PART D

GAS PIPELINE

CONTENTS:

1 CONSIDERATION OF PIPELINE ROUTING WITHIN HONG KONG WATERS

1.1 INTRODUCTION

1.1.1 *Background*

HEC proposes to develop a new 1800 MW power station in Hong Kong to meet forecast growth of electricity demand in the first few decades of the 21st century. In the autumn of 1997, reports on the *Site Search Study* and *Stage 1 EIA Study* for a proposed new power station were submitted to Government. These studies concluded that a gas-fired combined cycle plant located on an extension to the existing Lamma Power Station was the overall preferred option, taking into account the relevant environmental, engineering, economic and other considerations.

During the finalisation of the Stage 1 EIA Study Report, EPD indicated the need to define the environmental constraints associated with the laying of a gas pipeline from the proposed LNG Terminal in Shenzhen to the proposed gas-fired power station at Lamma Island. HEC appointed ERM to undertake a desk-top study of the likely environmental constraints associated with the routing of the gas pipeline.

The route selection for the gas pipeline comprised two phases:

- a desk-top assessment of the environmental constraints associated with the pipeline routing; and
- the subsequent formulation of alternative routing options which avoid these areas and thereby enhance the acceptability of the pipeline proposal.

The desk-top assessment focussed primarily on the environmental consideration, whereas the route optimisation was primarily an engineering feasibility exercise.

1.1.2 *Scope of the Route Selection for the Gas Pipeline*

It is HEC's intention that the new power station will be fuelled by gas to be provided by a dedicated new pipeline from the proposed regional liquefied natural gas (LNG) terminal in eastern Shenzhen (Cheng Tou Jiao). At the outset of the desk-top study a broad routing corridor for the laying of this pipeline was defined and is presented in *Figure 1.1a*. A scoping exercise was undertaken as an initial task in the identification of environmental constraints to determine the range of likely issues that would arise during the laying, maintenance and operation of the pipeline. In addition to a review of available environmental information, the scoping exercise also referenced the Marine Department's *Requirements for Pipeline Installation*. The pipeline laying methodology assumptions and the associated range of impacts to environmental resources are discussed in subsequent sections of this report.

The scoping exercise focused on available information regarding the resources, constraints and nature of the areas within which the corridor is located and identified the following issues:

- The southern waters of Hong Kong have been identified as the SAR's most productive commercial fisheries area and the eastern waters have long been recognised for the conservation value associated with their corals and rocky reefs.

- The proposed routing also passes near or through an active dredged material disposal site, a former sludge disposal site, two proposed Marine Park/Reserves (South Lamma and Ping Chau), and several sites soon to be proposed as artificial reefs under the AFD's Artificial Reefs Deployment Programme.

- Water and sediment quality are not likely to be major issues in the pipeline routing.

- Finally, a number of physical elements, including marine facilities and existing cables and pipelines (particularly in the southern section of the route), may present additional constraints.

In light of the scoping exercise, the key issues for evaluation in the desk top study were considered to comprise physical constraints (such as marine borrow areas, existing cables and pipelines, etc), marine ecological and fisheries resources and implications for water and sediment quality.

1.2 *PIPELINE ROUTING: PHYSICAL CONSTRAINTS*

1.2.1 *Introduction*

The evaluation of the routing corridor identified a number of physical constraints comprising marine borrow areas and open water disposal sites, navigation lanes, existing cables and pipelines, planned breakwaters and existing marine facilities.

Each of these physical constraints is discussed separately in the sub-sections that follow.

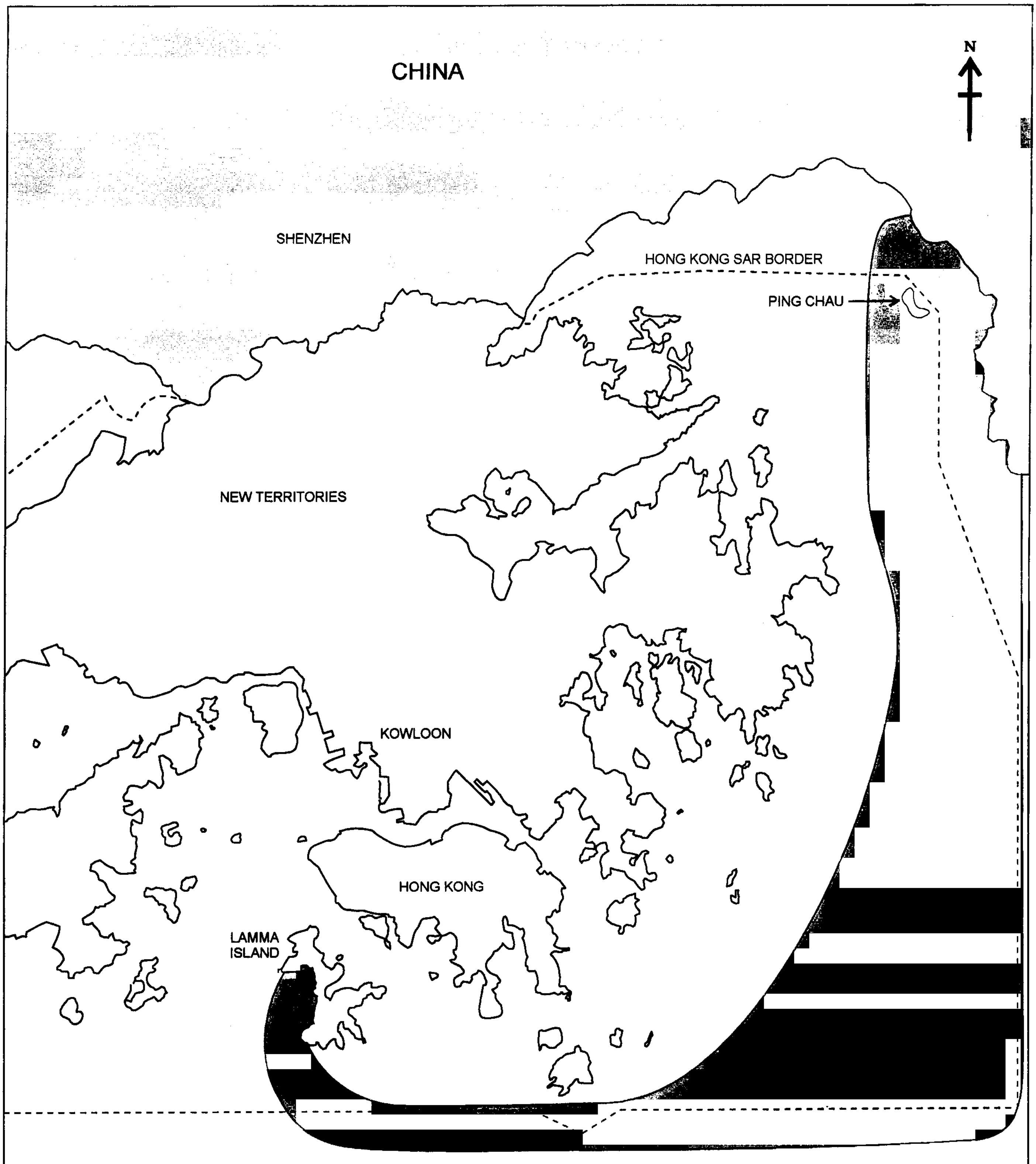
1.2.2 *Marine Borrow Areas and Open Water Disposal Sites*

As shown in *Figure 1.2a*, the Study Area includes within its boundaries three areas of constraint in relation to borrow areas and disposal sites. These comprise the proposed Eastern Waters Marine Borrow Area, the East of Ninepins Open Water Dredged Material Disposal Site, both of which lie to the east of the Ninepins and the inactive Mirs Bay Disposal Site.

As these constrained areas have been identified by Government at a strategic level, it is recommended that the routing of the proposed pipeline should avoid crossing these sites.

1.2.3 *Navigation Lanes*

Hong Kong is one of the busiest ports in the world and, as such, activities which may impinge upon access arrangements for the port must be assessed to determine likely levels of disruption.



KEY

STUDY AREA

NOT TO SCALE

FIGURE 1.1a

STUDY AREA CORRIDOR FOR THE SUBMARINE GAS PIPELINE FROM THE PROPOSED LNG TERMINAL IN SHENZHEN TO HEC'S PROPOSED NEW POWER STATION

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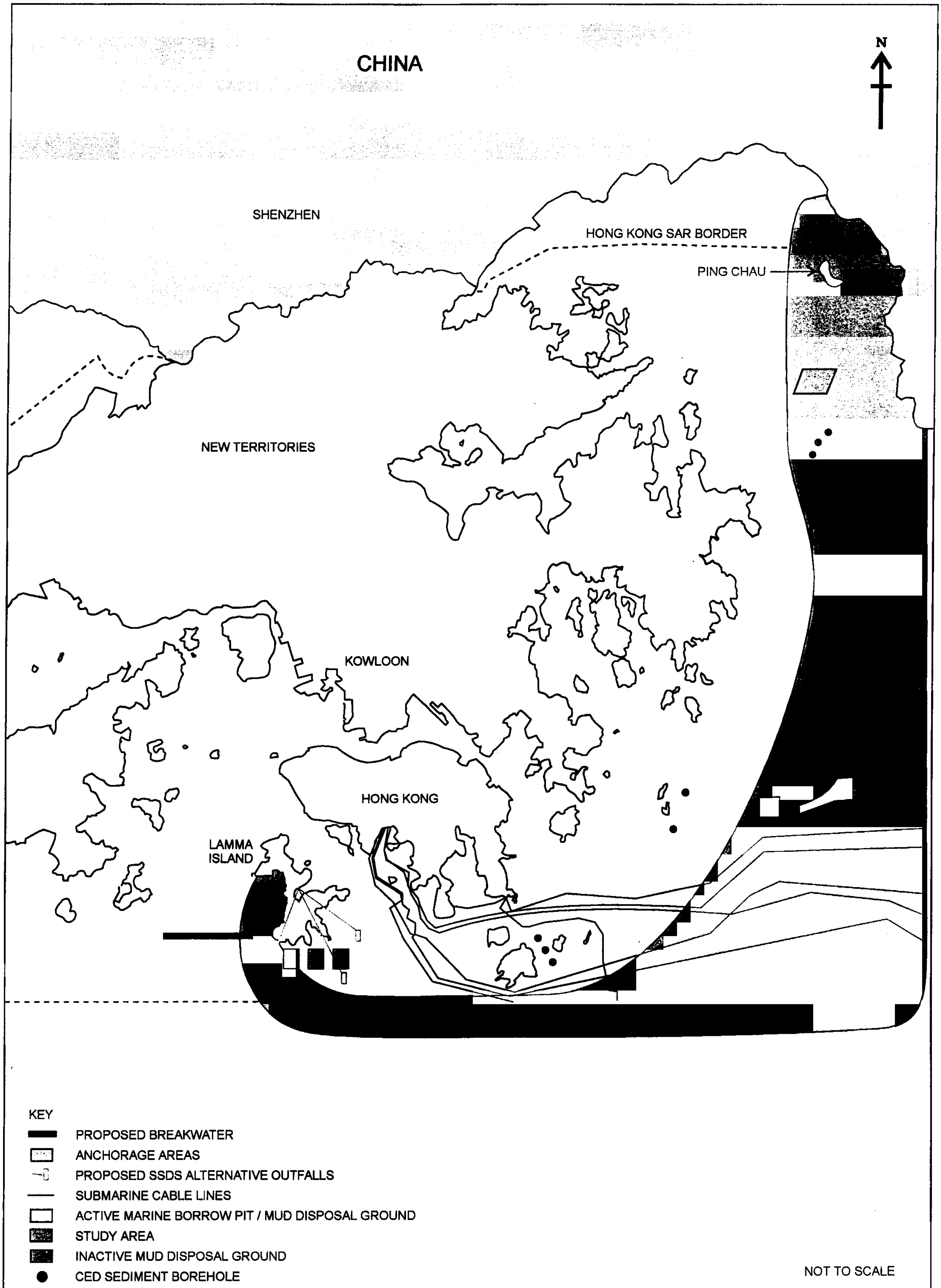

FIGURE 1.2a

PHYSICAL CONSTRAINTS WITHIN OR CLOSE PROXIMITY TO THE STUDY AREA CORRIDOR FOR THE ROUTING OF THE SUBMARINE GAS PIPELINE FROM THE PROPOSED LNG TERMINAL IN SHENZHEN TO HEC'S PROPOSED NEW POWER STATION

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DATE: 04/11/98

Environmental Resources Management

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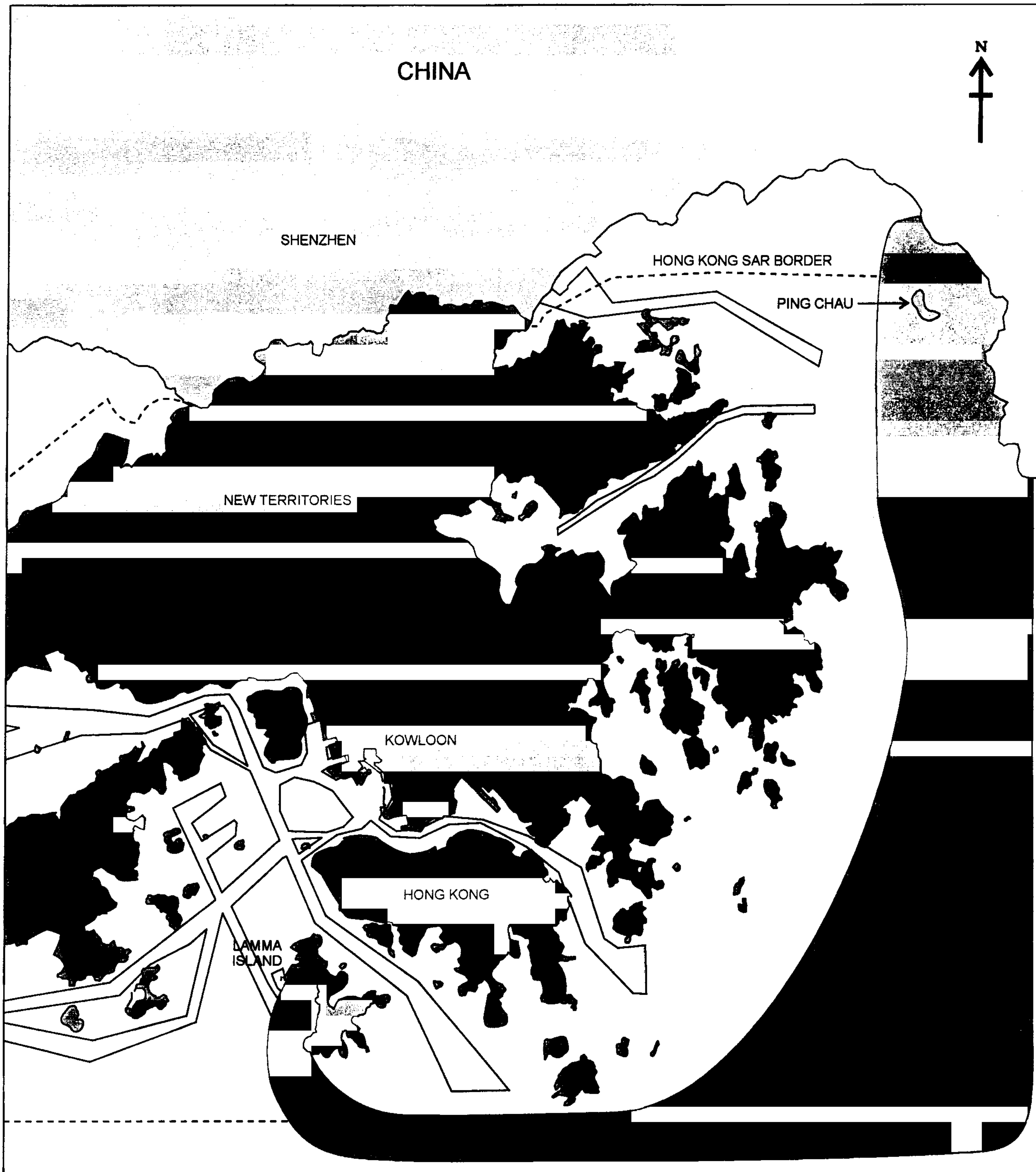

KEY

STUDY AREA

PRINCIPAL FAIRWAYS AND MAJOR SHIPPING LANES

NOT TO SCALE

FIGURE 1.2b

STUDY AREA CORRIDOR FOR THE SUBMARINE GAS PIPELINE FROM THE PROPOSED LNG TERMINAL IN SHENZHEN TO HEC'S PROPOSED NEW POWER STATION AND IT'S PROXIMITY TO PRINCIPAL FAIRWAYS AND MAJOR SHIPPING LANES

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The main navigational access channels into Hong Kong Harbour are the East Lamma Channel and the Tathong Channel, with the principal fairway situated within Victoria Harbour and extending from Lei Yue Mun to Ma Wan (*Figure 1.2b*). Other major shipping lanes of regional or deepwater significance include:

- the deep water route leading from Ma Wan Channel to Urmston Road, which leads to Pearl River Delta Ports such as Shekou;
- jetfoil routes from Hong Kong to Macau and China; and
- the extension of the Traffic Separation Schemes south of the East Lamma Channel.

Recent studies have indicated that the East Lamma Channel is primarily used by large, ocean-going vessels or those carrying dangerous goods, with some moderate movements by fishing boats and other local craft[1]. There are no designated major shipping routes in Mirs Bay or in the waters east of the Sai Kung peninsula. However, container traffic is known to pass through the channel between Shek Nga Chau and Ping Chau, although there are no data on exact movements or the ongoing effects of such traffic in this area.

Whilst all ocean-going vessels approaching Hong Kong Harbour, via either the East Lamma Channel or the Tathong Channel, must cross the Study Area for the pipeline routing, the establishment of standard good practice protocols during pipeline laying should ensure that no undue disruption will occur to navigation in Hong Kong waters.

1.2.4 *Existing Underwater Cables and Pipelines*

There are seven known existing underwater cables that pass through the southeastern waters of the Study Area (see *Figure 1.2a*). It is understood that these are mainly fibre optic cables.

Five of these cables originate at Deep Water Bay on the southern coast of Hong Kong Island. From Deep Water Bay, two of the five cables pass by the north of Lo Chau (Beaufort Island) and head eastward out of Hong Kong waters. Two of the cables follow broadly the same route, but pass south of Po Toi Island, before leaving Hong Kong waters. The remaining cable originating at Deep Water Bay leaves Hong Kong waters directly to the south of Hong Kong Island.

The remaining two cables that pass through the Study Area originate from Cape d'Aguilar. One of these cables heads south to pass to the east of Waglan Island before leaving Hong Kong waters. The remaining cable follows a similar east-bound route as those originating in Deep Water Bay[1]. There are also a number of underwater cables and pipelines that lie just outside Hong Kong waters, but within the Study Area. However, the number of cables and pipelines and their exact routing is currently unknown.

Each of the cable routes referred to above crosses the Study Area for the pipeline routing. Further research into the precise location, mode of laying and sensitivity to disturbance will need to be undertaken during the detailed pipeline planning stage to ensure that damage to the known existing cables is avoided

(1) ERM (1998a) Artificial Reefs Deployment Study: Technical Paper 3, Site Selection. For Agriculture and Fisheries Department, Hong Kong Government.

and to confirm the details of pipelines and cable alignments that lie outside of Hong Kong waters.

1.2.5 *Future Breakwaters*

During the Port and Airport Development Study, the possibility of establishing a Breakwater to the west of Lamma Island was identified. Whilst the status of the "Lamma Breakwater" remains unclear, the proposed location of the breakwater is to the west, and largely outside, of the corridor for the pipeline routing.

As the prospects for development of the breakwater and its possible location are uncertain, it is not considered a primary constraint to the pipeline routing. However, the current status of the breakwater within Government should be reviewed during the course of the detailed pipeline route planning.

1.2.6 *Marine Facilities*

Existing marine facilities within Hong Kong waters comprise all anchorages, mooring areas, floating docks, typhoon shelters, aids to navigation and approaches to any kind of pier, jetty or terminal. Three marine facilities have been identified as lying within the Study Area. These comprise three vessel anchorages, which are each located to the south of Lamma Island, as shown in *Figure 1.2a*. The anchorages are considered a primary constraint to the pipeline routing and these areas should be avoided during the detailed pipeline route planning.

1.2.7 *Proposed SSDS Alternative Outfalls*

As part of the *Strategic Sewage Disposal Scheme Stage 1 Study* a number of possible outfalls have been proposed. Three of these proposed outfalls lie within the Study Area and are shown in *Figure 1.2a.*

1.2.8 *Seabed Properties and Stability*

There is very little existing information regarding the properties and stability of the seabed, however, it is generally regarded that the seabed of Hong Kong is made up of fine silt or mud sediment (Shin and Thompson, 1982)[2]. More detail on seabed characteristics at a number of sites around Hong Kong has been provided as part of the recent *Artificial Reef Deployment Study* carried out by ERM[1]. As part of this study data were supplied by the Fill Management Committee of CED detailing the physical nature of the sediments of the proposed artificial reef deployment sites. Three of these deployment sites lie within close proximity to the Study Area and using the borehole data collected at these sites (*Figure 1.2a*) it is possible to make a prediction of the properties and stability of the seabed of the Study Area.

The records provided by CED detail the top 25 m of sediment but *Table 1.2a* below presents only information on the top 6 m of sediment as it is unlikely that sediment characteristics of any deeper layers will have any impact on the design or deployment of the gas pipeline.

(2) Shin PKS & Thompson GB (1982) *Spatial distribution of the infaunal benthos of Hong Kong*. Continental Shelf Research, 10:37-47

Table 1.2a ***Geophysical Information from Boreholes Taken in the Shek Nga Chau, Ninepins and East Po Toi Areas***

Site and Drillhole No.	0 - 2 m	Sediment Texture at 2 - 4 m	4 -6 m
Shek Nga Chau			
VD1/2	Very soft, brownish grey, silty clay with shell fragments	Greyish yellow brown, fine sand with shell fragments	Medium dense, dark yellowish brown fine sand with mica flakes
SMMD1/10	Very soft greenish grey slightly sandy silty clay with some shell fragments	Very soft greenish grey sandy silt/clay to very dense silty/clayey fine with some shell fragments	Very dense greenish grey silty/clayey fine to medium sand with some shell fragments.
SMMD1/16	Very soft, greenish grey, slightly sandy to sandy silty clay with some shell fragments	Very soft, greenish grey, slightly sandy to sandy silty clay with some shell fragments	Very soft, greenish grey, sandy silty clay to sandy silt/clay with some shell fragments
Ninepins			
VC2/12	Very soft, brown grey silty clay with shell fragments	Soft to firm, stiff grey silty clay	Firm, light white grey, silty clay with fine sand pockets and rounded gravels
ETMD3/2	Very soft, dark greenish grey slightly sandy clayey silt with some shell fragments	Very soft, dark greenish grey slightly sandy clayey silt with some shell fragments	Very soft, dark greenish grey slightly sandy clayey silt with some shell fragments
East Po Toi			
PTMD1/4	Very soft light greenish grey slightly sand to sandy, silt/clay with some shell fragments and silt pockets	Soft, dark grey, very silty/clayey fine to coarse sandy silt/clay, with occasional shell fragments and micro mica	Medium dense, dark grey, very silty/clayey fine to coarse sand
PTMD1/9	Very soft/loose, greenish grey, slightly gravelly, sandy silt/clay to gravelly very silty/clayey, with many shell fragments	Greenish grey mottled with yellowish brown, slightly silty/clayey, gravelly sandy to slightly sandy silt/clay with some fine sand lenses and occasional shell fragments	Medium dense greenish grey, angular, very silty/clayey fine to coarse sand, with some micro mica
PTMD4/3	Very soft, dark grey, slightly sandy silt/clay, with some shell fragments	Soft, dark grey, slightly sandy clayey silt with many shell fragments	Medium dense, dark grey very silty/clayey fine to coarse sand with some shell fragments

The above information indicates that the upper regions of the seabed at these sites are dominated by soft and silt clay sediments. There are, however, records of firm sandy sediments in the Ninepins region in the 4-6 m interval of the borehole. The Ninepins area has been shown in other studies to be characterised by many large boulders with vertical rock walls surrounding the islands to a depth of up to 20 m at some locations [3]. Observations of intermittent shell/sand bottoms between the large boulders and rubble habitat suggest that this area has a diverse bottom topography affected by currents and wave action. Further afield from the islands the substratum tends towards a silt/clay composition at the surface.

Similarly the Shek Nga Chau site information indicates that unlike most of Hong Kong much of the sediment contains a high sand content. This site also has a wide variety of physical characteristics ranging from rocky wall and large boulder habitat surrounding the islands to the mud flats in the channels between[3].

Based on the above information it is concluded that the Study Area comprises very soft surficial sediments extending to a depth of -2 m. Below this depth sediment characteristics are more variable with some areas showing dense sands and some areas showing fine silt/clay in the deeper strata (-2 to -6 m). From the available information, no constraints to pipeline laying due to seabed stability have been identified. Seabed stability surveys of the Study Area are underway and will provide more detailed information on this topic.

1.2.9 *Conclusions*

The primary physical constraints to the routing of the pipeline are the Eastern Waters Marine Borrow Areas and the East of Ninepins Open Water Dredged Material Disposal Site, and the anchorages south of Lamma Island.

In addition, it is recommended that:

- standard good practice protocols during pipeline laying are established to ensure that no undue disruption will occur to navigation in Hong Kong waters;
- further research into the precise location, mode of laying and sensitivity to disturbance will need to be undertaken during the detailed pipeline planning stage to ensure that damage to the known existing cables is avoided and to confirm the details of pipelines and cable alignments that lie outside of Hong Kong waters; and
- the current status of the Lamma Breakwater should be reviewed during the course of the detailed pipeline route planning.

1.3 *PIPELINE ROUTING: WATER QUALITY CONSTRAINTS*

1.3.1 *Introduction*

Sites of water quality, fisheries and marine ecological importance were organised into a tier system based on the statutory requirements and criteria of the *Water*

(3) Binnie Consultants Limited (1996a) *Coastal Ecology Studies: Ping Chau Quantitative Survey*. Final Report, for Geotechnical Engineering Office, Civil Engineering Department, Hong Kong Government.

Pollution Control Ordinance (WPCO), EPD *Technical Memorandum on Environmental Impact Assessment Process* (EIAO TM)[4] and the *Hong Kong Planning Standards and Guidelines* (HKPSG) . These tiers are designed to identify ecological, fisheries and water quality sensitive areas that should be avoided in the pipeline route. The tier system also provides information on existing sensitive areas that are not considered an environmental constraint to the routing of the pipeline. The criteria used for each tier are described below.

Tier 1: Sites of high ecological or fisheries importance based on their naturalness, size, diversity, rarity, re-creatability, fragmentation, ecological linkage, potential value, regeneration ability, age and abundance/richness of wildlife, or sites of high water quality importance, including bathing waters and other contact recreational facilities, Water Supplies Department flushing water intakes, and areas where human health, aesthetic enjoyment and the water bodies that are under stressed conditions. Because of the high level of water quality, fisheries and ecological importance or conservation value, potential impacts to these sites should be avoided to the maximum practicable extent such as adopting suitable alternatives, for example, change of route, design, construction method, etc. None of the fishing zones within the Study Area were classified as Tier 1, for the reason that it is expected that impacts to fisheries resources or operations are able to be mitigated.

Tier 2: Ecological habitats that are of medium ecological importance as they have a higher extent of resistance to impacts than Tier 1 habitats, or water sensitive receivers/users that are less sensitive to water pollution than Tier 1, including cooling water intakes, residential and non-contact recreational development and areas where tidal flushing is good. Given appropriate onsite mitigation methods, impacts to these habitats or water sensitive areas/users can be minimised to acceptable levels.

Tier 3: These habitats have been evaluated as having low ecological importance (according to the *Environmental Impact Assessment Ordinance Technical Memorandum*[6] criteria listed in Tier 1) or sites where water bodies or users are least sensitive to water pollution, including typhoon shelters, marinas and boat parks, and areas with strong tidal flushing. These sites are generally not considered as an environmental constraint to the pipeline routing.

The tiered system, outlined above, has been employed in the evaluation of water quality, fisheries and marine ecological impacts described below and in *Sections 1.4 & 1.5*. This approach allows the routing of the pipeline to be designed in order to minimise conflicts with marine ecological, fisheries and water quality sensitive receivers and/or users, thereby reducing impacts and lessening the need for further mitigation. This sub-section identifies the sites of water quality importance under the tiered system to highlight the environmental constraints associated with various areas.

1.3.2 *Tier 1 Water Sensitive Areas/Users*

Under the tiered System of Water Quality Protection, the bathing beaches at Hung Shing Ye and Lo So Shing on Lamma Island are identified as Tier 1 water sensitive areas/users within the Study Area.

(4) EPD (1997b) Technical Memorandum on Environmental Impact Assessment Process, Environmental Protection Department, Hong Kong Government.

Bathing Beaches at Hung Shing Ye and Lo So Shing

Hung Shing Ye and Lo So Shing are the two bathing beaches at the west of Lamma Island falling within the Study Area (*Figure 1.3a*). The bathing waters are within Southern WCZ and the water quality is under the control of WPCO. The water quality of these two beaches have been assessed as 'Good' and 'Fair', respectively[5].

The water quality impacts on bathing beaches will be essentially on the aesthetic aspects, essentially due to the elevation of SS arising from the dredging activities of the gas pipe laying works. Although the construction of the pipeline section near the beaches is likely to last for a few months and the water quality impact will be temporary, routing of the pipe should be located as far from the bathing beaches as possible.

1.3.3 *Tier 2 Water Sensitive Areas/Users*

With reference to the tiered system defined in Section 1.3.1, the cooling water intakes of the HEC Lamma Island Power Station are classified as Tier 2 water sensitive users (see *Figure 1.3a*).

HEC Lamma Island Power Station Cooling Water Intake

At HEC's existing Lamma Power Station, the submarine gas pipe installation may impact upon the water quality of the cooling water intakes. According to HEC's cooling water quality objectives for the Lamma Power Station, the SS level at the cooling water intake must not exceed 100 mg l^{-1}. As the water quality impact associated with the dredging works is likely to be localised and short term, direct impact upon the cooling water intake will only occur if dredging work is conducted in close proximity to the intake.

Routing of the gas pipe should thus avoid the intakes if possible. If this proves infeasible, temporary mitigation measures such as geotextile fabric silt screen and filter system should be installed to minimise the impact during the pipeline laying works.

1.3.4 *Tier 3 Water Sensitive Areas/Users*

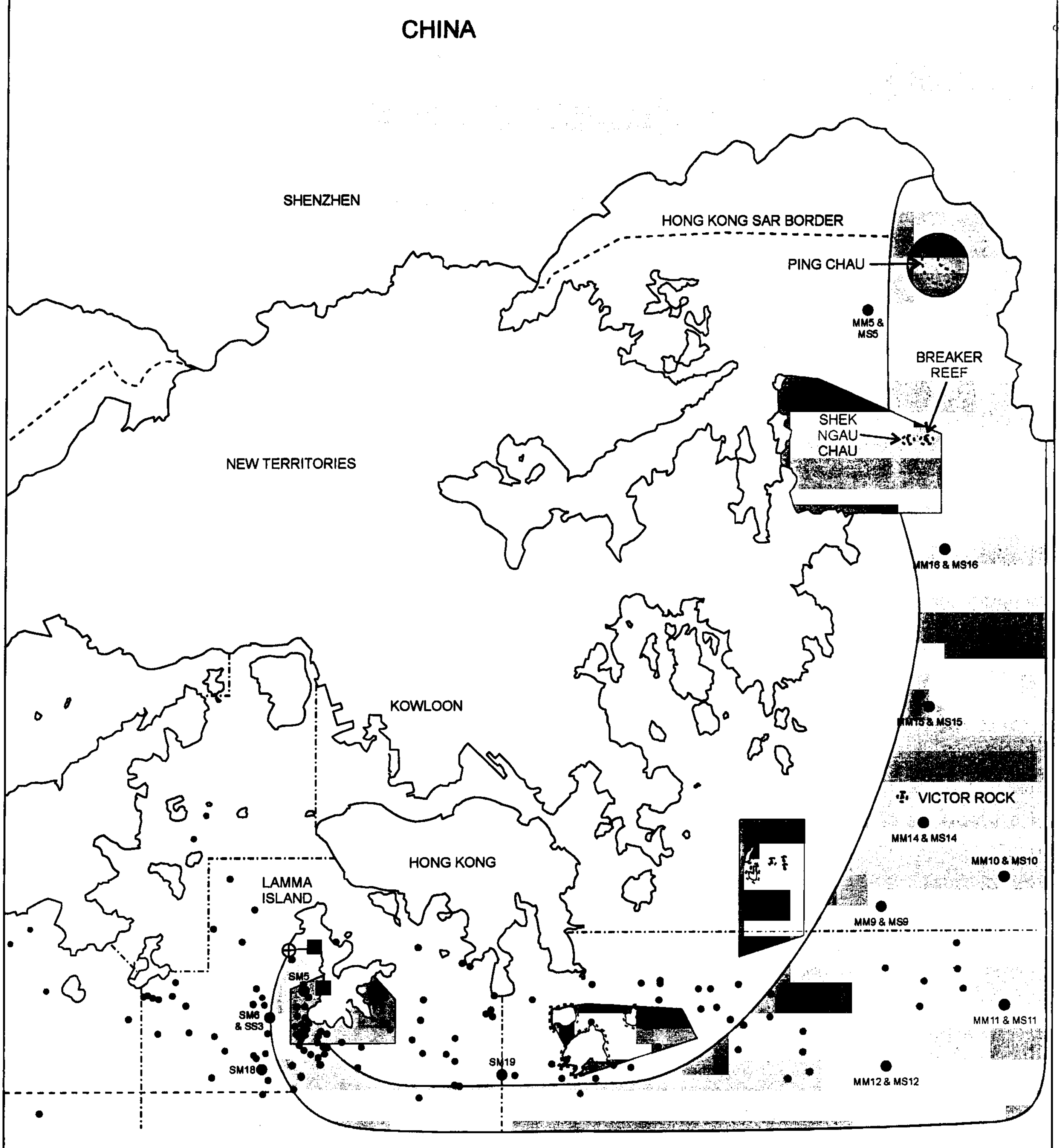
According to the tiered system developed in *Section 1.3.1*, most of the Mirs Bay and Southern WCZs within the Study Area can be classified as Tier 3 Water Sensitive Areas as they have strong tidal flushing and have no special sensitivities to the types of impacts that may be expected due to the laying of the gas pipeline.

1.3.5 *Summary & Conclusions*

The potential water quality impact arising from the construction of the proposed submarine gas pipeline will be the resuspension of marine sediment that elevates the levels of suspended solids and contaminants, and depletes the concentration of dissolved oxygen in the water column.

The review of existing information and the development of a tiered ranking system have identified those water sensitive areas or users that are of particular

(5) EPD (1997c) *Bacteriological Water Quality of Bathing Beaches in Hong Kong*, Environmental Protection Department, Hong Kong Government.



KEY

- POTENTIAL ARTIFICIAL REEF DEPLOYMENT SITES
- POTENTIAL MARINE PARK/RESERVE
- EXISTING CORAL REEF HABITATS
- STUDY AREA
- MARINE MAMMAL STUDY AREAS
- EXISTING MARICULTURE ZONES
- FINLESS PORPOISE SITINGS (DEC 96 - NOV 97)
- CHINESE WHITE DOLPHIN SITINGS (DEC 96 - NOV 97)
- OTHER MARINE MAMMAL SITINGS (DEC 96 - NOV 97)
- GREEN TURTLE NESTING AREA
- WATER QUALITY OR SEDIMENT MONITORING STATION
- GAZETTED BEACH
- COOLING WATER INTAKE

NOT TO SCALE

FIGURE 1.3a

MARINE SENSITIVE RECEIVERS LOCATED WITHIN OR IN CLOSE PROXIMITY OF THE STUDY AREA CORRIDOR FOR THE ROUTING OF THE SUBMARINE GAS PIPELINE FROM THE PROPOSED LNG TERMINAL IN SHENZEN TO HEC'S PROPOSED NEW POWER STATION

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concern during the construction of the proposed gas pipeline. Pipeline routing should avoid passing through the most water sensitive areas or users (Tier 1), while mitigation measures should be implemented to minimise water quality impact upon those less sensitive areas or users (Tiers 2 and 3). *Table 1.3a* summarises the water quality sensitive receivers and users that are identified under the tiered system.

Table 1.3a ***Classification of Sensitive Receivers under the Tiered System***

Classification	Water Quality Sensitive Receivers / Users
Tier 1	Gazetted bathing beaches at Hung Shing Ye and Lo So Shing (west of Lamma Island)
Tier 2	HEC Lamma Island Power Station Cooling Water Intake
Tier 3	Most of the Mirs Bay and Southern WCZs where tidal currents are strong and have no sensitive receivers / users nearby

1.4 *PIPELINE ROUTING: MARINE ECOLOGY CONSTRAINTS*

1.4.1 *Introduction*

This component of the study identified and evaluated marine ecological resources within the pipeline routing Study Area and, through the employment of the Tiering System outlined in *Section 1.3.1*, highlighted key constraints to the identification of a pipeline route. The constraints are presented according to the Tier classification in the sub-sections that follow.

1.4.2 *Tier 1 Habitats*

Introduction

Following guidelines set out in the *EIAO Technical Memorandum* , areas that have been classified as habitats of high ecological importance, and therefore Tier 1 habitats are:

- all established coral communities of any size;
- all habitats supporting significant numbers of marine mammals; and
- all existing and potential Marine Parks and Marine Reserves.

A detailed description of the marine ecological sensitive receivers that fall into the category of Tier 1 habitats is provided below.

Coral Communities

The general trend for coral communities in Hong Kong is one of increasing abundance and diversity from west to east. However, as the habitats within Hong Kong waters are constantly under stress from various sources, for the purposes of this report it is necessary to focus on specific sites to assess the state of the coral communities in terms of abundance and diversity, rather than rely on the above generalisation.

As part of the Coastal Ecology Studies for the Civil Engineering Department, extensive dive surveys were carried out throughout Hong Kong waters[6]. The objective of these studies was to undertake baseline ecological surveys of the Hong Kong underwater hard bottom environment, with a major focus on the hard and soft coral communities. Both qualitative and quantitative surveys were carried out and species abundance and diversity were estimated using quadrant measurements, transects and photographic records taken at each site. For the purpose of the Study, sites were classified on the basis of the terminology provided in the dive survey reports in terms of species abundance and diversity.

The Coastal Ecology Studies included a number of dives on areas of ecological importance either inside or fringing the Study Area. Using the information presented in these surveys, it is possible to prepare a relative assessment of the condition of known coral communities within, or near, the Study Area. Survey areas included:

- Ping Chau & Shek Ngau Chau;
- Breakers Reef; and
- Victor Rock.

The findings of the surveys at each of these locations are discussed below.

Ping Chau and Shek Ngau Chau: The sea around Ping Chau is presently being studied by scientists from the Chinese University of Hong Kong to assess its potential for designation under the Marine Parks Ordinance (Cap. 476) as a Marine Park/Marine Reserve with results expected in early 1999. The results of this assessment shall be available towards early 1999. However, the Coastal Ecology Studies described Ping Chau as being especially rich in hard corals, with a total of 30 species recorded, representing 61% of all hard coral species found in Hong Kong[8][3].

The coral habitat around Shek Ngau Chau was found to be less diverse than Ping Chau with hard corals common, but with approximately 30% less abundance and diversity [8]. Findings from these surveys also show there is evidence of adult corals and active coral reproduction in the area reflecting its ecological importance. There is also evidence of the reef providing shelter for large numbers of shrimp larvae, which in turn provide food for numerous fish[8].

Breakers Reef: Breakers Reef is located in the middle of Mirs Bay and has long been regarded, by recreational divers and sport fishermen, as one of the most diverse coral reefs in Hong Kong waters. Soft corals are extremely common and diverse here with the most abundant species *Dendronephyta* spp completely covering large patches of the seabed. In relation to all the dive sites studied during the Coastal Ecology Study, it was reported that Breakers Reef has the most abundant and diverse soft coral communities in all of Hong Kong waters[8]. Reef fish, including butterfly fish, chicken grunts and small grouper are regularly observed here and often found in large numbers[8]. The coral communities are similarly diverse with hard corals, especially *Tubastrea aurea*, encrusting the upper slopes of the reef. Below -15 m PD gorgonians are found to exhibit high cover and diversity.

It has been suggested that Breakers Reef plays an extremely important role in sustaining both Hong Kong's coral and reef fish communities. The reef is also

(6) Binnie Consultants Limited (1995b) Fill Management Study-Phase IV Investigation and Development of Marine Borrows Areas, Marine Ecology of Hong Kong, Report on Underwater Dive Surveys (October 1991- November 1994) Vol I, for Geotechnical Engineering Office, Civil Engineering Department, Hong Kong Government.

known as a common area for sightings of some of Hong Kong's larger species of fish, including eagle rays, black sting rays, tuna, mackerel, moray eels and jacks. The presence of such fish demonstrates a healthy reef and, therefore, places Breakers Reef as a site of high marine ecological importance.

Victor Rock: The isolated underwater pinnacle known as Victor Rock and its fringing series of pinnacles is also a popular site for recreational divers and spearfishermen, as well as for local hand line and cage trap fishermen. A series of dive surveys on the pinnacles[9] described the underwater habitat there as having a diverse benthic fauna with few fish. However, it has been suggested[7] that the fish populations inhabiting Victor Rock are highly seasonal with commercially important species using the site periodically.

The rock itself slopes steeply down to the muddy seabed at 25 m, with the shallower depths encrusted by hard corals, particularly *Favites pentagona* and *Tubastrea aurea*. Only low amounts of cover were recorded here due to the strong wave action experienced by the habitat. In the zone between -10 mPD and -17 mPD the slopes were observed to have abundant and diverse communities of soft corals, particularly of the genus *Dendronephyta*, ahermatypic hard corals, sponges and oysters with high cover (80 to 100%) in many areas. Below -17 mPD the numbers of gorgonian sea fans become more abundant with a reduction in soft coral cover.

Marine Parks and Marine Reserves

Under the *Marine Parks Ordinance (Cap. 476)* the Agriculture and Fisheries Department (AFD) have designated three Marine Parks and one Marine Reserve in Hong Kong waters. As public awareness, and the need for conservation due to Hong Kong's growing population increases, a further four Marine Parks/Marine Reserves are under consideration by AFD. None of the existing Marine Parks and Marine Reserves lie close enough to the Study Area to be considered as constraints for siting the pipeline, however, of the four proposed Marine Park/Marine Reserves, two lie within the Study Area (*Figure 1.3a*).

Ping Chau Island located within Mirs Bay, is part of the Plover Cove Country Park and is presently being studied by scientists from the Chinese University of Hong Kong to assess its potential for designation under the *Marine Parks Ordinance* (Cap. 476) as a Marine Park/Marine Reserve, with the results expected in early 1999. It has extensive rocky intertidal platforms unique to Hong Kong which in the subtidal zone support assemblages of reef building corals[8]. According to Morton 1997[9] the island and its adjoining waters are, along with Cape d'Aguilar, one of the most important marine rocky shore habitats in Hong Kong.

Similarly, South Lamma is also being studied to assess its potential for designation under the *Marine Parks Ordinance* (Cap. 476) as a Marine Park/Marine Reserve, with the results expected in early 1999. The southern end of Lamma Island was established as an SSSI (#36) in 1980 because of its ornithological interest. The area also includes a beach which is the only known

(7) Binnie Consultants Limited (1995c) . For Geotechnical Engineering Office, Civil Engineering Department, Hong Kong Government. Two-Day Ecological Survey of Victor Rock, Final Report

(8) Morton B & Morton J (1983) The Marine flora and Fauna of Hong Kong and Southern China III. Proceedings of the Fourth International Marine Biological Workshop: The Marine Flora and Fauna of Hong Kong and Southern China, Hong Kong 1989. Hong Kong University. pp.980

(9) Morton B (1997) *Hong Kong's Marine Parks Ordinance and Designation of the first Maine Parks and Reserve: Where Next?* The Marine Biology of the South China Sea. Proceedings of the Third International Conference on the Marine Biology of the South China Sea, Hong Kong 1996. Pages 541 - 561.

site in Hong Kong where the Green turtle (*Chelone mydas*) has attempted to nest[10]. The bay is also known to support a coral assemblage and is a popular marine recreational site. The southwestern coast of Lamma is also thought to be an important calving area for the finless porpoise *Neophocaena phocaenoides*.

On the basis of both of these areas being designated as future Marine Parks or Marine Reserves as a result of their ecological importance, they have been classified as Tier 1 routing constraints.

Critical Habitats for Marine Mammals

Under legislation which applies to marine species, which includes the *Wild Animals Protection Ordinance* (Cap. 170) 1980 and the *Animals and Plants (Protection of Endangered Species) Ordinance* (Cap. 187), all marine mammals found in Hong Kong waters are protected by law. At least one dozen marine mammal species occur in Hong Kong waters. However, only the Chinese White Dolphin (*Sousa chinensis*) and the Finless Porpoise (*Neophocaena phocaenoides*) are considered to be permanent residents. Both of these species, as well as being protected under Hong Kong Law are listed on the CITES endangered species list. The population and ecology of the local population of Finless Porpoise have only been the subject of detailed study in recent years.

It has been suggested that seasonal shifts in the abundance and location of sightings of the Finless Porpoise are not a result of migration, but rather as a result of movement due to feeding opportunities and for reasons associated with reproduction. Furthermore, a clear observation of the ERM marine mammal survey (*detailed in Section 5*) is that the highest abundance for Finless Porpoises occurs around Lamma Island, particularly the southwestern tip, during February to April. It has been suggested that the Finless Porpoise uses this area as a calving and nursery ground.

On the basis of these observations the waters around southwest Lamma have been classified as Tier 1. Although avoidance of the area is not possible in the construction and deployment routing of the gas pipeline it is possible to time the pipeline laying activities so that works occur when the porpoise is not present in the area (ie during the summer months).

1.4.3 *Tier 2 Habitats*

Introduction

Habitats that have been classified as Tier 2 are habitats of moderate ecological importance that have a higher assimilation capacity, and therefore a higher degree of resistance to impacts than those in Tier 1.

Marine Mammal Seasonal Use Habitat

Information from surveys conducted by ERM in the southern waters of Hong Kong indicated that some parts of the Study Area are used seasonally by the finless porpoise. These areas include the sea between Lamma and Po Toi Islands and east to the boundary of the Hong Kong SAR's waters. Sightings in these waters were highly seasonal, mainly occurring during the summer and autumn

(10) Morton B (1992) *The Marine Flora and Fauna of Hong Kong and Southern China III. Proceedings of the Fourth International Marine Biological Workshop*: The Marine Flora and Fauna of Hong Kong and Southern China, Hong Kong 1989. Hong Kong University Press. pp.980

(refer to *Section 5* for more details and a distribution map). The sea areas where seasonal abundances of the finless porpoise have been recorded are classified as Tier 2 constraints.

1.4.4 *Tier 3 Habitats*

Introduction

The final category of classification for the marine ecological sensitive receivers of the Study Area are the Tier 3 habitats. Sites categorised under Tier 3 are generally considered to be able to accommodate environmental impacts from the pipeline of a greater magnitude and duration than the habitats listed previously. Within the Study Area the open water seabed was classified as a Tier 3 constraint.

Open Water Seabed

A study of the marine benthos was carried out by Shin and Thompson in 1982 and provides a detailed guide to the seabed ecology of Hong Kong. The most recent and comprehensive examinations of benthic communities in Hong Kong waters were completed in 1997 for the Civil Engineering Department by ERM. The studies formed part of an ongoing series of marine monitoring studies designed to address the cumulative impacts of dredging and disposal projects on the marine environment in Hong Kong. Three of the sites selected for these Studies fall in, or are in close proximity, to the Study Area. These sites are South Lamma, Eastern Waters and East of Ninepins[(11)(12)(13)].

The South Lamma survey by ERM[(18)] found that the overall mean infaunal abundance recorded in the area was 1674 individuals m^{-2} which is comparably higher than that recorded by Shin and Thompson in 1982 (88 individuals m^{-2}). In common with the majority of the Hong Kong benthos, polychaetes were the most abundant group recorded in all samples. Overall mean biomass levels recorded were 30 g m^{-2} which was slightly lower than Shin and Thompson's finding in 1982 of 35 g m^{-2}. The South Lamma survey found that, in general, the benthic communities in close proximity to the shoreline recorded benthic communities with higher abundance, biomass and taxonomic richness, higher sediment TOC and larger sediment grain size than those further from the shore.

The Eastern Waters survey under the Seabed Ecology Studies[(12)] was primarily focused to act as a reference for assessing the effects of a proposed marine borrow area and the East of Ninepins survey[(13)] was used to assess the effects of open water disposal. The Eastern Waters study found polychaetes to represent 74% of the identified individuals, although only 10% of the total biomass. By contrast to this, molluscs constituted only 5% of the identified individuals but provided 74% of the total biomass recorded. The overall mean abundance was low in comparison to other sites in Hong Kong waters. Overall mean biomass levels recorded from the Eastern waters was typical of waters in the territory, at 33 g m^{-2} (Shin and Thompson recorded an average value of 35 g m^{-2} from Hong Kong waters in 1982)[(2)].

(11) ERM (1997a) *Seabed Ecology Studies: South Lamma Final Report.* Report to the Civil Engineering Department, Hong Kong Government.

(12) ERM (1997b) *Seabed Ecology Studies: Eastern Waters Final Report.* Report to the Civil Engineering Department, Hong Kong Government.

(13) ERM(1997c) *Seabed Ecology Studies: East of Ninepins Final Report.* Report to the Civil Engineering Department, Hong Kong Government.

Findings from the East of Ninepins Study[20] stated that there were noticeable differences between reference areas and areas of open water disposal sites, in both physical and biological characteristics. Mean total abundance of individuals was found to be higher in samples taken in areas of open water disposal, although the mean total biomass was lower. The Study concluded that the open water disposal sites had a mixed sediment type with low redox penetration depths, therefore little oxygen penetration, colonized by the opportunistic, hardy and pollution tolerant Spionidae polychaetes, rather than the more common dominating polychaete found in Hong Kong waters, Nemertinea.

According to the Technical Memorandum, areas that are undisturbed, support abundant and diverse assemblages containing uncommon species are considered to be of high ecological importance. However, Hong Kong's seabed is a highly perturbed environment, and therefore cannot be considered as an undisturbed area[14]. This disturbance originates from a number of sources, such as dredging, disposal, and other point sources of pollution. The major cause of this perturbation of the seabed is repeated trawling[12]. As a result of these disturbances the open water seabed of the Study Area has been classified as a Tier 3 habitat.

It is unlikely given the storm disturbed and repeatedly trawled nature of the seabed in offshore Mirs Bay that abundant or diverse epibenthic faunal assemblages will be present along the pipeline route. It is expected that as a result of dredging operations associated with the installation of the gas pipeline there will be an immediate effect of benthic disruption, however, on the basis of previous studies[15] it is expected that over a period of time, within a few weeks to months, natural disturbance in the area will transport both adult and larval recruits to the affected area returning the marine benthos to pre-dredging conditions.

1.4.5 *Summary and Conclusions*

The evaluation of marine ecological resource constraints to the routing of the proposed new pipeline employed a three a tiered ranking system to classify the level of constraint associated with marine ecological sensitive receivers, both existing and future. The following classification was derived:

Tier 1 Areas:	Coral communities Marine Parks and Marine Reserves Critical Habitats for Marine Mammals
Tier 2 Areas:	Areas seasonally used by marine mammals
Tier 3 Areas:	All other areas of open seabed

(14) Selby I & Evans NC (1997) *Origin of mud clasts and suspensions on the seabed in Hong Kong*. Continental Shelf Research 17: 57-78

(15) ERM (1998) *Seabed Ecology Studies - Composite Report*. Report to the Geotechnical Engineering Office, Civil Engineering Department, Hong Kong Government.

1.5 *Pipeline Routing: Fisheries Constraints*

1.5.1 *Introduction*

This component of the study identified and evaluated commercial fisheries resources within the pipeline routing Study Area and, through the employment of the Tiering System outlined in *Section 1.3.1*, highlighted key constraints to the identification of a pipeline route. The constraints are presented according to the Tier classification in the sub-sections that follow.

1.5.2 *Tier 1 Habitats*

Introduction

Following guidelines set out in the *EIAO Technical Memorandum*, areas that have been classified as habitats of high importance to commercial fisheries, and therefore Tier 1 habitats are:

- all nursery and spawning grounds.

In addition, the proposed Artificial Reef Deployment sites have been included in Tier 1. A detailed description of the commercial fisheries sensitive receivers that fall into the category of Tier 1 habitats is provided below.

Fishery Spawning & Nursery Areas

The southern waters of the Study Area are not only a productive area for fisheries in Hong Kong waters, but also a spawning ground and nursery for important and high value commercial species (see *Figure 1.5a*)[16]. South Lamma is used as a spawning ground for the Croaker *Johnius belengeri*, the Coastal Mud Shrimp *Solenocera crassicornis* and the Jinga Shrimp *Metapenaeus affinis*. Similarly, the waters surrounding Po Toi are used as spawning grounds for the Sole *Cynoglossus macrolepidotus* and the Yellow Croaker *Pseudosciaena crocea*. Research has also found that South Lamma is used as a nursery ground for the Shrimps *Metapenaeopsis barbata* and *Metapenaeopsis palmensis*, the Mantis Shrimp *Oratosquilla spp*, the Goby *Oxyurichthys tentacularis*, and Sciaenid and Serranid fry.

The *Technical Memorandum* classifies spawning and nursery grounds as areas of high ecological importance, as they are essential for the success of the local fishing industry. Based on this, the southern waters of the Study Area have been classed as a Tier 1 habitat. However, as the actual area of the pipeline and its deployment is of a relatively small scale it is suggested that with the incorporation of effective mitigation methods, the effect of the deployment on these nursery grounds and spawning areas can be limited to environmentally acceptable levels.

Artificial Reefs

In order to rebuild the depleted fisheries resources of Hong Kong, one of the measures adopted by the AFD is an extensive programme of deployment of artificial reefs. As a result of a detailed site selection process, six sites have been

(16) ERM (1998b) *Fisheries Resources and Fishing Operations in Hong Kong Waters. Final Report*, for Agriculture and Fisheries Department, Hong Kong Government.

chosen as deployment sites for artificial reefs in Hong Kong over the next few years[17]. One of the selected sites lie either in, or in close proximity, to the Study Area (Shek Nga Chau) (see *Figure 1.3a*). As this site is to consist of complex structures which are expected to be colonised by stationary organisms eg corals, as well as by mobile organisms such as commercial fish species, they are considered as potential Tier 1 marine ecological sensitive receivers.

1.5.3 *Tier 2 Habitats*

Introduction

Habitats that have been classified as Tier 2 are habitats of moderate fisheries importance that have a higher assimilation capacity, and therefore a higher degree of resistance to impacts than those in Tier 1.

Fisheries Resources and Fishing Operations

During the AFD Port Survey (1989-1991) all of Hong Kong waters were segregated into defined fishery zones. Using data from the most recent and comprehensive study of fishing operations in Hong Kong (AFD Port Survey 1996-97), it is possible to assess the environmental importance of these fishing zones based on their per hectare value to the Hong Kong fishing industry, and thus their respective classification within the tiered ranking system. The rank of each zone out of all the fishing zones, was calculated based on the per hectare value for each parameter to present a clearer picture of the zones importance. Those fishing zones with a total production value ($) ranked within the top fifty most valuable fishing zones in Hong Kong were classified as Tier 2, whereas those fishing zones ranked below this were classified as Tier 3. The Study Area passes through nine AFD fishing zones of which two are regarded as meriting Tier 2 status (*Figure 1.5a*):

- Po Toi South (Zone 92); and
- Po Law Tsui (Zone 97).

Further information on these fishing zones is presented in *Section 5*.

1.5.4 *Tier 3 Habitats*

Introduction

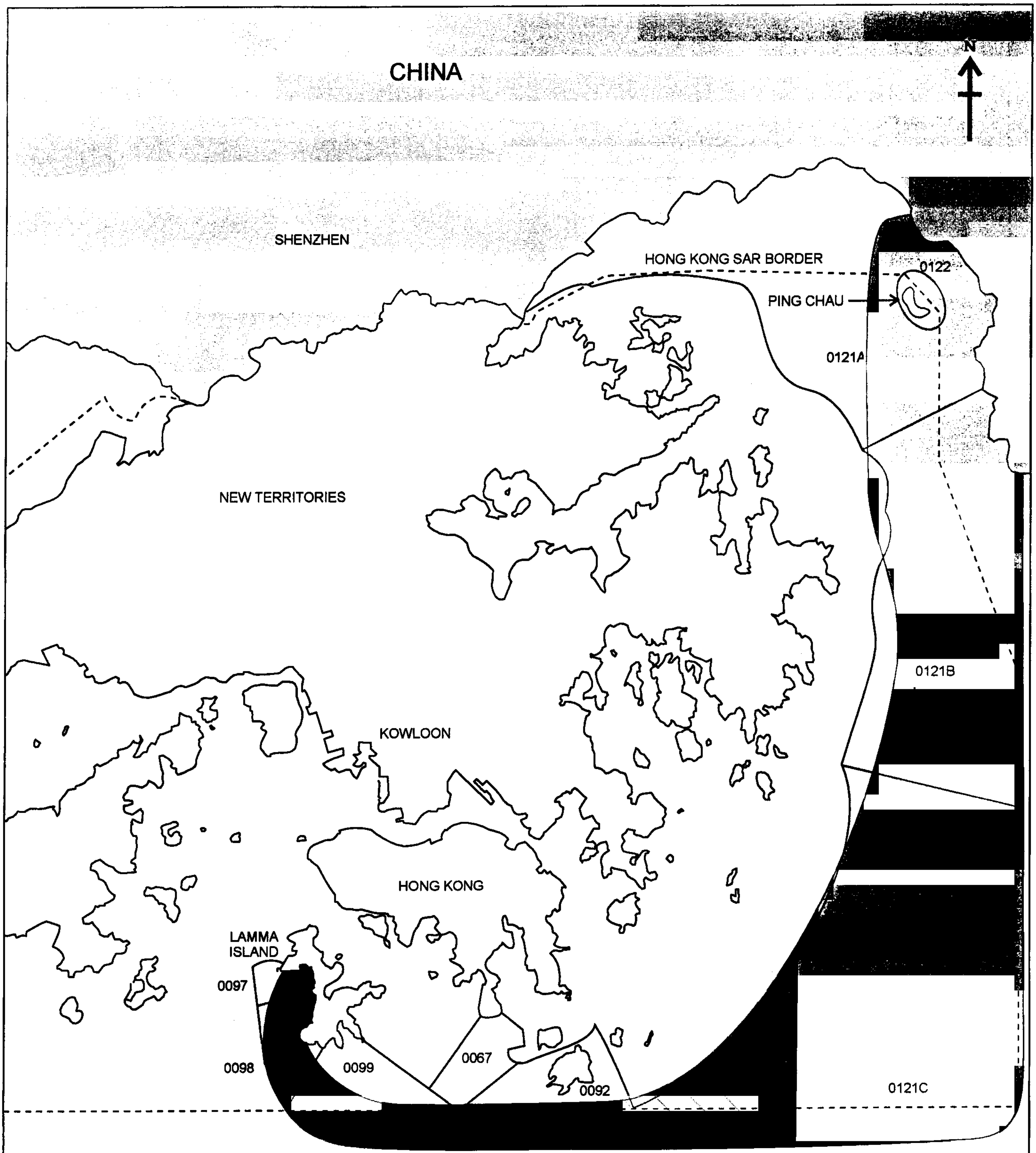
The final category of classification for the fisheries sensitive receivers of the Study Area are the Tier 3 habitats. Sites categorised under Tier 3 are generally considered to be able to accommodate environmental impacts from the pipeline of a greater magnitude and duration than the habitats listed previously.

Fisheries Resources and Fishing Operations

The Study Area passes through nine AFD fishing zones of which seven are regarded as meriting Tier 3 status (*Figure 1.5a*):

- Bluff Head (Zone 67);
- Ha Mei (Zone 98);

(17) ERM (1998c) *Artificial Reef Deployment Study Draft Final Report* for Agriculture and Fisheries Department, Hong Kong Government.



KEY

- 002 AFD FISHING ZONE & CODE
- STUDY AREA
- SPAWNING AREAS
- NURSERY AND SPAWNING AREAS

NOT TO SCALE

FIGURE 1.5a

AFD FISHING ZONES AND FISH NURSERY/SPAWNING AREAS WITHIN THE STUDY AREA CORRIDOR FOR THE SUBMARINE GAS PIPELINE FROM THE PROPOSED LNG TERMINAL IN SHENZHEN TO HEC'S PROPOSED NEW POWER STATION

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- Tai Kok (Zone 99);
- Mirs Bay (Zone 121A);
- Mirs Bay (Zone 121B);
- Mirs Bay (Zone 121C); and
- Ping Chau (Zone 122).

The production values and further details of the fisheries resources in each of these zones are presented in *Section 6*.

1.5.5 *Summary and Conclusions*

The evaluation of commercial fisheries resource constraints to the routing of the proposed new pipeline employed a three a tiered ranking system to classify the level of constraint associated with commercial fisheries sensitive receivers, both existing and future. The following classification was derived:

Tier 1 Areas:	Fishery spawning and nursery areas Artificial reefs
Tier 2 Areas:	AFD Fishing Zones - Po Toi South and Po Law Tsui
Tier 3 Areas:	AFD Fishing Zones - Bluff Head, Ha Mei, Tai Kok, Mirs Bay (A, B & C) and Ping Chau

1.6 *SUMMARY AND CONCLUSIONS*

1.6.1 *Introduction*

The desk-top study into the constraints to the routing of the proposed gas pipeline from the LNG terminal in Shenzhen to the HEC's new power station identified areas of variable constraint within the defined routing corridor. The findings of the desk-top study are presented below.

The overall constraints map is presented in *Figure 1.6a*.

1.6.2 *Physical Constraints*

The primary physical constraints to the routing of the pipeline are the Eastern Waters Marine Borrow Areas and the East of Ninepins Open Water Dredged Material Disposal Site, and the anchorages south of Lamma Island.

In addition, it was recommended that:

- standard good practice protocols during pipeline laying are established to ensure that no undue disruption will occur to navigation in Hong Kong waters;
- further research into the precise location, mode of laying and sensitivity to disturbance will need to be undertaken during the detailed pipeline planning stage to ensure that damage to the known existing cables is avoided and to confirm the details of pipelines and cable alignments that lie outside of Hong Kong waters; and

- the current status of the Lamma Breakwater should be reviewed during the course of the detailed pipeline route planning.

1.6.3 *Water Quality, Marine Ecological & Commercial Fisheries Constraints*

The review of existing information and the development of a tiered ranking system has identified those water sensitive areas or users that are of particular concern during the construction of the proposed gas pipeline. The pipeline routing should avoid passing through the most sensitive water areas or users (Tier 1), while mitigation measures should be implemented to minimise water quality impact upon those less sensitive areas or users (Tiers 2 and 3).

The potential water quality impact arising from the construction of the proposed submarine gas pipeline will be the resuspension of marine sediment that elevates the levels of suspended solids, and depletes the concentration of dissolved oxygen in the water column. The evaluation of marine ecological resources has identified a range of marine sensitive receivers and fishery resources that will be constraints to the routing of the pipeline. Full and complete details of the impact of the pipeline laying on Water Quality are presented in *Section 4*, Marine Ecology (*Section 5*) and Fisheries (*Section 6*). *Table 1.6a* summarises the classification of water quality sensitive receivers, marine ecological and commercial fisheries resources identified under the tiered ranking system.

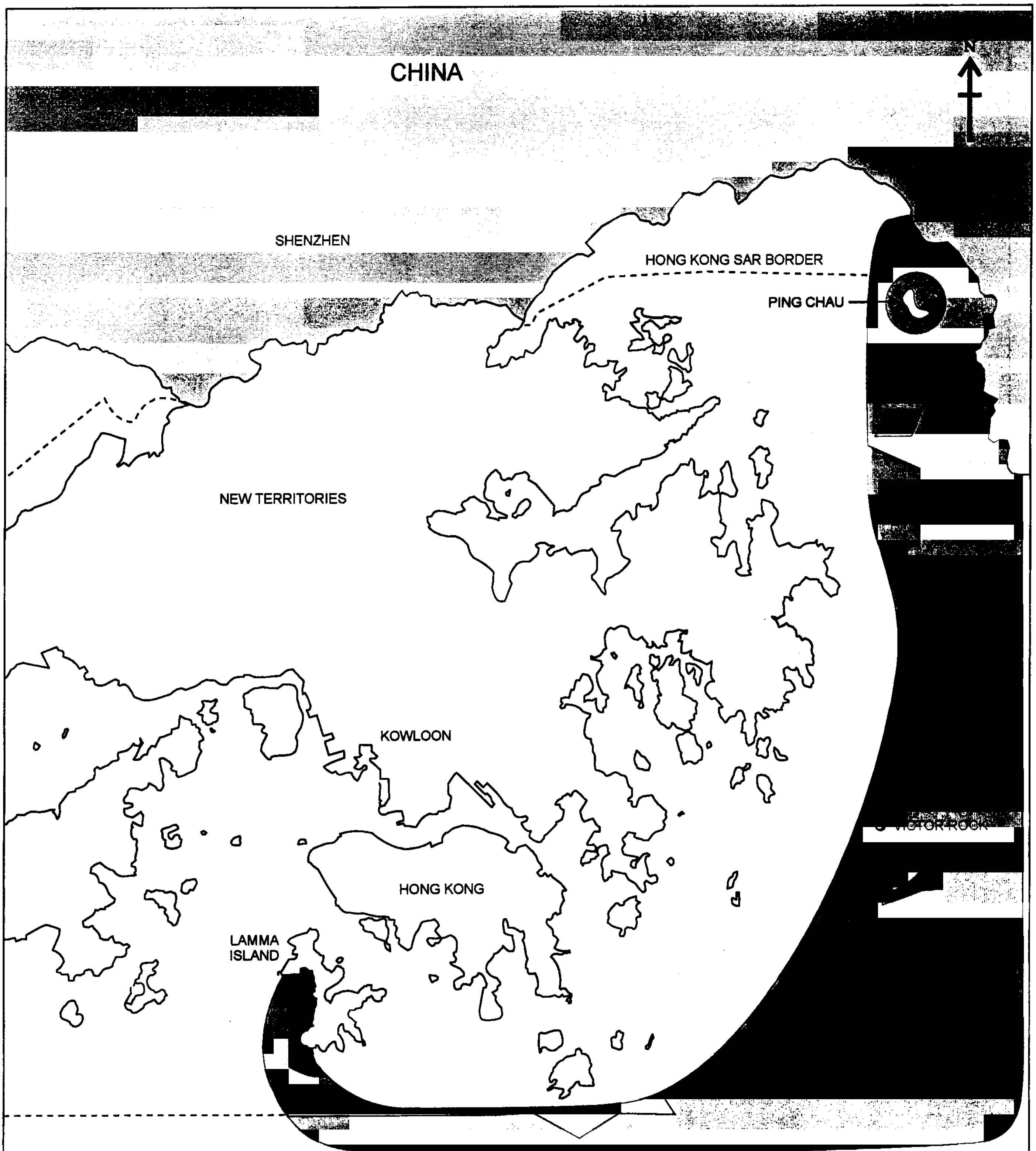
Table 1.6a *Classification of Sensitive Receivers under the Tiered Ranking System*

Classification	Water Quality Sensitive Receivers/Users	Marine Ecological & Fisheries Sensitive Receivers/Users
Tier 1	Gazetted bathing beaches at Hung Shing Ye and Lo So Shing (west of Lamma Island)	Coral Communities Fish Spawning and Nursery Areas Marine Parks and Marine Reserves Artificial Reefs Critical Habitats for Marine Mammals
Tier 2	HEC Lamma Island Power Station Cooling Water Intake	AFD Fishing Zones - Po Toi South and Po Law Tsui Areas seasonally used by Marine Mammals
Tier 3	Most of the Mirs Bay and Southern WCZs where tidal currents are strong and have no sensitive receivers/users nearby	AFD Fishing Zones - Bluff Head, Ha Mei, Tai Kok, Mirs Bay (A, B & C) and Ping Chau Open Water Seabed

1.7 ROUTE SELECTION

1.7.1 *Introduction*

The results of the desk-top environmental constraint mapping were provided to pipeline engineers, Kvaerner RJ Brown Pte Ltd (Kvaerner) as the basis for the route optimisation study for the proposed Shenzhen to Lamma gas pipeline. For those parts of the pipeline within Hong Kong SAR territorial waters, Kvaerner identified two route options and two options for the Lamma approach. The route options are presented in *Figure 1.7a*. The evaluation of the identified route options is discussed below.



KEY

- AREAS CLASSIFIED AS TIER 1
- AREAS CLASSIFIED AS TIER 2
- AREAS CLASSIFIED AS TIER 3

NOTE: FISHERY SPAWNING AND NURSERY AREAS ARE NOT SHOWN DUE TO THEIR ONLY SEASONAL CLASSIFICATION AS TIER 1

NOT TO SCALE

FIGURE 1.6a

TIER SYSTEM OF THE STUDY AREA CORRIDOR FOR THE SUBMARINE GAS PIPELINE FROM PROPOSED LNG TERMINAL IN SHENZHEN TO HEC'S PROPOSED NEW POWER STATION

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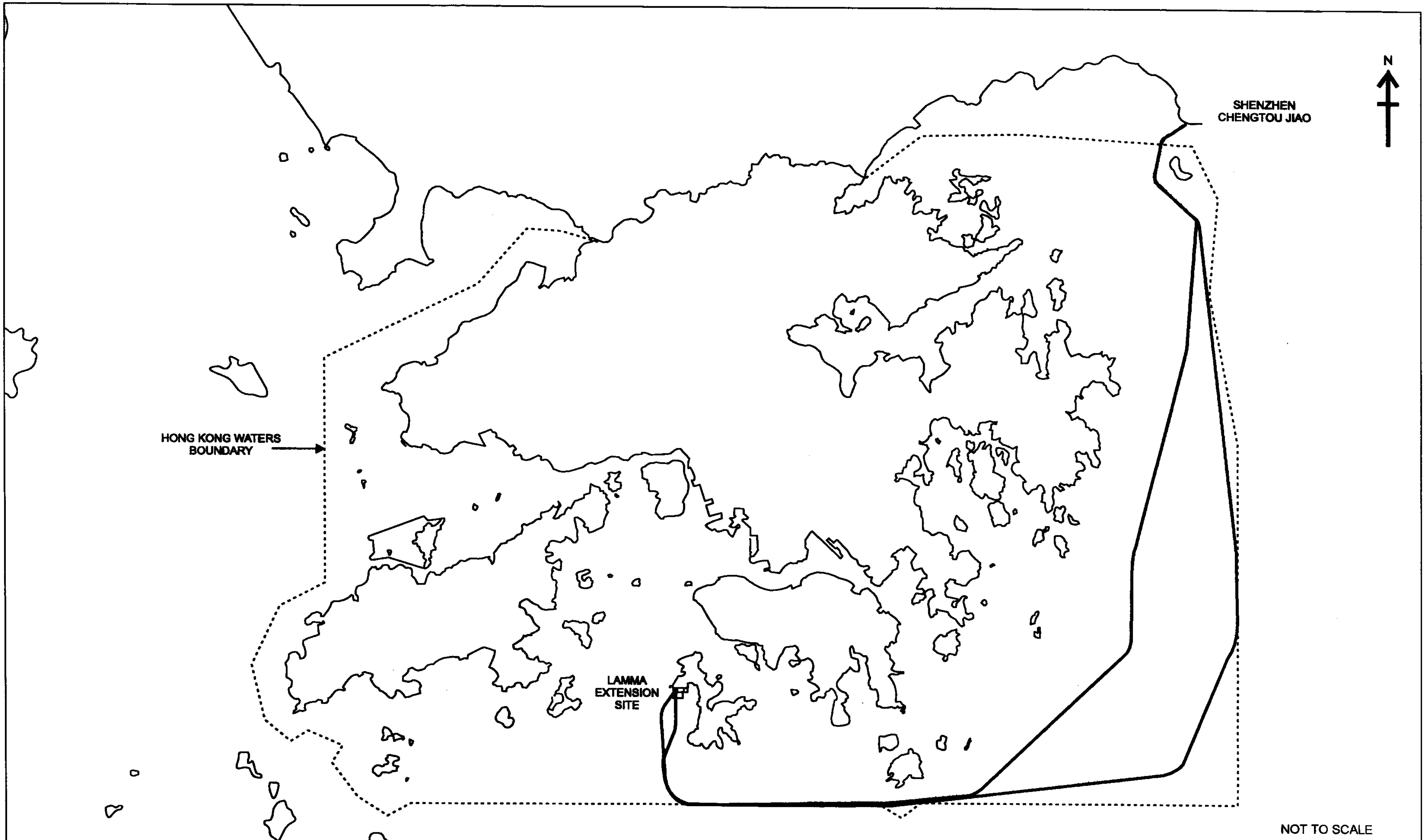

FIGURE 1.7a

ROUTE OF GAS PIPELINE

PREPERRED GAS PIPELINE ROUTE

ALTERNATIVE GAS PIPELINE ROUTE

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Management

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1.7.2 *Open Water Routing Options*

The two open water routing options share a common alignment from the point at which the pipeline enters Hong Kong territorial waters to a point south-southeast of Ping Chau. At this point the two options diverge, such that:

- Option 1 is closer to the land mass of Hong Kong and is routed to the west of the Ninepin Island marine borrow area. The pipeline route has a total length of 82 km.

- Option 2 is further from the land mass of Hong Kong and is routed to the eastern side of the Ninepin Island marine borrow area. The pipeline route has a total length of 90 km.

The two route options converge southeast of Waglan Island and share a common route to a point south of Lamma Island, where they diverge as the two Lamma approach options. As the two pipeline options comply with the environmental constraint criteria, the evaluation criteria applied in the selection of the preferred routing encompassed a range of engineering, indirect environmental, route curvature, cable crossing and financial issues. The comparative evaluation identified Option 2 as the preferred open water route for the following reasons:

- the Option 2 route is further offshore and in deeper water region with a consequent reduction in the probability of anchor damage as, it is envisaged that in an emergency situation, vessels will seek to anchor near shore rather than in an exposed offshore location;

- the additional route length of Option 2 is within 10% of Option 1 and, as such, will not have significant impact on material or construction costs;

- whilst both options avoid areas of ecological constraint, Option 2 is further away from ecological resource areas, thereby ensuring a greater buffer distance during pipeline laying; and

- the cable crossings associated with Option 2 are less acute than those associated with Option 1, thereby reducing contact area and consequential potential risks.

1.7.3 *Lamma Approach Options*

The Lamma Approach options diverge south of Lamma Island, such that:

- Option A takes a northern course but is routed to the west of the potential boundary of the proposed Marine Park/Reserve with a landfall on the western side of new reclamation.

- Option B takes a much more direct, northerly course to a landfall on the south side of the Lamma Extension reclamation. This route option encroaches within the potential boundary of the proposed Marine Park/Reserve.

The evaluation criteria applied in the selection of the preferred routing encompassed a range of engineering, environmental, route curvature, cable crossing and financial issues. The comparative evaluation identified Option A as the preferred Lamma Approach route for the following reasons:

- the Option A route is outside the potential boundary of the proposed Marine Park/Reserve which the desk-top study had identified as a Tier 3 water quality and ecological resource region; and
- the route curvature of Option A is considerably less with benefits to the laying of the pipeline.

1.7.4 *Conclusions*

The route optimisation exercise identified the open water Option 2 and the Lamma Approach Option A as the preferred gas pipeline route. This combination is described in greater detail in *Section 2* below and the environmental impacts are assessed in the remainder of Part D of the EIA Report.

2 PROJECT DESCRIPTION

2.1 INTRODUCTION

2.1.1 Background

Natural gas for the new power station will be supplied via a submarine pipeline from a regional LNG terminal located at Cheng Tou Jiao in Shenzhen. A broad assessment of the environmental impacts of the submarine gas pipeline was undertaken in *Stage I EIA for a New Power Station, Volumes 1 & 2*. As with the transmission cables, environmental impacts from the gas pipeline are only anticipated during the construction period.

Limited dredging will be required for laying of the submarine pipeline. For most of the pipeline route, a pipe jetting method will be used for laying of the pipeline under the seabed, which will not require the dredging of marine sediment. In areas where the pipeline crosses busy marine channels, the pipeline will be laid by jetting and covered by precast concrete slab. Dredging will only be necessary at the Lamma and Shenzhen approaches. As the sediment in the proposed Lamma approach is classified as Class A, the dredged sediment can be disposal of at designated marine dumping grounds.

2.2 PIPELINE INSTALLATION METHODOLOGY

A feasibility study for the installation of the submarine pipeline was conducted by Kvaerner. A summary of the recommendations are presented below, covering the four procedures required for the pipelines installation, namely:

- pipelaying method;
- shore approach installation method;
- trenching and backfill method; and
- cable crossing method.

2.2.1 Pipelaying Method

The Kvaerner study considered the laybarge method to be the most viable option for the installation of the gas pipeline. The basis of this conclusion was as follows:

- Due to the curved nature of the pipeline route, the flotation, bottom pull and controlled depth tow methods are not considered feasible.

- Due to the long route length (approximately 90 km) and problems with sea current s and sea bed abrasion, surface, bottom pull and controlled depth methods are not considered feasible.

- The laybarge method requires no stringing yard, giving it an advantage over other methods which require a full-sized stringing yard onshore. This is important in this case as onshore space is limited.

- The laybarge is capable of working to depths of 35 m at which other methods experience difficulties.

- The laybarge is able to abandon the pipeline during rough seas and return once calmer conditions prevail.

- The conventional laybarge is favoured over second and third generation laybarges because it is more common, less costly to mobilise and has a shallower vessel draft.

2.2.2 *Shore Approach Installation Method*

The recommended shore approach installation method is the laybarge-based pipe pull method. The reasons are given below:

- The steep shore approach method enables the laybarge to operate close to shore, which shortens the length of pipe to be pulled.

- It requires only a very small onshore land area for the onshore winch or sheave assembly with piled deadman anchor.

- It is less expensive than other methods and requires less equipment and manpower.

- It requires a shorter installation time compared to the other options.

- It has minimal impact on the environment.

2.2.3 *Trenching and Backfill Method*

The trenching methods recommended are jetting by liquefaction and clamshell dredging. The reasons are given below:

- Soil conditions make these options feasible.

- Based on previous experience in the same region, trenching produces only localised sediment disturbance.

- Jetting allows the trench to be backfilled naturally, hence saving part of trenching costs.

- The methods avoid blasting which is costly and environmentally damaging.

- Clamshell dredging is the only method that can dredge the shallow shore approach areas.

- Ploughing is difficult owing to the weight of the plow and the softness of the soil.

2.2.4 *Cable Crossing Method*

The cable crossing will be accomplished using mattresses to support the pipeline and prevent future settlement into the seabed. The pipeline will not be trenched at the crossings. Mattresses will be placed below and above the exposed pipeline at these locations. A system using pulse induction technology is recommended for cable detection.

3 SCOPE OF THE ASSESSMENT

3.1 INTRODUCTION

This Section describes the scope of the assessment work undertaken in the EIA Study for the gas pipeline component of the Lamma Extension project. This component includes the laying of pipeline between Shenzhen and the Lamma Extension, and the preparation of shore approaches at each end of the pipeline route.

The scope and contents of the assessments for the power station and transmission components of the project are described in *Section* 3 of Part B, and *Section* 3 of Part C, respectively.

3.2 ASSESSMENT AREAS ADDRESSED

The EIA Study Brief requires assessments to be undertaken, where relevant and appropriate, for both the construction and operational phases of the overall project in the following technical areas:

- air quality impacts;
- water quality impacts;
- noise;
- landscape and visual impacts;
- waste management impacts;
- land contamination;
- aquatic (marine) and terrestrial ecological impacts;
- fisheries impacts; and
- hazards to life.

Only four of these areas are considered relevant to the pipeline component of the project.

Water Quality

The water quality assessment in *Section 4* includes an evaluation of the impacts of the proposed pipeline laying method (ie jetting of trenches) and dredging at the shore approaches, including sediment dispersion modelling for the latter activities. The impacts of pipeline maintenance and repair activities were also considered .

Marine Ecology

Section 5 provides an assessment of potential impacts on marine ecological resources during the construction of the project, including an evaluation of the results of field surveys in areas potentially affected. Both direct (eg habitat loss) and indirect (eg water pollution and habitat disturbance) impacts were evaluated for both phases of the project.

Fisheries

As with marine ecology, the fisheries impact assessment (*Section 6*) considered both direct and indirect impacts on fisheries resources during the installation of the pipeline. Impacts associated with water pollution, especially as a result of dredging work, were evaluated.

Hazards to life

Section 7 presents an assessment of the hazards associated with pipeline operation, including consideration of the risks and consequences of corrosion, mechanical failure, operational errors, third party damage (eg from dropped anchors) and environmental factors (eg seabed mobility, or seismic activity).

Areas Not Considered

For the gas pipeline there are considered to be no impacts requiring assessment in the areas of air quality, noise, landscape and visual impact, waste management or land contamination.

4 WATER QUALITY IMPACTS

4.1 INTRODUCTION

This Section describes the assessment of impacts on water quality associated with the construction and operation of the submarine pipeline for supplying gas from the LNG terminal in Shenzhen to the Lamma Extension power station.

Computer modelling of sediment dispersion has been used to determine the impacts of pre-dredging a trench for the submarine pipeline at the Shenzhen approach, while the assessment of construction phase impacts for the remainder of the pipeline by jetting techniques has been carried out in a qualitative manner.

The purpose of the assessment was to evaluate the acceptability of predicted impacts to water quality from the construction and operation of the gas pipeline. Impacts have been assessed with reference to the relevant environmental legislation and standards and measures are proposed (where necessary) to mitigate potential adverse environmental impacts.

4.2 LEGISLATION AND STANDARDS

The following legislation are applicable to evaluating water quality impacts associated with the construction and operation of the transmission system:

- *Environmental Impact Assessment Ordinance (Cap. 499)*, and the *Technical Memorandum on EIA Process (EIAO TM)*, particularly *Annexes 6* and *14*; and
- *Water Pollution Control/Ordinance (WPCO)*.

4.2.1 Water Pollution Control Ordinance

The WPCO is the principal legislation for the control of water pollution and water quality in Hong Kong. Under the WPCO, Hong Kong waters are divided into 10 Water Control Zones (WCZs). Each WCZ has a designated set of statutory Water Quality Objectives (WQOs). The impacts from the construction and operation of the gas pipeline will fall within the Southern and Mirs Bay WCZs.

The WQOs for the Southern and Mirs Bay WCZs are presented in *Annex D4-1*, and are applicable as evaluation criteria for assessing compliance of any discharges during the construction and operation of the gas pipeline.

4.3 BASELINE CONDITIONS

4.3.1 Hydrodynamics

The route for the pipeline passes along the southern border of Hong Kong waters and north into Mirs Bay. The majority of the portion along the southern border of Hong Kong and a portion of the Mirs Bay section will be subject to the oceanic current in the Lema Channel which is unaffected by tidal changes. In the dry season the current flows consistently in a south westerly direction. In the wet season the dominant current direction is to the north east, although the current is less stable than in the dry season and is subject to periodic reversals in direction. These periodic reversals seem to be related to typhoon events. Tidal currents within Mirs Bay, along the pipeline route, are low with peak speeds less than 0.2 m s^{-1}. Salinity stratification along the pipeline route will be very weak in the wet season, because of the dominance of the oceanic current for some sections and the low freshwater discharge into Mirs Bay. During the dry season no salinity stratification is present.

4.3.2 *Water Quality*

The route for the pipeline passes from the Lamma Extension site around the southern end of Lamma Island, along the southern border of Hong Kong waters passing south of Po Toi Island, and then north to Shenzhen, passing west of Ping Chau. The route for the pipeline passes through the Southern and Mirs Bay WCZs. A summary of water quality along the pipeline route is shown in *Tables 4.3a* and *4.3b* below which presents EPD routine water quality monitoring data for the Southern and Mirs Bay WCZs. The locations of the stations are shown in *Figure 4.3a*.

Table 4.3a *EPD Routine Water Quality Monitoring in the Southern WCZ*

WQ Parameter	SM5	SM6	SM19
Temperature Surface (°C)	23.3 (16.5-28.4)	23.2 (16.6-28.2)	23.6 (17.7-28.4)
Temperature Bottom (°C)	22.3 (16.5-27.2)	22.0 (16.6-27.1)	22.0 (19.4-26.3)
DO Surface (mg l^{-1})	7.3 (6.4-9.7)	7.2 (5.9-8.5)	7.5 (5.8-9.3)
DO Bottom (mg l^{-1})	6.7 (3.7-8.8)	6.0 (3.3-7.3)	6.1 (3.4-7.5)
BOD (mg l^{-1})	0.4 (0.2-1.1)	0.4 (0.2-0.8)	0.6 (0.1-1.5)
SS (mg l^{-1})	9.5 (2.7-14.3)	5.4 (3.0-8.3)	3.7 (1.0-7.5)
TIN (mg l^{-1})	0.16 (0.03-0.44)	0.16 (0.04-0.37)	0.11 (0.01-0.30)
NH_3-N (mg l^{-1})	0.01 (<0.01-0.02)	0.02 (0.01-0.04)	0.02 (<0.01-0.03)
E.coli (cfu 100 ml^{-1})	3 (1-36)	5 (1-105)	2 (1-10)

Notes : 1. Data presented are depth-averaged, except as specified.
2. Data presented are annual arithmetic mean except for *E.coli* which are geometric means.
3. Data Enclosed in brackets indicate the ranges.

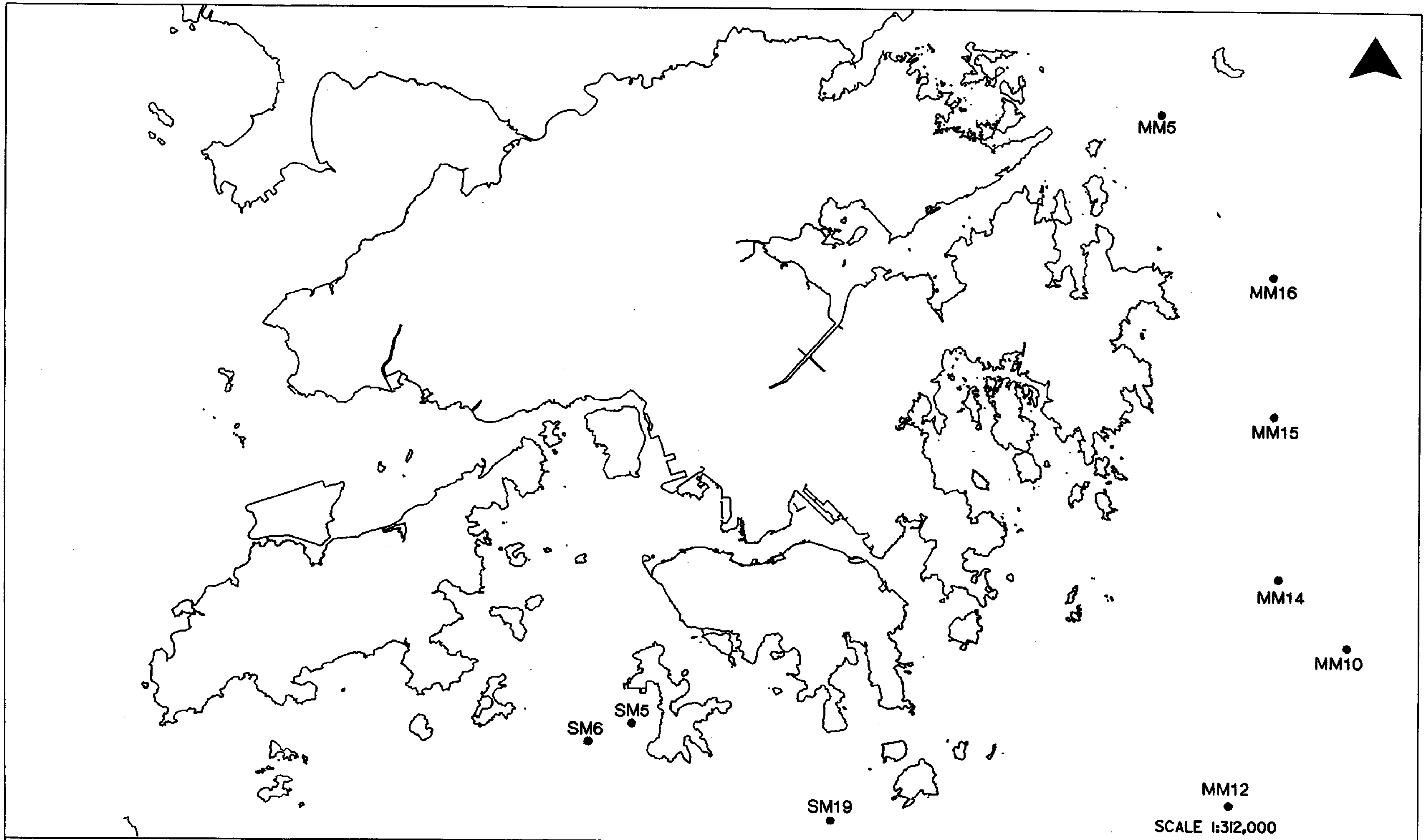

FIGURE 4.3a

EPD ROUTINE MONITORING STATIONS

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Table 4.3b *EPD Routine Water Quality Monitoring in the Mirs Bay WCZ*

WQ Parameter	MM12	MM10	MM14	MM15	MM16	MM5
Temp Surface (°C)	25.4 (18.8 -30.2)	25.4 (20.7-29.5)	23.9 (20.5 -28.3)	24.2 (20.3 -28.6)	24.4 (19.6 -30.1)	24.4 (18.0 -30.9)
Temp Bottom (°C)	23.1 (19.0 -27.9)	23.0 (18.8 -28.0)	22.5 (18.6 -28.1)	22.4 (18.4 -28.2)	22.4 (18.4 -28.2)	22.2 (17.9 -27.9)
DO Surface (mg L^{-1})	7.2 (6.3 -9.7)	7.4 (5.9 - 9.9)	6.6 (5.2 -9.0)	6.5 (5.2 -7.8)	6.3 (5.4 -7.0)	6.6 (5.7 -7.5)
DO Bottom (mg L^{-1})	6.5 (5.2 -7.8)	6.4 (5.1 - 7.7)	6.1 (5.2 -7.0)	6.1 (4.9 -7.0)	6.1 (5.1 -7.3)	6.1 (4.3 -7.4)
BOD (mg L^{-1})	0.6 (0.3 -1.1)	0.6 (0.3 - 1.3)	0.4 (0.1 -1.0)	0.4 (0.1 -0.8)	0.4 (0.1 -0.8)	0.5 (0.2 -1.0)
SS (mg L^{-1})	1.7 (0.6 -3.5)	1.8 (0.5 - 3.9)	2.0 (0.5 -3.3)	2.1 (0.5 -4.9)	1.2 (0.5 -2.7)	1.2 (0.7 -2.9)
TIN (mg L^{-1})	0.07 (0.01 -0.11)	0.06 (0.01 -0.12)	0.04 (0.01 -0.10)	0.03 (0.01 -0.08)	0.03 (0.02 -0.06)	0.03 (0.01 -0.05)
NH_3-N (mg L^{-1})	0.01 (<0.01-0.03)	0.01 (<0.01-0.03)	0.01 (<0.01-0.02)	0.02 (<0.01-0.03)	0.01 (<0.01-0.03)	0.02 (<0.01-0.03)
E.coli (cfu 100 mL^{-1})	2 (1 - 25)	1 (1 - 1)	1 (1 - 1)	1 (1 - 1)	1 (1 - 1)	2 (1 -16)

Notes:
1. Data presented are depth-averaged, except as specified.
2. Data presented are annual arithmetic mean except for *E.coli* which are geometric means.
3. Data Enclosed in brackets indicate the ranges.

In general the above data show extremely low pollution levels which reflect the large distances of these stations from any effluent discharges. The data show consistently high levels of dissolved oxygen, particularly at those stations to the south which are greatly influenced by the offshore Lema Channel currents which bring in oceanic water. It is worth noting that the data also indicate extremely low levels of suspended solids which may be because the stations are not influenced by the Pearl River discharge and are distant from any rainstorm run-off. This data, however, may not be representative of actual conditions due to the exposed nature of the stations which would preclude monitoring during rough weather when suspended sediment concentrations may be expected to be higher.

4.4 CONSTRUCTION PHASE

4.4.1 *Assessment Methodology*

A pipeline will be constructed from the Shenzhen LNG terminal to the Lamma Extension development to provide natural gas as fuel for a proposed new 1800 MW gas-fired power station. *Figure 4.4a* shows the route of the pipeline from Shenzhen to the Lamma Extension site. The programme for the pipeline construction is contained in *Annex D4-3*, which also includes further information on the pipeline laying methodology.

Except at the shore approaches to Shenzhen and Lamma Extension where a trench will be formed within which the pipeline will be laid, the entire pipelaying will be performed by a laybarge on which the pipes are welded and laid continuously on the sea bed at a speed of 1 to 3 km per day. The pipelaying operation will take about two months to complete and will not disturb the sea bed. After laying the whole pipeline on to the sea bed, the pipeline will be lowered down to about 3 m below sea bed using the jetting method. In this method low pressure, high volume water jets are employed to fluidise the sea bed sediment which allows the pipe to sink by its own weight into the sea bed. Typical travelling speed of the jetting machine is about 1 m per minute and it would take about 4 months to complete the jetting operation. At the Shenzhen and Lamma approaches where the pipeline is laid inside pre-dredged trenches, the pipe will be covered by sand and gravel.

The jetting machine consists of two legs which will be adjusted on site to suit the diameter of the pipeline. The jetting machine will be gradually lowered, with diver guidance, onto the submarine pipeline, which will already have been laid on the sea bed. The jetting nozzles will force out low pressure water to fluidise the sea bed around the pipeline and form a trench for the pipeline to sink into under the influence of gravity. Ejector tubes then suck part of the fluidised mixture of water and sediment and eject this through exhaust nozzles positioned a maximum of 3 m above the sea bed. The exhaust nozzles will be pointed downwards to prevent mixing of the sediment through the water column. Further details of the equipment and method of jetting are contained in *Annex D4-3*, which include figures detailing the equipment to be used and discussion of the selection of the preferred methods for laying the pipeline.

In areas near to shipping zones where jetting down of the pipeline has occurred the pipeline will be armoured with rockfill or mattress cover. Where the pipeline crosses submarine cables and other pipelines, the gas pipeline will be laid onto a geotextile mattress on the sea bed and covered with another mattress to provide protection. In other areas of jetting the trench will be allowed to naturally backfill with sediment settling into the trench over a period of time.

The assessment of the impacts from the jetting has been a qualitative assessment only, with reference to the above described methods of laying the pipeline, nearby sensitive receivers and the expected form of the impacts.

At the approaches to Shenzhen and Lamma a dredged trench will be formed, within which the pipeline will be laid. The trench will be dredged using small grab dredgers of 3 m^3 capacity. At each of the two approaches a one kilometre trench will be dredged. In the dredged trenches at the Shenzhen and Lamma approaches the pipe will be covered with sand and gravel which will act as protection.

Sediment dispersion modelling has been applied to simulate the loss to suspension and subsequent transport of fine sediment in suspension by tidal currents. The rate of working for the grab dredger on the pipeline trench will be 100 $m^3 hr^{-1}$, 7 days per week and 24 hours per day. It is likely that only a single grab dredger will operating at any time. The rate of loss of sediment to suspension from a small grab dredger was assumed to be 25 kg m^{-3} for the simulations of dredging at the new power station reclamation. The same loss value be used here, which provides a loss rate of 0.69 kg s^{-1}. Modelling has only been carried out to assess the impacts from dredging at the Shenzhen approach. Simulations for the trench dredging have been carried out for the wet and dry season spring and neap tides. Assessment of the impacts from the dredging of the Lamma approach has been made with reference to the simulations which have already been carried out for the dredging at the Lamma Extension reclamation site.

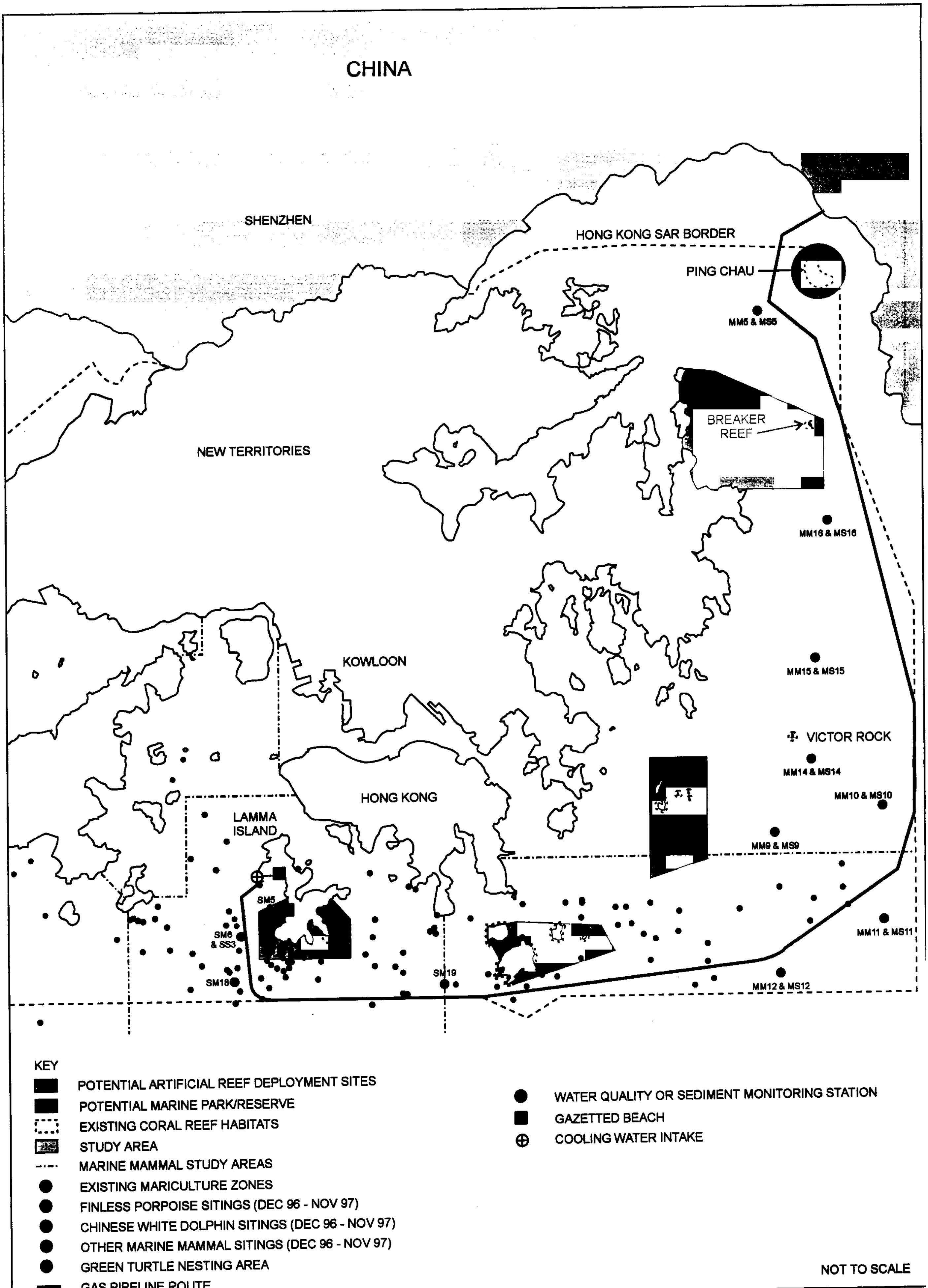

FIGURE 4.4a ROUTE OF THE SUBMARINE GAS PIPELINE, SHOWING SENSITIVE RECEIVERS

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4.4.2 *Uncertainties in Assessment Methodology*

The same modelling approach has been used here as for the Lamma Extension reclamation (see *Section* 5.4.2 of *Part B*) and similar uncertainties will apply:

Quantitative uncertainties in the sediment dispersion modelling should be considered when making an evaluation of the modelling predictions. Worst case conditions were adopted as model input in order to provide a conservative prediction of environmental impacts. It is therefore possible that the input data for the relevant parameters may cause an overestimation of the environmental impacts. Some examples of the conservative nature of the input parameters are given below:

- The simulations for generating flow data for the sediment dispersion modelling have been carried out with the pre-dredging bathymetry which will result in a greater amount of the sediment released during dredging remaining in suspension (use of the post-dredging bathymetry would mean that more sediment would deposit to the seabed, thus reducing plume extent and concentrations).

- The settling velocity of SS of 2 m day^{-1} was derived from the recent calibration of the upgraded Hong Kong water model based on the Delft 3D system. During the calibration, settlement rates were varied to determine the sensitivity of model predictions to this factor and it was found that higher rates lead to an under prediction of suspended sediment around Hong Kong Island. Therefore, the settling velocity in this Study is conservatively set at 2 m day^{-1} which is at the lower end of the wide range of values encountered in the general literature but represents the best available value in the absence of any more relevant field data.

4.4.3 *Identification of Impacts*

Impacts from dredging a trench at the Shenzhen approach for the gas pipeline have been simulated using computer modelling of sediment dispersion, while impacts from the jetting operations have been assessed qualitatively.

Impacts from trench dredging at the Shenzhen approach may be caused by sediment plumes being transported to sensitive areas, the closest of which to the dredging is Ping Chau. Ping Chau is currently being studied to determine whether it should be designated as a Marine Park/Reserve. Ping Chau is rich is hard corals which may be sensitive to deposition from suspended sediment plumes formed from the trench dredging. A number of points have been derived around Ping Chau, *Figure 4.4b*, at which suspended sediment concentrations have been output in order to monitor the impacts in this sensitive area. The four points have been termed PC1 to PC4 which simply represents Ping Chau points 1 to 4.

The determination of acceptability of any impacts from suspended sediment released during the dredging may be carried out in relation to the Water Quality Objectives, which for sediment is defined as being an allowable increase of 30% above the 90th percentile of the ambient. An analysis of the EPD monitoring data at Station MM5 has shown that the allowable increase in suspended sediment concentrations for the area would be 0.8 mg l^{-1} for the dry season and 0.4 mg l^{-1} for the wet season. Assessments of the potential for sediment settling onto the sea bed in high enough levels to cause adverse impacts have also been undertaken. The sediment to be dredged is likely to be uncontaminated due to its remoteness from human activity and consequently no analysis has been made of the impacts to dissolved oxygen or nutrient release.

Impacts from the jetting operation will be similar to the trench dredging in that the concerns will be related to the suspension of sea bed sediment into the water column. The potential for these impacts to occur has been assessed qualitatively. *Figure 4.4a* shows the sensitive receivers in the vicinity of the pipeline, which include coral areas, Marine Park/Reserves, mariculture areas, gazetted beaches. Impacts to these areas have been discussed in terms of water quality. Ecological impacts, including loss of habitat, have been discussed in the later sections of this report.

4.4.4 *Prediction and Evaluation of Impacts*

Prediction and evaluation of the impacts of laying of the gas pipeline has been carried out using qualitative assessments for the sections using jetting and quantitative assessment through sediment dispersion modelling of trench dredging at the Shenzhen approach. Trench dredging at the Lamma approach has been assessed with reference to the modelling carried out for the Lamma Extension reclamation.

The majority of the gas pipeline will be laid using jetting which involves using water jets to fluidise the sea bed sediments to form a trench for the pipeline to sink into. The total depth of the trench will be 3 m which will take three passes of the jetting machine to accomplish, with the time between each pass being over 2 days. Each 1 m pass can therefore be considered as an independent operation. The rate of sediment entering suspension may be calculated as follows :

release rate	=	cross section area trench * speed of jetting machine * material density * percentage loss
where		
trench depth	=	1 m (per pass)
trench width	=	3 m
cross sectional area	=	3 m^2
loss rate	=	20% - 50%
speed of jetting	=	0.008 m s^{-1} - 0.016 m s^{-1}
in situ dry density	=	600 kg m^{-3}
release rate	=	2.9 to 14.4 kg s^{-1}

During jetting the sediment is released at the bottom of the water column which results in high localised suspended sediment concentrations and rapid settling velocities. This is because at high concentrations the suspended sediment tends to form large flocs, the process of flocculation, which have a settling velocity much higher than individual sediment particles. Also the sediment starts closer to the sea bed. This is also important because tidal currents are much lower nearer to the sea bed than higher up the water column, particularly in the deeper waters south of Hong Kong. This would mean that the sediment would be transported much shorter distances from the dredging site.

Additional considerations relate to the mode of operation of the jetting machine and the physical characteristics of the area through which the pipeline is to pass. As jetting commences the machine will be positioned 3 m above the sea bed and this will be maximum height of the release of the sediment. As jetting progresses and the pipeline sinks into the trench the height of the machine above the sea bed will reduce in proportion to the depth of the trench which means that the height above the sea bed at which sediment is lost will reduce to almost zero. The closer the loss to the sea bed, the less chance there will be for the sediment to be transported away from the immediate vicinity. Along the majority of the pipeline route water depths are at least 30 m, so this means that the maximum

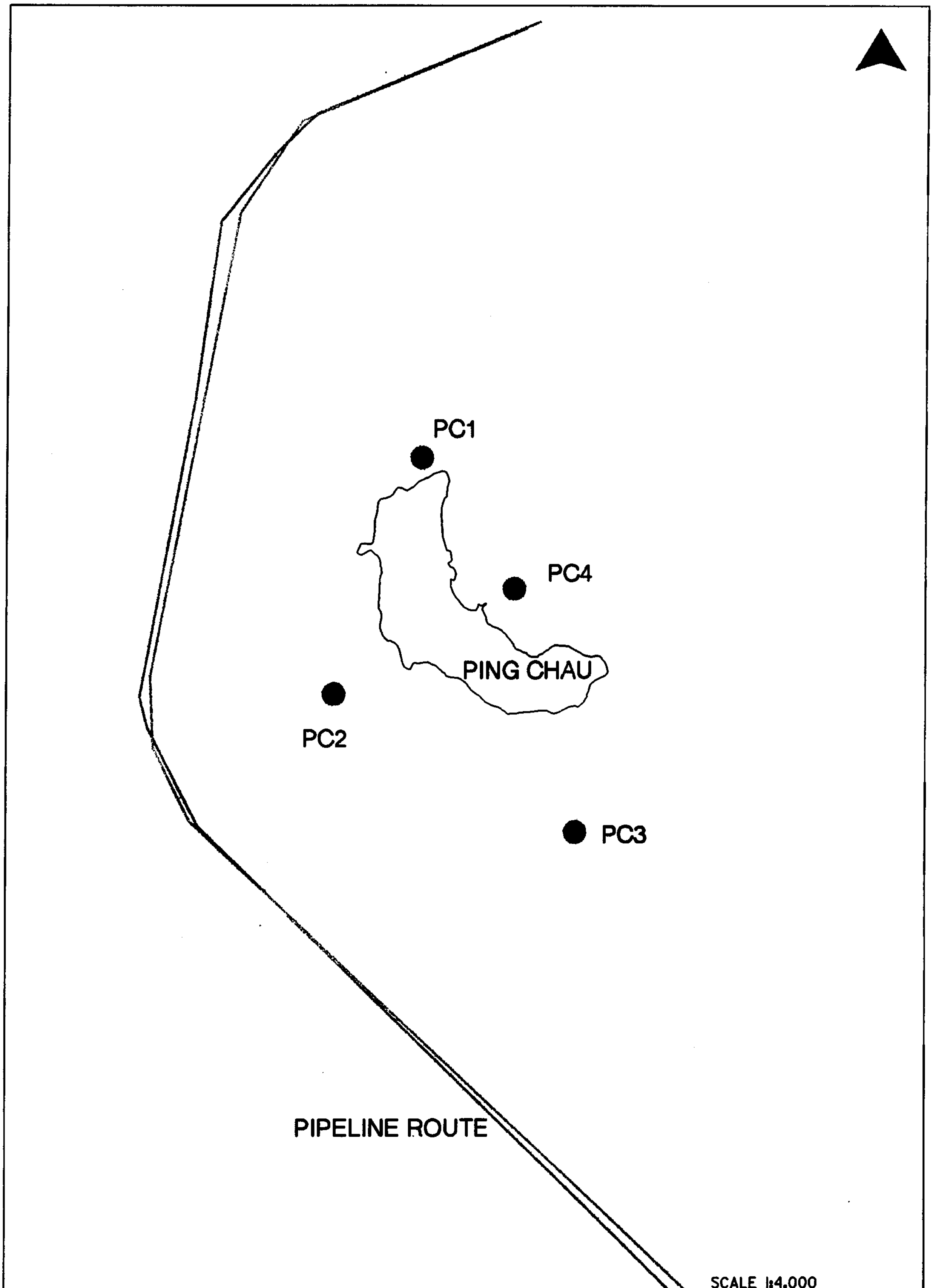

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FIGURE 4.4b **LOCATIONS OF SENSITIVE RECEIVERS FOR PIPELINE CONSTRUCTION**

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height that the sediment will enter suspension is in the lower 10% of the water column, and the average height will be in the lower 5%. The majority of the pipeline route will be influenced by the oceanic currents and during jetting this will be the north easterly wet season current. Jetting will be completed during the wet season because the larges waves in the dry season from the north east monsoon will prohibit this activity. This current is weak, with a maximum current of 5 m s^{-1} at the surface, so the potential to transport sediment in the lower layers of the water column will be very low and, were any sediment to be transported any distance from the jetting works. In the areas not influenced by the oceanic current in Mirs Bay the tidal currents are very weak and so transport of the suspended sediment would be very unlikely.

It is possible to provide a calculation of the likely distances sediment will be transported from the site of the jetting based upon loss rate, current speed and an assumed settling velocity/sediment concentration relationship.

Loss rate =	14.4 kg s^{-1} (maximum loss rate calculated above)
Current speed =	0.5 m s^{-1} (a conservative estimate for near bed current speeds, as the current speeds will lower near the bed than at the surface)
Height above sea bed =	3 m (maximum height of the exhaust nozzles)
Initial spread of sediment =	5 m either side of pipeline (assumes the nozzles are angles at 30° from the horizontal)

If it is assumed that the sediment evenly mixes over the lower 3 m of the water column, over the total width of the initial spread of sediment, including the width of the trench, and the flux of water through the site over unit time then the initial concentration will be:

Initial concentration = 0.738 kg m^3 (14.4/(3x13x0.5)

This is a conservative assumption because by using the total width (13 m) the sediment is spread over a larger area which reduces the initial concentration and the settling velocity.

The settling velocity may be calculated by the following relationship which is that which was derived during the WAHMO studies and successfully applied to a number of studies to determine the settling velocity of sediment suspended during dredging works in Hong Kong:

Settling velocity = $0.01xC^1$ (C is the suspended sediment concentration)

= 0.00738 m s^{-1} = 7.38 mm s^{-1}

However, as the sediment settles onto the sea bed concentrations will gradually reduce. In order to account for this reduced concentration the above settling velocity will be halved which gives a value of 3.69 mm s^{-1}.

The time taken for the sediment to settle out will thus be distance (the maximum height of the sediment) divided by velocity.

Time to settle = 813 seconds (3/0.00369)

The distance travelled by the sediment will thus be time multiplied by current speed.

Distance travelled = 407 m (813x0.5)

This will be the maximum distance the sediment travels in the direction of the current. In the worst case the current will be perpendicular to the pipeline route and cause the sediment to travel the furthest away from the jetting operation.

The above discussion has concluded that impacts from jetting would be confined to a dense suspension in the immediate vicinity of the jetting machine which would not be transported far from the machine, settling rapidly onto the sea bed within approximately 400m of the jetting machine in less than 15 minutes. This region 400 m from the jetting machine will be the 'mixing zone' within which the WQOs will be temporarily breached. There are, however, no sensitive receivers within 400m of the pipeline jetting. The closest sensitive receiver is the fish culture zone at Po Toi which is 650 metres from the pipeline. There are, therefore, no predicted impacts to water quality sensitive receivers. Loss of habitat and impacts to mobile ecological sensitive receivers are discussed in the ecology and fisheries sections of this report. In terms of water quality impacts the jetting operation is deemed to be environmentally acceptable due to the small size of the mixing zone, its temporary nature and the fact that no sensitive receivers are impacted.

The trench dredging at the Lamma approach is to be carried out with a small grab dredger operating at low rates of dredging which would give a loss rate of 0.69 kg s^{-1}. This loss rate is more than an order of magnitude less than the loss rates already simulated for the Lamma Extension reclamation, as detailed in *Section 5.4.1* of *Part B*. The impacts to water quality would thus be much less than those for the reclamation construction, which have already been found to be environmentally acceptable. Another point to consider is that the trench dredging would be carried out further offshore and would be exposed to higher tidal currents then the reclamation dredging and thus the rate of dispersion of the sediment would be greater. This would again result in lower impacts than the reclamation dredging. Based on the assessment presented here the impacts to water quality from dredging of the Lamma approach trench would be environmentally acceptable.

Water quality impacts from the trench dredging at the Shenzhen approach were simulated using computer modelling of sediment dispersion. The only identified sensitive receivers in the vicinity were at Ping Chau. Results from the sediment dispersion modelling have been presented as contours of maximum depth averaged suspended sediment concentrations and as maximum concentrations at sensitive receivers. The results are increases above background concentrations, which are not included in the simulations.

The maximum increases in suspended sediment concentrations above background at the sensitive receivers are given in *Table 4.4a* for the dry season and in *Table 4.4b* for the wet season.

Table 4.4a ***Maximum Increases in Suspended Sediment Concentrations above Ambient (mg l^{-1}) at Sensitive Receivers - Dry Season***

Sensitive Receiver	Dry Spring			Dry Neap		
	Surf	Mid	Bed	Surf	Mid	Bed
PC 1	0.2	0.6	0.4	0.1	0.3	0.3
PC 2	0.1	0.3	0.1	0.0	0.3	0.2
PC 3	0.0	0.3	0.2	0.1	0.4	0.3
PC 4	0.1	0.6	0.3	0.1	0.4	0.3

Notes : Shaded areas indicate exceedance of the WQOs

Table 4.4b ***Maximum Suspended Sediment Concentrations (mg l^{-1}) at Sensitive Receivers - Wet Season***

Sensitive Receiver	Dry Spring			Dry Neap		
	Surf	Mid	Bed	Surf	Mid	Bed
PC 1	0.0	0.2	0.1	0.0	0.0	0.0
PC 2	0.0	0.2	0.1	0.0	0.1	0.0
PC 3	0.0	0.2	0.2	0.1	0.0	0.0
PC 4	0.0	0.0	0.0	0.0	0.0	0.0

Notes : Shaded areas indicate exceedance of the WQOs

The results shown in *Tables 4.4a* and *4.4b* demonstrate that at all stations the WQO for suspended sediment concentrations is satisfied.

The contours of maximum depth averaged increases in suspended sediment concentrations above background are shown in *Figures 1, 2, 3* and *4* in *Annex D4-2*. In the dry season the mixing zone, defined by the 0.8 mg l^{-1} contour, would extend from the dredging area to the south east. The area is not shown to come into contact with the Ping Chau coastline. In the wet season the mixing zone, defined by 0.4 mg l^{-1}, is smaller than the dry season. The zone is shown extending in a easterly direction and does not impact at Ping Chau. The contours show the maximum concentrations at the dredging site to be greater than 4 mg l^{-1} for both seasons with a rapid decrease in concentrations away from the immediate vicinity of the dredging.

The rapid decrease in suspended sediment concentrations with distance from the dredging site indicates the majority of the suspended sediment settle onto the sea bed in the vicinity of the dredging works. This means that the sensitive areas will not be subject to high deposition rates.

Based on the above discussion it is concluded that dredging of the pipeline trench at the Shenzhen approach is fully compliant with the WQO and is thus environmentally acceptable.

4.4.5 *Mitigation of Environmental Impacts*

The impacts from the jetting for the gas pipeline laying were assessed to be very localised and of short duration. However, the following operational constraints should be applied.

- The maximum rate of dredging for the Lamma and Shenzhen approach trenches should be limited to 2,400 m^3 day^{-1}; and

- The forward speed of the jetting machine should be limited to a maximum of 1 metre minute^{-1}.

Should unacceptable impacts be found in the course of the EM&A programme, then the following measures could be implemented:

- reducing the speed of the jetting machine; and
- temporary suspension of the works.

The impacts from dredging the trench at the Lamma approach were assessed to be much less than those from dredging at the reclamation construction and as such were assessed to be environmentally acceptable. No particular operational constraints are presented here as mitigation measures.

The impacts from the trench dredging at the Shenzhen approach were assessed to be environmentally acceptable. No particular operational constraints on dredging are required as mitigation measures.

4.5 *OPERATIONAL PHASE*

4.5.1 *Identification and Evaluation of Impacts*

The only operational impacts from the gas pipeline would be if repairs were required to the pipeline. The impacts from this would be similar to those for the construction phase, which have been assessed in *Section 4.4*. No further assessment is considered necessary here, and no mitigation is required.

4.6 *EM&A REQUIREMENTS*

This section provides details of the environmental monitoring programme and presents technical requirements for monitoring water quality during the laying of the gas pipeline. Monitoring will only be required for the jetting operations, and this monitoring will only be undertaken at the beginning of the construction programme unless unacceptable impacts are found. Baseline monitoring will be conducted prior to the commencement of the jetting operation.

Water quality monitoring results will be compared to Action and Limit levels to determine whether impacts associated with pipeline laying are acceptable. An Event and Action Plan provides procedures to be undertaken when monitoring results exceed Action or Limit levels. The procedures are designed to ensure that if any significant exceedances occur (either accidentally or through inadequate implementation of mitigation measures on the part of the Contractor), the cause is quickly identified and remedied, and that the risk of a similar event re-occurring is reduced.

Action and Limit levels will be used to determine whether modifications to the pipeline laying operations are required. Action and Limit levels are environmental quality standards chosen such that their exceedance indicates potential deterioration of the environment. Exceedance of Action levels can result in an increase in the frequency of environmental monitoring, modification of laying operations and implementation of the proposed mitigation measures. Exceedance of Limit levels indicates a greater potential deterioration in environmental conditions and may require the cessation of works unless appropriate remedial actions, including a critical review of plant and working methods, are undertaken.

Water Quality Monitoring

The objectives of the water quality monitoring programme are as follows:

- to determine the effectiveness of the operational controls and mitigation measures employed, and the need for supplementary mitigation measures;
- to check compliance with relevant WQOs; and
- to verify the assessment of impacts.

The relevant WQOs for the Southern and Mirs Bay WCZs, in which the pipeline is to be laid, are as follows:

- *Suspended Solids (SS)*: SS should not be raised above ambient levels by an excess of 30% nor cause the accumulation of SS which may adversely affect aquatic communities.

Monitoring is to be employed as jetting progresses along the pipeline route, and should be designed to demonstrate the localised nature of the impacts from jetting. Control stations are to be positioned upstream of the jetting machine during monitoring at the impact stations. An indicative layout for the monitoring programme is shown in *Figure 4.6a*. In addition to the above described monitoring requirement, monitoring should also be carried out at the Po Toi FCZ when jetting passes within 1km of the FCZ. Impact monitoring should be carried out at the FCZ during such times.

Compliance Assessment

Water quality monitoring results will be evaluated against Action and Limit levels as shown in *Table 4.6a*.

Table 4.6a ***Action and Limit Levels for Water Quality***

Parameters	Action	Limit
SS in mg l^{-1} (depth-averaged)	95th percentile of baseline data or 120% upstream control station's SS at the same tide of the same day[4]	99th percentile of baseline data or 130% of upstream control station's SS at the same tide of the same day[4]

Notes:
1. Depth-averaged is calculated by taking the arithmetic mean of all three depths
2. For SS and Tby, non-compliance of the water quality limits occurs when monitoring result is higher than the limits.
3. All the figures given in the table are used for reference only and the EPD may amend the figures whenever it is considered necessary.
4. Whichever of the two values is greater shall be used for the Action and Limit Levels.

Water Quality Mitigation Measures

If unacceptable impacts are found at any stage of the monitoring programme then suitable mitigation should be employed. Such mitigation measures could include:

- reducing the speed of the jetting machine;
- reducing the pressure of the water jets; and
- temporary suspension of the works.

4.7 SUMMARY AND CONCLUSIONS

The impacts from the gas pipeline have been assessed in terms of construction and operation.

Construction impacts were assessed in terms of the laying of the pipeline which would be carried out using two methods:

- dredging trenches and the Lamma and Shenzhen approaches; and
- jetting for the remainder of the pipeline route.

The trench dredging at the Lamma approach was assessed qualitatively with reference to the sediment dispersion modelling results for the dredging at the Lamma Extension reclamation site (see *Section 5.4.1* of Part B). It was determined that the impacts from the trench dredging would be very small compared to the impacts from the reclamation construction because the loss rate for the trench dredging would be more than 10 times less than those simulated in reclamation dredging. This operation was assessed to comply with the WQOs and would be environmentally acceptable.

Computer modelling was used to simulate the loss of sediment to suspension during the dredging operations at the Shenzhen approach trench. Increases above background in suspended sediment concentrations above 1 mg l^{-1} were only found in the vicinity of the dredging. Suspended sediment concentrations above background at the nearest sensitive receiver, Ping Chau, were found to be less than 1 mg l^{-1}. This operation was also found to be in compliance with the WQOs and so was found to be environmentally acceptable.

The assessment for the jetting operations concluded that sediment would be suspended into the water column during jetting but that this sediment would rapidly settle back onto the sea bed. This means that there would be little transport of suspended sediment away from the dredging operations and would not impact upon sensitive receivers. This operation was also determined to be environmentally acceptable.

An Environmental Monitoring and Audit programme was devised to confirm that the assessment of the localised impacts jetting operations was accurate and that the operation would be environmentally acceptable.

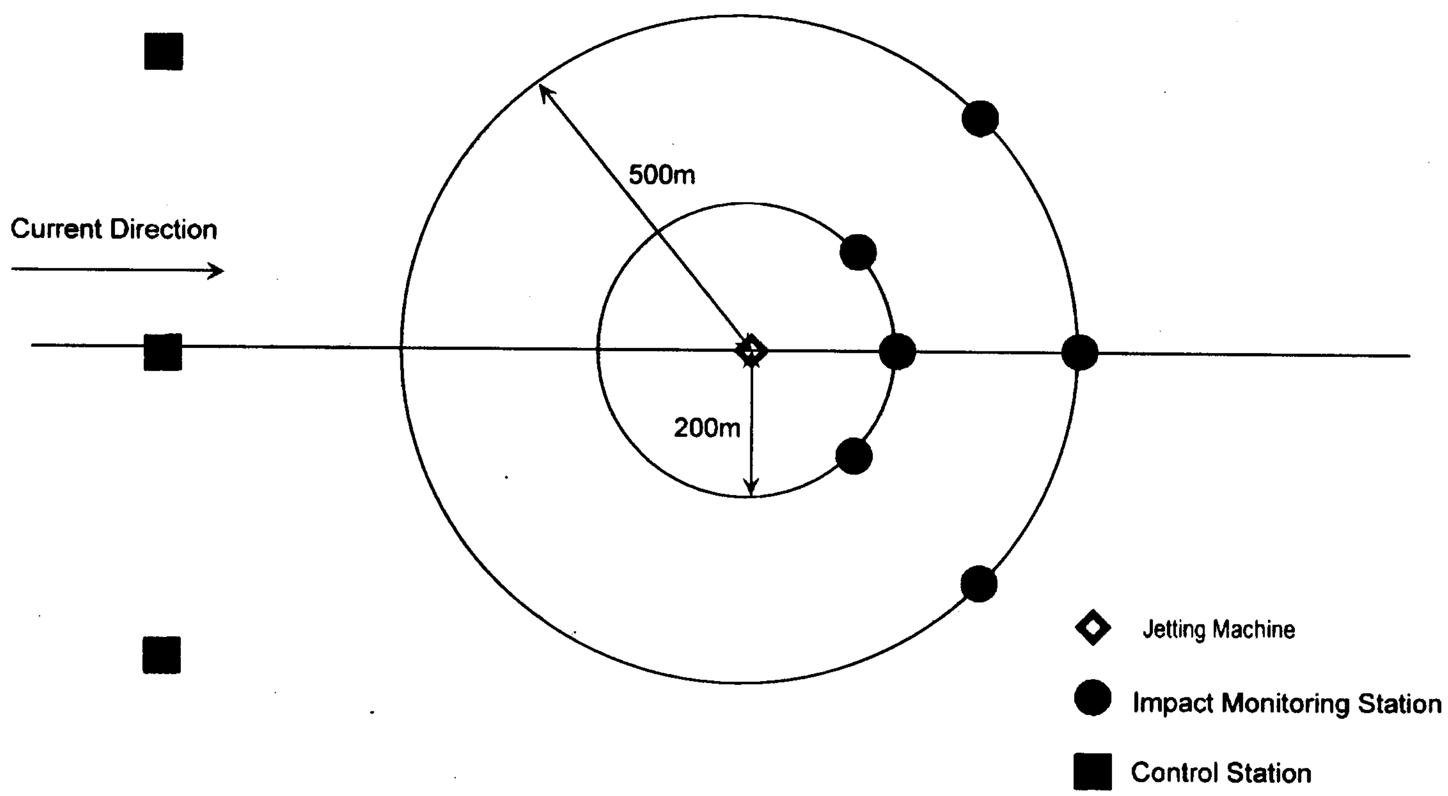

FIGURE 4.6a

INDICATIVE LOCATIONS OF MONITORING STATIONS FOR PIPELINE LAYING USING JETTING

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5 MARINE ECOLOGICAL IMPACTS

5.1 INTRODUCTION

This marine ecological assessment of the gas pipeline route from Shenzhen to the proposed Lamma power station extension has been based on the Consideration of Alternatives for the pipeline route (*Section 1*) and on the Project Description (*Section 2*) as presented above. This section of the report presents the findings of the marine ecological impact assessment. The report presents baseline information on the potentially affected existing marine ecological resources and also presents the findings of various field surveys conducted for the assessment.

The objectives of the assessment are as follows:

- to establish the ecological importance of the habitats affected by the works associated with the installation of the gas pipeline from Shenzhen to the proposed Lamma Extension;
- to identify marine ecological sensitive receivers;
- to assess the scale of possible marine ecological impacts from the installation of the gas pipeline;
- to identify any significant or unacceptable impacts on marine ecological resources from the installation of the pipeline;
- to identify any necessary mitigation measures and evaluate residual impacts; and
- to assess the need for a marine ecological monitoring and audit programme.

5.2 BASELINE CONDITIONS

5.2.1 Literature Review

The literature on the marine ecology of the waters surrounding the proposed pipeline route is variable. As with the majority of Hong Kong it appears that certain areas have been comprehensively studied whereas others have not. Due to the limited literature available, it was decided that a number of surveys would need to be undertaken to support complete and robust assessment of impacts to marine ecology. The findings of the field surveys are presented below as well as an outline of information on marine ecological resources based on information gathered through desk-top reviews of available literature.

Soft Benthos Assemblages

The most recent and comprehensive examination of these benthic communities was completed in 1997 for the Civil Engineering Department by ERM. The survey areas investigated were the Eastern Waters and East of Ninepins (see *Figure 10.3a* in *Section 10* of Part B)[18][19].

(18) ERM Hong Kong Ltd (1997) Seabed Ecology Studies - Eastern Waters Final Report. Report to the Civil Engineering Department, Hong Kong Government.

The Eastern Waters survey was primarily focused to act as a reference for assessing the effects of a proposed marine borrow area and the East of Ninepins survey was used to assess the effects of open water disposal. The Eastern Waters study found polychaetes to represent 74% of the identified individuals, although only 10% of the total biomass. By contrast to this, molluscs constituted only 5% of the identified individuals but provided 74% of the total biomass recorded. The overall mean abundance was low in comparison to other sites in Hong Kong waters. Overall mean biomass levels recorded from the Eastern waters were typical of waters in the territory, at 33 g m^{-2} (Shin and Thompson recorded an average value of 35 g m^{-2} from Hong Kong waters in 1982).

Findings from the East of Ninepins Study stated that there were noticeable differences between reference areas and areas of open water disposal sites, in both physical and biological characteristics. Mean total abundance of individuals was found to be higher in samples taken in areas of open water disposal, although the mean total biomass was lower. The study concluded that the open water disposal sites had a mixed sediment type with low redox penetration depths, therefore little oxygen penetration, colonized by the opportunistic, hardy and pollution tolerant Spionidae polychaetes, rather than the more common dominating polychaete found in Hong Kong waters, Nemertinea.

Hard Surface Assemblages

As part of the Coastal Ecology Study, surveys were conducted at a number of locations at areas that are considered to be within close proximity to the gas pipeline route (*Figure 10.3a* in Part B, *Section 10*). A review of the results of the relevant surveys is presented below. For the purpose of this report, site description is based on the terminology provided in the cited dive survey reports in terms of species abundance and diversity.

Surveys carried out off Sung Kong and Waglan[20] and other surveys around Po Toi and Beaufort Island[21] reported that the area contains a range of coral communities which vary depending on substrate type. The soft coral community is rich below -20 mPD at Waglan Island due to the steeply sloping rock walls, with *Dendronephthya* spp dominating. Gorgonians are also abundant and diverse below this depth at Waglan Island, with *Melithaea* spp found to be most abundant. Hard corals were not as abundant or diverse as compared to other reefs in Hong Kong, except for on the western walls of Sung Kong, where the species *Acropora candelabrum* and *Plesiastrea versipora* exhibited the greatest cover (6%). It is suspected that a combination of wave action and sediment accumulation are responsible for the lower abundance and diversity of hard corals at Waglan Island. The flexible structure and vertical growth of the gorgonians prevents sediment accumulation and may account for their abundance in the survey site.

The southern coasts of Po Toi were surveyed during the Coastal Ecology Studies, however these surveys were made during the dredging works associated with the Ninepins and Southern Borrow Areas taking place at the same time, therefore

(19) ERM Hong Kong Ltd (1997) Seabed Ecology Studies - East of Ninepins Final Report. Report to the Civil Engineering Department, Hong Kong Government.

(20) Binnie Consultants Limited (1996) Coastal Ecology Studies: Sung Kong / Waglan Quantitative Survey. Final Report. For the Geotechnical Engineering Office, Civil Engineering Department.

(21) Binnie Consultants Limited (1995) Marine Ecology of Hong Kong - Report on the Underwater Dive Surveys (October 1991 - November 1994) - Volume II. For the Geotechnical Engineering Office, Civil Engineering Department.

ecological assessment was difficult due to poor visibility[22]. The southwest point at Nam Kok Tsui, and the north and west sides of Mat Chau were described as being slopes with barnacles, tunicates, anemones, urchins and oysters mainly inhabiting the surfaces of the rock. The majority of the surface surveyed was described as being bare rock to a depth of - 5 mPD. Below this depth the substrate is described as bed rock and boulders with few hard corals. Colonies of soft corals primarily made up of sea whips was recorded at the depth of -15 mPD. Overall the site was rated as being of medium conservation value.

Breakers Reef is located in the middle of Mirs Bay adjacent to Shek Ngau Chau and has long been regarded, by recreational divers and sport fishermen, as one of the most diverse coral reefs in Hong Kong waters. Soft corals are extremely common and diverse here with the most abundant species *Dendronephthya* spp completely covering large patches of the seabed. In relation to all the dive sites studied during the Coastal Ecology Study, it was reported that Breakers Reef has the most abundant and diverse soft coral communities in all of Hong Kong waters[23]. Reef fish, including butterfly fish, chicken grunts and small grouper are regularly observed here and often found in large numbers. The coral communities are similarly diverse with hard corals, especially *Tubastrea aurea*, encrusting the upper slopes of the reef. Below -15 mPD gorgonians are found to exhibit high cover and diversity. It has been suggested that Breakers Reef plays an extremely important role in sustaining both Hong Kong's coral and reef fish communities. The reef is also known as a common area for sightings of some of Hong Kong's larger species of fish, including eagle rays, black sting rays, tuna, mackerel, moray eels and jacks. The presence of such fish demonstrates a healthy reef and, therefore, places Breakers Reef as a site of high marine ecological importance.

The sea around Ping Chau is presently being studied by scientists from the Chinese University of Hong Kong to assess its potential for designation under the *Marine Parks Ordinance (Cap. 476)* as a Marine Park/Marine Reserve with the results expected in early 1999. The results of this assessment shall be available towards the end of 1998. However, the Coastal Ecology Studies described Ping Chau as being especially rich in hard corals, with a total of 30 species recorded, representing 61% of all hard coral species found in Hong Kong [24].

The coral habitat around Shek Ngau Chau was found to be less diverse than Ping Chau with hard corals common, but with approximately 30% less abundance and diversity. Findings from these surveys also show there is evidence of adult corals and active coral reproduction in the area reflecting its ecological importance. There is also evidence of the reef providing shelter for large numbers of shrimp larvae, which in turn provide food for numerous fish[25]. Surveys conducted on the southwest coast of Lamma Island under the present Study indicated that hard and soft corals were present, though at low percentage cover, at Ha Mei Tsui. Full details on the surveys and results are presented in *Part B - Section 10* of this EIA Report.

(22) Binnie Consultants Limited (1995) *op cit.*
(23) Binnie Consultants Limited (1995) *op cit.*
(24) Binnie Consultants Limited (1996) Coastal Ecology Studies: Ping Chau Quantitative Survey. Final Report for Geotechnical Engineering Office, Civil Engineering Department.
(25) Binnie Consultants Limited (1995) *op cit.*

Sea Turtles

Three species of sea turtles have been reported within Hong Kong waters, however, only one of those species, the Green Turtle *Chelonia mydas*, has been identified as nesting[26]. Although there have been sightings of the Green Turtle, and other species, on a number of beaches in Hong Kong, the only known nesting beach is Sham Wan on the south of Lamma Island. The last recorded sighting of a nesting sea turtle at Sham Wan was during the nesting season of summer 1998. Based on this information the Agriculture and Fisheries Department are currently undertaking a feasibility study to investigate the possibility of designating the south of Lamma Island as a potential Marine Park/Marine Reserve under the Marine Parks Ordinance.

Marine Mammals

The Chinese White Dolphin (*Sousa chinensis*) and the Finless Porpoise (*Neophocaena phocaenoides*) are the only species of marine mammal regularly sighted in Hong Kong waters.

Chinese White Dolphin *Sousa chinensis*

The local population of *Sousa chinensis* is reported to be centred around the Pearl River Estuary and Hong Kong waters are thought to represent the eastern portion of its range[27]. North Lantau represents the major area of distribution of *Sousa* in Hong Kong waters, and is the only place in Hong Kong where dolphins are seen year round. Individuals are most frequently sighted in the western part of these waters around the Sha Chau & Lung Kwu Chau Marine Park and the Chek Lap Kok platform.

The Lamma Island area does not appear to represent important habitat for *Sousa* in Hong Kong[28]. Lamma Island appears to be at the eastern edge of the population's range. Only four sightings of this dolphin have been made during extensive surveys in the Lamma Island area since early 1996. Of the four sightings, three of them occurred during August with the other during early September. Based on the above information the Chinese White Dolphin is not considered as an issue of concern to the project and will not be discussed further.

Finless Porpoise *Neophocaena phocaenoides*

The finless porpoise is a small cetacean endemic to southern and eastern Asia and is protected under CITES Appendix I. The porpoises distribution is centred in a narrow coastal band from the Persian Gulf in the west to Japan in the east[29]. The porpoise is also recorded as inhabiting the Yangtze River system in China. The preferred habitat of this porpoise has been reported as including the following[30]:

(26) McGilvray S & Geermans S (1997) The Status of the Green Turtle in Hong Kong and an Action Plan for its Survival. The Hong Kong Marine Conservation Society.

(27) Jefferson TA (1998) Population Biology of the Indo-Pacific Hump-backed Dolphin (*Sousa chinensis* Osbeck, 1975) in Hong Kong Waters. Final Report to AFD.

(28) Jefferson TA (1998) *op cit.*

(29) Reeves RR, Wang JY, Leatherwood S (1997) The finless porpoise, *Neophocaena phocaenoides* (G Cuvier 1829): A summary of current knowledge and recommendations for conservation action. Asian Marine Biology 14: 111-143.

(30) Shirakihara M, Shirakihara K, Takemura A (1994) Distribution and seasonal density of the finless porpoise *Neophocaena phocaenoides* in the coastal waters of western Kyushu, Japan. Fisheries Science 60 (1): 41-46.

- inshore waters (within 5 km of the shore);
- waters protected from heavy seas and storm conditions;
- sandy or soft seabed; and
- water depths of less than 50 m.

In Hong Kong, until recently, little information was available regarding the distribution and abundance of the finless porpoise in local waters. Surveys were conducted for 12 months between December 1996 and November 1997. Two line transects were followed through southern water five times per month covering the sea areas between Cheung Chau and east of Waglan Island. Full details of the surveys, methodology and results are presented in *Annex D5 - 1 Marine Mammals Survey Report*. The surveys revealed that the finless porpoise is the most common and most important species of cetacean in the Lamma Island area and these waters appear to be the most important habitats in Hong Kong for this marine mammal. The presence of the porpoise in the waters around Lamma Island appears to vary on both a spatial and temporal basis.

The East Lamma Channel does not appear to be an area frequently used by the porpoises, a finding attributed to the heavy shipping traffic in the channel. Few porpoises have been sighted to the north of Lamma Island or in the vicinity of the existing power station (*Figure 5.2a*). The main areas used by the porpoises around Lamma Island are the nearshore waters off the southwestern coast (Ha Mei Tsui peninsula). The sightings to date of the porpoise in the waters around Lamma Island indicate that the only months of the year when this cetacean is absent are July and August (*Figure 5.2b*). During these months the porpoise is thought to move east to the waters around Po Toi, Waglan and Sung Kong Islands.

Preliminary abundance estimates indicate that the porpoise population around Lamma Island is largest during spring (47 individuals) and lowest during summer (2 individuals). In the waters around Po Toi Island the population is estimated to be 52 individuals in the spring and 12 in the summer (*Table 5.2a*). However, it should be noted that the coefficients of variation for these estimates are high, and thus they should be considered tentative.

Table 5.2a ***Abundance Estimates and Associated Parameters for the Finless Porpoise Neophocaena phocaenoides in the Waters Surrounding Lamma and Po Toi Islands.***

Area	Season	Number of Sightings	Sighting Rate (100 km^{-1})	Density (km^{-2})	Abundance	95% Cl	%CV
Finless Porpoise							
Lamma	Winter	16	1.56	0.15	28	13-61	40
	Spring	26	2.23	0.26	47	22-99	39
	Summer	4	0.45	0.01	2	1-8	60
	Autumn	11	1.26	0.03	5	3-11	34
Po Toi	Winter	2	0.79	0.04	7	1-80	123
	Spring	3	0.41	0.27	52	4-632	93
	Summer	12	1.60	0.10	18	7-45	47
	Autumn	16	2.57	0.12	23	10-49	38

Notes:-
CV - Coefficient of Variation
Cl - Confidence Limits

Information from survey work conducted by the Ocean Park Conservation Foundation indicates that the southwestern Lamma coast may be an important calving and nursery area for the finless porpoise. The seasons when peak abundances have been observed (winter and spring) are thought to represent the calving season. Small calves have been observed in this area.

5.2.2 *Field Surveys*

Introduction

It is HEC's intention that the new power station will be fuelled by gas to be provided dy a dedicated new pipeline from the proposed regional liquefied natural gas (LNG) terminal at Cheng Tou Jiao, in eastern Shenzhen. In order to define the constraints associated with the laying of the gas pipeline from the proposed LNG Terminal in Cheng Tou Jiao to the proposed gas-fired power station at Lamma extension, ERM Hong Kong Ltd undertook a desk-top study of the likely environmental constraints of these works (see *Section 1* above).

Based on the above identification of constraints, two possible routes for the gas pipeline were selected and are shown in *Figure 1.7a*. These routes follow generally the same path, passing from the Cheng Tou Jiao landfall, south through Mirs Bay and round past the Po Toi Island group along a southerly approach beside the West Lamma Channel to the Lamma power station extension. In order to investigate whether these routes are feasible on the basis of geophysical properties, a comprehensive survey and desk top study was conducted by EGS (Asia) Ltd during the month of June 1998. The objectives of the project were to carry out a preliminary desk top study of the proposed offshore routes, to map the sea bed using seismic, side scan and sonar sounding systems underlying significant geological horizons, and to define other parameters along and close to the proposed route which would affect pipeline route positioning.

The findings of the survey were that both of the proposed routes were feasible within the constraints outlined in the report. The geophysical survey of the proposed pipeline route surveyed an area 300 m either side of the recommended route. Within this corridor the seabed profile revealed numerous anchor and trawl scars, areas of dumped materials and areas of high reflectivity. Analysis of the detailed side scan pictures of the seabed revealed a number of areas of high reflectivity on the seabed, particularly around the west and north west of Ping Chau Island. As Ping Chau is currently being proposed as a future Marine Park/Marine Reserve, based on the coral assemblages found in the subtidal zones at the island, the areas of high reflectivity were identified as an area of concern. In order to address this concern a survey covering these areas and beyond was conducted using a Remotely Operated Vehicle (ROV) scoping the seabed to investigate the sites and identify their ecological value. The methodology and results of this survey are discussed below.

Methodology

The objective of the ROV survey was to cover as much ground as possible on and around the areas of high reflectivity in order to assess their ecological value. As a result, a total of 13 transects were laid out covering the previously surveyed corridor perpendicular to the recommended pipeline route. Each transect was 600 m in length and the location of the transects is shown in *Figure 5.2c*. The survey was conducted by EGS (Asia) Ltd during September and October 1998,

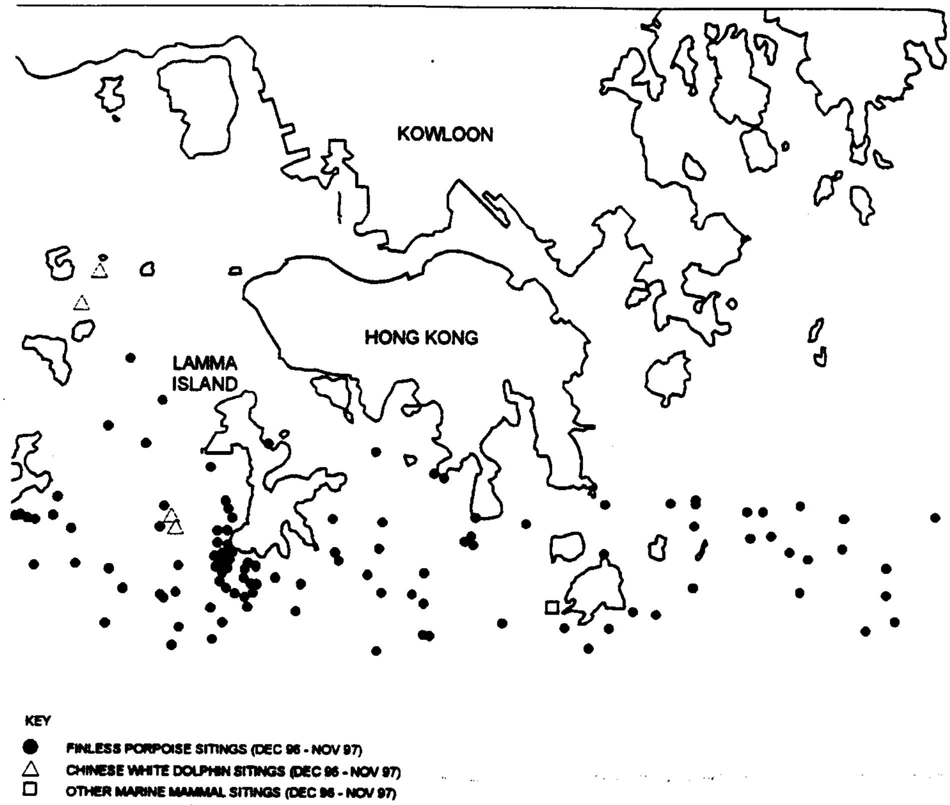

Figure 5.2a: Distribution of sightings of the Finless Porpoise *Neophocaena phocaenoides* in the southern waters of Hong Kong. Surveys were conducted along line transects during the period December 1996 to November 1997. One point is equivalent to one group of porpoises containing 1 - 3 individuals.

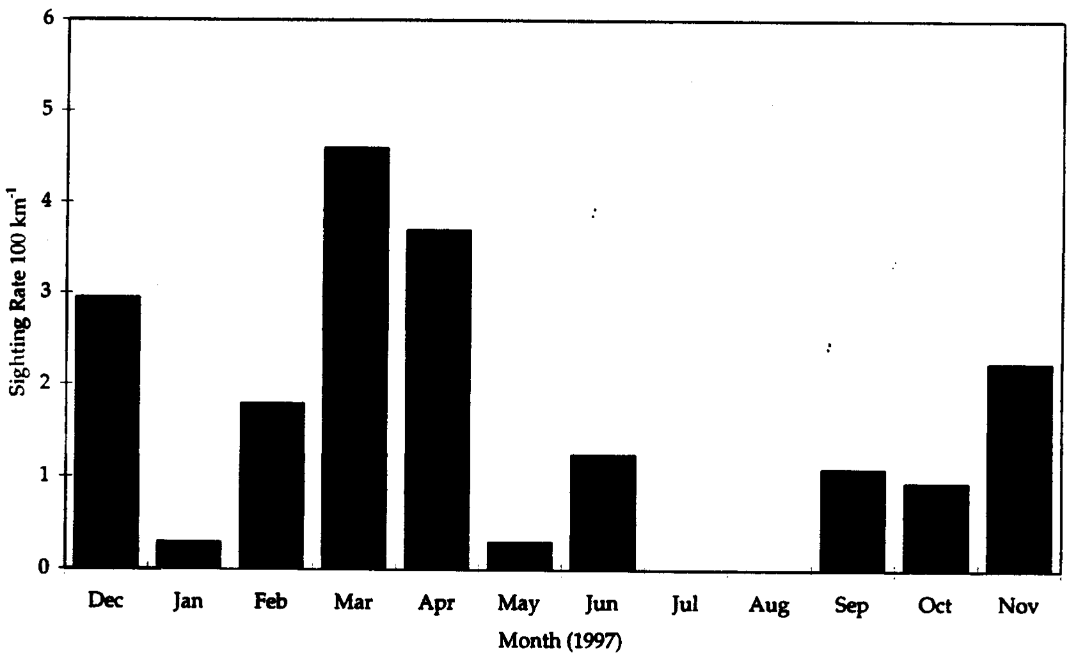

Figure 5.2b: Monthly sighting rate of groups of the Finless Porpoise *Neophocaena phocaenoides*, in the Lamma Island Area. Surveys were conducted along line transects during the period December 1996 to November 1997. Data are number of groups sighted per 100km of line transect.

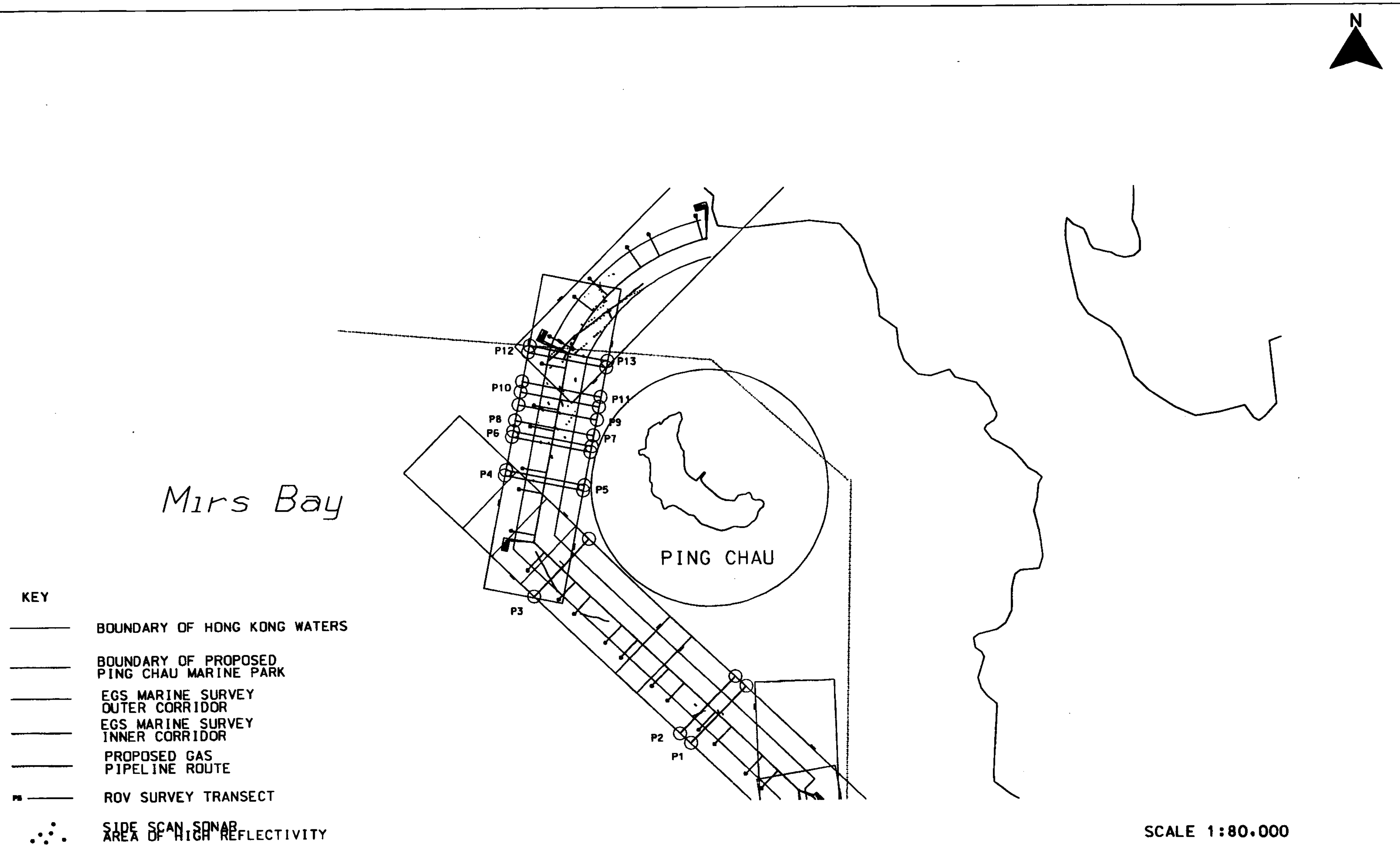

FIGURE 5.2c

REMOTELY OPERATED VEHICLE (ROV) SURVEY SITES AT PING CHAU

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using exactly the same methodology as was conducted for the ROV survey of the proposed reclamation site (Part B, *Section 10.3*). Under the prevailing survey conditions the ROV could capture images approximately 1 m either side of the transect line.

Results

Analysis of the footage recorded during the ROV survey at the 13 transects showed that the seabed covered by the ROV was revealed to be flat and muddy, with few features other than many burrow holes. On transect 11, 12 and 13 occasional solitary sea whips, of the order Gorgonacea, were seen on the footage, however, these were sporadic and of very low numbers. Similarly, two solitary sea anemones were recorded on transect 13. With the exception of these organisms, no epifaunal organisms or corals were identified within the survey. No areas were identified as being of any ecological value and therefore of a constraint to the pipeline installation. It has been concluded that the areas of high reflectivity as seen on the technical drawings from the geophysical surveys are probably areas of particularly dense clay or alluvium. Although the ROV survey was not able to reveal the abundance and diversity of infaunal benthic organisms it is considered that the lack of epifaunal organisms indicates that the sites suffers from some form of disturbance (eg trawling, storms, wave scour). The benthos is less likely , therefore, to support a diverse and abundant infaunal community.

5.2.3 *Ecological Importance*

According to the Technical Memorandum of the *EIAO (EIAO TM) Annex 8* the ecological value / importance of a habitat can be evaluated using the following criteria:

- naturalness;
- size;
- diversity;
- rarity;
- re-creatability;
- ecological linkage;
- potential value;
- nursery ground;
- age; and
- abundance.

The criteria listed above have been applied to the information gathered or reviewed on the marine ecology the gas pipeline route, and findings are presented below (*Table 5.2b*).

Table 5.2b ***Ecological Value of the Marine Habitats & Species Present Along the Gas Pipeline Route***

Criteria	Soft Bottom Habitat	Hard Bottom Habitat	Open Waters
Naturalness	A large proportion of the soft bottom habitat appears to be disturbed by human impact either by fishing operations or sand borrowing activities.	Hard bottom habitats in the area are comparatively undisturbed.	In comparison with inshore areas in Hong Kong the offshore water quality is good.

Criteria	Soft Bottom Habitat	Hard Bottom Habitat	Open Waters
Size	Majority of the Study Area (90 km long) is composed of soft bottom habitat.	Few hard bottom habitats are located within the Study Area.	n/a
Diversity	The open seabed route of the pipeline supports assemblages of low diversity.	Diverse and abundant assemblages at Ping Chau, Breakers Reef and Victor Rock.	n/a
Rarity	No organisms that are considered rare have been reported from the area.	No organisms along the pipeline route were considered rare but within the Study Area as a whole many hard coral assemblages are present.	The protected finless porpoise (*Neophocaena phocaenoides*) (CITES Appendix I) is known to seasonally inhabit the waters around Lamma Island and the Po Toi Islands Group.
Re-creatibility	Given that the natural backfilling of the trench containing the pipeline occurs, colonisation of the seabed should lead to a reinstatement of pre-pipeline laying conditions.	No permanent impacts to hard bottom habitats.	No permanent impacts to open water habitat.
Ecological Linkage	The surrounding environment contains few natural areas of undisturbed soft bottom seabed but many areas of high ecological value hard bottom seabed. Although remote from the route the proposed Marine Park/Reserves of South Lamma and Ping Chau represent areas of high ecological value.		
Potential Value	Unlikely that the soft bottom habitats can develop conservation interest.	Hard bottom habitats at Ping Chau and Breakers Reef are not within the pipeline route but are of high conservation value.	The waters surrounding the southern shores of Lamma Island and west of the existing power station are of high conservation value due to the seasonal importance of the habitat to the finless porpoise.
Nursery Area	All organisms that settle on the seabed do so through planktonic dispersal.	All organisms that settle on the seabed do so through planktonic dispersal.	The waters around southwest Lamma Island are thought to be an important calving and nursery area for the finless porpoise.
Age	The sediments in the area are constantly disturbed through trawling and storms and the fauna present in the seabed are typically short lived.	Coral colonies outside of the pipeline route are likely to be > 10 years old.	The lifespan for the finless porpoise is as yet unknown although it is predicted to be > 15 years.
Abundance	Sediment infauna abundances are low compared to other sites in Hong Kong.	No hard bottom habitats are present within the pipeline route.	Abundance of the finless porpoise is seasonal and peaks during the spring.
SUMMARY	The seabed of the pipeline route is considered to be disturbed by storms and trawler activity and generally of low ecological value supporting low abundances of common infaunal species. **Ecological Value - Low**	The hard bottom habitats of Ping Chau, Breakers Reef and Victor Rock, avoided by the pipeline route, are of high ecological value. **Ecological Value - High**	The importance of the water around the Po Toi Islands and Lamma Island classifies these waters as of ecological value for the finless porpoise. **Ecological Value - High**

Note: n/a: not applicable

5.3 *Impact Assessment & Prediction*

Although a final decision has yet to be made over the routing for the gas pipeline there exist two options, one of which is preferred. Both of the possible routes follow generally the same path, however, there are two distinguishable areas where the routes diverge and pass over differing areas of the seabed with a maximum total length of 90 km. Heading from the LNG terminal in Shenzhen, the first of these areas is in the eastern waters where the preferred route verges on a more easterly course. By following this route potential impacts are expected to be minimised due to the lower ecological value of this area in comparison with the alternative route.

The second divergence is around the west coast of Lamma Island. Again, by following the preferred route the possible impact of the cable routing will be minimised as the distance from the proposed South Lamma Marine Park/Reserve is increased. The proposed South Lamma Marine Park/Reserve, which is at present the focus of a feasibility study[(31)], is considered of high ecological value due to Sham Wan beach being identified as the only known nesting ground for the Green Turtle, *Chelonia mydas*, in Hong Kong[(32)].

The gas pipeline will be a submerged pipeline embedded in the seabed at a depth of 3 to 3.6 m. The pipeline will be armoured with rockfill of mattress cover in areas near shipping zones. Impacts to water quality are expected to occur through the deployment phase of the pipeline, however, these impacts will be of a small scale due to the localised impact.

Direct Impacts

No long term direct impacts are expected to occur through the deployment of the gas pipeline. Short term impacts are predicted to occur as a result of the dredging operations associated with the deployment, although once these operations have ceased marine ecological resources in the affected area are expected to return due to recolonisation of the seabed by benthic fauna. The width of the trench in the seabed that will be jetted is 2m and is according to *Table 5.2b* regarded to be of low ecological value.

Indirect Impacts

Indirect impacts are predicted to occur through elevations in SS and the resulting effects described above (Part B, *Section 10.4.1*) as a result of the dredging operations. Due to the methodology proposed to be employed to deploy the pipeline, only a low disturbance to the seabed is predicted to occur. Along the majority of the route the pipeline will be laid using the liquefaction method of jetting. In this method low pressure jets are employed to liquefy the seabed sediment which then allows the pipeline to sink into the trench. This method has previously been demonstrated to meet environmentally acceptable standards in Hong Kong[(33)(34)]. The majority of the affected sediment will form a fluidised suspension of sediment and water close to the seabed. This fluidised layer will very rapidly settle back onto the seabed in the immediate vicinity of its original location. A small portion of the sediment (50 %) may be lost to suspension but

(31) AFD (unpublished) Feasibility Study on The South Lamma Marine Park/Reserve.

(32) McGilvray S & Geermans S (1997) *op cit.*

(33) ERM (1996) Submarine Cable from Sha Chau to Lung Kwu Chau: Independent Environmental Review. Final Report for the China Light and Power Company Ltd.

(34) ERM (1996) Focussed Environmental Impact Assessment (EIA) Study: Laying a Second 132kV Submarine Transmission Link from Lau Fau Shan to Shekou. Final Report for the China Light and Power Company Ltd.

this lost sediment is likely to remain in the lower three metres of the water column and settle back onto the seabed in a short period of time (approximately ten minutes), having been transported only a short distance (400 m).

The remainder of the route (1 km approach to the LNG terminal in Shenzhen and 1 km approach to the power station) will be laid using grab dredging. Mathematical calculations on the loss rates due to this form of pipe laying have shown that the loss rate will be at least 14 times less than the values for the Lamma power station reclamation site dredging. Additionally the sites of the trench dredging will be more exposed in terms of tidal currents than the reclamation site which will mean that concentrations are further reduced due to greater dispersion. Based on these calculations the marine ecological resources in the area are not expected to be adversely affected. Similarly, the identified hard bottom habitat sensitive receivers at Ping Chau, are also not predicted to be affected by the works associated with the gas pipeline installation (elevations of < 1 mg L^{-1}). The water quality impact assessment has indicated that the grab dredging works at the approaches to Lamma Island and Shenzhen are fully compliant with the WQO (in terms of SS elevations) and are thus environmentally acceptable (*Part D - Section 4.4.4*).

Impacts to Hard Surface Habitats

Habitats where corals were recorded in sufficiently high abundances to warrant classification as high ecological value (and thus a marine ecological sensitive receiver) are the southwestern tip of Lamma Island, on Po Toi Island, on Waglan Island, at Breakers Reef and on Ping Chau. The routing for the gas pipeline was conducted so as to avoid these areas of hard surface habitat. Although this has been achieved, an assessment of impacts to these habitats through perturbations to water quality during the pipeline laying is included here for completeness.

As mentioned above, the water quality impact assessment indicates that suspended sediment will only travel 400 m from the jetting works and will settle within 10 minutes. All of the hard substrate marine ecology sensitive receivers are located greater than 400 m from the pipeline (Ping Chau = 1.36 km, Breakers Reef = 2.74 km, Po Toi = 0.65 km, Waglan = 2.90 km and S & SW Lamma = 1.6 km). This, therefore, infers that unacceptable impacts to corals arising from elevated SS levels would not occur.

Impacts to Marine Mammals

The Chinese White Dolphin (*Sousa chinensis*) and the Finless Porpoise (*Neophocaena phocaenoides*) are the only species of marine mammal regularly sighted in Hong Kong waters. Sightings of the Finless Porpoise have mainly been in the coastal waters of southwest Lamma Island and thus is an issue of concern for this Study. The southwestern part of Lamma Island shows a seasonal pattern in sightings of the dolphin. During the summer and autumn months few dolphins have been observed in the area, however, during spring and winter they have been regularly sighted. The construction operations associated with the deployment of the gas pipeline will have to take into account the occurrence of *Neophocaena phocaenoides* in the water around southwest Lamma Island and the potential impacts to them. Impacts to *Neophocaena phocaenoides* may arise through the following activities during construction of the gas pipeline:

Vessel Traffic: The construction of the gas pipeline could potentially result in an increase in marine traffic and underwater noise affecting *Neophocaena phocaenoides*. Studies have shown that because of the efficient transfer of sound in water, cetaceans can detect noises associated with vessels similar to dredgers at distances up to approximately 5 km. A moderate increase in the number of large, slow-moving (less than 10 knots) vessel traffic in the area should not cause a significant impact to dolphins or porpoises. Smaller, faster outboard-driven boats would be more of a concern, because of the fast approach speeds and higher potential for high frequency noise. However, it is not anticipated that vessels associated with laying of the gas pipeline will be of the latter type. In order to mitigate impacts to finless porpoises during the spring calving season and peak in abundance no pipeline laying will take place in the area off the southwestern Lamma coast during this period. Instead according to the current work programme jetting works for the pipeline laying will take place during the months of July - October, a period when the finless porpoise is rarely sighted in the area.

High & Low Frequency Noise: Cetaceans are animals that rely heavily on acoustic information to communicate and to explore their environment. Therefore, any noise that disrupts communication or echolocation channels would be potentially harmful. In general, low frequency noise would be of little consequence to the finless porpoises, which are relatively insensitive to sounds within and below our hearing range (ie, less than about 20 kHz). If there is a high frequency noise component (especially in the range of 100 - 140 kHz) to the construction activities, this would be a serious concern. Dredging and large vessel traffic generally results in mostly low frequency noise and, therefore, would not likely cause impacts to the finless porpoise.

Disruption to Food Supply: Mobile animals such as marine mammals have the ability to avoid areas where SS levels have increase, thus avoiding any impacts. Impacts can occur to these mammals as an indirect result of increased SS levels. The laying of the gas pipeline may cause perturbations to water quality which have the potential to impact the fisheries resources of the southwest Lamma area. *Neophocaena phocaenoides* is thought to be an opportunistic feeder with known prey including crustaceans (shrimps and prawns), cephalopods (squids and octopus) and small pelagic fish of low commercial value (anchovies - Engraulidae, croakers - Sciaenidae, sardines - Clupeidae). They are thus likely to be affected by changes in key water quality parameters (such as SS and DO) arising from the development. A deterioration in water quality is likely to cause these mobile fish to move out of the area thus interfering with the porpoises normal feeding patterns. As mentioned above for corals, the elevations of SS in areas where finless porpoises are frequently sighted (ie S Lamma Marine Park in *Part B Section 5 - Figure 5.4g*) are small and of short duration, and within environmentally acceptable levels (as defined by the water quality objectives for the southern water control zone). Consequently fisheries resources are not expected to move out of these areas (refer to *Parts B - Section 11* and *D - Section 6*). It is thus expected that unacceptable impacts to the high ecological value finless porpoise habitat off the SW coast of Lamma Island arising from elevated SS levels will not occur.

Impacts to the South Lamma Potential Marine Park / Marine Reserve

AFD are at present conducting a feasibility study examining the potential for the south Lamma area to be designated as a marine park or marine reserve. Although a boundary for the marine park has yet to be proposed it is likely that it will encompass the coastal habitats running south and east from Ha Mei Tsui headland on the southwest of Lamma Island to Tung O Wan on the east. This area would likely include the green turtle nesting area on the sandy shore at Sham Wan and the finless porpoise habitat off Ha Mei Tsui. Dispersed plumes of suspended sediment from the grab dredging at Lamma approaches and from pipeline jetting are not predicted to reach the likely area for the marine park/reserve (refer to water quality assessment discussed in *Part D - Section 4*). Sediment plumes are not predicted to reach the southern Lamma coast and will, therefore, not impact Sham Wan.

Impacts to the Ping Chau Potential Marine Park / Marine Reserve

AFD are at present conducting a feasibility study examining the potential for the water around Ping Chau to be designated as a marine park or marine reserve. Although a boundary for the marine park has yet to be proposed it is likely that it will encompass the coastal habitats and water around the island. Dispersed plumes of suspended sediment from the grab dredging at Shenzhen approaches and from pipeline jetting are not predicted to reach the likely area for the marine park/reserve (refer to water quality assessment discussed in *Part D - Section 4*). Sediment plumes are not predicted to reach the Ping Chau coastal waters and will, therefore, not impact the potential marine park/reserve.

5.4 *IMPACT EVALUATION SUMMARY*

5.4.1 *Marine Ecology Sensitive Receivers*

Information presented in the review of literature and in the results of comprehensive field surveys has indicated that the Study Area (defined in *Figure 1.3a* of *Part D Section 1*) contains the following marine ecology sensitive receivers:

- the soft coral and hard coral assemblages on the southwestern tip of Lamma Island, on Po Toi Island, on Waglan Island and on Ping Chau;
- the finless porpoise population in the waters surrounding Lamma and Po Toi Islands (mainly southwest Lamma);
- the potential South Lamma Marine Park/Marine Reserve; and
- the potential Ping Chau Marine Park/Marine Reserve.

The list of marine ecological sensitive receivers includes only habitats/populations of high ecological value. It is considered crucial to the environmental acceptability of the project that construction and operational activities of the gas pipeline do not impact these sensitive receivers. The following sections discuss and evaluate the impacts to marine ecological habitats, specifically focussing on the aforementioned sensitive receivers.

5.4.2 *Impacts Summary*

From the information presented above the marine ecological impact associated with the construction of the gas pipeline is considered to be low. An evaluation of the impact in accordance with the *EIAO TM* (*Annex 8, Table 1*) is presented as follows:

- *Habitat Quality*: Impacts are predicted to occur only to the low ecological value benthic habitats identified during reviews of available information. The selection of the route for the pipeline has avoided as far as possible habitats of high ecological value.

- *Species:* No species of ecological importance are predicted to be impacted through a combination of dredging constraints and operational constraints (ie no pipeline laying works in southwest Lamma during the spring peak in porpoise abundance).

- *Size:* The total length of the gas pipeline route is 90 km running from Shenzhen south through the eastern edges of Hong Kong waters to the southern border of Hong Kong. The route then moves west along the Hong Kong border pass the south of Po Toi till eventually the route turns north up to the power station extension. The width of the trench constructed through grab dredging and jetting works is approximately 2 m either side of the pipeline. Sediment will be deposited down current of the jetting works covering an distance of 400 m.

- *Duration:* The works operations for jetting the pipeline trench are predicted to last for four months for approximately 88 km of the route. The works are expected to progress at a rate of approximately 0.7 km day^{-1}. The grab dredging works for the Shenzhen and Lamma approaches (each = 1 km) are expected to take one month each. Although the entire operation is predicted to last six months, localised works will be relatively short term.

- *Reversibility:* Impacts to the assemblages inhabiting the soft bottom assemblages along the pipeline route are expected to be relatively short term and recolonisation of the sediments is expected to occur.

- *Magnitude:* Impacts to the ecologically sensitive habitats defined in this review will be of low magnitude during the dredging and jetting operations associated with the laying of the gas pipeline.

5.5 SUMMARY OF MITIGATION MEASURES

In accordance with the guidelines in the TM on marine ecology impact assessment the general policy for mitigating impacts to marine ecological resources, in order of priority, are:

Avoidance:	Potential impacts should be avoided to the maximum extent practicable by adopting suitable alternatives.
Minimisation:	Unavoidable impacts should be minimised by taking appropriate and practicable measures such as constraints on intensity of works operations (eg dredging rates) or timing of works operations.
Compensation:	The loss of important species and habitats may be provided for elsewhere as compensation. Enhancement and other conservation measures should always be considered whenever possible.

Impacts to marine ecological resources have largely been avoided during construction through constraints on the works operations associated with the following activities:

- grab dredging for the approaches to the Shenzhen LNG terminal and the Lamma Power Station Extension; and

- jetting for the pipeline trench.

These constraints were recommended to control water quality impacts to within acceptable levels, are also expected to control impacts to marine ecological resources. It is recommended that to avoid disruption to the *Neophocaena phocaenoides* population in the southwestern coastal waters of Lamma Island that works associated with the pipeline laying do not occur during the spring off the coast of southwest Lamma. According to the present programme jetting works are expected to take place for the entire pipeline route during the period July through October. The area to the southwest of Lamma will be jetted last and, hence, disturbance to the finless porpoises will be avoided as far as possible. Should changes to the work programme occur this mitigation requirement remains applicable, ie that no jetting works should be conducted during the spring peak in porpoise abundance off the southwest coast of Lamma.

5.6 *RESIDUAL IMPACT*

Taking into consideration the ecological value of the habitats discussed in the previous sections and the resultant mitigation requirements the residual impact can be determined. The only residual impact occurring as a result of laying of the gas pipeline is the loss of the subtidal assemblages present within the dredging/jetting areas. The residual impact is considered to be acceptable as the habitat is of low ecological value and because infaunal organisms and epibenthic fauna are expected to recolonise the sediments after the pipeline has been laid.

5.7 *EM&A REQUIREMENTS*

The dredging operations include constraints which act as appropriate mitigation measures to control environmental impacts to within acceptable levels. Actual impacts of construction activities will be monitored through impacts to water quality. Monitoring and audit activities designed to detect and mitigate any unacceptable impacts to water quality will serve to protect against unacceptable impacts to marine ecological resources.

The water quality monitoring programme will provide management actions and supplemental mitigation measures to be employed should impacts arise, thereby ensuring the environmental acceptability of the project. As no impacts of concern to ecological resources are predicted to occur, the development and implementation of a monitoring and audit programme specifically designed to assess the effects of the construction activities on marine ecological resources is not deemed necessary.

5.8 *SUMMARY AND CONCLUSIONS*

Literature reviews of existing information coupled with extensive field surveys of marine ecological resources have been undertaken for this impact assessment. Information in baseline conditions identified the following marine ecological sensitive receivers:

- the soft coral and hard coral assemblages on the southwestern tip of Lamma Island, on Po Toi Island, on Waglan Island and on Ping Chau;
- the finless porpoise (*Neophocaena phocaenoides*) population in the waters surrounding Lamma and Po Toi Islands (mainly southwest Lamma);
- the potential South Lamma Marine Park/Marine Reserve; and
- the potential Ping Chau Marine Park/Marine Reserve.

Potential impacts to marine ecological resources and the above sensitive receivers may arise from direct disturbances to habitats, or through changes to key water quality parameters, as a result of the installation of the gas pipeline. However, the loss of subtidal assemblages during the dredging and laying of the gas pipeline, are predicted to be short term as assemblages are expected to recolonise post construction.

As impacts arising from the proposed dredging and jetting works are predicted to be largely confined to the specific dredging and jetting areas, they are not expected to cause adverse impacts to any marine ecological resources (habitats or species). Constraints on dredging and jetting operations recommended to control impacts to water quality to within acceptable levels (water quality objectives) also mitigate impacts to marine ecological resources. The marine ecological sensitive receivers listed above are all remote from the dredging / jetting operations and are not predicted to be impacted. In the interests of avoiding impacts to the breeding population of finless porpoise present around the south of Lamma Island during the spring peak in abundance, it is recommended that jetting operations in this area avoid this time of year. According to the existing timetable the jet ploughing will occur during the autumn in waters to the south of Lamma.

Based on the ecological value of the habitats discussed in the previous sections and the resultant mitigation requirements the residual impact can be determined. The only residual impact occurring as a result of laying of the gas pipeline is the loss of the subtidal assemblages present within the dredging/jetting areas. The residual impact is considered to be acceptable as the habitat is of low ecological value and because infaunal organisms and epibenthic fauna are expected to recolonise the sediments after the pipeline has been laid.

6 FISHERIES

6.1 INTRODUCTION

This Section of the EIA Report presents the findings of a desk-top assessment of the impacts of the installation of the proposed gas pipeline for the Lamma Extension project on existing fisheries resources, fishing operations and fish culture activities.

6.1.1 *Objectives of the Assessment*

The objectives of the assessment are as follows:

- to establish the importance to Hong Kong's fisheries of the habitats affected by the works associated with the installation of the gas pipeline from Shenzhen to the Lamma Extension;
- to identify fisheries sensitive receivers;
- to assess the scale of potential impacts to fisheries from the pipeline installation, and identify any significant or unacceptable impacts;
- to identify any mitigation measures and residual impacts; and
- to assess the need for a fisheries monitoring and audit programme.

6.1.2 *Legislation and Standards*

For information on the criteria for fisheries assessment as well as the legislation and standards that apply to fisheries resources and operations please refer to *Section 11.2* of Part B of this Report.

6.2 BASELINE CONDITIONS

Capture Fisheries

The new power station will be fuelled by gas supplied via a new pipeline from a regional liquefied natural gas (LNG) terminal in eastern Shenzhen. Two possible routes for the pipeline have been identified as a result of earlier work for the project. Both of the routes pass through the same Fishing Zones. The proposed routing options and the Fishing Zones of concern are shown in *Figure 6.2a*, and *Table 6.2a* lists their size in hectares.

Table 6.2a ***Fishing Zones Within the Proposed Gas Pipeline Route (GPR) Study Area***

Code	Fishing Zone	Area (Ha)
0067	Bluff Head	1,555.15
0092	Po Toi South	1,510.17
0093	Po Toi North	799.47
0095	Waglan	4,474.32
0096	Pak Kok	873.35
0097	Po Law Tsui	402.88
0098	Ha Mei	1,635.66
0099	Tai Kok	2,133.91
0109	West Lamma Channel	4,537.59
0121A	Mirs Bay	13,961.51
0121B	Mirs Bay	17,495.75
0121C	Mirs Bay	22,786.58
0122	Ping Chau	2,843.22

Five Fishing Zones detailed in the Study Area are also included within the GPR Study Area (see *Section 11.3* of Part B). A further seven Fishing Zones have been identified as areas which will be affected by works associated with the installation of the gas pipeline. Details of the number of vessels operating within each of the zones within the GPR Study Area are listed below in *Table 6.2b*.

Table 6.2b ***Number of Vessels Operating During 1996 - 1997 in Each Fishing Zone Within the Proposed Gas Pipeline Route Study Area by Length Type***

Code	Fishing Zone	Vessels < 15 m	Vessels > 15 m	All Vessels
0067	Bluff Head	42	12	54
0092	Po Toi South	315	75	390
0093	Po Toi North	310	74	384
0095	Waglan	159	48	207
0096	Pak Kok	66	5	71
0097	Po Law Tsui	160	20	180
0098	Ha Mei	237	58	295
0099	Tai Kok	251	65	316
0109	West Lamma Channel	130	60	190
0121A	Mirs Bay	23	-	23
0121B	Mirs Bay	-	3	3
0121C	Mirs Bay	1	9	10
0122	Ping Chau	1	-	1

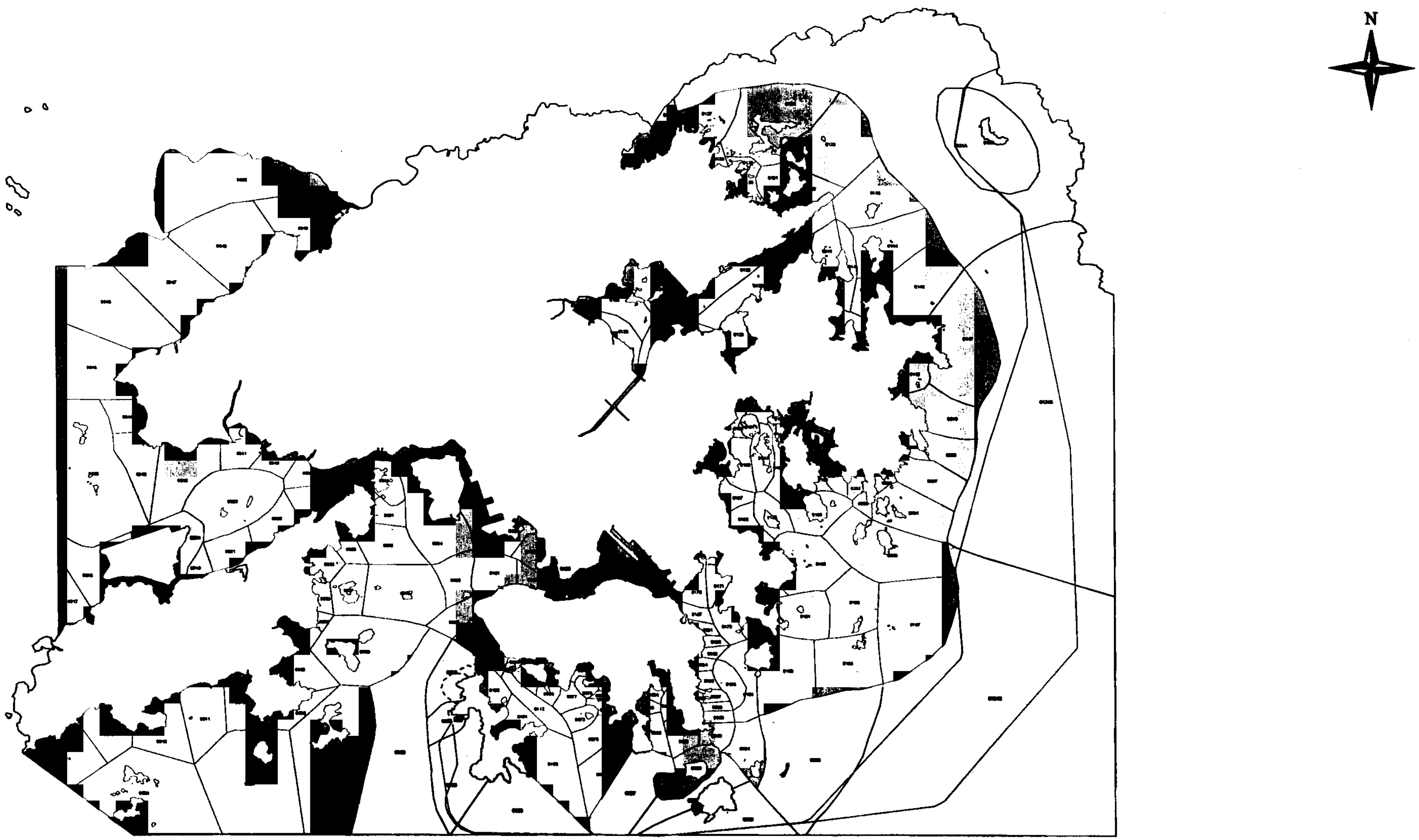

Figure 6.2a AFD FISHING ZONES AND FISH CULTURE ZONES WITHIN THE PROPOSED GAS PIPELINE ROUTE STUDY AREA

Date : 30 October 1998 Reference : G:\CONTRACT\C1830\GIS\ROUTE.APR

KEY

- Preferred Gas Pipeline Route
- Alternative Gas Pipeline Route
- Proposed Lamma Power Station Extension
- AFD Fishing Zones Within the Study Area
- AFD Fishing Zones
- Po Toi Fish Culture Zone

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From the above table it can be seen that the eastern waters of Hong Kong which lie within the GPR Study Area are not extensively fished. Only low numbers of vessels fish within these waters in comparison to the amount of vessels fishing in other areas. The waters around Po Toi appear to be heavily fished in, with up to 390 vessels operating in the waters of Po Toi South. Although the majority of these vessels are less than 15 m in length, a high number of larger vessels are recorded for the Fishing Zones Po Toi North and Po Toi South. The production values for the Fishing Zones within the GPR Study Area are shown in *Table 6.2c*.

The Fishing Zones in the eastern waters of Hong Kong are recorded as the lowest production value areas in Hong Kong waters, particularly the most northern of these at Ping Chau. The ranking based on these values places them last out of the 179 Fishing Zones that are actively operated in. In contrast to this, the AFD Fishing Zones around Po Toi are ranked amongst the highest in Hong Kong in terms of production and value on a per hectare basis. Mixed species were the most abundant fish group caught within these waters, although the highly valuable commercial species Silver Shrimp, *Acetes* spp, is recorded as second most abundant in terms of weight for both Po Toi North and Po Toi South.

In summary, the fisheries in the waters of the gas pipeline route vary from some of the most productive waters in Hong Kong in terms of value to the fishery as a whole, to some of the least productive. The northern and eastern waters of the GPR Study Area are of low commercial value and importance, whereas the southern waters are of high commercial value and of consequent high importance.

Fisheries Resources - Spawning and Nursery Areas

A previous study has shown that the southern waters of Hong Kong are not only a productive area for fisheries in Hong Kong waters, but are also a spawning ground and nursery area for important and high value commercial species[35]. The GPR Study Area has some of their waters within the known spawning and nursery areas. South Lamma is reported as a spawning ground for the Croaker *Johnius belengeri*, the Coastal Mud Shrimp *Solenocera crassicornis* and the Jinga Shrimp *Metapenaeus affinis*. Similarly, the waters surrounding Po Toi are used as spawning grounds for the Sole *Cynoglossus macrolepidotus* and the Yellow Croaker *Pseudosciaena crocea*. Research has also found that South Lamma is used as a nursery ground for the Shrimps *Metapenaeopsis barbata* and *Metapenaeopsis palmensis*, the Mantis Shrimp *Oratosquilla* spp, the Goby *Oxyurichthys tentacularis*, and Croaker (Sciaenidae) and Grouper (Serranidae) fry[36].

(35) ERM (1998a) Fisheries Resources and Fishing Operations in Hong Kong Waters. Submitted to the Agriculture and Fisheries Department, Hong Kong Government.

(36) ERM (1998a) *op cit.*

Table 6.2c ***Total Value ($), Adult Catch (kg) and Fry Catch (tails) Displayed on a Total Production, Production (Ha^{-1}) and Rank (Ha^{-1}) Basis for the Fishing Zones in the Proposed Gas Pipeline Route Study Area (All Fishing Vessels)***

AFD Code	Fishing Zone	Total Production			Production (Ha^{-1})			Rank Production (Ha^{-1})		
		Adult Fish (kg)	Fry (tails)	Value ($)	Adult Fish (kg)	Fry (tails)	Value ($)	Adult Fish	Fry	Value
0067	Bluff Head	46,366.24	-	1,023,977.42	29.81	-	658.44	143/210	-	157/210
0092	Po Toi South	501,471.34	65,287.20	8,909,013.33	332.06	43.23	5,899.36	21/210	48/210	42/210
0093	Po Toi North	523,714.87	65,287.20	8,786,741.53	655.08	81.66	10,990.76	8/210	38/210	12/210
0095	Waglan	268,088.96	1,875.00	7,045,621.92	59.92	0.42	1,574.68	120/210	89/210	121/210
0096	Pak Kok	64,686.73	55,544.34	1,211,979.53	74.07	63.60	1,387.73	108/210	43/210	128/210
0097	Po Law Tsui	85,552.86	62,904.34	3,073,371.69	212.35	156.14	7,628.49	43/210	39/210	27/210
0098	Ha Mei	246,277.79	79,464.34	6,078,196.23	148.93	48.05	3,675.61	66/210	45/210	70/210
0099	Tai Kok	407,638.34	86,824.34	6,884,342.15	191.03	40.69	3,226.16	50/210	49/210	84/210
0109	West Lamma Channel	504,234.67	-	8,090,005.44	111.12	-	1,782.89	87/210	-	113/210
0121A	Mirs Bay	6,551.67	19,617.65	340,104.03	0.47	1.41	24.36	176/210	88/210	174/210
0121B	Mirs Bay	7,363.44	-	179,000.00	0.42	-	10.23	177/210	-	178/210
0121C	Mirs Bay	25,183.87	-	493,800.00	1.11	-	21.67	173/210	-	176/210
0122	Ping Chau	744.86	-	17,105.36	0.26	-	6.02	179/210	-	179/210

Culture Fisheries

There is only one FCZ located within close proximity to the GPR Study Area and this is located on the western side of Po Toi Island (*Figure 6.2a*). As of 1996, Po Toi was the smallest operating FCZ in Hong Kong waters with only 7 licensed rafts and making up a total licensed area of only 566 m^2 (total gazetted area = 3,000 m^2). As explained above, no figures are available for the individual production at this or any other FCZ in Hong Kong.

6.2.1 *Sensitive Receivers*

Based on the above review of baseline fisheries conditions in the GPR Study Area, the following fisheries sensitive receivers which may be affected by the installation of the gas pipeline from Shenzhen to the proposed Lamma power station extension have been identified:

- the Fish Culture Zone Po Toi;
- the seasonal spawning ground in southern waters; and
- the seasonal nursery area in southern waters.

Fish Culture Zones

Due to its location, the aforementioned FCZ could potentially be impacted by the dredging works conducted in conjunction with the installation of the gas pipeline from Shenzhen to the proposed Lamma power station extension.

Spawning and Nursery Areas

The *EIAO TM* classifies spawning and nursery grounds as areas of high importance, as they are essential for the recruitment of juveniles and hence the health of adult fish stocks. The Study that identified areas in southern waters as spawning and nursery areas also highlighted the seasonal nature of these areas[37]. Spawning of fish species is reported to occur between June to September and spawning of commercial crustacean species between June to August. Juvenile resources have been reported in the water south of the existing power station during March to September with highest abundances between June and August.

6.2.2 *Fisheries Importance*

The GPR Study Area can be divided into two distinguishable areas of importance based on their production values in comparison with other areas in Hong Kong in terms of the catch weight, fry number and catch value. The eastern waters of the GPR Study Area mainly consisting of the waters within Mirs Bay and the eastern waters of Hong Kong are of low value to the fishery, whereas, the southern waters, consisting of the waters around Po Toi and south Lamma can be considered important and of high value. As the waters around these islands have also been identified as spawning and nursery areas, this further supports their clarification as important areas to the Hong Kong fishing industry.

6.3 *IMPACT ASSESSMENT*

The gas pipeline will be a submerged pipeline embedded in a 3 to 3.6 m deep channel in the seabed. The pipeline will be armoured with rockfill cover in areas

(37) ERM (1998a) *op cit.*

near shipping zones. Impacts to fishing operations are expected to occur only during the deployment phase of the pipeline. These impacts are predicted to be small scale and localised and may occur through the following mechanisms.

Direct Impacts

No long term direct impacts are expected to occur through the deployment of the gas pipeline. Short term impacts are predicted to occur as a result of the dredging operations associated with the deployment, although once these operations have ceased fisheries resources dependent on the affected area are expected to return due to recolonisation of the seabed by the supporting benthic fauna.

Indirect Impacts

Indirect impacts are predicted to occur through elevations in SS and the resulting effects described above as a result of the dredging operations. The impacts of changes to these key water quality parameters on fisheries resources are discussed in full in Part B, *Section 11.3*. Due to the methodology proposed to be employed to deploy the pipeline, only a low disturbance to the seabed is predicted to occur. Along the majority of the route the pipeline will be laid using the liquefaction method of jetting. In this method low pressure jets are employed to liquefy the seabed sediment which then allows the pipeline to sink into the trench. The majority of the affected sediment will form a fluidised suspension of sediment and water close to the seabed. This fluidised layer will very rapidly settle back onto the seabed in the immediate vicinity of its original location. A small portion of the sediment may be lost to suspension but this lost sediment is likely to remain in the lower part of the water column and settle back onto the seabed in a short period of time, having been transported only a short distance.

The remainder of the route (1 km approach to the LNG terminal in Shenzhen and 1 km approach to the power station) will be laid using grab dredging. Mathematical calculations on the loss rates due to this form of pipe laying have shown that the loss rate will be at least 14 times less than the values for the Lamma power station reclamation site dredging. Additionally the sites of the trench dredging will be more exposed in terms of tidal currents than the reclamation site which will mean that concentrations are further reduced due to greater dispersion. Based on these calculations the fisheries resources in the GPR Study Area are not expected to be adversely affected. Similarly, the identified sensitive receiver, Po Toi Fish Culture Zone, is also not predicted to be affected by the works associated with the gas pipeline installation.

6.4 *IMPACT EVALUATION*

An evaluation of the impacts described above in accordance with the *EIAO TM* (*Annex 9*) is presented as follows:

- *Nature of impact:* Short term impacts will occur to fisheries resources in the GPR Study Area as a result of the dredging activities and pipeline installation operations. These activities are not expected to be of concern as the associated impacts are both short term and of a low magnitude.

- *Size of affected area:* Although the pipeline itself is very long (90 km) the affected area of fisheries resources is predicted to be very small and localised to the works involved in pipeline installation.

- *Size of fisheries resources and production:* Due to the size of the GPR Study Area the fisheries resources and production range from high to very low in comparison to other areas in Hong Kong in terms of catch weight and value.

- *Destruction and disturbance of nursery and spawning grounds:* The southern sections of the pipeline route pass through previously identified spawning and nursery grounds for commercially important species. The majority of the impacts associated with the installation of the gas pipeline will be short term and restricted to within a close distance to the pipeline itself. Therefore, impacts to these important areas are expected to be small and short term.

- *Impact on fishing activity:* The pipeline passes through two distinguishable areas: a high fisheries production and activity area around the Lamma and Po Toi Islands, and a low production area in eastern waters and Mirs Bay. Impacts to fishing activities in either area are not expected to be of concern due to the small area physically disrupted during pipeline installation and the short time frame of disturbance. Such short term disturbances to fishing operations do not typically invoke claims for *ex gratia* allowances, however, these disturbances may still be the subject of claims. Decisions on the payment of such allowances rests with the Planning Environment and Lands Bureau.

- *Impact on aquaculture activity:* Due to the short duration and localised dispersion of increases in suspended sediments in the water column, impacts to the Fish Culture Zone at Po Toi are not predicted.

6.5 *SUMMARY OF MITIGATION MEASURES*

In accordance with the guidelines in the TM on fisheries impact assessment the general policy approaches for mitigating impacts to fisheries, in order of priority, are avoidance, minimization and compensation.

Impacts to fisheries resources and fishing operations have largely been avoided during construction through constraints on the works operations associated with the following activities:

- grab dredging for the approaches to the Shenzhen LNG terminal and the Lamma Power Station Extension; and

- high pressure jetting for the pipeline trench.

These constraints were recommended to control water quality impacts to within acceptable levels, are also expected to control impacts to fisheries resources. Hence, no fisheries-specific mitigation measures are required during construction.

Impacts to fisheries resources and fishing operations during operation of the pipeline are predicted to be within environmentally acceptable levels in areas of importance to the fishery. Hence, no fisheries-specific mitigation measures are required during operation of the pipeline.

6.6 *RESIDUAL IMPACT*

The only residual impact identified that may affect commercial fishing operations is the disturbance to fishing activity during the pipeline laying and jetting operations. The magnitude of this residual impact is low since the operations move at a rate of 1-3 km per day and thus impacts to specific fishing grounds will be of very short duration and fisheries production is low from the majority of the areas that the pipeline route passes through.

6.7 *ENVIRONMENTAL MONITORING AND AUDITING*

The dredging and jetting operations include constraints which act as appropriate mitigation measures to control environmental impacts to within acceptable levels. Actual impacts of these activities will be monitored through impacts to water quality. Monitoring and audit activities designed to detect and mitigate any unacceptable impacts to water quality will serve to protect against unacceptable impacts to fisheries resources.

The water quality monitoring programme will provide management actions and supplemental mitigation measures to be employed should impacts arise, thereby ensuring the environmental acceptability of the project. As impacts to the fisheries resources and fishing operations are small and of short duration, the development and implementation of a monitoring and audit programme specifically designed to assess the effects of these activities on commercial fisheries resources is not deemed necessary.

6.8 *SUMMARY AND CONCLUSIONS*

Reviews of existing information on commercial fisheries resources and fishing operations located within the GPR Study Area have been undertaken for this impact assessment. Information from a recent study on fishing operations in Hong Kong indicates that fisheries production values from these areas are highly variable within the Study Area.

Potential impacts to fisheries resources and fishing operations may arise from disturbances to benthic habitats on which the fisheries resources depend, or through changes to key water quality parameters, as a result of the installation of the gas pipeline. As impacts arising from the proposed dredging or jetting works are predicted to be largely confined to the specific works areas, they are not expected to cause adverse impacts to any fishing grounds or species of importance to the fishery. While no special mitigation measures are required for fisheries resources, constraints on dredging operations recommended to control impacts to water quality to within acceptable levels are also expected to mitigate impacts to fisheries resources.

7 HAZARDS

7.1 INTRODUCTION

This Section of the EIA Study Report presents the risk assessment for the gas supply pipeline. The assessment is qualitative in nature, focusing on identifying any new or unusual features of this project, in relation to other similar facilities operating elsewhere. This approach recognises that the hazards associated with submarine gas pipelines are generally well understood and that safeguards exist to ensure that risks are as low as reasonably practicable.

It should be noted that, at the time of writing this report, the design of the gas pipeline is at an early stage with preliminary design information only available.

7.2 DESCRIPTION OF THE GAS PIPELINE

The gas for the power station will be supplied via a 90 km single bore submarine pipeline from a Liquefied Natural Gas (LNG) plant to be located to the east of Shenzhen. The pipeline will be of steel construction with a concrete weight coating. It will be approximately 90 km in length , 24" in diameter and with an operating pressure of 80 bar (supply end) and 35 bar (delivery end).

The pipeline will enter Hong Kong SAR waters near the island of Ping Chau and run down the eastern coast of the SAR and then west to Lamma passing to the south of Po Toi. Various options for the pipeline route have been considered, as shown in drawing 4176-PLD-001, General Arrangement of Pipeline Route Options, Rev B, Kvaerner R J Brown, 28 August 98 (reproduced in *Annex D7-1).*

The sections of the pipeline at the Lamma and Shenzhen approaches will be located in a trench of approximately 3 metres depth which will be backfilled with rock armour. The majority of the pipeline in open waters will be jetted down to 3 metres below sea bed. At locations where there will be a possibility of pipeline damage by ship's anchors or dropped objects the pipeline will be protected by engineering backfill of rock armour, concrete slabs or grout mattresses.

The gas pipeline has motor-operated emergency shutdown valves at each end and scraper launching and receiving facilities. The primary use of the scraper will be for dewatering the pipeline during commissioning. It is not envisaged that the scraper will be required during normal operation, as the supply gas will be relatively clean with no liquid slugs, sludge etc. The scraper launching and receiving facilities may however serve for occasional remote inspection of the pipeline using an "intelligent" pig.

7.3 HAZARD IDENTIFICATION

7.3.1 *Overview of Hazards Associated with Submarine Gas Pipelines*

Loss of integrity of submarine gas pipelines can arise through a variety of causes including:

- corrosion (internal and external);
- mechanical failure (material defects, fabrication defects, fatigue etc);
- operational/maintenance error;

- third party damage (dropped objects, seabed fishing activity, anchor damage, vessel impact etc); and
- environmental factors (hydrodynamic loading, seabed mobility, marine growth and seismic activity).

Corrosion

Corrosion has, in the past, been a major cause of pipeline failure, but the use of better coatings, cathodic protection and "intelligent pigs" to inspect for corrosion has reduced the incidence of this type of failure.

Mechanical Failure

This category covers a wide variety of types of error, including design errors (eg inadequate material specification), fabrication errors (eg of the pipework, fittings or corrosion protection system) and installation errors (eg welding defects).

Operational/Maintenance Error

This category covers loss of integrity of pipelines which is directly attributable to human error during operation or maintenance of the pipeline, including non-routine or abnormal operations, start-up and shutdown. Examples of such errors are valve sequencing errors or failure to achieve adequate isolation prior to maintenance activities.

Third Party Damage

Third party damage can arise from a variety of sources, including:

- *Dropped objects*: Damage may arise, for example, due to objects dropped from work vessels or inadequately-secured cargo.

- *Anchors*: The nearest anchorage areas to the current pipeline routing are those situated to the south of Lamma, which are over 500 metres from the pipeline route. It is understood, however, that telecommunications cables in this area are subject to routine (monthly) damage by anchors. The current pipeline route also crosses a number of designated ocean-going shipping channels, ie the East Lamma Channel (the main access channel to the Port for ocean-going vessels), the West Lamma Channel (the future access route to the Lantau Port), the approaches to the Tathong channel and the approaches to Yantien (also likely to experience a significant future increase in marine traffic). Avoiding anchorage areas does not necessarily eliminate the risk of anchor damage as a ship may drop its anchors at any location in an emergency (eg following collision or on-board equipment failure, to bring it under control). This may result in damage due to direct impact of the anchor or subsequent dragging. It is understood that there have been a number of past instances in Hong Kong of damage to unprotected submarine power cables, telecommunication cables and water supply mains due to ship anchors. Anchors of large ocean-going vessels may weigh up to 10 tonnes and may be dragged of the order of 200 metres, depending on the seabed conditions.

- *Seabed fishing activity*: Incidents relating to fishing activity are relatively common for subsea pipelines around the world. The main hazard arises from bottom trawling vessels, involving either impact with the pipeline, snagging or pull-over of the trawl gear.

- *Vessel impact*: Vessel impact may take the form of either striking of a vessel on the riser, grounding of a vessel or sinking.

Environmental factors

Hazards of this nature arise from the difficulties which sometimes arise in predicting the loading on pipeline due to various factors such as seabed settlement, currents, storms etc. Failure to appreciate such loading conditions has, in the past, led to the phenomenon of upheaval buckling. However, this is not anticipated to be a major cause of failure for new pipelines due to the quality management techniques which are now widely applied throughout the design phase of the pipeline.

7.3.2 *Review of Past Incidents*

Pipeline and Riser Loss of Containment Study, PARLOC '94

The Pipeline and Riser Loss of Containment (PARLOC) study is an on-going study by the UK Offshore Operators Association (UKOOA) and the UK Health and Safety Executive (HSE) of incidents involving offshore pipelines and risers in the North Sea. The PARLOC '94 report (recently superseded in September 1998 by PARLOC '96) is a systematic compilation of the most complete databases of North Sea subsea pipeline and associated incidents up to the end of 1993. The report discusses the causes of incidents in detail and derives failure frequency data.

The PARLOC data cover all types of submarine pipelines, including those carrying liquids and multi-phase mixtures as well as gas. In the context of this study the data relating to gas pipelines are the most relevant but the complete dataset is relevant when considering, for example, the incidence of third party damage.

Up to the end of 1993 there were, in total, 292 incidents relating to offshore operating steel pipelines, risers, fittings and flexible lines. 154 related to operating steel pipelines/risers, 118 to fittings and 20 to flexible lines. The term "incident" refers to an occurrence which directly resulted, or threatened to result, in loss of containment of a pipeline or riser. The followings were identified to be the main causes of such incidents:

- anchoring;
- other impacts;
- corrosion;
- structural damage;
- material defects;
- natural hazards;
- construction faults;
- hydrotest and commissioning;
- maintenance;
- other incidents; and
- fitting faults.

A brief review of the incidents is presented in the following paragraphs, whilst *Table 7.3a* summarises the statistics relating to 154 incidents for operating steel pipelines (excluding fittings and flexible lines).

Anchoring accounted for 30 incidents out of the total of 292. These resulted in either loss of containment, damage to the pipe body or partial removal of the pipe by the anchor. Lesser damage involved denting but required no repair and damage to the concrete coating. There were several incidents related to flexible lines in which pipewall and valves were damaged. General causes were due to the presence of construction vessels, supply boats and tankers. The anchor chain of a drilling rig was found to be the cause in one case.

Impacts accounted for 43 incidents in total and the largest number of incidents for operating steel pipelines. However, in a large percentage of these incidents, denting was the only consequence (no leakage) and pipeline repair was not required. Some of the incidents to fittings resulted in loss of containment and damage to components such as the grout plug and connectors. The sources of impact included ships (impacting risers or sinking onto a pipeline), trawl gear, anchor chains, dropped objects and the presence of surface craft such as construction vessels and trenchers.

Corrosion, both internal and external, accounted for 39 of the 292 incidents and is the single largest contributor to loss of containment incidents relating to operating steel pipelines. Pipeline repair, abandonment, replacement of the line or implementation of inhibitor programmes were conducted to overcome this problem.

There were 16 cases related to structural damage in which 12 were related to operating steel pipelines, three to fittings and one to flexible pipelines. Some of these incidents resulted in leakage due to damage to a valve or fitting associated with a line. There was only one case of leakage associated with an operating steel pipeline. The buckling of a flexible line which resulted in a loss of containment was recorded. The general causes were identified as thermal expansion (including upheaval buckling) and clamp failure.

Nine incidents of material defects associated with operating steel pipelines were identified, the results being a loss of containment and leakage. Causes were due to defect in a weld, brittle fracture of a riser, a riser material being out of specification and crack at an anode lug on a riser. Three incidents on fittings and 8 associated with operating flexible lines were also recorded. For flexible lines, ageing and embrittlement of line due to operating conditions were recorded.

Natural hazards such as storm, vibration in current, scour and subsidence account for 12 of the 154 incidents associated with operating steel pipelines. However, no leakage was detected in any of the incidents, only damage to the coating. A loss of containment or leakage were recorded, however, in incidents related to fittings being damaged. A total of 3 incidents were reported, specific causes being failure of clamps, consequently causing a leak at a flange.

A total of four incidents of construction faults associated with flexible and operating steel pipelines were recorded and they were all found to occur 2 to 3 years after installation of the pipe. For operating steel pipeline, which accounts for two cases, only the coating was damaged. The other two cases (flexible lines) resulted in a slight leakage or line rupture.

Hydrotest or commissioning of a pipeline accounted for 25 incidents. They involved fittings, line rupture due to incorrect sequencing of valve operations during commissioning, damage incurred during trenching, weld defects, anchoring impact damage, and corrosion in a line being tested after repair.

There were also nine incidents for pipelines which had been operating but had been shut down when the incident occurred. They involved anchoring and impact, buckling of risers, accumulation of hydrates in a valve cavity at a tee stopping operation of the valve, a leak from pig trap valving, and a poorly fitted valve body bleed plug causing water ingress to the line.

There were a two incidents related to maintenance, one to an operating steel pipeline and the other to a flexible line. A maintenance tool aggravated earlier damage and caused a flexible line to rupture in the mid-line. In the other case a riser was gouged when the monel cladding was being ground off to facilitate inspection.

Other incidents cover various miscellaneous causes of pipeline failure. In one case, a line became blocked due to a build up of wax or hydrates. Although there was no leakage, a section of the pipe had to be replaced. Other incidents occurred due to procedural error where risers were displaced from their supports due to a pressure surge when full line pressure was experienced against closed emergency shut down valves.

Incidents involving fitting faults accounted for 98 out of the 292. As a result of defects in fittings or in the operation of valves, loss of containment from a pipeline occurred. The causes of fitting faults were failure of connectors such as hydrocouples, load limiting connectors, emergency shut down valves and other couplings. Leakage from a flange, failures of pig traps and human error were also identified as the causes in some incidents.

Table 7.3a ***Incidents Involving Operating Submarine Steel Pipelines (from PARLOC '94)***

Main cause	Specific cause	Number of incidents	Number of loss of containment incidents
Anchor	Supply Boat	7	5
	Rig or Construction	6	-
	Other / Unknown	13	1
Impact	Ship on Riser	7	-
	Trawl	13	2
	Dropper Object	2	-
	Wreck	1	1
	Construction	2	1
	Other / Unknown	18	1
Corrosion	Internal	21	12
	External	18	3
Structural Damage	Thermal Expansion	6	-
	Clamp Failure	1	1
	Buckling	5	-
Material	Weld Defect	6	3
	Steel Defect	3	2
Natural Hazard	Vibration	9	-
	Storm	1	-
	Scour	1	-
	Subsidence	1	-
Construction		2	-
Fire		1	1
Maintenance		1	-
Other Incidents		6	6
Human Error		2	-
Operation Problems		1	-
	Total	154	39

Major Hazards Incident Data Service, MHIDAS

The Major Hazards Incident Data Service (MHIDAS) is a database developed by AEA Technology on behalf of the UK Health and Safety Executive. The service has been created to record details of incidents involving hazardous materials that resulted in, or had the potential to result in, a significant impact on the public at large. The database contains details of incidents from over 95 countries throughout the world and has been commonly used for validating assumptions and judgments in safety assessment studies

Table 7.3b presents a selection of incidents for offshore pipelines which have occurred in the past 15 years. These are presented for illustration only as indicative of the sorts of incident which can arise for subsea pipelines. It is interesting to note that all five incidents relate to third party damage and, in two cases, fatal injuries were recorded for the crew of the vessel causing the pipeline damage.

Table 7.3b ***Incidents Relating to Subsea Pipelines (from the MHIDAS database)***

Date of incident	Location	Material Name	Incident type	General cause	No. of people affected	Abstract
26/10/84	(at sea) Texas, USA	Natural gas	Continuous release Gas cloud formation	Impact failure	0 killed 0 injured	Exxon 10" high-pressure gas pipeline severed by motor tug in Houston ship channel. Four million cubic ft. lost. Tug undamaged. Pipeline cut in two, but repaired.
3/10/89	Gulf of Mexico, Mexico	Pressurised liquefied gas	Explosion Fireball	Impact failure	8 killed 3 injured	Fishing boat collided with natural gas pipeline 0.5 mile offshore causing an explosion & fireball. 8 dead 3 injured and 3 missing. Boat foundered 5 hours after explosion.
1/6/92	Java sea	Crude oil	Continuous release	Mechanical failure	No info	Subsea pipeline ruptured when tender barge snagged pipeline support line <100 bbl escaped to sea.
28/10/87	Safaniya, Saudi Arabia	Crude oil	Fire	Impact failure	1 killed	Supply vessel accidentally ruptured subsea oil trunk line at the Safaniya Oil Field. A fire blazed on the sea surface for 24 hrs. One person was killed.
10/5/91	Santa Barbara, Los Angeles, USA	Crude oil	Continuous release	Impact failure	No info.	Skimmers cleaned 4200 galls crude oil slick when vessel punctured offshore pipeline. Leak capped off almost immediately by automatic shut off valve.

7.3.3 *Summary of Hazards Identified for Gas Pipeline*

The review of data on pipelines in the North Sea indicates that corrosion and third party damage (anchors/impacts) are major causes of pipeline failure, whilst mechanical failure (eg due to weld defects) is also significant. Corrosion and weld defects are causes of pipeline failure which have seen significant technological improvement in recent years, so they should not be such an important factor for new pipelines. However, third party damage is less easy to control and is highly environment-specific and therefore warrants further consideration for this study.

7.4 *CONSEQUENCES OF PIPELINE FAILURE*

A loss of integrity of the gas supply pipeline presents a potential significant hazard to anyone caught within the impact zone. Guillotine rupture of the pipeline would be expected to result in the immediate release of a large volume of gas which would then bubble to the surface and begin to disperse in the atmosphere. A particular hazard arises where the cause of the damage is a vessel, which itself might provide the source of ignition, leading to a fireball or flash fire with potentially fatal effects on the people on board the vessel. Injury may occur either through direct exposure to thermal radiation or as a result of secondary fires. If immediate ignition does not occur then the cloud will drift downwind and may be ignited after a delay by a passing ship, resulting in a large flash fire.

Apart from thermal radiation, the other hazards associated with loss of containment of gas pipelines are as follows:

- blast effects due to the sudden release of stored energy, which can be significant in close proximity to the pipeline but its serious effects may quickly diminish with distance;
- projectiles arising from the pipeline backfill material;
- the buoyancy of the gas release (particularly large instantaneous releases) which may cause vessels caught in its path to capsize; and
- asphyxiation due to the exclusion of oxygen in the immediate vicinity of the release.

7.5 *RISK ASSESSMENT*

7.5.1 *General*

High pressure submarine gas pipelines are a common feature of the energy supply system in many countries. Considerable experience has been built up in the risks associated with such pipelines and the means by which the risks can be reduced to as low a level as reasonably practicable. This is reflected in the various standards which exist for the design, construction, testing and commissioning of pipelines, including the British Standards Institute Code of Practice for Subsea Pipelines, the ANSI/ASME Code for Gas Transmission and Distribution Piping Systems and the Institute of Petroleum (IP) Pipeline Safety Code. High pressure gas pipelines already exist in Hong Kong (ie the gas supply pipeline from Hainan to China Light and Power's Black Point Power Station).

The following material summarises the risks associated with the gas supply pipeline, the requirements of the relevant standards and an outline the proposed safety measures for this project. Also covered, as separate topics, are the integrity monitoring system for the pipeline and emergency planning.

7.5.2 *Corrosion*

External corrosion is a well recognised problem for pipelines in salt water environments. The techniques used to combat external corrosion include coatings, cladding, use of corrosion-resistant materials of construction, cathodic protection (CP) and chemical inhibition of the environment (eg for a pipeline within a closed caisson). For internal corrosion, similar techniques apply and also internal linings, product composition control, chemical inhibition and operational pigging. To back-up these design measures the operation of the pipeline would typically include a corrosion monitoring programme. This would encompass such techniques as CP system surveys, use of corrosion coupons and "intelligent" pigs.

For the present pipeline it is proposed to protect against external corrosion by providing an asphalt enamel coating together with cathodic protection using a sacrificial anode. Internal corrosion will not be as significant a hazard, as the gas from the LNG plant is free of sulphur and moisture. Notwithstanding this, the pipeline internal surface will be coated with 50-75 microns of epoxy paint. The pipeline design includes facilities that would enable operation of an intelligent pig.

7.5.3 *Mechanical Failure*

Mechanical failures are becoming rarer due to better material specification, improved manufacturing controls and routine application of non-destructive application of field welds. BS 8010 specifies quality assurance requirements covering the design, construction, testing and commissioning phases of the pipeline, including requirements for preparation of a quality plan and maintenance of various documents, specifications, drawings and change orders relating to the pipeline.

7.5.4 *Operational/Maintenance Error*

The potential for human error to directly lead to pipeline failure needs to be addressed and suitable systems of work and design safeguards implemented. The PARLOC '94 data contained two incidents relating to human error, both involving procedural error which caused risers to be displaced from their supports due to pressure surge against closed emergency shutdown valves.

One of the key requirements for an operator of a hazardous pipeline is to establish an effective safety management system. Indeed such a system should be in a place for the entire project lifecycle from conceptual design through to decommissioning, to manage risks in a pro-active manner.

Guidance on what constitutes an effective safety management system is contained in the UK HSE's recent guide to the (UK) Pipeline Safety Regulations 1996. Specific guidance on maintenance activities is provided in documents such as the HSE's Guidance on Permit-to-Work Systems in the Petroleum Industry and the HSE Oil Industry Advisory Committee's Safe Isolation of Plant and Equipment. The latter document has specific guidance on pipeline isolation requirements. These are examples of best practice in the industry and the sorts of standards which it would be expected would be in place for this project.

7.5.5 *Third Party Damage*

Protection against third party damage of the type identified above is usually provided by such measures as concrete weight coating of the pipeline, trenching (and backfill), grout bags or mattresses, and other protective structures. For the pipeline under consideration in this study, concrete weight coating of the pipeline is proposed together with trenching to a depth of 3 metres and either backfilling with rock armour or provision of grout mattresses (for up to 50% of the route length). For risers, protection is usually afforded by suitable location of the riser and, if necessary, protection by fenders.

Four potential sources of damage were identified above: dropped objects, anchors, fishing/trawl gear, and vessel impact. The provision of trenching of the pipeline, with backfill (up to 50% rock armour) or grout mattresses should provide substantial protection against most sources of impact. However, protection is not guaranteed and the degree of residual risk will have to be considered further in a more detailed examination of the potential sources of third party damage. Fishing activity, although understood to be intense along the pipeline route, is not anticipated to present a significant hazard as the trawl gear is mostly lightweight (local boats only). However, damage from the other identified sources (dropped objects, anchors and vessel impact) could be significant for an inadequately protected pipeline.

There is some precedent in Hong Kong relating to CLP's pipeline to the Black Point Power Station. It is understood that this is protected with grout mattresses, similar to what is being considered for this project.

Two aspects of the pipeline route worthy of particular consideration are the locations where the pipeline crosses telecommunications cables and the crossing of the dredged channel used by large bulk carriers approaching the coal jetties at the existing Lamma power station.

At several points along the route the pipeline must cross telecommunications cables. The options at these locations are either for the pipeline to pass over the top of the cables (resulting in some protuberance of the backfill) or to use the technique of horizontal directional drilling to bore underneath the cables. The pipeline engineering consultants advise that the latter may not be technically feasible. For the former, it is proposed to place grout mattresses both above and below the pipeline to provide the necessary protection. In any case the water depth at these locations is in excess of 26 metres which is below the draught of even the largest vessels. The cable crossing angles (mostly 30 - 60°) are such that the exposed area of the pipeline protection is small. At all crossing points the profile of any protrusion will be made as smooth as possible so that any objects being dragged along the seabed (such as trawl gear) will pass over the top of the pipeline with minimal damage or disturbance.

The crossing of the approach channel to the coal jetties at the Lamma Power Station is significant because of the change in water depth from 10 metres to 15 metres (in the channel) and back to 10 metres. To protect against the possibility of damage due to grounding of a bulk carrier on the side of the channel, the pipeline engineering consultants propose to take the pipeline burial depth down to 15 metres (below sea level) well before the channel crossing.

7.5.6 *Pipeline Integrity Monitoring*

The corrosion monitoring referred to above would be part of an overall integrity monitoring system which would also include inspection (internal and external) and leak detection. Pipeline inspection activities include techniques such as use of "intelligent" pigs (to detect buckles and dents, loss of wall thickness and pipe wall defects) and visual surveys (use of remote-operated vehicles to detect gross movements, scour and freespans, as well as damage to coating and anodes).

Methods of leak detection include continuous mass/volume balances of the pipeline contents, continuous monitoring of the rate of change of pressure/flow, acoustic monitoring, low pressure alarms and high/reverse flow alarms. These enable rapid detection of leaks which can then initiate emergency shutdown, blowdown and temporary repair.

For this pipeline provision is made for use of intelligent pigs and the leak detection system is likely to be that developed recently by Shell, which is sensitive, yet avoids a lot of the spurious leak signals which characterised previous systems of its type.

7.5.7 *Emergency Planning*

Pipelines are considered a safe mode of transport of hazardous substances and are often safer than alternative methods, eg road or rail transport. However, there are occasions when pipeline failure results an accidental release of the hazardous material to the environment. Emergency plans are required to cover this contingency so that suitable actions can be taken to mitigate the effects of the release on members of the public. Guidance on pipeline emergency planning is provided in the IP Pipeline Safety Code and the UK HSE's Further Guidance on Emergency Plans for Major Accident Hazard Pipelines. In Hong Kong the Gas Supply (Registration of Gas Supply Companies) Regulations, which HEC will be required to comply with, require gas importers to have arrangements in force for dealing with gas emergencies and this includes emergency plans.

From the UK HSE guidance, the typical contents of an emergency plan are given which includes:

- details of the pipeline and pipeline operator;
- the hazards and risks associated with the pipeline (including details of foreseeable major accidents);
- details of plan activation (including alerting, initiation and initial actions by the pipeline operator and external parties);
- organisation (including the command structure, roles and responsibilities of concerned parties, coordination and implementation arrangements);
- incident control points and communication facilities;
- support services;
- public information and protection; and
- information to the media.

In many countries emergency planning (including the preparation of plans, their upkeep and testing through emergency exercises) is regarded as a matter of good practice for major hazard industries.

The advantages of effective emergency planning are not only that it helps minimise impacts to the public from an incident on the pipeline, but also that it enhances the pipeline reliability by establishing a system for dealing with any leakages which may arise and cause interruption of the gas supply.

7.6 EVALUATION OF IMPACTS

Overview

This report presents a high level assessment of the risks to the public associated with the gas supply pipeline.

The hazards associated with submarine gas pipelines are generally well-understood and this is reflected in the numerous standards and codes of practice which exist to cover the design, construction, installation, testing, commissioning, operation and maintenance of such facilities.

The purpose of the risk assessment is to determine whether there are any insurmountable risk issues for this project, by examining any new or unusual features. The risk assessment firstly identifies the hazards associated with the operation of power station and gas supply pipeline, then examines the potential impacts on the public and, finally, assesses the risks, making reference to the requirements of the various standards and codes of practice referred to above.

Hazard Identification

For the gas supply pipeline the primary hazard is loss of integrity which may be caused by corrosion, mechanical failure, operational/maintenance error, third party damage or environmental factors. Corrosion and third party damage are historically significant causes and third party damage in particular is a concern as it is difficult to control and is highly environment-specific. The particular issues with regard to third party damage are the crossings of the shipping channels (and areas nearby), in particular the East Lamma Channel, the crossings of telecommunications cables, and the approach to the Lamma Extension site where the pipeline crosses the dredged channel used by the bulk carriers.

Consequence Assessment

The consequences of a major release of gas could be severe with little scope for escape. For releases which are ignited a large fireball or flash fire may result with fatal effects extending several hundred metres from the release location. Fatalities can arise due impact of the pipeline by a ship, which itself provides the ignition source for the release and exposes the ship's crew to the effects of the fire.

Risk Assessment

Various standards and codes exist for submarine gas pipelines. These standards recognise all of the hazards which have been identified and offer a variety of design solutions.

For the pipeline the particular issue which has been identified for this project is third party damage. The established practice for this hazard is to bury the pipeline, if necessary with engineering back fill or grout mattress as protection. This is the approach currently proposed by the HEC's pipeline engineering consultants and follows the precedent established by CLP's pipeline from Hainan. Additional measures which could be considered are optimisation of the pipeline routing and navigational/anchoring restrictions. It is considered that one or more of these options provides a feasible solution to the hazard of third party damage. Therefore, whilst pipeline protection will be a key issue for the detailed design stage of the project and the detailed risk assessment, it is not considered an insurmountable problem.

One further issue which emerges from the risk assessment for the gas supply pipeline is the importance of safety management. While the standards of hardware for pipelines may be similar, the standards of "software" (eg people, training, organisation) may vary considerably and this is a key determinant of the risk posed by such facilities to the public. The need for effective safety management arises from the recognition that most industrial accidents have their root cause in human error. Comprehensive safety management systems are nowadays regarded as essential in the major hazard industries. They provide clear management commitment to safety and comprise all the necessary components for effective, pro-active management of risks including coordination between concerned parties, written work procedures, communication, contractor control, training, risk assessment, auditing and management of change. An effective safety management system will assist HEC in meeting the requirements which GSO may impose when HEC come to apply for registration as a gas supplier.

7.7 *SUMMARY OF MITIGATION MEASURES*

The high level risk assessment which has been undertaken for the gas supply pipeline confirms that there are no insurmountable risks, but identifies two key issues: third party damage to the gas pipeline and safety management.

The following recommendations are made in respect of these key issues:

Third Party Damage to Gas Supply Pipeline

Once the engineering feasibility of the submarine gas pipeline has been confirmed and the basic design parameters confirmed, HEC should consider proceeding towards a more formal, quantitative assessment of the risks associated with the pipeline. This will provide an indication of the significance of the pipeline risks in terms of the Government Risk Guidelines. It will also assist in gaining a better understanding of the potential for third party damage and the degree of protection which is justified by the risk which the pipeline poses. Cost-benefit analysis can be included where appropriate. This assessment would include a review of relevant pipeline failure rate data from around the world, which will also be useful in assessing the availability of the gas supply.

Safety Management

HEC should review their existing safety management system against current best practice, as outlined in documents such as the UK Health and Safety Executive's

Successful Health and Safety Management and A Guide to the (UK) Pipelines Safety Regulations 1996. The former document sets out the broad requirements for effective safety management, whilst the latter sets out more specific requirements for major hazard pipelines.

7.8 *SUMMARY AND CONCLUSIONS*

From the high level review which has been undertaken, it is concluded that there are no insurmountable risks associated with the operation of the submarine gas pipeline for this project. Key areas of risk identified in the assessment include third party damage (for which more detailed assessment is recommended) and safety management.

8 SUMMARY AND CONCLUSIONS

8.1 INTRODUCTION

This Section provides a summary of the results and conclusions of technical assessments of the gas pipeline component of the Lamma Extension project, as described in detail in the previous Sections of this Part of the EIA Report.

These assessments have evaluated potential environmental impacts during the construction and operational phases of the pipeline and along its proposed route between Lamma Island and Shenzhen, including its approaches at each end.

8.2 WATER QUALITY ASSESSMENT

The technical assessment of water quality impacts is described in detail in *Section 4*.

Impacts to water quality will occur as a result of jetting of the trench between Shenzhen and Lamma Island and dredging of the seabed at the approaches to Shenzhen and Lamma Island. Trench dredging at the Lamma approach was assessed with reference to sediment dispersion modelling already carried out for the Lamma Extension reclamation, while additional modelling work was undertaken for the Shenzhen approach. Impacts from the jetting operations were assessed qualitatively.

The potential impacts from jetting operations will be of a similar type to those from trench dredging as both arise from the suspension of seabed sediment in the water column. The sediment to be disturbed is unlikely to be contaminated due to its remoteness from human activities. Consequently, no analysis has been made of possible impacts on levels of dissolved oxygen or nutrients.

Dredging Impacts

Water quality impacts from trench dredging at the Shenzhen approach were simulated using computer modelling of sediment dispersion. The only identified sensitive receivers in the vicinity were at Ping Chau. The modelling results indicated that water quality objectives for suspended solids (SS) would be met at all four stations in the vicinity of Ping Chau. The results also indicated that SS concentrations would decrease rapidly with increasing distance from the works, so that sensitive areas would not be subject to unacceptable sediment deposition.

The sediment loss rate expected from trench dredging at the Lamma approach is more than an order of magnitude less than the loss rates already simulated for the Lamma Extension reclamation (see *Section 5.4* of Part B). Impacts to water quality would therefore be much less than those for the reclamation construction, which have already been found to be environmentally acceptable.

Impacts of Jetting Operations

The rate of release of sediment to the water column as a result of jetting operations was estimated from a consideration of trench design and jetting procedures. The potential distance that the suspended sediment could be transported from the jetting machine was estimated based upon initial suspended sediment concentrations in the vicinity of the jetting machine, settling velocity and current speed. This assessment concluded that the maximum distance the suspended sediment could be transported by tidal currents was 400 metres from the jetting machine. This meant that there would be impacts on sensitive receivers as the nearest sensitive receiver is the Po Toi Fish Culture Zone which is 650 metres from the pipeline route. The impacts from jetting were thus considered to be environmentally acceptable as the increased suspended sediment concentrations would be localised to the jetting machine and would not impact any sensitive receivers.

Conclusions

It was concluded that the water quality impacts of the gas pipeline installation were environmentally acceptable, and no mitigation measures were recommended.

8.3 *MARINE ECOLOGY ASSESSMENT*

Section 5 presents the findings of the marine ecological impact assessment, which examined the potential impacts of the installation of the gas pipeline on marine habitats and species.

8.3.1 ***Baseline Conditions***

Information presented in the review of literature and in the results of comprehensive field surveys has indicated that the area potentially affected by the gas pipeline contains the following marine ecology sensitive receivers:

- the soft coral and hard coral assemblages on the southwestern tip of Lamma Island, on Po Toi Island, on Waglan Island and on Ping Chau;
- the finless porpoise population in the waters surrounding Lamma and Po Toi Islands (mainly southwest Lamma);
- the potential South Lamma Marine Park/Marine Reserve; and
- the potential Ping Chau Marine Park/Marine Reserve.

The list of marine ecological sensitive receivers includes only habitats / populations of high ecological value. The ecological values of the marine habitats along the pipeline route were evaluated using the criteria in the *EIAO TM*, with the following results:

- soft bottom habitat along most of the route: *low* ecological value, with a low abundance of common species in an environment which is regularly disturbed by storms and trawling activity;
- hard bottom habitat at SW Lamma, Po Toi, Waglan, Ping Chau, Breakers Reef and Victor Rock (outside of the pipeline route): *high* ecological value, due to valuable soft and hard coral assemblages; and
- habitat of the Finless Porpoise in southern waters: *high* ecological value, as this protected species is known to seasonally inhabit waters around Po Toi and Lamma Islands.

8.3.2 *Impact Assessment*

No long-term direct impacts were expected to occur through the installation of the gas pipeline. Short term impacts will occur as a result of jetting operations but, once these operations have ceased, marine ecological resources in the affected area are expected to return due to recolonisation of the seabed by benthic fauna.

Indirect impacts are predicted to occur through elevations in SS concentrations, but impacts are expected to be localised and of short duration (see the above summary of the water quality assessment). Most of the disturbed material is expected to rapidly settle back onto the seabed in the immediate vicinity. A small portion may be lost to suspension but this should remain in the lower part of the water column and settle back onto the seabed over a short distance.

The pipeline along the remainder of the route (ie the one kilometre approaches to the LNG terminal in Shenzhen and the Lamma Extension) will be laid using grab dredging. Sediment loss rates will be at least 14 times less than for dredging of the Lamma Extension reclamation site, hence the water quality impacts were considered negligible. Similarly, impacts to the identified hard bottom habitat sensitive receivers at south Lamma, Po Toi Island, Waglan Island and Ping Chau are also negligible by the pipeline installation.

The Chinese White Dolphin (*Sousa chinensis*) and the Finless Porpoise (*Neophocaena phocaenoides*) are the only species of marine mammal regularly sighted in Hong Kong waters. Sightings of the Finless Porpoise have mainly been in the coastal waters of southwest Lamma Island, and there has been a seasonal pattern to these sightings. Installation works for the gas pipeline should take into account the occurrence of *Neophocaena phocaenoides* in the water around southwest Lamma.

Impacts to *Neophocaena phocaenoides* may arise through the following activities during construction of the gas pipeline:

- *Habitat Disturbance Due to Traffic and Noise*: The construction of the gas pipeline could potentially result in an increase in marine traffic and underwater noise affecting *Neophocaena phocaenoides*. Noise disturbance interferes with communication and echolocation pulses which are used for navigation and feeding, leading to behavioural changes. In addition, underwater noise and increases in marine traffic may disturb normal cetacean movement patterns through potential collision with vessels, increased turbidity generated by propellers, and submerged equipment.

- *Disruption to Food Supply*: The construction of the gas pipeline may cause perturbations to water quality which may potentially impact the fisheries resources of the southwest Lamma area. *Neophocaena phocaenoides* is thought to be an opportunistic feeder with known prey including shrimps, prawns, squids, octopus and small pelagic fish, and may be adversely affected by changes in key water quality parameters arising from construction work. A deterioration in water quality is likely to cause these mobile fish to move out of the area, thus interfering with their normal feeding patterns.

Provided care is taken to schedule construction work so that it does not adversely affect the Finless Porpoise (ie there should be no jetting works in southwest Lamma during the spring peak in porpoise abundance), the residual marine ecological impacts associated with the construction of the gas pipeline are considered to be low.

Potential impacts to marine ecological resources and the above sensitive receivers may arise from direct disturbances to habitats, or through changes to key water quality parameters, as a result of the installation of the gas pipeline. However, the loss of subtidal assemblages during the dredging and laying of the gas pipeline, are predicted to be short term as assemblages are expected to recolonise post construction.

As impacts arising from the proposed dredging and jetting works are predicted to be largely confined to the specific dredging and jetting areas, they are not expected to cause adverse impacts to any marine ecological resources (habitats or species). Constraints on dredging and jetting operations recommended to control impacts to water quality to within acceptable levels (water quality objectives) also mitigate impacts to marine ecological resources. The marine ecological sensitive receivers listed above are all remote from the dredging / jetting operations and are not predicted to be impacted. In the interests of avoiding impacts to the breeding population of finless porpoise present around the south of Lamma Island during the spring peak in abundance, it is recommended that jetting operations in this area avoid this time of year. According to the existing timetable the jet ploughing will occur during the autumn in waters to the south of Lamma.

Based on the ecological value of the habitats discussed in the previous sections and the resultant mitigation requirements the residual impact can be determined. The only residual impact occurring as a result of laying of the gas pipeline is the loss of the subtidal assemblages present within the dredging/jetting areas. The residual impact is considered to be acceptable as the habitat is of low ecological value and because infaunal organisms and epibenthic fauna are expected to recolonise the sediments after the pipeline has been laid.

8.4 *FISHERIES IMPACT ASSESSMENT*

As with the marine ecology assessment (*Section 5*), the fisheries impact assessment (*Section 6*) considered both the direct and indirect impacts on fisheries resources, fishing operations and fish culture activities associated with the laying of the gas pipeline. Potential impacts associated with the loss of habitat which supports fisheries and increased pollution during construction of the pipeline were evaluated.

8.4.1 *Baseline Conditions*

A desk top study was undertaken to establish the baseline conditions for the assessment. Five Fishing Zones examined in the power station component of this assessment are also included within areas that may be affected by the gas pipeline. A further seven Fishing Zones have been identified as areas which may be affected the pipeline. The southern waters are of areas of high commercial value and of consequent high importance, while the eastern and northern waters along the pipeline route appear to have little value or importance. The southern waters of Hong Kong are also a spawning ground and nursery area for important and high value commercial species.

The following fisheries sensitive receivers were identified for the purposes of this assessment:

- the seasonal spawning ground in southern waters; and
- the seasonal nursery area in southern waters.

8.4.2 *Impact Assessment*

No long-term direct impacts are expected to occur as a result of pipeline installation. Fisheries resources dependent on areas affected by the works are expected to return after works are complete, due to recolonisation of the seabed by the supporting benthic fauna.

Indirect impacts are predicted to occur through elevations in suspended solids (SS), however only low levels of disturbance to the seabed are expected. Most of the mobilised sediment will form a fluidised suspension of sediment and water close to the seabed. This fluidised layer will very rapidly settle back onto the seabed in the immediate vicinity. A small portion of the sediment may be lost to suspension but should settle back onto the seabed over a relatively short distance and time period.

The approaches to the LNG terminal in Shenzhen and Lamma Extension will be formed using grab dredging. The sediment loss rates are predicted to be at least 14 times less than the values for dredging of the Lamma Extension reclamation site, hence the water quality impacts were considered negligible. Based on these assessments, the impacts to fisheries resources are negligible.

The only residual impact identified that may affect commercial fishing operations is the disturbance to fishing activity during the pipeline laying and jetting operations. The magnitude of this residual impact is low since the operations move at a rate of 1- 3 km per day and thus impacts to specific fishing grounds will be of very short duration.

Based on an evaluation of the impacts in accordance with the *EIAO TM*, it was concluded that no unacceptable impacts to fisheries would occur as a result of these gas pipeline installation, because of the localised and short-term nature of the predicted impacts.

8.5 *HAZARDS ASSESSMENT*

The risk assessment undertaken for the gas supply pipeline (see *Section 7*) was essentially qualitative in nature, and focussed on identifying any new or unusual features of this project, in relation to other similar facilities operating elsewhere. This approach recognised that the hazards associated with submarine gas pipelines are generally well understood and that reliable safeguards exist to ensure that risks are as low as reasonably practicable.

Potential causes of loss of integrity of submarine pipelines which were identified during the assessment included the following:

- corrosion (internal and external);
- mechanical failure (material defects, fabrication defects, fatigue);
- operational or maintenance errors;
- third party damage (eg dropped objects, seabed fishing activity, anchor damage, vessel impact); and

- environmental factors (hydrodynamic loading, seabed mobility, marine growth and seismic activity).

Causes and Consequences of Pipeline Failure

A review of the available literature was undertaken to analyse the most frequent causes of loss of containment and identify potential consequences and impacts. The review indicated that mechanical failure (eg due to corrosion or weld defects) and third party damage are the major causes of pipeline failure. While there have been significant technological advances in prevention of mechanical failure in recent years, third party damage is considered to be harder to control and highly environment-specific.

Loss of pipeline integrity presents significant potential hazards to anyone in the vicinity. Guillotine rupture would release a large volume of gas which would bubble to the surface and begin to disperse in the atmosphere. A particular hazard arises where the cause of the damage is a vessel, which itself might provide a source of ignition, leading to a fireball or flash fire with potentially fatal effects on the people on board the vessel. Injury or death may occur either through direct exposure to thermal radiation or as a result of secondary fires. If immediate ignition does not occur then the cloud will drift downwind and may be ignited after a delay by a passing ship, resulting in a large flash fire.

Apart from thermal radiation, the other hazards associated with loss of containment of gas pipelines are as follows:

- blast effects due to the sudden release of stored energy;
- projectiles arising from the pipeline backfill material;
- the buoyancy of the gas release which may capsize vessels; and
- asphyxiation due to the exclusion of oxygen in the vicinity of the release.

Risk Assessment

High pressure submarine gas pipelines are a common feature of the energy supply system in many countries. Considerable experience has been developed in the risks associated with such pipelines and the means by which they can be reduced to as low a level as reasonably practicable. This is reflected in the various standards which exist for the design, construction, testing and commissioning of pipelines.

- Corrosion

Corrosion is a recognised problem for pipelines in salt water environments, with well-established techniques for combatting external and internal corrosion, backed up by corrosion monitoring programmes. For the present pipeline it is proposed to protect against external corrosion by providing an asphalt enamel coating together with cathodic protection using a sacrificial anode. Internal corrosion will not be a significant hazard, as the gas from the LNG plant is free of sulphur and moisture. The pipeline design includes facilities that would enable operation of an intelligent pig.

- Mechanical Failure

Mechanical failures are becoming rarer due to better material specification, improved manufacturing controls and routine application of non-destructive application of field welds. BS 8010, for example, specifies quality assurance requirements covering the design, construction, testing and commissioning phases of the pipeline.

- Operational or Maintenance Error

One of the key requirements for an operator of a potentially hazardous pipeline is to establish an effective safety management system. Detailed guidance on establishing and implementing such a system is available from a variety of recognised sources, which document best practice in the industry and the standards which this project would be expected to meet.

- Third Party Damage

The proposed pipeline will be installed with concrete weight coating, together with trenching to a depth of 3 metres and either backfilling with rock armour or provision of grout mattresses (for up to 50% of the route length). For risers, protection is usually afforded by suitable location of the riser and, if necessary, protection by fenders.

The four main potential sources of damage are dropped objects, anchors, fishing/trawling gear, and vessel impact. The provision of trenching with backfill (up to 50% rock armour) or grout mattresses should provide substantial protection against these sources of impact. However, absolute protection is not guaranteed and the degree of residual risk needs to be considered further in a more detailed examination of the potential sources of third party damage, for which a more formal quantitative assessment is recommended when more detailed design information is available.

Two aspects of the pipeline route worthy of particular consideration are the locations where the pipeline crosses telecommunications cables and the crossing of the dredged channel used by large bulk carriers approaching the coal jetties at the existing Lamma power station.

Where the pipeline route crosses telecommunications cables, the options are for the pipeline to pass over the top of the cables (resulting in some protuberance of the backfill) or to use the technique of horizontal directional drilling to bore underneath the cables. The pipeline engineering consultants have advised that the latter may not be technically feasible. For the former, it is proposed to place grout mattresses both above and below the pipeline to provide the necessary protection. Also, the water depth at these locations is in excess of 26 metres which is below the draught of even the largest vessels. At all crossing points the profile of any protrusion will be made as smooth as possible so that any objects being dragged along the seabed (such as trawl gear) will pass over the top of the pipeline with minimal damage or disturbance.

The crossing of the approach channel to the coal jetties at the Lamma Power Station is significant because of the change in water depth from 10 to 15 metres (in the channel) and back to 10 metres. To protect against the possibility of damage due to grounding of a bulk carrier on the side of the channel, the pipeline engineering consultants propose to take the pipeline burial depth down to 15 metres (below sea level) well before the channel crossing.

- Pipeline Integrity Monitoring

The corrosion monitoring referred to above would be part of an overall integrity monitoring system which would also include inspection (internal and external) and leak detection. Pipeline inspection activities include techniques such as use of "intelligent" pigs (to detect buckles and dents, loss of wall thickness and pipe wall defects) and visual surveys (use of remote-operated vehicles to detect gross movements, scour and free spans, as well as damage to coating and anodes).

- Emergency Planning

Pipelines are considered a comparatively safe mode of transport of hazardous substances. However, there are occasions when pipeline failure results an accidental release of the hazardous material to the environment. Emergency plans are required (and, indeed, mandated by Hong Kong regulations) to cover this contingency so that suitable actions can be taken to mitigate the effects of the release on members of the public, and detailed guidance is available on emergency planning from a variety of authoritative publications.

Conclusions

From the high level review which has been undertaken, it is concluded that there are no insurmountable risks associated with the operation of the submarine gas pipeline for this project. Key areas of risk identified in the assessment include third party damage (for which more detailed assessment is recommended) and safety management.

8.6 CONCLUSIONS

A detailed and comprehensive assessment of the potential impacts of the gas pipeline for the Lamma Extension project has been completed. No unacceptable or insurmountable impacts are expected from the proposed development, provided the recommended mitigation measures are adopted and implemented.