Ground-Water-Quality Data for a Treated-Wastewater Plume Undergoing Natural Restoration, Ashumet Valley, Cape Cod, Massachusetts, 1994–2004

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Contents

Figure

Tables

Conversion Factors, Vertical and Horizontal Datum, and Abbreviations

Multiply	By	To obtain
foot (ft)	0.3048	meter (m)
gallon (gal)	3.785	liter (L)
gram (g)	0.03527	ounce (oz)
inch (in.)	2.54	centimeter (cm)
mile (mi)	1.609	kilometer (km)
kilogram (kg)	2.205	pound (lb)
Aluminum [Al] (µM)	26.98	Aluminum [Al] (µg/L)
Ammonium [NH_4] (µM)	14.01	Ammonium [NH_4 as N] (µg/L)
Arsenic [As] (µM)	74.92	Arsenic [As] (µg/L)
Barium [Ba] (µM)	137.3	Barium [Ba] (µg/L)
Boron [B] (µM)	10.81	Boron [B] (µg/L)
Cadmium [Cd] (µM)	112.4	Cadmium [Cd] (µg/L)
Calcium [Ca] (µM)	40.08	Calcium [Ca] (µg/L)
Carbon, inorganic, dissolved [DIC] (µM)	12.01	Carbon, inorganic, dissolved [DIC] (µg/L)
Carbon, organic, dissolved [DOC] (µM)	12.01	Carbon, organic, dissolved [DOC] (µg/L)
Chloride [Cl] (µM)	35.45	Chloride [Cl] (µg/L)
Chromium [Cr] (µM)	52.00	Chromium [Cr] (µg/L)
Cobalt [Co] (µM)	58.93	Cobalt [Co] (µg/L)
Copper [Cu] (µM)	63.54	Copper [Cu] (µg/L)
Iron [Fe] (µM)	55.85	Iron [Fe] (µg/L)
Lead [Pb] (µM)	207.2	Lead [Pb] (µg/L)
Magnesium [Mg] (µM)	24.31	Magnesium [Mg] (µg/L)
Manganese [Mn] (µM)	54.94	Manganese [Mn] (µg/L)
Molybdenum [Mo] (µM)	95.94	Molybdenum [Mo] (µg/L)
Nickel [Ni] (µM)	58.71	Nickel [Ni] (µg/L)
Nitrate [NO_3] (µM)	14.01	Nitrate [NO_3 as N] (µg/L)
Nitrite [NO_2] (µM)	14.01	Nitrite [NO_2 as N] (µg/L)
Oxygen, dissolved [O_2] (µM)	31.99	Oxygen, dissolved [O_2] (µg/L)
Phosphorus [P] (µM)	30.97	Phosphorus [P] (µg/L)
Potassium [K] (µM)	39.10	Potassium [K] (µg/L)
Silicon [Si] (µM)	28.09	Silicon [Si] (µg/L)
Sodium [Na] (µM)	22.98	Sodium [Na] (µg/L)
Strontium [Sr] (µM)	87.62	Strontium [Sr] (µg/L)
Sulfate [SO_4] (µM)	96.06	Sulfate [SO_4] (µg/L)
Thallium [Tl] (µM)	204.3	Thallium [Tl] (µg/L)
Uranium [U] (µM)	238.0	Uranium [U] (µg/L)
Vanadium [V] (µM)	50.94	Vanadium [V] (µg/L)
Zinc [Zn] (µM)	65.37	Zinc [Zn] (µg/L)

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

$$°F=(1.8\times°C)+32$$

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

$$°C=(°F-32)/1.8$$

Vertical coordinate information is referenced to the North American Vertical Datum of 1929 (NGVD 29).

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

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

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 millimoles per liter (mM) or micromoles per liter (µM).

AFCEE	Air Force Center for Environmental Excellence
DIC	dissolved inorganic carbon
DOC	dissolved organic carbon
ICP-AES	inductively coupled plasma atomic emission spectroscopy
L/min	liter per minute
µM	micromoles per liter
µm	micrometer
µg/L	micrograms per liter
mL	milliliter
mL/min	milliliter per minute
mg/L	milligram per liter
mN	milliNormal
mm	millimeter
mM	millimoles per liter
MLS	multilevel sampler
MMR	Massachusetts Military Reservation
NAGT	National Association of Geoscience Teachers
NGVD 29	National Geodetic Vertical Datum of 1929
nm	nanometer
NRP	National Research Program
NTU	Nephelometric Turbidity Unit
PVC	polyvinyl chloride
USGS	U.S. Geological Survey
µS/cm	microsiemen per centimeter at 25°C

Ground-Water-Quality Data for a Treated-Wastewater Plume Undergoing Natural Restoration, Ashumet Valley, Cape Cod, Massachusetts, 1994–2004

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Denis R. LeBlanc[1], and Larry B. Barber[1]

Navigation note: text colored in blue will link to a table on single click.

Abstract

A plume of contaminated ground water extends from former disposal beds at the Massachusetts Military Reservation wastewater-treatment plant toward Ashumet Pond, and farther southward toward coastal ponds and Vineyard Sound, Cape Cod, Massachusetts. Treated sewage-derived wastewater was discharged to the rapid-infiltration beds for nearly 60 years before the disposal site was moved to a different location in December 1995.

Water-quality samples were collected periodically from monitoring wells and multilevel samplers during and after the disposal period to characterize the nature and extent of the contaminated ground water and to observe the water-quality changes after the wastewater disposal ceased. Data are presented here for water samples collected from 1994 through 2004 from 16 wells (at 2 locations) and 14 multilevel samplers (at 9 locations) along a longitudinal transect that extends through one of the disposal beds. Data collected from the treated-wastewater plume are presented in tabular format. These data include field parameters; concentrations of cations, anions, nitrate, ammonium, and organic and inorganic carbon species; and ultraviolet/visible absorbance. The natural restoration of the sand and gravel aquifer after removal of the nearly 60-year-long treated-wastewater source, along with interpretations of the water quality in the treated-wastewater plume on Cape Cod, have been documented in several published reports that are listed in the references.

Introduction

Treated wastewater was discharged to rapid-infiltration beds at the Massachusetts Military Reservation (MMR) wastewater-treatment plant on Cape Cod for nearly 60 years. The disposal created a ground-water contaminant plume that extends southward from the former disposal site toward Vineyard Sound. The plume, which was first described by LeBlanc (1984), is about 3,000 to 5,500 ft wide, 100 to 150 ft thick, and 18,000 ft long (Savoie and LeBlanc, 1998). The plume of wastewater-contaminated ground water is composed of a complex mixture of inorganic and organic solutes typical of treated sewage-derived wastewater (Barber, 1998; Barber and others, 1988; Ceazan and others, 1989; Field and others, 1992; Kent and others, 2000; Kent and Fox, 2004; Kent and Maeder, 1999; LeBlanc, 1984; Parkhurst and others, 2003; Repert and others, 2006; Stollenwerk, 1996; Thurman and others, 1986; and Walter and others, 1996). The plume supports a microbial ecosystem that includes bacteria and protozoa (Harvey and Barber, 1992; Harvey and George, 1987; Harvey and others, 1984; Kinner and others, 2002; Kinner and others, 1998; Kinner and others, 1997; and Metge and others, 1993) and has well-developed biogeochemical zones (Abrams and Loague, 2000; Abrams and others, 1998; Kent and others, 1994; LeBlanc and others, 1999; Lee and Bennett, 1998; Smith and others, 2004; Smith and Duff, 1988; Smith and others, 1991a; Smith and others, 1991b). Volatile organic compounds that were released from a former fire-training area near the wastewater-treatment plant also are found in the plume (Air Force Center for Environmental Excellence, 2005).

In an effort to document changes in ground-water quality after wastewater disposal was stopped, the U.S. Geological Survey (USGS) collected ground-water samples near the abandoned rapid-infiltration beds (fig. 1). The samples were analyzed for field parameters; concentrations of cations, anions, nitrate, ammonium, and organic and inorganic carbon species; and ultraviolet/visible absorbance.

This report compiles selected ground-water quality and water-level data that were collected as part of this study. The data set includes water-quality data from monitoring wells and multilevel samplers (MLS) that transect the plume along a flow line extending about 2,300 ft, beginning upgradient of the former infiltration beds at multilevel sampler site SDW 474 and ending near Ashumet Pond (fig. 1). The plume extends farther downgradient toward Vineyard Sound;

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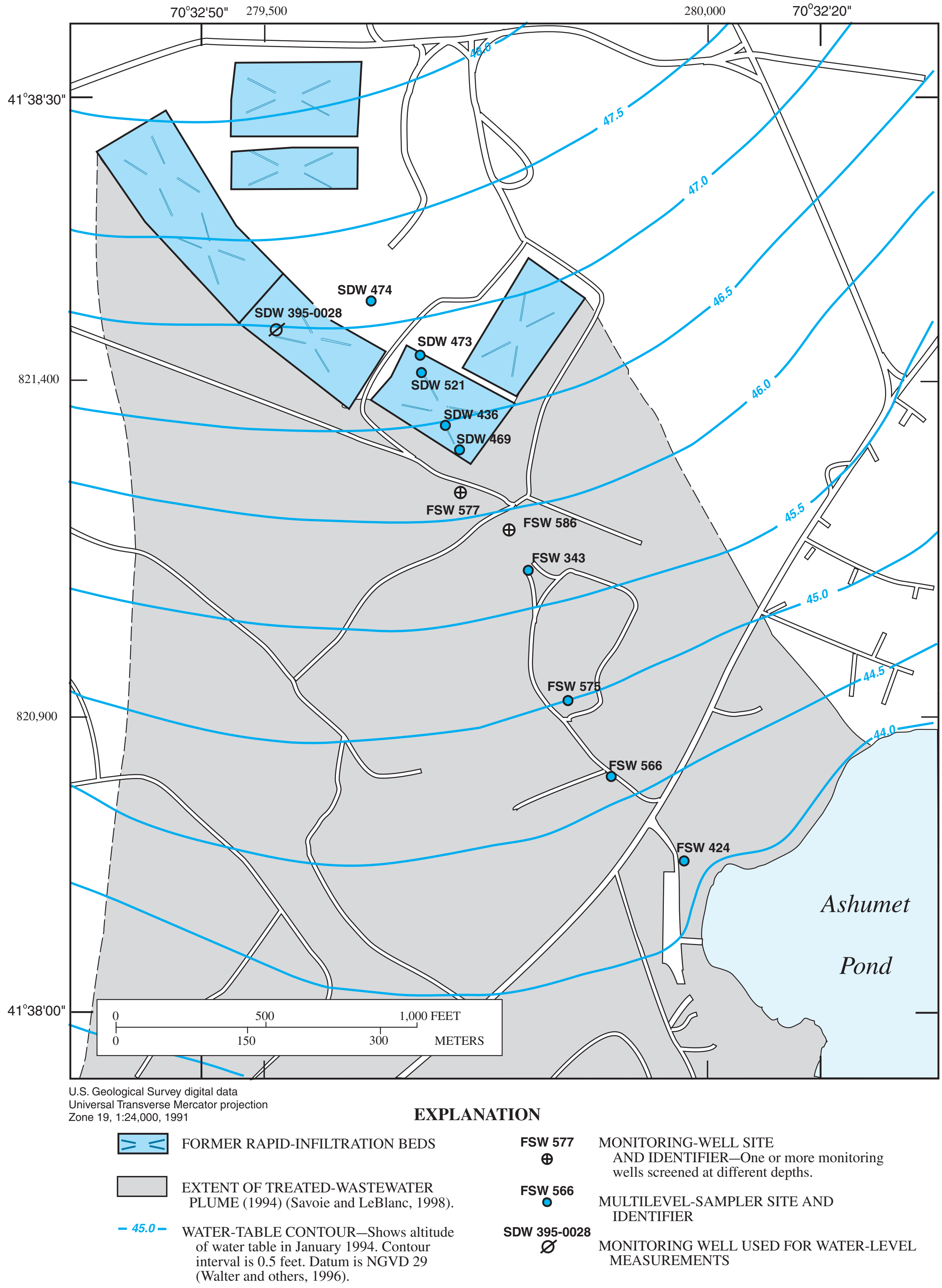
[1] U.S. Geological Survey.

[2] U.S. Environmental Protection Agency.



U.S. Geological Survey digital data
Universal Transverse Mercator projection
Zone 19, 1:24,000, 1991

Figure 1. Location of study area, monitoring-well and multilevel-sampler sites, partial extent of treated-wastewater plume, and water-table contours, Ashumet Valley, Cape Cod, Massachusetts.

additional water-quality data for that area can be found in Savoie and LeBlanc (1998). The data set also includes water levels from monitoring well SDW 395-0028, located in the abandoned rapid-infiltration beds near the sampled wells and multilevel samplers. Water levels were measured frequently in monitoring well SDW 395-0028 during the period of water-quality sampling. Findings from the first few years of water-quality monitoring have been presented elsewhere (Barber and Keefe, 1999; Campo and Hess, 1999; Kent and Maeder, 1999; LeBlanc and others, 1999; Smith and others, 1999). A comprehensive discussion of the effect of natural restoration on nitrogen and dissolved organic carbon (DOC) can be found in Repert and others (2006); on the fate of zinc contamination in Kent and others (2000); and on phosphate contamination in Parkhurst and others (2003). Other data, research projects, and reports related to the treated-wastewater plume can be found at the USGS Cape Cod Toxic Substances Hydrology Research Site website (U.S. Geological Survey, 2006).

Monitoring Ground-Water Quality in the Treated-Wastewater Plume

Ground-water quality samples included in this report were collected from 16 monitoring wells at 2 well-cluster sites and 14 MLS at 9 sites during 11 years (1994–2004) (table 1). The samples selected for this report were collected during large sampling rounds, in which many other wells and MLS within the plume were sampled in addition to those included in this report. The sites presented in this report were chosen because they complement research and previously published reports that are found in the references. The selected MLS and well-cluster sites are along a flow line through the treated-wastewater plume extending from the source area to Ashumet Pond (fig. 1). The wells and MLS vertically intersect the plume core where there are steep geochemical and microbiological gradients (Smith and others, 1991a).

Monitoring Wells

The monitoring wells were installed with a hollow-stem-auger drilling method. The wells are constructed with 2.0-inch-diameter polyvinyl chloride (PVC) well casing and screens and finished at the land surface with protective steel casings. The aquifer material was allowed to collapse naturally around the casings and screens. The wells were installed with 2-ft-long screens and were developed by pumping until the discharging water became clear. Monitoring-well information and water levels from monitoring well SDW 395-0028 are given in table 2 and table 3, respectively. Water levels at well clusters FSW 577 and FSW 586 are estimated from a water-table map based on measurements made in January 1994 (Walter and others, 1996).

Multilevel Samplers

The MLS also were installed with a hollow-stem-auger drilling method and natural collapse of the aquifer material. The MLS are constructed with 15 color-coded polyethylene tubes (0.25-inch outside diameter) within a 1.25-inch-diameter PVC casing. The color-coded tubes extend from land surface, down the PVC casing, and out into the aquifer through holes drilled in the PVC at various depths. The open bottom end of each polyethylene tube, referred to as the sampling port, is screened with a fine nylon fabric. The MLS sampling ports were developed by pumping until the discharging water became clear. Water levels were not measured in the MLS; however, water levels at the MLS locations were estimated from the water-table map of January 1994. Multilevel-sampler information is given in table 4.

Sample Collection

Ground-water samples were collected from the monitoring wells using a Keck Model SP-81 submersible pump fitted with Teflon tubing and an isolation packer. The pump intake was set about 2 ft above the top of the screen and the packer was inflated to isolate the water in the casing above the packer from the pump intake. The pumping rate was about 1 to 1.3 L/min, and a minimum of three casing volumes below the packer was evacuated before field water-quality measurements were made and samples were collected. Ground-water samples were collected from the MLS by using a GeoPump2 peristaltic suction pump fitted with Norprene tubing that was connected directly to the MLS tubing. The pumping rate for each MLS port was about 300 mL/min, and a minimum of three tubing volumes was evacuated before field water-quality measurements were made. Water-quality samples were collected after field water-quality parameters (specific conductance, pH, temperature, dissolved oxygen, and turbidity) measured in the discharge had stabilized.

Sample Analysis

The field water-quality measurements were made periodically during well purging until the measurements stabilized. The specific conductance was measured with a Hach Model 44600 or an Orion Model 126 conductivity meter. The pH was measured with an Orion Model 250A meter, an Orion Ross Sure-Flow Model 81-72 pH electrode, and an Orion stainless-steel temperature probe. Dissolved oxygen concentrations greater than 31 µM were generally measured with a Yellow Springs Instruments Model 54 dissolved oxygen meter and electrode in the field or laboratory. Dissolved oxygen concentrations less than 31 µM were generally measured in the field with a quantitative colorimetric method (CHEMetrics VVR Photometer and self-filling reagent ampoules). Temperature was measured by using the Orion stainless-steel probe in conjunction with the pH probe. Turbidity was measured with a Hach Model 2100P Portable Turbidimeter. Alkalinity was determined in the field on selected samples with expected elevated concentrations of iron(II) or in the laboratory on additional selected samples by an incremental titration method (Fishman and Friedman, 1989) with the endpoint determined by using Gran plots.

Samples for analysis of concentrations of cations, anions, metals, ammonium, DOC, dissolved inorganic carbon (DIC), and ultraviolet/visible absorbance were filtered through an in-line 0.45-µM polyvinylidene filter (Millex). A new filter was used at each well or multilevel sampler port. The cations and metals samples were preserved with nitric acid to pH less than 2, the ammonium samples were preserved with sulfuric acid to pH less than 2, and the anion samples were frozen. The pumps and sampling equipment were decontaminated after sampling each well or MLS with laboratory-grade deionized water. This method for decontamination was shown to be sufficient in other studies (Savoie and LeBlanc, 1998). Duplicate samples were collected and analyzed at about 10 percent of the wells and MLS ports that were sampled. At selected wells or MLS ports, an aliquot of the filtered sample was passed through a cartridge containing Chelex and preserved for cation analysis. Chelex is a cation exchanger that has a high selectivity for multivalent cations and, therefore, retains free metal ions while allowing strongly complexed metal ions to pass (Kent and Maeder, 1999).

Methods of analysis for all laboratory parameters changed during the study period and are described in table 5. Concentrations of selected anions, DIC, and DOC were determined for water samples by the USGS National Research Program laboratory in Boulder, CO. Concentrations of selected inorganic solutes were determined using inductively coupled plasma atomic emission spectroscopy by the USGS National Research Program laboratory in Menlo Park, CA. The descriptions of methods, limits of quantitation, precision, and accuracy for results of analyses for selected inorganic solutes are described in Savoie and others (2004). Minor changes in detection limits in the inorganic solutes analysis resulted from changes in instrumentation and minor modifications to the methods made during the 10-year study period.

Water-Quality Data for Samples Collected in the Treated-Wastewater Plume

Water samples collected from 16 wells and 14 MLS were analyzed for field parameters, concentrations of cations, anions, ammonium, DOC, and DIC, and ultraviolet/visible adsorbance. The field parameters are shown in table 6; concentrations of selected anions and ammonium are shown in table 7; concentrations of DOC and DIC, and ultraviolet/visible absorbance are shown in table 8; and concentrations of selected inorganic solutes are shown in table 9.

- part 1: aluminum, arsenic, boron, barium, calcium, cadmium, cobalt, chromium, copper
- part 2: iron, potassium, magnesium, manganese, molybdenum, sodium, nickel, phosphorous
- part 3: lead, silica, strontium, thallium, uranium, vanadium, zinc

Duplicate analyses for the analytes are included in the data tables and designated by “-D”. Samples that were filtered through the Chelex filter are designated by “-X” in table 9.

Summary

During 1994 to 2004, the U.S. Geological Survey collected ground-water samples from wells and multilevel samplers in the treated-wastewater plume that originates from rapid-infiltration disposal beds at the Massachusetts Military Reservation, Cape Cod, Massachusetts. The water samples were collected to study the natural restoration of water quality in the plume since wastewater disposal ended in 1995. This report presents data that complement published and planned research reports about the natural restoration of the plume. The sampled sites (16 monitoring wells and 14 multilevel samplers) are along a 2,300-ft-long transect from the infiltration beds to Ashumet Pond. The chemical data presented include field parameters (specific conductance, pH, dissolved oxygen concentrations, turbidity, temperature, alkalinity); concentrations of cations, anions, ammonium, dissolved organic carbon (DOC), and dissolved inorganic carbon (DIC); and ultraviolet/visible absorbance.

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