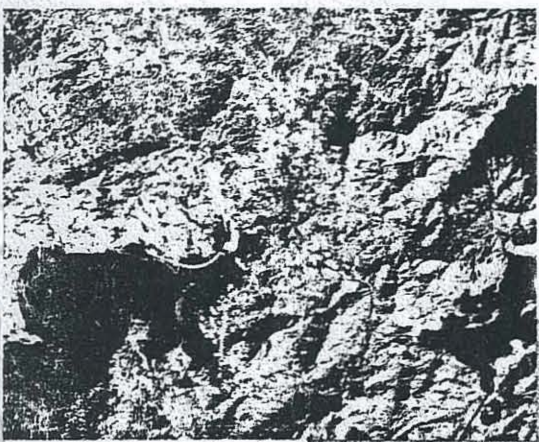
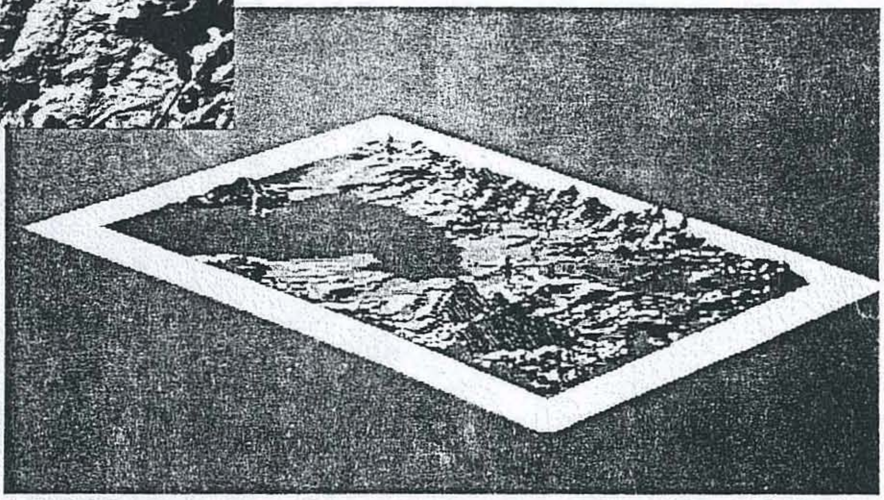
SHENZHEN RIVER REGULATION OFFICE OF MUNICIPAL GOVERNMENT

ENVIRONMENTAL IMPACT ASSESSMENT STUDY

ON SHENZHEN RIVER REGULATION PROJECT

EIA STUDY REPORT (I)





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ENVIRONMENTAL IMPACT ASSESSMENT FOR SHENZHEN RIVER REGULATION PROJECT

FINAL EIA STUDY REPORT (I)

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1 INTRODUCTION

1 INTRODUCTION

1.1 THE SHENZHEN RIVER

1.1.1 The Shenzhen River

The river originates near Niuweiling in the Wutong Mountains. Above Shenzhen Reservoir it is called the Shawan River. The Shawan River becomes the Shenzhen River below Shenzhen Reservoir and downstream of the confluence of the Shawan and Liantang Rivers at Sanchahe. The mouth of the river is at the eastern head of Deep Bay. The river course and Deep Bay are shown in Figure 1.1. The study area is considered to comprise any areas within the catchment of Deep Bay potentially affected by the Shenzhen River Regulation Project.

The Shenzhen River forms the border between Hong Kong and the Shenzhen Special Economic Zone (SEZ) of the PRC. The border fence and the restricted border area follows the general course of the river on the Hong Kong side. Access to the river is generally restricted. The original course of the river has been preserved over the past century to maintain the border. The realignment of the river therefore has serious implications in terms of political relations between Hong Kong and the PRC, operational issues in respect of the controlled border area, arrangements for access during construction and for after-use of any land affected by the works.

The Shenzhen River flows from northeast to southwest past Mankamto and Lo Wu Port. Its major tributaries include the Shawan and Buji Rivers on Shenzhen side, and the Ping Yuen and Indus Rivers on the Hong Kong side. The drainage pattern of the river is dendritic. The catchment area covers 312.5 km^2, of which 60% lies on the Shenzhen side and 40% lies in the New Territories of Hong Kong. The length of the river (from Sanchahe to the river mouth) is currently 16.9 km, upon completion of Stages 1 and 2 of the river training project, the river would be reduced to 13.6 km in length."

Upstream of Sanchahe, Shenzhen River is a mountain stream. The width of the River is approximately 20 m at Sanchahe, expanding gradually as it travels downstream to approximately 60 m at the Buji River confluent and approximately 230 m at the river mouth. In the area around Shenzhen City the river is contained within banks and is only some 20 m wide. Downstream of Sanchahe, as Shenzhen River meanders on the flat alluvial-marine plain, the river bends increase in size and the gradient decreases. The average gradient of the river bed is only 0.05%, decreasing to 0.02% below the Yunong Village.

The entire Shenzhen River is subject to tidal influence. The mud flat extends 4 km into the bay during low tide but totally disappears at high tide. The tidal regime in the area is a typical irregular diurnal tide. The shape of the tidal wave gradually changes upon entering the estuary, becoming faster during flood tide and slower during ebb tide, thus raising the tidal height and causing long retention time. During periods of low runoff at the upstream portion of the river, water retention time is 30-60 minutes longer in the vicinity of Yunong Village than at the mouth of the bay. The maximum tidal difference of the river is 10-30 cm higher than that of the bay during flood tide and 50-100 cm lower during ebb tide. The average duration of flood tide on the river is 1 hour less than that in the bay, while the duration of ebb tide is 1 hour more.

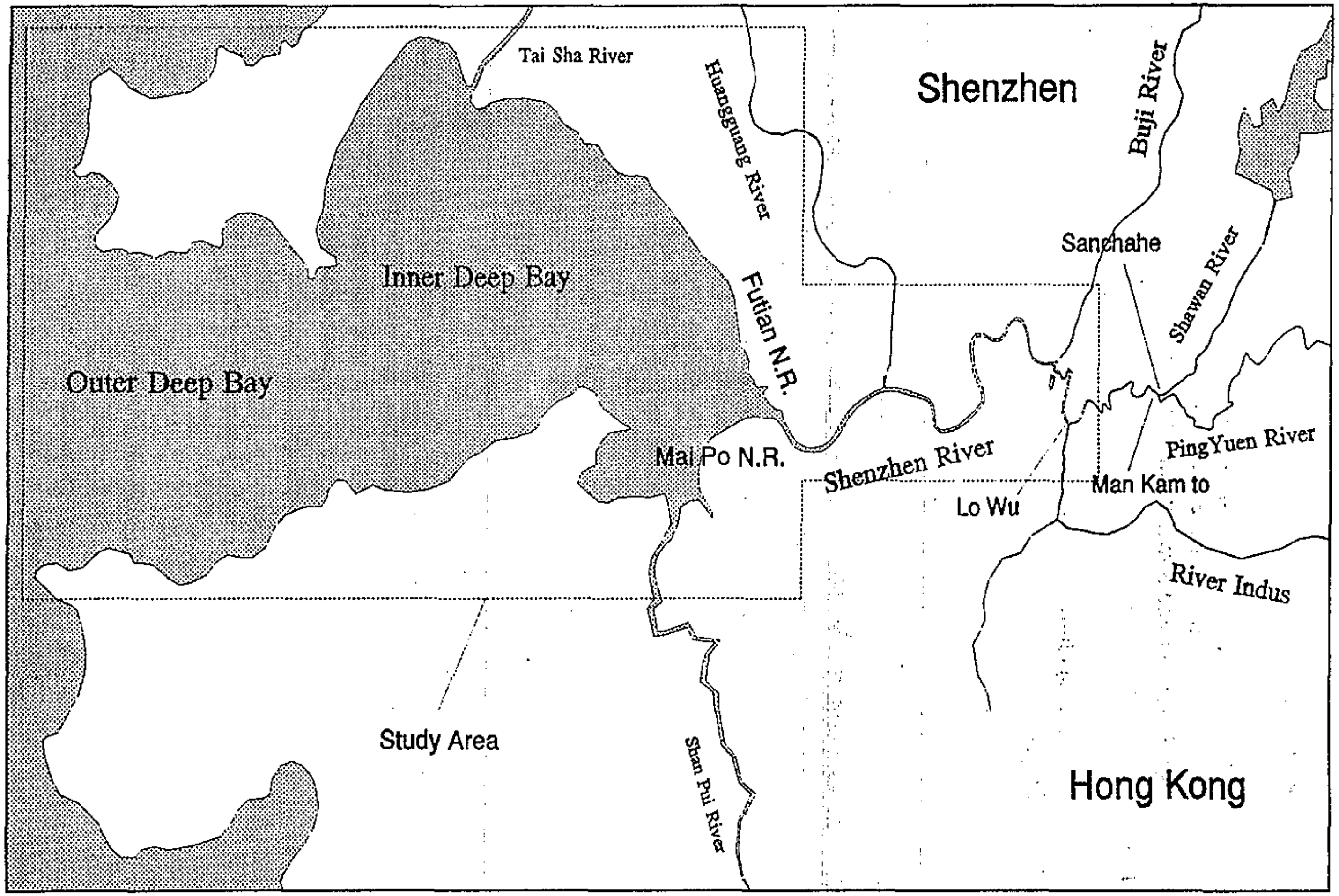


Figure 1.1 The Shenzhen River, Deep Bay, and the study area

Shenzhen River drains into Deep Bay, which receives water also from the Shan Pui River and the Tai Sha River, and joins the Lingding Sea on its seaward side. The bay is also influenced by flows from the Pearl River delta which are drawn into the bay from the coastal currents. Deep Bay has an area of 115 km^2. It is half enclosed and shallow, with an average depth of 2.9 m and an average capacity of 330 Mm^3. From the southern part of the bay a deep channel extends in a east-north-east direction to the Inner Bay. The bottom of the Bay slopes seaward and is deeper in the south than in the north because of the existence of the channel. This results in complicated hydrological conditions in the Bay. The annual average tidal difference is 1.37 m. The tide is influenced by the irregular mixed diurnal tide of the South China Sea.

1.1.2 Flooding

The study area is influenced by the southern subtropical monsoon climate with distinct wet and dry seasons. Rainfall in the catchment area is typically 1900 mm/year. The wet season is from April to October. Rainfall during this period constitutes 90% of the annual total. Shenzhen River water is mainly sourced from storm water runoff. Since precipitation and runoff intensity are closely interrelated, there is considerable variation in runoff volume between the wet and dry seasons. Wet season runoff volume is typically 87% or more of the annual total.

The upper portion of the river is short with a steep gradient and short retention time. Flow at flood peak is high, and this section of the river is characterized by sudden rise and fall in water depth. The flood peak reaches the downtown area of Shenzhen in a matter of hours following a storm. The river channel downstream is narrow and bending. The river embankment is low (approx 2m) and narrow (from 2m - 10m). Combined with tidal pressure, the river's safety flood-discharge capacity is only several hundred m^3/s. This corresponds to a 1 in 2 year storm capacity, and results in frequent flooding.

An area of about 15 km^2 on Shenzhen side (Lo Wu, Futian and other low-lying river bank districts) is inundated 1-2 times per year on average for a duration of 1-3 days each time. Following a decade of rapid economic growth these areas are now intensively developed for commercial, industrial and residential activities and have high population density. Each flood incident now causes serious economic losses and results in severe hardship to the local population. The south side of Shenzhen River is extensively used for fish culture and flooding here also causes serious economic losses and hardship.

1.1.3 Wetland

Adjoining the mouth of the river at the head of Deep Bay is an estuarine wetland which is of international importance. The Mai Po Reserve is managed by the World Wide Fund for Nature Hong Kong under license from the Hong Kong Government. The Futian National Nature Reserve is managed by the Neilingding-Futian National Nature Reserve. In March 1995, the Hong Kong Government announced that it would declare the Mai Po/Inner Deep Bay area a Wetland of International Importance under the Ramsar Convention.

1.1.4 Navigation

The Shenzhen River is one of the water access routes to the sea from the Shenzhen SEZ and therefore plays an important role in the economic development of the SEZ. The width and depth of the river at present restrict navigation and only motorized vessels of below 200 tonnes can come in on the tide as far as the Buji River New Port.

1.2 OBJECTIVE OF THE SHENZHEN RIVER REGULATION PROJECT

The Shenzhen and Hong Kong Authorities initiated cross border liaison meetings in 1982 to review and co-ordinate measures to prevent flooding and reduce pollution in the river catchment. As a result of these initiatives a scheme to realign and widen the Shenzhen River downstream of Lo Wu was proposed in 1985. This scheme has subsequently been refined and developed to provide the current Shenzhen River Regulation Scheme, hereafter referred to as the Project. The objectives for the Project as described in the Terms of Reference (TOR) for the Environmental Impact Assessment Study for Shenzhen River Regulation Project (hereafter referred to as the EIA) are to prevent flooding and reduce pollution. Flood protection is the dominant objective.

The full Project consists of a three stage scheme to realign, widen and deepen the Shenzhen River. Stage 1 involves relatively localized works to truncate two existing meanders of the river close to Shenzhen City. Stage 2 involves more extensive dredging works downstream of Lo Wu to increase the depth and width of the channel, and construction of flood protection works along both banks of the widened stream. Stage 3 involves dredging works upstream of Lo Wu. The project is described in detail in Section 2 of this report. The EIA is required to address only the first 2 Stages of the Project.

1.3 OBJECTIVES OF THE EIA

The primary purpose of the Project is to alleviate flooding in the lower catchment of the Shenzhen River. Both the Shenzhen and Hong Kong Authorities have given priority to the implementation of flood control programmes to overcome this severe problem. The Shenzhen River Regulation Project is central to these works programmes on both sides of the border. An outline design and programme for the Project has been developed jointly by the Shenzhen River Regulation Office and the Drainage Services Department of the Hong Kong Government. Both the Shenzhen and Hong Kong governments, however, have recognised that the Project may affect the internationally important Mai Po and Futian Nature Reserves at the mouth of the river. The Project also presents other potential environmental problems. The environmental impact assessment (EIA) has been jointly funded by the Shenzhen and Hong Kong Authorities to ensure that these environmental concerns are addressed. The EIA of the first two stages of the Project started on Dec.16, 1993 and will be finished by the middle of March, 1995.

The international importance of the wetlands potentially affected by the Project dictates that the environmental assessment process is comprehensive and thorough. The requirement to gather data over all seasons to construct and calibrate the hydrodynamic and sediment models, and to establish an ecological baseline which is essential to the study dictate that the study cover a 15 month period. However, it is also important that the environmental assessment process does not unnecessarily delay progress of the detailed design and planning for the Project and the implementation of environmentally sound proposals for flood control. The outline programme for the Project is aimed at the earliest possible introduction of flood protection measures and community benefits. This programme required an early start to the detailed design and contract preparation for the Stage 1 Works as a delay to these activities would potentially delay the Project by many months.

The EIA report on Stage 1 of the Project was submitted in June 1994 and approved by the Environmental Sub-group of Working Group in July 1994. This report concluded that the Stage 1 Works would have no significant environmental impacts which would prejudice the Stage 1 Works but made a range of recommendations for environmental mitigation and enhancement. The final EIA report on both Stage 1 and 2 is to be submitted by middle of March, 1995 to provide information to assist in a decision on the acceptability of Stage 1 and 2 of the Project and to recommend specific requirements for environmental protection which should be included in the detailed design of Stage 2 and maintenance activities.

The approach adopted in completing the assessment has been to utilise the available information with a view to defining an environmentally acceptable option for the works which offers greatest safeguards to the environment, presents no unacceptable risks to the viability of the conservation reserves in Deep Bay and enables the programme for the Project to be maintained. The analysis of impacts has progressed through the following stages:

1) To identify those potential key issues or impacts which might potentially be so severe as to influence key decisions on the design, programme or acceptability of the Project. Recommendations on the Project have been based on these issues.

2) To identify all potential activities that would contribute to these issues or impacts. These activities have then been analysed in terms of design, programme and construction decisions affecting the Project.

3) To identify opportunities to mitigate these effects so that short and long term environmental performance can be safeguarded and the progress of the Project can be maintained.

4) To adopt a conservative environmental approach aimed at providing least risk to environmental resources and accepting reasonable costs in terms of construction method or design.

5) To present clearly the risks and consequences associated with the recommended strategy and conclusions in terms of environmental performance.

The specific objectives of the final EIA Report are :

1) *To describe the Project including:*

   a. the outline design for the works which has been adopted as a basis for the EIA;
   b. the construction method and programme which is likely to be used and which has been adopted as a basis for the assessment;
   c. any practicable alternatives to the design and construction method which might be considered to reduce environmental effects of the project.

2) *To describe the environment and community likely to be affected by the project including:*

   a. to describe, qualitatively and quantitatively, the ecological resources affected by the project;

b. to evaluate and identify the most sensitive and critical ecological resources;
c. to describe the community potentially affected by the Project.

3) *To assess the potential environmental effects arising from the Project including:*

a. to identify and evaluate potential short term effects;
b. to identify and evaluate potential long term effects;
c. to identify key potential issues or impacts which might influence project decisions.

4) *To identify potential mitigation options including:*

a. to describe potential mitigation measures which could be applied to reduce effects from the Project;
b. to recommend on the most effective mitigation measures.

5) *To evaluate acceptability of mitigation measures including:*

a. to establish measures against which potential effects can be evaluated;
b. to evaluate the significance of nett impacts arising from the Project.

6) *To define the risks and consequences associated with conclusions and recommendations including:*

a. to define the lack of information or other uncertainties associated with the assessment;
b. to define the risks and consequences arising from the recommendations.

7) *To develop monitoring and audit requirements including:*

a. to develop a programme to monitor environmental effects during construction;
b. to develop a programme to audit environmental performance during construction to ensure compliance with applicable regulations, guidelines and contractual obligations;
c. to develop a programme to monitor long term effects for comparison with EIA predictions.

1.4 STRUCTURE OF THE EIA REPORT

This report is presented in 3 volumes. Volume 1 presents the main report which comprises 12 sections. Volumes 2 and 3 present the Appendices.

Within the main report, Sections 1, 2, and 3 set out the background for the assessment and comprises this introduction together with the description of the Project and the existing environment and community that could be affected by the Project. The technical approach and methodology are presented in Section 4. Hydrodynamics, sediment transport, and water quality modelling are discussed in Section 7. Impacts on air quality, noise, water quality, sedimentation, and ecology are addressed in Sections 5, 6, 8, and 10, respectively. Impacts of spoil disposal are presented in Section 9. Potential impacts of the Project, mitigation options, and the overall acceptability of the project are summarized in Section 11.

2 DESCRIPTION OF THE PROJECT

2.1 Overview of the Project

2.2 Outline Design

2.3 Construction Method

2.4 Programme

2 DESCRIPTION OF THE PROJECT

2.1 OVERVIEW OF THE PROJECT

Implementation of the Shenzhen River Regulation Project will be divided into three stages. Stage 1 Works involve realigning, widening and deepening the meandering sections of the river between Lo Wu and Liu Pok and at Lok Ma Chau. The Stage 2 Works involve widening and deepening works downstream of Lo Wu Bridge and construction of flood protection works. Stage 3 will involve similar works upstream of Lo Wu Bridge. The detailed design of Stage 1 has been completed, and an outline design has been prepared for Stage 2. Stage 3 will be undertaken at a later date and no plans of the works are available. Figure 2.1 shows the various stages of the Project.

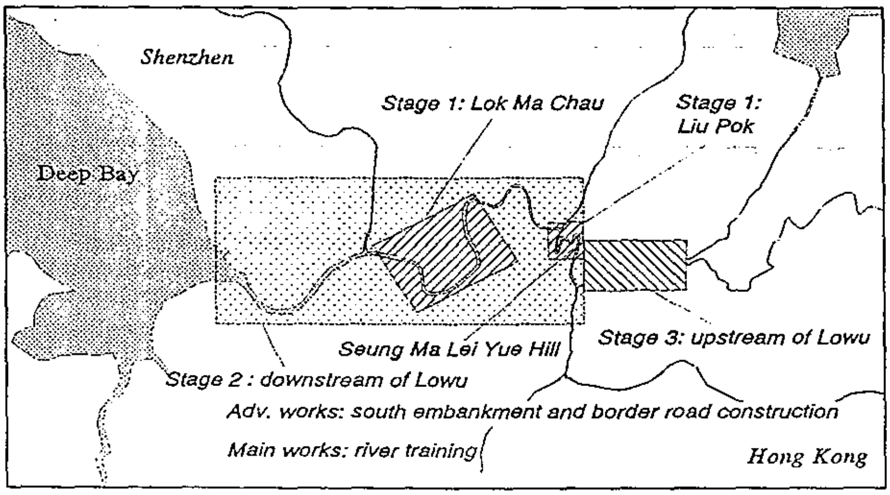


Figure 2.1 Shenzhen River Regulation Project

2.1.1 Stage 1 Works

The Stage 1 Works are shown in Figures 2.2 and 2.3. Upon completion of Stage 1 Works the length of this section of the river will be reduced by 3.3 km. The channels created at Lok Ma Chau and Liu Pok Bends will be temporarily some 65-110 m wider and 2.5-4.0 m deeper than the existing channels upstream and downstream.

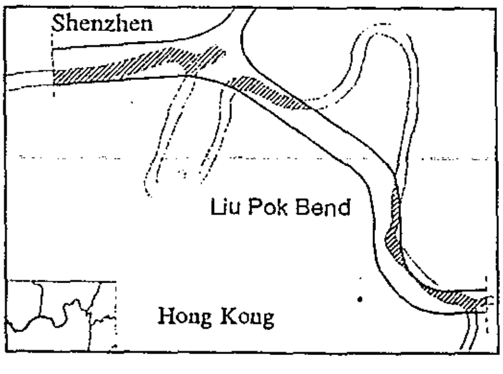


Figure 2.2 Liu Pok Bend

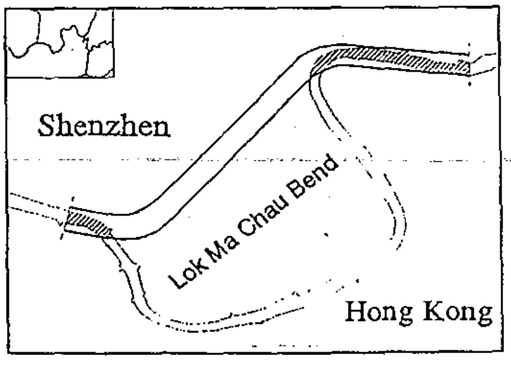


Figure 2.3 Lok Ma Chau Bend

2.1.2 Stage 2 Works

The Stage 2 Works are illustrated in Figure 2.4. The works comprised of two parts, Advanced works involve construction of the south embankment and relocation of the border fence from Ha Wan Tsun to Tam Kon Chau. Stage 2 Main Works involve widening and deepening of the river channel from the Lo Wu Bridge to the river mouth. At the mouth of the river a transition zone of 200 m is proposed linking the new river channel to the existing navigation channel in Deep Bay. The new river channel will be 2.5 m deeper than the existing navigation channel. The advance works of Stage 2 include construction of part of the south embankment and the border road from Lok Ma Chau to the river mouth, and the main works include river training from Lo Wu to the river mouth." to the end of the paragraph.

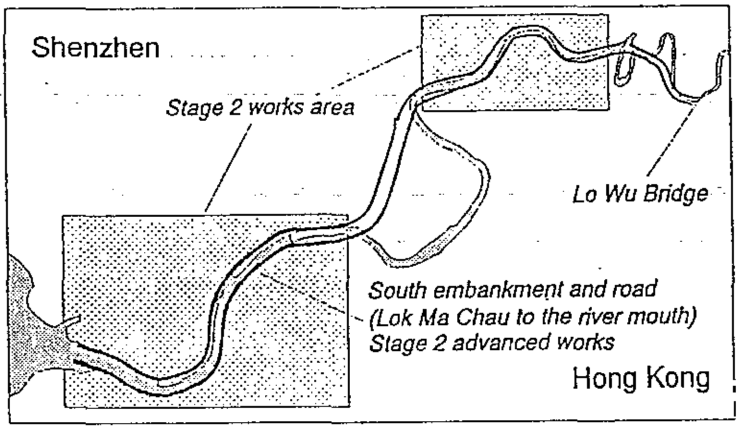


Figure 2.4 Shenzhen River Regulation Project

2.2 OUTLINE DESIGN

2.2.1 Hydraulic Design

A 1 in 50 year flood return period has been used for determining the maximum water levels in the river system. This return period has been agreed by the Joint Technical Group (JTG). Tables 2.1 and 2.2 give the discharge rates and flood levels respectively as estimated by the JTG.

Table 2.1 One in fifty years flood discharge(m^3/s) estimated by JTG

Location	upstream of Lo Wu	downstream of Lo Wu	Lok Ma Chau	San Tin
Discharge	870	1,500	1,900	2,100

Table 2.2 One in fifty years flood level(m) estimated by JTG

Location	Lo Wu Bridge	Buji River	Shangbu Pier	Lok Ma Chau
Now	6.63(7.48)	5.86(6.71)	5.21(6.06)	3.64(4.49)
Fully trained	3.87(4.72)	3.45(4.30)	2.98(3.83)	2.94(3.79)

* Yellow Sea Datum, ( ) m.P.D. Hong Kong

2.2.2 Long Section

It is assumed that because of hydraulic considerations the gradient and base level of the channel are fixed.

Under Stage 1 Works the existing channel at Lok Ma Chau Bend will be retained but in Stage 2 Works the new channel is shown as constructed across the inlet and outlet of the river. A final decision as to whether the old river channel is retained at this location will need to be made as part of the final design. The Stage 1 EIA report has recommended retaining the existing Lok Ma Chau Bend section of the river and restoring it to conditi ons suitable for wildlife as an ecological mitigation measure.

2.2.3 Channel Design and Lining

The channel cross section proposed in the Outline Design is presented in Figure 2.5. This provides for a regular trapezoidal shape bounded by flood control bunds.

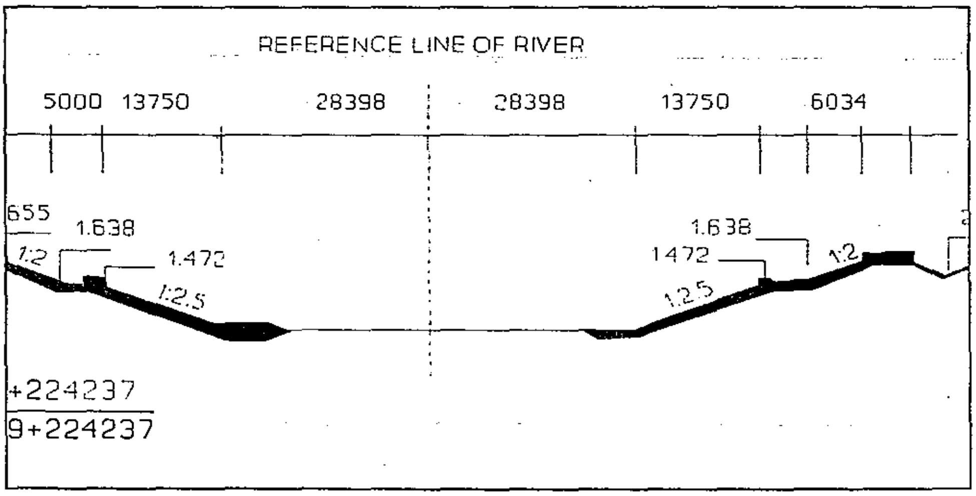


Figure 2.5 Channel cross section (levels refer to Yellow Sea Datum)

The Outline Design provides for channel banks below water level to be lined with rock. This will provide effective erosion protection and will be easier to place than concrete slabs or in-situ concrete in underwater conditions. Rock will also be used to line the ch annel slopes in the transition zone between Stage 1 Works and the existing river channel at Lok Ma Chau and Liu Pok Bends. Similar protection is likely to be required at the transitions from upstream and into Deep Bay on the completion of Stage 2 Works.

Lining of the channel slopes above water level will also be required to prevent erosion. The Outline Design proposes to line the channel with precast concrete slabs. There is however scope for modifying the design of slope protection measures, especially the embankment protection, by the use of reinforced grass planting or, in areas above 2.0 (YSD), vegetation which could withstand occasional flood flows of brackish water.

In the Stage 1 Works where ditches and culverts are connected to the river they generally discharge on to the intermediate berm. Additional protection may be required to prevent scour at these locations. This does not apply to the Futian and Buji rivers which discharge to the main channel through stilling basins and flood control structures.

As the flood water levels in the channel are dependent upon the cross-sectional area, roughness, and gradient, any significant improvement of these factors due to the works would result in the lowering of flood levels for any given tidal condition. The effect on flood levels after the completion of all the planned works would be in the order of 3 m reduction in flood heights at the Lo Wu bridge. This beneficial effect would extend into the drainage basins which discharge into the main river. Velocities are likely to be in the order of 0.6 m/s for normal flows, increasing to 2.0 m/s for flood flows. The Outline Design has assumed a roughness factor of 0.0225.

It has been assumed that the cross sectional area of the channel defined in the Outline Design is a minimum requirement to achieve flood protection objectives. Any significant revision to these parameters would require review of the engineering design which is outside the scope of the EIA. Given the size of the cross-section relative to the flows, however, minor adjustments of cross-sectional area, roughness and gradient are considered unlikely to have any major effect on water levels.

2.2.4 Geotechnical Conditions and Constraints

The areas adjoining the river and within the works area are characterised by deep sediments of silty material with low shear strength and high compressibility. These geotechnical conditions have influenced the design of the channel cross-section and flood control bunds. The channel design includes shallow side slopes for the channel and an intermediate berm which places the toe of the embankment some 5 to 15 m away from the top of the channel slope. This berm adds stability to the channel slope which otherwise might slip under the weight of the embankment and its compaction.

2.2.5 Embankment Design

The typical embankment design is illustrated in Figure 2.5. Within the Stage 1 Works it is proposed to use material excavated from Seung Ma Lei Yue Hill for construction of the embankments where possible. This material is better suited for use in embankment works than dredged material as it can be readily compacted and will be excavated in a dry state. Due to the likely settlement of the embankment over the construction period, regular topping up would be required.

Trials were carried out in 1986 to demonstrate the construction of embankments using dredged material. The trials indicated settlement of up to 1 m over a two-year period. This settlement is assumed to have resulted from the consolidation of the foundation and "punching in" of the fill material. This factor would support the use of non-rigid protection at the sides of the embankment.

The embankment design needs also to include for access for maintenance purposes and for security patrols along the border.

2.2.6 Access and Works Areas

Access is required to the berm and channel for maintenance. The outline design for Stage 1 Works provides for an access track along the top of the berm. However, given the soil conditions forming the underlying berm foundation, access along the berm may only be suitable for pedestrians or very light vehicles as the ground is unlikely to permit the passage of heavy machinery which would disturb or break the concrete slabs (presently proposed). It is assumed that similar designs will be used for Stage 2.

A co-ordinated site boundary has been indicated on the drawings for Stage 1 Works. It is assumed that all construction activities would take place within these limits. Part of the limits define the access between the two areas of work at Liu Pok Bend and Lok Ma Chau Bend. The width of the access will need to be at least 12 m to permit two way construction traffic. The programme in the Outline Design (Technical Design Manual) gives high priority to the construction of the haul road for moving the material from Seung Ma Lei Yue Hill for embankment construction.

Access points into the site are shown at the temporary river crossing to be constructed at chainage 8+150, at Shangbu Pier and at Futian Village (Figure 2.4). An access point(s) downstream of Lok Ma Chau has not been defined. The temporary river crossing at chainage 8+150 would enable material to be moved from Seung Ma Lei Yue Hill to the right bank and along the haul road to Lok Ma Chau Bend.

2.3 CONSTRUCTION METHODS

Construction will involve dredging of the existing channel, excavation of the new channel required in the Stage 1 Works, and associated excavation works at Seung Lei Yue Hill. Bund construction will involve extensive earth works, placement of erosion protection materials and landscaping. Materials for erosion protection may be cast on site or imported.

2.3.1 Construction of the Channel

There are two general options for construction of the river channel, i.e. "dry" land based conditions or "wet" dredging from within the channel. It is possible that a combination of both types of equipment could be used for Stage 1 Works. All dredging works will need to maintain navigation traffic and accommodate a range of weather conditions.

There are very significant environmental advantages in isolating the construction of the new river channel in Stage 1 Works from the existing river until the new channel is completed. This will prevent sediment entering the river, minimise disruptions to existing flows, and cause least disruption to navigation.

Excavation at Seung Ma Lei Yue Hill is expected to yield 665,000 m^3 of material, mostly composed of heavily and moderately weathered phyllitic metamorphic rock. This material can be won using large bulldozers and excavators. A small amount of slightly weathered rock may require blasting prior to excavation. Part of the material would be used for embankment construction. The remainder would be stockpiled at a designated area approximately 3 to 5 km away.

In Stage 1, embankments would be constructed in two phases. Phase 1, to be completed in approximately 6 months to one year, would require 210,000 m^3 of material to achieve a height of 2.5 m. Phase 2 would require 40,000 m^3 of material (excluding additional volume required due to settling) to take the embankment up to the designed height.

Construction methods in Stage 2 are expected to be similar to those proposed for Stage 1. The volume of dredged spoil material is estimated to be 3.04 Mm^3. Approximately 0.13 Mm^3 will be required for the construction of flood control bunds.

2.3.2 Sediment Control Measures

Where dredging must be carried out in the river under wet conditions consideration must be given to the control of sediment released during the dredging operation. The methods available are:

- Specification of particular types of dredging methods, transport, handling and downstream mitigation works.

- Specification of water quality objectives and monitoring requirements downstream of the dredging works in terms of permitted levels of suspended sediment above baseline limits.

The specification of trigger, action and target levels offers clear standards, for use by both supervisory staff and the contractor, by which acceptable and unacceptable standards of dredging can be defined. This approach has been shown to the most effective method to define and control the environmental performance of dredging works. With the use of on-site laboratory facilities, monitoring can be quickly carried out and the contractor instructed to implement remedial measures should the standards be exceeded. These standards, combined with appropriate action plans and specified mitigation requirements such as restricting dredging to periods of slack current and the use of silt curtains or settling basins, would retain the degree of flexibility that is required in a project of this nature. This approach has been successfully used in Hong Kong for a number of large dredging contracts.

Should the above procedure be adopted, it would be necessary to define water quality standards relative to baseline conditions in the river prior to dredging. The standards can be determined using data obtained in this study, or alternatively from dredging trials, or both. The dredging trial approach has the advantage that it would enable standards to be set which could be sensibly achieved, and if carried out pre-contract, would allow a certain degree of experimentation with different mitigation measures. Similarly if one method of dredging or one type of plant is found to be particularly successful, then this could be specified as the preferred option. Types of plant which may be considered are described in Section 2.3.4 (Plant Requirement).

The dredging and disposal of contaminated material would require special handling and disposal to designated sites which, depending on the degree of contamination, may be on site or off-site. Internationally, dredging plant is available which can deal with this type of material. It would be necessary to determine the depths of material to be classified as contaminated in order to ensure sufficient disposal areas are available either on or off site.

2.3.3 Spoil Disposal, Treatment and Storage

There will be 3 major sources of spoil material:

- Spoil dredged from the top portion of existing river channel which will generally be contaminated and unsuitable for other purposes. If stored on-site this material will generally require dewatering;

- spoil excavated from the new river channels which may generally be uncontaminated but will not be suitable for use in the embankments;

- spoil sourced from river side areas such as Seung Ma Lei Yue Hill. This spoil is unlikely to be contaminated and should be suitable for use in the embankments. Some quantities of rock may be available.

The quantities of river spoil have been estimated at 1.7 Mm^3 for Stage 1 and 3.04 Mm^3 for Stage 2. Of these quantities some 0.8 Mm^3 (0.056 Mm^3 from Stage 1 and 0.75 Mm^3 from Stage 2) are expected to be contaminated (See Section 9.3.2).

The storage, transport and disposal of excavated material is potentially a major source of environmental nuisance. The Outline Design for Stage 1 Works proposes to utilise areas along the river bank, and the enclosed area of the Lok Ma Chau Bend as major storage areas. Potential spoil disposal sites for Stage 2 have been identified at Shekou Reclamation, Tsing Yi Island South, North of Lantau Island (for uncontaminated spoil), East Sha Chau, and additional storage at Lok Ma Chau Bend (for contaminated spoil).

The majority of spoil will be removed in a semi-liquid state and is likely to be piped directly to on-site disposal points or barged directly to the remote disposal sites. Any use on-site is likely to require storage to permit drainage and consolidation prior to further handling or incorporation in the works. It will be necessary to categorise spoil according to its suitability for use as fill and contamination in order to separate the materials for allocation to different parts of the spoil storage site or to off-site disposal areas.

At any sites where saturated spoil material is stored, either permanently or for consolidation prior to further handling, adequate drainage facilities will be required to prevent contaminated water entering the river system, or affecting "clean" spoil.

2.3.4 Plant Requirement/Dredging Plant

Construction methods for the "dry" or "wet" conditions are unlikely to favour traditional earthmoving equipment such as bulldozers, lorries, draglines, etc. The soft silty surface material combined with high ground water levels would render the movement of heavy vehicles difficult without a network of specially prepared haul roads.

The ability to handle debris laden material, its shallow draft and the various attachments that can be used for slope cutting and to minimize turbidity, would suggest that small auger type suction dredger is well suited to the type of work involved, provided that machines of adequate capacity are available. Other dredging equipment such as grabs could be tested as part of the suggested dredging trials.

Mott MacDonald (1991) compared sediment resuspension characteristics of various dredging plant using the S factor, which is a ratio between the amount of sediments resuspended (in kg) to the amount of sediments dredged (in m^3). The lager the S factor, the more sediments would be resuspended and pass out of the immediate area (typically about 50 m from the dredger) of the dredging operation. The same report also described the operation of a number of dredging plant and indicated that the auger suction dredger was adopted to work in very soft soils in shallow waters. The S factor for small auger suction dredgers was 5 kg/m^3, which was the same as a closed grab dredger with silt screen. Without silt screen, the S factors for a closed grab dredger and an open grab dredger were 20 and 25 kg/m^3 respectively. At a reduced rate of advance, the auger suction dredger can possibly achieve an S factor of 3 kg/m^3.

In an EIA study for the main drainage channels for Ngau Tam Mei, Yuen Long and Kam Tin (BRM 1995), the extent of sediment plume dispersion on the Kam Tin River based on the above S factors was calculated for closed grab and auger suction dredgers. A 525% increase in SS level could be expected at a distance of 51 m downstream of a closed grab without silt screen. With an auger suction dredger or a grab dredger with silt screen, SS increase would be 131% at the same distance downstream. At 150 m downstream, SS increase was estimated at 52% for a closed grab without silt screen and 13% for an auger suction dredger or a closed grab with silt screen.

In view of marine traffic on the Shenzhen River, it is unlikely that a silt screen can be installed and maintained on the channel during dredging operations. The auger suction dredger is therefore superior to the grab dredger in terms of minimising the release of resuspended sediments.

Traditional equipment would be required to place lining material and form concrete structures where necessary. It is envisaged that properly constructed haul roads would be routed adjacent to the embankments to facilitate this work and the transportation, haulage and compaction of embankment material.

It is assumed that the river will be used where possible for the transport of materials from external sources (e.g. rocks). Where materials are transported by river, shallow draft derrick lighters could be used for placing such materials directly onto the works.

Excavation at Seung Ma Lei Yue Hill would require traditional earthmoving equipment and no extensive blasting is envisaged. Material would be transported by lorry or shallow draft barge where possible. The EIA assumes limited blasting will be required.

2.3.5 Contractual Matters

The Design Technical Manual indicates that the work would be implemented by contractors from either China or Hong Kong. Work open to tender in both Shenzhen and Hong Kong and projects of this size are likely to attract international contractors. It is assumed that the contracts would take the standard form of Drawings, Conditions of Contract, Specification, Method of Measurement and Bill of Quantities.

It is important that the contract documentation adequately supports the mitigation measures proposed for the Project. In terms of design, this is easily done by incorporating the design requirements in the drawings and the specifications. However, where the mitigation measures require adherence to environmental limits for dust, noise, water quality, etc. it would be necessary for the Specification to address these matters clearly in terms of the standards required, the procedures for monitoring and audit, and the remedial measures required in the event of exceedance of the standards.

2.4 PROGRAMME

2.4.1 Overview

The programme indicates that Stage 1 Works would take 28 months while Stage 2 Works would take 42 months, with completion of both stages tentatively scheduled for 1999. Key elements of the work include:

Task	Duration(months)
Stage 1 Works (Starts in 1995)	
• Relocation of the border fence	2
• Construction of the haul road	2
• Excavation of Lok Ma Chau Bend	18
• Excavation of Liu Pok Bend	18
• Excavation of Seung Ma Lei Yue Hill	22
Stage 2 Works (1995 - 1999)	
• Advanced works - south embankment and road from Lok Ma Chau to the river mouth construction	18
• Main works - river training from Lo Wu to river mouth	42

2.4.2 Programming Constraints

Major constraints in the planning of the Project arise from the need to dredge the existing channel whilst maintaining a passage for navigation as well as for normal and flood flows.

Dredging may not be possible at all times due to flow conditions, inclement weather, navigational requirements, or exceedance of environmental criteria etc. Criteria for the cessation of dredging need to be defined in the contract documents. Similarly, excavation of material from Seung Ma Lei Yue Hill and the placing and compaction of material in embankments would also be weather dependent. This has been partly addressed in the Technical Design Manual. A steady supply of revetment material obtained from outside the site would also be required.

It would be normal to include contract provisions for extensions of time to cater for the stoppage of dredging and other construction operations due to inclement weather, flood flows, etc. which are factors beyond the control of the contractor. Alternatively, these anticipated stoppages could be assessed and included in the contract period with no allowance for extension of time.

Dredging activities are restricted downstream of the Inner Deep Bay Works Exclusion Zone (IDBWEZ) from November to March 30. The IDBWEZ is shown in Figure 2.6.

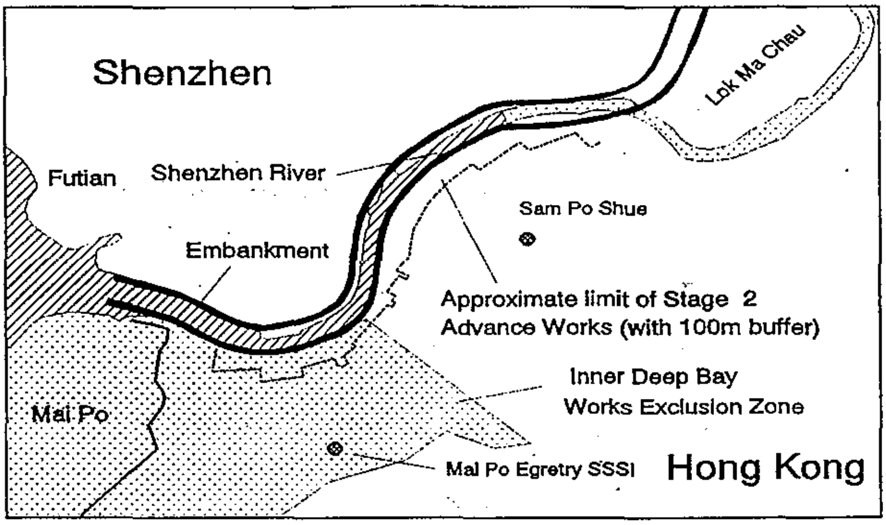


Figure 2.6 Inner Deep Bay Works Exclusion Zone(IDBWEZ)

References

BRM Hong Kong. 1995. Main drainage channels for Ngau Tam Mei, Yuen Long and Kam Tin: EIA study for Kam Tin Section (43 CD) and village flood protection works (30 CD). Final Report prepared for the Territory Development Department, NTN Development Office.

Mott MacDonald Hong Kong Ltd. 1991. Contaminated spoil management study. Final Report (Agreement CE 30/90) prepared for the Environmental Protection Department, Hong Kong Government.

3 ENVIRONMENT AND KEY ENVIRONMENTAL ISSUES

3.1 Environment

3.2 Key Environmental Issues

3 ENVIRONMENT AND KEY ENVIRONMENTAL ISSUES

3.1 ENVIRONMENT

3.1.1 Location and Political Significance

The Shenzhen River forms the border between the Shenzhen Special Economic Zone within the People's Republic of China and Hong Kong and is thus of political importance. The restricted border areas and the border fence follow the general course of the river on both sides of the river. Access to the river is generally restricted. The original course of the river has been preserved over the past century to maintain the border. The realignment of the river therefore has very serious implications in terms of political relations between Hong Kong and the PRC, operational issues in respect of the controlled border area, and arrangements for access during construction and for use of affected land after completion of the works.

3.1.2 Landuse Situation

The existing landuse situation within the study area is shown in Figure 3.1.

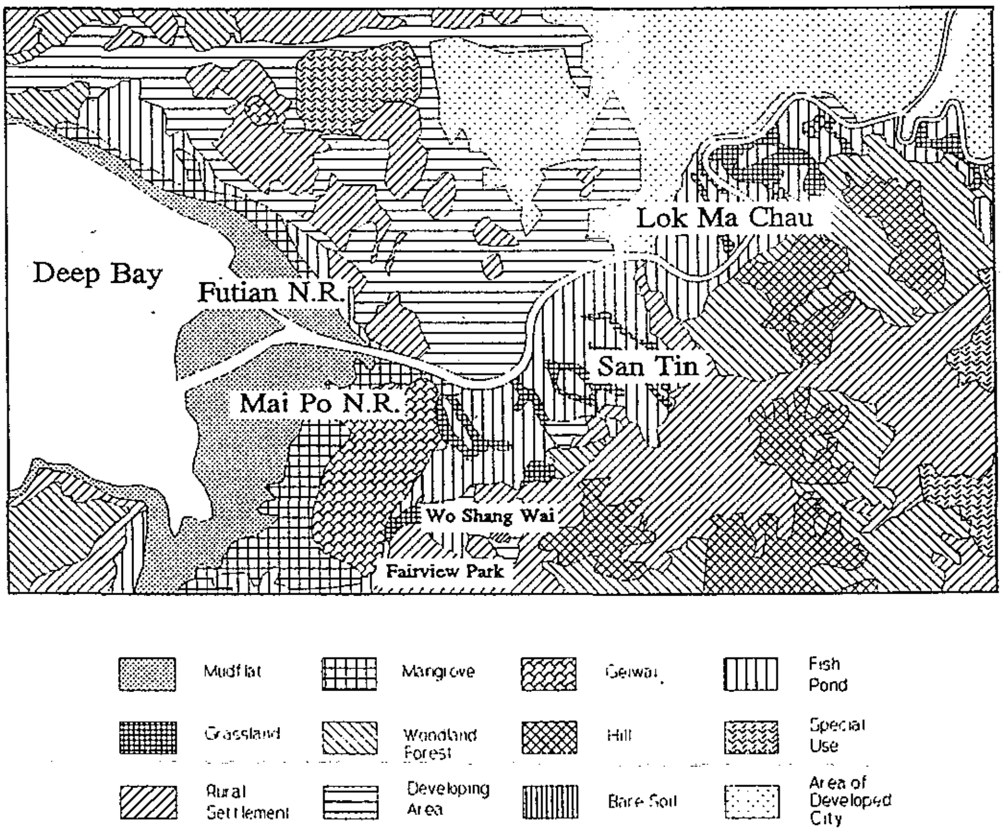


Figure 3.1 Existing land use situation

Most land to the north of the Shenzhen River has been or will soon be developed for residential or commercial purposes (Figure 3.1). At the mouth of Shenzhen River, there is Futian-Neilinding National Nature Reserve on the Shenzhen side.

The Mai Po Nature Reserve on the Hong Kong side (Figure 1.1) forms part of the broader Deep Bay ecosystem and is recognised as a wetland of international significance. Two designated buffer zones are intended to control development within the vicinity of the Nature Reserve. There are a number of recognised villages within these buffer zones, with areas dedicated for expansion.

To the south of Mai Po Nature Reserve lies the substantial suburban residential development of Fairview Park and Wo Shang Wai. The population of the area is 15,300 persons (1991 Census), about 85% of which lives in Fairview Park with the remainder in several villages including Mai Po Tsuen, Chuk Yuen Tsuen and Sheung San Wai. Some non-indigenous villagers also occupy the area.

To the east of the Mai Po Nature Reserve lies the San Tin area, which comprises the main border crossing at Lok Ma Chau, seven villages, actively cultivated fish ponds, villages within the Frontier Closed Border Area, and substantial areas of open storage and lorry parking.

Land-use options for the area have recently been considered in the Mai Po Development Statement, resulting in the preparation of the Mai Po Recommended Outline Development Plan (RODP), in which substantial new Conservation Areas around the Mai Po Egretry and a Conservation Area at Tai Law Hau are designated.

3.1.3 Flooding and Flood Prevention in Shenzhen River Drainage

The channel of the Shenzhen River is narrow and winding. The safety flood-discharge level of the channel is only a few hundred m^3/sec, equivalent to a flood with an one in two-year return period. Any storm exceeding 150-200 mm of rainfall per day causes a flood. Results of three rounds of continuous hydrological monitoring on 12-25 September 1983, 11-19 January 1984 and 12-19 August 1984 along the Yunong Village section of the River showed that each flood period lasted 1-5 days. In two major floods in 1964 and 1971, the areas affected by flooding on Shenzhen side alone were 8.7 km^2 and 5.3 km^2 respectively. It is estimated that the area theoretically affected by a flood with an one in 50 year return period would be approximately 17 km^2 on Shenzhen side and 13.5 km^2 on the Hong Kong side.

The flood area in the New Territories of Hong Kong on the left bank is approximately 1,350 ha in area. Loss on the Hong Kong side of Shenzhen River caused by flooding of Typhoon Dot was HK$164 million in 1993.

3.1.4 River Water Quality

The Shenzhen River is heavily polluted due to discharge of untreated effluents from industry, agriculture, poultry and livestock farming, and human sewage. The pollutants from Shenzhen include mainly commercial, industrial and domestic discharges while most pollutants from Hong Kong arise from livestock waste. Generally the water is so polluted as to be unsuitable for any beneficial uses except navigation.

The Hong Kong - Guangdong Environmental Protection Liaison Group (1992) reported that biochemical oxygen demand (BOD) loadings entering Deep Bay from Shenzhen River contributed over 55% (52,685 out of 95,049 kg/day) of the total from all catchments of Deep Bay in 1988. In that year BOD loading from Shenzhen side was estimated to be 19,922 kg/day (59% from commercial and 39% from domestic sources). BOD loading from the Hong Kong side was estimated to be 28,465 kg/day, with over 77% from livestock waste.

3.1.5 Wetland Ecosystem

The wetland ecosystem of the Shenzhen River, its estuary, and Deep Bay consists of the inner portion of Deep Bay together with the adjacent intertidal mudflats, *gei wais*, bay waters, Mai Po and Futian mangroves and the fish ponds of the northwestern New Territories, Hong Kong. This is a wetland ecosystem of international importance and one of the most important in the South China region. Its core is the Mai Po Marshes and Neilinding-Futian National Nature Reserve, along with the adjacent Sites of Special Scientific Interest (SSSIs). This area provides a habitat for numerous rare and endangered species, in particular waterfowl and migratory birds including a number of species under threat on a global scale. This system is also an important habitat for many other types of plants and animals. At least 19 new species of invertebrates have been discovered here. In March 1995 the Hong Kong Government announced that the Mai Po/inner Deep Bay area would be designated a Wetland of International Importance under the Ramsar Convention.

Five SSSIs have been established in the Inner Deep Bay area. Two additional SSSIs have been proposed for Inner Deep Bay. The SSSIs designate areas of particular importance to local ecology, such as mangroves and intertidal zones (Figure. 3.2).

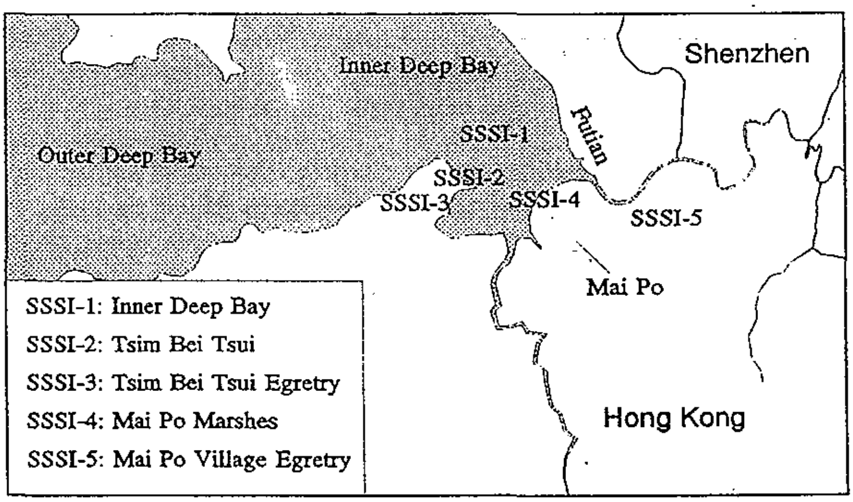


Figure 3.2 Mai Po, Futian, and SSSIs in Study Area

3.2 KEY ENVIRONMENTAL ISSUES

3.2.1 Overview

Sections 2 and 3 have introduced the Project and the environment which may be affected. The Project will involve a range of engineering activities within the river, the most critical from an environmental perspective are the dredging activities and related spoil transport and disposal.

At the outset of the study a preliminary analysis was completed of the range of operations involved in the Project, and the direct and indirect environmental impacts which would result from construction and operation of the works. This analysis was used to scope the assessment and focus the work on those issues which are critical to Project decisions.

3.2.2 Ecological Impacts

Of the various potential environmental impacts identified, by far the most critical to the environment and influential on Project decisions, related to the impact on ecological resources, and particularly potential effects on the nature reserves at Mai Po and Futian. The nature and extent of these impacts are fundamental to decisions on the acceptability of the Project in absolute terms, and to decisions on the design, operation and programme.

Other important potential impacts identified included noise and air pollution, and disposal of dredged materials. While these issues would affect Project design and operations they were not considered to be fundamental to decisions on the acceptability of the Project. The initial planning of the study was therefore focused strongly on the assessment of ecological impacts.

A panel of experts was convened in January 1994 to review the Project, identify and consider potential ecological impacts, to develop a framework for prediction and evaluation of these impacts, and to identify generic mitigation options.

The panel focused initially on the analysis of the conceptual ecological model developed to describe the estuarine system at the head of Deep Bay. This model is described more completely in Section 10. The model is based on trophic transfers within the system and attempts to describe the key linkages within the system.

The analysis reached a number of preliminary conclusions which were subsequently used as the basis for planning the investigations and overall methodology for the study. These preliminary conclusions, and the intended approach to the study, were presented to the Study Management Group at a meeting and endorsed as a framework for the study. The most important preliminary conclusions were:

1) The complexity of the ecological system at the head of Deep Bay would prevent any reliable quantification of the ecological model within the resources and time period available to the study. The seasonal and annual variation within the system would require extended measurement over several years to establish even basic quantification of the model. No examples of quantified models were available for comparable complex estuarine systems.

2) The estuarine system and mud flats within Deep Bay could be considered as a reasonably separate system from the related, but ecologically distinct, hinterland areas. In practice this permitted separate consideration of the estuary and mud flats from related but physically separate inland habitats including fish ponds.

3) Within the estuarine system the most critical determinant was likely to be the sediment flux within the critical areas of mud flats ie those areas of habitat value near to Mai Po and Futian. Particularly important is the consideration of any changes to the system that would affect its value for habitat. This would include:

   - changes to sedimentation affecting the physical stability of the mud flats, either a significant increase or decrease in sedimentation could potentially affect the physical stability of the mud flats and the availability of benthic fauna, particularly as food sources for bird species.

   - affect food sources. The basis for this conclusion is elaborated in Section 10 but is central to the study methodology which has focused on the prediction of future sedimentation as a result of the Project.

   - physical loss of estuarine habitat as a result of the Project.

4) The estuarine system is extremely variable, in both seasonal and annual terms. It would be impossible to undertake any experimentation which could establish direct causal relationships with any degree of confidence.

5) Generally there were three levels of ecological concern:

   - the viability of the overall system;

   - the viability of particular rare or endangered species, eg effects which put at risk critical food sources for rare species;

   - the need to maintain the diversity within the system.

In the short term this could result from sediment release during dredging, in the longer term from changes in hydrology and from regular maintenance dredging.

3.2.3 Impacts on Hydrological Characteristics, Siltation, and Water Quality

Due to the release and resuspension of sediments and pollutants combined therewith, dredging works during the construction may have an impact on water quality. Before it is possible to make any judgment on the impacts of dredging on the environment, it is necessary not only to understand the total losses directly attributable to dredging but also to consider the natural characteristics of sediment transport and the factors influencing the transport process.

During the operation phase, changes in the hydrology of trained Shenzhen River may have effects on siltation and water quality. The level of pollutant entering Deep Bay may vary due to changes in hydrological conditions. Heavy demand on maintenance dredging would also affect siltation pattern and water quality of river mouth and Deep Bay.

3.2.4 Air and Noise Impacts

Dust and noise from construction and traffic may be produced during the construction period. Based on experience in assessment of construction impacts, vehicle exhaust emission from construction and lighter traffic will not be a serious problem. Dumping of wastes, transport of dredged silt, movement of road traffic and dredging works may all produce dust. A dust problem will arise from such sources as disturbance of mud in storage pits. Noise from motorised equipment and construction traffic may be harmful to sensitive receivers.

No noticeable air quality problems will persist following completion of the Project. However, noise impacts may result from dredging and lighter traffic during maintenance dredging. Sensitive noise receivers along Shenzhen River will be subject only to short-term (e.g. several days) and infrequent (e.g. once per year) potential impact.

3.2.5 Impacts of Spoil Disposal

The major potential impact outside the construction area may result from disposal of dredged mud. The extent and nature of the impact will be determined by the quantity of the spoil, the degree of contamination, method of transport, and final site of disposition.

4 TECHNICAL APPROACH AND METHODOLOGY

4 TECHNICAL APPROACH AND METHODOLOGY

4.1 TECHNICAL APPROACH

The technical approach to the Environmental Assessment has progressed through the following process:

1) definition of the major potential impacts or key environmental issues through expert review and review of similar projects/situations;

2) definition of the existing environmental conditions for each impact through review of existing information, targeted monitoring programmes, and investigations;

3) prediction of environmental impacts using computer modelling, special investigations and expert review;

4) evaluation of these impacts against legislative or planning criteria, criteria developed through special investigations or the baseline studies;

5) development of mitigation measures for significant environmental impacts;

6) preparation of an environmental monitoring and audit programme by which the actual extent of impacts, and the efficacy of mitigation measures can be reviewed.

4.2 DEFINITION OF KEY ISSUES

The key features of the existing environment have been introduced in Section 3. The major potential environmental issues were identified through review of the Project in this context by a panel of specialists from relevant engineering and environmental disciplines. The most critical potential environmental impacts in terms of the Project were identified as: air and noise effects; the effect of dredging particularly the impact of increased sediment levels on estuarine and other wetland habitats; direct and indirect losses to other ecological resources; spoil disposal; and effects on water quality.

4.3 LITERATURE REVIEW

There is a substantial body of background information and previous research on the project area and similar river training projects. A thorough review has been completed of literature pertinent to the Project, including pollution sources, the environment of the study area, data from similar projects in Hong Kong and the PRC, and relevant international ecological studies. These sources are referenced within each Chapter of this report.

4.4 BASELINE SURVEYS

Baseline monitoring was completed to supplement existing environmental data. Surveys were completed for air quality, noise, water quality, sediment and soil quality, ecology and the socioeconomic setting. Where appropriate the monitoring undertaken as part of the baseline surveys were designed to complement the ongoing monitoring programme of the Shenzhen and Hong Kong Authorities. The baseline monitoring plan was designed around the monitoring programme drafted by the Shenzhen Municipal Environmental Monitoring

Station in 1994 and utilised existing stations set up by the Shenzhen Municipal Environmental Monitoring Station where possible.

A database management system was developed particularly for this study to ensure efficient storage and use of all information collected.

4.4.1 Air and Noise

Due to the differences in sampling procedures for Shenzhen and Hong Kong, and given that the most important air and noise Sensitive Receivers are in Shenzhen, the baseline monitoring for air quality and noise was focused on the Shenzhen side.

The main potential impact of the project on air quality arises from dust during the construction phase. Air quality baseline monitoring was therefore focused on characterising existing dust levels. Parameters monitored included settleable dust fall, total suspended particulate (TSP), respirable suspended particulate (RSP), wind direction and speed. Monitoring sites were established at the Yumin Village(A1) and Zhuanmatou(A2) (Figure 4.1). Monitoring was undertaken in April and May 1994. Dust fall was monitored for a continuous period of 30 days each time. TSP and RSP were measured for 5 days each time. Dust levels were determined using the gravimetric method.

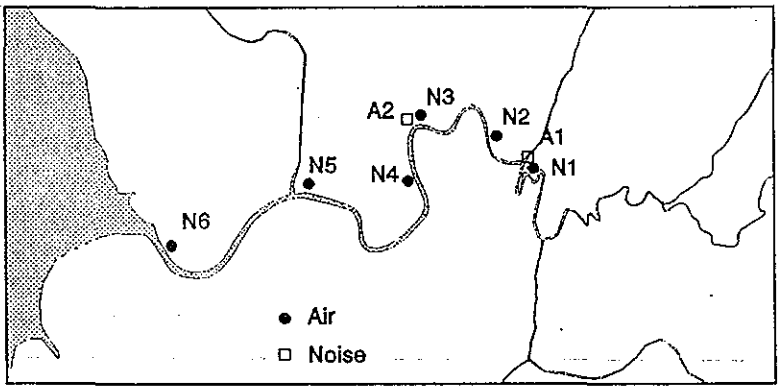


Figure 4.1 Air/noise sampling locations

Existing background noise levels were measured at Yumin Village(N1), Binjiangchang(N2), Zhuanmatou(N3), Lok Ma Chau(N4), Yunong Village (N5), and in the estuary(N6) in April and May 1994. Locations of the monitoring stations are also shown on Figure 4.1. L_{10}, L_{50}, L_{90} and Leq were determined using sound level meters.

4.4.2 Water Quality

Water quality was monitored six times on the Shenzhen River and three times in Deep Bay from January to October 1994. In-situ measurements or water samples were taken at both high tide and low tide on each occasion. Sampling locations on the Shenzhen River (Figure 4.2) include Jingdu(W0), Yumin Village (W1), Zhuan Matou (W2), Yunong Village (W3), an estuary station (W4), and a station outside of the estuary (W5).

Baseline monitoring on the Shenzhen River included water temperature, pH, suspended solids (SS), dissolved oxygen (DO), five-day biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), ammonia nitrogen (NH_3-N), nitrate nitrogen (NO_3-N), nitrite nitrogen (NO_2-N), total nitrogen (TN), total phosphorus (TP), copper (Cu), cadmium (Cd), lead (Pb), chromium (Cr), mercury (Hg), nickel(Ni), zinc(Zn), odour, color, salinity, conductivity, oil, arsenic, phenol, cyanide, and *E. coli*. Both total and dissolved metal content were determined. Organic carbon and carbohydrates were not measured because the former is correlated to COD and the later was replaced with oil.

For baseline monitoring in Deep Bay, parameters measured include water temperature, pH, colour, salinity, SS, DO, BOD_5, COD, NH_3-N, NO_3-N, NO_2-N, Cu, Cd, Pb, Cr and Hg, TN, TP, dissolved N and P, turbidity, oil, conductivity, chlorophyll-a and *E. coli*. Total and dissolved contents of all heavy metals were determined respectively. In-situ measurements or water samples were taken during low tide at 2 stations, the mouth of Deep Bay (W6) and Chiwan Harbour (W7), as shown in Figure 4.2.

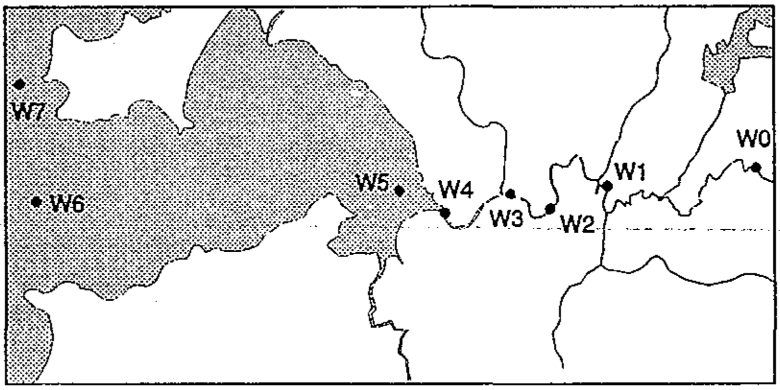


Figure 4.2 Water quality sampling locations

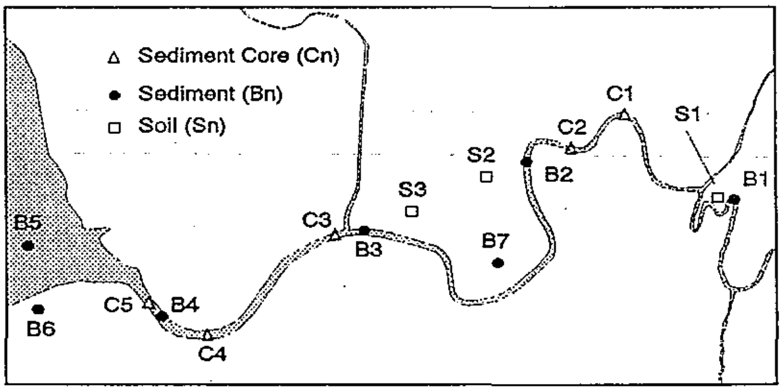


Figure 4.3 Soil/sediment sampling locations

4.4.3 Soil and Sediment

Soil and sediment monitoring was undertaken in May 1994. Figure 4.3 indicates the sampling locations. Soil samples were collected from Yumin Village(S1), Zhuanmatou(S2) and Yunong Village(S3). Sediments were sampled from Yumin Village(B1), Zhuanmatou(B2), Yunong Village(B3), estuary (B4), Inner Deep Bay(B5), a *gei wai*(B6) and a fish pond (B7). Parameters measured included organic matter, Pb, Cd, Hg, Ni, Zn, Cr, Cu, pH, redox potential (Eh), particle size distribution (PSD), DDT, BHC, and polycyclic aromatic hydrocarbons (PAHs). Both total and available contents of heavy metals were determined. The methodology for analysis is described in a separate working paper (Peking University, 1994).

Sediment core samples were collected from five locations along the Shenzhen River(C1 through C5 in Figure 4.3). The depth of the cores were from 50mm to 60mm. Pb, Cd, Hg, Ni, Zn, Cr, and Cu contents were measured to determine the vertical variation in heavy metal contamination of the bottom sediment.

4.5 SPECIAL INVESTIGATIONS

A number of special investigations were implemented as part of the study. Each investigation was targeted at providing information on particular issues of concern to the assessment, to refine baseline conditions or to establish criteria for evaluation.

The investigations included 50-hr continuous hydrodynamic, water quality, and sediment surveys, pollution sources investigation, elutriate tests, sedimentation rate study, and mangrove survival study. The results of these studies are outlined in the relevant technical sections of the report.

4.5.1 Special Monitoring for Input to Hydrodynamic, Sediment Transport and Water Quality Modelling

50-hr monitoring exercises were undertaken in March and July 1994 to provide dry and wet season data for hydrodynamic, water quality and sediment transport modelling. Monitoring was undertaken at four cross sections of Shenzhen River (S1-S4) and six stations of Deep Bay (S5-S10). Figure 4.4 shows the locations of the cross sections and sampling stations. In-situ measurements or water samples were taken for temperature, DO, BOD_5, COD, TN, TP, chloride, Cu, Pb, *E. Coli.*, SS, flow, current speed and water level. At Deep Bay cross sections, flow direction was also measured.

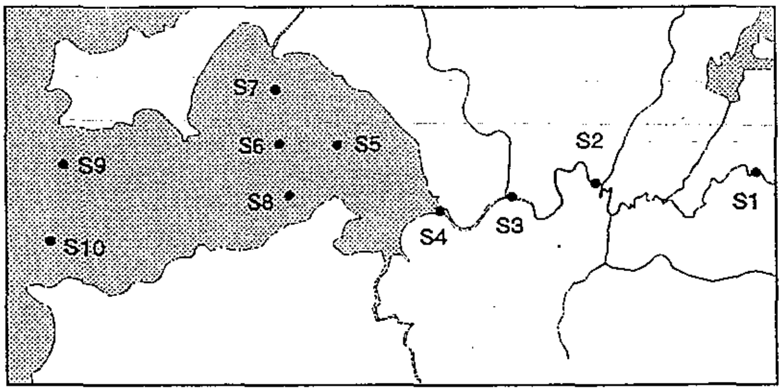


Figure 4.4 50h monitoring stations

4.5.2 Pollution Sources

Information was collected on pollution sources including water quality data of the main tributaries and outlets on both sides of Shenzhen River and in Deep Bay. Figure 4.5 shows the locations of the outlets and the tributaries along the river and in Deep Bay. The water quality data of tributaries in Hong Kong was provided by Hong Kong Environmental Protection Department. On the Shenzhen side, in addition to the routine monitoring data, a survey on main pollution sources was carried out to measure water temperature, COD, BOD_5, TN, TP, *E. coli.*, Cu, Pb, SS, and flow rate.

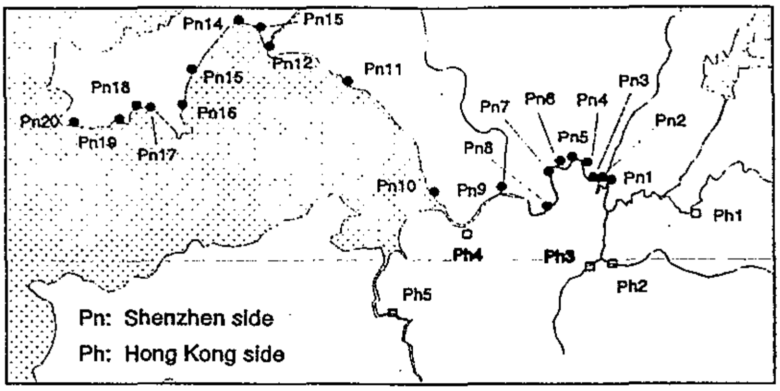


Figure 4.5 Pollution sources in the Deep Bay watershed

4.5.3 Measurement of Sediment Accumulation Rates

Five short sediment cores with length of 28-54 cm were taken and sampled on mudflats at the Shenzhen River mouth during Oct. 11-14, 1994. Sampling locations are indicated in Fig. 4.6. Low-background gamma counting was used to measure naturally occurring levels of ^{210}Pb in sediment samples to determine the sedimentation rates.

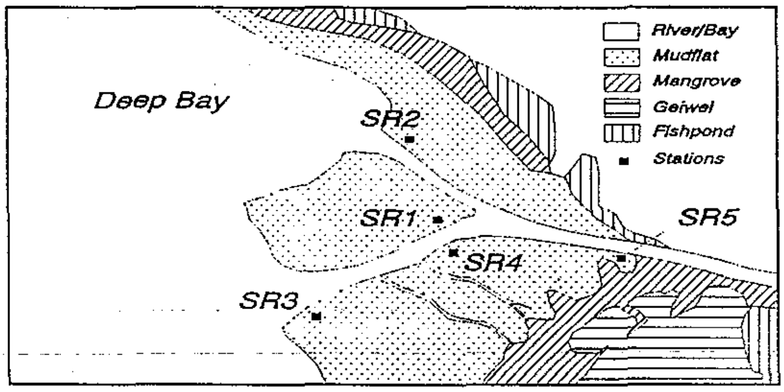


Figure 4.6 Location for sedimentation rate measurement

4.5.4 Elutriate Test

Potential release of oxygen-consuming organics, nutrients, and metals from the suspended sediment in either river or marine waters during dredging was estimated using an elutriate test. A sample of contaminated sediment collected from the Shenzhen River (Lok Ma Chau) was suspended in river water from the same location and marine water from Inner Deep Bay at a sediment/water ratio of 1:100 and 1:1000. The concentrations of COD, Cu, Pb, TN, and TP in raw water were measured. After addition of sediment of a fixed amount, the water samples were mixed, shaken for 4 hours, and settled overnight. The water was then sampled and analysed for the parameters again.

4.6 ECOLOGICAL BASELINE MONITORING AND SPECIAL INVESTIGATIONS

4.6.1 Ecology

The ecological surveys aimed to build on the existing data base by providing additional information required to better understand the ecosystem and permit evaluation of potential impacts. The surveys were directed at providing an understanding of the ecosystem as a whole as well as information on specific ecological features. Major elements of the ecological work included surveys of terrestrial ecology, mangroves, mud flat and mangrove invertebrates, and avifauna.

4.6.2 Terrestrial

Terrestrial ecology work was focused on the Sheung Ma Lei Yue Hill as it is the area of greatest habitat importance and will be severely affected by the construction. Habitat mapping and qualitative wildlife surveys were carried out to identify ecosystem components of conservation value.

4.6.3 Mangrove fauna and flora

Surveys were undertaken on various elements of the mangrove ecosystem to improve the understanding of food web relationships and energy transfer between different trophic levels. Studies involved stable isotope analysis (for carbon and nitrogen) on organisms (including mangrove species, mangal crustaceans and algae, mud flat invertebrates and fish) and organic matter to establish the linkage between major components of the mangrove ecosystem in terms of energy flow. Mangrove survey included analysis of aerial photographs followed by ground truthing to determine existing vegetation distribution. Further details on methodology are provided in Appendices 10.5, 10.6 and 10.7.

4.6.4 Benthic invertebrates

Benthic invertebrates were sampled by coring to determine species distribution and abundance along two transects on the Hong Kong side and one transect on the Shenzhen side. Each transect consisted of three stations. Five replicate samples were collected from each station in four seasons of 1994. Since benthic invertebrates provide virtually the sole source of food for water birds in Deep Bay, predator exclosure studies were carried out in every season to determine the impacts of predation on benthic organisms by birds.

4.6.5 Birds

Bird studies included population assessment and feeding observations. Bird populations were assessed by conducting monthly (once every three days during spring season and once a week during autumn season) bird counts at Mai Po Marshes and the Futian National Nature Reserve and twice monthly counts along the Hong Kong side of Shenzhen River from Lo Wu to the river mouth. The nocturnal feeding behaviour of water birds was observed monthly from 2 observation hides located on the mud flat off Mai Po Marshes near the benthos sampling transect. This information allowed better understanding of the food chain interactions.

4.6.6 Mangrove survival study

Three sites along the upper, middle and lower reaches of the Shenzhen River were selected and growth of one-year-old seedlings of *Kandelia candel* under varying environmental conditions with full, partial or no wave buffering was observed in order to clarify various habitat conditions that influence the growth and development of mangrove seedling.

4.7 PREDICTIVE MODELLING

Computer modelling techniques were used to predict air, noise and hydrodynamic and sedimentation impacts.

Air quality: The Fugitive Dust Model (FDM) was used to examine potential dust impacts during construction. Noise modelling was based on various Technical Memoranda (TM) published by the Environmental Protection Department in Hong Kong on construction noise. At this stage, both the dust and noise modelling is constrained by the lack of detailed information on construction activities. Details of the number, timing, and types of plant deployed during the construction phase will only be available following detailed design

Hydrodynamics, sedimentation and water quality: The hydrodynamics of Shenzhen River and Deep Bay was modelled by a 1-D unsteady flow model and a 2-D model respectively. A non-equilibrium sediment transport model was used for both Shenzhen River (1-D) and Deep Bay (2-D). A 1-D steady estuary model was used for water quality modelling and a 2-D model for Deep Bay. Both 1-D and 2-D dynamic water quality models were used for the evaluation of combined impact of Stage 1 and 2 Works. Both the flow and sediment models regarded Shenzhen River estuary (downstream from Sanchahe) and Deep Bay as one system with the transition between a 1-D model for the river and 2-D model for Deep Bay. Details of the above models are provided in Chapter 7 and Appendix 7.

Ecology: A conceptual model of the trophic linkages between major components of the Deep Bay ecosystem was developed as a basis for analysis of the ecosystem, and primary and secondary impacts. The initial intent was to expand this into an energy flow model based on biomass transfer. However, upon completion of literature review and preparation of the conceptual model, it was apparent that the biomass within each component showed considerable variation and decreased exponentially up the food chain. This indicated that within the trophic hierarchy, the higher trophic levels were insensitive to changes in the bottom compartments unless such changes were in orders of magnitudes greater than the existing levels. This was considered unlikely to happen. In addition the inherent variability of the system and lack of any reliable historic data base made quantification of the model unrealistic within the resources of the study.

In spite of this, trophic flow diagrams were developed and used effectively to illustrate linkages between major components of Deep Bay ecosystem and to identify critical potential effects on the overall system. Ecological impact evaluation was therefore focused on key pathways among the lower trophic levels rather than on changes that may occur in the higher trophic levels. The rationale was that if changes in the lower trophic pathways were within the limits of natural variation, there were unlikely to be adverse changes at the higher trophic level and impacts should thus be considered acceptable. Conversely, should changes lie outside the limits of natural variation, it would be necessary to determine the degree of change at the lower trophic level and whether such changes would be acceptable at both the lower and possibly higher trophic levels. Based on a review of trophic pathways of the Deep Bay ecosystem by a panel of experts on the study team, it was determined that sediment flux in Inner Deep Bay and its effects on the mud flat benthic invertebrates was the most important process. Ecological assessment was thus focused on this aspect.

4.8 EVALUATION

Wherever possible evaluation of the potential impacts has been undertaken through comparison with legislative standards or established guidelines. The appropriate standards or guidelines have been applied to potential impacts in Shenzhen and Hong Kong respectively. This approach has permitted the evaluation of air quality, noise, water quality, and sediment quality impacts to be undertaken against agreed performance criteria. The relevant standards for each administration are presented in the relevant technical section of the report.

The assessment of ecological impacts has been less straight forward as there are few defined criteria or planning guidelines for evaluating environmental performance. There are however various indicators of policy, precedents for habitat compensation and international conventions which provide a framework for decision making. These have been outlined in the relevant sections.

The general approach to evaluation of ecological impacts has been to establish, as accurately as possible within the constraints of the study, the level of natural variation within the existing system and to use these as indicators of acceptable changes in particular parameters within the system. For example sediment levels within the estuary have been predicted using computer modelling. The significance of these changes can be compared to the level of natural variation in sediment which occurs regularly during a major storm event. This approach is necessarily an oversimplification which addresses only individual elements of a complex system. The evaluation of specific issues therefore also considered the context of trends of the overall ecosystem and other general trends e.g. the progressive loss of wetlands, effects on endangered or rare species, and cumulative impacts from other committed projects. This process necessarily involves professional judgement.

Recommendations on the acceptability of the Project has been formed based on consideration of individual issues and the summation of nett effects. The recommendations have assumed that all recommended mitigation measures are adopted and that the Outline Design for the Project is not altered fundamentally from that described in Section 2.

4.9 DEVELOPMENT OF MITIGATION MEASURES

The development of mitigation measures has been undertaken as an integral component of the environmental assessment process. Where major potential environmental impacts or risks have been identified as the study progressed, proposals to mitigate these effects have been developed. The formal proposals for mitigation are restricted to those that can be addressed within the scope of the current projects. Additional proposals for environmental enhancement or wider action to address potential cumulative environmental impacts have been made in Appendix.

4.10 ENVIRONMENTAL MONITORING AND AUDIT

The various recommendations for environmental monitoring and audit developed through the assessment of Stage 1 Works have been consolidated and presented as an Environmental Monitoring and Audit Manual for Stage 1 Works. This report incorporates the necessary requirements for Stage 2 Works as well. The approach adopted is consistent with that applied to major development projects in Hong Kong but takes account of standards and monitoring procedures within Shenzhen.

References

Peking University, 1994, Manual for baseline monitoring of the Shenzhen River Regulation EIA.

5 AIR QUALITY

5 AIR QUALITY

5.1 INTRODUCTION

Air quality impacts arising from the Project would result mainly from dust emissions during the construction phase. Odour is already a renowned feature of the existing river and is not regarded as a key issue during the construction and operational phases of the Project. Based on previous experience on similar assessments, vehicle exhaust emissions of NO_x, CO and particulates from vehicles during construction should be minor and are not considered to be a key issue.

During Stage 1 and Stage 2 Works, dust will be generated from excavation, materials handling, vehicle movements over unpaved site surfaces, wind erosion of exposed site areas and possibly concrete batching. Dust levels at the sensitive receivers have been assessed using the Fugitive Dust Model (FDM) for Stage 1 and Stage 2 Works and compared against applicable PRC and Hong Kong regulations. Since Stages 1 and 2 Works may overlap for approximately 16 months, the cumulative effects have also been assessed. Comparisons of dust levels with and without mitigation measures have been made to determine residual impacts. Based on these results, additional mitigation measures that could further reduce dust levels to compliance levels are recommended.

5.2 APPLICABLE REGULATIONS, STANDARDS AND GUIDELINES

5.2.1 Hong Kong Legislation, Standards and Guidelines

The Air Pollution Control Ordinance (APCO) (Cap. 311, 1983) provides authority for controlling air pollutants from a variety of stationary and mobile sources, including fugitive dust emissions from construction sites, and encompasses a number of Air Quality Objectives (AQOs). Table 5.1 presents the statutory limits for controlling dust emissions, in terms of total and respirable suspended solids (TSP and RSP), during Stages 1 and 2 Works.

Table 5.1 Hong Kong air quality objectives (AQOs)

Parameter	Maximum Average Concentration $\mu g/m^3$		
	1-hour[1]	24-hour[2]	Annual
TSP	500[3]	260	80
RSP	-----	180	55

1 Not to be exceeded more than three times per year
2 Not to be exceeded more than once per year
3 In addition to the above established legislative controls, it is generally accepted that an hourly average TSP concentration of 500 $\mu g/m^3$ should not be exceeded. Such a control limit is particularly relevant to construction works and has been imposed on a number of construction projects in Hong Kong in the form of contract clauses.

The APCO also specifies a number of processes which require licensing and are subject to special controls. Recent amendments to the APCO have included concrete batching as a Specified Process. Concrete batching plants located on the Hong Kong side would require licensing and the use of Best Practicable Means (BPM) for dust suppression.

5.2.2 PRC Legislation

For the purpose of this EIA, Air Quality Standard Category 2 (GB3095-82) control limits have been applied. The standards for TSP and RSP are given in Table 5.2.

Table 5.2 PRC air quality standard category 2 (maximum average concentration in $\mu g/m^3$)

Parameter	Instantaneous	24-hour
TSP	1000	300
RSP	500	150

5.2.3 Reconciliation of Standards

Comparing the 24-hour maximum average concentrations in Tables 5.1 and 5.2, the Hong Kong standard for TSP is more stringent than the PRC standard, but the PRC standard for RSP is more stringent than the Hong Kong standard. As dust affects specific sensitive receivers, Hong Kong and PRC standards are applied to Hong Kong and PRC sensitive receivers respectively for assessing dust impacts in this study.

5.3 EXISTING CONDITIONS

5.3.1 Existing Conditions

According to the Hong Kong - Guangdong Environmental Protection Liaison Group (1992), daily TSP levels in the urban area of the Shenzhen in 1989 ranged from 50-640 $\mu g/m^3$, with an annual daily mean of 168 $\mu g/m^3$. Mean 24-hour TSP levels in Hong Kong ranged from 113 $\mu g/m^3$ in April to 235 $\mu g/m^3$ in November; mean 24-hour RSP levels were 60 and 102 $\mu g/m^3$ in April and November respectively, and total dust fall was 7.9 tonne/km^2/month in April and 6.3 tonne/km^2/month in November. Since the data from the Hong Kong side only showed averages for the monitoring periods, it could not be determined whether the individual daily averages were in compliance with the AQOs. With a maximum of 640 $\mu g/m^3$, the Shenzhen data show exceedance of the daily average criteria in the urban area on occasion.

Baseline air quality monitoring was conducted at Yumin Village and Zhuanmatou in late March and early April and then again in late May 1994 for a total of 10 days. Sampling locations and parameters have been described in Section 4.3.1. A summary of the monitoring results is presented in Table 5.3.

Wind monitoring during the same period showed variable wind directions with speeds ranging from 0.1 to 2.8 m/s. Higher wind speeds were generally recorded when wind was from the south, southwest or southeast. However, higher TSP levels were generally recorded at low wind speeds, indicative of reduced dispersion of dust at such speeds.

According to the historical data from routine air quality monitoring in Shenzhen, comparatively higher dust levels generally occur in winter and spring (Figure 5.1). In spring, TSP and RSP levels are approximately 60% and 30% higher than the annual averages respectively. Upon arrival of the rainy season in April / May, dust levels usually drop considerably, reaching minimum levels in June.

Table 5.3 Summary of air quality monitoring data

Parameter	Yumin Village	Zhuanmatou	Combined
24-hr Average TSP ($\mu g/m^3$)			
Minimum	111	49	49
Maximum	239	175	239
Average	200.80	119.60	160.20
Standard Deviation	40.62	37.58	56.44
95 Percentile	287.39	199.72	280.52
99 Percentile	352.99	260.42	371.68
Instantaneous RSP ($\mu g/m^3$)			
Maximum	8	4	8
Mean	4	3	3.5
Dust Fall (tonne/km²/month)	11.91	9.94	11.25

TSP levels at both monitoring locations complied with the PRC Category 2 standards. Total dust fall, however, exceeded the standard of 8 tonne/km²/month at both locations. According to the annual variation in TSP shown in Figure 5.1, the PRC Category 2 standard for instantaneous dust (1,000 and 500 $\mu g/m^3$) are unlikely to be exceeded even during dry season. RSP levels were measured instantaneously and in-situ using hand held light scattering instruments and therefore cannot be compared with the applicable standards.

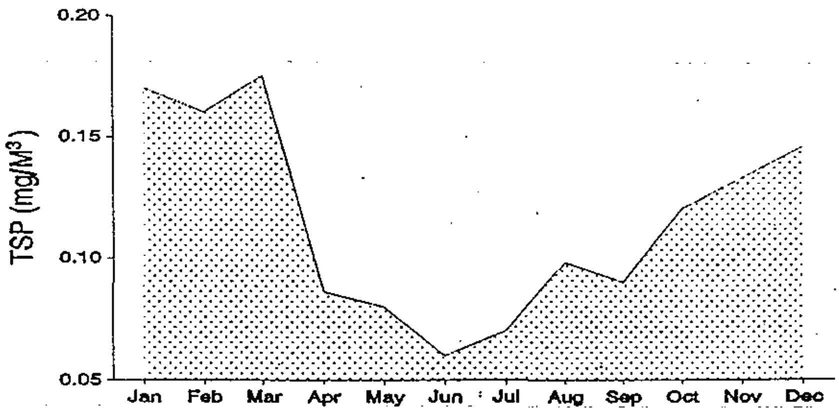


Figure 5.1 Variation in TSP level

TSP levels at both locations were within the Hong Kong AQO for 24 hours. The TSP collected at these monitoring stations were from either local construction or traffic. The relatively low levels of RSP indicates that the majority of the TSP were large size particles which settled within a short distance from the emission sources. The TSP levels on Hong Kong side of Shenzhen River are expected to be much lower than those observed on Shenzhen side in view of the lack of construction activities and heavy traffic.

Besides dust, odour from the river was also investigated. Compare to the control station upstream of the study area, strong and unpleasant odour was detected from all monitoring locations (water quality) along the river.

5.3.2 Future Development

Dust in terms of TSP will only be a problem during the construction phase. There is no known future development planned in the Stages 1 and 2 Works area during this period which will be affected by dust or are likely to influence the outcome of assessment.

5.3.3 Sensitive Receivers

Sensitive receivers of dust were identified and showed in Figure 5.2.

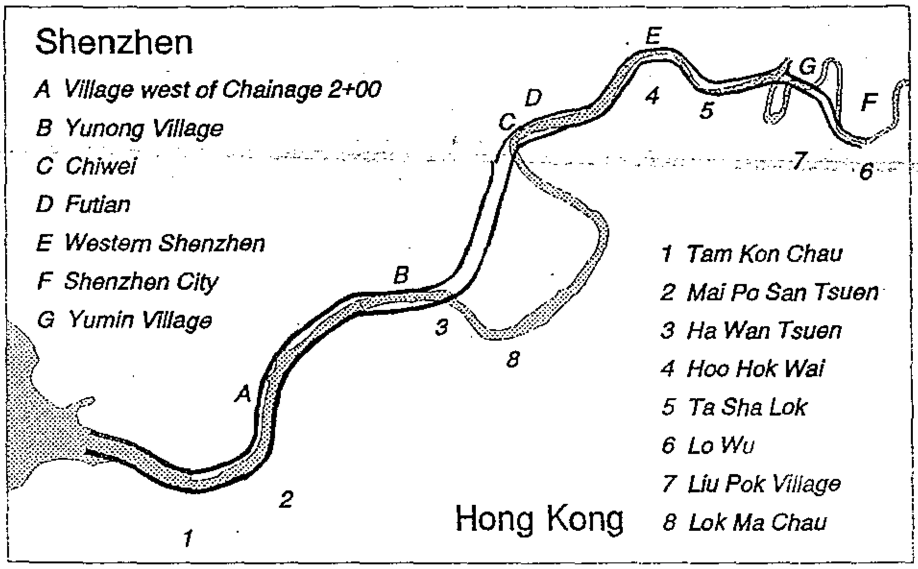


Figure 5.2 Location of air quality sensitive receivers

5.4 MODELLING

5.4.1 Assessment Methodology

The Fugitive Dust Model (FDM) approved by USEPA and Hong Kong EPD was used to assess potential dust impacts from the construction activities. This model was used in preference to the Industrial Source Complex Short Term (ISCST) model as it is specifically designed for estimation of impacts from fugitive dust sources using wind-dependent emission and advanced gradient-transfer deposition algorithm.

The FDM model is limited by its inability to simulate accurately the effects of complex terrain. The terrain in the study area is "rolling" rather than mountainous, so the model was considered suitable.

Dispersion modelling was undertaken for Stages 1 and 2 separately, as well as for both Stages combined since both stages may overlap for approximately 16 months.

5.4.2 Assumptions Used

Background Dust Level

A conservative background of 168 $\mu g/m^3$ 24-hour average TSP level was used. This was the annual daily TSP mean in the urban area of Shenzhen in 1989 according to the Hong Kong-Guangdong Environmental Protection Liaison Group (1989) (see Section 5.2.1). This was comparable to the average baseline TSP level of 160 $\mu g/m^3$ measured in this study during 10 days of monitoring (see Table 5.3).

Dust Emissions

The estimation of dust emissions was based on data from USEPA AP-42 and information on Stage 1 of the Project. The same embankment construction rate and activities as in Stage 1 of the Project were assumed for Stage 2. According to the information from "Shenzhen River Regulation Projects Stage 1 Specifications", the borrowing in Seung Ma Lei Yue Hill will be completed in Stage 1 and the surplus borrowed material will be stockpiled near Lok Ma Chau Bend for the construction of embankment in Stage 2. Emissions from the stockpiling area and the truck movements on the haulage roads to the northern and southern sites were incorporated in the assessment. Dredged spoil from Stage 1 will be deposited at the Lok Ma Chau Bend and those from Stage 2 will be hauled off site by barge for disposal. Due to high moisture content, dust emission is expected to be minimal (see below). At the time of this assessment, there was no indication of whether concrete batching would be on-site or ready mixed cement from off-site would be used for pre-casting of construction materials. Emissions from concrete batching activities were not incorporated in the assessment. Concrete batching in Hong Kong side will be regulated by the specified process license and thus must comply with licensing conditions on emissions and control measures.

Soil Moisture and Dust Erosion

From Section 4.5.1 of "Shenzhen River Regulation Project Stage 1 Technical Design Manual", natural moisture content of material from river channel excavation ranges from 53% to 64%, i.e. in semi-liquid state. It is reasonable to assume that the dredged material from Stages 1 and 2 of the Project will be similar. Therefore, river channel excavation and erosion of dredged material should result in minimal dust erosion if any.

Work Programme

In view of dust erosion, the worst case scenario will be during embankment construction. Dispersion modelling was undertaken for this period of construction.

Particle size

The model used the default particle size distribution in FDM, that is, the fraction in each of 0-2.5, 2.5-5, 5-10, 10-15 and >15 micrometer diameter is 0.0262, 0.0678, 0.1704, 0.1536 and 0.5820 respectively.

Silt Content

Material silt content and moisture content used for Stage 1 of the Project were assumed for both Stages 1 and 2 and were 29% and 19.5% respectively. Haulage road surface material silt content was taken as 8.4% from AP-42 (Table 11.2.1-1, Western surface coal mining, haul road).

Material Transport

Haulage trucks with 10 m^3 capacity were assumed for transferring materials in the site. Vehicle speeds of 15 km/hr and 30 km/hr were taken for traffic in the stockpiling area and other site areas respectively.

Dust Suppression Measures

Additional assessment was undertaken to determine residual dust impacts on sensitive receivers after implementation of dust suppression measures. The following measures were taken into account:

- reduction of speed of haul trucks to 10 km/hr in the stockpiling area and 20 km/hr in other site areas,
- reduction of grading speed of graders to 8 km/hr, and
- twice daily watering of all site roads and active site area (mitigation efficiency of 50% according to AP-42).

Based on the above assumptions and similar work rates as in Stage 1 of the Project, the quantities of dust emitted per day for various activities are given in Table 5.4. It is apparent that haul truck movements on unpaved roads and site erosion constitute the largest quantities of dust during construction.

Table 5.4 Predicted dust emissions from the construction activities (kg/day)

Location	Activity	Dust Emission (kg/day)	
		Without dust suppression	With dust suppression
Stockpiling area	Loading material from excavator to haul trucks	1	1
	Haul trucks on unpaved site roads	53	18
	Site erosion	71	35
Haul roads between stockpiling area and embankment construction area	Haul trucks on unpaved haul roads	755	252
Embankment construction area	Tipping material from haul trucks	1	1
	Bulldozing overburden	75	75
	Grading embankment material	255	74
	Haul trucks on unpaved site roads	1268	423
	Site erosion	457	229

5.4.3 Simulation Modelling

One hour sequential data for wind speed and direction were obtained from the Ta Kwu Ling meteorological station. Other surface observations required to process the meteorological data were obtained from the Hong Kong Royal Observatory. Data from the year 1990 were used for the assessment.

The FDM dispersion model was used to calculate 24-hour average TSP levels during periods of maximum construction activity at varying distances from the site.

5.5 POTENTIAL IMPACT

5.5.1 Construction Period

Tables 5.5 and 5.6 show the maximum 24-hr average TSP concentrations at the sensitive receivers with and without mitigation measures respectively. For each scenario, TSP levels during Stage 1, when Stages 1 and 2 overlap, and during Stage 2 were determined.

Table 5.5 Maximum 24-hour average TSP concentrations at sensitive receivers without adoption of mitigation measures

Side	SR	Location	TSP Concentration ($\mu g/m^3$)		
			Stage 1 alone	Stage 1 & 2	Stage 2 alone
Shenzhen	A	Village west of chainage 2+00	187	345[1]	328[1]
	B	Yunong Village	337[1]	507[1]	463[1]
	C	Chiwei	769[1]	819[1]	277
	D	Futian	277	318[1]	223
	E	Western Shenzhen	228	398[1]	338[1]
	F	Shenzhen City	607[1]	619[1]	184
	G	Yumin Village	812[1]	817[1]	184
Hong Kong	1	Tam Kon Chau	181	217	205
	2	Mai Po San Tsuen	189	248	248
	3	Ha Wan Tsuen	292[2]	528[2]	441[2]
	4	Hoo Hok Wai	295[2]	340[2]	240
	5	Ta Sha Lok	429[2]	585[2]	324[2]
	6	Lo Wu	405[2]	417[2]	183
	7	Liu Pok Village	286[2]	290[2]	193
	8	Lok Ma Chau	496[2]	561[2]	232

1 Exceedance of the 24-hour average TSP PRC limit
2 Exceedance of the 24-hour average TSP HKAQO

Without mitigation measures (Table 5.5), TSP levels at 4 sensitive receivers on the

Shenzhen side and 6 sensitive receivers on the Hong Kong side would exceed the respective limits. These same receivers would also encounter exceedance when Stages 1 and 2 overlap. During Stage 2 Works, TSP exceedance would occur at 3 sensitive receivers on the Shenzhen side and 2 sensitive receivers on the Hong Kong side. TSP exceedance would occur throughout Stages 1 and 2 at Yunong Village in Shenzhen and Ha Wan Tsuen and Ta Sha Lok in Hong Kong.

Table 5.6 Maximum 24-hour average TSP concentrations at sensitive receivers with adoption of dust suppression measures

Side	SR	Location	TSP Concentration ($\mu g/m^3$)		
			Stage 1 alone	Stage 1 & 2	Stage 2 alone
Shenzhen	A	Village west of chainage 2+00	177	250	242
	B	Yunong Village	251	326[1]	275
	C	Chiwei	455[1]	474[1]	206
	D	Futian	221	237	194
	E	Western Shenzhen	197	274	245
	F	Shenzhen City	385[1]	391[1]	175
	G	Yumin Village	486[1]	488[1]	175
Hong Kong	1	Tam Kon Chau	174	191	185
	2	Mai Po San Tsuen	178	207	207
	3	Ha Wan Tsuen	228	294[2]	259
	4	Hoo Hok Wai	231	252	203
	5	Ta Sha Lok	298[2]	369[2]	239
	6	Lo Wu	285[2]	292[2]	175
	7	Liu Pok Village	225	227	180
	8	Lok Ma Chau	332[2]	362[2]	198

1 Exceedance of the 24-hour average TSP PRC limit
2 Exceedance of the 24-hour average TSP HKAQO

With the implementation of the three dust suppression measures described in Section 5.4.2, the 24-hour average TSP levels at the sensitive receivers would be reduced by 10 to 40%. Table 5.6 shows that TSP exceedance would occur at 3 sensitive receivers in Shenzhen and Hong Kong respectively. The same receivers would also encounter TSP exceedance when Stages 1 and 2 overlap. No receiver on either side, however, would encounter TSP exceedance during Stage 2 Works. Yunong Village in Shenzhen and Ha Wan Tsuen in Hong Kong would encounter TSP exceedance only when Stages 1 and 2 Works overlap.

Table 5.7 shows the number of days in a year when the respectively TSP limits would be exceeded, based on 1990 meteorological data from Ta Kwu Ling. Chiwei in Shenzhen would be the worst affected among all receivers, especially when Stages 1 and 2 overlap. In Hong Kong, the number of exceedances would increase at Ha Wan Tsuen and Ta Sha Lok when Stages 1 and 2 overlap.

The high dust level at the sensitive receivers, especially during the period Stage 1 and 2 of the Project are in parallel, should be viewed with the fact that the probability of high wind speed with adverse wind direction in the area was low. Besides, background level ranging from 50 to 640 $\mu g/m^3$. The probability of high background dust level coinciding with maximum dust generating activities and worst-case meteorological conditions is low.

Table 5.7 Number of TSP exceedances per year based on modelling results

Side	SR	Location	No. of TSP Exceedances (Days/yr)		
			Stage 1 alone	Stage 1 & 2	Stage 2 alone
Shenzhen	A	Village west of chainage 2+00	0	0	0
	B	Yunong Village	0	1	0
	C	Chiwei	16	46	0
	D	Futian	0	0	0
	E	Western Shenzhen	0	0	0
	F	Shenzhen City	2	2	0
	G	Yumin Village	8	8	0
Hong Kong	1	Tam Kon Chau	0	0	0
	2	Mai Po San Tsuen	0	0	0
	3	Ha Wan Tsuen	0	5	0
	4	Hoo Hok Wai	0	0	0
	5	Ta Sha Lok	2	8	0
	6	Lo Wu	1	1	0
	7	Liu Pok Village	0	0	0
	8	Lok Ma Chau	2	2	0

Dust problems during construction are therefore unlikely to be insurmountable and can possibly be mitigation to acceptable levels. In addition, dust predictions are conservative, as they were based on maximum dust generating activity coinciding with worst-case meteorological conditions. In particular, maximum construction activities were assumed at both Stage 1 and Stage 2 Works areas during the period Stage 1 and 2 of the Project are in parallel.

Besides dust, adverse impact at the sensitive receivers caused by odour from disturbance of the river system and the discharge of dredged spoil is expected.

5.5.2 Operational and Maintenance Period

There should be no significant air quality impact during the operational and maintenance period after completion of the Stage 2 Works.

5.5.3 Risks and Uncertainties

The model used is internationally accepted and recognised as being appropriate for the situation. There is no exceptional uncertainty involved in the modelling exercise.

Uncertainties involved in the assessment include:

1) Specifications for plant and equipment were estimated based on reasonable requirements for this type of project. At this stage of the Project, planning information on actual plant to be used or specifications for plant were not available.

2) The contract conditions were not determined and may involve a mix of Hong Kong and Shenzhen requirements. The assessment assumes that the contract can include the environmental controls identified and that these can be enforced.

There is little risk that the air quality assessment is inaccurate in a significant way. The consequences of any inaccuracies are unlikely to be critical to decisions on the EIA.

5.6 MITIGATION MEASURES

Mitigation measures will be required by the contractors to minimise dust generation. Suitable contract conditions and a commitment by the contractors to adopt good operational practices will be necessary. A number of practical measures are listed below:

1) Frequently used site roads should be watered on a regular basis.
2) Vehicles should use wheel wash facilities or should be hosed before leaving the site.
3) Water sprinklers should be used at all material loading areas.
4) Deliveries of cement (if any) should be from tankers to silos through an enclosed system.
5) Open stockpiles should be avoided through the use of silos and storage bins.
6) Cement silos (if any) should be fitted with a high level alarm and all vents should be fitted with fabric filters.
7) The site should be watered and cleaned regularly, particularly during dry weather.
8) Speed controls for on-site vehicles should be applied and enforced. (Note: A maximum speed of 8 km/hr is recommended by Hong Kong EPD, and may become a legislative requirement)
9) During the selection of plant, consideration should be given to the level of dust suppression measures provided.
10) If concrete is batched, it should be loaded wet to the mixer trucks.
11) Side enclosure and covering of aggregate or dusty material storage piles to reduce fugitive erosions. Where this is not practical due to frequent usage, aggregate fines should be watered as needed to suppress dust.
12) Where possible, avoid placing dusty material storage piles and locating site exit points near sensitive receivers.
13) Tarpaulin covering of all dusty vehicle loads during transport to, from and between site locations.
14) Where feasible, routing of vehicle and positioning of construction plant at maximum separation distance from sensitive receivers.
15) Provision of a fixed spray bar system to wet loads prior to dumping on site.

For typical concrete batching, the use of filters on vents, regular watering, water sprays at vehicle loading points and partial or total enclosure of the truck loading area would reduce dust emission in the order of 90%. For concrete batching activities on the Hong Kong side, a license will be required and permissions and control measures must comply with licensing conditions.

Heavily contaminated spoil should be segregated and disposed to separate spoil storage sites and covered with uncontaminated spoil to reduce potential odour problems.

6 NOISE

6 NOISE

6.1 INTRODUCTION

Noise impacts would occur during Stages 1 and 2 works from construction equipment and traffic. Stage 1 and Stage 2 activities will overlap during the initial 16 months of the Stage 2 contract. However, Stage 1 and Stage 2 activities occur along different parts of the Shenzhen River, and affect different sets of NSRs. The cumulative noise level resulting from concurrent activity at Stage 1 and Stage 2 sites at a given NSR is expected to be little different from the noise level resulting from activity at the nearer of the two sites. It is appropriate therefore to consider noise impacts from the two works stages separately. Noise impacts from Stage 1 and Stage 2 are addressed in Sections 6.5 and 6.6 respectively.

Construction programme and equipment list for Stages 1 and 2 works were not available for this EIA. Hence, the approach was to determine the compliance noise levels at various NSRs or site boundary, then calculate sound power levels at the notional source that would achieve compliance at the receivers. Based on knowledge of commonly used construction equipment for similar activities, examples of the types and numbers of equipment that could be used without violating noise limits were proposed. Should these proposed items be used during construction, compliance with the applicable noise limits should be achievable. If different items or combinations of items are deployed, a detailed noise impact assessment based on actual items and deployment schedule should be undertaken.

Mitigation measures have been proposed to further reduce noise impacts, especially where construction activities occur during restricted hours.

6.2 APPLICABLE REGULATIONS, STANDARDS AND GUIDELINES

Noise impacts were assessed against applicable PRC and Hong Kong regulations. PRC noise regulations apply to the construction site boundary while Hong Kong noise regulations apply to the nearest noise sensitive receivers (NSR). Works at the river mouth, if located within the Deep Bay Works Exclusion Zone (Special Measures Zone), would further be constrained by noise limits.

6.2.1 PRC Standards and Guidelines

PRC standards, regulations and ordinances concerning noise are set by China's Environmental Protection Agency. The relevant noise standard for construction site boundary noise limits is the National Standard GB12523-90, summarized in Table 6.1.

Table 6.1 PRC construction site boundary noise level limits (standard GB12523-90)

Construction Stage	Major Noise Sources	Construction Site L_{eq} Limits	
		Daytime dB(A)	Night dB(A)
Site Preparation	Bulldozer,excavator,transport equipment	75	55
Structural Activity	Concrete mixer, poker vibrator	70	55

6.2.2 Hong Kong Standards and Guidelines

In Hong Kong, standards and guidelines set by the Noise Control Ordinance (NCO) and EPD's Practice Note for Professional Persons (ProPESS DP 2/93) regulate daytime construction noise. Hong Kong's *Deep Bay Guidelines*, discussed below, are also relevant to regulation of noise for construction projects in and around Deep Bay.

NCO restrictions are contained in the *Technical Memorandum on Noise from Construction Work other than Percussive Piling*, as indicated in Table 6.2. The Allowable Noise Levels (ANLs) depend upon the Area Sensitivity Rating (ASR) of the Noise Sensitive Receiver (NSR). In the areas surrounding the Shenzhen River construction site on the Hong Kong side, the ASRs are assumed to be "A", corresponding to rural areas (including villages) and low density residential areas.

Outside the restricted hours, these NCO requirements do not apply. Regardless of the ASR rating, construction noise may be assessed with reference to the ProPESS DP 93/2 guidelines, except where Deep Bay Guidelines apply.

Table 6.2 Hong Kong construction noise level limits

Time Period	Acceptable Noise Level L_{eq} (dB(A)) at Facade of nearest NSR[3]	
	ASR = A[4]	ASR = B
All days during the evening (1900 to 2300 hours) and general holidays during the daytime and evening (0700 to 2300 hours)[1]	60	65
All days during the night-time (2300 to 0700 hours)[1]	45	50
Non-holiday daytime (0700 to 1900 hours)[2]	75	75

1 From the NCO *Technical Memorandum on Noise from Construction Work other than Percussive Piling*.
2 From ProPESS DP 93/2 guidelines concerning daytime construction noise levels
3 Does not apply to noise from percussive piling.
4 ASR "A" includes the Deep Bay area.

Deep Bay is an internationally recognised conservation site for waterfowl and other birds, qualifying for protection under both the Ramsar and Bonn Conventions. It contains three Sites of Special Scientific Interest (Mai Po Egretry, Mai Po Marshes, and Inner Deep Bay) and two nature reserves (Mai Po and Futian). The westernmost reach of the planned Stage 2 Works, at the mouth of the Shenzhen River, is within the Deep Bay conservation area. In particular, the mouth of the river is within the Inner Deep Bay Special Measures Zone (SMZ), within which no works are normally permitted due to its conservation importance. Part of the Deep Bay area, including part of the Inner Deep Bay Special Measures Zone, relative to the Stage 2 Works area, is shown in Figure 6.1.

For Deep Bay to continue as an internationally recognised site of importance for both resident and migratory birds, it is necessary to avoid noise levels likely to deter birds from visiting or breeding in the Bay. Guidelines for noise control in the Deep Bay area are contained in the *Deep Bay Guidelines for Dredging, Reclamation and Drainage Works* (ERL, 1989). These requirements are:

a) Pre-project ambient noise levels at NSRs in the range of the site should be established. The extent of survey work depends on the number of NSR locations, and whether construction works are expected to extend into restricted times.

b) In addition to the NCO criteria set out above, additional noise control criteria to protect the sensitive habitats in the Deep Bay area, particularly in the Inner Deep Bay Special Measures Zone(SMZ) as shown in Figure 6.1, whichever is the most stringent in a particular case shall apply:

- 75 dB(A) should never be exceeded, for weekdays 0700 to 1900 hours as measured outside the nearest occupied property.
- 60 dB(A) should never be exceeded for all days 0700 to 2300 hours within the SMZ, as measured at a point 100m outside the construction site boundary. The approximate 100-m buffer zone is indicated in Figure 6.1.

Alternatively, it would be acceptable to specify the noise limit as 10 dB(A) above the ambient noise level between 0700 and 1900 hours.

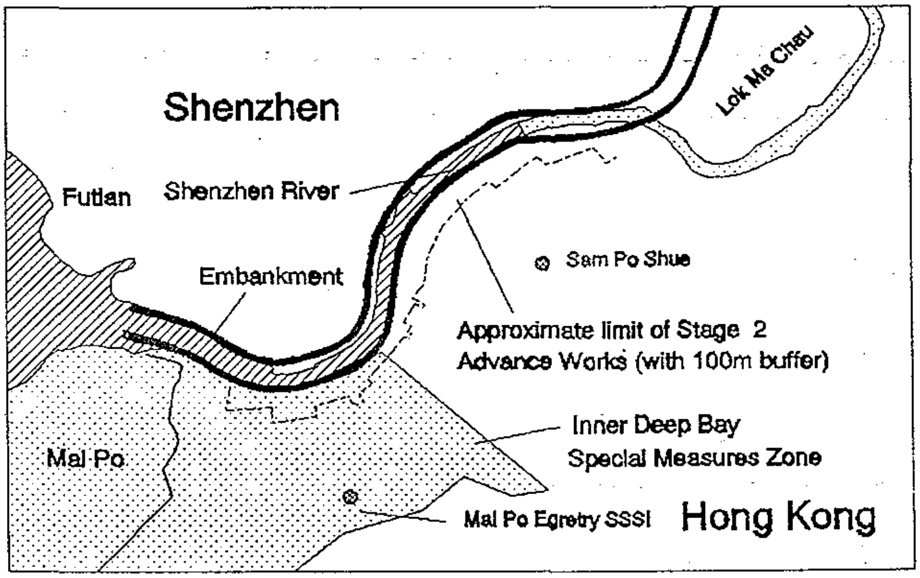


Figure 6.1 Inner Deep Bay Special Measures Zone

The Deep Bay noise guidelines are summarized in Table 6.3.

Within the Inner Deep Bay SMZ, the *Deep Bay Guidelines* specify that "works should be designed to minimise land-take, and programmed so as not to occur during the migratory bird over-wintering period (November to March). In addition, works should preferably not take place outside normal working hours" (08.00 to 17.00 hours).

Table 6.3 Noise level limits for construction works in the Deep Bay area

Within Deep Bay area, but excluding the Inner Deep Bay Special Measures Zone	
Time Period	Acceptable Noise Level (dB(A))[1]
Weekdays 0700-1900 hours[2]	75
Weekdays 1900-2300 hours	60
General holidays including Sundays 0700-2300 hours	60
All days 2300-0700 hours	45

1 (5min) L_{eq} measured at the building facade of a Noise Sensitive Receiver (NSR)
2 Alternative limit for weekdays, 0700-1900 hours, is 10 dB(A) above the ambient noise level (measured as 1-hour L_{90} dB(A))

Within the Inner Deep Bay Special Measures Zone	
Time Period	Acceptable Noise Level (dB(A))[1]
All days 0700-2300 hours[2]	60
All days 2300-0700 hours	45

1 (5min) L_{eq} measured freefield, 100m from the site boundary
2 Alternative limit for weekdays, 0700-1900 hours, is 5 dB(A) above the ambient noise level (measured as 1-hour L_{90} dB(A))

6.2.3 Reconciliation of Standards

The Hong Kong and PRC standards are significantly different in terms of their designation of receiver location and their maximum stipulated noise levels. The following differences between noise standards in the jurisdictions should be noted:

- The PRC guideline indicates that noise is assessed at the site boundary; the Hong Kong standard (other than that applying to the Inner Deep Bay SMZ) applies to noise measured at the facade of the nearest exposed NSR.
- Daytime noise levels are assessed against a specific maximum under the PRC guideline, but are assessed against a variable standard under the Hong Kong guideline.
- The nature of construction activities (i.e., whether site formation or structural work) is significant under the PRC standard, but not under the Hong Kong standard.

Noise impacts have been assessed with reference to the respective standards for the PRC and Hong Kong, according to the location of the sensitive receiver.

6.3 EXISTING CONDITIONS

Baseline noise monitoring was carried out in late March/early April and then again in late May/early June in 1994 at various sensitive receivers along the Shenzhen River on the Shenzhen side. There was a decreasing trend in both day time and night time noise from

Shenzhen City towards the river mouth, indicative of the urban environment in the former and a comparatively more rural setting in the latter. Existing night time noise levels already exceed the PRC night time noise standard at most locations. Noise monitoring results are presented in Figure 6.2, Figure 6.3 and Appendix 6.1.

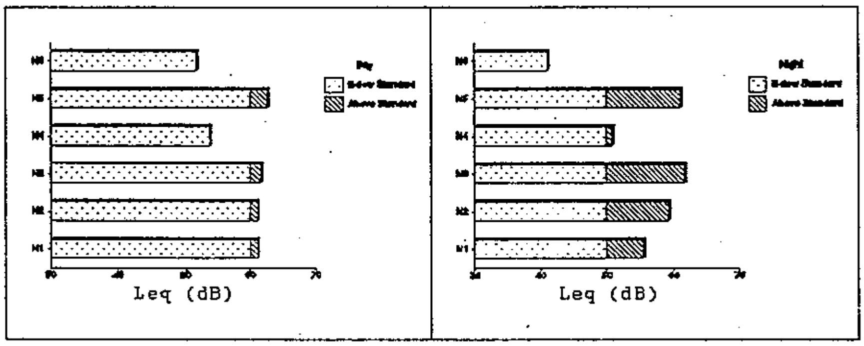


Figure 6.2 Baseline noise levels (dB(A))

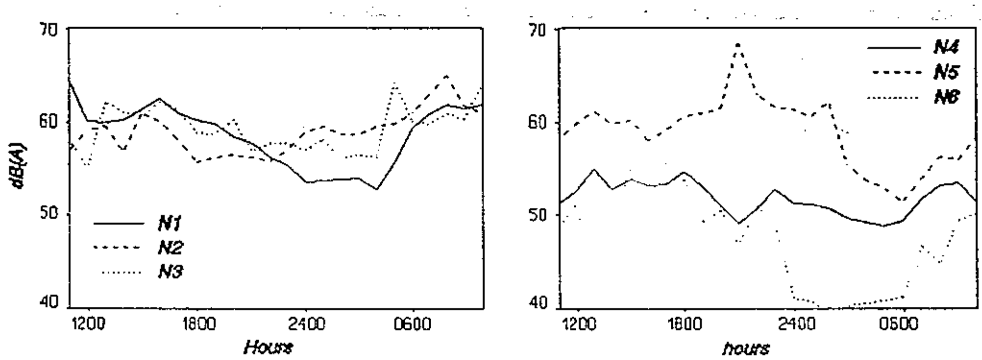


Figure 6.3 Daily variation in noise level (dB(A))

6.4 MODELLING METHODOLOGY

The Hong Kong NCO's *Technical Memorandum on Noise from Construction Work other than Percussive Piling* outlines an assessment methodology for calculating construction site noise. This methodology was used in this EIA for predicting construction noise for both the PRC and Hong Kong.

The *Technical Memorandum* requires that, for prediction purposes, a notional source position be determined, at which all items of PME are considered to be grouped. Assumptions of typical positions have been made based on the general location of major works.

The calculation methodology contained in Section A.3.4.2 of *BS 5228: Part 1: 1984* was used to calculate noise from traffic on the haul routes. The *BS 5228* methodology provides an equivalent L_{eq} noise level on the basis of sound power levels of mobile plant, the number of vehicles per hour, average vehicle speed, and the distance of the receiver from the haul road.

6.5 STAGE 1 WORKS

6.5.1 Major Works Tasks: Stage 1

The following tasks are involved in Stage 1 works:

Task 1: Site Preparation

A site fence extending 9 km will be constructed around much of the site, requiring two months. Site offices, residences and warehouses will also be constructed at this time.

Task 2: Temporary River Crossing near Buji River

Vehicles transporting fill from the Seung Ma Lei Yue Hill borrow area to sites west of the eastern works area will have to cross the Shenzhen River at the eastern works area. A floating bridge or other temporary river crossing will be built at this location (8+110 to 8+150).

Task 3: Preliminary Works near Mouth of Buji River

As part of establishing the haul route for fill from the Seung Ma Lei Yue Hill borrow area, the right riverbank near the mouth of the Buji River will be dredged to allow repairs, and two sections of the Shenzhen River (from 8+400 to 8+500 and 8+600 to 8+670) will be blocked.

Task 4: Excavation of Seung Ma Lei Yue Hill and Transport of Fill Material

The excavation of the Seung Ma Lei Yue Hill will provide the necessary earth material for embankment construction. Large bulldozers and excavators will be used at the borrow area. Except for a small amount of slightly weathered rock, limited blasting is expected at the excavation site.

Part of the borrowed material will be immediately transported for construction of the embankment, while the remainder will be stockpiled at designated areas. The transport route extends from the borrow area along the realigned riverbank, and will require improvement works at the following locations:

- The existing right embankment between 8+110 and 7+200 will be widened and reinforced.

- A new road about 400 m long will be built along the section extending from the western wall of the Shangbu Pier to the western works area.

Task 5: River Channel Excavation

The Shenzhen River estuary bed is currently between 2.5 and -3 m in elevation. Dredging to a depth of -5 m is planned. The excavation is assumed to employ small suction-operated dredgers. Mud will be conveyed by a pipe to a waste pile area, typically within 700 m of the work site. The type of dredger to be used is not certain. An earlier river dredging project on the Min River in the Fujian Province of the PRC used a trailing suction hopper dredger and several cutter suction dredgers. The trailing suction hopper dredger obtained power for the dredge pumps from the main propulsion engines, though separate generators for the dredge pumps were being considered. Land-based machinery will be used for the excavation of material above water level.

Task 6: Construction of Embankments

Embankments will vary in height from 4.5 to 5.3 m, and will be about 5.5 m wide. Each embankment will be built in two stages. In Stage 1, the embankment will be built to an average height of 2.5 m; in Stage 2, it will be finished to its final height.

Embankments will use excavated material from Seung Ma Lei Yue Hill. The fill will be placed by bulldozers and consolidated with compactors. Terraces from 5 to 15 m wide will be constructed on the landward slope of the embankment, and laid with turf.

Task 7: Revetment and Slope Protection Works

Revetments are required to prevent erosion of the embankments. Precast concrete slabs will be laid on the floodplain terrace in order to decrease the roughness of the river channel.

Bank revetment and slope protection works will use rock boulders. A membrane will first be laid, followed by a crushed rock layer. A cast rock layer will be placed on top, cast manually from river vessels or using purpose-built vessels.

The floodplain terrace surface will be laid with precast concrete slabs. The slabs will be cast and stockpiled at a casting area, transported to the site, and placed by small crane.

Revetment and slope protection works will start as soon as the channel excavation and Stage 1 embankment construction are completed.

Other Tasks

A flood control gate will be constructed just downstream of the western works area near Futian. Discharge culverts will be built, using conventional methods of reinforced concrete cast in-situ.

6.5.2 Construction Plant and Equipment: Stage 1

This assessment has assumed commonly-used major items of powered mechanical equipment (PME), with associated sound power levels (SWL), as indicated in Table 6.4.

It has been assumed that the haul road will be utilised for 12 hours a day. Based on a daily rate of 135 trips and a peak-hour factor of 1.5, 17 vehicle trips have been assumed for the one-hour assessment of haul road noise. An average vehicle speed of 30 kph has also been assumed, along with a SWL of 105.2 dB(A), based on a sample of six 20t and 24t dumptrucks in *BS 5228*.

Table 6.4 Typical construction equipment requirements for stage 1

Construction Activity	Possible Equipment (with *Technical Memorandum* identification code)	SWL per piece (dB(A))
Site Preparation	Circular saw (CNP 201)	108
	Lorry (CNP 141)	112
	Excavator/loader (CNP 081)	112
	Bulldozer (CNP 030)	115
Excavation of Shung Ma Lei Yue Hill	Bulldozer (CNP 030)	115
	Excavator/loader (CNP 081)	112
	20-t and 24-t dumptruck (BS 5228)	105
Construction of Haul Road near western works yard	Bulldozer (CNP 030)	115
	20-t and 24-t dumptruck (BS 5228)	105
	Road roller (CNP 185)	108
River Channel Excavation	Suction dredger	109
	Excavator (CNP 081)	112
	Water pump (petrol) (CNP 282)	103
Construction of Embankments	Bulldozer (CNP 030)	115
	Excavator/loader (CNP 081)	112
	20-t and 24-t dumptruck (BS 5228)	105
	Vibratory roller (CNP 186)	108
Revetment and Slope Protection Works	Barge-mounted crane (CNP 048)	112
	20-t and 24-t dumptruck (BS 5228)	105
	Road roller (CNP 185)	108
	Vibratory compactor (CNP 050)	105
	Lorry-mounted crane (BS 5228)	116
Works Yard	Concrete batching plant (CNP 022)	108
	Concrete mixer (CNP 045)	96
	Poker vibrator (CNP 170)	113
	Fork lift trucks (BS 5228)	114
	Winch (petrol) (CNP 263)	102
	Lorry (CNP 141)	112

6.5.3 Sensitive Receivers: Stage 1 Works

The Stage 1 works will affect receivers on both sides of the Shenzhen River. To the north of the river in the PRC are residential (urban and village), public, industrial and agricultural areas. Specific NSR areas to be considered (starting from upstream), and their approximate closest distance to the construction site boundary, are:

- Shenzhen City (20 m),
- Yumin Village (10 m),
- village across from Hoo Hok Wai (30 m),
- Futian (10 m),
- Yunong Village (170 m).

Bordering the river to the south is land within Hong Kong's Closed Area boundary. The density of development is less than that to the north, and the distances to the construction site boundary are greater. At the upstream reach of the Stage 1 works, wetlands and fishponds border the river, extending from Tak Yuet Lau downstream to Liu Pok, Ta Sha Lok, Hoo Hok Wai, and Lok Ma Chau. A stand of mangrove lies opposite the Shangbu Pier. Sensitive receivers consist largely of scattered dwellings, with larger receiver concentrations at:

- Lo Wu (140 m),
- Liu Pok Village (400 m),
- Lok Ma Chau (300 m),
- Ha Wan Tsuen (220 m).

Locations of these NSRs for Stage 1 works are shown in Figure 6.4.

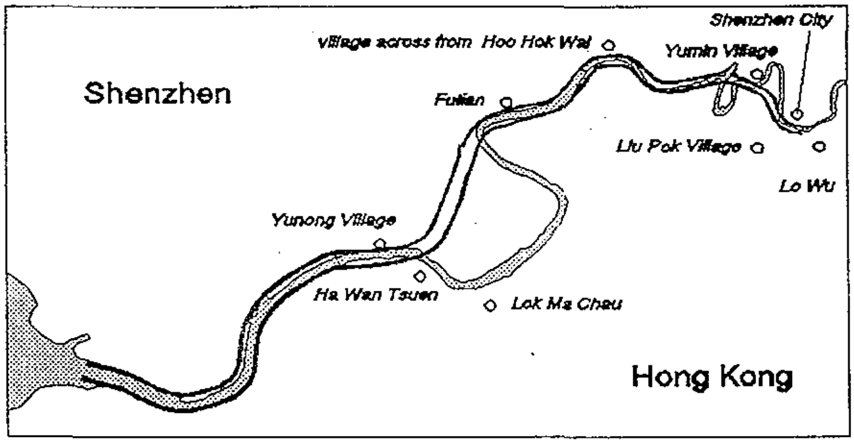


Figure 6.4 Locations of NSRs for Stage 1 Works

6.5.4 Potential Impacts: Stage 1 Works

In determining the allowable total SWL, the PRC standards have been assumed to be based on freefield noise measurement. Daytime Hong Kong standards have been assumed to be 75 dB(A).

Site Noise: Daytime

Table 6.5 shows the maximum total SWL of combined construction equipment (exclusive of haul road traffic) that still allows PRC and Hong Kong noise daytime standards to be met. For example, the Hong Kong daytime noise limit of 75 dB(A) would not be exceeded at an NSR facade 200 m from the notional source position if the total SWL of all operating equipment was 126 dB(A) or less. Similarly, the PRC standard for site preparation noise would not be exceeded at the site boundary 20 m away if the total SWL of all operating equipment remained below 109 dB(A). This assessment has assumed no pre-existing natural or purpose-built barriers.

Table 6.5 Daytime construction noise during stage 1

Source - Receiver Distance (m)	Allowable source sound power level (dB(A)) under:			
	PRC Standards		Hong Kong Standards	
	Site Preparation	Structural	ASR = A	ASR = B
5	97	92	94	94
10	103	98	100	100
20	109	104	106	106
50	117	112	114	114
75	121	116	118	118
100	123	118	120	120
150	127	122	124	124
200	129	124	126	126
250	131	126	128	128
300	133	128	130	130
500	137	132	134	134

Hong Kong

Hong Kong's noise restrictions are based on noise at the facades of NSRs. Most NSRs are 140 to 400 m away from the construction site boundary, and thus benefit from significant distance attenuation. It should be noted that individual isolated NSRs closer to the riverbank may benefit less from distance attenuation. The limits on total source SWL shown in Table 6.5 permit the concurrent use of several pieces of PME on each task. Examples of permitted equipment combinations include:

- Embankment Construction: 3 bulldozers, 3 excavators, 6 dumptrucks, and 3 rollers would produce a total SWL of about 123 dB(A), which would not exceed a 75 dB(A) daytime noise limit at villages on the Hong Kong side of the river.

- Revetment and Slope Protection Works: 1 barge-mounted crane and 2 each of dumptrucks, road rollers, vibratory compactors, and lorry-mounted cranes would generate a total SWL of about 121 dB(A), which also would not exceed a 75 dB(A) daytime noise limit at villages on the Hong Kong side of the river.

- Dredging: 3 suction dredgers, 3 excavators and 6 petrol water pumps would produce a total SWL of about 119 dB(A), which would not exceed a 75 dB(A) daytime noise limit at villages on the Hong Kong side of the Shenzhen River.

- Construction of Drainage Culverts: 6 vibratory pokers and 2 each of concrete mixer trucks, lorries and concrete pumps would produce a total SWL of about 123 dB(A), which would not exceed a 75 dB(A) daytime noise limit at villages on the Hong Kong side.

- Construction of Haul Road: 3 bulldozers, 6 dumptrucks and 3 road rollers generate a combined SWL of 121 dB(A), which would not exceed a 75 dB(A) daytime noise limit at villages on the Hong Kong side.

Excavations at Seung Ma Lei Yue Hill are expected to require blasting and the use of a substantial fleet of 20- and 24-tonne dumptrucks. The noise and vibration impacts of blasting have not been assessed, since no information is available concerning blasting techniques. In addition, the impulsive and intermittent nature of blasting noise is significantly different from the more steady nature of PME noise. Neglecting the noise from blasting, a fleet of 18 dumptrucks, 12 bulldozers and 12 excavators would generate a combined SWL of about 128 dB(A). At about 400 m, representing the approximate distance between Seung Ma Lei Yue Hill and Lo Wu, this would produce an acceptable facade noise level.

PRC

The PRC noise restrictions are based on noise at the construction site boundary. This criterion places significant restrictions on activity near the site boundaries. For example, concurrent use of a bulldozer, dumptruck and road roller for construction of the haul road near the western works yard would be expected to exceed the PRC Site Preparation noise standard at the site boundaries, which are close to the road. In each works yard, the concurrent operation of 1 concrete batching plant and 2 each of concrete mixers, poker vibrators, forklift trucks, winches and lorries would generate a notional source SWL of about 121 dB(A). This would result in noise exceedances at the boundaries of the works yards.

Site Noise: Evening and Night-time

Table 6.6 shows the maximum total SWL of combined construction equipment (exclusive of haul road traffic) that still allows PRC and Hong Kong evening and night-time noise standards to be met. For example, the Hong Kong night-time noise limit (ASR = A) of 45 dB(A) would not be exceeded at an NSR facade 200 m from the notional source position if the total SWL of all operating equipment was 96 dB(A) or less. Similarly, the PRC night-time standard for construction noise (55 dB(A) for either site preparation or structural activity) would not be exceeded at the site boundary 50 m away if the total SWL of all operating equipment remained below 97 dB(A). This assessment has assumed no pre-existing natural or purpose-built barriers.

As expected, more stringent evening and night-time noise standards require lower night time noise levels. Concurrent use of the equipment shown in Table 6.3 for a single activity (which is not an exhaustive inventory of equipment needed for each activity) would generally not be possible under either the PRC or Hong Kong standards.

Haul Road Noise

Given the assumed haul road traffic indicated in Section 6.5, the predicted noise levels at various distances from the source line are given in Table 6.7.

Table 6.6 Evening and night-time construction noise during stage 1

Source - Receiver Distance (m)	Allowable source sound power level (dB(A)) under:					
	PRC Standards (Night-time)		Hong Kong Standards			
			Evening		Night-time	
	Site Preparation	Structural	ASR=A	ASR=B	ASR=A	ASR=B
10	83	83	85	90	70	75
30	93	93	95	100	80	85
50	97	97	99	104	84	89
100	103	103	105	110	90	95
200	109	109	111	116	96	101
300	113	113	115	120	100	105
500	117	117	119	124	104	109
700	120	120	122	127	107	112
1000	123	123	125	130	110	115
1600	127	127	129	134	114	119
2000	129	129	131	136	116	121
3000	133	133	135	140	120	125

Table 6.7 Haul road noise during Stage 1

Distance (m) from source line to receiver	Predicted Haul Road Noise Level (dB(A))	
	Facade	Free-field
5	65.7	62.7
10	62.7	59.7
20	59.7	56.7
30	58.0	55.0
40	56.7	53.7
50	55.7	52.7
75	54.0	51.0
100	52.7	49.7
150	51.0	48.0
200	49.7	46.7
250	48.8	45.8
300	48.0	45.0

Unlike general site noise, the noise from haul road use is expected to remain within acceptable limits at all but the very nearest distances. Restrictions during the night-time may be necessary to meet PRC standards.

6.6 STAGE 2 WORKS AND MAINTENANCE DREDGING

6.6.1 Work Tasks: Stage 2 and Maintenance Dredging

The following major work tasks are involved in Stage 2 (only Task 3 is involved in maintenance dredging):

Task 1: Construction of Haul Road

It has been assumed that a haul road will be built along the southern riverbank to permit transport of equipment, labour, and materials.

Task 2: Construction of Embankments

Embankments will use excavated material from Seung Ma Lei Yue Hill. It has been assumed that material will be stockpiled at the Lok Ma Chau Bend during Stage 1 works. The fill will be placed by bulldozers and consolidated with compactors. Terraces from 5 to 15 m wide will be constructed on the landward slope of the embankment, and laid with turf.

The embankments started during Stage 1 will be completed during Stage 2. In Stage 1, the embankment will be built to an average height of 2.5 m. In Stage 2, it will be finished to its final height of 4.5 to 5.3 m.

Task 3: River Channel Excavation

The excavation will employ suction-operated dredgers. Mud will be conveyed by a pipe to a waste pile area, typically within 700 m of the work site; or to a barge for disposal off site. The type of dredger to be used is not certain. An earlier river dredging project on the Min River in Fujian Province of the PRC used a trailing suction hopper dredger and several cutter suction dredgers. The trailing suction hopper dredger obtained power for the dredge pumps from the main propulsion engines, though separate generators for the dredge pumps were being considered.

Land-based machinery will be used for the excavation of material above water level.

Task 4: Revetment and Slope Protection Works

Revetments are required to prevent erosion of the embankments. Precast concrete slabs will be laid on the floodplain terrace in order to decrease the roughness of the river channel.

Bank revetment and slope protection works will use rock boulders. A membrane will first be laid, followed by a crushed rock layer. A cast rock layer will be placed on top, cast manually from river vessels or using purpose-built vessels.

The floodplain terrace surface will be laid with 600x600x300 cm^3 precast concrete slabs. The treatment will consist of 3 layers: a membrane at the bottom, followed by gravel and concrete layers. The slabs will be cast and stockpiled at a casting area, transported to the site, and placed by small crane.

Revetment and slope protection works will start as soon as the channel excavation and Stage 1 embankment construction are completed.

6.6.2 Construction Plant and Equipment: Stage 2 and Maintenance Dredging

The assessment assumes the requirements for plant and equipment and associated sound power levels (SWL) presented in Table 6.8. The assumptions for use of the haul road are the same as for Stage 1 works.

Table 6.8 Typical construction equipment requirements for stage 2 and maintenace dredging

Construction Activity	Possible Equipment (with *Technical Memorandum* identification code)	SWL per piece (dB(A))
Construction of Haul Road	Bulldozer (CNP 030)	115
	20-t and 24-t dumptruck (BS 5228)	105
	Road roller (CNP 185)	108
River Channel Excavation	Suction dredger	109
	Excavator (CNP 081)	112
	Water pump (petrol) (CNP 282)	103
Construction of Embankments	Bulldozer (CNP 030)	115
	Excavator/loader (CNP 081)	112
	20-t and 24-t dumptruck (BS 5228)	105
	Vibratory roller (CNP 186)	108
Revetment and Slope Protection Works	Barge-mounted crane (CNP 048)	112
	20-t and 24-t dumptruck (BS 5228)	105
	Road roller (CNP 185)	108
	Vibratory compactor (CNP 050)	105
	Lorry-mounted crane (BS 5228)	116

6.6.3 Sensitive Receivers: Stage 2 Works and Maintenance Dredging

Stage 2 and miantenance dredging works would affect receivers on both sides of the Shenzhen River. To the north of the river in the PRC are residential (urban and village), public, industrial and agricultural areas. Bordering the river to the south is land within Hong Kong's Closed Area boundary. The density of development is less than that to the north. Sensitive receivers consist largely of scattered dwellings, with larger receiver concentrations at small villages. Tam Kon Chau and Mai Po Sun Tsuen are both within the Inner Deep Bay SMZ. A substantial part of the Stage 2 advance and main works and maintenance dredging falls within the Inner Deep Bay SMZ, and is thus subject to additional noise restrictions within a 100-m strip adjacent to the works site boundary. The main sensitive receivers are listed in Table 6.9 and their locations are indicated in Figure 6.5.

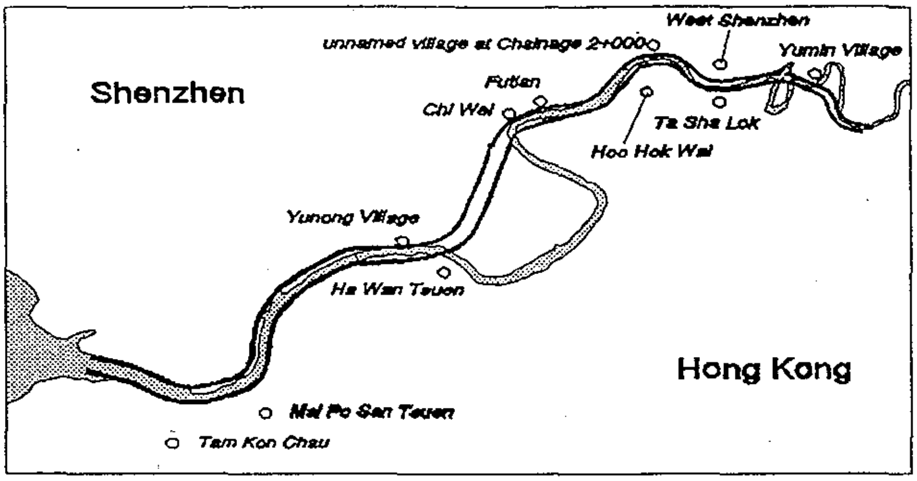


Figure 6.5 Locations of NSRs for Stage 2 Works

Table 6.9 Noise sensitive receivers for Stage 2 and maintenance dredging (PRC and Hong Kong)

Receiver Area	Distance to Construction Site Boundary[1]	
PRC Side		
West Shenzhen	50 m	
unnamed village at Chainage 2+000	75 m	
Chi Wei village at Chainage 5+500	10 m	
Futian	125 m	
Yunong village	20 m	
Hong Kong Side		
	To Advance Works Site Boundary[2]	To River Bank
Tam Kon Chau	110 m	280 m
Mai Po San Tsuen	275 m	500 m
Ha Wan Tsuen	5 m	225 m
Hoo Hok Wai	200 m	225 m
Ta Sha Lok	80 m	100 m

1 PRC distances provided for information only; PRC construction noise criteria is based on noise level at the construction site boundary
2 based on Drawings CE 352A and CE353A

6.6.4 Potential Impacts: Stage 2 and Maintenance Dredging

Tables 6.10 and 6.11 show the maximum total SWL of combined construction equipment (exclusive of haul road traffic) that still allows PRC and Hong Kong noise standards to be met. The methodology is consistent with that used for Stage 1 assessment.

Table 6.10 Daytime and evening construction noise outside Deep Bay during stage 2

Source -Receiver Distance (m) and Relevant Hong Kong NSR[1]		Allowable source sound power level (dB(A)) under:				
		PRC Standards		Hong Kong Standards		
				Evening		Day time
		Site Preparation	Structural	ASR A	ASR B	75 dB(A)
5	Ha Wa Tsuen[2]	97	92	79	84	94
10		103	98	85	90	100
20		109	104	91	96	106
50		117	112	99	104	114
80	Ta Sha Lok[2]	121	116	103	108	118
100	Ta Sha Lok[3]	123	118	105	110	120
110		124	119	106	111	121
125		125	120	107	112	122
150		127	122	109	114	124
200	Hoo Hok Wai[2]	129	124	111	116	126
225	Ha Wa Tsuen/ Hoo Hok Wai[3]	130	125	112	117	127
275	Mai Po Sun Tsuen[2], Tam Kon Chau[3]	132	127	114	119	129
300		133	128	115	120	130
500	Mai Po Sun Tsuen[3]	137	132	119	124	134
700		140	135	122	127	137

1 PRC receivers are not shown, since PRC standards apply to the construction site boundary rather than to sensitive receivers.
2 Distance of NSR to advance works site boundary (relevant to advanced works activities).
3 Distance of NSR to river bank (relevant to main works activities).

Table 6.11 Daytime and evening construction noise in Deep Bay during Stage 2 and maintenace dredging

Source-Receiver Distance (m)	and Deep Bay NSRs	Allowable source sound power level (dB(A)) under standards for: Deep Bay[1] Weekday Daytime	Deep Bay[1] Weekday Evening and Holidays	Inner Deep Bay SMZ[2] Daytime and Evening
5		94	79	--
10		100	85	--
20		106	91	--
50		114	99	--
80		118	103	--
100		120	105	108
110	Tam Kon Chau[3]	121	106	--
150		124	109	--
200		126	111	--
275	Tam Kon Chau[4] Mai Po San Tsuen[3]	129	114	--
300		130	115	--
500	Mai Po San Tsuen[4]	134	119	--
700		137	122	--

1 based on facade noise level
2 based on freefield noise level
3 Distance of NSR to advance works site boundary (relevant to advance works activities)
4 Distance of NSR to river bank (relevant to main works activities).

Advance Works in Hong Kong

Equipment and activities associated with the Advance Works (construction of the haul road and embankments along the southern bank) are generally closer to NSR's than for the Main Works and therefore greater controls may be needed.

Daytime Construction: Limits on daytime construction noise levels are expected to be achievable at most main village areas (outside the Deep Bay Area) with the following equipment combinations:

(i) *construction of haul road:* 1 bulldozer, 2 dumptrucks, and 1 road roller would generate a total SWL of about 117 dB(A), which would not to exceed a facade noise level of 75 dB(A) at NSRs in Ta Sha Lok village;

(ii) *construction of embankments:* 1 each of bulldozers, excavators/loaders, dumptrucks and vibratory rollers would generate a total SWL of about 118 dB(A), which would not to exceed a facade noise level of 75 dB(A) at NSRs in Ta Sha Lok village.

In the Inner Deep Bay SMZ, noise reduction measures will be required to keep construction noise below 60 dB(A) at a distance of 100 m from the site boundary. Concurrent use of the equipment shown in Table 6.8 for a single activity (which is not an exhaustive inventory of equipment needed for each activity) would not be possible. The use of temporary noise barriers or quieter working methods may have to be considered.

The small village of Ha Wan Tsuen is situated adjacent to the works site of Advance works. It may not be feasible to meet daytime and evening noise criteria by restricting the numbers and/or SWL of construction equipment when operating near Ha Wan Tsuen. Additional measures, such as temporary noise barriers or sensitive equipment/task programming, may be required due to the potentially short source-receiver distances.

Evening Construction: Limits on evening construction noise levels may be difficult to achieve if full-scale construction activities continue into the evening hours. Reasonable equipment combinations for the required Advance Works generate noise levels that are expected to result in NCO exceedances if activity is conducted close to the site boundaries.

In the Inner Deep Bay SMZ, the evening and daytime construction noise criteria are identical; thus, the additional noise reduction measures discussed above with reference to daytime construction noise levels will still be required to keep construction noise below criteria levels.

Main Works in Hong Kong

Equipment and activities associated with the Main Works (river channel excavation and slope protection works) are located further from NSR areas than those associated with the Advance Works. Thus, receivers will benefit more from distance attenuation.

Daytime Construction: Limits on daytime construction noise levels are expected to be achievable at most main village areas (outside the Deep Bay Area) with the following equipment combinations:

(i) *river channel excavation:* 1 suction dredger, 3 excavators, 3 water pumps will generate a total SWL of about 118 dB(A), which would not exceed a facade noise level of 75 dB(A) at NSRs in Ta Sha Lok village;

(ii) *slope protection works:* 1 barge-mounted crane, and 2 each of dumptrucks, road rollers, vibratory compactors, and lorry-mounted cranes will generate a total SWL of about 121 dB(A), which would only marginally exceed a facade noise level of 75 dB(A) at NSRs in Ta Sha Lok village.

In the Inner Deep Bay SMZ, noise reduction measures will be required to keep construction noise below 60 dB(A) at a distance of 100 m from the site boundary. If unmitigated, concurrent use of the equipment shown in Table 6.8 for a single activity (which is not an exhaustive inventory of equipment needed for each activity) would not be possible. However, the river embankments formed during the Advance Works may provide adequate shielding to reduce noise to acceptable levels, depending on their height. If they are not sufficiently high for this purpose, their effectiveness as noise barriers may be enhanced by placing temporary barriers atop them during the Main Works.

Evening Construction: Without the barrier effect of the embankments, limits on evening construction noise levels may be difficult to achieve if full-scale construction activities, using reasonable equipment combinations, continue into the evening hours. Concurrent use of the equipment shown in Table 6.8 for a single activity (which is not an exhaustive inventory of equipment needed for each activity) would not be possible. Depending on their height, the embankments formed during the Advance Works may provide adequate shielding to reduce otherwise unacceptable noise to acceptable levels. In order to be effective, the embankments must be of adequate height; if the embankments are not sufficiently high, they may be enhanced by placing temporary purpose-built barriers atop them during the Main Works.

In the Inner Deep Bay Works Exclusion Zone, the evening and daytime construction noise criteria are identical; thus, the additional noise reduction measures discussed above with reference to daytime construction noise levels will still be required to keep construction noise below criteria levels.

Construction Noise in Shenzhen

The PRC daytime noise restrictions are based on noise at the construction site boundary. This criterion places significant restrictions on activity near the site boundaries. For example, concurrent use of a suction dredger, excavator and water pump for river excavation would be expected to exceed the PRC Site Preparation noise standard at any site boundary closer than about 35 m to the equipment (neglecting the effects of any natural or man-made barriers). Similarly, the concurrent use of a barge-mounted crane, dumptruck, road roller, vibratory compactor, and lorry-mounted crane for slope protection works would be expected to exceed the PRC Structural noise standard at any site boundary closer than 100 m to the equipment.

Haul Road Noise

Given the assumed haul road traffic indicated above in Section 6.5.2, the following noise levels are predicted at various distances from the source line:

Table 6.12 Haul road noise during Stage 2

Distance (m) from source line to receiver	Predicted Haul Road Noise Level (dB(A))	
	Facade	Free-field
5	65.7	62.7
10	62.7	59.7
20	59.7	56.7
30	58.0	55.0
40	56.7	53.7
50	55.7	52.7
75	54.0	51.0
100	52.7	49.7
150	51.0	48.0
200	49.7	46.7
250	48.8	45.8
300	48.0	45.0

The noise from haul road use is expected to remain within acceptable limits, unless the alignment passes within about 20 m of sensitive facades on the Hong Kong side. The detailed design of haul road for Stage 2 Works should take this into consideration.

Maintenance dredging

With similar equipment combination as those for Stage 2 excavation, the shielding of the embankment on both sides of the river, and the mitigation measures described in Section 6.7, noise limits on daytime and evening for both sides of Hong Kong and Shenzhen are achievable.

6.7 MITIGATION MEASURES

The preceding discussion has shown that some degree of control is required in order to bring construction noise to acceptable levels. Noise control may take two forms: construction programming or the use of quietened equipment.

Construction Programming

When programming the construction, it is desirable to avoid concentrating large numbers of PME at one location. A less intensive construction programme may enable the number of operating items of PME to be reduced. Adequate planning may enable PME to be more evenly distributed around the site, rather than concentrated in a single location where the equipment may disturb nearby sensitive areas. Parallel operation of several sets of equipment should be avoided close to a sensitive area or the construction site boundary.

In addition, programming may permit a certain amount of self-mitigation to be achieved. This river training project is particularly amenable to self-mitigation, since it involves the formation of embankments during Stage 1 and the Stage 2 Advance Works that may act as noise barriers. The programming of the river dredging and embankment construction may take advantage of the natural noise barrier that the embankment will form. The embankment can protect receiver areas outside the river channel from the noise of works proceeding inside the channel. Thus, if the embankment can be formed prior to the start of river dredging, as appears to be planned, it can serve an early function as a noise barrier.

The *Deep Bay Guidelines* specify that, within the Inner Deep Bay SMZ, works should be programmed so as not to occur during the migratory bird over-wintering period (November to March). In addition, works should not take place outside the hours of 0800 to 1700.

Quietened Equipment

A second effective way of mitigating construction noise is to control it at its source, either through the selection of silenced equipment or through the use of mufflers, silencers or acoustic barriers.

The following measures will be useful in reducing the overall construction noise level:

(1) Stationary and earth-moving plant such as excavators, bulldozers and dumptrucks are amenable to noise reduction through exhaust silencers and isolation of vibrating engine components. Noise-generating components may be partially or fully enclosed, and

vibrating panels dampened.

(2) PME and activities should be sited as far from sensitive areas as is possible. Practical requirements limit the application of this measure at many locations.

(3) Idle equipment should be turned off or throttled down when it is not in use.

(4) All PME should be adequately maintained. Poorly maintained equipment can generate high noise levels from vibration of loose components or deterioration of noise-reducing features such as mufflers.

(5) Temporary noise barriers may be constructed. The barriers may be positioned at the construction site boundary, atop existing embankments, or may be located closer to the noise-generating PME if it is reasonably stationary. The barrier material should have a mass per unit of surface area of at least 7 kg/m^2. Noise reflections may be reduced if the barrier is provided with an acoustic lining. Sandbags are an alternative to a purpose-built barrier.

Whether noise control is pursued through the use of quietened equipment or through programming, control measures should be incorporated into the contract documents.

Though not effective in reducing noise levels, the establishment of good community relations can be of great assistance to both the contractors and NSRs. Residents exposed to the noise from the river training works, and Mai Po/Inner Deep Bay Ramsar site and Futian National Nature Reserve administrators, should be notified in advance of planned operations and informed of progress. If necessary, a liaison body can be established to bring together representatives of the affected communities, the governments, and the contractors. In addition, residents may be provided with a complaint hotline number, where they may lodge complaints concerning excessive noise. If justified, the Resident Engineer may authorise noisy operations to cease or to be conducted at more restricted hours.

This noise impact assessment has been based on typical PME requirements, but not on any preliminary construction programme or equipment lists. It is recommended that a detailed construction noise impact assessment be performed when more comprehensive information is available concerning the construction programme, construction methodology, and equipment requirements. An accurate prediction of construction noise is particularly important given the conservation significance of the Deep Bay area, within which part of the river training works are expected to occur.

It is recommended that evening and night time construction activities are prohibited unless it can be demonstrated in a detailed noise impact assessment that mitigation measures proposed by the Contractor can achieve compliance with applicable standard and guideline limits of the PRC and Hong Kong. Further, for evening and night time works on the Hong Kong side, Construction Noise Permits (CNP) are required and that noise assessment criteria cited in the relevant TM shall be followed and conditions specified in the CNPs must be strictly adhered to.

It is recommended that construction works within the Inner Deep Bay SMZ (applicable to the Hong Kong side only) follow the recommendations of the Deep Bay Guideline, i.e., works to be minimised and subject to specific control and approval from November to March during the year and limited to 0800 hr to 1700 hr.

6.8 CONCLUSION

The noise from construction activity has been assessed with reference to both the Hong Kong and PRC construction noise standards. In Hong Kong, the Deep Bay Guidelines, incorporating more stringent restrictions on construction noise, apply to activity at the western end of the works. The calculation procedure used in the assessment has closely followed that outlined in Hong Kong's *Technical Memorandum on Noise from Construction Work other than Percussive Piling*, with some modifications to account for the current lack of detail concerning construction practices.

The construction site is closely bordered on the north by villages and agricultural areas, with some industrial sites. On the south, the site is bordered by wetlands and fishponds, beyond which lie small villages. At the mouth of the Shenzhen River, construction works lie within Deep Bay and the Inner Deep Bay SMZ.

The assessment has indicated that daytime Hong Kong construction noise standards should not be difficult to meet outside the Deep Bay Area. In the Inner Deep Bay SMZ, noise reduction measures will be required to keep construction noise below 60 dB(A) at a distance of 100 m from the construction site boundary. PRC daytime standards will also be more difficult to meet, since they stipulate noise at the construction site boundary. The use of items of PME near the construction site boundaries will thus be restricted. In addition, evening noise criteria are more stringent, and necessitate the implementation of restrictions on the use of PME if construction activity continues past daytime hours.

Haul roads for Stage 2 Works should be aligned at least 20 m from sensitive facades.

Noise reductions can be achieved through construction programming. The Advance Works involve the construction of earth embankments, which, if they are built early enough, may act as noise barriers for subsequent activity within the river channel. In addition, planning of works will allow concentrations of PME at a single location to be avoided. These concentrations result in high noise levels at locations close by. Planning to distribute equipment more evenly over the site is preferred.

In addition to construction programming, the use of quietened PME and barriers (particularly in the Inner Deep Bay SMZ) is proposed. Establishing communication lines with the affected communities and with administrators of the Mai Po bird sanctuary is also proposed.

7 HYDRODYNAMIC, SEDIMENT TRANSPORT AND WATER QUALITY MODELLING

7.1 Overview

7.2 Hydrodynamic Models

7.3 Sediment Transport Models

7.4 Water Quality Models

7.5 Model Predictions

7 HYDRODYNAMIC SEDIMENT TRANSPORT AND WATER QUALITY MODELLING

7.1 OVERVIEW

This section describes the models which have been developed and applied as part of the EIA to assess the effects of the proposed works on the water quality and sediment transport in the Shenzhen River and Deep Bay.

7.1.1 Objective

The prime objective of these models is to provide a quantitative assessment of the impact of the Project works on the water quality and sediment transport processes in the key sensitive areas of Futian Mai Po and the inter-tidal mud flats at the mouth of Shenzhen River and more generally in the Shenzhen River and Deep Bay.

The models have been used to consider the impacts of the Project both during construction activities and after the works are completed. Long term impacts short term impacts and the cumulative impacts of undertaking Stage 1 and Stage 2 Works simultaneously have all been considered.

In order to meet these objectives it is necessary for the models to be able to simulate the following:

1) Hydrodynamic processes in the river and in Inner Deep Bay including the flood alleviation characteristics of the proposed works;
2) Sediment transport erosion and deposition; and
3) Water quality for a wide range of conservative and non-conservative pollutants.

Satisfying the study objectives requires the use of several models with varying degrees of inter-dependency. The principles of the models are described below.

7.1.2 Limitations of Models

All models are of necessity a simplification of the natural processes which occur in the environment. The critical requirement is to determine those key processes which dominate the observed behaviour and to ensure that these are properly represented within the models used. Similarly the ability to be able to express in numerical terms the processes is clearly fundamental. Finally the quality and quantity of available information directly influences the confidence with which it is possible to establish and apply a model.

These concerns are especially valid then attempting to model a physical system where the key events or processes are related to episodic events such as major storms. When the model is being established attempting to determine the significance of extreme events by quantifying their effects compared with other less episodic events is particularly difficult. Especially as observations during extreme events are typically extremely scarce or non-existent.

For the current study two particular problems exist; firstly it is widely recognised that the modelling of sediment transport is one of the most complex environmental modelling tasks and secondly the highly episodic nature of the flows in the river has a very substantial impact on the sediment load derived from erosion in the catchment.

For these reasons it is considered essential to recognise that the models are only tools to assist in the professional assessment of potential impacts. They cannot substitute for professional judgement and considerable care must be taken in interpreting their results.

7.1.3 Overview of the Models

Following a review of the basic geometry of Deep Bay and the Shenzhen River it was agreed that the dominant processes in the river were longitudinal whilst both longitudinal and lateral transport was important in the Bay.

For the river the key features were the longitudinal transport due to the river flow and the tidal oscillation rather than the lateral or vertical transport within the river channel. Therefore the river can be adequately represented by a one dimensional (1D) model in which the lateral and vertical gradients are zero.

For the bay the much greater width of the channel and the relatively shallow depth mean that circulation patterns are no longer simply linear along the axis of the main channel. Lateral transport and concentration gradients become important particularly for sediment transport. However the relatively shallow depth means that mixing in the vertical will be good with frequent or stable periods of stratification being unlikely so that vertical concentration gradients and transport will be less significant than longitudinal or lateral processes. Therefore the bay can be adequately represented by a two dimensional (2D) depth averaged model in which the vertical gradients are zero.

7.2 HYDRODYNAMIC MODELS

Underlying both the sediment transport and water quality models it is necessary to reproduce the hydrodynamic water transport under a range of conditions: spring or neap tides wet or dry season and a range of storm events. Therefore a 1D model of the river and a 2D model of the bay were setup and validated. In order to ensure continuity these two models have been numerically coupled at a boundary in the lower Shenzhen River and are able to be run as a single model. Both elements of the model (river and bay) make use of internationally respected systems of equations to describe the physical processes and employ standard computational systems.

7.2.1 The River

The hydrodynamic flow model for the river utilizes a standard approach based on a multi-segment computation using the De Saint Vernant equations with a Preissman scheme adopted for numerical computation. A detailed specification of the mathematical formulae underlying the model is given in Appendix 7.1.

The principle of the model is as follows. The river from the upper Sancha River to the estuary mouth is divided into segments. This representation includes the tributaries of the Buji River and the Sheung Shui River as direct inputs and incorporates representation of Shenzhen Reservoir to enable its effect to be determined during storm flows.

Each segment of the model is defined in terms of the characteristic cross-section the length and resistance to flow (friction coefficient) together with details of discharges to the river within each segment. At each time step the model computes the water depth in each segment together with the discharge from one segment to the next.

The model does not directly consider over bank flows. This means that although the model predicts that the water level in a certain segment will exceed the known bank height the model considers the banks to be vertical at the cross-section limits so no loss of water volume will occur and the flow will continue to the next segment. This has the advantage that the anticipated water levels along the full length of the river is predicted allowing the effect of upstream flood alleviation schemes on downstream levels to be anticipated.

The model has been implemented using topographic data on longitudinal slope and cross-sections obtained from both Shenzhen and Hong Kong sides for the existing situation and for the project.

The information on discharge characteristics of the river and its tributaries is from EPD and has been used for assessment of the Project under a broad range of design conditions. The data made available for the preparation of this model is considered adequate for the purpose of the study.

In 1-D model the time steps are taken as 60 seconds for flood and 600 seconds (or 900 seconds) for tide flow. Cross sections along the river are derived from the topographic map of the channel measured in 1985. Within the study reach from Sancha River section to the Shenzhen River estuary 168 cross sections are divided for the existing channel and 148 ones for the channel after realignment. The roughness along the river are from the designed values suggested by Guangdong Institute of Hydraulic and Electric Survey and Design as shown in Table 7.1.

Table 7.1 Roughness of Shenzhen River

Area	Estuary-Yunong village	Yunong village-Lo Wu	Lo Wu-Sancha River
Main flume	0.020	0.025	0.0275
Floodplain	0.0267	0.0333	0.0367

The preliminary model runs have assumed the design parameters included in the Outline Design. This reflects the early stage of modelling work and is appropriate as any changes of the channel design will have greatest influence on Stage 2 Works.

The verification of the flood level in the main channel is based on the record of the flood trace at five locations along the river provided by the joint survey of Shenzhen Sanfang Office and Guangdong Institute for Hydraulic and Electric Survey and Design (May 1989). The recorded actual tide type at Tsim Bei Tsui(as the boundary condition of the lower end) on the same day is used to match the flood equivalent to that with the return period of 1 in 5 years. Maximum errors for water level were 0.33m as shown in Table 7.2. The data obtained at Yumin Village and Wenjindu in 1983 (typical tide from April to May and November covering either neap or spring tide) are used for the verification of the tide level. Maximum errors for elevation were 0.2m and for phasing of HW or LW were 40 mins.

Table 7.2 Calibration of the model

Location	Distance(m)	Elevation(m)	Calculated(m)
Huanggang vill.	3050	2.56	2.58
Shaosuo	3650	2.82	2.90
6 zhongdui	5700	3.43	3.58
Yumin village	11068	4.00	4.08
Qiaoshe	12437	4.32	4.65

The model is therefore considered to be validated for the purposes of this study.

7.2.2 Interface Between River and Bay

Since the flux between the bay and the river is anticipated to be critical to the processes directly affecting the key sensitive areas it was decided to dynamically couple the hydrodynamic models for the bay and the river. Thus the river model is configured as a subroutine within the bay model.

During the decreasing tide period the discharge at the interface may be considered as the upper inflow condition of the two dimensional model. The water level at the same location is considered as the boundary condition at the lower end of the one-dimensional model. On the other hand during the increasing tide period the discharge at the interface is considered as the boundary condition at the lower end of the one-dimensional model and the water level here is taken as the boundary condition of the upper end of the two-dimensional model.

7.2.3 Deep Bay

It is recognized that the outer part of Deep Bay is subject to stratification during the wet season as a result of the complex mixing occurring in the area of the Kongsu Bank described in previous studies (Binnie and Partners 1983). In summary the large wet season freshwater discharge from the Pearl River can periodically be observed overlaying the denser waters moving north through the Urmston Road resulting in stratification at the mouth of Deep Bay extending into the Bay under certain conditions.

However this is an extremely complex process and its influence on sediment transport into Inner Deep Bay cannot be determined on the basis of available data. Since the majority of Deep Bay is extremely shallow with good mixing characteristics and as indicated stratification is considered unlikely to occur in the areas at the head of the bay which are of specific concern in this study it is considered that the use of a 2D depth averaged model is adequate for the purposes of this study and additional sensitivity testing has been undertaken to assess the significance of this assumption.

The hydrodynamic model of Deep Bay utilizes a standard approach based on the horizontal two-dimensional shallow flow equations expressed using a finite difference scheme on the regular 100m square grid. The flow equations are solved using the alternating-direction-implicit (ADI) procedure. A detailed specification of the mathematical formulae underlying the model are given in Appendix 7.1.

The principle of the model is as follows. Deep Bay is divided into a grid of cells each of which is regarded as vertically homogenous. The model extends from an open boundary at the western end of the bay between Black Point and Chiwan to the interface with the river at Shenzhen Estuary. It includes the key sensitive areas of Mai Po Futian and the inter-tidal mud flats.

Each cell is described in the model in terms of its average depth and its roughness coefficient as shown in Figure 7.1. The boundary cells. are driven by and input file defining the elevation at each time step. At each time step the model computes the new water depth in the cell and the flux between the cell and its neighbors.

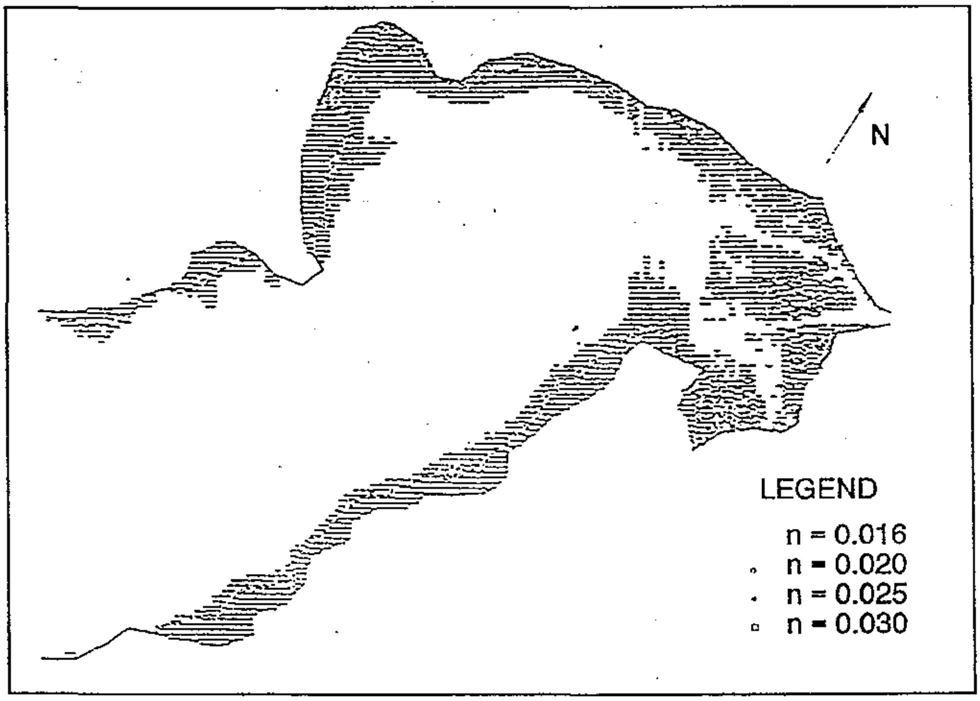


Figure 7.1 Roughness distribution in Deep Bay

One of the most important features of the model for the current study is the handling of intertidal areas i.e. those areas which are under water for part of the tide and exposed at other times. It is important for the model to be able to accurately calculate the changing boundary and to cope with the flows into or from flooding especially as this will have a significant impact on the predicted sediment deposition or erosion.

The changing boundary of the intertidal areas is handled with the so called Fluctuating Boundary method by introducing an osmotic coefficient. The osmotic coefficient takes values of 0.05 to 0.1 for the exposed areas and 1 for the normal conditions. The roughness interior the mudflat media is considered "large" e.g. n=1.0. Thus the water level in the whole bay including that in the mudflat media may be obtained and the fluctuating variation of the intertidal areas may be modeled.

Detail of the bathymetry of the bay has been obtained from a number of sources including

Admiralty Charts data supplied by Hong Kong Civil Engineering Department and other sources. Additional information on the topography of the inter-tidal areas at the mouth of the river has been derived from the analysis of satellite images. The improved bathymetric map of the bay is shown in Figure 7.2.

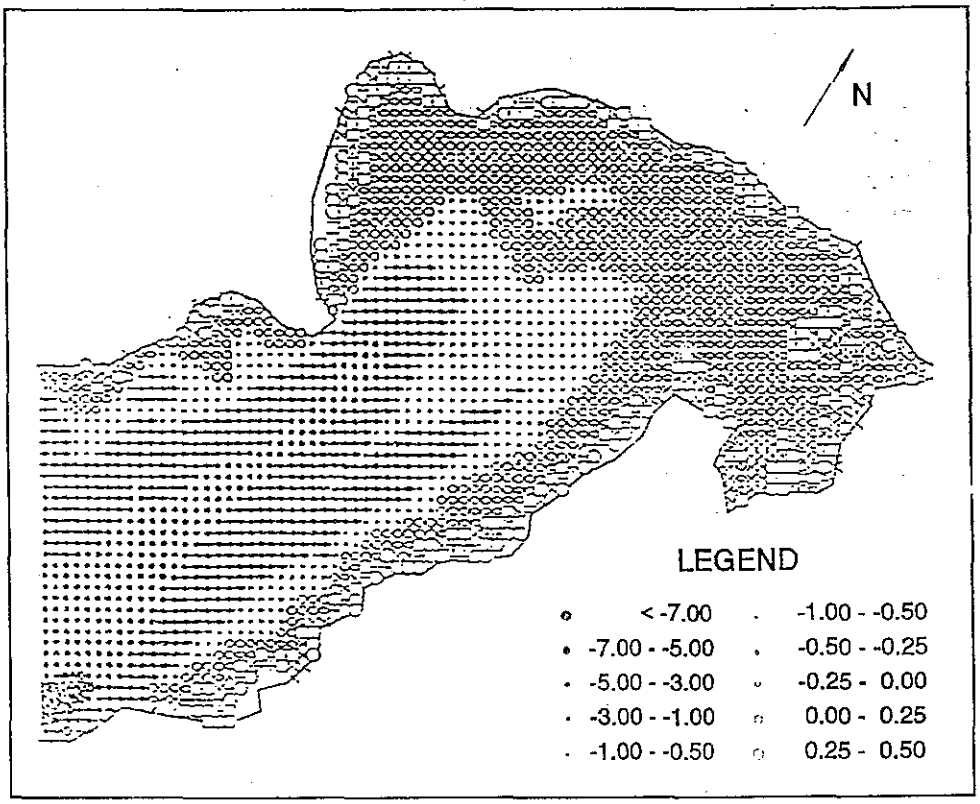


Figure 7.2 Bathymetric map of the Deep Bay

Water level data for the open western boundary has come from the field work undertak en for this study plus long term tide gauge records for Chiwan Station and two 50 hr s hort term records for Black Point.

The available data for this model is considered generally poor in particular the paucity of detailed bathymetric for the inner bay and topographic information in the inter-tidal areas. In addition the lack of coherent data for both ends of the open boundary together with the problems of transferred level datums compromises the model boundary information.

The Bay model was verified based on the modelling monitoring data obtained in Mar.1-4 1994. 4 flow velocity monitoring locations were set up in Deep Bay (Figure 4.4). The test results of tide flow velocity show the good coexistence between the numerical and the measured results at S7 S8 and S9 in the Bay as shown in Figure 4.4 with the maximum error of 20%. However a larger error(about 40%) is found at S10 owing to the complex bathymetry there.

Despite the identified inadequacy of the available bathymetric and topographic data the model is considered to be validated in terms of the overall circulation patterns within the bay and the exchange volumes between outer Deep Bay and the waters of the Pearl

Estuary. However it is recognised that on a local scale particularly in areas where the bathymetry is complex or with significant local gradients depths may have been estimated incorrectly introducing errors into the forecast of current velocities.

On balance it is considered that the models are adequate for the purpose of this study subject to professional judgement in the interpretation of local phenomena.

7.3 SEDIMENT TRANSPORT MODELS

One of the key aspects in determining the potential impact of the Project is to quantify its effect on deposition and erosion rates relative to the existing conditions. This requires that the relative contributions of any sediment deposited on the mudflats from the river and from outer Deep Bay have to be assessed.

The models used to predict sediment transport erosion and deposition are uncoupled from the hydrodynamic model. The output files from the hydrodynamic model are used as input files together with information on sediment sources (boundary concentrations and direct inputs). This uncoupled structure is more efficient allowing the sediment transport model to be run relatively quickly and avoiding duplicate calculations.

The river model was developed and applied independently for the assessment of the Stage 1 Works. This model was then configured as a subroutine within the larger model for the whole bay and the estuary. Effectively at each time step the boundary conditions between the models at the mouth of the Shenzhen river are determined by the output from the appropriate model according to whether the flow is into or out of the river estuary.

The models used in this study incorporate the results from an extensive body of research carried out within the PRC on sediment transport in alluvial channels. The work is essentially and empirical approach developed using data sets from a range of alluvial river channels including the Pearl River which are considered to have sediment transport characteristics which are directly comparable to those of the Shenzhen River.

The research considers the non-equilibrium transport of suspended sediment. For each channel the relationship between channel stability channel shape(slope and cross-section) flow and suspended solids concentration is assessed. For a stable channel the sediment carrying capacity(expressed as a function of the speed at which the water is moving the depth of the water and the settling velocity of the sediment) and the flow are matched on an annualized basis resulting in no net erosion or deposition.

The sediment model equations are essentially the same in both the river model and the bay model merely being expressed differently to cope with the 1D or 2D systems employed respectively. In each case at each model time step the model calculates the sediment carrying capacity for the cell or segment and compares this with the current suspended sediment concentration. If the actual suspended sediment concentration exceeds the sediment carrying capacity deposition will occur and the bed level will increase. If the actual suspended sediment concentration is less than the sediment carrying capacity erosion will occur and the bed level will decrease. A detailed description of the mathematics of the sediment transport model is presented in Appendix 7.2.

The empirical nature of the approach adopted avoids the necessity to explicitly consider such factors as bed load transport cohesive and non-cohesive sediments and sediment consolidation since these characteristics are all incorporated into the net behaviour described by the equations used and governed by the calibration coefficients.

The model equations involve a number of coefficients relating to the capacity the potential rate of erosion and the particle settling velocity which would ideally be derived for the study river. However since this requires an extensive data set collected over many years it is not possible to derive these coefficients for Shenzhen River explicitly. Thus figures previously employed for studies in the Pearl River as well as Chiantang River which are based on actual observations and a well calibrated model have been employed. Given the similarities in the sediment transport environments it is considered that this approach is sufficient for the purposes of the current study.

The impact of wave action on the inter-tidal areas is extremely complex and assessing it would necessitate detailed observations under a range of conditions. However given the relatively sheltered location of the mud flats it is not anticipated that this will be one of the dominant factors controlling their maintenance and it has therefore not been considered further in this study.

A significant problem in attempting to model sediment transport is the difficulty in establishing the sediment fluxes across the model boundaries. For the current study this includes both direct inputs from tributaries and other discharges and the inputs across the open water boundary of material from the Pearl Estuary.

7.3.1 River Model

The desired data for the river catchment sources is a detailed sediment hydrography based on extensive observations and providing the relationship between river flow and sediment load. This would indicate both the total sediment input to the river and the proportion of that load associated with storm events. Unfortunately collecting such data requires detailed observations under a full range of flow conditions and would take several years to collect. It has therefore been necessary to utilise the limited available information together with previously derived empirical relationships to produce an estimate of the sediment load derived from the river catchment.

The only existing estimate of the sediment load arising from erosion in the study area is the estimate used in the Basin Management Plan studies undertaken for Hong Kong Government Drainage Services Department as part of the Territorial Flood Control & Strategy Studies (Binnie Maunsell Consultants 1993). The study looked at three sub-catchments i.e. San Tin(Basin No.10) Indus(Basin No.11) Ganges(Basin No.12) and produced estimates of the absolute sediment yield due to erosion and the proportion of that sediment yield entering the river as shown in Table 7.3. From the catchment areas of each of the three basins the sediment yield per unit area is calculated to be $149.64 m^3/km^2.yr$ of which an average of 44.9% actually enters the river.

The catchments considered in the BMP study are rural and are considered representative of the entire catchment of the Shenzhen river prior to 1986. However the rapid development of the Shenzhen Special Economic Zone since 1986 has led to a significant increase in the average suspended sediment concentrations in the river as can be seen by the results from the long term monitoring undertaken at a number of monitoring points in the river and its tributaries (see Table 7.4). This indicates a substantial increase in the sediment load to the river due to the changed landuse.

Table 7.3 Sediment yield in basins of Shenzhen River (HK side)

Basin	Basin10	Basin11	Basin12	Total
A(m^3/yr.)	4000	11300	3300	18600
B(m^3/yr.)	400	5650	2310	8360
B/A	10%	50%	70%	44.9%

Note: A sediment yield in the basin; B sediment volume entering the river.

Table 7.4 Measured results of suspended solids along the river(mg/l)

Station	Jingdu	Buji estuary	Zhuanmatou	Estuary	Yumin Village
85-86 average	9.9	26.8	87.9	95.9	
87-92 average	4.6	106.1	215.3	269.3	133.6
85-92 average	5.9	78.6	183.9	225.9	

An estimate of the increased sediment yield has been derived from a simple scaling in proportion to the observed increase in suspended sediment concentrations weighted according to the relative flows from the tributaries. This gives a revised estimate of the sediment yield from the catchment on the Shenzhen side of 547.8m^3/km^2.yr for the period since 1986.

By contrast with the Shenzhen SEZ the Hong Kong administered area of the catchment has remained largely rural and the estimated sediment yield is assumed to have remained the same.

Given the 60:40 split on the catchment between the Shenzhen and Hong Kong sides post-1986 the overall average sediment yield is estimated to be 389.06m^3/km^2.yr.

The BMP study provides an estimate of the proportion of the sediment yield which enters the river. However since the method for estimating the increase in yield has been based on the change in average suspended sediment concentrations in the river any substantial changes in the proportion of the sediment yield entering the river compared with the BMP study will have been compensated for. The BMP study gave a range from 10% to 70% with a weighted average of 44.9% see Table 7.3. For the purposes of this study the assumed proportion has been taken as 50%.

The input loads to the Shenzhen River have been calculated using the estimated average yield and the assumed proportion released to the river and have been distributed across the main tributaries for which hydrographs were available. The resulting loads are shown in Table 7.5. The table includes figures for pre-1986 post-1986 and a post-1986+50% figure which is used in sensitivity testing.

Having determined the total load it is necessary to estimate the sediment hydrography and apportion the total load to different flow conditions. The relationship between flow and sediment load is empirically modelled as an exponential relationship $S=kQ^a$ where S is sediment concentration in kg/m^3 Q is river flow in m^3/s and k and a are coefficients. A typical value for a is 2.5. This gives an extremely narrow sediment hydrography with the vast majority of sediment load being associated with high flows. For the purposes of the study it has been assumed that all of the sediment flux occurs during a single 1 in 1 year storm ($P_{100\%}$).

Table 7.5 Sediment distribution along Shenzhen River(m^3/yr)

	Sancha River	Sheung Shui River	Buji River	Total
before 1986	10403	5777	7149	23329
after 1986	29881	5777	24997	60655
after 1986 +50%Q_s	44820	8666	37496	90982

The hydrographs of the standard 1 in 1 year storm for the various major tributaries are specified in the design characteristics for the Project and have been used accordingly. The sediment hydrography was constructed from this flow hydrography using the standard empirical relationship described above with the standard exponential coefficient of 2.5 and the coefficient k was scaled to give the correct total sediment load during the duration of the storm. Figure 7.3 shows the combined sediment hydrography. Note that the sediment transport model deals with the accumulative effects in comparison with the equilibrium state rather than the extreme cases during a short time as the hydrodynamic model does 1 in 1 year storm is the reasonable choice for the present study. However the works will reduce the sediment amounts entering into the bay for the storms with any frequencies.

7.3.2 Deep Bay Model

The model configuration used for Deep Bay is identical to that employed in a previous study for the Qian Tang River estuary and the Pearl River estuary. None of the key calibration coefficients were changed from those previously employed. This approach was adopted because of the directly similar sediment transport environments of the two areas being relatively shallow with a complex tidal environment and the sediment is similar with a high percentage of very fine material. It is therefore considered an appropriate approach for the current study.

Information on the sediment flux at the mouth of Deep Bay is extremely limited. Suspended sediment monitoring data does exist but this is not associated with simultaneous current measurements and rarely includes sufficient vertical distribution information to enable the sediment flux to be accurately determined.

Furthermore it is recognized that the mouth of Deep Bay is subject to periodic stratification during the wet season which will coincide with the maximum sediment loads from the Pearl River. Since these occurrences are naturally episodic their impact on longer term net sediment flux is extremely difficult to quantify.

Due to the problems in defining appropriate boundary conditions suitable levels were proposed in the agreed Working Paper of the Modelling and have been used subject to a satisfactory validation of the model.

The model results provide forecast deposition rates over a three day period using the last two days of each simulation to allow the model to stabilise. In order to facilitate consideration of the results the inner bay has been considered as divided into a number of areas reflecting the major variations in depositional environment (see Figures 7.4 and 7.6).

7.3.3 Model validation

Lack of data makes the preferred procedure of calibration and verification impossible either for the river model alone or for the integrated bay and river model.

Two data sets have been used in determining the acceptability of the models: 1) multiple channel cross-section information for the river collected during 1981 and repeated during 1985; and 2) a limited set of five sediment cores from the area of specific concern for this study which have been analysed for ^{210}Pb deficiency to determine the rate of deposition. The river model has been validated using the first of these data sets the integrated model of the river and the bay has been validated using both data sets.

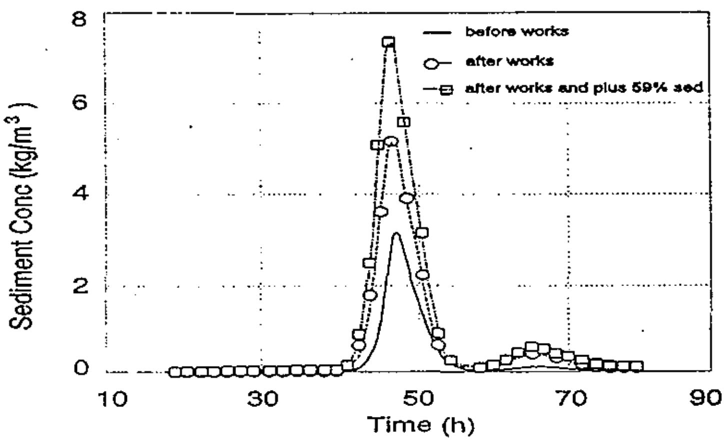


Figure 7.3 Typical sediment hydrography at Shenzhen estuary during the flood with P=100%

River Model

Extensive processing of numerous cross-sections of the river channel made during 1981 and repeated during 1985 has been used to determine the net annual erosion within the river channel during that period. This has given an estimated annual rate of erosion during this period of 19 500m^3.

During the assessment of the Stage 1 Works the river model was validated in stand alone configuration. The river hydrodynamic model has an open boundary located at Tsim Bei Tsui and the tidal record from there was used to model the hydrodynamics in the river for the whole of 1984. The sediment transport model was run using this hydrodynamic data. The model was run with no flow or sediment input from the river except during a single two day 1 in 1 year ($P_{100\%}$) storm when the input appropriate to the pre-1986 condition was released according to the calculated sediment hydrography. The suspended sediment concentration at the open water boundary was set at 0.1 kg/m^3 based on the long term monitoring data at that site.

Table 7.6 shows the results of this work. During the two day storm period a total of 14 260m^3 of sediment is predicted to be deposited in the river channel. However during the rest of the year the effect of the tidal flows was to erode a total amount of 33 658m^3 of sediment given a net erosion of 19 398m³. This compares extremely favourable with the calculated annual rate of erosion of 19 500m³.

Table 7.6 Annual variation of sediment erosion or deposition in the river (from 1-D model)

Annual variation	Flood (P=100%)	7-11 tide	12-1 tide	2-6 tide	Total
Sediment variation(m^3)	14 260	-14 930	-5 668	-13 060	-19 398

Integrated Model

The integrated model was calibrated in a similar manner although rather than run the model for a whole year periods representative of spring average and neap tides were selected from the tidal record at Chiwan. The hydrodynamic model was run under where representative tides and the sediment model was run using the output files. The boundary suspended sediment concentrations used were 0.03kg/m³ in the dry season 0.06kg/m³ in the wet season and 0.1kg/m³ in the period of the $P_{100\%}$ storm conditions. The model has been run for storm conditions representing both the pre-1986 and post-1986 conditions and sediment loads.

Analyzed results have been calculated assuming 60 days under each of the six representative conditions: wet season or dry season and spring average or neap tides plus a single storm period with an average tide. The model results have been assessed to determine the predicted rate of erosion in the river channel for the pre-1986 conditions and for the post-1986 conditions at the sites from which the cores were taken for ^{210}Pb determination of deposition rates.

Table 7.7 shows the revised calculation of the erosion rate under pre-1986 conditions. During the storm period a total amount of 14 260m³ of sediment is deposited whilst during the rest of the year a total of 29 294m³ of material is eroded. The cumulative effect being an erosion of 15034m³ in comparison to the value estimated from observations of 19 500m³ the error is 23%.

Figure 7.4 shows the locations from which the cores were taken with SR1 SR2 SR3 SR4 and SR5 representing somewhere in the central mudflat Futian Maipo 1 Maipo 2 and the river mouth respectively. Table 7.8 shows both the results of the analysis of the cores and the forecast annual deposition rates for the identified region of inner Deep Bay to which the cores related. The table includes comparison between the deposition rates calculated from the analysis of the cores and the model predictions for post-1986 condition. The model results show the range of forecast annual deposition rates over the entire sub-region and provide an indication of the sensitivity of the model.

Table 7.7 Annual variation of sediment erosion or deposition (from the integrated model)

Annual variation	Flood(P=100%)	1-12 Tide Flow	Total
Sediment load(m^3)	14260	-29294	-15034

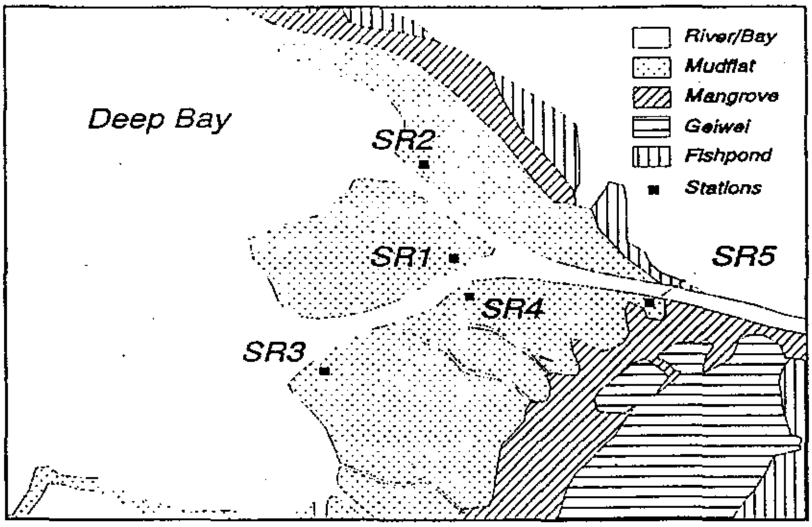


Figure 7.4 Locations of ^{210}Pb sedimentation rate measurements

Table 7.8 Comparison of the modelling results with ^{210}Pb data (Current rate of erosion/deposition in the sensitive area in cm/yr)

Area	Modelling Results	Variation Range	^{210}Pb data
Mudflats(D_3)	1.70	1.0-1.90	3.33
Futian(D_4)	1.64	0.71-1.87	3.12
Maipo(D_2)	2.70	1.5-3.66	3.04
River (D_1)	8.66	22.0-10.0	3.68

In consideration that the error of the ^{210}Pb data itself as well as the calculated error in the narrow complex area such as the river mouth and the sub-channel in the mudflats where the grid number is too few to give the detailed information in the cell the comparison shown in Table 7.8 is fair for the present study. Since the figures in the table represent the averaged analyzed current change over several typical sub-areas the range of the variation must also be considered. The maximum range is indicated because of the eminent variation of the topography from the deep channel to the mudflat near the river mouth. The general trend of the variation of sediment deposition rate is to decrease in the bay-mouth direction.

In general the predicted areas of erosion or deposition is quite accord with the observed ones as shown in Figure 7.4. Since the cores were taken in the areas near the sub-channels where deposition occur in greater rate than in the mudflats the larger figures by ^{210}Pb analysis than the calculated ones are predicable. However the core in the location of D_1 is taken from the floodplain rather than the deep channel. Thus the data provided there is significantly small in comparison to the modelling result primarily reflecting the main flume features.

Model Constraints

There are two significant constraints on the interpretation of the model predictions: firstly the accuracy of topographical information and the impact of discretising the depths for input to the model on local scale features and secondly the fact that the models are for sediment transport rather than morphological models.

As highlighted with reference to the hydrodynamic model for Deep Bay the availability of detailed bathymetric data for inner Deep Bay and topographic data for the inter-tidal areas especially the mudflats is severe constraints on the interpretation of deposition and erosion rates on a local scale. This effect is further exacerbated by the fact that model cells must have average depths therefore small scale features such as narrow channels are lost. These effects require that the model outputs be considered in terms of the predictions for larger spatial areas rather than looking at the detailed predictions for specific sites.

Since the models used in this study are not full morphological models the hydrodynamic predictions of flow velocities are not revised on the basis of the deposition or erosion predicted by the sediment transport model. This is particularly important when extrapolating analyzed effects from the relatively short two day period predictions.

The implications of this for the predictions of deposition and erosion are different. In the event that erosion occurs in an area the current velocities are likely to decrease and the potential for erosion reduces. Thus erosion in an open water environment dominated by tidal currents is to some degree self-limiting as erosion in one area is likely to be compensated by deposition in an adjacent area. However deposition can lead to consolidation (especially in areas of limited wave action) making re-erosion less likely. In conclusion it is considered that the estimation of analyzed effects is more likely to be correct for deposition than for erosion.

7.4 WATER QUALITY MODELS

There are many mathematical water quality models that describe pollutant migration and transformation processes in tidal rivers estuaries and bays including dynamic or steady state models one-dimensional or multi-dimensional models. Selection of water quality models is primarily based on water quality characteristics of the water modelled as well as the principal concern of the modelling.

Shenzhen River is a typical tidal river with a narrow shallow channel where pollutants are circulated in the river and subject to continuous mixing dilution transformation and degradation. The pollutant concentrations are uniformly distributed vertically and transversely according to a series of measurements. Therefore the average water quality of Shenzhen River may be reasonably represented using one-dimensional modelling. The water quality variation within a tidal cycle may be described by dynamic modelling.

Two types of water quality model will be used for this study: a steady state model to consider longer-term effects and a dynamic model to consider the tide varying behavior. Each model is run in a similar fashion to the sediment transport model being uncoupled from the hydrodynamic model.

Shenzhen River is not suitable for water supply. Therefore the differences in water quality between tidal cycles can be simply documented by choosing the environmental objectives in order to compare water quality during different tidal cycles or different seasons. A one-dimensional steady state model with finite divisions of reaches of the river can be used to predict the time averaged water quality in an estuary such as Shenzhen River estuary over tide cycles.

The Thomann Model has been used in the assessment. The results of studies carried out by the South China Institute of Environmental Sciences and others comparing different water quality models indicated that the Thomann Model can reliably predict water quality variation in Shenzhen River and Deep Bay. The model is considered to be satisfactory to predict accurately water quality effects in Shenzhen River and Deep Bay for their average conditions.

The model includes the dispersive phenomenon in opposing directions of river flow in the estuary (upstream and downstream tidal movements) and the opposing dispersive phenomenon can be well reflected when the time-averaged treatment over the tide cycles is made. However the tidal flow also influences the net discharge into the estuary. By input fluid volume in the dynamic term in the model the effect of tide on estuary flow can be considered for both steady state or time-averaged treatments over tide cycles.

More than 80% of fresh water discharge into Inner Deep Bay are from Shenzhen and Yuen Long Rivers. Residual flow within the bay runs along the thalweg beneath the surface water in the bay. The tidal current into the bay is dominated by oscillation flow. Therefore the bay can be considered as an extension of the river. Consequently the river and the bay can be considered as an integrated system and it may reasonably be generalized as an one-dimensional system. The one-dimensional time-averaged water quality model over tide cycles is taken as the primary mechanism to predict the environmental impact before and after the Stage 1 and Stage 2 Works in Shenzhen River and Deep Bay.

The dynamic variation of water quality including seasonal variation in Shenzhen River and Deep Bay can be predicted by using the 1-dimensional and 2-dimensional dynamic model with the monitoring data from both dry and wet seasons.

Except for the BOD-DO coupled model all other pollutants (for example COD Coliform Cl TN TP Cu and Pb) are described with a single factor model. By use of standard simple determination methods of decay coefficients these models have shown their rationality for Shenzhen River and Deep Bay.

7.4.1 River Model

1-D steady state model

The water quality model is a finite-reach model in which the original river is divided into a number of reaches of finite length located sequentially in the stream-wise direction. For each of the finite reaches the water body is assumed to be fully mixed or able to be described by a 0-D model so that the entire estuary can be simulated by a 1-D model. With the finite-reach model the modeled quantities including the state variables and model parameters represent the time average over tidal cycles and the flow rate of the model is the river runoff. The phenomena of convection dispersion and material decay which are related to the mass transport have been fully considered for each of the river reaches.

The so called Comprehensive Search Method(see Appendix 7.3) is adopted to estimate the dispersive coefficient and other parameters in the estuary region to permit the results to be cross verified. The results are shown in Table 7.9 and 7.10. It should be noted the irregular features of the river since the parameters vary with the distance downstream. The division of the reaches and the section numbers are well defined in Figure A7-26. Given the pollutant sources water quality in the sense of time-averaged state over tide cycles will be predicted.

Table 7.9 Estimation of parameters for BOD_5-DO model

Section	1#	2#	3#	4#	5#	6#	7#	8#	9#	10#
K_d(1/d)	0.246	0.204	0.143	0.146	0.184	0.756	0.325	0.264	0.203	0.283
K_a(1/d)	0.556	0.568	0.625	0.628	0.525	0.264	0.566	0.566	0.656	0.632
K_x(m^2/s)	186	65.0	300	210	400	487	58	60	64	70

K_d: BOD Decay coefficient; K_a: O_2 recovery coefficient in each reach; D_x: Longitudinal dispersive coefficient.

Table 7.10 Decay coefficient for different pollutants (d^{-1})

Section	1#	2#	3#	4#	5#	6#	7#	8#	9#	10#
COD	0.08	0.08	0.08	0.08	0.05	0.05	0.01	0.01	0.01	0.01
TN	0.1	0.1	0.1	0.1	0.05	0.05	0.01	0.01	0.01	0.01
TP	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Coli.	2550	2580	2 420	3000	2800	20000	20000	20000	20000	20000
Cu	1.94	2.82	1.19	0.407	0.154	0.782	0.744	0.456	0.643	0.533
Pb	0.834	0.832	0.739	0.729	0.424	0.142	0.144	0.162	0.043	0.033

Monitoring data including the pollutant loads information has been provided by Shenzhen Environmental Protection Monitoring Station. Those for the modelling calibration and validation are the latest monitoring results of water quality and tide flow in Shenzhen River and Deep Bay simultaneously. The prediction of pollution sources at the time of the Stage 1 or Stage 2 Works and for the year 2000 planning horizon are primarily based on the universal exponential relationship correlating the rate of population or economy growth to the total amounts of contaminants giving an overall increase in pollutant loads of 75% by the year 2000.

The predicted results of the pollutant sources are subsequently used as input parameters of water quality model so that the water quality in the construction and operational period for Stage 1 or Stage 2 Works may be further predicted. It is worthwhile to indicate that the above estimation for the increase of pollutant loads is relatively conservative when no available information. The actual loads in the near future will be smaller than the proposed figure of 75% since some controlling measures such as Livestock Waste Control Scheme North District SMP Water pollution Control Ordinance in Hong Kong side and others in Shenzhen side have been proposed and will be adopt.

The model has been widely used for the simulation and prediction of water quality in estuary region and is described in detail in Appendix 7.3.

Comparisons of the calculated results and the measured ones are listed in Table 7.11 and 7.12 as well as Figures A7-27 to A7-34. The relative errors are less than 31.4 percent.

It is noted that the die-off rate of E.Coli. in Shenzhen River is "large" in comparison with that in the usual case. The model is calibrated by all of the monitoring data and thus the parameters used are comprehensive ones. The reason for "large" die-off rate is principally attributed to the dramatic change of environment from the polluted water to the brackish water in the Shenzhen River.

Table 7.11 Verification of BOD-DO model (A calculated; B measured; C error)

Index	Section	1#	2#	3#	4#	5#	6#	7#	8#	9#	10#
BOD_5	A	21.8	35.47	33.37	31.76	26.64	19.23	4.53	1.07	0.98	1.05
(mg/l)	B	--	37.09	--	--	24.41	17.56	4.04	--	--	1.05
	C(%)	--	-4.37	--	--	9.14	8.51	12.1	--	--	1.05
DO	A	0.38	0.18	0.10	0.11	0.23	0.27	4.71	6.98	7.01	6.63
(mg/l)	B	--	0.16	--	--	0.25	0.25	5.25	--	--	6.68
	C(%)	--	12.5	--	--	-8.0	8.0	-10.3	--	--	-0.7

Table 7.12 Verification of other models (A calculated; B measured; C error)

Index	Section	1#	2#	3#	4#	5#	6#	7#	8#	9#	10#
COD	A	17.6	20.83	19.90	19.79	18.90	17.06	11.03	6.14	4.37	3.05
(mg/l)	B	--	19.82	--	--	21.90	17.08	--	5.79	--	3.2
	C(%)	--	2.8	--	--	-13.7	-0.1	--	6.0	--	-4.7
TN	A	8.74	12.14	11.87	11.59	10.07	9.60	5.98	2.98	1.87	1.05
(mg/l)	B	--	12.70	--	--	12.51	11.47	--	2.54	--	1.03
	C(%)	--	-4.4	--	--	-14.5	-16.3	--	17.3	--	1.9
TP	A	1.48	1.72	1.73	1.74	1.69	1.52	0.97	0.46	0.25	0.084
(mg/l)	B	--	1.98	--	--	2.12	2.2	--	0.40	--	0.083
	C(%)	--	-13.1	--	--	-20.3	-30.9	--	15.0	--	1.2
Cu	A	2.65	2.39	1.23	1.54	1.62	1.13	0.158	0.079	0.24	0.10
(mg/l)	B	--	2.1	--	--	2.2	0.86	--	0.075	--	0.12
	C(%)	--	13.8	--	--	-26.4	31.4	--	5.3	--	20
Pb	A	8.91	7.19	7.230	8.46	11.1	8.31	2.98	1.06	1.18	1.10
(mg/l)	B	--	6.9	--	--	9.40	10.6	--	1.2	--	1.10
	C(%)	--	4.2	--	--	15.3	-21.6	--	-11.7	--	0.0
	A	6913	13734	5295	29545	26375	9660	1.89	1.53	3.48	1.03
Col.	B	--	13985	--		26145	9400	--	1.39	--	1.03
	C(%)	--	-1.8	--		0.88	2.8	--	10.07	--	0.0

Dynamic model

The dynamic water quality model has been developed in order to describe the dynamic variations of pollutant in Shenzhen River and Deep Bay. As for the steady state model the Comprehensive Search Method is used for the parameter estimation since the salinity variation within the main study area was too small to be used for the calculation of dispersion coefficients as stressed in the monitoring report.

The 1-D model for Shenzhen River is verified with monitoring data acquired in dry season

(March 1-4 1994) and wet season (June 29-July 1 1994) as shown in Tables A7-27 and A7-13.

The comparisons of modelling and measured results show a maximum error of 30% for most circumstances. Detailed modelling results are given in Figures A7-51 to A7-58.

7.4.2 Integrated Model

The purpose of the dynamic water quality modelling is to provide a quantitative assessment of the dynamic behaviours of water quality in Shenzhen River and Deep Bay before and after the Stage 2 Works or in the planning year of 2000. A 1-D model is used for Shenzhen River and a 2-D model for the Bay with the connection of the two models in the river mouth. The pollutants modeled are BOD_5, DO, COD, TN, TP, Cu, Pb and E.Coli.

The flow data and topographic information required are the same as those described in the hydrodynamic model. Pollution source data are the same as described in Appendix 7.3. The monitoring data obtained in Sanchahe section is taken as the upper boundary condition. The mathematical descriptions are given in Appendix 7.3.

With the time step of 30 seconds the model runs for four designed conditions and verified by the data obtained in March and June in 1994 within the reasonable range of the maximum error of 25% for most runs as shown in Appendix 7.4.

7.5 MODEL PREDICTIONS

With the verified models of hydrodynamics sediment transport and water quality the information necessary for the present study may be obtained with varying designed computer runs.

7.5.1 Hydrodynamic Modelling

Interpretation of the runs of the River and Deep Bay bay models suggests that the water surface curve in the longitudinal direction of the river will fall slightly after the Stage I Works. Flow fields in both the River and Bay would not be changed significantly. There would be a small increase in tidal exchange volume (and hence flushing) and flume storage owing to the Stage I Works but this should be relatively minor. The effect on water quality in the lower reaches of the river would be a minor improvement due to greater flushing by the relatively "clean" water from Deep Bay. In absolute terms the effect would not be significant. As described in Stage I report comparisons of the elevations of the embankments have been made with the predicted supreme water levels along the river before and after the Stage I Works using different tide levels of the Bay matched with different designed floods (return periods of 1-in-5 year 1-in-10 year 1-in 20 year and 1-in-50 year). Given that the embankments are not available after the construction of Stage 1 Works the occurrence of the extreme floods during this period would still result in widespread flooding.

The modelling results corresponding to Stage 2 Works are obtained based on 4 designed conditions with P equals to 2%, 5% and 10% as shown in Figures A7-2 to A7-6 including the water level and discharge variation before and after the works. The variations in estuary with spring average and neap tides are also predicted. The calculated results show that the water surface level will decrease from 1 to 3 meters along the river after Stage

2 Works. Meanwhile the increase of tidal discharge is up to 1/3. Thus Shenzhen river will have enough capacity for the flood with the return period of 1-in-50 years after Stage 2 Works provided that sediment deposition is fully controlled after the Project.

The range of modelling is from the upper end of Shenzhen Estuary to the mouth of Deep Bay bordered Chi Wan and Black Point. 100x100m square grids are used and the time steps are 40 seconds. Fluctuating boundary method is used to simulate the change of intertidal areas due to the rise and fall of the tide flow.

The result of hydrodynamic calculation was verified based on the monitoring data of Mar. 1-4 and June 29-July 2 1994. 4 flow velocity monitoring locations were set up in Deep Bay and the test results of tide flow velocity has been presented in the Stage 1 report. In general the verification shows a relative error less than 10%.

According to the modelling results the flow fields in Deep Bay after Stage 2 Works are primarily the same as those before the works (as shown in Figures A7-12 to A7-14) which implies that the tidal characteristics in Deep Bay will remain the same after the works except for a slightly increase of tidal exchange near the river mouth. During the very beginning of the increasing and decreasing tide the water flow oscillate around the Bay mouth. During the increasing tide water flows into the Bay from the southwestern direction and leaves the Bay from northwestern direction; During the decreasing tide water flows into the Bay from the northwestern direction and leaves the Bay from southwestern direction. The flow of water in the Inner Deep Bay is controlled by Tsim Bei Tsui to a certain extent and form a kind of flow pattern around Tsim Bei Tsui. The velocity in these areas is also high up to 0.65 m/s as the maximum. The decreasing tide can bring sediments from the river mouth to a certain distance of the Bay. During the spring tide the flow velocity in the river mouth is low with little turbulence; and during the neap tide the flow is mainly along the two sub-channels with significant turbulence. Compared with the inner side of the Bay the flow velocity in the intertidal area of Deep Bay is low with the maximum of between 0.2-0.25m/s.

Since the Stage 2 Works have no significant influence on the flow characteristics in the Bay detailed descriptions may refer to Stage 1 report.

7.5.2 Sediment Transport Modelling

Given the information currently available on hydrology and sediment movements in Shenzhen River and Deep Bay it is possible to make a reasonable analysis of the likely effect of the Stage 1 and Stage 2 Works on sediment transport and deposition. The issue of primary concern is how the sediment deposition rates will be affected in the ecologically important intertidal areas and mud flats.

For the Stage 2 Works the primary concern is whether the release of sediment due to dredging works in the river could result in severe sedimentation affecting benthic infauna and mangroves.

The best available measure of the significance of any changes is the comparison of predicted rates of deposition with naturally occurring sediment deposition rates which cause no ill effects on the estuarine ecological system. The following analyses explores this issue based on available information.

The predicted results of sediment erosion and deposition for Shenzhen River after Stage 2 Works are given in Table 7.13.

Table 7.13 Sediment erosion and deposition in Shenzhen River after Stage 2 Works

Location	Above Lo Wu Bridge	Lo Wu-Yunong	Yunong-Huanggang	River mouth	Total
Length(m)	3600	4400	3200	2400	13600
After 1 year (m^3)	-60100	105000	4600	0	49500
After 3 year(m^3)	-70180	218060	15900	0	163780
After 5 year (m^3)	-76180	315560	27400	35000	301780

It is indicated that sediment will be deposited in Shenzhen River either during or after Stage 2 Works. Erosion principally occurs in upstream reaches above Lo Wu Bridge during the initial period after Stage 2 Works and then the river tends to the equilibrium state in that reaches; and deposition occurs in downstream reaches. Bars are first formed in Lo Wu and migrate downstream. From the modelling results as shown in Figures A7-17 and A7-18 in order to keep the designed flood prevention standard the maintenance dredging is necessary during or after Stage 2 Works since sediment deposition occurs in the channel. The annual averaged deposition rate is about 50,000m^3/yr.

Similar runs are used for the Deep Bay for Stage 2 Works on the 2-day time scale. For the sake of convenience the Runs description and the modelling results for Stage 1 Works are cited in Tables 7.14 and 7.15.

Table 7.14 Sediment entering Deep Bay during 2 days

Stages		Spring Tide		Average Tide		Neap Tide	
		combinations	sediment (m^3)	combinactions	sediment (m^3)	combine actions	sediment (m^3)
F	Before works	Run1	14846(0.1)	Run4	14848(0.1)	Run7	14846(0.1)
	After works	Run2	29700(0.1)	Run5	29700(0.1)	Run8	29700(0.1)
	After works+50%S	Run3	42300(0.1)	Run6	42300(0.1)	Run9	42300(0.1)
A	Before works(Wet season)	Run10	916(0.06)	Run14	511(0.06)	Run18	320(0.06)
	Before works(Dry season)	Run11	842(0.03)	Run15	500(0.03)	Run19	305(0.03)
	During works	Run12	969(0.06)	Run16	540(0.06)	Run20	351(0.06)
	After works	Run13	1012(0.06)	Run17	569(0.06)	Run21	351(0.06)

Note: The value in the parentheses are concentration (in kg/m^3)in the mouth of Deep Bay.
F: stands for Flood Period A: for average period.
The data in the () represent the contents of sediment in the outlet of the Deep Bay(kg/m^3).

As far as the construction period of Stage 2 Works is considered the sediment concentration in the river mouth region will be increased to 0.15kg/m^3 which is larger than the value of 0.08kg/m^3 during the construction period of Stage 1 Works. Correspondingly the sediment deposition in the river mouth Futian and Maipo will also be increased to some extent. Comparisons are made in Table 7.16 for both Stage 1 and Stage 2 Works within 2 days during the construction.

Table 7.15 Distribution of Sediment concentration and deposition thickness in Deep Bay (during 2 days)

	Estuary			Futian			Mai Po			Middle Bay			Tim Bi Tsui			Bay Mouth		
	$\Delta\eta$	C_{max}	C_{mean}	$\Delta\eta$	C_{max}	C_{mean}	$\Delta\eta$	C_{max}	C_{mean}	$\Delta\eta$	C_{max}	C_{mean}	$\Delta\eta$	C_{max}	C_{mean}	$\Delta\eta$	C_{max}	C_{mean}
Run1	2.8	3.2	0.40	0.55	0.24	0.05	0.45	0.10	0.03	0.28	0.7	0.08	0.14	0.12	0.04	0.5	0.1	0.1
Run2	5.7	5.0	0.80	0.72	0.26	0.09	0.49	0.17	0.04	0.50	0.9	0.11	0.18	0.14	0.08	0.5	0.1	0.1
Run3	6.8	7.2	1.3	1.1	0.60	0.12	1.03	0.20	0.06	0.69	1.4	0.18	0.22	0.20	0.09	0.5	0.1	0.1
Run4	2.9	3.3	0.45	0.53	0.23	0.05	0.4	0.15	0.03	0.2	0.5	0.05	0.14	0.12	0.04	0.62	0.1	0.1
Run5	5.9	5.2	0.9	0.70	0.30	0.11	0.48	0.16	0.03	0.44	0.8	0.06	0.16	0.16	0.04	0.62	0.1	0.1
Run6	7.2	7.2	1.6	0.96	0.55	0.12	0.9	0.19	0.06	0.54	1.3	0.1	0.21	1.75	0.08	0.62	0.1	0.1
Run7	3.0	3.3	0.5	0.5	0.2	0.04	0.40	0.11	0.03	0.08	0.15	0.03	0.10	0.11	0.03	0.75	0.1	0.1
Run8	6.0	5.2	1.0	0.6	0.28	0.10	0.40	0.12	0.03	0.1	0.20	0.03	0.10	0.14	0.035	0.75	0.1	0.1
Run9	7.4	7.2	1.9	0.98	0.50	0.12	0.45	0.14	0.03	0.10	0.21	0.03	0.13	0.16	0.035	0.75	0.1	0.1
Run10	0.55	0.32	0.1	0.15	0.18	0.04	0.30	0.18	0.035	-0.06～0.09	0.08	0.05	-0.3	0.13	0.045	-0.05～0.20	0.065	0.06
Run11	0.55	0.32	0.09	0.15	0.18	0.04	0.30	0.8	0.035	-0.07～0.05	0.075	0.04	0.3	0.13	0.04	-0.28	0.045	0.035
Run12	0.60	0.36	0.1	0.16	0.19	0.04	0.32	0.19	0.35	-0.06～0.09	0.08	0.06	-0.3	0.13	0.045	-0.05～0.20	0.065	0.06
Run13	0.00	0.37	0.1	0.16	0.18	0.04	0.32	0.18	0.035	-0.07～0.05	0.075	0.04	-0.3	0.13	0.04	-0.28	0.045	0.035
Run14	0.51	0.25	0.075	0.06	0.1	0.035	0.07	0.09	0.03	-0.07	0.07	0.03	-0.08	0.08	0.03	0	0.065	0.06
Run15	0.50	0.20	0.08	0.06	0.1	0.035	0.07	0.09	0.03	-0.06	0.06	0.03	-0.08	0.08	0.03	-0.07	0.035	0.03
Run16	0.52	0.27	0.08	0.06	0.1	0.035	0.07	0.09	0.03	-0.07	0.07	0.03	-0.08	0.08	0.03	0	0.065	0.06
Run17	0.51	0.26	0.075	0.06	0.1	0.035	0.07	0.09	0.03	-0.07	0.07	0.03	-0.08	0.08	0.03	0	0.065	0.06
Run18	0.30	0.16	0.60	0	0.04	0.02	0	0.035	0.01	0	0.045	0.02	-0.05	0.05	0.02	0.2	0.065	0.06
Run19	0.3	0.15	0.06	0	0.04	0.02	0	0.035	0.01	0	0.045	0.02	-0.05	0.05	0.02	0	0.04	0.03
Run20	0.31	0.17	0.065	0	0.04	0.02	0	0.035	0.01	0	0.045	0.02	-0.05	0.05	0.02	0.2	0.065	0.06
Run21	0.30	0.16	0.06	0	0.04	0.02	0	0.035	0.01	0	0.045	0.02	-0.05	0.05	0.02	0.2	0.065	0.06

$\Delta\eta$ deposition thickness(in mm) within 2 days

C_{max} Maximum sediment within 2 days (in kg/m^3)

C_{mean} Average sediment within 2 days (in kg/m^3).

Table 7.16 Deposition thickness (in mm) within 2 days or in a year during the construction

Tides	River mouth		Futian		Maipo	
	Stage 1	Stage 2	Stage 1	Stage 2	Stage 1	Stage 2
Spring tide	0.60	0.66(0.15)	0.16	0.45	0.32	0.49
Average Tide	0.52	0.58(0.15)	0.06	0.10	0.07	0.20
Neap Tide	0.31	0.52(0.11)	0	0.05	0	0.10
Total in a year	85.8	105.6	13.2	36.0	23.4	47.4

Note: The figures in the brackets are corresponding sediment concentrations in kg/m^3

After the Stage 2 Works the sediment concentration inflowing into Deep Bay will be apparently decreased (see Figure 7.5) owing to the increasing deposition within the river channel. However the deposition in other part in Deep Bay will not be changed except a slight decrease of deposition rate in Futian.

Sediment deposition in the river mouth region of Deep Bay will be decreased after Stage 2 Works during floods because of sediment concentration in flowing into Deep Bay as shown in Figure 7.5.

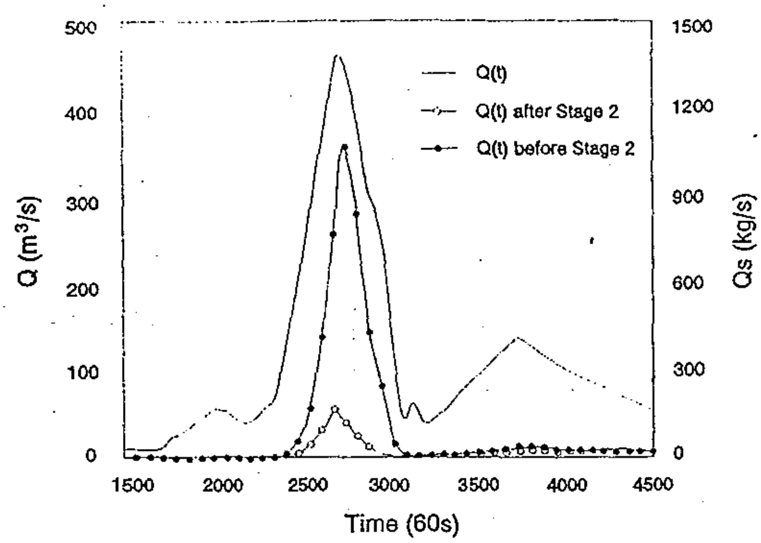


Figure 7.5 Comparison of Qs(t) of flood at river mouth in Stage 2

Table 7.17 Sediment characteristics in river mouth within 2 days(after Stage 2 Works)

Runs	$\Delta\eta$		C_{max}		C_{min}	
	After Stage 2	After Stage 1	After Stage 2	After Stage 1	After Stage 2	After Stage 1
Spring Tide wet season	0.15	0.55	0.13	0.32	0.03	0.10
Average Tide Wet season	0.10	0.51	0.09	0.25	0.03	0.075
Neap Tide Wet season	0.0	0.30	0 03	0.16	0.01	0.06
Spring Tide Dry season	0.14	0.55	0.12	0.32	0.03	0.09
Average Tide Dry season	0.10	0.50	0.09	0.20	0.03	0.08
Neap Tide Dry season	0.0	0.30	0.03	0.15	0.01	0.06

$\Delta\eta$ deposition thickness(in mm) within 2 days
C_{max} Maximum sediment within 2 days (in kg/m³)
C_{mean} Average sediment within 2 days (in kg/m³).

It worthwhile to give special illustration that the modelling results summarized in Table 7.15 provide the sediment distributions in the whole Deep Bay only for 2 days. The annual sediment deposition or erosion in different locations must be estimated according to the different compositions in terms of the tide types flood or seasons and the stage of works either in the existing condition or in the construction or operation stage. As an example if the deposition thickness at any location during 2 days before the realignment is obtained according to the results from Run no.1 which corresponds to the alternative of flood-spring tide and the annual deposition thickness therein is also obtained for the normal case according the results from Run No.10 11 14 15 18 and 19 then the total annual deposition thickness there should be the sum of them for the existing condition.

Detailed modelling results are given in Figures A7-20 to A7-25.

In order to provide the basic information of the present study the weighted average figures for typical areas in the bay is given in Table 7.18 and shown in Figure 7.6. The column "current without river" provides a basis of the sensitivity evaluation of the river impact on the bay area. The variation ranges of erosion or deposition rate over each sub-region have been shown in Table 7.18.

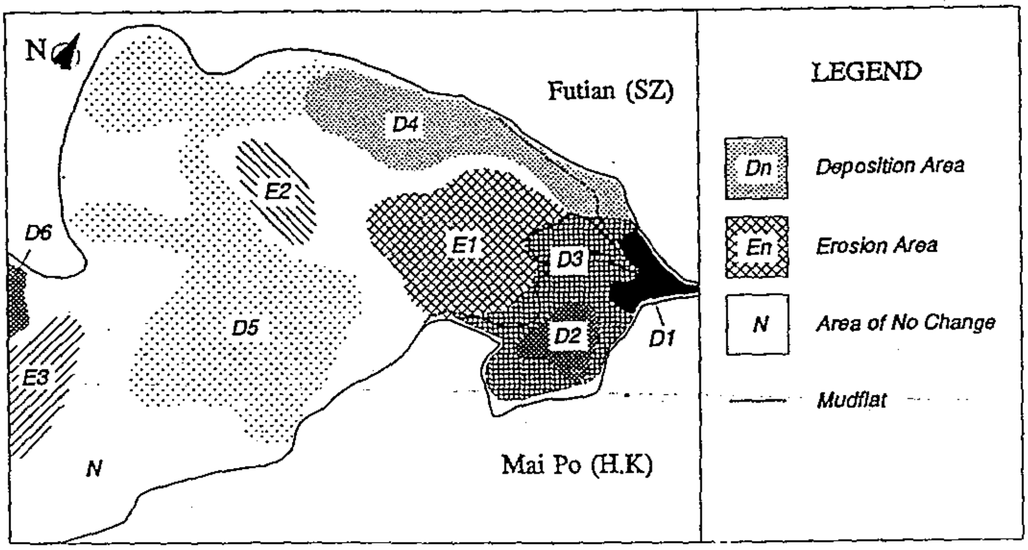


Figure 7.6 Deposition and erosion before and after the Project

Table 7.18 Weighted averages deposition/erosion rates before and after the Project (mm/yr)

Area	Current with River	Current without River	During Stage 1	After Stage 1	During Stage 2	After Stage 2
D_1	86.6	82.8	92.5	87.0	115	34.0
D_2	27.0	25.9	31.0	28.1	37	21.0
D_3	17.0	15.6	19.5	18.3	21.0	13.0
D_4	16.4	15.4	18.8	17.9	22.5	12.0
D_5	5.3	5.3	5.3	5.3	5.3	5.3
D_6	10.7	10.7	10.7	10.7	10.7	10.7
E_1	-53.1	-53.1	-52.0	-52.6	-50.0	-54.0
E_2	-7.5	-7.5	-7.5	-7.5	-7.5	-7.5
E_3	-10.9	-10.9	-10.9	-10.9	-10.9	-10.9

From the modelling results the Shenzhen River itself has little impact on the sediment erosion or deposition in Deep Bay. Even in the river mouth the deposition rate changes several millimeters over a year when compare the cases of "Current with River" and the

"Current without River". As for the bay area far from the river mouth the river has no effect at all since both the river flow and sediment discharge in the normal cases are so small in comparison with those from the outer Bay. The minor impact of the river is principally reflected by the flood normally with the duration of 1 or 2 days. For the rest period of the year the average flow discharge from Shenzhen River is only $10m^3/s$ with the sediment concentration less than $0.001kg/m^3$. Moreover the statistical results in Table 7.19 may tell us a magnitude order that the total marine resulted sediment volume within 1 day during flood or ebb tide will be approximately equivalent to the total incoming river sediment within several mouth!

The predicted annualised deposition rates in each of the regions of inner Deep Bay and at the mouth of the Shenzhen River under a range of conditions existing during Stage 1 Works post Stage 1 during Stage 2 Works and post Stage 2 show the changes between the various scenarios modelled are minimal for the majority of the regions. This reflects the dominance of the sediment from Outer Deep Bay in controlling the deposition in the inner bay. The changes in the mouth of the river and the areas immediately adjacent show a reduction in deposition rates reflecting the increased sediment deposition in the lower reaches of the river after Stage 2 Works covering the range from the largest reduction of 52.6mm/yr owing to the aforementioned reasons(see 7.3.3) to those of 4.4mm/yr 6.0mm/yr and 4mm/yr for Futian Maipo and the central mudflats respectively. During the Stage 2 Works the deposition rates in all the sensitive areas near the river mouth will be increased in comparison with either the current rate or that during Stage 1 Works. This predictable variation does not have significant impact on the Deep Bay since the increase rates are also very limited.

Table 7.19 Total marine resulted sediment load from outer Bay (in $10^4m^3/day$)

Tides	Wet Season	Dry Season
Spring Tide	1.37	0.68
Average Tide	1.14	0.57
Neap Tide	0.90	0.45

Considering the possibility of the short period overlapping of Stage 1 and Stage 2 Works the impacts caused by the potential overlapping are primarily the same as that during Stage 2 Works since the impact of Stage 1 Works is proved minor in comparison with that of Stage 2. In view of the long term effect of the works the temporal maintenance dredging each year will have very little impact on the Deep Bay environments because of the "small" released sediment which is much smaller than that released during the proposed works.

In summary little change in sediment deposition around the wet land of Deep Bay will occur after the Stage 2 Works although the sediment concentration or deposition will increase slightly during the works and will decrease after the works. The supreme sediment deposition in Deep Bay occurs during the spring tide with the flood. The reduced sediment deposition rate in the river mouth and its ambient sensitive areas will tends to increase again to the current rate when Shenzhen River tends to the equilibrium condition in the long term process of evolution after the works.

7.5.3 Water Quality Modelling

The proposed 1-D water quality model includes 1-D steady model and 1-D dynamic model. The former deals with the time-averaged water quality of the Shenzhen River and Deep Bay over tidal cycles prior to or post Stage 2 Works. However the latter provide a quantitative assessment of the dynamic behaviours of water quality in Shenzhen River for the corresponding periods. The pollutants modeled are BOD_5 DO COD TN TP Cu Pb and Col. Given the input information such as the pollutant sources shown in Tables from A7-13 to A7-16 the variation of water quality due to the works may be predicted.

The modelling results from 1-D steady model are sumarized in Tables 7.20 to 7.22 as well as in Figures A7-26 to A7-50 where the pollutants concentrations pre or post Stage 2 Works as well as in the planning year of 2000 are predicted for the wet season. The contaminants in the outlets of different pollutant sources are increased by 75% in 2000.

Table 7.20 BOD_5-DO modelling results pre or post the works

Index	Section		1#	2#	3#	4#	5#	6#	7#	8#	9#	10#
BOD_5 (mg/l)	pre	current	21.28	35.47	33.37	31.76	26.64	19.23	4.53	1.07	0.98	1.05
		2000	28.76	58.48	55.27	53.02	44.68	32.34	7.59	1.67	1.29	1.05
	post	current	21.68	25.84	21.49	18.09	12.79	3.05	3.69	0.93	0.94	1.05
		2000	33.66	42.68	35.69	30.22	21.45	15.21	6.17	1.43	1.22	1.05
DO (mg/l)	pre	current	0.380	0.180	0.100	0.110	0.230	0.270	4.71	6.98	7.01	6.63
		2000	0.01	0.01	0.01	0.01	0.01	0.010	2.66	6.54	6.68	6.63
	post	current	0.2400	0.620	1.150	1.630	2.300	2.590	4.95	7.06	7.03	6.63
		2000	.01	0.01	0.01	0.01	0.01	0.01	3.06	6.68	6.69	6.63

Table 7.21 Modelling results for other pollutants pre or post the works

Index	Section	1#	2#	3#	4#	5#	6#	7#	8#	9#	10#
COD (mg/l)	pre	17.60	20.38	19.90	19.79	18.90	17.06	11.03	6.14	4.37	3.05
	post	17.19	17.86	16.56	15.60	14.10	12.93	10.40	5.90	4.27	3.05
TN (mg/l)	pre	8.74	12.14	11.87	11.59	10.70	9.60	5.98	2.98	1.87	1.05
	post	9.27	10.26	9.41	8.71	7.70	7.03	5.53	2.80	1.80	1.05
TP (mg/l)	pre	1.48	1.72	1.73	1.74	1.69	1.52	0.97	0.46	0.25	
	post	1.55	1.60	1.53	1.46	1.33	1.22	0.97	0.46	0.25	
Col.	pre	$6.9x10^3$	$1.4x10^4$	$5.3x10^3$	$3.0x10^4$	$2.6x10^4$	$9.7x10^3$	1.89	1.53	3.48	1.03
	post	$9.1x10^2$	$1.3x10^4$	$2.5x10^3$	$6.7x10^3$	$1.9x10^4$	$2.5x10^3$				
Cu (mg/l)	pre	0.027	0.024	0.012	0.015	0.016	0.011	0.002	0.00079	0.002	0.001
	post	0.012	0.014	0.012	0.011	0.009	0.006	0.002	0.006	0.002	0.001
Pb (mg/l)	pre	0.0089	0.0072	0.0072	0.0085	0.011	0.0083	0.003	0.001	0.001	0.0011
	post	0.005	0.005	0.005	0.005	0.005	0.004	0.002	0.0007	0.001	0.001

1-D dynamic model is further used to model the detailed variations of the pollutants. Five representative combinations are studied i.e. variations of COD, BOD_5, DO, TN, TP, Cu, Pb, and Coli. in dry season after Stage 1 Works variations of the aforementioned index in wet season after Stage 1 Works variation in dry season after Stage 2 Works variation in wet season after Stage 2 Works variation in dry season in 2000.

Table 7.22 Pollutant concentrations in 2000 pre or post the works

Index	Section	1#	2#	3#	4#	5#	6#	7#	8#	9#	10#
COD (mg/l)	pre	24.97	33.34	32.77	32.88	31.48	28.28	17.64	8.87	5.56	3.05
	post	26.47	28.92	26.95	25.47	22.95	20.93	16.49	8.42	5.38	3.05
TN (mg/l)	pre	11.03	19.44	19.18	18.94	17.57	17.56	9.60	4.45	2.51	1.05
	post	13.84	16.45	15.20	14.15	12.52	11.39	8.84	4.16	2.39	1.05
TP (mg/l)	pre	1.82	2.68	2.24	2.79	2.75	2.48	1.57	0.71	0.36	0.084
	post	2.25	2.50	2.43	2.34	2.14	1.97	1.56	0.71	0.35	0.084
Coli.	pre	1.2×10^4	2.4×10^4	9.3×10^3	5.2×10^4	4.6×10^4	1.7×10^4	3.31	2.68	6.09	1.03
	post	1.5×10^3	2.3×10^4	4.4×10^3	1.2×10^4	3.3×10^4	4.4×10^3	3.27	2.68	6.09	1.03
Cu (mg/l)	pre	0.037	0.039	0.020	0.026	0.027	0.009	0.003	0.013	0.004	0.001
	post	0.018	0.024	0.020	0.018	0.015	0.010	0.003	0.010	0.004	0.001
Pb (mg/l)	pre	0.012	0.011	0.011	0.014	0.019	0.014	0.005	0.002	0.002	0.001
	post	0.007	0.008	0.008	0.008	0.009	0.007	0.004	0.010	0.001	0.001

Some of the predicted results are shown in Figures A7.51 to A7.70 for the dry season reflecting the worst case of water quality.

Based on the modelling results the realignment of the river channel is beneficial to the water quality in Shenzhen River. However the water quality in the upper reach would be deteriorated to some extent owing to the increasing tide flow discharge. The distance of the reach is about 6km from Sancha River.

Meanwhile it should be indicated that although the works is generally beneficial to the water quality of Shenzhen River and Deep Bay the water quality in 2000 will still be seriously deteriorated owing to the increase of the contaminants released from various pollutant sources. Special engineering control works for waste water is still needed in order to thoroughly improve water quality in Shenzhen River and Deep Bay.

The purpose of the dynamic water quality modelling is to provide a quantitative assessment of the dynamic behavious of water quality in Shenzhen River and Deep Bay prior to or post the Stage 2 Works or in the planning year of 2000. The 2-D model for the bay is dynamically connected with the 1-D model as mentioned above in the similar manner used in the hydrodynamics modelling.

Figures A7-71 to A7-86 in the proportional scale of 1:210000 contour maps are obtained based on the 25-hour complete tidal cycles. However only part of the huge number of results which are beneficial to represent the most important characteristics during a tide cycle are depicted in the report.

According to the modelling results the water quality in Deep Bay is not impacted by the works except around the river mouth region. The slight increase of TN and TP concentrations are found in the upper end area of the Bay which is directly resulted from the shorten of the channel by the Stage 1 and Stage 2 Works.

8 WATER QUALITY AND SEDIMENT TRANSPORTATION

8 WATER QUALITY AND SEDIMENT TRANSPORTATION

8.1 INTRODUCTION

Assessment of potential effects on water and sediment quality was restricted to Shenzhen River downstream of Lo Wu Bridge and Deep Bay.

8.2 APPLICABLE REGULATIONS, STANDARDS AND GUIDELINES

8.2.1 Hong Kong Legislation and Standards

River Water Quality

In Hong Kong, regulations for protecting Hong Kong's watercourses are the Water Pollution Control Ordinance (Cap.358) and the Waste Disposal (Livestock Waste) Regulations 1988 under the Waste Disposal Ordinance (Cap.354). Water quality objectives for the Shenzhen River are tabulated in Table 8.1.

Table 8.1 Water quality objectives of rivers (Hong Kong)

Parameter	WQOs	Zone
Bacteria	The level of *E.coli* should be zero per 100 ml, calculated as the running median of the most recent 5 consecutive samples taken at intervals of between 7 and 21 days.	*
	The level of *E.coli* should not exceed 100 per 1000 ml, calculated as the running median of the most recent 5 consecutive samples taken at intervals of between 7 and 21 days.	All other inland waters
DO	Waste discharges shall not cause the level of dissolved oxygen to be less than 4mg/l	All inland waters
SS	Waste discharges shall not cause the annual median of suspended solids to exceed 20 milligrams per litre	All inland waters
Ammonia	The un-ionized ammoniacal nitrogen level should not be more than 0.021mg/l, calculated as the annual average(arithmetic mean)	Whole zone
Nutrients	Nutrients shall not be percent in quantities sufficient to cause excessive or nuisance growth of algae or other aquatic plants	Inner and Outer Marine subzones
	No specific parameter has been set up	Inland waters
BOD_5	Waste discharges shall not cause BOD_5 to exceed 3mg/l	*
	Waste discharges shall not cause BOD_5 to exceed 5mg/l	All other inland waters
COD	Waste discharges shall not cause COD to exceed 15mg/l	*
	Waste discharges shall not cause COD to exceed 30mg/l	All other inland waters

* Yuen Long, Kam Tin (upper), Beas, Indus, Ganges, Water Gathering Ground subzones

Marine Water Quality

The waters of Hong Kong are protected by the Water Pollution Control Ordinance (WPCO Chapter 358). The study area is within the Deep Bay Water Control Zone. Water quality objectives for the zone are presented in Table 8.2.

Table 8.2 Water quality objectives for Deep Bay Water Control Zone

Parameters	Objective
E. coli (annual geometric mean)	≤ 610/100ml (mariculture zone) ≤ 180/100ml (bathing beach)
DO (2 m from bottom)	≥ 2mg/l for 90% samples
DO (depth average)	≥ 4mg/l for 90% samples
DO (1 m below surface)	≥ 4 mg/l for 90% samples, ≥ 5mg/l for mariculture zone
pH	6.5-8.5, change ≤ 0.2
Salinity	change ≤ 10% of natural ambient level
Unionized ammonium N	annual mean ≤ 0.021 mg/l
inorg. N (depth average) (annual mean)	≤ 0.7 mg/l (Inner Deep Bay) ≤ 0.5 mg/l (Outer Deep Bay)

8.2.2 PRC Legislation and Standards

River Water Quality

In PRC the pollution of inland waters is controlled by the Water Pollution Prevention and Control Act. The relevant standards for river water quality in the PRC are the National Environmental Quality Standard on Surface Water of PRC (GB3838-88). This sets 5 categories of beneficial uses for classification. Shenzhen River falls within the lowest (Category 5) with objectives designated primarily for landscape with no direct water uses. The main requirements of these standards are summarised in Table 8.3.

Table 8.3 PRC surface water quality standards (category 5) (mg/l)

Parameter	NH_3-N*	NO_2-N	NO_3-N	TN*	TP	DO	COD	BOD_5	SS*	Hg	Cd
Standard	0.2	1.0	25	1.0	0.2	2	10	10	150	0.001	0.01

* the standard of NH_3-N recommended by the National Environmental Monitoring Centre for urban rivers is adopted (already adopted by Shenzhen Environmental Monitoring Station), category 3 of GB-83 Standard is used for TN (not available in GB-88), and for suspended solids 150 mg/l is used (not available in GB-88).

Marine Water Quality

There is a range of beneficial marine water uses within Deep Bay. Impact assessment was based on The National Environmental Quality Standard on Marine Water of PRC (category 2). The main requirements are summarised in Table 8.4.

Table 8.4 PRC marine water quality standards (category 2, mg/l)

parameter	SS*	COD	DO	E.Coli	Hg	Cd	Pb	Cr	Cu	Zn	P
standard	50	4	>4	1000/l	0.001	0.01	0.1	0.5	0.1	1.0	0.03

* Increment less than 50mg/l.

8.2.3 Reconciliation of Standards

The Shenzhen River forms the boundary between Hong Kong and PRC, and water quality standards from both administrations are relevant to the study. At present the Shenzhen River is grossly polluted and water quality does not meet any of the relevant water quality standards. In evaluating water quality impacts it has been necessary to apply the criterion of relative improvement or degradation to current conditions.

Within Deep Bay the individual water quality standards (PRC and Hong Kong standards, as well as Water Quality Standards for Deep Bay agreed by Guangdong and Hong Kong) were used in the assessment. However, given the focus of this study on ecological resources, there is a need also to consider any changes in water quality which would result in a detrimental effect on critical ecological resources. These are, *prima facie*, the habitat at Futian and Mai Po and the oyster beds within Deep Bay. The water quality standards agreed by Guangdong and Hong Kong are given in Table 8.5.

Table 8.5 Deep Bay water quality objectives for scenic area (Guangdong & Hong Kong) (mg/l)

Parameter	Inorg. N	Inorg. P	COD	NH_3-N	BOD_5	DO[1]	*E.coli*[2]	pH	SS[3]
Standard	0.7	0.1	5	0.05	5	>4	1000	6.5-8.5	30%

1 depth average, 90% of samples of the year
2 geometrical mean(nos/100ml)
3 increased due to anthropogenic activities should be less than 30% of the ambient level.

8.3 EXISTING CONDITIONS

8.3.1 Existing water quality of Shenzhen River

Water quality of the river was considered to be satisfactory until the 1960's. From that time economic development on both sides of the river resulted in growing discharge of industrial and organic pollutants and water quality progressively deteriorated. Water flows in the Shenzhen River are dominated by direct runoff. At times of low flows the quantity of sewage frequently exceeds the natural flows. The middle and downstream reaches are tidal which further reduces flushing capacity. Except during flood flows, the retention time of pollutants entering the tidal sections of the river is believed to be 2-7 days.

Baseline monitoring of water quality has been carried for the EIA study as described in Section 4.5.2. The results are presented in Appendix 8.2. Figure 8.1 shows the variation of major pollutants along Shenzhen River.

Within PRC river water quality is assessed using a number of indices which reflect overall pollution levels. The most relevant for the Shenzhen River is the Pollution Sharing Rate which describes the contribution of various pollutants to the total pollution loads. Details of the index are given in Appendix 8.3

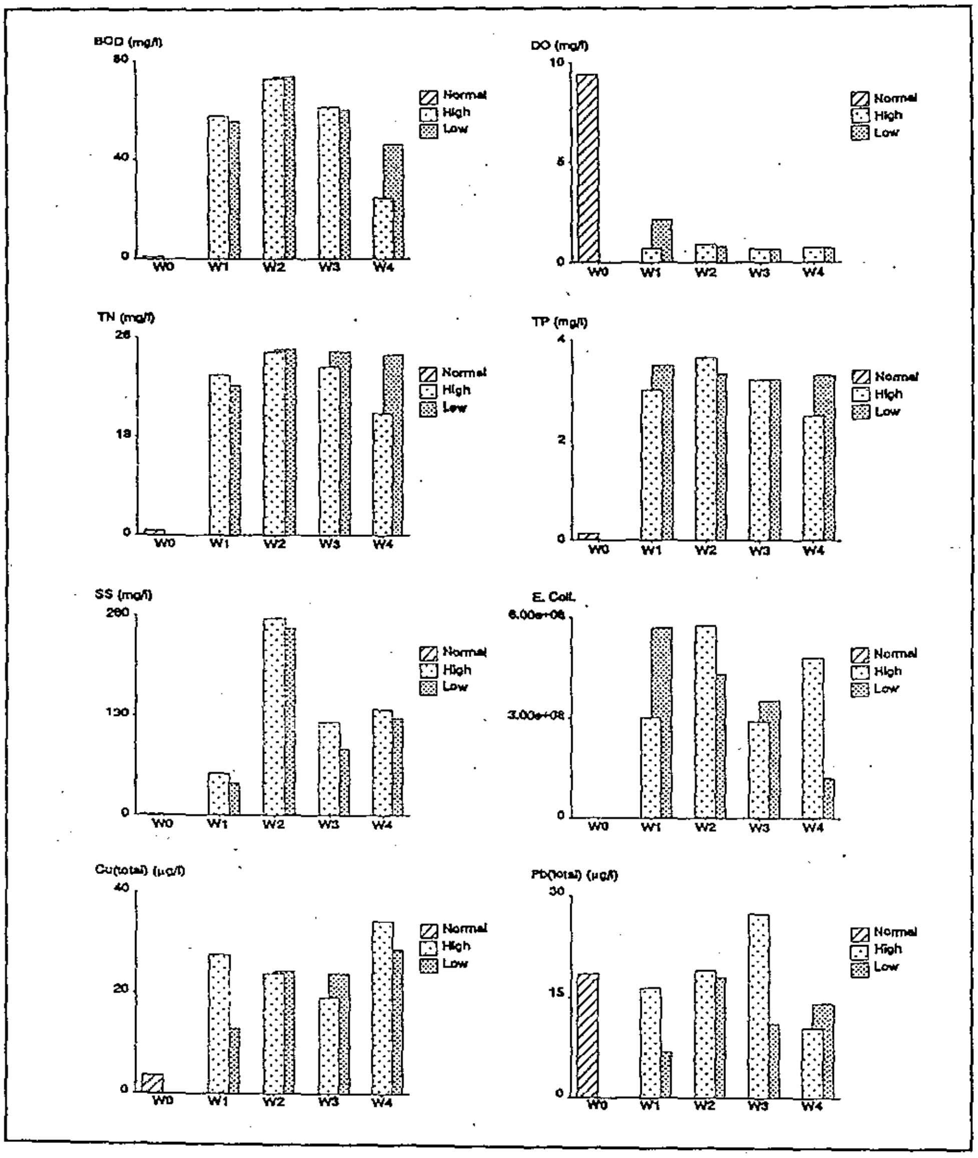


Figure 8.1 Water quality of the Shenzhen River (at normal, high, and low water levels) in dry season of 1994

Figure 8.2 demonstrates the pollution sharing rate of major pollutants in various sampling locations along Shenzhen River. It can be seen from the Figures 8.1 and 8.2 that the ex isting water quality of the middle and downstream sections of Shenzhen river are severe ly polluted and that nitrogen and phosphorus are the principle pollutants. The river wat er quality does not comply with any water quality standards applied by the Hong Kong or Shenzhen Authorities. Water quality deteriorates downstream as pollutant load increases due to increasing industrial and sewage discharges. The most polluted section is around Zhuanmatou.

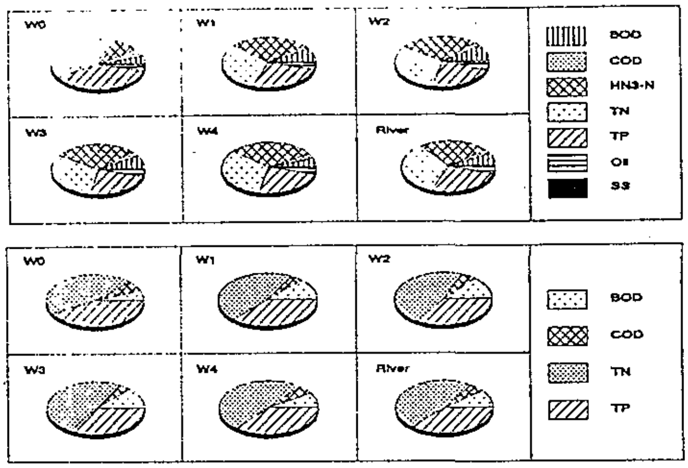


Figure 8.2 Pollution sharing rate of major pollutants in Shenzhen River

8.3.2 Existing Water Quality of Deep Bay

The flushing time for water entering Deep Bay is on average about 15 days, which is relatively short when compared to other estuaries with similar mid-tide volumes. However, the complex circulation patterns cause the actual retention times to vary considerably.

The principal sources of pollution entering Deep Bay are domestic sewage, agricultural wastes derived from livestock rearing and industrial effluents. Of these the largest source of pollution is untreated domestic sewage and livestock waste water discharged into the Bay via Shenzhen River. The water quality within Deep Bay is poor and is characterized by high levels of nutrients. Levels of inorganic nitrogen ranged up to a maximum of 11.3mg/l in 1991. The levels of Chlorophyll-a encountered in inner Deep Bay during 1991 showed a four fold increase on the previous year annual average value. The high BOD_5 levels (1991 annual mean was 2.7mg/l) recorded in Deep Bay are indicative of the large amounts of organic pollution in the water bodies. The levels of *E.coli* are among the highest encountered in Hong Kong waters and are comparable with the levels encountered in Victoria Harbour.

Results of the baseline monitoring (Section 4.3.2) carried out in 1994 are listed in Appendix 8.2. The data were used for calculation of the sharing ratio.

The results of current and previous monitoring showed that water quality in Deep Bay is polluted referring to PRC, Hong Kong, or Joint Guangdong-Hong Kong standards. The dominant pollutants were nitrogen and phosphorus as shown in Figure 8.3. The most severed polluted area was in the estuary region (W5).

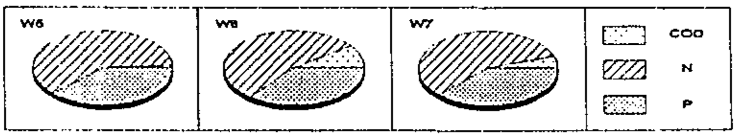


Figure 8.3 Pollution sharing rate of major pollutants in Deep Bay

8.3.3 Current Sedimentation rate

Limited core sampling of tidal flats in Inner Deep Bay indicates that there has been a doubling in the rate of sediment accumulation since the mid-1980s, with current deposition rates ranging from 2.58mm to 36.8mm (Table A9.9, Appendix 9.4). These rates are not dissimilar to current estimates from visual observations on the mudflat off Mai Po (McChesney unpublished; Table 8.6).

Table 8.6 Estimates of sedimentation rates in Deep Bay

Rate mm/yr	Time Period	Location	Reference
1.1	6000BC-present	whole Bay	Anon 1985, Yim 1984 (total deposition)
8	1898-1949	whole Bay	Wong and Li 1990 (maps)
14.9/16.6/12.7	1984-1986	outer/mid Bay	Wong and Li 1990 (^{210}Pb)
25-30	1992-1994	Mai Po	McChesney unpubl. (direct observation)
28.4-36.8	1994	Inner Bay	this study (^{210}Pb)
20-105	1994	Inner Bay/River mouth	this study (model)
36.6	1994	Mai Po	this study (model)
11	1993	Mai Po mangroves*	Duke and Kahn unpubl. (survey)
12	1986	Mai Po *gei wai***	Lee 1989

* average figure across whole mangrove area
** sedimentation within a *gei wai* - not directly comparable with other data

This apparent increase in sedimentation rate coincides with a period of rapid development within the Shenzhen River catchment, with very extensive infilling of wetlands, especially on the Shenzhen side. Runoff from filled areas after rain is frequently seen to be heavily laden with sediment and it is not unreasonable to assume that at least part of the increase in the rate of sedimentation is derived from such sources. This is supported by Table A7.7 (Appendix 7), which indicates a 1.6 times increase in estimated sediment load in the River after 1986, compared with before 1986.

8.4 POTENTIAL IMPACTS ON HYDRODYNAMICS AND SEDIMENT TRANSPORTATION

8.4.1 Changes in Hydrodynamics

Stage 1 Works

According to the results of hydrodynamic modelling presented in Section 7, no significant changes in hydrodynamics of Shenzhen River and Deep Bay are expected after the Stage 1 Works. The water surface curve in the longitudinal direction of the river would fall slightly after the Stage 1 Works (Appendix 7, Figures A7.2 to A7.4). Flow fields in both the River and the Bay would not be significantly changed (Appendix 7, Figures A7.12 to A7.14). There would be a minor increase in the tidal exchange volume (and hence flushing) and flume storage owing to the Stage 1 Works.

Stage 2 Works

The unsteady flow model for Stage 2 Works showed that the water levels under different flood frequencies (P equals to 2, 5 or 10 percent) decreased greatly after stage 2 Works (Appendix 7, Figures A7.2 to A7.4). At the upper end of the river (Sancha River Section), the water level in the river falls about 3 meters. The water level falls more than 1.2 meters at the lower end at the river mouth. The modeling results of the study are quite close to the previous results from the steady flow model undertaken by both Shenzhen and Hong Kong Authorities.

The tidal exchange of the Shenzhen River is increased due to the works, with the net increase of tidal discharge around one third (Section 7.5.1).

No significant differences in hydrodynamic of Deep Bay were predicted by the modelling results except for an increase in the tidal exchange and local increases of the tide velocity in the river mouth (Section 7.5.1).

8.4.2 Effect on Sediment Flux

Impact of Stage 1 Construction Works

The sedimentation transport model predicted that a slight increase in sediment flux from the Shenzhen River would be expected during construction of the Stage 1 Works. As shown in Figure 8.4, conservatively estimated maximum SS contents are 65-100mg/l (Table 7.15, Runs 12, 16, and 20), indicating a slight increase from baseline levels of 60-100mg/l (Table 7.15, Runs 10, 11, 14, 15, 18, and 19) at the head of the Bay.

Impact of Stage 2 Construction Works

Unlike the Stage 1 during which the main excavation works will be isolated from the river channel, more sediment would be expected to be resuspended during Stage 2 dredging than Stage 1. As predicted by sediment transport model, the SS contents in the river month will reach 150mg/l on average (Section 7.5.2) comparing to 80mg/l as a baseline (Table 7.15, Run 15).

Potential Impact after the Project

Owing to the deepened and widened channel, more sediment from upstream will deposit in the trained channel after the regulation project. The sediment flux into Deep Bay will consequently decrease significantly (Figure 8.4).

Potential Impact of Maintenance Dredging

It was predicted by the sedimentation model that within 5 years after the Stage 2 Works of the Project, a large volume of sediment will deposit immediate downstream of Lo Wu (Appendix 7, Figure A7.16 to 7.18). Maintenance dredging, therefore, will be operated in this section of the channel where is far away (6-7 km) from the river month and the sediment flux into Deep Bay caused by the works will not increase significantly comparing to Stage 2 Works.

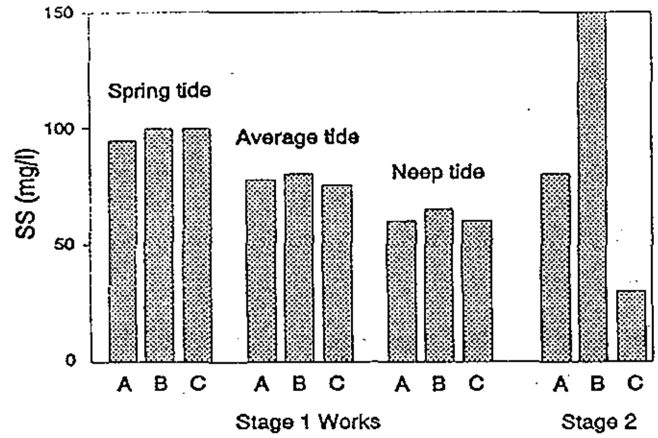


Figure 8.4 Sediment flux before(A), during(B), and after(C) Stages 1 and 2 Works

8.4.3 Effect on Sediment Erosion and Deposition

Impact of Stage 1 Construction Works

Due to the slight increase in sediment flux from the Shenzhen River, a moderate change in sedimentation rate on the mudflat would be expected during construction of the Stage 1 Works.

Calculated annual increases based on the modelling results indicate that sedimentation depth due to the Stage 1 Works would increase from 16.4mm/yr to 18.8mm/yr for Futian (D_4, Table 7.18) and from 17.0mm/yr to 19.5mm/yr for Mai Po (D_3, Table 7.18) respectively with intertidal areas in river mouth increasing from to 86.6mm/yr to 92.5mm/yr (D_1, Table 7.18).

Impact of Stage 2 Construction Works

The sediment flux from Shenzhen River to Deep Bay will increase significantly during Stage 2 Works, especially when low reach of the channel is to be dredged. Consequently, sediment deposition rate in Inner Deep Bay will increase considerably. Modelling results indicate that sediment rate in Futian and Mai Po mudflat will increase from 16.4mm/yr to 22.5mm/yr and from 17.0mm/yr to 21.0mm/yr (D_4 and D_3, Table 7.18). Within a small area of river month, a even large increase from 86.6mm/yr to 115mm/yr would be expected (D_1, Table 7.18).

The increase in sediment deposition rate in Inner Deep Bay area during Stages 1 and 2 Works are shown in Figure 8.5 (data from Table 7.18). It appears that currently only a small portion of sediment deposited in Inner Deep Bay are originally from Shenzhen River, a large increase in the sediment deposition rate due to river input during the construction works (286% on average) will cause only a relatively small rise in overall sediment deposition rate in the area (23.5% on average).

Potential Impact after the Project

The trend of the increase in sediment flux from the river and in the sedimentation rate would continue after the Stage 1 Works of the Project. The extra sediments would most likely deposit in deep channels within the River. The mud flat at the head of the Bay would not be affected significantly by sedimentation after the Stage 1 Works of the Project.

The length of the river will be reduced to 13.6km after implementation of Stages 1 and 2 of the project. The new channel will undergo a readjustment process to reach a new equilibrium condition. Since the channel upstream of Lo Wu will remain narrow and shallow, the river bed above Lo Wu will be eroded dramatically in first few years after the completion of the Stage 2 Works and gradually reach a quasi-equilibrium state. Meanwhile, there will be a large volume of sediment deposited in the section immediately downstream form Lo Wu. The potential erosion and deposition within 5 years after the Project are shown in Figure 8.6.

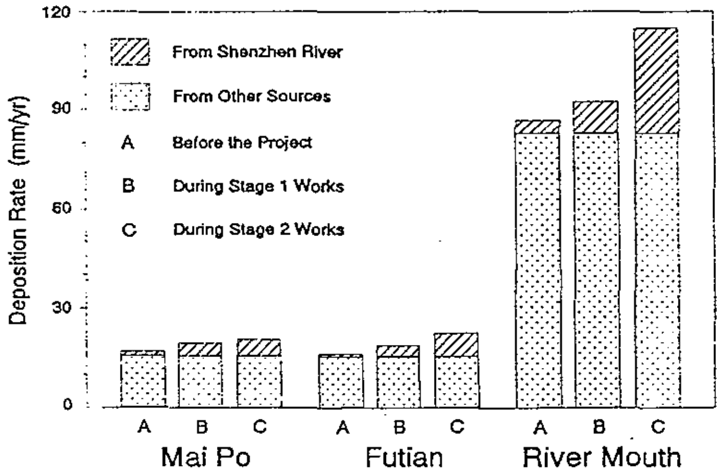


Figure 8.5 Change in sediment deposition rate after Stages 1 and 2

Upon completion of Stage 2 Works, in addition to a slight increase in hydraulic strength, a large portion of sediment carried down by the river will deposit along the new channel and the sediment flux reach the river month will decrease significantly as shown in Table 7.18 and Figure 8.4. The sediment deposition rate will drop down from 17.0mm/yr to 13.0mm/yr in Mai Po and from 16.4mm/yr to 12.0mm/yr in Futian respectively. In a small area near the river month, based on conservative modelling assumptions, the predicted deposition rate will be, at most, reduced from 86.6 mm/yr to 34.0 mm/yr.

As indicated in the modelling results in Table 7.18, deposition in the study area are shown to be mainly come from the Pearl River through the bay mouth of Chiwan and Black Point, other than from the Shenzhen River. The deep channel, therefore is the only place where flow energy concentrate and erosion takes place. For the mudflat in Futian and Mai Po, no active erosion was predicted and deposition rate would, however, be significantly reduced in the river month area (D1 in Figure 7.6).

The anticipated increase in shipping activity and disturbance on the new channel are ex pected. It is likely to be necessary to enforce a strict speed limit on shipping in the She nzhen River and Inner Deep Bay area to eliminate wake wash and erosion.

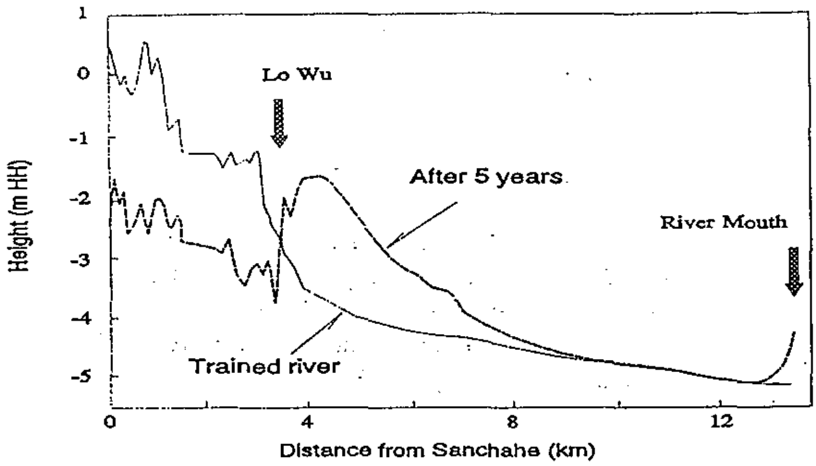


Figure 8.6 Erosion and deposition of Shenzhen River 5 years after the Project

Potential Impact of Maintenance Dredging

The settling of increased amounts of sediment in the new river channel following completion of Stage 2 Works, as shown by the model (Section 7.5.2), indicates a need for maintenance dredging. With most maintenance dredging operated in 6 km upstream from river mouth (Figure 8.6), however, sediment resuspended by maintenance dredging would be expected to deposit again in river channel before reaching river month. As a result, there is no evident impact on mudflat deposition rate would be expected.

8.4.4 Risks and Uncertainty

All predictions have been based on the results of hydrodynamic and sediment transport models described in Section 7. The modelling has been based on conservative assumptions and the models themselves are inherently conservative.

8.5 POTENTIAL IMPACTS ON WATER QUALITY

8.5.1 Direct Effect on Water Quality

Stages 1 and 2 construction works

There would be no direct influence on water quality of the Shenzhen River and Deep Bay during the construction phase of the Project, simply because pollution load will not be directly altered by the construction itself.

Operation period

According to the modelling results for Stage 1 Works, the effect of the increase in tidal exchange volume on water quality of the Shenzhen River would be a minor improvement due to greater flushing and dilution by the relatively cleaner water from Deep Bay. In absolute terms the effect of the Stage 1 Works would not be significant.

The effect of the significant increase in tidal exchange volume on water quality of the Shenzhen River would be a minor improvement according to the modelling results of the Stage 2 Works (Tables 7.20 and 7.21). However, if there is no effective control on the pollution sources along the Shenzhen River, this improvement would soon be masked by the increase in pollution loads. No noticeable improvement in water quality is likely to be measurable or observable as a result of the works.

With a significant increase in tidal exchange volume, together with a relatively short channel of trained river, the tidal influence to the upstream after the Project would be more strong than that of before. The pollutants discharged along the new channel from Lo Wu to Lok Ma Chau (the most heavily polluted reach) will be pushed up during high tide causing deterioration of water quality upstream from Lo Wu. The prediction was confirmed by the result of water quality modelling (Appendix 7, Figures A7.59 to A7.70).

Maintenance dredging

In operation phase, water quality may suffer periodically as a result of maintenance dredging of the river channel. The extent of such effects will depend on the type of equipment used, the number of dredgers employed at one time, season in which dredging is done, and most importantly, the location of dredging operation. Since most dredging will operated immediately downstream of Lo Wu (6-10 km upstream from river mouth, the impact on water quality in Inner Deep Bay would be less significant than that of Stage 1 Works.

8.5.2 Indirect Effect on Water Quality

The bottom sediments of the Shenzhen River are contaminated by inorganic and organic pollutants. The dredging operation of Stages 1 and 2 Works and maintenance will affect water quality through resuspension and release of pollutants from the sediments.

The dredging operation in the existing river course would give rise to an unavoidable increase in the concentrations of suspended materials in the lower river, the estuary and Deep Bay receiving waters. The quantity of the resuspension and the migration distance of the suspended solids downstream would depend largely on the flow rate at the time of dredging. Generally, less suspended solids will be produced and they will travel shorter distances during the dry season.

Since the water of the Shenzhen River is heavily polluted the increase in pollutant content from resuspended solids is unlikely to cause a noticeable effect in river water. The distortion in water quality of Deep Bay due to the release of contaminants from the river's resuspended solids, however, will cause potential impacts.

According to the model prediction of Stage 1 Works, during non-flood period, the maximum suspended sediment contents (during high tide) will be 320mg/l and 360mg/l (90mg/l and 100mg/l on average) before and during the construction period, respectively (Table 7.15, Runs 11 and 12). Estimated increase in SS content during the dredging operation of the Stage 1 Works would not, therefore, exceed 40mg/l (10mg/l on average), less than 20% of the total concentration of the SS content at the head of the Bay.

The results of the elutriate tests (Section 4.3.6) shown in Table 8.7 indicate that the percentages of increase in pollutant concentration in sea water after mixing with contaminated sediments at a ratio of 1,000:1(w/w) are generally less than 30%, and a maximum of 60% for Pb. Although the linear extrapolation of the results to a much lower SS content is not valid, it is apparent that no more than a 5% increase in all pollutant concentrations is expected at a SS increase of 40mg/l. Since 40mg/l is a conservative estimation, it can be concluded that no significant impact on water quality at the head of the Bay will be caused by the release of pollutant from the re-suspended solid due to the Stage 1 Works.

Table 8.7 Results of the elutriate tests(mg/l)

	(w/w)	TN	TP	COD	Cu	Pb
River Water	no sediment	26.97	2.82	19.39	0.018	0.048
	1:100	24.50*	0.55*	20.13(3.8%)	0.014*	0.048*
	1:1000	28.48(5.6%)	1.87*	21.06(8.6%)	0.014*	0.048*
Sea Water	no sediment	5.98	1.41	6.36	0.014	0.0016
	1:100	8.67(47%)	0.14*	7.93(25%)	0.014*	0.0019(19%)
	1:1000	7.66(28%)	0.95*	4.98*	0.014*	0.0026(63%)

* decrease due probably to adsorption or degradation

Modelling results show that during dredging operation of Stage 2 Works, a 2-day average SS concentration would be 150 mg/l (Section 7.5.2), comparing to 80 mg/l before the Project (Table 7.15, Run 15). This is a significant increase in comparison with Stage 1 Works and could give rise to water quality effects due to release of contaminants.

As for the Stage 2 Works, a 70mg/l increase in SS content (150mg/l - 80mg/l) will cause less than 10% (the most conservative estimation) increase in pollutants released. Due to large volume of tidal flow and quick dilution of the contaminated river water by marine water, pollution effects caused by release of contaminants from suspended sediments would be localised confined to a small area of river month.

The predicted increase in SS contents are conservative estimates in the worse case. It is, therefore, environmentally acceptable with implementation of following mitigation measures (Section 8.6.1 and 8.6.2).

It is anticipated that there will be an increase in shipping using the River and Inner Deep Bay as a result of the project and thus there may be an increased risk of oil spills in both the River and Deep Bay. Oil could adversely impact mangroves, benthos and other wildlife. Hong Kong already has a contingency plan for dealing with oil spills in the marine waters of the Territory, but this does not extend to the Shenzhen River. It will be necessary to formulate an oil spill contingency plan, together with an assessment of current regulations concerning shipping traffic in the area jointly between Hong Kong and Shenzhen.

8.5.3 Risks and Uncertainty

All predictions have been based on the results of hydrodynamic and water quality models described in Section 7. The modelling has been based on conservative assumptions and the models themselves are inherently conservative.

8.6 MITIGATION MEASURES

8.6.1 Construction Methods

The use of a works method which isolates the main excavation works from the river channel in Stage 1 Works will reduce the extent of environmental risk from the Project.

One of the key issues arising from the Project is the resuspension of the sediment during the dredging operation. The selection of dredging equipment is identified as the key mitigation measures to protect water quality.

Mott MacDonald (1991) compared sediment resuspension characteristics of various dredging plant using the S factor, which is a ratio between the amount of sediments resuspended (in kg) to the amount of sediments dredged (in m^3). The larger the S factor, the more sediments would be resuspended and pass out of the immediate area (typically about 50 m from the dredger) of the dredging operation. The same report also described the operation of a number of dredging plant and indicated that the auger suction dredger was adopted to work in very soft soils in shallow waters. The S factor for small auger suction dredgers was 5 kg/m^3, which was the same as a closed grab dredger with silt screen. Without silt screen, the S factors for a closed grab dredger and an open grab dredger were 20 and 25 kg/m^3 respectively. At a reduced rate of advance, the auger suction dredger can possibly achieve an S factor of 3 kg/m^3.

Since auger suction dredgers can operate at a much higher rate, the dredging losses per unit time and hence the suspended solid levels in the water column generated by auger suction dredgers could be higher than that by grab dredgers. Dredging by auger suction dredgers will also increase the bulk volumes of the spoils which in turn will demand greater dumping capacities and effluent treatment facilities. These aspects should be looked at during the detailed design.

In an EIA study for the main drainage channels for Ngau Tam Mei, Yuen Long and Kam Tin (BRM 1995), the extent of sediment plume dispersion on the Kam Tin River based on the above S factors was calculated for closed grab and auger suction dredgers. A 525% increase in SS level could be expected at a distance of 51 m downstream of a closed grab without silt screen. With an auger suction dredger or a grab dredger with silt screen, SS increase would be 131% at the same distance downstream. At 150 m downstream, SS increase was estimated at 52% for a closed grab without silt screen and 13% for an auger suction dredger or a closed grab with silt screen.

Selection of dredging method should be carefully considered during the detailed design. If a silt screen can not be installed and maintained during the operation due to marine traffic, the auger suction dredger is superior to the grab dredger. Otherwise, grab dredgers undoubtedly offer the greatest flexibility due to their ability to work in very shallow water and handle debris and rubbish with relative ease. Sediment loss could be minimized by using specialised equipment such as sealed grabs, or by adopting special methods such as reducing the grab lowering and hoisting speeds. The production rate of grab dredgers is much lower than suction dredgers and the resulting loss of production with respect to programming would be a constraint for the Project, unless several grabs or sealed grabs can be deployed simultaneously to make up for such loss.

8.6.2 Works Programme

Benefit can be gained from the timing of the works. The worse case of resuspension of sediments during dredging can be easily avoided if the construction is programmed in dry season. By reducing significantly the quantity of sediment resuspended and transported downstream, the risk of any significant effect of the works on downstream sedimentation and water quality will be reduced greatly.

Similarly the timing of the opening of the channel can be used to reduce any possible downstream effect. Opening the channel during a period of low river flow and low tides will greatly reduce sedimentation risks.

8.6.3 Stage 3 Works of the Project

As predicted by sedimentation modelling (Section 8.3.3) that active erosion will occur upstream of Lo Wu and a large volume mud material will deposited in trained new channel downstream of Lo Wu within a period of 3-5 years (Figure 7.6).

To reduce mud volume which has to be dredged and disposed of during maintenance period and to protect the bridges at Lo Wu which could be damaged, it is, therefore, recommended that the construction works be followed by Stage 3 works of the Project, which will mainly deepen and widen the old channel upstream of Lo Wu.

By consequently carrying out the Stage 3 works immediately after the first two stages, total volume of spoil to be dredged and disposed of during maintenance period of 5 years will be cut down dramatically while no special erosion protection works at the transition near Lo Wu will be required.

References

BRM Hong Kong. 1995. Main drainage channels for Ngau Tam Mei, Yuen Long and Kam Tin: EIA study for Kam Tin Section ($#CD) and village flood protection works (30 CD). Final Report prepared for the Territory Development Department, NTN Development Office.

Mott MacDonald Hong Kong Ltd. 1991. Contaminated spoil management study. Final Report (Agreement CE 30/90) prepared for the Environmental Protection Department, Hong Kong Government.

Coments on the Interrelationship between Course Way and Shenzhen River Regulation Projects (SRRP)

As requested by Hong Kong EPA, additional comments for the potential impacts of Course Way from Shekou to Futian through Deep Bay are also roughly stated as follows. The construction of project of Course Way will inevitably change the local boundary conditions in the north side of Deep Bay which is within the area of EIA for Shenzhen River reguiation project and thus will result in, more or less, some local variations in characteristics of hydrodynamics, water quality and sediment transport in the bay. The other environmental impacts resulted from the project will be minor and temporal, and easy to be controled by proper mitigation measures.

1. Construction of Course Way will not change the essential conclusion that SRRP is beneficial environmentally

The principal purpose for Shenzhen River Regulation Project is to incease the capacity of flood protection and to improve water quality in Shenzhen River. In addition, the predicted results from the modellings in EIA of Shenzhen regulation project have clearly shown the obvious positive effects of the project.

Note that the impact area is limited to the whole river and the ambient region of the river mouth, the finite variations in hydrodynamics and water quality will unllikly to change the function of SRRP. In other words, SRRP will be beneficial environmentally no matter if the Course Way is constructed or not.

2. Construction of Course Way will not increase the habitat losses due to SRRP

It is almost independent for the two items of projects in resulting in habitat losses. As for the loss of 20 ha of mangroves as well as 95 ha of fishponds resulted from SRRP, the corresponaing mitigation measures have been given in the present report.

3. Construction of Course Way will not increase the sediment yields due to SRRP

According to the modelling results presented in the EIA report for SRRP, the sediment transport characteristics in Deep Bay, including Maipo and Futian National Nature Reserve, are primarily controled by the Pearl River rather than Shenzhen River. The impact of the Course Way project on the sediment transport in Deep Bay is something similar to that of changed sediment concentration into the bay from the bay mouth. If the sediment concentration variation is limited to some extent as discussed in EIA report, the variation of accumulative volume of sediment aggradation and degradation in the bay within certain time span will not be changed significantly, in particular to the river mouth region. Therefore, the orgional assessment on the ecological impact of the project will hold correspondingly.

In summary, the construction of Course Way is possibly to result in certain impacts in the ambient area of the project on the characteristics of hydrodynamics, water quality and local sediment transport, but it will not change the essential assessement conclusions that SRRP is beneficial both environmentally and economically. The detailed examination of the impact of Course Way should be made in specific studies basing on the complete data related to the project.

9 SEDIMENT QUALITY AND SPOIL DISPOSAL

9 SEDIMENT QUALITY AND SPOIL DISPOSAL

9.1 INTRODUCTION

Potential environmental impact may be caused by the disposal of dredged mud resulting from the Project. Assessment of river sediment quantity and quality, options of spoil disposal, potential impacts caused by transportation and disposal of the dredged spoil, and mitigation measures recommended are addressed in this section.

9.2 APPLICABLE REGULATIONS, STANDARDS AND GUIDELINES

9.2.1 Hong Kong Legislation and Standards on Contaminated Sediments

A license would be required from the Environmental Protection Department for marine disposal of contaminated mud. Dredged sediments are classified into three categories according to their level of contamination by toxic metals (Table 9.1, refers to Technical Circular No. [TC] No. 1-1-92). There is no classification criteria for hydrocarbon levels in sediment.

Table 9.1 Hong Kong Classification of Sediments by Metal Content (mg/kg dry weight)

Class	Cd	Cr	Cu	Hg	Ni	Pb	Zn
A	0.0-0.9	0-49	0-54	0.0-0.7	0-34	0-64	0-140
B	1.0-1.4	50-79	55-64	0.8-0.9	35-39	65-74	150-190
C	>1.5	>80	>65	>1.0	>40	>75	>200

The requirements for disposal of the three categories of mud are as follows :

Class A Uncontaminated, for which no special dredging, transport, and disposal methods are required;

Class B Moderately contaminated, which requires special care during dredging and transport, and which must be disposed of in a manner which minimises the loss of pollutants either into solution or by resuspension;

Class C Seriously contaminated, which must be dredged and transported with great care, which cannot be dumped in the gazetted marine disposal ground and which must be effectively isolated from the environment upon final disposal.

For Class C materials, a site in East Sha Chau has been designated for their disposal.

9.2.2 PRC Legislation and Standards on Contaminated Sediments

There is no standard or regulation for disposal of sediment or dredged mud in the PRC.

9.2.3 Reconciliation of Standards on Contaminated Sediment

Dredged spoil to be disposed on the Hong Kong side will be classified into 3 categories according to the HK standard and will be treated respectively.

On the Shenzhen side, Hong Kong's classification was referred for marine disposal and Hakanson's (1981) Potential Ecological Risk Index was applied to evaluate sediment quality and to assess potential environmental impact of land disposal. The preindustrialisation maximum background values were adopted as references for calculation of the index and the ratio of the biotoxicity of the elements to geochemical abundance was used for the assessment. Detailed calculation procedures are given in Appendix A9.3.

9.3 EXISTING CONDITIONS ON THE CONTAMINATION OF SEDIMENT AND SOIL

9.3.1 Qualities of Sediments and Bank Soils

The Shenzhen River has not been dredged for many years, nor has pollution discharge been controlled. Therefore, unconsolidated sediments on the river bottom are polluted. The bottom sediments of Inner Deep Bay have also been polluted to some extent. The contents of various pollutants including heavy metals in sediments from the Shenzhen River, Inner Deep Bay, adjacent fish pond and *gei wais*, as well as bank soils measured under the monitoring scheme of this study are listed in Appendix A9.1 (and Database Management System in diskette format) and summarized in Table 9.2. The Potential Ecological Risk Index (RI) calculated using metal contents and Hong Kong's classification based on each metal are tabulated in Table 9.2 as well.

Table 9.2 Monitoring results of surface sediments and soils (mg/kg, dry)[1]

Stations[2]	Cr	Cu	Hg	Ni	Pb	Zn	Cd	RI[3]	DDT	HBC
Bank Soil(S1-S3)	60.9	39.7	0.15	27.7	65.2	67.1	0.27	42	nd	0.04
River Mouth Sediment(C5)	**93.2**	57.7	0.20	38.7	32.6	**221.7**	0.14	48	nd	nd
Fish Pond Sediment(C6)	53.0	21.7	0.07	23.1	49.0	122.7	0.08	21	nd	5.77
Gei Wai Sediment(C7-C8)	**95.5**	30.5	0.15	**42.3**	**75.5**	166.4	0.09	38	nd	nd
River Sediment(C1-C4)	**93.5**	**83.7**	0.30	39.8	72.8	**311.7**	0.29	74	nd	nd

1 Classes A, B and C (based on Hong Kong Classification) are shown by normal, underline, or bold font respectively

2 sampling locations are shown in Section 4, Figure 4.4

3 Potential Ecological Risk Index (Appendix A9.3)

nd non-detectable (detection limits: DDT 0.02 mg/kg, HBC 0.01 mg/kg)

Of the three samples collected on the north bank of the Shenzhen River, soil from Yumin Village showed considerably higher metals levels than those from Zhuanmatou and Yunong Village, which are within the background range of the area (Shenzhen Environmental Monitoring Station 1990). Traces of DDT, HBC and PAHs were detected at some samples (Appendix A9.1 and A9.2).

According to the baseline monitoring results listed in Table 9.2 and Appendix A9.1, the sediment samples, especially those from the river bottom, are seriously contaminated by oxygen consuming organics, characterized by high contents of organic matter and negative

Eh values. The abundances of heavy metals are also higher than local soil background (Shenzhen Environmental Monitoring Station 1990).

Metal levels were in general higher at the Yumin Village station than those at other stations. The contents of both DDT and HBC in the river and bay sediments are very low (Appendix 9, Tables A9.4 and A9.6). Based on metal levels, sediments in the river and inner Deep Bay, except those in the vicinity of Zhuanmatou, were Class C materials according to the Hong Kong classification scheme, mostly due to high levels of chromium, copper and zinc. Sediments at Zhuanmatou were Class B materials.

On the other hand, however, the calculated Potential Ecological Risk Index based on metal contents is 74 (Table 9.2) much less than the upper limit of mild ecological hazard of 150 (Appendix A9.3), indicating that the river sediments have only mild, if any, ecological hazard to terrestrial ecosystems when to be disposed of on land (Hakanson 1981).

The fish pond sediments showed comparatively low metals levels but this was the only station where the pesticide HBC was detected. *Gei wai* sediments also show low metals levels except arsenic which was considerably higher than at other locations.

Five core samples were collected within the works area along the Shenzhen River (C1 to C5 in Figure 4.3). The samples were sliced and measured for metal contents at various depths. The data are presented in Appendix A9.2 and the vertical distributions of metal contents along the profile of C3 are presented in Figure 9.1 as an example (similar pattern of vertical distribution was observed for metal contents along other core samples). It is demonstrated that the contents of the heavy metals are randomly varied vertically and the sediments are more or less equally contaminated within the observed depth.

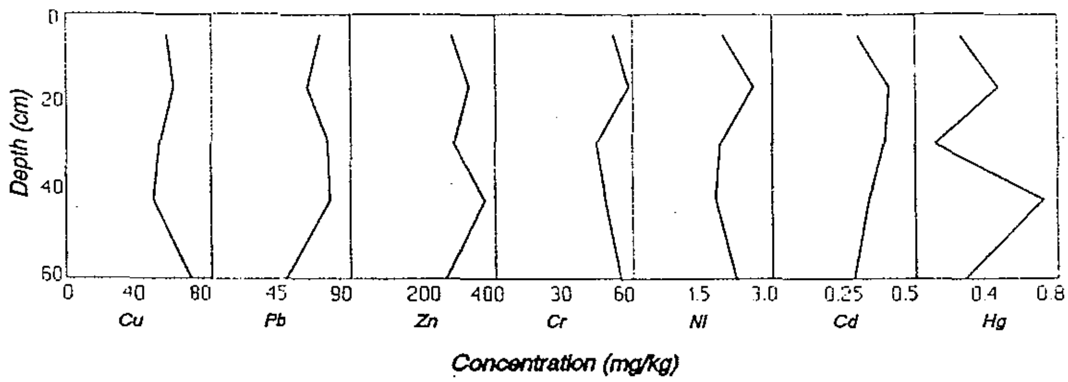


Figure 9.1 Vertical distribution of metal contents in river sediment(C3)

Due to the limitation of hand-held sampling corer and compactness of the sediment, the depth of the core samples collected was limited to the upper 60cm. The thickness of the unconsolidated mud at these locations was measured by hand and is listed in Table 9.3. Since there was no significant change in metal discharge load into the river system during the past decade, it is assumed that the vertical variation pattern showed in Figure 9.1 may be extrapolated to represent the situation along the whole profile of the unconsolidated mud.

Table 9.3 Depth of unconsolidated mud in the Shenzhen River

Sample *	C1	C2	C3	C4	C5
depth(m)	1.5	1.2	0.95	1.8	1.9

* sampling locations are shown in Figure 4.3

9.3.2 Quantities of Dredged Spoil

Most of the Stage 1 Works will be completed in isolation from the existing river channel. The dredged materials from these sites will not be contaminated. Only portions of the existing river channel measuring 70,000 m^2 will be dredged. The dredged spoils from near or below the old river channel will be contaminated. The average thickness of the bottom mud in the existing river channel at Liu Pok and the Lok Ma Chau Bend is conservatively estimated to be 0.8 m. The polluted spoils which must be placed in the fish ponds will total 56,000m^3. Contaminated spoils will constitute only 3-4% of the total amount of dredged spoils.

Since the Stage 2 Works inv[illegible]inly dredging operations in the existing river course, a relatively large volume of contaminated spoil has to be handled with care. The total area of old channel to be dredged during Stage 2 Works measured using GIS technique was approximately 0.5 Mm^2. Taking average depth of mud of 1.5m (medium value of measured depth of unconsolidated mud shown in Table 9.3), the total volume of contaminated mud to be dredged, therefore, was estimated to be 0.75Mm^3 (all from the main works of that stage).

Based on modelling results (Table 7.13), after the completion of the Project, roughly 0.11Mm^3 of sediment will be deposited in the first year and another 0.12Mm^3 during the following two year period in the trained river channel. This will result in the need for maintenance dredging. The total volume of maintenance dredging during 5 years after the completion of the Project would be around 0.38Mm^3.

To sum up, a relatively larger portion (25%) of dredged spoil from Stage 2 Works (as dredging would be mainly in the existing river channel) will be contaminated mud (0.75 Mm^3 out of 3.04 Mm^3) comparing to less than 4% from Stage 1 Works (as open excavation would be mainly at the new straightening channel) (0.056 Mm^3 out of 1.7 Mm^3) (Table 9.4). The contents of heavy metal are generally higher than background values and are uniformly distributed along the vertical profile. The dredged spoil are basically Class C material according to Hong Kong's classification of contaminated mud for marine disposal (Table 9.2). The calculated Potential Ecological Risk Index (74), however, is well below the upper limit of mild ecological hazard of 150 (Appendix A9.3, Hakanson 1981), indicating minor potential impact of the material to terrestrial ecosystems.

Table 9.4 Volume of mud to be dredged during construction and maintenance phases (Mm^3)

	Total volume	Volume of contaminated mud
Stage 1 Works	1.70	0.056
Stage 2 Works	3.04	0.75
5 years maintenance	0.38	0.38

The values estimated in Table 9.4 are final volumes after consolidation, which are usually much smaller than those of dredged mud before dewatering. It is estimated mud volumes will double if mechanical methods are to be used for dredging and the volume will increase by around four times for hydraulic dredging.

9.4 OPTIONS FOR DREDGED SPOIL DISPOSAL

9.4.1 Sites of Disposal for Stage 1 Works

According to the design, dredged material from Stage 1 Works will be disposed of in the old River channel at Liu Pok and in the fish ponds in the Lok Ma Chau bend. The method of disposal was detailed in "Study Report for Stage 1 Works"

9.4.2 Possible Marine Disposal sites for Stage 2 Works

Detailed planning for disposal of spoil dredged during Stage 2 Works has not been decided yet. Possible dumping sites for contaminated or uncontaminated spoil currently used by both governments are listed as follows.

- Uncontaminated mud to Shekou reclamation, Shenzhen;
- Contaminated sediment to approved contaminated mud pits in East Sha Chau, Hong Kong;
- Uncontaminated sediment to approved disposal sites south of Tsing Yi or North of Lantau Island, Hong Kong;

As there is enough capacity at Shekou site, the uncontaminated spoil dumping sites in Hong Kong (i.e. the Tsing Yi/North Lantau sites) might not be required.

All these are marine dumping sites, of which, East Sha Chau on the Hong Kong side is the only one can be used for contaminated sediment disposal. It should be pointed out that even the East Sha Chau marine dumping site was purposely designed for disposal of material from marine engineering works and its remaining capacity is not necessary sufficient to accommodate the disposal requirements of Stage 2 Works (0.75 Mm^3 of contaminated channel sediment) and subsequent maintenance dredging requirements (0.38 Mm^3 of contaminated mud).

Although there is no PRC regulation governing the disposal of contaminated mud, it would not be environmentally acceptable to use contaminated sediments for reclamation in Shekou unless it can be ensured that contaminants are totally isolated from the environment during reclamation and from future end users upon completion of reclamation.

If the disposal sites are confined to these alternatives, therefore, a large quantity of dredged mud of Class C material has to be transported to a long distance to East Sha Chau.

9.4.3 Possible Land Disposal Site for Stage 2 Works

Article I of London Convention (Her Majesty's Stationery Office 1976, Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter) requires contracting Parties 'to take all practicable steps to prevent the pollution of the sea by the dumping of waste and other matter that is liable to create hazards to human health, to harm living resources and marine life, to damage amenities or to interfere with other legitimate uses of the sea'.

In view of environmental performance of the operation, as well as the operational cost, the possibility of using the Lok Ma Chau Bend as an alternative on land dumping site was studied by the Consultant. Figure 9.2 shows the location of Lok Ma Chau land-based dumping site. A schematic diagram of the proposed dumping pit is given in Figure 9.3. Detail arrangements (such as: design of capping layer, embankment, sedimentation pit and weir design, laboratory and field tests programme) should be further evaluated and studied in the Detailed Design of the Stage 2 Works.

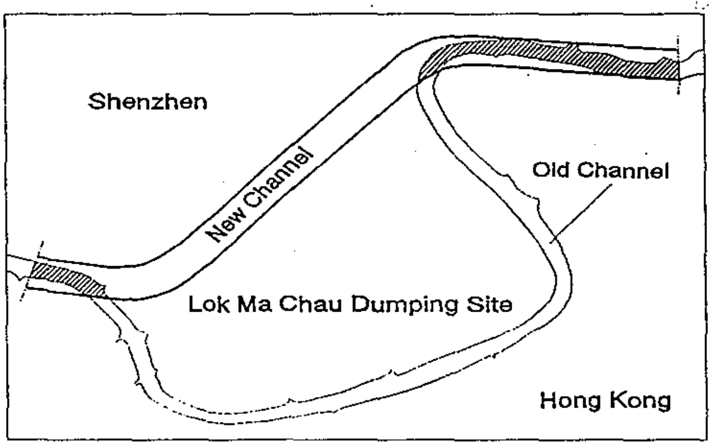


Figure 9.2 Location of Lok Ma Chau dumping site

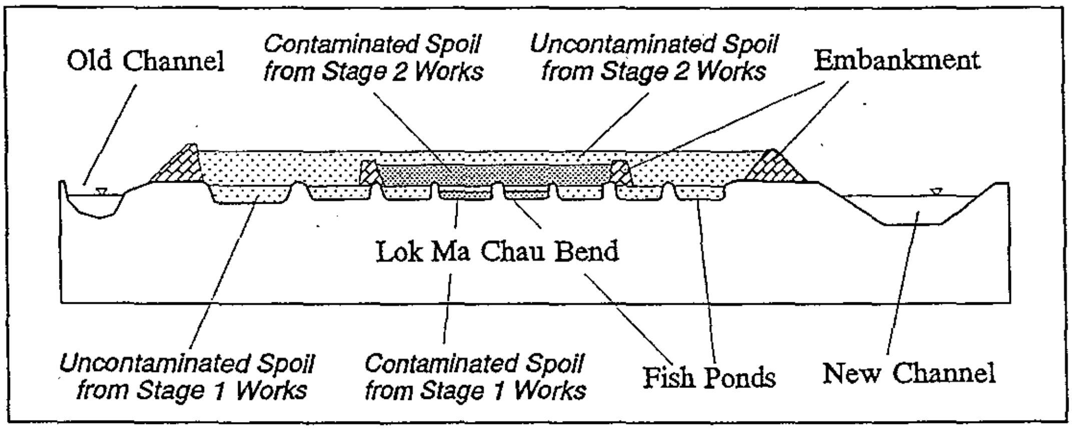


Figure 9.3 Schematic diagram for the Disposal of spoil at Lok Ma Chau Bend

According to available information, capacity of Shekou reclamation site, where is much closer to the construction area than other proposed sites, is large enough to handle all uncontaminated mud from the Project.

With a total area of 84 ha (0.84 Mm^2) enclosed by the old and new river channels, the dredge spoil can be dumped at the Lok Ma Chau Bend area. As stated in the "Study

Report for Stage 1 Works", disposal of contaminated and uncontaminated mud from Stage 1 Works would fill up 65 ha fish ponds. If the whole area can be embanked and piled with dredged material to 3 m (or 2.5 m) height, it will create a further capacity of 2.5Mm³ (or 2.1 Mm³). In that case, not only all contaminated mud (0.75Mm³) and a portion of uncontaminated material (0.8 Mm³ as 1m thick capping material) from Stage 2 can be disposed of on land, enough capacity can also be reserved for future maintenance dredging for at least 5 years (0.38 Mm³ for the first 5 years and the volume would decrease afterwards).

9.4.4 Options for Dredged Spoil Disposal for Stage 2 Works

Based on all alternative sites, two options were thus developed for dredged mud dispos al. The major difference between the following two options is the way of dumping the heavy metal contaminated mud on land or at sea. The environmental impacts of these options and the Consultant's recommendation based on the analysis are addressed in Section 9.5.

Option A

Contaminated mud from Stage 2 Works is to be disposed of at the Lok Ma Chau Bend on top of Stage 1 disposal site, covered and embanked with clean material (Figure 9.3). Uncontaminated materials can be either used as capping material at the Lok Ma Chau Bend disposal site or shipped to and dumped at the marine dump site 20 km west in Shekou on the Shenzhen side.

Option B

Contaminated mud from Stage 2 Works is to be shipped to approved contaminated mud pits in East Sha Chau, Hong Kong, while uncontaminated sediment can be treated in the same manner as Option A.

The volumes of mud to be disposed of (Table 9.4) are given in Table 9.5.

Table 9.5 Volumes of mud from Stage 2 Works to be disposed of

Option	Contaminated mud	Uncontaminated mud for disposal of	Uncontaminated mud for capping
A	0.75Mm³	1.49Mm³	0.8Mm³
B	0.75Mm³	2.29Mm³	

9.5 POTENTIAL IMPACTS FROM DREDGED SPOIL

9.5.1 Impact from Marine Disposal of Contaminated Spoil

The coastal environment of the Pearl River estuary has already been contaminated by heavy metals (Zhen Jianlu 1992). Desorption and release of heavy metals from disposed fresh water sediment into the water column of Pearl River Estuary have been demonstrated in the literature (Li Yongfei 1983, Luo Weiquan 1984, Zhen Jianlu 1985). The introduction of more contaminated sediment into the estuarine environment can lead to a significant increase in metal contamination (Förstner 1983). The impacts can be indirect or direct, long-term or short-term (Windom 1976). The release of these heavy metals from the contaminated mud during and after disposal into coastal water could be dangerous to marine organisms (Parrish *et al.* 1989, Langston 1990).

According to Hong Kong's criteria for marine disposal of contaminated mud (PRC has no such standard), the bottom sediments (total 0.8Mm^3) from the old river dredging are severely polluted by heavy metals, especially copper, chromium and zinc. According to the dredged spoil classification standards of Hong Kong, they are class C materials. If they were to be disposed of in Hong Kong, they must be transported to East Sha Chau and requires intensive monitoring and other engineering works. On the Shenzhen side, however, there is no marine dumping site currently available, which has been assessed for contaminated sediment dumping. Shekou reclamation on the Shenzhen side provids dump site for uncontaminated mud only.

For disposal of contaminated and uncontaminated sediment at approved sites in Hong Kong, environmental impacts from such disposal should have already been assessed prior to site designation for such use.

9.5.2 Impact from land Disposal of Contaminated Spoil

Landfill is believed to be, by far, the most prevalent final disposal procedure for solid waste but the problem of potential contamination of surrounding land or water tables due to plant uptake or the leaching of heavy metals from the sludge must be considered (Sittig 1976).

Plant uptake

Plant uptake of heavy metals has been intensively investigated and it is well established in literature that plants accumulate heavy metals in response to their availability in the soil. However, a large fraction of metals in the soil is strongly bound to clay and organic matter and will not be readily available for plant uptake even in soils or sediments with higher level of metals and lower contents of organic matter and clay than those in Shenzhen River sediment (Central Unit on Environmental Pollution, Dept of Environment 1974, Bartlett and James 1979, Wu Yanyu and Zhou Qixing 1992, Xia Jiaqi 1992, Bengtsson and Tranvik 1989). It is apparent that it would be much safer to store contaminated mud on land than to dump them at sea.

The possible ecological hazards of heavy metals in mud to the terrestrial ecosystem can be evaluated using Hakanson's index. The calculated index is 74 for the river sediments, indicating that only mild ecological hazard is expected if the contaminated spoil is to be disposal of on land (Table 9.2 and Appendix A9.3).

More serious problems may occur when dredged materials are deposited onto agricultural areas. Although some components, for example, P, N, and K may be beneficial for plant growth, other elements, especially Cd, Cu, and Zn can be harmful and may even lead to metal enrichment in foodstuffs (Förstner 1983).

Allowable applications of several heavy metals for US cropland soils are listed in Table 9.6 (Lee *et al.* 1991). The contents of almost all metals except zinc (measured concentration is 312 mg/kg comparing to 304 mg/kg allowable) in sediments from the

Shenzhen River are less than those tabulated, suggesting that the metals at the current level are acceptable to farmland.

Table 9.6 Comparison of heavy metal levels in Shenzhen River sediments and allowable applications on US cropland (mg/kg)

Metal	Pb	Zn	Cu	Ni	Cd
Measured Content *	72.8	311.7	83.7	39.8	0.29
Allowed Conc. for US Cropland Soils **	511.0	304.0	144.0	82.0	2.7

* from Table 9.2
** Median of background concentration in surface soils + allowed application

According to the development trend of the Shenzhen area, the site will certainly not be used for agriculture purpose. In that case, heavy metals will not enter the human food chain through crops.

A general classification of soil contamination (Table 9.7) was provided by the Greater London Council Definitions (Kelly 1980). The classification is based on a policy of clean-up to a level suitable for any use. It offers a quantitative means of assessing contamination levels (Hobson 1993). The ranges of metal contents in uncontaminated soils are compared with measured metal contents in Shenzhen River sediments in Table 9.7. It should be noted that the standards for copper, nickel, and zinc are given as contents of available fraction. It has been well demonstrated by many fractionation studies that in most soils or sediments, especially those with high organic matter contents and clay material, the available fraction of heavy metals is usually a very small portion (usually several percent or less) of the total contents (Nissenbaum 1972, Gibbs 1973 1977, Eganhouse *et al.* 1982). It can be, therefore, concluded that the sediments from the Shenzhen River is acceptable to be disposed on land-based disposal site. Detailed arrangement, however, should be worked out in the Detail Design of Stage 2 Works.

Table 9.7 Comparison of metal content(mg/kg) in Shenzhen River sediment and typical range of uncontaminated soils following Greater London Council Definitions (Kelly 1980)

Metals	Cr	Cu	Hg	Ni	Pb	Zn	Cd
Content in Shenzhen River sediment*	93.5	83.7	0.30	39.8	72.8	311.7	0.29
typical values for uncontaminated soils**	0-100	0-100*	0-1	0-20*	0-500	0-250*	0-1

* Listed as contents of available fraction of the total amount (after Lee *et al.* 1991)
** Defined by Greater London Council Definitions

Contamination of ground water

Contaminated wastes have long been recognized as potential sources of groundwater pollution (Moriyama *et al.* 1989, Vedy and Greter-Dimergue 1989). The hazards to groundwater from addition of contaminated wastes depend on a number of factors. In a series of papers LeGrand (1964, 1965, 1967) discussed the management problem of the ground water pollution and indicated that management requires that the hydrogeological environments be classified along lines of the relevant factors including permeability, sorption, hydraulic gradient, position of water table, and distance from contamination source.

The permeability of the fish pond mud and the underlying marine mud is expected to be low. Based on 35 boreholes drilled from fish ponds in the northwest New Territories in Hong Kong (Maunsell Geotechnical Services Ltd 1993), the vertical profile of fish pond substrata includes on the average 2m pond mud (soft to firm sandy clay/silt), 3m marine deposit (soft to slightly sandy clay/silt with occasional shell fragments) and 15m of underlying alluvium. Laboratory tests on cores taken from these boreholes indicated an average permeability of $1.6x10^{-9}$ m/s for pond mud and marine deposit. This is equivalent to a 1m migration in 20 years and can thus be regarded as practically impermeable.

In addition to the low permeability of the underlying material at the proposed disposal site, the high affinity of most heavy metals to either organic fraction, or clay particles has been well demonstrated by many studies (Chao 1984; Robinson 1984; Shuman 1986; Belzile *el al.* 1989; Rule and Alden 1990). Gupta and Chen (1975) confirmed that sulfides and organic bound metals are two major reservoirs for heavy metals in anaerobic dredged material. Rule and Alden (1992) reported that up to 92% of Cd added as soluble Cd compounds into an anaerobic estuarine sediments was converted into sulfide and organic bound fractions and became immobilised within 2 weeks. Wanger (1992) evaluated the retention of heavy metals in sludge by a clayey subsoil with organic matter and clay contents similar to those in Shenzhen River sediment and reported that heavy metals had been totally retained and the risk of heavy metal migration to groundwater was deemed to be extremely low.

The chemical partitioning of studied metals between water soluble and insoluble fractions of sediment matrix strongly suggested that after disposal the equilibrium will shift towards immobilisation (Nissenbaum 1972, Gibbs 1973 1977, Eganhouse *et al.* 1982). The results of the elutriate tests given in Table 8.6 show that the concentrations of copper and lead in river water with contaminated sediment added were the same as, or even lower than, those in the raw river water sample, indicating very low leaching potential for copper or lead in fresh water. The adsorption tendency of metals by sediments under anaerobic conditions should be even stronger than that under the conditions of the elutriate tests (Rule and Alden 1992).

In order to identify the potential for leachate production, the European Community Directive on the landfill of waste has suggested the use of leaching (elutriate) tests to provide qualitative information on the composition of leachates and mobilised potentially toxic substances (European Community 1991). The classification standards based on the test results suggested by the EC are tabulated in Table 9.8 together with the elutriate test results on Cu and Pb from this study. It is obvious that the metal concentrations in leachates from Shenzhen River sediments are 1 to 2 orders of magnitude lower than those from hazardous waste identified by the European Community Directive on landfill of waste.

Compared to marine disposal or upland dumping, the heavy metal contaminated material will only be moved from the bottom of the old river channel to adjacent land immediately next to it. The disposal site is surrounded by the old and new river channel. From a regional points of view, as shown in Figure 9.4, none of the factors including permeability (for water) and affinity (to metals) of the underlying material, the distance from the mud to the groundwater table and the hydraulic gradient between them, will be changed, implying that the pathway of heavy metals from the sediment to groundwater will be identical before and after dredging and disposal. In other words, regardless whether there is any connection between metals in the river bottom sediment and groundwater, the basic situation of the region will not be changed as a result of the Project.

Table 9.8 Waste classification standards(mg/l) for assessing leachate potential based on elutriate test

Metals	Eluate conc. (1:100)*	Eluate conc. (1:1000)*	Hazardous waste defined by EC**
Cu	0.014	0.014	2-10
Pb	0.048	0.048	0.4-2.0

* See Sections 4.5.4 and 8.3.4 for detailed methodology
** Elutriated concentration for hazardous waste designation, after European Community (1991)

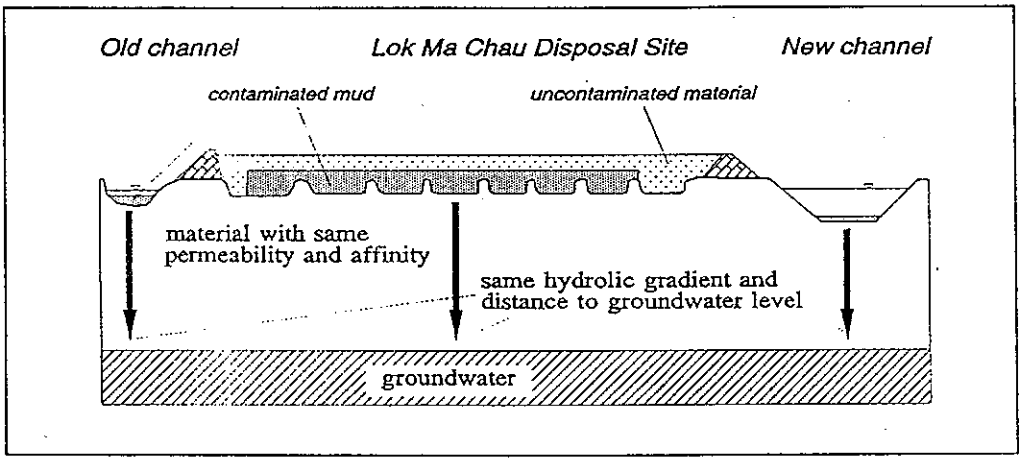


Figure 9.4 Comparison of pathways to groundwater from river bottom and disposal site

Erosion of surface runoff

The water quality effects of the effluent discharge during active disposal operations have been identified as one of the greatest environmental impacts of dredged material disposal. The dredged material placed in the disposal pit will undergo sedimentation, while clarified supernatant waters are discharged from the site as effluent during active dredging operations. The effluent may contain levels of toxic dissolved and particulate-associated contaminants. A large portion of the total contaminant level is particulate-associated. Suitable tests, e.g. modified elutriate test should be carried out to evaluate effluent water quality and to detail the design of sedimentation facility and the need for treatment to meet to water quality criteria. The prospect of discharging the effluent to any public foul sewer should be explored. Detailed arrangement should be worked out in the detailed design stage.

The majority of spoil will be removed in a semi-liquid state and is likely to be piped or barged directly to the disposal site. Dewatering and consolidation will generally be required during the disposal operation. The erosion of the contaminated spoil by surface runoff during or after disposal operation, especially in the wet season will result in remobilisation of the metals and secondary pollution to the surface water. Adequate measures should be studied in the Detailed Design stage and implemented to prevent the erosion by surface runoff during and after the disposal if on land disposal practice is to be considered.

9.5.3 Impact from Transportation of Dredged Spoil

All contaminated mud from Stage 2 Works (0.75 Mm^3) must be transported to East Sha Chau for disposal if Option B is to be selected. Release of sediment or leachate during transportation would cause secondary pollution along the long transportation route. In Option A, however, because the spoil will be disposed in the immediate vicinity, the impact of contaminated spoil transport would be minimised.

For either Option A or Option B, there will be a large quantity of uncontaminated mud which has to be shipped and dumped to one of several marine dumping site. Transportation of uncontaminated material, if proper measures are implemented, should not cause unacceptable environmental impacts. Considering the distance to the work sites and the cost of the transportation, Shekou reclamation on the Shenzhen side is the preferred site for uncontaminated mud disposal. Based on available information, there should be enough capacity at the Shekou reclamation site.

However, it is likely to necessary to dredge an access channel across the Futian mudflats to the Shekou disposal site.

9.5.4 Impact from Disposal of Spoil from Maintenance Dredging

Similar environmental impacts addressed in Sections 9.5.1, 9.5.2 and 9.5.3 will be relevant if the above disposal strategy is used for the disposal of contaminated spoil from maintenance dredging.

9.6 MITIGATION MEASURES

9.6.1 Dredging Methods

Separate dredging of contaminated and uncontaminated material will greatly reduce the volume of contaminated spoil to be disposed. The volumes of contaminated spoil from Stage 1 Works were estimated based on separate dredging.

9.6.2 Disposal of Dredged Spoil

The contaminated spoil from the existing river course should be disposed separately in isolated locations without mixing with uncontaminated material. The contaminated spoil disposal area should be capped with uncontaminated spoil to prevent erosion of the contaminated sediments as well as to keep the anaerobic condition of the sediment (Figure 9.3). A schematic spoil disposal is proposed as follows (Detail arrangement will be worked out during Detailed Design):

Contaminated spoil from Stage 1 Works should be placed in the fish ponds in the middle of the Lok Ma Chau Bend, to be surrounded by ponds filled with clean spoil, thus maximizing the distance separation from river channels. Contaminated spoil from Stage 2 Works, as well as from maintenance dredging, should be placed in the middle part of the Lok Ma Chau Bend after constructing bunds surrounding the area (Figure 9.2). Area outside of the bunds should be filled with uncontaminated spoil and contaminated spoil should not be filled higher than 1m below the bund height and the top 1m should then be capped with clean spoil to prevent erosion of contaminated sediments. The cap must be properly designed and suitable drainage must be provide to prevent contact of surface runoff with the contaminants.

To prevent erosion by runoff during disposal operations, drainage ditches should be constructed around the disposal site to collect runoff water.

A series of temporary oxidation ponds can be constructed during dewatering and consolidation operation. The supernatant can be treated on-site by physical/chemical precipitation and aerobic oxidation before been discharged into river channel. Details of the facilities should be worked out in Detailed Design of Stage 2 Works.

9.7 RECOMMENDATION

Both Options A and B listed in Section 9.4 should be environmentally acceptable provided that mitigation measures suggested are taken. The heavy metals in contaminated sediment, however, will have less chance to be remobilised if disposed of on land (Option A). This is the main reason that the London Dumping Convention prefers on-land disposal over marine dumping. In view of the distance to the East Sha Chau dumping site, cost may also be an important consideration for Option B.

Option A is recommended by the Consultant. Contaminated and uncontaminated spoil from Stage 1 Works is to be disposed of in fish ponds at Lok Ma Chau and Liu Pok. All contaminated mud and a portion of uncontaminated mud from Stage 2 Works, as well as from maintenance dredging are to be disposed of at the Lok Ma Chau Bend on top of the Stage 1 disposal site. The remaining of uncontaminated material from Stage 2 can be transported to the Shekou reclamation site for disposal.

At the Lok Ma Chau site, contaminated mud from various stages of the Project must be disposed of with great care, and necessary mitigation measures should be taken to prevent release of sediment and pollutants. Further tests on water contents of the dredged material, dewatering process, time-rate of consolidation, storage capacity requirement for unconsolidated material, and quality of effluent from the dewatering process are also suggested to be taken during detailed engineering design of the dumping pit. Minimisation of mud exposure time and possible leachation should be properly addressed during the design.

With adequate care taken during disposal and prevention of potential for erosion by surface runoff, the disposal of contaminated spoil at Lok Ma Chau should not cause short or long term ecological damage. Due to disposal of contaminated spoil at Lok Ma Chau it is recommended that a comprehensive EIA be carried out to evaluate the environmental acceptability of any future proposal for land use change. For validation of the assumptions made, suitable field test and evaluation should be carried out in the detailed design of the Stage 2 works.

REFERENCES

Bartlett,R. and B. James, 1979, Environ. Quality, 8,31

Belzile, N., P.Lecomte, and A.Tessier, 1989, Testing readsorption of trace elements during partial chemical extractions of bottom sediments, Environ. Sci. and Technol., 23,1015-1020.

Bengtsson,G. and L.Tranvik, 1989, Critical metal concentrations for forest soil invertebrates. Water Air oil Pollut. 47:381

Central Unit on Environ Pollution, Dept of Environ, 1974, Lead in the Environment and its Significance on Man, HMSO, London

Chao, T.T., 1984, Use of partial dissolution techniques in geochemical exploration, J. of Geochem. Exploration, 20, 101-135.

Eganhouse,D.R., L.J.Lund, A.L Page, and A.C.Chang, 1982, Solid phase forms of heavy metals in sewage sludge-treated soils, J. Environ. Quality, 11,178-181

European Communities, 1991, Proposal for a Council Directive on the landfill of waste, 91/C190/01, Official Journal of the European Communities C190/33, EC

Förstner, 1983, Assessment of metal pollution in rivers and estuaries, In: I. Thornton, (ed), Applied Environmental Geochemistry, Academic Press, London

Gibbs,T.J., 1973, Mechanisms of trace metal transport in river, Sci., 180,71-73\

Gibbs,T.J., 1977, Transport phases of transition metals in the Amazon and Yukon Rivers, Geol. Soc. Am. Bull., 88,829-843

Gupta, S.K. and K.Y. Chen, 1975, Partitioning of trace metals in selective chemical fractions of nearshore sediments, Environ. Letters, 10,129-158.

Hakanson,L., 1981, Water Res., 14,975

Hobson,D.M., Rational site investigations, *in* T.Cairney (Ed.) Contaminated Land, Problems and Solutions, Blackie Academic & Professional, London

Kelly,R.T., 1980, Site investigation and material problems, *in* Reclamation of Contaminated Land, B2/1-B2/13, Society of Chemical Industry.

Langston,W.J. 1990, Toxic effect of metals and the incidence of metal pollution in marine ecosystems, p.101-122. In: R.W.Furness and P.S.Rainbow (eds.) Heavy metals in the Marine Environ., CRC Press, Inc., Boca Raton. FL. USA

Lee,C.R., H.E.Tatem, D.L.Brandon, S.H.Kay, R.K.Peddicord, M.R.Palermo,

N.R.Francingues, Jr., 1991, General decision making framework for management of dredged material, Dept. of Ecol., Olympia, Washington, 98504, Seattle Washington, USA

LeGrand,H.E., 1964, Management aspects of groundwater contamination, J. Water Pollution Control Fed., 36,1133

LeGrand,H.E., 1967. A broad view of waste disposal in the ground, Water and Sewage Works, 114,R167

LeGrand,H.E., 1965, Patterns of contaminated zones of water in the ground, Water Resources Res., 20,254

Li Yongfei, 1983. Fractionation of zinc, cadmium, lead, and copper in marine sediment, Oceanography, 5,178

Luo Weiquan, 1984, Fractionation of mercury and cadmium in marine sediments from Pearl River Estuary, Tropic Ocean, 3,58

Maunsell Geotechnical Services Ltd., 1993, Geotechnical Assessment Report on permeability of soils at Sunnyville estate development, Nam San Wai

Moriyama,K., T.Moti, H.Arayashiki, H.Saito and M.Chino, 1989, The amount of heavy metals derived from domestic wastewater, Water Sci. Technol., 21,1913

Nissenbaum,A., 1972, Distribution of several metals in chemical fractions of sediment core from the sea of Okhotsk, Israel J. Earth Sci., 21,143-154

Parrish,P.R., J.C.Moore and J.R.Clark, 1989, Dredged material effects assessment. In Oceans '89. Proceedings of an International Conference, V.2. Mar. Technol. Soc., Washington, DC, USA

Robinson, G.D., 1984, Sequential chemical extraction and metal partitioning in hydrous Mn-Fe-oxide coatings: reagent choice and substrate composition affect results, Chem. Geog., 47,97-112.

Rule, J.H. and R.W.Alden 1990, Cadmium bioavailability to three estuarine animals in relation to geochemical fractions of sediments, Archives of Environ. Contamination and Toxicology, 19,878-885.

Rule, J.H. and R.W.Alden, 1992, Partitioning of Cd in geochemical fractions of anaerobic estuarine sediments, Estuarine, Coastal and Shelf Sci., 34,487-499.

Shenzhen Environmental Monitoring Station, 1990, Background Contents of Trace Elements in Soils of Shenzhen, NEPA 75-60-01-01-33

Shuman, L.M., 1986, Effect of liming on the distribution of manganese, copper, iron, and zinc among soil fractions, Soil Sci., Soc. of Am. J., 50,1236-1240.

Sittig,M., 1976, Toxic Metals, Pollution control and worker protection, Noyes Dat Corp., Park Ridge, New Jersey, USA

Vedy,J.C. and F.L.Greter-Dimergue, 1989, Heavy metals in polluted lysimetric waters of composed sludge-parent material columns, In: Vernet(ed.), Heavy metals in the environment, V.2, CEP Consult, Ltd, Edinburgh, U.K.

Wagner,J.F., 1991, Retention of heavy metals from blast-furnace dedusting sludge by a clayey subsoil, Water Air and Soil Pollu., 57-58, 351

Windom,H.L., 1976, CRC Critical Review on Environ. Control, 5,91

Wu Yanyu and Zhou Qixing, 1992, Mercury and cadmium criteria in soils, In: Proceedings of the Conference on Pollutants and their biological effects, Sci. Press., Beijing.

Xia Jiaqi, 1992, Geochemical fractions of copper and their effect on plant, In: Proceedings of the Conference on Pollutants and their biological effects, Sci. Press., Beijing.

Zheng Jianlu, 1992, Heavy Metals in Pearl Harbor Estuary, In: Chen Jingshen and Zhou Jiayi(eds), Study on Heavy Metals in Aquatic Environment of China, Chinese Environmental Science Press, Beijing.

Zhen Jianlu, 1985, Chemical Fractionation of heavy metals in sediment from Pearl River Estuary, Tropic Ocean, 4,6

Her Majesty's Stationery Office, 1976, Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter, Treaty Seriew No.43

10 ECOLOGY

10 ECOLOGY

10.1 APPLICABLE REGULATIONS, STANDARDS AND GUIDELINES

10.1.1 International Conventions

Hong Kong, through the United Kingdom, is a Party to two international conventions which are relevant to the Project. These are listed below, and described in detail in Appendix 10.1.

- The Convention on Wetlands of International Importance Especially as Waterfowl Habitat (the Ramsar Convention)
- The Convention on the Conservation of Migratory Species of Wild Animals (the Bonn Convention)

The PRC is only a Party to the Ramsar Convention.

In March 1995 the Hong Kong Government announced that the Mai Po/Inner Deep Bay area would be designated as a Wetland of International Importance under the Ramsar Convention (Figure 10.1).

10.1.2 Hong Kong Legislation and Guidelines

Hong Kong legislation relating to the protection of fauna and flora and of relevance to the Deep Bay includes:

1) The Forests and Countryside Ordinance, Cap. 96
2) The Forestry Regulations
3) The Town Planning Ordinance, Cap. 131
4) The Wild Animals Protection Ordinance, Cap. 170
5) The Fisheries Protection Ordinance, Cap. 171
6) The Fisheries Protection Regulations

Three sets of Guidelines are relevant to the Project:

1) The Hong Kong Planning and Environmental Guidelines:
   Chapter 9. Environment
   Chapter 10. Conservation
2) The Deep Bay Guidelines for dredging, reclamation and drainage works
3) Town Planning Board Guidelines for application for development within Deep Bay Buffer Zones under Section 16 of the Town Planning Ordinance.

Relevant portions of these statutes and guidelines are described in detail in Appendix 10.2.

10.1.3 PRC regulations and bilateral migratory bird agreements

The following national regulations govern habitat and wildlife protection in China. Relevant portions of the Regulations are described in Appendix 10.3.

1) The Wildlife Protection Law of the PRC;
2) Wildlife Protection Implementation Regulation of the PRC;
3) Guideline for Nature Reserves for Wildlife Species in the PRC;
4) Nature Reserve Regulations, Provision 32;
4) The National Protection List of Important Wild Animals;

In addition to the various national regulations there are also provincial regulations promulgated by Guangdong Province. These include:

1) The Management Measures for Forests of Guangdong Province, Guangdong Government [1992] No.138;
2) The Environment Management Regulations for Construction Projects in Guangdong Province, Section 4;
3) The Provincial Government's Official Reply to the "Implementary Detail Regulations for Natural Reserves of Forest and Widelife Species", Guangdong Government [1986] No.13;
4) Guangdong Provincial Implementary Detailed Regulations for Natural Reserves of Forest and Wildlife Species, Section 12.

Relevant portions of these Regulations, together with a list of species occurring in the Deep Bay area protected under the Wildlife Protection Law, are given in Appendix A10.3. Chen (1993) discusses legislation relevant to mangrove conservation in China.

Futian was declared a National Nature Reserve by the State Council in 1988. In July 1993, Futian was included in the China Biosphere Reserve network.

As noted in 10.1.1, China is a Party to the Ramsar Convention. The Futian National Nature Reserve, as part of the Deep Bay wetland system, harbours wildlife which qualify it as a wetland of international importance under that Convention.

China has entered into a number of bilateral agreements to protect migratory birds. These include agreements with both Japan and Australia. Birds passing through the Deep Bay area are known to migrate to/from both of these countries (Melville and Galsworthy 1993; Appendix 10.3) and thus these agreements are relevant in the context of this study.

Relevant extracts of the text of these conventions, together with a list of bird species covered by them, are given in Appendix 10.3.

10.2 EXISTING ECOLOGICAL CONDITIONS

Inner Deep Bay and the adjacent wetland habitats comprise a wetland of international importance for conservation (Scott 1989, Lu 1990). This has been recognised by the Hong Kong Government (Anon 1994a), which in March 1995 announced that the Mai Po/Inner Deep Bay area would be designated as a Wetland of International Importance under the Ramsar Convention.

A general introduction to the area is given by Irving and Morton (1988), Melville (1989a), Melville and Morton (1983), Morton and Morton (1983), and Young and Melville (1993). An extensive bibliography covering material relating to the flora and fauna of Deep Bay is given in Appendix 10.14. The following accounts make reference to only some of the titles listed in the bibliography.

10.2.1 Location

Deep Bay is situated between 22°24'N and 22°33'N and 113°58'E and 114°03'E. It separates the northwest coast of the New Territories, Hong Kong from the southwest coast of the Shenzhen Special Economic Zone, Guangdong Province, People's Republic of China. The Bay has a surface area of some 115 km^2 and a catchment of 312.5 km^2. It has an average depth of 2.9 m and is nowhere deeper than 6 m at low tide. With a maximum tidal range of about 2.8 m, an estimated 1.8 km^2 of intertidal mudflats are exposed at spring low low tide.

10.2.2 Regional Context

Deep Bay lies on the east side of the Pearl River estuary. Extensive reclamation around the estuary results in Deep Bay being the only area within the system with a relatively undisturbed coastline. There are few areas with comparable coastal wetland habitat within 400 km of Deep Bay (Melville 1984), thus the Bay is of regional conservation importance as an example of a South China sheltered soft-shore/mangal community.

Current land use, principal vegetation cover and habitats in the Inner Deep Bay area and the Shenzhen River Catchment are shown in Figure 10.2. The Deep Bay wetlands comprise areas of both natural and man-made habitats. An inventory of wetland and related habitats in the study area is given in Table 10.1.

Table 10.1 Inventory of habitats in the Inner Deep Bay Area and the Shenzhen River Catchment

Habitat type	Condition[1]	Security[2]
River	bad	secure
Mudflat (Mai Po)	poor/moderate	threatened
Mudflat (Futian)	poor/moderate	threatened
Mangrove (Mai Po)	good	secure
Mangrove (Futian)	good	secure ?
Mangrove (Shenzhen River)	poor	to be destroyed
Gei wais	good	secure
Fish ponds	good	threatened
Wet grassland	good	threatened
Woodland	moderate	secure/threatened
Hill grassland	moderate	secure/threatened
Urban	n.a.	n.a.

[1] Subjective grading system:
Bad — physically degraded and/or heavily polluted
Poor — polluted, but not severely degraded
Moderate — affected by human abuse, but capable of rapid recovery
Good — not physically or chemically degraded in any obvious way

[2] Subjective grading based on known developments and plans in the catchment area.

There have been very significant changes in the extent and mix of habitats within Hong Kong and Shenzhen over the past decade. The rate of development in both Hong Kong and Shenzhen has accelerated, particularly over the past 5 years, with a marked reduction in the extent of wetland habitats, notably fish ponds, on both sides of the Bay (Appendix 10.13).

Consequently, extensive areas of wetland on both sides of the Bay have been filled for industrial and residential development, open storage and other uses. The rate of change is illustrated by the loss of fish ponds. On the Hong Kong side of the Bay, the area of fish pond has declined by some 26% over the past 14 years, from 1,830 ha in 1979 (Anon. 1988a) to <1,350 ha in 1993 (Hong Kong Agriculture and Fisheries Department). In Shenzhen the loss of wetlands has been even more marked, with some 80% of fishponds/*gei wais*/paddi and other wetland habitats being lost between 1988 and 1992. Some areas, especially in Hong Kong, which were formerly used for fish farms are now abandoned and are being invaded by emergent macrophytes such as *Phragmites*, *Scirpus*, *Cyperus* and *Juncus*.

These trends are important background in the decisions on the relative importance of various habitat areas.

10.2.3 Physical Conditions

Deep Bay receives water and sediment directly from the Shenzhen River in the northeast and from the Shan Pui River in the southeast. There is also a considerable inflow of water from the Pearl River. During the wet season (April-October, when 90% of the total annual rain falls) salinity in the Bay drops to nearly 0‰, whereas in the dry season salinity may increase to 20‰. Further details regarding hydrology and sedimentation are given in Section 7.

10.2.4 Land Use

The intertidal flats of the Bay are used for cultivation of oysters *Crassostrea gigas* (70% of the harvest) and *C. rivularia* (30%). The area of flats used for oyster cultivation varies considerably from year to year, and the amount of oyster cultivation in Inner Deep Bay has declined in recent years. Aerial photographs taken in May and November 1993 indicate no active oyster cultivation on the Hong Kong side of Inner Deep Bay (Hong Kong Government photo. refs. A34375 and A36363-A36367). Deep Bay oysters are frequently contaminated with faecal bacteria (Leung *et al.* 1975) and metal levels (notably cadmium, Phillips *et al.* 1982) are often high. Anon. (1988b) notes that in 1986, 10% of the oysters sampled from Deep Bay had wet weight cadmium concentrations in the range 2.1-2.3 ppm, compared with the limit for human consumption of 2 ppm.

The area landward of the mangroves has been reclaimed for use as *gei wais* for the culture of *Metapenaeus ensis*. *Gei wais* are traditionally operated shrimp ponds which are stocked using naturally occurring shrimp larvae from Deep Bay, which are flushed into the *gei wai* through a sluice at high tide. The shrimps feed on invertebrates, which in turn feed on detritus from mangroves and reeds growing within the *gei wai*, as well as organic matter which enters the pond from the Bay through the sluice on selected high tides.

Each *gei wai* at Mai Po covers some 9-10 ha and, although shrimp production appears to have declined in recent years (Melville *et al.* 1989), can currently yield up to 600 kg of shrimps each year (Young and Wong 1993). In 1993, WWF Hong Kong harvested shrimps worth HK$ 300,000 from eight *gei wais* at Mai Po. Various fish also occur in the *gei wais* including mullet *Mugil cephalus/Liza*, Giant Perch *Lates calcarifer*, Japanese Sea-perch *Lateolabrax japonicus* and Yellow-finned Bream *Sparus latus*. Further details on *gei wai* operation are given by Young and Wong (1993).

The area of brackish/freshwater fish ponds increased greatly on the Hong Kong side of Deep Bay in the 1960s and 1970s through the conversion of former *gei wais* and paddi (Irving and Leung 1987). Most ponds are used for polyculture of Grey Mullet *Mugil cephalus* and up to five species of carp: Big Head *Aristichthys nobilis*, Mud Carp *Cirrhinus molitorella*, Grass Carp *Ctenopharyngodon idellus*, Common Carp *Cyprinius carpio*, and Silver Carp *Hypoghthalmichthys molitrix*. Polyculture ponds may be integrated with duck, chicken or pigeon farming, the droppings being used to fertilise the water. Some ponds are used for monoculture of snakehead *Ophicephalus* sp. and Catfish *Clarias fuscus*.

The average production from polyculture ponds is 5.2 tonnes/ha/yr, whereas that from monoculture ponds is 12 tonnes/ha/yr (Anon. 1988a). The ponds and cleaner watercourses also contain populations of tilapia *Oreochromis mossambicus/niloticus* and mosquitofish *Gambusia affinis*, as well as the freshwater shrimp *Macrobrachium nipponense*, all of which provide an important food source for herons and egrets (Young 1994), and Black-faced Spoonbills (Appendix 10.13). The ponds also support high densities of chironomid midges which are an important food source for a variety of birds (Chu 1993, Melville *et al.* 1994).

In Shenzhen there was also extensive conversion of former paddi to fish pond cultivation in the late 1970s and early 1980s (Wong 1982; Hong Kong Government aerial photographs). In recent years large areas of fish ponds have been filled in on both sides of the Bay for residential development, industrial development and open storage, resulting in significant loss especially on the Shenzhen side (see Section 10.2.2). Further details of land use are given by Irving and Morton (1988).

10.2.5 Flora

There have been limited studies on phytoplankton in the Bay, with most attention being given to 'red tides' (Huang *et al.* 1989, Qian *et al.* 1989, Wang and Jin 1989). Phytoplankton production, which has been estimated to be 0.4-4 tonnes Carbon/ha/yr, is thought to be limited by low light penetration in the turbid waters (Anon. 1988). A study of macroalgae inside the Mai Po *gei wais* is ongoing (B. Corker unpublished).

No studies have been made of diatoms or other microalgae on the surface muds of Deep Bay although these directly provide food for at least some mudskippers and crabs (Anderson unpublished, Appendix 10.8). It is also likely that these organisms play an important role in stabilisation of the mudflats (Coles 1979, Severn Estuary Research Group 1992, Lin 1987, Fan *et al.* 1993, see also Section 8).

The intertidal flats support few higher plants. There are small areas of *Halophila beccarii* on both the Hong Kong and Shenzhen sides of the Bay (Hodgkiss and Morton

1978, Morton 1984). The grass *Eleocharis* c.f. *acicularis* occurs in limited areas on the Hong Kong side (Figure 10.3), and appears to be spreading (Melville, Young and McChesney unpublished).

Ruppia maritima has recently been discovered inside the *gei wais* at Mai Po, this being the first record in Hong Kong for nearly 100 years (Melville and Chan 1992).

The intertidal flats of Inner Deep Bay are fringed along the landward side by mangrove. The mangrove area, which covers some 220 ha, is the largest in Hong Kong and the sixth largest area of protected mangrove remaining in China (Fan 1993) and is of regional conservation importance (Scott 1989, Lu 1990).

Although the mangrove *Kandelia candel* occurs as far north as 32° in Japan, the Deep Bay mangal is one of the most northerly to support a wide assemblage of typical mangrove species and associated flora and fauna. The Deep Bay mangrove community comprises six species, viz.:

Euphorbiaceae	*Excoecaria agallocha*
Rhizophoraceae	*Bruguiera gymnorrhiza, Kandelia candel*
Aegicerataceae	*Aegiceras corniculatum*
Avicenniaceae	*Avicennia marina*
Acanthaceae	*Acanthus ilicifolius*

Mangrove associates include the fern *Acrostichum aureum*, and the climbers *Derris trifoliata* and *Canavalia maritima*. The low straggling shrub *Clerodendrum inerme* is another mangrove associate on the landward side of the mangal. Due to the sandy conditions at Futian National Nature Reserve, the beach flora includes additional species such as *Pandanus* sp. and *Phoenix* sp. In recent years there has been a noticeable increase in the spread of *Derris* in the Mai Po mangal, which now appears to be threatening the landward trees (Young unpublished).

Further details of the Deep Bay mangal are provided by Thrower and Cheng (1975), Morton and Morton (1983), and in Appendices 10.5, 10.6 and 10.7.

The present study indicated that, although specimens are reproducing along the Shenzhen River, recruitment of mangroves is very low, if at all, except near the River mouth. This appears to be a result of the very high organic pollution load in the river which is thought to inhibit seedling growth. A similar situation was found by Anon (1992) in Shan Pui River. Wake wash from passing boat traffic may be a confounding problem, making conditions more difficult for propagule establishment (Appendix 10.4).

The biology of the mangroves in the Mai Po *gei wais* has been studied by Lee (1988, 1989, 1990a, 1990c, 1991), and those in Deep Bay by Anderson (1993, unpublished), Anderson and Lee (in press), Tam *et al.* (1993), Wong *et al.* (1993), Wang *et al.* (1993). The results of an international mangrove workshop held at Mai Po in September 1993 are being finalised (S.Y. Lee pers. comm.). Fungi associated with the Deep Bay mangals have been studied by Sadaba *et al.* (1993). A study on mangrove productivity and nutrient cycling is nearing completion (Anderson unpublished; Appendix 10.8).

On both sides of Inner Deep Bay the landward mangal has been converted to fish ponds, and *gei wais* for prawn culture. The vegetation on the banks of these ponds mostly comprises typical adventitious wasteland species, including:

grasses: *Paspalum distichum*, *Phragmites australis*, *Zoysia sinica*;
herbs: *Achyranthes aspera*, *Amaranthus viridis*, *Bidens* sp., *Dianella ensifolia*, *Gynura bicolor*, *Solanum nigrum*;
creepers: *Mikania micrantha*, *Paederia scandens*, *Passiflora foetida*, *Strophanthus divaricatus*;
shrubs: *Hibiscus tiliaceus*, *Lantana camara*, *Wikstroemia indica;*
trees: *Celtis sinensis*, *Ficus superba*, *Ficus microcarpa*, *Macaranga tanarius*, *Sapium sebiferum*;

Further details of bund vegetation around fish ponds are given by Chu (1993). *Phragmites* has been studied by Lee (1990b) and G. Reels (unpublished).

On the Shenzhen side there has been extensive development of urban parks with plantings of *Ficus microcarpa*, *F. altissima*, *Magnolia surratensis*, *Bauhinia variagata* and *Rhododendron* spp.

10.2.6 Intertidal Benthos

A general description of the Deep Bay fauna is given by Morton and Morton (1983). More detailed work has recently been undertaken by McChesney (unpublished), and this study (Appendix 10.9 and 10.10).

Deep Bay currently supports an impoverished fauna in terms of species diversity, undoubtedly related to the highly enriched waters and sediments which result from years of heavy organic pollution input (Section 8). However, as is frequently the case in enriched estuaries, there is a high biomass of benthos (Pearson and Rosenburg 1978, Green *et al.* 1992, Piersma *et al.* 1993).

The standing crop biomass of benthic invertebrates on the Mai Po mudflats ranges between 10.2 and 101.9 g dry wt. (Appendix 10.9). Total annual benthic invertebrate biomass production in Deep Bay off Mai Po is estimated at 41.5 g ash free dry weight (AFDM) per m^2 (McChesney unpublished).

Notably, the Bay supports the highest biomass of polychaetes so far recorded worldwide (Piersma *et al.* 1993), which undoubtedly contributes to the importance of the site as a feeding area for waterfowl (Section 10.2.10, Appendix 10.12).

The lower intertidal benthos is characterised by bivalves including *Sinonovacula* spp., *Theora* spp. and *Macoma* spp. Large individuals of *Sinonovacula constricta* can be harvested commercially for human food, and the smaller *Glauconome chinensis* is harvested as food for domestic ducks. The lower mudflat also harbours other invertebrates, notably large polychaetes such as *Dendronereis* sp.

The upper intertidal habitat contrasts with the lower mudflat by having fewer individuals of the bivalves noted above, but very high densities of a very small bivalve, for which Deep Bay is the type locality - *Pseudopythina maipoensis* (Morton and Scott 1989). The proportion of abundance and biomass of polychaete worms is also much higher on the upper mudflat compared to the lower mudflat. Crabs occur across the mudflats, with high densities of small Ilyoplax species particularly along the banks of tidal creeks where the substrate is firmer.

The mangal harbours a different suite of invertebrates with sesarmine crabs, notably *Perisesarma bidens*, being particularly abundant and playing a major role in detritus cycling (Anderson unpublished).

Further details of the intertidal benthos are given by McChesney (1993, unpublished and Appendix 10.9). Fiddler crabs have been studied by Choi (1991). The effects on macrofauna of municipal wastewater runoff through the Futian mangal have been studied by Yu *et al.* (1993), and Chiu (1992) has investigated the occurrence of heavy metals in several marine invertebrates, including *Balanus amphrite*, *Perisesarma bidens* and *Uca arcuata*.

Studies of many invertebrate groups are still at a preliminary descriptive/taxonomy stage. To date, over 13 species new to science have been described from the Mai Po/Deep Bay area (Lee 1993).

Species of commercial importance include the oysters *Crassostrea gigas* and *C. rivularis*, the razor-shell *Sinonovacula constricta*, and the crab *Scylla serrata*. The gei wai shrimp *Metapenaeus ensis* breeds in the Pearl River estuary and the larvae migrate through Deep Bay to the mangroves, and thence to the *gei wais*.

10.2.7 Fish

Very little is known about fish in Deep Bay, but the area is thought to be a valuable nursery ground for some species. Despite this, there has been an extensive stake- net fishery in the Bay since about 1986, especially on the Shenzhen side. It is not known whether this is aimed at any particular species, or is a 'catch all' system.

Occasionally mullet *Mugil/Liza* fry are caught in the Bay for stocking local fish ponds. Details of fish found in local ponds are given in Section 10.2.4.

Only mudskippers have been studied (Chan 1989; K.W. Ho pers. comm.; Young unpublished). Crude estimates of human predation on *Boleophthalmus boddaerti* indicate that approximately 5.4% of the total mudskipper population is being harvested from the Deep Bay mudflats during the spawning season (Young and Melville 1993). The impact of this harvest on populations is unknown, but since breeding adults are trapped it could be significant. Mudskippers also provide an important source of food for egrets and herons and some shorebirds, such as Whimbrel *Numenius phaeopus* (Young 1994, Melville unpublished).

10.2.8 Amphibians

Little is known of the amphibians occurring in the Deep Bay area. None occur in the tidal areas, but some (notably Gunther's Frog *Rana guentheri*) do breed in the very slightly brackish ponds inland. Most water courses entering Deep Bay are so polluted with livestock waste that no amphibians can be found, but freshwater marshes support a varied fauna.

Anon. (undated) recorded the following species from Mai Po:

Asian Common Toad	*Bufo melanostictus*
Gunther's Frog	*Rana guentheri*
Paddy Frog	*Rana limnocharis*
Chinese Bullfrog	*Rana tigrina*
Brown Tree Frog	*Polypedates leucomystax*

Chu (1993) noted the following as also occurring in the Deep Bay area:

Narrow-mouthed Frog	*Kalophrynus pleurostigma*

10.2.9 Reptiles

Little is known of the reptiles occurring in the Deep Bay area. Anon. (undated) listed the following species as occurring at Mai Po:

Gold-headed Terrapin	*Cuora trifasciata*
Reeve's Terrapin	*Chinemys reevesi*
Red-eared Terrapin	*Pseudemys scripta*
Soft-shelled Terrapin	*Trionyx sinensis*
Four-clawed Gecko	*Gehyra multilata*
Bowring's Gecko	*Hemidactylus bowringii*
Chinese Gecko	*Gekko chinensis*
Crested Tree Lizard	*Calotes versicolor*
Chinese Skink	*Eumeces chinensis*
Reeve's Smooth Skink	*Leiolopisma reevesi*
Water Monitor	*Varanus salvator*
King Cobra	*Ophiophagus hannah*
Chinese Cobra	*Naja naja*
Many-banded Krait	*Bungarus multicinctus*
Red-necked Keelback	*Rhabdophis subminiatus*
Common Rat Snake	*Ptyas mucosus*
Bennett's Water Snake	*Enhydris bennetti*
Chinese Water Snake	*Enhydris chinensis*
Plumbeous Water Snake	*Enhydris plumbea*
Checkered Keelback	*Xenochrophis piscator*
Buff-striped Keelback	*Amphiesma stolata*

Although there is one recent record of Water Monitor from near Lok Ma Chau it is considered that the specimen had escaped from captivity. One specimen of the Burmese Python *Python molurus* has been found in mangroves near Tsim Bei Tsui (A.J. Brandt pers. comm. to D.S. Melville), and it may occur in the hills near Lok Ma Chau. The one Hong Kong record of the Slender Sea Snake *Hydrophis gracilis* is from Deep Bay (Karsen *et al.* 1986).

The only species regularly found in the mangroves and intertidal areas of Deep Bay is Bennett's Water Snake, which is known to feed on fish (Lau and Melville 1992). This is a little-known species occurring in the coastal areas of Hainan, Guangdong and Fujian Provinces (Tian and Jiang 1986). Chinese Water Snakes are also occasionally found on the mudflats and drowned in fish nets.

10.2.10 Birds

Deep Bay supports internationally important numbers of at least 18 species (Table 10.2). Most notably some 24% of the world population of the Black-faced Spoonbill *Platalea minor* winters in the area (Kennerley 1990, Rose and Scott 1994, Dahmer and Felley in press, Hong Kong Bird Watching Society unpublished).

Table 10.2 Bird species for which Deep Day is of international importance*

Deep Bay supports 1% or more of the world population of the following species:

Black-faced Spoonbill	*Platalea minor*	24%
(Oriental White Stork	*Ciconia boyciana*	1+%)**
(Asiatic Dowitcher	*Limnodromus semipalmatus*	1%)**
Spotted Greenshank	*Tringa guttifer*	6%
Saunders' Gull	*Larus saundersi*	5%

Deep Bay supports 1% or more of the regional/flyway population of:

Dalmatian Pelican	*Pelecanus crispus*
Cormorant	*Phalacrocorax carbo*
Shelduck	*Tadorna tadorna*
Lesser Sandplover	*Charadrius mongolus*
Greater Sandplover	*Charadrius leschenaultii*
Grey Plover	*Pluvialis squatarola*
Curlew Sandpiper	*Calidris ferruginea*
Broad-billed Sandpiper	*Limicola falcinellus*
Spoon-billed Sandpiper	*Eurynorhynchus pygmaeus*
Black-tailed Godwit	*Limosa limosa*
Eurasian Curlew	*Numenius arquata*
Greenshank	*Tringa nebularia*
Styan's Grasshopper Warbler	*Locustella pleskei****

Other species recognised as 'threatened' or 'near threatened' which occur in the Deep Bay area:

Chinese Egret	*Egretta eulophotes*
Schrenck's Bittern	*Ixobrychus eurhythmus*
Baikal Teal	*Anas formosa*
Baer's Pochard	*Aythya baeri*
Mandarin Duck	*Aix galericulata*
Black Vulture	*Aegypius monachus*
Imperial Eagle	*Aquila heliaca*
Little Whimbrel	*Numenius minutus*
Relict Gull	*Larus relictus*

* after: Chan 1991, Collar and Andrew 1988, Groombridge 1993, Rose and Scott 1994, Perennou *et al.* 1994, and Watkins 1993.

** Although ~1% of the world population of these species have been recorded at Mai Po, usually numbers are smaller.

*** Mai Po is the only known wintering area for this species (Kennerley and Leader 1993).

The birds are the best studied component of the Deep Bay fauna, with records for the area dating back over 50 years. To date, over 280 species of birds have been recorded from the Mai Po area and the number continues to increase each year (Hong Kong Bird Watching Society records).

Although there is a large body of information concerning seasonal occurrence of birds there is relatively little information available on species populations and biology. Only one detailed ecology study has been conducted, on egrets and herons (Young 1994).

The Hong Kong Bird Watching Society has conducted a mid-winter waterfowl count in January each year since 1979 (except 1980) and these provide a very valuable indication of trends in waterfowl using Deep Bay in winter (Figures 10.4, 10.5 and 10.6). The reason (s) for the generally increasing trend for most species/groups remain uncertain, but are thought to relate, at least in part, to destruction of other wetland sites nearby in China, and possibly increasing prey populations/availability in Deep Bay (Melville 1989, 1991). Hunting pressure elsewhere in the Pearl River estuary probably is another important factor (McChesney unpublished). Perennou *et al.* (1994) discuss the regional/international importance of Hong Kong's wintering waterfowl populations.

Counts of shorebirds during the spring and autumn migration have only been conducted on a reasonably systematic basis in recent years by members of the Hong Kong Bird Watching Society, and an analysis of these data is currently in preparation (Carey and Leader in prep.). Details of regular counts during the present study made at Mai Po and Futian are given in Appendices 10.11 and 10.12.

Deep Bay is of international importance to the waterfowl which visit the area, either to over-winter, or to use the site to rest and re-fuel during their migrations.

Ringing of shorebirds is beginning to reveal details of the migration routes used, as a result of overseas recoveries/controls and analysis of biometric data (e.g. Melville and Galsworthy 1993, Tulp *et al.* 1995). Figure 10.7 shows recorded movements of shorebirds to/from Hong Kong. Observations of birds leg-flagged in Australia and seen on migration in Deep Bay further highlight the importance of Deep Bay in the East Asia/Australasia flyway system (Minton 1993, 1994, Appendix 10.12).

The intertidal flats of Deep Bay are of great importance to long- distance migratory birds as they provide rich feeding grounds which permit birds to accumulate fat (and protein reserves) quickly during stop-over periods whilst on migration (Appendix 10.12; Melville and Leader unpublished).

Young and Melville (1993), note that Curlew Sandpipers *Calidris ferruginea* departing Hong Kong in autumn probably can fly non- stop to northwest Australia, whilst in spring they depart from Hong Kong at lower weights and probably can only reach the Bo Hai, in northeast China. Red Knots *C. canutus* departing Hong Kong in autumn also appear to be able to reach northwest Australia non-stop (Barter 1992).

There has been increasing interest in Europe in the concept of the 'carrying capacity' of estuaries (their ability to support birds) to enable a prediction of the likely effects of habitat loss (e.g. Goss-Custard 1985, Sutherland and Goss-Custard 1991). A question which is frequently asked when considering the effect of loss of feeding areas on populations is:

Will it increase mortality and emigration and so reduce the numbers of birds able to use the estuary?

Loss of habitat in an estuary may affect shorebirds in many ways, including:

- reducing the feeding area available to birds
- removing favoured prey species (through habitat loss)
- increasing crowding on feeding grounds and, through interference, reducing prey intake rates
- reducing the time available to feed (when intertidal areas are lost)

Even if there is no physical reduction in the area of habitat, factors such as eutrophication are likely to cause changes to habitat which will result in changed feeding conditions, and hence affect the carrying capacity of a site.

Various authors have used the term 'carrying capacity' in different ways. In this report, the non-breeding season carrying capacity is defined as the density at which the addition of one further bird would result in another either starving or leaving that locality to seek a better feeding area. When this point is reached, no net increase in bird density can take place, and the carrying capacity has been reached.

Thus, if part of an estuary is lost and carrying capacity has not been reached, then the population size of the species concerned should remain the same, but density should increase.

A conceptual model of the factors influencing the occurrence of waders in an estuary was developed by Meire (1993) (Figure 10.8). Ideally all these factors should be studied for any estuary facing potential habitat loss to permit predictions to be made of likely impacts.

Due to the limited duration of the present study, and a general lack of information previously available on many of the required inputs to the model, detailed predictions are not possible for Deep Bay. The model does, however, provide a framework for reviewing potential impacts from the Project on waterfowl.

In the case of habitat loss at migration staging sites, Evans *et al.* (1991) and Evans and Davidson (1990) note that the greatest impact is likely to be on those species which are long distance migrants and that breed in the high arctic. Since densities at staging areas usually are already high, any further crowding could result in a failure to achieve sufficiently high food intake rates to maintain correct migration timings.

High-arctic breeding shorebirds usually have very precise time- schedules when migrating, particularly in spring. The timing of their arrival on the breeding grounds, and the condition that they arrive in, are likely to have a direct effect on their chances of successful breeding. Thus birds arriving late and/or with little or no remaining fat reserves may have lower breeding output than birds arriving earlier and in better condition (Green *et al.* 1977, Pienkowski and Evans 1984).

About 60% of the total number of shorebirds which passed through Deep Bay in spring 1994 breed in the high-arctic (Table 10.3).

Table 10.3 Species of high-arctic breeding shorebirds which use Deep Bay as a migration staging area

Lesser Sandplover	*Charadrius mongolus (mongolus/stegmanni)*
Pacific Golden Polver	*Pluvialis fulva*
Grey Plover	*Pluvialis squatarola*
Great Knot	*Calidris tenuirostris*
Red Knot	*Calidris canutus*
Sanderling	*Calidris alba*
Little Stint	*Calidris minuta*
Red-necked Stint	*Calidris ruficollis*
Temminck's Stint	*Calidris temminckii*
Sharp-tailed Sandpiper	*Calidris acuminata*
Pectoral Sandpiper	*Calidris melanotos*
Curlew Sandpiper	*Calidris ferruginea*
Dunlin	*Calidris alpina*
Broad-billed Sandpiper	*Limicola falcinellus*
Spoon-billed Sandpiper	*Eurynorhynchus pygmaeus*
Ruff	*Philomachus pugnax*
Bar-tailed Godwit	*Limosa lapponica*
Whimbrel	*Numenius phaeopus*
Little Whimbrel	*Numenius minutus*
Spotted Redshank	*Tringa erythropus*
Grey-rumped Sandpiper	*Tringa brevipes*
Turnstone	*Arenaria interpres*
Red-necked Phalarope	*Phalaropus lobatus*
Grey Phalarope	*Phalaropus fulicarius*

Evans *et al.* (1991) noted that different species may obtain the necessary extra food required for successful migration in different ways, e.g. lengthening the time spent feeding, or increasing food intake rate. Thus, partial loss of staging habitats could affect different species differently.

In view of the international importance of Deep Bay for waterfowl, and the relatively poor state of knowledge about waterfowl ecology in the area, an important part of the present study consisted of gathering relevant information on waterfowl abundance, distribution and feeding (Appendix 10.12).

This study has found that most migrant shorebirds and wintering ducks in Deep Bay had restricted feeding times owing to the fact that they preferentially fed along the moving tide edge on both rising and falling tides. This accords with studies elsewhere, where such behaviour has been attributed to increased prey availability (Puttick 1984). This study has also recorded nocturnal foraging by waterfowl in Deep Bay (Appendix 10.12).

It appears unlikely that birds in Deep Bay could increase their food intake rates significantly if the area of feeding habitat and/or prey populations were to be reduced, or if the available feeding time were reduced. Results from both predator exclusion experiments (Appendix 10.9) and energy requirement calculations (Appendices 10.9 and 10.12) indicate that consumption of the available benthos is already high. Energetic calculations indicate that as much as 41.5% of production is being consumed (Appendix 10.12). It is thus considered likely that Deep Bay is probably nearing its carrying capacity for ducks and shorebirds. Potentially the most critical time for waterfowl is in spring, following heavy overwinter utilisation by ducks and gulls. This is the period when migrant shorebirds need to rapidly gain energy reserves for their onward northbound flight (Figure 10.9, Appendix 10.12).

Deep Bay is also of international importance as a wintering ground for the endangered Saunders' Gull, *Larus saundersi*. These birds feed entirely on benthos taken from exposed intertidal flats in the Bay (Appendix 10.12) and thus may be affected by changes in benthos distribution and abundance, and may be affected through possible competition for food resources with ducks and shorebirds.

The Deep Bay wetlands, including the fish ponds, are of international/regional importance in view of the numbers of herons, egrets, Cormorants *Phalacrocorax carbo*, and Black-faced Spoonbills which they support (Melville *et al.* 1994). This study has found that most feeding activity by the highly endangered Black- faced Spoonbills is in drained down fish ponds and *gei wais* (Appendix 10.12). The loss of fish ponds is a threat to these species (Appendix 10.13) and the conservation importance of fish ponds has now been recognised by the Hong Kong Government (Town Planning Board 1994).

The Deep Bay wetlands, including fish ponds and the Mai Po *gei wais* also provide important habitat for a wide variety of species other than waterfowl. The area supports regionally important numbers of Imperial Eagles *Aquila heliaca* (Appendix 10.12) and is the only recorded wintering site of Styan's Grasshopper Warbler *Locustella pleskei* (Kennerley and Leader 1993). The Phragmites areas, which appear to be among the largest in Guangdong Province (Gao Yuren pers. comm. to L. Young) provide rich feeding grounds for various migrant passerines and appear to be particularly important for species such as the Great Reed Warbler *Acrocephalus arundinaceus* which achieves rapid weight increases in the spring whilst migrating northwards (Melville unpublished).

Information on birds in upland habitats within the study area, notably at Seung Ma Lei Yue hill, are given in the Stage 1 Study Report.

10.2.11 Mammals

Little work has been conducted on mammals in the Deep Bay area. Species recorded from the Deep Bay area are:

Pangolin	*Manis pentadactyla*
Leopard Cat	*Felis bengalensis*
Otter	*Lutra lutra*
Crab-eating Mongoose	*Herpestes urva*
Javan Mongoose	*Herpestes javanicus*
Small Indian Civet	*Viverricula indica*
Bandicoot Rat	*Bandicota indica*
Brown Rat	*Rattus norvegicus*
'Black' Rat	*Rattus rattus*
House Mouse	*Mus musculus*
Ryuku Mouse	*Mus carroli*
House Shrew	*Suncus murinus*

Japanese Pipistrelle	*Pipistrellus abramus*
Dog-faced Fruit Bat	*Cynopterus sphinx*
Lesser Yellow Bat	*Scotophilus kuhli*
Chinese White Dolphin	*Sousa chinensis*

In recent years the Otter has reappeared after an absence of about 40 years. The Javan Mongoose has only recently been recorded in Hong Kong where it now seems to be expanding its range (Chan *et al.* 1992, Melville unpublished). Limited trapping of rodents has been undertaken in the Mai Po area (Chandrasekar-Rao 1994).

The Chinese White Dolphin is a species of local conservation concern (Anon. 1993), the Hong Kong population having apparently been affected considerably by major dredging, dumping and reclamation activities and associated increases in boat traffic in the North Lantau area (L. Porter and C. Parson unpublished). The Chinese White Dolphin has been recorded in Deep Bay off Pak Nai (Melville 1976) and in the Shenzhen River near Lok Ma Chau (Melville pers. comm.). The IUCN Cetacean Specialist Group considers the Hong Kong population to be of regional conservation importance (S. Leatherwood, pers. comm. to D.S. Melville).

10.3 ECOLOGICAL MODELLING

There are two interrelated ecological systems within the study area. One is the estuarine system comprising Inner Deep Bay, the alluvial mudflats at the river mouth, and the habitats within the Mai Po and Futian Nature Reserves. The second is the broader ecosystem comprising the river basin and surrounding areas. This system includes important terrestrial and wetland habitats such as fish ponds.

The two systems interact and the Shenzhen River is an important physical link between the estuary and upstream areas. The river is both a physical means of transport of nutrients and pollutants between the systems and a corridor for movement of wildlife, particularly waterbirds.

An ecological model has been developed for the EIA and is out-lined in Figure 10.9. This is a conceptual model focused on trophic transfers within the estuarine system. Due to the complexity of the system, the limited amount of data available in the literature, and the very limited scope of investigation able to be undertaken under the present study, it is not possible within this EIA to develop a comprehensive energy flow model for wetlands within Deep Bay.

The model identifies links between the estuarine system and upstream wetlands and other habitats in the surrounding areas. However, review by the consultants' expert panel (A.I. Robertson, S.Y. Lee pers. comm.) has concluded that these links are of little importance compared to the energy transfers within the estuarine system itself. The assessment has therefore addressed ecological effects of these two systems separately.

The major direct effect of Stage 1 and Stage 2 works is the direct loss of habitat. This effect will impact directly on the broader ecological system and must be assessed in this context. Stage 2 Works will add to the area of riparian habitat lost during Stage 1 due to widening of the River channel.

Secondary effects of Stage 1 and Stage 2 works, such as sedimentation and erosion, and resuspension of toxic materials will potentially affect the estuarine system downstream, either by pollutant transfer or changes in the hydrodynamic balance at the mudflats. Secondary effects must therefore be considered in the context of the estuarine model and the effect of the river in influencing this system.

10.3.1 Inner Deep Bay Foodwebs

An understanding of the complex foodweb within the Inner Deep Bay key is central to determining the nature, extent and significance of the impacts arising from the Project. One key preliminary conclusion of the Expert Panel was that the food web was driven by the benthic infauna, and that the role of mangal and other potential food sources was likely to be relatively minor.

An attempt was made to elucidate the key estuarine foodweb relationships using stable isotope analysis of carbon and nitrogen. The results from this preliminary study are detailed in Appendix 10.8. The available data indicate that mangrove-derived material does not constitute a large portion of the particulate organic matter (POM) found in the waters of Inner Deep Bay. Most of the POM is derived from allochthonous inputs, including river-borne terrestrial material and organic effluents from domestic sewage and livestock farming.

Three of the heterotrophs examined relied upon allochthonous POM and river-borne organics. Autochthonous inputs are important to some species and to the overall system. Although mangrove detritus may contribute only slightly to the POM in the Bay waters, It is thought to be the main food source for certain species, such as the mangal crab *Perisesarma bidens* (Appendix 10.8).

The results of the isotope analysis support the preliminary conclusion that the benthic infauna are the key driver to the overall foodweb and ecosystem. a main consideration of the assessment is therefore to determine the likely effect of the Project on the benthic community, and any interaction with higher levels of the food chain.

10.3.2 Expected Changes in Hydrology, Sedimentation and Water Quality

Sections 7 and 8 detail the development of models to predict changes in hydrology, sedimentation and water quality resulting from the Project. The model is based on the outline engineering design and assumes that there will be no navigation channel within Deep Bay. The model results, and conclusions drawn from them, will not be valid for any other design assumptions.

The models have been validated using the best available data, however, it has been emphasised in the relevant sections, that there is need for caution in interpreting the model results because of the inherent variability in the natural system, and particularly the influence of severe storm events on hydraulic conditions and sedimentation in Deep Bay. Notwithstanding this, the models provide the most reliable predictive tool presently available for the system. The assessment of ecological impacts is based on conservative interpretation of the model results and any empirical data available.

10.4 POTENTIAL ECOLOGICAL IMPACTS

The most conspicuous direct impacts on flora and fauna will result from the initial construction works. these are:

- the loss of the majority of vegetation and associated fauna along both sides of the River;
- the loss of vegetation and fauna from part of the hill at Seung Ma Lei Yue;
- the loss of fish pond habitant adjacent to the River;

The indirect impacts on flora and fauna will result from both the construction and operational phases. Potential indirect effects will result from:

- changes in sediment dynamics;
- changes in water quality;
- water quality from shipping and dredging;
- air quality effects due to shipping and dredging;
- noise from shipping and dredging;
- human disturbance.

Some impacts will be cumulative and need to be considered in the light of other current and planned changes to the Deep Bay environment.

Table 10.4 summarises the expected impacts on different components of the Deep Bay flora and fauna. The following sections identify potential impacts on ecology in greater detail and summarise the main nett impacts arising from the Project.

The impacts for the Stage 1 Works were addressed in the stage 1 Study Report. Additional data are now available regarding the baseline ecology of the area (Appendix 10.12), but these do not warrant a review of the findings of the earlier report on stage 1 Works with respect to ecology.

Table 10.4 Schematic representation of expected impacts of the Shenzhen River Regulation Project on various components of the Deep Bay flora and fauna

	habitat loss	dust	noise	water qual.	sedi-ment	human dist.	hydro-dynamics
mangroves	-	(-)	o	-	(-)	o	(-)
'sea grass'	-	o	o	-	-	o	(-)
bund vegetation	-	(-)	o	o	o	o	o
benthic invertebrates	-	o	o	-	-	o	(-)
oysters	-	o	o	-	-	o	(-)
shrimps	-	o	o	-	-	o	(-)
fish	-	o	o	-	-	o	(-)
birds	-	o	(-)	(-)	(-)	-	(-)
mammals	-	o	(-)	o	o	-	o

- negative impact expected
+ positive impact expected
o no impact expected
() impact likely, but degree of severity uncertain

10.4.1 Habitat Loss

10.4.1.a Introduction

The Shenzhen River Regulation Project will result in the direct loss of habitats along both banks of the River, including loss of intertidal mud, mangroves, fishponds and associated bunds, and part of the hill at Seung Ma Lei Yue.

Habitat loss will be a long term impact of the Project, although it may be possible to mitigate for some losses through both on- and off- site conservation compensation measures (Section 10.5).

The areas of habitat which are expected to be lost as result of the construction of the Shenzhen River Regulation Project are shown in Table 10.5.

Table 10.5 Direct habitat loss expected as a result of the construction works for the Shenzhen River Regulation Project.

Habitat	Estimated Area Lost (ha)		Total in Study Area (ha)	% lost
	Stage 1	Stage 2		
Intertidal mudflats 112km^2	0	4.5	~11,200	<1%
sea grass*	0	0.5	~1.5	33%
mangrove	0	10.8	~223	4.8%
fish pond/bund	84	22	1,200	8.8%
wet grassland/abandoned fish pond	0.6		N/A	-
shrub/grassland	2.5	0	N/A	-
pine woodland	2.0	0	N/A	-
broadleaf woodland	0.3	0	N/A	-
open pine woodland	0.4	0	N/A	-

* c.f. *Eleocharis acicularis*

Although the areas of habitat to be destroyed directly as a result of the Project are small, from Table 10.5 it is apparent that the Project will result in the loss of significant proportions of the total area of certain habitats within the Deep Bay wetlands system, notably sea grass, mangroves and fish ponds.

10.4.1.b Loss of Intertidal Mudflats

Shenzhen River: The project will result in the direct loss of 4.5 ha of existing intertidal mudflats along the River margins from Lo Wu to the River mouth due to dredging for channel widening and straightening. For the Stage 1 Works the new channel banks will be lined with concrete slabs and there will be no new intertidal flats in those areas. Design of channel banks for Stage 2 Works is undecided and options are discussed in Sections 2.2 and 10.5.

Sediments in the River are heavily polluted and devoid of benthic infauna, except at the River mouth (McChesney unpublished). The loss of these areas is therefore of no consequence to flora and fauna except where covered by mangrove (see Section 10.4.1.d).

The loss of intertidal mudflats along the Shenzhen River is not significant.

Deep Bay: Intertidal mudflats in Deep Bay may be affected by the Project, depending on future patterns of erosion and deposition, either of which could affect habitat availability.

The sedimentation model (Sections 7 and 8, also 10.4.3) indicates that the Shenzhen River is of relatively minor importance to sediment erosion and deposition within Inner Deep Bay due to the dominating effect of the Pearl River flows into the Bay. The input of marine-sourced sediments on a single flood or ebb tide are shown to be equivalent to the total river-sourced sediments over several months. this result is supported by observation from satellite photography which illustrates graphically the dominance of Pearl River well into Deep Bay.

There will however be an increase in sediment deposition at areas near the head of the Bay as a result of the Project construction works. These are the areas of prime concern to the assessment. Model results indicate a maximum sediment deposition as a result of the Project (over 1 year) of 49 mm and 71 mm at Futian and Mai Po respectively (see Table 7.16) compared with existing levels of 16.4 and 27.0.

Following the works there will be a reduction in sedimentation in Inner Deep Bay (see Figures 7.6, 8.4, 8.5). However, there will still be a depositional environment with sedimentation at levels comparable to those experienced during the late 1980s. The sedimentation and hydrology models indicate a reduction in current sedimentation rates of 60.7% and 22.2% at the River mouth and Mai Po mudflats respectively following completion of the Works (Table 7.18).

It is estimated to take in the order of 7 years after completion of Stage 2 works before the total deposition 'equals' the depositional levels without the Project, given known influences on the river system and Deep Bay (see Figure 10.10). It should be noted however that there appears to have been a dramatic increase in sedimentation rates over the past 8 years as a result of the rapid urbanisation in shenzhen (results of ^{210}Pb analysis).

The prime issue in terms of the assessment of ecological impacts is whether these short term and long term changes in hydrology, water quality and sedimentation will have any significant impact on the ecological system, and particularly the foodweb linkages between the benthic community and higher trophic levels.

Key factors affecting this relationship are the area of mudflats available, the accessibility of these to key species, particularly waterbirds, and any detrimental effects to the benthos due to pollutants.

The loss of up to 4.75 ha of mudflats by colonisation by mangroves has been found to be a key potential impact of the Project (Section 10.4.3.c.i). This outcome, while an extension of a natural succession evident in the Bay over many years, would be a negative effect in terms of bird populations as it would reduce areas available for feeding by waterbirds. In other situations the loss of mangroves is viewed as a negative impact because of their key role in maintaining the ecosystem.

Aerial photographs of the Hong Kong side of the Bay, taken between 1954 and 1994, show no obvious expansion of the mudflat off Mai Po. It appears that this mudflat is delimited by the Shenzhen and Shan Pui River channels. The model results are consistent with this observation and indicate a large erosion area off the mouth of the Shenzhen River, and lower rates of deposition on the north shore of the Bay (Figure 7.6).

The intertidal flats in the north of the Bay are already being reduced by natural mangrove encroachment, planting of mangroves at the Futian National Nature Reserve, and reclamation for road construction and other developments. Mangroves are also encroaching on the mudflat at Mai Po. Thus, loss of mudflat due to mangrove encroachment is likely to be permanent unless active management is used to limit the spread of mangrove colonisation.

Following completion of the Project the predicted sedimentation rate on the Mai Po mudflats will decline but will still be greater than that in the early 1980s, thus mangrove encroachment could be expected to be slower than at present. The causes of accretion of the mudflats and colonisation by mangroves are complex and the Project is likely to be less influential on long term mangrove colonisation than erosion and long term development activity in the Deep Bay catchment. the management of mangroves over the mudflats is expected to be necessary to maintain optimal habitat areas for waterbirds regardless of the Project.

One option for disposal of uncontaminated sediment arising from the Project is to use it for landfill at Shekou (Section 9.2.4). The exact site proposed has yet to be determined but it is expected to be behind the new Futian-Shekou road causeway. If so, this will result in the permanent loss of an additional tidal area in Deep Bay. It should be noted that this area falls outside the study area for the Project and potential impacts of dumping in this area, together with the anticipated requirement for dredging an access channel for barges, have not been assessed.

Potential loss of intertidal mudflats in Inner Deep Bay resulting from the Project is not identified as a key impact. However, active management of mangrove colonisation of mudflats is likely to be necessary to maintain feeding areas for waterbirds due to indirect effects.

10.4.1.c Loss of Sea Grass

The sea grass at the mouth of the Shenzhen River occurs at one other site in Deep Bay, near the mouth of the Shan Pui River (Figure 10.3). The presence of this 'sea grass' was first observed in 1988 near Tin Shui Wai (D.S. Melville unpublished) and was identified as *Eleocharis acicularis*. Griffiths (1983) notes *E. acicularis* as 'common in paddy fields, ponds and wet soil', but there has been a loss of such habitats throughout the Territory and it now appears to be locally restricted in distribution.

The Deep Bay sites are of potential interest in that they are intertidal. However, a preliminary survey of invertebrates found associated with the area of 'sea grass' at the mouth of the Shenzhen River has not revealed any species which are not found elsewhere in Deep Bay (D. Cha pers. comm.). The distribution of *E. acicularis* off Mai Po appears to be spreading as it has recently been discovered on the mudflats off the WWF Hong Kong boardwalk.

Construction Phase Impacts: Some areas of the seagrass will be lost directly through dredging works associated with Stage 2. An increase in suspended solids in the River resulting from dredging activities may adversely affect the seagrass. This will be mitigated through measures to reduce release of sediment during dredging.

Operational Phase Impacts: Given that a depositional environment will be maintained at the mouth of the River and on the mudflats off Mai Po following completion of the Project there is unlikely to be any long term indirect effects due to changes in overall sedimentation patterns. The effect of wake wash from larger vessels could affect sea grass beds and this should be mitigated by imposing speed restrictions on vessels in the River.

Loss of sea grass as a result of the Project is not identified as a key impact.

10.4.1.d Loss of Mangroves

A area of 10.8 ha of mangroves will be destroyed as a result of the Project; 7.8 ha on the Hong Kong side of the River, and 3.0 ha on the Shenzhen side.

The mangroves which will be directly lost on the Hong Kong side have been surveyed and include a mature specimen of *Bruguiera gymnorrhiza*, which is locally uncommon, as well as more abundant species, such as *Kandelia candel* and *Aegiceras corniculatum* (Appendix 10.6).

Creeks upstream of the proposed River embankment will continue to be tidal with culverts installed in the new River embankment. Existing channels may be eroded by post-construction downcutting as the River bed will be lowered. Further drainage works in those tidal creeks which discharge into the lower reaches of the River. An assessment of these impacts is beyond the scope of the present study.

The effect of removing up to 10.8 ha of mangrove from the Deep Bay wetland system (4.8% of the total intertidal mangrove in Inner Deep Bay) may result in various impacts on the system as a whole. Potential impacts include:

- loss of habitat for wildlife;
- loss of nursery shelter for species of importance to commercial fisheries;
- impact on nutrient cycling through reduced nutrient uptake and detritus input;
- loss of coastal protection functions.

The cumulative impacts of mangrove loss within Deep Bay is also of potential concern. In addition to the 10.8 ha lost as a result of the Project, 13 ha are to be lost due to the Yuen Long/Kam Tin Main Drainage Project and further losses will result from the new road reclamation to the west of the Futian National Nature Reserve.

Binnie Consultants Ltd. (1992) assessed potential impacts of loss of mangroves resulting from engineering works associated with the Yuen Long/Kam Tin Main

Drainage Project and concluded that, due to the very high organic pollution loadings entering Deep Bay, the role of mangroves in the nutrient dynamics of Deep Bay was insignificant. However, mangroves act as important nutrient sinks for the system and are a critically important component of the overall ecosystem. The nitrogen content of mangroves in Deep Bay may be as much as 1.5 ~ 1.6% dry weight, Indicating that 465 kg/ha of nitrogen may be stored in mangroves at any one time (S.Y.Lee pers. comm). Although mangroves may not contribute significantly to productivity in the Bay at present, they do act as an important buffer against pollution impacts.

The current high levels of organic input to the Bay are expected to be reduced in future as a result of implementation of the Livestock Waste Control Regulations and the Northwest New Territories Master Sewerage Scheme. These measures are expected to reduce BOD loadings, with an overall improvement in water quality (Section 8). Following the reduction in waste and sewage inputs, mangroves may assume a more important role in nutrient cycling in the system, but it is not possible to further assess this at present.

Mangroves are the primary food source for various benthic organisms including the crab *Perisesarma bidens*. The Deep Bay mangroves are also the type locality for several species new to science including the mite *Dometorina rostrata* and the crab *Chiromanthes/Perisesarma Maipoensis*.

Mangroves in Deep Bay provide an important habitat for various wildlife, in particular nesting and roosting sites for birds, and the mangroves along the Shenzhen River currently also act as a corridor for wildlife. The loss of the mangrove corridor will adversely affect wildlife movements along the River as well as reducing nesting and roosting habitat for birds.

The Shenzhen River is grossly polluted (Section 8) and the river waters and bottom sediments support virtually no life upstream of the river mouth (McChesney unpublished). Mangroves in the river are unlikely to have any important role for habitat apart from providing shelter and roosting sites for birds.

Construction Stage Impacts: There will be loss of approximately 20 ha of mangrove due to construction of the Project. This will result in the loss of a significant storage compartment for nitrogen (9,347 kg), as well as nesting and protection for birds. The loss of coastal mangroves will have important implications to the stability of the ecosystem and should be compensated.

Operational Stage Impacts: The only potential impact of concern is the effect of wash from shipping on mangrove establishment near to the River mouth.

The loss of littoral mangroves is a significant impact of the Project. The mangrove is important to the viability of the overall system and the loss of mangrove should be compensated as far as possible with additional planting. The development of a mangrove management plan by the relevant Authorities and NGO's responsible for the area may be desirable to ensure compensation of losses while maintaining a balance of mangrove intrusion into mudflat habitats in Deep Bay.

10.4.1.e Loss of Freshwater Marshes

A small area (approximately 0.6 ha) of marshland at Liu Pok adjacent to Seung Ma Lei Yue hill will be directly lost as a result of Stage 1 Works.A further 0.4 ha is likely to be adversely affected. This area supports various fish and amphibians, as well as wetland birds, and is a habitat type which is becoming increasingly uncommon in both Hong Kong and Shenzhen. Due to the small size of the area the loss is unlikely to have a significant impact, and implementation of the proposed mitigation measures for Stage 1 Works should adequately compensate for its loss.

An indirect impact of the Project will be the likely further loss of freshwater marshes in the Ma Tso Lung area following completion of Stage 2 Works. At that time the area will no longer be subject to periodic flooding, and thus will be more attractive for infilling and subsequent development. This potential outcome should be considered in development planning for the area.

Construction Stage Impacts: Loss of freshwater marshes as a result of the Project is not identified as a key impact however the maintenance of existing areas of freshwater marshes should be considered in future landuse planning activities.

Operational Stage Impacts: There are no identified impacts during the operational stage.

10.4.1.f Loss of Fish Ponds

The Project will result in the direct loss of 106 ha of fishpond habitat as a result of both Stage 1 and Stage 2 Works: 41 ha will be lost on Hong Kong side, and 65 ha on the Shenzhen side. There has been a significant loss of fish ponds in the northwest New Territories, Hong Kong in the past 20 years due to large-scale infilling for planned developments as well as extensive unauthorised and illegal filling for open storage. The total area lost exceeds 780 ha. Loss of fish ponds in Shenzhen has been almost complete. Part of the Futian National Nature Reserve has also been lost to industrial development.

The extent of fish pond loss around Deep Bay is cause for concern. Chu (1993) provides a valuable review which confirms the importance of fish ponds to wildlife, noting that they are of direct value in providing habitat for a considerable range of bird and mammal species, as well as 'exporting' chironomid midges to surrounding areas, e.g. Mai Po Marshes.

Studies on egrets and herons in Hong Kong (Young 1991, 1994, Wong 1991, Britton 1993) have also demonstrate the importance of fish ponds to these birds. Elsewhere, studies on the breeding productivity of egrets and herons has been linked to availability and proximity of suitable feeding grounds to colony sites (Fasola and Barbieri 1978). The reduction in fish pond area already appears to have contributed to the demise of two egretries in Deep Bay (Young 1994) and further loss of fish ponds is likely to further reduce breeding populations.

The breeding egret and heron populations of Hong Kong are of regional significance, where being few such colonies in Guangdong (Gao Yu Ren in litt. to L. Young unpublished). The wintering populations of egrets and herons, which feed extensively in drained fish ponds, are also of regional importance (Melville *et al.* 1994, Appendix 10.13).

Fish ponds are also a very important habitat for the highly endangered Black-faced Spoonbill. Deep Bay is of global important for the conservation of this species since some 24% of the world population winter in the area. Observations during winter 1993/94 indicated that most feeding activity was in recently drained fish ponds (Appendix 10.12), highlighting the importance of this habitat to the species.

Fish ponds also provide some food for Cormorants, although the majority of these birds feed in Deep Bay rather than fish ponds (Hong Kong Bird Watching Society and WWF HK unpublished). The wintering Cormorant population of Deep Bay is the largest known in East Asia (Perennou *et al.* 1994), and therefore of conservation importance. The wintering population of Imperial Eagles *Aquila heliaca*, which is also considered to be of regional importance (Appendix 10.12), is associated with the fish ponds and freshwater wetlands in the Lok Ma Chau/Ma Tso Lung area.

The fish ponds which will be lost as a result of the project are currently used by a variety of waterbirds, notably egrets and herons, for feeding throughout the year (Appendix 10.12).

Construction Stage Impacts: The loss of 95 ha of fish ponds as a result of the project will reduce the feeding habitat available to egrets, herons, Black-faced Spoonbills, Cormorants and other species. The impact of loss of feeding habitat cannot be accurately assessed at present due to a lack of detailed knowledge of bird/fish pond relationships, but a reduction in bird populations can be expected (Appendix 10.13; Melville *et al.* 1994).

Operational Stage Impacts: Unless land use is suitably controlled, in the long term the Project may promote a further loss of fish ponds and other freshwater wetlands adjacent to the new River as these areas will be more attractive for infilling and development. This could potentially result in a further loss of c.210 ha of wetlands (both fish ponds and freshwater marshes) in the Ma Tso Lung area (Appendix 10.13).

There is an urgent need to assess the cumulative impact of wetlands loss in the Deep Bay area (Appendix 10.13), but such a study falls outside the scope of the present assessment. The need for cumulative impact assessments of projects affecting such complex wetlands is highlighted in the Appendix to Resolution C.5.6. passed at the Fifth Meeting of the Conference of the Parties to the Ramsar Convention in 1993.

Loss of fish ponds is identified as a significant impact of the Project. To avoid further impacts due to fish pond loss, dredged spoil from Stage 2 Works should not be disposed of in existing fish ponds other than those that have already been designated for such use in the Project, at Lok Ma Chau bend.

10.4.1.g Loss of Hillside/Uplands

Destruction of the northern part of the hill at Seung Ma Lei Yue during Stage 1 Works will result in the loss of scrub grassland, broadleaf woodland, pine woodland and open pine woodland, totalling some 5 ha.

There will be a loss of roosting and nesting sites for birds, including the locally rare Bonnelli's Eagle *Hieraaetus fasciatus*, which may breed in the area.

Construction Stage Impacts: The loss of habitat and impact on flora and fauna is not considered to be significant. Mitigation measures for the loss of upland habitats have been detailed in the Stage 1 Report.

Loss of hillside/upland habitats resulting from the Project is not identified to be a significant impact.

10.4.1.h Summary

There will be significant loss of habitat during construction of the Project. Much of the habitat can be replaced through planting and other mitigation works. The loss of fish ponds and littoral mangroves is a significant impact of the Project. Habitat loss will be a long-term impact of the Project but provided that adequate mitigation measures are implemented the loss should not result in significant changes in most wildlife populations.

Habitat loss is identified as a key impact of the Project, particularly with respect to:

- Potential loss of intertidal mudflats due mainly to encroachment by mangroves. This can be controlled through management and selective harvesting.
- Loss of approximately 10.8 ha of mangroves due to the works. The losses are unavoidable to implement the works.
- Loss of 104 ha of fish ponds due to the works. This loss will contribute to cumulative losses occurring due to other projects and will potentially affect food sources for egrets and Black-faced Spoonbills.

10.4.2 Water Quality

10.4.2.a Introduction

The sediments and water of the Shenzhen River are effectively devoid of fauna and thus a worsening of water quality within the River channel during construction is unlikely to have any noticeable ecological impact within the channel. However there may be impacts where the River flows into Deep Bay.

Section 8 and Appendix A8.1 detail the current water quality in the Shenzhen River and Deep Bay. Water quality is poor, reflecting the high input of human sewage and livestock waste, and increasing industrial effluent. The water quality model results indicate that the dredging activities will not cause any significant decrease in water quality either in the Shenzhen River or in Deep Bay, and is predicted to result in some slight improvements. The key findings of the water quality model relevant to ecological impacts are:

- for Stage 1 Works there will be a maximum increase in suspended solids of less than 20% above current background levels;
- no more than 5% of increase in any pollutant would be expected due to increase in suspended solids in the water column at the head of river mouth;
- for Stage 2 the content of suspended solids in the river mouth was conservatively

estimated to reach 150 mg/l on average comparing to 80 mg/l as a baseline;

- the effect of mobilisation of most metals during construction will be insignificant;
- after completion of the Project there will be a slight improvement in water quality in Deep Bay, e.g. TP and TN will decrease by 4 and 2mg/l respectively, while BOD will remain the same.

There is a pollution gradient in the Bay away from the River mouth which appears to be reflected by the benthic species assemblage. Pearson and Rosenberg (1978) developed a model to elucidate the relationships between species diversity, abundance and biomass along a pollution gradient (Figure 10.11).

Information currently available on the benthic assemblage of Inner Deep Bay indicates an abundance of capitellid polychaetes around the mouth of the river, and suggests that pollution in Inner Deep Bay has already pushed the benthic community far towards the right side of the Pearson/Rosenberg model (Figure 10.11). This is expected given the history of gross pollution in the Bay.

There is a potential risk therefore that an increase in pollutant loadings entering Inner Deep Bay during construction might result in further changes, typically reducing average body size of benthos, eliminating some important species (larger bivalves), and shifting the benthic assemblage towards abundant, small sized, opportunistic species, such as capitellid polychaetes. The pollution situation at the mouth of the River is such that a further significant increase in pollution loadings could result in defaunation. Such shifts in the benthos could result in a reduced food supply for waterfowl.

The major source of pollutant release from the works would result from the release of pollutants currently held in the sediments during dredging activities. There are several sources of potential contaminants, including metals, organics and pesticides. The modelling work has predicted that level of contaminants released based on elutrite test of surface sediments from the Shenzhen River. The tests indicated that the release of contaminants due to dredging activities would generally be insignificant (Table 8.7).

The tests did not include the analysis of deep sediments due to difficulties in obtaining suitable samples. However, given that industrial pollution has increased in recent years, there is no reason to believe that the level of metal contaminants in deeper sediments would be significantly greater than in surface sediments, or that the character of contamination would be significantly different from that in surface layers.

It is possible that pesticide concentrations are greater at depth due to higher deposition at a time when there was greater agricultural activity in the catchment (D.J.H. Phillips in litt.). Any occurrences of heavy pesticide accumulation would be expected to be localised however, being associated with former drainage outlets to the river or other point sources. It is unlikely that any limited survey programme of deep sediments undertaken for this assessment would be able to detect localised areas of high pesticide concentrations. Therefore, rather than take isolated samples of deep sediments, it is proposed to initiate a comprehensive monitoring programme for pesticides and metals during the dredging works. Suitable controls on dredging could be implemented in response to any identified significant contamination. This approach is considered to be more prudent than reliance on isolated sampling prior to dredging.

10.4.2.a.i Construction Phase Impacts on Water Quality

Fish ponds adjacent to the River will be drained before engineering works start. There will be a 'one off' discharge of water from the ponds to the River and limited maintenance pumping may be needed in the wet season. Water quality in the ponds is better than that in the River (Section 8) and no adverse effects on flora and fauna are expected from this discharge.

Water quality will be affected during the construction phase due to dredging activities stirring up bottom sediments, with concomitant release/resuspension of nutrients and other pollutants (Section 8). The effects on water pollution in the River and Bay are described in Sections 7 and 8 and summarised above. There is no evidence that the additional short term pollutant load will have any significant effect on the benthic ecology at the head of the Bay except possibly around the River mouth. It is important however that all possible measures are taken in the construction works programme (timing and location of dredging) to minimise sediment release and consequent effects on water quality (Section 12.6).

There is no evidence based on the elutriate tests and modelling results to expect any impact on ecology due to declining water quality during construction works.

10.4.2.a.ii Long term impacts of Changes in Water Quality

In the operational phase, water quality will be affected by any changes in pollutant load entering Deep Bay or the Rive from the Project caused by maintenance dredging or from increased shipping activities.

Using current and predicted pollution inputs to the Shenzhen River, the model indicates that the enlarged River channel will result in slightly reduced amounts of pollution entering the Bay due to greater fall out of pollutants in the slower moving water. No significant impacts are expected from this decrease.

The effect of maintenance dredging will depend on the type of equipment used, the number dredgers employed at one time, season in which dredging is done etc. Detailed information on these is not available. The extent of maintenance dredging will be relatively very minor compared to construction activities. Only recent surface deposits will be disturbed and these are less likely to be contaminated with organic wastes as pollution these parameters is not available.

An increase in shipping activity on the new River is expected which will result in additional resuspension of bottom sediments. As the River is effectively devoid of life and is expected to remain grossed polluted for many years, the additional resuspension will have no significant effect within the River.

Operational Impacts: Based on the modelling results no significant impacts on ecology are predicted due to changes in water quality during the operation of the Project.

10.4.2.a.iii Cumulative impacts of Changes in Water Quality

The assessment has identified potentially significant cumulative effects arising from the Project and various other dredging and infilling projects in Deep Bay area.

The major projects of concern include:

1) The Yuen Long/Kam Tin Main Drainage project is likely to result in changes in both hydrology and water quality in the southern part of Inner Deep Bay. An EIA for that project is currently in progress, but it is uncertain whether it will consider cumulative impacts from the Shenzhen River Project.

2) Possible dredging of the main channel through Inner Deep Bay from the mouth of the Shenzhen River towards Tsim Bei Tsui also could have profound impacts on hydrology and, hence, water quality.

In considering cumulative impacts it is necessary also to consider the broad changes in Deep Bay which may impact on ecology over the life of the Project. During the projected time frame for the initial construction works it is expected that there will be a reduction in organic loadings entering the River from the Hong Kong side as a result of the enforcement of the Waste Disposal (Amendment) Ordinance, Cap. 354, and the Waste Disposal (Livestock Waste) Regulations. There should be a further reduction in organic input from the Hong Kong side after 1997 (during the operational phase of the Project) when mains sewerage facilities will be provided throughout much of the catchment.

Because organic sewage loading provides the majority (>60%) of the nutrients driving the foodweb (Appendix 10.8), reducing organic inputs into Deep Bay may affect the foodweb. The invertebrate assemblage of areas near the river mouth could be expected to shift to resemble that observed on the less-polluted transect. Corresponding increases in diversity, increased individual body sizes, and possibly lower total biomass would be expected to accompany the reduction in pollution. However, the presence of individuals of prey species of larger body size may mean that an improvement in water quality would not necessarily result in a decrease in carrying capacity for migrant birds (Section 10.4.2.d.ii).

Levels of inorganic pollution entering the River and Deep Bay are increasing as a result of industrialisation on both sides of the catchment. No information is available on expected trends in inputs of such contaminants at present.

Future trends in pollution loads entering the River from the Shenzhen side are currently unavailable. There is a need to determine the likely cumulative impacts of these projects, but this is beyond the scope of the present study. The proposed 'Deep Bay Water Quality:Regional Control Strategy Study ' will address the issue of cumulative impacts of development on water quality in the Bay, including an assessment of its assimilation capacity.

The need for cumulative impact assessments is highlighted in the Appendix to Resolution C.5.6. passed at the Fifth Meeting of the Conference of the Parties to Ramsar in 1993.

Water quality impacts predicted by the models indicate that there will have a slight improvement in water quality following completion of the Project (Section 8).

- Construction Stage effects will not be significant provided that operations are designed and programmed to minimise release of sediments into the river.

- Operational Stage impacts will not be significant.
- There is an urgent need to address the cumulative effect of the various dredging and related projects in progress or planned for Deep Bay.

It is recommended that the cumulative impacts of the various projects impacting on Deep Bay be assessed in detail to determine potential change to the intertidal flats in Deep Bay.

10.4.2.b Water Quality Impacts on Mangroves

Mangrove systems are generally more resilient to organic loading than most other coastal systems (Nedwell 1974). Mangroves also act to remove pollution by trapping particulate pollutants transported in tidal water during normal sediment accretion processes and absorbing dissolved pollutants from tidal water.

Mangroves can however be affected by pollution and/or nutrient enrichment. Effects include reduced growth, biomass accumulation, productivity and foliar nutritional status (Onuf *et al.*1997, Boto and Wellington 1988, Naidoo 1990).

The interactions between tidal water and mangroves are complex, being dependent on the specific physical features of the mangal (tidal inundation, sediment type, topography; Alongi *et al.* 1992) and chemical characteristics of the substrate (salinity, redox:Boto and Wellington 1988). High nutrient loads may decrease biomass (in vitro N-enrichment experiment: Naidoo 1990). Nutrient enrichment may also affect secondary producers (Onuf *et al.* 1997), and cause changes in the structure or function of mangrove assemblages.

10.4.2.b.i Short Term Water Quality impacts on Mangroves

The major potential short term impact of water quality on the mangrove community relates to the deposition of organically enriched sediments. The oxygenated layer in the mudflat at Mai Po is shallower than 40 mm in depth in summer. Only a very thin layer (~1 mm) is oxygenated in the mangrove adjacent to the river mouth in January (McChesney unpublished) which could indicate that the flushing of organic/nutrient rich material to the Bay in the summer wet season is already causing oxygen depletion in the mudflats.

Potential effects of deposition of organic sediment include:

1) An increase in oxygen demand in the sediments, reducing oxygen supply to below-ground parts of mangroves. Reduced oxygen is recognised as an existing constraint on growth, and a further reduction due to deposition of oxygen demanding sediments may have an adverse impact on mangroves. Furthermore, hypoxia in the water column due to nutrient release from sediments could adversely affect mangroves, particularly *Avicennia*.

2) Adverse effects on benthos affecting oxygen demand (Section 10.4.2.c.). Crabs and burrowing worms play a significant role in increasing oxygenation of sediments in mangals through their burrowing activities. A reduction in benthos populations could have a further adverse knock-on effect on mangroves.

3) Release of other pollutants. Some mangrove species are susceptible to herbicides (Odum *et al.* 1985). Sublethal herbicide effects include reduced production.

4) During the construction period increased marine traffic associated with the Project may increase the probabilities for collision and spillage of oil and other chemicals. Oil pollution impacts on mangroves are well documented and may lead to death (Odum *et al.* 1985, Boer 1994). Impacts can be minimised through control of shipping and implementation of a spill contingency plan.

The water quality model predicts no major change in water quality as a result of sediment deposition in the Bay. Therefore no significant impact on the mangrove due to changes in water quality is expected provided the recommended measures to minimise sediment release are adopted.

10.4.2.b.ii Long Term Water Quality Impacts on Mangroves

Pollution effects have been reported in the mangals of Deep Bay. These include enhanced mangroves productivity and increased seeding size both of which may be either a response to nutrient input or a "detoxifying" effect (Chiu 1992). Whether further inputs of pollutants in these areas would affect productivity further, or exceed the tolerance limits of the trees, is unknown. However, as noted above (Section 10.2.5) low seedling recruitment rates in stands along the banks of the Shenzhen River (Appendix 10.6) and Kam Tin River (Binnie Consultants Ltd. 1992) are attributable, at least in part, to pollution levels.

Most of the mangrove stands lining the Shenzhen River will be lost due to the engineering works. As a slight improvement in long term water quality is predicted by the model as a result of the Project, survival of planted mangroves which has been recommended a mitigation measure (Section 10.5.1.b) should not be impaired. Appropriate baffling against wave wash will be necessary. (Appendix 10.4)

The slight improvement in water quality following completion of the Project predicted by the model, in terms of decreased organic loads and decreased nutrients (N,P), could decrease primary production of the mangrove forest. However nutrient levels would have to drop very considerably before the mangroves would be expected to be limited by a lack of nutrients (Boto 1983), and such a reduction is not expected to result from the Project.

No long term impacts on mangroves due to changes in water quality are predicted.

10.4.2.c Water Quality Impacts on Benthic Invertebrates

The existing benthos largely derives its nutrient supply from allochthonous organic loads discharged to the Bay by the Shenzhen River and others Rivers and Pearl River (Appendix 10.8). The Project will cause a small short term increase in pollution load during construction but will not affect overall pollution loads entering the Bay in the longer term.

Studies in Europe indicate that limited levels of organic enrichment in estuaries may result in increased densities of some benthic organisms (Pearson and Rosenberg 1978, McLusky 1981). If these organisms are favoured prey for waterfowl, then organic enrichment may lead to improved feeding conditions for some bird species (Harrison and Grant 1976, Tubbs 1977, Prater 1981, van Impe 1985). However, as Tubbs (1977) noted, 'On general biological grounds, there is reason to view with great caution any proposal to increase the volume of effluent entering [an enclosed estuary]'.

Pearson and Rosenberg (1978) reviewed several studies and generalised that moving closer to a source of organic pollution, or increasing organic loads at a given site, will produce the following effects. First, species diversity decreases as intolerant species die off, and the tolerant species increase in numbers due to increased availability of resources. Next, more and more tolerant species die off, and the remaining tolerant species tend to be small in size. Finally, only large numbers of very small bacteria survive (Figure 10.11).

Species diversity of Deep Bay benthos is limited due to pollution levels. This is evidenced by high densities of organic pollution-tolerant species such as tiny capitellid polychaetes and oligochaetes (Appendix 10.9). Further degradation of water quality due to increased organic loads could result in further reduction of benthos species diversity, favouring the small-bodied, pollution tolerant species.

Possible effects of worsening water quality on populations of individual benthic species in Deep Bay are uncertain, but pollution levels are so high at present that it is considered unlikely that any further enrichment of waters entering the Bay could be beneficial. Evidence from the current study (Appendix 10.9) indicates that the benthic community is already stressed and it is considered that pollution levels around the River mouth have already pushed the benthic assemblage far to the right of the Pearson/Rosenberh graph (Figure 10.11).

10.4.2.c.i Short Term Water Quality Impacts on Benthic Invertebrates

The abundance, biomass, and species diversity of invertebrate benthos in Deep Bay already are affected by organic pollution (Appendix 10.9). Potential short term impacts could arise from release of nutrients (as well as heavy metal toxins and organochlorine compounds) from dredging bottom sediments during both construction and subsequent maintenance of the Project.

The effect of nutrients release will depend on its timing and severity. The distribution of abundance, biomass and species diversity of benthos at the head of the Bay appear to be related to the gradient in organic loading. This is shown in the transects illustrated in Figure A10.9.1. The Shenzhen River bottom sediments are devoid of benthos, whereas the ET transect contains pollution indicator species (capitellids), and the RB transect shows the most diverse benthic assemblages in any season (Appendix 10.9). The RB transect area contains animals of larger individual body size, and contains bivalve molluscs that appear to be important to migrant shorebirds.

A short term release of nutrients will cause a varying degree of eutrophication depending on the season in which it occurs. In the cooler months, greater dissolved oxygen levels buffer against impacts of hypertrophication on benthos. However during warmer weather, additional eutrophication is more likely to occur. Any large pulses of organic release from dredging during this period could potentially defaunate the mudflat, particularly in the area adjacent to the Shenzhen River mouth. During the summer period river flows are generally higher however providing some greater dilution of any release.

It is however critically important that the works design and programme avoid any major pulse of pollution entering the Bay. This can be achieved through programming of the works and use of settlement ponds to trap nutrient rich sediments.

Based on the results of water quality and sediment modelling there is no evidence to indicate potential impacts on benthic invertebrates from the Project due to deposition of sediments rich in organic material and subsequent oxygen depletion away from the River mouth. All recommended measures to minimise the release of sediment as a result of the dredging works should be implemented.

10.4.2.c.ii Long Term Water Quality Impacts on Benthic Invertebrates

The Project is predicted to result in a slight improvement in water quality in Deep Bay (see Section 8). Any significant improvement in water quality and reduction in nutrient levels could result in reduced abundance of certain pollution-tolerant benthic species (Figure 10.11). Any significant overall improvement in water quality would be expected to push the benthos species richness-abundance-biomass curves to the left of the Pearson/Rosenberh model (Figure 10.11),i.e. result in a more species rich assemblage, probably with a higher biomass.

Reduction in pollution-favouring benthic species following an improvement in water quality may result from reduced ability to compete and/or an increase in fish predation as fish populations increase in the estuary (Andrews and Rickard 1980, Andrews 1984, Funess *et al.* 1986). Such a decrease in benthic invertebrate populations has been documented in the Clyde and Thames estuaries in the U.K.

As modelling for this Project indicates no substantial change in water quality due to the Project there is no evidence of any significant long term impacts on benthic invertebrates due to changes in water quality.

10.4.2.d Potential Water Quality Impacts on Waterbirds

Effects of changes in water quality resulting from the Project (other than oil pollution incidents) will be conveyed to birds through changes in the benthic fauna which they feed upon. The plasticity of feeding habits of most waterfowl suggests that minor changes in benthic species composition are unlikely to result in significant changes in waterfowl populations or species composition, but changes in total available prey (e.g. through changes in species composition, or standing crop/productivity) could result in major population changes in waterfowl.

Studies of impacts of habitat loss on waterfowl are still at a relatively early stage of development and to date have highlighted that consequences for animals living within an estuary may differ considerably amongst themselves, and from area to area (McLusky *et al.* 1992).

Animals, especially those at or near the top of food chains such as waterfowl, may accumulate metals, organochlorine compounds, etc. Accumulation of such substances may result in both direct and indirect effects, which may be either lethal or sub-lethal. These include direct mortality through poisoning and indirect mortality due to reduced immunity to infection, reduced breeding output, and mutagenic problems (Anon. 1990a, Anon. 1990b, Bryan and Langston 1992, Cooke and Prestt 1976, Custer *et al.* 1983, Eisler 1986a, 1986b, 1987, Faber *et al.* 1972, Fry and Toone 1981, Goldberg and Yuill 1990, Honda *et al.* 1986, McLusky *et al.* 1986, Sheehan *et al.* 1987, Stone and Okoniewski 1988, van der Molen *et al.* 1982).

Toxic effects on wildlife are complex, with responses to the same element or compound differing between different organisms, even if closely related. There also may be complex interactive effects when several contaminants are present at one time, and the toxicity of a combination of two pollutants may be substantially greater than the summation of the toxicities of the individual compounds (Bryan and Langston 1992, Johnston *et al.* 1989, 1994, Walker *et al.* 1993). The bioavailability of contaminants also may be affected by factors such as salinity, pH, and organic content of sediments (Bryan and Langston 1992, Haslam 1990, McLusky *et al.* 1986).

10.4.2.d.i Short Term Water Quality Impacts on Waterbirds

The elutriate and model results for Stage 1 Works indicate that 'no significant impact on water quality at the head of the Bay will be caused by the release of pollutant from the resuspended solid'. There could , however, be adverse impacts on water quality from Stage 2 works at times of high flow (Section 8.4.2). Of the metals present in the River sediments, lead is most likely to be released to the water column (Tables 9.6 and 9.7).

There remains uncertainty over levels of some metals and organochlorines in the River sediments, and hence the potential risk which these might pose to waterfowl. To address these uncertainties it is proposed to undertake an extended monitoring programme during the works in order the any elevated contaminant levels can be detected promptly and suitable controls implemented.

A further potential concern relates to any short term deterioration in oxygen levels at the areas adjacent to the Shenzhen River mouth. These areas are preferred foraging areas for duck and waders, and any loss of benthic fauna in these areas, particularly in spring, would have a detrimental impact on the ability of migrants to accumulate the fat/protein reserves necessary for successful migration to the next staging site along the migration route.

Evans *et al.* (1991) note that such a scenario would have the greatest impact on long distance migrating, high arctic-breeding shorebirds. The timing of their migration is critical, as is the condition in which they arrive on the breeding grounds (Section 10.2.9). Given that different species forage on different prey, the effects of reduction of the benthos due to hypertrophication may vary between predatory bird species.

Spalding *et al.* (1993) note the epizootics of the nematode infestation Eustrongylidosis which affects Ardeids in the USA, seem to be linked to nutrient pollution. There is no information available regarding nematode infestations in Hong Kong.

The model results do not indicate deterioration in any parameters which may impact on waterbirds as a result of the construction of the Project. This conclusion assumes that all necessary mitigation measures to control nutrient release during dredging are implemented by careful scheduling of works near the River mouth.

10.4.2.d.ii Long Term Water Quality Impacts on Waterbirds

Long term improvements in water quality as a result of the Project could potentially result in a reduction in benthos and hence a reduction in the waterfowl prey base. On other estuaries reduced abundance of benthic invertebrates following an improvement in water quality apparently has resulted in a reduction in populations of some waterfowl (Furness *et al.* 1986, Swift 1976), or a change in waterfowl species composition (Prater 1981, McLusky 1981).

Green *et al.* (1992). however, note that:'Previous studies of the effect of organic inputs on bird populations suggest that moderate levels of organic inputs may enhance the carrying capacity of intertidal areas for wintering bird populations. Studies of estuaries showing declines in organic inputs show correlated declines in wintering bird populations. Although such declines can be shown to be accompanied by decreases in food availability, no author is prepared to say that decreases in organic inputs have been responsible, because of the existence of other confounding factors in each case. It is unclear from published work whether there is a direct causal link between organic enrichment and bird population or whether the effects of organic enrichment on birds are exerted indirectly through their impacts on invertebrates'.

The very slight long term improvement in water quality anticipated as a result of the Project (Section 8) is unlikely to result in any noticeable change in benthos (Section 10.4.2.c.ii) and thus is unlikely to affect waterfowl. Inner Deep Bay is currently so polluted that, should there be a long term improvement in water quality due to improved management of the catchment, it is expected that this would result in an increase in species richness and probably in biomass of the benthos (Figure 10.11, Section 10.4.2.c.ii), and thus could be expected to benefit waterfowl.

No long term impacts on waterbirds are predicted due to long term improvements to water quality as a result of the Project.

10.4.2.e Water Quality Impacts on Commercial Species

Commercial activities in Deep Bay of potential concern include oyster production, shrimp farming and commercial fisheries.

Oyster Cultivation: Deep Bay has been a major oyster cultivation area for many decades, however the industry has been in declined for the past decade and 1993 aerial photographs (the most recent available) indicate no oyster culture taking place on the Hong Kong side of Inner Deep Bay. it is unlikely that oyster cultivation will return to the Bay due to continuing pollution and changing landuse patterns. No impact on oyster cultivation will occur.

Shrimp Farming: The commercial shrimp *Metapenaeus ensis* could be affected both in the Bay and in the Mai Po *gei wais*. Wong *et al.* (1993a) state that 'heavy metals may be one of the major environmental factors reducing larval recruitment of penaeid shrimp in the heavily polluted waters of Hong Kong and the Zhiujiang River estuary' and found that copper was more toxic to larvae and postlarvae of M. ensis than chromium or nickel.

Changes in seasonal flow of freshwater into the Bay are unlikely to result from the

Project. However, if significant changes do occur, settlement of larval invertebrates could be adversely affected, as could migration into the mangroves of some commercially important species, such as *Metapenaeus ensis*. No impact on shrimp farming is expected due to changes in water quality.

Commercial Fisheries: There is no information available regarding fin-fishery harvests in Inner Deep Bay. It is known that fish fry (*Mugil/Liza* spp.) are collected in Inner Deep Bay for seeding fish ponds, and adult mudskippers *Boleophthalmus boddaerti* are trapped for food (Section 10.2.6). A worsening of water quality could be expected to reduce fish populations, but a reduction in organic loading would improve conditions and might result in increased species diversity/numbers (Section 10.4.2.c).

Modelling results indicate that water quality should not be noticeably changed as a result of the Project and could improve slightly after completion of Stage 2 Works. No significant effects on commercial species are expected as a direct result of the Project.

No impacts on commercial species due to water quality changes are expected as a result of the Project.

10.4.2.f Water Quality Impacts on Mammals

Inorganic pollutants could adversely affect mammals, notably Otters, and possibly Chinese White Dolphins. Dolphins may be affected if contaminated sediment from the Project is dumped at the East Sha Chau dumping ground however this would be part of the broader marine disposal programme and is beyond the scope of this assessment.

There will be no impacts on mammals due to water quality changes from dredging activities for the Project.

10.4.2.g Summary: Water Quality Impacts

Change in water quality during construction will be minimised through measures to limit release of sediment. Any short term impacts are expected to be limited to the area of the River mouth. Long term change in water quality is not expected to result in any significant ecological impacts. There are uncertainties regarding the extent of contamination due to release of some metals, pesticides and PCBs during construction. This uncertainty cannot be effectively addressed through the assessment and an extended monitoring programme is proposed to ensure that any unexpected levels of contamination are detected promptly and suitable controls on dredging implemented. The required mitigation measures are described in Section 8.5.

10.4.3 Potential Impacts from Erosion and Sedimentation

10.4.3.a Introduction

Impacts of the Shenzhen River Regulation Project on sediment quality and sedimentation are discussed in Section 7 and 8. The major findings relevant to potential ecological impacts are:

- The model does not predict any significant change in hydrology in the Bay resulting from the Project, thus existing channels are expected to remain essentially unchanged.

- The maximum discharge rate predicted during flood events could result in localised erosion at the River mouth but there will continue to be nett deposition.

- Core sampling of tidal flats in Inner Deep Bay indicates that there has been a doubling in the rate of sediment accumulation since the mid-1980s, with current deposition rates ranging from 28.4 mm to 36.8 mm per year (Appendix 9). These rates are not dissimilar to current estimates from visual observations on the mudflat off Mai Po (McChesney unpublished; Table 10.6) and compare favourably with the model result of 27 mm off Mai Po (Table 7.18).

- The model indicates that there will be an increase in the rate of sediment deposition around the River mouth during the Stage 1 Works (6.8%) and, more particularly, during the Stage 2 Works (32.8%) (Table 7.18).

- If Stage 1 and 2 Works overlap for 18 months, as currently anticipated, it is predicted that there would be a 39.6% increase over current sediment deposition levels during this period around the River mouth. [The equivalent figures for the mudflats off Mai Po are: Stage 1 increase 14.8%, Stage 2 increase 37%, if Stage 1 and 2 Works overlap an increase of 51.8%. Those for Futian are: Stage 1 an increase of 14.6%, Stage 2 an increase of 37.2%, and if Stages 1 and 2 overlap an increase of 51.8%.]

- Following completion of the Project the rate of sediment deposition around the mouth of the River is expected to be reduced by more than half (60.7%) of the current rate (average 34 mm vs 86.6 mm). The reduction of sedimentation rate on the Mai Po mudflats, following completion of the Stage 2 Works, is predicted to be 22.2% and at Futian 26.8% below current (1995) levels. The sedimentation rates at these sites would still be greater than in the early 1980s.

- Sediment loads from the Shenzhen River can be expected to be reduced further than the model indicates as a consequence of the implementation of the Livestock Waste Controls in Hong Kong, and further development in Shenzhen.

Table 10.6 Estimates of sedimentation rates in Deep Bay

Rate (mm/yr)	Time Period	Location	Reference
1.1	6000BC-present	whole Bay	Anon 1985, Yim 1984(total deposition)
8	1898-1949	Whole Bay	Wong and Li 1990 (maps)
14.9/16.6/12.7	1984-1986	outer/mid Bay	Wong and Li 1990 (^{210}Pb)
25-30	1992-1994	Mai Po	McChesney unpubl.(direct observation)
28.4-36.8	1994	Inner Bay	this study (^{210}Pb)
20-105	1994	Inner Bay/River mouth	this study (model)
36.6	1994	Mai Po	this study (model)
11	1993	Mai Po mangroves*	Duke and Kahn unpubl. (survey)
12	1986	Mai Po *gei wais***	Lee 1989

* average figure across whole mangrove area
** sedimentation within a *gei wai* - not directly comparable with other data

10.4.3.b Impacts due to Erosion

The model predicts no widespread erosion in the Inner Bay as a result of the works (Figure 7.6). The general condition will be one of deposition with erosion occurring during major flood events. This pattern is similar to the existing situation.

Following the works there may be small areas of localised erosion but the overall trend will continue to be to deposition. Localised erosion may affect small areas of mangrove and benthic invertebrates.

10.4.3.b.i Erosion Impacts on Mangroves

Localised downcutting of existing tidal creeks and the river channel may erode sediment from around the roots and stems of mangroves. In extreme cases this may cause death. Such an effect has been observed in a tidal creek at Mai Po where regular wash generated by a floating walkway has resulted in erosion of the bank and creek bed (C. Anderson, unpublished).

Back-cutting of tidal creeks, as a result of river bank erosion by marine traffic effects, may also result in loss of mangroves. This is most likely at the north end of Mai Po near the River mouth. This could be mitigated by enforcement of speed limits on vessels using the River.

Impacts on mangroves in Deep Bay caused by erosion will be localised and are considered to be insignificant.

10.4.3.b.ii Erosion Impacts on Benthic Invertebrates

Previous work on the Mai Po mudflats (McChesney unpublished) indicates that few benthic invertebrates are present below 20 cm depth. The majority of the density and diversity of benthos is in the upper 4 cm of mud. This implies that a massive and concentrated erosion event on the mudflat would be likely to result in decreased availability of benthos.

A gradual erosion of surface sediments is unlikely to result in defaunation since the benthos would be expected to burrow deeper in response to a gradual lowering of the mudflat surface. An overall reduction in the height of the mudflat surface could result in changes in species composition and distribution due to changes in the length of time of exposure and inundation over a tide cycle.

The Project will not result in any extended, or severe localised erosion and no impact due to loss of benthic invertebrates due to erosion is predicted.

10.4.3.b.iii Erosion Impacts on Waterbirds

Given that it appears that Deep Bay may be nearing carrying capacity for waterfowl (Section 10.2.9), any reduction in mudflat area will reduce feeding areas and is likely to affect bird populations in Deep Bay. Erosion over the intertidal flats could also result in a reduction of the time available for birds to feed, as the flood tide would inundate eroded areas earlier.

The model predicts no significant change in erosion regimes and thus waterbirds should not be affected by erosion.

10.4.3.c Sedimentation

10.4.3.c.i.i Sedimentation Impacts on See Grasses and Mangroves

Sea Grasses:

The sea grass *Halophila becarii* grows on the mudflats in front of the Futian National Nature Reserve (Morton 1984) and on the Hong Kong side (Hodgkiss and Morton 1978). The Futian *Halophila* could be adversely affected by increased rates of sedimentation during construction, as appears to be happening at present to *Zostera japonica* and *H. ovata* at Tung Chung, Lantau as a result of dredging and filling associated with the construction of the Chek Lap Kok airport (Lee 1994).

During the construction stage the area of 'sea grass' (c.f. *Eleocharis acicularis*) at the mouth of the Shenzhen River is likely to be lost through dredging (Section 10.4.1.c). Those areas remaining could be adversely affected by increased levels of suspended solids during construction and maintenance dredging.

During the operational Stage the predicted reduction in sedimentation will result in rates similar to those of the mid 1980s and there is no evidence to suggest that either *H. ovata* or the 'sea grass' will be affected.

Seagrass communities near to the River mouth could potentially be affected by increased sediment.

Mangroves:

Potential impact on mangroves could result from elevated levels of sediment levels due to the Project. Growth could be affected by reduced gas exchange due to silt covering the pneumatophores of *Avicennia marina* or from blockage of the lenticels on the trunks of other species. There is anecdotal evidence of such an effect in Tolo Harbour, where mangroves died after sediments from spoil dumping runoff were deposited around the tree roots (Melville unpublished).

10.4.3.c.i.ii Short Term Sedimentation Impacts on Mangroves

Mangroves are typically found in areas where sediment accumulation is occurring through geological processes (Woodroffe 1992). The mangroves themselves often promote accretion of sediment by physically slowing the flow rates of sediment laden tidal waters. Accretion may be balanced in the long term by erosion caused by storm events. (Lugo and Snedaker 1974).

Extreme levels of sedimentation can have a detrimental effect on mangrove species. It is estimated that deposition of > 5 cm on the floor of mangal would cover the pneumatophores of *Avicennia marina*, and the lenticels of *Kandelia candel*, impairing their functional. Sediment accumulation around the trunk (*Kandelia candel*) or over the pneumatophores (*Avicennia marina*) is likely to kill mangrove trees since oxygen transportation to the roots will be inhibited.

The model predicts that there will be an increase of up to 51.8% in sedimentation rates on the mudflats in the Inner Bay when Stage 1 and 2 Works overlap and/or during Stage 2 Works, with up to about 14 mm additional sediment being deposited annually. It is estimated that the Mai Po mangal is currently accreting at a rate of 1.1 cm per year (Duke and Khan, unpublished data) (Appendix 10.7).

There is no evidence to indicate a negative effect on mangrove communities due to increased sedimentation as a result of construction works.

10.4.3.c.i.iii Long Term Sedimentation Impacts on Mangroves

The mangal is currently encroaching onto the mudflat at a mean rate of approximately 3.5m per year. Increased rates of sediment accretion will, therefore, cause encroachment rates to be increased at an estimated rate of 2.86m per cm of sediment (Appendix 10.7). Rates will be higher along the banks of tidal creeks which are slightly high than the adjacent flats. This accretion will lead to decreased areas of mudflat in Deep Bay.

The mangrove forest at the northern end of Mai Po was destroyed in the 1970's by fish pond excavation (Appendix 10.7). Regrowth of mangrove forest seaward of the pond bunds was rapid but it has yet to attain the characteristics of a mature stand, i.e., clear zonation patterns, high biomass and high basal area. If this is indicative of the patterns of regrowth following disturbance or removal, a similar pattern may be expected at the mouth of the river following construction of the Project. It is probable that loss of mudflat through mangal encroachment will occur in this area.

Based on the above figures and the sedimentation rates in Table 7.18 it is possible to estimate the potential increase in mangrove area attributable to the Project (Table 10.7). This suggests that between 1.59 and 4.57 ha of mudflat at Mai Po could be colonised by mangrove as a result of the Project. The higher estimate is an extreme-case as the rate of sediment deposition away from the River mouth may be reduced, and the rate of encroachment is based on accretion within the mangrove not on the mudflat. These estimates indicate a likely need to manage mangrove colonisation as a long term conservation measure to conserve mudflat areas.

An increase in sedimentation during construction would also be expected to result in an increased rate of colonisation at Futian.

The sedimentation model predicts that following completion of the Project there will be a reduction in sedimentation rates on the mudflats of Inner Deep Bay compared to existing levels. Sedimentation rates will still be at levels greater than those recorded in the early 1980s. Since mangroves appear not to have suffered from varying rates of accretion during the period 1980-1994 it is considered that the predicted reduction in sedimentation is unlikely to adversely affect the mangal, although the rate of encroachment onto the mudflat is likely to be reduced.

The Project is likely to increase the rate of mangrove colonisation within Deep Bay. A mangrove management scheme may be necessary to maintain an optimal balance of mangrove and mudflat areas for conservation objectives.

Table 10.7 Estimation of mangrove encroachment on Mai Po mudflat due to increased sedimentation resulting from the Project

Stage 1	
increase in sedimentation rate	4 mm/yr (Table 7.18)
construction period	28 months
total sediment increase	9.32 mm
rate of mangrove encroachment	2.86 m/cm sediment
total encroachment	2.7 m
Stage 2	
increase in sedimentation rate	10 mm/yr (Table 7.18)
construction period	42 months
total sediment increase	35 mm
rate of mangrove encroachment	2.86 m/cm sediment
total encroachment	10 m
Stage 1 + Stage 2	
total encroachment	12.7 m

Assuming an equal rate of encroachment all along the front of the Mai Po mangrove this results in 3,600 m × 12.7 = 4.57 ha

Possible mangrove may also be calculated based on the assumption that the average gradient of the Mai Po mudflat from the present mangrove edge to the River channel is 1:1,000. If it is further assumed that the mudflat elevation at the mangrove edge is the optimum for mangrove establishment, and that increased sediment loads are spread evenly over the mudflat, then:

total increase in sediment/deposition	9.32 + 35 mm = 44.32 mm
encroachment	4.32 m
total area of mangrove	3,600 m × 4.43m = 1.59 ha

10.4.3.c.ii.i Sedimentation Impacts on Benthic Invertebrates

Potential impacts on the benthic community could arise from a change in particle size distribution within the mudflat due to changes in hydrology or to extreme short term deposition which smothers the benthic community.

10.4.3.c.ii.ii Short Term Sedimentation Impacts on Benthic Invertebrates

The shore at Futian at present is coarser than that at Mai Po. Grain size for samples from Mai Po is given in Table 10.8. The differences in substrate result in differences in the benthic infauna (Morton 1984, McChesney unpublished, Appendices 10.9 and 10.10).

If the sediment particle was to change as a result of the Project, impacts on benthos may differ between Futian and Mai Po, especially if there is an increase in fine-grained sediment deposited at Futian. The 37.2% increase in the sedimentation at Futian during

Stage 2, as predicted by the model, is expected to comprise mainly fine material. This could result in a change in benthic species composition in favour of those species which favour softer substrate.

Table 10.8 % frequencies of grain size and total organic carbon (TOC) of sediments collected at Mai Po*

	January 1994				May 1994			
	TOC (%)	Size Classes (μm)			TOC (%)	Size Classes (μm)		
		>100	>50	<50		>100	>50	<50
rbo	2.82	0	8.81	91.2	2.24	0	11.1	88.8
rbo	2.49	0	15.2	84.7	2.55	0	9.29	90.7
rb3	3.25	0	3.07	96.9	3.00	0	1.71	98.2
rb3	3.00	0	1.92	98.0	2.55	0	1.78	98.2
ch1	2.90	0	2.10	97.8				
ch1	3.75	0	2.02	97.9				
450	3.57	0	0.70	99.2	2.81	0	0.70	99.2
450	3.22	0	0.97	99.0	2.79	0	1.01	98.9
et4	3.83	0	1.22	98.7	2.66	0	0.68	99.3
et4	3.22	0	0.85	99.1	2.82	0	0.58	99.4
et3	2.83	0	2.11	97.8				
et3	2.94	0	1.20	98.7				
et2	2.96	0	2.03	97.9	2.32	0	1.17	98.8
et2	3.39	0	2.29	97.7	2.45	0	1.41	98.5
et1	3.06	0	9.77	90.2	2.20	0	7.83	92.1
et1	2.64	0	16.7	83.2	2.06	0	6.81	93.1

* for sampling locations see Appendix 10.9, Figure A10.9.1

Any changes in particle size or composition are expected to be relatively minor within the context of the total system and will have little impact on the overall ecosystem and food supply to waterbirds.

The model results predict an increase in sedimentation rates during both Stage 1 and Stage 2 works. The potential effect of a sudden increase in sediment smothering invertebrates was investigated to determine if the rates of sedimentation caused by the Project might potentially smother benthic species or change species composition.

Immediate deposition of 5 cm of sediment on the mudflat in winter resulted in a 31.2% reduction in abundance and a 73.9% reduction in biomass of benthos after 10 days . There was a further reduction in benthos if the sample to which 10 cm of sediment was added, and no benthos was found in the 20 cm and 30 cm treatments.

The trials were commenced prior to model results being available and conservative depths of cover were therefore used. The model results have subsequently indicated the any short term smothering of benthos caused by the works will be an order of magnitude less than the lowest used in the trial. The effect of increased sedimentation due to the Project on the benthos is likely to be negligible.

Current levels of natural, episodic, deposition would not appear to adversely impact the total biomass of benthos available on the mudflats since wintering waterfowl numbers do not appear to fluctuate in relation to the occurrence of storm events during the previous year.

In 1993 Typhoon Dot deposited 223.9mm of rain on 26 September, and contributed to the total of 655.9mm rainfall recorded that month-compared with a September average (1951-1980) of 320.4mm. this unusually heavy rainfall, which presumably resulted in considerable sediment transport to Deep Bay did not, however, result in a reduction in wintering waterfowl in January 1994 (Figures 10.4 and 10.6). It thus appears that the benthic community may be quite resilient to natural extreme sedimentation events. Sediment deposition and erosion during such extreme storm events are typically at least an order of magnitude greater than rates due to the Project works.

No significant effect on benthos is expected due to short term sedimentation caused by the Project.

10.4.3.c.ii.iii Long Term Sedimentation Impacts on Benthic Invertebrates

The model predicts that, when completed, the Project will result in a reduction of sedimentation rates but there will still be a depositional environment in the Inner Bay. Deposition rates are likely to remain higher than those in the early 1980s. A depositional environment would also continue if the Project did not proceed.

Continuing increases in sedimentation on the mudflat will raise the height of the mudflat in relation to the tide, such that inundation frequencies and duration change. This may have effects on the faunal composition and abundance in the mudflat. Channel levees generally support less biomass of benthos than elsewhere in the mudflat (Appendix 10.9).

Further changes in benthos, both in species composition and biomass, are likely to result from mangrove encroachment over the tidal flats unless management controls mangrove colonisation (Section 10.4.3.i.iii). The natural process of accretion of the mudflats and colonisation by the mangroves will dominate any long term impact of the Project.

The Project is not expected to have any significant long term effects on benthic fauna due to sedimentation.

10.4.3.c.iii.i Sedimentation Impacts on Waterbirds

Potential impacts of sedimentation on waterbirds could be caused by changes to the feeding distribution of shorebirds, which are related to prey abundance/availability (e.g. Wolff 1969), and are closely related to sediment characteristics (e.g. Yates *et al.*

1993).

Observations indicate the shorebirds tend to favour the finer, softer sediments on the Mai Po side of the Bay for feeding, although this may be partly related to human disturbance on the Shenzhen side of the Bay (Section 10.4.6). Any changes in the distribution of sediments within Inner Deep Bay could result in changes in the feeding distribution of shorebirds and other waterfowl, as has been recorded elsewhere (e.g. Ferns 1983). Quammen (1982) has suggested that sand may interfere elsewhere (e.g.Ferns 1983). Quammen (1982) has suggested that sand may interfere in prey detection or capture in some species.

10.4.3.c.iii.ii Short Term Sedimentation Impacts on Waterbirds

Potential short-term impacts of sedimentation on water birds due to the Project include increased turbidity as a result of dredging works, changes in the areas available for feeding, or reduction in the duration of feeding opportunities.

Effect on Turbidity: Changes in turbidity potentially affect piscivorous species which are 'prusuit divers' and reliant on clear water. The Cormorant *Phalacrocorax carbo*, is the most common (c.5,000-6,000) and is a winter visitor to Deep Bay, feeding on fish in the Bay and , to a lesser extent, in fish ponds and *gei wais*.

The feeding habits of Cormorants in Deep Bay have not been studied, but it could be expected that a reduction in transparency in the Bay's waters might result in more birds feeding in *gei wais* and ponds, where water transparency may be greater. This could be important in the winter dry season, when water transparency in Deep Bay would be expected to be greater due to reduced levels of silt input from rivers at the head of the Bay and the Pearl estuary.

Displacement of Cormorants to fishponds could have economic implications for fishermen. In November 1994 fishermen in Hong Kong complained about alleged increases inpredation by Cormorants on pond fish at a time when dredging works for the Yuen Long/Kam Tin Main Drainage Project was in progress. It is not known whether the dredging works increased turbidity and, if so, whether this affected the Cormorants. It is understood that this matter is under investigation by the Agriculture and Fisheries Department.

The model predicts that sediment released during dredging will be retained within the River, or considerably diluted by tidal water, providing that mitigation guidelines are implemented. The increase in sedimentation rate indicates that increases in turbidity will occur, at least at some times and locations. The effect may have local importance to farmers but is not considered significant in terms of the Project or overall effects on waterbirds.

Effect on feeding Areas: The increase in sediment deposition per se during construction is unlikely to significantly change the biomass of benthos (Section 10.4.3.c.ii.ii), and thus food supplies for waterbirds should not be significantly affected.

However, increased sediment deposition during construction is expected to increase the rate of encroachment of mangrove over the tidal flats, and this could result in the loss of 1.59-4.57 ha of tidal flats by the end of Stage 2 Works (Section 10.4.3.c.i.iii).

Without active management the mangrove colonisation will potentially result in a reduction in area available for most birds to feed, since the majority of waterbird species feed on the open tidal flats, rather than in the mangrove (Appendix 10.12).

Effect on Feeding Opportunities: The spread of mangrove will also reduce the time available for birds to forage. This will occur due to the reduction in the distance which the tide will move across the intertidal flats (Figure 10.12). Most duck and migrant shorebirds forage almost entirely along the strand line when the tide is moving (Appendix 10.12), and thus any reduction in distance the tide moves could reduce feeding time, unless this was accompanied by a slowing of tidal flows.

Given the it appears that the Deep Bay mudflats may be nearing carrying capacity for waterfowl (Section 10.2.9), any reduction in foraging area or time could adversely affect bird numbers. Sedimentation as a result of Project works will not directly result in any significant change to the extent of mudflats at the head of the Bay and no significant impacts on benthos are predicted. It is unlikely therefore that the Project works will have any significant effect on carrying capacity of the system for water birds provided that an active management programme to restrict mangrove colonisation is implemented.

10.4.3.c.ii.iii Long Term Sedimentation Impacts on Waterbirds

The predicted reduction in sedimentation rates following completion of the Project should result in a reduction in the rate of mangrove encroachment on the mudflat from current levels. As noted above (Section 10.4.3.c.ii.ii), loss of intertidal mudflats to mangrove is likely to negatively impact waterbird populations and thus the reduction in sedimentation could be beneficial to waterbirds. The Project will contribute to a reduction in the continuing natural process of accretion and this effect should be beneficial.

10.4.3.c.iv.i Sedimentation Impacts on Commercial Species

As noted in Section 10.4.2.e there is no active oyster cultivation remaining on the Hong Kong side of Deep Bay. Potential effects of increased sedimentation on commercial species are primarily concerned with effects on *gei wais*.

Sediment accretion in the mai Po *gei wais* has been estimated at 17mm per year (Lee 1989). This results in a requirement for regular maintenance dredging of the channels within the *gei wais*. An increase in suspended sediment in Inner Deep Bay during construction for the Project could result in increased rates of sedimentation within the *gei wais*, resulting in a need for increased frequency of dredging. Alternatively it may be necessary to reduce water exchange at times of high sediment load in the Bay waters which could adversely affect harvests of M. ensis both through pollution effects as well as by reducing harvesting opportunities.

Given the relatively low level of increased sedimentation in areas outside of the main channel of Deep Bay it is unlikely that the increased level of sedimentation due to the Project will require any increase in maintenance dredging in the gei wais. The Scheduling of construction works to reduce sedimentation will contribute also to reducing ~~this~~ potential problem.

10.4.3.c.iv.i Sedimentation Impacts on Mammals

Sediment loads, erosion and sedimentation are not expected to have any serious impacts on mammal species.

10.4.3.d Summary of Sedimentation Impacts

Changes in sediment, erosion and sedimentation are identified as key impacts of the Project on biota. During the construction phase increased sedimentation will result in an acceleration of the accretion of the mudflats and of the natural colonisation by mangroves. As management scheme to control the extent of mangrove colonisation is likely to be required to maintain the extent of waterfowl feeding areas. The increased sedimentation is unlikely however to have any significant effects on waterbirds or to cause any disruption to the integrity of the ecosystem.

Following completion of the works the rate of sedimentation in the head of the Bay will be reduced compared to existing rates, returning to rates similar to those during the mid 1980's prior to major development programmes in the catchments. The accretion of the mudflats should be reduced as a result of the reduced sedimentation. There are no identifiable impacts which will affect waterbirds significantly or affect the integrity of the mudflat system.

10.4.4 Impacts due to Human Disturbance

Potential impacts due to human disturbance to wildlife include reduced food intake rates, reduced breeding output, abandonment of breeding attempts and increased predation. Increased human disturbance will result from both the construction and operational phases of the Project. Potential disturbance includes passage of plant within the works area, boat and dredger traffic, and human activity within Deep Bay or along the banks of the River.

Of the wildlife in the Deep Bay area, waterfowl are expected to suffer the most from human disturbance from the project. There are a number of recent reviews on the effect of disturbance on waterfowl (Dahlgren and Korschgen 1992, Hockin *et al.* 1992, Davidson and Rothwell 1993, Pfister *et al.* 1992).

Types of disturbance to waterfowl, as classified by Hockin *et al.* (1992), are shown in Table 10.9, together with their likely effects.

Disturbance to feeding waterfowl may result in reduced food intake and/or increased energy expenditure due to increased time spent in flight. In turn this can adversely affect the birds (Belanger and Bedard 1990) during periods of migration when birds at stop-over sites feed voraciously to increase weight to enable them to continue on their journeys.

Nocturnal feeding may help to compensate for reduced day time intake rates in some situations for some species (Swennen *et al.* 1989), but migratory shorebirds in Inner Deep Bay already feed extensively at night (Appendix 10.12), thus it is likely that any increase in disturbance levels could adversely affect waterfowl.

Reduced food intake and/or increased energy expenditure in migrant shorebirds staging in Deep Bay are likely to result in birds staying longer before migrating, or else departing with sub-optimal fat/protein loads. Currently there is insufficient information available on the migration routes of shorebirds in East Asia to permit a detailed assessment of the likely impacts of such changes on migration routes and populations. Work elsewhere indicates that the deposition of adequate energy reserves is crucial to the successful completion of migration (Piersma and Jukema 1990).

Table 10.9 Type of disturbance to waterfowl, their likely effects and some examples

Type of disturbance*	passive low level continuous ⇓ waders and wildfowl become accustomed to disturbance	medium-level continuous ⇓ most species tolerate disturbance ⇓ site is unattractive to most vulnerable species	active high-level infrequent ⇓ most birds displaced for short periods ⇓ on the whole site maintains its attractiveness	active high-level continuous ⇓ most birds displaced all the time ⇓ only very tolerant species remain ⇓ site becomes and remains species poor
Examples	Pumping station Industry with no visible human presence	Gravel pit in progress Humans screened in vehicles	Fishing birds returning to nest after disturbance by researcher	Power boating Shooting Walking humans Industry with high outside exposure by people

* after Hockin *et al.* 1992

Young and Melville (1993) suggest that Curlew Sandpipers (a high arctic breeding species) leaving Hong Kong in spring probably fly to the Bo Hai, northeast China before stopping to 're-fuel' again. If they were to leave Hong Kong with reduced fat loads they might be unable to reach the Bo Hai, and thus would need to stop further south. Suitable habitat occurs around the Yangtze estuary and coast of Jiangsu but this is heavily utilised by other populations of shorebirds (Pook 1992, M. Barter and Wang Tianhou pers. comm., Melville unpublished) and thus competition for food resources would be increased.

The timing of arrival of shorebirds on high arctic breeding grounds may impact on breeding success, this varying somewhat from year to year depending on weather conditions (Green *et al.* 1977). Thus a delay in arrival on the breeding grounds resulting from a delayed departure from a staging area could adversely affect breeding success and affect populations.

Activity by fishermen on the exposed tidal flats is a potential cause of disturbance. The fishermen move around the flats on 'mud-scooters'.setting fish traps, tending nets etc..At times there may be as many as 35-40 spread over the flats on the Hong Kong side, and shorebirds trying to feed suffer considerable disturbance. Plans are in hand to list the mudflats off Mai Po in the Sixth Schedule of the Wild Animals Protection Ordinance. This would enable human access to the area to be controlled and should result in a reduction in disturbance on the Hong Kong side of the Bay.

10.4.4.a Disturbance Impacts on Waterfowl

Currently the main sources of disturbance to waterfowl in Inner Deep Bay are:

- boat traffic
- fishermen working on the flats at low tide, and
- people shooting from boats in the Bay

Shooting of wildlife is prohibited in Hong Kong and in the Futian National Nature Preserve, nonetheless some shooting still occurs in Deep Bay. Waterfowl subject to hunting pressure tend to be more vigilant than those which are not shot at (Combs 1987), and will take flight at greater distances when approached (Smit and Visser 1993),thus continued hunting in Deep Bay will exacerbate other disturbance effects.

Improved navigation is not a stated objective of the Project but it is reasonable to expect river traffic to increase as a result of the works. Disturbance of the mudflats will increase as a result of increased traffic in the river. Disturbance of the waterfowl on the mudflats is already caused by river traffic. Any increase in disturbance may reduce the area and time available for foraging. Any increase in disturbance during those periods of the tide cycle when most birds are actively feeding (Appendix 10.12) is likely to be more detrimental.

Loss of potential feeding areas in fish ponds for egrets, herons and Black-faced Spoonbills resulting from disturbance during construction work will compound the physical losses to storage of spoil and more widespread losses within the Deep Bay area through development.

There will be a loss of feeding potential to waterfowl as a result of the Project but the full implications of the effect cannot be determined with confidence. Measures should be implemented to minimise all forms of human disturbance as a result of the Project.

10.4.4.b Disturbance Impacts on Other Species

Human disturbance to other wildlife is not considered to be a major problem with respect to the Project. The larger terrestrial mammals are mostly nocturnal (the two mongooses *Herpestes* also being active in daytime) and habitat destruction is expected to pose a greater threat to these species.

One species of conservation concern which may suffer from increased boat traffic associated with the Project is the Chinese White Dolphin, which occasionally has been recorded in Deep Bay and as far up the Shenzhen River as Lok Ma Chau (Melville 1976 and unpublished). This species is currently affected by disturbance from increased shipping and other factors in its Hong Kong main habitat area located off North Lantau (Section 10.2.10).

10.4.4.c Summary

Human disturbance to waterfowl is a key impact of the Project but the extent of the impact cannot be quantified.

10.4.5 Air Quality

Impacts of the Project on air quality are discussed in Section 5 of this report. Air quality impacts on wildlife are unlikely to be severe. The most important impact identified is the potentially adverse effect of dust on vegetation.

At sites with no dust abatement measures, or where measures are poorly implemented, large volumes of dust can be generated, especially along haul routes. Fugitive dust may cause a severe nuisance to people living/working in the vicinity of the site. It may also adversely affect vegetation when it settles on plant leaves. Fall-out on vegetation is also likely to adversely affect various insects, especially phytophagous species.

It is expected that dust control measures will be implemented as part of the works contracts for the Project. Dust will only be a short-term impact during the construction phase of the project.

Air quality is not identified as a key impact on wildlife with respect to the Project.

10.4.6 Noise

Noise impacts of the Project are discussed in Section 6 of this Report. In the construction stage, the Project will result in noise from plant and equipment (dredgers, bulldozers, backhoe excavators, trucks etc.) and possibly piling. There will also be noise from drilling and blasting of rock on Seung Ma Lei Yue Hill.

During the operation phase noise will be caused only by boat traffic on the river, including dredgers, and maintenance and security vehicles on the embankments. Noise levels will be lower than during the construction phase, therefore nuisance will be limited, with the exceptio of the use of loud hailers on boats.

The auditory range of birds is broadly similar to that of man (Pettingill 1985), but generally birds cannot detect low sounds as well as humans. Birds hear best within the frequency range of 1-5 kHz (Dooling 1985).

Contrary to general public opinion, birds often are remarkably tolerant to noise/acclimate to noise quickly. Hence the regular occurrence of birds on airfields (Melville 1980, 1990).

Noises have regularly been used in attempts to scare birds off airfields, but generally with a notable lack of success (Wright 1963, Blokpoel 1976). This is true even when modern technology is used to generate high levels of synthetic noise (Briot 1988).

Studies on the effects of sonic booms resulting from aircraft passing the sound barrier have produced somewhat mixed results. Lynch (1978) found that booms did not cause abnormal behaviour that would result in decreased productivity in wild Turkeys *Meleagris gallopavo*. Welty (1982), however, reported that terns nesting on the Dry

Tortugas rose in 'panic flights' upon hearing a boom and that 'this probably interrupted their normal incubation rhythm and caused mass nest desertion'. Cottereau (1978) noted that studies on real and simulated booms came to the general conclusion that booms 'have very little effect on the animal's behaviour'. Recently Berthold and Querner (1991) have reported variable reactions by Blackcaps *Sylvia atricapilla* to the discharge of shotguns near nests, but none deserted.

In other studies of the disturbance impacts of low flying aircraft on birds it has not been possible to determine whether it was noise and/or the appearance of the aircraft which caused the observed reaction (e.g. Koolhaas *et al.* 1993). Other aspects of disturbance are considered above (Section 10.4.4).

Weise (1979) investigated the impact of noise from pile driving using a steam hammer associated with tower construction for a power line in the U.S.A. and found that nesting egrets, herons and ibises were unaffected at the noise levels recorded. Noise from the steam hammer operating 1.6 km from the breeding colony resulted in a maximum 60 dB (A), and averaged 51 dB (A). Ambient background noise (i.e. from leaf rustle) averaged 45 dB (A) outside the heronry, but 56-64 dB (A) in the nesting areas.

Berger (1977) reported that Snow Geese *Chen caerulescens* were sensitive to noise on the breeding grounds and would not feed within 2.4 km of a device simulating noise of an oil field compressor station. Owen (1972), however, reported that noise was not as disturbing to White-fronted Geese *Anser albifrons* in winter as sightings of moving objects. Recent work in the Netherlands, however, indicated that noise generated by vehicle traffic on roads through woods was associated with reduced densities of breeding birds (Reijen *et al.* 1995).

It is not expected that noise generated as a result of the construction of the Shenzhen River Regulation Project will significantly impact birds, except possibly in the immediate vicinity of particularly noisy activities such as blasting on Seung Ma Lei Yue Hill and pile driving. In such a situations, impacts could be reduced by using 'quiet' piling equipment.

The use of loud hailer/loud speakers on vessels in Deep Bay does adversely affect wildfowl (Appendix 10.12) and should be controlled under a joint Hong Kong/Shenzhen agreement. A license condition should be included in the Works contracts for the Project controlling use of loud hailers/loud speakers, and the Shenzhen authorities should seek ways to control noise on other vessels.

Potential noise impacts on mammals in the study area also are considered to be slight.

Noise effects on wildlife are not identified as a key impact of the Project.

10.5 MITIGATION MEASURES

This study has identified the following as potential key ecological impacts of the Project:

- Habitat loss, especially of:
  - intertidal mudflats in Deep Bay (direct and indirect)

- mangroves
- fish ponds

- Changes in water quality
  - organic/nutrient inputs
  - metals and organochlorines

- Changes in sedimentation
  - erosion
  - deposition

- Human disturbance

The key impacts resulting from the project can be addressed, to a greater or lesser extent, through the following:

- design of engineering works;
- timetabling of the construction programme;
- physical controls;
- inclusion of contract clauses and legislation; and
- on/off site habitat creation/management.

Mitigation measures with respect to water quality and sediment are detailed in Section 8.6 and 9.6.

Proposals for mitigating impacts on the ecology resulting from Stage 1 Works are outlined in the Stage 1 Report (1994a).

10.5.1 Mitigation for Habitat loss

Mitigation proposals must consider land tenure. Current land ownership patterns in the Lok Ma Chau - Mai Po area are shown in Figure 10.13.

As noted in the draft Mai Po Planning Statement'.. the Shenzhen river Training, whilst reducing flooding effects in the area, [is] likely to have environmental and planning implications elsewhere '[in the sub region]. Habitat management on the Hong Kong side will need to take account of future development planning for the Northwest of the New Territories, Hong Kong.

Deep Bay Buffer Zones provide an outline for development control to protect the Mai Po/ Inner Deep Bay area. Future land use on the Hong Kong side of the Deep Bay area is outlined in the Mai Po Development Statement. The Hong Kong Government Ramsar Working Group is currently looking into possible future conservation management of the Deep Bay wetlands. There are also various conservation management proposals being developed by the private sector (e.g. Grant 1994). The Planning Department of the Hong Kong Government in March 1995 commissioned a 'Study of the ecological value of fish ponds in the Deep Bay Area'.

'Initial options' for the North East New Territories Development Strategy Review (which includes the Ma Tso Lung area) were published in September 1994 (Anon. 1994b). Future land use within the Hong Kong side of the catchment will depend upon which development scenario is selected. The Mai Po Development Statement was published in December 1994 (Anon. 1994a).

In all development options for the North East New Territories (low growth, moderate growth, high growth, extra high growth) the Ma Tso Lung area is shown as 'agricultural priority area'. The proposed port rail link runs south of the Ma Tsö Lung hills, with a possible transshipment centre near Kwu Tung.

Details for the 'other specified uses' area at San Tin are uncertain. The landward area has been designated for open storage. In the short-medium term it is proposed that the area within the Frontier Closed Area extending to the River should be reserved for conservation purposes. The future status of the Frontier Closed Area post 1997 is uncertain, but if in the long term FCA restrictions are lifted the MPDS envisages the development of high-tech industrial and commercial facilities with intermodal transport interchange facilities.

The Mai Po Development Statement identifies the San Tin area as the a possible site for a cross border town and notes that the short term designation of land uses should not prejudice such future development (Nortwest New Territories (Yuen Long District, Development Statement Study 1994a).

The Mai Po Development Statement Concept Plan shows the area of hills by the Lok Ma Chau Police Post as 'Conservation-planned public access'. The Tam Kon Chau area is shown as 'Conservation Management Area'.

It is stressed that , given the political and land use issues involved in the Project and the areas around the border in general, any decisions on the most acceptable form of mitigation will need to take account of a wide range of issues.

10.5.1.a Mitigation for Loss of Fish ponds

Stage 1 of the Project will involve the loss of a total of 84 ha of fish ponds - 19 ha on the Hong Kong side, and 65 ha on the Shenzhen side. The consultants were advised by the Client not to consider mitigation options for the loss of 65 ha of fish ponds on the Shenzhen side of the River, since these had been excavated from former paddi in the late 1970s and early 1980s, while waiting for the project to begin after being designated as a spoil disposal area (Stage 1 Study Report).

The Hong Kong and Shenzhen Governments have agreed to compensate for the loss of 19 ha of fish ponds on the Hong Kong side of the River resulting from Stage 1 Works through the establishment of a new wetland habitat suitable for wildlife. An area of 20 ha of wetland will be rehabilitated in the old River channel at the Lok Ma Chau bend. The River in this area is devoid of fauna due to extreme pollution and the mitigation is effectively a habitat creation exercise.

Design and management options for the area at the Lok Ma Chau bend are now being further developed as part of the detailed design for the Project.

The further loss of 22 ha resulting directly from Stage 2 of the Project requires mitigation, either through the creation of new wetland areas or through enhancement management for conservation purposes of existing wetland areas (Appendix 10.13).

Although part of the area of fish ponds lost will become river this will not be suitable wildlife habitat because of the gross pollution in the river.

There is no opportunity to create new wetland habitat for wildlife through the restoration of further section of the old river channel in the Stage 2 area. No areas suitable for habitat creation are available on the Hong Kong side of the River since most of the area near the Project is already wetland. On the Shenzhen side, large areas of wetland have been infilled for development. Since creation of new wetland is not possible, any measures to mitigate for the loss of 22 ha of pond resulting from Stage 2 must involve enhancement management.

Options for mitigation through habitat management are outlined below:

Option 1 - Futian National Nature Reserve

Mitigation of the loss of 22 ha of fish ponds on the Hong Kong side resulting from Stage 2 works could be achieved through enhancement management of ponds in the Futian National Nature Reserve. Currently the Reserve management authority only has control over hunting of wildlife within the ponds in the Reserve, and has no control over management. If the Reserve were to acquire management control over the ponds this would permit conservation management activities which could substantially enhance the value of the area to wildlife.

Ponds within the Reserve are currently operated commercially by local farmers. It is not known what arrangements would need to be made to allow the Reserve to take over management control of the area. The cost of fish ponds in Shenzhen is estimated to be RMB 3 million per ha.

An advantage of this Option is the potentially it could be implemented in advance of the Stage 2 Works, thus allowing waterbirds to use the area when displaced by the Project.

The introduction of cross border issues into mitigation management is likely to present administrative difficulties, but it is beyond the scope of the present study to address these issues.

Option 2 - Stage 2 Project Works Area

The works area for Stage 2 includes the whole area of those fishponds adjacent to the new proposed embankment on the Hong Kong side, regardless of how much or little of the pond will be occupied by the embankment - a total area of 60.5 ha (Figure 10.10). It is assumed that all such ponds will be drained during the construction phase. There is potential to reinstate the 38.5 ha Works Area as wetland following completion of the Project.

Ideally, mitigation measures for habitat loss should be in place before the habitat is destroyed, thus allowing wildlife to use the mitigation site when displaced by the project. None of the management options relating to the Temporary Works Area would provide any habitat for displaced waterbirds and other wildlife until after the engineering works for embankment construction are completed.

Option 2a - enhancement management fish ponds

All of the Works Area could be reinstated as fish pond managed to enhance its conservation value to compensate for the area permanently lost.

Since the total area of ponds temporarily lost during the construction phase and subsequently available for rehabilitation and enhancement management is 30 ha this could be sufficient area to compensate for the 11 ha permanently lost based on a ratio of 2:1, provided that carrying capacity can be adequately" increased.

The narrowness of the area is likely to affect its conservation value, particularly by reducing its potential as a feeding area for large birds such as Black-faced Spoonbills, Ardeids, and other piscivorous birds such as Cormorants. The area will be adjacent to the border road and will be subject to frequent disturbance. Smaller species such as rails and warblers, however, could be attracted if the area were suitably managed and revegetated.

The active management of such ponds to attract piscivorous birds, such as Ardeids and Cormorants, to an area adjacent to commercial fish ponds may raise objections from fish farmers.

Management of the ponds (for details see Option 3) would need to be undertaken by Government or contracted out.

Although there is scope for enhancement management there is considerable doubt as to whether the area available is sufficiently large to compensate for areas permanently lost.

Option 2b - reedbeds

An alternative management scenario for the restoration of the temporary works area is to create a reed bed of *Phragmites*. The reed bed would be easy to establish, and require little or no subsequent management. A reedbed system would be of considerable conservation benefit, especially for species such as *Acrocephalus* warblers which, unlike Black-faced Spoonbills and Ardeids, will not be affected by disturbance caused by pedestrian and vehicular traffic on the border road.

Following completion of the Stage 2 works all construction materials, waste etc. should be removed from site. Planting of *Phragmites* would be done using rhizome stock (Thunhorst 1993, Merritt 1994). Small areas of open water, suitable for various species of rails and bitterns could be maintained by excavation of deeper areas in the pond bottoms into which *Phragmites* would not encroach (Figure 10.16). Consideration should be given to establishing some areas with other aquatic plants, such as *Juncus, Scirpus* and *Eichhornia crassipes* - the latter would need to be contained to prevent smothering of open water areas.

Following initial establishment there would be minimal requirement for subsequent management. Establishment of reedbeds has been achieved elsewhere (Merritt 1994) and there is no doubt that this Option could be implemented.

This Option would not compensate for the permanent loss of 22 ha of fishpond resulting from the Stage 2 Works, and would result in the replacement of 30 ha of fish ponds by another wetland type. It would nonetheless provide a useful area for wildlife conservation and would also prevent these areas becoming derelict.

Option 2c - conservation-cum-commercial ponds

In view of the possible difficulties of management of ponds under Option 2a, consideration could be given to returning the ponds to 'conservation-cum-commercial' use following completion of Stage 2 construction works.

All ponds to be included in the works area are on Government land (Figure 10.13). If existing licenses are canceled and the land resumed for the Project, there exists an opportunity to subsequently re-license the land for 'conservation' activities - as has been done at Mai Po for land currently managed by WWF Hong Kong. This would permit some constraints on operation to be incorporated in the license (as has been done at Mai Po).

Under such a system of control it is proposed that license conditions would be included to control the following activities:

- *maintenance bulldozing* - this would be only permitted every 3 years. A system should be implemented to ensure that different areas/ponds are bulldozed on rotation, so that each year only one third of the ponds are subject to earthmoving.
- *winter draindown* - this would be required every winter. Drying of ponds results in consolidation of sediment, thus helping to maintain depth and reducing the need for frequent excavation.
- *vegetation* - vegetation along the bund at the foot of the new River embankment should not be managed. Based on experience elsewhere in Hong Kong, this should allow a mat of floating vegetation to extend up to 5 m from the bank, in order to provide habitat for aquatic invertebrates.

Apart from the above, normal commercial fish pond operations would be permitted. This Option would require no management input from Government other than usual enforcement of license conditions.

This Option would not compensate for the loss of 11 ha of fish pond as a result of the Stage 2 Works, but would ensure appropriate reinstatement of the 38.5 ha of temporary Works Area. There is some uncertainty regarding the issue of a land license with operational constraints, but this is unlikely to be insurmountable.

Option 2d - ponds and reedbeds

A fourth option for the temporary Works Area would be a combination of Options 2a and 2b. Areas of ponds smaller than 0.5 ha would be managed as reedbeds (being too small to be effectively operated as fish ponds), while large ponds managed as fish ponds. Pond management could be in accordance with either Options 2a or 2c.

This Option would result in suitable reinstatement of the temporary Works Area, but would not compensate for the 22 ha of fishponds lost during Stage 2 Works.

Option 3 - Mai Po Conservation Management Area

Given the difficulties of locating suitable conservation enhancement areas within the Stage 2 Works Area consideration could be given to development of alternative sites in Hong Kong for conservation habitat.

Land in the Ma Tso Lung/Lok Ma Chau/San Tin area is a complex mosaic of Government Land and private ownership (Figure 10.14). Although the land adjacent to the River in the Sam Po Shue area is Government Land and thus relatively easier to acquire, future land use plans for this area indicate that it is unlikely to be available for conservation enhancement management (Figure 10.15).

The Mai Po Development Statement shows three proposed Conservation Management Areas to the northwest of the present Mai Po Reserve (Figure 10.17). The location of this land adjacent to the existing Mai Po Marshes Nature Reserve would enhance its conservation value (MacKinnon *et al.* 1986, Shafer 1990). These three areas cover a mixture of Government and private land (Figure 10.14). The Mai Po Development Statements Study has discussed the location of conservation management action areas and their future management (MPDS Table 8.4). It is proposed that Conservation Management Area CM8 should be considered for resumption to allow conservation management once design details of the Shenzhen River Project are known. For CM9 it is proposed that the existing fish ponds in Buffer Zone 2 are actively managed for conservation. It is further proposed that the private fish ponds in CM7b should be retained as operational fish ponds, but no details are given of proposed management for those ponds on Government land. It is understood that the Hong Kong Government's Ramsar Working Group is reviewing management options for these areas, which largely fall within the Inner Deep Bay/ Mai Po Ramsar site. The current ex gratia compensation rate for agricultural land in Zone D is HK$105.3 per sq ft.

In view of the foregoing it would be appropriate to undertake enhancement management of an area of ponds within these Conservation Management Areas to compensate for the loss of 22 ha resulting from the Stage 2 Works.

The Hong Kong Government currently does not have any policy regarding appropriate ratios for off-site mitigation for wetland habitat loss. The recommended ratio of area managed to area lost in the USA is between 2:1 and 3:1 for wetland enhancement projects (Kosian *et al.* 1992). If this is adopted it would require 44-66 ha to be set aside for enhancement management. The location of the ponds for enhancement management should be determined by the Hong Kong Government in the light of their current management plans for the Mai Po/Inner Deep Bay Ramsar Site.

It is proposed that management of the Conservation Enhancement Management Area be principally aimed at providing suitable feeding conditions for the highly endangered Black-faced Spoonbill, Ardeids and other piscivorous birds such as Cormorants, for which the existing Deep Bay fish ponds are of international importance (Rose and Scott 1994).

If the Conservation Enhancement Management Area is to be maintained to provide food for piscivorous birds, the management regime would be broadly similar to that of a commercial fish pond, however there will be a need to vary stocking densities, species stocked, drawdown regime etc.

The forthcoming Hong Kong Agriculture and Fisheries Department study to review management options for the Mai Po/Inner Deep Bay Ramsar Site will include a review of fish pond management protocols. The Hong Kong Planning Department study into the ecological value of fish ponds will also address a wide range of potential ecological values.

Potential management scenarios for the Conservation Enhancement management Area cannot be defined in detail pending the outcome of the forthcoming Mai Po/Inner Deep Bay Ramsar Site Management Plan study. Broad guidelines are outlined below.

- The ponds in the Conservation Enhancement Management Area would generally retain their present structure, shape, size and form, although some grading of the banks to produce a more gently shelving shore may be desirable.

- Management would aim at having high populations of the freshwater shrimp *Macrobrachium niponense,* mosquito fish *Gambusia affinis* and Tilapia *Oreochromis mossambicus*. Pond management would aim at producing large numbers of small Tilapia suitable as waterfowl prey with high stocking densities (in the order of 10,000-35,000/ha).

- Management would aim at promoting production of chironomid midges.

- Aerators are likely to be needed from March to September as phytoplankton respiration in the ponds will cause low dissolved oxygen level. The particularly important time of the day for aerator use is around dawn (0300-0800h), when oxygen stress in the water is greatest.

- In summer water levels would be kept high to reduce heat stress to the fish, but low enough so that the gently sloping pond margin would be available to feeding egrets and herons and other species.

- In winter, the ponds in the Conservation Management Area would be drained in succession so that the fish, shrimps and other prey in the ponds can become more available for egrets, herons and Black-faced Spoonbills.

- Vegetation management may be required to control the encroachment of plants (e.g. *Paspalum* spp. and *Phragmites* spp.) around the pond margins, and to control undesirable invasive species such as *Mikania micrantha.*

- Earth-moving would be required, probably on a three-year cycle (as in Option 2c). Earthmoving should be scheduled on a rotation basis so that one third of all ponds in the Conservation Enhancement Management Area are bulldozed each year.

This Option involves a system of management which is little different from traditional pond management and thus there is little uncertainly regarding its implementation. The future administrative arrangements for managing the area should be reviewed together with those proposed for the Deep Bay/Mai Po Ramsar site. These currently are being considered by the Hong Kong Government.

This Option would allow for sufficient area for adequate mitigation and could provide *wetland habitat under enhancement management before commencement of Stage 2 Works.*

Summary

If preference is given measures within the boundary of the Project, then a restoration plan based on Option 2 is recommended. It is understood that Government authorities prefer Option 2d, but find acceptable all options which specify reinstatement of works areas into fish ponds or reed beds or fish ponds plus reed beds. If wider mitigation options are able to be considered then both Option 1 and 3 are preferred as they provide the most effective response to the loss of fish ponds. Short term impacts due to fish pond loss can be minimised if the advance works for Stage 2 are carried out under a separate contract and are reinstated immediately after completion. This should be considered in detailed design.

10.5.1.b Mitigation for Loss of Mangroves

Experience in both Hong Kong and Shenzhen demonstrates that new areas of mangrove can be successfully established in suitable areas through planting propagules and young seedlings. This study has demonstrated that mangrove seedlings can be established in the lower reaches of the Shenzhen River if suitably protected from wave action (Appendix 10.4).

Any planting of mangroves should be restricted to locally occurring species. Thus although the Futian National Nature Reserve is experimenting with the planting of exotic species such as *Rhizophora mucronata, Ceriops tangal* and *Sonneratia apetala,* these should not be planted in this Project. It must be noted that any planting of mangroves outside the River channel will inevitably result in the loss of intertidal areas which are of importance as waterfowl feeding habitat (Section 10.4.5.c.i).

Three Options are available.

Option 1

The Hong Kong Drainage Services Department have designed the new Kam Tin/Yuen Long Main Drainage Scheme to accommodate new mangroves plantings along the sides of the main channel. It is proposed that a similar design be adopted for the Stage 2 Works area downstream of the Lok Ma Chau border crossing bridge on both banks of the river.

The modified design would accommodate the need for rock facing to the main dredged channel and limited use of concrete slabs to prevent erosion of the channel banks, together with a rock wave baffle to protect the mangroves from wake wash from shipping (Figure 10.18).

Detailed design works for Stage 2 have yet to be undertaken. The experience incorporating mangrove planting into other current flood alleviation schemes will assist in detailed design for the Stage 2 works area.

The elevation of the planting area will be critical to the success of the scheme. Based on information from natural mangals in Hong Kong, the area of planting should be between 1.3 and 2.0 m above Chart Datum.

The proposed mangrove planting works could be undertaken adjacent to the River, irrespective of which embankment alignment is chosen (Appendix 10.13).

The mangrove planting trials conducted as part of this study (Appendix 10.4) indicate that planting of seedling mangroves along the River channel is feasible provided that adequate wave baffles are provided. 'Bagged Seedlings' grown in a nursery would provide the most suitable stock for planting. In view of the poor water quality in the River, it is recommended that seedlings 1-2 years old should be used for planting. It is recommended that the planting should comprise a combination of *Kandelia candel*, *Aegiceras corniculatum* and *Acanthus ilicifolius* in the ratio of 50:40:10. Planting stock should be from populations within Deep Bay, as has been agreed by the Hong Kong Drainage Services Department for the Yuen Long/Kam Tin main drainage project. The Futian National Nature Reserve advises that planting costs for mangroves are about RMB 340,000 per ha.

Planting a 5m band of mangrove along the trained river channel would result in a total area of some 1.6 ha along the Hong Kong bank to as far upstream as the Lok Ma Chau Border Crossing. A similar area could be planted along the Shenzhen bank, giving a total of some 3.6 ha. The hydraulic performance of the river channel during flood would be affected by these works. This measure, therefore, can not be adopted without detailed modelling and evaluation. It is understood that the Hong Kong and Shenzhen authorities will arrange for a discussing by experts to assess the hydraulic implications of this proposal.

This Option would allow for limited compensation for the loss of mangroves resulting from Stage 2 works without potentially impacting waterfowl populations through loss of feeding habitat. We understand that experts from Hong Kong and Shenzhen governments will conduct discussions to confirm whether planting of a narrow strip of mangrove along the river bank as recommended in Option 1 is technically feasible and acceptable from a hydraulic point of view.

Option 2

An alternative mitigation option would be to establish an additional area of mangrove elsewhere in Deep Bay. The Futian National Nature Reserve has been very successful in establishing new areas of mangrove and there is little doubt that establishment of a new mangrove area would be successful. However, the establishment of further mangrove areas at either Mai Po or Futian would be at the expense of potential waterbird feeding areas on the intertidal mudflats.

It appears that Deep Bay may be nearing carrying capacity for waterfowl (Appendices 10.9 and 10.12) and future loss of intertidal mudflats due to mangrove encroachment has already been identified as a potential key impact of the project (Section 10.4.4, 10.4.5 and 10.5). Planting of new mangrove areas on the mudflats off Mai Po is not recommended.

Although a practical alternative in terms of physical establishment of mangrove, the adverse impacts of this Option due to resulting loss of feeding habitat for waterbirds, particularly ducks, waders and gulls, would need to be very carefully considered.

Further planting of mangrove at Futian might enhance the Ardeid breeding site (Appendix 10.11), but without an increase in suitable feeding areas the numbers of birds are unlikely to increase (c.f.Appendix 10.13). There would seem to be little point in attempting to increase Ardeid breeding habitat unless firm action is taken to increase the area of wetland and/or its carrying capacity for the breeding population.

The new reclamation project for the road linking the area to the west of Futian to the Shekou peninsula (Section 10.4.1b) will result in the loss of some areas of mangrove (e.g. at Yai-ying Shan). It is understood that the Shenzhen Government has already agreed to the planting of mangroves along the seaward side of the new causeway. There is the possibility of additional planting in this area to compensate for at least part of the loss of 3.0 ha of mangrove on the Shenzhen side of the River resulting from Stage 2 Works.

Details of the causeway construction are unavailable, thus the practicality of the proposed planting cannot be determined at present. It would be necessary for the planting area to be between 1.3m and 2.0m above Chart Datum. It might be possible to dump uncontaminated sediment form the Project along the seaward side of the causeway to improve conditions for mangrove planting, but this could result in further loss of mudflat due to the expected need to dredge an access channel for barges (Section 10.4.1b).

The potential impact of loss of feeding area for waterfowl resulting from mangrove planting would need to be assessed.

This Option could compensate for the whole area of mangrove being lost as a result of Stage 2 Works, but this would be at the expense of intertidal areas in the Bay which it is expected could adversely impact waterfowl through a reduction in feeding areas.

Option 3

The loss of mangroves as a result of the Project may be compensated for by:

1. planting a line of trees on both sides of Shenzhen River embankment to compensate the mangrove loss along the river;
2. planting 5.8 ha of mangrove to the south off the river mouth within the works boundary to compensate the loss on Hong Kong side;
3. planting 3 ha of mangrove in the Futian Reserve to compensate the loss on Shenzhen side.

Summary

The Project will result in the loss of mangroves along the River channel. In view of the fact that it appears that Deep Bay may be approaching carrying capacity for waterfowl (some of which are globally endangered/threatened), the planting of a large area of mangroves on the Inner Deep Bay mudflats is not recommended as it will result in further loss of waterfowl feeding habitat. Planting a 5m band of mangrove along the trained river channel would result in a total of some 3.6ha. However, the hydraulic performance of the river channel during flood would be affected by these works. The measure, therefore, can not be adopted without detailed modelling and evaluation. The Option 3, therefore, is recommended.

10.5.1.c Mitigation for Loss of Mudflats

The creation of mudflats is not feasible within the bounds of the Project and so it will be necessary to ensure that loss of the existing mudflat due to either erosion or mangrove encroachment is reduced to a minimum. Engineering design and the implementation of mitigation measures should reduce erosion during the construction and operational phases (Section 8).

Proposals have been made previously for the construction of polders for the disposal of mud in Hong Kong. Such polders could, if sensitively designed, provide wildlife habitat (Anon. 1978), including suitable feeding areas for waterfowl and areas for mangrove establishment. The location of such polders would require very careful consideration and a thorough EIA, especially with regard to possible locations. Further consideration of this matter lies out with the present study, but clearly there is potential for habitat creation outside the study area.

10.5.2 Landscaping

The destruction of mangroves along the banks of the River will remove a valuable wildlife corridor. Even if it is possible to incorporate mangrove planting into the design for the Stage 2 Works downstream of the Lok Ma Chau Border Crossing (Section 10.5.1.b), consideration should be given to tree planting along the river side of the new embankment. Such planting could provide a valuable corridor for wildlife. Wherever possible native species should be used for planting to increase the value of the vegetation to wildlife. Some suggested species for planting on the Hong Kong embankment are shown in Table 10.10. If it is proposal to undertake enhancement management of fishponds adjacent to the embankment then tall vegetation on the landward side of the embankment may be undesirable. This will need to be considered in detail once fish pond management details and security requirements are known.

Table 10.10 Suggested planting list for new River embankment

Aralia chinensis	*Bridelia tomentosa*
Celtis sinensis	*Disospyros morrisiana*
Eleocarpus sylvestris	*Eurya* spp.
Evoldia leptra	*Evodia meliaefolia*
Ficus microcarpa	*Litsea rotunda*
Machilus thunbergii	*Mallotus paniculatus*
Melastoma spp.	*Microcos paniculata*
Rhapiolepsis indica	*Sapium discolor*
Sapium sebiferum	*Schefflera octophylla*
Scolopia spp.	*Sterculia lanceolata*

10.5.3 Alternative Channel Alignment

Since the northern bank of the river has been developed for either industry or housing, realign the river channel northward is infeasible at current situation. Moving the whole channel, say a few hundred meters towards south, is technically possible.

By realign the channel southward, habitats for waterfowl and other species and a corridor for widelife movement along the river channel may be created by replanning both sides of the new channel. On the other hands, more fish ponds, which are very important habitat for some waterbirds (10.4.1.f), on south bank of exiting channel will be lost by the realignment. Even the ecological cost-benefit of the realignment can not be evaluated exactly at this stage, not much can be either gained or lost.

10.5.4 Changes in Water Quality

Release of nutrients and other contaminants to the water column should be kept to a minimum. Mitigation measures relating to changes in water quality resulting from construction and optation of the Project are discussed in Section 8.5.

It is anticipated that there will be an increase in shipping using the River and Inner Deep Bay as a result of the project and thus there may be an increased risk of oil spills in both the River and Deep Bay. Oil could adversely impact mangroves, benthos and other wildlife. Hong Kong already has a contingency plan for dealing with oil spills in the marine waters of the Territory, but this does not extend to the Shenzhen Rive.It will be necessary to formulate an oil spill contingency plan, together with an assessment of current regulations concerning shipping traffic in the area jointly between Hong Kong and Shenzhen.

The Hong Kong Environmental Protection Department's CGIS sensitivity Map for the Protection of the Marine Environment in Hong Kong's will address issues of oil spills in Deep Bay with respect to identifying sensitive sites, and considering the appropriate use of oil dispersants at the site of a spill.

10.5.5 Changes in Sedimentation

The release of sediment during dredging should be kept to a minimum. Mitigation measures relating to changes in sedimentation resulting from construction and operation of the Project are addressed in Section 8.4.

The control of boat speeds in both Inner Deep Bay and the River will be necessary to reduce erosion of mudflat and mangroves.

10.5.6 Human Disturbance

Human disturbance resulting from construction works along the River is inevitable. This is likely to negatively impact waterfowl and other wildlife adjacent to the works areas, but in view of the nature of the Project there is little which can be done to reduce the impact beyond implementation of the Deep Bay Guidelines. If it is decided to permit working in the Deep Bay Special Measures Zone it will be necessary to monitor disturbance to waterfowl and may be necessary to amend work programmes if disturbance is recorded.

This study has noted that waterfowl in Inner Deep Bay suffer considerable disturbance from boats with loudspeakers broadcasting loud music/human voices. This is an impact which can be controlled through suitable conditions being attached to the works contract prohibiting the use of loudhailers in Inner Deep Bay. This is an issue which should also be addressed by the relevant Chinese authority with respect to other shipping in the Bay and controlling movement of dredging vessels.

The Hong Kong Government has indicated that, as part of the management programme for the Mai Po/Inner Deep Bay Ramsar Site, it intends to restrict access to the mudflat off Mai Po under the Wild Animals Protection Ordinance. This should reduce the current level of human disturbance in this area. All efforts should be made to ensure that access to the Mai Po mudflat is controlled before work starts on the Project so that disturbance effects on waterfowl are kept to a minimum.

10.6 REFERENCES

Anon. undated. Reptiles and amphibians: Mai Po Nature Reserve. WWF Hong Kong, Hong Kong.

Anon. 1988a. Environment Review: Deep Bay management. Working Paper 1. Status of Deep Bay. ERL, Hong Kong.

Anon. 1988b. Deep Bay integrated environmental management. Key issues. ERL, Hong Kong.

Anon. 1988c. Environment review. Deep Bay management. Executive summary. ERL, Hong Kong.

Anon. 1991. Deep Bay guidelines for dredging, reclamation and drainage works. ERL (Asia) Ltd, Hong Kong.

Anon. 1992. Assessment of effects of mangrove removal on water quality in Deep Bay. Binnie Consultants Ltd., Hong Kong.

Anon. 1993. North Lantau development. Topic Report TR22. Detailed study of potential impacts of the sewage outfall on Chinese White Dolphins. Mott MacDonald, Hong Kong.

Alongi, D.M., Boto, K.G., and Robertson, A.I. 1992. Nitrogen and phosphorus cycles. pp. 251-292 in Alongi, D.M. and Robertson, A.I. (eds.). Tropical mangrove ecosystems. Coastal and Estuarine Studies 14. American Geophysical Union, Washington, D.C.

Anderson, C. 1993. Detritus production and defoliation in Avicennia marina in Hong Kong. Asia-Pacific Symp. Mangrove Ecosystems, abstract.

Anderson, C. and Lee, S.Y. in press. Defoliation of the mangrove Avicennia marina in Hong Kong: cause and consequence. Biotropica

Andrews, M.J. 1984. Thames estuary: pollution and recovery. pp. 195-227 in Sheehan, P.J., Miller, D.R., Butler, G.C. and Bourdeau, P. (eds.). Effects of pollution at the ecosystem level. Wiley.

Andrews, M.J. and Rickard, D.G. 1980. Rehabilitation of the Inner Thames estuary. Marine Pollution Bull. 11: 327-332.

Barter, M. 1992. Distribution, abundance, migration and moult of the Red Knot Calidris canutus rogersi. pp. 64-70 in Piersma, T. and Davidson, N. (eds.). The migration of Knots. Wader Study Group Bulletin 64, Supplement.

Belanger, L. and Bedard, J. 1990. Energetic cost of man-induced disturbance to staging Snow Geese. J. Wildl. Management 54: 36- 41.

Berger, T.R. 1977. The Berger report: northern frontier, northern homeland. Living Wilderness 41: 4-33. (included in Dahlgren and Korschgen 1992)

Berthold, P. and Querner, U. 1991. Reaction of Blackcap to sudden noise. British Birds 84: 68-69.

Blokpoel, H. 1976. Bird hazards to aircraft. Clarke Irwin.

Boto, K.G. and Wellington, J.T. 1983. Phosphorus and nitrogen nutritional status of a northern Australian mangrove forest. Marine Ecol. Prog. Ser. 11: 63-69.

Briot, J.L. 1988. The use of synthetic noise generators in French airports. pp. 505-532 in: Bird Strike Committee Europe Working Papers, 19th. Meeting, Madrid, 23-26 May 1988. Aeropuertos Espanoles, Madrid.

Britton, A.R.C. 1993. Feeding behaviour of the Little Egret at Mai Po, Hong Kong. Hong Kong Bird Report 1992: 176-184.

Chan, K.Y. 1989. The ecology of mudskippers (Pices: Periophthalmidae) at the Mai Po Marshes Nature Reserve, Hong Kong. Unpublished thesis, University of Hong Kong.

Chan, S. 1991. The historical and current status of the Oriental White Stork. Hong Kong Bird Report 1990: 128-148.

Chan, S.S.Y., Au, J., and Young, L. 1992. A new species of mammal for Hong Kong: the Javan Mongoose Herpestes javanicus. Mem. Hong Kong nat. Hist. Soc. 19: 137-138.

Chandrasekar-Rao, A. 1994. Distribution and ecology of Hong Kong small mammals, with special reference to seasonality. M.Phil. thesis, University of Hong Kong - submitted.

Chen, Z.Y. 1993. Legislation on mangrove ecosystem conservation in China. J. Guangxi Academy Sciences 9: 132-135. (in Chinese)

Chiu, K.T. 1992. An assessment of the water pollution status in the Mai Po Marshes

Nature Reserve, Hong Kong. Ph.D. thesis, University of Hong Kong.

Choi, K.C. 1991. The ecology of Fiddler crabs (Crustacea: Ocypodidae) at the Mai Po Marshes Nature Reserve. Unpublished thesis, University of Hong Kong.

Chu, K. 1993. An evaluation of the ecological importance of fish ponds in the Inner Deep Bay wetland system. Unpublished report, WWF Hong Kong.

Coles, S.M. 1979. Benthic microalgae populations on intertidal sediments and their role as precursors to salt marsh development. pp. 25-42 in Jefferies, R.L. and Davy, A.J. (eds.). Ecological processes in coastal environments. Blackwell Scientific Publications, Oxford.

Collar, N.J. and Andrew, P. 1988. Birds to watch. The ICBP world checklist of threatened birds. ICBP, Cambridge.

Combs, D.L. 1987. Ecology of male mallards during winter in the Upper Mississippi alluvial valley. Ph.D. thesis, University of Missouri, Columbia. 223 pp. (included in Dahlgren and Korschgen 1992)

Cottereau, P. 1978. Effect of sonic boom from aircraft on wildlife and animal husbandry. pp. 63-79. in Fletcher, J.L. and Briot, R.G. (eds.). Effects of noise on wildlife. Academic Press, New York.

Dahlgren, R.B. and Korschgen, C.E. 1992. Human disturbances of waterfowl: an annotated bibliography. U.S. Dept. Interior Fish and Wildl. Serv. Res. Publ. 188.

Dahmer, T.D. and Folley, M.L. in press. Census and conservation on Black-faced Spoonbills during winter 1993-1994. Hong Kong Bird Report 1993.

Davidson, N.C. and Rothwell, P. 1993. Disturbance to waterfowl on estuaries. Wader Study Group Bull. 68. Special Issue.

Dooling, R.J. 1985. Hearing and balance. pp. 276-277 in Campbell, B. and Lack, E. (eds.). A dictionary of birds. Poyser, Calton.

Evans, P.R. and Davidson, N.C. 1990. Migration strategies and tactics of waders breeding in arctic and north temperate latitudes. pp. 387-398 in Gwinner, E. (ed.). Bird migration. Springer-Verlag, Berlin.

Evans, P.R., Davidson, N.C., Piersma, T. and Pienkowski, M.W. 1991. Implications of habitat loss at migration staging posts for shorebirds. Acta XX Congressus Internationalis Ornithologici: 2228-2235.

Fan, H.Q. 1993. Necessity of establishing China Mangrove Research Center and its tasks. J. Guangxi Academy of Sciences 9: 122-129. (in Chinese)

Fan, H.Q., Cheng, Z.D., Liu, S.C. and Gao, Y.H. 1993. Species of benthic diatoms in Guangxi mangrove habitats. J. Guangxi Academy of Sciences 9: 37-42. (in Chinese)

Fasola, M. and Barbieri, F. 1978. Factors affecting the distribution of heronries in northern Italy. Ibis 120: 537-540.

Ferns, P.N. 1983. Sediment mobility in the Severn Estuary and its influence upon the distribution of shorebirds. Can. J. Fish. Aquat. Sci. 40 (suppl. 1): 331-340.

Furness, R.W., Galbraith, H., Gibson, I.P. and Metcalfe, N.B. 1986. Recent changes in numbers of waders on the Clyde Estuary, and their significance for conservation. Proc. Roy. Soc. Edinburgh 90B: 171-184.

Goss-Custard, J.D. 1985. Foraging behaviour of wading birds and the carrying capacity of estuaries. pp. 169-188 in Sibly, R.M. and Smith, R.H. (eds.). Behavioural ecology: ecological consequences of adaptive behaviour. Blackwell, Oxford.

Grant, G. 1994. Deep Bay conservation and development strategy. Consultation draft. CES, Hong Kong.

Green, G.H., Greenwood, J.J.D. and Lloyd, C.S. 1977. The influence of snow conditions on the date of breeding of wading birds in north-east Greenland. J. Zool. 183: 311-328.

Green, P.T., Hill, D.A. and Clark, N.A. 1992. The effects of organic inputs to estuaries on overwintering bird populations and communities. BTO Research Report No. 59. Department of Energy, U.K.

Griffiths, D.A. 1983. Grasses and sedges of Hong Kong. Urban Council, Hong Kong.

Groombridge, B. (ed.). 1993. 1994 IUCN Red list of threatened animals. IUCN, Cambridge.

Harrison, J. and Grant, P. 1976. The Thames transformed. Deutsch, London.

Hockin, D., Ounsted, M., Gorman, M., Hill, D., Keller, V. and Barker, M.A. 1992. Examination of the effects of disturbance on birds with reference to its importance in ecological assessments. J. Env. Manage. 36: 253-286.

Hodgkiss, I.J. and Morton, B. 1978. Halophila beccarii Ascherson (Hydrocharitaceae) - a new record for Hong Kong with notes on other Halophila species. Mem. Hong Kong nat. Hist. Soc. 13: 28-32.

Huang, Y.R., Qian, H.L., Ou, Q., Huang, Y.L., Liu, J.Y. and Yu, W.G. 1989. (The zooplankton of Shenzhen Bay under eutrophicational state). Journal of Jinan University (Natural Science and Medicine) 1989: 73-78. (in Chinese)

Hulme, M., Wigley, T., Tao, J., Zhao, Z.C., Wang, F.T., Ding, Y.H., Leemans, R., Markham, A. 1992. Climate change due to the greenhouse effect and its implications for China. WWF, Gland.

Irving, R.T.A. and Leung, K.W. 1987. Land-use and land-use change in the reclaimed coastal areas of Deep Bay. Centre of Urban Studies & Urban Planning, University of Hong Kong.

Irving, R. and Morton, B. 1988. A geography of the Mai Po Marshes. WWF Hong Kong, Hong Kong.

Karsen, S.J., Lau, M.W.N. and Bogadek, A. 1986. Hong Kong amphibians and reptiles. Urban Council, Hong Kong.

Kennerley, P.R. 1990. A review of the status and distribution of the Black-faced Spoonbill. Hong Kong Bird Report 1989: 116-125.

Kennerley, P.R. and Leader, P.J. 1993. Identification of Middendorf's and Styan's Grasshopper Warblers. Dutch Birding 15: 241- 248.

Koolhaas, A., Dekinga, A. and Piersma, T. 1993. Disturbance of foraging Knots by aircraft in the Dutch Wadden Sea in August- October 1992. Wader Study Group Bull. 68: 20-22.

Lambeck, R.H.D. 1991. Changes in abundance, distribution and mortality of wintering Oystercatchers after habitat loss in the Delta area, SW Netherlands. Axta XX Congressus Internationalis Ornithologici: 2208-2218.

Lau, M.W.N. and Melville, D.S. 1992. Notes on the feeding of Enhydris bennetti (Gray) (Reptilia, Squamata, Colubridae) in Hong Kong. Mem. Hong Kong nat. Hist. Soc. 19: 117.

Lee, S.Y. 1988. The ecology of a traditional tidal shrimp pond, the production and fate of macrodetritus and implications for management. Ph.D. thesis, University of Hong Kong.

Lee, S.Y. 1989. The importance of inundation frequency and sesarmine crabs (Chiromanthes spp.) on the decomposition of mangrove (Kandelia candel (L.) Druce) leaf litter in a Hong Kong tidal shrimp pond. J. Exp. Mar. Biol. Ecol. 130: 23-43.

Lee, S.Y. 1990a. Primary productivity and particulate organic matter flow in an estuarine mangrove-wetland in Hong Kong. Marine Biology 106: 453-463.

Lee, S.Y. 1990b. Net aerial primary productivity, litter production and decomposition of the reed Phragmites communis in a nature reserve in Hong Kong: management implications. Marine Ecology Progress Series 66: 161-173.

Lee, S.Y. 1990c. The intensity and consequences of herbivory on the mangrove Kandelia candel (L.) Druce at the Mai Po Marshes, Hong Kong. pp. 717-725. In: Morton, B.S. (ed.) The marine flora and fauna of Hong Kong and south China II. Hong Kong University Press, Hong Kong.

Lee, S.Y. 1991. Herbivoury as an ecological process in a Kandelia candel (Rhizphoraceae) mangal in Hong Kong. Journal of Tropical Ecology 7: 337-348.

Lee, S.Y. 1992. Assessment of effects of mangrove removal on water quality in Deep Bay. Binnie Consultants Ltd., Hong Kong.

Lee, S.Y. 1992a. The management of traditional tidal ponds for aquaculture and wildlife conservation in southeast Asia: problems and prospects. Biol. Conserv. 63: 113-118.

Lee, S.Y. 1993. Invertebrate species new to science recorded from the Mai Po Marshes, Hong Kong. pp. 199-209 in Morton, B. (ed.). The marine biology of the South China Sea. Hong Kong University Press, Hong Kong.

Leung,C., Shortridge, K.F., Morton, B and Wong, P.S. 1975. The incidence of faecal bacteria in the tissues of the commercial oyster Crassostrea gigas Thunberg 1793 correlated with the hydrology of Deep Bay, Hong Kong. pp. 114-127 in Morton, B. (ed.). Proceedings of the Pacific Science Association Special Symposium on Marine Sciences, Hong Kong 1973. Government Printer, Hong Kong.

Lin, P. 1987. The mangrove ecosystem in China. pp. 40-52 in Field, C.D. and Dartnall, A.J. (eds.). Mangrove ecosystems of Asia and the Pacific: status, exploitation and management. Australian Institute of Marine Science Press.

Lu, J.J. 1990. Wetlands in China. East China Normal University Press, Shanghai. (in Chinese)

Lugo, A.E. and Snedakar, S.C. 1974. The ecology of mangroves. Ann. Rev. Ecol. Syst. 5: 39-64.

Lynch, T.E. 1978. Eastern Wild Turkey behavioural responses induced by sonic boom. pp. 47-61 in Fletcher, J.L. and Briot, R.G. (eds.). Effects of noise on wildlife. Academic Press, New York.

MacKinnon, J., MacKinnon, K., Child, G. and Thorsell, J. 1986. Managing protected areas in the tropics. IUCN, Gland.

McChesney, S. 1993. Mai Po mudflat invertebrate assemblage - changes through one year. Asia-Pacific Symp. Mangrove Ecosystems, abstract.

McClusky, D.S. 1981. The estuarine ecosystem. Blackie, Glasgow.

McClusky, D.S., Bryant, D.M. and Elliott, M. 1992. The impact of land-claim on the Forth Estuary, eastern Scotland. Aquatic Conservation: Marine and Freshwater Ecosystems 2: 211-222.

Meire, P. 1993. Wader populations and macrozoobenthos in a changing estuary: the Oosterschelde (The Netherlands). Thesis, University of Gent.

Melville, D.S. 1976. Gulls feeding in association with dolphins. Hong Kong Bird Report 1975: 50.

Melville, D. 1980. Birds at Kai Tak Airport, Hong Kong. Agriculture and Fisheries Department, Hong Kong.

Melville, D.S. 1984. Notes on intertidal flats and mangroves in southern China. Unpublished report to IUCN.

Melville, D.S. 1989. Wintering waterfowl in Deep Bay, Hong Kong. pp. 180-187 in Parish, D. and Prentice, R.C. (eds.). Wetland and waterfowl conservation in Asia. AWB/IWRB, Kuala Lumpur.

Melville, D.S. 1989a. Hong Kong. pp. 283-294 in Scott, D.A. (comp.). A directory of Asian wetlands. IUCN, Gland.

Melville, D.S. 1990. Birdstrike hazard to aircraft and the importance of environmental management. pp. 609-639 in: Airports into the 21st. Century. Hong Kong Institution of Engineers, Hong Kong.

Melville, D.S. 1991. Potential impacts of development on waterfowl using the internationally important Inner Deep Bay wetland, Hong Kong. pp. 869-883 in Boxall, J. (ed.). Polmet'91. Pollution in the metropolitan and urban environment. Hong Kong Institution of Engineers, Hong Kong.

Melville, D.S. and Chan, S.S.Y. 1992. The discovery of Ruppia maritima L. (Ruppiaceae) at Mai Po, Hong Kong. Mem. Hong Kong nat. Hist. Soc. 19: 123-125.

Melville, D.S. and Galsworthy, A.C. 1993. Report on bird ringing in Hong Kong in 1992. Hong Kong Bird Report 1992: 81-99.

Melville, D.S., Lee, S.Y. and Cheng, W.W. 1989. Some aspects of the management of the Mai Po Marshes, Deep Bay, Hong Kong. pp. 94-104 in Parish, D. and Prentice, C. (eds.). Wetland and waterfowl conservation in Asia. Asian Wetland Bureau/IWRB, Kuala Lumpur.

Melville, D.S. and Morton, B. 1983. Mai Po Marshes. WWF Hong Kong, Hong Kong.

Melville, D.S., Young, L. and Leader, P.J. 1994. The importance of fish ponds around Deep Bay to wildlife, especially waterbirds, together with a review of potential impacts of wetland loss and mitigation measures. WWF Hong Kong unpublished report.

Minton, C. 1993. Sightings of waders leg-flagged in Victoria, Australia (reported up to October 1993). VWSG Bull. 17: 26-37.

Minton, C. 1994. Further sightings of leg-flagged waders and terns from Victoria. Report No. 2. VWSG Bull. 18: 58-62.

Morton, B. 1984. Report on Futien mangrove and bird nature reserve. 5pp. WWFHK MS

Morton, B. and Morton, J. 1983. The sea shore ecology of Hong Kong. Hong Kong University Press, Hong Kong.

Morton, B. and Scott, P.H. 1989. The Hong Kong Galeommatacea (Mollusca: Bivalvia) and their hosts, with descriptions of new species. Asian Marine Biology 6: 129-160.

Morton, B. and Wong, P. 1975. The Pacific Oyster industry in Hong Kong. J. Hong Kong Branch Roy. Asiatic Soc. 15: 139-149.

Naidoo, G. 1990. Effects of nitrate, ammonium and salinity on growth of the mangrove Bruguiera gymnorrhiza (L.). Lam. Aquatic Biology 38: 209-219.

Nedwell, D.B. 1974. Sewage treatment and discharge into tropical coastal waters. Search 5: 187-190.

Odum, W.E. and Johannes, R.E. 1975. The response of mangroves to man-induced environmental stress. pp. 52-62 in Wood, E.J.F. and Johannes, R.E. (eds.). Tropical marine pollution. Elsevier, Amsterdam.

Odum, W.E., McIvor, C.E., and Smith, T.J. 1982. The ecology of the mangroves of South Florida: a community profile. U.S. Fish Wildlife Service, Office of Biological Services, Washington.

Onuf, C.P., Teal, J.M. and Valiela, I. 1977. Interactions of nutrients, plant growth and herbivory in a mangrove ecosystem. Ecology 58: 514-526.

Owen, M. 1972. Movements and feeding ecology of white-fronted geese at the New Grounds, Slimbridge. J. appl. Ecol. 9: 385-398.

Pearson, T.H. and Rosenburg, R. 1978. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceanogr. Mar. Biol. Ann. Rev. 16: 229-311.

Peking University 1994. Environmental Impact Assessment Study on Shenzhen River Regulation Project. Study report for Stage 1 Works.

Peking University 1994a. Environmental Impact Assessment Study on Shenzhen River Regulation Project. Addendum to Stage 1 EIA.

Peking University 1994a. Environmental Impact Assessment Study on Shenzhen River Regulation Project. Ecological mitigation programmes.

Perennou, C., Mundkur, T. and Scott, D.A. 1994. The Asian waterfowl census 1987-91: distribution and status of Asian waterfowl. AWB Publication No. 86. IWRB Publication No. 24. AWB, Kuala Lumpur, Malaysia and IWRB, Slimbridge, UK.

Pettingill, O.S. 1985. Ornithology in laboratory and field. 5th. ed. Academic Press, Orlando.

Pfister,C., Harrington, B.A. and Lavine, M. 1992. The impact of human disturbance on shorebirds at a migration staging area. Biol. Conserv. 60: 115-126.

Phillips, D.J.H., Ho, C.T. and Ng, L.H. 1982. Trace elements in the Pacific Oyster in Hong Kong. Arch. Environ. Contam. Toxicol. 11: 533-537.

Pienkowski, M.W. and Evans, P.R. 1984. Migratory behavior of shorebirds in the western Palearctic. pp. 74-123 in Burger, J. and Olla, B.L. (eds.). Shorebirds:

migration and foraging behavior. Behavior of marine animals. Vol. 6. Plenum, New York.

Piersma, T. and Jukema, J. 1990. Budgeting the flight of a long- distance migrant: changes in nutrient reserve levels of Bar- tailed Godwits at successive spring staging sites. Ardea 78: 315- 337.

Piersma, T., de Goeij, P. and Tulp, I. 1993. An evaluation of intertidal feeding habitats from a shorebird perspective: towards relevant comparisons between temperate and tropical mudflats. Neth. J. Sea Res. 31: 503-512.

Pook, J. 1992. Banding round-up: a complete list. Stilt 20: 51- 76.

Prater, A.J. 1981. Estuary birds of Britain and Ireland. Poyser, Calton.

Puttick, G.M. 1984. Foraging and activity patterns in wintering shorebirds. pp. 203-231 in Burger, J. and Olla, B.L. (eds.). Shorebirds: migration and foraging behaviour. Behavior of marine animals. Vol. 6. Plenum, New York.

Quammen, M.L. 1982. Influence of subtle substrate differences on feeding by shorebirds on intertidal flats. Marine Biology 71: 339-343.

Qian, H.L., Huang, Y.R., Ou, Q., Huang, Y.L., Yu, W.G., Liu, J.Y., Liu, G.C., Ren, L.P. and Huang, Z.X. 1989. (The zooplankton population structure in Shenzhen Bay after the occurrence of red tide). Journal of Jinan University (Natural Science and Medicine) 1989: 79-82. (in Chinese)

Rose, P.M. and Scott, D.A. 1994. Waterfowl population estimates. IWRB Publication No. 29. IWRB, Slimbridge.

Sadaba, R.B., Vrijmoed, L.L.P., Jones, E.B.G. and Hodgkiss, I.J. 1993. An ecological survey of mangrove fungi associated with Acanthus ilicifolius in Mai Po, Hong Kong. Asia-Pacific Symp. Mangrove Ecosystems, abstract.

Scott, D.A. 1989. A directory of Asian wetlands. IUCN, Gland.

Severn Estuary Research Group. 1992. Algal stabilisation off estuarine sediments. ETSU TID 4088-P1. Department of Trade and Industry, U.K.

Shafer, C. L. 1990. Nature reserves: island theory and conservation practice. Smithsonian Institution Press, Washington.

Smit, C.J. and Visser, G.J.M. 1993. Effects of disturbance on shorebirds: a summary of existing knowledge from the Dutch Wadden Sea and Delta area. Wader Study Group Bull. 68: 6-19.

Sutherland, W.J. and Goss-Custard, J.D. 1991. Predicting the consequences of habitat loss on shorebird populations. Acta XX Congressus Internationalis Ornithollogici: 2199-2207.

Swennen, C., Leopold, M.F. and Bruijin, L.L.M. 1989. Time- stressed

Oystercatchers, Haematopus ostralegus, can increase their intake rate. Anim. Behav. 38: 8-22.

Swift, J. 1976. Waterfowl feeding in the Thames. Appendix. pp. 226-227 in Harrison, J. and Grant, P. The Thames transformed. Deutsch, London.

Tam, N.F.Y., Li, S.H., Lan, C.Y., Chen, G.Z., Li, M.S. and Wong, Y.S. 1993. Nutrient and heavy metal contamination of plants and sediments in Futian mangrove swamp. Asia-Pacific Symp. Mangrove Ecosystems, abstract.

Thrower, L.B. and Cheng, D.W.K. 1975. Mangroves. pp. 64-77 in Thrower, L.B. (ed.). The vegetation of Hong Kong.

Thunhorst, G.A. 1993. Wetland planting guide for the northeastern United States: plants for wetland creation, restoration and enhancement. Environmental Concern, St. Michaels.

Tian, W. and Jiang, Y. 1986. (Handbook on the identification of Chinese amphibians and reptiles). Scientific Publications, Beijing. (in Chinese).

Town Planning Board. 1994. Town Planning Board Guidelines for application for developments within Deep Bay Buffer Zones under Section 16 of the Town Planning Ordinance. TPB PG-NO. 12A (Revised November 1994).

Tubbs, C.R. 1977. Wildfowl and waders in Langstone Harbour. British Birds 70: 177-199.

Tulp, I., McChesney, S. and de Goeij, P. in press. Migratory departures of waders from north-western Australia: behaviour, timing and possible migration route. Ardea

van Impe, J. 1985. Estuarine pollution as a probable cause of increase of estuarine birds. Mar. Poll. Bull. 16: 271-276.

Wang, J.Y., Chen, G.Z., He, S.H., Li, S.H., Lan, C.Y., Tam, N.F.Y. and Wong, Y.S. 1993. Capacity of Futian mangrove ecosystem in purifying oil-containing municipal sewage. Asia-Pacific Symp. Mangrove Ecosystems, abstract.

Wang, X.P., and Jin, G.Y. 1989. Preliminary study of eutrophication in waters in Shenzhen Bay. Journal of Jinan University (Natural Science and Medicine) 1989: 68-72. (in Chinese).

Watkins, D. 1993. A national plan for shorebird conservation in Australia. Australasian Wader Studies Group, Royal Australasian Ornithologists Union, and World Wide Fund for Nature. RAOU Report No. 90. Melbourne.

Weise, J.H. 1979. A study of the reproductive biology of herons, egrets, and ibis nesting on Pea Patch Island, Delaware. Delmarva Power and Light Co., Wilmington.

Welty, J.C. 1982. The life of birds. 3rd. ed. Saunders, Philadelphia.

Wolff, W.J. 1969. Distribution of non-breeding waders in an estuarine area in relation to the distribution of their food organisms. Ardea 57: 1-28.

Wong, F.K.O. 1991. Habitat utilisation by Little Egrets breeding at Mai Po. Hong Kong Bird Report 1990: 185-190.

Wong, Y.S., Lan, C.Y., Chen, G.Z., Li, S.H., Li, M.S., Chen, X.R. and Tam, N.F.Y. 1993. Effect of wastewater discharge on nutrient contamination on mangrove soil and plants. Asia-Pacific Symp. Mangrove Ecosystems, abstract.

Wong, C.K., Chu, K.H., Tang, K.W., Tam, T.W. and Wong, L.J. 1993a. Effects of chromium, copper and nickel on survival and feeding behaviour of Metapenaeus ensis larvae and postlarvae (Decapoda: Penaeidae). Mar. Environ. Res. 36: 63-78.

Woodroffe, C. 1992. Mangrove sediments and geomorphology. pp. 7- 43 in Alongi, D.M. and Robertson A.I. (eds.). Tropical mangrove ecosystems. Coastal and Estuarine Studies 41. American Geophysical Union, Washington, D.C.

Wright, E.N. 1963. A review of bird scaring methods used on British airfields. pp. 113-119 in Busnel, R.G. and Giban, J. (eds.). Colloque: le probleme des oiseaux sur les aerodromes. Institute National de la Recherche Agronomique, Paris.

Yates, M.G., Goss-Custard, J.D., McGrorty, S., Lakhani, K.H., Durrel, S.E.A. le V. dit, Clarke, R.T., Rispin, W.E., Moy, I., Yates, T., Plant, R.A. and Frost, A.J. 1993. Sediment characteristics, invertebrate densities and shorebird densities on the inner banks of the Wash. J. appl. Ecol. 30: 599-614.

Young, L. 1991. Conservation of wildlife in the Deep Bay area: with particular reference to heron species. pp. 813-822 in Boxall, J. (ed.). Polmet'91. Pollution in the metropolitan and urban environment. Hong Kong Institution of Engineers, Hong Kong.

Young, L. 1994. The ecology of Hong Kong Ardeidae (Aves) with special reference to the Chinese Pond Heron at the Mai Po Marshes Nature Reserve. Ph.D. thesis, University of Hong Kong. @O13

Young, L. and Melville, D.S. 1993. Conservation of the Deep Bay environment. pp. 211-231 in Morton, B. (ed.). The marine biology of the South China Sea. Hong Kong University Press, Hong Kong.

Young, L. and Wong, K.M. 1993. Traditional gei wai shrimp cultivation at the Mai Po Marshes Nature Reserve, Hong Kong. Asia- Pacific Symp. Mangrove Ecosystems, abstract.

Yu, R.Q., Chen, G.Z., Lan, C.Y., Tam, N.F.Y. and Wong, Y.S. 1993. Benthic macrofauna of the mangrove swamp treated with municipal wastewater. Asia-Pacific Symp. Mangrove Ecosystems, abstract.

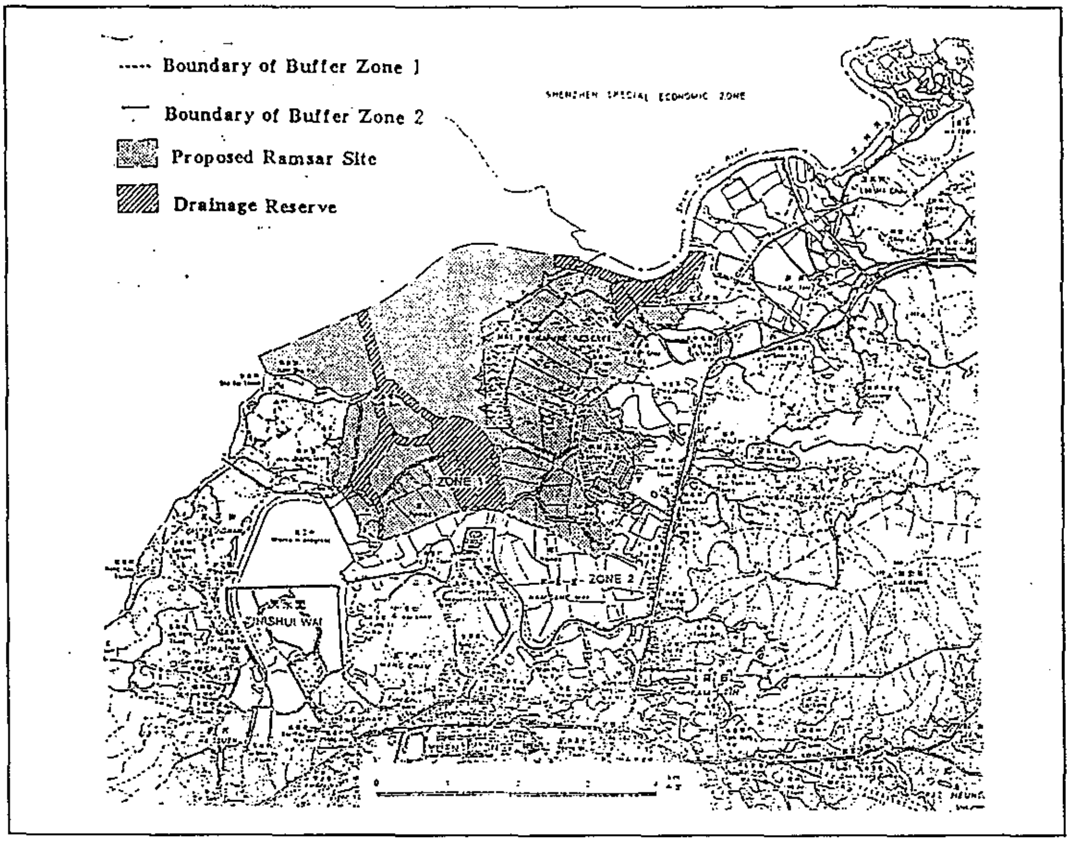


Figure 10.1 Boundary of Deep Bay Ramsar Site

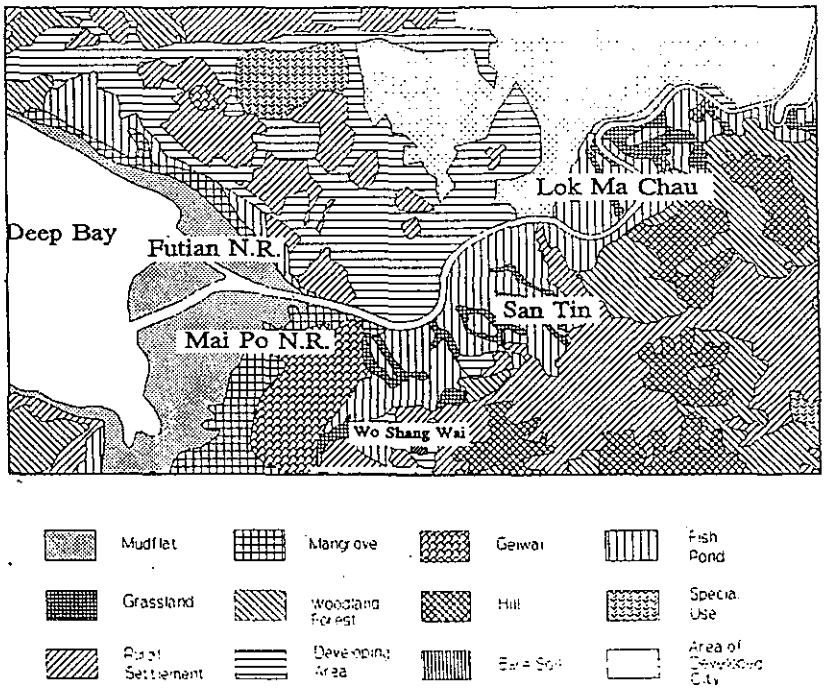


Figure 10.2 Habitat types in the Shenzhen River catchment

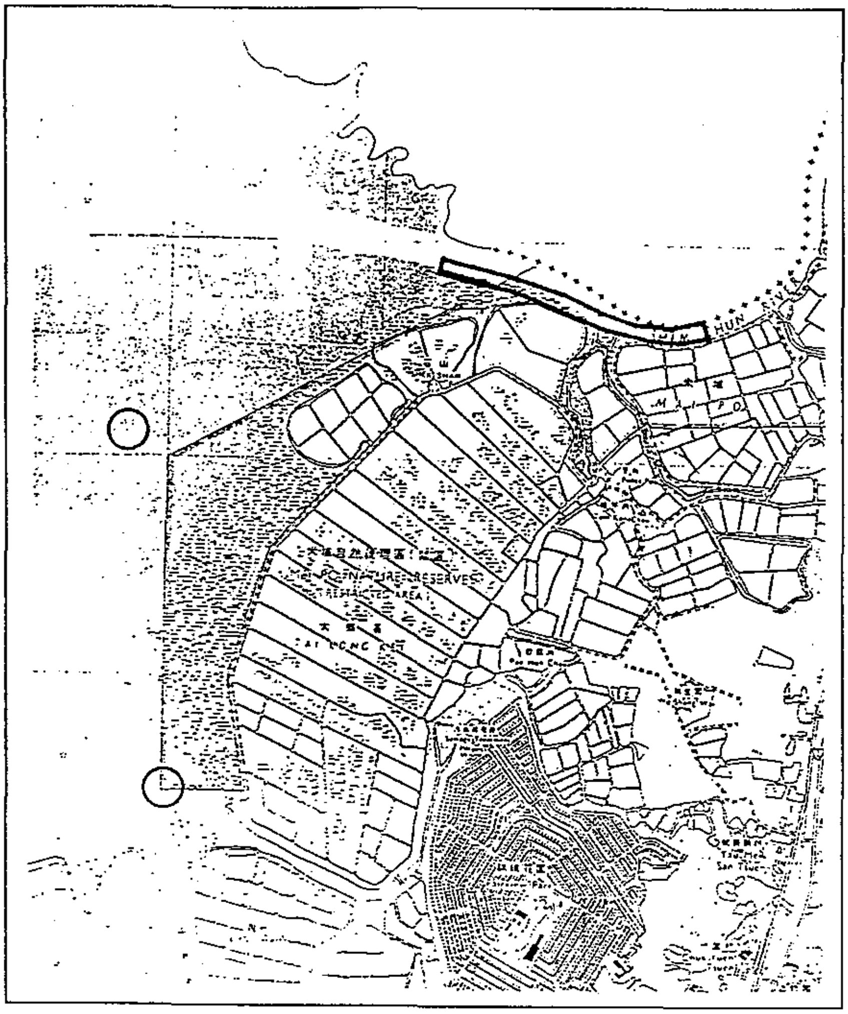


Figure 10.3 Distribution of *Eleocharis cf. acicularis*

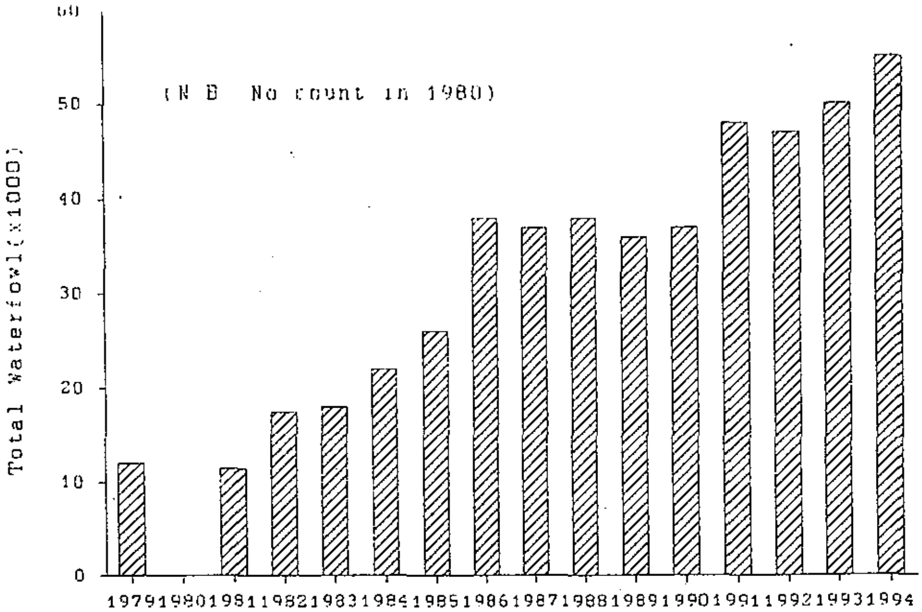


Figure 10.4 Mid-January waterfowl count data (Hong Kong, 1979-94, data supplied by Hong Kong Bird Watching Society)

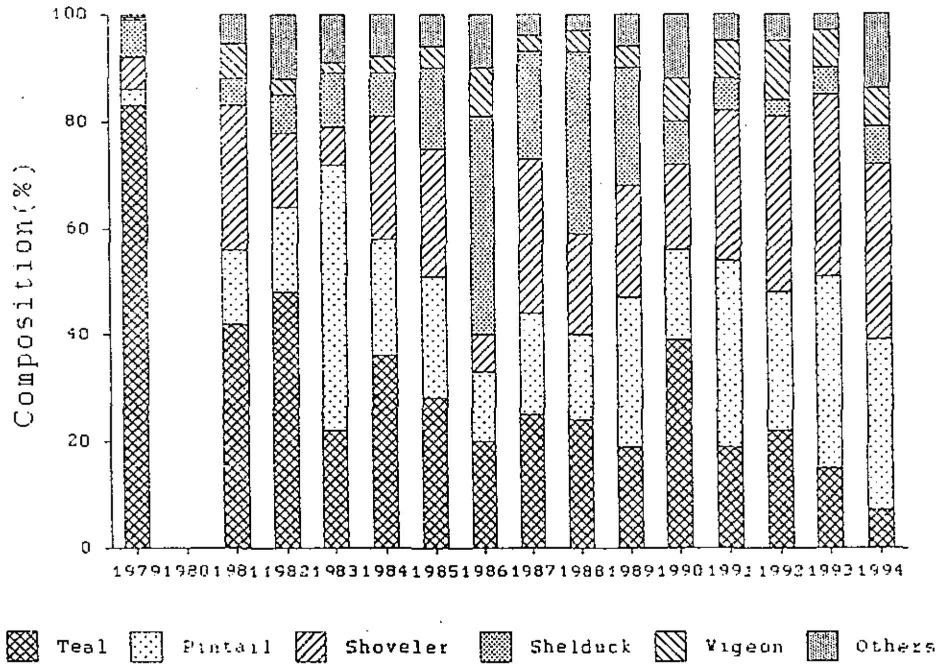


Figure 10.5 Species composition of ducks in Deep Bay (1979-1994, data supplied by Hong Kong Bird Watching Society)

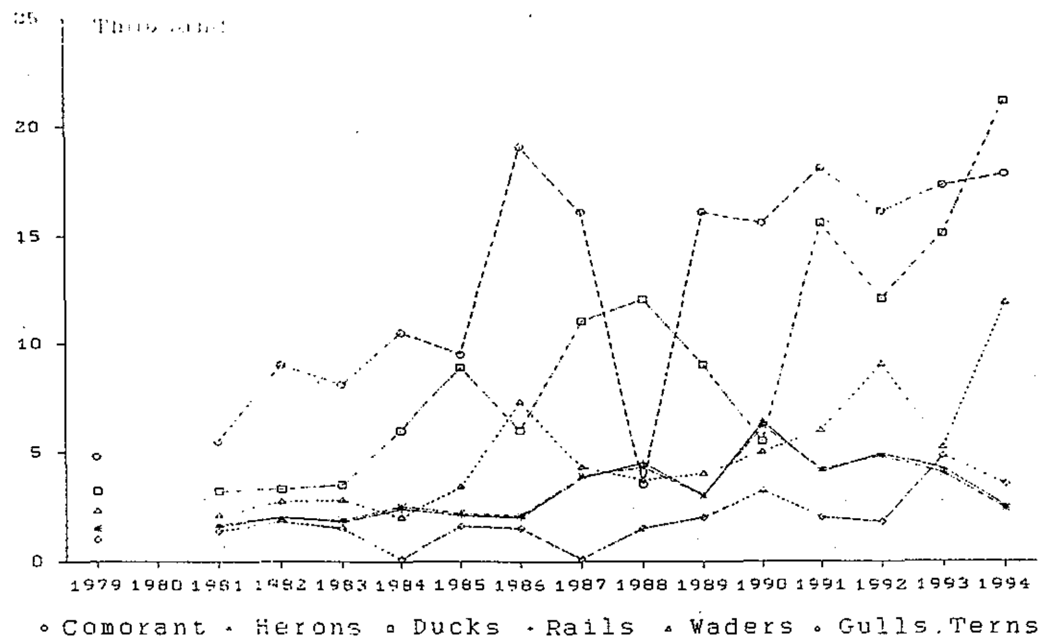


Figure 10.6 Mid-January waterfowl count data, Hong Kong, 1979-1994 (supplied by Hong Kong Bird Watching Society)

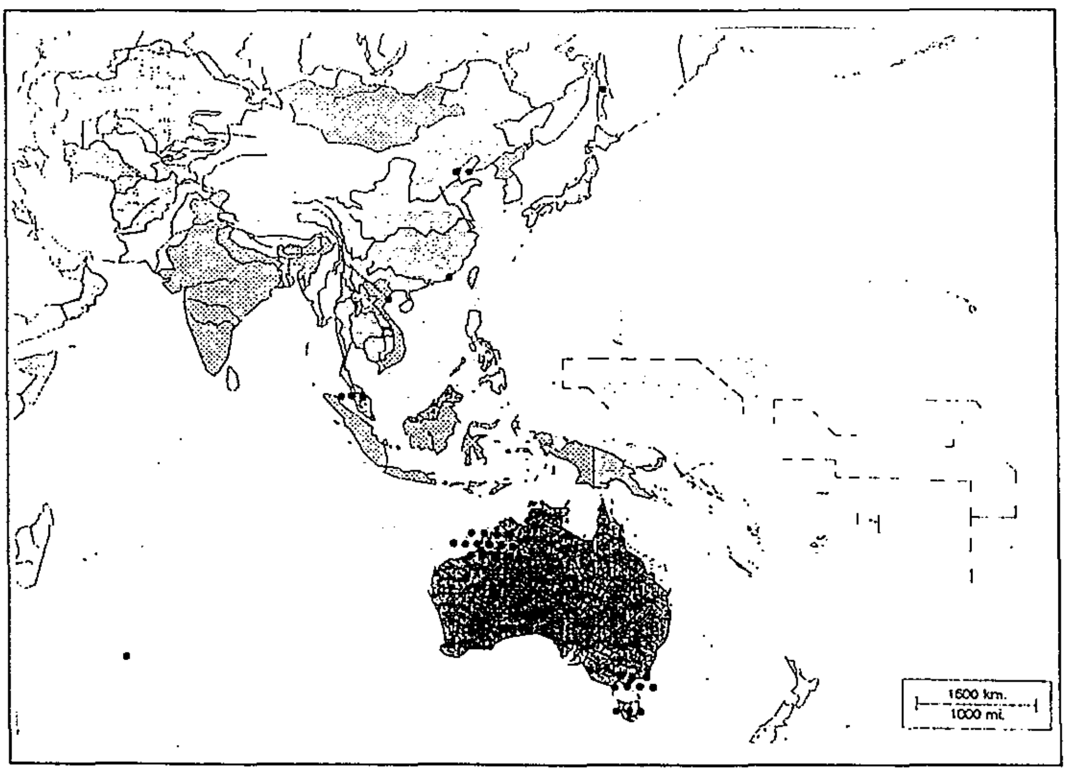
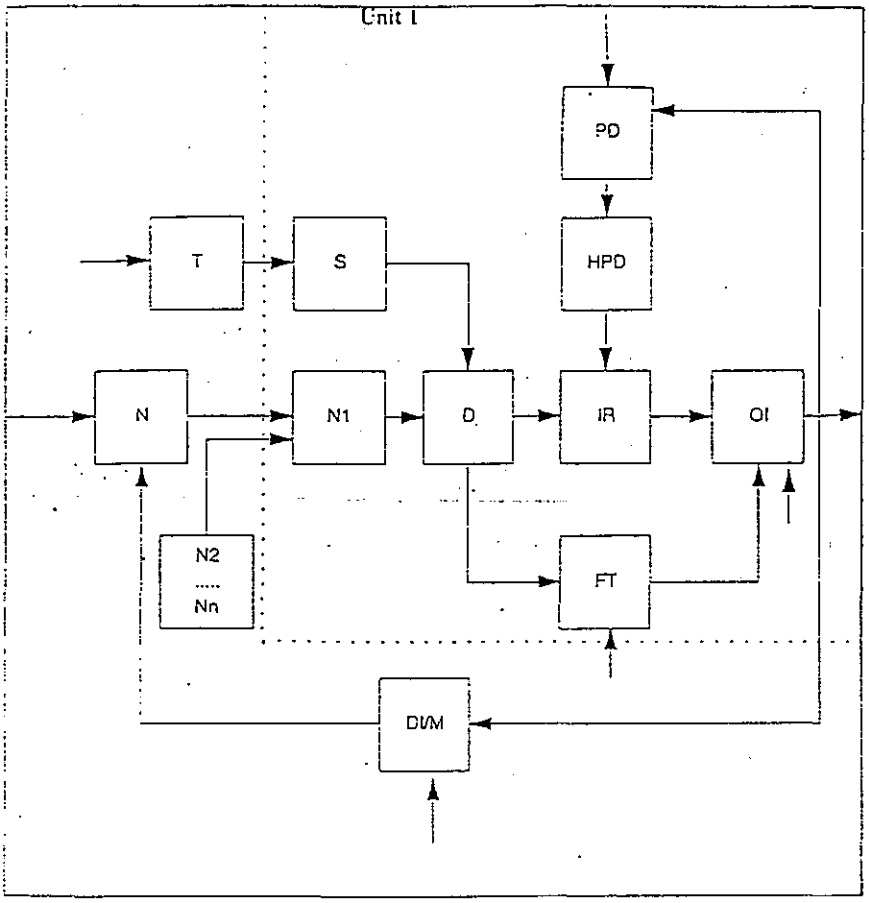


Figure 10.7 Recorded movements of shorebirds to/from Hong Kong



Key :

N	:	Total number of birds present
N1	:	Number of birds in unit 1 (benthic community of area with a given prey density)
N2-Nn	:	Number of birds in units 2-n
D	:	Density of birds
IR	:	Intake rate
OI	:	Overall intake rate
T	:	Tidal conditions
S	:	Surface of the feeding area
PD	:	Prey density
HPD	:	Harvestable prey density
FT	:	Feeding time
DI	:	Dispersal
M	:	Mortality

Figure 10.8 Conceptual model of factors influencing the occurrence of Waders in an estuary (after Meire 1993)

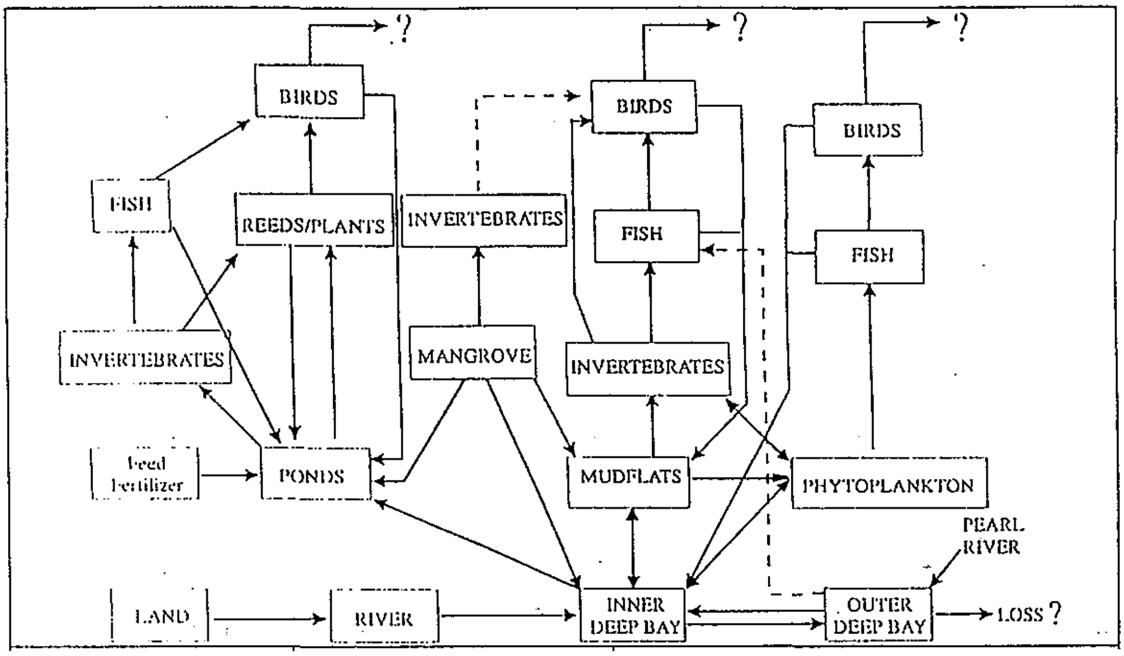


Figure 10.9 Framework for ecological model

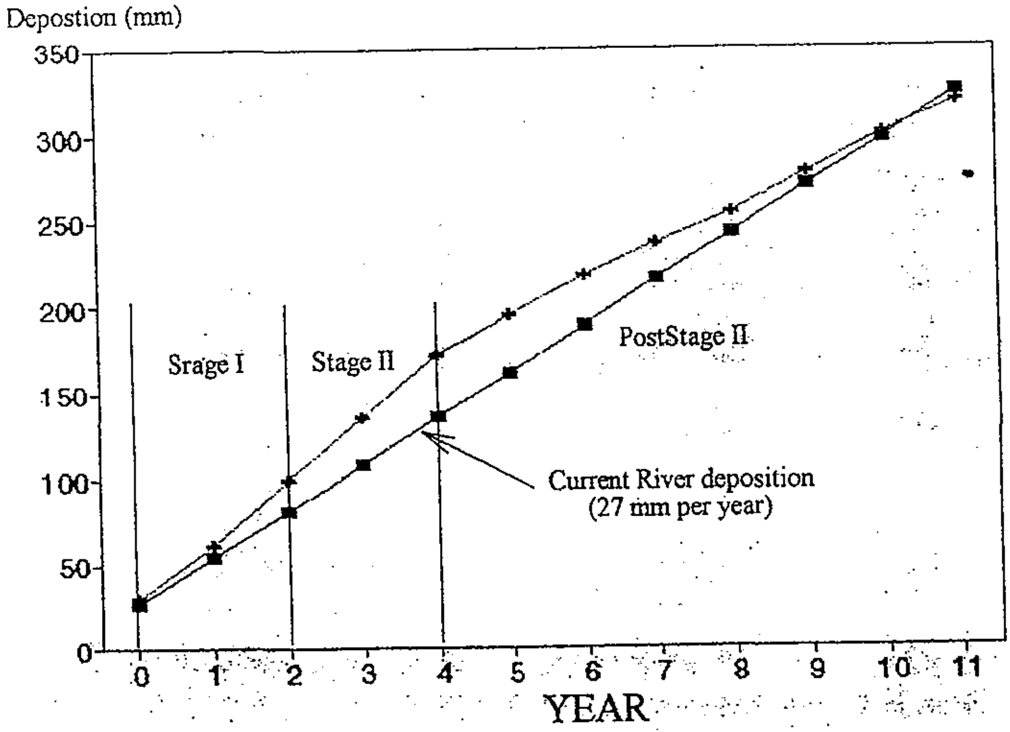


Figure 10.10 Annual average deposition on mudflat off Mai Po

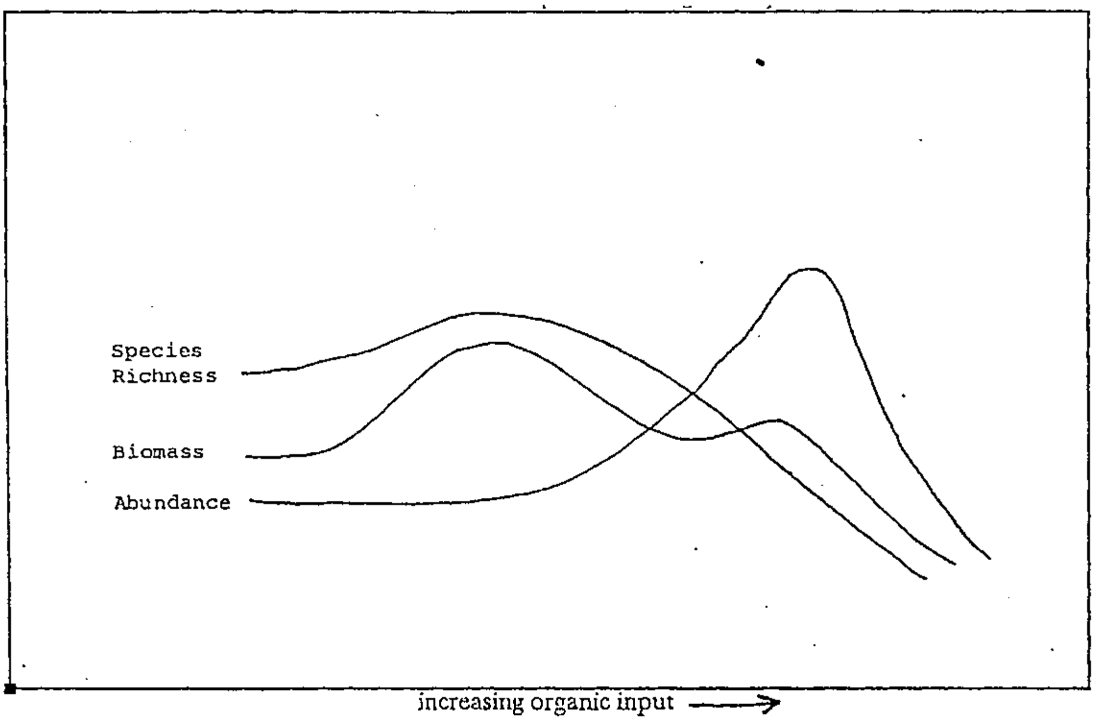


Figure 10.11 General species richness - abundance - biomass curves with distance in time or space from organic inputs

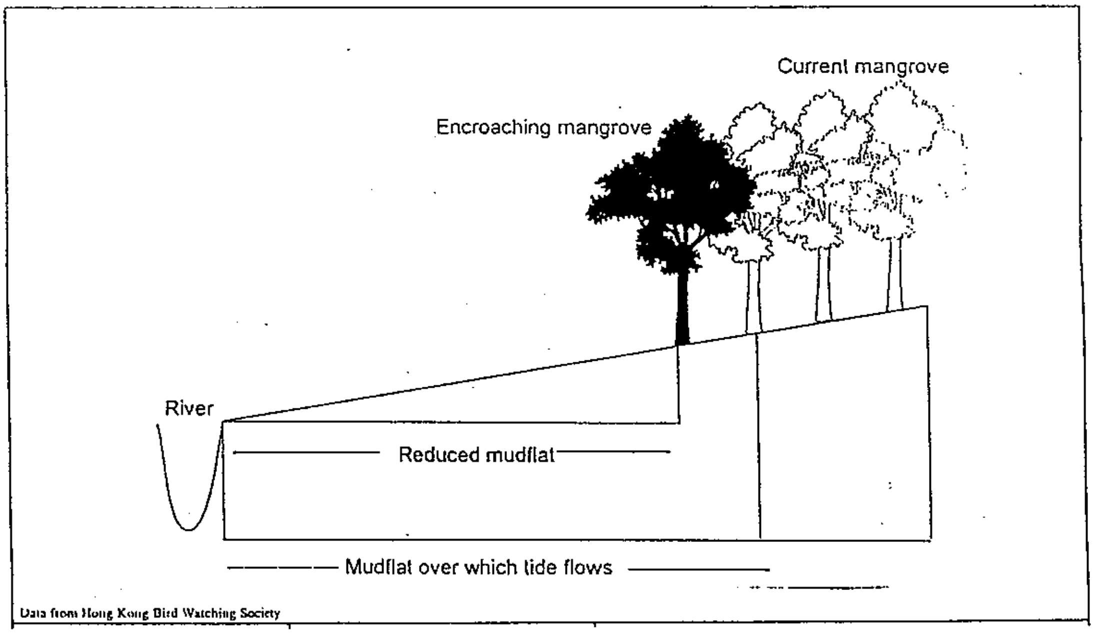


Figure 10.12 Potential impacts of mangrove encroachment on the mudflat at Mai Po

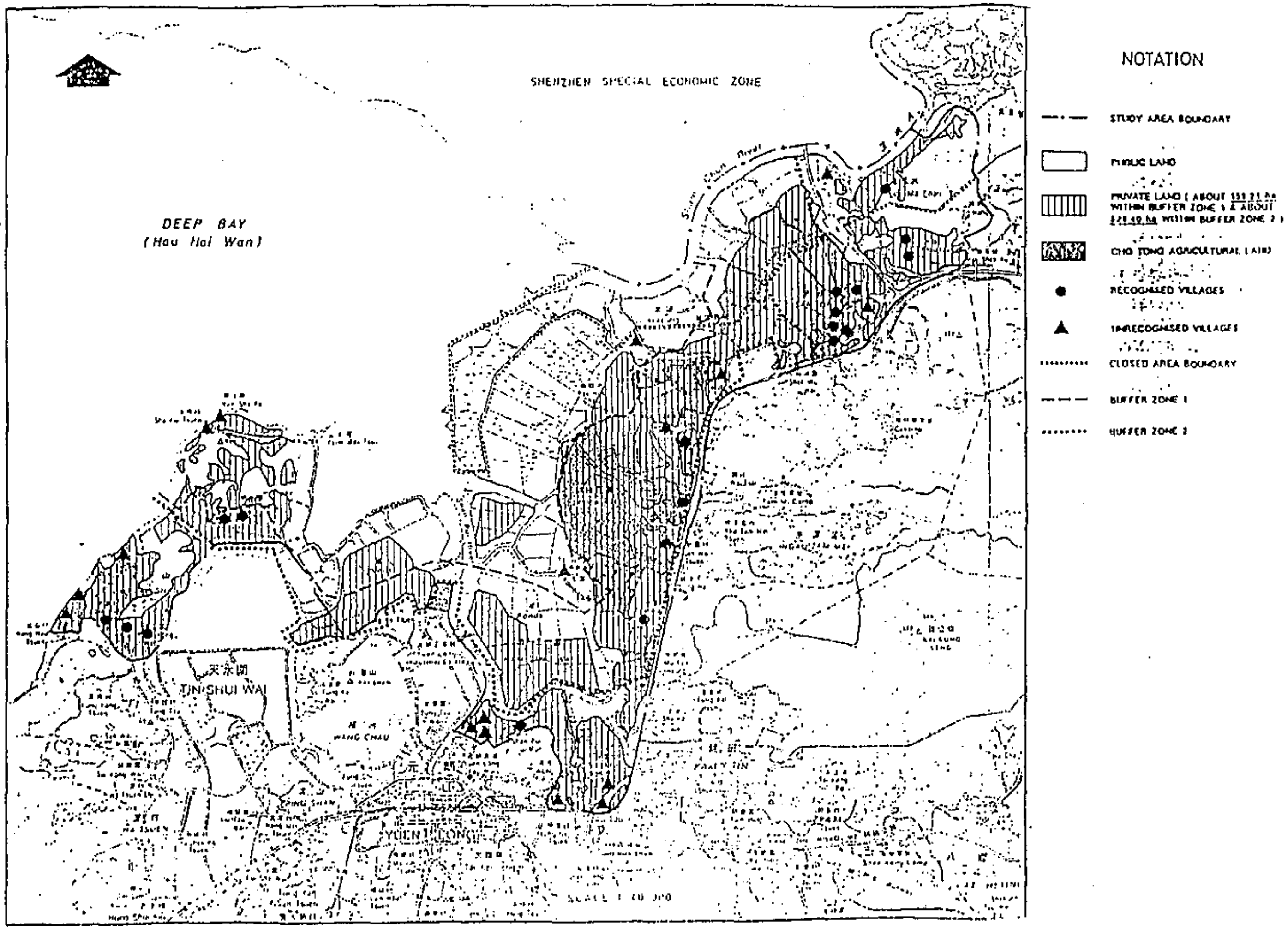


Figure 10.13 Land ownership in the Lok Ma Chau/Mai Po Area, Mai Po Development Statement (HK Planning Department, 1994)

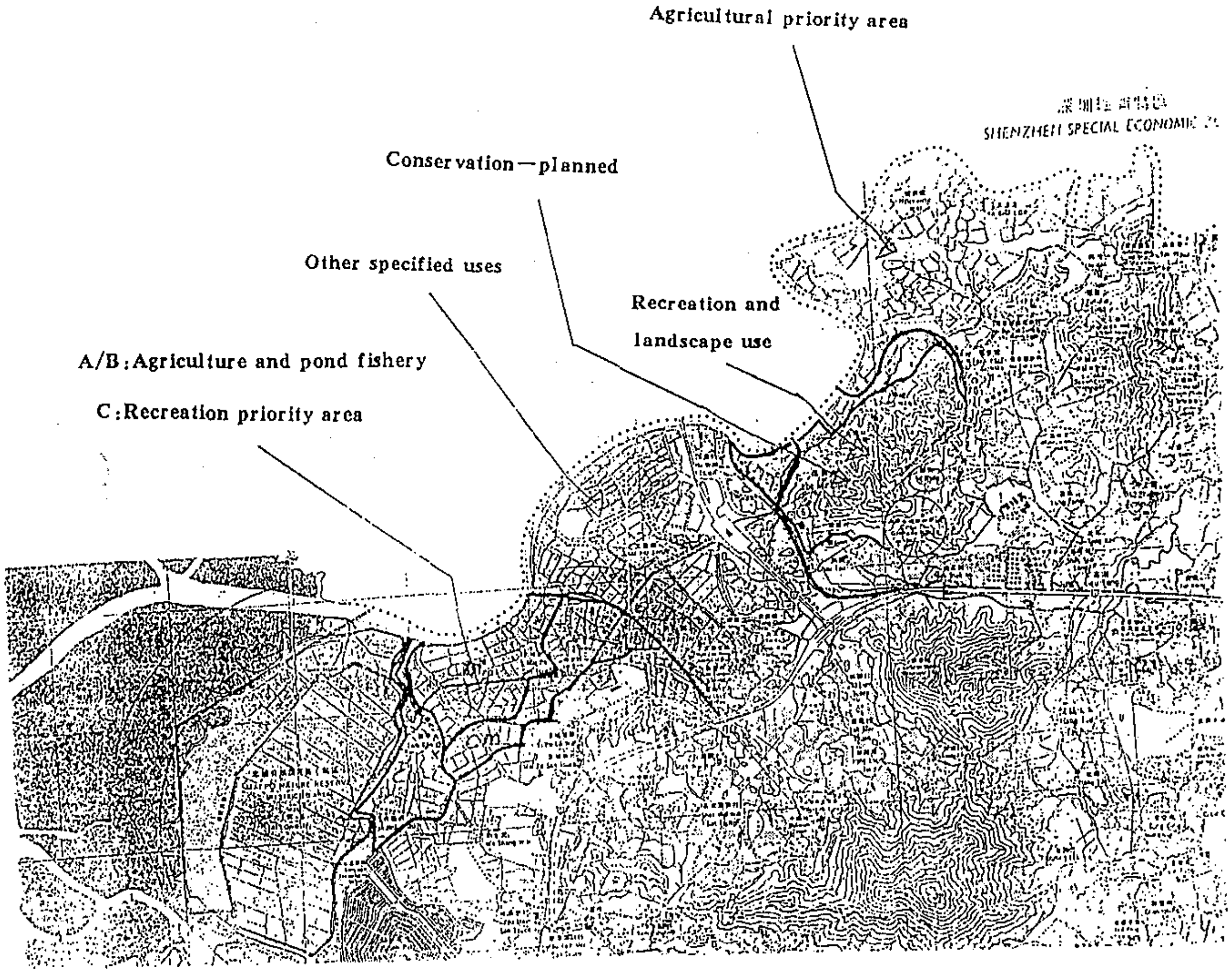


Figure 10.14 Land use scenarios for the Hong Kong side of the Shenzhen River

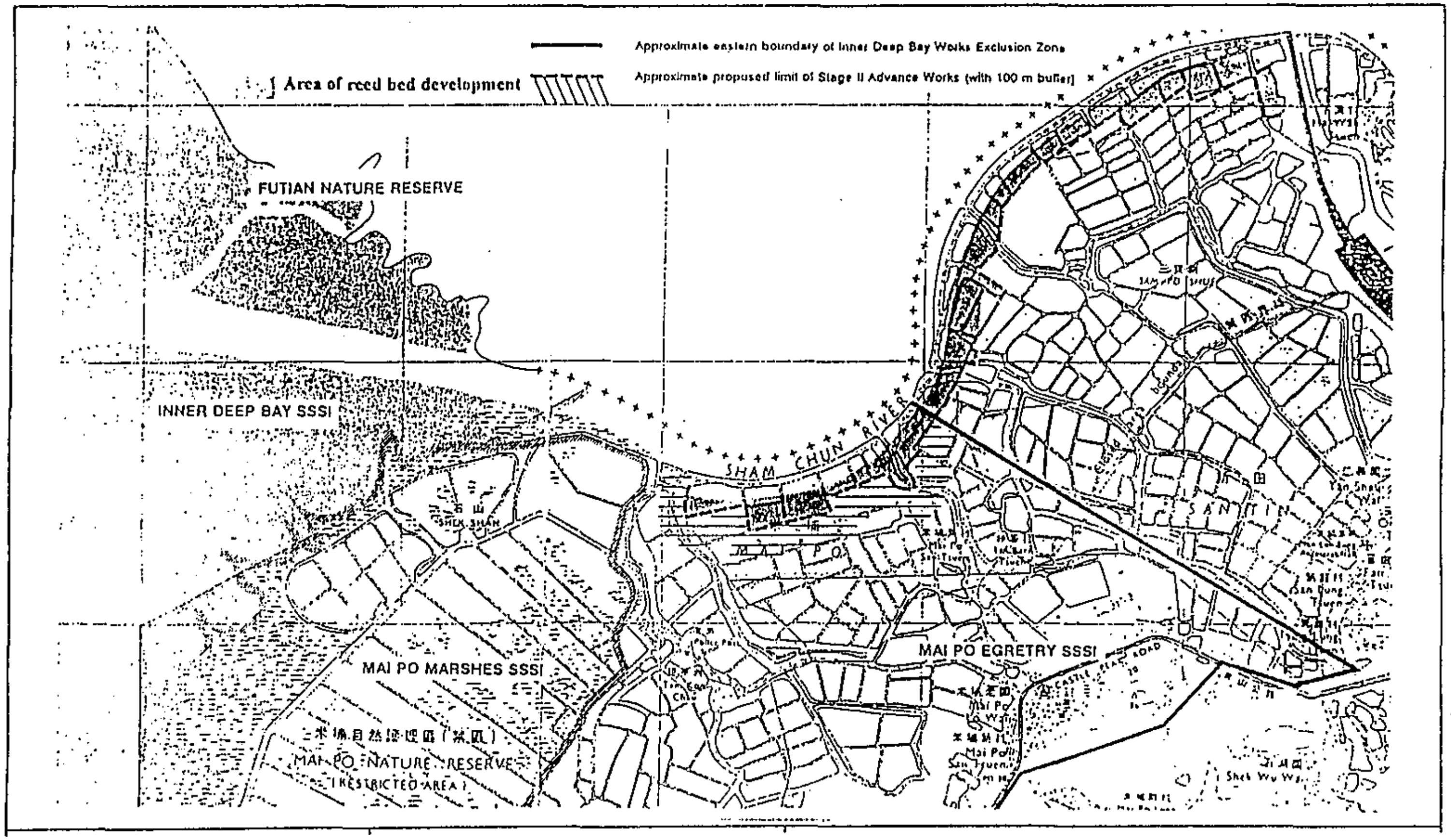


Figure 10.15 Approximate boundary of the Stage 2 Advance Work Area

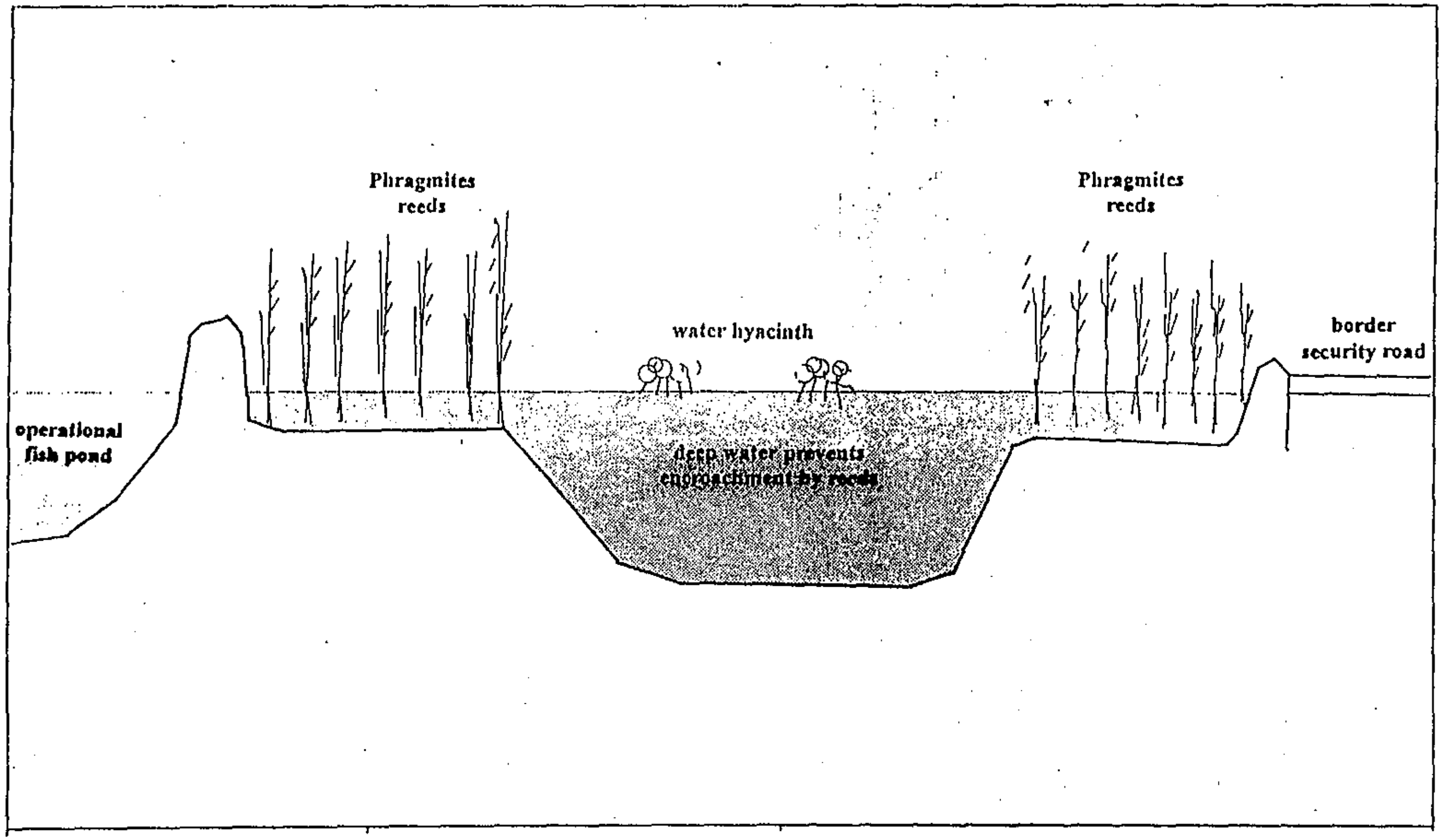


Figure 10.16 Cross-section of south bank of Shenzhen River after completion of Stage 2 Works showing planted reedbed in rehabilitated

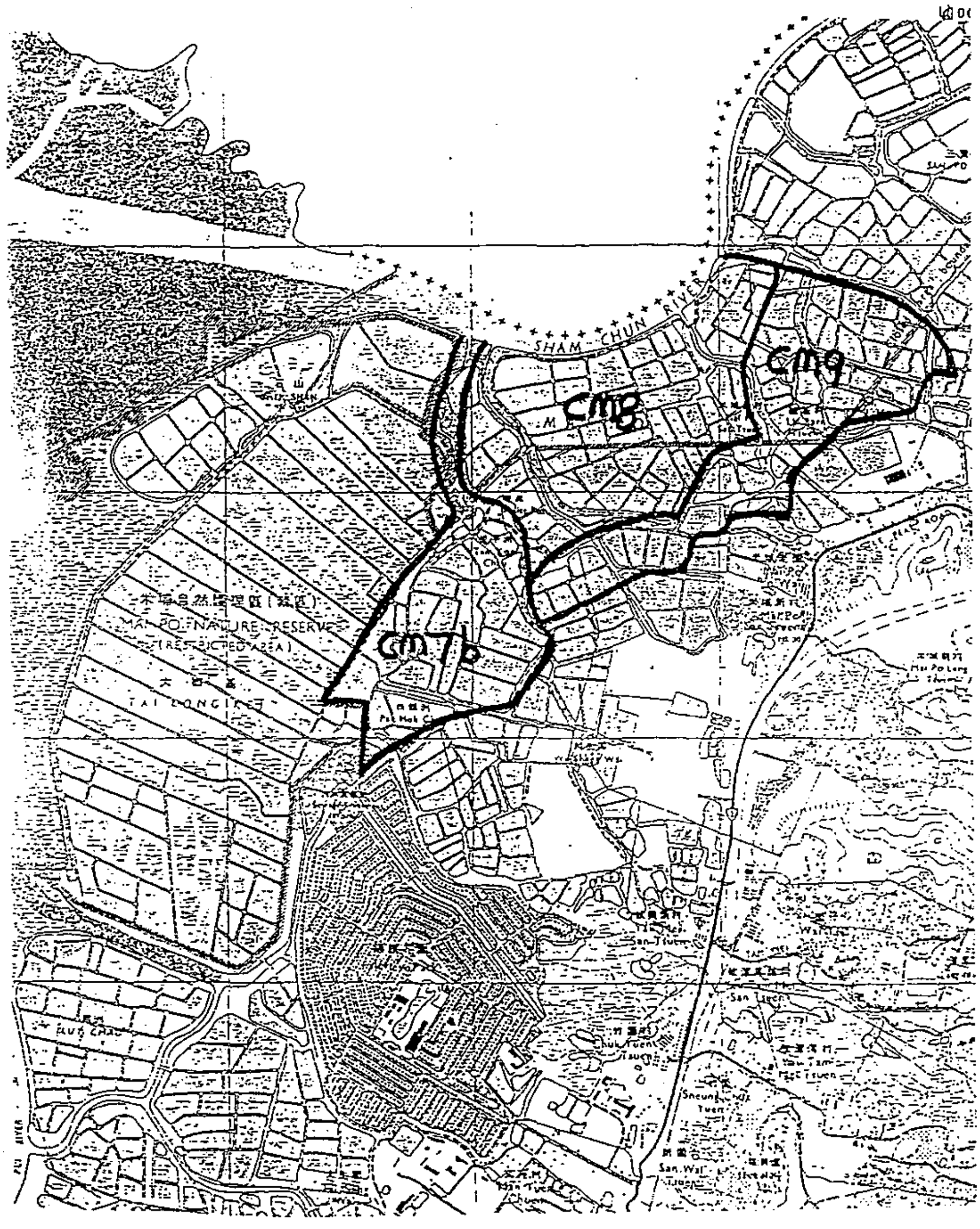


Figure 10.17 Proposed conservation management areas at Mai Po Development Statement, Hong Kong Planning Department 1994

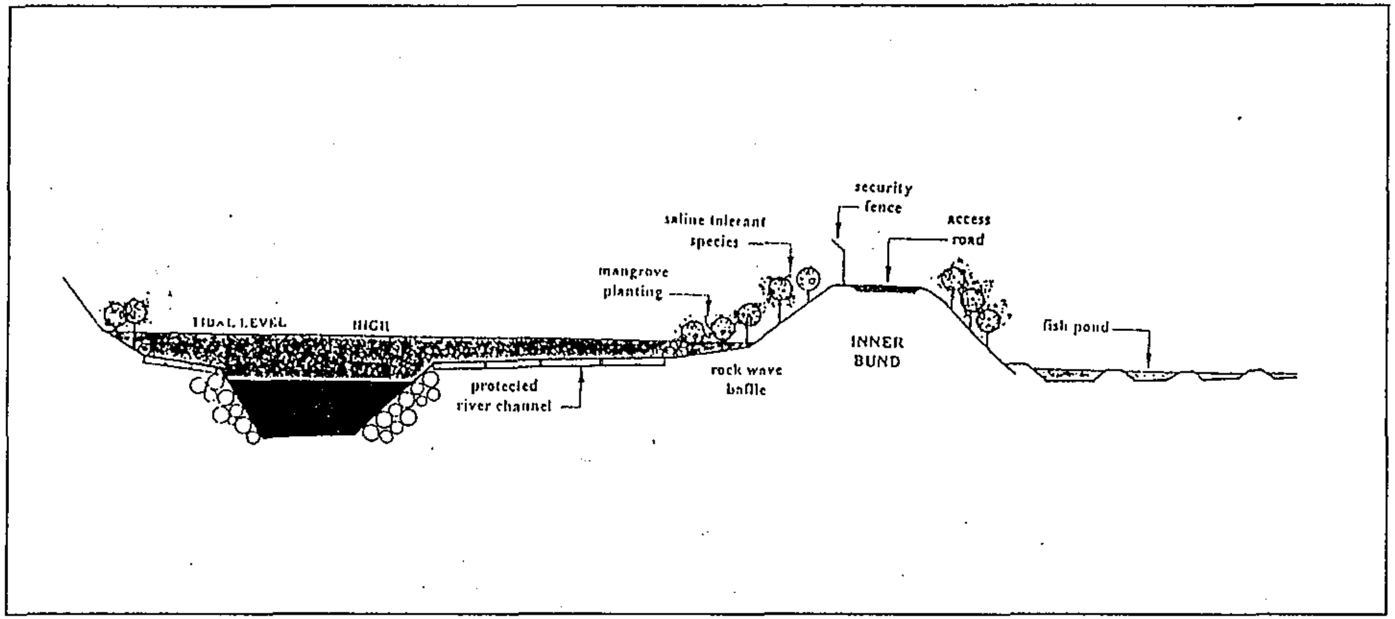


Figure 10.18 Cross-section of south bank of Shenzhen River after completion of Stage 2 Works showing mangrove planting theme

11 CONCLUSION

11.1 Introduction

11.2 Environmental Impacts

11.3 Mitigation Measures

11.4 Feasibility of the Regulation Project

11 CONCLUSION

11.1 INTRODUCTION

This section summarizes the major conclusions drawn from the Environmental Impact assessment of the Shenzhen River Regulation Project.

11.2 ENVIRONMENTAL IMPACTS

11.2.1 Impacts on Air Quality

The major source of air pollution will be dust resulting from the handling and transportation of spoil during embankment construction and site erosion. Without mitigation it is expected that dust levels at 4 sensitive receives in Shenzhen and 6 sensitive receivers in Hong Kong would exceed the relevant standards. The worst affected areas are at Chiwei in Shenzhen and at Lok Ma Chau and Ta Sha Lok in Hong Kong when Stages 1 and 2 overlap.

With suggested mitigation measures implemented it is expected that the dust problems will be reduced to acceptable levels during the construction period.

During the operational period the only air pollution impact relates to dust from maintenance dredging. No significant effects are predicted.

11.2.2 Noise Impacts

Noise impacts will occur due to construction activities during stages 1 and 2, and from periodic works associated with maintenance dredging. Given the physical and temporal separation of Stage 1 and 2 Works, the noise impact of these operations can be considered separately.

The assessment has indicated that daytime Hong Kong construction noise standards should not be difficult to meet in the Deep Bay Area. In the Inner Deep Bay Special Measures Zone, noise reduction measures will be required to keep construction noise below 60 dB(A) at a distance of 100 m from the construction site boundary.

PRC daytime standards will also be more difficult to meet, since they stipulate noise at the construction site boundary. The use of items of PME near the construction site boundaries will be restricted.

In addition, evening noise criteria are more stringent, and necessitate the implementation of restrictions on the use of PME if construction activities continues past daytime hours.

11.2.3 Impacts on Hydrodynamics

No significant changes in hydrodynamics of Shenzhen River and Deep Bay was predicted as the result of the Stage 1 Works.

After Stage 2 Works, however, water levels in the trained river channel would decrease greatly. No significant differences in hydrodynamics of Deep Bay were predicted except for an increase in the tidal exchange and local increase of the tide velocity in the river mouth.

11.2.4 Impacts on Sediment Transportation

Unlike the Stage 1 Works or anticipated maintenance dredging, during which only a slight increase in sediment flux from the River would be expected, the SS contents generated during Stage 2 dredging in the river mouth will reach 150 mg/l on average compared to 80 mg/l as the baseline.

During Stage 2 Works, especially when the lowest reaches of the channel are dredged, the sediment deposition rate in Inner Deep Bay is predicted to increase considerably(from 16.4 mm/yr to 22.5 mm/yr, 17.0 mm/yr to 21.0 mm/yr, and 86.6 mm/yr to 115 mm/yr for Futian, Mai Po, and adjacent to the river mouth, respectively).

Currently only a small portion of sediments deposited in Inner Deep Bay are from the Shenzhen River and majority are exogenous. A large increase in the sediment deposition rate due to river input during the Stage 2 construction works (286% on average) will cause only an average of 23.5% rise in overall sediment deposition rate in Inner Deep Bay.

The river bed above Lo Wu will be eroded dramatically during the first few years after completion of the Project and gradually reach a quasi-equilibrium state. There will be a large volume of sediment deposited in the section immediately downstream from Lo Wu. Meanwhile, the sediment deposition rate will decline from 17.0 mm/yr to 13.0 mm/yr in Mai Po and 16.4 mm/yr to 11.0 mm/yr in Futian respectively.

More sediment from upstream will deposit in the trained channel after the regulation project. The sediment flux into Deep Bay from the River will consequently decrease significantly.

During the operation period, the deep channel near the river mouth is the only place where flow energy would concentrate and erosion would take place. For the mudflat in Futian and Mai Po, no active erosion is predicted, however the deposition rate will be reduced in the river mouth area.

Because most maintenance dredging would take place in the 6 km upstream from river mouth, sediment resuspended by maintenance dredging would be expected to deposit in the river channel before reaching the river mouth.

11.2.5 Impacts on Water Quality

There will be no direct influence on water quality during the construction phase of the Project.

The dredging operation of Stages 1 and 2 Works and maintenance dredging, however, affect water quality through resuspension of contaminated sediments. The increase in pollutant content from resuspended solids would be unlikely to cause a noticeable effect on the heavily polluted river water. However, the reduction of water quality in Deep Bay would cause potential impacts.

It was estimated conservatively that no more than a 5% increase in all pollutant concentrations would be expected during the Stage 1 Works and during dredging operation of Stage 2, a 70mg/l increase in SS content would cause less than 10% increase in some pollutants released(the conservative estimation). Due to dilution, pollution effects caused by release of contaminants from suspended sediments would be confined to a small area adjacent to the river mouth.

The effect of the significant increase in tidal exchange volume on water quality of the Shenzhen River would be a minor improvement.

During the operational phase, water quality may suffer periodically as a result of maintenance dreading of the river channel. Since most dredging will be done immediately downstream of Lo Wu, the impact on water quality in Inner Deep Bay will be insignificant.

11.2.6 Impacts of Spoil Disposal

A relatively larger portio(25%) of dredged spoil from Stage 2 Works will be contaminated mud (0.75 Mm^3 out of 3.04 Mm^3) compared to less than 4% from Stage 1 Works (0.056 Mm^3 out of 1.7 Mm^3). The total volume of maintenance dredging during the first 5 years after the completion of the Project would be around 0.38 Mm^3. The contents of heavy metal are uniformly distributed along the vertical profile. The contaminated mud is basically Class C material according to Hong Kong's classification.

It is recommended that contaminated and uncontaminated spoil from Stage 1 Works is to be disposed of in fish ponds at Lok Ma Chau. All contaminated muds and a portion of uncontaminated muds from Stage 2 Works, as well as from maintenance dredging are to be disposed of at the Lok Ma Chau Bend on top of Stage 1 disposal site. The remaining uncontaminated material from Stage 2 can be transported to the Shekou reclamation site for disposal.

Based on evaluation using Hakanson's index, only mild ecological hazard of the river sediment to terrestrial ecosystem is expected. Due to high affinity of most heavy metals to the sediment matrix and low permeability of the underlying material, the leaching potential of metals would be very low.

The water quality effects of the effluent discharge during active disposal operations was identified as one of the more important environmental impacts of dredged material disposal. The erosion of the contaminated spoil by surface runoff during or after disposal operation especially in the wet season will result in remobilisation of the metals and secondary pollution to the surface water.

Transportation of uncontaminated material, if proper measures are implemented,should not cause unacceptable environmental impacts.

11.2.7 Ecological Impacts

The key issues raised by the Project are the potential effect on ecological resources. The most important broad potential effects of the Project on ecology are derived from physical loss of habitat, release of pollutants into the system, and changes in sedimentation rates at the mudflats.

Habitat Loss

Habitat loss is identified as a key impact of the Project, particularly with respect to intertidal mudflat, mangroves(10.8 ha), fishponds and associated bunds(106 ha), and part of Seung Ma Lei Yue Hill(5 ha).

Intertidal Mudflats: Increased rates of sedimentation during the construction phase of the Project could result in mangroves encroaching over the mudflat, thus resulting in mudflat habitat loss. The loss of intertidal mudflats within Inner Deep Bay is identified as a key impact. The major concern relates to cumulative loss due to other drainage and flood control projects with the Deep Bay area. The loss of intertidal mudflats along the Shenzhen River, which are grossly polluted, is not identified as a key impact.

Mangroves: The loss of mangrove as a result of the project is identified as a key impact. Potential effects include loss of habitat for wildlife, loss of nursery shelter, and coastal protection. Mangroves along the Shenzhen River also provide an important habitat and corridor for wildlife between the hinterland and Mai Po/Futian.

Fish Ponds: Direct loss of fishponds is identified as a key impact. The fishponds are used as food sources by Black faced Spoonbills, Cormorants, Imperial Eagles, as well as egrets and herons. The cumulative loss of fishponds in the Deep Bay area has accelerated to unprecedented proportions over the past decade and is considered to be approaching critical levels. the loss of fishpond associated with the project is significant in this context.

Hillside and Upland Habitat: Loss of Hillside/upland habitats are identified as a key impact. Construction of Stage 1 Works will result in the loss of approximately 5 ha of hillside and upland habitat at Seung Ma Lei Yue Hill, with effects on roosting and nesting areas for birds including the Bonnelli's Eagle. A range of measures have been recommended to minimize these losses and to compensate through new plantings.

Impacts of Water Quality Change

The extent of any release of contaminants has been shown to be insignificant in the context of the Deep Bay system and existing contamination levels. The effect of any release of contaminant is expected to be localize and not to have any significant effect on the broader ecological system. Change in water quality within a small area immediately adjacent to the River mouth is identified as a key impact of the Project during construction.

No large-scale effects of water quality change on the mangrove forests are anticipated in either short or long term.

Species diversity of Deep Bay benthos is limited due to pollution levels. Further degradation of water quality due to increased organic loads could result in further reduction of benthos species diversity. Only short term impacts, which are likely to arise from release of nutrients upon dredging of bottom sediments, on benthic invertebrates within a small area near the river mouth, preferred foraging areas for duck, are identified.

The very slight improvement in water anticipated as result of the Project is unlikely to result in any noticeable change in benthos and waterfowl.

Impacts of Erosion and Sedimentation

The model predicts no widespread erosion in the Inner Bay, except in the deep channel at the river mouth. Localized erosion of mangrove and intertidal mudflats in Deep Bay may, however, result from wakes from river traffic and localized downcutting of the river channel near the river mouth. Back-cutting of tidal creeks, as a result of river bank erosion through ship traffic effects, may result in loss of mangroves, especially at the north end of Mai Po at the mouth of the River.

The increased sediment loads resulting from the Project will occur throughout the year, and may result in impacts on benthic community within a small area near the river mouth, but would not adversely affect the mangroves.

The Project would result in a reduction of sedimentation rates when completed, but deposition rates are still likely to be higher than those in the early 1980s. The predicted reduction in sedimentation is unlikely to adversely affect the mangle, although the rate of encroachment onto the mudflat is likely to be reduced.

Loss of intertidal mudflats due to mangrove encroachment is likely to negatively impact waterbird populations. Thus any reduction foraging area due to mangrove encroachment could adversely affect bird numbers, while the reduction in sedimentation after the Project could be beneficial to waterbirds.

Human Disturbance

Human disturbance will result from both the construction and operational phases of Project including passage of plant within the works area, boat traffic on the River and humans moving within Deep Bay or along the banks of the River. Of the various groups of wildlife in the Deep Bay area, waterfowl are expected to suffer the most from human disturbance. Human disturbance to other wildlife is not considered to be a major problem with respect to the Project.

Air and Noise Impacts

Air quality and noise are not identified as key impacts on wildlife with respect to this Project.

11.3 MITIGATION MEASURES

Mitigation measures with respect to air quality, noise, sediment, water quality, disposal site, and ecology are detailed in Sections 5 to 10 and summarized as follows:

11.3.1 Construction Method

A range of practical mitigation measures has been recommended for dust suppression, the most important of which are the need for watering of works areas and stockpiles, controls on delivery and handling of cement and other dusty materials, and speed restrictions on vehicles.

The use of quietened PME and barriers(particularly in the Deep Bay Special Measures Zone) is proposed for noise reductions.

The use of a works method which isolates the main excavation works from the existing river channel in Stage 1 Works will reduce the extent of environmental risk from the project.

Separate dredging of contaminated and uncontaminated material will greatly reduce the volume of contaminated spoil to be disposed.

Selection of dredging method should be carefully considered during the detailed design. If a silt screen can not be installed and maintained during the operation due to marine traffic, the auger suction dredger is superior to the grab dredger. Otherwise, grab dredgers is preferred.

The human disturbance on waterfowl can be partially controlled through suitable conditions being attached to the works contract prohibiting the use of loudhailers in Inner Deep Bay. All efforts should be made to ensure that access to the Mai Po mudflat is controlled before work starts on the Project so that disturbance effects on waterfowl are kept to as minimum.

11.3.2 Construction Programme

Noise reductions can be achieved through construction programming. The Advance Works involve the construction of earth embankments, which, if they are built early enough, may act as noise barriers for subsequent activity within the river channel. In addition, planning of works will allow concentrations of PME at a single location to be avoided. These concentrations result in high noise levels at locations close by. Planning to distribute equipment more evenly over the site is preferred.

The worst case of re-suspension of sediments during dredging can be avoided if construction is programmed in the dry season. By reducing significantly the quantity of sediments resuspended and transported downstream, the risk of any significant effect downstream due to sedimentation will be reduced greatly.

Similarly the timing of the opening of the channel during Stage 1 Works can be used to reduce any possible downstream effect of increased sedimentation. Opening the channel during a period of low river flow and low tides will greatly reduce potential impacts.

The river channel outside of the Deep Nay SMZ should be dredged in the dry season to reduce the sediment re-suspension and nutrient mobilisation. The construction works within the Deep Bay SMZ are controlled and restricted during over-wintering period (November to March). Any dredging and embankment activities near the river mouth during the bird migration season should be minimized and if required, be subject to specific controls and approval.

To avoid the worst case of sediment resuspension during overlapping of Stages 1 and 2 Works, the dredging of the old channel in Stage 1 should be programmed during the time when dredging activities of Stage 2 Works are far away from the river mouth.

11.3.3 Spoil Disposal

The contaminated spoil from the existing river course should be disposed separately in isolated locations without mixing with uncontaminated material. The contaminated spoil disposal area should be capped with uncontaminated spoil to prevent erosion of the contaminated sediments as well as to maintain the anaerobic condition of the sediment. The cap must be properly designed and suitable drainage must be provided to prevent contact of surface runoff with the contaminants.

To prevent erosion by runoff during disposal operations, drainage ditches should be constructed around the disposal site to collect runoff water. A series of temporary oxidation ponds can be constructed during dewatering and consolidation operation. The supernatant can be treated on-site by physical/chemical precipitation and aerobic oxidation before being discharged into the river channel.

11.3.4 Habitat Creation and Management

Upland habitats

Impacts due to loss of upland habitats on Seung Ma Lei Yue Hill can be mitigated by successful restoration of vegetation on the proposed cut slope and adjacent slopes of the Hill. Further impact mitigation can be achieved by habitat creation on materials storage areas.

Fish ponds

The loss of 19 ha of fish ponds in Stage 1 Works could be mitigated by restoration of the old Shenzhen River channel at Lok Ma Chau Bend.

Three options are proposed to compensate for the loss of fish ponds due to Stage 2 Works:

Option 1: Enhancement management of ponds in the Futian National Nature Reserve.

An advantage of this option is that potentially it could be implemented in advance of the Stage 2 Works, thus allowing waterbirds to use the area when displaced by the Project.

Option 2: Reinstating fish ponds in Stage 2 Works Area.

Fish ponds in the Stage 2 Works Area on the Hong Kong side could be reinstated either as fish ponds, reed(Phragmites) beds, or conservation-cum-commercial ponds to enhance conservation value. These options suffer from the fact that they would not provide any habitat for displaced waterbirds and other wildlife until after the engineering works for embankment construction are completed and are unlikely to compensate for the loss of fish ponds during Stage 2 Works.

Option 3: Management of the Conservation Enhancement Management Area.

Management of the Conservation Enhancement Management Area to the northwest of the present Mai Po Reserve would provide suitable feeding conditions for the highly endangered Black-faced spoonbill, Aortitis and other piscivorous birds. This Option would allow for sufficient area for adequate mitigation.

If mitigation of adverse impacts on wildlife due to loss of habitat are restricted to the works boundary for the Project, then a restoration plan based on Option 2 is recommended. If wider mitigation options are able to be considered then both options 1 and 3 are preferred as they would provide the most effective response to the losses of fish ponds.

Mangroves

Two options are proposed to establish new mangroves.

Option 1: Mangrove planting along trained river bank.

Planting a 5m wide mangrove stand within the existing channel would result in a total area of some 1.6 ha being planted along the Hong Kong bank. This option would allow for limited compensation for the loss of mangroves resulting from Stage 2 Works without potentially impacting waterfowl populations. The option, however, would unavoidably affect the hydraulic performance of the river channel.

Option 2: Mangrove planning at Futian

New areas of mangrove can be established at Futian National Nature Reserve. This option could compensate for the whole area of mangrove being lost as a result of Stage 2 Works, but this would be at the expense of potential waterbird feeding areas on the intertidal mudflats.

Option 3: Planning on both sides

Planting a line of trees on both sides of Shenzhen River embankment, planting 5.8 ha of mangrove to the south off the river mouth within the works boundary, and planting 3 ha of mangrove in the Futian Reserve.

The hydraulic performance of the river channel during flood would be affected by planting mangrove along the trained river channel. the Option 1, therefore, can not be adopted without detailed modelling and evaluation. The carrying capacity of the Deep Bay area should be carefully assessed before the planting mangroves on the Inner Deep Bay mudflats. Option 3 is, therefore, recommended.

Landscaping

Consideration should be given to tree planting along the new embankment. Wherever possible native species should be used for planting to increase the value of the vegetation to wildlife.

11.3.5 Stage 3 Works

By carrying out the Stage 3 Works soon after the first two stages, the total volume of spoil to be dredged and disposed of during the maintenance porion of 5 years will be reduced dramatically.

11.4 FEASIBILITY OF THE REGULATION PROJECT

The purpose of the Shenzhen River Regulation EIA Study is to provide relevant information to assist in decisions on the environmental acceptability of the Project and to recommend on any specific environmental protection measures which should be included in the detailed design of the Stages 1 and 2 Works.

Upon implementation of adequate mitigation measures proposed in Sections 5.6, 6.7, 8.6, 9.6 and 10.5, the regulation project would not create any unacceptable air, noise, water quality, sedimentation, erosion, or ecological impacts. The Project is considered to be acceptable environmentally provided that the recommended environmental mitigation measures are adopted.

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To (Company)	:	EPD	Fax No.	:	2591-0558
Attention	:	Mr. Tom Tam	Date	:	13 November 1995
From	:	Alan Y. Kwok	No. of Pages	:	4
Subject	:	Shenzhen River EIA	Job/Ref No.	:	95810/FAK51113.05

If you do not receive all the pages, please contact us immediately.

Enclosed please find revised addenda to the Executive Summary and the Final Report of the Shenzhen River Regulation Project EIA Study.

Regards,

Alan Y. Kwok

cc DSD Mr. K W Cheung -2771-9858
AFD Mr. K W Cheung - 2311-3731
Axis Mr. Brian Ashcroft - 2827-2891

URGENT

Addendum to the Executive Summary

Section 1.3 Last Sentence

The sentence should be amended to read as "Stage 1 of the project has commenced in 1995 and is expected to complete in mid 1997. Stage 2 is expected to commence in 1996 and to complete in 2000".

Section 6.1 First Paragraph

The second sentence "the Guideline further recommend ..... and works should not take place outside the hours of 08.00 to 17.00" should be replaced with "It is recommended that construction works within the Inner Deep Bay Special Measures Zone (applicable to Hong Kong side only) follow the recommendations of the Deep Bay Guidelines. The Study Management Group agreed and advised that works such as dredging with the Inner Deep Bay SMZ can be carried out during the dry season (from November to March) subject to proper control to minimise the disturbance to wildlife. The works should be limited to 0800 to 1700 hr. The necessary detailed arrangement on the control will be defined before the commencement of the works."

Section 10.1 Third Bullet Point

The first sentence of thr fishpond loss paragraph should read as "Loss of 106 ha of permanent fishponds due to Stage 1 and 2 works. 41 ha (19 ha in Stage 1 and 22 ha in Stage 2) on the Hong Kong side and 65 ha (in Stage 1) on the Shenzhen side."

Section 11.2 Second Bullet Point

The sentence should read as "The Study Management Group agreed and advised that works within the Inner Deep Bay SMZ can be carried out during the dry season (from November to March) subject to proper control to minimise the disturbance to wildlife. The works should be limited to 0800 hr to 1700 hr. The necessary detailed arrangement on the control will be defined before the commencement of the works."

Section 12.5

Delete the last paragraph.

Addendum to the Final Report

Section 2.4.1 (Page 2-9)

Replace the first sentence with "Stage 1 of the Project has commenced in 1995 and is expected to complete in mid 1997. Stage 2 is expected to commence in 1996 and to complete in 2000."

Section 4.5.3 (Page 4-5)

Replace "Fig. 4.6" with "Figure 4.6".

Section 6.7 (Page 6-21)

Insert the following as the last paragraph of the Section: "At the Study Management Group meeting held on 23 May 1995 involving the consultants and all relevant departments, it was agreed that works can be carried out in the Inner Deep Bay Special Measures Zone from November to March with proper control measures."

Table 7.7 (Page 7-12)

Replace "1-12" with January to December"

Section 8.4.2 Second Paragraph (Page 8-7)

Replace "month" with "mouth".

Figure 8.5 (Page 8-9)

Replace "after Stages 1 and 2" with "during Stages 1 and 2".

Section 10.2 First Paragraph (Page 10-2)

Add the following sentence to the end of the paragraph: "The Ramsar site was subsequently designated in September 1995."

Section 10.5.1.a Insert the following as the second paragraph under *Summary*

At the Study Management Group meeting held on 5 September 1995 involving the consultants and all relevant departments, it was agreed that the reinstatement and enhancement management of 38.5 ha of fishponds temporarily lost to Stage 2 works within the works area along the south side of the river is the maximum allowable on-site mitigation. Permanent loss would be compensated through enhanced managment of reinstated ponds.

Section 10.5.1.b Option 3 First Paragraph (Page 10-59)

Add "mangrove related" before "tree" in point 1.

Section 10.5.1.c *Insert the following as the last paragraph of the Section*

The Study Management Group was of the view that the potential loss of intertidal mudflats due to encroachment by mangroves should be considered as a temporary impact of the project. The rate of mangrove encroachment, though accelerated during Stage 2 works, would be decreased to less than existing encroachment rate after completion of Stage 2 works due to less sediment input into Deep Bay from the Shenzhen River. The long term outcome is that mangrove encroachment would decrease. It was therefore deemed unnecessary to control mangrove encroachment during Stage 2 works through management and selective harvesting.

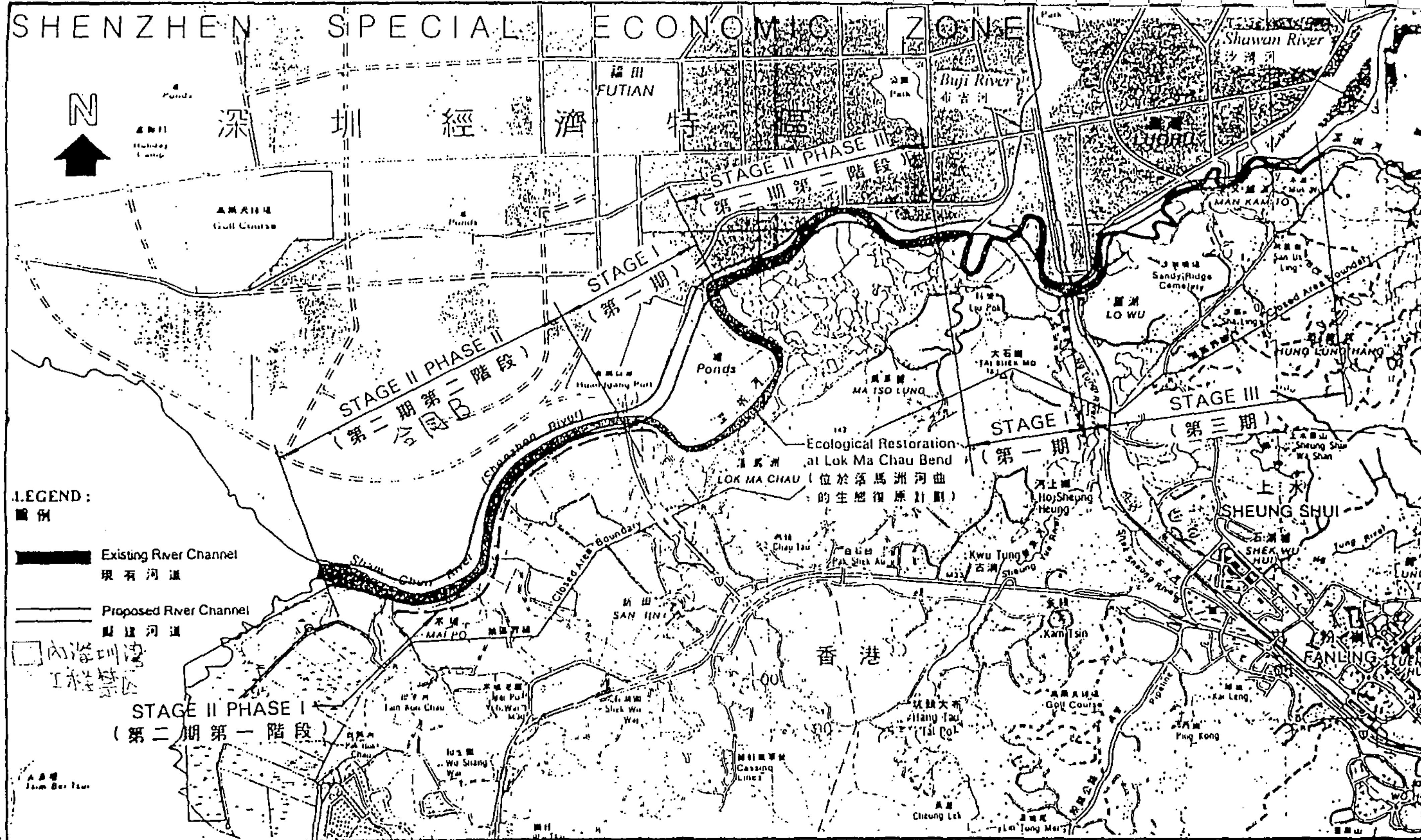
Section 10.5.6 First Paragraph (Page 10-61)

Add the following to the end of the paragraph: "The Study Management Group agreed that works such as dredging within the Inner Deep Bay SMZ can be carried out during the dry season (November to March) subject to proper control on the works being applied to minimise the disturbance to wildlife. Any necessary detailed arrangement on the control will be defined before the commencement of the works."

Section 11.3.2 Fourth Paragraph (Page 11-6)

Replace first sentence with: "The river channel outside of the Inner Deep Bay SMZ should be dredged in the dry season as far as practicable to reduce the sediment re-suspension and nutrient mobilisation.

Replace the second sentence with: "The construction works within the Inner Deep Bay SMZ are controlled and restricted to between 0800 to 1700 hr during over-wintering period (November to March)."



Drawing title :
圖則標題 :

SHENZHEN RIVER REGULATION PROJECT
治理深圳河計劃

Figure 1-1

Scale 比例尺 1 : 50 000

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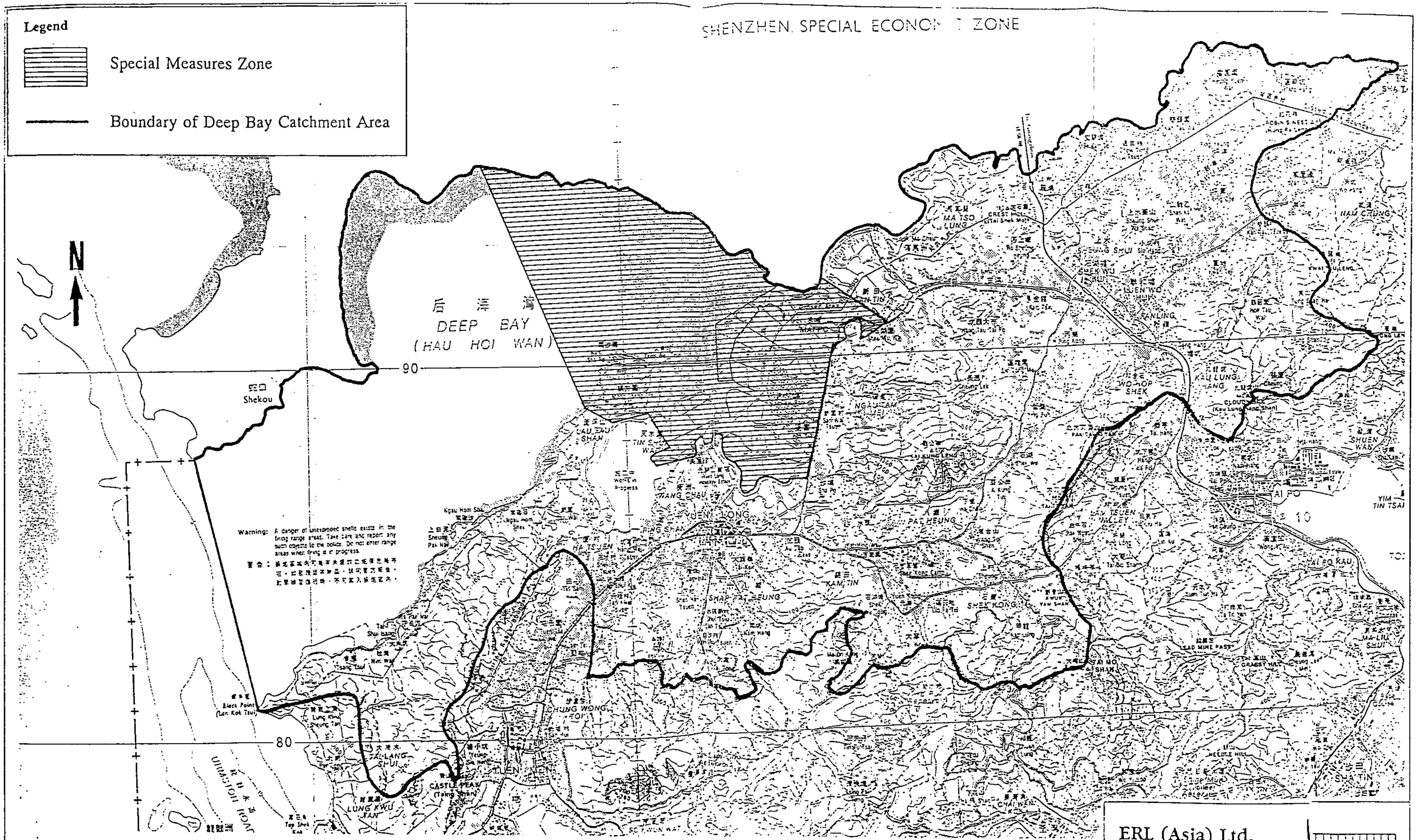

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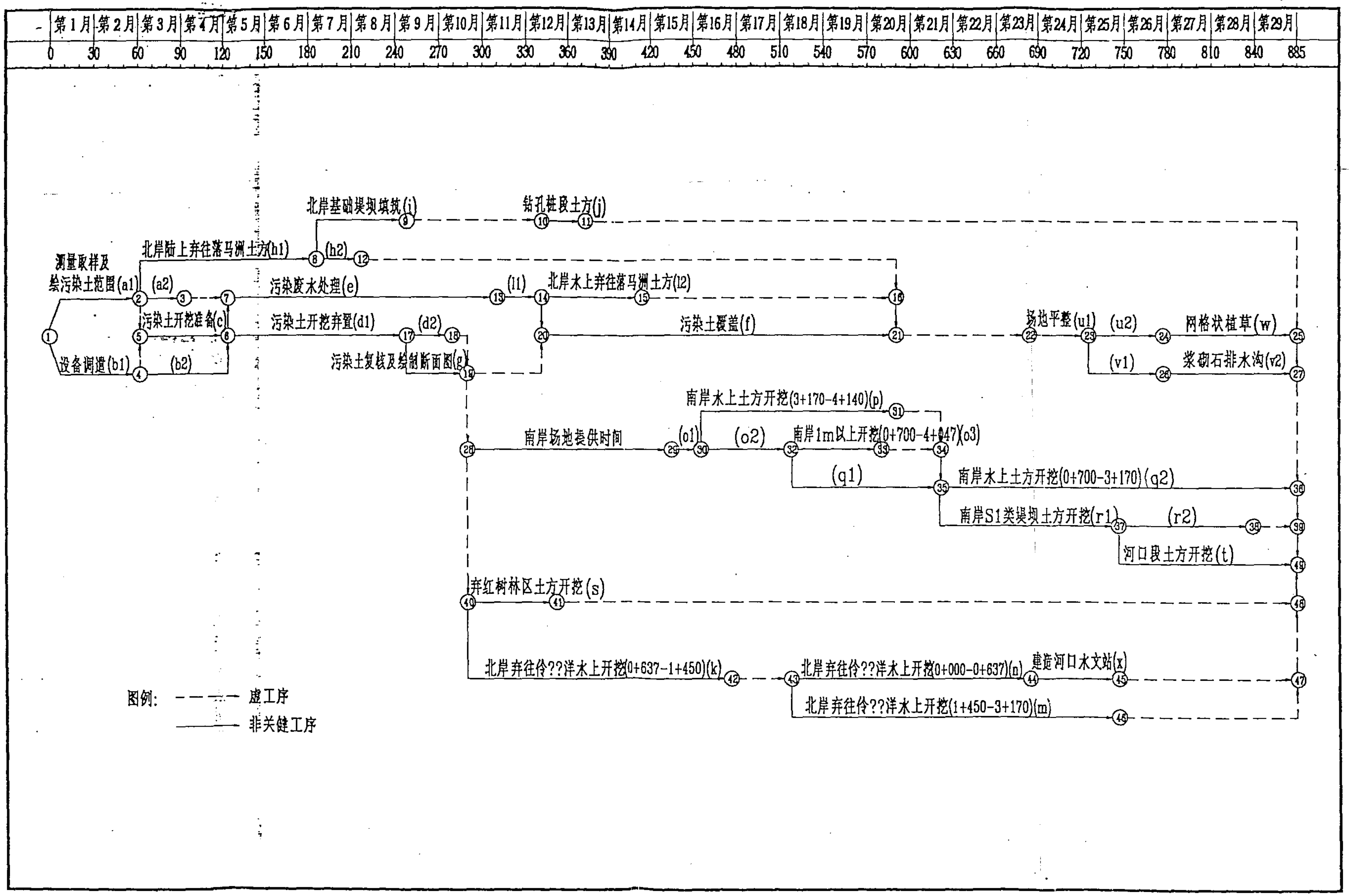
Figure 3.1(a) Location of the Special Measures Zone

Scale 1 : 100 000

治理深圳河第二期第二阶段工程合同B第二分项施工进度计划网络图

表3-3-4



治理深圳河第二期第二阶段工程合同B第三分项施工进度计划横道图

表3-3-5

序号	工程项目名称	单位	工程量
一	北岸真空预压		
1	铺砂垫层	m^3	39200
2	打砂井桩	m^3	2304?
3	插塑料排水板	m	649000
4	真空预压	m^2	74365
5	卸荷及退场		
二	钻孔桩直立岸墙施工		
1	补充地质钻探	项	
2	拆迁及施工区三通一平	项	1
3	C25钻孔灌注桩Φ1000	m^3	4110
4	旋喷桩Φ700	m^3	1150
5	浇注C25桩顶梁	m^3	646
6	筑粘土施工围堰	m^3	8400
7	斜拉锚杆L=14-27m	根	415
8	浇C20挂网衬砌混凝土	m^3	473
9	堤顶结构施工	m	538.4
三	河道防护施工		
1	砼预制施工	万m^3	5.2
2	北岸河道防护		
a	0+637～1+450段	米	813
b	3+509～4+200段	米	691
c	0+000～0+637段	米	637
d	1+450～3+170段	米	1720
3	南岸河道防护		
a	S2类堤顶河道防护	米	3215
b	S1类堤顶河道防护	米	785
4	河口段护坡	米	200
5	北岸砼直立式挡墙	万m^3	2.07
四	建筑物、构筑物施工		
1	北岸堤外排水沟施工	米	4012
2	北岸排水管施工		
a	0+000～1+573段1-4#	座	4
b	1+573～3+170段5-8#	座	4
c	3+679～4+200段9-11#	座	3
3	北岸操作口施工	项	1
4	南岸操作口施工	座	1
5	南岸排水箱涵出口处理	座	5