Technical Report No. 22
for PE/K1.5/T-1

25 May 1982

TECHNICAL REPORT ON COASTAL EROSION IN KIRIBATI; VISIT TO SOUTH TARAWA, 22 January - 10 February 1982

by
Russell Howorth

Prepared for:

Committee for Co-ordination of Joint Offshore Prospecting for Mineral Resources in South Pacific Offshore Areas (CCOP/SOPAC) Work Programme.

As a Contribution by:

Dr. R. Howorth,
Department of Geology,
Victoria University,
Wellington, New Zealand;

Advisor/Consultant to
CCOP/SOPAC Project Office,
Suva.

C O N T E N T S

Technical Report No. 1
for PE/K1.5/T-1

25 May 1982

COASTAL EROSION IN KIRIBATI
VISIT TO SOUTH TARAWA
22 January - 10 February 1982

INTRODUCTION and BACKGROUND

Coastline movements are recognised as an important hazard on coral atolls by the Kiribati Government. Kiribati is spread over 3 million square kilometres of the Central Pacific and comprises 33 inhabited atolls of the Gilbert, Phoenix and Line Groups. This report concentrates on south Tarawa atoll (Fig. 1).

The administrative and commercial centre of Kiribati is on south Tarawa atoll and located in Betio (port and government departments), Bairiki (seat of Government), Bikenibeu (main hospital/nurses training school, principal secondary school and some government departments) and Bonriki (international airport). The coastline and beaches of south Tarawa atoll are being modified by erosion and accretion. Tarawa, in common with many other atolls has a long coastline per unit area of land and since land areas are in short supply, even small changes in the coastline may be of considerable significance.

Population density (Table 1) is high in south Tarawa, especially on Betio (20 per acre); and with limited natural resources, not only the land but also the lagoon and adjacent ocean areas are of prime concern to the Gilbertese people. Thus the consequences of changing sediment transport patterns particularly man-induced erosion that, for example, may result from building causeways, must be determined not only for the coastline but also for fishing and pollution of the lagoon environment.

	POPULATION	% TOTAL POPULATION OF KIRIBATI	AREA (acres)	POPULATION DENSITY		
				acre	sq.km.	sq.mile
SOUTH TARAWA EAST	5882	10.5	1441**	4	1009	2612
SOUTH TARAWA WEST (excludes Betio)	4413	7.9	580***	7.6	1880	4870
BETIO	7626	13.6	380*	20	4959	12843
SOUTH TARAWA TOTAL	17921	32.0	2401	7.5	1860	4817

* excludes 19 acres port, jetties, fuel tanks; and 15 acres sand spit east of Betio Clubhouse.

** excludes 61 acres airport; 282 acres Bonriki water reserve; and 946 acres Temaiku reclaimed area - fish ponds.

*** excludes 4 acres port; 67 acres Tearoraereke water reserve; 79 acres Ambo fish ponds; and 24 acres causeways.

TABLE 1: Population data extracted from the 1978 Census on Population and Housing, Ministry of Home Affairs, Kiribati (1980, Volume 1).

Coastline surveillance and coastal protection measures are hampered by (i) shortage of funds, (ii) shortage of expertise, (iii) lack of basic data, and (iv) high material costs. A coastal surveillance and protection programme is particularly important in con-

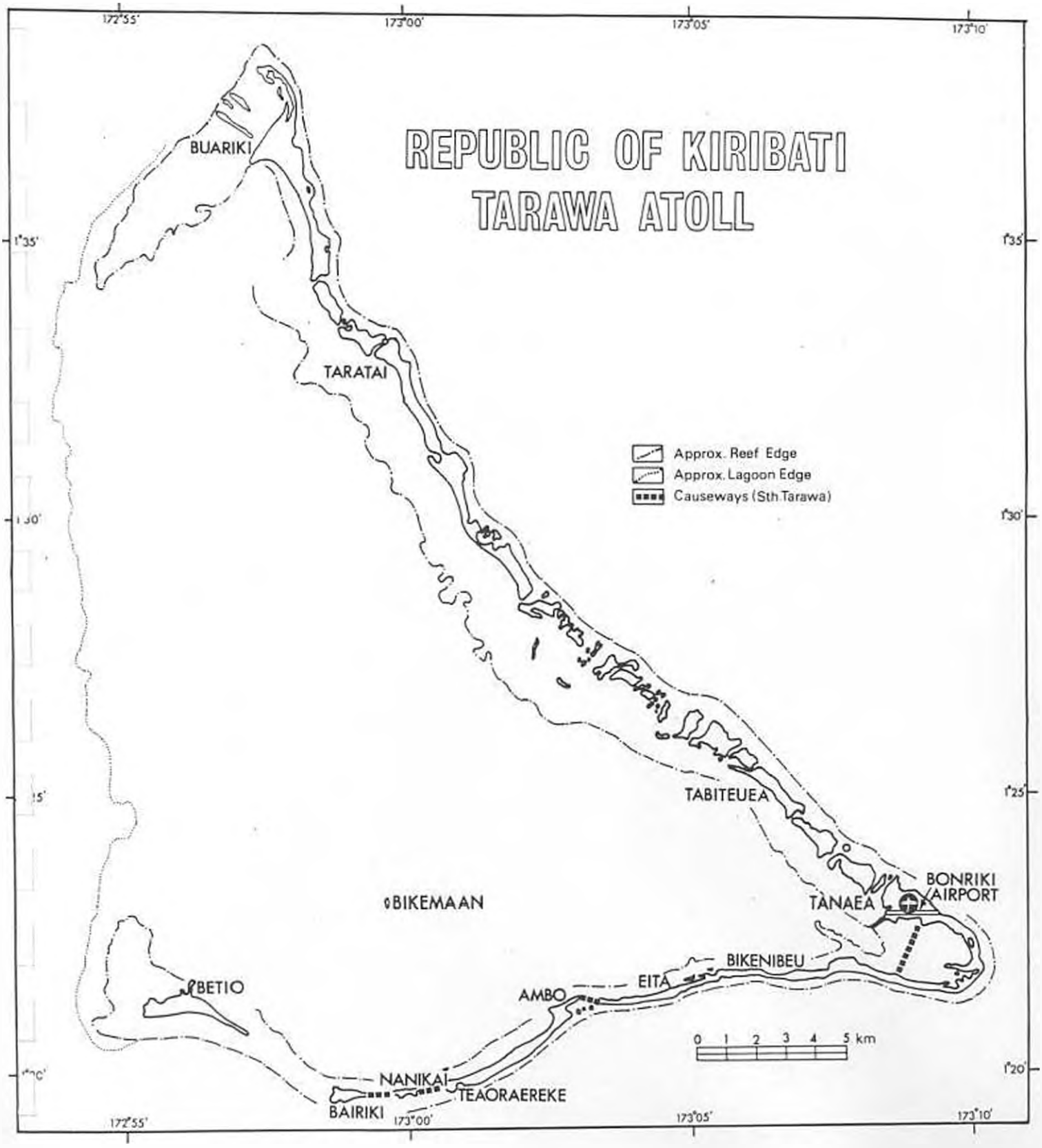

REPUBLIC OF KIRIBATI
TARAWA ATOLL
172°55'
173°00'
173°05'
173°10'
1°35'
1°30'
1°25'
1°20'
BUARIKI
TARATAI
TABITEUEA
BONRIKI AIRPORT
TANAEA
BIKEMAAN
BIKENIBEU
EITA
AMBO
BETIO
NANIKAI
TEAORAEREKE
BAIRIKI
Approx. Reef Edge
Approx. Lagoon Edge
Causeways (Sth Tarawa)
0 1 2 3 4 5 km

Fig. 1

nection with existing or proposed coastal engineering projects which include a proposed causeway between Betio and Bairiki a combined road-runway causeway between Betio and Bairiki, extension of port facilities, desalination plant, land reclamation, refuse disposal and sand/coral rock aggregate mining. A study of land reclamation, causeway construction, sea defence work and refuse disposal proposals was commissioned by the British Foreign and Commonwealth Office (Holmes 1976, 1979). More specifically, problems of coastal equilibrium were discussed in the design report for the Betio-Bairiki road causeway (Wilton and Bell 1977). In fact, construction of the causeway as a sand berm built of dredged lagoon sediment built on the existing sand shoal between Betio and Bairiki commenced in late 1978 only to cease in April-May 1979 due to contractual difficulties. The project is at present under review.

OBJECTIVES

(i) Mapping of coastal protection zones.

(ii) Investigation of historical shoreline changes.

(iii) Wave studies.

(iv) Longshore sediment transport.

(v) Determination of immediate causes of shoreline changes.

(vi) Beach and offshore surveys.

(vii) Determination of sand composition and origin.

(viii) Prediction of effects of development on sand transporting processes.

PERSONNEL PARTICIPATING

(i) Dr. Russell HOWORTH, Geologist, Principal Investigator; Geology Department, Victoria University, Wellington, New Zealand.

(ii) Messrs. Ian GRAINGER and David ROBSON, Chief Engineer and Senior Civil Engineer respectively, Liaison personnel; Ministry of Communication and Works, Kiribati Government.

(iii) Mr. Mapuola IOSUA, Gilbertese assistant; Ministry of Communication and Works, Kiribati Government.

(iv) The following personnel provided valuable help in many, varied ways. Without that help it would have been impossible to carry out the field work and data research in Tarawa:

- Mr. Paul TACIRATA; Secretary, Ministry of Natural Resources.
- Mr. Dominic MOSS; Director, Lands and Surveys Department.
- Dr. Gordon GROVES; Director, Atoll Research Centre (USP).
- Dr. Keith SULLIVAN; Director, USP Centre.
- Mr. Tapetulu MERANG; Superintendent, Works Department, Bairiki.
- Mr. Geoff LEECH; Officer-in-Charge, NZ Meteorological Office.
- Mr. Mike SULLIVAN; Manager, Tarawa Sewerage Project.
- Mr. Peter KANERA; Gilbertese resident on Betio 1943-1944.
- National Archives of Kiribati.

EQUIPMENT and FACILITIES

(i) Gilbertese field assistant.

(ii) Made available from Senior Civil Engineer's office, Ministry of Communication and Works, Betio, was the necessary surveying equipment for beach profiling: a level, legs, staff and 100m tape.

(iii) Daily transport to/from Otintai Hotel (Bikenibeu) and Bairiki was by taxi on instruction from Ministry of Natural Resources.

(iv) Motorcycle from Works Department vehicle pool used occasionally on Betio.

(v) Landrover for visit to Tabiteuea coral aggregate mining area provided by Works Department, Bairiki.

(vi) Lands and Surveys provided on request, maps and plan printing facilities.

(vii) Standard automatic exposure SLR camera - proved very difficult to get first class photographs of coastal protection zones; manual exposure should prove more successful.

RESULTS

It cannot be overstressed that the programme to investigate coastline processes and changes in Kiribati received the enthusiastic support from all government officials encountered.

Notwithstanding that social/economic pressures may over-ride any geological/physical constraints on development, the real physical implications of a development project and monitoring the "before" and "after" physical setting must be recognised to be of prime concern. In Kiribati, it is recognised that to initiate coastal zone surveys the country does not have, and is not likely to acquire in the near future, either the resources or manpower. Furthermore, a good deal of basic data is lacking.

The objectives defined were too ambitious to complete in a one man-three week visit. After discussion with local personnel, and consultation with the Project Office, it was resolved to concentrate during the visit on the Betio-Bairiki area of south Tarawa. The following results unless otherwise specified are thus applicable only to that area.

(i) Mapping of coastal protection zones.

The field survey carried out as part of this project defined 10 coastal protection zones on Betio and 8 coastal protection zones on Bairiki. Typical coastal protection measures are 1 to 2 metres high and include:

- vertical-near vertical walls of coral rock-coral head boulders; with or without a cement mortar;
- berms of coral rock-coral head boulders and, or concrete bagwork; with or without a cement mortar;
- gabion baskets and occasionally reno mattresses;
- dumped scrap metal.

Coastal protection has developed not only from initiation of new areas of erosion but also from the deterioration of earlier protection measures. Furthermore, any coastal protection programme has to recognise the following on site problems:

- supply of local coral boulders is becoming severely restricted in south Tarawa. The ocean reef platform, the traditional source area for the boulders, has been increasingly depleted in recent times and is now virtually exhausted. In addition, it should be considered that the very act of removing this material may encourage erosion of the ocean-beaches by reducing the frictional drag of the reef platform on the waves,
- supply (costs plus shipment) of imported materials is becoming increasingly expensive: these materials include cement, aggregate, gabion baskets,
- local labour though not in short supply is becoming more expensive and it is often difficult to provide adequate supervision,
- running costs for local heavy plant are escalating and it is uneconomic to consider shifting local materials large distances (more than 15-20km). The crusher at Bonriki processes coral rock collected by hand from the ocean reef platform at Tabiteuea (Fig. 1) and transported by tractor/trailer and barge. Cost at present A$65/cubic metre of 3/4 inch gravel,
- any project which involves a disturbance of the land (including reef platform) generally creates an outcry from the local people for compensation by the government.

In consideration of the above criteria the objectives of the field survey may be defined:

- to define coastal protection zones,
- to describe the morphology and structure of these zones,
- indicate areas for remedial work,
- establish, where possible, deterioration rates,
- establish rates of development in metres/year of coastline being protected,
- determine expected costs of continuing present development and remedial rates,
- consider alternative protection measures.

The coastal protection zones are defined as CPZ 1, 2, 3 ... for Betio and Bairiki and illustrated on Figure 2. The description of morphology and structure of each of these zones and indicated areas for remedial work is given in Appendix 1.

It has been possible to estimate deterioration rates. The vertical coral rock and mortar wall (Betio CPZ 2; Plate 19) has been in existence for some 20 years and shows no signs of deterioration.

New vertical coral rock walls without mortar (Bairiki CPZ 5 and 6; Plates 67 and 69) are a larger scale of traditional Gilbertese coastline protection measures. A good deal of the coral rock is platey in shape. It is important in loose rock wall construction that platey rock boulders be stacked vertically to reduce the effect of hydraulic lift.

Concrete bagwork berms with a cement mortar are common only around the harbour areas (Betio CPZ 1, 10 and Bairiki CPZ 8; Plate 56). In places this structure is beginning

to collapse, has been repaired, and major refurbishing of the harbour moles is likely to be necessary in the near future.

Loose rock berms (Betio CPZ 3, 9 and Bairiki CPZ 1) appear to require continual maintenance, particularly where poorly constructed. There is a tendency to repair loose rock berms with gabbions (Plate 20).

No new rock walls or berms are likely to be built due to the lack of coral rock. It is envisaged that maintenance of the present ones will be continued until such time as alternative protection is desirable. It should be noted that the recent new rock walls built in Bairiki (CPZ 5, 6) were constructed using beachrock blasted from the reef platform during the construction of the new sewerage outfall in 1981. In situ beachrock breaks up as a result of wave action (Plate 63), but this process should not be accelerated by man to meet a demand for coral rock.

The typical gabion is constructed from plastic covered galvanised hexagonal wire mesh panels. These panels are assembled into baskets on site, and adjacent baskets wired together where necessary. Common sizes are 2m x 1m x 1m and 2m x 1m x 0.5m.

Gabions have been in use at least since 1975, and gabion walls were referred to by Holmes (1976, 1979) who reported on the various coastal protection areas in existence in July 1975 and September/October 1978.

The main problem with existing gabions that result in deterioration and need for repairs may be summarised:

- coral boulders, especially coral heads, are difficult to pack into the baskets.
- lack of adequate tension on internal tie wires.
- movement of coral boulders abraids plastic coating and exposes bare metal.
- poor site preparation for gabion wall footing.

Lack of adequate tension on tie wires, poor site preparation and in part packing are likely to be eliminated by supervision. Abrasion of the gabion and in part packing problems are consequential on the shape of coral boulders and can only be eliminated by using other material to fill baskets. As the supply of coral rock is now virtually zero, a new fill material is required. The only reasonable alternative at present appears to be concrete blocks which are made locally in Bairiki. Some 125 blocks (400mm x 200mm x 200mm) stack neatly into a 2m x 1m x 1m basket with their flat surfaces horizontal. It is important that the top/bottom of the block faces the waves and a timber baffle is placed at the back of the gabion to prevent scouring of sand from behind.

A trial area of concrete block filled gabions has been constructed in Betio CPZ 5. (However, these gabions have been filled with the sides of the blocks face on to the waves! Plates 28, 29).

Holmes (1979) indicated costs for building a 1m high gabion wall using 2m x 1m x 1m baskets and coral rock as fill, to be close to A$52/basket (A$26/linear metre of wall). In 1982 the estimated cost to fill a similar gabion using concrete blocks is A$213 (Table 2).

By comparing the numbers of gabion baskets in the coastal protection zones in February 1982 with those reported by Holmes (1979, Table 1 and Figs. 4, 5, 6), it is

	1979	1982
Basket	36	83
Labour	8	12
Blocks @ 0.85¢	-	106
Plant Hire	8	12
TOTAL COST PER BASKET	52	213
	(Australian Dollars)	

TABLE 2: To illustrate relative costs of erecting a 2m x 2m x 1m gabion; (i) in 1978 and filled with coral rock; (ii) in 1982 and filled with concrete blocks.

evident that approximately 100 baskets/year have been erected during the past 3½ years (Table 3).

Though some gabions constructed were, without doubt for repair work, by far the majority were for new coastal protection. If a quarter of these were used for construction of 2m high "walls" (2 baskets, one on top of the other) then around 150m of new 1m high gabion coastal protection is at present being constructed per year.

Capital expenditure of around A$20,000/year will be needed to sustain the present development rate of gabion construction.

Coastal Defence Zone		September/October 1978*		February 1982	
		2x1x1	2x1x0.5	2x1x1	2x1x0.5
Betio	1	65	69	140	85
	2	-	-	-	-
	3	36	-	60	-
	4	20	-	26	-
	5	44	-	121	26
	6	27	-	27	-
	7	19	-	99	-
	8	-	-	52**	-
	9	-	-	83	3
	10	5	-	9	-
Bairiki	1	-	-	-	-
	2	-	-	-	-
	3	-	-	-	-
	4	-	-	10	-
	5	30?	-	3	27
	6	-	-	-	-
	7	-	-	-	-
	8	-	-	16	4
Total gabions		246	69	594	145
Equivalent 2x1x1 gabions		281		666	

* Data ex. Holmes (1979).

** Gabion walls erected out of choice rather than necessity, by Marine Training School.

TABLE 3: To illustrate that approximately 100 gabions (2m x 1m x 1m) have been erected per year between September/October 1978 and February 1982.

(ii) Investigation of historical shoreline changes.

Prior to 1943; there is very little reliable data.

November 1943-1945;
Battle of Tarawa and the latter part of World War II; there is good data for Betio from battle records, photos and emplacements/ruins.

1945;
US Naval Intelligence vertical air photo survey from which 1:25,000 maps produced in 1947.

1953-1954;
Government lease documents/plans. Lease titles include a tape and compass sketch plan of each property. On many titles the "coast" is marked, and this is presumed to be the high-water spring tide line. Main problem is locating a known point of reference - most reliable seems to be roads. Even so it is likely that some roads have been at least in part re-aligned. For example, original road on south edge of Betio airstrip was repositioned and straightened several metres to the north between 1954 and 1969.

1958;
Vertical air photo survey by New Zealand Aerial Mapping. These only cover Bairiki and the southeast tip of Betio.

1968-1969;
Vertical air photo survey by Fiji Department of Lands and Mineral Resources, from which the Department of Overseas Surveys in United Kingdom produced maps.

1972;
1:1250 and 1:2500 maps published by Department of Overseas Surveys. Maps still in use.

post 1972;
No recent vertical aerial photography and no attempt by local Department of Lands and Surveys to update coastline changes.

Interpretations from above data sources are in part confirmed and supplemented by discussion with Mr. Peter Kanera.

Prior to the Japanese occupation of Betio the only development of the coast had taken place on the north side of Betio; the government jetty dating from the 1920s was an open berm with wooden deck structure that extended north across the lagoon reef platform from a point close to the entrance to the present boat yard. To the east, a smaller jetty belonging to Burns Philp comprised a wooden deck on piles (Fig. 2).

The only modification by the Japanese was to add a small V-shaped extension to the government jetty. These jetties did not restrict either the flow of water or longshore transportation of sand along the lagoon reef platform.

Japanese troops constructed a landing strip and heavily fortified the coastline with large gun emplacements on the northwest, southwest and southeast corners of Betio.

Following the Battle of Tarawa, and prior to the 1945 air photo survey, the Americans developed the port area. A channel was dredged across the lagoon reef flat immediately east of the government wharf. This channel had solid moles on either side built of dredged reef mud/sand protected with aircraft landing matting.

Between existing jetty and new channel some reclamation was carried out to create a harbour/wharf area.

The Americans also cleaned up the reef platform and piled up the wrecked equipment in a "war graveyard" on the west coast of Betio.

It can be seen on the 1945 photo of Betio taken by US Navy Intelligence that little or no accretion of sand had occurred on the east side of harbour and the entire graveyard area is clearly visible adjacent to the concave west coast.

Betio coastline changes 1945-1982

In the 37 year period of data it appears that the northeast and south coasts of Betio have been fluctuating by up to 20m (Fig. 2 and Fig. 3). For example, the gun emplacements in southeast Betio are now well within the tidal zone (Plate 43). Similarly the gun emplacement near the cemetry (Plate 33), whereas the 1953 lease titles indicate the coastline to be 15 $\pm$ 5m to the south. To the east along the south coast, however, the lease title data indicate accretion of some 15 $\pm$ 5m.

It is likely that this definite fluctuation of the coastline is natural, and in response to the interplay of the dynamic physical processes at work. If this is so then the rates and limits are still poorly defined. At the same time the stranded pontoon on the beach in central-south Betio has had an affect on sand transport rates (see below).

To the east of the harbour by 1954 substantial sand build up had taken place, at a rate close to 10,000m^3/year. Further accretion occurred between 1954 and 1969. To the west of the harbour erosion commenced in the region of CPZ 2 and 3.

West and northwest Betio coasts have undergone substantial changes since 1945. There has been a maximum of between 75-100m of accretion in both areas. An amphibious vehicle and a landing craft stranded during the Battle of Tarawa on US Navy "Red Beach One" can be seen today in the area known locally as "Te Makin Accretions", northwest Betio (Plates 1, 2 and 3).

Similarly the 1945 war graveyard in the concave beach of West Betio is now almost completely buried, and that coastline virtually straight (Plate 24).

The development of the northwest corner of Betio which has undoubtedly undergone progradation is now totally confused by the Betio Council rubbish dump.

The southwest corner of Betio has undergone recession of 40-50m since 1945 if one presumes that the gun emplacements were originally above tide level (Plate 32).

Construction of the Betio-Bairiki road causeway began in late 1978 from the Betio end. A total of 44,000m^3 had been dredged from the lagoon and emplaced in two areas separated by a channel to the southeast of Takoranga Point before construction ceased (Wilton and Bell Consulting Engineers Monthly Report for March/April 1979). Subsequent modification has resulted in an extension of Takoranga Point of some 500m. This area is now becoming vegetated (Plates 44, 45). Between 1945-1969 Takoranga Point appears to have receded up to 50m together with erosion on the south side. A tidal passage immediately off the point in 1969 is now completely closed off by the recent development.

Bairiki coastline changes 1945-1982

In contrast to Betio more coral beachrock is evident, and clearly this acts as a holdfast for sand and controls the shape of the southwest corner of Bairiki.

A comparison of the lease titles with the 1969 air photos (1972 maps) indicates a nett increase in width (north-south) of up to 20m (Fig. 2). Reasons for this are uncertain, whether both the north and south coast have accreted is unknown. Undoubtedly some accretion occurred on the north coast after construction of the harbour. The effect of constructing the causeway to the east from Bairiki to Nanikai is also unknown.

In 1981 blasting of the beachrock off the southwest corner of Bairiki for the sewerage outlet destroyed part of the beachrock platform protecting the beach. As a result some 10-20m of coastline recession occurred.

At this stage it is of interest to note that from a study of air photos, Wilton and Bell Consulting Engineers (1977) report in Sect-on 5.1.9 "The general conclusion we have reached after studying all photographs covering the 32 year period since 1945 is that the islands of Betio and Bairiki are stable and show minimal signs of offshore sand movements and longshore drift movements".

The data presented above does not support that statement.

(iii) Wave Studies.

At about the time of the Wilton and Bell Consulting Engineers design report for the Betio-Bairiki Causeway (February, 1977), a waveboard was installed on the ocean reef platform off southeast Betio, and data was recorded on a daily basis. More recently (Dave Robson, pers. comm.) data has been recorded, but may be unreliable.

I had discussions about the establishment of a surf observation programme on the ocean side of south Tarawa with Dr. Groves, Dr. Sullivan and Mr. Leech. There was agreement on the desirability of such a programme. If it could be initiated, the following observation areas are recommended:

Observation area:	Principal observer:
Bonriki (south end of Causeway)	Dr. Groves.
Bikenibeu (School)	School staff (?).
Teaoraereke (USP Centre)	Dr. Sullivan.
Southeast Betio (existing waveboard)	Ministry of Communication and Works.
Southwest Betio (Meteorological Office residence)	Mr. Leech.

(iv) Longshore sediment transport.

No data available for Bairiki except for accretion east of harbour.

Along northeast and south Betio there are several sites where an east-west longshore beach sediment direction is indicated by a "groyne effect". The groyne effect is seen where an obstruction in the longshore transport zone has produced a build-up of sand on the updrift side and a corresponding depletion of sand on the downdrift side. No rates have been calculated.

Sites where the groyne effect can be observed include (compare Plates 6, 7, 8, 9):

- Betio harbour.
- Marine Training School wharf.

- Stranded dredge hulk used for 1978-1979 causeway development.
- Stranded pontoon from World War II in centre of south coast.
- Gun/bunker emplacements southeast Betio.

In west and northwest Betio, after considering shoreline changes since World War II, it is evident that longshore sediment transport occurs from south to north. Further sand is carried around the northwest corner and into the large bay.

Prior to construction of the harbour, northwest Betio was evidently in dynamic equilibrium with respect to south/north and east/west current movements. Subsequently, the latter no longer operates and as a result substantial accretion has occurred.

Large sand shoals to the west of Betio occur on the western reef platform. This sand was derived from east/west transport and is presumably still being derived from movements along the south coast.

Large scale movements of sand are known to occur when strong (30 knots) occasional westerly winds coincide with spring tides. Fish traps on the western reef platform fill with sand only to be cleared during following "normal" conditions. It is during these westerly conditions when most of the accretion has taken place.

Wilton and Bell Consulting Engineers (1977, Section 3.3; Fig. 7) suggested that longshore drift for the proposed Betio-Bairiki causeway was in the order of 80,000 cubic yards/year split approximately equally between ocean and lagoon beaches. This estimate was based on 1970-74 wind records, and was noted to be unreliable because of the numerous assumptions.

(v) Determination of immediate causes of shoreline changes.

It is evident from the preliminary work that Betio and Bairiki shoreline changes are of two distinct types:

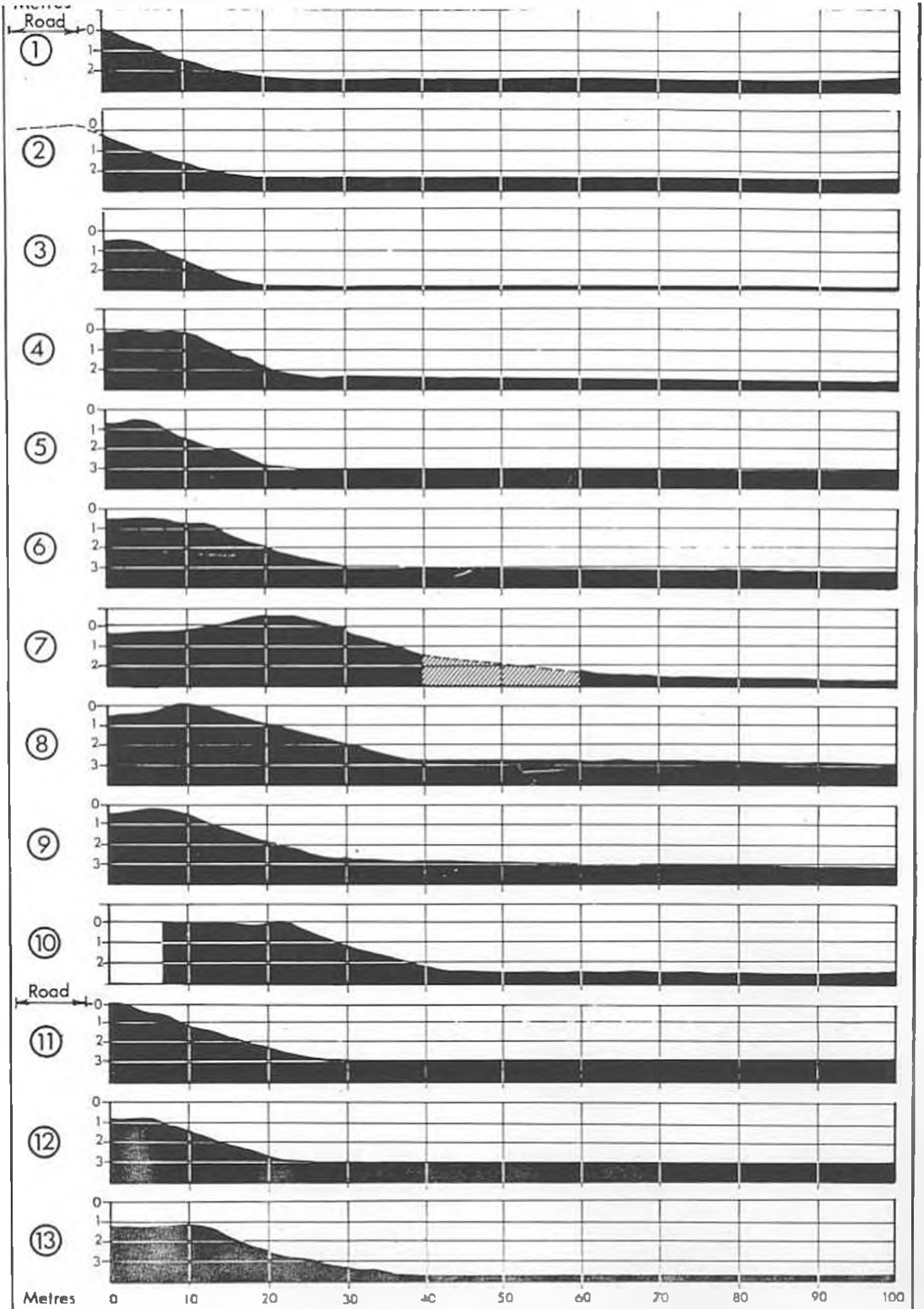
- generally small scale definite changes in position of beach. Limits and rates yet to be defined. These changes are natural and result from an interplay of the dynamic physical processes at work.
- permanent changes induced by man, modified shoreline now subject to natural fluctuations. Most dramatic change brought about by construction of Betio harbour. It remains to be established whether a substantial increase in size of Bairiki was a response to causeway construction to the east.

(vi) Beach and Offshore Surveys.

Offshore surveys have been carried out in late 1981 to the north of proposed Betio-Bairiki causeway and off Betio harbour by Dr. G. Gauss (separate CCOP/SOPAC report).

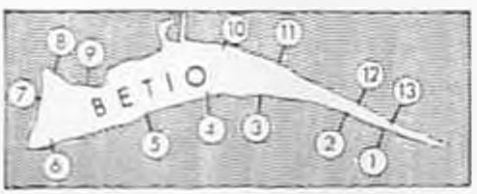
Several (10) beach profiles on the north and south sides of southeast Betio were levelled once in 1978. Unfortunately only one datum peg could be located in January 1982.

A total of 11 beach profiles in Bairiki and 13 in Betio were levelled in February 1982 (Figs. 4 and 5). Rather than put in datum pegs which are subject to local curiosity, care was taken to use fixed points (concrete) within the present environment.



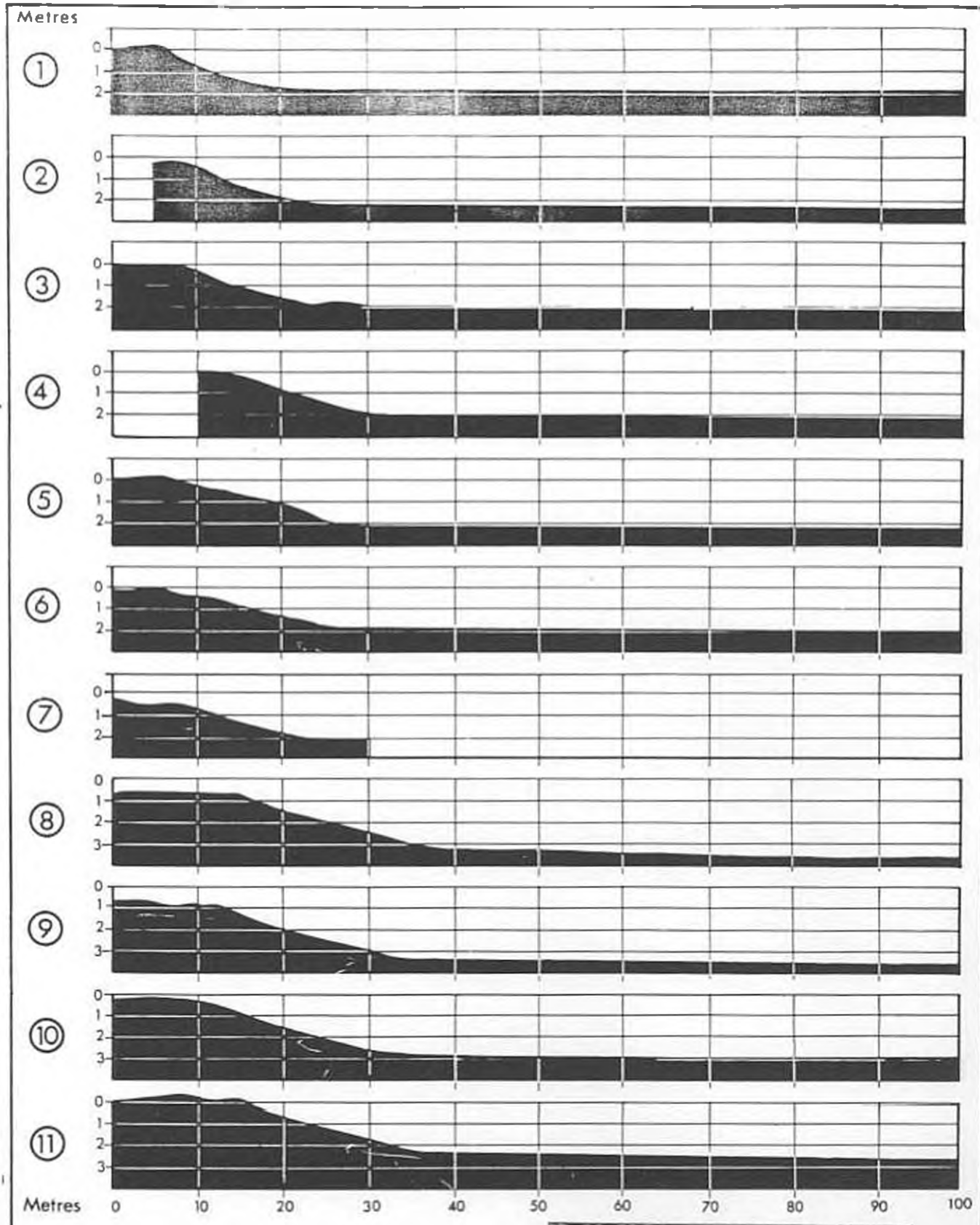
BETIO BEACH PROFILES

VERTICAL EXAGGERATION = 2·5



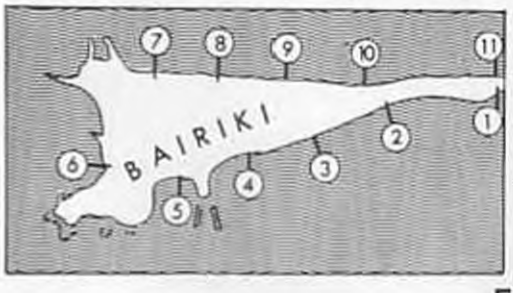
February 1982

FIG.4



BAIRIKI BEACH PROFILES

VERTICAL EXAGGERATION = 2·5



February 1982

FIG.5

The positions of horizontal and vertical datum for each profile are shown in Appendix 2.

A tide gauge exists in Betio harbour and a levelled datum has been established outside the Lands and Survey Office, Bairiki. Various levels also appear on maps throughout south Tarawa but datum are uncertain and thought to be tied to a former hydrographic chart. At this stage it is not necessary to tie the vertical datum for the beach profiles with respect to each other.

It is hoped to monitor these, and any additional profiles as might be surveyed, every six months or whenever significant changes occur. As a result a detailed description of beach morphology will be developed.

(vii) Sand composition and origin.

No work attempted.

(viii) Prediction of effects of development on sand transporting processes.

At this stage with minimum data it would be unwise to predict the effects on sand transporting processes of any major developments. For example, would it have been possible to predict the coastline changes consequent upon the construction of Betio harbour? Clearly though, one is now much wiser about the processes at work with this documented case history.

Similarly, at this stage it is not possible to predict what if any permanent coastline changes will result from a causeway between Betio and Bairiki. At the same time it is not evident that any coastline changes that may take place will be detrimental.

Coastal protection zones in areas where secular erosion has occurred were evidently developed (usually involves building a dwelling) during a period of progradation.

From the point of view of coastal protection, it would appear quite sensible to replenish the beach in areas which are undergoing secular erosion.

The sand to replenish these beaches must come from a source almost/or entirely lost to the present beach system. This source should be easily accessible. It would seem logical to test the feasibility of using a front-end loader and tractor/trailer working at low-tide to recover sand from the sand shoals to the west of Betio and stockpile it on Betio. This may well be a very viable economic alternative to the existing gabion style of coastline protection.

If it takes $25m^3$ to replenish a linear metre of beach following 5m of lateral erosion, then to supercede the present gabion construction rate would require $3750m^3$ of sand per year. This could be recovered from a circular shoal one metre thick and approximately 35m radius.

CONCLUSIONS

(i) Erosion, accretion and longshore transport are occurring as natural processes and man-induced processes on Betio and Bairiki, south Tarawa atoll.

(ii) These processes are hazardous in that they induce coastline changes. An historical record of changes exists for the past 39 years (1943-1982).

(iii) Population density on Betio and Bairiki is high, and the coastline long compared with land area, therefore people and property are at risk.

(iv) Government recognises the risk, but does not have the resources or man power to assess the level of risk and determine ways to mitigate the risk.

(v) Coastal protection measures at present involve extensive use of coral rock. Coral rock to construct rock walls, rock berms and for use in filling gabion baskets is becoming scarse. Gabions filled with concrete blocks will be expensive (estimated close to A$20,000/year at the present rate of construction).

(vi) Beach replenishment using sand recovered from shoals on the reef platform west of Betio may be a feasible alternative to present coastal protection measures.

(vii) CCOP/SOPAC should seek to continue and develop this work programme and encourage the Kiribati Government in the idea of setting up a Coastal Protection Unit.

RECOMMENDATIONS

(i) Re-level existing beach profiles on Betio-Bairiki, and locate additional profiles where necessary, especially along coast of south Betio.

(ii) Carry out coastal mapping of remainder of south Tarawa from Nanikai to Bonriki, and locate beach profiles where necessary.

(iii) Assess the effects of the construction of the three causeways already in existence in south Tarawa.

(iv) Determine the directions of sediment movement, and estimates of amounts being shifted, together with rates, in south Tarawa.

(v) Initiate a surf observation programme on the ocean (and possibly lagoon) sides of south Tarawa, local personnel must take responsibility on a daily basis.

(vi) Determine quantity of sand on the reef platform off west Betio. Establish the feasibility of this sand as a likely source area for beach replenishment.

(vii) Continue regular monitoring of beach profiles (every 6 months).

(viii) Commence assessment of data being collected.

(ix) Visit other islands in Kiribati, as requested by Government.

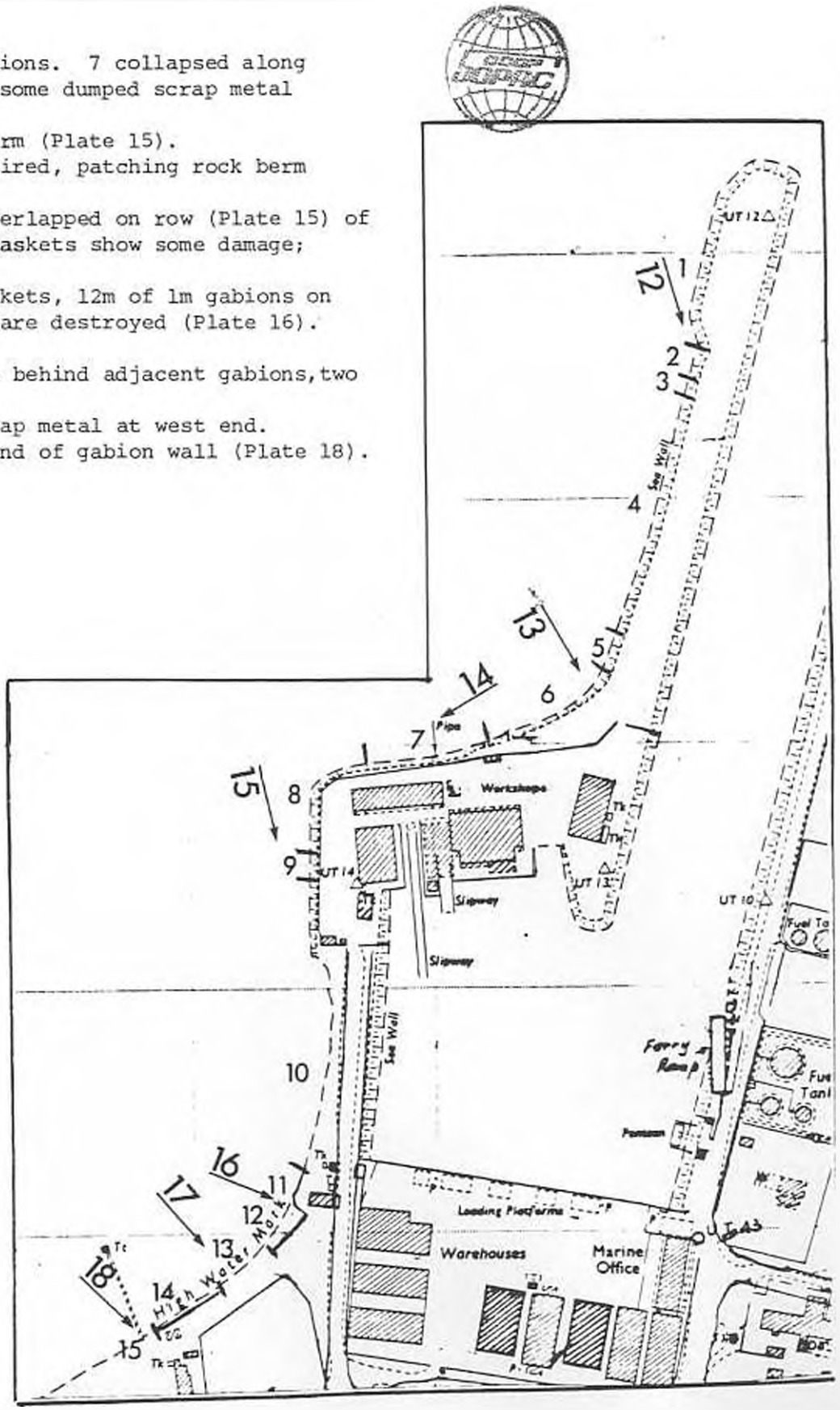
(x) Train local staff wherever possible in monitoring/observation/recording tasks.

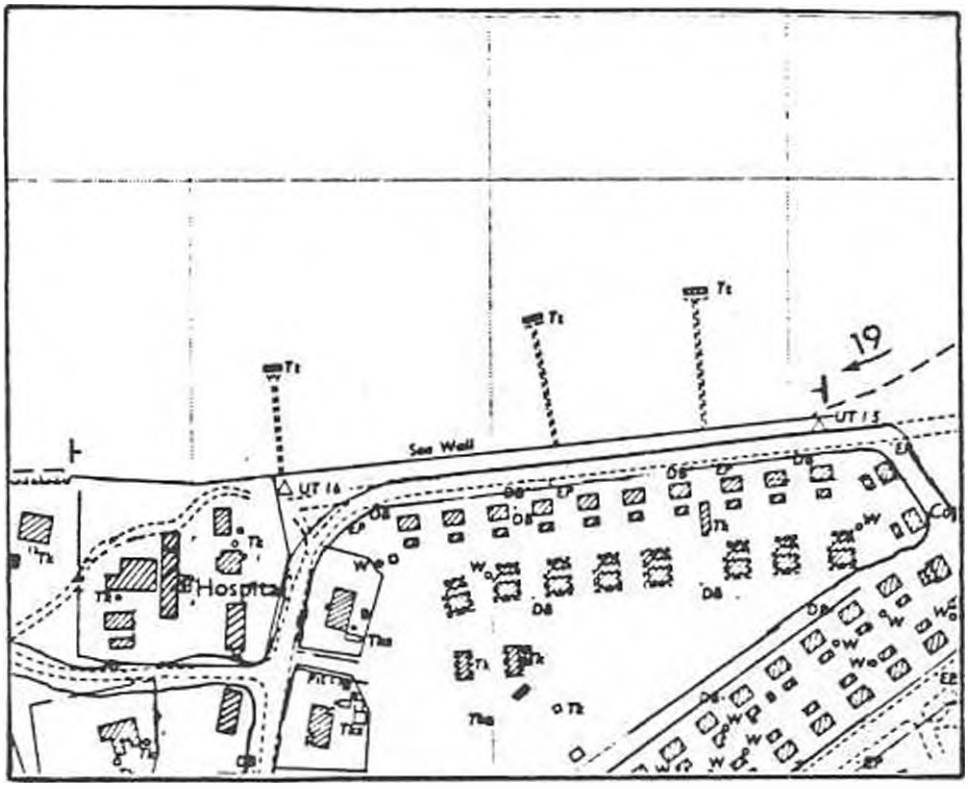
Appendix 1: Coastal Protection Zones, Betio and Bairiki, February 1982. (Areas for remedial work are shown by an asterisk).

Beach CPZ 1

Generally, west harbour mole is on a concrete bag berm structure.

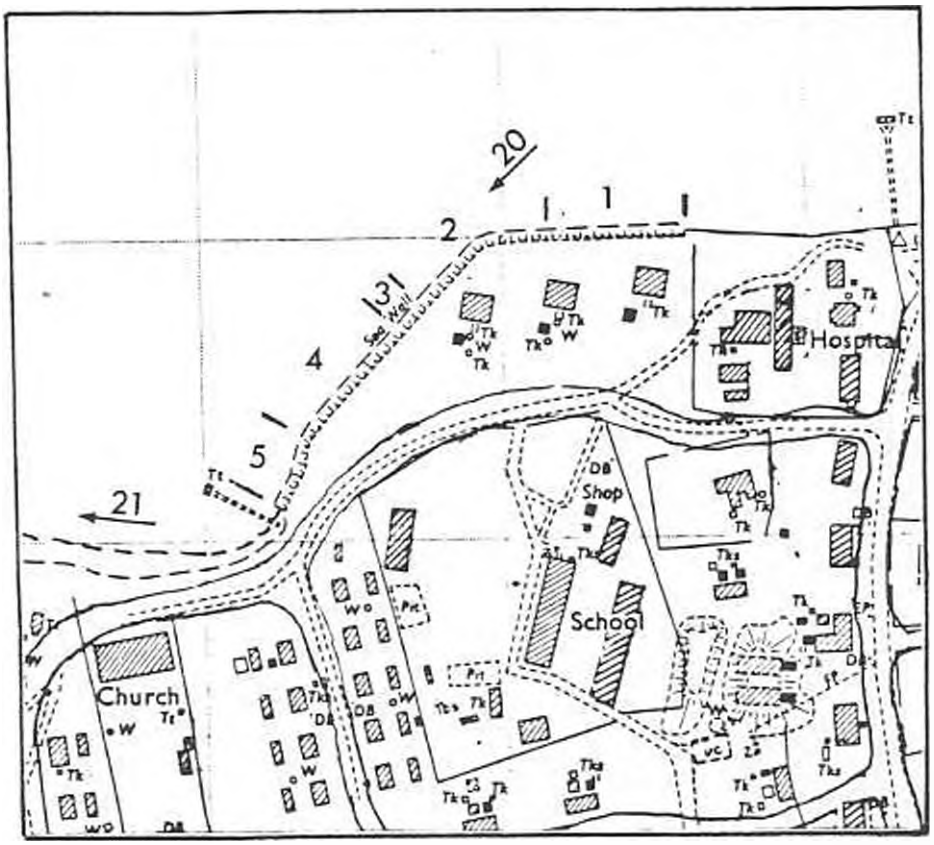
1. Bag berm.
2. 14m of 1m gabions behind row of 0.5m gabions. Poorly filled with mortar on top; existed in 1978; Generally in good repair.
3. 6m loose rock berm collapsed.
4. Rock berm.
5. 12m of 0.5m gabions all empty; existed in 1978; some dumped boatyard scrap metal; 30cm erosion scarplet at HWS line.
6. Beach (Plate 13).
7. 36m double layer of 1m gabions. 7 collapsed along front; existed in 1978; some dumped scrap metal (Plate 14).
8. Concrete veneer on rock berm (Plate 15).
9. 3 gabions damaged and repaired, patching rock berm (Plate 15).
10. 116m of 1m gabions half overlapped on row (Plate 15) of 0.5m gabions, almost all baskets show some damage; existed in 1978.
11. 14m double row of 0.5m baskets, 12m of 1m gabions on corner return, 4 of which are destroyed (Plate 16).
12. 30m of 1m gabions.
13. 26m gap for canoe, erosion behind adjacent gabions, two trees lost (Plate 17).
14. 30m of 1m gabions some scrap metal at west end.
15. Erosion occurring behind end of gabion wall (Plate 18).





Betio CPZ 2

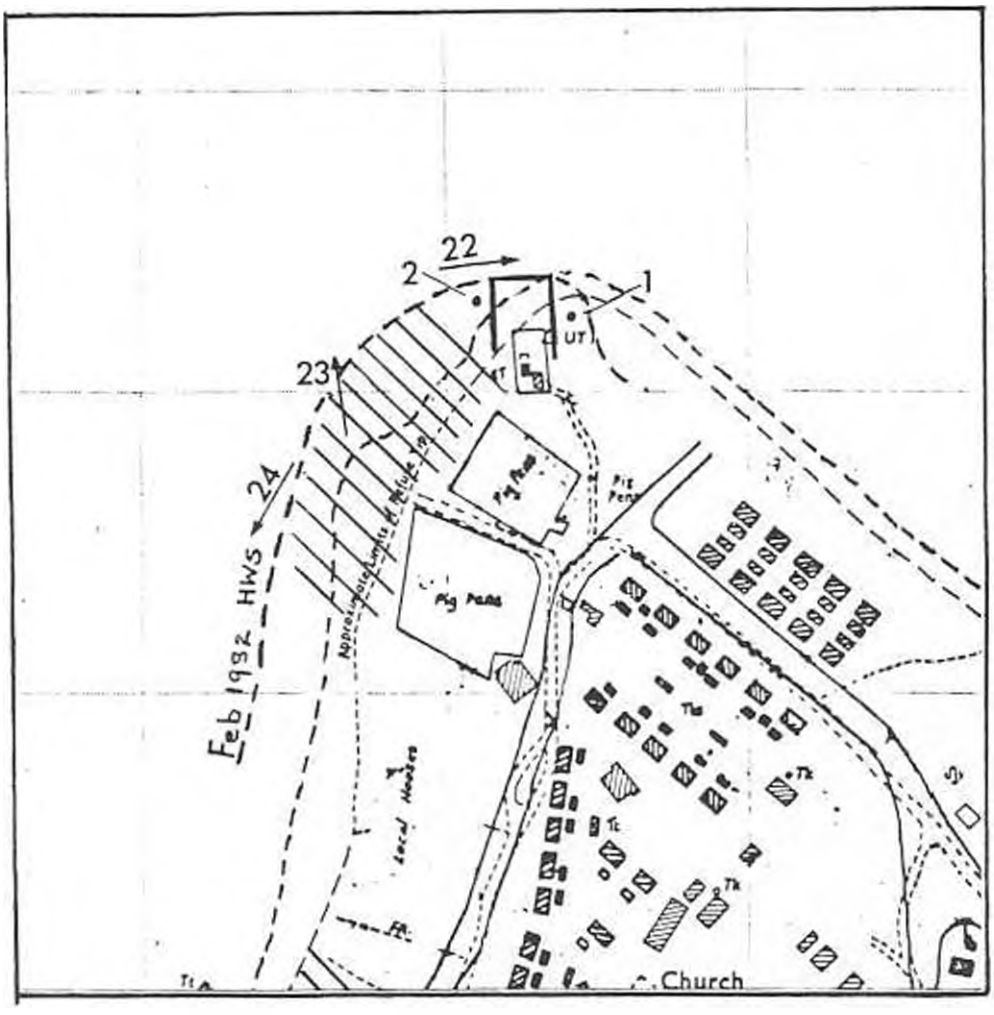
Vertical seawall up to 40cm thick; 1.5-2.0m high of cemented coral rock, coral heads and concrete. In 1978 wall in good condition showing no signs of erosion or accretion. In February 1982 wall in good condition, in one or two places local yard extensions for house sites existed in front of seawall (Plate 19).



Betio CPZ 3

Original seawall uncemented concrete bag berm; only area 3 remains undamaged (Plate 20).

1. 36m of 1m gabions, existed in 1978, now damaged and repaired with 0.5m gabions.
2. 28m of 1m gabions in good repair.
3. Berm.
* 4. 36m of 1m gabions, existed in 1978, now 7 need repair.
* 5. 20m of 1m gabions, in good repair but some scouring behind.

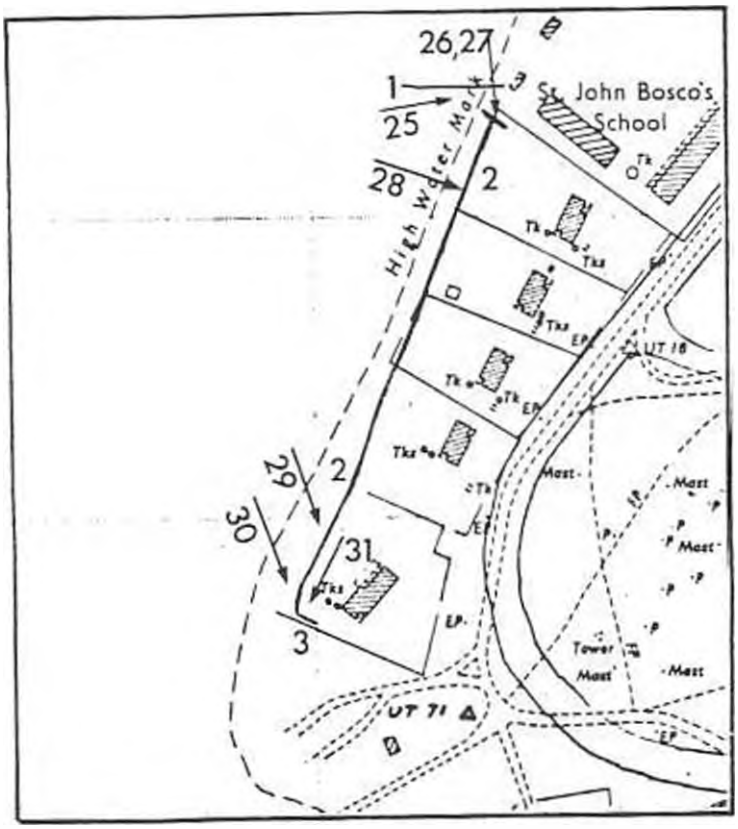


Betio CPZ 4

* In 1978 20 1m gabions badly filled and slumped but not abraided. In February 1982 these baskets were in place, generally full but need repairs. 6 new gabions had been placed on top of existing gabions along front with one reno mattress at east corner, and two at west corner (Plate 22).

* Te Makin Rubbish Dump (Plate 23, 24). It would be an advantage to control the emplacement of rubbish so as to minimise reworking onto reef platform at high tide. A scheme similar to that suggested by Holmes (1979) for Nanikai would be acceptable.

1. Accretion burying gabions.
2. Accretion since 1978.

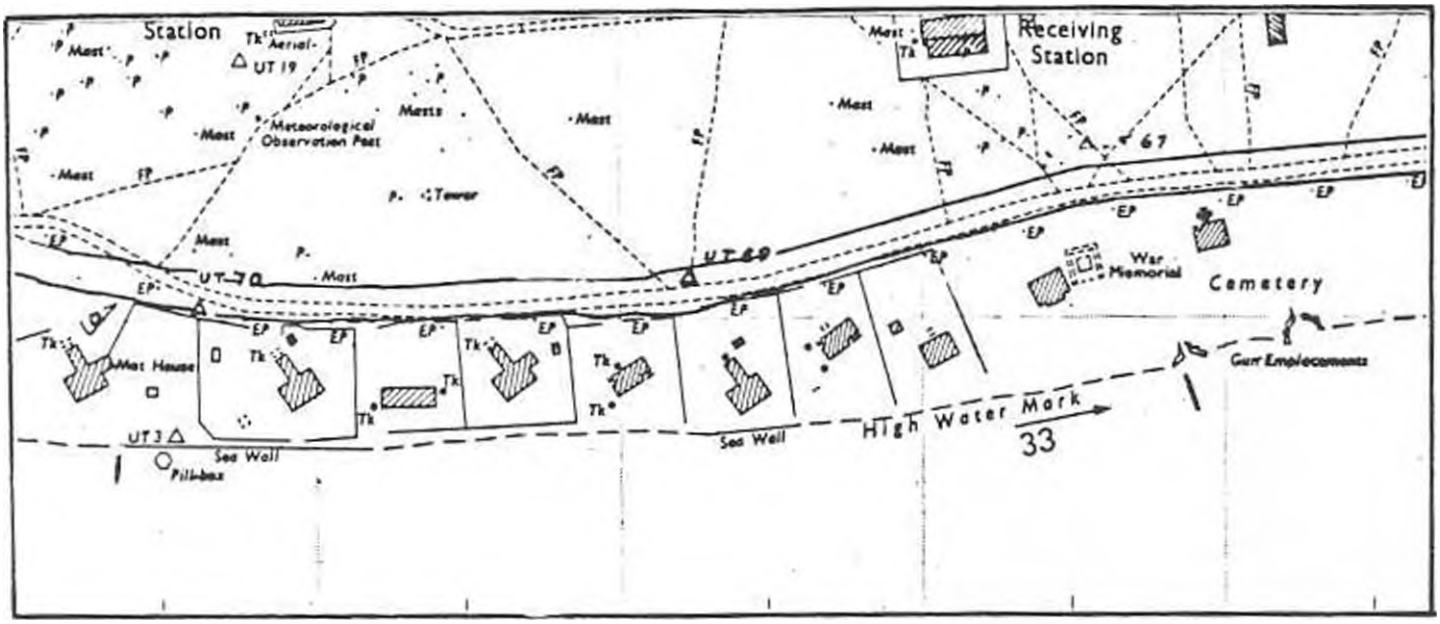


Betio CPZ 5

In 1978, 44m of southern end of a new gabion wall under construction, baskets loosely filled and distorted. Eventually completed for approximately 150m. Overtopped and badly damaged by high spring tides during period of westerly winds in December 1980.

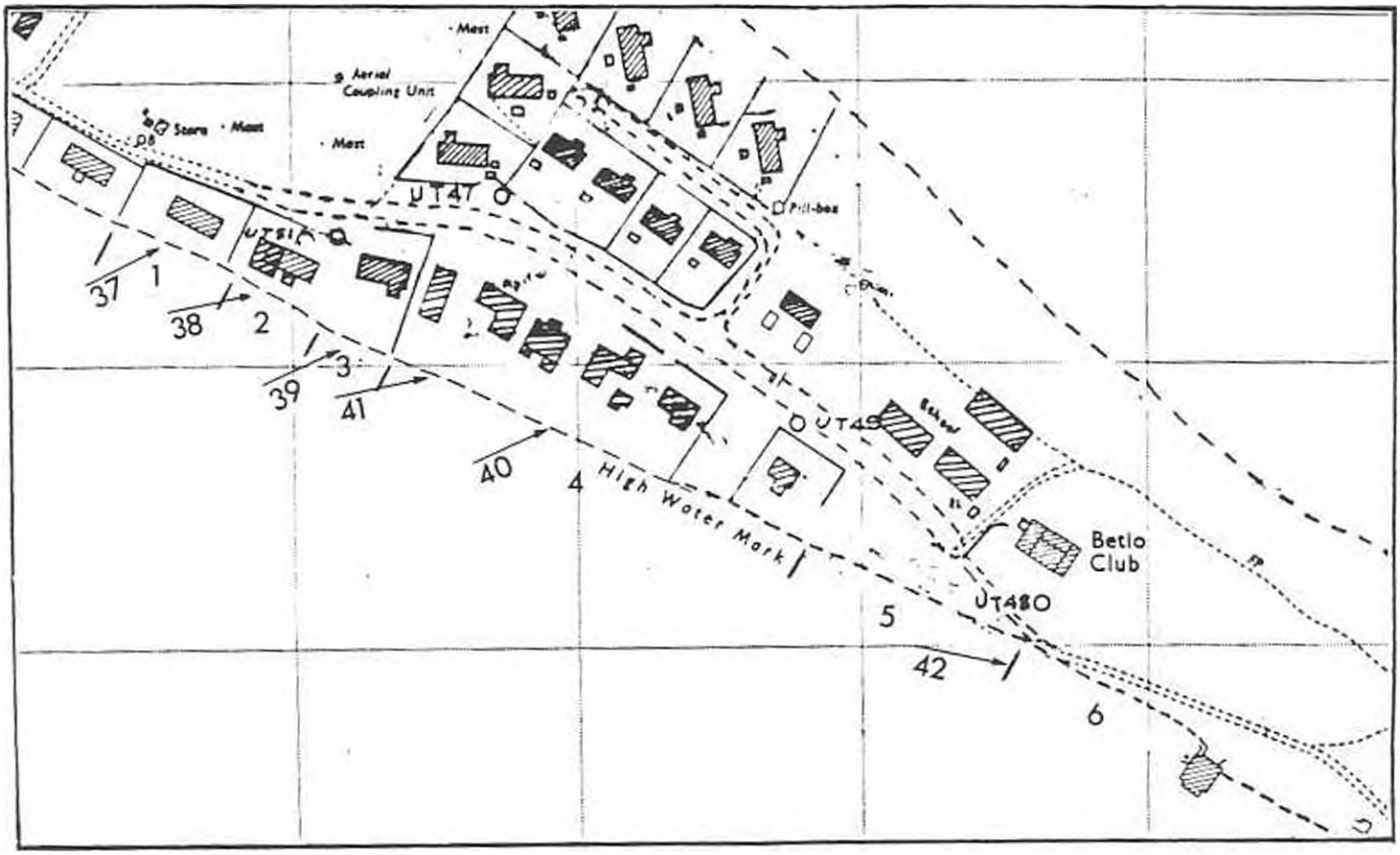
February 1982,

* 1. Southwest corner of school toilet block being undermined (Plate 25), erosion occurring between toilet block and north end of gabion wall (Plate 26).
* 2. Approximately 165m gabion wall, generally double layer of 1m gabions but some single layer on damaged earlier gabion wall; 15 gabions filled with concrete blocks, blocks need restacking face down in baskets; in gabions at north end platey coral rock stacked vertically following local custom (Plate 27, 28, 29, 30, 31).
3. Accretion at south end to top of gabions during last 12 months (Plate 30, 31).



Betio CPZ 6

Date of construction of seawalls marked on 1972 base maps is unknown. These walls no longer evident, presumed buried. In 1978, 54m of 1m gabions in good repair at head of beach west of gun emplacements. 22m of gabions were clearly visible at east end, rest buried.
In 1982, gabions buried and grassed over (Plate 33) except for 10m at east end; 30cm of each basket visible.

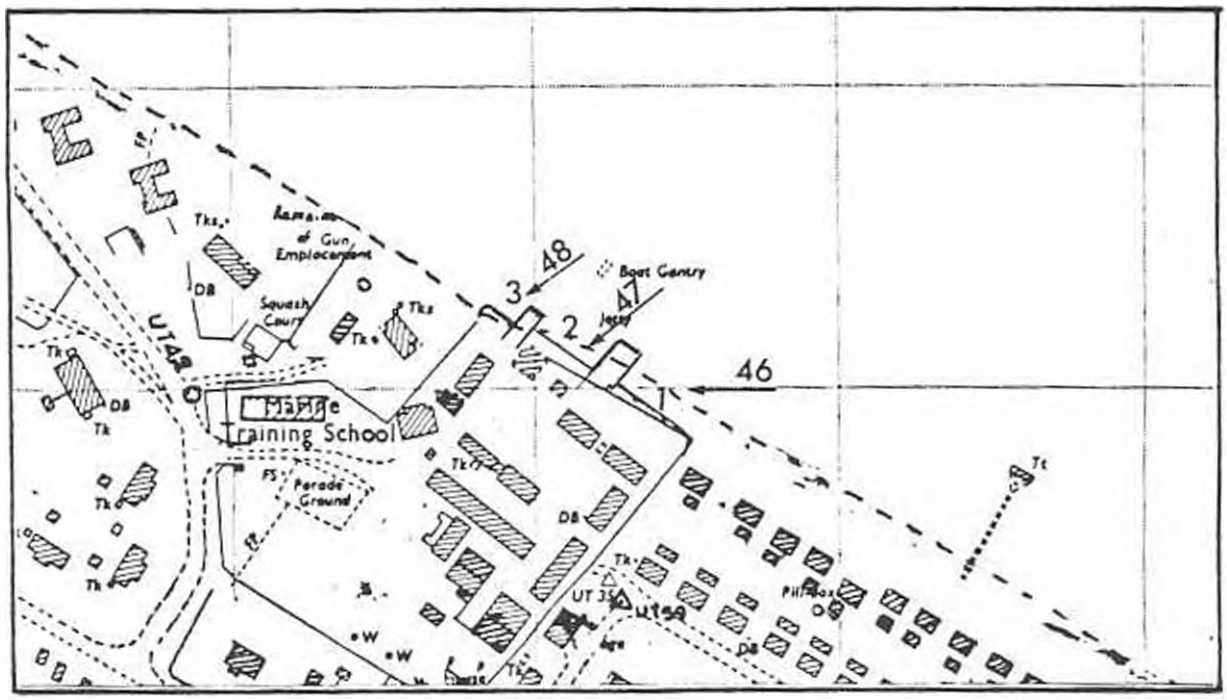


Betio CPZ 7

* 1. Erosion occurring, 3m retreat in front of house and two trees lost (Plate 37).
* 2. 38m of 1m gabions of which 3 are damaged and some being refilled, existed in 1978 (Plate 38).
* 3. Gap for boat access, scouring around adjacent ends of gabion walls (Plate 39).
* 4. 160m of 1m gabions of which 27 are damaged (Plate 40, 41).

5. Beach.

6. Former seawall to west of bunker marked on 1:1250 map (1972), now beach; wall presumed eroded (Plate 42).



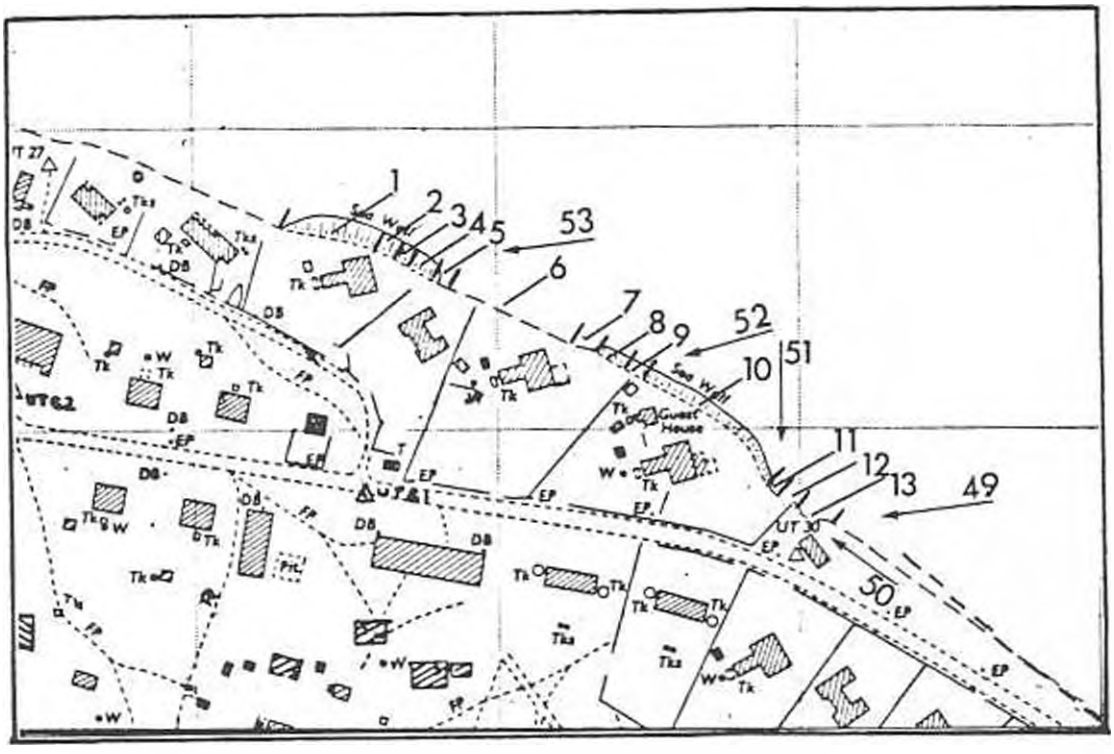
Betio CPZ 8

Gabions around boat ramp and jetty of Marine Training School.

* 1. 14, 1m gabions around head of boat ramp, two alongside ramp broken (Plate 48).

2. Double layer of 10, 1m gabions (including two on jetty corner), lower layer cemented over except two covered in scrap metal, front face of upper layer exposed with top surface almost entirely cemented over (Plate 47).

3. What appears to be a layer of reno mattresses are now almost completely buried as a result of accretion (Plate 46).



Betio CPZ 9

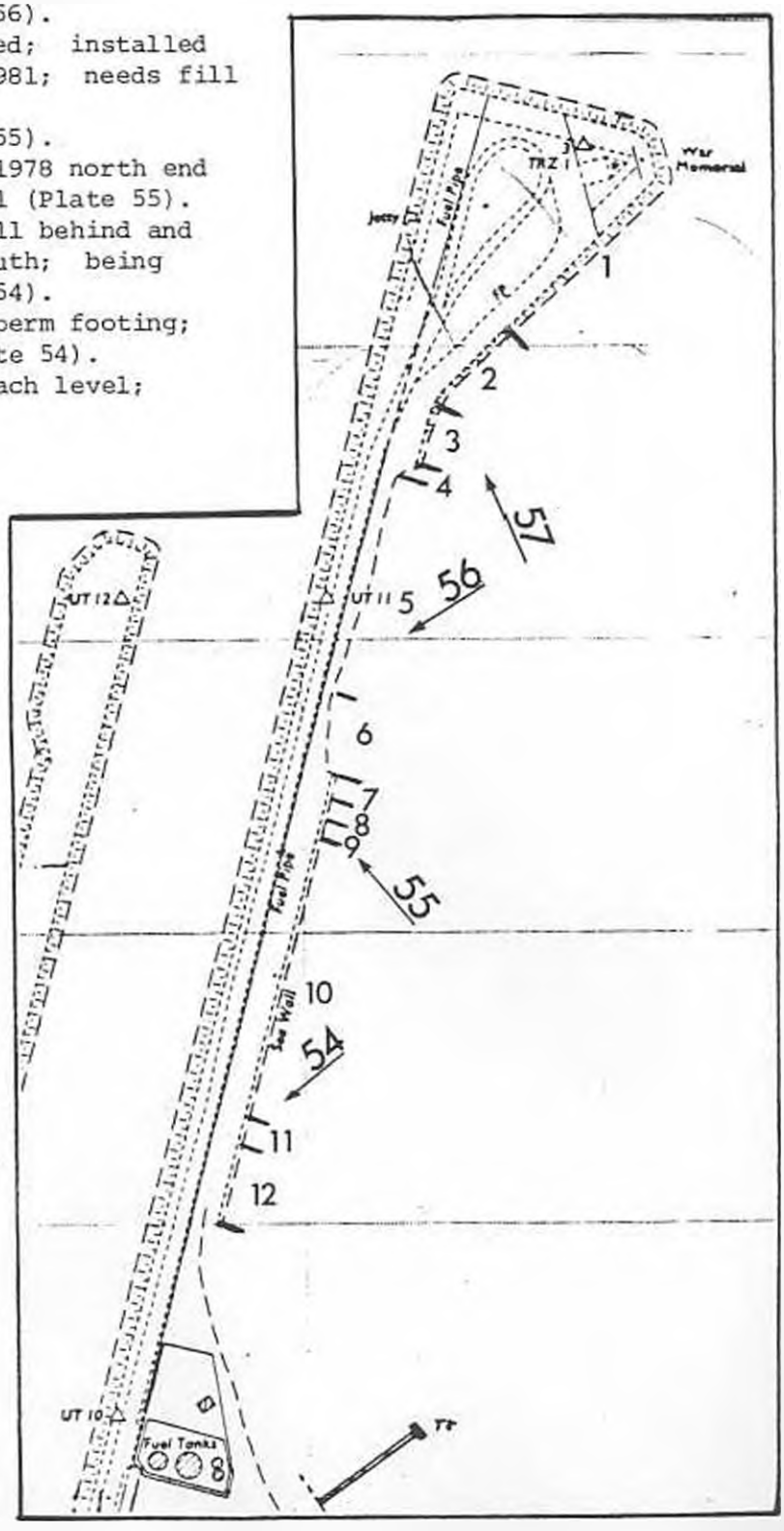
Original protection was a loose rock berm, now extensively modified by repairs.

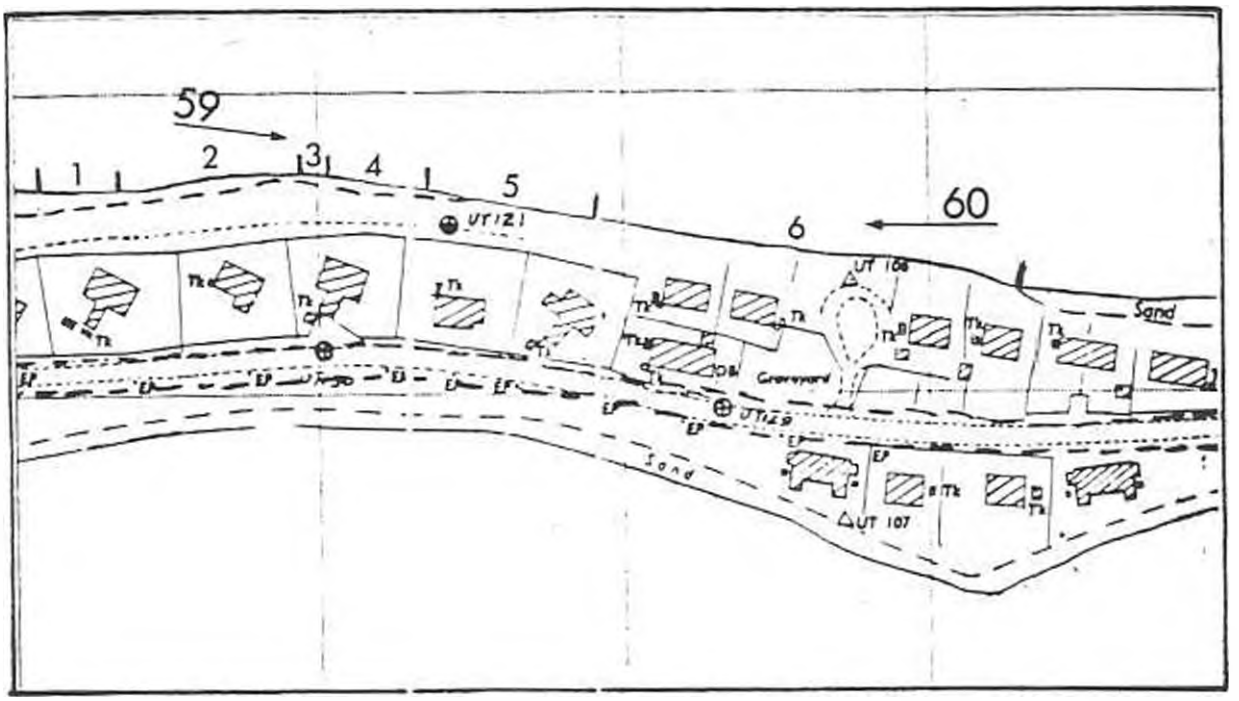
1. 30m of 1m gabions (except one 0.5m gabion at east end), poorly filled and deformed but intact, some sand build-up at base, existed in 1978 (Plate 53).
2. c. 5m loose rock berm (Plate 53).
3. 4m of 0.5m gabions, new and well filled (Plate 53).
4. 6m of 1m gabions, one broken at east end. Existed in 1978.
5. c. 7m loose cement bag berm (Plate 53).
6. 42m of 1m gabions, five damaged, rest poorly filled (Plate 53).
7. c. 5m loose rock berm.
8. 10m of 1m gabions except one new 0.5m gabion at west end, 1m gabions existed in 1978 (Plate 52).
9. c. 10m rock berm (Plate 52).
10. 58m of 1m gabions of which at least 12 need repair; existed in 1978 (Plate 51).
11. 6m of 1m gabions; new, almost completely buried by sand.
12. Beach, some large concrete slabs, some scouring in past.
13. 16m of 1m gabions almost completely buried, existed in 1978 (Plates 49, 50).

Betio CPZ 10

East harbour mole is a concrete bag berm structure, now repaired in many places generally by a loose rock berm or gabions.

1. Concrete bag berm.
2. Loosely packed coral rock berm - repairs to original berm (Plate 57).
3. Concrete bag berm, some scouring at base (Plate 57).
* 4. Collapsed concrete bag berm (Plate 57).
* 5. Concrete bag berm repaired at base with large concrete slabs at base where scoured; further scouring evident (Plate 56).
6. Loose coral rock berm (Plate 56).
* 7. Coral rock berm, cement grouted; installed after collapse in April/May 1981; needs fill at back (Plate 55).
8. Loose coral rock berm (Plate 55).
9. 10m of 1m gabions existed in 1978 north end gabion replaced April/May 1981 (Plate 55).
10. Loose coral rock berm; no fill behind and reducing in height towards south; being repaired at north end (Plate 54).
11. 8m of 1m gabions on low rock berm footing; some scrap metal at rear (Plate 54).
12. Low rock berm virtually at beach level; submerged at HWS (Plate 54).

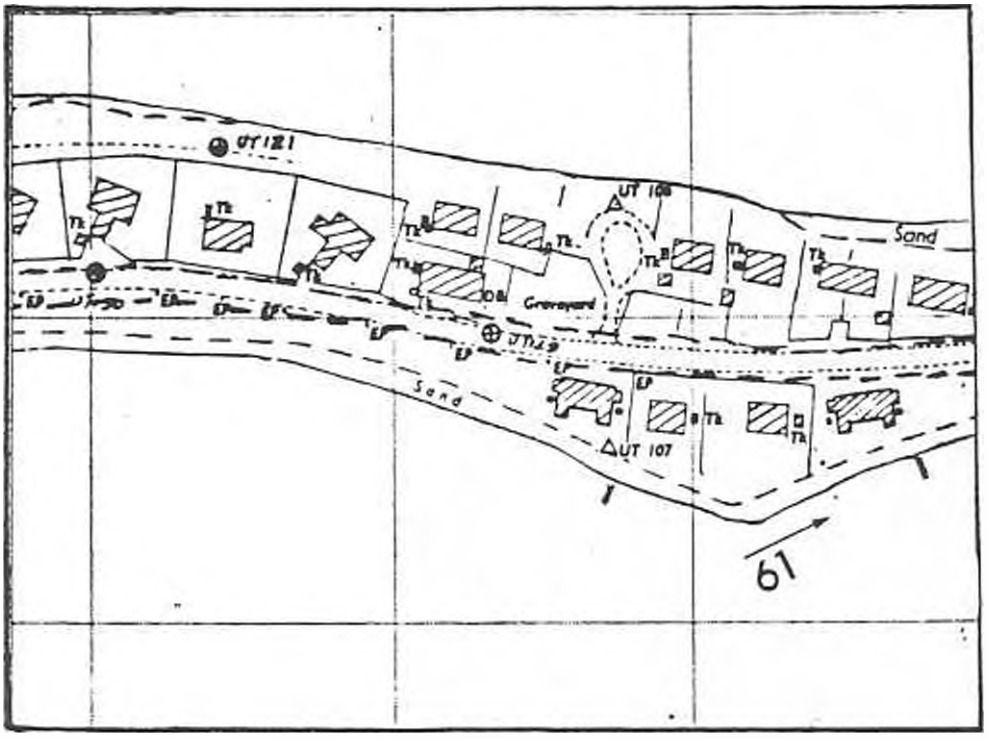




Bairiki CPZ 1

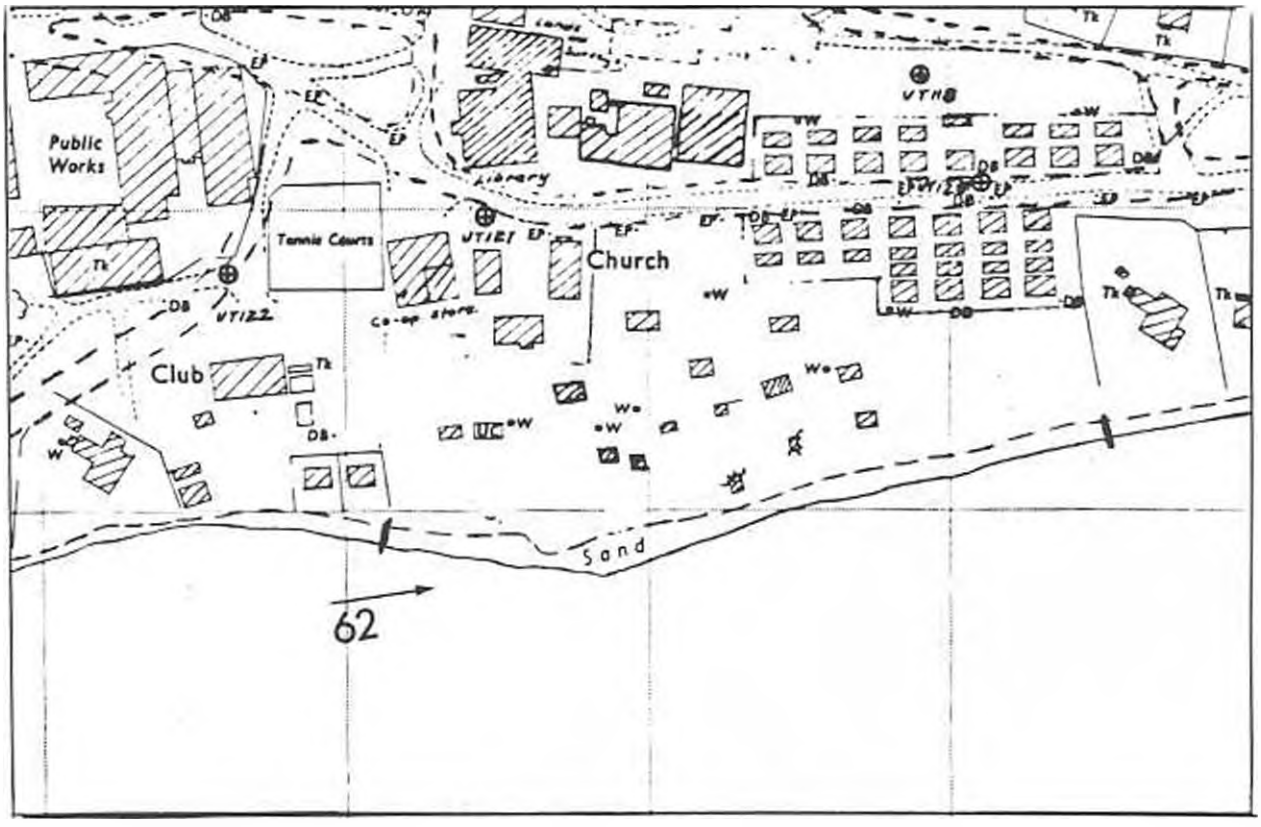
Original coastal protection was a low coral rock berm now extensively repaired, and generally showing some sand build-up at base.

* 1. Deteriorated rock berm (Plate 59).
2. Rock berm on beach rock platform and/or sand.
3. Grouted rock wall.
* 4. Poorly repaired rock berm.
* 5. Repaired rock berm, deteriorated boat ramp separated 5 and 6.
6. Repaired rock berm with sand build-up at base (Plate 60).



Bairiki CPZ 2

* At present no protection exists. However, erosion is occurring along HWS line exposing tree roots in a 20-30cm scarplet along the frontage of three properties (Plate 61).



Bairiki CPZ 3

Beach frontage for Bairiki village community.
All along beach head villagers have taken their own precautions against erosion. Measures generally include a coconut log wall with dead vegetation packed in behind logs. Erosion does not appear serious at this point in time (Plate 62).

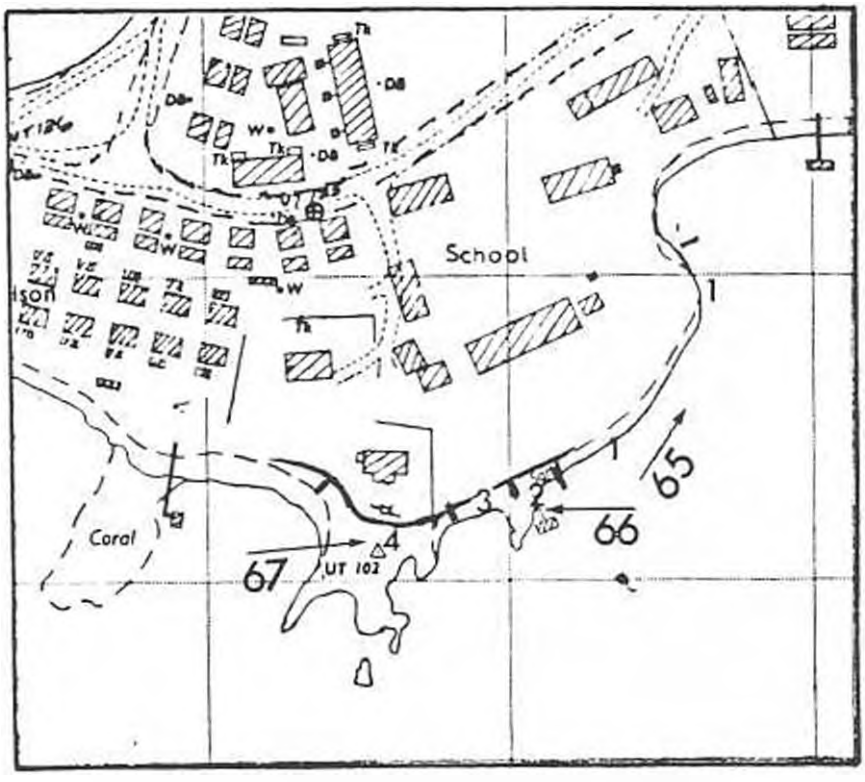
Bairiki CPZ 4

Residency Point protected by beachrock coral breccia platform, platform is being steadily broken up by scouring beneath it and then cracking into slabs. Seawall around point built onto platform.

* 1. Low, vertical wall of loose coral rock and old concrete slabs around point, some scouring of tree roots behind wall at HWS tides (Plate 63).

2. 20m of new 1m gabions (2-3 years old), well filled.

* 3. At west end of gabions natural beach profile exists but scouring occurring behind gabions (Plate 64).



Bairiki CPZ 5

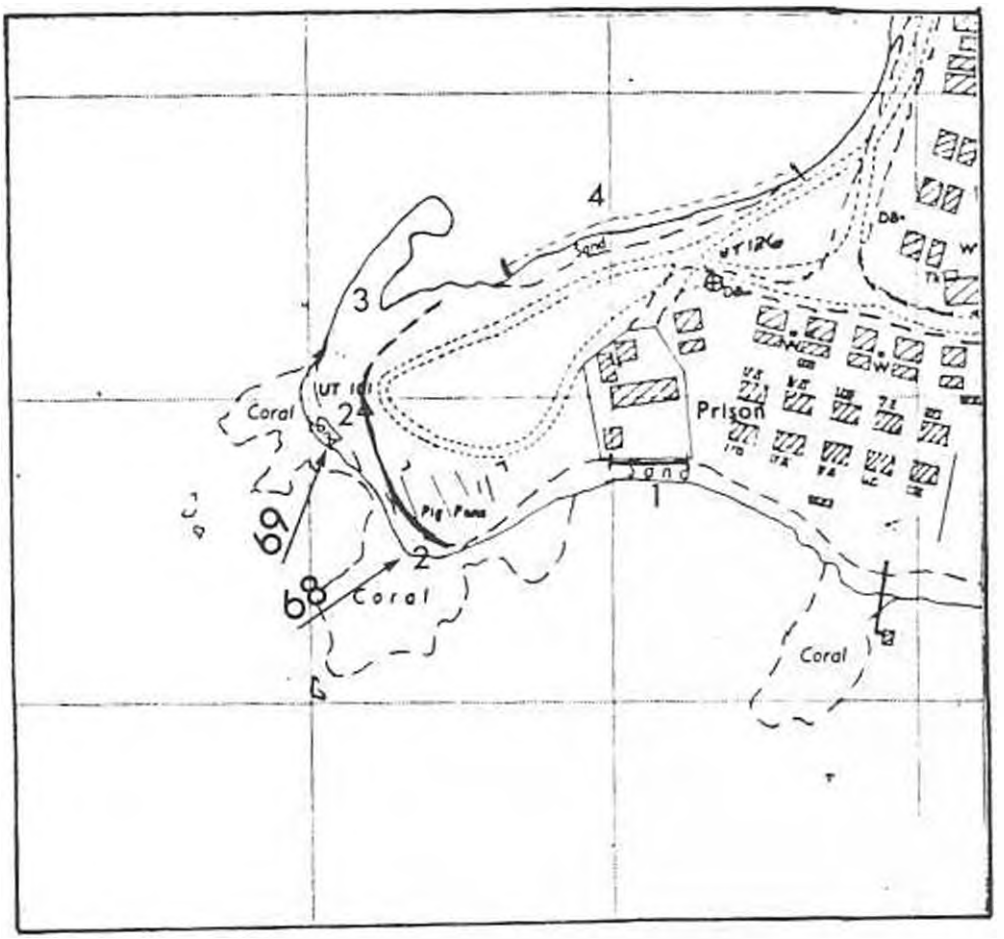
In 1978 this area, at Bairiki Primary School was being eroded, and a wall comprising a single layer of 1m gabions was being constructed. Erosion has continued and this gabion wall is now largely replaced by a loose vertical coral rock wall.

* 1. Erosion occurring, exposing up to 1m from ground surface to beachrock platform, plenty of exposed roots, five coconut trees washed out (Plate 65).

* 2. Loose, coral rock wall, 0.5-1.0m high, scoured behind.

3. 18m triple layer wall of 0.5m gabions, top 2 layers set back on bottom layer (Plate 66).

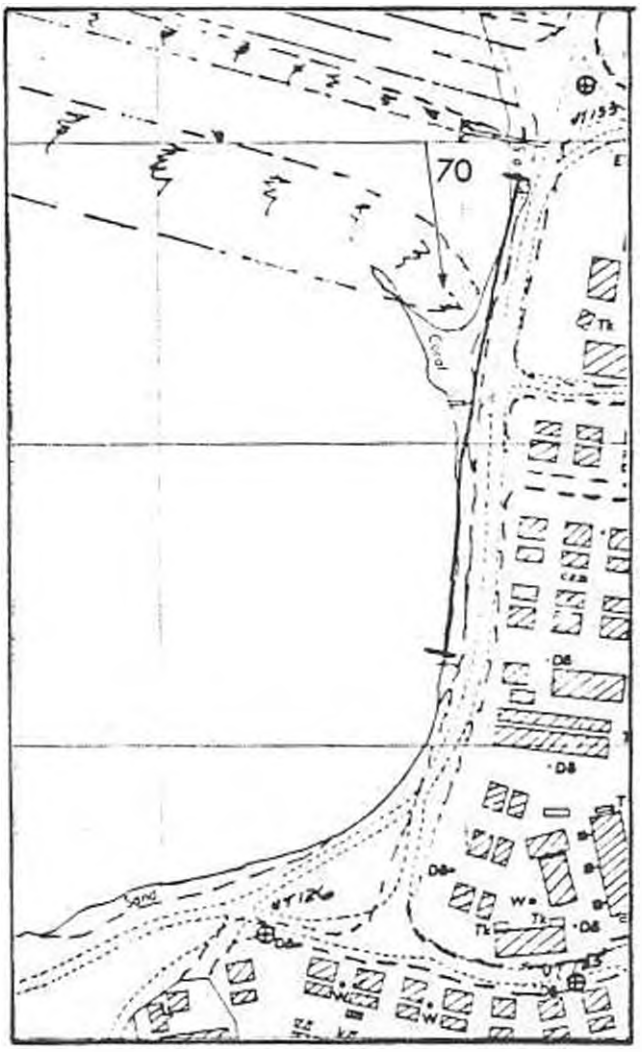
* 4. New, loose coral rock vertical wall with 3 old gabions still to be replaced on point, at western end wall needs finishing into beach profile (Plate 67).



Bairiki CPZ 6

Southwest corner of Bairiki, shape of coast controlled by position of beachrock coral platform. Recent blasting of this platform during construction of outlet for new Bairiki sewerage scheme has disturbed the platform and resulted in up to 20m recession of the coastline at the pig pens.

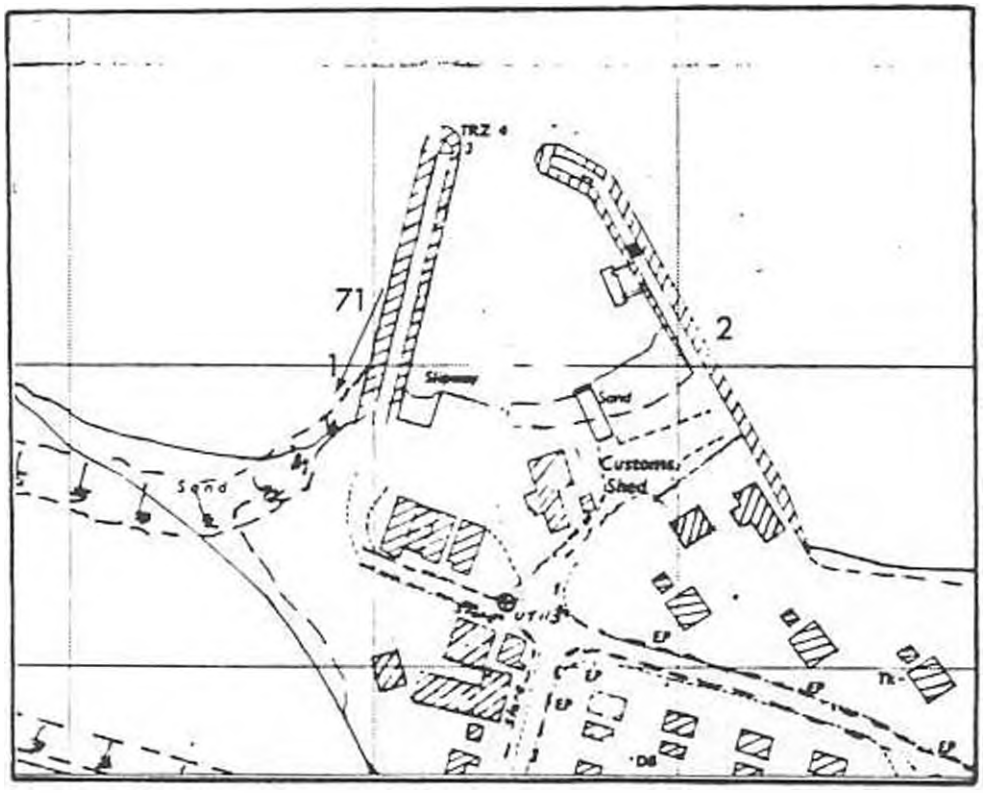
1. Loose coral rock wall built by prisoners during late 1981; already collapsed because of bad construction.
2. Loose vertical coral rock wall being built around point, using large platey coral rock broken from beachrock platform by blasting; stacking of rock as vertical "plates" following local practice, north end of wall needs profiling to beach (Plates 68, 69).
3. Sand spit no longer exists, eroded following blasting of reef platform.
4. Sandy reef platform reclaimed by prisoners.



Bairiki CPZ 7

Close to Bairiki end of proposed road causeway to Betio.

* Poor attempt at loose coral rock seawall and backfill to protect road needs upgrading though some build up of sand has occurred. In 1979 sand filled bitumen drums were being used for protection (Plate 70).



Bairiki CPZ 8

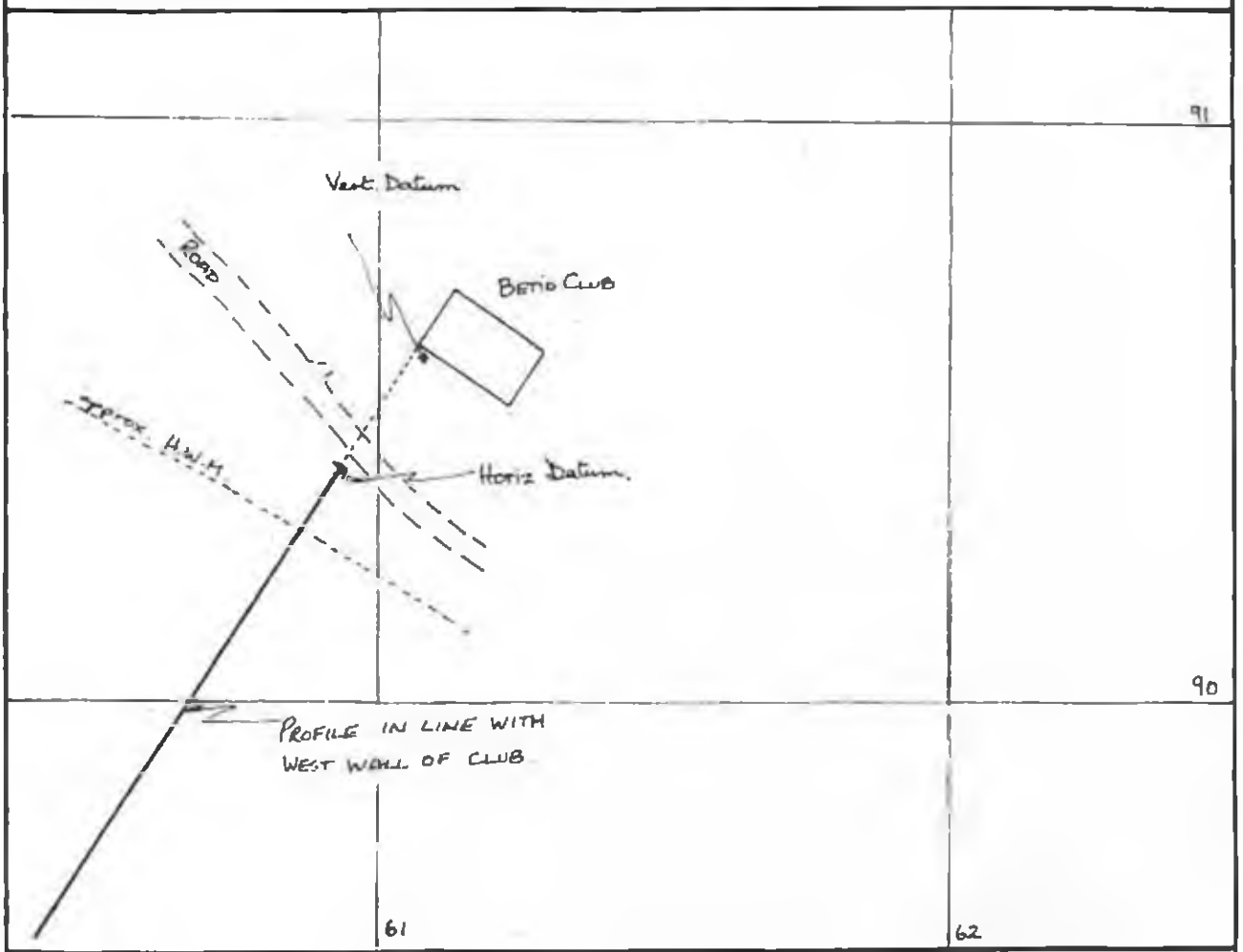
Bairiki harbour moles generally concrete bag berms.

* 1. Erosion on southwest end of mole, 16m gabion wall c. 2.5m high extending from end of mole, and 15m low wall, original gabions largely collapsed and grouted stone wall erected, some gabions repaired (Plate 71).

* 2. East mole has been repaired, at present only one small area in need of repair.

Appendix 2: Beach Profiles, Betio and Bairiki, February 1982; sketch maps showing location of vertical and horizontal datum plus tabulated survey data.

BETIO/[redacted] Beach Profile No. 1

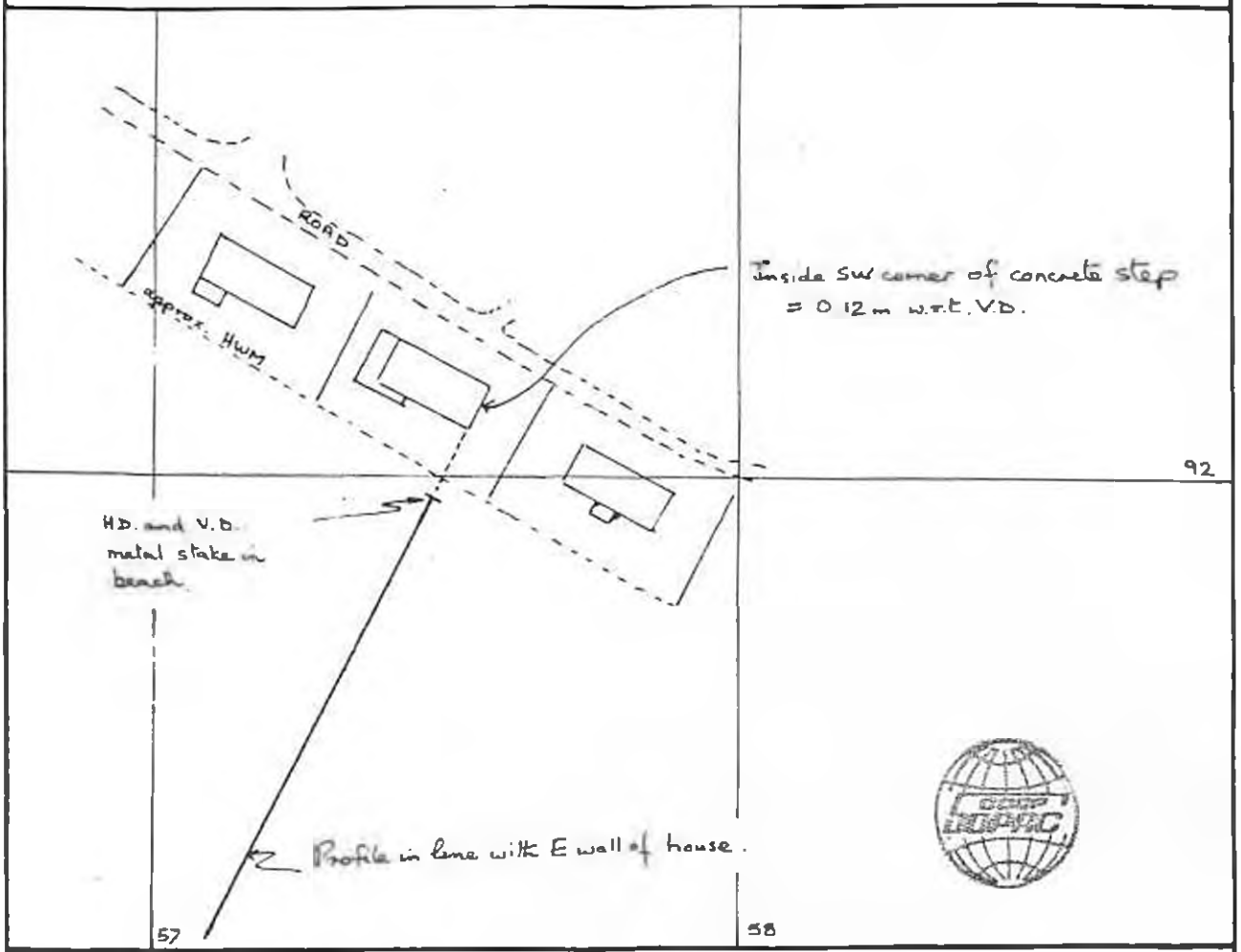


Horizontal Datum: 25m from SW corner of Betio Club.

Vertical Datum : NW corner of concrete toilet vent.

Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.
0	0.00	14	1.97		
0.5	0.00	15	2.03		
1	0.06	16	2.09		
1.5	0.15	18	2.19		
2	0.27	20	2.28		
2.5	0.33	25	2.40		
3	0.42	30	2.43		
5	0.76	35	2.43		
7	1.09	45	2.43		
9	1.42	60	2.40		
11	1.60	80	2.40		
13	1.82	100	2.37		

BETIO/BAIRIKI Beach Profile No. 2

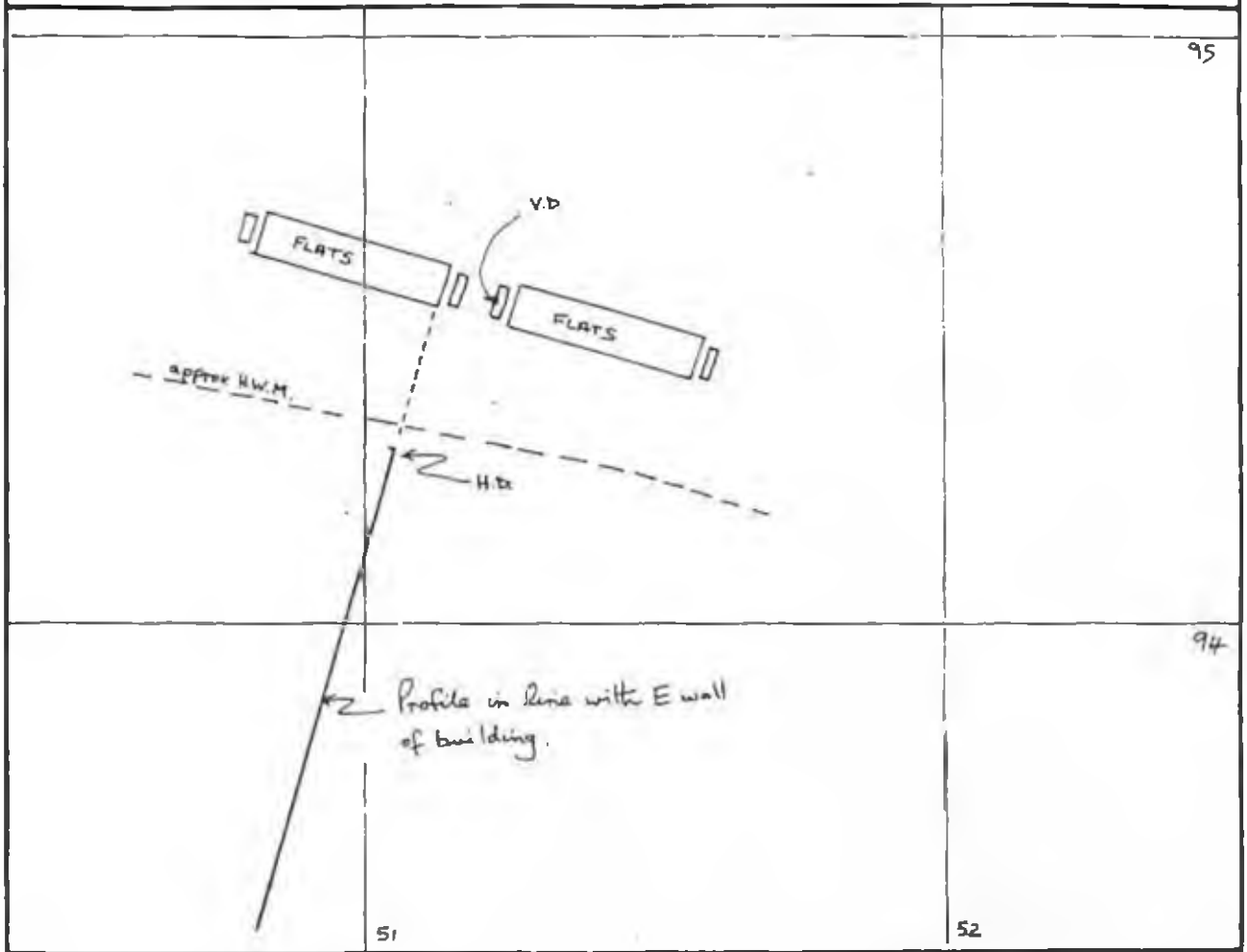


Horizontal Datum: Metal stake in beach.

Vertical Datum : Top of metal stake in beach.

Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.
-11	0.07	4	0.91	35	2.31
- 7.5	-0.11	6	1.18	50	2.31
- 6	-0.18	8	1.46	75	2.37
-5	-0.24	10	1.70	100	2.40
-4	-0.27	11	1.79		
-3.5	-0.27	12	1.91		
-3	-0.23	13	2.01		
-2.5	-0.18	15	2.10		
-2	-0.09	17	2.22		
-1	0.09	20	2.31		
0	0.27	25	2.37		
2	0.58	30	2.37		

BETIO/[redacted] Beach Profile No. 3

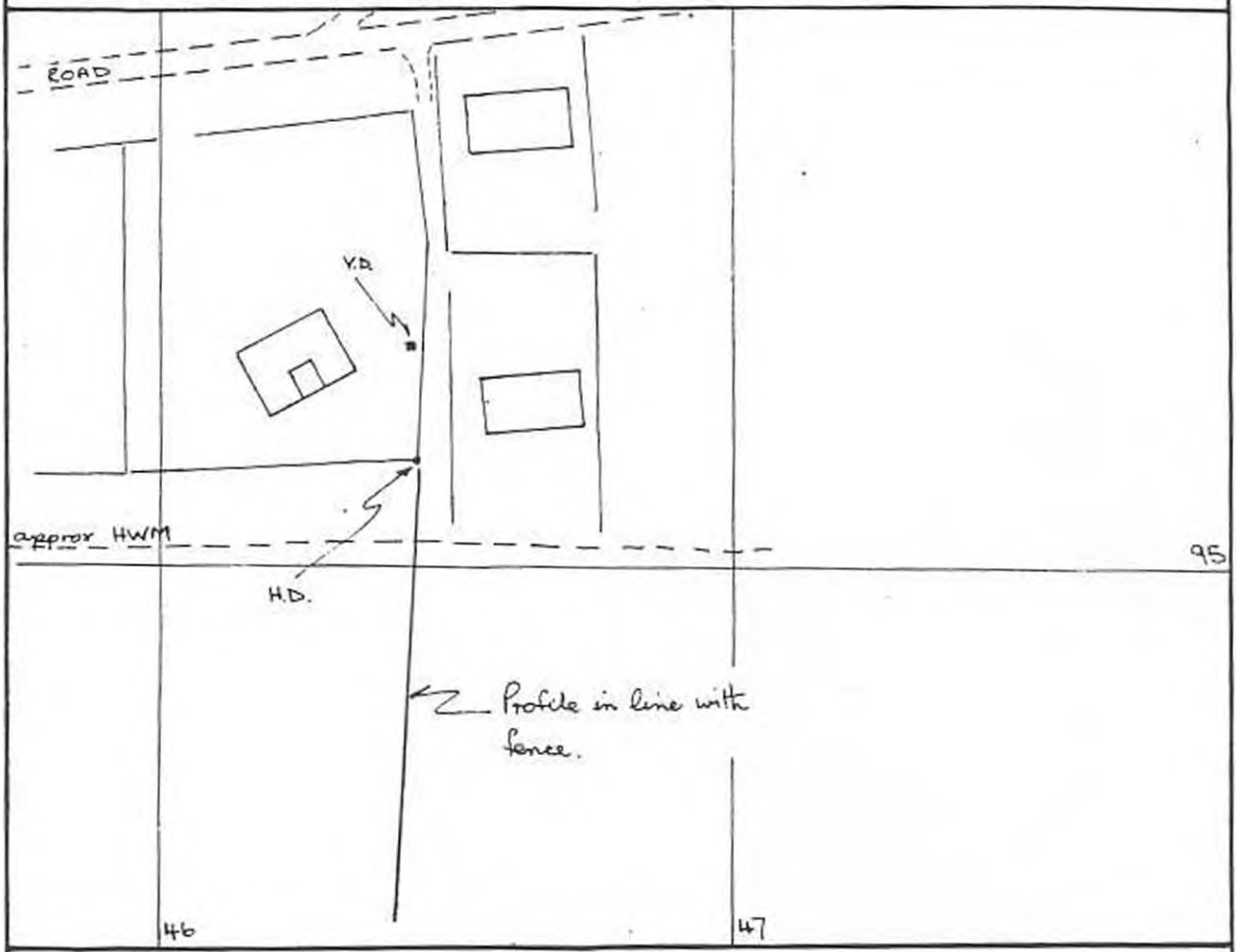


Horizontal Datum: 25m from SE corner of house block.

Vertical Datum : Halfway along concrete footing of water tank.

Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.
0	0.58	10	1.55	30	2.95
1	0.58	12	1.85	40	2.86
2	0.58	14	2.19	50	2.86
3	0.52	15	2.28	75	2.92
3.5	0.52	16	2.46	100	2.89
4	0.55	17	2.58		
4.5	0.61	18	2.64		
5	0.64	19	2.70		
5.5	0.73	20	2.74		
6	0.82	22	2.83		
7	0.97	24	2.92		
8	1.13	26	2.89		

BETIO/[illegible] Beach Profile No. 4

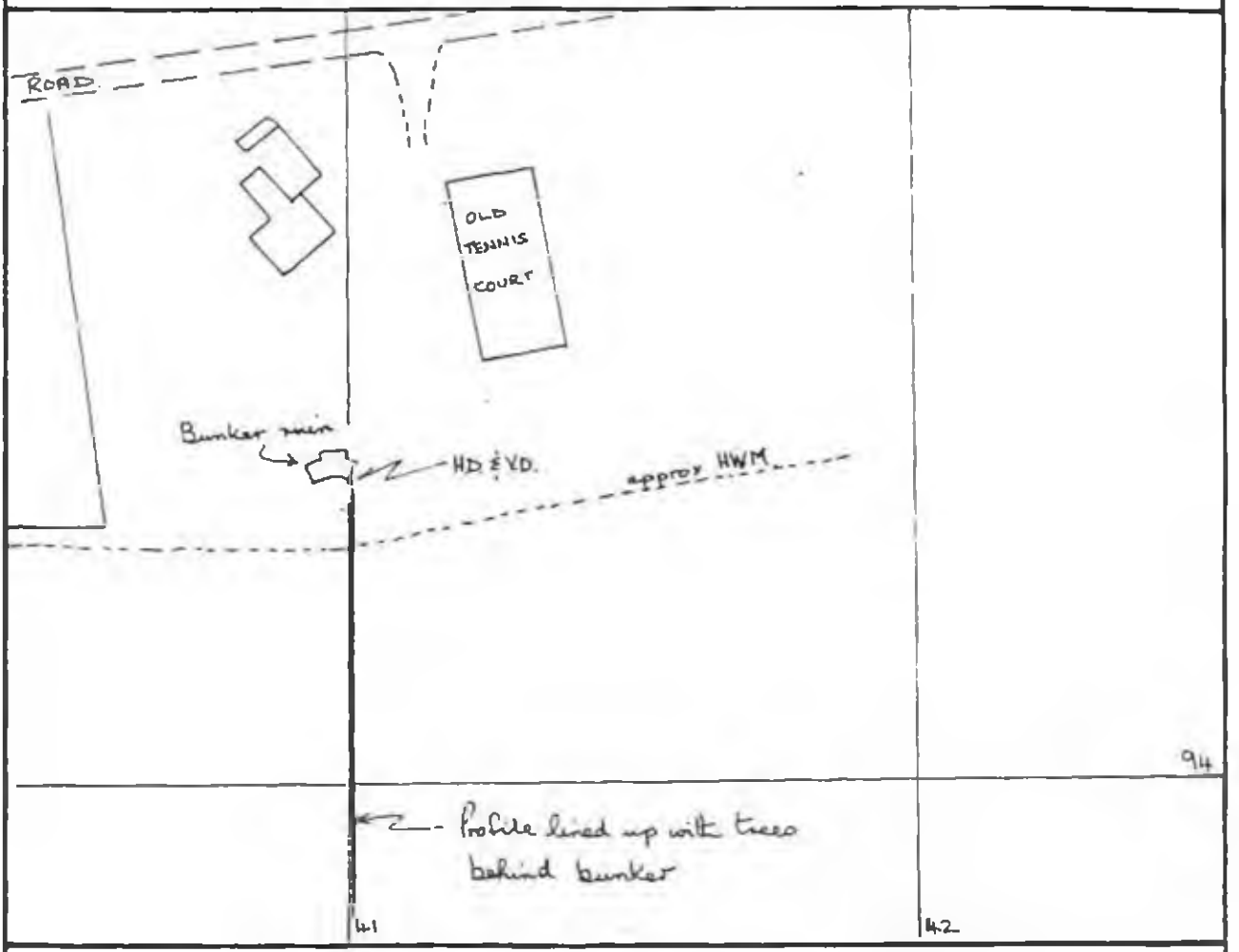


Horizontal Datum: Base of iron pipe at end of fence.

Vertical Datum : SE corner of concrete block.

Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.
0	0.28	17	1.37	75	2.53
2	0.19	18	1.40	100	2.59
4	0.13	19	1.68		
6	0.16	20	1.77		
8	0.10	21	1.98		
10	0.13	22	2.13		
11	0.16	23	2.19		
11.5	0.28	25	2.31		
12	0.37	27	2.43		
12.5	0.46	30	2.38		
13	0.55	40	2.34		
15	1.01	50	2.41		

BETIO/~~BARROSA~~ Beach Profile No. 5

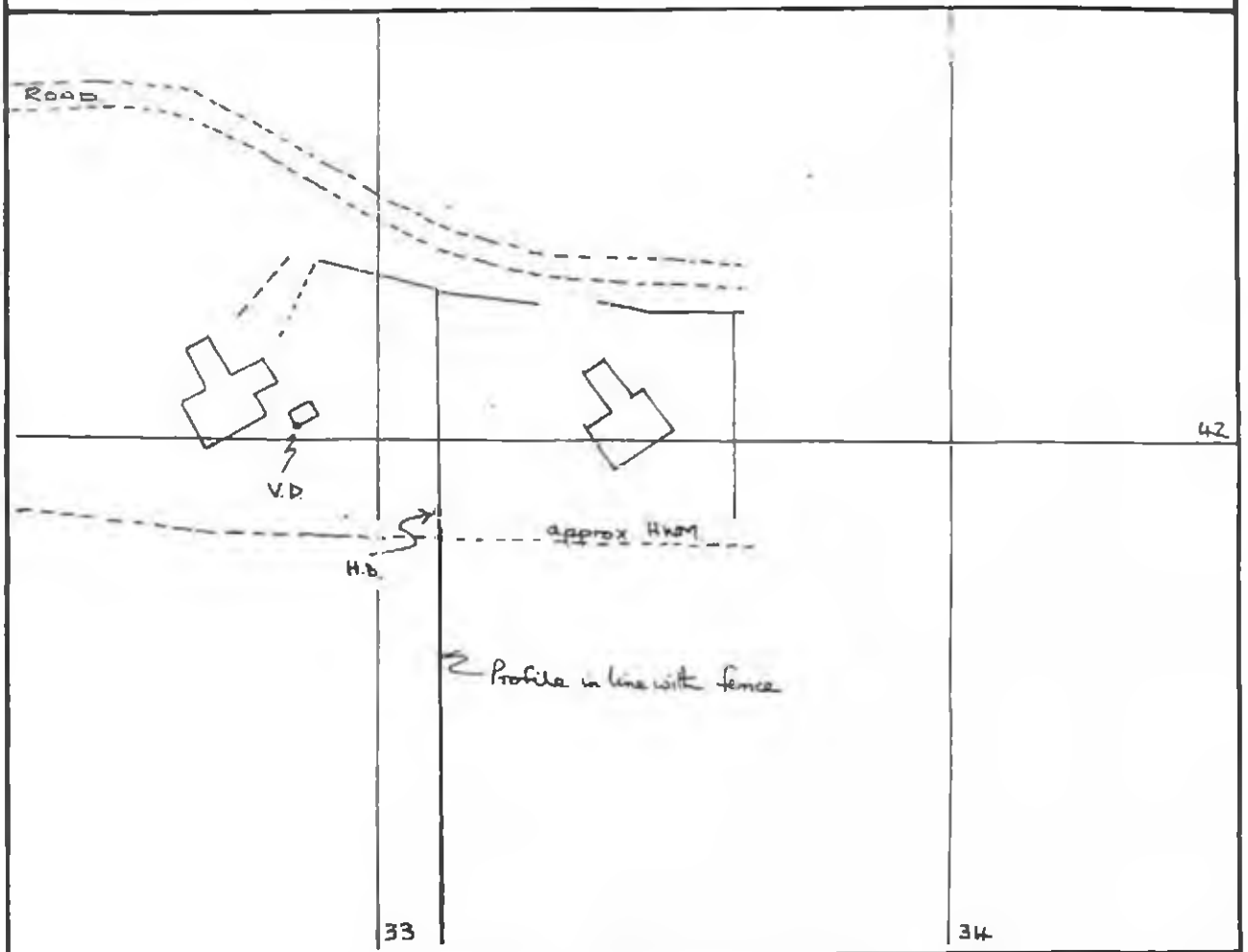


Horizontal Datum: SE corner of wrecked concrete bunker.

Vertical Datum : Smooth ledge on SE broken corner of bunker.

Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.
0	0.73	10	1.43	50	3.06
1	0.76	12	1.76	75	3.03
2	0.73	14	2.03	100	3.12
3	0.61	16	2.15		
4	0.52	17	2.34		
5	0.55	17.5	2.43		
5.5	0.61	19	2.64		
6	0.64	20	2.82		
6.5	0.76	21	2.85		
7	0.85	23	2.97		
7.5	1.00	25	3.06		
8	1.09	30	3.06		

BETIO/[redacted] Beach Profile No. 6

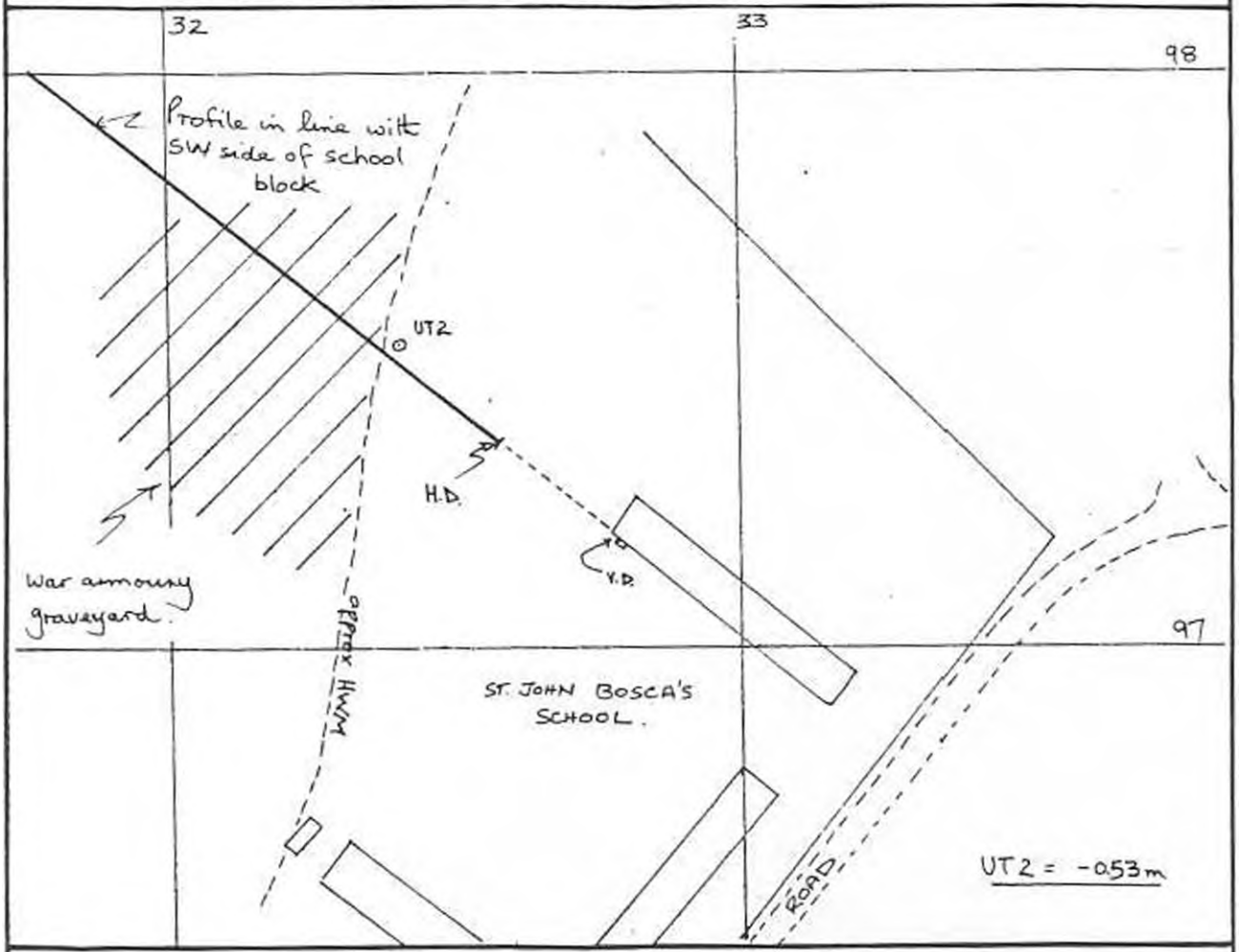


Horizontal Datum: Heavy metal stake at end of fence.

Vertical Datum : S corner of concrete footing of water tank.

Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.
0	-	21	2.15		
2	0.6	22	2.31		
8	0.6	23	2.37		
10	0.82	24	2.52		
12	0.82	25	2.61		
12.5	0.79	26	2.67		
13	0.85	27	2.76		
13.5	0.94	30	2.98		
14	1.09	40	3.07		
15	1.33	50	3.04		
17	1.67	75	3.13		
19	1.88	100	3.19		

BETIO/[redacted] Beach Profile No. 7

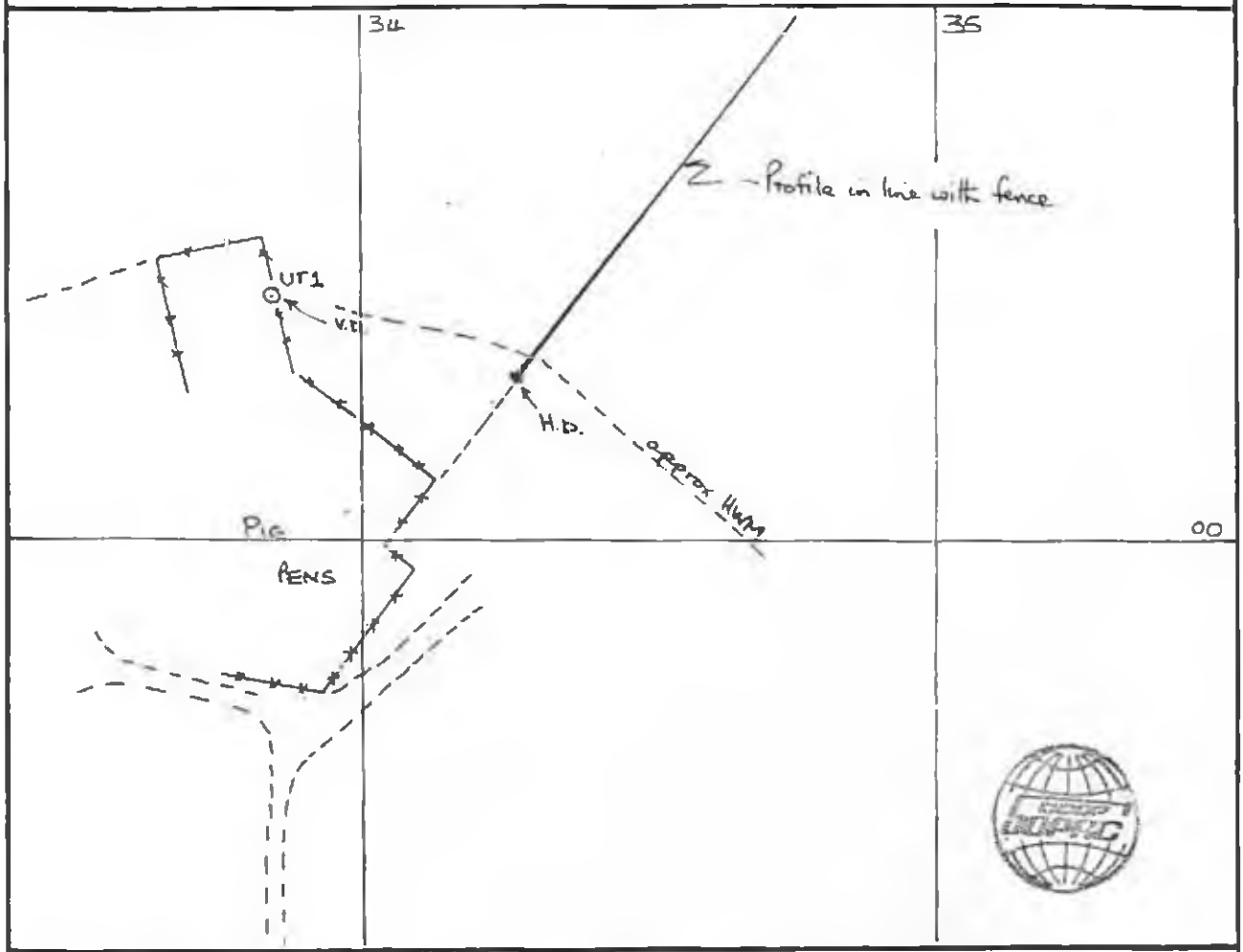


Horizontal Datum: 25m from SW corner of school block.

Vertical Datum : W inside corner of concrete step.

Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.
0	0.38	33	0.57		
5	0.32	35	0.87		
10	0.23	37	1.07		
15	-0.14	39	1.31		
17	-0.39	41	1.54		
19	-0.50				
21	-0.53	64	2.39		
24	-0.54	70	2.44		
25	-0.38	80	2.54		
27	-0.18	90	2.60		
29	0.11	100	2.63		
31	0.38				

BETIO/~~BAIRIKI~~ Beach Profile No. 8

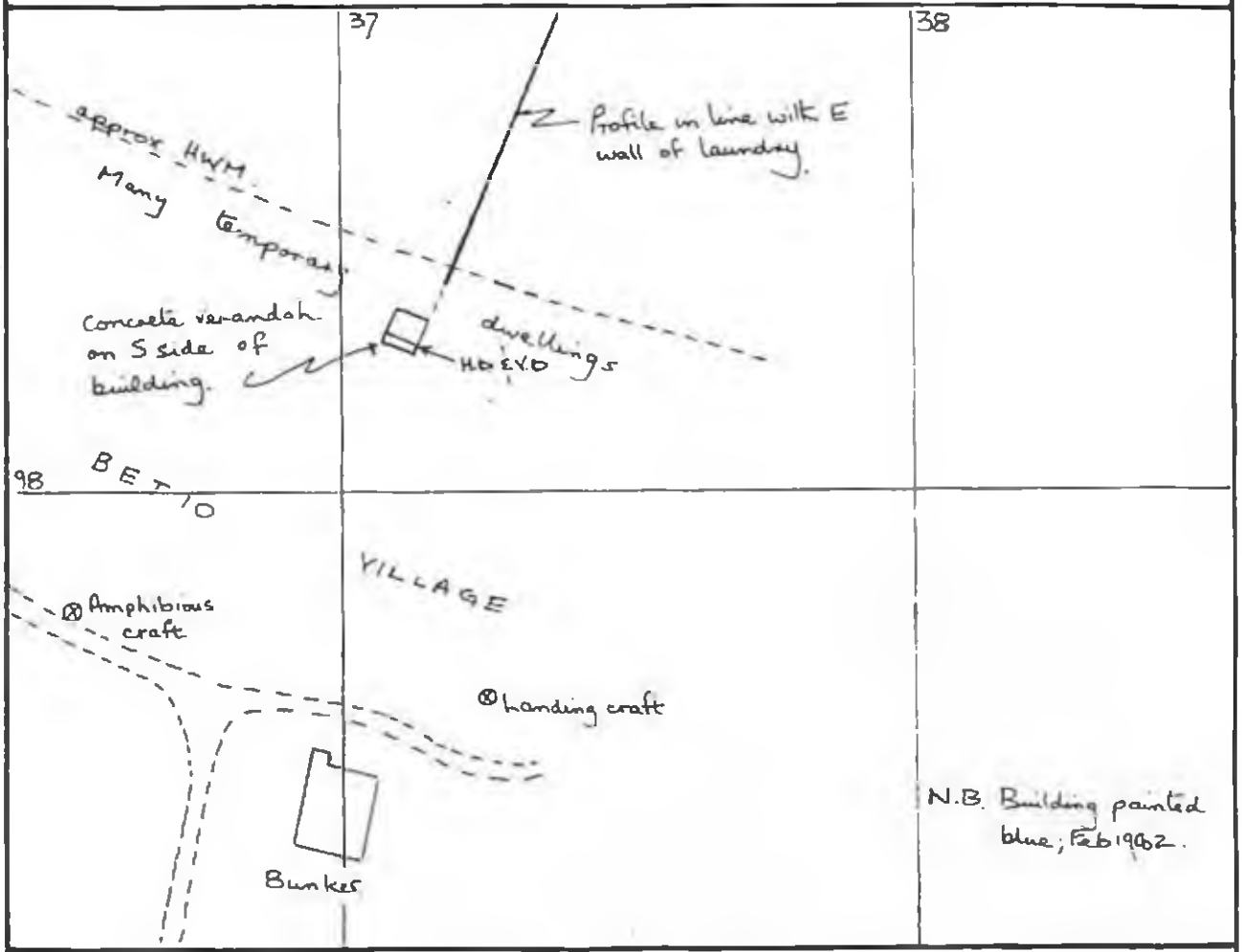


Horizontal Datum: 20m from NE corner of pipe/wire mesh fence.

Vertical Datum : UT1 bench mark.

Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.
0	0.54	22	1.19	75	2.77
2	0.53	24	1.50	100	2.80
4	0.50	26	1.73		
6	0.30	28	1.89		
8	0.16	30	2.11		
10	0.07	32	2.29		
12	0.08	34	2.46		
14	0.20	36	2.53		
15	0.37	38	2.61		
16	0.53	40	2.58		
18	0.73	45	2.68		
20	0.97	50	2.65		

BETIO/~~BAKKXXXX~~ Beach Profile No. 9

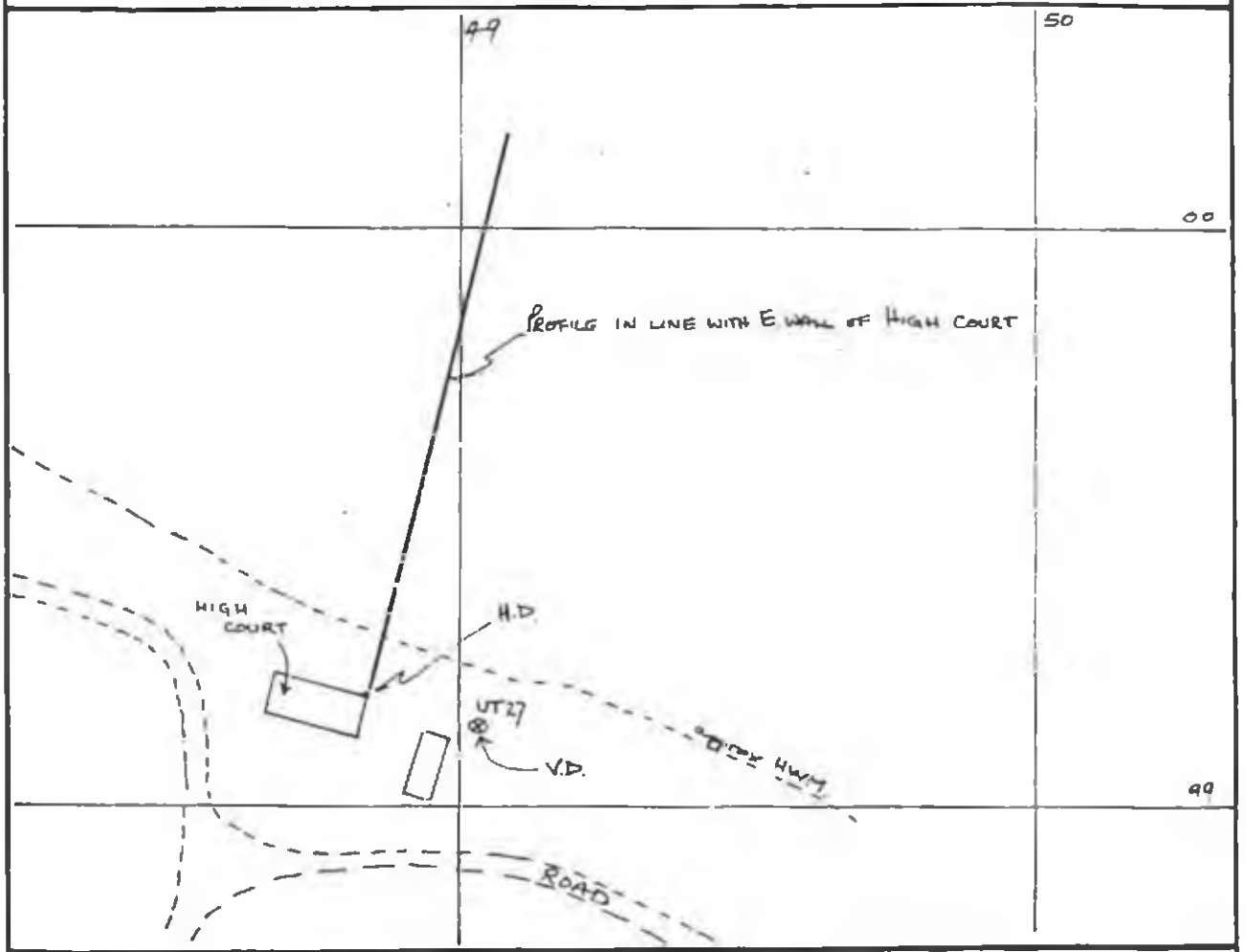


Horizontal Datum: 20m from NE corner of concrete verandah.

Vertical Datum : NE corner of concrete verandah.

Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.
0	0.24	22	2.13		
2	0.21	24	2.34		
4	0.24	25	2.46		
6	0.28	27	2.63		
9	0.44	29	2.71		
10	0.52	31	2.75		
11	0.70	35	2.83		
12	0.93	40	2.86		
14	1.17	50	2.89		
16	1.44	75	3.03		
18	1.66	100	3.07		
20	1.91				

BETIO/~~XXXXXX~~ Beach Profile No. 10

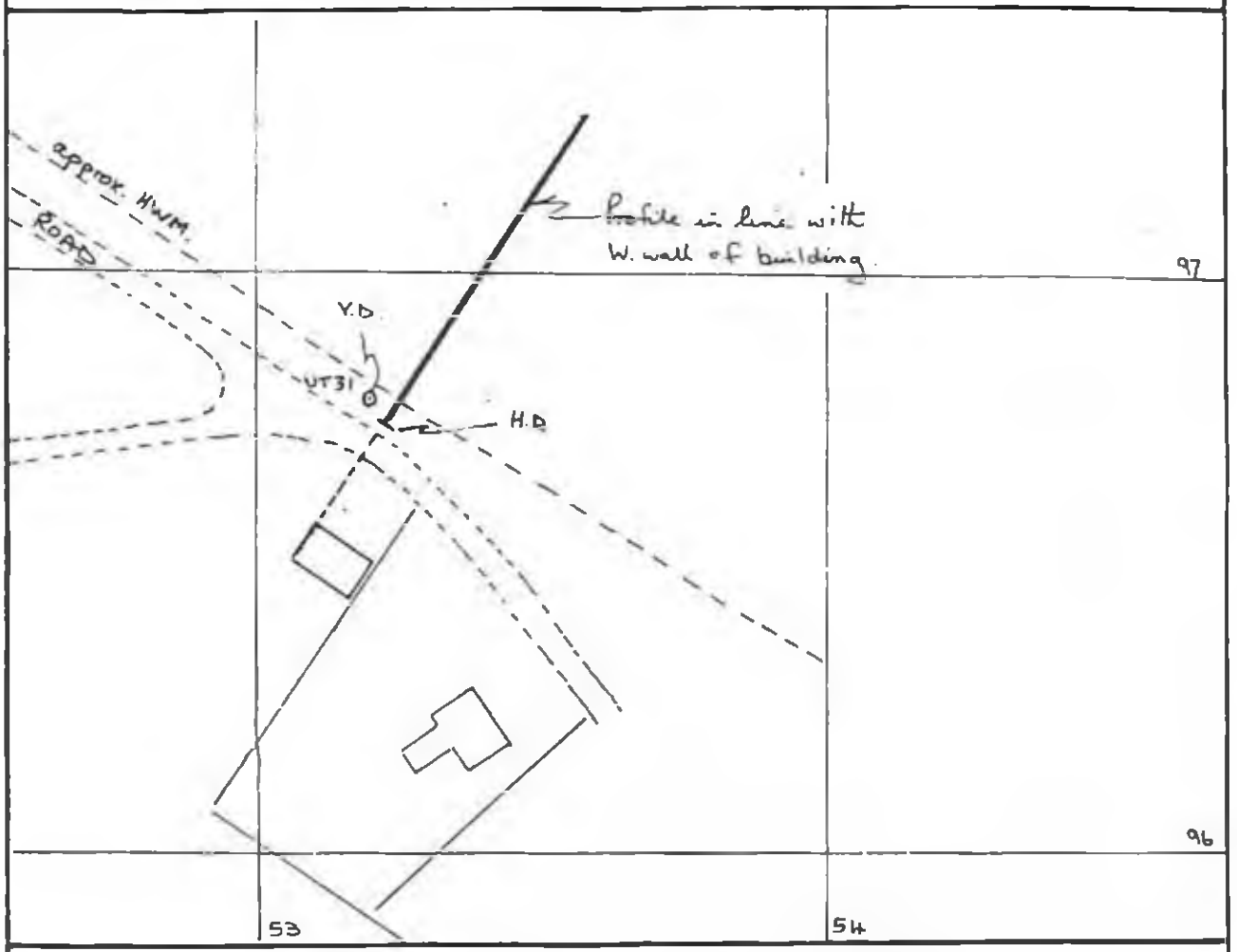


Horizontal Datum: NE corner of High Court building.

Vertical Datum : UT27 bench mark.

Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.
0	-	27	0.79	75	2.52
8	0.00	29	1.06	100	2.49
10	0.06	31	1.31		
12	0.07	33	1.56		
14	0.09	35	1.72		
16	0.07	37	1.88		
18	0.10	39	2.07		
20	0.03	41	2.28		
22	-0.02	43	2.40		
23	0.07	45	2.46		
24	0.27	47	2.40		
25	0.44	50	2.43		

BETIO/[redacted] Beach Profile No. 11

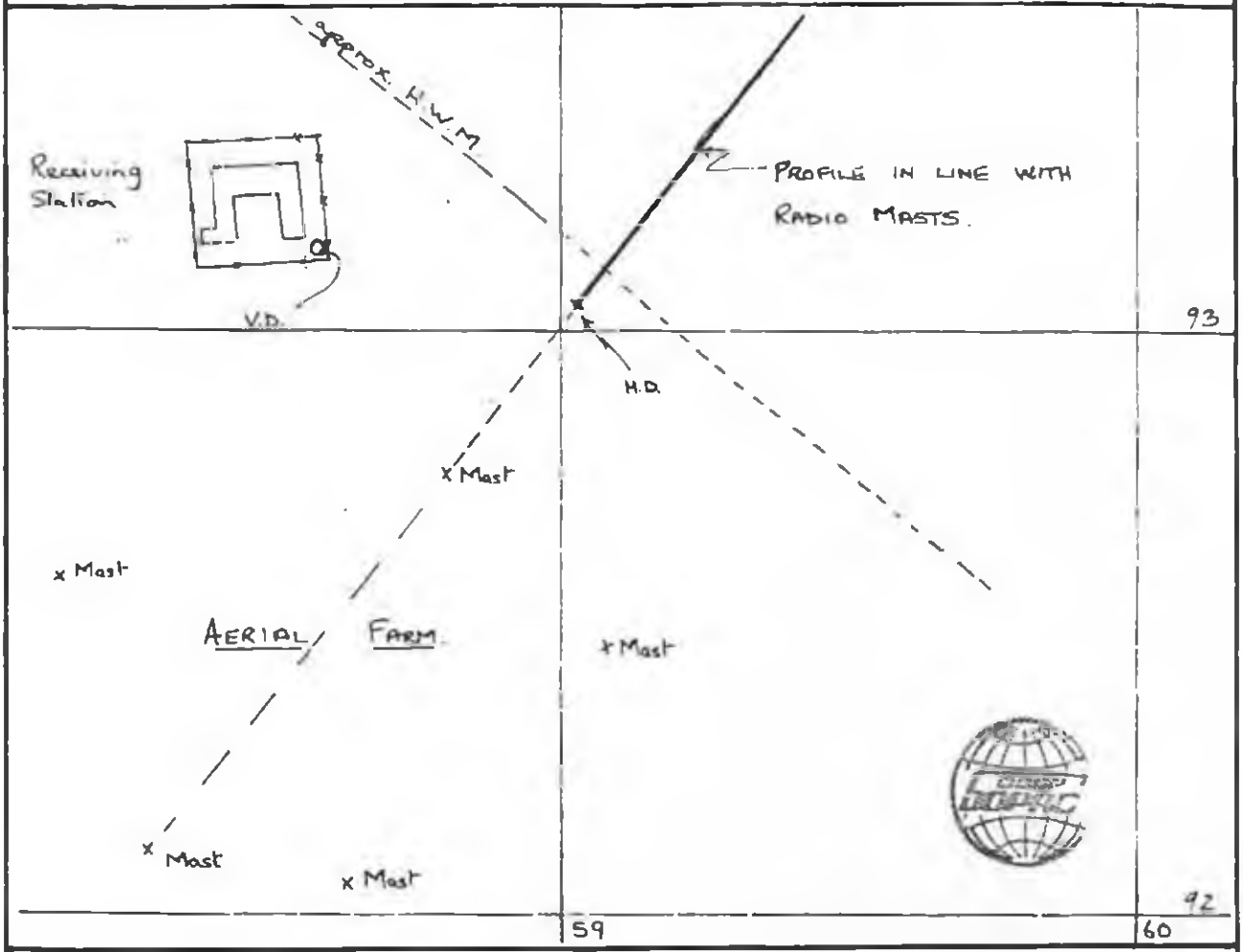


Horizontal Datum: 25m from NW corner of concrete block house.

Vertical Datum : UT31 bench mark.

Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.
0	0.08	16	1.89		
1	0.08	18	2.11		
2	0.22	20	2.30		
3	0.22	22	2.52		
4	0.39	24	2.73		
5	0.57	26	2.85		
6	0.56	28	2.85		
7	0.62	30	2.88		
8	0.86	50	2.89		
10	1.15	75	2.85		
12	1.41	100	2.85		
14	1.62				

BETIO/[redacted] Beach Profile No. 12

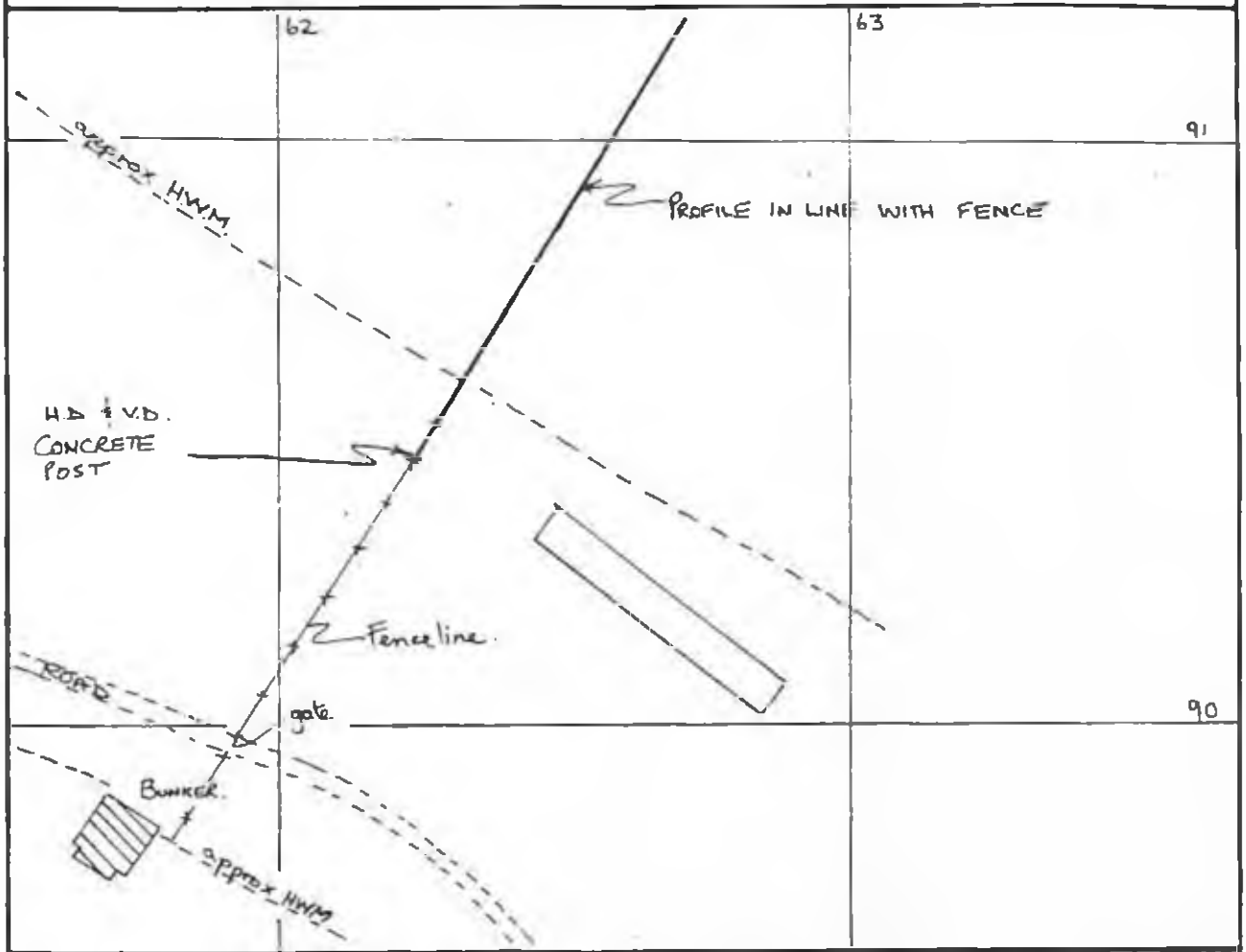


Horizontal Datum: 50m N of radio mast.

Vertical Datum : E corner of concrete footing of water tank.

Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.
0	0.89	14	2.06		
2	0.82	16	2.20		
4	0.80	18	2.50		
6	0.89	20	2.75		
6.5	0.97	22	2.90		
7	1.08	24	2.94		
7.5	1.14	26	2.99		
8	1.20	28	2.99		
9	1.30	30	2.93		
10	1.36	50	2.94		
11	1.52	75	2.99		
12	1.67	100	3.06		

BETIO/[illegible] Beach Profile No. 13

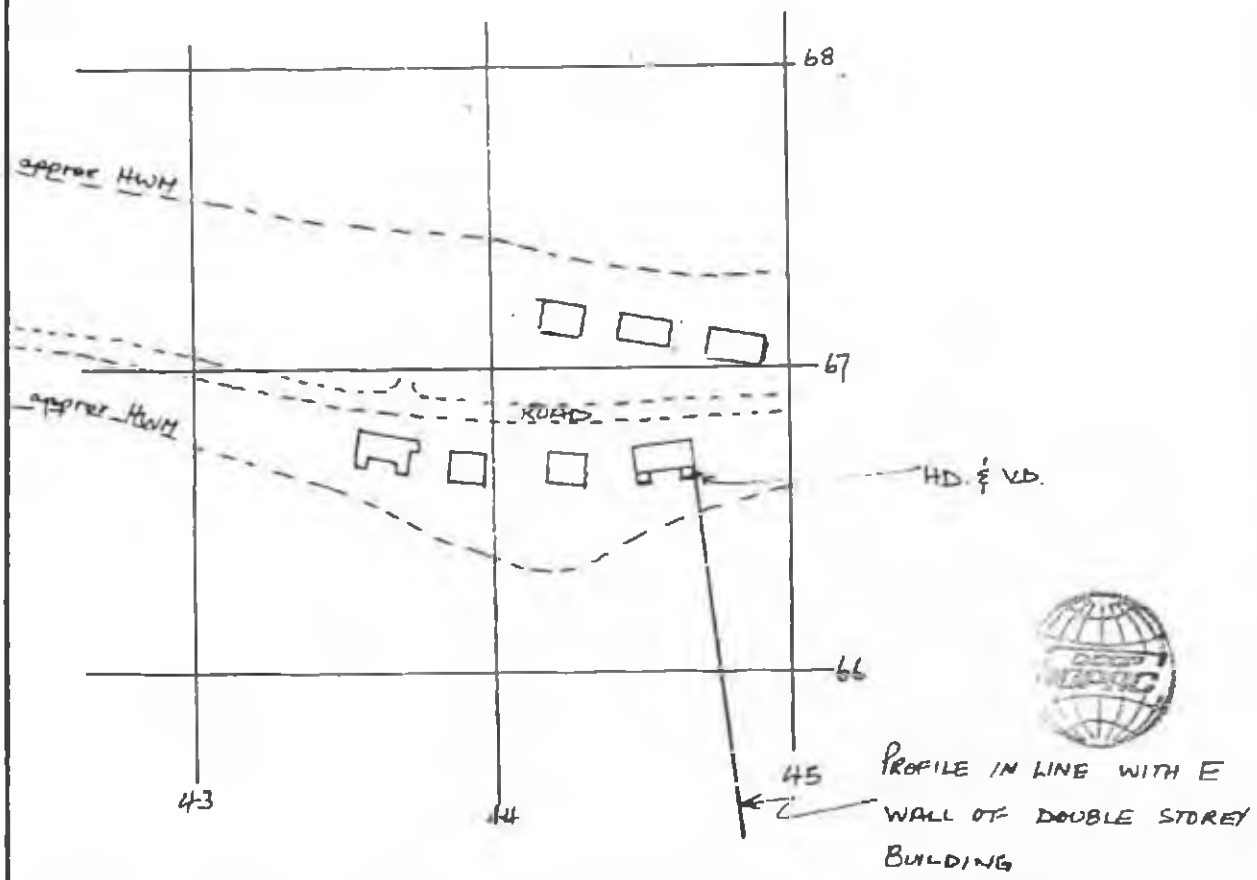


Horizontal Datum: Concrete post in fence.

Vertical Datum : Top of concrete post in fence.

Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.
0	-	26	3.09		
8	1.22	28	3.29		
9	1.16	30	3.47		
10	1.18	32	3.48		
12	1.21	34	3.44		
13	1.36	36	3.44		
14	1.63	40	3.41		
16	1.96	50	3.45		
18	2.27	75	3.51		
20	2.51	100	3.47		
22	2.71				
24	2.89				

~~BEXXX~~/BAIRIKI Beach Profile No. 1

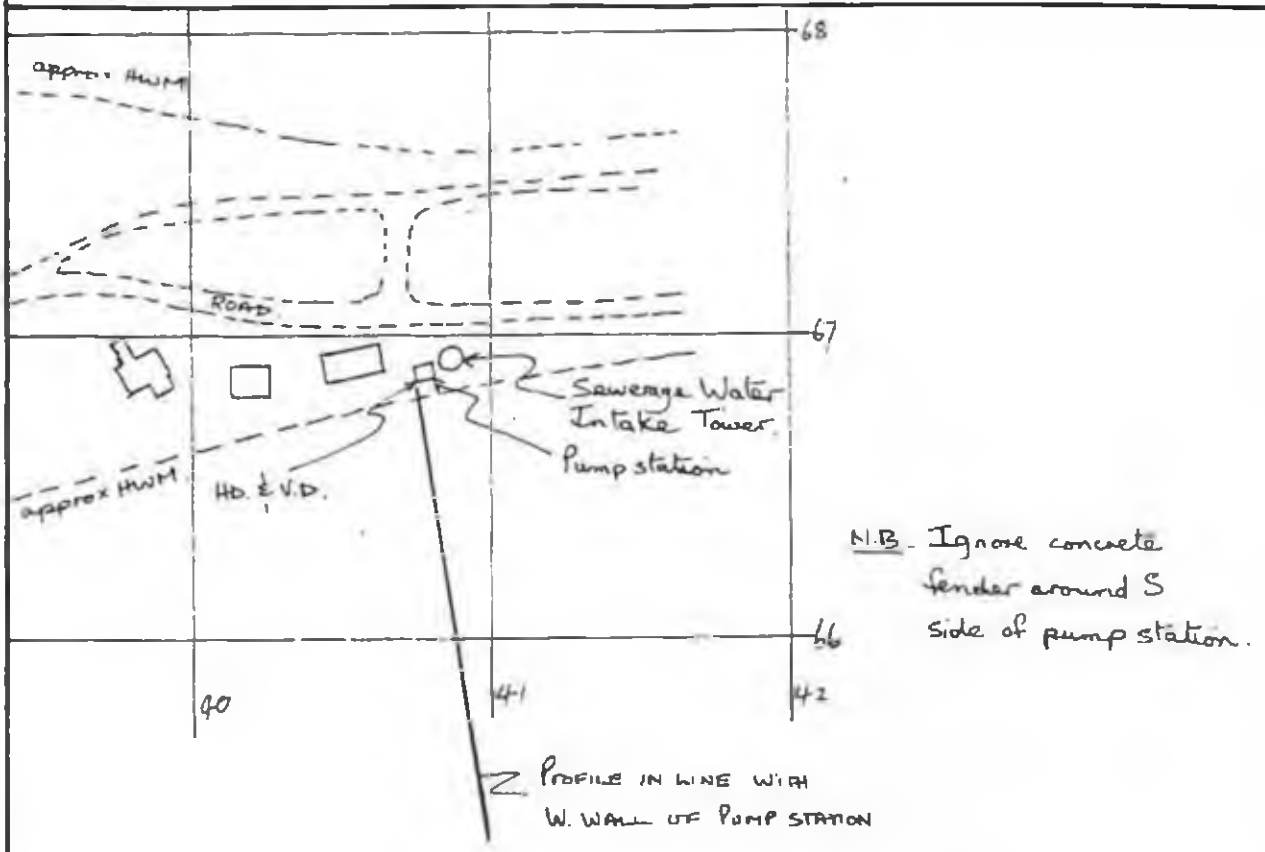


Horizontal Datum: Post on E end of covered concrete verandah.

Vertical Datum : By post on concrete verandah.

Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.
0	-	14	1.25		
2	-0.08	16	1.43		
4	-0.15	18	1.61		
5	-0.24	20	1.70		
5.5	-0.24	22	1.79		
6	-0.21	24	1.83		
6.5	0.06	26	1.85		
7	0.15	30	1.85		
7.5	0.30	40	1.85		
8	0.41	50	1.81		
10	0.76	75	1.83		
12	1.06	100	1.83		

~~BETIO~~/BAIRIKI Beach Profile No. 2

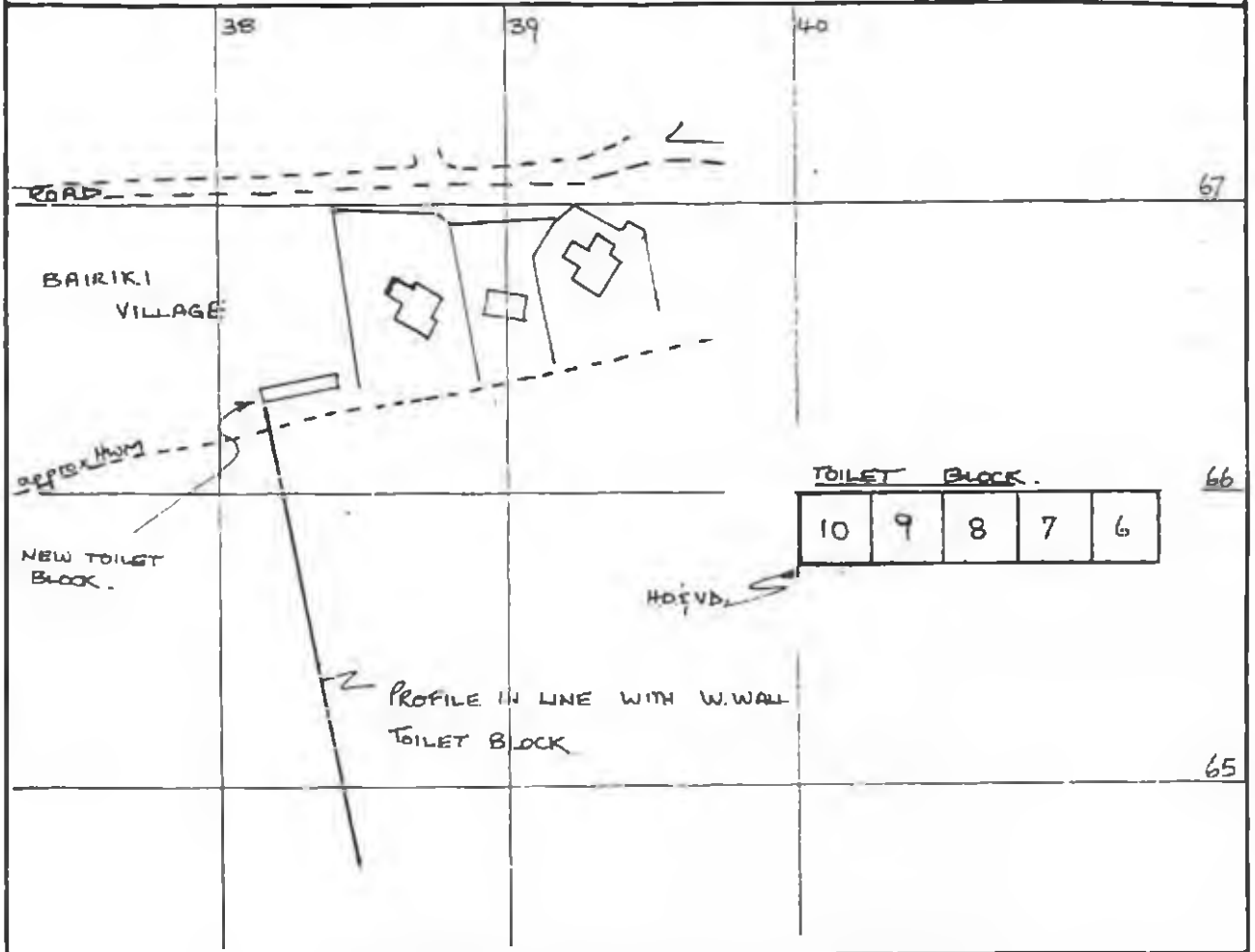


Horizontal Datum: SW corner of pump station block house.

Vertical Datum : SW corner of pump station on concrete footing.

Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.
0	-	22	2.04		
2	-	24	2.09		
4	0.32	26	2.10		
6	0.28	28	2.13		
8	0.20	30	2.11		
9	0.26	40	2.07		
10	0.41	50	2.13		
12	0.79	75	2.22		
14	1.16	100	2.25		
16	1.43				
18	1.63				
20	1.87				

~~BAIRIKI~~/BAIRIKI Beach Profile No. 3

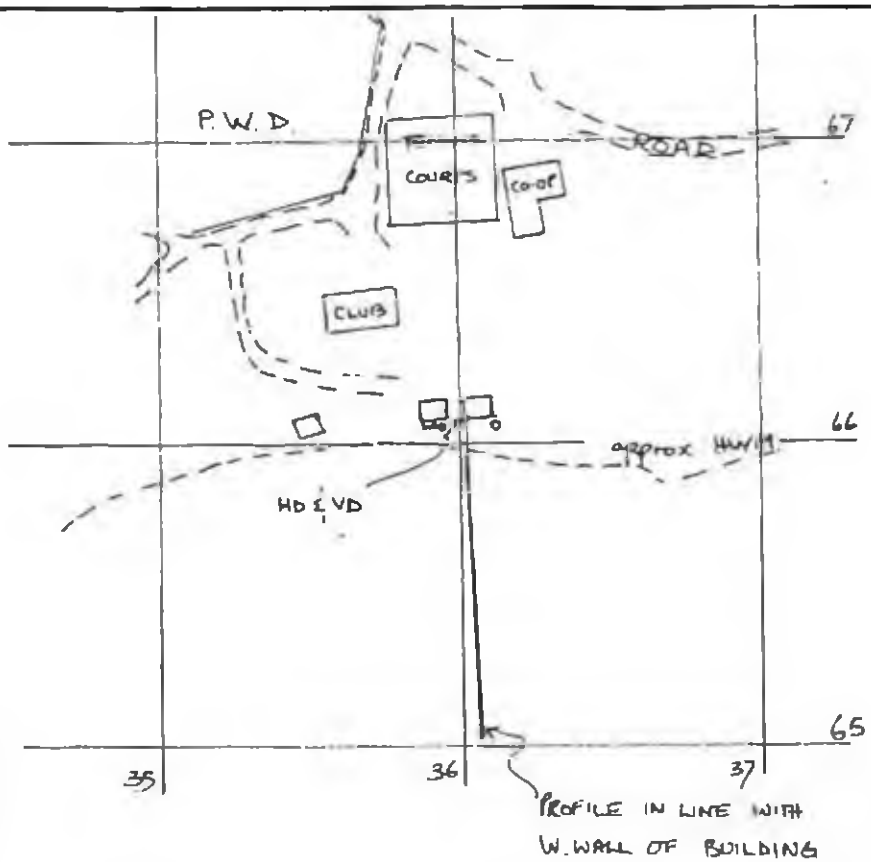


Horizontal Datum: SW corner of toilet block.

Vertical Datum : NW corner of step to No.10 toilet.

Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.
0	-0.03	28	1.83		
6	-0.06	30	1.86		
8	0.09	40	1.89		
10	0.34	50	1.85		
12	0.67	75	1.95		
14	0.95	100	1.96		
16	1.19				
18	1.40				
20	1.61				
22	1.80				
24	1.83				
26	1.75				

~~XXXXXX~~/BAIRIKI Beach Profile No. 4

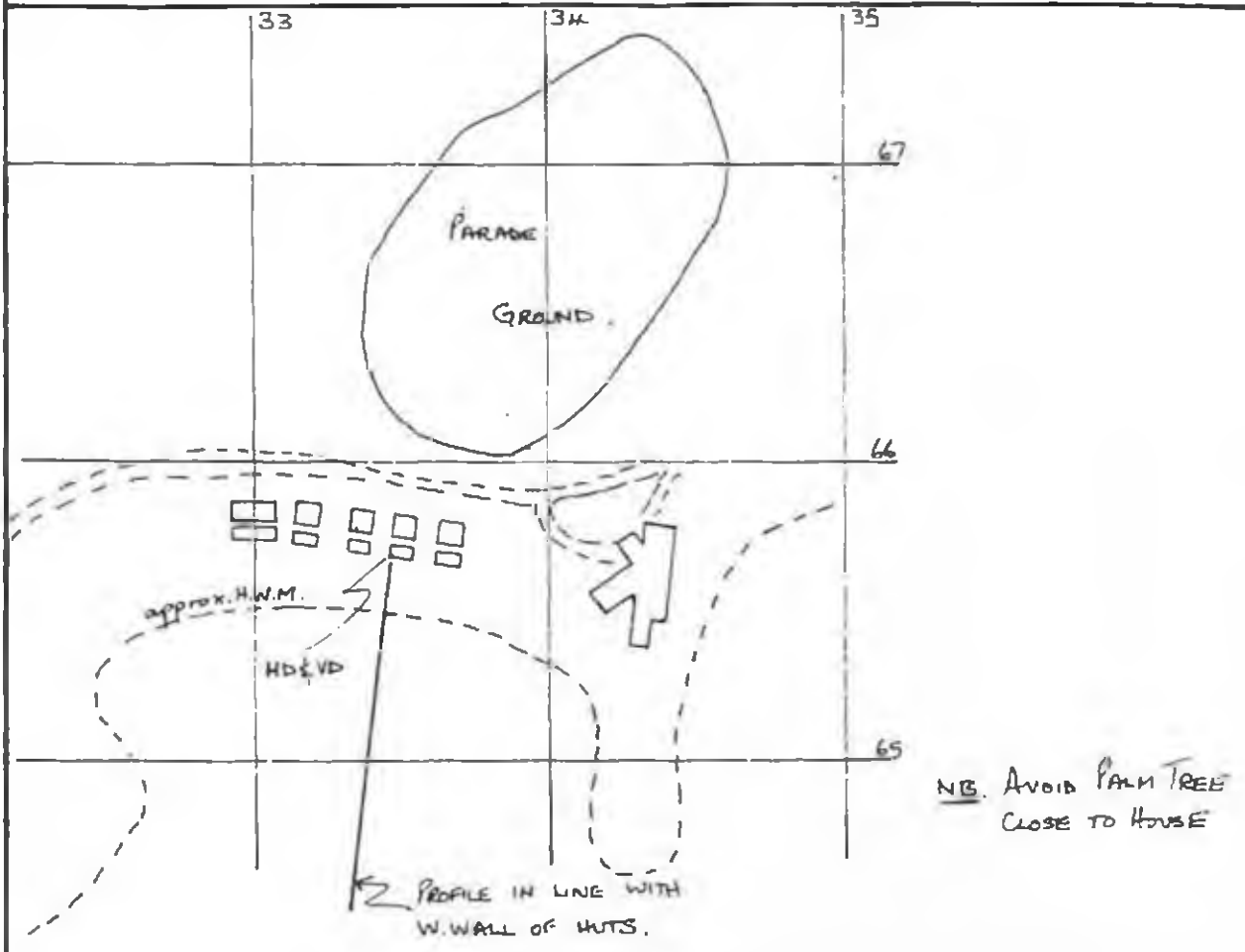


Horizontal Datum: SW corner of wooden building.

Vertical Datum : Concrete footing, SW corner of building.

Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.
				24	1.32
				26	1.52
				28	1.70
				30	1.90
		0	-	32	1.97
		10	-0.07	34	2.00
-		12	-0.02	36	2.02
		14	0.01	38	2.00
		16	0.24	40	1.98
		18	0.57	50	1.98
		20	0.89	75	1.97
		22	1.06	100	2.03

BAIRIKI Beach Profile No. 5

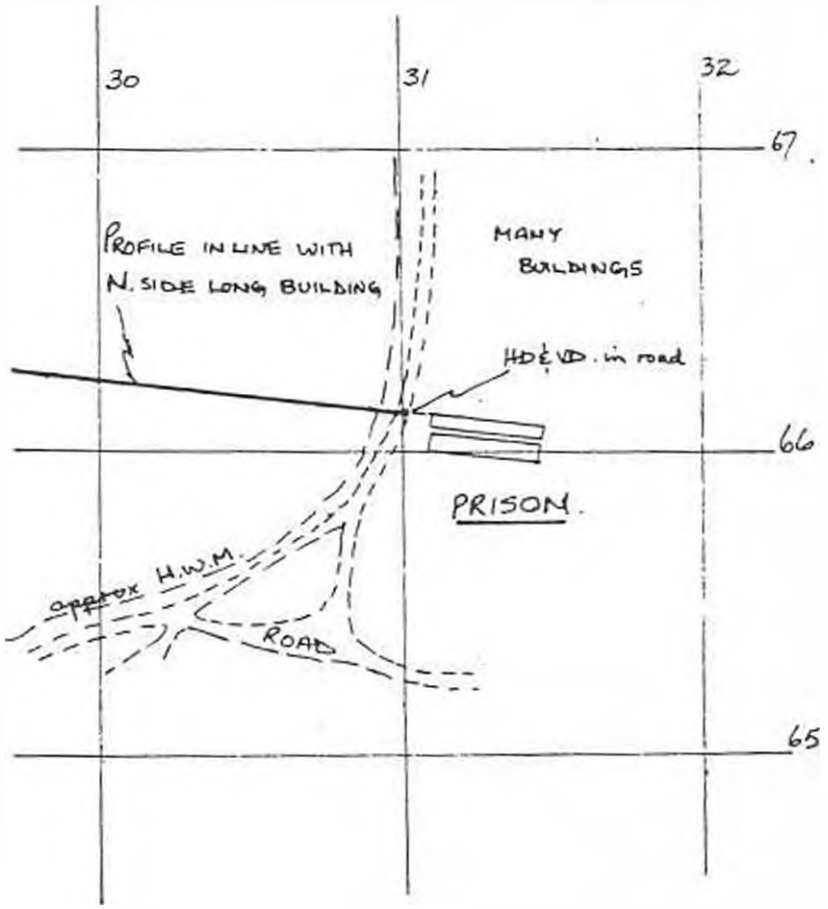


Horizontal Datum: 20m from SW corner of house.

Vertical Datum : Piece of concrete footing on SW corner of house.

Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.
0	-0.01	21	1.67		
2	-0.04	23	1.92		
4	-0.13	25	1.84		
6	-0.20	30	2.01		
7	-0.13	40	2.01		
8	0.02	50	2.04		
9	0.16	75	2.07		
11	-	100	2.07		
13	0.87				
15	1.13				
17	1.31				
19	1.46				

BETIO/BAIRIKI Beach Profile No. 6

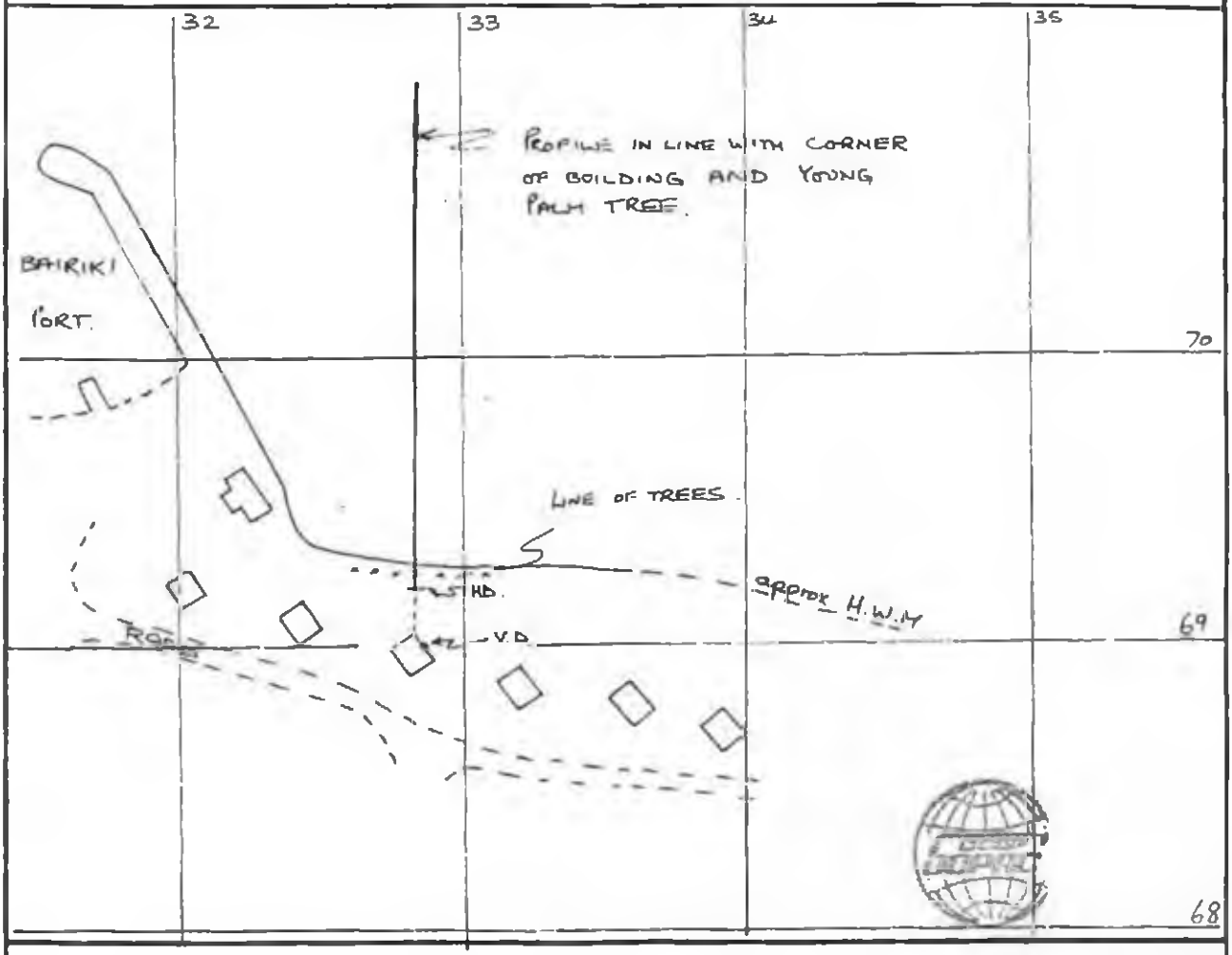


Horizontal Datum: Seaward side of concrete housing to sewage valve manhole.

Vertical Datum : Concrete adjacent to SW corner of inspection cover.

Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.
0	-	23	1.53		
2	-	25	1.73		
3	0.09	27	1.76		
5	-0.04	29	1.78		
7	0.21	35	1.78		
9	0.37	50	1.79		
11	0.49	75	1.82		
13	0.65	100	1.88		
15	0.84				
17	1.03				
19	1.20				
21	1.35				

~~XXXXX~~/BAIRIKI Beach Profile No. 7

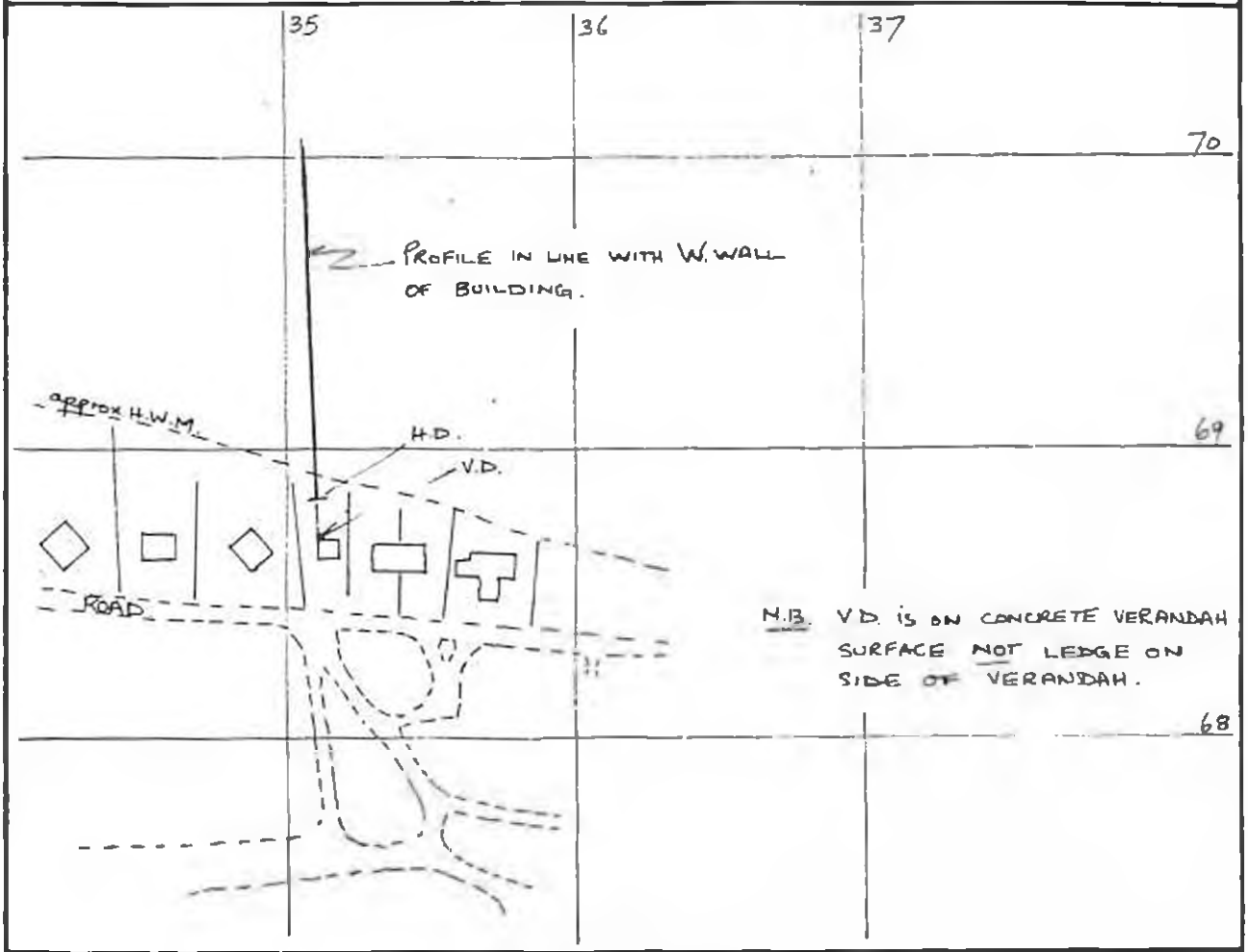


Horizontal Datum: 20m from house corner.

Vertical Datum : N inside corner to step for double door.

Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.
0	0.15	20	1.76		
2	0.33	22	1.96		
4	0.52	24	2.10		
6	0.41				
7	0.41				
8	0.41				
9	0.55				
10	0.67				
12	0.91				
14	1.13				
16	1.34				
18	1.54				

XXXXX/BAIRIKI Beach Profile No. 8

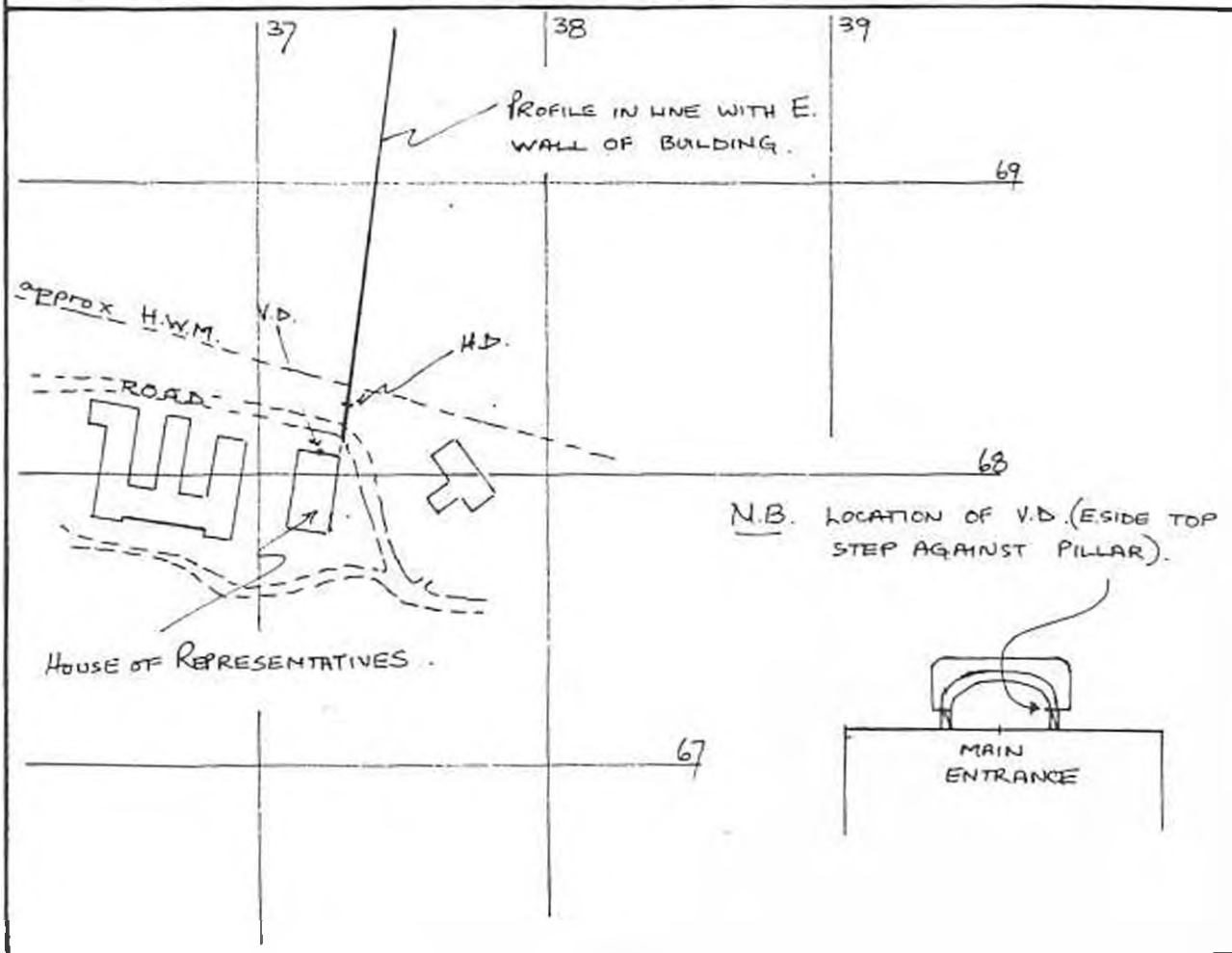


Horizontal Datum: 20m from NW corner of house.

Vertical Datum : Concrete verandah surface adjacent to house.

Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.
0	0.64	18	1.11	45	3.20
2	0.58	20	1.37	50	3.24
4	0.58	22	1.61	75	3.44
6	0.58	24	1.82	100	3.41
8	0.55	26	2.04		
10	0.58	28	2.22		
12	0.61	30	2.42		
14	0.61	32	2.66		
14.5	0.64	34	2.83		
15	0.67	36	3.06		
15.5	0.73	38	3.13		
16	0.79	40	3.19		

BXXXXX/BAIRIKI Beach Profile No. 9

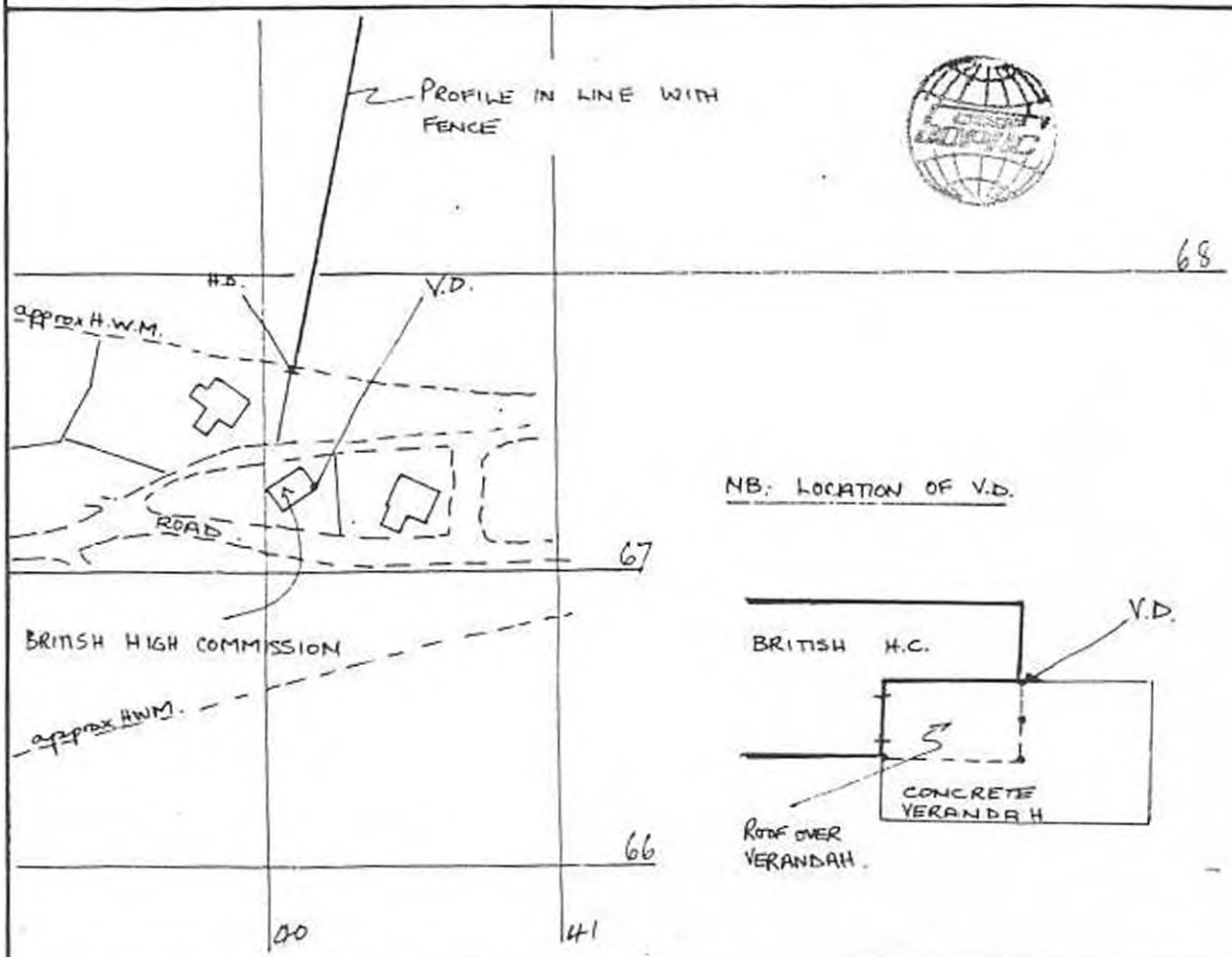


Horizontal Datum: 25m from NE corner of House of Representatives.

Vertical Datum : E side top step against pillar.

Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.
0	0.7	19	1.76	100	3.42
2	0.66	21	1.99		
4	0.65	23	2.19		
6	0.78	25	2.39		
8	0.81	27	2.58		
10	0.78	29	2.80		
11	0.84	31	3.01		
12	0.87	33	3.18		
13	0.91	35	3.24		
14	1.06	40	3.30		
15	1.22	50	3.33		
17	1.50	75	3.34		

XXXXX/BAIRIKI Beach Profile No. 10

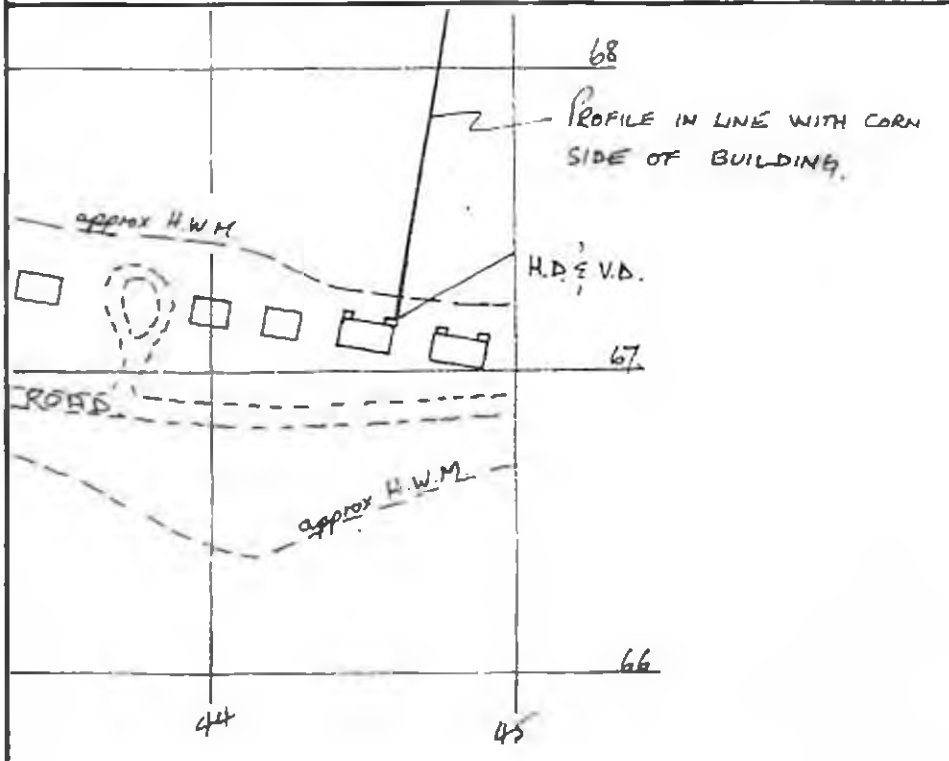


Horizontal Datum: Concrete post at N end of fence line.

Vertical Datum : Surface of concrete verandah at E side of British High Commission.

Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.
0	0.24	20	1.49	100	2.87
2	0.17	22	1.69		
4	0.17	24	1.87		
6	0.18	26	2.07		
8	0.25	28	2.30		
10	0.31	30	2.51		
11	0.37	32	2.66		
12	0.40	34	2.66		
13	0.53	36	2.67		
14	0.70	40	2.71		
16	0.99	50	2.78		
18	1.26	75	2.84		

~~ARORO~~/BAIRIKI Beach Profile No. 11



Horizontal Datum: Post supporting verandah roof.

Vertical Datum : Concrete verandah surface by post.

Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.
0	-	20	0.62	100	2.40
2	-0.07	22	0.85		
4	-0.20	24	1.05		
6	-0.28	26	1.23		
8	-0.34	28	1.40		
10	-0.23	30	1.59		
12	-0.21	32	1.81		
14.5	-0.16	34	2.03		
15	-0.15	36	2.17		
15.5	-0.05	40	2.19		
16	0.04	50	2.18		
18	0.36	75	2.31		