

Survey of Lake Ontario Bottom Sediment off Rochester, New York, to Define the Extent of Jettisoned World War II Matériel and its Potential for Sediment Contamination

U.S. GEOLOGICAL SURVEY

Open-File Report 99-237

Also Contribution Number 1081 of the USGS Great Lakes Science Center.



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By Gregory Kennedy and William Kappel

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Prepared in cooperation with the
New York State Department of
Environmental Conservation



Ithaca, New York
2000

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CONVERSION FACTORS, ABBREVIATIONS, AND DATUMS

Multiply	By	To obtain
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
acre	.4047	hectare
square mile (mi ²)	2.59	square kilometer
square yards (yd ²)	.8361	square meters
square yards (yd ²)	.0002066	acres
gallon	3.785	liter
miles per hour (mi/h)	1.609	kilometers per hour
miles per hour (mi/h)	.4470	meters per second

Other Units and Abbreviations

kilohertz (kHz)
 nanogram per liter (ng/L)
 milliamper (mA)
 micrograms per gram ($\mu\text{g/g}$)
 micrograms per kilogram ($\mu\text{g/kg}$)

Vertical datum: In this report “sea level” refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Horizontal datum: The North American Datum of 1927 (NAD 27) is the horizontal control datum for the United States that was defined by a location and azimuth on the Clarke spheroid of 1866, with its origin at (the survey station) Meades Ranch.

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ABSTRACT

Military-type matériel was recovered from the bottom of Lake Ontario near Rochester, N.Y., during bottom-trawl, fish-stock surveys at depths of 75 to 180 feet each year from 1978 through 1996. The recovered matériel included many shell-detonator nose cones (2 inches in diameter by about 3.5 inches long); several electronic components; one corroded box of detonators; a corrugated container of mercury-filled capsules; and corroded batteries. Most of the recovered matériel has been identified as defective components of shell detonators (proximity-fuze assemblies) that were jettisoned in the lake to protect them from discovery during World War II.

Side-scan SONAR, metal-detector, and ROV (remotely-operated-vehicle) surveys found no evidence of any large piles of matériel containing potentially hazardous, toxic, or polluting materials within the 17-square-mile study site. Many scattered magnetic anomalies were detected in this area, but chemical analysis of bottom sediment and of zebra- and quagga-mussel (*Dreissena spp.*) tissue indicate that the concentrations of mercury and other heavy metals are within the previously documented ranges for Lake Ontario sediment. The failure of ROV videos and of SCUBA-diver surveys and probes of the lake bottom to locate any debris indicates that most, if not all, of the debris is scattered and buried under a layer of fine-grained sediment and, possibly, mussels.

INTRODUCTION

The U.S. Geological Survey Great Lakes Science Center's Lake Ontario Biological Station (LOBS) in Oswego, N.Y., (fig. 1) has conducted bottom-trawl surveys of fish stocks in Lake Ontario since 1978. The bottom trawl technique entails dragging a net along the lake bottom to capture resident fish. LOBS recovered military-type matériel or debris from the lake bottom near Rochester, N.Y. during bottom trawls at depths of 75 to 180 ft each year from 1978 through 1996, after which the nets were modified (in 1997) to minimize net clogging by zebra and quagga mussels (*Dreissena spp.*, hereafter referred to as "mussels") from the lake bottom; this also eliminated the collection of any debris that may be on or just below the lake bottom. The recovered debris included mostly shell-detonator nose-cones (see appendix), some electronic components, a corroded box of detonators, a container of mercury-filled capsules, and some corroded batteries. Most of the recovered debris has been identified as defective shell-detonator (proximity fuze) assemblies that were jettisoned in Lake Ontario during World War II, probably so that they could not reach enemy hands. None of the recovered debris contained any mercury switches (appendix fig. A1-B), but their possible presence is of concern to the New York State Department of Environmental Conservation (NYSDEC) and the U.S. Environmental Protection Agency (USEPA).

Discussions with the U.S. Army and Navy indicate that the Navy operated a GOCO (government-owned and contractor-operated) site for the production of proximity fuzes in the Rochester area from the mid-1940's to the early 1990's (David Olson, Office of the Chief of Naval Operations, Arlington, Va., oral commun., 1998). No records of the early production or

disposal activities of the GOCO facility were maintained; therefore, the precise location of the disposal area(s) is unknown. The recovery of a single box containing what may have been mercury switches indicates that the potential for mercury contamination of lake-bottom sediment is small. A small amount of

mercury was spilled onto the research vessel deck during recovery from one bottom trawl, but this spill probably resulted from damage during retrieval, whereby the box and its contents were crushed as it was pulled onto the ships deck. If the switches had leaked mercury onto the bottom, little if any would

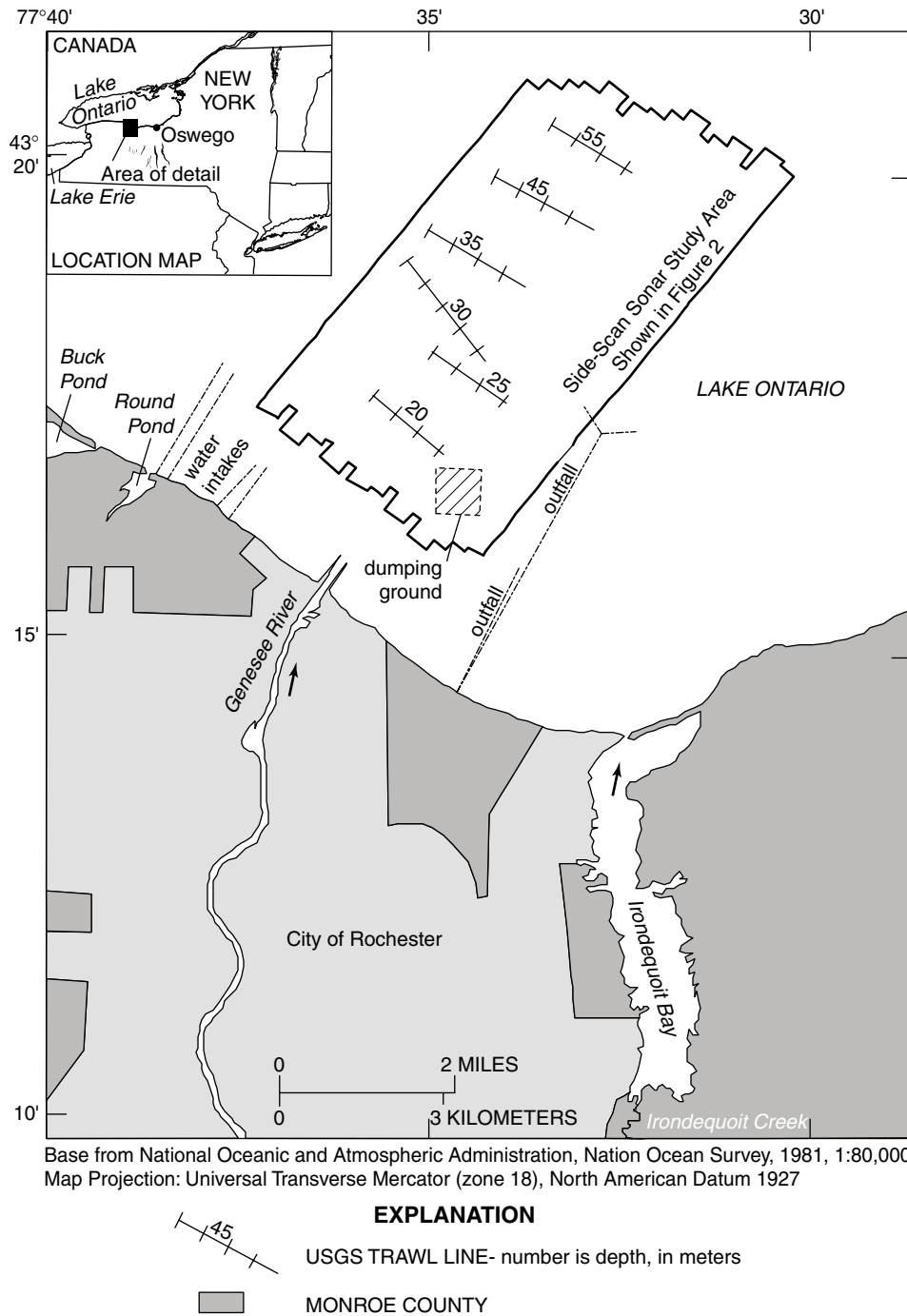


Figure 1. Map showing location of side-scan SONAR and remote-operated-vehicle (ROV) underwater video survey area in Lake Ontario, north of Rochester, N.Y., and locations of U.S. Geological Survey (USGS) trawl survey.

have remained in the box or have been brought up onto the ship.

The recovered debris was routinely thrown overboard until the recovery of the mercury capsules in 1993, whereupon the NYSDEC was notified. (See appendix.) Representative samples of the military debris found in the trawl nets were saved from 1994 through 1996 and temporarily stored at LOBS. In 1996, the NYSDEC obtained funds from Region II of the U.S. Environmental Protection Agency to delineate the extent of the debris on the lake bottom and to evaluate its potential to contaminate the bottom sediment with mercury and (or) other heavy metals. The NYSDEC in 1997 began a study in cooperation with the U.S. Geological Survey (USGS) to conduct a preliminary assessment of the 17-mi² lake-bottom area in which debris had been found (fig. 1) to locate debris piles or fields.

Purpose and Scope

This report summarizes the results of: (1) more than 90 mi of SSS (side-scan SONAR) transects covering about 17 mi² (10,572 acres) of the lake bottom off Rochester, N. Y., (2) more than 2 dozen ROV (remotely operated vehicle) underwater-video surveys of the lake bottom at sites selected through examination of the SSS surveys, (3) about 8 mi of magnetometer (metal-detector) transects of suspected debris areas, (4) four SCUBA dives to locate and recover debris from the lake bottom and to assess the presence of mercury and other potentially-polluting metals, and (5) two SCUBA dives for water-column, bottom-sediment, and mussel-tissue and pseudofeces (predigestive mucous excretions) samples, and bottom probing for military debris. The results of this study provide a basis for decisionmaking by State and Federal agencies for action in regard to the presence of these components in Lake Ontario.

Study Site (Fish-Survey Area)

The lake area historically surveyed for fish by the LOBS in the Rochester offshore area is about 2 mi north-northeast of the mouth of the Genesee River, near Rochester (fig. 1). Bottom-trawl tows have been conducted in this area from mid-April through mid-May, in June, from mid-July through mid-August, and

in October of each year since 1978 at depth intervals averaging 33 ft (16 ft during July-August), through a depth range of 33 to 500 ft. The location of each trawl line was located with Loran-C through 1995 and since then with Global Positioning System (GPS) navigation equipment; depth is measured with an electronic depth sounder.

Standard trawl tows run for 10-minute periods at a speed of about 3 mi/h and sweep an area of 2.1 acres (Robert O'Gorman, Lake Ontario Biological Station, written commun., 1997). The trawl net has a 1.5-in.-square mesh at the opening and a 0.35-in.-square mesh at the closed end. The foot rope and chain drag along the bottom and probably cut into the upper few inches of soft sediment. Colonies of mussels began to appear in the early 1990's, and trawl catches included increasing amounts of mussels. In response, the LOBS switched to a new foot-rope design in 1997 to minimize clogging; the new foot rope on the bottom-trawl net rolls over the bottom and captures few mussels and, thus, none of the manmade debris.

Acknowledgments

Thanks are extended to the crew of the Research Vessel (R/V) *Kaho* (USGS Lake Ontario Biological Station at Oswego, N. Y.) for their assistance during the side-scan sonar and ROV data collection, and to the Great Lakes Science Center dive team; to Jeffery Allen, Glen Black and Marc Blouin for their assistance with the SCUBA surveys and sediment and mussel-tissue collection; and to thank George Williams and Gregory Bayuga of the U.S. Army Corps of Engineers (Huntsville, Ala. and Rock Island, Ill., respectively) for their assistance in the identification of the proximity fuze components.

METHODS OF INVESTIGATION

On May 24, 1997, the USGS Great Lakes Science Center (GLSC), Ann Arbor, Mich. began SSS and ROV underwater video reconnaissance surveys of the 17-mi² study site (figs. 1, 2) from the research vessel *Kaho*. The surveys were completed by May 29, 1997. Data collection included (1) SSS mapping (100-kHz frequency) of the 17-mi² study area at 1:4,000-scale, and detailed SSS mapping (100- and 500-kHz frequency) at 1:1,000-scale, of three selected sites

within the mapped area for comparison with the 1:4,000-scale data), and (2) ROV surveys at 15 selected sites within potential debris fields that were identified through examination of the 1:4,000-scale SSS data. Subsequent processing and analysis at the GLSC included assembly of the 1:4,000-, and 1:1,000-scale SSS strip-data into mosaic maps, Geographic Information Systems (GIS) overlay of ROV site locations onto the SSS-mosaic map, and detailed analysis of the ROV video-image data.

On September 2, 1997, USGS personnel returned to the study site for additional ROV and SCUBA dives; they made 12 additional ROV underwater-video surveys at locations identified through the GIS assessment of the SSS-mosaic images, and detailed SCUBA surveys were conducted at four of these additional dive sites immediately after the ROV survey in an attempt to locate debris buried under the lake-bottom sediment and mussels. Diver surveys were also completed in the general vicinity of the LOBS trawl lines. The divers' mission was to make a detailed metal-detector sweep of each site using a hand-held submersible metal detector, then manually probe the substrate subsurface in disturbed areas where depressions or mounding of the sediment under mussel beds had been observed. This method of debris detection was preferable to the towed magnetometer sweeps because the debris in this area probably is scattered and buried just under the lake bottom surface by sediment discharged from the Genesee River. The magnetometer originally planned for this study would have been more efficient than the hand-held detectors in surveying the entire study area but would be able to detect only large piles of debris (several square yards in width) (Lawrence Stephenson, Harvey Lynch Inc., oral commun., 1998). The submersible hand-held detector, by contrast, can sample only a small area (several square feet), but can detect small, single objects. Results of initial ROV survey indicated that the scattered pieces of debris were too small to be detected with the original magnetometer. A third and final metal-detector survey and sample-collection cruise in October 1997 was cancelled in response to poor weather conditions and was rescheduled for the summer of 1998.

A 10-day cruise was begun on June 18, 1998 to select two sites for bottom-sediment and mussel sampling. The May and September 1997 cruises had detected no debris that could be sampled; therefore, the June 1998 cruise used a new submersible metal

detector, capable of detecting small objects within a distance of 10 ft and at depths of 8 to 10 ft in lake-bottom sediment with the ROV to identify possible debris areas in and around the transect lines of the original fish-trawl surveys.

The new sled-mounted metal detector was attached directly to the ROV such that the sled, which was towed along the bottom, and a submersible meter attached to the detector, were in constant view on the video monitor (fig. 3) onboard the *Kaho*. The combined apparatus was pulled along the bottom following the *Kaho*'s drift through the study area (fig. 2). A mapping-grade differential GPS was used to track the vessel's drift for each transect, and subsequent transects were oriented to maximize coverage within the area accessible by SCUBA (depths of 100 ft or less). As the coil passed over or near a metallic object, the meter's needle would fluctuate, and at that moment the GPS position was noted so that the location of the magnetic response indicated by the needle deflection could be relocated later. With the coil and the surrounding substrate in the ROV's video-camera view, the video image would indicate whether the object was visible on the lake bottom (fig. 3). Upon completion of the drift transects, the video tapes were reviewed, and two sites were chosen for sampling on the basis of detector response and the physical characteristics (mounds and depressions) of each area.

The two selected sites were relocated from the GPS information obtained in the previous surveys. The ROV was sent to the bottom, where the tracks left previously by the detector sled could be seen, and the hand-held magnetic detector mounted on the ROV was used to locate the magnetic anomalies detected during the previous survey. Once each site was located, the divers followed the ROV cable to the site and collected samples of mussels and bottom sediment for metals analysis. Attempts to collect mussel pseudofeces for analysis failed at both sites because the pseudofeces were too fragile, and the bottom time for sample collection too short, but sediment and mussel samples were collected. The divers then probed the area of the magnetic anomaly at each site but found no debris of any type. During bottom-sample collection, water-column samples were collected at depths of 10 and 50 ft with a peristaltic pump with Teflon¹ tubing from the deck of

¹Use of brand names is for identification purposes only and does not imply endorsement by the U.S. Government

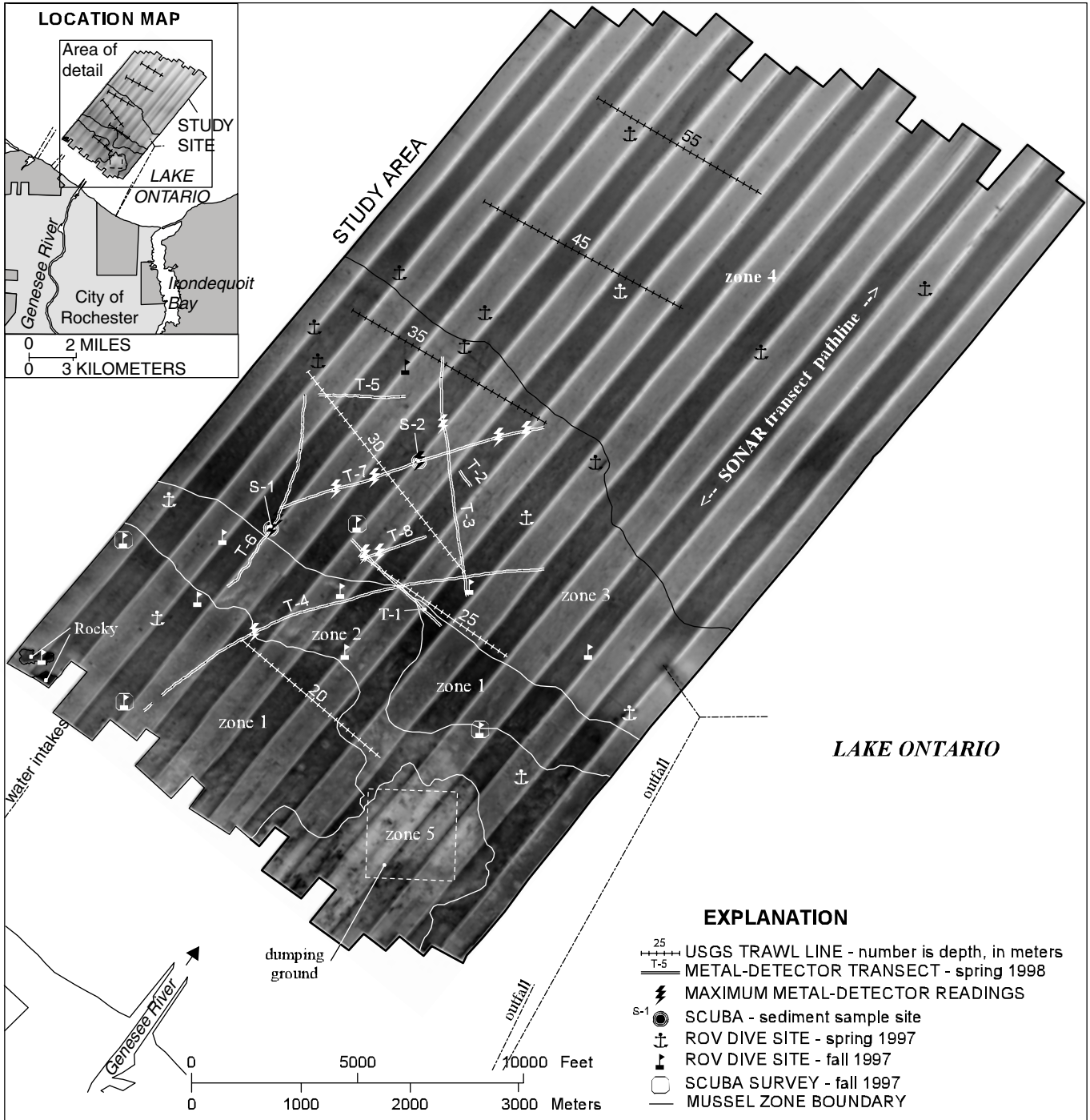
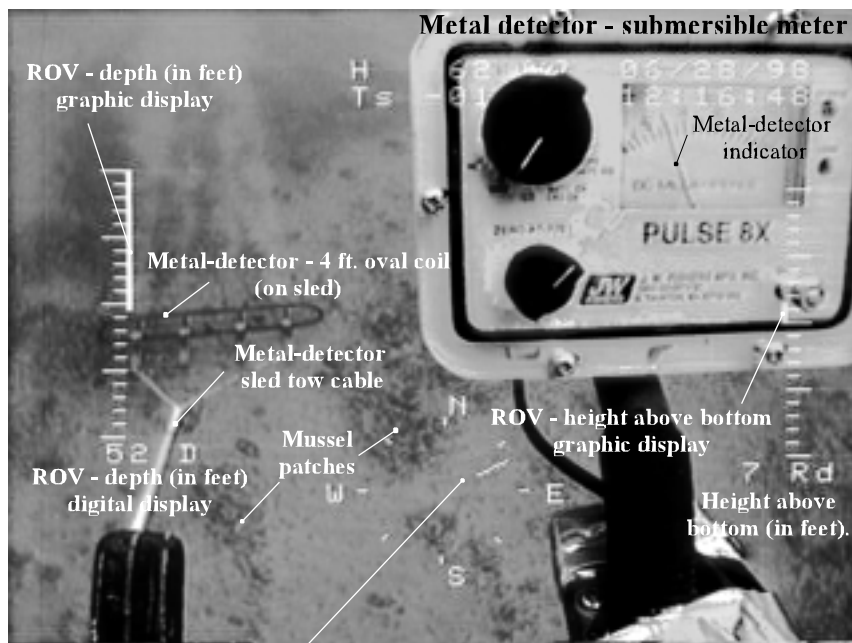


Figure 2. Side-scan SONAR mosaic showing reflectance patterns from surficial substrate, locations of metal-detector surveys and of maximum readings, ROV underwater video surveys, and SCUBA sediment-sampling sites in Lake Ontario, north of Rochester, N.Y.



Compass needle graphic, indicating northeast heading
(Direction of view only - ROV is being pulled backwards in a southwest heading.)

Figure 3. Example of ROV image showing towable metal detector used to locate magnetic anomalies in Lake Ontario, north of Rochester, N.Y.

the *Kaho*. Bottom-sediment samples were analyzed for metals (arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, and zinc) at the USGS Central Laboratory in Denver, Colo. Bottom-sediment, mussel-tissue, and water-column samples were analyzed for ultra-low (parts per billion) concentrations of total mercury and methyl mercury at the USGS Mercury Analysis Laboratory in Madison, Wisconsin

SURVEY RESULTS

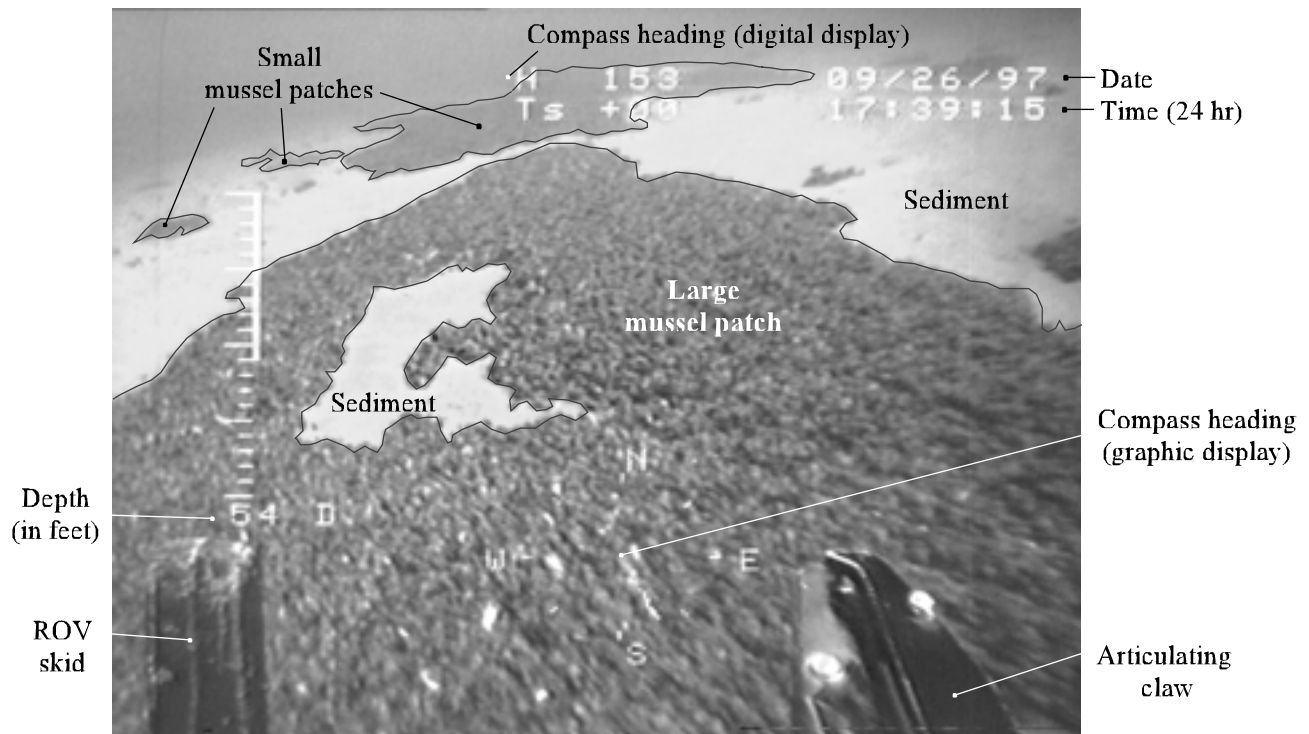
Preliminary examination of the 1:4,000-scale SSS images from May 1997 showed many potential targets (high SONAR reflectance areas) that appear on the SONAR record as dark “patches,” of which 15 were chosen for the initial, (June 1997) ROV underwater-video surveys. Analysis of the underwater video indicated that all targets were large patches of mussels (fig. 4). The mat of mussel shells forms an acoustic reflective surface that contrasts with the surrounding soft sand, silt, and clay substrate and, when displayed as a SONAR image, appears similar to the image expected from a small pile of debris. This is consistent with findings by the GLSC in Lake Erie, where similar patterns of mussel encrustation of soft substrates have been observed (Berkman and others, 1998). The ROV

video identified no fields of manmade debris and provided no evidence that the mussels were attached to, or obscuring, any debris. Numerous probes of the sediment under the mussel mats by the ROV claw also failed to detect any substantial hard substrate or attachment of mussels to the sediment.

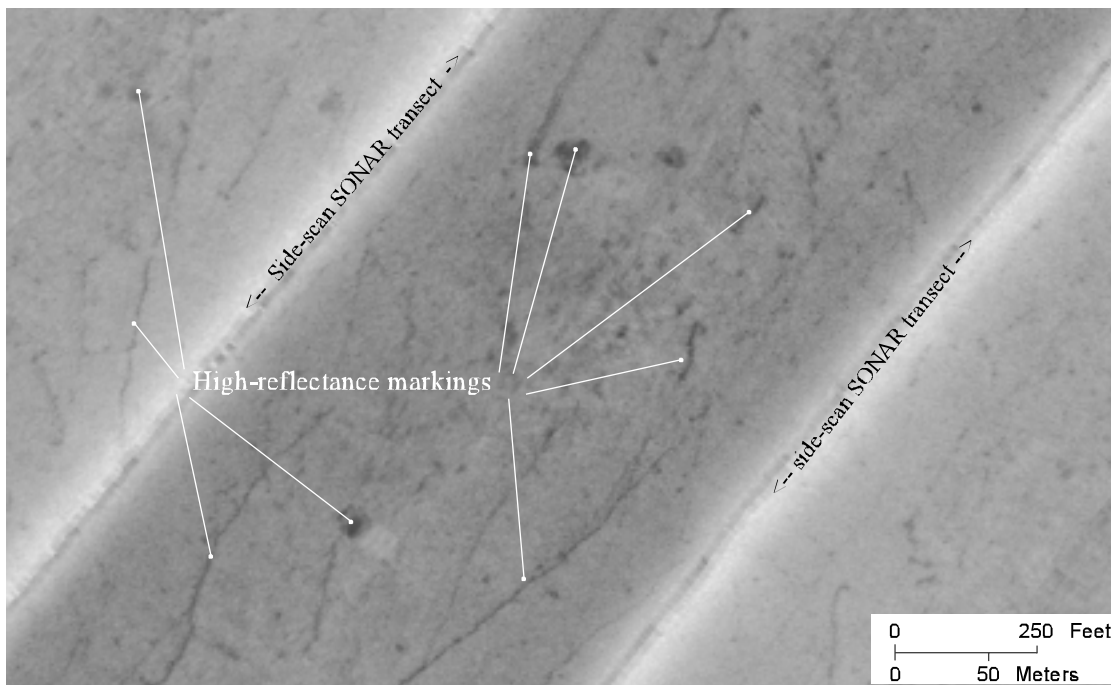
Examination of the 1:4,000-scale SSS images from the mussel patches within the mapped area (figs. 2 and 5-8) indicated five zones of differing reflectance intensity and pattern, as follows;

Zone 1

Zone 1 is closest to shore, and depths are less than 65 ft. Mussel patches are in the form of “bands” on the sediment surface (fig. 5); the underlying sediment appears to be mostly sand and silt. These bands appear similar to large sand ripples and average about 15 ft in width. Zone 1 is mostly within the west-southwest corner of the study area but is separated into two parts by an area that roughly coincides with the dredge-spoil-disposal area for sediment dredged from the Genesee River (fig. 1) and by part of Zone 2 (fig. 2). Zone 1 encompasses about 15 percent of the 17-mi² study area. The ROV video from Zone 1 indicates that more than 80 percent of the sediment is encrusted with mussels.



A. ROV video image.



B. Side-scan SONAR image

Figure 4. Sample ROV video image (fall 1997) showing bed of mussels observed during initial ground-truthing dives to inspect high-reflectance targets recorded on spring, 1997 side-scan SONAR survey in Lake Ontario, north of Rochester, N.Y.

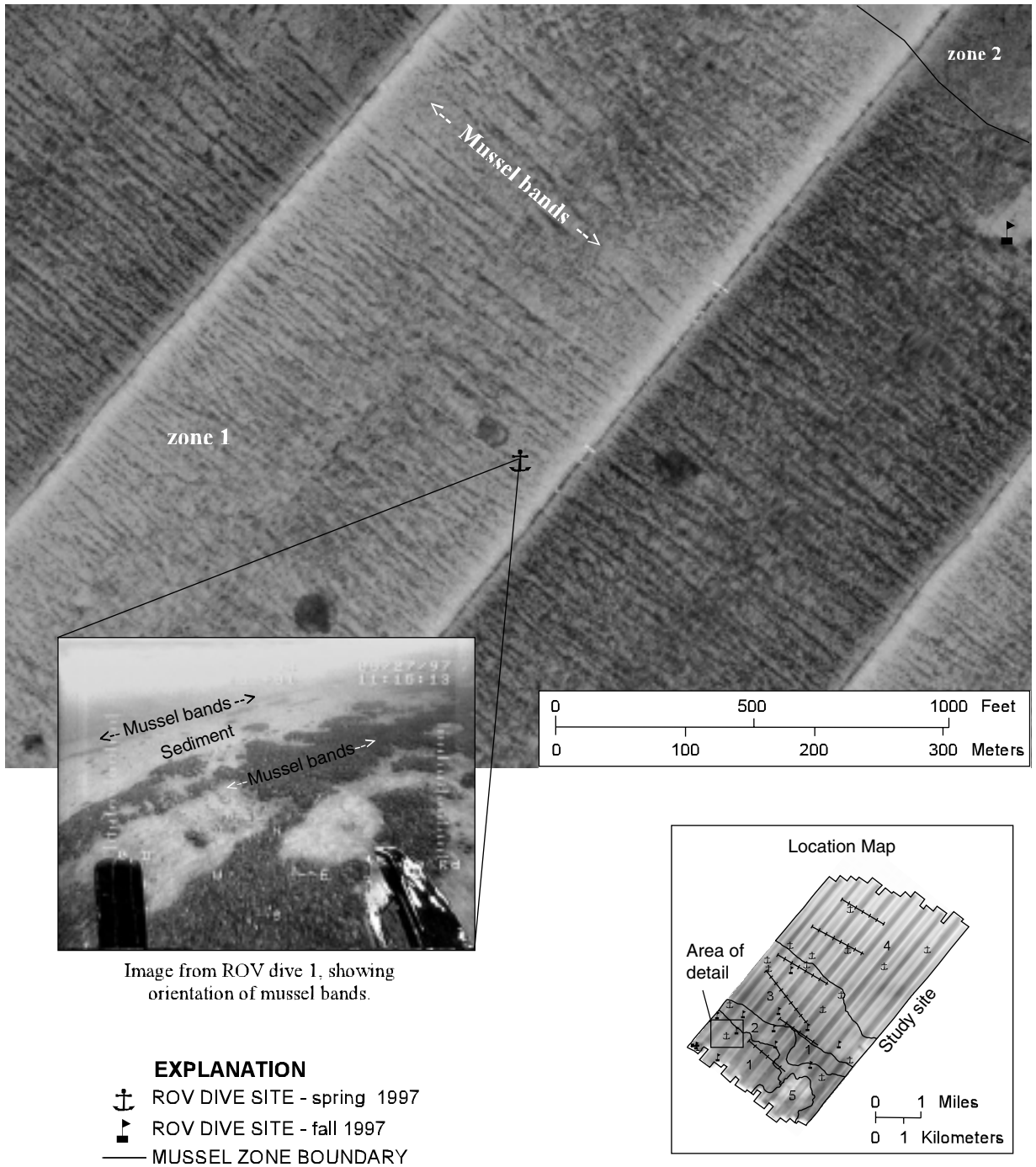


Figure 5. Close-up view of side-scan SONAR mosaic image showing mussel “bands”, locations of ROV dive sites in zone 1, and image from ROV dive 1 (spring 1997), showing mussel band in the Lake Ontario study area, north of Rochester, N.Y.

Zones 2 and 3

Zones 2 and 3 occupy the middle third of the survey area and contain a random distribution of mussel “patches” (fig. 6A) and linear “scars” (fig. 6B). The “patches” (Zone 2) range from 6 to 30 ft in diameter, and the linear “scars” (Zone 3) can exceed 300 ft in length. The sediment in this zone shows a considerable number of furrows that generally run parallel to shore. These furrows may have been caused by the trawl-net “doors” that drag along the bottom and keep the mouth of the net open during the fish-survey tows. Estimated water depth in zones 2 and 3 ranges from 65 ft to 130 ft. ROV video images indicate that mussels cover more than 50 percent of the lake bottom in Zone 2, which is closer to shore than Zone 3, the “scarred” zone, in which mussel coverage was around 25 percent. The linear furrows initially seemed to hold the highest probability for detection of debris, but the ROV surveys found only mussel encrustation.

Zone 4

Zone 4 is the area farthest from shore and occupies the deepest parts of the surveyed area (fig. 7). This zone is characterized by relatively little acoustic reflectance on the SONAR records, except for several scattered, small spots no greater than 10 ft in diameter that together occupy no more than 5 percent of the zone. The great depths (130 to 200 ft) and the small size of the echoes made these spots difficult to identify with the ROV, but the ROV images confirmed that the sediment was soft (probably clay with some silt) and contained a few widely scattered, fist-sized clumps of mussels. The small spots observed on the SSS records could be slight depressions, which can deflect some of the acoustic signal. Analysis of the data from the seven ROV dives in Zone 4 indicated that the spots on the SSS image were either natural, dimple-like depressions in the lake bottom or small mussel “druses” (fist-sized clumps of interconnected mussels); the larger mats or patches are essentially thousands of loosely connected druses.

Zone 5

Zone 5 is in the southeastern corner of the surveyed area and contains a substrate that roughly coincides with the dredge-spoil dumping grounds identified on lake charts. This area receives sediment dredged from the Genesee River. The dredged spoil

appears clearly on the SSS records as a doughnut-shaped rings 30 to 75 ft in diameter, in which the main dredge material forms the center, and the displaced sediment forms the ring (fig. 8). The disturbed nature of this area prevents recognition of World War II matériel amid the deposited dredged material. An assessment of one dredge pile by the ROV to confirm the SSS echoes indicated much disturbed sediment and some manmade debris, including, in this case, a mussel-encrusted 55-gal drum (fig 8).

Survey Analysis and Followup

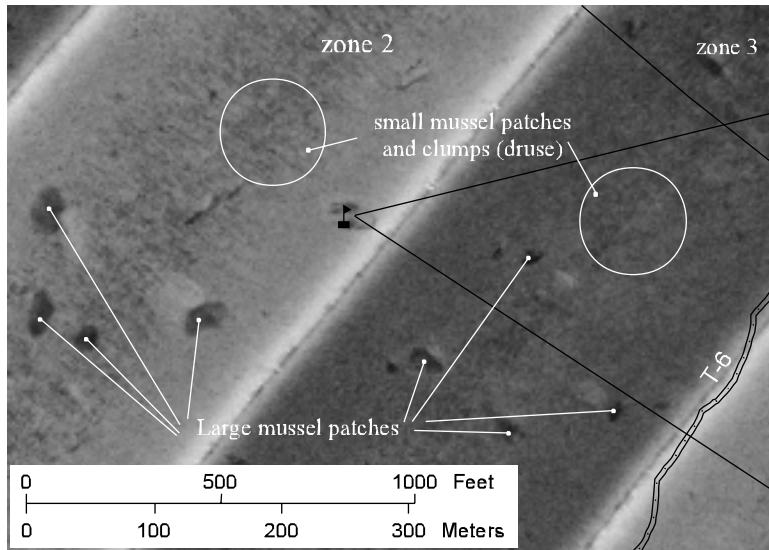
The resolution of the 1:4,000-scale mosaic map (minimum resolution about 1 yd²) was considered adequate for the purpose of this study which was to identify debris piles or fields within the 17-mi² study area. A more detailed (1:1,000-scale SSS) survey was conducted within a shallow zone in the western quarter of the study site (beyond the dredge-spoils area) to identify features that might have been missed in the general 1:4,000-scale survey. The detailed survey first used 500-kHz frequency SONAR transducers, but the signals were inconsistent; therefore, the survey was rerun with the 100-kHz SONAR. Where the 500-kHz SONAR was successful, images were compared with those from the 100-kHz SONAR, but no differences in interpretation resulted. Inspection of small, individual targets was best suited to the ROV, which can provide visual images in areas much smaller than those viewed by SONAR.

SCUBA Dives of September 1997

The diver inspections during September 1997 covered a total area of about 2,500 ft² and found no manmade debris. Areas that were too deep for SCUBA were surveyed with the ROV and attached metal detector. Although the metal detector had leaking seals, which limited the number of detector-assisted dives, the information provided by all SSS and ROV records indicate no large, concentrated military-type debris within the 17-mi² study area.

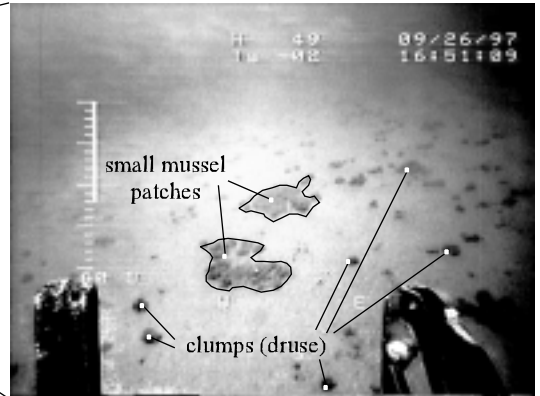
ROV Transects of June 1998

Eight drift transects covering a total distance of more than 8 mi were completed within the study area with the ROV and metal detector sled during June 1998

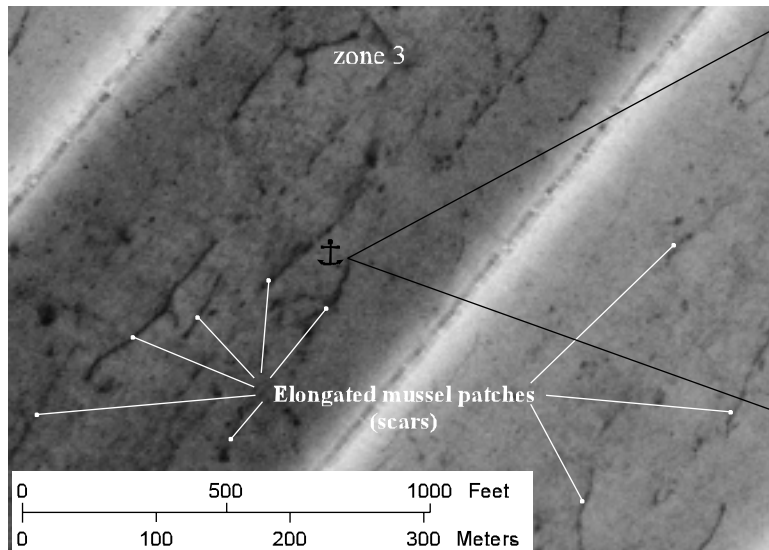


A. zone 2

Image from ROV dive 5, fall 1997



Small patches in this image are about 1-2 feet in diameter. Clumps are about 2-6 inches in diameter.



B. zone 3

Image from ROV dive 9, spring 1997



Image shows the trailing edge of an elongated patch that is about 2-3 feet wide, and stretches (beyond the view) for about 100 feet. A small clump (about 3 inches in diameter) can be seen on the right side of the image.

- EXPLANATION**
- METAL-DETECTOR TRANSECT - spring 1998
 - ROV DIVE SITE - fall 1997
 - ROV DIVE SITE - spring 1997
 - MUSSEL ZONE BOUNDARY

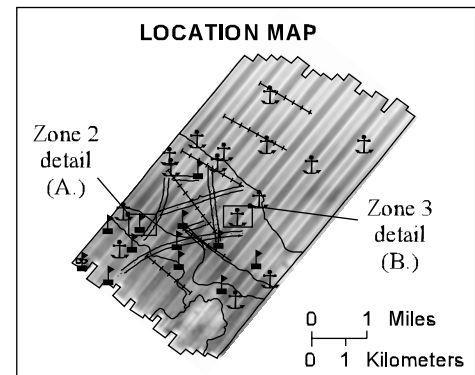


Figure 6. Close-up view of side-scan SONAR mosaic images showing mussel settlement in random distribution (“patches”) in zone 2, and in linear features (“scars”) in zone 3, and ROV dive images: A. Mussel “patches” in zone 2, fall 1997. B. Mussel “scars” in zone 3, spring 1997, in Lake Ontario study area, north of Rochester, N.Y.

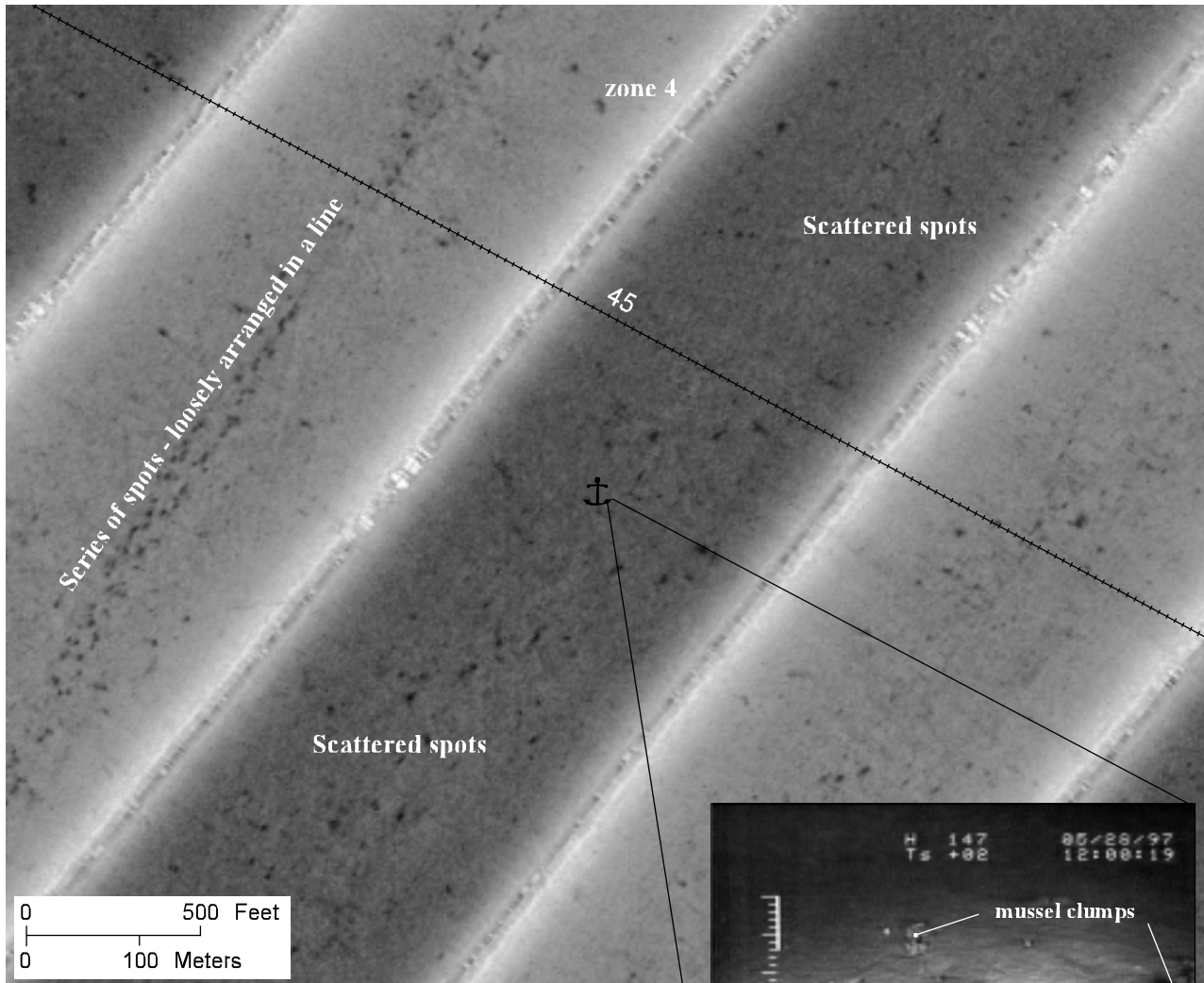
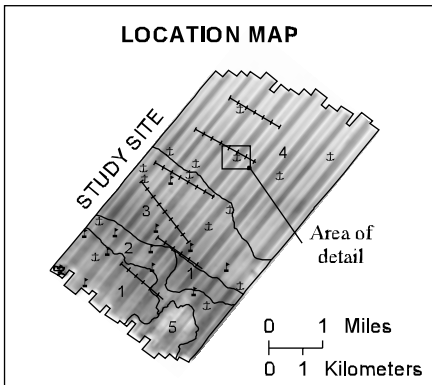


Image from ROV dive 12, typical of what was observed within this zone - mostly soft sediment with very widely scattered, small clumps of mussels.



EXPLANATION

- 45 USGS TRAWL LINE - number is depth, in meters
- ⚓ ROV DIVE SITE - spring 1997

Figure 7. Close-up view of side-scan SONAR mosaic image showing widely scattered and small reflectance patterns typical for zone 4, and image from ROV dive 12 (spring 1997) in the Lake Ontario study area, north of Rochester, N.Y.

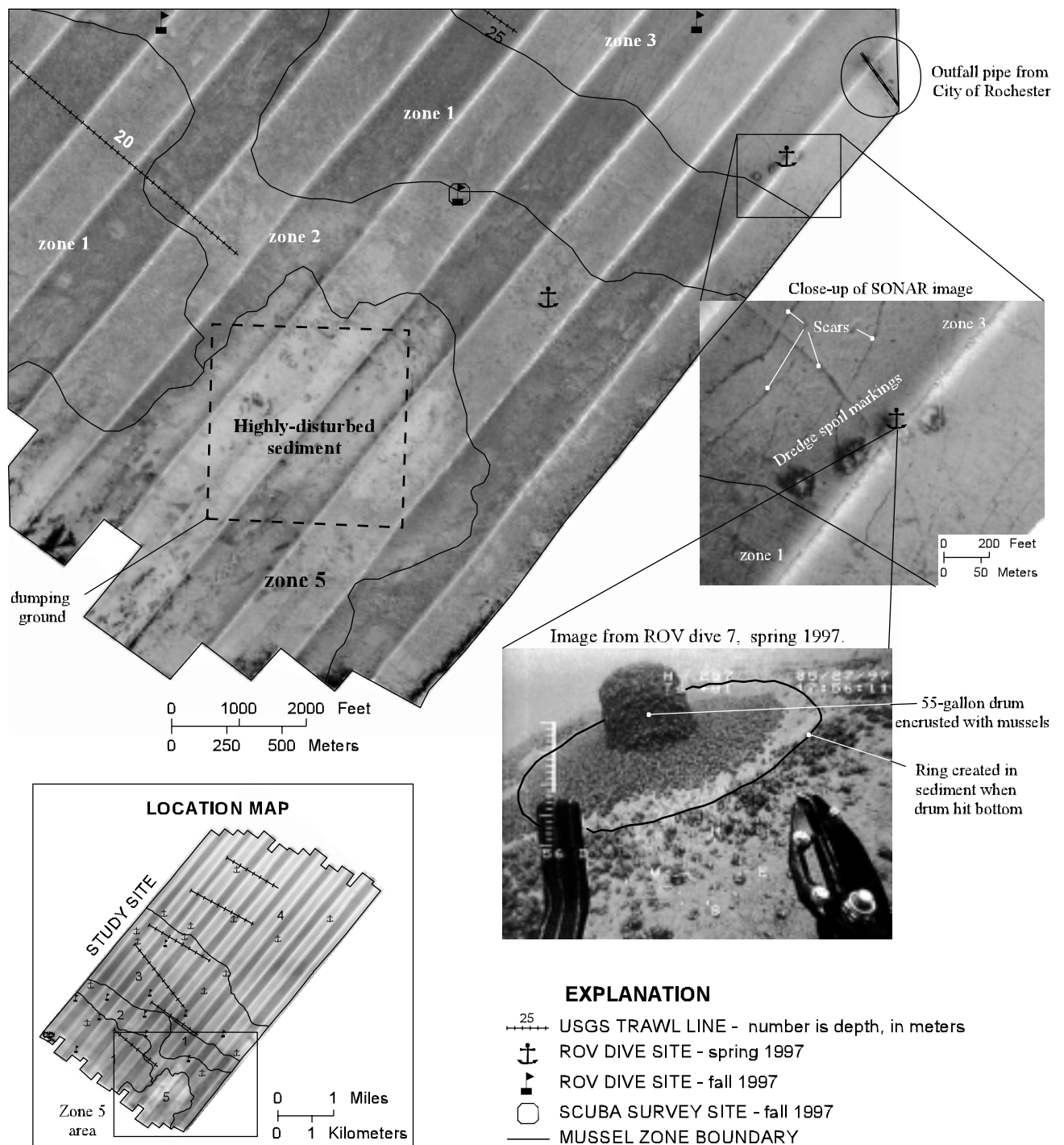


Figure 8. Close-up views of side-scan SONAR mosaic image showing highly-disturbed sediment within zone 5 area and identified as “dumping ground” in figure 1, enlarged view of SONAR image showing reflectance patterns from individual dredge-spoil dumping, and image of ROV dive 7 (spring 1997) showing a mussel-encrusted 55-gallon drum in the Lake Ontario study area north of Rochester, N.Y.

(fig. 2 and table 1). The estimated substrate area surveyed, as conservatively estimated from the detector's swath width of about 17 ft (8.5 ft to either side of the midpoint of the coil), is just over 16 acres, or about 0.15 percent of the study site. This survey focused on substrate reachable by SCUBA divers, generally in water depths less than 100 ft. These ROV and metal-detector surveys indicated several areas of magnetic anomalies (table 1). Anomalies were distributed randomly throughout the area surveyed, but most were associated with mussel patches and raised mounds of sediment (fig. 6). Two sites (at depths of 97 and 79 ft) were chosen, on the basis of ROV video-tape records, for close inspection and sampling (figs. 2, 9, 10). Divers collected sediment and mussel samples from the mounded areas, then thoroughly probed each mound with gloved hands to find the debris that was activating the magnetometers, but no debris was found at either site.

Chemical Analyses

Samples of Lake Ontario bottom-sediment were collected from the two selected sites and sent to the USGS Central Laboratory in Denver, Colo. for analyses of metals. Water, bottom sediment, and mussels were collected at the same sites and sent to the USGS Mercury Laboratory in Madison, Wis. for analyses of total mercury and methyl mercury.

Bottom Sediment and Lake Water

Metals. The concentrations of metals typically found in Lake Ontario bottom sediment as reported by Mudroch and others (1988) were compared with those found in this study (table 2); the results do not indicate any unusual concentrations of common metals except iron. Most concentrations are similar (within 1 order of magnitude) to those obtained in 1994 at slightly greater depths in the Rochester near-shore area by the New York State Department of Health for the NYSDEC (table 2). Iron concentrations in bottom sediment found

in this study, although much higher than those found by Mudroch and others (1988), were similar to those found in Genesee River sediments near its mouth, and in Irondequoit Bay and associated Irondequoit Creek wetland sediment, just east of the city of Rochester (fig. 1, table 2).

Mercury. The concentrations of total mercury and methyl mercury in the water column (table 3) are within 1 order of magnitude of those found in other studies of the Great Lakes by Gill and Bruland (1990). The total and dissolved methyl-mercury concentrations in all water-column samples collected in this study were below the detection limit of 0.025 ng/l.

The concentrations of total mercury in the upper inch of bottom sediment (table 4) are similar to those found in a survey of the Great Lakes by Thomas (1972, 1974), who obtained a mean total mercury concentration of 650 µg/kg for 248 samples from the upper inch of Lake Ontario bottom sediment collected throughout the lake. The total mercury concentration in dredge samples collected by the NYSDEC in 1994, and of the deeper sediment samples collected in this study, are about 1 order of magnitude greater than those in shallow samples. This discrepancy could be due to differences in (1) the sample-collection technique and equipment used, (2) the sample depth and volume, and/or (3) depth-profile concentration gradients and local variability in mercury concentrations (David Kabbenhoff, USGS Mercury Laboratory, Madison, Wis., oral commun., 1998).

Mussel Tissue

Results of total-mercury and methyl-mercury analyses in mussel tissue are included in table 4. The concentrations of total mercury in mussel tissue from the lake bottom are lower than those obtained by Secor and others (1993) in mussels taken from the Genesee River in 1991. The methyl-mercury concentrations are about half the total mercury concentrations; the significance of these concentrations is unknown because no corresponding values could be found in current literature for comparison.

Table 1. Results of ROV and metal-detector survey in Lake Ontario bottom sediment north of Rochester, N.Y., June 1998 (GPS, Global positioning system. ROV, remotely operated vehicle. ft/s, feet per second. Dashes indicate no data. Locations shown in fig.2.)

Transect no.	GPS transect data			ROV magnetometer response ¹				Transect coverage (average)		
	Length (feet)	Duration (minutes)	Drift rate (ft/s)	Open sediment	Mussel patch, small	Mussel patch, large	Total no. of responses	Percentage of transect viewed	Adjusted length (feet)	Area surveyed (acres)
1	3,780	54	1.1	S = 0 M = 0 L = 0	S = 5 M = 0 L = 0	S = 0 M = 0 L = 2	7	99.5	3,755	1.46
2	577	13	.72	---	---	---	0	0.0	0.0	0.0
3	7,290	76	1.6	None observed in poor light ³			3	88.4	6,440	2.51
4	12,420	134	1.5	S = 2 M = 2 L = 0	S = 7 M = 2 L = 2	S = 1 M = 0 L = 3	19	95.3	11,840	4.62
5	2,500	28	1.6	S = 0 M = 0 L = 0	S = 0 M = 0 L = 0	S = 0 M = 0 L = 0	0	96.8	2,420	0.94
6	6,540	112	.98	S = 2 M = 0 L = 0	S = 4 M = 0 L = 0	S = 1 M = 1 L = 2	10	99.1	6,485	2.53
7	8,370	110	1.3	S = 4 M = 2 L = 3	S = 7 M = 0 L = 2	S = 1 M = 2 L = 4	25	99.2	8,310	3.24
8	2,110	24	1.4	S = 1 M = 0 L = 1	S = 1 M = 0 L = 0	S = 0 M = 0 L = 0	3	100	2,110	0.82
TOTALS	43,597	551 (9.2 h)	1.3	S = 9 M = 4 L = 4	S = 24 M = 2 L = 4	S = 3 M = 3 L = 11	67	84.8	41,360	16.1 ⁴
PERCENTAGE OF TOTAL				Σ = 17 25%	Σ = 30 45.0%	Σ = 17 25%	3 unknown 5.0%			

¹ Magnitude of fluctuation:

S = Small fluctuation (meter detection greater than background but not strong) because object was at outer range of meter, or very small; range of meter deflection 0.1 to 0.25 milliamps (mA).

M = Moderate fluctuation because object was larger (greater metallic content) or object was closer to the detection coil; meter deflection greater than 0.25 mA but short of full range.

L = Large fluctuation because object was large (cola-can size) or passed directly under the detection coil; meter detection caused the meter to go to a full-scale reading.

² Dive 2 - Magnetic detector malfunctioned at beginning of survey, and ROV survey did not indicate any "observable" objects.

³ Dive 3 - Dive was in deep water, below ambient light penetration.

⁴ 16.1 acres represents about 0.15 percent of study area.

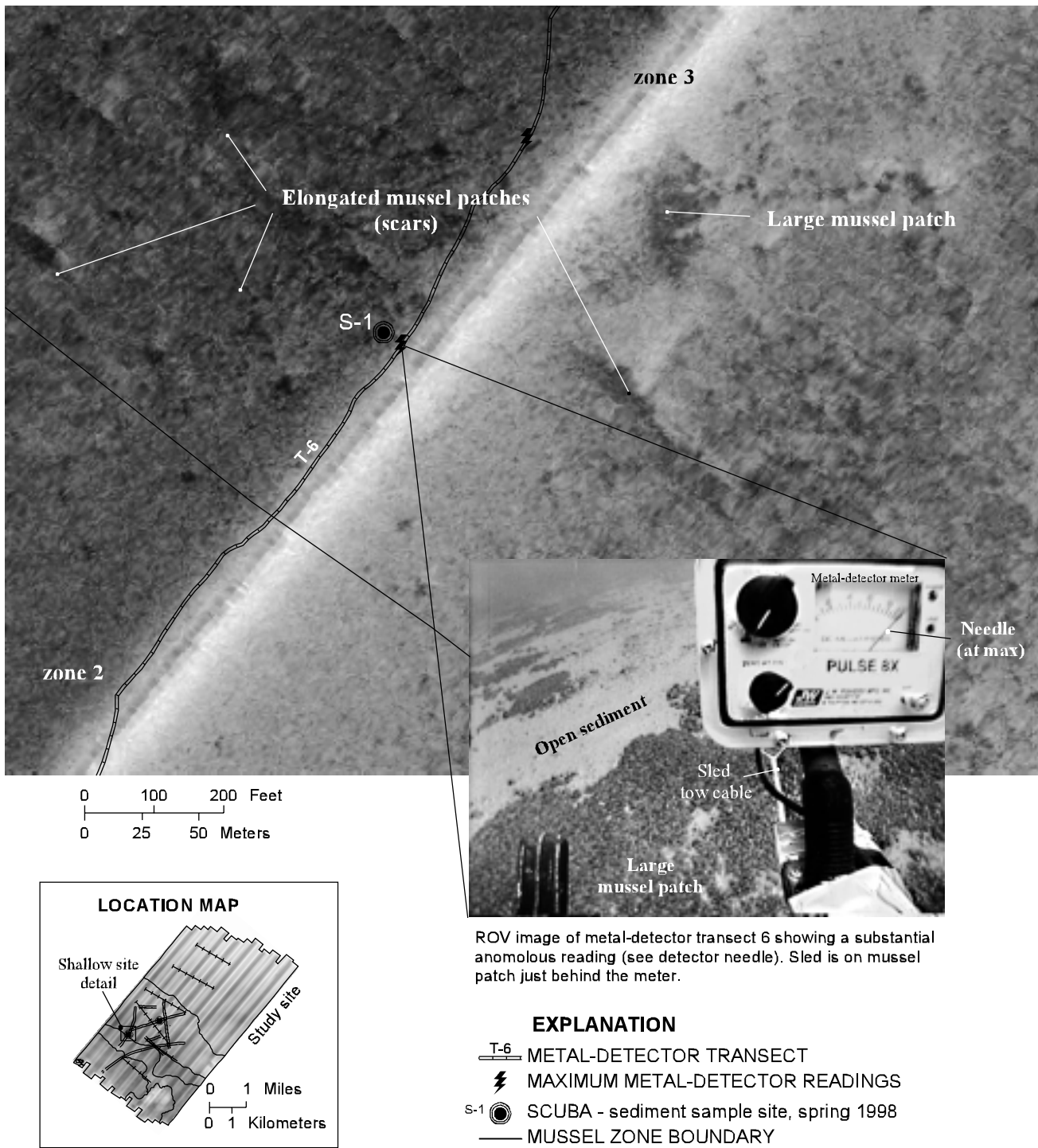


Figure 9. Close-up view of side-scan SONAR mosaic image showing location of shallow sediment-sampling site (zone 3) north of Rochester, N.Y., that was sampled June 29, 1998, for mercury and other metals, and ROV image of sampling site

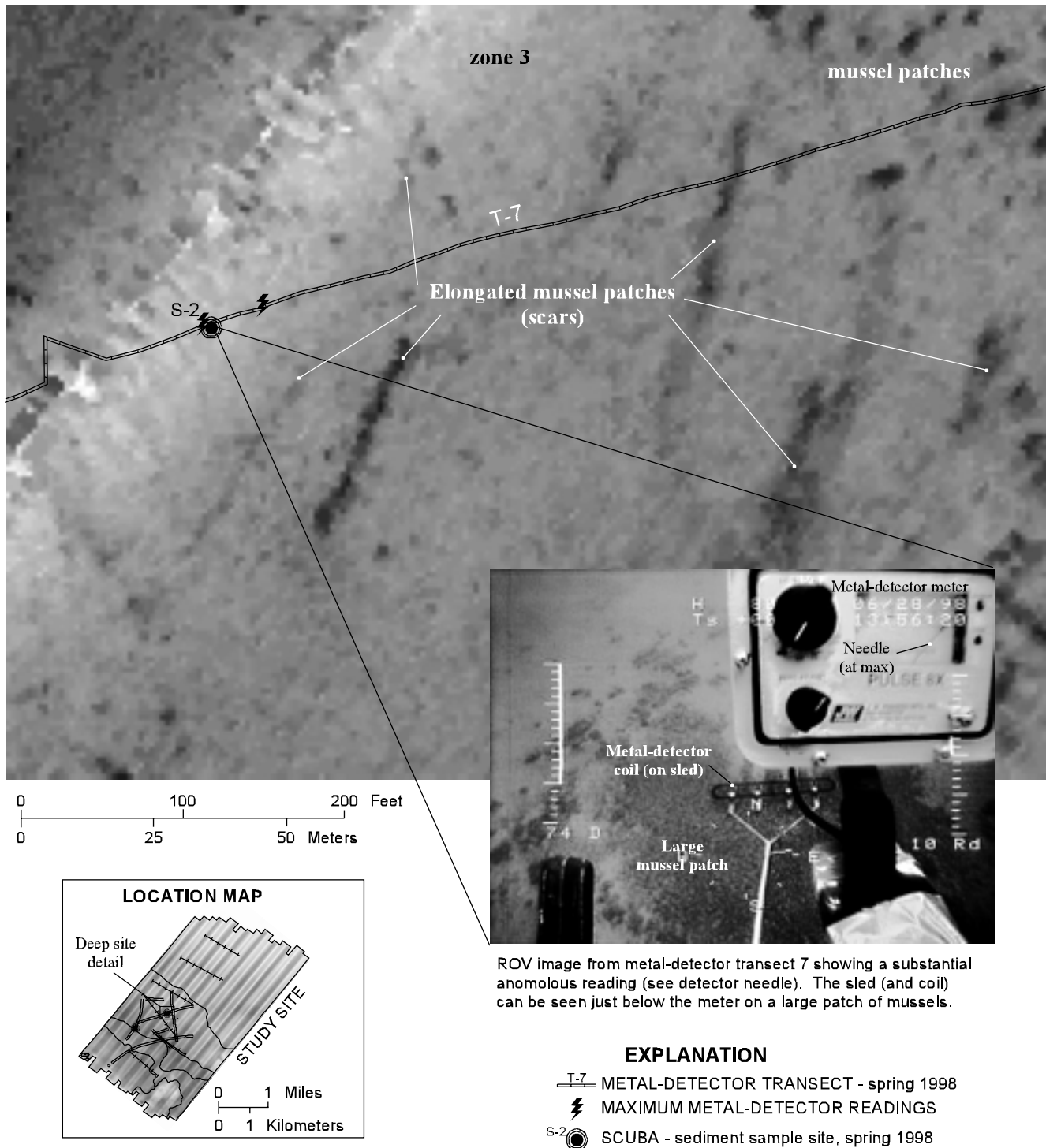


Figure 10. Close-up view of side-scan SONAR mosaic image showing location of deep sediment-sampling site (zone 3) north of Rochester, N.Y., that was sampled June 29, 1998, for mercury and other metals, and ROV image of sampling site.

Table 2. Concentrations of total metals in bottom-sediment samples collected on April 29, 1994 at 115- and 148-foot depths, and on June 29, 1998 at 79- and 97-foot depths, in Lake Ontario study area off Rochester, N.Y., and range of concentrations measured in other Lake Ontario studies.

[NYSDEC, New York State Department of Environmental Conservation, USGS, U.S. Geological Survey. Concentrations in micrograms per gram; Dashes indicate no data. Locations are shown in fig.2.]

Location and depth of samples	Arsenic as As	Cadmium as Cd	Chromium as Cr	Copper as Cu	Lead as Pb	Manganese as Mn	Zinc as Zn	Iron as Fe
NYSDEC - site 1 at 115 ft	0.6	<1.0	7.2	6.6	97.4	157	26.8	6,000
NYSDEC - site 2 at 148 ft	0.8	<1.	5.4	7.4	<8	271	22.1	6,250
USGS - site 1a at 79 ft	3.	.50	8.75	10	15	255	50	11,200
USGS - site 1b at 79 ft	8	1.0	17.7	20	27	464	107	18,800
USGS - site 2a at 97 ft	5	1.	12.8	14	29	309	80	9,270
USGS - site 2b at 97 ft	13	1.	28.5	27	47	517	91	14,300
Mudroch and others (1988) - Lake Ontario surface sediment	0.2 - 17.0	0.1 - 6.4	8.0 - 133	26 - 109	7.0 - 285	---	87- 3,500	2,410- 9,620
Irondequoit Creek wetlands (average of 7 samples) ¹	4.21	1.49	---	44.6	54.8	697	210	25,400
Irondequoit Bay - four bottom cores, each about 3 feet long ¹	---	---	---	15 - 130	8.0 - 206	350 - 1,060	65 - 415	18,000 - 37,000
Genesee River-bottom sediment near mouth at Charlotte Docks, (average of 2 samples) (USGS 1989, 1990)	---	<1.	---	15.0	20.0	515	55.0	14,500

¹ Data from files of U.S. Geological Survey, Ithaca, N.Y.

Table 3. Mercury concentrations in water samples collected on June 29, 1998 from Lake Ontario study area near Rochester, N.Y., and in other Great Lakes studies.

[Concentrations are in nanograms per liter. Dashes indicate no data. Site locations are shown in fig. 2.]

Location and depth	Total mercury as Hg	Dissolved mercury as Hg	Total methyl mercury as Hg	Dissolved methyl mercury as Hg
This study on Lake Ontario June 29, 1998				
Lake Ontario, site 1 at 10 feet	0.73	0.47	<0.022	<0.025
Lake Ontario, site 1 at 50 feet	.83	.29	<.023	<.023
Lake Ontario, site 2 at 10 feet	.55	.35	<.023	<.023
Lake Ontario, site 2 at 50 feet	.53	.32	<.024	<.023
Other studies, August 1987 (Gill and Bruland, 1990)				
Lake Erie, August 22, 1987	3.61	1.80	---	---
Lake Ontario, August 12, 1987	.92	.68	---	---

Table 4. Mercury concentrations in lake-bottom-sediment and mussel-tissue samples collected from Lake Ontario study area off Rochester, N.Y., on June 29, 1998, and corresponding data from other Great Lakes studies.

[Concentrations are in microgram per kilogram; dashes indicate no data. NYSDEC, New York State Department of Environmental Conservation. This study's site locations are shown in fig. 2.]

Location, sampled material, and depth	Total mercury as Hg	Total methyl- mercury as Hg
Bottom-sediment samples		
Upper 1 inch of sediment		
Site 1 at 79 feet, dry weight (this study)	344	0.613
Site 2 at 97 feet, dry weight (this study)	207	.611
Lake Ontario, mean of 248 samples (Thomas, 1974)	650	---
Lake Erie, mean of 243 samples (Thomas, 1974)	610	---
Upper 2.5 inches of sediment		
Site 1 at 79 feet, dry weight (this study)	3,460	---
Site 2, at 79 feet, dry weight (this study)	2,510	---
Off Rochester, at 148 ft, NYSDEC study, April 1994	1,700	---
Off Rochester, at 115 ft, NYSDEC study, April 1994	1,900	---
Other studies		
Lake Ontario, surface of bottom sediment (Mudroch and others., 1988)	140 - 3,950	---
Lake Erie, surface of bottom sediment (Mudroch and others, 1988)	450 - 4,800	---
Onondaga Lake (near Syracuse, N.Y.), upper inch of sediment, 1 sample (Effler, 1987)	12,000	---
Mussel-tissue samples		
Site 1 at 79 feet, wet weight (this study)	1.77	.947
Site 2 at 97 feet, wet weight (this study)	1.38	.789
Site 1 at 79 feet, dry weight (this study)	16.1	8.61
Site 2 at 97 feet, dry weight (this study)	12.5	7.17
Genesee River upstream from mouth, dry weight (Secor and others, 1993)	380	---
Genesee River at mouth, dry weight (Secor and others, 1993)	160	---

CONCLUSIONS

The 1997-98 side-scan sonar, metal-detector, and remote-operated vehicle surveys provided no evidence of any large piles of military-type matériel or debris fields containing potentially hazardous, toxic, or polluting materials within the 17-mi² study area in Lake Ontario, north of Rochester, N.Y. Although many scattered magnetic anomalies were observed in this area, the ROV videotapes and the several probes by SCUBA divers did not reveal military debris on the lake bottom or within the upper sediment. Analyses of bottom sediments and of mussel tissue indicate that concentrations of mercury are within the ranges reported from other Lake Ontario studies. The SCUBA

surveys and their physical probes of the lake bottom found no debris; therefore most, if not all, of the debris is probably widely scattered and buried under a layer of sediment and, possibly, mussels. The debris recovered in the research vessel nets before the trawl-net modification in 1997 corroborates that the debris is scattered and buried under several inches of sediment; the nets have recovered no debris since the foot rope design was modified in 1997.

Most of the recovered debris was the upper part of shell detonators (proximity fuzes), which do not contain a mercury switch (appendix fig. A1-B). The recovery of a single box containing what may have been mercury switches indicates that the potential of mercury contamination of lake-bottom sediment is

small because the mercury release probably resulted from damage during retrieval, whereby the box and its contents were crushed as it was pulled onto the deck. If the switches had leaked mercury onto the bottom, little if any would have been brought up onto the ships deck. Further information on the amount, types of materials, and location of disposal areas for the fuzes would be needed before a detailed assessment of the contamination potential could be made. Because no records of the early production or disposal activities of the GOCO facility were maintained, the location of the disposal area and of the recovered items prior to capture by the trawl net is unknown. The information presented herein is limited to the 17-mi² study area; therefore, additional study would be needed to extend these conclusions to areas outside the boundaries of this study.

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APPENDIX: IDENTIFICATION AND FUNCTION OF COMPONENTS CAUGHT IN FISH-SURVEY BOTTOM TRAWLS IN LAKE ONTARIO NEAR ROCHESTER, N.Y., 1978-96

The most common type of material found in the past 20 years of lake-bottom surveys has been the nose cones of shell detonators (proximity fuzes); an inventory is given in Table A1, and a photograph and schematic diagram of a proximity fuze is given in figures A-1-A and A-1-B, respectively. All nose cones are crushed, but are about 2 in. in diameter, by about 3.5 in. long, and appear to have two sections— a lower cylindrical section and an upper cone section.

Table A-1. Inventory of debris found in Lake Ontario off Rochester, N.Y., 1994-96 by research vessel *Kaho* of Lake Ontario Biological Station, Oswego, N.Y.

[in., inch].

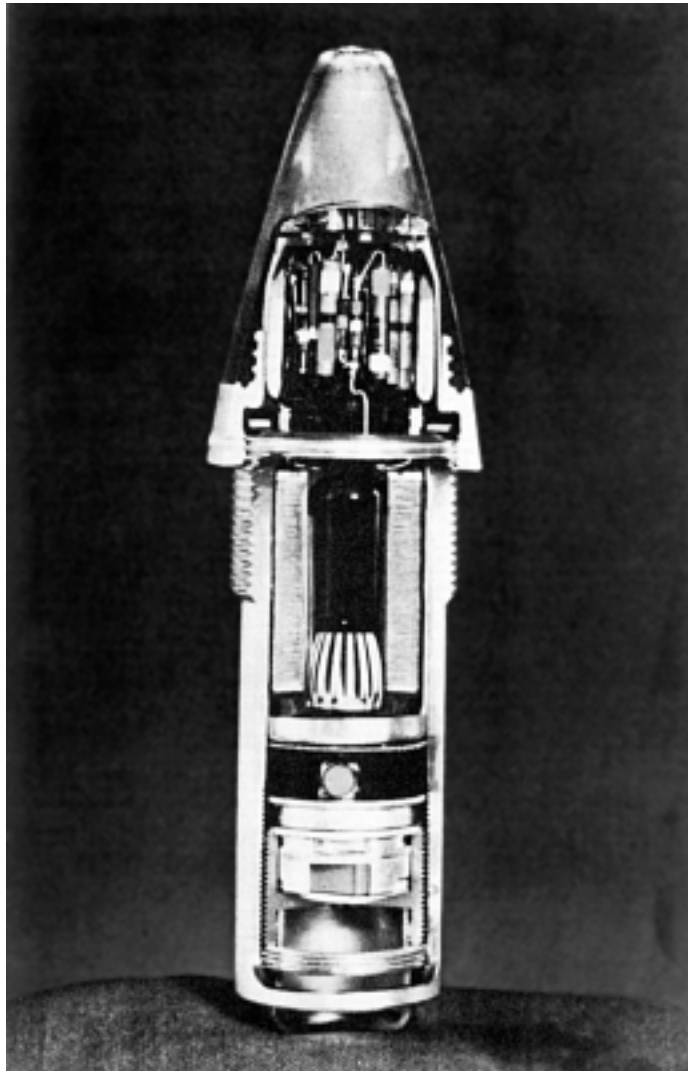
Item Number	Description ¹
1	Four “bricks” of compressed nose cones (12 in. by 10 in. by 8in.)
2	One 5-gallon bucket of nose cones
3	One large plastic bag of nose cones - unmarked
4	One small plastic bag of nose cones - marked “50 meters, Roch. 07/25/94”
5	One small plastic bag of crushed components - marked “30 meters, Roch. 07/25/94”
6	One small plastic bag of nose cones - marked “55 meters, Roch. 07/25/94”
7	One small plastic bag of crushed components - marked “43° 19.07’ north latitude, 77° 34.93’ west longitude, W-end of transect; and 43° 18.54’ north latitude, 77° 33.59’ west longitude, E-end of transect, 35 meters, Roch. 6/12/95”
8	One small plastic bag of nose cones - marked “55 meters, Roch. 04/26/95”
9	One small plastic bag of crushed components - marked “43° 20.16’ north latitude, 77° 33.31’ west longitude, W-end of transect; and 43° 19.71’ north latitude, 77° 32.18’ west longitude, E-end of transect, 55 meters, Roch. 6/12/95”
10	10 pounds of unmarked nose cones and components

¹ nose cone = upper end of proximity fuze, defined in text and illustrated in fig. A-1.

Identification of the nose cones and other components was made with the assistance of the U.S. Army Corps of Engineers in Huntsville, Ala., and Rock Island, Ill. These components are parts of proximity fuzes made for the U.S. and British Army and Navy during World War II. The fuzes were the detonator for various-sized shells shot from howitzers and anti-aircraft guns (fig. A1). Their function of these devices, described by Baldwin (1980, p. 20-21), is as follows:

The fuze is simply a specialized radio set. There is a battery whose electrical energy is released by a setback, the shock of the firing of a gun. The battery furnished three different voltages: one for the filaments of the vacuum tubes, one for the plates, and one for the grids. One of the tubes is an oscillator. In the nose of the fuze is a metallic cap, which together with the rest of the shell acts like a dipole. The oscillator tube thus has an antenna and emits a high-frequency radio wave in particular directions from the shell. This continuous radio wave surrounds the moving shell, and when the shell passes close to a target, the latter reflects a small amount of radio wave energy back to the fuze where it is detected by the same tube as sent out the wave in the first place. The plate voltage is “modulated” by the reflected wave, which is at a slightly different frequency than the outgoing wave due to the relative motion of the shell and target. Thus, a beat note is set up and the plate voltage varies in frequency within the audio range of a few, to a few thousand cycles per second. This audio frequency voltage variation is then passed through a three tube amplifier. When the period of the audio frequency wave and also its amplitude or intensity are

A. Mark 45 Fuze



B. Fuze Diagram

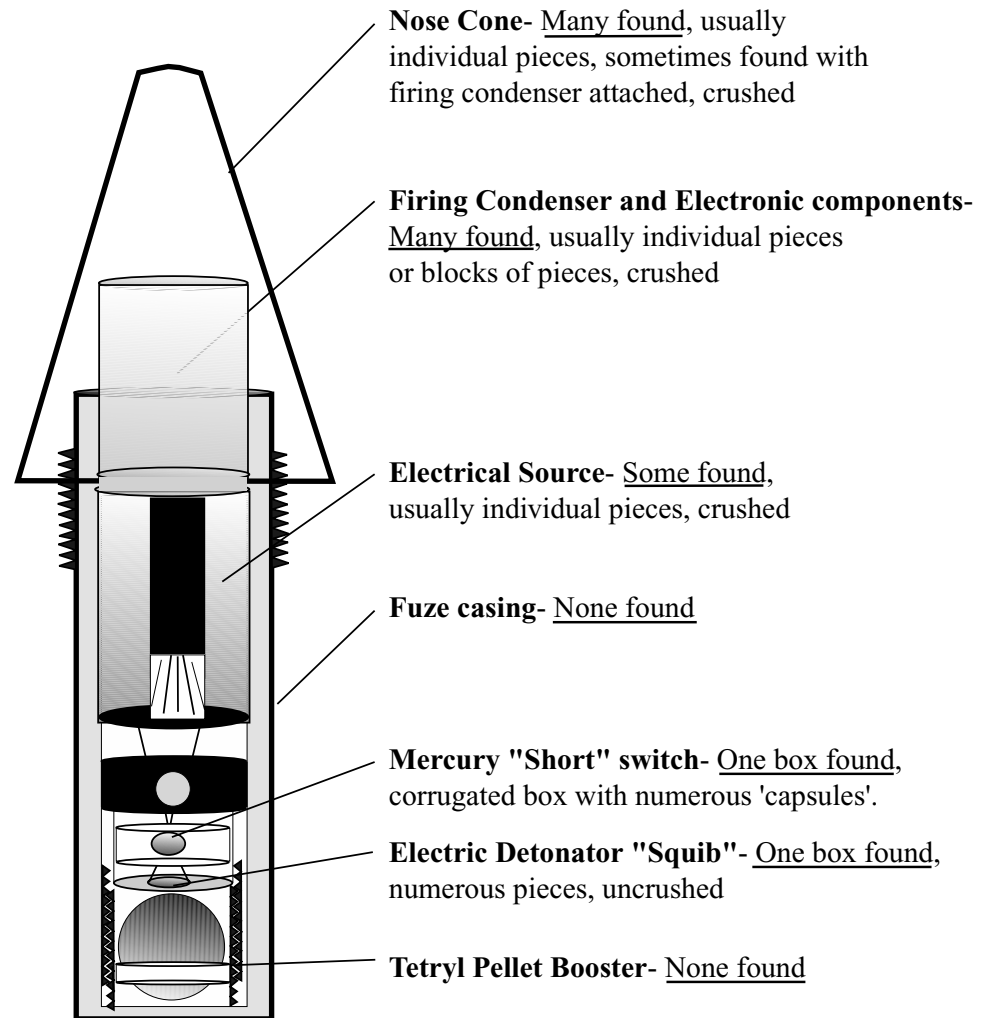


Figure A-1. Proximity fuze of the type found by Lake Ontario Biological Station during fish trawls, 1974-96: A. Interior view of fuze. (with permission of Eastman-Kodak). B. Diagram showing major components of fuze, frequency of detection off Rochester, and condition of parts found.

exactly right, a thyratron tube, serving as a switch, is discharged. It completes a circuit that releases an electrical charge, which meanwhile has been stored in a condenser. The surge of electricity goes through a tiny wire in an electric squib (detonator), much like a dynamite cap. The wire gets hot and the explosive in the squib goes off. This tiny explosion sets off...[another] sensitive explosive...at the bottom of the fuze. This explosion sets off the explosive loading of the shell and it bursts the steel shell body into hundreds of high velocity fragments.

Mercury Switches and a Mercury Component of the Fuze

Concern over the potential for mercury contamination of lake-bottom sediment was prompted by the discovery of a box of small mercury capsules by the *Kaho* in 1993. The discovery is documented in a letter dated November 29, 1993 and was sent from Captain Edward Perry (R/V *Kaho*) to Mr. Frank Estabook of the NYSDEC:

On 18 October 1993, the R/V Kaho was dragging a 39 ft bottom trawl between 43° 19.07" N and 77° 34.93" W. At a depth of 35 meters we pulled up what appeared to be old electrical components that had mercury switching devices in them. The switches (?) consisted of a board approximately 3 in. by 4 in. with a dozen or so capsules about the size of a pill mounted on the board. Some of the capsules were starting to rust through, that's how we discovered the mercury inside.

Further investigation of proximity-fuze components heightened the concern over the potential for mercury contamination, as described in Baldwin (1980, p. 128-129):

The mercury unshorter switch was developed for prefire safety and post fire delay.... the mercury switch was only 0.315 inch in diameter and 0.530 inch long. It contained two chambers; an inner or contact chamber in which mercury maintained an electrical short between the central stud and the outside case of the switch and an outer chamber or sump that was empty prior to spin. The two chambers were separated by a porous diaphragm with the switch mounted on its side in the rear fitting [at the base of the fuze assembly]. The spin of the shell after firing forced the mercury out of the contact chamber through the porous diaphragm into the sump, thereby removing the short between the center contact and the outside shell [arming the fuze].

Whether the mercury components found in 1993 are the same mercury switches that were used in proximity fuzes is unknown. The fuze switches were small, single elements, whereas the components described by Captain Perry were much different and considerably larger. Discussions with some of the ship's crew members who were present at the 1993 discovery indicate that the individual "pill-sized" switches may have been in some type of corrugated fiberboard package material — possibly a shipping container that had contained several of the boards described by Captain Perry.

Nose Cone and Condenser Components of the Fuze

Background information and examination of retrieved proximity fuzes indicated that nearly all debris recovered by the *Kaho*, other than the box of mercury components and the box of detonators (squibs) referred to in figure A-1-B, were merely the upper ends of proximity fuzes; that is, the nose cone and the condenser. Nearly all of the recovered components were crushed. Crushing was apparently a required means of destroying defective components (every component was tested and required to meet strict quality-assurance standards during the manufacturing process); crushing also was a means of preventing any of the components from reaching enemy hands during the war; as indicated by Baldwin (1980, p. 111).

A batch of radio tubes produced in the early days proved defective, so one lot was disposed of by dumping at sea rather than by the crushing process regulations specified. A few of them later showed up in the Boston Fish Market. Security was very embarrassed.

Source of Components

The above information indicates what the components are, but how they got into Lake Ontario is unknown; one possible explanation is that the crushed, defective fuze components were jettisoned in the lake for security reasons; as stated above by Baldwin (1980, p. 111).

Baldwin (1980, p. 213) cites a Rochester firm as a principal member of the team that developed and manufactured components for the proximity fuze. This firm also was cited by Rowland and Boyd (1947, p. 285) as one of five companies responsible for the final assembly of over 22 million fuzes during the war. No records of these activities could be found by the Navy or the GOCO contractor, however.