18	51	6.8	438	14
	06-19-03	<.01	8.2	30	6.6	425	16
	06-18-04	<.01	.33	45	6.3	422	9.5
	06-23-05	<.01	.71	40	6.6	420	11
	06-13-06	<.01	6.3	29	6.6	437	26
	06-20-07	<.01	6.1	15	6.3	391	15
	06-18-08	<.01	4.7	11	6.8	358	7.3
	06-15-09	<.01	3.4	35	6.7	406	6.6
	06-14-10	<.01	4.1	50	6.7	431	6.5
	06-21-11	<.01	3.6	40	6.8	407	5.6
	06-05-12	<.01	7.5	15	6.8	410	6.5

Table 2. Groundwater geochemical data collected at wells and piezometers at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1996–2012.—Continued

[All other data were published in Dinicola and others (2002), Dinicola (2003, 2004, 2006), Dinicola and Huffman (2004, 2006, 2007, 2009, 2012), and Huffman and Dinicola (2011); prior to 2000, bicarbonate was calculated from an unfiltered sample. Reported concentrations less than the detection limit usually are estimated. A range of dissolved hydrogen concentrations is shown when equilibration at a single value was never achieved. **Well or piezometer No.:** MW, monitoring well; P, piezometer. **Abbreviations:** nM, nanomolar; mg/L, milligram per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius. **Symbols**: E, estimated value; R, data rejected (selected 1996 dissolved-oxygen data were rejected because of inadequate well purging; selected 2002 dissolved-hydrogen data were rejected because of interference from downhole instruments, 2011, dissolved-hydrogen data were rejected pending further investigation between U.S. Geological Survey field analysis and analyzing laboratory; *, concentration is microgram per liter (µg/L); <, actual value is less than value shown; >, actual value is greater than value shown; –, not analyzed]

Well or piezometer No.	Date sampled	Dissolved hydrogen (nM)	Dissolved oxygen (mg/L)	Filtered (dissolved) organic carbon (mg/L)	Filtered nitrate + nitrite (mg/L as N)	Filtered manganese (mg/L)	Filtered iron (II) (mg/L)	Filtered sulfate (mg/L)
				Intermediate aquifer				
MW1-25	09-17-96	0.4	2.7R	–	0.14	0.16	0.74	16
	04-17-97	.8	.1	–	<.02	–	.88	15
	03-05-98	.3	.3	–	–	.20	.73	–
	10-05-98	.2	.1	–	–	.19	.99	–
	06-22-00	.4	.2	–	–	.16	.80	13
	06-12-01	2.8–4.3	.2	6.8	<.05	.16	.99	13
	06-14-02	0.7–2.4	.1	6.2	<.05	.18	1.1	9.7
	06-19-03	.3	.1	6.5	<.06	.18	1.1	11
	06-16-04	.2	.1	6.2	–	.17	1.0	10
	06-21-05	.1	.1	5.9	<.06	.16	1.0	9.5
	06-14-06	.1	.1	6.3	<.06	.14	.97	8.1
	06-18-07	.2	<.1	6.6	<.06	.14	.87	7.1
	06-17-08	<.1	.1	6.4	<.04	.13	.86	6.9
	06-17-09	.2	.1	6.7	<.04	.15	1.1	6.9
	06-15-10	.3	.8	6.6	.05	.13	.78	6.6
	06-22-11	1.2R	.2	7.2	<.02	.14	.25	7.2
	06-06-12	–	.1	6.9	<.02	.15	1.0	6.6
MW1-28	09-16-96	.3	2.1R	–	<.02	.20	1.0	48
	04-17-97	1.0	<.1	–	.04	–	.99	51
	03-05-98	.4	.5	–	–	.20	.67	–
	10-07-98	.6	<.1	–	–	.19	1.0	–
	06-22-00	.3	<.1	–	–	.16	.66	44
	06-12-01	4.1–5.7	.5	6.9	<.05	.16	.90	45
	06-14-02	>100R	.1	7.0	<.05	.16	.92	39
	06-19-03	2.5	.1	6.8	<.06	.16	.66	39
	06-16-04	.2	.1	5.9	–	.18	<.01	36
	06-21-05	.1	.2	6.3	<.06	.16	.98	37
	06-14-06	.1	.1	6.1	<.06	.16	.78	35
	06-18-07	.1	<.1	6.7	<.06	.16	.87	33
	06-17-08	.1	<.1	7.1	<.04	.15	.85	33
	06-17-09	.1	.2	6.5	<.04	.16	.96	33
	06-15-10	.2	.8	6.6	<.04	.15	.76	31
	06-22-11	1.1R	.2	7.0	<.02	.15	.69	5.8
	06-06-12	.1	.2	6.8	<.02	.14	.67	28
MW1-38	10-09-98	–	.1	–	–	.20	.08	–
	06-20-00	.1	.2	–	<.05	.08	.10	2.3
	06-12-02	1.4	<.1	–	<.05	.08	.42	2.9
	06-16-04	.2	.1	4.9	–	.06	.04	1.2
	06-24-05	.3	.1	4.4	<.06	.06	.09	3.3
	06-14-06	.1	.1	2.4	<.06	.01	.05	1.0
	06-21-07	.2	.6	4.7	<.06	.04	.04	3.1
	06-17-08	<.1	.1	5.0	<.04	.04	.03	2.5
	06-17-09	.1	.4	4.5	<.04	.05	.10	3.4
	06-15-10	.3	<.1	4.3	<.04	.05	.03	2.3
	06-22-11	1.8R	.3	5.1	<.02	.05	.04	1.6
	06-06-12	.4	.2	4.9	<.02	.05	.02	1.1

Table 2. Groundwater geochemical data collected at wells and piezometers at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1996–2012.—Continued

[All other data were published in Dinicola and others (2002), Dinicola (2003, 2004, 2006), Dinicola and Huffman (2004, 2006, 2007, 2009, 2012), and Huffman and Dinicola (2011); prior to 2000, bicarbonate was calculated from an unfiltered sample. Reported concentrations less than the detection limit usually are estimated. A range of dissolved hydrogen concentrations is shown when equilibration at a single value was never achieved. **Well or piezometer No.:** MW, monitoring well; P, piezometer. **Abbreviations:** nM, nanomolar; mg/L, milligram per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius. **Symbols**: E, estimated value; R, data rejected (selected 1996 dissolved-oxygen data were rejected because of inadequate well purging; selected 2002 dissolved-hydrogen data were rejected because of interference from downhole instruments, 2011, dissolved-hydrogen data were rejected pending further investigation between U.S. Geological Survey field analysis and analyzing laboratory; *, concentration is microgram per liter (µg/L); <, actual value is less than value shown; >, actual value is greater than value shown; –, not analyzed]

Well or piezometer No.	Date sampled	Unfiltered sulfide (mg/L)	Dissolved methane (mg/L)	Dissolved carbon dioxide (mg/L)	pH (units)	Specific conductance (µS/cm)	Filtered chloride (mg/L)
			Intermediate aquifer				
MW1-25	09-17-96	<0.01	3.6	–	7.1	–	140
	04-17-97	<.01	7.9	–	7.0	–	–
	03-05-98	<.01	–	–	–	–	–
	10-05-98	<.01	–	–	6.9	1,240	–
	06-22-00	<.01	.79	–	6.9	1,230	170
	06-12-01	<.01	4.7	–	6.7	1,180	160
	06-14-02	<.01	7.0	83	6.7	1,030	170
	06-19-03	<.01	8.1	65	6.7	1,180	170
	06-16-04	<.01	1.4	40	7.1	1,210	160
	06-21-05	<.01	2.1	33	6.9	1,150	160
	06-14-06	<.01	2.4	27	6.9	1,090	140
	06-18-07	<.01	1.3	27	6.6	1,040	140
	06-17-08	<.01	2.8	35	6.9	1,040	140
	06-19-09	–	5.1	<10	6.5	923	124
	06-15-10	<.01	4.7	30	6.7	1,050	131
	06-22-11	<.01	2.6	40	6.7	1,040	127
	06-06-12	<.01	3.9	18	6.8	1,070	122
MW1-28	09-16-96	<.01	1.7	–	–	–	380
	04-17-97	<.01	5.3	–	7.4	–	–
	03-05-98	<.01	–	–	–	–	–
	10-07-98	.02	–	–	6.6	2,630	–
	06-22-00	<.01	.45	–	7.3	2,460	510
	06-12-01	<.01	4.1	–	7.4	2,200	490
	06-14-02	<.01	3.9	40	7.2	2,580	460
	06-19-03	<.01	1.7	32	7.1	2,440	490
	06-16-04	<.01	.77	21	7.2	2,280	450
	06-21-05	<.01	1.0	23	6.9	2,210	472
	06-14-06	.01	.83	21	7.0	2,110	443
	06-18-07	.02	.67	25	7.1	2,060	430
	06-17-08	<.01	1.5	13	7.1	2,080	420
	06-17-09	<.01	2.2	<10	7.2	1,860	415
	06-15-10	<.01	2.2	27	7.2	2,030	399
	06-22-11	<.01	1.5	30	7.3	2,020	78
	06-06-12	<.01	2.4	17	7.3	1,920	390
MW1-38	10-09-98	.02	–	–	7.8	1,460	–
	06-20-00	.03	.10	–	7.8	1,240	230
	06-12-02	.04	1.1	7.7	7.6	1,350	230
	06-16-04	.03	.13	11	7.4	1,130	200
	06-24-05	.03	.05	<10	7.7	1,210	230
	06-14-06	<.01	.41	<10	7.5	1,120	62
	06-21-07	.05	.31	9.0	7.4	1,190	230
	06-17-08	.02	.32	<10	7.7	1,140	220
	06-17-09	.03	.77	<10	7.7	1,140	214
	06-15-10	<.01	.64	–	7.5	864	180
	06-22-11	.02	.85	<10	7.8	1,050	198
	06-06-12	.03	2.4	<10	7.6	1,060	186

Table 2. Groundwater geochemical data collected at wells and piezometers at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1996–2012.—Continued

[All other data were published in Dinicola and others (2002), Dinicola (2003, 2004, 2006), Dinicola and Huffman (2004, 2006, 2007, 2009, 2012), and Huffman and Dinicola (2011); prior to 2000, bicarbonate was calculated from an unfiltered sample. Reported concentrations less than the detection limit usually are estimated. A range of dissolved hydrogen concentrations is shown when equilibration at a single value was never achieved. **Well or piezometer No.:** MW, monitoring well; P, piezometer. **Abbreviations:** nM, nanomolar; mg/L, milligram per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius. **Symbols**: E, estimated value; R, data rejected (selected 1996 dissolved-oxygen data were rejected because of inadequate well purging; selected 2002 dissolved-hydrogen data were rejected because of interference from downhole instruments, 2011, dissolved-hydrogen data were rejected pending further investigation between U.S. Geological Survey field analysis and analyzing laboratory; *, concentration is microgram per liter (µg/L); <, actual value is less than value shown; >, actual value is greater than value shown; –, not analyzed]

Well or piezometer No.	Date sampled	Dissolved hydrogen (nM)	Dissolved oxygen (mg/L)	Filtered (dissolved) organic carbon (mg/L)	Filtered nitrate + nitrite (mg/L as N)	Filtered manganese (mg/L)	Filtered iron (II) (mg/L)	Filtered sulfate (mg/L)
				Intermediate aquifer—Continued				
MW1-39	09-16-96	0.6	2.0R	–	<0.02	0.02	<0.01	0.7
	04-17-97	4.5	<.1	–	<.02	–	.05	13
	03-03-98	.3	.3	–	–	.10	.03	–
	10-09-98	.5	<.1	–	–	<.01	.04	–
	06-07-99	1.0	.3	–	–	.10	.02	–
	06-20-00	.5	.1	–	<.05	.01	.07	.2
	06-12-01	1.4	.3	3.3	<.05	.01	<.01	.1
	06-12-02	>30R	<.1	2.8	<.05	.01	.10	.1
	06-19-03	1.8	.1	2.5	<.06	.01	<.01	1.2
	06-16-04	2.0	.1	2.4	–	.01	.05	.1
	06-14-06	.7	.1	4.5	<.06	.05	.05	1.7
	06-21-07	1.0	<.1	2.3	<.06	.01	.04	.98
	06-17-08	1.8	.6	2.7	<.04	.01	.04	1.0
	06-17-09	1.8	.4	2.0	<.04	.008	<.01	1.0
	06-15-10	.7	<.1	2.0	<.04	.01	.04	E.1
	06-22-11	2.4R	.1	2.1	<.02	.01	.03	<.09
	06-06-12	1.0	<.1	2.0	<.02	.09	.08	.12

Table 3. Concentrations of selected volatile organic compounds in groundwater samples from monitoring wells and piezometers and passive-diffusion samplers collected by the U.S. Geological Survey at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1999–2012.

[All data except those shaded were published previously in Dinicola and others (2002), Dinicola (2003, 2004, 2006), Dinicola and Huffman (2004, 2006, 2007, 2009, 2012), and Huffman and Dinicola (2011). Laboratory data qualifier codes, such as "D" for dilution, are not shown. **Well or piezometer No.:** MW, monitoring well; P, piezometer; S, passive-diffusion sampler; T, denotes samplers deployed in an access tube. **Volatile organic compounds (VOCs)**: PCE, tetrachloroethene; TCE, trichloroethene; *cis*-DCE, *cis*-1,2-dichloroethene; *trans*-DCE, *trans*-1,2-dichloroethene; VC, vinyl chloride; 1,1,1-TCA, 1,1,1-trichloroethane; 1,1-DCA, 1,1-dichloroethane; CA, chloroethane; 1,1-DCE, 1,1-dichloroethene; total BTEX, sum of benzene, toluene, ethylbenzene, and xylene; total CVOCs, sum of chlorinated volatile organic compounds. **Abbreviations:** E, estimated value; M, presence verified but not quantified; µg/L, microgram per liter; <, actual value is less than value shown; ND, not detected; –, not analyzed]

Well or piezometer No.	Date sampled	PCE (µg/L)	TCE (µg/L)	*cis*-DCE (µg/L)	*trans*-DCE (µg/L)	VC (µg/L)	Ethane (µg/L)	Ethene (µg/L)
				Upgradient				
MW1-3	06-20-00	–	–	–	–	–	–	0.12
	06-15-04	–	–	–	–	–	<5.0	<5.0
	06-12-06	–	–	–	–	–	<5.0	<5.0
	06-15-09	–	–	–	–	–	<5.0	<5.0
	06-14-10	–	–	–	–	–	<5.0	<5.0
	06-20-11	–	–	–	–	–	<5.0	<5.0
	06-04-12	–	–	–	–	–	<.6	<.4
MW1-20	06-21-00	–	–	–	–	–	–	<.10
	06-12-02	<0.20	<0.20	<0.20	<0.20	<0.20	–	–
	06-15-04	–	–	–	–	–	<5.0	<5.0
	06-13-06	–	–	–	–	–	<5.0	<5.0
	06-15-09	–	–	–	–	–	<5.0	<5.0
	06-14-10	–	–	–	–	–	<5.0	<5.0
	06-20-11	–	–	–	–	–	<5.0	<5.0
	06-05-12	–	–	–	–	–	<.6	<.4
				Upper aquifer northern plantation				
1MW-1	06-21-00	–	–	–	–	–	–	8.6
	06-16-04	<20	<20	130	130	730	E10	50
	06-12-06	–	–	–	–	–	E21	61
	06-19-07	–	–	–	–	–	E9.0	E38
	06-17-08	–	–	–	–	–	E47	110
	06-15-09	–	–	–	–	–	E19	E95
	06-14-10	–	–	–	–	–	E43	100
	06-20-11	–	–	–	–	–	10	50
	06-04-12	–	–	–	–	–	13	79
MW1-2	06-21-00	–	–	–	–	–	–	.26
	06-18-03	<2.0	<2.0	58	4.0	79	–	–
	06-17-04	<50	E12	630	E13	110	6.0	E1.1
	06-12-06	–	–	–	–	–	5.0	<5.0
	06-19-07	–	–	–	–	–	E4.0	<5.0
	06-17-08	–	–	–	–	–	7.0	E.70
	06-15-09	–	–	–	–	–	E10	<25
	06-14-10	–	–	–	–	–	12	E1.7
	06-20-11	–	–	–	–	–	9.4	<5.0
	06-04-12	–	–	–	–	–	7.6	<.4
MW1-17	06-22-00	–	–	–	–	–	–	<.10
	06-17-04	<1.0	<1.0	E0.68	E.23	E.48	E2.0	<5.0
	06-20-07	–	–	–	–	–	E11	<50
	06-18-08	–	–	–	–	–	E17	E13
	06-15-09	–	–	–	–	–	E21	<250
	06-14-10	–	–	–	–	–	E34	<100
	06-20-11	–	–	–	–	–	8.9	<5.0
	06-04-12	–	–	–	–	–	16	E13

Table 3. Concentrations of selected volatile organic compounds in groundwater samples from monitoring wells and piezometers and passive-diffusion samplers collected by the U.S. Geological Survey at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1999–2012.—Continued

[All data except those shaded were published previously in Dinicola and others (2002), Dinicola (2003, 2004, 2006), Dinicola and Huffman (2004, 2006, 2007, 2009, 2012), and Huffman and Dinicola (2011). Laboratory data qualifier codes, such as “D” for dilution, are not shown. **Well or piezometer No.:** MW, monitoring well; P, piezometer; S, passive-diffusion sampler; T, denotes samplers deployed in an access tube. **Volatile organic compounds (VOCs)**: PCE, tetrachloroethene; TCE, trichloroethene; *cis*-DCE, *cis*-1,2-dichloroethene; *trans*-DCE, *trans*-1,2-dichloroethene; VC, vinyl chloride; 1,1,1-TCA, 1,1,1-trichloroethane; 1,1-DCA, 1,1-dichloroethane; CA, chloroethane; 1,1-DCE, 1,1-dichloroethene; total BTEX, sum of benzene, toluene, ethylbenzene, and xylene; total CVOCs, sum of chlorinated volatile organic compounds. **Abbreviations:** E, estimated value; M, presence verified but not quantified; µg/L, microgram per liter; <, actual value is less than value shown; ND, not detected; –, not analyzed]

Well or piezometer No.	Date sampled	1,1,1-TCA (µg/L)	1,1-DCA (µg/L)	CA (µg/L)	1,1-DCE (µg/L)	Total BTEX (µg/L)	Total CVOCs (µg/L)
			Upgradient				
MW1-3	06-20-00	–	–	–	–	–	–
	06-15-04	–	–	–	–	–	–
	06-12-06	–	–	–	–	–	–
	06-15-09	–	–	–	–	–	–
	06-14-10	–	–	–	–	–	–
	06-20-11	–	–	–	–	–	–
	06-04-12	–	–	–	–	–	–
MW1-20	06-21-00	–	–	–	–	–	–
	06-12-02	<0.20	<0.20	<0.20	<0.20	ND	ND
	06-15-04	–	–	–	–	–	–
	06-13-06	–	–	–	–	–	–
	06-15-09	–	–	–	–	–	–
	06-14-10	–	–	–	–	–	–
	06-20-11	–	–	–	–	–	–
	06-05-12	–	–	–	–	–	–
			Upper aquifer northern plantation				
1MW-1	06-21-00	–	–	–	–	–	–
	06-16-04	<20	E11	<40	<20	ND	1,000
	06-12-06	–	–	–	–	–	–
	06-19-07	–	–	–	–	–	–
	06-17-08	–	–	–	–	–	–
	06-15-09	–	–	–	–	–	–
	06-14-10	–	–	–	–	–	–
	06-20-11	–	–	–	–	–	–
	06-04-12	–	–	–	–	–	–
MW1-2	06-21-00	–	–	–	–	–	–
	06-18-03	<2.0	M	5.0	<2.0	E2.0	150
	06-17-04	<50	<50	<100	<50	ND	760
	06-12-06	–	–	–	–	–	–
	06-19-07	–	–	–	–	–	–
	06-17-08	–	–	–	–	–	–
	06-15-09	–	–	–	–	–	–
	06-14-10	–	–	–	–	–	–
	06-20-11	–	–	–	–	–	–
	06-04-12	–	–	–	–	–	–
MW1-17	06-22-00	–	–	–	–	–	–
	06-17-04	<1.0	<1.0	<2.0	<1.0	E3.1	E1.4
	06-20-07	–	–	–	–	–	–
	06-18-08	–	–	–	–	–	–
	06-15-09	–	–	–	–	–	–
	06-14-10	–	–	–	–	–	–
	06-20-11	–	–	–	–	–	–
	06-04-12	–	–	–	–	–	–

Table 3. Concentrations of selected volatile organic compounds in groundwater samples from monitoring wells and piezometers and passive-diffusion samplers collected by the U.S. Geological Survey at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1999–2012.—Continued

[All data except those shaded were published previously in Dinicola and others (2002), Dinicola (2003, 2004, 2006), Dinicola and Huffman (2004, 2006, 2007, 2009, 2012), and Huffman and Dinicola (2011). Laboratory data qualifier codes, such as "D" for dilution, are not shown. **Well or piezometer No.:** MW, monitoring well; P, piezometer; S, passive-diffusion sampler; T, denotes samplers deployed in an access tube. **Volatile organic compounds (VOCs)**: PCE, tetrachloroethene; TCE, trichloroethene; *cis*-DCE, *cis*-1,2-dichloroethene; *trans*-DCE, *trans*-1,2-dichloroethene; VC, vinyl chloride; 1,1,1-TCA, 1,1,1-trichloroethane; 1,1-DCA, 1,1-dichloroethane; CA, chloroethane; 1,1-DCE, 1,1-dichloroethene; total BTEX, sum of benzene, toluene, ethylbenzene, and xylene; total CVOCs, sum of chlorinated volatile organic compounds. **Abbreviations:** E, estimated value; M, presence verified but not quantified; µg/L, microgram per liter; <, actual value is less than value shown; ND, not detected; –, not analyzed]

Well or piezometer No.	Date sampled	PCE (µg/L)	TCE (µg/L)	*cis*-DCE (µg/L)	*trans*-DCE (µg/L)	VC (µg/L)	Ethane (µg/L)	Ethene (µg/L)
Upper aquifer northern plantation—Continued								
MW1-41	06-21-00	–	–	–	–	–	–	<0.10
	06-17-04	<1.0	<1.0	E0.27	<1.0	E0.23	E10	<100
	06-12-06	–	–	–	–	–	<100	<100
	06-19-07	–	–	–	–	–	<100	<100
	06-16-08	–	–	–	–	–	<120	<120
	06-15-09	–	–	–	–	–	<250	<250
	06-14-10	–	–	–	–	–	<250	<250
	06-20-11	<.1	<.1	.2	<.1	<.2	<5.0	<5.0
	06-04-12	–	–	–	–	–	<1.1	<.8
P1-1	06-09-99	<2.0	11	6.1	<1.0	<4.0	–	–
	06-11-02	<.20	<0.20	.20	.10	<.20	–	–
	06-18-03	<1.0	<1.0	E.30	<1.0	<1.0	–	–
	06-17-04	<1.0	<1.0	<1.0	<1.0	<1.0	E29	E8.6
	06-22-05	<1.0	<1.0	E.16	<1.0	<1.0	<100	<100
	06-12-06	<1.0	<1.0	<1.0	<1.0	<1.0	<100	<100
	06-19-07	–	–	–	–	–	<100	<100
	06-16-08	<1.0	<1.0	E.18	<1.0	<2.0	<250	<250
	06-15-09	<1.0	<1.0	E.19	<1.0	<2.0	<500	<500
	06-14-10	<.1	<.1	<.1	<.1	<.2	<500	<500
	06-20-11	<.1	<.1	<.1	<.1	<.2	<5.0	<5.0
	06-04-12	<.1	<.1	<.1	<.1	<.2	<1.1	<.8
P1-3	06-09-99	<16	35	450	20	120	–	–
	06-11-02	<.20	<.20	53	4.3	72	–	–
	06-18-03	<2.0	<2.0	58	4.0	79	–	–
	06-17-04	<1.0	<1.0	15	2.4	41	E33	E27
	06-22-05	<1.0	<1.0	11	1.3	35	E44	E30
	06-12-06	<1.0	<1.0	4.6	1.2	16	E35	E21
	06-19-07	<1.0	<1.0	1.8	1.0	15	E42	E27
	06-17-08	<1.0	<1.0	E.17	E.31	E.67	E64	E20
	06-15-09	<1.0	<1.0	E.73	E.71	5.8	E60	<500
	06-14-10	<.1	<.1	<.1	.2	<.2	E67	<250
	06-20-11	<.2	<.2	<.2	<.2	<.4	<5.0	<5.0
	06-04-12	<.1	<.1	.2	.2	<2.0	26	<.8
P1-4	06-09-99	<130	160	4,800	56	540	–	–
	06-13-01	<20	<20	4,900	46	652	–	–
	06-11-02	<.20	1.2	3,600	41	640	–	–
	06-18-03	<100	<100	3,200	E42	440	–	–
	06-17-04	<130	<130	2,300	E29	370	E7.0	E29
	06-21-05	<67	<67	2,100	E30	360	E7.0	E20
	06-12-06	<50	<50	1,600	E24	280	E6.0	E19
	06-19-07	<40	<40	1,500	E24	280	E11	E29
	06-16-08	<50	<50	1,600	E24	750	E14	E29
	06-15-09	<40	<40	1,300	E34	350	E21	E50
	06-14-10	<2.0	<2.0	1,200	16.9	314	E32	50
	06-20-11	<10	<10	895	29	192	10	16
	06-04-12	<10	<10	1,000	15.5	249	12	32

Table 3. Concentrations of selected volatile organic compounds in groundwater samples from monitoring wells and piezometers and passive-diffusion samplers collected by the U.S. Geological Survey at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1999–2012.—Continued

[All data except those shaded were published previously in Dinicola and others (2002), Dinicola (2003, 2004, 2006), Dinicola and Huffman (2004, 2006, 2007, 2009, 2012), and Huffman and Dinicola (2011). Laboratory data qualifier codes, such as "D" for dilution, are not shown. **Well or piezometer No.:** MW, monitoring well; P, piezometer; S, passive-diffusion sampler; T, denotes samplers deployed in an access tube. **Volatile organic compounds (VOCs)**: PCE, tetrachloroethene; TCE, trichloroethene; *cis*-DCE, *cis*-1,2-dichloroethene; *trans*-DCE, *trans*-1,2-dichloroethene; VC, vinyl chloride; 1,1,1-TCA, 1,1,1-trichloroethane; 1,1-DCA, 1,1-dichloroethane; CA, chloroethane; 1,1-DCE, 1,1-dichloroethene; total BTEX, sum of benzene, toluene, ethylbenzene, and xylene; total CVOCs, sum of chlorinated volatile organic compounds. **Abbreviations:** E, estimated value; M, presence verified but not quantified; µg/L, microgram per liter; <, actual value is less than value shown; ND, not detected; –, not analyzed]

Well or piezometer No.	Date sampled	1,1,1-TCA (µg/L)	1,1-DCA (µg/L)	CA (µg/L)	1,1-DCE (µg/L)	Total BTEX (µg/L)	Total CVOCs (µg/L)
Upper aquifer northern plantation—Continued							
MW1-41	06-21-00	–	–	–	–	–	–
	06-17-04	<1.0	<1.0	E1.7	<1.0	E.27	E2.2
	06-12-06	–	–	–	–	–	–
	06-19-07	–	–	–	–	–	–
	06-16-08	–	–	–	–	–	–
	06-15-09	–	–	–	–	–	–
	06-14-10	–	–	–	–	–	–
	06-20-11	<0.1	<0.1	–	<0.1	0.3	0.2
	06-04-12	–	–	–	–	–	–
P1-1	06-09-99	<2.0	M	<4.0	<2.0	18	17
	06-11-02	<.20	0.50	<.20	<.20	6.8	.80
	06-18-03	<1.0	M	<2.0	<1.0	4.0	E.30
	06-17-04	<1.0	<1.0	<2.0	<1.0	4.4	ND
	06-22-05	<1.0	<1.0	E.19	<1.0	3.5	E.35
	06-12-06	<1.0	<1.0	<2.0	<1.0	3.1	ND
	06-19-07	–	–	–	–	–	–
	06-16-08	<1.0	<1.0	<2.0	<1.0	3.9	E.18
	06-15-09	<1.0	<1.0	<2.0	<1.0	3.5	E.19
	06-14-10	<.1	<.1	–	<.1	1.3	ND
	06-20-11	<.1	<.1	–	<.1	1.2	ND
	06-04-12	<.1	<.1	–	<.1	ND	ND
P1-3	06-09-99	<16	<16	4.0	<16	ND	630
	06-11-02	<.20	.60	9.9	.20	3.3	140
	06-18-03	<2.0	M	5.0	<2.0	E2.0	150
	06-17-04	<1.0	E.38	6.9	<1.0	2.4	66
	06-22-05	<1.0	E.31	2.6	<1.0	2.3	50
	06-12-06	<1.0	E.32	4.4	<1.0	2.2	26
	06-19-07	<1.0	E.42	5.6	<1.0	2.2	24
	06-17-08	<1.0	E.24	9.1	<1.0	3.9	10
	06-15-09	<1.0	E.26	6.4	<1.0	2.3	14
	06-14-10	<.1	.2	–	<.1	3.5	.4
	06-20-11	<.2	<.2	–	<.2	1.9	ND
	06-04-12	<.1	E.1	–	<.1	2.0	.5
P1-4	06-09-99	<130	<130	<270	<130	ND	5,550
	06-13-01	<20	<20	<20	<20	ND	5,600
	06-11-02	<.20	<10	.80	9.9	1.1	4,290
	06-18-03	<100	<100	<200	<100	ND	3,680
	06-17-04	<130	<130	<270	<130	ND	2,700
	06-21-05	<67	<67	<130	<67	ND	2,490
	06-12-06	<50	<50	<100	<50	ND	1,900
	06-19-07	<40	<40	<80	<40	66	1,800
	06-16-08	<50	<50	<100	<50	ND	2,370
	06-15-09	<40	<40	<80	<40	ND	1,680
	06-14-10	<2.0	<2.0	–	<2.0	ND	1,530
	06-20-11	<10	<10	–	<10	ND	1,120
	06-04-12	<10	<10	–	<10	ND	1,260

Table 3. Concentrations of selected volatile organic compounds in groundwater samples from monitoring wells and piezometers and passive-diffusion samplers collected by the U.S. Geological Survey at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1999–2012.—Continued

[All data except those shaded were published previously in Dinicola and others (2002), Dinicola (2003, 2004, 2006), Dinicola and Huffman (2004, 2006, 2007, 2009, 2012), and Huffman and Dinicola (2011). Laboratory data qualifier codes, such as "D" for dilution, are not shown. **Well or piezometer No.:** MW, monitoring well; P, piezometer; S, passive-diffusion sampler; T, denotes samplers deployed in an access tube. **Volatile organic compounds (VOCs)**: PCE, tetrachloroethene; TCE, trichloroethene; *cis*-DCE, *cis*-1,2-dichloroethene; *trans*-DCE, *trans*-1,2-dichloroethene; VC, vinyl chloride; 1,1,1-TCA, 1,1,1-trichloroethane; 1,1-DCA, 1,1-dichloroethane; CA, chloroethane; 1,1-DCE, 1,1-dichloroethene; total BTEX, sum of benzene, toluene, ethylbenzene, and xylene; total CVOCs, sum of chlorinated volatile organic compounds. **Abbreviations:** E, estimated value; M, presence verified but not quantified; µg/L, microgram per liter; <, actual value is less than value shown; ND, not detected; –, not analyzed]

Well or piezometer No.	Date sampled	PCE (µg/L)	TCE (µg/L)	*cis*-DCE (µg/L)	*trans*-DCE (µg/L)	VC (µg/L)	Ethane (µg/L)	Ethene (µg/L)
Upper aquifer northern plantation—Continued								
P1-5	06-08-99	<13	440	400	4.0	11	–	–
	06-10-02	<0.20	<0.20	0.30	0.80	0.40	–	–
	06-18-03	<25	<25	E7.8	<25	<25	–	–
	06-17-04	<10	<10	<10	<10	<10	23	<10
	06-21-05	<10	<10	<10	<10	<10	E23	<100
	06-12-06	<10	<10	<10	<10	<10	E16	<100
	06-19-07	–	–	–	–	–	E19	<100
	06-16-08	<50	<50	<50	<50	<100	E45	<100
	06-15-09	<20	<20	<20	<20	<40	E25	<250
	06-14-10	<2.0	<2.0	<2.0	<2.0	<4.0	E56	<250
	06-20-11	<2.0	<2.0	<2.0	<2.0	<4.0	<5.0	<5.0
	06-04-12	<.1	<.1	.2	.5	<.2	11	<.8
Upper aquifer southern plantation								
MW1-4	06-22-00	–	–	–	–	–	–	12
	06-18-04	<1,000	32,000	15,000	<1,000	1,600	E32	200
	06-13-06	–	–	–	–	–	E39	200
	06-20-07	–	–	–	–	–	6.0	32
	06-18-08	–	–	–	–	–	30	120
	06-16-09	–	–	–	–	–	5.0	28
	06-15-10	–	–	–	–	–	87	260
	06-21-11	–	–	–	–	–	58	180
	06-05-12	–	–	–	–	–	23	120
MW1-5	06-22-00	–	–	–	–	–	–	8.6
	06-18-04	<1.0	E0.26	E0.29	<1.0	E0.74	E7.0	<50
	06-13-06	–	–	–	–	–	E9.0	E30
	06-20-07	–	–	–	–	–	E3.0	<25
	06-18-08	–	–	–	–	–	E6.0	E7.2
	06-15-09	–	–	–	–	–	E6.0	<50
	06-15-10	–	–	–	–	–	E12	E16
	06-21-11	–	–	–	–	–	<5.0	<5.0
	06-05-12	–	–	–	–	–	<0.6	<0.4
MW1-16	06-22-00	–	–	–	–	–	–	70
	06-22-04	<10	<10	E2.3	E4.2	E2.2	E38	E33
	06-13-06	–	–	–	–	–	E23	E6.8
	06-20-07	–	–	–	–	–	E24	E18
	06-18-08	–	–	–	–	–	E19	E6.3
	06-16-09	–	–	–	–	–	E53	<250
	06-15-10	–	–	–	–	–	E37	E5
	06-21-11	–	–	–	–	–	8.6	<5.0
	06-06-12	–	–	–	–	–	<.6	<.4

Table 3. Concentrations of selected volatile organic compounds in groundwater samples from monitoring wells and piezometers and passive-diffusion samplers collected by the U.S. Geological Survey at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1999–2012.—Continued

[All data except those shaded were published previously in Dinicola and others (2002), Dinicola (2003, 2004, 2006), Dinicola and Huffman (2004, 2006, 2007, 2009, 2012), and Huffman and Dinicola (2011). Laboratory data qualifier codes, such as "D" for dilution, are not shown. **Well or piezometer No.:** MW, monitoring well; P, piezometer; S, passive-diffusion sampler; T, denotes samplers deployed in an access tube. **Volatile organic compounds (VOCs)**: PCE, tetrachloroethene; TCE, trichloroethene; *cis*-DCE, *cis*-1,2-dichloroethene; *trans*-DCE, *trans*-1,2-dichloroethene; VC, vinyl chloride; 1,1,1-TCA, 1,1,1-trichloroethane; 1,1-DCA, 1,1-dichloroethane; CA, chloroethane; 1,1-DCE, 1,1-dichloroethene; total BTEX, sum of benzene, toluene, ethylbenzene, and xylene; total CVOCs, sum of chlorinated volatile organic compounds. **Abbreviations:** E, estimated value; M, presence verified but not quantified; µg/L, microgram per liter; <, actual value is less than value shown; ND, not detected; –, not analyzed]

Well or piezometer No.	Date sampled	1,1,1-TCA (µg/L)	1,1-DCA (µg/L)	CA (µg/L)	1,1-DCE (µg/L)	Total BTEX (µg/L)	Total CVOCs (µg/L)
			Upper aquifer northern plantation—Continued				
P1-5	06-08-99	<13	<13	15	<13	47	870
	06-10-02	<0.20	0.30	21	<0.20	18	23
	06-18-03	<25	<25	E19	<25	ND	E27
	06-17-04	<10	<10	23	<10	E4.5	23
	06-21-05	<10	<10	21	<10	8.2	21
	06-12-06	<10	<10	E14	<10	E4.2	E14
	06-19-07	–	–	–	–	–	–
	06-16-08	<50	<50	<100	<50	ND	ND
	06-15-09	<20	<20	E19	<20	ND	E19
	06-14-10	<2.0	<2.0	–	<2.0	2.2	ND
	06-20-11	<2.0	<2.0	–	<2.0	ND	ND
	06-04-12	<.1	0.1	–	<.1	7.0	0.8
			Upper aquifer southern plantation				
MW1-4	06-22-00	–	–	–	–	–	–
	06-18-04	<1,000	<1,000	<2,000	<1,000	ND	48,600
	06-13-06	–	–	–	–	–	–
	06-20-07	–	–	–	–	–	–
	06-18-08	–	–	–	–	–	–
	06-16-08	–	–	–	–	–	–
	06-15-10	–	–	–	–	–	–
	06-21-11	–	–	–	–	–	--
	06-05-12	–	–	–	–	–	--
MW1-5	06-22-00	–	–	–	–	–	–
	06-18-04	<1.0	E0.36	3.0	<1.0	E0.92	E4.6
	06-13-06	–	–	–	–	–	–
	06-20-07	–	–	–	–	–	–
	06-18-08	–	–	–	–	–	–
	06-16-09	–	–	–	–	–	–
	06-15-10	–	–	–	–	–	–
	06-21-11	–	–	–	–	–	–
	06-05-12	–	–	–	–	–	–
MW1-16	06-22-00	–	–	–	–	–	–
	06-22-04	<10	590	290	<10	367	890
	06-13-06	–	–	–	–	–	–
	06-20-07	–	–	–	–	–	–
	06-18-08	–	–	–	–	–	–
	06-16-09	–	–	–	–	–	–
	06-15-10	–	–	–	–	–	–
	06-21-11	–	–	–	–	–	–
	06-06-12	–	–	–	–	–	–

Table 3. Concentrations of selected volatile organic compounds in groundwater samples from monitoring wells and piezometers and passive-diffusion samplers collected by the U.S. Geological Survey at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1999–2012.—Continued

[All data except those shaded were published previously in Dinicola and others (2002), Dinicola (2003, 2004, 2006), Dinicola and Huffman (2004, 2006, 2007, 2009, 2012), and Huffman and Dinicola (2011). Laboratory data qualifier codes, such as "D" for dilution, are not shown. **Well or piezometer No.:** MW, monitoring well; P, piezometer; S, passive-diffusion sampler; T, denotes samplers deployed in an access tube. **Volatile organic compounds (VOCs)**: PCE, tetrachloroethene; TCE, trichloroethene; *cis*-DCE, *cis*-1,2-dichloroethene; *trans*-DCE, *trans*-1,2-dichloroethene; VC, vinyl chloride; 1,1,1-TCA, 1,1,1-trichloroethane; 1,1-DCA, 1,1-dichloroethane; CA, chloroethane; 1,1-DCE, 1,1-dichloroethene; total BTEX, sum of benzene, toluene, ethylbenzene, and xylene; total CVOCs, sum of chlorinated volatile organic compounds. **Abbreviations:** E, estimated value; M, presence verified but not quantified; µg/L, microgram per liter; <, actual value is less than value shown; ND, not detected; –, not analyzed]

Well or piezometer No.	Date sampled	PCE (µg/L)	TCE (µg/L)	*cis*-DCE (µg/L)	*trans*-DCE (µg/L)	VC (µg/L)	Ethane (µg/L)	Ethene (µg/L)
Upper aquifer southern plantation—Continued								
P1-6	06-08-99	<400	74	16,000	170	5,400	–	–
	06-14-01	<20	370	16,000	220	9,900	–	–
	06-13-02	<20	<20	3,700	170	5,100	–	–
	06-20-03	<50	470	1,100	E39	1,300	–	–
	06-18-04	<20	<20	220	E11	570	7.0	210
	06-22-05	<130	<130	4,200	E90	2,900	E30	590
	06-13-06	<100	<100	300	E77	770	82	1,300
	06-20-07	<8.0	<8.0	84	E5.4	140	7.0	180
	06-18-08	<200	<200	8,800	E130	9,700	57	720
	06-16-09	<100	180	3,900	E93	2,600	E40	450
	06-15-10	<10.0	23.2	8,600	78.2	2,860	53	560
	06-21-11	<10	<10	2,020	32	1,470	14	180
	06-06-12	<10	<10	78.5	<10	151	E1.0	48
P1-7	06-08-99	<670	26,000	35,000	210	3,100	–	–
	06-22-00	3.6	27,000	44,000	220	3,800	–	68
	06-14-01	<20	26,000	37,000	190	4,000	–	–
	06-14-02	<20	37,000	62,000	400	5,700	–	–
	06-20-03	<2,000	28,000	35,000	<2000	2,800	–	–
	06-18-04	<3,300	37,000	61,000	<3300	5,100	E36	520
	06-22-05	<2,000	28,000	59,000	E330	5,000	E45	480
	06-13-06	<2,000	24,000	43,000	<2000	3,800	E44	400
	06-20-07	<2,000	33,000	44,000	E320	4,000	E47	460
	06-18-08	<2,000	38,000	65,000	E370	14,000	88	850
	06-16-09	<2,000	40,000	92,000	3,900	10,000	140	1,100
	06-15-10	<50.0	10,900	27,700	184	3,480	140	550
	06-21-11	<100	7,580	18,500	305	1,640	63	200
	06-05-12	<100	9,230	19,000	129	2,380	60	330
P1-8	06-07-99	<710	190	25,000	210	3,400	–	–
	06-14-01	<20	810	8,600	62	4,200	–	–
	06-13-02	<20	<20	24,000	190	7,700	–	–
	06-20-03	<10	230	31	<10	E7.0	–	–
	06-18-04	<1.0	E.26	2.7	<1.0	23	<50	E4.2
	06-23-05	<1.0	<1.0	7.0	<1.0	21	<50	<50
	06-13-06	<20	<20	620	E4.0	58	<50	E9.5
	06-20-07	<4.0	E2.4	29	<4.0	41	<100	E13
	06-18-08	<10	<10	160	<10	280	E6.0	E16
	06-15-09	<5.0	<5.0	97	<5.0	120	<250	<250
	06-15-10	<1.0	<1.0	188	<1.0	147	E16	<250
	06-21-11	<10	<10	9,090	71	774	E3.0	7.1
	06-06-12	<10	<10	39	<10	120	E4.6	16

Table 3. Concentrations of selected volatile organic compounds in groundwater samples from monitoring wells and piezometers and passive-diffusion samplers collected by the U.S. Geological Survey at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1999–2012.—Continued

[All data except those shaded were published previously in Dinicola and others (2002), Dinicola (2003, 2004, 2006), Dinicola and Huffman (2004, 2006, 2007, 2009, 2012), and Huffman and Dinicola (2011). Laboratory data qualifier codes, such as "D" for dilution, are not shown. **Well or piezometer No.:** MW, monitoring well; P, piezometer; S, passive-diffusion sampler; T, denotes samplers deployed in an access tube. **Volatile organic compounds (VOCs)**: PCE, tetrachloroethene; TCE, trichloroethene; *cis*-DCE, *cis*-1,2-dichloroethene; *trans*-DCE, *trans*-1,2-dichloroethene; VC, vinyl chloride; 1,1,1-TCA, 1,1,1-trichloroethane; 1,1-DCA, 1,1-dichloroethane; CA, chloroethane; 1,1-DCE, 1,1-dichloroethene; total BTEX, sum of benzene, toluene, ethylbenzene, and xylene; total CVOCs, sum of chlorinated volatile organic compounds. **Abbreviations:** E, estimated value; M, presence verified but not quantified; µg/L, microgram per liter; <, actual value is less than value shown; ND, not detected; –, not analyzed]

Well or piezometer No.	Date sampled	1,1,1-TCA (µg/L)	1,1-DCA (µg/L)	CA (µg/L)	1,1-DCE (µg/L)	Total BTEX (µg/L)	Total CVOCs (µg/L)
			Upper aquifer southern plantation—Continued				
P1-6	06-08-99	<400	1,500	300	<400	E87	23,400
	06-14-01	<20	4,800	600	12	88	31,800
	06-13-02	<20	4,300	1,400	<20	63	14,600
	06-20-03	<50	380	270	<50	ND	3,550
	06-18-04	<20	200	88	<20	ND	1,090
	06-22-05	<130	370	400	<130	ND	7,960
	06-13-06	<100	1,200	2,600	<100	E68	4,940
	06-20-07	<8.0	69	78	<8.0	E1.4	380
	06-18-08	<200	400	1,200	<200	E46	20,200
	06-16-09	<100	130	310	<100	ND	7,210
	06-15-10	<10.0	211	–	<10	ND	11,700
	06-21-11	<10	74	–	<10	ND	3,600
	06-06-12	<10	4.2	–	<10	ND	230
P1-7	06-08-99	<670	<670	<1,300	<670	ND	64,300
	06-22-00	0.24	17	8.4	72	–	75,100
	06-14-01	<20	<20	<20	44	ND	67,200
	06-14-02	<20	14	<20	64	ND	105,100
	06-20-03	<2,000	<2,000	<4,000	<2,000	ND	65,800
	06-18-04	<3,300	<3,300	<6,700	<3,300	ND	103,100
	06-22-05	<2,000	<2,000	<4,000	<2,000	ND	92,800
	06-13-06	<2,000	<2,000	<4,000	<2,000	ND	70,800
	06-20-07	<2,000	<2,000	<4,000	<2,000	ND	81,300
	06-18-08	<2,000	<2,000	<4,000	<2,000	ND	117,300
	06-16-09	<2,000	<2,000	<4,000	<2,000	ND	145,900
	06-15-10	<50	<50	–	<50	ND	42,200
	06-21-11	<100	<100	–	<100	ND	28,000
	06-05-12	<100	<100	–	<100	ND	30,700
P1-8	06-07-99	<710	<710	<1,400	<710	ND	28,800
	06-14-01	<20	<20	<20	<20	ND	13,700
	06-13-02	<20	<20	<20	16	ND	31,900
	06-20-03	<10	E4	<20	<10	ND	270
	06-18-04	<1.0	<1.0	<2.0	<1.0	ND	26
	06-23-05	<1.0	<1.0	<2.0	<1.0	ND	28
	06-13-06	<20	<20	<40	<20	ND	680
	06-20-07	<4.0	<4.0	<8.0	<4.0	ND	72
	06-18-08	<10	<10	<20	<10	ND	440
	06-15-09	<5.0	<5.0	<10	<5.0	ND	220
	06-15-10	<1.0	<1.0	–	<1.0	ND	330
	06-21-11	<10	<10	–	<10	ND	9,930
	06-06-12	<10	<10	–	<10	ND	160

Table 3. Concentrations of selected volatile organic compounds in groundwater samples from monitoring wells and piezometers and passive-diffusion samplers collected by the U.S. Geological Survey at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1999–2012.—Continued

[All data except those shaded were published previously in Dinicola and others (2002), Dinicola (2003, 2004, 2006), Dinicola and Huffman (2004, 2006, 2007, 2009, 2012), and Huffman and Dinicola (2011). Laboratory data qualifier codes, such as "D" for dilution, are not shown. **Well or piezometer No.:** MW, monitoring well; P, piezometer; S, passive-diffusion sampler; T, denotes samplers deployed in an access tube. **Volatile organic compounds (VOCs)**: PCE, tetrachloroethene; TCE, trichloroethene; *cis*-DCE, *cis*-1,2-dichloroethene; *trans*-DCE, *trans*-1,2-dichloroethene; VC, vinyl chloride; 1,1,1-TCA, 1,1,1-trichloroethane; 1,1-DCA, 1,1-dichloroethane; CA, chloroethane; 1,1-DCE, 1,1-dichloroethene; total BTEX, sum of benzene, toluene, ethylbenzene, and xylene; total CVOCs, sum of chlorinated volatile organic compounds. **Abbreviations:** E, estimated value; M, presence verified but not quantified; µg/L, microgram per liter; <, actual value is less than value shown; ND, not detected; –, not analyzed]

Well or piezometer No.	Date sampled	PCE (µg/L)	TCE (µg/L)	*cis*-DCE (µg/L)	*trans*-DCE (µg/L)	VC (µg/L)	Ethane (µg/L)	Ethene (µg/L)
Upper aquifer southern plantation—Continued								
P1-9	06-08-99	<2,000	48,000	88,000	470	7,200	–	–
	06-22-00	E5.0	88,000	64,000	320	5,800	–	37
	06-14-01	<40	29,000	7,300	32	450	–	–
	06-13-02	<20	90,000	79,000	590	7,900	–	–
	06-20-03	<1,000	60,000	27,000	<1,000	1,800	–	–
	06-18-04	<1,300	50,000	23,000	<1,300	2,100	16	200
	06-23-05	<20	230	700	E3.2	97	<5.0	E4.0
	06-13-06	<5,000	74,000	140,000	E850	10,000	66	1,200
	06-20-07	<1,000	55,000	40,000	E200	4,200	32	340
	06-18-08	<400	9700	13,000	E80	2,000	12	160
	06-16-09	<2,500	62,000	100,000	E1,100	8,700	100	1,300
	06-14-10	<10.0	1,720	7,090	28.8	660	5.7	88
	06-21-11	<200	10,200	30,900	262	2,590	10	190
	06-05-12	<200	193	495	<10	107	E1.8	31
P1-10	06-07-99	<1,000	14,000	34,000	270	2,500	–	–
	06-22-00	1.0	8,700	13,000	100	2,300	–	2.3
	06-13-01	<20	6,600	12,000	68	1,800	–	–
	06-12-02	<20	4,600	7,000	55	2,000	–	–
	06-19-03	<400	2,300	9,400	<400	1,100	–	–
	06-18-04	<200	1,600	3,900	<200	890	E12	E46
	06-23-05	<100	1,100	3,000	E29	700	E3.0	7.0
	06-13-06	<1,000	2,200	27,000	E160	2,500	E19	E53
	06-20-07	<500	1,500	14,000	E130	1,700	E24	E34
	06-18-08	<200	490	5,800	E60	1,100	E20	E23
	06-15-09	<20	250	1,000	34	140	E11	E18
	06-14-10	<10.0	4,130	940	16.2	43.2	E16	E20
	06-21-11	<10	423	936	12.7	182	5.6	20
	06-05-12	<10	93	4,390	20	996	15	97
Intermediate aquifer								
MW1-25	06-22-00	–	–	–	–	–	–	5.8
	06-14-02	<20	276	1,830	31	278	–	–
	06-19-03	<67	E14	1,800	E34	210	–	–
	06-16-04	–	–	–	–	–	E5.0	E15
	06-21-05	<67	<67	1,700	E30	220	E6.0	E13
	06-14-06	–	–	–	–	–	E7.0	E14
	06-18-07	–	–	–	–	–	E4.0	E8.1
	06-17-08	<50	<50	1,700	E28	510	E9.0	E15
	06-17-09	<40	E7.3	1,600	49	240	E11	E19
	06-15-10	–	–	–	–	–	E17	E26
	06-22-11	<10	<10	1,140	26	150	E3.3	7.7
	06-06-12	–	–	–	–	–	E4.7	16

Table 3. Concentrations of selected volatile organic compounds in groundwater samples from monitoring wells and piezometers and passive-diffusion samplers collected by the U.S. Geological Survey at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1999–2012.—Continued

[All data except those shaded were published previously in Dinicola and others (2002), Dinicola (2003, 2004, 2006), Dinicola and Huffman (2004, 2006, 2007, 2009, 2012), and Huffman and Dinicola (2011). Laboratory data qualifier codes, such as “D” for dilution, are not shown. **Well or piezometer No.:** MW, monitoring well; P, piezometer; S, passive-diffusion sampler; T, denotes samplers deployed in an access tube. **Volatile organic compounds (VOCs)**: PCE, tetrachloroethene; TCE, trichloroethene; *cis*-DCE, *cis*-1,2-dichloroethene; *trans*-DCE, *trans*-1,2-dichloroethene; VC, vinyl chloride; 1,1,1-TCA, 1,1,1-trichloroethane; 1,1-DCA, 1,1-dichloroethane; CA, chloroethane; 1,1-DCE, 1,1-dichloroethene; total BTEX, sum of benzene, toluene, ethylbenzene, and xylene; total CVOCs, sum of chlorinated volatile organic compounds. **Abbreviations:** E, estimated value; M, presence verified but not quantified; µg/L, microgram per liter; <, actual value is less than value shown; ND, not detected; –, not analyzed]

Well or piezometer No.	Date sampled	1,1,1-TCA (µg/L)	1,1-DCA (µg/L)	CA (µg/L)	1,1-DCE (µg/L)	Total BTEX (µg/L)	Total CVOCs (µg/L)
			Upper aquifer southern plantation—Continued				
P1-9	06-08-99	<2,000	<2,000	<4,000	<2,000	ND	143,600
	06-22-00	<10	E2.6	<20	47	–	158,100
	06-14-01	<40	<40	<40	<40	ND	36,700
	06-13-02	<20	<20	<20	54	11	177,500
	06-20-03	<1,000	<1,000	<2,000	<1,000	ND	88,800
	06-18-04	<1,300	<1,300	<2,700	<1,300	ND	75,100
	06-23-05	<20	<20	<40	<20	ND	1,030
	06-13-06	<5,000	<5,000	<10,000	<5,000	ND	224,800
	06-20-07	<1,000	<1,000	<2,000	<1,000	ND	99,400
	06-18-08	<400	<400	<800	<400	ND	24,700
	06-16-09	<2,500	<2,500	<5,000	<2,500	ND	171,800
	06-14-10	<10	<10	–	<10	ND	9,500
	06-21-11	<200	<200	–	<200	ND	43,900
	06-05-12	<200	<200	–	<200	ND	790
P1-10	06-07-99	<1,000	<1,000	<2,000	<1,000	ND	50,700
	06-22-00	<0.10	1.2	E.10	16	–	24,100
	06-13-01	<20	<20	<20	11	ND	20,400
	06-12-02	<20	<20	<20	<20	ND	13,600
	06-19-03	<400	<400	<800	<400	ND	12,800
	06-18-04	<200	<200	<400	<200	ND	6,390
	06-23-05	<100	<100	<200	<100	ND	4,820
	06-13-06	<1,000	<1,000	<2,000	<1,000	ND	31,800
	06-20-07	<500	<500	<1,000	<500	ND	17,300
	06-18-08	<200	<200	<400	<200	ND	7,450
	06-15-09	<20	<20	<40	<20	ND	1,420
	06-14-10	<10.0	<10	–	<10	ND	5,120
	06-21-11	<10	<10	–	<10	ND	1,550
	06-05-12	<10	<10	–	<10	ND	5,500
			Intermediate aquifer				
MW1-25	06-22-00	–	–	–	–	–	–
	06-14-02	<20	<20	<20	<20	ND	2,410
	06-19-03	<67	<67	<130	<67	ND	2,050
	06-16-04	–	–	–	–	–	–
	06-21-05	<67	<67	<130	<67	ND	1,950
	06-14-06	–	–	–	–	–	–
	06-18-07	–	–	–	–	–	–
	06-17-08	<50	<50	<100	<50	ND	2,200
	06-17-09	<40	<40	<80	<40	ND	1,890
	06-15-10	–	–	–	–	–	–
	06-22-11	<10	<10	–	<10	ND	1,310
	06-06-12	–	–	–	–	–	–

Table 3. Concentrations of selected volatile organic compounds in groundwater samples from monitoring wells and piezometers and passive-diffusion samplers collected by the U.S. Geological Survey at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1999–2012.—Continued

[All data except those shaded were published previously in Dinicola and others (2002), Dinicola (2003, 2004, 2006), Dinicola and Huffman (2004, 2006, 2007, 2009, 2012), and Huffman and Dinicola (2011). Laboratory data qualifier codes, such as "D" for dilution, are not shown. **Well or piezometer No.:** MW, monitoring well; P, piezometer; S, passive-diffusion sampler; T, denotes samplers deployed in an access tube. **Volatile organic compounds (VOCs)**: PCE, tetrachloroethene; TCE, trichloroethene; *cis*-DCE, *cis*-1,2-dichloroethene; *trans*-DCE, *trans*-1,2-dichloroethene; VC, vinyl chloride; 1,1,1-TCA, 1,1,1-trichloroethane; 1,1-DCA, 1,1-dichloroethane; CA, chloroethane; 1,1-DCE, 1,1-dichloroethene; total BTEX, sum of benzene, toluene, ethylbenzene, and xylene; total CVOCs, sum of chlorinated volatile organic compounds. **Abbreviations:** E, estimated value; M, presence verified but not quantified; µg/L, microgram per liter; <, actual value is less than value shown; ND, not detected; –, not analyzed]

Well or piezometer No.	Date sampled	PCE (µg/L)	TCE (µg/L)	*cis*-DCE (µg/L)	*trans*-DCE (µg/L)	VC (µg/L)	Ethane (µg/L)	Ethene (µg/L)
Intermediate aquifer—Continued								
MW1-28	06-22-00	–	–	–	–	–	–	2.6
	06-14-02	<20	69	1,600	72	700	–	–
	06-19-03	<50	<50	1,200	68	470	–	–
	06-16-04	–	–	–	–	–	E4.0	26
	06-21-05	<67	<67	1,500	84	650	E4.0	E22
	06-14-06	–	–	–	–	–	<50	E18
	06-18-07	–	–	–	–	–	E3.0	E15
	06-17-08	<50	<50	1,400	64	930	E6.0	28
	06-17-09	<40	<40	1,400	84	730	E6.0	E35
	06-15-10	–	–	–	–	–	E10	E41
	06-22-11	<10	<10	1,400	77	590	E1.4	19
	06-06-12	–	–	–	–	–	E3.9	E31
MW1-38	06-20-00	–	–	–	–	–	–	0.57
	06-12-02	<0.20	<0.20	<0.20	<0.20	<0.20	–	–
	06-16-04	–	–	–	–	–	<5.0	<5.0
	06-24-05	<1.0	<1.0	<1.0	<1.0	<1.0	<5.0	<5.0
	06-14-06	–	–	–	–	–	<5.0	<5.0
	06-21-07	–	–	–	–	–	<5.0	<5.0
	06-17-08	–	–	–	–	–	E.26	<5.0
	06-17-09	–	–	–	–	–	<25	<25
	06-15-10	–	–	–	–	–	<5.0	<5.0
	06-22-11	<.1	<.1	<.1	<.1	<.2	<5.0	<5.0
	06-06-12	–	–	–	–	–	<.6	<.4
MW1-39	06-07-99	<1.0	<1.0	.30	<.50	1.0	–	–
	06-20-00	–	–	–	–	–	–	0.26
	06-12-01	–	–	–	–	–	–	–
	06-12-02	–	–	–	–	–	–	–
	06-19-03	<1.0	<1.0	E.60	<1.0	1.0	–	–
	06-16-04	–	–	–	–	–	<5.0	<5.0
	06-14-06	–	–	–	–	–	<50	<50
	06-21-07	–	–	–	–	–	<25	<25
	06-17-08	<1.0	<1.0	E.53	<1.0	3.0	<20	<20
	06-17-09	<1.0	<1.0	E.42	<1.0	2.1	<50	<50
	06-15-10	–	–	–	–	–	<50	<50
	06-22-11	<.1	<.1	.6	<.1	1.8	<5.0	<5.0
	06-06-12	–	–	–	–	–	<.6	<.4

Table 3. Concentrations of selected volatile organic compounds in groundwater samples from monitoring wells and piezometers and passive-diffusion samplers collected by the U.S. Geological Survey at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1999–2012.—Continued

[All data except those shaded were published previously in Dinicola and others (2002), Dinicola (2003, 2004, 2006), Dinicola and Huffman (2004, 2006, 2007, 2009, 2012), and Huffman and Dinicola (2011). Laboratory data qualifier codes, such as "D" for dilution, are not shown. **Well or piezometer No.:** MW, monitoring well; P, piezometer; S, passive-diffusion sampler; T, denotes samplers deployed in an access tube. **Volatile organic compounds (VOCs)**: PCE, tetrachloroethene; TCE, trichloroethene; *cis*-DCE, *cis*-1,2-dichloroethene; *trans*-DCE, *trans*-1,2-dichloroethene; VC, vinyl chloride; 1,1,1-TCA, 1,1,1-trichloroethane; 1,1-DCA, 1,1-dichloroethane; CA, chloroethane; 1,1-DCE, 1,1-dichloroethene; total BTEX, sum of benzene, toluene, ethylbenzene, and xylene; total CVOCs, sum of chlorinated volatile organic compounds. **Abbreviations:** E, estimated value; M, presence verified but not quantified; µg/L, microgram per liter; <, actual value is less than value shown; ND, not detected; –, not analyzed]

Well or piezometer No.	Date sampled	1,1,1-TCA (µg/L)	1,1-DCA (µg/L)	CA (µg/L)	1,1-DCE (µg/L)	Total BTEX (µg/L)	Total CVOCs (µg/L)
Intermediate aquifer—Continued							
MW1-28	06-22-00	–	–	–	–	–	–
	06-14-02	<20	<20	<20	<20	ND	2,440
	06-19-03	<50	<50	<100	<50	ND	1,730
	06-16-04	–	–	–	–	–	–
	06-21-05	<67	<67	<130	<67	ND	2,230
	06-14-06	–	–	–	–	–	–
	06-18-07	–	–	–	–	–	–
	06-17-08	<50	<50	<100	<50	ND	2,390
	06-17-09	<40	<40	<80	<40	ND	2,210
	06-15-10	–	–	–	–	–	–
	06-22-11	<10	<10	–	<10	ND	2,060
	06-06-12	–	–	–	–	–	–
MW1-38	06-20-00	–	–	–	–	–	–
	06-12-02	<0.20	<0.20	<0.20	<0.20	ND	ND
	06-16-04	–	–	–	–	–	–
	06-24-05	<1.0	<1.0	<2.0	<1.0	ND	ND
	06-14-06	–	–	–	–	–	–
	06-21-07	–	–	–	–	–	–
	06-17-08	–	–	–	–	–	–
	06-17-09	–	–	–	–	–	–
	06-15-10	–	–	–	–	–	–
	06-22-11	<.1	<.1	–	<.1	ND	ND
	06-06-12	–	–	–	–	–	–
MW1-39	06-07-99	<1.0	<1.0	<2.0	<1.0	ND	1.3
	06-20-00	–	–	–	–	–	–
	06-12-01	–	–	–	–	–	–
	06-12-02	–	–	–	–	–	–
	06-19-03	<1.0	<1.0	<2.0	<1.0	ND	1.6
	06-16-04	–	–	–	–	–	–
	06-14-06	–	–	–	–	–	–
	06-21-07	–	–	–	–	–	–
	06-17-08	<1.0	<1.0	<2.0	<1.0	ND	3.5
	06-17-09	<1.0	<1.0	<2.0	<1.0	ND	2.5
	06-15-10	–	–	–	–	–	–
	06-22-11	<.1	<.1	–	<.1	ND	2.4
	06-06-12	–	–	–	–	–	–

Table 3. Concentrations of selected volatile organic compounds in groundwater samples from monitoring wells and piezometers and passive-diffusion samplers collected by the U.S. Geological Survey at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1999–2012.—Continued

[All data except those shaded were published previously in Dinicola and others (2002), Dinicola (2003, 2004, 2006), Dinicola and Huffman (2004, 2006, 2007, 2009, 2012), and Huffman and Dinicola (2011). Laboratory data qualifier codes, such as "D" for dilution, are not shown. **Well or piezometer No.:** MW, monitoring well; P, piezometer; S, passive-diffusion sampler; T, denotes samplers deployed in an access tube. **Volatile organic compounds (VOCs)**: PCE, tetrachloroethene; TCE, trichloroethene; *cis*-DCE, *cis*-1,2-dichloroethene; *trans*-DCE, *trans*-1,2-dichloroethene; VC, vinyl chloride; 1,1,1-TCA, 1,1,1-trichloroethane; 1,1-DCA, 1,1-dichloroethane; CA, chloroethane; 1,1-DCE, 1,1-dichloroethene; total BTEX, sum of benzene, toluene, ethylbenzene, and xylene; total CVOCs, sum of chlorinated volatile organic compounds. **Abbreviations:** E, estimated value; M, presence verified but not quantified; µg/L, microgram per liter; <, actual value is less than value shown; ND, not detected; –, not analyzed]

Well or piezometer No.	Date sampled	PCE (µg/L)	TCE (µg/L)	*cis*-DCE (µg/L)	*trans*-DCE (µg/L)	VC (µg/L)	Ethane (µg/L)	Ethene (µg/L)
				Marsh (passive-diffusion samplers)				
S-1 T	10-19-12	<0.1	3.6	7.9	0.3	0.2	–	–
S1	07-07-00	<.1	1.4	8.2	.69	1.5	–	–
	06-29-05	<1.0	3.5	26	E.83	20	E2.0	E2.9
	06-18-10	<.1	0.7	5.3	.8	13	–	–
S-2 T	10-19-12	<.1	1.4	6.4	0.2	1.0	–	–
S-2	07-07-00	<.1	.6	11	1.3	2.8	–	–
	06-29-05	<2.5	6.4	92	E.69	17	E0.69	E1.4
	06-18-10	<1.0	41.7	549	21.8	91	–	–
	10-19-12	<.1	5.5	13	1.2	.9	–	–
S-2B T	10-19-12	<.1	.2	.6	.5	.8	–	–
S-2B	06-29-05	<1.0	4.9	34	1.1	11	E2.0	E2.4
	06-18-10	<.1	1.9	26	2.2	15	–	–
S-3 T	10-19-12	<.1	.2	.8	.8	.4	–	–
S-3	07-07-00	<.1	0.63	9.9	9.5	223	–	–
	06-29-05	<4.0	<4.0	E2.6	4.0	E2.2	E4	88
	06-18-10	<1.0	<1.0	13	6.7	181	–	–
S-3B T	10-19-12	<.1	1.0	4.5	.2	0.4	–	–
S-3B	06-29-05	<2.0	4.6	100	E0.88	39	5.0	7.3
	06-18-10	<.1	3.2	28	1.6	14	–	–
S-4 T	10-19-12	<10	141	20,900	90	3,200	–	–
S-4	07-07-00	<.1	45	19,100	136	5,610	–	–
	07-15-04	<1,000	<1,000	23,000	<1,000	17,000	22	1,100
	06-29-05	<2,000	12,000	53,000	<2,000	5,300	16	180
	06-18-10	<.1	.1	3.9	.4	5.8	–	–
	10-19-12	<10	23,200	73,200	492	5,130	–	–
S-4B T	10-19-12	<1.0	2.0	297	<1.0	80	–	–
S-4B	06-29-05	<4.0	120	140	E1.2	13	<5.0	<5.0
	06-18-10	<.1	.2	1	<.1	<.2	–	–
S-5 T	10-19-12	<1.0	111	1,210	4.4	52	–	–
S-5	07-07-00	<.1	49	80	1.3	17.5	–	–
	07-15-04	<50	E16	730	<50	97	E0.87	12
	06-29-05	<20	730	940	E7.8	60	<5.0	<5.0
	06-18-10	<.1	.4	1.2	<.1	.3	–	–
S-5B T	10-19-12	<1.0	1.9	434	3.0	418	–	–
S-5B	06-29-05	<400	1,200	12,000	E100	E330	<5.0	E2.4
	06-18-10	<1.0	4,550	3,020	146	576	–	–
S-6 T	10-19-12	<.1	5.0	9.8	<.1	.8	–	–
S-6	07-07-00	<.1	.2	8.0	.2	1.1	–	–
	07-15-04	<1.0	10	4.6	<1.0	<1.0	<5.0	<5.0
	06-29-05	<1.0	<1.0	3.0	E.24	2.5	E9.0	E12
	06-18-10	<.1	1.0	1.3	<.1	<.2	–	–

Table 3. Concentrations of selected volatile organic compounds in groundwater samples from monitoring wells and piezometers and passive-diffusion samplers collected by the U.S. Geological Survey at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1999–2012.—Continued

[All data except those shaded were published previously in Dinicola and others (2002), Dinicola (2003, 2004, 2006), Dinicola and Huffman (2004, 2006, 2007, 2009, 2012), and Huffman and Dinicola (2011). Laboratory data qualifier codes, such as "D" for dilution, are not shown. **Well or piezometer No.:** MW, monitoring well; P, piezometer; S, passive-diffusion sampler; T, denotes samplers deployed in an access tube. **Volatile organic compounds (VOCs)**: PCE, tetrachloroethene; TCE, trichloroethene; *cis*-DCE, *cis*-1,2-dichloroethene; *trans*-DCE, *trans*-1,2-dichloroethene; VC, vinyl chloride; 1,1,1-TCA, 1,1,1-trichloroethane; 1,1-DCA, 1,1-dichloroethane; CA, chloroethane; 1,1-DCE, 1,1-dichloroethene; total BTEX, sum of benzene, toluene, ethylbenzene, and xylene; total CVOCs, sum of chlorinated volatile organic compounds. **Abbreviations:** E, estimated value; M, presence verified but not quantified; µg/L, microgram per liter; <, actual value is less than value shown; ND, not detected; –, not analyzed]

Well or piezometer No.	Date sampled	1,1,1-TCA (µg/L)	1,1-DCA (µg/L)	CA (µg/L)	1,1-DCE (µg/L)	Total BTEX (µg/L)	Total CVOCs (µg/L)
Marsh (passive-diffusion samplers)							
S-1 T	10-19-12	<0.1	0.7	–	<0.1	ND	13
S1	07-07-00	<.1	4.6	24	<.10	2.6	40
	06-29-05	<1.0	3.6	3.7	<1.0	E.30	57
	06-18-10	<.1	1.4	–	<.1	.5	21
S-2 T	10-19-12	<.1	.8	–	<.1	ND	9.8
S-2	07-07-00	<.1	6.1	10	<.10	2.6	31
	06-29-05	<2.5	2.5	E2.6	<2.5	E.53	121
	06-18-10	<1.0	2.1	–	<1.0	ND	705
	10-19-12	<.1	1.1	–	<.1	0.5	22
S-2B T	10-19-12	<.1	1.0	–	<.1	0.8	3.1
S-2B	06-29-05	<1.0	3.4	6.1	<1.0	E0.94	60
	06-18-10	<.1	2.8	–	<.1	.3	47
S-3 T	10-19-12	<.1	.2	–	<.1	0.2	2.4
S-3	07-07-00	<.10	454	36	<.10	4.5	733
	06-29-05	<1.0	100	40	<4.0	E.9	148
	06-18-10	<1.0	64	–	<1.0	ND	264
S-3B T	10-19-12	<.1	0.3	–	<.1	0.3	6.4
S-3B	06-29-05	<2.0	2.1	7.7	<2.0	E1.3	154
	06-18-10	<.1	.3	–	<.1	.4	47
S-4 T	10-19-12	<10	10	--	14	ND	24,350
S-4	07-07-00	<.1	42	20	76	2.9	25,000
	07-15-04	<1,000	<1,000	<2,000	<1,000	ND	40,000
	06-29-05	<2,000	<2,000	<4,000	<2,000	ND	70,300
	06-18-10	<.1	<.1	–	<.1	ND	10
	10-19-12	<10	11	--	64	12	102,100
S-4B T	10-19-12	<1.0	<1.0	–	<1.0	ND	370
S-4B	06-29-05	<4.0	<4.0	<8.0	<4.0	ND	274
	06-18-10	<.1	<.1	–	<.1	ND	1.2
S-5 T	10-19-12	<1.0	<1.0	–	<1.0	ND	1,370
S-5	07-07-00	<.1	<.1	–	.2	.1	148
	07-15-04	<50	<50	<100	<50	ND	843
	06-29-05	<20	<20	<40	<20	ND	1,730
	06-18-10	<.1	<.1	–	<.1	ND	1.9
S-5B T	10-19-12	<1.0	<1.0	–	<1.0	ND	850
S-5B	06-29-05	<400	<400	<800	<400	ND	13,600
	06-18-10	<1.0	<1.0	–	5.4	ND	8,290
S-6 T	10-19-12	<.1	<.1	–	<.1	ND	15
S-6	07-07-00	<.1	<.1	–	<.1	.6	9.5
	07-15-04	<1.0	<1.0	<2.0	<1.0	ND	14
	06-29-05	<1.0	<1.0	<2.0	<1.0	ND	5.7
	06-18-10	<.1	<.1	–	<.1	ND	2.3

This page intentionally left blank.

Appendix A. Quality Assurance and Control of U.S. Geological Survey 2012 Geochemical Sampling

Quality assurance and control of geochemical sampling included collecting duplicate and field blank samples for selected redox-sensitive analytes and volatile organic compounds (VOCs). The field blank was collected by pumping inorganic blank water and VOC-free water through clean tubing to determine possible sampling contamination. Complete laboratory quality assurance and control data from TestAmerica Laboratories are on file with the U.S. Geological Survey (USGS) Washington Water Science Center in Tacoma, Washington.

A duplicate sample was collected and analyzed by the National Water Quality Laboratory (NWQL) for organic carbon, manganese, nitrate plus nitrite, sulfate, and chloride for piezometers P1-7 and P1-9 (table A1). The relative percent difference of duplicate results for these constituents for the sample collected at P1-7 agreed within 4.3 percent. The relative percent difference for the same constituents collected from piezometer P1-9 did not compare as favorably, ranging from 4.0 to 21.5 percent. Duplicate samples were collected and analyzed for VOCs by the NWQL and dissolved gases (ethane and ethene) by TestAmerica Laboratories at piezometers P1-7 and P1-9, with relative percent difference between as high as 4.2 and 80 percent, respectively. Piezometer P1-9 historically has had highly variable constituent concentrations in samples, and the duplicate sample does not reflect poor precision and or accuracy from field sampling or laboratory techniques.

Chloroethenes, chloroethanes, and BTEX (benzene, toluene, ethylbenzene, and xylene) compounds were not detected in the field blank sample collected at piezometer P1-10. No changes were made to the data set based on these quality control data.

Table A1. Quality assurance data collected by the U.S. Geological Survey at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 2012.

[**Well or piezometer No.:** D denotes duplicate sample; FB denotes field blank sample. **Volatile organic compounds (VOCs):** PCE, tetrachloroethene; TCE, trichloroethene; *cis*-DCE, *cis*-1,2-dichloroethene; *trans*-DCE, *trans*-1,2-dichloroethene; VC, vinyl chloride; TCA, 1,1,-trichloroethane; 1,1-DCA, 1,1-dichloroethane; 1,1-DCE, 1,1-dichloroethene; BTEX, benzene, toluene, ethylbezene, and xylene; CVOCs, sum of all chloroethenes and chloroethane concentrations shown in table. **Abbreviations:** µg/L, micrograms per liter; mg/L, milligrams per liter; ND, not detected. **Symbols**: <, actual value is less than the value shown; –, not analyzed. *, concentration is in micrograms per liter]

Well or piezometer No.	Date sampled	PCE (µg/L)	TCE (µg/L)	*cis*-DCE (µg/L)	*trans*-DCE (µg/L)	VC (µg/L)	Ethane (µg/L)	Ethene (µg/L)	TCA (µg/L)	1,1-DCA (µg/L)	1,1-DCE (µg/L)
P1-7	06-05-12	<200	9,230	19,000	129	2,380	60	330	<100	<100	<100
P1-7D	06-05-12	<200	9,950	20,200	125	2,530	57	320	<100	<100	<100
P1-9	06-05-12	<400	193	495	<10	107	E1.8	31	<200	<200	<200
P1-9D	06-05-12	<400	581	1,430	11	219	<0.6	11	<200	<200	<200
P1-10FB	06-06-12	<0.2	<0.1	<0.1	<0.1	<0.2	<0.6	<0.4	<0.1	<0.1	<0.1

Well or piezometer No.	Date sampled	Total BTEX (µg/L)	Total CVOCs (µg/L)	Filtered (dissolved) organic carbon (mg/L)	Filtered nitrate + nitrite (mg/L as N)	Filtered manganese (mg/L)	Filtered sulfate (mg/L)	Dissolved methane (mg/L)	Filtered chloride (mg/L)
MW1-25	06-05-12	ND	31,000	5.25	<0.02	1.5	10	4.6	26
MW1-25D	06-05-12	ND	33,000	4.94	<0.02	1.6	10	4.3	27
MW1-38	06-05-12	ND	800	0.47	<0.02	0.11	8.9	0.30	7.7
MW1-38D	06-05-12	ND	2,200	0.64	<0.02	0.12	8.4	0.17	13
P1-10FB	06-06-12	ND	ND	<0.23	<0.02	<0.16*	<0.09	<0.2*	<0.06

Publishing support provided by the U.S. Geological Survey
Publishing Network, Tacoma Publishing Service Center

For more information concerning the research in this report, contact the
Director, Washington Water Science Center
U.S. Geological Survey
934 Broadway, Suite 300
Tacoma, Washington 98402
http://wa.water.usgs.gov

Huffman—**Geochemical and Selected Volatile Organic Compound Data, OU1, Naval Undersea Warfare Center, Keyport, Washington, June and October 2012**—Data Series 766