5 Contingent Alternatives of Port Development

5.1 Selection of Contingent Alternatives

5.1.1 Formulation of Contingent Alternatives

(1) Layout of Contingent Alternatives

"Feasibility of Port Expansions at Walvis Bay" in 1994 raised several issues, some of which are still issues at present. They are:

- Movement of sediment in the bay
- Associated future maintenance dredging
- Navigational aspects of the proposed berth and channel layout, and
- Possible ecological effects that the extended harbour may have on especially the Walvis Bay lagoon and other ecologically sensitive areas in the southern part of the bay.

Meanwhile, the minutes of the meeting made in December 2008 between JICA and Namport details the arrangement of a study on the alternative development of the port expansion. The agreed items to be studied are as follows:

- Review of existing alternative development scenarios/plans
- Provide contingent alternative development scenarios/plans for environmental and technical consideration
- Evaluation of the contingent alternative plan

The review of existing alternative development scenarios/plans are discussed in the section "Previous Expansion Study of Walvis Bay" of this report. Therefore, in this section, discussed are the contingent alternatives for environmental and technical consideration.

The JICA Study Team has been working on the alternatives from the following view points:

Point 1: To avoid adverse impact to the lagoon environment.
Point 2: To harmonize the plan with other development plans.
Point 3: To make the layout expandable for further port expansion.
Point 4: To limit the cost for the first phase construction not more than about 20% of the original expansion plan.

For point 1, there is no alternative site at the south of the bay for port expansion. The site has to be selected significantly distant from the mouth of the lagoon at the east side of the approach channel. For Point 2, the alternative sites including access should not conflict with the city planning or naval base requirements. In this regard, Figure 5.1.1 should be referred to as the land use plan of the northern shore of Walvis Bay. Even though this plan indicates a "potential site for a cargo handling facility (restricted to "clean" goods)," the site is almost exposed to the open sea and considered not technically feasible, as it requires huge amount of dredging plus breakwater. For Point 3, considerable water area or land is required in the vicinity of the first phase construction. And Point 4 is considered critical to make the alternative plan viable. Dredging, the most costly components of marine works in shallow water like Walvis Bay, has to be limited in laying out the alternative plans.

As a result of the above considerations, the JICA Study Team has selected three contingent alternatives: Contingent Alternatives A, B, and C as shown in Figure 5.1.2, Figure 5.1.3, and Figure 5.1.4, respectively.

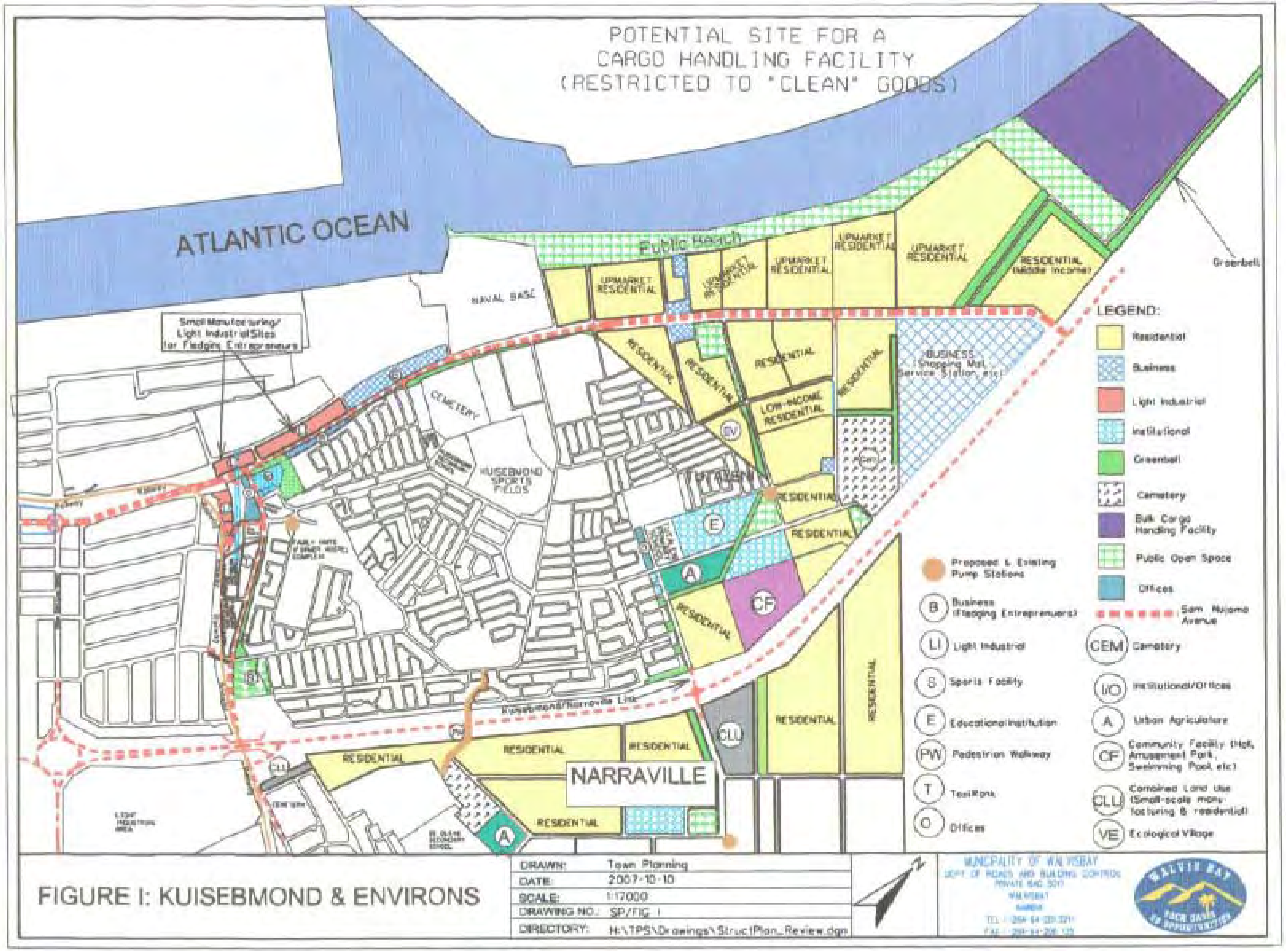


Figure 5.1.1 Land Use Plan

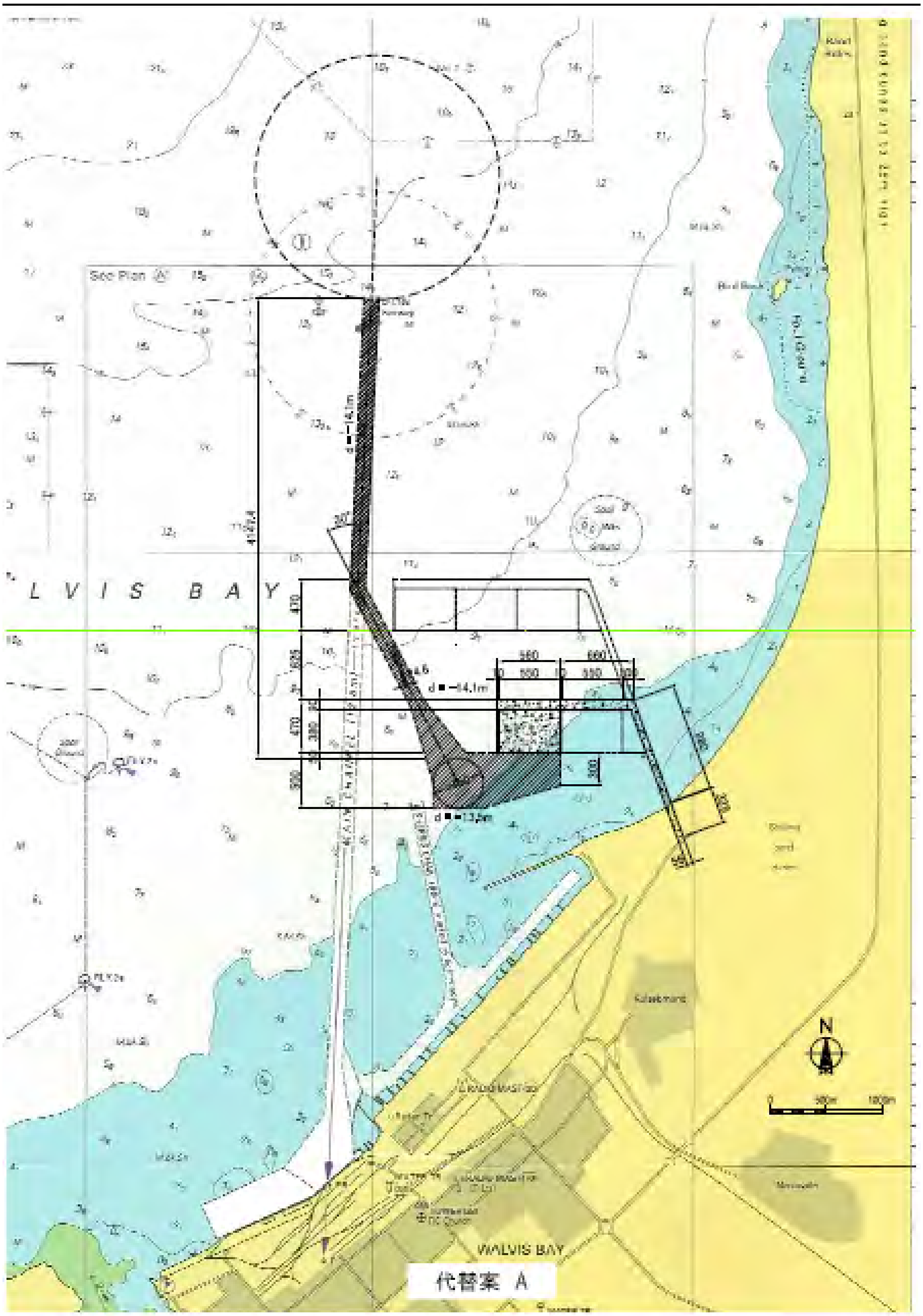


Figure 5.1.2 Contingent Alternative A

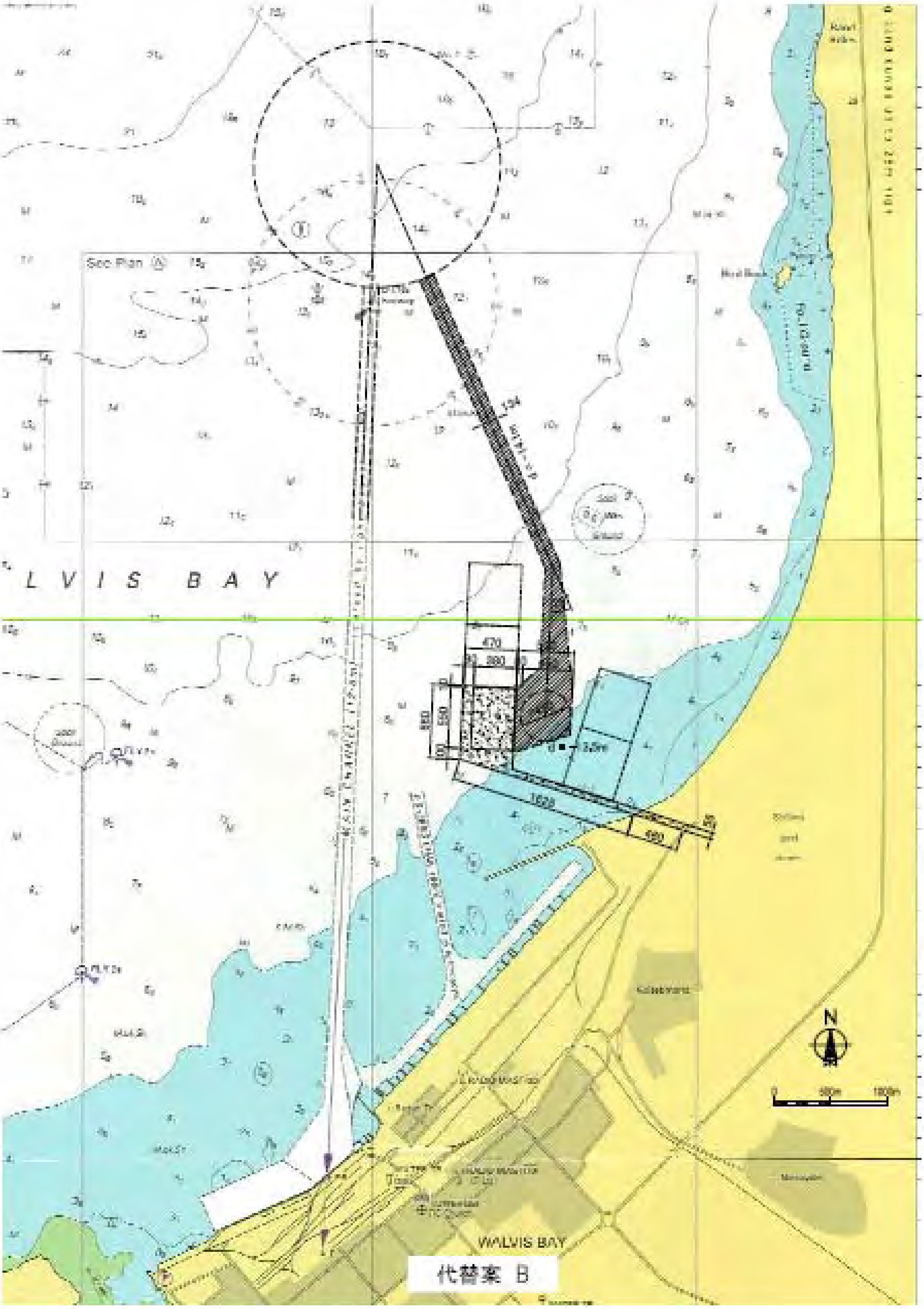


Figure 5.1.3 Contingent Alternative B

Figure 5.1.4 Contingent Alternative C

1) Contingent Alternative A

This alternative is similar to the mirror image of the port expansion with respect to the approach channel, which is presented as “Proposed Future Extensions to the Port of Walvis Bay” in “Feasibility of Port Expansions at Walvis Bay” in 1994.

The existing approach channel is used and from its mid way to the harbour a new channel is diverted to the south-southeast. A turning basin is provided offshore of the existing north breakwater. A man-made island will be built with the dredged materials to shelter the harbour basin. The access to the island from the coast has to be extended from the land strip between the naval base and planned residential area along the coast. As it is agreed among concerned parties like Namcor (the operator of the oil jetty and tank farm at Walvis Bay), the Navy and Namport, the reclamation is only possible with a proper distance from the existing north breakwater of the port.[1]

The access road will be extended from the exiting right of way reaching behind the naval base. The railway will be extended from the existing railway tracks connecting the chanting yard behind the port. A switch-back is necessary to alter the train direction.

The second phase expansion of Alternative A is considered next to first phase reclamation. Additional dredging and reclamation will be needed. Further expansion, however, should be a man-made island further offshore as shown in Figure 5.1.2. In expanding offshore, attention should be paid that there lay a very soft silty seabed found by the resistivity survey conducted by Namport.

2) Contingent Alternative B

The site of Alternative B is fairly close to the site considered for the “Future Bulk Cargo Handling Terminal” shown in the “Proposed Future Extensions to the Port of Walvis Bay” in “Feasibility of Port Expansions at Walvis Bay” in 1994. However, the berth of this alternative is laid out in a manner that it is protected from waves coming from the west while the man-made island is located nearer to the shore. The berth is laid out sheltered from the waves coming from the west and the terminal is behind the berth.

A new approach channel is to be dredged from the offshore water and a turning basin is provided in front of the planned berth. The access to the island from the location is the same as Alternative A. The access road and railway will be laid out similar to Alternative A.

The second phase expansion of Alternative B is considered to the north next to the first phase. Further expansion can be made closer to the shore as shown in Figure 5.1.3, if no conflict with city planning takes place. No soft silty seabed may exit at the expansion area.

3) Contingent Alternative C

Alternative C is a variation on Alternative B. The berth and marine terminal are separated. The berth is laid out sheltered from the waves while the terminal is moved closer to the coast. Future expansion will be less costly than other alternatives. As the berth is located at almost the same location as Alternative B, the numerical simulation of waves and currents in Alternative C is omitted.

---

[1] On April 8, 2009 at the Navy Head Office in Walvis Bay, the Namibian Navy, Namport, and Namcor (operating an oil jetty and tank farm) discussed the location of the new oil terminal. It is noted in the minutes of the meeting that “should the offloading facility become a security target, it would directly affect the mobility of the Navy, and this cannot be allowed. Therefore Site 5 has a fatal flaw.” Site 5 was located close to the north breakwater adjacent to the Navy Base.

The second phase expansion of Alternative C may be to the north next to the first phase. However, conflicts with the city planning will become a serious issue as the expansion will block the sea horizon from the planned “Upmarket Residential” area. Expansion will depend on compromises with city planning.

(2) Dimensions of Port Facilities

Approach Channel: For the Contingent Alternative A, the existing approach channel is utilized to minimize the dredging volume. For Contingent Alternatives B and C a new approach channel is to be dredged from the entrance area. In each alternative, the depth and width of the approach channel are set as CD −14.1 m and 134 m, respectively, in accordance with the dimensions of Panamax vessels in computing the dredging volume.

Turning Basin: The new turning basin of each alternative is located close to and almost in front of the terminal berth. From the long-term perspective, the water area for the turning basin has to be wide enough to turn an 8000 TEU container vessel. The diameter and depth of the turning basin for Phase 1 are 450 m and CD −13.5 m, respectively, to accommodate Panamax container vessels. In the future (for 8000 TEU container vessels) the turning basin will be deepened and widened to CD –15.5 m and 575 m, respectively. Therefore, a wide water area is reserved between the reclamation in each Alternative.

Area required for Reclamation: In Alternatives A and B, as square land can be reclaimed, the terminal yard will be m 550 long and 380 m deep, including the quay apron. Meanwhile in Alternative C, as the berth will be separated, the terminal yard will be 550 m long and 365 m deep. The terminal layout will be discussed in the following section. The space adjacent to the container terminal in case of Alternatives A and B will have a right of way with a 32 m width, a railway terminal with a 45 m width, a reserved strip of 3 m and an area for seawall with a 10 m width, consequently the width will be 90 m in total. In case of Alternative C, the apron is 60 m wide for loading and unloading containers and the access part is 33 m consisting of 4 carriage ways plus one queuing lane (4 m x 5 = 20 m), a 3 m wide reserve strip, and a 10 m wide area for seawall, consequently 33 m in total. A 90 m wide strip adjacent to the container terminal will be similarly reclaimed in case of Alternative C but the 10 m strip will be used for the green belt as well as for the slope protection because this side of the terminal will face a residential area planned on the shore in city planning.

Causeway to Container Terminal: The width of the causeway of each Alternative is fixed as follows:

<u>Alternative A</u>

Slope protection north side:	5.0 m
Reservation for future use:	3.0 m
Railway:	15.0 m (3 tracks)
Right of way:	28.0 m (including 2 pedestrian strips)
Slope protection south side:	5.0 m
Total:	56.0 m

<u>Alternative B</u>

Slope protection north side:	5.0 m
Right of way:	28.0 m
	(including 2 pedestrian strips)
Railway:	15.0 m
	(3 tracks)
Reservation for future use:	3.0 m
Slope protection south side:	5.0 m
Total:	56.0 m

<u>Alternative C (to terminal)</u>

Slope protection north side:	5.0 m
Right of way:	24.0 m
	(No queuing lane but truck parking to be provided on land)
Railway:	15.0 m
	(3 tracks)
Slope protection south side:	5.0 m
Total:	49.0 m

<u>Alternative C (to berth)</u>

Slope protection north side:	5.0 m
Right of way:	16.0 m
	(4 carriage ways only)
Railway:	15.0 m
	(3 tracks)
Slope protection south side:	5.0 m
Total:	41.0 m

(3) Container Terminal Plan

The following explains the three alternatives from the point of view of container terminal operation.

1) Contingent Alternative A

The shape of the terminal is rectangular, and the berthing vessels can berth along the portside. No problem is foreseen for container operations.

The waiting lane for outside trucks must be secured in the access road.

2) Contingent Alternative B

Contingent Alternative B is not significantly different in container operations in contrast to the above Alternative A. The size and shape of the terminal is same. The berthing vessels will go on berth along the starboard side. The vessels can easily turn in front of the berth on departure towards the port exit.

There may be little difference of the location of inside facilities, but generally no problem in container operations.

3) Contingent Alternative C

The position of the quay is 700 m distant from the container handling yard. Yard trailers are compelled to carry containers one by one the distance of about 4 km on one round. A great numbers of tractor heads and chassis are needed. Since these two operations are separated, it is assumed to be difficult to individually coordinate drivers and yard equipment operators.

The key point in container operations is the loading sequence. If orders and actions are divergent, systematic operation cannot be achieved. Each coordinating manager at quayside and yard side control must be able to simultaneously grasp the operating environment.

Transhipment containers, the majority and most profitable throughput the new container terminal at Walvis Bay has to capture, will encounter some issues since they cannot be stowed close to the area of the connecting vessels.

There is no merit to charge transhipment containers here at a cheaper tariff charge than transit/local containers.

Generally Alternative C is the most undesirable plan from the standpoint of container operations.

(4) Railway Alignment

The causeway is 4 km or more away from the existing Walvis Bay station and 3 km away from the line which passes closest there in each alternative. So, new tracks have to be constructed there.

The land for railway is along an unpaved road, flat and with no obstacles such as residences. According to the development plan, the area along the railway will be planned as a residential area for the future. It is necessary to consider harmony with its plan and measurement for safety such as level crossings and barriers to prevent entry into the track.

It is difficult to connect with Windhoek and the container terminal directly because there is a flyover at the place where the new track branches from the existing line. Therefore, a train arriving inbound must go to the container terminal after it enters the existing Walvis Bay station.

1) Contingent Alternative A

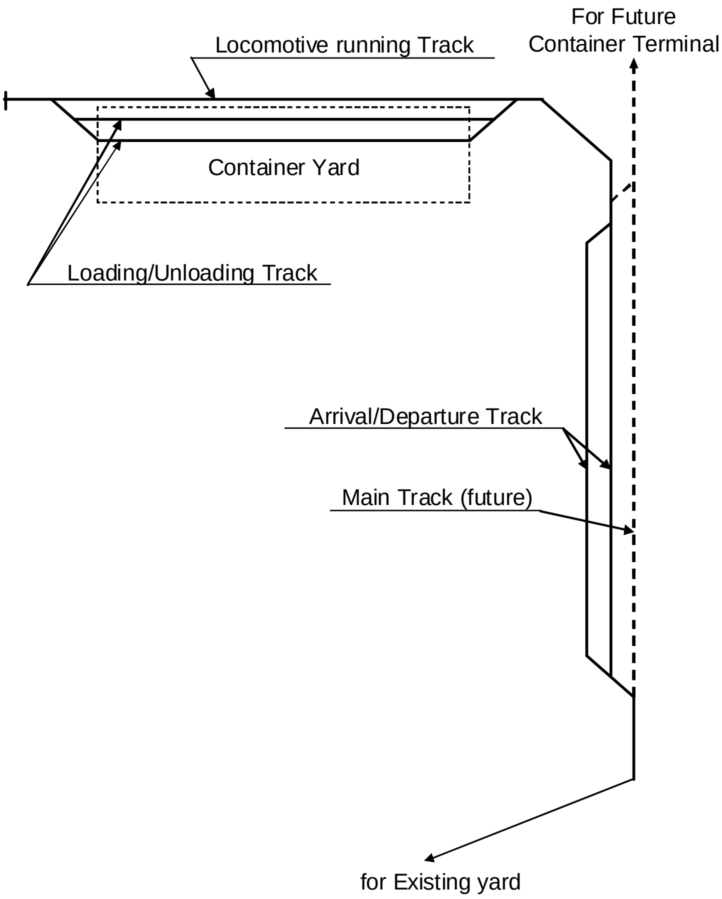


Figure 5.1.5 Track Layout of Alternative A

Alternative A has over 500 m of loading/unloading tracks, so trains can unload and load without dividing and efficiency of loading/unloading is better than the original plan.

2) Contingent Alternative B

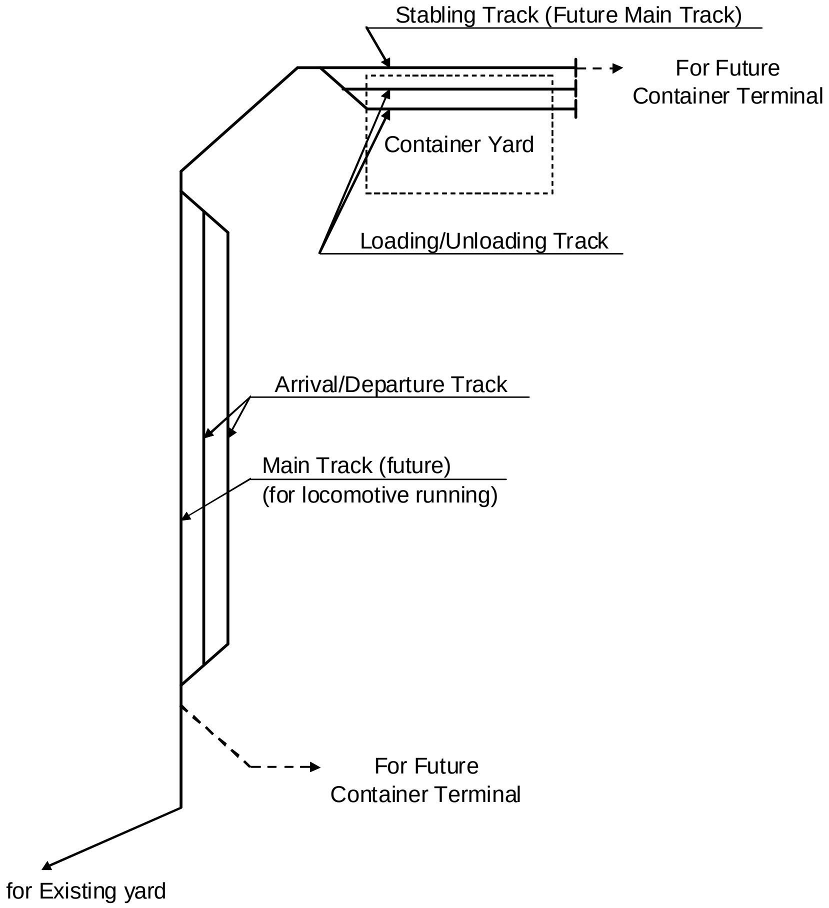


Figure 5.1.6 Track Layout of Alternative B

Concept of track layout of Alternative B is almost the same as the original plan. Stabling track in the container yard will use the main track for second phase expansion. And, for further expansion, siding track which braches from the south side of the shunting yard is also planned.

3) Contingent Alternative C

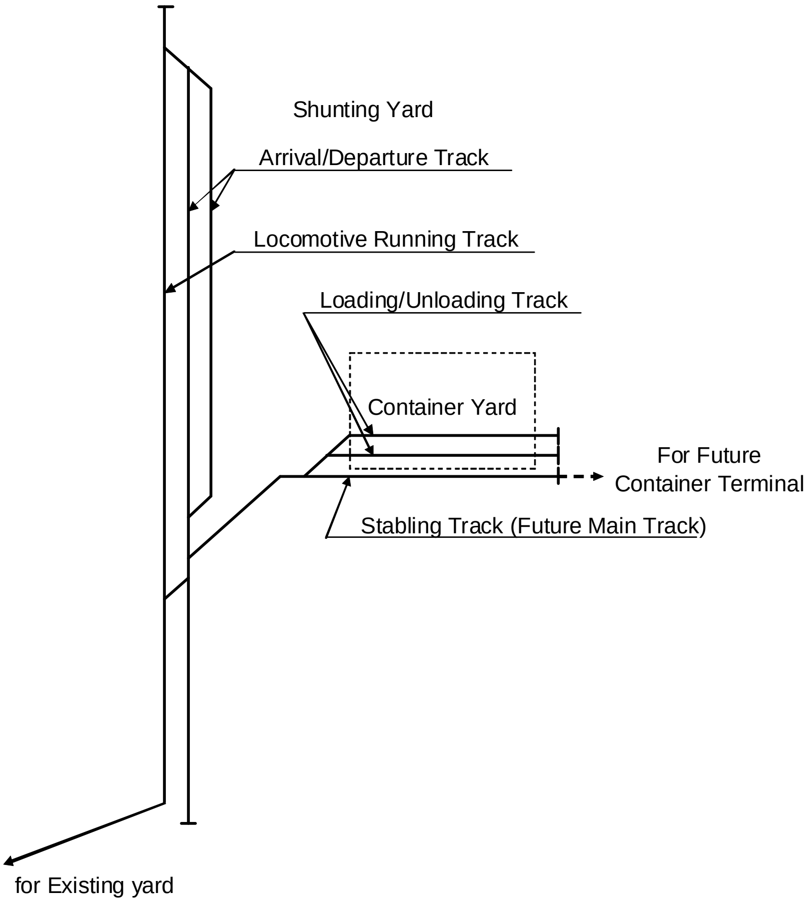


Figure 5.1.7 Track Layout of Alternative C

In Alternative C, the container yard is located just beside the shunting yard. Trains go to the container yard after shunting to a siding track. Train loading/unloading must be divided into two or three because length of loading/unloading tracks is insufficient unlike the original plan and Alternative B.

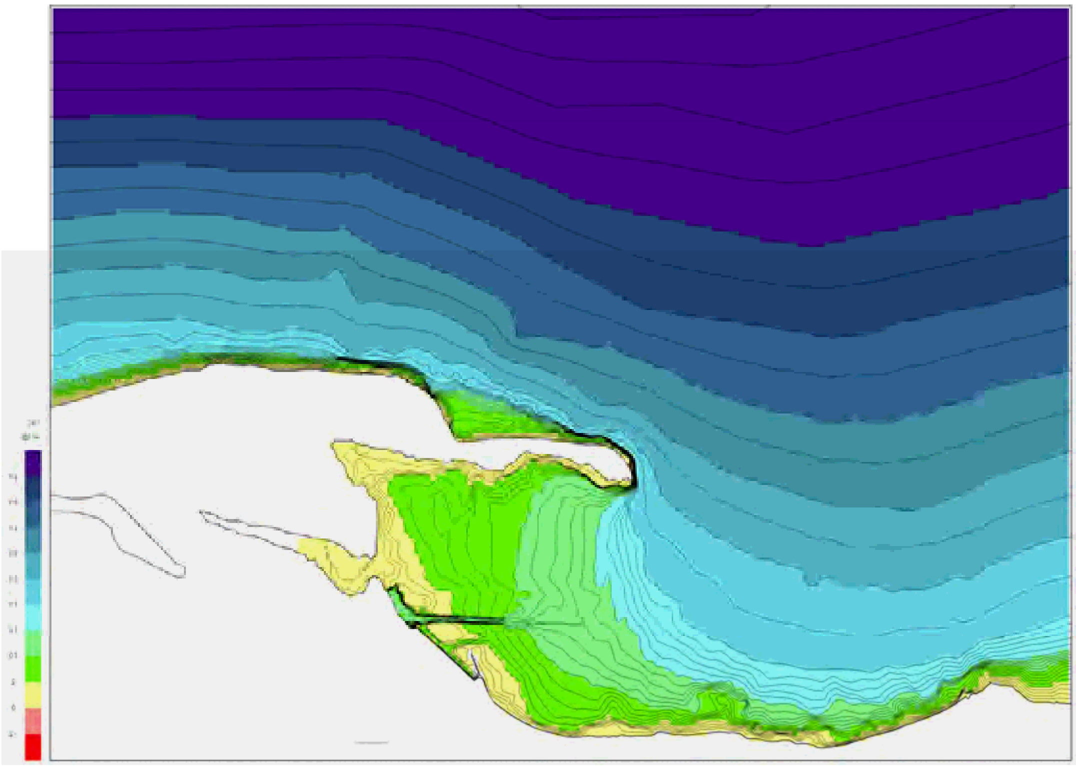
5.1.2 Influence to Lagoon

(1) Outline of Simulations

In the current simulations, fundamental equations are based on equations of motion, continuity, thermodynamic and salinity equilibrium. The conditions of calculations for currents are indicated in Table 5.1.1. The bathymetry of Port of Walvis Bay is shown in Figure 5.1.8.

Table 5.1.1 Conditions of Calculations

Conditions	Description
Bathymetry	• see Figure 5.1.8
Widths of grids	• 20 m
Time step	• 2.0 s
Input tidal components	• M_2
Duration of calculations	• 360 hours (15 days)
Layers	• 1^{st} layer : from 0 to 5 m • 2^{nd} layer : from 5 to 10 m • 3^{rd} layer : under 10 m
Maximum depth	• 90 m
Minimum layer thickness	• 1 m
Eddy viscosity coefficient	• 5.0×10^{6} cm^2/s
Sea surface friction coefficient	• 0.0013
Internal friction coefficient	• 0.1
Bottom friction coefficient	• 0.0026
Coriolis coefficient	• $f=2\omega\sin\varphi$ $\varphi=22.85°$



Source: JICA Study Team

Figure 5.1.8 Bathymetry

(2) Comparisons with Observed Currents

The results of currents simulations are compared with measured current data below.

The observation data at St.3 have errors of current amplitude. So the comparisons for St.3 can not be conducted. Comparing with the observation data at St.1 and St.2, a little difference is found at phase and amplitude. But in general, it is good fit and currents for future layout are predicted with enough accuracy.

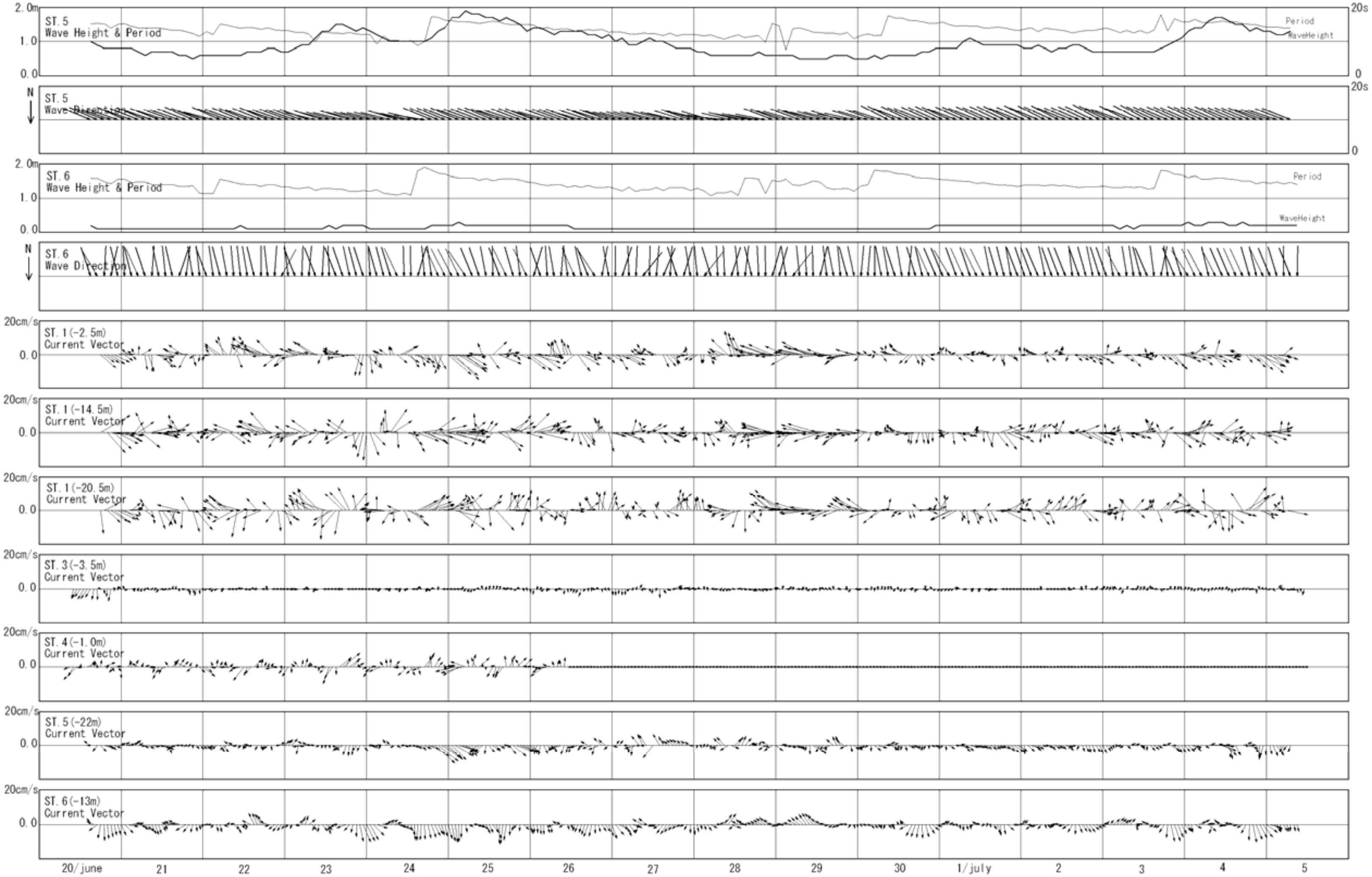


Figure 5.1.9 Current Data

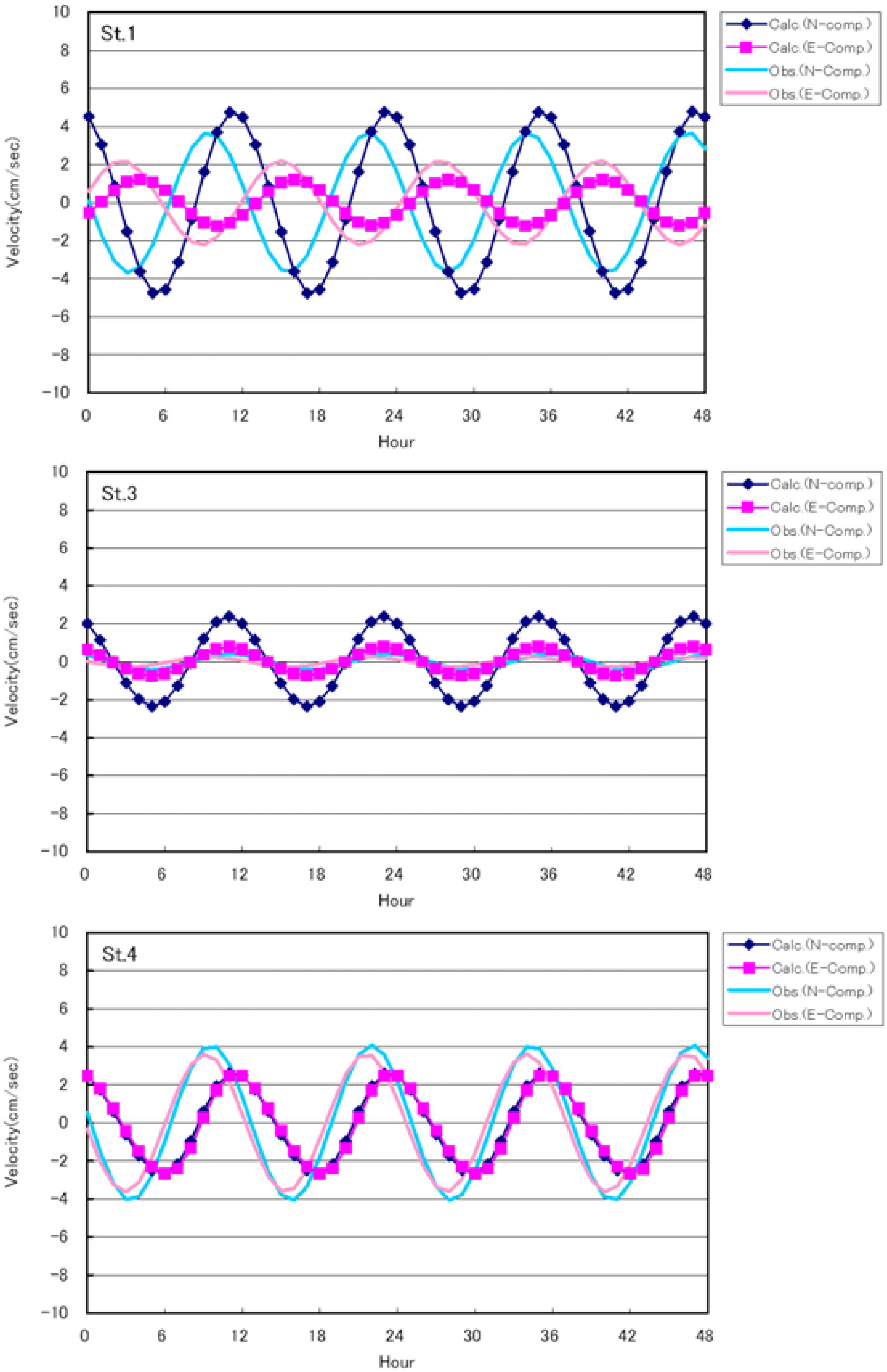


Figure 5.1.10 Time Series of Observed and Calculated Currents

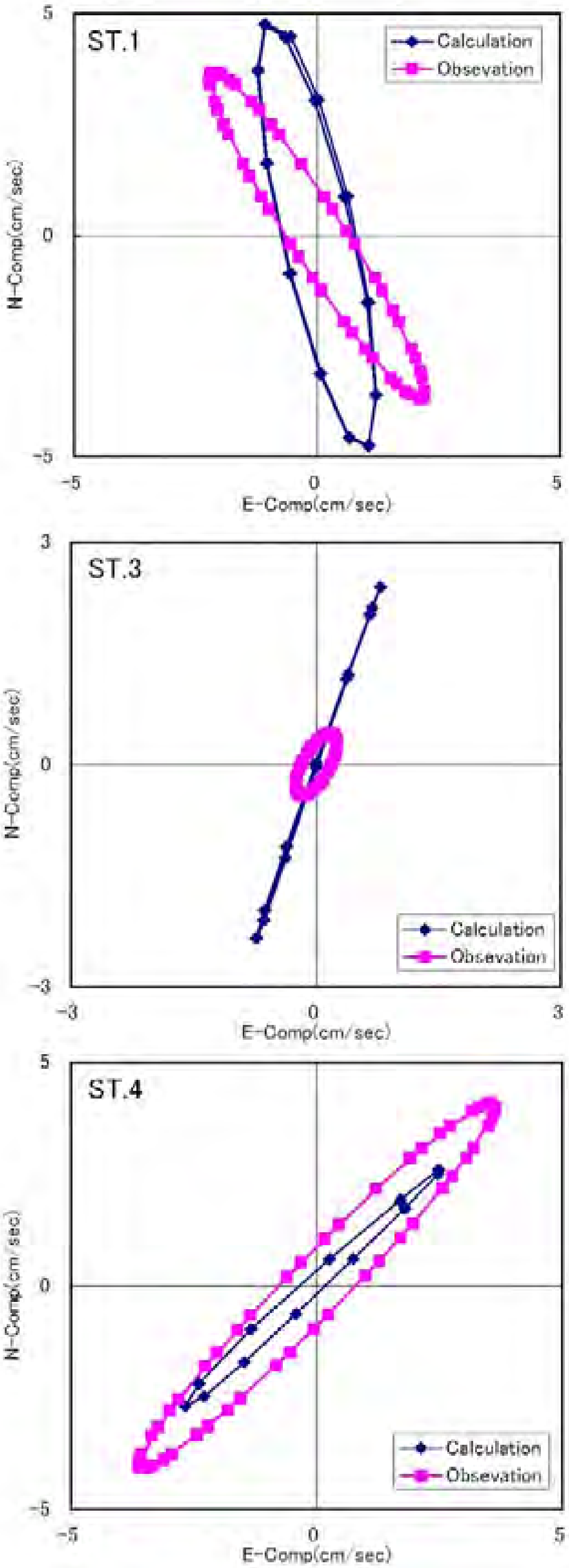
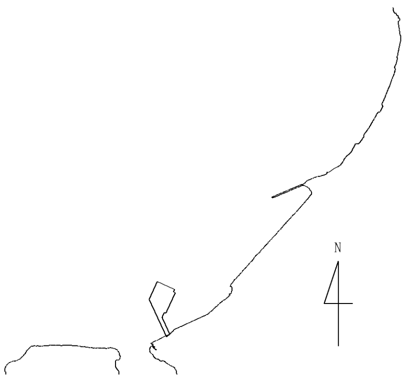
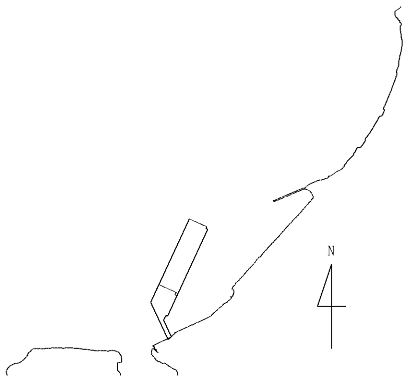
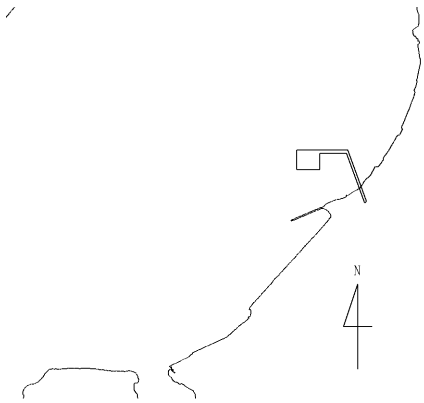
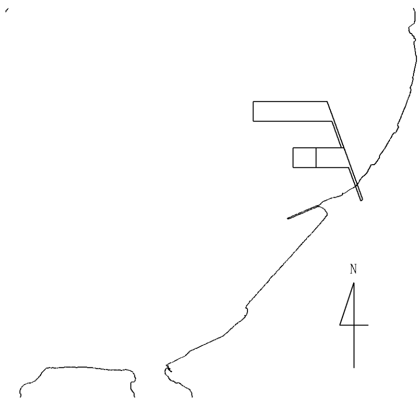
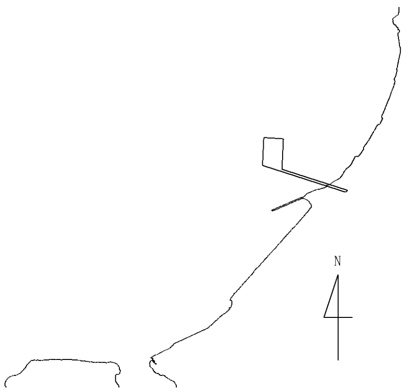
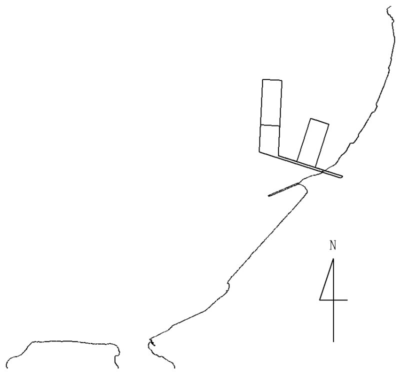


Figure 5.1.11 Tidal Ellipses of Observed and Calculated Currents

(3) Layouts

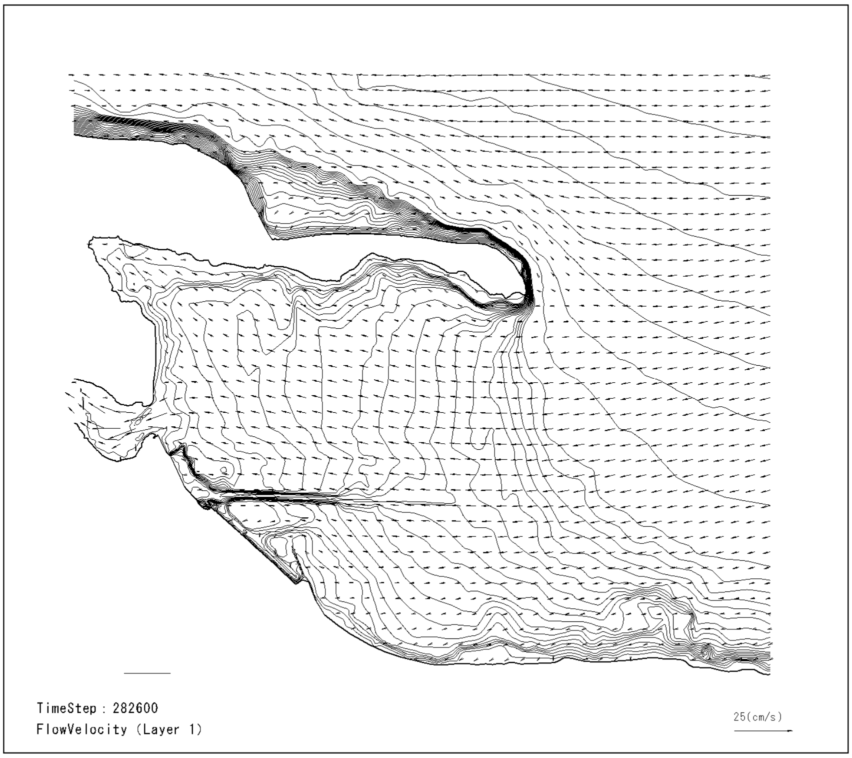
The layouts of expansion plans are indicated in Table 5.1.2. The current simulations are predicted according to the plans.

Table 5.1.2 Layouts of Expansion Plan

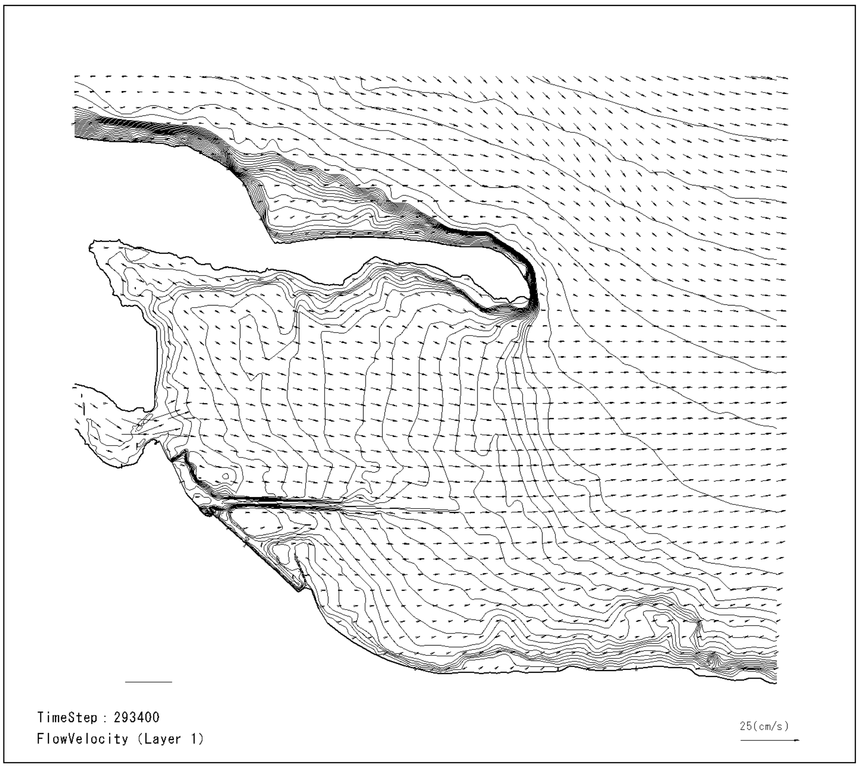
	Phase 1	Master Plan
Original Plan		
Alternative Plan A		
Alternative Plan B		

(4) Results

The results of current simulations of the expansion plans are shown below. The figures are the vectors distributions of currents at flood and ebb tide. And the variations between the currents of these expansion plans and that of the present bathymetry are also indicated below.

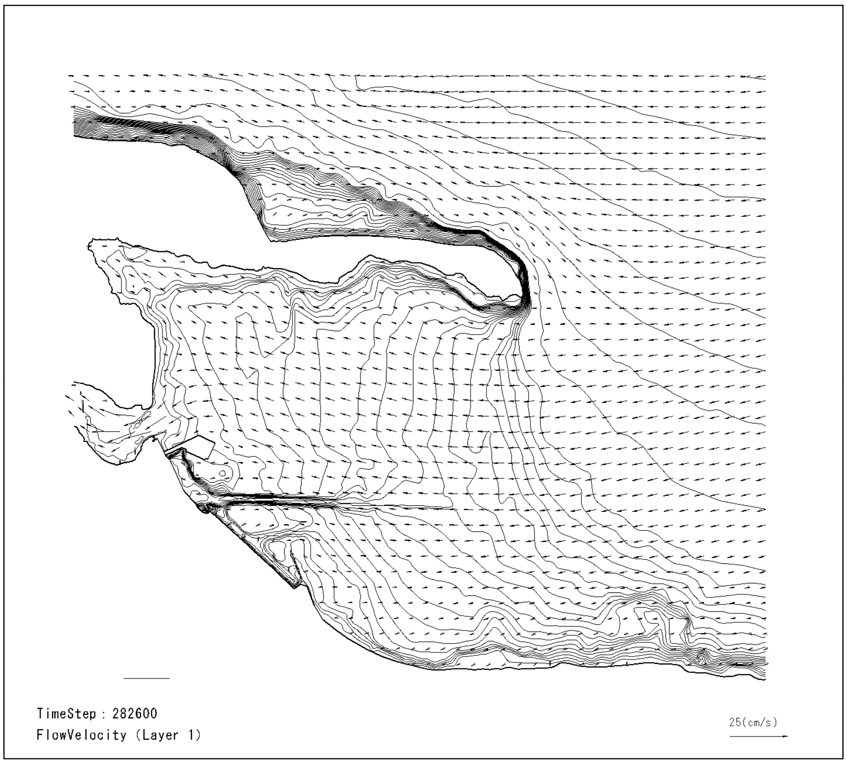


A

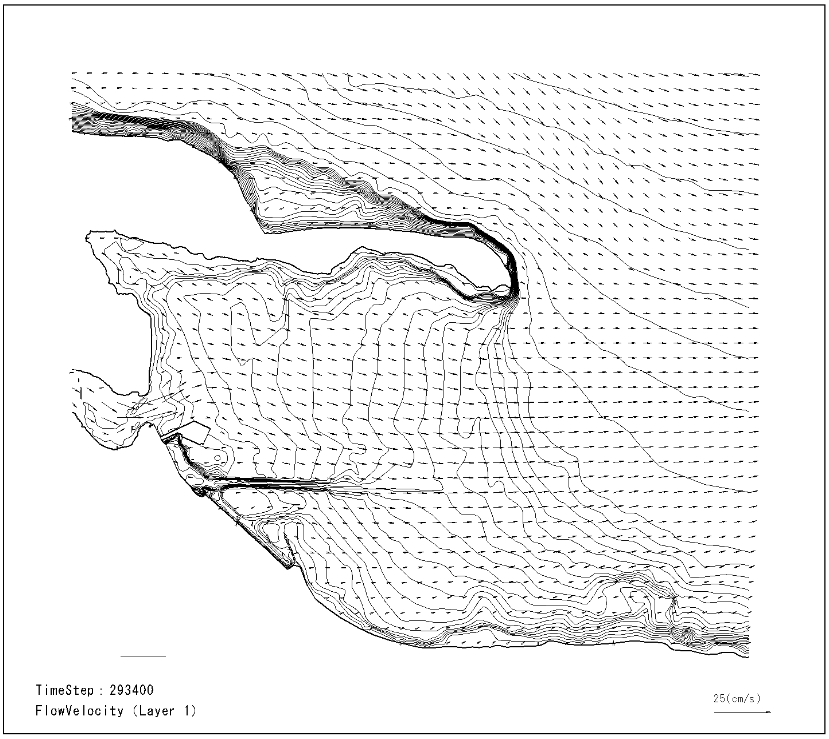


B

Figure 5.1.12 Vectors of Currents at Present Bathymetry (A: flood, B: ebb tide)

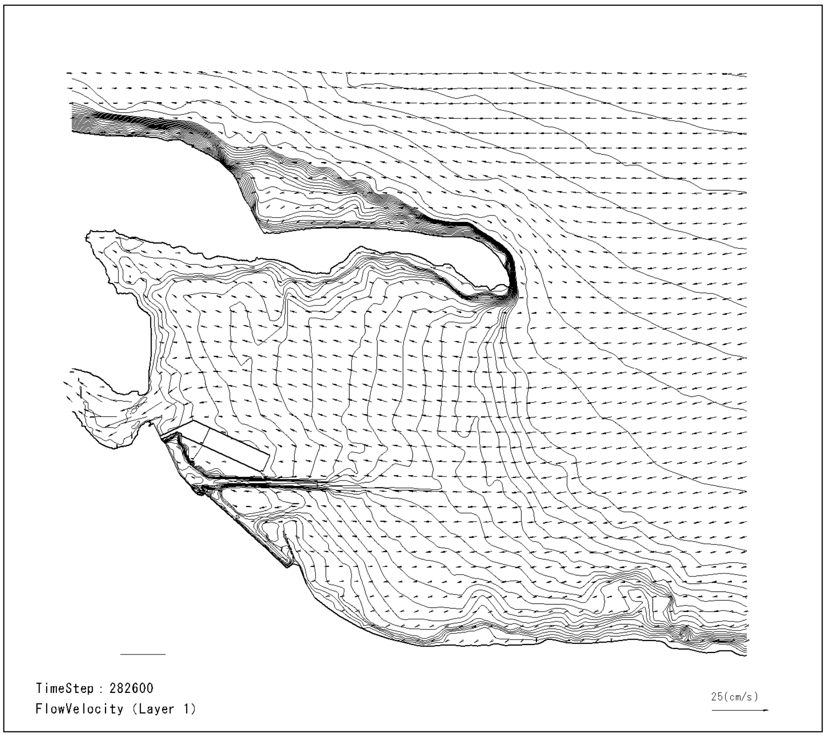


A

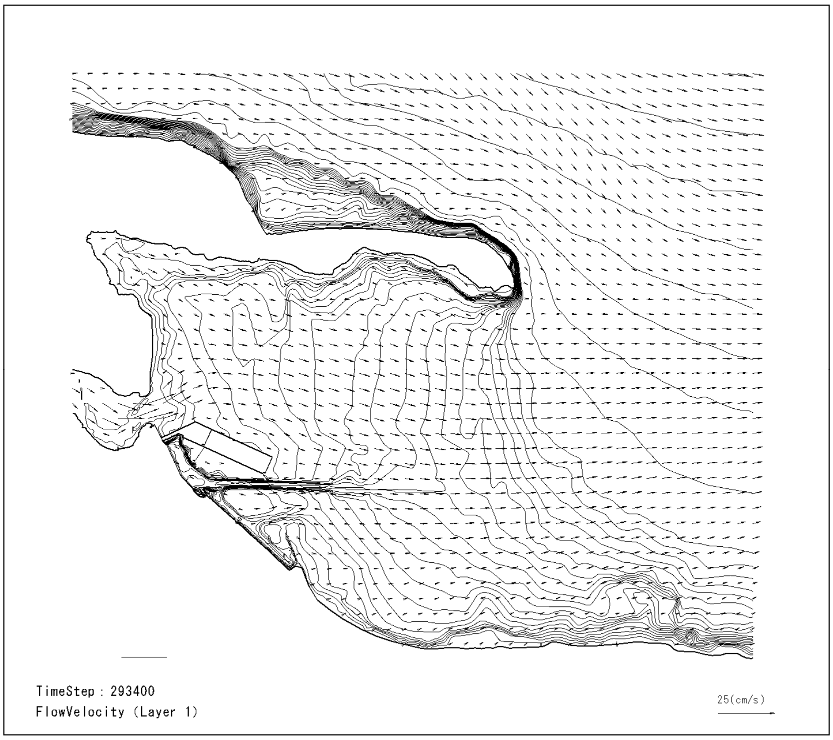


B

Figure 5.1.13 Vectors of Currents at Original Plan Phase1 (A: flood, B: ebb tide)

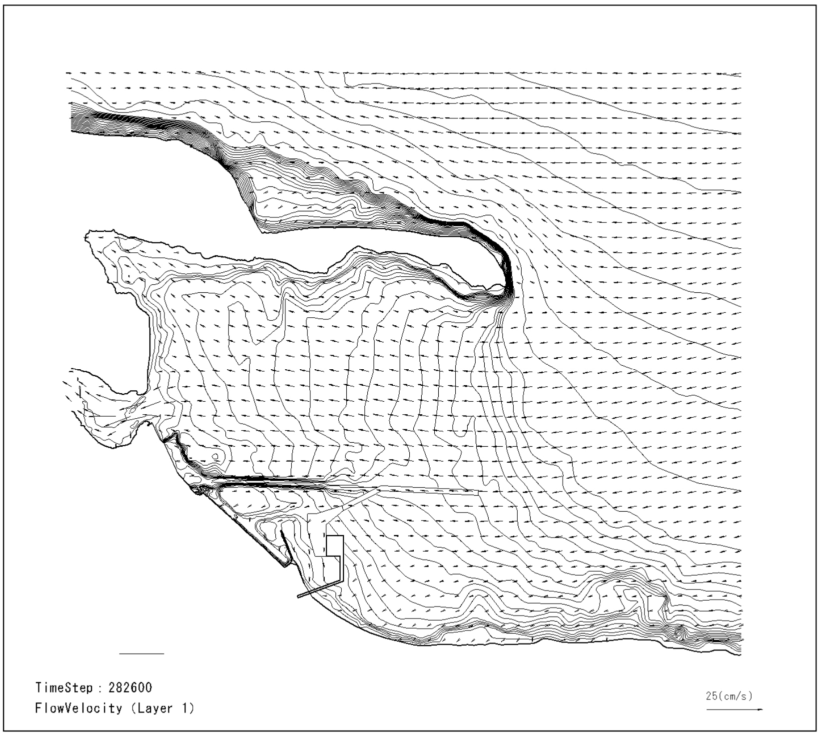


A

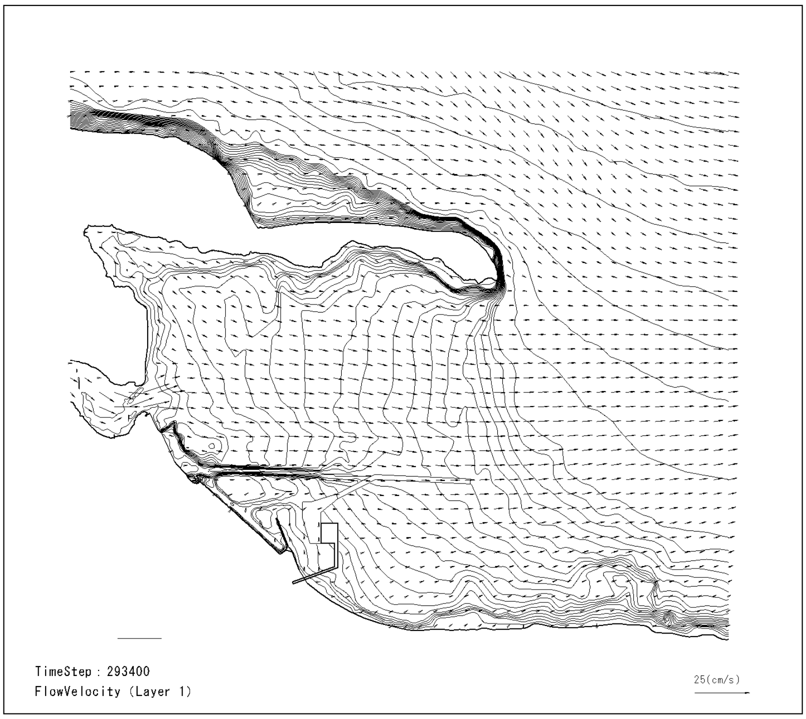


B

Figure 5.1.14 Vectors of Currents at Original Master Plan (A: flood, B: ebb tide)



A



B

Figure 5.1.15 Vectors of Currents at Alternative Plan A Phase1 (A: flood, B: ebb tide)

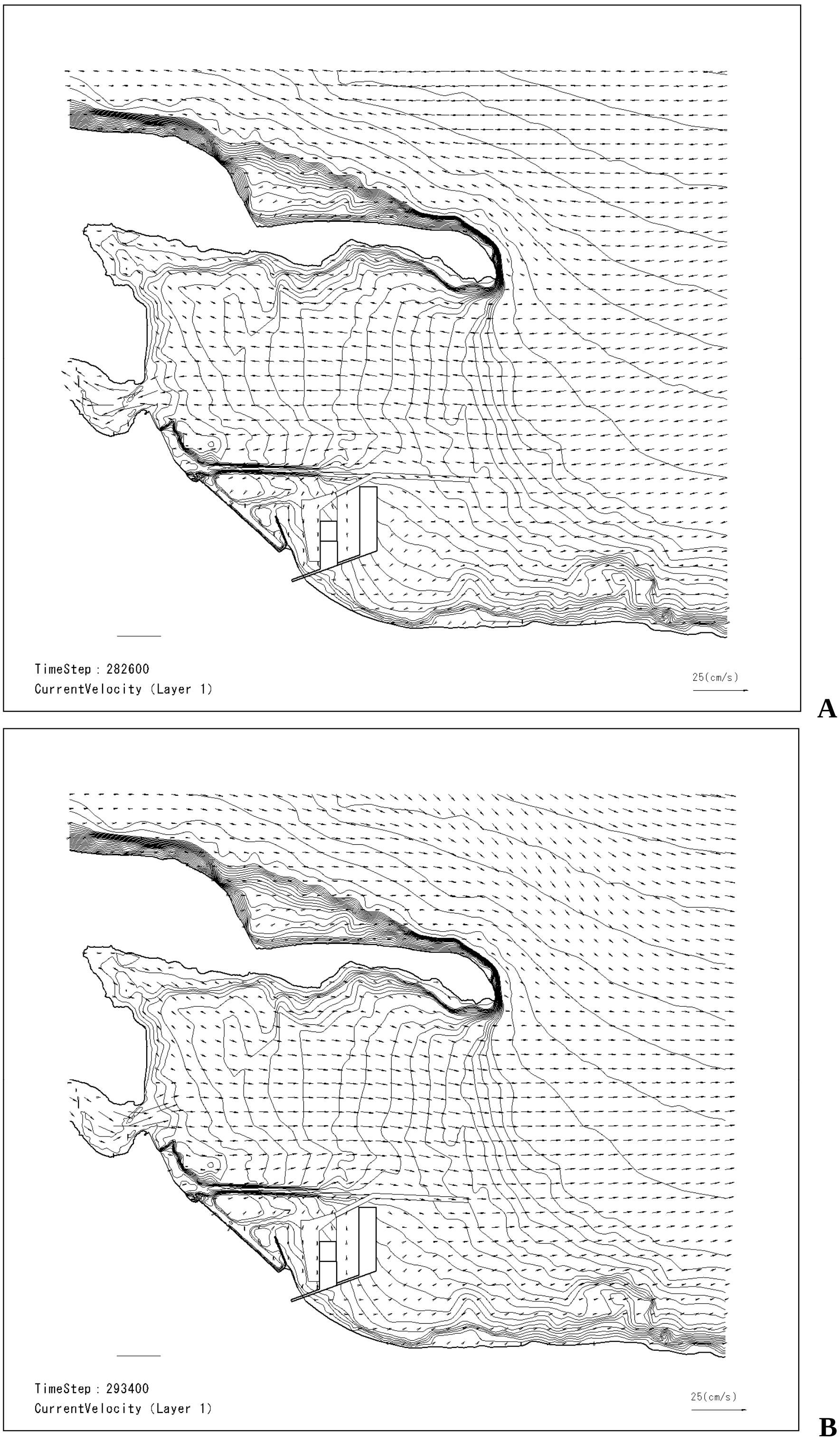
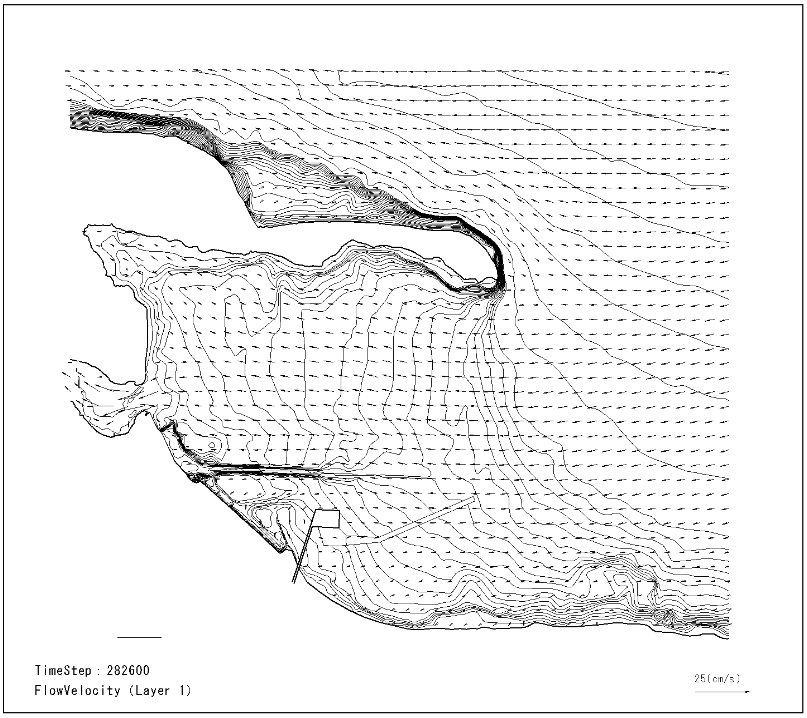
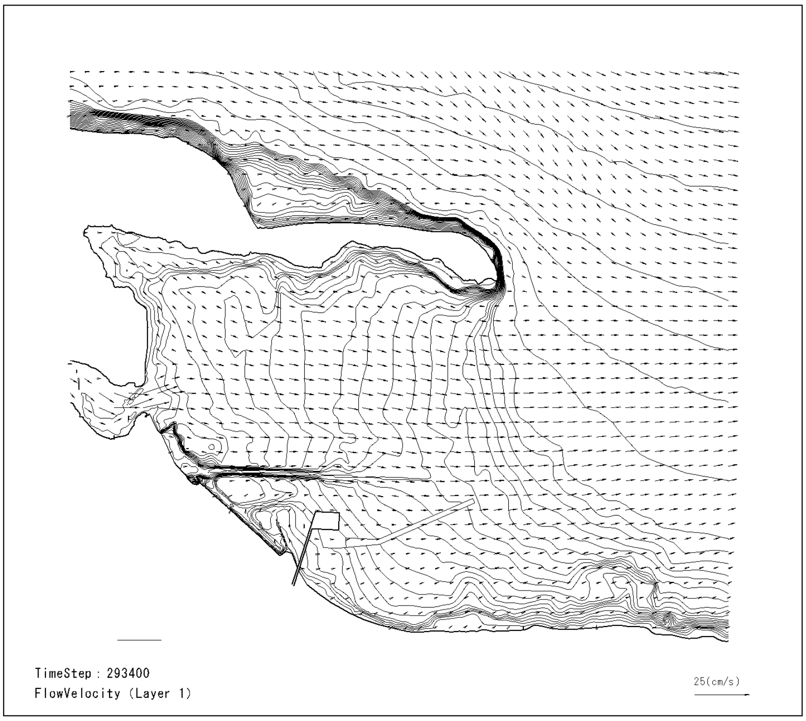


Figure 5.1.16 Vectors of Currents at Alternative Plan A Master Plan (A: flood, B: ebb tide)

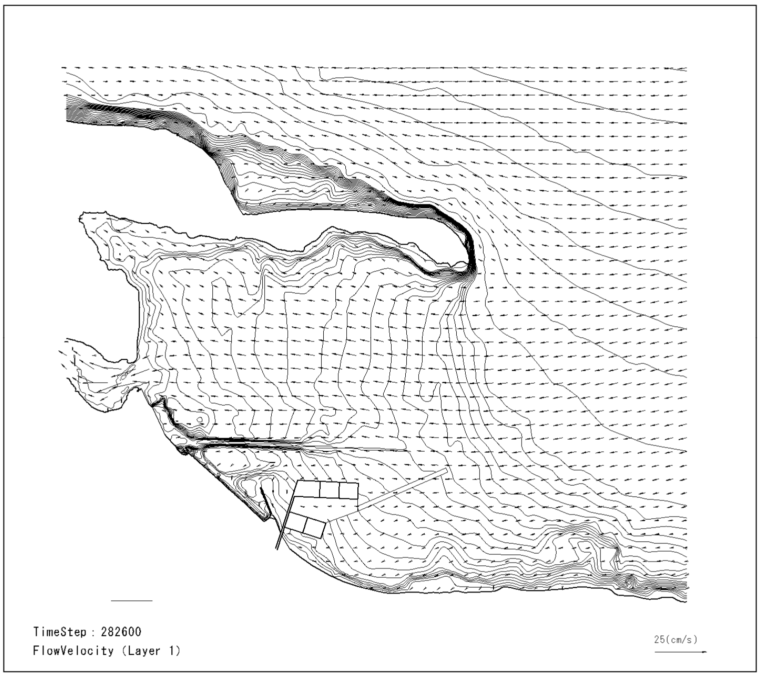


A

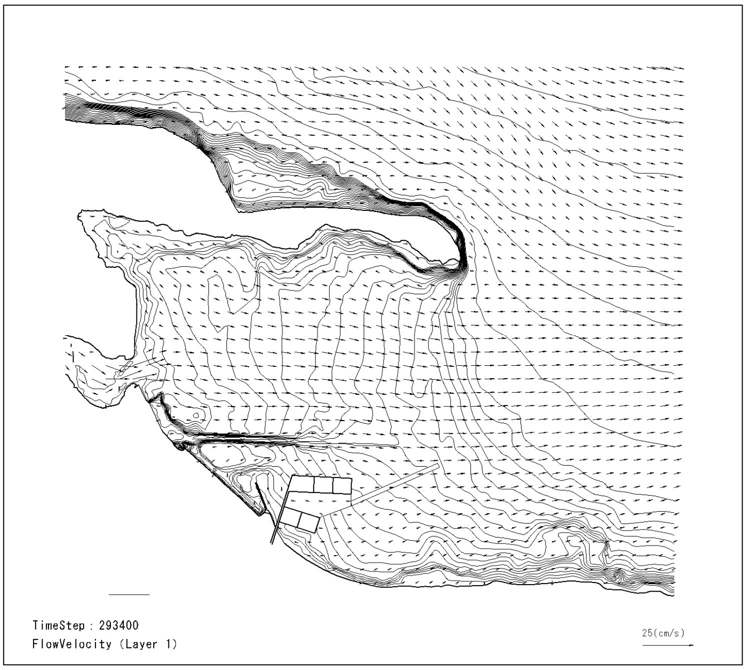


B

Figure 5.1.17 Vectors of Currents at Alternative Plan B Phase1 (A: flood, B: ebb tide)

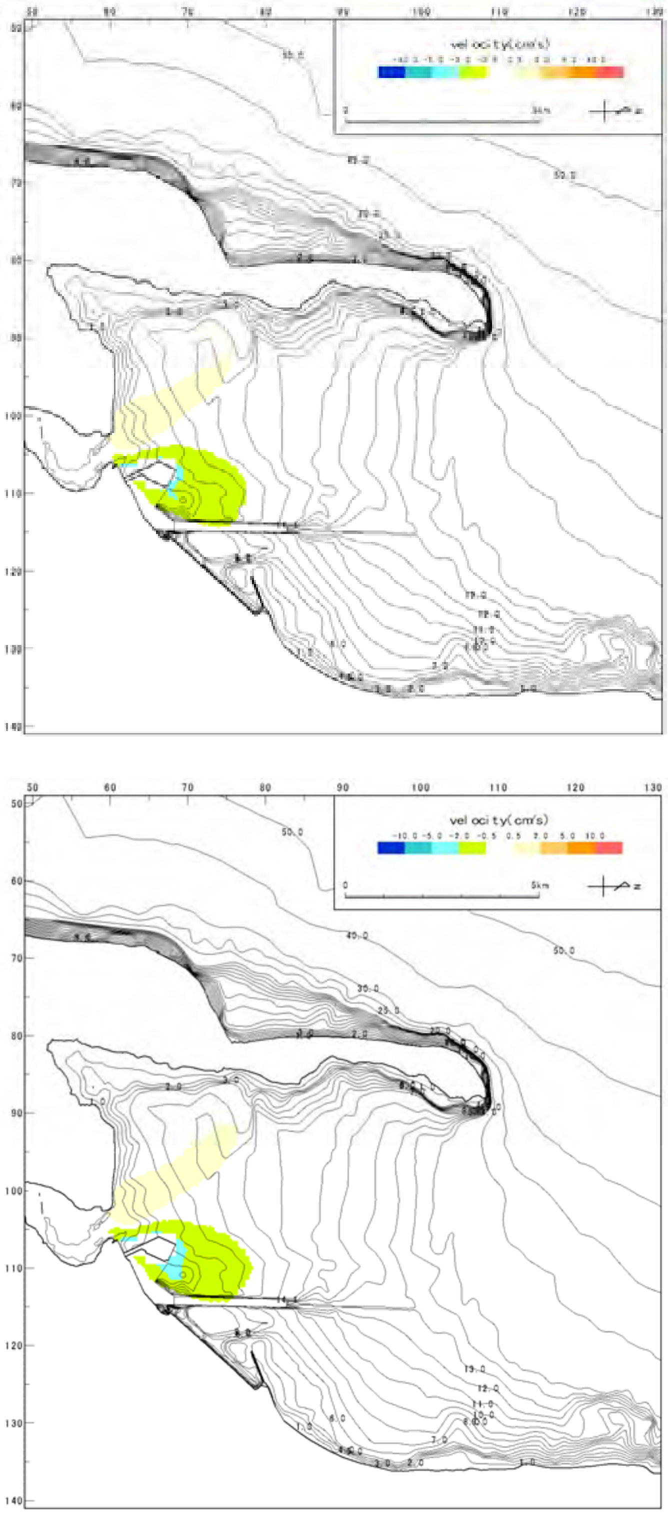


A



B

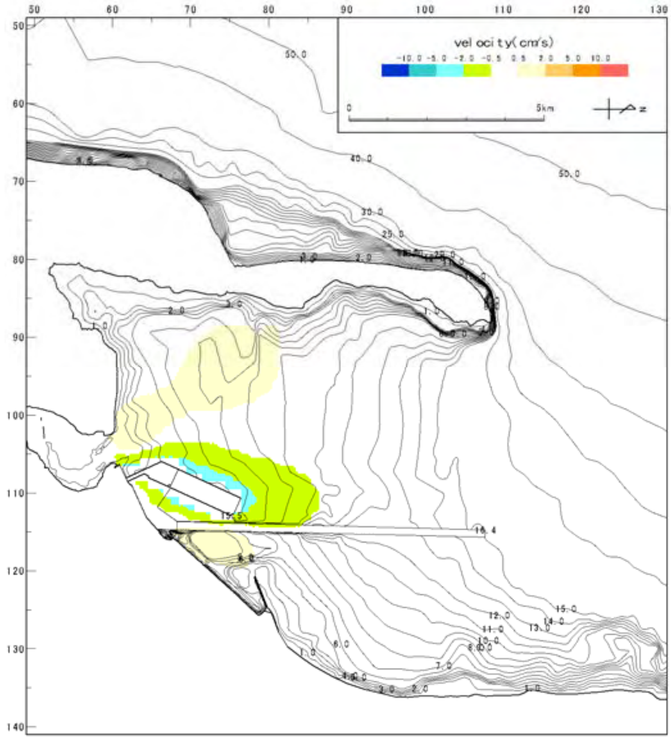
Figure 5.1.18 Vectors of Currents at Alternative Plan B Master Plan (A: flood, B: ebb tide)



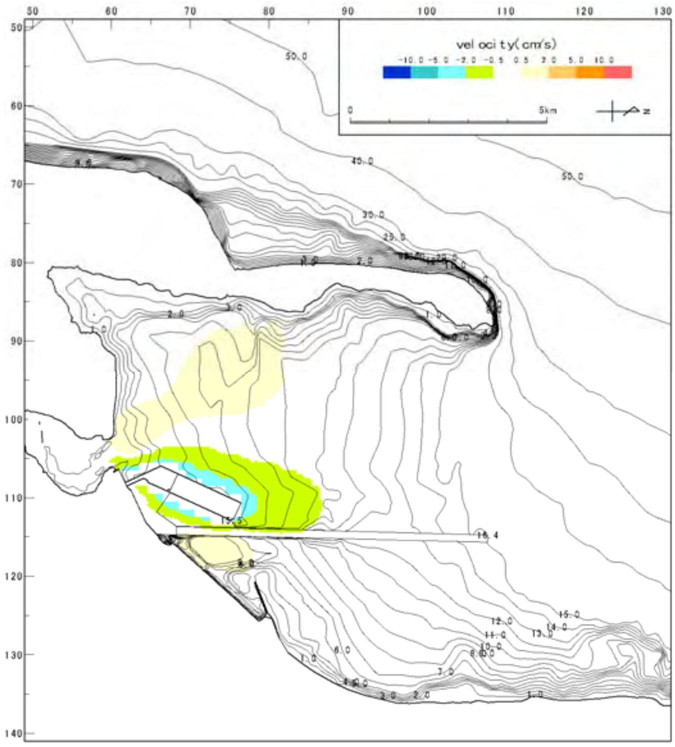
A

B

Figure 5.1.19 Variations of Currents at Original Plan Phase1 (A: flood, B: ebb tide)



A



B

Figure 5.1.20 Variations of Currents at Original Master Plan (A: flood, B: ebb tide)

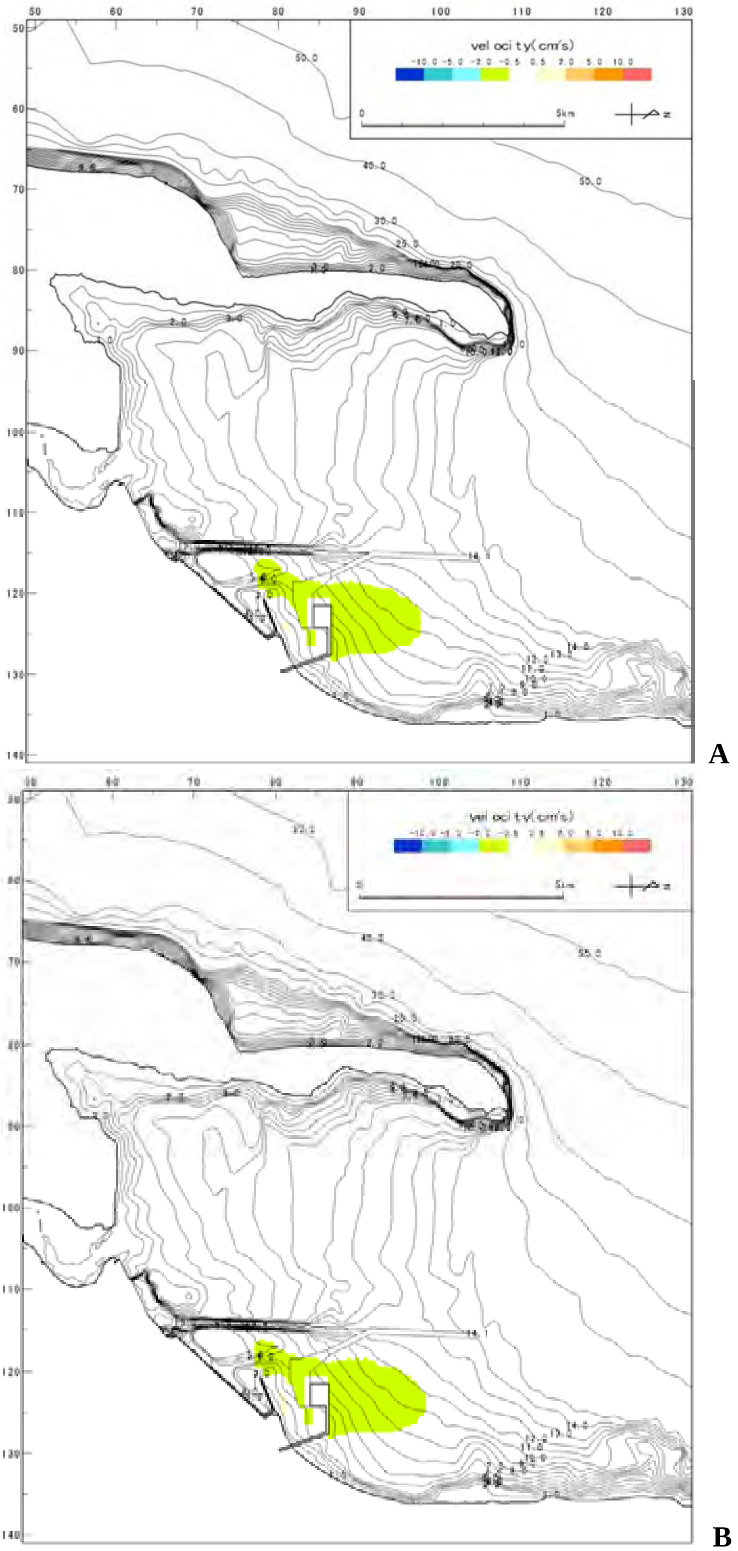
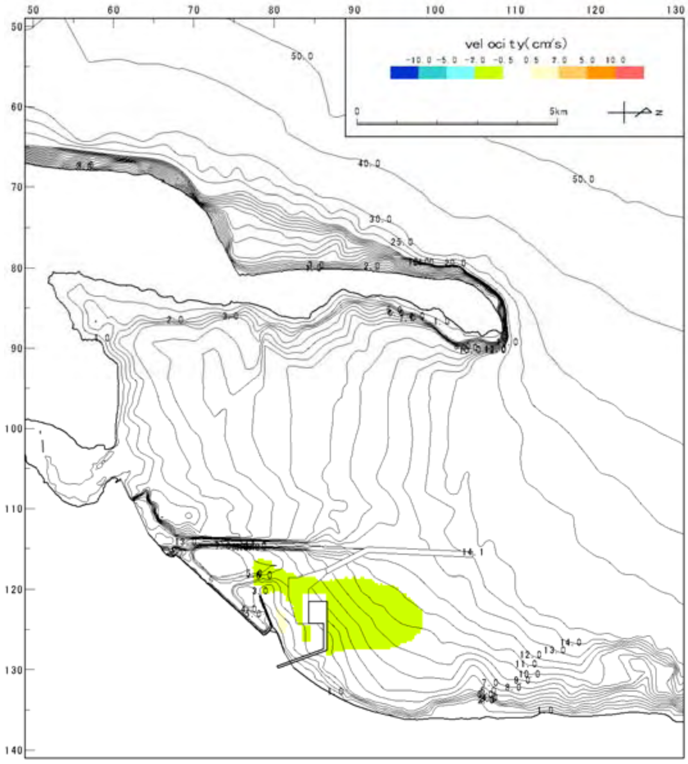
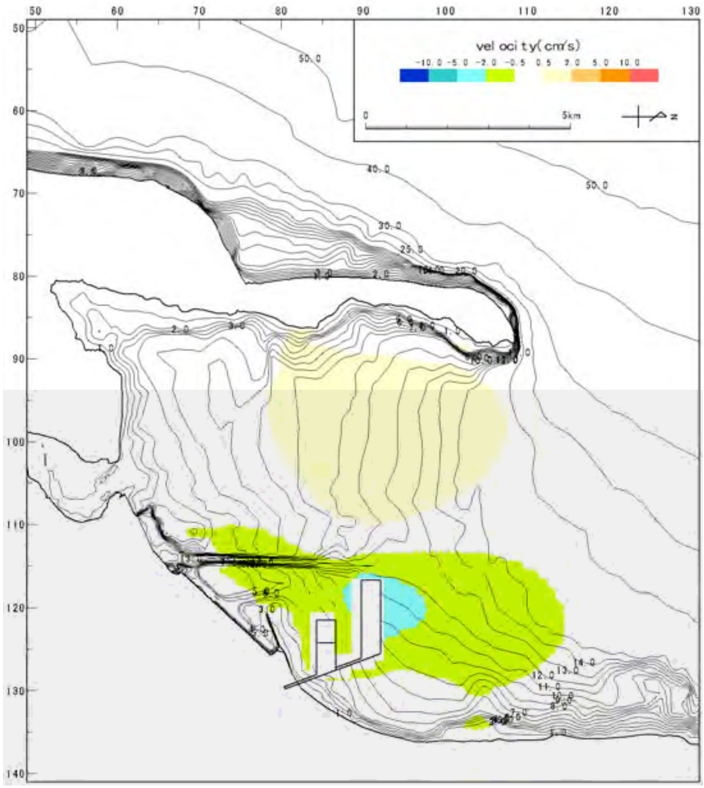


Figure 5.1.21 Variations of Currents at Alternative Plan A Phase1 (A: flood, B: ebb tide)



A



B

Figure 5.1.22 Variations of Currents at Alternative Plan A Master Plan (A: flood, B: ebb tide)

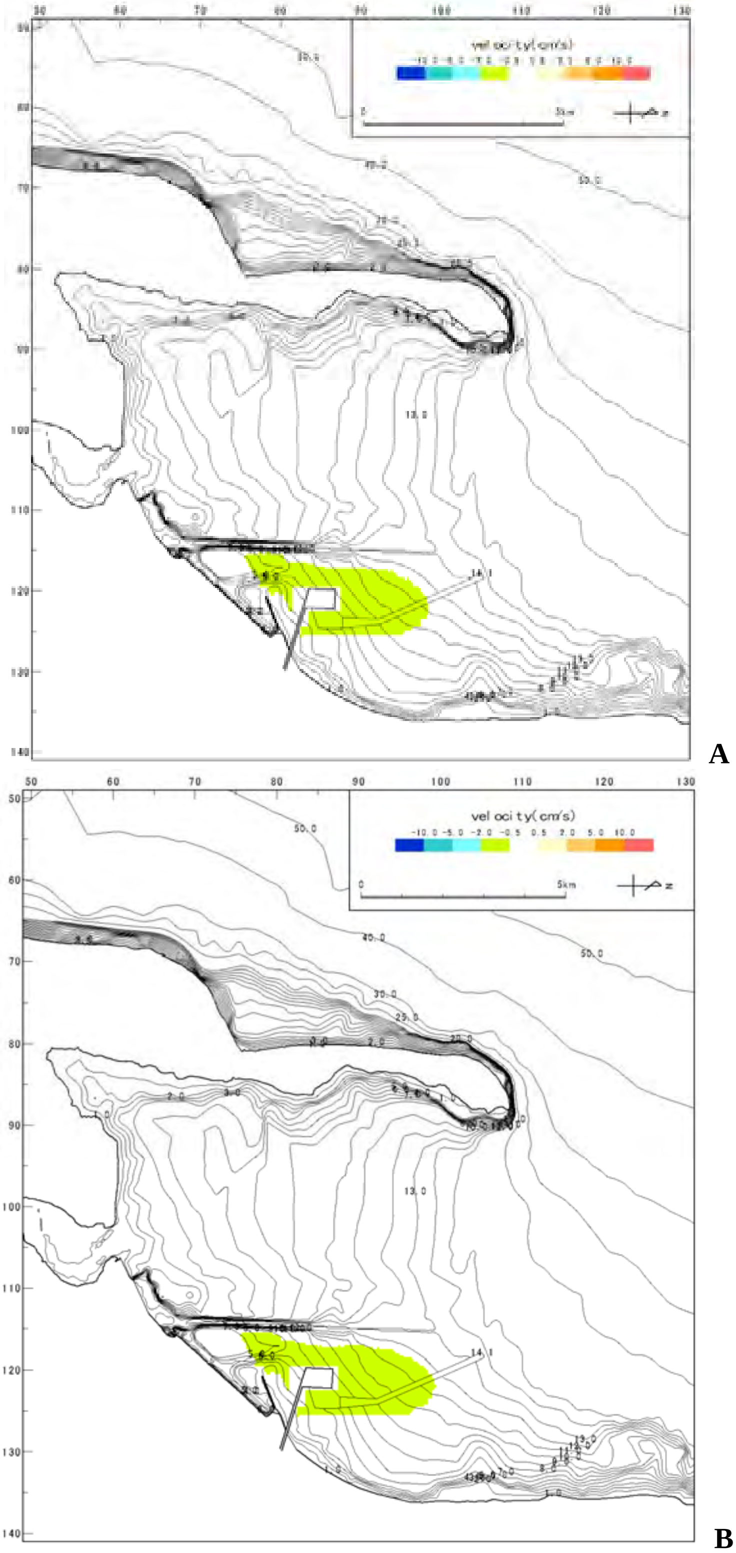


Figure 5.1.23 Variations of Currents at Alternative Plan B Phase1
(A: flood, B: ebb tide)

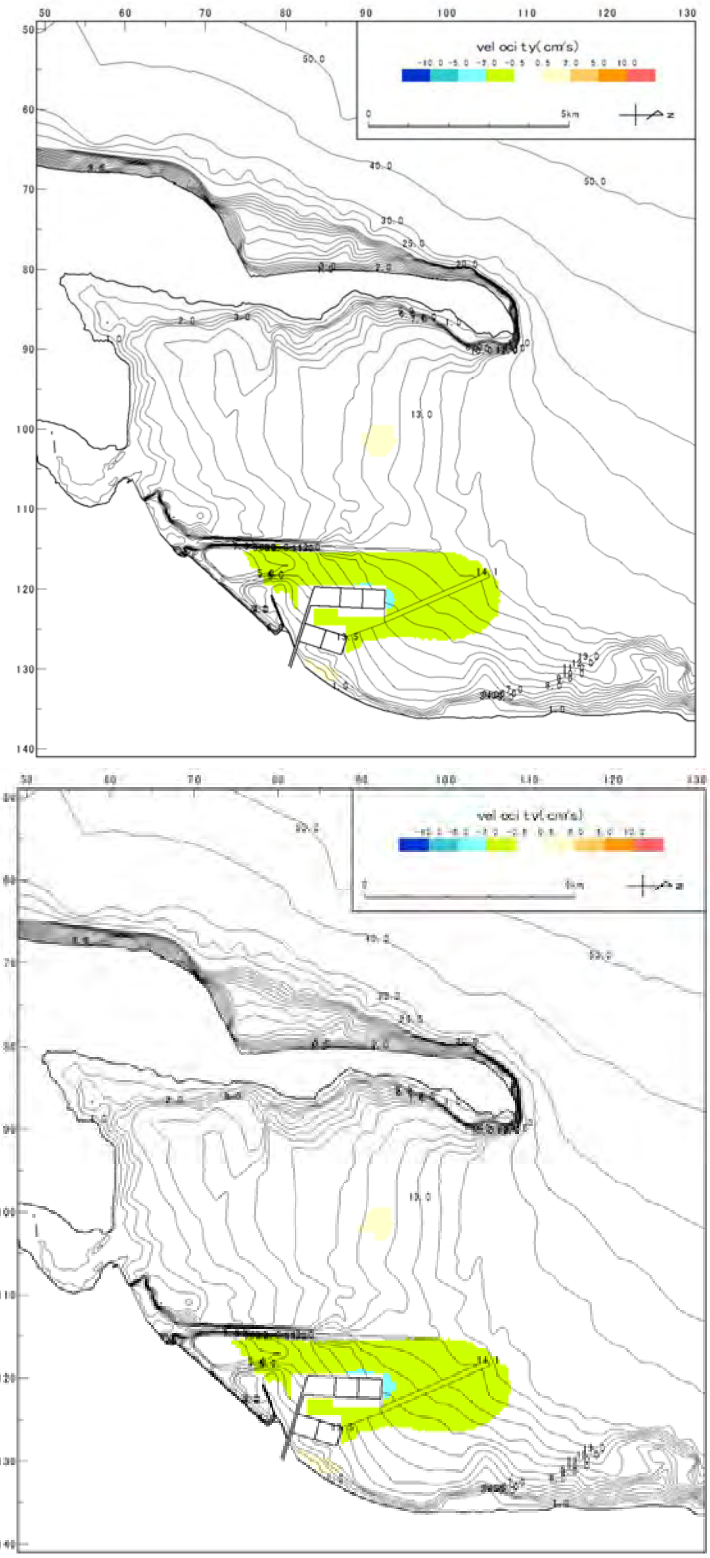


Figure 5.1.24 Variations of Currents at Alternative Plan B Master Plan (A: flood, B: ebb tide)

(5) Influence to Lagoon

In order to grasp the influence to the Lagoon by the expansion of the container terminal, current velocities and directions at the 6 points indicated in Figure 5.1.25 are extracted and analyzed below.

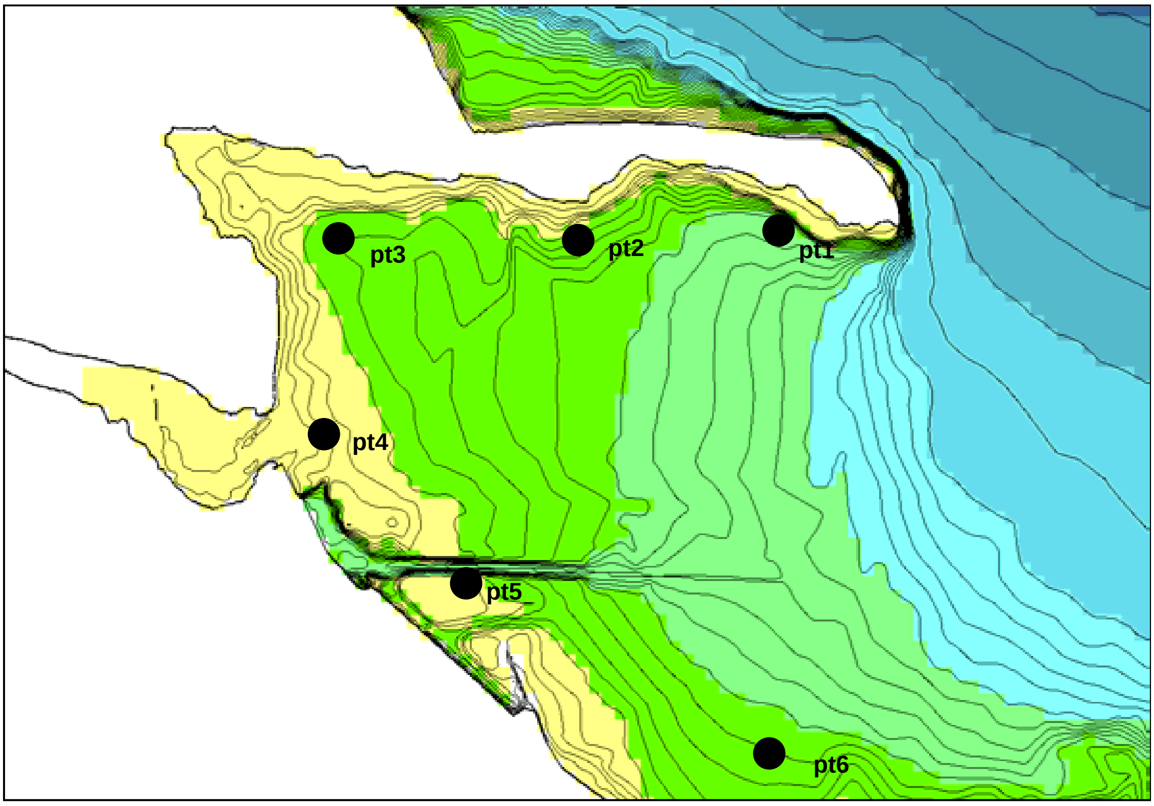


Figure 5.1.25 Locations of Output Points

1) Pt1: Vicinity of Pelican Point

There is little divergence from the original plan and the alternative plan B against present layout at Pt1. As for the master plan of the alternative plan A, however, the current velocity increases by 0.4cm/s and current directions are changed by 3–4 degrees. In general, the reclamation of the container terminal will not influence this area.

2) Pt2: Vicinity of Oysters Aquaculture Points

There is little divergence from alternative plan B against the present layout at Pt2. As for the master plan of the original plan and the alternative plan A, however, the current velocity increases by 0.4 to 0.6 cm/s. In general, the reclamation of container terminal will not influence to this area.

3) Pt3: Vicinity of Salt Works

There is little divergence from the alternative plan A and B against the present layout at Pt3. As for original plans, however, current directions are changed by 5–6 degrees to a N-S direction. In general, the reclamation of the container terminal will not influence this area.

4) Pt4: Vicinity of Lagoon Mouth

There is little divergence from the alternative plan A and B against the present layout at Pt4. As for the original plan, however, the current velocity increases by 0.4–0.5 cm/s and current directions are changed to an E-W direction by 15–20 degrees. Although the velocity at this point is fastest of the six points and changes of current directions due to reclamation of the original plan occur, the reclamation of the container terminal will not influence this area because the current velocity remains fast.

5) Pt5: Present Approach Channel

As for the original plan and the alternative plan A and B, against the present layout at Pt5. the current velocity are changed by −0.9 to 0.9 cm/s and current directions are changed by 2–35 degrees. Although currents at this point are influenced by the expansion land, the reclamation of the container terminal will not influence the Lagoon.

6) Pt6: East Side of Bay

There is little divergence from the original plan against the present layout at Pt6. As for the master plan of the alternative plan A and B, however, the current velocity increases by 0.2–0.4 cm/s and current directions are changed to an E-W direction by 10–20 degrees. In general, the reclamation of the container terminal will not influence this area.

Table 5.1.3 Summation of Data for Influence on Lagoon

Velocity (cm/s): Flood tide

	Present	Original Plan		Alternative A		Alternative B	
		Phase 1	Master Plan	Phase 1	Master Plan	Phase 1	Master Plan
pt1	1.4	1.4	1.4	1.5	1.8	1.5	1.5
pt2	2.3	2.5	2.7	2.5	2.9	2.5	2.6
pt3	2.4	2.4	2.4	2.4	2.4	2.4	2.4
pt4	10.3	10.7	10.7	10.3	10.4	10.3	10.3
pt5	2.6	2.3	3.5	2.1	1.7	2.0	1.9
pt6	1.8	1.8	1.7	1.4	1.4	1.5	1.6

Direction (deg): Flood tide

	Present	Original Plan		Alternative A		Alternative B	
		Phase 1	Master Plan	Phase 1	Master Plan	Phase 1	Master Plan
pt1	209	209	209	208	206	208	208
pt2	191	191	190	189	186	189	188
pt3	217	212	211	217	216	217	216
pt4	170	155	155	170	170	170	170
pt5	179	177	167	165	142	160	158
pt6	163	163	162	160	142	160	152

Velocity (cm/s): Ebb tide

	Present	Original Plan		Alternative A		Alternative B	
		Phase 1	Master Plan	Phase 1	Master Plan	Phase 1	Master Plan
pt1	1.5	1.5	1.5	1.6	1.9	1.6	1.7
pt2	2.4	2.6	2.8	2.5	3.0	2.6	2.7
pt3	2.4	2.5	2.5	2.5	2.5	2.5	2.5
pt4	11.1	11.4	11.4	11.1	11.1	11.1	11.1
pt5	2.8	2.5	3.8	2.4	1.9	2.2	2.2
pt6	1.9	1.8	1.8	1.5	1.4	1.5	1.7

Direction (deg): Ebb tide

	Present	Original Plan		Alternative A		Alternative B	
		Phase 1	Master Plan	Phase 1	Master Plan	Phase 1	Master Plan
pt1	34	34	34	33	30	33	32
pt2	13	13	12	11	8	11	10
pt3	38	33	32	38	37	38	37
pt4	357	335	335	351	350	351	351
pt5	358	356	347	346	326	341	339
pt6	344	343	343	340	322	339	332

(6) Remarks

The following is a summation of major remarks:

- As for the original expansion plan, current velocity and directions at the mouth of the lagoon are changed by 0.4–0.5 cm/s and 15 to 20 degrees, respectively.
- There will be no significant change in the tidal current at the lagoon mouth in case of development of Contingent Alternatives A and B. In this regard, the Contingent Alternatives will have less impact on the lagoon than the original expansion plan.

5.1.3 Siltation of Approach Channel

(1) Outline of Simulations

In this simulation of the siltation of Approach channel, the continuity equations for sediment transports are fundamental. Modelling is adapted so that soil particles are moved by the currents of waves and tide. The conditions of this simulation are the following.

Table 5.1.4 Conditions of Calculations

Conditions	Description
Bathymetry	• See Figure 5.1.26
Widths of grids	• 20 m
Time step	• 1200 s
Durations of calculations	• 360 hours (15 days)
Coefficient of sediment transport rate by currents Ac	• 2.0
Coefficient of sediment transport rate by waves Aw	• 0.3

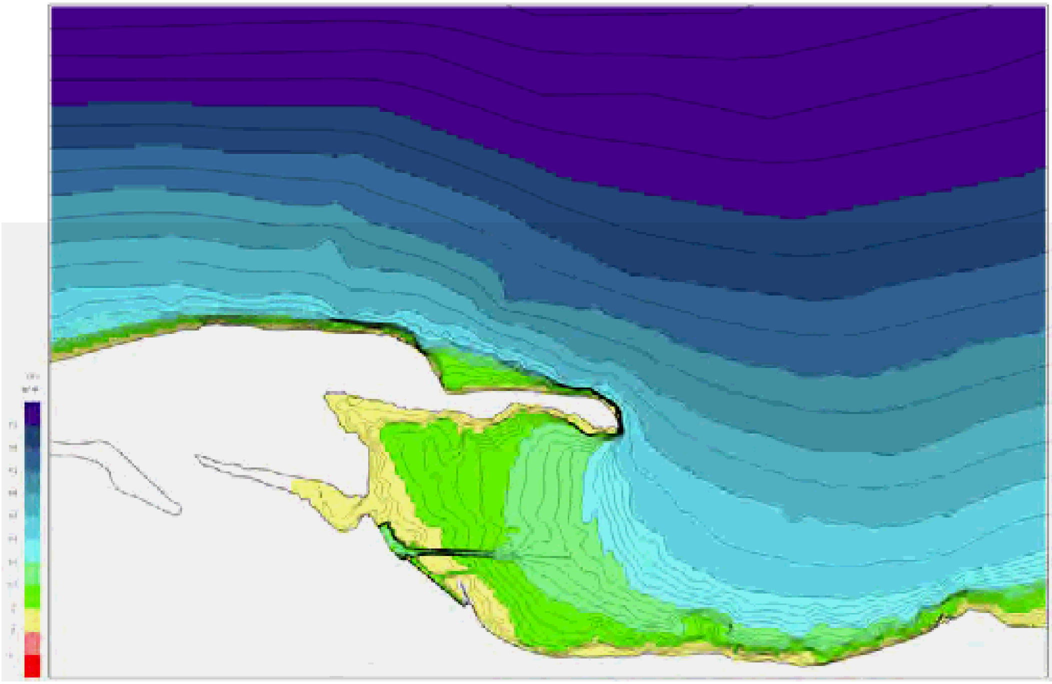


Figure 5.1.26 Bathymetry

(2) Results at the Present Bathymetry

The results of the simulations for the present bathymetry are shown in Figure 5.1.27. The variations of sediments occur at the slope of the approach channel and shore area along the coast.

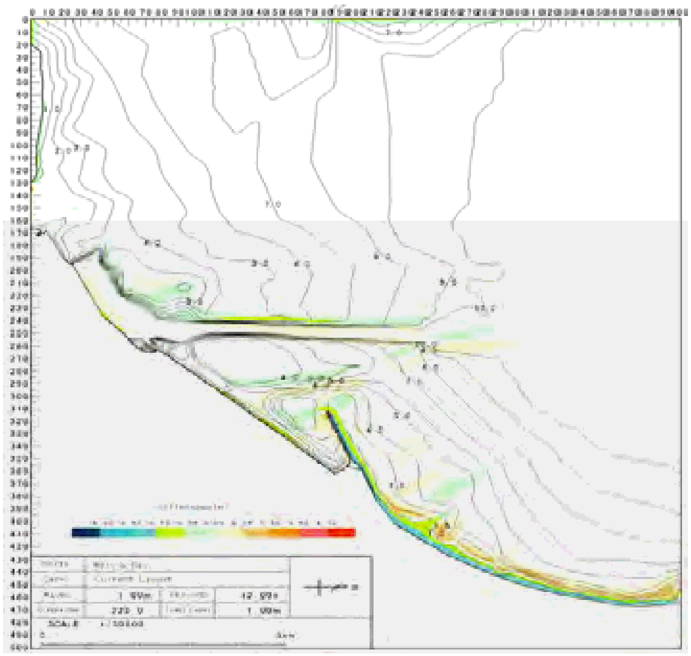


Figure 5.1.27 Variations of Sediment at the Present Bathymetry

(3) Estimations of Sedimentations about the Port Expansion Plans

The volume of sedimentations for the original expansion plan, alternative plan A and B are estimated. After simulations, the volume of sedimentations in the area of approach channels and turning basins, shown in Figures 5.1.28 to 5.1.30, are computed. The results of estimations are indicated in Table 5.1.5. The table shows that the annual sediments of the original plan, alternative plan A and B at phase 1 are 497,000 m^3/yaer, 626,000 m^3/year, 774,000 m^3/year, respectively. Among the master plans, the annual sediments of the original plan, alternative plan A and B are 611,000 m^3/year, 402,000 m^3/year, 604,000 m^3/year, respectively.

Phase 1 of original plan has less sediment than the alternative plan A and B. On the contrary, the master plan of alternative A has less than the original master plan and alternative plan B. That is why the master plan of alternative plan A is a reclamation layout which shelters from currents and waves.

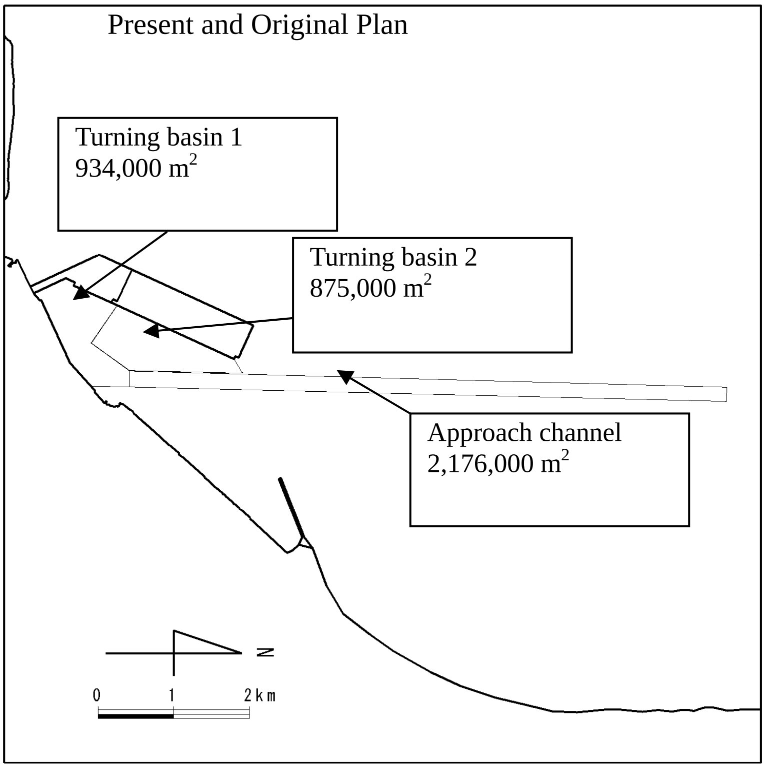


Figure 5.1.28 Area of Approach Channel and Turning Basin (The Present and Original Layout)

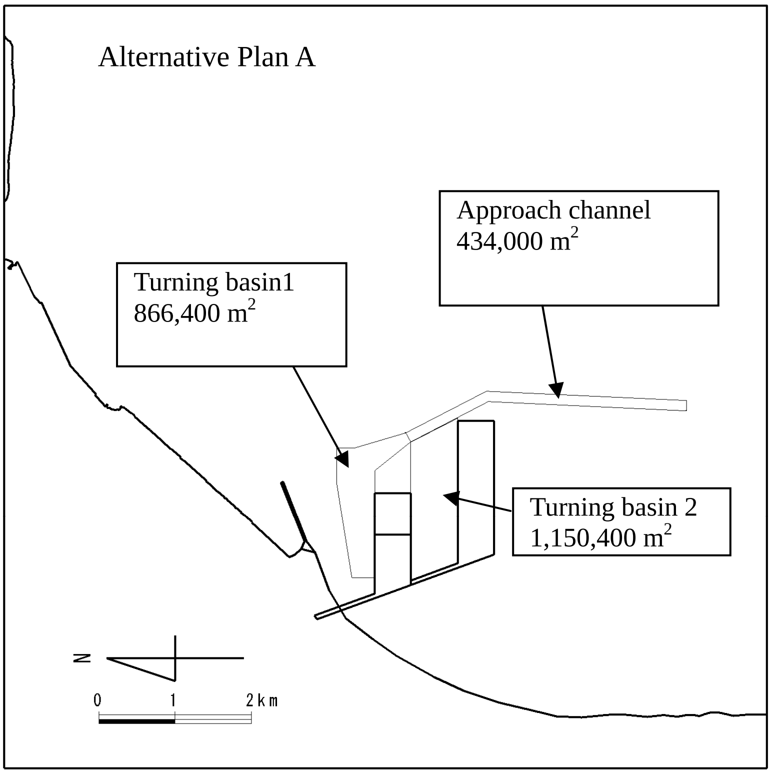


Figure 5.1.29 Area of Approach Channel and Turning Basin (Alternative Plan A)

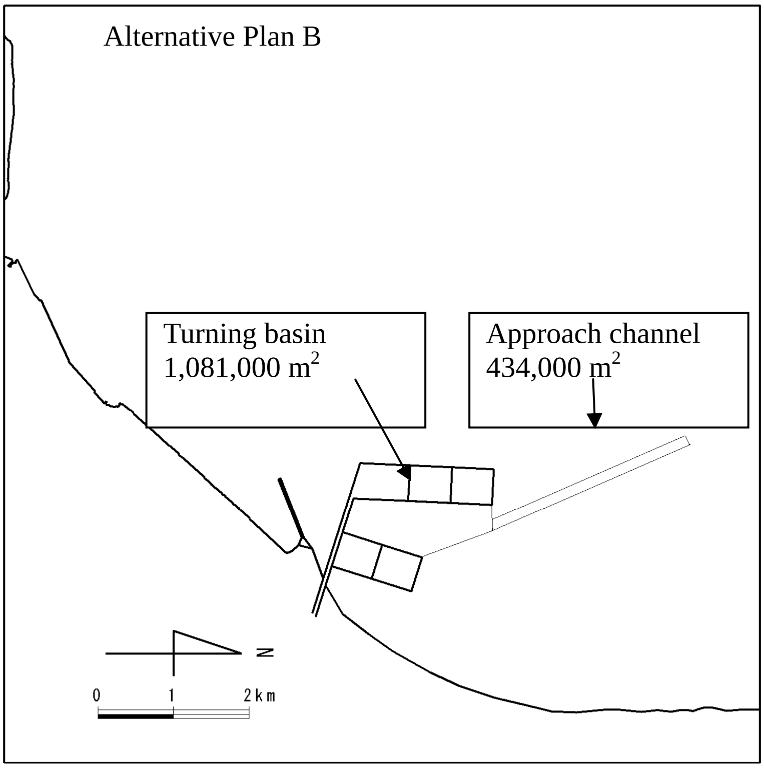


Figure 5.1.30 Area of Approach Channel and Turning Basin (Alternative Plan B)

Table 5.1.5 Sedimentation Results

Case	Area	Size (m^2)	Deposition (m^3/ 2 week)	Rate of deposition (cm/ 2 week)	Expected deposition (m^3/year)	Expected rate of deposition (cm/year)
Without projects	approach channel	2,176,000	14,749	0.68	358,892	16.55
Original Plan Phase 1	approach channel	2,176,000	19,100	0.88	464,767	21.41
	turning basin 1	934,000	1,320	0.14	32,120	3.41
Original Master Plan	approach channel	2,176,000	23,496	1.08	571,736	26.28
	turning basin 1	934,000	1,525	0.07	37,108	1.70
	turning basin 2	87,500	108	0.12	2,628	2.92
Alternative Plan A Phase 1	approach channel	596,400	16,578	2.78	403,398	67.65
	turning basin 1	643,200	9,152	1.42	222,699	34.55
Alternative Plan A Master Plan	approach channel	596,400	4,042	0.68	98,355	16.55
	turning basin 1	866,400	10,182	1.18	247,762	28.71
	turning basin 2	1,150,400	2,276	0.20	55,383	4.87
Alternative Plan B Phase 1	approach channel	434,000	16,578	3.82	403,398	92.95
	turning basin	1,081,000	15,218	1.41	370,305	34.31
Alternative Plan B Master Plan	approach channel	434,000	16,362	3.77	398,142	91.74
	turning basin	1,081,000	8,470	0.78	206,103	18.98

Source: JICA Study Team

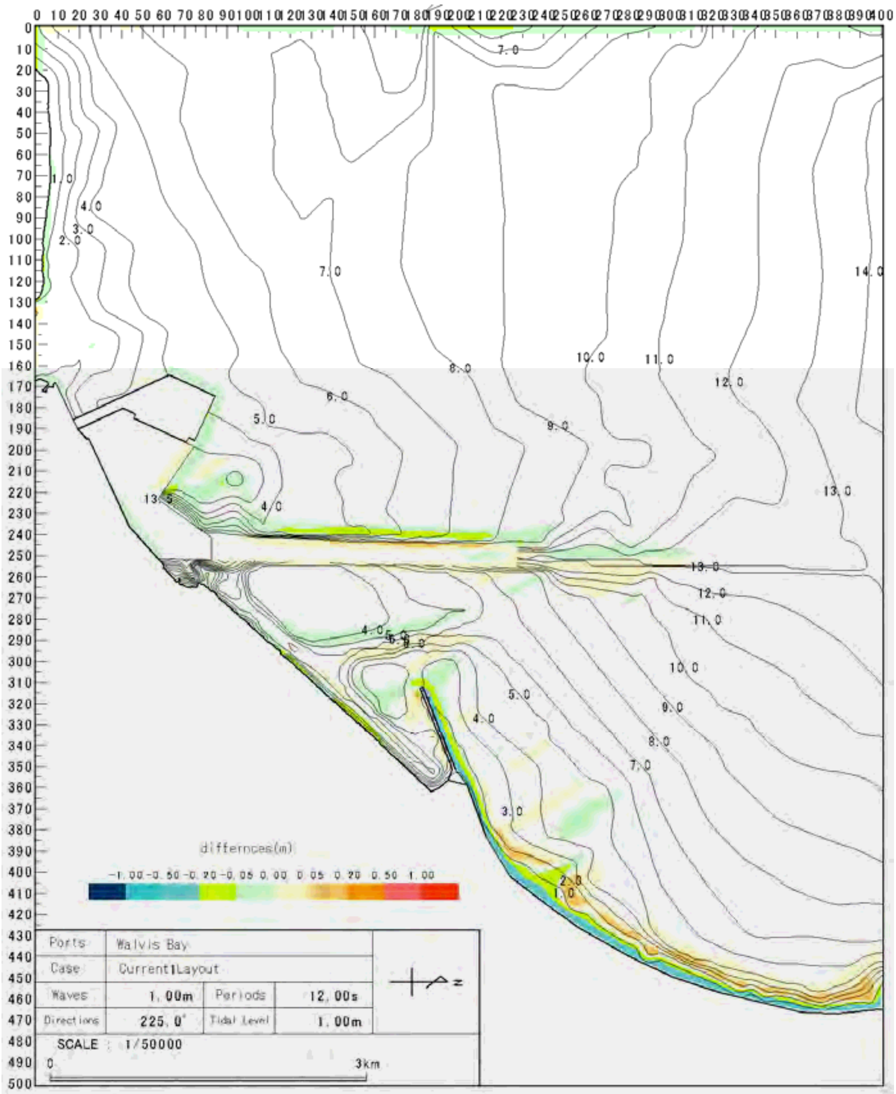


Figure 5.1.31 Variations of Sediments at Original Plan Phase 1

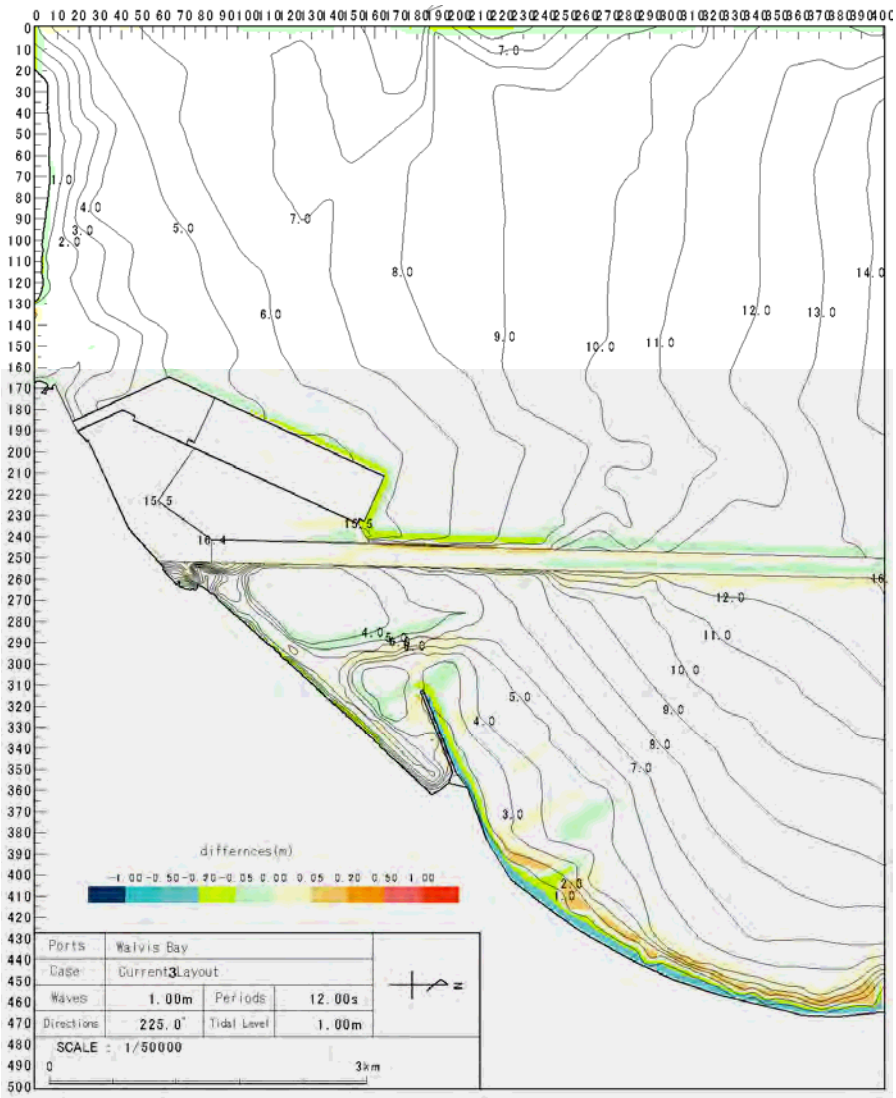


Figure 5.1.32 Variations of Sediments at Original Master Plan

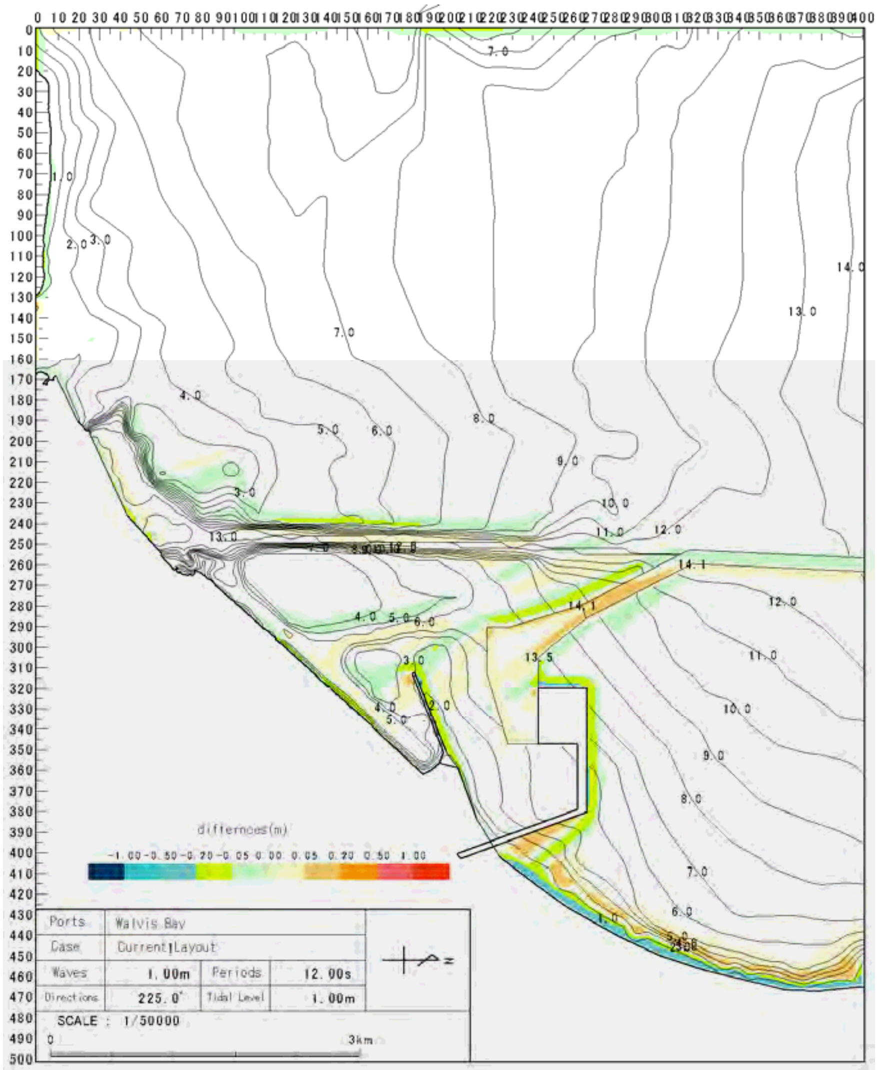


Figure 5.1.33 Variations of Sediments at Alternative Plan A Phase 1

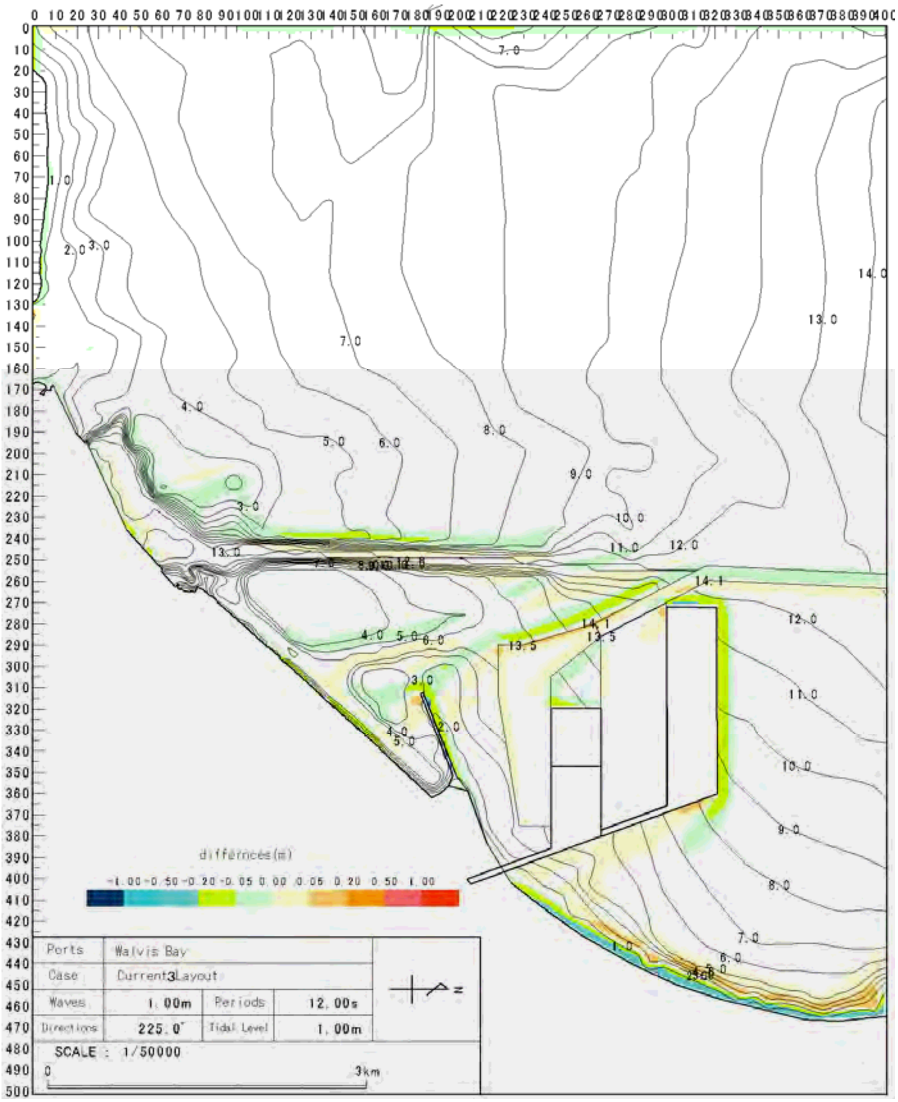


Figure 5.1.34 Variations of Sediments at Alternative Plan A Master Plan

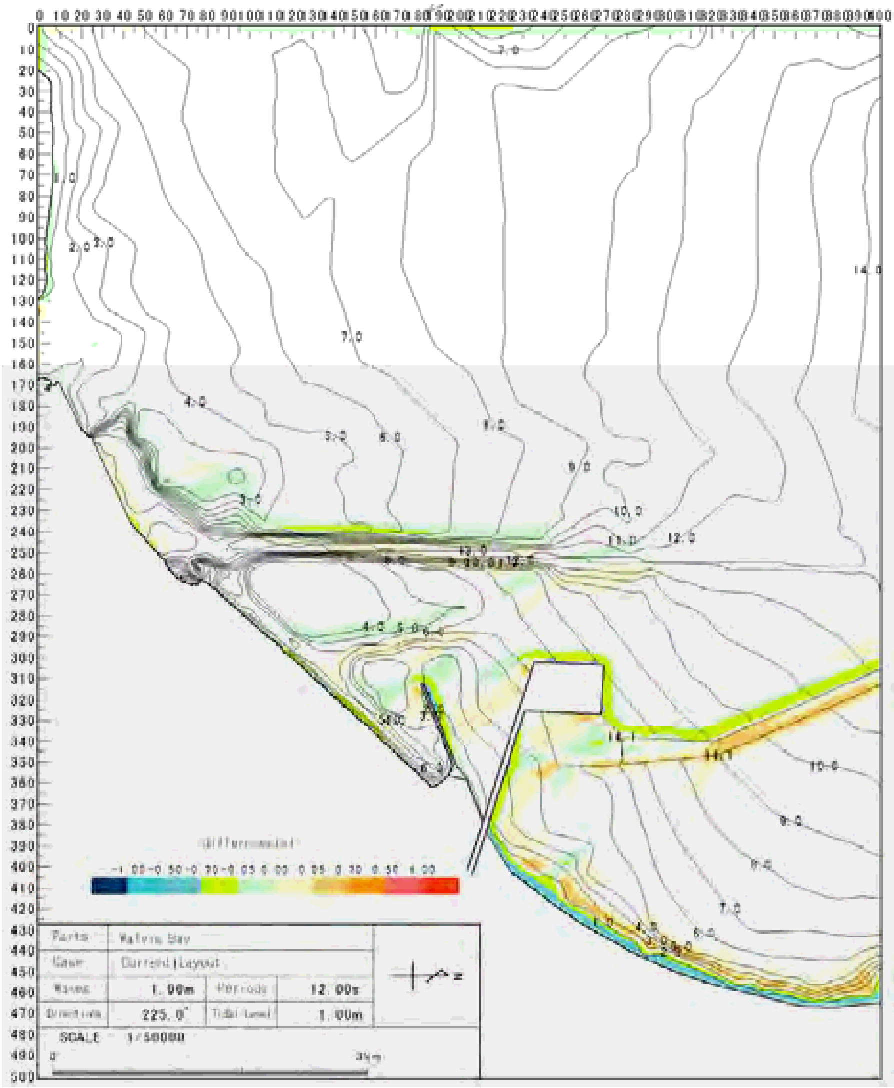


Figure 5.1.35 Variations of Sediments at Alternative Plan B Phase 1

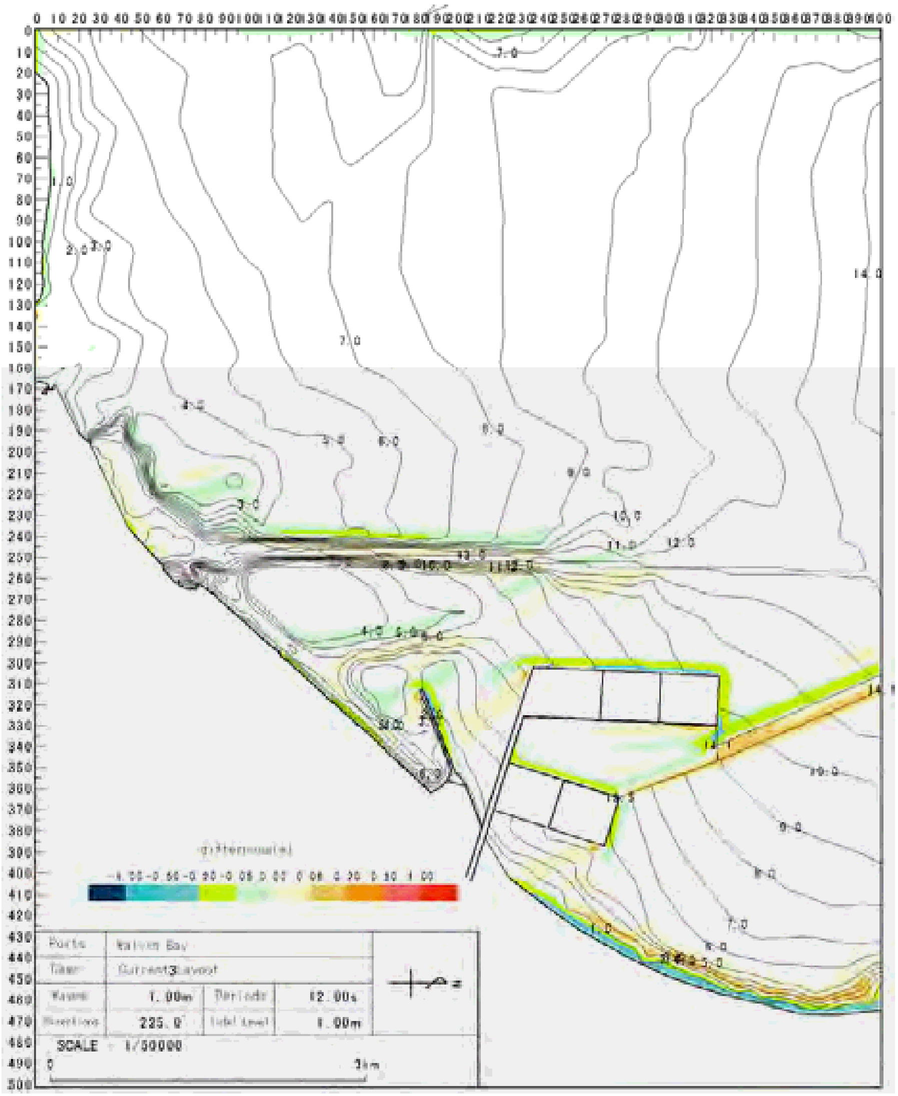


Figure 5.1.36 Variations of Sediments at Alternative Plan B Master Plan

5.1.4 Harbour Calmness of Contingent Alternatives

(1) Objective of Wave Simulation

Numerical simulations of wave transformation and deformation were carried out in the Port of Walvis Bay. Accuracy of the replication of the numerical simulation model was first verified. Then, harbour calmness was estimated for the Contingent Alternatives A and B and verified to meet the required operational rates of the berth of the container terminal.

(2) Simulation Method

1) Simulation Model

In this calculation, from the high seas outside of Walvis Bay to the mouth of the bay wave transformation was analysed by averaging the phases of individual wave spectrum in a continuity equation by applying an energy equilibrium equation which mainly analyses the wave deflection. Within the more confined area in the harbour of the port the Takayama method is used, as it can analyse wave refraction in more detail.

A simulation model composed of an energy equilibrium equation can numerically analyse the transport of the wave energy expressed in a directional spectrum when waves are progressing at places where the depth and topography are changed. This model is used to estimate the deflection and shoaling effects of irregular waves.

2) Calculation Assumptions/Conditions

In this calculation, in consideration of the waves that will affect the area, a depth of about 200 m was the area set for the calculation. The details of the calculations are shown below and displayed in the figure after that.

Table 5.1.6 Calculation Area
(Wide Area Calculation, Energy Equilibrium Equation Model)

	X-grid	Y-grid	Grid width
Area 1	226	166	100 m
Area 2	193	109	500 m
Area 3	112	60	2,000 m

Table 5.1.7 Calculation Area (Detailed Area Calculation, Takayama Method)

	X-grid	Y-grid	Grid width	Representative Depth
Area	165	109	500 m	−10 m

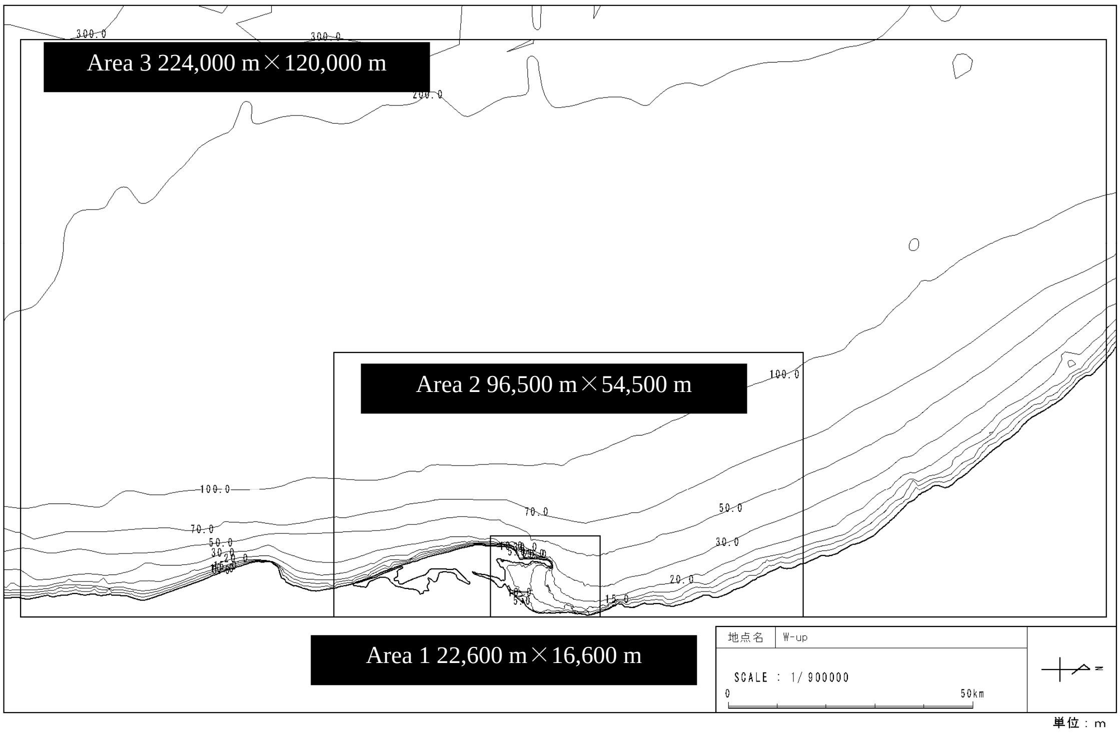


Figure 5.1.37 Calculation Area Map
(Wide Area Calculation, Energy Equilibrium Equation Model)

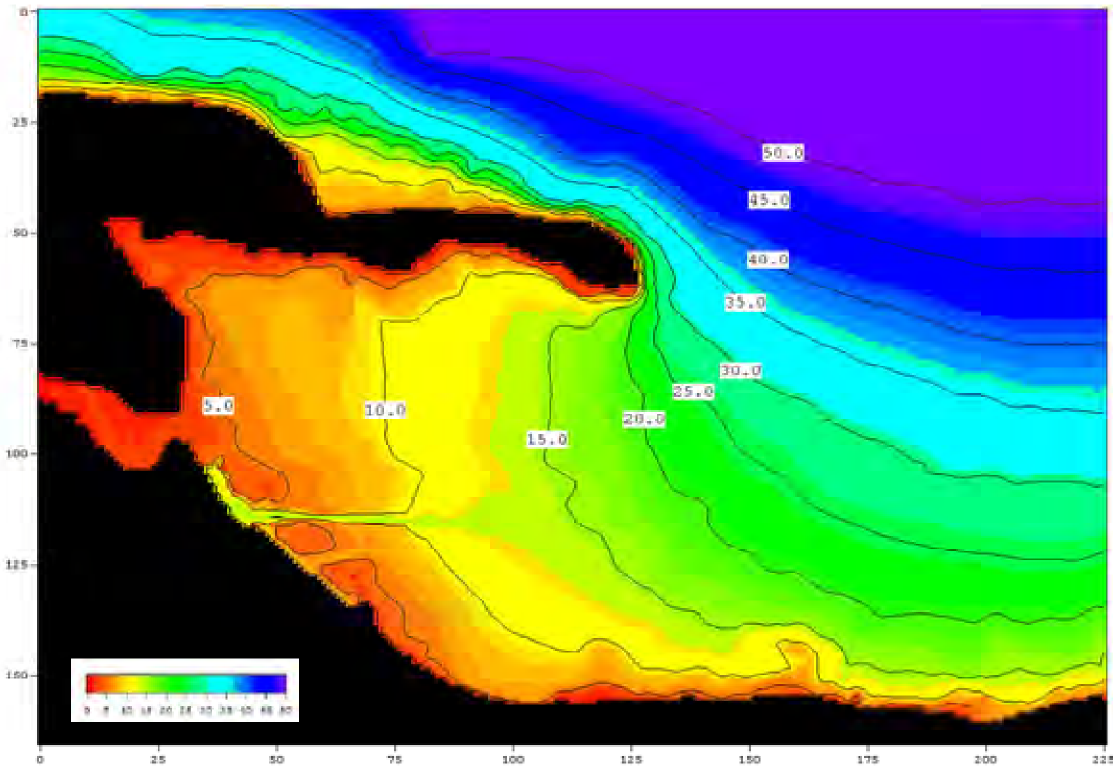


Figure 5.1.38 Area 1 Depth Chart (Wide Area Calculation, Depth in Meters)

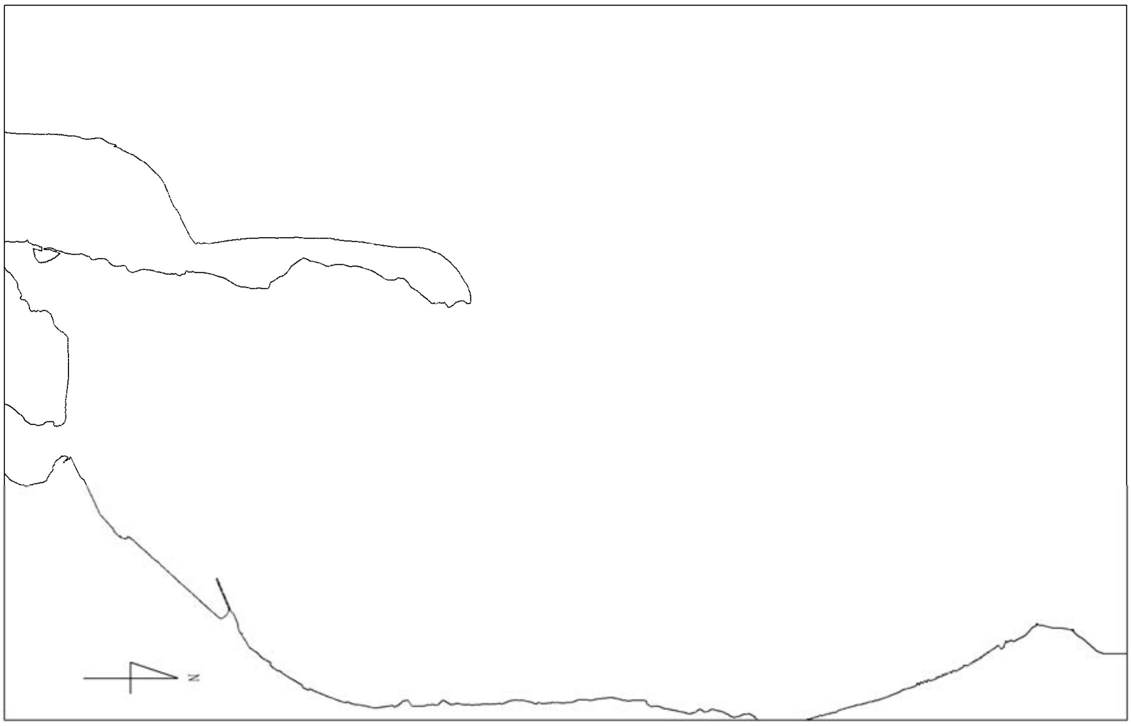


Figure 5.1.39 Calculation Area Map (Detailed Area Calculation, Takayama Method)

(3) Results of Observed Waves

1) Place of Observation

From June 20, 2009 to July 5, 2009 wave observations were implemented for a period of 15 days at the two points shown below.

Figure 5.1.40 Observation Site

2) Observation Results

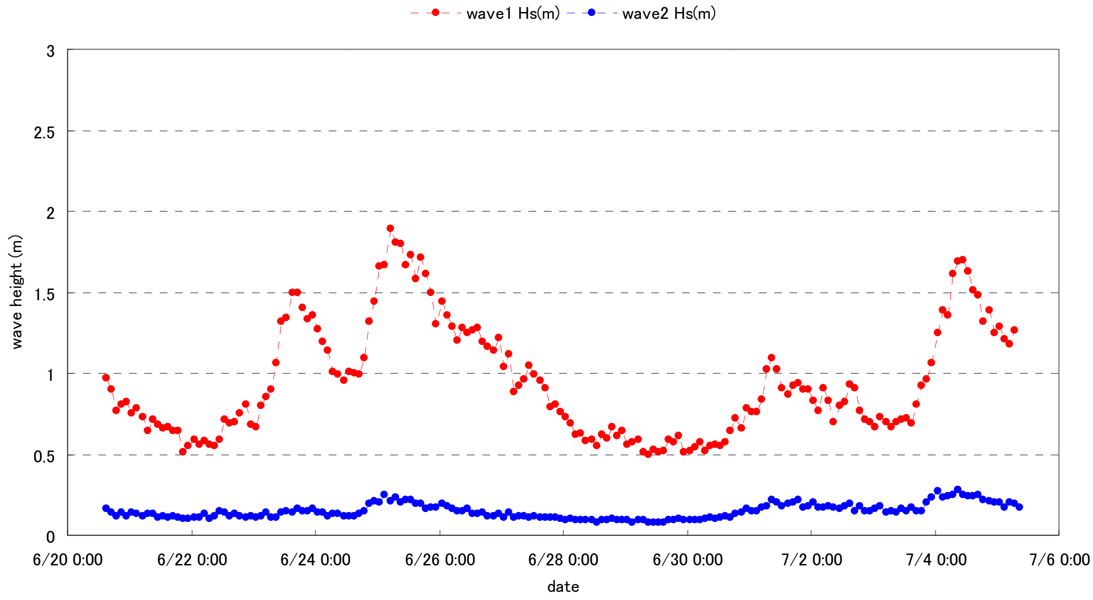


Figure 5.1.41 Time Series of Observed Wave Heights

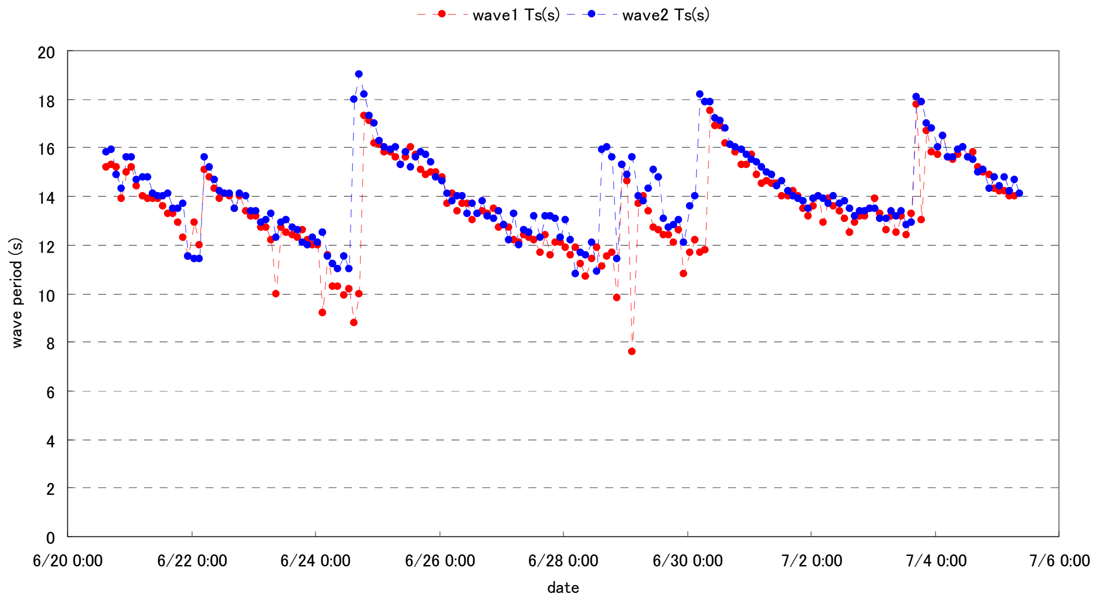


Figure 5.1.42 Time Series of Observed Wave Periods

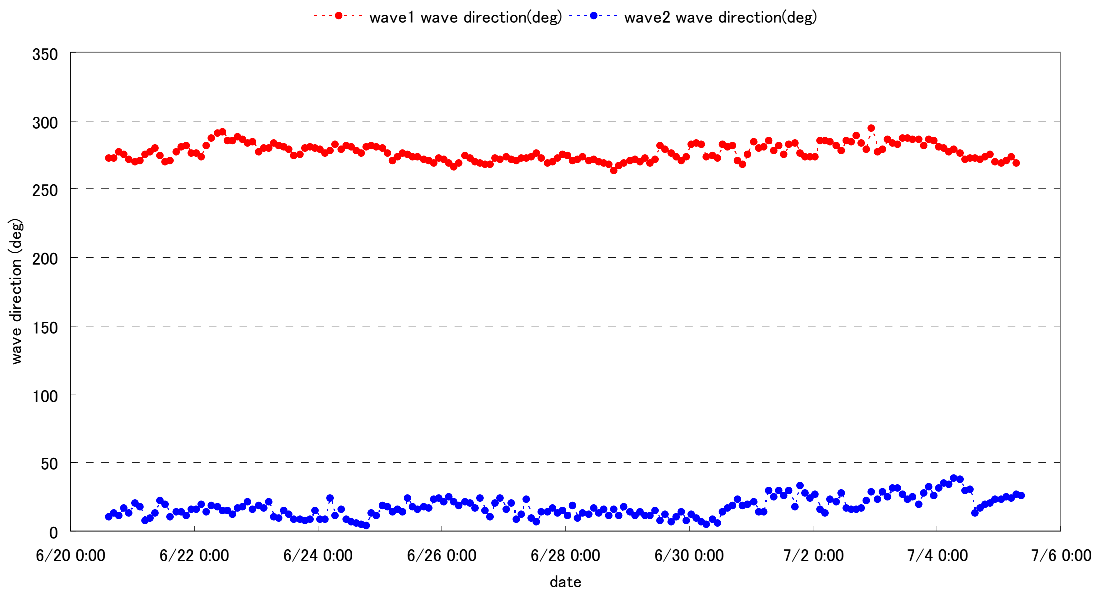


Figure 5.1.43 Time Series of Observed Wave Direction

3) Extraction of High Wave Occurrences

Within this observation period, the wave at WAVE1 had the largest height recorded on June 5, 2009 at 17:00 and calculations were based on this. The status of waves at that time is given in the table below.

Table 5.1.8 Largest Wave Recorded and Conditions

YYYY / MM / DD	HH	point	Hs	Ts	Dir
			(m)	(s)	(deg)
2009/6/25	05:00:00	wave1	1.89	15.8	270.1
		wave2	0.21	15.9	13.6

(4) Present Condition Replication Calculation

1) Calculation Conditions

The calculation conditions are shown below.

Table 5.1.9 Wave Incidence Conditions

YYYY / MM / DD	HH	point	Hs (m)	Ts (s)	Dir (deg)
2009/6/25	05:00:00	off shore	2.50	15.8	225
		wave1	1.89	15.8	270.1
		wave2	0.21	15.9	13.6

2) Calculation Results

<u>Wide-Area Calculation (Energy Equilibrium Equation Model)</u>

The result of the wide-area replication calculation is shown below.

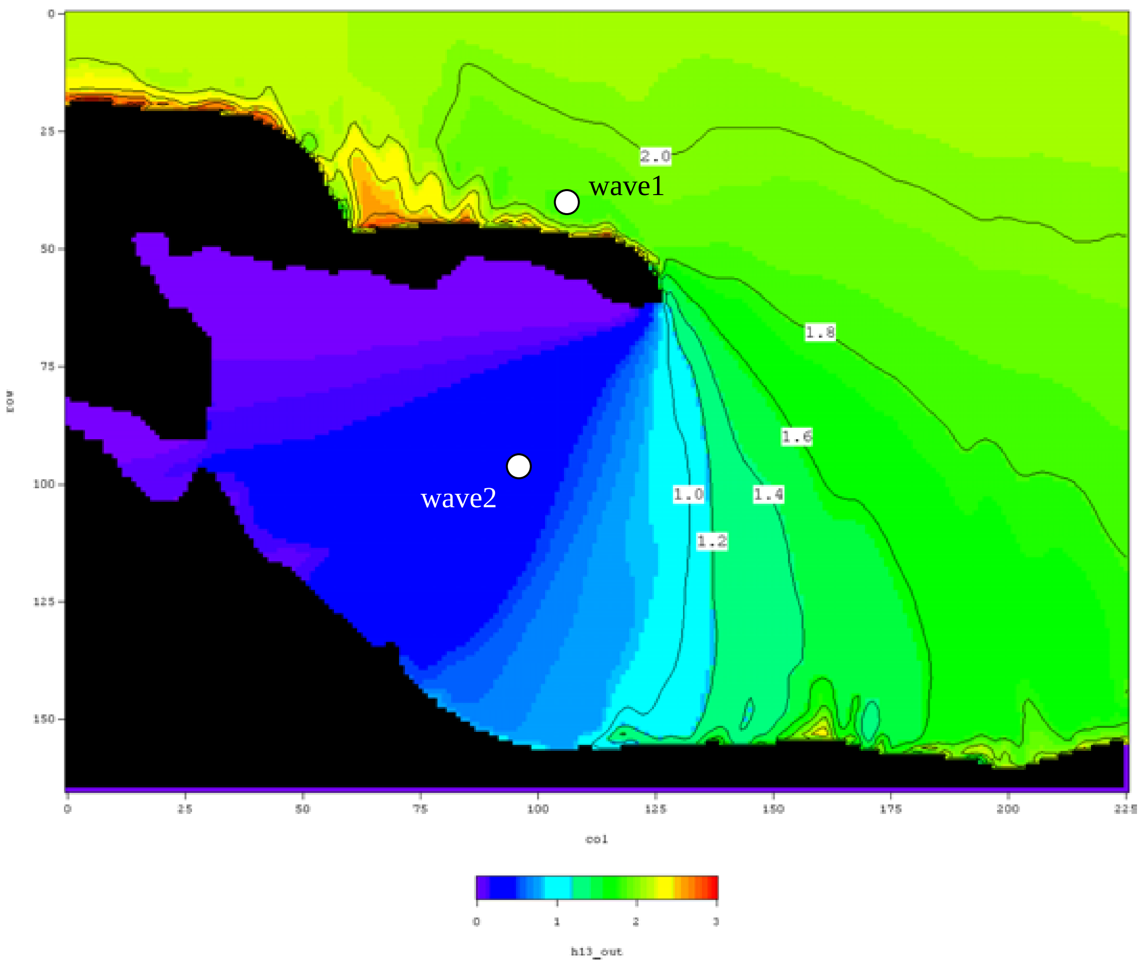


Figure 5.1.44 Wave Simulation Result (Energy Equilibrium Equation Model)

<u>Detailed-Area (Takayama Model)</u>

Detailed area calculation results are shown below.

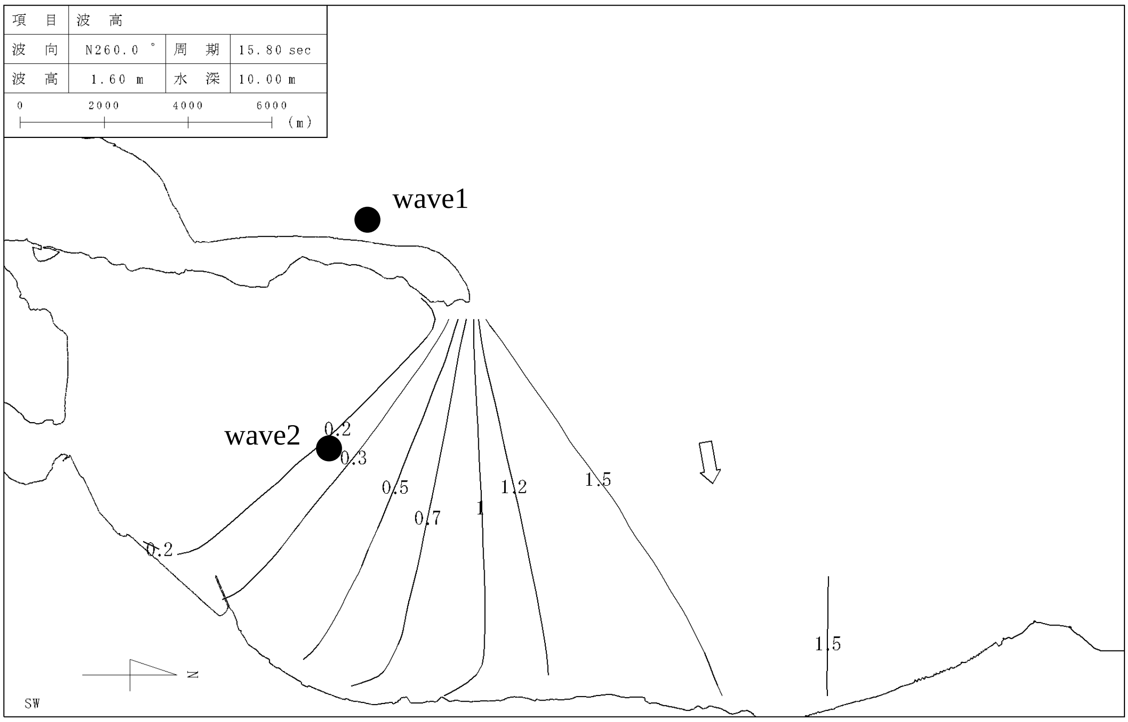


Figure 5.1.45 Wave Simulation Result (Takayama Model)

The incidence conditions and calculation results at WAVE1 and WAVE2 are summarized below. In the table below, calculations determine that the conditions at WAVE1 and WAVE2 are recurring phenomena. Using this model, wave predictions were made.

Table 5.1.10 Calculation Results

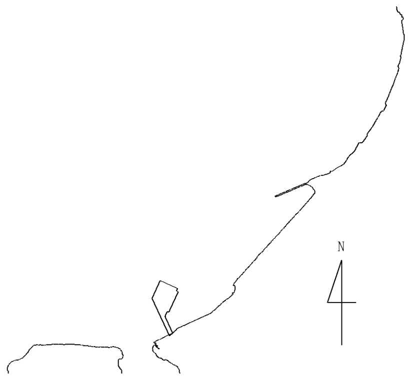
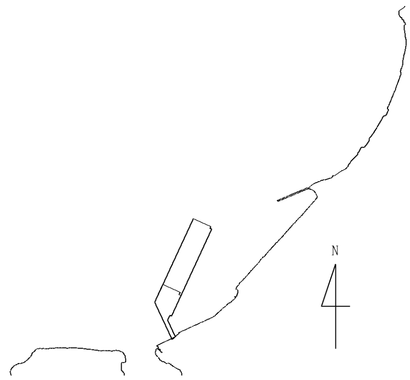
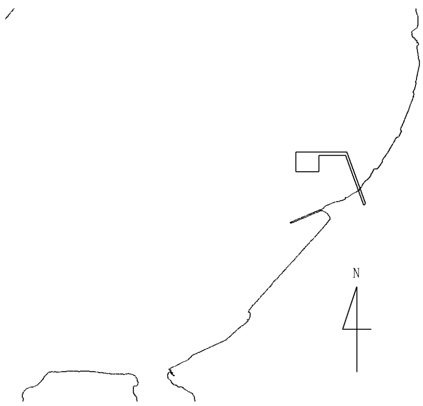
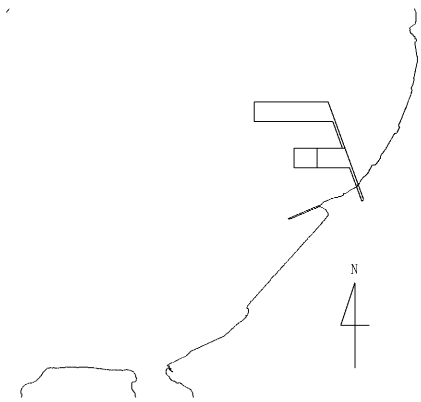
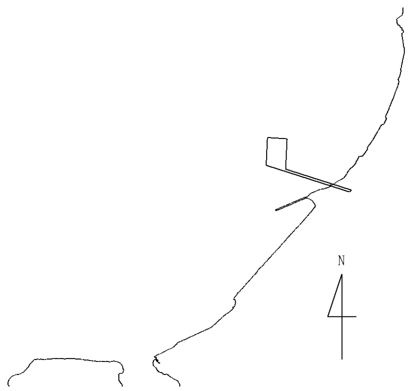
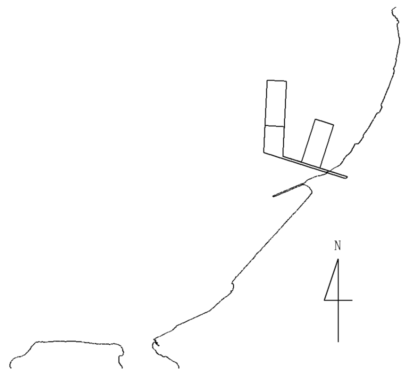
	Offshore			**Wave1**			**Wave2**		
	H1/3 (m)	**T1/3 (s)**	**Dir (deg)**	**H1/3 (m)**	**T1/3 (s)**	**Dir (deg)**	**H1/3 (m)**	**T1/3 (s)**	**Dir (deg)**
Input	2.5	15.8	225	—	—	—	—	—	—
Output	—	—	—	1.87	15.8	265	0.24	15.8	13.6
Observation	—	—	—	1.89	15.8	270	0.21	15.6	—
				OK			OK		

(5) Predicted Calculation

1) Relevant Harbour Shapes

The harbour shapes that are applicable to the present calculation are shown in the 6 harbour shapes below.

Table 5.1.11 Harbour Shapes for Calculation

	Phase 1	Master Plan
Original Plan		
Alternative Plan A		
Alternative Plan B		

(6) Calculation Conditions

1) Wave Statistical Analysis Data

In order to calculate the operational rate, it is required to observe at various points around the area to gain hindcasting data for statistical analyses. In the observation area, long-term observations are not available. Because of this, in the study area a 10 year data series from WW3 (Wave Watch III) was used for wave hindcasting. The tables below show the statistical process for the analysed data. Table 5.1.12 shows the number of occurrence in height and direction and Table 5.1.13 shows the frequency of occurrence of such waves. Table 5.1.13 shows the frequency of waves in period and direction.

Table 5.1.12 WW3 Statistical Analysis Data (Wave Height vs. Wave Direction)

	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	Total
0.0–1.0m			51	16	63	8		2		140
1.0–2.0m		2	2,412	3,247	4,688	330	2	9		10,697
2.0–3.0m		1	4,469	7,350	6,571	318				18,709
3.0–4.0m			1,186	2,817	2,116	46				6,165
4.0–5.0m			132	328	404					864
5.0–6.0m			9	56	30					95
6.0–7.0m			2		1					3
7.0–8.0m										
8.0–9.0m										
9.0–10.0m										
		3	8,261	13,814	13,873	702	2	11		36,673
	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	Total
1.0–2.0m		0.0%	6.6%	8.9%	12.8%	0.9%	0.0%	0.0%		29.2%
2.0–3.0m		0.0%	12.2%	20.0%	17.9%	0.9%				51.0%
3.0–4.0m			3.2%	7.7%	5.8%	0.1%				16.8%
4.0–5.0m			0.4%	0.9%	1.1%					2.4%
5.0–6.0m			0.0%	0.2%	0.1%					0.3%
6.0–7.0m			0.0%		0.0%					0.0%
7.0–8.0m										
8.0–9.0m										
9.0–10.0m										
		0.0%	22.4%	37.6%	37.7%	1.9%	0.0%	0.0%		100%

Table 5.1.13 WW3 Statistical Analysis Data (Wave Period vs. Wave Direction)

	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	Total
0.0–2.0s										
2.0–4.0s		0.0%	0.0%			0.0%				0.0%
4.0–6.0s		0.0%	2.7%	0.2%						3.0%
6.0–8.0s			11.3%	2.1%						13.4%
8.0–10.0s			7.5%	11.6%	1.7%	0.1%				21.0%
10.0–12.0s			0.8%	13.8%	15.3%	0.6%				30.5%
12.0–14.0s			0.1%	8.6%	17.3%	0.7%	0.0%	0.0%		26.8%
14.0–16.0s			0.0%	1.3%	3.2%	0.4%		0.0%		4.9%
16.0–18.0s				0.1%	0.3%	0.1%				0.5%
18.0–20.0s					0.0%					0.0%
		0.0%	22.5%	37.7%	37.8%	1.9%	0.0%	0.0%		100%

From the above data, it is observed that S, SSW, SW, and WSW make up about 99.9% of the wave directions. In addition, in the periodical band, the wave periods are divided into four bands, each represented with one period of time and the calculation conditions are set in the table below.

Table 5.1.14 Calculation Conditions

Periodical Band	Representative Wave Period	Wave Height	Wave	Smax
0~10s	10s	1.0 m	WSW / SW / SSW / S	25
10~12s	12s			
12s~14s	14s			
14s~20s	16s			

Note: "Smax" denotes directional spreading parameter of wave spectrum. Smax = 25 is applied for swell with a short attenuation distance.

2) Wide-Area Calculation (Energy Equilibrium Equation Model) Result

The wide-area calculation result of the energy equilibrium equation model is shown below. Based on this calculation result as the input data to the detailed area, the calculation is carried out with the Takayama Method to estimate the wave transformation result in the detailed area.

Table 5.1.15 Wide-Area Calculation Result

Input			result	
Wave Height (m)	Wave Period (s)	Direction	Ratio of H	Direction
1.0	10	WSW	0.69	269
1.0	10	SW	0.50	262
1.0	10	SSW	0.28	260
1.0	10	S	0.16	257
1.0	12	WSW	0.69	271
1.0	12	SW	0.52	264
1.0	12	SSW	0.32	262
1.0	12	S	0.19	260
1.0	14	WSW	0.70	273
1.0	14	SW	0.55	266
1.0	14	SSW	0.36	264
1.0	14	S	0.23	262
1.0	16	WSW	0.72	274
1.0	16	SW	0.58	268
1.0	16	SSW	0.40	266
1.0	16	S	0.27	264

3) Detailed Area Calculation (Takayama Method) Result

By use of the transformation result in the detailed area as well as the port expansion layouts of each alternative, the final wave transformation is simulated. The results are shown from Table 5.1.16 to 5.1.18.

Table 5.1.16 Original Plan

＜Phase1＞

Input				result
Wave Height (m)	Wave Period (s)	Direction	Direction (deg)	Ratio of H
1.0	10	WSW	269	0.09
1.0	10	SW	262	0.08
1.0	10	SSW	260	0.07
1.0	10	S	257	0.07
1.0	12	WSW	271	0.10
1.0	12	SW	264	0.09
1.0	12	SSW	262	0.08
1.0	12	S	260	0.08
1.0	14	WSW	273	0.11
1.0	14	SW	266	0.09
1.0	14	SSW	264	0.09
1.0	14	S	262	0.09
1.0	16	WSW	274	0.13
1.0	16	SW	268	0.10
1.0	16	SSW	266	0.10
1.0	16	S	264	0.09

＜Master Plan＞

Input				result
Wave Height (m)	Wave Period (s)	Direction	Direction (deg)	Ratio of H
1.0	10	WSW	269	0.18
1.0	10	SW	262	0.11
1.0	10	SSW	260	0.10
1.0	10	S	257	0.09
1.0	12	WSW	271	0.19
1.0	12	SW	264	0.13
1.0	12	SSW	262	0.11
1.0	12	S	260	0.10
1.0	14	WSW	273	0.22
1.0	14	SW	266	0.15
1.0	14	SSW	264	0.13
1.0	14	S	262	0.11
1.0	16	WSW	274	0.23
1.0	16	SW	268	0.17
1.0	16	SSW	266	0.15
1.0	16	S	264	0.13

Table 5.1.17 Alternative Plan A

＜Phase1＞

Input				result
Wave Height (m)	Wave Period (s)	Direction	Direction (deg)	Ratio of H
1.0	10	WSW	269	0.12
1.0	10	SW	262	0.09
1.0	10	SSW	260	0.08
1.0	10	S	257	0.07
1.0	12	WSW	271	0.16
1.0	12	SW	264	0.12
1.0	12	SSW	262	0.11
1.0	12	S	260	0.10
1.0	14	WSW	273	0.13
1.0	14	SW	266	0.10
1.0	14	SSW	264	0.09
1.0	14	S	262	0.08
1.0	16	WSW	274	0.14
1.0	16	SW	268	0.11
1.0	16	SSW	266	0.10
1.0	16	S	264	0.09

＜Master Plan＞

Input				result
Wave Height (m)	Wave Period (s)	Direction	Direction (deg)	Ratio of H
1.0	10	WSW	269	0.12
1.0	10	SW	262	0.09
1.0	10	SSW	260	0.08
1.0	10	S	257	0.07
1.0	12	WSW	271	0.13
1.0	12	SW	264	0.10
1.0	12	SSW	262	0.09
1.0	12	S	260	0.08
1.0	14	WSW	273	0.14
1.0	14	SW	266	0.11
1.0	14	SSW	264	0.10
1.0	14	S	262	0.09
1.0	16	WSW	274	0.15
1.0	16	SW	268	0.12
1.0	16	SSW	266	0.11
1.0	16	S	264	0.10

Table 5.1.18 Alternative Plan B

＜Phase1＞

Input				result
Wave Height (m)	Wave Period (s)	Direction	Direction (deg)	Ratio of H
1.0	10	WSW	269	0.33
1.0	10	SW	262	0.26
1.0	10	SSW	260	0.24
1.0	10	S	257	0.21
1.0	12	WSW	271	0.33
1.0	12	SW	264	0.26
1.0	12	SSW	262	0.24
1.0	12	S	260	0.22
1.0	14	WSW	273	0.36
1.0	14	SW	266	0.28
1.0	14	SSW	264	0.26
1.0	14	S	262	0.25
1.0	16	WSW	274	0.38
1.0	16	SW	268	0.30
1.0	16	SSW	266	0.28
1.0	16	S	264	0.26

＜Master Plan＞

Input				result
Wave Height (m)	Wave Period (s)	Direction	Direction (deg)	Ratio of H
1.0	10	WSW	269	0.41
1.0	10	SW	262	0.32
1.0	10	SSW	260	0.30
1.0	10	S	257	0.27
1.0	12	WSW	271	0.43
1.0	12	SW	264	0.35
1.0	12	SSW	262	0.32
1.0	12	S	260	0.30
1.0	14	WSW	273	0.47
1.0	14	SW	266	0.37
1.0	14	SSW	264	0.35
1.0	14	S	262	0.32
1.0	16	WSW	274	0.47
1.0	16	SW	268	0.38
1.0	16	SSW	266	0.36
1.0	16	S	264	0.34

4) Operational Rate Calculation

To examine the availability of the cargo handling at the berth, a value of 0.5 m (significant wave height) is referred to in "Technical Standards and Commentaries for Port and Harbour Facilities in Japan" for medium to large ships (500 GT–50,000 GT).[2] The occurrence rate of waves in front of the berth as the percentage of the waves exceeding this value should not be more the 2.5%. For practical purpose, 3 points are selected in front of the berth concerned in calculation.

In the table below, the Original Plan as well as the Alternative Plan A-Phase 1 and Master Plan meet the operation rate referred to the above, but for Alternative B-Phase 1 and Master Plan the operation rate are not met and breakwater must be installed to make the harbour calmer.

Table 5.1.19 Operational Summary

Layout	Berth Availability		Remarks
Original Plan Phase1	99.9%	> 97.5%	Satisfactory
Original Master Plan	99.7%	> 97.5%	Satisfactory
Alternative Plan A Phase1	99.9%	> 97.5%	Satisfactory
Alternative Plan A Master Plan	99.9%	> 97.5%	Satisfactory
Alternative Plan B Phase1	89.8%	< 97.5%	Need breakwaters
Alternative Plan B Master Plan	72.2%	< 97.5%	Need breakwaters

After the next page, each layout is described with operational availability details. The blue areas of the tables on the left fulfill the criterion referring to the tables on the right and sum of the frequency (%) of the blue areas brings the berth availability for each expansion plan.

2 Wave Height Criteria for Cargo Handling Limit
Criteria for the limit of undulating waves and long frequency waves in order to have no impact on cargo handling:

Ship Type	Cargo Handling Wave Limit ($H_{1/3}$)
Small Ship	0.3 m
Medium-Large Ship	0.5 m
Very Large Ship	0.7–1.5 m

Note: Here, small ships are those up to 500 GT anchored or moored in a port basin, very large ships are large ships that mainly use dolphin or sea berth mooring and can be up to and above 50,000 GT, medium-large ships are those other than small ships and very large ships.

Table 5.1.20 Original Plan Phase1 (Operation Rate: 99.9%)

T=0.0−10.0s

	S	SSW	SW	WSW	Total
0.0−1.0m	0.1%	0.0%	0.0%	0.0%	0.2%
1.0−2.0m	6.5%	4.2%	1.3%	0.1%	12.1%
2.0−3.0m	11.7%	7.4%	0.4%	0.0%	19.5%
3.0−4.0m	3.0%	2.2%	0.0%		5.2%
4.0−5.0m	0.2%	0.1%			0.3%
5.0−6.0m	0.0%	0.0%			0.0%
6.0−7.0m					
7.0−8.0m					
8.0−9.0m					
9.0−10.0m					
	21.6%	14.0%	1.7%	0.1%	37.4%

T=0.0−10.0s

	S	SSW	SW	WSW
0.0−1.0m	0.012	0.020	0.040	0.062
1.0−2.0m	0.023	0.039	0.080	0.124
2.0−3.0m	0.035	0.059	0.120	0.186
3.0−4.0m	0.047	0.078	0.160	0.248
4.0−5.0m	0.059	0.098	0.200	0.311
5.0−6.0m	0.070	0.118	0.240	0.373
6.0−7.0m	0.082	0.137	0.280	0.435
7.0−8.0m	0.094	0.157	0.320	0.497
8.0−9.0m	0.106	0.176	0.360	0.559
9.0−10.0m	0.117	0.196	0.400	0.621

T=10.0−12.0s

	S	SSW	SW	WSW	Total
0.0−1.0m	0.0%	0.0%	0.1%	0.0%	0.1%
1.0−2.0m	0.1%	3.5%	7.3%	0.4%	11.3%
2.0−3.0m	0.4%	7.9%	7.0%	0.2%	15.5%
3.0−4.0m	0.2%	2.2%	0.9%		3.3%
4.0−5.0m	0.1%	0.2%	0.0%		0.3%
5.0−6.0m	0.0%	0.0%			0.0%
6.0−7.0m	0.0%				0.0%
7.0−8.0m					
8.0−9.0m					
9.0−10.0m					
	0.8%	13.8%	15.3%	0.6%	30.5%

T=10.0−12.0s

	S	SSW	SW	WSW
0.0−1.0m	0.015	0.027	0.047	0.071
1.0−2.0m	0.030	0.053	0.094	0.143
2.0−3.0m	0.046	0.080	0.140	0.214
3.0−4.0m	0.061	0.107	0.187	0.285
4.0−5.0m	0.076	0.133	0.234	0.357
5.0−6.0m	0.091	0.160	0.281	0.428
6.0−7.0m	0.106	0.187	0.328	0.499
7.0−8.0m	0.122	0.213	0.374	0.570
8.0−9.0m	0.137	0.240	0.421	0.642
9.0−10.0m	0.152	0.267	0.468	0.713

T=12.0−14.0s

	S	SSW	SW	WSW	Total
0.0−1.0m		0.0%	0.0%	0.0%	0.0%
1.0−2.0m	0.0%	1.0%	3.7%	0.3%	4.9%
2.0−3.0m	0.0%	4.2%	9.1%	0.4%	13.8%
3.0−4.0m	0.1%	2.9%	3.8%	0.0%	6.8%
4.0−5.0m	0.0%	0.5%	0.6%		1.1%
5.0−6.0m		0.0%	0.0%		0.0%
6.0−7.0m					
7.0−8.0m					
8.0−9.0m					
9.0−10.0m					
	0.1%	8.6%	17.3%	0.7%	26.8%

T=12.0−14.0s

	S	SSW	SW	WSW
0.0−1.0m	0.021	0.032	0.050	0.077
1.0−2.0m	0.041	0.065	0.099	0.154
2.0−3.0m	0.062	0.097	0.149	0.231
3.0−4.0m	0.083	0.130	0.198	0.308
4.0−5.0m	0.104	0.162	0.248	0.385
5.0−6.0m	0.124	0.194	0.297	0.462
6.0−7.0m	0.145	0.227	0.347	0.539
7.0−8.0m	0.166	0.259	0.396	0.616
8.0−9.0m	0.186	0.292	0.446	0.693
9.0−10.0m	0.207	0.324	0.495	0.770

T=14.0s−

	S	SSW	SW	WSW	Total
0.0−1.0m		0.0%	0.0%	0.0%	0.0%
1.0−2.0m		0.1%	0.5%	0.1%	0.8%
2.0−3.0m		0.5%	1.5%	0.2%	2.2%
3.0−4.0m	0.0%	0.4%	1.1%	0.1%	1.6%
4.0−5.0m		0.1%	0.4%		0.6%
5.0−6.0m		0.1%	0.1%		0.2%
6.0−7.0m			0.0%		0.0%
7.0−8.0m					
8.0−9.0m					
9.0−10.0m					
	0.0%	1.3%	3.5%	0.5%	5.3%

T=14.0s−

	S	SSW	SW	WSW
0.0−1.0m	0.025	0.040	0.058	0.091
1.0−2.0m	0.050	0.080	0.116	0.182
2.0−3.0m	0.076	0.120	0.174	0.274
3.0−4.0m	0.101	0.160	0.232	0.365
4.0−5.0m	0.126	0.200	0.290	0.456
5.0−6.0m	0.151	0.240	0.348	0.547
6.0−7.0m	0.176	0.280	0.406	0.638
7.0−8.0m	0.202	0.320	0.464	0.730
8.0−9.0m	0.227	0.360	0.522	0.821
9.0−10.0m	0.252	0.400	0.580	0.912

Table 5.1.21 Original Master Plan (Operation Rate: 99.7%)

T=0.0–10.0s

	S	SSW	SW	WSW	Total
0.0–1.0m	0.1%	0.0%	0.0%	0.0%	0.2%
1.0–2.0m	6.5%	4.2%	1.3%	0.1%	12.1%
2.0–3.0m	11.7%	7.4%	0.4%	0.0%	19.5%
3.0–4.0m	3.0%	2.2%	0.0%		5.2%
4.0–5.0m	0.2%	0.1%			0.3%
5.0–6.0m	0.0%	0.0%			0.0%
6.0–7.0m					
7.0–8.0m					
8.0–9.0m					
9.0–10.0m					
	21.6%	14.0%	1.7%	0.1%	37.4%

T=0.0–10.0s

	S	SSW	SW	WSW
0.0–1.0m	0.014	0.027	0.055	0.122
1.0–2.0m	0.028	0.054	0.110	0.244
2.0–3.0m	0.042	0.081	0.165	0.366
3.0–4.0m	0.055	0.108	0.220	0.488
4.0–5.0m	0.069	0.135	0.275	0.610
5.0–6.0m	0.083	0.162	0.330	0.731
6.0–7.0m	0.097	0.189	0.385	0.853
7.0–8.0m	0.111	0.217	0.440	0.975
8.0–9.0m	0.125	0.244	0.495	1.097
9.0–10.0m	0.139	0.271	0.550	1.219

T=10.0–12.0s

	S	SSW	SW	WSW	Total
0.0–1.0m	0.0%	0.0%	0.1%	0.0%	0.1%
1.0–2.0m	0.1%	3.5%	7.3%	0.4%	11.3%
2.0–3.0m	0.4%	7.9%	7.0%	0.2%	15.5%
3.0–4.0m	0.2%	2.2%	0.9%		3.3%
4.0–5.0m	0.1%	0.2%	0.0%		0.3%
5.0–6.0m	0.0%	0.0%			0.0%
6.0–7.0m	0.0%				0.0%
7.0–8.0m					
8.0–9.0m					
9.0–10.0m					
	0.8%	13.8%	15.3%	0.6%	30.5%

T=10.0–12.0s

	S	SSW	SW	WSW
0.0–1.0m	0.018	0.036	0.066	0.133
1.0–2.0m	0.037	0.073	0.132	0.267
2.0–3.0m	0.055	0.109	0.198	0.400
3.0–4.0m	0.073	0.145	0.263	0.534
4.0–5.0m	0.092	0.181	0.329	0.667
5.0–6.0m	0.110	0.218	0.395	0.800
6.0–7.0m	0.129	0.254	0.461	0.934
7.0–8.0m	0.147	0.290	0.527	1.067
8.0–9.0m	0.165	0.326	0.593	1.201
9.0–10.0m	0.184	0.363	0.659	1.334

T=12.0–14.0s

	S	SSW	SW	WSW	Total
0.0–1.0m		0.0%	0.0%	0.0%	0.0%
1.0–2.0m	0.0%	1.0%	3.7%	0.3%	4.9%
2.0–3.0m	0.0%	4.2%	9.1%	0.4%	13.8%
3.0–4.0m	0.1%	2.9%	3.8%	0.0%	6.7%
4.0–5.0m	0.0%	0.5%	0.6%		1.1%
5.0–6.0m		0.0%	0.0%		0.0%
6.0–7.0m					
7.0–8.0m					
8.0–9.0m					
9.0–10.0m					
	0.1%	8.6%	17.3%	0.7%	26.7%

T=12.0–14.0s

	S	SSW	SW	WSW
0.0–1.0m	0.026	0.048	0.081	0.154
1.0–2.0m	0.052	0.096	0.161	0.308
2.0–3.0m	0.078	0.144	0.242	0.462
3.0–4.0m	0.104	0.192	0.323	0.616
4.0–5.0m	0.130	0.240	0.403	0.770
5.0–6.0m	0.156	0.288	0.484	0.924
6.0–7.0m	0.182	0.336	0.565	1.078
7.0–8.0m	0.209	0.384	0.645	1.232
8.0–9.0m	0.235	0.432	0.726	1.386
9.0–10.0m	0.261	0.480	0.807	1.540

T=14.0s–

	S	SSW	SW	WSW	Total
0.0–1.0m		0.0%	0.0%	0.0%	0.0%
1.0–2.0m		0.1%	0.5%	0.1%	0.8%
2.0–3.0m		0.5%	1.5%	0.2%	2.2%
3.0–4.0m	0.0%	0.4%	1.1%	0.1%	1.5%
4.0–5.0m		0.1%	0.4%		0.6%
5.0–6.0m		0.1%	0.1%		0.1%
6.0–7.0m			0.0%		
7.0–8.0m					
8.0–9.0m					
9.0–10.0m					
	0.0%	1.3%	3.5%	0.4%	5.2%

T=14.0s–

	S	SSW	SW	WSW
0.0–1.0m	0.036	0.060	0.099	0.166
1.0–2.0m	0.072	0.120	0.197	0.331
2.0–3.0m	0.108	0.180	0.296	0.497
3.0–4.0m	0.144	0.240	0.394	0.662
4.0–5.0m	0.180	0.300	0.493	0.828
5.0–6.0m	0.216	0.360	0.592	0.994
6.0–7.0m	0.252	0.420	0.690	1.159
7.0–8.0m	0.288	0.480	0.789	1.325
8.0–9.0m	0.324	0.540	0.887	1.490
9.0–10.0m	0.360	0.600	0.986	1.656

Table 5.1.22 Alternative Plan A Phase1 (Operation Rate: 99.9%)

T=0.0−10.0s

	S	SSW	SW	WSW	Total
0.0−1.0m	0.1%	0.0%	0.0%	0.0%	0.2%
1.0−2.0m	6.5%	4.2%	1.3%	0.1%	12.1%
2.0−3.0m	11.7%	7.4%	0.4%	0.0%	19.5%
3.0−4.0m	3.0%	2.2%	0.0%		5.2%
4.0−5.0m	0.2%	0.1%			0.3%
5.0−6.0m	0.0%	0.0%			0.0%
6.0−7.0m					
7.0−8.0m					
8.0−9.0m					
9.0−10.0m					
	21.6%	14.0%	1.7%	0.1%	37.4%

T=0.0−10.0s

	S	SSW	SW	WSW
0.0−1.0m	0.011	0.023	0.047	0.085
1.0−2.0m	0.022	0.047	0.093	0.170
2.0−3.0m	0.034	0.070	0.140	0.255
3.0−4.0m	0.045	0.093	0.187	0.340
4.0−5.0m	0.056	0.117	0.233	0.426
5.0−6.0m	0.067	0.140	0.280	0.511
6.0−7.0m	0.078	0.163	0.327	0.596
7.0−8.0m	0.090	0.187	0.373	0.681
8.0−9.0m	0.101	0.210	0.420	0.766
9.0−10.0m	0.112	0.233	0.467	0.851

T=10.0−12.0s

	S	SSW	SW	WSW	Total
0.0−1.0m	0.0%	0.0%	0.1%	0.0%	0.1%
1.0−2.0m	0.1%	3.5%	7.3%	0.4%	11.3%
2.0−3.0m	0.4%	7.9%	7.0%	0.2%	15.5%
3.0−4.0m	0.2%	2.2%	0.9%		3.3%
4.0−5.0m	0.1%	0.2%	0.0%		0.3%
5.0−6.0m	0.0%	0.0%			0.0%
6.0−7.0m	0.0%				0.0%
7.0−8.0m					
8.0−9.0m					
9.0−10.0m					
	0.8%	13.8%	15.3%	0.6%	30.5%

T=10.0−12.0s

	S	SSW	SW	WSW
0.0−1.0m	0.019	0.034	0.062	0.110
1.0−2.0m	0.038	0.068	0.125	0.221
2.0−3.0m	0.057	0.102	0.187	0.331
3.0−4.0m	0.076	0.137	0.250	0.442
4.0−5.0m	0.095	0.171	0.312	0.552
5.0−6.0m	0.114	0.205	0.374	0.662
6.0−7.0m	0.133	0.239	0.437	0.773
7.0−8.0m	0.152	0.273	0.499	0.883
8.0−9.0m	0.171	0.307	0.562	0.994
9.0−10.0m	0.190	0.341	0.624	1.104

T=12.0−14.0s

	S	SSW	SW	WSW	Total
0.0−1.0m		0.0%	0.0%	0.0%	0.0%
1.0−2.0m	0.0%	1.0%	3.7%	0.3%	4.9%
2.0−3.0m	0.0%	4.2%	9.1%	0.4%	13.8%
3.0−4.0m	0.1%	2.9%	3.8%	0.0%	6.8%
4.0−5.0m	0.0%	0.5%	0.6%		1.1%
5.0−6.0m		0.0%	0.0%		0.0%
6.0−7.0m					
7.0−8.0m					
8.0−9.0m					
9.0−10.0m					
	0.1%	8.6%	17.3%	0.7%	26.8%

T=12.0−14.0s

	S	SSW	SW	WSW
0.0−1.0m	0.018	0.034	0.053	0.091
1.0−2.0m	0.037	0.067	0.106	0.182
2.0−3.0m	0.055	0.101	0.160	0.273
3.0−4.0m	0.074	0.134	0.213	0.364
4.0−5.0m	0.092	0.168	0.266	0.455
5.0−6.0m	0.110	0.202	0.319	0.546
6.0−7.0m	0.129	0.235	0.372	0.637
7.0−8.0m	0.147	0.269	0.425	0.728
8.0−9.0m	0.166	0.302	0.479	0.819
9.0−10.0m	0.184	0.336	0.532	0.910

T=14.0s−

	S	SSW	SW	WSW	Total
0.0−1.0m		0.0%	0.0%	0.0%	0.0%
1.0−2.0m		0.1%	0.5%	0.1%	0.8%
2.0−3.0m		0.5%	1.5%	0.2%	2.2%
3.0−4.0m	0.0%	0.4%	1.1%	0.1%	1.6%
4.0−5.0m		0.1%	0.4%		0.6%
5.0−6.0m		0.1%	0.1%		0.2%
6.0−7.0m			0.0%		0.0%
7.0−8.0m					
8.0−9.0m					
9.0−10.0m					
	0.0%	1.3%	3.5%	0.5%	5.3%

T=14.0s−

	S	SSW	SW	WSW
0.0−1.0m	0.025	0.040	0.066	0.101
1.0−2.0m	0.050	0.080	0.131	0.202
2.0−3.0m	0.076	0.120	0.197	0.302
3.0−4.0m	0.101	0.160	0.263	0.403
4.0−5.0m	0.126	0.200	0.329	0.504
5.0−6.0m	0.151	0.240	0.394	0.605
6.0−7.0m	0.176	0.280	0.460	0.706
7.0−8.0m	0.202	0.320	0.526	0.806
8.0−9.0m	0.227	0.360	0.592	0.907
9.0−10.0m	0.252	0.400	0.657	1.008

Table 5.1.23 Alternative Plan A Master Plan (Operation Rate: 99.9%)

T=0.0–10.0s

	S	SSW	SW	WSW	Total
0.0–1.0m	0.1%	0.0%	0.0%	0.0%	0.2%
1.0–2.0m	6.5%	4.2%	1.3%	0.1%	12.1%
2.0–3.0m	11.7%	7.4%	0.4%	0.0%	19.5%
3.0–4.0m	3.0%	2.2%	0.0%		5.2%
4.0–5.0m	0.2%	0.1%			0.3%
5.0–6.0m	0.0%	0.0%			0.0%
6.0–7.0m					
7.0–8.0m					
8.0–9.0m					
9.0–10.0m					
	21.6%	14.0%	1.7%	0.1%	37.4%

T=0.0–10.0s

	S	SSW	SW	WSW
0.0–1.0m	0.011	0.023	0.045	0.085
1.0–2.0m	0.022	0.047	0.090	0.170
2.0–3.0m	0.034	0.070	0.135	0.255
3.0–4.0m	0.045	0.093	0.180	0.340
4.0–5.0m	0.056	0.117	0.225	0.426
5.0–6.0m	0.067	0.140	0.270	0.511
6.0–7.0m	0.078	0.163	0.315	0.596
7.0–8.0m	0.090	0.187	0.360	0.681
8.0–9.0m	0.101	0.210	0.405	0.766
9.0–10.0m	0.112	0.233	0.450	0.851

T=10.0–12.0s

	S	SSW	SW	WSW	Total
0.0–1.0m	0.0%	0.0%	0.1%	0.0%	0.1%
1.0–2.0m	0.1%	3.5%	7.3%	0.4%	11.3%
2.0–3.0m	0.4%	7.9%	7.0%	0.2%	15.5%
3.0–4.0m	0.2%	2.2%	0.9%		3.3%
4.0–5.0m	0.1%	0.2%	0.0%		0.3%
5.0–6.0m	0.0%	0.0%			0.0%
6.0–7.0m	0.0%				0.0%
7.0–8.0m					
8.0–9.0m					
9.0–10.0m					
	0.8%	13.8%	15.3%	0.6%	30.5%

T=10.0–12.0s

	S	SSW	SW	WSW
0.0–1.0m	0.016	0.029	0.050	0.087
1.0–2.0m	0.032	0.058	0.101	0.175
2.0–3.0m	0.048	0.086	0.151	0.262
3.0–4.0m	0.063	0.115	0.201	0.350
4.0–5.0m	0.079	0.144	0.251	0.437
5.0–6.0m	0.095	0.173	0.302	0.524
6.0–7.0m	0.111	0.202	0.352	0.612
7.0–8.0m	0.127	0.230	0.402	0.699
8.0–9.0m	0.143	0.259	0.452	0.787
9.0–10.0m	0.158	0.288	0.503	0.874

T=12.0–14.0s

	S	SSW	SW	WSW	Total
0.0–1.0m		0.0%	0.0%	0.0%	0.0%
1.0–2.0m	0.0%	1.0%	3.7%	0.3%	4.9%
2.0–3.0m	0.0%	4.2%	9.1%	0.4%	13.8%
3.0–4.0m	0.1%	2.9%	3.8%	0.0%	6.8%
4.0–5.0m	0.0%	0.5%	0.6%		1.1%
5.0–6.0m		0.0%	0.0%		0.0%
6.0–7.0m					
7.0–8.0m					
8.0–9.0m					
9.0–10.0m					
	0.1%	8.6%	17.3%	0.7%	26.8%

T=12.0–14.0s

	S	SSW	SW	WSW
0.0–1.0m	0.021	0.035	0.059	0.098
1.0–2.0m	0.043	0.070	0.117	0.196
2.0–3.0m	0.064	0.104	0.176	0.294
3.0–4.0m	0.086	0.139	0.235	0.392
4.0–5.0m	0.107	0.174	0.293	0.490
5.0–6.0m	0.129	0.209	0.352	0.588
6.0–7.0m	0.150	0.244	0.411	0.686
7.0–8.0m	0.172	0.278	0.469	0.784
8.0–9.0m	0.193	0.313	0.528	0.882
9.0–10.0m	0.215	0.348	0.587	0.980

T=14.0s–

	S	SSW	SW	WSW	Total
0.0–1.0m		0.0%	0.0%	0.0%	0.0%
1.0–2.0m		0.1%	0.5%	0.1%	0.8%
2.0–3.0m		0.5%	1.5%	0.2%	2.2%
3.0–4.0m	0.0%	0.4%	1.1%	0.1%	1.6%
4.0–5.0m		0.1%	0.4%		0.6%
5.0–6.0m		0.1%	0.1%		0.2%
6.0–7.0m			0.0%		0.0%
7.0–8.0m					
8.0–9.0m					
9.0–10.0m					
	0.0%	1.3%	3.5%	0.5%	5.3%

T=14.0s–

	S	SSW	SW	WSW
0.0–1.0m	0.027	0.043	0.070	0.106
1.0–2.0m	0.054	0.085	0.139	0.211
2.0–3.0m	0.081	0.128	0.209	0.317
3.0–4.0m	0.108	0.171	0.278	0.422
4.0–5.0m	0.135	0.213	0.348	0.528
5.0–6.0m	0.162	0.256	0.418	0.634
6.0–7.0m	0.189	0.299	0.487	0.739
7.0–8.0m	0.216	0.341	0.557	0.845
8.0–9.0m	0.243	0.384	0.626	0.950
9.0–10.0m	0.270	0.427	0.696	1.056

Table 5.1.24 Alternative Plan B Phase1 (Operation Rate: 89.8%)

T=0.0–10.0s

	S	SSW	SW	WSW	Total
0.0–1.0m	0.1%	0.0%	0.0%	0.0%	0.2%
1.0–2.0m	6.5%	4.2%	1.3%	0.1%	12.1%
2.0–3.0m	11.7%	7.4%	0.4%	0.0%	19.5%
3.0–4.0m	3.0%	2.2%	0.0%		5.2%
4.0–5.0m	0.2%	0.1%			0.3%
5.0–6.0m	0.0%	0.0%			0.0%
6.0–7.0m					
7.0–8.0m					
8.0–9.0m					
9.0–10.0m					
	21.6%	14.0%	1.7%	0.1%	37.4%

T=0.0–10.0s

	S	SSW	SW	WSW
0.0–1.0m	0.033	0.066	0.128	0.230
1.0–2.0m	0.066	0.133	0.257	0.460
2.0–3.0m	0.099	0.199	0.385	0.690
3.0–4.0m	0.132	0.265	0.513	0.920
4.0–5.0m	0.165	0.331	0.642	1.150
5.0–6.0m	0.198	0.398	0.770	1.380
6.0–7.0m	0.231	0.464	0.898	1.610
7.0–8.0m	0.265	0.530	1.027	1.840
8.0–9.0m	0.298	0.596	1.155	2.070
9.0–10.0m	0.331	0.663	1.283	2.300

T=10.0–12.0s

	S	SSW	SW	WSW	Total
0.0–1.0m	0.0%	0.0%	0.1%	0.0%	0.1%
1.0–2.0m	0.1%	3.5%	7.3%	0.4%	11.3%
2.0–3.0m	0.4%	7.9%	7.0%	0.2%	15.3%
3.0–4.0m	0.2%	2.2%	0.9%		2.4%
4.0–5.0m	0.1%	0.2%	0.0%		0.3%
5.0–6.0m	0.0%	0.0%			0.0%
6.0–7.0m	0.0%				0.0%
7.0–8.0m					
8.0–9.0m					
9.0–10.0m					
	0.8%	13.8%	14.3%	0.4%	29.3%

T=10.0–12.0s

	S	SSW	SW	WSW
0.0–1.0m	0.042	0.078	0.135	0.230
1.0–2.0m	0.084	0.156	0.270	0.460
2.0–3.0m	0.125	0.234	0.406	0.690
3.0–4.0m	0.167	0.311	0.541	0.920
4.0–5.0m	0.209	0.389	0.676	1.150
5.0–6.0m	0.251	0.467	0.811	1.380
6.0–7.0m	0.293	0.545	0.946	1.610
7.0–8.0m	0.334	0.623	1.082	1.840
8.0–9.0m	0.376	0.701	1.217	2.070
9.0–10.0m	0.418	0.779	1.352	2.300

T=12.0–14.0s

	S	SSW	SW	WSW	Total
0.0–1.0m		0.0%	0.0%	0.0%	0.0%
1.0–2.0m	0.0%	1.0%	3.7%	0.3%	4.7%
2.0–3.0m	0.0%	4.2%	9.1%	0.4%	13.4%
3.0–4.0m	0.1%	2.9%	3.8%	0.0%	2.9%
4.0–5.0m	0.0%	0.5%	0.6%		0.5%
5.0–6.0m		0.0%	0.0%		
6.0–7.0m					
7.0–8.0m					
8.0–9.0m					
9.0–10.0m					
	0.1%	8.6%	12.8%	0.0%	21.6%

T=12.0–14.0s

	S	SSW	SW	WSW
0.0–1.0m	0.058	0.094	0.156	0.254
1.0–2.0m	0.115	0.187	0.312	0.509
2.0–3.0m	0.173	0.281	0.468	0.763
3.0–4.0m	0.230	0.374	0.623	1.017
4.0–5.0m	0.288	0.468	0.779	1.272
5.0–6.0m	0.345	0.562	0.935	1.526
6.0–7.0m	0.403	0.655	1.091	1.780
7.0–8.0m	0.460	0.749	1.247	2.035
8.0–9.0m	0.518	0.842	1.403	2.289
9.0–10.0m	0.575	0.936	1.558	2.543

T=14.0s–

	S	SSW	SW	WSW	Total
0.0–1.0m		0.0%	0.0%	0.0%	0.0%
1.0–2.0m		0.1%	0.5%	0.1%	0.6%
2.0–3.0m		0.5%	1.5%	0.2%	0.5%
3.0–4.0m	0.0%	0.4%	1.1%	0.1%	0.4%
4.0–5.0m		0.1%	0.4%		
5.0–6.0m		0.1%	0.1%		
6.0–7.0m			0.0%		
7.0–8.0m					
8.0–9.0m					
9.0–10.0m					
	0.0%	1.1%	0.5%	0.0%	1.6%

T=14.0s–

	S	SSW	SW	WSW
0.0–1.0m	0.071	0.113	0.176	0.271
1.0–2.0m	0.142	0.227	0.352	0.542
2.0–3.0m	0.213	0.340	0.528	0.814
3.0–4.0m	0.284	0.453	0.704	1.085
4.0–5.0m	0.356	0.567	0.880	1.356
5.0–6.0m	0.427	0.680	1.056	1.627
6.0–7.0m	0.498	0.793	1.232	1.898
7.0–8.0m	0.569	0.907	1.407	2.170
8.0–9.0m	0.640	1.020	1.583	2.441
9.0–10.0m	0.711	1.133	1.759	2.712

Table 5.1.25 Alternative Plan B Master Plan (Operation Rate: 72.2%)

T=0.0–10.0s

	S	SSW	SW	WSW	Total
0.0–1.0m	0.1%	0.0%	0.0%	0.0%	0.2%
1.0–2.0m	6.5%	4.2%	1.3%	0.1%	12.0%
2.0–3.0m	11.7%	7.4%	0.4%	0.0%	19.5%
3.0–4.0m	3.0%	2.2%	0.0%		5.2%
4.0–5.0m	0.2%	0.1%			0.3%
5.0–6.0m	0.0%	0.0%			0.0%
6.0–7.0m					
7.0–8.0m					
8.0–9.0m					
9.0–10.0m					
	21.6%	14.0%	1.7%	0.0%	37.3%

T=0.0–10.0s

	S	SSW	SW	WSW
0.0–1.0m	0.043	0.084	0.160	0.281
1.0–2.0m	0.085	0.168	0.320	0.561
2.0–3.0m	0.128	0.252	0.480	0.842
3.0–4.0m	0.171	0.336	0.640	1.122
4.0–5.0m	0.213	0.420	0.800	1.403
5.0–6.0m	0.256	0.504	0.960	1.684
6.0–7.0m	0.299	0.588	1.120	1.964
7.0–8.0m	0.341	0.672	1.280	2.245
8.0–9.0m	0.384	0.756	1.440	2.525
9.0–10.0m	0.427	0.840	1.600	2.806

T=10.0–12.0s

	S	SSW	SW	WSW	Total
0.0–1.0m	0.0%	0.0%	0.1%	0.0%	0.1%
1.0–2.0m	0.1%	3.5%	7.3%	0.4%	10.9%
2.0–3.0m	0.4%	7.9%	7.0%	0.2%	8.3%
3.0–4.0m	0.2%	2.2%	0.9%		2.4%
4.0–5.0m	0.1%	0.2%	0.0%		0.1%
5.0–6.0m	0.0%	0.0%			0.0%
6.0–7.0m	0.0%				0.0%
7.0–8.0m					
8.0–9.0m					
9.0–10.0m					
	0.8%	13.6%	7.3%	0.0%	21.8%

T=10.0–12.0s

	S	SSW	SW	WSW
0.0–1.0m	0.056	0.102	0.180	0.299
1.0–2.0m	0.113	0.205	0.361	0.598
2.0–3.0m	0.169	0.307	0.541	0.897
3.0–4.0m	0.225	0.410	0.721	1.196
4.0–5.0m	0.282	0.512	0.901	1.495
5.0–6.0m	0.338	0.614	1.082	1.794
6.0–7.0m	0.395	0.717	1.262	2.093
7.0–8.0m	0.451	0.819	1.442	2.392
8.0–9.0m	0.507	0.922	1.622	2.691
9.0–10.0m	0.564	1.024	1.803	2.990

T=12.0–14.0s

	S	SSW	SW	WSW	Total
0.0–1.0m		0.0%	0.0%	0.0%	0.0%
1.0–2.0m	0.0%	1.0%	3.7%	0.3%	4.7%
2.0–3.0m	0.0%	4.2%	9.1%	0.4%	4.3%
3.0–4.0m	0.1%	2.9%	3.8%	0.0%	2.9%
4.0–5.0m	0.0%	0.5%	0.6%		0.0%
5.0–6.0m		0.0%	0.0%		
6.0–7.0m					
7.0–8.0m					
8.0–9.0m					
9.0–10.0m					
	0.1%	8.1%	3.8%	0.0%	12.0%

T=12.0–14.0s

	S	SSW	SW	WSW
0.0–1.0m	0.074	0.125	0.202	0.327
1.0–2.0m	0.147	0.250	0.403	0.653
2.0–3.0m	0.221	0.374	0.605	0.980
3.0–4.0m	0.294	0.499	0.807	1.307
4.0–5.0m	0.368	0.624	1.008	1.633
5.0–6.0m	0.442	0.749	1.210	1.960
6.0–7.0m	0.515	0.874	1.412	2.287
7.0–8.0m	0.589	0.998	1.613	2.613
8.0–9.0m	0.662	1.123	1.815	2.940
9.0–10.0m	0.736	1.248	2.017	3.267

T=14.0s–

	S	SSW	SW	WSW	Total
0.0–1.0m		0.0%	0.0%	0.0%	0.0%
1.0–2.0m		0.1%	0.5%	0.1%	0.6%
2.0–3.0m		0.5%	1.5%	0.2%	0.5%
3.0–4.0m	0.0%	0.4%	1.1%	0.1%	0.0%
4.0–5.0m		0.1%	0.4%		
5.0–6.0m		0.1%	0.1%		
6.0–7.0m			0.0%		
7.0–8.0m					
8.0–9.0m					
9.0–10.0m					
	0.0%	0.6%	0.5%	0.0%	1.1%

T=14.0s–

	S	SSW	SW	WSW
0.0–1.0m	0.091	0.145	0.222	0.338
1.0–2.0m	0.182	0.291	0.445	0.677
2.0–3.0m	0.273	0.436	0.667	1.015
3.0–4.0m	0.364	0.581	0.889	1.354
4.0–5.0m	0.455	0.727	1.112	1.692
5.0–6.0m	0.545	0.872	1.334	2.030
6.0–7.0m	0.636	1.017	1.556	2.369
7.0–8.0m	0.727	1.163	1.779	2.707
8.0–9.0m	0.818	1.308	2.001	3.046
9.0–10.0m	0.909	1.453	2.223	3.384

5.1.5 Usability of Contingent Alternatives

(1) Ship Manoeuvrability

The direction of the new approach channel of Alternatives B and C is south-southwest. Meanwhile the existing approach channel for Alternative A lies almost directly to the south. The straight lengths of Alternatives A, B and C are 2,600 m, 2,800 m and 2,300 m, respectively. As the prevailing winds blow from the south and each straight length is sufficiently long for an 8,000 TEU container vessel to stop, there is no significant difference among the alternatives in manoeuvring ships from the entrance to the turning basins.

As the ship will be controlled with tugboats at the turning basin, there is no significant difference in ship manoeuvring there. Berthing, however, in case of Alternative A will be more difficult in comparison with Alternatives B and C, as the prevailing winds blow from the south to the ship's hull. Tug control has to be carefully carried out when berthing in case of Alternative A.

(2) Berth Availability

It is standard to express the occurrence rate of waves in harbour as the percentage of the waves exceeding a certain height. For the berth availability of the alternatives with respect to the calmness of the harbour, 3 points are selected in front of the berth in question at both ends and the centre. The availability criterion set forth with berths to accommodate 500 GT to 50,000 GT vessels is an availability percentage of more than 97.5 % with respect to waves of 0.5 m height.

The results of the numerical simulation of waves are shown in Table 5.1.26.

Table 5.1.26 Numerical Simulation of Waves

Port Expansion		Berth Availability	Remarks
Original	Phase 1 Berth	99.9%	Satisfactory
	Master Plan	99.7%	
Alternative A	Phase 1 Berth	99.9%	Satisfactory
	Master Plan	99.9%	
Alternative B	Phase 1	89.8%	May need a breakwater.
	Master Plan	72.2%	

Note: Berth availability of "Master Plan" is the availability computed at the most exposed berth of the original and alternative plans.

The original port expansion that Namport is planning to implement satisfies the calmness criterion for the harbour. Contingent Alternative A can also satisfy the criterion but Contingent Alternative B, and supposedly Contingent Alternative C, will not satisfy the criterion and will need a breakwater to ensure satisfactory harbour calmness.

(3) Accessibility from Land

Available land for access to the man-made island of each alternative is very limited and may be an issue to be discussed among the concerned parties such as the Municipal Government, the Navy and Namport. As shown in the city planning, the shore at the northern part of Walvis Bay is dedicated to "Upmarket Residential" area. Possible access to the sea is located between the naval base and "Upmarket Residential" area while the further northern shore is exposed to the open sea. This land strip has to be approved for use as access for each Contingent Alternative.

The right of way has been extended to the point to which the access to the man-made island should be connected. There should be no issue about the access road in this regard. As to the railway connection to the existing railway track, the direct divert from the main railway from

Swakopmund is not advisable, as this will need one more fly-over on the road. It is rather recommendable to switch back the trains at the railway tracks laid in parallel with those for the oil storage.

5.2 Preliminary Design of Contingent Alternatives

5.2.1 Design of Revetment

(1) Design Condition

Design Wave at the Project Site: Apply the following waves predicted at Location A (at the west of the existing channel entrance of an 11 m water depth within the Walvis Bay) for diffracted deep sea waves from Pelican Point according to the previous report.

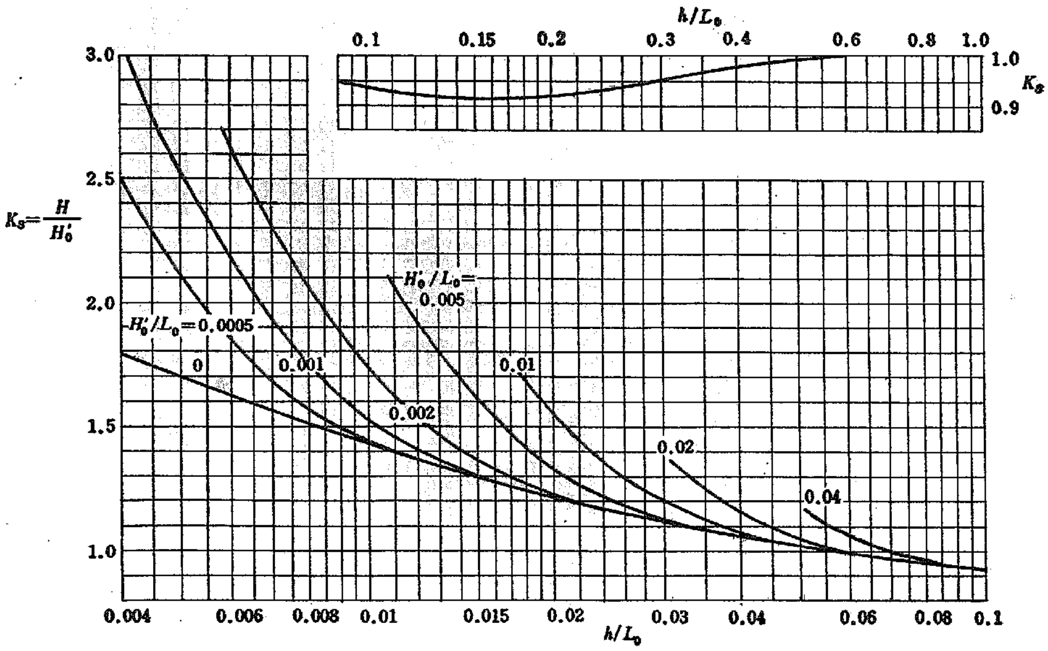
Table 5.2.1 Wave Height H1/3 (m)

Location	Location	Return Period				
		1 Yrs	5 Yrs	10 Yrs	50 Yrs	100 Yrs
A	West of the existing channel entrance	1.7	(2.7)	3.0	(3.4)	3.6

Source1): Report on "Design, Feasibility and Tender Berth 0/1, Concept and Feasibility for Ship Repair Hub & Dedicated Fish Terminal: Inros Lacker Ag, June 2008
Source2): Wave height in bracket estimated by JICA Study Team

The above wave may be generated from the deep sea water wave of 6.4 m and the Point "A" locates at the water depth of CD-10.0 m according to the report cited in the table above. The project site for the Contingent Plan is around CD -5 m, therefore, the 1 in 50 year wave height at the Project Site is calculated backward as follows:

Equivalent Deep-sea Wave Height at Point A as well as the Project Site:
    Ho'= Kr x Kd x Ho=3.1 m (assumed)
Shoaling Coefficient at Point A based on Shuto's nonlinear long wave theory:
    Water Depth (h)=11.0 m
    Length of Wave (Lo) =1.56 x T^2 =1.56 x 13.0^2 =264m
    Ks=1.1 for h/Lo=11.0/264=0.042, Ho'/Lo=3.1/264=0.012
Significant Wave Height at Point A:
    H1/3=K x Ho'= 1.1 x 3.1=3.4m

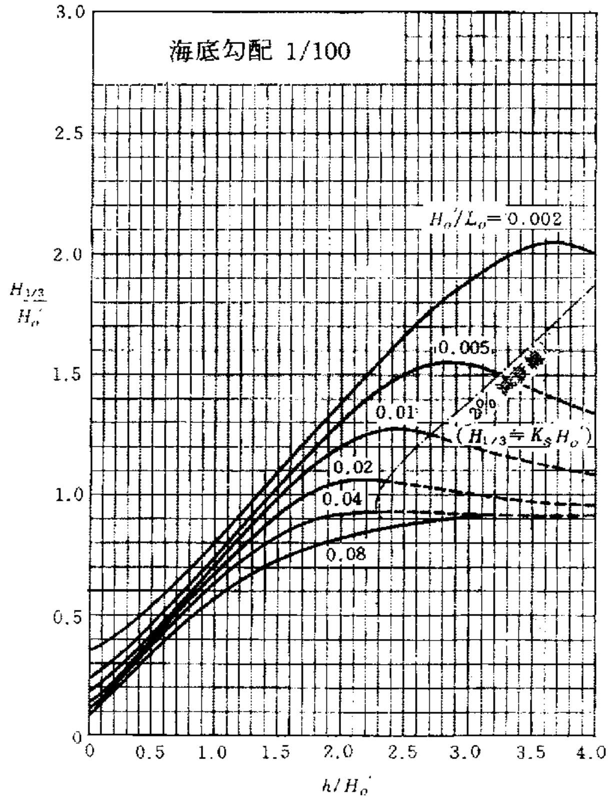


Source: Technical Standards and Commentaries for Port and Harbour Facilities in Japan

Figure 5.2.1 Shuto's Graph for Evaluation of Shoaling Coefficient

Considering water depth (h) of 6 m at the Project site, h/Ho'=6/3.1=1.94, Ho'/Lo=3.1/264=0.012 and seabed slope of 1/100, the coefficient of wave height change at the site water area will be $H_{1/3}$/Ho'=1.17 by applying Goda's diagram of significant wave height change in breaker zone for irregular wave. Therefore:

Significant Wave at Contingent Plan Area: H1/3=1.17 x 3.1 m=3.6m



Source: Technical Standards and Commentaries for Port and Harbour Facilities in Japan

Figure 5.2.2 Diagram of Significant Wave Height in Breaker Zone for Bottom Slope of 1/100

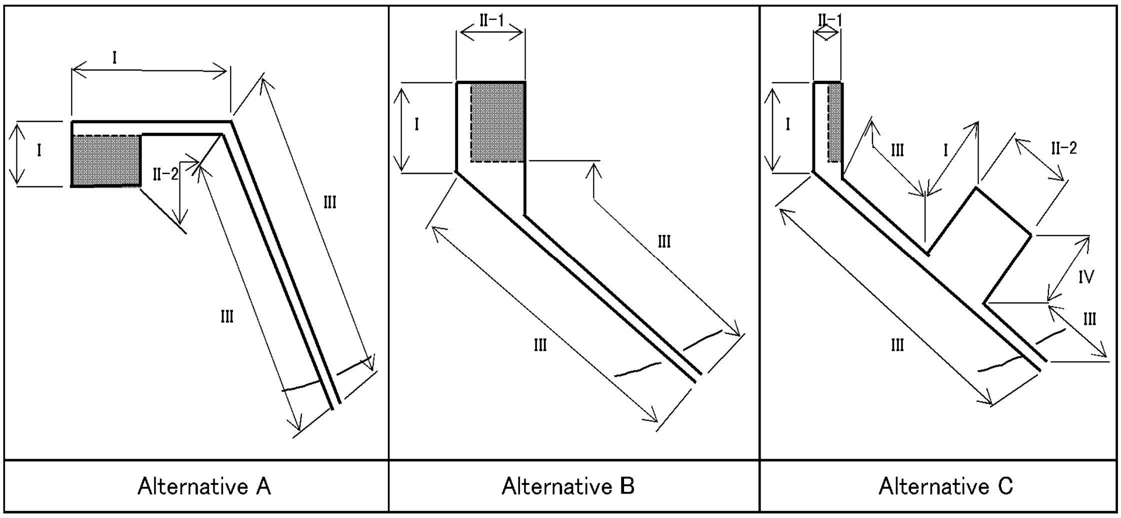
The following design wave is used for designing water front structures for the Contingent Alternative Plans.

Wave Height	H1/3 = 3.6 m (50 Yrs Return Period)
Wave Period	T1/3 = 13.0 sec
Wave Direction	NW diffracted from Pelican Point

Soil Conditions: So far, no offshore boring works have been carried out around the proposed offshore area.

(2) Type of Revetment

The revetments required for the contingent plans may be classified into the following four (4) types of structure in view of the design wave heights.



Source: JICA Study Team

Figure 5.2.3 Contingent Alternatives for Revetment

Table 5.2.2 Type of Revetment for Contingent Alternatives

Type	Design Wave	Application		
		Plan A	**Plan B**	**Plan C**
Type I Seawall	H1/3=3.6 m (In 1 to 50 yrs)	1) West & North of Terminal 2) North of Future Terminal Expansion Area	West of Terminal	1) West of Quay Apron 2) Northwest of Terminal Yard
Type II-1 Temporary Revetment	H1/3=2.7 m (In 1 to 5 yrs)		North of Future Terminal Expansion Area	North of Quay Apron
Type II-2 Temporary Revetment	H1/3=1.0 to 1.2 m (1 to 5 yrs wave height diffracted from turning basin area for the new terminal)	1) East of Terminal 2) South of Future Terminal Expansion Area		Northeast of Future Terminal Yard Expansion Area
Type III Causeway Revetment	H1/3=1.5 to 2.5 m (The equivalent wave in 1 to 50 yrs wave height of 3.5 m which may approach to the causeway alignment in 45 degrees)	Both Sides of Causeway	1) Both Sides of Causeway 2) South of Terminal Area	Both Sides of Causeway
Type IV Terminal Yard Revetment	H1/3=1.0 to 1.2m (The equivalent wave in 1 to 50 yrs wave height of 3.5 m which is diffracted from the new terminal yard area)			Southeast of Terminal Yard

Source: JICA Study Team

(3) Design of Revetment

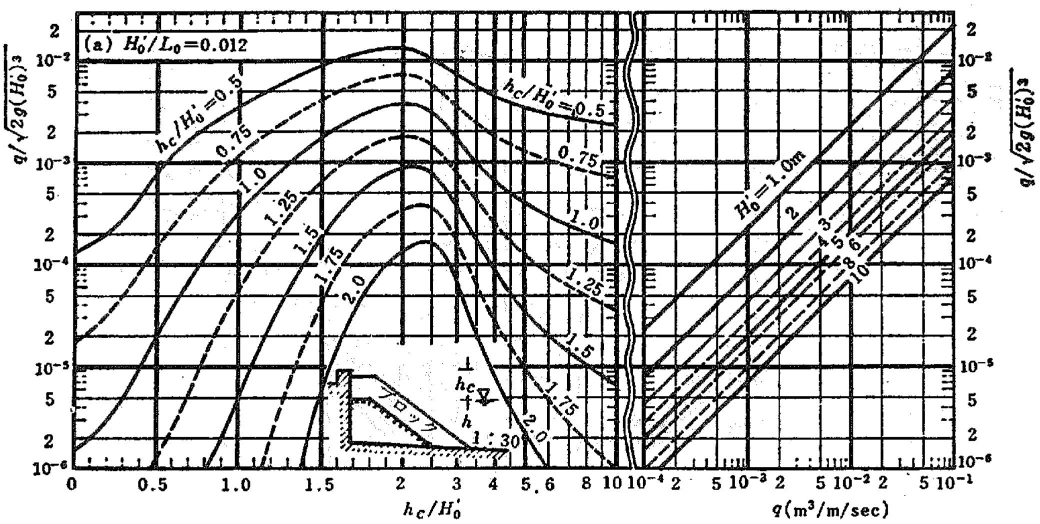
Revetment Type-I (Seawall): The Revetment Type-I (Seawall) is designed in the form of sloped protection from the wave action covered by armour stones. Based on the wave heights estimated at offshore point "A" referred to above, waves of 1 in 50 years is used and around 4 tons per piece is required for natural quarry stone armour. Therefore, wave dissipating pre-cast concrete units are used for armour stones for the revetment. The size (weight) of the armour unit (Md) is calculated at 4 t/pc using Hudson's equation for 50 year return period wave of H=3.5 m as follows:

$Md = \rho H^3/Ns^3(Sr-1)^3$
$= 2.3 \times 3.6^3/12.45(2.3/1.03 - 1)^3 = 4.6$ t/pc

where $Ns^3 = Kd \cot \alpha = 8.3 \times 1.5 = 12.45$

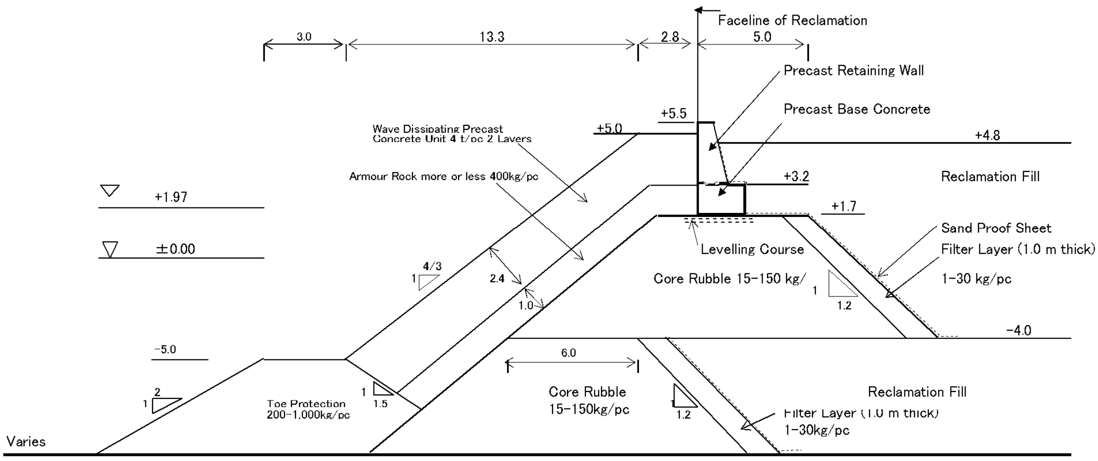
A riprap mound between 15 kg and 150 kg per piece is placed in a seaside slope in 1 (V) to 4/3 (H) on which vertical pre-cast concrete gravity walls are installed. The seaside front surface is protected by two layers of armour stones units, 4 ton/pc wave dissipating pre-cast unit for the first layer and armour stones of more or less 400 kg/pc for the second layer placed on the riprap mound. The toe of the seaside slope is protected by 200–1,000 kg/pc stones.

The cope-line height of revetment is positioned at CD +5.5m, which is roughly equivalent to the elevation of high water level +1.97 plus design wave height 3.6 m. The rate of overtopping will be estimated to be $q/\sqrt{2g(Ho')^3} = 2 \times 10^3$, i.e. $q = 0.05$ m^3 /m/s for Ho'= 3.1m, h/Ho'=6.0/3.1=1.94, Ho'/Lo=3.1/264=0.012 and hc/Ho'= (5.5-2.0)/3.1=1.13 by using Goda's graph for estimating the rate of overtopping for a wave absorbing seawall as follows. This rate of overtopping is the allowable range of overtopping for a revetment with an unpaved apron.



Source: Technical Standards and Commentaries for Port and Harbour Facilities in Japan

Figure 5.2.4 Goda's Graph for Estimating the Rate of Overtopping for a Wave Absorbing Seawall (Bottom Slope 1/30)

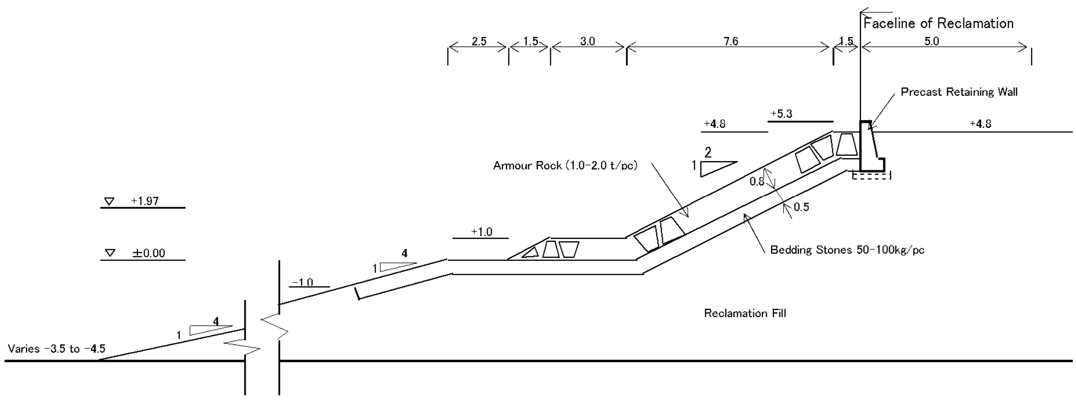


Source: JICA Study Team

Figure 5.2.5 Revetment Type – I (Seawall)

Revetment Type II-1 (Temporary Revetment for Plan B): Along the North Revetment of the proposed terminal for Contingent Plan B (Temporary Revetment for Future Expansion), the reclamation fill may be placed in a gentle slope of 1 (V) to 4 (H) under water level. The same type of revetment as for temporary revetment designed in Chapter 4 is applicable. Armour stones will be 1.0 to 2.0 t/pc assuming wave height of 2.7 m for waves of 5 years return period as follows.

$$Md = \rho H^3/Ns^3(Sr-1)^3$$
$$= 2.65 \times 2.7^3/8(2.65/1.03 - 1)^3 = 1.67 \text{ t/pc}$$
where $Ns^3 = Kd \cot \alpha = 4 \times 2 = 8$

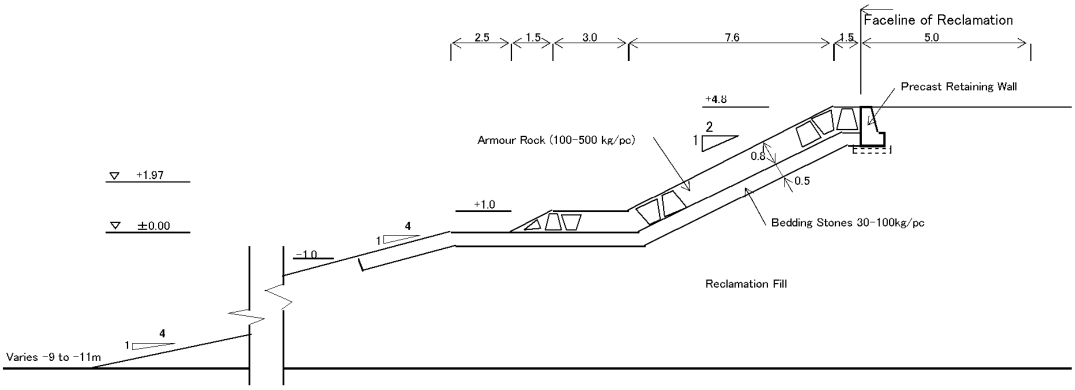


Source: JICA Study Team

Figure 5.2.6 Revetment Type II-1 (Temporary Revetment for Plan A)

Revetment Type II-2(Temporary Revetment for Plan A): Along the north/ south Revetment for future expansion area of the proposed Plan, reclamation fill may be placed in a gentle slope of 1 (V) to 4 (H) under water level. The same type of revetment as for temporary revetment designed in Chapter 4, except for armour stone, is applicable. Armour stones will be 100 to 500 kg/pc assuming wave height of 1.0 to 1.2 m in 1 to 5 years diffracted from new terminal berthing water area.

$Md = \rho H^3/Ns^3(Sr-1)^3$
$= 2.65 \times 1.2^3/8(2.65/1.03 - 1)^3 = 0.15$ t/pc
where $Ns^3 = Kd \cot \alpha = 4 \times 2 = 8$

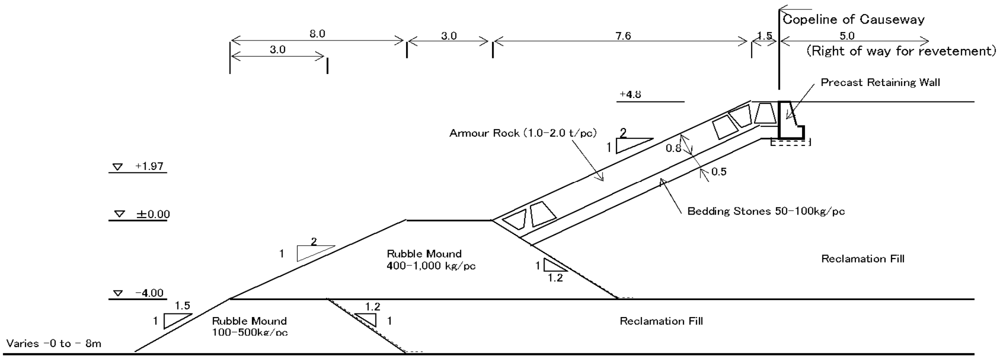


Source: JICA Study Team

Figure 5.2.7 Revetment Type II-2 (Temporary Revetment for Plan A)

Revetment Type III (Causeway Revetment): Revetment along the Causeway is formed by a rubble mound base whose elevation is CD±0.0 m on which a sloped face revetment in a slope of 1 (V) to 2 (H) is provided to the top level of causeway CD +4.8 m. Design wave of 2.5 m height is applied to determine the weight of the armour stones in considering wave direction 45 degrees diagonal to the revetment alignment for 50 year return period of 3.5 m wave height, i.e. 3.5 x cos 45°= 2.33m.

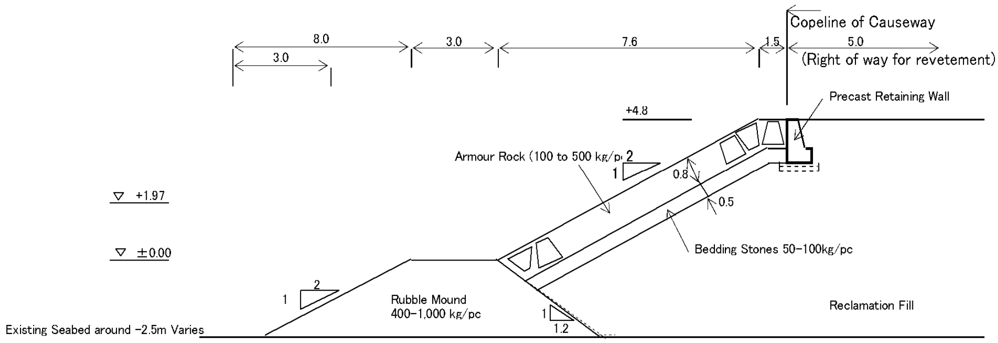
$Md = \rho H^3/Ns^3(Sr-1)^3$
$= 2.65 \times 2.5^3/8(2.65/1.03 - 1)^3 = 1.33$ t/pc
where $Ns^3 = Kd \cot \alpha = 4 \times 2 = 8$



Source: JICA Study Team

Figure 5.2.8 Revetment Type III (Causeway Revetment)

Revetment Type IV (Landside Terminal Yard Revetment for Plan C): The same sloped revetment as Type III for Causeway is applied. However, because the design wave for this revetment is expected to be remarkably decreased, armour rock of 100 to 500 kg/pc is used on the outer slope.



Source: JICA Study Team

Figure 5.2.9 Revetment Type IV (Landside Terminal Yard Revetment for Plan C)

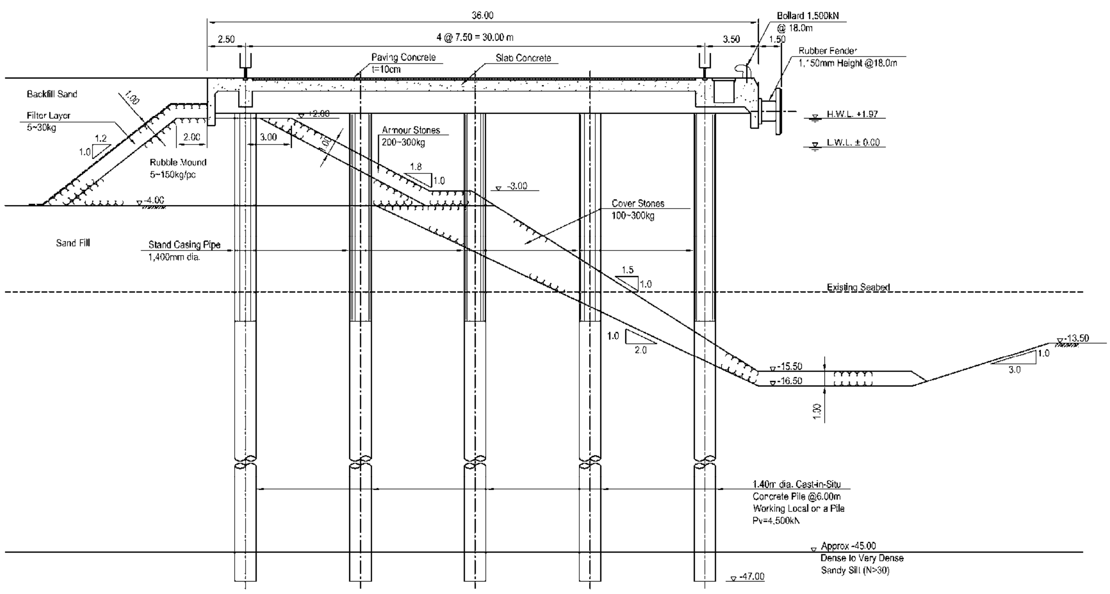
5.2.2 Design of Quay Wall

(1) Design Condition

The same design conditions as those for the quay wall designed in Chapter 4 are adopted.

(2) Typical Section of Quay Wall

Alternative Plan A to C: The same open type of quay wall as designed in Chapter 4 will be applied for Alternative Plan A to C. But, the water depth at the site for quay wall structure is around −5 m for Plan A, −5 to −8 m for Plan B and −8 to −9 m for Plan C. Therefore, though the same type of quay wall is applied to Alternative Plans, sand filling work is first carried out to fill up the offshore site for quay wall to the elevation of CD −4.0 m by sand filling and then, the stand casing pile is installed on the filled seabed to proceed to cast-in place concrete piling work at the site. This sequence of works will minimize the length of stand casing pile required to construct cast-in-place concrete piles at deep offshore area. The typical section of quay wall for the contingent plans is shown in the following figure.



Source: JICA Study Team

Figure 5.2.10 Quay Wall for Contingent Alternative Plan A to C

5.2.3 Design of Pavement

The same container terminal yard pavement structure as for the Implementation Plan is applied. Asphalt surfacing pavement is applied for the access road area.

5.3 Construction Planning of Contingent Alternative

5.3.1 Outlook

In this section, three types of alternative plans each with a separate function are studied concerning their construction methods and sequences compared with the original plan.

Basic facilities such as the container terminal and their structures are the same in each plan, and basic working items do not have a big difference in comparison with the original plan. However, a few modifications occurred due to their location, particularly in revetment works and quay works affected by the water depth, construction works that were mainly planned to be carried out on land in the original plan and would change to marine works under these alternative plans.

Here, representative basic work contents (dredging, reclamation, shore protection, quay construction) are explained that are common to each plan but diverge with the original plan. It is supplemented with information on the characteristic construction points of each alternative plan afterwards. Please refer to Chapter 4.3 about basic work points.

5.3.2 Basic Work Items of the Alternative Plans and Differences with the Original Plan

(1) Dredging and Reclamation Works

Dredging is basically the same as in the original plan. Dredging the existing channel is planned to be carried out by TSHD in order to prevent interrupting navigation. However, dredging the channel by CSD is considered in the case of short discharge pipelines within 3 km. The basin dredging is planned to be carried out by CSD and pushing and levelling by bulldozer and backhoes as well as the original plan. On the other hand, the dredging at the quay is carried out by a grab dredger as in the original plan, due to narrower dredging areas.

(2) Revetment Works

There is large difference in construction methods between original and alternative plans for revetment works. The structure of the revetment in the alternative plan is revised in design because of the deeper water depth and the more severe wave condition compared with the original plan. The causeway of the alternative plan and the revetments are multi-stage (two-step) structures built with small rubble mounds for the sake of economy, and armoured by blocks of 4t (wave dissipation blocks). It is planned to start on a mound of single-layered rubble which is constructed to the surface of the sea surface as per the original plan, and to fill up the inside, but in case of the alternative plan, it is necessary to repeat building a rubble mound work and the reclamation work. Therefore, rubble stones which are carried by dump trucks could not be dumped directly as in the original plan. Rubble stones which are carried to the pier by dump trucks are unloaded to a stone carrying vessel with a 3 m^3 bucket (below called a gat barge) and transported to the site to be dumped.

Basically all the stone will be carried by a gat barge with a 3 m^3 bucket, but in shallow water, this can be accomplished by barge with a crane due to its draft. The capacity of dumping stone is estimated to be provided with the unloading jetty within 3 km from dumping site. Furthermore, the dumping of stone must be controlled under a diver’s supervision.

The stone dumping work for the temporary road is performed by night and day in the original plan, but in case of the alternative plan, it is necessary to be carried out in the day for safety in marine work.

In original plan, rubble mounds are partially planned to be utilized as temporary construction roads in order to carry out works smoothly by transporting materials and using land equipments, but all construction works of rubble mounds for alternative plans are to be carried out on the sea since there will be no temporary construction road. Therefore alternative plans have more risks in construction scheduling than the original plan because of marine weather conditions.

(3) Quay Works

There are no changes in the basic work items of the quay wall construction. All work is carried out on the sea since there will be no temporary roads. Therefore, all materials and equipments are transported on the sea, and all work is assumed to be carried out by the working vessels with equipment and temporary plants for construction.

This construction will be constrained by marine weather conditions. But, if a procedure for reclamation for temporary construction roads is devised, the possibility of construction by using the temporary road is higher in some sections of the piling works and structural concrete works of quay construction. But in this report, this kind of procedures is not considered in planning the construction schedule.

5.3.3 Construction Planning of Each Plan

Alternative plan-A: Alternative plan A consists of: dredging 6.85 million m^3, reclamation of 3.93 million m^3, dumping dredged material of 2.93 million m^3, laying rubble stones of 0.4 million m^3, and installing wave dissipating blocks of 15,400 pieces.

Dredging and reclamation are carried out by CSD and TSHD. Existing channel dredging or big volume dredging with long distance transportation should be carried out by TSHD, basically.

Installation of rubble stones is planned to be carried out by a few gat barges (carrying stone vessel) with 3 m^3 bucket. Wave dissipation blocks of 4t are installed by a barge with a crane. A fabrication yard of about 2 ha is needed to produce 70 concrete blocks per day and stock 2000 blocks for construction. The construction method of quay is almost the same as the original plan.

The period of construction for this plan is estimated at about 35 months.

Alternative plan-B: Alternative plan B consists of: dredging of 5.40 million m^3, reclamation of 4.50 million m^3, dumping dredged material of 0.90 million m^3, laying rubble stones of 0.38 million m^3, and installing work wave dissipation blocks of 8,700 pieces.

Dredging and reclamation are carried out by CSD and TSHD. Dumping rubble stones for revetment is carried out by a few gat barges. The water depth in this plan is so deep that the revetment has to be built by 2 cycle works of dumping and reclamation. Therefore the reclamation at the terminal yard is delayed compared with other plans, although it is possible to reduce the time of dumping stone of 120,000 m^3 at revetment by increasing one gat barge. Almost all construction of the quay will be carried out on the sea. The fabrication yard for wave dissipation blocks is needed at only half the scale of plan A.

From these conditions, the period of construction is estimated at 38 months.

Alternative plan-C: Alternative plan C consists of: dredging of 3.99 million m^3, reclamation of 3.75 million m^3, dumping dredged material of 0.49 million m^3, laying rubble stones of 0.49 million m^3, and installing work wave dissipation blocks of 14,100 pieces.

In this plan, the quay is located in a deep sea area and the container terminal yard is located in a shallow sea area. Therefore, there are much smaller quantities of dredging and reclamation with a greater balance in comparison with the original plan. Under this plan, it is scheduled to build 2 manmade islands each for the quay and container terminal. Therefore the length of revetment is so long that the construction of the revetment becomes critical to the overall schedule.

The productive capacity of the quarry is equivalent to three gat barges. Therefore, dumping stones are planned to be carried out by a maximum of three gat barges. The reclamation at the container terminal area is assumed to be delayed. In addition, the fabrication yard needed is the same size as that of plan B (about 10,000 m^2).

The construction period is estimated at 36 months, and the process of alternative plan C is delayed a degree in comparison with the original plan.

No	Location	Work items	Quantities	Unit	Capacity /day	No	working day	Calend day	Remark
1	Preparatory works								
		Temporary House.etc							
		Temporary unloading jetty							
		Precaast yard	20,000	m2					
2	Dredging								
		Approach channel	1,900,000	m3	12,000	1	158	198	TSHD
		Basin	3,330,000	m3	12,000	1	278	347	THSD
		Basin	1,480,000		8,000	1	185	231	CSD
		Quay	136,000	m3	1,000	1	136	170	GD
3	Causeway area Type3①②								
		Rubble mound 100-500kg	1,730	m3	550	1	3	4	
		Rubble mound 400-1000kg	73,700	m3	450	1	164	205	
		Bedding stone 50-100kg	8,500	m3	550	1	15	19	
		Aromor rock 1.0-2.0t	14,500	m3	350	1	41	52	
	Reclamation		530,000	m3	8000	1	66	83	CSD
		Concrete blocks	540	No	40	1	14	17	
	Causeway area Type1③								
		Core rubble 15-150kg③	49,900	m3	550	1	91	113	
		Armour rock more or less 400kg③	9,400	m3	550	1	17	21	
		Wave dissipiate precast comcrete block	8,000	No	34	1	235	294	
		Filter layer 1-30kg③	6,800	m3	550	1	12	15	
		Consrete block③	1,210	No	40	1	30	38	
		Sand proof sheet③	12,400	m2	520	1	24	30	
	Causeway area Type2-2④							0	
		Bedding stone 50-100kg④	6,700	m3	550	1	12	15	
		Aromour stone 100-500kg④	6,150	m3	550	1	11	14	
		Concrete blocks④	150	No	40	1	4	5	
	Reclamation ③④		632,000	m3	8000	1	79	99	CSD
4	Container yard area							0	
		Type1⑤							
		Core rubble 15-150kg⑤	51,800	m3	550	1	94	118	
		Toe protection 200-1000kg⑤	4,800	m3	450	1	11	13	
		Armour rock more or less 400kg⑤	9,500	m3	550	1	17	22	
		Wave dissipiate precast comcrete block	7,400	No.	34	1	218	272	
		Filter layer 1-30kg⑤	7,200	m3	550	1	13	16	
		Consrete block⑤	1,040	No.	40	1	26	33	
		Sand proof sheet⑤	12,050	m2	520	1	23	29	
		Type2-1⑥							
		Bedding stone 50-100kg⑥	5,150	m3	550	1	9	12	
		Aromour stone 100-500kg⑥	4,700	m3	550	1	9	11	
		Concrete blocks⑥	110	No.	40	1	3	3	
		Type2-2（－5.0）⑦						0	
		Bedding stone 50-100kg⑦	4,200	m3	550	1	8	10	
		Aromour stone 100-500kg⑦	3,800	m3	550	1	7	9	
		Concrete blocks⑦	90	No.	40	1	2	3	
	Reclamation		2,760,000	m3					
		Reclamation（mean-6.2m to-4.0mCD)	550,000	m3	8000	1	69	86	C&T
		Reclamation（-4.0m to+2mCD)	1,510,000	m3	12000	1	126	157	
		Reclamation(+2m to+4.8mCD)	700,000	m3	12000	1	58	73	
5	Quaywall								
		Rubble mound5-150kg	45,920	m3	550	1	83	104	
		Filter layer 1-30kg	6,552	m3	550	1	12	15	
		Bored pile						0	
		Stand Pipe	480	No.	3	1	160	200	
		Bored pile	480	No.	0.5	3	320	400	
		Dredging	136,000	m3	1,000	1	136	170	GD
		Slope Protection							
		Filter layer 1-30kg	1,700	m3	480	1	4	4	
		cover stone 100-300kg	43,000	m3	270	2	80	100	
		Rubble mound 5-150kg	16,900	m3	480	1	35	44	
		Armour stone 200-300kg	8,100	m3	270	2	15	19	
		Sandproof sheet	8,000	m2	520	1	15	19	
		Concrete Deck	34,000	m3	85	1	400	500	
		Concrete Pavement	15,400	m2	980	2	8	10	
		Bollard	32	No.	0.5	4	16	20	
		Rubber Fender	32	No.	0.5	4	16	20	
		Cran Rail	1,100	m	40	4	7	9	
		Gatry Crane							
6	Road								
7	Drainage								
8	Building								
9	Cleaning								

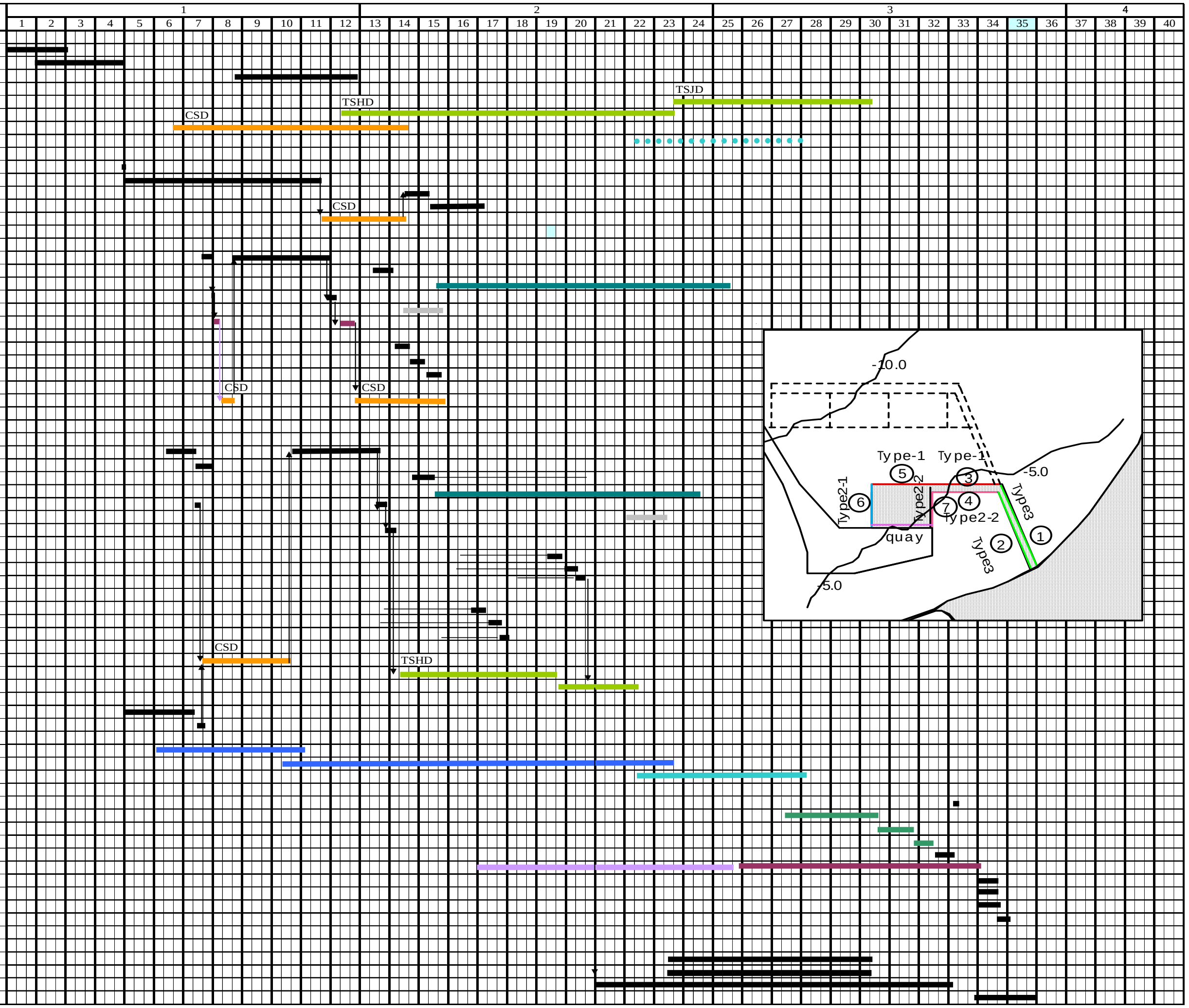


Figure 5.3.1 Construction Schedule: Alternative Plan-A

No	Location	Work items	Quantities	Unit	Capacity /day	No	working day	Calendar day	Remark
1	Preparatory works								
		Temporary house.etc							
		Temporary unloading jetty							
		Precast yard	10,000	m2					
2	Dredging								
		Approach channel	3,160,000	m3	12,000	1	263	329	TSHD
		Basin	2,070,000	m3	8,000	1	259	323	CSD
		Quay	180,000	m3	1,000	1	180	225	Grab
3	Causeway								
		RevetmentType3①②③④							
		Rubble mound 100-500kg①②③	16,300	m3	550	1	30	37	
		Rubble mound 400-1000kg①②③	120,500	m3	450	2	134	167	
		Bedding stone 50-100kg①②③	13,500	m3	550	1	25	31	
		Aromor rock 1.0-2.0t①②③	13,800	m3	350	1	39	49	
		Type3 ④(on land)							
		Rubble mound 400-1000kg④	5,300	m3	450	1	12	15	
		Concrete blocks④	2,650	No.	40	1	66	83	
	Reclamation①②③④		730,000	m3	8000	1	91	114	
4	Container Yard								
		Type1⑤(depth-7.0)							
		Core rubble 15-150kg⑤	65,200	m3	550	1	119	148	
		Toe protection 200-1000kg⑤	8,600	m3	450	1	19	24	
		Armour rock more or less 400kg⑤	11,400	m3	550	1	21	26	
		Wave dissipiate precast comcrete block 4t⑤	8,700	No.	34	1	256	320	
		Filter layer 1-30kg⑤	9,000	m3	550	1	16	20	
		Consrete block⑤	1,230	No.	40	1	31	38	
		Sand proof sheet⑤	14,600	m3	520	1	28	35	
		Type2-1⑥(depth-7.2)							
		Bedding stone 50-100kg⑥	5,100	m3	550	1	9	12	
		Aromour stone 1-2t⑥	4,700	m3	350	1	13	17	
		Concrete blocks⑥	355	No.	40	1	9	11	
	Reclamation⑤⑥⑦		3,770,000	m3					
		Recla,mation(mean-6.5m to-4.0mCD)	830,000	m3	8000	1	104	130	TSHD
		Recla,mation(-4.0m to+2mCD)	2,000,000	m3	12000	1	167	208	TSHD
		Recla,mation(+2.0m to+4.8mCD)	930,000	m3	12000	1	78	97	TSHD
5	Quaywall							0	
		Reclamation sand fill⑦	94,500	m3	8000	1	12	15	
		Rubble mound(5-150kg)⑦	30,700	m3	600	1	51	64	
		Filter layer 1-30kg⑦	5,300	m3	550	1	10	12	
		Bored pile⑦							
		Stand Pipe⑦	480	No.	3	1	160	200	
		Bored pile⑦	480	No.	0.5	3	320	400	
		Dredging⑦	180,000	m3	1,000	1	180	225	Grab Dredger
		Slope Protection							
		Filter layer 1-30kg⑦	1,700	m3	480	1		0	
		cover stone 100-300kg⑦	40,000	m3	270	2	74	93	
		Rubble mound 5-150kg⑦	17,000	m3	480	1	35	44	
		Armour stone 200-300kg⑦	8,100	m3	270	2	15	19	
		Sandproof sheet⑦	8,000	m2	520	1	15	19	
		Concrete Deck⑦	34,000	m3	85	1	400	500	
		Concrete Pavement⑦	15,400	m2	980	2	8	10	
		Bollard⑦	32	No.	0.5	4	16	20	
		Rubber Fender⑦	32	No.	0.5	4	16	20	
		Crane Rail⑦	1,100	m	40	4	7	9	
		Gatry Crane⑦							
6	Road								
7	Drainage								
8	Building								
9	Cleaning								

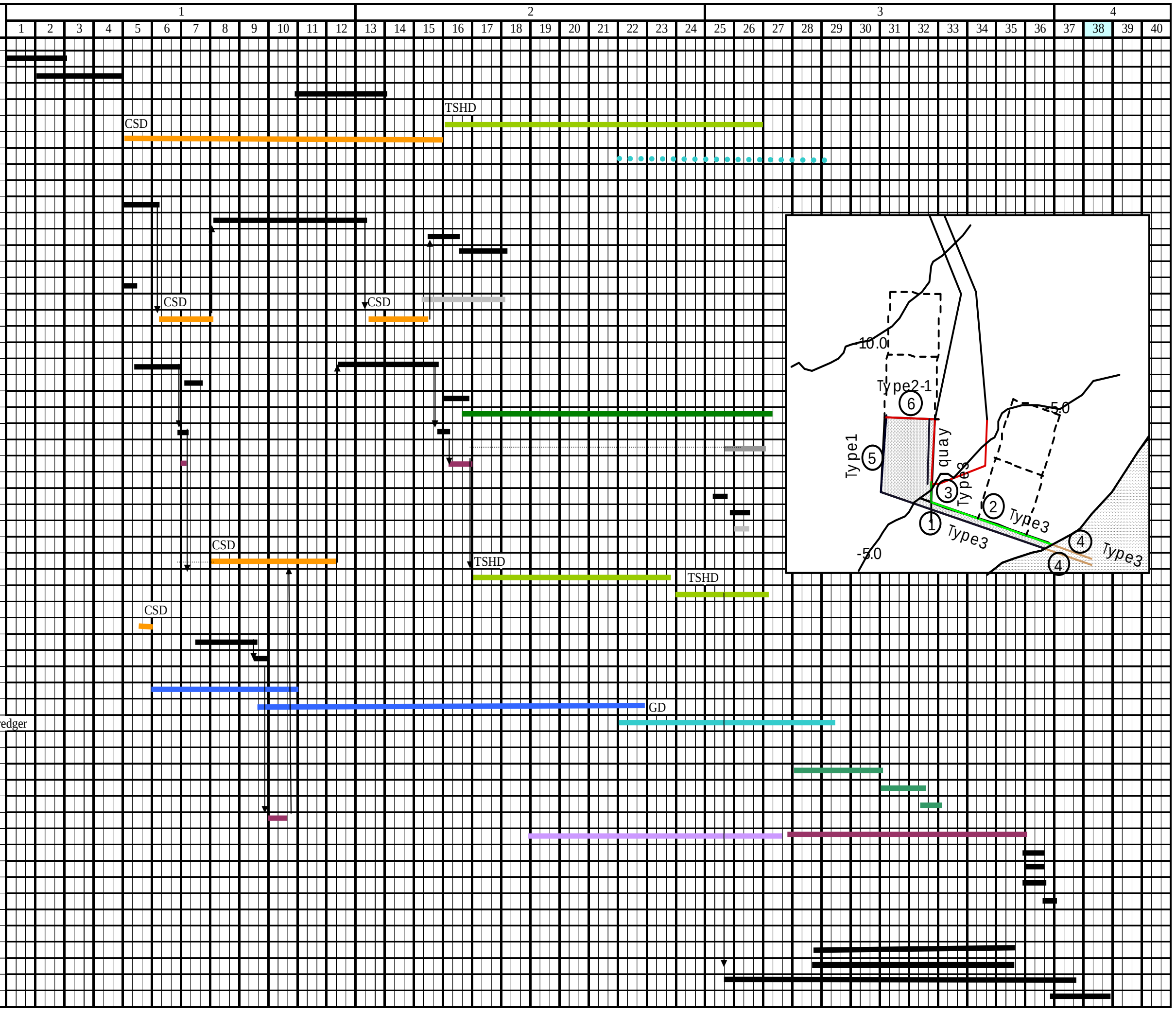


Figure 5.3.2 Construction Schedule: Alternative Plan-B

No	Locatio	Work items	Quantities	Unit	Capacity /day	No	working day	Calend day	Remark
1	Preparatory works								
		Temporary house.etc							
		Temporaryunloading jetty							
		Precast yard	10,000	m2					
2	Dredging								
		Approach channel	2,260,000	m3	12,000	1	188	235	TSHD
		Basin	1,550,000	m3	8,000	1	194	242	CSD
		Quay	180,000	m3	1,000	1	180	225	Grab
3	Causeway area①②③④								
		RevetmentType3①②③④							
		Rubble mound 100-500kg①②	26,000	m3	550	1	47	59	
		Rubble mound 400-1000kg①②③	120,800	m3	450	2	134	168	
		Bedding stone 50-100kg①②③	12,800	m3	550	1	23	29	
		Aromor rock 1.0-2.0t①②③	13,200	m3	350	1	38	47	
		Rubble mound 400-1000kg④	4,500	m3	450	1	10	13	
		Concrete blocks①②③④	800	No	40	1	20	25	
	Reclamation①②③④		730,000	m3	8000	1	91	114	C&T
4	Container yard area							0	
		Type2-2⑦ depth-4.0						0	
		Bedding stone 50-100kg⑦⑧⑨	5,000	m3	550	1	9	11	
		Aromour stone 100-500kg/pcs⑦	4,600	m3	550	1	8	10	
		Concrete blocks⑦	115	No	40	1	3	4	
		Type1⑧(depth -4.5m)							
		Core rubble 15-150kg⑧	45,050	m3	550	1	82	102	
		Armour rock more or less 400kg⑧	8,400	m3	550	1	15	19	
		Wave dissipiate precast comcrete block 4	7,200	pcs	34	1	212	265	
		Filter layer 1-30kg⑧	5,500	m3	550	1	10	13	
		Concrete block⑧	1,200	No	40	1	30	38	
		Sand proof sheet⑧	10,200	m3	520	1	20	25	
		Type2-2⑨(depth -4.0)						0	
		Rubble mound 400-1000kg⑨	36,000	m3	450	1	80	100	
		Bedding stone 50-100kg⑨	2,939	m3	550	1	5	7	
		Aromor rock 100-500kg⑨	5,000	m3	550	1	9	11	
	Reclamation⑦⑧⑨		2,720,000	m3	8000	1	340	425	C&T
5	Quay area⑤⑥⑩								
		Type1⑤(depth-8.0)							
		Core rubble 15-150kg⑤	25,000	m3	550	1	45	57	
		Core rubble 15-150kg⑤	39,000	m3	550	1	71	89	
		Toe protection 200-1000kg⑤	13,100	m3	450	1	29	36	
		Armour rock more or less 400kg⑤	8,100	m3	550	1	15	18	
		Wave dissipiate precast comcrete block 4	6,900	No	34	1	203	254	
		Filter layer 1-30kg⑤	3,500	m3	550	1	6	8	
		Filter layer 1-30kg⑤	5,000	m3	550	1	9	11	
		Consrete block⑤	1,050	No	40	1	26	33	
		Sand proof sheet⑤	13,300	m3	520	1	26	32	
		Type2-1⑥depth-8.5				1		0	
		Bedding stone 50-100kg⑥	1,000	m3	550	1	2	2	
		Aromour stone 1-2t⑥	950	m3	350	1	3	3	
		Concrete blocks⑥	70	No	40	1	2	2	
	Reclamation		310,000	m3	8000	1	39	48	C&T
		Revetment							
		Reclamation sand fill⑩	142,000	m3	8000	1	18	22	
		Rubble mound(5-150kg)⑩	31,000	m3	550	1	56	70	
		Filter layer 1-30kg⑩	5,300	m3	550	1	10	12	
		Bored pile⑩							
		Stand Pipe⑩	480	No.	3	1	160	200	
		Bored pile⑩	480	No.	0.5	3	320	400	
		Dredging⑩	180,000	m3	1,000	1	180	225	GD
		Filter layer 1-30kg⑩	1,700	m3	480	1	4	4	
		cover stone 100-300kg⑩	40,000	m3	270	2	74	93	
		Rubble mound 5-150kg⑩	16,900	m3	480	1	35	44	
		Armour stone 200-300kg⑩	8,100	m3	270	2	15	19	
		Sandproof sheet⑩	8,000	m2	520	1	15	19	
		Concrete Deck⑩	34,000	m3	85	1	400	500	
		Concrete Pavement⑩	15,400	m2	980	1	16	20	
		Bollard⑩	32	No.	0.5	4	16	20	
		Rubber Fender⑩	32	No.	0.5	4	16	20	
		Crane Rail⑩	1,100	m	40	4	7	9	
		Gatry Crane							
6	Road								
7	Drainage								
8	Building								
9	Cleaning								

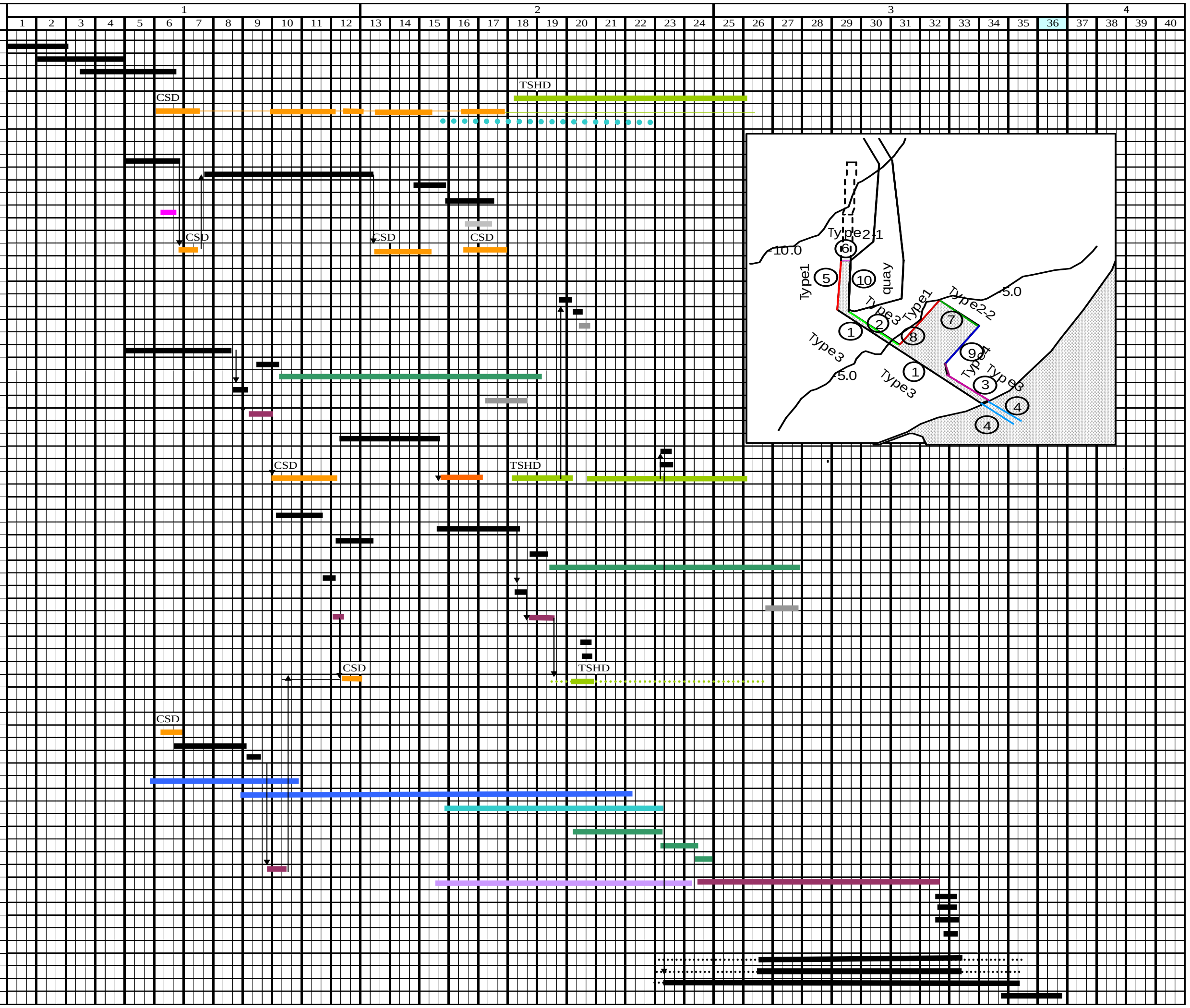


Figure 5.3.3 Construction Schedule: Alternative Plan-C

5.4 Preliminary Cost Estimate of Contingent Alternatives

5.4.1 Civil Works and Equipment Costs

(1) Estimate Conditions

1) Objective of Cost Estimate

The purpose of the preliminary cost estimate is to evaluate the costs of each contingent alternative as described in section 5.5 and compare them with the Original Plan.

2) Targeted Scope of Works

The Civil Works costs are estimated for three Contingent Alternatives—i.e. Contingent Alternative-A, Contingent Alternative-B, and Contingent Alternative-C. Each civil works cost is estimated based on the preliminary layout and design of port facilities as described in Section 5.1 and Section 5.2.

The targeted scope of Civil Works for each contingent alternative is same as the original plan based on the scope of works as described in Section 4.5.1.

The targeted scope of equipment procurement relevant to each contingent alternative plan is identical to the one of original plan as described in Section 4.5.1 except for Contingent Alternative-C as the number of Tractor Heads and Yard Type Chassis to be procured for this particular plan has to be changed to 42 and 45, respectively.

3) Basis of Cost Estimate

The basis of the cost estimate is as described in Section 4.5. Same unit prices are applied to each work items as used for the original plans, except for the revetment works. The unit rates are increased in consideration of construction of the temporary jetty and employment of gat barges for loading and dumping the stones in the sea.

(2) Civil Works and Equipment Costs

Table 5.4.1 summarises and compares project cost between the original plan and three contingent alternatives. Equipment procurement cost is identical with the one of the original plan and applied for contingent alternatives except for Contingent Alternative-C as described in Estimate Conditions in Sub-section (1), Section 5.4.1.

Tables 5.4.2, 5.4.3, and 5.4.4 summarize the breakdown of civil works construction costs for Contingent Alternatives-A, B and C, respectively.

Table 5.4.1 Summary of Project Costs for Original Plan and Contingent Alternatives

(Unit: N$)

Description	Original Plan including Terminal Yard Expansion in 2015		Contingent Alternatives					
			A		B		C	
Civil Works	Total							
1.Mobilization, Demobilization, Temporary Works, etc.	68,742,600	100%	91,093,170	133%	79,926,169	116%	80,755,949	117%
2. Dredging, Reclamation & Revetment	624,501,000	100%	1,045,484,274	167%	825,527,803	132%	830,473,809	133%
3. Quay Wall (550m long)	446,320,000	100%	451,134,720	101%	456,778,176	102%	457,203,776	102%
4. Terminal Yard	139,919,000	100%	138,938,400	99%	138,938,400	99%	138,938,400	99%
5. Access Causeway	31,925,000	100%	66,119,000	207%	57,092,000	179%	68,316,000	214%
6. Building Works (9,245㎡)	70,187,000	100%	70,187,000	100%	70,187,000	100%	70,187,000	100%
7. Power Supply facilities, including substations	62,000,000	100%	50,000,000	81%	50,000,000	81%	50,000,000	81%
Engineering and Head Office Expenses (15% of Total):	216,539,190	100%	286,943,485	133%	251,767,432	116%	254,381,240	117%
Total of Civil Works Cost:	**1,660,133,790**	**100%**	**2,199,900,049**	**133%**	**1,930,216,980**	**116%**	**1,950,256,174**	**117%**
Equipment Procurement **Total of Equipment Procurement Cost** (equipment procurement cost in 2014 as per Table 4.5.)	**451,000,000**	**100%**	**451,000,000**	**100%**	**451,000,000**	**100%**	**489,750,000** Note: Tractor Head (42Nos.) and Yard Type Chasis (45 Nos.) required for this plan.	**109%**
Total Amount of Civil Works and Equpment Procurement Cost:	**2,111,133,790**	**100%**	**2,650,900,049**	**126%**	**2,381,216,980**	**113%**	**2,440,006,174**	**116%**

Source: JICA Study Team

Table 5.4.2 Breakdown of Civil Works Cost for Contingent Alternative-A

Description of Works	Quantity	Unit	Unit Price: Local Portion (N$)	%	Unit Price: Foreign Portion (N$)	%	Unit Price: Total (N$)	Amount: Local Portion (N$)	Amount: Foreign Portion (N$)	Amount: Total (N$)
CIVIL WORKS COST										
1.General: (including mobilization, demobilization, temporary works, benchmarks, preparation works, testing laboratory and submittals)	5	%	12,753,044	70%	5,465,590	30%	18,218,634	63,765,219	27,327,951	91,093,170
Subtotal 1:								63,765,219	27,327,951	91,093,170
2. Dredging, Reclamation & Revetment										
(1) Mobilization & Demobilization of dredging and reclamation equipment including installation and dismantling of equipment	1	LS	13,390,000	10%	120,510,000	90%	133,900,000	13,390,000	120,510,000	133,900,000
(2) Dredging and reclamation by	3,928,509	m3	8	10%	68	90%	76	29,856,669	268,710,019	298,566,688
(3) Dredging and disposal by TSHD	879,278	m3	6	10%	52	90%	58	5,099,812	45,898,309	50,998,121
(4) Dredging and disposal by CSD	1,902,601	m3	5	10%	46	90%	51	9,703,267	87,329,407	97,032,674
(5) Revetment	394,371	m3	850	100%	0	0%	850	335,215,591	0	335,215,591
(6) Wave dissipating precast concrete	49,912	m3	1,300	50%	1,300	50%	2,600	64,885,600	64,885,600	129,771,200
Subtotal 2:								393,265,340	522,447,735	1,045,484,274
3. Quay Wall (550m long)										
(1) Piling (cast-insitu bored pile, 1400mm dia, 50m long)	480	No.	97,100	20%	388,400	80%	485,500	46,608,000	186,432,000	233,040,000
(2) Deck concrete including re-bars, foremworks and scaffoldings and all associated works.	34,000	m3	3,518	70%	1,508	30%	5,025	119,595,000	51,255,000	170,850,000
(3) Paving concrete including re-bars and formworks and all associated works	1,650	m3	2,100	70%	900	30%	3,000	3,465,000	1,485,000	4,950,000
(4) Dredging under Quay Wall	136,360	m3	30	20%	122	80%	152	4,145,344	16,581,376	20,726,720
(5) Quay Wall Fittings (Crane rail, fenders, bollards, etc)	1	LS	4,313,600	20%	17,254,400	80%	21,568,000	4,313,600	17,254,400	21,568,000
Subtotal 3:								178,126,944	273,007,776	451,134,720
4. Terminal Yard										
(1) Interlocking paving including drainage and preparation	170,000	m2	565	100%	0	0%	565	96,050,000	0	96,050,000
(2) Concrete slabs for RTG lanes	7,500	m3	4,000	100%	0	0%	4,000	30,000,000	0	30,000,000
(3) Yard lighting	10	No.	100,000	20%	400,000	80%	500,000	1,000,000	4,000,000	5,000,000
(4) Fencing with gates	1,310	m	1,400	100%	0	0%	1,400	1,834,000	0	1,834,000
(5) Utility facilities, excluding power supply facilities	1	LS	4,843,520	80%	1,210,880	20%	6,054,400	4,843,520	1,210,880	6,054,400
Subtotal 4:								133,727,520	5,210,880	138,938,400
5. Access Causeway										
(1) Road, footpath and Container Handling Area	101,860	m2	360	90%	40	10%	400	36,669,600	4,074,400	40,744,000
(2) Railway	7,250	m	3,150	90%	350	10%	3,500	22,837,500	2,537,500	25,375,000
(3) Landscaping and Irrigation	0	m2	297	90%	33	10%	330	0	0	0
Subtotal 5:								59,507,100	6,611,900	66,119,000
6. Building Works (9,445㎡)										
(1) Security Office (RC/1F)	15	m2	18,360	90%	2,040	10%	20,400	275,400	30,600	306,000
(2) Terminal Office (RC/5F+PH)	5,100	m2	6,660	90%	740	10%	7,400	33,966,000	3,774,000	37,740,000
(3) Maintenance Shop (S/partly 2F)	2,500	m2	6,390	90%	710	10%	7,100	15,975,000	1,775,000	17,750,000
(4) Checking Gate (1F w/catwalk)	580	m2	9,180	90%	1,020	10%	10,200	5,324,400	591,600	5,916,000
(5) Amenity Building (RC/2F)	1,250	m2	6,030	90%	670	10%	6,700	7,537,500	837,500	8,375,000
(6) Car Shed	20	No.	4,500	90%	500	10%	5,000	90,000	10,000	100,000
Subtotal 6:								63,168,300	7,018,700	70,187,000
7. Power Supply facilities, including substations	1	LS	40,000,000	80%	10000000	20%	50,000,000	40,000,000	10,000,000	50,000,000
Subtotal 7:								40,000,000	10,000,000	50,000,000
Total (1～7)								931,560,422	851,624,942	1,912,956,564
Engineering and Head Office Expenses (15% of Total): (including Administration Cost and Engineering Fee)										286,943,485
Grand Total for Civil Works Cost including O/H and Profit										2,199,900,049

Source: JICA Study Team

Table 5.4.3 Breakdown of Civil Works Cost for Contingent Alternative-B

Description of Works	Quantity	Unit	Unit Price					Amount		
			Local Portion		Foreign Portion		Total	Local Portion	Foreign Portion	Total
			(N$)	%	(N$)	%	(N$)	(N$)	(N$)	(N$)
CIVIL WORKS COST										
1.General: (including mobilization, demobilization, temporary works, benchmarks, preparation works, testing laboratory and submittals)	5	%	11,189,664	70%	4,795,570	30%	15,985,234	55,948,318	23,977,851	79,926,169
Subtotal 1:								55,948,318	23,977,851	79,926,169
2. Dredging, Reclamation & Revetment										
(1) Mobilization & Demobilization of dredging and reclamation equipment including installation and dismantling of equipment	1	LS	13,390,000	10%	120,510,000	90%	133,900,000	13,390,000	120,510,000	133,900,000
(2) Dredging and reclamation by CSD	2,423,169	m3	7	10%	66	90%	73	17,689,134	159,202,203	176,891,337
(3) Dredging and reclamation by	2,070,153	m3	8	10%	68	90%	76	15,733,163	141,598,465	157,331,628
(4) Dredging and disposal by CSD	738,288	m3	5	10%	46	90%	51	3,765,269	33,887,419	37,652,688
(5) Revetment	376,179	m3	850	100%	0	0%	850	319,752,150	0	319,752,150
(6) Wave dissipating precast concrete	28,197	m3	1,300	50%	1,300	50%	2,600	36,656,100	36,656,100	73,312,200
Subtotal 2:								370,329,715	455,198,088	825,527,803
3. Quay Wall (550m long)										
(1) Piling (cast-insitu bored pile, 1400mm dia, 50m long)	480	No.	97,100	20%	388,400	80%	485,500	46,608,000	186,432,000	233,040,000
(2) Deck concrete including re-bars, foremworks and scaffoldings and all associated works.	34,000	m3	3,518	70%	1,508	30%	5,025	119,595,000	51,255,000	170,850,000
(3) Paving concrete including re-bars and formworks and all associated works	1,650	m3	2,100	70%	900	30%	3,000	3,465,000	1,485,000	4,950,000
(4) Dredging under Quay Wall	173,488	m3	30	20%	122	80%	152	5,274,035	21,096,141	26,370,176
(5) Quay Wall Fittings (Crane rail, fenders, bollards, etc)	1	LS	4,313,600	20%	17,254,400	80%	21,568,000	4,313,600	17,254,400	21,568,000
Subtotal 3:								179,255,635	277,522,541	456,778,176
4. Terminal Yard										
(1) Interlocking paving including drainage and preparation	170,000	m2	565	100%	0	0%	565	96,050,000	0	96,050,000
(2) Concrete slabs for RTG lanes	7,500	m3	4,000	100%	0	0%	4,000	30,000,000	0	30,000,000
(3) Yard lighting	10	No.	100,000	20%	400,000	80%	500,000	1,000,000	4,000,000	5,000,000
(4) Fencing with gates	1,310	m	1,400	100%	0	0%	1,400	1,834,000	0	1,834,000
(5) Utility facilities, excluding power supply facilities	1	LS	4,843,520	80%	1,210,880	20%	6,054,400	4,843,520	1,210,880	6,054,400
Subtotal 4:								133,727,520	5,210,880	138,938,400
5. Access Causeway										
(1) Road, footpath and Container Handling Area	84,980	m2	360	90%	40	10%	400	30,592,800	3,399,200	33,992,000
(2) Railway	6,600	m	3,150	90%	350	10%	3,500	20,790,000	2,310,000	23,100,000
(3) Landscaping and Irrigation	0	m2	297	90%	33	10%	330	0	0	0
Subtotal 5:								51,382,800	5,709,200	57,092,000
6. Building Works (9,445㎡)										
(1) Security Office (RC/1F)	15	m2	18,360	90%	2,040	10%	20,400	275,400	30,600	306,000
(2) Terminal Office (RC/5F+PH)	5,100	m2	6,660	90%	740	10%	7,400	33,966,000	3,774,000	37,740,000
(3) Maintenance Shop (S/partly 2F)	2,500	m2	6,390	90%	710	10%	7,100	15,975,000	1,775,000	17,750,000
(4) Checking Gate (1F w/catwalk)	580	m2	9,180	90%	1,020	10%	10,200	5,324,400	591,600	5,916,000
(5) Amenity Building (RC/2F)	1,250	m2	6,030	90%	670	10%	6,700	7,537,500	837,500	8,375,000
(6) Car Shed	20	No.	4,500	90%	500	10%	5,000	90,000	10,000	100,000
Subtotal 6:								63,168,300	7,018,700	70,187,000
7. Power Supply facilities, including substations	1	LS	40,000,000	80%	10000000	20%	50,000,000	40,000,000	10,000,000	50,000,000
Subtotal 7:								40,000,000	10,000,000	50,000,000
Total (1～7)								893,812,289	784,637,259	1,678,449,548
Engineering and Head Office Expenses (15% of Total): (including Administration Cost and Engineering Fee)										251,767,432
Grand Total for Civil Works Cost including O/H and Profit										1,930,216,980

Source: JICA Study Team

Table 5.4.4 Breakdown of Civil Works Cost for Contingent Alternative-C

Description of Works	Quantity	Unit	Unit Price					Amount		
			Local Portion		Foreign Portion		Total	Local Portion	Foreign Portion	Total
			(N$)	%	(N$)	%	(N$)	(N$)	(N$)	(N$)
CIVIL WORKS COST										
1.General: (including mobilization, demobilization, temporary works, benchmarks, preparation works, testing laboratory and submittals)	5	%	11,305,833	70%	4,845,357	30%	16,151,190	56,529,164	24,226,785	80,755,949
Subtotal 1:								56,529,164	24,226,785	80,755,949
2. Dredging, Reclamation & Revetment										
(1) Mobilization & Demobilization of dredging and reclamation equipment including installation and dismantling of equipment	1	LS	13,390,000	10%	120,510,000	90%	133,900,000	13,390,000	120,510,000	133,900,000
(2) Dredging and reclamation by CSD	2,198,999	m3	7	10%	66	90%	73	16,052,693	144,474,234	160,526,927
(3) Dredging and reclamation by	1,553,595	m3	8	10%	68	90%	76	11,807,322	106,265,898	118,073,220
(4) Dredging and disposal by CSD	61,012	m3	5	10%	46	90%	51	311,161	2,800,451	3,111,612
(5) Revetment	488,073	m3	850	100%	0	0%	850	414,862,050	0	414,862,050
(6) Wave dissipating precast concrete	45,922	m3	1,300	50%	1,300	50%	2,600	59,698,600	59,698,600	119,397,200
Subtotal 2:								456,423,226	374,050,583	830,473,809
3. Quay Wall (550m long)										
(1) Piling (cast-insitu bored pile, 1400mm dia, 50m long)	480	No.	97,100	20%	388,400	80%	485,500	46,608,000	186,432,000	233,040,000
(2) Deck concrete including re-bars, foremworks and scaffoldings and all associated works.	34,000	m3	3,518	70%	1,508	30%	5,025	119,595,000	51,255,000	170,850,000
(3) Paving concrete including re-bars and formworks and all associated works	1,650	m3	2,100	70%	900	30%	3,000	3,465,000	1,485,000	4,950,000
(4) Dredging under Quay Wall	176,288	m3	30	20%	122	80%	152	5,359,155	21,436,621	26,795,776
(5) Quay Wall Fittings (Crane rail, fenders, bollards, etc)	1	LS	4,313,600	20%	17,254,400	80%	21,568,000	4,313,600	17,254,400	21,568,000
Subtotal 3:								179,340,755	277,863,021	457,203,776
4. Terminal Yard										
(1) Interlocking paving including drainage and preparation	170,000	m2	565	100%	0	0%	565	96,050,000	0	96,050,000
(2) Concrete slabs for RTG lanes	7,500	m3	4,000	100%	0	0%	4,000	30,000,000	0	30,000,000
(3) Yard lighting	10	No.	100,000	20%	400,000	80%	500,000	1,000,000	4,000,000	5,000,000
(4) Fencing with gates	1,310	m	1,400	100%	0	0%	1,400	1,834,000	0	1,834,000
(5) Utility facilities, excluding power supply facilities	1	LS	4,843,520	80%	1,210,880	20%	6,054,400	4,843,520	1,210,880	6,054,400
Subtotal 4:								133,727,520	5,210,880	138,938,400
5. Access Causeway										
(1) Road, footpath and Container Handling Area	107,790	m2	360	90%	40	10%	400	38,804,400	4,311,600	43,116,000
(2) Railway	7,200	m	3,150	90%	350	10%	3,500	22,680,000	2,520,000	25,200,000
(3) Landscaping and Irrigation	0	m2	297	90%	33	10%	330	0	0	0
Subtotal 5:								61,484,400	6,831,600	68,316,000
6. Building Works (9,445㎡)										
(1) Security Office (RC/1F)	15	m2	18,360	90%	2,040	10%	20,400	275,400	30,600	306,000
(2) Terminal Office (RC/5F+PH)	5,100	m2	6,660	90%	740	10%	7,400	33,966,000	3,774,000	37,740,000
(3) Maintenance Shop (S/partly 2F)	2,500	m2	6,390	90%	710	10%	7,100	15,975,000	1,775,000	17,750,000
(4) Checking Gate (1F w/catwalk)	580	m2	9,180	90%	1,020	10%	10,200	5,324,400	591,600	5,916,000
(5) Amenity Building (RC/2F)	1,250	m2	6,030	90%	670	10%	6,700	7,537,500	837,500	8,375,000
(6) Car Shed	20	No.	4,500	90%	500	10%	5,000	90,000	10,000	100,000
Subtotal 6:								63,168,300	7,018,700	70,187,000
7. Power Supply facilities, including substations	1	LS	40,000,000	80%	10000000	20%	50,000,000	40,000,000	10,000,000	50,000,000
Subtotal 7:								40,000,000	10,000,000	50,000,000
Total (1～7)								990,673,366	705,201,569	1,695,874,934
Engineering and Head Office Expenses (15% of Total): (including Administration Cost and										254,381,240
Grand Total for Civil Works Cost including O/H and Profit										**1,950,256,174**

Source: JICA Study Team

5.5 Evaluation of Contingent Alternatives

The original port expansion plan and the Contingent Alternatives A, B and C are compared with respect to the following points:

- Impacts to the lagoon
- Intensity of siltation on approach channel and port basin
- Ship manoeuvrability
- Berth availability (harbour calmness)
- Accessibility from land

5.5.1 Impacts to the Lagoon

The EIA Consultants have carried out the hydrodynamic and water-quality modelling for the Base Case (existing situation) as well as future development Phase 1 and 3 of the original port expansion plan and concluded the following:

1. The new container terminal has negligible influence on the water levels in the Bay and the lagoon.
2. The current pattern in the Bay changes such that the large scale eddy is shifted further to the north. The actual flow velocities change to smaller extent.
3. The new container terminal reduces the water exchange rates in the Lagoon due to the artificial extension of the Lagoon neck. This occurs independent of the development of Phase and is most distinct during spring tides and near the lagoon entrance. The water refreshment rate in the Lagoon can not be positively influenced by incorporation of open piled causeway or by dredging the Lagoon entrance. Whether this is acceptable or not needs to be studied in the EIA.
4. The sediment transport only changes to minor extent. Local adjustment to the changed flow conditions occur, which is normal in dynamic coastal systems. No significant erosion or accretion patterns have been observed.

However, the EIA Consultants did not conclude the impacts to the environments but strongly recommended that the following additional tasks be followed up:

1. **Analysis:** The numbers of each key bird species need to be determined.
2. **Estimate of energy consumption:** The total energy consumption by bird species and fish larvae has to be estimated.
3. **Demarcation of feeding areas:** The feeding areas, Salt Works and lagoon are to be demarcated.
4. **Evaluation of potential impact:** Simulation of the transport of particles (=phytoplankton) into the lagoon should be conducted under present and future hydrodynamic regimes.
5. **Assessment of potential impact:** The distribution of feeding areas under a changed regime, i.e., after implementation of the expansion, will be compared with those at present.

Meanwhile the simulation model the JICA Study Team used resulted in the following predicted phenomena: (i) at the entrance of the lagoon in the original port expansion plan, the tidal current will be augmented by 0.4 – 0.5 m/sec and its direction will divert to east-westward by 15 to 20 degree, (ii) meanwhile there will be no significant change in the tidal current at the lagoon entrance in case of development of Contingent Alternatives A and B. In this regard, the Contingent Alternatives will much less impact to the lagoon.

Besides the impacts to the entrance of the lagoon, the original expansion plan and Contingent Alternative A will change the tidal current at the oyster farm. The Contingent Alternative B, on the other hand, will not cause any significant change of tidal current to the oyster farm. In general, the Contingent Alternatives have much bigger impact than the original expansion plan to the tidal currents in the bay as a whole.

5.5.2 Intensity of Siltation on Approach Channel and Port Basin

The JICA Study Team conducted the numerical simulation on the changes of the seabed and seashore bathymetry in order to estimate the maintenance dredging volumes of the approach channel and port basin with respect to four cases: (i) without the project case, (ii) original port expansion plan, (iii) Contingent Alternative A and (iv) Contingent Alternative B.

The annual siltation volumes for the cases above are summarized in the table below:

Table 5.5.1 Annual Siltation Volume

Case/Alternatives	Phase	Siltation/year (m^3/year)
Without-the-project	-	359.000
Original Expansion Plan	Phase 1	497.000
	Master Plan	611,000
Contingent Alternative A	Phase 1	626,000
	Master Plan	402,000
Contingent Alternative B	Phase 1	774,000
	Master Plan	604,000

Source: JICA Study Team

From the table above, among Phase 1 expansions, the original plan will have less siltation than the Contingent Alternatives. On the contrary, among the master plans, Contingent Alternative A will have the least siltation.

5.5.3 Ship Manoeuvrability

The EIA Consultants conducted a detailed ship manoeuvring simulation for the original expansion plan both for the initial phase and full expansion. The simulation has confirmed the dimensions of the approach channel and turning basin for safe navigation. Meanwhile, as the JICA Study Team did not conduct any simulation study, only a preliminary assessment of the safe navigation can be discussed on Contingent Alternatives as follows:

Alternative A: Entering to the turning basin, a ship has to turn to portside about 30 degrees. As the ship may have not sufficient speed at the turn, tug assistance is technically mandatory. As the distance from the bend to the centre of the turning basin is almost 1,000 m, the ship can stop at the turning basin safely. Turning the ship and leading it to berth, however, will have to be carefully manoeuvred in comparison with other plans, as strong winds are prevailing from the south in the bay. The wind pressure will act on the ship hull and push her to the berth. On leaving the port before gaining sufficient thrust, a ship needs tug assistance to resist the prevailing south winds in order to avoid being run aground to the starboard channel ridge.

Alternative B: A completely new navigation channel will be excavated in the direction of south-southwest. From the entrance of the channel, it is straight about 2,800 m and an entering ship will be totally controlled by tugboats when reaching the bend from where the channel will gradually be widened to the turning basin. As the portside berthing is necessary, the ship will be turned 180 degrees at the turning basin and push to the berth. This will not be difficult manoeuvring, as the winds are prevailing from the south. Ships manoeuvring to leave the port will have no difficulty, as the ship hull will not be exposed to the prevailing south winds.

5.5.4 Berth Availability (Harbour Calmness)

As previously discussed, the original plan and Contingent Alternative A have sufficient harbour calmness to accommodate ships from 500 GT to 50,000 GT. However, Alternative B needs a breakwater to improve harbour calmness.

5.5.5 Accessibility from Land

Accessibility from land is ensured for the original expansion plan as the expansion is connected to the existing port premises. The Contingent Alternatives both A and B require the consent among the concerned parties such as the Municipality, Navy, and residents close to the site where the causeway will be located.

5.5.6 Summary

From the discussion above, the summary of the evaluation is tabulated below:

Table 5.5.2 Evaluation of Alternative Expansion Plans

		Original Expansion	**Contingent Alternatives**		
			A	**B**	**C**
Layout	**Quay Wall and Reclamation**	Reclaim at the south of the bay offshore from the existing berths. The causeway is rather short.	Reclaim at the north of the bay. Berth alignment is on east-west. The causeway is long.	Reclaim at the north of the bay. Berth alignment is on north-south. The causeway is long.	Similar to B. But the berth is separated from the container yard.
	Navigation Channel	Use the existing approach channel by deepening and widening.	Divert to the southeast from the existing approach channel.	Excavate a new channel from the entrance to SSE direction.	Similar to B
	Access from Land	Extend the existing port road and rail tracks.	Use a land strip between Navy Base and "Up-market Residential" shown in the city plan.		
Construction Period and Remarks		Need 30 months. Use CSD and TSHD for dredging and 3 sets of drilling machines for cast-in-situ concrete piles.	35 months Need a temporary jetty , a pre-cast yard (2.0 ha) and gat barge for revetment works Others are same as Original plan.	38 months Similar to A except pre-cast yard (1.0 ha)	36 months Similar to B
Items to Evaluate	**Environmental Impact**	Augment the speed of tidal current at both the lagoon entrance and oyster farm.	Will not augment the speed of tidal current at the lagoon entrance but the oyster farm.	Will not augment the speed of tidal current at both the lagoon entrance and oyster farm.	May be similar to B (no numerical simulation is done).
	Siltation on Channel and Basin	Phase 1 497,000 m^3/year Master Plan 611,000 m^3/year	Phase 1 626,000 m^3/year Master Plan 402,000 m^3/year	Phase 1 774,000 m^3/year Master Plan 604,000 m^3/year	
	Navigation	Confirmed safe for ship maneuvering simulation.	Prevailing south winds may make turning and berthing comparatively difficult.	May be safer than A.	Similar to B.
	Harbour Calmness (Phase 1)	99.9% available for loading and unloading.	99.9% available for loading and unloading.	89.8% available for loading and unloading. Need a breakwater.	Similar to B.
	Access from Land	Extend the existing road and railway.	Require the consensus from the municipality government and Navy in laying out the causeway.		
Cost (Million N$)	**Civil Works**	1,660 (100%)	2,199 (133%)	1,930 (116%)	1,950 (117%)
	Breakwater to Satisfy Harbour Calmness	Not necessary	Not necessary	Necessary Approx. 386 [3]	Necessary Approx. 390 [4]
	Equipment	451 (100%)	451 (100%)	451 (100%)	490 (109%)
	Total	2,111 (100%)	2,650 (126%)	2,767 (131%)	2,830 (134%)
Remarks		Cost for yard expansion is included.		Cost for breakwater is included.	Cost for break water is included.

[3] As the sea is very calm and seabed elevation is not too deep, 20 % of the above civil work cost is assumed as the cost of breakwater.
[4] Ditto

5.6 Implementation of Recommended Contingent Alternative

5.6.1 Recommended Contingent Alternative

So far as the results of both the EIA study and feasibility study are concerned, the execution of the original port expansion plan is the most recommendable from the following viewpoints:

- It is financially and economically viable. Its project cost is less than those of the contingent alternatives.
- It will not cause serious environmental impacts to both the lagoon and the bay.
- It needs a shorter period of time to complete than the alternatives.

Should the original port expansion plan be aborted to preserve the lagoon environments in compliance with Ramsar Convention or for other reasons, the most probable alternative port expansion would be Contingent Alternative A. The reasons for this are that:

- Impact to the lagoon is considered less than the original port expansion plan.
- Alternative A has sufficient harbour calmness.
- Alternatives B and C will be more expensive than Alternative A when the breakwater is taken into account to satisfy the harbour calmness.
- Maintenance of the approach channel and port basin of Alternative A is less costly than that of the Contingent Alternatives B and C.

In the case of Contingent Alternative A, safe navigation will be ensured by employing sufficiently powerful tugboats, the necessary capacity of which can be determined by ship manoeuvring simulations.

The second phase construction of Contingent Alternative A will be made in between Phase 1 reclamation and the causeway. This construction may need a shorter period to complete than Phase 2, as the construction site is sheltered from the invading waves and the working conditions will be much more favourable for marine works.

The main comparative aspects among the original plan and contingent alternative plans are summarised in the Table 5.6.1 below.

Table 5.6.1 Major Aspects among Port Expansion Plans

	Original Plan	Contingent Plans		
		Alternative A	**Alternative B**	**Alternative C**
Impacts on Natural Environments	-	Acceptable	Acceptable	Acceptable
Impacts on Social Environments	-	Acceptable	Serious to City Planning	Serious to City Planning
Project Cost	100%	126%	131%	134%
Operation	-	Similar to the Original	Similar to the Original	More costly

5.6.2 Implementation Schedule of Contingent Alternative Plan

(1) Overall Schedule

Should the original port expansion plan be aborted, the following administrative, technical and environmental activities will be needed:

1. Financial arrangement for several investigations, engineering study (E/S) and an environmental impacts assessment (EIA)
2. Selection of the consultants for E/S and EIA as well as selection of contractors for subsoil investigation, seabed materials survey, bathymetric survey, etc.
3. Basic design to be prepared by the consultant assigned for E/S
4. Social and natural environmental clearance by EIA consultant assigned for EIA of Phase 1
5. Selection of contractor for civil works for Phase 1
6. Execution of the civil works construction of Phase 1
7. Basic design by the consultant assigned for E/S of Phase 2
8. Selection of contractor for civil works for Phase 2
9. Execution of the civil works construction of Phase 2

For the purpose of the hypothetical discussion hereinafter, it is assumed that the decisions on the contingent actions will take place in April 2010 should a negative EIA report on the original port expansion plan be submitted in March 2010. It is also assumed that Namport will use its own financial mechanism to implement the project to expedite the completion.

(2) Financial Arrangement

Namport will need about 3 months time to prepare the financial arrangement to employ the contractors for geotechnical investigation including borehole exploration, seismic survey, seabed materials survey at the alternative site and consultants for E/S and EIA. Namport will prepare the contract documents including their TOR (terms of reference) of the works or services at this stage.

In discussing the hypothetical project implementation, it is assumed that Namport would use its own financial resources to employ geotechnical survey contractors and engineering and environment consultants.

(3) Selection of Geotechnical Contractors and Consultants for E/S and EIA

As Namport has many experiences in the employment of geotechnical contractors, the selection of the contractor can be made in parallel with the financial arrangement.

The selection of the E/S consultant should be made timely on the completion of the geotechnical investigation at the alternative site—i.e. within 7 months after the decision making on the contingent plan. The selection may need 3 months, as the tender will be an international competitive bid (ICB).

As the basic design may need 6 months for the consultants to complete, the selection of the EIA consultant will be made within 13 months after the decision making. The selection may need 3 months, as the tender will be an ICB.

(4) Basic Design of Civil Works and Preparation of Tender Documents

No detailed drawings will be produced by the E/S consultants since the civil works construction will be executed under DB (design and build) or EPC (engineer, procure and construct) contract. The consultants will be able to produce the basic design within 6 months because all the design conditions consisting of all the natural conditions including geotechnical information and design vessels would have been available with the E/S consultants when they begin the engineering study. Two additional months will be required for the E/S consultants to complete the tender documents incorporating the contractor’s obligations required by CEMP (construction environmental management plan) which will be prepared by the EIA consultants.

(5) EIA Study

The EIA consultants will estimate the social and natural environmental impacts caused by the Contingent Alternative A. The main issues related to the natural environments will be the morphology of seashore and seabed as well as the changes of tidal currents in the Walvis Bay. However, as Namport has already acquired plenty of study results in this regard, the environmental assessments will not take a long time. The main issue related to social environments will be comparatively big issues. First, the reclamation offshore of the “Upmarket Residential” area has to be agreed upon with the municipal government. Second, as the access has to be allocated in between Navy Base and “Upmarket Residential” area, consensus on the rather heavy traffic caused by the container transport is required. In this regard, there should be more public meetings and stakeholders meetings to be held and, therefore, a considerable period of time may be necessary. Based on the experience of the EIA study on the original port expansion, 8 months are allocated for that of the Contingent Alternative A.

(6) Selection of Civil Works Contractor

As previously mentioned, the civil works contractor will be selected based on a DB or EPC contract according to ICB. The tendering will need 3 months. The contract negotiation will need other 3 months to conclude the lump sum contract. As a result, the selection of the civil works contractor may need 6 months in total.

(7) Completion of Civil Works

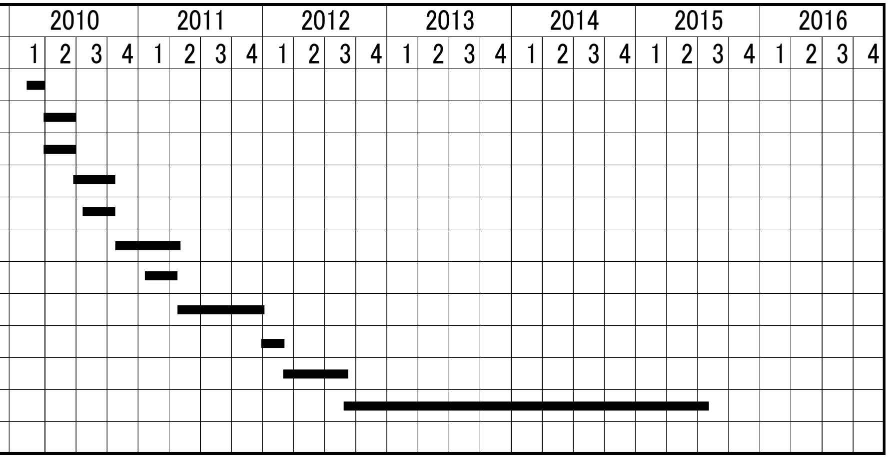
From the discussions above, the commencement of the civil works construction will take place in the 29th month after the decision making on the contingent plan.

As discussed in the previous section, the time to complete the Phase 1 of the Contingent Alternative A is estimated to be 35 months. This will result in the start of the container terminal operation in the 64th month after the decision making, in other words, in July 2015 if the decision on the contingent alternative is made in March 2010.

The implementation schedule can reviewed in Table 5.6.2.

Table 5.6.2 Implementation Schedule of Contingent Alternative A (Own Finance)

	Year	
	Quarter	
	Namport Decision on Contingent Alternative A	March 2010
1	Financial Arrangement for the Project	3 months
2	Selection of Geotechnical Contractors	3 months
3	Subsoil Investigation	4 months
4	Selection of Consultants for E/S	3 months
5	Basic Design	6 months
6	Selection of Consultants for EIA	3 months
7	EIA Study	8 months
8	Tender Documentation	2 months
9	Tender and Selection of Contractor of Civil Works Phase 1	6 months
10	Phase 1 Construction	35 months



Source: JICA Study Team