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Mercadante, A.M., Colman, J.A., and Buursink, M.L., 1999, Map showing morphometry, bathymetry, and soft-sediment thickness of Plow Shop Pond and Grove Pond, Ayer, Massachusetts

INTRODUCTION

High concentrations of trace metals have been measured in bed sediments in Plow Shop Pond and Grove Pond near the former Fort Devens U.S. Army Installation in Ayer, Massachusetts, during investigations from 1993–1995 (ABB Environmental Services, 1995). These trace metals, listed as priority pollutants by the U.S. Environmental Protection Agency (USEPA), include arsenic, cadmium, chromium, lead, mercury, and zinc. The pollutants likely are confined to the soft, surficial sediments, deposited behind the Plow Shop Pond dam, which was already in place in 1887 (Groton quadrangle topographic map, U.S. Geological Survey and State of Massachusetts, 1887). The USEPA and the U.S. Army Environmental Center are evaluating the extent and environmental significance of the trace-metal deposits.

This report presents the morphometry, bathymetry, and sediment thickness of Grove and Plow Shop Ponds in map form. Orthophoto features in the area surrounding the ponds are included to facilitate field use of the map in future studies. Knowledge of the volume of water and of the soft sediments in the ponds, and of the topographic distribution of the pond sediments, will facilitate the evaluation of the trace-metal deposits.

COLLECTION OF WATER-DEPTH AND SEDIMENT-THICKNESS DATA

Data for water depth and soft-sediment thickness were collected from October 27 to 29, 1998, from a 14-ft boat using a fathometer (Innerspace Technology, Inc., model 448)[1], which transmits high-frequency acoustic energy, and a ground-penetrating radar (GPR) unit (Geophysical Survey Systems, Inc., model SIR-10)[1], which transmits radio-frequency electromagnetic energy. A 12-ft fiberglass boat containing a 300-MHz GPR antenna was towed beside the first boat. More than 1,000 position points, shown on the map, indicate the transects along which data were collected and interpreted. Locations of the position points were recorded with a sub-meter-accuracy global positioning system (GPS) unit (Trimble Pro-XR)[1]. No data were collected in some of the pond coves because thick weeds and shallow water depths prevented boat access.

Depth calculations for water and sediment layers are based on the time that elapses between the initial transmission of energy and the reception of the reflected energy. Acoustic energy is reflected to the fathometer either by the sediment-water interface or by aquatic weeds. Radio-frequency energy is transmitted through homogeneous material but is reflected back to the antenna at boundaries where the physical or chemical properties of the material change, such as the sediment-water interface and at interfaces between soft sediments and hard sediments (Beres and Haeni, 1991). The fathometer and GPR data were recorded on paper charts. GPR data also were recorded in electronic files as were the GPS data. In addition, GPS position numbers were recorded manually on the fathometer and GPR charts at the beginning and end of each transect. Position interpolation between recorded numbers was assured by maintaining constant chart and GPS recording speed.

Ground-truth values for water depth and sediment thickness were determined using 1 x 0.5 in., 8 ft., rough-cut pine sticks, which were pushed manually into the sediment until refusal at hard deposits such as sand. The depth to the interface between soft and hard sediments was recorded and the stick retrieved. The thickness of the soft upper sediment layer was indicated by the length of black sediment adhering to the wood. At deeper sites, the wooden stick was extended by attachment to a 10 ft aluminum pole. Numbered buoys were positioned temporarily at 11 of the ground-truth locations so that data-collection transects could be easily compared.

Water-column depth was recorded in relation to the pond surface, the elevation of which was monitored daily during data collection by measurements at two shore reference points: a staff gage at Grove Pond and a culvert in Plow Shop Pond. Surveying from known elevations to the reference points established that the water surface in both ponds remained at 66.1 m above sea level during data collection.

DATA INTERPRETATION

Fathometer data could be read directly from the paper charts because the speed of acoustic energy in freshwater is constant. About one third of the fathometer data was valid for determining water depth; interference by thick aquatic-weed cover invalidated the remainder. The valid fathometer data was used to check water depths determined by GPR. Energy reflector depths for GPR were calculated using radar velocity and two-way travel time (Beres and Haeni, 1991). Radar velocities of 3.4 and 6.1 cm per nanosecond were used for water and saturated sediment, respectively. A good correspondence was achieved between the interpreted sediment thickness and ground-truth values using these radar velocities. At most locations, GPR penetrated the water and sediment to the interface between the soft and hard sediments. In the southeast part of Plow Shop Pond, however, the interface was deeper than the maximum GPR energy-penetration depth. Maximum thickness of sediment penetrated by the energy signal depends on depth of the overlying water, because both water and sediment attenuate the energy. Sediment thicknesses greater than the energy penetration depth are represented on the map as being greater than the contoured value.

Contours were computed and drawn using the GRID module of ARC/Info, version 7.1.1 from the Environmental Systems Research Institute, Inc. (ESRI™)[1]. The contours indicate the known value of depth and sediment thickness at surveyed position points and are based on computer interpolations elsewhere.

MORPHOMETRY, BATHYMETRY AND WATER VOLUME

Morphometric data (table 1), such as pond perimeter and surface area, were computed by ARC/Info from a digitized orthophoto map obtained from the Massachusetts Executive Office of Environmental Affairs. Grove Pond has about twice the perimeter and 2.4 times the surface area of Plow Shop Pond. The bathymetry of Grove Pond, generally 1 to 1.5 m deep, is slightly deeper toward the culvert outlet in the west than in the east. From the westernmost transect to the upstream bridge, Grove Pond is navigable only in a sinuous channel. Plow Shop Pond is somewhat deeper than Grove Pond. The maximum measured depth (table 1), located at the north end of the northeast arm of Plow Shop Pond, may be associated with a former drainage route from this arm. Deep water extends from the center of the pond through the northern arm. The volume of water (table 1), computed using the TIN module of ARC/Info, is about 35 percent greater in Grove Pond than in Plow Shop Pond.

Table 1. Morphometric, bathymetric, and soft-sediment thickness data for Grove Pond and Plow Shop Pond, Ayer, Massachusetts, 1998

[m, meter; m^2, square meter; m^3, cubic meter]

Pond	Perimeter (m)	Area (m^2)	Maximum depth (m)	Water volume (m^3)	Soft-sediment volume (m^3)
Grove Pond	4,355	282,900	1.93	209,000	230,000
Plow Shop Pond	2,072	119,600	2.43	149,000	>340,000

SOFT-SEDIMENT THICKNESS AND VOLUME

Soft-sediment thickness was relatively uniform throughout Grove Pond, ranging from 1 to 2 m in areas away from the shore. Soft-sediment deposits thicker than 5 m were measured in Plow Shop Pond. A portion of these soft sediments may have been emplaced before the dam was constructed. Although Grove Pond's surface area is larger than Plow Shop Pond's, the greater thickness of sediments in Plow Shop Pond results in a volume of sediment substantially greater than that in Grove Pond (table 1).

The shallow water permitted GPR energy signal penetration through the soft sediment over most of the surface areas of the ponds. Shallow water and the large number of transects run resulted in accurate depth determinations and good quantification of the water and soft-sediment volumes in the ponds.

REFERENCES

ABB Environmental Services, 1995, Fort Devens Feasibility Study For Group 1A Sites, Draft, Plow Shop Pond and Grove Pond Sediment Evaluation Data Item A009, v. I, U.S. Army Environmental Center Aberdeen Proving Ground, Maryland.

Beres, M., and Haeni, F.P., 1991, Application of ground-penetrating radar methods in hydrogeologic studies: Ground Water, V. 29, no 3, p. 375-386.

U.S. Geological Survey and State of Massachusetts, 1887, Topographic map, Groton quadrangle.

1. The use of trade or product names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

Orthophoto mosaic from Massachusetts Executive Office of Environmental Affairs, 1997, originally 1:5,000 rescaled to 1:2,300, Massachusetts Coordinate System 500 meter grid shown
Hydrogeology by Ariane M. Mercadante, John A.Colman, and Marc L. Buursink,1999

MAP SHOWING MORPHOMETRY, BATHYMETRY AND SOFT-SEDIMENT THICKNESS OF PLOW SHOP POND AND GROVE POND, AYER, MASSACHUSETTS

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