7 WATER QUALITY

7.1 Introduction

Key water quality issues during construction will pertain to the impacts of dredging and reclamation and stormwater runoff from the construction works. Modifications to the tidal regime during construction of the reclamation and local breakwater and dredging the access channel could also have an impact. These impacts are discussed in this chapter in relation to changes in the water quality and sedimentation patterns. The effects of the water quality changes on marine ecology are discussed in Chapter 8.

7.2 Methodology

7.2.1 Water Quality Studies

The water quality assessment has followed a multi-stage approach as follows:

(a) studies of impacts resulting from the reclamations, breakwater and access channel.

The WAHMO hydraulic and water quality models were run to identify the impacts on water circulation, water quality and sedimentation resulting from construction of CT10 and 11, the Ancillary Works, the breakwater and the approach channel. The models were used to simulate baseline conditions for both the wet and dry seasons on the spring and neap tides before construction of any of the reclamations, an Interim Scenario (representing the Advance Works) and completion of Stage I.

(b) study of impacts during construction

Impacts during construction will be from construction of reclamations and dredging. The key issue will be dredging. The WAHMO sediment plume model was run to establish the extent and magnitude of the sediment plumes from different dredging scenarios. The model was also modified to provide an assessment of dissolved oxygen (DO) depletion that could result from dredging impacts. One of the key issues that has been identified during the study is the potential for pollutants to be washed out of the sediments during dredging. The sediments in the study area have been tested to determine the degree of pollution and the potential for adverse impacts.

(c) studies of pollution during operation of the port

A box model has been used to determine the potential for high levels of nutrients in the Discovery Bay embayment as a result of pollution loads from storm runoff from the port and Discovery Bay catchments and effluent discharges from Discovery Bay and Peng Chau. The planned diversion of the effluent discharges to the new sewage treatment works at Siu Ho Wan has been taken into account in this assessment.

7.2.2 Presentation of Results

The results of the water quality studies are presented in this Chapter. Full details of the mathematical modelling used to identify the impacts and the assessment of the results are presented in Appendix F.

7.3 Impacts from Reclamations on Water Circulation

7.3.1 Modelling Scenarios

Figure 7.1 shows the scenarios that were tested during the Interim and Stage 1 WAHMO model runs and the locations of the stations used for assessing the impacts. The models have been run for neap and spring tides in the wet and dry seasons although attention has focused on the neap tide of the dry season, which has the smallest tidal range, and the spring tide of the wet season, which has the largest tidal range.

7.3.2 Water Circulation

The model studies have concluded that there will be significant changes in water movements in the wet season at:

(a) station F9A where substantial reductions in velocities are forecast with the development of a quiescent zone following the construction of the breakwater;

(b) station F3A where the velocities will reduce by about 17 percent and change in direction from east/west to north/south-west;

(c) station 5 where the flows will be realigned in a south-west/north-east direction and there will a reduction in velocity of about 15 percent on the flood tide; and

(d) stations 2 and 4 where velocities at the entrance to Discovery Bay reduce.

Changes in water movements in the dry season will be as follows :

(a) at the north of the study area, with a reduction in velocities at station F9A of the order of 50 to 70 percent;

(b) tidal flows will weaken in Discovery Bay; and

(c) to the north of Peng Chau velocities will reduce at stations 2, 4 and F3.

The overall pattern that can be seen from the hydrodynamic studies is of a reduction of flow in and out of the Discovery Bay embayment and a reduction in the flushing capacity of the embayment. The implications of this on water quality are discussed in Section 7.3.4.

7.3.3 Sedimentation

Existing Sediment Load and Patterns

A massive sediment and pollution load is conveyed into Hong Kong waters by the Pearl River during the wet season. In recent field studies it has been confirmed that the mainly oceanic waters control the ingress of sediments from the Pearl River; while on the ebb tide a part of the sediment load is deposited to the east of the Study Area. These field data accord with the predictions made by the WAHMO sediment model demonstrating the dynamic nature of the seabed deposits within the study area.

Existing sedimentation patterns in both the wet and dry season were defined using the WAHMO sedimentation and erosion model which indicated that deposition rates in the study area are of the order of 0.10kg/m^2/tide in the dry season, increasing to up to 0.40kg/m^2/tide during the wet season.

Changes in Sedimentation Patterns

Not unexpectedly the results of the models reveal changes in deposition patterns during the wet season as a result of the alterations to flows caused by the reclamation and the construction of the local breakwater. The extent of the far field changes predicted during the wet season are illustrated on Figures 7.2 and 7.3 which show the contour for deposition of 0.20kg/m^2/tide for wet season spring and neap tides as a comparison between the Baseline and Interim Scenarios. The far field changes result mainly from the breakwater so the impacts from the Stage 1 Scenario will be similar to those from the Interim Scenario. The most noticeable feature of the changes is an increase in sediment deposition rates to the north and west of Lamma due to reductions in velocities following construction of the breakwater.

A summary of the changes in sediment erosion and deposition patterns is given in Table 7.1.

Table 7.1 Summary of Changes in Sediment Erosion and Deposition Patterns following Construction of the Ancillary Works

Dry Season Neap Tide	Dry Season Spring Tide	Wet Season Neap Tide	Wet Season Spring Tide
Ambient mud deposition rate in the Study Area is <0.10kg/m^2/tide. Both scenarios indicate reductions in the areal extent of deposition between Penny's Bay and Peng Chau, and alterations to the deposition pattern to the northeast of Hei Ling Chau	Main difference lies in the fact that the sediment "toe" which forms between Cheung Chau and Lamma Island, is extended further south once the breakwater is in place (ie Interim Scenario and Stage I). In Stage I increased deposition experienced north of Lamma Island Ambient sediment deposition rates in the Study Area are <0.10kg/ m^2/tide	During the wet season the sedimentation patterns alter considerably under both the Interim Scenario and Stage I. Victoria Harbour : deposition now observed throughout the harbour Between Peng Chau, Hei Ling Chau and Cheung Chau extensive reworking of the sediment deposition due to realignment of flows created by the breakwater in terms of area and volume. Study Area now witnesses significant increases in sediment loads deposited between the Study Area and west of Lamma Island. Increased deposition in Ha Mei Wan (near to the Lamma Island Power Station) Predicted deposition rates expected to increase, locally by a factor of five. Offshore, between the Chi Ma Wan and Shek Pik Peninsulas extensive deposition now observed towards the shoreline. Increase in areal extent of sediment deposition between Peng Chau and Discovery Bay.	During this event the pattern is more complex with alteration of sediment patterns to the west and south of Lamma Island due to realignment of flows, also observed changes in deposition patterns in the eastern waters around Po Toi on account of the changes in flows. In the immediate Study Area the general pattern remains generally the same although changes in deposition rates are forecast round Hei Ling Chau which could affect the plans for a new typhoon shelter, the viability of the fish nursery areas and the substantially of benthic fauna. The West Lamma Channel appears to suffer greater sediment deposition between Lamma and Hei Ling Chau and to the south of Lantau Island, although sediment deposition is at least 1km further offshore (compared with the baseline) the areal extent and the deposition rates are considerably increased as a consequence of constructing both the Interim and Stage I Scenarios.

The implications of the changes in sediment deposition and erosion are that the deposition in the area will double (from 21 kg/m^2 to 44 kg/m^2 each year) once the approach channel has been dredged. The deposition rate could be expected to increase from 12 kg/m^2 to 30 kg/m^2 each year once the breakwater is in place. Sediment deposition will be about twice as rapid as the present situation and consequently maintenance dredging could be required.

7.3.4 WAHMO Water Quality Modelling

The extent to which the reclamation, breakwater and approach channel could affect future water quality was considered by using the WAHMO water quality models. The modelling has used existing pollution loads; the effect of removing the pollution loads from Discovery Bay and Peng Chau is discussed in Section 7.5.

The relative changes in water quality from the existing situation to the Interim and Stage I scenarios are presented in Table 7.2

Table 7.2 Relative Changes in Water Quality

Parameter	Changes Arising from Interim Scenario		Changes Resulting from Stage I	
	Dry Season	Wet Season	Dry Season	Wet Season
DO	-0.2%	-2.6%	<-0.01%	-1.9%
BOD	5.9%	-0.2%	4.5%	-0.5%
NH_3	19.4%	10.5%	5.9%	-7.6%
Oxid N	15.6%	18.3%	9.8%	14.2%
Org N	-4.0%	-3.4%	-3.7%	-3.2%
Chl-a	-9.2%	-22.2%	-9.3%	-17.8%
E.coli	5.0%	-2.2%	10.6%	10.5%

Note : -ve indicates a deterioration in water quality

Dissolved oxygen levels are forecast to only change during the wet season and even then only marginally. As the monitoring data for this study area indicate the water body is well oxygenated (90% DOS) the small deterioration forecast does not represent a significant impact nor does it pose a threat to overall WQO's. Small improvements in BOD levels are forecast for both scenarios in the dry season with little alteration in the wet season (present BOD levels are generally acceptable at about 1 mg/l). Both ammonia and oxidised nitrogen levels are forecast to improve (except for Stage I wet season).

Of some concern however are the increases which are predicted for both organic nitrogen and chlorophyll-a, and these are especially marked during the wet season. These indicate that there is potential for an increased occurrence of algal blooms, especially within relatively quiescent bodies of water. Areas of particular concern include Discovery Bay (stations 1 - 4) and to the northeast of Peng Chau (station 5).

As the data provided above represent general, or "average" conditions in the study area further consideration needs to be given to individual areas. Thus the following assessment focuses on inner Discovery Bay (station 1), outer Discovery Bay (stations 2 and 4) and outside Discovery Bay (station 3). In addition consideration was also given to the water quality implications for the area between the container terminals and the breakwater (station 5). Mean seasonal alterations in water quality at these locations are given in Table 7.3. The values in the table for the Interim and Stage I scenarios are the changes from the Baseline with a negative value representing a reduction in that parameter.

Table 7.3 Changes in Water Quality

Station	DO (mg/l)				BOD (mg/l)				NH3(mg/l)[2]		
	Base-line	Interim	Stage I	WQO[1]	Base-line	Interim	Stage I	WQO[1]	Base-line	Interim	Stage I
dry season											
1	6.7	0.0	0.0	4	1.01	-0.03	-0.03	5	0.00	0.00	0.00
2	6.6	-0.1	-0.1	4	1.06	-0.03	-0.03	5	0.01	0.00	0.00
3	6.5	-0.1	-0.1	4	1.12	-0.02	0.00	5	0.01	0.00	0.00
4	6.6	-0.1	0.0	4	1.04	-0.04	-0.02	5	0.00	0.00	0.01
5	6.5	0.0	-0.1	4	1.07	-0.02	-0.01	5	0.00	0.00	0.00
wet season											
1	6.5	0.1	0.1	4	1.26	-0.15	-0.14	5	0.00	0.00	0.00
2	6.3	0.1	0.1	4	1.32	-0.15	-0.14	5	0.00	0.00	0.00
3	6.3	0.1	0.1	4	1.37	-0.14	-0.11	5	0.01	0.00	0.01
4	6.2	0.1	0.2	4	1.32	-0.16	-0.15	5	0.00	0.01	0.01
5	6.0	0.0	0.0	4	1.39	-0.09	-0.08	5	0.00	0.00	0.00

Station	OXD N (mg/l)[2]			ORG N (mg/l)[2]			CHL-A (μg/l)			E.Coli (no/100ml)			
	Base-line	Interim	Stage I	Base-line	Interim	Stage I	Base-line	Interim	Stage I	Base-line	Interim	Stage 1	WQO[3]
dry season													
1	0.03	0.00	0.00	0.26	0.02	0.03	1.43	0.13	0.22	433	-13	-41	610
2	0.03	0.00	0.00	0.26	0.02	0.03	1.33	0.10	0.17	1717	-55	-230	610
3	0.03	0.00	0.00	0.27	0.02	0.02	1.27	0.05	0.06	5455	18	206	610
4	0.03	0.00	0.00	0.25	0.03	0.04	1.21	0.15	0.27	672	4	-5	610
5	0.04	0.00	0.00	0.20	0.01	0.01	0.94	-0.01	-0.01	224	90	-82	610
wet season													
1	0.03	0.00	0.00	0.44	-0.01	-0.01	3.20	0.38	0.61	562	-40	-114	610
2	0.03	-0.01	0.00	0.44	-0.01	-0.01	3.02	0.36	0.54	2209	-107	-339	610
3	0.03	-0.01	0.00	0.44	-0.01	-0.01	2.98	0.23	0.29	6025	-35	206	610
4	0.04	-0.01	-0.01	0.43	0.00	0.01	2.63	0.52	0.86	1146	-26	-119	610
5	0.06	-0.01	-0.01	0.38	0.00	0.00	1.85	0.10	0.10	230	-71	-54	610

Notes (1) depth average; (2) WQO for Total Inorganic Nitrogen 0.1mg/l; (3) WQO for secondary contact subzone

Levels of dissolved oxygen are predicted to be marginally lower in the dry season than they are at present in the inshore water recreation area but there will be a marginal improvement in the wet season. There will be a small reduction in BOD levels in the dry season with a slightly larger reduction in the wet season. The most significant indicators of the potential deterioration in water quality are organic nitrogen and chlorophyll-a (although the increases should be judged with caution as the model is very sensitive to alterations in nitrogen). Increases in these pollutants could result in an increase in algal blooms. Levels of organic nitrogen are predicted to increase in the dry season but will remain similar to the present levels in the wet season. The levels of chlorophyll-a are predicted to increase in both the wet and dry seasons.

The predictions serve to highlight the potential problems of enhanced eutrophication in this area, even when no additional pollution loads are generated by the Lantau Port Development, and also emphasise the need to eliminate existing effluent discharges, or at the very least improve the levels of treatment, and minimise the pollution load from the Lantau Port Development. This is considered further in Section 7.5 of this report.

7.4 Impacts from Dredging

7.4.1 Introduction

The purpose of this section of the report is to present the results of an assessment of the impacts on the water quality in the study area from dredging and reclamation. The impacts that have been considered are:

(a) pollution from any contamination of the sediments;

(b) increases in suspended sediment loads;

(c) reductions in dissolved oxygen levels;

(d) increases in levels of nutrients in the water column as a result of pollutants being washed out of the sediments during dredging; and

(e) the effects of sedimentation.

The dredging and reclamation that will be required for this project is shown in Table 7.4. The Advance Works impacts were at first assessed on the basis of a drained design, involving only a small amount of dredging essential for the seawall foundation. It was subsequently decided by Government to adopt a dredged design for the Advance Works so as to leave the options open for the container terminals reclamation design. The current assessment has been made on the basis of the dredged design. The remainder of the Ancillary Works will be a drained design and there will only be minimal dredging of this option. The locations of the works detailed in Table 7.4 are shown on Figure 7.4.

Table 7.4 Dredging and Reclamation Works

Location	Dredging Mm^3	Reclamation Mm^3	Programme	
			Dredging (months)	Reclamation (months)
Advance Works Dredged Design: Section 1 Section 2 Section 3 (drained)	 3 2 -	 4 3 1.4 (+0.7)	 3 2.5 -	 4 3 3
Ancillary Works (excl Advance Works) + Excl. Cheong Lee Shipyard	1.1	8.2 (+1.9)	6	24 (9)
Breakwater	2.5		5	
Approach Channel	13.0	-	14	-
Ancillary Works (Back Up Area) (Drained Reclamation)	-	11.5	-	9

Notes (1) figures in brackets are surcharge

Sediment Quality

Analyses of the marine mud to be dredged for this Project has revealed that there is no contamination by heavy metals except in the area of the local breakwater where the top 0.5m is defined as being contaminated and therefore requires special dredging and disposal methods. There is approximately 165,000 cu m of contaminated mud in this area. Dredging techniques which should be adopted for the contaminated mud include the following. Recent analysis of the marine mud in the approach channel has confirmed that it is slightly contaminated. Quantities of contaminated mud to be removed are yet to be determined.

The contaminated mud will be disposed of at the Contaminated Mud Pits east of Shau Chau in accordance with the requirements of the FMC and EPD.

(a) dredging will need to be carried out in accordance with the requirements of the EPD and FMC, using inter alia closed grabs;

(b) no material will be allowed to overflow while being lifted;

(c) the Contractor will be required to apply for a licence to dispose of the marine mud at East Shau Chau and will need to provide details of timing of waste arisings, volumes and levels of contamination to the FMC in his application.

The remainder of the material is uncontaminated and will be disposed of at the gazetted dumping ground south of Cheung Chau. There will be about 21.5Mm^3 of material to be dumped at gazetted dumping grounds.

Table 7.5 Summary of the Impacts of Dredging on Sensitive Receivers

Location	Impact (mg/L above ambient)
Ma Wan W.	2
Ma Wan E.	< 1
East of Approach Channel	5
Inner Discovery Bay	-
Outer Discovery Bay	1
Tai Lei Channel	-
Tung Wan	< 1
Ma Wan Fishery	2
Ma Wan Mariculture	2

Suspended Sediment Loads

The suspended sediment loads that have been predicted by the sediment models for the far field are summarised in Table 7.5. These calculations assume that the construction programme discussed in Chapter 3 of this report will be adopted. The impacts in Table 7.5 are cumulative and include the Ancillary Works, Container Terminals CT 10 and 11, the breakwater and the approach channel. The impact from the container terminals is,

however, small since a drained reclamation design has been assumed. The impacts are within acceptable levels.

Near field impacts are summarised in Table 7.6. The assessment has shown that the near field impacts are within acceptable levels except very close to the dredger. The impacts reduce to ambient within about 200m of the dredger.

Table 7.6 Near Field Suspended Sediment Loads from Dredging

Distance from Dredger (m)	Impact (mg/l above ambient)
25	1000
50	450
75	250
100	150
125	75
150	50
200	0

Dissolved Oxygen

The computer modelling of dissolved oxygen depletion during dredging has shown that the impacts will be very small and will not cause any WQOs to be breached.

Nutrient Loads

The assessment of nutrient loads from the dredging has considered the amount of sediment that could be suspended in the water column during dredging and reclamation and the nutrient load that could be washed out from the sediment. The suspended sediment loads are discussed in the previous section. The potential for washing of pollution into the water column has been assessed by carrying out elutriate tests on samples of the sediments collected during site investigations. A summary of the elutriate test results is given in Table 7.7. The tests show quite a large range of results but it appears that there is a higher level of nutrients in sediments to the east of the study area than to the west. This is to be expected since a large part of the pollution load is carried southwards by the Pearl River and it appear likely that this pollution would be deposited in the main ebb tide channels which run along the eastern side of the study area.

The predicted levels of pollution in the water column at distances from the dredger, assuming a dredging rate of 40,000 cu m per day and a loss of sediment of five percent are shown in Table 7.8.

The figures in Table 7.8 show that the increase in nutrient levels will be very localised around the dredger and the nutrient levels will reduce to almost ambient at about 100m from the dredger. The levels will still be exceed the WQOs but this is inevitable since the ambient conditions already exceed the WQOs. The increase above ambient will be very small except in Penny's Bay where there could be a build up of pollutants due to the limited movement of water in and out of the bay. This, however, is not likely to have serious consequences since the whole of Penny's Bay will in effect be a works area for the project and there are no sensitive receivers in the bay. The impact will also be short term during the early part of the construction since Penny's Bay will be filled for the Ancillary Works.

Table 7.7 Summary of Elutriate Test Results

Parameter	Range (mgN/l)
Ammoniacal nitrogen	<0.05 to 5.3
Nitrite nitrogen	0.02 to 0.07
Nitrate nitrogen	0.10 to 0.17
Total inorganic nitrogen	0.22 to 5.54

Table 7.8 Impacts of Total Inorganic Nitrogen from Dredging

Distance from Dredger (m)	Impact (mgN/l above ambient)
25	0.100
50	0.044
75	0.026
100	0.017
125	0.011
150	0.007
200	0.003
250	0
WQO	0.1
Ambient	0.31

7.5 Cumulative Water Quality Impacts

The WAHMO modelling studies showed that a quiescent zone will be formed in the area between the local breakwater and the approach channel following the construction of the breakwater. It was also predicted that there will be a reduction in the flushing capacity of the water body in Discovery Bay.

Only minor depletions in dissolved oxygen are forecast in the study area as a whole, and as the water quality monitoring data indicate these waters are well oxygenated these changes do not present a challenge to the WQO's. However, significant increases in both organic nitrogen and chlorophyll-a were predicted, especially during the wet season. A minor reduction in dissolved oxygen levels was forecast in the inshore water recreation area proposed in Discovery Bay. Potential deterioration in water quality is forecast in terms of increased levels of nutrients and chlorophyll-a.

The WAHMO studies considered the existing pollution loads into the embayment and the effect on water quality of the reclamation, breakwater and approach channel. There will be additional pollution loads from storm runoff from the port, Peng Chau and Discovery Bay catchments and from pollutants washed out of sediments during dredging. These are all discussed in earlier sections of this report. In addition the Islands Sewage Master Plan recommended that the effluent discharges from Discovery Bay and Peng Chau should be diverted to the new sewage treatment works at Siu Ho Wan. A cumulative impact analysis has been carried out to measure the effect of these.

A box model was developed and used in conjunction with the mathematical modelling studies to predict the water quality if the only pollution source was the Lantau Port, if the stormwater from Discovery Bay and Peng Chau were added and if the recommendations of the SMP were deferred until a later date. The box model subdivided the study area into segments as shown in Figure 7.5.

The contribution of nutrients from all of the sources was estimated and the flow rates derived. The box modelling assumed conservation of mass between the segments which permitted mass balances to be calculated.

At present stormwater from the catchment discharges directly into Discovery Bay via a series of culverts and drains. On the basis of the results given above the existing sources in and around Discovery Bay have a much greater impact (16 times) on water quality than stormwater from the Lantau Port Development.

The potential effect of the late implementation of the effluent export scheme for Discovery Bay (and Peng Chau) was assessed using the population forecasts and flow rates from the SMP (9,000 for Peng Chau and 25,000 for Discovery Bay and Yi Pak). The assumed effluent loads are given in Table 7.9 along with the pollution concentrations.

Table 7.9 Effluent Loads from Discovery Bay and Peng Chau (2011)

Parameter	Discovery Bay and Yi Pak	Peng Chau
Population	25,000	9,000
Daily Flow Rate	7,850m^3	2,100m^3/d
BOD (0.042kg/cap/d)	1050kg/d : 135mg/l	378kg/d : 180mg/l
COD (0.090kg/cap/d)	2250kg/d : 285mg/l	810kg/d : 386mg/l
Suspended Solids (0.040kg/cap/d)	1000kg/d : 130mg/l	360kg/d : 171mg/l
TKN (0.0077kg/cap/d) NH_4 (0.0050kg/cap/d)	190kg/d : 25mg/l 125kg/d : 16mg/l	69kg/d : 33mg/l 45kg/d : 21mg/l

Sources : Sewage Strategy Study 1989, for Pollution load factors
Lantau Port and Western Harbour Development Studies, for population forecasts
Islands Sewerage Master Plan

A summary of the predicted concentration of pollutants in each section of the study area is given in Table 7.10 for the four scenarios tested with each impact being expressed as a ratio compared with the impact from the first scenario.

Table 7.10 Summary of Mass Transfer of Pollutants and Resulting Concentrations

Scenario	Segment P, (volume 7.4Mm^3)	Segment A, (volume 4.4Mm^3)	Segment B, (volume 9.87Mm^3)	Segment C, (volume 2.87Mm^3)	Segment D, (volume 1.69Mm^3)
i. Stormwater from CT10 and 11	1	1	1	1	1
ii. Stormwater from Penny's Bay and CT10 and 11	1	1	.9	.9	.9
iii. as ii plus stormwater from Discovery Bay and Peng Chau	1	1	.9	.3	.5
iv. as iii. plus domestic effluent from Discovery Bay and Peng Chau (ie late implementation of SMP)	1	1	6	17	20

The results are considered conservative as no account is taken of the advection of pollutants northwards on the flood tide, dispersion due to the local flow regime or reactions within the receiving waters. However the results illustrate the relative significance of the potential impacts of discharges from various sources.

The assessment has used average pollution loads and stormwater flows but there will, of course, be occasions where pollution loads could be much higher, for example during the first flush of a storm after a period of dry weather. No data are available to quantify these impacts and no detailed studies of pollution in stormwater have been carried out in Hong Kong. The impact on the water body could be much higher during these periods, although the impact will only be for a short period of time.

It is apparent that the late implementation of the recommendations of the SMP will have a very significant impact in the outer part of Discovery Bay (an order of magnitude decrease in water quality), with a 50% decrease forecast in water quality in the inner part of Discovery Bay. The predicted impacts diminish over a comparatively short distance but the situation could deteriorate further when the later phases of the Lantau Port are developed.

On the basis of the foregoing, it may be concluded that the future water quality in the study area should not deteriorate significantly assuming that effluent from Discovery Bay and Peng Chau is exported to Siu Ho Wan Sewage Treatment Work. Pollution loads from the Lantau Port Development should be assimilated by the water body without having an adverse impact on water quality in Discovery Bay assuming that this recommendation is adopted. Every effort should still be made to reduce pollution loads from the port in view of the occasional high impact that could be experienced from stormwater.

7.6 Monitoring and Audit

7.6.1 Water Quality

Water quality monitoring will be required during construction to confirm the works are not contributing to an unacceptable deterioration in receiving water quality.

The Engineer will establish, in agreement with EPD and AFD, a series of monitoring stations with each station having a defined target limit for dissolved oxygen, suspended solids and turbidity.

Baseline monitoring should be carried out at all monitoring stations for a period of four consecutive weeks within a period of six weeks prior to the commencement of the marine works on four days of each week. Monitoring should be undertaken at each station on the mid-flood and mid-ebb tides at three depths, namely one metre below the water surface (upper), mid water depth (middle) and one metre above the seabed (lower).

The baseline results, control station monitoring results and WQO should form the basis for calculating the trigger, action and target levels (TAT) to be used in impact monitoring.

During the course of the works impact monitoring should be undertaken on three working days per week at each monitoring station. The interval between each sampling series (mid ebb and mid flood) should not be less than 36 hours. Two sets of turbidity, DO, DOS and temperature levels should be measured and water samples for suspended solids taken at each depth. Where the difference in value between the first and second reading of each set is more than 25% the readings should be discarded and further readings shall be taken.

If the monitoring data of turbidity or suspended solids or dissolved oxygen show a deteriorating trend or where TAT levels for any of these three parameters are exceeded, the Contractor shall be required to take action in accordance with an action plan which shall be submitted to and agreed with the Engineer.

The monitoring stations will be defined for each individual component of the marine works to be undertaken during the execution of the Advanced Works and Stage I Contracts. Specific areas of concern such as mariculture and fish nursery zones, which could be within the area influenced by dredging shall be included in the monitoring schedule. Other specific areas of concern include, but are not limited to Tung Wan (on Peng Chau where concern has been expressed that water quality within the Bay will deteriorate), Discovery Bay and Penny's Bay. The monitoring programme will need to be reviewed on a regular basis, and in response to any complaints received, to ensure that its aims and objectives are being achieved. It may be necessary to establish new monitoring stations part way through marine works contracts if it is found that adverse water quality impacts are reported. However it should be noted that the baseline stations should all be maintained to provide a complete and continuous data record.

Action on detecting a deterioration in water quality should include all necessary steps taken by the Contractor to halt the deterioration and to establish the status quo. The steps should include but not be limited to :

(a) checking of all marine plant and equipment;
(b) maintenance or replacement of any marine plant or equipment contributing to the deterioration;
(c) checking and maintenance of all silt screens; and
(d) review of all working methods.

The general procedures to avoid pollution during dredging works include the requirement that the Contractor should design his working methods and use equipment that minimises the risk of silt and other contaminants being released into the water column or deposited in other than the designated locations.

An action plan for water quality monitoring is presented in Table 7.11.

AFD have provided guidelines for the water quality objectives and action to be taken in the event of exceedance of the TAT levels at fish culture zones as given in Table 7.12.

Table 7.11 Action Plan for Water Quality Monitoring

Event	Action by	
	Engineer	**Contractor**
Monitoring results on a single occasion indicate unacceptable water quality.	Notifies Contractor.	Acknowledges verbally.
Monitoring results on two consecutive occasions indicate unacceptable conditions.	Notifies Contractor. Requires deployment of Contractor's existing plant and methods to be adjusted to meet WQR. Increases monitoring frequency to daily.	Reviews plant and working methods. Submits remedial proposals to Engineer for written approval. Implements remedial action immediately on receipt of approval.
Monitoring results on three or more consecutive occasions indicate unacceptable conditions.	Notifies Contractor and Environmental Protection Department. Requires Contractor to deploy alternative or additional plant and/or methods to meet WQR. Continues to monitor on a daily basis and takes water samples to confirm suspended solids concentrations.	Reviews plant and methods. Submits proposals for alternative or additional plant and/or methods to Engineer for written approval. Implements remedial actions immediately on receipt of approval.

Event	Action by	
	Engineer	Contractor
Monitoring results indicate persistently unacceptable conditions.	Notifies Contractor and Environmental Protection Department in writing. If approved remedial measures have not been implemented, Engineer directs Contractor to cease related works or parts of works until approved measures have been implemented and plant and methods made to comply with the required approvals. Continues to monitor on a daily basis and takes water samples to confirm suspended solids concentrations.	Implements approved remediation measures and ensures compliance of plant and methods.

Table 7.12 The Trigger, Action and Target Levels Requirements for Suspended Solids at Monitoring Stations Adjacent to Fish Culture Zones

	Trigger Level	Action Level	Target Level
Water Quality Criteria	50mg/l suspended solids less allowance for errors involved from estimating SS from turbidity measurements.	50mg/l suspended solids.	80mg/l suspended solids.
Actions on Exceedance	Increase monitoring to more than twice per day until compliance achieved.	Increase monitoring to high frequency level at least six times per day until compliance achieved. Alternatively 24 hour turbidity monitoring equipment would be acceptable.	Increase monitoring to high frequency level preferably at least six times per day until compliance achieved. Alternatively 24 hour turbidity monitoring equipment would be acceptable.
	Inform contractor who should undertake remedial action(s) if necessary.	Inform contractor who should undertake remedial action(s) if necessary. Inform AFD if exceedance confirmed from SS determination within 48 hours.	Inform contractor who should undertake remedial action(s) including stop work if necessary. Inform AFD if exceedance confirmed from SS determination within 48 hours.

Note : The requirements are for suspended solids levels at surface level and mid depth.

7.7 Conclusions

The conclusions of the water quality studies are as follows:

(a) water circulation

Circulation rates in the Discovery Bay area will be changed as a result of the construction of the reclamation for the port, the approach channel and the breakwater. There will be a noticeable reduction on water circulation throughout the study area and a quiescent zone will form close to the breakwater. Flows immediately outside Discovery Bay will reduce by up to about twenty percent and the velocities in the mouth of the bay will reduce to almost zero.

(b) sedimentation patterns

There will be changes in sedimentation patterns as a result of the changes in water circulation. The changes in sedimentation patterns will be noticeable both locally to the port and in the far field. Local changes could include increased sedimentation in the vicinity of the breakwater due to the very low water circulation rates. Maintenance dredging may be needed although is not possible to estimate the frequency of the dredging based on the environmental studies. The frequency of maintenance dredging will be low but there will be an environmental impact from sediment losses whenever dredging is carried out.

Far field changes will include a greater potential for sedimentation to the west of Lamma resulting from changes in water circulation after construction of the breakwater. The changes are small but could be significant in the long term and the increased sedimentation rates may result in a requirement for maintenance dredging. This could result in additional environmental impacts in the future since there is potential for sediments in the port area to become contaminated as a result of pollution from the port. These contaminants could be washed out of the sediments during dredging with an impact on the water quality.

(c) dredging

Some sediments in the vicinity of the breakwater have been found to be contaminated and special dredging techniques will be required. These sediments will be disposed of at the Contaminated Mud Spoil Pits at Sha Chau. Other dredged materials will be disposed of at a gazetted dumping ground.

Sediment testing has shown that there is potential for an impact on nutrient levels in the water body as a result of pollutants washed out of the sediments during dredging. The assessment of the impact of the nutrients on the water body has shown that the impacts will be small in comparison with the high background levels but this is still a key issue, particularly in view of the fact that the existing levels of nutrients are high and it has been concluded that measures should be taken to minimise the impacts. The mitigation measures that have been considered include reducing the rate at which the pollutants would be put into the water column by reducing dredging rates or quantities wherever this is practical.

Impacts from changes in suspended sediment loads and dissolved oxygen levels resulting from dredging will be small and within acceptable levels except in the immediate vicinity of the marine plant. Impacts from suspended sediments in the near field will be high but will reduce to close to ambient within about 200m from the dredger.

(d) reclamation

Impacts from reclamation will be within acceptable levels. Impacts could be reduced if the main part of the reclamation is either formed behind a seawall or if bunds and settlement lagoons are used to restrain sediment runoff from hydraulic filling.

(e) water quality

Water quality impacts will result from the increases in the nutrient levels during dredging and from changes in water circulation patterns. The former will be a temporary impact and may be mitigated as discussed above. The water quality modelling studies have concluded that there will be a longer term increase in nutrient levels in the Discovery Bay embayment and increased potential for eutrophication. This may be mitigated by an early implementation of the recommendation of the Islands Sewage Master Plan that the effluent loads from Discovery Bay and Peng Chau should be diverted to the new treatment works at Siu Ho Wan on North Lantau. Water quality in the Discovery Bay embayment should not deteriorate from that which exists at present assuming that this recommendation is implemented. The study has concluded that pollution from other contaminants should be within acceptable levels but there could be occasional high impacts from pollutants in stormwater. All possible measures to minimise pollution loads should be implemented and stormwater outfalls should discharge away from the Discovery Bay embayment wherever possible.

Water quality in Penny's Bay could deteriorate during the works as there could be a build up of pollutants over a period of time.

The assessment has concluded that there will be minimal pollution from the construction works other than that discussed above in relation to dredging. A number of recommendations are made in the next section in order to ensure that pollution from the construction works does not have an impact.

(f) monitoring and audit

The study has concluded that monitoring and audit will be required both during construction and operation of the port. The operation stage monitoring and audit will need to take account of the fact that construction activities will proceed over a very long period of time and there will be cumulative impacts from construction and operation. These will need regular review to take account of changes such as construction programmes and methods of operation of the port. It has been concluded that an environmental project office (ENPO) should be set up so that the cumulative impacts can be given due consideration.

An environmental monitoring and audit manual has been prepared.

7.8 Recommendations

The recommendations of the water quality assessment are as follows:

(a) to minimise the water quality impacts from dredging:

(i) all dredging should be carried out using low impact dredging techniques, that is dredgers that minimise the amount of spillage. Suction dredgers should be banned from overflowing of spoil at any time during dredging or transportation of spoil to the dumping ground. Consideration should be given to specifying grab dredgers with sealed grabs if this can be done without compromising the programme;

(ii) the construction programme should be designed to reduce the daily production rates and contracts should be written stating that the contractor may not increase the dredging rate unless he can demonstrate that water quality impacts will be acceptable. For example the dredging for the approach channel should be carried out over as long a period as possible;

(iii) a drained design should be adopted for reclamations wherever possible; and

(iv) about 165,000 cu m of marine deposits to be dredged in the vicinity of the breakwater must be considered as contaminated and should be dredged in accordance with the requirements of the Fill Management Committee and Environmental Protection Department. The marine deposits from this area must be dredged using sealed grabs. The Contractor will be required to apply for a license to dispose of the contaminated deposits at East Sha Chau.

(b) to reduce impacts from reclamation

(i) rehandling basins should not be used unless alternative methods prove not to be practical. However, in the case of the Advance Works rehandling basins will be required to meet the construction programme;

(ii) as far as practicable sand should be placed behind seawalls or retaining bunds and settlement lagoons should be used to minimise the sediment load in tailings; and

(iii) rainbowing to place fill should not be allowed.

(c) to reduce water quality impacts from construction sites

(i) reduce the amount of water used to dampen any surfaces or stockpiles;

(ii) prevent uncontrolled runoff from site by provision of perimeter drains at the seaward extremity of the sites in Penny's Bay;

(iii) any liquid generated on-site should be treated and disposed of in accordance with the provisions of the Technical Memorandum on Standards for Effluents Discharged into Drainage, Sewerage, Inland and Coastal Waters (TM);

(iv) all domestic effluent arising from the construction work force, any work camps, or canteen facilities should also be collected, treated and disposed of according to the provisions of the TM. Temporary sewage treatment and disposal facilities will be required and discharges from these should be to the east way from Discovery Bay;

(v) any special works areas which may be provided for material storage or mixing, should be surrounded by bunds and have drainage collection systems to contain any spillages; and

(vi) avoid spillages of oil, debris and other floatables. Under the provisions of the WPCO, the WQO's and the Shipping and Port Control Ordinance, no discharges of oily or fuel based wastes are permitted to be made to coastal waters or to the Southern Water Control Zone. The Contractor will be required to provide a spill response plan covering all areas in which he will be operating (dredging and disposal sites) which will define his plan of action for dealing with spillages and accidents.

(d) to avoid reductions in water quality:

(i) the recommendation of the Islands Sewage Master Plan to divert effluent from Discovery Bay and Peng Chau to the new treatment works at Siu Ho Wan should be implemented as soon as possible;

(ii) contaminants from storm runoff from private lots could be reduced by using stormwater pollution control devices. This can be accommodated during the detailed design of the drainage within the individual plots and should be included within the lease conditions; and

(iii) consideration should be given in the detailed design of the terminals to diverting stormwater drainage channels from CT10 and 11 to the east so that they do not drain into the Discovery Bay embayment.

(e) monitoring and audit

(i) monitoring and audit of water pollution and ecology should be carried out throughout the construction of the project; and

(ii) an environmental project office (ENPO) should be set up so that cumulative impacts can be taken into account and mitigated.

Figure 7.1
Location of Water Quality Modelling Stations

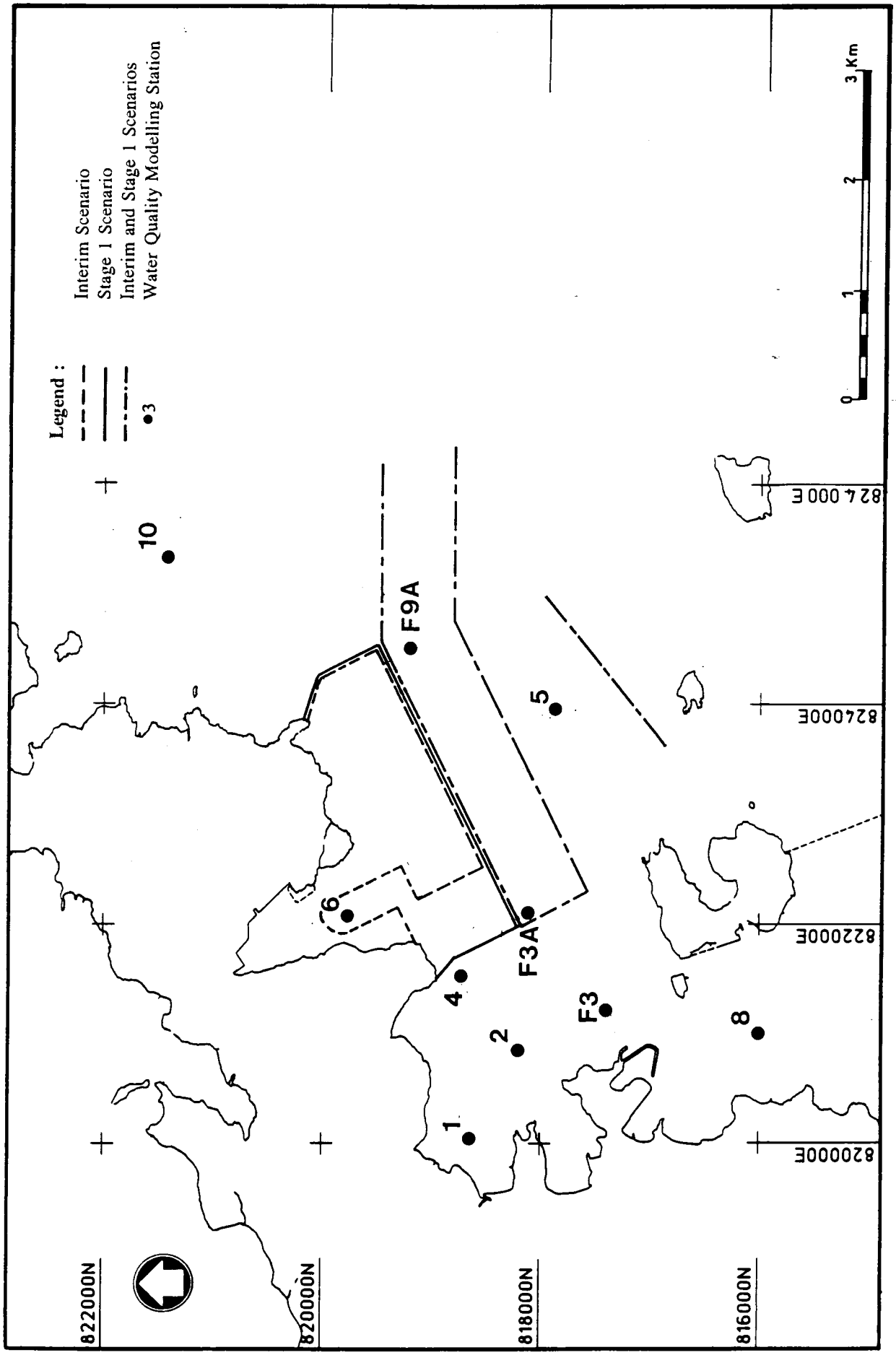

Figure 7.2
Sediment Changes : Wet Season Spring Tide
Baseline to Interim Scenario

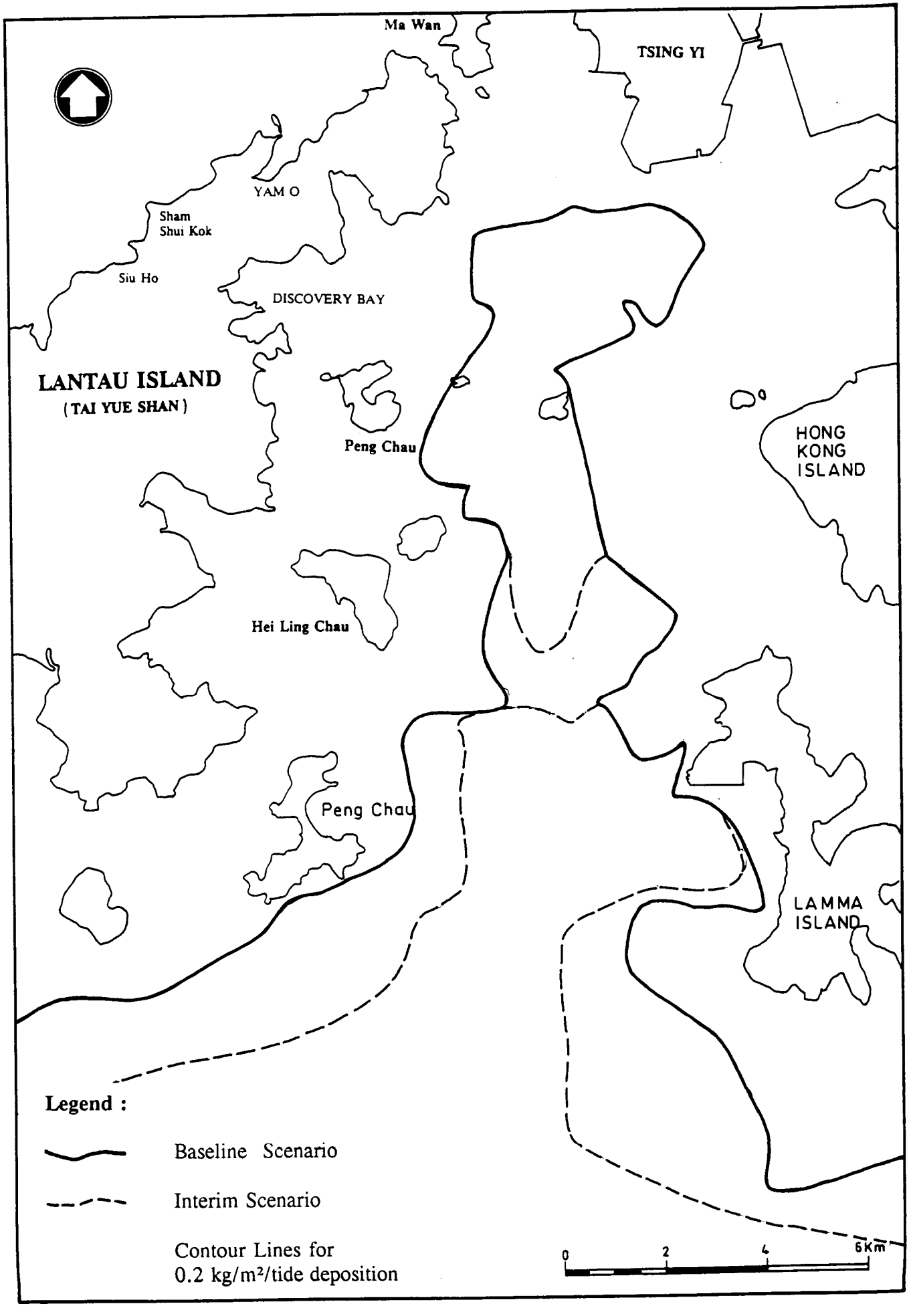

Figure 7.3
Sediment Changes : Wet Season Neap Tide
Baseline to Interim Scenario

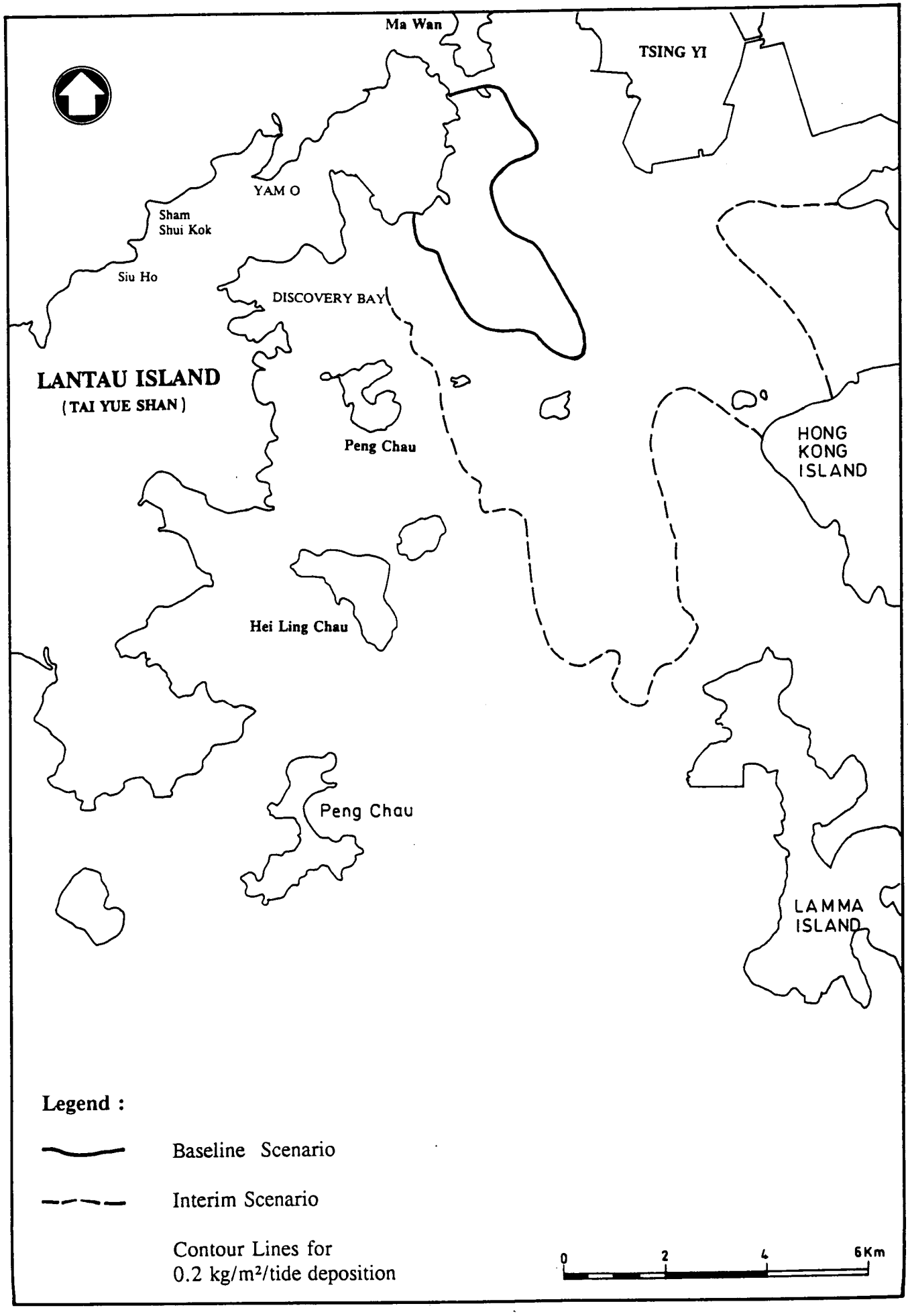

Figure 7.4
Location of Works