Field Tests of Nylon-Screen Diffusion Samplers and Pushpoint Samplers for Detection of Metals in Sediment Pore Water, Ashland and Clinton, Massachusetts, 2003

By Marc J. Zimmerman, Don A. Vroblesky, Kimberly W. Campo,
Andrew J. Massey, and Walter Scheible

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Contents

Abstract 1
Introduction 2
Study Areas 3
Study Design 6
Preliminary Laboratory Testing and Analysis 6
    Sampler Equilibration 6
    Equipment Blanks 7
Sediment Pore Water Field-Sampling Techniques 11
    Nylon-Screen Diffusion Samplers 11
    Pushpoint Samplers 12
    Site Selections 13
    Quality-Control Sampling and Results 13
Comparison of Metal Concentrations in Pore Water Collected with Nylon-Screen Diffusion and Pushpoint Samplers 15
    Time Series of Nylon-Screen Diffusion Sampler Data 16
    Comparison of all Nylon-Screen Diffusion Samples and Pushpoint Samples by Site 17
Summary and Conclusions 18
Acknowledgments 19
References Cited 19

Figures

1–3. Photographs showing:
    1. The 125-milliliter nylon-screen diffusion sampler 2
    2. PVC shovel for inserting nylon-screen diffusion sampler into sediments 3
    3. *A*, The 91-centimeter PushPoint Extreme Sampler; and *B*, Detail of tip 3
4. Map showing locations of study areas: *A*, Mill Pond, Sudbury River, Ashland, Massachusetts; and *B*, Rigby Brook, Clinton, Massachusetts 4
5, 6. Graphs showing:
    5. Comparisons of *A*, concentrations; and *B*, relative percent differences between water samples obtained from the test container and from nylon-screen diffusion samplers after 4 days of equilibration 7
    6. Laboratory quality-control data for *A*, barium; and *B*, zinc for components of sampling equipment 10
7. Photograph showing collection of a field sample from nylon-screen diffusion sampler by using syringe, filter, and hypodermic 12
8. Schematic showing distribution of sampling sites at the *A*, Nyanza study area, Ashland; and *B*, Rigby Brook study area, Clinton 14

9, 10. Boxplots showing:
- 9. Selected metals concentrations in 25 samples collected with nylon-screen diffusion samplers and 35 samples collected with pushpoint samplers at the Nyanza study area, Ashland, May 2003 16
- 10. Selected metals concentrations in 24 samples collected with nylon-screen diffusion samplers and 34 samples collected with pushpoint samplers at the Rigby Brook study area, Clinton, May to June 2003 17

11–14. Graphs showing:
- 11. Time series data for *A*, aluminum; *B*, arsenic; *C*, barium; *D*, cobalt; *E*, iron; *F*, manganese; and *G*, zinc at the Nyanza study area, Ashland, May 2003 21
- 12. Time series data for *A*, aluminum; *B*, arsenic; *C*, barium; *D*, cobalt; *E*, iron; *F*, manganese; and *G*, zinc at the Rigby Brook study area, Clinton, May to June 2003 25
- 13. Results for final round of sampling with nylon-screen diffusion samplers and pushpoint samplers for *A*, aluminum; *B*, barium; *C*, cobalt; *D*, iron; *E*, manganese; and *F*, zinc at all Nyanza study-area sampling sites, Ashland, May 2003 29
- 14. Results for final round of sampling with nylon-screen diffusion samplers and pushpoint samplers for *A*, aluminum; *B*, barium; *C*, cobalt; *D*, iron; *E*, manganese; and *F*, zinc at all Rigby Brook study-area sampling sites, Clinton, June 2003.......... 35

Tables

1. Concentrations of solutes in water collected from bucket by using peristaltic pump and from 125-micron-mesh nylon-screen diffusion samplers immersed in the bucket, November 2000 6
2. Concentrations of metals detected during quality-control testing of the sampling process 8
3. Target analytes, their project action limits, and minimum reporting levels used for this study.......... 9
4. Medians of paired relative percent-difference values for individual metals in nylon-screen diffusion samples and pushpoint samples collected at the Nyanza study area, Ashland, Massachusetts, and at the Rigby Brook study area, Clinton, Massachusetts 15
5. Concentrations of metals detected in ground water 20 cm below sediment surface at selected well locations for the Nyanza Superfund Site, Ashland, June 2001 18
6. Concentrations of metals in quality-control samples during field studies at the Nyanza study area, Ashland, and the Rigby Brook study area, Clinton 41
7. Concentrations of metals detected in samples from the Nyanza study area, Ashland 46
8. Concentrations of metals detected in samples from Rigby Brook study area, Clinton 49

Conversion Factors, Datum, and Abbreviations

Multiply	By	To obtain
centimeter (cm)	0.3937	inch (in.)
liter (L)	0.2642	gallon (gal)
meter (m)	1.094	yard (yd)
micron (µ)	0.00003937	inch (in.)
milliliter (mL)	61,020	cubic inch (in^3)
millimeter (mm)	0.03937	inch (in.)

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

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).

Ag	silver
Al	aluminum
As	arsenic
Ba	barium
Be	beryllium
Cd	cadmium
Co	cobalt
Cr	chromium
Cu	copper
Fe	iron
Hg	mercury
Mn	manganese
Mo	molybdenum
Ni	nickel
Pb	lead
Sb	antimony
V	vanadium
Zn	zinc
DO	dissolved oxygen
ICP-MS	inductively coupled plasma—mass spectrometry
NSDS	nylon-screen diffusion sampler
PAL	project action limit
PPS	pushpoint sampler
RPD	relative percent difference
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
VOC	volatile organic compound

Field Tests of Nylon-Screen Diffusion Samplers and Pushpoint Samplers for Detection of Metals in Sediment Pore Water, Ashland and Clinton, Massachusetts, 2003

By Marc J. Zimmerman[1], Don A. Vroblesky[2], Kimberly W. Campo[1],
Andrew J. Massey[1], and Walter Scheible[3]

Abstract

Efficient and economical screening methods are needed to detect and to determine the approximate concentrations of potentially toxic trace-element metals in shallow groundwater-discharge areas (pore water) where the metals may pose threats to aquatic organisms; such areas are likely to be near hazardous-waste sites. Pushpoint and nylon-screen diffusion samplers are two complementary options for use in such environments.

The pushpoint sampler, a simple well point, is easy to insert manually and to use. Only 1 day is required to collect samples. The nylon-screen diffusion sampler is well suited for use in sediments that do not allow a pump to draw water into a pushpoint sampler. In this study, both types of devices were used in sediments suitable for the use of the pushpoint sampler. Sampling with the nylon-screen diffusion sampler requires at least two site visits: one to deploy the samplers in the sediment, and a second to retrieve the samplers and collect the samples after a predetermined equilibration period.

Extensive laboratory quality-control studies, field testing, and laboratory analysis of samples collected at the Nyanza Chemical Waste Dump Superfund site along the Sudbury River in Ashland, Massachusetts, and at a Superfund site-assessment location on Rigby Brook in Clinton, Massachusetts, indicate that these two devices yield comparable results for most metals and should be effective tools for pore-water studies. The nylon-screen diffusion samplers equilibrated within 1–2 days in homogeneous, controlled conditions in the laboratory. Nylon-screen diffusion samplers that were not purged of dissolved oxygen prior to deployment yielded results similar to those that were purged. Further testing of the nylon-screen diffusion samplers in homogeneous media would help to resolve any ambiguities about the data variability from the field studies.

Comparison of data from replicate samples taken in both study areas shows that even samples taken from sites within a half-meter radius of one another have distinct differences in pore-water trace-element concentrations. Sequential replicate samples collected with the pushpoint sampler yield consistent results; moving the pushpoint sampler even 5 to 10 centimeters, however, generally produces a second set of data that differs enough from the first set of data to indicate a heterogeneous environment. High concentration biases for barium and zinc in laboratory and field samples collected with nylon-screen diffusion samplers, however, may make their use inappropriate for studies of these metals.

Analyzing samples with high iron concentrations required sample dilution by factors of 2 or 10. Because these dilutions caused increases in the reporting levels by the same proportion, a substantial fraction of the data was censored. The results from undiluted samples, however, indicate that both devices should be useful for sampling ground water with metal concentrations close to reporting limits.

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Introduction

Metal-enriched ground water may pose threats to aquatic organisms in ground-water discharge areas in many environmental settings, particularly near hazardous-waste sites. The development of efficient and economical screening devices to detect metal-enriched ground water in streambed sediments near the ground-water/surface-water interface would enable investigators to assess potential threats to aquatic organisms and to identify areas of contaminated ground-water discharge. The data obtained from such reconnaissance-level sampling would then provide a basis for intensive site investigations. Because of this need for reconnaissance-level sampling devices, the U.S. Geological Survey (USGS), in cooperation of the U.S. Environmental Protection Agency (USEPA), through the Measurement and Monitoring for the 21st Century Initiative (21M2), conducted an investigation of the effectiveness during 2003 of the stainless-steel push-point sampler (PPS) and the nylon-screen diffusion sampler (NSDS). This Office of Solid Waste and Emergency Response (OSWER) initiative is designed to identify and encourage the use of promising measurement and monitoring technologies in response to waste-management and site-cleanup program needs by matching existing and emerging technologies with OSWER program and client needs. The investigation was carried out at two study areas with previously reported contamination: the Nyanza Chemical Waste Dump Superfund site (Campbell and others, 2002) along the Sudbury River in Ashland, MA, and at a Superfund site-assessment location along Rigby Brook in Clinton, MA. In particular, screening with these devices was intended to determine whether trace-metal concentrations exceeded guidelines (Project Action Limits, or PALs, also known as Surface Water Benchmarks, including Ambient Water Quality Criteria; Bart Hoskins, Ecological Risk Assessor, U.S. Environmental Protection Agency, written commun., 2002) intended to protect aquatic life, not to determine whether drinking-water criteria were exceeded or to detect these metals at trace-level concentrations.

The report includes results of laboratory-based quality-control studies. The chemical analyses for this investigation include results for 21 metals; however, the report focuses on the few metals that were most frequently detected.

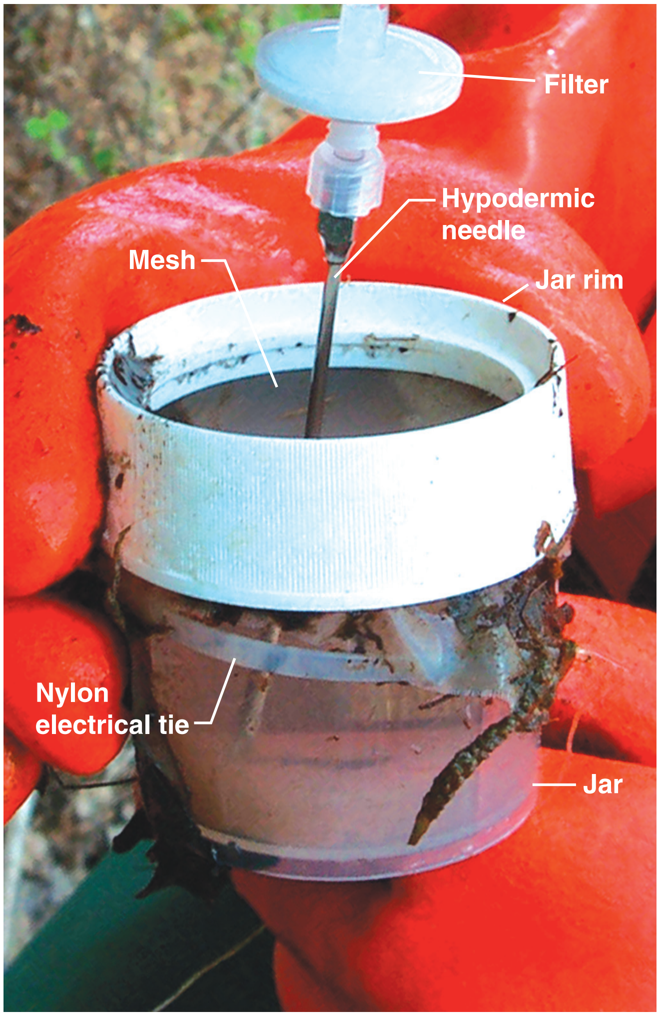


Figure 1. The 125-milliliter nylon-screen diffusion sampler.

The NSDS consists of a 63-mm diameter, 125-mL polypropylene jar (Thomas Scientific) with the center of the cap removed, and with only a screw-on rim for securing a piece of 120-µ nylon-screen mesh (Small Parts, Inc.). The mesh, approximately 10 cm by 10 cm, is placed over the jar's mouth and secured by screwing the rim back onto the jar (fig. 1). The 125-mL volume of the NSDS is sufficient to meet the USEPA laboratory's 100-mL sample-volume requirement. In practice, the NSDS is filled with deionized water, buried in the sediment and allowed to equilibrate with its environment. To minimize the possibility of contaminating the site with a metal shovel when inserting the NSDS into the sediment, a shovel-like device constructed from 10-cm polyvinyl chloride (PVC) pipe (with 6.4-mm wall thickness) is used for sampler deployment (fig. 2). Beveled edges enable this shovel to penetrate even the coarsest sediments to a depth of at least 20 cm. Preliminary tests showed that concentrations of inorganic constituents in well water and arsenic (As) in streambed sediments in samples collected by NSDSs compared favorably with concentrations measured in samples collected by other methods (Vroblesky and others, 2002).

A PPS is designed to sample sediment pore water with minimal disturbance to the site. The PushPoint Extreme Sampler (fig. 3), the commercially produced model used in this study, consists of a 6.4-mm diameter, stainless-steel tube with a machined point and 4-cm-long slotted screen (0.635-mm slots) near the tip (Henry, 2001); this study used a 91-cm-long version of the sampler. An internal guard rod positioned within the bore adds rigidity to the sampler during insertion.

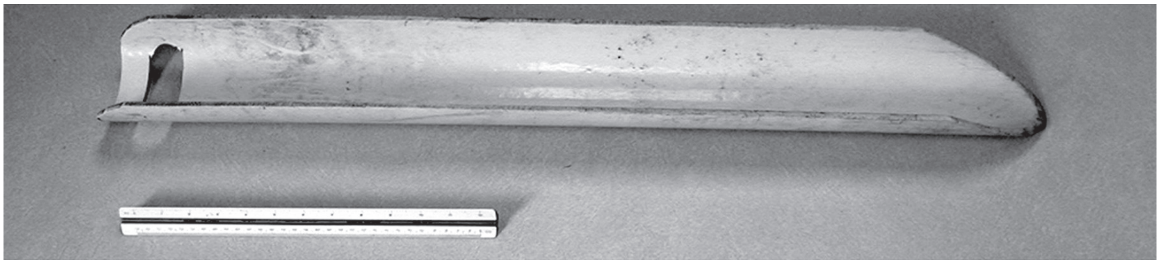


Figure 2. PVC shovel for inserting nylon-screen diffusion sampler into sediments.

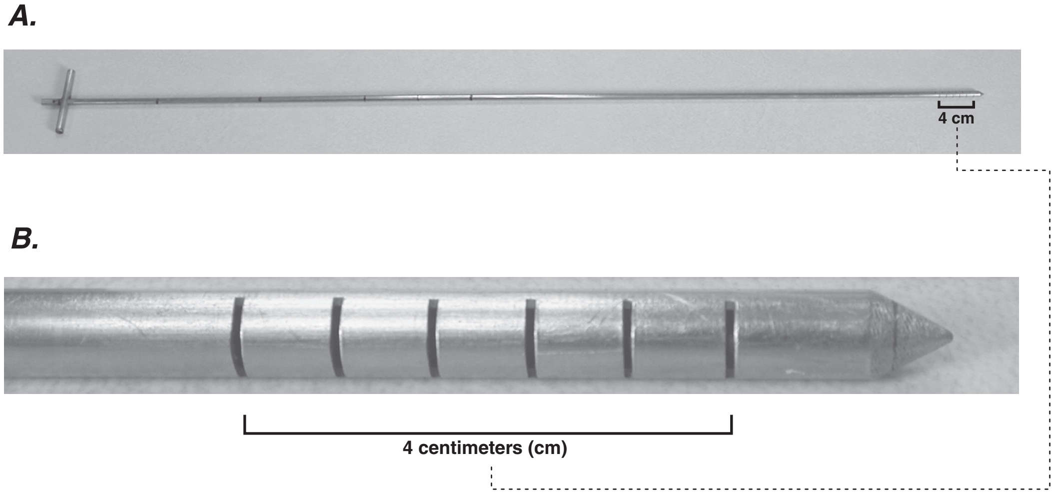


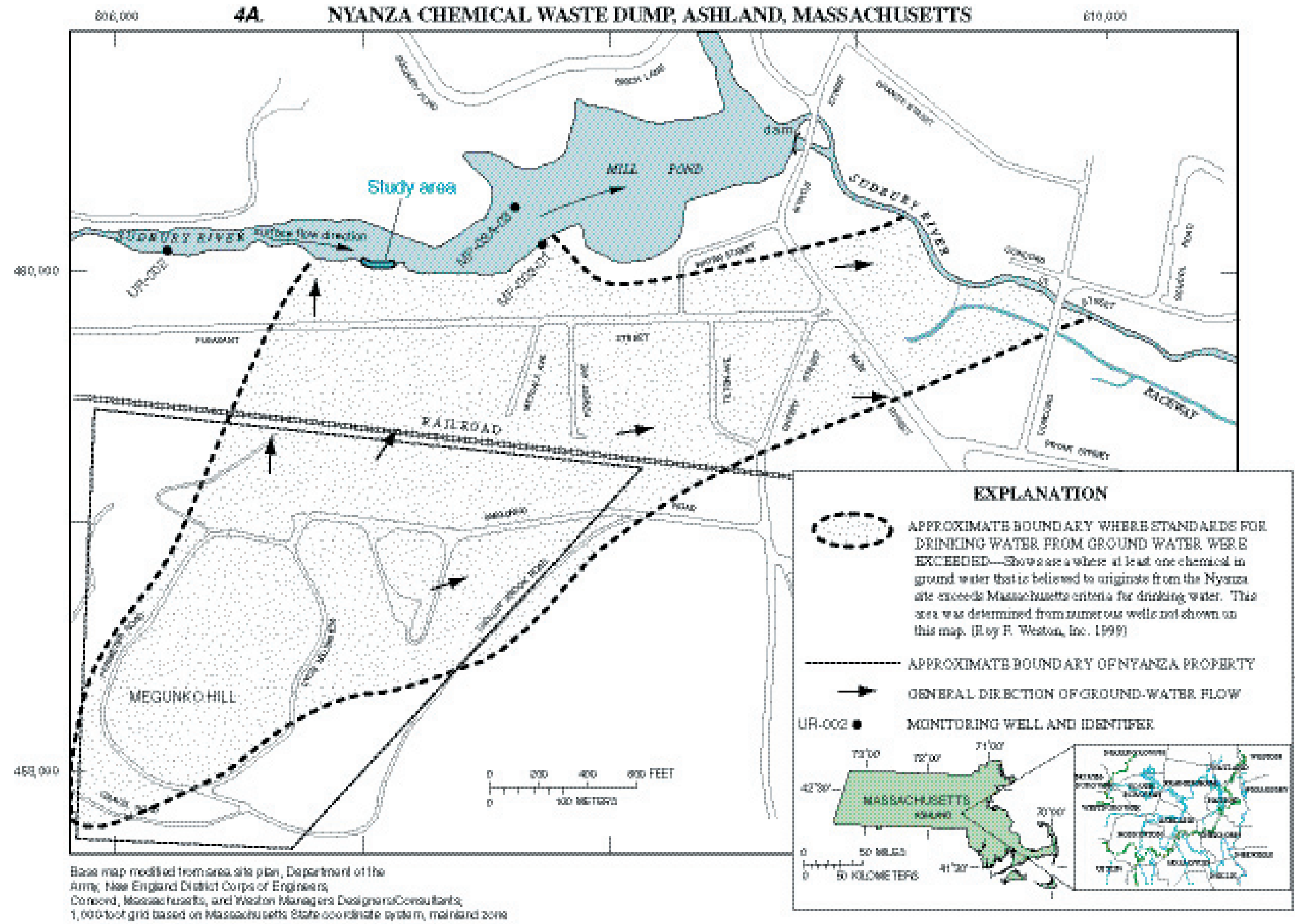
Figure 3. *A*, The 91-centimeter PushPoint Extreme Sampler; and *B*, Detail of tip. Screen is 4 centimeters long and tube diameter is 6.4 millimeters.

The PPS has been used to collect water for analysis of volatile organic compounds (VOCs) (Henry, 2001; Church and others, 2002; Zimmerman and others, 2005), but has not been tested for characterization of metals in pore water. Although USGS manuals recommend against using metal sampling devices to collect samples for metal analysis (Wilde and others 1999), that guidance is intended for sampling to determine low-level concentrations near detection levels, not the higher concentrations usually associated with contamination.

Not all sediments have physical characteristics that allow water to be drawn in readily through the PPS; fine organic material, silt, and clay may block the openings (Zimmerman and others, 2005). In these situations, the NSDS, which can be left buried in the sediments for any length of time, may prove more appropriate. Therefore, the efficacy of both tools was examined in this study.

Study Areas

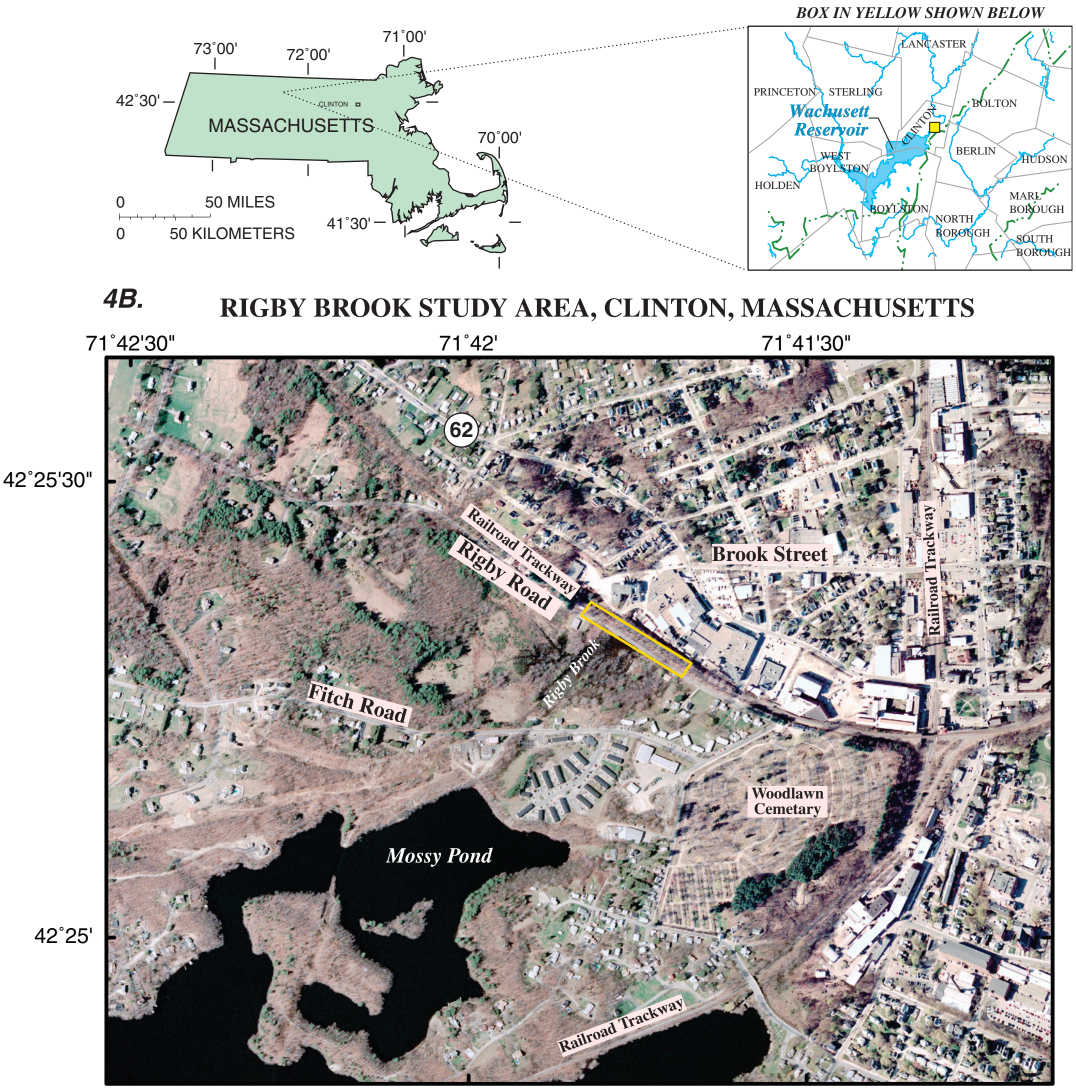
The study areas (fig. 4) were selected because the composition and texture of their sediments differ from one another and may affect the efficacy of the two sampling devices. According to a previous study (Roy F. Weston, Inc., 2001), the Nyanza study area is within a zone affected by a ground-water plume that includes organic contaminants and metals such as As, beryllium (Be), chromium (Cr), cobalt (Co), manganese (Mn), and mercury (Hg). The local hydrogeologic setting includes glacial lake deposits, till, and fractured granite. The surficial streambed sediments at the Nyanza site contain decayed and living plant material.



Base map modified from area site plan, Department of the Army, New England District Corps of Engineers, Concord, Massachusetts, and Weston Managers Designers/Consultants; 1,000-foot grid based on Massachusetts State coordinate system, mainland zone

Figure 4. Locations of study areas: *A*, Mill Pond, Sudbury River, Ashland, Massachusetts; and *B*, Rigby Brook, Clinton, Massachusetts.

4B.



Base from Massachusetts Executive Office of Environmental Affairs, MassGIS, 1:24,000, 2004
Polyconic projection, 1983 North American Datum
Massachusetts coordinate system mainland zone

EXPLANATION

Figure 4—Continued. Locations of study areas: *A*, Mill Pond, Sudbury River, Ashland, Massachusetts; and *B*, Rigby Brook, Clinton, Massachusetts.

The Rigby Brook study area, which was the subject of a Superfund site-assessment investigation (Forest Lyford, U.S. Geological Survey, oral commun., 2002), is impounded by a beaver dam. An abandoned manufacturing plant and a former waste dump adjacent to the impounded area on Rigby Road were thought to be sources of contamination, prompting the site assessment. The sediments of flooded areas of the Rigby Brook study area contained the remnants of plant matter, but many sampling sites there were primarily silty or sandy in nature. The coarse, sandy sediments of the Rigby Brook study area contrasted with the fine-grained sediments of the Nyanza study area.

Study Design

The study was divided into two distinct phases. First, the equilibration time for the NSDS units was determined. Equilibration was tested at the USGS's South Carolina Water Science Center in Columbia, SC, and at Columbia Analytical Services in Rochester, NY. Quality-control testing was done at the MA-RI Water Science Center in Northborough, MA, to determine whether the NSDSs, PPSs, or other equipment used introduced unacceptable contamination to samples. A commercial laboratory in South Carolina and Columbia Analytical Services analyzed the equilibration samples; the USEPA Region I Laboratory in Chelmsford, MA, used inductively coupled plasma-mass spectrometry (ICP-MS) to analyze the quality-control and field samples for dissolved metals.

The field investigation with the two types of sampling devices constituted the second phase of the study. The NSDS units were deployed for up to 2 weeks at 15 sites in each study area. One to five NSDSs were left at each site. Samples were collected at intermediate times at five sites in each study area. At the end of the 2-week period, the remaining NSDS and PPS samples were collected.

The field-study design, which included the insertion of multiple NSDS units at the same sites, was based on the implicit assumption of a homogeneous sedimentary environment. Coarse, and occasionally impenetrable, substrate, however, made it difficult to place samplers within 20 cm of each other. In practice, multiple samplers were deployed within about a 0.5-m radius. In addition, the PPSs were expected to capture the same pore water as the NSDSs during the same time intervals. Nonetheless, variability among the NSDS samples, in particular, and between the NSDS and PPS samples was expected. Replicate PPS samples collected without removing and reinserting the PPSs were expected to produce the most consistent results; replicate PPS samples collected from the same site after removing and reinserting the PPS 5 to 20 cm away from the original position were expected to demonstrate more variability than the other replicate PPS samples.

Preliminary Laboratory Testing and Analysis

Before deployment and sampling, the samplers were subjected to a series of laboratory quality-control tests. These tests determined the rate at which water inside the NSDS units equilibrated with the external environment and whether either the equipment or the sampling process could provide a source of sample contamination.

Sampler Equilibration

To determine the minimum time required for equilibration with the external medium, various NSDS units were filled with deionized water and placed in a bucket of water containing arsenic and chloride at concentrations of about 230 µg/L and 265 mg/L, respectively. On the first and fourth days of equilibration, one NSDS unit was removed from the bucket to provide a water sample for analysis. On the seventh day, two NSDS units were removed to provide duplicate water samples. On each of these days, water also was pumped from the test bucket for analysis. Arsenic and chloride concentrations in the NSDS units had equilibrated with concentrations in the test-bucket water by the first day (table 1). In a separate test, NSDSs were filled with deionized water and allowed to equilibrate in test containers holding solutions of 16 dissolved metals. Once a day, during a 4-day period, one NSDS was removed and samples from the NSDS and the test container were analyzed. After 4 days, concentrations of all but one metal in water from the samplers corresponded closely to concentrations in the test solution (fig. 5). Only the results for Ag had a high relative percent difference (RPD); this difference probably was a result of decreased analytical accuracy because the Ag concentration was lower than that of the other analytes.

Table 1. Concentrations of solutes in water collected from bucket by using peristaltic pump and from 125-micron-mesh nylon-screen diffusion samplers immersed in the bucket, November 2000.

[NS, not sampled; NSDS, nylon-screen diffusion samplers]

Day	Arsenic, in micrograms per liter		Chloride, in milligrams per liter	
	Sample pumped from bucket	Sample from NSDS	Sample pumped from bucket	Sample from NSDS
0	NS	0	NS	0
1	240	240	260	270
4	240	250	270	260
7	240	250	270	260
7	230	240	270	270

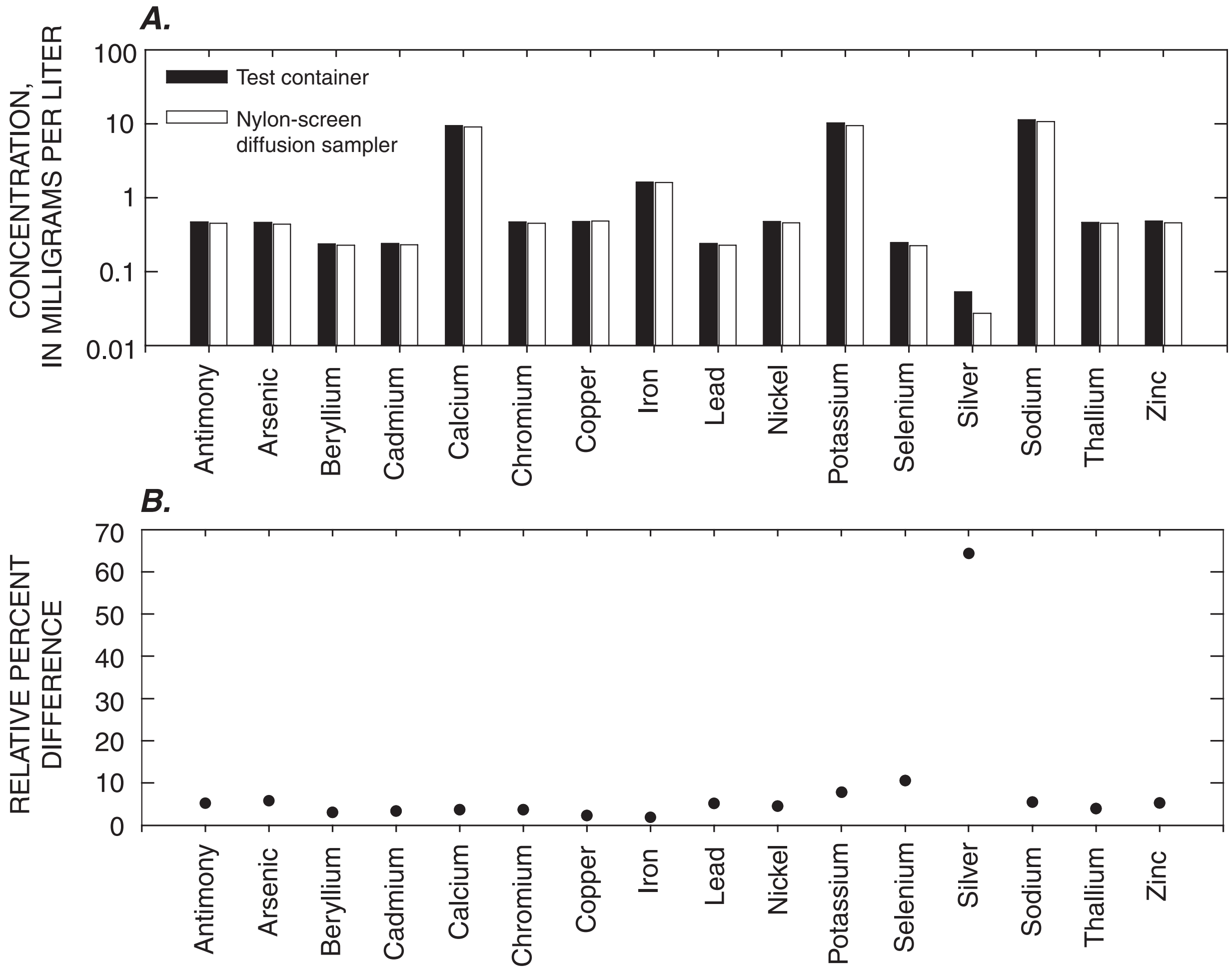


Figure 5. Comparisons of *A*, concentrations; and *B*, relative percent differences between water samples obtained from the test container and from nylon-screen diffusion samplers after 4 days of equilibration.

Equipment Blanks

NSDS parts, PPSs, and other pieces of sampling equipment were subjected to a series of equipment-blank tests in triplicate under controlled laboratory conditions. These tests were designed to determine if the equipment would release metals in concentrations high enough to interfere with the interpretation of analytical results from field-sampling applications.

Various NSDS units were separated into their constituent parts and soaked in 5 percent HCl in 19-L acid-cleaned plastic buckets for 3 days. The units were then rinsed with tap water and deionized water before soaking for 7 days in 4 L of deionized water obtained from the USEPA Region I Laboratory. Samples were collected from all of the containers and acidified to pH 2 with Ultrex-grade nitric acid, as were all samples in this study. All samples were analyzed by the USEPA. The data (table 2) indicate that, over the 7-day period, the plastic components did not release metals in concentrations that would compromise an investigation of a contaminated site. Three metals were detected: Barium (Ba), Copper (Cu), and Zinc (Zn). Ba was detected at the reporting level of 0.2 µg/L in a single sample; Cu was detected in two samples at concentrations slightly higher than the reporting level of 1.0 µg/L (according to the official USEPA laboratory-data reports, the low-level Cu concentrations detected were caused by laboratory or trip-blank contamination); and only one set of samples (the water from the bucket containing the plastic NSDS jar bottoms and nylon mesh) yielded consistent indications of a metal leaching from the sampler components; these samples had a mean (n=3, where n is the number of samples) Zn concentration of 15 µg/L, approximately 12.5 percent of the PAL (table 3).

Table 2. Concentrations of metals detected during quality-control testing of the sampling process.

[All laboratory (lab) blank water was obtained from the U.S. Environmental Protection Agency. Concentrations in micrograms per liter (parts per billion); NSDS, nylon-screen diffusion sampler; nd, not detected; PPS, pushpoint sampler; SS, stainless steel]

Quality-control sample	Barium	Calcium	Copper	Chromium	Lead	Manganese	Nickel	Zinc
Soaking NSDS Components								
Lab blank water	nd	nd	nd	nd	nd	nd	nd	nd
Lab blank water	nd	nd	nd	nd	nd	nd	nd	nd
Lab blank water	nd	nd	nd	nd	nd	nd	nd	nd
Lab blank water collected from bucket	0.20	nd	1.2	nd	nd	nd	nd	8.3
Lab blank water collected from bucket	nd	nd	1.1	nd	nd	nd	nd	7.2
Lab blank water collected from bucket	nd	nd	nd	nd	nd	nd	nd	7.1
Lab blank water from bucket with plastic jars and nylon mesh	nd	nd	nd	nd	nd	nd	nd	16
Lab blank water from bucket with plastic jars and nylon mesh	nd	nd	nd	nd	nd	nd	nd	14
Lab blank water from bucket with plastic jars and nylon mesh	nd	nd	nd	nd	nd	nd	nd	14
Lab blank water from bucket with plastic jar caps	nd	nd	nd	nd	nd	nd	nd	nd
Lab blank water from bucket with plastic jar caps	nd	nd	nd	nd	nd	nd	nd	nd
Lab blank water from bucket with plastic jar caps	nd	nd	nd	nd	nd	nd	nd	nd
NSDS Sampling Procedure								
Lab blank poured from NSDS that was assembled then disassembled	nd	100	nd	nd	nd	nd	nd	29
Lab blank poured from NSDS that was assembled then disassembled	nd	nd	nd	nd	nd	nd	nd	nd
Lab blank poured from NSDS that was assembled then disassembled	nd	nd	nd	nd	nd	nd	nd	5.8
Lab blank from NSDS using syringe only	nd	nd	nd	nd	nd	0.21	nd	13
Lab blank from NSDS using syringe only	nd	nd	nd	nd	nd	nd	nd	11
Lab blank from NSDS using syringe only	nd	nd	nd	nd	nd	nd	nd	10
Lab blank from NSDS using syringe and SS hypodermic	0.23	nd	1.0	nd	nd	nd	nd	16
Lab blank from NSDS using syringe and SS hypodermic	.26	nd	2.0	nd	1.2	nd	0.5	23
Lab blank from NSDS using syringe and SS hypodermic	nd	nd	2.0	nd	1.1	nd	nd	15
Lab blank from NSDS using syringe, SS hypodermic, and filter	23	nd	2.0	nd	nd	nd	nd	5.5
Lab blank from NSDS using syringe, SS hypodermic, and filter	30	nd	nd	nd	nd	nd	nd	nd
Lab blank from NSDS using syringe, SS hypodermic, and filter	51	nd	1.0	nd	nd	nd	nd	17

Table 2. Concentrations of metals detected during quality-control testing of the sampling process.—Continued

[All laboratory (lab) blank water was obtained from the U.S. Environmental Protection Agency. Concentrations in micrograms per liter (parts per billion); NSDS, nylon-screen diffusion sampler; nd, not detected; PPS, pushpoint sampler; SS, stainless steel]

Quality-control sample	Barium	Calcium	Copper	Chromium	Lead	Manganese	Nickel	Zinc
PPS Sampling Procedure								
PPS external rinse water	nd	nd	2.0	2.8	nd	1.9	2.7	41
PPS external rinse water	nd	nd	nd	.73	nd	1.1	.76	16
PPS external rinse water	nd	nd	1.0	1.9	nd	1.0	2.4	29
Peristaltic pump and tubing	nd	nd	nd	nd	nd	nd	nd	7.8
Peristaltic pump and tubing	nd	nd	nd	nd	nd	nd	nd	7.3
Peristaltic pump and tubing	nd	nd	nd	nd	nd	nd	nd	8.1
Peristaltic pump, tubing, and PPS	nd	nd	nd	nd	nd	10	.75	12
Peristaltic pump, tubing, and PPS	nd	nd	nd	nd	nd	9.5	.45	11
Peristaltic pump, tubing, and PPS	6.3	nd	nd	nd	nd	12	.54	11
Peristaltic pump, tubing, PPS, and filter	nd	nd	nd	nd	nd	11	.7	nd
Peristaltic pump, tubing, PPS, and filter	16	nd	nd	nd	nd	.61	nd	nd
Peristaltic pump, tubing, PPS, and filter	10	nd	nd	nd	nd	.34	nd	nd

Table 3. Target analytes, their project action limits, and minimum reporting levels used for this study.

[na, not available]

Analyte	Project action limit (micrograms per liter)	Reporting level (micrograms per liter)
Aluminum (Al)	87	5
Antimony (Sb)	30	.5
Arsenic (As)	150	.5
Barium (Ba)	4	.2
Beryllium (Be)	.66	.2
Cadmium (Cd)	2.2	.2
Calcium (Ca)	116,000	100
Chromium (Cr)	74	.5
Cobalt (Co)	23	.2
Copper (Cu)	9	.2
Iron (Fe)	1,000	50
Lead (Pb)	2.5	.2
Magnesium (Mg)	82,000	100
Manganese (Mn)	120	.2
Molybdenum (Mo)	na	.5
Nickel (Ni)	52	.2
Selenium (Se)	5	1.0
Silver (Ag)	.36	.2
Thallium (Tl)	12	.5
Vanadium (V)	20	.2
Zinc (Zn)	120	5

In addition, a second series of quality-control tests assessed the capacity for the sampling process to contaminate samples (table 2). Samples of deionized water were collected as components were sequentially added to the sampling apparatus. For example, an NSDS sample was first collected with only a syringe; next, a sample was collected with a syringe and a hypodermic needle; finally, a sample was collected after a 0.45-µ Millipore HPF Millex-HN filter unit was added to the syringe and hypodermic needle. Zn was detected in most of the samples; the highest average Zn concentration, 18 µg/L (n=3), or 15 percent of the PAL, was associated with the use of the stainless-steel hypodermic needle to collect the sample. Ba, at an average concentration (n=3) of 35 µg/L, was detected in association with the filter apparatus; this concentration exceeds the PAL (4 µg/L). On the other hand, use of the filter may have decreased the Zn concentrations in the samples. Detections of Cu were ascribed by the laboratory analytical data report to lab-blank or trip-blank contamination, not to the samples themselves. Other analytes were detected sporadically and at concentrations below their respective PALs.

A similar series of tests was performed on the PPS sampling components. Some Ba contamination was again detected in association with the filter. Cu, Cr, Mn, nickel (Ni), and Zn were detected in the external rinse water (fig. 6). The highest concentrations of Zn, the only commonly detected metal in these tests, was found in external rinse-water samples from the PPS at 41 µg/L, substantially less than the PAL of 120 µg/L. Cu was once more ascribed to lab or trip-blank contamination. The concentrations of Cr, Mn, and Ni were also substantially less than their PALs of 74 µg/L, 120 µg/L, and 52 µg/L, respectively.

As stated previously, this process generally showed that maximum detected analyte concentrations were lower than the PALs. Ba exceeded its PAL in these quality-control tests only when the filter unit was included. Thus, if appropriate quality-control samples are collected, it is reasonable to assume that contamination from these devices is unlikely to affect data interpretations when investigating suspected sites of possible high contamination.

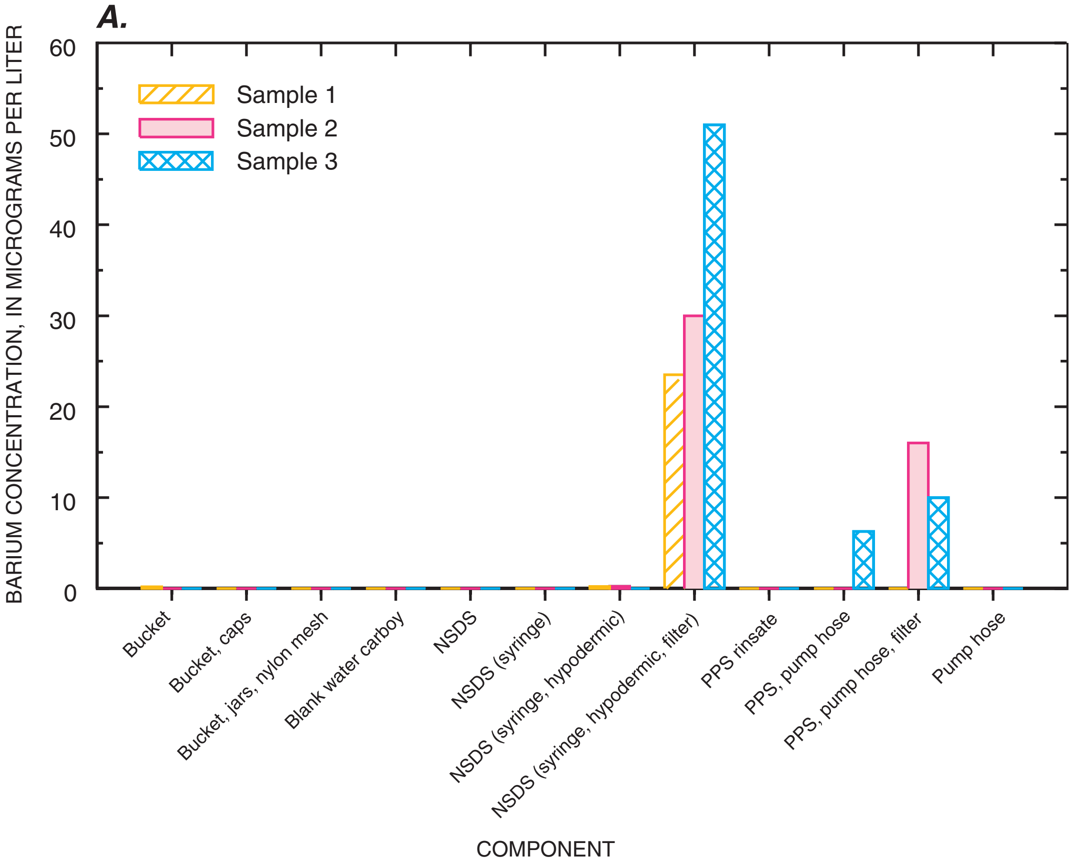


Figure 6. Laboratory quality-control data for *A*, barium; and *B*, zinc for components of sampling equipment. (NSDS, nylon-screen diffusion sampler; PPS, pushpoint sampler)

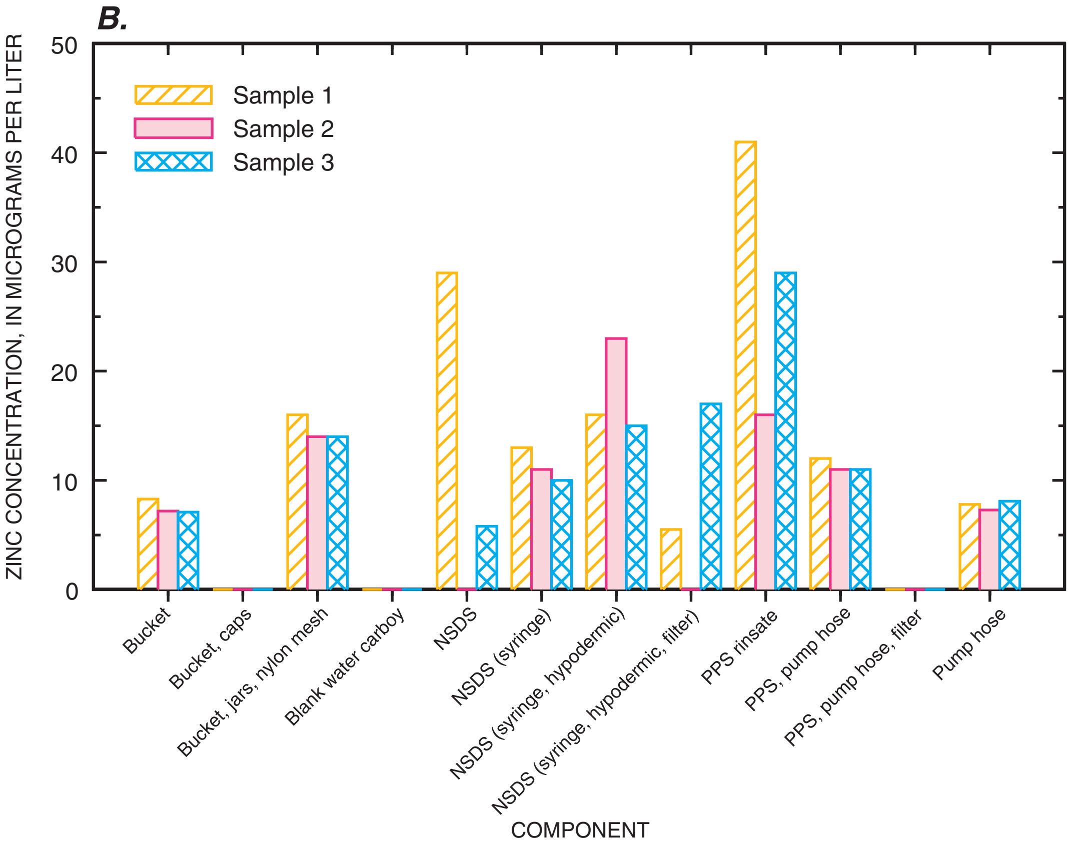


Figure 6—Continued. Laboratory quality-control data for *A*, barium; and *B*, zinc for components of sampling equipment. (NSDS, nylon-screen diffusion sampler; PPS, pushpoint sampler)

Sediment Pore Water Field-Sampling Techniques

Field work was done during May and June 2003. Field activities consisted of the deployment and retrieval of NSDSs and the collection of water samples from the NSDSs and the PPSs.

Nylon-Screen Diffusion Samplers

The NSDS units were assembled in the laboratory prior to transport to the study areas. Preliminary testing during a previous investigation indicated that deployment of samplers containing oxygenated water might affect the measured concentrations of contaminants (Forest P. Lyford, Hydrologist, U.S. Geological Survey, oral commun., 2003); there was concern that iron hydroxides could precipitate on the mesh screen and prevent dissolved metals from diffusing into the NSDS. To prevent this precipitation, the NSDS units were assembled in water that had been purged of dissolved oxygen (DO) by sparging with nitrogen for at least 1 hour. Nitrogen was continuously bubbled through the 19-L buckets in which the samplers were being prepared. These samplers were transported to the field sites in the buckets under a nitrogen atmosphere that was maintained by keeping the buckets covered except during the removal of a sampler. Because maintaining low DO concentrations proved difficult, several NSDS units were prepared and deployed with deionized water that had not been purged of DO to determine whether deoxygenating made an appreciable difference in the results.

To deploy, or insert, the NSDSs into the sediment, the PVC shovel was pushed into the sediment and used to create a hole that would allow the sampler to be buried approximately 20 cm below the sediment surface. Each NSDS was covered with sediment after the shovel was removed. Samplers were placed on their sides to decrease the danger of puncturing the mesh during insertion and retrieval. To locate the samplers for retrieval, each NSDS unit was wrapped tightly with a nylon electrical tie attached to nylon monofilament and a brightly colored fishing bobber. During the study period, two bobbers were lost; because the monofilaments remained attached to the samplers, however, they were all retrieved. Although some force was occasionally required to pull an NSDS loose from the sediment, it was usually possible to remove a sampler by gently gripping its sides. Any sediment covering the mesh usually fell off while the NSDS was being lifted through the overlying water. When it was necessary to use a gloved fingertip to flick off a small amount of retained sediment, negligible loss of water from the sampler resulted.

NSDS samples were collected by using a 60-mL disposable syringe with a 13-gage, 8.9-cm hypodermic needle and a 25-mm, 0.45-µm filter unit (Millipore HPF Millex-HN) mounted between the syringe and hypodermic. After the NSDS was retrieved, the sharp tip of the hypodermic was thrust through the nylon mesh to extract the sample (fig. 7). Two withdrawals were required to retrieve a volume (100 mL) sufficient for analysis. Occasionally, more than one filter unit was required because of the build-up of solids on the filter membrane.

Pushpoint Samplers

During this study, a peristaltic pump was used to draw samples through the PPS. Approximately 2 m of silicone tubing connected the pump directly to the PPS. One of the Millipore filter units was attached to the opposite end of the tubing where the sample flowed into the 125-mL, high-density-polyethylene sample container before being acidified with Ultrex-grade nitric acid. After setting the PPS in the sediment at the desired depth, the guard rod was removed and samples were drawn with a peristaltic pump. During the flushing of the PPS and tubing prior to the collection of an environmental sample, specific conductance was monitored with a multiprobe meter to ensure that the PPS samples represented pore water and not infiltrating surface water.

Figure 7. Collecting a field sample from nylon-screen diffusion sampler by using syringe, filter, and hypodermic.

Site Selections

On May 12, 2003, 15 sites were selected approximately 0.5 to 1.5 m from shore in the Sudbury River (fig. 8*A*) at the Nyanza study area in Ashland. Samplers were inserted about 20 cm below the sediment surface in water 15 to 30 cm deep and were retrieved on May 13, 15, 19, 27, and 28, 2003.

On May 20, on either side of Rigby Road, Clinton, 15 sites (fig. 8*B*) were selected in sediments at the bottom of ditches or a beaver-dammed impoundment. All sampling sites remained submerged during the sampling period. As at the Nyanza study area, samplers were inserted about 20 cm below the sediment surface. Samples were collected on May 21, 23, 28, June 4, and June 5, 2003.

Quality-Control Sampling and Results

Field quality-control sampling for the NSDS units consisted of retrieving duplicate samplers deployed in close proximity to each other at some of the 15 sites. Quality-control sampling for the PPSs included equipment blanks, sequential replicate samples from the same site without removal of the PPS, and replicate samples from a nearby spot at the same site. NSDS and PPS replicate sample results are discussed with the other field data.

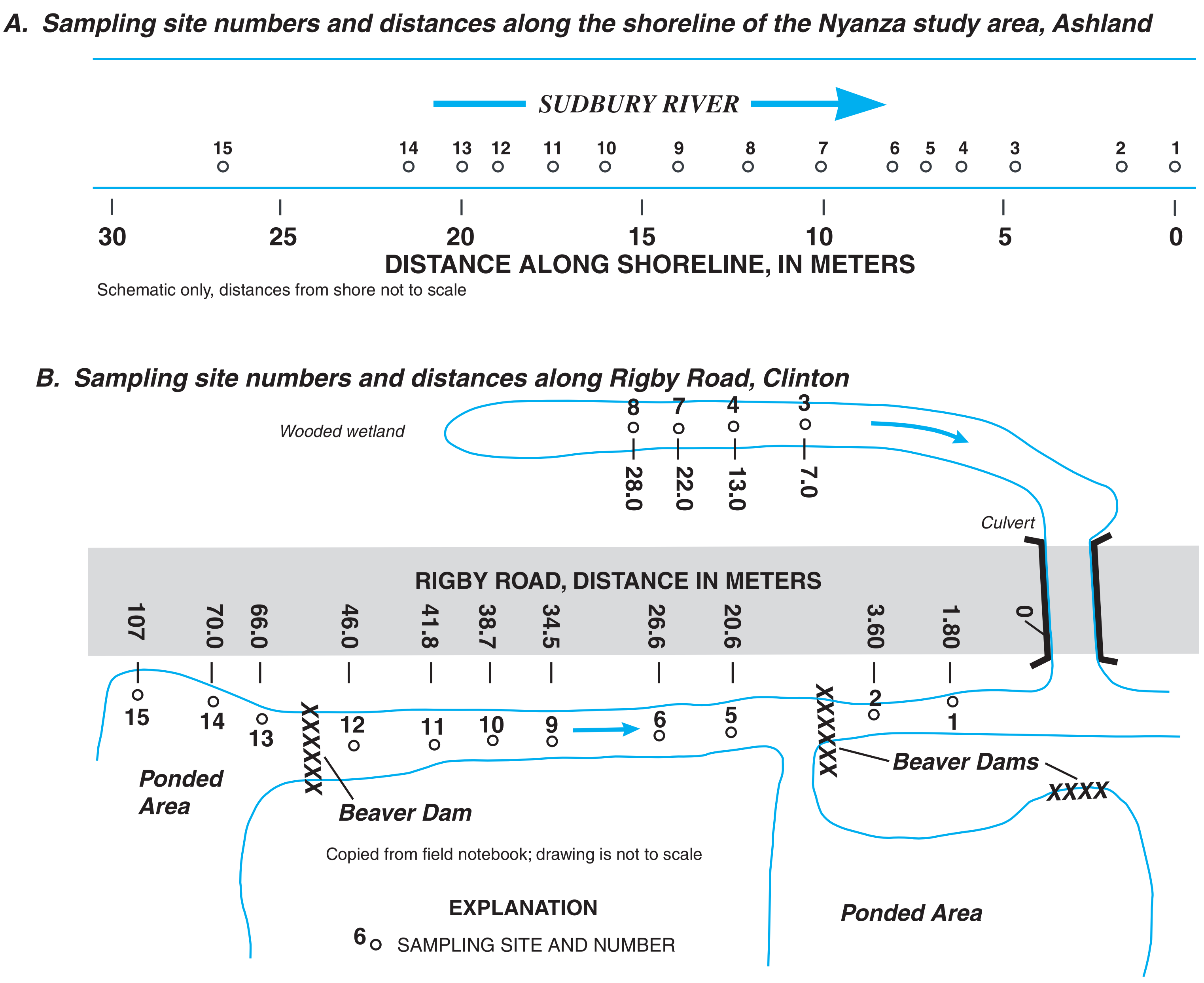
After the PPS had been flushed out and its exterior rinsed with deionized water supplied by the USEPA laboratory, equipment blanks were collected. Approximately 1 L of deionized water was pumped from a Pyrex 1-L beaker through the PPS before a sample was collected. This volume was approximately the same volume of water that was used to flush the sampling system before routine sample collection.

Analysis of the PPS field-equipment blanks (table 6, at back of report) indicated that neither sampling equipment nor procedure introduced contamination to the field samples sufficient to qualify the use of the samplers in detecting contamination near or above PALs. Only two metals, As and Ba, were detected in the samples: As detected once at 0.71 µg/L and Ba at an average concentration of 3.3 µg/L (n=5). (Cu was detected in the laboratory analysis, but these detections were ascribed to contamination of laboratory blanks.) Ba likely came from the filter unit, as observed during lab quality-control studies.

High concentrations of iron (Fe) and Mn in the environmental samples required the analysts to dilute samples to minimize interferences affecting the analyses. Diluting the samples increased reporting levels for all metals by the same factor. Field-blank samples were not all segregated from environmental samples during analysis, however, and, thus, some were diluted by the laboratory. The dilution increased their reporting levels and effectively censored some of the data. In particular, the field blanks from Nyanza were all diluted 10:1 and the Rigby Brook field blanks were undiluted.

Variability in the results by method at each study area was calculated by using the medians of Relative Percent Difference (RPD) (table 4); reporting levels were substituted for nondetects. In this case, this substitution may have diminished the RPD values. A comparison of the nitrogen-sparged NSDS units and those that were not sparged (NSDSX in tables 4; 6–8, at back of report) yields ambiguous results. Reporting levels in the Nyanza samples higher than in the Rigby Brook samples make the Nyanza results appear less variable than those from Rigby Brook. In reality, the concentrations of numerous nondetects among the metals at Nyanza were replaced by reporting-level concentrations for the RPD calculations. The large number of 0.0 median RPD values (As, Co, lead (Pb), Ni, and V) at the Nyanza site reflects this situation. Because the lower number of nondetects at the Rigby Brook site allowed calculations to be based on real measured concentrations, the median RPD values were higher. Overall, the median RPD calculations indicate a high variability between the NSDS and NSDSX units. The differences between the units may be exaggerated because there are fewer NSDSX than NSDS samples. If the NSDS is to become a common field-sampling device, additional testing in more homogeneous media may be useful.

Sequential replicate samples collected at the same location with the PPSs (PP1 in tables 4, 6–8) generally exhibit low median RPD values. Only the results for Zn are higher than for other metals. The higher median RPD values for PP2 samples (replicate samples collected from sites within a 0.5-m radius of one another) at both study areas further demonstrate substantial environmental variability over short distances.



A. Sampling site numbers and distances along the shoreline of the Nyanza study area, Ashland

Schematic only, distances from shore not to scale

B. Sampling site numbers and distances along Rigby Road, Clinton

Copied from field notebook; drawing is not to scale

Figure 8. Distribution of sampling sites at the *A*, Nyanza study area, Ashland, Massachusetts; and *B*, Rigby Brook study area, Clinton, Massachusetts.

Table 4. Medians of paired relative percent-difference values for individual metals in nylon-screen diffusion samples and pushpoint samples collected at the Nyanza study area, Ashland, Massachusetts, and at the Rigby Brook study area, Clinton, Massachusetts.

[For these calculations, values for censored data were set at the reporting level (table 3). NSDS, nylon-screen diffusion sampler; NSDSX, nylon-screen diffusion sampler inserted without nitrogen sparging; PP1, pushpoint sampler—sequential replicate-sample pairs collected without moving sampler; PP2, pushpoint sampler—discrete sample pairs collected from nearby, but separate, locations]

Sampler type	Aluminum	Arsenic	Barium	Cobalt	Iron	Lead	Manganese	Nickel	Vanadium	Zinc
					Nyanza					
NSDS only	26.1	0.0	7.1	4.3	40.0	0.0	7.2	0.0	0.0	22.2
NSDS and NSDSX	16.5	.0	6.5	.0	54.9	.0	18.2	.0	.0	48.5
PP1 only	2.3	.0	6.4	.0	.0	.8	2.1	.0	1.4	25.4
PP1 and PP2	12.8	.0	6.7	20.3	17.8	.0	6.1	23.9	.0	18.2
					Rigby					
NSDS only	44.3	25.4	12.1	29.2	33.1	40.0	7.9	21.3	24.2	5.1
NSDS and NSDSX	58.3	32.5	8.1	26.1	39.8	68.8	46.6	55.8	29.1	4.4
PP1 only	2.3	.0	6.4	.0	.0	.8	2.1	.0	1.4	25.4
PP1 and PP2	16.2	16.2	10.4	40.5	18.2	27.3	12.2	23.0	22.2	40.0

Comparison of Metal Concentrations in Pore Water Collected with Nylon-Screen Diffusion and Pushpoint Samplers

The distribution, frequency of detection, and concentrations of metals differed at sampling sites within each of the Nyanza and Rigby Brook study areas (tables 7 and 8). Some of these differences may reflect matrix interferences that, in all but the first eight samples from the Nyanza study area, made it necessary for the analyst to dilute the sample by a factor of 10; this dilution effectively raised the reporting level by the same factor, and probably caused a decrease in the frequency of low-level detections in these samples. Similarly, 46 of 78 samples from the Rigby Brook site required 2:1 dilution because of interference caused by the high concentrations of Fe in the samples. Thus, differences in the extent of matrix interference between samples from the Nyanza and Rigby Brook study areas may account more for concentration differences in As, Cr, Pb, Mo, V, and Zn than differences between the physical characteristics of the study areas (tables 7 and 8; figs. 9 and 10). These decreases in analytical method sensitivities to low concentrations of metals, however, should not be considered as affecting the capacity of the two types of sampling devices to provide acceptable data from highly contaminated environments.

Although the Nyanza and Rigby Brook sampling areas were expected to yield detections of a large number of metals in concentrations substantially exceeding their PALs and, therefore, classifying the concentrations as toxic, this result did not prove to be the case. At Nyanza, only aluminum (Al), Ba, Fe, and Mn were detected frequently at concentrations higher than their PALs. These elements are not generally classified with the trace elements or contaminants of concern As, cadmium (Cd), Cr, Cu, Hg, Pb, and Ni. These results contrast with findings from a Nyanza Chemical Dump Superfund Site monitoring study (ICF Consulting, 2003) conducted in June 2001 (table 5). Single water samples collected from 20-cm sediment depths in three monitoring wells in the vicinity of the present study site (fig. 4) and analyzed by ICP-MS yielded data with relatively high concentrations of metals; the concentrations of Al, As, Cr, Pb, V, and Zn were particularly high in comparison with the concentrations detected during this study. The differences were generally consistent irrespective of whether the Superfund monitoring well was located within the plume zone (wells MP-03A-03 and MP-003-01) or outside the zone (well UR-002).

At Rigby Brook, concentrations of As, Ba, Fe, Mn, and Zn frequently exceeded their PALs. For these reasons, comparisons are limited primarily to these frequently detected trace metals (Al, As, Ba, Co, Fe, Mn, and Zn). The low concentrations and relatively infrequent detections reported for antimony (Sb), Cu, Cr, Pb, molybdenum (Mo), Ni, and V, however, show that even the metallic PPS can collect samples yielding barely detectable concentrations of these metals.

Boxplots noting the actual reporting levels and substituting these reporting levels for nondetects (figs. 9 and 10) are useful in comparing the results for the two devices at the two study areas. This substitution may create an overestimation in the concentration distribution of frequently detected metals, but the inclusion of the reporting levels provides perspective and shows how the different reporting levels affect the data.

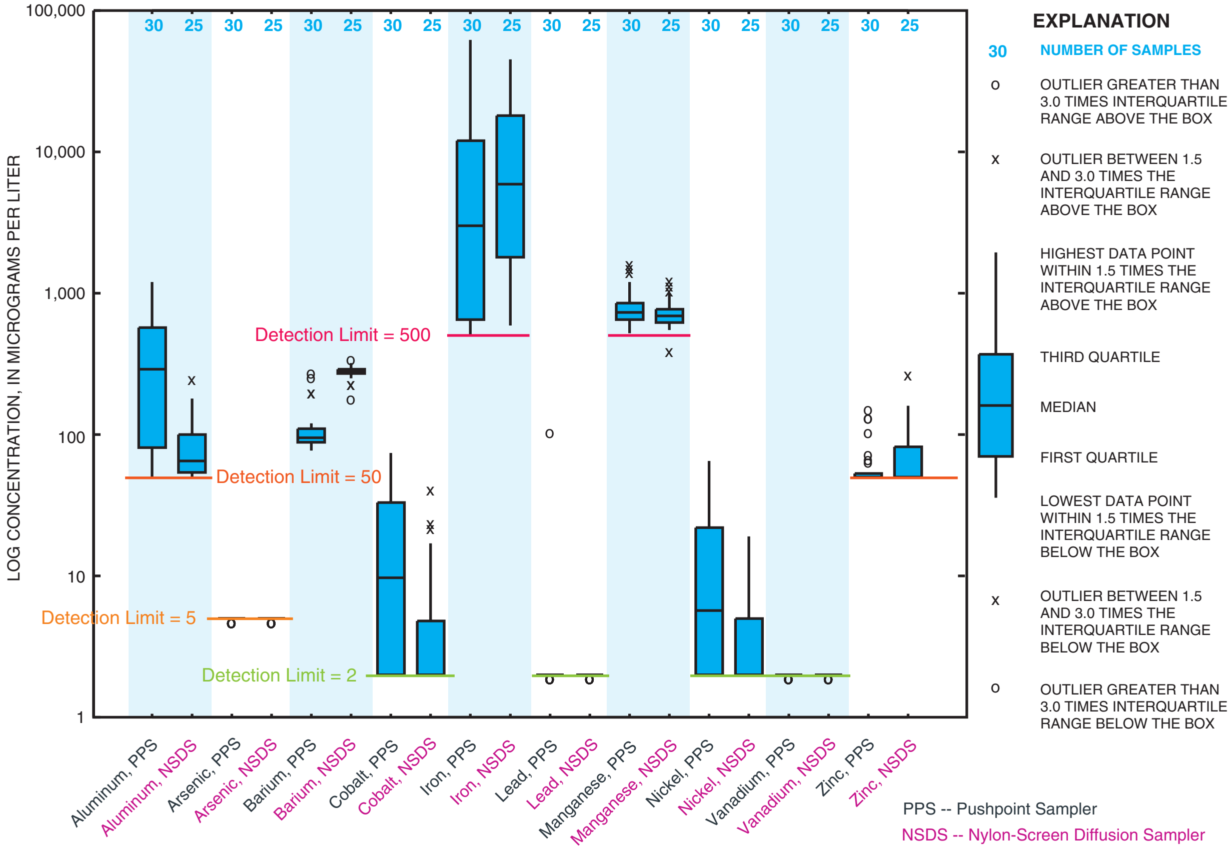


Figure 9. Selected metals concentrations in 25 samples collected with nylon-screen diffusion samplers and 35 samples collected with pushpoint samplers at the Nyanza study area, Ashland, Massachusetts, May 2003.

For most of the metals depicted in the boxplots for the Nyanza study area (fig. 9), the reporting level was 2.0 μ/L; the exceptions were Al, 50 μ/L; As, 5 μ/L; Fe, 500 μ/L; and Zn, 50 μ/L. Medians for As, Pb, and V for both devices did not exceed the reporting level; that is, most of the data were censored. At the Rigby Brook study area, the reporting level was generally 0.4 μ/L, with the result that most of the data that appear in the boxplots were uncensored (fig.10).

For the uncensored data, the boxplots show that the ranges of concentrations for the two devices are comparable (figs. 9 and 10). For the most part, the median concentrations for the two devices lie within each other's interquartile ranges. Only Al and Ba at the Nyanza study area and Ba and Zn at the Rigby Brook study area do not conform to this pattern; in these cases, except for the Al comparison, the median concentrations associated with the NSDS samples were higher than the median concentrations for the PPS samples. Therefore, for a general screening study in an area where conditions were unfavorable for the use of the PPS, the NSDS could serve as an adequate alternative method, if these concerns are adequately considered.

Time Series of Nylon-Screen Diffusion Sampler Data

In general, the metal concentrations from the NSDS units increased slightly after 1 day or remained approximately the same (figs. 11 and 12, at back of report). If the unit is used, 1 week would seem to suffice for the water inside NSDS units in sediments comparable to those studied here to reach concentrations comparable with concentrations in the outside water. Notable differences in metal concentrations among specific locations further indicate the environmental heterogeneity of the two study areas. Fe, Mn, and Zn concentrations at Nyanza site 12 were highest early in the study period, and then gradually decreased (fig. 11). Some of the changes in concentrations reflected variations in reporting levels between sampling dates. This situation was most apparent for As and Zn in the Nyanza time series. With the need for dilution, the As reporting level changed from 0.5 μg/L on the first sampling date to 5.0 μg/L for the remainder of the samples; thus, As was detected at first, but not thereafter. Similarly, the reporting

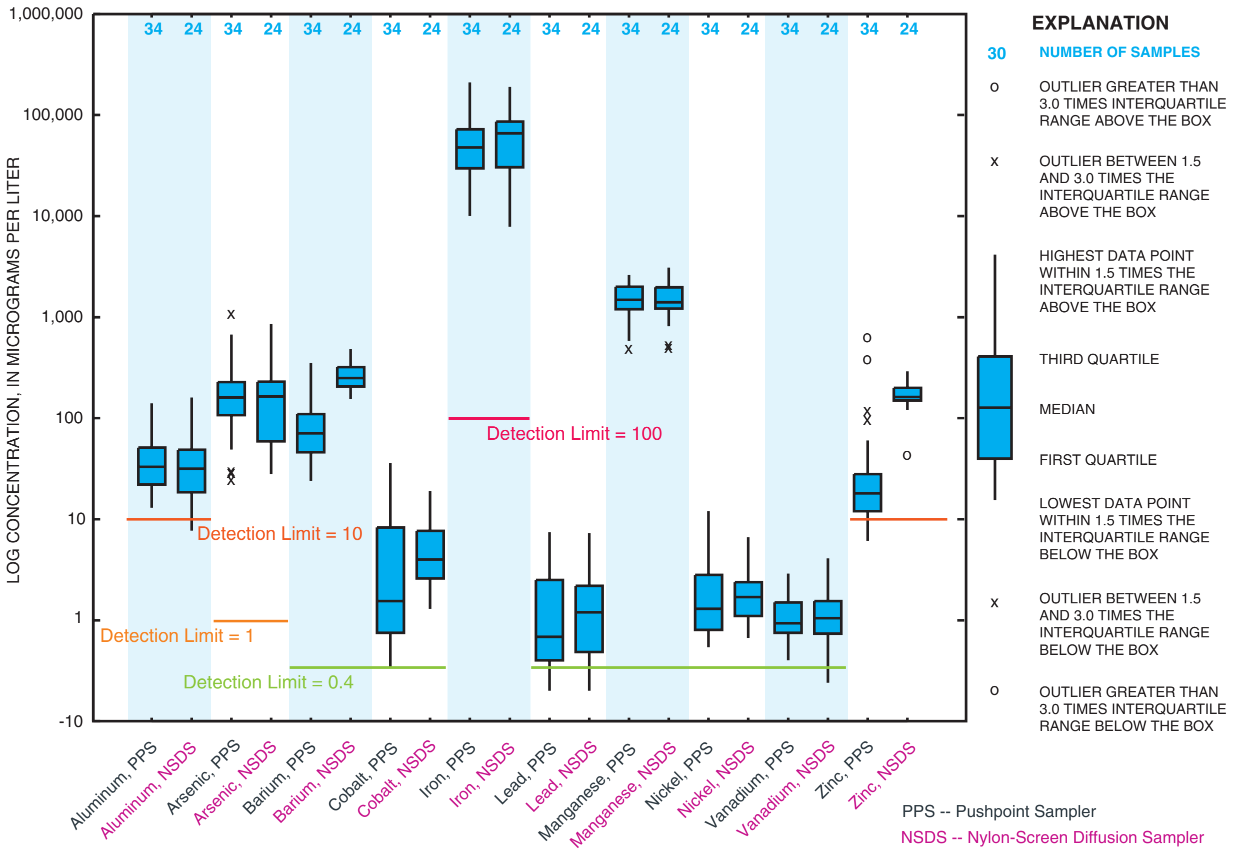


Figure 10. Selected metals concentrations in 24 samples collected with nylon-screen diffusion samplers and 34 samples collected with pushpoint samplers at the Rigby Brook study area, Clinton, Massachusetts, May to June 2003.

level for Zn changed from 5.0 to 50 µg/L, which likely caused the nondetects or censored values at sites 3, 9, and 15 on and after May 19.

At the Rigby Brook study area, most of the concentration patterns for individual metals during the 2-week period were similar among the stations (fig. 12). In general, the final concentrations of Co, Fe, Mn, and Zn were relatively high (compared to all sites) at sites 12 and 15 on the edge of the beaver-dam impoundment. Most of the initial and final concentrations did not differ substantially.

Comparison of all Nylon-Screen Diffusion Samples and Pushpoint Samples by Site

Comparing the results from samples collected from all sites at both study areas (figs. 13 and 14, at back of report) after the 2-week study period provides more insight into the relative usefulness of the two sample-collection devices. Because of the differences in detection frequencies and reporting levels (tables 6 and 7) between study areas, comparing results for the same sets of metals is not practical. For example, the detections of Zn were infrequent at Nyanza, but frequent at Rigby Brook (figs. 11*G* and 12*F*).

The differences at the Nyanza sites for the NSDS and PPS results for Al were striking (fig. 13*A*). At sites 1 through 9 and 15, the PPS samples had higher Al concentrations than the NSDS samples. The mean Al concentration in the PPS samples was 519 µg/L, but 103 µg/L in the NSDS samples; the PPS sample concentrations were generally 300 µg/L or greater, whereas the NSDS sample concentrations were generally less than 200 µg/L. For sites 10 through 14, the concentrations of Al were approximately equal, but low. The similarity of values at these sites suggests that a local environmental difference, pH, for example, may have affected the chemical form in which Al occurred and retarded the diffusion of Al into the NSDS units at sites 1 through 9, but did not affect passage through the openings of the PPS. The similarities in Al concentrations for both methods at Rigby Brook further support this hypothesis (fig. 14*A*).

Table 5. Concentrations of metals detected in ground water 20 cm below sediment surface at selected well locations for the Nyanza Superfund Site, Ashland, Massachusetts, June 2001.

[Data from ICF Consulting, 2003. Concentrations in micrograms per liter; --, not detected]

Metal	Monitoring wells		
	UR-002	MP-03A-03	MP-003-01
Aluminum	22,300	98,900	1,610
Antimony	3.7	--	--
Arsenic	20.8	43.6	4.5
Barium	169	396	48.4
Beryllium	2.2	17.4	--
Cadmium	2.4	6.4	.5
Calcium	15,500	141,000	13,700
Chromium	46.4	165	--
Cobalt	31.3	58.3	5.9
Copper	45.4	103	--
Iron	29,500	128,000	4,100
Lead	192	191	28.2
Magnesium	6,380	50,800	3,660
Manganese	1,210	30,500	673
Nickel	20.7	59.1	--
Silver	--	4.1	--
Vanadium	57.3	246	--
Zinc	995	2,630	--

With the exceptions of site 10 at Nyanza and site 11 at Rigby Brook, Ba concentrations in the NSDS samples at both study areas were generally two to three times higher than in the collocated PPS samples (figs. 13*B* and 14*C*). The Ba concentrations had a smaller range in the NSDS samples at Nyanza than those at Rigby Brook, but the ratio between the concentrations of Ba measured in the NSDS and PPS samples was approximately the same for the two study areas. Because there is no reason to expect the environmental concentrations of Ba in the NSDS samples to exceed those in the PPS samples, it seems reasonable to assume that Ba came either from the plastic containers or the filter units. The concentrations of As in samples taken by the PPS and NSDS at Rigby Brook (fig. 14*B*) did not indicate any systematic differences. Moreover, the concentrations of As in duplicate NSDS and PPS samples hardly differed.

Co concentrations in the Nyanza study-area samples (fig. 13*C*) were generally less than 40 µg/L, but differed systematically between the PPS and NSDS. In a manner similar to that for Al, a local environmental condition may be responsible for the differences in Co concentrations between the PPS and NSDS. The PPS concentrations are generally higher than the NSDS sample concentrations. The mean Co concentration in PPS samples was 37 µg/L, but 27 µg/L in the NSDS samples. The differences were most obvious for sites 3 through 9, where all concentrations ranged from about 10 to 75 µg/L.

Fe and Mn concentrations from Nyanza showed similar distribution patterns at all sites (figs. 13*D* and 13*E*). At sites 1 through 9, the concentrations were lowest and varied little. At sites 10 through 14, the concentrations increased markedly as did their variations. At site 15, the concentrations converged again. There was no pattern of difference in concentrations between the two types of samplers for the Nyanza or Rigby Brook study areas (figs. 14*D* and 14*E*). At Rigby Brook sites 1 through 12 and 15, the concentrations of Fe and Mn were highest and most variable. At sites 13 and 14, Fe concentrations were lowest and varied only slightly; Mn concentrations were slightly lower at sites 13 and 14, but generally consistent between the samplers.

The concentrations of Zn in the NSDS samples from Rigby Brook were approximately an order of magnitude greater than those in the PPS samples (fig. 14*F*); generally, the concentration ranges were from 150 to 300 µg/L and from 10 to 25 µg/L for the NSDS and PPS samples, respectively. Only at site 11 were both PPS sample concentrations higher than those from the NSDS. Because Zn was commonly detected in the laboratory-blank samples from plastics, it is possible that leaching of Zn from the NSDS units was a source of the elevated concentrations.

Summary and Conclusions

To assist investigators of environmental hazards in making reconnaissance surveys of the sources and distribution of potentially hazardous metal concentrations, simple and economical devices are needed. The USGS, in cooperation with the USEPA, tested nylon-screen diffusion samplers and stainless-steel pushpoint samplers to determine and compare their efficacies in sampling shallow pore water for metal contaminants. The investigation was carried out at two study sites with previously reported contamination: the Nyanza Chemical Waste Dump Superfund site along the Sudbury River in Ashland, MA, and a Superfund site-assessment location along Rigby Brook in Clinton, MA.

Clearly, nylon-screen diffusion samplers and pushpoint samplers can serve as field screening tools for most metals. Laboratory quality-control samples indicate that some low-concentration detections result from the use of either type of sampling device or from laboratory or field procedures. The results from the field studies indicate that metal concentrations in the PPS samples seem less affected by the sampler itself than those in the NSDS samples. With the exceptions of data that indicate leaching of Ba and Zn from the plastic NSDS, the differences in concentrations and frequencies of detection of the other metals among sites appear to be real, not artifacts of the devices used. The general comparability among the data from the PPS and NSDS samples show that the NSDS should prove effective at sites where the physical characteristics of the substrate might interfere with PPS use. The PPS is simpler and more convenient to use than the NSDS, however, because the NSDS requires assembly, preparation, insertion, and two site visits. In contrast, only one site visit is required to collect a sample with the PPS. Although NSDS units were left in place for 2 weeks during this study, the time-series data indicate that 1 week would have allowed adequate time to obtain a representative sample given the environmental heterogeneity that contributes to substantial variation in concentrations.

Most of the samples prepared for analysis were diluted by factors of 2 or 10 because of interferences affecting the analytical equipment. These dilutions raised the reporting levels for the metals by the same proportion and caused more analyses of the diluted samples than of undiluted samples to be reported as nondetects. The dilutions made it impossible to compare all sample concentrations with the lowest possible detection limits.

The data from samples from sparged and unsparged NSDS units analyzed for this report do not indicate that the use of the unsparged NSDS units would seriously affect the outcome of a screening survey of a contaminated site. Additional testing of NSDS units at sites with a greater variety of detectable metals could provide further support for this conclusion. Although demonstrating the use of the stainless-steel PPS for detecting low-level concentrations of trace-element metals was not an objective of this study, the results from undiluted samples indicate that the PPS may be useful in studies where low concentrations of trace metals are expected. With adequate quality-control sampling, scientifically sound results can be obtained for many applications.

Acknowledgments

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Figures 11–14 and Tables 6–8

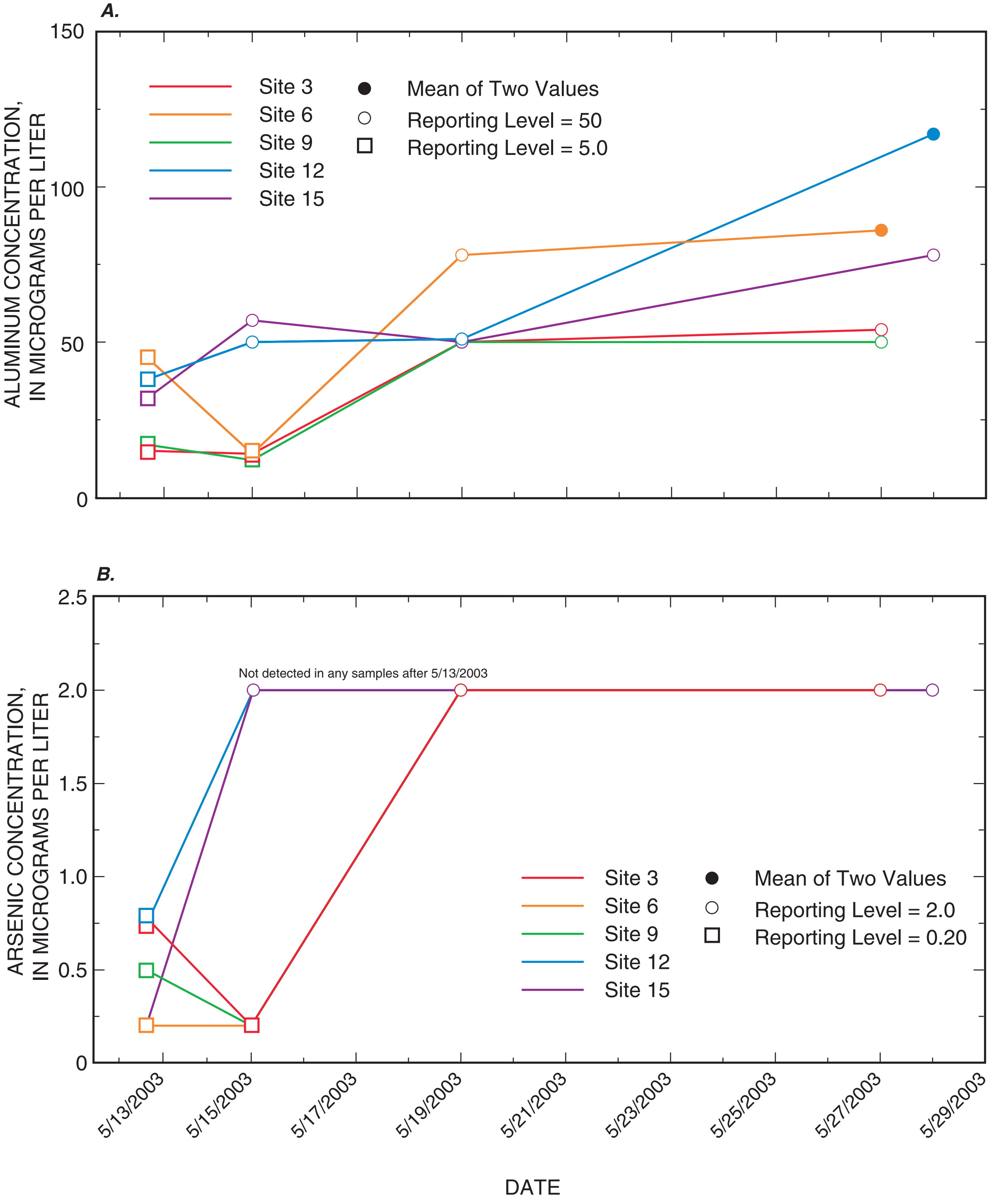

Figure 11. Time series data for *A*, aluminum; *B*, arsenic; *C*, barium; *D*, cobalt; *E*, iron; *F*, manganese; and *G*, zinc at the Nyanza study area, Ashland, Massachusetts, May 2003. Site locations are shown in figure 8.

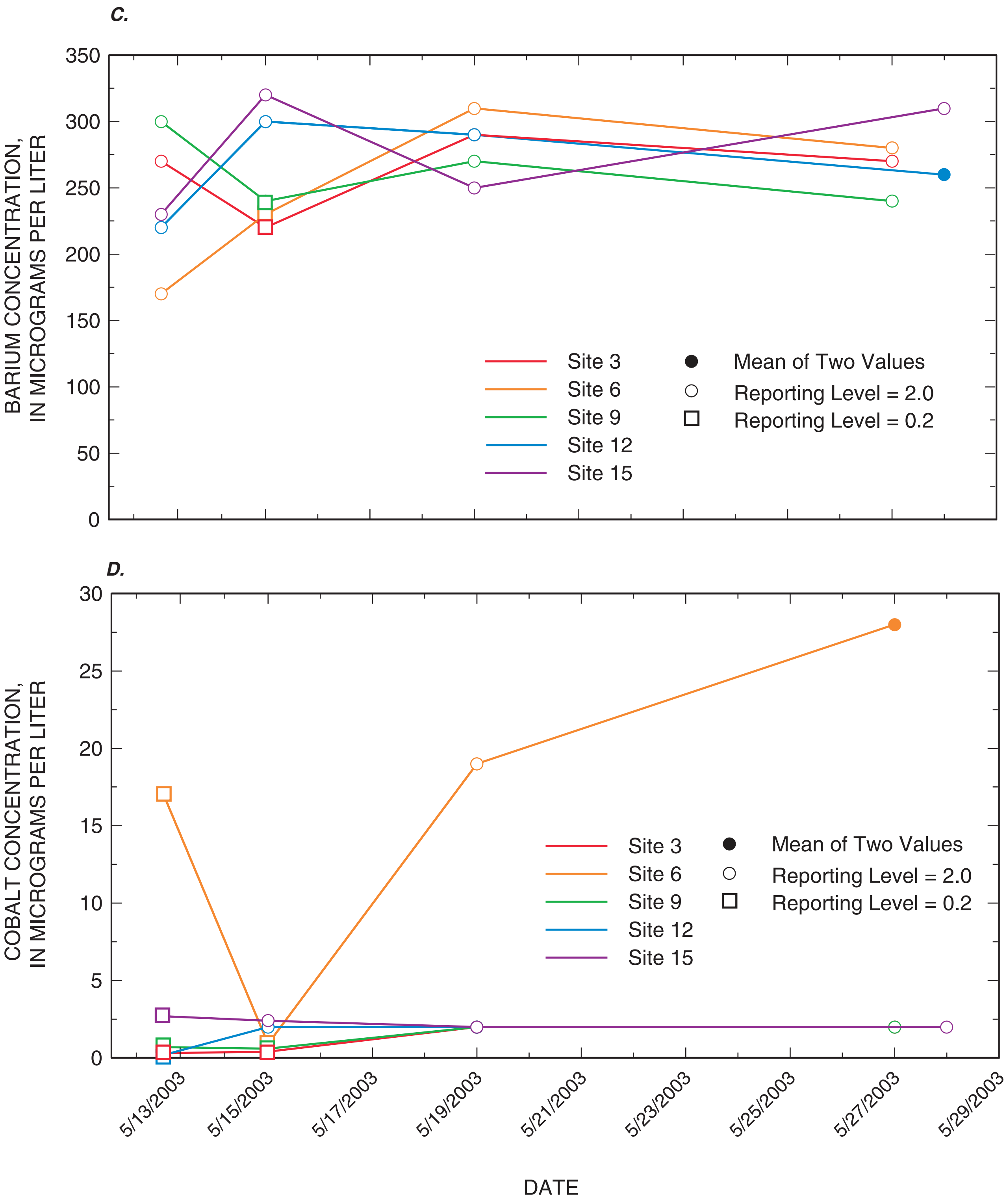

Figure 11—Continued. Time series data for *A*, aluminum; *B*, arsenic; *C*, barium; *D*, cobalt; *E*, iron; *F*, manganese; and *G*, zinc at the Nyanza study area, Ashland, Massachusetts, May 2003. Site locations are shown in figure 8.

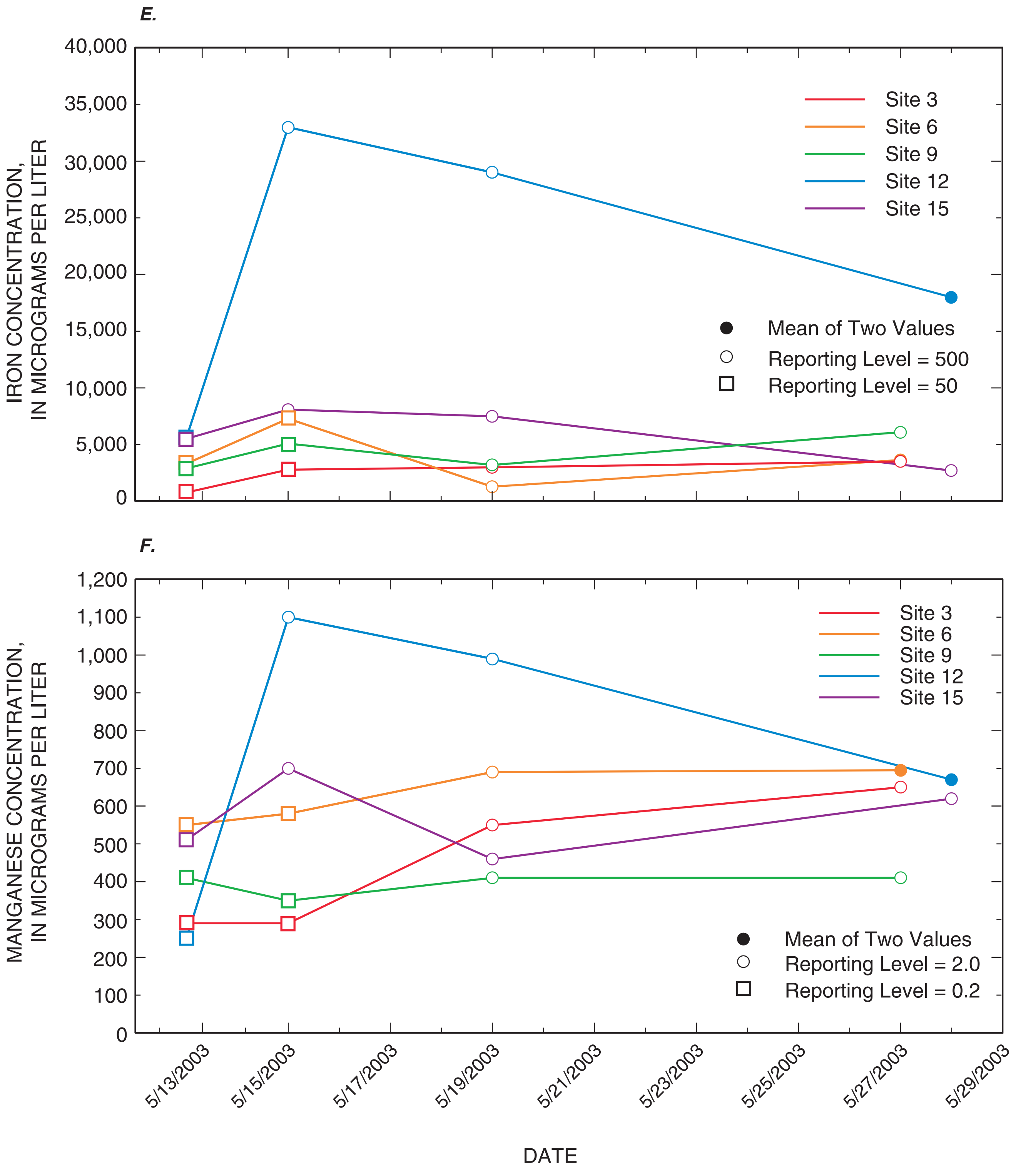

Figure 11—Continued. Time series data for *A*, aluminum; *B*, arsenic; *C*, barium; *D*, cobalt; *E*, iron; *F*, manganese; and *G*, zinc at the Nyanza study area, Ashland, Massachusetts, May 2003. Site locations are shown in figure 8.

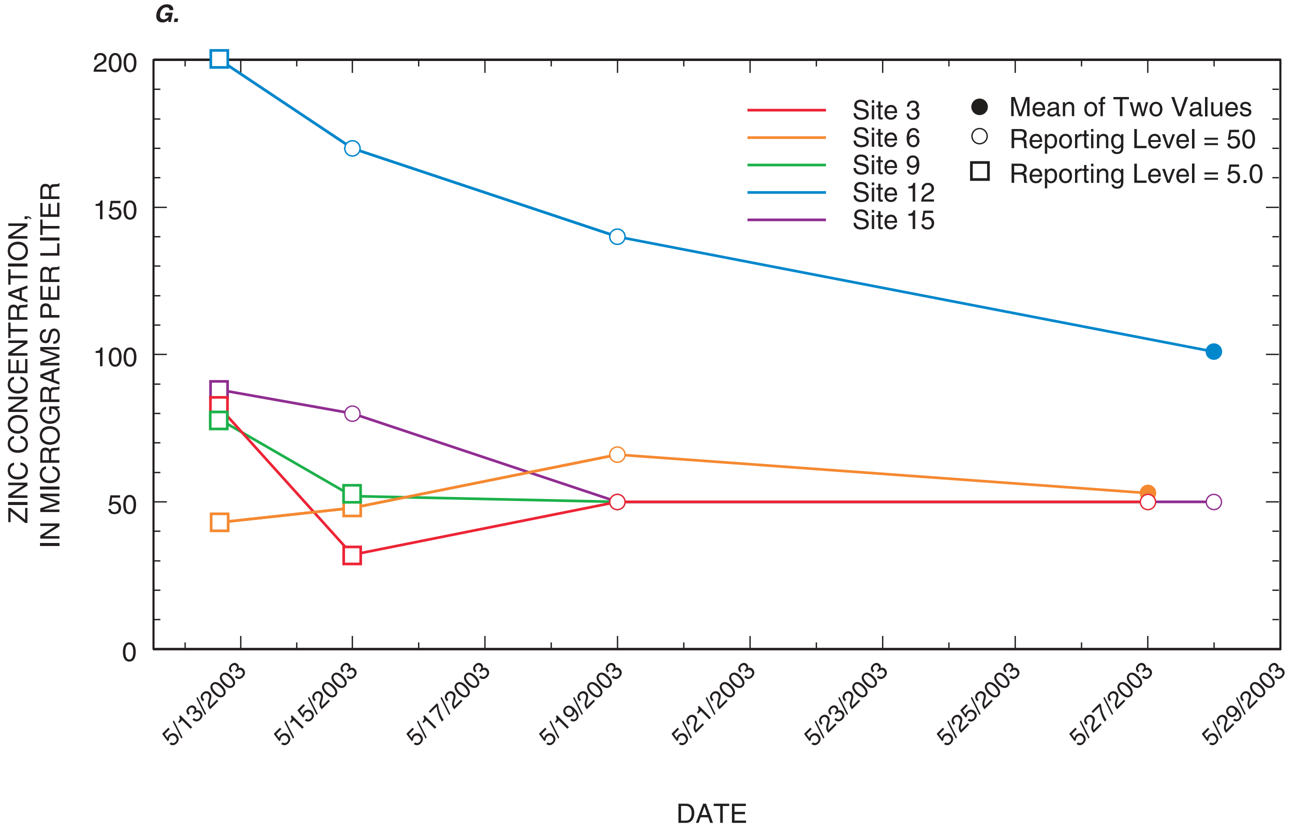

Figure 11—Continued. Time series data for *A*, aluminum; *B*, arsenic; *C*, barium; *D*, cobalt; *E*, iron; *F*, manganese; and *G*, zinc at the Nyanza study area, Ashland, Massachusetts, May 2003. Site locations are shown in figure 8.

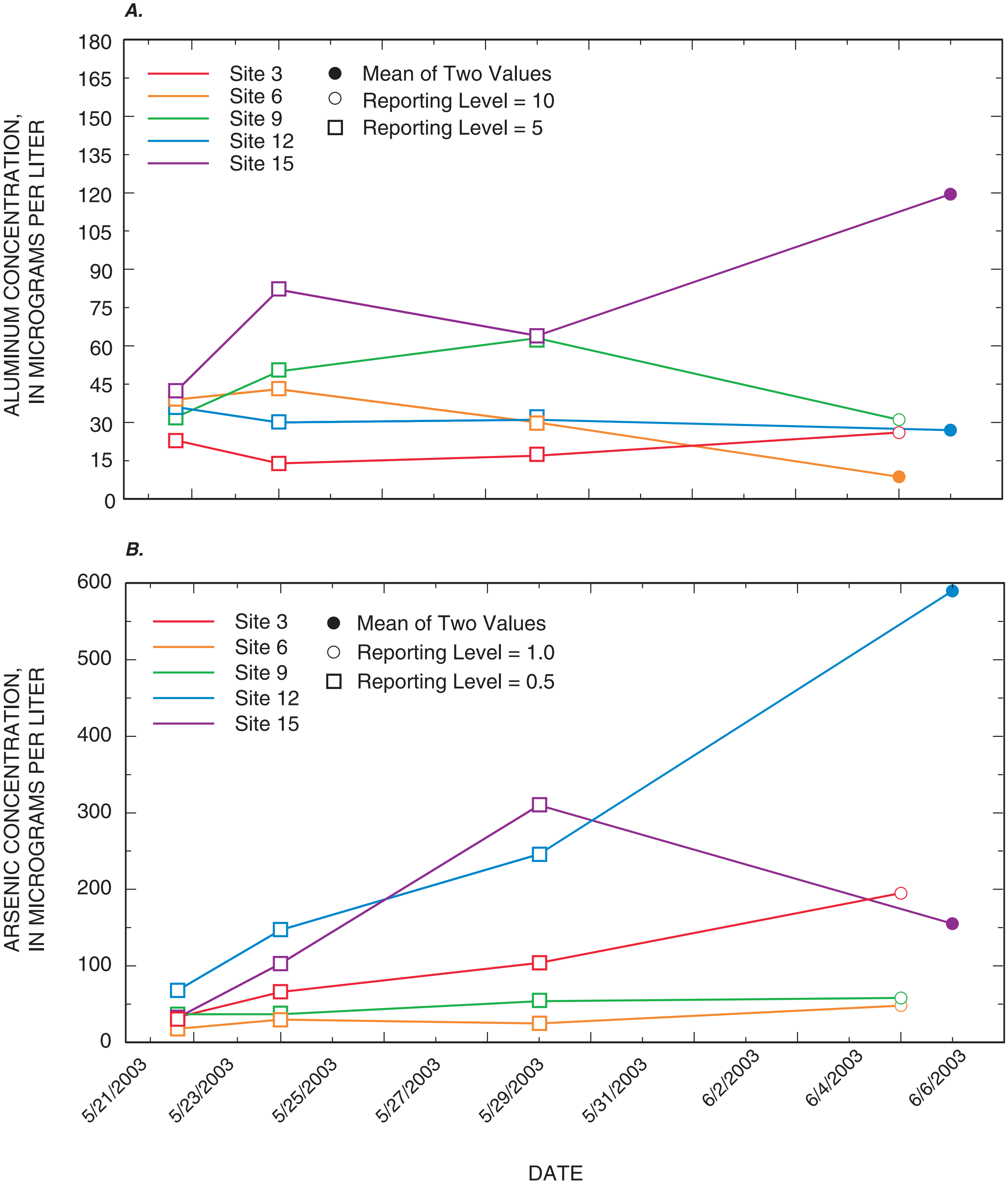

Figure 12. Time series data for *A*, aluminum; *B*, arsenic; *C*, barium; *D*, cobalt; *E*, iron; *F*, manganese; and *G*, zinc at the Rigby Brook study area, Clinton, Massachusetts, May to June 2003. Site locations are shown in figure 8.

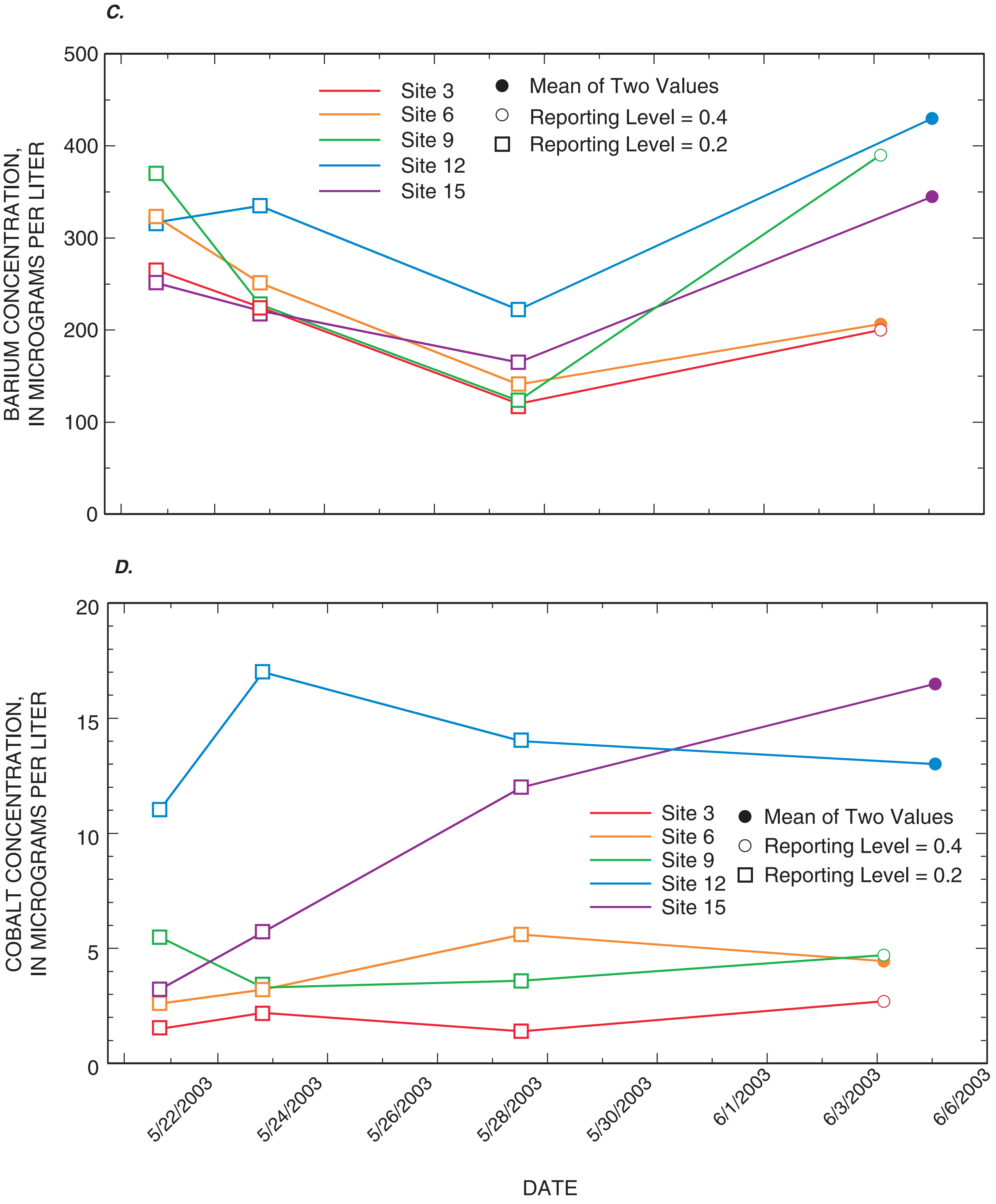

Figure 12—Continued. Time series data for *A*, aluminum; *B*, arsenic; *C*, barium; *D*, cobalt; *E*, iron; *F*, manganese; and *G*, zinc at the Rigby Brook study area, Clinton, Massachusetts, May to June 2003. Site locations are shown in figure 8.

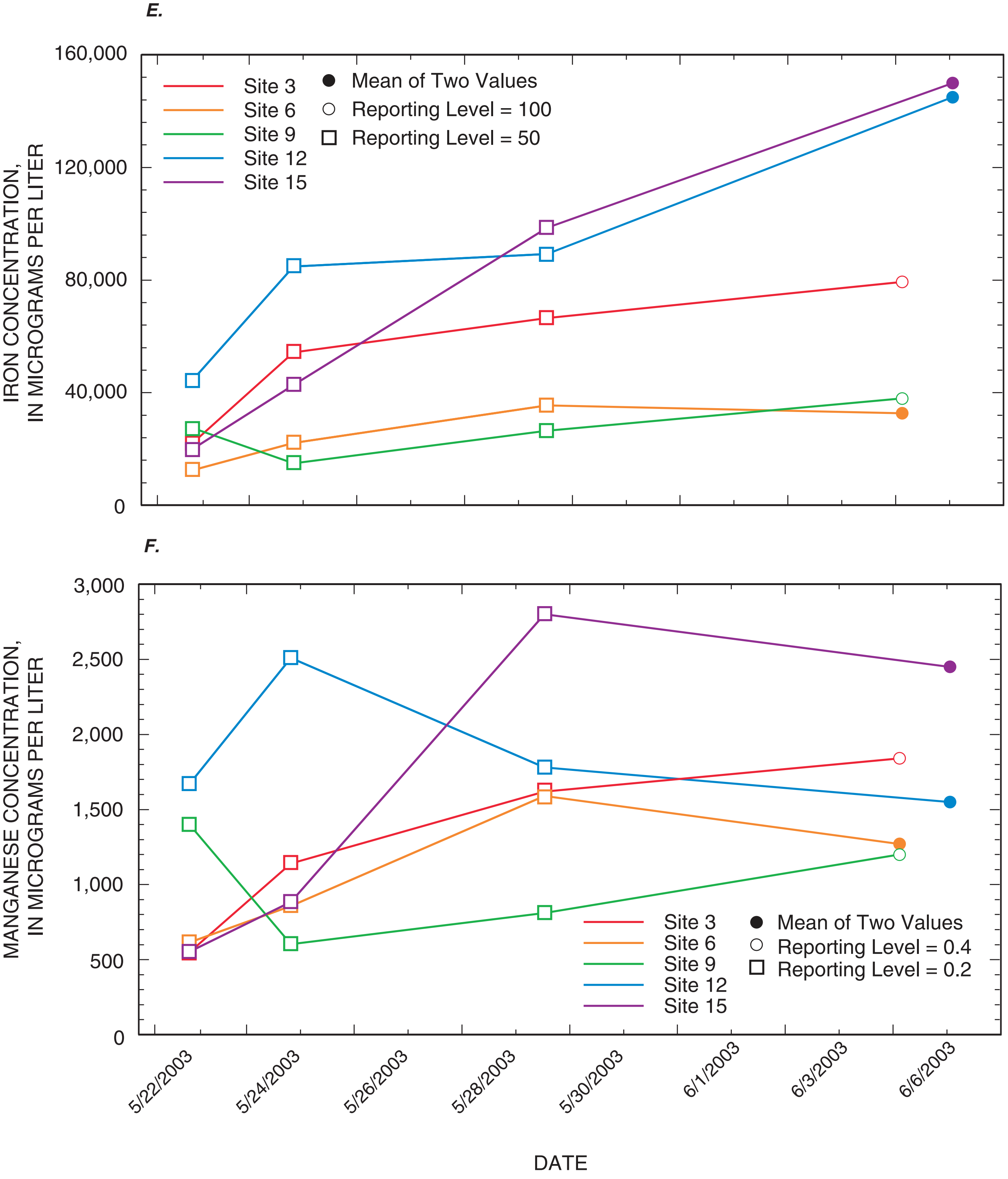

Figure 12—Continued. Time series data for *A*, aluminum; *B*, arsenic; *C*, barium; *D*, cobalt; *E*, iron; *F*, manganese; and *G*, zinc at the Rigby Brook study area, Clinton, Massachusetts, May to June 2003. Site locations are shown in figure 8.

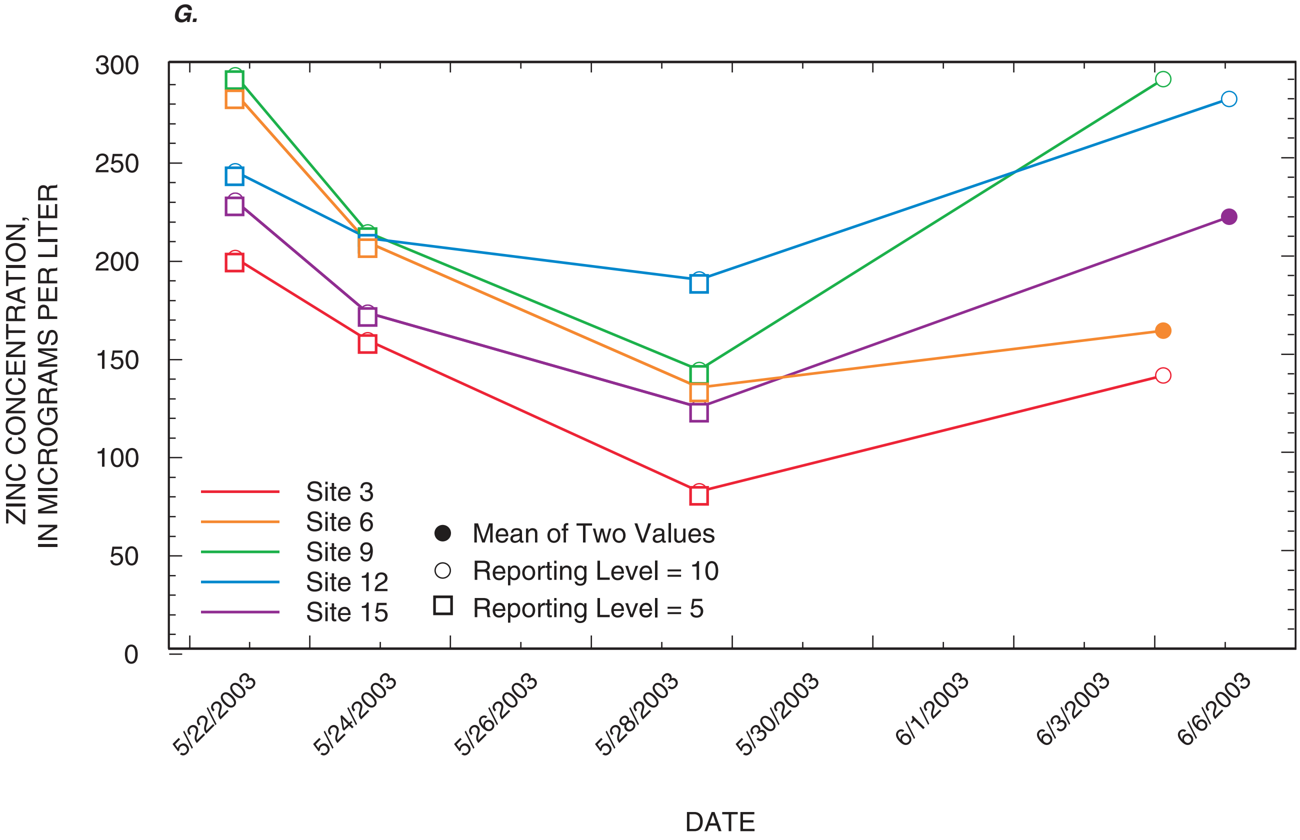

Figure 12—Continued. Time series data for *A*, aluminum; *B*, arsenic; *C*, barium; *D*, cobalt; *E*, iron; *F*, manganese; and *G*, zinc at the Rigby Brook study area, Clinton, Massachusetts, May to June 2003. Site locations are shown in figure 8.

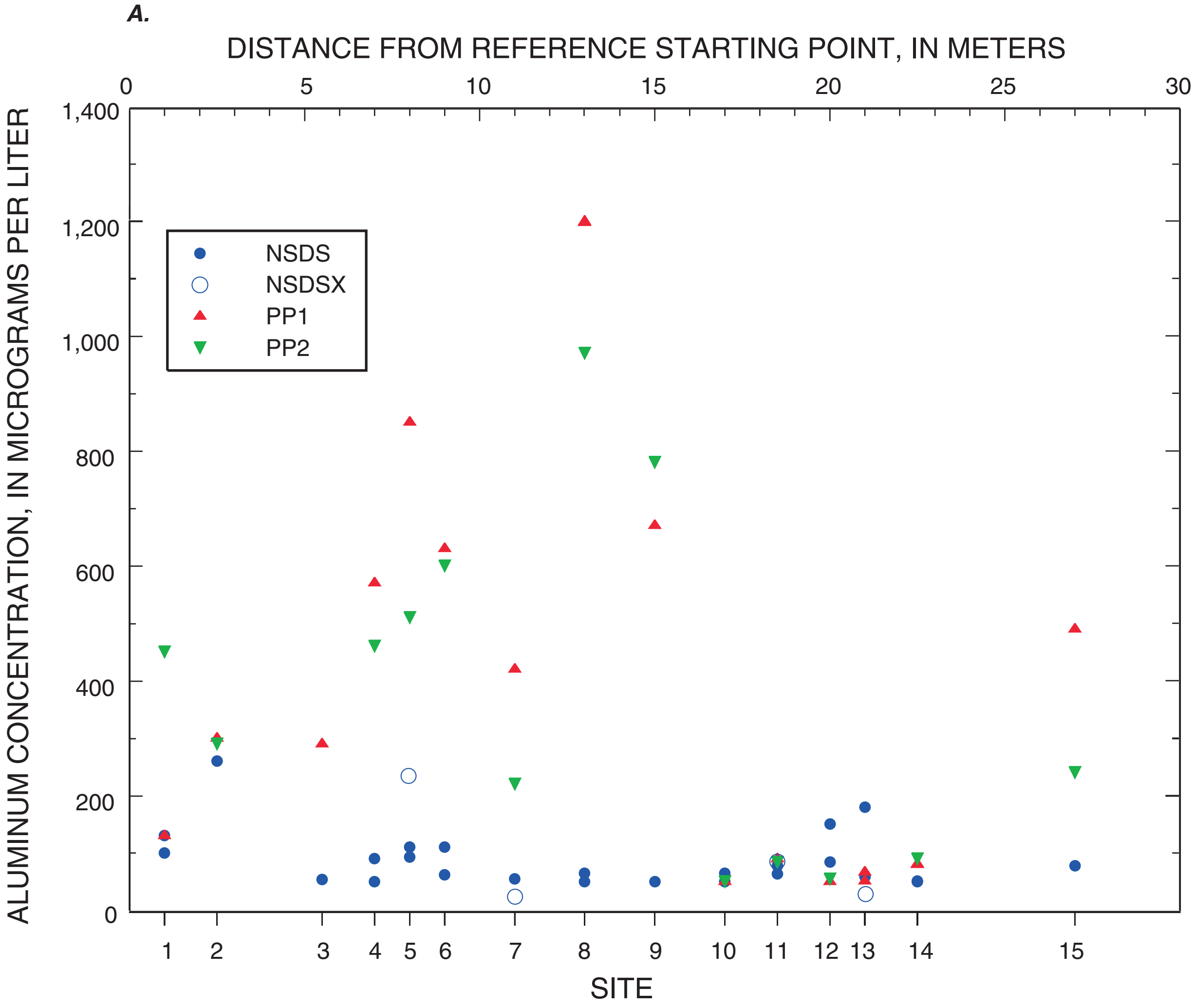

Figure 13. Results for final round of sampling with nylon-screen diffusion samplers and pushpoint samplers for *A*, aluminum; *B*, barium; *C*, cobalt; *D*, iron; *E*, manganese; and *F*, zinc at all Nyanza study-area sampling sites, Ashland, Massachusetts, May 2003. NSDS, nylon-screen diffusion sampler; NSDSX, nylon-screen diffusion sampler initially filled with aerated deionized water; PP1, sample from first pushpoint-sampling location; PP2, sample from second pushpoint-sampling location. Site locations are shown in figure 8.

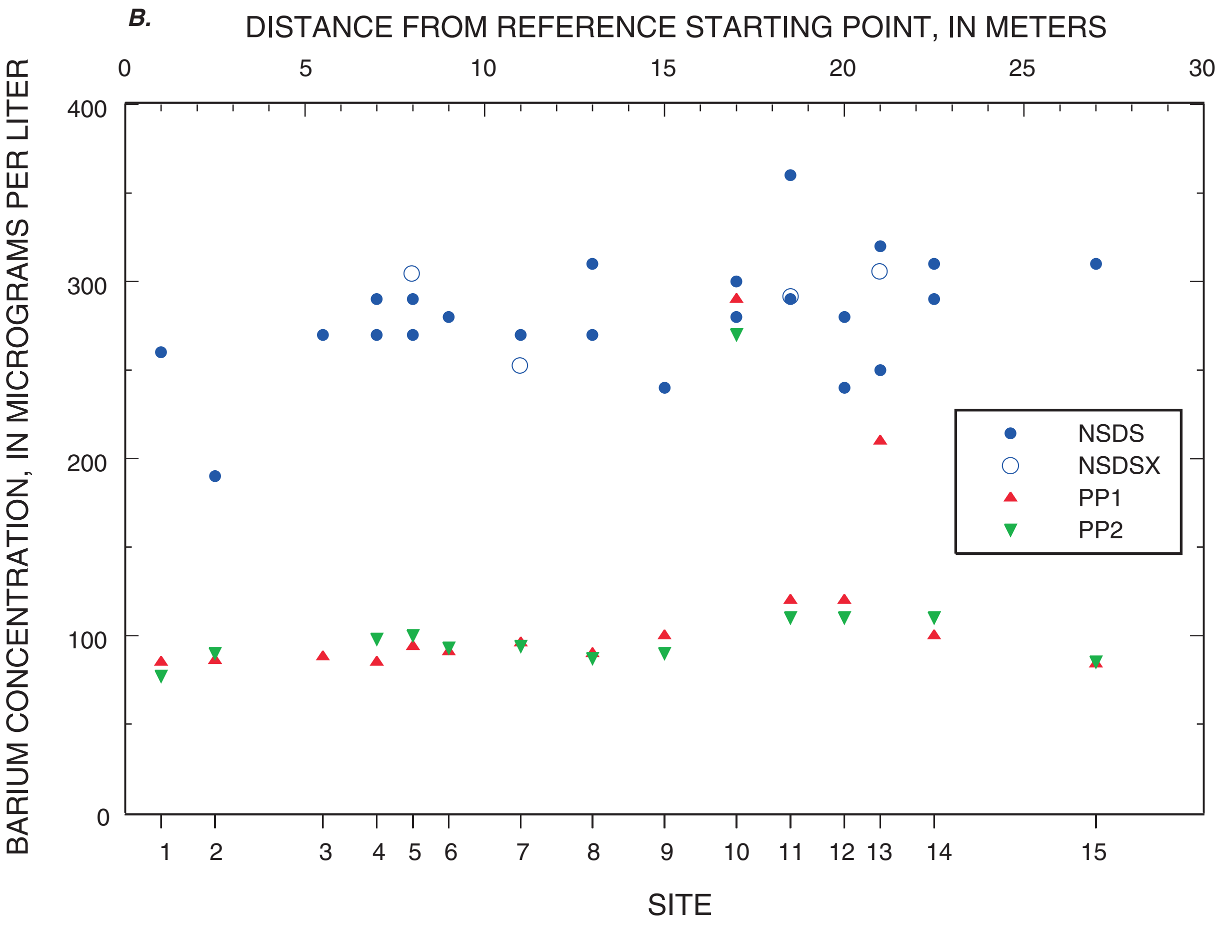

Figure 13—Continued. Results for final round of sampling with nylon-screen diffusion samplers and pushpoint samplers for *A*, aluminum; *B*, barium; *C*, cobalt; *D*, iron; *E*, manganese; and *F*, zinc at all Nyanza study-area sampling sites, Ashland, Massachusetts, May 2003. NSDS, nylon-screen diffusion sampler; NSDSX, nylon-screen diffusion sampler initially filled with aerated deionized water; PP1, sample from first pushpoint-sampling location; PP2, sample from second pushpoint-sampling location. Site locations are shown in figure 8.

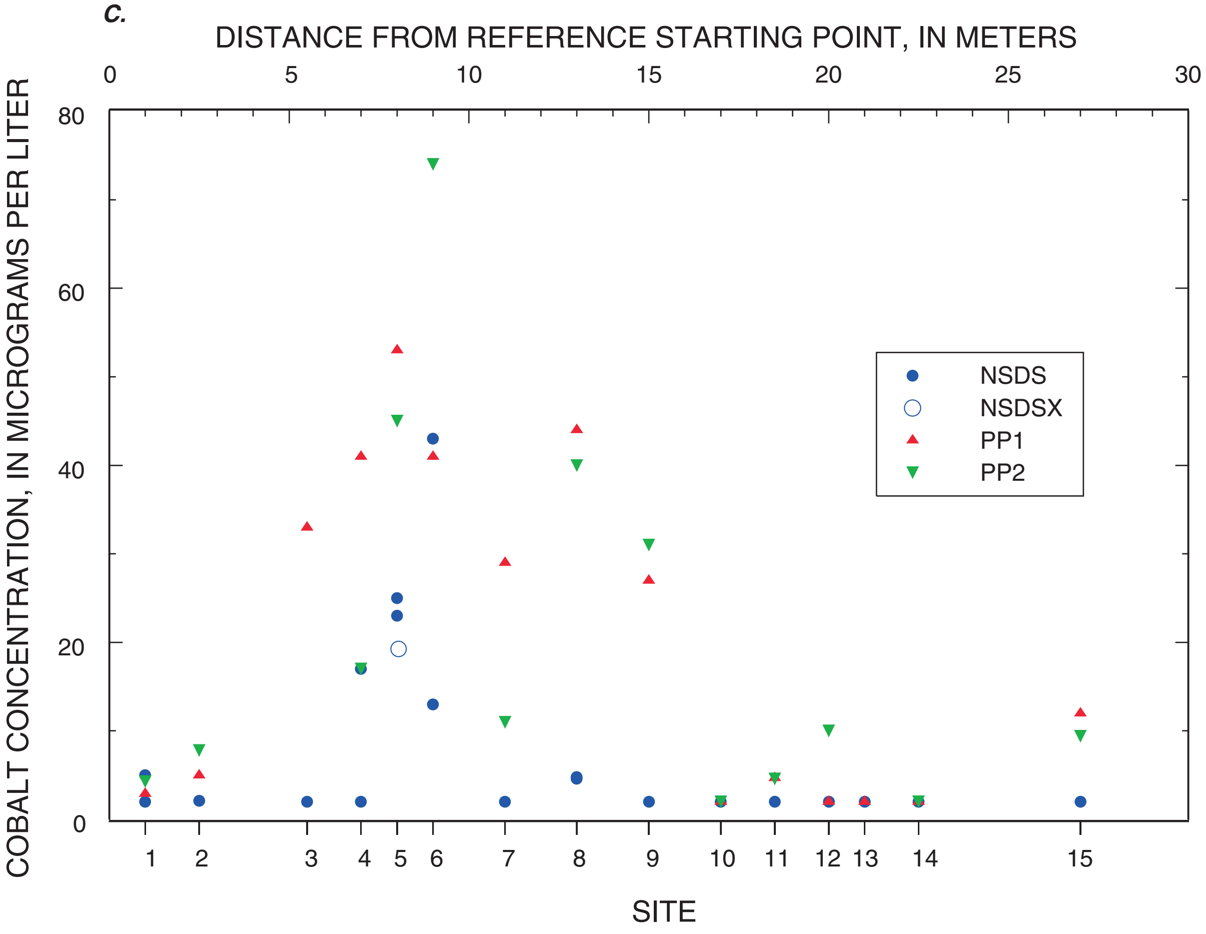

Figure 13—Continued. Results for final round of sampling with nylon-screen diffusion samplers and pushpoint samplers for *A*, aluminum; *B*, barium; *C*, cobalt; *D*, iron; *E*, manganese; and *F*, zinc at all Nyanza study-area sampling sites, Ashland, Massachusetts, May 2003. NSDS, nylon-screen diffusion sampler; NSDSX, nylon-screen diffusion sampler initially filled with aerated deionized water; PP1, sample from first pushpoint-sampling location; PP2, sample from second pushpoint-sampling location. Site locations are shown in figure 8.

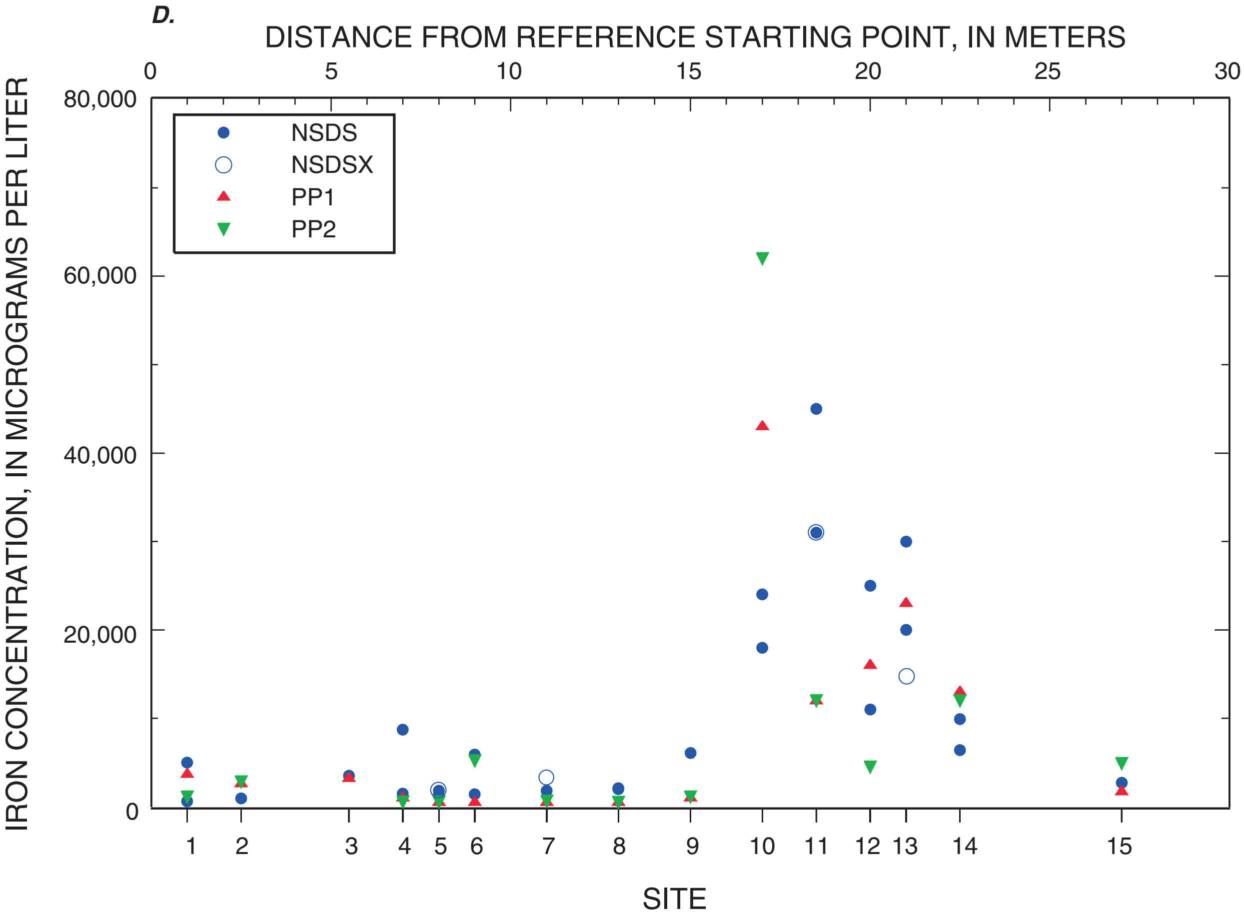

Figure 13—Continued. Results for final round of sampling with nylon-screen diffusion samplers and pushpoint samplers for *A*, aluminum; *B*, barium; *C*, cobalt; *D*, iron; *E*, manganese; and *F*, zinc at all Nyanza study-area sampling sites, Ashland, Massachusetts, May 2003. NSDS, nylon-screen diffusion sampler; NSDSX, nylon-screen diffusion sampler initially filled with aerated deionized water; PP1, sample from first pushpoint-sampling location; PP2, sample from second pushpoint-sampling location. Site locations are shown in figure 8.

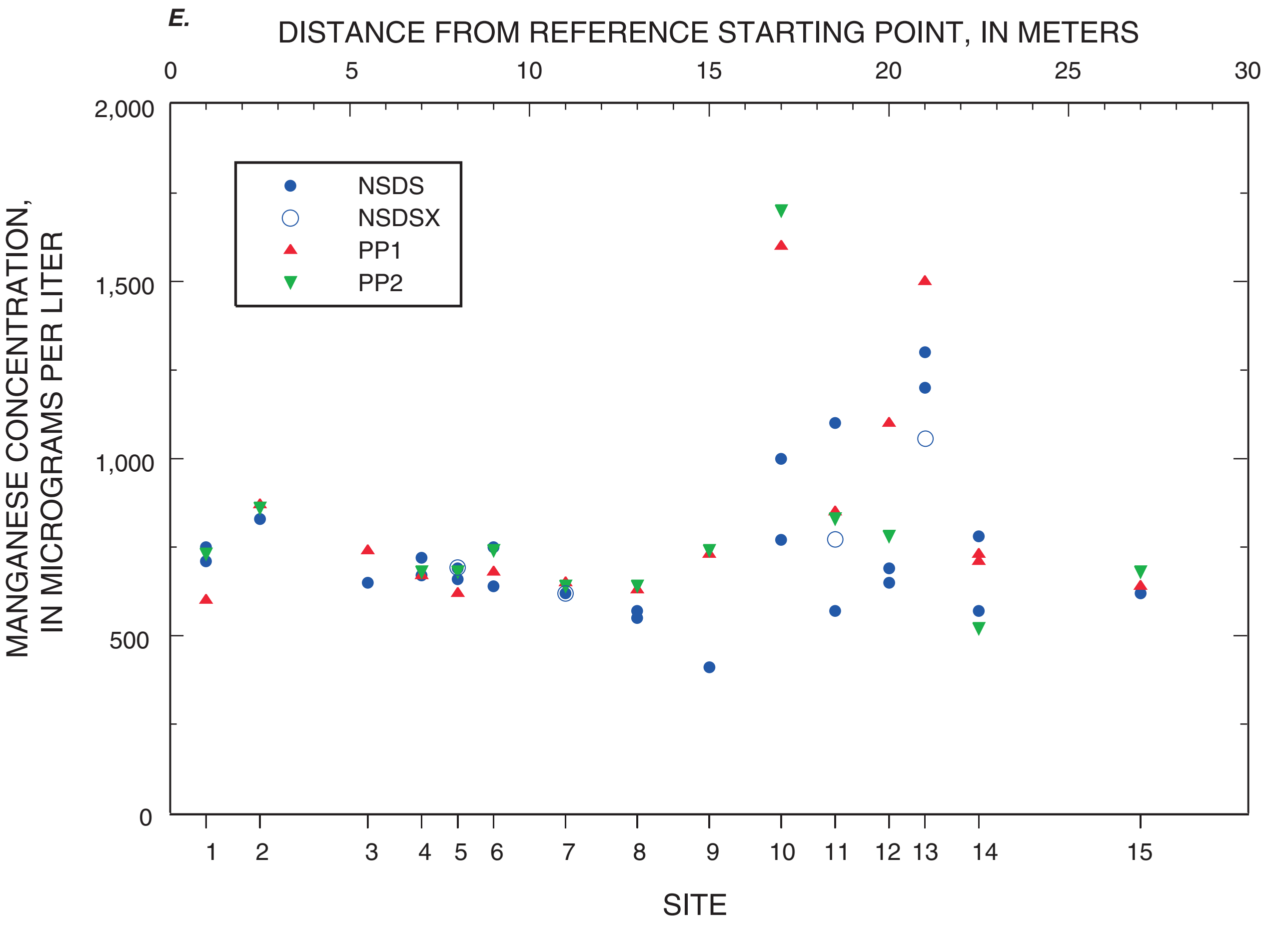

Figure 13—Continued. Results for final round of sampling with nylon-screen diffusion samplers and pushpoint samplers for *A*, aluminum; *B*, barium; *C*, cobalt; *D*, iron; *E*, manganese; and *F*, zinc at all Nyanza study-area sampling sites, Ashland, Massachusetts, May 2003. NSDS, nylon-screen diffusion sampler; NSDSX, nylon-screen diffusion sampler initially filled with aerated deionized water; PP1, sample from first pushpoint-sampling location; PP2, sample from second pushpoint-sampling location. Site locations are shown in figure 8.

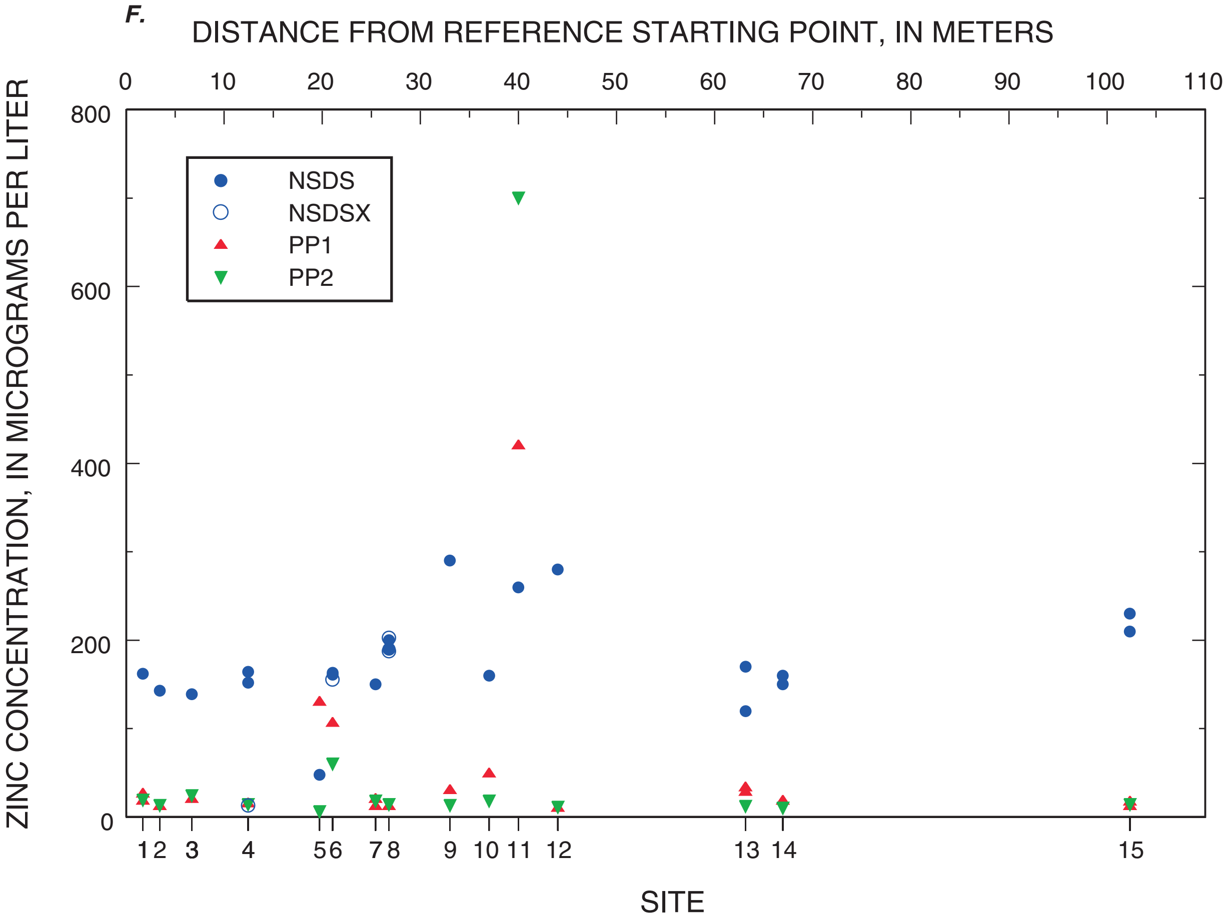

Figure 13—Continued. Results for final round of sampling with nylon-screen diffusion samplers and pushpoint samplers for *A*, aluminum; *B*, barium; *C*, cobalt; *D*, iron; *E*, manganese; and *F*, zinc at all Nyanza study-area sampling sites, Ashland, Massachusetts, May 2003. NSDS, nylon-screen diffusion sampler; NSDSX, nylon-screen diffusion sampler initially filled with aerated deionized water; PP1, sample from first pushpoint-sampling location; PP2, sample from second pushpoint-sampling location. Site locations are shown in figure 8.

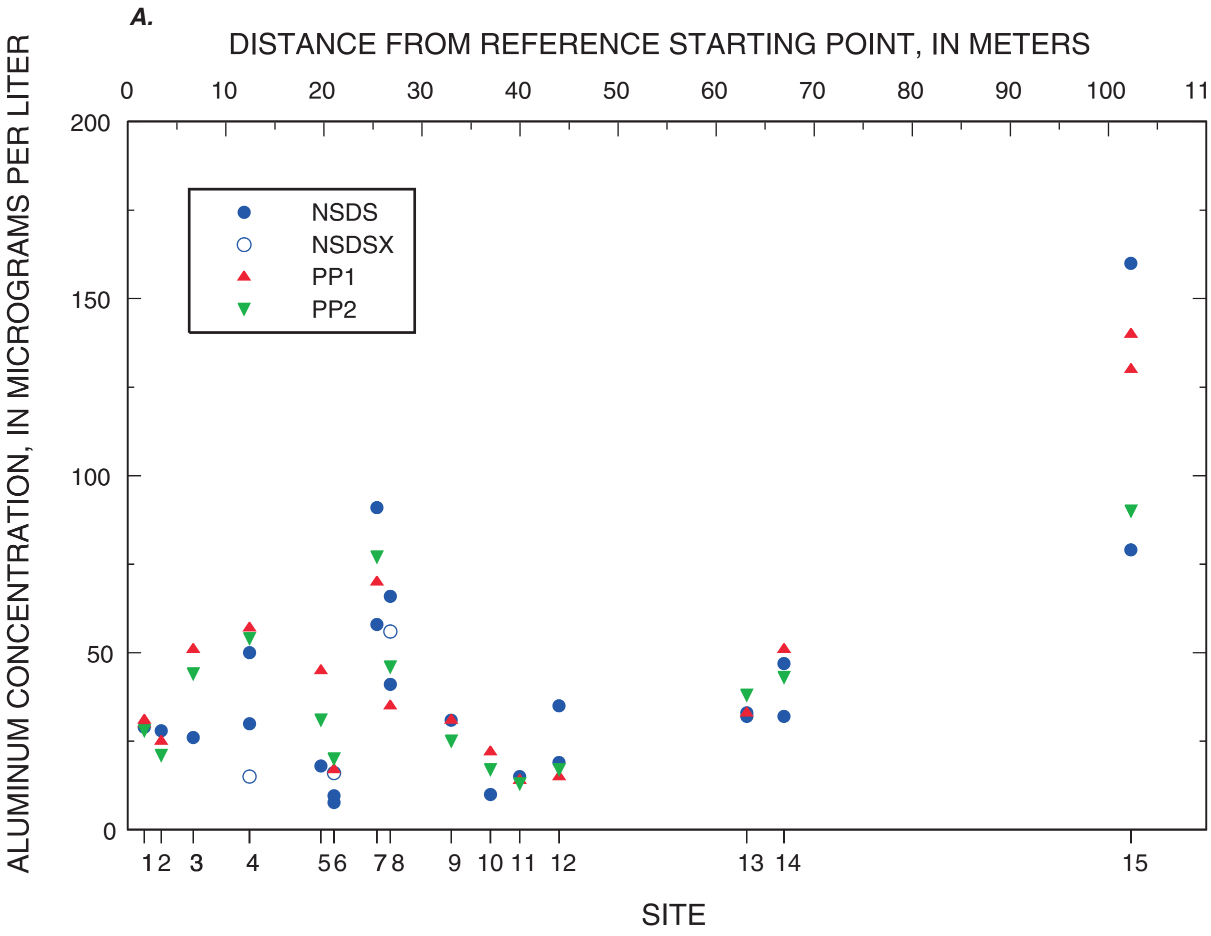

Figure 14. Results for final round of sampling with nylon-screen diffusion samplers and pushpoint samplers for *A*, aluminum; *B*, arsenic; *C*, barium; *D*, iron; *E*, manganese; and *F*, zinc at all Rigby Brook study-area sampling sites, Clinton, Massachusetts, June 2003. NSDS, nylon-screen diffusion sampler; NSDSX, nylon-screen diffusion sampler initially filled with aerated deionized water; PP1, sample from first pushpoint-sampling location; PP2, sample from second pushpoint-sampling location. Site locations are shown in figure 8.

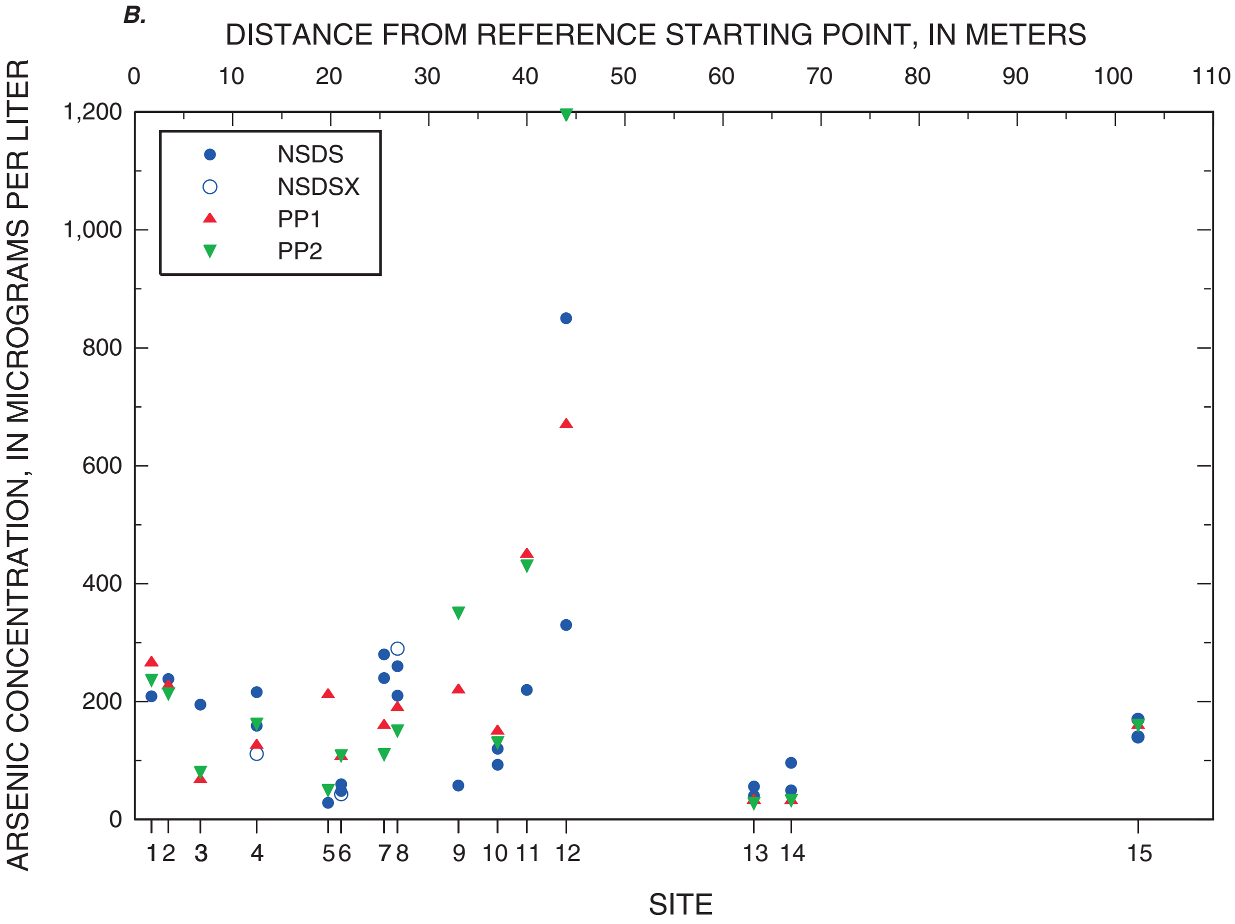

Figure 14—Continued. Results for final round of sampling with nylon-screen diffusion samplers and pushpoint samplers for *A*, aluminum; *B*, arsenic; *C*, barium; *D*, iron; *E*, manganese; and *F*, zinc at all Rigby Brook study-area sampling sites, Clinton, Massachusetts, June 2003. NSDS, nylon-screen diffusion sampler; NSDSX, nylon-screen diffusion sampler initially filled with aerated deionized water; PP1, sample from first pushpoint-sampling location; PP2, sample from second pushpoint-sampling location. Site locations are shown in figure 8.

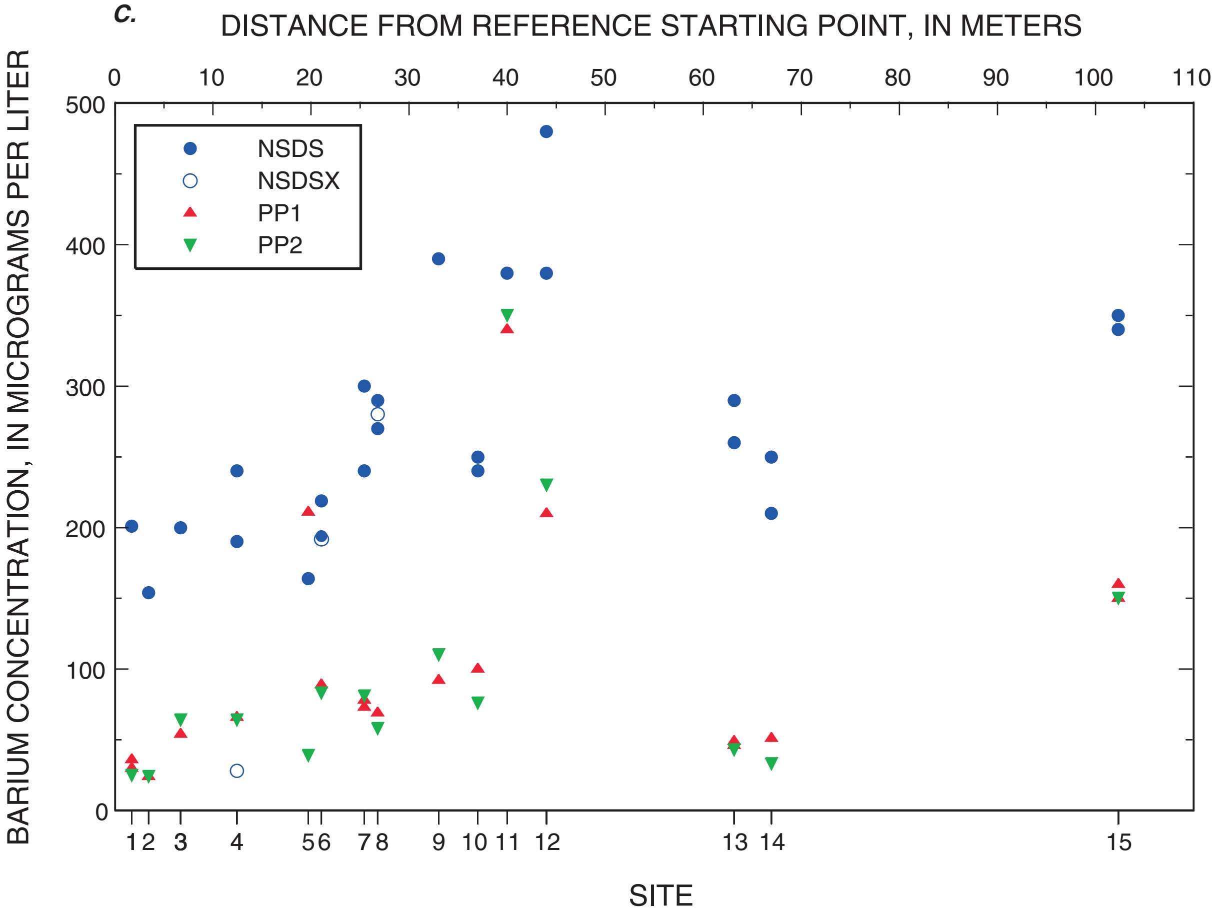

Figure 14—Continued. Results for final round of sampling with nylon-screen diffusion samplers and pushpoint samplers for *A*, aluminum; *B*, arsenic; *C*, barium; *D*, iron; *E*, manganese; and *F*, zinc at all Rigby Brook study-area sampling sites, Clinton, Massachusetts, June 2003. NSDS, nylon-screen diffusion sampler; NSDSX, nylon-screen diffusion sampler initially filled with aerated deionized water; PP1, sample from first pushpoint-sampling location; PP2, sample from second pushpoint-sampling location. Site locations are shown in figure 8.

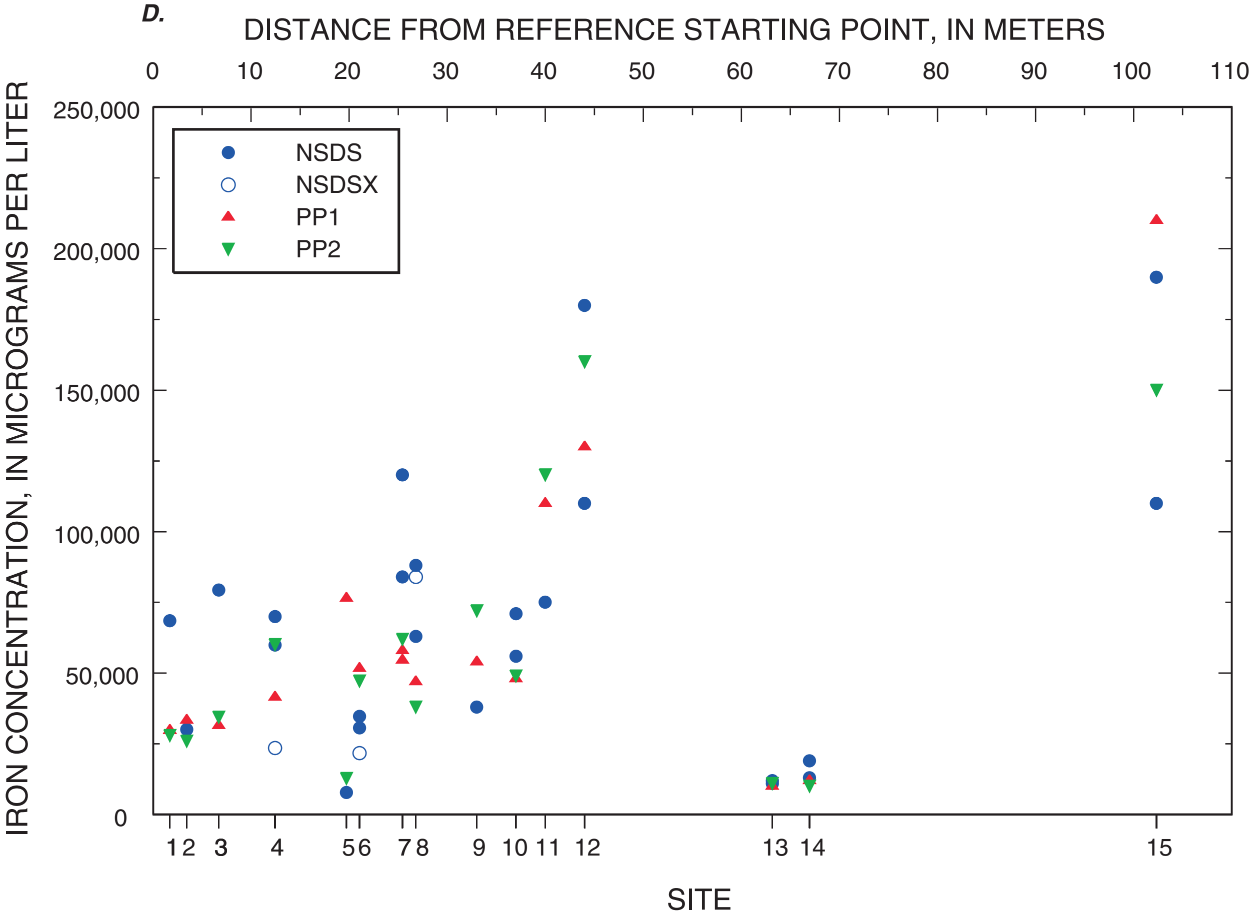

Figure 14—Continued. Results for final round of sampling with nylon-screen diffusion samplers and pushpoint samplers for *A*, aluminum; *B*, arsenic; *C*, barium; *D*, iron; *E*, manganese; and *F*, zinc at all Rigby Brook study-area sampling sites, Clinton, Massachusetts, June 2003. NSDS, nylon-screen diffusion sampler; NSDSX, nylon-screen diffusion sampler initially filled with aerated deionized water; PP1, sample from first pushpoint-sampling location; PP2, sample from second pushpoint-sampling location. Site locations are shown in figure 8.

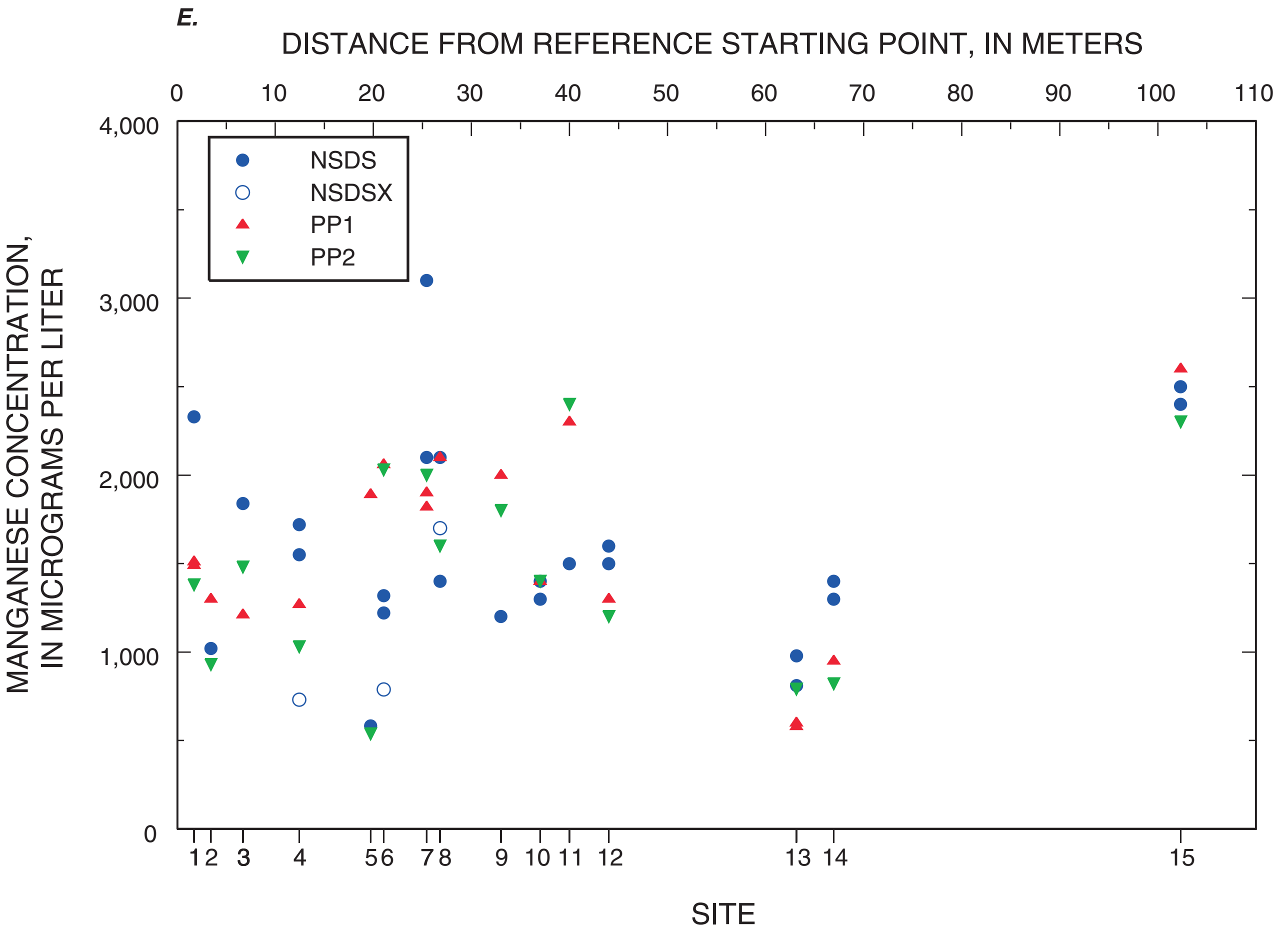

Figure 14—Continued. Results for final round of sampling with nylon-screen diffusion samplers and pushpoint samplers for *A*, aluminum; *B*, arsenic; *C*, barium; *D*, iron; *E*, manganese; and *F*, zinc at all Rigby Brook study-area sampling sites, Clinton, Massachusetts, June 2003. NSDS, nylon-screen diffusion sampler; NSDSX, nylon-screen diffusion sampler initially filled with aerated deionized water; PP1, sample from first pushpoint-sampling location; PP2, sample from second pushpoint-sampling location. Site locations are shown in figure 8.

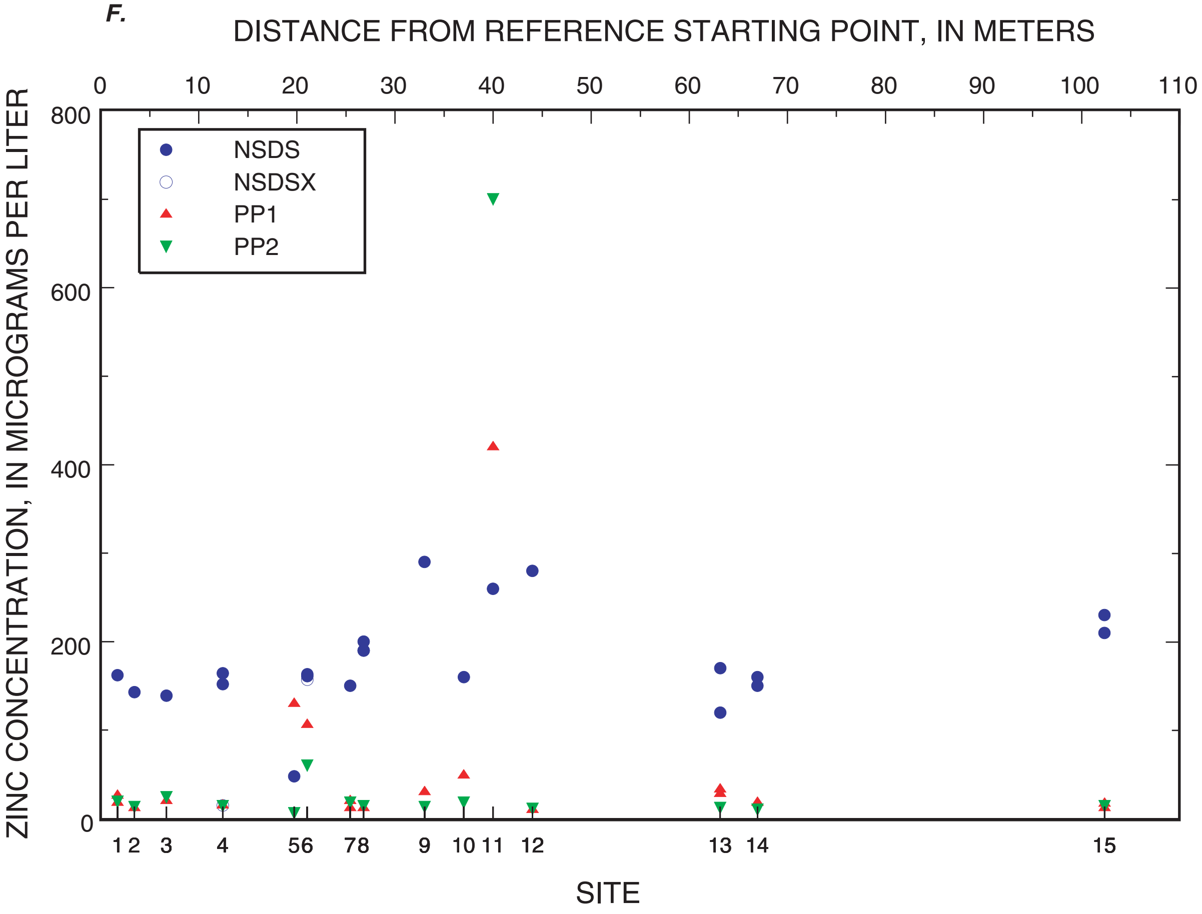

Figure 14—Continued. Results for final round of sampling with nylon-screen diffusion samplers and pushpoint samplers for *A*, aluminum; *B*, arsenic; *C*, barium; *D*, iron; *E*, manganese; and *F*, zinc at all Rigby Brook study-area sampling sites, Clinton, Massachusetts, June 2003. NSDS, nylon-screen diffusion sampler; NSDSX, nylon-screen diffusion sampler initially filled with aerated deionized water; PP1, sample from first pushpoint-sampling location; PP2, sample from second pushpoint-sampling location. Site locations are shown in figure 8.

Table 6. Concentrations of metals in quality-control samples during field studies at the Nyanza study area, Ashland, Massachusetts, and the Rigby Brook study area, Clinton, Massachusetts.

[See table 3 for definitions of atomic symbols (analytes). Reporting level for bold data was 10 times the nominal reporting level (table 3); reporting level for shaded data was twice the nominal reporting level. All concentrations are in micrograms per liter, except for calcium and magnesium, which are in milligrams per liter. Sample identifiers and site numbers preceded by the letter R are associated with the Rigby Brook study area; others are from the Nyanza study area. NSDS, nylon-screen diffusion sampler; NSDSX, nylon-screen diffusion sampler initially filled with aerated deionized water; PP1, sample from first pushpoint-sampling location; PP2, sample from second pushpoint-sampling location; nd, not detected]

Sample identifier	Site number (fig. 8)	Date	Time	Sampler type	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	V	Zn
										NSDS Duplicates												
18	**1**	**5-27-2003**	**1025**	**NSDS**	**100**	**nd**	**nd**	**260**	**nd**	**nd**	**29**	**nd**	**nd**	**4.8**	**5,000**	**nd**	**2.4**	**750**	**nd**	**nd**	**nd**	**65**
19	**1**	**5-27-2003**	**1035**	**NSDS**	**130**	**nd**	**nd**	**260**	**nd**	**nd**	**31**	**nd**	**5.0**	**3.0**	**590**	**nd**	**3.0**	**710**	**nd**	**nd**	**nd**	**67**
28	**4**	**5-27-2003**	**1210**	**NSDS**	**90**	**nd**	**nd**	**290**	**nd**	**nd**	**34**	**nd**	**17.0**	**4.0**	**1,500**	**nd**	**2.5**	**720**	**nd**	**5.2**	**nd**	**nd**
29	**4**	**5-27-2003**	**1220**	**NSDS**	**nd**	**28**	**nd**	**270**	**nd**	**nd**	**32**	**nd**	**nd**	**7.0**	**8,700**	**nd**	**2.4**	**670**	**nd**	**5.0**	**nd**	**nd**
32	**5**	**5-27-2003**	**0110**	**NSDS**	**93**	**nd**	**nd**	**290**	**nd**	**nd**	**31**	**nd**	**23.0**	**29.0**	**1,800**	**nd**	**2.3**	**660**	**nd**	**8.4**	**nd**	**nd**
33	**5**	**5-27-2003**	**0125**	**NSDS**	**110**	**nd**	**nd**	**270**	**nd**	**nd**	**31**	**nd**	**25.0**	**6.0**	**1,300**	**nd**	**2.3**	**690**	**nd**	**8.5**	**nd**	**nd**
34	**5**	**5-27-2003**	**0135**	**NSDSX**	**210**	**nd**	**nd**	**300**	**nd**	**nd**	**31**	**nd**	**17.0**	**8.0**	**740**	**nd**	**2.3**	**690**	**nd**	**8.3**	**nd**	**82**
37	**6**	**5-27-2003**	**1420**	**NSDS**	**110**	**nd**	**nd**	**280**	**nd**	**nd**	**32**	**nd**	**43.0**	**4.0**	**1,400**	**nd**	**2.3**	**750**	**nd**	**18.0**	**nd**	**65**
38	**6**	**5-27-2003**	**1430**	**NSDS**	**62**	**nd**	**nd**	**280**	**nd**	**nd**	**28**	**nd**	**13.0**	**4.0**	**5,900**	**nd**	**2.1**	**640**	**nd**	**6.5**	**nd**	**nd**
42	**7**	**5-27-2003**	**0315**	**NSDS**	**55**	**nd**	**nd**	**270**	**nd**	**nd**	**28**	**nd**	**nd**	**4.8**	**1,800**	**nd**	**2.1**	**620**	**nd**	**2.9**	**nd**	**nd**
43	**7**	**5-27-2003**	**0325**	**NSDSX**	**nd**	**nd**	**nd**	**260**	**nd**	**nd**	**28**	**nd**	**nd**	**4.0**	**3,500**	**nd**	**2.2**	**630**	**nd**	**nd**	**nd**	**nd**
46	**8**	**5-27-2003**	**0400**	**NSDS**	**nd**	**nd**	**nd**	**310**	**nd**	**nd**	**25**	**nd**	**4.8**	**11.0**	**2,000**	**nd**	**1.9**	**550**	**nd**	**4.0**	**nd**	**nd**
47	**8**	**5-27-2003**	**0415**	**NSDS**	**65**	**nd**	**nd**	**270**	**nd**	**nd**	**25**	**nd**	**4.6**	**4.0**	**2,100**	**nd**	**2.0**	**570**	**nd**	**4.3**	**nd**	**nd**
53	**10**	**5-27-2003**	**0540**	**NSDS**	**nd**	**31**	**nd**	**300**	**nd**	**nd**	**31**	**nd**	**nd**	**11.0**	**18,000**	**nd**	**1.7**	**1,000**	**nd**	**nd**	**nd**	**120**
54	**10**	**5-27-2003**	**0600**	**NSDS**	**65**	**nd**	**nd**	**280**	**nd**	**nd**	**29**	**nd**	**nd**	**18.0**	**24,000**	**nd**	**1.8**	**770**	**nd**	**nd**	**nd**	**150**
57	**11**	**5-28-2003**	**0940**	**NSDS**	**78**	**nd**	**nd**	**360**	**nd**	**nd**	**21**	**nd**	**nd**	**5.2**	**31,000**	**nd**	**1.6**	**570**	**nd**	**nd**	**nd**	**280**
58	**11**	**5-28-2003**	**1000**	**NSDS**	**64**	**nd**	**nd**	**290**	**nd**	**nd**	**34**	**nd**	**nd**	**6.6**	**45,000**	**nd**	**2.4**	**1,100**	**nd**	**nd**	**nd**	**160**
59	**11**	**5-28-2003**	**1010**	**NSDSX**	**73**	**nd**	**nd**	**290**	**nd**	**nd**	**27**	**nd**	**nd**	**24.0**	**31,000**	**nd**	**1.9**	**780**	**nd**	**nd**	**nd**	**170**
62	**12**	**5-28-2003**	**1045**	**NSDS**	**84**	**nd**	**nd**	**280**	**nd**	**nd**	**22**	**nd**	**nd**	**4.0**	**11,000**	**nd**	**1.1**	**650**	**nd**	**nd**	**nd**	**82**
63	**12**	**5-28-2003**	**1100**	**NSDS**	**150**	**nd**	**nd**	**240**	**nd**	**nd**	**26**	**nd**	**nd**	**12.0**	**25,000**	**nd**	**1.2**	**690**	**nd**	**nd**	**nd**	**120**
67	**13**	**5-28-2003**	**1130**	**NSDS**	**59**	**nd**	**nd**	**250**	**nd**	**nd**	**29**	**nd**	**nd**	**7.0**	**30,000**	**nd**	**1.5**	**1,200**	**nd**	**nd**	**nd**	**140**
68	**13**	**5-28-2003**	**1137**	**NSDS**	**180**	**nd**	**nd**	**320**	**nd**	**nd**	**31**	**nd**	**nd**	**9.0**	**20,000**	**nd**	**1.7**	**1,300**	**nd**	**nd**	**nd**	**66**
69	**13**	**5-28-2003**	**1142**	**NSDSX**	**nd**	**nd**	**nd**	**300**	**nd**	**nd**	**34**	**nd**	**nd**	**24.0**	**15,000**	**nd**	**2.7**	**1,000**	**nd**	**nd**	**nd**	**76**
R29	R4	6-4-2003	1205	NSDS	30	nd	159	190	nd	nd	20	2.30	2.40	3.0	60,000	nd	3.20	1,550	nd	1.6	1.10	152
R30	R4	6-4-2003	1209	NSDS	50	nd	216	240	nd	nd	26	4.40	2.80	3.3	70,000	0.44	3.70	1,720	nd	1.40	1.70	164
R31	R4	6-4-2003	1307	NSDSX	15	nd	111	28	nd	nd	13	.52	4.60	1.0	23,500	.85	2.40	730	nd	.74	.79	15

Table 6. Concentrations of metals in quality-control samples during field studies at the Nyanza study area, Ashland, Massachusetts, and the Rigby Brook study area, Clinton, Massachusetts.—Continued

[See table 3 for definitions of atomic symbols (analytes). Reporting level for bold data was 10 times the nominal reporting level (table 3); reporting level for shaded data was twice the nominal reporting level. All concentrations are in micrograms per liter, except for calcium and magnesium, which are in milligrams per liter. Sample identifiers and site numbers preceded by the letter R are associated with the Rigby Brook study area; others are from the Nyanza study area. NSDS, nylon-screen diffusion sampler; NSDSX, nylon-screen diffusion sampler initially filled with aerated deionized water; PP1, sample from first pushpoint-sampling location; PP2, sample from second pushpoint-sampling location; nd, not detected]

Sample ident-ifier	Site number (fig. 8)	Date	Time	Sampler type	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	V	Zn
NSDS Duplicates—Continued																						
R37	R6	6-4-2003	1419	NSDS	9.6	nd	48	194	nd	nd	14	nd	5.10	2.0	30,700	3.7	1.90	1,220	2.7	2.70	0.88	163
R38	R6	6-4-2003	1430	NSDS	7.7	nd	60	219	nd	nd	20	0.50	3.80	2.0	34,700	1.7	2.70	1,320	2.1	1.60	.69	161
R39	R6	6-4-2003	1440	NSDSX	16	nd	43	193	nd	nd	12	nd	3.60	2.0	21,800	5.3	1.60	789	2.0	4.50	.89	157
R43	R7	6-4-2003	1527	NSDS	91	nd	240	300	nd	nd	35	1.80	6.40	8.0	120,000	nd	5.10	3,100	nd	1.80	1.60	150
R44	R7	6-4-2003	1537	NSDS	58	nd	280	240	nd	nd	20	1.60	2.70	5.0	84,000	nd	3.10	2,100	nd	1.10	1.30	150
R47	R8	6-4-2003	1625	NSDS	66	nd	260	290	nd	nd	18	1.50	4.20	5.0	88,000	1.7	3.10	2,100	nd	1.20	1.90	200
R48	R8	6-4-2003	1631	NSDS	41	nd	210	270	nd	nd	15	nd	3.10	4.0	63,000	nd	2.20	1,400	nd	1.10	.86	190
R49	R8	6-4-2003	1640	NSDSX	56	nd	290	280	nd	nd	17	1.20	3.70	4.0	84,000	.86	2.90	1,700	nd	1.20	1.90	190
R55	R10	6-4-2003	1822	NSDS	nd	nd	93	240	nd	nd	14	nd	4.80	3.0	56,000	1.2	1.80	1,300	2.7	2.00	.56	160
R56	R10	6-4-2003	1825	NSDS	nd	nd	120	250	nd	nd	17	nd	4.60	6.0	71,000	1.6	2.10	1,400	4.0	1.80	.77	160
R63	R12	6-5-2003	1045	NSDS	35	nd	330	380	nd	nd	18	nd	15.00	4.0	110,000	7.3	2.50	1,600	3.4	6.60	1.20	280
R64	R12	6-5-2003	1050	NSDS	19	nd	850	480	nd	nd	23	nd	11.00	5.0	180,000	1.2	2.80	1,500	3.8	4.10	1.00	280
R68	R13	6-5-2003	1145	NSDS	33	nd	56	290	nd	nd	6.6	nd	1.40	3.0	12,000	1.2	1.40	810	nd	.83	nd	170
R69	R13	6-5-2003	1150	NSDS	32	nd	40	260	nd	nd	7.8	nd	1.30	2.0	11,000	.91	1.50	980	nd	.67	.48	120
R72	R14	6-5-2003	1220	NSDS	47	nd	49	250	nd	nd	8.4	nd	1.70	5.0	13,000	2.8	1.60	1,400	nd	.86	.95	150
R73	R14	6-5-2003	1230	NSDS	32	nd	96	210	nd	nd	9.6	nd	1.60	3.0	19,000	1.7	2.00	1,300	nd	.85	1.20	160
R77	R15	6-5-2003	1325	NSDS	79	1.3	140	340	nd	nd	18	nd	14.00	5.0	110,000	3.8	2.90	2,400	nd	3.30	1.50	230
R78	R15	6-5-2003	1335	NSDS	160	3.3	170	350	nd	nd	11	3.70	19.00	5.0	190,000	5.7	3.10	2,500	1.2	6.60	4.10	210
PPS Field Blanks																						
21	2	5-27-2003	1055		nd	nd	nd	2.5	nd	nd	nd	nd	nd	2.0	nd	nd	nd	nd	nd	nd	nd	nd
39	7	5-27-2003	1445		nd	nd	nd	5.6	nd	nd	nd	nd	nd	6.0	nd	nd	nd	nd	nd	nd	nd	nd
64	13	5-28-2003	1110		nd	nd	nd	3	nd	nd	nd	nd	nd	12.0	nd	nd	nd	nd	nd	nd	nd	nd
R27	4	6-4-2003	1140		nd	nd	nd	1.5	nd	nd	nd	nd	nd	.3	nd	nd	nd	nd	nd	nd	nd	nd
R61	12	6-5-2003	1015		nd	nd	0.71	4	nd	nd	nd	nd	nd	.2	nd	nd	nd	nd	nd	nd	nd	nd

Table 6. Concentrations of metals in quality-control samples during field studies at the Nyanza study area, Ashland, Massachusetts, and the Rigby Brook study area, Clinton, Massachusetts.—Continued

[See table 3 for definitions of atomic symbols (analytes). Reporting level for bold data was 10 times the nominal reporting level (table 3); reporting level for shaded data was twice the nominal reporting level. All concentrations are in micrograms per liter, except for calcium and magnesium, which are in milligrams per liter. Sample identifiers and site numbers preceded by the letter R are associated with the Rigby Brook study area; others are from the Nyanza study area. NSDS, nylon-screen diffusion sampler; NSDSX, nylon-screen diffusion sampler initially filled with aerated deionized water; PP1, sample from first pushpoint-sampling location; PP2, sample from second pushpoint-sampling location; nd, not detected]

Sample identifier	Site number (fig. 8)	Date	Time	Sampler type	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	V	Zn
PPS Sequential and Duplicate Samples																						
Nyanza																						
16	1	5-27-2003	1000	PP1	130	nd	nd	85	nd	nd	29	nd	2.9	13.0	3,700	nd	2.6	600	nd	3.3	nd	nd
17	1	5-27-2003	1010	PP2	450	nd	nd	77	nd	nd	32	nd	4.3	250.0	1,100	nd	2.4	730	nd	3.7	nd	nd
20	2	5-27-2003	1045	PP1	300	nd	nd	86	nd	nd	35	nd	5.0	7.6	2,600	nd	2.8	870	nd	4.3	nd	nd
22	2	5-27-2003	1105	PP2	290	nd	nd	90	nd	nd	38	nd	7.8	60.0	2,800	nd	3.0	860	nd	4.9	nd	nd
30	5	5-27-2003	1230	PP1	850	nd	nd	94	nd	nd	30	nd	53.0	9.0	nd	nd	2.1	620	nd	41.0	nd	160
31	5	5-27-2003	1250	PP2	510	nd	nd	100	nd	nd	31	nd	45.0	5.0	520	nd	2.2	680	nd	23.0	nd	nd
35	6	5-27-2003	1400	PP1	630	nd	nd	91	nd	nd	31	nd	41.0	3.0	nd	nd	2.3	680	nd	25.0	nd	nd
36	6	5-27-2003	1410	PP2	600	6.2	nd	93	nd	nd	32	nd	74.0	19.0	5,200	nd	2.3	740	nd	65.0	nd	140
40	7	5-27-2003	1450	PP1	420	nd	nd	96	nd	nd	31	nd	29.0	6.0	nd	nd	2.3	650	nd	18.0	nd	nd
41	7	5-27-2003	0305	PP2	220	nd	nd	94	nd	nd	30	nd	11.0	3.0	650	nd	2.1	640	nd	6.8	nd	nd
44	8	5-27-2003	0335	PP1	1,200	nd	nd	90	nd	5.0	30	nd	44.0	4.0	nd	110	2.1	630	nd	32.0	nd	110
45	8	5-27-2003	0345	PP2	970	nd	nd	87	nd	nd	30	nd	40.0	130.0	nd	nd	2.0	640	nd	34.0	nd	71
48	9	5-27-2003	0425	PP1	670	nd	nd	100	nd	nd	29	nd	27.0	3.0	1,000	nd	2.0	730	nd	17.0	nd	53
49	9	5-27-2003	0435	PP2	780	nd	nd	90	nd	nd	30	nd	31.0	11.0	1,100	nd	2.1	740	nd	22.0	nd	nd
51	10	5-27-2003	0500	PP1	nd	nd	nd	290	nd	nd	35	nd	nd	5.3	43,000	nd	1.9	1,600	nd	nd	nd	nd
52	10	5-27-2003	0520	PP2	nd	nd	nd	270	nd	nd	33	nd	nd	5.9	62,000	nd	2.0	1,700	nd	nd	nd	77
55	11	5-28-2003	0915	PP1	90	nd	nd	120	nd	nd	35	nd	4.7	4.0	12,000	nd	2.6	850	nd	3.5	nd	nd
56	11	5-28-2003	0925	PP2	84	nd	nd	110	nd	nd	35	nd	4.6	4.9	12,000	nd	2.6	830	nd	2.8	nd	nd
60	12	5-28-2003	1025	PP1	nd	nd	nd	120	nd	nd	33	nd	nd	4.6	16,000	nd	1.3	1,100	nd	nd	nd	nd
61	12	5-28-2003	1035	PP2	55	nd	nd	110	nd	nd	31	nd	10.0	13.0	4,500	nd	1.9	780	nd	4.0	nd	68
65	13	5-28-2003	1120	PP1	51	nd	nd	210	nd	nd	35	nd	nd	3.0	23,000	nd	2.2	1,500	nd	nd	nd	nd
66	13	5-28-2003	1122	PP1	67	11	nd	210	nd	nd	35	nd	nd	12.0	23,000	nd	2.2	1,500	nd	nd	nd	nd
70	14	5-28-2003	1155	PP1	81	nd	nd	100	nd	nd	33	nd	nd	4.0	13,000	nd	2.3	730	nd	nd	nd	nd
71	14	5-28-2003	1200	PP1	80	nd	nd	100	nd	nd	32	nd	nd	5.0	13,000	nd	2.3	710	nd	nd	nd	nd
72	14	5-28-2003	1210	PP2	90	nd	nd	110	nd	nd	33	nd	nd	38.0	12,000	nd	2.8	520	nd	nd	nd	nd
75	15	5-28-2003	1240	PP1	490	nd	nd	84	nd	nd	28	nd	12.0	12.0	1,700	nd	2.1	640	nd	9.5	nd	140
76	15	5-28-2003	1255	PP2	240	nd	nd	85	nd	nd	30	nd	9.4	18.0	4,900	nd	2.0	680	nd	6.6	nd	nd

Table 6. Concentrations of metals in quality-control samples during field studies at the Nyanza study area, Ashland, Massachusetts, and the Rigby Brook study area, Clinton, Massachusetts.—Continued

[See table 3 for definitions of atomic symbols (analytes). Reporting level for bold data was 10 times the nominal reporting level (table 3); reporting level for shaded data was twice the nominal reporting level. All concentrations are in micrograms per liter, except for calcium and magnesium, which are in milligrams per liter. Sample identifiers and site numbers preceded by the letter R are associated with the Rigby Brook study area; others are from the Nyanza study area. NSDS, nylon-screen diffusion sampler; NSDSX, nylon-screen diffusion sampler initially filled with aerated deionized water; PP1, sample from first pushpoint-sampling location; PP2, sample from second pushpoint-sampling location; nd, not detected]

Sample identifier	Site number (fig. 8)	Date	Time	Sampler type	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	V	Zn
PPS Sequential and Duplicate Samples—Continued																						
Rigby																						
R16	1	6-4-2003	0902	PP1	30	nd	267	30	nd	nd	18	nd	0.34	1.0	29,800	0.71	2.40	1,510	nd	0.65	0.73	18
R17	1	6-4-2003	0920	PP1	31	0.54	266	36	nd	nd	18	nd	.35	1.0	29,700	.64	2.50	1,490	nd	.80	.75	26
R18	1	6-4-2003	0644	PP2	28	nd	236	25	nd	nd	17	nd	.65	1.0	27,900	.63	2.30	1,380	nd	.90	.83	19
R20	2	6-4-2003	1005	PP1	25	nd	227	24	nd	nd	18	nd	.97	.5	33,400	.2	2.30	1,300	nd	.69	.65	12
R21	2	6-4-2003	1017	PP2	21	nd	213	24	nd	nd	17	0.80	.61	.7	26,000	.83	2.00	930	nd	.79	.83	13
R23	3	6-4-2003	1050	PP1	51	nd	68	54	nd	nd	18	1.60	.76	2.0	31,500	nd	2.50	1,210	nd	1.30	.90	20
R24	3	6-4-2003	1107	PP2	44	nd	80	64	nd	nd	21	2.50	.78	1.0	34,400	nd	2.90	1,480	nd	1.50	1.10	24
R26	4	6-4-2003	1137	PP1	57	nd	126	66	nd	nd	21	4.50	1.30	2.0	41,500	nd	3.40	1,270	nd	1.50	1.70	15
R28	4	6-4-2003	1200	PP2	54	nd	162	64	nd	nd	22	4.90	1.70	3.0	60,100	.41	3.10	1,030	nd	1.30	2.90	14
R32	5	6-4-2003	1322	PP1	45	nd	212	211	nd	nd	27	2.90	3.80	4.1	76,500	nd	4.20	1,890	nd	1.40	1.60	130
R33	5	6-4-2003	1327	PP2	31	nd	49	39	nd	nd	12	nd	1.30	1.0	12,800	1.4	2.10	538	nd	.87	.87	6.1
R35	6	6-4-2003	1350	PP1	17	nd	107	89	nd	nd	20	1.90	10.00	1.0	51,700	4.5	2.20	2,060	5.5	4.30	1.90	106
R36	6	6-4-2003	1405	PP2	20	nd	108	83	nd	nd	19	1.70	11.00	12.0	47,200	3.7	2.20	2,030	5.1	5.20	2.10	60
R40	7	6-4-2003	1453	PP1	70	nd	160	73	nd	nd	20	2.50	1.50	3.3	54,600	nd	3.40	1,820	nd	1.10	1.50	12
R41	7	6-4-2003	1457	PP1	70	nd	160	78	nd	nd	19	1.00	1.50	3.0	58,000	nd	3.00	1,900	nd	1.10	1.20	20
R42	7	6-4-2003	1505	PP2	77	nd	110	81	nd	nd	22	1.40	1.30	4.0	62,000	nd	3.40	2,000	nd	1.30	1.20	18
R45	8	6-4-2003	1551	PP1	35	nd	190	69	nd	nd	16	8.30	8.30	2.0	47,000	.37	3.20	2,100	nd	.68	.97	12.00
R46	8	6-4-2003	1615	PP2	46	nd	150	58	nd	nd	11	nd	1.60	2.0	38,000	.47	2.40	1,600	nd	.54	1.20	14
R50	9	6-4-2003	1700	PP1	31	nd	220	92	nd	nd	11	nd	7.30	3.0	54,000	7.4	2.10	2,000	3.2	2.30	2.00	30
R51	9	6-4-2003	1717	PP2	25	nd	350	110	nd	nd	10	nd	2.60	1.0	72,000	.99	1.60	1,800	3.1	1.10	1.30	13
R53	10	6-4-2003	1759	PP1	22	nd	150	100	nd	nd	11	nd	9.80	2.0	48,000	2.5	1.80	1,400	2.9	5.00	1.10	49
R54	10	6-4-2003	1810	PP2	17	nd	130	76	nd	nd	9.5	nd	6.50	1.0	49,000	1.9	1.50	1,400	2.4	3.10	.80	18
R57	11	6-5-2003	0940	PP1	14	nd	450	340	nd	nd	21	nd	36.00	2.0	110,000	1.3	2.90	2,300	3.3	12.00	.69	420
R58	11	6-5-2003	0950	PP2	13	nd	430	350	nd	nd	23	nd	33.00	2.0	120,000	.91	3.30	2,400	4.3	12.00	.73	700

Table 6. Concentrations of metals in quality-control samples during field studies at the Nyanza study area, Ashland, Massachusetts, and the Rigby Brook study area, Clinton, Massachusetts.—Continued

[See table 3 for definitions of atomic symbols (analytes). Reporting level for bold data was 10 times the nominal reporting level (table 3); reporting level for shaded data was twice the nominal reporting level. All concentrations are in micrograms per liter, except for calcium and magnesium, which are in milligrams per liter. Sample identifiers and site numbers preceded by the letter R are associated with the Rigby Brook study area; others are from the Nyanza study area. NSDS, nylon-screen diffusion sampler; NSDSX, nylon-screen diffusion sampler initially filled with aerated deionized water; PP1, sample from first pushpoint-sampling location; PP2, sample from second pushpoint-sampling location; nd, not detected]

Sample identifier	Site number (fig. 8)	Date	Time	Sampler type	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	V	Zn
PPS Sequential and Duplicate Samples—Continued																						
Rigby—Continued																						
R60	12	6-5-2003	1005	PP1	15	nd	670	210	nd	nd	20	nd	6.90	8.0	130,000	nd	2.80	1300	1.9	2.50	0.75	nd
R62	12	6-5-2003	1030	PP2	17	nd	1,200	230	nd	nd	20	nd	5.00	1.0	160,000	nd	2.80	1200	2.5	1.60	nd	11
R65	13	6-5-2003	1108	PP1	33	nd	32	46	nd	nd	9.7	nd	.60	2.0	10,000	6	1.90	580	nd	1.10	.60	33
R66	13	6-5-2003	1120	PP1	33	nd	33	49	nd	nd	9.9	nd	.58	3.0	10,000	5.9	1.90	600	nd	1.10	.62	28
R67	13	6-5-2003	1128	PP2	38	nd	27	43	nd	nd	7.6	nd	.65	1.0	11,000	2.6	1.60	790	nd	.61	.75	12
R70	14	6-5-2003	1200	PP1	51	nd	32	51	nd	nd	7.6	nd	.44	4.0	12,000	6.2	1.60	950	nd	.75	.82	18
R71	14	6-5-2003	1210	PP2	43	nd	32	33	nd	nd	7.6	nd	.75	3.0	10,000	2.9	1.60	820	nd	.71	.66	nd
R74	15	6-5-2003	1255	PP1	130	2	160	150	nd	nd	13	3.50	19.00	4.0	210,000	.7	3.80	2600	nd	3.90	2.50	12
R75	15	6-5-2003	1257	PP1	140	2.1	160	160	nd	nd	14	3.70	19.00	3.0	210,000	.67	3.90	2600	nd	3.90	2.50	17
R76	15	6-5-2003	1320	PP2	90	nd	160	150	nd	nd	23	1.20	8.60	3.0	150,000	nd	4.20	2300	nd	2.80	1.30	14

Table 7. Concentrations of metals detected in samples from the Nyanza study area, Ashland, Massachusetts.

[See table 3 for definitions of atomic symbols (analytes). All concentrations are in micrograms per liter, except for calcium and magnesium, which are in milligrams per liter. Concentrations in bold type exceed the project action limit. Shaded data represent samples that were diluted 10:1 due to sampler interferences. Reporting levels for those samples are 10 times the nominal reporting levels (table 3). NSDS, nylon-screen diffusion sampler; NSDSX, nylon-screen diffusion sampler initially filled with aerated deionized water; PP1, sample from first pushpoint-sampling location; PP2, sample from second pushpoint-sampling location; nd, not detected]

Sample number	Site number (fig. 8)	Date	Time	Sampler type	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	V	Zn
1	3	5-13-2003	1205	NSDS	15	nd	0.78	**270**	nd	nd	15	nd	0.3	2.0	770	0.37	1.3	**290**	nd	1.4	0.22	82
2	6	5-13-2003	1225	NSDS	45	nd	nd	**170**	0.27	nd	25	nd	17.0	2.0	**3,300**	nd	1.9	**550**	nd	10.0	nd	43
3	9	5-13-2003	1240	NSDS	17	nd	.5	**300**	nd	nd	19	nd	.7	1.0	**2,900**	nd	1.5	**410**	nd	1.7	nd	78
4	12	5-13-2003	1250	NSDS	38	nd	.74	**220**	nd	nd	8.8	nd	.2	3.0	**5,500**	1.9	.7	**250**	nd	1.1	nd	**200**
5	15	5-13-2003	1305	NSDS	32	nd	nd	**230**	.24	nd	19	0.80	2.7	2.0	**5,500**	nd	1.6	**510**	nd	3.2	nd	88
6	3	5-15-2003	1145	NSDS	14	nd	nd	**220**	nd	nd	14	nd	.4	1.0	**2,800**	nd	1.3	**290**	nd	2.0	nd	32
7	6	5-15-2003	1155	NSDS	14	nd	nd	**230**	nd	nd	25	nd	.9	3.0	**7,300**	nd	1.7	**580**	nd	2.4	nd	48
8	9	5-15-2003	1210	NSDS	12	nd	nd	**240**	nd	nd	16	nd	.6	1.0	**5,100**	nd	1.4	**350**	nd	1.9	nd	52
9	12	5-15-2003	1220	NSDS	nd	nd	nd	**300**	nd	nd	27	nd	nd	2.5	**33,000**	nd	1.5	**1,100**	nd	nd	nd	**170**
10	15	5-15-2003	1230	NSDS	57	nd	nd	**320**	nd	nd	29	nd	2.4	2.0	**8,100**	nd	2.1	**700**	nd	3.4	nd	80
11	3	5-19-2003	1140	NSDS	nd	nd	nd	**290**	nd	nd	24	nd	nd	nd	**3,000**	nd	1.8	**550**	nd	nd	nd	nd
12	6	5-19-2003	1150	NSDS	78	nd	nd	**310**	nd	nd	30	nd	19.0	**11.0**	**1,300**	nd	2.1	**690**	nd	5.9	nd	66
13	9	5-19-2003	1200	NSDS	nd	nd	nd	**270**	nd	nd	19	nd	nd	6.7	**3,200**	nd	1.5	**410**	nd	nd	nd	nd
14	12	5-19-2003	1210	NSDS	51	nd	nd	**290**	nd	nd	31	nd	nd	3.4	**29,000**	nd	1.4	**990**	nd	nd	nd	**140**
15	15	5-19-2003	1220	NSDS	nd	nd	nd	**250**	nd	nd	20	nd	nd	2.4	**7,500**	nd	1.4	**460**	nd	nd	nd	nd
16	1	5-27-2003	1000	PP1	**130**	nd	nd	**85**	nd	nd	29	nd	2.9	**13.0**	**3,700**	nd	2.6	**600**	nd	3.3	nd	nd
17	1	5-27-2003	1010	PP2	**450**	nd	nd	**77**	nd	nd	32	nd	4.3	**250.0**	**1,100**	nd	2.4	**730**	nd	3.7	nd	nd
18	1	5-27-2003	1025	NSDS	**100**	nd	nd	**260**	nd	nd	29	nd	nd	4.8	**5,000**	nd	2.4	**750**	nd	nd	nd	65
19	1	5-27-2003	1035	NSDS	**130**	nd	nd	**260**	nd	nd	31	nd	5.0	3.0	590	nd	3.0	**710**	nd	nd	nd	67
20	2	5-27-2003	1045	PP1	**300**	nd	nd	**86**	nd	nd	35	nd	5.0	7.6	**2,600**	nd	2.8	**870**	nd	4.3	nd	nd
21	2	5-27-2003	1055	BLANK	nd	nd	nd	2.5	nd	nd	nd	nd	nd	2.0	nd	nd	nd	nd	nd	nd	nd	nd
22	2	5-27-2003	1105	PP2	**290**	nd	nd	**90**	nd	nd	38	nd	7.8	**60.0**	**2,800**	nd	3.0	**860**	nd	4.9	nd	nd
23	2	5-27-2003	1115	NSDS	**260**	nd	nd	**190**	nd	nd	37	nd	2.1	3.0	930	nd	2.9	**830**	nd	2.3	nd	nd
24	3	5-27-2003	1135	PP1	**290**	nd	nd	**88**	nd	nd	31	nd	33.0	5.0	**3,200**	nd	2.2	**740**	nd	19.0	nd	52
25	3	5-27-2003	1145	NSDS	54	nd	nd	**270**	nd	nd	31	nd	nd	5.0	**3,500**	nd	2.2	**650**	nd	nd	nd	nd
26	4	5-27-2003	1150	PP1	**570**	nd	nd	**85**	nd	nd	31	nd	41.0	6.0	**1,000**	nd	2.3	**670**	nd	25.0	nd	nd
27	4	5-27-2003	1200	PP2	**460**	nd	nd	**98**	nd	nd	31	nd	17.0	**21.0**	550	nd	2.3	**680**	nd	10.0	nd	nd
28	4	5-27-2003	1210	NSDS	**90**	nd	nd	**290**	nd	nd	34	nd	17.0	4.0	**1,500**	nd	2.5	**720**	nd	5.2	nd	nd
29	4	5-27-2003	1220	NSDS	nd	28	nd	**270**	nd	nd	32	nd	nd	7.0	**8,700**	nd	2.4	**670**	nd	5.0	nd	nd
30	5	5-27-2003	1230	PP1	**850**	nd	nd	**94**	nd	nd	30	nd	**53.0**	9.0	nd	nd	2.1	**620**	nd	41.0	nd	**160**

Table 7. Concentrations of metals detected in samples from the Nyanza study area, Ashland, Massachusetts.—Continued

[See table 3 for definitions of atomic symbols (analytes). All concentrations are in micrograms per liter, except for calcium and magnesium, which are in milligrams per liter. Concentrations in bold type exceed the project action limit. Shaded data represent samples that were diluted 10:1 due to sampler interferences. Reporting levels for those samples are 10 times the nominal reporting levels (table 3). NSDS, nylon-screen diffusion sampler; NSDSX, nylon-screen diffusion sampler initially filled with aerated deionized water; PP1, sample from first pushpoint-sampling location; PP2, sample from second pushpoint-sampling location; nd, not detected]

Sample number	Site number (fig. 8)	Date	Time	Sampler type	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	V	Zn
31	5	5-27-2003	1250	PP2	**510**	nd	nd	**100**	nd	nd	31	nd	**45.0**	5.0	520	nd	2.2	**680**	nd	23.0	nd	nd
32	5	5-27-2003	110	NSDS	**93**	nd	nd	**290**	nd	nd	31	nd	23.0	**29.0**	**1,800**	nd	2.3	**660**	nd	8.4	nd	nd
33	5	5-27-2003	125	NSDS	**110**	nd	nd	**270**	nd	nd	31	nd	**25.0**	6.0	**1,300**	nd	2.3	**690**	nd	8.5	nd	nd
34	5	5-27-2003	135	NSDSX	**210**	nd	nd	**300**	nd	nd	31	nd	17.0	8.0	740	nd	2.3	**690**	nd	8.3	nd	82
35	6	5-27-2003	1400	PP1	**630**	nd	nd	**91**	nd	nd	31	nd	**41.0**	3.0	nd	nd	2.3	**680**	nd	25.0	nd	nd
36	6	5-27-2003	1410	PP2	**600**	6.2	nd	**93**	nd	nd	32	nd	**74.0**	**19.0**	**5,200**	nd	2.3	**740**	nd	**65.0**	nd	**140**
37	6	5-27-2003	1420	NSDS	**110**	nd	nd	**280**	nd	nd	32	nd	**43.0**	4.0	**1,400**	nd	2.3	**750**	nd	18.0	nd	65
38	6	5-27-2003	1430	NSDS	62	nd	nd	**280**	nd	nd	28	nd	13.0	4.0	**5,900**	nd	2.1	**640**	nd	6.5	nd	nd
39	7	5-27-2003	1445	BLANK	nd	nd	nd	**5.6**	nd	nd	nd	nd	nd	6.0	nd	nd	nd	nd	nd	nd	nd	nd
40	7	5-27-2003	1450	PP1	**420**	nd	nd	**96**	nd	nd	31	nd	**29.0**	6.0	nd	nd	2.3	**650**	nd	18.0	nd	nd
41	7	5-27-2003	305	PP2	**220**	nd	nd	**94**	nd	nd	30	nd	11.0	3.0	650	nd	2.1	**640**	nd	6.8	nd	nd
42	7	5-27-2003	315	NSDS	55	nd	nd	**270**	nd	nd	28	nd	nd	4.8	**1,800**	nd	2.1	**620**	nd	2.9	nd	nd
43	7	5-27-2003	325	NSDSX	nd	nd	nd	**260**	nd	nd	28	nd	nd	4.0	**3,500**	nd	2.2	**630**	nd	nd	nd	nd
44	8	5-27-2003	335	PP1	**1,200**	nd	nd	**90**	nd	**5.0**	30	nd	**44.0**	4.0	nd	**110**	2.1	**630**	nd	32.0	nd	110
45	8	5-27-2003	345	PP2	**970**	nd	nd	**87**	nd	nd	30	nd	**40.0**	**130.0**	nd	nd	2.0	**640**	nd	34.0	nd	71
46	8	5-27-2003	400	NSDS	nd	nd	nd	**310**	nd	nd	25	nd	4.8	**11.0**	**2,000**	nd	1.9	**550**	nd	4.0	nd	nd
47	8	5-27-2003	415	NSDS	65	nd	nd	**270**	nd	nd	25	nd	4.6	4.0	**2,100**	nd	2.0	**570**	nd	4.3	nd	nd
48	9	5-27-2003	425	PP1	**670**	nd	nd	**100**	nd	nd	29	nd	**27.0**	3.0	1000	nd	2.0	**730**	nd	17.0	nd	53
49	9	5-27-2003	435	PP2	**780**	nd	nd	**90**	nd	nd	30	nd	**31.0**	**11.0**	**1,100**	nd	2.1	**740**	nd	22.0	nd	nd
50	9	5-27-2003	445	NSDS	nd	nd	nd	**240**	nd	nd	17	nd	nd	3.0	**6,100**	nd	1.4	**410**	nd	nd	nd	nd
51	10	5-27-2003	500	PP1	nd	nd	nd	**290**	nd	nd	35	nd	nd	5.3	**43,000**	nd	1.9	**1,600**	nd	nd	nd	nd
52	10	5-27-2003	520	PP2	nd	nd	nd	**270**	nd	nd	33	nd	nd	5.9	**62,000**	nd	2.0	**1,700**	nd	nd	nd	77
53	10	5-27-2003	540	NSDS	nd	**31**	nd	**300**	nd	nd	31	nd	nd	**11.0**	**18,000**	nd	1.7	**1,000**	nd	nd	nd	120
54	10	5-27-2003	600	NSDS	65	nd	nd	**280**	nd	nd	29	nd	nd	**18.0**	**24,000**	nd	1.8	**770**	nd	nd	nd	**150**
55	11	5-28-2003	915	PP1	**90**	nd	nd	**120**	nd	nd	35	nd	4.7	4.0	**12,000**	nd	2.6	**850**	nd	3.5	nd	nd
56	11	5-28-2003	925	PP2	84	nd	nd	**110**	nd	nd	35	nd	4.6	4.9	**12,000**	nd	2.6	**830**	nd	2.8	nd	nd
57	11	5-28-2003	940	NSDS	78	nd	nd	**360**	nd	nd	21	nd	nd	5.2	**31,000**	nd	1.6	**570**	nd	nd	nd	**280**
58	11	5-28-2003	1000	NSDS	64	nd	nd	**290**	nd	nd	34	nd	nd	6.6	**45,000**	nd	2.4	**1,100**	nd	nd	nd	**160**
59	11	5-28-2003	1010	NSDSX	73	nd	nd	**290**	nd	nd	27	nd	nd	**24.0**	**31,000**	nd	1.9	**780**	nd	nd	nd	**170**
60	12	5-28-2003	1025	PP1	nd	nd	nd	**120**	nd	nd	33	nd	nd	4.6	**16,000**	nd	1.3	**1,100**	nd	nd	nd	nd

Table 7. Concentrations of metals detected in samples from the Nyanza study area, Ashland, Massachusetts.—Continued

[See table 3 for definitions of atomic symbols (analytes). All concentrations are in micrograms per liter, except for calcium and magnesium, which are in milligrams per liter. Concentrations in bold type exceed the project action limit. Shaded data represent samples that were diluted 10:1 due to sampler interferences. Reporting levels for those samples are 10 times the nominal reporting levels (table 3). NSDS, nylon-screen diffusion sampler; NSDSX, nylon-screen diffusion sampler initially filled with aerated deionized water; PP1, sample from first pushpoint-sampling location; PP2, sample from second pushpoint-sampling location; nd, not detected]

Sample number	Site number (fig. 8)	Date	Time	Sampler type	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	V	Zn
61	12	5-28-2003	1035	PP2	55	nd	nd	**110**	nd	nd	31	nd	10.0	**13.0**	**4,500**	nd	1.9	**780**	nd	4.0	nd	68
62	12	5-28-2003	1045	NSDS	84	nd	nd	**280**	nd	nd	22	nd	nd	4.0	**11,000**	nd	1.1	**650**	nd	nd	nd	82
63	12	5-28-2003	1100	NSDS	**150**	nd	nd	**240**	nd	nd	26	nd	nd	**12.0**	**25,000**	nd	1.2	**690**	nd	nd	nd	120
64	13	5-28-2003	1110	BLANK	nd	nd	nd	3	nd	nd	nd	nd	nd	**12.0**	nd	nd	nd	nd	nd	nd	nd	nd
65	13	5-28-2003	1120	PP1	51	nd	nd	**210**	nd	nd	35	nd	nd	3.0	**23,000**	nd	2.2	**1,500**	nd	nd	nd	nd
66	13	5-28-2003	1122	PP1	67	11	nd	**210**	nd	nd	35	nd	nd	**12.0**	**23,000**	nd	2.2	**1,500**	nd	nd	nd	nd
67	13	5-28-2003	1130	NSDS	59	nd	nd	**250**	nd	nd	29	nd	nd	7.0	**30,000**	nd	1.5	**1,200**	nd	nd	nd	**140**
68	13	5-28-2003	1137	NSDS	**180**	nd	nd	**320**	nd	nd	31	nd	nd	9.0	**20,000**	nd	1.7	**1,300**	nd	nd	nd	66
69	13	5-28-2003	1142	NSDSX	nd	nd	nd	**300**	nd	nd	34	nd	nd	**24.0**	**15,000**	nd	2.7	**1,000**	nd	nd	nd	76
70	14	5-28-2003	1155	PP1	81	nd	nd	**100**	nd	nd	33	nd	nd	4.0	**13,000**	nd	2.3	**730**	nd	nd	nd	nd
71	14	5-28-2003	1200	PP1	80	nd	nd	**100**	nd	nd	32	nd	nd	5.0	**13,000**	nd	2.3	**710**	nd	nd	nd	nd
72	14	5-28-2003	1210	PP2	**90**	nd	nd	**110**	nd	nd	33	nd	nd	**38.0**	**12,000**	nd	2.8	**520**	nd	nd	nd	nd
73	14	5-28-2003	1220	NSDS	51	nd	nd	**310**	nd	nd	30	nd	nd	3.0	**9,900**	nd	2.1	**780**	nd	nd	nd	nd
74	14	5-28-2003	1230	NSDS	nd	nd	nd	**290**	nd	nd	29	nd	nd	**11.0**	**6,400**	nd	2.0	**570**	nd	nd	nd	nd
75	15	5-28-2003	1240	PP1	**490**	nd	nd	**84**	nd	nd	28	nd	12.0	**12.0**	**1,700**	nd	2.1	**640**	nd	9.5	nd	140
76	15	5-28-2003	1255	PP2	**240**	nd	nd	**85**	nd	nd	30	nd	9.4	**18.0**	**4,900**	nd	2.0	**680**	nd	6.6	nd	nd
77	15	5-28-2003	110	NSDS	78	nd	nd	**310**	nd	nd	28	nd	2.0	3.0	**2,700**	nd	2.1	**620**	nd	nd	nd	nd

Table 8. Concentrations of metals detected in samples from Rigby Brook study area, Clinton, Massachusetts.

[See table 3 for definitions of atomic symbols (analytes). All concentrations are in micrograms per liter, except for calcium and magnesium, which are in milligrams per liter. Concentrations in bold type exceed the project action limit. Shaded data represent samples that were diluted 2:1 due to sampler interferences. Reporting levels for those samples are two times the nominal reporting levels (table 3). NSDS, nylon-screen diffusion sampler; NSDSX, nylon-screen diffusion sampler initially filled with aerated deionized water; PP1, sample from first pushpoint-sampling location; PP2, sample from second pushpoint-sampling location; nd, not detected]

Sample number	Site number (fig. 8)	Date	Time	Sampler type	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	V	Zn
R1	3	5-21-2003	1040	NSDS	23	nd	33	**265**	nd	nd	6.6	nd	1.50	3.0	**21,900**	0.84	1.00	**548**	nd	0.92	0.24	**199**
R2	6	5-21-2003	1055	NSDS	39	nd	18	**323**	nd	nd	7.3	nd	2.60	4.0	**12,400**	**18**	1.00	**615**	1.0	1.60	.73	**283**
R3	9	5-21-2003	1105	NSDS	32	nd	37	**371**	nd	nd	10	nd	5.50	4.0	**27,500**	**7.8**	1.40	**1,400**	1.6	3.00	1.00	**292**
R4	12	5-21-2003	1115	NSDS	36	0.52	68	**317**	nd	nd	15	nd	11.00	4.0	**44,300**	**9.1**	2.00	**1,670**	2.7	4.30	1.10	**243**
R5	15	5-21-2003	1130	NSDS	42	1.00	32	**251**	nd	nd	3.8	nd	3.20	5.0	**19,900**	**11**	.75	**552**	nd	1.70	.85	**228**
R6	3	5-23-2003	1010	NSDS	14	.51	66	**225**	nd	nd	13	nd	2.20	3.0	**54,300**	.37	1.90	**1,140**	.6	.87	.38	**157**
R7	6	5-23-2003	1020	NSDS	43	nd	30	**251**	nd	nd	9.4	nd	3.20	4.0	**22,100**	**16**	1.20	**857**	2.2	2.10	.87	**207**
R8	9	5-23-2003	1035	NSDS	50	nd	37	**228**	nd	nd	5.4	nd	3.30	4.0	**14,900**	**35**	.99	**604**	1.3	2.00	1.20	**212**
R9	12	5-23-2003	1045	NSDS	30	nd	147	**335**	nd	nd	22	0.80	17.00	6.0	**84,800**	6.4	2.90	**2,510**	6.0	6.40	1.60	**209**
R10	15	5-23-2003	1055	NSDS	82	.98	103	**221**	nd	nd	5.5	.61	5.70	4.0	**42,700**	**12**	1.10	**884**	.6	2.30	1.70	**171**
R11	3	5-28-2003	1600	NSDS	17	.7	104	**120**	nd	nd	19	nd	1.40	2.0	**66,500**	.31	2.70	**1,620**	.6	.93	.43	80
R12	6	5-28-2003	1615	NSDS	30	nd	25	**141**	nd	nd	16	nd	5.60	2.0	**35,500**	**8.4**	2.10	**1,590**	2.5	3.10	.92	**133**
R13	9	5-28-2003	1625	NSDS	63	.51	54	**123**	nd	nd	8.2	nd	3.60	**21.0**	**26,500**	**18**	1.30	**810**	1.7	2.00	1.30	**142**
R14	12	5-28-2003	1635	NSDS	31	nd	**246**	**222**	nd	nd	19	nd	14.00	2.0	**89,300**	**7.1**	2.90	**1,780**	3.0	6.30	1.20	**188**
R15	15	5-28-2003	1650	NSDS	64	.85	**310**	**165**	nd	nd	18	.80	12.00	2.0	**98,600**	**12**	2.60	**2,800**	1.1	3.30	1.80	**123**
R16	1	6-4-2003	902	PP1	30	nd	**267**	**30**	nd	nd	18	nd	.34	1.0	**29,800**	.71	2.40	**1,510**	nd	.65	.73	18
R17	1	6-4-2003	920	PP1	31	.54	**266**	**36**	nd	nd	18	nd	.35	1.0	**29,700**	.64	2.50	**1,490**	nd	.80	.75	26
R18	1	6-4-2003	644	PP2	28	nd	**236**	**25**	nd	nd	17	nd	.65	1.0	**27,900**	.63	2.30	**1,380**	nd	.90	.83	19
R19	1	6-4-2003	947	NSDS	29	.52	**209**	**201**	nd	nd	31	.54	9.20	2.0	**68,600**	.53	3.90	**2,330**	2.1	3.00	1.60	**162**
R20	2	6-4-2003	1005	PP1	25	nd	**227**	**24**	nd	nd	18	nd	.97	.5	**33,400**	.2	2.30	**1,300**	nd	.69	.65	12
R21	2	6-4-2003	1017	PP2	21	nd	**213**	**24**	nd	nd	17	.80	.61	.7	**26,000**	.83	2.00	**930**	nd	.79	.83	13
R22	2	6-4-2003	1020	NSDS	28	nd	**238**	**154**	nd	nd	17	.93	3.10	4.6	**30,000**	1.5	2.10	**1,020**	nd	2.10	.97	**143**
R23	3	6-4-2003	1050	PP1	51	nd	68	**54**	nd	nd	18	1.60	.76	2.0	**31,500**	nd	2.50	**1,210**	nd	1.30	.90	20
R24	3	6-4-2003	1107	PP2	44	nd	80	**64**	nd	nd	21	2.50	.78	1.0	**34,400**	nd	2.90	**1,480**	nd	1.50	1.10	24
R25	3	6-4-2003	1125	NSDS	26	nd	**195**	**200**	nd	nd	24	3.60	2.70	2.0	**79,300**	nd	3.40	**1,840**	nd	1.40	1.50	**139**
R26	4	6-4-2003	1137	PP1	57	nd	126	**66**	nd	nd	21	4.50	1.30	2.0	**41,500**	nd	3.40	**1,270**	nd	1.50	1.70	15
R27	4	6-4-2003	1140	BLANK	nd	nd	nd	1.5	nd	nd	nd	nd	nd	.3	nd	nd	nd	nd	nd	nd	nd	nd
R28	4	6-4-2003	1200	PP2	54	nd	**162**	**64**	nd	nd	22	4.90	1.70	3.0	**60,100**	.41	3.10	**1,030**	nd	1.30	2.90	14
R29	4	6-4-2003	1205	NSDS	30	nd	**159**	**190**	nd	nd	20	2.30	2.40	3.0	**60,000**	nd	3.20	**1,550**	nd	1.6	1.10	**152**
R30	4	6-4-2003	1209	NSDS	50	nd	**216**	**240**	nd	nd	26	4.40	2.80	3.3	**70,000**	.44	3.70	**1,720**	nd	1.40	1.70	**164**

Table 8. Concentrations of metals detected in samples from Rigby Brook study area, Clinton, Massachusetts.—Continued

[See table 3 for definitions of atomic symbols (analytes). All concentrations are in micrograms per liter, except for calcium and magnesium, which are in milligrams per liter. Concentrations in bold type exceed the project action limit. Shaded data represent samples that were diluted 2:1 due to sampler interferences. Reporting levels for those samples are two times the nominal reporting levels (table 3). NSDS, nylon-screen diffusion sampler; NSDSX, nylon-screen diffusion sampler initially filled with aerated deionized water; PP1, sample from first pushpoint-sampling location; PP2, sample from second pushpoint-sampling location; nd, not detected]

Sample number	Site number (fig. 8)	Date	Time	Sampler type	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	V	Zn
R31	4	6-4-2003	1307	NSDSX	15	nd	111	28	nd	nd	13	0.52	4.60	1.0	**23,500**	0.85	2.40	**730**	nd	0.74	0.79	15
R32	5	6-4-2003	1322	PP1	45	nd	**212**	**211**	nd	nd	27	2.90	3.80	4.1	**76,500**	nd	4.20	**1,890**	nd	1.40	1.60	**130**
R33	5	6-4-2003	1327	PP2	31	nd	49	**39**	nd	nd	12	nd	1.30	1.0	**12,800**	1.4	2.10	**538**	nd	.87	.87	6.1
R34	5	6-4-2003	1330	NSDS	18	nd	28	**164**	nd	nd	16	nd	2.50	2.0	**7,840**	.64	2.40	**583**	nd	1.80	.70	48
R35	6	6-4-2003	1350	PP1	17	nd	107	**89**	nd	nd	20	1.90	10.00	1.0	**51,700**	**4.5**	2.20	**2,060**	5.5	4.30	1.90	106
R36	6	6-4-2003	1405	PP2	20	nd	108	**83**	nd	nd	19	1.70	11.00	**12.0**	**47,200**	**3.7**	2.20	**2,030**	5.1	5.20	2.10	60
R37	6	6-4-2003	1419	NSDS	9.6	nd	48	**194**	nd	nd	14	nd	5.10	2.0	**30,700**	**3.7**	1.90	**1,220**	2.7	nd	.88	**163**
R38	6	6-4-2003	1430	NSDS	7.7	nd	60	**219**	nd	nd	20	.50	3.80	2.0	**34,700**	1.7	2.70	**1,320**	2.1	1.60	.69	**161**
R39	6	6-4-2003	1440	NSDSX	16	nd	43	**193**	nd	nd	12	nd	3.60	2.0	**21,800**	**5.3**	1.60	**789**	2.0	4.50	.89	**157**
R40	7	6-4-2003	1453	PP1	70	nd	**160**	**73**	nd	nd	20	2.50	1.50	3.3	**54,600**	nd	3.40	**1,820**	nd	1.10	1.50	12
R41	7	6-4-2003	1457	PP1	70	nd	**160**	**78**	nd	nd	19	1.00	1.50	3.0	**58,000**	nd	3.00	**1,900**	nd	1.10	1.20	20
R42	7	6-4-2003	1505	PP2	77	nd	110	**81**	nd	nd	22	1.40	1.30	4.0	**62,000**	nd	3.40	**2,000**	nd	1.30	1.20	18
R43	7	6-4-2003	1527	NSDS	**91**	nd	**240**	**300**	nd	nd	35	1.80	6.40	8.0	**120,000**	nd	5.10	**3,100**	nd	1.80	1.60	**150**
R44	7	6-4-2003	1537	NSDS	58	nd	**280**	**240**	nd	nd	20	1.60	2.70	5.0	**84,000**	nd	3.10	**2,100**	nd	1.10	1.30	**150**
R45	8	6-4-2003	1551	PP1	35	nd	**190**	**69**	nd	nd	16	8.30	8.30	2.0	**47,000**	.37	3.20	**2,100**	nd	.68	.97	12.00
R46	8	6-4-2003	1615	PP2	46	nd	150	**58**	nd	nd	11	nd	1.60	2.0	**38,000**	.47	2.40	**1,600**	nd	.54	1.20	14
R47	8	6-4-2003	1625	NSDS	66	nd	**260**	**290**	nd	nd	18	1.50	4.20	5.0	**88,000**	1.7	3.10	**2,100**	nd	1.20	1.90	**200**
R48	8	6-4-2003	1631	NSDS	41	nd	**210**	**270**	nd	nd	15	nd	3.10	4.0	**63,000**	nd	2.20	**1,400**	nd	1.10	.86	**190**
R49	8	6-4-2003	1640	NSDSX	56	nd	**290**	**280**	nd	nd	17	1.20	3.70	4.0	**84,000**	.86	2.90	**1,700**	nd	1.20	1.90	**190**
R50	9	6-4-2003	1700	PP1	31	nd	**220**	**92**	nd	nd	11	nd	7.30	3.0	**54,000**	**7.4**	2.10	**2,000**	3.2	2.30	2.00	30
R51	9	6-4-2003	1717	PP2	25	nd	**350**	**110**	nd	nd	10	nd	2.60	1.0	**72,000**	.99	1.60	**1,800**	3.1	1.10	1.30	13
R52	9	6-4-2003	1730	NSDS	31	nd	58	**390**	nd	nd	9.9	nd	4.70	5.0	**38,000**	**5.7**	1.60	**1,200**	1.8	2.10	1.60	**290**
R53	10	6-4-2003	1759	PP1	22	nd	150	**100**	nd	nd	11	nd	9.80	2.0	**48,000**	2.5	1.80	**1,400**	2.9	5.00	1.10	49
R54	10	6-4-2003	1810	PP2	17	nd	130	**76**	nd	nd	9.5	nd	6.50	1.0	**49,000**	1.9	1.50	**1,400**	2.4	3.10	.80	18
R55	10	6-4-2003	1822	NSDS	nd	nd	93	**240**	nd	nd	14	nd	4.80	3.0	**56,000**	1.2	1.80	**1,300**	2.7	2.00	.56	**160**
R56	10	6-4-2003	1825	NSDS	nd	nd	120	**250**	nd	nd	17	nd	4.60	6.0	**71,000**	1.6	2.10	**1,400**	4.0	1.80	.77	**160**
R57	11	6-5-2003	940	PP1	14	nd	**450**	**340**	nd	nd	21	nd	**36.00**	2.0	**110,000**	1.3	2.90	**2,300**	3.3	12.00	.69	**420**
R58	11	6-5-2003	950	PP2	13	nd	**430**	**350**	nd	nd	23	nd	**33.00**	2.0	**120,000**	.91	3.30	**2,400**	4.3	12.00	.73	**700**
R59	11	6-5-2003	1000	NSDS	15	nd	**220**	**380**	nd	nd	16	nd	12.00	4.0	**75,000**	2	2.20	**1,500**	4.1	4.10	.76	**260**
R60	12	6-5-2003	1005	PP1	15	nd	**670**	**210**	nd	nd	20	nd	6.90	8.0	**130,000**	nd	2.80	**1,300**	1.9	2.50	.75	nd

Table 8. Concentrations of metals detected in samples from Rigby Brook study area, Clinton, Massachusetts.—Continued

[See table 3 for definitions of atomic symbols (analytes). All concentrations are in micrograms per liter, except for calcium and magnesium, which are in milligrams per liter. Concentrations in bold type exceed the project action limit. Shaded data represent samples that were diluted 2:1 due to sampler interferences. Reporting levels for those samples are two times the nominal reporting levels (table 3). NSDS, nylon-screen diffusion sampler; NSDSX, nylon-screen diffusion sampler initially filled with aerated deionized water; PP1, sample from first pushpoint-sampling location; PP2, sample from second pushpoint-sampling location; nd, not detected]

Sample number	Site number (fig. 8)	Date	Time	Sampler type	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	V	Zn
R61	12	6-5-2003	1015	BLANK	nd	nd	0.71	4	nd	nd	nd	nd	nd	0.2	nd	nd	nd	nd	nd	nd	nd	nd
R62	12	6-5-2003	1030	PP2	17	nd	**1,200**	**230**	nd	nd	20	nd	5.00	1.0	**160,000**	nd	2.80	**1,200**	2.5	1.60	nd	11
R63	12	6-5-2003	1045	NSDS	35	nd	**330**	**380**	nd	nd	18	nd	15.00	4.0	**110,000**	**7.3**	2.50	**1,600**	3.4	6.60	1.20	**280**
R64	12	6-5-2003	1050	NSDS	19	nd	**850**	**480**	nd	nd	23	nd	11.00	5.0	**180,000**	1.2	2.80	**1,500**	3.8	4.10	1.00	**280**
R65	13	6-5-2003	1108	PP1	33	nd	32	**46**	nd	nd	9.7	nd	.60	2.0	**10,000**	6	1.90	**580**	nd	1.10	.60	33
R66	13	6-5-2003	1120	PP1	33	nd	33	**49**	nd	nd	9.9	nd	.58	3.0	**10,000**	**5.9**	1.90	**600**	nd	1.10	.62	28
R67	13	6-5-2003	1128	PP2	38	nd	27	**43**	nd	nd	7.6	nd	.65	1.0	**11,000**	**2.6**	1.60	**790**	nd	.61	.75	12
R68	13	6-5-2003	1145	NSDS	33	nd	56	**290**	nd	nd	6.6	nd	1.40	3.0	**12,000**	1.2	1.40	**810**	nd	.83	nd	**170**
R69	13	6-5-2003	1150	NSDS	32	nd	40	**260**	nd	nd	7.8	nd	1.30	2.0	**11,000**	.91	1.50	**980**	nd	.67	.48	120
R70	14	6-5-2003	1200	PP1	51	nd	32	**51**	nd	nd	7.6	nd	.44	4.0	**12,000**	**6.2**	1.60	**950**	nd	.75	.82	18
R71	14	6-5-2003	1210	PP2	43	nd	32	**33**	nd	nd	7.6	nd	.75	3.0	**10,000**	**2.9**	1.60	**820**	nd	.71	.66	nd
R72	14	6-5-2003	1220	NSDS	47	nd	49	**250**	nd	nd	8.4	nd	1.70	5.0	**13,000**	**2.8**	1.60	**1,400**	nd	.86	.95	**150**
R73	14	6-5-2003	1230	NSDS	32	nd	96	**210**	nd	nd	9.6	nd	1.60	3.0	**19,000**	1.7	2.00	**1,300**	nd	.85	1.20	**160**
R74	15	6-5-2003	1255	PP1	**130**	2	**160**	**150**	nd	nd	13	3.50	19.00	4.0	**210,000**	.7	3.80	**2,600**	nd	3.90	2.50	12
R75	15	6-5-2003	1257	PP1	**140**	2.1	**160**	**160**	nd	nd	14	3.70	19.00	3.0	**210,000**	.67	3.90	**2,600**	nd	3.90	2.50	17
R76	15	6-5-2003	1320	PP2	**90**	nd	**160**	**150**	nd	nd	23	1.20	8.60	3.0	**150,000**	nd	4.20	**2,300**	nd	2.80	1.30	14
R77	15	6-5-2003	1325	NSDS	79	1.3	140	**340**	nd	nd	18	nd	14.00	5.0	**110,000**	**3.8**	2.90	**2,400**	nd	3.30	1.50	**230**
R78	15	6-5-2003	1335	NSDS	**160**	3.3	**170**	**350**	nd	nd	11	3.70	19.00	5.0	**190,000**	**5.7**	3.10	**2,500**	1.2	6.60	4.10	**210**