14.3 Development Sites

14.3.1 Characteristics of the Project Area

The topography of the coastal areas to the east and west of Port Salalah differs sharply. The coast to the east of the port is a flat beach open to the sea. The coast to the west of the port is a rocky cliff with small bays. Neither coast can provide a natural harbor. The existing port was developed taking advantage of a small peninsula, thereby reducing the construction costs. Further expansion of the existing port, however, can not count on a natural shelter for vessels and thus requires new breakwaters to provide calm basins.

The western coast is out of the question as a development site for the port expansion. The land behind the coast is hilly and not suitable for development. In addition, the cliffs precipitously fall into the sea to the depth of 30m within one kilometer from the shoreline. Therefore, neither the land side nor the seaside of the shoreline can be a development site for new terminals.

On the other hand, the eastern coast provides a gentle slope with a gradient of 1 to 200. The land behind the coast is basically flat terrain and can provide an easy access to the trunk road. Development sites are therefore limited to the eastern coasts.

14.3.2 Constraints to the Port Expansion

The eastern coast has the following constraints as a development site:

(1) Wadis

There are two wadis, Wadi Adawnib and Wadi Nar, to the north of the port. Those wadis may pose a serious problem to the port operation due to the sedimentation in case of a flood. This issue should be given due consideration in preparing port layout alternatives.

(2) Fishery harbor

A new fishery harbor was created in 1998 to substitute for the inner harbor beach which had been used by fishery boats. Since it would be undesirable to relocate those boats again after such a short period of time, the northward expansion seems to be limited.

(3) Mangrove communities

Mangrove communities are found on both sides of the Salalah Hilton, approximately 4km to the north of the existing port facilities. Mangrove communities support the coastal ecosystem through various ecological functions such as providing shoreline protection, recycling nutrients, and serving as habitats for fish and birds. And these communities are part of a larger scenic area which has the potential to attract tourists. Negative impacts on the mangrove communities therefore need to be minimized.

(4) Coastal erosion

The beach material found in the eastern coasts consists of very fine powder sand with light density. Consequently the beaches are rather prone to erosion. Port layouts need to be prepared so that coastal erosion will be minimized.

(5) Wave

The eastern coasts are open to the Arabian Sea, and thus requiring appropriate protective facilities to provide sufficiently calm basins.

14.3.3 Evaluation of the Project Area

The Study Team evaluated the project area to identify prospective development sites. The project area was divided into one square kilometer grids and then each grid was evaluated taking into account the above mentioned constraints. The outlook for the construction costs of deep-draft quay was examined as well (See Table 14.3.1, Figure 14.3.1 to 14.3.4).

Taken together, the study findings support a port expansion in the direction of east to northeast.

Table 14.3.1 Evaluation of the Project Area

Block		Average Depth	Evaluation Items					
			Construction costs		Wave	Coastal erosion	Mangrove community	Wadis
			Dredging	Quay				
	1	-	-	◎	-	-	-	-
	2	-1.0m	-	◎	○	△	△	◎
A	3	-5.0m	△	◎	△	△	△	◎
	4	-6.0m	△	◎	△	◎	◎	◎
	5	-7.5m	△	◎	△	◎	◎	◎
	1	-1.0m		◎	◎	△	△	◎
	2	-3.0m	△	◎	○	△	△	◎
B	3	-7.5m	△	◎	△	◎	◎	◎
	4	-10.0m	○	○	△	◎	◎	◎
	5	-12.0m	○	○	△	◎	◎	◎
	1	-3.0m	△	◎	◎	◎	◎	△
	2	-5.0m	△	◎	○	◎	◎	△
C	3	-10.0m	○	○	△	◎	◎	◎
	4	-13.0m	○	○	△	◎	◎	◎
	5	-15.0m	◎	△	△	◎	◎	◎
	1	-3.0m	△	◎	◎	◎	◎	△
	2	-6.0m	△	◎	○	◎	◎	△
D	3	-15.0m	◎	△	△	◎	◎	◎
	4	-17.5m	◎	△	△	◎	◎	◎
	5	-20.0m	◎	△	△	◎	◎	◎
	1	-		-	◎	-	-	-
	2	-		-	◎	-	-	-
E	3	-20.0m	◎	△	△	◎	◎	◎
	4	-22.0m	◎	△	△	◎	◎	◎
	5	-25.0m	◎	△	△	◎	◎	◎
Evaluation criteria			◎: Low cost		◎: Low wave	◎: Little impact		
			○: Medium cost		○: Medium wave			
			△: High cost		△: High wave	△: Considerable impact		

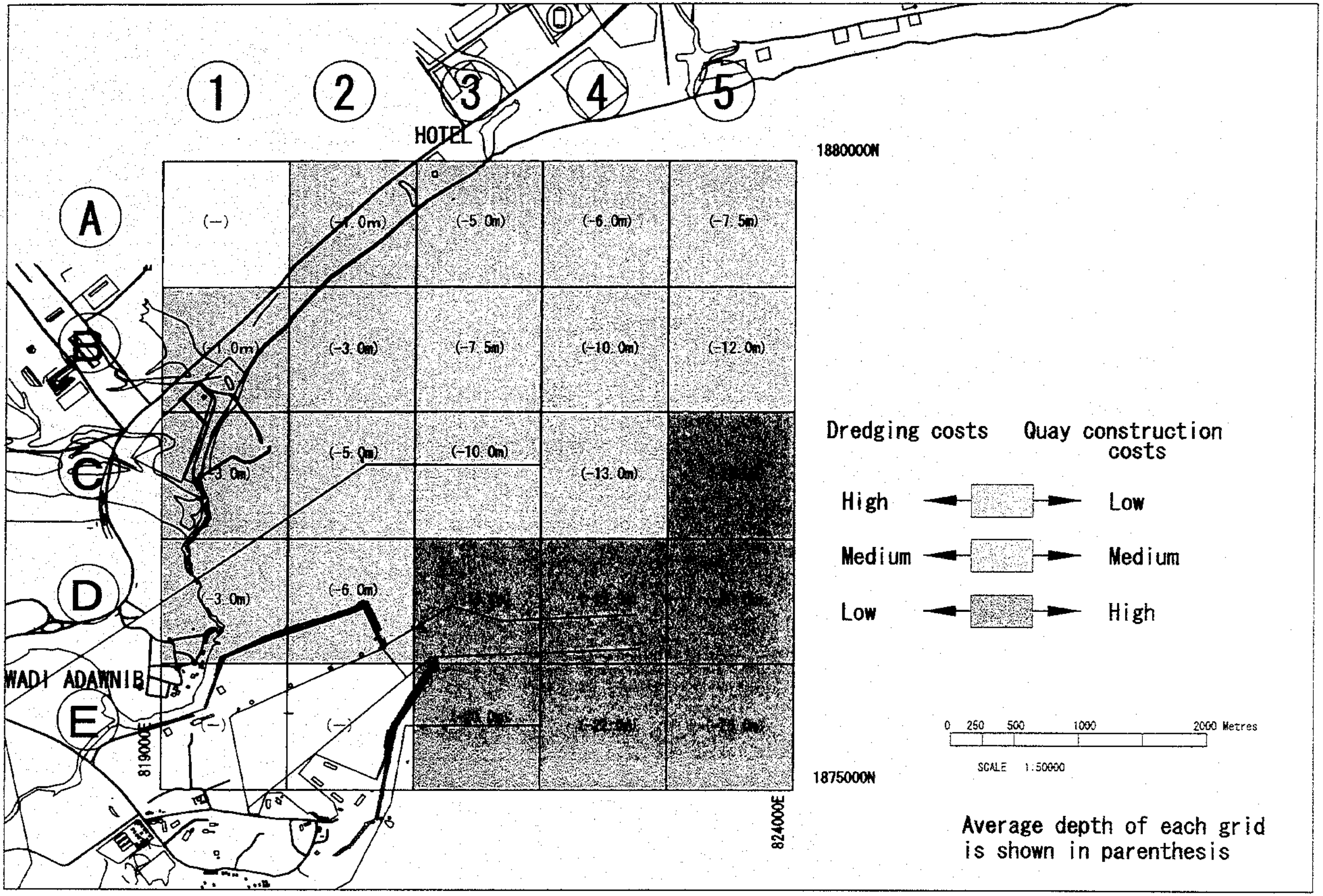


Figure 14.3.1. Construction Costs

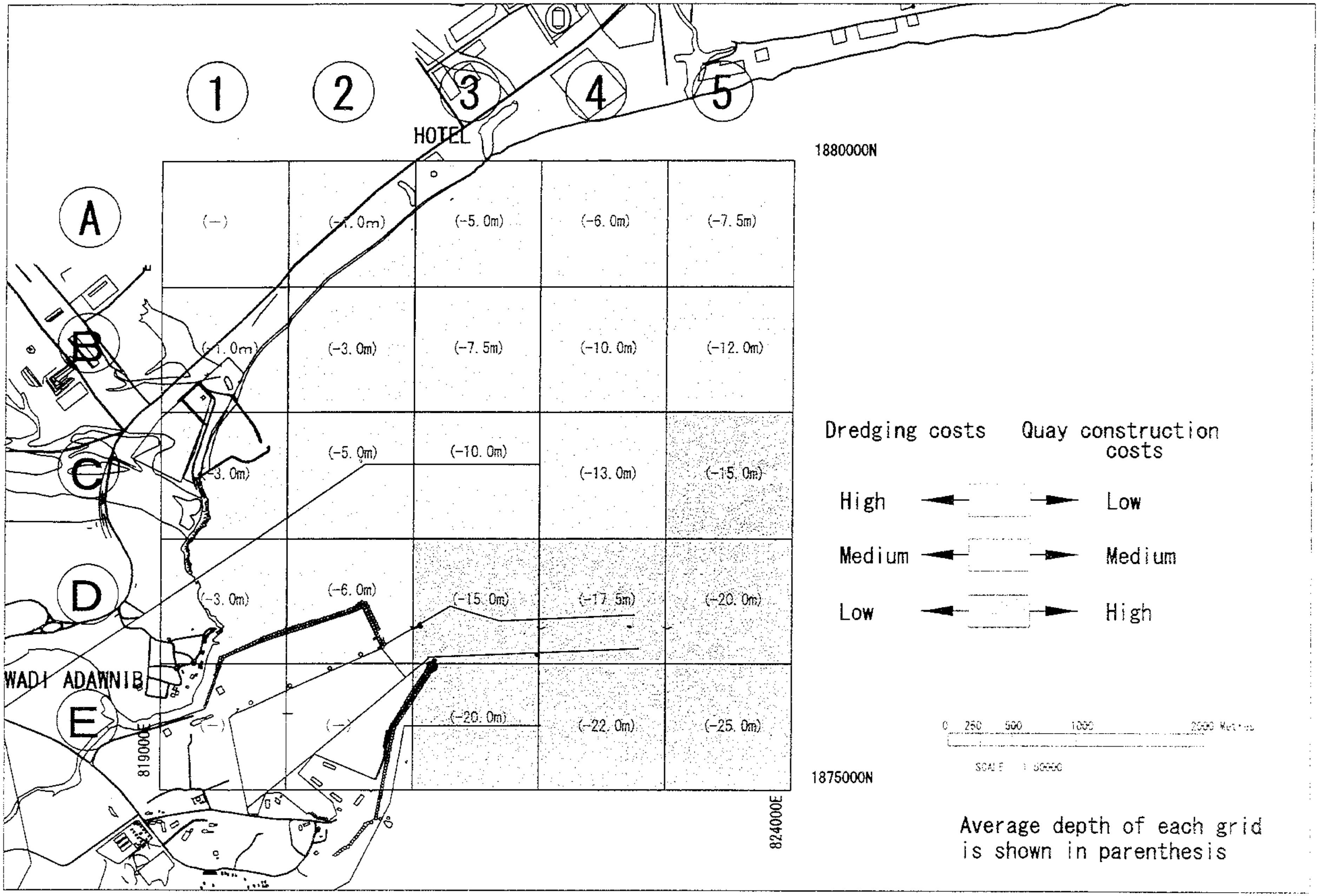


Figure 14.3.1. Construction Costs

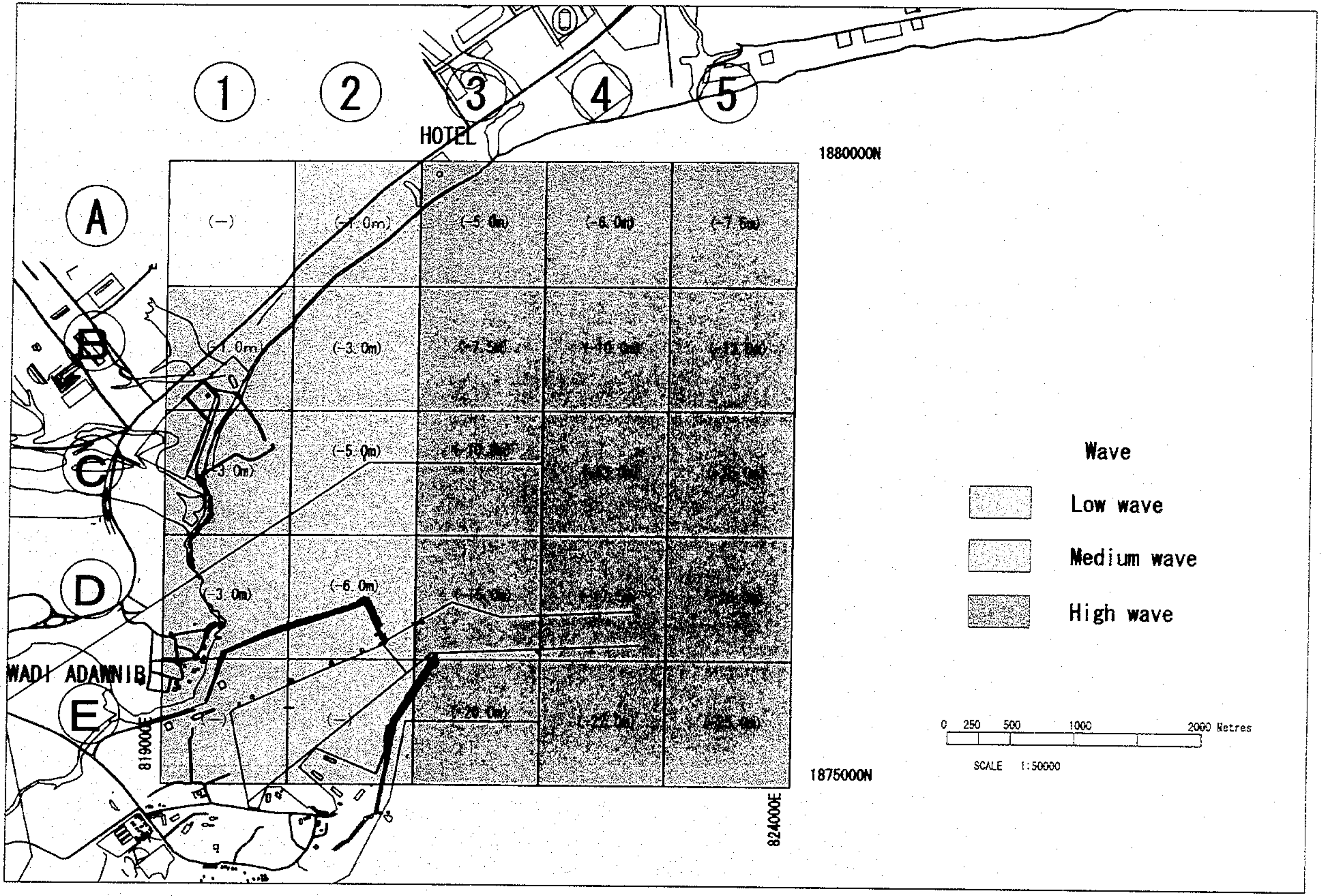


Figure 14.3.2. Wave

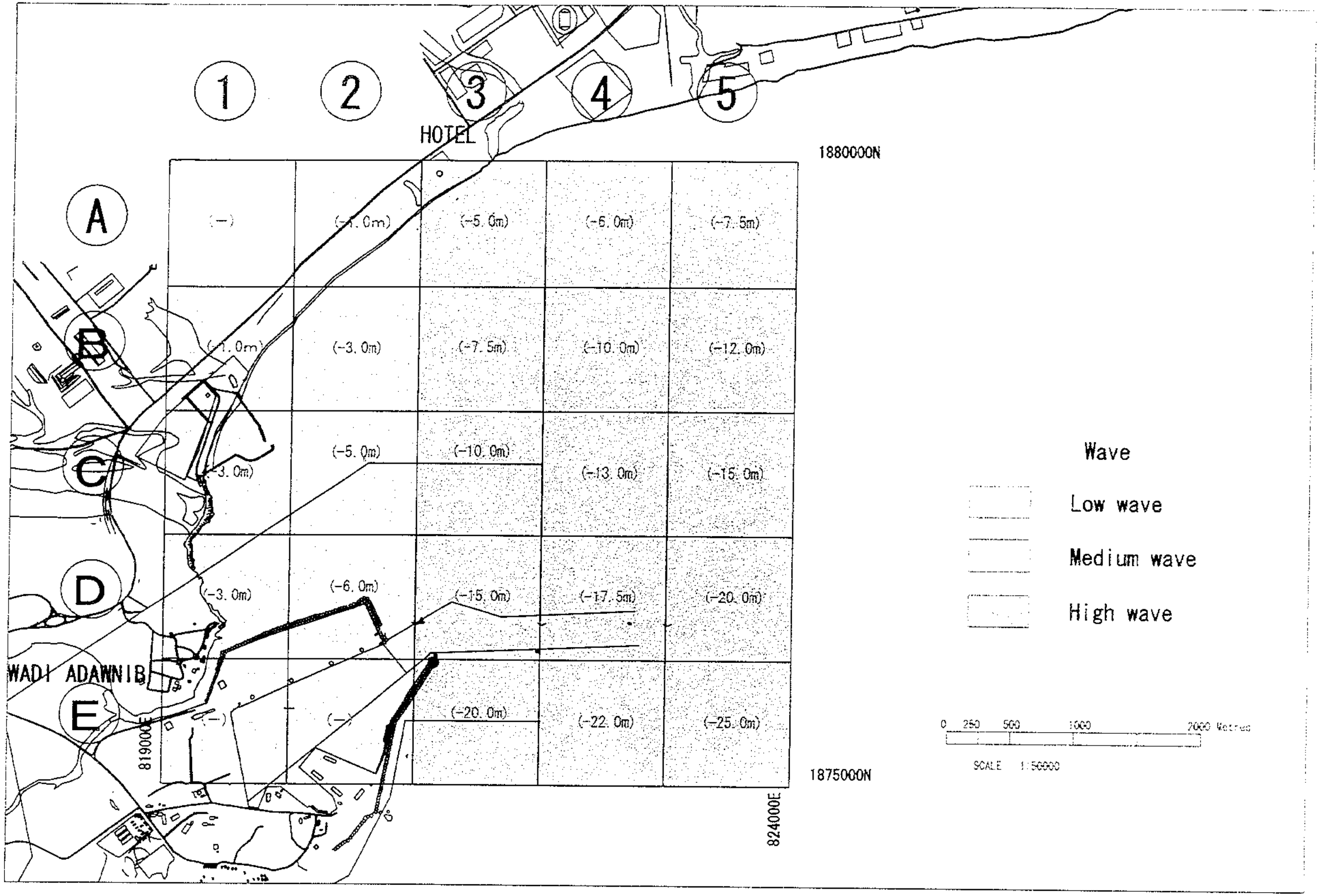


Figure 14.3.2. Wave

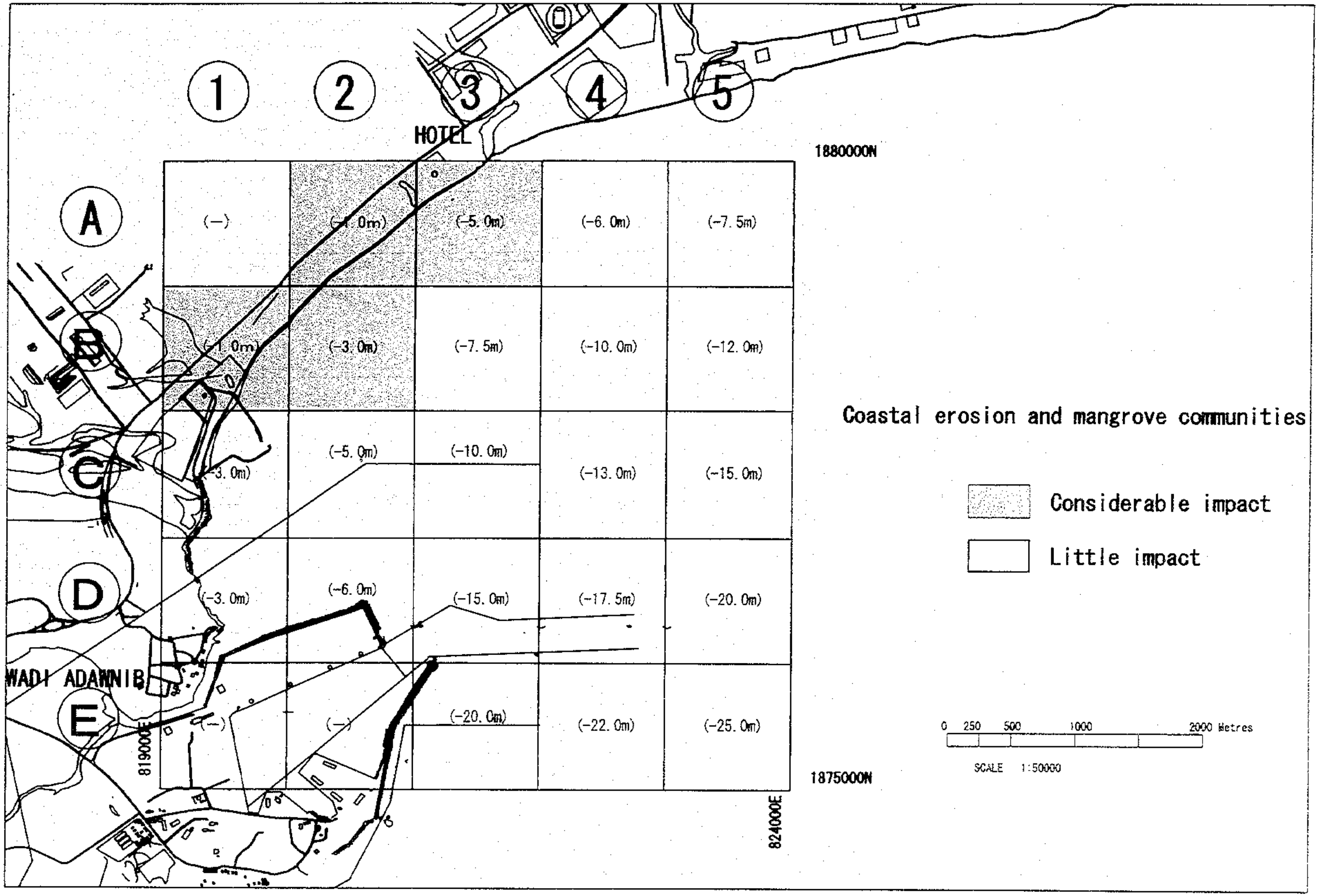


Figure 14.3.3. Coastal Erosion and Mangrove Communities

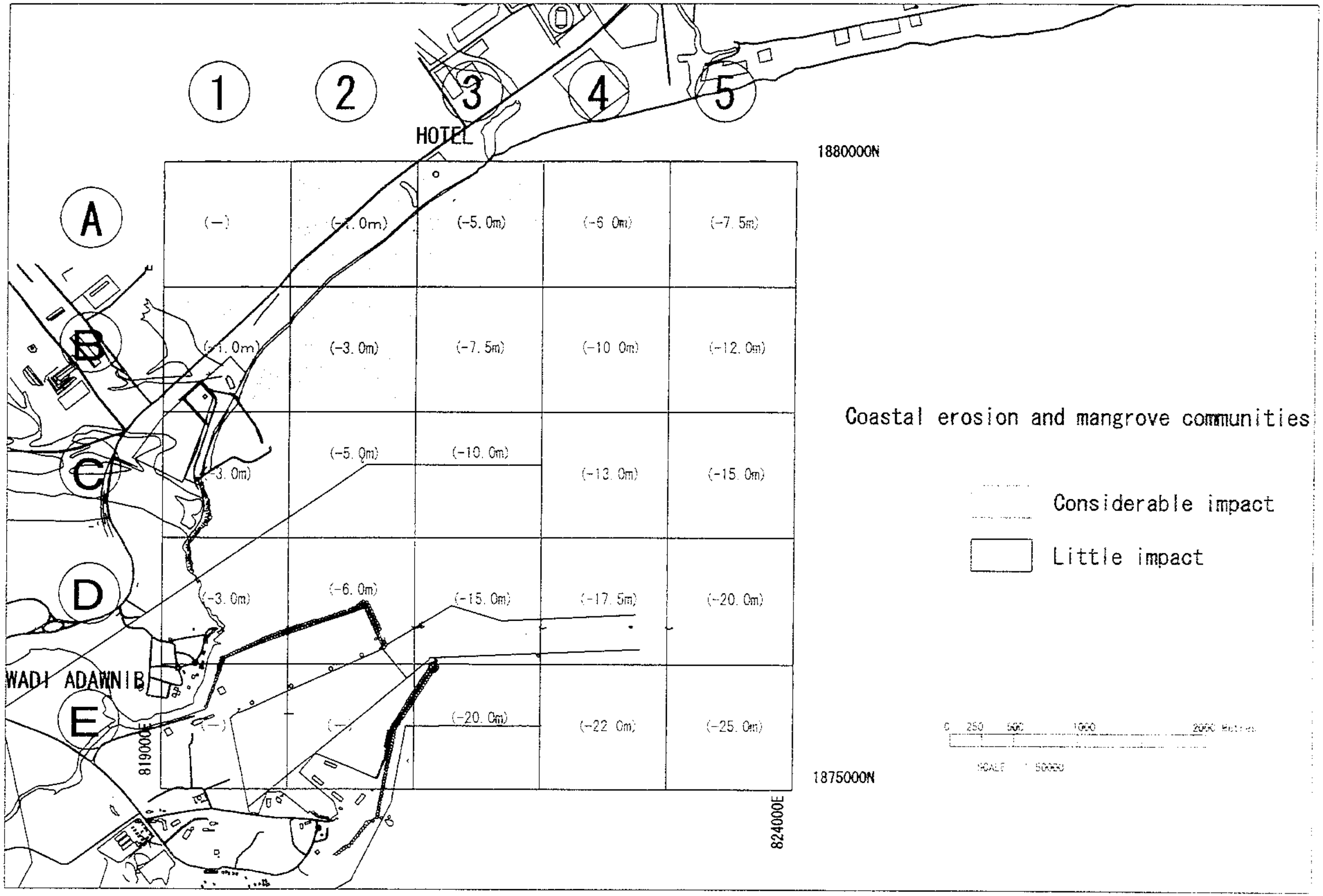


Figure 14.3.3. Coastal Erosion and Mangrove Communities

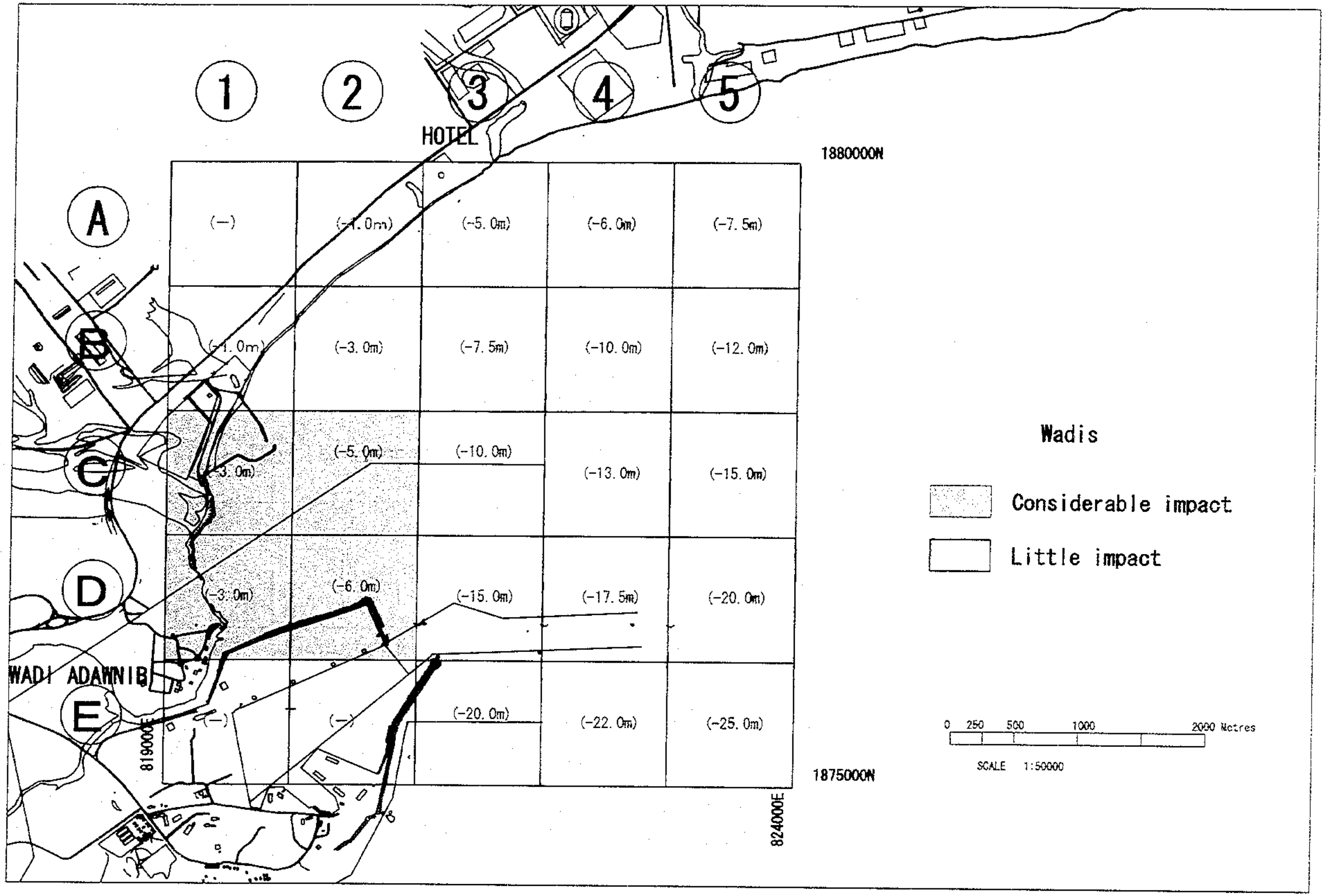


Figure 14.3.4. Wadis

14.4 Alternative Layouts

14.4.1 Identification of the Prospective Development Sites

The Study Team identified five prospective development sites taking into account the evaluation of the project area, the layout of the existing facilities, and the topography of the area (See Figure 14.4.1). The five sites were then evaluated from various viewpoints (See Table 14.4.1). Though each site has advantages and disadvantages, Site A is slightly preferable to Site B and C from a viewpoint of natural conditions. Site D is clearly inferior to the other four because of environmental concerns.

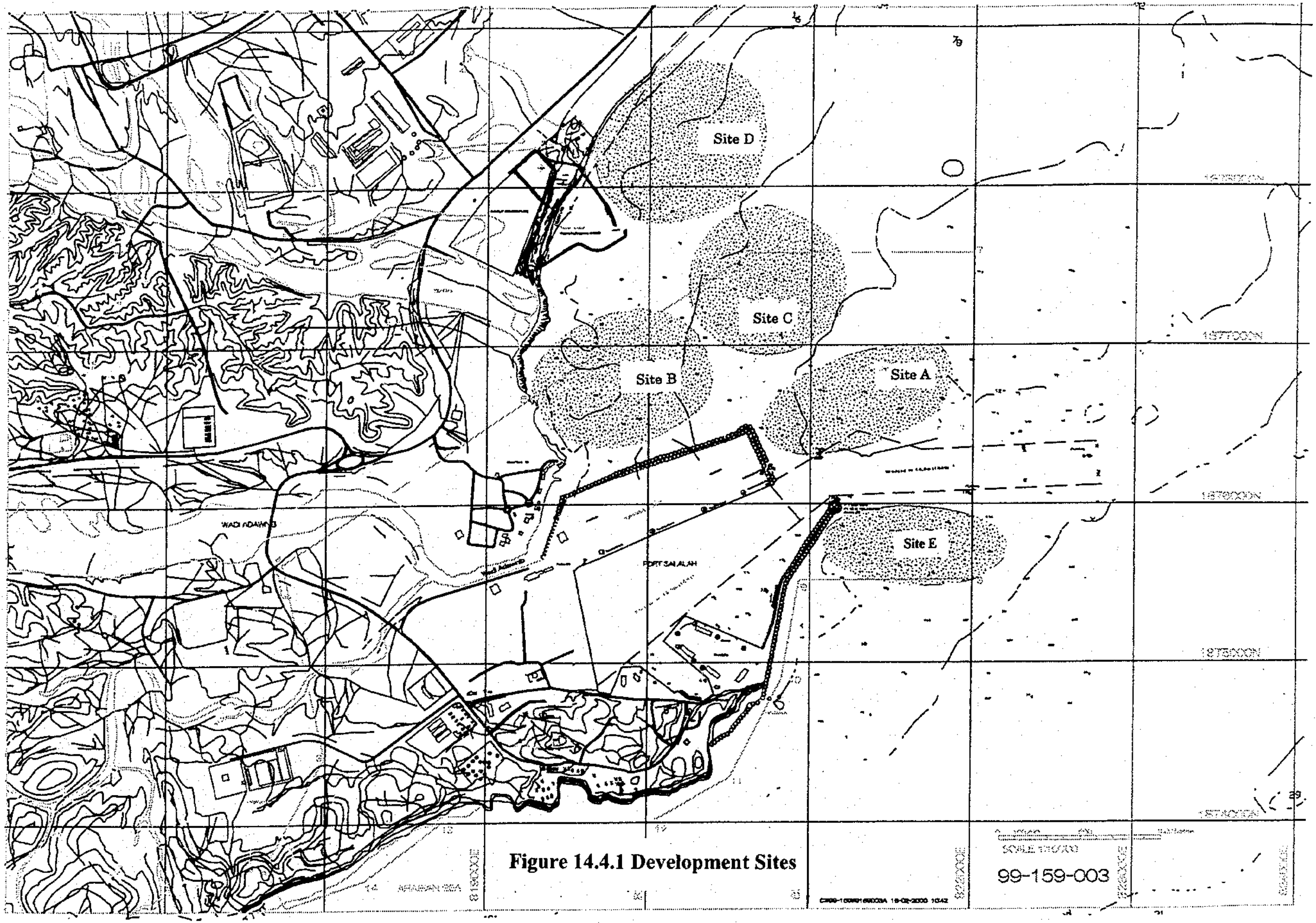


Figure 14.4.1 Development Sites

Table 14.4.1 Observation on the Prospective Development Sites

Alternative sites / Factors	Site A	Site B	Site C	Site D	Site E
Deep-draft quays	Suitable	Large volume of dredging is required	Suitable	Large volume of dredging is required	Suitable
Surge issue	Change in the natural period of the basin needs to be examined	No surge is expected unless another closed basin is created	No surge is expected unless another closed basin is created	No surge is expected unless another closed basin is created	Change in the natural period of the basin needs to be examined
Initial investment	Extension of the east breakwater is necessary	Some measure needs to be taken to provide sufficient shelter from the south to southeast waves	New breakwater is required to provide sufficient shelter from the south to southeast waves	Some measure needs to be taken to provide sufficient shelter from the south to southeast waves	Extension of the east breakwater is necessary
Access from hinterland	Existing terminal road needs to be expanded	New access road is required	New access road connected to other site is required	New access road is required	Existing terminal road needs to be expanded
Maintenance	No major issue is in sight	Wadi Adawnib and Wadi Nar may cause sedimentation	Wadi Adawnib and Wadi Nar may cause sedimentation	Littoral drift needs to be examined	No major issue is in sight
Balance between dredging and reclamation	Reasonable balance is attainable	Dredging volume surpasses reclamation volume	Reasonable balance is attainable	Dredging volume surpasses reclamation volume	Reclamation volume surpasses dredging volume
Coastal erosion	Effects of the extension of the breakwater need to be examined	No major erosion is expected	Effects of the new breakwater need to be examined	Adjacent beach will experience the effects of littoral drift	Effects of the extension of the breakwater need to be examined
Mangrove community	Little impact is expected	Little impact is expected	Little impact is expected	Considerable impact is expected	Little impact is expected

14.4.2 Conceptual Layouts

Due to the topographical constraints mentioned in section 14.3.2, a large-scale reclamation directly extended from the present shoreline behind Site B was excluded in the alternative formulation. A large-scale development at Site D was also excluded for the reasons mentioned in section 14.4.1. Bearing these factors in mind, the Study Team prepared three conceptual layout plans and then compared them with the concept of the H.P.A. Layout Plan (See Table 14.4.2).

Conceptual Layout 1 (See Figure 14.4.2)

The expanded port comprises a single wharf group. The present container terminal is extended from the tip toward the northeast, parallel to the contour. In order to create a new turning basin, the east breakwater is extended and an offshore breakwater is constructed. Government berths are created on the shore side of the extended container terminal. A bridge connects the expanded terminal to the hinterland.

Conceptual Layout 2 (See Figure 14.4.3)

The expanded port comprises two wharf groups. The present container terminal is extended along the quay line and also expanded to the north. Another pier is created to the north of the present container terminal, thereby providing a basin between the two piers. The east breakwater is extended long enough to ensure calmness in both basins. Government berths are created on the north side of the expanded container terminal. A bridge connects the expanded terminal to the hinterland.

H.P.A. Layout Concept (See Figure 14.4.4)

The expanded port comprises three wharf groups plus an area for future expansion. The present container terminal is extended along the quay line and also expanded to the north. Another pier is created to the north of the present container terminal, thereby providing a basin between the two piers. The east breakwater is extended long enough to ensure calmness in both basins. Government berths are created on the west side of the northern basin.

Conceptual Layout 3 (See Figure 14.4.5)

The expanded port comprises two wharf groups and a marshalling area plus future provision for bulk jetties and a ship repair yard. The present container terminal is extended along the quay line and also expanded to the north. Another pier is created to the north of the present container terminal, thereby providing a basin between the two piers. The two piers are connected offshore so that floods of the wadis do not interfere with the port operation. A bridge connects the new pier to a new marshalling area which is reclaimed to the north. Another bridge connects the expanded pier to the hinterland. The east breakwater is extended long enough to ensure calmness in both basins. Government berths are created on the north side of the expanded container terminal.

Conclusions

Based on the comparison among the four conceptual layouts (See Table 14.4.2), the Study Team proposes that Conceptual Layout 3 and H.P.A. layout be further examined. Conceptual Layout 1 is discarded because of a great imbalance between dredging volume and reclamation volume. Conceptual Layout 2 is not recommendable either because it can not respond to further expansion needs in future.

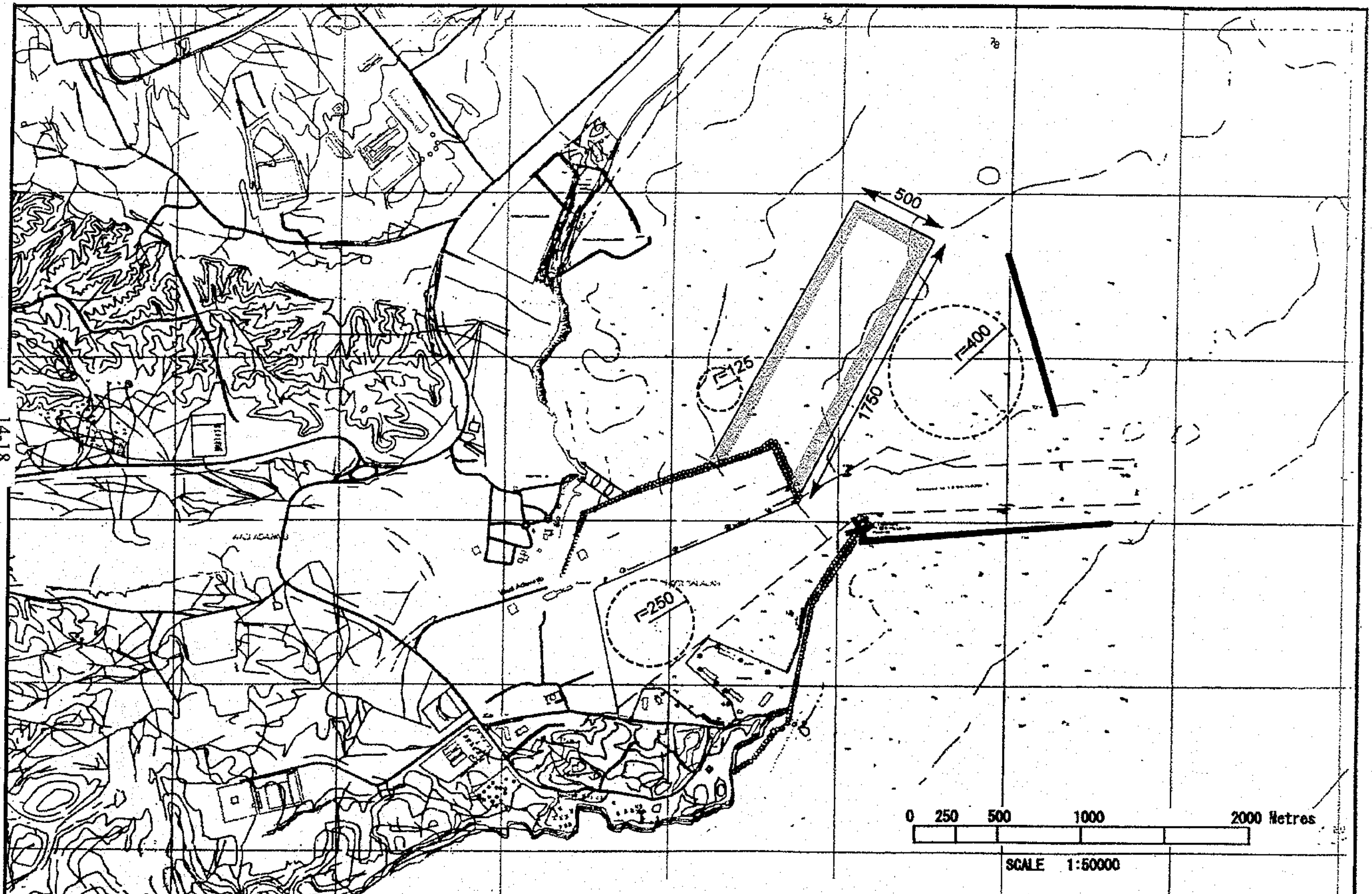


Figure 14.4.2 Conceptual Layout 1

Conceptual Layout 1

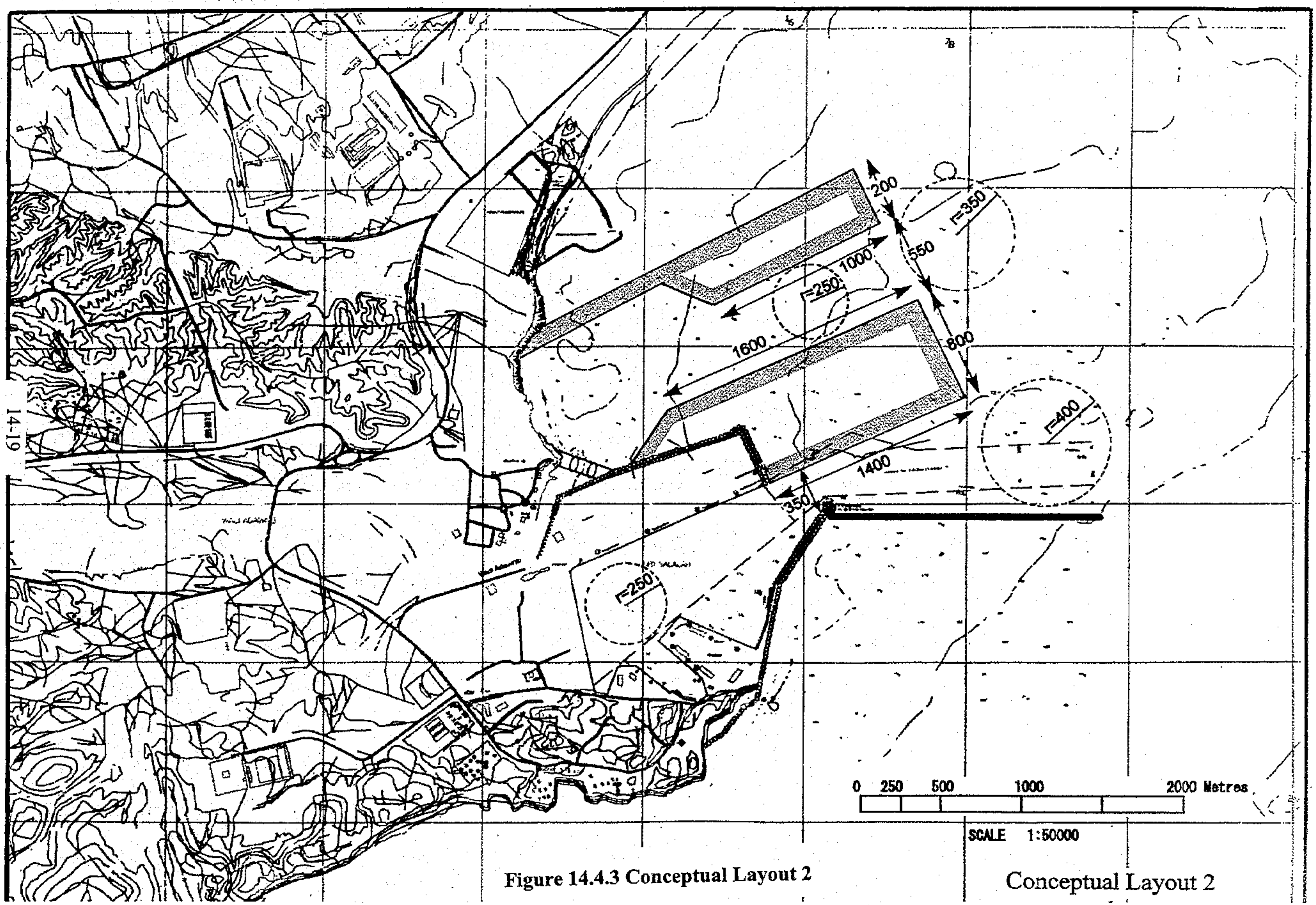


Figure 14.4.3 Conceptual Layout 2

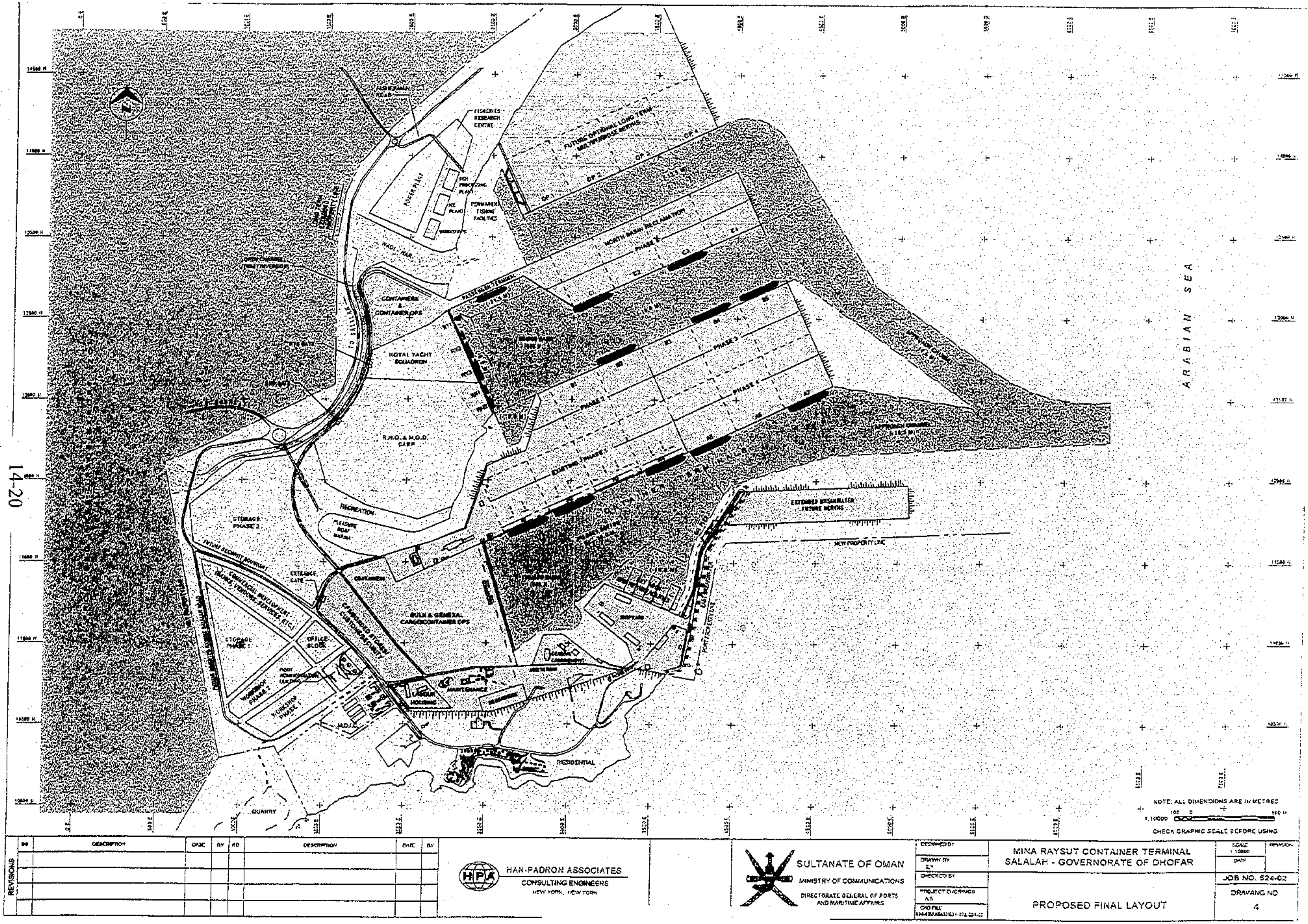


Figure 14.4.4 H.P.A. Layout

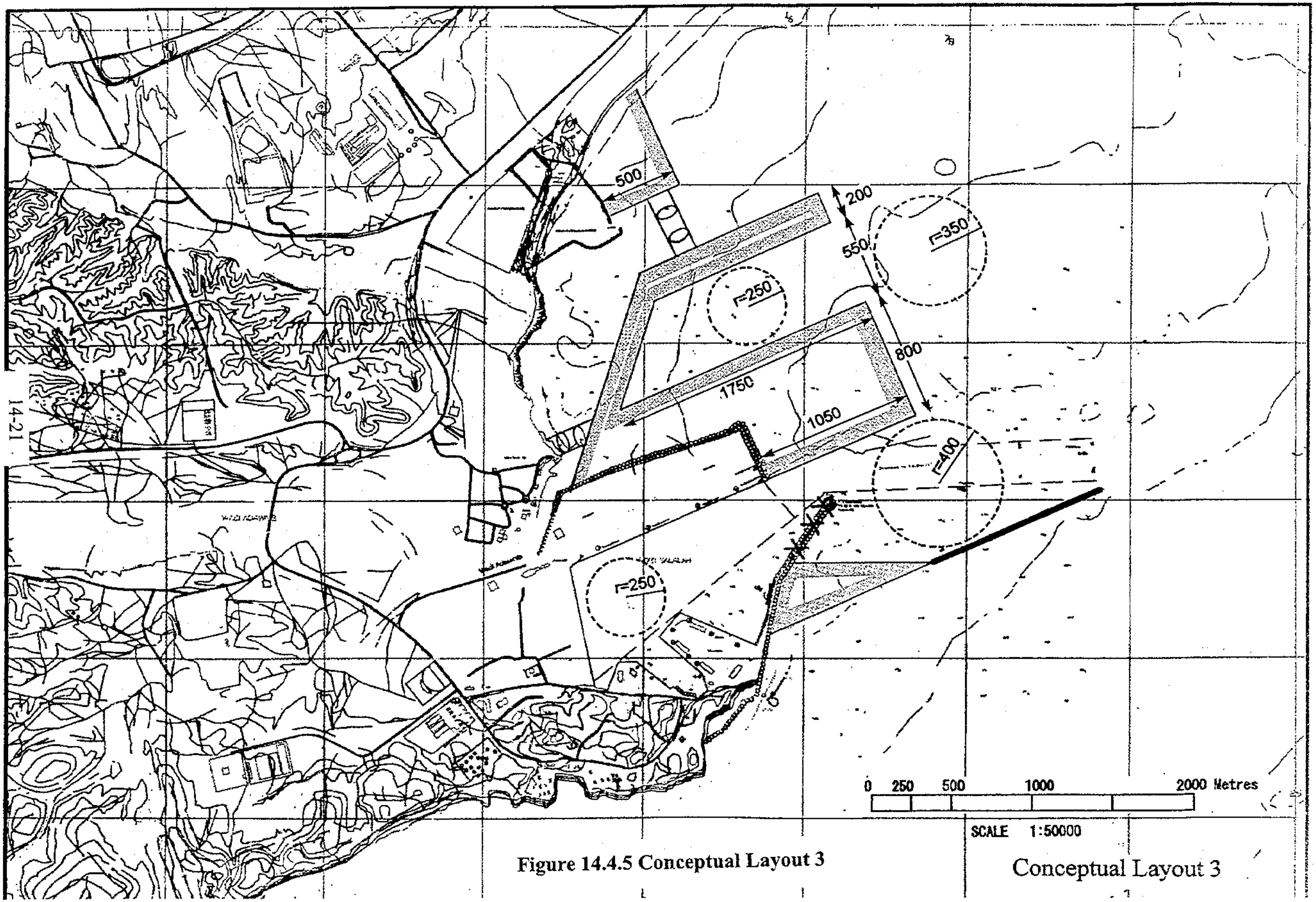


Figure 14.4.5 Conceptual Layout 3

Table 14.4.2 Comparison among the Conceptual Layouts

Alternative Layouts / Factors	Conceptual Layout 1	Conceptual Layout 2	H.P.A. Layout Cpncept	Conceptual Layout 3
Access to the hinterland	Three	Two	Four	Four
Navigational safety	Congestion at the harbor entrance needs to be examined	No major issue is in sight	Additional approach channel has a sharp bend, posing difficulty for vessel maneuvers	Vessel maneuvers at the present harbor entrance become much easier
Initial investment	Extension of the east breakwater is needed	Extension of the east breakwater and creation of a offshore breakwater are needed	Extension of the east breakwater is needed	Removal of the half of the east breakwater and construction of a new east breakwater is needed
Future expansion	Further extension of the two piers	Rather difficult	Envisaged at Site D	Envisaged at Site E
Surge issue	Numerical simulation is required for two basins	Numerical simulation is required for the existing basin	Numerical simulation is required for three basins	Numerical simulation is required for two basins
Wadis	Threat from Wadi Adawnib is significantly reduced Wadi Nar poses no problem	Threat from both wadis is significantly reduced	Siltation from Wadi Adawnib needs to be carefully examined	No threat from wadis is expected
Balance between dredging and reclamation	Reclamation volume greatly exceeds dredging volume	Dredging volume exceeds reclamation volume	Reclamation volume exceeds dredging volume unless the future expansion at Site D is included	Reclamation volume exceeds dredging volume
Coastal erosion	Effects of the breakwater extension need to be examined	Change in coastal currents is expected due to the creation of a offshore breakwater	Effects of the breakwater extension and future development at Site D need to be examined	Effects of the breakwater extension need to be examined
Mangrove community	Little impact is expected	Change in coastal currents may have an impact	Future expansion at Site D has an impact	Little impact is expected

14.5 Capacity Requirements

14.5.1 Container Berths

(1) Transshipment

The estimated demand of transshipment container for the year 2020 differs sharply depending on the development scenario. It is estimated to be in the range of 2.5 million to 9.3 million TEUs. Taking into account future eventuality as well as the risk arising from the port's high degree of dependency on a single alliance at present, the Study Team proposes 6.2 million TEUs for the high growth scenario and 5.1 million TEUs for the low growth scenario (See section 13.3). The high growth scenario envisages a high economic growth and unchanged strategic advantage, while the low growth scenario envisages a low economic growth and strengthened strategic advantage. Consequently the additional capacity required for 2020 is in the range of 3.1 million to 4.2 million TEUs. The number of the additional berths is obtained by dividing the required capacity addition by the productivity of a berth (See Table 14.5.1). The Study Team applied 500 thousand TEUs as the maximum annual productivity of a berth (See section 13.2).

The Study Team proposes a throughput estimate in the year 2005 with the same sets of scenarios as above. This time the high growth scenario envisages a low economic growth and strengthened strategic advantage, while the low growth scenario envisages a high economic growth and unchanged strategic advantage.

Table 14.5.1 Additional Container Berths

Year	2005	2020
Container throughput	2.5-3.0 million TEUs	5.1-6.2 million TEUs
Additional berths	2	6-8

Out of the 6-8 berths required for a long-term master plan, two berths need to have an alongside depth of 18m to cater for 8,000 TEU vessels. Each berth needs to be equipped with three super post-panamax gantries.

(2) Import/Export Containers

The annual throughput of import/export container is estimated to be 0.3 million TEUs at the year 2020 and thus negligibly small compared to the throughput of transshipment container. Consequently, the additional berths created to handle transshipment container can cater for import/export container. The Study Team carried out a set of numerical simulation studies to check if the berths proposed in the master plan can efficiently handle calling vessels (See section 14.10).

14.5.2 Conventional Berths

(1) Bulk Cargo

The annual throughput of bulk cargo in 2020 is estimated to be 1.9 million tons excluding fuel (See section 13.4). The main item is animal feed (0.6 million tons), cereals (0.8 million tons), and cement (0.5 million tons). Since the cargo volume is relatively small, the new bulk terminal should be used as a multi-user terminal rather than as a single user terminal. Although cereals are now unloaded by tank trucks, the new bulk terminal will require grabbing cranes to increase its productivity. Grabbing cranes can handle variety of commodities with different sets of grabs.

If a grabbing crane of 800 t/h capacity are installed in one of the new terminal, they can handle up to 1.7 million tons of dry bulk cargo by 24-hour a day service with the berth occupancy of 50%.

handling capacity = 800 t/h × 0.6 (efficiency) × 0.8 (operation ratio) ×365 days × 24 hours × 0.5 (berth occupancy) = 1,682,000 t/year

On the other hand, exporting cement can be loaded to a ship at the rate of 5000 t/24 hours with the berth occupancy of 50% at another berth. That is equivalent to 0.9 million tons a year. Therefore, the new bulk terminal has more than enough capacity towards the target year.

(2) General Cargo

The annual throughput of general cargo in 2020 is estimated to be 0.3-0.4 million tons, or 0.2-0.3 million tons greater than the current throughput (See section 13.4). The berth occupancy ratio of berths 1-4 is around 40 % at present (See section 13.3). If the bulk cargo is handled at the new bulk terminal, the berth occupancy ratio goes down to 20 %. Assuming the berth occupancy ration of 60 %, the four-berth group can additionally handle 0.9 million tons. Therefore, general cargo can be catered for at berths 1-4 towards the target year.

14.5.3 Oil Terminal

(1) Local Use

The local demand of fuel is expected to experience a marked decline upon completion of a LNG pipeline. Although the demand will gradually increase afterwards, it will not greatly surpass the current level.

(2) Bunker Fuel

Since Salalah is located at the halfway between Singapore and Rotterdam, two of the world's busiest bunkering points, it has a potential to become a major bunkering port. If the bunkering costs in Salalah are competitive against other ports, the bunkering demand in Salalah could reach as much as 1.5-3.0 million tons a year. Since bunker oil prices are high in Salalah at present, the prices should be sharply cut in order to materialize the potential demand.

14.5.4 Passenger Terminal

In the year 2020, cruise ships are expected to call at Port Salalah 44-64 vessels a year, or twice to three times as frequently as in 1999. In 1999, 60 % of the total cruise ship calls was in March and April. Although berths 1-4 and the new bulk terminal can cater for cruise ships for now, one dedicated passenger terminal is needed toward the end of the planning period.

14.6 Master Plan for 2020

14.6.1 Planning Principles

This master plan is targeted to develop Port Salalah toward 2020 in line with the development needs of the region. Since many economic factors and variables are incorporated as the preconditions, the depth of the master plan is limited to the basic directions of development. Economic viability of the specific projects is dealt with in section 14.8. The master plan also allocates some areas for future expansion which is not required up to 2020 according to the demand forecast.

14.6.2 Layout Plan

The layout plan for 2020 is shown in Figure 14.6.1. This plan comprises two main basins with deep alongside draft which are protected from waves and sedimentation by a breakwater and groin. Main components of the plan are shown in the following table.

Table 14.6.1 Master Plan for 2020

Facility	Dimensions
Additional berths	18m draft container quay: 1,050m 16m draft container quay: 1,750m Passenger berth: 350m Government berth: 800m (Future expansion: 980m with 12m depth)
Additional terminal area	112ha (Additional 42ha for future expansion)
Handling equipment	Container: 15 gantries (18 rows), 9 gantries (22 rows), 48 RTGs, 96 yard tractors Conventional: 1 grab bucket crane
Container handling capacity	6 million TEUs/year
Breakwater	2,550 m
Dredging	17,393,000 m^3 (Additional 331,000 m^2 for future expansion)
Reclamation	15,062,000 m^3 (Additional 7,271,000 m^2 for future expansion)
Total cost	310 million R.O.

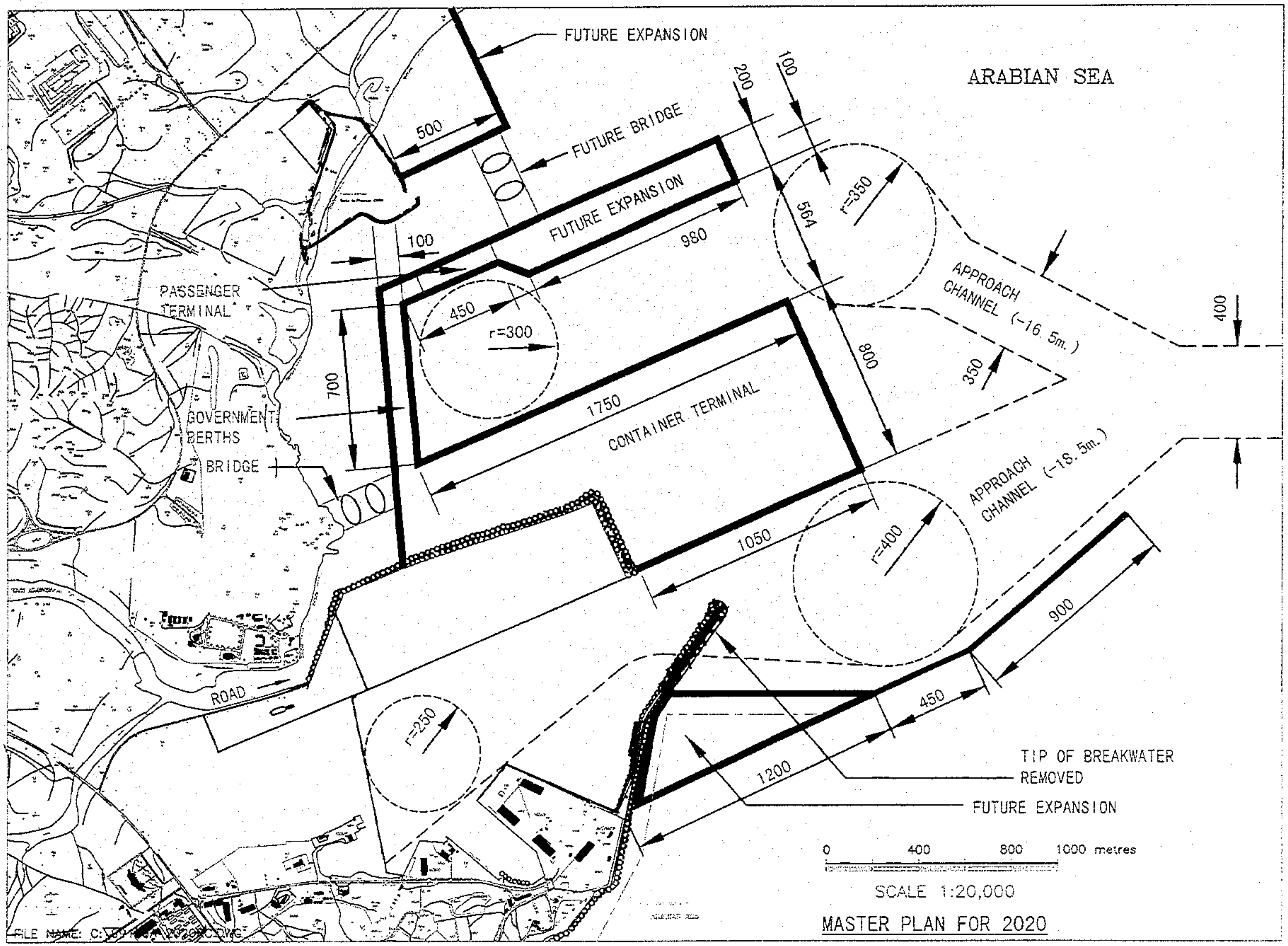


Figure 14.6.1 Master Plan

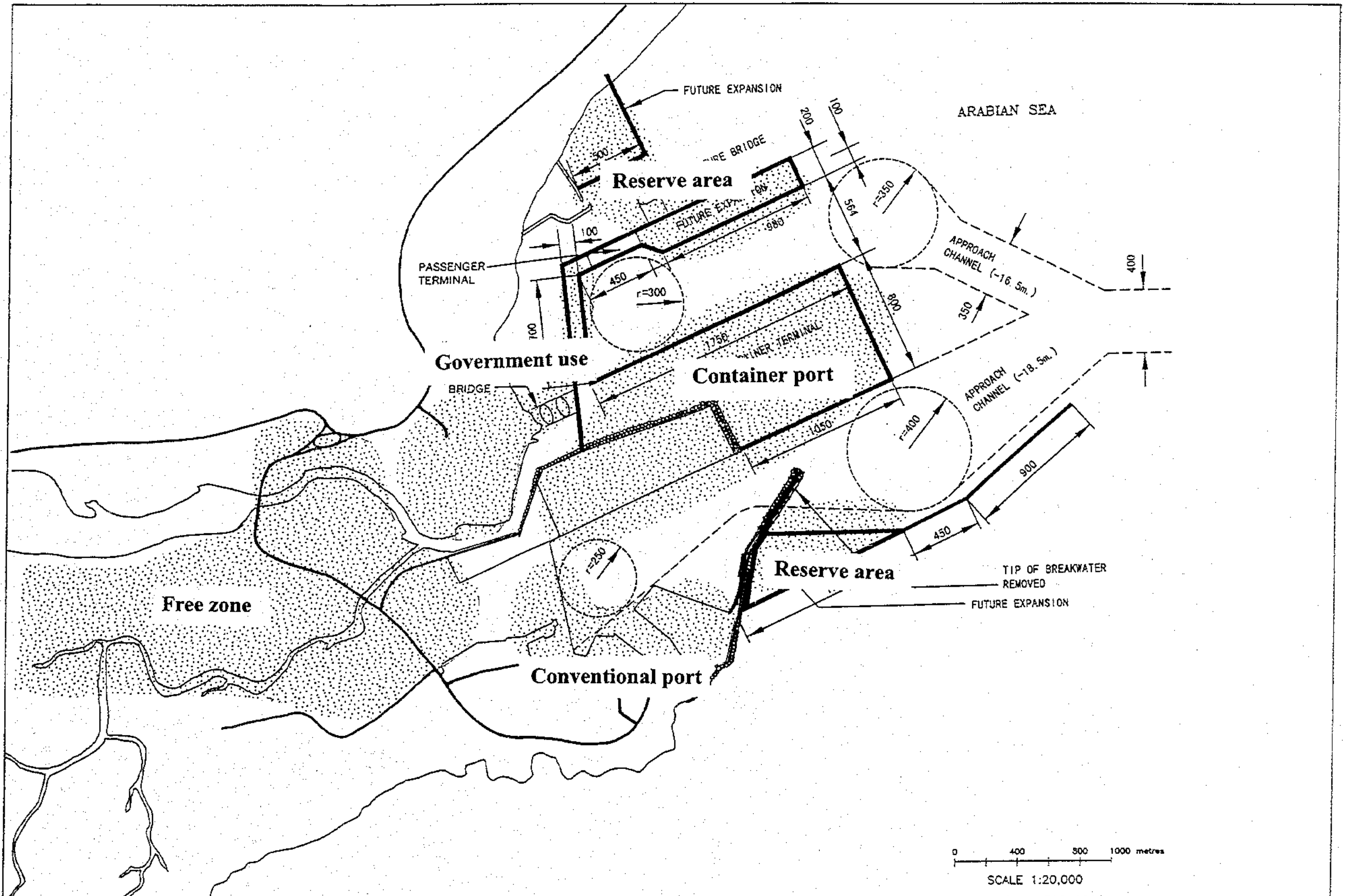


Figure 14.6.1(2) Zoning Plan

14.6.3 Container Terminals

(1) Quay length

The Study Team sets an 8,000 TEU vessel as the maximum design ship for the master plan (See section 8.1). An 8,000 TEU vessel is 390m in length and 48m in width. Consequently, a berth for this size of vessel, if constructed separately, needs to have a quay length of around 470m, or the sum of the ship length and 1.7 times the ship width. However, the maximum design vessel will make up only a part of the calling ships. At the same time, large vessels can use a part of the next berth taking advantage of a linear quay alignment. Taking these factors into account, the Study Team sets 350m as the standard quay length in the master plan. Currently 99% of container vessels are shorter than 300m and thus can safely berth at a 350m quay (See Figure 14.6.2).

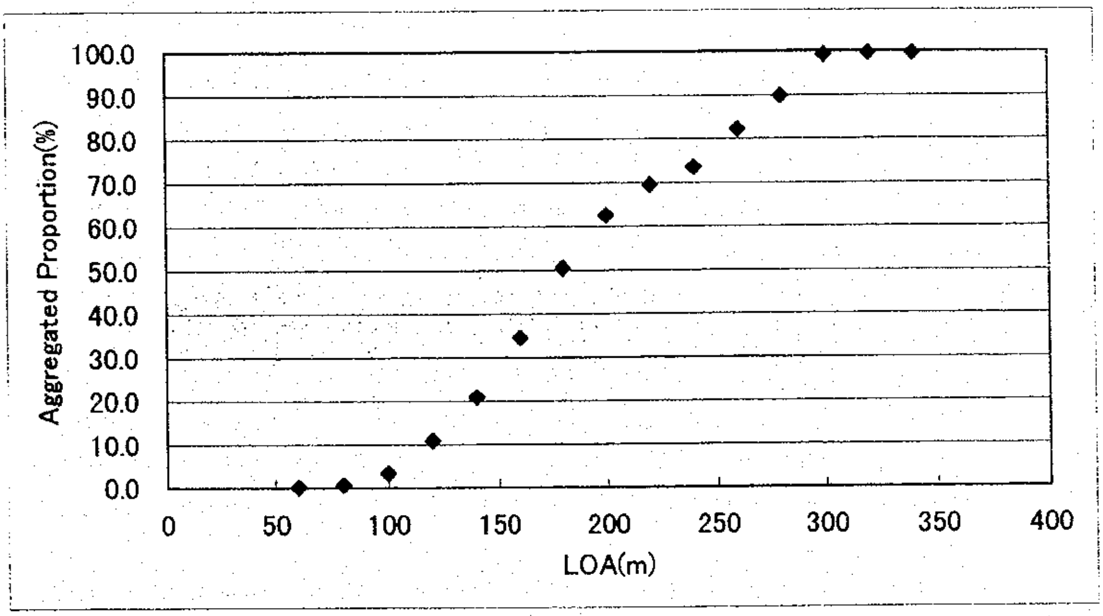


Figure 14.6.2 Distribution of Container Vessel Length

Source: Port and Harbor Research Institute, Ministry of Transport, Japan, based on LMIS

(2) Quay depth

As analyzed in section 13.1.2, container vessels have experienced a constant increase of size. Currently, Maersk, P&ON, and NYK deploy over-6000 TEU vessels. In addition, CMA-CGM, Hyundai, and Evergreen have already ordered over-6000 TEU vessels. Since world carriers are in a fierce competition and trying hard to reduce operation costs by realizing economies of scale, it is logical to assume the trend of enlargement on ship size will continue (See Table 14.6.2). This assumption is supported by the fact that major ports including Salalah, Rotterdam, Yokohama, and

Bremerhaven have ordered 22-rows gantries which can cater for vessels larger than the biggest container ship currently in operation.

Table 14.6.2 Transportation Costs according to the Ship Size

Vessel size on weekly service	Average cost per TEU (US$)
6,000 TEU	800
4,800 TEU	850
3,200 TEU	1,000
2,400 TEU	1,550

Source: Strategy of Container Ports, Cargo Systems

Some of the major transshipment hubs already have quays with alongside depth of 16 m and even deeper quay depth is planned in some ports (Table 14.6.3). As the master plan envisages port development up to 2020, the Study Team proposes a depth of 18m which can cater for the next generation of container vessels.

Table 14.6.3 Deep Draft Container Ports

Port	Maximum draft (m)
Algeciras	16 (expansion project is underway with provision for 18m)
Piraeus	16.5
Rotterdam	16.6
Valencia	16
Barcelona	16
Aden	16 (with provision for 18 m)
Freeport	16

Source: Strategy of Container Ports, Cargo Systems, Mediterranean Container ports and Shipping, Drewry

In setting the quay depth, the Study Team took into account the dimensions of the maximum design vessel and the distribution of the size of container vessels. The Study Team proposes that two berths have a depth of 18m and the remaining berths of the terminal have a depth of 16m.

Table 14.6.4 indicates that over 6,000 TEU vessels are employed in only one service among the trunk lines calling at Salalah. This service (AE5E) is the most important trunk line of Maersk Sealand. The other trunk line services are handled with smaller size vessels. On the other hand, 1300-1600 TEU vessels are currently providing feeder services. For these reasons, the Study Team proposes that only a part of the expanded container terminal should have the draft needed to cater for 8,000 TEU vessels. The master plan envisages two 18m draft berths with the length of 1050m and five 16m draft berths with the length of 1750m.

Table 14.6.4 Trunk Line Vessels Calling at Salalah

Service/schedule	Vessel size (TEU)	Origin	Destination
AE1W Thu-Fri (weekly)	4000	Singapore	Suez Canal
AE3E Fri(weekly)	3500	Rotterdam	Jebel Ali
AE3W Tue (weekly)	3500	Jawarharlal Nehru	Jeddah
AE4E Thu (weekly)	4300	Jeddah	Port Klang
AE4W Wed-Thu (weekly)	4300	Colombo	Gioia Tauro
AE5E Wed (weekly)	6600	Algeciras	Singapore
MSC (Africa- Mid East- India) (biweekly)	1000	Jebel Ali	Mombasa
MSC (Africa-Europe) (biweekly)	2800	Mombasa	Jeddah

Source: SPS

(3) Terminal

The area for the proposed container terminals can be estimated with the following formulas.

(Container terminal area) = (Container yard area) / (Yard area ratio) = 14.7 ha / berth
(Container yard area) = (Ground slots) / (Land use ratio) = 8.8 ha / berth
(Ground slots) = (Container volume) × (Dwelling time) / (Yard operation ratio) / 365 / (Stacking height) = 2,280 TEUs / berth

where:
Yard area ratio: 0.6
Land use ratio: 260 TEU / ha (RTG system)
Dwelling time: 4 days
Yard operation ratio: 0.6
Stacking height: 4 (mainly transshipment)
Container volume: 500,000 TEUs / berth

Taking the quay length of 350m into account, the terminal area behind the quay needs to have a depth of 400m.

(4) CFS

Although most of the container cargo is transshipment, some portion of import/export container will be LCL and thus requires CFS. The area for the proposed container terminals can be estimated with the following formulas. Since most of LCL cargo will be generated by free zone activities and spread over all the container terminals, CFS should be concentrated in one area. Considering the limited space of the terminal and the need for efficient terminal operation, CFS can be located off dock, preferably within the free zone area.

$S = (W \times D \times p) / (w \times r \times T)$

Where:

W: cargo volume for CFS (ton) = (import/export container cargo volume) × (LCL cargo ratio)

D: average dwelling time (days)

p: peak ratio

w: average stacking weight in CFS (ton/m^2)

r = effective use ratio of floor area in CFS

T: annual operating days (days/year)

These parameters are assumed as follows:

W = 1,203,000 × 0.05 = 60,000 (in 2003)

= 2,166,000 × 0.05 = 108,000 (in 2020)

D = 5 days, p = 1.5, w=1.0, r = 0.6, T = 300 days

On the above assumptions, S is calculated as follows:

S = 2,500 m^2(in 2003)

S= 4,500 m^2(in 2020)

(5) Handling equipment

Taking into account the following factors, transfer crane (RTG) system is recommended in the expanded terminals.

a) the terminal will continue to be transshipment oriented
b) the terminal will be open to multiple users
c) the terminal requires high stowing capacity to maximize the operational income
d) rectangular shape of the terminal
e) compatibility with the existing terminal

Since 99% of containers handled in Salalah is transshipment and thus land-side operation is minimal, two RTGs and eight yard tractors per gantry crane will be sufficient for the time being (See Table 14.6.5).

Table 14.6.5 Container Handling in Port Salalah (Jan-May, 2000)

	Inbound			Outbound		
	Import (boxes)	T/S (boxes)	T/S ratio (%)	Export (boxes)	T/S (boxes)	T/S ratio (%)
January	233	18,113	98.7	115	18,542	99.4
February	233	20,297	98.8	329	19,353	98.3
March	182	23,796	99.2	178	23,998	99.3
April	125	22,432	99.4	43	23,289	99.8
May	128	22,291	99.4	1,403	20,942	93.7
Total	901	106,929	99.2	2,068	106,124	98.1

Source: SPS

(6) Gate

There are currently three lanes in the gate. The container terminal may need additional lanes as import/export container increases due to the expansion of FTZ activity. The Study Team carried out a simplified calculation with the following formula to identify traffic volume of import/export container cargo:

(Traffic volume) = (Annual cargo handling volume) $\times$(20ft container + 40 ft container)/ (20ft container + 2$\times$40ft container) $\times$ $\beta/12$ $\times$ $\gamma/30$ $\times$ $\sigma/12$ = 93 vehicles/hour/each way

where:

(Annual cargo handling volume)=279,000 TEU (Scenario 1)

(20ft container + 40 ft container)/ (20ft container + 2$\times$40ft container) = 2/3

β : Monthly variation = (cargo volume in the peak month) / (average monthly cargo volume) = 1.2

γ : Daily variation = (cargo volume in the peak day) / (average daily cargo volume) = 1.5

σ : Hourly variation = (vehicle traffic volume during the peak hour) / (daily traffic volume) = 1.2

(In-gate capacity) = 60 minutes / (gate processing time) $\times$ (working ratio) = 21.6 vehicle / hour

where:

(gate processing time) = 2.5 minutes / vehicle

(working ratio) = 0.9

(Out-gate capacity) = 60 minutes / (gate processing time) $\times$ (working ratio) = 43.2 vehicle / hour

where:

(gate processing time) = 1.25 minutes / vehicle

(working ratio) = 0.9

According to the above scenario, the gate needs 4 in-lanes and 2 out-lanes. This issue needs further consideration when the exact nature of the free zone operation comes into light.

14.6.2 Conventional Terminal

Conventional cargo will be handled at the existing berths and the new bulk terminal. In order to achieve high efficiency, general cargo should be handled in berths 1-4 while bulk cargo should be catered for at the new bulk terminal.

Capacity of a bulk terminal widely varies depending on the handling equipment. There are three types of handling equipment for grain, which is one of the main bulk cargoes of Port Salalah. Table 14.6.6 shows the comparison among the three types. The specifications shown here are exemplified for equipment with the capacity of 600t/hour. Since the bulk cargo projected for 2020 is relatively small and diversified, the master plan proposes to equip the new bulk terminal with grab bucket cranes, which are the most versatile among the three.

To realize the high efficiency, the bulk terminal needs to be provided yard-side facility including silos and conveyers. These facilities will be likely to be provided by private investors, and thus the timing of the introduction of bulk handling equipment needs to be coordinated among the government, SPS, and the private sector.

Table 14.6.6 Handling Equipment for Bulk Grain

Type / Feature	Grab bucket	Pneumatic	Belt
Handling	Intermittent	Consecutive	Consecutive
Weight	530t	310t	320t
Rail span	14-18m	9-12m	9-12m
Power consumption	0.4-0.7kwh/t	0.99kwh/t	0.28kwh/t
Handling efficiency factor	60-65%	75-80%	75-80%
Noise	Moderate	Little	Significant
Versatility	Excellent	Poor	Fair

14.6.3 Oil Terminal

Since Port Salalah can be a major bunkering point if bunkering service is offered at a competitive price, the master plan allocates an area for an additional oil terminal inside the extended eastern breakwater. The Study Team learned that tender procedure for bunkering service is currently underway. The demand for bunkering will widely vary depending on the price. The timing and scale of further development of the oil terminal therefore need to be reviewed after bunkering service is started at the refurbished oil pier.

14.6.4 Passenger Terminal

Standard dimensions of cruise vessels and those of the corresponding berth are shown in Table 14.6.7. The master plan allocates the new northern basin with 16m draft for a passenger terminal. Since this basin can provide sufficient depth, the Study Team proposes that the terminal is 350m in length and 11m in depth which can cater for the longest cruise vessel, Queen Elizabeth 2.

Table 14.6.7 Standard Dimensions of Cruise Vessels and Passenger Berth

Ship size (GT)	Ship length (m)	Ship draft (m)	Berth length (m)	Berth draft (m)
20,000	180	8.0	220	9.0
30,000	207	8.0	260	9.0
50,000	248	8.0	310	9.0
70,000	278	8.0	340	9.0

Source: Ministry of Transport, Japan

14.6.5 Government Berths

The master plan allocates a quay of 700m to government use, 300m for the Royal Navy and 400m for the Royal Yacht Squadron. The depth alongside is 8.5m to cater for the largest design vessel. The western side of the new northern basin allocated to government use can provide a sufficient turning circle and calm harbor. Another 100m berth frontage with a pontoon is allocated to the Royal Yacht Squadron for smaller boats.

In order to avoid the mixture of different types of traffic, the government berths are linked with the hinterland by a bridge.

14.6.6 Bridge

The master plan proposes a bridge to link the port area with the hinterland. The width of the bridges should be determined according to the traffic volume. Since the proposed bridge will handle only the traffic to/from the government berths and passenger terminal, it needs only two lanes.

14.7 Preliminary Engineering Studies

14.7.1 General

The basic engineering concept will be compiled in accordance with the results of the following survey to be conducted at the site.

(1) Oceanography & Bathymetry
(2) Geotechnic field
(3) Environmental aspect
(4) Existing port facilities
(5) Construction material
(6) Manpower

14.7.2 Design Codes and Standard

In the Sultanate of Oman, there are no specific design codes and design manuals which are applicable exclusively to port facilities.

Accordingly, the design of marine structures such as quay walls revetment, etc. for Salalah Port has been carried out on the basis of Technical Standard for Port and Harbor Facilities in Japan which are used as the basis for port design in Japan as well as in many developing countries world wide.

In the process of designing, technical information in the Sultanate of Oman was adopted with duly considered to reflect local conditions, particularly in the interpretation of structural properties of construction materials available on site and various kinds of environmental conditions, including seismic disturbances. This was mostly given by the engineers of MOTH and SPS.

14.7.3 Comparison Study of Quaywall

Before finalizing the berth structure in the port development plan, it is necessary to select the prospective structural types of the berth for cost and technical comparison.

The soil condition of the proposed site is generally hard rock layer, and steel piles cannot easily be driven in this layer.

For comparison of quaywall type, the following three types was selected; namely,

(1) Block Wall Type
(2) Pile Supported Platform Type
(3) Caisson Type

The advantages and the disadvantages of each type are summarized in Table 14.7.1.

As a result, block wall type is recommended based on the soil condition, construction cost, construction equipment, and adjacent terminal quay structures.

14.7.4 Breakwater

The concrete caisson type breakwater was studied for the proposed site. However, this type is not recommended because it would required large size floating dock or large caisson yard with special equipment.

The rubble mound type, same as existing east breakwater, is recommended for proposed breakwater considering availability of construction materials, subsoil condition of proposed site, construction cost and construction time.

14.7.5 Dredging and Reclamation

The dredging and reclamation is one of the key factor for the construction of proposed port facilities at Salah Port.

When the present container terminal was being constructed from 1997 to 1998, the channel area was dredged effectively by a cutter suction pump dredger.

Most of the dredged material was sand, gravel and soft to medium limestone; therefore, reduction of soil improvement cost and construction period are expected.

The same dredging and reclamation method will be recommended for the proposed port facilities of Salalah Port.

14.7.6 Construction Cost

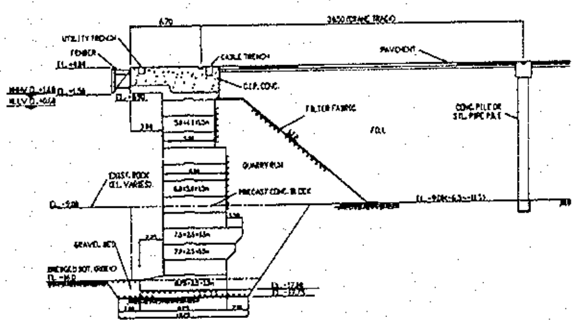
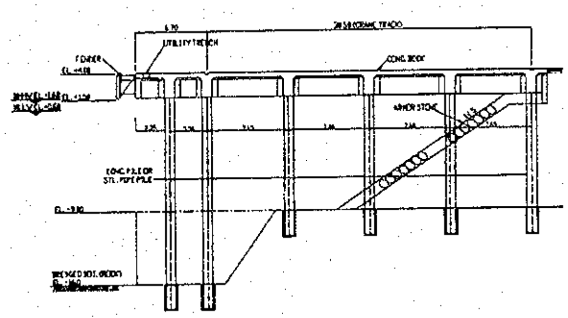
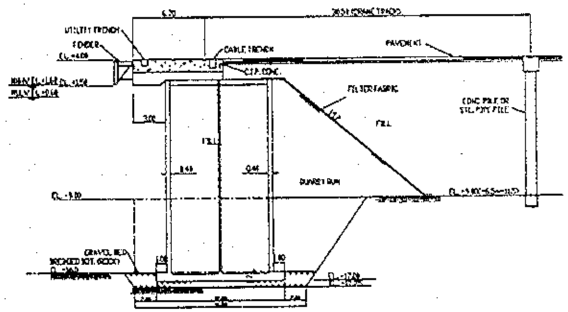
The cost estimates are primarily based on the unit prices and rates in Salalah derived from the construction material and equipment price survey conducted by the Study Team in Jan. 2000.

The construction cost for Salalah Container Terminal which was completed in 1998 was inferred.

14.7.7 Construction Period

The construction period is primarily based on the natural conditions, material quantity, dredging volume, ability of construction equipment, and existing container terminal construction period are the decisive factor in the overall construction time. These factors were taken into full consideration for the entire construction period.

Table 14.7.1 Evaluation of Berths Structual Alternatives

	BLOCK WALL	PILE SUPPORTED PLATFORM(VERTICAL PILES)	CAISSON
Structurel Plan			
Cost	8,193(OR/m)	20,428(OR/m)	27,750(OR/m)
Advantages	Large number of standardized blocks can be prefabricated Same structural plan was already used for port expansion of SPS terminal during 1996 through 1998.	Concrete volume is less compared to the one used in the the gravity wall type.	Relatively higher quality of structure.
Disadvantages	Concrete volume is significantly large.	Requiring higher maintenance cost than gravity wall alternative. Requiring large number of predrilled holes for pile installation in existing rock strata Requiring longer time for cast in place(CIP).	Requiring large size floating dock or large caisson yard constructing concrete caisson.

14.8 Phased Planning

14.8.1 Concepts

The rapidly changing marketing strategy of international shipping companies is dramatically transforming the business environment. On the other hand, large-scale port expansion conceived in various ports in the region might lead to excessive capacity. Given the fierce competition among free zones in the region, some uncertainty is involved in projecting the outlook for the free zone business in Salalah.

The master plan encompasses the port expansion envisaged in 2020. The Study Team classified the port development projects into the following three phases taking into account the demand forecast and the risks entailed:

- Phase 1: Container terminal expansion and creation of the government berths (short term)
- Phase 2: Further expansion of the container terminal, installment of cargo handling equipment in the new bulk terminal, and creation of a passenger terminal (long term)
- Phase 3: Overall port development (future expansion)

14.8.2 Short-term Plan

The capacity of the present container terminal is estimated to be 2 million TEUs. According to the demand forecast, the container throughput is expected to reach that capacity in 2002-2003 (See section 13.3). The demand forecast projects an increase of the throughput to 2.5-3 million TEUs in 2005. In order to meet this growth, construction works for at least two berths should start in 2001 (See Figure 14.8.1). A two-berth group is the minimum requirement for providing efficient container handling operation.

The Study Team prepared two alternatives for the short-term development within the scope of the master plan for 2020 (See Figure 14.8.2, 14.8.3). One is the northward expansion (Plan A) and the other is the eastward extension (Plan B). An outline of both alternatives is given in Table 14.8.1. Advantages and disadvantages of each alternative are compared in Table 14.8.2. Due to the port geometry envisaged in the master plan, Plan A includes a 700m container quay while the quay length in Plan B is 1,050m. These alternatives are further evaluated from an economic viewpoint (See section 14.11, 14.12).

Plan A requires dredging for the new northern basin and an approach channel, while widening and deepening of the existing approach channel is needed in Plan B. Expansion of the existing harbor entrance is also proposed to alleviate the harmful effects of long-period waves as well as to enable two-way traffic at the entrance. The extension length of the breakwater required for each alternative greatly differs.

Table 14.8.1 Outline of the Two Alternatives for the Short-term Expansion

Facility	Plan A	Plan B
Additional berths	16m draft container quay: 700m Government berth: 800m	18m draft container quay: 1,050m Government berth: 800m
Additional terminal area	28ha	42ha
Handling equipment	Six gantry cranes (18 rows) 12 RTGs 24 yard tractors	Nine gantry cranes (22 rows) 18 RTGs 36 yard tractors
Container handling capacity	3 million TEUs/year	3.5 million TEUs/year
Breakwater	1,200m	2,550m
Dredging	13,779,000 m^3	6,722,000 m^3
Reclamation	3,060,000 m^3	7,003d,000 m^3
Total cost	118 million R.O.	164 million R.O.

Both alternatives include the creation of an 800m quay for government use. This structure serves as a groin as well which prevents wadis from entering into the new northern basin. A bridge linking the government berths with the hinterland is needed to prevent the interflow of different types of traffic.

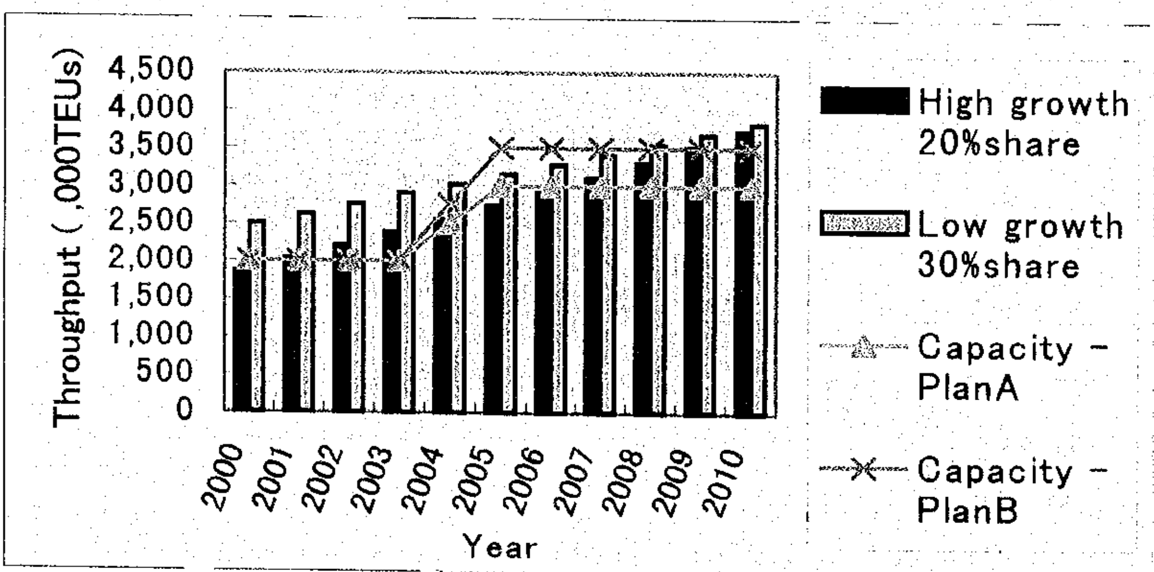


Figure 14.8.1 Estimated Transshipment Demand and Capacity Addition

One of the biggest differences between the two alternatives is the added capacity; Plan A can provide sufficient capacity only up to 2004-2007 while the capacity of Plan B is large enough to cover the demand up to 2008-2009 (See Figure 14.8.1). Consequently, Plan A requires further expansion right after its completion.

The Study Team evaluated the two alternatives from various viewpoints (See Table 14.8.2). The conclusion is that Plan B is undoubtedly superior to Plan A from the viewpoints of flexible terminal operation, vessels waiting time, and wave disturbance. Actually, Plan A also needs the same length of breakwater to provide sufficient cover for all the main quays (See section 14.9).

A model layout of the container terminal for the Plan B short-term expansion is shown in Figure 14.8.4.

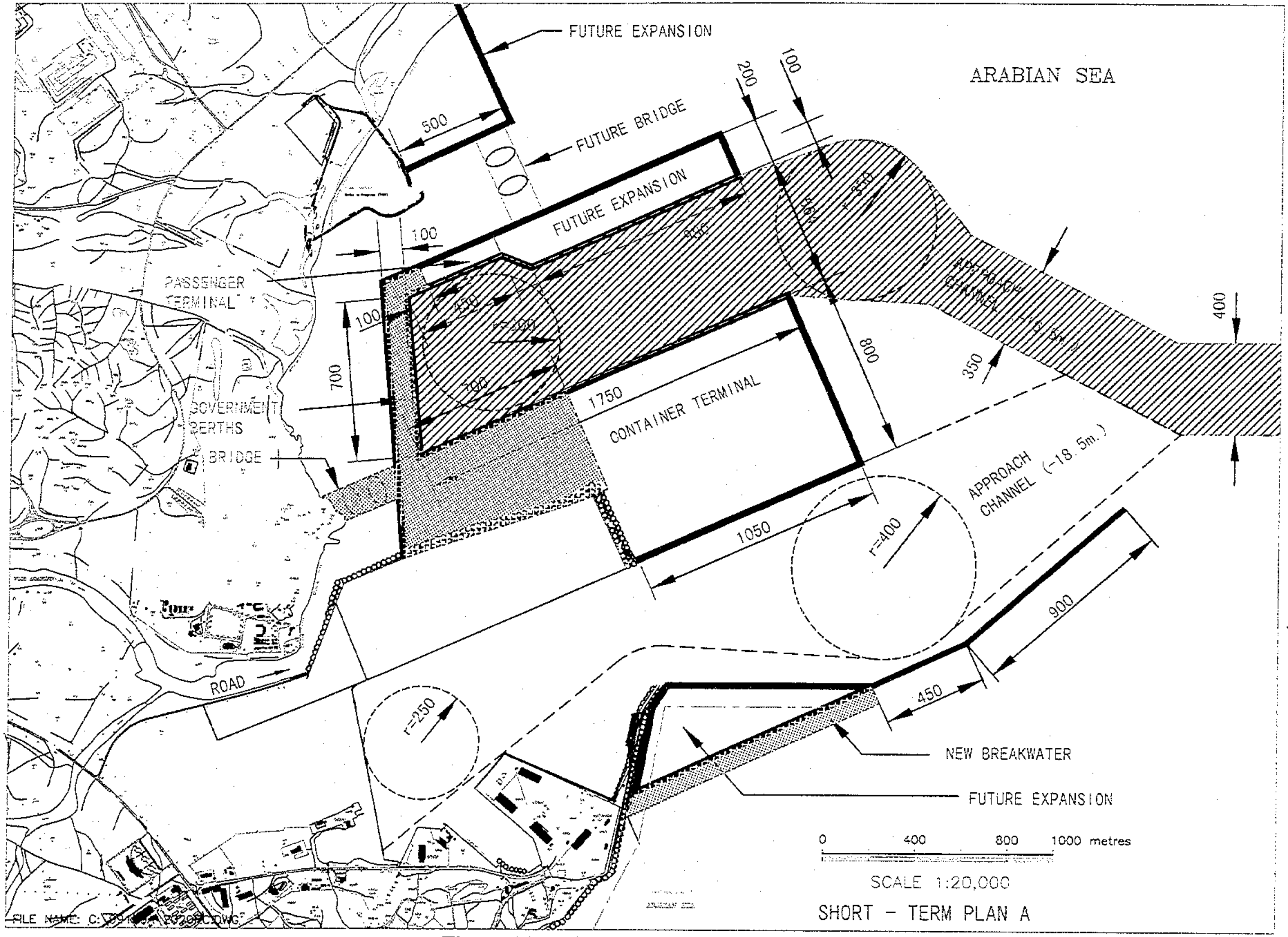


Figure 14.8.2 Short-term Plan A

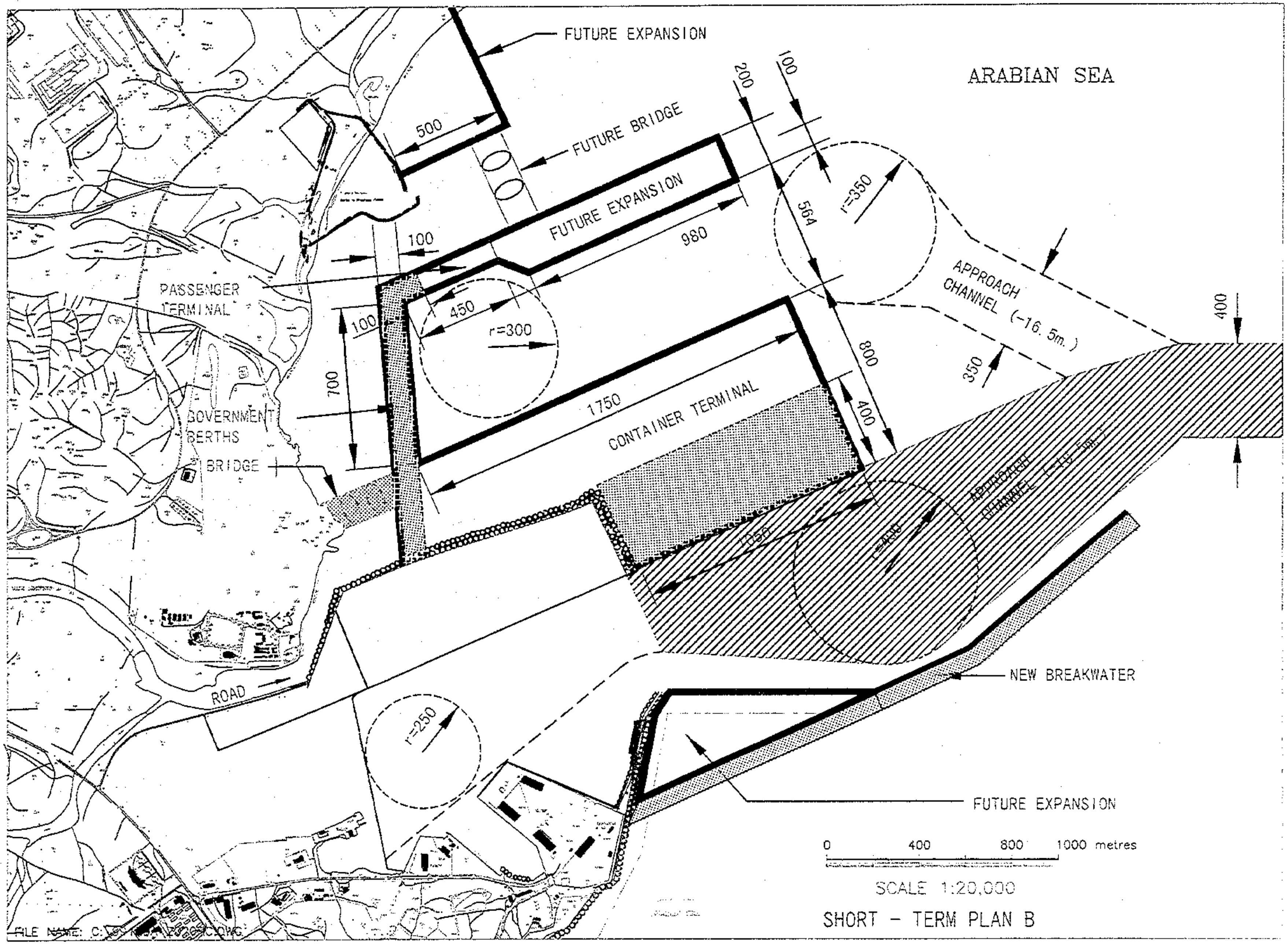


Figure 14.8.3 Short-term Plan B

Table 14.8.2 Features of the Two Alternatives for the Short-term Expansion

Factors	Northward expansion (Plan A)	Eastward extension (Plan B)
Additional container quay	700m with 16m depth alongside	1,050m with 18m depth alongside
Aggregated capacity	Sufficient up to 2004-2007	Sufficient up to 2008-2009
Marketing	Smaller risk is envisaged	Depth alongside of 18m will be an attractive feature vis-a-vis competitors Greater risk is entailed unless there is a commitment from new customers
Flexible terminal operation	Operation of the existing four berths and additional two berths should be organized separately	All quay cranes can be employed simultaneously responding to the cargo handling needs
Vessels waiting time (See section 14.10)	Long	Short
Investment program	Large initial investment is needed to procure quay cranes Initial investment for the breakwater extension is minimal	Investment for additional quay cranes can be done on a incremental basis responding to the demand Large initial investment is needed to extend the eastern breakwater.
Breakwater extension	Desirable to provide a sufficient cover to berth no.4 The tip of the breakwater has to be removed to widen the harbor entrance	Necessary to provide a sufficient cover to the extended berths The tip of the breakwater has to be removed to widen the harbor entrance
Wave disturbance (See section 14.9)	Existing container terminal and new government berths can not have sufficient protection	Sufficient protection is provided for all the main quays
Dredging volume	Little for reclamation Large for basin and channel	Little for basin and channel Large for reclamation
Future expansion	Next stage will be eastward extension of berth no.1-4	Next stage will be northward expansion of berth no.5-7

Container terminal expansion (Plan B)

- Gantry cranes: 9 units (22 boxes across)
- RTG: 18 units (1 over 4 operation)
- Yard tractors: 36 units
- Ground slots: 6,864 TEUs

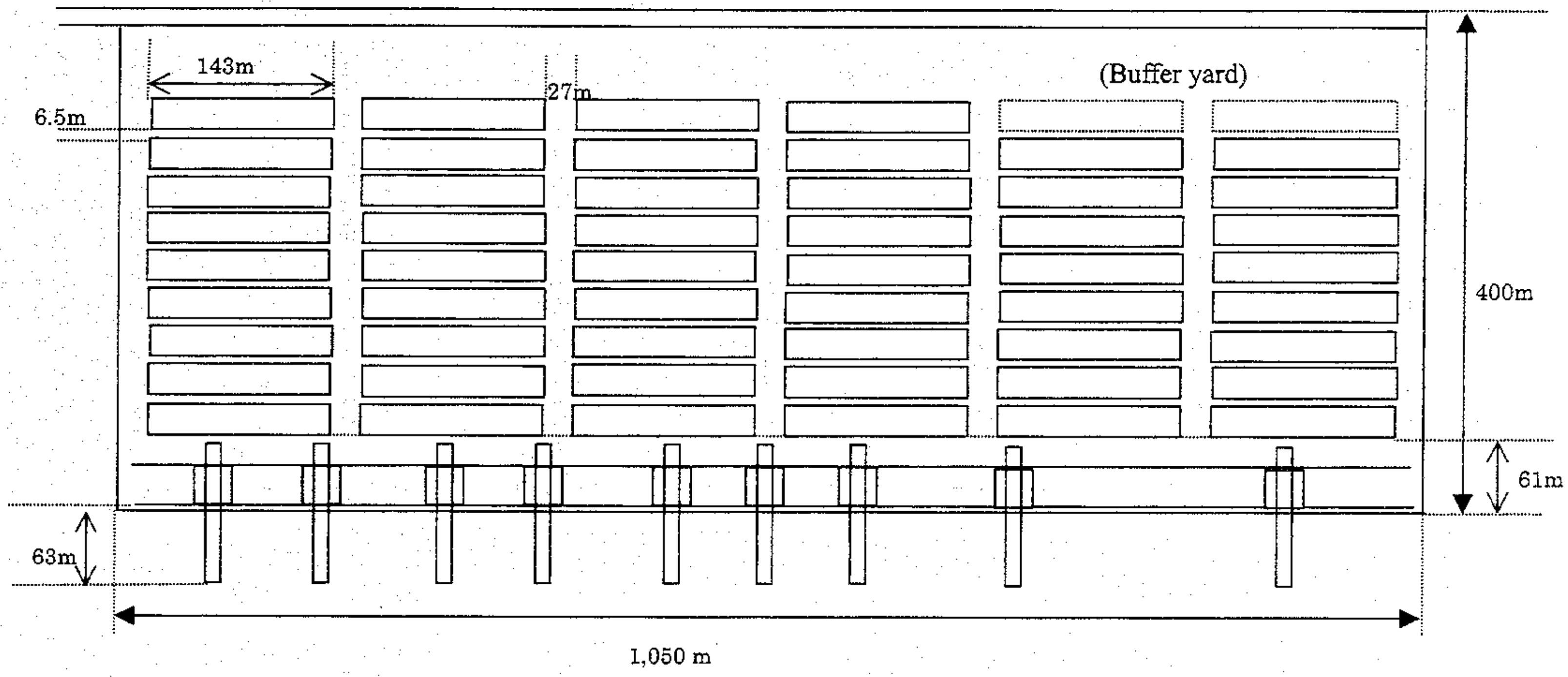


Figure 14.8.4 Model Layout (Short-term Plan B)

14.8.3 Long-term Plan

(1) Container terminal

The long-term plan proposes an additional 1750-2100m container quay which will increase the handling capacity to 6 million TEUs. This capacity can respond to the cargo volume envisaged in plausible scenarios (See section 13.3 and Figure 14.8.5).

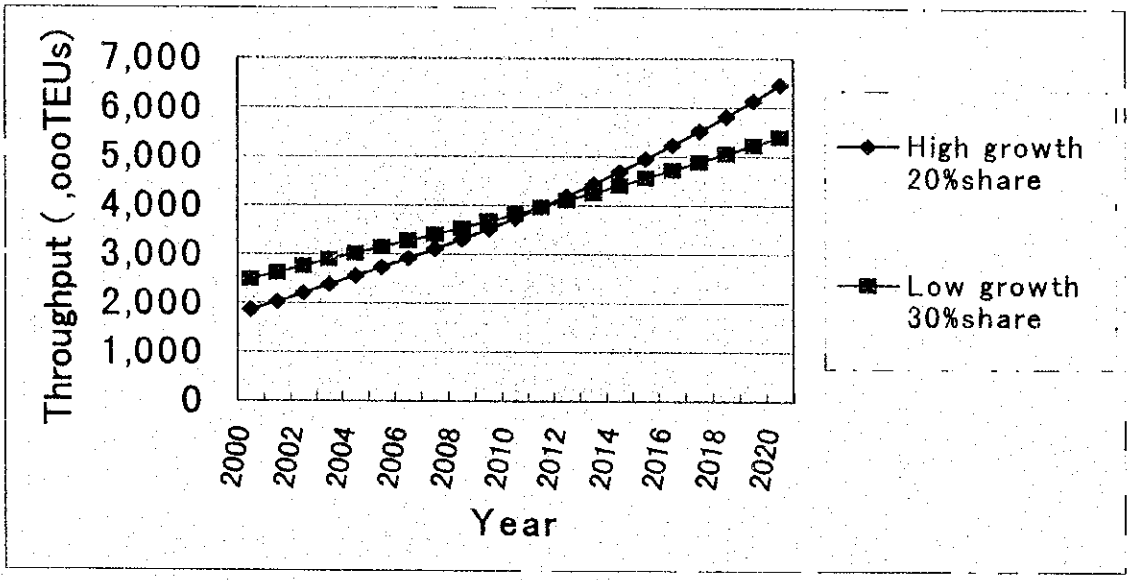


Figure 14.8.5 Forecast – Container Throughput

The pace of development is one of the key elements for Port Salalah to keep a competitive edge over its competitors. Marketing efforts will not be successful without a spare capacity on hand. Although further expansion after the short-term development will at some point be needed, criteria to guide the decision process should be set out.

The demand forecast projects an annual growth of 150-200 thousand TEUs throughout the planning period. Since it takes at least two years to complete an expansion project, Port Salalah should always have a spare capacity of not less than 300-400 thousand TEUs/year to capture the potential growth. For that reason, the relevant authorities should take appropriate actions when the spare capacity of the terminal comes close to the minimum spare capacity (See Figure 14.8.6).

As mentioned earlier, a transshipment port is likely to experience a sudden increase in demand. An expansion project therefore needs to provide a capacity addition of at least 600-800 thousand TEU/year, or double the minimum spare capacity (See Figure 14.8.6).

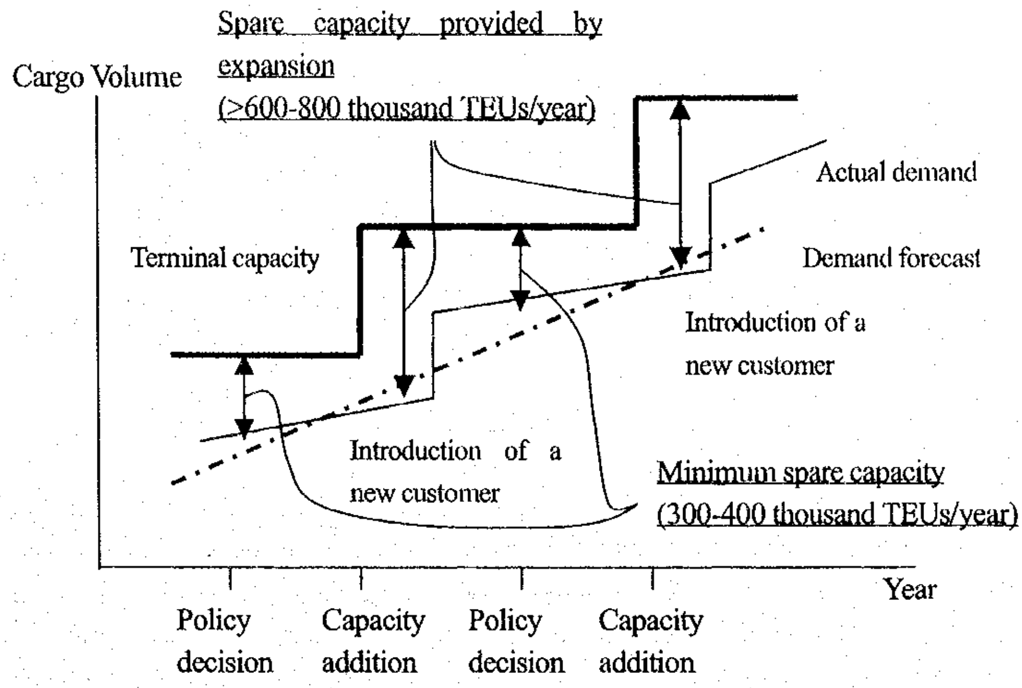


Figure 14.8.6 Spare Capacity

The Study Team applied this concept to the demand projection and worked out a phased development plan (See Figure 14.8.7).

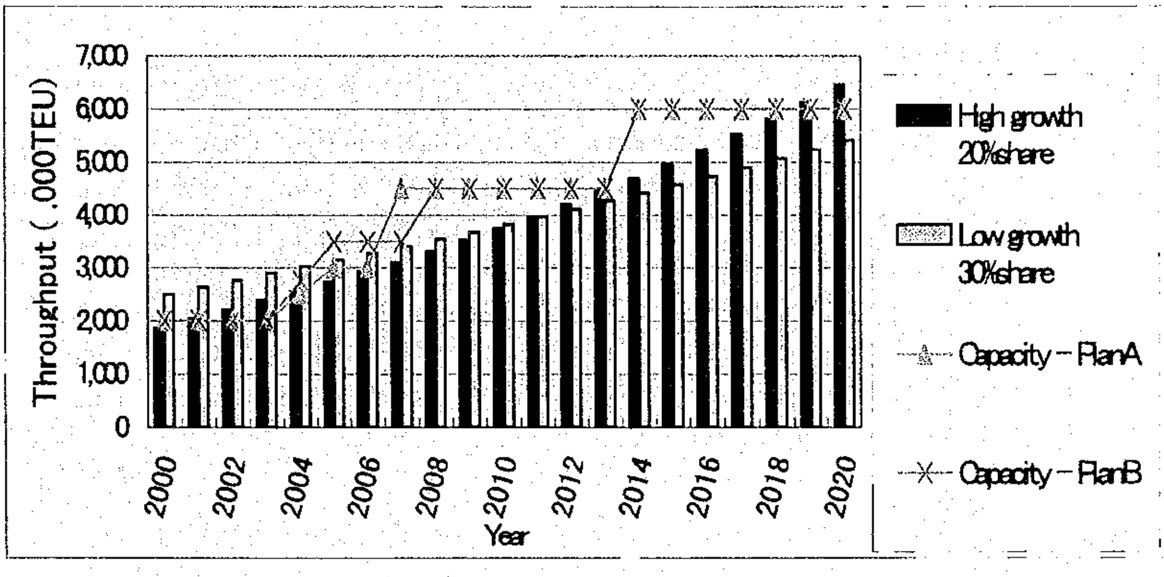


Figure 14.8.7 Proposed Phasing Plan

(2) Passenger berth

A passenger berth of 350m in length is included in the long-term plan. The land transportation for the cruise passengers goes through the bridge. On the other hand, cruise vessels can be catered for at either the container terminal or the bulk terminal for the time being. The pace of development therefore needs to be carefully considered paying due consideration to the increase in demand. Congestion of the container terminal and the bulk terminal needs to be monitored to determine at what point the construction works of the passenger terminal should be started.

(3) Conventional terminal

In order to make good use of the new bulk terminal, efficient handling equipment is indispensable. However, it will require users' investment in conveyers and silos as well. Since the existing conventional terminal has capacity large enough to deal with a sizable increase in demand, users are not likely to embark on a large investment in the foreseeable future. Efficient bulk cargo handling system needs to be provided when a large-scale private sector investment in the grain industry comes to the port. For the economic and financial analysis, the Study Team tentatively assumes that new large-scale grain factories will start the operation in 2010.

As long as the cargo mix does not greatly change, the Study Team recommends grab bucket cranes for their versatility.

14.8.4 Future Expansion

The Study Team allocated areas for future expansion in the master plan to respond to the projects which can not be proven viable at this time. Those projects include a ship repair yard, a bunker fuel terminal, and additional bulk handling terminals. Judging from the present economic activities in the hinterland, the expansion area in the north is suitable for bulk cargo handling, while the expansion area in the south can fit in a ship repair yard and a bunker fuel terminal. The pertinent agencies should monitor the economic environment relative to the port and review the master plan periodically to determine how these expansion areas can better serve the needs of the region.