NAVY UNDERWATER CONSTRUCTION

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NAVY UNDERWATER CONSTRUCTION

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ABSTRACT

Compared with their terrestrial counterparts underwater construction methods and equipment are very much underdeveloped. To improve the success record and to decrease excessive costs, it is essential that each contributor to the field attempt to openly describe and draw conclusions from his experience. The community may then be stimulated to objectively compare and generalize these conclusions as a basis for substantial improvement in the techniques and equipment for underwater construction. It is toward this goal that this paper is presented.

INTRODUCTION

The U. S. Naval Facilities Engineering Command (NAVFAC) and the Navy Seabees have completed successfully three major underwater construction projects within the past two years. These projects were undertaken with very short lead times varying from three to five months. Schedule and financial constraints forced innovations believed to be of importance to the general field of underwater construction. While these innovations were successful, substantial development under less constraining conditions will be required to achieve their full potential.

Within the limits of time, I will describe the underwater construction accomplished in support of Project Tektite I, the Azores Fixed Acoustic Range (Array Test Installation), the Azores Fixed Acoustic Range (Inshore Cable). Conclusions concerning comparative construction methods and equipment will be drawn for each.

PROJECT TEKTITE I

NAVFAC engineered, planned, and performed the underwater construction and recovery operations in support of Project Tektite I. These construction operations were performed for the Office of Naval Research within the originally scheduled one month period in late winter 1969 off St. John, Virgin Islands. Elements of the Navy's Amphibious and Mobile Construction Battalions were used for underwater construction operations. Figure I depicts the extensive facilities required to support Project Tektite I. Only those operations which involved unique underwater construction methods will be described in detail.

Figure II shows the General Electric Habitat, aboard a NAVFAC Ammi pontoon, as it is moved from the well deck of a Landing Ship Dock into Lameshure Bay. Pontoon transport resulted from the requirement for an on-site "dry, integrated systems test" of the habitat and support systems prior to installation. The cost of a floating crane to lift the 160-ton habitat into the sea would have been prohibitive. To overcome this problem, an underwater elevator was developed by NAVFAC using the transport pontoon as the major element. Figure III depicts some of the basic elements of this system. Cylindrical piles were threaded through the pontoon spud wells and driven into the sediment bottom with a pattern precision of $\pm$ 1 inch by means of the template shown. Flood ports had been placed in the bottom surface of each pontoon compartment and capped. Vent lines were provided through the top surface of each compartment. The vent lines were extended to a control manifold on an adjacent construction support pontoon by means of flexible hose. Submergence of the habitat launch pontoon was accomplished using this flooding system. Stability of the launch platform was maintained after submergence of its short wing walls, through the use of winches. A manual winch of several tons capacity was mounted atop each pile and connected to a corner of the launch pontoon by means of wire rope and a single snatch block. The wire rope terminated at a five-ton tensiometer mounted on the winch frame.

Figure IV shows the habitat mid-way into launch operations. The operations sequence consisted of (1) venting symmetrical launch pontoon compartments until about 2,000 pounds average force was observed on each tensiometer, (2) simultaneously paying out each winch rope until tensiometers approached zero, and (3) checking depth markers to ascertain a horizontal pontoon deck. This sequence, which minimized free surface augmentation of the winch loads, was repeated until the habitat floated free. With favorable seas, the 160-ton habitat was launched with a total winch capacity less than 10% of the habitat weight. The habitat was then towed to its emplacement site. Here Seabees divers winched it to the 49 foot, prepared bottom utilizing clump anchors and eight 3,000 pound chainfalls to overcome the habitat's 5,000 pound positive buoyancy. Once on the bottom, approximately 20 tons of pig iron ballast were moved down from the diving platform by means of a chute and stacked by divers into the habitat's ballast trays.

To minimize on-site work, NAVFAC and the Seabees had pre-assembled in the continental United States all habitat support systems on a smaller Ammi pontoon. The support systems consisted of a water supply, high and low pressure gas supplies, a power generation system, and a habitat monitoring and control van. As shown in Figure V, the habitat support platform was jacked-out of the water on cylindrical piles legs which rested on the igneous rock bottom. The bottom varied in depth from three to ten feet. Jack-out was required to (1) prevent significant disturbing, machinery noises from entering the water, (2) provide personnel comfort, and (3) eliminate mooring line maintenance problems. The pontoon lift system had been developed for driven piles. In this application there the piles rested on an uneven rock bottom and the load was 100 tons, it was limited in elevation capability to about three feet.

Large, armored power and signal cables and pneumatic and water hoses were layed by conventional techniques to unite the habitat with its support systems, and complete the underwater construction operations.

CONCLUSIONS

The "underwater elevator" concept possesses inherent geometric advantages over the "over-the-side" methods for launching large, heavy objects which possess low in-water weights. This concept minimizes platform stability and winch capacity requirements. It provides for more rapid and safer load detachment and deployment and is substantially more economical than the "floating crane" especially for remote employment.

AZORES FIXED ACOUSTIC RANGE (ARRAY TEST INSTALLATION)

NAVFAC and the Seabees assembled, installed, and performed post-test recovery of a massive acoustic communications antennae array for the Naval Underwater Sound Laboratory. The construction operations took place in the Navy's AUTEC Range during March of 1970. The array was emplaced at a water depth of 1300 feet and cabled to a control van as shown in Figure VI.

Due to the large floating draft of the array structure, it had to be launched at sea. The high cost of a suitable, floating crane led to an innovation which utilized (1) a standard NAVFAC Ammi pontoon converted to a submersible platform, (2) standard amphibious pontoon modules to form stabilizing fixed wing walls, and (3) standard salvage pontoons to form elevatable, wing walls for stability during the later stage of submergence. Figure VII shows the acoustic array which has been assembled by the Seabees on the unique launch platform.

The array launch platform was propelled to the launch site where two single quad, armored cables were mechanically and electrically spliced into the array. The deep sea cables had been previously layed and buoyed off at the surface through use of the primary underwater construction platform which is shown in Figure VIII with the array launch platform. The construction platform was a large Ammi pontoon with one outboard propulsion unit mounted on each corner. A pneumatic, throttle control mechanism integrated these propulsion units into a "joy stick" controlled, dynamic positioning system for cable laying operations. The constant tension cable laying winch shown forward of the crane was additionally utilized to lower the array. The construction platform was equipped with a standard, 10-ton crane for handling heavy buoys and other lift functions. An air compressor and manifold were used to control array launch and launch platform recovery operations. A fathometer and Decca navigation equipment were provided to back-up the visible, linear range for cable laying, and array emplacement operations.

A single taut line moor had been placed in 1800 feet of water about 400 fet seaward of the array emplantment site. To prepare for array launch, the single line shown in Figure VIII was secured to the taut moor and winched in. This extended the array cable catenary and effectively constrained the position of the array overcoming the need for station keeping. The construction platform was then separated from the launch platform by paying out the breast and spring lines connecting the two platforms. The launch platform flood system was similar to the one used to launch the Tektite I habitat.

Figure IX shows the array at an advanced stage in launching. Between sequential launch platform flooding events, divers used manual winches to lower the launch platform from the salvage pontoons at the surface. The salvage pontoons constrained the launch platform to a horizontal position as verified by use of the depth rods located at each corner of the launch platform. The array was lowered until only one foot of the syntactic foam center column remained above water. This provided an upward force on the lines which secured the array to the launch platform. With the array anchor clump secured to the launch platform deck and connected to the array by a long pendant, the constraining lines were cut. The array rose rapidly from the launch platform under its own positive buoyancy. It was pulled away from the launch platform by the lateral force of the extended array cables. These two motions were intentionally executed to prevent swell induced impact between the sensitive array and the array support towers of the launch platform. Swells had built to about three feet at the time of launch.

The braided polypropylene lowering line from the constant tension winch located on the construction platform (Figure X) was attached to the array structure. The launch platform was brought back to the surface from its 43 foot depth. The array anchor clump was then lowered from the launch pontoon until the array accepted its full weight. Successive deflation of the two salvage pontoons attached to the array brought the array to a position 50 feet below the fairlead on the construction platform and transferred the array weight to the lowering line. This technique was used to prevent the maximum dynamic loads at resonance from being imposed on the lowering line. After diver removal of the salvage pontoons, the lowering operation was initiated. As the array was lowered, the construction platform was winched toward the taut moor. Using this method, the array was emplaced on the seafloor midway between two sea cliffs which were separated by about 300 feet. The positively buoyant lowering line was cut and buoyed off at the surface for later use in a successful recovery effort.

CONCLUSIONS

The "underwater elevator" concept can be extended to accomplish open sea launching. It should be developed to provide a more reliable, economic method for launching massive objects which possess low in-water weights.

Simple, economic taut moors can be effectively utilized in certain deep ocean construction operations to minimize or eliminate dependence upon precise position control and dynamic positioning systems.

AZORES FIXED ACOUSTIC RANGE (INSHORE CABLE)

NAVFAC and the Seabees installed four large, double armored electrical and coaxial cables through the surf zone to a laboratory on Santa Maria, Azores Island during the three summer months of 1970. The cables had to be stablized and protected against the damaging effects of a maximum 40 foot winter surf. The cable ends were to be brought ashore in an isolated bay to which there was no vehicle access and up a 500 foot slope which terminated in a cliff. The seafloor consisted of basalt with deep, wide, vertical walled ravines running transverse to the cable path. Techniques and certain equipment developed by

NAVELEX (Project CAESAR) were utilized most effectively. One NAVFAC innovation, developed in response to climatic conditions, cut the total time to complete the project by a factor of two and the specific function by a factor of fifteen. This innovation will be described.

The underwater construction operations consisted of (1) breaking down the steep sides of the underwater ravines by use of explosives, (2) laying armored inshore cables utilizing the Italian Cable Ship, SALERNUM, and the British Cable Ship, BULLFINCH, as cable sources, (3) application of heavy pipe armor to each cable from the shore out to a distance of 1500 feet, and (4) pinning each pipe armored cable to the rock bottom at specified points along the 1500 foot path.

Removal of steep slopes along the cable path was accomplished by the use of dynamite and surface placed, plastic explosives and hose charges. Hand held and crawler track driven drills were used for producing dynamite holes. Figure XI shows a detonation of 5,000 pounds of C-4 plastic explosives to prepare a portion of the cable path.

Laying of the first two cables was accomplished with a system approximately as shown in Figure XII. Figure XIII shows a portion of the range upon which the cable ship was positioned to ensure deposition of the cable along the prepared path. It shows the grapnel rope leader (used to pull the cable ashore) as it passes through the sheaves. The sheaves were utilized to protect the cable from sharp bends at points where direction changes were necessary. Stoppers used to secure the cable, to the concrete deadman are also shown. Figure XIV shows the cable with floats applied being hauled ashore from the cable ship. A landing craft is being used to hold the sea and wind caused catenary out of the cable. Divers then cut the floats to deposit the cable on the seafloor along the prepared path.

The accepted commercial technique for applying the heavy, split pipe armor (shown in Figure XV) to the cable is to lower the three foot mating sections to the seafloor. Divers apply and bolt it on section by section. The estimated application time using this method was one month per cable for a work force of twenty divers. An innovative technique was substituted for the commercial practice. Split pipe was installed on shore in 30 foot lengths, towed along the cable by the motorized causeway as shown in Figure XV and connected to the previously pulled section. The process was repeated until 1500 feet of pipe had been applied to each of the first two cables. This operation required two weeks for each cable thereby cutting the installation time by a factor of two. This technique could not be used on the latter two cables since their diameters approached the inside diameter of the split pipe.

A second innovation was prepared in time for laying the third and fourth cables. In this technique, a standard amphibious causeway section was placed in a four point moor about 600 feet off shore and just outside the prevailing surf zone. The cable was pulled from the cable ship over the causeway where about 75 feet of split pipe was applied after each movement of the cable. Figure XVI shows the Seabees applying the split pipe to a length of cable. Pneumatic tools for assembly were supplied by a compressor aboard the causeway. The causeway carried sufficient pipe for one cable, a crude brake for securing the cable to the causeway during pipe application, and a pneumatic winch to aid in forcing the armored length overboard without straining the moor. Each time a length was completed, adequate floats were applied and the length was moved off the causeway as shown in figure XVII. Figure XVIII displays the 600 foot armored length after floats had been cut and the length had been deposited on the seafloor. At this point, the cable ship began laying the remaining two miles of cable to sea. The next day the causeway section was used to under-run the cable and apply split pipe along the remaining 900 feet. By this method, 1500 feet of protective pipe was applied to each of the remaining two cables in a two day period for each. This method reduced by a factor of 15 the time required by accepted practices. Because of increasing weather interruption beginning in September, this one innovation is estimated to have reduced the total project time by a minimum factor of two.

As an additional safeguard against the weather, holes were drilled in the basalt bottom on each side of the split pipe on ten foot centers where blast-produced rubble did not interfere. "Hair pins" fabricated from large diameter reinforcing bar were cemented into these holes with hydraulic cement. With this final operation, NAVFAC and the Seabees successfully completed what was probably the most difficult inshore cable project ever accomplished. Fortunately weather conditions were favorable throughout the operation.

CONCLUSIONS

An economic, shallow draft pontoon capable of being rapidly jacked to avoid developing surf is required for use in (1) drilling for underwater blasting and (2) surface application of split pipe during cable laying operations in moderate surf. The jacking devices must be capable of operating on rough rock seafloor.

Economic methods for underwater excavation blasting must be developed which minimize diver operations and provide for efficient, short range removal of the rubble produced.

An improved design to accommodate rapid application of protective armor is needed.

SUMMARY

It is rare in terrestrial construction to discover methods which improve the efficiency and lower the cost of major elements of a project by a factor of two. Perhaps this is because people have been at terrestrial construction for centuries. Recent NAVFAC-Seabee experience in u erwater construction indicates that at least for some tasks an order magnitude improvement in efficiency is achieveable. In the interests of national security, the time appears ripe for the "military-industrial-university complex" to team up with the best talent it can muster, and produce the breakthroughs, and major strides to improve the success record and decrease the excessive cost of ocean construction operations.

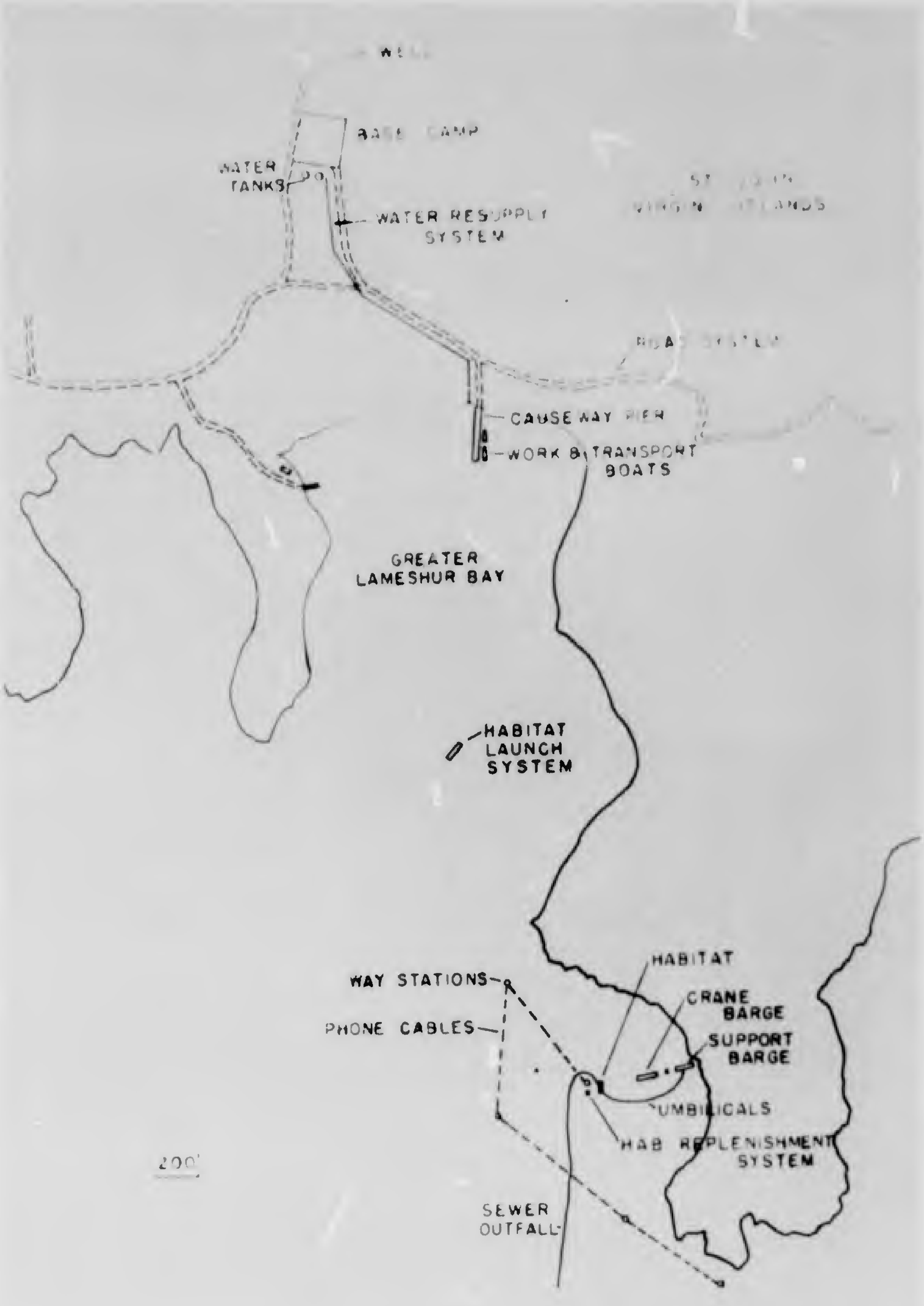

FIGURE I: PROJECT TEKTITE I FACILITIES

FIGURE II: HABITAT ON LAUNCH PLATFORM

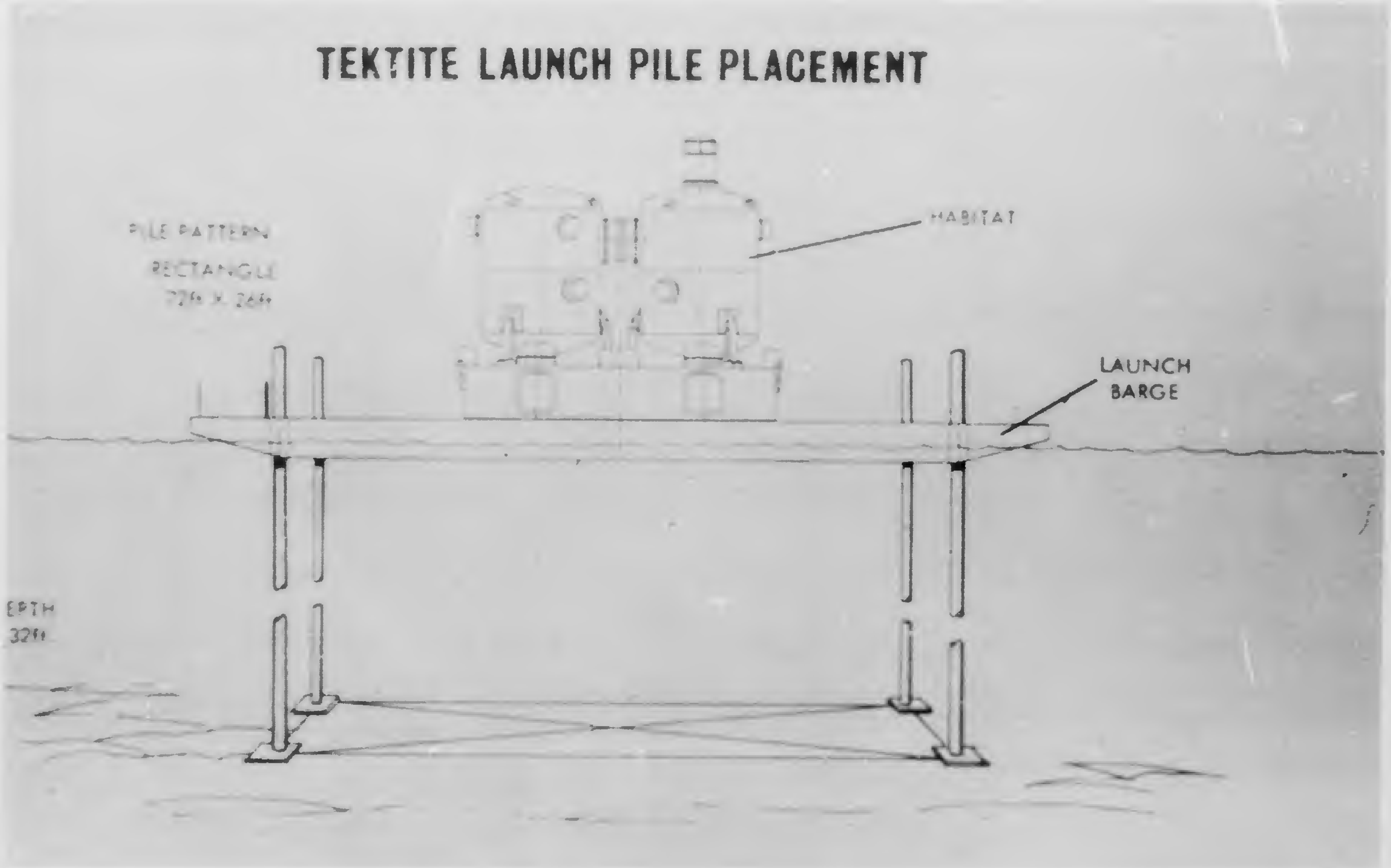

FIGURE III: LAUNCH PLATFORM PILE PLACEMENT

FIGURE IV: HABITAT LAUNCH SYSTEM

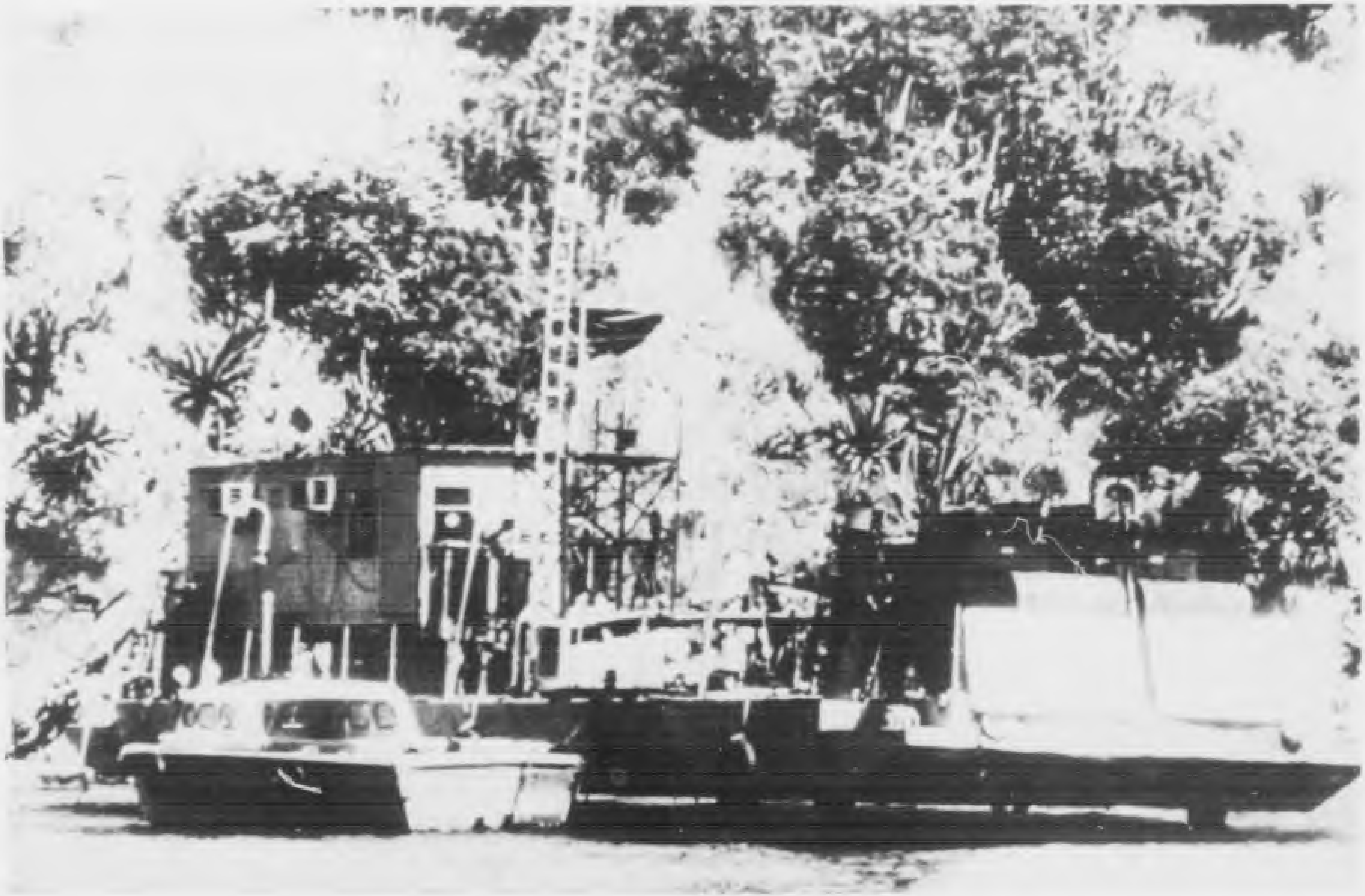

FIGURE V: HABITAT SUPPORT SYSTEM

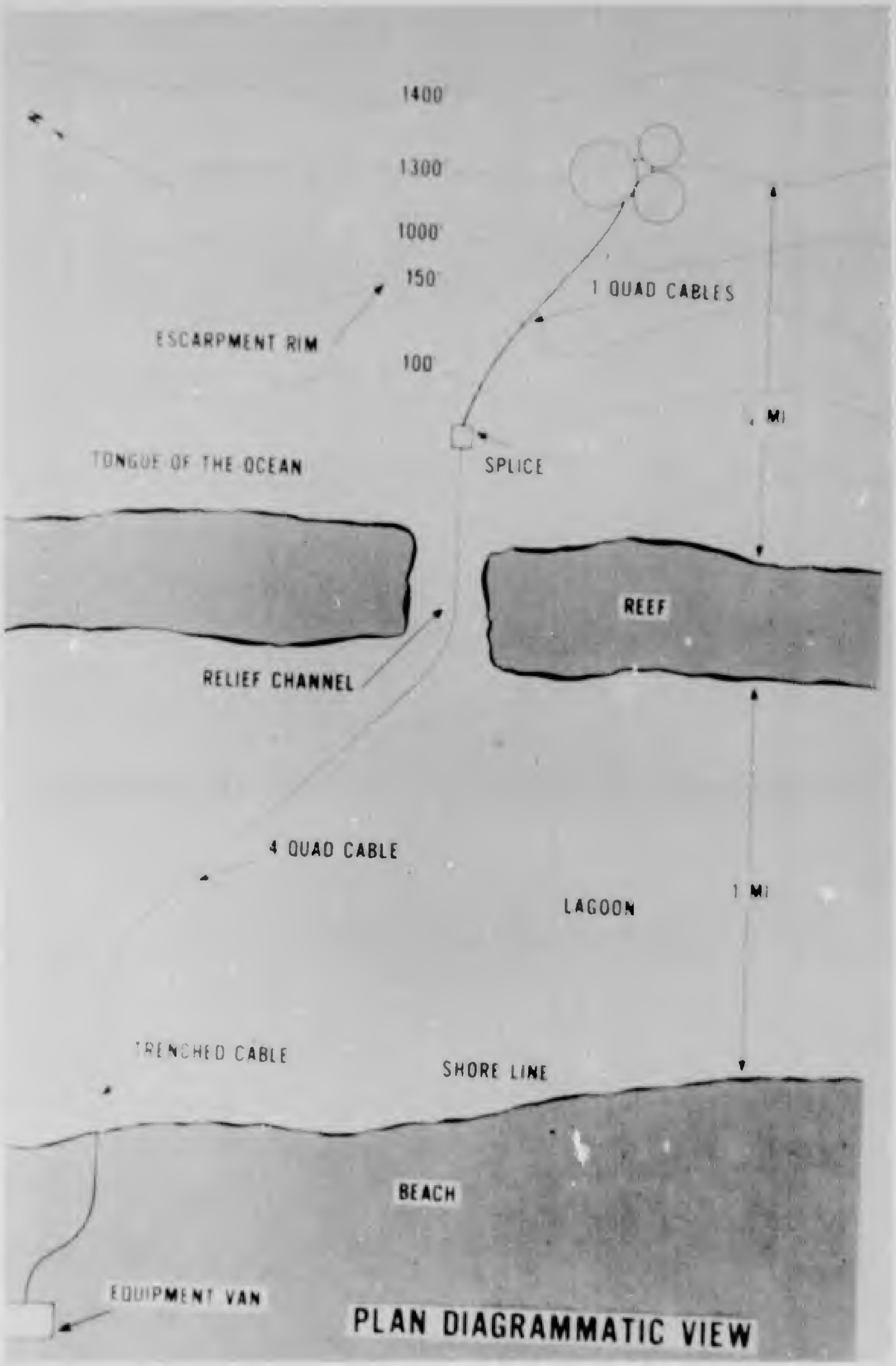

FIGURE VI: AZORES FIXED ACOUSTIC RANGE (AUTEC TEST INSTALLATION)

FIGURE VII: AFAR ARRAY ON LAUNCH PLATFORM

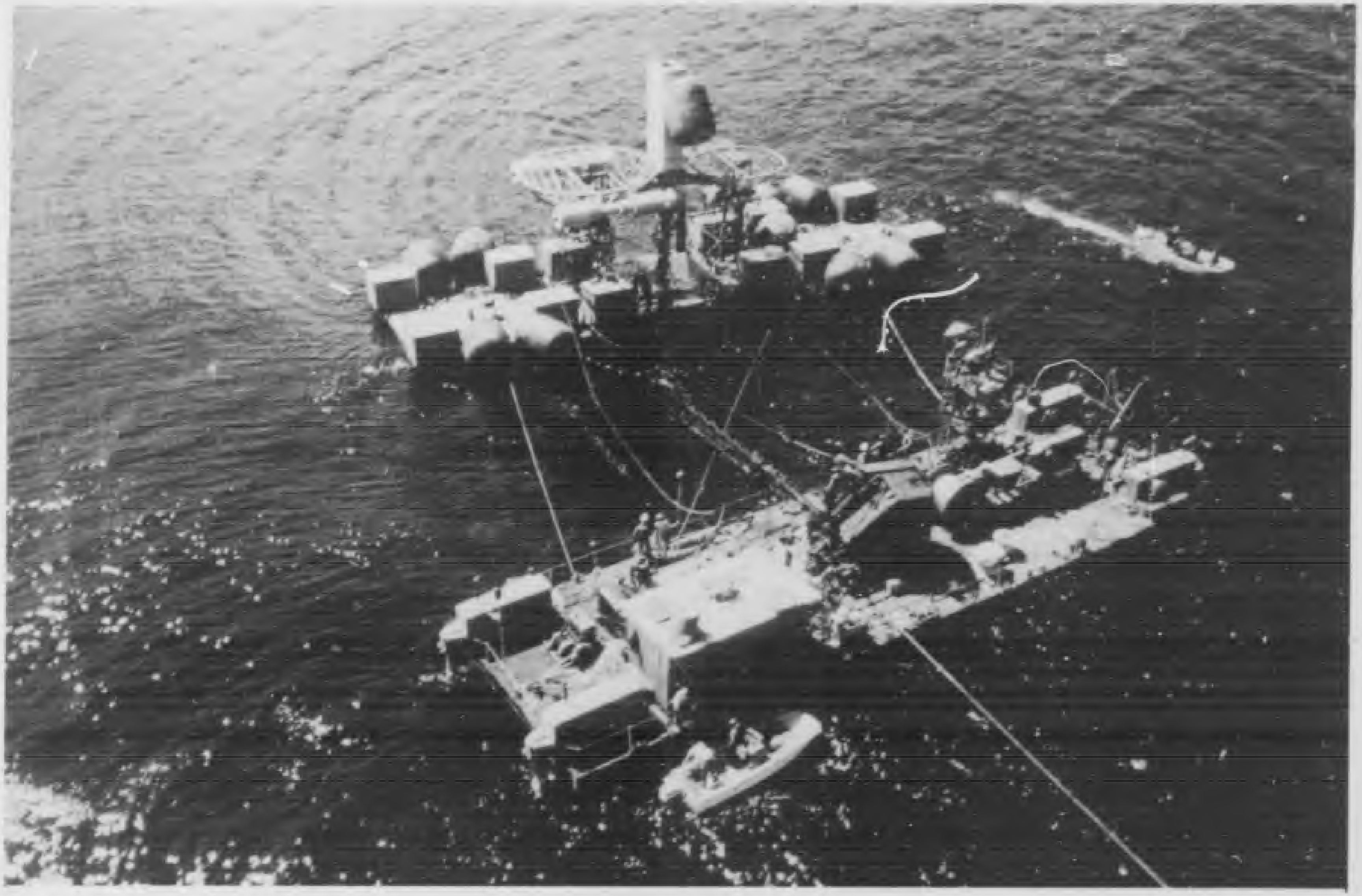

FIGURE VIII: UNDERWATER CONSTRUCTION PLATFORM PREPARED FOR LAUNCH OPERATIONS

FIGURE IX: AFAR ARRAY DURING LAUNCH

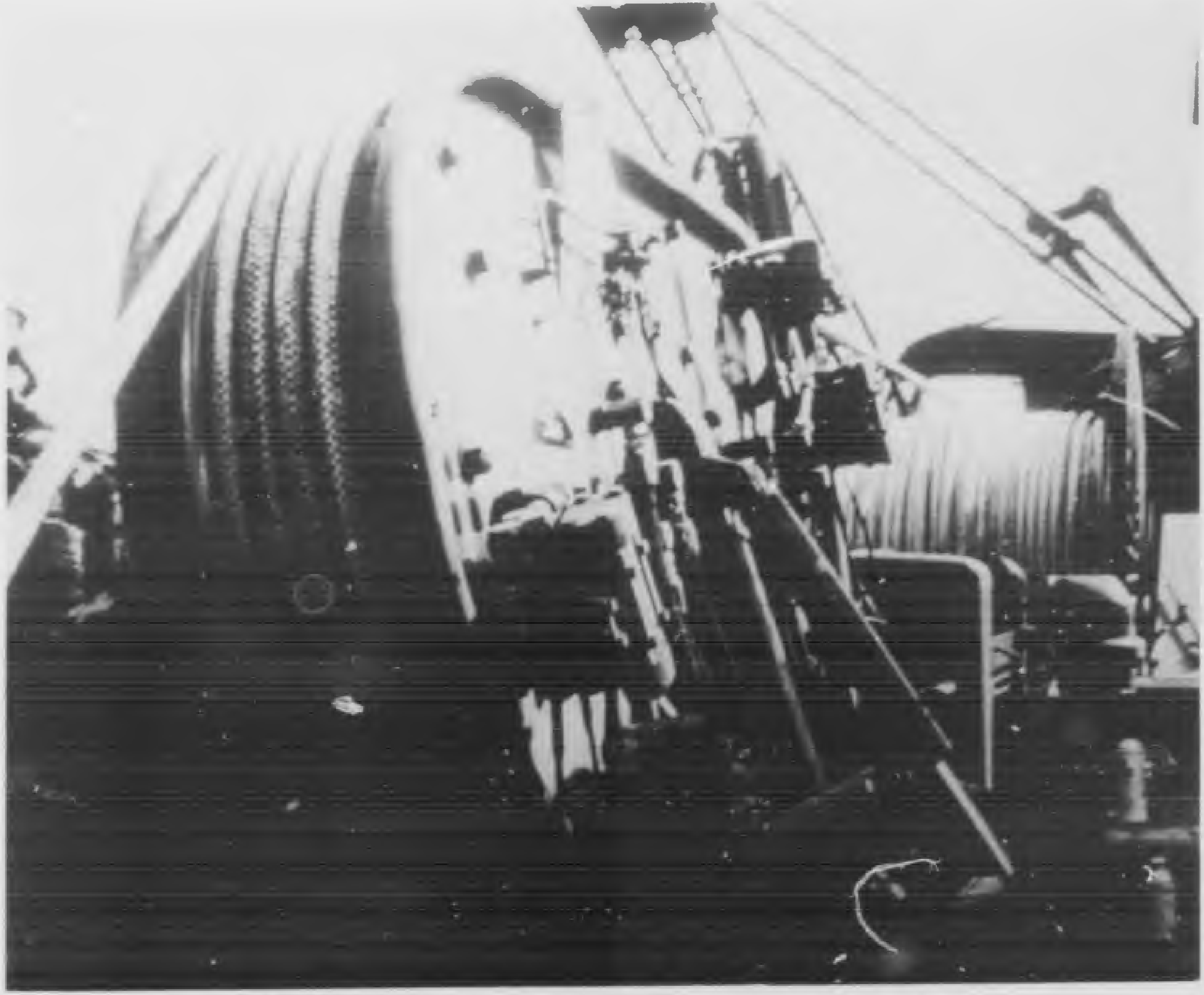

FIGURE X: CABLE LAYER USED AS CONSTANT TENSION LOWERING WINCH

FIGURE XI: REMOVAL OF UNDERWATER ESCARPMENT ALONG CABLE PATH

PLAN VIEW OF CABLE LAYING OPERATION

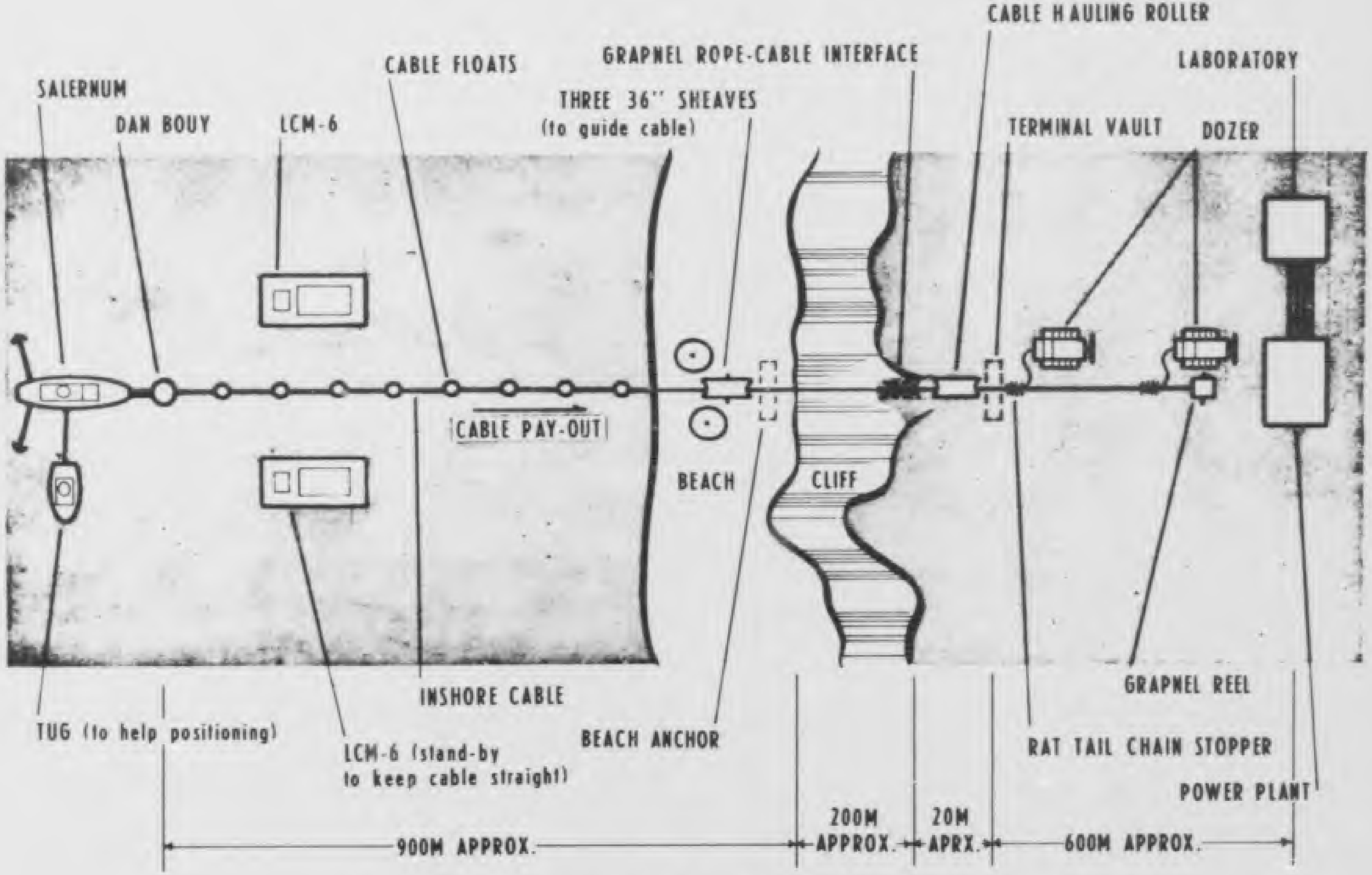

FIGURE XII: INSHORE CABLE EMPLACEMENT SYSTEM

FIGURE XIII: CABLE INSTALLATION AIDS

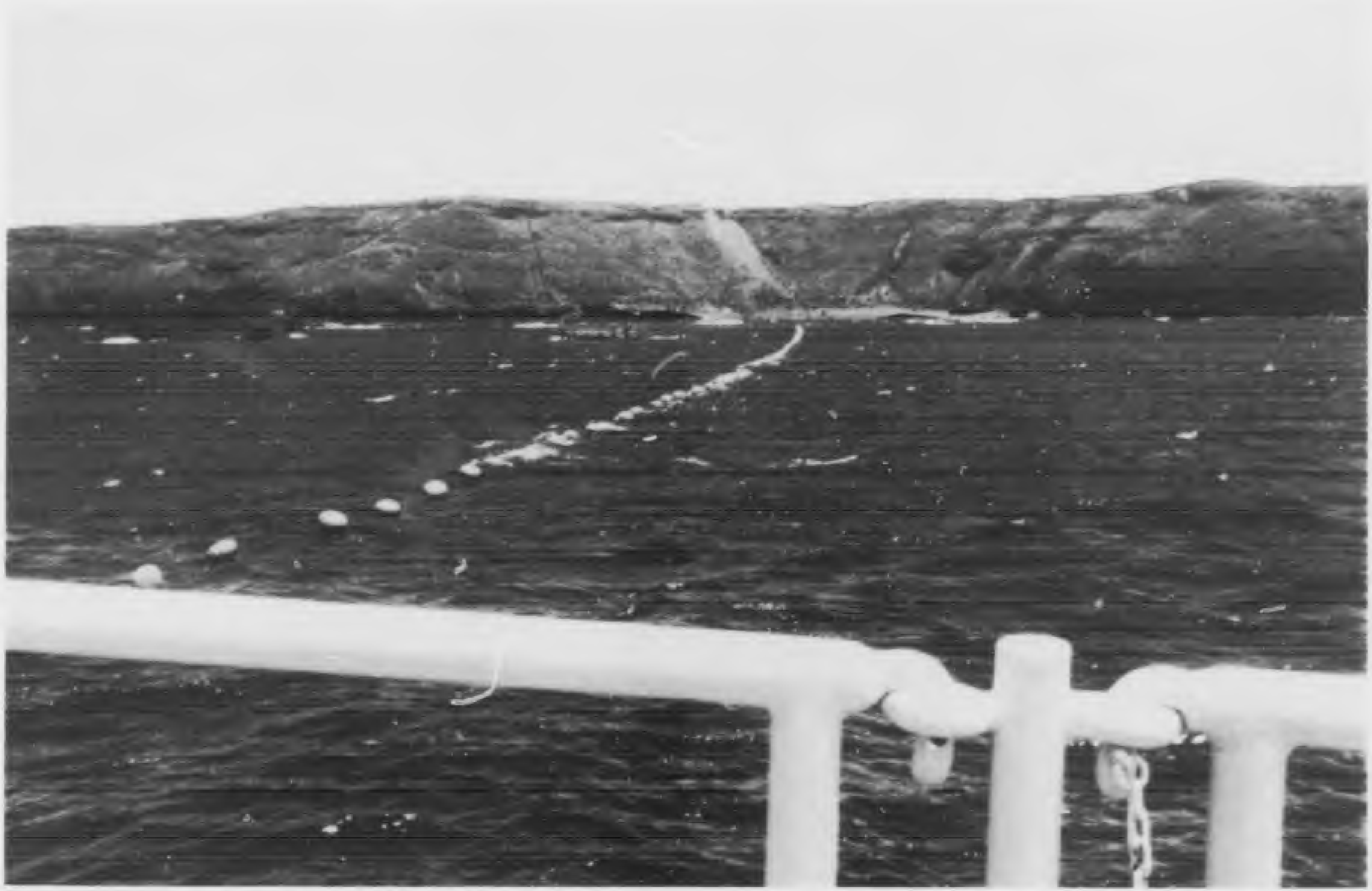

FIGURE XIV: CABLE FLOATING TECHNIQUE

FIGURE XV: IMPROVED TECHNIQUE FOR APPLYING CABLE PROTECTORS

FIGURE XVI: ADVANCED METHOD FOR APPLYING CABLE PROTECTORS

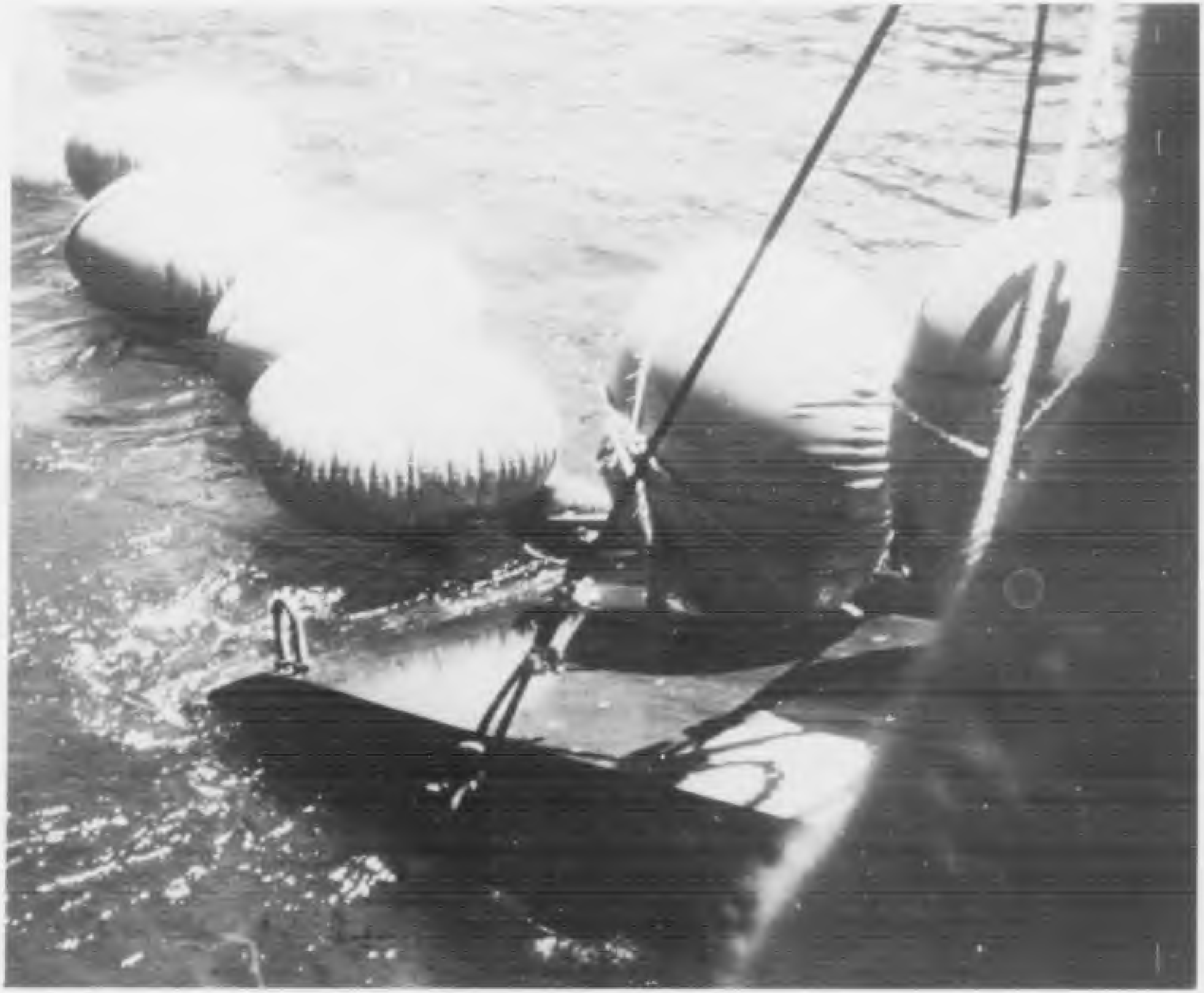

FIGURE XVII: FLOATING PROTECTED CABLE OVERBOARD

FIGURE XVIII: PROTECTED SECTION ON SEAFLOOR