CHAPTER 2

PRESENT SITUATION OF APIA PORT

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2.1 Natural Conditions

In addition to the collection and analysis of existing data and information on natural and environmental conditions, the natural condition surveys have been carried out in Apia Port as summarized below.

2.1.1 Topographic Conditions

Samoa comprises two main islands, seven smaller islands (two of which are inhabited), and islets and rocks. Upolu extends about 72 km from east to west and up to 24km from north to south. With the exception of areas of recent lava flows, both islands are mostly surrounded by shallow lagoons and fringing reef. Both islands have coastal plains four to five km wide, then rise to central mountains. Upolu has chain of volcanic peaks running from one end of the island to the other, with hills and coastal plains on either side.

On the two main islands, Upolu, the smaller, is the more populous. More than half of total area of Samoa is suitable for cultivation, and the majority of the population live on the coastal plain.

Figure 2.1.1-1 shows the vicinity of Apia Port.

2.1.2 Oceanographic Conditions

(1) Wave

The climate of Samoa is a tropical oceanic, tempered by the ocean environment, and marked by a distinctive wet season (November-April) and a dry season (May-October). During dry season, south-easterly trade winds persist throughout the season. Apia Port is well protected from waves by surrounding reef flat with its entrance stretching open to north. However, during wet season, which is also called as cyclone season, north-westerly waves and swells enter the harbor through the wide entrance and agitate water area of the inner harbor.

The following wave appearance rate is analyzed on the basis of wind data recorded at Apia and wave data recorded at a point offshore of Apia by the U. S. Navy.

Wave height	Over 1m to 2m	32 days
	Over 2m to 3m	16 days
	Over 3m to 4m	8 days
	Over 4m	3 days

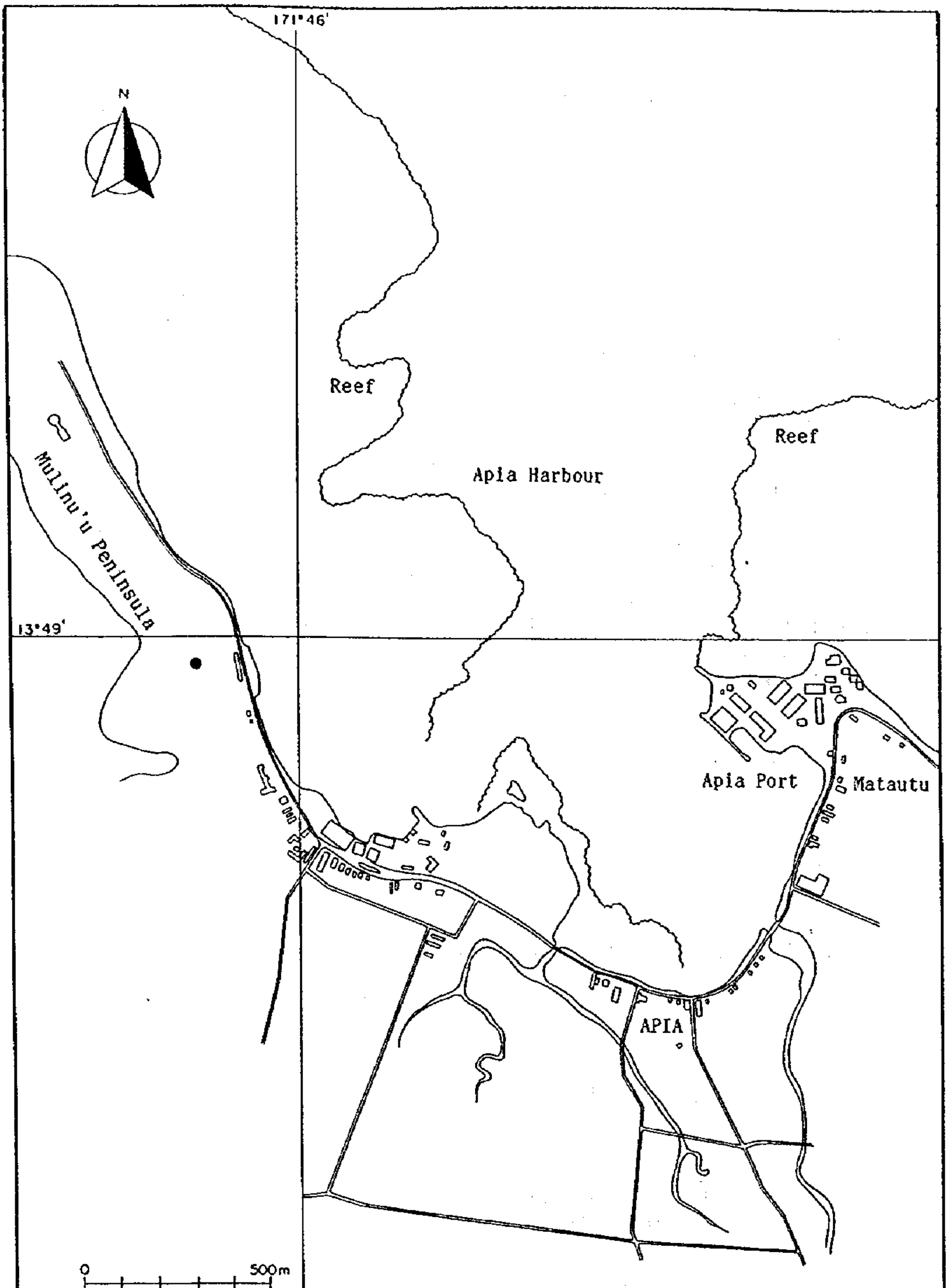


Figure 2.1.1-1 Vicinity of Apia Port

The wave height off Apia Port generated by Cyclone "Ofa"is estimated by computer simulation as below,

		Height	Period	Wave direction
Deepwater Wave		8.6m	12sec	North
Wave in front of wharf	$H_{1/3}$	2.67m		

(2) Current

Samoa is located within the band of the south subtropical current running from east to west. The current speed around the Samoa Island ranges from 16km to 20km per day throughout the year. However, Apia Harbor is not affected by the current because of offshore reef surrounding the harbor.

(3) Tide

Tidal data have been recorded at the Tide Station in Apia Port, and the following tides are defined.

Highest Astronomical Tide	(HAT)	+1.2m
Mean High Water Spring	(MHWS)	+1.0m
Mean High Water Neap	(MHWN)	+0.8m
Mean Sea Level	(MSL)	+0.5m
Mean Low Water Neap	(MLWN)	+0.2m
Mean Low Water Spring	(MLWS)	+0.0m(Chart Datum)
Lowest Astronomical Tide	(LAT)	- 0.2m

(4) Bathymetric Survey

It is reported that two cyclones have caused sedimentation in Apia Bay and the water depth has become shallower by some 2m. Sounding survey has been carried out in the bay and at the proposed new wharf site. Figure 2.1.2-1 shows comparison of water depth in Apia Bay with the previous survey.

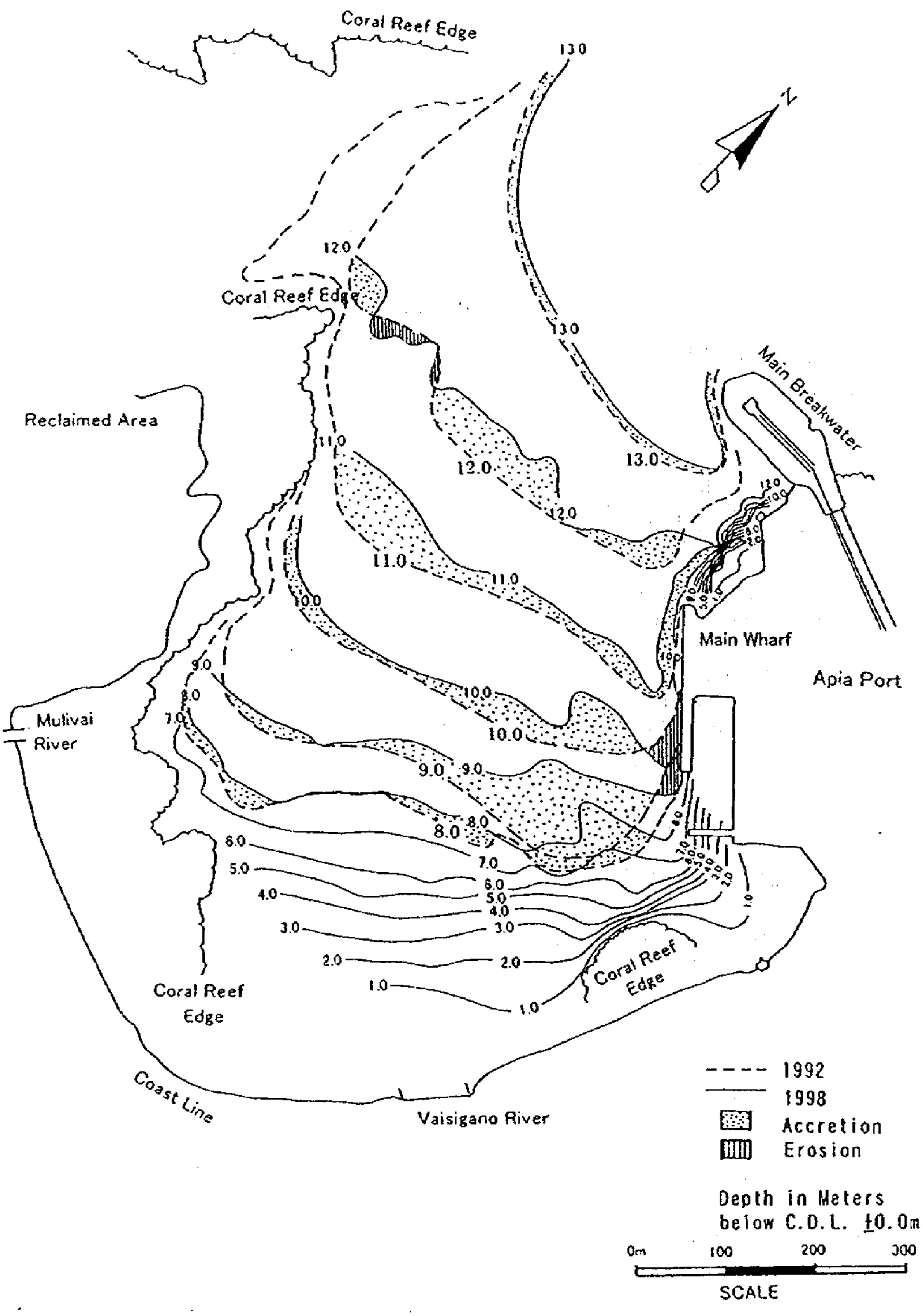


Figure 2.1.2-1 Comparison of Water Depth, 1992 and 1998

2.1.3 Soil Conditions

The results of eight boring survey are shown in Figures 2.1.3-1 and 2.1.3-2.

The present Apia Port has been constructed by reclaiming the shallow reef area. The existing wharf was connected to the reclaimed area through the causeways. The proposed site for the construction of a new wharf has a more complex nature of soil. Before boring work is carried out, underwater survey was conducted by divers to grasp the under water topography. As regards the coral rocks, samples have been collected to measure hardness for designing excavation and pile driving works.

The results of soil investigation are summarized as follows.

1) BH-1

From seabed (-11m) up to -12.4m, coral sand layer (N value=26) is observed. From -12.4m up to -21m, a thick layer is composed of very hard coral. The compressive strength of this hard coral is approximately 100 kgf/cm^2. BH-1 is very singular soil constitution as compared with other boreholes.

2) BH-2

From seabed (-3m) up to –6 m, hard coral layer (N value=20 to 40) is observed. Below this layer up to –27m, the subsoil is composed of very soft silty sand (N value=less than 10). In this layer, approximately 50cm thick non-cemented coral layers (N value= 15 to 30) are included. Under silty sand layer, coral sand layer (N value=15 to 25) is observed down to –30m to reach the weathered rock layer.

3) BH-3

From seabed (-12m) up to –15m, very soft silty sand layer is observed and from –15m up to –17m, hard coral layer (N value=51) is observed. Below this layer up to –30m, the subsoil is composed of coral sand and silty sand (N value= 5 to 20). The weathered rock layer is observed at –30m.

4) BH-4

From seabed (-11m) up to –11.5m, a thin coral layer is observed and below this layer up to –27m, the subsoil is composed of very soft silty sand (N value=less than 8). In this layer, a 30cm thick non-cemented coral layer is included. Under silty sand layer, hard coral layer (N value=40 to 55) is observed down to –30m to reach the weathered rock layer.

5) BH-5

From seabed (-8m) up to –10m, coral layer is observed. Below this layer up to –28m, the subsoil is composed of very soft silty sand (N value=less than 10). Under silty sand layer, coarse sand layer (N value=10 to 20) is observed down to –32m to reach the weathered rock layer.

6) BH-6

From seabed (-12m) up to –15m, very soft silty sand layer (N value=less than10) is observed. Below this layer up to –22m, the subsoil is composed of coarse sand with shell fragments (N value=10). Under coarse sand layer, very soft silty sand layer and coarse sand layer are observed down to –33m to reach the weathered rock layer.

7) BH-7

From seabed (-12m) up to –13m, a thin coral layer is observed and below this layer up to –21m, the subsoil is composed of coarse sand (N value=10 to 20). Under coarse sand layer, very soft silty sand layer (N value=less than 10) is observed down to –33m to reach the weathered rock layer.

8) BH-8

From seabed (-12m) up to –21m, fine sand with shell fragments (N value=10 to 20) is observed. Under this layer, the subsoil is composed of coarse sand with shell fragments (N value= 20). The weathered rock layer is observed at –33m.

The subsoil at the proposed site for a new wharf is composed of very complicated soil layers. Face line of the new wharf proposed in the Master Plan is followed in determining the location of boreholes.

2.1.4 Environmental Conditions

Any significant and substantial environmental effects by this particular project are not expected as detailed in Chapter 6.

Since the environmental information in the Apia bay is limited, sea water and seabed materials are sampled in order to assess the environmental conditions. Investigation on marine ecology has been carried out so as to study the effects of construction work to the marine environment.

No coral nor mangrove grows in the vicinity of the proposed site. Major effort is concentrated to National Marine Reserve, Palolo Deep, located about 1 km north to the port from view point of environmental impact by dispersion of suspended solid caused by construction works.

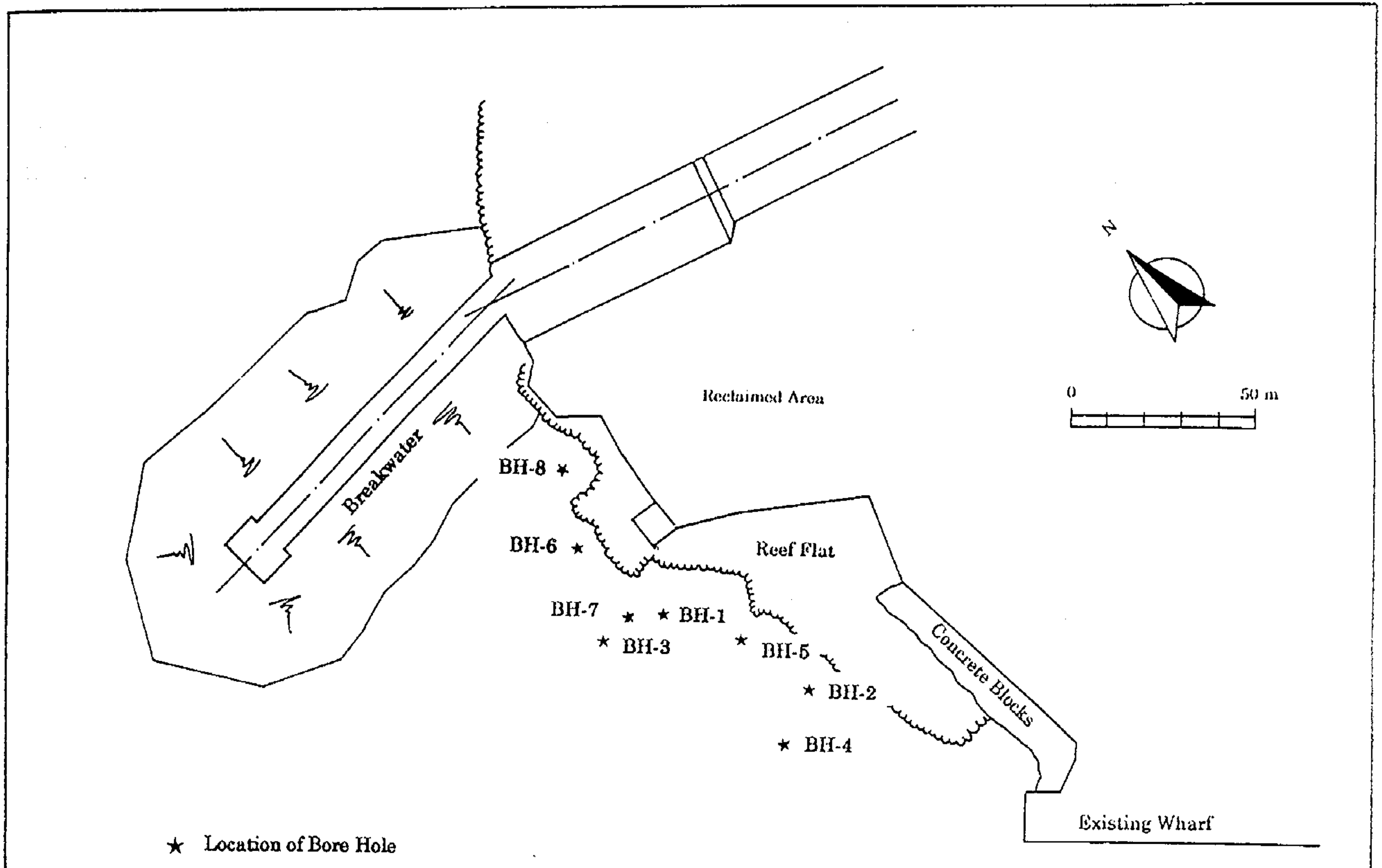


Figure 2.1.3-1 Location of Boring Survey

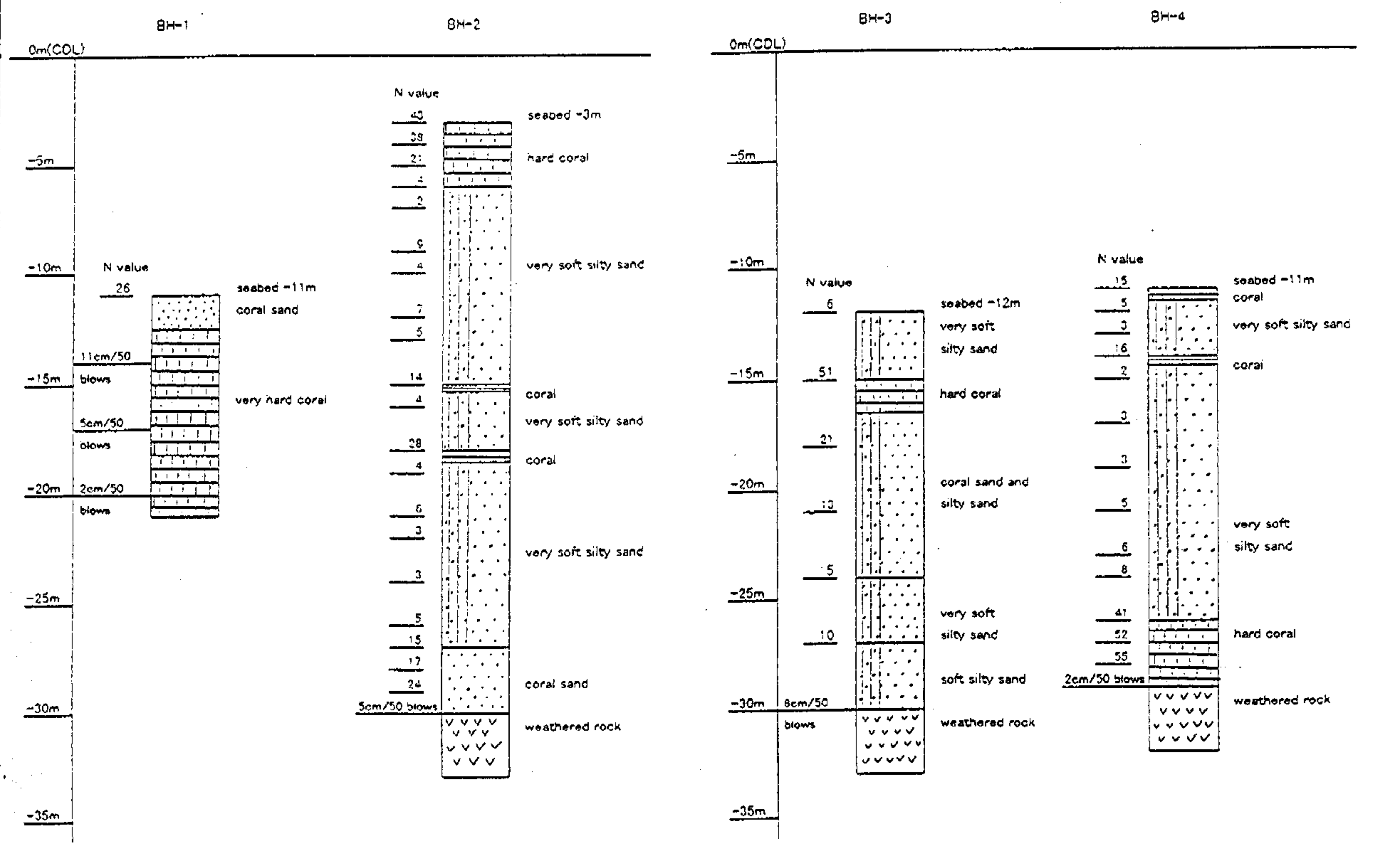


Figure 2.1.3-2 (1) Boring Records (BH-1, BH-2, BH-3, BH-4)

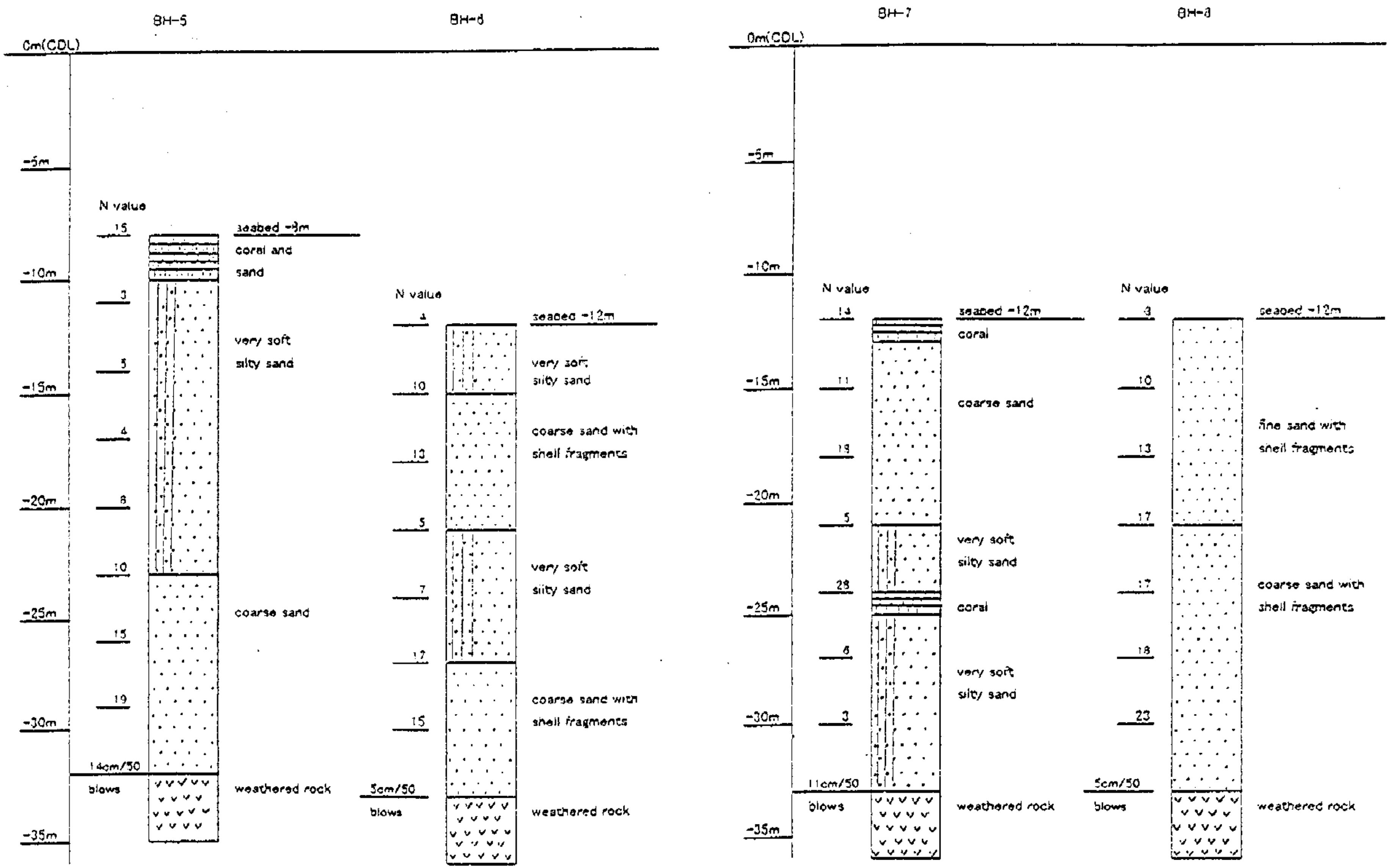


Figure 2.1.3-2 (2) Boring Records (BH-5 ,BH-6, BH-7, BH-8)

2.2 Port Facilities and Activities

Apia Port handles about 97% of international cargos of Samoa (12,000 TEU, in 1997) and 10 international freighters from Japan, Australia, USA and European countries call the port on a regular basis. The main wharf built in 1966 has the dimension of 185m long and 11m deep. The steel piles supporting the concrete deck have been considerably corroded during the period of 30 years after construction.

In 1987, in response to the request from the Government of Samoa a study was conducted to prepare a Master Plan for the Development of the Port in Samoa in 1987. In line with the Master Plan whose target year was set at 2005, the JICA recommended to implement a short-term improvement project including the corrosion prevention works to the piles.

Japan has so far provided assistance on the improvement and rehabilitation of Apia Port three times under the Grant Aid Scheme, which included rehabilitation programs for the damages caused by Cyclone "Ofa" and "Val".

2.2.1 Port Layout and Facilities

Layout of Apia Port is shown in Figure 2.2.1-1.

(1) Approach Channel and Turning Basin

The existing channel is a natural cut of a reef surrounding the island and is deep with minimum depth of about 12 m and wide with the minimum width of 450 m up to the breakwater. Two beacons at 194 degree N mark the outer approach channel to Apia Port and a pilot boarding point is about 1.5 miles off the wharf. The turning area has been silted at the rate of 7.5 cm/year. For instance, water depth in front of the wharf has decreased from 11 m to 9 m due to cyclone attack in 1990.

In this study, the sounding survey was carried out. The turning area is shown in Figure 2.2.1-2 and Figure 2.2.1-3 shows a sectional comparison between the sounding data of 1992 and 1998. The siltation volume in turning basin in front of the wharf (with a radius of 200 m) is estimated at 5,600 m^3/year, i.e. 4.1 cm/year in an average.

(2) Breakwater

The existing breakwater was constructed in 1989 and damaged by cyclones. Damages caused by cyclone have already been rehabilitated. The breakwater is of a structural type of a rubble mound covered with 20 t concrete blocks as shown in Figure 2.2.1-4.

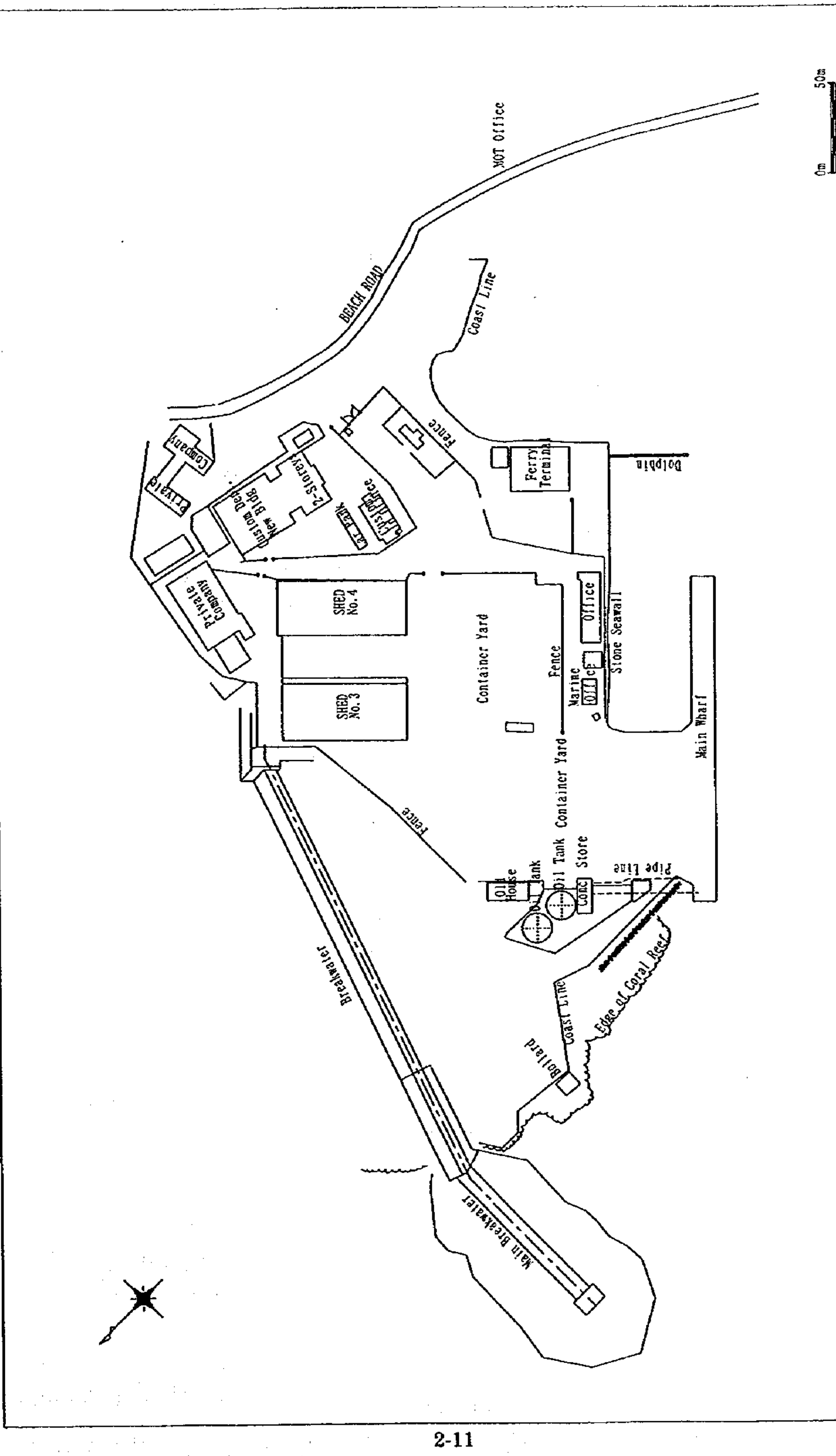


Figure 2.2.1-1 Layout of Apia Port

(3) Main Wharf

The existing main wharf was constructed in 1966 with the structural type of a concrete deck supported by H shaped steel piles encased in concrete piles as shown in Figure 2.2.1-5. The concrete deck is one continuous slab over the entire length of 185 m supported by two batter piles in the center with two vertical piles on both sides. Anti-corrosion anodes were installed to the piles in 1989. Number of containers which can be placed on the deck during container handling operation is limited to three per ship's crane due to deterioration of the wharf. The rubber fenders installed on the northern half of the wharf are badly damaged.

(4) Ferry Wharf

Ferry wharf was constructed under the previous project in 1989. The concrete slopes and mooring dolphin of the wharf are damaged.

(5) Mooring Buoy for Tanker

Three mooring buoys are installed for tankers and are exclusively used by Mobil Oil Company. The marking lights of the buoys are damaged and out of operation.

(6) Open Storage

Open storage for bulk cargo is secured in an unpaved area north to Shed No. 3.

(7) Container Yard

The existing container yard is all concrete paved under Japan's grant aid and ADB finance. The yard is 12,700m^2 wide and is allocated to stevedoring companies as shown in Figure 2.2.4-1. Stacking height of container in the yard is limited to two to prevent accident caused by strong wind. The area at the back of wharf apron is used for common working area where empty containers are stacked ready for shipment before ship's arrival.

(8) Cargo Shed

The existing two cargo sheds are allocated to stevedoring companies as shown in Figure 2.2.4-1. Roofs and doors of both sheds are damaged.

(9) Oil Tanks

Two coconut oil tanks with capacity of 1500 t each are owned by Treasury Department and leased to Coconut Oil Product Company. Recently, Coconut Product Company ceased a lease contract and one of them has been leased to

Mobil Oil Company. Mobil Oil Company has installed pipeline between the tank and the wharf for unloading oil and bunkering services and miscellaneous facilities of fence, separation wall, etc. with the construction cost of about 0.5 million Tala.

(10) Access Road

Access road to Apia Port is of two lanes accommodating traffic volume of about 450 vehicles per day. Total load is limited to 40 t for trailer and 25 t for truck on Visigano Bridge near the port. The present access road is connected to the main city road Beach Road.

(11) Ferry Terminal Building

Ferry terminal building was constructed in 1989.

(12) Marine Office

Marine office was constructed under the previous project in 1993.

(13) Tug Boat

There are two tug boats currently working in the port. One tug boat was purchased under the previous project in 1989 and the other in 1972.

(14) Navigation Aids

Navigation aids have already been improved under the previous projects.

(15) MOT Office

The existing MOT Office is located near the port along Beach Road and the floor layout is shown in Figure 2.2.1-6.

(16) Cargo Handling Equipment

Currently, all the stevedoring machinery and equipment working in the port are owned by private sectors such as Pacific Forum Line, Betham Brothers, Transam and Apia Haulage.

A new custom office building has been constructed funded jointly by Samoan and Australian Governments. Samoa contributed 1/4 million tala where as Australia contributed 1.5 million Australia dollars.

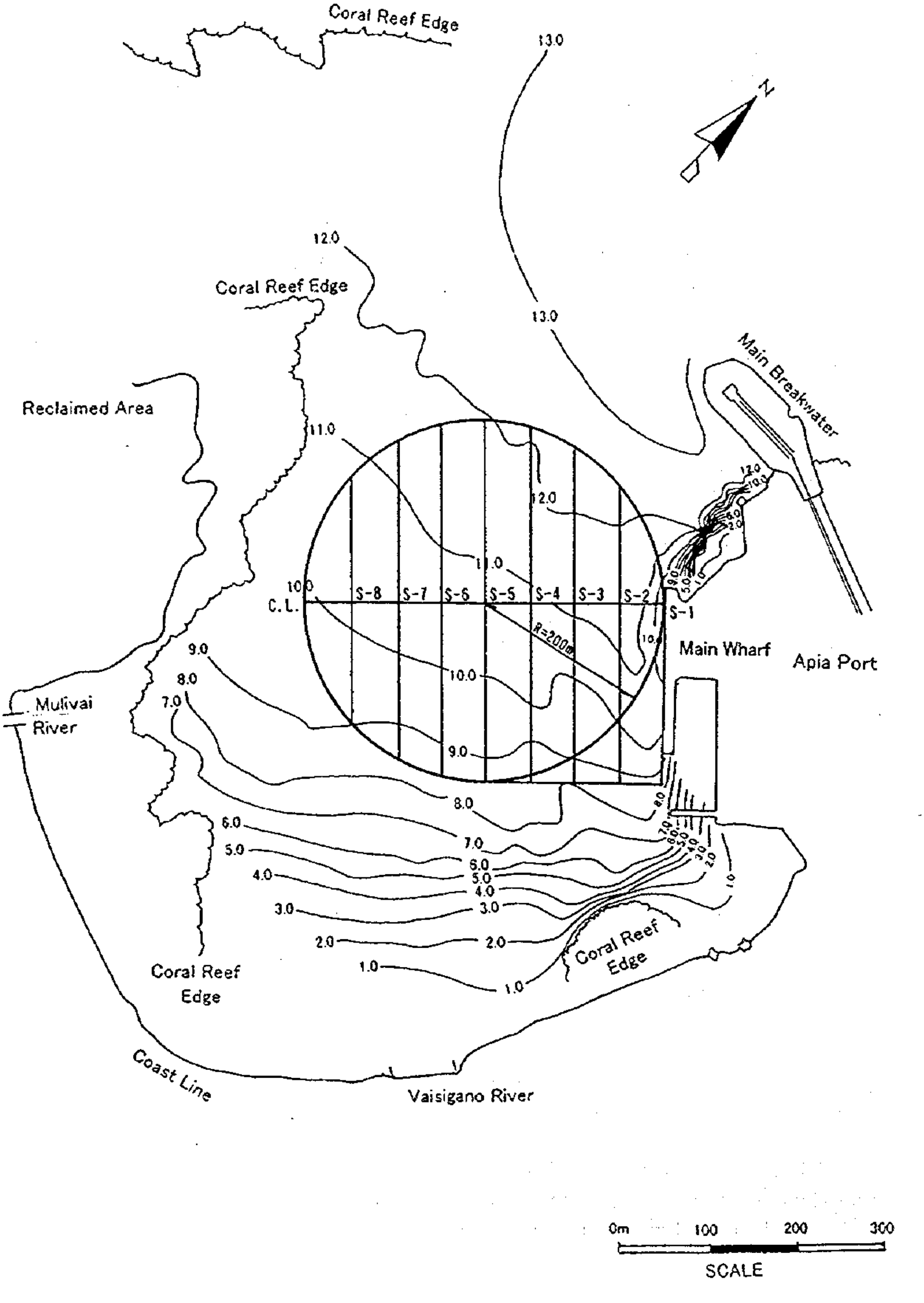


Figure 2.2.1-2 Turning Area

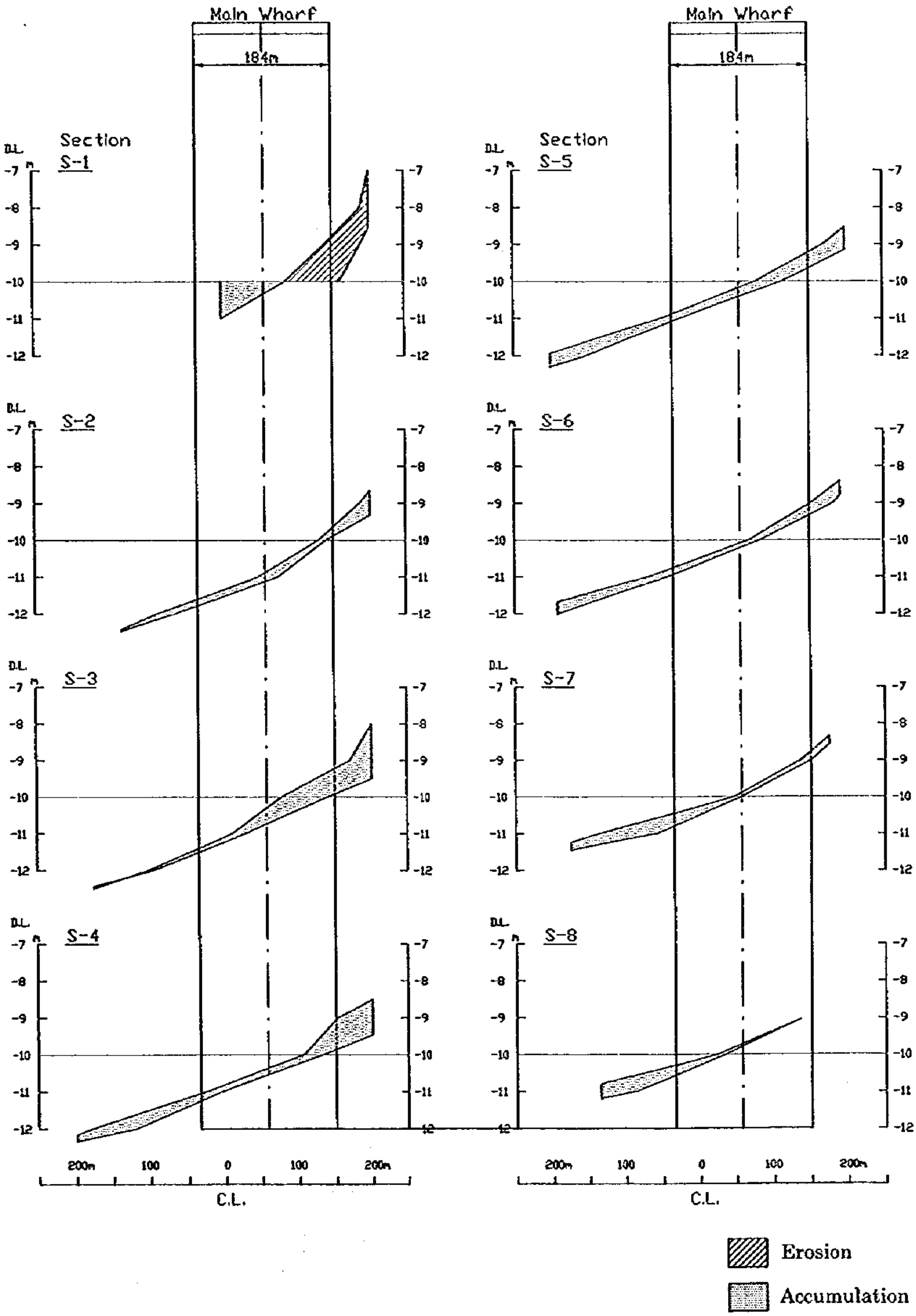


Figure 2.2.1-3 Comparison of the Past Sounding Charts

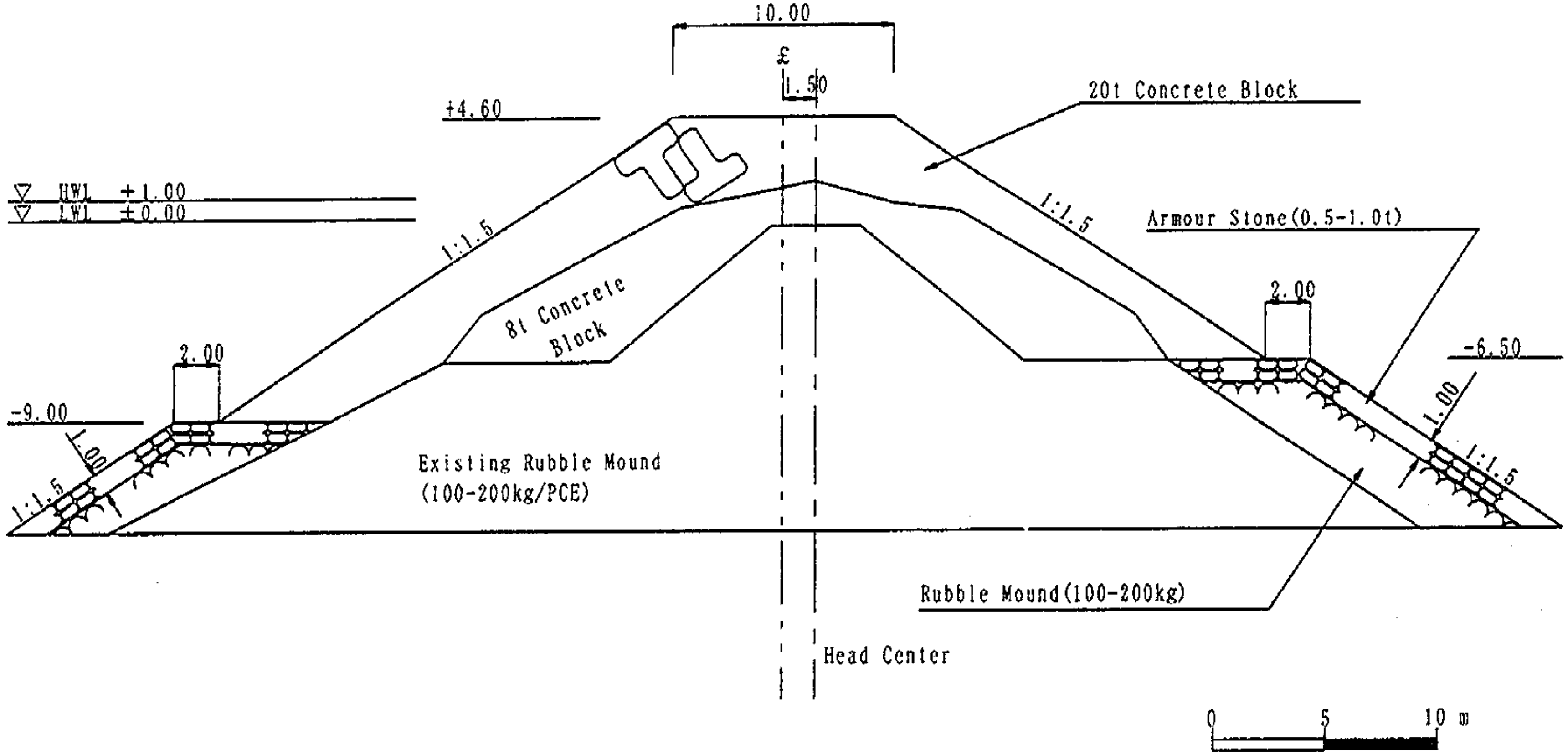


Figure 2.2.1-4 Cross Section of Breakwater

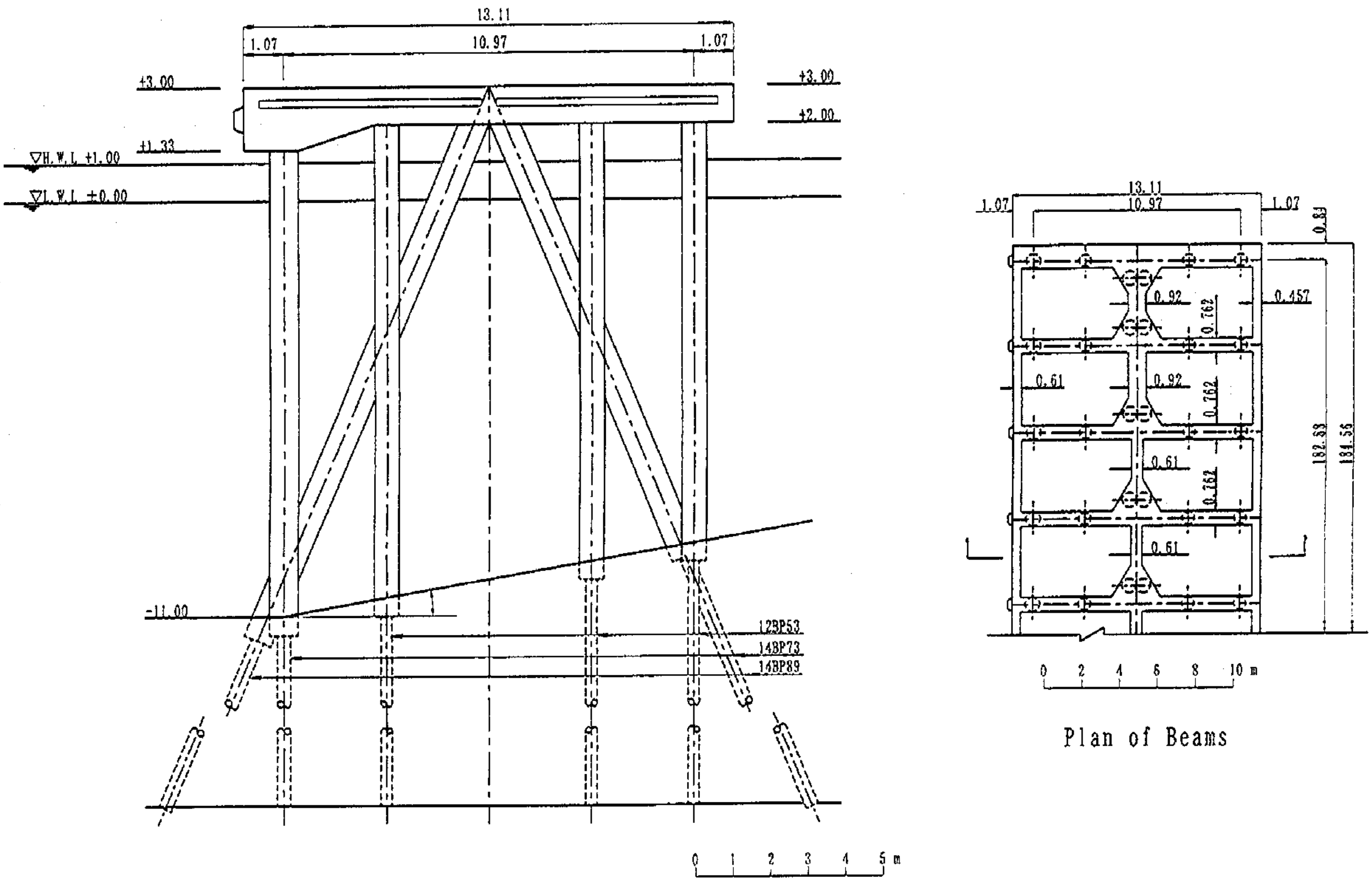
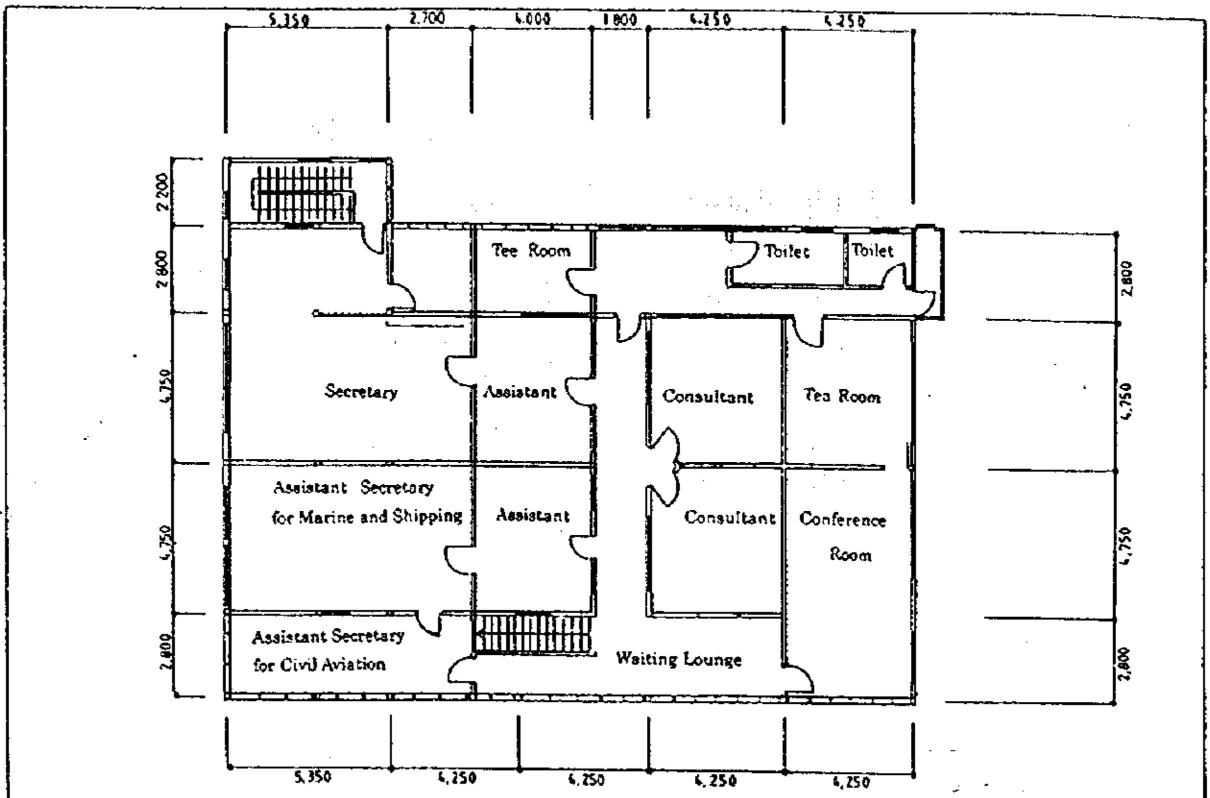
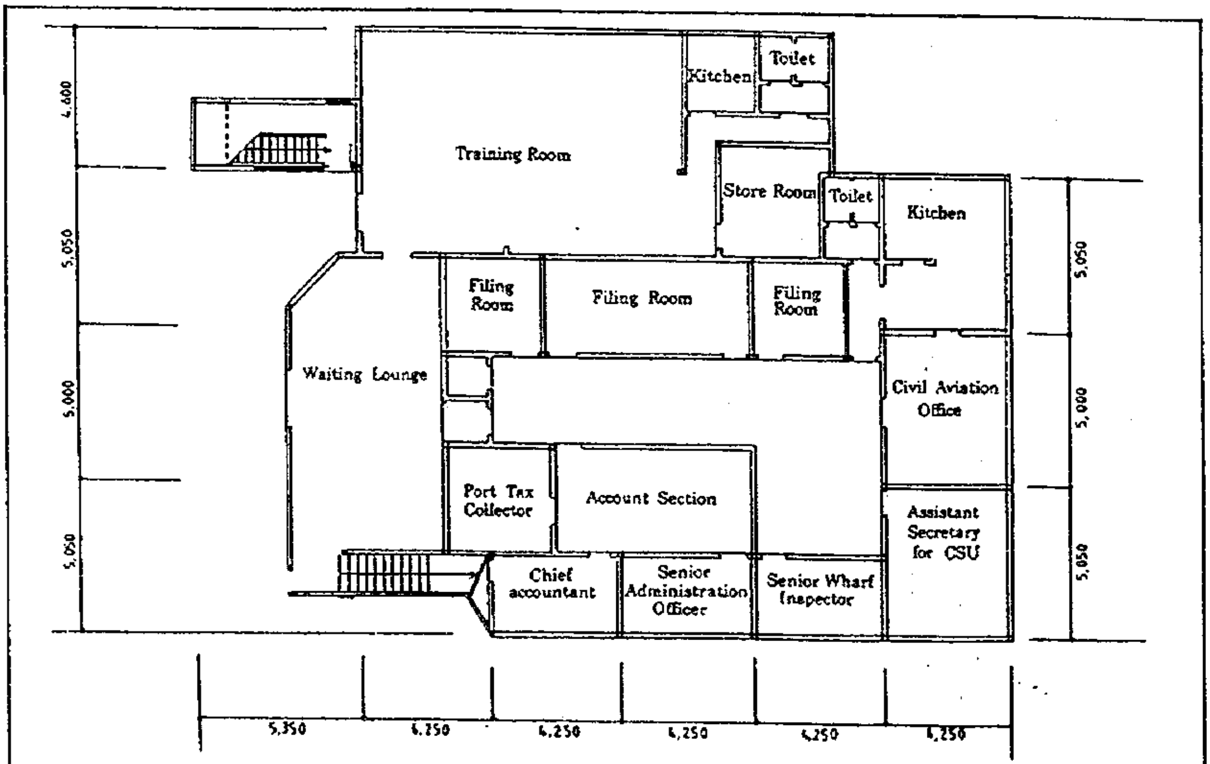


Figure 2.2.1-5 Cross Section of Apia Wharf



UPPER FLOOR



GROUND FLOOR

Figure 2.2.1-6 Floor Layout of Exiting MOT Office

2.2.2 Cargo Statistics

Apia Port is connected with South Pacific countries such as New Zealand and Australia, Far East including Japan, United States and Europe. Most of them are served with semi-container and Ro-Ro ships. In the South Pacific region in particular, Pacific Forum Line (PFL) established in 1977 by member countries of the South Pacific Forum to facilitate marine transportation in the region provides a shipping service to Apia Port with 2 container ships.

A regular ferry service (approximately 2 trips/week) is provided by Western Samoa Shipping Corporation (WSSC) between Apia Port and Pago Pago Port in American Samoa which carries 20,000 passengers/year. Irregular services are provided by small cargo vessels and oil tankers, and passenger boats cruising the South Pacific call at Apia Port several times a year.

The activities of Apia Port are outlined as follows.

1) The number of ship's call is 200 - 250/year.
2) The annual cargo volume is about 260,000 tons, of which 210,000 tons are dry cargoes and 50,000 tons are fuel oil and coconut oil .
3) The number of passengers embarking/disembarking through the ferry wharf is 20,000 a year.

Table 2.2.2-1 and Figure 2.2.2-1 show the volume of dry cargoes and oil handled in Apia Port. In 1996, total import cargo (203,216 m/tons) is 7 times more than total export cargo (28,545 tons) and the share of import and export of general cargo are 74% and 10%,respectively. where as the import and export of oil are 13% and 3%, respectively.

Table 2.2.2-2 and Figure 2.2.2-2 show the remarkable decrease of major agricultural exports such as Coconut oil, Copra, Copra meal and Cocoa from 1990 to 1994, and taro export by leaf blight disease after 1994.

Table 2.2.2-1 Cargo Volume Handled in Apia Port

(unit : tons)

year	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Import	70,607	89,483	91,516	80,396	102,164	105,694	99,897	139,196	110,029	120,509	81,500	88,497	113,091	180,047	133,593	171,317	187,490
Export	33,117	40,148	35,260	45,816	43,970	38,070	30,548	36,767	22,171	17,045	21,645	11,001	16,898	20,491	22,621	22,056	27,296
General Car	103,724	129,631	126,776	126,212	146,134	143,764	130,445	175,963	132,200	137,554	103,145	99,498	129,989	200,538	156,214	193,373	214,786
Import	29,125	14,392	20,985	22,470	23,960	23,074	10,245	39,076	20,713	9,635	20,639	43,864	41,255	35,197	27,050	31,899	39,530
Export		8,027	12,188	10,537	12,099	13,801	11,527	10,330	6,292	5,188	35	837	0	60	6,782	6,489	4,315
Total of Oil	29,125	22,419	33,173	33,007	36,059	36,875	21,772	49,406	27,005	14,823	20,674	44,701	41,255	35,257	33,832	38,388	43,845
Import	99,732	103,875	112,501	102,866	126,124	128,768	110,142	178,272	130,742	130,144	102,139	132,361	154,346	215,244	160,643	203,216	227,020
Export	33,117	48,175	47,448	56,353	56,069	51,871	42,075	47,097	28,463	22,233	21,680	11,838	16,898	20,551	29,403	28,545	31,611
Total	132,849	152,050	159,949	159,219	182,193	180,639	152,217	225,369	159,205	152,377	123,819	144,199	171,244	235,795	190,046	231,761	258,631

Figure 2.2.2-1 Cargo Volume Handled in Apia Port

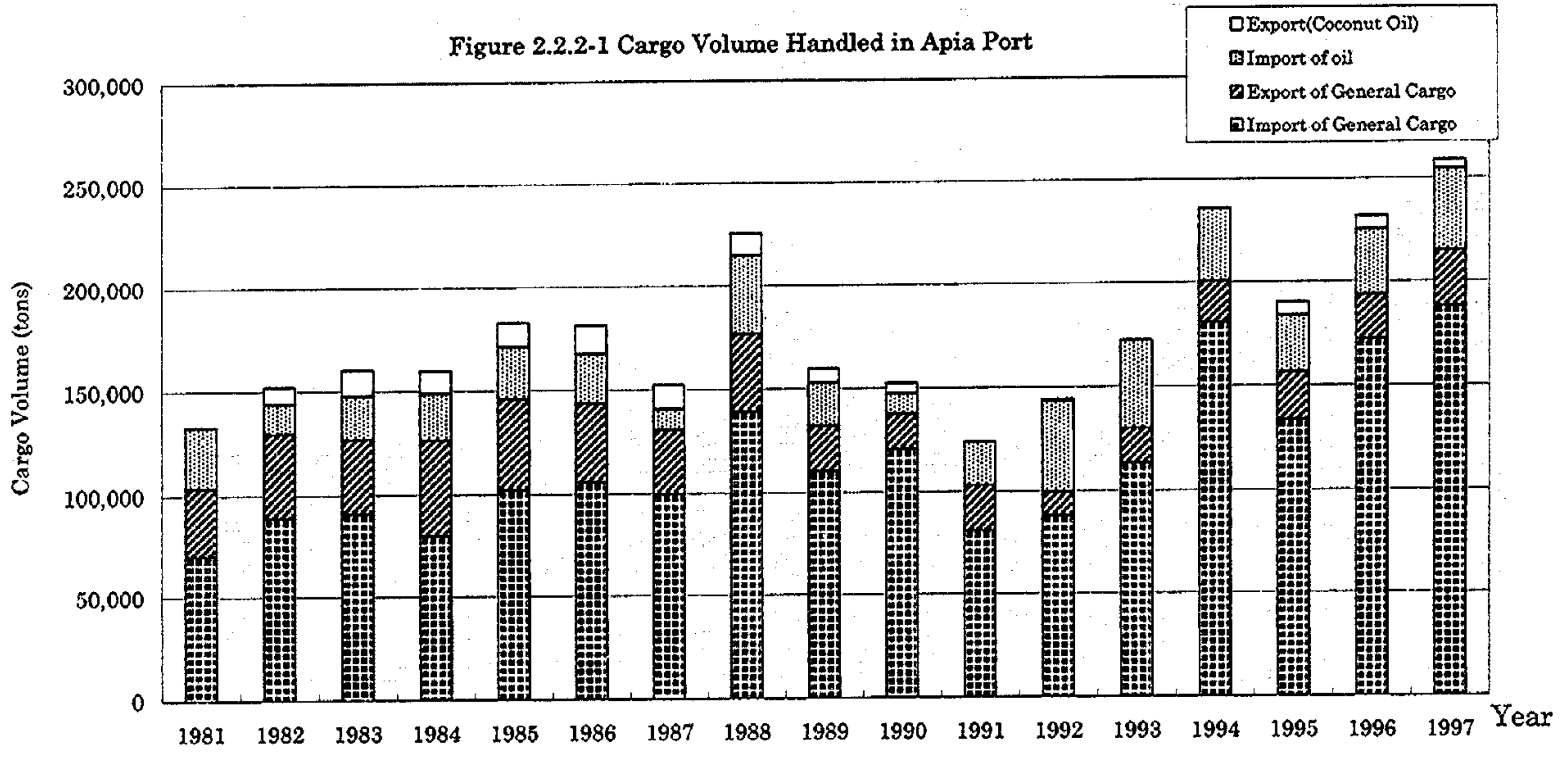
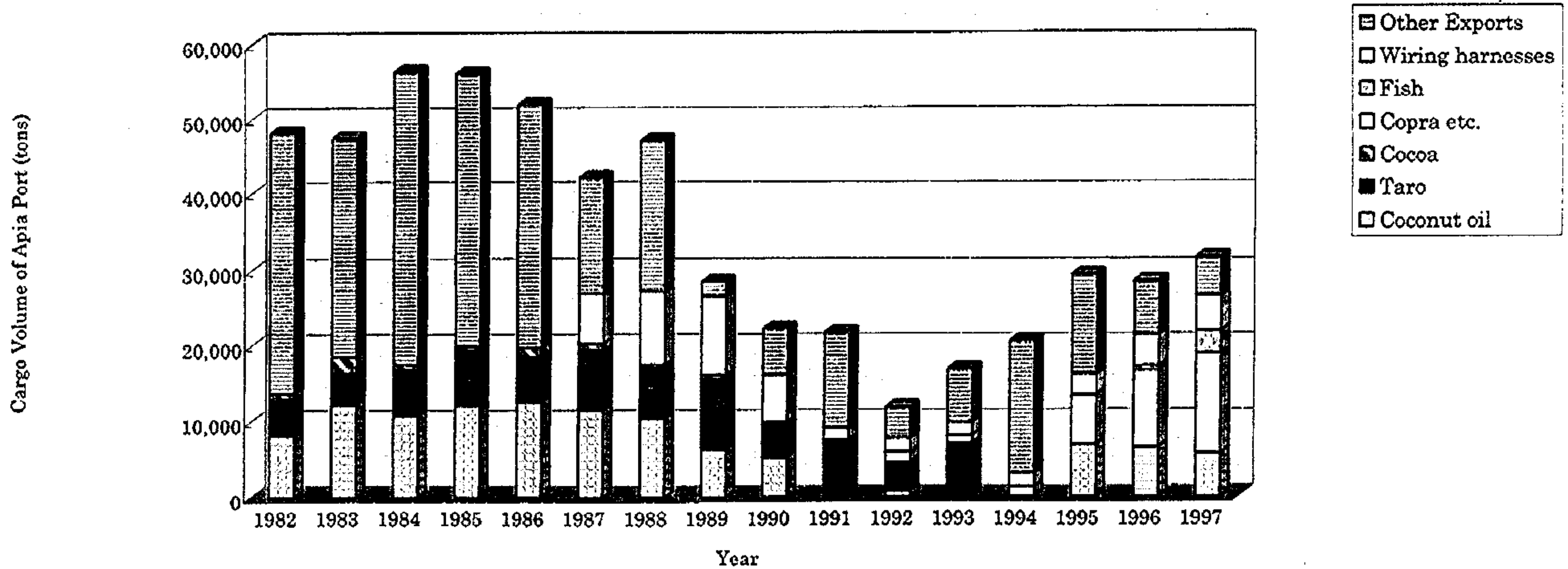


Table 2.2.2-2 Exports by Major Commodity of Apia Port

(unit : tons)

Commodities	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Coconut oil	8,027	12,188	10,651	12,103	12,555	11,527	10,330	6,292	5,188	35	837			6,782	6,489	5,675
Taro	4,893	4,264	6,186	7,200	5,942	7,829	6,675	9,227	4,474	7,409	3,740	7,060	70	70	35	35
Cocoa	770	2,123	709	569	1,240	839	467	595	222	2						
Copra meal						5,170	5,281	3,058	2,215		36			2,624	4,064	3,205
Copra						561	3,230	5,850	2,400				64	2,502	4,659	8,555
Coconut cream						1,002	1,166	1,499	1,576	1,557	1,295	960	1,211	1,380	1,413	1,343
Copra etc.						6,733	9,677	10,407	6,191	1,557	1,331	960	1,275	6,506	10,136	13,103
Fish									54	26	18	39	40	106	562	3,031
Wiring harnesses										104	1,787	1,788	1,788	2,700	4,050	4,696
Other Exports	34,485	28,913	38,807	36,197	32,134	15,147	19,948	1,942	6,104	12,547	4,126	7,051	17,378	13,240	7,273	5,071
Total of Exports	48,175	47,488	56,353	56,069	51,871	42,075	47,097	28,463	22,233	21,680	11,838	16,898	20,551	29,403	28,545	31,611

Figure 2.2.2-2 Exports by Major Commodity of Apia Port



2.2.3 Ship's Call

Number of ship's call by ship type in 1994-1997 is shown in Table 2.2.3-1, while number of call of cargo ship by size is shown in Table 2.2.3-2. Number of cargo ships and tankers are in clear increasing trend while the other ships show considerable fluctuation. Most of the cargo ships fall in the range of 3000 – 10000 GRT. Imported cargo volume is shown in Table 2.2.3-3. Figure 2.2.3-1 shows number of ship's call by ship size and imported cargo volume. Appendix 5 shows detailed data of ship's call and operation in 1995-1998.

In the last five years, ship's call is about 200-250, and import cargo volume is in order of about 200,000 freight tons.

(1) Shipping Company

Table 2.2.3-4 shows representative shipping companies in Samoa and cargo types which they handle.

Table 2.2.3-4 Shipping Companies in Samoa

Shipping Company	Type of Cargo
PFL (Pacific Forum Line Ltd.)	Container, General Cargo, Tanker
Transam Samoa Ltd.	Container, General Cargo
BBE (Betham Brothers Enterprises Ltd.)	Container, General Cargo
MH(Morris Hedstrom Samoa Ltd.)	Liquid Bulk
Apia Haulage Ltd.	Dry Cargo (Cement)
WSSC(Western Samoa Shipping Corporation Ltd.)	Passenger

(2) Shipping Schdule

Typical shipping schedule and routes are shown in Table 2.2.3-5 and Figure 2.2.3-2.

(3) Pilotage

Pilotage is compulsory in Apia Port. Appendix 5 shows the pilot services offered in Apia Port. Night navigation is allowed except for tanker.

(4) Ship Size

Table 2.2.3-6 shows size of ships which regularly call at Apia Port. The largest ships by ship type are as follows;

ShipType	Ship'sName	GRT(t)	LOA(m)
ContainerShip	Kassiakos	16,872	165
Tanker	CaptainMartine	25,060	176
CruiseShip	CrystalSymphony	51,044	238

Table 2.2.3-1 Number of Ship's Call

Ship Type \ Year	1994	1995	1996	1997
Cargo Ship	146	146	143	174
Tanker	19	18	20	26
Cruise Ship	5	15	16	7
Others	48	26	15	33
Total	218	205	194	240

Table 2.2.3-2 Number of Ship's Call by Ship Size (Cargo Ship)

Ship Size(GRT) \ Year	1994	1995	1996	1997
0-1000	2	8	9	20
1000-3000	20	30	31	46
3000-10000	69	61	56	62
10000-	50	47	47	46

Table 2.2.3-3 Import Cargo Volume

Year	1994	1995	1996	1997
Cargo Volume	215,244	166,676	203,718	227,020

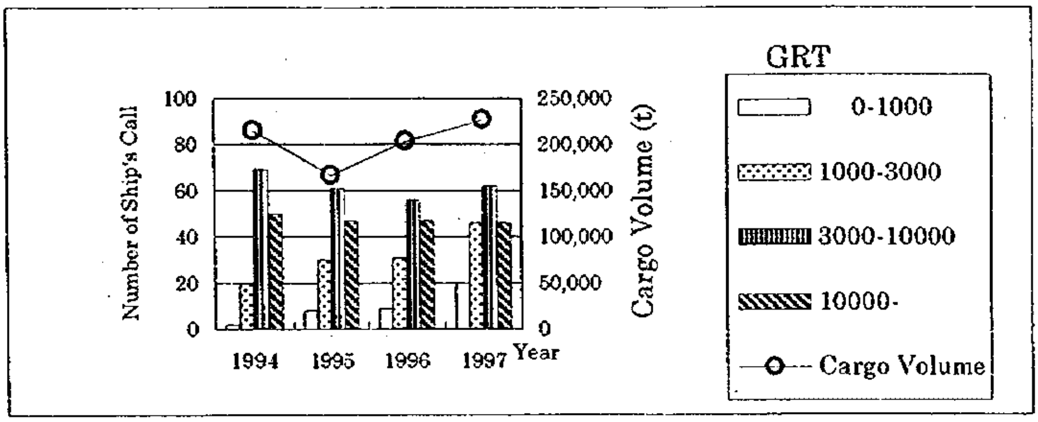


Figure 2.2.3-1 Number of Ship's Call and Cargo Volume

Table 2.2.3-5(1) Shipping Schedule and Routes

Vessel	Voyage No.	Port LYTL	NPE	AKL	LTK	SUV	APW	PPG	NUKU
Forum Samo	303	6/13	6/17	6/19,20	6/24	6/25	6/27	6/28	7/1
ditto	304	7/6,7	7/8	7/10,11	7/15	7/16	7/18	7/19	7/22
ditto	305	7/27,28	7/29	7/31,8/1	8/5	8/6	8/8	8/9	8/21
ditto	306	8/17,18	8/19	8/21,22	8/27	8/27	8/29	8/30	9/3

Vessel	Voyage No.	BNE	SYD	MEL	LTK	SUV	APW	PPG	NUKU	LTK	SUV
Fua Kavenga	229	-	-	6/13	6/20	6/22	6/23	6/24	6/27	6/29	-
Catp. Tasman	12	6/23	6/26	6/29	7/7	7/8	7/10	7/11	7/14	-	7/17
Fua Kavenga	230	7/6	7/9	7/12	7/20	7/21	7/23	7/24	7/27	7/30	-
Catp. Tasman	13	7/23	7/26	7/29	8/6	8/7	8/9	8/10	8/13	-	8/16
Fua Kavenga	231	8/5	8/8	8/11	8/13	8/19	8/21	8/22	8/23	8/28	-
Catp. Tasman	14	8/20	8/23	8/26	9/3	9/6	9/6	9/7	9/10	-	9/13

Vessel	Voyage No.	AKL	NUKU	VAVAU	PPG	APW	RARO
Thor Lisbeth	54	-	6/13	6/15	6/16	6/17	6/22
ditto	55	6/30	7/6	7/8	7/9	7/10	7/14
ditto	56	7/22	7/27	7/29	7/30	7/31	8/4
ditto	57	8/12	8/17	8/19	8/20	8/21	8/25
ditto	58	9/2	9/7	9/9	9/10	9/11	9/15

Vessel	Voyage No.	LA	S.F.O	PPT	PPG	APW	PAGO	LA
Polynesia	263	6/16	6/17	6/26	7/1	7/1	7/3	7/15
ditto	264	7/16	7/17	7/27	8/1	7/31	8/2	8/14
ditto	265	8/13	8/16	8/25	8/30	8/29	8/31	9/12
ditto	266	9/13	9/14	9/24	9/28	9/27	9/29	10/11

Note:

LYTN	Lytelton(New Zealand)	SYD	Sydney
NPE	Napier	MEL	Melbourne
AKL	Auckland	VAVAU	Tonga
LTK	Lautoka(Fiji)	RARO	Rarotonga(Cook Is.)
SUV	Suva(Fiji)	PPT	Papeete(Tahiti)
APW	Apia		
PPG	Pagopago(American Samoa)		
NUKU	Nukualofa(Tonga)		
BNE	Brisbane		

Table 2.2.3-5(2) Shipping Schedule and Routes

Vessel	Voyage No.	Port HongKong	Kaohsiung	Busan	Tokuyama	Kobe	Nagoya	Yokohama	Majuro	Tarama	Honiara	Lautoka	Suva	Apia
Kyowa Cattleya	17										6/5	6/11	6/12	6/13
Coral Islander	51					6/5	6/6	6/8	6/16			6/21	6/23	6/24
Kyowa Hibiscus	30	6/5	6/7	6/10	6/12	6/13	6/15	6/16,17			6/27	7/4	7/5	7/7
Pacific Islander	102	6/23	6/24,25	6/28,29		7/1	7/2	7/3,4		7/13,14		7/18	7/20	7/21
Kyowa Cattleya	18			7/11	7/13	7/14	7/15	7/16,17			7/27	8/3	8/4	8/5
Coral Islander	52	7/24	7/25,26	7/29,30		8/1	8/2	8/4,5	8/13			8/18	8/19	8/20
Kyowa Hibiscus	31	8/4	8/5,6	8/9,10	8/11	8/12	8/13	8/14,15			8/26	9/3	9/4	9/5
Pacific Islander	103	8/23	8/24,25	8/28,29		8/30,31	9/1	9/2,3		9/11,12		9/15	9/16,17	9/18
Kyowa Cattleya	19		9/3	9/6,7	9/9	9/11	9/12	9/14,15			9/25	10/2	10/3	10/5

Vessel	Voyage No.	Port Apia	Pagopago	Papeete	Nukualofa	Noumea	Port Vila	Santo	Noro
Kyowa Cattleya	17	6/13	6/14	6/18		6/27,28	6/7		
Coral Islander	51	6/24	6/25	6/30	7/5	7/8,9	7/11	7/12	7/15
Kyowa Hibiscus	30	7/7	7/8	7/13		7/22,23	6/30		
Pacific Islander	102	7/21	7/22	7/27	8/3	8/7,8	8/10	8/11	8/14
Kyowa Cattleya	18	8/5	8/6	8/10		8/19,20	7/29		
Coral Islander	52	8/20	8/21	8/25	8/30	9/2,3	9/5	9/6	9/9
Kyowa Hibiscus	31	9/5	9/6	9/10		9/19,20,21	8/29		
Pacific Islander	103	9/18	9/19	9/24	9/29	10/3,4,5	10/7	10/8	10/11
Kyowa Cattleya	19	10/5	10/6	10/10		10/19,20	9/28		

Vessel	Voyage No.	Port Honolulu	Port Allen	Kawahae	Christmas Is.	Papeete	Vaitope	Apia	Pagopago	Suva	Lautoka	Auckland	Wellington	Sydney
MS Deutschland		1999/1/5	1/6	1/7	1/10	1/13	1/15	1/18	1/20	1/23	1/24	1/27	1/29	2/1

Vessel	Voyage No.	Puert Quetzal	Acapulco	Nuku-Hiva	Fakarawa	Moorea	Papeete	Borabora	Pagopago	Apia	Nukualofa	Bay of Island	Auckland	Sydney
Albatros		12/1	12/4	12/11	12/13	12/14	12/14	12/16	12/19	12/20	12/23	12/26	12/27	12/31

Vessel	Voyage No.	Port Lytlleton	Auckland	Nukualofa	Apia	Pagopago	Auckland
Southern Cross	261	6/12	6/16	6/20	6/24	6/25	7/1
ditto	262	6/28	7/2	7/7	7/8	7/9	7/16
ditto	263	7/13	7/17	7/22	7/23	7/24	8/2
ditto	264	7/31	8/3	8/8	8/9	8/10	8/17

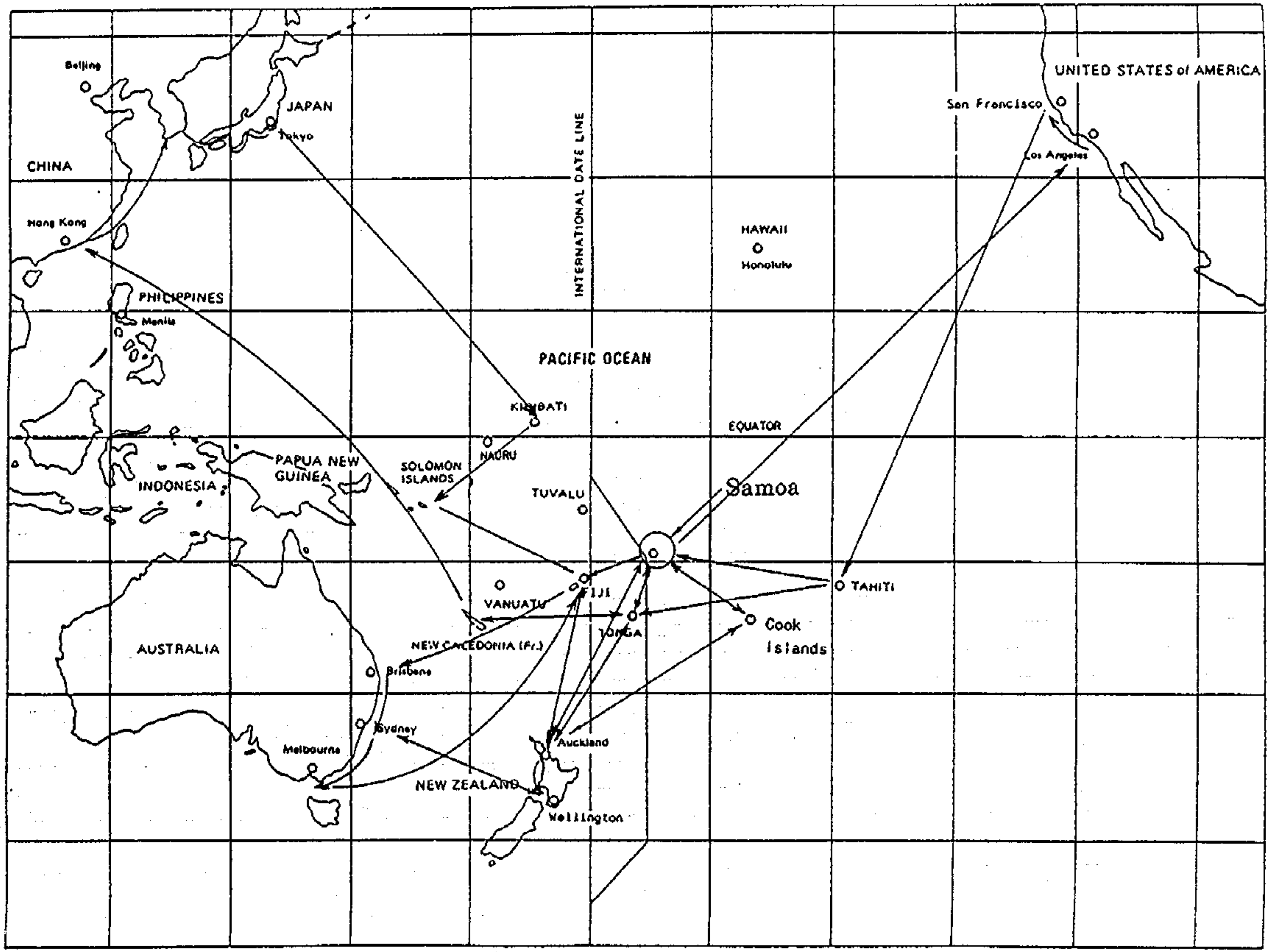


Figure 2.2.3-2 Shipping Routes

(5) Arrival Time

Figure 2.2.3-3 shows distribution of arrival/departure time of vessels. Arrival time is concentrated in 6 to 8 AM when wind velocity is normally low. Vessels arriving in 6:00-8:00 AM account for 30 %. Departure time also has the same distribution.

(6) Port Time

Table 2.2.3-7 shows ships' call and average port time by ship type and size. Table 2.2.3-8 shows annual port time excluding data of tankers and 3 vessels ("Forum Tokelau", "Tutolu", "Cape Don") which have abnormally long port time. Average annual port time is about 3380 hours. Occupancy of the main wharf for annual working days of 298 days (7272 hours:365-52 Sundays and 15 stormy days) is about 47%.

Table 2.2.3-8 Port Time (hour)

1995	1996	1997	
3195.42	2875.85	4061.25	Average 3377.50

As shown in Appendix 5, there are observed about 10 cases in a year, where one ship arrived within 2 hours after the other ship departed. These cases suggest that the later ship waited for departure of the former ship.

(7) Cargo Volume

Table 2.2.3-9 shows cargo volume by vessel type and size. Appendix 6 shows detail data of cargoes handled for all the ships called the port in 1997-1998. Average number of containers handled per ship is 100-120 TEU.

Table 2.2.3-9 Cargo Size per Ship, 1995-1997

Unit: freight ton

GRT / Type of Vessel	- 1000	1000 - 3000	3000 -10000	10000 -	Total
Cargo	101.8	615.0	1384.8	992.1	1019.9
Tanker	379.6	774.9		3185.6	1598.9
Car arrier			160.9	36.1	149.6
Ferry	13.6				13.6
Total	114.1	622.5	1319.7	1286.9	1042.8

Table 2.2.3-6 Ship Dimension

Name of Vessel	Type	Loa	Beam	Draft	GRT	NRT	No. of Crane	With Bow
Crystal Symphony	Cruise Ship	238.01	30.2	8.5	51044	20201		1
Sky Princess	ditto	240.4	29.8	8.17	46087	21617		1
SS Rotterdam	ditto	228.17	28.69	8.4	39674	17692		1
Royal Viking Sun	ditto	204	27.53	7.31	37845	14054		1
Arkona	ditto	164	22.4	6.2	18591	6719		
Club Med 2	ditto				14983	5053		
Seabourn Pride	ditto	133.4	19	5.6	9975	3025		1
Seabourn Legend	ditto	134	19	5.6	9961	3019		1
Daphne(r2)	ditto	162	21.36	8.6	9436	4381		
Sea Dancer	ditto	100.95	14.6	5.22	3745	1123		
Bosei Maru	Reseach	87.98	12.8	5.6	2174	726		1
Fua Kavenga	RoRo/LoLo	118.83	19.2	6.6	6861	2586	1	1
Forum Samoa	ditto	118.83	19.2	6.6	6861	2586	1	1
Southern Queen	Container	86.2	14	7.33	2481	1463	1	
Pacific Islander	ditto	155.52	20.2	7.8	14146	6190	2	
Moana Pacific	ditto	91	14.7	5	14023	8304	2	1
Capt. Tasman	ditto	113.12	18.9		8030	3602	2	
Kyowa Cattleya	ditto	117.52	20.2	6.4	7945	2842	2	1
Kyowa Hibiscus	ditto	117.52	20	6.4	7945	2847	2	1
Socofl Stream	ditto	111.3	13		4885	2221	2	
Rybnovsk	ditto		17.3	5.6	3936	1612	2	
Southern Cross	ditto	93	15	6.28	3186	1372	2	1
Queen Amelia	ditto	79.65	13.25	5.18	1829	1123	2	
Thor Rikke	ditto	73.5	11.53	3.7	1395	540	2	1
Thor Lisbeth	ditto	73.5	11.53		1395	547	2	1
Moana 3	ditto	86.68	13.3	4.24	920	415	2	1
Coral Islander	ditto	155.52	25	7.31	14294	5512	3	
Tui Pacific	ditto	156.7	31.49	8.62	11998	5701	3	1
Seven Pioneer	ditto	146.07	18.9		18791		4	
Acoriano	ditto	79.45	13	6.3	1988	996	4	
Kassiakos	ditto	165	26	10.47	16872	8705	5	1
Ariki Pacific	ditto	164	23	9	13998	7542	5	1
Ostfriesland	ditto	160	22.8	10.07	12974	7348	5	
Forum Tokelau	General	59	10	4.2	808	371	1	
Toyofuji #8	Car Carrier	156	24.4	7.78	18337	5501		1
Captain Martine	Tanker	176		10.872	25060	11128		
Sachem	ditto	170.49			18325			
Shabnee	ditto	170.49		9.9	18225	11046		

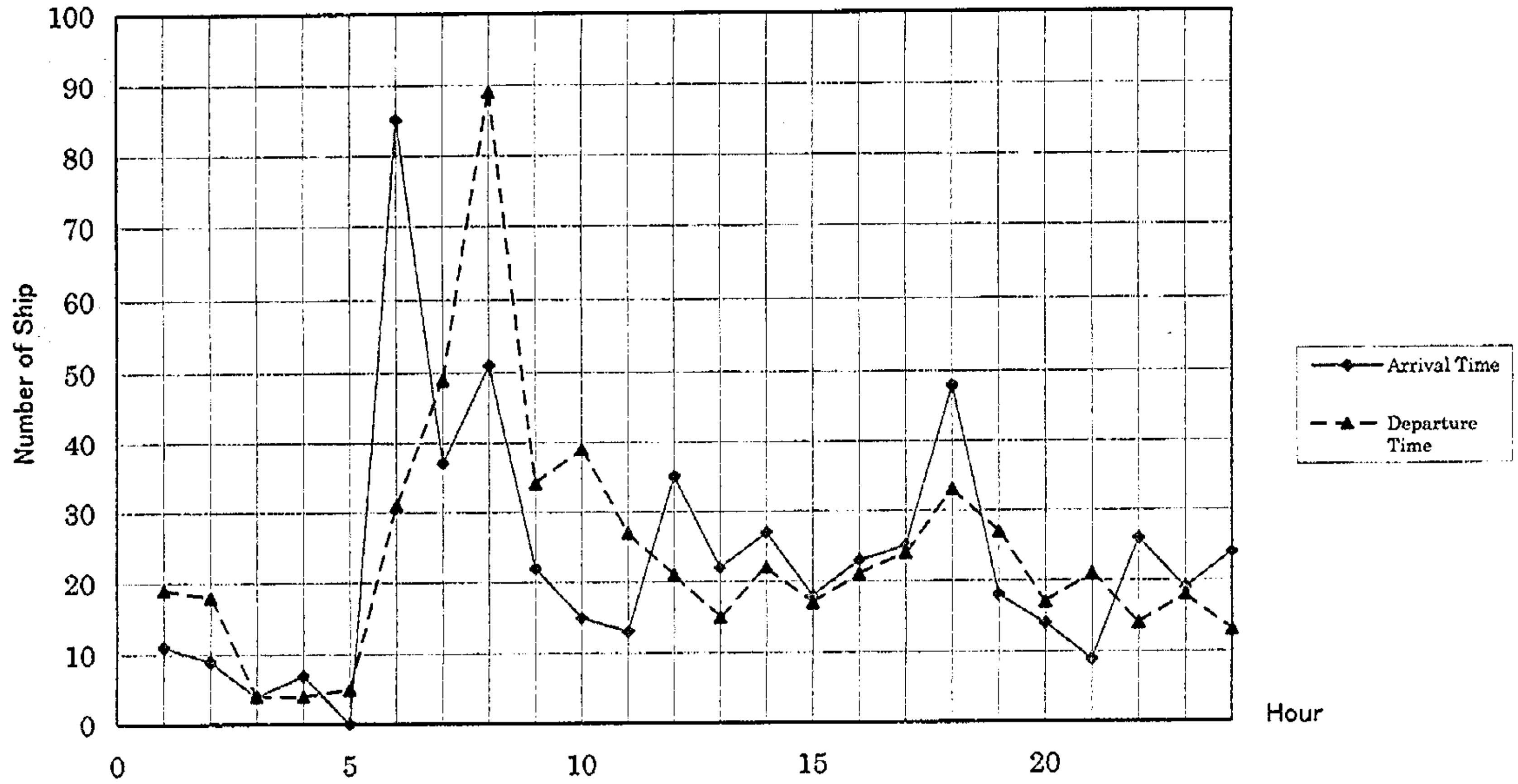


Figure 2.2.3-3 Distribution of Arrival/Departure Time(Cargo Ship, 1995-1997)

Table 2.2.3-7(1) Ships' Call and Average Port Time (1995-1997)

Type of Vessel \ GRT	- 1000	1000 - 3000	3000 -10000	10000 -	Total
Cargo	37	107	179	140	463
	87.7	15.2	16.8	14.0	20.0
Passenger	6	12	7	13	38
	112.5	78.4	13.8	14.3	45.5
Tanker	3	36		25	64
	24.7	19.4		27.0	22.7
Naval	2	2	4	2	10
	62.8	72.5	52.5	84.0	64.9
Car Carrier			11	2	13
			1.3	13.0	3.3
Fishing	11	8			19
	59.0	22.6			40.8
Ferry	15				15
	79.5				79.5
Others	10	4	3		17
	62.9	51.2	72.0		61.0
Total	84	169	204	183	639
	77.0	22.1	16.9	16.6	24.8

Upper : Number of Vessel
Lower : Average Port Time

Table 2.2.3-7(2) Average Port Time(1994-1998)

Type of Vessel \ GRT	- 1000	1000 - 3000	3000 - 10000	10000 -	Un known	Total
Cargo	51	144	287	215	5	697
	78.9	17.6	17.2	14.2		20.1
Passenger	7	13	10	27	2	57
	112.5	74.1	14.3	12.1		35.5
Tanker	5	56	1	37	1	99
	25.4	17.6	79.0	28.0		22.6
Naval	4	2	4	2		12
	31.4	72.5	52.5	84.0		54.0
Car Carrier			17	2	2	21
			2.0	13.0		3.4
Fishing	17	10				27
	46.2	20.3				36.1
Ferry	15					15
	79.5					79.5
Others	10	4	3		38	55
	62.9	51.2	72.0			61.0
Total	84	169	322	283	48	983
	77.0	22.1	17.0	16.9		25.0

Upper : Number of Vessel
Lower : Average Port Time

Table 2.2.3-7(3) Ships' Call and Average Port Time(1995)

GRT / Type of Vessel	- 1000	1000 - 3000	3000 - 10000	10000 -	Total
Cargo	8	30	61	47	146
	10.4	15.7	18.1	11.9	15.2
Passenger	1	5	3	6	15
	61.0	171.4	13.8	10.9	61.0
Tanker	2	8		8	18
	24.0	14.6		31.8	23.8
Naval	1		3	2	6
	48.0		54.0	84.0	63.0
Car Carrier			8	1	9
			1.5	23.5	3.9
Fishing	2	1			3
		94.5			94.5
Ferry	3				3
	137.3				137.3
Others	2	2	1		5
	36.0	68.9	72.0		56.4
Total	19	46	76	64	205
	36.7	33.9	18.3	16.8	22.8

Upper : Number of Vessel
Lower : Average Port Time

Table 2.2.3-7(4) Ships' Call and Average Port Time(1996)

GRT / Type of Vessel	- 1000	1000 - 3000	3000 - 10000	10000 -	Total
Cargo	9	31	56	47	143
	33.1	14.5	17.8	14.2	16.6
Passenger	2	6	2	6	16
	64.5	7.5	9.0	17.2	19.9
Tanker	1	12		7	20
	26.0	15.6		23.5	18.7
Naval			1		1
			48.0		48.0
Car Carrier			2		2
			0.6		0.6
Fishing		2			2
		12.0			12.0
Ferry	4				4
	29.1				29.1
Others	4		2		6
	68.8		72.0		69.6
Total	20	51	63	60	194
	42.3	13.9	18.6	15.4	18.6

Upper : Number of Vessel
Lower : Average Port Time

Table 2.2.3-7(5) Ships' Call and Average Port Time(1997)

GRT / Type of Vessel	- 1000	1000 - 3000	3000 - 10000	10000 -	Total
Cargo	20	46	62	46	174
	160.5	15.2	14.6	16.2	27.2
Passenger	3		2	2	7
	160.5		16.1	17.0	74.1
Tanker		16		10	26
		24.1		245.0	24.5
Naval	1	2			3
	77.5	72.5			74.2
Car Carrier			1	1	2
				2.5	2.5
Fishing	9	5			14
	59.0	12.4			41.1
Ferry	8				8
	96.6				96.6
Others	4	2			6
	72.0	33.5			59.2
Total	45	71	65	59	240
	113.0	19.3	13.8	17.5	31.5

Upper : Number of Vessel
Lower : Average Port Time

(8) Passenger

The operating performance of Queen Salamasina along Apia-Pago Pago ferry service in 1996 is shown in Table 2.2.3-10.

Table 2.2.3-10 Apia-Pago Pago Ferry Service,1996

Route	Number of Trips	Total Number of Passengers
Apia-PagoPago	56	9,992
PagoPago-Apia	61	8,867

2.2.4 Cargo Handling Operation

The productivity of cargo handling operation at Apia Port is analyzed by measuring cycle time.

(1) Allocation of Container Yard and Shed

Allocation of the existing container yard and shed to private stevedoring companies is shown in Figure 2.2.4-1. Number of containers stacked in the yard are counted at 450 on July 7, 1998.

(2) Cargo Handling Equipment

Table 2.2.4-1 shows cargo handling equipment owned by private shipping companies.

Table 2.2.4-1 Cargo Handling Equipment

Shipping Company	PFL		Transam		BBE		Apia Haulage	
Forklift	24t	1	–	–	25t	1	–	–
	25t	2	–	–	13t	1	9t	2
	7t	1	–	–	4t	2	5t	3
	3t	2	3t	1	3t	3	3t	3
Truck	3		–		3		2	
Trailer	3		–		5		–	
Side-lifter			–		2		–	

(3) Cargo Handling Operation

To transfer the containers and general cargo from ship to shore or vice-versa, the stevedores go on board vessels, and using the ship's gear, discharge the containers/general cargo onto the wharf.

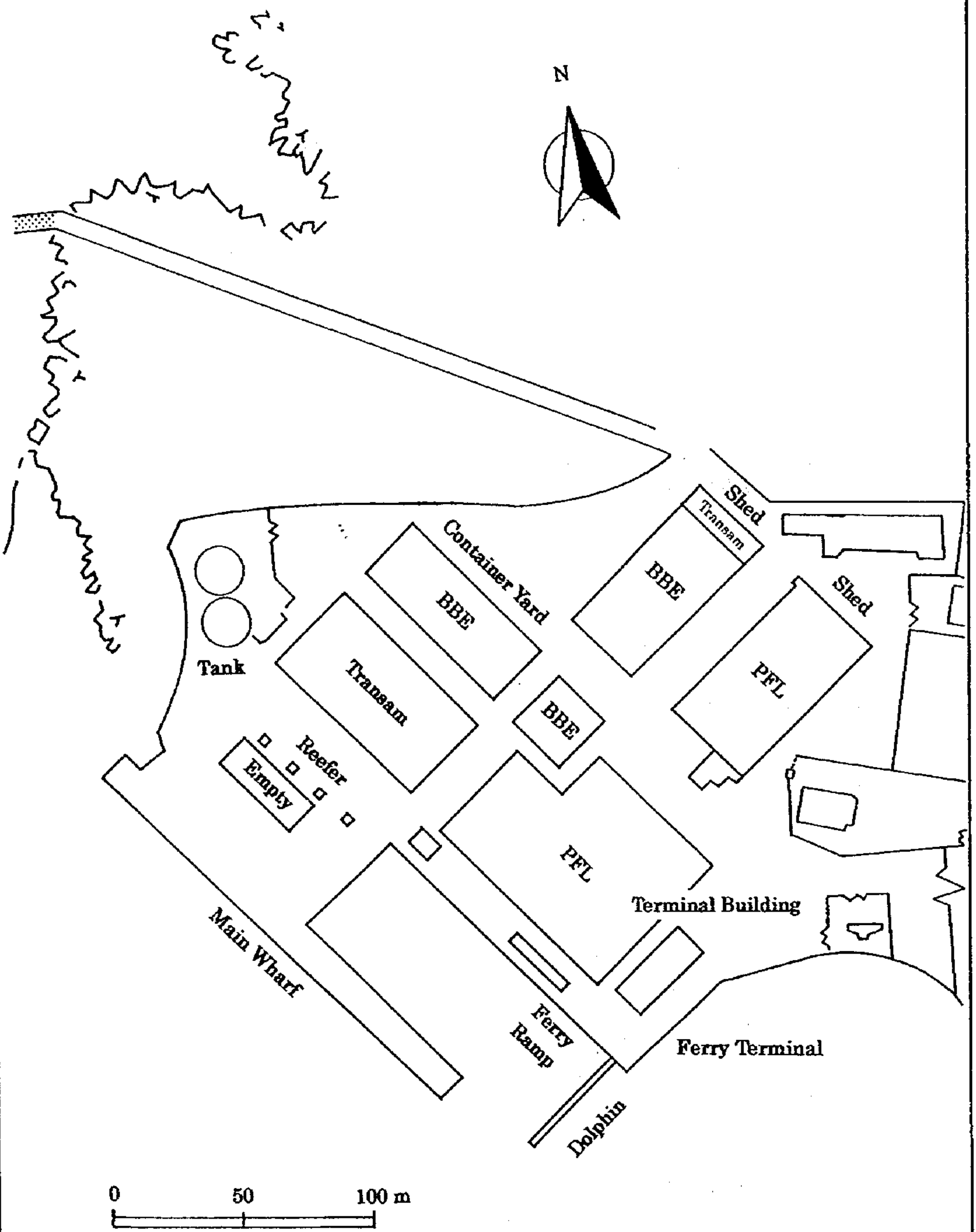


Figure 2.2.4-1 Allocation of Private Stevedoring Companies

To transfer the containers and general cargo from wharf to a container yard or shed or vice-versa, forklifts, trailers and side-lifters are used.

(4) Cycle Time of Cargo Handling

Cycle time of cargo handling operation from ship to wharf is measured and the results are shown in Table 2.2.4-2.

Table 2.2.4-2 Cycle Time of Cargo Handling

Vessel	Arrival Date	Number of Discharged	Container Loaded	Cycle Time
Tui Pacific	6/19	62	39	3 min 9 sec
Fua Kavenga	6/24	85	90	2 min 36 sec
Coral Islander	6/25	49	48	4 min 15 sec
Southern Cross	6/26	28	22	3 min 0 sec
Forum Tokelau	6/29	(break bulk)		3 – 4 min

2.2.5 Problems and Constraints

(1) Deterioration of the Existing Wharf

The most serious problem, which Apia Port is facing at present, is deterioration of the existing wharf. Public Works Department has determined 38 t as the maximum safe axle load allowed on the concrete deck of the existing wharf and this load limitation significantly reduces cargo handling efficiency. Unloading operation of containers from ship is frequently interrupted at times when a load on the wharf reaches the limitation. Since the wharf will continue to deteriorate, a time to cease container handling operation on the existing wharf will come in near distant future.

Some of the other port facilities are more or less insufficient in capacity for efficient and safe port operation. However, they could not be so destructive to port activities as a possible collapse of the existing wharf.

Since the entrance channel and the wharf of Asau Port in Savaii are insufficient in dimensions to accommodate a large container ship and its location is too remote from an economic activity center of the country, practically Apia Port is the only one port open to an international trade.

If the existing wharf of Apia Port will collapse and close port services down, it will totally paralyze the country's economic activities. This is the main reason why the Government of Samoa has given the top priority to this particular project.

(2) Insufficient Berthing Capacity

Length of the existing wharf in Apia Port is only 185 m and is not capable to accommodate two ships of 3000 GRT or more at the same time. Large container carriers calling Apia Port are 15000 GRT class with LOA over 120 m and fully occupies the existing wharf. Priority of berthing is given to cruise ships and diplomatic ships. Recently, occasions of waiting for berth of cargo ships have become more frequent.

Loading operation of copra normally takes one week and obliges the ships calling the port during this period to wait for several days. Information on berth availability is given to shipping agents in advance and shipping schedules are adjusted to avoid otherwise unnecessary clash and waiting. However, adjustment of shipping schedule can not necessarily remove all the waiting time and in many cases requires extra shipping cost. This situation will worsen as the port cargoes and a number of ships will increase and the cargo handling efficiency will decrease due to load limitation to the wharf.

(3) Swell Disturbance

Swell with a long period over 9 second generated by North-Eastern Trade Wind, causes disturbance in Apia Bay obstructing cargo handling operation at the wharf. Swell moves a ship to the extent that she has to stop cargo handling operation, may damage fenders and her hull, break mooring ropes and further has to unberth and stay at anchorage. This swell disturbance is experienced several times a year.

(4) Shortage of Container Yard Area

The area of the container yard was expanded by 2,000m^2 in the Improvement Project of Apia Port in 1989, and it was expanded by the ADB project implemented in the same year. Further, it was expanded by paving the floor area of the demolished Shed No. 1 damaged by cyclone. Volume of import cargoes shows sharp increase in recent years after recovery from damages caused by cyclones. Area of the existing container yard becomes insufficient for efficient yard operation.

(5) Shortage of Storage Area of Cargo Shed

At present there exist only the warehouses No.3 (3,645m^2) and No 4 (2,230m^2) and the storage area of cargo shed will become short for increasing port cargoes.

2.3 Deterioration of Existing Wharf

To examine the deterioration of the existing wharf, the survey on displacement, breakage and corrosion of the existing wharf has been carried out.

Surveys have been conducted on deterioration of the wharf slab, curbings, fenders, bollards, beams, piles, casing concrete, galvanic anodes, thickness of H shaped steel piles, concrete strength, and inclination/deformation of slab and piles as detailed in the following.

2.3.1 Visual Observation

The plan and cross section of existing wharf are shown in Figures 2.3.1-1 and 2.3.1-2.

Corrosion of steel piles, deformation of concrete slab and beams, present condition of curbings, fenders and bollards of the existing wharf have been first investigated by visual observation.

(1) Steel Piles

The results of visual survey of all steel piles are shown in Appendix 7.

1) Pile Head

Location of piles damaged on pile head is shown in Figure 2.3.1-3. Vertical cracks on pile head in both vertical and batter piles are observed in 209 piles (68%) out of 307 piles including central and north approaches. The width of cracks on damaged pile head is more than 1mm upto 10 mm.

The piles in rows E and F and the piles in the central row of the wharf are heavily damaged. As the center part of the wharf is mainly used for handling containers, it can be considered that piles in the center part take large stress from the entire structural load onto the wharf.

2) Piles in Underwater

92 damaged piles are observed as shown in Figure 2.3.1-4. Piles 1A to 1F are heavily damaged. A part of concrete casing is missing and H piles are exposed.

39 (3 piles x 13 places) piles have been reinforced at 1.5m height above seabed with underwater concrete blocks which were installed in the Project for Apia Port Development in 1990.

(2) Concrete Slab

A visual observation was carried out and only a limited number of hairline cracks were observed on the concrete slab. These small cracks don't have any effect to the structural strength of the wharf.

(3) Beams

The beams were checked by visual observation and 35 damaged beams were observed as shown in Figure 2.3.1-5 and Appendix 7.

(4) Curbings

No significant damage of curbings was observed.

(5) Fenders

The rubber fenders have been damaged in the northern half of the wharf with three fenders cracked and two fenders torn off. Two rubber fenders and steel plates in front of piles 11A and 12A were torn off and lost. Three rubber fenders in front of piles 8A, 9A and 10A were cracked over half the entire length.

(6) Bollards

No significant damage was observed on bollards.

2.3.2 Corrosion Survey on Steel Piles

At present, JICA Study Report prepared in 1987 is the latest report containing information on the deterioration level of the existing wharf. Current load limitation on the existing wharf is based on this report. Corrosion of H shaped steel underwater has been measured by an ultrasonic thickness meter.

The corrosion rate after installation of anti corrosion anodes in 1990 measured in this study is compared with the design data.

(1) Results of Thickness Measurement of H Piles

1) Plies in Underwater

38 spots (5 points/spot and 3 times/point) on 14 piles were measured for steel thickness and the results are shown in Table 2.3.2-1 and Figure 2.3.2-1. Data of measured thickness were presented in Appendix 7. The summary of corroded thickness is shown in Table 2.3.2-2.

The average of corroded thickness (mean of 5 spot measurements) of 12BP53 is 0.30 mm. The average of maximum corroded thickness (maximum of 5 spot measurements) is 1.04 mm.

The average of corroded thickness of 14BP73 is nearly zero. The average of maximum corroded thickness is 0.51 mm.

The average of corroded thickness of 14BP89 is 0.35 mm. The average of maximum corroded thickness is 1.05 mm.

The corroded thickness of 12BP53 is larger than 14BP73.

The results of thickness measurement of H piles in 1987 is shown in Table 2.3.2-3. In 1998 survey, the measurement on the same points as those in 1987 except –4.5 m depth on pile 1E were not able to be carried out due to underwater concrete installed in 1990. The comparison of thickness measurement on pile 1-E in 1987 and 1998 surveys is shown in Table 2.3.2-4. The range of corroded thickness in 1998 survey is smaller than that in 1987 and the range of maximum corroded thickness in 1998 is bigger than that in 1987. Consequently, the values of corroded thickness in 1987 survey are considered to be the maximum corroded thickness.

2) Pile Head

Thickness at 10 points on 10 piles in splash zone were measured after chipping the concrete casing and tremie concrete around H pile. The results are shown in Table 2.3.2-5 and Appendix 7.

Average of corroded thickness on pile head is about 2 mm and corrosion of H piles is progressing by oxygen supply through cracks.

H pile was exposed over 0.5m length in pile 3C. The corroded thickness of pile 3C in splash zone is 3.4 mm.

The test for water-soluble chloride in concrete chips on 10 piles was conducted and the results are presented in Appendix 7. The chloride ratio in casing concrete is 0.56 to 2.04 % and ratio of tremie concrete is 0.06 to 0.71 %.

(2) Corrosion Rate

1) Underwater

The corrosion rates of steel piles for both non protection and protection duration are calculated by the following equation (Estimation System of Corrosion of Port Facilities, No. 501 Dec. 1984, Technical Note of the Port and Harbour Research Institute, Ministry of Transport, Japan).

$$v_c = \frac{c}{y_c + (1-p)\, y_p}$$

$$v_p = \frac{c - v_c y_c}{y_p}$$

where v_c: corrosion rate for non protection duration (mm/year)
v_p: corrosion rate for protection duration (mm/year)
y_c: non protection duration (year), y_c=24 (1966 to 1990)
y_p: protection duration (year), y_p=7 (1991 to 1998)
c : corroded thickness (mm)
p : protective rate (p=90%, 75%)

Using the thinnest datum (pile 1E), the corrosion rate for non protection duration in water was calculated as 0.08 mm/year (1E, 1.6 mm/20 year) in 1987 survey (JICA Study Report). The corrosion rate for protection duration in water was assumed as 0.02 mm/year. However, the protective rate is recommended as 90% in the Technical Note. The corrosion rate in JICA Report corresponds to protective rate 75 %.

The corrosion rates in 1998 survey are calculated by using the above equation and are shown in Table 2.3.2-6 and Appendix 7.

In the case of the protective rate 75%, the average corrosion rate of corroded thickness for non protection duration is calculated at 0.015 mm/year and the same for protection duration is 0.004 mm/year based on the measurement results obtained in this study. The corrosion rate of maximum corroded pile are 0.039 and 0.010 mm/year.

With reference to corrosion rate for protection duration, comparison of corrosion rate on pile 1E is shown in Table 2.3.2-7. The corrosion rate is considered to be 0.01 to 0.02 mm/year.

Corrosion rate underwater is summarized in Table 2.3.2-8.

Table 2.3.2-8 Corrosion Rate of H Piles (Underwater)

	Pile Head (mm/year)	
	Non-protection	Protection
Average	0.015	0.004
Maximum Corroded Pile	0.039	0.010

2) Pile Head

The corrosion rate in splash zone is calculated by the thickness measured on 10 piles and shown in Table 2.3.2-9 and Appendix 7. Since the wharf was constructed in 1966, two major external loads acted on the wharf in 1990 and 1991. In 1990 and 1991 waves of cyclones Ofa and Val attacked the wharf and caused large cracks on pile head. The average corrosion rate is 0.3 mm/year and corrosion rate of maximum corroded pile is 0.443 mm/year.

Table 2.3.2-9 Corrosion Rate of H Piles (Pile Head)

	Pile Head (mm/year)
Average	0.30
Maximum Corroded Pile	0.443

2.3.3 Pile Inclination and Others

(1) Pile Inclination

The angle of pile inclination on 26 vertical piles were measured by a slant scale. The results of pile inclination survey are shown in Appendix 7. The piles located on the south-eastern side of the Wharf (pile No.41) are observed to be inclined ranging from 1.25° to 3.50° toward land side. The piles in the center part of the Wharf (pile No.28) are inclined ranging from 3.5° to 4.25° toward land side.

(2) Settlement Survey

According to the Government of Samoa, north-western portion of the wharf has been settling recently. The elevation of the concrete deck was measured by a level and the results of settlement survey are shown in Appendix 7. North-western portion of the concrete deck is calculated to have settled 3 to 5 cm from 1987 to 1998.

(3) Investigation of Galvanic Anode

The durability of galvanic anode installed in 1990 is 15 years. Measurement of the electric voltage by reference anodes has been conducted to determine the efficiency of cathodic anodes and durability of the existing wharf. Also measurement of shape of remaining galvanic anodes has been carried out to forecast the remaining life of existing galvanic anodes.

132 galvanic anodes were observed by visual survey and the volume of remaining anodes are 70% to 90%. The electrode potential of galvanic anodes are measured to be less than −780 mV and shown in Appendix 7. The existing anodes are considered to be effective.

(4) Strength of the Concrete Slab

The field test of concrete strength by using Schmit hammer has been carried out to evaluate deterioration of concrete slab.

The compressive strength is measured as follows.

Slabs	: 400 to 500 kgf/cm^2
Beams	: 300 to 500 kgf/cm^2
Concrete casings of piles	: 300 to 500 kgf/cm^2

Three concrete core samples of the concrete slab have been taken for compressive strength tests. The results of compressive strength show approximately 400 kgf/cm^2.

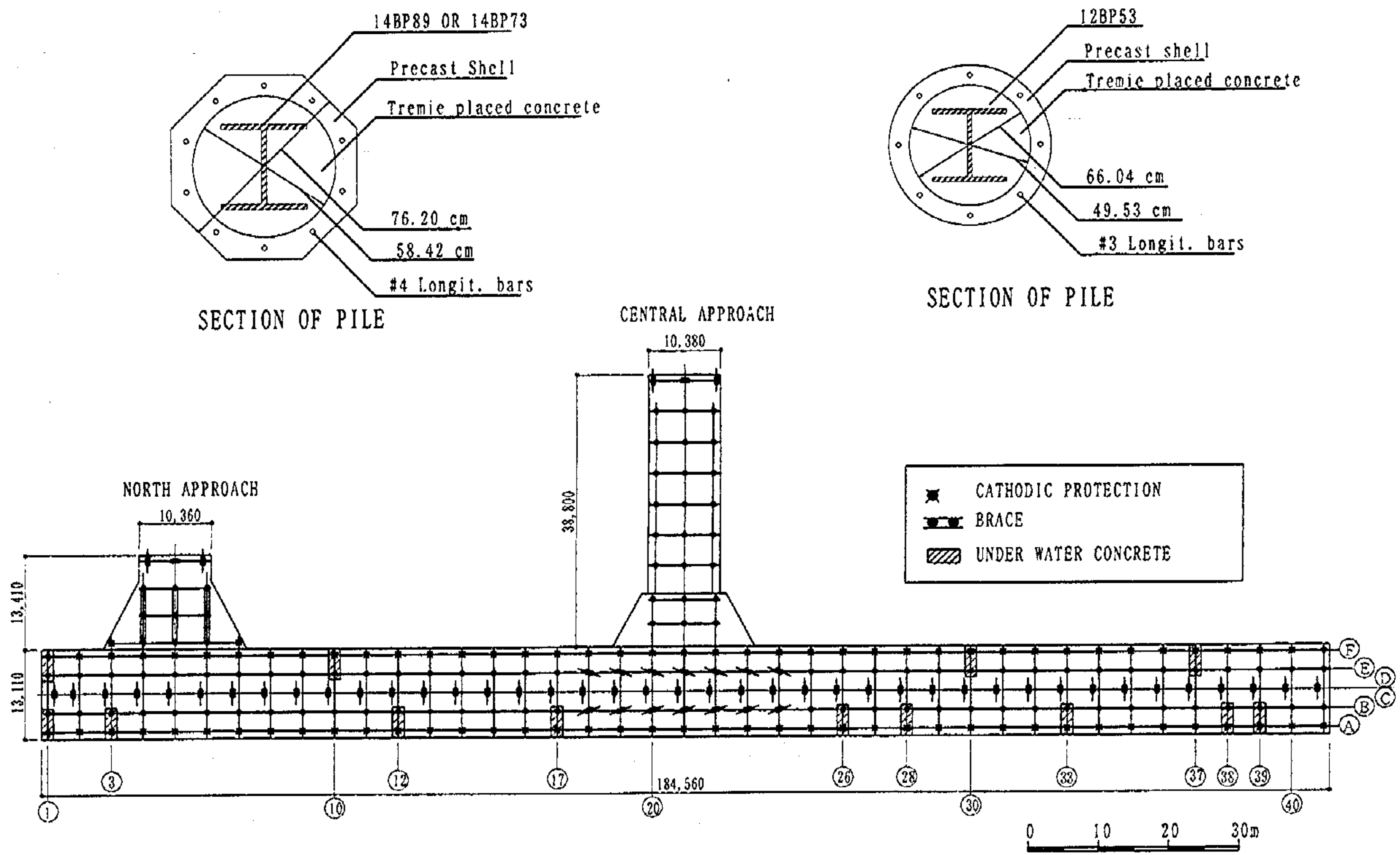


Figure 2.3.1-1 Plan of Existing Wharf

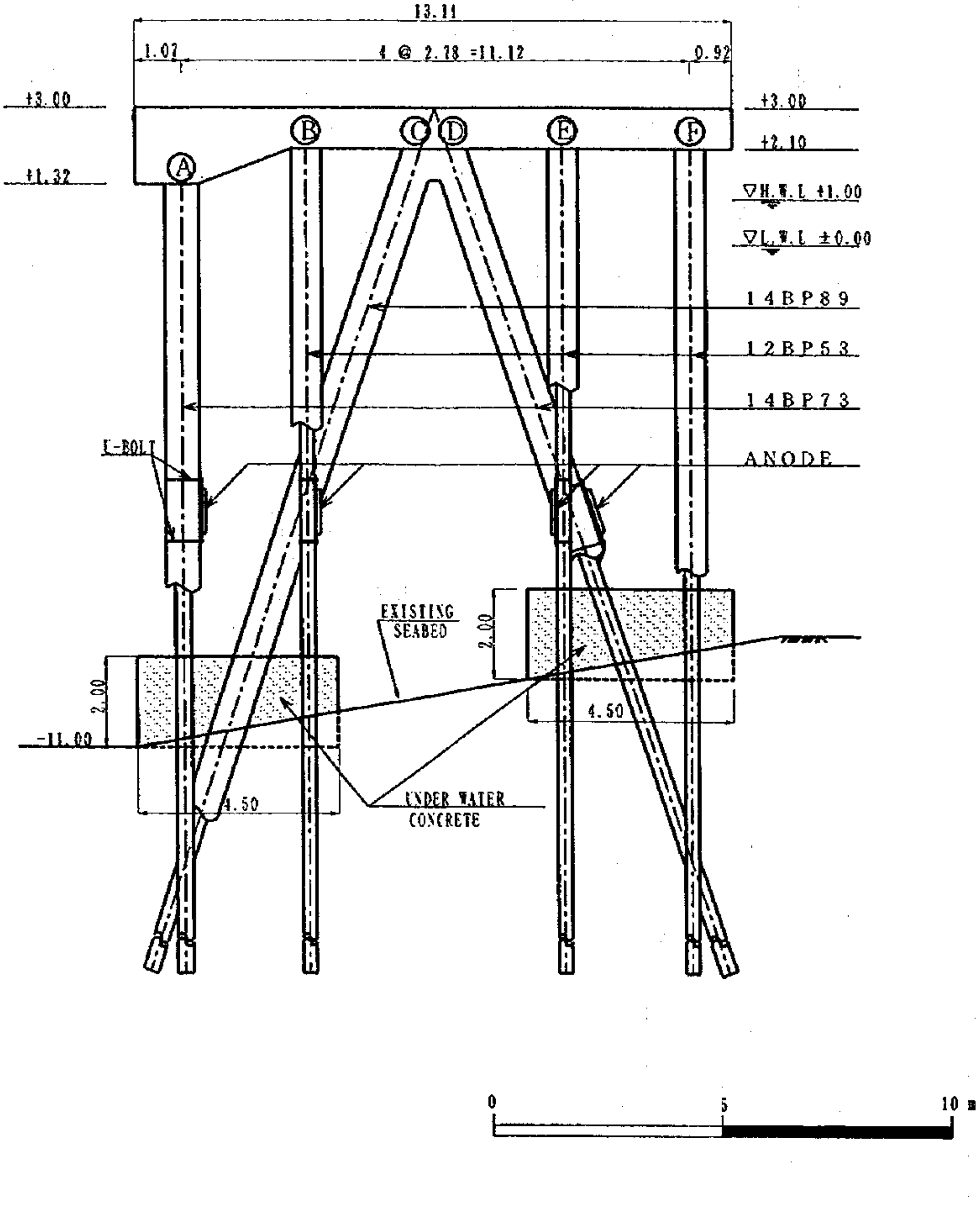


Figure 2.3.1-2 Cross Section of Existing Wharf

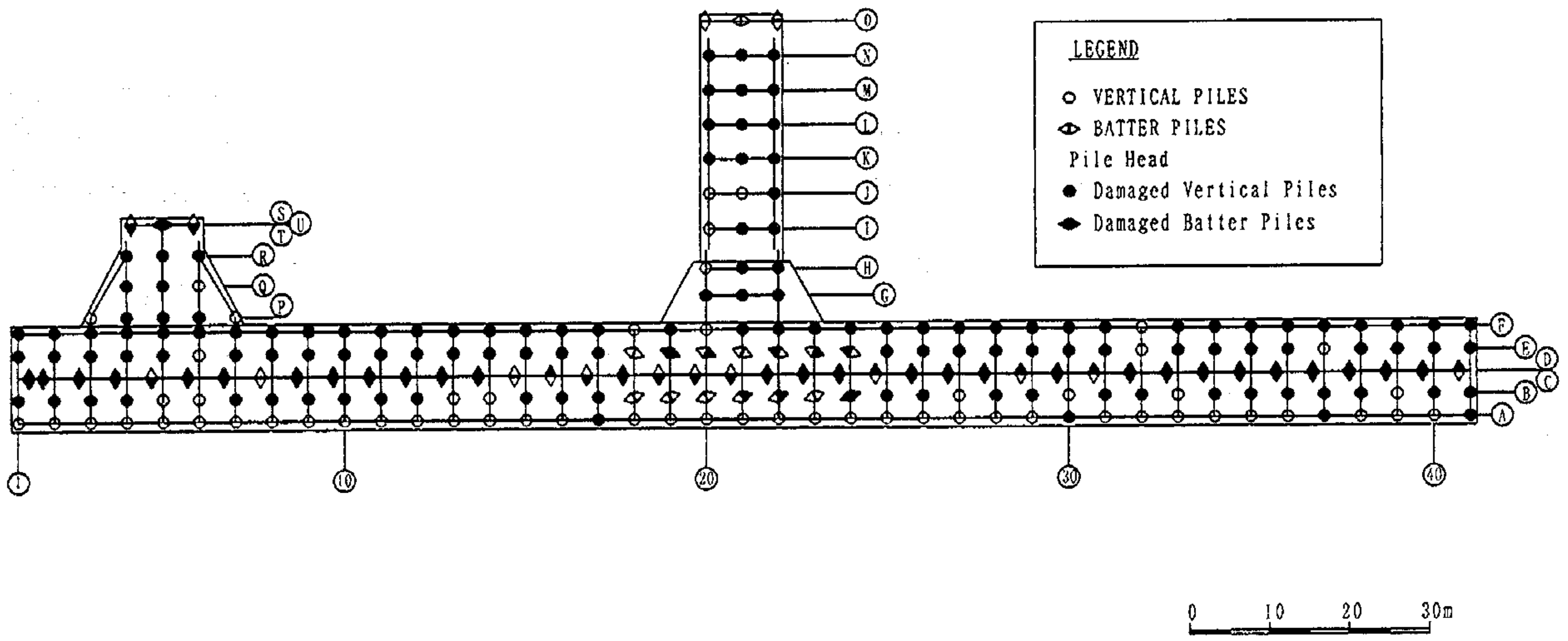


Figure 2.3.1-3 Location of Piles Damaged in Pile Head

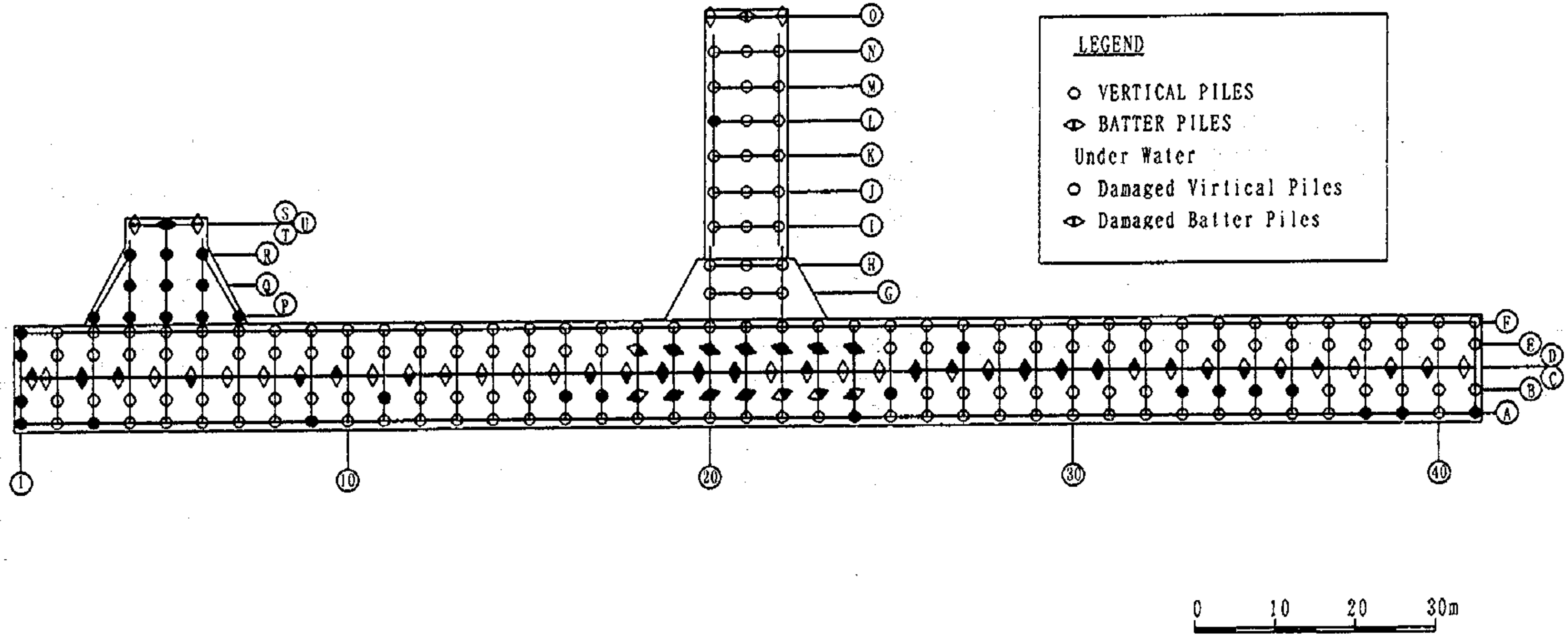


Figure 2.3.1-4 Location of Piles Damaged in Underwater

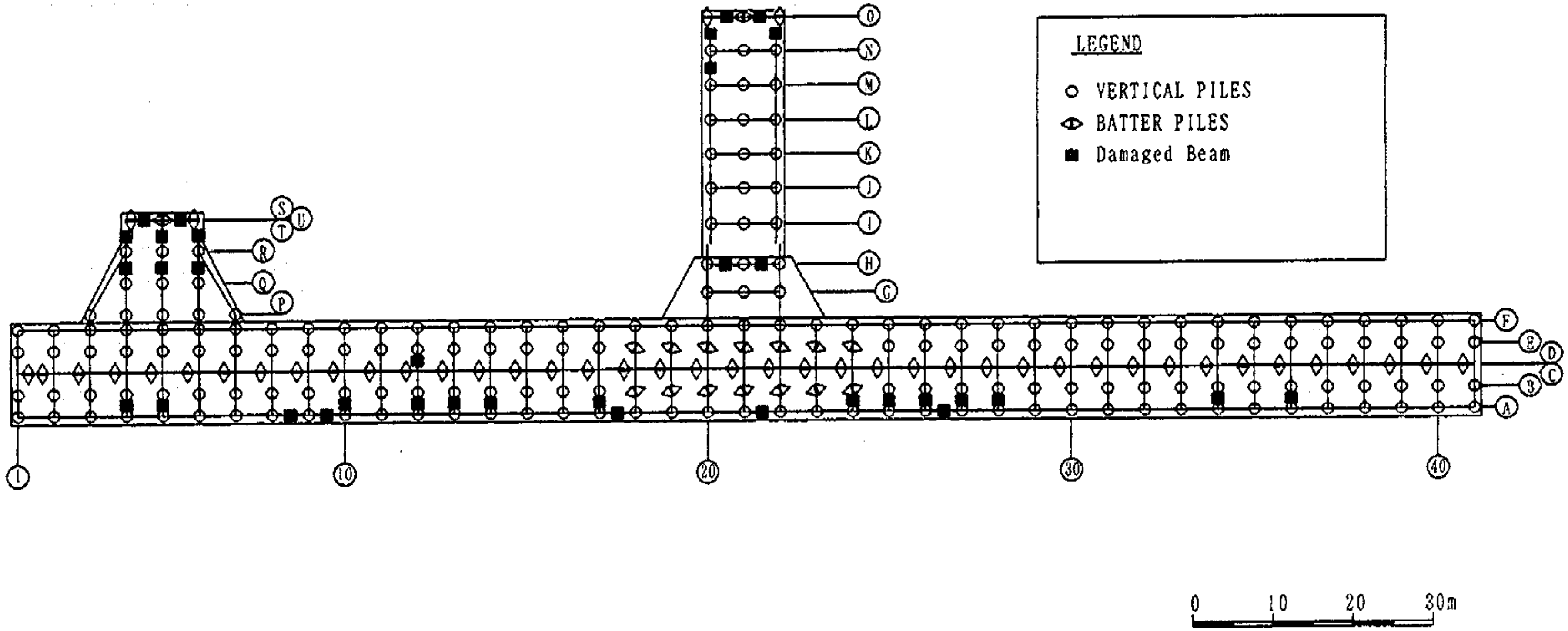


Figure 2.3.1-5 Location of Beams Damaged

Table 2.3.2-1(1) Results of Thickness Measurement of H Shaped Steel Piles (underwater)

Pile No.	Type of H Pile	Measured Location (m)	Original Thickness T1(mm)	Measured Thickness T2(mm)	Corroded Thickness T1-T2 (mm)
1-A	14BP73	-5.0 (frange)	12.9	12.5	0.4 (0.7)
1-B	12BP53	-2.5 (Web)	11.1	11.3	-0.2 (0.5)
1-D	14BP73	-5.0 (frange)	12.9	12.9	0.0 (0.9)
	14BP73	-5.0 (frange)	12.9	12.8	0.1 (0.5)
	14BP73	-5.0 (Web)	12.9	12.8	0.1 (1.1)
	14BP73	-6.0 (frange)	12.9	13.2	-0.3 (0.2)
	14BP73	-6.0 (frange)	12.9	13.3	-0.4 (-0.3)
	14BP73	-6.0 (Web)	12.9	13.0	-0.1 (0.2)
1-E	12BP53	-1.5 (frange)	11.1	10.4	0.7 (2.0)
	12BP53	-1.5 (frange)	11.1	10.8	0.3 (1.9)
	12BP53	-1.5 (Web)	11.1	10.8	0.3 (0.6)
	12BP53	-2.5 (frange)	11.1	10.9	0.2 (0.9)
	12BP53	-2.5 (frange)	11.1	10.9	0.2 (1.5)
	12BP53	-2.5 (Web)	11.1	11.1	0.0 (0.3)
	12BP53	-4.8 (frange)	11.1	10.4	0.7 (1.0)
	12BP53	-4.8 (frange)	11.1	10.1	1.0 (1.8)
	12BP53	-4.8 (Web)	11.1	10.6	0.5 (0.6)
	12BP53	-6.0 (frange)	11.1	10.3	0.8 (1.7)
	12BP53	-6.0 (frange)	11.1	10.9	0.2 (0.8)
	12BP53	-6.0 (Web)	11.1	10.8	0.3 (0.8)
1-F	12BP53	-5.0 (frange)	11.1	10.7	0.4 (1.3)
	12BP53	-5.0 (frange)	11.1	11.1	0.0 (0.2)
	12BP53	-5.0 (Web)	11.1	10.7	0.4 (0.8)
	12BP53	-6.0 (frange)	11.1	10.9	0.2 (1.2)

Note: ( ) Maximum Corroded Thickness

Table 2.3.2-1(2) Results of Thickness Measurement of H Shaped Steel Piles (underwater)

Pile No.	Type of H Pile	Measured Location (m)	Original Thickness T1(mm)	Measured Thickness T2(mm)	Corroded Thickness T1-T2 (mm)
4-P	12BP53	-2.5 (frange)	11.1	10.3	0.8 (1.3)
	12BP53	-3.5 (frange)	11.1	10.6	0.5 (1.9)
4-R	12BP53	-2.0 (frange)	11.1	11.3	-0.2 (0.2)
5-Q	12BP53	-1.5 (frange)	11.1	11.4	-0.3 (0.2)
	12BP53	-2.0 (frange)	11.1	10.5	0.6 (1.1)
	12BP53	-2.5 (frange)	11.1	10.9	0.2 (2.0)
5-R	12BP53	-1.0 (frange)	11.1	10.5	0.6 (1.7)
6-Q	12BP53	-2.0 (frange)	11.1	10.4	0.7 (1.8)
	12BP53	-2.0 (frange)	11.1	10.9	0.2 (0.6)
6-R	12BP53	-1.0 (frange)	11.1	11.2	-0.1 (0.8)
	12BP53	-1.0 (frange)	11.1	11.6	-0.5 (-0.3)
17-C	14BP89	-5.6 (frange)	15.6	15.2	0.4 (1.0)
30-D	14BP89	-4.0 (frange)	15.6	15.3	0.3 (1.1)
37-D	14BP73	-3.5 (frange)	12.9	13.0	-0.1 (0.8)
				average	0.23 (0.92)

Note: ( ) Maximum Corroded Thickness

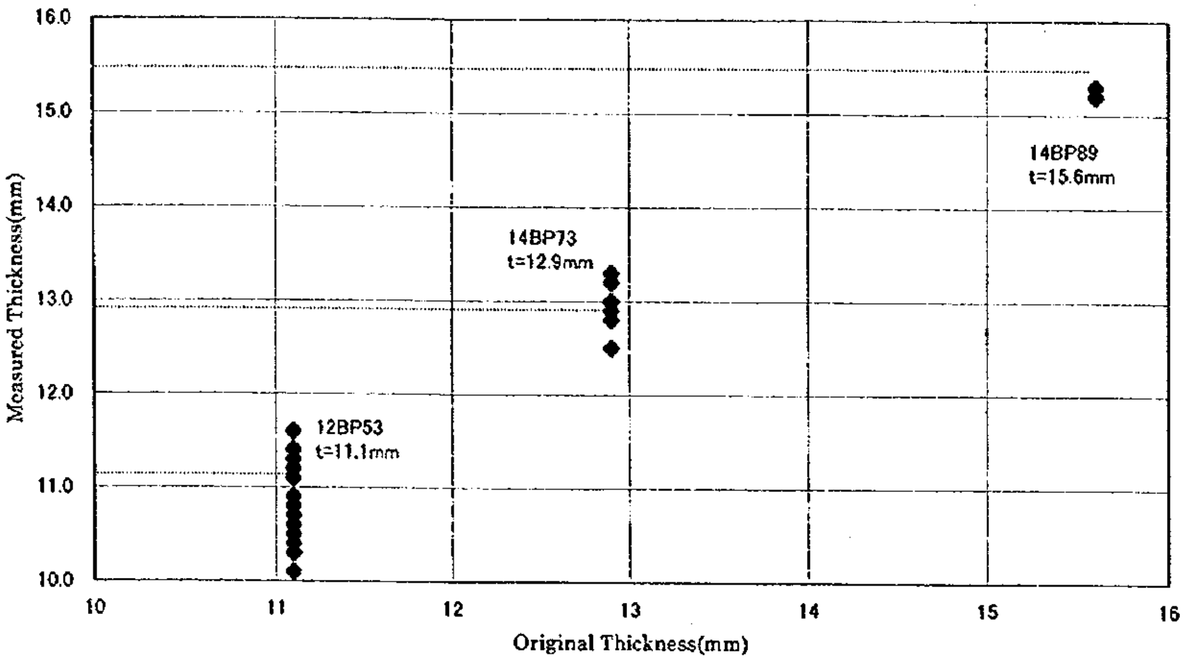


Figure 2.3.2-1 Results of Thickness Measurement (underwater)

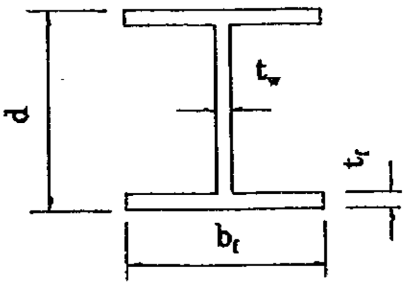
Table 2.3.2-2 Summary of Corroded Thickness (underwater)

Type of Pile	Original Thickness (mm)	Average of Corroded Thickness (mm)
12BP53	11.1	0.30 (1.04)
14BP73	12.9	-0.03 (0.51)
14BP89	15.6	0.35 (1.05)

Note: ( ) Maximum Corroded Thickness

Table 2.3.2-3 Results of Thickness Measurement in 1987

Pile No.	H-steel Type	Original Dimension (mm)	Measured Value(mm)	Measured Location(m) below L.W.L.	Balance (mm)
1A	14BP73	12.9	12.5	-8.0	0.4
1B	12BP53	11.1	11.1	-9.3	±0.0
			12.8		-0.1
1D	14BP73	12.9	13.5	-9.0	0.6
			14.0		1.1
			10.2		-0.9
1E	12BP53	11.1	9.5	-4.5	-1.6
			10.3		-0.8
			9.6	-7.5	-1.5
			11.1		±0.0
1F	12BP53	11.1	10.4	-9.5	-0.7
			11.2		0.1
			11.0	-7.5	-0.1
17B	12BP53	11.1	11.1	-8.5	±0.0
19D	14BP73	12.9	14.7	-8.0	1.8



Original Dimensions

(Unit:mm)

Type of H-steel Type	d	b_f	t_f	t_w
12BP53	299.2	306.0	11.1	11.1
14BP73	346.5	370.5	12.9	12.9
14BP89	352.0	373.3	15.6	15.6

Table 2.3.2-4 Comparison of Thickness Measurement on 1E (underwater)

Pile No.	Original Thickness T1(mm)	Survey in 1998 Measured Location (m)	Measured Thickness T2(mm)	Corroded Thickness T1-T2 (mm)	Measured Location (m)	Measured Thickness T2(mm)	Corroded Thickness T1-T2 (mm)
1-E	11.1	-4.8 (frange)	10.4	0.7 (1.0)	-4.5	10.2	0.9
	11.1	-4.8 (frange)	10.1	1.0 (1.8)	-4.5	9.5	1.6

Note: ( ) Maximum Corroded Thickness

Table 2.3.2-5 Results of Thickness Measurement of H Shaped Steel Piles (Pile Head)

Pile No.	Type of H Pile	Measured Location (m)	Original Thickness T1 (mm)	Measured Thickness T2 (mm)	Corroded Thickness T1-T2 (mm)
2-C	14BP89	+1.7 (frange)	15.6	13.3	2.3 (2.9)
3-A	14BP73	+1.1 (frange)	12.9	10.9	2.0 (2.8)
3-B	12BP53	+1.7 (frange)	11.1	9.2	1.9 (2.3)
3-C	14BP89	+1.5 (frange)	15.6	12.2	3.4 (3.6)
3-D	14BP73	+1.8 (frange)	12.9	10.7	2.2 (3.1)
3-E	12BP53	+1.6 (frange)	11.1	9.3	1.8 (2.2)
3-F	12BP53	+1.6 (frange)	11.1	9.3	1.8 (2.1)
4-Q	12BP53	+1.7 (frange)	11.1	8.0	3.1 (3.6)
5-F	12BP53	+1.8 (frange)	11.1	9.4	1.7 (1.7)
5-P	12BP53	+1.7 (frange)	11.1	9.3	1.8 (2.4)
6-P	12BP53	+1.7 (frange)	11.1	9.0	2.1 (2.6)
				average	2.07 (2.57)

Note: ( ) Maximum Corroded Thickness
Average and range of value were calculated except pile 3-C

Table 2.3.2-6 Corrosion Rate of H Piles (underwater)

	Corrosion Rate			
	Protective Rate 90%		Protective Rate 75%	
	Non-Protection Vc (mm/year)	Protection Vp (mm/year)	Non-Protection Vc (mm/year)	Protection Vp (mm/year)
Average Rate	0.016 (0.047)	0.002 (0.005)	0.015 (0.045)	0.004 (0.011)
Maximum Rate	0.040 (0.081)	0.004 (0.008)	0.039 (0.078)	0.010 (0.019)

Note: ( ) Maximum Corrosion Rate

Table 2.3.2-7 Corrosion Rate of Protective Duration (underwater)

Pile No.	1998		1987		1987-1998	
	Measured Thickness T2(mm)	Corroded Thickness T1-T2 (mm)	Measured Thickness T2(mm)	Corroded Thickness T1-T2 (mm)	Corroded Thickness (mm)	Corrosion Rate (mm/year)
1-E	10.4	0.7 (1.0)	10.2	0.9	-0.2 (0.1)	– (0.009)
	10.1	1.0 (1.8)	9.5	1.6	-0.6 (0.2)	– (0.018)

Note: ( ) Maximum Corroded Thickness

2.4 Structural Analysis of Existing Wharf

2.4.1 Outline of Structural Analysis

Structural analysis of the existing wharf is conducted in the following process.

(1) Evaluation of Load Limit of Existing Wharf

According to the recommendation of Public Works Department in Samoa, load limitation of 38 ton has been imposed as maximum safe axle load on the existing wharf. Based on the field survey of this study and the current load conditions, appropriateness of present load limit is evaluated.

(2) Structural Analysis of Existing Wharf

Based on the annual corrosion rate of piles, the buckling strength of piles of the existing wharf are calculated. Then, the maximum allowable load to the existing wharf in future is determined.

(3) Durability Evaluation of Existing Wharf

Based on the results of corrosion survey of H-shaped steel piles and the damage investigation on pile head concrete, the remaining life of the existing wharf is examined by the computer analysis. Also, the necessity and scale of reinforcement to the existing wharf and durability of the existing wharf are evaluated for different anti-corrosion measure and repair/ reinforcing methods.

2.4.2 Flow of Structural Evaluation

Generally, port facilities such as steel pile wharf and steel sheet pile wharf are designed based on the condition that all steel materials have the uniform strength. The H-shaped piles of the existing wharf are corroded and the strength is different in vertical direction for each pile. Although the structural analysis of such 3-dimensional non-uniform structures can be performed by the finite-element method, large-scale computers are needed for such analysis, and generally, it is not used for simple civil structures. The 3-dimensional structural analyses are performed for complex steel structures such as offshore oil platform and the earthquake dynamic analysis of the structures.

Flow chart to evaluate structural strength of the existing condition in this study is shown in Figure 2.4.2-1.

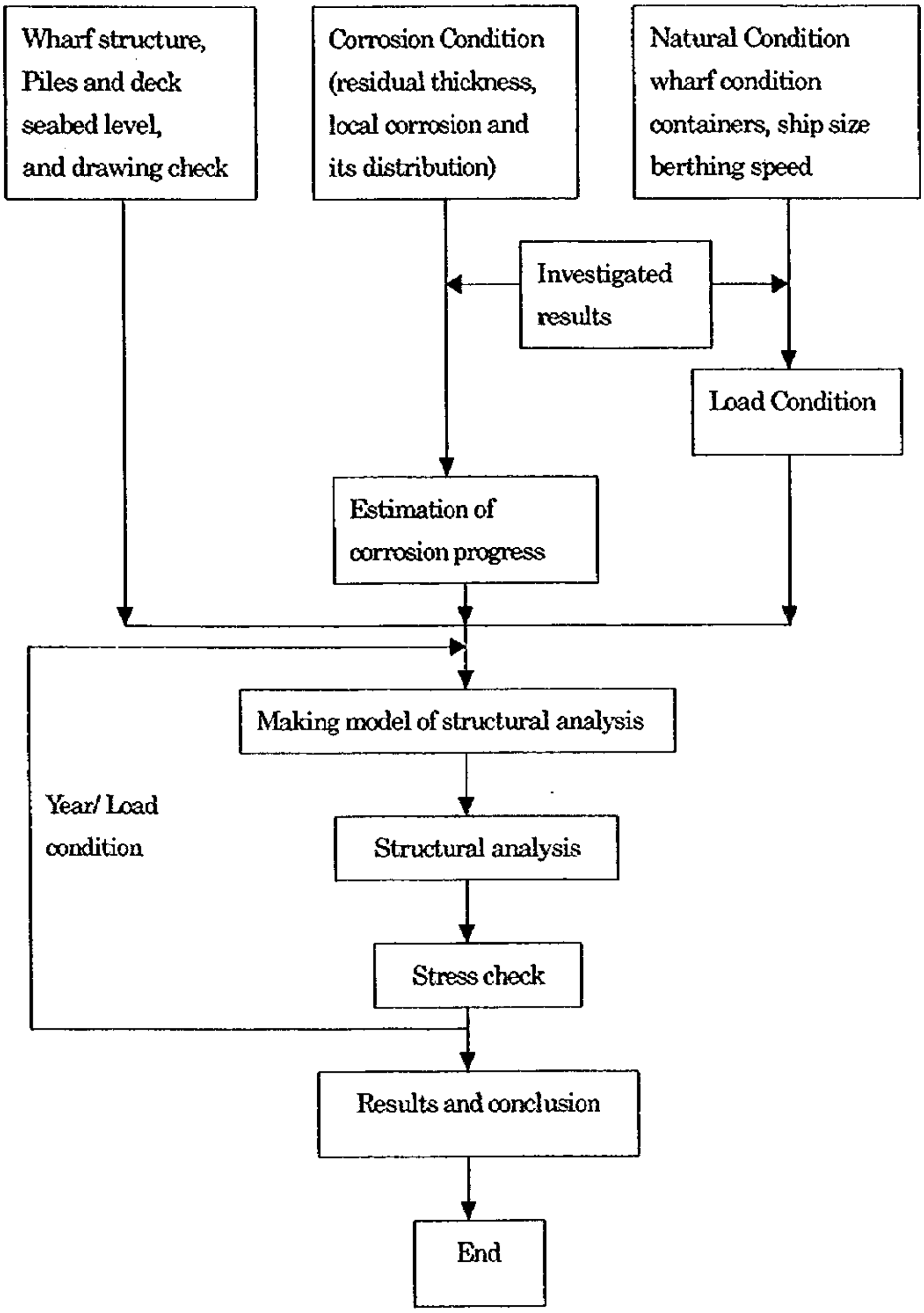


Figure 2.4.2-1 Flowchart of Evaluating the Structural Strength

In order to simulate the various load conditions and the actual corrosion conditions as exactly as possible, 3-dimensional frame structural model shown in Figure 2.4.2-2 is used. The pile under the seabed is modeled using the $1/\beta$ method (virtual fixed-point method).

Base on the results of the corrosion investigation of piles, the following assumptions are made in this model.

a) Nodes are added at the points where the section changes due to the corrosion, and at these nodes the stress level is calculated for each corroded section.

b) The structural model is assumed to be linear. The non-linearity of earth resistance and member deformation is not considered.

c) The deck is modeled using the equivalent dummy member to model the RC beam and the shear rigidity of slab.

d) The pile section is regarded as a composition of concrete (precast and tremie) and H-shaped steel. The stress is checked on the H-shaped steel section only, while the effect of the concrete component is considered in the member rigidity for the other section.

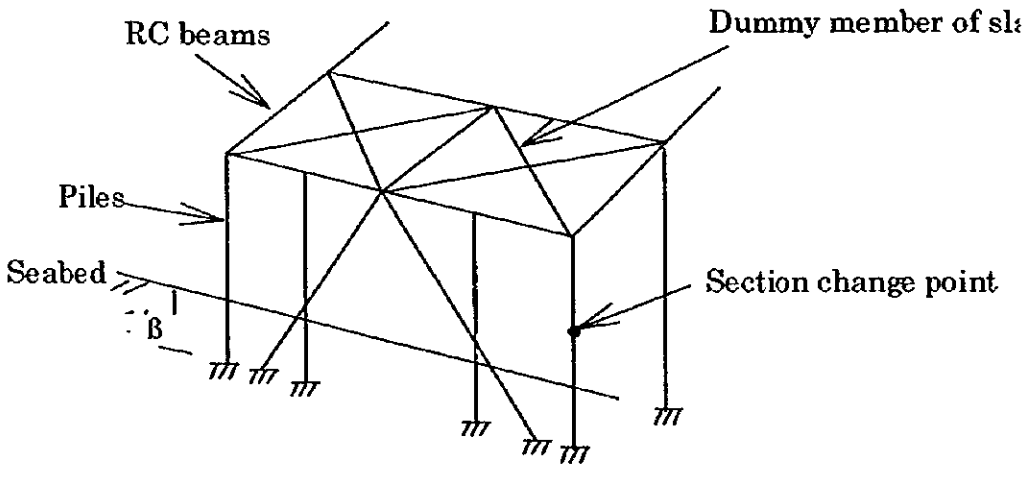


Figure 2.4.2-2 3-dimensional Frame Structural Model

The structural analysis program of space frame is used to perform structural analysis in which the space distribution of corroded sections and concrete damages of piles is taken into consideration.

It is assumed that loading of the wharf deck is caused by following;

a) Weight of slab and beam
b) Fork lift trucks handling containers
c) Weight of containers
d) Berthing force (ship size and berthing speed)
e) Seismic force(seismic coefficient)
f) Uniform surcharge

The results of structural analysis are used to evaluate the strength of the existing wharf and estimate the necessity of corrosion protection and reinforcement in future.

2.4.3 Results of Analysis

(1) Analysis Model

The results of the investigation on the damage of piles are considered in the structural model of the exiting wharf. The nodes are set at the points having large holes in the concrete sleeves where only H-shaped steel section is taken into account in structural strength. The sections where the concrete sleeves of piles are missing are modeled as only H-shaped steel pile.

H-shaped steel sections change due to the corrosion. The corrosion rates are different according to the positions of H-shaped steel (for example, under seabed, in seawater, or above sea surface). Corrosion rates and corroded sections of H-shaped steel piles are given in subsequent section.

(2) Load Condition

Vertical load includes the dead load, the weight of 2 containers of 24 ton, forklift handling container and surcharge.

1) Dead load: slab and beam (it is computed by program automatically)

2) Weight of containers: the weight of 2 containers of 24 ton is assumed to be placed on both sides of forklift truck.

3) Live load

(a) Based on the current load condition, the maximum axle loading is assumed as

Pl=58.3 ton

Here, the forklift truck of 33.6 ton [TCM(FD240)] and the container of 24 ton are considered. An impact allowance of 10% is included in the axle load additionally. The front wheel span of 2.2 m is considered for forklift truck.

(b) Maximum safe axle load limitation at the existing wharf

Pl=41.8 ton

According to the recommendation of Public Works Department in Samoa, load limitation of 38 ton as max safe axle load on the existing wharf has been imposed. An impact allowance of 10% is included in the above value additionally. The front wheel span of 2.2 m is considered for forklift truck.

4) Design Surcharge

$w=3.0 \text{ ton/m}^2$

The horizontal force comprises the berthing force, impact force and the seismic force.

a) Berthing force: (ship size: 10,000 GRT, berthing speed: 0.15 m/s.)

Pb=80 ton

b) Impact force: the impact force assumed between the ship and the wharf when the ship's crane working.

Pt=30 tf

c) Seismic force: design surcharge $w'=1.5 \text{ tf/m}^2$ and weight of the wharf are considered.

$Ps = kw'$

where

k : seismic coefficient (0.15)

w' : design surcharge ($w'=1.5\text{tf/m}^2$)

Ps : seismic force

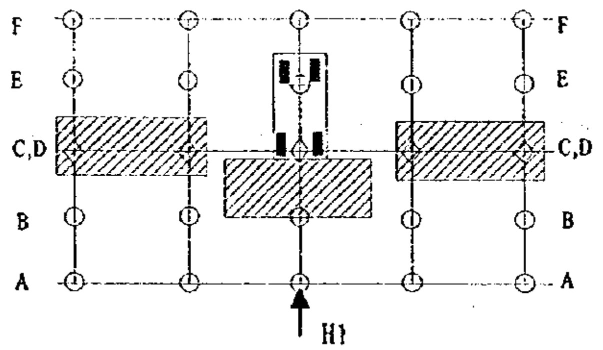
The analysis cases and combination of loads in this study are shown in Table 2.4.3-1 and the position of forklift and container is shown in Figure 2.4.3-1.

Table 2.4.3-1 Analysis Cases and Combination of Loads

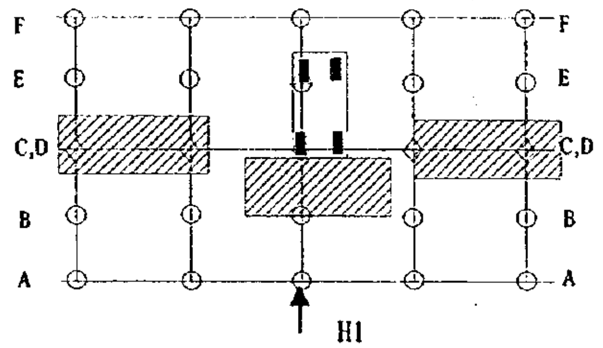
	Vertical Force			Horizontal Force	
	Axle Load		Containers (uniformly distributed)	Impact Force	Berthing force
	Value(tf)	Position	(tf/m^2)	H1(tf)	H2(tf)
CASE-1a	41.8	Fig. 2.4.3-1(1)	Weight of Two Containers(24t)	30	
CASE-2a	41.8	Fig. 2.4.3-1(2)	Weight of Two Containers(24t)	30	
CASE-3a	41.8	Fig. 2.4.3-1(3)	Weight of Two Containers(24t)	30	
CASE-4a	41.8	Fig. 2.4.3-1(4)	Weight of Two Containers(24t)	30	
CASE-1b	58.3	Fig. 2.4.3-1(1)	Weight of Two Containers(24t)	30	
CASE-2b	58.3	Fig. 2.4.3-1(2)	Weight of Two Containers(24t)	30	
CASE-3b	58.3	Fig. 2.4.3-1(3)	Weight of Two Containers(24t)	30	
CASE-4b	58.3	Fig. 2.4.3-1(4)	Weight of Two Containers(24t)	30	
CASE-5	Berthing force		w=3.0		80
CASE-6	Seismic Load		w=1.5 kH=0.15		
CASE-7	Design surcharge		w=3.0		
CASE-8	Berthing force		w=3.0		100

Note: Dead load is considered for all the analysis cases.

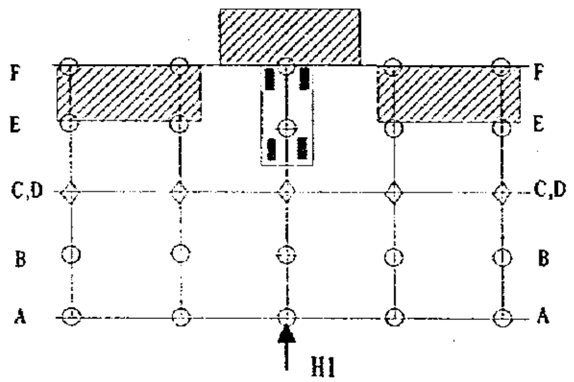
Position (1)



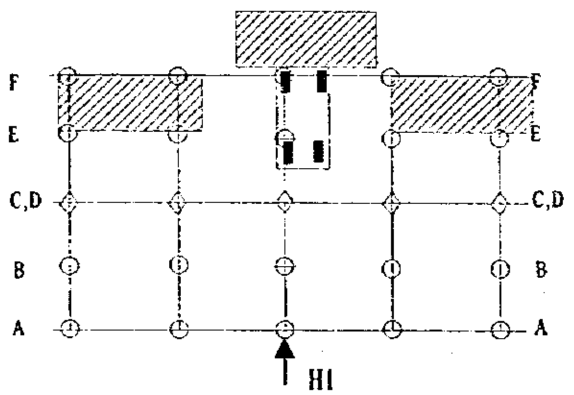
Position (2)



Position (3)



Position (4)



○ : Vertical Pile A,B,E,F

△ : Batter Pile C,D

Figure 2.4.3-1 Position of Forklift and Containers

(3) Corrosion Rate

Based on the results of corrosion survey on H-shaped steel piles and the damage investigation of pile head concrete, corrosion rates of H-shaped piles are assumed as shown in Table 2.4.3-2.

Table 2.4.3-2 Corrosion Rate of H Pile for Structural Analysis

	Pile Head (mm/year)	Under Water	
		Non-Protection (mm/year)	Protection (mm/year)
Average of Corrosion Rate	0.30 ≒0.30	0.015 ≒0.02	0.004 ≒0.005
Corrosion Rate of Maximum Corroded Pile	0.443 ≒0.45	0.039 ≒0.04	0.01 ≒0.01

(4) Evaluation Method of Calculation Results

The actual acting axial force on the pile is checked for buckling strength. The U.C. value (Unity Check) of axial force for buckling strength is calculated as follows;

$$U.C. = \frac{N}{N_a}$$

where

N : axial force

N_a : allowable axial force

The stress is checked on the H-shaped steel section only on pile head, while the effect of the concrete component is considered in the undamaged member for the other section. The U.C. value (Unity Check) is calculated as follows;

$$U.C. = \frac{\sigma_a}{\sigma_{aa}} + \frac{\sigma_b}{\sigma_{ba}}$$

where

σ_a : axial stress

σ_b : bending stress

σ_{aa} : allowable axial stress

σ_{ba} : allowable bending stress

U.C. value less than 1.0 is safe where as the U.C. value 1.0 or more means unsafe.

(5) Results of Analysis

In consideration of above-mentioned combination of loads and corrosion rate, the cross section force and stresses of pile head of the existing wharf are calculated.

The maximum actual acting stress and U.C. value on pile head in 1998 and 2003 are shown in Table 2.4.3-3, and the actual acting axial force and buckling load in 1998 and 2003 are shown in Table 2.4.3-4. Detailed results of stress on pile head are presented in Appendix 8. The results of acting force on each pile and calculation of allowable buckling load are presented in Appendix 8.

According to the results of analysis on the existing wharf, it is evaluated that the structural durability of the existing wharf has reduced to the critical limitation (U.C. value 1.0) in 1998 and will exceed that in 2003 under the present loading condition.

Table 2.4.3-3 Maximum Stress of Pile Head and U.C. Value

	1998		2003	
	Stress (kgf/cm²)	U.C. Value	Stress (kgf/cm²)	U.C. Value
Average of Corrosion Rate	1,361	0.97	1,632	1.17
Corrosion Rate of Maximum Corroded Pile	1,538	1.10	2,137	1.53

Allowable stress = 1400kgf/cm²

Table 2.4.3-4 Allowable Buckling Load and Actual Acting Axial Force

	1998			2003		
	Axial Force (tf)	Allowable Buckling Load (tf)	U.C. Value	Axial Force (tf)	Allowable buckling Load (tf)	U.C. Value
Average of Corrosion Rate	60	64.7	0.93	60	64.5	0.93
Corrosion Rate of Maximum Corroded Pile	60	61.5	0.98	60	61.2	0.98

U.C. Value = Axial Force/ Allowable Buckling Load

CHAPTER 3

MASTER PORT DEVELOPMENT PLAN

CHAPTER 3 MASTER PORT DEVELOPMENT PLAN

In this chapter, the master port development plan with the target year of 2015 is examined and formulated to meet the traffic demand forecast in the previous chapter. The master plan of Apia Port was worked out in 1987, and thereafter several improvement and rehabilitation projects were implemented.

The previous projects implemented in Apia Port and their scopes are listed below and the master development plan of Apia Port with target year of 2005 was drawn up by the JICA Study 1) below in 1987.

1) The Study on the Development of the Port in Samoa, Sep.1987 JICA Master Plan of Apia Port, Asau Port, Salelologa Port, Mulifanua Port. Examination of Short Term Improvement Plan for Apia Port

2) The Study for Development of Apia Port in Samoa, Apr.1988 JICA Basic Design of Short Term Improvement Plan for Apia Port

3) The Study for Rehabilitation of Cyclone-Damaged Ports and Construction of Quarry Plant in Samoa, Jun 1990. -Rehabilitation of Damaged Ports by Cyclone "Ofa"

4) The Study for Rehabilitation and Improvement of Cyclone-Damaged Ports and Foreshore Protection in Samoa, Jul. 1992. -Rehabilitation of Damaged Ports and Seawall by Cyclone "Val"

The present study basically follows the results of Feasibility Study done in 1987 by JICA with amendments through consideration of updated data and information.

3.1 Master Plan Proposed in 1987

3.1.1 Demand Forecast

In 1987 Master Plan, the volume of general cargo is forecast as 338,000 tons based on the target real GDP of 150 million Tala in 2005 as shown in Table 3.1.1-1. Actual cargo volume handled in 1981 – 1985 are also presented in the same table.

Table 3.1.1-1 Cargo Volume and Real GDP

(unit : million Tala)

	1981	1982	1983	1984	1985	2005
(A) Real GDP at 1980 prices	92.7	93.2	95.2	97.1	98.6	150
(B) GDP at current prices	130.4	154.4	183.5		202.1	
© Population ('000)	156.3	156.8	157.3	157.8	158.4	169
(A/C) Per Capita GDP(Tala)	593.1	594.4	605.2	615.3	622.5	
(B/A) GDP Deflator (1980=100)	140.7	165.7	192.8			
(D) General Cargo (tons)	103,724	129,631	126,776	126,212	146,134	338,000

The method of cargo forecast in 1987 Master Plan is shown in Table 3.1.1-2. Macro forecast was made by assuming that the port cargoes increase with the growth of real GDP (by factor cost at 1980 prices) which were reported in the only official report "Western Samoa Socio-economic Situation Development Strategy and Assistance Needs". And, based on the forecast real GDP, the total general cargo volume was forecast as 338,000 tons in 2005.

Then, the cargo volume of each commodity was determined based on the socio-economic statistics/forecast and economic development plan. As the main commodity group, oil imports consisted of motor spirits, jet fuel and diesel oil. Imports of general cargo consisted of sugar, cement, steel, cereals and others. Exports consisted of taro, cocoa, copra meal, other fresh agricultural products, timber, coconut oil and others.

Table 3.1.1-3 shows the cargo volume in 1990-2015 forecast by the method of 1987 Master Plan. Table 3.1.1-4 and Figure 3.1.1-1 show the real GDP at 1980 prices by industrial origin in 1980 –1996 and forecast GDP of 1987 Master plan. After 1990, forecast GDP is higher than actual GDP. Table 3.1.1-5 and Figure 3.1.1-2 show the correlation between the actual cargo volume from 1981 to 1996 and the forecast cargo volume by 1987 Master Plan from 1996 to 2005. As shown in Figure 3.1.1-2, the correlation between the actual and forecast import volumes is high, while the correlation between the actual and forecast export is low. Cargo volume handled in Apia Port is less than the volume forecast in 1987 Master Plan.

Table 3.1.1-2 Metod of Forecast in 1987 Master Plan

(1) Macro-Forecast	unit	1985	1986	2005	Method of Forecast
Population	1000 p.		158.9	169	Y=7,611*X^0.433 (r = 0.999)
					Y : Increased population from 1966 (131,377 p.)
					X : Year from 1966
					r : Correlation coefficient
Real GDP at 1980 prices	Tala million	98.6	103.6	150	
(Ave. annual growth rate)	%	1.54%	5.07%	(+2.12%)	estimation of 1987 Master Plan
Real GDP-max	Tala million	98.6		159	
(Ave. annual growth rate)	%			(+2.5%)	the only official forecast of government
Real GDP-min	Tala million	98.6		144	
(Ave. annual growth rate)	%			(+1.9%)	annual growth rate in 1985
Gross Investment at 1980 prices	Tala million	28.8		52.1	
Share in GDP	%	29.7		34.7	Forecast of government in 1985-1990
General Cargo Volume of Samoa	tons	146,134	146,800	338,000	V= 3,823* X - 235,821 (r = 0.807)
	Import	102,164	105,700		V : cargo volume (tons)
	Export	43,970	41,100		X : Real GDP (in Tala million)

(2) Micro-Forecast

Commodity	unit	1985	1986	2005	Method of Forecast
(A)Motor Vehicles	numbers	4,372		7,170	29,600 = 18,044 tons / 4,372 *7,170
(B)Population	1000 p.	158		169	Oil products 18,044 tons in 1985; Unit number of vehicles 42.4
(A)/(B)	numbers	27.9		42.4	4,372 = number of vicles in 1985, = icreased at +2.1% per annum
Oil Products	tons	18,044		29,600	7,170 = forecast in 2005 = 169,000 p * 42.4/1000p.
Oil for airplanes (+4.3% per ann	tons	6,100		14,200	14,200= 6100 * 1.043^(2005-1985)
Diesel oil (-6.2% per annum)	tons	2,900		800	800=(-6.2% per annum) from 2,900 tons in 1985
Oil Product total	tons	27,044	25,500	44,600	
Sugar (56.5 kg per Capita)	tons	8,870		9,500	9500=169,000p. in 2005 * 56.5 kg per Capita
Gross Investment, 1980 price	(Tala million)	28.8		52.1	
Cement	tons	9,700		17,600	17,600= 9,700*52.1/28.8
Steel Products	tons	6,000		10,900	10,900= 6,000*52.1/28.8
Cereals (+4.72% per annum)	tons	8,807		24,300	24,300= Av. annual increase rate +4.72% in 3-year moving average 1978-1983
Others-max in 1983 (+5.36% per annum)	tons	62,200		196,000	196,000=annual rate +5.36% in 1982-1983 from 62,200 tons in 1983
Others-min in 1991, (+5.36% per annum)	tons	52,200		174,000	174,000= +5.36% in 1982-1983 from 52,200 of 3-years moving average in 1982
Import-max Total (Other-max)	tons	122,621	131,200	302,900	
Import-min Total (Other-min)	tons	112,621		280,900	

Commodity	unit	1985	1986	2005	Method of Forecast
Taro (+0.53% per annum)	tons	7,200		8,000	8,000= estimated based on data from the Agriculture Department
Cocoa (+10.6% per annum)	tons	600		4,500	4,500= estimated based on data from the Agriculture Department
Copra meal (+2.84% per annum	tons	6,000		10,500	10,500= estimated based on data from the Agriculture Department
Other fresh products (+2.8%)	tons			10,000	10,000= estimated based on data from the Agriculture Department
Agricultural Products	tons			33,000	
Coconut Oil (+2.8%)	tons	12,100	13,800	21,000	21,000= estimated based on data from the Agriculture Department
Others (+2.8% per annum)	tons	24,300		41,000	
Export Total of Apia Port	tons			95,000	
Timber of Asau Port (+9.95% per annum)	tons	3,000		20,000	20,000= estimated based on data from the Agriculture Department

Table 3.1.1-3 Cargo Volume in 1990-1996 Forecast by the Method of 1987 Master Plan

(1)Macro-Forecast	unit	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	2003	2005	2015
Population	1000 p.		159.2	159.8	160.4	161.0	161.5	162.050	162.6	163.1	163.6	164.1	164.6	167.7	169	172.4
Real GDP at 1980 prices	Tala million	98.6	100.7	102.8	105.0	107.2	109.5	111.8	114.2	116.6	119.1	121.6	124.2	143.8	150.0	185.0
(Ave. annual growth rate)	%		2.12%	2.12%	2.12%	2.12%	2.12%	2.12%	2.12%	2.12%	2.12%	2.12%	2.12%	2.12%	(+2.12%)	2.12%
Gross Investment at 1980 prices	Tala million	28.8	34.9	35.7	36.4	37.2	38.0	38.8	39.6	40.5	41.3	42.2	43.1	49.9	52.1	64.2
Share in GDP	%	29.7	34.7	34.7	34.7	34.7	34.7	34.7	34.7	34.7	34.7	34.7	34.7	34.7	34.7	34.7
General Cargo Volume of Samoa	tons	146,134	149,118	157,279	165,613	174,123	182,814	191,689	200,752	210,007	219,459	229,111	238,967	314,069	338,000	471,482

(2) Micro-Forecast

Commodity	unit	1985	1,986	1,987	1,988	1,989	1990	1991	1992	1993	1994	1995	1996	2003	2005	2015
(A)Motor Vehicles	numbers	4,372	4,490	4,605	4,721	4,841	4,963	5,087	5,215	5,345	5,477	5,613	5,752	6,813	7,170	9,062
(B)Population	1000 p.	158	159	160	160	161	162	162	163	163	164	164	165	168	169	172
(A)/(B)	numbers	27.9	28.2	28.8	29.4	30.1	30.7	31.4	32.1	32.8	33.5	34.2	35.0	40.6	42.4	52.6
Oil Products	tons	18,044	18,531	19,004	19,486	19,979	20,483	20,997	21,522	22,058	22,607	23,167	23,739	28,118	29,600	37,399
Oil for airplanes (+4.3% per annum)	tons	6,100	6,362	6,636	6,921	7,219	7,529	7,853	8,191	8,543	8,910	9,293	9,693	13,015	14,200	21,570
Diesel oil (-6.2% per annum)	tons	2,900	2,720	2,552	2,393	2,245	2,106	1,975	1,853	1,738	1,630	1,529	1,434	916	800	425
Oil Product total	tons	27,044	27,613	28,191	28,801	29,443	30,118	30,825	31,565	32,339	33,147	33,989	34,867	41,873	44,600	59,395
Sugar (56.5 kg per Capita)	tons	8,870	8,996	9,030	9,062	9,094	9,125	9,156	9,185	9,215	9,243	9,271	9,298	9,476	9,500	9,742
Gross Investment, 1982 prices (Tala million)		39.2	35	36	36	37	38	39	40	40	41	42	43	50	52	64
Cement	tons	9,700	11,768	12,017	12,272	12,532	12,798	13,069	13,346	13,629	13,918	14,213	14,515	16,810	17,600	21,623
Steel Products	tons	6,000	7,279	7,433	7,591	7,752	7,916	8,084	8,255	8,430	8,609	8,792	8,978	10,398	10,900	13,375
Cereals (+4.72% per annum)	tons	8,807	10,114	10,591	11,091	11,615	12,163	12,737	13,338	13,968	14,627	15,317	16,040	22,152	24,300	38,528
Others-max in 1983 (+5.36% per annum)	tons	62,200	72,747	76,647	80,755	85,083	89,644	94,449	99,511	104,845	110,465	116,386	122,624	176,728	196,000	330,685
Others-min in 1991, (+5.36% per annum)	tons	52,200	64,324	67,772	71,404	75,232	79,264	83,513	87,989	92,705	97,674	102,909	108,425	156,265	17,400	292,395
Import-max Total (Other-max)	tons	122,621	138,518	143,910	149,573	155,520	161,764	168,320	175,202	182,426	190,009	197,968	206,322	277,439	302,900	473,348
Import-min Total (Other-min)	tons	112,621	130,094	135,035	140,222	145,668	151,384	157,384	163,680	170,286	177,218	184,492	192,123	256,975	280,900	435,058

Commodity	unit	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	2003	2005	2015
Taro (+0.53% per annum)	tons	7,200	7,238	7,277	7,315	7,354	7,393	7,432	7,471	7,511	7,551	7,591	7,631	7,919	8,000	8,437
Cocoa (+10.6% per annum)	tons	600	664	734	812	898	993	1,098	1,215	1,343	1,486	1,643	1,817	3,679	4,500	12,326
Copra meal (+2.84% per annum)	tons	6,000	6,170	6,346	6,526	6,711	6,902	7,098	7,299	7,507	7,720	7,939	8,165	9,933	10,500	13,900
Other fresh products (+2.8%)	tons		5,917	6,083	6,253	6,429	6,609	6,794	6,984	7,179	7,380	7,587	7,799	9,463	10,000	13,180
Agricultural Products	tons		19,990	20,439	20,906	21,391	21,896	22,422	22,969	23,540	24,137	24,760	25,412	30,993	33,000	47,843
Coconut Oil (+2.8%)	tons	12,100	12,439	12,787	13,145	13,513	13,892	14,281	14,680	15,091	15,514	15,948	16,395	19,891	21,000	27,706
Others (+2.8% per annum)	tons	24,300	24,980	25,680	26,399	27,138	27,898	28,679	29,482	30,308	31,156	32,029	32,925	39,947	41,000	55,642
Export Total of Apia Port	tons	-	57,409	58,906	60,450	62,043	63,686	65,381	67,132	68,939	70,807	72,737	74,733	90,831	95,000	131,191
Timber of Asau Port (+9.95% per annum)	tons	3,000	3,299	3,627	3,988	4,384	4,821	5,300	5,828	6,407	7,045	7,746	8,517	16,544	20,000	51,639

Table 3.1.1-4 Real GDPat 1980 and Forecast GDP

(unit : Tala million)

Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	2005
(A) Real GDP at 1980 prices(Tala million)	93.7	92.7	93.2	95.2	97.1	98.6	103.6	104.8	103.5	106.2	98.3	95.9	95.7	99.7	93.2	102.2	108.2	
(A') Real GDP added estmate wiring harnesses												96.1	99.8	103.7	96.6	107.1	115.2	
(B) Forecast GDP in 1987 (+2.1% per annum)	93.7	92.7	93.2	95.2	97.1	98.6	100.7	102.8	105.0	107.2	109.5	111.8	114.2	116.6	119.1	121.6	124.2	150.0

Figure 3.1.1-1 Real GDP at 1980 and Forecast GDP

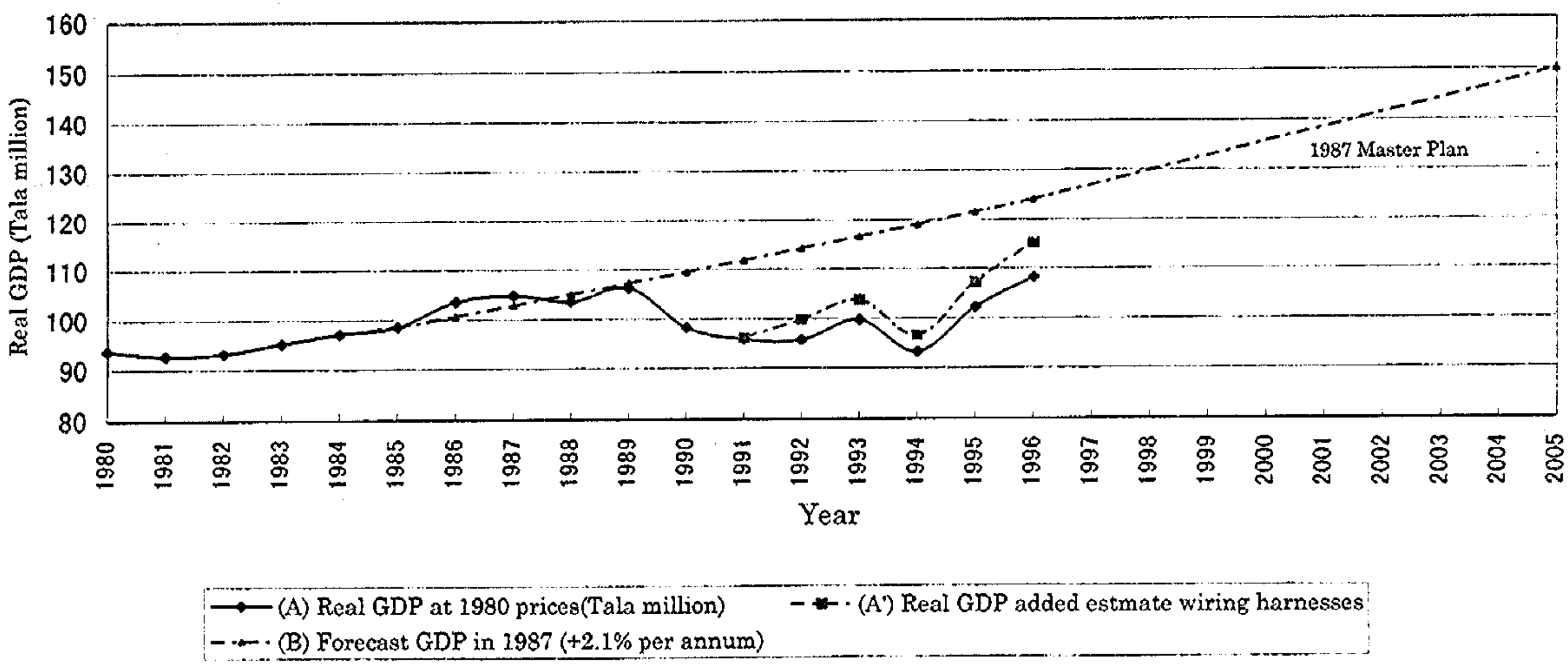


Table 3.1.1-5 Comparison between Forecast ans Actual Cargo Volume

Year			1981	1983	1985	1987	1989	1991	1993	1995	1996	2003	2005	2005
Real GDP at 1980 prices			92.7	95.2	98.6	104.8	106.2	96.1	103.7	107.1	115.2			
Forecast GDP in 1987			92.7	95.2	98.6	102.8	107.2	111.8	116.6	121.6	124.2	143.8	150.0	

(unit of cargo volume : metric.tons, unit of GDP : Tala million)

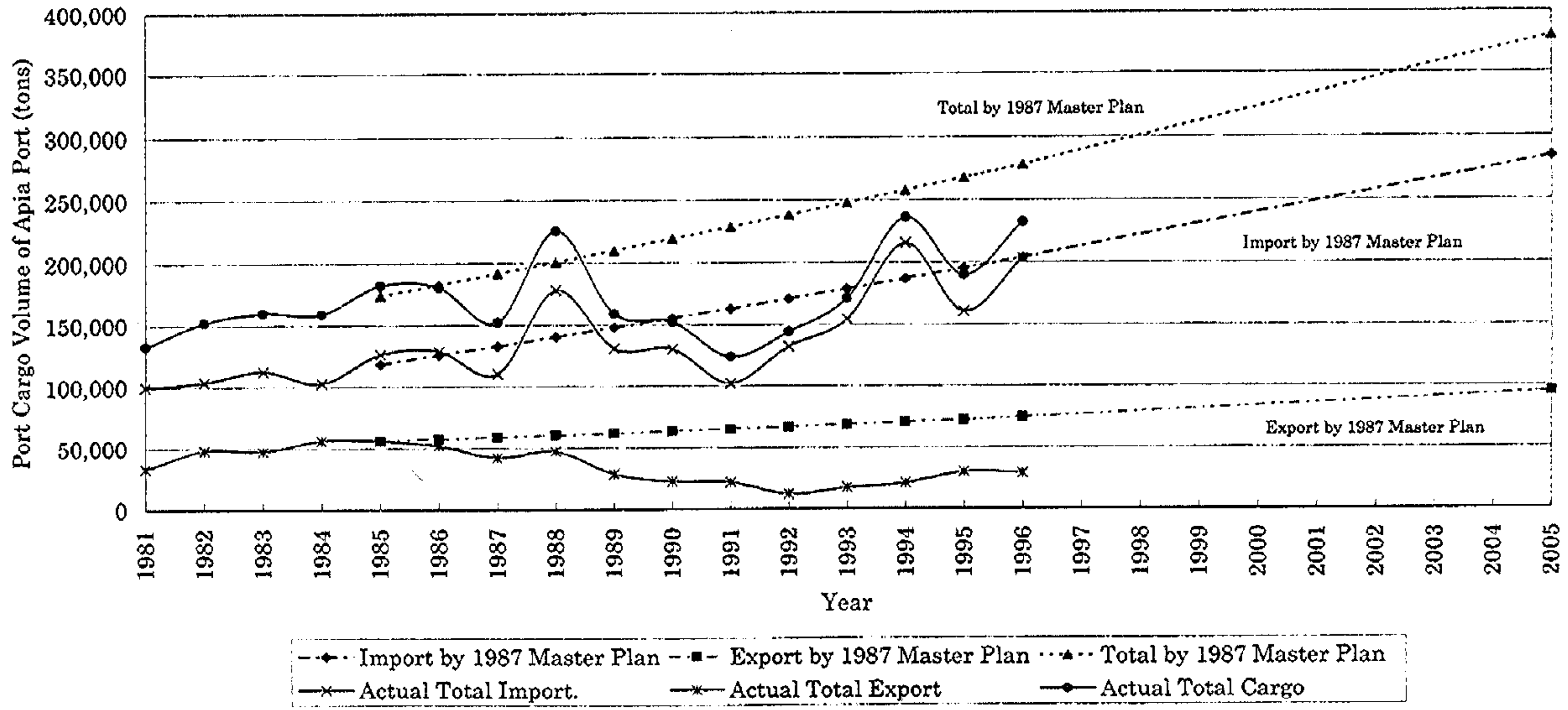
														Asau Port
1987 Master Plan Forecast (Actual data till 1985)		Import	83,401	90,387	94,157	107,533	121,209	135,288	149,752	164,576	172,113	226,585	244,000	
		Export	33,117	35,260	43,970	46,119	48,529	51,101	53,848	56,789	58,338	70,940	74,000	20,000
	General Cargo		116,518	125,647	138,127	153,652	169,739	186,389	203,600	221,365	230,451	297,525	318,000	20,000
		Import	29,125	20,985	23,960	25,281	26,443	27,724	29,127	30,655	31,468	37,953	40,500	4,100
		Export		12,188	12,099	12,787	13,513	14,281	15,091	15,948	16,395	19,891	21,000	
	Total of Oil		29,125	33,173	36,059	38,068	39,956	42,004	44,218	46,604	47,863	57,845	61,500	4,100
		Import	112,526	111,372	118,117	132,814	147,652	163,012	178,879	195,231	203,581	264,538	284,500	4,100
		Export	33,117	47,448	56,069	58,906	62,043	65,381	68,939	72,737	74,733	90,831	95,000	20,000
Forecast of Total Cargo			145,643	158,820	174,186	191,720	209,695	228,393	247,818	267,969	278,314	355,370	379,500	24,100
Actual Cargo Volume of Apia Port (tons)		Import	70,607	91,516	102,164	99,897	110,029	81,500	113,091	133,593	171,317			
		Export	33,117	35,260	43,970	30,548	22,171	21,645	16,898	22,621	22,056			
	General Cargo		103,724	126,776	146,134	130,445	132,200	103,145	129,989	156,214	193,373			
		Import	29,125	20,985	23,960	10,245	20,713	20,639	41,255	27,050	31,899			
		Export(Coconut Oil)		12,188	12,099	11,527	6,292	35	0	6,782	6,489			
	Total of Oil		29,125	33,173	36,059	21,772	27,005	20,674	41,255	33,832	38,388			
		Import	99,732	112,501	126,124	110,142	130,742	102,139	154,346	160,643	203,216			
		Export	33,117	47,448	56,069	42,075	28,463	21,680	16,898	29,403	28,545			
		(Total	132,849	159,949	182,193	152,217	159,205	123,819	171,244	190,046	231,761			

Note 1) Average annual growth rate of Forecast GDP in 1987 Master Plan is +2.12% per annum.

Table 3.1.1-6 Comparison between Forecast and Actual Cargo Volume

Year	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	2005
Import by 1987 Master Plan					118,117	125,594	132,814	140,167	147,652	155,267	163,012	170,883	178,879	186,996	195,231	203,581	284,500
Export by 1987 Master Plan					56,069	57,409	58,906	60,450	62,043	63,686	65,381	67,132	68,939	70,807	72,737	74,733	95,000
Total by 1987 Master Plan					174,186	183,003	191,720	200,617	209,695	218,953	228,393	238,014	247,818	257,803	267,969	278,314	379,500
Actual Total Import.	99,732	103,875	112,501	102,866	126,124	128,768	110,142	178,272	130,742	130,144	102,139	132,361	154,346	215,244	160,643	203,216	
Actual Total Export	33,117	48,175	47,448	56,353	56,069	51,871	42,075	47,097	28,463	22,233	21,680	11,838	16,898	20,551	29,403	28,545	
Actual Total Cargo	132,849	152,050	159,949	159,219	182,193	180,639	152,217	225,369	159,205	152,377	123,819	144,199	171,244	235,795	190,046	231,761	

Figure 3.1.1-2 Comparison between Forecast and Actual Cargo Volume



3.1.2 Proposed Facilities

To meet the traffic demand forecast in the previous section, port facilities are proposed for Master Plan with the target year 2005 as shown in Figure 3.1.2-1 and Table 3.1.2-1. Major facilities and their construction costs are summarized as follows,

Facility	Cost million Tala
Dredging	1.9
Breakwater	5.0
New Wharf	25.6
Ferry Wharf	3.2
Small Boat Wharf	2.1
Container Yard	8.4
CFS	2.0
SPA Office	4.1
Tug Boat 2Nos	5.5
Marina	2.4
Others	25.4
Total	85.6

Of the above facilities, a breakwater, a ferry wharf, a part of container yard and purchase of one tug boat were selected as project components of a short term development plan and have already been implemented under Japan's grant aid program.

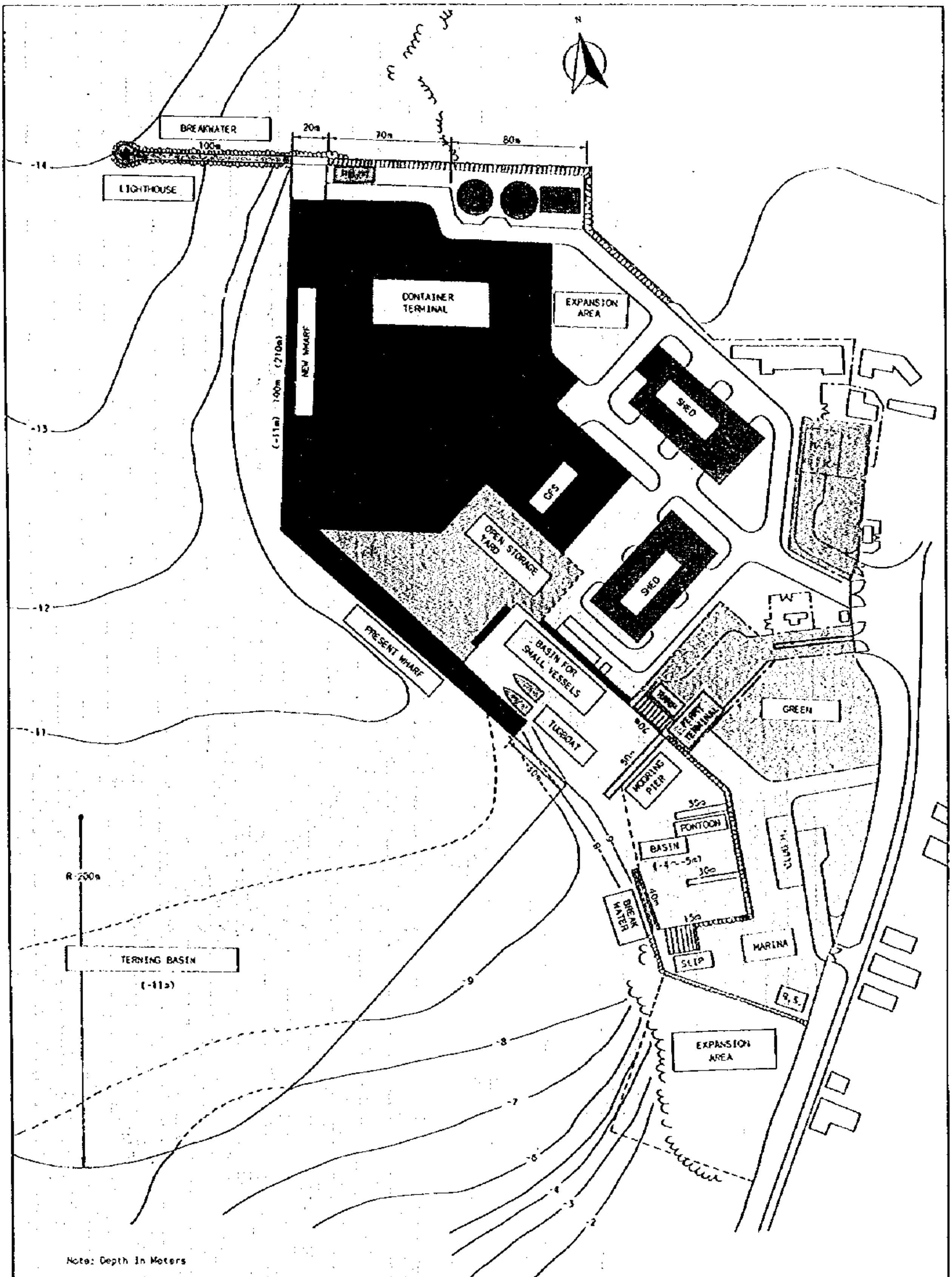


Figure 3.1.2-1 Port Layout, 2005 (Proposed in JICA F/S, 1987)

Table 3.1.2-1 MASTER DEVELOPMENT PLAN 2005, APIA PORT

1US$=2.08WS$=152¥

Port Facilities proposed in Master Plan '87							
Function	Facility	Required Work	Unit	Quantity	Unit Cost WS¥	Cost 1000WS$	Remarks
Sea Access to Port	Turning Basin	Dredging	m^3	111,000	17	1,870	Diameter=400m, Depth D=-11m
	Mooring Basin	Dredging					D=-11m
Wave Shelter	Breakwater	New Construction	m	100	49,700	4,970	Length L=100m
Berthing	Existing Wharf	Rehabilitation	LS	1	496,000	496	Some repairs
	New Wharf	New Construction	m	210	122,000	25,620	L=200-225m, D=-11m Container Wharf
	Ferry Wharf	New Construction	m^2	3,600	880	3,168	L=50m
	Small Boat Wharf	New Construction	m	100	21,300	2,130	Improvement of coastline
	Tanker Bouy	Lighting	LS	1	16,000	16	
	Tanker Bouy	Relocation	LS	1	250,000	250	1) Installation of Lights, 2) Offshore Relocation
Storage and Maintenance	Expansion of Yard	Pavement	m^2	6,000	850	5,100	Behind the Main Wharf
	Container Yard	Pavement	m^2	25,000	130	3,250	Area 263 slots
	CFS	New Construction	m^2	1,200	1,700	2,040	30 x 40 = 1200m^2
	Maintenance Shop	New Construction	m^2	200	1,400	280	200m^2
	Cargo Shed	Rehabilitation	m^2	5,000	1,100	5,500	2500m^2 x 2
	Oil Tanks	Relocation	LS	1	463,000	463	Relocation
Land Access to Port	Access Road	Gate Upgrade					based on the layout
Passenger Transport	Ferry Term'l Building	New Construction					710m^2
Administration	Administration Office	New Construction	m^2	1,500	2,700	4,050	1500m^2
	Marine Office	New Construction	m^2	200	2,400	480	200m^2
Port Service	Tug Boat	Purchase 2 Boats	PC	2	2,740,000	5,480	Replace (2 boats)
Aid to Navigation	Beacon	Renovation	PC	2	70,000	140	Improvement
	Light House	New Construction					Construction on the New Breakwater
Marina	Pontoon	New Construction	m^2	10,000	240	2,400	60m (20 yachts)
	Club House	New Construction					450m^2
	Anchorage Area	New Construction					-4~-5m
Landscaping	Green Area	New Construction	m^2	5,000	90	450	
Mobilization						6850	
S. Total						75003	
Engineering Services						3134	
Contingency						7479	
S. Total						10613	
G. Total						85616	