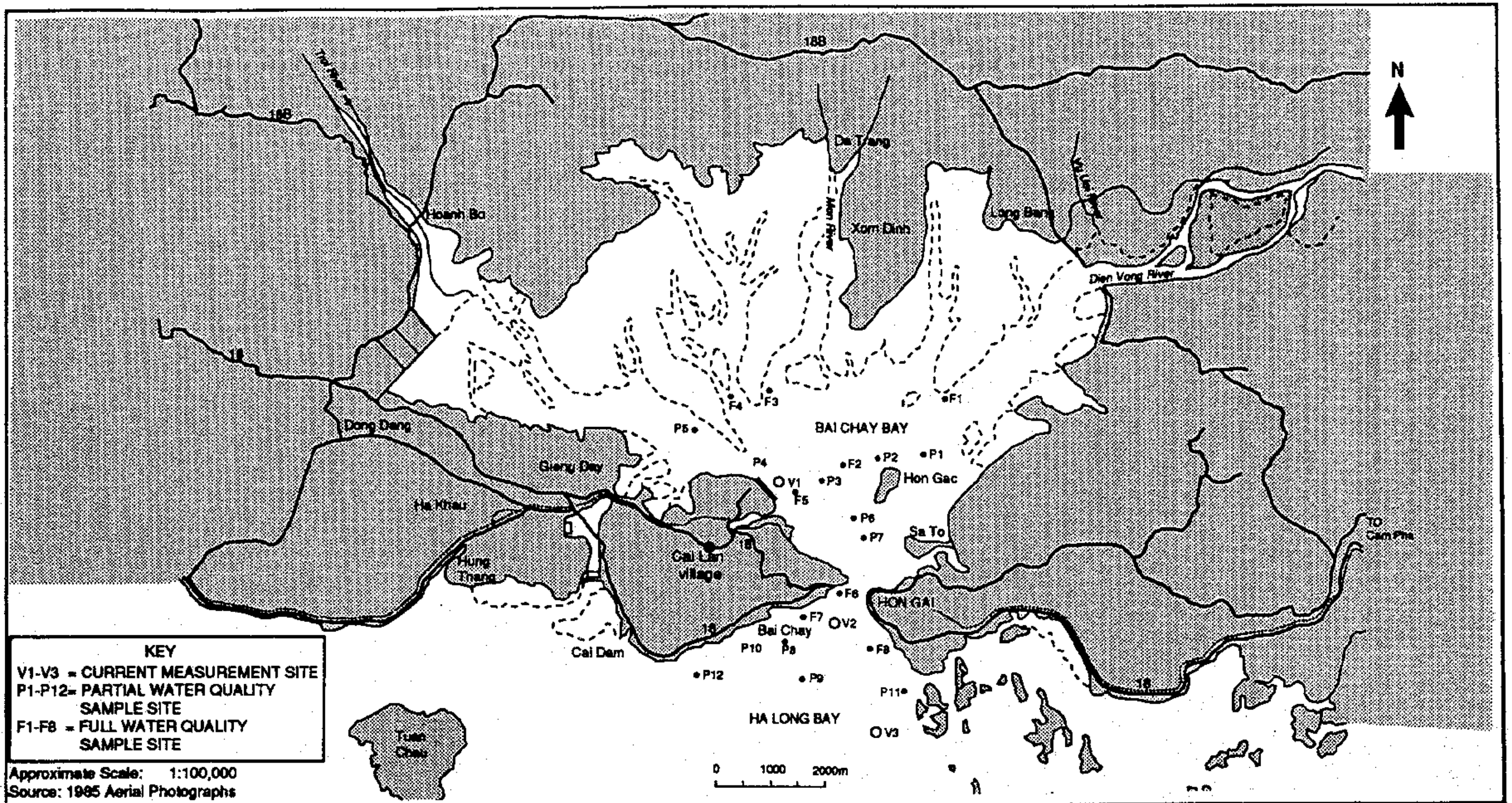



LOCATION OF WATER QUALITY, SEDIMENT AND CURRENY SURVEY POINTS

FIG. 5-1

FEASIBILITY STUDY FOR CAI LAN PORT CONSTRUCTION PROJECT

During the spring tide, current direction on the incoming tide at V1, offshore of Cai Lan Port tended to be in a north-westerly direction, horizontal to the shoreline, except around one hour before the high tide when the current speed slowed and the current direction tended toward the shoreline. On the outgoing tide, the current flowed horizontal to the shoreline in a south-westerly direction. On the neap tide the current speed was much slower, but the directions remained similar.

At V2, in Cua Luc Strait on the spring incoming tide, the current direction was parallel to the channel sides or tending towards Bai Chay. On the outgoing spring tide, the current direction swung around to the east, to the south and finally to the south-west over a three hour period. During neap tide, current movement at V2 was very slow, flowing parallel to the shoreline and into Bai Chay Bay on the incoming tide, and was stationary over some periods. On the outgoing tide, the current again swung around to the east and south.

At V3, on the incoming spring tide, the current flow was toward the north west, tending toward the Bai Chay Peninsula. On the outgoing tide, the flow was toward the south-west to south. On the incoming neap tide, the current direction was similar to the spring tide, toward the Bai Chay Peninsula. On the ebb tide, current speed was slow and the current moved around to the east and south.

Tidal elevations were a maximum of 3.71 m on 26 January 1994 and a minimum of 0.52 m on the same day.

#### 5.3.5 Waves

The wave regime off Cai Lan Port was observed during the period of 1965 - 1968 and reported in TEDI (1988). For more than 90 % of the time, the waves over this period could be categorised as "calm", which means that the wave climate was mild, posing no major obstacle in terms of port planning. Waves rarely exceeded 1.0 m in height. The predominant wave direction was NE (refer Appendix 2 Table A2-8.

More recent data provide by DCQNP reports wave conditions at Hon Gai Station for the period 1980 to 1992 (Table A2-9) Similar to the information summarised above, the sea was calm for the great majority of the time (85 %). Waves greater than 1 m occurred only 0.1 % of the time. Waves were most frequently from the north to north-east, but at Hon Gai waves from the south to south-east were also common.

The location of Cai Lan Port on the northern shoreline of Bai Chay Peninsula means that waves from the northerly points of the compass could most affect the port site. The greatest fetch across Bai Chay Bay to Hon Gai is approximately 8 km from the north-east and 9 km from the north-west at high tide. At Cai Lan the fetch is also 8 - 9 km to the north-east, into the Dien Vong River, but only approximately 6 km to the north. Cai Lan may thus experience slightly smaller waves from the north than those recorded at Hon Gai.

### 5.3.6 Storm Surges

Storm surges occur frequently along the Quang Ninh Coastline in the vicinity of Cai Lan Port. The combination of winds, tide, and decreases in atmospheric pressure associated with typhoons or tropical depressions can contribute to development of a storm surge.

In the period 1960-1990, 37 storm surges landed on the coast between Mon Cai and Quang Ninh, the area in which Cai Lan Port is located. Most occurred between June and October. Storm surge maximum height was 2.5 m. Only 2 % of all surges recorded were of this magnitude. Most were lower than 1 m (88 %). More detailed information about storm surges in this vicinity is reported in Appendix 2.

### 5.3.7 Sediment Load in Rivers

There is considerable variation in the sediment load in river waters in Quang Ninh Province. Detailed data is not available for all of the rivers entering Bai Chay Bay, except for a tributary of the Dien Vong River. Data from this and other stations within the province are reported below.

Monthly suspended solids and sediment flow were recorded at three stations over the period 1980 to 1990. These were Binh Lieu Station, on a tributary of the River Pho Cu, north-east of Bai Chay; Duong Huy, on a tributary of the Dien Vong River, which drains into Bai Chay Bay; and Bang Ca, on the Yen Lap River, to the west of Bai Chay. The sediment levels and flow rates recorded at each station are presented in Appendix 2 along with the average sediment discharge in the same three rivers.

The highest suspended solids loading in the Binh Lieu River was 102 g $m^{-3}$ and in the Bang Ca River, 145.7 g $m^{-3}$. Both these maxima were recorded in May. By comparison, the maximum suspended solids concentration recorded at Duong Huy which drains to Bai Chay Bay was 49.4 g $m^{-3}$, recorded in August. In this river, suspended solids concentrations decrease to below 10 g $m^{-3}$ in winter under low flow conditions.

The average annual sediment discharged from the Duong Huy catchment was 91 tonnes per square kilometre, higher than that discharged from the Bang Ca Catchment, but considerably lower than that discharged from the Binh Lieu Catchment (133 tonnes per square kilometre). There are no comparative figures available for the other rivers draining into the Bai Chay Catchment.

## 5.4 Geology

### 5.4.1 Introduction

The following information is derived from a geophysical survey carried out in April 1994 by Electronic and Geophysical Services Ltd, of Hong Kong, with the assistance of TEDI. Information from a borehole drilling programme undertaken by TEDI in 1976 is also included.

### 5.4.2 Geological Succession

The coastline of Vietnam is a drowned coastline consequent on the rise of mean sea level of some 80 m over the past 10,000 years. Older (alluvial) sediments containing weathered rock fragments were overlain during this period by recent deposits which are likely to comprise soft silty clays or clayey silts offshore. Inshore, these recent deposits may comprise loose silty fine / medium sands.

The most visible rock type in the area is the karst limestone which is responsible for the dramatic island topography offshore in Ha Long Bay. However, intrusive / extrusive rock is likely to be present but it is not known of what type is the older formation.

The seismic records can be interpreted to give the following four elements of the geologic succession:

(Seabed)
Horizon 1: Soft, silty clayey sediments.
Horizon 2: Gravels with clays and sands / weathered debris / alluvium.
Horizon 3: Rock of any type (sandstone, quartzite, limestone, extrusive / intrusive rock.
Horizon 4: Extrusive / intrusive rock.

In places one or more of the sedimentary units may be missing, for example, where soft silty / clayey sediments pinch out against the underlying gravels / alluvium and rock, close to the shorelines.

This succession is generally confirmed by borehole logs recorded by TEDI during a drilling programme undertaken in 1976. Fig. 5-2 shows a typical cross section of the seabed from that survey. The borehole profiles reveal the following information. The upper layer consists of sandy silt at a consistency of running plasticity. Near the shoreline, there is a surface layer of black-grey silt sand and clay mixed with clam shells and organic matter. Somewhat similar material also forms a layer in the deepest part of the channel. Below this surface layer is a layer of clayey sand in a hard-plastic state. The bed rocks appear below this sandy silt at variable depths of around -6.0 m to -12.0 m elevation. The rock is limestone and the top layer of this is weathered to a depth of approximately 3-5 m.

### 5.4.3 Dredgeability

There are no available in situ or laboratory test results for use in assessing dredgeability, but dredging is likely to become more difficult with depth. Table 5-1 shows a possible dredging scenario.

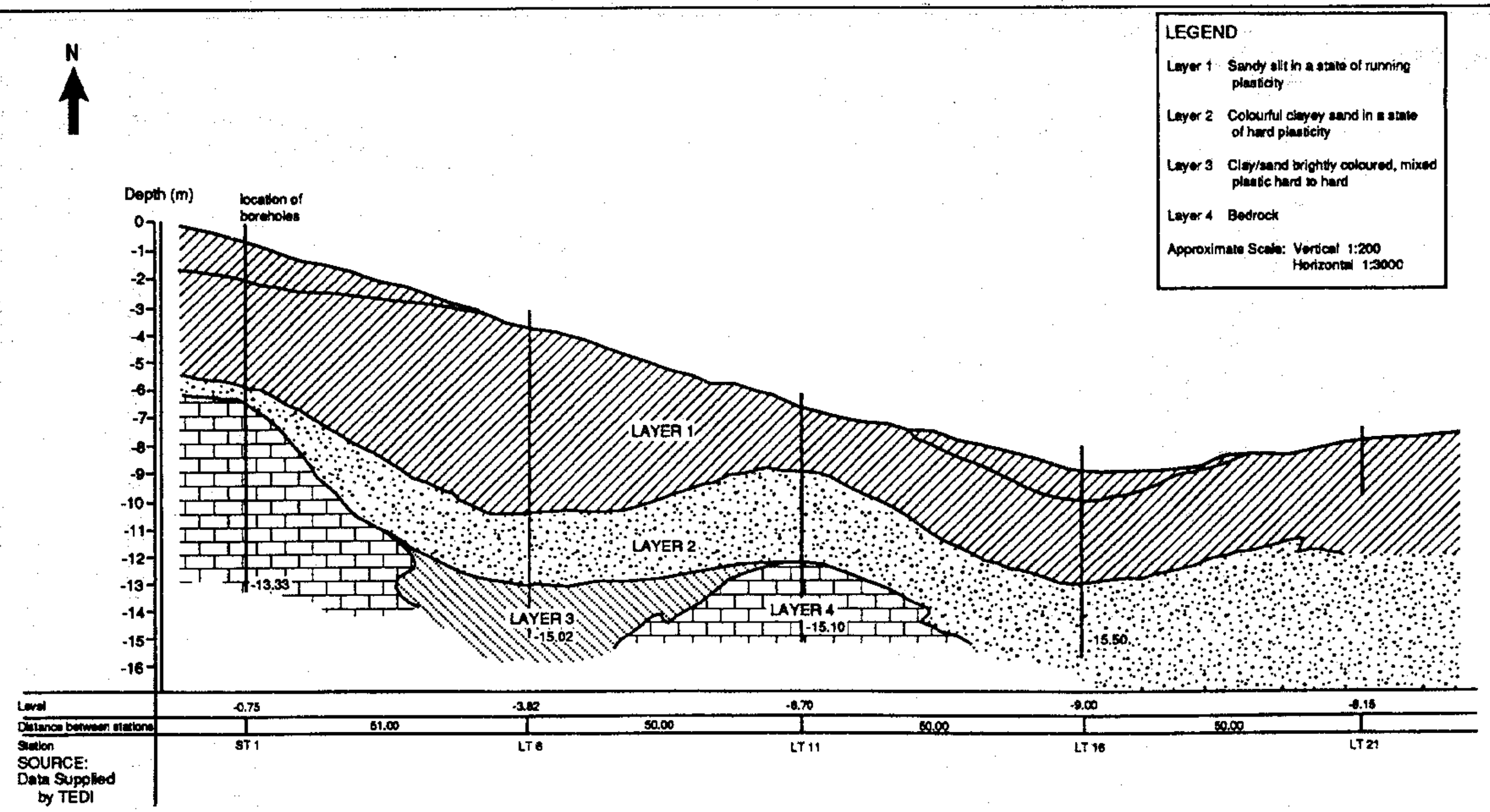
Table 5-1: Possible dredging scenario.

| Material | Method |
|---|---|
| Horizon 1: Recent soft silty clayey sediments. | Clam shell, trailer suction, bucket. |
| Horizon 2: Alluvial material with weathered rock pieces. | Clam shell (?), cutter suction. |
| Horizon 3: Rock of any type. | (Possibly) drilling and blasting. |

Source: Electronic and Geophysical Surveys Ltd, 1994.

### 5.4.4 Seismic Disturbance

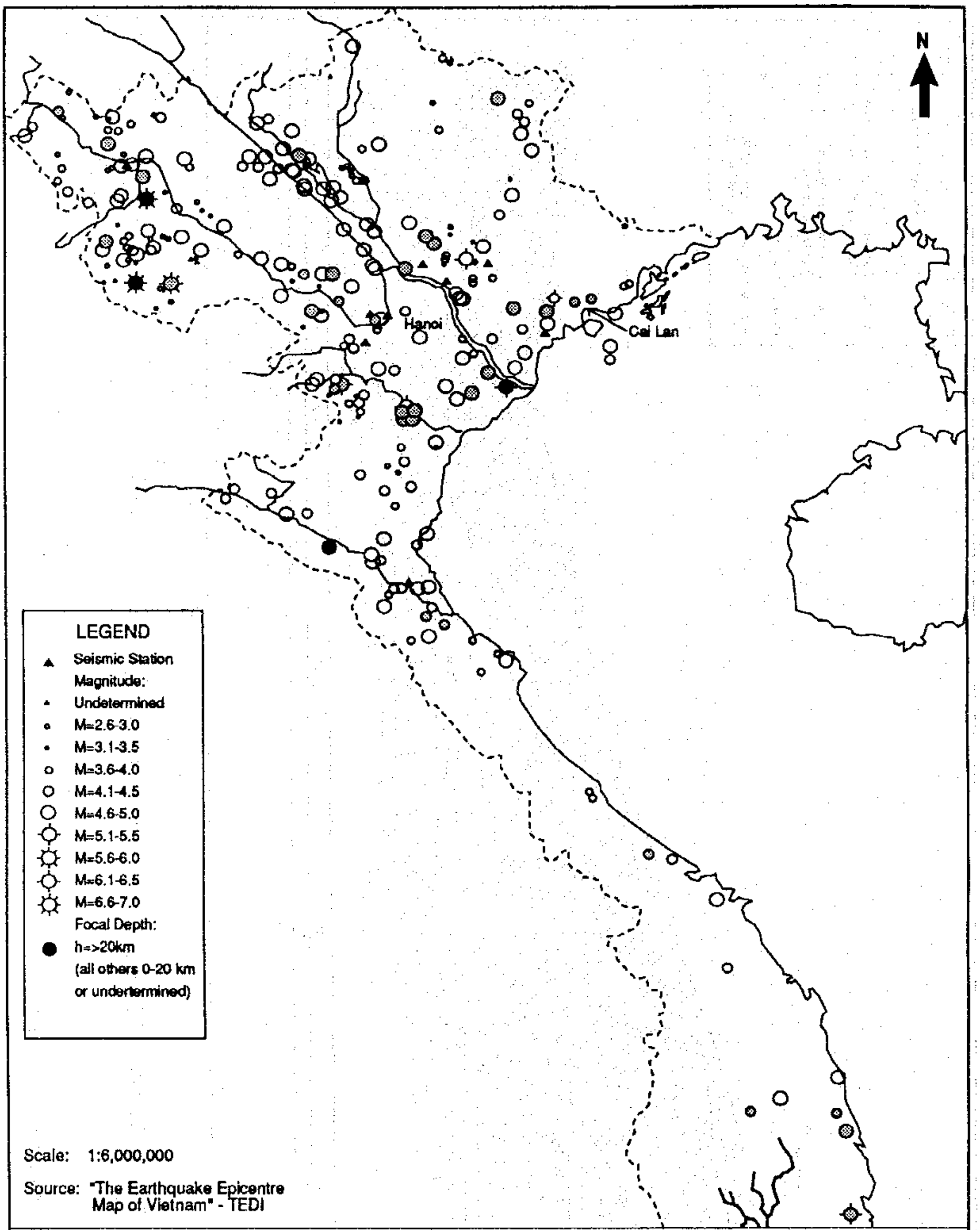
In Vietnam, more earthquakes occur in the northern part than the southern part. In North Vietnam near the project area, there are three seismic stations; Hai Phong, Hanoi and Bac Giang. According to TEDI's information, a large fault line lies along the Red River and earthquakes have been frequently recorded along this zone. The local seismic map indicates that this belt area belongs to a seismographic zone with a magnitude of 6.1 - 6.5 on Richter scale. The project site at Cai Lan is slightly away from this high seismic intensity zone, having a potential magnitude of 5.6 - 6.0. This magnitude can be translated into a design force of Kh = 0.05. The past records of earthquakes and the seismic zone of North Vietnam are shown in Fig. 5-3 and Fig. 5-4.




REPRESENTATIVE GEOLOGICAL CROSS-SECTION IN THE VICINITY OF CAI LAN PORT

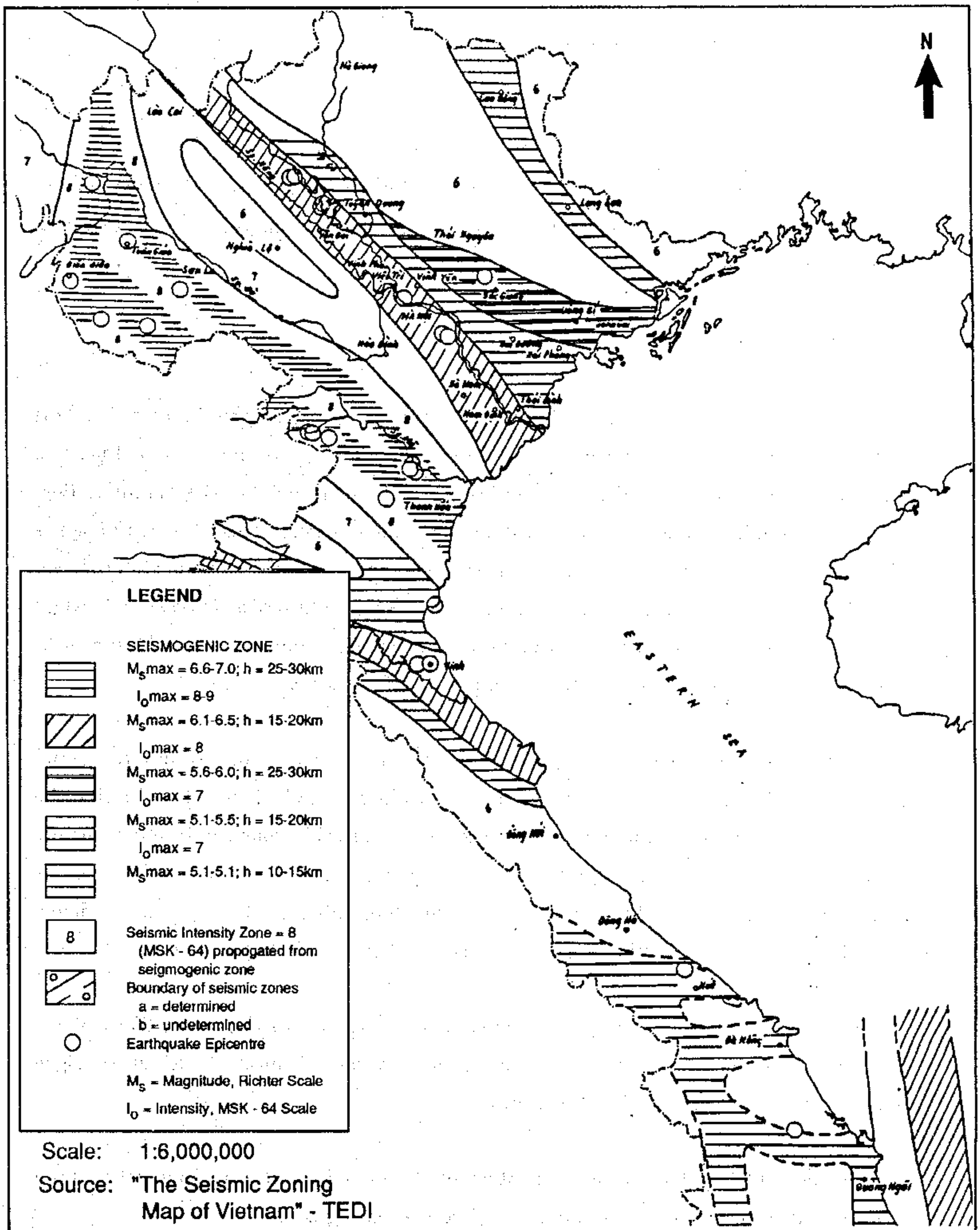
FIG 5-2

FEASIBILITY STUDY FOR CAI LAN PORT CONSTRUCTION PROJECT




LOCATION OF EARTHQUAKE EPICENTRES IN NORTHERN VIETNAM FIG. 5-3

FEASIBILITY STUDY FOR CAI LAN PORT CONSTRUCTION PROJECT




Scale: 1:6,000,000

Source: "The Seismic Zoning Map of Vietnam" - TEDI

SEISMIC ZONES IN NORTHERN VIETNAM

FIG. 5-4

## 5.5 Vegetation of Cai Lan Port Area

### 5.5.1 Introduction

The vegetation and ecological characteristics of the Cai Lan Port area were surveyed in February 1994 by the Project Team's Environmental Specialists. The coastal and terrestrial vegetation are described below.

### 5.5.2 Coastal Vegetation

The intertidal vegetation along the shoreline west of the existing berth at Cai Lan Port is limited to a few isolated, squat mangrove trees. The main species found was *Avicennia marina* growing typically as a dwarf shrub less than 0.5 m in height. The laminae (leaf blades) were small, indicating stressed growth in a difficult substrate. This consisted of stones and rocks in the mid and upper intertidal zone with mud and estuarine sediments in the lower littoral. Beyond mean high water were maritime grasses such as *Cyanodon dactylon* and sedges such as *Cyperus malaccensis*. Scattered grasses and occasional opportunist trees such as self-sown *Eucalyptus* sp. occurred behind the coastal patches of *Cyanodon*.

East of the existing berth, a sparse zone of *Avicennia* extends around the stony intertidal area. This grades into a zone of sparse grasses and herbs before leading into the denser grasses and shrubs of the lower hill slopes. A considerable quantity of refuse, mainly plastic bags and other plastic scrap, was present in the upper intertidal zone in this area. A pagoda is present approximately 100 m from the berth along this shoreline and it seems likely that the plastic wrappers and other debris were discarded by visitors to the pagoda.

Intertidal macroalgae were poorly represented at the time of inspection (December - January 1994). On the pneumatophores of the sparse *Avicennia* shrubs, colonies of red algae (Rhodophyceae) were occasionally established.

The intertidal and maritime vegetation of the area was of very low value, both ecologically and economically, and could best be described as degraded.

### 5.5.3 Terrestrial Vegetation

The port area is mainly comprised of flat land and some small hillocks, lying between the seashore and the low hills which rise to the south. Considerable areas are bare of vegetation, possibly due to development activities during construction of the existing berth and to earlier activities during the period when the area was used as a navy base. In general, the area could be said to have been completely modified. All of the vegetation is regrowth and no natural forest vegetation is present. Plate 5-1 shows the vegetation of the area as seen from a hill behind the port. Table 5-2 lists the species identified from this area.

On the small hillocks in the port area the vegetation consists of grasses such as *Panicum maximum* and *Imperata cylindrica*. These contribute up to 90% of the vegetation cover on these hillocks. Occasional trees and shrubs are present such as *Hibiscus tiliacea, Phyllanthis emblica, Psidium guyava* and *Pueraria thomsonii* along with a large vine (Fabaceae). Members of the *Mimosa* family are also present. The dry, clayey soil supports a very sparse ground covering vegetation of grasses and herbs amongst the larger clumps of *Panicum* and the shrubs. There is evidence of burning on the top of one hillock and small craters in the surface (depth approximately 1.5 m).

The umbrella fern *Dicranopteris linearis* has colonised a large part of the side of one of these hillocks and is present elsewhere in the area.

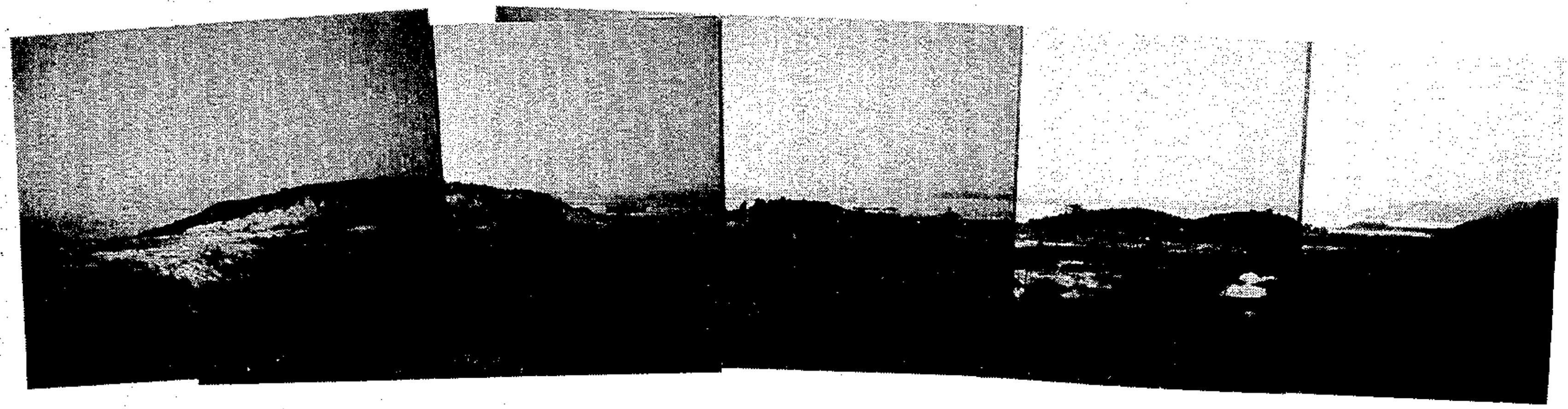
East of the existing berth, the largest of the hillocks supports a denser shrub and forest cover. Species present include many of those found elsewhere on the site, but here the canopy is taller (up to around 5-10 m, and occasionally much larger trees are present. This hill has not been affected by recent activities in the port area, but is likely to have been cleared or burned in the past.

On the flat land around the port the vegetation is generally very sparse, consisting of grasses and herbs. In damp areas some sedges and rushes are present, including *Eleocharis* sp., *Scleria oryzoides* and *Cyperus polystachus*. Occasional clumps of *Panicum maximum* and the large bamboo-grass (?*Mischanthus* sp.) are present and one juvenile palm *Phoenix lancearis* was found. A prostrate member of the Mimosidae was occasionally present on the flat ground near the bases of the hillocks.

Table 5-2: Plant species collected at Cai Lan Port site.

| | |
|---|---|
| FERNS AND ALLIES | Rushes and sedges |
| *Dicranopteris linearis* | *Cyperus polystachus* |
| *Lycopodium sernuum* | *Eleocharis sp.* |
| | *Eriocaulon hookerianum* |
| MONOCOTS | *Scleria oryzoides* |
| Monocot herbs | *Spilanthes paniculata* |
| *Phylidrum languinosum* | *Stachytaphyta japonica* |
| | |
| Monocot trees | DICOTS |
| *Cuscuta japonica* | Dicot trees and shrubs |
| *Phoenix lancearis* | *Cassia sp.* |
| | *Catharanthus roseus* |
| Grasses | *Fabaceae* |
| *Cyanodon dactylon* | *Hibiscus tillaceus* |
| *Dactylotenium aegyptiacum* | *Melastomia candidum* |
| *Eragrostis tremula* | *Memecylon edule* |
| *Eragrostis montana* | *Mimosoidae* |
| *Eulalia phaeothrix* | *Phyllanthus emblica* |
| *Imperata cylindrica* | *Psidium guyava* |
| *Leptochloa chinensis* | *Pueraria thomsonii* |
| *Panicum maximum* | *Rhodomyrtus tomentosa* |
| *Panicum repens* | |
| *Saccharum spontanem* | |
| *Uraria lagopoides* | |

Note: Species identified by Biogeography Division, Institute of Geography, Vietnam Centre of Natural Science and Technology, Hanoi.



VEGETATION OF CAI LAN PORT SITE

PLATE: 5-1

DATE: DECEMBER 1993

FEASIBILITY STUDY FOR CAI LAN PORT CONSTRUCTION

Behind the western-most hillock is a quarry area which is apparently being mined for low-grade coal and may also be used as a source of fill material in the construction of the existing berth and apron area. Here
the ground was cracked and dry and supported very little vegetation. However, in some damp hollows, small stands of sedges such as *Eleocharis* sp. and *Eriocaulon hookerianum* were present. The occasional *Rhodomyrtus tomentosa* shrub was found in the area. On the hill above the quarry escarpment the vegetation was similarly composed of grasses and shrubs as that described above. Some self-sown *Pinus* trees were present.

On the flat ground directly below the eroded slope of the quarry a sward of rushes, sedges, grasses and other monocots was present. In particular, a large area of *Phylidrum lanuginosum* was present growing in marshy ground near a well in the centre of this flat area. Grass and sedge vegetation extended across this low plain to the causeway at the edge of the small Cai Lan Estuary. The topography was uneven over much of the area nearest the causeway and parts of it were flooded. Rush and sedge vegetation dominated this area.

The hills behind the port area support large plantations of fruit crops such as pineapple, and timber plantations, mostly *Eucalyptus* sp. Some of the latter have been very recently planted and there are recent burn scars in areas which are about to be cultivated.

By way of general summary, the whole area has been severely modified by activities including burning, quarrying, forestry and agriculture, as well as the port construction activities themselves. The existing vegetation bears little resemblance to the original forest vegetation which would have covered this area. Although it is likely to provide a habitat for various birds, rodents, invertebrates and other animals, there are large areas of similar habitat on the hills behind Cai Lan and elsewhere in the local area.

## 5.6 The Marine and Intertidal Environment

### 5.6.1 Introduction

In this section of the report the effects of existing land uses on the marine and intertidal environment are described. The historical land use practices that have contributed to current status are described in section 5.6.2. Section 5.6.3 describes the overall status of the marine and coastal environment (this is discussed in more detail in Chapter 6). Sections 5.6.4 and 5.6.5 describe the water quality and sediment quality of the Bai Chay Bay and Inner Ha Long Bay areas. These two latter sections report the results of surveys undertaken by the Centre for Marine Mechanics, Institute of Mechanics, at 20 sites during winter and summer, 1994.

Existing water quality data collected from coastal stations in Quang Ninh Province is presented (information provided by DCQNP) and some additional water quality data provided by Quang Ninh Province is also included.

### 5.6.2 Existing Status of the Environment due to Land Use Practices

The land use practices in the vicinity of Bai Chay Bay have already had an effect on the environment and these are described below. Effects of the development of Cia Lan Port and other new industries will thus be overlaid on the existing effects. The effects of Cai Lan Port development are described in Chapter 7.

As described in Chapter 3, land use around Bai Chay Bay varies from intensive agriculture to aquaculture, forestry, shipping and other industries such as brick and tile manufacturing. In addition there are a number of population centres around the southern edge of Bai Chay Bay, and a large rural population along the northern shoreline. A number of observations can be made about the general effects on the environment that are the result of current and historical land uses around Bai Chay Bay. Of particular importance are land uses that have increased sediment loads in the rivers entering Bai Chay Bay, and the effects of agriculture and harvesting around the shoreline on the intertidal fauna and flora.

The hilly areas north of Bai Chay Bay, originally forested, have been cleared of much of their forest cover. Some re-afforestation has been carried out using plantation species such as *Pinus, Eucalpytus* and *Casuarina*. As has occurred in many other areas of Vietnam, removal of forest cover has led to considerable erosion of the hill soils. This is likely to have increased the sediment loads being carried into Bai Chay Bay over the past few decades.

Aerial photographs of the Northern Bai Chay area (1:30,000, 1985) show intensive agriculture across the coastal plans and low foot-hills behind the large mangrove estuary. The flat or gently sloping land available for agriculture in this area is quite limited and agriculture is intensive right to the edges of the estuary. In many places, the local people have reclaimed land along the coastal margin for agriculture.

The intensity of agriculture means that there is no longer any natural terrestrial vegetation bordering much of the estuary and thus the natural filtering effects of this vegetation have been lost. Small-scale coastal erosion is also adding to the increased sediment loads entering Bai Chay Bay.

In the north-eastern hinterland of Bai Chay, some large coal mines are located. It is likely that mine water from this area enters Bai Chay Bay and this may also affect its water quality. Coal stockpiles are present in several locations along the eastern shoreline of Bai Chay Bay. Coal is deposited in these places to await transportation by barge to Hon Gai, or to ships in the floating port. Examples of such sites are Dao Sa To, just north of Hon Gai and in the upper reaches of Dien Vong Channel. Coal is piled directly adjacent to the shoreline in these areas and there appear to be no sediment or water control systems. Sediment control was similarly lacking at the brick works which are located at various places around the estuary, for example, at Gieng Day, a few kilometres west of Cai Lan. Here the clay materials and factory are located beside the water's edge and sediment is freely entrained during rainfall. These coal and brick operations have been present for many years and are probably having a continued deleterious effect on estuarine water quality.

Other land use factors which may be having an adverse effect on water quality within the Bai Chay Bay Estuary, as well as in the coastal waters of Ha Long Bay, are the discharge of sewage and stormwater from the populated areas of Hon Gai, Bai Chay, Gieng Day, Dong Dang and Hoanh Bo. Seawater quality parameters such as suspended solid load, turbidity presence of human-borne bacteria, oil and grease and trace elements such as lead may be adversely affected by effluent from these various sources.

### 5.6.3 Status of the Coastal and Marine Environment

Within Bai Chay Bay there are many hectares of mangrove vegetation. Several species of mangrove are present, including *Aegiceras corniculatum, Avicennia marina, Bruguiera gymnorrhiza, Clerodendron inerme, Excoecaria agallocha* and *Kandelia candel.* These species are used to a greater or lesser extent as a source of firewood by the local inhabitants and also as grazing for cattle. For these reasons most of the mangrove vegetation in the estuary is low and stunted. While these species are capable of reaching a height of several meters in this area, according to local scientists, frequent grazing and cutting means that they rarely reach a height of 2 m and most are much smaller.

Fisheries in the estuary include finfish, shrimp and shellfish. As with many of the estuarine and inshore coastal areas of Vietnam, there is heavy pressure on these fisheries. Fish and shellfish provide a food source for the local populace as well as being marketed elsewhere. No quantitative data about fisheries stocks in these areas was available.

Aquaculture in Bai Chay Bay has also had a large effect on the mangrove vegetation. Development of dykes and ponds to trap water for shrimp farming has had a detrimental effect on the mangroves. As a healthy mangrove ecosystem is a crucial factor in maintaining good fish stocks, the development of aquaculture may have a detrimental impact on other fisheries in the long term. The marine and intertidal environment of which the mangrove ecosystem is an important component are described in the next section.

### 5.6.4 Water Quality

A sampling programme was designed by the Environmental Specialists to assess the existing water quality both within Bai Chay Bay and in the near-shore coastal waters of Ha Long Bay. The samples were collected and analysed by the Centre for Marine Mechanics.

The results of the water quality survey conducted in Bai Chay Bay, Cua Luc Strait and Ha Long Bay give an indication of the effects that the different land uses around Bai Chay Bay are having on the waters of Bai Chay Bay and Inner Ha Long Bay. The results are generally supported by data provided by Quang Ninh Province which indicates poorer water quality at site 11 between Hon Gai and Cam Pha.

The higher E. coli levels in the vicinity of Hon Gai and Bai Chay, and in the mouths of the Vien Dong and Mon Rivers indicate the effects of discharge of sewage from these populated areas.

For several parameters, namely COD, oil content, phosphate, total sulphur and sulphate, and suspended solids, the sites in Cua Luc Strait, and offshore of Bai Chay and Hon Gai (sites F6, F7 and F8 respectively) have higher concentrations than elsewhere, suggesting that these sites have somewhat poorer quality than those in Bai Chay Bay. This poorer quality indicates the effects of discharges such as stormwater, sewage and other discharges from local industry above entering the water from the port and residential areas.

Concentrations of total phosphorus, phosphate and sulphur were higher at sites F1 and F2 in the north-eastern part of Bai Chay Bay were higher than those in the western part of the Bay. Elevations in these nutrients are likely to be due to agricultural practices in the Dien Vong Catchment.

Suspended solids were higher in Bai Chay Bay, due to the influx of the rivers which drain into the catchment. Elevated hydrogen sulphide concentrations were found in the mangrove ecosystem due to the reducing conditions there. Salinity was slightly lower in Bai Chay Bay, as might be expected in the estuarine environment. The slightly higher temperatures in the open coastal waters probably reflect the temperature dynamics of the open water. Dissolved oxygen was lower within the Bay than in Ha Long Bay, possibly indicating the better mixing of the waters in the coastal sea than in the tidal inlet of Bai Chay Bay.

Seasonal fluctuations in most of the parameters were recorded, most being explained by the greater rainfall and river discharge into Bai Chay Bay, and higher summer water temperatures.

Data on trace element concentrations provided by Quang Ninh Province indicated that concentrations of cadmium and lead near the B-12 Oil Port were high, relative to international criteria (e.g., USEPA). It should be noted that on the basis of Vietnamese Criteria of 50 ppm the results from sites near B-12 Oil Port are not high. However, other international standards for lead are significantly lower.

Details of the survey design and results are presented below.

#### 5.6.4.1 Survey Design

Twenty sites were selected for sampling, to cover the water quality of Bai Chay Bay and Ha Long Bay near river mouths and near possible sources of pollution such as towns and villages. The locations are shown on Fig. 5-1. Eight of the sites were designated full water sample sites and twelve were designated partial water sampling sites. The parameters measured at the full and partial sites are shown in Table 5-3.

Samples were taken at three depths: surface; 0.5 m; and just above the maximum depth of the water column. The sample depths were selected to cover the estuarine behaviour of fresh versus salt water layering. Samples were taken on the ebbing tide.

The equipment used for sampling and the analytical methods are given in Appendix 5.1.

For comparison, data collected by Quang Ninh Province at 19 stations in the Province's hydrometeorological network is shown in Table 5-4. The sites referred to in the table are shown in Fig. 5-5.

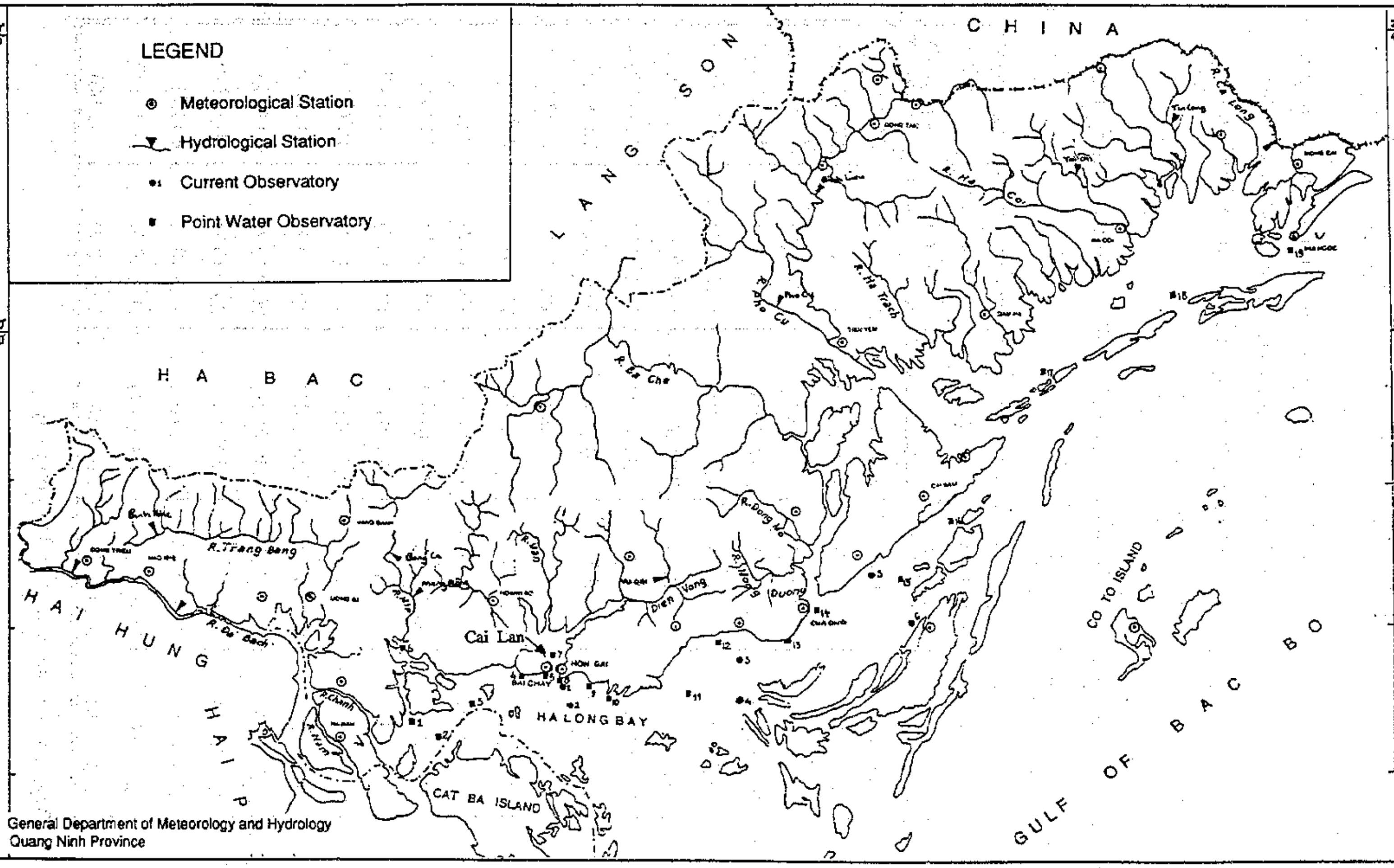
Table 5-3: Parameters measured at full and partial water quality sampling sites in February and June, 1994.

| Full sampling programme | Partial sampling programme | |
|---|---|---|
| Parameter | Parameter | Units |
| Salinity | Salinity | ppt |
| pH | pH | pH units |
| Dissolved oxygen DO | Dissolved oxygen | % |
| Transparency | Transparency | m |
| E. coli | E. coli | cells/ml |
| Redox value | | mV |
| Biochemical oxygen demand BOD | | ppm |
| Chemical oxygen demand COD | | ppm |
| Temperature | | °C |
| Oil content | | ppb |
| Suspended solids | | $mg\ l^{-1}$ |
| Phosphate | | $mg\ l^{-1}$ |
| Total phosphorus | | $mg\ l^{-1}$ |
| Total sulphur | | $mg\ l^{-1}$ |
| Sulphate | | $mg\ l^{-1}$ |

Table 5-4: Coastal water quality in Quang Ninh Province (all units mg $L^{-1}$ unless stated.)

| Site * | Date Dec 92 | Time | Temp (°C) | Oil | S (%) | pH | $NH_4$ | $P_2O_5$ | DO | $NO_3$ | $SO_4$ | $HCO_3$ | COD | $BOD_5$ | Zn | Cd | Hg μg 1-1 | Pb | $NO_2$ | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 30 | 0830 | 21.0 | 0.000 | 22.2 | 8.20 | | | | | | | | | | | | | | |
| 2 | 28 | 1345 | 22.6 | 0.140 | 16.8 | 8.15 | 0.040 | 0.118 | 6.1 | 0.542 | 1520 | 2.400 | 1.1 | 0.00 | | | | | 0.070 | 3.9 |
| 3 | 28 | 1320 | 22.6 | 4.720 | 23.7 | 8.21 | | | | | | | | | | | | | | |
| 4 | 23 | 1330 | 22.8 | 0.095 | 34.0 | 8.33 | | | 8.2 | | | | | | | | | | | |
| 5 | - | 1430 | 22.4 | 0.105 | 34.0 | 8.47 | | | 7.4 | | | | | | | | | | | |
| 6 | - | 1000 | 22.8 | 0.195 | 15.5 | 8.19 | 0.000 | 0.123 | 7.6 | 0.548 | 1480 | 2.600 | 2.9 | 0.6 | 0.050 | 0.0016 | 0.03 | 0.01 | 0.063 | 4.3 |
| 7 | - | 1630 | 20.6 | 0.140 | 33.8 | 8.40 | 0.061 | 0.091 | 7.0 | 0.048 | 2520 | 2.600 | 3.4 | 0.0 | 0.037 | 0.0039 | 0.03 | 0.012 | 0.019 | 2.1 |
| 8 | 24 | 0830 | 20.8 | 0.080 | 30.5 | 8.55 | 0.059 | 0.101 | 7.5 | 0.029 | 2360 | 3.100 | 4.0 | 0.4 | 0.030 | 0.0007 | 0.03 | 0.010 | 0.006 | 1.2 |
| 9 | | | | | | | | | | | | | | | | | | | | |
| 10 | 24 | 1000 | 18.2 | 0.090 | 32.8 | 8.59 | 0.000 | 0.101 | 7.3 | 0.149 | 2440 | 2.900 | 4.5 | 0.6 | 0.037 | 0.0036 | 0.06 | 0.075 | 0.028 | 1.7 |
| 11 | 28 | 1145 | 22.5 | 1.225 | 20.0 | 8.81 | 0.039 | 0.085 | 9.6 | 0.041 | 2280 | 2.500 | 1.3 | 2.7 | | | | | 0.016 | 2.6 |
| 12 | 24 | 1100 | 20.0 | 0.060 | 31.5 | 8.68 | | | 7.5 | | | | | | | | | | | |
| 13 | 24 | 1030 | 20.0 | 0.000 | 31.2 | 8.7 | 0.000 | 0.075 | 7.4 | 0.038 | 2360 | 2.850 | 4.0 | 0.2 | 0.037 | 0.0035 | 0 | 0.015 | 0.010 | 1.9 |
| 14 | 24 | 1230 | 20.0 | 0.275 | 30.5 | 8.66 | | | 7.7 | | | | | | | | | | | |
| 15 | 28 | 0950 | 21.1 | 0.140 | 22.7 | 8.02 | 0.022 | 0.101 | 7.6 | 0.038 | 2320 | 2.500 | 1.4 | 0.5 | 0.043 | 0.0039 | 0.02 | 0.003 | 0.019 | 1.3 |
| 16 | 28 | 0850 | 22.0 | 0.145 | 25.0 | 0.08 | | | | | | | | | | | | | | |
| 17 | 28 | 0700 | 22.0 | 0.215 | 27.0 | 8.24 | | | | | | | | | | | | | | |
| 18 | 28 | 0515 | 22.0 | 0.000 | 19.1 | 8.27 | | | | | | | | | | | | | | |
| 19 | 24 | 1400 | 15.8 | 0.130 | 24.2 | 9.00 | 0.026 | 0.128 | 8.5 | 0.136 | 1960 | 2.300 | 1.8 | 1.3 | 0.028 | 0.0004 | 0.02 | 0.055 | 0.029 | 4.3 |

**Notes:** Refer to Fig. 5-5 for site locations.




Source: General Department of Meteorology and Hydrology Quang Ninh Province

HYDROMETEOROLOGICAL NETWORK OF QUANG NINH PROVINCE

FIG. 5-5

FEASIBILITY STUDY FOR CAI LAN PORT CONSTRUCTION PROJECT

### 5.6.4.2 Survey Results

(1) Parameters measured at both full and partial sites

Four parameters were measured *in situ* at all 20 sites. These were salinity, temperature, dissolved oxygen, pH. In additions, from all 20 sites samples were taken for E. coli analysis. Means and standard deviations for the three sampling depths are given in Table 5-5 for the February samples and in Table 5-5a for the June samples.

Table 5-5: Results for water quality parameters measured at all 20 sites, February 1994: means and (standard deviations).

| Site | Location | Salinity (ppt) | Dissolved oxygen (%) | pH | Temperature (°C) | E. coli (cells/ml) |
|---|---|---|---|---|---|---|
| F1 | B | 30.4 (0.52) | 88.3 (1.9) | 7.63 (0.02) | 19.2 (0.2) | 92 (93.5) |
| F2 | B | 31.2 (0.20) | 83.4 (1.7) | 7.66 (0.04) | 19.1 (0.2) | 17 (18.0) |
| F3 | B | 27.4 (0.46 ) | 76.6 (2.7) | 7.50 (0.01) | 20.4 (0.6) | 38 (0) |
| F4 | B | 29.7 (0.15) | 76.7 (0.6) | 7.57 (0.05) | 19.3 (0.2) | 30 (13.3) |
| F5 | B | 30.7 (0.35) | 80.3 (0.2) | 7.65 (0.04) | 18.9 (0.1) | 14 (1.7) |
| F6 | C | 32.5 (0.1) | 87.8 (0.7) | 7.80 (0.01) | 19.8 (0.2) | 146 (93.5) |
| F7 | H | 32.7 (0.0) | 87.7 (4.1) | 7.81 (0.01) | 20.2 (0.2) | 23 (13.3) |
| F8 | H | 32.6 (0.1) | 89.3 (0.9) | 7.80 (0.02) | 19.9 (0.2) | 92 (93.5) |
| P1 | B | 31.4 (0.06) | 87.0 (3.8) | 7.77 (0.01) | 19.5 (0.6) | 23 (14.6) |
| P2 | B | 30.8 (0.17) | 87.0 (1.0) | 7.67 (0.02) | 19.1 (0.2) | 2 (2.5) |
| P3 | B | 29.6 (0.12) | 82.4 (0.3) | 7.62 (0.0) | 19.8 (0.2) | 9 (6.5) |
| P4 | B | 29.6 (0.91) | 80.0 (1.7) | 7.59 (0.07) | 19.6 (0.5) | 10 (5.0) |
| P5 | B | 29.4 (1.13) | 87.3 (1.5) | 7.66 (0.03) | 19.5 (1.0) | 23 (13.3) |
| P6 | B | 31.4 (0.32) | 85.3 (0.6) | 7.72 (0.02) | 19.1 (0.2) | 16 (19.9) |
| P7 | B | 31.9 (0.52) | 88.0 (0.6) | 7.76 (0.03) | 19.7 (0.2) | 70 (113) |
| P8 | H | 32.7 (0.0) | 87.5 (4.0) | 7.80 (0.01) | 20.0 (0.2) | 10 (9.2) |
| P9 | H | 32.2 (0.12) | 87.8 (1.5) | 7.77 (0.02) | 20.0 (0.2) | 20 (18.0) |
| P10 | H | 32.5 (0.10) | 88.8 (2.5 ) | 7.78 (0.02) | 19.8 (0.2) | 4 (4.7) |
| P11 | H | 32.5 (0.0) | 86.0 (1.1) | 7.83 (0.01) | 20.1 (0.3) | 28 (16.7) |
| P12 | H | 33.0 (0.29) | 89.0 (2.1) | 7.81 (0.03) | 19.9 (0.2) | 2 (2.50) |

Note: B=Bai Chay Bay; C=Cua Luc Strait; H=Ha Long Bay.

Table 5-5a: Results for water quality parameters measured at all 20 sites, June 1994: means and (standard deviations).

| Site | Location | Salinity (ppt) | Dissolved oxygen(%) | pH | Temperature (°C) | E.coli (cells/ml) |
|---|---|---|---|---|---|---|
| F1 | B | 24.4 (0.05) | 65.5 (3.4) | 6.92 (0.02) | 30.7 (0.2) | 40 (0.0) |
| F2 | B | 26.5 (0.09) | 60.1 (0.7) | 7.08 (0.07) | 30.9 (0.0) | 14 (6.0) |
| F3 | B | 25.5 (0.12) | 61.0 (0.0) | 6.38 (0.10) | 31.6 (0.05) | 50 (26.8) |
| F4 | B | 26.7 (0.05) | 55.4 (0.7) | 6.74 (0.01) | 30.7 (0.0) | 19 (0.9) |
| F5 | B | 26.5 (0.14) | 62.4 (2.1) | 7.08 (0.05) | 31 (0.1) | 43 (19.7) |
| F6 | C | 27.2 (0.36) | 76.0 (1.8) | 7.41 (0.02) | 30.8 (0.0) | 20 (0.0) |
| F7 | H | 27.9 (0.40) | 78.0 (2.0) | 7.42 (0.00) | 30.6 (0.0) | 69 (71.2) |
| F8 | H | 26.2 (0.65) | 78.4 (2.0) | 7.42 (0.02) | 30.6 (0.1) | 35 (10.8) |
| P1 | B | 27.4 (0.05) | 59.1 (1.3) | 7.41 (0.01) | 30.6 (0.0) | 45 (0.0) |
| P2 | B | 27.1 (0.16) | 59.7 (0.8) | 7.38 (0.01) | 30.7 (0.0) | 20 (0.0) |
| P3 | B | 27.1 (0.00) | 55.8 (1.5) | 7.29 (0.01) | 31.2 (0.0) | 20 (0.0) |
| P4 | B | 27.4 (0.09) | 55.6 (0.9) | 7.41 (0.01) | 30.6 (0.1) | 20 (0.0) |
| P5 | B | 27.1 (0.00) | 55.5 (1.5) | 7.37 (0.01) | 30.7 (0.1) | 20 (0.0) |
| P6 | B | 27.8 (0.08) | 63.6 (3.2) | 7.53 (0.01) | 30.7 (0.0) | 33 (12.5) |
| P7 | B | 26.3 (0.28) | 73.0 (2.2) | 7.16 (0.15) | 30.8 (0.1) | 50 (7.5) |
| P8 | H | 27.6 (0.25) | 63.7 (0.2) | 7.64 (0.01) | 30.3 (0.1) | 86 (48.1) |
| P9 | H | 28.2 (0.57) | 66.1 (0.5) | 7.68 (0.01) | 30.5 (0.1) | 30 (10.0) |
| P10 | H | 26.0 (2.01) | 77.4 (1.0) | 7.02 (0.40) | 30.4 (0.1) | 45 (0.0) |
| P11 | H | 27.1 (1.25) | 69.8 (0.8) | 7.69 (0.03) | 30.5 (0.1) | 20 (0.0) |
| P12 | H | 25.0 (1.04) | 75.2 (4.5) | 7.67 (0.00) | 30.2 (0.1) | 95 (75.0) |

Note: B=Bai Chay Bay; C=Cua Luc Strait; H=Ha Long Bay

The results obtained are compared below with standards proposed by the Vietnamese "Provisional Environment Criteria" (Hy *et al.* 1993), and other international standards where relevant or available. Standards consulted include United States Environment Protection Agency, Australian and New Zealand Environment Council, Japanese, Indonesian and Indian guidelines. For some of the parameters discussed below, some of these countries do not have guidelines, or (as in the case of USEPA) the guidelines are narrative and are thus difficult to present simply in direct comparison.

### Salinity

Salinity values from the winter survey ranged from a high of 33.2 ppt at site P12, near Cai Dam, and a low of 27.0 ppt in the mouth of the Mon River, at site F3. There was little change in salinity from the surface to the bottom of the water column. Means presented in Table 5-5 show that salinity was higher (all sites >32 ppt) in Ha Long Bay, while within Bai Chay Bay all sites were <32 ppt. However, the close salinity values overall indicate good mixing of tidal and riverine waters, at least in the winter waters of this estuarine system. During the summer survey, salinity values were lower overall, reflecting the much higher riverine component in the estuarine waters. The lowest value was 24.4 at site F1, in the mouth of the Dien Vong River, and the highest (28.2) was recorded at site P9 in Ha Long Bay.

### Dissolved oxygen

In February 1994, dissolved oxygen measured at the surface ranged from 76.3 % at site F4, in the mouth of the Mip River, and 91.0 % at site F8, offshore of Hon Gai, in Ha Long Bay . The DO measured at the bottom of the water column was a minimum of 73.5 % at site F3, in the mouth of the Mon River and a maximum of 90.0 % at site P1, in central Bai Chay Bay.

The mean values in Table 5-5 indicate lower DO values in the mouths of the Mon River and the unnamed river directly to the west. Sites F3, F4, F5 and P4 all had DO values less than 80.5 %. All other sites had mean values greater than 82.0 %, and most were around 86 - 88 %.

The Vietnamese Provisional Criterion for dissolved oxygen is 5 mg $l^{-1}$. The Australian and New Zealand Environment Council recommend a normal value of >6 mg $l^{-1}$ for marine waters (greater than approximately 80-90% saturation could be considered normal). Dissolved oxygen in winter in the mouths of the Mon River and the adjacent river could therefore be considered to be at the low end of normal levels, DO was much lower than in summer. The other sites were within the normal range of concentrations.

However in winter, within Bai Chay Bay several sites had DO of around 56 %. The maximum values were recorded in Ha Long Bay, at sites F7 and F8 at around 78 %. The lower values recorded in summer reflect the much higher temperatures of the water, decreasing the available oxygen in the water.

The values recorded at the Quang Ninh Province stations (refer Table 5-4) show that DO was above the Vietnamese Criterion value at all sites. However, it is only just above that value at site 2, in Ha Long Bay near the Mip River Mouth (6.1 mg $l^{-1}$). DO was highest at site 11, offshore and mid-way between Cam Pha and Hon Gai, at 9.6 mg $l^{-1}$.

pH

In winter, mean pH values tended to be slightly lower in Bai Chay Bay (all sites < 7.77 pH) than in Ha Long Bay (all sites >7.77 pH).

pH ranged from 7.49 to 7.84 overall. Often, but not consistently, pH was slightly higher at the bottom of the water column than at the surface (but by less than 0.1 pH unit). This is within the range for coastal waters provided in the Vietnamese Provisional Environment Criteria, which is 6.5 - 8.5 pH units.

In summer, slightly lower values were recorded at the Bai Chay Bay sites, the lowest being 6.38 at site F3 at the mouth of the Mon River. Within Bai Chay Bay mean pH values ranged from 6.38 - 7.53, while in Ha Long Bay they were slightly higher (7.02 - 7.69). All sites but site F3 were within the range recommended by the Vietnamese Criterion. This site was lowest in winter as well and may reflect activities upstream.

pH values were generally higher at the coastal sites as reported by Quang Ninh Province. All were above 8.0 pH units, with a high of 9 in the north, at Mui Ngoc. The very low pH value at site 16 is likely to be due to a reporting error.

Temperature

In winter, mean temperatures were very similar, ranging from 18.9 to 20.2 °C. At the Ha Long Bay sites, mean temperatures tended to be slightly higher (overall mean 20.0 °C, standard deviation 0.13 °C) while in Bai Chay Bay all sites except F3 has temperatures less than 20.0 °C (overall mean excluding site F3 19.4 °C, standard deviation 0.3 °C). The higher temperature at F3 may be due to warming effects in the shallow estuary, or to warming of the slow-moving river water upstream.

Surface temperatures ranged from 18.9 °C to 21.0 °C over the period of the survey. The lowest surface temperature was recorded at site F5, offshore of Cai Lan Port, and the highest at site F3, in the mouth of the Mon River on the northern shoreline of Bai Chay Bay .

The lowest bottom temperature was recorded at site P5, in Truc Vong River, Western Bai Chay Bay, and the highest bottom temperature was recorded at site F7, offshore of Bai Chay, in Ha Long Bay.

Generally there was a decrease in temperature between the surface of the water and the bottom of the water column, but occasionally the water at 0.5 m below the surface was coldest. The greatest range between the surface and bottom samples was 1 ℃, recorded at sites P4, just north of Cai Lan Port and F3 in the mouth of the Mon River.

Over summer, the mean temperature range was 30.2 - 31.6 ℃. Temperatures were lower, in the Ha Long Bay ranging from 30.2 - 30.6 ℃. In Bai Chay Bay they ranged from 30.6 - 31.6 ℃. Little temperature stratification occurred, the greatest surface to bottom gradient being 0.5 % at site F1.

E. coli

The E. coli measured in winter, ranged from 0 to 200 cells / ml. There was no consistency of increase or decrease in E. coli between the surface samples and the bottom samples. The highest surface values found (38 - 200 cell / ml at all three sampling depths) were found at sites F6 and F8, in Cua Luc Strait and off the Hon Gai Coast respectively. This is not surprising considering that untreated sewage is discharged into the sea from Hon Gai and Bai Chay near these sites. Similar high values were also recorded at sites F1 and F3, in the mouths of the Vien Dong and Mon Rivers (two of the three samples at each site >38 cells / ml). These levels are likely to be due to sewage from populations upstream.

A count of 200 cells / ml was recorded for the bottom sample, site P7. This site is within Bai Chay Bay, but is the site closest to Cua Luc Strait. The higher E. coli level compared to other sites in Central Bai Chay Bay may be due to incomplete mixing of waters entering from near Bai Chay and Hon Gai on the incoming tide.

In summer, E.coli counts ranged from 20 - 170 cells / ml. Samples collected at sites F7, P8 and P12 had high E.coli counts (170, 120 and 170 cells / ml respectively). At site P8 both the surface and middle samples were 120 cells / ml.

The Vietnamese "Provisional Environmental Criteria" for E. coli is 1,000 per 100 ml (100 cells / ml) in the beach zone and 5,000 per 100 ml (500 cells / ml) in "other" zones. The counts recorded for sites F6 and F8 are high by the first standard, but as this area is not a beach zone they are within acceptable Vietnamese limits. By comparison, the standard for Japan, for sensitive fish, or bathing, is <100 cells / ml. The New Zealand limit for Class B waters is 2 cells / ml. In shellfish, for human consumption, the maximum number of coliform bacteria per 100 g wet weight is 230.

Compared to Hong Kong coastal waters, these Bai Chay values are, at present, indicative of desirable waters in terms of eco-tourism potential.

(2) Parameters measured only at sites F1 -F8

Samples from the F-series sites were analysed for 9 additional parameters (refer Table 5-3). Mean values and standard deviations of the three depth samples at each site are presented in Table 5-6 and 5-6a. The results are described below.

Total Phosphorus

In winter, for all sites, total phosphorus was between 0.01 and 0.04 mg $l^{-1}$. Sites F6, F7 and F8 had similar values, around (0.031 - 0.038 mg $l^{-1}$), possibly indicating the effects of pollutants entering the sea in the Hon Gai and Bai Chay areas.

Within Bai Chay Bay the values were more variable. Sites F1 and F2 (0.02 - 0.034 mg $l^{-1}$) also recorded concentrations above 0.03 mg $l^{-1}$, but the other three Bai Chay Bay sites recorded lower values (0.01 - 0.02 mg $l^{-1}$). This may indicate a higher level of phosphorus entering the Bay from the Dien Vong River.

In summer, total phosphorus values ranged between 0.032 and 0.056, generally higher than those recorded in winter. The highest values were recorded at the western end of Bai Chay Bay (site F3 and F4) and offshore at Bai Chay and Hon Gai (sites F7 and F8). These higher values are likely to reflect the higher runoff component in summer.

Phosphate

In winter, phosphate concentrations ranged from 0.0382 mg $l^{-1}$ at site F5 to 0.1162 mg $l^{-1}$ at site F8. A similar trend in the results for total phosphorus was observed for phosphates. The Cua Luc and Ha Long Bay sites (F6, 7 and 8) and sites F1 and F2 recorded similar slightly elevated levels of phosphate compared to sites F3, F4 and F5, in the western part of Bai Chay Bay.

There was a tendency for mean phosphate concentrations to increase slightly with depth in the water column.

In summer, the values were quite similar, slightly high levels being found at sites F7 and F8, and sites F3 and F4.

Table 5-6: Water quality summary statistics, sites F1 - F8, February 1994, means and (standard deviations). (All units mg $l^{-1}$).

| Site | | Total-Phosphorus | Phosphate | Sulphate | Total-Sulphur | BOD |
|---|---|---|---|---|---|---|
| F1 | B | 0.0325 (0.0054) | 0.0674 (0.002) | 2468.0 (8.5) | 885.2 (1.5) | 1.27 (0.15) |
| F2 | B | 0.0342 (0.0078) | 0.0823 (0.006) | 2485.0 (2.3) | 895.2 (0.2) | 1.37 (0.21) |
| F3 | B | 0.0228 (0.0038) | 0.0519 (0.006) | 2366.7 (2.9) | 907.5 (7.5) | 1.17 (0.25 ) |
| F4 | B | 0.0206 (0.0038) | 0.0519 (0.006) | 2385.1 (4.3) | 837.9 (10.9) | 1.2 (0.1) |
| F5 | B | 0.0162 (0.0019) | 0.0439 (0.01) | 2403.6 (21.3) | 875.8 (17.4) | 1.13 (0.15) |
| F6 | C | 0.0361 (0.0073) | 0.0853 (0.0) | 2487.8 (8.7) | 900.6 (2.2) | 1.37 (0.21) |
| F7 | H | 0.0317 (0.0073) | 0.0764 (0.002) | 2484.3 (6.9) | 881.9 (16.1) | 1.4 (0.1) |
| F8 | H | 0.0387 (0.0) | 0.1162 (0.0) | 2494.0 (7.7) | 903.3 (5.0) | 1.1 (0.15) |
| **Site** | | **COD** | **Oil Content** | **Suspended solids** | **Hydrogen sulphide** | |
| F1 | B | 9.03 (0.14) | 0.156 (0.001) | 41.5 (1.5) | 0.040 (0.014) | |
| F2 | B | 10.41 (0.88) | 0.110 (0.005) | 39.0 (1.3) | 0.026 (0.007) | |
| F3 | B | 9.96 (0.57) | 0.135 (0.007) | 41.2 (1.8) | 0.051 (0.002) | |
| F4 | B | 10.76 (0.86) | 0.157 (0.005) | 40.9 (4.1) | 0.033 (0.009) | |
| F5 | B | 9.71 (0.88) | 0.091 (0.004) | 44.5 (5.0) | 0.023 (0.005) | |
| F6 | C | 16.13 (5.55) | 0.41 (0.24) | 32.2 (4.1) | 0.009 (0.001) | |
| F7 | H | 12.59 (0.74) | 0.180 (0.004) | 25.6 (0.5) | 0.004 (0.001) | |
| F8 | H | 13.17 (0.64) | 0.132 (0.018) | 27.4 (2.3) | 0.005 (0.002) | |

Note: B=Bai Chay Bay; C= Cua Luc Strait; H= Ha Long Bay.
Two values for Total-S at site F5 were assumed to be typographical errors and the decimal places have been adjusted accordingly.

Sulphate

In winter, mean sulphate values ranged from 2366 mg $l^{-1}$ at site F3 to 2,494 mg $l^{-1}$ at site F8. As for total phosphorus and phosphate, slightly higher values were found in Cua Luc Strait, at the Ha Long Bay sites F7 and F8 and at sites F1 and F2 in the north-east of Bai Chay Bay than at sites F3, F4 and F5 in the western part of Bai Chay Bay.

In summer, mean sulphate values were lower, ranging from 1951 mg $L^{-1}$ at site F3 to 2129 mg $L^{-1}$ at site F4. No pattern of concentrations could be associated within site location.

There was a slight increase in sulphate with depth at each site.

Table 5-6a: Water quality summary statistics, site F1 - F8, June 1994, means and (standard deviations). (All units mg $l^{-1}$)

| Site | | Total-Phosphorus | Phosphate | Sulphate | Total-Sulphur | BOD |
|---|---|---|---|---|---|---|
| F1 | B | 0.0322 (0.0070) | 0.0480 (0.0111) | 2052.7 (35.1) | 695.8 (13.3) | 1.13 (1.14) |
| F2 | B | 0.0368 (0.0012) | 0.0550 (0.0017) | 2040.4 (22.7) | 695.7 (8.5) | 1.27 (0.06) |
| F3 | B | 0.0517 (0.0055) | 0.0793 (0.0090) | 1951.2 (71.5) | 671.7 (23.7) | 1.03 (0.06) |
| F4 | B | 0.0558 (0.0025) | 0.0847 (0.0042) | 2129.7 (31.2) | 728.5 (13.6) | 1.00 (0.10) |
| F5 | B | 0.0375 (0.0098) | 0.0567 (0.0147) | 2079.4 (33.9) | 712.1 (12.8) | 1.03 (0.06) |
| F6 | C | 0.0350 (0.0022) | 0.0528 (0.0028) | 2113.4 (67.3) | 726.4 (23.1) | 1.23 (0.06) |
| F7 | H | 0.0492 (0.0024) | 0.0733 (0.0029) | 2071.0 (92.1) | 722.4 (19.8) | 1.23 (0.06) |
| F8 | H | 0.0408 (0.0115) | 0.0608 (0.0176) | 2103.6 (73.9) | 722.9 (25.5) | 0.97 (0.12) |
| **Site** | | **COD** | **Oil Content** | **Suspended solids** | **Hydrogen sulphide** | |
| F1 | B | 12.4 (0.8) | 0.149 (0.010) | 52.1 (02.1) | 0.039 (0.007) | |
| F2 | B | 11.40 (1.00) | 0.108 (0.006 | 49.1 (01.0) | 0.029 (0.005) | |
| F3 | B | 11.03 (0.06) | 0.126 (0.004) | 50.0 (01.4) | 0.041 (0.005) | |
| F4 | B | 11.33 (0.92) | O.190 (0.047) | 52.5 (00.6) | 0.041 (0.002) | |
| F5 | B | 10.13 (0.81) | 0.094 (0.009) | 47.7 (02.2) | 0.023 (0.003) | |
| F6 | C | 13.07 (1.01) | 0.0491 (0.273) | 33.0 (03.4) | 0.017 (0.002) | |
| F7 | H | 12.13 (1.42) | 0.233 (0.082) | 32.5 (00.9) | 0.013 (0.001) | |
| F8 | H | 12.67 (2.57) | 0.304 (0.160) | 31.8 (00.5) | 0.009 (0.002) | |

Note: B=Bai Chay Bay; C=Cua Luc Strait; H= Ha Long Bay.

Total Sulphur

In winter, mean total sulphur values ranged from a low of 837 mg $l^{-1}$ at site F4 to a high of 907 mg $l^{-1}$ at site F3. Sites F6 and F8 were higher than the other sites, similar to F3. The slight elevation in values at these three sites are likely to reflect activities on land in the Troi River (upstream of site F3) and at Hon Gai.

In summer, values were lower, within a range of 671 mg $l^{-1}$ to 728 mg $l^{-1}$. Values at sites F6, F7 and F8 were similar and slightly elevated, but site F4 had the highest concentration.

Biochemical Oxygen Demand

In winter, the range of BOD was 0.9 to 1.6 mg $l^{-1}$. The summer range was 0.9 - 1.3 mg $l^{-1}$. No trend in the data was found with respect to the site locations. The Vietnamese Provisional Criterion for BOD is 15 - 20 mg $l^{-1}$, and the values recorded at well within this guideline. Few other countries have promulgated a standard for BOD, but India, by comparison has a criterion of <6 mg $l^{-1}$. In New Zealand, a level of 3 mg $l^{-1}$ or less would be considered normal. Clearly, the values recorded are within acceptable levels.

At the Quang Ninh Hydrological Stations the BOD concentrations were generally lower (<1.0 mg $l^{-1}$) than those reported above, with the exception of site 11, offshore between Hon Gai and Cam Pha, where the level was higher at 2.7 mg $l^{-1}$.

Chemical Oxygen Demand

In winter, COD ranged from a low of 8.97 mg $l^{-1}$ at site F5 to a high of 22.27 mg $l^{-1}$ at site F6 in Cua Luc Strait. As with other parameters reported above, higher values were recorded in Cua Luc Strait and in the Ha Long Bay sites F7 and F8 (mean for the three sites of 14.0 mg $l^{-1}$) than at the sites in Bai Chay Bay (overall mean of 10.0 mg $l^{-1}$). No trend of increase or decrease with depth in the water column was found.

In summer, the range of COD was narrow, from 10.13 mg $l^{-1}$ at site F5 to 13.07 mg $1^{-1}$ at site F6.

COD was lower at all of the sites measured in the Quang Ninh Hydrological Network (1.1 - 4.5 mg $l^{-1}$).

Oil Content

In February, the oil content was considerably higher at site F6, in Cua Luc Strait, with a mean of 0.4 mg $l^{-1}$. The highest content was found at the surface at this site and the concentration decreased with depth. The higher oil content here is likely to be due to the shipping that occurs in the Strait. A visible sheen is frequently visible on the surface both at Hon Gai and Bai Chay ferry terminals. It should be noted that the difficulty of obtaining representative measurements of oil content are well known. Even with a heavy sheen it is possible to find results of less than 1 ppm.

In June the oil content at site F6 was relatively low at 0.05 mg $l^{-1}$, while oil content at sites F7 and F8 were highest (0.23 - 0.30 mg $l^{-1}$).

By comparison, in both February and June sites within Bai Chay Bay were below 0.2 mg $l^{-1}$, with site F4 the highest of these at 0.19 mg $l^{-1}$ in June. The oil content of the surface water was not consistently higher than that below the surface at these sites.

The Vietnamese Provisional Criterion for oil and grease is 0.3 mg $l^{-1}$. This is exceeded within Cua Luc Strait but not at any of the other sites. Some comparative guidelines for oil content are <0.5 mg $l^{-1}$ (Japan - common coastal water); <0.1 mg $l^{-1}$ (India - for fisheries) and <10 mg $l^{-1}$ (India - harbour water). The levels are above 0.1 mg $l^{-1}$ at all but site F5. Considering that fishing and aquaculture take place in Bai Chay Bay and are likely to expand in future, the existing levels indicate that better control on oil entering the harbour will be needed.

By comparison, the oil content measured at the Quang Ninh Province sites was similar to the values reported above, (between approximately 0.1 and 0.2 mg $l^{-1}$), but was much higher at site 3 in the inshore waters near Tuan Chau Island (4.720 mg $l^{-1}$) and site 11 offshore between Hon Gai and Cam Pha (1.225 mg $l^{-1}$). Both these values are above the Vietnamese Provisional Criterion.

Suspended Solids

In winter, suspended solids were higher within Bai Chay Bay than in Cua Luc Strait or Ha Long Bay, reflecting the influx of sediments from the rivers entering the Bay. Mean values for sites F1 -F5, within Bai Chay Bay were 39 mg $l^{-1}$ to 44 mg $l^{-1}$. In Cua Luc Strait the concentration was lower, at 32.2 mg $l^{-1}$, while at site F7 and F8 in Ha Long Bay the concentrations were 25.6 and 27.4 mg $l^{-1}$ respectively. There was no consistent trend of increasing suspended solids with depth. This was the case at all of the sites within Bai Chay Bay, but not in Cua Luc Strait or Ha Long Bay.

In summer, suspended solids concentrations was higher at all sites than in winter. The range was 31.8 - 52.5 mg $l^{-1}$, within the concentrations was again higher in Bai Chay Bay.

The Vietnamese Provisional Criterion for suspended solids is 25 - 200 mg $l^{-1}$ and all of the values recorded are at the lower end of this scale. By comparison, the Indonesian guideline is <80 mg $l^{-1}$.

Hydrogen Sulphide

In winter, hydrogen sulphide ranged from a low of 0.0032 mg $l^{-1}$ at site F7 to a high of 0.0525 mg $l^{-1}$ at site at F3. Similar trends in the data for $H_2S$ were found as for suspended solids, above. The Bai Chay Bay sites had consistently higher concentrations (mean of 0.034 mg $l^{-1}$) than site F6 in Cua Luc Strait (0.009 mg $l^{-1}$) and sites F7 and F8 in Ha Long Bay (mean of 0.005 mg $l^{-1}$). This trend is not unexpected as $H_2S$ is a normal chemical product of sulphide bacteria associated with mangrove.

In summer, the concentrations were quite similar, with the lowest values again recorded at the Ha Long Bay sites, and the highest inside Bai Chay Bay.

Trace Elements

Quang Ninh Province have provided data on trace element concentrations at sites in the hydrometeorological network (refer Table 5-4). In addition, data collected in Cua Luc Strait has also been provided by the province (Table 5-7).

The concentrations of lead, cadmium, arsenic and mercury are within the limits suggested by the Vietnamese Provisional Criteria. However, compared to other international standards, the concentrations of cadmium, lead and mercury would be considered high. It is unclear what the source of these contaminants would be, but possibilities include acid drainage from coal mine overburden. Considering the high concentrations recorded, it is recommended that tissues of fish and shellfish from Bai Chay Bay and Inner Ha Long Bay be tested to establish the existing levels of trace elements in the fish. This is important from a public health perspective, but also as a baseline measure against which future monitoring of fish tissues can be compared.

The maximum zinc concentration was 3.7 times higher than the guideline figure at Bai Chay Ferry and the B-12 Oil Port. The copper concentration at the oil port was also higher than the criterion.

Concentrations of trace elements reported in the Quang Ninh Province Hydrometeorological Network data set (refer Table 5-4) show that, for the sites where samples were collected, the concentrations of all metals were below the Vietnamese Provisional Criteria.

Table 5-7: Trace element concentrations in the vicinity of Hon Gai (all units ppb).

| Location | Cu | Pb | Zn | Cd | As | Hg |
|---|---|---|---|---|---|---|
| B-12 Oil Port | 12.5 | 12 | 37 | 3.9 | 5 | 0.03 |
| Bai Chay Ferry | 2.7 | 7 | 37 | 0.7 | 3 | 0.03 |
| Hon Gai Port | 1.2 | 7 | 28 | 0.7 | 2 | 0.02 |
| VN Criterion | 10 | 50 | 10 | 50 | 50 | 1 |

Source: Urban and Rural Planning Institute, Ministry of Construction.

Summary of Exceedances

In summary, the Vietnamese provisional criteria for coastal water quality were exceeded only by the following cases: dissolved oxygen (at Site F3 in February); pH (at site F3 in June); oila and grease (site F6 in February and site F8 in June0; zinc (near site F7); and copper (near site F6)."

### 5.6.5 Sediment Quality

To assess the water content and the existing concentrations of organics and trace elements in sediments in Ha Long Bay and Bai Chay Bay sediment samples were collected at the same sites as those used in the water quality sampling programme (refer Fig. 5-1). The analyses performed are listed in Table 5-8. The analytical methods are provided in Appendix 5-1. The results are provided in Tables 5-9 and 5.9a.

Water Content

Water content (loss on drying) for the 20 sites was lowest at site F3 (15.34 ppm), and highest at site P12 (30.02 ppm). For all other sites however, the values were within a narrow range of 20.35 to 25.80 ppm. There was no apparent trend in water content of the sediment with location.

Table 5-8: Parameters measured in sediment samples collected in February and June, 1994.

| Parameters | |
|---|---|
| Water content (loss on drying)<br>Organic content (loss on ignition)<br>Cadmium (Cd)<br>Lead (Pb)<br>Mercury (Hg) | Arsenic (As)<br>Phosphorus (P)<br>Sulphur (S)<br>Chemical oxygen demand (COD) |

Table 5-9: Results of sediment analyses for samples collected at 20 sites, February, 1994 (all units ppm).

| Site | Water Content | Loss on ignition | Cd | Pb | Hg | As | P | S | COD | PAH |
|---|---|---|---|---|---|---|---|---|---|---|
| F1 B | 25.80 | 13.45 | 1.65 | 30.40 | 0.29 | 0.87 | 279.6 | 2256 | 2815 | 4760 |
| F2 B | 24.63 | 10.57 | 1.46 | 50.82 | 0.12 | 0.95 | 198.2 | 2153 | 2431 | - |
| F3 B | 15.34 | 3.02 | 0.30 | 15.39 | 0.10 | 0.25 | 105.7 | 1084 | 417 | 85 |
| F4 B | 24.06 | 10.10 | 1.08 | 1.92 | 0.08 | 0.73 | 217.4 | 2457 | 2535 | 1060 |
| F5 B | 20.95 | 11.15 | 2.71 | 125.71 | 0.11 | 0.92 | 267.3 | 2105 | 2316 | 6530 |
| F6 C | 24.15 | 10.57 | 4.95 | 126.27 | 0.13 | 1.75 | 391.3 | 7108 | 2502 | 790 |
| F7 H | 22.06 | 10.17 | 2.72 | 126.40 | 0.17 | 1.36 | 366.6 | 1403 | 2417 | 1780 |
| F8 H | 24.01 | 11.15 | 0.18 | 0.30 | 0.14 | 1.01 | 465.5 | 3427 | 2722 | 4420 |
| P1 B | 23.78 | 9.99 | 3.09 | 129.53 | 0.54 | 1.82 | 229.4 | 1356 | 2315 | 2580 |
| P2 B | 22.11 | 6.85 | 3.54 | 84.42 | 0.78 | 1.06 | 224.7 | 3082 | 1162 | 2230 |
| P3 B | 21.35 | 8.08 | 3.81 | 71.31 | 0.12 | 1.15 | 198.0 | 3364 | 1748 | - |
| P4 B | 23.06 | 10.92 | 3.54 | 55.43 | 0.01 | 0.94 | 124.5 | 1125 | 2643 | - |
| P5 B | 23.12 | 11.44 | 3.72 | 50.85 | 0.13 | 1.55 | 291.6 | 3330 | 2872 | - |
| P6 B | 30.16 | 10.92 | 1.46 | 56.57 | 0.01 | 1.72 | 254.7 | 1105 | 2696 | - |
| P7 B | 24.11 | 13.45 | 3.30 | 70.00 | 0.01 | 1.14 | 384.1 | 1406 | 2974 | - |
| P8 H | 21.62 | 10.57 | 4.40 | 144.92 | 0.01 | 0.97 | 296.0 | 1300 | 2547 | - |
| P9 H | 24.79 | 9.69 | 1.46 | 55.00 | 0.30 | 0.95 | 217.1 | 6712 | 2217 | 1210 |
| P10 H | 24.11 | 10.11 | 1.33 | 78.69 | 0.01 | 0.63 | 341.5 | 1054 | 2463 | - |
| P11 H | 24.64 | 10.53 | 8.31 | 36.86 | 0.46 | 0.76 | 391.2 | 4055 | 2576 | - |
| P12 H | 30.02 | 10.21 | 5.30 | 192.00 | 0.11 | 1.94 | 384.0 | 1352 | 2472 | - |

Note: L=Location: B=Bai Chay Bay; C=Cua Luc Strait; H=Ha Long Bay.

Table 5-9a: Results of sediment analyses for samples collected at 20 sites, June 1994 (all units ppm).

| | Water Content | Loss on ignition | Cd | Pb | Hg | As | P | S | COD | PAH |
|---|---|---|---|---|---|---|---|---|---|---|
| F1 B | 20.20 | 15.37 | 1.12 | 30.40 | 0.28 | 0.90 | 288.7 | 2170 | 2841 | 790 |
| F2 B | 20.46 | 10.03 | 2.10 | 47.51 | 0.14 | 1.12 | 144.3 | 1820 | 2396 | 1250 |
| F3 B | 11.83 | 5.86 | 1.10 | 9.46 | 0.09 | 0.36 | 126.2 | 1360 | 593 | 1060 |
| F4 B | 17.64 | 10.20 | 1.21 | 7.58 | 0.10 | 0.68 | 266.2 | 3020 | 2555 | 920 |
| F5 B | 17.15 | 13.13 | 2.58 | 134.82 | 0.18 | 0.93 | 244.0 | 2900 | 2381 | 1050 |
| F6 C | 18.18 | 11.72 | 5.16 | 116.03 | 0.17 | 1.70 | 380.0 | 5100 | 2496 | 1720 |
| F7 H | 19.46 | 12.05 | 3.19 | 117.19 | 0.06 | 1.53 | 366.1 | 2432 | 1680 | 1130 |
| F8 H | 15.44 | 17.08 | 0.18 | 10.71 | 0.18 | 1.15 | 476.0 | 1680 | 2786 | 2910 |
| P1 B | 20.17 | 12.76 | 3.10 | 122.22 | 0.84 | 1.76 | 288.0 | 1970 | 2398 | 1040 |
| P2 B | 18.46 | 7.15 | 3.13 | 9.23 | 0.78 | 1.20 | 220.3 | 2900 | 1185 | - |
| P3 B | 16.73 | 7.52 | 2.15 | 71.59 | 0.52 | 1.17 | 170.0 | 4010 | 1893 | - |
| P4 B | 21.00 | 11.25 | 2.15 | 60.72 | 0.06 | 1.05 | 176.5 | 1130 | 2696 | - |
| P5 B | 22.16 | 9.17 | 2.10 | 52.85 | 0.16 | 1.50 | 254.7 | 4610 | 2903 | - |
| P6 B | 24.63 | 11.25 | 2.16 | 53.11 | 0.03 | 1.51 | 304.2 | 1730 | 2871 | - |
| P7 B | 18.47 | 12.38 | 3.24 | 72.13 | 0.02 | 1.26 | 376.4 | 1280 | 2981 | - |
| P8 H | 15.21 | 9.98 | 2.20 | 132.12 | 0.02 | 1.08 | 288.4 | 1910 | 2603 | - |
| P9 H | 22.64 | 12.50 | 1.21 | 63.10 | 0.30 | 0.94 | 220.0 | 6940 | 2248 | 2720 |
| P10 H | 21.17 | 12.50 | 1.20 | 71.03 | 0.02 | 0.67 | 420.0 | 2160 | 2456 | - |
| P11 H | 19.35 | 13.65 | 6.15 | 40.19 | 0.49 | 0.91 | 432.0 | 4480 | 2611 | - |
| P12 H | 25.17 | 14.60 | 6.29 | 198.20 | 0.04 | 1.75 | 366.5 | 1200 | 2465 | - |

Note: L=Location: B=Bai Chay Bay: C=Cua Luc Strait: H=Ha Long Bay.

Organic Content

Trends in the data were consistent between summer and winter organic content (loss on ignition) was lowest at site F3 in both winter and summer (3.02 and 5.86 ppm respectively). Elsewhere the organic content ranges from 6.85 ppm at site P2 to 13.45 ppm at sites F1 and P7 in winter. In summer the values tended to be slightly higher, ranging from 7.15 at site P2 to 15.37 at site F1.

Apart from site F3, the sites with the lowest organic content were are all located in deeper water in channels in Bai Chay Bay or offshore in Ha Long Bay, suggesting that organic materials are normally deposited in shallower water near the shorelines or as the rivers enter Bai Chay Bay.

At the other sites the values are within a narrow range suggesting that the sediment characteristics at these sites are similar. The lower organic and water content at site F3 indicate that this site has somewhat different sediment characteristics than the other sites.

Trace Elements

There was considerable variation in cadmium, lead and arsenic values. For cadmium, relatively high levels were found in winter at sites P8, P11, P12 and F6. In summer, cadmium was highest at sites P11, P12 and F6 showing a similar trend to the winter results. Site F6 in Cua Luc Strait, site P11 is in the vicinity of the floating port. Lead was relatively high both summer and winter at P8, P12, F6 and F7, also all near the shoreline within Ha Long Bay. However, relatively high levels were also found at sites P1 and F5, within Bai Chay Bay. These sites are at a distance from B-12 Oil Port and Hon Gai. The mercury concentrations also ranged quite widely.

Analyses of sediments near in Brunei Darussalam (Seng et al 1990), in an area where pollutants from oil industry and residential sources are present in the water, can be compared with the above results. Cadmium concentrations in the Brunei Study ranged from <10 to 30 ppm. Those in the present study were lower, all were <10 ppm and most were <5 ppm. However, lead values in the present survey, which had a maximum of 145 ppm in the February survey and 198 ppm in the June survey, were much higher than those reported from Brunei (range <2 - 22 ppm). The results for mercury in the present study were relatively low (all concentrations <1 ppm) compared to the Brunei samples where the range was 0.66 - 2.1 ppm.

There was much variation in arsenic concentrations. The values tended to be highest in the vicinity of Hon Gai Port and Cua Luc Strait, with lower values associated with the Inner Bai Chay Bay sites F1 - F4.

Other Parameters

Phosphorus concentrations tended to be higher (>340 ppm) at sites along the Bai Chay Coastline in Ha Long Bay, in Cua Luc Strait and at sites P11 and F8, near Hon Gai in both the summer and winter results. This may indicate an accumulation of phosphorus from runoff entering the waters in the industrial and residential areas. These results are similar to the water quality results for total phosphorus and phosphate.

The highest sulphate concentrations were found at sites F6 (7108 ppm) within Cua Luc Strait and at site 9 (6940 ppm) in the summer survey. Elsewhere there was considerable variation in the data and no pattern is evident.

COD concentrations at sites F3, P2 and P3 are somewhat lower than those at the other sites, but there is no pattern evident in the data.

Polyaromatic Hydrocarbons

Polyaromatic hydrocarbons in the sediments varied widely across the 10 sites for which analyses were carried out. In winter relatively high values were found at sites within Bai Chay Bay at sites F1 and F5 (4,760 and 6,530 ppb), and also at site F8, near Hon Gai (4,420 ppb). In summer, sites F6 and F8 had the highest concentrations. The relatively high levels found in Bai Chay Bay in winter are difficult to explain. There is no known source of hydrocarbons upstream in any of the rivers which drain into the Bay. It is possible that oils from the B-12 port are entering the Bay and accumulating in the sediments, but in that case it could be expected that other sites within Bai Chay Bay would display a similar response. Further studies are needed to confirm these results.

# CHAPTER 6 THE MANGROVE ECOSYSTEM

## 6.1 Introduction

The aim of this chapter is to describes the mangrove ecosystem of Bai Chay Bay in relation to the proposed Cai Lan Port Project. The account focuses on several key aspects of relevance to the mangrove ecosystem. It describes the estuarine biology which should be taken into consideration during both the construction and operational phases of the port development.

These key aspects include :

- Mangrove species in Northern Vietnam and their status in relationship to mangroves elsewhere in Vietnam and, where relevant, to mangrove vegetation in the Indo-Pacific Biogeographic Region.

- The ecological and economic value of the mangrove ecosystem.

Sections 6.4 to 6.6.8 address some of the outstanding features of the mangrove ecosystem within Bai Chay Bay. Although the size and diversity of mangrove species found in this northern province of Vietnam does not match that of Southern Vietnam where temperatures are consistently warmer, the biological importance of the remaining 2,000 ha of mangrove in Bai Chay Bay to a host of finfish, shellfish and crustaceae and to numerous communities of local people is immeasurable.

Two case studies about the economic importance of the mangrove ecosystem are reported in section 6.7. These indicate the high economic value of mangroves as a firewood resource to the local inhabitants, and the even higher economic value of shellfish.

## 6.2 Survey Methods

### 6.2.1 Survey Approach

The findings of this chapter are based on field work in Bai Chay Bay conducted by the Environmental Specialists. First hand data and observations were gained on field surveys conducted over a total of five days in December 1993 and in January and June 1994 (Table 6-1). Both foreign and Vietnamese co-workers were involved in the field surveys.

The first hand data and observations, and the available published data and other printed literature (local reports, papers, documents, books, etc.) have been used to put the environmental issues regarding the mangrove ecosystem into perspective in this EIA.

### 6.2.2 Field Methods

#### 6.2.2.1 Aerial Reconnaissance

Aerial reconnaissance from a helicopter and a light sea plane was undertaken during the December 1993 and June 1994 field excursions respectively. This enabled an overview to be taken of the macro-ecological and geographic setting of the Cai Lan Port area and Bai Chay Bay and its agricultural hinterland. Some patterns of water current and surface dynamics were also detectable by this method.

#### 6.2.2.2 Ground Surveys

Both the paddy and farm lands behind the extensive (~ 2,000 ha) mangrove zones and the mangroves themselves were visited on foot. The locations of the sites are described in Table 6-1 and shown in Fig. 6-1. Approximately 10 km of paddy, paddy-mangrove fringe, aquaculture zones, sand flats and mud flats were covered on foot during the surveys.

The seaward mangrove area on the northern side of Bai Chay Bay was examined while the tress were partly submerged (water depth ~ 25 to 40 cm). This enabled the condition of the seaward belt of pioneer species (*Avicennia marina* and *Kandelia candel*) to be inspected and later compared with that towards the landward zone of the mangrove vegetation. In addition, these excursions into the outer mangrove zones of *Rhizophora stylosa*, where the subtraction is soft and muddy, enabled assessments to be made of such matters as the relative importance of different mangrove species in the day to day economic activities of the local people.

Table 6-1: Field surveys of the mangroves of Bai Chay Bay.

| Date | Location | Main Activity | Personnel<br>Foreign (F)<br>Vietnamese (V) |
|---|---|---|---|
| 27-28 Dec, 1993 | Cai Lan Port area | Site inspection of port coastal environment.<br>Visual reconnaissance of Bai Chay Bay; aerial reconnaissance. | Dr R. Bartlett (F)<br>Dr G. Maxwell (F) |
| 6-8 Jan, 1994 | Bai Chay Bay<br>i. Kend dong<br>ii. Le Loi<br>iii. Lang Bang | Mangrove and mud studies including vegetation transects and mud macrochemistry with LD80A | Dr G. Maxwell<br>Mr Dang Viet Khoa (V) |
| 9-10 June, 1994 | i. Yen Lap Experimental Enterprise, Yen Hung Town, Quang Ninh Province | Interview with Mr Le Dinh Tram (Director Yen Lap EE) and discussion with Hoang Cong Dang (PhD student at EE) | Dr G. Maxwell<br>Dr Nguyen Hoang Tri (V)<br>(Mangrove Ecosystem Research Centre) |
| | ii. Le Loi Experimental Production Project | Field visit and inspection of Le Loi dyke, aquaculture and mangrove scheme | " |
| | iii. Bai Chay Bay and Yen Hung District | Aerial reconnaissance. Inspect and evaluate Dai Yen coastal mangrove as potential mitigation area. Meeting with Mr Le Dinh Tram | Dr G. Maxwell<br>Dr N. H. Tri<br>Mr H. C. Dang (V) |

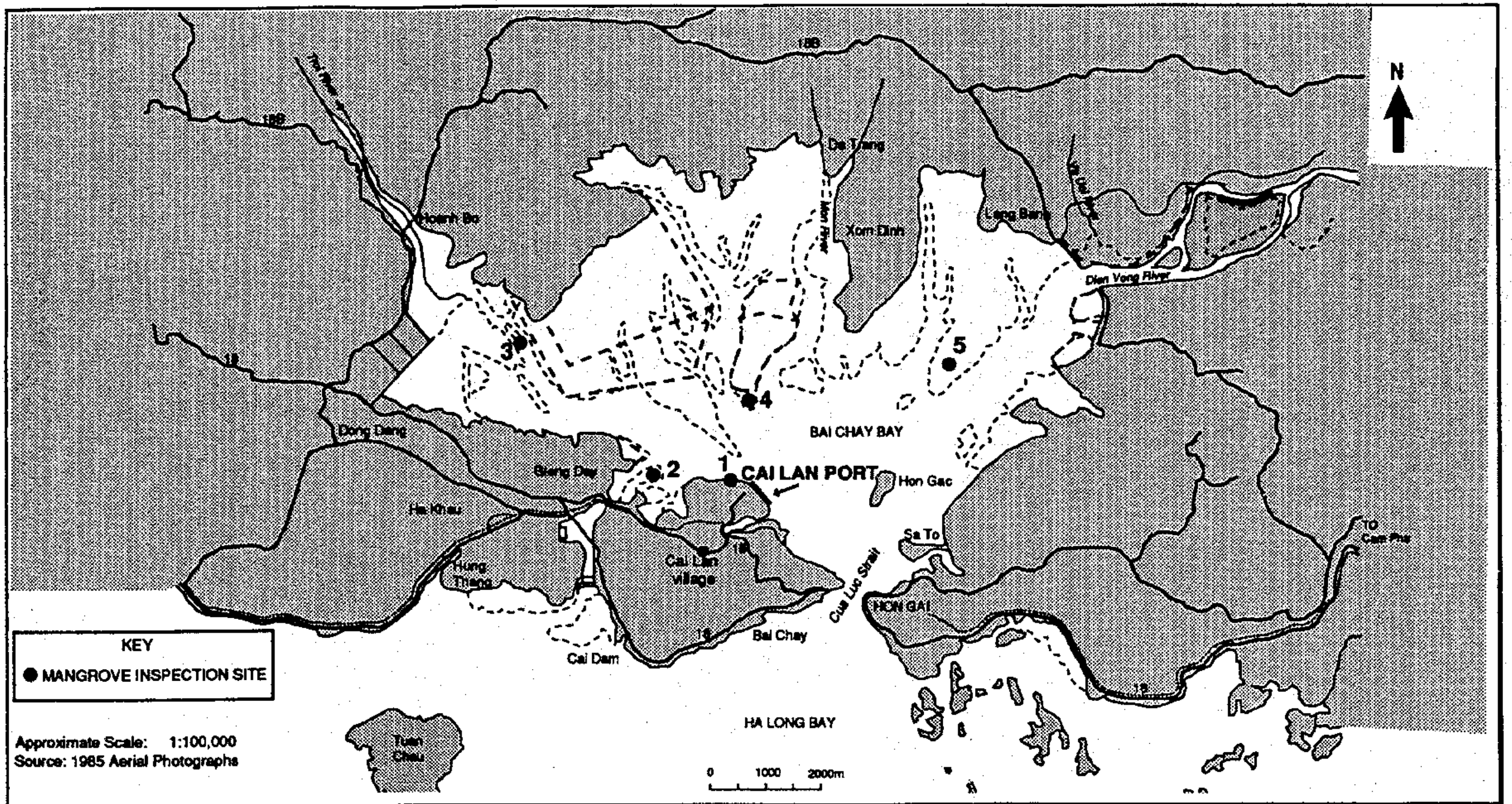
#### 6.2.2.3 Interviews and Instrumentation

Interviews were conducted in both January and June 1994 with local people encountered on the field excursions. In January, some San Diu people were interviewed near Xom Trai (site 5 in Fig. 6-1). In June local mangrove firewood gatherers were interviewed, along with soldiers involved in dyke and flood gate construction on the Le Loi Experimental Production Project.

Instrumentation used during the field work is described in Table 6-2 and shown in Plate 6-1. In addition to the above instruments, basic ecological equipment such as binoculars, camera, diameter at breast height (dbh) tape, transect tapes and sediment bottles were also used.

Table 6-2: Instrumentation used during field surveys.

| Date | Instrument | Function | Source |
|---|---|---|---|
| 7.1.94 | D-section corer (see Plate 6-1). | To take un-compacted soil or mud samples. | Environmental Specialist. |
| 9-10.6.94 | LD80A redox, pH and temperature probe system (see Plate 6-1). | To measure mud anoxic status in the field; macrochemistry of sulphate-sulphite and oxygen status. | Environmental Specialist. This was involved in technology transfer to Vietnamese counterparts. The instrument is computer-compatible and recommended in "The Mangrove Ecosystem - Research Methods", UNESCO 1984. |
| | Salinity refractometer (Atogo brand, calibrated in ppt) | To determine water salinity. | Dr N. H. Tri, Mangrove Ecosystem Research Centre. |




FIELD SURVEY SITES IN BAI CHAY BAY

FIG. 6-1

FEASIBILITY STUDY FOR CAI LAN PORT CONSTRUCTION PROJECT


Plate 6-1: Instrumentation utilized in the BCBA field surveys, January 1994.

(A) The LD 80A electronic redox meter (blue box beside back pack) with Platinum-spike tip probe placed into fresh sample of mangrove substratum obtained with stainless steel D - section corer.

(B) Tree in lower inter tidal mangrove on North side Bai Chay Bay. Approx. height 2.1m. D - section corer beside *R. stylosa* aerial pro root system.

(C) and (D) forester tape beside dwarf and stunted *Avicenia marina* tree in upper tidal zone of extensive *Avicennia* mangrove sand flats near Le Loi village (site 4 on Fig 6.2). These stunted trees are a growth form induced by the combined prolonged effects of cattle foraging and firewood cutting.

## 6.3 The Eco-Geographic Setting of Bai Chay Bay

The physical environment of Bai Chay Bay is described in detail in Chapter 5 and is not revisited here. The aim of this section is to characterise the combined ecological and geographic features of Bai Chay Bay which are most important in the understanding of the mangrove ecosystem. Of paramount importance is the fact that this environment is an estuarine ecological system.

Five rivers (the Troi, My, Man, Thanh and Dien Vong Rivers) together with their tributaries and extensive catchment areas drain into Bai Chay Bay. A system of mud flat deltas has evolved. Tidal waters bring saline water into the fresh riverine water and a complex estuarine environment has been created. Wide variations in soil and water salinities occur due to the estuarine environment and to climate and rainfall conditions. The complexities of the aquatic environment are, to some extent, mirrored in the complex soil system. A mosaic of sand, loamy sand, silty clay sand and clay make up the substrata of the deltaic system. A recent study (Anh, 1992) showed that these various soil types had the following representation in Bai Chay Bay:

| | |
|---|---|
| Sandy soil: | 7-9 % of Bai Chay Bay |
| Loamy sand: | 50-60 % |
| Silty clay sand: | 30 % |
| Clay: | 6-8 % |

There is some evidence that the loam and silt components have increased in recent decades. This trend is thought to be associated with deforestation on the hillsides beyond the river deltas and the consequent erosion of soil and subsoil.

Another salient point is climatic. On occasions cool (~ 7 °C) winter days occur and place ecophysiological stress on the growth of mangrove species. Some mangrove are more cold tolerant than others. *Kandelia candel* especially, and to some extent *Avicennia marina*, are well adapted to withstand both cold and the wide variety of soil types which exist in this estuarine system.

The ecologically important mangrove species of this northern province of Vietnam are *Kandelia candel*, *Avicennia marina*, *Aegiceras corniculatum*, *Bruguiera gymnorrhiza* and *Rhizophora stylosa*. *Kandelia*, *Avicennia* and *Aegiceras* may be eco-dominant in Bai Chay Bay because they are suited to the physical challenges of the habitat. These include cold, variable substrata and variable salinities, and moreover, the human factors of firewood harvesting and buffalo grazing and foraging.

Thus the eco-geographic characteristics of Bai Chay Bay may not be entirely natural; human factors have a long history and are very important. This consideration is crucial in the management of the mangrove ecosystem, the rehabilitation of degraded mangrove stands and the assessment of environmental impacts associated with the development of Cai Lan Port and the attendant economic and industrial developments in the future.

## 6.4 The Abiotic Mangrove Environment

### 6.4.1 Introduction

This section briefly addresses the main physico-chemical features of the mangrove soils, estuarine water and the waters of Bai Chay Bay itself. Some of the salient features of the soil were mentioned above.

### 6.4.2 Chemical Analyses of Mangrove Soils

The chemistry of the mangrove soils is shown in Table 6-3. The data is based on two sources: Anh (1992) and field work conducted by the Environmental Experts.

The values for the various chemical species are within the range for mangrove substrata in the Asia-Pacific Region. The soil water salinities are somewhat lower than expected, while those for pH are more acidic than expected. However, values for the more important macro-chemical parameter of mud redox status were indicative of low anoxia. They are not extreme values and indicate that in terms of the complex sulphate-sulphide oxidation-reduction reactions typical of mangrove mud, the muds and sands of Bai Chay Bay are favourable for mangrove growth.

Table 6-3: Chemical analysis of mangrove substrates typical of Bai Chay Bay.

| Parameter | Value |
|---|---|
| Organic matter upper layer | 1-30 % |
| lower layer | 4-5 % |
| Total-N | 0.05-0.2 % |
| Total-P | 1-4 mg $P_2O_5$ per 100 g soil |
| K | 30-80 mg $K_2O$ per 100 g soil |
| pH | 4.5-5.5 |
| $Al^{3+}$ | 5-10 mg per 100 g soil |
| $Fe^{3+}$ | 150-300 mg per 100 g soil |
| Soil water salinity | 10-30 % |
| $Cl^-$ | 0.3-0.6 % |
| $SO_4^{2-}$ | 1-3 % |
| Mud redox status (LD80A instrument) | i) 0-3 cm depth= -106 mV |
| | ii) 10-15 cm depth= -200 mV |
| | iii) max recorded in soft estuarine ooze = -215 mV |

### 6.4.3 Chemical Analyses of Mangrove Waterways and Bai Chay Bay Water

The results of a chemical analysis of mangrove waterways and Bai Chay Bay waters (Anh 1992) are shown in Table 6-4.

The results are within the ranges expected for estuarine, riverine and mangrove ecosystems. The pH values (7.2 to 7.5) are rather different from the equivalent values in mangrove soils. This is not surprising as a host of microbe-mediated chemical reactions occur within the mangrove substratum. At times, pH values can vary depending on the state of the tide, peaks in microbial activity, temperature and the anoxic status of a given mud sample. It is possible that the pH readings for mangrove mud

Table 6-4: Chemical composition of mangrove waterways and Bai Chay Bay waters (from Anh 1992).

| Parameter | Value (all units mg $l^{-1}$ except pH and salinity) | |
|---|---|---|
| | Mangrove | Bai Chay Bay |
| pH | 7.2-7.5 | 7.3-7.5 |
| $Al^{3+}$ | 0.05-0.07 | 0.0 |
| $Fe^{3+}$ | 0.03-2.0 | 0.02-0.05 |
| P | 3-10 | 3-15 |
| $Ca^{2+}$ | 7-20 | 20-40 |
| $Mg^{2+}$ | 14-60 | 120-160 |
| $SO_4^{2-}$ | 121-164 | 288-300 |
| $Cl^-$ | 0.25-2.59 | 5.1-7.55 |
| Salinity * | 9-18 parts per thousand | 24-30.5 |

Note: * June refractometer readings after heavy rain, Environmental Specialist, 9.6.94.

were taken at a time of peak microbial action involving the release of complex organic acids associated with the tannin-laden derivatives of decomposing mangrove material. The pH patterns in mangrove mud especially and to a lesser extent in mangrove waterways require further study in a long term programme involving seasonal variations.

#### 6.4.4 Underground Waters

The results of an analysis of underground waters associated with the paddy-mangrove transition zone are presented in Table 6-5. They contain no surprises. The ground water within the mangrove-paddy transition zone is similar to what would be expected in waterlogged soils and old estuarine and alluvial sedimentary deposits.

Table 6-5: Chemical composition of underground waters associated with the paddy-mangrove transition zone.

| Parameter | Value (mg l-1) |
|---|---|
| pH | 6.9-7.1 |
| $Al^{3+}$ | 4-10 |
| $Fe^{3+}$ | 0.08-0.4 |
| P | 10-17 |
| $Ca^{2+}$ | 18-68 |
| $Mg^{2+}$ | 88-206 |
| $SO_4^{2-}$ | 170-330 |
| $Cl^-$ | 13-15 |

## 6.5 Mangrove Vegetation

### 6.5.1 Introduction

Mangrove vegetation is an outstanding feature of protected maritime locations throughout the tropical and subtropical regions of the world. Plants which make up mangroves come from a wide variety of taxonomic groups, many of which are not closely related. An important concept in the understanding of the ecology and biology of these "trees which grow in the sea" is that they represent, in biological terms, a life form and not one particular type or even family of flowering plants.

In the past decade, mangrove research has seen dramatic growth. It is now possible to state, with much confidence and scientific power, that the battle of viewpoints between the conflicting social forces of mangrove forest conservation and conversion is at last, over. Very few mangrove scientists now doubt the ecological and economic importance of mangroves. They have been aptly described as perhaps the most productive ecosystem on earth.

It is against this background that we must assess the importance of the 2,000 ha of remaining mangrove that exists in Bai Chay Bay.

### 6.5.2 The Mangrove Zones of Vietnam

The mangrove vegetation of Vietnam has been divided into four major eco-geographic zones (Hong 1984, 1993). The use of the term eco-geographic to describe aspects of mangrove biogeography has been advocated recently by Maxwell (1994) and used in relation to ecotypes by Aksornkoae *et al.* (1992).

Hong and San (1993) subdivide the major zones into 12 subzones. All zones are essentially based on latitude. The major zones are:

Zone 1: North-east Coast from Ngoc Cape to Do Son Cape
(~ 22° to 21°N).

Zone 2: Northern Delta Do Son Cape to Lach Truong River
(~ 21°to 20°N).

Zone 3: Central Coast from Lach Truong to Vung Tau Cape
(~ 20°to 10°30'N)

Zone 4: Southern Delta from Vung Tau Cape to Ha Tien
(~ 10 °30' to 9°30'N).

Bai Chay Bay is thus in Zone 1.

### 6.5.3 The Present Status of Mangrove Forest in Vietnam

Largely due to the two Indochina Wars, which together lasted almost 30 years, the quantity and composition of mangroves have changed markedly (Hong and San, 1993). The estimated present status of mangrove in Vietnam is shown in Table 6-6.

To place these 1983 estimates in perspective it is useful to mention that before the second Indochina War (1962-1971), mangrove forests in Vietnam covered some 400,000 ha (Maurand, 1943).

Table 6-6: Mangrove forest in Vietnam (ha) based on 1983 studies.

| Zone | Estimated Total Area | Natural forest Trees | Natural forest Shrubs | Plantation |
|---|---|---|---|---|
| 1. North-east | 39,400 | 3,000 | 36,400 | - |
| 2. Northern delta | 7,000 | 2,800 | - | 4,200 (i) |
| 3. Central | 14,300 | - | 14,300 | - |
| 4. Southern delta | 191,800 | 135,900 | 13,500 | 42,400 |

Note: Hong (1994) reports investigations under way to plant circa 2,000 ha of *Kandelia candel* mangroves in Thai Binh and Nam Ha Provinces. The plantation potential is considerable.

### 6.5.4 The Bai Chay Bay Mangroves in Relation to Other Zone 1 Mangroves

Zone 1 has the most complex physical environment of all the mangrove zones. Salinity, for example, ranges from 21 parts per thousand (ppt) to 27 ppt, depending on seasonal rainfall. (By comparison, normal seawater has salinity of 35 ppt). Cool winter temperatures in this northern zone tend to limit the growth potential of mangrove trees.

Hong and San (1993) subdivide Zone 1 into 3 subzones, designated 1A, 1B and 1C. Zone 1A covers around 55 km of coastline from Mong Cai to Cua Ong. The relatively low human population in many parts of Zone 1A has enabled many species of mangrove here to reach their climatically controlled growth potential. Some trees have reached 8 m in height and 20-30 cm in diameter.

Zone 1B covers some 40 km of coastline from Cua Ong to Cua Luc. Bai Chay Bay is included in Zone 1B. The mangroves in Zone 1B are not as extensively developed as those in other zones. The area is close to coal mines. Exploitation of this resource has worked against the mangrove stands. In addition, trees have been used by local people for many functions, from firewood to cattle fodder. Typically, the mangroves do not reach their full growth potential in Zone 1B. Stunted trees and shrubs are common, although *Kandelia* and *Bruguiera gymnorrhiza* can reach 2-3 m tall in places.

Zone 1C covers over 5 km of coastline from Cua Luc to Do Son Cape. Like the trees in Zone 1B, the mangroves of Zone 1C tend to be small-sized trees.

Generally speaking, the mangroves throughout Zone 1 are notably smaller than their counterparts in Zone 2. The main factors responsible for this condition include cool winters, higher salinities, human exploitation and a complex natural physical environment, especially of the soils (alluvium, sand and sandy mud).

### 6.5.5 Characteristics of the Mangroves of Zones 2, 3 and 4

#### 6.5.5.1 Zone 2 Mangroves

Like Zone 1, Zone 2 can be subdivided into Zones 2A and 2B. Zone 2A is, essentially, a transition area between Zone 1 and Zone 2.

In Zone 2A brackish water species typify the area. Some very large (6-8 m tall) *Sonneratia caseolaris* occur. Under these substantial trees a shrub layer of *Aegiceras* and *Acanthus* occurs. In recent years the expansion of shrimp ponds has resulted in the depletion of the dominant *Sonneratia* forest here. Zone 2B is centred on the Hong River system and, as with Zone 2A, brackish water mangrove species characterise the area. A huge input of water-borne sediment (114 million tonnes of suspended particles are carried every year, according to Pho 1983) enters the Hong River. Mangrove development potential is great but monsoons and storms inhibit the expansion of mangrove vegetation. *Kandelia candel* has been used successfully as a mangrove protector of dykes and soil, and appears to be a key species in mangrove rehabilitation.

#### 6.5.5.2 Zone 3 Mangroves

Due to monsoons and storms and the lack of suitable alluvium, mangrove areas in Zone 3 are few and far between. They are restricted to a limited number of protected sites and situations. Nevertheless, compared to Zones 1 and 2, the species diversity is relatively high, with many more species here than are found in the northern zones.

#### 6.5.5.3 Zone 4 Mangroves

Relatively free from floods and storms, blessed with some very large river systems and biogeographically close to the tropical mangroves of the Indo-Malaysian archipelago, conditions in Zone 4 are most favourable for the extensive development of mangroves (Hong and San 1993). Most of the 32 true mangrove species listed for Vietnam (Hong 1991) can be found in Zone 4.

The tree growth potential (height and girth) is very good indeed. *Avicennia marina* occurs in the far north (Quang Ninh Province) and in the far south, and illustrates the difference between Northern and Southern Vietnam Mangrove conditions very well. During the survey in January 1994 many small (< 0.5 m) squat bonsai-like *Avicennia marina* shrubs were observed in Northern Bai Chay Bay. By contrast, Hong and San (1993) report *Avicennia marina* trees with diameters of 35 - 50 cm in the Bo De Estuary of Zone 4.

Both natural and man-assisted mangrove forest regeneration following defoliation and mangrove mortality due to herbicidal sprays during the Second Indochina War, is an important feature of Zone 4.

### 6.5.6 Summary of the Mangrove Vegetation of Vietnam

The mangroves of Vietnam can usefully be divided into 4 major eco-geographic zones based on latitude, climate, hydrography and topography. Zone 4, which covers the coast of Southern Vietnam, provides the most favourable conditions for mangrove development. This is mirrored in their size (potential for maximum growth), abundance and ecological pattern. Zone 1, on the other hand, in which Bai Chay Bay is located, suffers from the north west monsoon and relatively low (10-15 ∞C) temperatures. Tree growth and species diversity are therefore limited.

### 6.5.7 Ecological and Economic Classification of Mangrove Vegetation in Bai Chay Bay

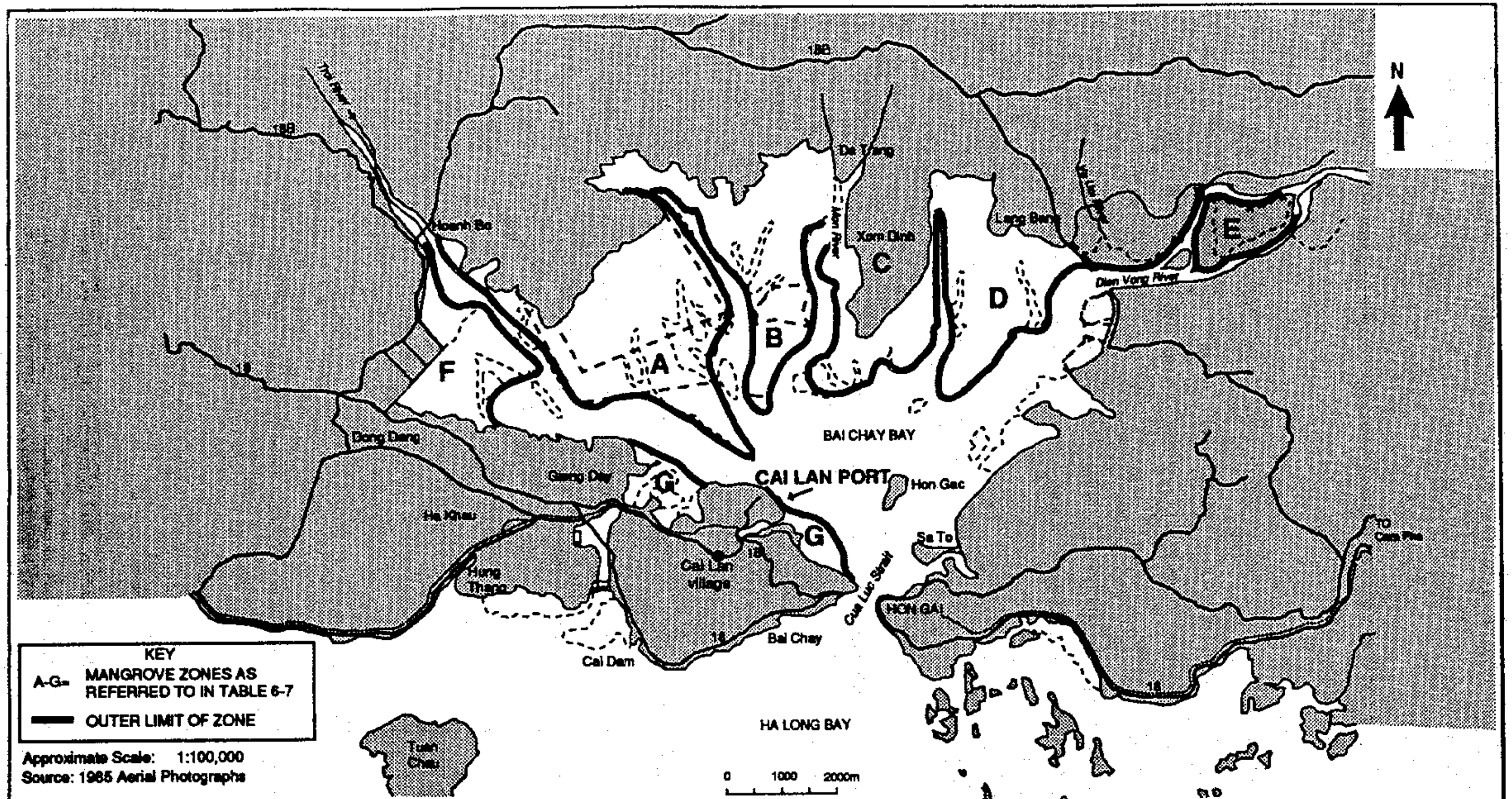
Based on the combined result of the field studies in January and June 1994, it is possible to broadly classify the Bai Chay Bay Mangrove Stands into several eco-economic categories as shown in Table 6-7.

Table 6-7: Estimation of ecological-economic status of Bai Chay Bay Mangroves.

| Zone | Present Ecological-Economic Status |
|---|---|
| A | Medium plus (M+) |
| B | High plus (H+) |
| C | High minus (H-) |
| D | H- |
| E | M+ |
| F | M- |
| G | Low |

Note: Refer Fig. 6-2 for location of each zone.

The classification given in Table 6-7 and shown in Fig. 6-2 is based on professional estimations but should not be regarded as absolute. The scheme is tentative. Mangrove




CLASSIFICATION OF BAI CHAY MANGROVES

FIG. 6-2

FEASIBILITY STUDY FOR CAI LAN PORT CONSTRUCTION PROJECT

research is on-going and the full biological, economic, ecological and even medicinal value of mangrove materials is yet to be realised. In this context, the traditional medicinal uses of mangrove extracts such as leaf extracts of *Acanthus ilicifolius* in treating rheumatism (Chapman 1976; Hong 1993) are a reminder that when the full pharmaceutical, biochemical and medical aspects of mangrove products are known the dollar value of these plants may increase. It was recently found, for example, that extracts of *Avicennia marina* (an important mangrove species in Bai Chay Bay) may have anti-fertility properties and could be useful in the drug industry.

It is emphasised that the tentative eco-economic classification given above could change considerably in the future. Very recently even in Bai Chay Bay the importance of mangrove in sustainable integrated agro-forestry-aquacultural systems has been realised in a pragmatic way. Some experimental planting schemes are now under way.

## 6.6 Mangrove Dependent Biota

### 6.6.1 Introduction

This section describes the fauna of ecological and economic importance which is either directly or indirectly dependent on the primary producers of the mangrove ecosystem - the mangrove trees themselves. These plants furnish the fundamental food supplies in the form of leaf and other plant material. Such primary products are the basis of the food chain and the complex food webs of estuarine ecosystems. The system is interesting and complex. Subtle systems, such as coprophagy, are involved. This system involves the use and reuse of fragments of mangrove leaf matter by first order consumers such as detritivorous crabs including the fiddler crab (*Uca* spp.) and the opportunist members of the genus *Chiromanthes* which consume a wide range of mangrove products such as leaf fragments, propagules (droppers) and other reproductive material. Some mangrove-inhabiting crustaceae ingest leaf fragments, digest the microbial film that has developed on the leaf material and egest the remaining leaf tissue. This tissue is again colonised by microbes and may once more be ingested by the crustaceae. The crabs are, in turn, food for higher order consumers such as resident populations of estuarine finfish which dine in the shallow, tranquil (low velocity) water of the mangrove at high tide. In addition, many pelagic finfish also visit the mangrove estuary at high tide or feed on the resident finfish.

This section describes the main groups of animal biota which are dependent on the mangroves. These include:

- Shellfish.
- Crustaceae.
- Finfish.
- Other vertebrates (birds, mammals, reptiles and amphibians).
- Other mud-dwelling macro invertebrates such as polychaetes and sipunculid worms.

### 6.6.2 Shellfish

The mangrove vegetation supports important populations of edible molluscs, including oysters, mussels and other bivalves as well as a variety of snails. Some of these shellfish are illustrated in Plates 6-2 and 6-3. Oysters (*Ostrea* sp.) are collected by hand. Some mud-dwelling burrowing species such as *Cylina sinensis*, *Meretrix meretrix* and *Mactra quadrangularis* require digging, usually with simple implements (Plate 6-2 C).

The mangrove ecosystem of Northern Vietnam supports a rich and diverse mollusc fauna. Due (1991) reports that over a 23 year period of study, 169 different species of molluscs representing 51 families have been found in the mangrove-dependent ecosystem of Quang Ninh Province. This is a huge resource in term of biodiversity alone.

The molluscan fauna of Quang Ninh Province, including Bai Chay Bay, appears to equate with the highly valued mangrove mollusc resources of Malaysia as described by Wong *et al.* (1984). The biological richness of the Quang Ninh shellfish resource is underscored by the biogeographically interesting fact that of the 254 known species of mollusc within the Asia-Pacific Region, almost 70 % of them can be found in Quang Ninh Province. The most important in terms of abundance and distribution include *Nerita, Clithon, Litorina, Cerithium* (whose abundance can reach 200-300 $m^{-2}$ as observed during the field surveys), *Natica maculosa, Modiolus, Ostrea* (Plate 6-3 A and C) *Mactra quadrangularis, Teredo* and *Bankia.*

Shellfish densities depend on mangrove productivity. Loss of mangrove biomass, due to excessive exploitation by local residents or destruction during the construction of aquaculture ponds, results in a decline in mollusc numbers and species diversity. This fact is illustrated in Table 6-8.

Table 6-8: Variation in numbers of mollusca within mangrove forest compared to fish culture ponds.

| Class | Species Number in Pond | Species Number on Mangrove Flat Outside Pond | Number of Species Common to Both Areas |
|---|---|---|---|
| Gastropoda | 16 | 23 | 11 |
| Bivalvia | 10 | 22 | 11 |

Note: Data based on a 1982-1983 study near Coastal Hai Phong (Duc 1993).

A well planned scientific approach to mangrove resource management is required to ensure sustainable use of these variable molluscan resources. The integrated, experimental dyke-aquaculture-mangrove system being set up near Le Loi in Bai Chay Bay may provide a model for the future.

### 6.6.3 Crustaceae

Some 46 different species of sesarmids (crabs) inhabit the mangrove ecosystem of the Indo-Malaysian region. Many of these penetrate into the long coastline of Vietnam. There is some decline in diversity with increasing latitude.

Detailed studies of crabs with little known economic importance in Quang Ninh Province have not yet been carried out. However the surveys reported here have shown them to be ecologically important throughout the mangrove intertidal zone. Sand processors such as *Uca* sp. and opportunistic, broad-spectrum herbivores such *Chiromanthes* spp. were


Plate 6-2: Fuel and food from the mangroves in zone D (Fig 6.2).

(A) A harvest of firewood from the mangrove *Avicennia marina* growing extensively on salt flats, northern Bai Chay Bay.

(B) Bundles of firewood collected from the mangrove *Aegiceras corniculatum* left to dry near a village landward of the mangrove belt.

(C) Recently harvested mangrove mud-dwelling mollusks (*Meretix* and *Mactra sp*) ; up to 2 kg per hour can be gathered in places.

(D) Discussions with local people.

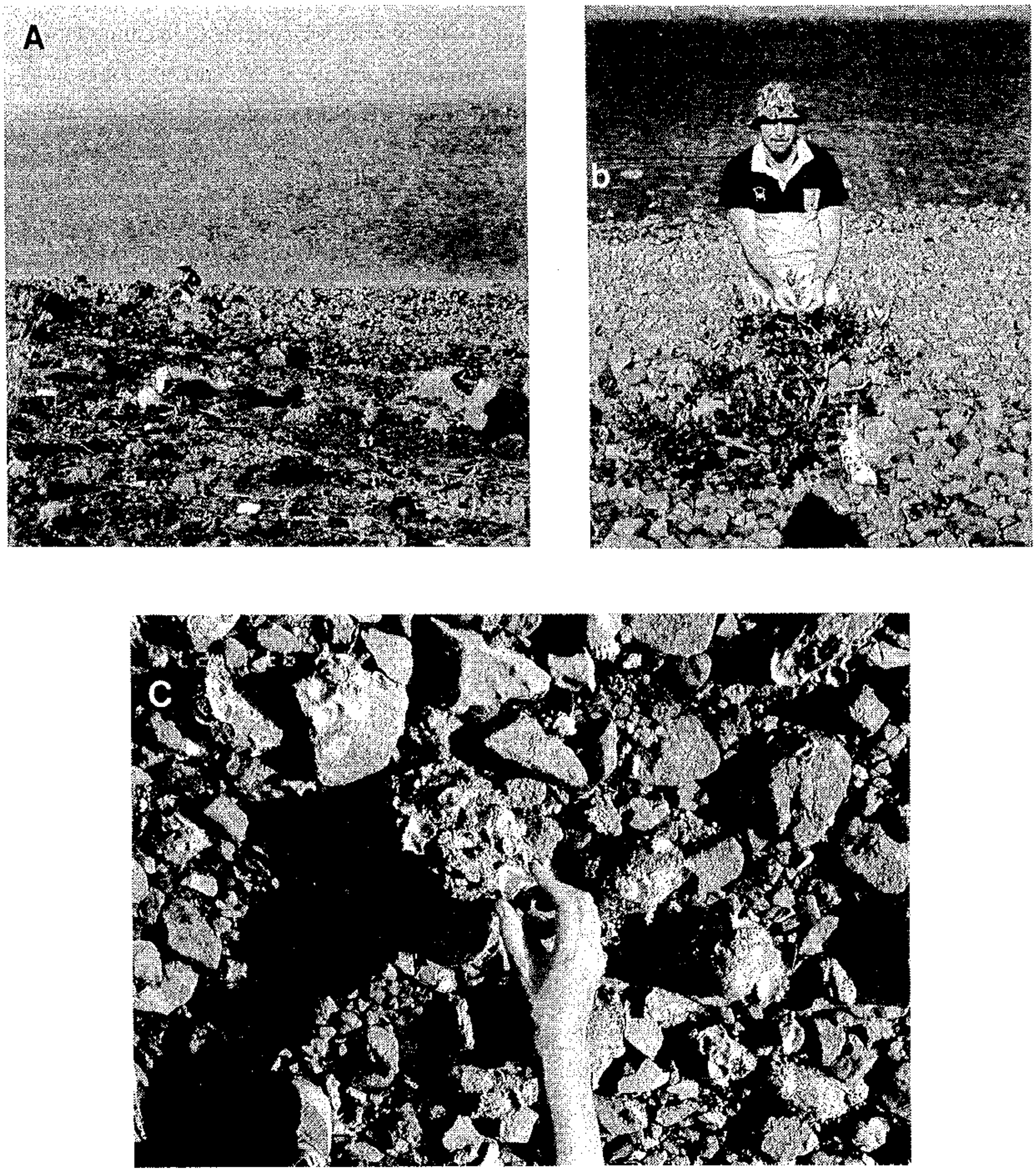



Plate 6-3 : Zone G shorescape near Cai Lan Port, December 1993.

(A) Local people obtaining oyster (*Ostrea* sp.) from rocks in lower littoral.

(B) Stunted mangrove (*Avicennia marina*).

(C) Zone G has very limited remaining shellfish resources.The zone has been classified as having low ecological-economic status.

observed in good numbers at the sites visited. Some of the sesarmids belonging to the important mangrove crab genus *Chiromanthes* are well known propagule predators. Evidence of propagule damage was observed in the mid and lower littoral zones, were the mangrove *Kandelia candel* occurred.

The best known crab is the economically important "mangrove crab", *Scylla serrata.* This is the largest edible crab in the Indo-Pacific region and is very common in Vietnam's Coastal zone (Hong and San, 1993). The meat of this crab is highly valued and very tasty with an excellent nutrient status. *Scylla serrata* are caught in crab traps and with long iron hooks and sold in local markets. A large number are exported. The ecology of this species should be fully studied in the context of Bai Chay Bay as the dollar value of farmed populations of this large "mangrove crab" would be considerable in export terms.

Other crustaceae are important too. Both traditional aquaculture and more advanced systems of aquaculture feature prawn culture. Like the molluscs mentioned above, the prawns are very important in both the daily and market activities of the local people of Bai Chay Bay. Plate 6-4C illustrates a more traditional aquacultural system, typical of the northern shores of Bai Chay Bay

The most important shrimp and prawn species found in Bai Chay are *Penaeus merguiensis, Palaemon carinicanda, Metapenaeus ensis,* and *M. joyneri* (Anh, 1992).

#### 6.6.4 Other Mud-dwelling Macro-invertebrates

As well as the shrimps and crabs described above there are other mangrove-dependant biota which are usually not seen. These live hidden inside the mud and are termed "infauna". The most important infauna include the polychaete and sipunculid worms. Observations were made of polychaetes during mud excavations with the D-section core sampling (refer Plate 6-1). The most common was a member of the genus *Perinereis,* probably *P. singaporensis.*

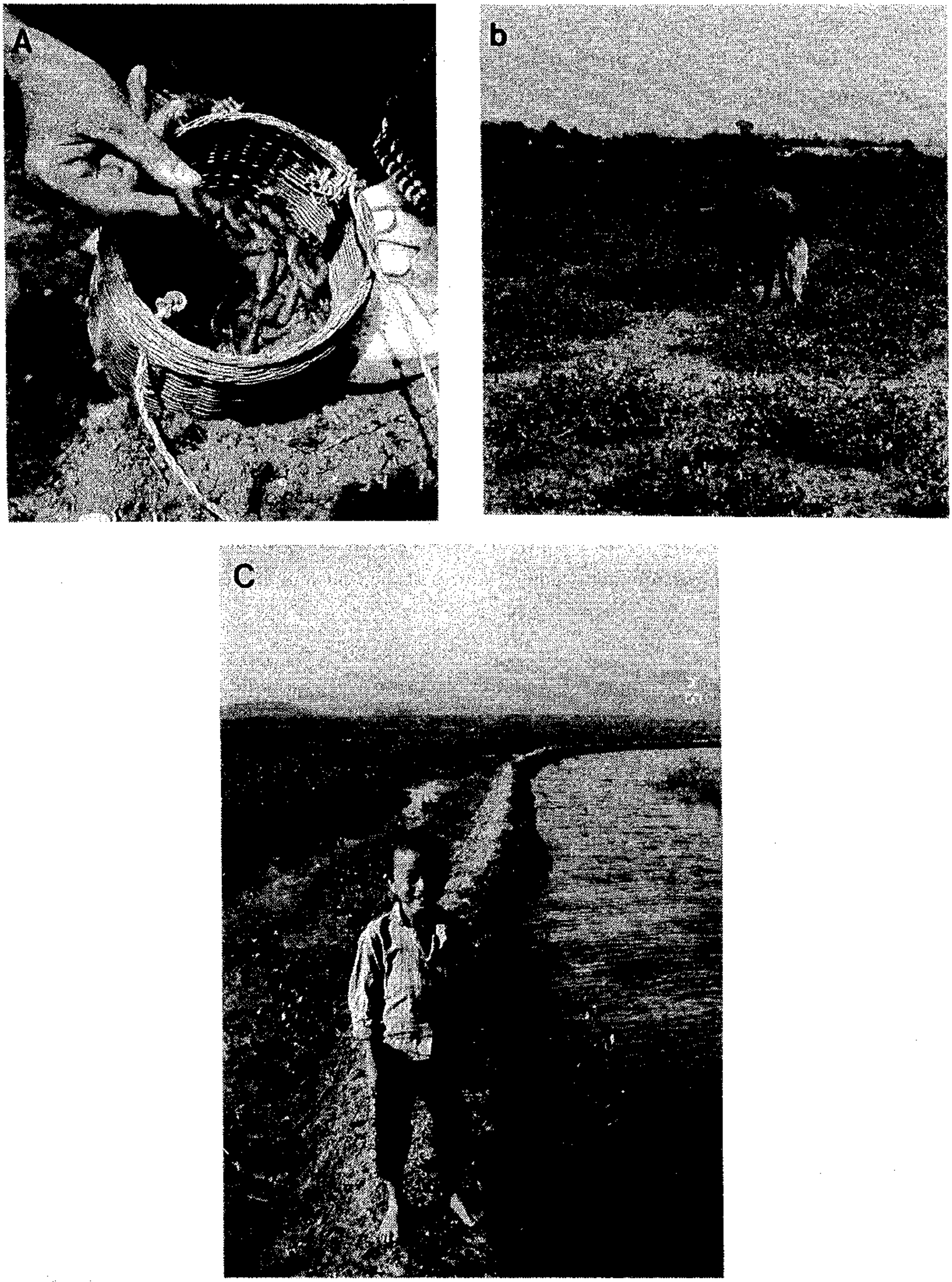



Plate 6-4: Food, fodder and the future.

(A) Sipunculid worm collected in upper littoral near *Aegiceras* mangrove trees near site 3 (Fig 6.2).
(B) Cattle grazing on the nutritious sweet and sour leaves of *Avicennia marina* : the minerals (salt) contained in these mangrove leaves are important for cattle health.
(C) Man-made dyke beside extensive mangrove belt.

Counts of the edible sipunculid *Siphonosoma* (or similar species, *Phascolosoma lurco*) were made during the field survey. Densities of around 30-42 $m^{-2}$ were harvested at site 5 (refer Fig. 6-1) by local people. These densities equate with those recorded in parts of East Coast Peninsular Malaysia, which ranged from 8.3 to 266 $m^{-2}$ (Wong *et al.* 1984).

The full economic value of these macro-invertebrates remains to be determined. They are sold at markets near the Vietnamese-China Border. Some of the customers are Chinese. Also, the importance of these and other macro-invertebrates as a protein source for the local inhabitants must be emphasised.

### 6.6.5 Finfish

The widespread use of baited fish traps and various type of nets (casting and gill) in Bai Chay Bay demonstrates the variety, availability and importance of many species of finfish in the estuarine system here. Some features of the finfishing industry are illustrated in Plate 6-5.

Finfish associated with the mangrove ecosystem in Quang Ninh Province have been listed in the Red Data Book of Vietnam, Vol 1 (1992). This important volume included a section on the Cai Lan Region. Finfish found in this region are many and varied and include well known species such as the eel (*Anguilla japonica*) and sharks such as *Rhincodon typicus*, which are also sustained indirectly by mangrove ecosystems. Likewise the scientifically unusual species such as *Branchiostoma belcheri* (*Amphioxus belcheri*) and *Hippocampus histrix* (seahorse) are also sustained by complex food webs driven by mangroves as primary producers. It is thought useful to mention species such as *Amphioxus* and *Hippocampus* as they are examples of marine vertebrates which are yet to be fully studied both zoologically and economically. The capture and fish culture of such species may well fill a niche market in the future.

### 6.6.6 Other Vertebrates

The avifauna (birds), mammals, reptiles and amphibian associated with the mangrove ecosystem have declined over the years. Excessive hunting and trapping of birds for the feather industry, mammals (e.g., for tiger products) and reptiles (for items such as skin and bile) have resulted in many species, which were once part of the broader mangrove and coastal ecosystems, becoming rare, endangered or extinct.

During the field surveys, sightings of vertebrates were limited to sea eagles and the kingfisher (*Halcyon coromando*). An unconfirmed sighting of the black-headed duck, *Aythya baeri*, was made at site 5 in January, 1994.

The setting aside of limited-access bird reserves at remote areas within Bai Chay Bay (e.g., zone E in Fig. 6-2) may attract birds back to Bai Chay Bay. If such returnees include keystone species such as the black-faced spoonbill, *Platalea minor*, then the eco-tourism potential of Bai Chay Bay could be enhanced. This species has of late attracted considerable international attention, having just two known remaining breeding sites in the world. One of these is in Northern Vietnam, the other in Southern Taiwan. The species is endangered and of much interest ornithologically around the world. To take action to help bird species such as the black-faced spoonbill which feeds in mangrove areas would help promote Bai Chay Bay as an eco-tourism destination. Such action would be in keeping with the multi-use master plan concept for natural resources in Vietnam.

If such action (establishment of bird reserves or bird preservation sites) took place alongside the development of a new port at Cai Lan, then this would be very positive situation, in which both industrial and eco-tourism developments could proceed hand in hand.

No snakes were seen in the area surrounding Bai Chay Bay. Amphibia (frogs) were observed in the paddy-mangrove transition zone but not within the mangrove habitat itself.