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TOXIC SUBSTANCES HYDROLOGY PROGRAM

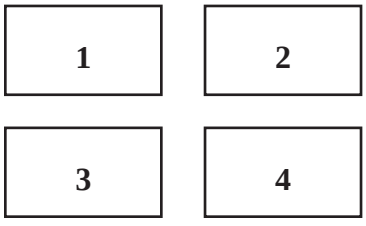
Prepared in cooperation with the
AIR FORCE CENTER FOR ENGINEERING AND THE ENVIRONMENT

Water-Quality Data from Shallow Pond-Bottom Groundwater in the Fishermans Cove Area of Ashumet Pond, Cape Cod, Massachusetts, 2001–2010

Data Series 588

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

Cover Photographs. (1) Groundwater samples being collected in Fishermans Cove, Ashumet Pond, Massachusetts (view looking west) (2) pond-bottom piezometers being installed from a barge using a vibratory ATV-mounted drilling rig; (3) excavators digging out pond-bottom materials to a depth of 3 feet, and a mixing bucket (red apparatus on the right) mixing iron filings into the pond-bottom sediment; and (4) U.S. Geological Survey scientists installing samplers below the bottom of Ashumet Pond to monitor the effectiveness of the geochemical barrier.



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By Timothy D. McCobb and Denis R. LeBlanc

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U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

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Conversion Factors, Data, and Abbreviations

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
square foot (ft^2)	0.09290	square meter (m^2)
square inch (in^2)	6.452	square centimeter (cm^2)
	Volume	
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
inch per hour (in/h)	0 .0254	meter per hour (m/h)
	Mass	
ounce, avoirdupois (oz)	28.35	gram (g)

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

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

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

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Water-Quality Data from Shallow Pond-Bottom Groundwater in the Fishermans Cove Area of Ashumet Pond, Cape Cod, Massachusetts, 2001–2010

By Timothy D. McCobb and Denis R. LeBlanc

Abstract

The U.S. Geological Survey (USGS) collected water-quality data between 2001 and 2010 in the Fishermans Cove area of Ashumet Pond, Falmouth, Massachusetts, where the eastern portion of a treated-wastewater plume, created by more than 60 years of overland disposal, discharges to the pond. Temporary drive points were installed, and shallow pond-bottom groundwater was sampled, at 167 locations in 2001, 150 locations in 2003, and 120 locations in 2004 to delineate the distribution of wastewater-related constituents. In 2004, the Air Force Center for Engineering and the Environment (AFCEE) installed a pond-bottom permeable reactive barrier (PRB) to intercept phosphate in the plume at its discharge point to the pond. The USGS monitored the performance of the PRB by collecting samples from temporary drive points at multiple depth intervals in 2006 (200 samples at 76 locations) and 2009 (150 samples at 90 locations). During the first 5 years after installation of the PRB, water samples were collected periodically from five types of pore-water samplers that had been permanently installed in and near the PRB during the barrier's emplacement. The distribution of wastewater-related constituents in the pond-bottom groundwater and changes in the geochemistry of the pond-bottom groundwater after installation of the PRB have been documented in several published reports that are listed in the references.

Introduction

A plume of groundwater contaminated by treated wastewater was created by more than 60 years of disposal to infiltration beds at a former wastewater-treatment facility at the Massachusetts Military Reservation (MMR) (fig. 1) (LeBlanc, 1984; Savoie and LeBlanc, 1998). The eastern side of this plume discharges to Ashumet Pond, a kettle-hole pond about 1,600 ft downgradient of the disposal beds. Since the early 1990s, the U.S. Geological Survey (USGS), in cooperation with the Air Force Center for Engineering and the Environment (AFCEE), has studied the distribution and transport of phosphate in the plume, including the discharge of phosphate to the Fishermans Cove area of the pond (fig. 2) (Walter and others, 1996; McCobb and others, 2003; Parkhurst and others, 2003; McCobb and others, 2009a; McCobb and others, 2009b). These studies at the MMR indicated that phosphate transport in the groundwater is greatly retarded because phosphate sorbs strongly to the aquifer sediments. Phosphate concentrations in the groundwater will remain above background levels for many decades as uncontaminated groundwater flushes the aquifer (disposal ended in 1995), and phosphate is desorbed from the sediments (Parkhurst and others, 2003). These investigations have been prompted by the need to better understand the distribution and transport of phosphate in the glacial sand and gravel aquifer so that the potential effects of continued phosphate input on the ecology of Ashumet Pond can be evaluated (Air Force Center for Environmental Excellence (AFCEE) 2002a; AFCEE 2002b).

This report documents all of the water-quality data collected by the USGS between 2001 and 2010 in the area of Fishermans Cove, Ashumet Pond, Falmouth, MA. In 1999, McCobb and others (2003) mapped the distribution of phosphate and other treated-wastewater constituents discharging to Ashumet Pond by using drive-point sampling. This Data Series report documents the sampling results from two subsequent drive-point surveys in 2001 and 2003 that covered the same area as the 1999 study. In addition, in 2004, a drive-point-sampling round that focused on the area of greatest phosphate concentrations north of Fishermans Cove was conducted. A zero-valent-iron permeable reactive barrier (PRB) was mixed into the bottom sediment of Ashumet Pond in August 2004 by AFCEE to reduce phosphate concentrations in groundwater discharging to the pond (AFCEE, 2004; McCobb and others, 2009a). The 2004 drive-point survey was the last mapping of the discharge area of the phosphate plume prior to the installation of the PRB. In 2006 and 2009, the performance of the PRB was evaluated by using drive-point sampling at multiple depths in and adjacent to the PRB. These datasets and accompanying index maps are also included in this report.

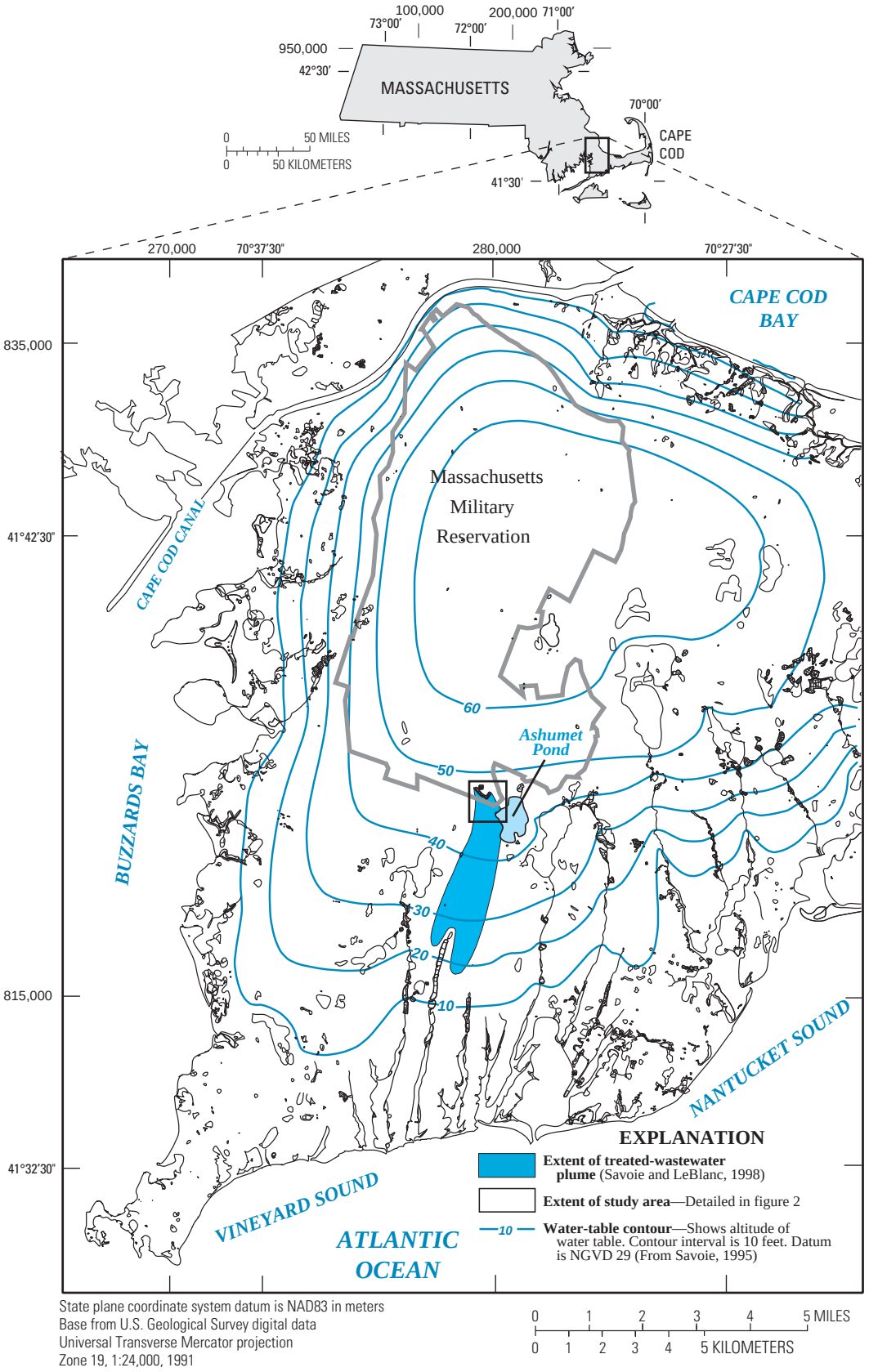
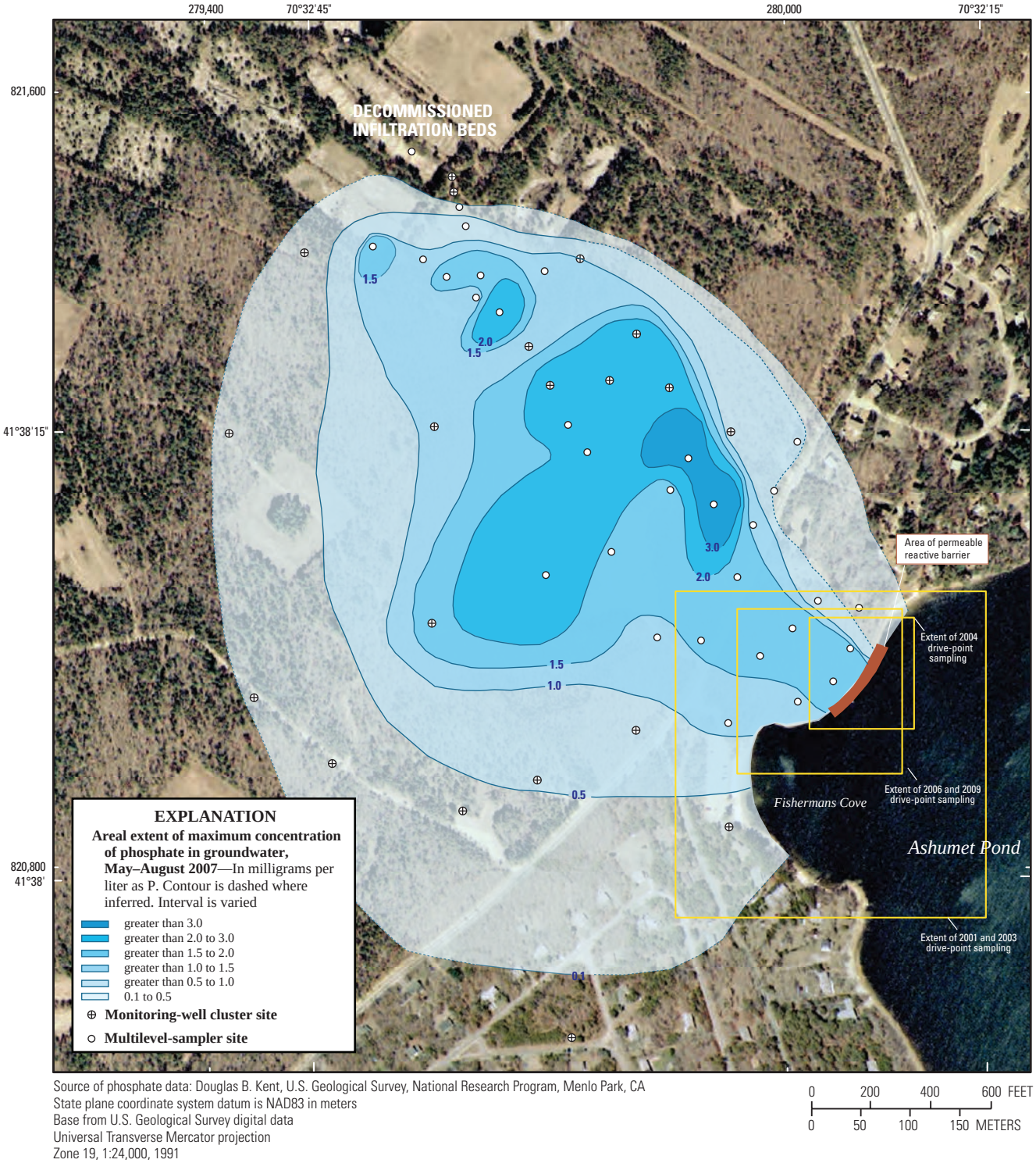


Figure 1. Location of the Massachusetts Military Reservation, extent of the treated-wastewater plume, and altitude of the water table, western Cape Cod, Massachusetts.



Source of phosphate data: Douglas B. Kent, U.S. Geological Survey, National Research Program, Menlo Park, CA
State plane coordinate system datum is NAD83 in meters
Base from U.S. Geological Survey digital data
Universal Transverse Mercator projection
Zone 19, 1:24,000, 1991

Figure 2. Areal distribution of maximum phosphate concentrations in groundwater upgradient of Ashumet Pond, Cape Cod, Massachusetts, May–August 2007. The extent of each drive-point-sampling event by date and the area of the permeable reactive barrier (PRB) are delineated.

As part of the PRB-performance monitoring, multiple types of permanent pond-bottom instrumentation were designed, developed, and installed in and near the PRB. McCobb and others (2009a) describe these devices in detail and provide results from the first 24 months following installation of the PRB. Data collected by using these instruments between July 2004 and August 2010 also are tabulated in this report. The data presented in this document are summarized in table 1 by date, sampling method, extent of sampling area, and sample analyses performed.

Water-Quality Data for Samples Collected from Temporary Drive Points

The methods used to obtain the data presented in this report, including the sample-collection and chemical-analysis methods for both the temporary drive points and permanently placed PRB instrumentation, have been previously described in detail in reports by McCobb and others (2003; 2009a; 2009b) and are summarized by date in table 1.

Between 2001 and 2009, samples were collected from 603 locations in the Fishermans Cove area of Ashumet Pond from well points (Macho Model, K-V Associates, Inc., Mashpee, MA) and small-diameter microwells (PushPoint Sampler, MHE Products, East Tawas, MI) driven temporarily into the pond bottom. Although the objectives of these sampling events differed, the sampling procedures and methodology described by McCobb and others (2003) were followed closely. In general, after being placed over a targeted location, the sampling device was advanced into the pond-bottom sediment to a targeted depth. A peristaltic pump was used to collect water samples through a sampling tube connected to the device. Selected water-quality parameters, including specific conductance, pH, and concentrations of dissolved oxygen and orthophosphate, were determined in the field. Samples were generally collected for subsequent laboratory analysis of selected inorganic solutes, including phosphate, nitrate, and ammonium.

Temporary drive-point sampling covering the complete area of Fishermans Cove was used in August–September 2001 and June 2003 to delineate the discharge area of the treated-wastewater plume; these efforts covered the same area as the 1999 sampling round reported in McCobb and others (2003). In 2001, 167 locations were sampled for field parameters, inorganic solutes (including phosphate), and nitrogen species (including nitrate, nitrite, and ammonia) (fig. 3 and table 2). In 2003, 150 locations were sampled for the same set of parameters and constituents (fig. 4 and table 3).

In 2004, drive-point sampling at 120 locations in an area where previous (2003) phosphate detections were greater than 1 mg/L as P yielded a similar discharge footprint as that observed in 1999 (McCobb and others, 2003; McCobb and others, 2009b) (fig. 5 and table 4). Samples from these drive points provided a background dataset that represented conditions prior to the installation of the PRB. A map showing the 2004 distribution of phosphate concentrations in groundwater below the pond bottom is available in McCobb and others (2009b).

In August 2006 and August 2009, drive points were used to delineate the distributions of treated-wastewater indicators (including phosphate) at multiple depths in the area of the PRB to evaluate the performance of the remedial system (figs. 6 and 7). In 2006, 200 drive points were installed at 76 locations and pumped to collect water samples for analysis of field parameters and species of phosphate and nitrogen. The drive-point sampling-site characteristics and results from the chemical analyses are tabulated in table 5. A graphical display of these data in McCobb and others (2009b) shows each parameter and constituent, mapped by depth, below the pond bottom. In August 2009, 150 drive points were installed at 90 locations and pumped to collect water samples for analysis of the same parameters and species. The drive-point characteristics and results from the chemical analyses are tabulated in table 6.

Water-Quality Data for Samples Collected from Permanent Instrumentation near the Permeable Reactive Barrier

Prior to and during installation of the pond-bottom permeable reactive barrier (PRB), which was intended to intercept the phosphate plume at its discharge point to the pond, the USGS installed five types of groundwater-sampling devices in the PRB area to evaluate changes in geochemistry over time. Placement of the PRB was based on the area indicated by prior temporary drive-point sampling where phosphate detections were greater than 1 mg/L as P. Thirty tons of zero-valent iron (Fe^0) was mixed into excavated pond-bottom sediment and placed back onto the pond bottom to a thickness of about 2 ft. AFCEE (2004) describes the PRB design and installation in detail.

The sampling devices installed to monitor the performance of the PRB over time are distributed horizontally and vertically throughout and adjacent to the PRB area (fig. 8). Details about the design, construction, and placement of these devices, as well as a presentation of the results from the first two years of data collection, are given in McCobb and others (2009a) and only briefly presented here. The devices include vertical multilevel samplers (VMLS), multilevel diffusion chambers (MLDC), horizontal multiport samplers (HMPS), pond-bottom piezometers, and seepage meters. Tables 7–11 present sampling-site characteristics and chemical analysis by sampling device type for 2004–10.

VMLS are miniwells consisting of five 1/8-in.-diameter polyurethane tubes that are fitted with fiberglass screens and extend to different vertical positions below the pond bottom,

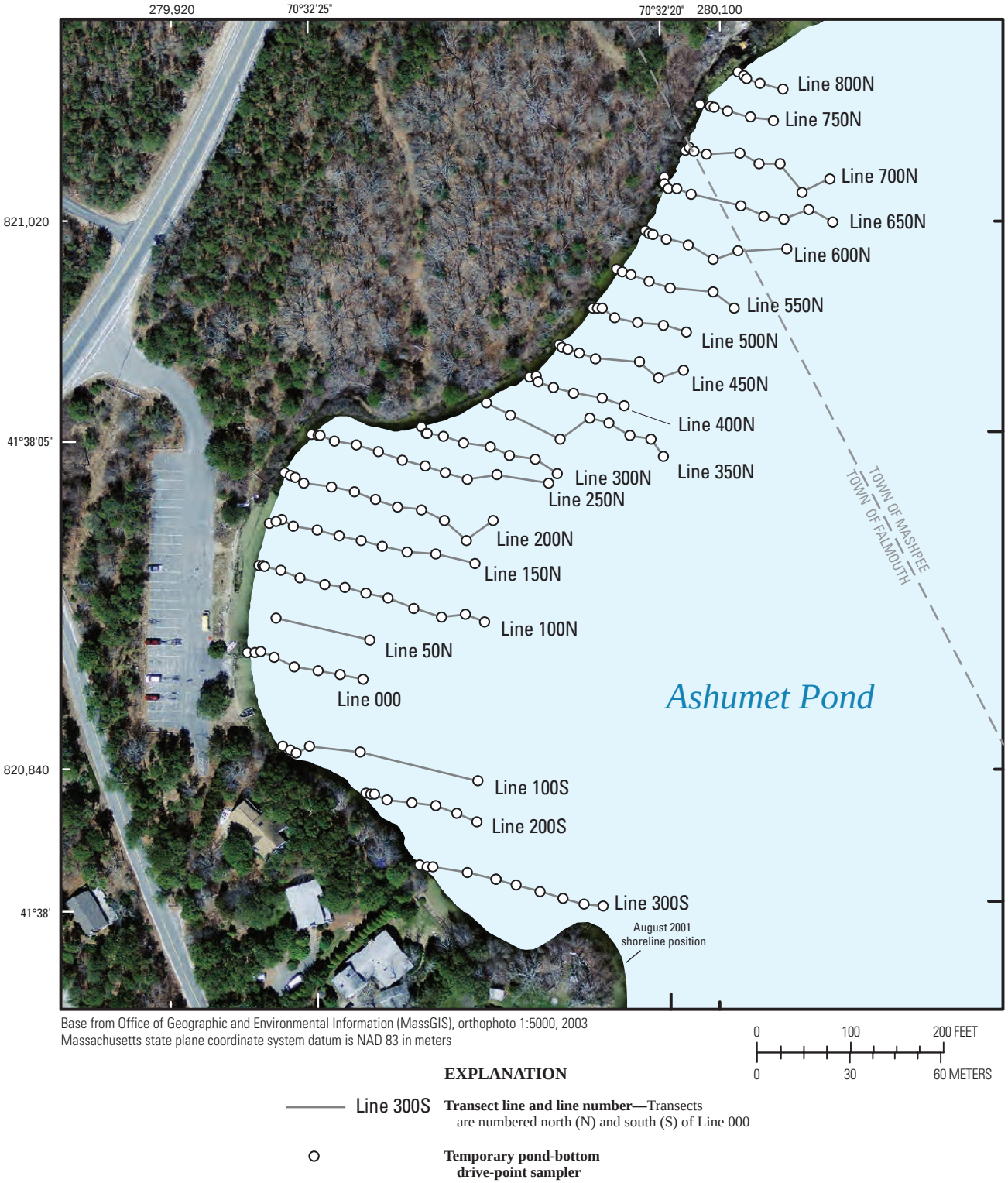


Figure 3. Locations of temporary drive points installed in August–September 2001 to delineate the discharge area of treated-wastewater-plume constituents, Ashumet Pond, Cape Cod, Massachusetts.

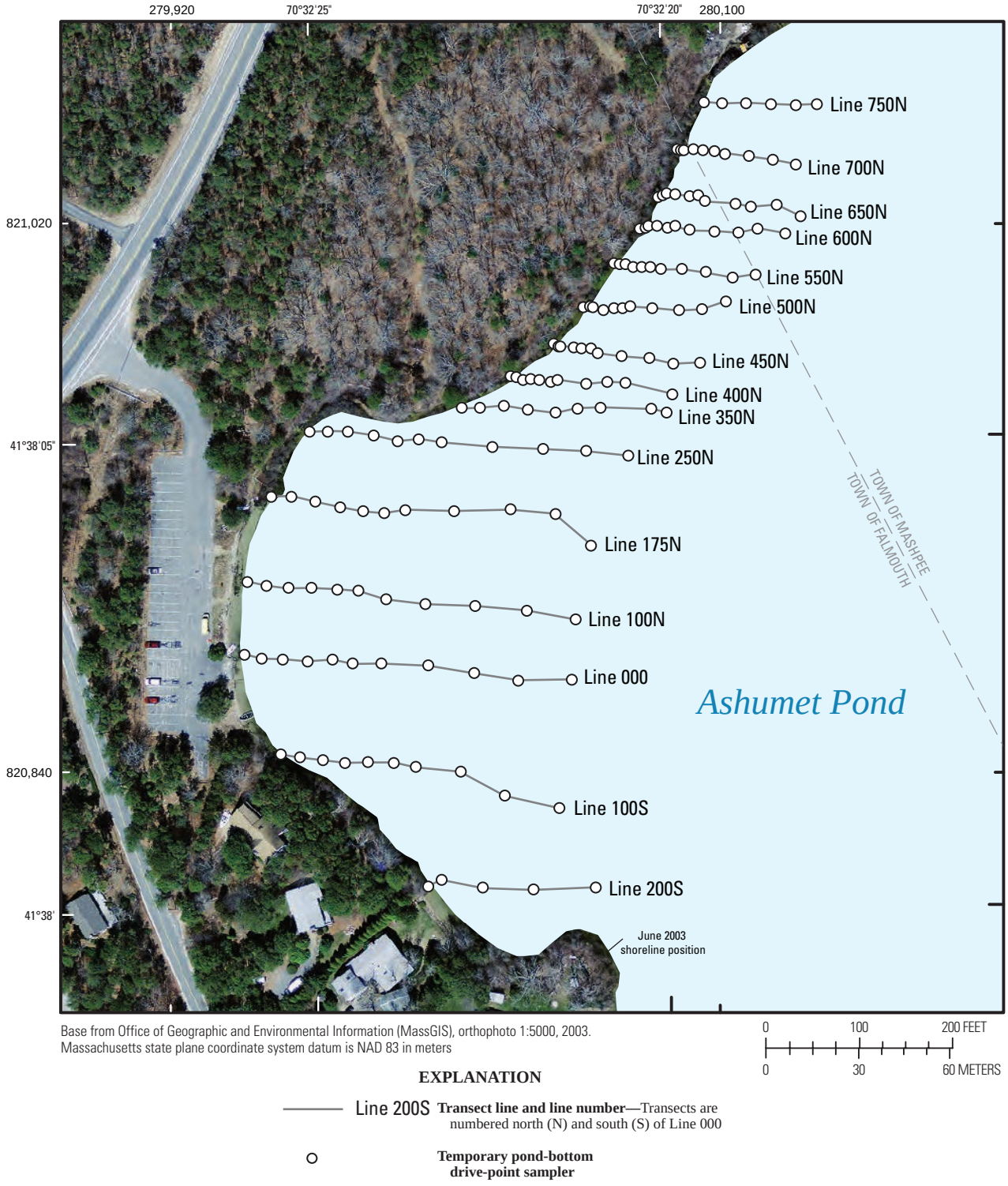


Figure 4. Locations of temporary drive points installed in June 2003 to delineate the discharge area of treated-wastewater-plume constituents, Ashumet Pond, Cape Cod, Massachusetts.

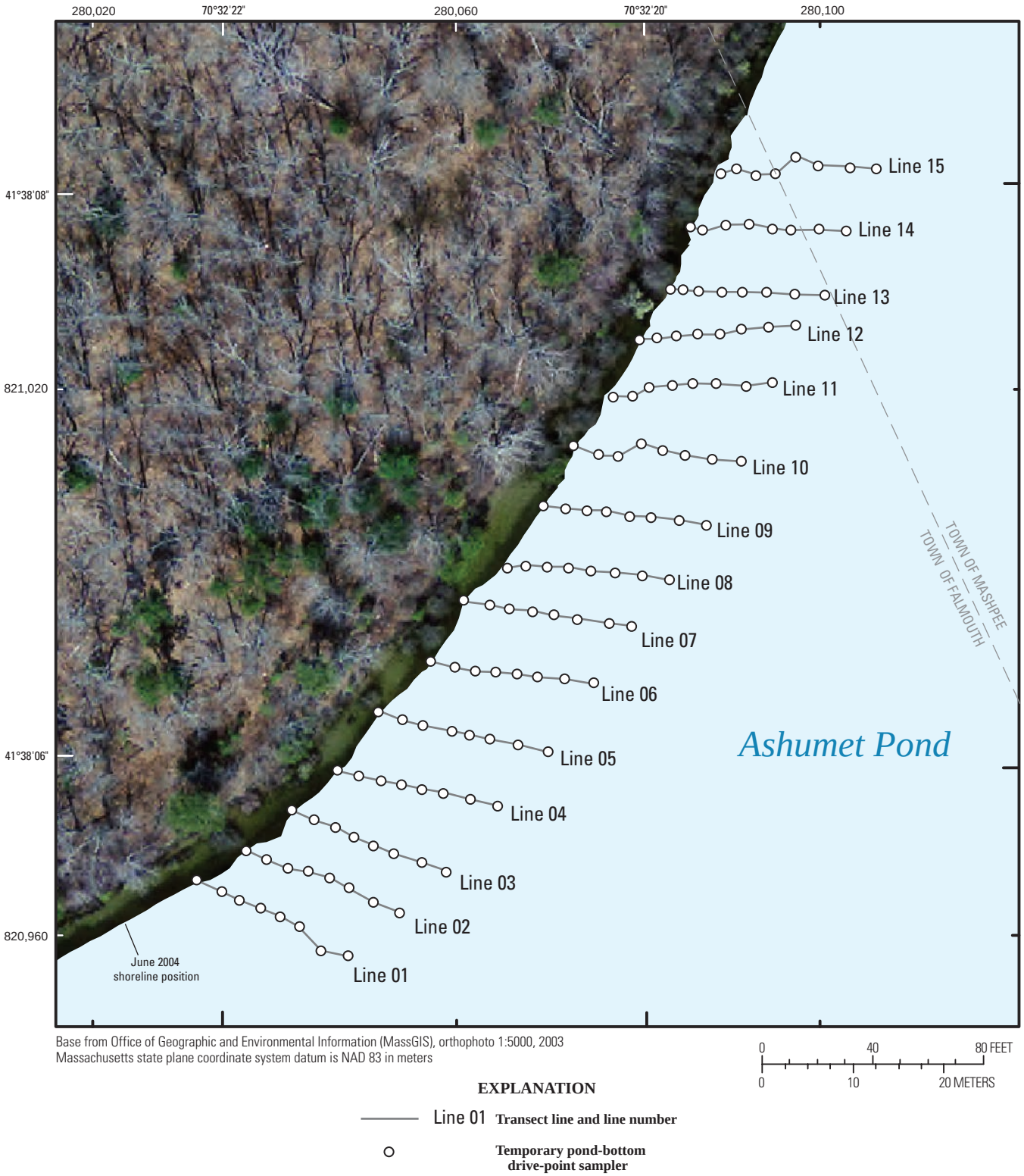


Figure 5. Locations of temporary drive points installed in June–July 2004 to delineate the discharge area of treated-wastewater-plume constituents prior to the installation of a pond-bottom permeable reactive barrier, Ashumet Pond, Cape Cod, Massachusetts.

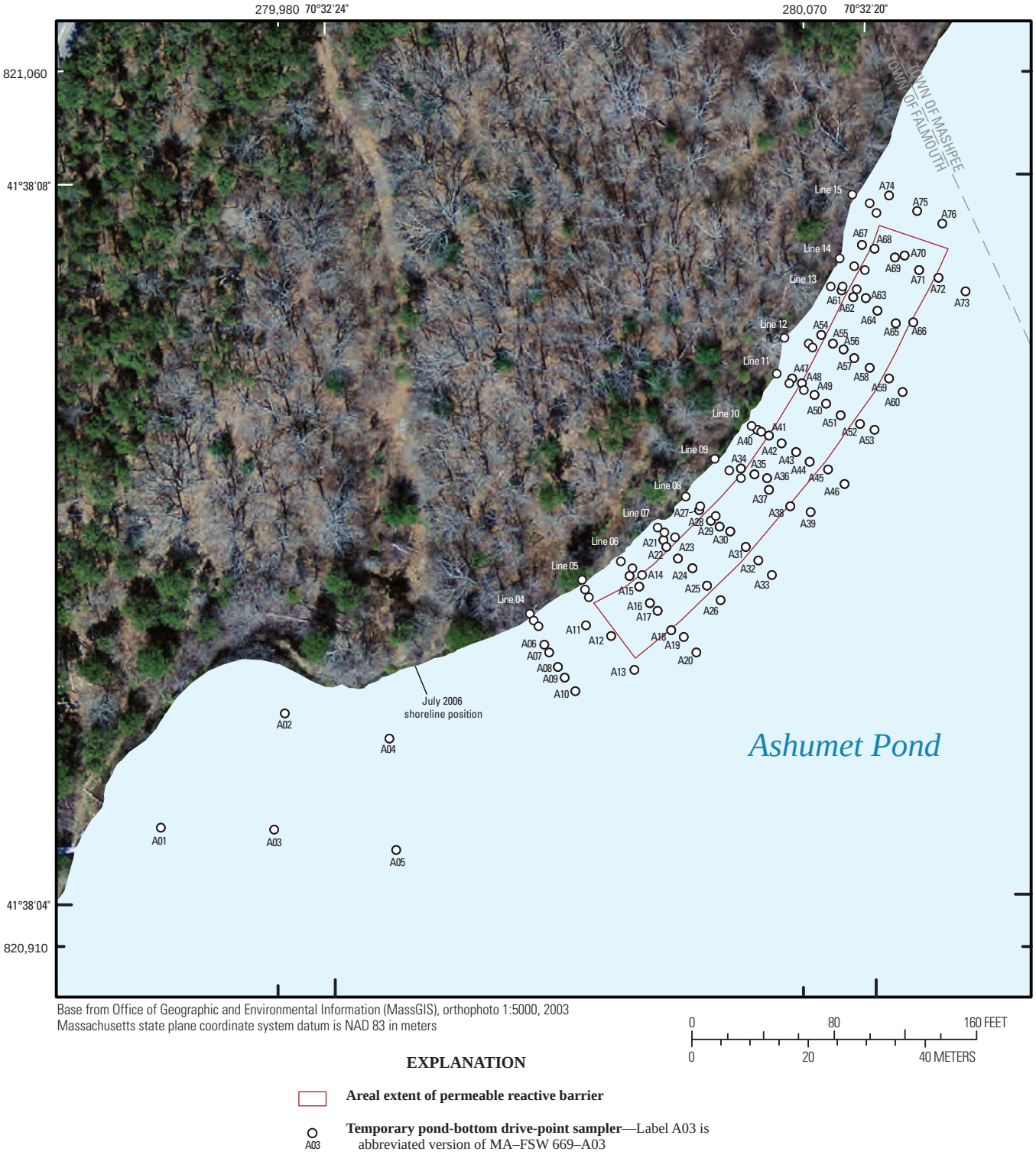


Figure 6. Locations of temporary drive points installed in August 2006 at 0.5, 1.5, and 3.0 feet below the pond bottom in the area of the permeable reactive barrier, Ashumet Pond, Cape Cod, Massachusetts. The unlabeled nearshore sampling points represent locations of temporary drive-point samplers that collected groundwater at the 0.5-foot depth. The sampling points are listed at the end of table 5 by line number and distance from shore.

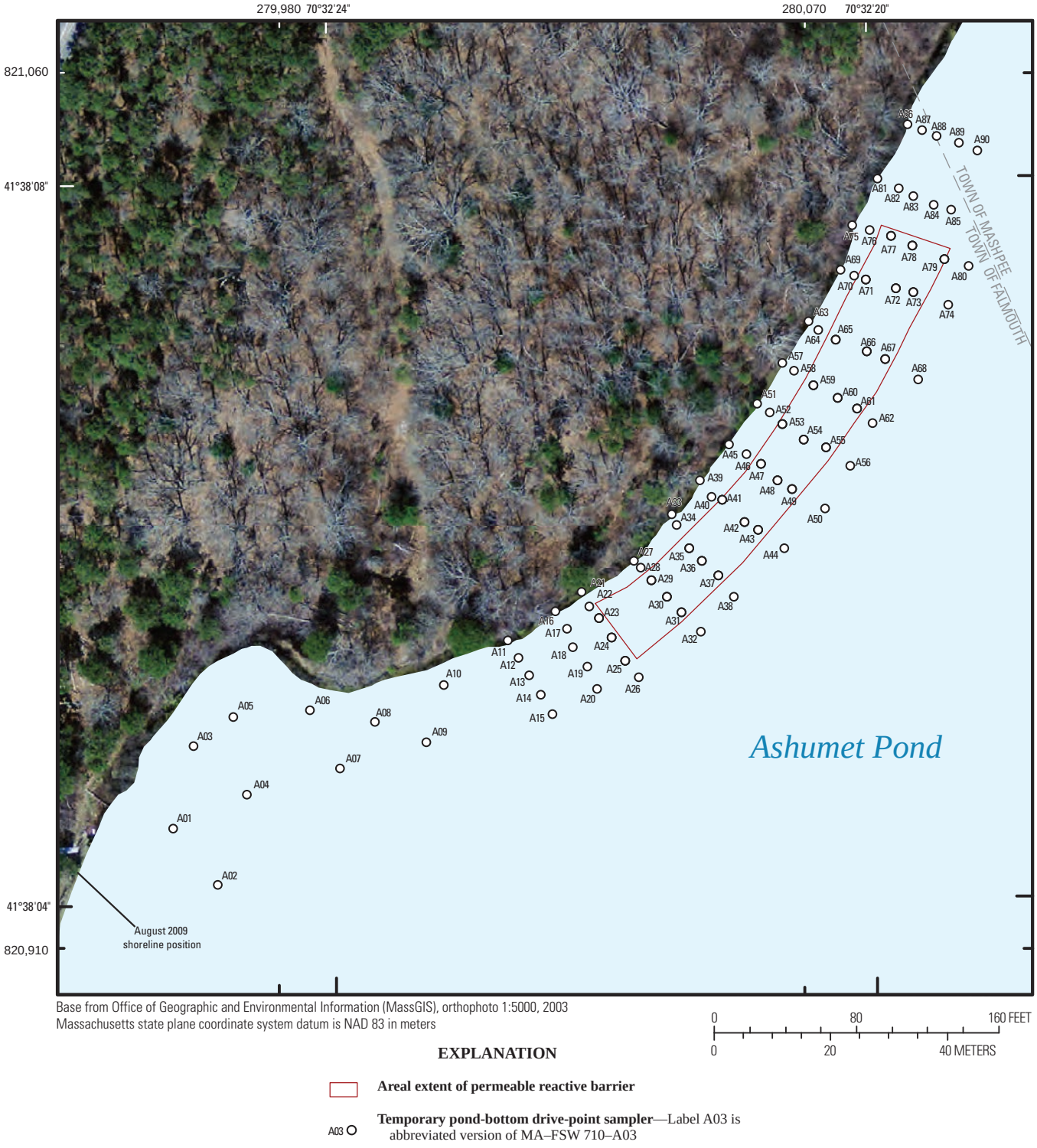


Figure 7. Locations of temporary drive points installed in August 2009 at 0.5, 1.5, and 3.0 feet below the pond bottom in the area of the permeable reactive barrier, Ashumet Pond, Cape Cod, Massachusetts.

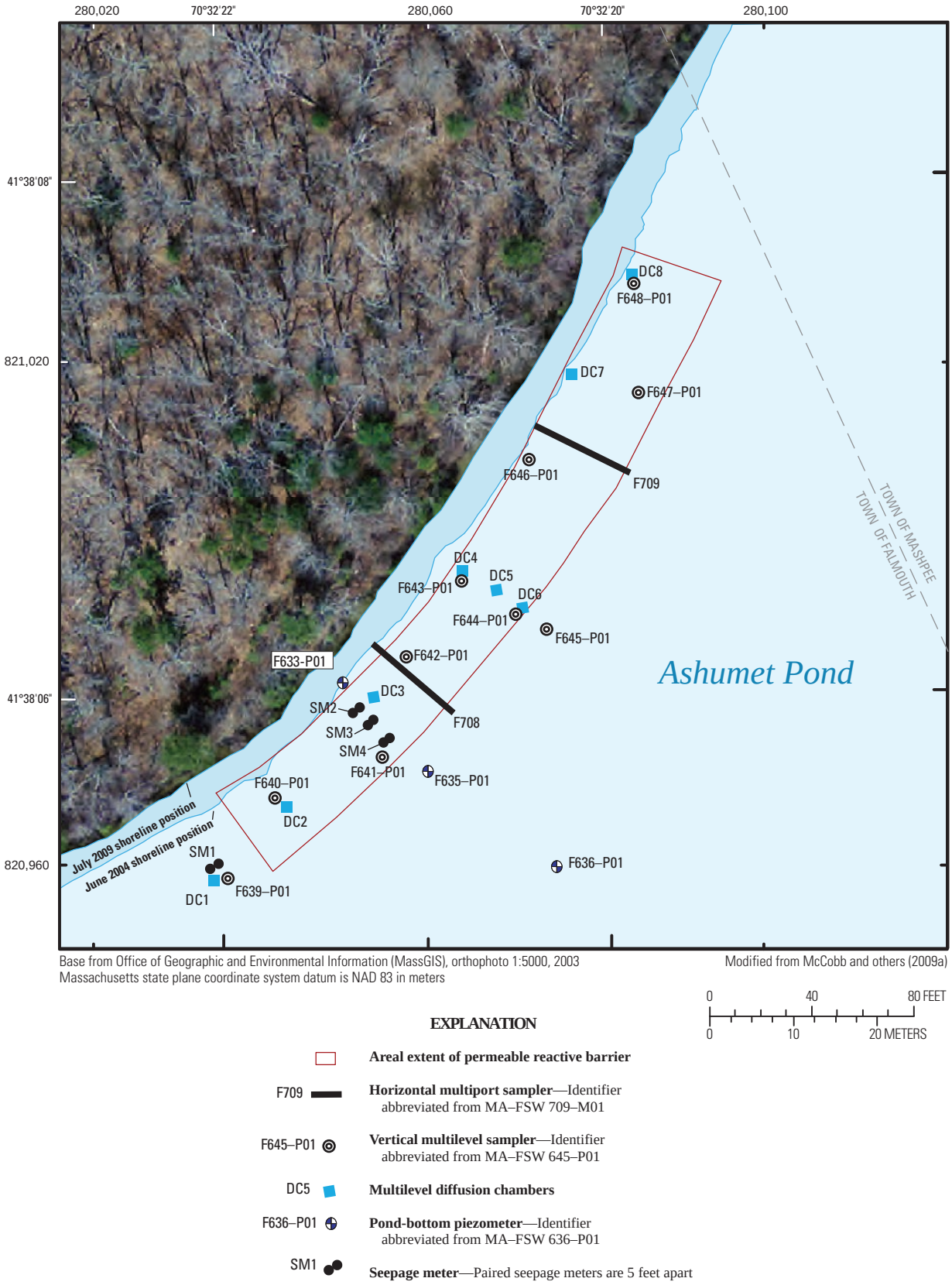


Figure 8. Locations of vertical multilevel samplers, multilevel diffusion chambers, horizontal multiport samplers, pond-bottom piezometers, and seepage meters in and near the permeable reactive barrier at Ashumet Pond, Cape Cod, Massachusetts.

with the deepest sampling port installed slightly below the PRB layer (fig. 8). Data from samples collected from the VMLS between July 2004 and July 2010 are reported in table 7.

MLDC consist of a 4-ft-long, square, hollow polyvinyl chloride (PVC) post with 13 holes drilled vertically along one face (fig. 8). Each hole is covered with a fiberglass screen to limit the entry of outside materials into the interior of the post. During a sampling event, a rack holding 13 diffusion samplers, which are 60-mL polyethylene bottles filled with deionized water and covered with a 10-µm nylon mesh, is set in the external chamber for a 2-week equilibration period. At the end of the 2-week period, the specific conductance and phosphate concentration were determined for the water in each sample bottle. In addition, the color of the nylon mesh was noted as an indicator of the presence of the the iron-containing PRB. MLDCs were sampled on nine occasions between October 2004 and August 2010 (table 1). Data from samples collected since the PRB was installed are reported in table 8.

HMPS are horizontal multiport wells that are positioned under the pond bottom perpendicular to the shoreline (fig. 8). Two samplers were emplaced in tandem, one in the untreated sediment just below the barrier (3.0 ft below the pond bottom) and one just below the sediment/water interface in the barrier (0.5 ft below the pond bottom). Each HMPS consists of a 1.25-in.-diameter PVC pipe containing 15 color-coded, 0.25-in.-diameter polyethylene tubes. The tubes exit the PVC pipe at different distances from shore and are screened with nylon material (McCobb and others, 2009a). HMPS were sampled on eight occasions between October 2004 and July 2010 (table 1). Data from samples collected from the HMPS since the installation of the PRB are reported in table 9.

Twelve pond-bottom piezometers were installed in August 2004, prior to the installation of the PRB, to monitor the phosphate plume before its discharge to Ashumet Pond (fig. 8). Each piezometer consists of a ¾-in.-diameter steel pipe with a mill-slotted 1-ft-long steel well screen. The wells were installed in three clusters (MA-FSW 633-P01, MA-FSW 635-P01, and MA-FSW 636-P01), with each cluster consisting of four piezometers extending to 10, 30, 60, and 100 ft below the pond bottom. The piezometers were installed by a vibratory-drilling rig mounted on an all-terrain vehicle placed on a barge. On eight occasions between July 2004 and August 2010, the piezometers were sampled with the assistance of divers for field parameters and laboratory analyses of selected inorganic solutes (including phosphate), nitrate, and ammonium. Results of the field and laboratory analyses from the pond-bottom piezometers are reported in table 10.

Four pairs of permanent Lee-type seepage meters (Lee, 1977) were installed in and adjacent to the PRB during the barrier's installation (fig. 8). Each meter consists of a 55-gal polyethylene drum cut to a length of 2.5 ft and fitted with a removable lid. An outlet hole drilled into the removable lid allows for the outflow or inflow to be measured. The meter design and sampling procedure are described in detail in McCobb and others (2009a). Multiple discharge measurements at each seepage meter were made on seven occasions. The water discharging through each meter was analyzed in the field to determine the specific conductance and phosphate concentration. The results of each sampling round are reported in table 11.

Summary

From 2001 to 2010, the U.S. Geological Survey, in cooperation with the Air Force Center for Engineering and the Environment, collected groundwater samples and measured pond-bottom discharge in the area of a treated-wastewater plume, which originates from wastewater-disposal beds at the Massachusetts Military Reservation and discharges to the Fishermans Cove area of Ashumet Pond, Falmouth, Cape Cod, Massachusetts. Analyses of groundwater samples provided data on the distribution, transport, and fate of phosphate, a constituent of the treated-wastewater plume. This Data Series report complements published reports about the discharge of the phosphate plume to the pond and the performance of a pond-bottom permeable reactive barrier. The data presented include (1) physical properties for the devices installed at each sampling location, including position, depth, and altitude information; (2) field parameters, including specific conductance, pH, and field-measured concentrations of dissolved oxygen and phosphate, and (3) laboratory results, including concentrations of selected inorganic solutes (including phosphate) and nitrogen species.

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