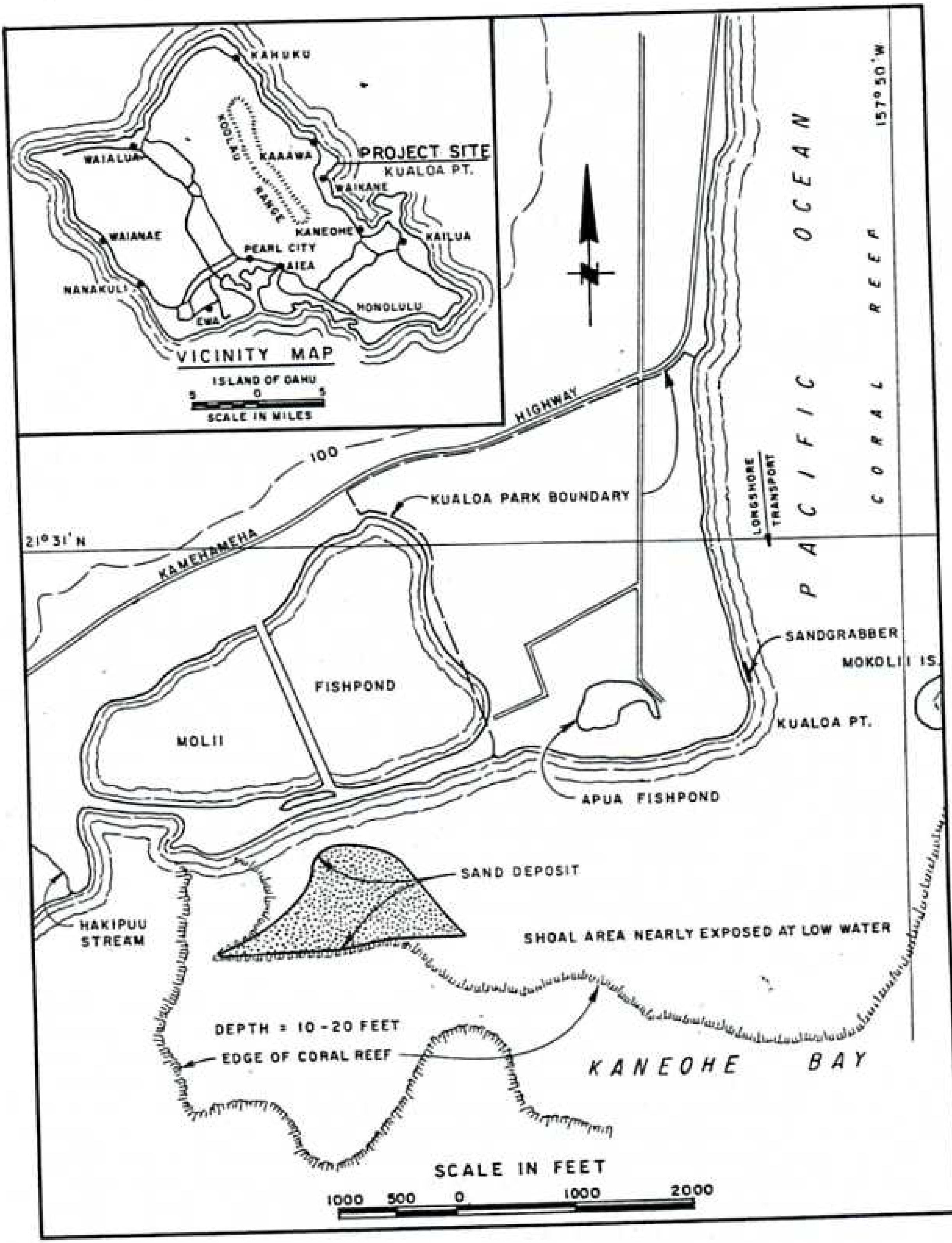


Figure 2-597. Location map of Kualoa, Hawaii, monitoring site.

(b) Geomorphology, Soils, and Vegetation. The Kualoa site is located on the northeast flank of the prehistoric Koolau Volcano. Several periods of marine and subaerial erosion of the volcano and isostatic sinking of the island have contributed to the present appearance of the core and flanks. In addition to the periods of erosion, a geomorphic pattern of fringing, patch, and barrier reefs developed, and the reefs were modified by changes in sea level resulting from the advance and retreat of continental glaciers. A fringing coral reef extends about 2,000 feet seaward of the eastern park shoreline and about 1,800 feet southward into Kaneohe Bay. A large deposit of sand lies about 1,500 feet southwest of the southern park shore, directly offshore Molii Fishpond.

The Kualoa peninsula is a large, dynamic sandpit which was incrementally built in a southward direction into Kaneohe Bay by the net southward movement of sand from the reefs and beaches north of Kualoa. Most of the peninsula consists of unconsolidated marine calcareous sediments, and the very permeable beach sand consists of grains of worn coral, coralline algae, and shells. Vegetation in the immediate area of the monitoring site consists of grass, extending from the top of bluff landward, and a few palm trees randomly spaced behind the bluff.

(c) Waves, Longshore Transport, and Erosion. The LEO data (Table 1-3) indicate that wave heights average 0 to 1 foot with a maximum of 1.7 feet. The wave climate is classified as intermediate. Although the energy-flux analysis indicates a small net potential for southward longshore transport at this site, only 30 observations were made throughout the 3-month analysis period, and the results probably reflect this shortage of basic data. The actual net transport rate appears to be much greater than the analysis indicates. Results of a study of littoral currents at Kualoa Park in August 1979, carried out under the prevailing trade-wind conditions, indicated southward transport at an average speed of 6 feet per minute. On the southern shoreline, the current had a strong westward movement of about 10 feet per minute. Sand-tracing studies concluded that littoral transport of sand moves in a clockwise direction around Kualoa Point. Other causes of erosion at Kualoa Beach have been the building of manmade structures in the area. For example, groins built north of Kualoa Beach may have caused a temporary disruption of the longshore transport of material that provides the area with part of its sand supply.

(d) The Problem. The eastern beach at Kualoa Regional Park has undergone continuous erosion. Resulting shoreline changes are shown in Figure 2-598. The average annual loss of sand from the eastern beach area from 1949 to 1975 was 4,800 cubic yards. During this period, the eastern shoreline had receded at an average rate of about 4 feet per year, and the shoreline near Kualoa Point had receded at about 7 feet per year. Although most of the park's southern shoreline accreted during 1949-75, there was a net loss of 80,000 cubic yards for the whole park. This represents more than 6 acres of parklands lost. Studies have indicated that, from 1949 to 1975, 30,000 cubic yards of sand was lost from the littoral system at Kualoa, probably to the offshore sand deposit south of Molii Fishpond. Beach erosion appears almost continuous during trade-wind conditions, and a period of higher than normal tides under typical trade-wind conditions can accelerate shoreline erosion.

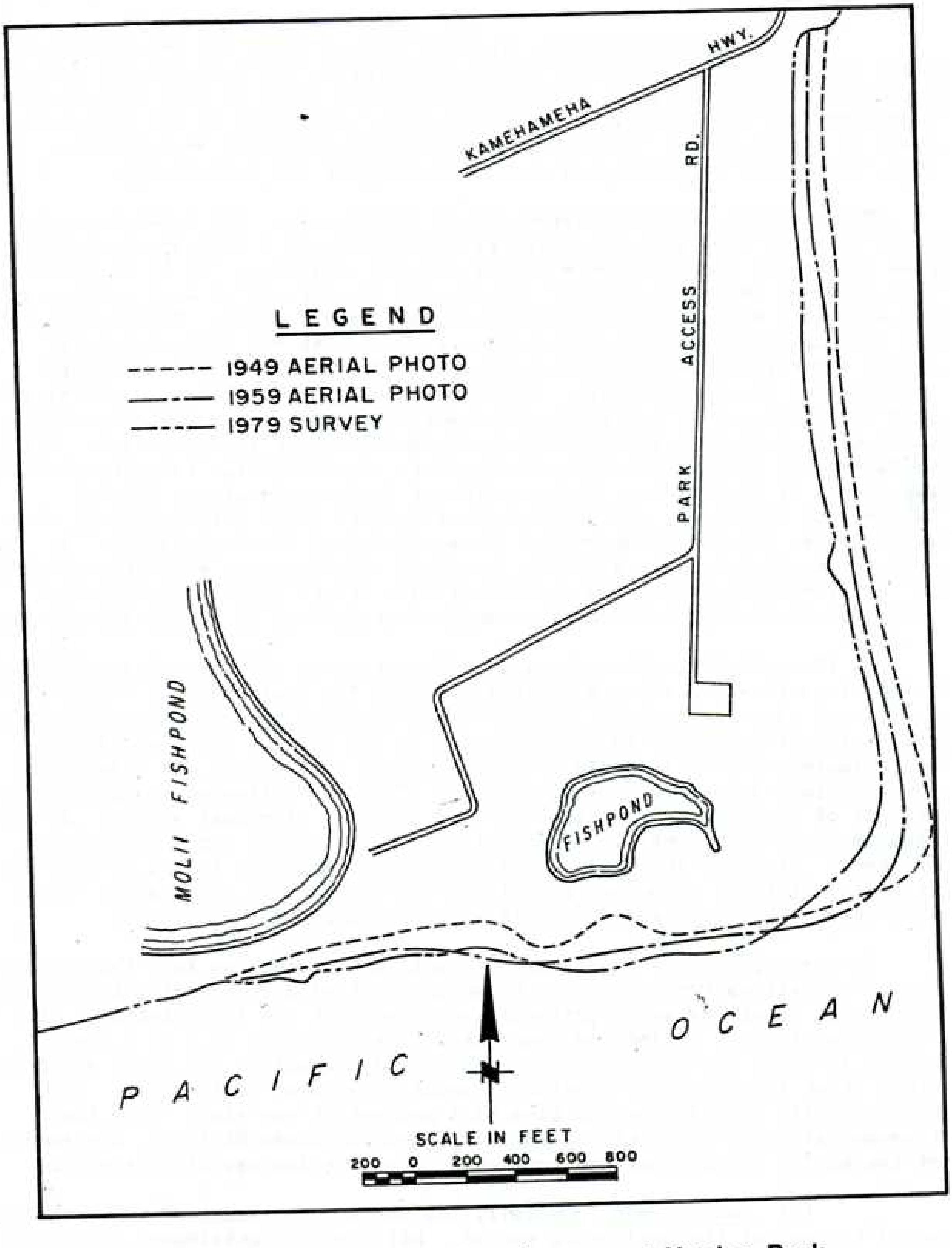


Figure 2-598. Shoreline changes at Kualoa Park.

(2) Monitoring Project. In late fall of 1977, the Department of Parks and Recreation, City and County of Honolulu, had a contractor install a 200-foot-long Sandgrabber just north of Kualoa Point to test its effectiveness in controlling erosion of the park shoreline. A profile of the device is shown in Figure 2-599. After the structure was completed on 5 December 1977, the Department conducted a 2-month study of its performance.

Two problems became apparent almost immediately. The seaward course of blocks consisted largely of red cinder blocks, of a lighter consistency than the blocks used for the main body of the structure. By 26 December 1977, most of these blocks had broken under the effects of wave action, and the structure seemed to be gradually working itself apart. Shortly thereafter, the contractor removed the broken blocks along with the entire seaward course and retightened the loose tie rods. This restored the structural integrity of the Sandgrabber. The second problem which became apparent was that the south end of the Sandgrabber was not curved far enough toward the beach berm to prevent wave attack on the back side of the structure. This southeasterly wave attack was not expected. Aerial photos indicate that it was caused by diffraction of the northeast trade waves around Mokolii Island, and subsequent refraction over the reef. When this occurred, the waves eroded the sand from behind the south end of the Sandgrabber. A protective extension was added to the south end; however, even this extension did not completely solve the problem of wave attack from the southeast. There was continuing evidence that waves were getting in behind the structure.

By the end of the 2-month study, the structure had settled approximately 1 foot into the sand along a 10-foot reach at the south end and along a 15-foot reach near the center. The structure remained intact, and there was a smooth transition from the slumped areas to the rest of the Sandgrabber. Approximately 148 cubic yards of sand accreted both behind and seaward of the structure along its 200-foot length. This was estimated to be about 15 percent of the material available in the littoral transport system. Severe erosion occurred downstream of the structure, extending for a distance of 300 feet. Although the Sandgrabber contributed somewhat to the erosion by retarding littoral transport past the site, it appeared that larger waves than normal, combined with high tides, caused most of the erosion.

In conclusion, the Department of Parks and Recreation felt that longer term observations were needed to allow a more credible determination of the structural stability and functional performance of the installation. The 2-month monitoring period was considered representative only of a typical winter in which the trade winds blow about 63 percent of the time, and Kona winds (from the southwest quadrant), about 20 percent of the time. On a yearly basis, the trade winds blow 82.6 percent of the time. Upon the recommendation of the Division Engineer, Pacific Ocean Division, monitoring of the Kualoa Sandgrabber was continued under the demonstration program.

(3) Performance. Overall, the Sandgrabber remained structurally sound throughout the monitoring period. Differential settlement along its midsection, and of individual blocks, was observed in April 1978 (Figs. 2-600 and 2-601). The entire structure was also rotating downward on the seaward side. The short section on the south end had a seaward slope of 13° (Fig. 2-602). By May, although this short section had continued to settle, the seaward slope was only 8°.

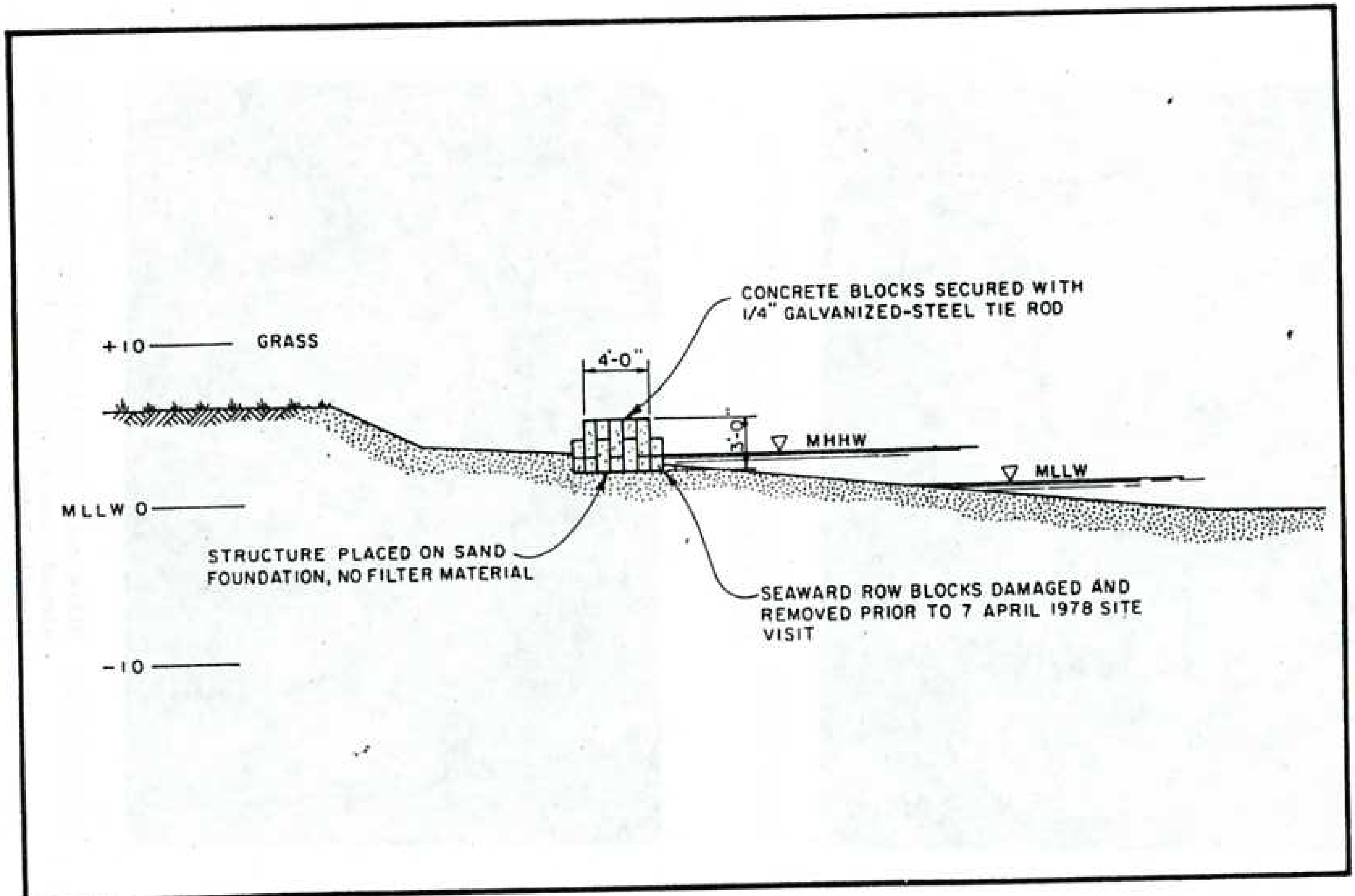


Figure 2–599. Sandgrabber profile at Kualoa site.

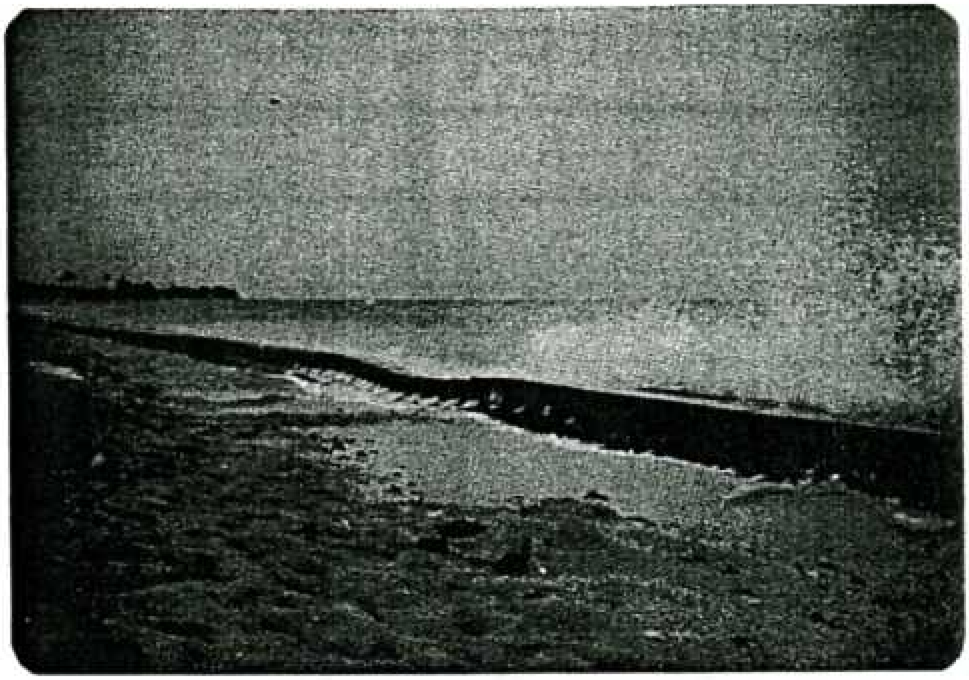

Figure 2-600. Settlement of blocks along midsection, Kualoa, Hawaii, 7 April 1978.

Figure 2-601. Differential settling of individual blocks viewed from structure's midsection, Kualoa, Hawaii, 7 April 1978.

Figure 2-602. Seaward slope of south end of Sandgrabber, Kualoa, Hawaii, 7 April 1978.

Differential settlement of individual blocks continued over the following 18 months. Although the tie rods were loosening and many of the blocks on the seaward face broke, the structure ceased to rotate. By January 1979, four blocks had been damaged--two near the south end were vertically displaced, and two near the center of the structure had broken away (Figs. 2-603 and 2-604). By May 1979 most of the tie rods were rusted and loose, and in November 1979 several blocks in the seaward face were broken apart (Figs. 2-605 and 2-606). Despite this component damage, the Sandgrabber remained functionally effective.

By June 1978, the preliminary effects of the Sandgrabber at the Kualoa site were identified. Sand accumulated on the landside of the structure as expected, but not along the seaward face. The northern and southern beach areas near the Sandgrabber accreted somewhat at first, but erosion of the downdrift bank was accelerated (Fig. 2-607). Between June 1978 and August 1979, erosion of the downdrift bank averaged +1 foot per month. The rate of erosion decreased through November 1979. Figure 2-608 shows the progressive erosion downdrift of the Sandgrabber from November 1978 to November 1979. Between November 1979 and January 1980, +10 feet of downdrift shoreline was lost as a result of winter storms.

In January 1979, there was slight accretion along the seaward face (compare Figs. 2-609 and 2-610); however, this trend did not continue. Accretion of sand landward of the structure continued until September 1979, when minor scouring along the central segment of the landward face was observed.

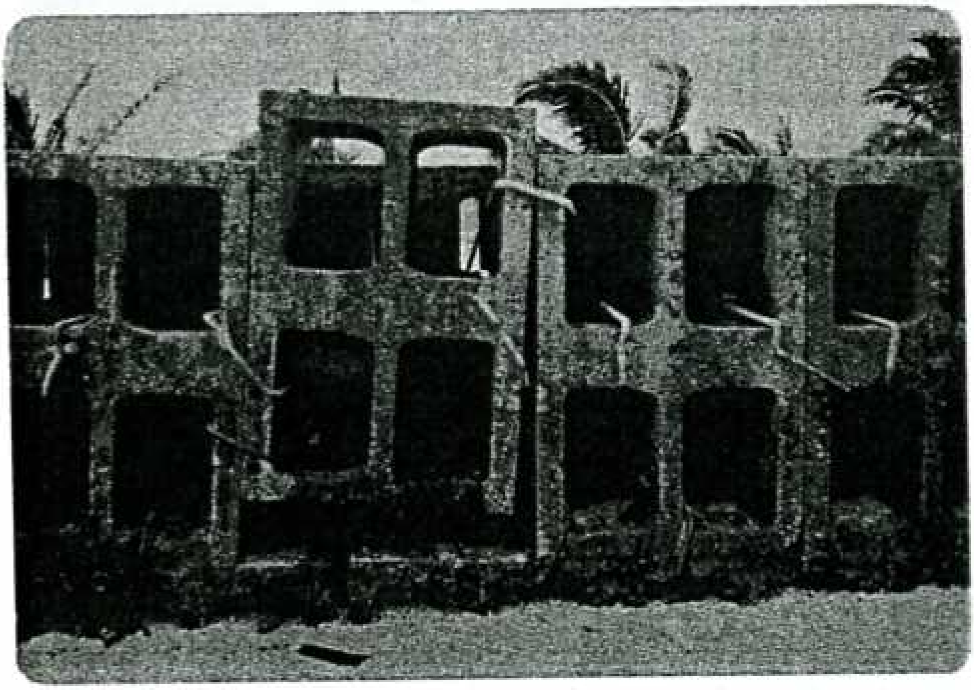

Figure 2-603. Vertically displaced block toward the south end of the structure, Kualoa, Hawaii, 4 January 1979.

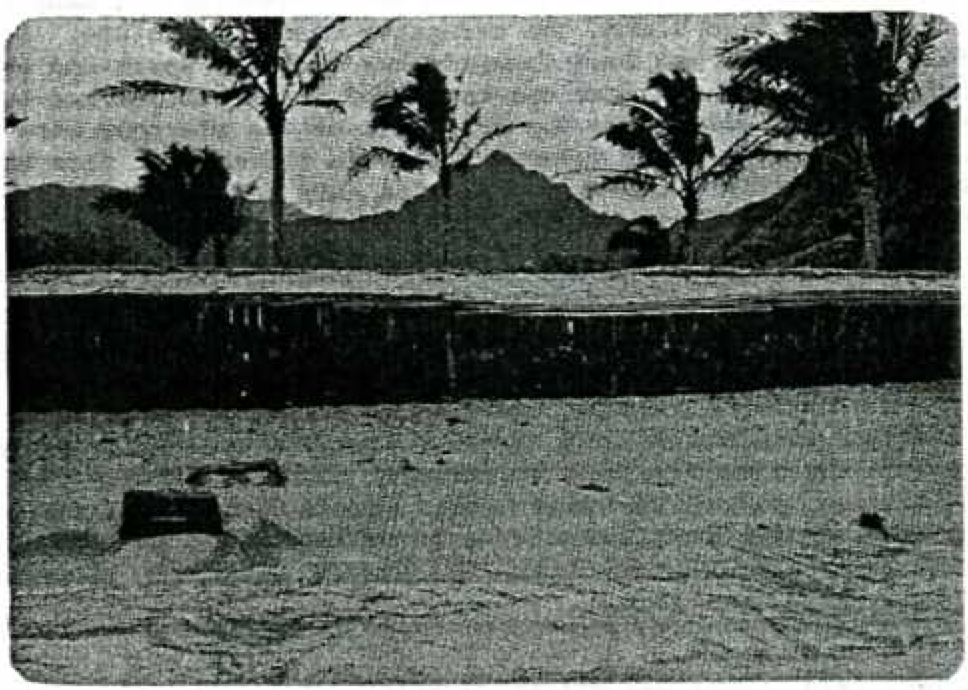

Figure 2-604. Displaced blocks lying in sand along mid-section of the structure, Kauloa, Hawaii, 4 January 1979.

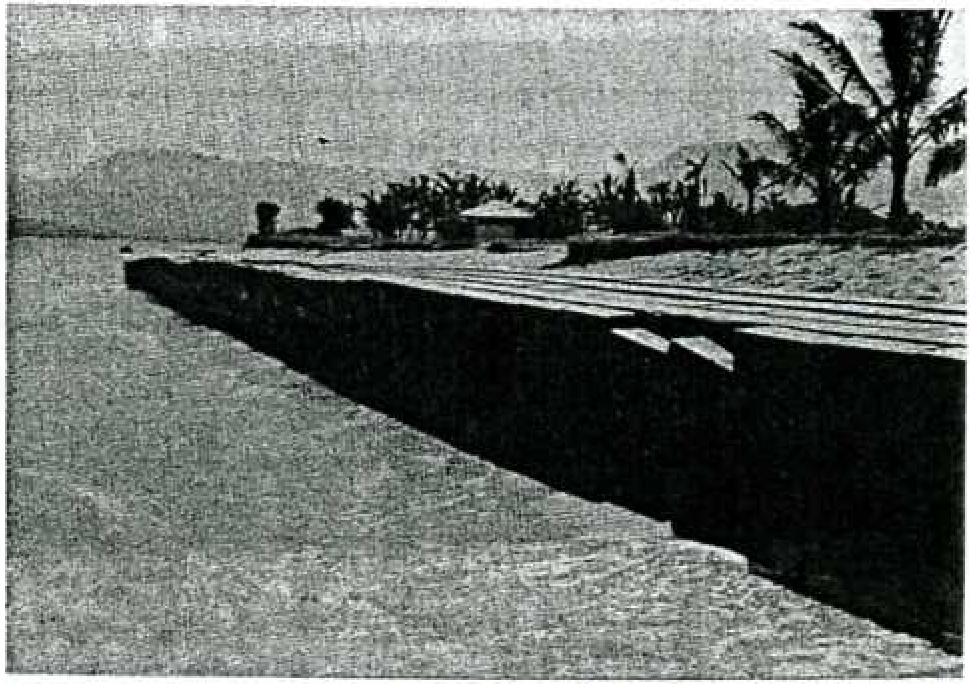

Figure 2-605. Broken blocks viewed from midsection of structure, Kualoa, Hawaii, 8 November 1979.

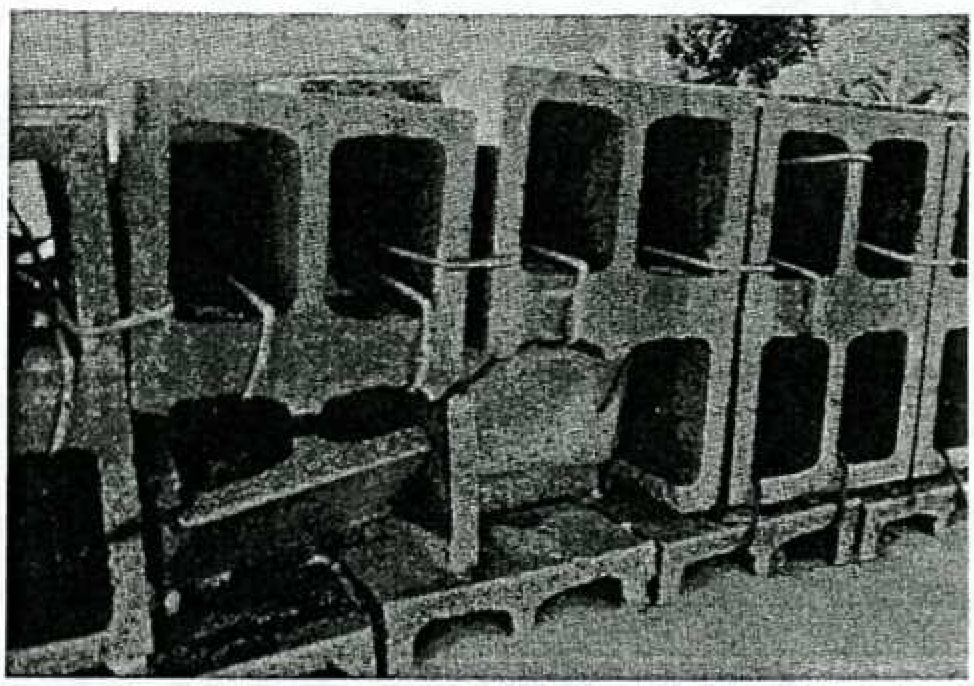

Figure 2-606. Broken blocks near north end of structure, Kualoa, Hawaii, 8 November 1979.

Figure 2-607. Erosion of downdrift bank, Kualoa, Hawaii, 19 June 1978.


Figure 2-608. Progressive erosion south of Sandgrabber, Kualoa, Hawaii, 25 November 1978 and 12 November 1979.

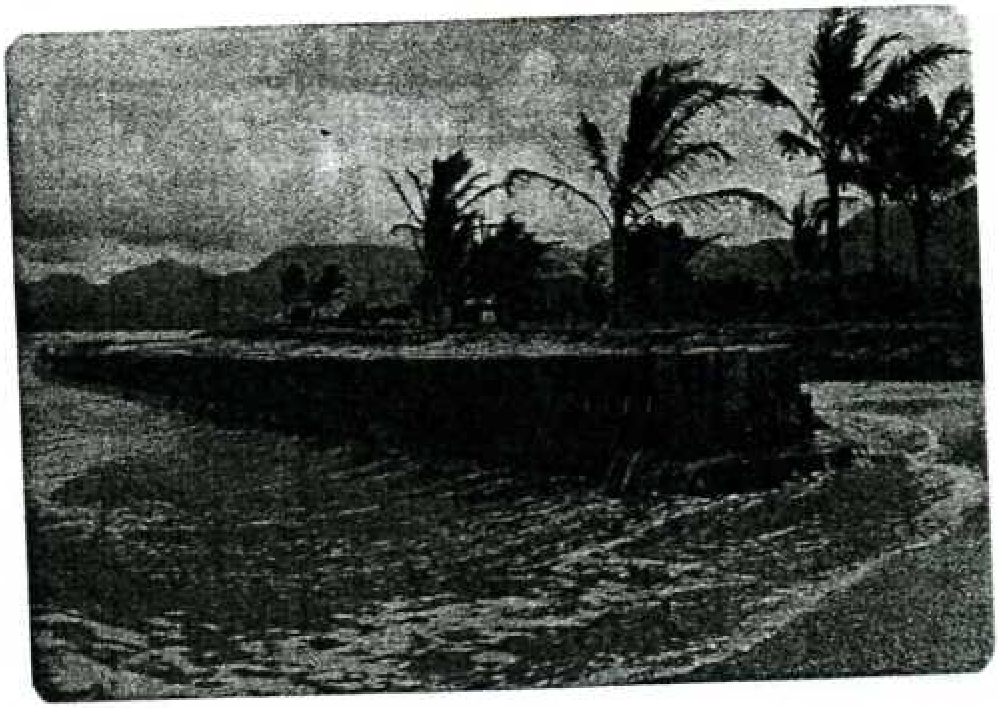

Figure 2-609. Seaward face of structure, Kualoa, Hawaii, 19 June 1978.

Figure 2-610. Sand accumulation on seaward face of structure, Kualoa, Hawaii, 4 January 1979.

A storm in January 1980 damaged the structure significantly. Four blocks on the landside were broken and 14 were broken on the seaside. Thirteen blocks were missing from the Sandgrabber, five double blocks and eight single blocks from the seaside. Structural damage was progressive. Typically, the bottom half of the seaward double blocks broke, then the remaining unsupported top half worked loose; the single-block second row from seaward was then exposed and became dislodged (Fig. 2-611). Waves eroded the adjacent beach to the south and flattened the slopes. Continued erosion of the beach to the south has occurred (Figs. 2-612 and 2-613).

Figure 3-79, which was put in Section III for comparison of similar devices shows a series of profiles through the sandgrabber. The profiles show the accretion and erosion trends and depict the uneven settlement of the structure.

(4) Analysis. The Sandgrabber demonstrated its usefulness in trapping sand and stabilizing the immediate shoreline at Kualoa. However, it is important, where beach stability depends on nourishment by longshore transport, that the littoral supply to downdrift beaches not be totally cut off by a sand conservation device. The Sandgrabber removed material from the littoral system, causing accelerated downdrift erosion. The lost land area has not been recovered.

The structural integrity of the installation was compromised by differential settlement of the foundation blocks. Some differential settelement is provided for by the tie-rod arrangement, but the allowable limits were exceeded. This resulted in cracked blocks and loosened tie rods, which eventually would hasten structural failure to the extend that the Sandgrabber would no longer function as intended. Two solutions to this problem are suggested: (a) Provide a suitable bedding foundation or initially excavate the foundation to the

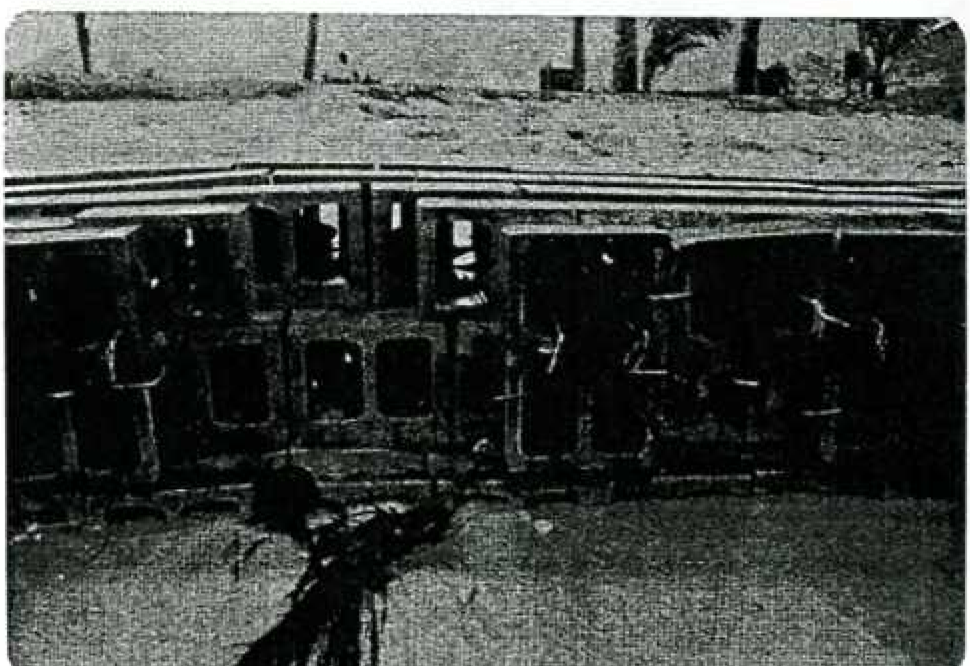

Figure 2-611. A damaged section of the Sandgrabber at Kualoa, Hawaii, 17 January 1980.

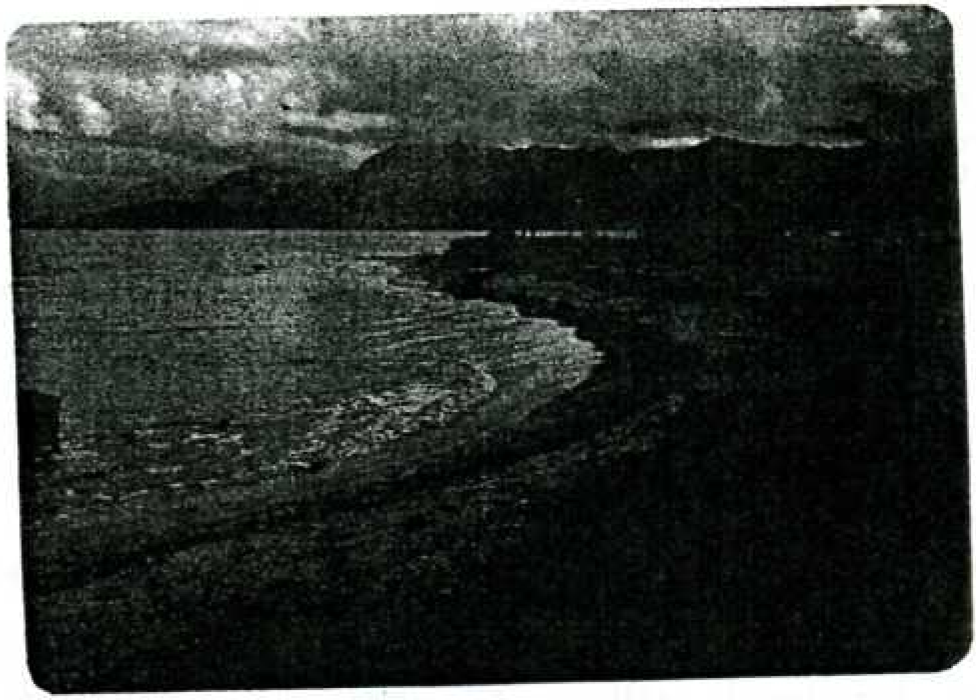

Figure 2-612. The beach south of the structure was eroded by storm waves, Kualoa, Hawaii, 17 January 1980.

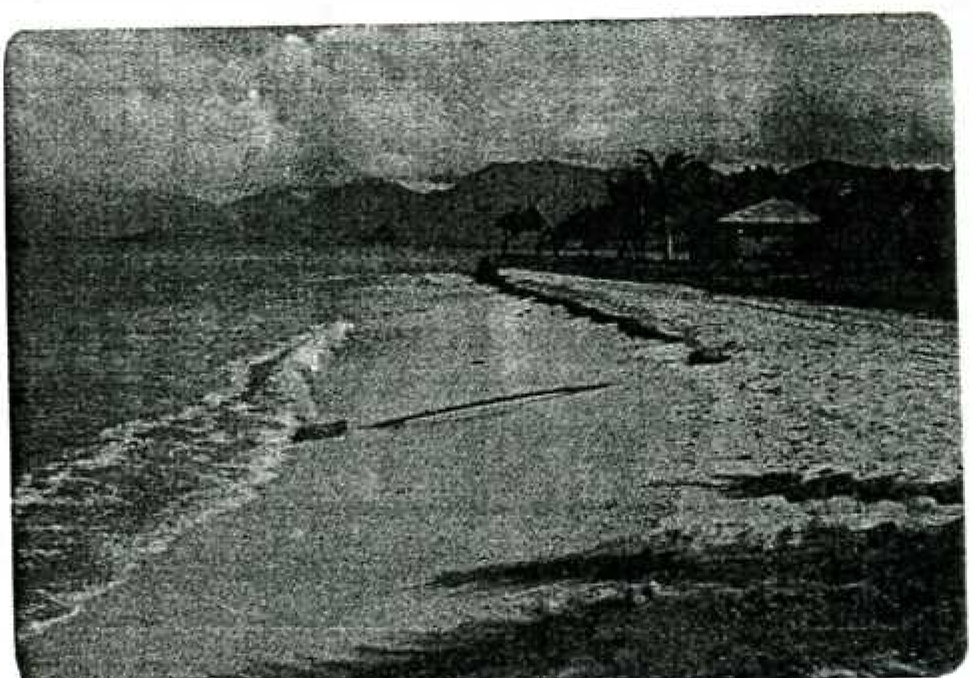

Figure 2-613. Continued erosion of the beach south of the structure, Kualoa, Hawaii, 29 May 1980.

estimated stable depth and tilt angle, and (b) provide a method of interconnecting the blocks that will allow more differential settlement without compromising the structural integrity of the system.

Failure of blocks is also due to wave impact and uplift forces. Strength limits were exceeded, even in the relatively mild wave climate at Kualoa. Use of this structure is recommended for wave conditions in which wave heights do not exceed 3 feet at the structure toe.

Table 2-106 gives volume calculations for changes between profile stations that occurred from March 1978 to May 1980. The base line for the surveys is stationed from north to south, the direction of longshore transport. The table shows that littoral material accreted at the profiles where the Sandgrabber was located. Immediately south of the structure, the downdrift shoreline shows erosion. In this situation, the use of a Sandgrabber (in an area of strong littoral transport) has caused erosion of the downdrift shoreline.

Table 2-106. Volumetric analysis of beach profiles at Kualoa, Hawaii (16 March 1978 to 30 May 1980).

| Device | Station | Erosion ($yd^3$) | Accretion ($yd^3$) | Net accretion ($yd^3$) |
|---|---|---|---|---|
| Sandgrabber | 25+50 | 6.0 | 178.8 | 172.2 |
| Sandgrabber | 26+50 | 43.3 | 180.7 | 137.4 |
| Sandgrabber | 27+50 | 64.7 | 85.0 | 20.3 |
| Sandgrabber | 28+00 | 119.7 | 58.3 | -61.3 |
| -- | 28+50 | 120.1 | 56.0 | -64.2 |
| -- | 29+0 | 196.5 | 72.4 | -124.1 |
| -- | 29+50 | 372.6 | 70.6 | -302.0 |
| -- | 30+00 | 543.7 | 88.4 | -455.3 |
| -- | 30+50 | 725.5 | 71.1 | -654.4 |
| -- | 31+00 | 725.7 | 61.4 | -664.3 |
| -- | 31+50 | 1,154.0 | 110.3 | -1,043.6 |
| -- | 32+50 | 516.4 | 288.0 | -228.4 |
| -- | 33+50 | | | |
| | Totals | 4,588.1 | 1,320.3 | -3,267.8 |

c. Bellows Air Force Station, Hawaii.

(1) Site Description.

(a) Geographical Setting. This monitoring site is located at Bellows Air Force Station near the north end of Waimanalo Bay, about 12 miles southeast of Kualoa Point (Fig. 2-614). The shore segment from Wailea Point to the south boundary of the Air Station is known as Bellows

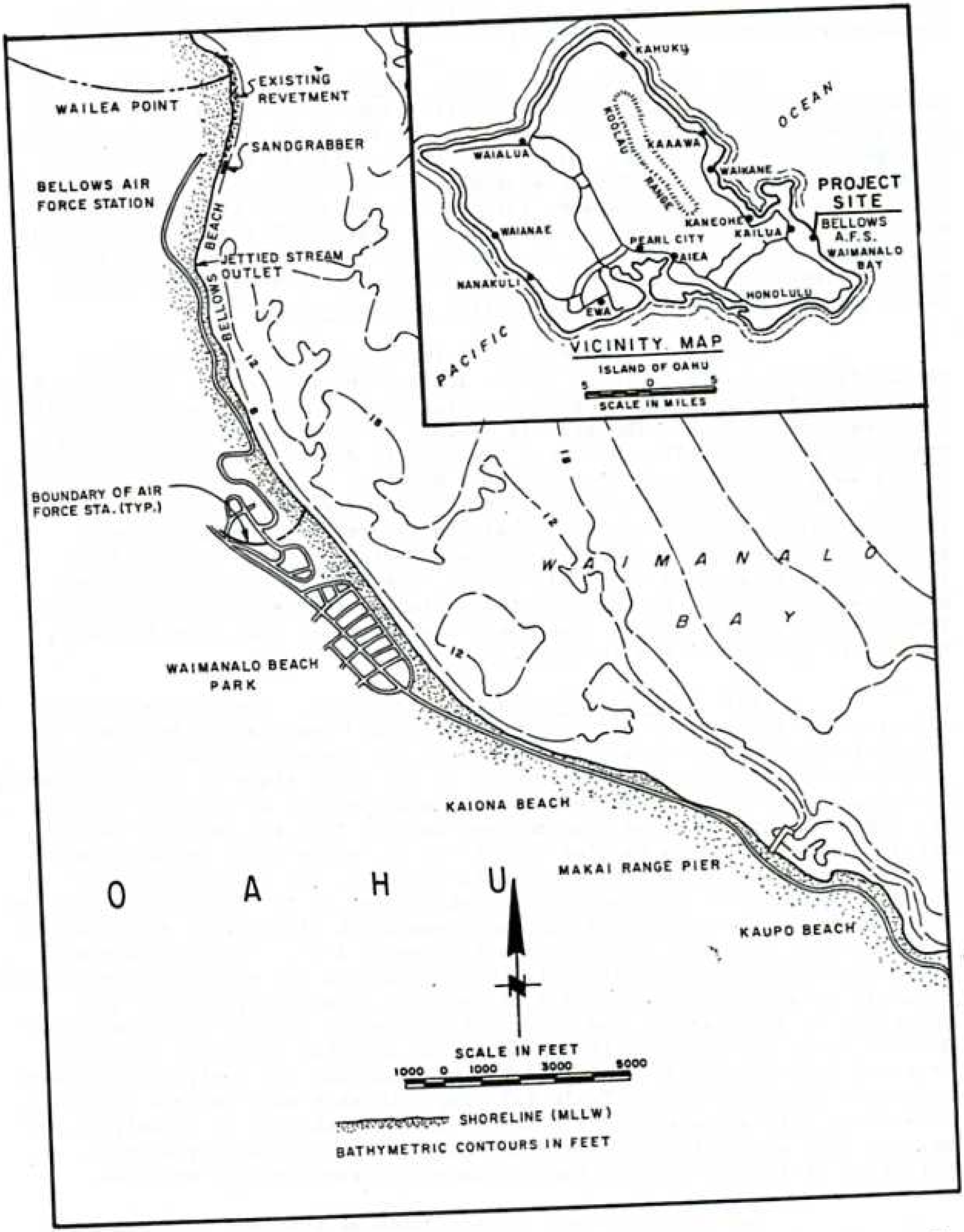


Figure 2-614. Location map of Bellows Air Force Station, Hawaii, monitoring site.

Beach. At the monitoring site, the shoreline trends about N.20°E. Two stream-mouth jetties are located 3,000 feet south of the project site.

(b) Geomorphology, Soils, and Vegetation. A shallow reef extends approximately 3,000 feet offshore. Some patch reefs north of the site are exposed at MLLW. The reef lying to the east and southeast varies in depth from 6 to 12 feet. Beach sand at the site is light colored and fine, except in front of the coral rock revetment just north of the Sandgrabber site, where the sand is coarser. The beach in this area has been eroded, with waves reaching the reveted bank during most tidal stages. The coarser sand may be indicative of selective transport that has removed the finer grains. Vegetation adjacent to the beach is comprised of native ground cover and many ironwood trees (*Casuarina equisetifolia*).

(c) Wave Conditions. Waimanalo Bay is protected from direct deepwater wave approach by the offshore barrier reef. The protection is greatest for waves approaching from the north, which encounter the patch reefs exposed at MLLW. The site is exposed to higher waves approaching from the east and southeast, where the reef is deeper. In a December 1978 study, wave parameters at the site were observed in accordance with the LEO format. The LEO study consisted of six measurement periods over 3 days, thus providing only basic and approximate information. Measured wave periods ranged from 5 to 8.5 seconds, and average breaker heights were estimated to range from 1.3 to 1.7 feet. The maximum estimated breaker height was 2.5 feet. During the study, breaker type was consistently of the spilling-plunging type. The observers estimated that breaking wave heights of greater than 4 feet would be unusual.

(d) Longshore Transport and Erosion. The LEO 3-day study also yielded information on longshore currents. Dye tracing indicated a longshore current moving alternately south and north with almost uniform frequency and no apparent relationship to the tidal stage or to the breaking wave angle. Current speeds ranged up to a maximum of 85 feet per minute. The observed angle of wave approach was usually from the north at angles off the normal-to-shore ranging from 5° to 8°, which would be expected to generate a southward longshore current. However, the dye occasionally moved to the north. This anomaly was attributed to the confused pattern of wave crests in the study area and the presence of rip-current cells, which were apparent in aerial photos taken 7 November 1978. The data base was too meager to determine whether littoral transport was predominantly onshore-offshore or alongshore, nor could the seasonal characteristics of the transport be determined. The causes of the severe erosion problems along Bellows Beach are not readily apparent, and littoral transport processes have not been adequately studied. The LEO data for the monitoring project under the Federal program (Table 1-3) indicate that wave heights average 1 to 2 feet, with a maximum of 5.6 feet. The wave climate is classified as severe. The energy-flux analysis indicated a net longshore transport potential of 130,000 cubic yards southward for the 6 months analyzed.

(e) The Problem. A comparison of 1967 and 1978 aerial photos showed that Bellows Beach had severely eroded during that 11-year period. In 1967, a 350-foot-long coral rock revetment existed 1,200 feet south of Wailea Point. An 80-foot-wide sand beach extended 1,200 feet from the south end of the revetment to the project site, where the beach was 100 feet wide. By 1978, the revetment had extended in both directions until it was continuous from Wailea Point to the project site, and the beach in front of the revetment was narrow or nonexistent. A 1978 visual inspection indicated that erosion was occurring along most of the shoreline between the project site and the stream-mouth jetties, exposing the roots of numerous ironwood trees.

(2) Monitoring Project. In early February 1979, a 100-foot-long Sandgrabber was installed by the U.S. Air Force on Bellows Beach (Fig. 2-615). This structure was selected for monitoring under the demonstration program.

(3) Construction. Construction was accomplished by enlisted U.S. Air Force personnel under the supervision of the Sandgrabber contractor. The blocks were trucked to a stockpile above the site and transferred to the beach with a forklift (Fig. 2-616). As a base for the bottom row of blocks, a structure-wide width of beach along the structure axis was leveled. The blocks were then placed in section and tied together with galvanized tie rods (Fig. 2-617). The north end of the structure was built flush against the existing revetment to provide continuity (Figs. 2-618 and 2-619).

(4) Performance. Generally, the concrete blocks and galvanized-steel tie rods of the Sandgrabber withstood the natural forces of waves and tides. Some settlement was detected about 1 week after installation, but there was negligible differential shifting of individual blocks. One block and one tie rod were broken at the north end as the structure settled against the adjacent revetment stone (Fig. 2-619). Over the next 5 months, the structure continued to settle, rotating downward on the seaward side. This resulted in a few loose tie rods, but the blocks remained intact. During August 1979, the seaward settlement increased, with a seaward slope of 5° on the south end, 11° along the midsection, and 15° on the north end (Fig. 2-620). About eight blocks on the northern landside were broken apart by tension forces exerted by the tie rods as a result of seaward settlement (Fig. 2-621).

The effects of the Sandgrabber on Bellows Beach were detectable within days of its installation. Sand accumulation on the landside of the structure had began, evidenced by the coarser nature of the trapped material relative to the existing beach material. For 2 months after installation, sand continued to accrete on both the landward and seaward sides of the structure. In April 1979, sand accumulation reached a maximum (Figs. 2-622 to 2-625). By June 1979, the sand level on the seaward face of the structure had dropped about 6 inches; the landward sandline was unchanged since April. At that time, some slight scouring on the landward side of the structure along the north end was reported. The July 1979 visit revealed that the scouring along the north end was continuing, but otherwise the sand accumulation was holding (Fig. 2-625). A major change occurred during August 1979. The scouring along the north end worsened, creating a trench landward of the Sandgrabber which worked its way southward along the length of the structure (Figs. 2-620 and 2-626). The north end of the structure was then completely scoured out and rested on the existing revetment stones. Settlement of the structure continued until January 1980, when accretion of the entire beach completely buried it. The structure was still buried in June 1980, and it appears to be in equilibrium with the beach material; i.e., the structure is floating in sand. Figure 3-79 (see Sec. III) shows a series of profiles through the Sandgrabber, depicting its uneven settlement. However, the accuracy of some of the survey data is questionable.

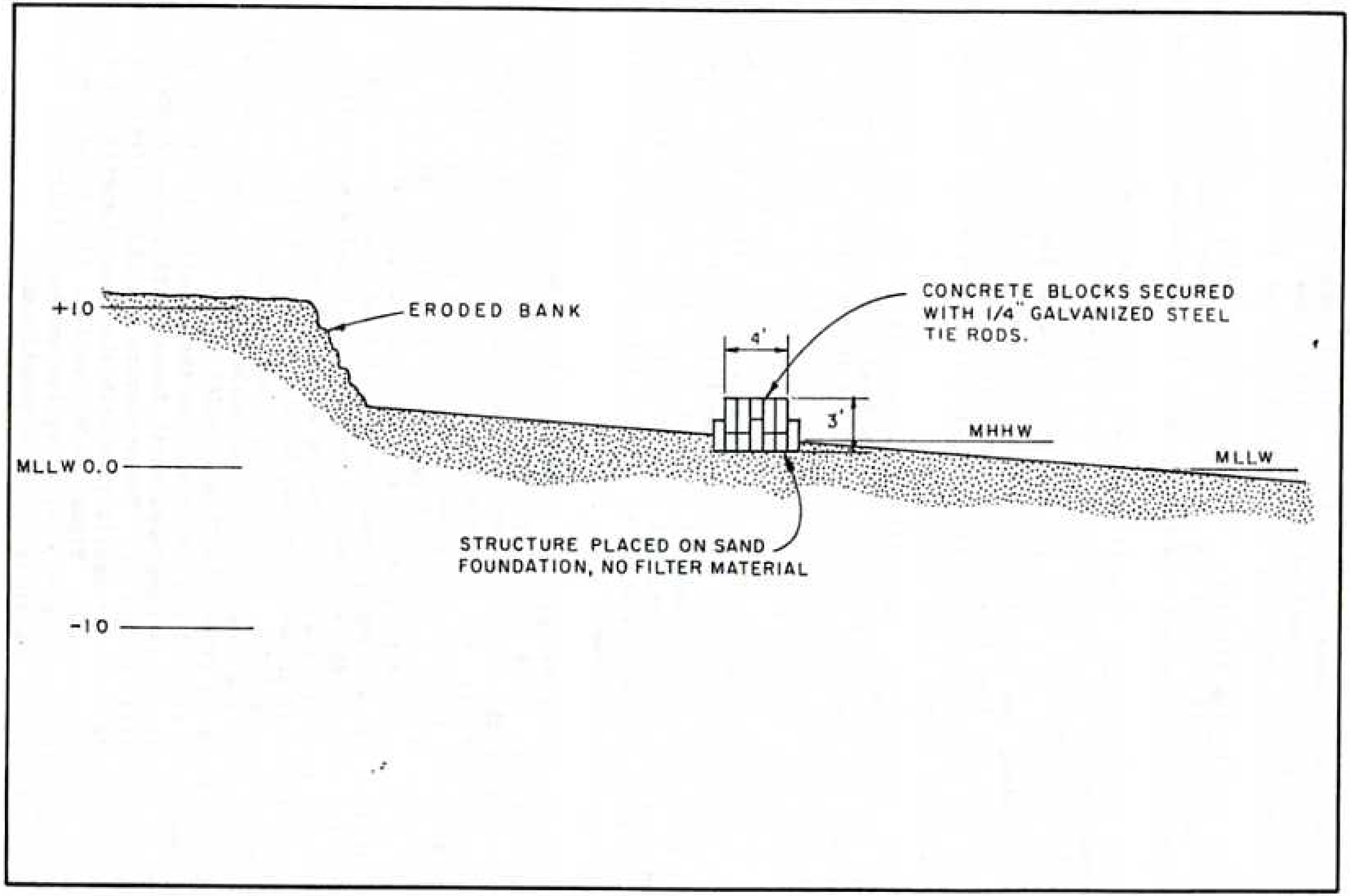


Figure 2-615. Sandgrabber profile at Bellows Air Force Station site.

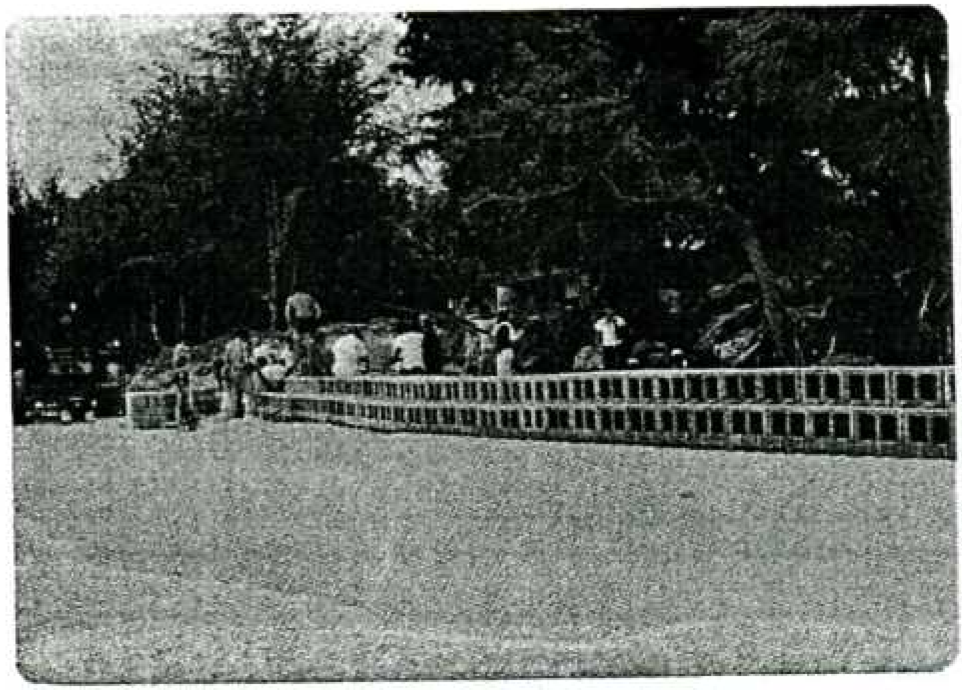

Figure 2-616. Forklift used to transport blocks, Bellows Beach, Hawaii, 8 February 1979.

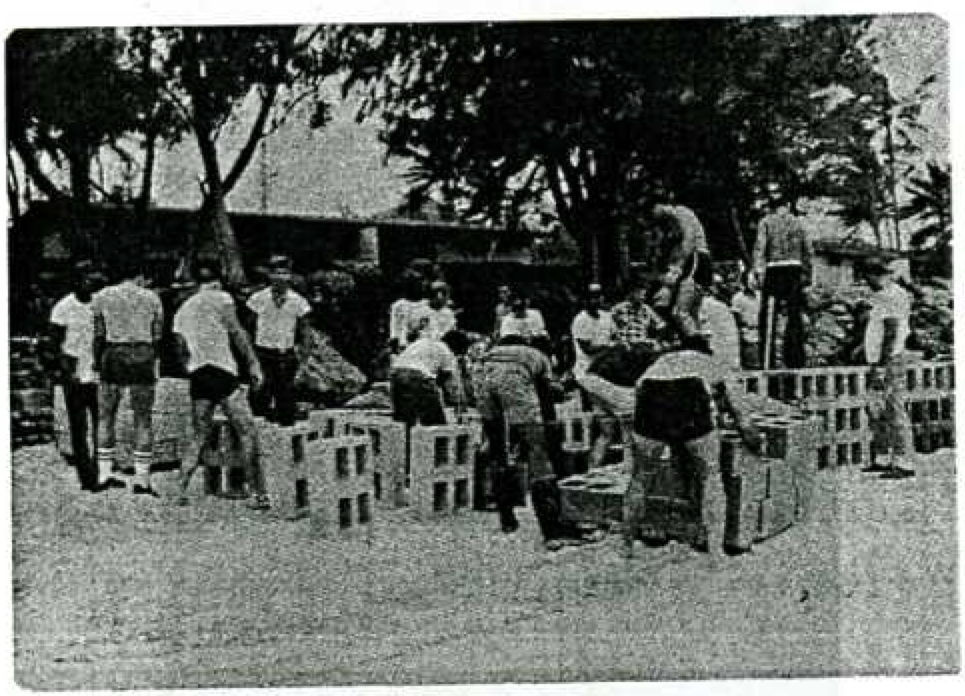

Figure 2-617. Placing blocks by hand, Bellows Beach, Hawaii, 8 February 1979.

Figure 2-618. Finishing Sandgrabber construction, Bellows Beach, Hawaii, 8 February 1979.

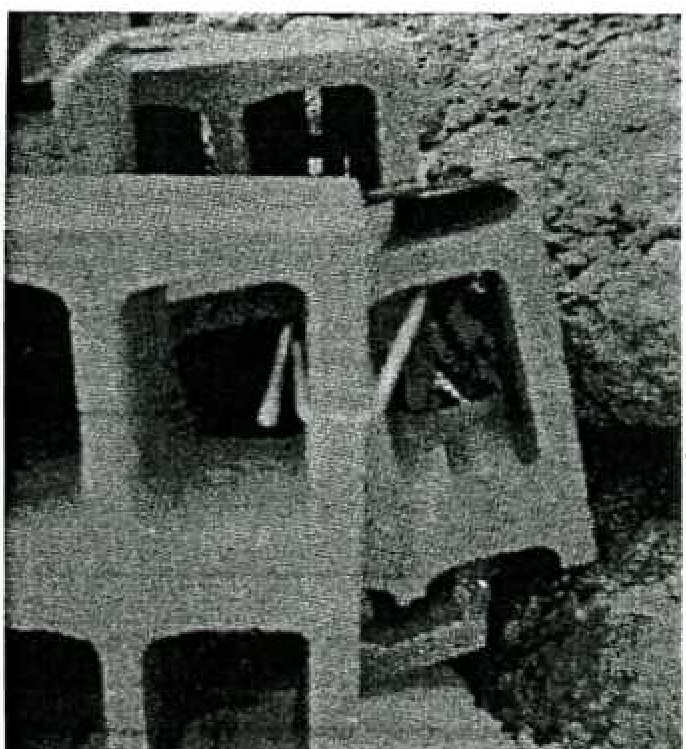

Figure 2-619. Broken block and tie rod, north end, Bellows Beach, Hawaii, 14 February 1979.

Figure 2-620. Seaward settlement of Sandgrabber, Bellows Beach, Hawaii, 5 September 1979.

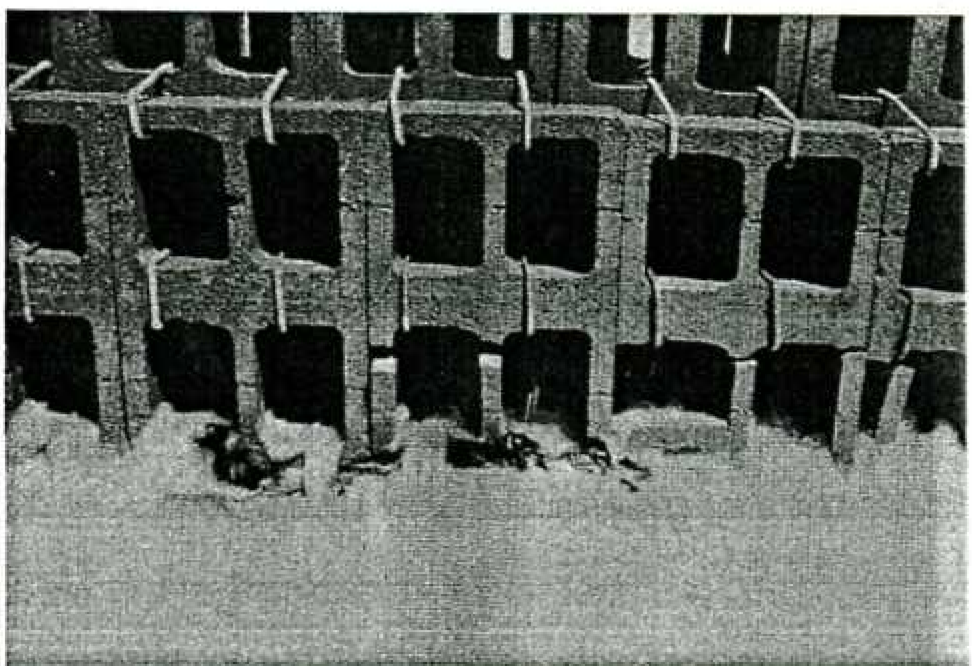

Figure 2-621. Broken blocks, landward side, Bellows Beach, Hawaii, 5 September 1979.

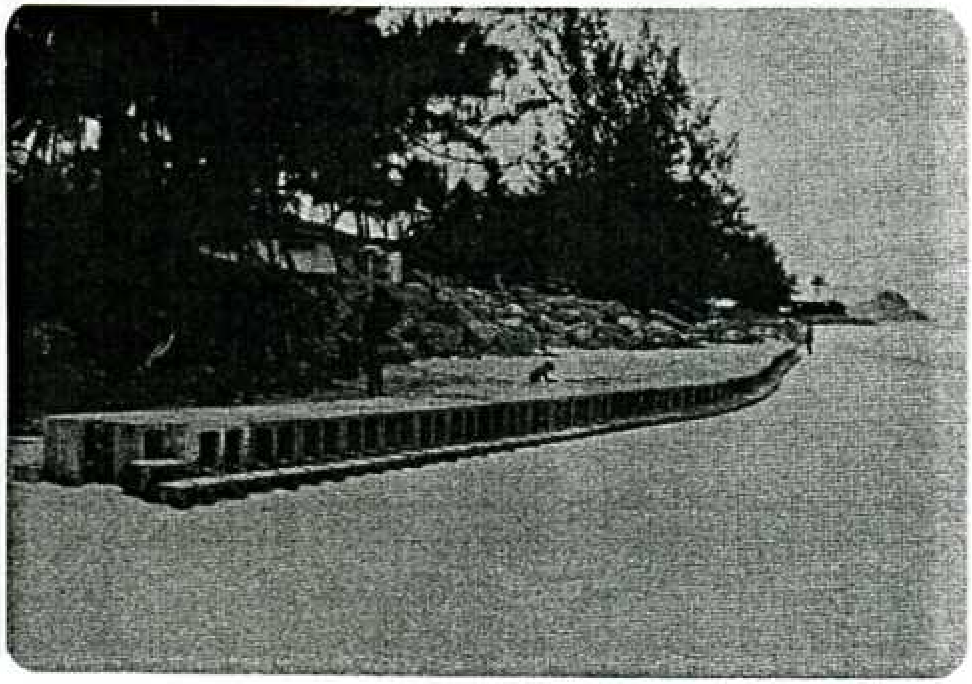

Figure 2-622. Sand accumulation, seaward side of south end, Bellows Beach, Hawaii, 12 April 1979.

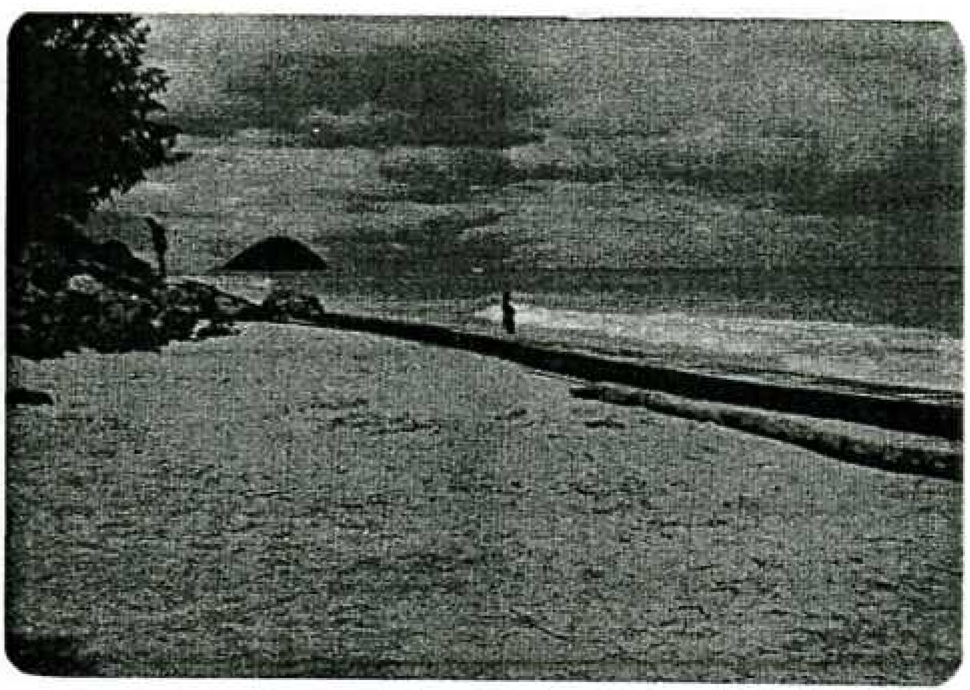

Figure 2-623. Sand accumulation, landward side of north end, Bellows Beach, Hawaii, 12 April 1979.

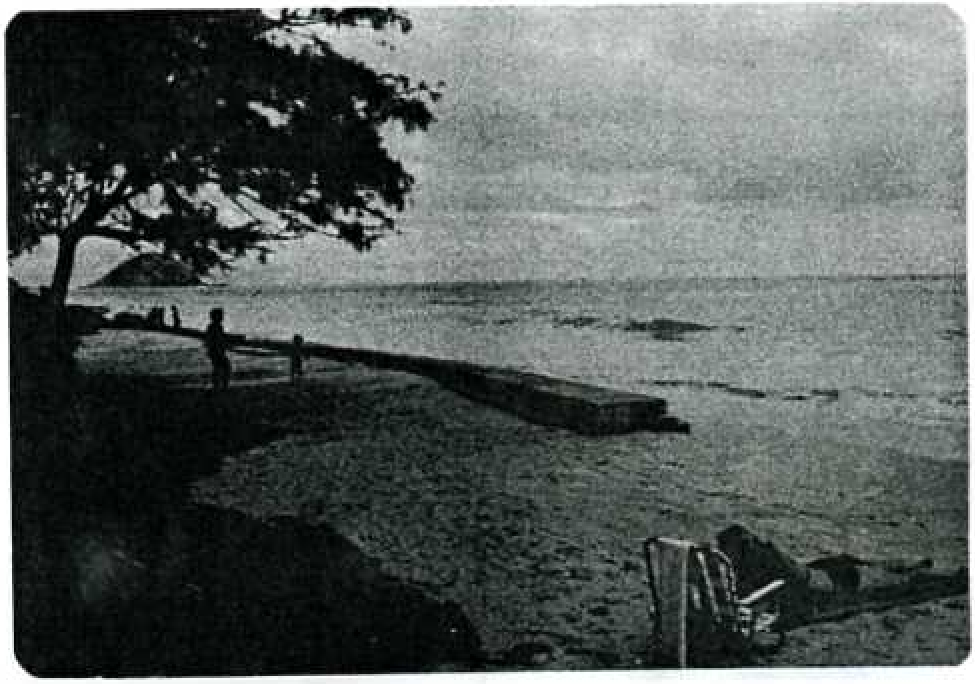

Figure 2-624. Sand accumulation, landward side of south end, Bellows Beach, Hawaii, 12 April 1979.

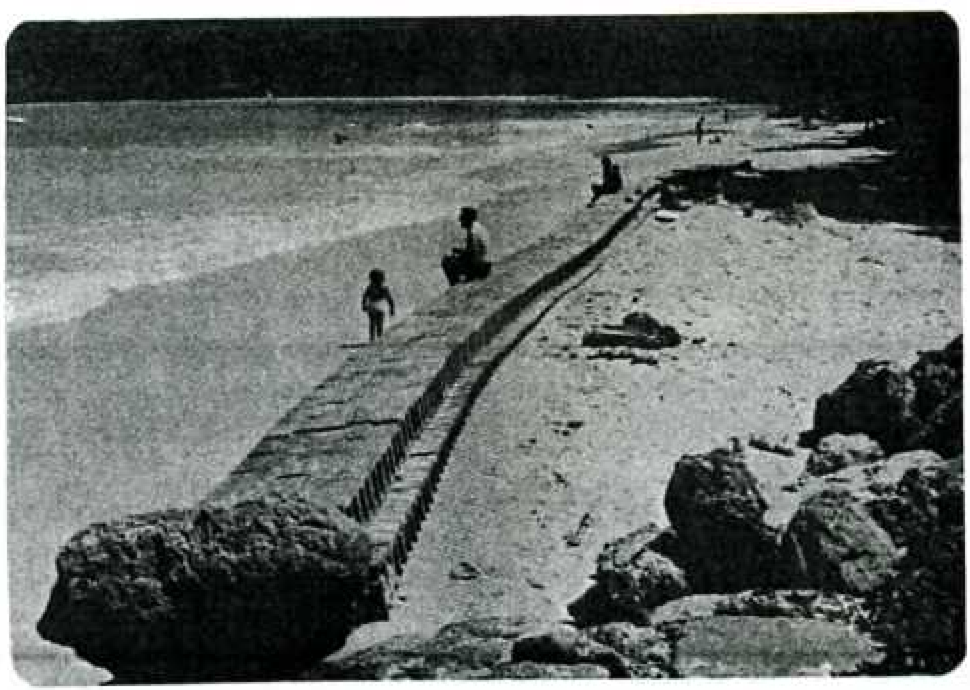

Figure 2-625. Scour beginning at the north end, Bellows Beach, Hawaii, 3 July 1979.

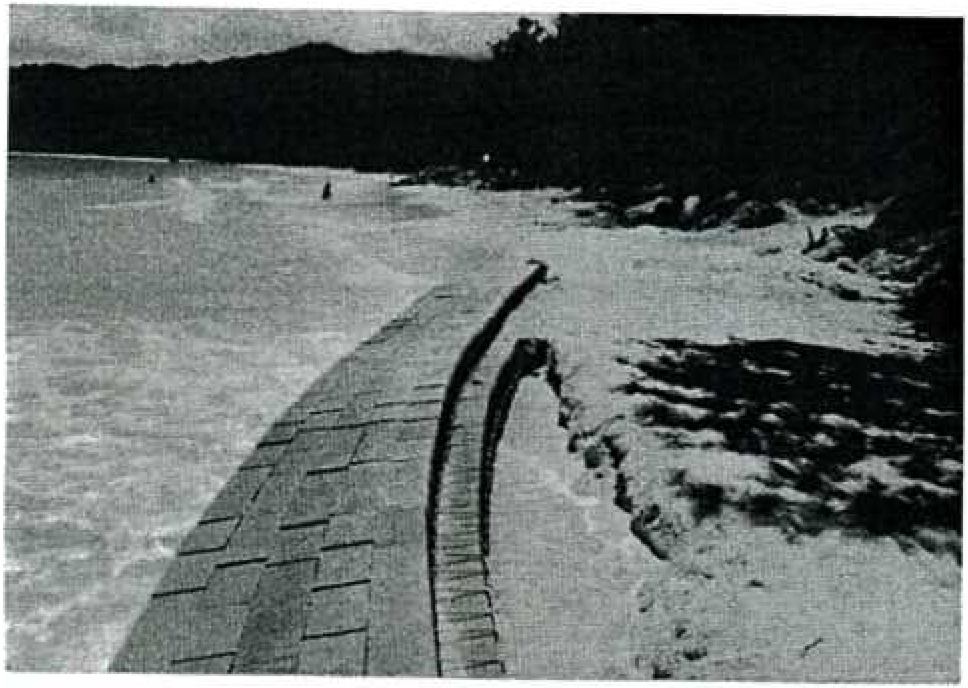

Figure 2-626. Trench working its way south landward of structure, Bellows Beach, Hawaii, 5 September 1979.

(5) Analysis. The Sandgrabber at Bellows Beach demonstrated its short-term ability to trap sand and enhance accretion trends of the immediate beach. Being permeable, this device allowed the beach profile to change with the wave conditions, although not as much as with an unprotected beach. The Bellows Sandgrabber removed considerable sand from the littoral system initially, but erosion of the adjacent beaches was not as apparent as at Kualoa. This points to the hypothesis that sand transport at the Bellows site is predominantly onshore-offshore rather than alongshore.

Some structural performance problems developed at this site which a few comments might help to mitigate at future installations. First, since the sand at Bellows is fine grained, the settlement of the seaward side of the structure due to toe scour should have been anticipated, and bedding should have been provided or the foundation trench should have been excavated to the anticipated scour depth. Second, the Sandgrabber is not sufficiently flexible; it can be damaged by uneven settlement. This was clearly demonstrated at this site by comparing the north and south ends of the installation (Figs. 2-627 to 2-630). At the north end, the Sandgrabber settled on the adjacent, existing coral rock revetment and, due to inflexibility, was unable to conform to the scouring bottom (Fig. 2-630). As a result, the north end of the structure was damaged. This problem might have been avoided had the structure not settled as much, had the structure been more flexible, or had the north end of the Sandgrabber not been constructed such that it settled onto the rock structure. Third, if differential settlement of the Sandgrabber is anticipated, elastic "ties" of some sort might be substituted for the steel tie rods. This would eliminate the breaking of blocks that results from excessive stresses due to inflexibility of

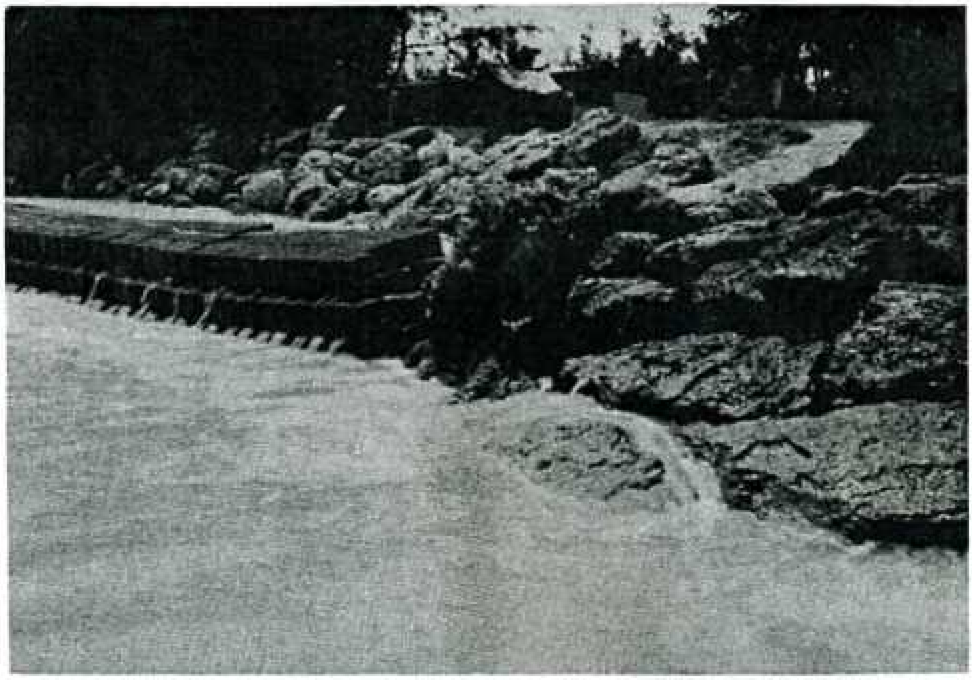

Figure 2-627. North end of Sandgrabber abutting rock revetment, Bellows Beach, Hawaii, 5 September 1979.

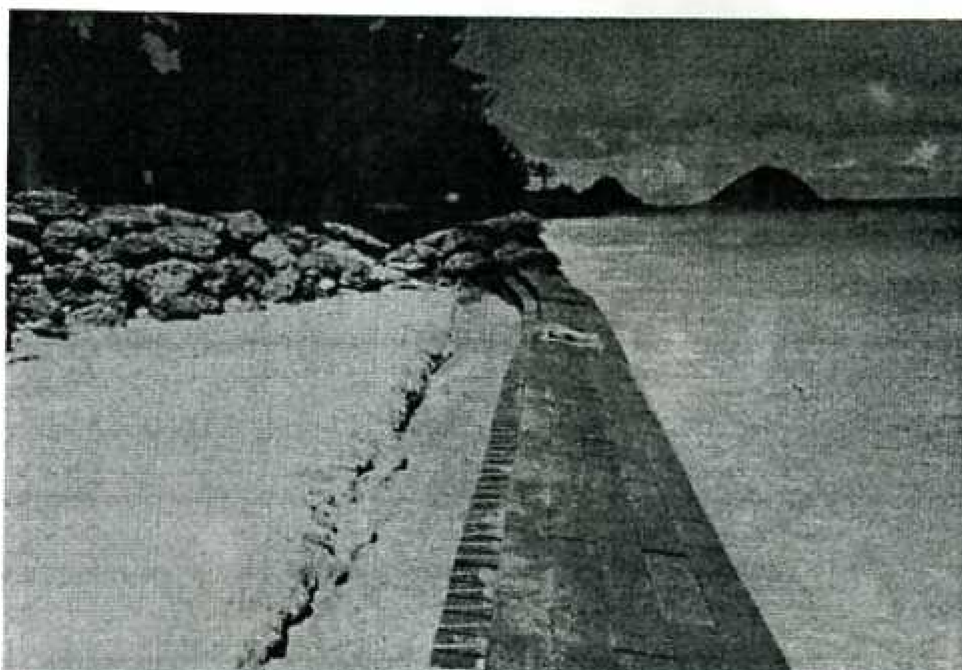

Figure 2-628. Scour trench along north end of structure, Bellows Beach, Hawaii, 5 September 1979.

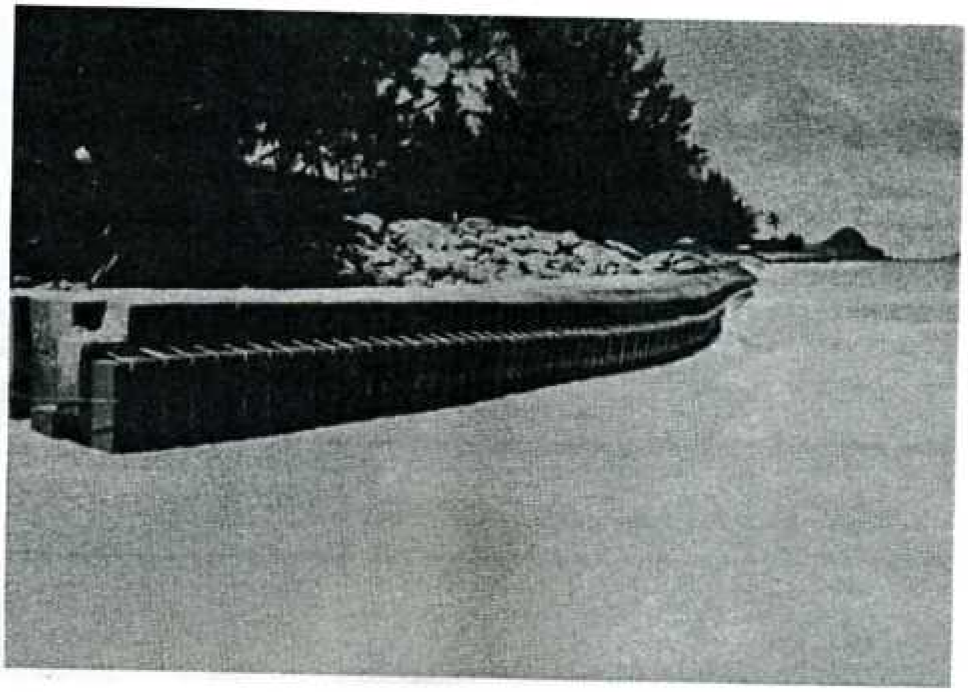

Figure 2-629. South "free end" of the Sandgrabber, Bellows Beach, Hawaii, 5 September 1979.

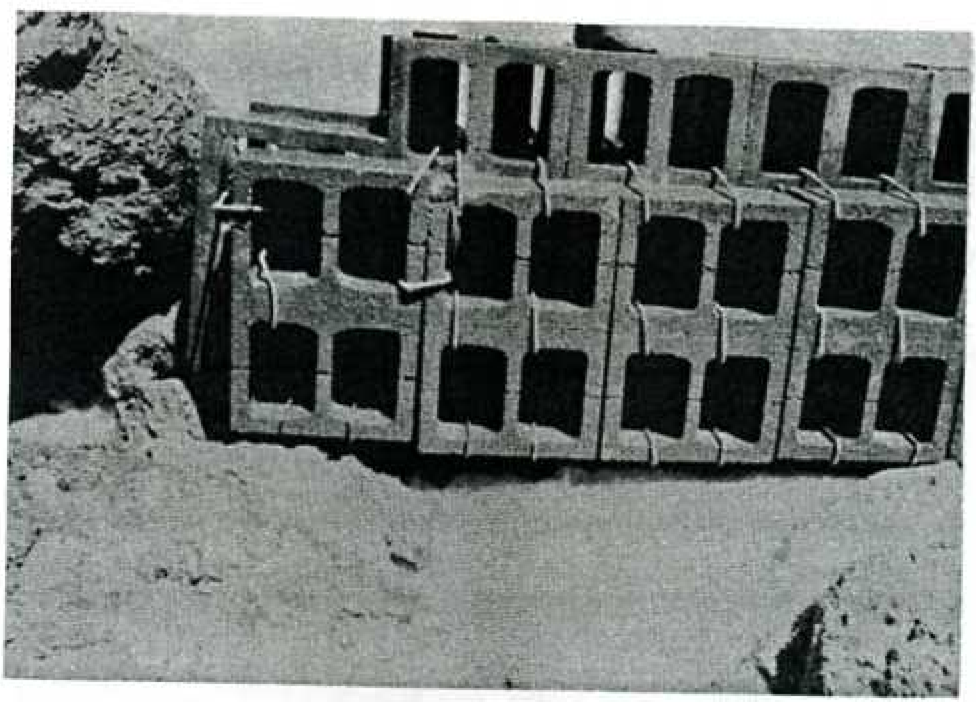

Figure 2-630. Landside of north end of Sandgrabber settling on the existing coral rock revetment, Bellows Beach, Hawaii, 5 September 1979.

the interconnections. A comparision of the Sandgrabber installations at Kualoa and Bellows yields some pertinent observations:

(a) The Kualoa Sandgrabber suffered little scouring and settlement compared to the Bellows Sandgrabber. Scouring and settlement were more localized for Kualoa than for Bellows, where the Sandgrabber settled uniformly over its entire length. The sand is much coarser at Kualoa than at Bellows, therefore providing a better foundation. When the water level is high at Bellows, the sand probably fluidizes, allowing the structure to sink.

(b) Southward longshore transport is much more predominant at Kualoa than at Bellows. There was therefore a significant impact on the downdrift shoreline at Kualoa, whereas virtually no impact on adjacent beaches was discernible at Bellows.

Table 2-107 provides volume calculations for changes between profiles that occurred between October 1978 and May 1980. The base line for this survey is stationed from approximately north to south. The direction of littoral transport is assumed to be onshore-offshore at the Bellows Air Force Station site. The table shows that the beach accreted during the monitoring period. This accretion seems due to the presence of the Sandgrabber, but it may also have been the result of a long-term trend of net accretion. Paradoxically, the volumetric analysis shows less accretion at the Sandgrabber than elsewhere at the Bellows site.

Table 2-107. Volumetric analysis of beach profiles at Bellows Air Force Station, Hawaii (30 October 1978 to 14 May 1980).

| Device | Station | Erosion ($yd^3$) | Accretion ($yd^3$) | Net accretion ($yd^3$) |
|---|---|---|---|---|
| --- | 0+00 | | | |
| | | 9.8 | 190.6 | 180.8 |
| --- | 0+50 | | | |
| | | 19.0 | 238.0 | 218.9 |
| Sandgrabber | 1+00 | | | |
| | | 15.1 | 220.4 | 205.4 |
| Sandgrabber | 1+50 | | | |
| | | 15.9 | 213.2 | 197.3 |
| Sandgrabber | 2+00 | | | |
| | | 30.8 | 101.9 | 71.1 |
| Sandgrabber | 2+25 | | | |
| | | 31.6 | 100.6 | 69.0 |
| --- | 2+50 | | | |
| | | 42.5 | 233.7 | 191.2 |
| --- | 3+00 | | | |
| | | 33.2 | 271.4 | 238.2 |
| --- | 3+50 | | | |
| | | 29.3 | 343.2 | 313.9 |
| --- | 4+00 | | | |
| | | 30.6 | 520.2 | 489.7 |
| --- | 4+50 | | | |
| | Totals | 257.8 | 2,433.3 | 2,175.5 |

## III. PROGRAM ANALYSIS BY SYSTEMS

The various shore protection systems evaluated at the demonstration and monitoring sites are reviewed in this section to compare their performance and to summarize lessons learned during construction and monitoring. Where performance was poor and possible methods of improving the system were considered too costly, the system was considered unsuccessful in that it demonstrated the futility of further experimentation with that particular system, and the concept was rejected. Where performance was good, the system was considered successful. Where damage occurred but the evidence indicated that the structure might be modified to perform better, within reasonable cost limits, the system was considered partially successful, and suggestions are offered as to possible improvements and methods of decreasing the cost of construction. Where appropriate, suggestions are also made as to (a) limitations of use that might be imposed by specific site conditions, (b) circumstances under which the system should perform best, (c) need for further research and testing, and (d) criteria for future design of similar systems.

The basic information presented in Section II is repeated in this section only to the extent necessary to avoid frequent back-referencing. This section categorizes the various systems under five general headings: bulkheads and seawalls, revetments, breakwaters and sills, groins, and nonstructural devices. Table 3-1 provides a listing of the shore protection systems evaluated and their locations.

### 1. Bulkheads and Seawalls.

a. Hogwire Fence and Sandfilled Bags. This type of bulkhead was demonstrated at one site only--Basin Bayou, Florida. Half of the structure (Fig. 3-1) was built with ultraviolet-resistant bags, which failed when forced outward into the wire mesh by backfill pressure as the retained embankment slumped from saturation. Concurrently, the bags were undermined by toe scour and dropped downward while being held tightly against the fence. As a result, many bags were torn open, and many fenceposts tilted seaward. The other half of the structure (Fig. 3-2) was built with polypropylene Advance Bags, which failed in about 6 months, mainly by decomposition of the bag material. No filter material was placed under or behind the bags in either half of the bulkhead, but the methods of failure indicated that this may not have been a contributing cause of structural failure. The demonstration proved rather conclusively that this type of construction cannot survive under conditions encountered at this site without major modification of construction methods. Moreover, the test results were not considered site-sensitive, because failure was attributed to inadequate structural design rather than to unusual site conditions. In fact, the wave characteristics were generally the same as or even less severe than those at many other sites, and the soil at Basin Bayou was no more friable that at most other sites.

The estimated low cost of this structure ($30 per foot) encourages a search for methods of improving the system to perform satisfactorily, considering soil properties and landforms existing at the site. Improvements might include the following: