

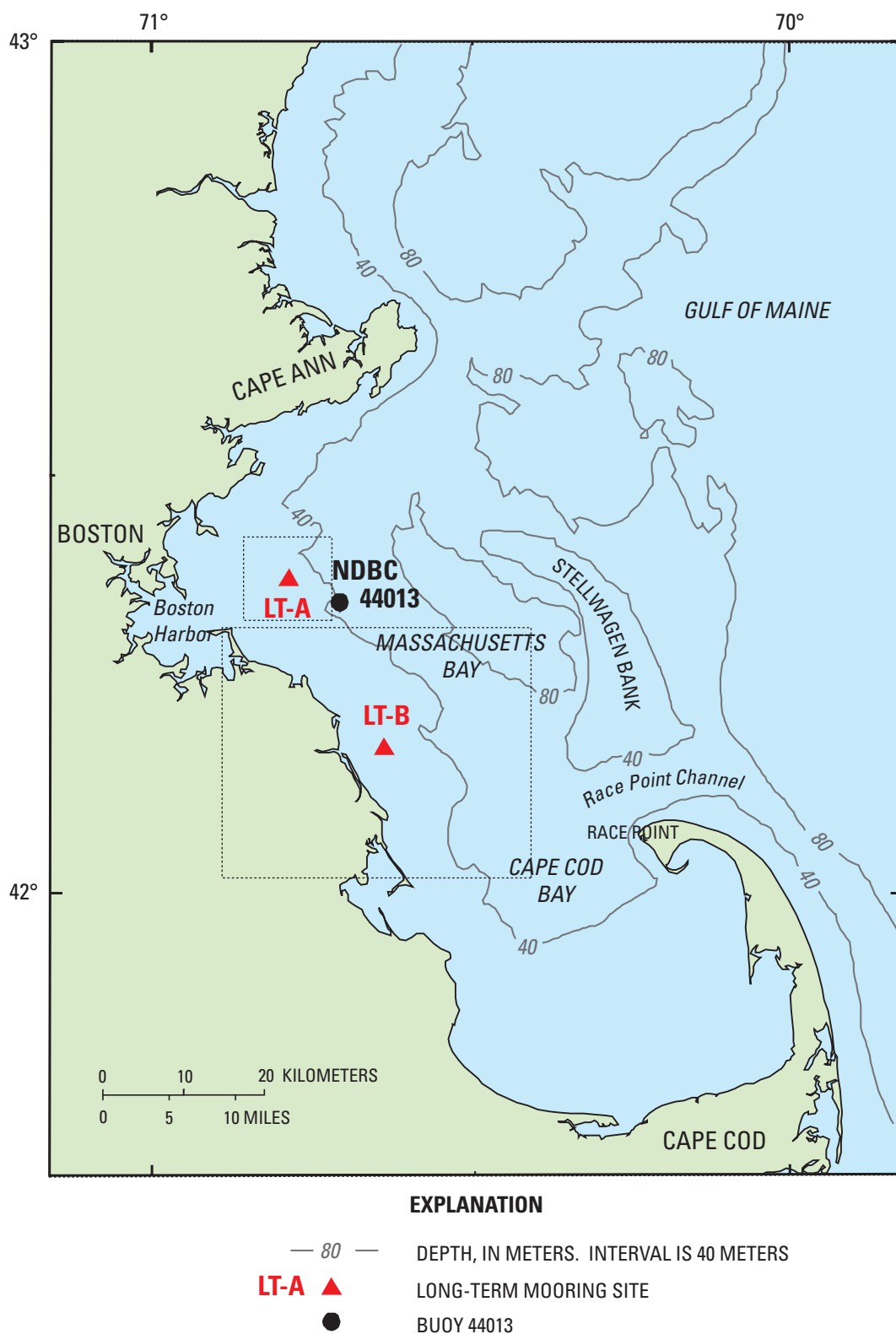


Figure 1. Locations of long-term sites LT-A and LT-B in western Massachusetts Bay. The mooring at LT-A is about 1 kilometer south of the new ocean outfall in about 32 meters water depth. The mooring at LT-B is in about 22 meters water depth. The dotted rectangles outline detailed site maps shown in figure 6 (LT-A) and figure 12A (LT-B). NDBC 44013 is the location of the National Data Buoy Center discus buoy where ongoing meteorological observations were obtained. Meteorological observations prior to 1994 were obtained from the Large Navigational Buoy maintained at LT-A.

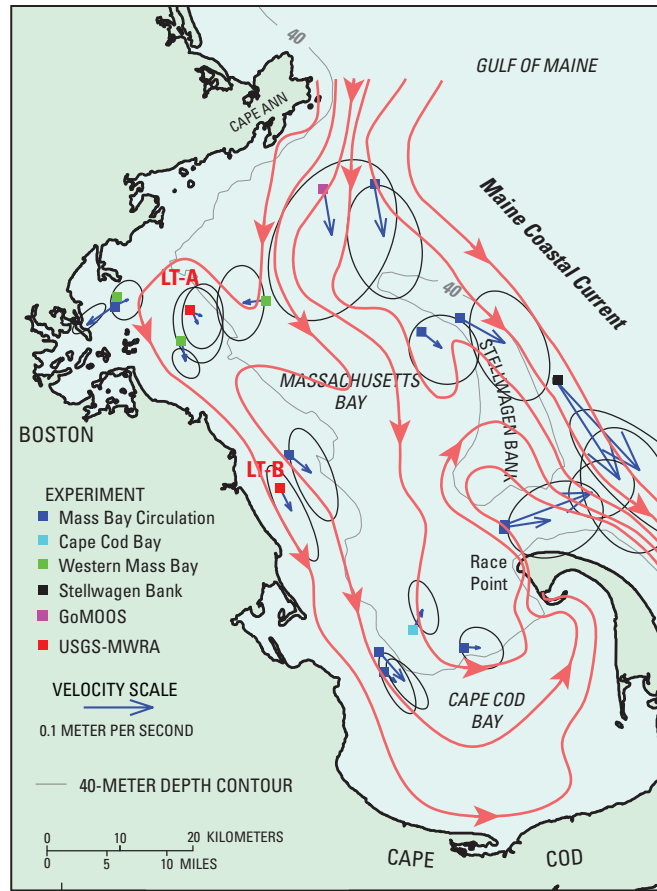


Figure 2. Winter (November through February) mean flow in Massachusetts Bay (modified from Butman and others, 2007b). The observed winter mean flow (blue arrows) and variability (shown as an ellipse centered around the tip of the mean-flow arrow) are shown for near-surface currents (measured 2-8 meters below sea surface) during experiments conducted from 1986 to 2005. Typically, the daily averaged current originates at the station symbol (colored squares) and flows toward any location within the ellipse. In general, the low-frequency fluctuations are larger than the mean. The red lines are streamlines of the depth-averaged mean flow in Massachusetts Bay in winter calculated from numerical simulations for the months November-February 1990-92, when the water column is vertically well mixed. The simulations show a flow to the southeast of 0.05 to 0.1 meter per second in the Gulf of Maine east of Massachusetts Bay (the Maine Coastal Current), some of which enters the Bay south of Cape Ann. Within Massachusetts Bay, the depth-averaged residual flow is strongest (about 0.05 meter per second) along the western shore.

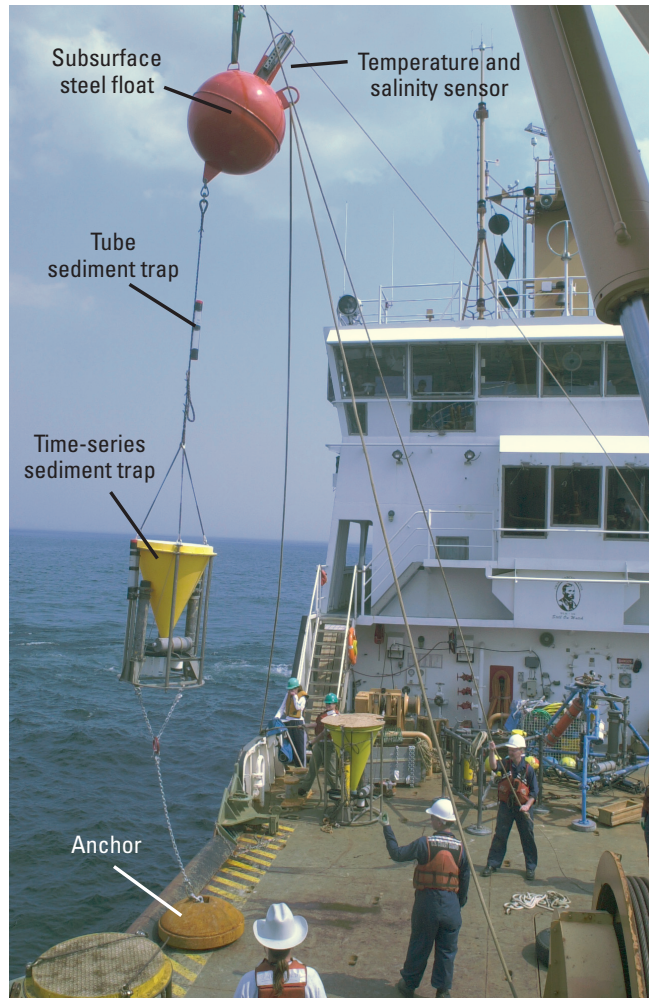


Figure 3. A subsurface mooring being deployed at site LT-B from the U.S. Coast Guard Cutter *Marcus Hanna*. Photograph by Dann Blackwood, U.S. Geological Survey.

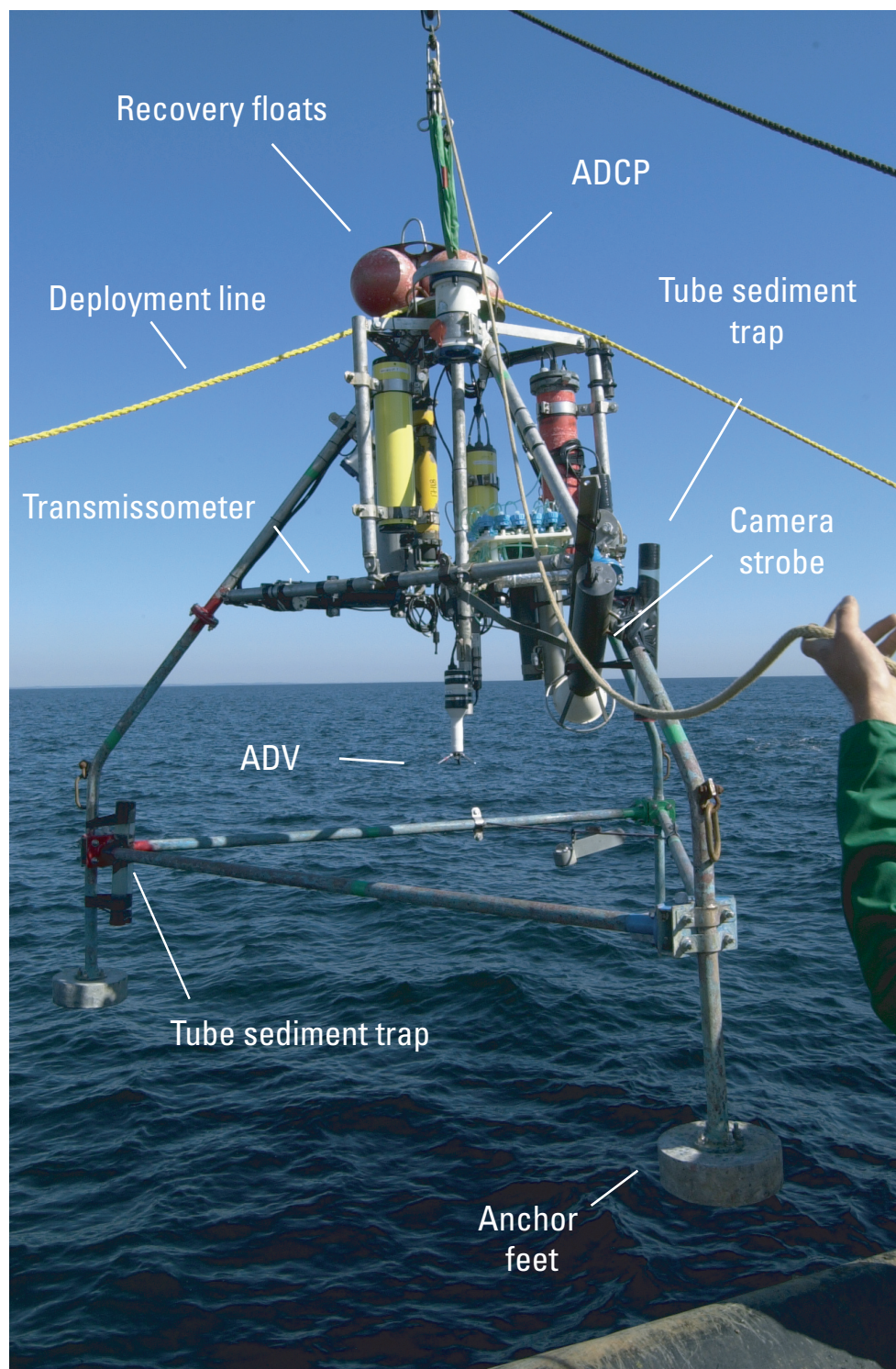


Figure 4A. Large tripod frame used to deploy instrumentation at site LT-A being deployed from the U.S. Coast Guard Cutter *Marcus Hanna*. The frame and attached instruments are lowered to the sea floor where they collect and record data unattended for about four months. For recovery, an acoustic signal releases floats on the top of the tripod that pull a recovery line to the surface. The current sensors on this tripod include an acoustic Doppler current profiler (ADCP) and an acoustic Doppler velocimeter (ADV). Photograph by Dann Blackwood, U.S. Geological Survey.

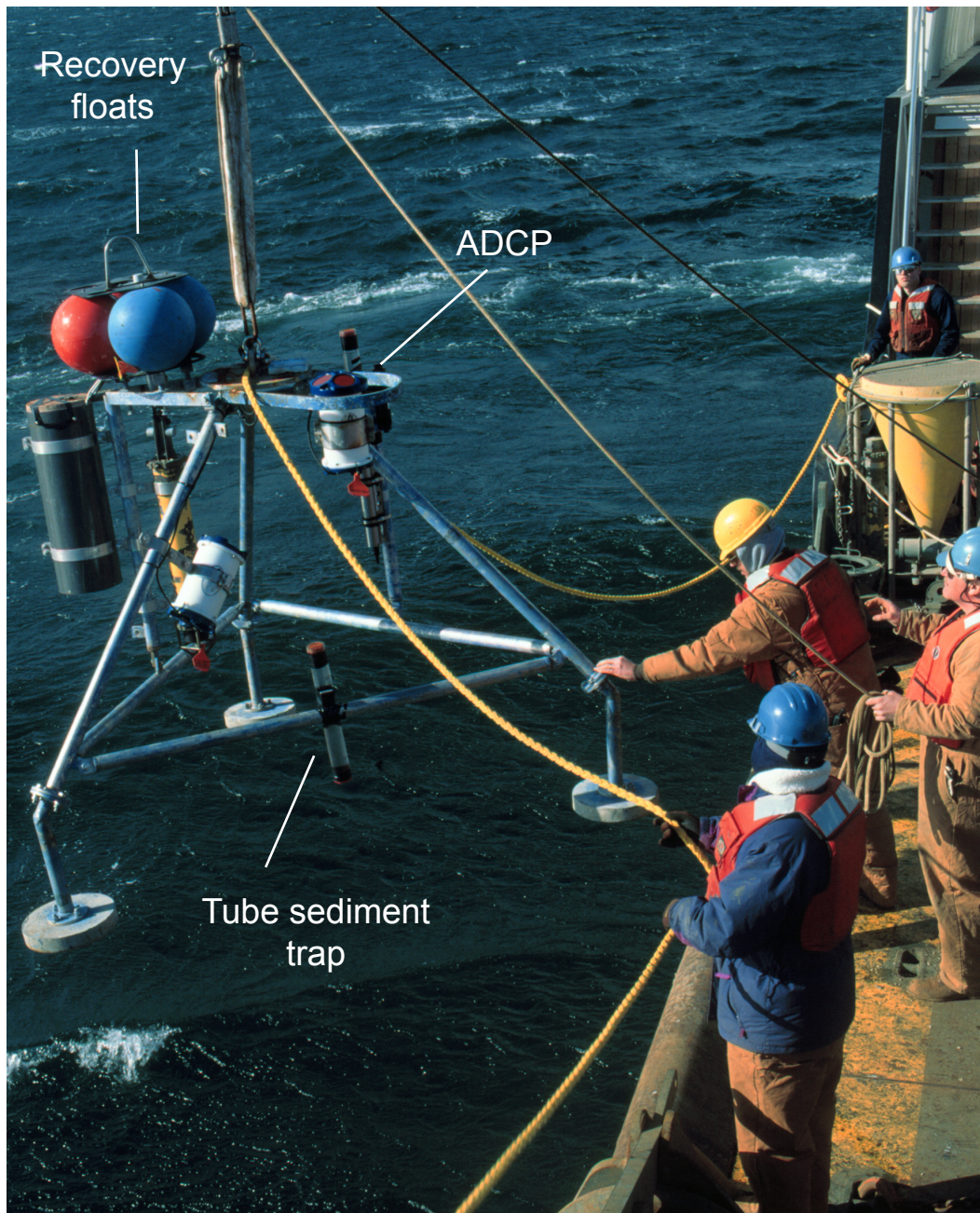


Figure 4B. Small tripod frame used to deploy instrumentation at site LT-B being deployed from the U.S. Coast Guard Cutter *White Heath*. An acoustic Doppler current profiler (ADCP) and tube sediment traps are attached to the tripod. The recovery floats on the top of the frame are released by an acoustic release (yellow case) and pull a recovery line to the surface. Photograph by Dann Blackwood, U.S. Geological Survey.



Photograph by Dann Blackwoord, U.S. Geological Survey.

Figure 5A. Two views of U.S. Coast Guard Cutter *White Heath*. This vessel was used for deployment and recovery of the long-term moorings in Massachusetts Bay from December 1989 to February 1998.



Photograph courtesy of U.S. Coast Guard.



Figure 5B. U.S. Coast Guard Cutter *Marcus Hanna*. This vessel was used for deployment and recovery of the long-term moorings in Massachusetts Bay from June 1998 to February 2006. Photograph by Dann Blackwood, U.S. Geological Survey.



Figure 5C. Fishing Vessel *Christopher Andrew*. This vessel was used for occasional servicing of the long-term moorings at sites LT-A and LT-B in western Massachusetts Bay. Photograph by Dann Blackwood, U.S. Geological Survey.

Figure 6. Map showing the location of moorings deployed at site LT-A, the location of U.S. Coast Guard Boston Approach Buoy, and the location of sea-floor photographs (see figs. 7A, 7B). The water depth at the mooring site is nominally 32 meters. LT-A is located on the southern flank of a ridge that rises to within about 25 meters of the sea surface. All moorings were located within a circle about 500 meters in diameter. Water depth ranged from 29 to 34 meters.

The map shows sea-floor topography in shaded-relief view colored by backscatter intensity (from Butman and others, 2004). The backscatter intensity is represented by a suite of eight colors ranging from blue, which represents low intensity, to red, which represents high intensity. The shaded-relief image was created by vertically exaggerating the topography four times and then artificially illuminating the relief by a light source positioned 45 degrees above the horizon from an azimuth of 350 degrees. The resulting image displays light and dark intensities within each color band that result from a feature's position with respect to the light source. For example, north-facing slopes, receiving strong illumination, show as a light intensity within a color band, whereas south-facing slopes, being in shadow, show as a dark intensity within a color band. Site LT-A is located in a region of relatively high backscatter intensity. The sea floor at the long-term site is cobbles and gravel.

The 55 individual diffuser heads for the ocean outfall that discharges treated sewage effluent from the Boston metropolitan region into Massachusetts Bay extend across the northern part of this figure. The most notable features are two parallel rows of individual mounds of material; these mounds are the material discarded on the sea floor from the holes drilled for the risers that extend to the outfall tunnel below. The diffuser heads, about 3 meters high and 4 meters in diameter, are located between the rows and are not well resolved at this scale.



Figure 7A. The sea floor (station 5077, photo 01140026, Gutierrez and others (2000)) on the crest of a ridge about 0.6 kilometers north of site LT-A (see fig. 6 for location). Water depth is approximately 22 meters. The field of view is approximately 50 centimeters by 75 centimeters. The crests of the submerged ridges in western Massachusetts Bay are covered with gravel and boulders and there is little or no accumulation of fine-grained sediments. The bright pink color is a calcareous algae that grows on the boulders in water depths shallower than about 25 meters where sufficient light reaches the sea floor. See Gutierrez and others (2000) for additional photographs of the sea floor in western Massachusetts Bay.



Figure 7B. The sea floor (station 5088, photo 13010035, Gutierrez and others (2000)) in a topographic low about 0.7 kilometers south of site LT-A (see fig. 6 for location). Water depth is approximately 37 meters. The field of view is approximately 50 centimeters by 75 centimeters. The photograph shows cobbles and patches of medium to fine sand. The fish is most likely a young cod. See Gutierrez and others (2000) for additional photographs of the sea floor in western Massachusetts Bay.

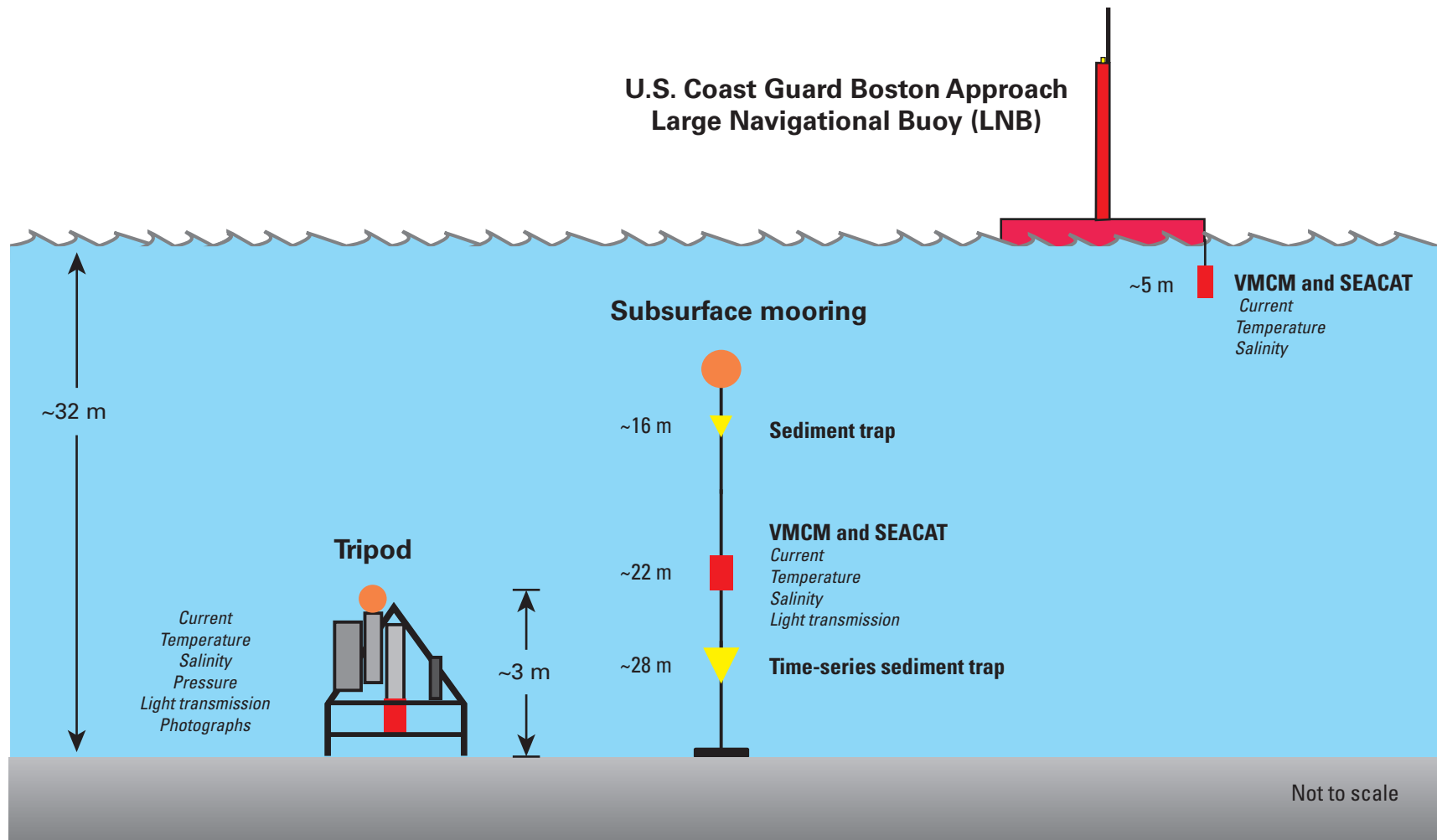


Figure 8A. Schematic diagram showing instruments deployed at site LT-A in western Massachusetts Bay (figs. 1 and 4) from 1989 to 1994. During this period, instruments were deployed from the U.S. Coast Guard Large Navigational Buoy, on a subsurface mooring, and on a tripod frame that rests on the sea floor. Nominal measurement depths for current velocity and temperature (red rectangles) were 5 meters, 22 meters (10 meters above bottom), and 31 meters (1 meter above bottom). [m, meters; VMCM, vector-measuring current meter; ~, about]

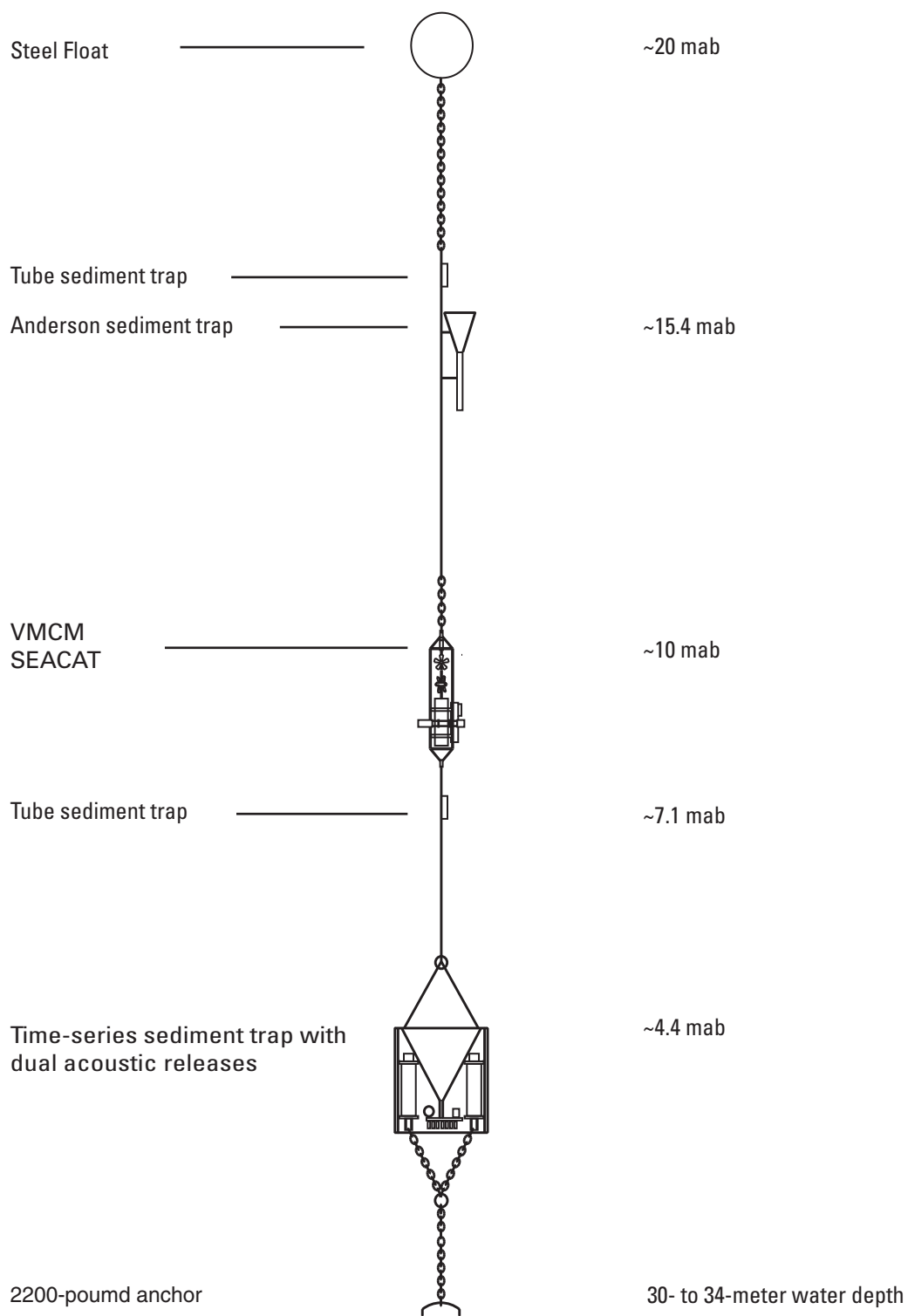


Figure 8B. Schematic diagram of the subsurface mooring deployed at site LT-A in western Massachusetts Bay from 1989 to 1994. The subsurface mooring supported a time-series sediment trap at 4.5 meters above bottom, a Vector-Measuring Current Meter (VMCM) and SEACAT at 10 meters above bottom (about 22 meters), an Anderson sediment trap at about 16 meters above bottom, and tube traps at about 4.4, 7.1, and 16.3 meters above bottom. Nominal water depth was 32 meters. [mab, meters above bottom; ~, about]



Figure 8C. The near-surface Vector-Measuring Current Meter (VMCM) with transmissometer attached being hung from the side of the Large Navigational Buoy in March 1990. The VMCM was supported on a $\frac{3}{4}$ -inch chain. A 100-pound lead weight was hung below the VMCM to provide tension across the instrument. Photograph by Dann Blackwood, U.S. Geological Survey.

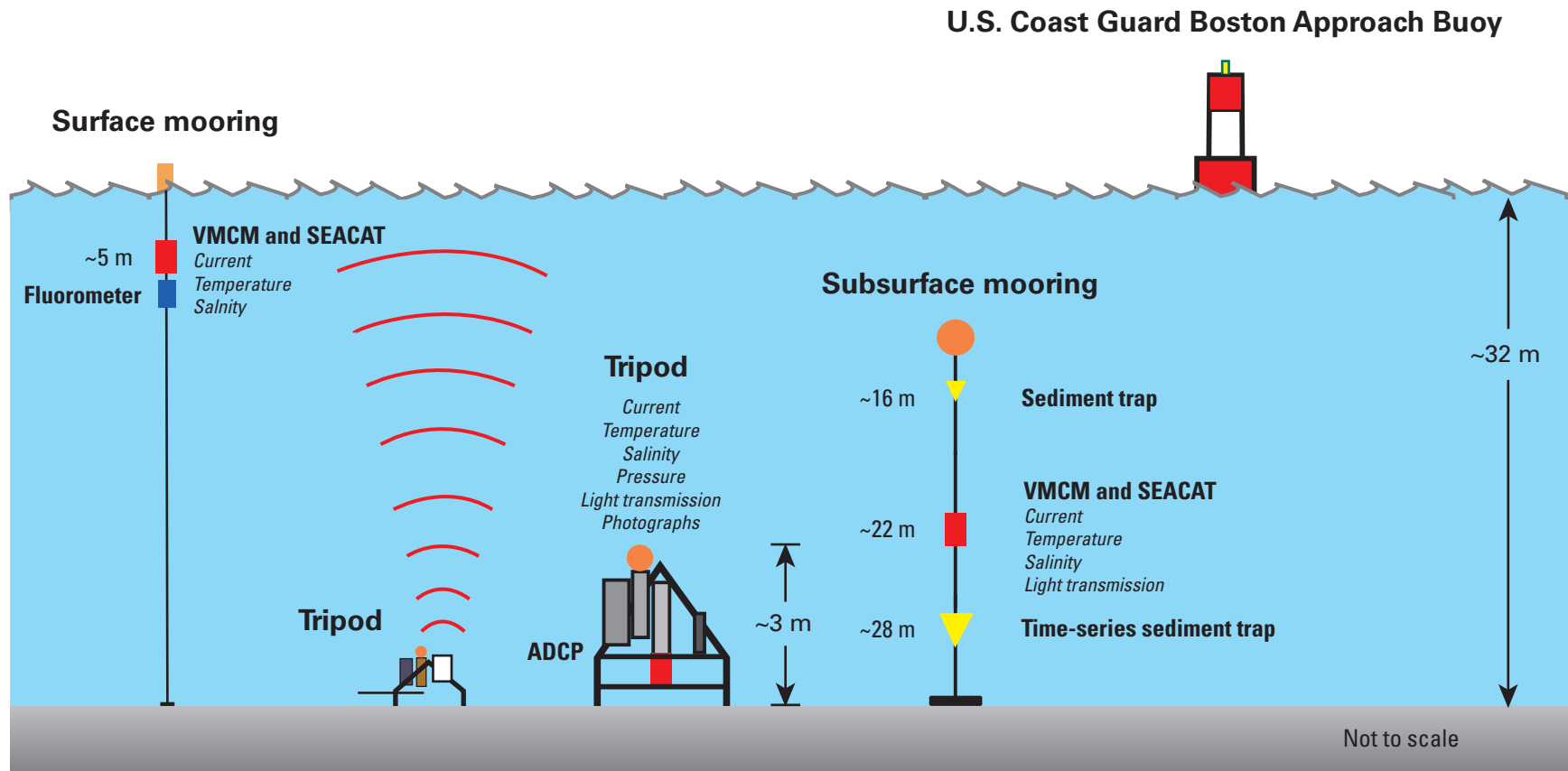


Figure 9A. Schematic diagram of moored instruments deployed at site LT-A in western Massachusetts Bay (figs. 1 and 4) from 1995 through 1996. During this period, instruments were deployed on a surface mooring, on a subsurface mooring, and on two bottom tripods. Nominal measurement depths for current velocity and temperature (red rectangles) were 5 meters below the surface, 22 meters (10 meters above bottom), and 31 m (1 meter above bottom). The acoustic Doppler current profiler (ADCP), mounted on the bottom tripod, obtains a profile of current throughout the water column in 2-meter bins. Several configurations were used for the surface mooring (both slack-moored and taut-moored using elastic tethers). [m, meters; VMCM, vector-measuring current meter; ~, about]

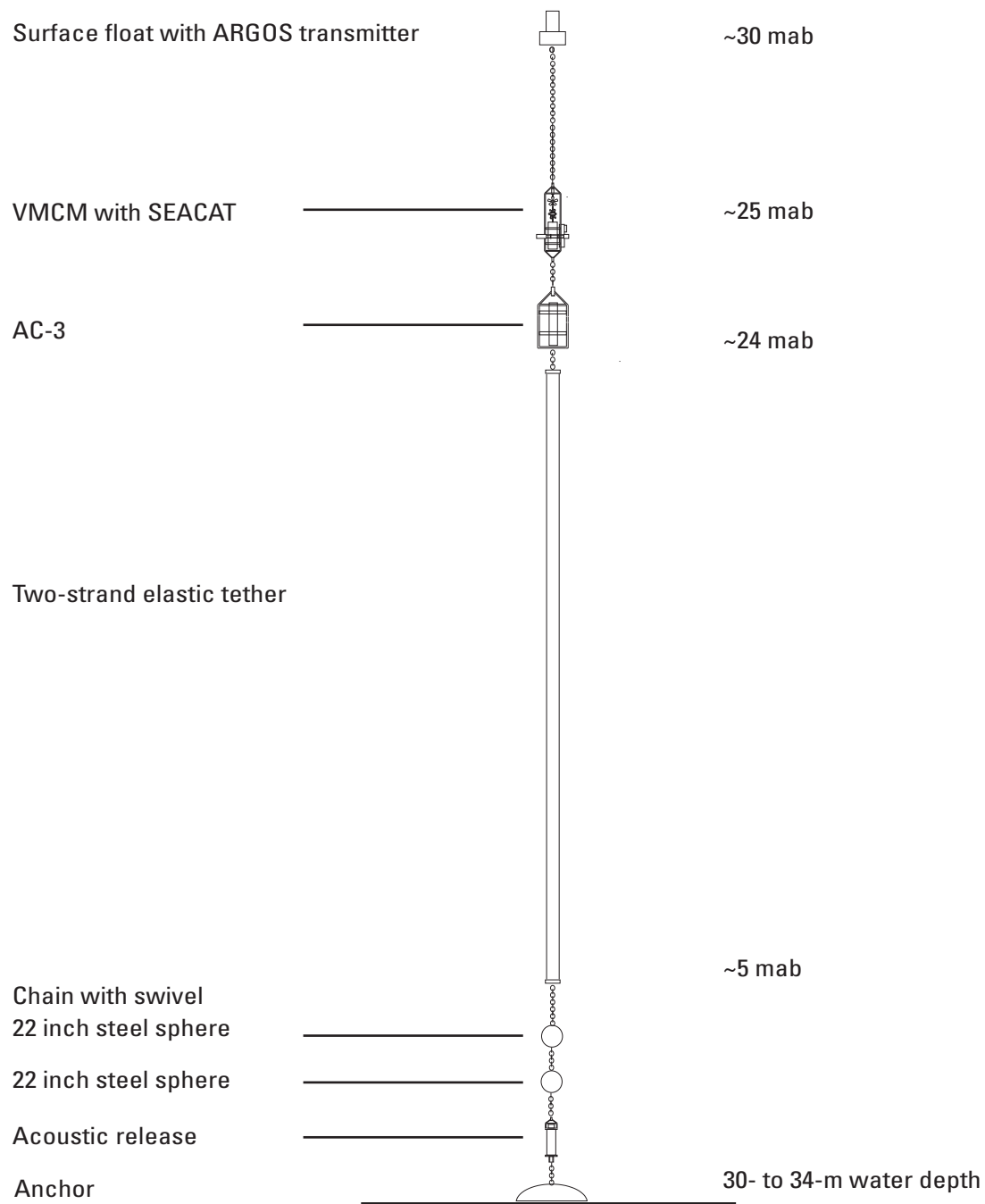


Figure 9B. Schematic diagram of one of the surface-mooring configurations deployed at site LT-A in western Massachusetts Bay from 1994 to 1996. The surface mooring supported a Vector-Measuring Current Meter (VMCM) at 5 meters below the surface, and on some deployments an ACM-3, at about 6 meters below the surface. The mooring utilized an elastic tether. This mooring proved very difficult to maintain in the area of high vessel traffic, and was discontinued once the acoustic Doppler current profiler (ADCP) measurements, measuring currents in the upper water column, became routine. The ARGOS transmitter provided satellite tracking of the surface float in the event the mooring was separated. Nominal water depth was 32 meters. [mab, meters above bottom; ~, about]

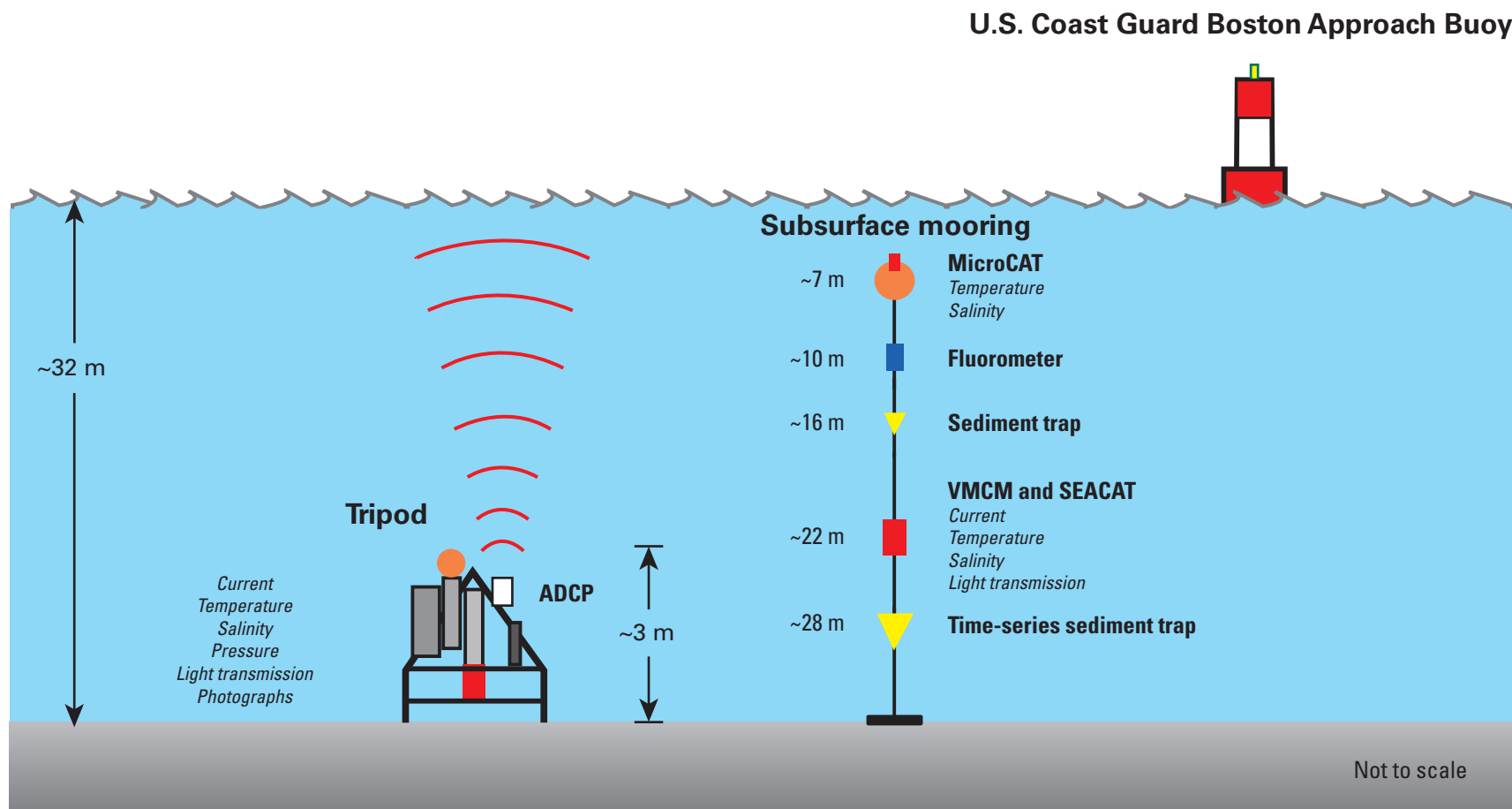


Figure 10A. Schematic diagram of moored instruments deployed at site LT-A in western Massachusetts Bay (figs. 1 and 4) from 1998 through 2002. During this period, instruments were deployed on a subsurface mooring and on a bottom tripod. Nominal measurement depths for current velocity and temperature, were 5 meters, 22 meters (10 meers above bottom) and 31 meters (1 meters above bottom). The Acoustic Doppler Current Profiler (ADCP), mounted on the bottom tripod, obtains a profile of current throughout the water column in 2-meter bins. During 1998, the fluorometer was at about 7 meters and there were no measurements on the subsurface float. [m, meters; VMCM, vector-measuring current meter; ~, about]

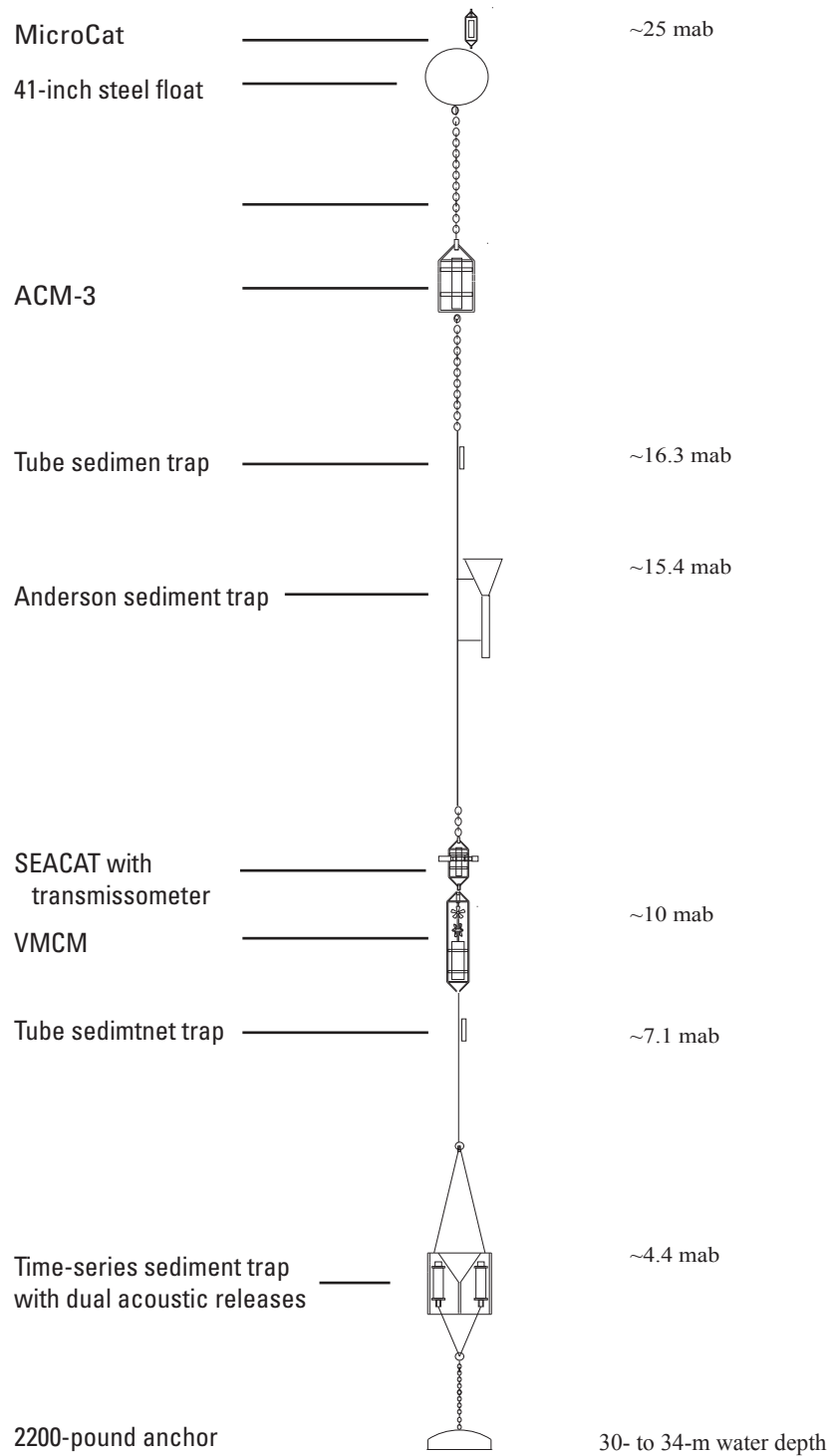


Figure 10B. Schematic diagram of the subsurface mooring deployed at site LT-A in western Massachusetts Bay from 1998 through 2002. The subsurface mooring supported a time-series sediment trap at 4.5 meters above bottom, a Vector-Measuring Current Meter (VMCM) and SEACAT at about 22 meters (10 meters above bottom), an Anderson sediment trap at about 16 meters (15.4 meters above bottom), an ACM-3 flurometer at 10 meters, and a MicroCAT at 7 meters (25 meters above bottom). Tube sediment traps were at about 4.2, 7.1, and 16.3 meters above bottom. Nominal water depth was 32 meters. [mab, meters above bottom; ~, about]

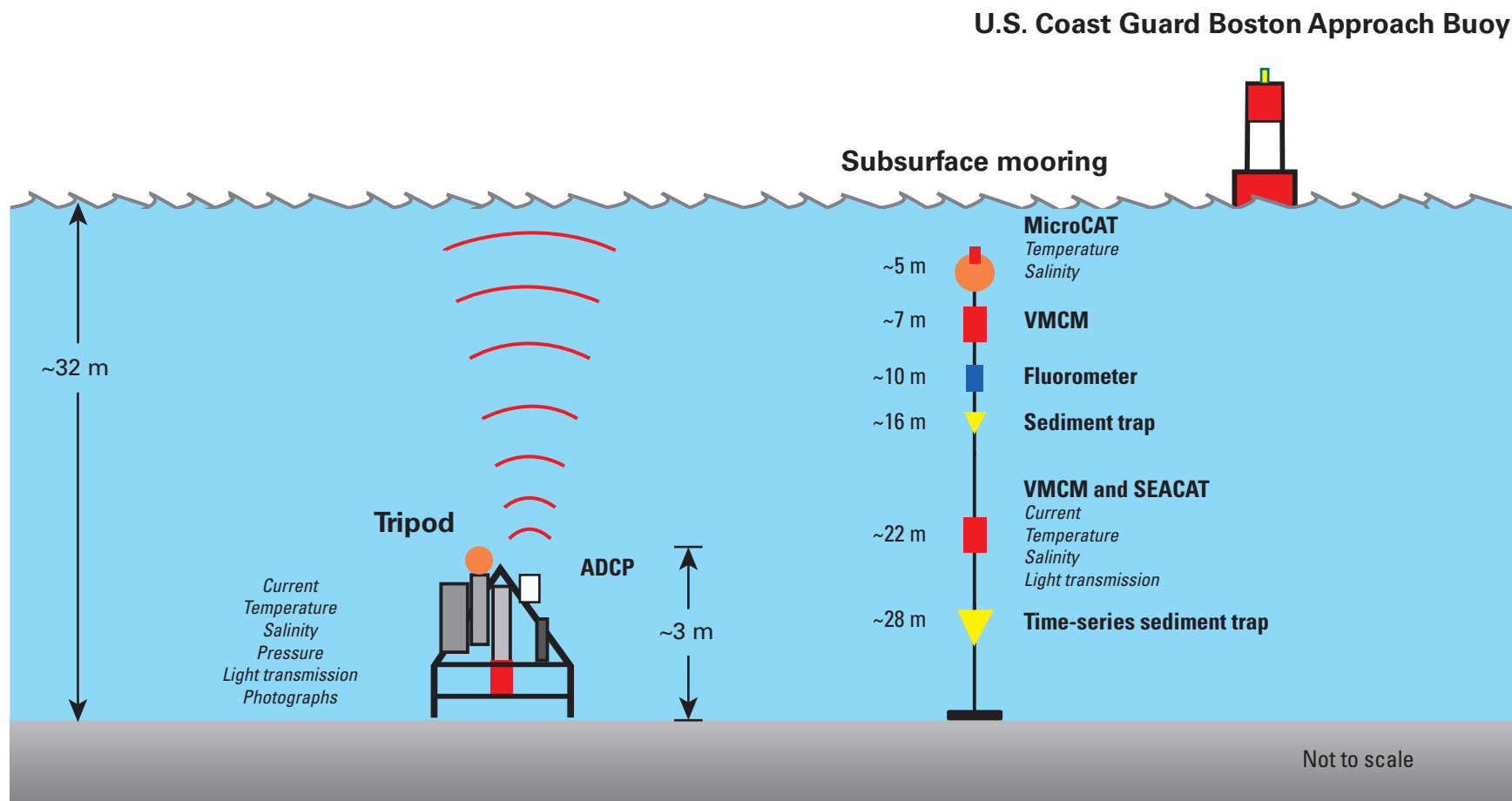


Figure 11A. Schematic diagram of moored instruments deployed at site LT-A in western Massachusetts Bay (figs. 1 and 4) from 2003 to 2006. During this period, instruments were deployed on a subsurface mooring and on a bottom tripod. Nominal measurement depths for temperature, salinity, and current velocity (red rectangles) were 5 meters, 22 meters (10 meters above bottom) and 31 meters (1 meter above bottom). The acoustic Doppler current profiler (ADCP), mounted on the bottom tripod, obtains a profile of current throughout the water column in 2-meter bins. [m, meters; VMCM, vector-measuring current meter; ~, about]

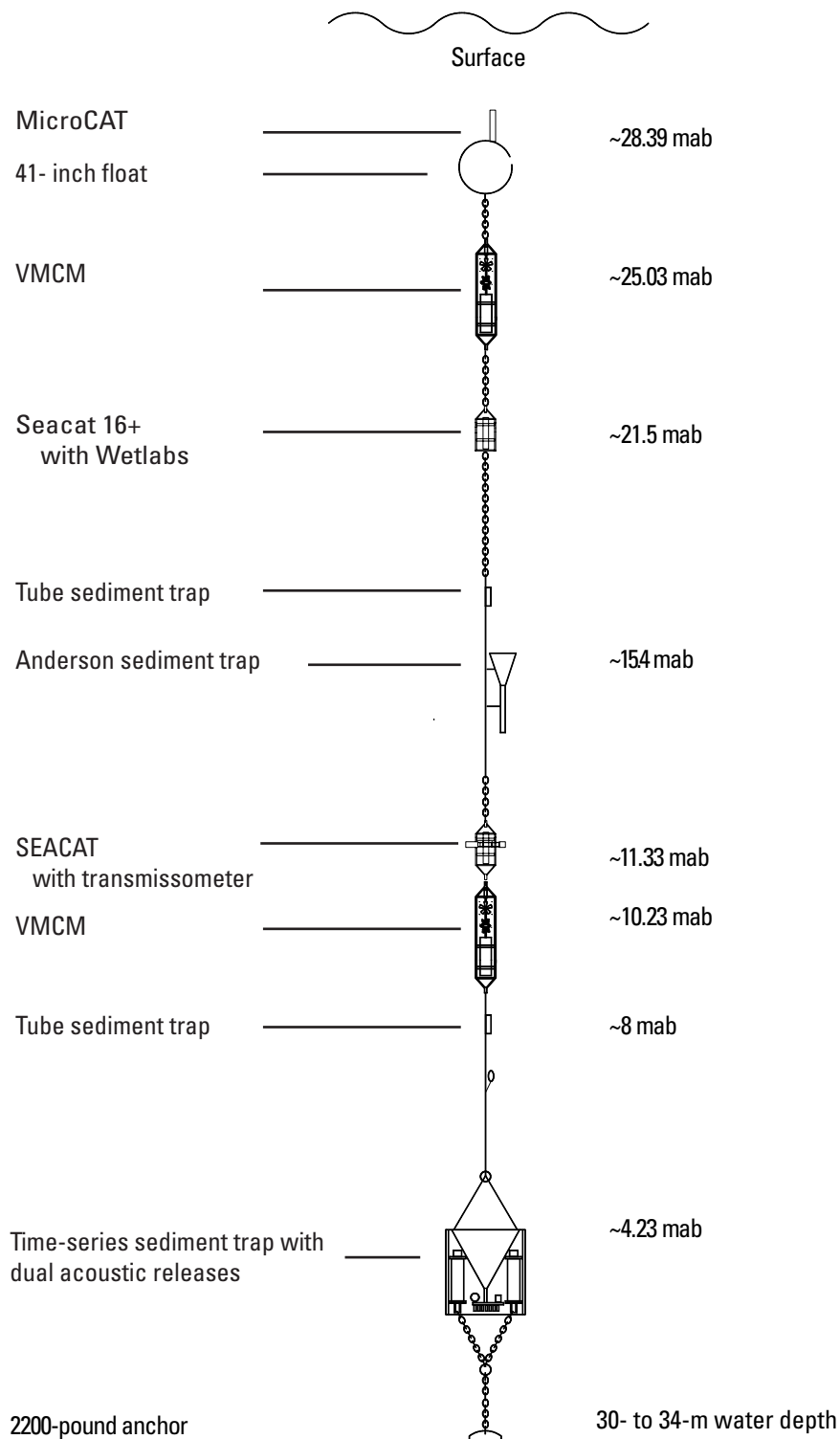


Figure 11B. Schematic diagram of the subsurface mooring deployed at site LT-A in western Massachusetts Bay from 2003 to 2006. The subsurface mooring supported the time-series sediment trap at 4.2 meters above bottom, a Vector-Measuring Current Meter (VMCM) and SEACAT at about 22 meters (10 meters above bottom), an Anderson sediment trap at about 16 meters (15.4 meters above bottom), a Fluorometer at about 10 meters (21.5 meters above bottom), a VMCM at about 7 meters (25 meters above bottom), and a MicroCAT at about 4 meters (28 meters above bottom). Tube sediment traps were at about 4.2, 7.1, and 16.3 meters above bottom. Nominal water depth was 32 meters. [mab, meters above bottom; ~, about]

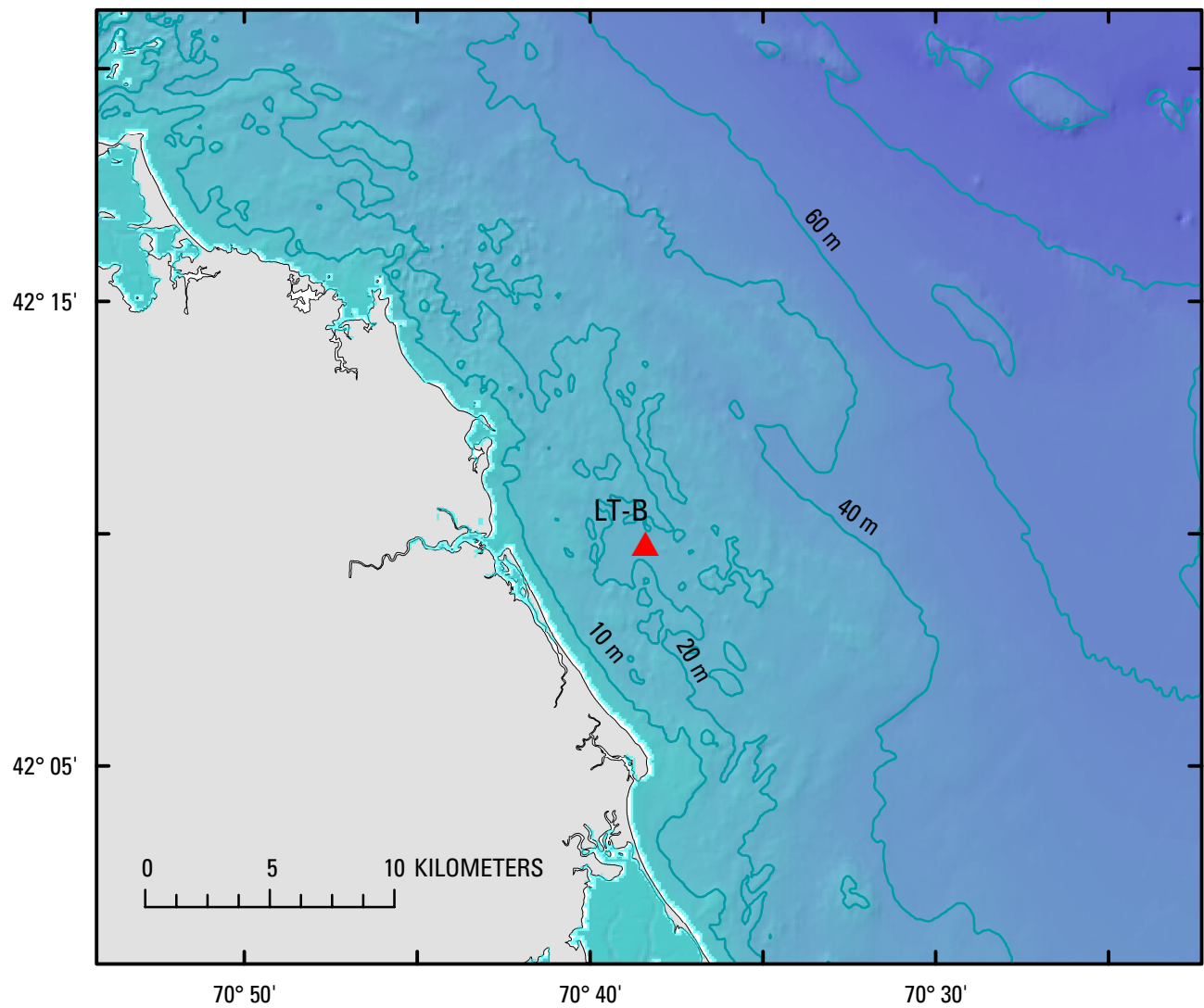


Figure 12A. Map of western Massachusetts Bay showing the location of long-term mooring site LT-B. Water depth is 20 to 22 meters. Shaded relief bathymetry from Divens and Metzger. Coastline from Butman and Lindsay (1999).

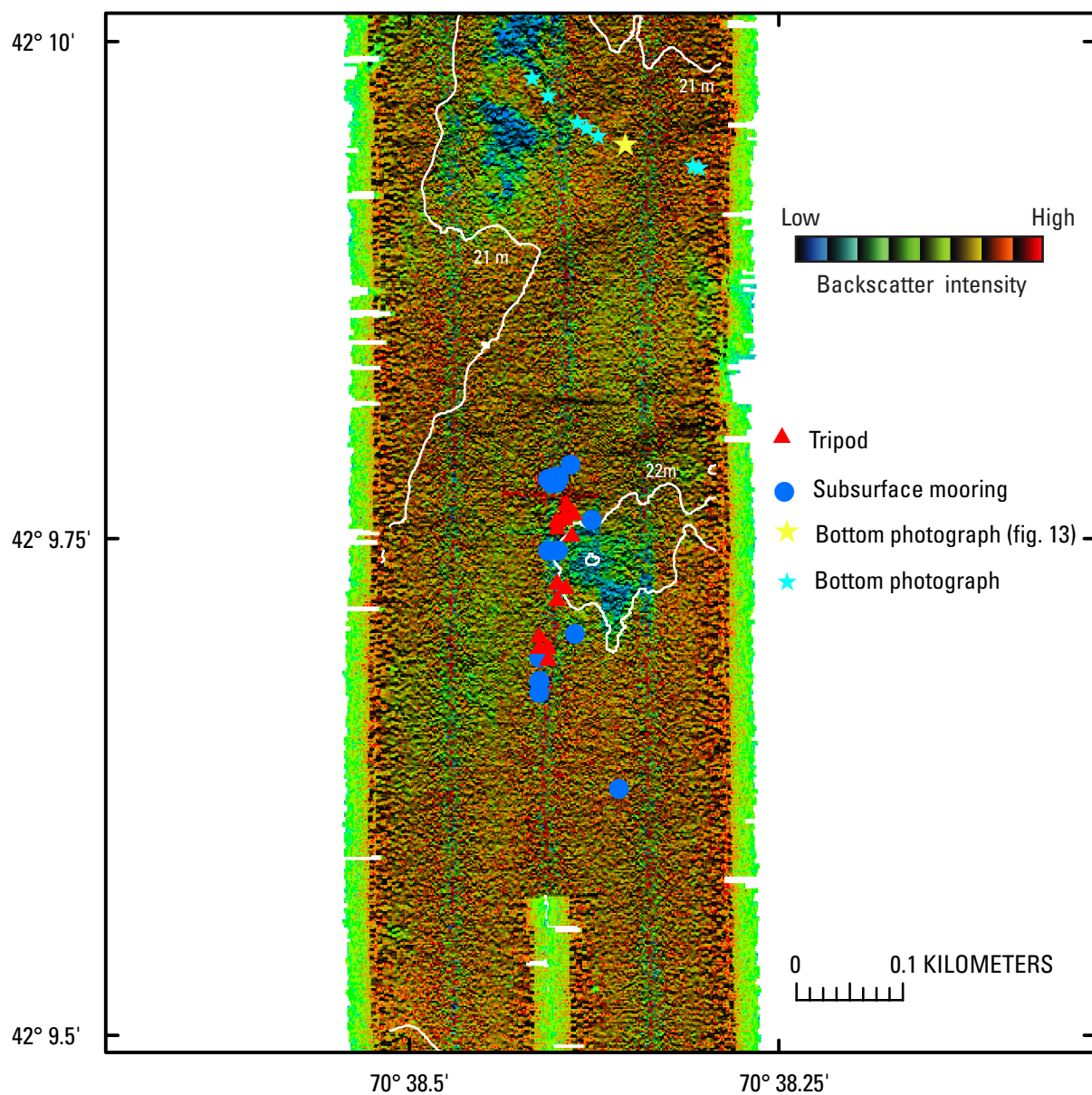


Figure 12B. Map of the sea floor of western Massachusetts Bay showing the location of the long-term subsurface and tripod moorings at site LT-B. The water depth at the mooring site is about 21 meters. The mooring locations are shown on a map of backscatter intensity. The multibeam survey was limited to a strip about 0.4 kilometers in east-west extent. The backscatter intensity is represented by a suite of eight colors ranging from blue, which represents low intensity, to red, which represents high intensity. Site B is located in a region of relatively high



Figure 13. The sea floor (station 5131, photograph 13100012, Gutierrez and others (2000)) about 0.3 kilometers to the north of site LT-B (see fig. 12B for location). Water depth is approximately 21 meters. The field of view is approximately 50 centimeters by 75 centimeters. The bright pink color is a calcareous algae that grows on the cobbles and boulders in water depths shallower than about 25 meters where sufficient light reaches the sea floor. The fish is a skate. See Gutierrez and others (2000) for additional photographs of the sea floor in western Massachusetts Bay.

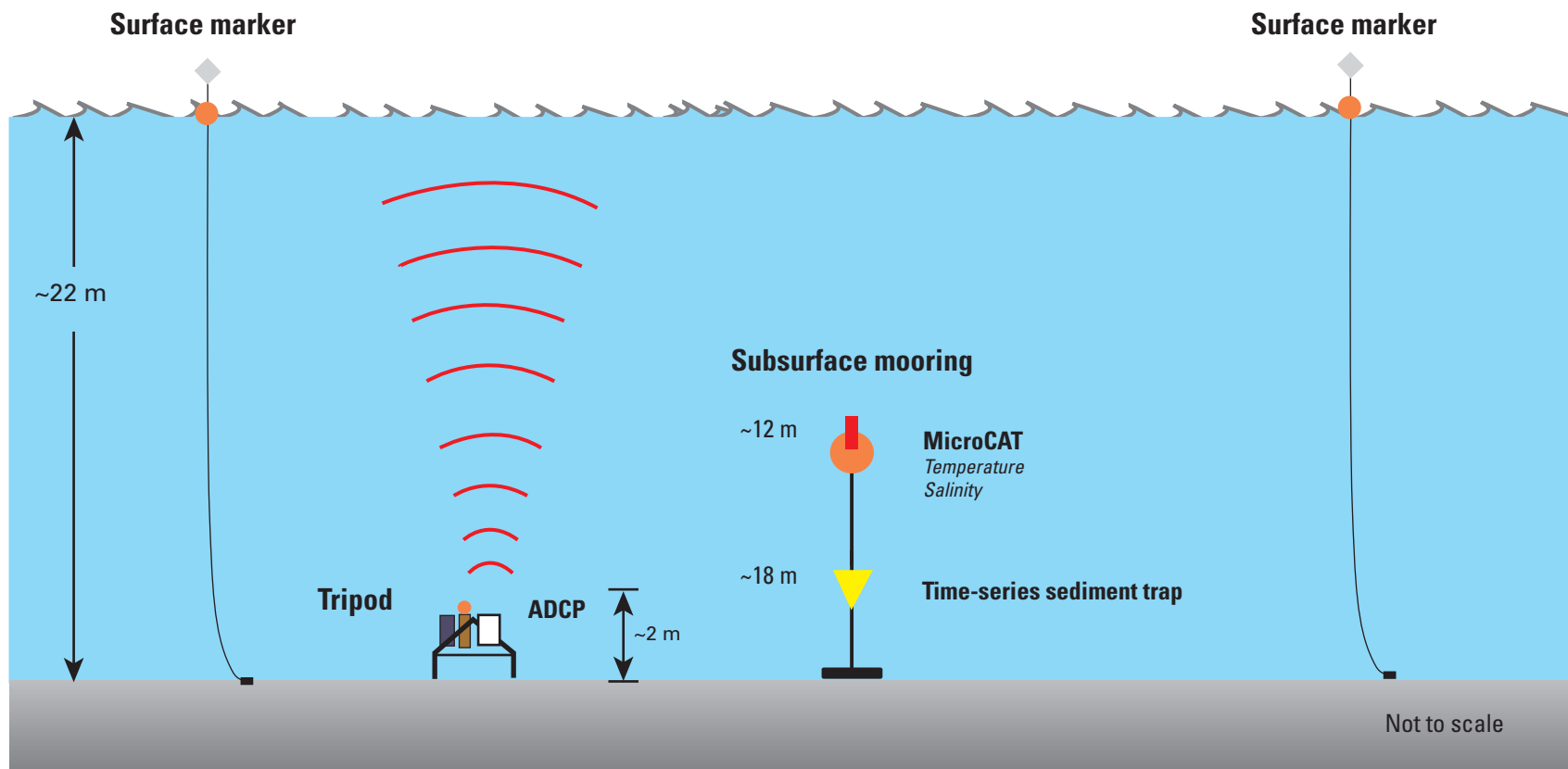


Figure 14A. Schematic diagram of moored instruments deployed at site LT-B in western Massachusetts Bay (figs. 1 and 12A) from 1997 to 2004. During this period, instruments were deployed on a subsurface mooring and on a bottom tripod. The acoustic Doppler current profiler (ADCP), mounted on the bottom tripod, obtains a profile of current throughout the water column in 2-meter bins. [m, meters; ~, about]

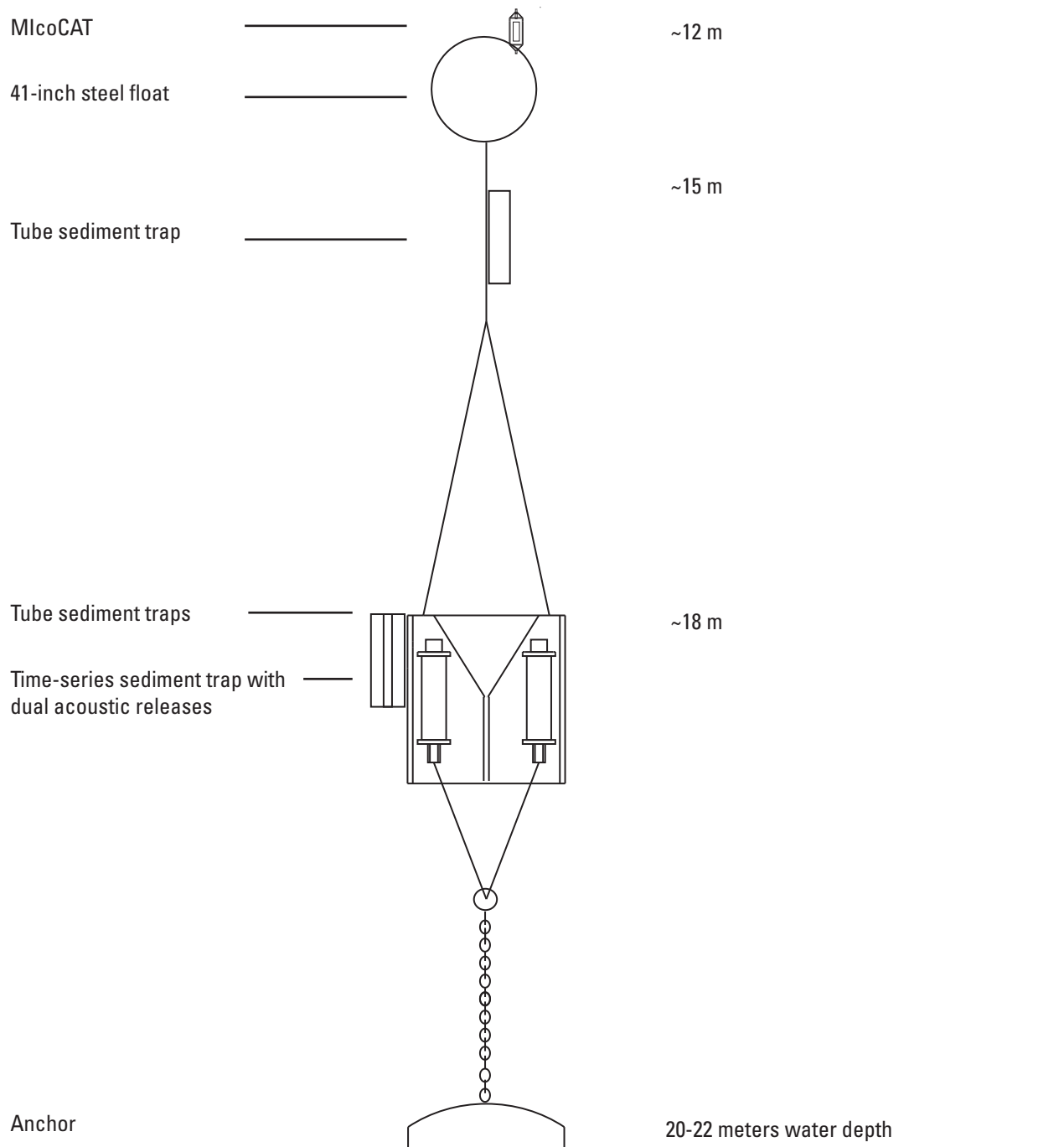


Figure 14B. Schematic diagram of the subsurface mooring deployed at site LT-B in western Massachusetts Bay from 1997 to 2004. The subsurface mooring supported the time-series sediment trap at about 18 meters (4.2 meters above bottom), tube traps at 4.2 and 7 meters above bottom and a MicroCAT at 12 meters (10 meters above bottom). Nominal water depth was 22 m. [m, meters; ~, about]

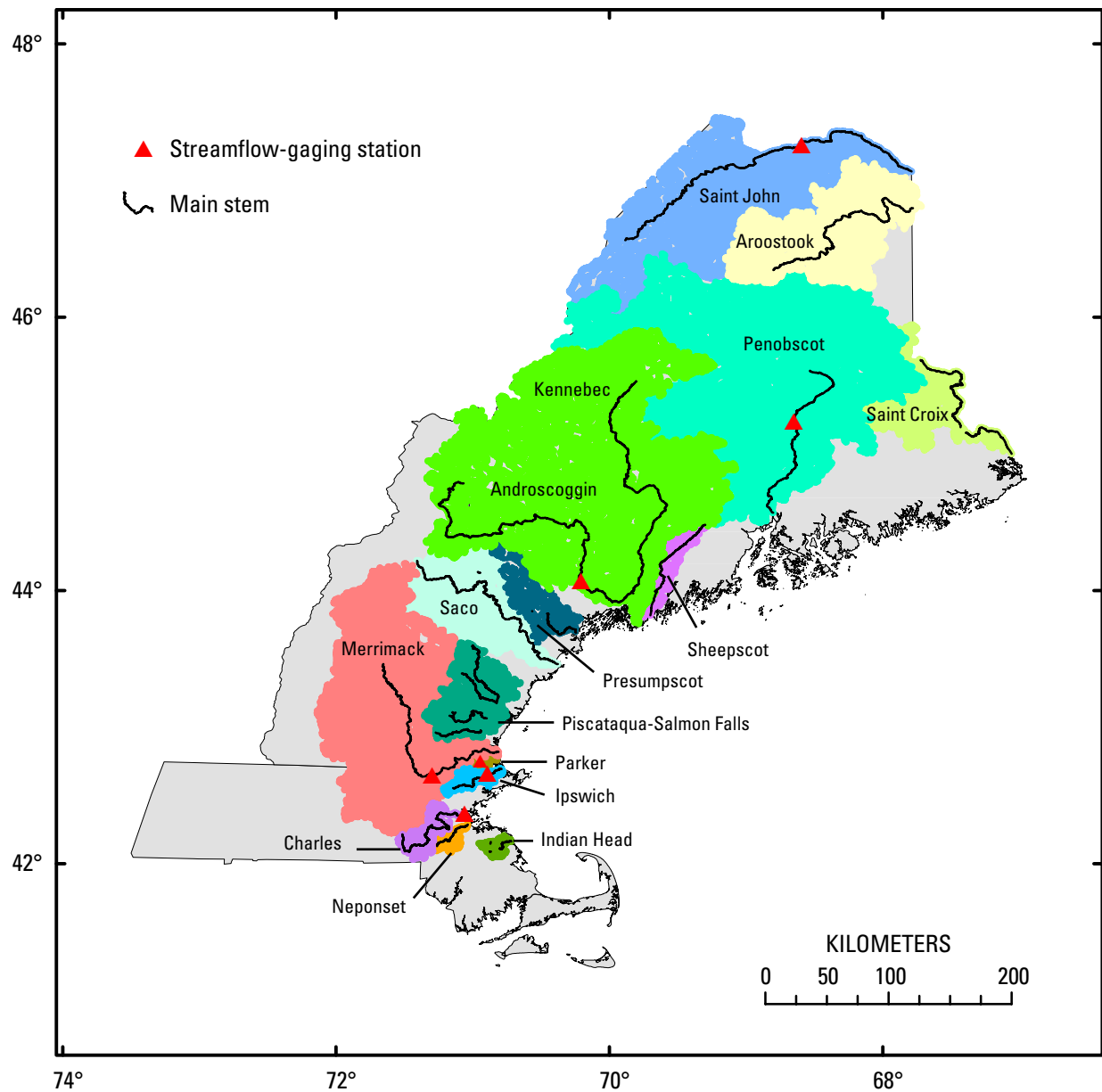


Figure 15. River basins in the western Gulf of Maine and locations of U.S. Geological Survey streamflow-gaging stations on Saint John, Penobscot, Androscoggin, Merrimack, Parker, Ipswich, and Charles Rivers. Most streamflow gages do not measure flow from the entire basin.

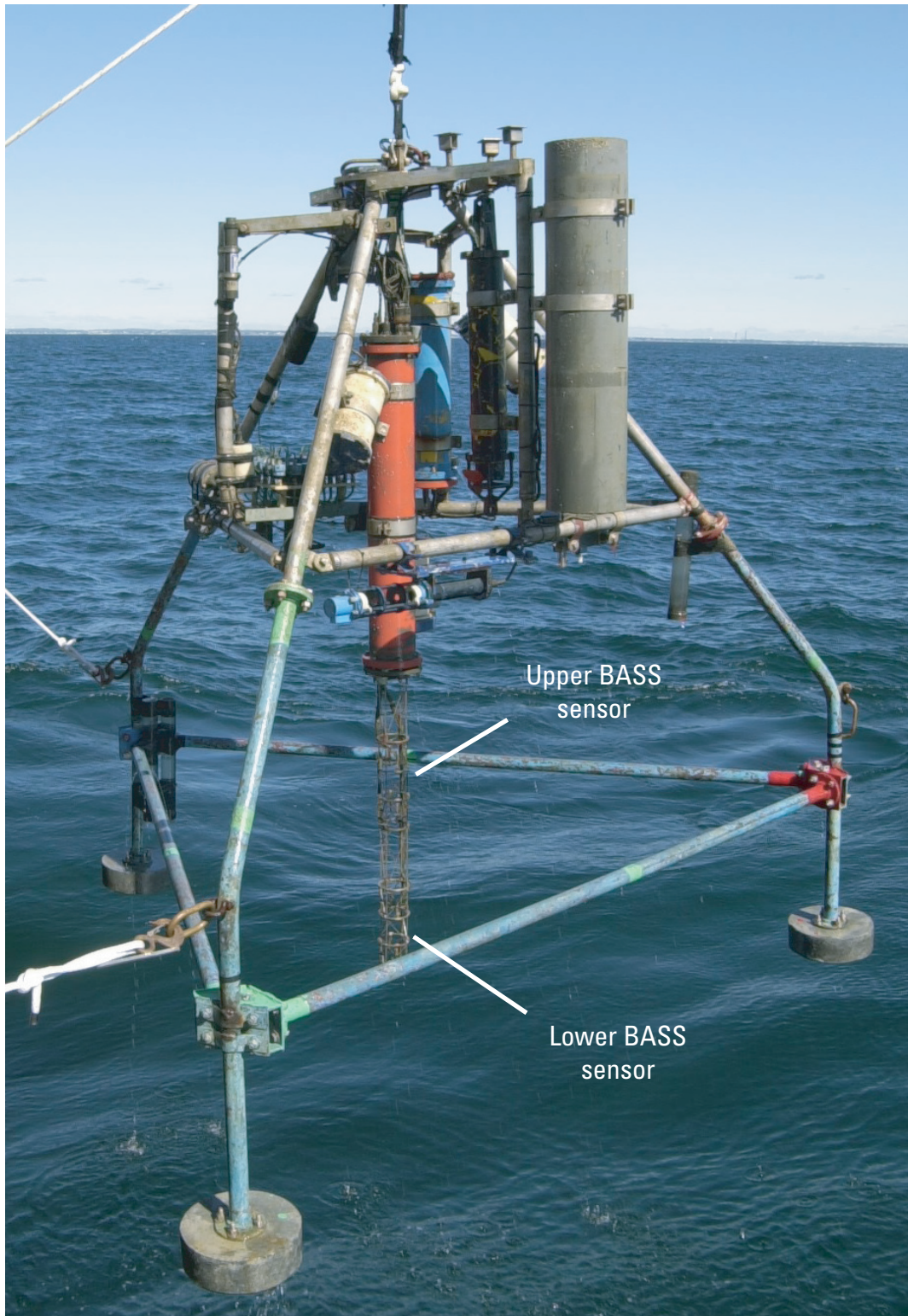


Figure 16A. Benthic Acoustic Stress Sensor (BASS) attached to a large tripod being recovered from site LT-A. The sensors measured current at two levels (nominally at 1 and 0.45 meters above bottom). Photograph by Dann Blackwood, U.S. Geological Survey.

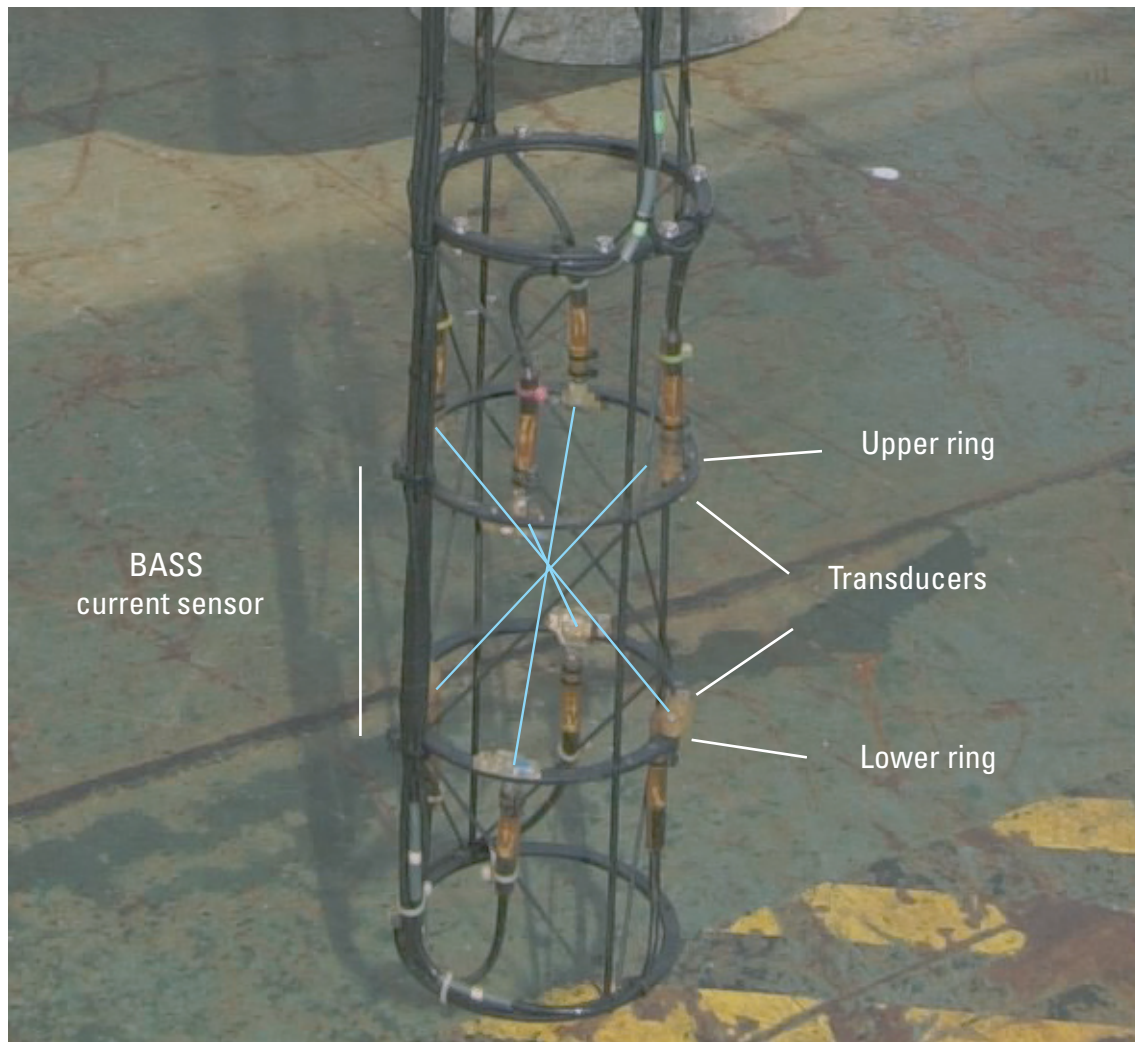


Figure 16B. BASS current sensor. Currents are measured by pairs of acoustic sensors mounted on two rings spaced 20 centimeters apart vertically. The light blue lines indicate the acoustic paths between the four pairs of transducers on the upper and lower ring. Photograph by Dann Blackwood, U.S. Geological Survey.

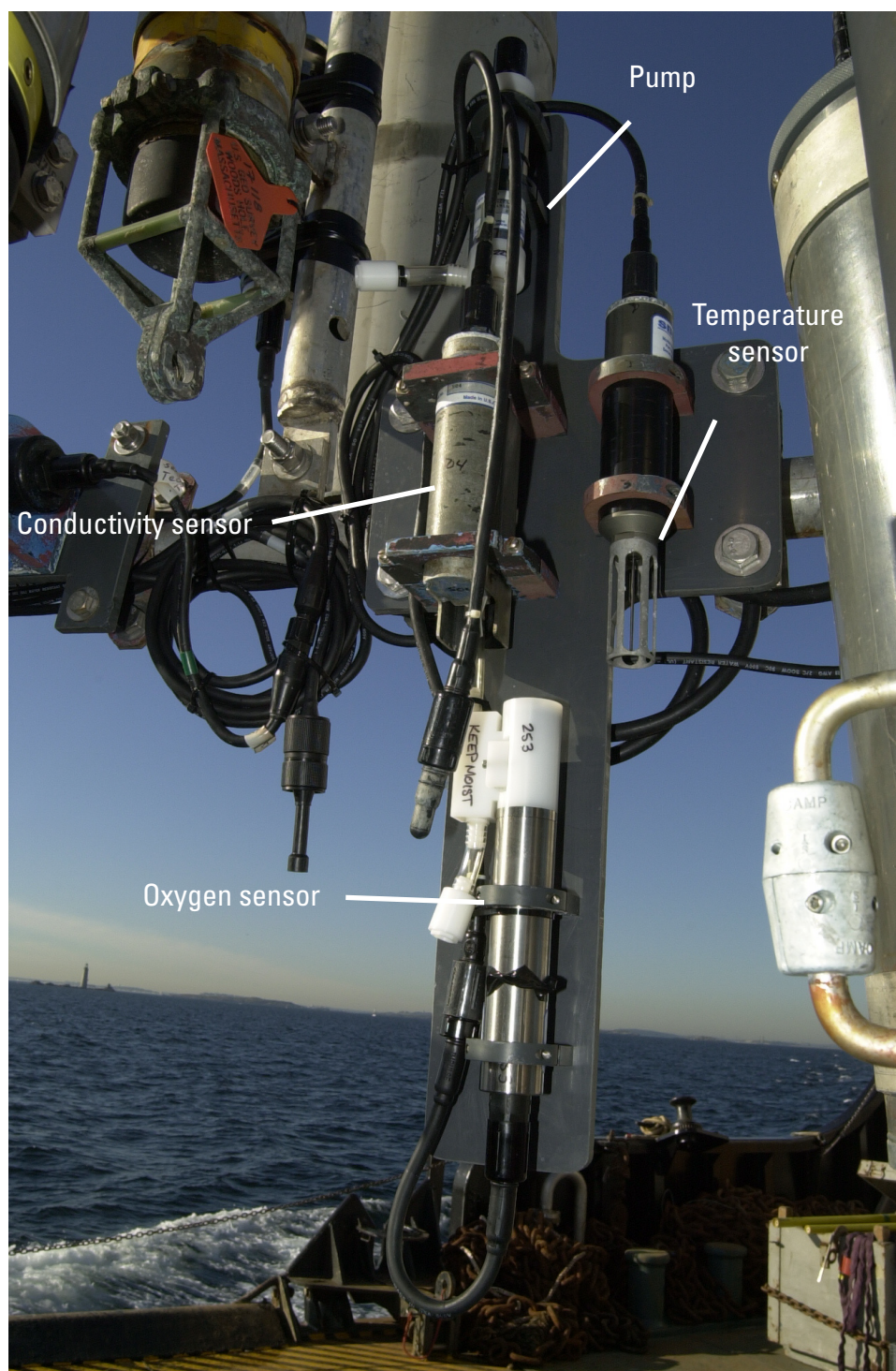


Figure 17. Sea-Bird oxygen, conductivity, and temperature sensors and pump mounted on tripod frame (shown in fig. 4A). Photograph by Dann Blackwood, U.S. Geological Survey.



Figure 18. Benthos 35-millimeter underwater camera mounted on tripod frame (shown in fig. 4A). Photograph by Dann Blackwood, U.S. Geological Survey.

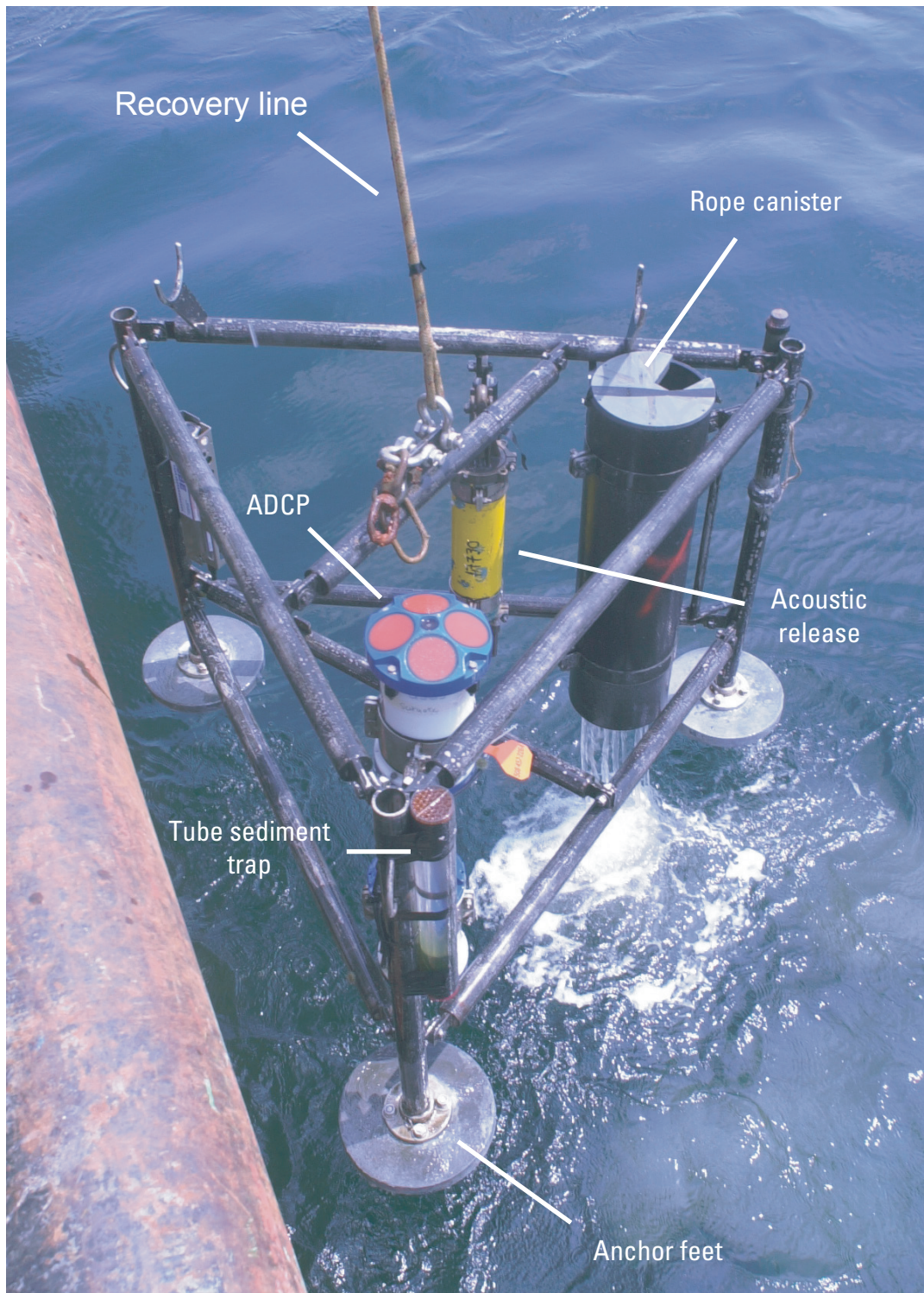


Figure 19. Acoustic Doppler current profiler (ADCP) mounted on a small tripod frame being recovered at site LT-B. The upward-looking ADCP, mounted in a corner of the frame, has two pairs of transducers that remotely measure currents throughout the water column. Photograph by Dann Blackwood, U.S. Geological Survey



Figure 20. Vector Measuring Current Meter (VMCM) being deployed at site LT-A. The VMCM uses two bidirectional propellers mounted at right angles to measure current. A SEACAT data logger, which measures temperature, conductivity, and light transmission, is bolted to the VMCM frame. Beginning in February 1998, the SEACAT was no longer attached to the VMCM and was deployed in a separate frame (see fig. 21). Photograph by Dann Blackwood, U.S. Geological Survey.

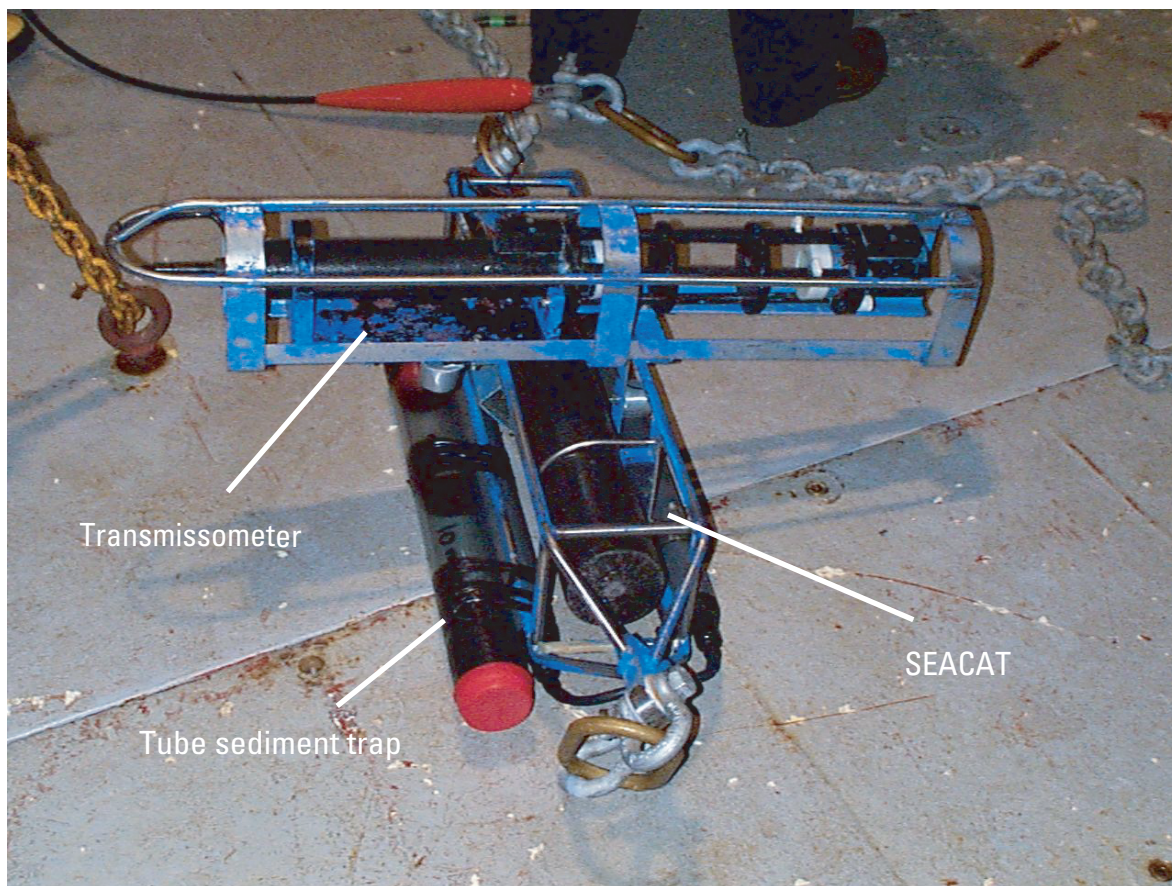


Figure 21. SEACAT data logger. The instrument measures temperature, conductivity, and light transmission. The SEACAT is mounted in a load cage to be deployed inline in the subsurface mooring at site LT-A. A transmissometer is mounted horizontally to the load cage and a tube sediment trap is taped to the cage (the red cap is removed at deployment). Photograph by Dann Blackwood, U.S. Geological Survey.



Figure 22. A MicroCAT mounted on the top of a 41-inch steel float. This mounting was used at site LT-A to measure temperature and salinity within about 5 meters of the sea surface. The inset shows a close-up of the MicroCAT installed in a protective bracket. Photograph by Dann Blackwood, U.S. Geological Survey.

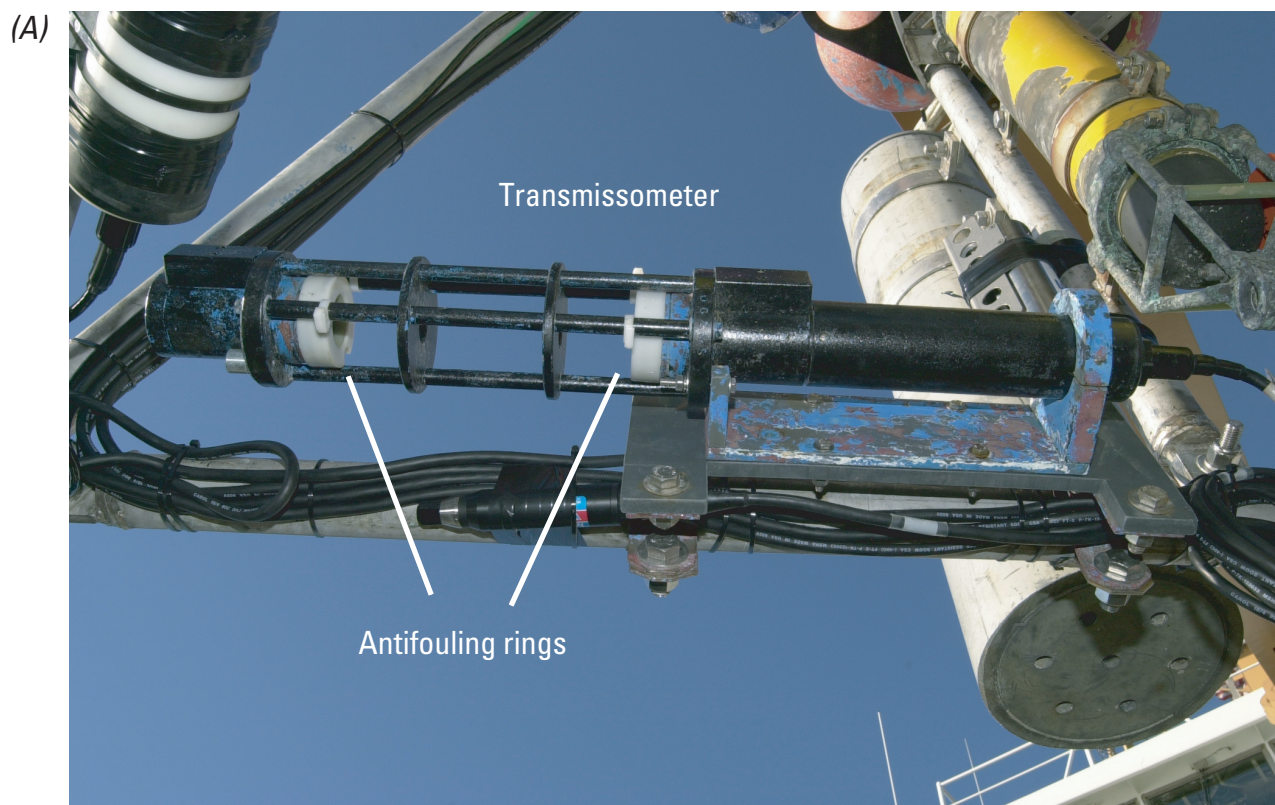


Figure 23. (A) A Sea-Tech 25-centimeter folded-path transmissometer mounted horizontally on the large tripod frame (see fig. 4A) and (B) a Delrin(TM) anti-fouling ring (white ring) mounted around the transmissometer window. Photographs by Dann Blackwood, U.S. Geological Survey.



Figure 24. Time-series sediment trap deployed at sites LT-A and LT-B. The yellow funnel (0.8-meter diameter) directs suspended material into one of 13 plastic jars (500-milliter capacity), which are sequentially moved under the funnel for a 9-day interval during a typical 4-month deployment. Photograph by Dann Blackwood, U.S. Geological Survey.

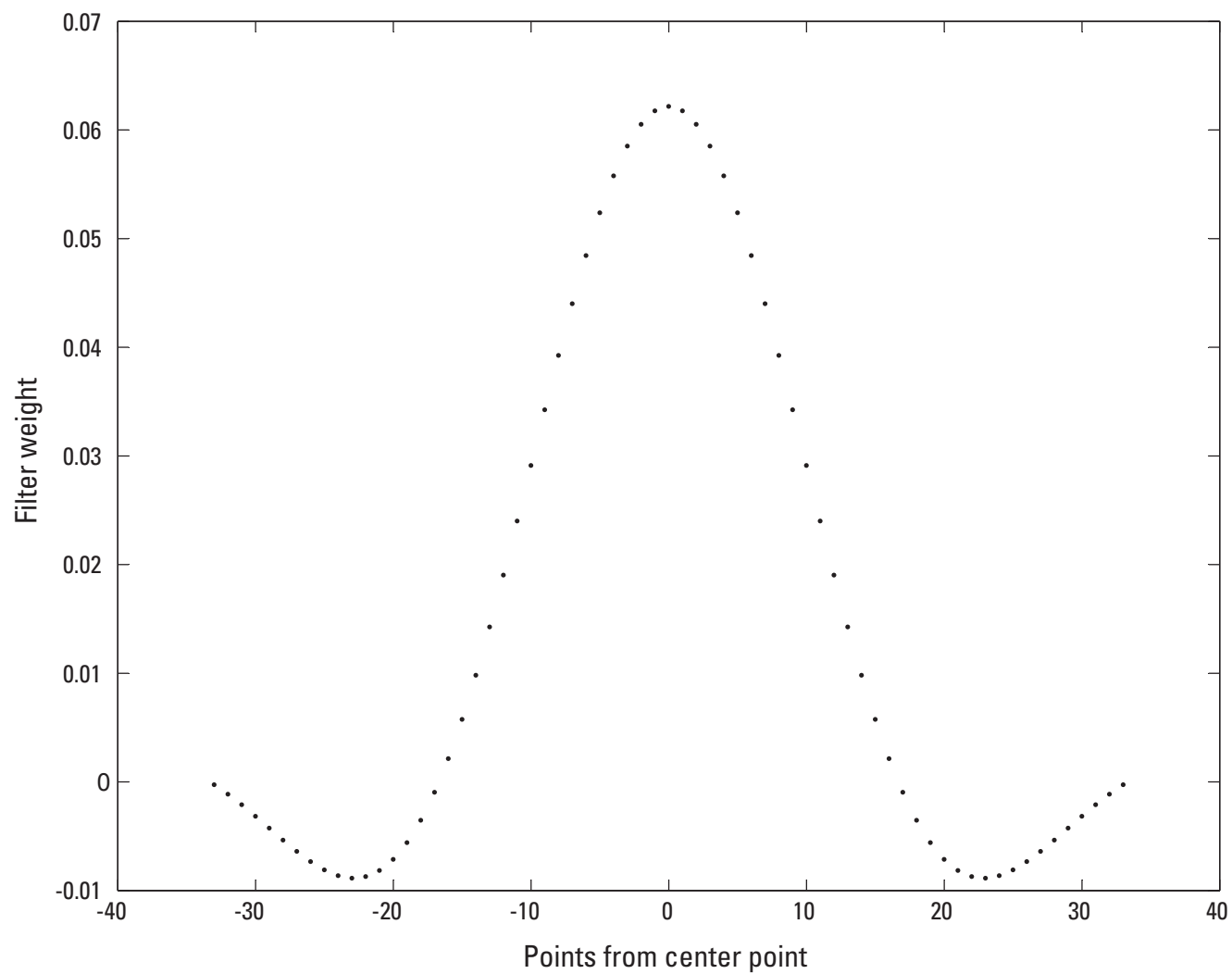


Figure 25. Filter weights applied to the time-series data in the low-pass filter PL33. The filter truncates 33 points from the beginning and end of each time series.

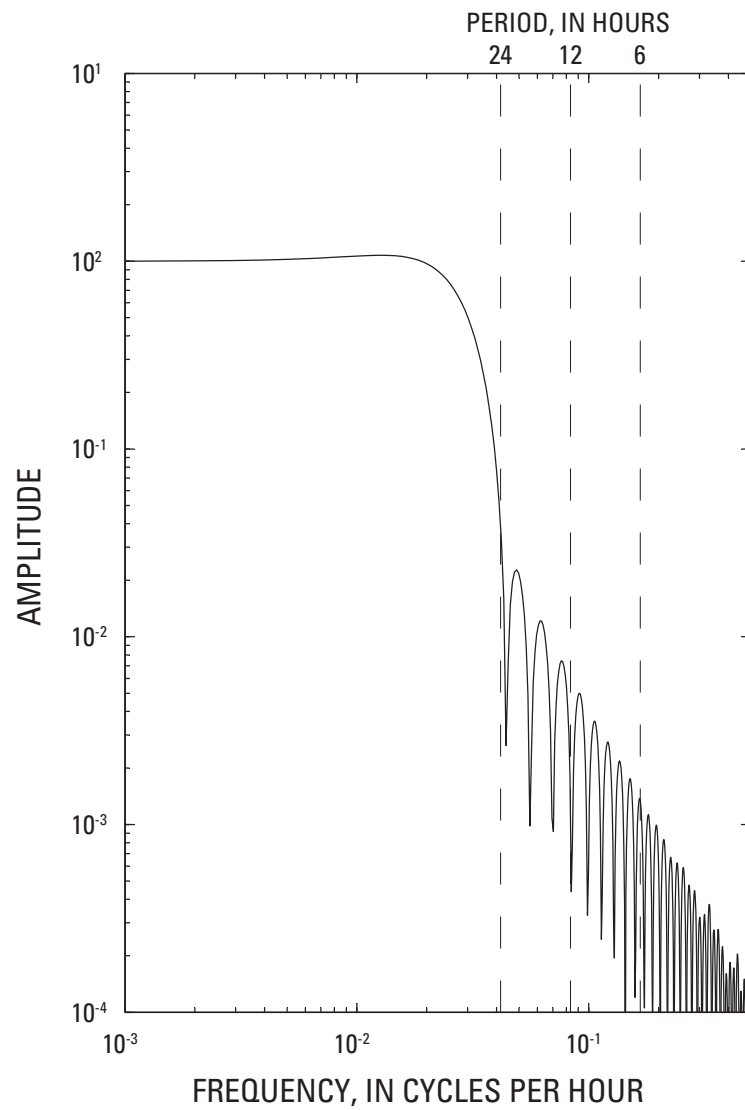


Figure 26. Amplitude transfer function for the low-pass filter PL33, showing the amplitude response as a function of frequency.

(A)



(B)



Figure 27. (A) Surface of a 41-inch subsurface float that was deployed at about 10 meters and (B) tripod recovery floats that were deployed about 3 meters above the bottom from September 1998 to February 1999. Both floats were deployed without anti-fouling paint. Extensive barnacles grew on the lower floats during this period, while only a thin layer of organic material grew on the upper float. The color of both floats when deployed was orange. Photographs by Dann Blackwood, U.S. Geological Survey.



Figure 28A. A Vector-Measuring Current Meter (VMCM) deployed on mooring 348 at about 22 meters (10 meters above bottom) from July to October 1990. The blue and white color is antifouling paint. Note the growth on the unpainted lower end cap of the instrument housing, and slight growth on the rotor hub. Photograph by Bradford Butman, U.S. Geological Survey

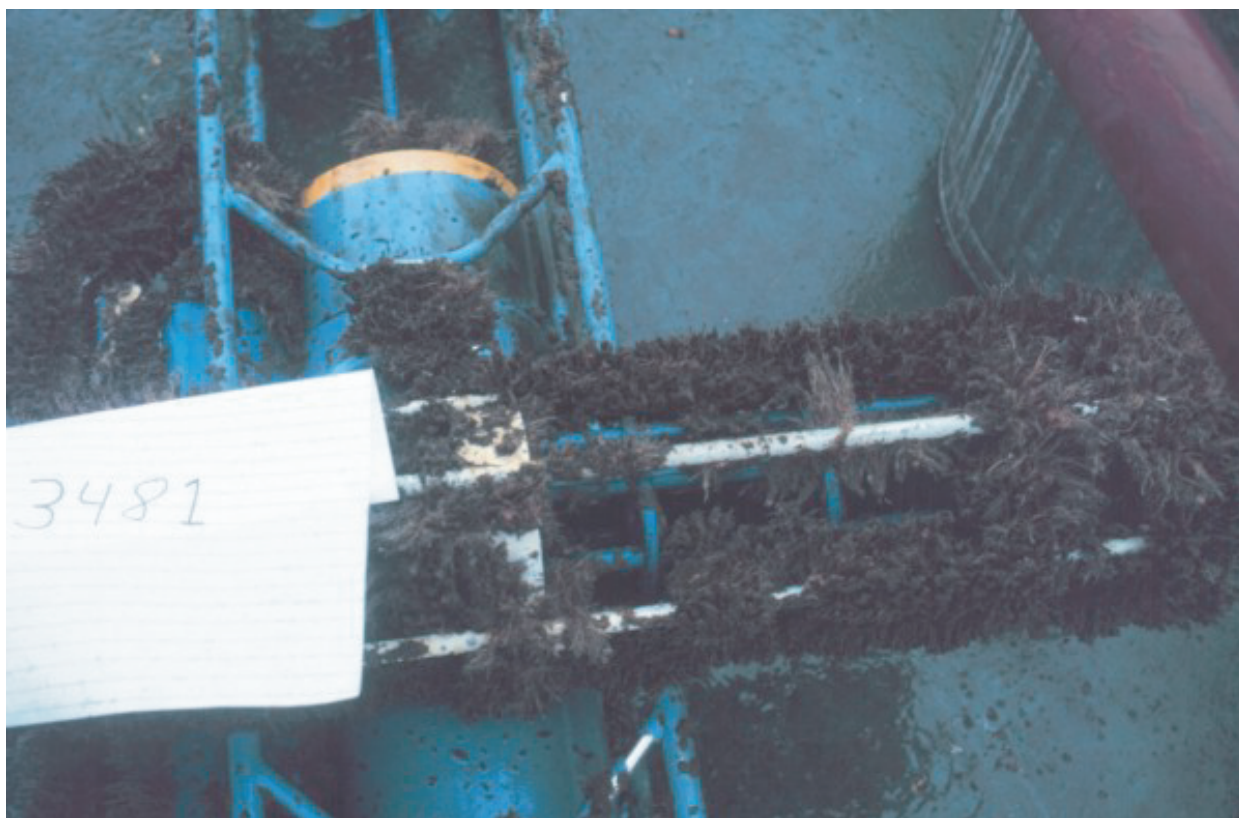


Figure 28B. A portion of the Vector-Measuring Current Meter (VMCM) (top of picture) and the transmissometer deployed at 5 meters from July to October 1990 on mooring 348. Both instruments were heavily fouled despite the antifouling paint. Photograph by Bradford Butman, U.S. Geological Survey.

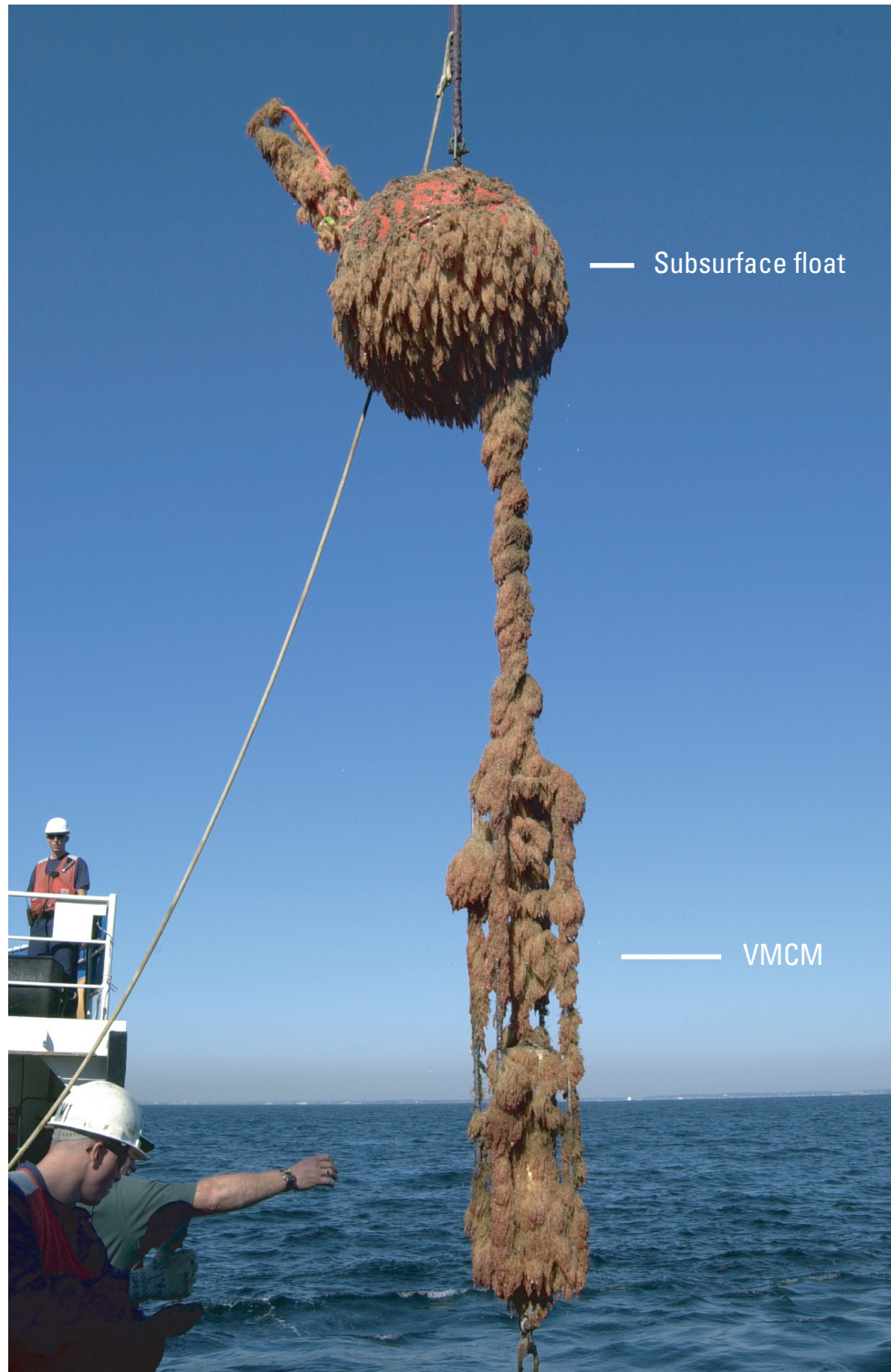


Figure 28C. A heavily fouled subsurface float and Vector-Measuring Current Meter (VMCM) deployed at about 5 and 8 meters below the surface, respectively, at site LT-A from March to September 2003 on mooring 707. This experimental near-surface deployment illustrates the biological fouling of instrumentation deployed in the warm surface waters in the summer months. See figure 20 for a photograph of an unfouled VMCM. Photograph by Dann Blackwood, U.S. Geological Survey.



Figure 29. The lens of the bottom camera (left) and battery case (right) deployed from May to September 1999 on mooring 569 at site LT-A. Photograph by Dann Blackwood, U.S. Geological Survey.

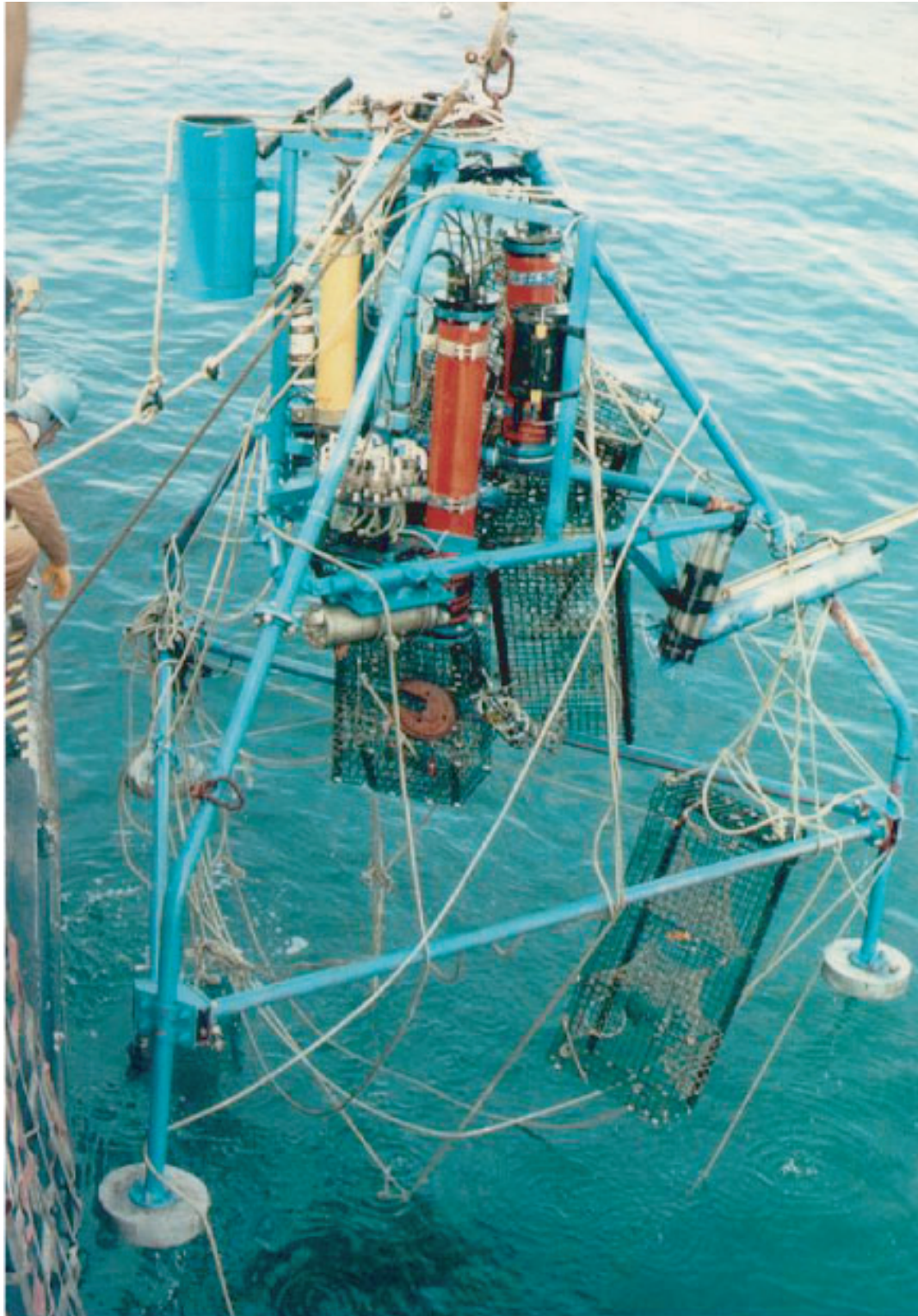


Figure 30. A tripod tangled with lobster gear recovered from site LT-A in February 1993 (mooring 407). This recovery in followed the intense December 1992 storm; it is hypothesized that drifting gear became entangled on the tripod. Entanglements with fishing gear were very rare. Photograph by Bradford Butman, U.S. Geological Survey.



Figure 31. The top of a time-series sediment trap with exceptional bio-fouling (estimated 95-percent coverage) after a summer deployment (May 2000 to September 2000) at site LT-B. The line across the baffle is a section of the three-part nylon rope mooring bridle. A nylon screen (1 centimeter grid) and a plastic honeycomb baffle are placed at the open end of the trap funnel in order to reduce turbulence and to prevent large animals from entering the trap. The trap opening is 0.8 meters in diameter.