FINAL REPORT

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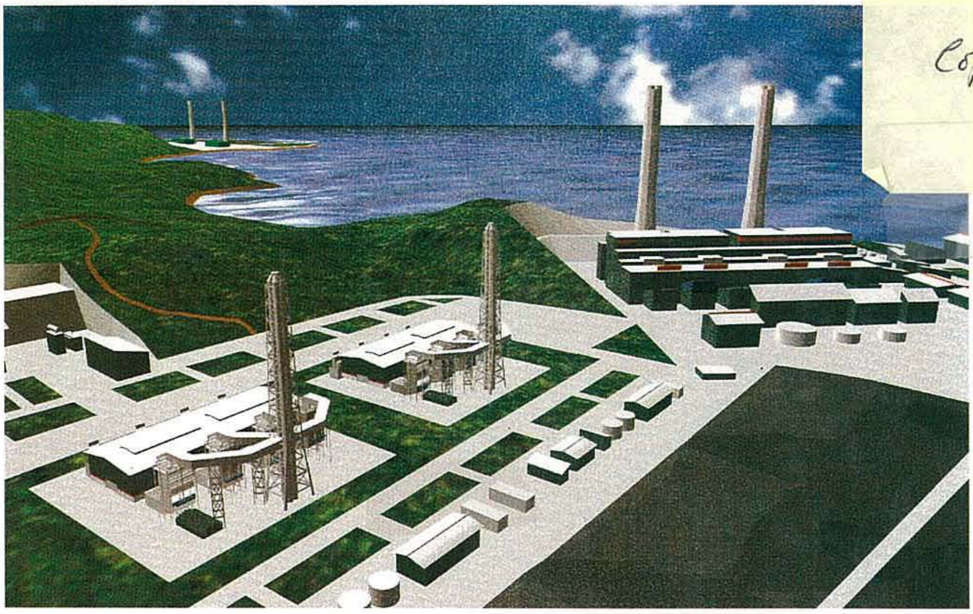

EIA of the Proposed 6000MW Thermal Power Station at Black Point: *Key Issue Assessment*

Marine Water Quality

September 1993

ERM Hong Kong
10 & 11/F Hecny Tower
9 Chatham Road, Tsimshatsui
Kowloon, Hong Kong
Telephone 722 0292 (11/F)
Telephone 367 0378 (10/F)
Facsimile 723 5660

ERM

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Castle Peak Power Company Limited

EIA of the Proposed 6000MW Thermal Power Station at Black Point: *Key Issue Assessment*

Marine Water Quality

September 1993

Project No. C1015

For and on behalf of ERM Hong Kong

Approved by: A H

Position: PROJECT MANAGER

Date: 10th September 1993

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1. *INTRODUCTION*

1.1. *BACKGROUND TO THE KEY ISSUE ASSESSMENT (KIA)*

1.1.1 *The Proposed Development*

Castle Peak Power Company Ltd (CAPCO), a joint venture of Exxon Energy Limited and China Light and Power Company Limited (CLP), proposes to develop a large thermal power station (LTPS) in Hong Kong to meet forecast electricity demand during the late 1990s and into the next century. It is anticipated that the LTPS would ultimately provide 6000MW of power. CLP will act on behalf of CAPCO as the Project Manager for the construction and operation of the LTPS. Studies to date have assumed that approximately 5000MW would be generated from coal-fired units or a combination of 50% coal and 50% gas fired units and up to 1000MW from gas turbine units fired on oil. Throughout this Key Issue Assessment (KIA) Water Quality, 'worst case' (i.e. all coal firing) scenarios have been assumed and hence the conclusions presented in this report are expected to be conservative.

1.1.2 *Project History*

In November 1989 CLP commissioned ERM Hong Kong (formerly ERL (Asia) Ltd) to undertake a Site Search Study for the LTPS. The recommendations of this study were presented in the Site Search Report[1] and the Site Search Executive Summary[2] in the selection of Black Point.

In April 1991 a draft initial assessment report[3] (IAR) was prepared and submitted to Government. Following the recommendations in the IAR, environmental key issues were identified by the Consultants and their scope agreed with the Environmental Protection Department (EPD). These key issues are addressed in separate KIA reports as follows;

- Stack Emissions;
- Water Quality; and
- Solid By-products Management.

The results of the Water Quality KIA are presented in this report.

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[1] ERL (1990) 6000MW Thermal Power Station Site Search Report. ERL (Asia) Ltd September 1990 for CLP.

[2] ERL (1990) 6000MW Thermal Power Station Site Search Executive Summary ERL (Asia) Ltd September 1990 for CLP

[3] ERL (1991) EIA of the Proposed 6000MW Thermal Power Station at Black Point, Draft Initial Assessment, April 1991 for CLP.

1.2 *SCOPE OF THE STUDY*

The Site Search and Initial Assessment studies identified two aspects of the LTPS construction and operational activities that could potentially affect water quality, in the Deep Bay area, namely the marine dredging works and the discharge of cooling water from the LTPS. The specific tasks undertaken to address these potential impacts were outlined in the Study Brief of the Water Quality KIA and are:

- Assessment of temperature modelling;
- Assessment of nutrients/metals dispersion modelling;
- Assessment of turbidity effects;
- Development of mitigation measures.

To address these tasks, the dispersion of the thermal, nutrient and metal components of the cooling water discharge were modelled using the WAHMO suite of models approved by the Hong Kong EPD. The loadings used in the modelling exercise are "worst case" in that they assume all coal (8 units) firing scenario i.e. Scenario I as identified in the EIA Initial Assessment Report and a limestone/gypsum dissolution flue gas desulphurisation (FGD) system.

For Scenario II, the 4 gas–4 coal unit option, total metal loadings are approximately 50% of those of Scenario I, since the FGD plant is the principal source of metals from the power generation process. However, it is now anticipated that, should Scenario II be adopted, two discharge outfalls will be constructed, one serving the gas fired units, and one serving the coal–fired units. Thus the metal concentrations discharged from the Scenario II outfall serving the coal–fired units will be the same as those from the Scenario I, 8 coal–fired outfall(s). Throughout this report, therefore, figures are given for Scenario I, i.e. the overall "worst case". The "worst case" status of Scenario I is reinforced by the fact that if FGD was not fitted to the 4 coal–fired units under Scenario II, which the Stack Emissions EIA has established is conceivable with regard to maintaining the SO_2 AQO, the metal input from the coal–fired units to the effluent discharge would be reduced by about 80%.

Detailed background information against which the modelling results were assessed was obtained from marine ecological surveys and a monthly seawater and sediment monitoring exercise carried out by CLP since October 1990.

1.3 *STRUCTURE OF THE REPORT*

Section 2, 'Baseline Monitoring', discusses the background water quality and sediments analysis data, the statutory requirements for water quality and guidelines for contaminated marine sediments for the Outer Deep Bay area. The water sensitive receivers (WSRs) in the North Western New Territories (NWNT) are illustrated, and the extensive baseline water quality, sediment monitoring programmes and ecological surveys undertaken by CLP are described. The sampling procedures and analytical techniques are presented and the mean results are summarised for water quality, sediments and ecology for October 1990 to August 1991 inclusive.

Section 3, 'Cooling Water Impacts and Their Significance' addresses the potential water quality and ecological impacts from the cooling water discharged from the LTPS. The mathematical modelled results are interpreted and discussed with respect to their impacts on the baseline environment described in Section 2.

Section 4, 'Dredging activities' describes potential water quality impacts during construction works. Increases in resuspended sediment concentrations, disposal of marine mud and mobilisation of trace metals are discussed.

Section 5, Presents the conclusions and recommendations of the study.

2. *BASELINE MONITORING*

2.1 *INTRODUCTION*

As shown in Figure 2.1(a), the site for the proposed LTPS at Black Point is at a coastal location on the northwestern tip of the North West New Territories. Potential water quality impacts from the LTPS were identified as a Key Issue at the onset of the project[1,2] and confirmed during the Initial Environmental Assessment[3] Report (IAR). The IAR concluded that potentially significant construction impacts on water quality would be mainly confined to mud dredging activities whilst operational impacts would principally be associated with the elevated temperature and contaminant loading of cooling and Flue Gas Desulphurisation (FGD) process waters to be discharged from the power station.

Whilst the cooling water will be the dominant liquid effluent from the LTPS, it is the intention to mix other effluents on the premises with the cooling water. The effluent inventory and total predicted flow rates from the LTPS are given in Table 2.1(a). The resulting composition of the liquid effluent arising from the LTPS is based on the estimates shown in Table 2.1(a), and the composition of liquids discharged from other sources such as the ash pits, run–off, and flue gas desulphurisation units is presented in the IAR (see Sections V3/5.6.1, V3/5.6.2, V3/5.6.3 of the IAR).

2.2 *GENERAL OCEANOGRAPHY NEAR BLACK POINT*

Compared to many parts of the world, tidal conditions in Hong Kong are not severe. The maximum change in sea level between low tide and high tide is about 2.5m and this only occurs perhaps once a year. More often the largest change in tidal level is only around 2m on the highest or spring tides and around 1m on the smaller or neap tides. Because of Hong Kong's latitude, the shape of the tide is rather irregular. The tide is described as being 'mixed' and is made up of 2 main components where one component has a period of about 12½ hours (semi–diurnal) and the other has a period twice as long, of about 25 hours (diurnal). At some times of year, the two components combine to generate the largest tides and, within a few days of this happening, tend to cancel each other to generate some of the smallest tides (June and December). In September and March, however, the semi–diurnal component is very small and at some times only the diurnal tide occurs. Again, within a few days of this happening, the diurnal component becomes very small and basically only a 12½ hour tide is observed. At other times of the year, between these periods of 'extremes' the tide shape slightly changes each day, and a typical example of the tidal level at North Point is shown in Figure 2.2(a).

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[1] ERL (1990) 6000MW Thermal Power Station Site Search Report. ERL (Asia) Ltd September 1990 for CLP.

[2] ERL (1990) 6000MW Thermal Power Station Site Search Executive Summary ERL (Asia) Ltd September 1990 for CLP.

[3] ERL (1991) EIA of the Proposed 6000MW Thermal Power Station at Black Point, Draft Initial Assessment.

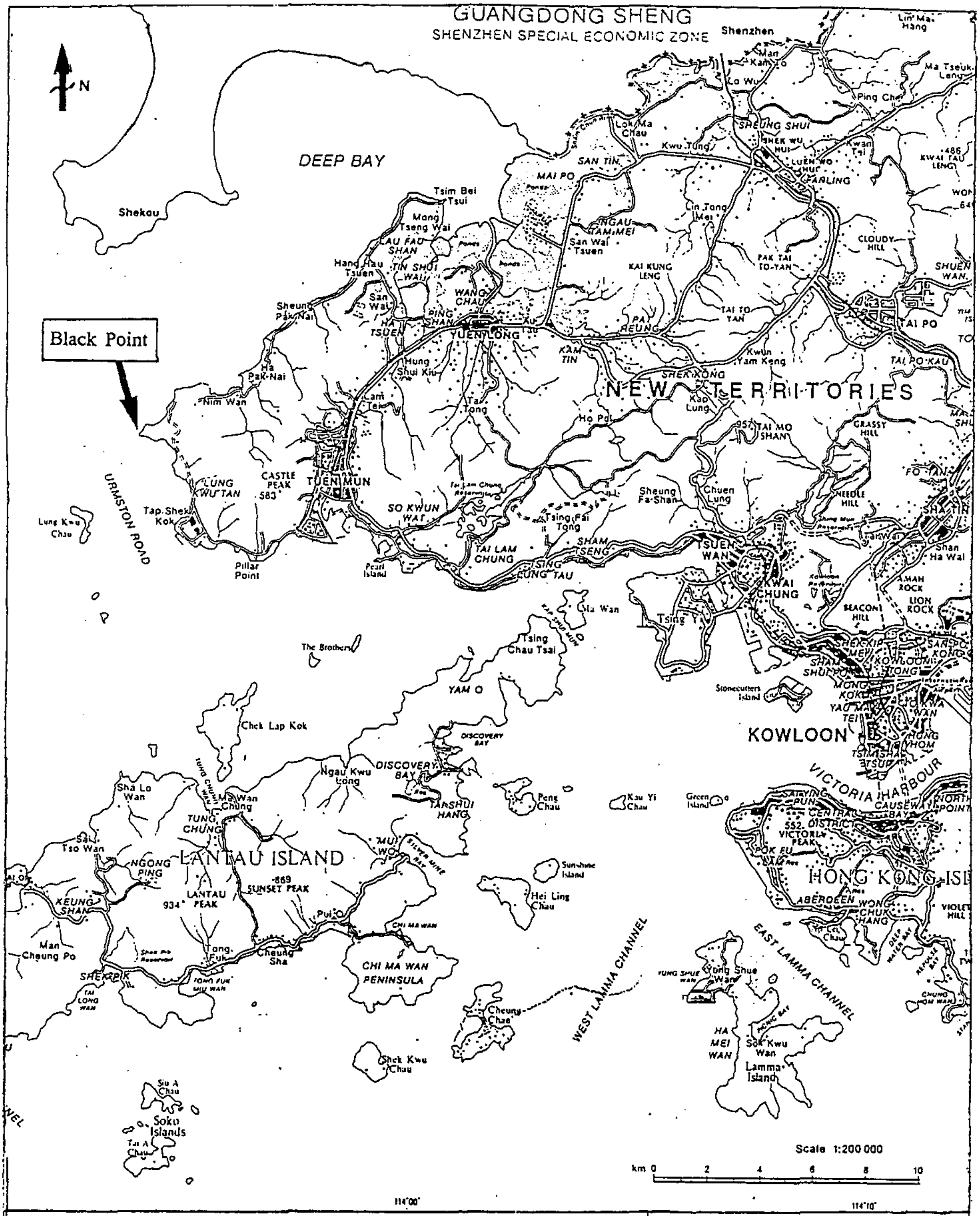

Figure 2.1(a)

The Location of Black Point within the Territory of Hong Kong

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Table 2.1 (a)
Summary of Effluent Flows/Cooling Water

Contributor	Flow Rate m^3/yr	
	Scenario I	Scenario II
Water Treatment Plant	6 x 10^5	4 x 10^5
Ash Pit	2 x 10^6	1 x 10^5
Treated Domestic Sewage	6 x 10^5	6 x 10^5
Coal Stockyard Run-off	1.2 x 10^6	6 x 10^5
FGD Plant[1]	1.4 x 10^7	7 x 10^6
Boiler Water Blowdown	3 x 10^5	3 x 10^5
Oil Separator Water	6 x 10^7	6 x 10^7
Precip/FGD Run-off	2 x 10^5	1 x 10^5
Sub Total[1]	**7.9 x 10^7**	**7.0 x 10^7**
Cooling Water	3.7 x 10^9	2.5 x 10^9
Combined Outfall (all above contributors)[1]	**3.78 x 10^9**	**2.57 x 10^9**

Note 1 – Figures are for the "worst case" limestone/gypsum FGD system.

Scenario I (All coal)

- 8 x 680 MW (normal) steam cycle units fired by coal.
- 10 x 100 MW (normal) gas turbine units fired by distillate.

Scenario II (Coal/Gas)

- 4 x 680 MW (normal) steam cycle units fired by coal.
- 4 x 600 MW sets of gas turbines with waste heat recovery boiler and steam turbine.
- 10 x 100 MW (normal) turbines fired by distillate

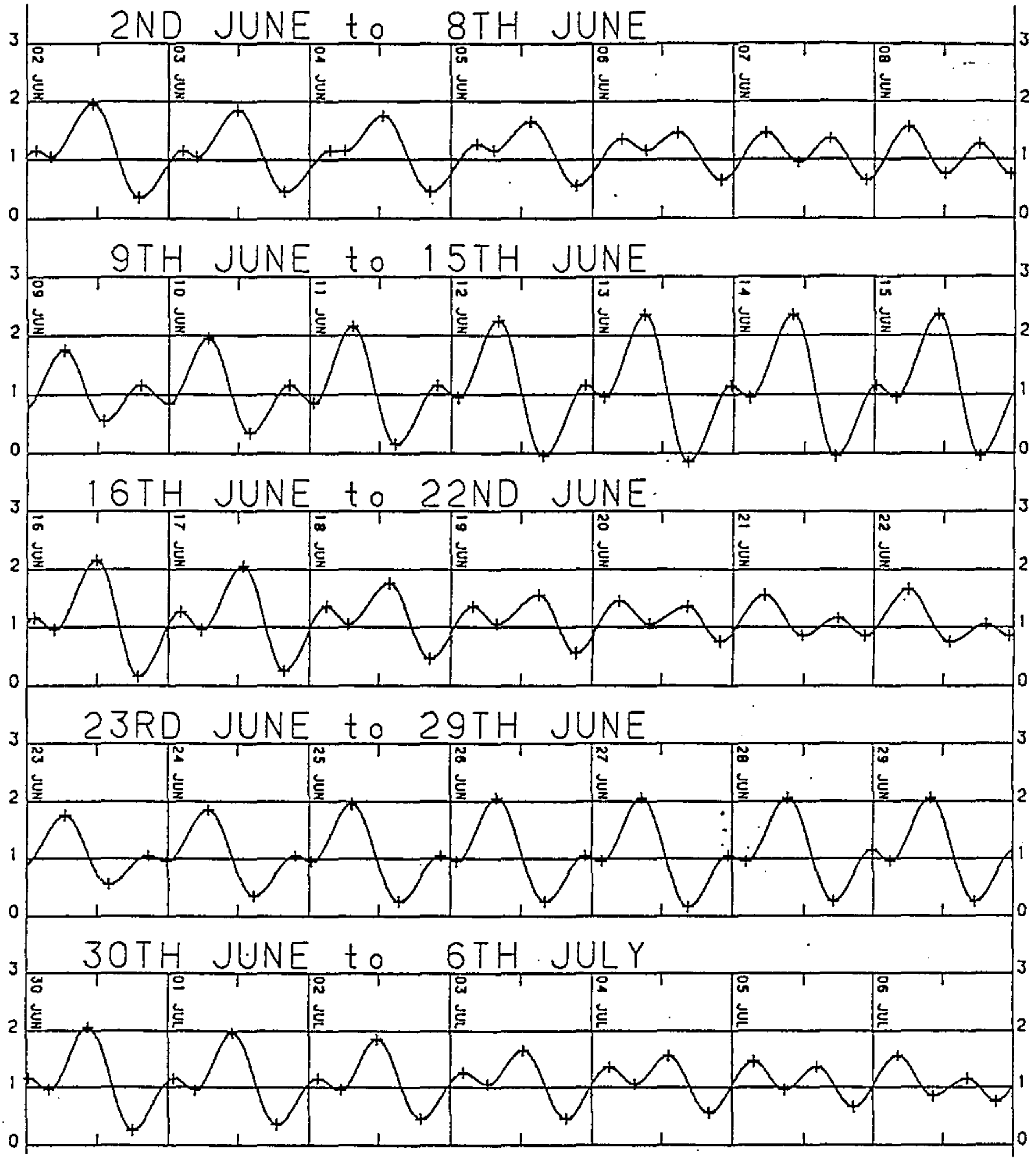

Figure 2.2(a) Typical tidal height curves for North Point

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Even though the tidal range is small much of the time, the water speeds in some parts of Hong Kong are high and huge volumes of water pass through Hong Kong on each tide. Hong Kong lies at the mouth of the Pearl River Delta and much of the water passing through Victoria Harbour and the Western Harbour supplies the tide in the upper parts of the Pearl Estuary. The Urmston Road in the North West New Territories is one of the main flow routes (Figure 2.2(b)) into and out of the Pearl Estuary and carries significant volumes of water on each tide. Typically, on the spring tides, 30,000–40,000m^3/s of water pass through the North Lantau Straits and along the coastline of the North West New Territories which is equivalent to approximately 1,000 Million cubic metres per day passing through on both the rising and falling tides. This huge volume of water will head North on the rising tide where some of it will mix with the seawater coming up the main estuary to the west of Lantau Island. On the falling tide, much of this same water will come back again discharging past North Lantau into the Western Harbour.

The rising and falling tides are not exactly equal, however, and the freshwater discharge from the Pearl River means that, on average, more water leaves the estuary on the falling tide than enters it on the rising tide. In the dry winter months the difference between the rising and falling tides is relatively small and in the wet, summer months, the difference can be quite large. The situation is made more complex because the fresh water from the Pearl River is not as dense as seawater and tends to remain near the surface sitting on top of the seawater as a partially saline layer. As might be expected, the freshwater spreads out at the surface and heads seaward at a steady rate. However, in doing this, it sets up a circulation which draws seawater landwards near the bed. For example, in the Urmston Road in winter, averaged over the tide, the water near the surface heads seawards at the rate of 370m^3/s while drawing in seawater at the rate of 120m^3/s. In the summer, because the wet season discharge from the Pearl River is large and pushes the salt water towards the sea, there is a constant net seaward discharge of around 4–5,000m^3/s in the waters just off Black Point. The main impact of these residual flows is to ensure that it is not the same body of seawater each day which oscillates back and forth past the same piece of coastline on each tide and there is a steady flushing of the coastal waters.

Water quality in Hong Kong's coastal waters may not be good despite this constant flushing. The main problem is the rate at which effluent is being discharged compared to the rate at which the tide can mix and dilute it before the residual discharges carry it away. The ability of the tidal flows to disperse effluent at any point will vary depending on the location within Hong Kong's waters. In the Urmston Road, tidal speeds are high and, between high and low water, the tide will move the water body by up to 20km. Because of the strong tidal currents and deep water, the Urmston Road has been chosen as the site for a large new sewage outfall and studies have been carried out to ensure that the effluent from this outfall will be dispersed by the currents. On the same principal, the proposed cooling water discharge from the Black Point power station is also expected to discharge into the Urmston Road. However, in order to address the worst–case eventuality, the modelling discussed in this KIA has assumed the cooling water discharging into the more shallow Deep Bay area immediately north of Black Point, and east of the Urmston Road.

2.3 *STATUTORY REQUIREMENTS FOR MARINE WATERS NEAR BLACK POINT*

The potential water quality impacts from the LTPS should be placed in the context of the background water quality and the statutory requirements for the Black Point area. Black Point is situated near the boundary between the Deep Bay and North Western Waters Water Quality Control Zones (WQCZ) (Figure 2.3(a)). The Deep Bay WQCZ was declared in November 1990 and the North Western Water Quality Objectives recently came into effect in January 1992. These WQOs are shown in Tables 2.3(a) and 2.3(b). The standards for effluent discharges in the Technical Memorandum on Effluent Standards of the Water Pollution Control Ordinance are based on a set of 12 flow rate ranges, the largest flow rate being $> 5000 \leq 6000$ m^3/day. As Table 2.1(a) indicates the effluent flow from the ultimate station development under either the all-coal or the half gas-half scenario will be several orders of magnitude larger than the greatest TM category (i.e. in the order of 10^9 rather than 10^3). The TM points out that standards for effluents outside the listed flow ranges will be set on a case by case basis, and consultation with the Water Policy Group of EPD has indicated that consideration[1] of appropriate standards for the LTPS effluents will be based on the results of the mathematical modelling of the temperature, metals and nutrients dispersion from the cooling water discharge discussed in later Sections of this report. In addition, the wider ecological implications of potential water quality impacts due to cooling water discharge from the LTPS are also assessed in this Water Quality KIA.

(The background marine water quality and sediments, in the vicinity of Black Point are described in Sections 2.7 - 2.8).

2.4 *WATER SENSITIVE RECEIVERS IN THE BLACK POINT REGION*

In addition to considering the water quality statutory requirements and sediment guideline for the Black Point region, the potential impacts from the construction and operation of the LTPS on the nearby water sensitive receivers (WSRs) must also be evaluated.

As discussed in the IAR, WSRs near Black Point fall into the following categories;

- bathing and recreational beaches in the NWNT;
- Mariculture subzone;
- sensitive ecosystems;

Specifically, these WSRs are shown in Figure 2.4(a) are as follows;

- Beaches (Yung Long, Lung Kwu Tan, Lung Kwu Sheung Tan).
- Mariculture subzone (Deep Bay Mariculture subzone).
- Terrestrial and coastal Sites of Scientific Interest (SSIs) (Pak Nai, Lung Kwu Chau Islands, Inner Deep Bay SSIs, including Mai Po Marshes).

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[1] Technical Memorandum 'Standards for effluent discharged into Drainage and Sewerage Systems, Inland and Coastal Waters', HK government, November 1990.

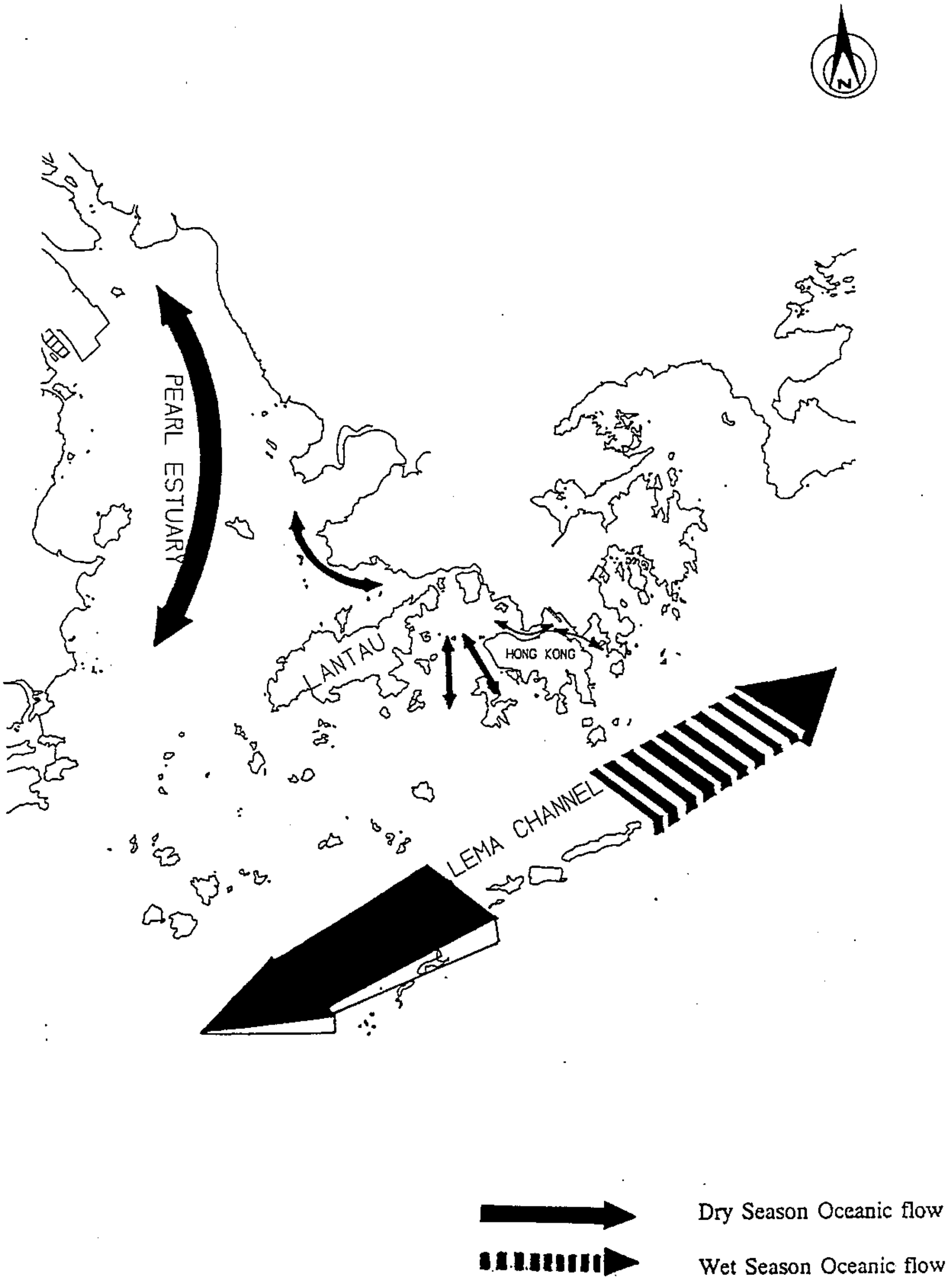

Figure 2.2(b) Typical Tidal Flow Pattern

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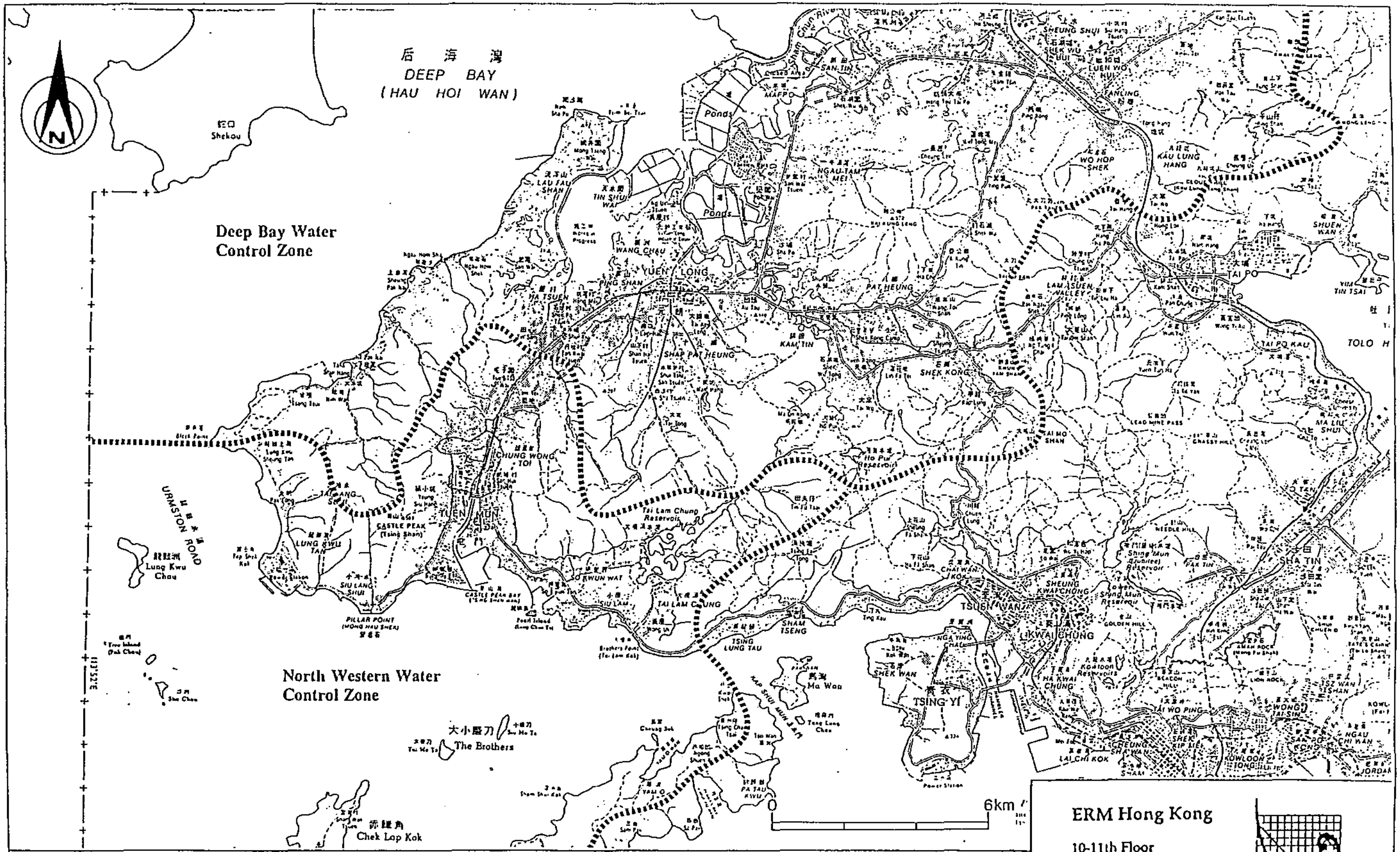

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Figure 2.3(a) Delination of Deep Bay Water Control Zone and North Western Water Control Zone

* To be declared in december 1991.

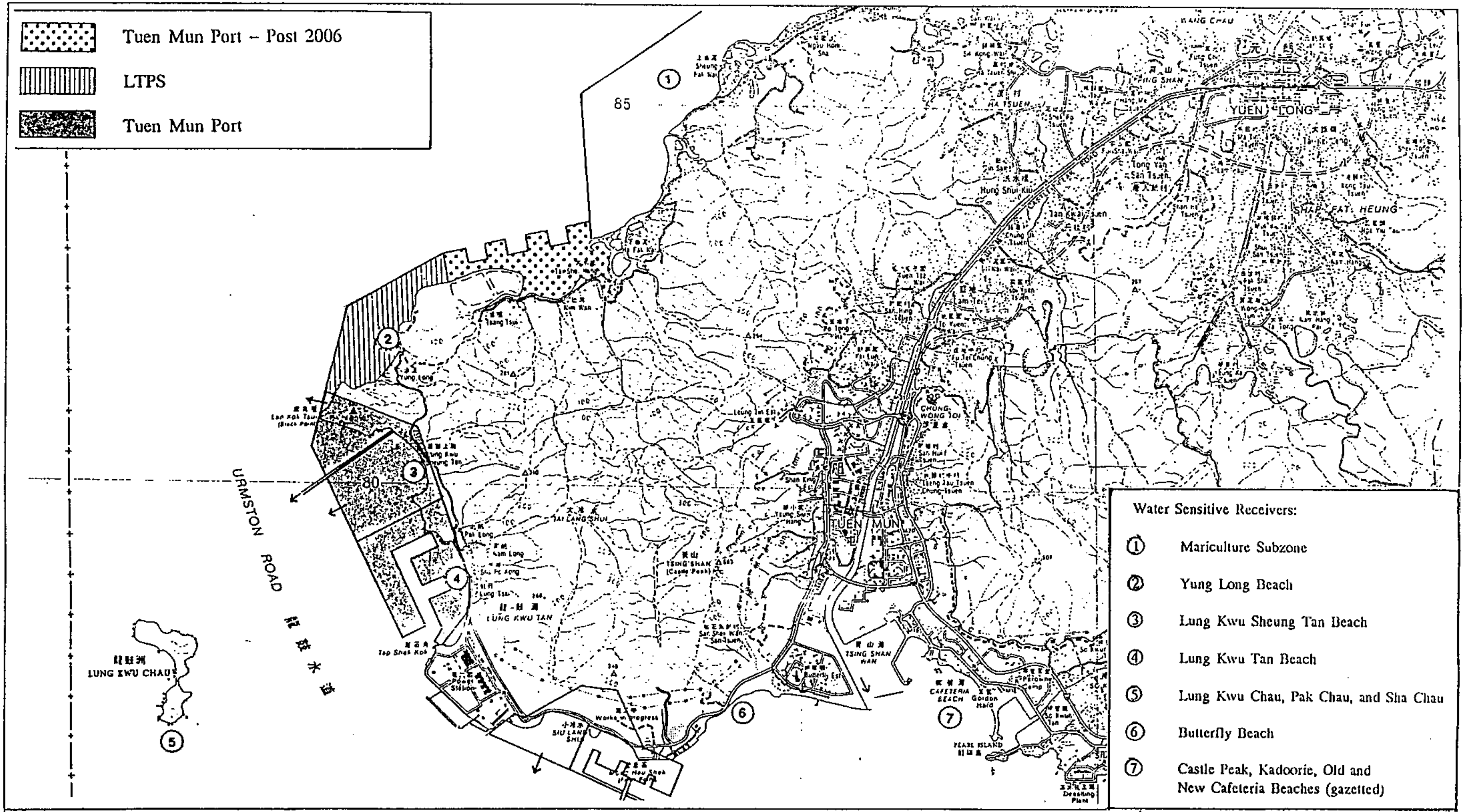

Figure 2.4 (a) Approximate Locations Water Sensitive Receivers Near Black Point

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Potential water quality impacts from the cooling water discharge and dredging activities are discussed in Section 3 with reference to these WSRs.

Table 2.3(a)
Summary of Water Quality Objectives for Deep Bay Water Control Zones

Water Quality Parameters	**Sub-zone**	**Water Quality Objective**
Offensive odour, tints and colours	whole zone	not to be present
Visible foam, oil grease, scum, litter	whole zone	not to be present
E. Coli	secondary contact recreation subzone	annual geometric mean not to exceed 610/100 ml
D.O. within 2 m of bottom	outer marine subzone except mariculture subzone	not less than 2 mg/l for 90% samples
Depth average D.O.	outer marine subzone except mariculture subzone	not less than 4 mg/l for 90% samples
D.O. at 1 m below surface	inner marine subzone except mariculture subzone	not less than 4 mg/l for 90% samples
	mariculture subzone	not less than 5 mg/l for 90% samples
pH	whole zone except bathing beaches	to be in the range 6.5 - 8.5, change due to waste discharge not to exceed 0.2
Salinity	whole zone	change due to waste discharge not to exceed 10% of natural ambient level
Temperature change	whole zone	change due to waste discharge not to exceed 2°C
Suspended solids	whole zone	waste discharge not to raise the natural ambient level by 30% nor accumulation of suspended solids
Toxicants producing significant toxic effect	whole zone	not to be present
Ammonia	whole zone	annual mean not to exceed 0.021 mg/l calculated as unionised form
Nutrients	whole zone	quantity shall not cause excessive algal growth
	inner marine subzone	annual mean depth average inorganic nitrogen not to exceed 0.7 mg/l
	outer marine subzone	annual mean depth average inorganic nitrogen not to exceed 0.5 mg.l

D.O. = Dissolved oxygen

Table 2.3(b)
Summary of Water Quality Objectives for North Western Waters Water Control Zone

Water Quality Parameters	**Sub-zone**	**Water Quality Objective**
Offensive odour, tints and colours	whole zone	not to be present
Visible foam, oil grease, scum, litter	whole zone	not to be present
E. Coli	secondary contact recreation subzone	annual geometric mean not to exceed 610/100 ml
	bathing beach subzone	annual geometric mean not to exceed 180/100 ml
D.O. within 2 m of bottom	marine waters	not less than 2 mg/l for 90% samples
Depth average D.O.	marine waters	not less than 4 mg/l for 90% samples
pH	marine waters except bathing beach subzones	to be in the range 6.5 - 8.5, change due to waste discharge not to exceed 0.2
	bathing beach subzone	to be in the range 6.0 - 9.0, change due to waste discharge not to exceed 0.5
Salinity	whole zone	change due to waste discharge not to exceed 10% of natural ambient level
Temperature change	whole zone	change due to waste discharge not to exceed 2°C
Suspended solids	marine waters	waste discharge not to raise the natural ambient level by 30% nor accumulation of suspended solids
Toxicants producing significant toxic effect	whole zone	not to be present
Ammonia	whole zone	annual mean not to exceed 0.021 mg/l calculated as unionised form
Nutrients	marine waters	quantity shall not cause excessive algal growth
	Castle Peak Bay subzone	annual mean depth average inorganic nitrogen not to exceed 0.3 mg/l
	marine waters except Castle Peak Bay Subzone	annual mean depth average inorganic nitrogen not to exceed 0.5 mg/l

D.O. = Dissolved Oxygen

Figure 2.4(a) also shows the existing and planned major effluent producers near Black Point, namely, the North West New Territories outfall, Pillar Point and the Tuen Mun Port Development.

2.5 MARINE WATER AND SEDIMENT SAMPLING PROGRAMMES

The marine waters and sediments near Black Point are routinely monitored by the Environmental Protection Department (EPD) and CLP at the sampling locations shown in Figures 2.5 (a and b). This section summarises the findings of the initial water quality and sediment results from the EPD and CLP monitoring surveys that were presented in the IAR.

In general, agreement between the EPD and CLP survey results were reasonable given the differences between the EPD and CLP sampling locations, times and techniques. Preliminary results from both data sets suggest that the marine water quality and sediments were generally good near Black Point, and were within the Deep Bay and Northwestern Water Quality Objectives, and Deep Bay Interim Threshold Values for contaminated mud. For example, Initial CLP water quality results demonstrated that in Northwestern Waters and Outer Deep Bay, mean Biological Oxygen Demand (BOD) is low, ranging from 0.5 – 1.2 mg/l, and dissolved oxygen (DO) is relatively high (eg. 7.3 – 8.7 mg/l), whereas sediment concentrations for all metals were well below the Deep Bay Interim Values. However, it is understood that the present criteria for contaminated mud[1] is currently under review by the Hong Kong Government. The assessment of marine sediment quality in this KIA will therefore take these new sediment contamination threshold values into account. Since submission of the IAR in April 1991, CLP have continued with their marine sampling programme and the updated results of this baseline survey are presented in the following sections.

2.6 SAMPLING AND ANALYTICAL PROCEDURES

2.6.1 Marine Water Quality and Sediments

A total of 42 determinants of marine water and sediments have been analysed in replicate by CLP using standard analytical procedures with reference to 'Standard Methods for the examination of Water and Wastewater[2], 1989. The methods used to generate the data set presented here are detailed in Annex A and the accuracy of the CLP results are intermittently checked by inter–laboratory comparison. Seawater and sediment samples were analysed for all parameters using standard solutions and artificial seawater matrices prepared from high purity reagents and deionised water. Sample blanks were determined and blank concentrations varied between 0 to 50% of sample concentrations for the determinands measured.

Seawater constituents are reported for seawater samples taken at different water depths (ie. surface, mid, and bottom) for the CLP near field, far field and marine buoy sampling stations shown in Figure 2.5(a). The data set presented in this KIA almost covers an annual cycle for the period October 1990 to August 1991.

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[1] Deep Bay Guidelines for Dredging, Reclamation and drainage works, September 1991, Hong Kong Government, ERL (Asia).

[2] 17 Edition published by APHA AWWA and WPCF.

The detection limits for analyses based on UV spectroscopy were defined as 0.01ppm. For metal determinations the detection limit was defined as 5 times the standard deviation of the sample blank. For most measurements, concentrations of the majority of constituents in the samples analysed were above the detection limit.

Long term precision of analytical methods were evaluated by replicate analyses of standards and results showed good agreement. Accuracy of Mn and As determinations were determined by analyses of CASS-2 standard seawater solutions.

The results of these CLP baseline water quality and marine sediment are presented later in Sections 2.7 to 2.8.

2.6.2 *Marine Ecology Studies*

Marine ecology studies[1] were commissioned for this KIA and these were divided into four main survey areas:

- sea shore;
- fish and invertebrates;
- soft-bottom animal community; and
- marine mammals.
- *Seashore Survey*

For the sea shore survey, sandy shore and rocky shore communities were surveyed, along a total of four transects, and two (winter and summer) general surveys were carried out to substantiate the detailed information provided by the transect surveys.

- *Fish and Invertebrate Survey*

Information on the numbers and diversity of fish and invertebrates near Black Point was obtained by surveys conducted by the Study Team and from information supplied by the Agriculture and Fisheries Department (AFD). For the mid-water and bottom-dwelling fish and invertebrates, trawling was carried out along transect lines, and samples collected were identified, counted, and weighed in the home (as opposed to field) laboratory. Data on Commercial Fisheries resources were supplied by AFD. Dominant species and levels of biological diversity were calculated with reference to the "Biological Index of Dominance" and "Species Diversity Indices".

- *Soft-bottom animal community survey*

Soft-bottom animal communities were collected by grab methods from 20 stations near the LTPS outfall position. These samples were sorted, weighed, and counted in the laboratory and the data analysed using multivariate statistics.

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[1] Report available from ERL (Asia)

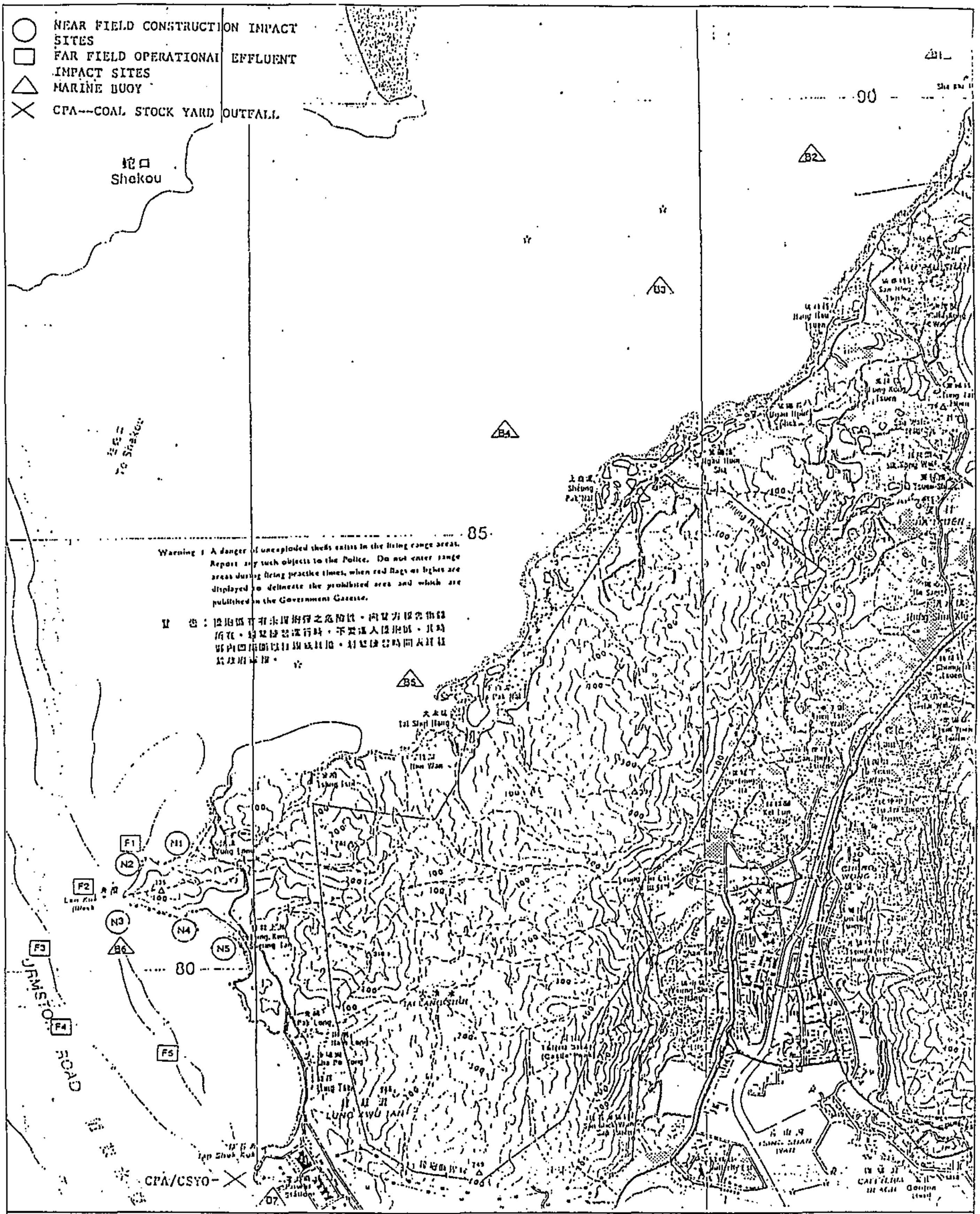

Figure 2.5 (a)

CLP Marine Water Quality and Sediment Monitoring Stations

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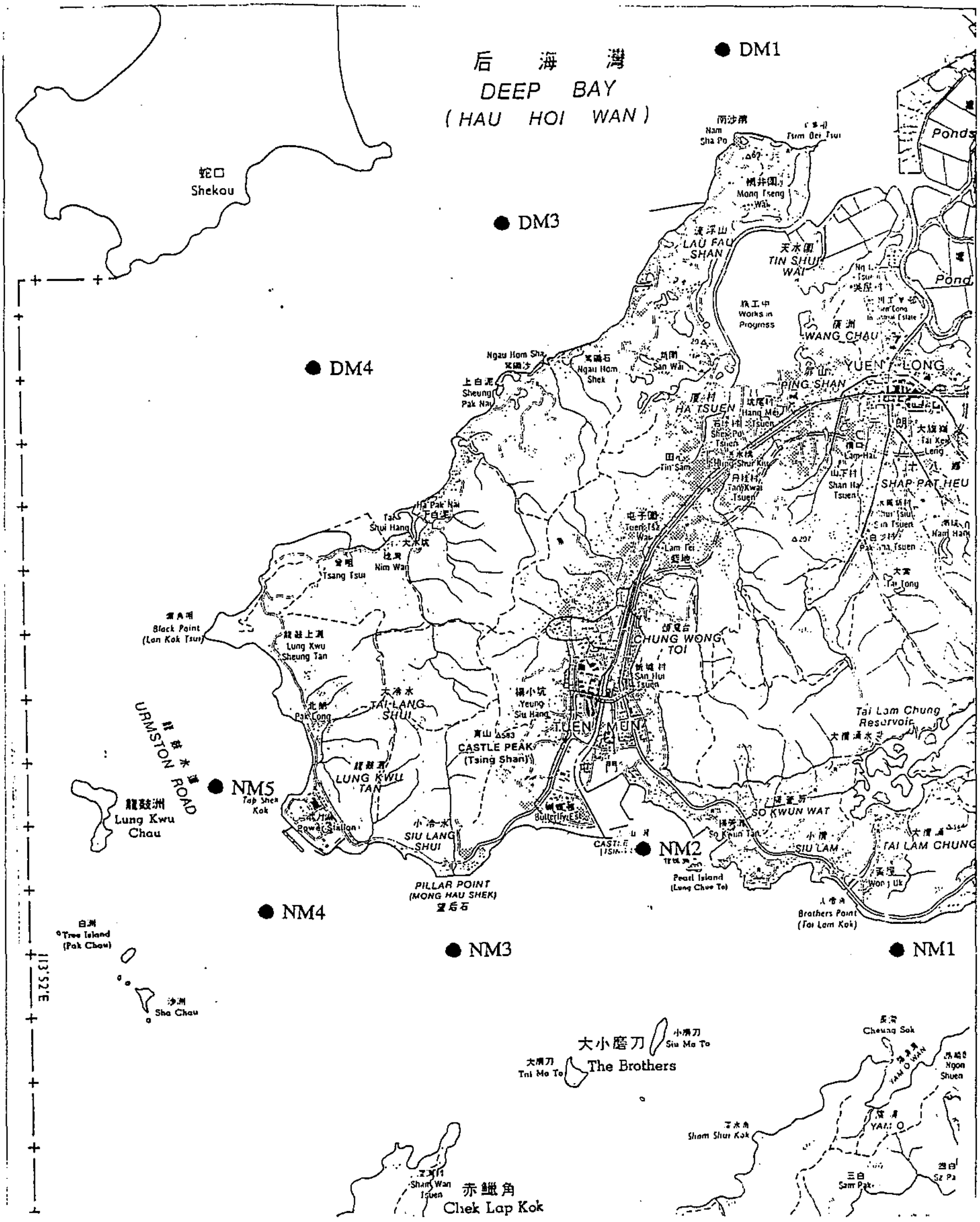

Figure 2.5 (b)

General Marine Water Quality Monitoring Station in North Western Waters (NM) and Deep Bay (DM) (Environmental Protection Department)

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- *Marine mammal survey*

Sightings of marine mammals (eg. dolphin and whales) were compiled from AFD and WWF records.

The marine ecological impacts associated with cooling water discharge from the proposed LTPS are discussed in Section 3.4.

2.7 *MARINE WATER QUALITY NEAR BLACK POINT*

The mean results of the CLP water quality survey are summarised in Table 2.7(a) and fully presented in Annex B. In this KIA, 'short-term' results refer to the data collected from October 1990 to December 1990 and 'Long-term' results refer to samples collected from October 1990 to August 1991.

At the initial assessment stage of the LTPS study, the available CLP marine water quality data covered the months from October 1990 to December 1990. Although these short-term (October-December 1990) results were necessary to assess background water quality near Black Point for the IAR, these data did not reflect the seasonal variations that occur over a longer time scale. The long-term (October 1990-August 1991) data presented in this KIA are extensive and are more representative of background water quality near Black Point than the short-term data initially reported in the IAR. The long-term CLP water quality data shown here are discussed in two respects; first, with reference to the short-term data presented in the IAR and secondly, with regard to water quality elsewhere in the Territory and by comparison to the Deep Bay Water Quality Objectives (DBWQOs and NWWQOs).

2.7.1 *Comparison of Short-Term (October 1990 - December 1990) with Long-Term (October 1990-August 1991) CLP Water Quality data sets.*

The short and long-term CLP water quality data sets presented in the IAR and in this KIA are in reasonable agreement for temperature, BOD and several metals (eg. Cd, Cu, Fe, Zn, As, Mn and Se). However, the long-term data set indicates that other seawater constituents (eg. turbidity. total suspended solids, dissolved oxygen (DO), oil and grease, lead and E. Coli) are higher than previously suggested by the short-term data reported in the IAR. In general the increase in background seawater concentration for turbidity, suspended solids, DO, in the long term data set are, relatively low (ie. 70%) compared to the short-term data. However, oil and grease, and lead concentrations are higher by an order of magnitude in the long-term data set than the short-term data set. E. Coli counts are also significantly higher in the long-term averages (ie. 321-900 mg/l) compared to the short-term averages (ie. 200-300 mg/l). Comparatively higher concentrations of BOD, E. Coli and metals in seawater near Black Point as observed over the long-term sampling period may be attributable to seasonal variations as discussed below.

The short-term data set presented in the IAR is representative of relatively dry months (October-December) whilst the long-term data set includes the wet summer months when surface and fluvial run-off rates are higher. During the wet periods, elevated suspended solid concentrations in seawater and hence higher turbidity is expected in estuarine regions, (such as Outer Deep Bay) due to higher fluvial inputs from the Pearl River. Similarly high E. Coli counts may be attributed to increased organic loading that occur via increased surface run-off and fluvial inputs during the wet summer months.

Table 2.7(a)
Analyses of Marine Water for the Black Point area for Offshore Waters Near Black Point (October 1990 - August 1991[1])

	Parameter		Monitoring Sites						
			Near-Field	Far-Field			Marine Bouys		
			S	S	M	L	S	M	L
1.	pH	(pH unit)	7.9	7.9	7.9	7.9	7.9	8.0	8.0
2.	Temperature	(C)	24.86	24.40	22.02	21.99	29.49	24.41	24.22
3.	Turbidity	(NTU)	5.35	5.92	6.84	11.80	7.71	8.01	8.54
4.	Conductivity	(ms cm-1)	40.32	39.87	42.68	42.81	40.10	42.04	43.90
5.	Salinity	(g Kg-1))	21.89	19.89	21.79	21.25	20.77	17.53	17.55
6.	Dissolved oxygen	(mg 1-1)	7.71	7.73	7.66	7.62	7.82	7.62	7.72
7.	TSS	(mg 1-1)	27.27	35.74	39.65	43.43	30.76	26.41	24.57
8.	BOD (5 day)	(mg 1-1)	1.00	0.96	0.84	0.84	1.09	1.04	0.96
9.	Eh	(mV)	-----	-----	-----	-----	-----	-----	-----
10.	Organic carbon	(mg 1-1)	-----	3.97	4.13	4.16	4.26	5.61	4.91
11.	Grain size	(%)	-----	-----	-----	-----	-----	-----	-----
12.	Grease and oil	(mg 1-1)	0.20	4.71	6.65	6.18	5.51	8.56	9.06
13.	Sulphates	(mg 1-1)	1947	1911	2057	2117	1865	214	2194
14.	Bicarbonates	(mg 1-1)	-----	8.28	8.58	8.23	8.25	8.67	8.14
15.	Phosphorus	(mg 1-1)	-----	0.06	0.07	0.08	0.11	0.06	0.07
16.	Nitrate-N	(mg 1-1)	-----	0.39	0.34	0.32	0.47	0.30	0.29
17.	Ammonia-N	(mg 1-1)	-----	0.05	0.05	0.05	0.12	0.04	0.04
18.	Organic-N	(mg 1-1)	-----	0.44	0.88	0.50	0.42	0.82	0.39
19.	Chlorophyll 'A'	(mg 1-1)	-----	3.47	2.12	2.88	3.85	2.07	2.17
20.	Chloride	(mg 1-1)	17800	13545	14472	14305	13249	13709	13309
21.	Bromide	(mg 1-1)	-----	72.1	50.2	69.1	66.6	75.0	68.5
22.	Total sulphide	(mg 1-1)	-----	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
23.	Chlorine	(mg 1-1)	-----	<0.1	-----	-----	<0.1	<0.1	<0.1
24.	Detergents	(mg 1-1)	-----	0.03	0.01	0.02	0.03	0.04	0.04
25.	Magnesium	(mg 1-1)	-----	844	-----	885	815	-----	878
26.	Calcium	(mg 1-1)	-----	317	-----	352	323	-----	367
27.	Potassium	(mg 1-1)	-----	285	-----	283	301	-----	280
28.	Sodium	(mg 1-1)	-----	7090	-----	7353	7209	-----	7577
29.	Cadmium	(ug 1-1)	-----	0.12	-----	0.06	0.09	-----	0.06
30.	Mercury	(ug 1-1)	-----	<1	-----	<1	<1	-----	<1
31.	Chromium	(ug 1-1)	-----	1.20	-----	2.01	1.19	-----	1.04
32.	Copper	(ug 1-1)	-----	<5	-----	4.5	<5	-----	<5
33.	Lead	(ug 1-1)	-----	0.91	-----	2.02	1.70	-----	1.40
34.	Nickel	(ug 1-1)	-----	<0.5	-----	1.92	<5	-----	<5
35.	Zinc	(ug 1-1)	-----	6.42	-----	6.84	6.432	-----	7
36.	Arsenic	(ug 1-1)	-----	0.52-1.1	-----	0.83	<1	-----	<1
37.	Manganese	(ug 1-1)	-----	12.90	-----	34	21.16	-----	11.2
38.	Selenium	(ug 1-1)	-----	<1	-----	<1	<1	-----	<1
39.	Iron	(ug 1-1)	-----	228	-----	1131	259	-----	531
40.	Aluminium	(ug 1-1)	-----	233	-----	949	267	-----	497
41.	Fecal coliform	CFU/100ml	-----	645	933	884	499	-----	1091
42.	E. coli	CFU/100ml	-----	415	659	478	321	-----	848

1. Results ae expressed as means for the sample period (October 1990 - August 1991) for the CLP Baseline Water Quality Monitoring Survey.

2. For CLP Baseline Monitoring Survey Sampling Sites, see Figure 2.5 (a)
BOD = Biological Oxygen Demand
TSS = Total suspended solids
S = Monthly sample taken just below surface of seawater
M = Monthly sample taken at mid-depth of seawater when depth is more than 10 metres (only for marine buoy 87)
L = Monthly sample taken just above the seabed when the depth of seawater is more than 5 metres

By contrast, other seawater constituents (eg. total nitrogen, ammonia nitrogen and phosphorus) show a decrease in the long-term data set compared to the short-term averages. This is surprising since nitrogen (N) and phosphorus (P) have significant land sources and thus, during the wet season N and P concentrations in seawater near the mouth of the Pearl River estuary (ie. Black Point) is also expected to be higher during the wet season. (ie. fluvial inputs of N and P might be expected to be higher during the wet season when surface run-off is highest.) However, biological uptake of N and P by marine phytoplankton may possibly reduce N and P concentrations in surface seawater near Black Point, thus accounting for the comparatively low N (eg. ammonia-N: 0.04-0.12 mg/l) and P (eg. 0.06-0.11 mg/l) seawater concentrations (Table 2.7(a)).

In general, the long and short-term water quality data sets from the CLP baseline monitoring programme are in reasonable agreement for most seawater constituents except for oil and grease, E. Coli and lead concentrations; all of which are much higher in the long-term than the short-term results.

2.7.2 *Comparison of water quality near Black Point with Territorial waters and the Deep Bay and Northwestern Water Quality Objectives (DBWQOs and NWWQOs)*

Both EPD and CLP water quality surveys suggest that marine waters near Black Point are reasonably unpolluted compared to marine waters elsewhere in the Territory, notably in regions such as inner Deep Bay and Tolo Harbour[1]. The results of the long-term CLP marine water quality survey are discussed below with respect to marine waters elsewhere in the Territory, the DBWQOs and NWWQOs.

In marine waters near Black Point, pH measurements (eg. pH ≈ 7.9) are generally low, whereas turbidity (eg. 5-12 NTU) and suspended solid concentrations (eg. 27-43 mg/l) are relatively high, presumably due to Pearl River run-off. Organic pollution in outer Deep Bay is generally not severe, as indicated by low BOD (eg. 0.8-1.1 mg/l) in seawater sampled from this region. However, results from the CLP baseline monitoring data suggests that nutrient (N and P) concentrations in seawater can be moderately high near Black Point. For example, mean concentrations of inorganic nitrogen (eg. ammonia and nitrate) are in the range of 0.3-0.6 mg/l for total inorganic N (ammonia-N and nitrate-N) and 0.06-0.11 mg/l for P.

According to the DBWQOs and NWWQOs, ammonia levels should be less than 0.021 mg/l in the Deep Bay Water Control Zone (DBWCZ) and Northwestern Water Control Zone (NWWCZ). Mean CLP seawater measurements for ammonia range from 0.04-0.12 mg/l. Thus, ammonia concentrations in seawater near Black Point are in exceedence of these WQOs (see Section 3.2).

E. Coli levels should be less than 610 counts per 100 cm^3 in all parts of the DBWCZ except for Yuen Long, Kam Tin subzone and other inland waters, where E. Coli limits are <1000/100cm^3 and 321-900 counts per 100cm^3 respectively. The mean E. Coli (603 counts/100cm^3) from the CLP long-term data for marine waters near Black Point are higher than the permitted levels (eg. 180 counts/100m^3) for the Yung Long Bathing Beach Subzone but close to the E. Coli limit (eg. 610 counts/100cm^3) for the Mariculture Subzone.

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[1] Marine Water Quality in Hong Kong, Environmental Protection Department 1990.

2.8 *MARINE SEDIMENT QUALITY*

The results of the CLP marine sediment survey are reported in Annex B and mean sediment concentrations are given in Table 2.8 (a). In Hong Kong, the level of contamination of marine sediments in Deep Bay are presently classified according to their metal concentrations[1], although the introduction of new criteria is under consideration by government (see later). As metal concentrations in sediments are generally a reliable indication of the level of contamination in marine mud, metal concentrations from the baseline monitoring survey are discussed below.

2.8.1 *Comparison of Short-Term (October-November 1990) and Long-Term (October 1990-August 1991) marine sediment results with Deep Bay Guidelines*

For most metals (eg. cadmium, chromium, copper, lead, nickel and manganese,) metal concentrations in sediments are generally slightly higher in the long-term (October 1990-August 1991) data set than the short-term (October-November 1990) results. However, zinc (Zn) and arsenic (As) sediment concentrations are almost twice as high in the long-term results compared to the short-term mean (Zn and As) concentrations. The exception is mercury (Hg), for which concentrations are close to detection limits and therefore any differences between the short and long-term data sets may not be measurable.

By comparison to the Deep Bay Interim Guidelines for marine sediments, all metal concentrations in sediments sampled near Deep Bay are well within the Interim Threshold limits. However, more stringent criteria for metals in sediments are being considered by Government as mentioned earlier. Comparison of these 'new' criteria with mean metal concentration in sediments sampled near Black Point show that all metals are within these 'new' sediment criteria (if adopted) (see Table 2.8(a)).

In addition to the sediment baseline monitoring results, sediment samples were also collected in the access channel and basin. These sediment samples were analysed for metals and the results obtained differ from the short and long-term data discussed above. Such differences are unsurprising given the different sampling locations and sampling periods of the sediment samples. Analyses of sediments collected from the access channel and basin are presented in Section 5.

2.9 *SUMMARY*

In general, the CLP water quality monitoring results suggest that the marine waters near Black Point are relatively unpolluted, and confirm the preliminary monitoring data presented in IAR. For seawater, BOD (eg. 0.8-1.0 mg/l), DO (eg. 7.6-7.8 mg/l) and metal concentrations are well within the DBWQOs, the Deep Bay Guidelines, and the NWWWQOs. However, ammonia concentrations exceed the DBWQO and mean E. Coli counts exceed the permitted level for the Yung Long bathing beach subzone. This beach will however be lost when the proposed LTPS development proceeds and hence the statutory E. Coli limits will not apply here. At the Mariculture Subzone, mean E. Coli counts are close to, but within the DBWQOS.

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[1] Deep Bay Guidelines for Dredging, Reclamation and Drainage Works, 1991, ERL (Asia).

Mean metal concentrations in sediments sampled around the Outer Deep Bay region suggest that background levels of all metals are within both the Deep Bay Interim Guidelines and the 'new' sediment criteria.

Table 2.8 (a)
Marine Sediment Analyses for the Black Point area (October 1990 - August 1991)

Parameter			Monitoring Sites[1]			
			Far Field	**Marine Buoy**	**Deep Bay Interim[2] Guidelines**	**Action Levels[3]**
1.	Eh	(mV)	-136	-184	-----	-----
2.	Organic carbon	(mg 1-1)	0.76	1.02	-----	-----
3.	Sulphate	(mg 1-1)	3332	4489	-----	-----
4.	Phosphorus	(mg 1-1)	190	213	-----	-----
5.	Organic-N	(mg 1-1)	1985	2247	-----	-----
6.	Total Sulphide	(mg 1-1)	44	339	-----	-----
7.	Cadmium	(mg/kg)	0.07	0.13	15	1.5
8.	Mercury	(mg/kg)	0.21	0.21	5	1.0
9.	Chromium	(mg/kg)	10.16	12.07	500	80
10.	Copper	(mg/kg)	37.5	51.8	500	65
11.	Lead	(mg/kg)	27.01	33.27	2000	75
12.	Nickel	(mg/kg)	14.75	13.92	500	40
13.	Zinc	(mg/kg)	45.08	61.77	500	200
14.	Arsenic	(mg/kg)	0.80	0.75	-----	-----
15.	Manganese	(mg/kg)	463	465	-----	-----
16.	Selenium	(mg/kg)	<0.1	<0.1	-----	-----
17.	Iron	(mg/kg)	1.87	1.26	-----	-----
18.	Aluminium	(mg/kg)	0.44	0.39	-----	-----
19.	Fecal coliform	CFU/100ml	6086	3216	-----	-----
	E. Coli	CFU/100ml	4080	2475	-----	-----

1. For CLP Baseline Monitoring Survey Sites see Figure 2.5 (a)

2. Deep Bay Interim Threshold Guidelines for contaminated mud.

3. Action levels of contaminated mud, Contaminated Spoil Management Study, Draft Final Report, Mott McDonald Hong Kong Ltd, June 1991

3. *COOLING WATER IMPACTS AND THEIR SIGNIFICANCE*

As discussed in the Introduction (Section 2.1), water effluents discharged from the LTPS originate from several sources:

- Water Treatment Plant;
- Ash Pit;
- Sewerage;
- Flue Gas Desulphurisation (FGD) Plant and FGD run-off;
- Boiler blow down;
- Oil Separator water;
- Cooling Water.

CLP proposes to combine effluent streams whenever possible, which will subsequently be discharged via a submarine outfall. The combined effluent will hereafter be referred to as 'Cooling Water' discharge.

This section addresses the potential impacts of the cooling water from the LTPS on temperature, nutrient and trace metal concentrations on the marine ecology of the surrounding waters.

3.1 *TEMPERATURE EFFECTS*

3.1.1. *Introduction*

Vertical temperature profiles indicate that temperature stratification in the Hong Kong waters is spacially and seasonally dependent[1] and can fluctuate by as much as 15°C annually. This variation in sea surface water temperature in Hong Kong waters is a reflection of the combined effects of the ambient[2] air temperature, surface run-off, intrusion of ocean currents, and marine topographical and hydrographical features.

In coastal waters during the winter months, turbulent mixing within the water column can result in a relatively homogenous vertical temperature profile. In the summer months, the temperature profile in Deep Bay is comparatively shallow with temperature fluctuations of <2-4°C in the upper 0-5m of the water column. However, in Northwestern Waters, EPD's vertical temperature profiles indicate that there is an absence of a well defined thermocline near Pillar Point and that the water column temperature is relatively homogenous with depth during the summer.

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[1] Marine Water Quality in Hong Kong Environmental Protection Department 1990.

[2] Ambient is defined as existing background temperature.

On a regional basis, the maximum surface and bottom water temperatures to the west of Hong Kong (near Black Point) are generally 1–2°C higher than the eastern Territorial waters. This spacial temperature variation in marine waters is thought to be partially attributable to the large volumes of relatively warm river water discharging to waters to the west of the Territory from the Pearl, Shenzhen and Yuen Long Rivers.

Thus, any potential thermal impacts due to the discharge of cooling water from the proposed LTPS should be interpreted in context with considerable temperature variations in the coastal waters near Black Point.

3.1.2 *Hydrothermal Modelling*

The dispersion of the hydrothermal plume from the cooling water discharge of the proposed LTPS was simulated using a 300 metre grid, 2–layer, hydrothermal model. The model parameters were based on a 'worst case' fuel design scenario assuming that 8 coal combustion generating units would be used in the proposed LTPS. Other model parameters for the LTPS are as follows;

Water flow	:	192 m^3/Sec
Temperature at outfall	:	+12°C above ambient[1]
Intake location	:	South of Black Point
Outfall location	:	Entrance of Deep Bay (50% at seawall, 50% offshore) 8m depth.

It should be noted that the figure of 192 m^3/sec used in the modelling of the hydrothermal plume dispersion equates to an annual discharge volume of about 4.31×10^9 m^3, (assuming 50,000 operating hours per year allocated between 8 units) whereas the concentrations of metals in the outfall effluent are based on an annual discharge of 3.78×10^9 m^3 (see Table 2.1(a)).

The reason for this difference is that both figures reflect the "worst–case" for their respective analyses. The conservative discharge volume figure used in the hydrothermal modelling gives a conservative figure for the temperature loading from the LTPS effluent, as the whole volume is assumed to be at 12°C above its intake temperature; whereas the discharge volume assumed in the calculation of the metal concentrations within the effluent gives conservative estimates of these metal levels, as the overall "dilution" of the metal components of the outfall effluent is less.

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[1] Ambient is defined as existing background temperature.

The outfall location chosen for the study is not necessarily that which will be used for the station development but represents the worst case scenario. The hydrothermal model presented here accounts for the cumulative effects of thermal discharge from both the existing Castle Peak Power Station (CPPS) at Tap Shek Kok and the proposed LTPS at Black Point. As stipulated by EPD, temperature assessment was evaluated against the natural background temperature in the absence of anthropogenic thermal inputs from both the CPPS and the LTPS.

The orientation and location of the outfall is shown in Figure 3.1(a).

3.1.3 Data Presentation of the Hydrothermal Plume Dispersion Model

The hydrothermal data generated by the hydrothermal plume dispersion model is graphically presented as;

- time history temperature plots for the surface and bed layers;
- contour surface and bed layer temperature plots;

Both time history and contour temperature plots were modelled for 15 Stations (Figure 3.1(b)) and for different stages of four tidal flows as follows;

Model Runs	*Tide*
3F	Dry Neap
4F	Dry Spring
6F	Wet Spring
7F	Wet Neap

The results of the hydrothermal plume dispersion model are discussed below, although it should be borne in mind that these thermal impacts refer to an instantaneous worst case scenario, whilst over the great majority of the tidal period, temperature levels would be lower.

3.1.4 Time History Temperature Plots.

The key time history temperature plots from the hydrothermal plume dispersion are shown in Figure 3.1(c) and the remaining plots are presented in Annex D. In general, the differences in temperature between the surface and bed layers are relatively minor compared to the daily variations for all tides. The largest maximum temperature variations occur during the dry season with temperature differences of about 1.1°C and 1.6°C predicted for Stations 1B and 13 (Figure 3.1 (c), dry season, spring tide) near Sheung Pak Nai and in Outer Deep Bay respectively. These model results imply that the thermal effect of the cooling water discharge is most pronounced during the dry season (spring tide) when the surface run–off is at its lowest.

3.1.5 *Contour Temperature Plots*

Selected runs from the contour temperature plots of the hydrothermal model are shown in Figures 3.1(d)–(i) (for the complete set of results see Annex D). As with the 2–D time history temperature plots, the difference in surface and bed layer temperatures are relatively small. Where there is a difference, the surface temperatures are higher in the upper than the lower layers of the water column by less than about 1°C.

Again, the greatest lateral dispersion of the hydrothermal plume is predicted for the dry season both in the upper and lower layers. The selected hydrothermal runs shown in Figures 3.1 (d)–(i) represent the 'worst case' temperature impacts (i.e. greatest spatial dispersion of the plume) for all seasonal and tidal conditions.

For the surface layer, these model runs are;

Dry Season, ***Spring*** tide, HHW (high water)
Dry Season, ***Neap*** tide, HLW (low water)
Dry Season, ***Spring*** tide, HHW (high water)

For the bed layer, the 'worst case' model predictions occur for;

Dry Season, ***Neap*** tide, LHW (high water)
Dry Season, ***Neap*** tide, LLW (low water)
Dry Season, ***Neap*** tide, HHW (high water)

The water quality impacts resulting from the spatial dispersion of the thermal plume from the LTPS is important with respect to nearby water sensitive receivers (eg. Mariculture Subzone in Deep Bay, Lung Kwu Tan, Lung Kwu Sheung Tan beaches, Lung Kwu Chau) and the Deep Bay water quality objectives, and will subsequently determine the appropriate licensing conditions for the operation of the LTPS. Consultations with EPD during the course of this KIA have established that licensing conditions will be based on a 2°C temperature–increase envelope around the LTPS. Further discussions with EPD indicate that licence conditions are likely to be subject to on–going water quality monitoring and compliance of a 2°C temperature increase (above the ambient water temperature) outside a 'temperature envelope'. It will therefore be necessary to specify a temperature envelope' beyond which a 2°C temperature rise will not be permitted. The boundary of this 2°C temperature envelope is hereafter referred to as 'permitted 2°C temperature envelope'. As noted previously, the envelope is to be based on the combined effects of the cooling water discharged from the Castle Peak Power station and the proposed LTPS at a 12°C discharge temperature above the natural background.

Surface and bed layer envelopes have been derived by superimposing 'worst case' temperature contour plots (i.e. which exhibit the greatest spatial dispersion of the thermal plume) (Figures 3.1 (d)–(i)), and then creating an envelope at the interface between 2°C and > 2°C temperature contour line. The resulting upper and lower layer '2°C envelopes' are shown in Figure 3.1 (j)–(k). The results presented here assume a discharge temperature of 10°C above background from the CPPS. If however, the effluent from CPPS was discharged at 12°C, this would increase the 'permitted 2°C temperature exceedence envelope' by about 250–300 m from the temperature envelopes shown in Figure 3.1(j)(k).

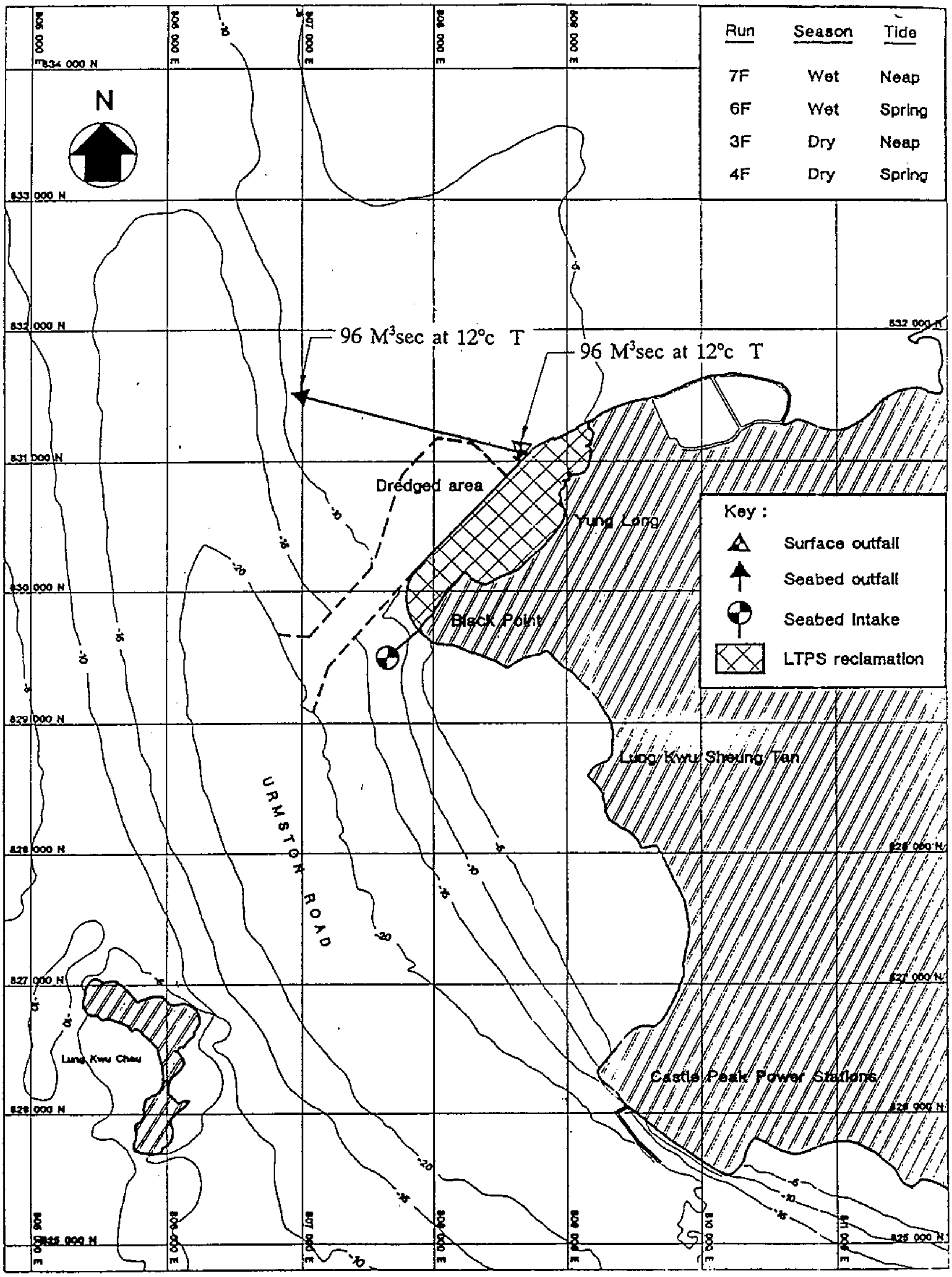

Figure 3.1 (a)

Cooling Water Outfall Location for the LTPS in the Far Field 8 Coal Units Model Simulation

ERM Hong Kong

10-11th Floor
Hecny Tower
9 Chatham Road
Tsimshatsui, Kowloon
Hong Kong

ERM

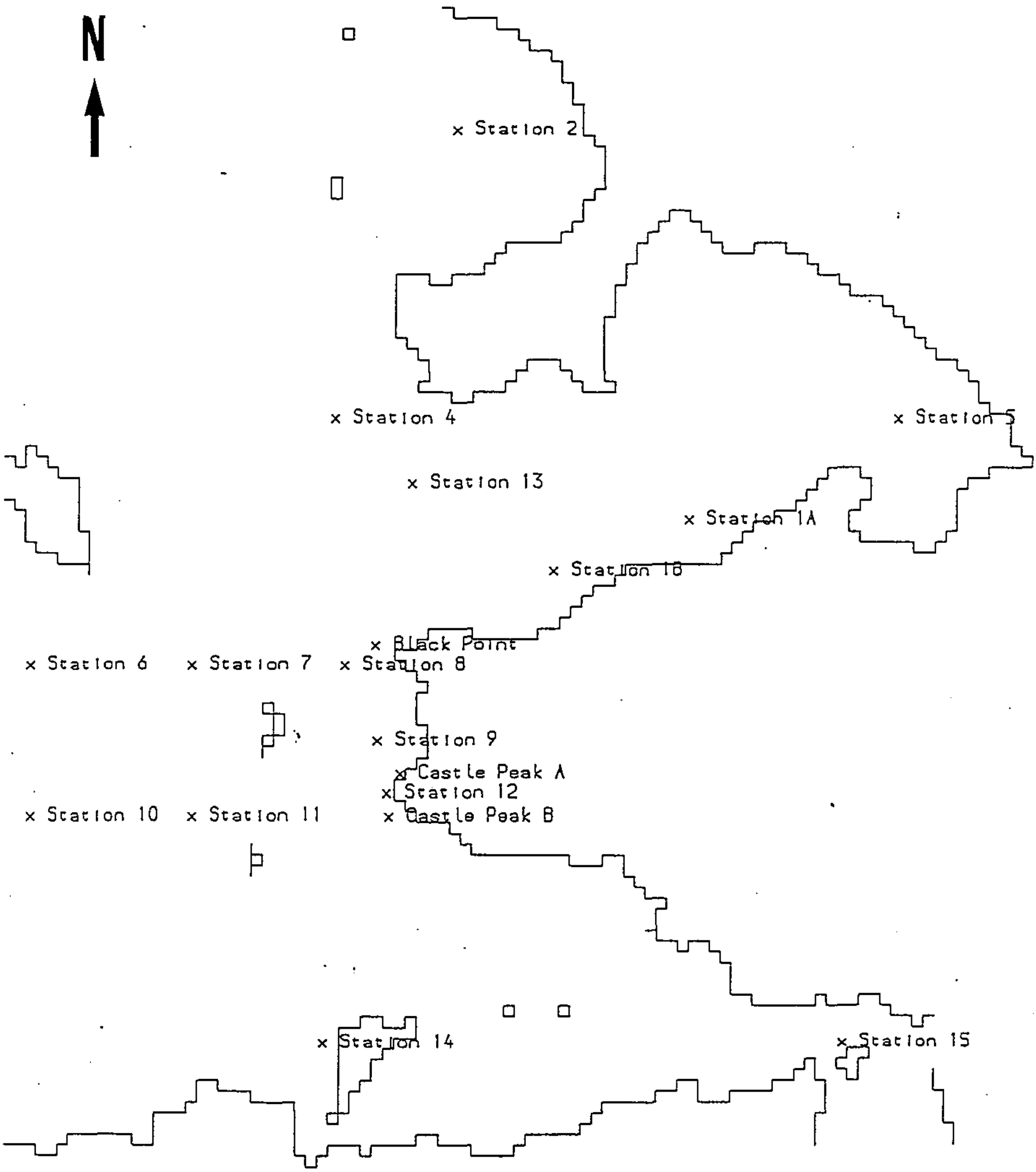

Figure 3.1 (b)

LTPS Black Point Far Field Thermal Modelling Station Locations

ERM Hong Kong

10-11th Floor
Hecny Tower
9 Chatham Road
Tsimshatsui, Kowloon
Hong Kong

ERM

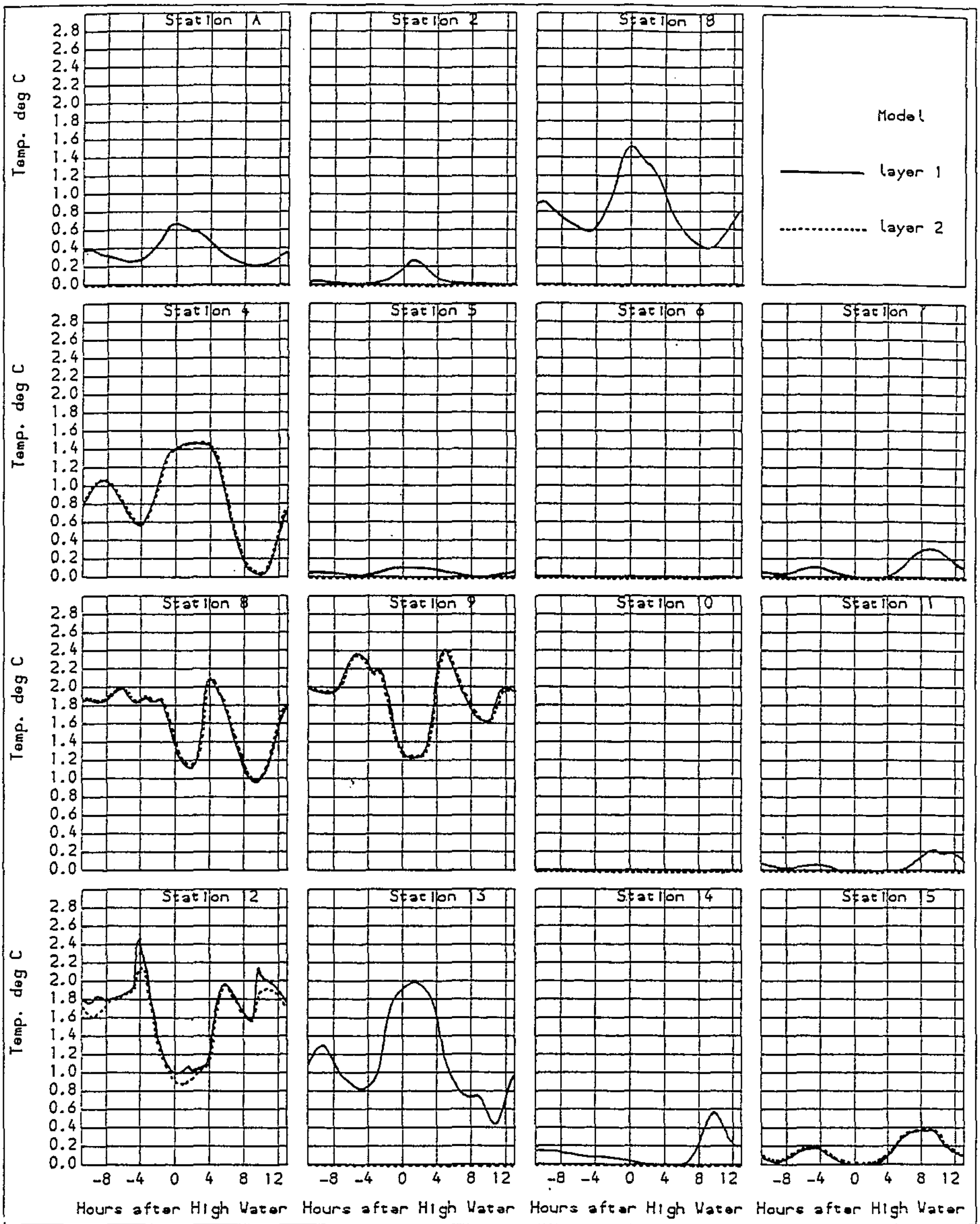

Figure 3.1 (c)
LTPS Black Point Far Field Thermal Modelling
Temperature including Castle Peak
Black Point 12 degree discharge
Run 4F : 8 Coal Dry Season Spring Tide

ERM Hong Kong

10-11th Floor
Hecny Tower
9 Chatham Road
Tsimshatsui, Kowloon
Hong Kong

An interesting feature demonstrated by the contour plots is the limited extent of lateral dispersion and confinement of the thermal plume (for temperature > 2°C contour line) to within a maximum distance of about 8km in any direction from the LTPS point source. (Figures 3.1 (j) (k)). In a North–North Easterly direction from Black Point, a temperature of greater than 2°C in the surface layer can be expected up to 5.2km from Black Point (Figure 3.1 (j). In a South–South Easterly direction, a greater than 2°C temperature rise is anticipated up to a distance of 8.2 km from the site of the proposed LTPS (Figure 3.1 (k). The predicted distance travelled by the plume in a South-Westerly Direction towards Lung Kwu Chau is about 2.5 km (Figure 3.1(j)).

Consequently, the extent of a 'permitted 2°C temperature exceedence envelope' appear to be relatively confined near to the LTPS in Outer Deep Bay and Northwestern waters. Potential thermal impacts on WSRs are discussed below.

3.1.6 *Thermal impacts on water sensitive receivers*

As discussed in the Section 2.5, water sensitive receivers (WRSs) near Black Point are:

- Beaches (Yung Long, Lung Kwu Tan, Lung Kwu Sheung Tan).
- Mariculture subzone (Deep Bay Mariculture subzone).
- Terrestrial and coastal Sites of Scientific Interest (SSSIs) (Pak Nai, Lung Kwu Chau Islands, Inner Deep Bay SSIs, including Mai Po Marshes.

Thermal impacts from the LTPS cooling water on WSRs can be estimated by considering the extent of the permitted '2°C exceedence temperature envelope'. It is interesting to note that the '2°C temperature envelope' has a north-south centre line with limited North-Easterly drift into Outer Deep Bay westerly dispersion. This suggests that the only WSRs likely to experience a 2°C temperature rise above the background would be ungazetted beaches at Yung Long, Lung Kwu Sheung Tan and Lung Kwu Tan. Gazetted beaches near Tuen Mun are unlikely to be affected by thermal impacts from the LTPS. However, Yung Long beach will be lost as a result of the proposed LTPS and the other two beaches will probably be lost if the Tuen Mun Port Development proceeds according to the Port and Airport Development Strategy.

Notably, none of the Sites of Special Scientific Interest (SSSIs) at Lung Kwu Chau or in inner Deep Bay, or the oyster beds are expected to experience a >2°C surface temperature rise. This implies that the potential marine ecological impacts caused by temperature rise at SSSIs near Black Point will not be significant (see Section 3.4).

3.1.7 *Potential Effects on the North West New Territories Sewage Outfall*

3.1.7.1 *Density Effects*

The cooling water discharge from the LTPS will increase the natural temperature gradients between the water surface and the sea bed near the outfall. As a result, the increased temperature in the surface layer will decrease the water density and the naturally occurring density stratification will be enhanced. However, the increases in the degree of stratification will probably not be significant but a small impact is possible which will re-enforce the naturally occurring stratification. As this was a design factor in the North West New Territories (NWNT) Sewage Outfall, enhanced stratification due to the cooling water discharge is considered to be advantageous (see below).

With respect to water quality impacts of cooling water on effluent discharge from the NWNT outfall, two phenomena are important. First, the vertical density gradients will encourage the trapping of effluent in the lower part of the water column. Second, the vertical density gradients in the receiving waters inhibit turbulent mixing. This means that effluent trapped in the lower layers of the water column initially will only mix slowly vertically through the receiving waters. The impact of the cooling water discharges would be beneficial to the sewage dispersal, since it will add to, rather than destroy, the present density structure in the receiving waters. Thus, the dispersion of effluent from the NWNT outfall to the surface waters, which is environmentally undesirable, will be limited by the cooling water discharge.

3.1.7.2 *Temperature Effects*

A potential issue is the warming effect of the cooling water on the decay rate of E. Coli in the sewage from the NWNT outfall. The Environmental Assessment of the NWNT sewage outfall estimated daytime E. Coli mortality rates of 4 – 6 hours (as induced by variations in temperature, salinity and turbidity of seawater). With the addition of the LTPS cooling water, bacterial mortality rates are expected to be in the order of about 4 hours during the day depending on the turbidity and light penetration, (i.e. the 4 hour E. Coli mortality rate for the LTPS cooling water is within the estimated 4 – 6 hour E. Coli decay rate for the NWNT outfall). Hence the temperature effect from the LTPS cooling water on bacteriological decay from the NWNT outfall is expected to be insignificant.

3.2 *NUTRIENTS DISPERSION*

3.2.1 *Introduction*

The degree of nutrient enrichment, if any, which may be encountered upon discharge of the cooling water of the LTPS to the receiving water body requires assessment. Levels of nutrients in the waters of Hong Kong have been causing concern for many years. The overloading of the coastal waters particularly with domestic sewage effluents rich in nutrients has been reflected by a number of incidents of algal, including toxic dinoflagellate blooms.

3.2.2 *Background Levels of Nutrients*

As detailed in Section 2.5, a site specific extensive data gathering programme is continuously being carried out by CLP as part of the EIA monitoring of the LTPS. Annex B contains average values for several parameters of marine water quality off the LTPS site at Black Point. The results of the monitoring programme have previously been presented in Section 2.7 but are discussed in further detail below.

The average values of ammonia found by CLP exceed the 0.021 mg/l of ammonia stipulated in the DBWQOs at all monitoring sites (see Annex B). Site B1, a marine buoy located furthest into Deep Bay, was characterised by an average ammonia value as high as 0.35 mg/l. Similarly the nitrate and organic nitrogen levels are particularly high at this location. The DBWQO set for total inorganic nitrogen (depth and annually averaged) is 0.1, 0.3 or 0.5 mg/l depending upon the location. The value of 0.3 mg/l is given for enclosed or semi–enclosed waters in the NWWCZ and this value is far exceeded especially at this, but also at the other monitoring sites.

Phosphate levels are moderate and are not a matter of concern.

Depending upon the specific use, dissolved oxygen standards as outlined in the DBWQO vary from greater than 2 mg/l for industrial use to greater than 5 mg/l for commercial fisheries. In contrast to the nutrient content, the dissolved oxygen levels at all the CLP monitoring sites are comfortably above this DBWQO. Also BOD values are low, averaging at 1 mg/l.

The elevated levels of both ammoniacal nitrogen and nitrates are not reflected by a concomitant increase in chlorophyll *a* values which can be taken to represent the phytoplankton biomass. The average chlorophyll *a* values around Black Point vary, but show relatively moderate values of approximately 1-5 mg/l, since the actual monthly values will depend to a great extent on the time of the year. Chlorophyll *a* peaks occur during the summer months and are more pronounced in the surface waters (i.e. photic zone) and decrease in their intensity with increasing depth. The water quality data that has been collected by CLP (and which correlates well with EPD data for the years 1987-1990) also show that as Deep Bay is approached, the annual chlorophyll *a* values and the frequency summer "algal blooms" increase.

3.2.3 *Discharge of Nutrients from the LTPS*

3.2.3.1 *General*

The effluent from the water treatment plant will contain some nitrogen in the form of ammonium (NH_4^+). It is estimated that the effluent will contain approximately 4000 mg/l of total dissolved solids, most of which will consist of Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-} and CO_3^{2-} in addition to ammonium. The total quantity of the effluent will be about 6 x $10^5 m^3$/yr for LTPS Scenario 1. Following dilution by the other effluent streams it is estimated that the NH_4^+ concentration at the outlet will be 0.15 mg/l (compared with 0.04 mg/l at the intake) during the limited period of approximately 3 hours over which the discharge will take place.

Nitrate inputs will arise from the FGD plant, and coal stock run-off. However, the bulk of the contribution will arise from the FGD plant comprising approximately 5,400 tonnes of NO_3 per annum (based on an uptake at NO_2 at a rate of 22 g/s).

The only other effluent which may cause some concern as regards the input of nutrients into the marine environment is the treated domestic sewage. On site, biological sewage treatment will be provided for the LTPS. The maximum daytime working population, however, will be only approximately 1,000 and the resulting flow rate of treated sewage effluent will be about 566,000 m^3/year.

Biological sewage treatment in its basic form serves mainly to reduce the BOD of the incoming waste. Some reduction in nitrogen does occur due to microbial action, but unless specific measures for nitrogen and phosphorus stripping (for example chemical precipitation) are taken, the resulting treated effluent will still contain relatively high levels of these nutrients. However, for only 1,000 people this form of sewage treatment is adequate.

The other effluents contributing to the total flow discharged with the cooling water are not expected to contain any "nutrients".

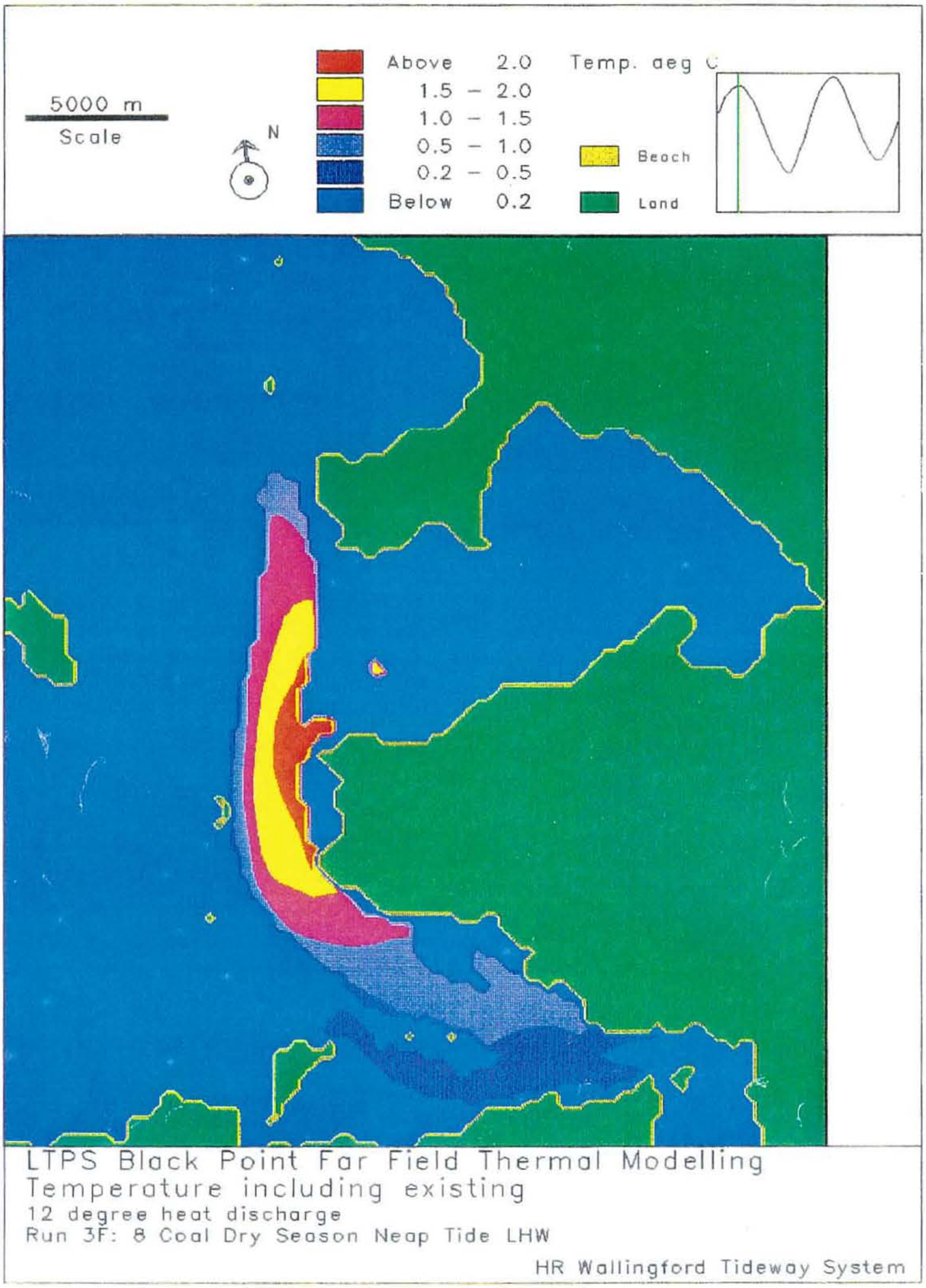

Figure 3.1 (d) Run 3F Dry Season Neap Tide Bed Layer Temperature LHW

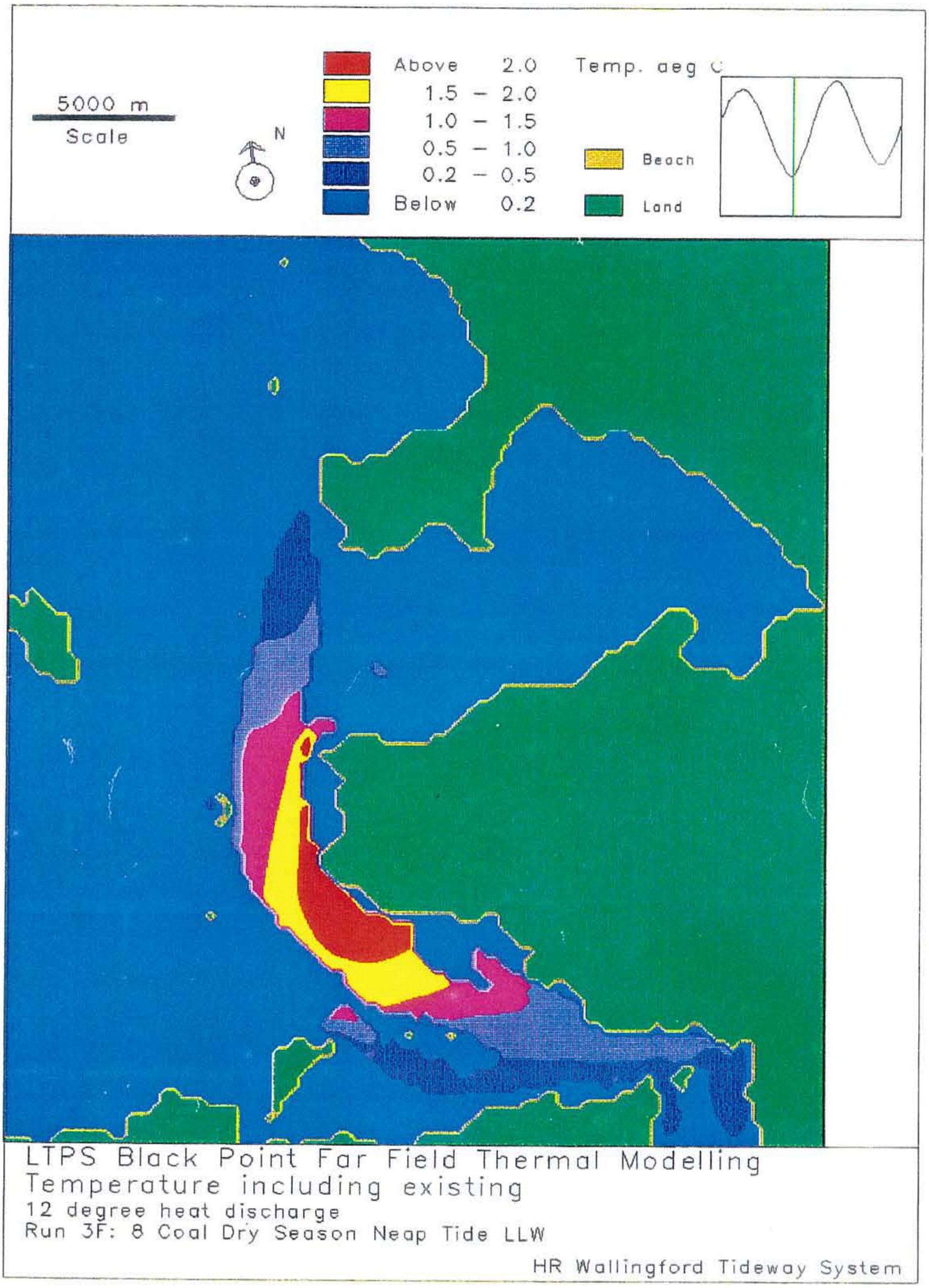

Figure 3.1 (e) Run 3F Dry Season Neap Tide Bed Layer Temperature LLW

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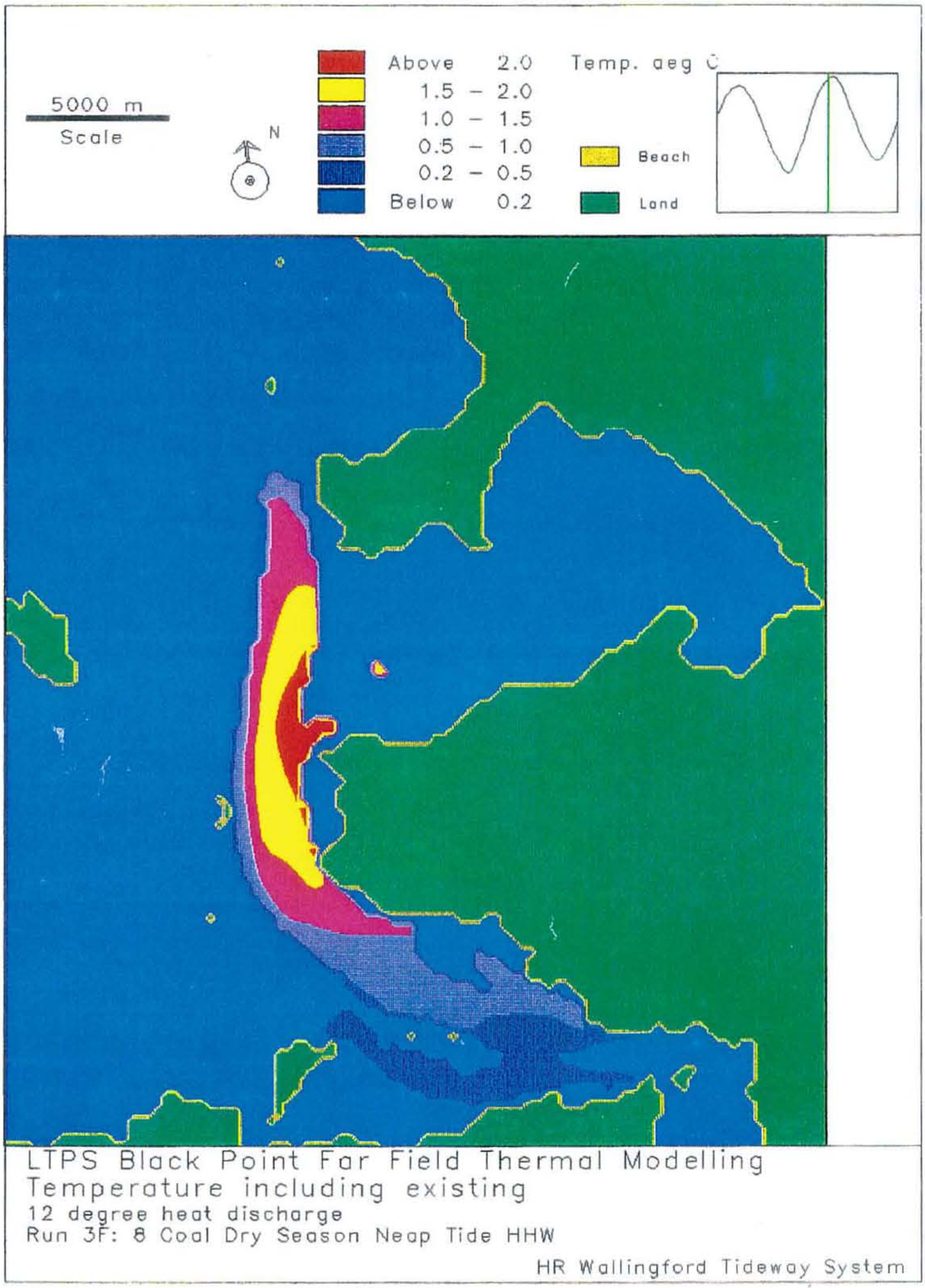

Figure 3.1 (f) Run 3F Dry Season Neap Tide
Bed Layer Temperature HHW

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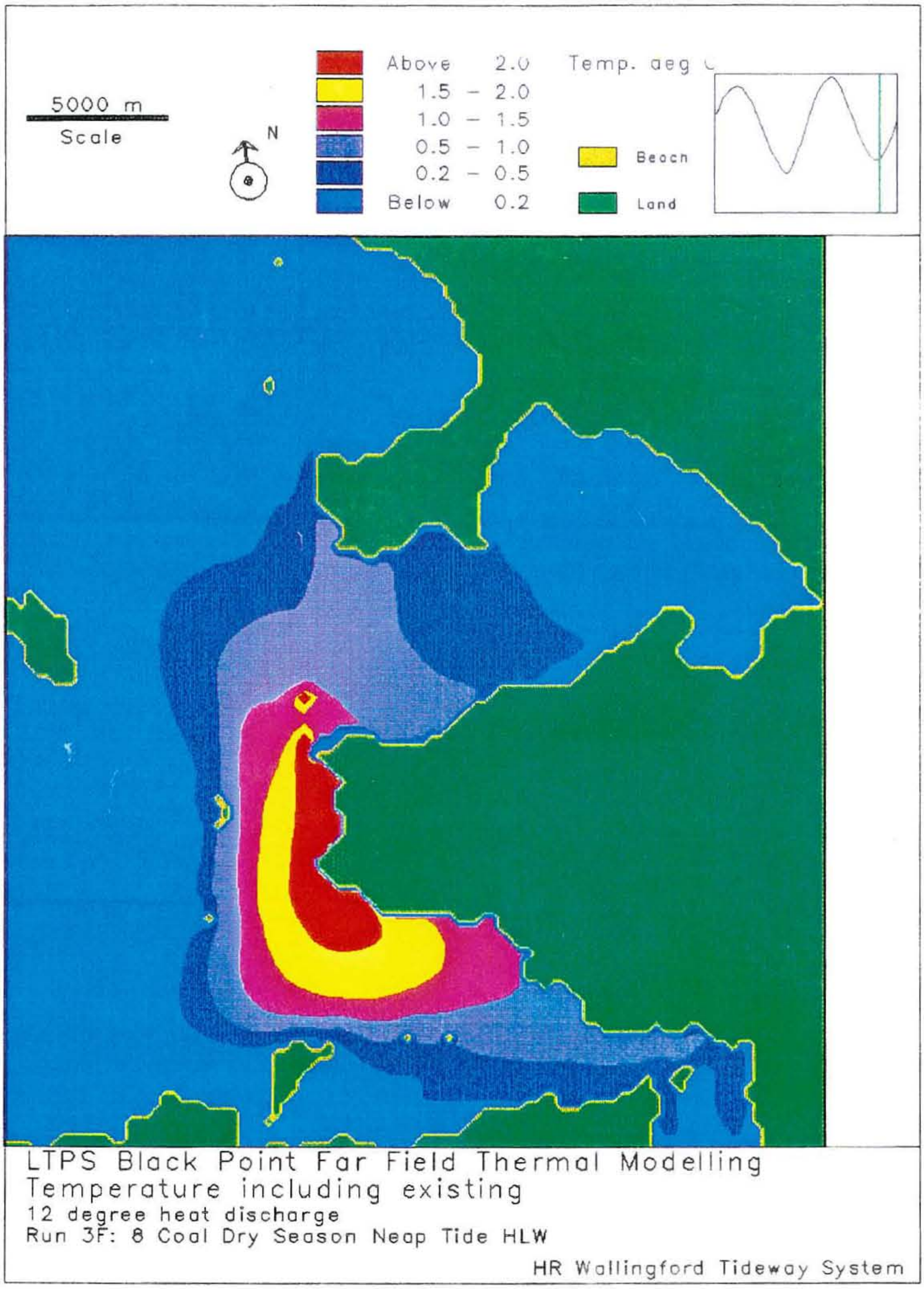

Figure 3.1 (g) Run 3F Dry Season Neap Tide Surface Layer Temperature HLW

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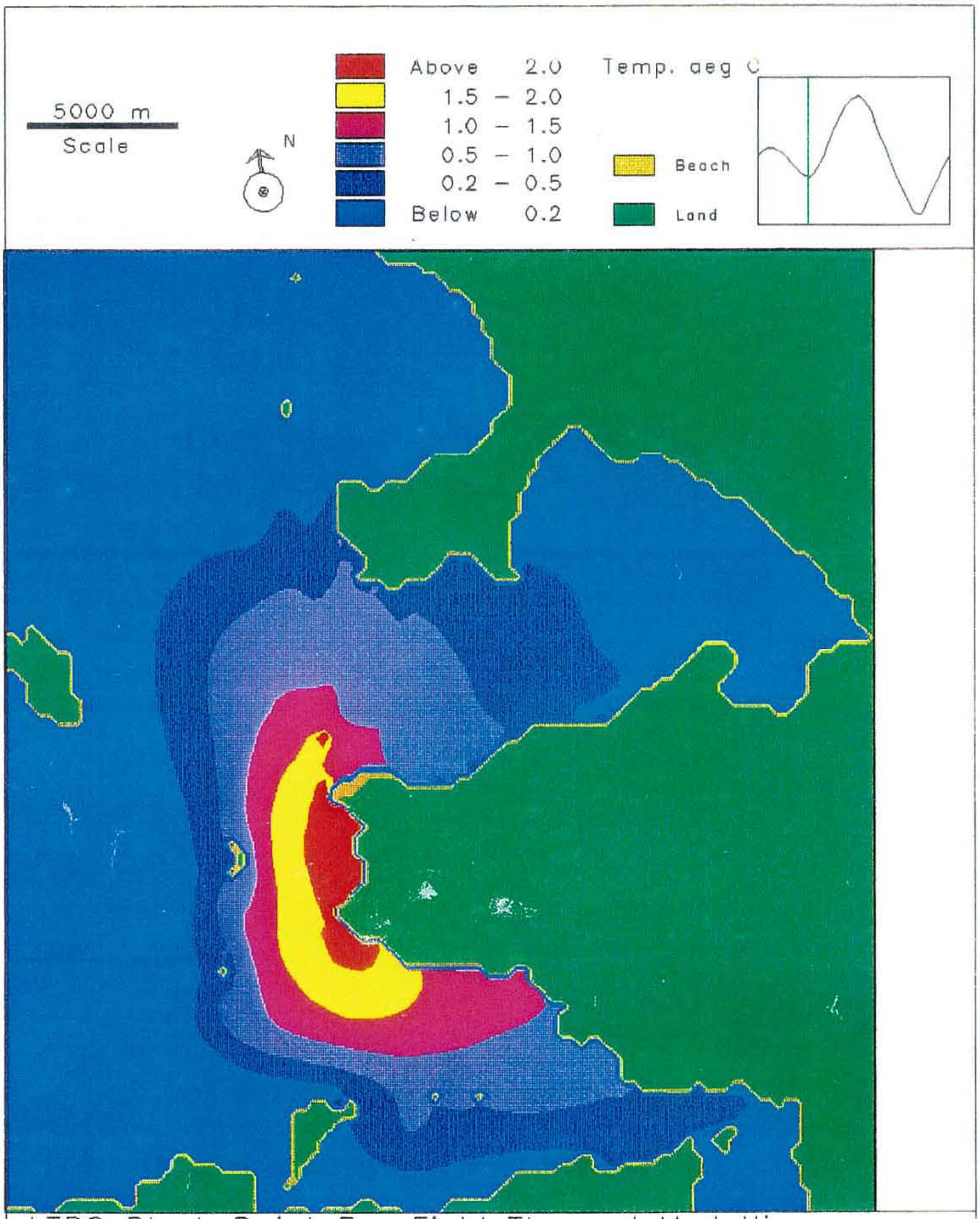

LTPS Black Point Far Field Thermal Modelling
Temperature including existing
12 degree heat discharge
Run 4F: 8 Coal Dry Season Spring Tide HLW

HR Wallingford Tideway System

Figure 3.1 (h) Run 4F Dry Season Spring Tide Surface Layer Temperature HLW

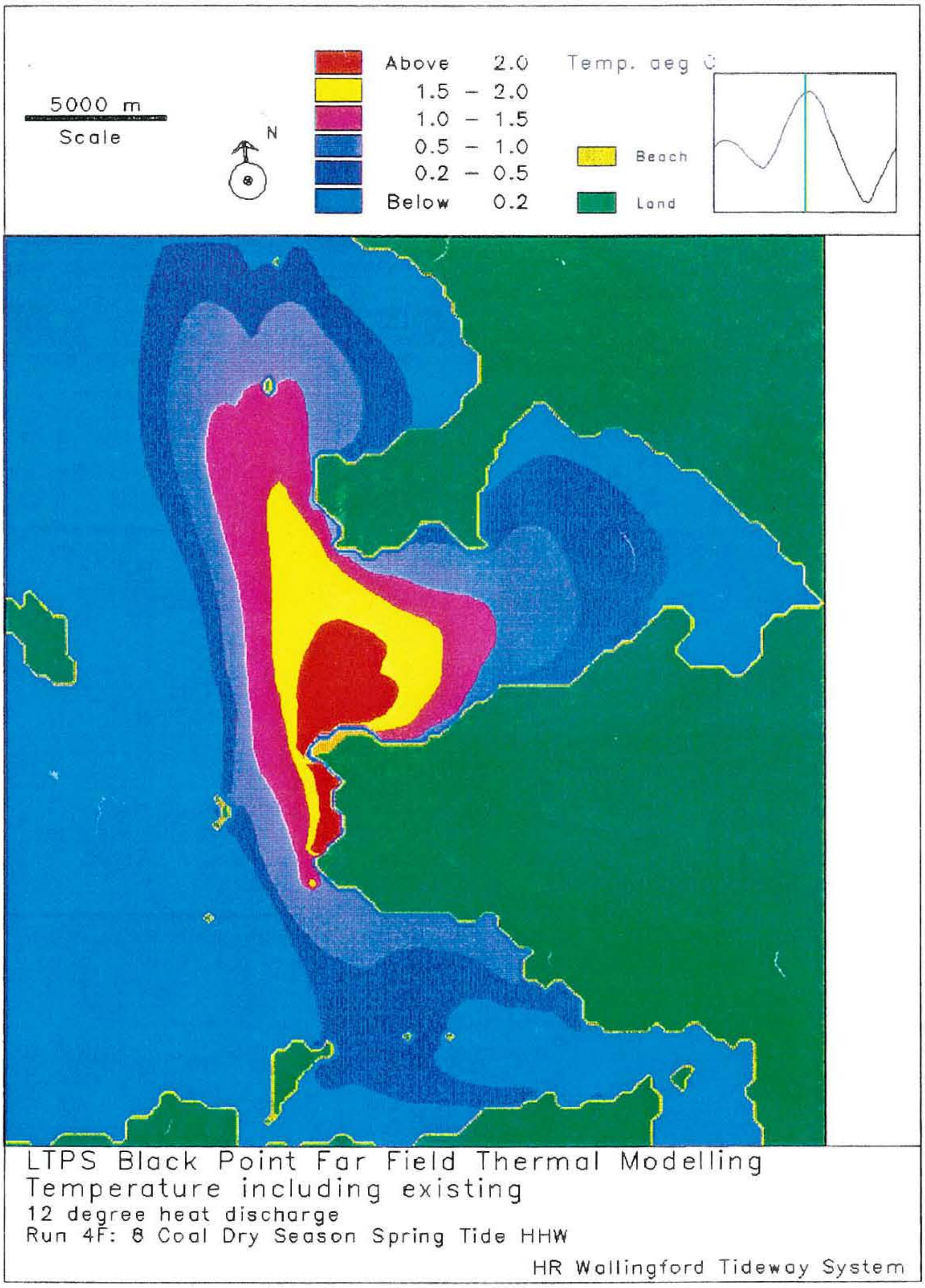

Figure 3.1 (i) Run 4F Dry Season Spring Tide Surface Layer Temperature HHW

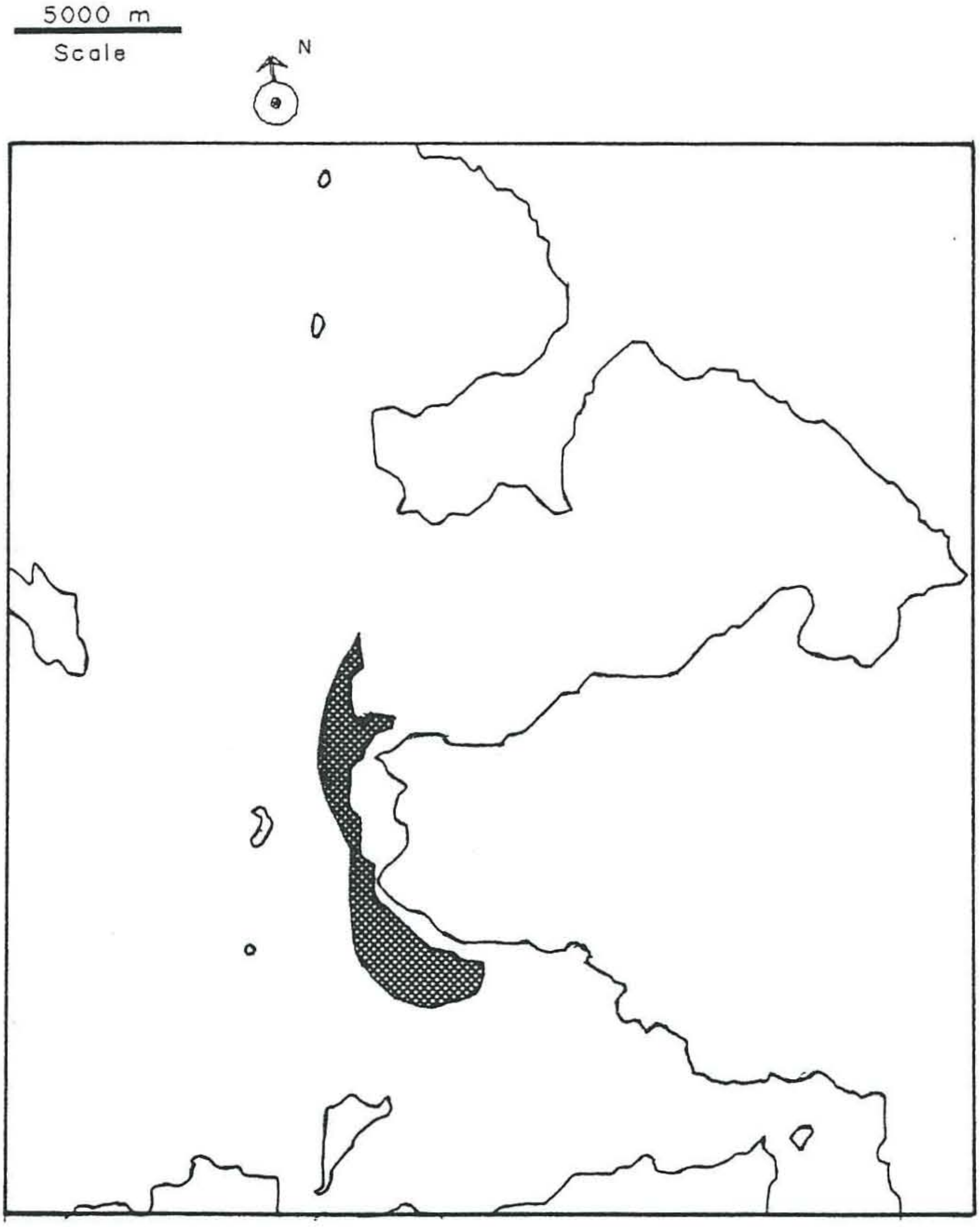

Figure 3.1 (j)

Permitted '2°C Exceedence Temperature Envelope' for Surface Water as Predicted by Hydrothermal Modelling

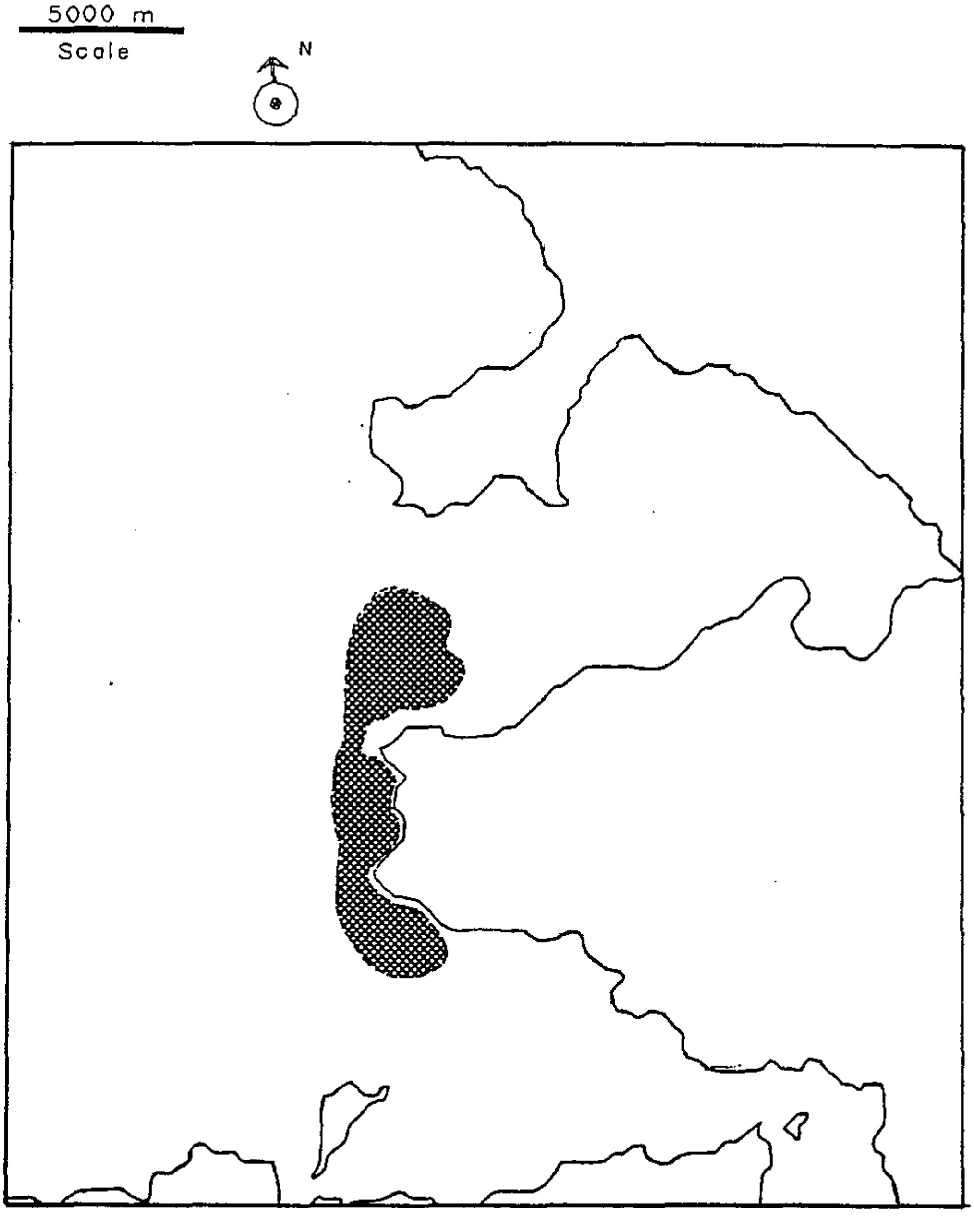

Figure 3.1 (k)

Permitted '2°C Exceedence Temperature Envelope' for Bed Layer Water as Predicted by Hydrothermal Modelling

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3.2.3.2 *FGD Effluents*

The FGD effluents will be combined with other process effluents prior to their discharge via the outfall as noted previously. The cooling water effluent will dominate flows, in volumetric terms, comprising 14.4 x 10^6 m^3 day^{-1} (Scenario I) yielding a concentration of NO_3^- in the combined discharge effluents of 1.02 mg/l.

This concentration is in addition to the nitrate load in the intake cooling water. Baseline nitrate concentrations (as opposed to $NO_3 - N$) in the intake cooling water are likely to be in the range 1.3 - 1.8 mg/l and thus the concentration will be raised to 2.3 - 2.8 mg/l.

3.2.3.3 *Sewage Effluents*

According to Gloyna (1971), fresh domestic sewage might be expected to contain 5–10g nitrogen per capita per day and 1-2g phosphorus per capita per day. This would equate to 5–10 x 10^3 g and 1–2 x 10^3 g of nitrogen and phosphorus respectively per day for the LTPS. The volume flow rate for the sewage effluent will be approximately 1,550 m^3/ day. This yields nutrient concentrations in the sewage effluent alone as follows:

- 3.2-6.4 mg/l nitrogen (14–28 mg/l as nitrate, NO_3^-;)
- 0.64–1.3 mg/l phosphorus (2–4 mg/l as phosphate, $P0_4^{3-}$).

The sewage effluent will be combined with the overall liquid effluent output from the LTPS, prior to its discharge to sea. The predominant effluent will be seawater for cooling at a rate of 14.4 x 10^6 m^3/day. Total nutrient levels in the intake water are likely to be in the range of 1.3–1.8 mg/l and 0.06–0.08 mg/l for nitrate–N and phosphate–P respectively (based on baseline measurements). To take a simplistic (and worst case) approach, (ie dilution of the upper concentration ranges in the sewage effluent by the upper concentration ranges in the cooling intake seawater) the following nutrient concentrations in the overall effluent are estimated.

- For 28 mg/l nitrate in the sewage effluent and 1.8 mg/l nitrate in the intake cooling water the overall discharge would contain 1.803 mg/l nitrate.

- For 4 mg/l phosphate in the sewage effluent and 0.08 mg/l phosphate in the intake cooling water the overall discharge would contain 0.0804 mg/l phosphate.

To summarise, the sewage effluent input to the nutrient content of the discharge will result in an imperceptible rise in the concentrations of nitrate and phosphate above naturally occurring levels. This is due to the dilution effect of the cooling water. Concentrations of sewage-derived nutrients in the plume will fall rapidly to levels indistinguishable from the background, within a short distance of the outfall.

3.2.3.4 *Other Possible Sources of Nutrients*

Nutrients can also be derived from marine biota that become entrained at the intake and which subsequently pass through the cooling system. The various stresses imposed on these organisms can result in the release of dissolved or readily assimilable forms of nutrients once the cooling water is discharged. An estimate of how much nutrient material is released can be made from the following:

- a knowledge of chlorophyll–a concentrations in bottom waters near the intake;

- the chlorophyll–a to carbon ratio for plankton (approximately 1 Chlorophyll–a to 20–100 C);
- the C:N:P ratios for plankton, approximately 106:16:1.

The Chl–a:N:P ratio can be broadly estimated as 1:0.16–0.8: 0.01–0.05; for the purposes of this assessment the worst case upper limit will be taken, ie 1:0.8:0.05.

From baseline monitoring measurements undertaken in the vicinity of the proposed site it is clear that chlorophyll–a concentrations in bottom and near bottom waters in the vicinity of the intake are unlikely to exceed 5 mg/m^3 (5 μg/l) even during blooms. Thus if all the nutrients associated with entrained plankton etc were to be released during passage through the cooling system then this would contribute 4 μg/l and 0.25 μg/l of N and P respectively to the nutrient load of the receiving waters; ie approximately 17.5 and 0.8 μ/gl nitrate and phosphate respectively. These values are clearly overestimates, however, since a significant proportion of plankton etc will survive passage through the cooling system alive and intact, while a further proportion, though damaged, will not release substantial amounts of dissolved nutrients to the receiving water. If an upper limit of 10% of the nutrients associated with the entrained biota is assumed to be released this would yield values of 1.85 and 0.08 μg/l nitrate and phosphate respectively, as the contribution from damaged entrained biota to nutrient levels in the discharged cooling water. These values are approximately three orders of magnitude less than the ambient natural concentrations of dissolved N and P in the cooling (and receiving) waters. Even if all the nutrients associated with the entrained biota were to be released this would only yield a barely perceptible rise in nutrient concentrations in the discharged cooling water.

It should however, be emphasized that velocities at the inlet ports of intake structures would be limited and the intakes designed to avoid fish entrainment (and ingestion of oil and floating debris) which will assist in minimising the amount of nutrient derived from the ingestion of living organisms. A typical precast concrete intake structure for the cooling water system is shown in Figure 3.2(a).

3.2.3.5 *Summary of Nutrient Inputs*

To summarise, it is apparent that operation of the LTPS will not constitute a significant input of phosphate. The FGD effluent will provide the dominant source of nitrate at a rate of approximately 5,400 tonnes per annum, resulting in nitrate concentrations in the overall effluent being elevated by 1 mg/l above the background of 1.3 – 1.8 mgl^{-1}. In concentration terms this a relatively small increase, although it does constitute a relatively large load of nitrate to the receiving waters, and HR have modelled this input. The model and results thereof are discussed in the following section.

3.2.4. *Nutrient Modelling Results*

3.2.4.1 *Mathematical Modelling*

The model POLL FLOW – 3 DSL which was used to predict nutrient distributions, is based on the same model of water quality associated with the three–dimensional seasonal model of flow and gravitational circulation developed by HR Wallingford (HR) for the North West New Territories (NWNT) Sea outfall Study in 1989. For this KIA study, however, appropriate amendments and expansions were made to the original model to give a better representation of the areas in the vicinity of the proposed discharge at Black

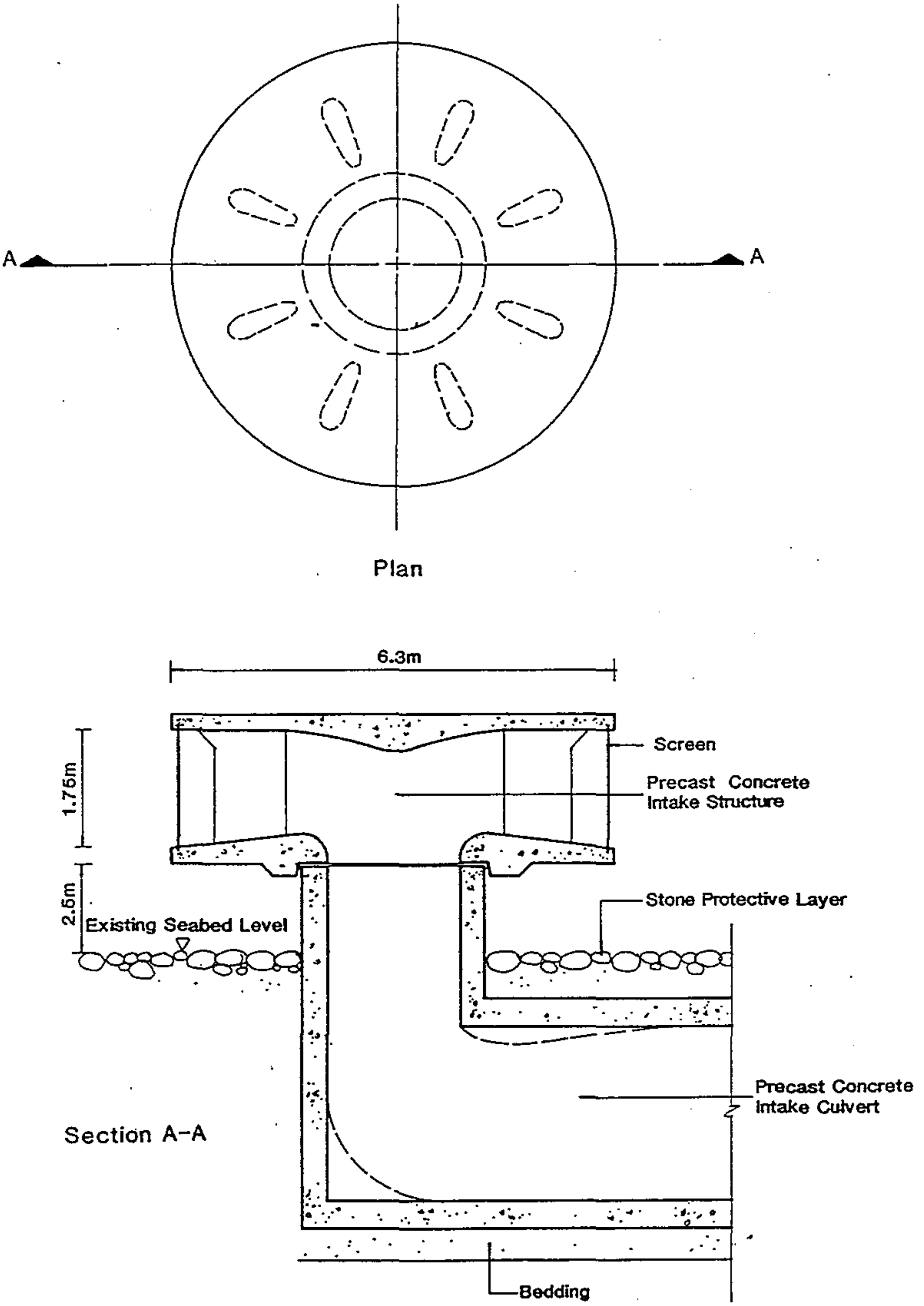

Figure 3.2(a)
Cooling Water System – Typical Precast Concrete Intake Structure

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Point.

The boundary conditions used for this study were those used in the NWNT study. Boundary data relating to the seasonal variation in water quality variables were prescribed using EPD monitoring data together with other published data.

The water quality model was run using data from the Deep Bay Integrated Environmental Management Study which was undertaken by ERL (Asia) Ltd in 1988 and pollutant loadings as estimated during the NWNT study.

The simulation assumed two major nutrient inputs - one at the surface at 808700E, 831100N and one at the bed at 807000E 831500N, just north of the interface between model segments 75 and 82. A nitrate loading of 2700 tonnes per annum was input into the surface layer of segment 82 with 1350 tonnes per year into the second layer of each of segments 75 and 82. This loading derives principally from the FGD effluent contribution.

The model simulated the following water quality variables: nitrate, phosphate, oxygen and chlorophyll and took into account temperature rise due to the LTPS input. The results are summarised in the following section.

3.2.4.2 *Results of the Model*

Nitrate

The effect of the proposed discharge on nitrate concentrations is illustrated in Figure 1(a)–(h) of Annex F. The largest effect is seen at the surface of segment 82 where there is an increase in nitrate concentration of about 0.05 mg/l. This represents a 25% increase in the dry winter months and an increase of about 12 - 15% in the wet winter months. These are average values for the whole of the segment area and higher values could be expected in the immediate vicinity of the discharge.

The residual discharges in the Pearl estuary are seaward at the surface and so with the exception of segment 75, which had a direct nitrate input, there was no significant effect landward of the discharge points. The effect decreased seaward of segment 82 with an average increase of about 0.025 mg/l in the surface layer of segment 87 and no significant impact in segment 17.

Chlorophyll–a

The effect of the proposed discharge on chlorophyll–a concentrations is illustrated in Figure 2(a)–(h) of Annex F. There is a small increase in the surface layers of segments 75 and 82 with a maximum increase of about 0.5 mg/m^3 or 5% of the summer value. The relative insensitivity of chlorophyll–a concentration, despite the much larger increase in nitrate concentration, is explained by the fact that phosphorus was the limiting nutrient during this simulation. Any increase in phosphorus would be expected to result in an increase in chlorophyll–a concentrations since nitrate is in surplus. There was no effect on chlorophyll–a concentrations further afield.

Dissolved oxygen

The effect of the proposed discharge on dissolved oxygen is illustrated in Figures 3(a)–(h) of Annex F, and is twofold. Firstly, the increase in temperature results in small increases in reaction rates for BOD and ammonia (about 5% for each degree C rise in temperature), and a corresponding decrease in dissolved oxygen, as it is taken up by the BOD and ammonia reactions. The temperature increases are however small (Table 1) and are fairly localised. Secondly there is an increase in oxygen production, caused by the temperature effect, on algal growth (the warmer temperature increases growth), and by the increase in algal growth resulting from the increased nitrate concentration which represents an increased food supply. The overall effect is a small nett increase in dissolved oxygen levels in the surface layers of segments 75 and 82 of about 2% saturation.

Phosphate

The effect of the proposed discharge on phosphate concentrations is illustrated in Figures 4(a)–(h) of Annex F. The only impact on phosphate is due to the increased algal growth, referred to above resulting in a small decrease in phosphate concentrations. The result is that phosphorus, which under existing conditions is probably the limiting nutrient in the vicinity of the discharge for most of the year, becomes the limiting nutrient all of the time. Additional inputs of phosphate would therefore be readily utilised.

3.2.5 Conclusions

It is apparent from the modelling study that inputs of nitrate from the LTPS will influence nitrate concentrations in the receiving waters and that this will in turn influence biological activity. However, the effects are fairly small and the enhanced biological production is not proportional to increases in nitrate concentrations, since phosphate will act as the limiting nutrient all year round, as opposed to most of the year which is the present case. As regards the DBWQO's, which are in any case exceeded by the background ammoniacal nitrogen and nitrate levels, the cooling water discharge of the LTPS will not significantly add to the existing problem of nutrient enrichment.

According to the results of the model, the inherent nutrient enriched nature of the water surrounding Black Point (which is also indicated by the O_2 sag near the bottom in summer) will not be affected by the cooling water outfall.

3.3 METAL DISPERSION

3.3.1 Introduction

Various effluent streams from the operational LTPS, when combined with the cooling water outflow, are likely to contain trace metals at concentrations in excess of the natural levels in the receiving waters. The trace metal load of the combined discharge from the LTPS has been provisionally quantified in the IAR, and the sources of trace metals present in the discharge were also identified. As part of the KIA, mathematical modelling has been carried out of trace metal dispersion from the LTPS outfall, together with the predicted deposition of adsorbed (particle–phase) trace metals to the sediments.

This section discusses the results of the dispersion modelling study, together with the implications for water quality and marine ecology.

3.3.2 *Existing Conditions*

Since a principal requirement of cooling water is that it should have as low a temperature as possible when it is taken into the cooling system, far-field lower depth trace metal concentrations were taken to be representative of the intake cooling water at the LTPS site. These are summarised (for October 1990 to August 1991) in Table 3.3(a); ranges are also quoted for all depths.

Concentrations of trace metals in sediment samples were summarised in Table 2.8(a).

Table 3.3(a)
Metal concentrations: means (lower depth) and ranges in seawater (surface, mid-depth, lower-depth) μg/l October 1990–August 1991[1]

Metal	Mean, μg/l	Range, μg/l
Hg	<1	<1
Cd	0.060	<0.05 - 0.54
Cr	2.01	0.3 - 4.2
Cu	<5.9	<5.0 - 12.0
Pb	2.02	0.325 - 3.45
Ni	1.92	0 - 6.0
Zn	8.84	4.05 - 13.0
As	0.83	0.52 - 2.3

(1) The means are for <u>lower depths</u> (since it is water from lower depths which will be drawn in at the intake). The ranges are for <u>all depths</u> hence the inconsistency with the lower depth means. The data is presented purely for comparative purposes.

3.3.3 *Potential Sources of Impact*

According to Nriagu and Pacyna (1988) human activities have become the most important element in the biochemical cycling of the trace metals. This has potentially important consequences, and a degree of unknown risk, as regards the inevitable transfer of enhanced levels of trace metals to the human food chain.

Trace metals are not a conservative element in the marine environment and both biological and physico-chemical processes are critical in dictating their concentrations.

All trace metals have the potential to be toxic to marine organisms but some metals, below threshold concentrations (eg. Cu), are essential to the healthy growth of such organisms. Toxic effects, typically sub-lethal rather than lethal, occur to marine organisms at a threshold bioavailability. The threshold concentrations vary between species, individuals specimens, physico-chemical characteristics of the medium (eg temperature, salinity etc) and the chemical speciation of the metal itself.
The responses of marine organisms to trace metals in their ambient environment or food is quite variable.

- Higher organisms can regulate levels of many metals.

- Invertebrates can regulate levels of some metals up to limit.

- Avoidance responses (eg by fish) or behavioural responses (eg closure of shells by bivalve molluscs, such as mussels) can be exhibited.

- Where organisms (such as phytoplankton) do not have the capacity to control physiological levels of metals they are able to detoxify metals (eg by exuding organic chelates which can complex trace metals) and store them in relatively harmless (to that organism) forms.

The degree to which an organism is able to cope with ambient changes in trace metal concentrations can be reflected at the individual population or ecosystem level; species composition and production levels may be also effected. A typical effect, as with many other pollutant-induced stresses on natural populations, is a noticeable change in species composition whereby species sensitive to trace metal pollution disappear, or are reduced in abundance, in comparison with more tolerant species. In other words, although overall biomass may not be significantly affected, species diversity will be reduced. The species remaining may typically display above-average trace metal composition. At its extreme, such an effect can constitute a threat to human health (eg the `Minimata disease'), although more typically severe trace metal pollution might manifest itself, for example, in the loss of commercially exploited/exploitable shellfish stocks or restrictions on their exploitation.

Of the two principal physical mechanisms whereby trace metals are removed from the coastal waters (ie long distance transport and/or incorporation in the sediments) the latter still provides a significant pathway for trace metals into the food chain, adsorption of trace metals onto the surfaces of particles (and the deposition of dead organisms into the sediments) can enhance trace metal concentrations in the sediments several orders of magnitude over their concentrations in the water column. A significant proportion of adsorbed metal will be readily assimilable by benthic biota and potentially available for uptake by higher organisms.

3.3.4 *Effluent Composition*

Trace metal concentrations in effluents discharged to Hong Kong waters are specified in terms of effluent standards. These standards vary according to the receiving water zone and the effluent volumetric flow rate. Whichever scenario/case is eventually adopted, the volume flow rate of the combined effluents from the outfall will be outside the range of volume flows covered by the effluent standards. Consequently, the authorities will set effluent standards on a single case-by-case basis.

The main sources of trace metals in the CW discharge are;

- the natural levels present in the intake cooling water;
- ash pit effluent;
- coal stockyard run-off;
- FGD effluent;
- PFA decantrates

Other sources, (eg. sewage) will not make a significant contribution in comparison with those listed above. The sources listed above have been quantified, in terms of their trace metal contributions, in the IAR, and are summarised in this KIA, in terms of the following:

- metal loads (kg/yr) produced by the LTPS under scenario I (see Table 3.3b);

- metal concentrations in discharges from the LTPS (see Table 3.3c);
- percentage difference between metal concentrations in the intake water and discharge (See Table 3.3d).

Table 3.3b
Metals discharged from the LTPS (kg/yr) (Scenario I)

	LTPS Load	Seawater Load[1]	Total
Hg	850	3800	4650
Cd	950	250	1200
Cr	6000	7600	13600
Cu	2800	22300	25100
Pb	4000	7650	11650
Ni	5000	7250	12250
Zn	9000	33450	42450
As	950	3150	4100

[1] The intake cooling water will contribute, together with the LTPS, to the total load, since it will contain natural levels of metals (see Table 3.3a).

Table 3.3c
Metal concentrations in discharges from LTPS

(µg/l)		
Metal	**LTPS Scenario I**	**Range in Seawater[1]**
Hg	<1.2	<1
Cd	0.311	<0.05 – 0.54
Cr	3.60	0.3 – 4.2
Cu	<6.6	<5.0 – 12
Pb	3.08	0.325 – 3.45
Ni	3.24	2.0 – 6.6
Zn	11.22	4.05 – 13
As	1.08	0.9 – 2.3

[1] Based on monitoring data October 1990 – August 1991, lower depth waters.

Table 3.3d
Percentage change between metal concentrations in discharge from LTPS and intake water mean concentrations

Metal	Scenario I
Hg	<20
Cd	420
Cr	79
Cu	12
Pb	52
Ni	69
Zn	27
As	30

From the summarised data in these tables, a number of points are apparent.

- The predicted total heavy metal discharge from the worst case scenario of eight coal-fired units with dissolved gypsum FGD system is almost 30,000 kg/yr. This compares with Total Toxic Metal figures for the new NWNT outfall sewer used in the EIA for the NWNT Sewerage Scheme (Final Report 1990 Table 10.3), of 3,910 kg/day for a sewage flow of 303524 m^3/day, which represents an annual load of 1,427,150 kg/yr. The EIA identified no adverse impact from this discharge from the sewer.

- Notwithstanding the above comparison, in absolute quantities the discharged metal loads from the LTPS are substantial, even when the natural contribution made by the intake cooling water is subtracted.

In terms of metal concentrations, a comparison between the existing ranges in seawater and the predicted discharge concentrations (Table 3.3c) shows the following points:

- Cu, Ni and As have discharge concentrations well within the likely upper levels of their concentration ranges in the receiving water;

- Cd, Cr, Pb and Zn have discharge concentrations which approach the likely upper levels of their concentration ranges in the receiving waters;

- All the metals listed above have concentrations (when the discharged load is superimposed on the mean seawater concentrations) which are within the ranges of concentrations presently encountered.

When comparing the percentage increase in metal concentrations in the discharge over those in the intake water mean seawater trace metal concentrations have been used, as opposed to the maximum concentrations recorded during monitoring. This approach is justified as follows:

- The maximum intake (or existing) concentrations would give an unrealistically worst case picture of the likely quality of the discharge whereas the mean intake concentrations give a better indication (when added to the LTPS effluent streams) of what is likely to occur for most of the time.

- Were the maximum recorded trace metal concentrations in the intake water to be used then this would result in unrealistically low percentage increases (as given in Table 3.3(d); i.e. this approach would be less valid for comparative purposes.

No direct comparison can be made for Hg as the concentrations in seawater were below detection limits (i.e. less than 1 μg/l), however, the added contribution from the LTPS of 0.2 μg/l is small in absolute terms.

It is important to note that truly valid comparisons are difficult to make between the respective quality of the discharge and receiving waters. The comparisons above are based on the intake water mean trace metal concentrations being representative of lower-depth waters, whereas the concentration ranges for the receiving waters are for all depths. This latter assumption is based on the likely degree of mixing that will result from the large volume discharge.

In Table 3.3(d) a more stringent 'worst case' approach has been adopted where percentage changes between mean metal concentrations in the lower-depth intake waters and concentrations in the discharge have been estimated. Furthermore, it has been assumed that all the metals discharged from the LTPS are in the dissolved biologically available form but in reality some of these metals will be in the particulate form and therefore potentially less available for marine biota.

It can be seen that, dilution factors of up to three times are generally sufficient to bring discharge concentrations down to typical mean background values. The exception is Cd, where a dilution factor of about five times would be required.

To summarise, dilution factors of the magnitude described above are generally achieved within a fairly short distance of outfalls. This, together with the fact that likely discharge metal concentrations are largely within the baseline ranges recorded for the receiving waters, indicates that impacts to water quality and marine biota resulting from the slight elevation in metal concentrations alone are unlikely to be significant.

Of wider concern is the overall load of metals to the receiving waters and possible far-field effects, especially deposition of adsorbed metals to the sediments where long-term build-up and assimilation, in excess of the norm, by benthic biota may potentially occur. In order to address this concern both far-field metal concentrations and metal deposition have been studied by Hydraulics Research Ltd using a mathematical model. The modelling procedure and results are discussed in the following Section.

3.3.5 Dispersion Modelling Results

3.3.5.1 Details of the Modelling Procedure

The far field metal modelling was undertaken by Hydraulics Research using the standard HR METALFLOW-2D2L model. The model used results from a two-layer tidal flow model to advect and disperse metal by tidal currents subject to adsorption, desorption and settling.

The receiving waters are subject to seasonal changes resulting from fresh water discharge from the Pearl Estuary; this is at a maximum in the summer wet season. During the wet season as the freshwater discharge increases in the Pearl estuary, saline water moves seawards and a limited degree of mixing takes place in the middle estuary. A brackish layer of water then forms on top of denser oceanic water and the water column is effectively divided into two layers. Hence, to simulate tidal flows in this area a two-layer model was used.

The objective of the metal dispersion model is to simulate the levels of dissolved and absorbed metal that will result from the discharge of the combined effluent streams from the LTPS. The modelling runs were performed for one metal (zinc was chosen) and an assessment made of the likely dispersion of other metals. The condition chosen for study was the 8 coal-fired units operating, which has two outfalls each discharging approximately 96 cumecs of cooling water.

The modelling made use of previous simulations of suspended mud transport in the area. The initial and boundary conditions of the suspended sediment for the present study were taken from this work for the dry season but for the wet season the starting values were taken from a simulation made for the Black Point Study.

In modelling zinc, a rapid adsorption rate well in excess of the desorption rate was used. This resulted in the discharged dissolved metal initially adsorbing rapidly (eg a third of it in the first tide) as it encountered uncontaminated mud.

The model runs were carried out with a discharge from the LTPS of 192 cumecs, with 96 cumecs (50%) discharged at the seawall location used in runs 1F and 2F of the heat flow study and 96 cumecs (50%) discharged through an offshore outfall situated at 807000E and 831500N. The discharge condition was 9000kg of zinc per annum (ie about 25kg per day contributed by the LTPS) which was divided equally between the two outfalls. The discharged metal was conservatively assumed to be initially all in the dissolved state but rapid adsorption may occur in the presence of suspended sediment due to scavenging processes.

The designated outfall location has a water depth of about 8m PD and is within the upper layer of the model so all the discharged metal was input to the upper layer. The results represent the situation after running, with continuous discharge, three tides on a background field of adsorbed and dissolved metal computed from 6 cycles of a spring and a neap tide.

The modelling of Zn distribution was conducted during different weather and tidal conditions. In addition, the modelling of Zn distribution was also carried out in the oceanic layers which exist around Black Point. The four different weather and tidal conditions under consideration were:

- dry neap tide;
- dry spring tide;
- wet neap tide;
- wet spring tide.

Finally, the results of the various tides were added together to give an estimate of a year's deposition of adsorbed zinc. This assumes 25% each of wet and dry, spring and neap tides and also assumes that deposits from one kind of tide (eg wet season neap tide) are not removed by another.

3.3.5.2 *Modelling Results - Zinc*

The modelling outputs in the form of spacially plotted concentration contours are discussed below.

For a dry neap tide the maximum dissolved metal concentrations over a tidal cycle are shown in Figures 3.3(a) and (b) for surface and bed layers respectively. The equivalent particulate values are shown in Figures 3.3(c) and (d). The amount of metal deposited on the bed on each tide is shown in Figure 3.3(e). The shapes of the contours of dissolved metal are similar in general to those previously found for the background temperature study (as is the case for all the simulations). The amount of metal in the dissolved state is about three times the amount of particulate metal in this case. Some deposits occur in the coastal zones, neither very near the coast (because of the effect of waves, the model made the assumption that no deposition occurred whenever the depth was less than 2m) nor further away where the bed stress peaked at more than the 0.11 N/m2, which was taken as the critical shear stress for erosion. The simulated concentrations are generally very low with peak values somewhat larger than 0.2 parts per billion (ie 0.2 mg per cubic metre of water) above background levels.

For a dry spring tide the maximum dissolved metal contours are shown in Figures 3.3(f) and (g) for surface and bed layers respectively. The particulate values and the bed deposits for a 25 hour tide are shown in Figures 3.3(h), (i) and (j). The results are similar to those for a neap but the ratio of dissolved to particulate metal in this case is about 2 as more mud is available in suspension on the spring tide so more metal is adsorbed on to the mud. The bed deposits in this case occur rather closer to the coast as the bed stresses are higher and as the high water level is higher deposition can occur where it would be impossible on a neap tide. As in the case of a neap tide the adsorbed metal increases landward in Deep Bay. This is due to there being a higher suspended sediment concentration there and so more metal is adsorbed.

On a wet spring tide the maximum dissolved Figures 3.3(k), (l), (m) and (n) and particulate metal for the two model layers over the tide are shown in Figure 3.3(o). The corresponding net deposits are shown in Figure 3.3(o). Considerably less metal is found either in dissolved or particulate form compared to the dry season spring tide. This is because this tide has strong dispersive properties as was found also in the background temperature study. The deposits are also correspondingly smaller than those in the dry season.

On a wet neap tide the dissolved and particulate metal concentrations shown in Figures 3.3(p), (q), (r) and (s) show that, as in the background temperature study, the concentrations lie further north for the wet season neap tide than for the dry season one. This is particularly so for the adsorbed metal which increases near to the model's north boundary where larger mud concentrations are found, causing adsorption to occur. The amount of metal depositing on the bed in this case is low and some of it is clearly located where another tide will erode it (see Figure 3.3(t)).

In order to quantify Zn deposition over a one year period the results of the various tides have been simply added together (see Figure 3.3(u)). This assumes 25% each of wet and dry, spring and neap tides and also assumes that deposits from one kind of tide (eg wet season neap tide) are not removed by another, ie it is a worst case estimate.

3.3.5.3 Modelling Results – Other Metals

The modelling results obtained for the dispersion of zinc were analysed to obtain the value for the ratio of the dissolved concentration to the concentration of particulate zinc per kilogramme of suspended sediment. If the zinc were in equilibrium the ratio would just equal the equilibrium partition coefficient. For the case examined (dry season spring tide) it was found that over a large area where the concentrations were largest the ratio was between 0.7 and 1. Near to the outfalls the value was larger because the metal is discharged in the dissolved form. Further away (where the concentrations are lower and where net deposition is predicted to occur) the value of the ratio was lower, presumably because, while the metal is rapidly adsorbed by the mud, it desorbs much more slowly. For the purpose of the present assessment and based on previous metal dispersion studies it was reasonable from this analysis to deduce that the metal was very close to being in equilibrium.

Assuming that the other metals are also in equilibrium it is possible to scale the results for zinc approximately, knowing the equilibrium partition coefficient for the other metal, to give an estimate of the adsorbed and dissolved concentration of the metal. The validity of such an approach is further reinforced by the principal area of concern being far field effects and metal deposition at distances away from the outfall.

The metals for which values of the discharge rates from Black Point power station are available are shown in Table 3.3(f).

Table 3.3(f)
Metal Discharge Rates and Partition Coefficients

Metal	Discharge Rate (kg/yr)	Equilibrium Partition[1] Coefficient
Mercury	850	0.14
Cadmium	950	3.9
Arsenic	950	0.016
Chromium	6000	0.016
Copper	2800	0.016
Lead	4000	0.14
Nickel	5000	0.36
Zinc	9000	0.1

[1] The partition coefficients for mercury, chromium and arsenic are not directly available, but have been derived from Balls (1989). It has been assumed for this study that the partition coefficient of mercury is similar to lead, and arsenic and chromium have the same coefficient as copper. The latter represents a "worst case" assumption since the copper coefficient is the lowest of the metals and thus it gives rise to the highest possible particulate metal concentration.

Scale factors have been deduced for these metals as compared with zinc. Because the partition coefficient is a measure of the ratio of the dissolved metal to the particulate it can be seen that of the metals for which equilibrium partition coefficients are known cadmium is the most soluble and copper the least soluble.

The scale factors shown in Table 3.3(g) can be applied to the concentration contour plots for zinc to obtain results for the other metals.

Table 3.3(g)
Scale Factors for Other Metals

Metal	Scale factor (adsorbed)	Scale factor (dissolved)
Zinc	1	1
Cadmium	.004	.16
Copper	.7	.11
Nickel	.18	.65
Lead	.32	.45
Mercury	.07	.10
Arsenic	.26	.04
Chromium	1.60	.25

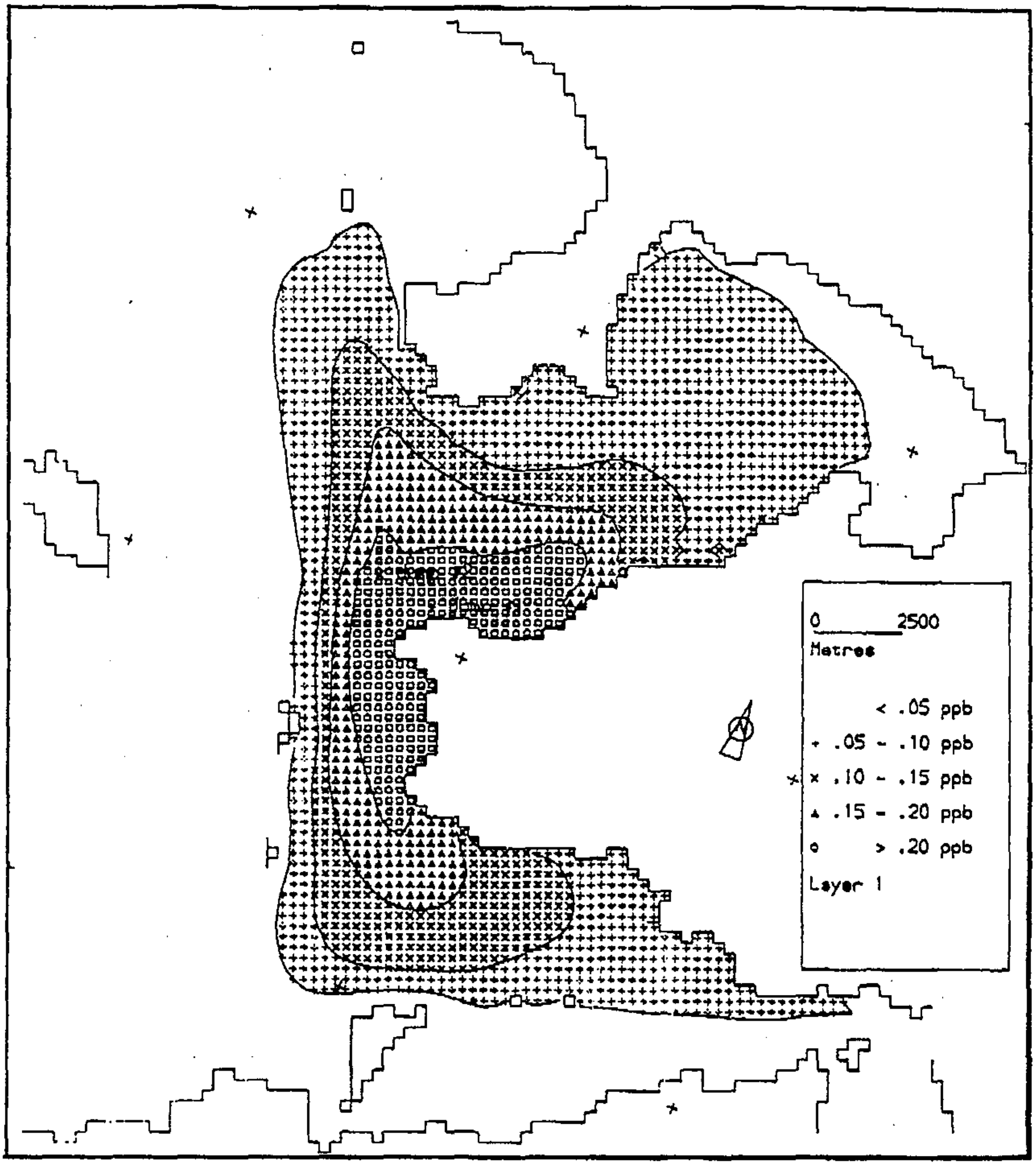

Figure 3.3(a)
Black Point Heavy Metal Study Maximum Dissolved Metal (zinc) Dry Neap Tide (Layer 1)

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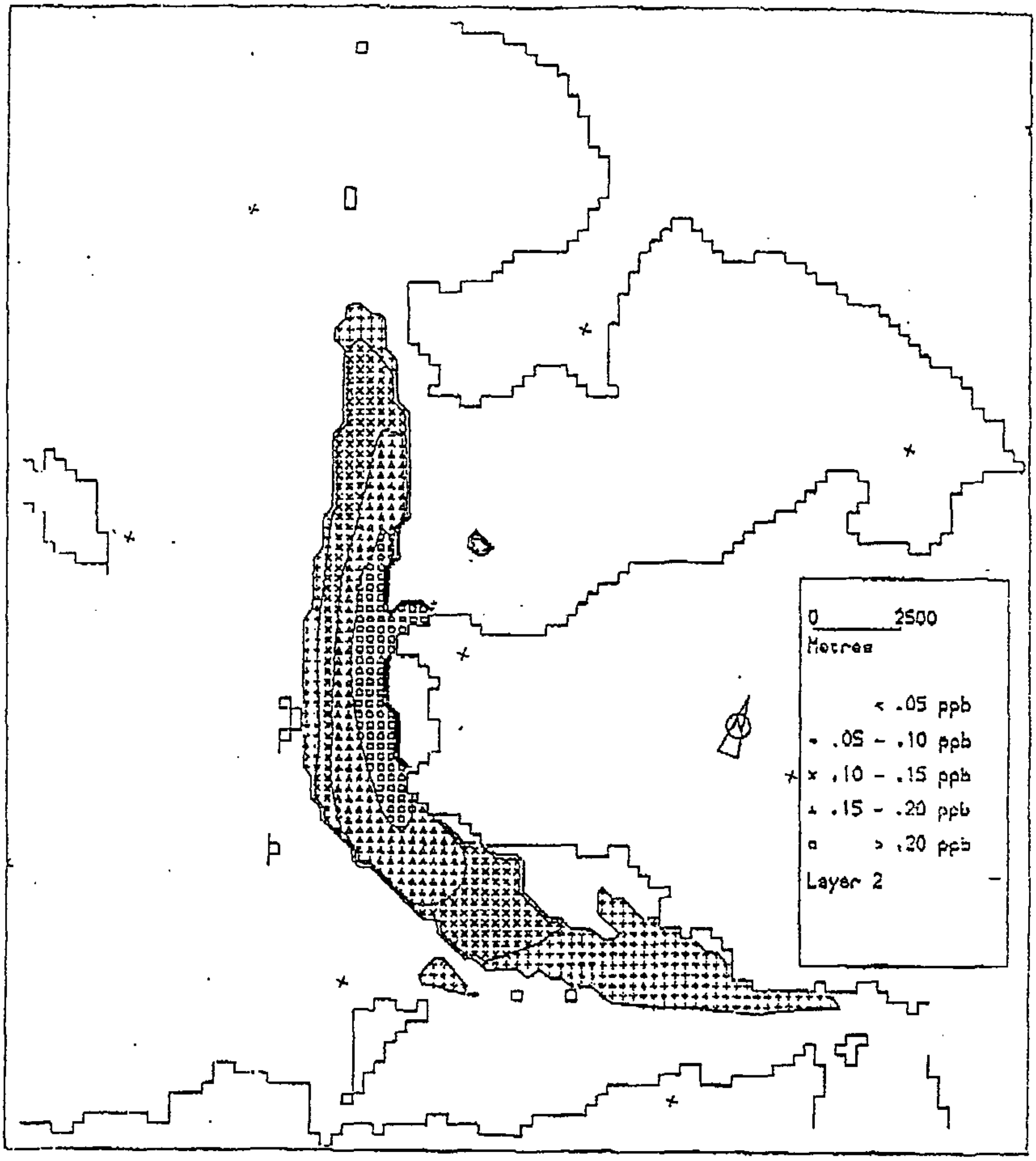

Figure 3.3(b)
Black Point Heavy Metal Study Maximum Dissolved Metal (zinc) Dry Neap Tide (Layer 2)

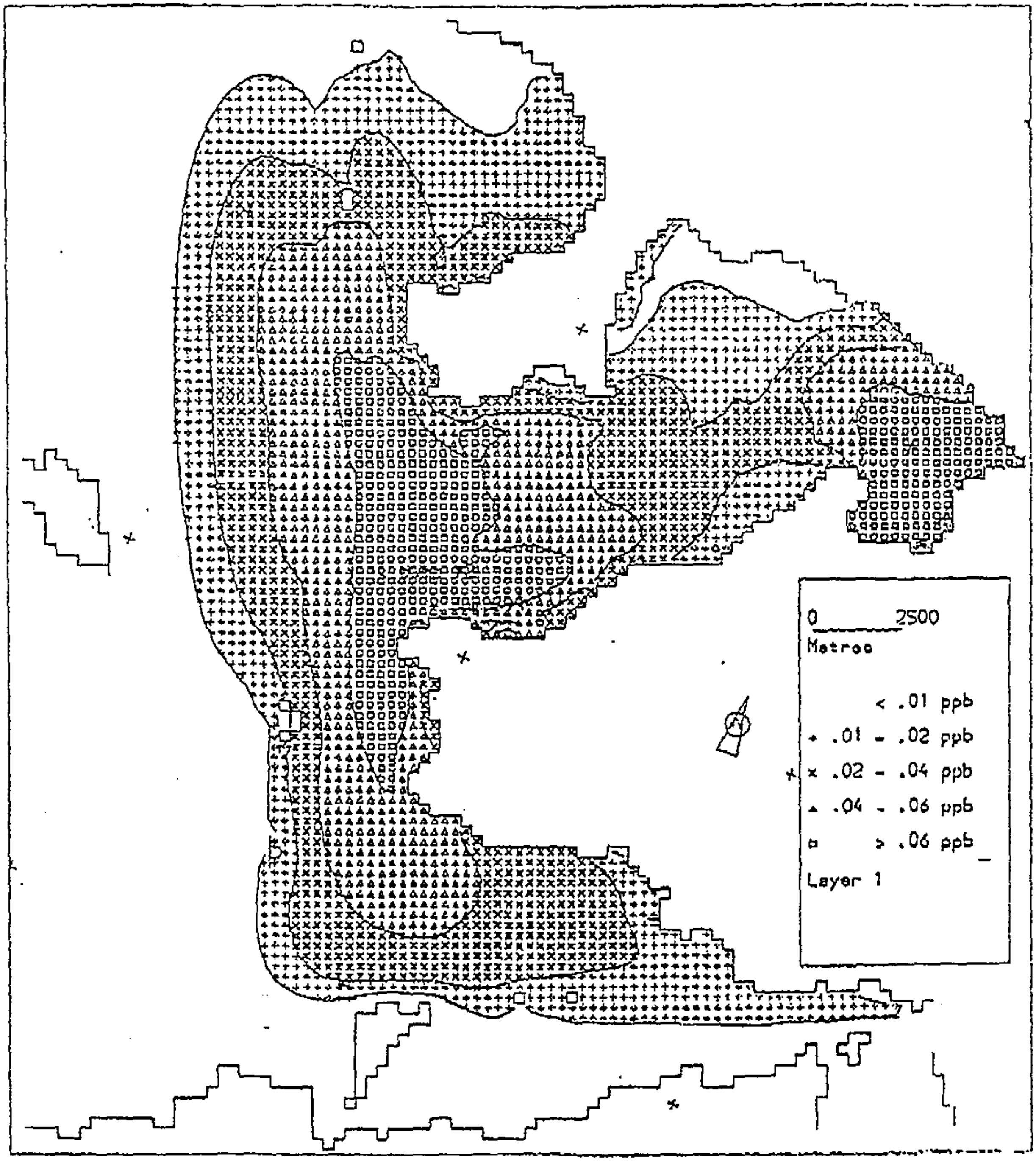

Figure 3.3(c)
Black Point Heavy Metal Study Maximum Adsorbed Metal (zinc) Dry Heap Tide (Layer 1)

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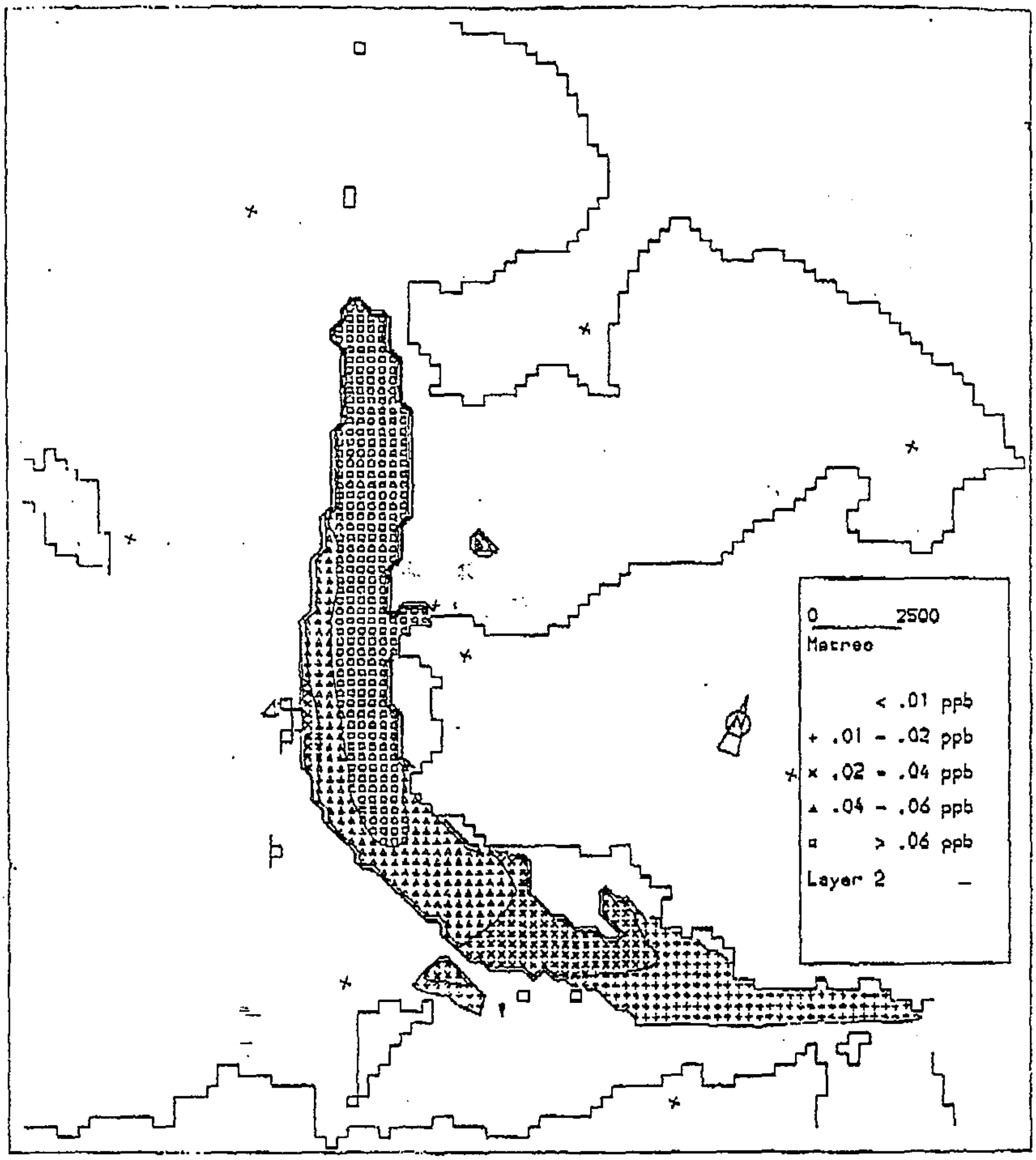

Figure 3.3(d)
Black Point Heavy Metal Study Maximum Adsorbed Metal (zinc) Dry Heap Tide (Layer 2)

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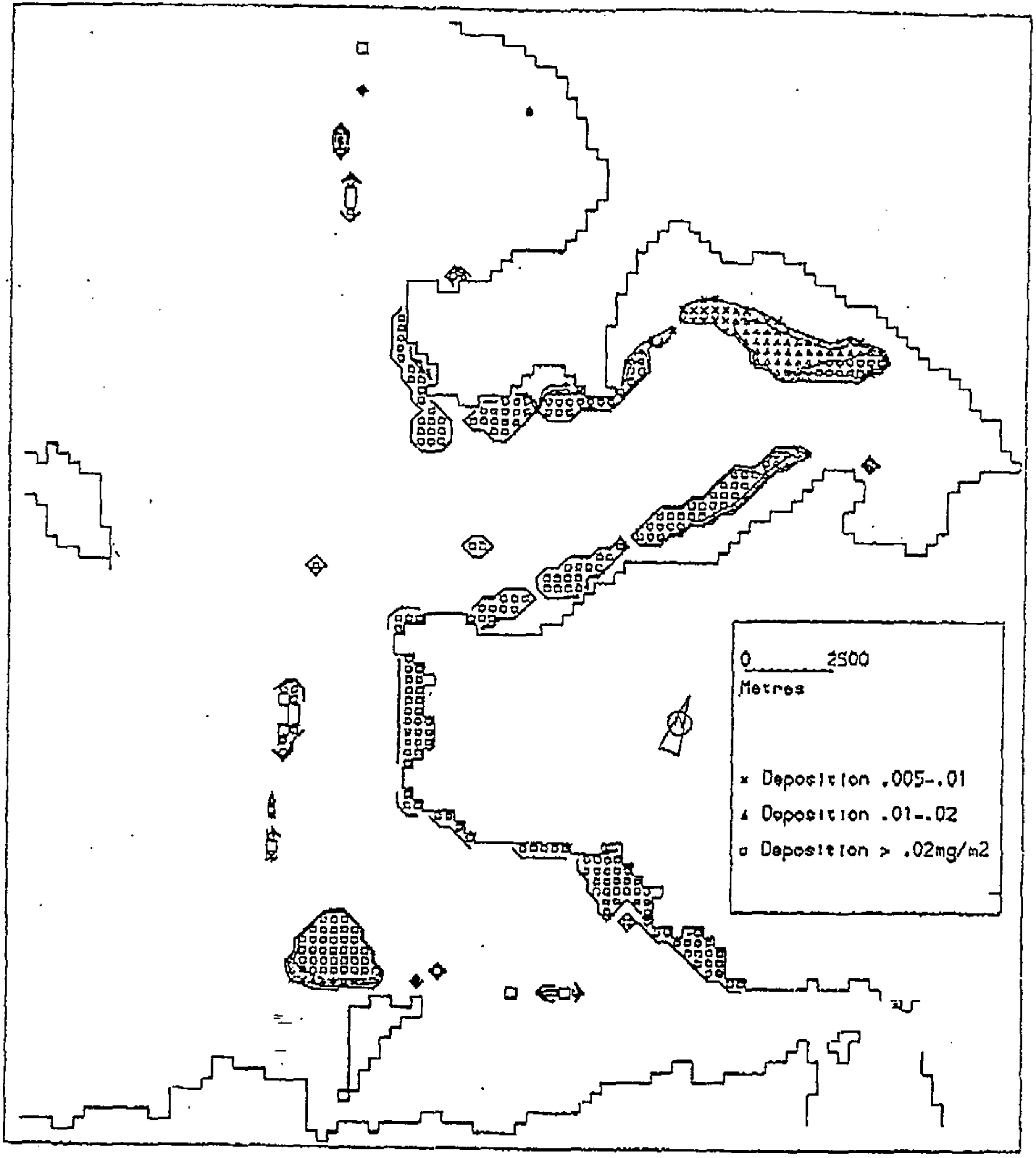

Figure 3.3(e)
Black Point Heavy Metal Study Net change in simulated metal deposits/25 hrs Dry Season Neap Tide

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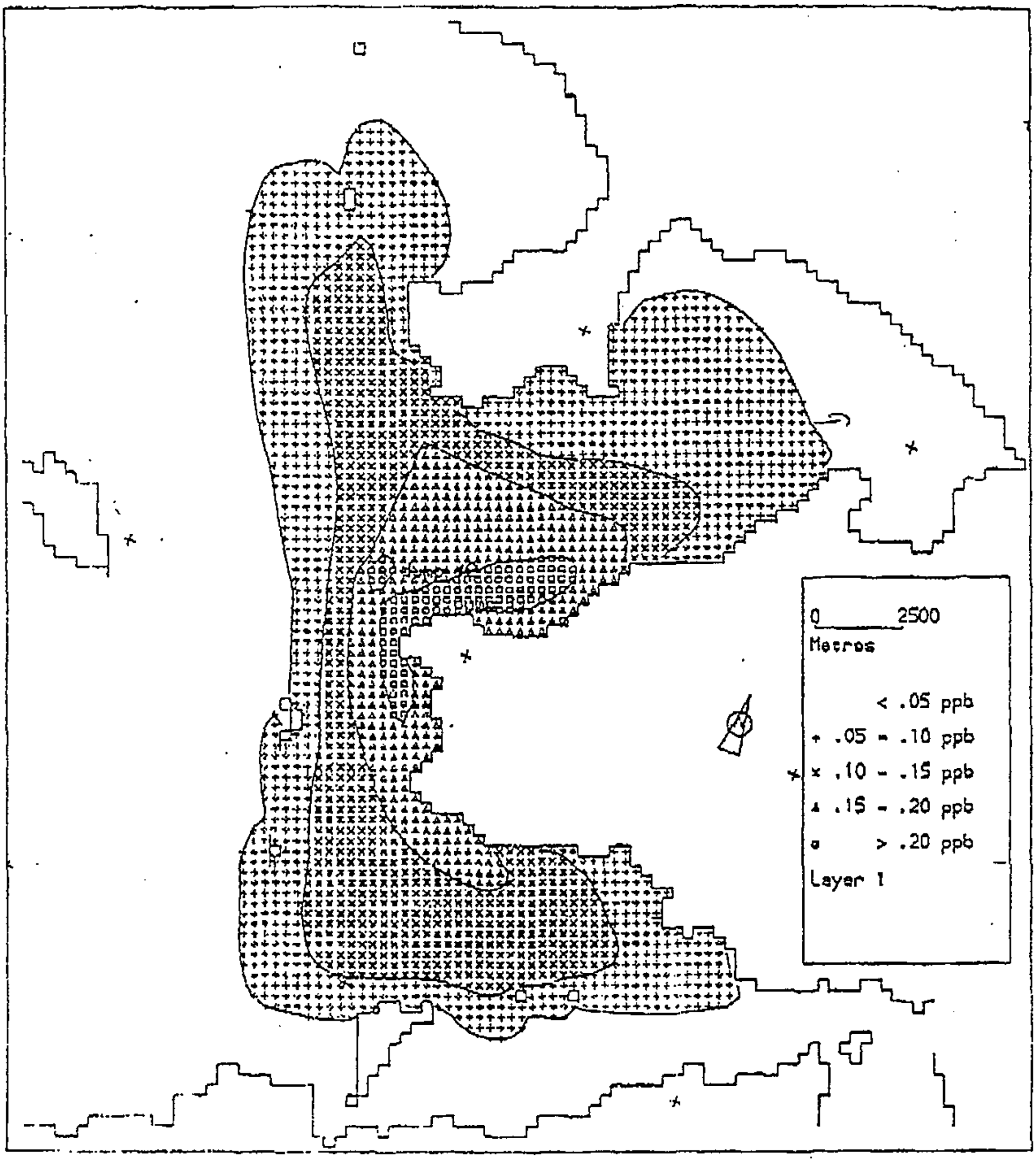

Figure 3.3(f)
Black Point Heavy Metal Study Maximum Dissolved Metal (zinc) Dry Spring Tide (Layer 1)

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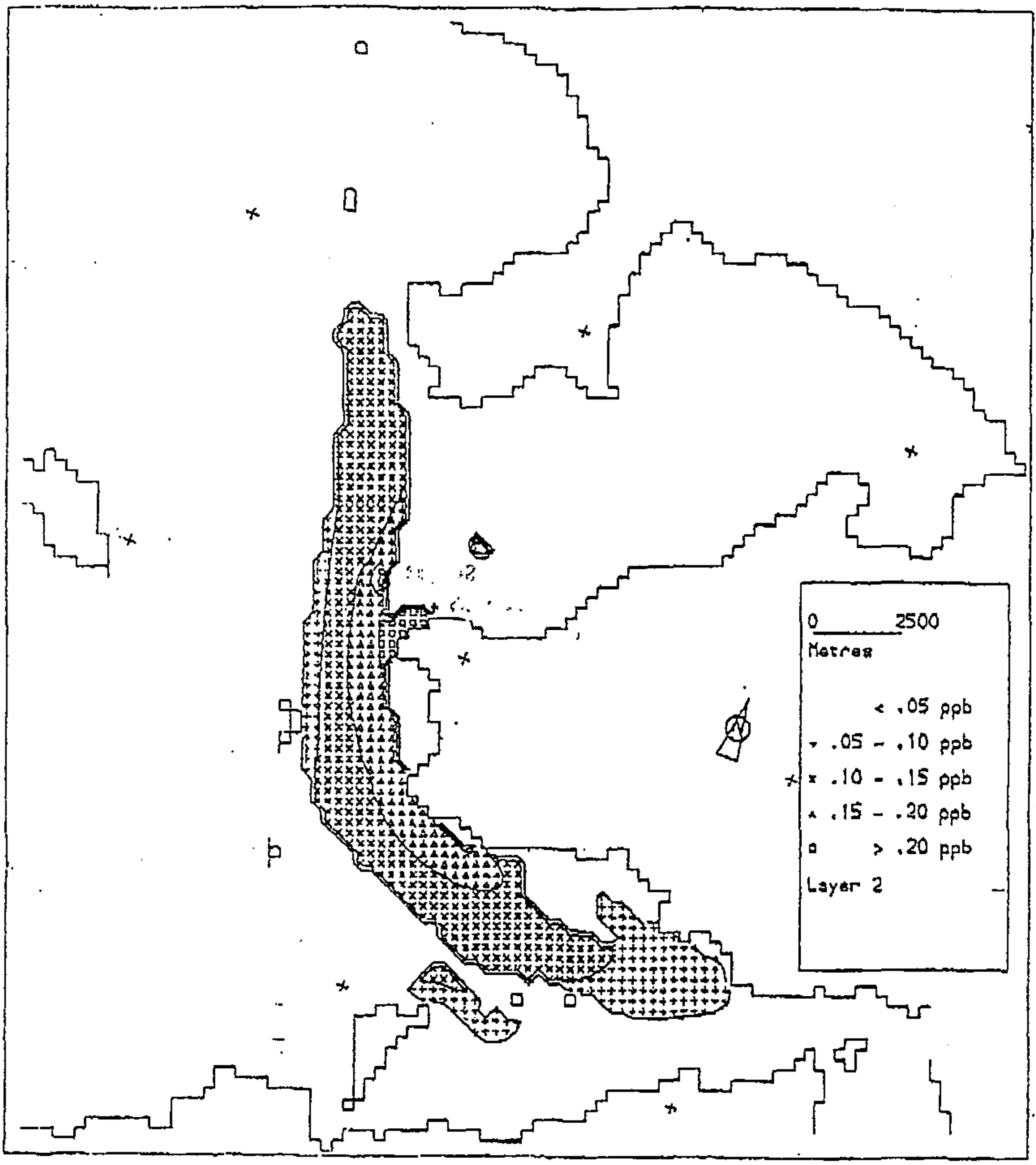

Figure 3.3(g)
Black Point Heavy Metal Study Maximum Dissolved Metal (zinc) Dry Spring Tide (Layer 2)

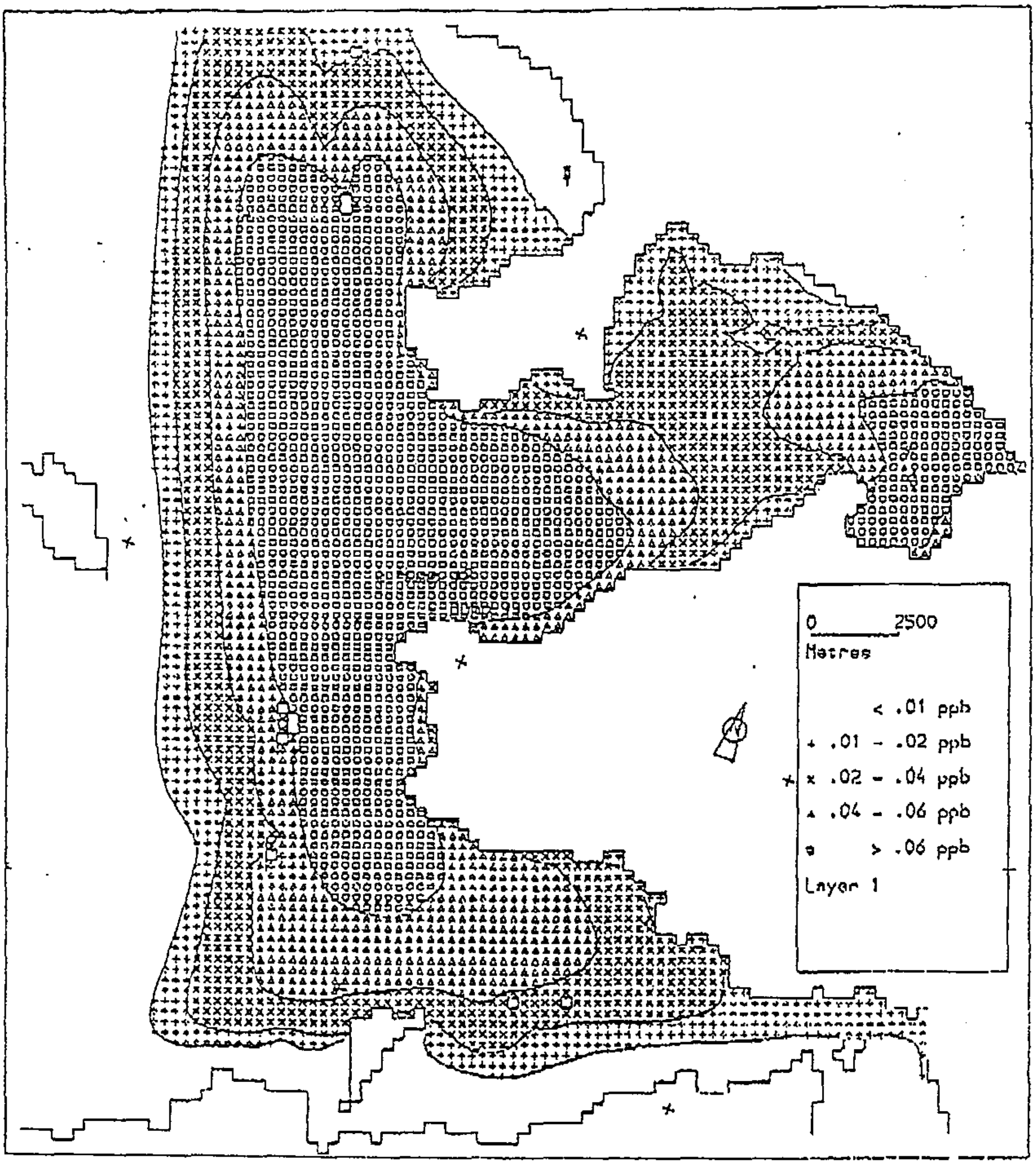

Figure 3.3(h)
Black Point Heavy Metal Study Maximum Adsorbed Metal (zinc) Dry Spring Tide (Layer 1)

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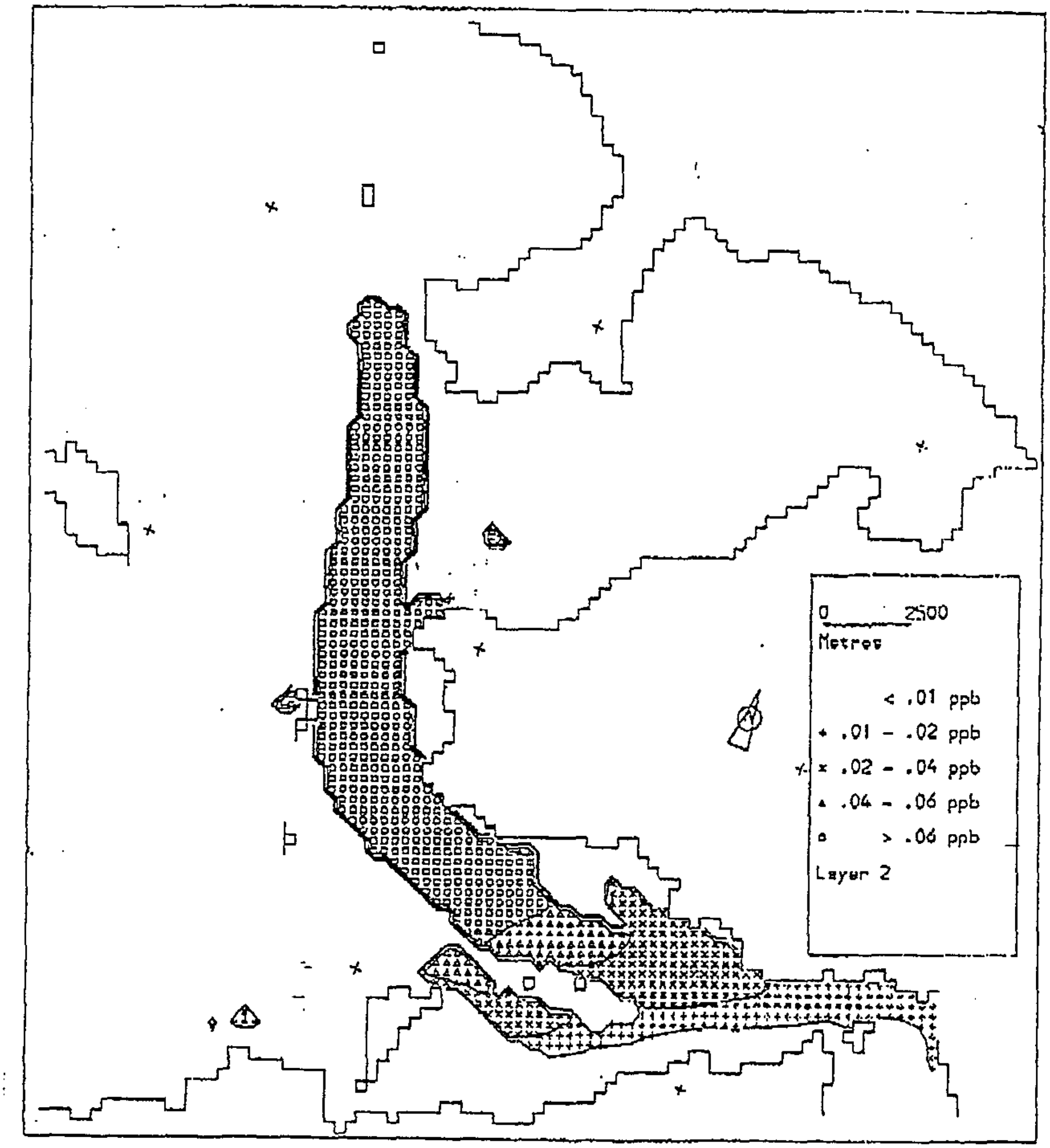

Figure 3.3(i)
Black Point Heavy Metal Study Maximum Adsorbed Metal (zinc) Dry Spring Tide (Layer 2)

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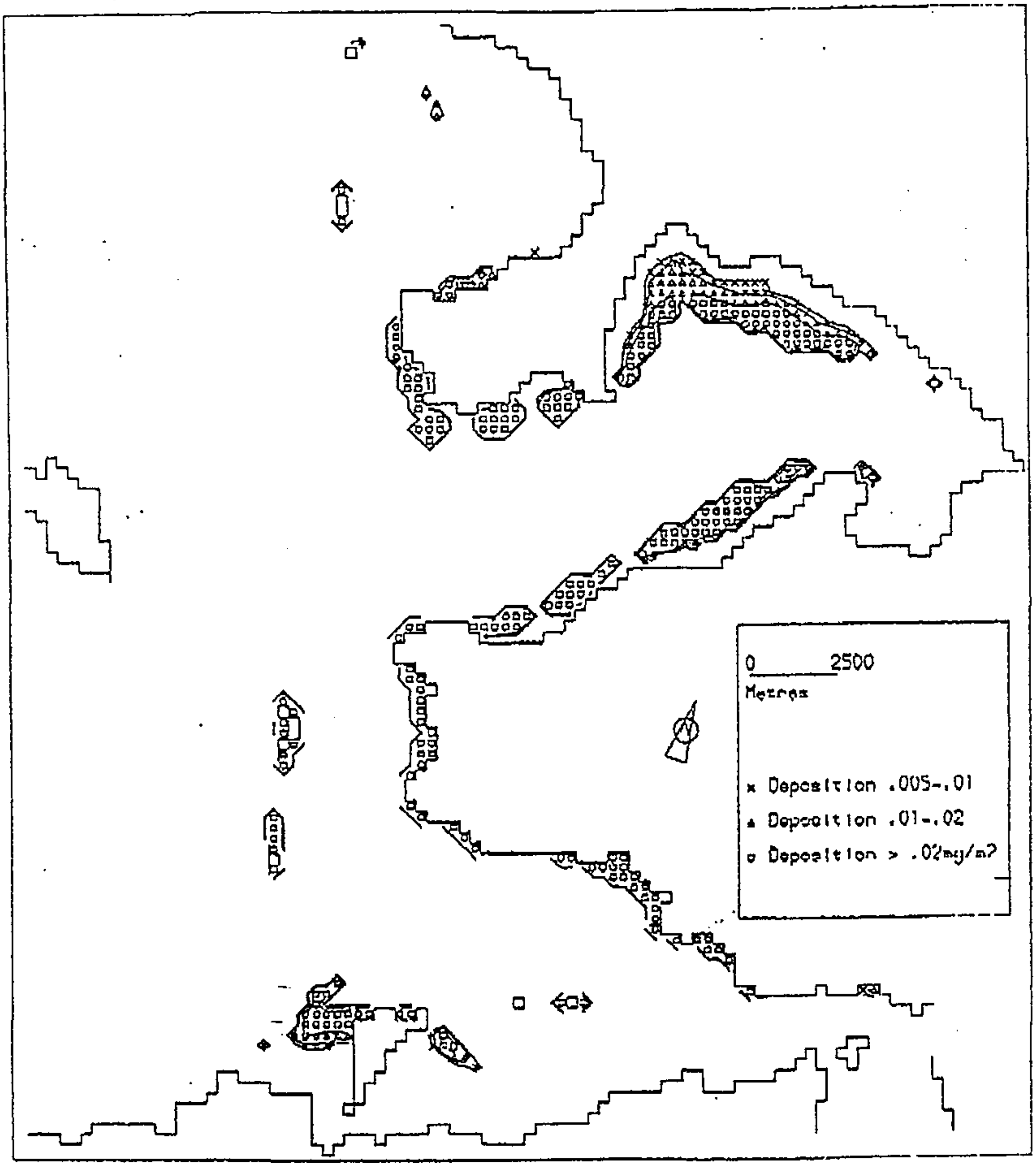

Figure 3.3(j)
Net change in simulated metal deposits/24 hrs
Dry Season Spring Tide

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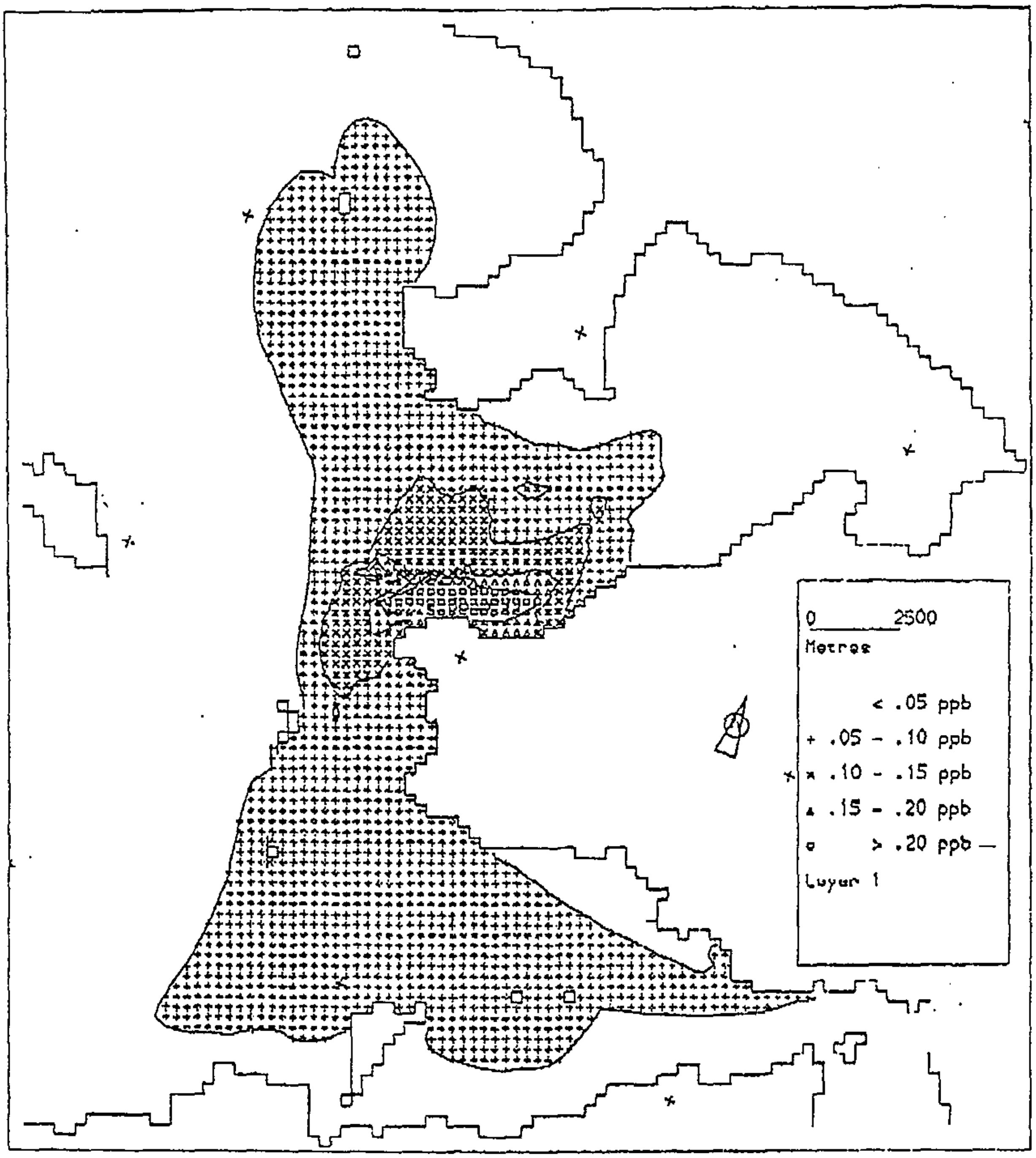

Figure 3.3(k)
Black Point Heavy Metal Study Maximum Dissolved Metal (zinc) Wet Spring Tide (Layer 1)

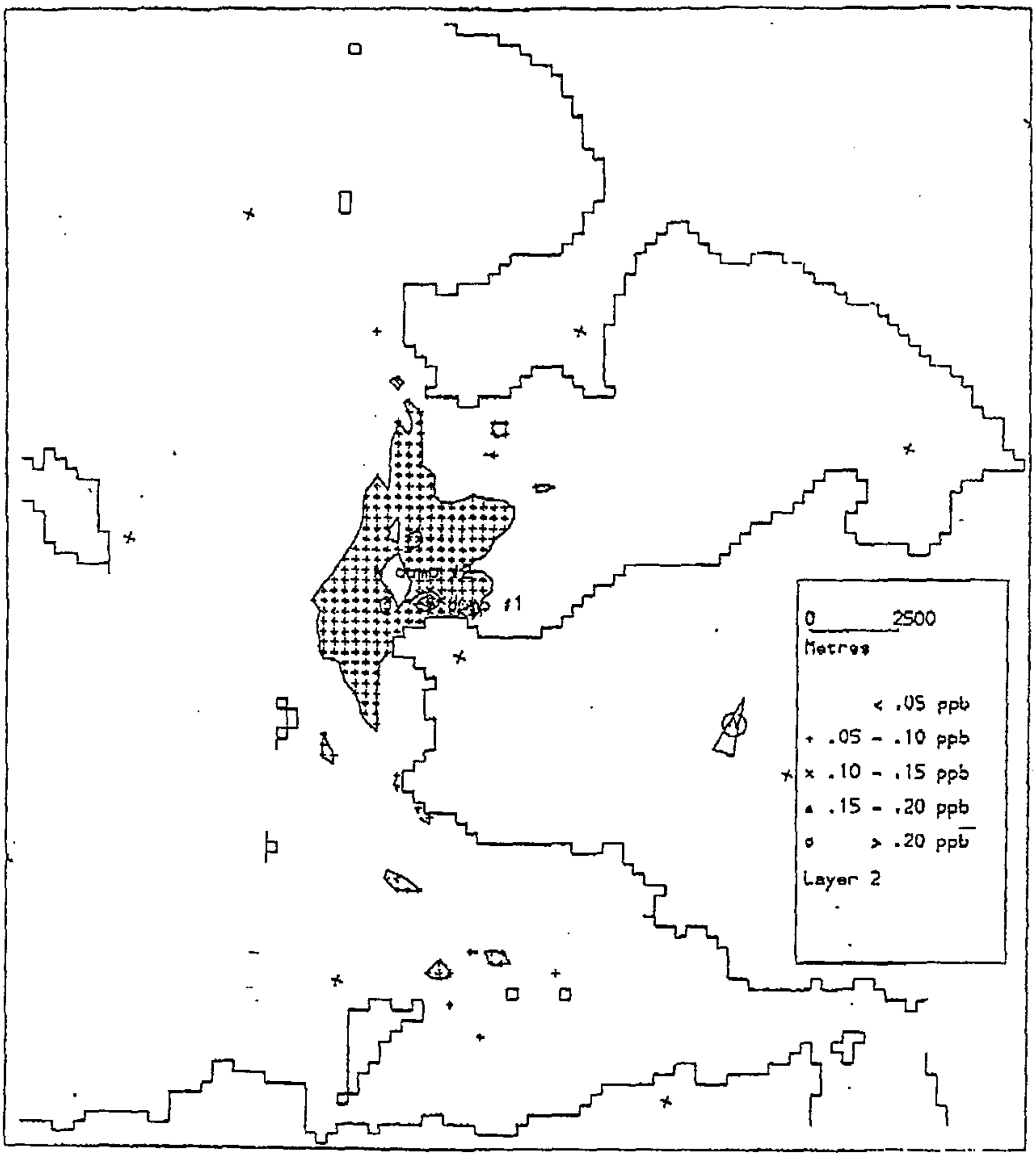

Figure 3.3(l)
Black Point Heavy Metal Study Maximum Dissolved Metal (zinc) Wet Spring Tide (Layer 2)

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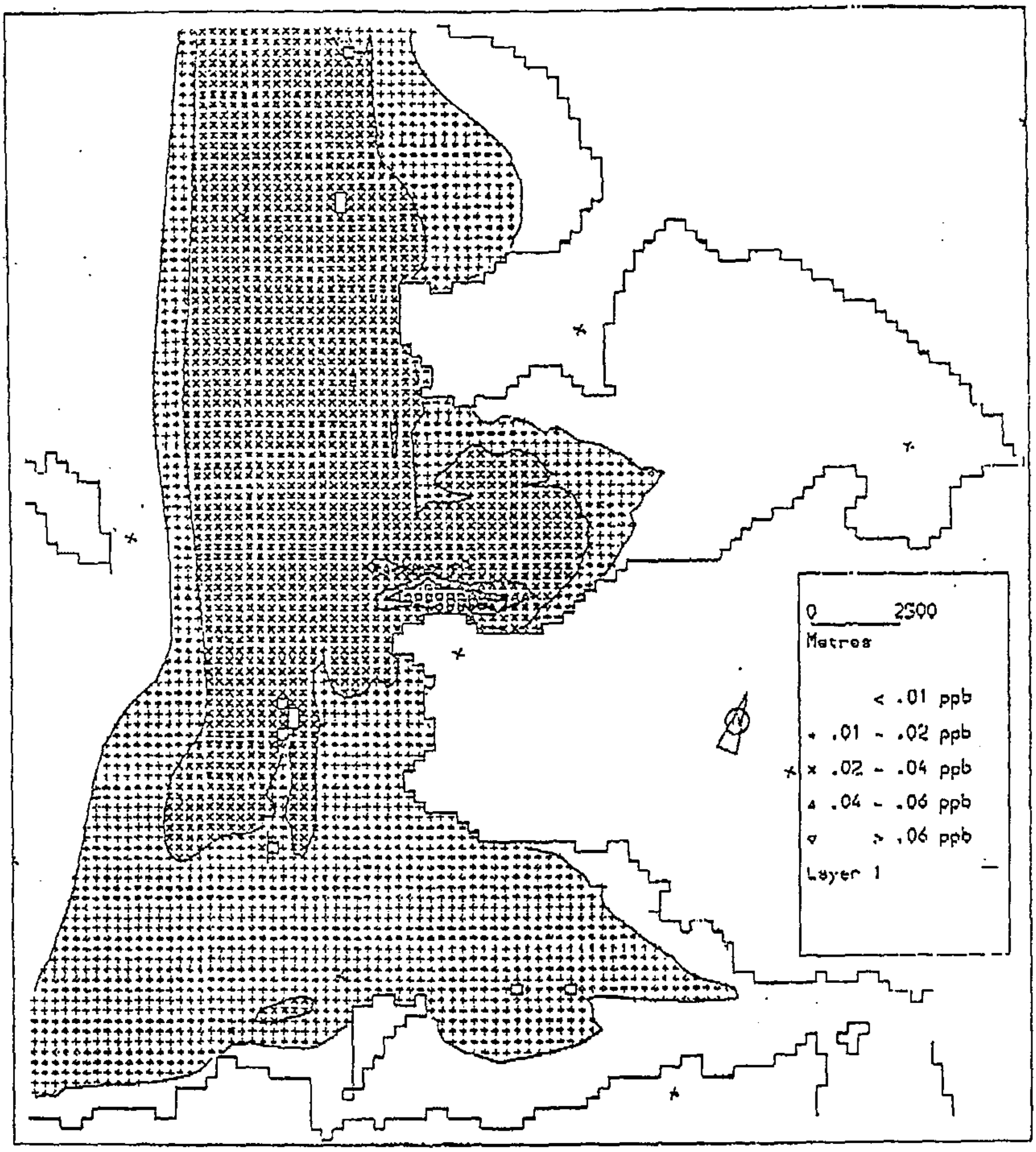

Figure 3.3(m)
Black Point Heavy Metal Study Maximum Absorbed Metal (zinc) Wet Spring Tide (Layer 1)

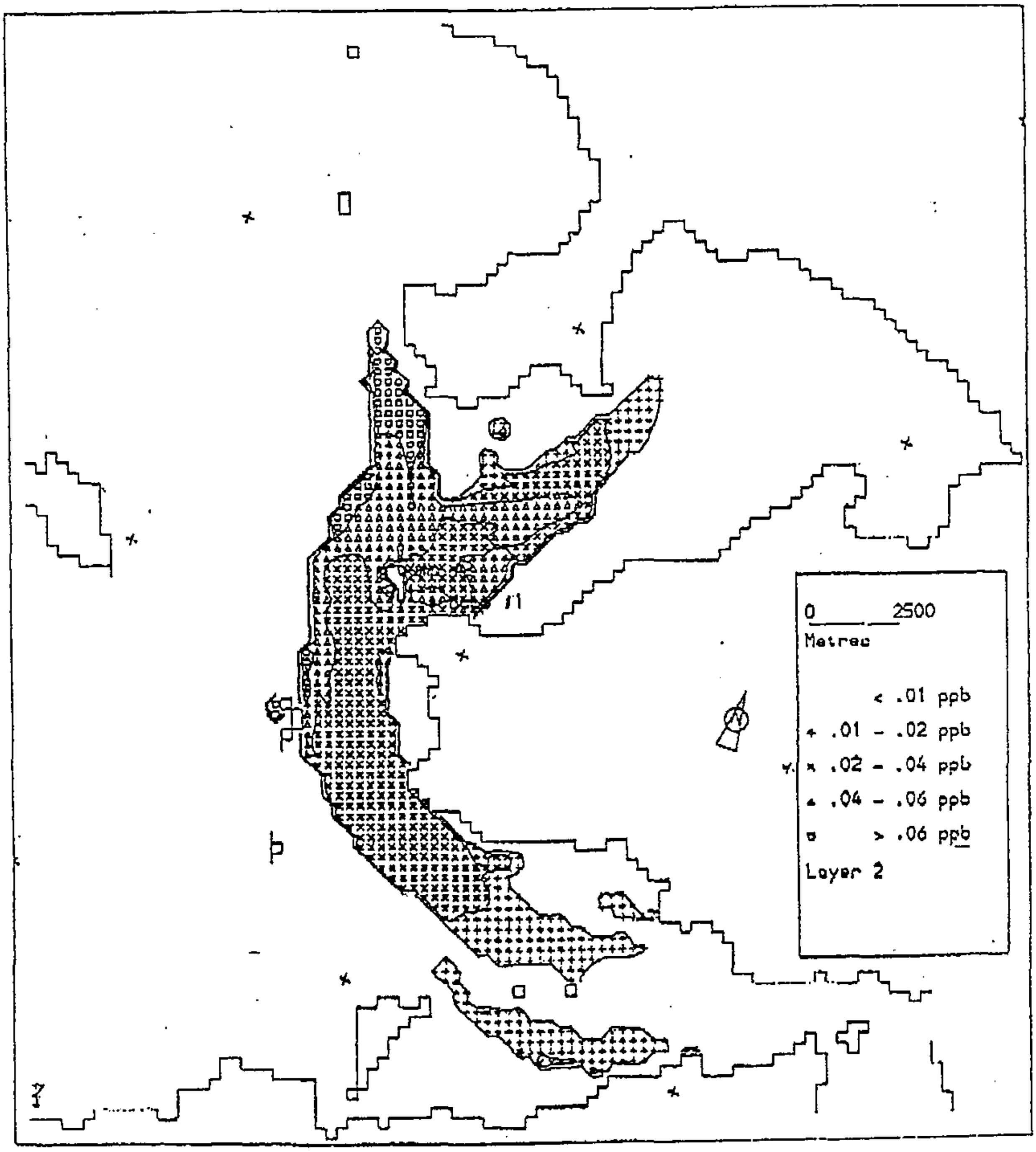

Figure 3.3(n)
Black Point Heavy Metal Study Maximum Absorbed Metal (zinc) Wet Spring Tide (Layer 2)

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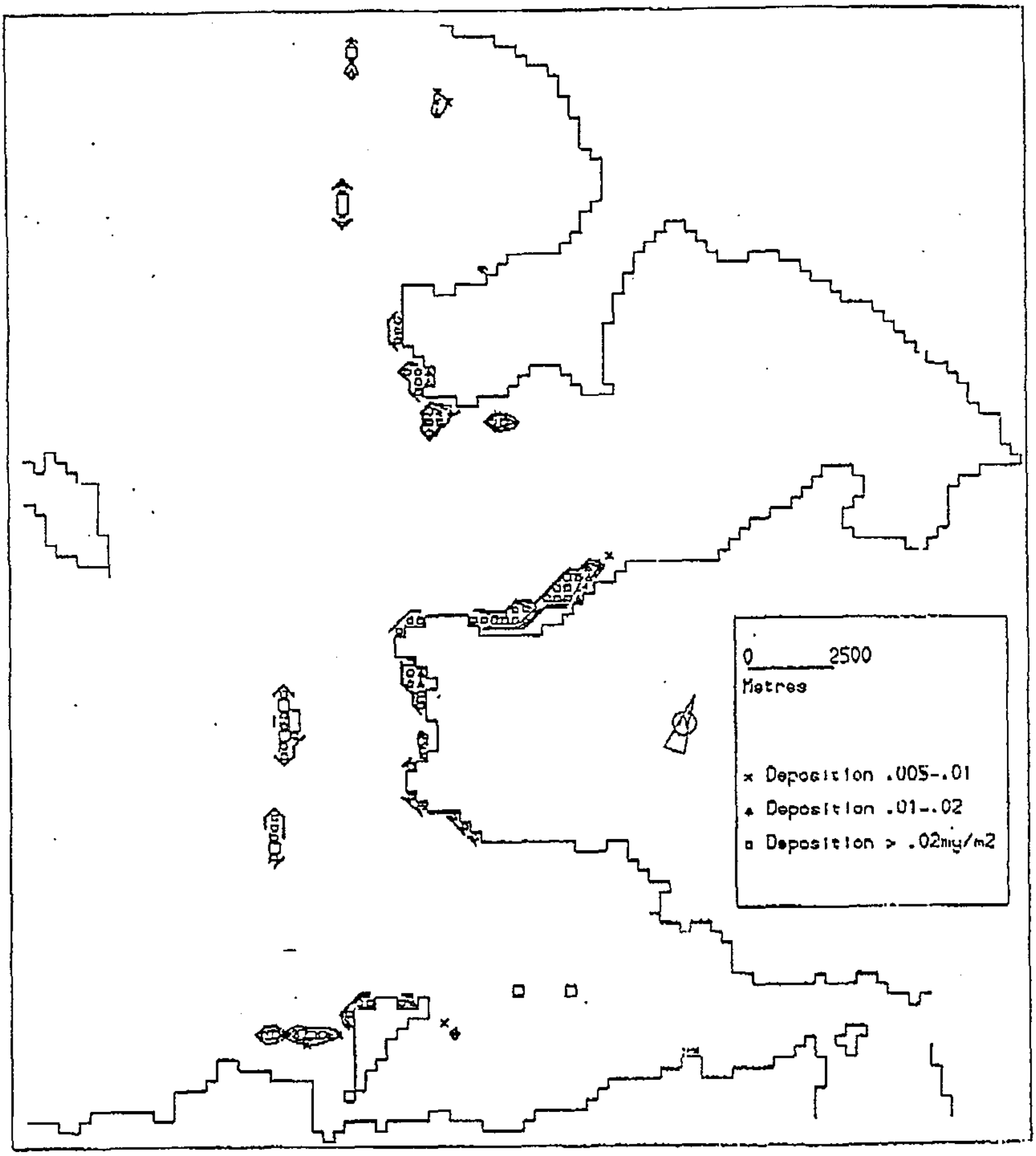

Figure 3.3(o)
Net change in simulated metal deposits/25 hrs
Wet Season Spring Tide

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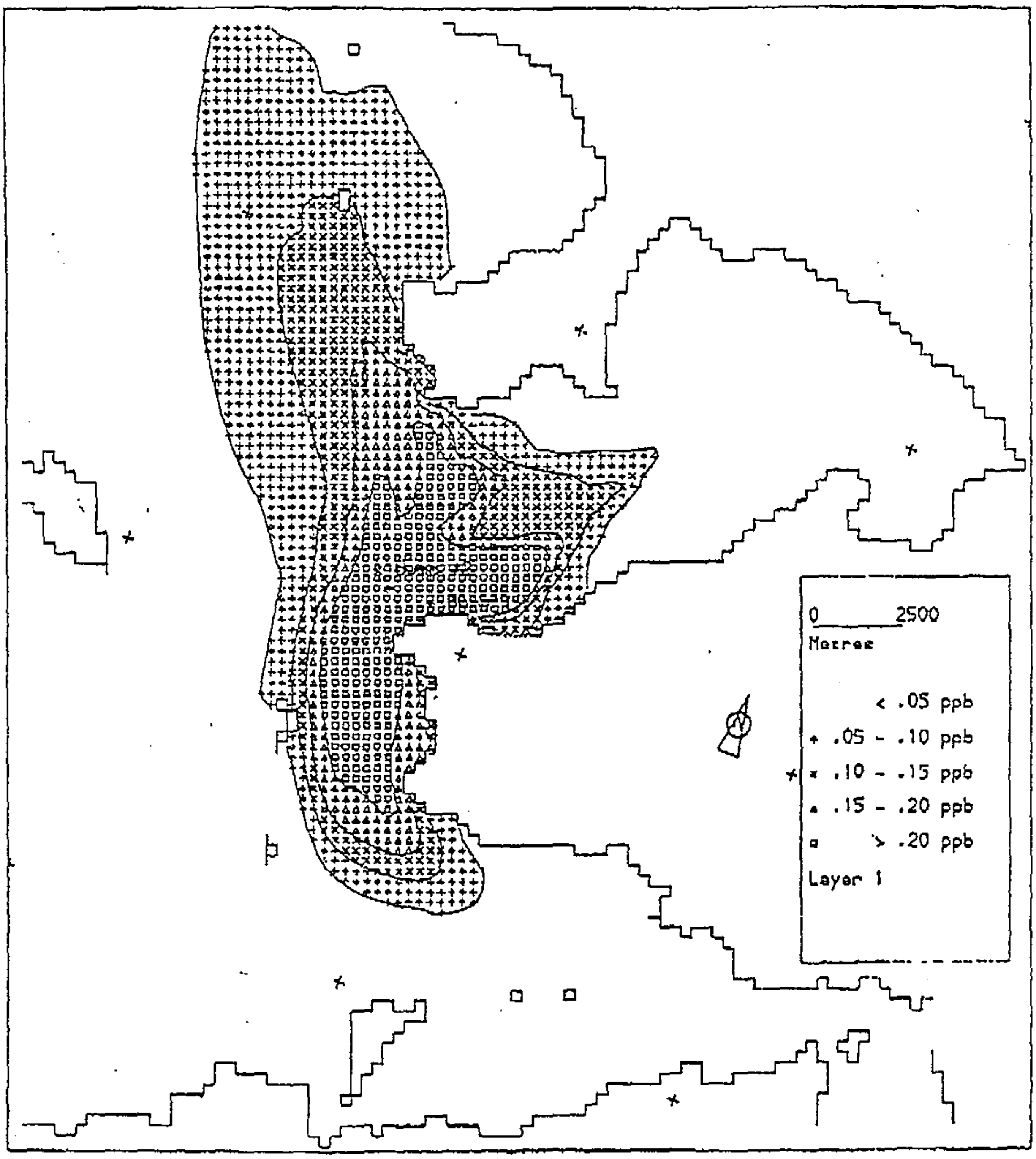

Figure 3.3(p)
Black Point Heavy Metal Study Maximum Dissolved Metal (zinc) Wet Neap Tide (Layer 1)

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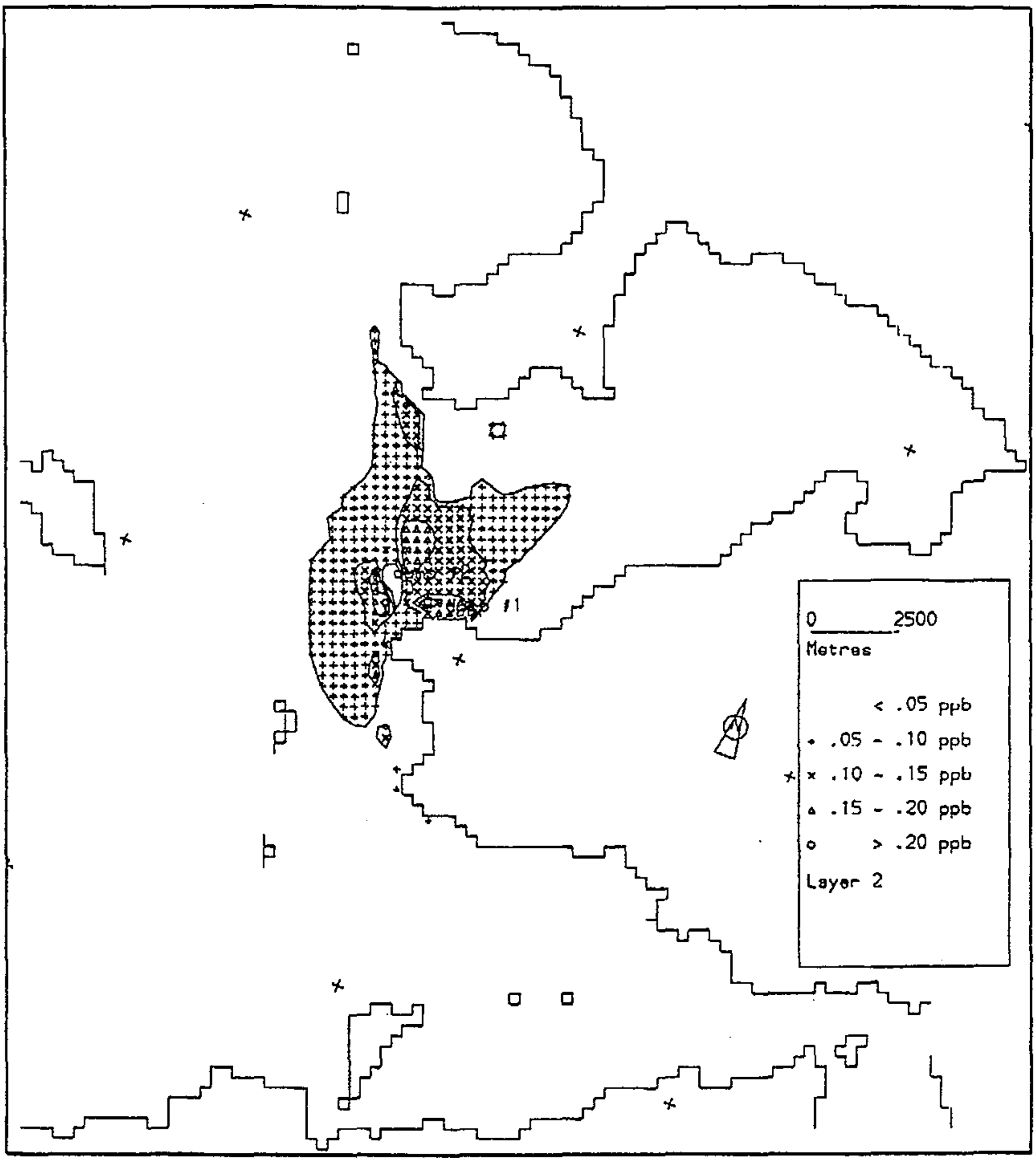

Figure 3.3(q)
Black Point Heavy Metal Study Maximum Dissolved Metal (zinc) Wet Neap Tide (Layer 2)

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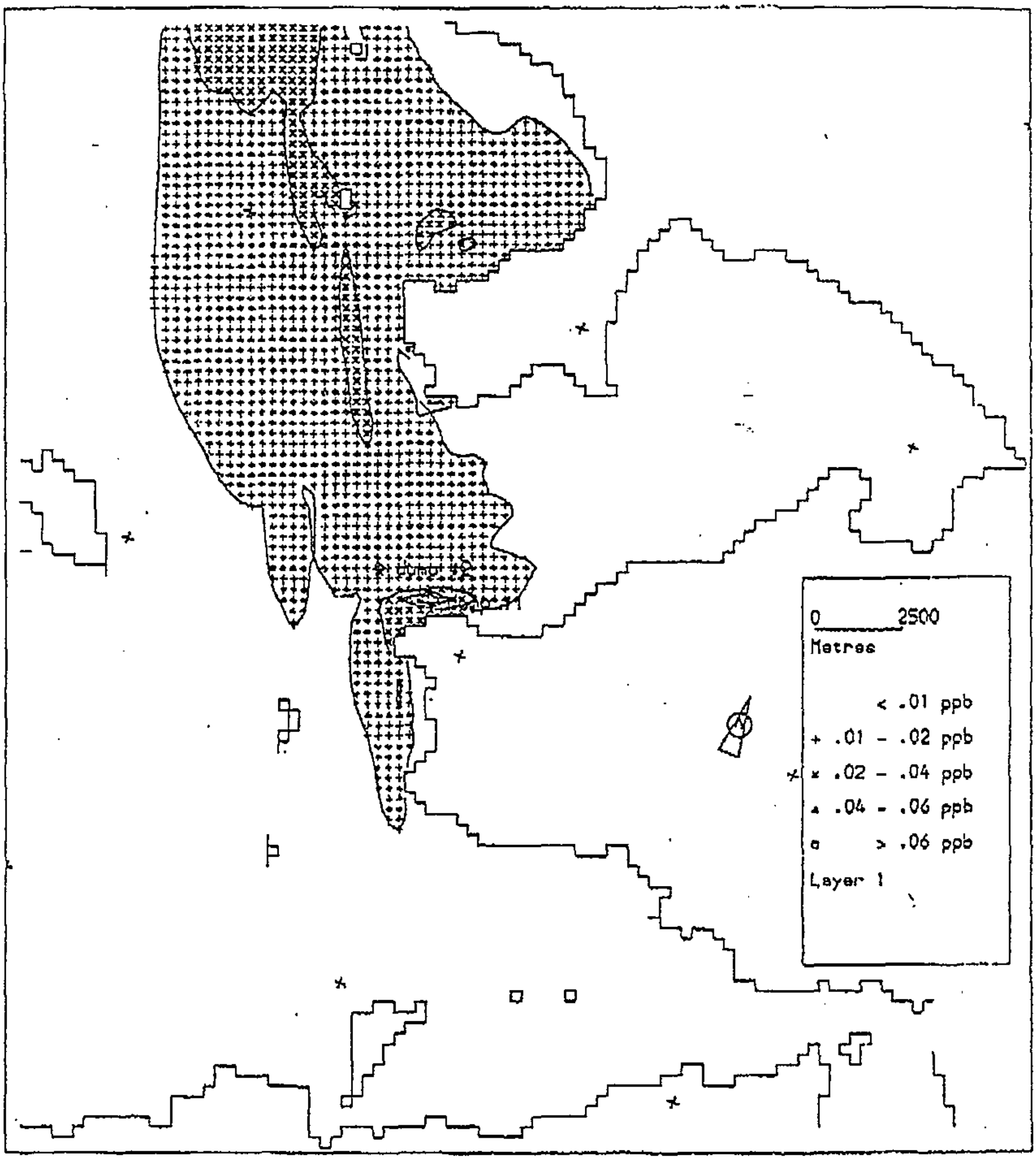

Figure 3.3(r)
Black Point Heavy Metal Study Maximum Absorbed Metal (zinc) Wet Neap Tide (Layer 1)

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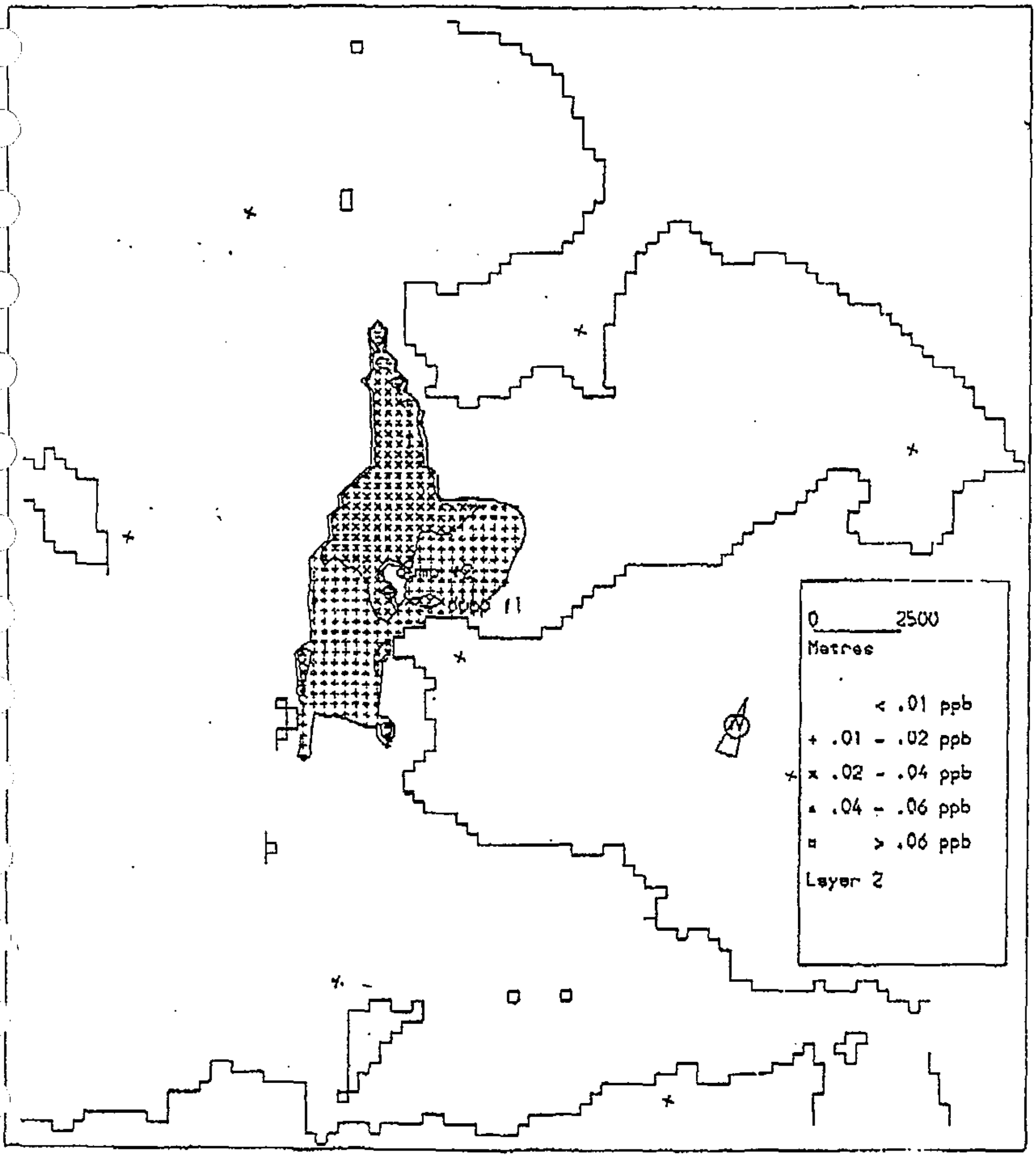

Figure 3.3(s)
ack Point Heavy Metal Study Maximum Absorbed Metal (zinc) Wet Neap Tide (Layer 2)

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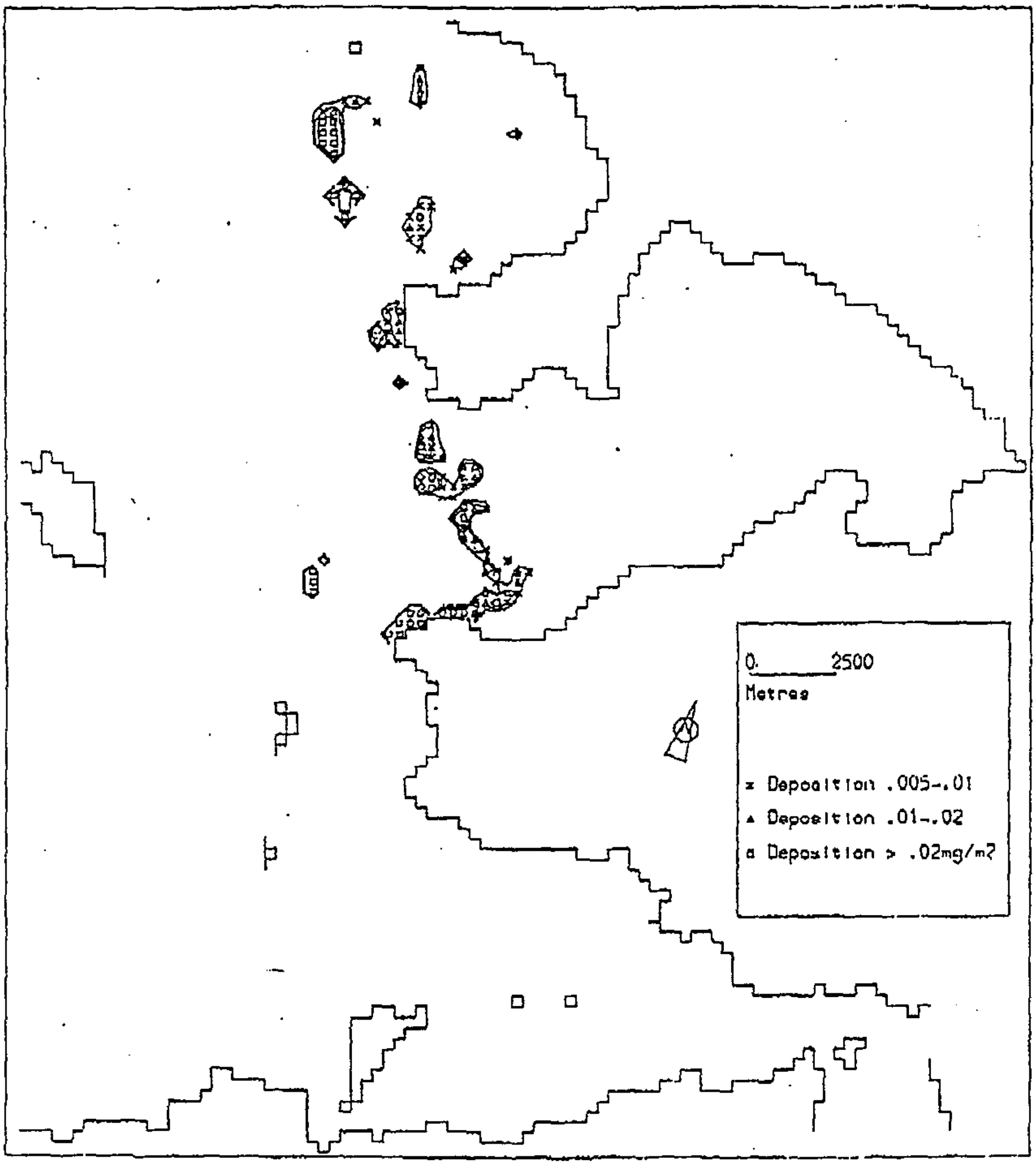

Figure 3.3(t)
Net change in simulated metal deposits/25 hrs
Wet Season Spring Tide

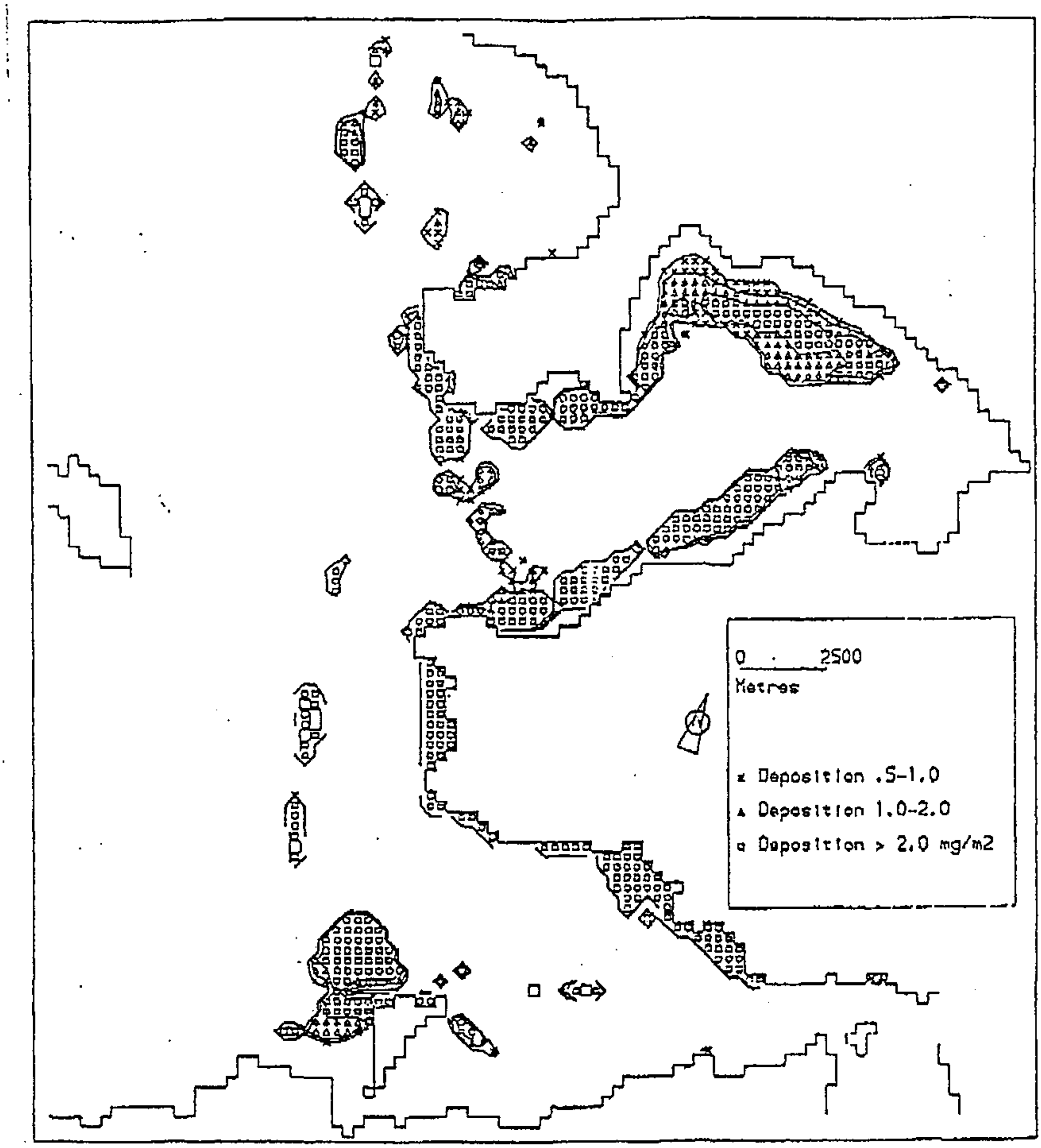

Figure 3.3(u)
Net change in simulated metal deposits Over a year

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These scale factors apply to the results for zinc to give the equivalent results for other metals. The scale factor for adsorbed metal applies also to metal deposits as they are a comparatively small proportion of the total metal discharged.

The modelling of the metal dispersion under worst case conditions shows the greatest net change in simulated zinc deposits at any location over a year to be slightly in excess of 2 mg/m^2 of sediment (see Figure 3.3(u)). Thus by extrapolation the following net changes in deposition rates would apply for the other metals at the equivalent location:

- Cd: 0.008 mg/m^2/yr;
- Cu: 1.4 mg/m^2/yr;
- Ni: 0.36 mg/m^2/yr;
- Pb: 0.64 mg/m^2/yr;
- Hg: 0.14 mg/m^2/yr;
- As: 0.52 mg/m^2/yr;
- Cr: 3.2 mg/m^2/yr.

It should be noted however, that metal deposits over most of the study area are predicted to be substantially lower than these figures.

3.3.6 *Trace Metal Effects on Marine Biota*

For the metals of interest, (see Section 3.3), i.e. Cd, Pb, Zn, Cr, Cu, Ni and As (and probably Hg) the discharge concentrations (on average) will typically lie within the concentration ranges presently observed in the receiving waters for these metals. The far field modelling results show that at varying distances from the outfall the contribution of the LTPS to concentrations of these metals will be negligible. This is clearly illustrated in Figure 3.3b for zinc where it can be seen that due to elongation of the plume, concentrations at 0.2 ppb[1] above ambient are limited to within 1,000–3,000m of the LTPS. Figures 3.3(c)–(t) show how the distances can vary for different layers, tidal conditions and seasonal factors. Although increases in the loads of trace metals to natural water bodies are generally undesirable, the effects on marine biota of the increases in Cu, Ni and As are unlikely to be significant, even at the mouth of the LTPS outfall.

However, Cd, Cr, Pb and Zn discharge concentrations approach the upper limits of their present concentration ranges in the receiving water. Whilst this is unlikely to result in direct noticeable adverse effects on marine organisms, adsorption of dissolved Cd, Pb and Zn followed by increased deposition rates of these metals may have potential indirect effects, especially to benthic biota. Similar conditions apply to Pb.

In Section 3.3.5, summarising the result of the modelling study, it has been shown that the maximum localised metal deposition rates are likely to be as follows:

- Zn: 2 mg/m^2/yr;
- Cd: 0.008 mg/m^2/yr;
- Cu: 1.4 mg/m^2/yr;
- Ni: 0.36 mg/m^2/yr;
- Pb: 0.64 mg/m^2/yr;
- Hg: 0.14 mg/m^2/yr;
- As: 0.52 mg/m^2/yr;
- Cr: 3.2 mg/m^2/yr.

---

[1] 0.2 ppb represents approximately a 2% increase on the existing mean baseline zinc concentration.

These peak deposition rates can be placed in context by comparing them with estimates of the present deposition rates in the Deep Bay area. This can be achieved based on the following:

- a deposition rate of sediment in the order of 1.1 mm/yr in places where it accretes (i.e. in places where the model predicts a net deposition of trace metal) (see e.g. Binnie and Partners, 1985).
- the sediment trace metal concentrations given in Table 3.2.6 (far field operational effluent impact monitoring sites) are representative of the present trace metal concentrations of suspended solids;
- the density of sand and clay (which are likely to predominate in these sediments) varies between 1.5 and 2.8 g/cm^3 (Handbook of Chemistry and Physics), so allowing for a pore water content of approximately 40% the deposited sediment will have an overall density of approximately 2 g/cm^3.

Therefore, a deposition rate of 1.1 mm/yr sediment gives a total volume of 1,100 cm^3 sediment per square metre per year; or approximately 2.2 kg/m^2/yr.

From Table 2.8(a), mean metal concentrations in the sediments are:

- Cd - 0.07 (range 0.01 - 0.1) mg/kg;
- Pb - 27 (range 19 - 33) mg/kg;
- Zn - 45 (range 5 - 72) mg/kg;
- Cu - 37.5 (range 1 - 65) mg/kg;
- Hg - 0.21 (range 0.1 - 0.55) mg/kg;
- Cr - 10.2 (range 0.4 - 15.7) mg/kg;
- As - 0.80 (range 0.1 - 1.3) mg/kg;
- Ni - 14.75 (range 1 - 23.6) mg/kg.

These yield the following background metal deposition rates:

- 0.15 mg/m^{2}yr Cd (range 0.02 - 0.2);
- 59 mg/m^{2}yr Pb (range 41 - 73);
- 99 mg/m^{2}yr Zn (range 11 - 158);
- 82.5 mg/m^{2}yr Cu (range 2.2 - 143);
- 0.46 mg/m^{2}yr Hg (range 0.2 - 1.2);
- 22.4 mg/m^{2}yr Cr (range 0.9 - 34.5);
- 1.8 mg/m^{2}yr As (range 0.2 - 2.9);
- 32.5 mg/m^2 yr Ni (range 2.2 - 52).

Table 3.3(h) gives a comparison between the estimated present metal deposition rates and the incremental increases predicted by the modelling study.

Table 3.3(h)
Comparison between estimated present metal deposition rate and predicted contribution from the LTPS (mg/m²/yr)

Metal	Present Deposition Rate	Predicted Contribution From LTPS	Percentage increase
Cd	0.15	0.008	5.3%
Pb	59	0.64	1.1%
Zn	99	2.00	2.0%
Cu	37.5	1.4	3.7%
Hg	0.46	0.14	30%
Cr	22.4	2.6	11.6%
As	1.8	0.5	28%
Ni	32.5	0.36	1.1%

The increases predicted in Table 3.3(h) are relatively small, considering the natural variability, except for Hg and As. It should also be noted that the estimated background deposition rate of chromium is likely to be underestimated, since the analysis of chromium in marine sediments generally do not measure all the chromium in the minerals and thus underestimate the concentrations in the sediments.

A further factor, however, is the extent to which the metals contributed by the LTPS are readily bio-available in comparison with metals currently deposited to the sediments in association with particulate material. The metals measured in sediments during the baseline monitoring study are likely to include some refractory, non-reactive and non-bioavailable fractions, whilst the predicted net increase of Cd, Pb and Zn concentrations resulting from the LTPS (i.e. adsorbed metal) is likely to be present in a generally bioavailable form. A more realistic approach, as far as effects on benthic biota are concerned, would be to compare the present rate of bioavailable metal deposition with a predicted net increase in the rate of bioavailable metal deposition. Such comparisons are likely to increase the percentages shown in Table 3.3(h). However, the marine waters and sediments near Deep Bay are heavily influenced by estuarine and pollutant inputs (from anthropogenic sources on both the Hong Kong and Chinese sides of the estuary). For example, whereas in uncontaminated outer estuaries, up to 25% of the Zn and Pb are potentially bioavailable, a far greater proportion of Cd (Luoma, 1990) would be readily extractable in more contaminated sediments (i.e. the percentages can exceed 50%).

However, assuming a conservative, "uncontaminated estuary" percentage figure of 25% of the existing total deposited metal and 100% of the trace metals from the LTPS were readily bioavailable, the percentages in Table 3.3(h) would only increase to 21, 4 and 8% for Cd, Pb and Zn, and 120, 146 and 112% for Hg, Cr and As respectively.

It is generally recognised that for the majority of coastal (and offshore) environments, metal concentrations are commonly below 'effect levels' observed in field and laboratory tests (Langston, 1990). In recent years a variety of sensitive responses (i.e. growth, morphology or reproduction/development) have been observed in marine organisms which have shed some light on the subtle effects of trace metal pollution in marine organisms. However, it is still currently difficult to explain the ecological significance of many of the observed responses. In a major review, Langston (1990) established with the development of a wide range of criteria that the effects of metals on marine organisms are now recognised at much lower levels than were suspected from, for example, earlier LC_{50} studies. Key conclusions of this study were as follows:

- On present evidence Cu and Hg were recognised as the most hazardous metals.
- Organic forms of some metals, especially tributyl-tin, organo-leads etc, have quite severe effects on marine biota.
- For metals such as Cd, Zn, Pb and Cr effects might only be expected in highly contaminated inshore areas, and usually as a result of their joint action.
- As a result of its low toxicity, Ni presents few problems for aquatic organisms and is relatively harmless to marine biota, although it can adversely affect phytoplankton at around five times its background concentration.

However these generic observations on metal effects together with percentage increases in bioavailable metal estimated above need to be viewed in the context of the following:

- the iron content of the LTPS outflow;
- the trace metal interactions that will occur with the iron.

This iron will be deposited as highly amorphous iron oxyhydroxides which provide additional binding sites for trace metals. The increase in concentration would be about 750 mg Fe/kg, which would provide approximately 5 moles of additional binding/kg of sediment, based on the data of Luoma and Davis (1983). Given the typical composition of various forms of iron in sediments, and the total concentration of iron of i.e. 1.3%, the existing amorphous iron oxyhydroxide content can be estimated at 4,000-5,000 mg/kg (Towner, 1984[1]); this would represent about 26-32 moles of binding sites/kg of sediment. Therefore, the LTPS would increase the provision of these binding sites by 15-20%. Langston and Bryan (1984)[2] show that the bioavailability for metals such as Pb, As, Zn and Ni (to a lesser extent Cu and Cr) is dependent on the iron content of the sediments, while for Hg (and to a limited extent Cu) the bioavailability is affected more by organic matter content. Cadmium bioavailability is less dependent on organic or iron oxyhydroxide substrate concentrations. It can be seen, therefore, that with the exception of Hg, the deposition of iron oxyhydroxides will lead to an increase in the binding site concentration of the sediments that exceeds the increases in metal content.

Therefore, for all metals except Hg and Cd, the relative bioavailability of the aggregate metals deposited would be expected to decrease. For Cd, a slight relative increase in bioavailability might occur, although this would not be expected to affect overall uptake by organisms from sediments, especially since the predicted concentrations would be relatively low. For mercury, the provision of organic matter binding sites is important. In isolation, the LTPS will not provide such additional sites, therefore mercury bioavailability would be expected to be enhanced slightly; this is based on the assumption that less preferred weaker/sites would be occupied. However, the sediments in the region have relatively high organic carbon contents and this may be expected to result in a large excess of sites being present, and therefore the relative increase in bioavailability would be small (<10%). When the additional input of organic carbon from the NWNT sewer, currently under construction, is taken into account, the increase in bioavailability is reduced still further, and is thus unlikely to be significant. Thus, bioavailable

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[1] PhD Thesis University of Liverpool

[2] Langston W.J. and Bryan, G.W. (1984) The relationships between metal speciation in the environment and bioaccumulation in Aquatic organisms, Kramer CJM and Drinker, J.C. (eds) Complexation of Trace Metals in Natural Waters, Martins Nilhoff/Dr W. Junk Publishers, The Hague, 1984.

mercury would occur in similar proportion to total mercury as occurs presently.

Generalising the effects of metal pollution on the marine environment must be approached with caution. This is primarily due to the large number of environmental and physiological factors which can influence the toxicity effects of metals; most notably the wide range of tolerances which can be displayed by different marine species. In addition, the indirect effects which might be caused by the elimination, or reduction in numbers, of sensitive species (which may be predators on, or the principal food source for other species) could possibly have a greater significance for marine communities than is indicated in the toxicity responses of single species.

An assessment of impacts based on toxicity responses to individual metals of a limited number of species may thus not provide a full picture of the likely consequences of the discharge from the LTPS. A more comprehensive approach is provided by examining the overall ecological character of the receiving waters, together with any apparent trends and/or responses to existing pressures; this is dealt with in Section 3.4 below.

3.4 COMBINED EFFECTS OF OPERATIONAL LTPS DISCHARGES ON MARINE BIOTA

3.4.1 Introduction

In the previous Sections of the Report, the effects of discharges from the LTPS have been discussed in terms of individual pollutants (heat, nutrients and trace metals). For a comprehensive assessment of the effects of the discharge on marine biota, it is necessary to examine the possible combined effects of effluent inputs.

3.4.2 Potential Impacts

Nutrient inputs, in conjunction with thermal effects are of potential concern, primarily with regard to the possibility of enhanced productivity potentially leading to nuisance algal blooms and/or eutrophication. It is apparent, however, that the levels of nutrient input involved will only result in a marginal increase above existing levels, and will certainly not reach a level where algal blooms or eutrophication could occur. Temperature rises will far outweigh any effects on productivity associated with the relatively insignificant increase in nutrient input.

Temperature effects in conjunction with trace metal inputs have a greater potential for impact, and primarily relate to an increase in the stress induced on organisms in the receiving waters. The stresses imposed by temperature elevation on marine biota are well documented and include:

- heat shock from sudden exposure to the thermal plume;
- cold shock to organisms which have acclimatised to the plume;
- blockage of migration routes;
- excessive harvesting of species attracted to the plume;
- adverse effects on reproduction;
- adverse effects on growth;
- alteration to community structures and important species interactions.

Some of these stresses are exclusively thermal effects. The first two are generally only associated with discharge canals and thus not applicable to the LTPS. The third effect is also not applicable to the present situation. However, the latter three can also be influenced by chemical (i.e. trace metal) effects. Not–withstanding this, as identified above, the increases in trace metal discharge concentrations and deposition to the sediments are small. Combined effects with thermal inputs are unlikely to be distinguishable from thermal inputs alone. Thus a discussion of the thermal effects on marine biota with illustrate the likely combined effects of the overall discharge to marine biota.

The thermal plume modelling study has identified on envelope within which temperature rises of 2°C, or more, above ambient will be experienced. This shows that sensitive receivers, most notably the oyster beds and the SSSI's at Lung Kwu Chau or in Inner Deep Bay, are unlikely to be significantly affected.

Within the >2°C above ambient zone, and especially close to the outfall, effects on marine biota will occur. Generally fish and other mobile species will exhibit behavioural responses whereby, subject to food availability (and individual temperature tolerances), they may avoid the plume or be attracted to it.

Non–swimming biota (e.g. phytoplankton, etc) and sessile benthic organisms will not be able to avoid the plume and will be subjected to increases in temperature corresponding with their distance from the outfall. The most typical effects on plankton is an increase in productivity, subject to other factors such as light penetration and, nutrient availability. The modelling study predicts only slight variations in chlorophyll–a concentrations and it appears that the most likely effect on non–swimming biota will be some zonation around the outfall according to temperature tolerances. Given that previous studies on marine communities around CPPS and elsewhere in the area have indicated little change with time, it is reasonable to assume that any zonation effects or changes in species structures will be limited to an area within a few hundred metres of the outfall at most.

3.4.3 *Assessment of Ecological Impacts*

The principal aims of the four season baseline ecological studies of the shores and inshore waters in the vicinity of the proposed LTPS were to:

- determine the species present,
- measure their abundance,
- establish the community structure,
- identify any rare or endangered species, and
- assess the commercial importance of the ecological resources.

The habitats surveyed were:

- the sandy and rocky shores between Yung Long and Tap Shek Kok,
- the surface of the sea bed at a distance of about 0.5km from the shore at Yung Long, Black Point, Lung Kwu Sheung Tan and Tap Shek Kok,
- the mid–water column at sites between Yung Long and Lung Kwu Sheung Tan, and
- the soft sediments to a depth of about 0.25m from Yung Long to Tap Shek Kok.

From the survey, the marine ecology of these habitats can be summarised as follows:

The rocky shore community at Black point was represented by an algal zone, an oyster and barnacle zone and a periwinkle zone. A total of 18 species was recorded and species were typical of exposed igneous rocky communities elsewhere in Hong Kong. The sandy shore at Yung Long was exposed and virtually a biological desert, and only one species of sand worm was found. The sandy shore at Lung Kwu Sheung Tan was diversified and a total of 32 species of snails and a species of shore crab. Species found were also typical of other sandy shore communities in Hong Kong.

Biological diversity of bottom dwelling fish and invertebrates was relatively high in the study area and a total of 135 species was found. The community was mainly dominated by a species of sea urchins, a species of croaker, two species of crab and a species of sea pen, and the community was similar at all stations in the study area. Except fora species of croaker, however, the number and weight of all other fish species were low. Mid–water dwelling fish and invertebrates were typically characterised by low number of animals, low number of species, low biomass and low diversity. The mid–water community was dominated by two species of croakers and a species of white herring. Most of the species were not found all year round ("non–resident" species), while community characteristics were generally similar at all stations.

Juveniles of several species of fish and shrimps and brooding crabs were found in low numbers in September, suggesting that the area may serve as a spawning and nursery ground for these species. Commercial fish landing from the area was low, indicating that the area is not an important commercial fishing ground.

Studies on the soft bottom animal community indicated that the area is fairly homogeneous and essentially comprised of a large, single soft bottom community dominated by sand worms, crabs and sea cucumbers. Species composition of the soft bottom community in the study area was generally similar to those found elsewhere in Hong Kong, while species diversity was generally lower.

Except for two species of horseshoe crab, no species of special scientific/ecological interest were recorded in the survey. The great majority of the species identified in the fish and invertebrate surveys, soft bottom animal surveys and shore surveys were those commonly found in Hong Kong coastal waters and have been reported before.

The marine communities near the Tap Shek Kok power station are similar to their counterparts at other stations.

In addition, records of sightings of cetaceans (whales and dolphins) during the period July 1980 – February 1991 in the Pearl River Estuary near North Lantau, Black Point and Deep Bay were collected.

The results show that no rare or endangered species were identified during the surveys of any of the habitats.

Two species of horseshoe, or king crab, Tachypleus gigas and Tachypleus tridentatus were found, however, Tachypleus tridentatus in February. March and May during trawls of the sea bed near Yung Long, Black Point North, Black Point South and Tap Shek Kok, and Tachypleus gigas at Tap Shek Kok in May.

The interest in the horseshoe crabs lies principally in their status as "living fossils". Their form has changed little over long (geological) periods of time and they are the only extant group closely related to the large fossil group the eurypterids, and possibly the trilobites. They were once common in Hong Kong waters and have become increasingly uncommon in the past two decades.

It is therefore of considerable interest that the ecological survey found that both species were present at Tap Shek Kok. Lam (1987) showed that the subsurface inshore water temperatures near the outfall from CLP.A, ranged from 18.2°C in April to 35°C in June, although there was a rapid fall–off with distance from the pipe. Thus, it seems that these interesting animals may be rather tolerant of high temperatures. The biogeography of Tachypleus indicates that Hong Kong waters are by no means the warmest they occupy. The genus is found from Japan to

Malaysia and India.

The breeding stage of organisms is often the most vulnerable to environmental stress, including high temperatures. Tachypleus has been reported to breed on the beaches closest to the proposed LTPS, during the period around April and May, and as a result the larvae will be sheltered temporally from the most elevated water temperatures but information regarding the requirements of these species in Hong Kong water is limited, and warrants further study.

Sightings of marine mammals in the past eleven years have involved one species, the Chinese White Dolphin, Sousa chinensis. The observations showed that this animal has been recorded 26 times; 18 as live sightings, and 8 as carcasses.

This cetacean is not a true freshwater species, but is an estuarine one. Thus, it is likely that the organism is well adapted to marked changes in temperature, salinity, turbidity etc. In addition, these animals are sensitive and intelligent and will avoid hot spots. The Pearl River Estuary is hardly a pristine environment, and the dolphins still survive in it. It seems from recent sightings that only adults have been reported, so that the area in question may be a feeding, rather than a breeding area. It is, however, possible that a zone of elevated temperature between Lantau and Castle Peak may form a barrier to the movement of these animals; further study may clarify these points.

In general, the species composition and the community structure revealed by the ecological surveys was similar to that at other shores and inshore waters of comparable substrate in Hong Kong. The seasonal differences were large, with fewer species present in winter in the dry season, compared with the summer, wet season composition. There was rather little overlap in the species composition of the two seasons, indicating that the animal populations are extremely mobile and opportunistic; the assumed resident populations comprise a minority of those observed, although direct statistical comparisons are not possible owing to the change of sampling areas during the study (This was due to the potential site of the cooling water outfall being changed after the surveys were initiated).

The patterns of community structure exhibited in the survey results are typical of fluctuating, unstable habitats, where the physical and chemical constituents of the environment change with time. The Pearl River Estuary is a classical example of such a habitat; marked fluctuations have been noted since scientific measurements began. In particular, the wet season modes are characterised by low salinity, high turbidity, high inorganic nutrient concentrations, and pronounced hydrological stratification. In contrast, the dry season waters are dominated by a vertically mixed hydrography, high light penetration and low nutrients. It is noteworthy that these differences are superimposed on a strong tidal-mixing regime.

The generally low species diversity and rather loose community structure revealed in the baseline ecological surveys should be interpreted in this context. Hence, a differentiation of cause of this low diversity between the natural environment and pollutant inputs from Hong Kong sources or others higher in the estuarine catchment, is hard to determine. The consequence for the assessment of the impact of the LTPS is, however, clear.

The plant and animal communities present in the study area are likely to be robust in terms of their response to disturbances such as thermal inputs. The lack of clear differences between the species composition and community structure of habitats north of Black Point and those near Tap Shek Kok provides evidence that the biota can be expected to resist changes caused by the proposed LTPS. It seems reasonable to hypothesise, however, that some long-term reduction in species diversity will result, but that the precise extent of this can only be ascertained by long-term monitoring. Further study of the three species of note in the area, the two kingcrabs and the Pearl River Dolphin would assist in clarifying and confirming their ecological requirements and hence their responses to the overall development of the coastal area of the Western New Territories.

3.5 *OTHER EFFLUENT COMPONENTS*

In addition to the thermal, nutrient and metal components of the effluent discharge from the LTPS, the utilisation of an FGD system involving the dissolution of gypsum would give rise to the discharge of around 550,000 te/yr of calcium sulphate, together with up to 25,000 te/yr of inert insoluble material. Calcium and sulphate ions are natural components of seawater at average levels of about 350 mg/l and 2,200 mg/l respectively and are not regarded as toxic. The dissolution of the LTPS calcium sulphate in the cooling water flow would increase the concentration over that of the intake water by about 40 and 100 mg/l respectively (i.e. 10% and 5%), which is not expected to give rise to any significant impact on the marine ecology in the area.

The limestone reagent used in the FGD process will also contain inert, insoluble material that may make up to about 5% by weight of the limestone, which could contribute up to about 20,000 te/yr to the effluent discharge, or an increase over intake concentrations of 5.3 mg/l. In addition, small quantities of fly ash which evade capture by the electrostatic precipitators (which are expected to capture in excess of 99.7% of the fly ash from the boilers) will be entrained by the scrubbing fluid and subsequently discharged. This could contribute a further 3,500 te/yr (if no prescrubber is fitted to the discharge) which will increase concentrations above those of the intake water by about 1 mg/l. The combined increase in suspended solid concentrations from these sources is thus expected to be up to 6.5 mg/l which in view of the natural range of suspended solids levels near the sea bed in the area (100–150 mg/l) are not considered significant.

3.6 *MITIGATION OPPORTUNITIES*

Notwithstanding the conclusion of the above sections that the predicted maximum effluent discharges are unlikely to give rise to significant effects on the marine ecology of the area, opportunities exist to reduce the total effluent loading to the marine environment.

3.6.1 *Toxic Metals*

Of the total projected metals load of the eight primary toxic metals, almost 80% emanates from the Flue Gas Desulphurisation process, and between five and ten per cent each from the other effluent streams. Mitigation of effluents from a limestone/gypsum plant can be achieved by treatment of the purge stream which is expected to contain individual metal concentrations of up to 10 mg/l. Reductions of metal loadings by about 75% can be expected with resultant concentrations of 0.1 mg/l for Mercury and Cadmium and 1.0 mg/l for Arsenic, Chromium, Copper, Lead, Nickel and Zinc. Lower concentrations cannot be guaranteed using established hydroxide and sulphide precipitation techniques. Such a scheme would produce about 65,000t of sludges per annum and consume substantial quantities of chemicals. For seawater scrubbing plants the concentration of metals in the effluent stream is too low for effective removal with such techniques although some removal could be accomplished by the use of a prescrubber with appropriate water treatment. Prescrubbers are, however, not generally favoured due to reliability and scaling problems.

Metal concentrations in the other waste water streams are generally too low to be treated successfully and the flow volumes too large to handle. Some effluents may however be diverted through an FGD plant treatment facility should one be installed.

3.6.2 *Nutrients*

The condensate polishing process of the Water Treatment Plant produces an effluent containing up to 200ppm of ammonium ion in the form of Ammonium sulphate which equates to an annual discharge of around 15 tonnes.

Further mitigation to remove the ammonium is very difficult and may require bacterial treatment which is difficult to justify on cost or land requirement grounds for this quantity of effluent.

FGD plant nutrient quantities are difficult to assess as little monitoring has been performed anywhere in the world. Moreover, the technology for reducing nutrient levels on FGD plant effluents is not well established. In a generic sense however nitrate removal is possible by reverse osmosis, ion exchange or biological degradation. The first two options cannot be readily used on waters having such high TDS levels and in any case only concentrate the product which would require disposal. The third option – biological treatment is possible but only after massive dilution and the addition of phosphoric acid and methanol as food for the bacteria. The dilution alone could require the use of 25 thousand cubic metres a day of fresh water and such consumption of fresh water would be difficult to justify.

3.6.3 *Water Recycling*

As an alternative approach primary effluent flows from the boiler ash hopper, water treatment plant, boiler blowdown and coalstock drains could, after removal of suspended solids be combined into a central raw water supply. This supply of water could then be used for processes such as FGD as boiler bottom ash quenching in place of towns water. Some bleed to the cooling water would still be required to maintain TDS levels however this would be a small proportion of the total flow and could perhaps be directed to the ash lagoons.

Overall significant reductions in aqueous discharges are likely to be possible.

4. *DREDGING ACTIVITIES*

4.1 *INTRODUCTION*

In the IAR, it was concluded that the main source of potential water quality impacts during the construction of the LTPS would arise from dredging activities. Therefore, this section of the KIR addresses water quality impacts due to increased suspended solid concentrations whilst dredging particularly with respect to three areas of potential concern;

- resuspension and dispersion of sediments during dredging activities;
- disposal of contaminated muds; and
- mobilisation of metals.

4.1.1 *Volume of marine sediments*

To provide adequate foundations for the reclamation, seawall line, and a shipping access channel and turning basin for the LTPS, approximately 0.7–16.0 Mm^3 of marine mud are likely to be removed (depending on the Scenario), as follows:-

- dredging of seawall;
- dredging access channel and basin.

Disposal of the dredged mud will depend on the degree of metal contamination in the sediments (see Section 4.3 below). The following section is concerned with bottom sediment disturbance which inevitably occurs during dredging. The quantity of sediments mobilised will depend on both the dredger, its mode of operation, the dredged material, as well as the marine environment. These factors are described below.

4.2 *RESUSPENSION AND DISPERSION OF SEDIMENTS DURING DREDGING*

4.2.1 *Quantification of Sediment Resuspension*

The amount of suspended sediment generated by dredgers can be quantified in two ways. The turbidity, measured in milligrams of suspended solids per litre of water, is one indication. Another is the total amount of sediment lost from the immediate dredging area per cubic metre of soil dredged (kg/m^3).

For most dredging operations, the main consideration with respect to sediment resuspension and the environment is the amount which is lost from the dredging site, rather than the turbidity in the immediate vicinity of the dredger. This is highly dependent on the hydrodynamics of the site and the nature of the bed material. If there are no currents, for example, then all the sediment which is put into suspension may be expected to settle on the seabed close to the dredger. In areas where currents prevail, the loss will be a function of the turbidity around the dredger, the current speed and the duration of the dredging works.

Some dredgers produce low levels of turbidity but also have a low rate of production. By contrast, other dredgers produce high levels of turbidity but work rapidly. Therefore suspended sediment generation and production rates of dredgers determine the 'cleanliness' of dredgers and both factors must be taken into account in evaluating their environmental performance.

For the purposes of this KIA, the total quantity of sediment released by the dredger, per cubic metre dredged, has been adopted as the principal measure by which the dredging activities should be assessed. This is termed the 'S' factor (expressed in kg/m^3) and gives an indication of the amount of sediments which are likely to be exported out of the immediate vicinity of the dredger (i.e. more than 50 metres from dredged site). The figures which are quoted here are based on research undertaken in the U.S.A., Europe and Japan and represent the losses which might be expected in a moderately active hydrodynamic regime (such as the Urmston Road) when dredging marine muds. These 'S' factors give an indication of the suspended sediment generation rates of dredgers which are expected to be used for the LTPS works as follows:

- Trailer Suction Hopper Dredger;
- Cutter Suction Dredger; and
- Grab Dredger.

These dredgers and their associated 'S' factors are described and compared below.

4.2.2 *Trailer Suction Hopper Dredger*

The trailer suction hopper is one of the most likely dredgers to be used for the LTPS. The main cause of suspended sediment generation from this type of dredger is overflow from the hopper and the use of de-gassing and Automatic Lean Mixture OverBoard (ALMOB) systems. The excavated fluid is discharged into a hopper where the solids settle whilst excess water is discharged via an overflow to minimize the water and maximise the solid content of the material transported to the dump site. Sediment resuspension may also occur as a result of propeller and bow-thruster wash when working in shallow water, and leakage through poorly-maintained bottom doors or valves.

'S' factors in excess of 10kg/m^3 may be expected when the dredger is overflowing and using ALMOB systems when dredging muds. However these S factor could be considerably greater if overflow continues for any length of time. Suspended sediment concentrations can be of the order of several thousand mg/1 near the base of the water column but near-surface concentrations are generally less than 100mg/1 except immediately behind the dredger.

If overflow, ALMOB and de-gassing discharge is prohibited, the trailer dredger is substantially 'cleaner'. 'S' factors of less than 5kg/m^3 might be expected and sediment concentrations are likely to be significantly less than 100mg/1 and restricted to the near-bottom parts of the water column.

There appears to be little relationship between 'S' factors and dredger size but absolute levels of turbidity can be expected to increase with increasing dredger size.

4.2.3 *Cutter Suction Dredger*

The main causes of sediment resuspension during operation of the cutter suction dredger are;

- disturbance of the ground around the cutterhead;
- gas release from the soil;
- impact and removal of spuds;
- cutter ladder dragging on the bottom when dredging in shallow water.

Cutter suction dredgers generate quite high suspended sediment concentrations but these are usually restricted to the area in the immediate vicinity of the cutterhead. 'S' factors are low and typically less than 5kg/m^3. Turbidity can be reduced by restricting cutter rotation and swing speeds but this could result in increased 'S' factors because of the reduced rate of production.

4.2.3 *The Grab Dredger*

Grab dredgers are not inherently 'clean' operations. 'S' factors in excess of 20 kg/m^3 can be typical and suspended sediment concentrations may exceed 100 mg/l throughout the water column. Suspended sediments concentrations at this level would probably exceed the DBWQOs (see later). The use of watertight grabs appears to reduce the sediment concentrations in the upper parts of the water column but there is some evidence to suggest that they may increase concentrations near the bottom. Dredging within silt screens significantly reduces the loss of material from the dredging area, perhaps by as much as 75%.

Whilst absolute levels of suspended sediment concentrations tend to increase as the size of the dredger increases, 'S' factors may actually decrease. Therefore in environmentally sensitive areas, it is preferable to use large dredgers rather than small dredgers.

4.2.4 *Comparison between dredgers*

Table 4.2(a) shows estimated 'S' factors for trailer suction, cutter suction and grab dredgers.

Table 4.2(a)
Range of 'S' factors for Trailer Suction Hopper, Grab, and Cutter Suction

Dredger	'S' factor kg/m^3
Trailer Suction Hopper Dredger	
• ALMOB, overflow, degassing	>10
• without ALMOB	<5
Grab (open, silt screen)	12-25
Grab (closed, no silt screen)	11-20
Grab (closed, silt screen)	2-5
Cutter Suction	<5

Intrinsically, open or closed grab dredgers without siltscreens have the potential to generate comparatively high concentrations of suspended solids (i.e. highest 'S' factors). Trailer suction hopper dredgers using ALMOB, overflow and de-gassing systems also have high 'S' factors (i.e. >10 kg/m^3) associated with their operation. However, the performance of closed grab dredgers and trailer suction hopper dredgers (without ALMOB overflow, degassing) with silt screens are comparable to cutter suction dredgers. Therefore from the table above, it can be seen that;

- cutter suction,
- grabs (closed, silt screen); and
- trailer suction hopper dredgers (without ALMOB)

are the environmentally acceptable dredgers due to their low 'S' factors.

The amount of resuspended sediments released during dredging into the nearby marine environment should be minimised for these dredgers providing good house keeping practices are adhered to during their operation.

4.2.5 *Increase in suspended solids*

There are three criteria which must be considered when evaluating the increases in suspended solids due to dredging in Deep Bay. These are:

- background suspended solid concentrations in the water column;
- increase in suspended solid concentrations while dredging; and
- whether the increase in suspended solids is greater than permitted statutory limits for Deep Bay (i.e. 30% above background concentrations).

The amount of material that is resuspended during dredging is highly variable and contingent upon factors specific to the dredging programme, location of the borrow or dredged site, and hydrodynamic conditions, (as mentioned earlier). In order to help predict water quality impacts, the increase in suspended sediment concentrations and the dispersion of the subsequent sediment plume, mathematical modelling can be used. The methodology would, firstly, involve an estimation of the sediment production (based on construction programme), secondly, a calculation of the sediment resuspension rate (based on 'S' factors) and then, finally, model simulations of sediment plume dispersion under various seasonal and tidal flow conditions (based on sediment resuspension rates).

During the course of this KIR it was agreed with EPD that such model predictions would be of limited practical value as this was a planning study and the detailed construction programme necessary for accurate model predictions was not available at this stage of the study. A more strategic approach would be to recommend appropriate monitoring conditions which could be incorporated into the licence that would eventually be awarded to the licensee for the LTPS works.

This approach is appropriate as monitoring is the only accurate means of assessing sediment concentrations in the water column during construction works. Furthermore, there are several planned concurrent dredging activities in the Urmston Road area (Figure 4.2(a)) which emphasizes the importance of water quality monitoring in the area.

4.2.6 *Marine Quality Monitoring*

4.2.6.1 *Monitoring Locations*

The marine borrow areas and dumping grounds for the marine sediments for the LTPS are yet to be identified and agreed with the Fill Management Committee. Hence monitoring requirements for the dredging and filling of marine fill and mud for the reclamation cannot be specified at this stage of the study. However dredging for the sea walls and berthing areas for the LTPS will be definitely required and monitoring for suspended solids in the vicinity of construction works can be outlined for this activity. Two factors of critical importance are the locations of the monitoring sites and establishment of baseline conditions of suspended solids.

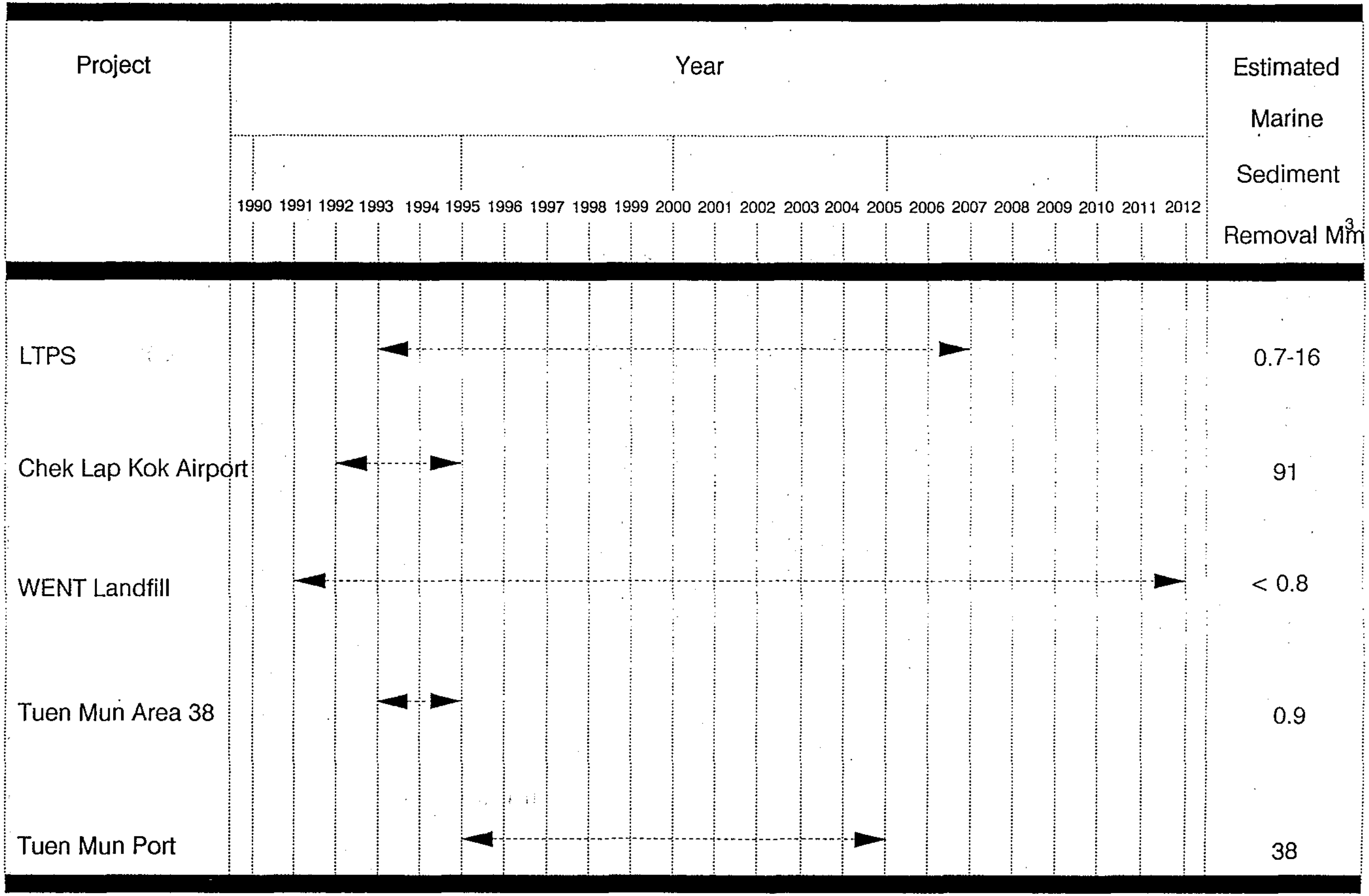

Figure 4.2(a)
Concurrent Proposed or Planned Projects in the Urmston Road Area

The location of monitoring sites should be selected according to their proximity to water sensitive receivers (WSRs) and Special Sites of Special Scientific Interest (SSSI) that could potentially be affected by dredging at Black Point. The nearest WSR and SSSI are the Mariculture Subzone in Deep Bay and Lung Kwu Chau respectively, both of which are situated about 4 km from the proposed site. Lung Kwu Chau may be sensitive to water quality impacts as deterioration in the surrounding marine water quality may decrease fish stocks available as a food source to transitory or roosting birds at Lung Kwu Chau.

To assess the anticipated increase in suspended solid concentrations in the water column and their dispersion towards these two WSRs, five sampling locations are recommended as shown in Figure 4.2(b) i.e. one monitoring site at Black Point close to the dredged site and the remaining monitoring locations between the dredged site and the Mariculture Subzone and Lung Kwu Chau. It should, however, be noted that any increases in suspended solids observed at these monitoring sites and violations of license conditions may be difficult to assign to a particular operator, if several operations were concurrently occurring.

4.2.6.2 *Baseline Conditions*

In an estuarine region such as Deep Bay, particulate loadings can be highly seasonal and hence baseline conditions for suspended solids are difficult to establish from monitoring programmes conducted over short-time scales (i.e. weeks). The CLP monitoring programme suggests that suspended solid concentrations can vary over 2 orders of magnitude with biannual peaks in January and July during the wet and dry seasons. Baseline conditions which are to be included in the licence conditions for the construction phase of the programme should therefore take into account the seasonal fluctuation of suspended solid concentrations, according to the duration and the season.

Baseline data from the CLP monitoring programme for individual sampling sites would be available to help establish background suspended solid concentrations together with any short-term (i.e. weeks) sampling data obtained by the contractor.

4.3 *DISPOSAL OF MARINE MUD*

The CLP and EPD marine sediment data presented in the IAR indicated that metal levels in bottom sediments near Black Point were generally one to two orders of magnitude below the Deep Bay Interim Threshold Guidelines and would therefore be classified as uncontaminated. In view of the more stringent criteria[1] for contaminated sediments currently under review by the Hong Kong Government, this earlier conclusion needs to be re-evaluated with reference to the recent sediment data generated by CLP.

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[1] Contaminated Spoil Management Study, Mott McDonald Hong Kong Ltd, 1991

4.3.1 *Average Metal Concentrations in Sediments near Black Point*

The 'new' criteria of toxic metals for marine sediments, which if adopted in Hong Kong would supecede the Deep Bay Interim Guidelines for contaminated mud are shown in Figure 4.3(a).

Table 4.3 (a)
Background concentrations, Target Values, Trigger Levels and Action Levels of metals in marine sediments (in mg/kg).

Class	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Background	0.05	7	7	0.07	10	19	40
Target (A)	0.4	25	20	0.2	20	35	75
Trigger (B)	1.0	50	55	0.8	35	65	150
Action (C)	1.5	80	65	1.0	40	75	200

The critical values shown in Table 4.3(a) are the 'trigger' and 'action' metal concentrations; the implication being that if metal concentrations in sediments exceed 'action' levels these sediments may need to be disposed of in designated sites. In this case, special mud disposal techniques may need to be adopted to prevent mobilisation of metals from the dumped material (eg. capping).

Under these 'new' criteria (see Table 4.3(a)), the yearly average trace metal concentrations of sediments from CLP's on-going monitoring programme generally indicate that surface sediments near the Black Point (see Table 2.8(a)) are uncontaminated, since both the trigger and action values for all metals would not exceed the 'new' criteria. Consequently, the dredged spoil could be safely disposed of to any of the Government dump sites considered appropriate. Given the location of the site, the worked-out borrow pits of Urmston Road and Outer Deep Bay would be the most suitable choice on logistical grounds.

4.3.2 *Metal Concentrations of Sediments from the dredged channel*

In addition to their on-going monitoring programme, CLP have also sampled sediments from within the proposed dredged channel at five sampling locations (Figure 4.3(a)) and on two separate occasions. The results of the sediment analyses are shown in Table 4.3(b).

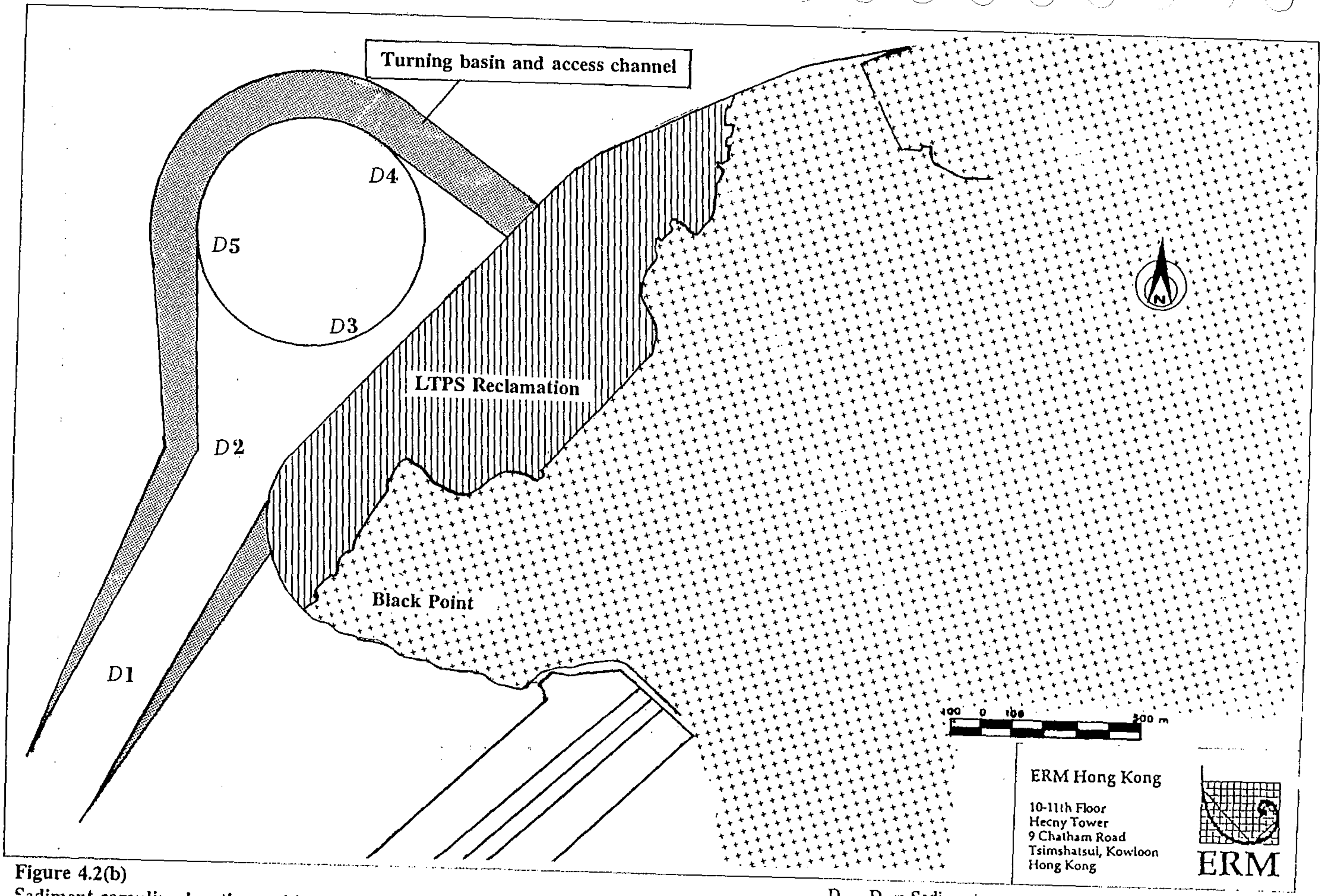
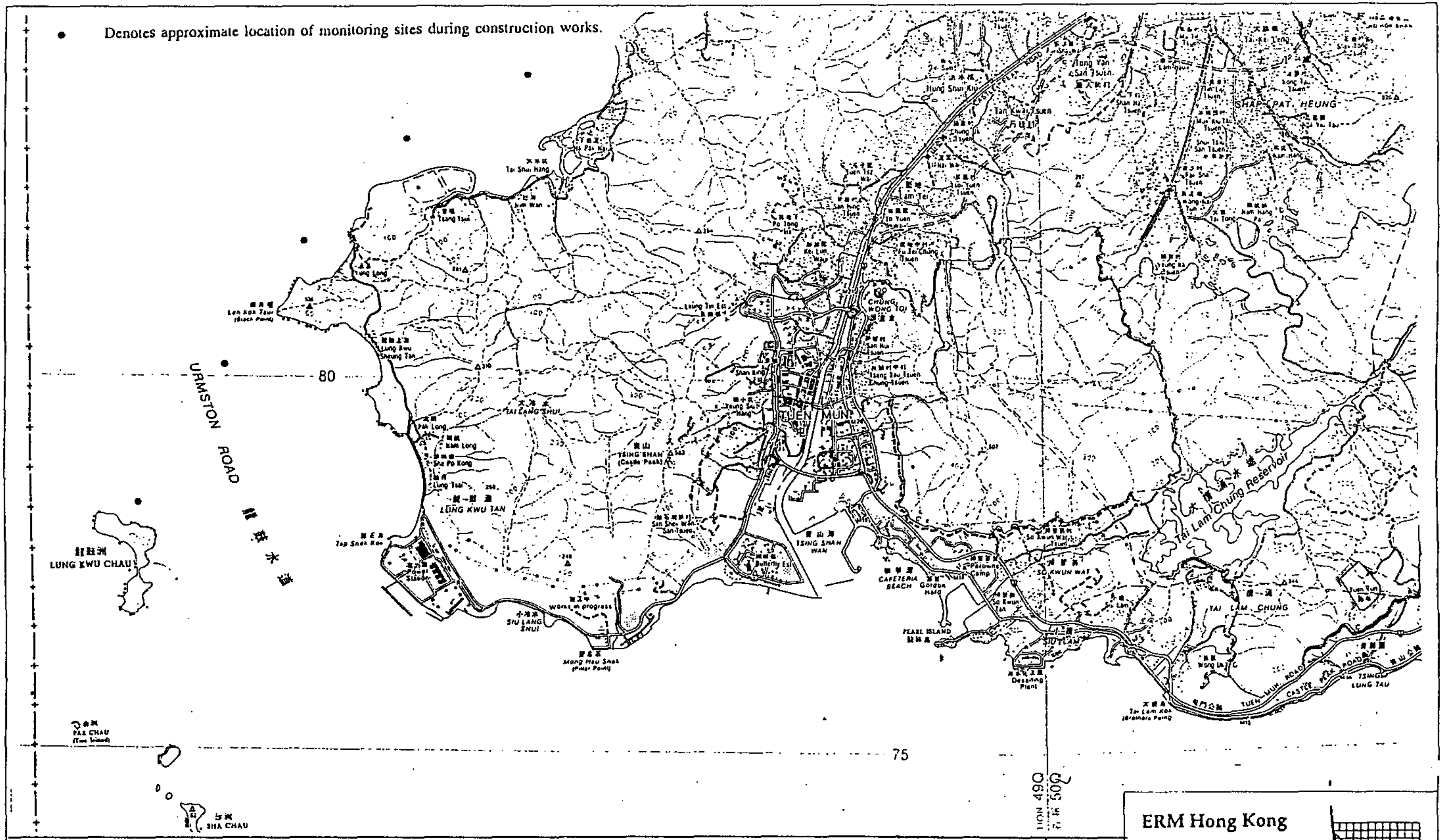


Figure 4.2(b)

Sediment sampling locations with the turning basin and access channel off Black Point

D_1 – D_5 = Sediment Sampling locations



• Denotes approximate location of monitoring sites during construction works.

Figure 4.3(a) Recommended Water Quality Monitoring Sites During the LTPS Construction Works

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10-11th Floor
Hecny Tower
9 Chatham Road
Tsimshatsui, Kowloon
Hong Kong

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Table 4.3(b)
Comparison of Trace Metal Contents in Black Point Sediments

Sample Sites	Test Method(1)	Trace Metal Content mg/kg							
		As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
D1	MPD	<0.005	1.9	39.1	80.4	0.452	19.3	<15	122
	CAD	0.25	<0.2	21	9.5	<0.2	12.5	14	35.5
D2	MPD	<0.005	2.4	16.6	12.8	0.242	8.7	25.2	66.4
	CAD	0.7	<0.2	17.5	31.5	0.25	16	15.5	64.5
D3	MPD	<0.005	1.5	28.8	57.6	0.212	13.9	<15	92.9
	CAD	0.5	<0.2	15	25	0.3	14	17	47
D4	MPD	<0.005	1.2	26.5	43.8	0.061	12.4	<15	82.1
	CAD	<0.2	<0.2	0.9	2.75	<0.2	1.5	3.8	7.9
D5	MPD	<0.005	3.1	29.0	60.3	0.18	13.7	<15	111
	CAD	0.8	<0.2	19	40	0.4	16.5	23.5	61.5
Black Point Yearly Average	CAD	1.01	0.10	11.1	38.7	0.17	15.5	28.5	48.9
Gov't Future Action (C) Limits		–	1.5	80	65	1.0	40	75	200

(1) – Test method & data: MPD – Microwave Pressure Digestion, Aug., 91
CAD – Conventional Acid Digestion, Feb., 92

(2) – The second D4 sample contains large amount of sand grains

The two sets of results shown in Table 4.3(b) are not directly comparable with each other as the sediment samples were collected during separate sampling campaigns and then analysed using different analytical methods (ie. by microwave pressure digestion (MPD) and conventional acid digestion (CAD)). The CAD method is similar to the analytical method used by the Government chemist (e.g. APHA 3030A, 3030F). However, for the vast majority of samples, metal concentrations are higher, or similar, in the sediment samples digested by MPD than by CAD. This observation is unsurprising as MPD is a more severe method of extraction than CAD, thus a higher proportion of the total trace metals in the sediments would be dissolved by the former method. Metal concentrations of sediments subjected to MPD should therefore be regarded as representative of upper limits of the labile fraction of total metals.

Comparison of the MPD and CAD results with the action levels of the 'new' sediment criteria shows that metal concentrations of chromium, mercury, nickel, lead and zinc in both data sets are within the action limits (Table 4.3(b)). Cadmium concentrations however are too high by a factor of between 1.5 to 3.1 at all sampling sites (ie. D1–D5) within the dredged channel for samples treated by MPD (see Table 4.3(b)). However, cadmium concentrations of sediments analysed by CAD are well within the action limits of the 'new' criteria. Similarly copper concentrations of sediments (ie. D1 and D5) analysed by MPD exceed the action level of copper by 45 % and 9 % respectively. Such exceedances of copper, however, should not raise undue concern as these differences are well within the expected sampling and analytical uncertainties. In the case of cadmium, interpretation of the MPD and CAD data sets is less clear (ie. the MPD cadmium concentrations exceed the action levels and are unacceptable whilst the CAD concentrations of cadmium approach target values (Table 4.3(a)). As metal concentrations of sediments analysed by CAD are generally more representative of the biologically available fraction of metals in sediments (i.e. labile fraction), it would be appropriate to classify these sediments according to the CAD data, thus rendering sediments off Black Point as uncontaminated. Such a sediment classification is consistent with the long term yearly averages which suggest that the sediments off Black Point are generally clean (Table 4.3(b)).

- Release of dissolved toxic metals

The potential release of dissolved toxic metals from resuspended sediments during dredging works directly relate to a number of factors, such as the chemical nature (eg. redox potential, partition coefficient, speciation) of the metal and external factors (eg. salinity, temperature of seawater.) In addition to these factors, release of metals from resuspended particulates would also depend on the concentration of an element in the dissolved and particulate phases. Because of the complex chemistry of dissolved/particulate aquatic metal systems, the mobilisation of metals from particulates are difficult to accurately predict, as discussed in Section 3.2.

However the 'new' sediment criteria shown in Table 4.3(a) are based on ecological considerations and hence these values can be used to estimate the significance of potential ecological impacts due to metal mobilisation from marine sediments. As pointed out in the previous section, the mean metal concentrations of sediments from the Black Point area are within the 'new' (action tigger) sediment criteria and therefore the potential ecological impacts due to metal mobilisation from resuspended solids are not expected to be significant in this case.

- Release of particulate toxic metals

Even if the metals in bottom sediments are not mobilised into the marine environment, they have the potential to cause ecological impact. Any particulates that are released during dredging into the water column, transported towards the Mariculture Subzone and subsequently ingested by filter feeders (i.e. oysters), could potentially elevate the metal content of such organisms. This emphasizes the importance of monitoring for suspended solids near the Mariculture Subzone during the construction phase (Section 4.2.6) of the LTPS.

4.4 *SUMMARY*

In the IAR, it was concluded that potential Water Quality impacts may arise during dredging activities. The three areas of potential concern addressed in this KIR are resuspension of sediments, disposal of contaminated mud and mobilisation of metals from suspended solids.

- Resuspension of sediments

Suspended solid generation rates would be highly dependent upon the construction programme, production rates, in-situ marine conditions and the type of dredgers used for the LTPS. At this stage of the study, works details are not available and hence associated marine impacts cannot be specifically addressed. However, for an ecologically sensitive marine area such as Deep Bay, the use of dredgers with low 'S' factors, (i.e. cutter suction, closed grabs with silt screens and trailers without ALMOB) would be preferable.

- Disposal of marine mud

The CLP baseline monitoring survey indicates that the level of metal contamination in marine sediments near Black Point are relatively low. Under both the Deep Bay Interim Guidelines and the 'new' sediment criteria, marine sediments from the dredged channel near Black Point and analysed by CAD for toxic metals would be classified as uncontaminated. Therefore the dredged spoil could be disposed of at any of the government dump sites and mobilisation of metals from resuspended sediments is not expected to be significant.

- Mobilisation of metals

Any suspended solids produced during dredging and subsequently transported towards the Mariculture Subzone, have the potential to elevate metal concentrations of filter feeders, if significant quantities of particulates were ingested by such organisms. Therefore the inclusion of a stringent monitoring programme, with sampling locations near the Mariculture Subzone, into the licence conditions for contractors, is considered to be of paramount importance. An estuarine region such as Deep Bay has high seasonal fluctuations in suspended solids and therefore long-term (i.e. months) baseline conditions may be difficult to establish from any short-term (i.e. weeks) sampling programmes conducted prior to works commencement. Data from the CLP monitoring programme would be available to supplement any short-term data collected by a contractor.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

5.1.1 Construction Phase

As noted in the IAR, the major source of water quality impacts during construction of the LTPS would be related to marine dredging activities, as follows:

- Resuspension of bottom sediments

One factor affecting suspended solid generation rates is the type of dredger that is used. Of the dredgers that are most likely to be deployed for the LTPS, Trailer Suction Hopper (without ALMOB), Grab (closed, silt screen) and Cutter Suction dredgers are the most environmentally acceptable due to their comparatively low 'S' factors (i.e. <5 kg/m^3).

However, due to concurrent dredging activities planned for other projects in the Urmston Road area, suspended solid concentrations may increase considerably as a result of cumulative impacts. Given the proximity of water sensitive receivers in the area (i.e. Deep Bay Mariculture Subzone, Lung Kwu Chau), appropriate water quality monitoring would be required (see below).

- Disposal of contaminated marine muds

The dredged spoil removed from the access channel and turning basin off Black Point would require disposal. Trace metal analyses, by conventional acid digestion of sediments sampled in this area, indicate that the metals, cadmium, chromium, mercury nickel, lead and zinc are comfortably within the action limits of the 'new' Government criteria for contaminated sediments. Copper concentrations approach the action levels in some of the samples but concentrations are still within the limits. Therefore according to these 'new' criteria, the sediments off Black Point are classified uncontaminated and hence could be disposed of to any of the government dump sites.

- Mobilisation of metals from sediments

The 'new' sediment criteria for trace metals are based on ecological studies (i.e. LC$_{50}$ tests). As the sediments near Black Point would be classified as uncontaminated (according to their metal levels), the release of dissolved metals from bottom sediments off Black Point are not anticipated to significantly impact upon marine organisms. However, it would be important to minimise the transport of suspended sediments towards the oyster beds in Deep Bay, as high particulate loads (if ingested) could potentially elevate metal concentrations in filter feeders.

5.1.2 Operational Phase

Operation of the LTPS will result in the discharge of large volumes (e.g. 2.6 – 3.8 x 10^9 m^3/yr) of cooling water to the Pearl River estuary. At the outfall, the temperature of the discharged water may be up to 12°C above ambient temperatures and will contain concentrations of trace metals and nutrients slightly, above natural levels.

The dispersion of the effluent has been established by detailed modelling study. Key elements of the results of the study are as follows:

- Although the zones of the thermal plume where temperatures will exceed 2°C above ambient are quite extensive they do not impinge upon any areas of marine ecological sensitivity.

- The shape of the plume varies according to tidal and seasonal factors and only rarely will waters in excess of, 0.5 °C above ambient extend into Deep Bay; generally temperature elevations, on the occasions when they do occur, will be restricted to outer Deep Bay and lie in the range <0.2 - 0.5°C above ambient.

- Elevations in the concentrations of trace metals in the discharge, and predictions in increases of net deposition of absorbed metal in certain places, are marginal and are considered to constitute no significant impact to marine biota.

- Nutrient concentrations likewise will only be marginally elevated and are unlikely to lead to noticeable changes in production and will certainly not lead to eutrophication.

- Generally the balance of effects on marine biota will be those associated with the thermal element of the discharge, with the exception of possible scouring effects immediately around the outfall. The most notable way in which such impacts will be manifested will be changes in community structures in the discharge vicinity. Such changes may follow a seasonal pattern and are unlikely to be noticeable beyond the 2°C above ambient temperature envelope. Generally the changes will be most noticeable close to the outfall at distances in the order of hundreds of metres at most from it.

- Such changes in community structure are unlikely to constitute a significant impact in terms of Hong Kong, or even the outer Pearl Estuary context. The receiving environment is not an especially productive area and the community present, characterised by low species diversity and, in most cases moderate to low abundance, is generally a stable and stress (or pollutant) tolerant one.

Overall, operation of the LTPS is unlikely to lead to significant long term impacts to the marine environment beyond an immediate zone of influence around the outfall. However, a strict monitoring regime will be programmed to detect possible significant adverse effects, thus allowing future mitigatory action, where practicable, to be undertaken.

5.2 *RECOMMENDATIONS*

5.2.1 *Construction Phase*

The Deep Bay Water Quality Objectives specify that concentrations of suspended solids should not exceed the natural ambient concentrations by more than 30%. Therefore, during dredging, monitoring at the dredged site off Black Point and at strategic monitoring locations close to the Deep Bay Mariculture Subzone (WSR) and Lung Kwu Chau (SSSI) is strongly recommended by this study. In addition, the concentrations of suspended sediments in Deep Bay are highly variable and thus the long–term (i.e. months–year) marine water quality data available from CLP would be valuable to supplementary short–term (i.e. weeks) monitoring data gathered by a contractor, prior to works commencement. This data gathering would ensure that appropriate seasonally adjusted baseline conditions of suspended solid concentrations are used.

5.2.2 *Operational Phase*

Overall, the input of trace metals from the LTPS will result, in the worst case, in a small incremental increase for some metals; the trace metal of most concern being Mercury. Some enhanced deposition may also occur, however, this is anticipated to result in only a marginal (and possibly only barely detectable) increase over the present situation. Thus the two prime concerns of trace metal discharge concentrations and metal deposition (leading to long–term build up) are largely considered to be of minor significance. When other factors, for example a major sewage effluent input are considered, the contribution from the LTPS is put further into context.

Of perhaps secondary concern is changes to species/community structure resulting from the combined effects of the discharge. Such an effect, should it occur to any significant extent, will be localised around the outfall. Whilst it is not regarded that trace metal inputs are a matter for concern in view of the total loads concerned it may be prudent to undertake a limited study in conjunction with on–going marine monitoring studies e.g.:

- monitor trace metal contents of sessile benthic organisms present in the plume–affected zone and at selected areas where enhanced metal deposition is predicted to occur (in conjunction with monitoring of a control population);
- monitor species abundance and diversity at selected distances from the outfall.

One note of caution concerns other discharges in the area, in the future, particularly as the area is undergoing considerable development (i.e. NWNT outfall, Tuen Mun Port Development, Area 38). The monitoring strategy would need to take into account such local external factors.

6 *WATER QUALITY IMPACTS FOR PHASE I*

6.1 *INTRODUCTION*

The previous sections of this KIA report has assessed the likely 'worst–case' impacts associated from the operation of the LTPS according to Scenario I (all coal firing units). This section of the KIA summarises the predicted water quality impacts which are likely to result from the operation of the Phase I under the following configuration:

- 4 x 600MW sets of gas turbines with waste heat recovery boiler and stream turbine.

This assessment has been performed employing a similar methodology as that for Scenario I in the previous sections of this KIA. For the most part, duplication of information provided in previous sections has been avoided and where appropriate, reference made to the relevant preceding section.

In agreement with EPD (see *Section 7* – EPD's Position and the Way Forward), this KIA assesses the potential impacts from the LTPS during Phase I. A detailed, quantitative assessment of the impacts from Phase II will be assessed in conjunction with any application CLP may submit to Government for the expansion of the LTPS to Phase II.

As discussed in *Section 3* cooling water effluents discharged from the LTPS from Phase I can originate from several sources. Namely:

- Water Treatment Plant
- Sewerage
- Boiler blow down
- Oil separator water
- Cooling water

The effluent inventory and total predicted flow rates from the LTPS, have been presented in the following summary table.

Table 6.1a
Summary of Effluent Flows/Cooling Water for Phase I

Contributor	**Phase I (Flow Rate m^3/year)**
Water Treatment Plant	1 x 10^5
Treated Domestic Sewage	3 x 10^5
Boiler Water Blowdown	1.5 x 10^5
Oil Separator Water	6 x 10^7
Sub Total	*6.1 x 10^7*
Cooling Water	6.5 x 10^8
Combined Outfall (all above contributors)	*7.11 x 10^8*

CLP propose to combine effluent streams whenever possible, which for Phase I will be discharged via a surface outfall at the seawall, as shown in the following *Figure 6.1a.*

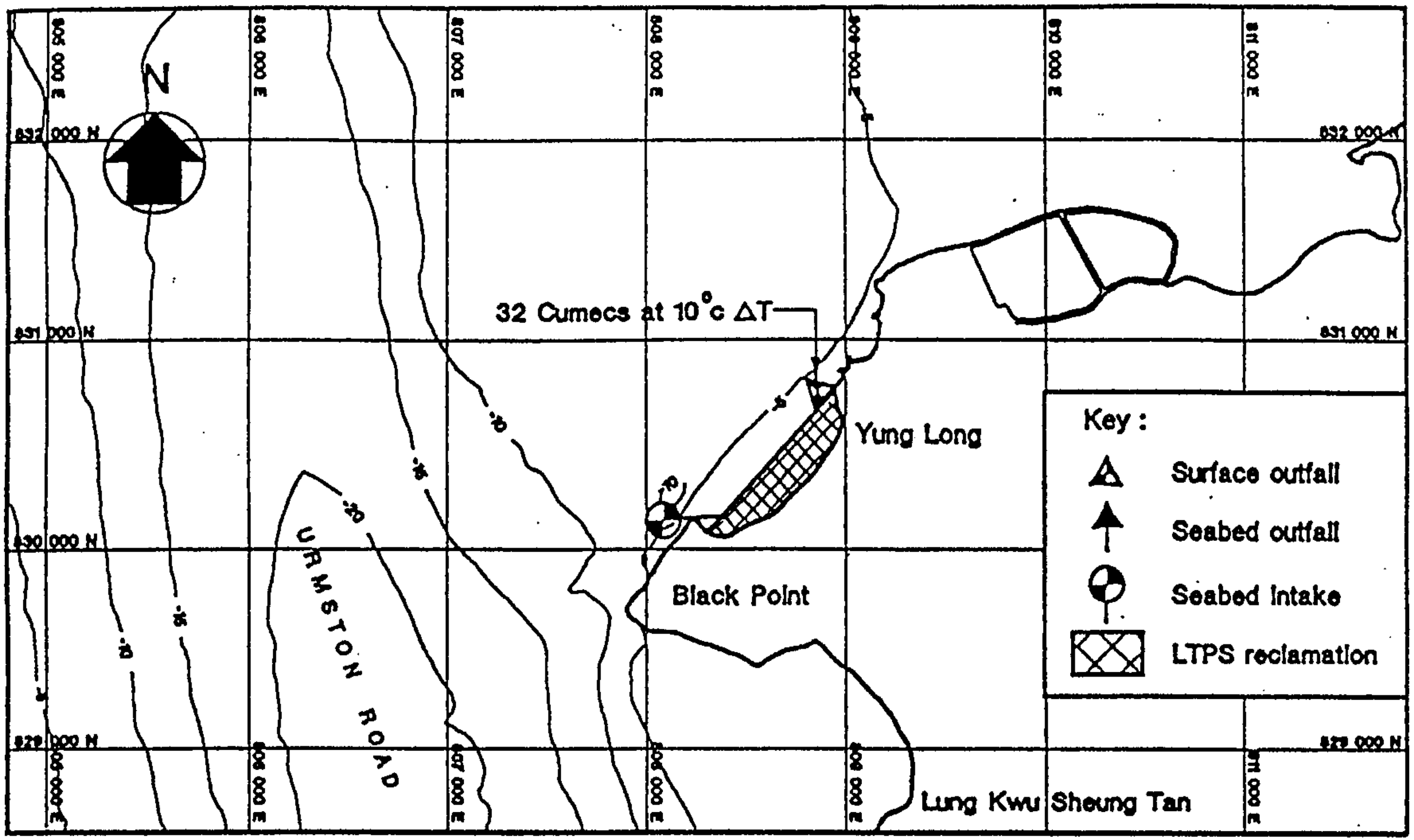

Figure 6.1a
Discharge Location Of Outfall During Phase 1

ERM Hong Kong

10-11th Floor
Hecny Tower
9 Chatham Road
Tsimshatsui, Kowloon
Hong Kong

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The following sub-sections address the potential impacts of the cooling water from the LTPS on temperature, nutrient and trace metal concentrations on the marine environment of the surrounding waters.

6.2 *BASELINE CONDITIONS*

The baseline conditions are as described previously in *Section 2* of this KIA and which have formed the basis for this assessment.

6.3 *TEMPERATURE EFFECTS*

6.3.1 *Introduction*

As described in *Section 3.1*, there is a considerable natural temperature variation within the coastal waters near Black Point and any assessment of potential thermal impacts should be evaluated in this context.

6.3.2 *Refined Hydrothermal Modelling for LTPS Phase I*

6.3.2.1 *Rationale*

Following the adoption of the 4 combined cycle gas powered unit scenario for Phase I of the LTPS, the extent of the temperature envelope from the cooling water discharge was remodelled to take advantage of the greater level of detailed information concerning the cooling water discharge.

For this exercise, the Phase I design information was used for refinement of the discharge and intake locations, and the discharge rate and temperature.

In view of the smaller geographical area anticipated to be affected by the thermal plume (because of the lower volumes and input temperatures than those previously modelled), the opportunity was taken to carry out the remodelling using the smaller scale WAHMO grid, so as to give a finer resolution to the model outputs and hence a more accurate delineation of the 2°C temperature envelope.

In addition, the remodelling took account of the proposed changes in the coastal morphology of the Black Point area by including the Tuen Mun Port Development in the base model. This was considered appropriate since the LTPS Phase I development will be complete around the year 2000, with Tuen Mun Port being progressively implemented between 1998 and 2006 . However, it should be noted that if the Tuen Mun Port Development does not proceed as currently planned, the effect on the results predicting the extent of the 2°C temperature envelope from the LTPS will not be significant as the reclamation will principally effect flows to the south of Black Point, through the removal of the Lung Kwu Tan embayment.

From the previous simulations of the temperature rise in the ambient waters generated by the proposed Large Thermal Power Station (LTPS) at Black Point, the model results were re-examined in order to determine which tide types, of the wet and dry season spring and neap tides previously simulated generated the worst case conditions for cooling water discharged into Deep Bay. The worst case conditions were defined as those in which the +2°C contour in the cooling water plume had the largest extent in both an east and west direction.

Initially, it was thought that different tide types would be responsible for generating the maximum extent in each direction but, on examination of previous simulations, it was found that the +2°C contour had its maximum extent in both directions on the dry season neap tide. On spring tides, when tidal excursions are largest, the dispersion of the cooling water is more rapid than on neap tides with the result that, while the overall area of the receiving waters affected by the cooling water discharge may be greatest on spring tides, the increases in background water temperatures near the outfall are generally lower than on neap tides. Under wet season conditions, when the water body is stratified with a brackish layer near the surface overlying the denser oceanic waters, the dispersion of the cooling water plume is also more rapid than under dry season conditions. The impact of the stratified conditions on the initial dilution and buoyancy of the plume and the greater variation in water velocity over the depth in stratified conditions all help to disperse the cooling water plume and so reduce the increase in the surface water temperatures.

Having identified the dry season neap tide as creating the largest area with surface temperature increases in excess of +2°C, the three-dimensional thermal model previously used in the engineering studies was re-run to simulate this tide. The model has a resolution of 100m and the boundary conditions for the thermal simulations were obtained from previous simulations of the far field temperature distributions which used a 300m two-dimensional two-layer model.

The updated and refined input parameters for the temperature dispersion remodelling were:

LTPS Discharge

Flow rate; 52.8m/s
Discharge temperature; +8.8°C
Outfall location; at seawall

Castle Peak Discharge

Flow Rate; 132m/s
Discharge temperature; +12°C

6.3.2.2 *Results and Discussion*

The model results were processed to select the maximum temperature which occurred at any time during the tidal cycle in each model grid cell. Surface layer and lower water column contour plots of this maximum temperature distribution were then produced. It should be noted that, because it represents a compilation of maxima, this maximum temperature distribution would never occur it any one instant in time. The plots, however, show the maximum extent of the cooling water plume contours and so the total areas which would experience increases in water temperature at some time during the tidal cycle.

Figures 6.3a and *6.3b* thus illustrates the maximum 2°C temperature envelope for Phase I of the LTPS.

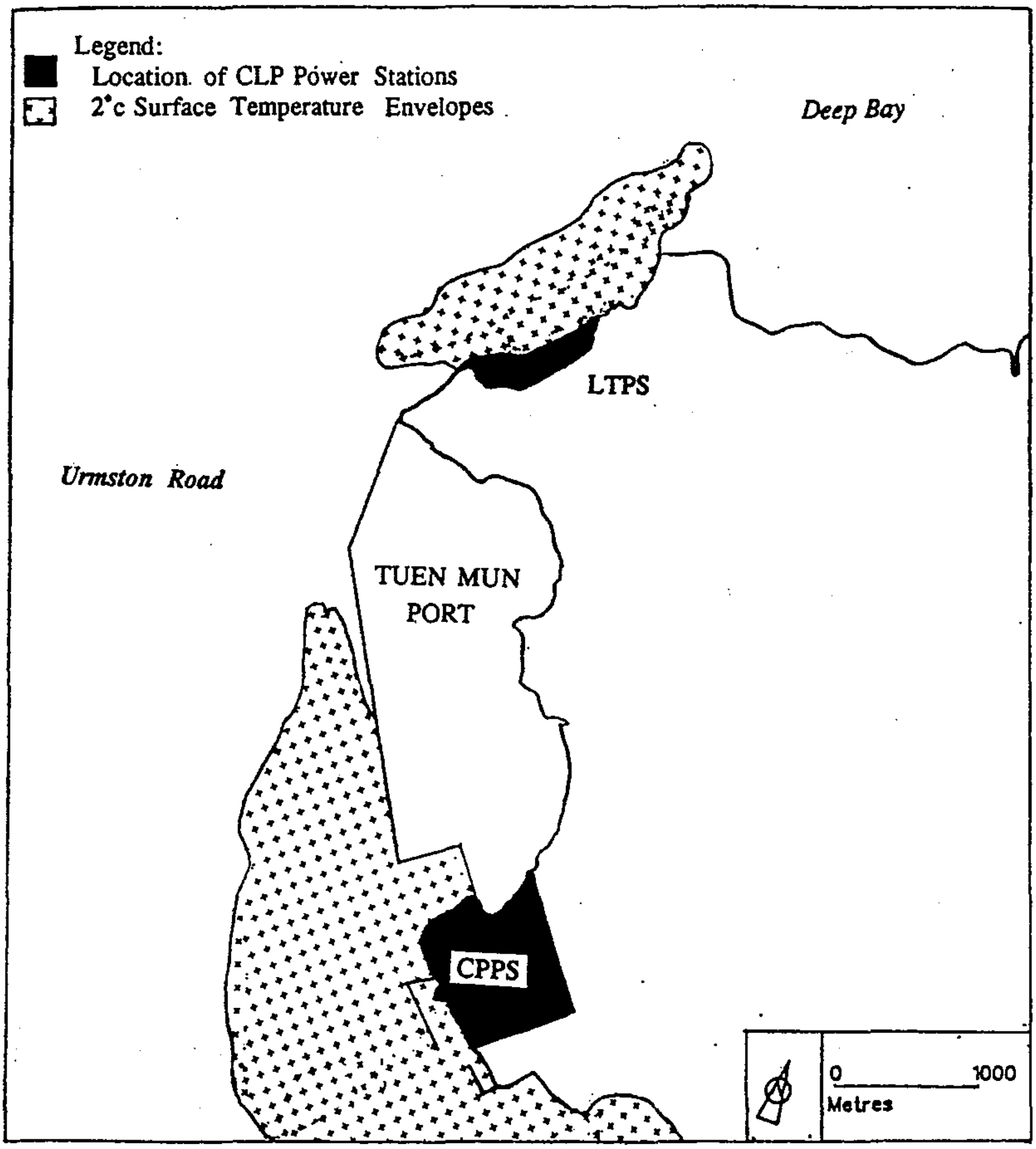

Figure 6.3a
2°c Surface Temperature Envelope For Phase 1 LTPS
(with CPPS for reference)

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10-11th Floor
Hecny Tower
9 Chatham Road
Tsimshatsui, Kowloon
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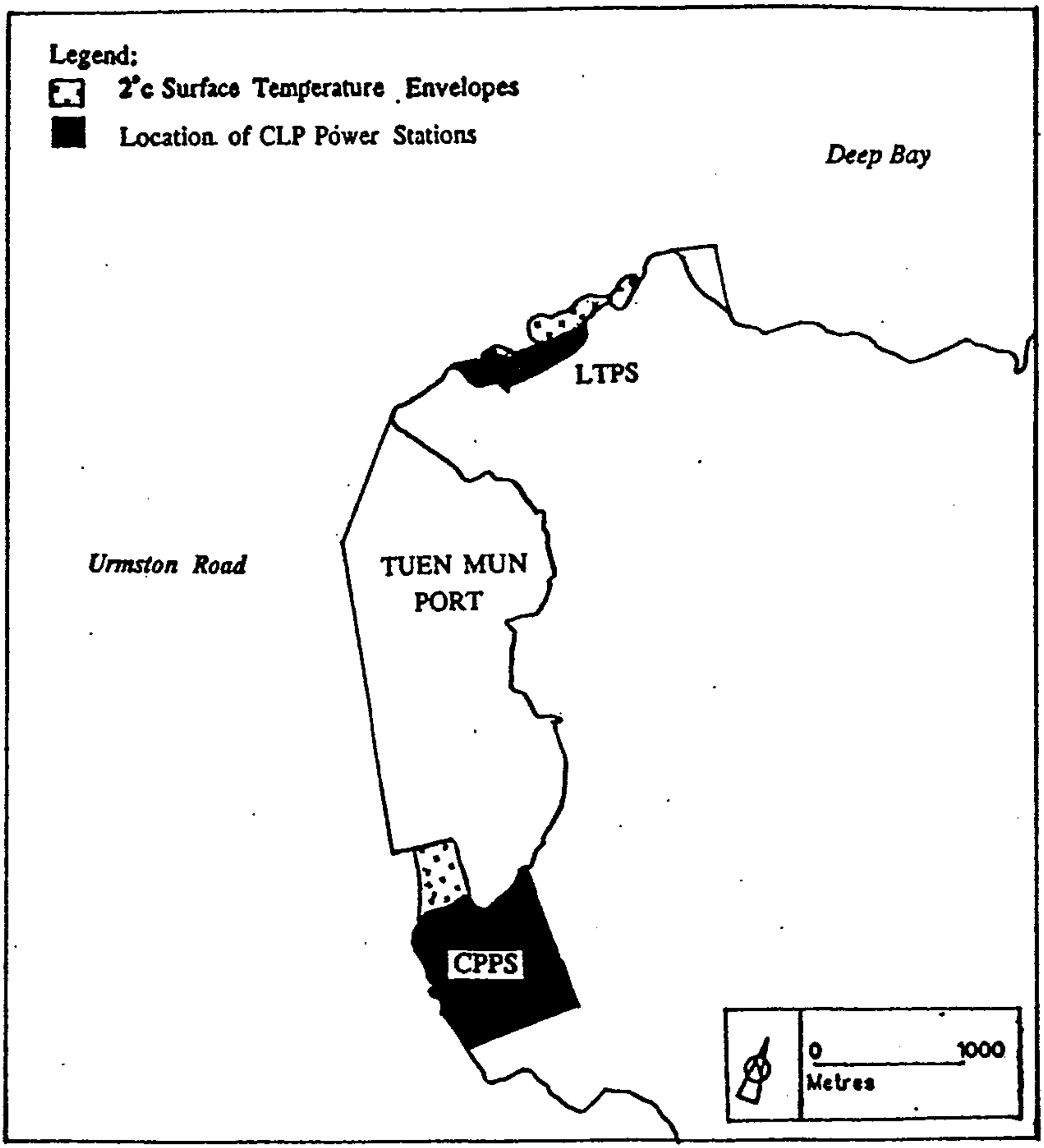


Figure 6.3b
2°c 2m to Seabed Temperature Envelope for Phase 1 LTPS (with CPPS for reference)

As *Figure 6.3a* indicates, the maximum surface easterly extent of the 2°C contour approximately corresponds to the eastern limit of the Tsang Tsui ash lagoons, whilst the maximum western extent corresponds to the western tip of Black Point. In both cases, the maximum extent actually occurs some distance offshore; about 600m for the eastern extent, and about 300m for the western extent. *Figure 6.3b* indicates that the 2°C envelope for the lower and bed portion of the water column is far more limited, remaining close to the coast and within the Yung Long embayment between the ash lagoons to the east of the site and the centre of the embayment.

This indicates that none of the SSSI's in the area, or the oyster beds to the east of the power station, will experience water temperature increases of more than 2°C above the natural range; the increases at these locations are predicted to be in the range of 0.5 to 1°C.

The thermal plume from the Phase I LTPS will thus not cause significant impacts to the Water Sensitive Receivers in the area, and no specific mitigation measures for the thermal output from the cooling water discharge are required.

6.4 NUTRIENT EFFECTS

6.4.1 Introduction

The existing background levels of nutrients in the marine waters off the LTPS site at Black Point have been presented in *Section 2.7* and *3.2.2* of this KIA and are summarised in the following table.

Table 6.1b
Summary of Background Nutrient Levels

Parameter	**Existing Quality**
Ammonia	Exceeds level 0.021 mg/l as stipulated in DBWQOs. With a high average of 0.35 mg/l at one location.
Nitrates and Organic Nitrogen	Average values range from 0.1, 0.3 to 0.5 mg/l. The guideline value of 0.3 mg/l as given in the NWWCZ is exceeded at various monitoring locations.
Phosphate	Moderate levels and not of major concern
Dissolved Oxygen	Comfortably meets the DBWQO of above 5 mg/l.

6.4.2 Water Treatment Plant (WTP)

The effluent from the water treatment plant will contain some nitrogen in the form of ammonium (NH_4^+). It is estimated that the effluent will contain approximately 4000 mg/l of total dissolved solids, most of which will consist of Na^+, K^+, Ca^{2+}, Cl^-, SO_4^{2-} and CO_3^{2-} in addition to ammonium. The total quantity of the effluent is expected to be 1 x 10^5 m^3/yr.

During Phase I the only source of ammonia from the WTP is from the Condensate Polishing Plant (86 mg/l as N). As shown in *Table 6.7a* this effluent stream is in compliance with the TM.

Following mixing with effluent streams and assuming that the water treatment plant is the only significant source of NH_4^+ it is estimated that the NH_4^+ concentration at the outlet will be 0.8 mg/l during Phase I during the limited period of approximately 3 hours over which the discharge will take place. This is compared with 0.04 mg/l at the intake.

Nitrate inputs from Phase I are not expected to be significant given the absence of the FGD plant and coal stockyard run–off with the major nitrate contributions coming from the sewage effluent.

6.4.3 *Sewage*

According to Gloyna (1971), fresh domestic sewage might be expected to contain 5–10g nitrogen per capita per day and 1–2g phosphorus per capita per day. For a working population of about 500 during Phase I, this would equate to 2.5–5 x 10^3 g and 0.5–1 x 10^3 g of nitrogen and phosphorus respectively per day for the LTPS during Phase I. The volume flow rate for the sewage effluent will be approximately 775 m^3/day. This will yield nutrient concentrations in the sewage effluent as follows :

- 3.2–6.4 mg/l nitrogen (14–28 mg/l as nitrate, NO_3^-;)
- 0.64–1.3 mg/l phosphorus (2–4 mg/l as phosphate, PO_4^{3-}).

This discharge is well within the TM guidelines of 100 mg/l total nitrogen and 10 mg/l phosphorous.

The sewage effluent will be combined with the overall liquid effluent output from the LTPS, prior to its discharge to sea. The predominant effluent will be seawater for cooling at a rate of 2.5 x 10^6 m^3/day. Total nutrient levels in the intake water are likely to be in the range of 1.3–1.8 mg/l and 0.06–0.08 mg/l for nitrate–N and phosphate–P respectively (based on baseline measurements). To take a simplistic (and worst case) approach, (ie. mixing of the upper concentration ranges in the sewage effluent by the upper concentration ranges in the cooling intake seawater) the following nutrient concentrations in the overall effluent are estimated.

- For 28 mg/l nitrate in the sewage effluent and 1.8 mg/l nitrate in the intake cooling water the overall discharge would contain 1.81 mg/l nitrate if only these two streams are combined.

- For 4 mg/l phosphate in the sewage effluent and 0.08 mg/l phosphate in the intake cooling water the overall discharge would contain 0.081 mg/l phosphate if only these two streams are combined.

Therefore, the nitrate contributions from the sewage effluent will result in a barely perceptible rise in nitrate and phosphate loadings. In actual fact, the sewage effluent will be combined with all other effluent streams. The total combined outfall is hence expected to have a maximum nitrate and phosphate concentration of 1.35 mg/l and 0.075 mg/l.

To summarise, the sewage effluent will not have any significant impact on the nitrate levels in the surrounding waters and as an independent stream meets the TM. After mixing with other effluent streams the overall concentrations of nitrate and phosphate will be well within naturally occurring levels.

6.4.4 *Other Possible Sources of Nutrients*

A further source of nutrients can also be derived from marine biota. *Section 3.2.3.4* discusses this issue, and determined that if the maximum quantity of nutrients from entrained biota were released, this would yield a barely perceptible rise in nutrient concentrations.

6.5 *METAL DISPERSION*

6.5.1 *Introduction*

Operation of the LTPS may potentially result in an elevation of trace metal concentrations in excess of the natural levels in the receiving waters. The source of these metals would be from various effluent streams in addition to those already present in the cooling water..

This section discusses the likely affect of these trace metals on water quality and marine ecology.

6.5.2 *Existing Conditions*

Since a principal requirement of cooling water is that it should have as low a temperature as possible when it is taken into the cooling system, far-field lower depth trace metal concentrations were taken to be representative of the intake cooling water at the LTPS site. These are summarised in *Table 6.5a* (reproduced from *Section 3.3.2*).

Table 6.5a
Metal Concentrations: Means (lower depth) and ranges in seawater (surface, mid-depth, lower-depth) μg/l October 1990-August 1991(1)

Metal	Mean, μg/l	Range, μg/l
Hg	<1	<1
Cd	0.060	<0.05 - 0.54
Cr	2.01	0.3 - 4.2
Cu	<5.9	<5.0 - 12.0
Pb	2.02	0.325 - 3.45
Ni	1.92	0 - 6.0
Zn	8.84	4.05 - 13.0
As	0.83	0.52 - 2.3

(1) The means are for *lower depths* (since it is water from lower depths which will be drawn in at the intake). The ranges are for *all depths* hence the inconsistency with the lower depth means. The data is presented purely for comparative purposes.

6.5.3 *Potential Sources of Impact*

The response and tolerance levels of marine organisms to trace metal in their environment or food is quite variable. *Section 3.3.3* describes in detail the potential sources of impacts on these organisms to trace metals.

6.5.4 *Effluent Composition*

Trace metal concentrations in effluents discharged to Hong Kong waters are specified in terms of effluent standards. These standards vary according to the receiving water zone and the effluent volumetric flow rate. Whichever scenario/case is eventually adopted, the volume flow rate of the combined effluents from the outfall will be outside the range of volume flows covered by effluent standards. Consequently, the authorities will set effluent standards on a single case-by-case basis.

The main sources of trace metals in the cooling water discharge are:

- the natural levels present in the intake cooling water;

No other effluent streams are expected to make an significant contribution to the metal loadings.

Therefore, Phase I will result in a negligible contribution to trace metal loadings.

6.6 *MITIGATION OPPORTUNITIES*

Notwithstanding the conclusion of the above sections that the predicted maximum effluent discharges are unlikely to give rise to significant effects on the marine ecology of the area, opportunities exist to reduce the total effluent loading to the marine environment. These measures presented below.

The only parameters of concern during Phase I, given the absence of the FGD units, coal stockyard and ash pit, are nutrient inputs and thermal discharges.

6.6.1 *Nutrients*

The condensate polishing process of the Water Treatment Plant produces an effluent containing up to 200 ppm of ammonium ion in the form of Ammonium sulphate which equates to an annual discharge of around 10 tonnes. This corresponds to a total nitrogen loading of 86 mg/l and fulfils the limit of 100 mg/l for Total Nitrogen given in the TM. After mixing of the effluent in the CW system the concentration is reduced to less than 0.01ppm.

The sewage effluent will be biologically treated. This form of mitigation is considered adequate as the nitrate inputs from this effluent will have a negligible effect on the existing natural nitrate levels in the surrounding waters.

6.7 SUMMARY OF INDIVIDUAL STREAMS FOR PHASE I AND CONCLUSIONS

The summary of the most recent compositions from individual streams is presented in *Table 6.7a.*

The summary table shows that all of the individual streams would meet the TM requirement for direct discharge into Deep Bay. The cumulative impacts from these effluents and consideration of the *total loadings* has been assessed in the previous sections. It has been determined that operation of the LTPS under Phase I should not result in any adverse impact to the water quality of the surrounding marine environment.

Table 6.7a Summary of Individual Streams for Phase I

Effluent Stream	Parameters	Discharge Level (mg/l except pH)	TM Value	Mitigation Measures
Boiler Blowdown (700m^3/day)	pH Ammonia (as N)	9–10 0.8	6–9 100	Neutralisation
Water Treatment Plant Regeneration Cation and Anion Beds Only 80 m^3/day for 6 days/week	pH Suspended Solids Nitrate (as Total N)	6–9 30 4.5	6–9 50 100	None Required to meet TM
Regeneration of Cation, Anion and Mixed Beds 107 m^3/day for one day/week	pH Suspended Solids Nitrate (as Total N)	6–9 22 3	6–9 50 100	None Required to meet TM
Condensate Polishing Plant (250m^3)	pH Ammonia (as Total N) Total Suspended Solids	6–9 86 15	6–9 100 50	None required to meet TM
Sewage Treatment (770m^3/day)	Nitrate Phosphate	14–28 2–4	100 10	None required to meet TM
Oil Separator	Oil	<5 ppm	20 ppm	None Required to meet TM

7 *EPD'S POSITION AND THE WAY FORWARD*

Water Quality

With regard to the impact on the marine water quality, the Director of Environmental Protection is of the following view:

(a) the best practicable technology should be adopted to reduce or eliminate the pollutants arisings from the operation of the plant. Emphases should be given on replacement, minimisation, recycling and reuse of effluent streams. Appropriate treatment and disposal methods for the residual discharges should then be recommended. The Deep Bay Water Quality Objectives must be achieved and the concept of "zero discharge" into Deep Bay should be taken into consideration. Adequate assessment should be carried out to demonstrate that the impacts of the residual discharges (after treatment) to the receiving water bodies are insignificant;

(b) though the total discharge flow rate of the "worst case" exceeds the largest flow rate stipulated in the Technical Memorandum (TM), reference should still be made to the TM's effluent standards and the principle of not permitting standards to be met BY dilution should apply.

(c) before the formal approval of the Phase II development, a detailed water quality assessment, as a follow-up study to the Phase 2 EIA study, shall be carried out to examine the following issues and any other unresolved water quality issues associated with the Phase II development.

  (i) to review the validity of the assumptions and the applicability of the findings in the Phase 2 EIA Study Key Issue Report on Marine Water Quality, taking into account the control technologies and environmental standards at the time of the study;

  (ii) to investigate and recommend best practicable measures to reduce, reuse and recycle the pollutants in the various effluent streams arising from the operation of the plant. Wherever possible, the individual effluent streams should be properly treated to reduce the pollution loads;

  (iii) to assess the thermal impacts on the marine biota within the zone subject to >2°C above the ambient;

  (iv) to further assess the acceptability of the impacts of the increase in nitrogen, TSS and heavy metal levels resulting from the discharge effluent and cooling water discharges (taking into account the transportation, transformation, ultimate fate and effects of any heavy metals discharged), and to recommend effective mitigation measures, taking into account the control technologies and the environmental standards or policies at the time of the study; and

  (v) to further assess the cumulative effects of discharges in respect of nutrients and heavy metal levels, taking into account the background water quality conditions, the discharges from the Castle Peak Power Station and NWNT sewage outfall, and the environmental standards or policies at the time of the study.

ANNEXES

Annex A

Analytical Methods of Seawater Samples

A. *METHODS OF MEASUREMENT ON SEA WATER SAMPLES*

- *TEMPERATURE : Method 2250B*

  In situ measurement are conducted using an NBA Multi-parameter System Model TDS-7 with thermistor temperature sensor.

  Results are reported to ±0.1°C.

- *pH : Method 4500-H^+*

  In situ measurements are conducted with glass electrodes using an NBA Multi-parameter System Model TDS-7 having automatic temperature compensation facility.

  Results are reported to ±0.1 pH unit.

- *SALINITY : Method 2520B*

  In situ measurements are carried out by conductivity using an NBA Multi-parameter System Model TDS-7.

  After temperature compensation, the results are reported to ±1 g per kg.

- *DISSOLVED OXYGEN : Method 4500-0G*

  In situ measurements are conducted by membrane electrode using a NBA Multi-paramenter System Model TDS-7.

  After compensation for temperature and salinity, results are reported to ±0.1 mg per litre.

- *CHLORINE (RESIDUAL) : fee chlorine + mono - and dichloramine by Method 4550-Cl^-G*

  In situ measurements are carried out using colour disc comparator.

  Note : Method 4550-CL^{-G} actually measures bromine concentration but records it as chlorine, due to the presence of bromide. Chlorine cannot exist freely in seawater because of the following reaction:

  $$Cl_2 + 2Br^- \rightarrow 2CL^- + Br_2$$

  Results are reported to ±0.1 mg Cl_2 per litre.

- *TURBIDITY : Method 2130B*

  Turbidity is measured using Hach Turbidimeter Model Ratio/XR.
  Results are reported to ±0.1 NTU
  (Nephelometric Turbidity Units)

- *CONDUCTIVITY : Method 2510B*

  Conductivity is measured in situ using a conductivity meter; Schott Gerate Model CG858.

  Results are reported to ±0.1 mS per cm.
  The instrument is calibrated against a standard solution of potassium chloride.

- *NITRATE NITROGEN: Method 4,500 - NO_3^-E*

  Measurements are carried out by a colourmetric method using a Hitachi Spectrophometer Model 220S after nitrate reduction and subsequent diazotisation and complexation of the nitrate by-product.

  Standards are blank corrected and prepared in a seawater matrix. Results are reported to be nearest 0.01 ppm.

- *AMMONIA NITROGEN: Method reported in Analytical Chemistry (Vol 58, 585-587pp, 1986)*

  Measurements are carried out using colourmetric spectroscopy after formation of a coloured indophenot complex.

  Standards are blank corrected and prepared in a seawater matrix. Results are reported to the nearest 0.01ppm.

- *ORGANIC NITROGEN: Method 4,500 B for organic nitrogen followed by ammonia determination reported in Analytical Chemistry (Vol 58, 585-587pp, 1986)*

  Unfiltered seawater samples are digested in sulphuric acid, potassium sulphate and a mecuric catalyst to convert organic nitrogen to ammonium sulphate. The ammonium salt this formed is measured colourmetrically using the method described above from ammonia nitrogen.

  Standards are blank corrected and prepared in a seawater matric. Results are reported to the nearest 0.01ppm.

Annex B

Mean Water Quality Results from CLP Baseline Monitoring Survey

PARAMETERS		Near field construction impact monitoring sites											
		OCT 90	NOV 90	DEC 90	JAN 91	FEB 91	MAR 91	APR 91	MAY 91	JUN 91	JUL 91	AUG 91	Mean
		S	S	S	S	S	S	S	S	S	S	S	
1. pH	(pH unit)	7.76	8.22	7.88	7.845	7.882	7.998	7.98	7.962	7.738	7.99	7.88	7.921
2. Temperature	(°C)	23	22.76	18.94	16.9	19.76	25	27.64	28.66	28.75	29.84	29.26	24.66
3. Turbidity	(NTU)	2.82	5.42	1.26	7.46	2.34	1.84	7.22	2.58	5.82	11.38	10.92	5.350
4. Conductivity	(ms cm- 1)	46.96	43.95	49.06	48.28	46.98	41.34	46.84	35.77	25.37	19.99	38.96	40.32
5. Salinity	(g Kg- 1)	28	34.2	28.2		*	*	*	*	12.8	8.46	18.9	21.69
6. Dissolved oxygen	n (mgl- 1)	7.46	8.04	8.56	9.42	7.52	7.822	7.74	8.22	6.5	-----	5.78	7.708
7. TSS	(mg l- 1)	4	2.2	2	207	2.6	1.46	1.6	1.26	2.96	65.82	9.04	27.27
8. BOD (5 day)	(mg l- 1)			1			-----	-----	-----	-----	-----	-----	1
9. Eh	(mV)						-----	-----	-----	-----	-----	-----	
10. Organic carbon	(mg l- 1)						-----	-----	-----	-----	-----	-----	
11. Grain size	(%)						-----	-----	-----	-----	-----	-----	
12. Grease and oil	(mg l- 1)	0.19	0.258	0.148		*	*	*	*	-----	-----	-----	0.198
13. Sulphates	(mg l- 1)		2680	2420	2274	2454	1924	2318	1367.	1422.	1007	1604	1947.
14. Bicarbonates	(mg l- 1)					-----	-----	-----	-----	-----	-----	-----	
15. Phosphorus	(mg l- 1)					-----	-----	-----	-----	-----	-----	-----	
16. Nitrate- N	(mg l- 1)					-----	-----	-----	-----	-----	-----	-----	
17. Ammonia- N	(mg l- 1)					-----	-----	-----	-----	-----	-----	-----	
18. Organic- N	(mg l- 1)					-----	-----	-----	-----	-----	-----	-----	
19. Chlorophyll 'A'	'(mg l- 1)					-----	-----	-----	-----	-----	-----	-----	
20. Chloride	(mg l- 1)		17800			-----	-----	-----	-----	-----	-----	-----	17800
21. Bromide	(mg l- 1)												
22. Total sulphide	(mg l- 1)					-----	-----	-----	-----	-----	-----	-----	-----
23. Chlorine	(mg l- 1)					-----	-----	-----	-----	-----	-----	-----	-----
24. Detergents	(mg l- 1)					-----	-----	-----	-----	-----	-----	-----	-----
25. Magnesium	(mg l- 1)					-----	-----	-----	-----	-----	-----	-----	-----
26. Calcium	(mg l- 1)					-----	-----	-----	-----	-----	-----	-----	-----
27. Potassium	(mg l- 1)					-----	-----	-----	-----	-----	-----	-----	-----
28. Sodium	(mg l- 1)					-----	-----	-----	-----	-----	-----	-----	-----
29. Cadmium	(ug l- 1)					-----	-----	-----	-----	-----	-----	-----	-----
30. Mercury	(ug l- 1)					-----	-----	-----	-----	-----	-----	-----	-----
31. Chromium	(ug l- 1)					-----	-----	-----	-----	-----	-----	-----	-----
32. Copper	(ug l- 1)					-----	-----	-----	-----	-----	-----	-----	-----
33. Lead	(ug l- 1)					-----	-----	-----	-----	-----	-----	-----	-----
34. Nickel	(ug l- 1)					-----	-----	-----	-----	-----	-----	-----	-----
35. Zinc	(ug l- 1)					-----	-----	-----	-----	-----	-----	-----	-----
36. Arsenic	(ug l- 1)					-----	-----	-----	-----	-----	-----	-----	-----
37. Manganese	(ug l- 1)					-----	-----	-----	-----	-----	-----	-----	-----
38. Selenium	(ug l- 1)					-----	-----	-----	-----	-----	-----	-----	-----
39. Iron	(ug l- 1)					-----	-----	-----	-----	-----	-----	-----	-----
40. Aluminium	(ug l- 1)					-----	-----	-----	-----	-----	-----	-----	-----
41. Facal coliform	CFU/100ml					-----	-----	-----	-----	-----	-----	-----	-----
42. E. coli	CFU/100ml					-----	-----	-----	-----	-----	-----	-----	-----

NOTES: 1. S - monthly sample taken just below surface of seawater

PARAMETERS		Marine buoys and operational effluent impact monitring sites															
		OCT 90				NOV 90				DEC 90				JAN 91			
		S	M	L	O	S	M	L	O	S	M	L	O	S	M	L	O
1. pH	(pH unit)	7.8	7.8	7.8		8.175	8.2	8.2		8.05	7.8	8		7.847	7.97	7.97	
2. Temperature	('C)	74.75	23	23		21.8	22.7	22.7		19.55	19.9	19		19.1	18.8	18.8	
3. Turbidity	(NTU)	3.975	3.5	1.1		4.075	1.3	9.7		1.1	0.3	2.6		10.32	18.5	15.6	
4. Conductivity	(ms cm– 1)	47.87	45.9	46.5		42.57	43.46	43.3		46.85	50	51.5		48.87	50.1	49.6	
5. Salinity	(g Kg– 1)	29	29	29		28.25	31	31		28.75	31	31		21.95	29.3	25.0	
6. Dissolved oxygen	n (mgl– 1)	7.825	7.8	7.4		7.775	7.8	7.9		8.8	8.2	8.1		9.025	8.8	8.7	
7. TSS	(mg l– 1)	6	4	5		2	2	2		2	2	2		211.2	220	220	
8. BOD (5 day)	(mg l– 1)	1	1	1		0.75	1	1		1.25	1	1		1.1	*	*	
9. Eh	(mV)														------	------	
10. Organic carbon	(mg l– 1)	3.5	3	4										1.7	1.0	3.4	
11. Grain size	(%)														------	------	
12. Grease and oil	(mg l– 1)	0.112	0.05	0.05		0.047	<0.01	<0.01		0.357				6.8	6.8	6.2	
13. Sulphates	(mg l– 1)	2150	2600	2800		2350	2600	2700		2367.	2640	2490		2270	2360	2380	
14. Bicarbonates	(mg l– 1)	6	6	6		11	11	11		6	12	6		13.97	13.9	12.1	
15. Phosphorus	(mg l– 1)	0.177	0.13	0.13		0.395	0.12	0.15						0.067	0.05	0.1	
16. Nitrate– N	(mg l– 1)	0.075	0.08	0.08		0.097	0.04	0.06						0.4	0.23	0.33	
17. Ammonia– N	(mg l– 1)	0.01	<0.01	0.02		0.772	0.07	0.07						0.02	0.02	0.02	
18. Organic– N	(mg l– 1)	0.127	0.12	0.12		0.235	0.05	0.06						0.247	0.17	0.34	
19. Chlorophyll 'A'	'(mg l– 1)	1.9	1.5	1.3		2.365	1.38	1.35						1.366	2.8	3.0	
20. Chloride	(mg l– 1)	13750	13000	17000		16500	18000	18000		17202	18100	18000		17300	17700	17100	
21. Bromide	(mg l– 1)	60	65	66		73.25	85	71									
22. Total sulphide	(mg l– 1)	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01							------	------	
23. Chlorine	(mg l– 1)	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1		<0.1	<0.1	<0.1		< 0.1	------	------	
24. Detergents	(mg l– 1)	0.012	0.01	0.02										0.065	0.07	0.07	
25. Magnesium	(mg l– 1)	797.2				918.2				1092.				1034.	------	------	
26. Calcium	(mg l– 1)	347.2				380.7				387.7				356	------	------	
27. Potassium	(mg l– 1)	395.2				437				469				327.5	------	------	
28. Sodium	(mg l– 1)	8362.				9560				8777.				9166.	------	------	
29. Cadmium	(ug l– 1)	<0.05				<0.05							13.32	0.082	------	------	
30. Mercury	(ug l– 1)													< 1	------	------	
31. Chromium	(ug l– 1)	0.875				2.2				1.4			1.201	1.825	------	------	
32. Copper	(ug l– 1)	< 5				< 5				< 5			865.1	< 5	------	------	
33. Lead	(ug l– 1)	6.325				0.575				0.87			8.71	0.9	------	------	
34. Nickel	(ug l– 1)	< 5				< 5				< 5				< 5	------	------	
35. Zinc	(ug l– 1)	11.07				6.475				6.25			2995.	6.85	------	------	
36. Arsenic	(ug l– 1)	< 1				< 1				< 1			16.22	< 1	------	------	
37. Manganese	(ug l– 1)	25				49.25				28.75				25	------	------	
38. Selenium	(ug l– 1)	< 1				< 1				< 1			17.07	< 1	------	------	
39. Iron	(ug l– 1)	281				163.7				62.25				137	------	------	
40. Aluminium	(ug l– 1)	260.2				196.2				64.5				166	------	------	
41. Fecal coliform	CFU/100ml	477.5	900	900		1240	310	550		2050	8400	8400		205	440	440	
42. E. coli	CFU/100ml	395	900	800		1125	300	370		1050	7200	6600		105	320	300	

NOTES:
1. S – monthly sample taken just below surface of seawater
2. M – monthly sample taken at mid- depth of seawater when depth is more than 10 metres (only for marine buoy B7)
3. L – monthly sample taken just above the seabed when the depth of seawater is more than 5 metres
4. O – sample of oysters taken at three monthly intervals

PARAMETERS		Marine buoys and operational effluent impact monitring sites															
		FEB 91				MAR 91				APR 91				MAY 91			
		S	M	L	O	S	M	L	O	S	M	L	O	S	M	L	O
1. pH	(pH unit)	7.875	7.93	7.95		7.967	7.94	7.92	-----	7.942	8.1	8.1		8.005	8.04	7.96	
2. Temperature	(°C)	19.77	19.6	18.4		25	25	25	-----	27.22	27.3	27.4		28.9	29	28.4	
3. Turbidity	(NTU)	3.475	2.4	5.3		3.325	3	4.6	-----	8.4	8	7.5		3.35	3.5	3.9	
4. Conductivity	(ms cm- 1)	51.9	52.5	52.3		38.65	40.1	40.9	-----	44.15	45.8	46.5		40.03	40.28	43.5	
5. Salinity	(g Kg- 1)	28.1	29.0	22.5		25.22	25.5	16.0	-----	12.27	16.0	5.4		15.3	20.0	16.7	
6. Dissolved oxygen	n (mgl- 1)	7.7	7.5	7.5		7.922	7.05	7.02	-----	8.225	8.7	8.5		8.475	7.8	8.2	
7. TSS	(mg l- 1)	1.25	3	4		2.75	7	1	-----	3	2	1		1.925	2.5	2.2	
8. BOD (5 day)	(mg l- 1)	1.425	1.03	1		1.577	1.65	1.51	-----	0.965	1.29	0.66		0.58	0.73	0.62	
9. Eh	(mV)	-----	-----	-----		-----	-----	-----	-----	-----	-----	-----		-----	-----	-----	
10. Organic carbon	(mg l- 1)	2.9	5.0	3.8		4.2	3.3	0.7	-----	1.05	1	0.6		0.95	1.2	0.7	
11. Grain size	(%)	-----	-----	-----		-----	-----	-----	-----	-----	-----	-----		-----	-----	-----	
12. Grease and oil	(mg l- 1)	6.525	11.6	5.7		7.075	7.9	6.8	-----	6.525	5.7	6.8		22	45	56	
13. Sulphates	(mg l- 1)	2210	2440	2290		2037.	2110	2080	-----	2125	2160	2230		1309.	1822	2011	
14. Bicarbonates	(mg l- 1)	8.05	8.8	9		8.95	8.8	8.7	-----	9.125	7	6.6		6.75	9.2	12.8	
15. Phosphorus	(mg l- 1)	0.087	0.06	0.06		0.08	0.05	0.05	-----	0.065	0.04	0.05		0.017	0.01	<0.01	
16. Nitrate- N	(mg l- 1)	0.217	0.03	0.03		0.42	0.29	0.37	-----	0.27	0.17	0.21		0.59	0.39	0.32	
17. Ammonia- N	(mg l- 1)	0.175	0.09	0.08		0.165	0.09	0.09	-----	0.01	0.01	0.01		0.055	0.05	0.05	
18. Organic- N	(mg l- 1)	0.17	0.08	0.05		0.066	0.19	0.13	-----	1.167	1.01	1.13		0.387	0.4	0.23	
19. Chlorophyll 'A'	(mg l- 1)	2.37	1.79	1.98		1.505	1.36	0.81	-----	3.233	2.8	3.3		16.32	3	8	
20. Chloride	(mg l- 1)	16200	16800	17200		14425	15600	15100	-----	15075	15600	15800		10440	12875	13879	
21. Bromide	(mg l- 1)																
22. Total sulphide	(mg l- 1)	-----	-----	-----		-----	-----	-----	-----	-----	-----	-----		-----	-----	-----	
23. Chlorine	(mg l- 1)	< 0.1	-----	-----		< 0.1	-----	-----	-----	-----	-----	-----		< 0.1	-----	-----	
24. Detergents	(mg l- 1)	0.047	0.04	0.05		0.015	0.04	0.05	-----	0.012	0.03	0.02		0.045	0.04	0.05	
25. Magnesium	(mg l- 1)	1021.	-----	1043		940.5	-----	-----	-----	974.2	-----	1017		746.7	-----	1029	
26. Calcium	(mg l- 1)	395.2	-----	402		356	-----	-----	-----	408	-----	433		272.5	-----	360	
27. Potassium	(mg l- 1)	338	-----	365		277.7	-----	-----	-----	306.7	-----	336		198.7	-----	307	
28. Sodium	(mg l- 1)	8761	-----	9027		7736	-----	-----	-----	7883.	-----	8258		5476.	-----	7234	
29. Cadmium	(ug l- 1)	<0.05	-----	<0.05		0.125	-----	-----	12.97	0.09	-----	0.07		0.157	-----	0.07	
30. Mercury	(ug l- 1)	< 1	-----	<1		< 1	-----	-----	-----	< 0.1	-----	<1		< 1	-----	< 1	
31. Chromium	(ug l- 1)	1.55	-----	2.4		0.8	-----	-----	1.364	1.475	-----	0.8		0.575	-----	0.7	
32. Copper	(ug l- 1)	< 5	-----	<5		< 5	-----	-----	642	< 5	-----	<5		< 5	-----	< 5	
33. Lead	(ug l- 1)	1	-----	1		1.625	-----	-----	5.862	1.125	-----	1.7		0.825	-----	0.6	
34. Nickel	(ug l- 1)	< 5	-----	<5		< 5	-----	-----	-----	< 5	-----	<5		< 2	-----	< 2	
35. Zinc	(ug l- 1)	6.3	-----	10		3.875	-----	-----	1828	6	-----	7		3.25	-----	4	
36. Arsenic	(ug l- 1)	1.225	-----	1.2		2.225	-----	-----	13.35	1.1	-----	1.0		< 1	-----	< 1	
37. Manganese	(ug l- 1)	20	-----	31		11.12	-----	-----	-----	17.75	-----	34		8.75	-----	9	
38. Selenium	(ug l- 1)	< 1	-----	<1		< 1	-----	-----	14.25	< 1	-----	<1		< 1	-----	< 1	
39. Iron	(ug l- 1)	143.5	-----	302		196.7	-----	-----	-----	464.7	-----	859		115.7	-----	135	
40. Aluminium	(ug l- 1)	123.7	-----	308		221.2	-----	-----	-----	437.7	-----	764		129.7	-----	139	
41. Fecal coliform	CFU/100ml	45	80	100		50	100	100	-----	110	20	20		250	360	460	
42. E. coli	CFU/100ml	30	60	60		5	80	80	-----	45	0	0		95	200	360	

NOTES: 1. S – monthly sample taken just below surface of seawater
2. M – monthly sample taken at mid- depth of seawater when depth is more than 10 metres (only for marine buoy B7)

Marine buoys and operational effluent impact monitoring sites

PARAMETERS		JUNE 91				JUL 91				AUG 91				Mean			
		S	M	L	O	S	M	L	O	S	M	L	O	S	M	L	O
1. pH	(pH unit)	7.832	7.95	7.94		7.835	7.98	7.96		7.932	8	8.02		7.942	7.973	7.983	------
2. Temperature	('C)	29.5	*	*		29.2	30	29.8		29.6	28.8	29.7		29.49	24.41	24.22	------
3. Turbidity	(NTU)	15.17	20.1	11.9		13.52	15.8	20.2		18.05	11.7	11.6		7.706	8.009	8.545	------
4. Conductivity	(ms cm– 1)	20.51	29.73	34.11		19.17	23.9	32.2		38.8	40.7	42.5		40.10	42.04	43.90	------
5. Salinity	(g Kg– 1)	10.02	14.9	17.4		10.37	11.8	16.7		19.22	20.4	21.4		20.77	17.53	17.55	------
6. Dissolved oxygen	n (mgl– 1)	7.125	7.4	7.6		7.287	6.98	6.87		6.057	6.22	7.11		7.619	7.620	7.718	------
7. TSS	(mg l– 1)	7.675	11.5	17.9		75.1	146.2	156.6		25.47	36.6	15.2		30.76	26.41	24.57	------
8. BOD (5 day)	(mg l– 1)	2.06	1.67	2.07		0.725	0.52	0.51		0.562	0.34	0.21		1.090	1.043	0.956	------
9. Eh	(mV)	------	------	------		------	------	------		------	------	------		------	------	------	------
10. Organic carbon	(mg l– 1)	7.333	12	14		8.75	21	8		8	9	9		4.284	5.611	4.911	------
11. Grain size	(%)	------	------	------		------	------	------		------	------	------		------	------	------	------
12. Grease and oil	(mg l– 1)	0.15	<0.1	<0.1		< 0.1	<0.1	<0.1		< 0.1	<0.1	<0.1		5.510	8.561	9.061	------
13. Sulphates	(mg l– 1)	1208.	1729	1908		951	1462	1504		1540	1620	1750		1865.	2143.	2194.	------
14. Bicarbonates	(mg l– 1)	5.775	4.84	4.84		6.25	7.46	6.82		6.9	6.8	5.7		6.252	6.674	6.141	------
15. Phosphorus	(mg l– 1)	0.042	0.04	0.05		0.057	0.03	0.03		0.082	0.09	0.08		0.107	0.082	0.068	------
16. Nitrate– N	(mg l– 1)	1.252	0.79	0.58		0.842	0.59	0.51		0.56	0.4	0.45		0.472	0.301	0.294	------
17. Ammonia– N	(mg l– 1)	0.035	0.05	0.05		0.037	0.03	0.04		0.06	0.06	0.06		0.121	0.042	0.042	------
18. Organic– N	(mg l– 1)	0.57	0.89	0.3		0.79	4.49	1.12						0.417	0.822	0.386	------
19. Chlorophyll 'A'	(mg l– 1)	4.082	2.75	1.34		2.202	1.1	1.65		3.165	2.2	2.2		3.853	2.07	2.173	------
20. Chloride	(mg l– 1)	6017.	9516	10990		6124.	11220	12230		12707	13510	14320		13249	13709	13309	------
21. Bromide	(mg l– 1)													66.62	75	66.5	------
22. Total sulphide	(mg l– 1)	------	------	------		------	------	------		------	------	------		< 0.01	< 0.01	< 0.01	------
23. Chlorine	(mg l– 1)	< 0.1	------	------		< 0.1	------	------		< 0.1	------	------		< 0.1	< 0.1	< 0.1	------
24. Detergents	(mg l– 1)	< 0.01	<0.01	<0.01		0.02	0.03	0.02		0.03	0.03	<0.01		0.027	0.036	0.035	------
25. Magnesium	(mg l– 1)	315	------	633		315.2	------	669			------	------		615.6		679.2	------
26. Calcium	(mg l– 1)	159.5	------	313		166.7	------	326			------	------		322.7		367.2	------
27. Potassium	(mg l– 1)	101.5	------	163		144.2	------	207			------	------		301.5		279.8	------
28. Sodium	(mg l– 1)	3080	------	5670		3287.	------	7500			------	------		7209.		7577.	------
29. Cadmium	(ug l– 1)	0.19	------	0.1		0.175	------	0.06			------	------		0.091		0.06	13.14
30. Mercury	(ug l– 1)	< 1	------	< 1		< 1	------	< 1			------	------		< 1		< 1	------
31. Chromium	(ug l– 1)	0.625	------	0.5		0.8	------	1			------	------		1.192		1.04	1.282
32. Copper	(ug l– 1)	< 5	------	< 5		< 5	------	< 5			------	------		< 5		< 5	753.5
33. Lead	(ug l– 1)	1.35	------	1.2		2.425	------	2.5			------	------		1.702		1.4	7.296
34. Nickel	(ug l– 1)	< 5	------	< 5		< 5	------	< 5			------	------		< 5		< 5	------
35. Zinc	(ug l– 1)	5.5	------	7		8.75	------	7			------	------		6.432		7	2411.
36. Arsenic	(ug l– 1)	< 5	------	< 1		< 1	------	< 1			------	------		< 1		< 1	14.79
37. Manganese	(ug l– 1)	9.5	------	12		18.5	------	23			------	------		21.16		11.2	------
38. Selenium	(ug l– 1)	< 1	------	< 1		< 1	------	< 1			------	------		< 1		< 1	15.66
39. Iron	(ug l– 1)	499.2	------	601		487	------	760			------	------		259.1		531.4	------
40. Aluminium	(ug l– 1)	605.5	------	630		443.2	------	644			------	------		256.8	0	497	------
41. Fecal coliform	CFU/100ml	45	80	100		630	680	580		390	260	360		499.3	1057.	1091.	------
42. E. coli	CFU/100ml	20	40	40		340	600	520		320	200	200		320.9	900	843.1	------

NOTES:
1. S – monthly sample taken just below surface of seawater
2. M – monthly sample taken at mid– depth of seawater when depth is more than 10 metres (only for marine buoy B7)
3. L – monthly sample taken just above the seabed when the depth of seawater is more than 5 metres
4. O – sample of oysters taken at three monthly intervals

PARAMETERS		Far field operational effluent impact monitoring sites																	
		OCT 90			NOV 90			DEC 90			JAN 91			FEB 91			MAR 91		
		S	M	L	S	M	L	S	M	L	S	M	L	S	M	L	S	M	L
1. pH	(pH unit)	7.8	7.8	7.8	8.22	8.1	8.1	7.94	7.95	7.975	7.872	7.845	7.885	7.892	7.925	7.902	7.932	7.865	7.913
2. Temperature	('C)	23	23	23	22.3	22.45	22.52	18.9	18.75	18.8	18.16	16.9	18.37	19.98	19.5	19.25	25	25	25
3. Turbidity	(NTU)	4	1.1	1.5	2.82	1.85	3.575	3.36	4.65	4.225	8.26	10.85	12.45	3.84	2.9	2.95	4.44	4	12.15
4. Conductivity	(ms cm- 1)	49.6	47.35	48.62	43.34	43.15	43.4	49.04	48.9	50.37	48.74	48.94	49.32	50.13	51.7	50.95	40.24	43	43.27
5. Salinity	(g Kg- 1)	29.8	29	29.5	30.4	30	28.5	28	29.5	30.25	23.9	22.7	16.7	18.98	27.85	24.1	23.72	21.8	21.13
6. Dissolved oxygen	n (mgl- 1)	7.28	7.15	7.2	8.02	8.1	7.65	8.46	8.3	8.4	8.38	8.8	8.725	7.68	7.8	7.7	8.34	8.585	8.342
7. TSS	(mg l- 1)	3.48	2	1.75	2	2	2	1.2	1	1.5	254.2	251	263.5	4	2.5	2	3.2	5	9
8. BOD (5 day)	(mg l- 1)	1.2	1	1	0.8	0.5	0.5	1	< 1	0.25	0.9	0.9	0.9	1.252	1.4	1.135	1.462	1.81	1.557
9. Eh	(mV)																		
10. Organic carbon	(mg l- 1)	3.8	3	2.25							1.96	1.35	3.2	2.12	2.25	3.175	2.58	3.1	1.733
11. Grain size	(%)																		
12. Grease and oil	(mg l- 1)	0.12	0.05	0.037	0.072	0.055	0.062	0.072			7.12	6.5	5.7	6.06	5.7	6.4	6.14	7.65	7.833
13. Sulphates	(mg l- 1)	2080	2350	2325	2620	2500	2650	2430	2545	2562.	2244	2320	2330	2224	2325	2350	1902	2170	2175
14. Bicarbonates	(mg l- 1)	6	6	6	10.2	10	10.75	7	8	7.5	12.5	13	11.67	9.9	10.15	9.8	7.68	7.8	7.5
15. Phosphorus	(mg l- 1)	0.152	0.145	0.142	0.116	0.105	0.077				0.056	0.06	0.082	0.062	0.09	0.065	0.074	0.09	0.09
16. Nitrate- N	(mg l- 1)	0.056	0.06	0.055	0.024	0.03	0.017				0.304	0.325	0.29	0.098	0.09	0.09	0.458	0.395	0.345
17. Ammonia- N	(mg l- 1)	0.014	0.01	0.005	0.058	0.05	0.08				0.05	0.025	0.022	0.108	0.115	0.11	0.114	0.1	0.102
18. Organic- N	(mg l- 1)	0.092	0.09	0.09	0.068	0.055	0.065				0.142	0.075	0.175	0.192	0.585	0.105	0.14	0.14	0.198
19. Chlorophyll 'A'	'(mg l- 1)	1.74	1.25	1.175	1.164	0.835	1.065				4.58	2.8	3.375	1.77	1.95	1.505	1.132	1.39	1.205
20. Chloride	(mg l- 1)	14600	15500	15500	17200	17500	17750	16560	17100	17250	17580	17200	17650	16980	16550	16775	13980	14500	10850
21. Bromide	(mg l- 1)	59.8	57.5	59	84.4	43	79.25												
22. Total sulphide	(mg l- 1)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01				-----			-----	-----	-----	-----	-----	-----
23. Chlorine	(mg l- 1)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1				< 0.1			< 0.1	-----	-----	< 0.1	-----	-----
24. Detergents	(mg l- 1)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05				0.088	0.05	0.037	0.043	0.025	0.036	0.036	0.02	0.058
25. Magnesium	(mg l- 1)	946						1115.			1025.			1079.	-----	1094	857	-----	992
26. Calcium	(mg l- 1)	310						388.5			354			402.5	-----	400	329.5	-----	351.5
27. Potassium	(mg l- 1)	359						455.5			336			349.5	-----	388	263	-----	302
28. Sodium	(mg l- 1)	7817						8724			8989.			9447	-----	9556	6902	-----	7724
29. Cadmium	(ug l- 1)	0.54			<0.05			< 0.05			0.105			< 0.05	-----		0.125	-----	0.085
30. Mercury	(ug l- 1)													< 1	-----		< 1	-----	< 5
31. Chromium	(ug l- 1)	0.8			1.4			1.8			2.2			1.15	-----	1.5	1.25	-----	4.2
32. Copper	(ug l- 1)	< 5			< 5			< 5			0			< 5	-----	0	< 5	-----	12
33. Lead	(ug l- 1)	0.9			0.325			0.635			0.85			0.9	-----	0.75	1.45	-----	3.45
34. Nickel	(ug l- 1)	< 5			< 5			< 5			0			< 5	-----	0	< 5	-----	5.5
35. Zinc	(ug l- 1)	13			5.8			5.95			6			7.7	-----	4.05	4.75	-----	9
36. Arsenic	(ug l- 1)	< 1			< 1			< 1			1.1			1.25	-----	1.3	1.9	-----	2.3
37. Manganese	(ug l- 1)	20			12.5			12.5			18.5			12	-----	13	11.5	-----	67.5
38. Selenium	(ug l- 1)	< 1			< 1			< 1			< 1			< 1	-----	0	< 1	-----	< 1
39. Iron	(ug l- 1)	222			137			100.5			138.5			119.5	-----	98	247	-----	2139.
40. Aluminium	(ug l- 1)	208			142.5			73.5			208			95	-----	97.5	295.5	-----	1782.
41. Fecal coliform	CFU/100ml	1638	1425	1250	418	1300	1575	1720	3800	3100	444	380	390	240	480	265	512	540	560
42. E. coli	CFU/100ml	1298	1050	825	340	980	460	1148	3200	1900	140	270	178.2	18	30	25	208	220	210

NOTES:
1. S– monthly sample taken just below surface of seawater
2. M– monthly sample taken at mid- depth of seawater when depth is more than 10 metres
3. L– monthly sample taken just above the seabed when the depth of seawater is more than 5 metres
4. O– sample of oysters taken at three monthly intervals

PARAMETERS		Far field operational effluent impact monitoring sites																	
		APR 91			MAY 91			JUN 91			JUL 91			AUG 91			Mean		
		S	M	L	S	M	L	S	M	L	S	M	L	S	M	L	S	M	L
1. pH	(pH unit)	7.922	7.91	7.915	8.016	8.115	8.017	7.864	7.92	7.837	7.976	7.965	7.965	7.9	7.89	7.925	7.94	7.935	7.932
2. Temperature	(°C)	27.82	26.25	27.32	29.06	28.7	28.35	*	*	*	29.76	30.15	29.65	28.96	28.55	28.65	24.40	22.02	21.99
3. Turbidity	(NTU)	6	5.75	14.62	2.3	5.45	6.6	7	15.15	27.17	11.96	16.45	30.07	9.14	5.1	12.32	5.92	6.640	11.60
4. Conductivity	(ms cm- 1)	46.16	46.65	46.67	34.16	36.07	40.89	24.58	32.56	33.82	14.66	27.35	21.37	37.64	41.9	42.25	39.87	42.66	42.81
5. Salinity	(g Kg- 1)	9.06	11.1	13.12	16.54	21.3	21.95	12.5	16.55	17.22	7.6	9.4	10.65	18.22	20.5	20.62	19.59	21.79	21.25
6. Dissolved oxygen	n (mgl- 1)	8.06	7.6	8.15	8.4	8.2	7.725	6.96	6.55	6.375	7.652	7.405	7.295	5.84	5.975	6.317	7.73	7.660	7.625
7. TSS	(mg l- 1)	3.4	4	3	2.74	0.45	4.425	7.3	13.5	20.5	107.0	145.1	161.8	4.52	9.55	8.275	35.74	39.65	43.43
8. BOD (5 day)	(mg l- 1)	0.836	0.815	0.717	0.4	0.41	0.302	1.32	1.13	1.23	0.82	0.565	0.727	0.568	0.71	0.905	0.96	0.64	0.838
9. Eh	(mV)																		
10. Organic carbon	(mg l- 1)	0.58	1.1	0.825	0.74	1.9	0.8	7.8	8	8.25	7.8	6	9.25	6.4	6.5	6	3.97	4.133	4.164
11. Grain size	(%)																		
12. Grease and oil	(mg l- 1)	6.14	7.35	7.325	21.2	39	32.5	0.12	< 0.1	< 0.1	-----	-----	< 0.1	< 0.1	< 0.1	< 0.1	4.71	6.850	6.185
13. Sulphates	(mg l- 1)	2332	2290	2315	1333.	1497.	1726.	1488.	1906.	1931.	671	1073.	1208.	1494	1650	1720	1910.82	2057.	2117.
14. Bicarbonates	(mg l- 1)	9.82	9.65	9.625	6	5.55	6.125	5.412	5.72	5.665	7.578	8.14	7.37	8.94	10.55	8.75	8.28	8.578	8.232
15. Phosphorus	(mg l- 1)	0.048	0.055	0.072	0.012	0.015	0.007	0.034	0.05	0.062	0.036	0.07	0.077	0.048	0.045	0.062	0.06	0.072	0.078
16. Nitrate- N	(mg l- 1)	0.158	0.11	0.155	0.596	0.535	0.442	0.75	0.685	0.67	0.616	0.675	0.672	0.602	0.49	0.495	0.39	0.339	0.323
17. Ammonia- N	(mg l- 1)	0.012	0.02	0.01	0.042	0.055	0.077	0.018	0.02	0.032	0.018	0.045	0.035	0.036	0.035	0.047	0.05	0.047	0.050
18. Organic- N	(mg l- 1)	0.594	1.165	0.742	0.536	0.405	0.382	0.724	0.54	0.705	1.432	4.61	2.082				0.44	0.675	0.504
19. Chlorophyll 'A'	'(mg l- 1)	3	2.9	2.775	13.96	5.1	11.15	2.244	0.63	1.652	2.42	2.475	3.027	2.644	1.79	1.927	3.47	2.122	2.885
20. Chloride	(mg l- 1)	15660	16150	16350	10656	11964	12992	7909	10591	10909	5647.	8668	7604.	12006	13470	13730	13545.3	14472	14305
21. Bromide	(mg l- 1)																72.10	50.25	69.12
22. Total sulphide	(mg l- 1)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	< 0.01	< 0.01	< 0.01
23. Chlorine	(mg l- 1)	<0.1	-----	-----	-----	-----	-----	< 0.1	-----	-----	< 0.1	-----	-----	< 0.1	-----	-----	< 0.1	-----	-----
24. Detergents	(mg l- 1)	0.01	0.01	0.02	0.05	0.02	0.02	< 0.01	< 0.01	< 0.01	0.022	< 0.01	< 0.01	0.022	0.02	0.015	0.03	0.014	0.018
25. Magnesium	(mg l- 1)	1030	-----	1052.	766	-----	971	459	-----	675	316	-----	524		-----		844.06		864.7
26. Calcium	(mg l- 1)	413.5	-----	429.5	261	-----	345.5	231.5	-----	320.5	165.5	-----	263		-----		317.33		351.6
27. Potassium	(mg l- 1)	309.5	-----	345	201.5	-----	254	125	-----	219.5	159.5	-----	211.5		-----		294.81		283
28. Sodium	(mg l- 1)	8235	-----	8316.	5612	-----	6968	4685	-----	5355	3420	-----	5195		-----		7090.17		7353.
29. Cadmium	(ug l- 1)	0.075	-----	0.055	0.1	-----	0.08	0.145	-----	0.09	0.095	-----	0.08		-----		0.12		0.065
30. Mercury	(ug l- 1)	< 1	-----	<1	< 1	-----	< 1	< 1	-----	< 1	< 1	-----	< 1		-----		< 1		< 1
31. Chromium	(ug l- 1)	1.75	-----	2.1	0.5	-----	1.1	0.3	-----	1.55	1	-----	1.8		-----		1.20		2.008
32. Copper	(ug l- 1)	< 5	-----	<5	6.5	-----	11.5	< 5	-----	< 5	< 5	-----	3.5		-----		< 5		4.5
33. Lead	(ug l- 1)	1.5	-----	1.75	0.55	-----	1.8	1.3	-----	2.2	0.85	-----	2.15		-----		0.91		2.016
34. Nickel	(ug l- 1)	< 5	-----	<5	2	-----	6	< 5	-----	< 5	< 5	-----	< 5		-----		< 0.5		1.916
35. Zinc	(ug l- 1)	4.5	-----	7.5	7.5	-----	8.5	4.5	-----	6.5	4.5	-----	5.5		-----		6.42		6.841
36. Arsenic	(ug l- 1)	0.9	-----	1.4	< 1	-----	< 1	< 1	-----	< 1	< 1	-----	< 1		-----		0.52- 1.11		0.833
37. Manganese	(ug l- 1)	22	-----	32.5	6	-----	34	7	-----	30.5	7	-----	26.5		-----		12.90		34
38. Selenium	(ug l- 1)	< 1	-----	<1	< 1	-----	< 1	< 1	-----	< 1	< 1	-----	< 1		-----		< 1		≤ 1
39. Iron	(ug l- 1)	658.5	-----	1056	61	-----	864	357.5	-----	1708.	235.5	-----	923.5		-----		227.70		1131.
40. Aluminium	(ug l- 1)	565.5	-----	883	92.5	-----	605	439	-----	1659	210.5	-----	665.5		-----		233.00		948.7
41. Fecal coliform	CFU/100ml	296	360	390	318	310	480	32	50	25	772	770	815	712	850	875	645.09	933.1	864.0
42. E. coli	CFU/100ml	108	70	160	136	160	240	0	0	0	592	550	555	584	720	705	415.27	659.0	478.0

NOTES:
1. S – monthly sample taken just below surface of seawater
2. M – monthly sample taken at mid- depth of seawater when depth is more than 10 metres
3. L – monthly sample taken just above the seabed when the depth of seawater is more than 5 metres
4. O – sample of oysters taken at three monthly intervals

Annex C

Mean Marine Sediment Results from CLP Baseline Monitoring Survey

PARAMETERS		Far field operational effluent impact monitoring sites											
		OCT 90	NOV 90	DEC 90	JAN 91	FEB 91	MAR 91	APR 91	MAY 91	JUN 91	JUL 91	AUG 91	Mean
		BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	
1. pH	(pH unit)						-----	-----	-----	-----	-----	-----	-----
2. Temperature	('C)						-----	-----	-----	-----	-----	-----	-----
3. Turbidity	(NTU)						-----	-----	-----	-----	-----	-----	-----
4. Conductivity	(ms cm– 1)						-----	-----	-----	-----	-----	-----	-----
5. Salinity	(g Kg– 1)						-----	-----	-----	-----	-----	-----	-----
6. Dissolved oxygen	n (mgl– 1)						-----	-----	-----	-----	-----	-----	-----
7. TSS	(mg l– 1)						-----	-----	-----	-----	-----	-----	-----
8. BOD (5 day)	(mg l– 1)						-----	-----	-----	-----	-----	-----	-----
9. Eh	(mV)	– 63.2	– 84.6	– 145.	– 116.	– 116.	– 191.	– 147.	– 128.	– 165.	– 165.	– 173.	– 136.
10. Organic carbon	(mg l– 1)		2.28		0.372	0.422	0.63	0.48	0.588	0.688	0.77	0.68	0.765
11. Grain size	(%)												
12. Grease and oil	(mg l– 1)					-----	-----	-----	-----	-----	-----	-----	-----
13. Sulphates	(mg l– 1)		1640	2234	2740	4980	5160	3330	2665	3660	3699.	2998.	3332.
14. Bicarbonates	(mg l– 1)					-----	-----	-----	-----	-----	-----	-----	-----
15. Phosphorus	(mg l– 1)		7.44		230	235	243.2	196.6	169	159.2	113.8	336.6	190.0
16. Nitrate– N	(mg l– 1)		1.46			-----	-----	-----	-----	-----	-----	-----	
17. Ammonia– N	(mg l– 1)		69.6			-----	-----	-----	-----	-----	-----	-----	
18. Organic– N	(mg l– 1)				669.2	1281.	490.6	1156.	1222.	5178	3921.		1965.
19. Chlorophyll 'A'	'(mg l– 1)					-----	-----	-----	-----	-----	-----	-----	-----
20. Chloride	(mg l– 1)					-----	-----	-----	-----	-----	-----	-----	-----
21. Bromide	(mg l– 1)												
22. Total sulphide	(mg l– 1)		37.6		9.97	31.01	62.14	40.28	19.63	95.05	52.52	-----	43.52
23. Chlorine	(mg l– 1)					-----	-----	-----	-----	-----	-----	-----	-----
24. Detergents	(mg l– 1)					-----	-----	-----	-----	-----	-----	-----	-----
25. Magnesium	(mg l– 1)					-----	-----	-----	-----	-----	-----	-----	-----
26. Calcium	(mg l– 1)					-----	-----	-----	-----	-----	-----	-----	-----
27. Potassium	(mg l– 1)					-----	-----	-----	-----	-----	-----	-----	-----
28. Sodium	(mg l– 1)					-----	-----	-----	-----	-----	-----	-----	-----
29. Cadmium	(mg / Kg)	0.01 (F1)	0.117	0.1	0.073	0.065	0.05	0.05	0.053	0.103	0.08	-----	0.070
30. Mercury	(mg / Kg)	< 0.2 (F1)	0.1	< 0.2	0.1	0.55	0.166	0.168	0.133	0.233	0.233	-----	0.210
31. Chromium	(mg / Kg)	0.4 (F1)	15.25	10	10	10	8.333	12.66	9.333	15.66	10	-----	10.16
32. Copper	(mg / Kg)	1 (F1)	85.5	54.33	55	57	49	22.33	17	32.33	21.66	-----	37.51
33. Lead	(mg / Kg)	20 (F1)	31	32.66	27.33	24.5	24.33	32.66	19.33	29	29.33	-----	27.01
34. Nickel	(mg / Kg)	1 (F1)	18	13.33	14.33	16.5	14.33	19.33	12.66	23.66	14.33	-----	14.75
35. Zinc	(mg / Kg)	5 (F1)	52	44	40.33	47.5	43.33	53	46.33	72	47.33	-----	45.08
36. Arsenic	(mg / Kg)	0.1 (F1)	0.725	0.866	0.933	0.75	0.6	0.766	1.033	1	1.266	-----	0.804
37. Manganese	(mg / Kg)	27 (F1)	515.2	458.6	476.3	551.5	504.3	542.3	498.6	578	484	-----	483.4
38. Selenium	(mg / Kg)	< 0.05 (F1)	< 0.05	< 0.1	0	0	< 0.1	< 0.1	0	< 0.1	0	-----	< 0.1
39. Iron	(mg / Kg)	0.1 (F1)	1.25	1.476	2	2.675	2.01	2.89	2.053	2.35	1.836	-----	1.869
40. Aluminium	(mg / Kg)	0.03 (F1)	0.3	0.293	0.353	0.42	0.363	0.673	0.626	0.753	0.606	-----	0.442
41. Fecal coliform	CFU/100ml	3500	10760	4000	-----	-----	-----	-----	-----	-----	-----	-----	6086.
42. E. coli	CFU/100ml	1950	6980	3300	-----	-----	-----	-----	-----	-----	-----	-----	4030

Note:
1. (F1) – One sample from F1.
2. BS – Monthly sediment of benthic sediment
3. Sadiment Fe & Al as % wt/wt
4. Grain size on separate sheet
5. Sediment on unsieved samples
6. Sediment results as mg/Kg

PARAMETERS		Marine buoys and operational effluent impact monitoring sites											
		OCT 90	NOV 90	DEC 90	JAN 91	FEB 91	MAR 91	APR 91	MAY 91	JUN 91	JUL 91	AUG 91	Mean
		BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	
1. pH	(pH unit)					-----	-----	-----	-----	-----	-----	-----	-----
2. Temperature	('C)					-----	-----	-----	-----	-----	-----	-----	-----
3. Turbidity	(NTU)					-----	-----	-----	-----	-----	-----	-----	-----
4. Conductivity	(ms cm– 1)					-----	-----	-----	-----	-----	-----	-----	-----
5. Salinity	(g Kg– 1)					-----	-----	-----	-----	-----	-----	-----	-----
6. Dissolved oxygen	(mg / l)					-----	-----	-----	-----	-----	-----	-----	-----
7. TSS	(mg l– 1)					-----	-----	-----	-----	-----	-----	-----	-----
8. BOD (5 day)	(mg l– 1)					-----	-----	-----	-----	-----	-----	-----	-----
9. Eh	(mV)	– 83.7	– 96.2	– 137.	– 141.	– 169.	– 230.	– 214.	– 251.	– 219.	– 205	– 277.	– 184.
10. Organic carbon	(mg l– 1)		2.65		0.72	0.865	0.537	0.865	0.877	0.75	0.777	0.935	1.021
11. Grain size	(%)								-----			-----	-----
12. Grease and oil	(mg l– 1)					-----	-----	-----	-----	-----	-----	-----	-----
13. Sulphates	(mg l– 1)		2375	2112.	4975	7312.	6475	5300	5825	3687.	3203.	3827.	4489.
14. Bicarbonates	(mg l– 1)					-----	-----	-----	-----	-----	-----	-----	-----
15. Phosphorus	(mg l– 1)		9.3		244	168	290.5	169.7	180.7	309.7	135.7	413.2	213.4
16. Nitrate– N	(mg l– 1)		1.925			-----	-----	-----	-----	-----	-----	-----	1.925
17. Ammonia– N	(mg l– 1)		184.2			-----	-----	-----	-----	-----	-----	-----	184.2
18. Organic– N	(mg l– 1)				1162.	1076	1242.	1437.	1381.	6017.	3412	-----	2247.
19. Chlorophyll 'A'	'(mg l– 1)					-----	-----	-----	-----	-----	-----	-----	-----
20. Chloride	(mg l– 1)					-----	-----	-----	-----	-----	-----	-----	-----
21. Bromide	(mg l– 1)												
22. Total sulphide	(mg l– 1)	62.5	471		799.0	222.6	167.0	550.4	326.3	425.0	28.47	-----	339.5
23. Chlorine	(mg l– 1)					-----	-----	-----	-----	-----	-----	-----	-----
24. Detergents	(mg l– 1)					-----	-----	-----	-----	-----	-----	-----	-----
25. Magnesium	(mg l– 1)					-----	-----	-----	-----	-----	-----	-----	-----
26. Calcium	(mg l– 1)					-----	-----	-----	-----	-----	-----	-----	-----
27. Potassium	(mg l– 1)					-----	-----	-----	-----	-----	-----	-----	-----
28. Sodium	(mg l– 1)					-----	-----	-----	-----	-----	-----	-----	-----
29. Cadmium	(mg / Kg)	0.072	0.195	0.177	0.145	0.152	0.102	0.092	0.127	0.15	0.132	-----	0.134
30. Mercury	(mg / Kg)	0.175	0.2	< 0.2	0	0.75	0.125	0.125	0.2	0.3	0.275	-----	0.215
31. Chromium	(mg / Kg)	12.75	16.25	12	12.25	9	8.5	11.25	9.25	17.25	11.25	-----	12.07
32. Copper	(mg / Kg)	58.5	72.25	60.75	57.75	48.25	44.5	39.5	38.5	64	34	-----	51.8
33. Lead	(mg / Kg)	38.25	35.75	42.75	43.75	30.75	24.75	20	19	40.25	36.5	-----	33.27
34. Nickel	(mg / Kg)	14	16.5	14	12.75	12.5	10.75	11.75	10	23.5	13.5	-----	13.92
35. Zinc	(mg / Kg)	48.75	77	53	54.25	54.5	58.25	57.25	54	102.5	55.25	-----	61.77
36. Arsenic	(mg / Kg)	0.425	0.725	0.8	0.75	0.65	0.725	0.9	0.6	0.825	1.125	-----	0.752
37. Manganese	(mg / Kg)	397	504	469	438.7	474.5	454.2	451.7	444	527.5	488.7	-----	464.9
38. Selenium	(mg / Kg)	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	-----	< 0.1
39. Iron	(mg / Kg)	1.175	1	1.185	1.322	1.255	1.17	1.297	1.142	1.592	1.452	-----	1.259
40. Aluminium	(mg / Kg)	0.325	0.325	0.307	0.345	0.352	0.335	0.47	0.397	0.57	0.45	-----	0.387
41. Fecal coliform	CFU/100ml	2725	2925	4000		-----	-----	-----	-----	-----	-----	-----	3216.
42. E. coli	CFU/100ml	2125	1925	3375		-----	-----	-----	-----	-----	-----	-----	2475

NOTES:
1. BS – montaly sample of benthic sediment
2. Sediment Fe & Al as % wt/wt
3. Grain size on separate sheet
4. Sediment on unsieved samples
5. Sediment results as mg/Kg

Annex D

Temperature Time History Plots

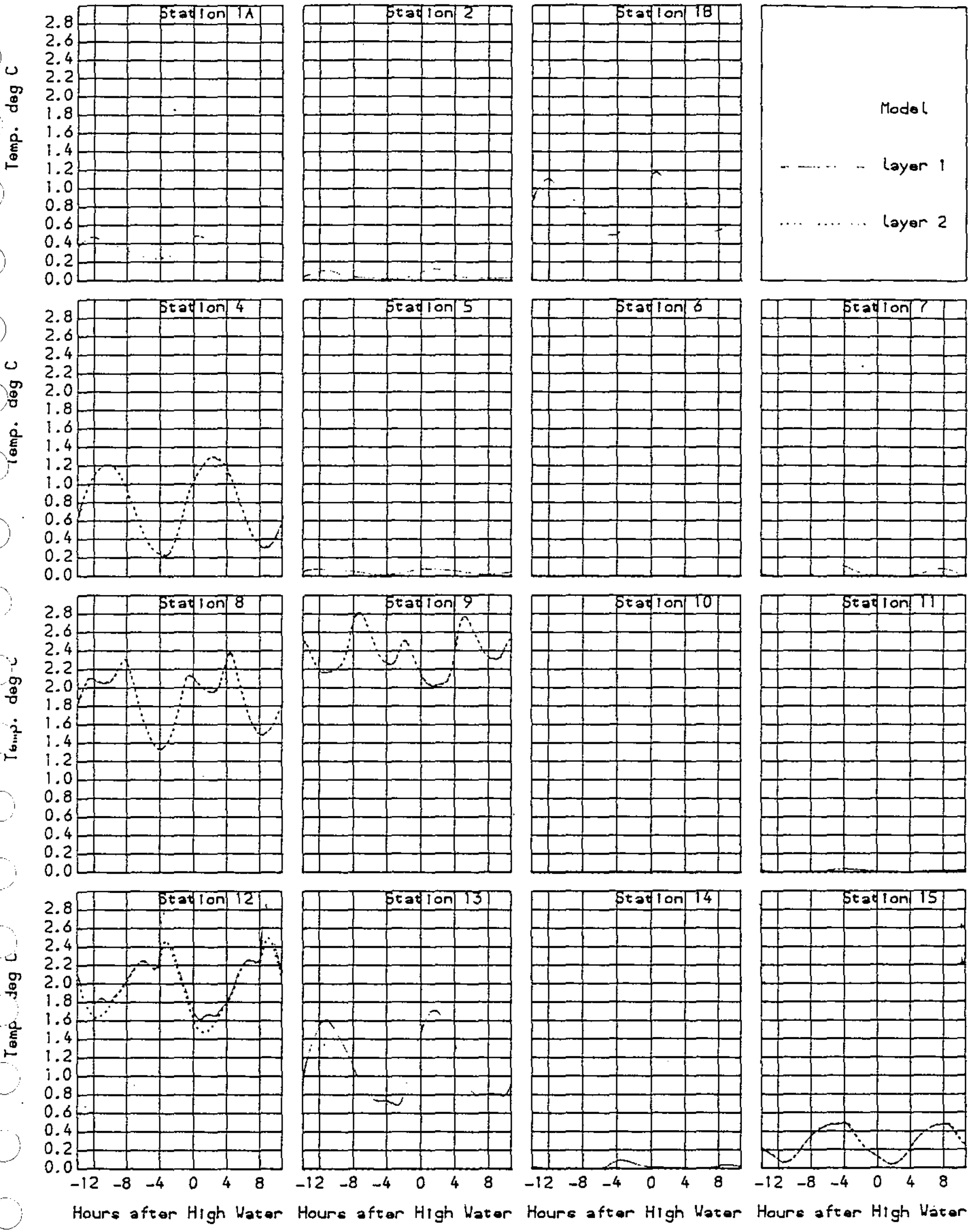


Fig 2 LTPS Black Point Far Field Thermal Modelling
Temperature including Castle Peak
Black Point 12 degree discharge
Run 3F: 8 Coal Dry Season Neap Tide

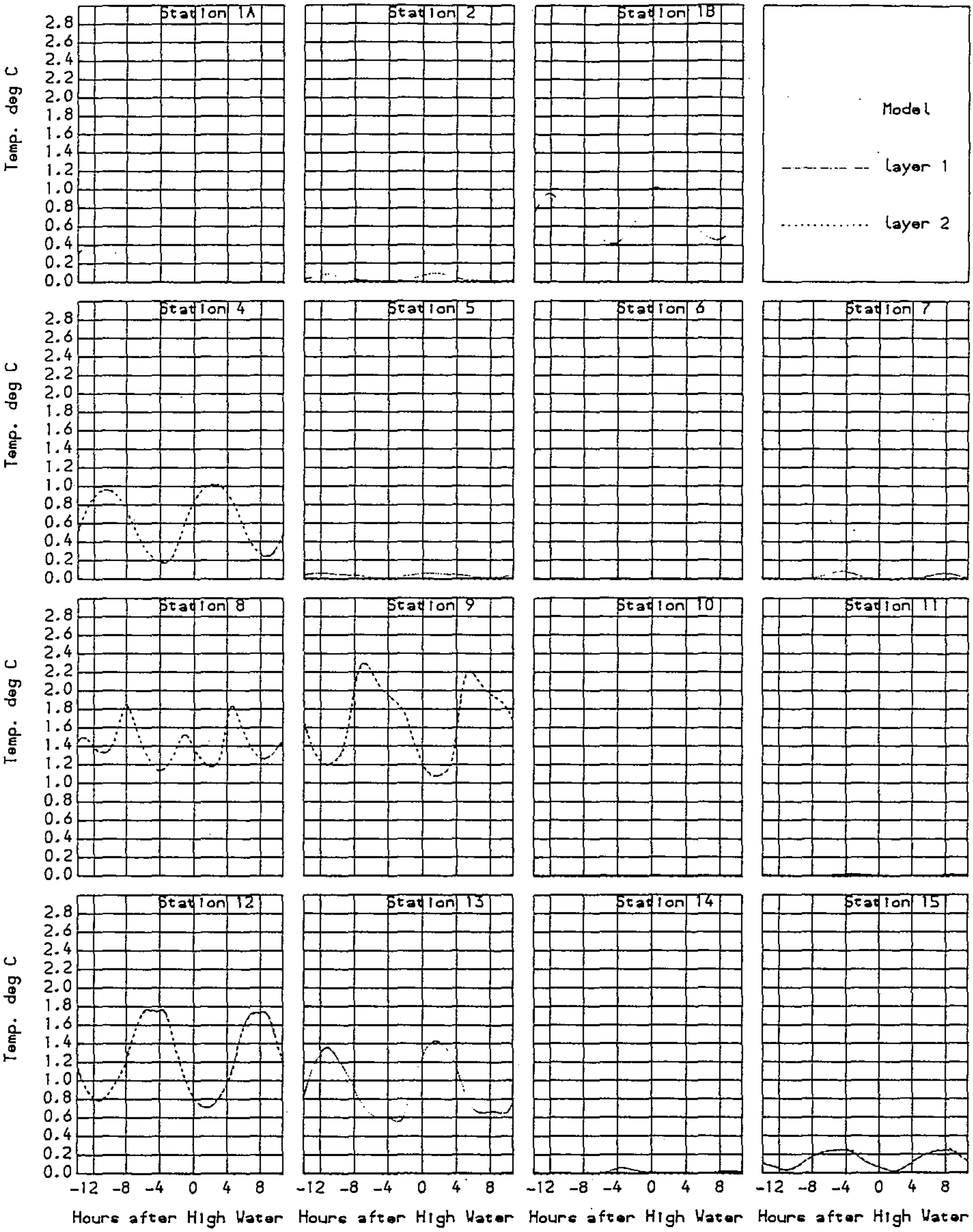


Fig 2 LTPS Black Point Far Field Thermal Modelling
Excess temperature above existing
Black Point 12 degree discharge
Run 3F: 8 Coal Dry Season Neap Tide

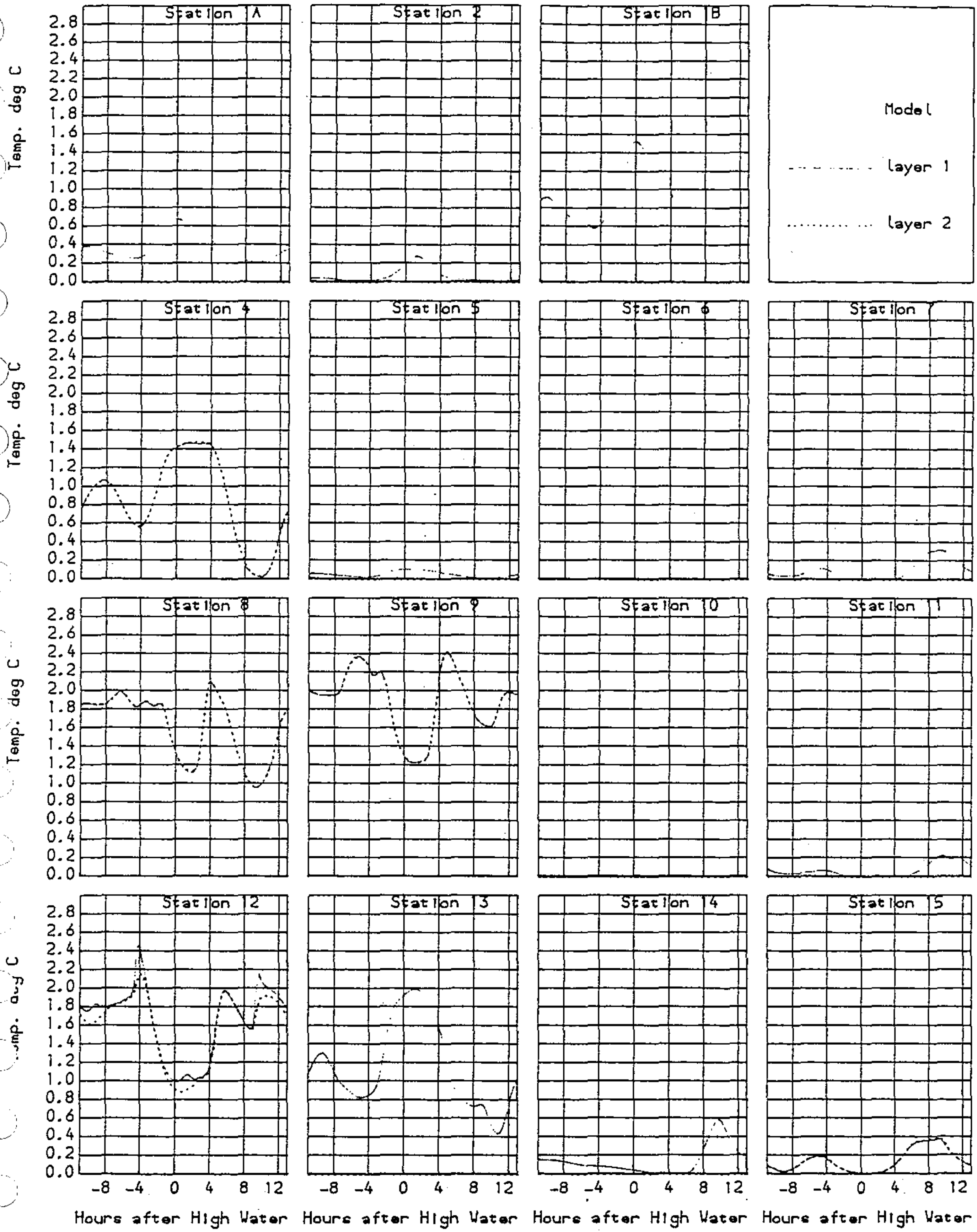


Fig 3 LTPS Black Point Far Field Thermal Modelling
Temperature including Castle Peak
Black Point 12 degree discharge
Run 4F: 8 Coal Dry Season Spring Tide

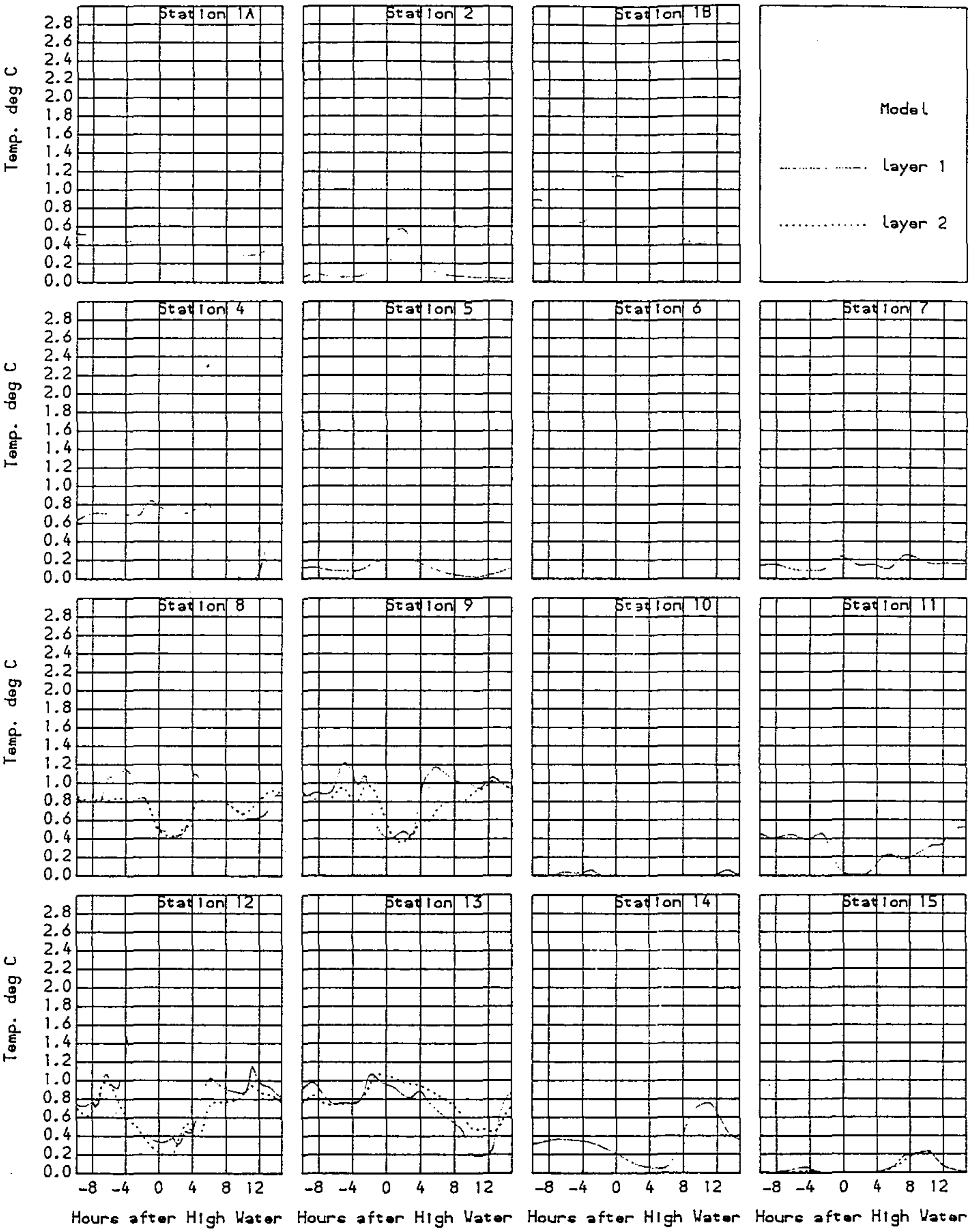


Fig 4 LTPS Black Point Far Field Thermal Modelling
Temperature including Castle Peak
Black Point 12 degree discharge
Run 6F: 8 COAL Wet Season Spring Tide

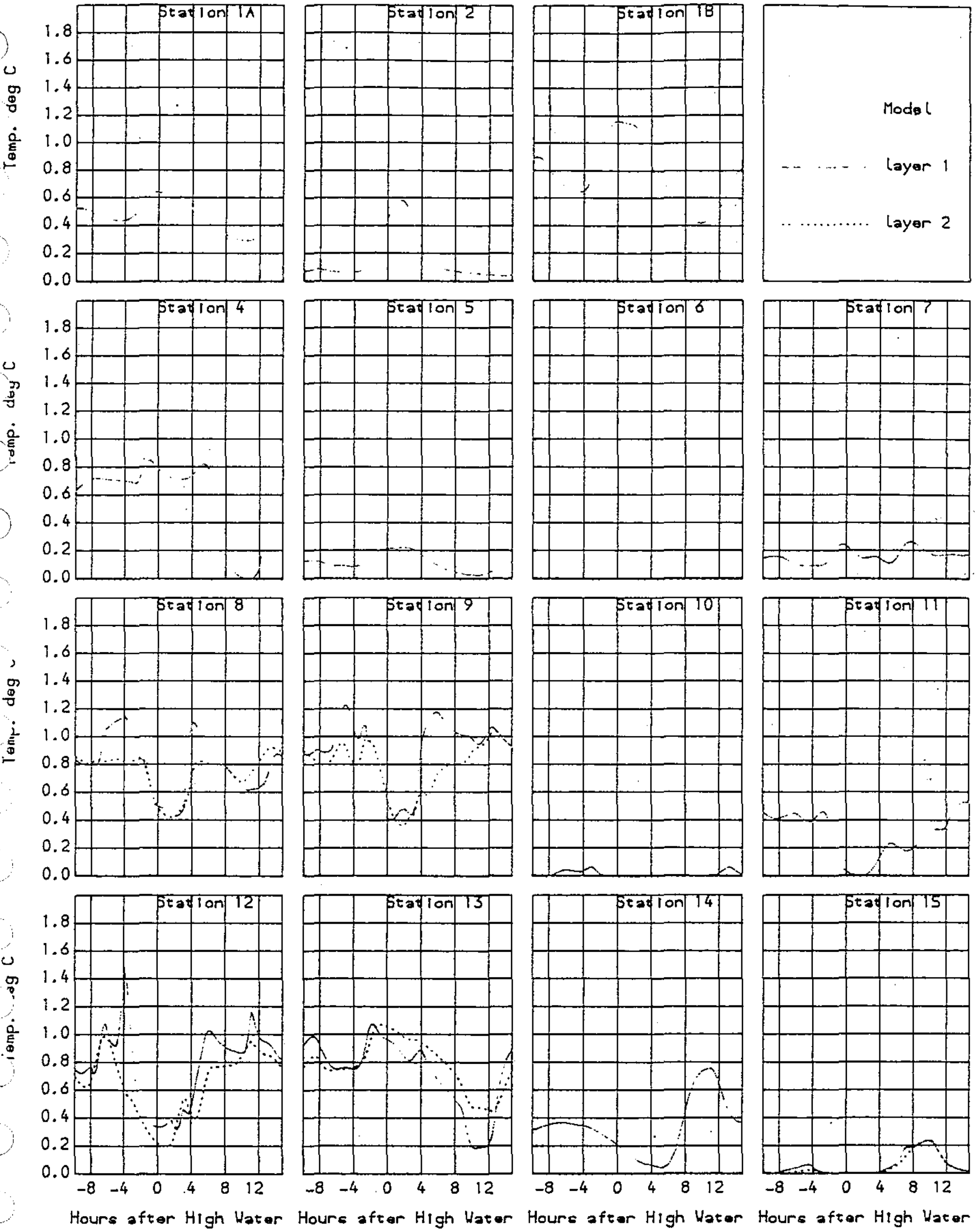


Fig 4 LTPS Black Point Far Field Thermal Modelling
Temperature including Castle Peak
Black Point 12 degree discharge
Run 6F: 8 Coal Wet Season Spring Tide

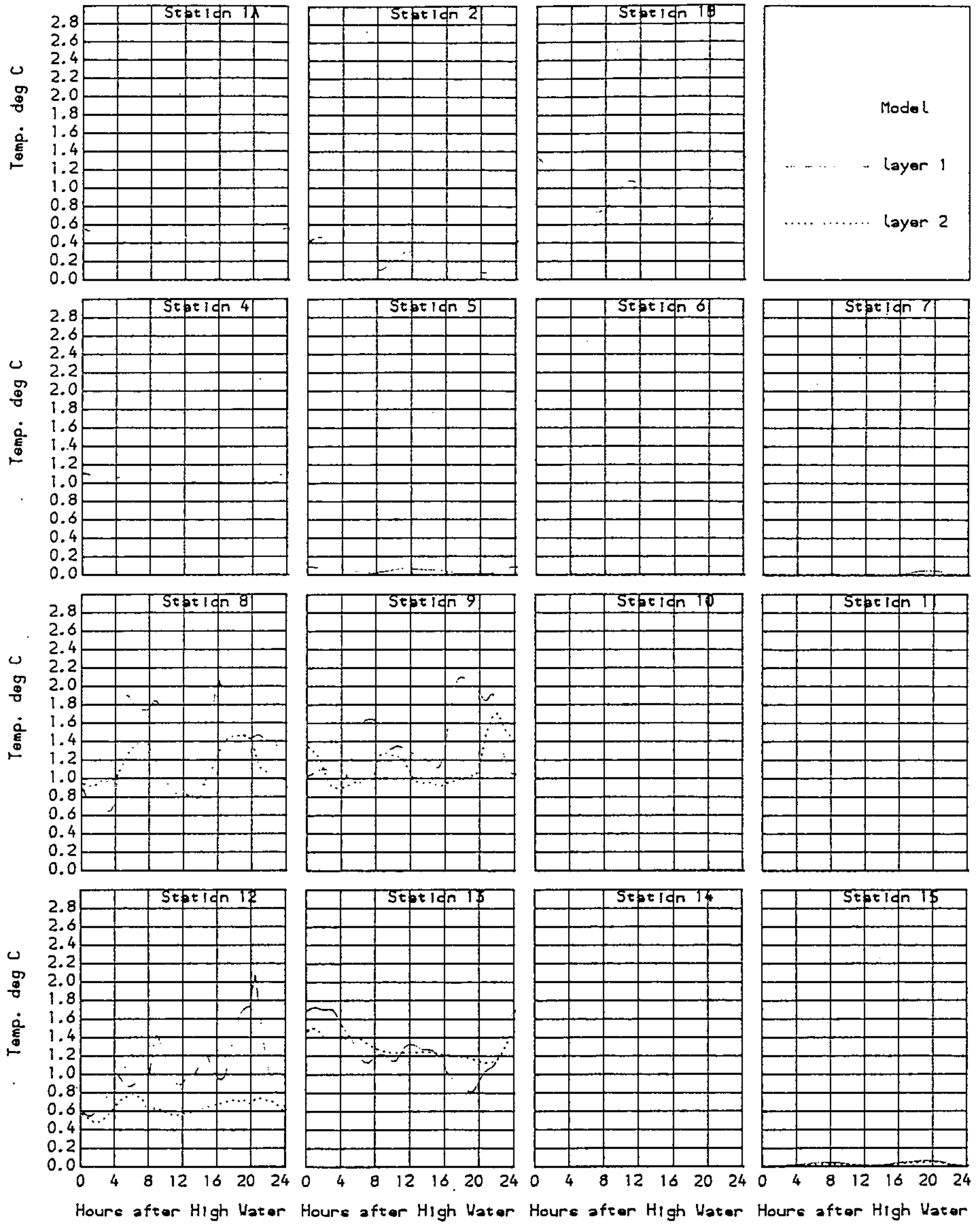


Fig 5 LTPS Black Point Far Field Thermal Modelling
Temperature including Castle Peak
Black Point 12 degree discharge
Run 7F: 8 COAL Wet Season Neap Tide

Annex E

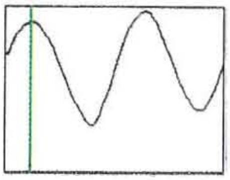
Temperature Contour Plots

KEY

🟥 Above 2.0
🟨 1.5 – 2.0
🟪 1.0 – 1.5
🟦 0.5 – 1.0
🟦 0.2 – 0.5
🟦 Below 0.2

🟨 Beach
🟩 Land

Temperature Increase Above Background (°C)



Vertical Line Denotes Point in Tidal Cycle

5000 m

Scale

Note:

Discharge Temperature at LTPS = 12° above Intake Temperature
Discharge Temperature at CPPS = 10° above Intake Temperature

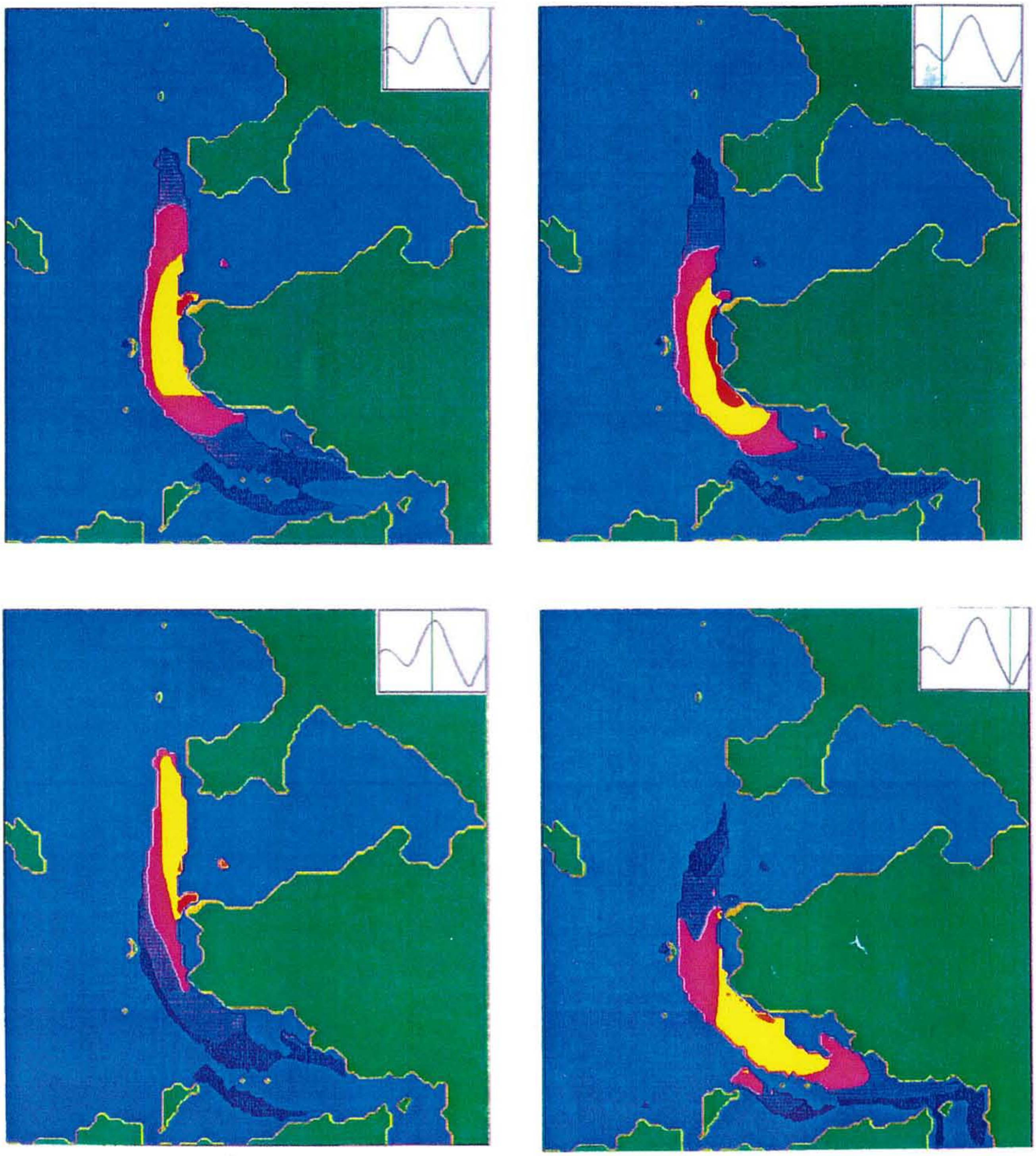


Figure E1 – Dry Season Spring Tide Bed Layer

ERM Hong Kong

10-11th Floor
Hecny Tower
9 Chatham Road
Tsimshatsui, Kowloon
Hong Kong

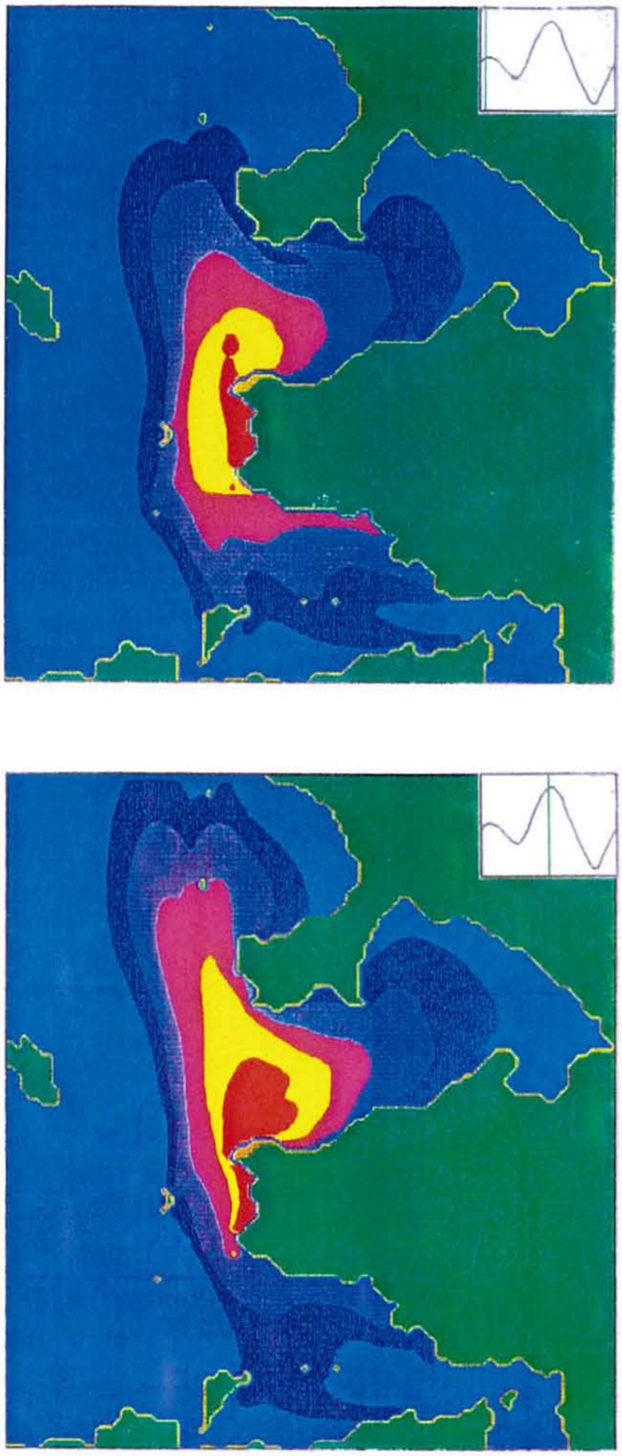


Figure E2 - Dry Season Spring Tide Surface Layer

ERM Hong Kong

10-11th Floor
Hecny Tower
9 Chatham Road
Tsimshatsui, Kowloon
Hong Kong

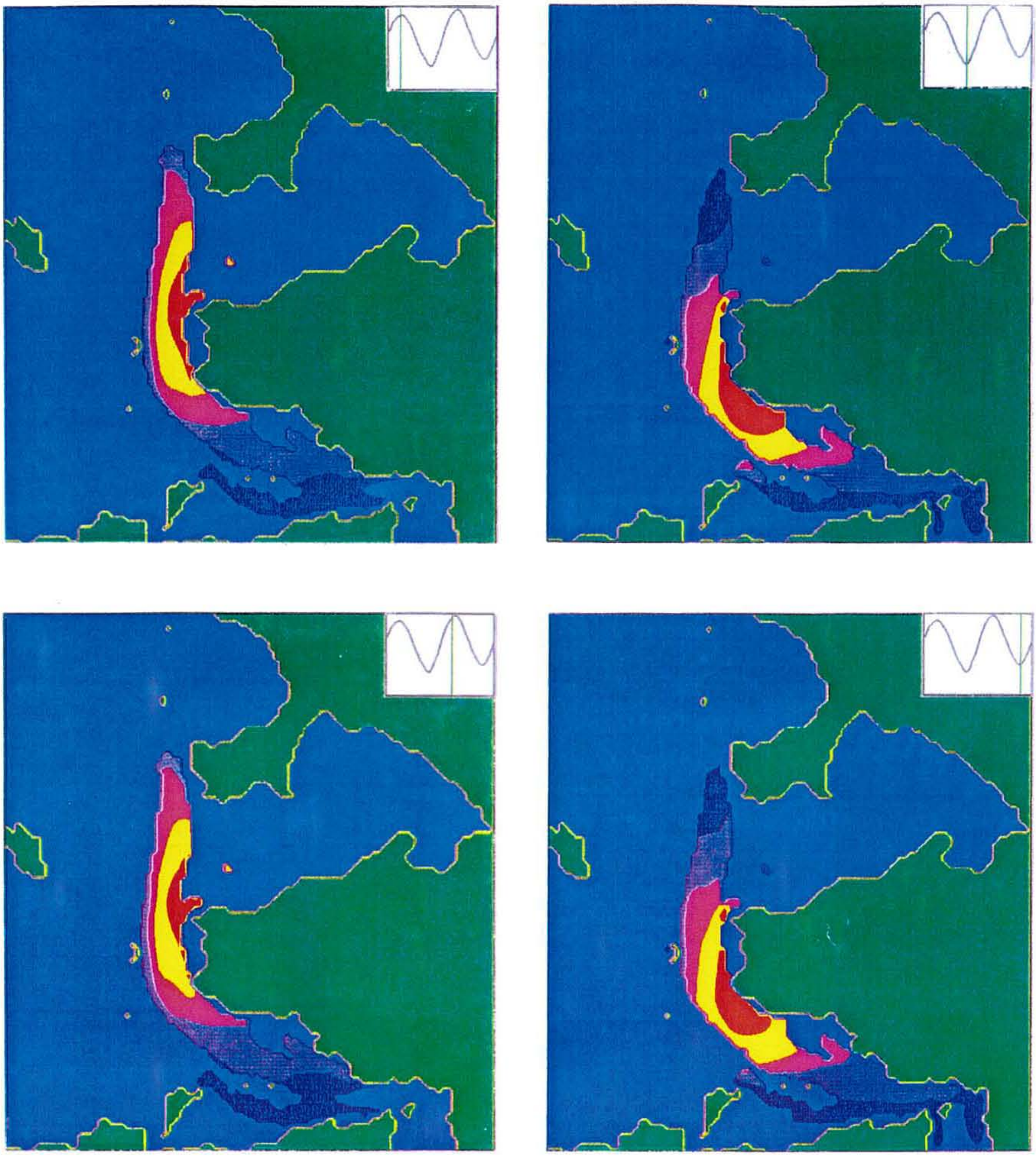


Figure E3 – Dry Season Neap Tide Bed Layer

ERM Hong Kong

10-11th Floor
Hecny Tower
9 Chatham Road
Tsimshatsui, Kowloon
Hong Kong

ERM

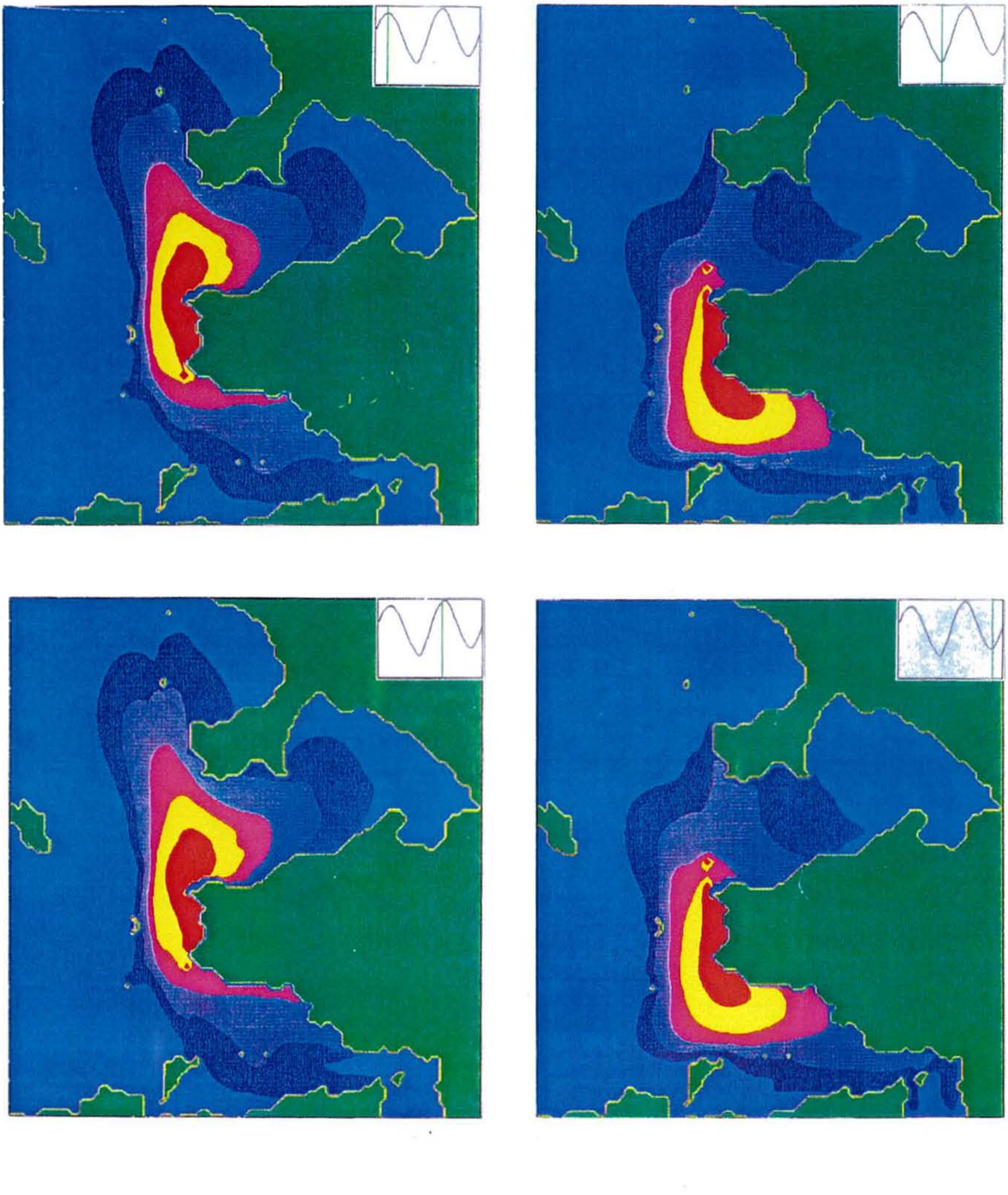


Figure E4 - Dry Season Neap Tide Surface Layer

ERM Hong Kong

10-11th Floor
Hecny Tower
9 Chatham Road
Tsimshatsui, Kowloon
Hong Kong

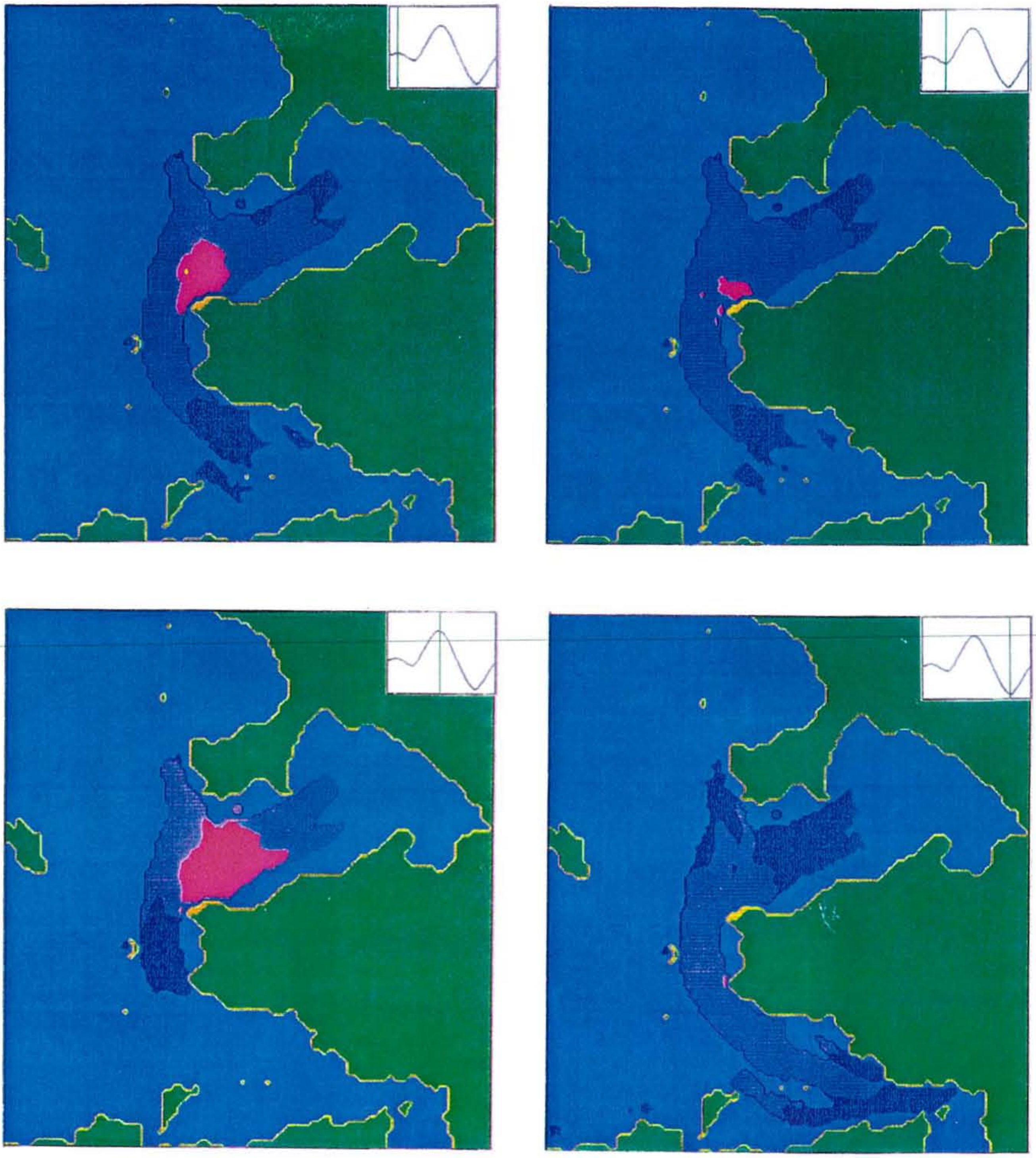


Figure E5 – Wet Season Spring Tide Bed Layer

ERM Hong Kong

10-11th Floor
Hecny Tower
9 Chatham Road
Tsimshatsui, Kowloon
Hong Kong

ERM

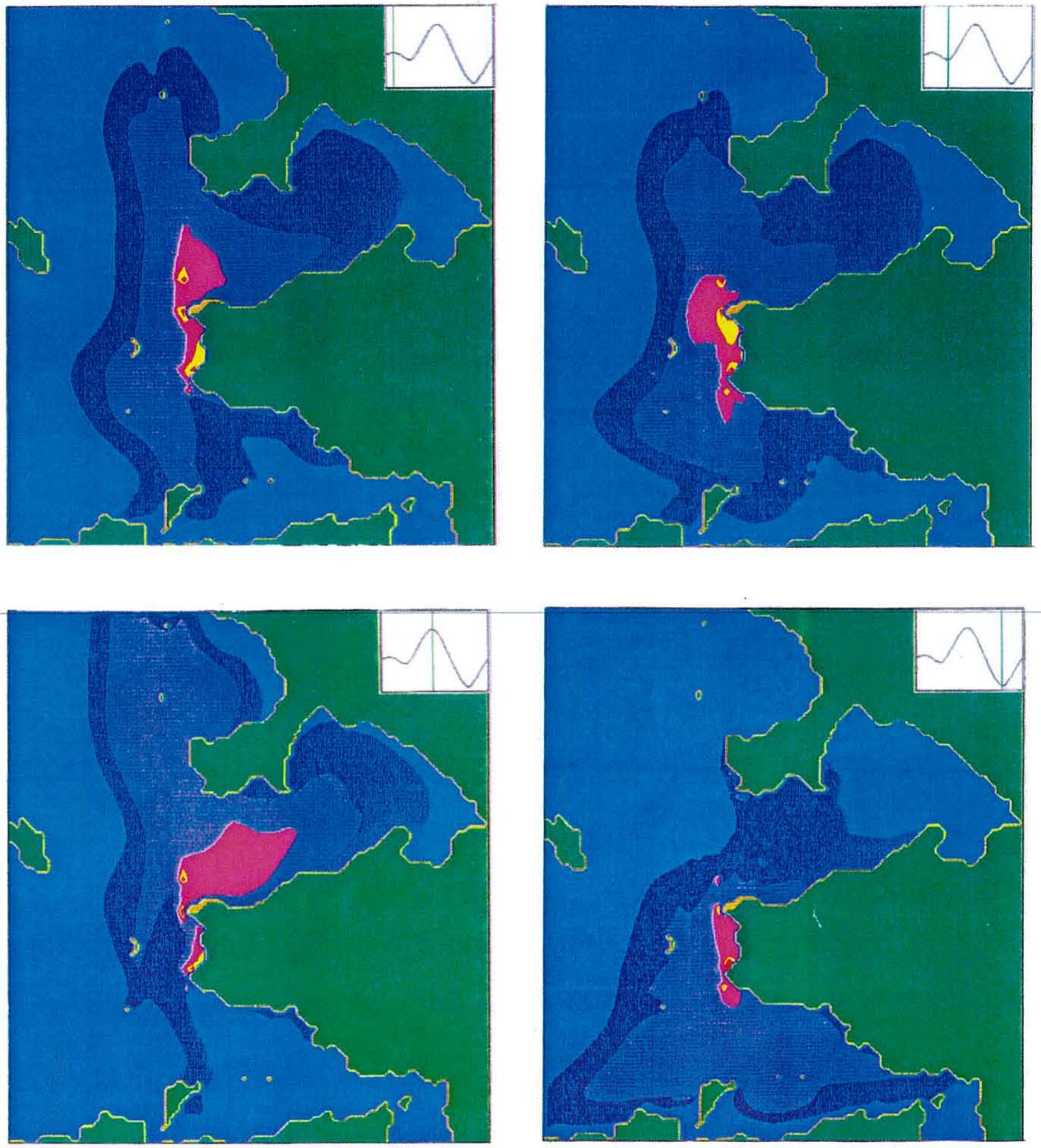


Figure E6 – Wet Season Spring Tide Surface Layer

ERM Hong Kong

10-11th Floor
Hecny Tower
9 Chatham Road
Tsimshatsui, Kowloon
Hong Kong

ERM

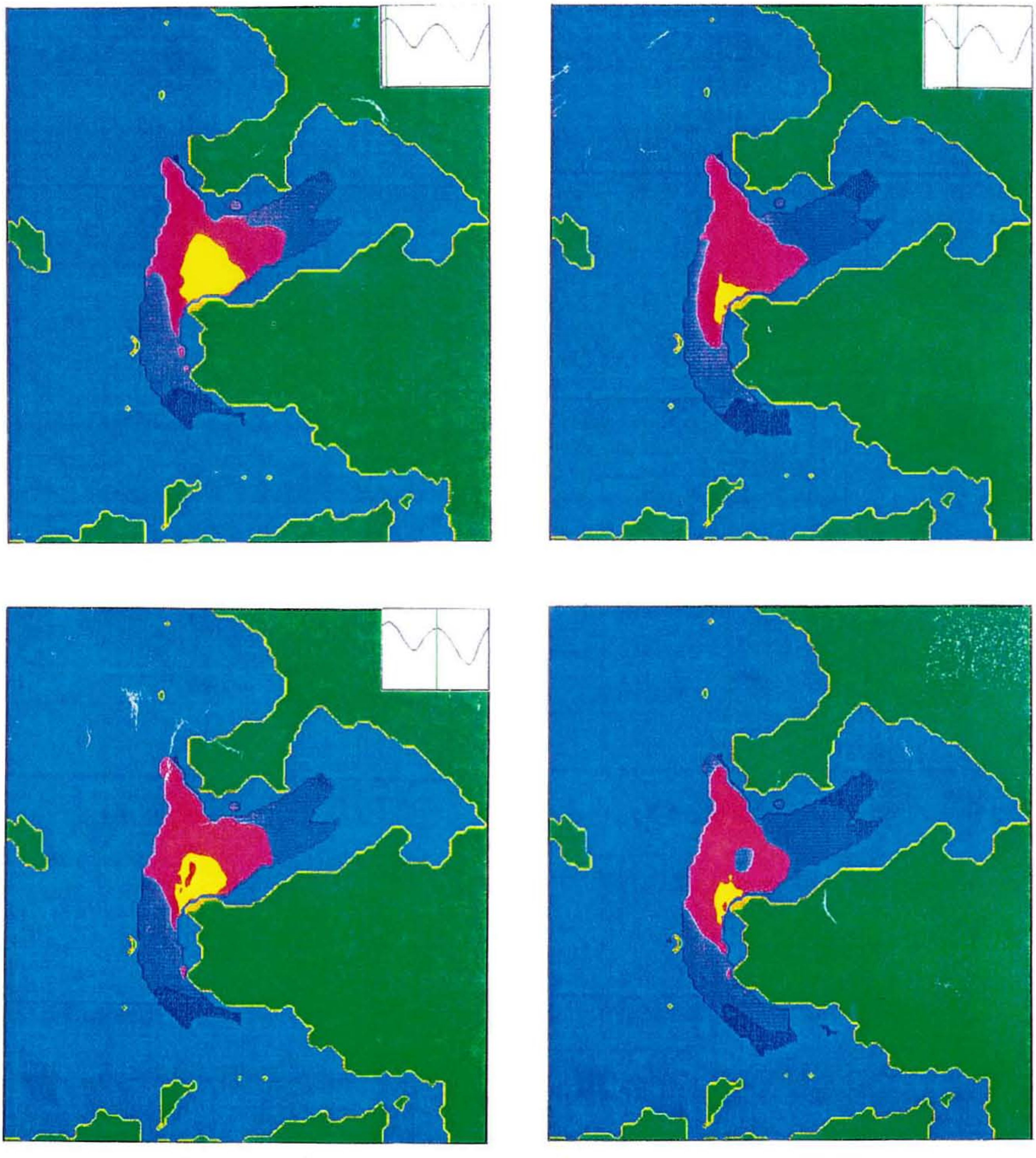


Figure E7 – Wet Season Neap Tide Bed Layer

ERM Hong Kong

10-11th Floor
Hecny Tower
9 Chatham Road
Tsimshatsui, Kowloon
Hong Kong

ERM

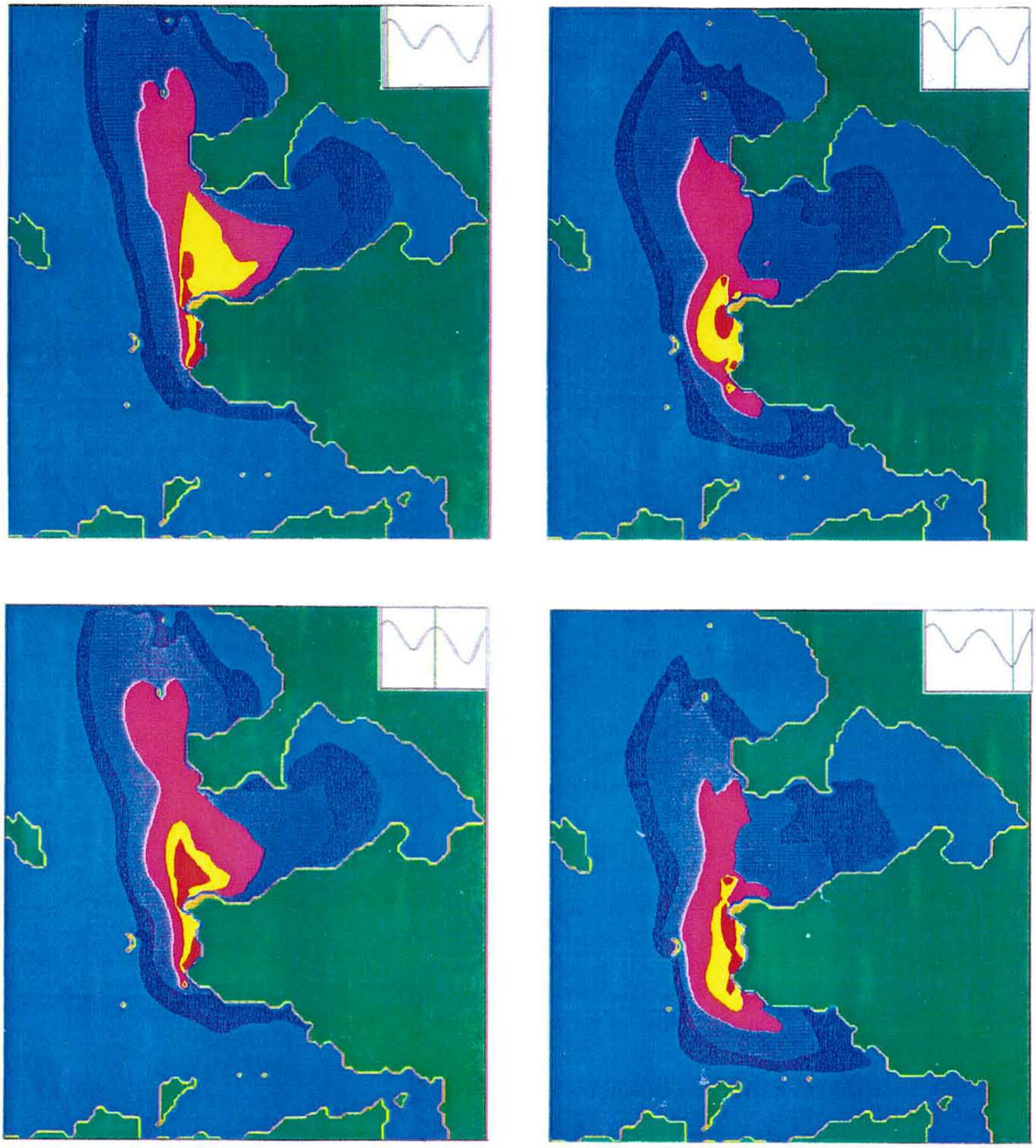


Figure E8 – Wet Season Neap Tide Surface Layer

ERM Hong Kong

10-11th Floor
Hecny Tower
9 Chatham Road
Tsimshatsui, Kowloon
Hong Kong

ERM

Annex F

Results of Seasonal Water Quality Modelling

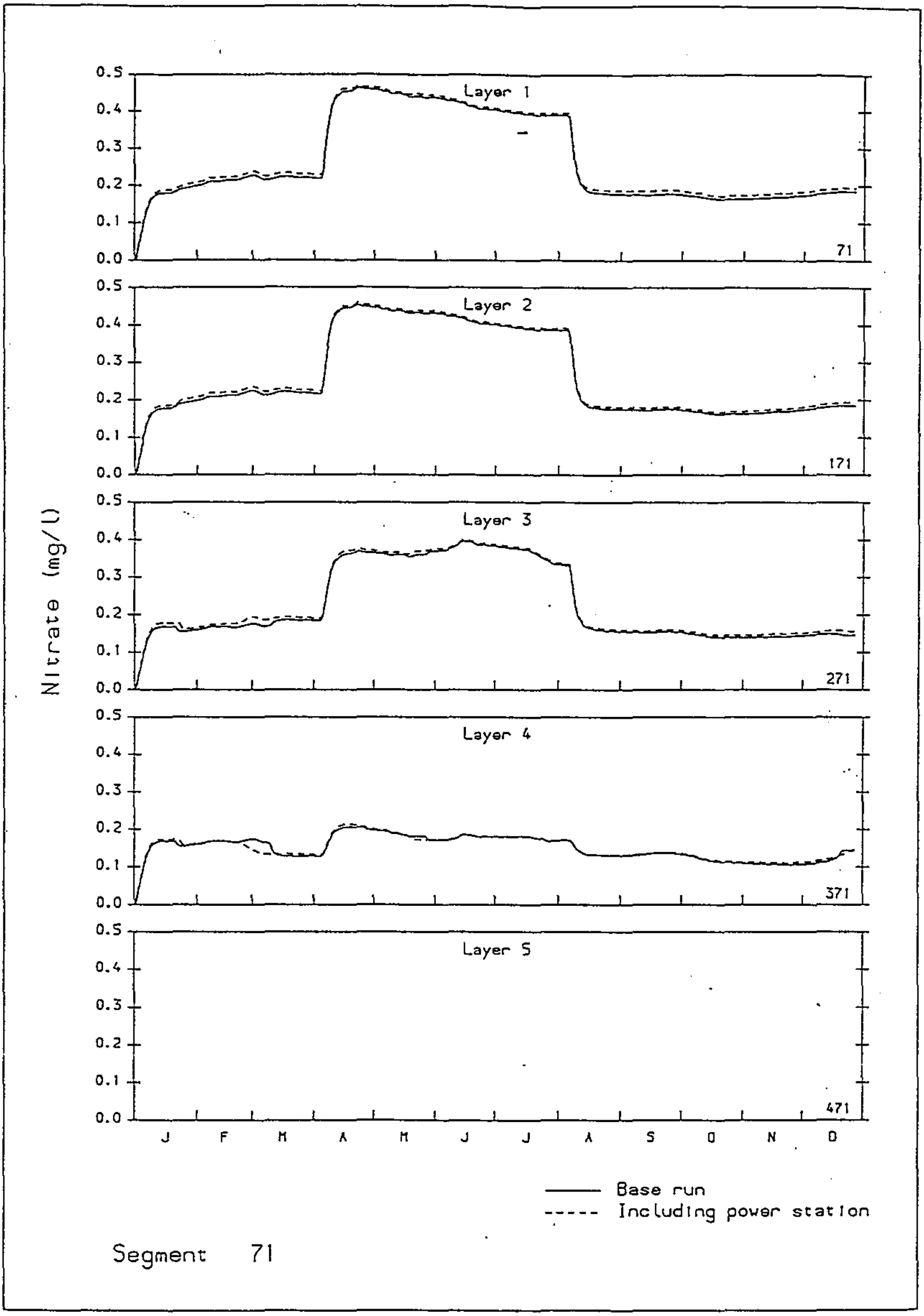


Fig 1 a Effect of proposed discharge on nitrate

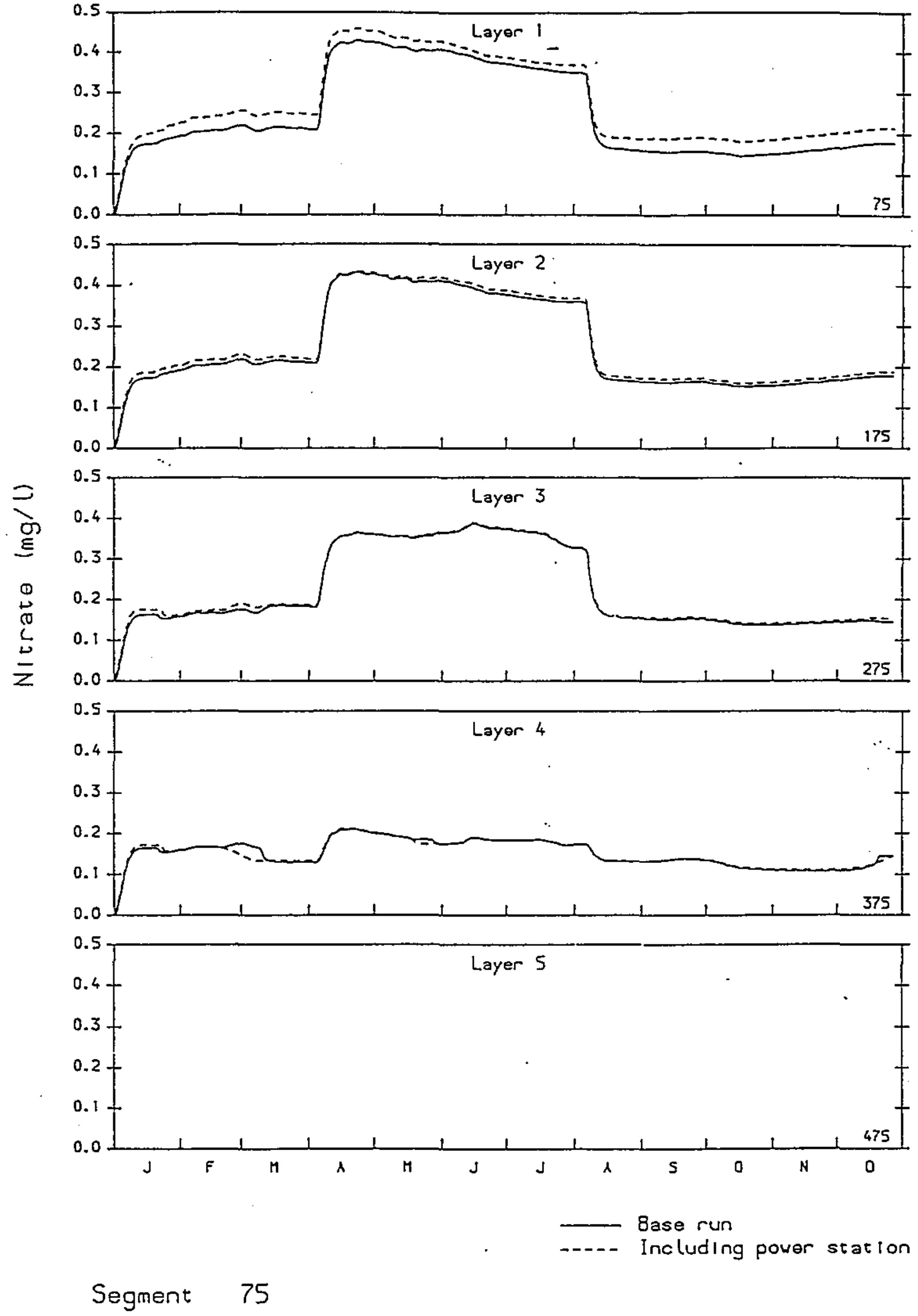


Fig 1 b Effect of proposed discharge on nitrate

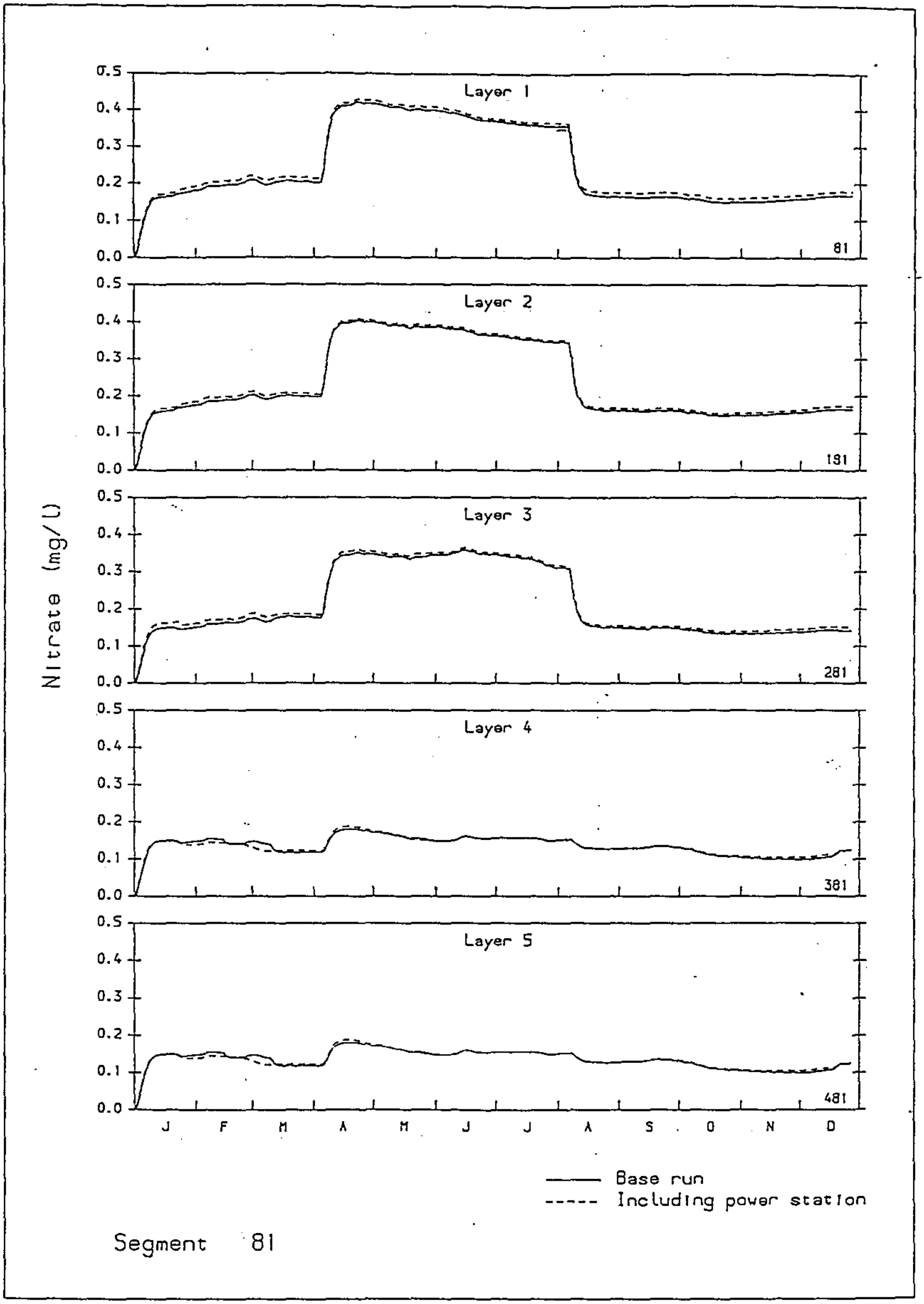


Fig 1 c Effect of proposed discharge on nitrate

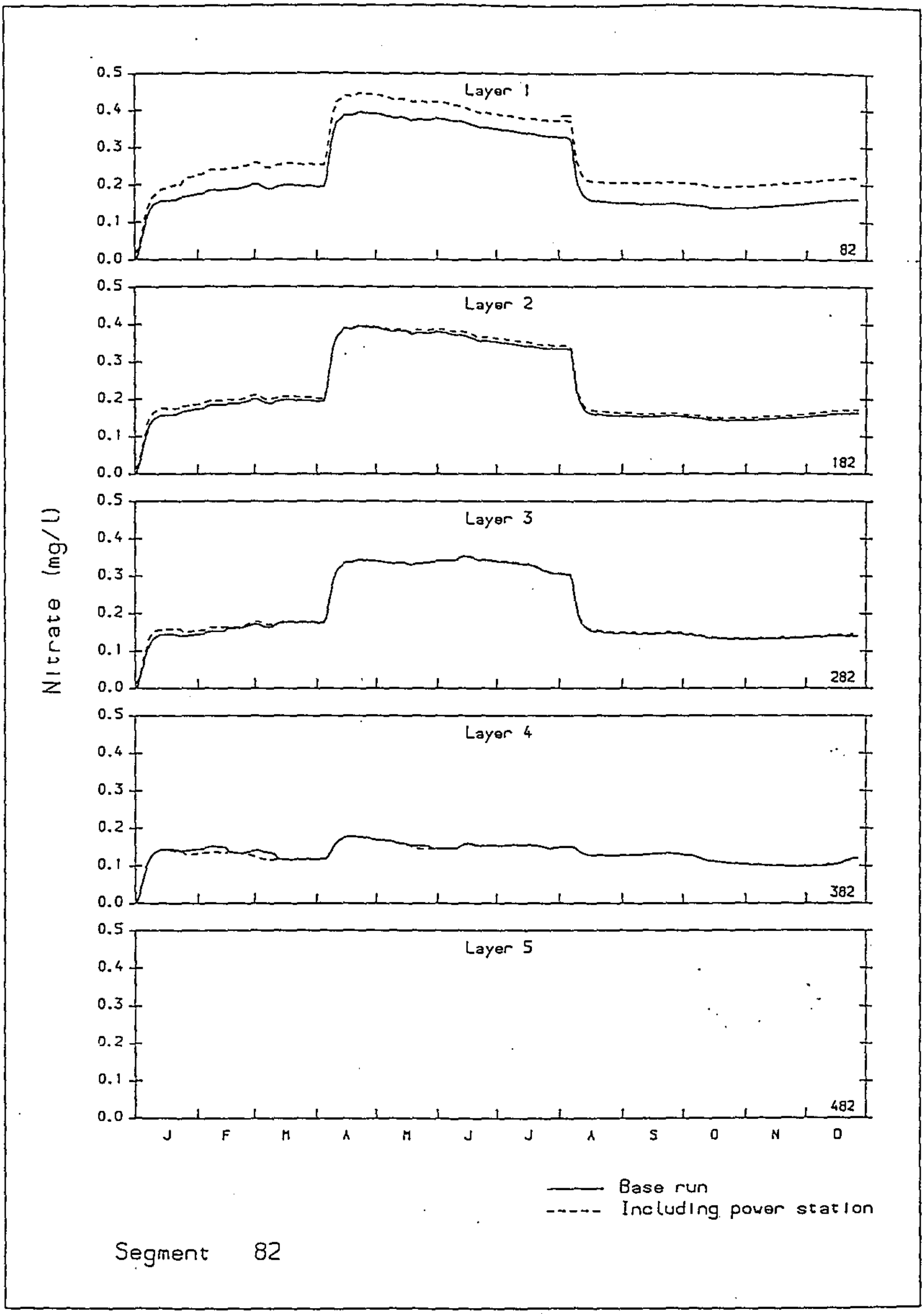


Fig 1 d Effect of proposed discharge on nitrate

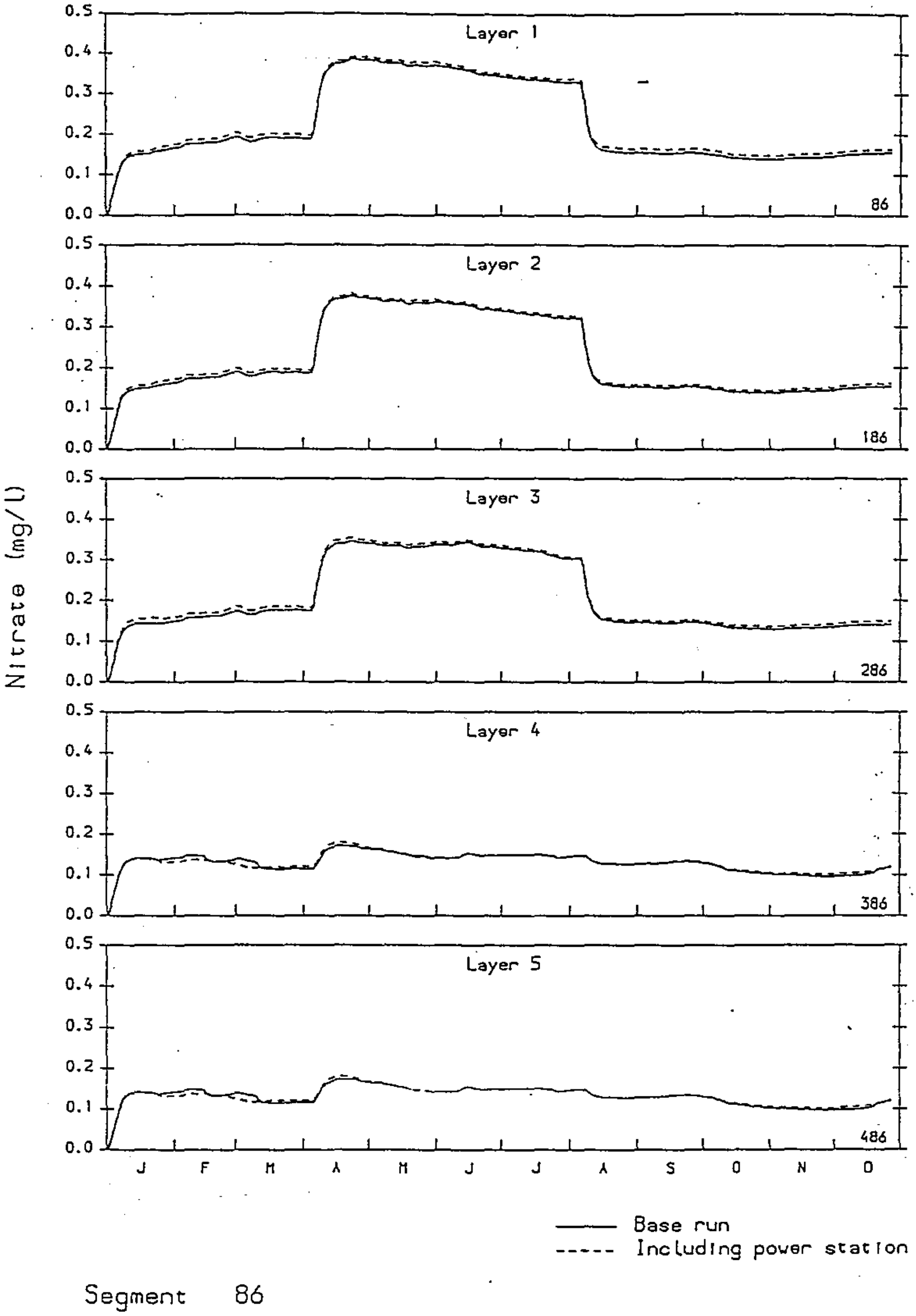


Fig 1 e Effect of proposed discharge on nitrate

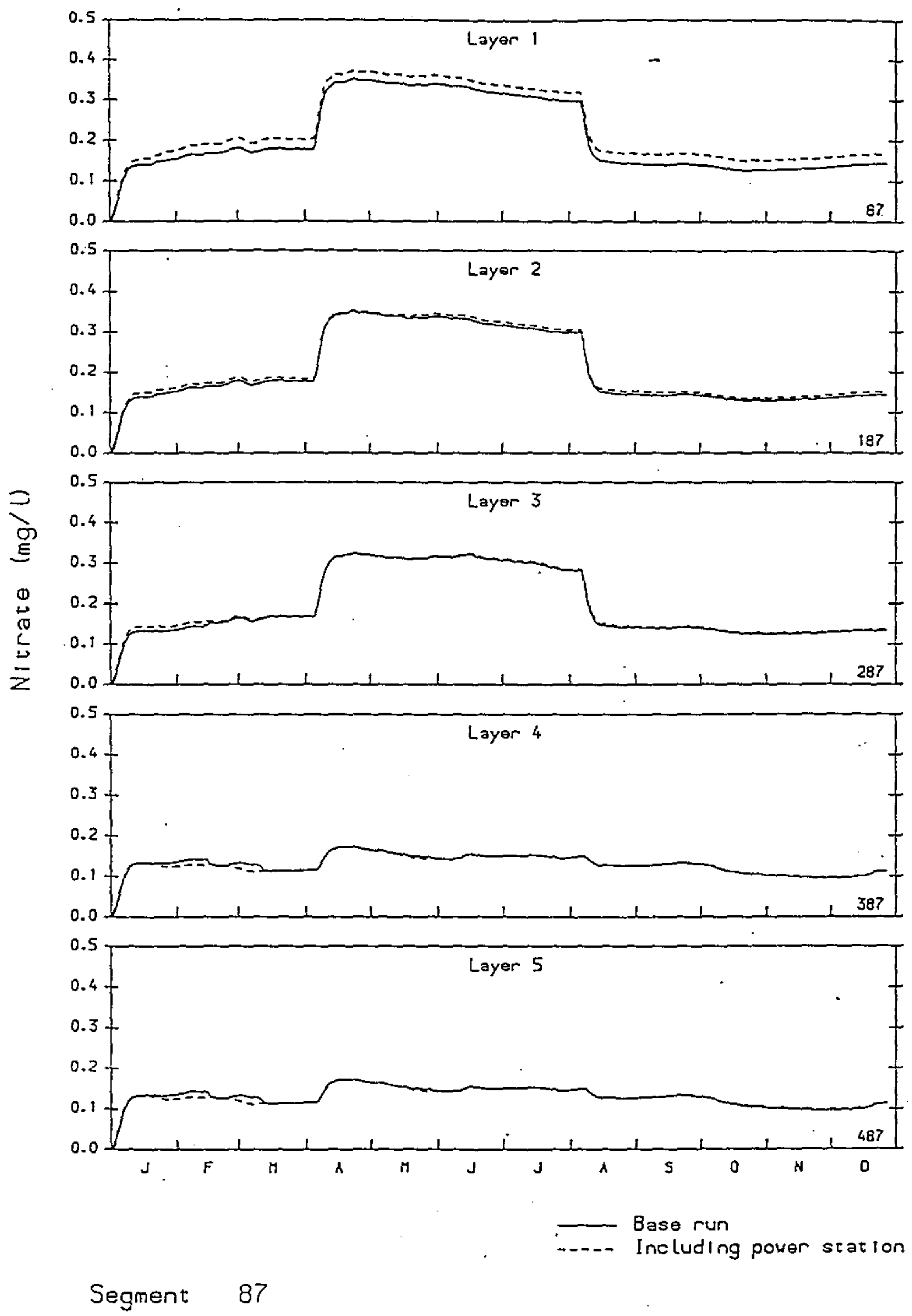


Fig 1 .f Effect of proposed discharge on nitrate

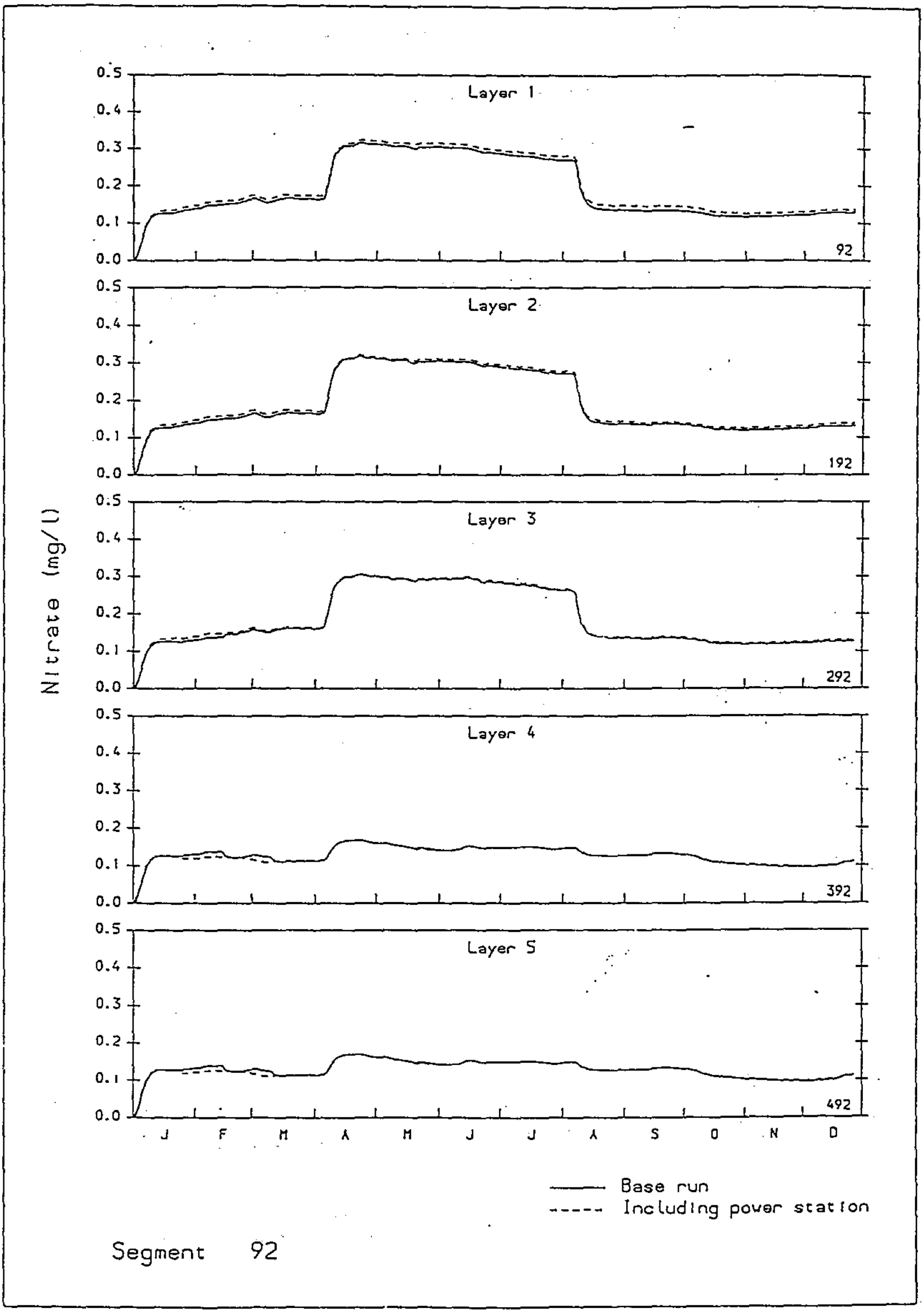


Fig 1 .g Effect of proposed discharge on nitrate

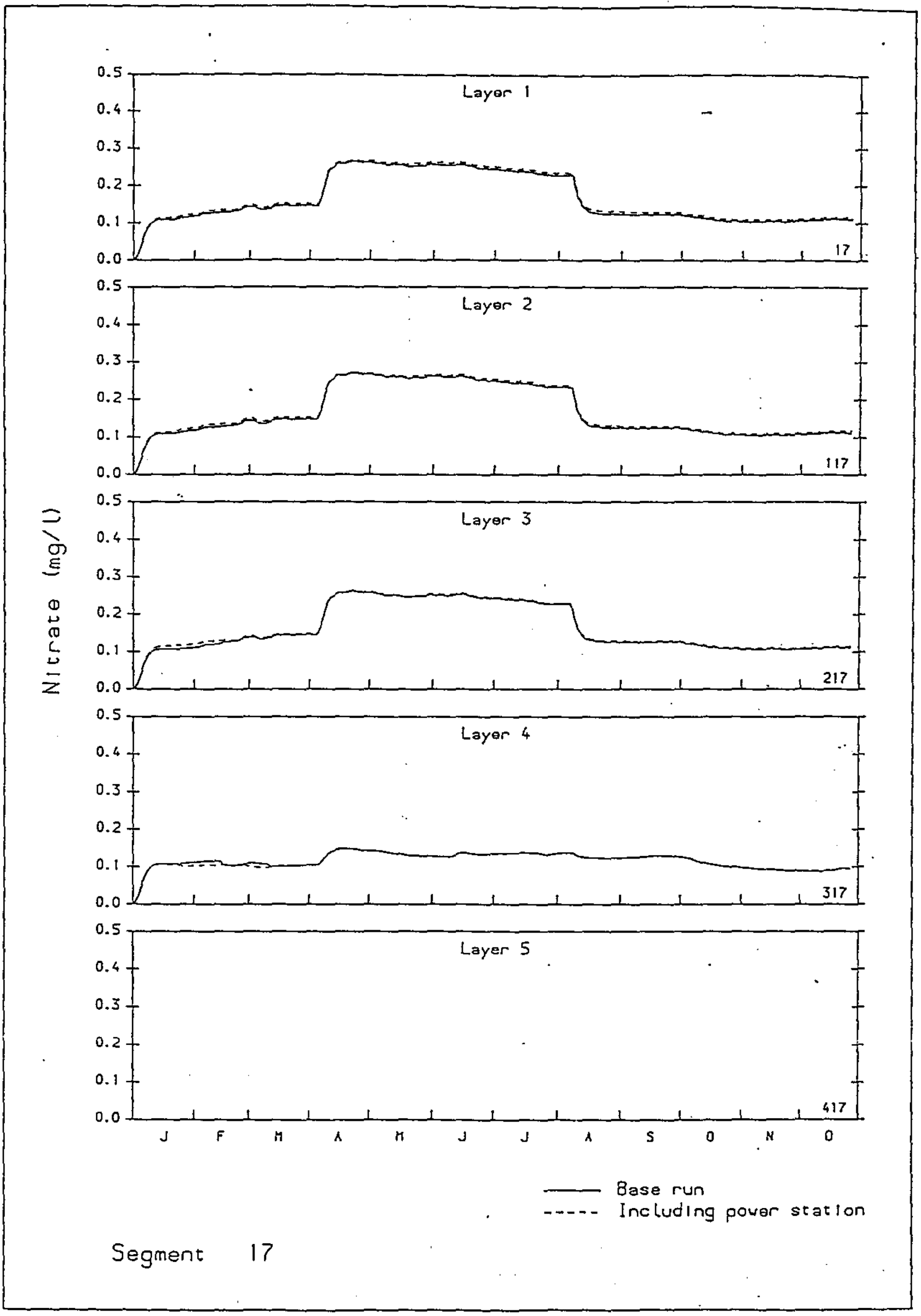


Fig 1 .h Effect of proposed discharge on nitrate

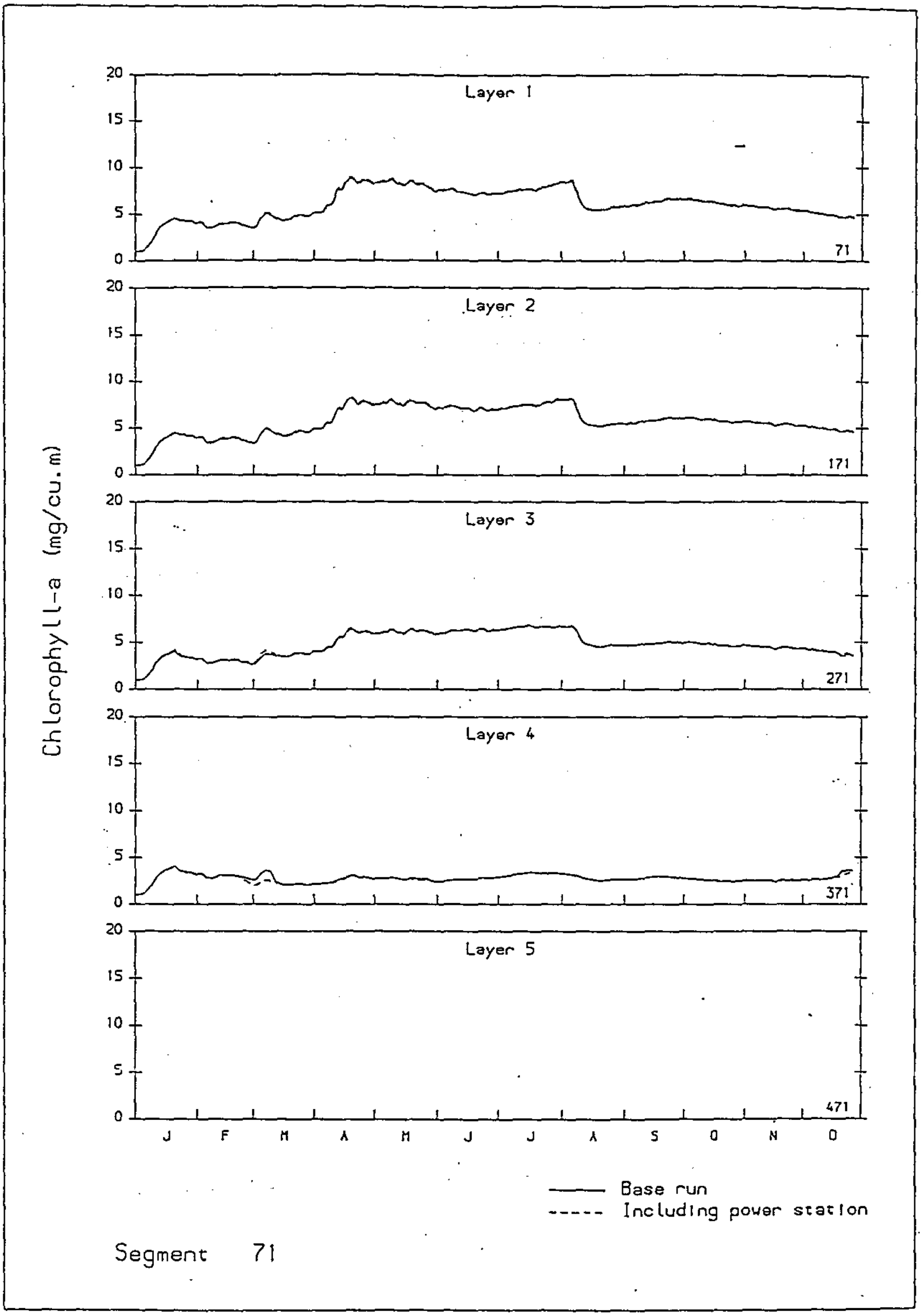


Fig 2a Effect of proposed discharge on chlorophyll-a

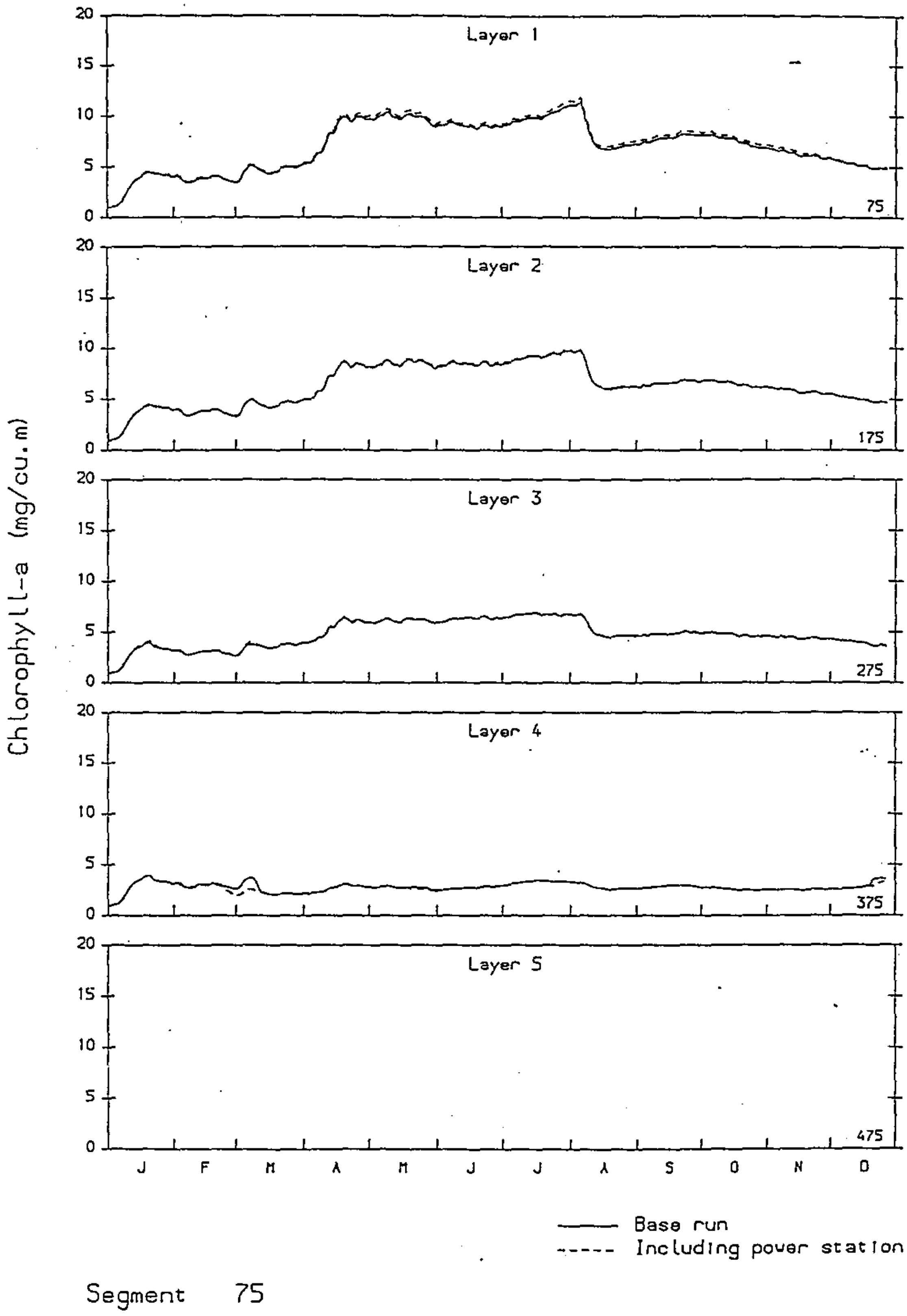


Fig 2b Effect of proposed discharge on chlorophyll-a

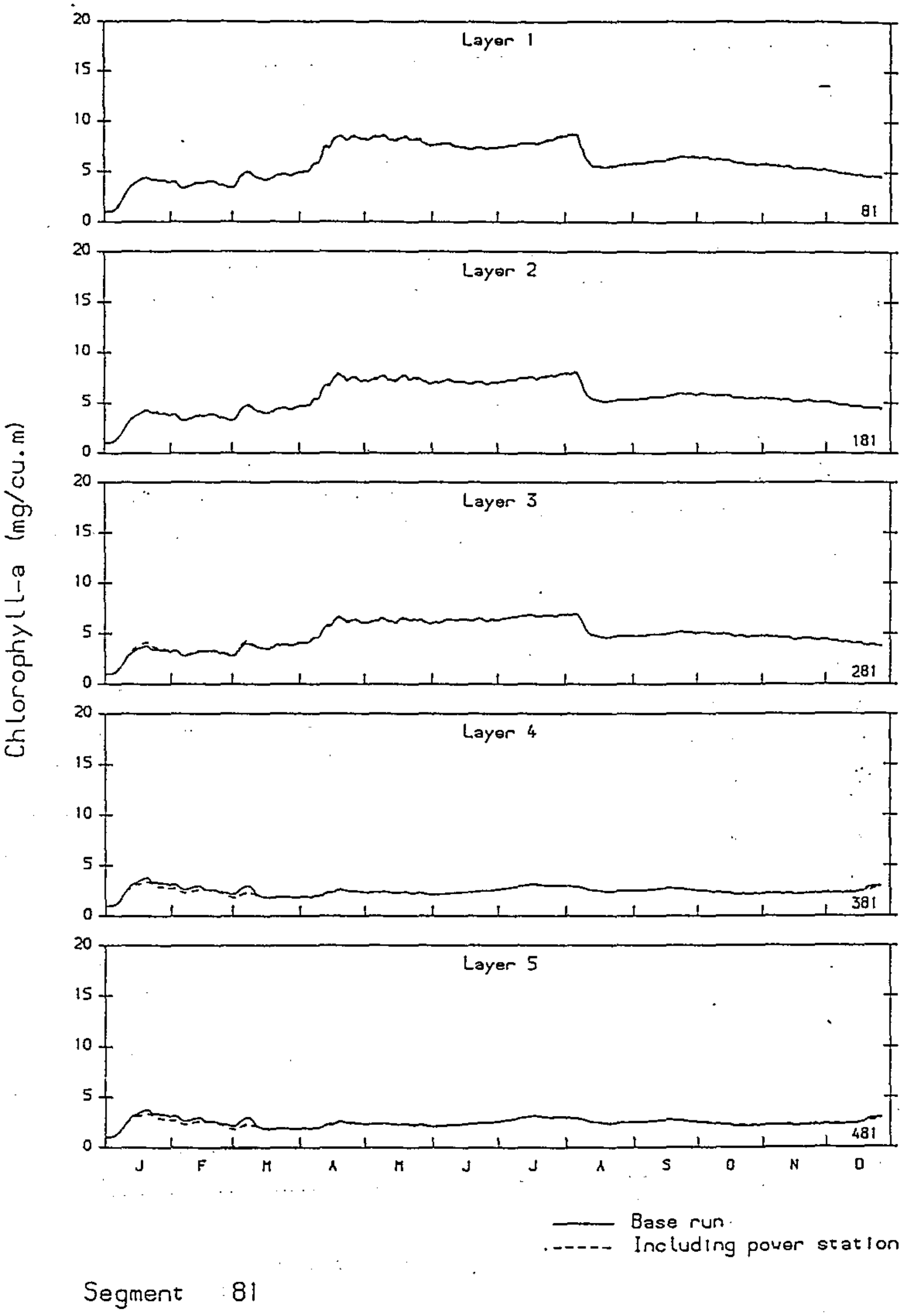


Fig 2c Effect of proposed discharge on chlorophyll-a

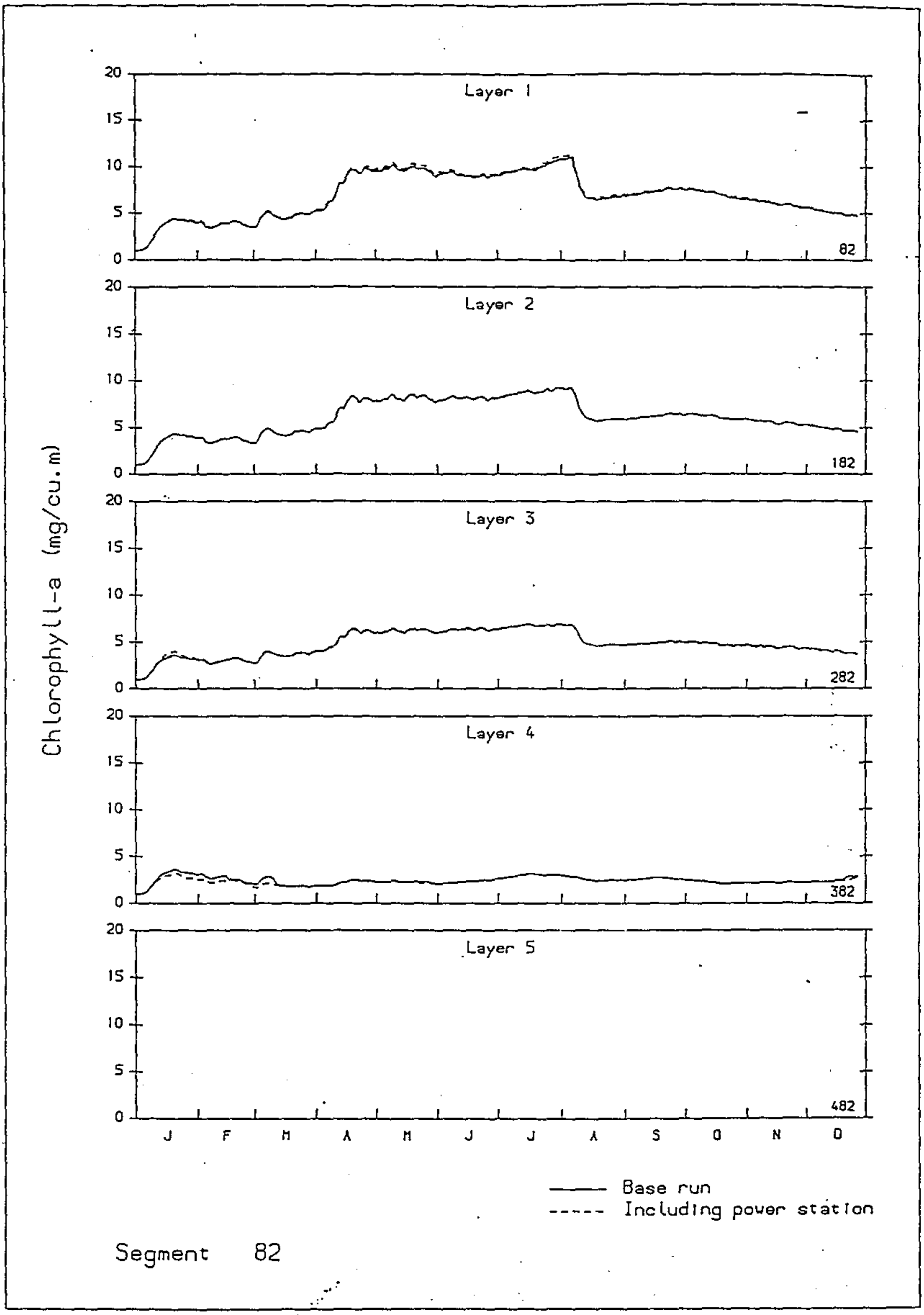


Fig 2d Effect of proposed discharge on chlorophyll-a

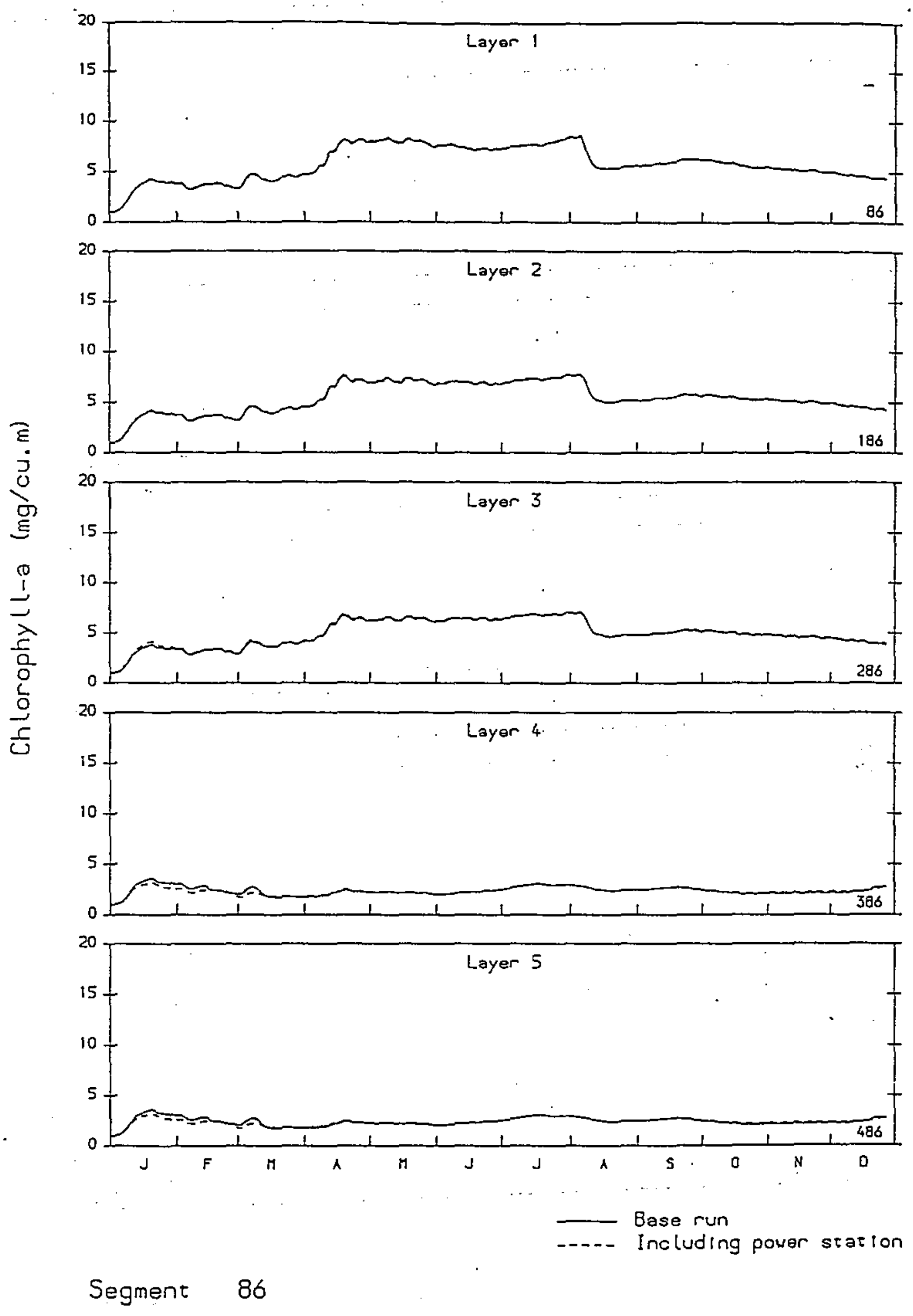


Fig 2e Effect of proposed discharge on chlorophyll-a

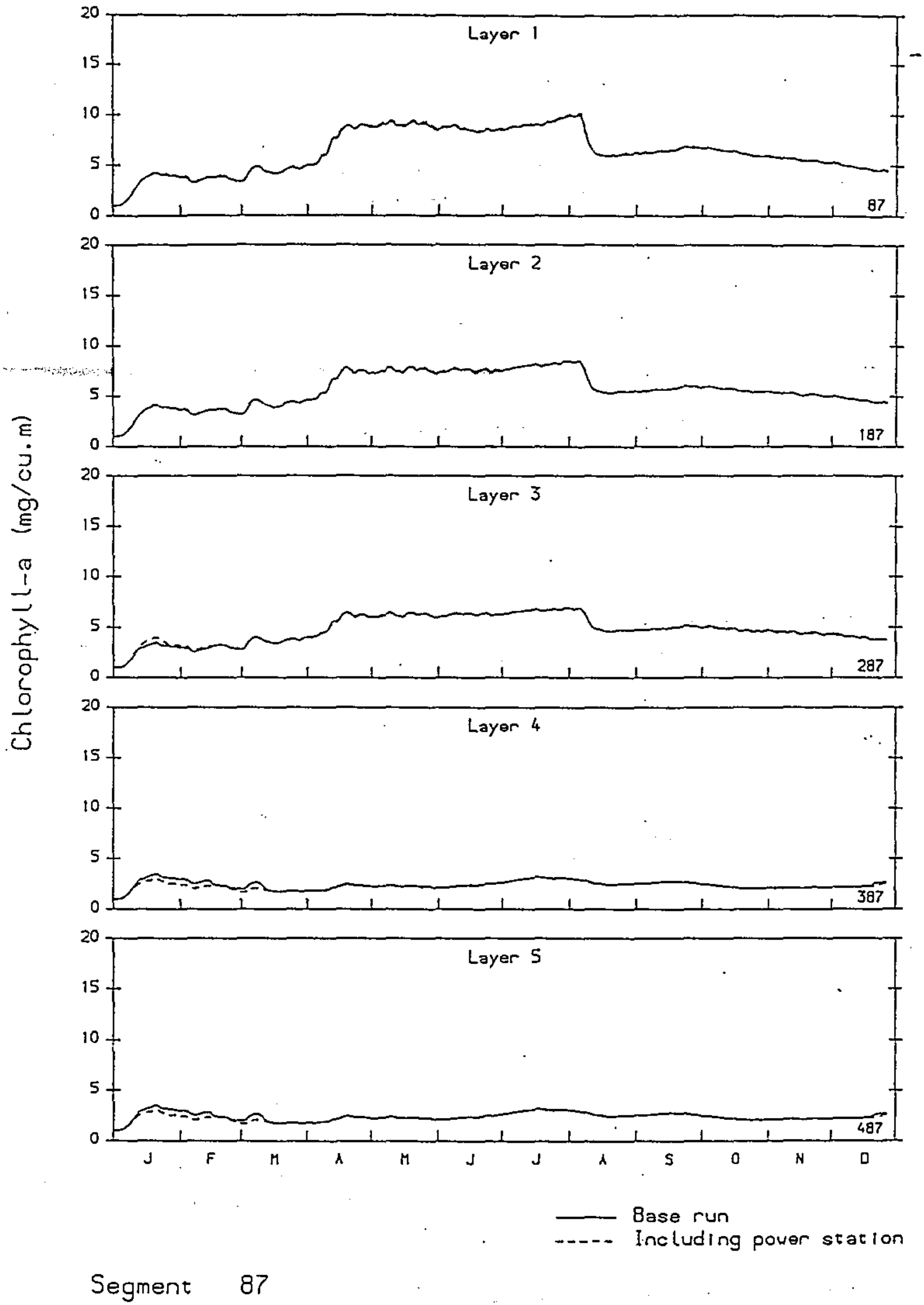


Fig 2f Effect of proposed discharge on chlorophyll-a

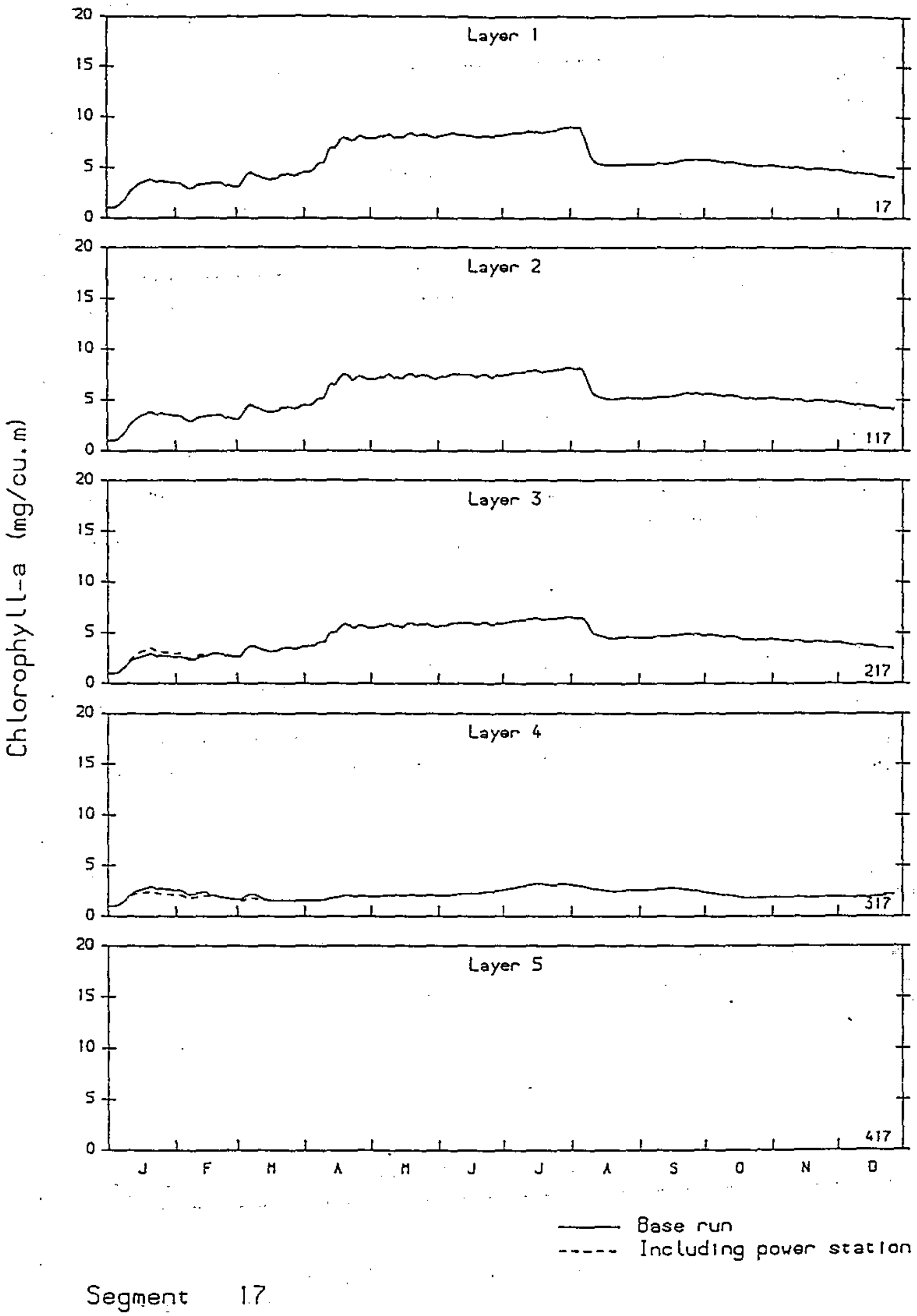


Fig 2g Effect of proposed discharge on chlorophyll-a

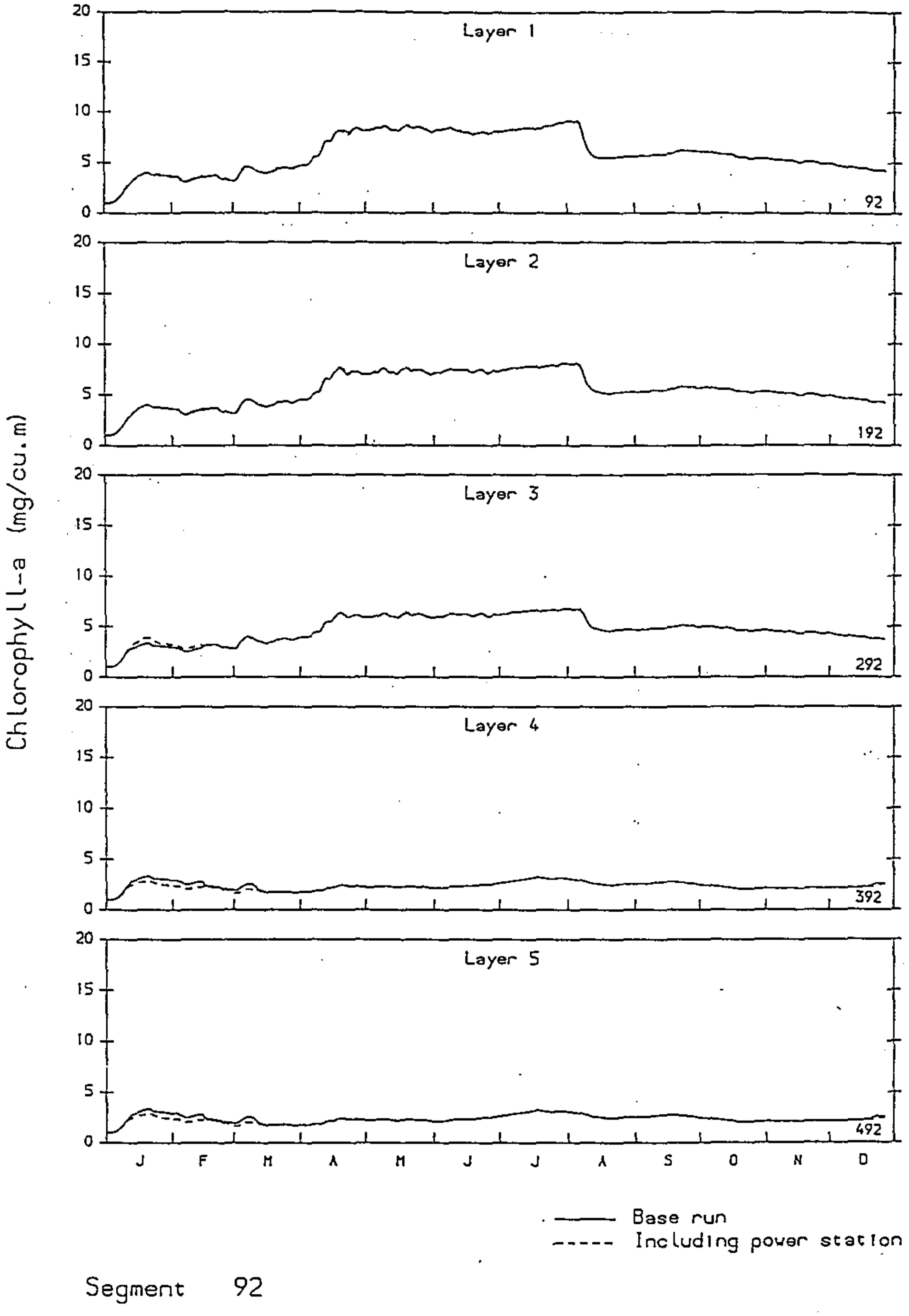


Fig 2h Effect of proposed discharge on chlorophyll-a

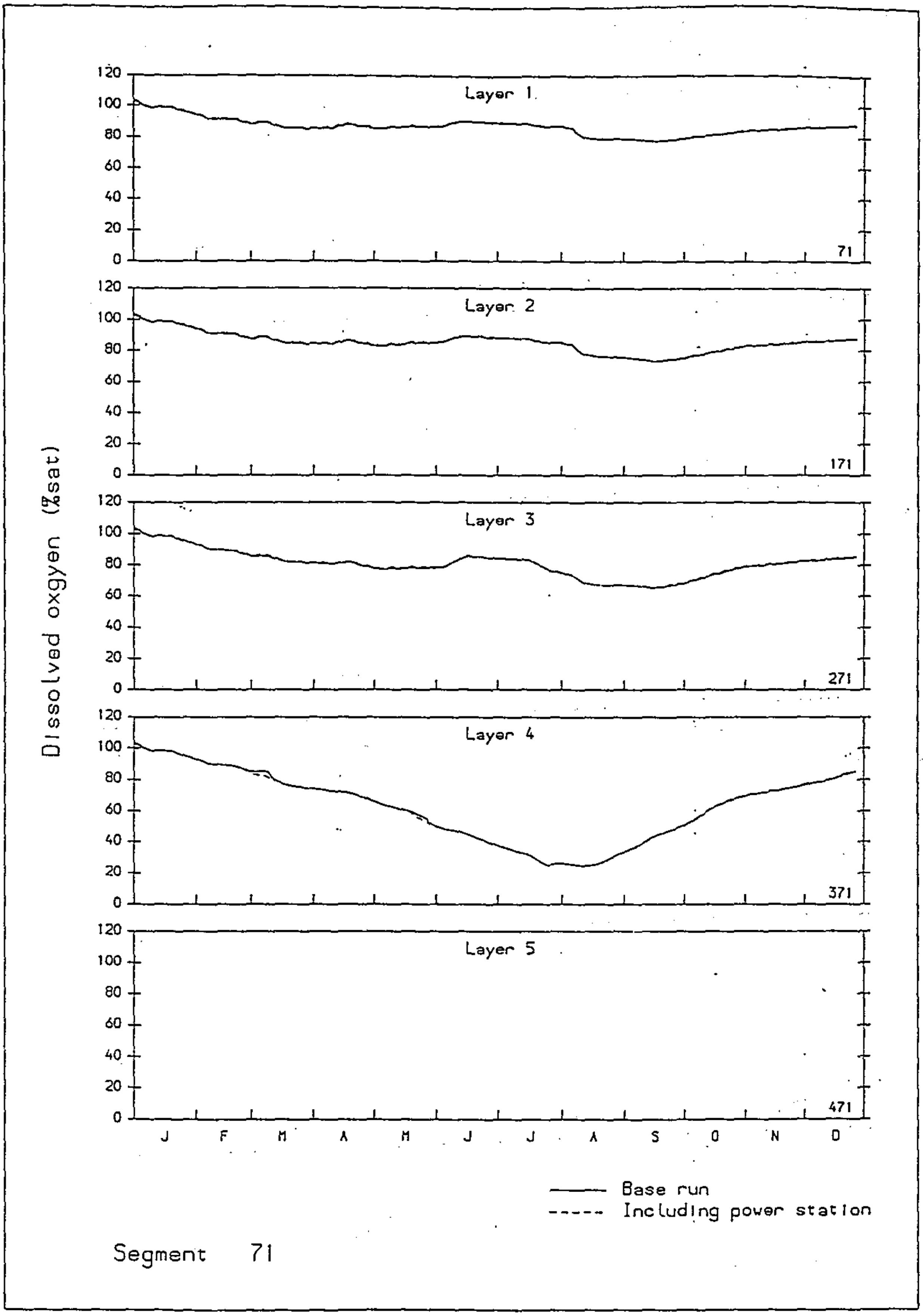


Fig 3a Effect of proposed discharge on dissolved oxygen

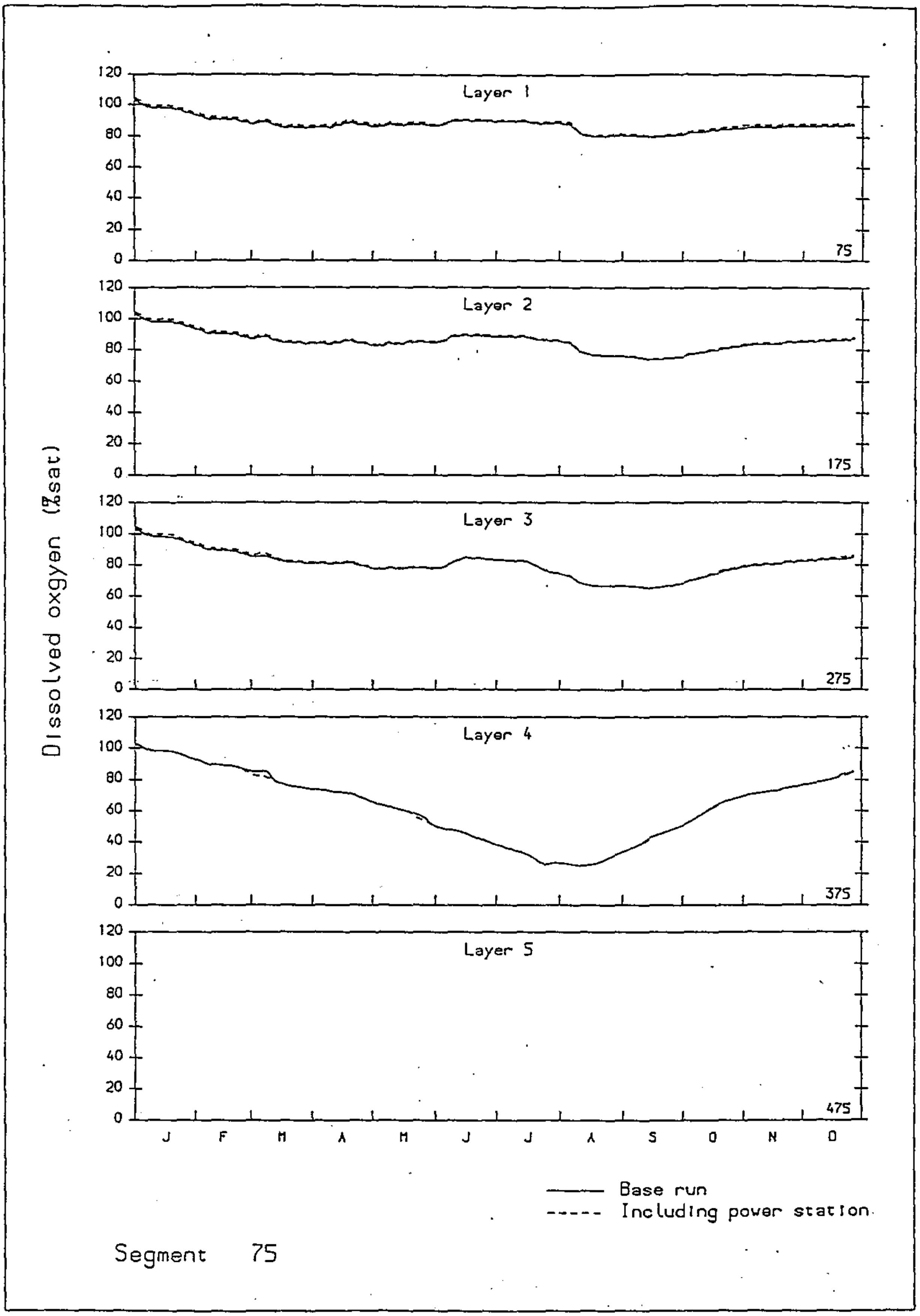


Fig 3b Effect of proposed discharge on dissolved oxygen

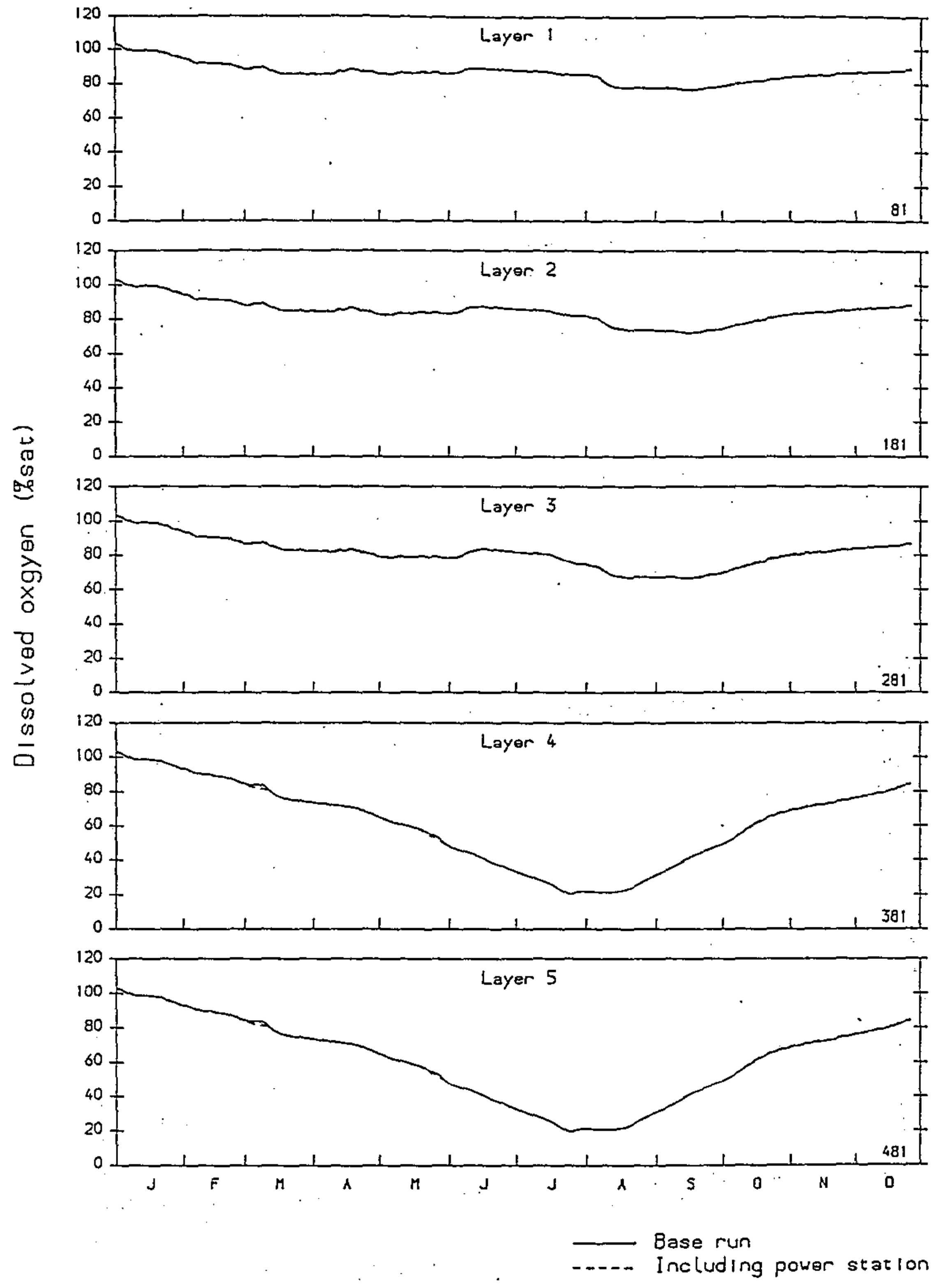


Fig .3c Effect of proposed discharge on dissolved oxygen

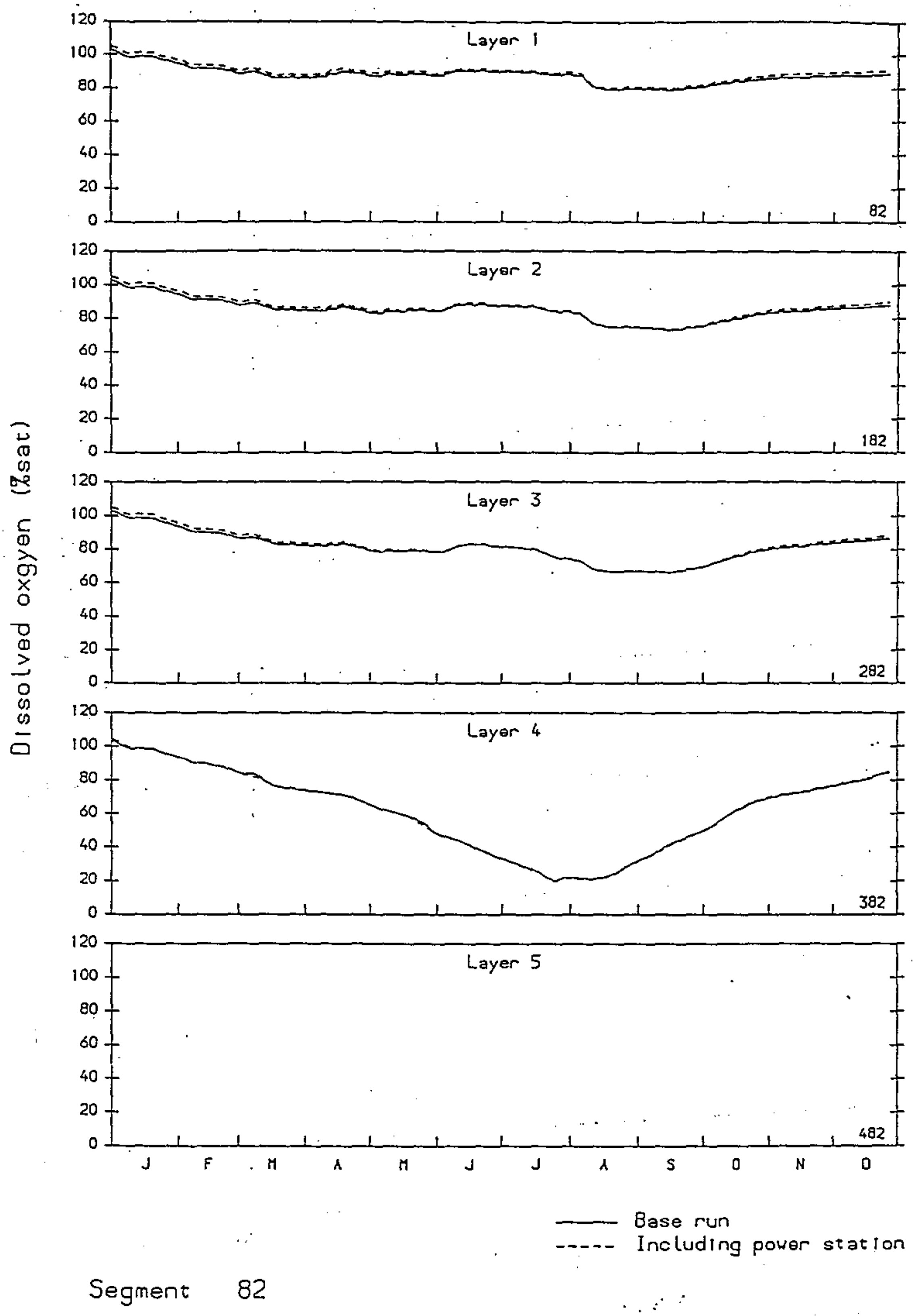


Fig .3d Effect of proposed discharge on dissolved oxygen

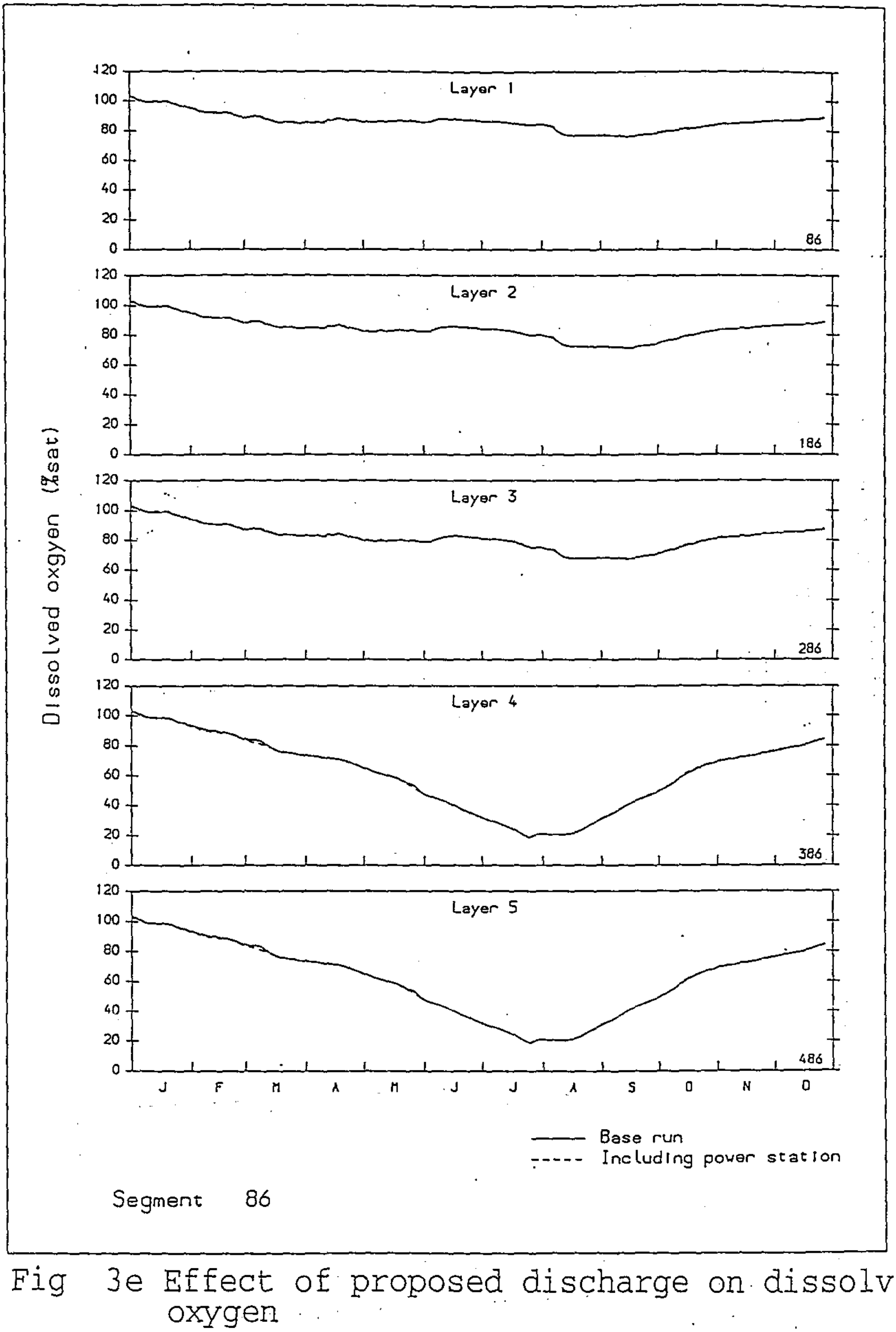


Fig 3e Effect of proposed discharge on dissolved oxygen

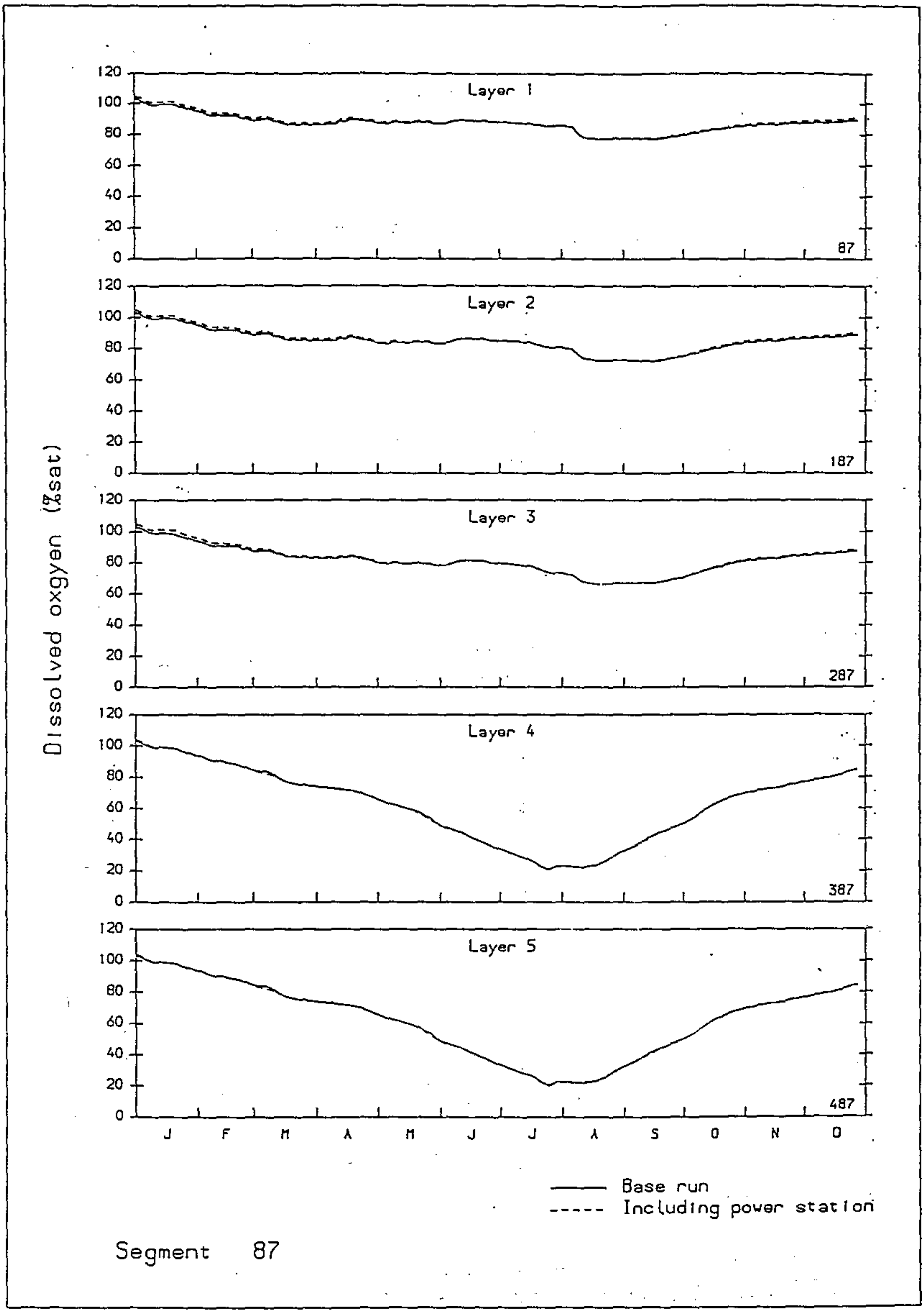


Fig 3f Effect of proposed discharge on dissolved oxygen

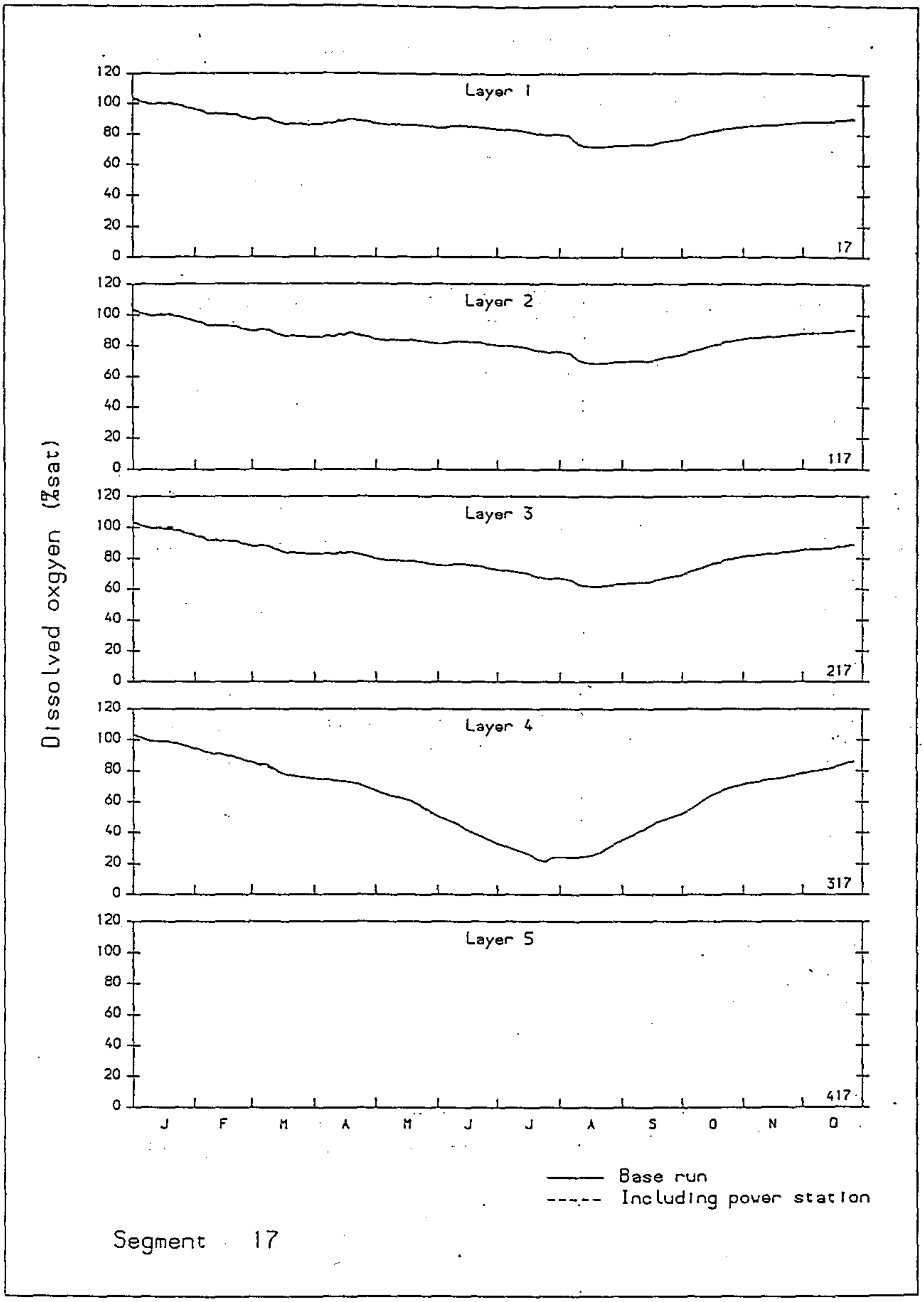


Fig 3g Effect of proposed discharge on dissolved oxygen

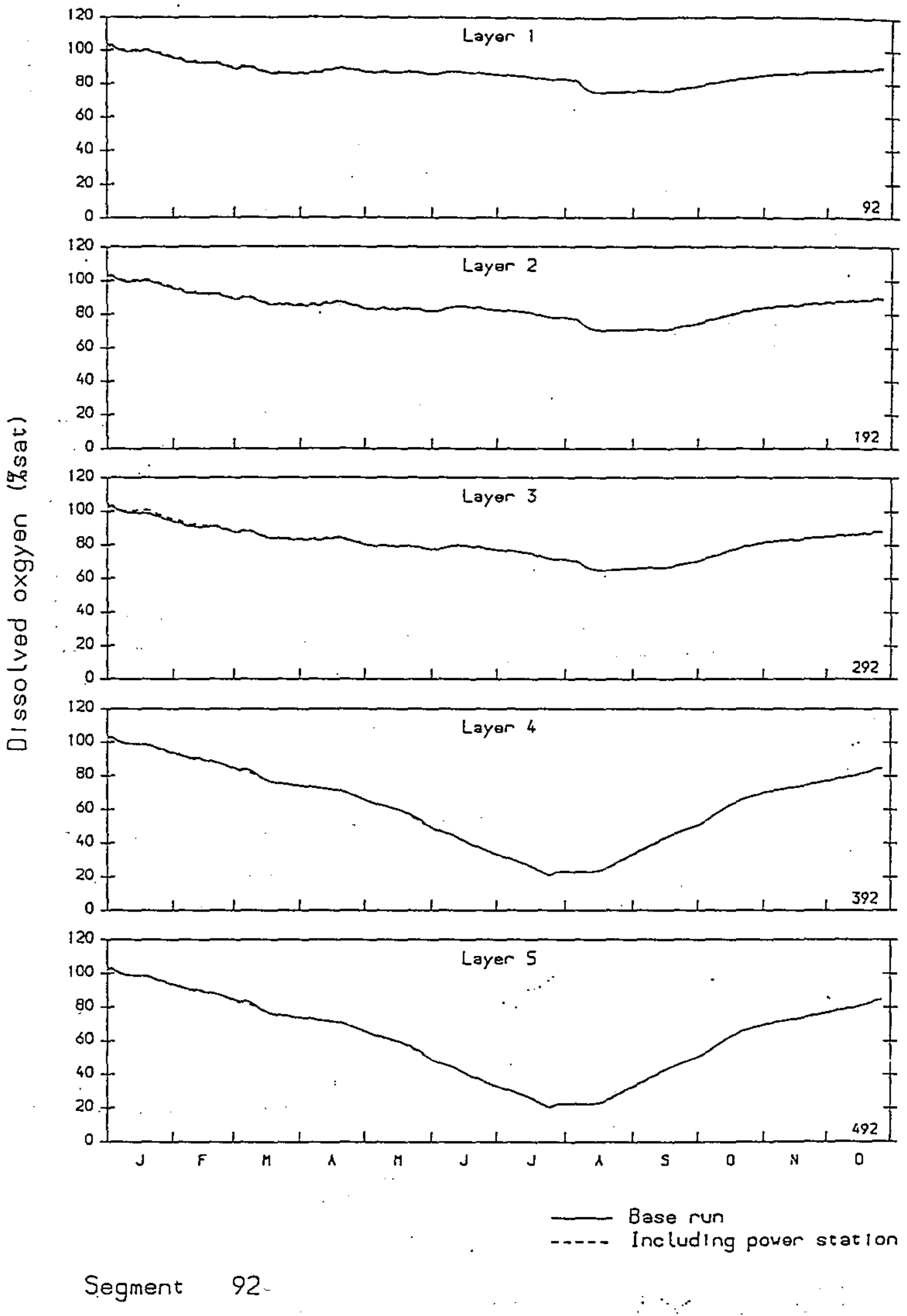


Fig 13h Effect of proposed discharge on dissolved oxygen

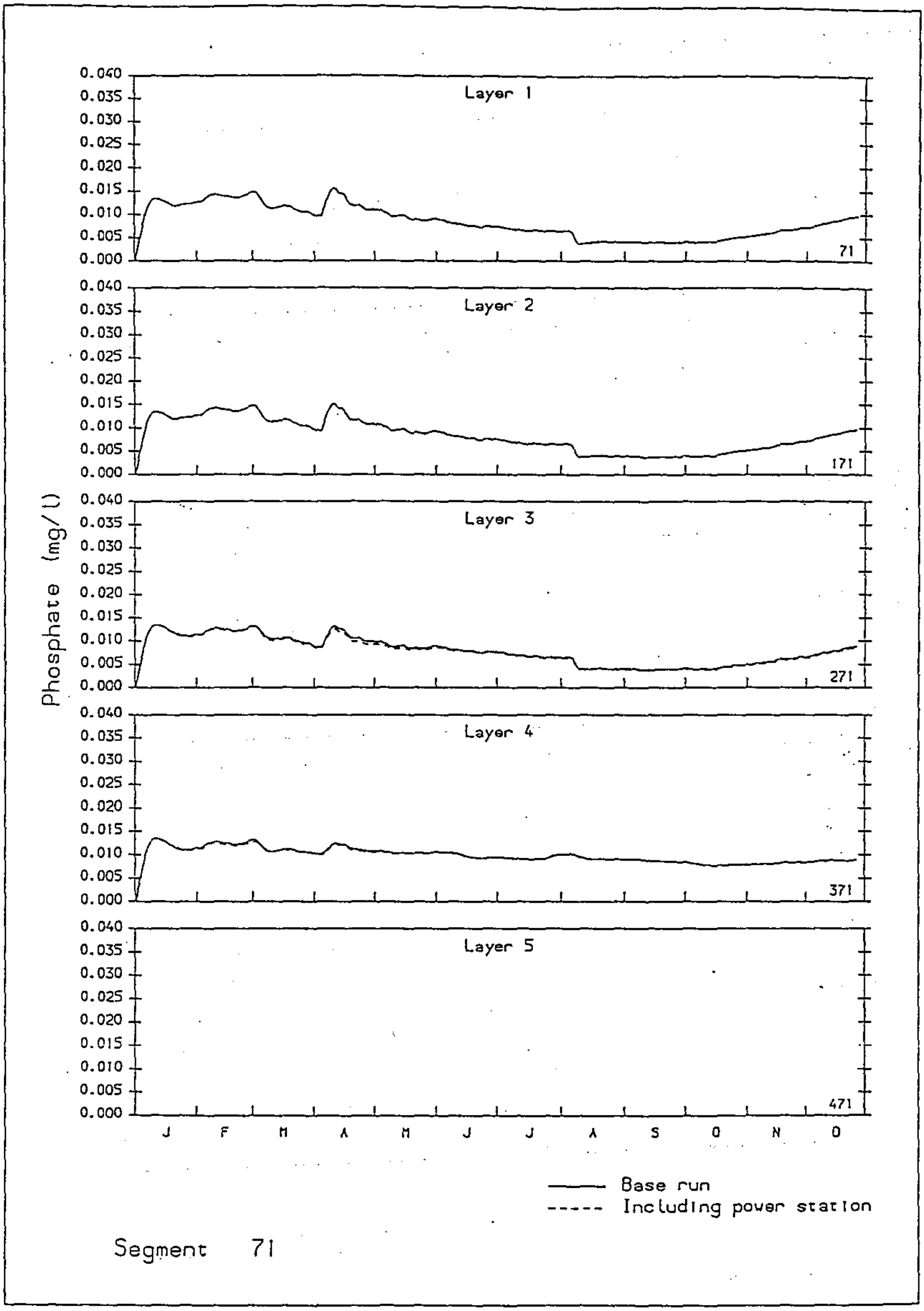


Fig .4a Effect of proposed discharge on phosphate

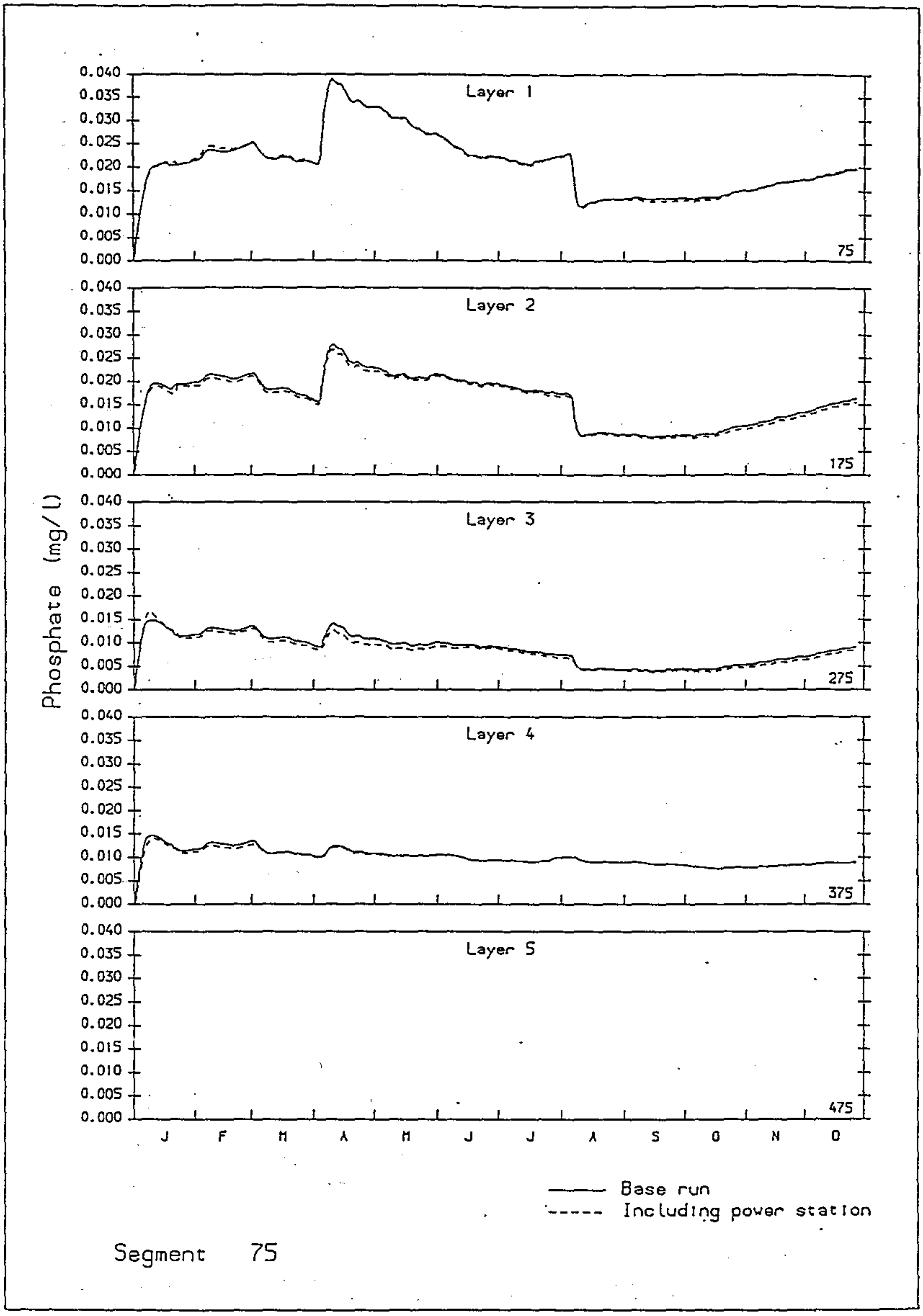
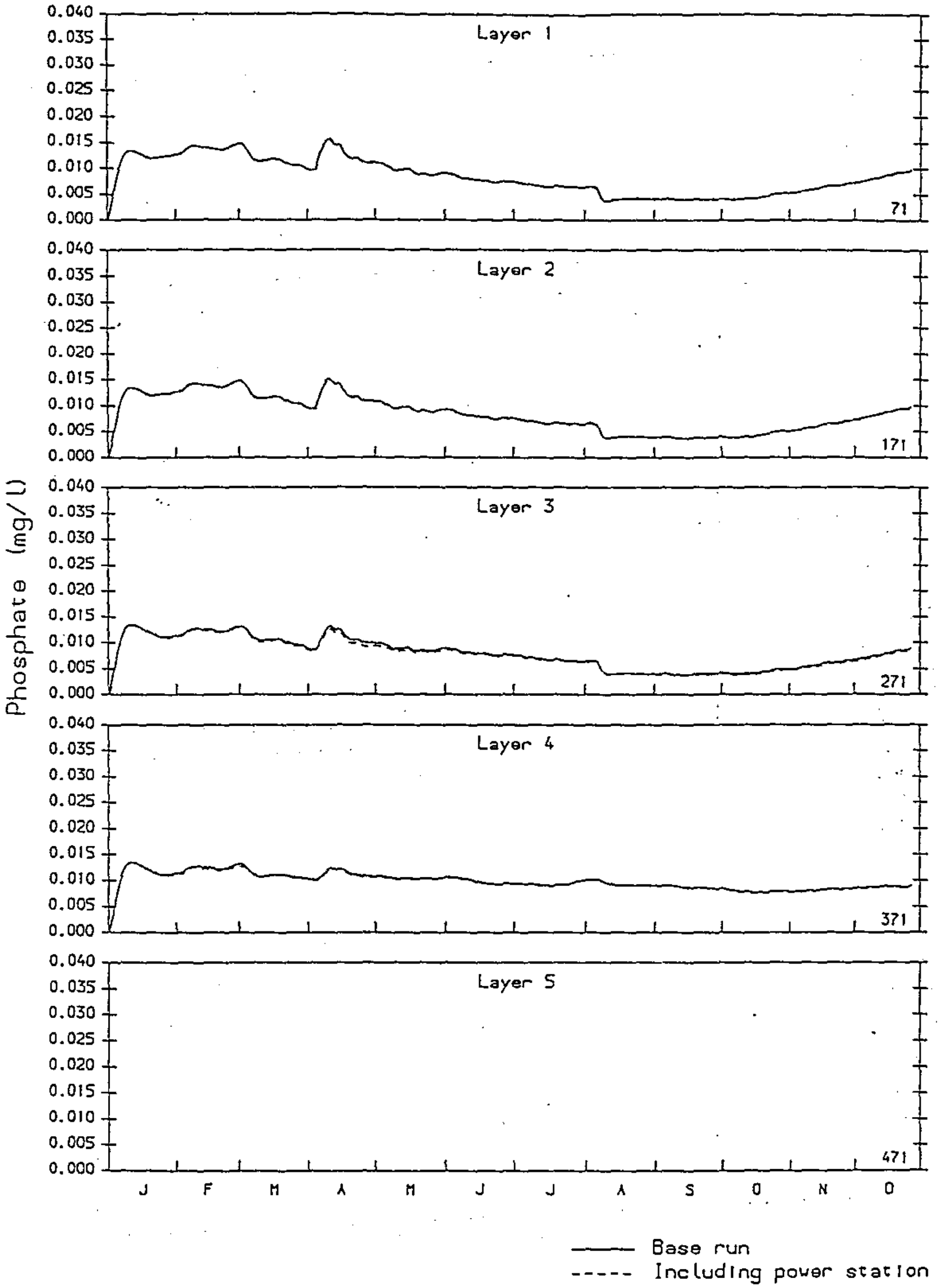


Fig . 4b Effect of proposed discharge on phosphate



Segment 71

Fig 4a Effect of proposed discharge on phosphate

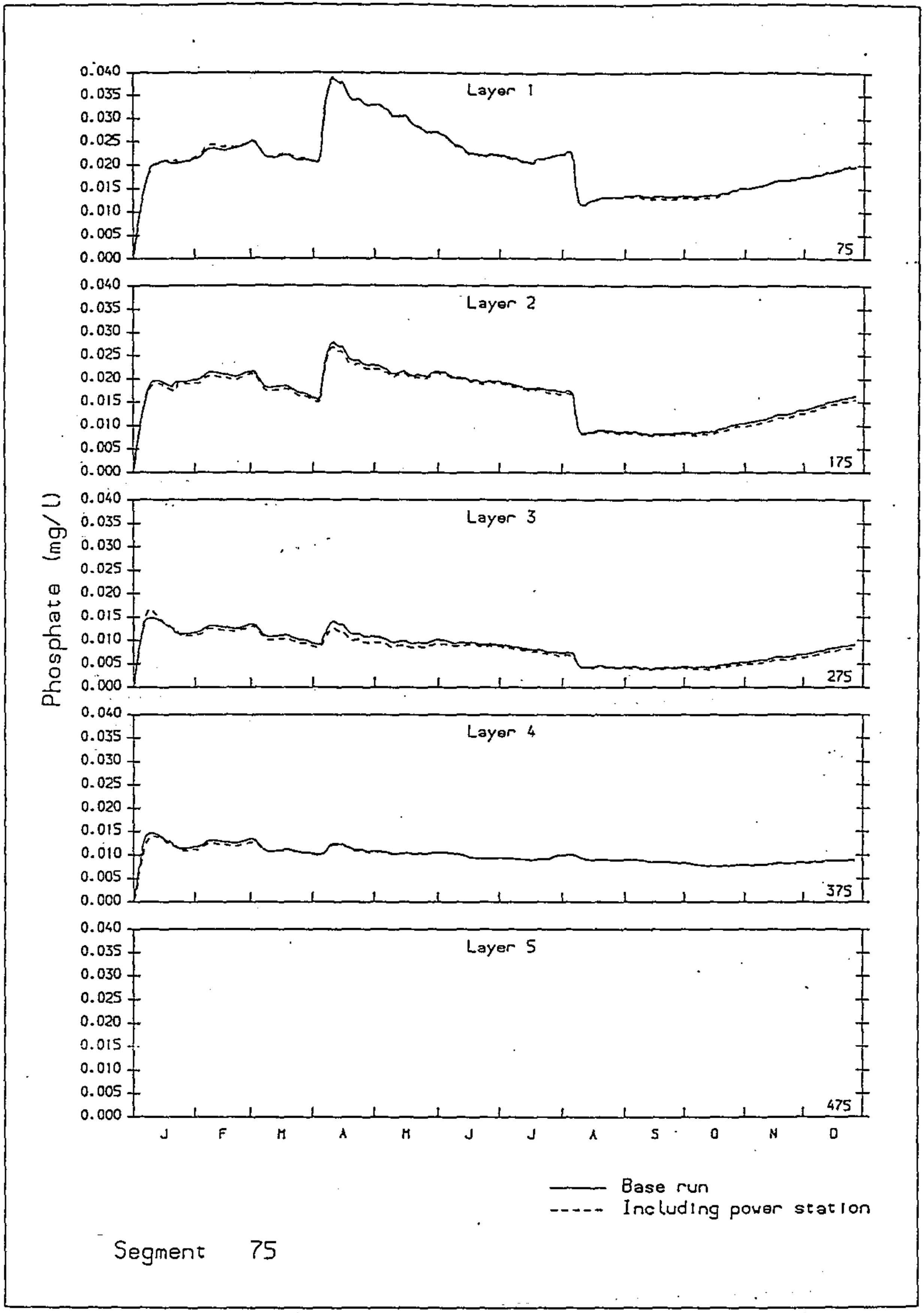


Fig 4b Effect of proposed discharge on phosphate

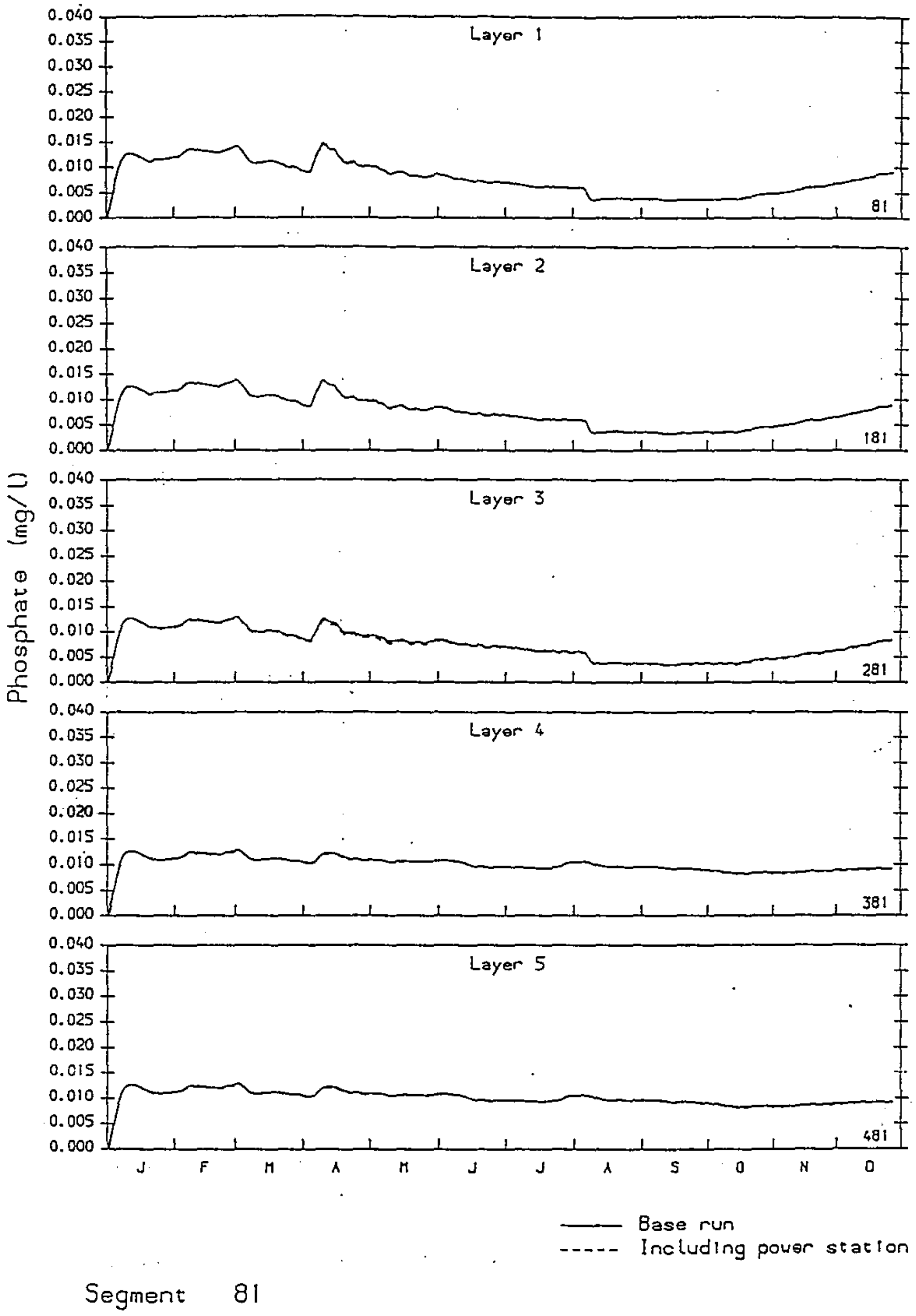


Fig . 4c Effect of proposed discharge on phosphate

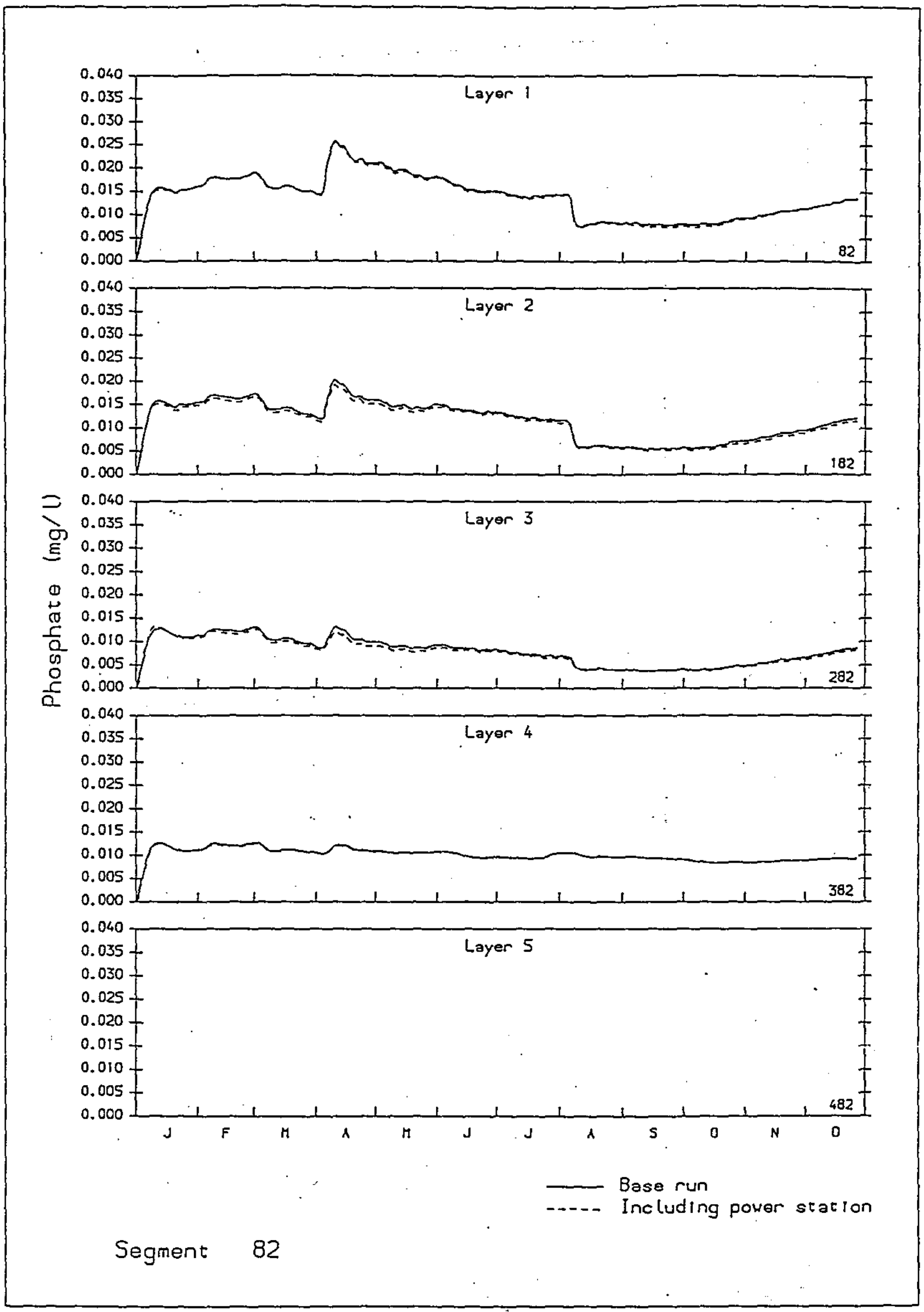


Fig 4d Effect of proposed discharge on phosphate

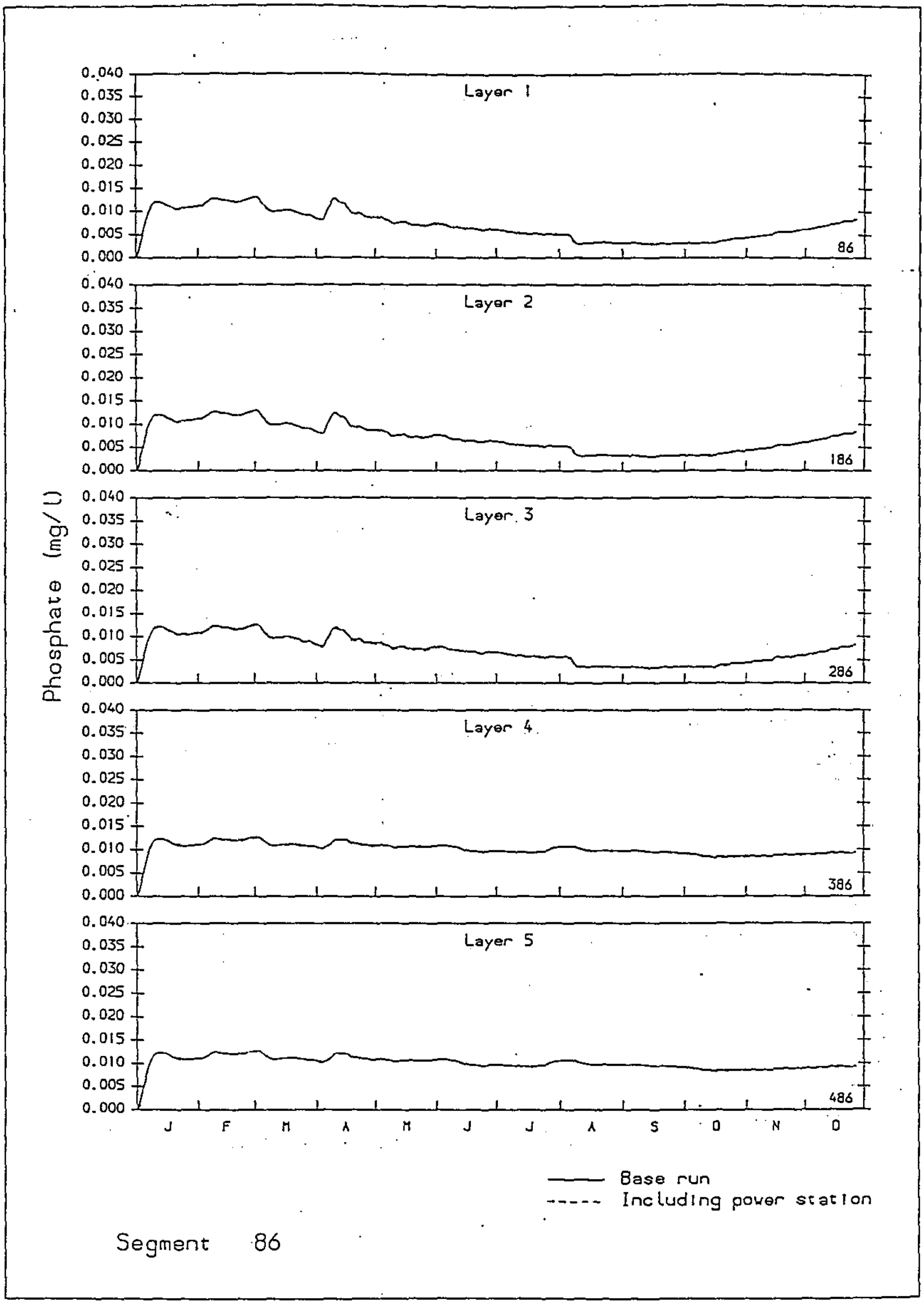


Fig .4e Effect of proposed discharge on phosphate

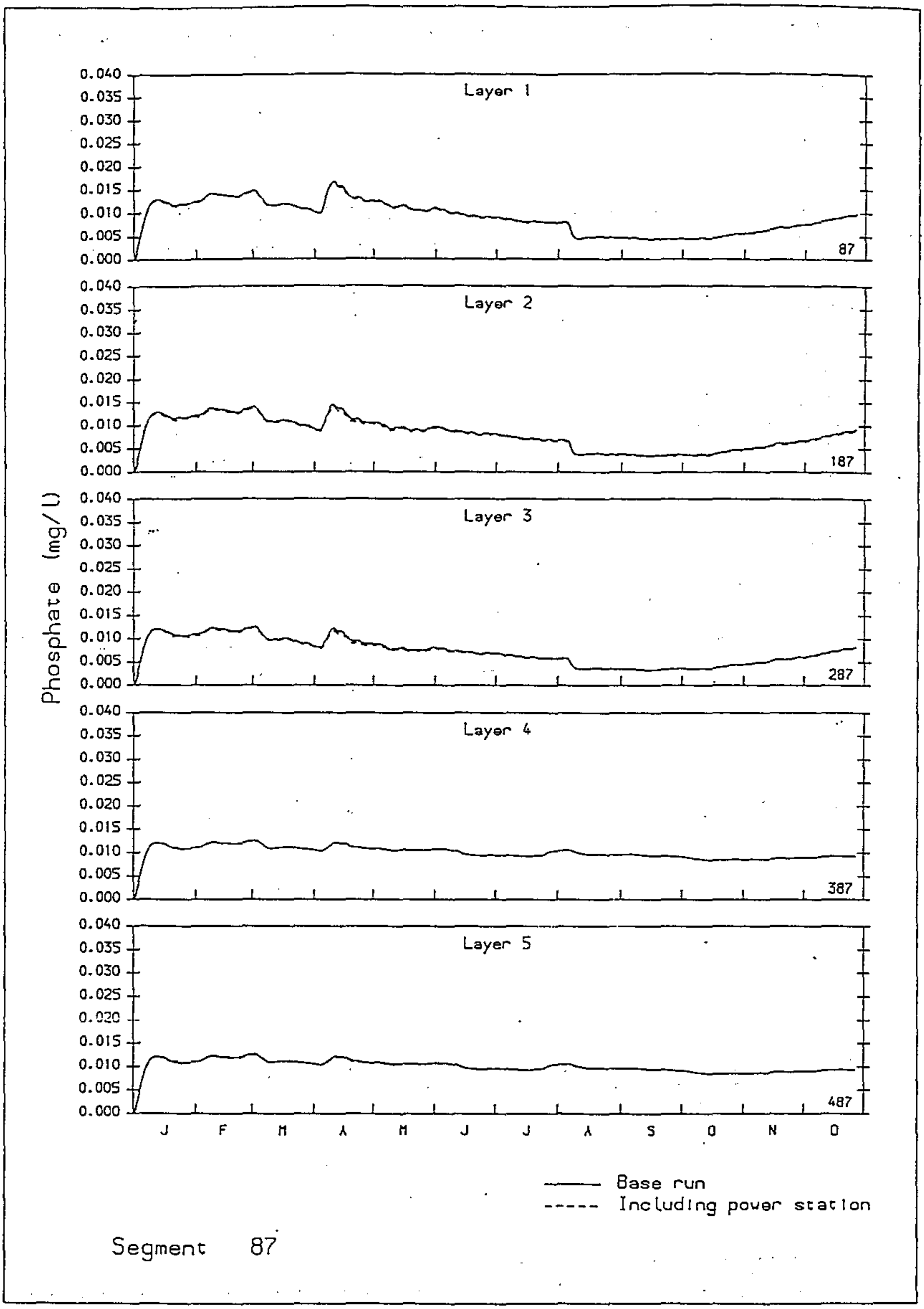


Fig 14f Effect of proposed discharge on phosphate

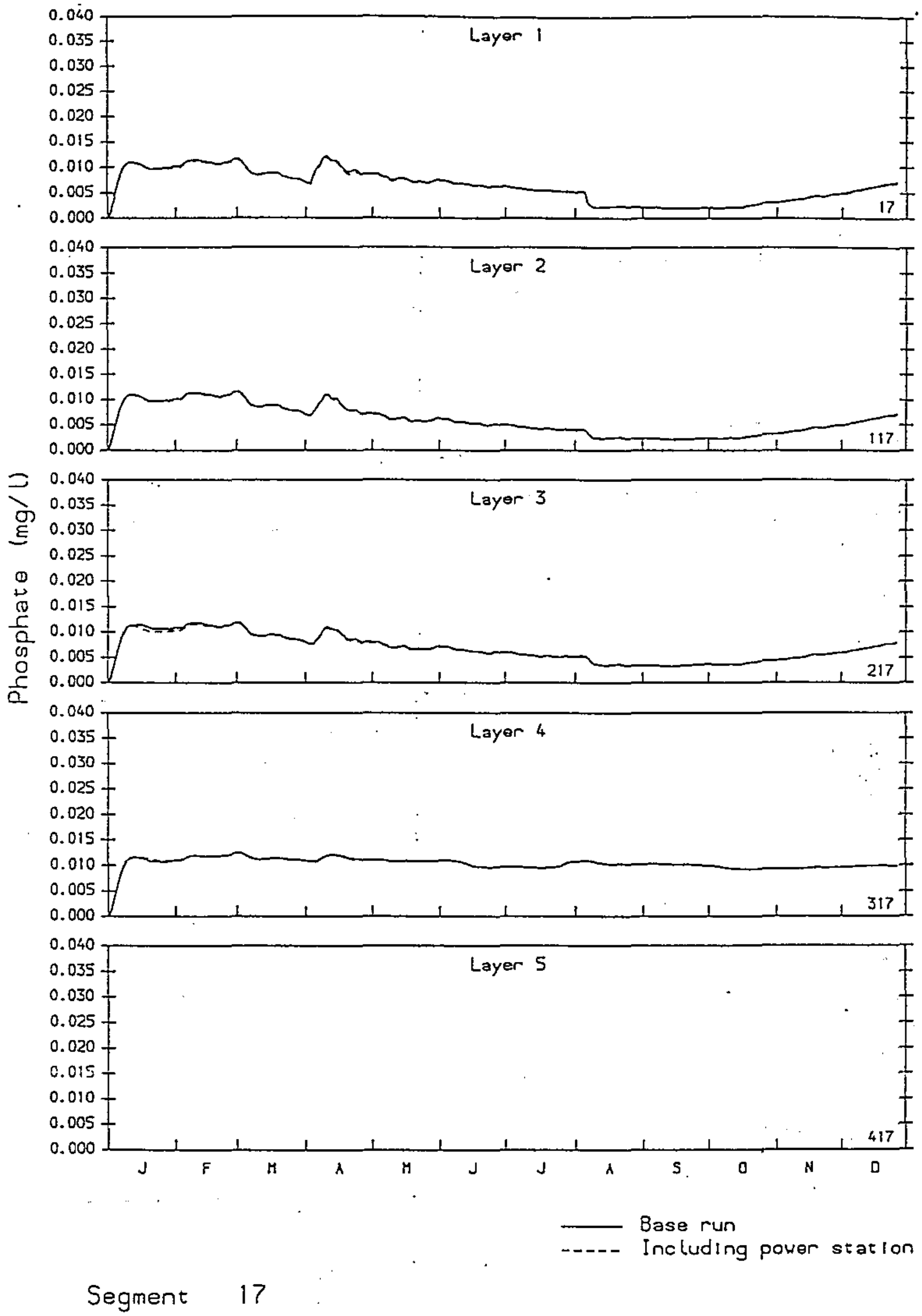
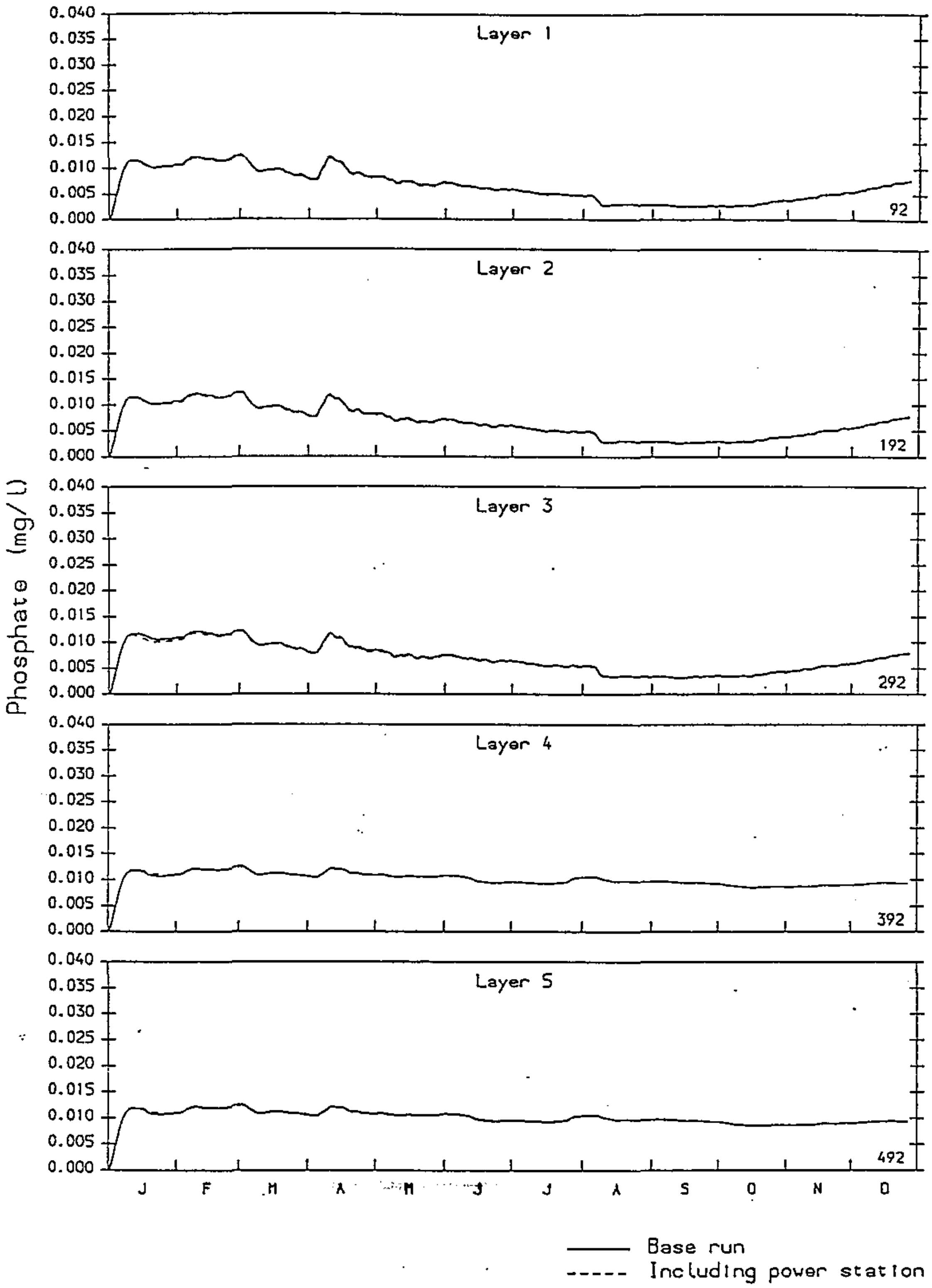


Fig 4g Effect of proposed discharge on phosphate



Segment 92

Fig 4h Effect of proposed discharge on phosphate

RESPONSE TO GOVERNMENT COMMENTS

Annex G

EPD Consolidated Comments

EIA for the LTPS at Black Point
Water Quality Key Issue Assessment (WKIA) Report

EPD Consolidated Comments

A. Overall Comments

EAPG

i) The assessment in the report is based on two assumed firing scenarios (ie all coal-fired and half coal- and half gas-fired), in which the all coal-fired scenario is taken as the worst case scenario. As far as we are aware, the likely stage 1 development is going to be gas-fired. The consultants or CLP should confirm the intended firing scenario so that the impacts can be accurately assessed and appropriate mitigation measures can be determined.

R CLP have advised that the first four units are most likely to be gas fired, dependant upon a number of factors, which they have discussed previously with EPD. The EIA for the LTPS has been premised on an assessment of the worst-case scenario; for Water Quality aspects, this is represented by the eight coal-fired unit scenario.

ii) It was clearly stipulated in the 1st SMG meeting that "mere dilution would not be acceptable" and that "each effluent stream should be looked at separately and removal of heavy metals be considered before diluting in the cooling water" (re: item 3.12.2, Notes of 1st SMG meeting on 31.5.91). The WKIA should therefore be carried out along these principles. The report as it is now is unacceptable to us.

R Noted. Please refer to Annex I for projected effluent stream breakdowns for coal/oil and gas/oil scenarios.

iii) Despite our reminder (vide our fax dated 12.11.91) that the cumulative effects of the dredging/dumping activities in the area (eg PAA's dredging work for the new airport) should be addressed in the WKIA, the cumulative effect is hardly addressed in the report. Chapter 4 should be expanded to fully cover this including the concerns we raised in our fax mentioned above.

R Dredging for the airport is scheduled for 1993-4, which will not co-incide with the main dredging effort which could be required at LTPS, ie the coal bulk carrier access channel and turning basin.

iv) The report discusses a number of "mitigation opportunities" but stops short of recommending the treatment/mitigation measures (re: S3.6). Would the consultants please advise us of their recommendations on the mitigation measures?

R 'Mitigation Opportunities' is intended to identify areas offering the potential for mitigation, although the degree of impact identified in the KIA does not require that such measures should be mandatory. Specific mitigation measures under consideration by CLP are identified in Annex I.

v) It appears that the consultants have done an in-depth research on various FGD processes. But little discussion on this area is presented nor is there any recommendation on which type of FGD process should be adopted. Would the consultants please provide us the relevant details and their recommendations.

R The aim of the WQKIA is to establish the potential worst-case impacts to the marine environment, and, if necessary, recommend mitigation measures, rather than to recommend specific processes.

vi) It appears that the consultants are suggesting the dissolution of gypsum as a means of disposal. It is clear from the comments of our Water Groups (see below) that we have strong reservation on this. The consultants must provide full justification if they wish to pursue their case.

R Gypsum dissolution is considered the most secure disposal option; dissolution of the crystals would be a requirement of the Tender Specification were this option pursued.

vii) The cumulative effects due to NWNT Sewerage Scheme has hardly been covered in the assessment. This must be fully addressed as part of the WKIA. For specific comments, please see our Water Groups' comments below.

R The cumulative effects have been dealt with to the extent allowed by the level of detail used in the modelling of the NWNT sewer outfall.

WPG/LOG:

i) Based on the worst scenario (ie all coal firing), the consultants have not depicted a clear account of the liquid effluent problem in the above report. The consultants are requested to provide a detailed summary (preferably in a tabulated form) of all the effluent streams giving the following information:

a) individual discharge quantities;

b) individual effluent characteristics in terms of pollutant concentrations both before and after treatment;

c) the proposed effluent treatment, if any;

d) individual discharge routes (ie whether the effluent is mixed with cooling water before discharge or pumped elsewhere for discharge); and

e) the extent of possible reuse/recycling shown alongside each effluent stream.

f) a summary of the total flow, metal and nutrient contents.

R Noted. This information, based on the projected effluent make-up is presented in Annex I.

ii) We must emphasize that dilution with cooling water should not be taken as a means to control the final effluent discharge standards. This is particularly relevant for power stations where cooling water discharge is so large. As stated in Para 93 of the TM, the Authority will not allow dilution as a means of meeting effluent standards. This would cause excessive loading on the receiving waters and their biological systems.

R Noted.

iii) From an environmental point of view, the approach is therefore to consider the total pollution loads in respect of various parameters (metals, nutrients, etc) and to assess the total effect that these discharges will have on the water quality of the receiving waters.

R Agreed. This approach is addressed in the report.

iv) It is the acceptable practice to impose different standards on *both* individual effluent streams before mixing with cooling water *and* the final cooling water effluent after mixing with the waste streams. This is the current practice for CLP's Castle Peak 'A' & 'B' Power Stations. In setting these standards, the Authority will be guided by the Technical Memorandum (TM) on effluent discharge standards. However, as the total discharge rate of most waste streams far exceed the flow ranges listed in the TM, separate consideration will be given. Conditions more stringent than those recommended in the TM may be imposed if necessary.

R Noted, however, as pointed out in the KIA report, there are practical and economic limits to the degree of effluent treatment achievable, and discharge conditions, to be worthwhile need to take this into account.

v) From our experience, gypsum tends not to dissolve in water. Flushing of gypsum with cooling water will create high SS or turbidity to the surrounding environment. Other mitigation measures, such as selling it back to the lime supplier, should be proposed.

R The 'buy back'option of gypsum management is discussed in the Solid Byproducts KIR, and cannot be regarded as a fully secure option. Dissolution of the gypsum crystals would bwe a requirement of the Tender Spec. if this option were pursued.

vi) Although the thermal/nutrient/metal modelling output provide clear pictures of the effects due to the LTPS discharge, it is not clear whether the cumulative effect of the discharges from Castle Peak Power Station and the NWNT sewage outfall would have any serious impact to the nearby receiving waters and their biological systems. Modelling, or any objective methods, must be done to evaluate the combined effects from all these discharges.

R The report indicates that cumulative effects are not anticipated to give rise to significant impacts. This aspect will be clarified in the Final report.

vii) In conclusion, the aspects in relation to liquid effluent have not been adequately covered.

R Noted. The following comments are aimed at addressing this concern.

B. Specific Comments

(1) WPG:

S2.2

A number of figures concerning the flow pattern were mentioned in this section. Could the consultants verify these figures.

R These are estimated figures, intended to give the reader an indication of the magnitude of flows involved, and were obtained from broad calculations of flow issues cross sectional area of the Urmston Road, and typical outputs of residual flows from the WAHMO models.

S2.3

The consultants have mis–compared the *annual* discharge rate (10^9) of Table 2.1(a) with the *daily* discharge limit (10^3) in the TM.

R There is a typing error in the figure quoted; 10^9 should read 10^6.

Table 2.7(a)

Sulphates contents of "M" samples from marine buoys are considerably less than that of the other samples. Is it a misprint, or are there other reasons for such a differences?

R This is a typing error, the correct figure is 2144.

S2.7, 2.9, 3.2.2, 3.2.3, 3.2.3.1, 3.2.5 & 3.2.9

The consultants misquoted the limit of ammonia level in WQO, as the limit value for the unionized ammonia level is usually much smaller than the total ammonia level. This has led to a wrong conclusion to disregard the WQO for ammonia level. Notwithstanding this, the current level of unionized ammonia level is still within the WQO of 2.0 mg/l as indicated in Table 2.7(a) and our routine monitoring data.

R Noted, text amended to reflect appropriate reference.

S2.9

If it is CLP's intention to close Yung Long bathing beach, RSD should be consulted.

R The loss of Yung long beach is fully addressed in the Initial Assessment Report. In addition, RSD are a party to the gazettal procedures, and have raised no objection.

Chapter 3

i) It is included in S5.2/V3, DIAR that:

a) run–off from coal stock year;
b) PFA decantrate;
c) other contaminated drainage;
d) marine oil spills during fuel delivery; and
e) maintenance dredging;

are sources of effluents during operation, in addition to the 7 sources listed here. These effluent streams should also be addressed in the KIR. Although these items might be handled by the facilities of CPPS, the cumulative effects of these pollutants to those already mentioned in the report may create serious impacts to the nearby waters.

R Items a) and b) are dealt with in the WQKIR. Item c) is also considered, within the 'other effluents' heading. Items d) and e) are not effluents, but are dealt with in the IAR.

ii) The consultants used mathematical models to simulate thermal, nutrient and metal dispersion effects. They should submit the detailed assumptions, boundary values and the various reaction/dispersion coefficients used in running these models for our considerations. These information could be included as an appendix to the KIA.

R These data will be made available.

S3.1

All the discussions here are based on models or predictions. They should be validated by monitoring surveys.

R Noted. Proposals for environmental monitoring of the power station emissions to the atmospheric and aquatic environments are to be presented in a future document, as agreed with EAPG.

S3.1.2

i) 1st sentence, Para 1, P.20:

No section in this KIR evaluate the proposed outfall location against any other locations. Therefore, the consultants cannot jump into conclusion of not following this proposed outfall location in the actual development.

R The outfall locations considered are shown in AnnexII. The location selected for the modelling study represents the worst case with regard to potential impacts to the sensitive Deep Bay area. Since this location was judged to be acceptable with respect to impacts on Deep Bay, the alternative locations can also be considered acceptable under the same criterion.

ii) The cumulative effects due to NWNTSS should also be addressed (data can be quoted from the NWNTSS report).

R Please see Section 3.1.7 P.23. Cumulative effects have been addressed so far as the information in the NWNTS report permits.

Fig 3.1 (d)-(i)

A +5°C contour should also be given in the temperature plots.

R The form and presentation of the temperature information was agreed with EPD at our meeting of 14.8.91. the 5 C requirement is a new development. This would in any event be very small in areal extent and difficult to define on the plots, and hence extremely difficult to pin point the exact location concerned at sea.

S3.1.6

We observe that there could also be thermal impacts to the mariculture zone. The potential marine ecological impacts caused by LTPS, with a large area of +1°C surface temperature rise, would cause some impacts - especially at the peak flood of Spring tide in wet seasons (Fig 3.1). Would the consultants please comment on this observation?

R The temperature guideline for Deep Bay has been set in the Deep Bay WCZ WCO at a 2°C rise above the natural temperature fluctuation, as recommended in the Deep Bay Integrated Environmental Management Study, which aimed, inter alia, to protect the ecology of the area from significant ecological impacts. When coupled with the evidence from the Marine Surveys commissioned for the LTPS study, that none of the species in the area were living close to the geographical southern range limit, and that species diversity increased during the warm summer months, the consultants consider that a 1°C surface temperature rise will have minimal effects on ecological resources.

S3.1.7

As mentioned in our comments on S3.1.2, the consultants should also include a section assessing the cumulative effects due to CPPS, LTPS and NWNTSS.

R Metal contributions from the CPPS are considered to be insignificant when compared with the LTPS and, particularly, the NWNTSS contributions, and would not be detectable from the modelling output. Cumulative thermal contributions from the LTPS and CPPS are included in the temperature dispersion modelling.

S3.1.7.2

Please explain why the bacterial mortality rates are "expected" to be in the order of "about" 4 hours.

R This information was obtained from the NWNTSS report which adopted the 4 hour mortality rate in the specification of the model runs. The figure was qualified to avoid implying unwarranted precision in the estimate.

S3.2.3.5

An increase of 1 mg/l of nitrate above a background of 1.3 - 1.8 mg/l, ie 70% increase, is considered to be a big increase and is of great concern because the total load would be very significant.

R Noted. Text modified - see Annex III.

S3.2.4.1

A section assessing cumulative effects is required. As the plume from CPPS, LTPS and NWNTSS would interact in certain ways, the cumulative impact assessment is essential in our evaluation of this KIR. Details can follow the assessment pattern in this report.

R Please see responses provided above.

S3.2.4.2

If the chlorophyll-a level is expected to change insignificantly, there should not be a noticeable increase in DO level.

R Agreed. The KIR presents the same conclusion.

S3.3

The manner in which the data for metals are presented in S3.3 and Annex B makes it difficult to assess the impacts easily. For example, Table 3.3(c) should be comparing means with means, not only means with ranges, as these ranges are frequently extended by one or two measurements which could be outliers.

R The ranges were used in an effort to illustrate the natural variation in the elements concerned. Since this appears to have confused the reader, means will be substituted in the Final version.
Table 3.3(c)

The monitoring for lower depth waters from metals only begins in Feb–Mar 91, not Oct 90 as stated. Would the consultants please explain?

R Unfortunately, logistical difficulties caused a delay in the commencement of the monitoring of the lower depth waters, thus no data is available for the period Oct 1990 to Jan 1991.

Table 3.3(f)

Reference is made to Balls (1989) in the derivation of the partition coefficients. Would the consultants please provide us a copy of the reference materials for our checking purposes?

R Balls will be provided.

S3.3.6

i) We cannot find the Table 3.2.6 referred in the 2nd bullet point of the last para, p.39. Could the consultants please provide us details?

R Typo. This should read Table 2.8(a).

ii) The section referring to Langston (1990) (P.41) draws very broad conclusions, which imply that metal pollution in the marine environment rarely has any "effect". We cannot check the consultants' interpretation against the paper's contents as the source of this paper has not been provided, but it does not sound convincing. Would the consultants please provide us the reference materials and other supporting evidences?

R The section referring to Langston proposes the exact opposite of the implication refered to in this comment; the passage on P.41 'effects of metals on marine organisms are now recognised at much lower levels than were suspected from...earlier studies' is considered a clear illustration of this. A copy of the Langston paper will be provided in Annex III.

iii) On the basis of Table 2.8(a) and the ranges presented on P.40, the upper limit of the existing concentrations of Cu is already at the "Action Level" of 65 mg/kg. Given this, any additional loads must be evaluated carefully, even if the projected increases in the deposition rates do not seem high. Therefore, Cu should not be excluded from the subsequent discussion, particularly as it is recognised by Langston (1990) as one of the most hazardous metals in the aquatic environment (as quoted by the consultants).

R Noted. Further discussion of Cu levels will be provided in the Final Report. It should be noted that whilst additional inputs of Cu to the sediments will not necessarily result in its elevated concentration in the sediments, since it will be co-deposited with other material.

On the basis that at some locations the concentration of Cu in the sediments reaches the 'action level', adverse biological effects will not necessary follow, since:

- not all the Cu will be bioavailable;

- studies of faunal diversity versus sediment copper concentrations show minimal correlation between the two features at Cu concentrations below 100 mg kg^{-1} (see Langston, 1990).

S3.4

i) Quantitative information and details regarding the following are lacking:

- species lists
- population densities
- species diversity
- sampling techniques
- thermal tolerance of species found
- effects of the discharges on recruitment of oysters and the impacts on the mariculture in Deep Bay.

R Much of this information was obtained in the course of the marine ecology monitoring surveys and will be provided as separate reports. With regard to thermal tolerance and oyster recruitment, we would comment as follows:

Thermal Tolerance

Please see response to S4.3.2.

The requested quantitative information for all the species identified in the ecological survey was not given in the Key Issue Assessment simply because detailed results of thermal tolerance experiments do not exist for these species.

Hence, there are only two methods by which predictions of the effects of the additional thermal load may be made:

- to extrapolate from results from related genera where these exist; and

- to use distributional or biogeographic information, since this tends to be more widely available than thermal tolerance data.

In the Key Issues Report, both approaches were used for the species of particular scientific/ecological interest. As for the rest, the distribution evidence was shown to suggest that since species diversity was higher during the summer, and that since none of these organisms were living close to their southern limit, their survival was unlikely to be threatened by modest thermal inputs. In para 1. p47, the hypothesis was advanced that any subtle, long-term reduction in species diversity could only be ascertained by long-term, detailed monitoring. It is of course, equally plausible to suggest that slight warming of winter waters will lead to an increase in species diversity, since Hong Kong waters exhibit rather low winter temperatures for their latitude.

Oyster recruitment and impacts on mariculture in Deep Bay.

The hydrographic and chemical environment of Deep Bay has been the subject of a number of studies over recent years. It is clear that this environment is characterised by great physical, chemical, and biological variability. Against this background, the inputs from LTPS are extremely difficult to predict in detail.

It is clear, however, that the changes caused by developments in the North-West New Territories will cause greater changes both for the remnants of the oyster industry, and for mariculture, than will the those from LTPS. Recruitment of oysters has for many years been determined largely by the import of juveniles from the PRC rather than from natural sources, and the subsequent growth of oysters is principally governed by the nutritional quality of suspended material.

ii) Since the thermal plume would attract marine biota, with high SS of discharge tends to block out sunlight together with warm temperature to increase the bacteria survival rate, the interaction with the discharge from NWNT outfall should be addressed. Furthermore, the combined effect of the thermal and metal effects was not discussed.

R The UK Water Research Council's bacteriological specialists have advised that the temperature increases concerned would have so little effect that the differences would be within the margin of accuracy of the model.

iii) There is no map showing the sampling sites.

R Noted. This is provided in the Marine Ecology survey report, and will be inserted into the final Marine Water Quality KIA.

S3.4.2

i) We do not agree with the statement that "the combined effects with thermal inputs are unlikely to be distinguishable from the thermal inputs alone". (re: Line 5–6, Para 3, P.43) Temperature is one of the major factors for chemical reaction, hence affects the Equilibrium Partition Coefficients in Table 3.3(f) and the Scale Factor in Table 3.3(g). Temperature also affects the activities of marine biota and the absorption rate of heavy/trace metals. The consultants should address these points in details.

R The consultants consider that the relatively small temperature variations concerned will not significantly effect the coefficients and scale factors.

ii) The combined effect of +1°C and the trace metals plume for marine biota must be addressed. For non–swimming biota, an area greater than "a few hundred metres" from the outfall would be affected (against the consultants' conclusion in the last sentence of the section).

R The Consultants disagree with this assertion, refer to our response to the comment on S3.1.6 above, and would welcome sight of any evidence to support the assertion for the study area.

S3.4.3

For the consultants' information, a study will be conducted shortly on the Chinese White Dolphins under the North Lantau Development project (re: Para 1, P.47).

Noted. We would very much appreciate a copy of the findings of the study.

S3.5

i) As mentioned in our overall comments, dilution with cooling water is not allowed in the TM. Dissolution of gypsum in cooling water would create problems to nearby waters.

R Dissolution is considered a distinct process, and is not synonymous with dilution. As Section 3.5 indicates, dissolution of gypsum in cooling water is not anticipated to cause significant impacts, given the natural range in monitored values of 775–2900 mg/l for sulphate and 111–435 mg/l for calcium, as illustrated in the detailed monitoring records presented in Appendix IV.

ii) Dumping of 25,000 te/yr of insoluble material at sea cannot be disregarded so easily. The consultants are too quick to jump into a conclusion of additional SS generated is insignificant.

R The conclusion was reached following consideration of the natural loading of SS derived from the Pearl River, which discharges on average, some 13,500 te. of SS past Black Point per day. The LTPS contribution is thus insignificant when compared to natural loading.

S3.6

i) The conclusion that significant effects on the marine ecology is unlikely (re: Para 1, P.47) is unacceptable. Excess SS, combined thermal, nutrient and trace metal effects and the cumulative effects from the other major discharges (CPPS & NWNTSS) would have serious environmental impacts to the nearby water bodies and sensitive receivers.

R The consultants are unable to appreciate how the statement that serious environmental impacts would arise can be arrived at or justified, given the discussion provided in Section 3 of the report, and the relatively small contribution of metals, and nutrients from the LTPS in comparison with the NWNTSS, which EPD have accepted as having no significant impact on nearby water bodies. Presumably WPG have evidence to support their statement, which the Consultants would appreciate sight of, since it is so far at odds with their own findings.

ii) From the loading shown in the KIR, the total nutrient/metal loading will be dramatically reduced if CLP can re–use or treat properly the effluent from the FGD plant.

R For conventional limestone/gypsum FGD plant, reductions in metal can be achieved, but not to the TM standards. Nutrients, however, cannot be readily removed for the reasons stated in the KIA. A seawater scrubbing system does not involve an effluent as such.

iii). We usually require an assessment of pH, residual chlorine and oil/grease for outfall discharge. However, it is not mentioned in the scope of study (re: S1.2) nor covered in this KIR. The consultants should also examine these items in details. For control purposes, these items will be included in the discharge license.

R

pH, oil and grease are not anticipated to be significant with respect to the TM figures and were not included in the Brief agreed with EPD. Alternative strategies for chlorination have been examined and will be reported separately.

iv) As no conclusion was drawn by the consultants, could we assume that all these (or more) mitigation measures would be implemented by CLP? Please confirm the mitigation measures to be adopted.

R The mitigation measures to be applied by CLP will be dependant upon the type of process system to be implemented. The majority of the effluent originates from the FGD process, the "worst-case" of which was examined in the KIA and no specific mitigation requirements more identified. The mitigation measures to be adopted to further reduce contributions as a general principal will be selected when the FGD process (if required) to be adopted has been agreed.

S3.6.1

A central collection and treatment facility for FGD and other wastewater should be installed.

As indicated in the report, many of the effluent streams are already too diluted and involve too great a volume, to benefit from precipitation processes involved in FGD plant effluent treatment.

S3.6.2

i) Para 1 mentioned dilution by cooling water which is prohibited by the TM.

Noted. Text amended to remove reference to dilution.

ii) As in STW, denitrification is possible. Consideration should be given to these treatment facilities.

Noted, however, see second para of 3.6.2.

iii) In order to lower the discharge ammonia level, the effluent from WTP should be diverted to an upgraded Domestic STP.

CLP will consider this possibility at the detailed design stage, it is likely to have significant design implications.

S3.6.3

HEC have adopted a "Zero discharge" approach in devising their mitigation measures for their extension project. CLP are encouraged to adopt a similar approach and should maximise the reuse/recycling of wastewater.

R CLP are aware of this issue, as indicated in Section 3.6.3. However, since the LTPS is not an extension to existing plant, a zero discharge option is unlikely to be achievable.

Chapter 4

A sediment plume modelling exercise of the works mentioned in Fig 4.2(a) would be useful in assessing the dredging effects in the Outer Deep Bay/Urmston Road area (see also comments on S4.2.5). From Fig 4.2(a), 1993–95 seems to be the critical years when all the 5 projects proceed concurrently.

R At the outset of the KIA, it was agreed that sediment modelling would not be required to enable appropriate mitigation measures to be developed. It should also be noted that the concurrent dredging operations including CLP is now unlikely to occur.

S4.2.5

During the early days of this KIA, the sediment plume model was not available. As HR have recently conducted one for CED (in assessing PADS dredging work), it should not be difficult for the consultants to input the additional loading from the other projects for a better dredging simulation and assess the turbidity problems in that area. This simulation would also help in establishing the locations of the monitoring stations to trace the sediment plume.

R Since a plume dispersion study has been carried out in the very near vicinity of the area to be dredged for the LTPS, further dispersion simulation is considered to be an unnecessary duplication of effort which will not contribute significantly to the establishment of mitigation measures to control the effects of dredging in the area (Reference to the ED data should be sufficient). It was understood that the Deep Bay Guidelines for Dredging and Reclamation works were produced specifically to avoid such repetitious studies.

S4.2.6

The consultants should also provide/suggest some monitoring programme in this report. We could assist you by providing for your reference some monitoring clauses for other projects. Apart from ordinary DO, SS and turbidity measurements, nutrient levels and heavy metal levels should also be monitored, Shellfish/phytoplankton monitoring should be done to provide early warnings to the impacts on the mariculture zone at Outer Deep Bay. As suggested in S4.2.6.2, seasonal effects should be taken into account in drawing up the baseline conditions.

S4.2.6.1

As the construction impact is expected to be a major problem, 5 monitoring stations (as suggested) are not adequate to monitor the situation. A more detail monitoring programme including DO, SS and other metal testing should be submitted for EPD's endorsement.

R Noted. As agreed with EAPG, a separate document covering monitoring requirements will be produced.

We would very much welcome the provision of monitoring clauses for other projects. Monitoring and auditing recommendations will be made separately following the agreement of the principal findings of the LTPS KIA's, but would point out that nutrient, heavy metal and shellfish monitoring would not seem appropriate for short term dredging activities, and would not provide an "early morning" function as suggested.

S4.3.2

i) The comments regarding the 2 methods of metal extraction need to be validated. It is not appropriate to disregard the elevated levels measured when the microwave pressure digestion method is used, simply because they do not like the results. The lower concentrations obtained when using conventional acid digestion may indicate incomplete digestion due to uneven heating. Both methods are designed to extract all but residual metal fractions from sediments when performed correctly. The CAD measurements of <0.2 for Cd suggest that the levels were "undetectable", which should have led to the method being questioned given earlier results. The rationale for falling back onto CAD extractions for the second sampling run, when MPD methods were available and used previously, needs to be justified.

R To avoid any confusion or disagreements regarding sampling and analysis methods for the sediments to be dredged, the sampling and analysis exercise has been expanded by independent engineers following consultation with EPD. The results are attached in Appendix V and will be discussed in a modified version of Section 4.3.

ii) Similarly, if the Copper "action limits" are exceeded simply due to "expected sampling and analytical uncertainty" as suggested, this should be substantiated. We would have thought that the action values, as all values given in Table 4.3(a), would have already taken such variability into account.

R See comment S.4.3.2(i) above.

iii) The issues raised above need to be addressed before the question of dissolved toxic metals can be disregarded.

R See 4.3.2(i) above.

iv) S4.2.6 is mentioned in the discussion on release of particulate toxic metals (P.56). We wish to point out that the possible effects of particulate-bound metals on oyster growing areas are not adequately dealt with in S4.2.6. It does not outline how these will be monitored or how dredging operations could be modified if elevated levels of metals are detected in oysters.

R Noted. These aspects will be covered in the report to be produced subsequent to agreeing the broad findings of the KIA's.

v) The 5 sampling points are not labelled on Fig 4.3(a).

R Noted. This will be corrected.

S4.4

i) The disposal of marine mud from dredging site requires further consideration in the light of the elevated levels of Cd and Cu (when extracted using MPD).

R Please see response to S4.3.2 above.

ii) The use of dredgers with low "S" factors should be required, not preferred.

R Noted, text amended to "should be used, where operational practicability allows"

iii) Event/action plan on measures to be taken prior or consequent to adverse changes in environmental quality should be recommended in addition to monitoring programme (re: last para, P.57).

R See Response to S4.2.6 above.

Chapter 5

We find it difficult to follow the consultants' conclusions. The following are the major areas needed to be further addressed:

i) For the resuspension of bottom, sediments, no prediction nor mitigation measure is proposed. The consultants should address these points in details.

R Please see response to S4.2.5 above.

ii) For thermal effects, the consultants should address more on the impacts due to +1°C to the mariculture zone.

R The Deep Bay WQO's refer to a 2°C rise above ambient temperature. Given the natural variation in water temperature in the area, a 1°C increase in water temperature is not considered to have any significant effect on the mariculture zone. See also response to S3.1.6 above.

iii) For metal effects, the consultants should reassess the effects in the light of our comments on the respective sections. Reference materials and supporting evidences should also be provided to support the consultants' arguments.

R Supporting references are provided in Annex III, and the arguments and conclusions presented stand.

iv) For combined effects, the consultants have not addressed the effects of temperature on metal equilibrium coeff/scaling factor and the absorption rate of marine biota.

R See response to S3.4.2 above.

v) For nutrient level, the consultants have mixed up the unionized ammonia with total ammonia.

R Please see response to S2.7 above.

S5.2

Environmental Audit is absent from the recommendations.

R Please see Response to S4.2.6 above.

Annex F

i) Segment locations were not indicated on any maps in the report.

R A segment map will be included in the final version and is shown in Annex VI.

ii) Fig 3 indicates DO level of 20% in layer 4/5, which contradicts with the monitoring data in Annex B. This also shows a serious deterioration in water quality in that area for marine lives.

R The Consultants do not consider that the DO level decrease for Layer 4/5 will constitute a "serious deterioration ... for marine lines", as the "base run" (ie the current situation) shows an identified DO level. The consultants would welcome sight of any information to support this assertions for the study area. It should also be noted that the model used. POLLFLOW - 3DSL has a tendancy to underpredict DO in lower layers in Urmston Road, due to strong stratification.

(2) **LCG:**

Table 2.1(a) & S3.2.3.2

In Table 2.1(a), the flow rate of cooling water is said to be $3.7 \times 10^9 m^3/yr$ but in Section 3.2.3.2, the discharge rate of cooling water is said to be $14.4 \times 10^6 m^3/day$. Should the latter figure be $10.1 \times 10^6 m^3/day$ instead?

R No. As stated in Section 3.1.2, the effluent discharge volume is based on 50,000 operating hours per year, thus giving a discharge of 604,800 m^3/hr or 14.5 x $10^6 m^3/day$. FGD effluent should also be based on 50,000 hrs, so giving 1.44 mg/l.

Table 2.1(a) & S3.6

The consultants should include PFA decantrate in the summary of effluent flows since the all coal scenario is assumed here. The type of treatment proposed and the extent of possible reuse/recycling should also be provided.

R Noted. PFA decantrate flows have been added to the effluent flow summary. The type of treatment and extent of possible recycling is dealt with in Section 3.6.

Chapter 3

We support WPG's comments to include the other effluent streams in the assessment. A comprehensive list of all effluent streams should have been given in the KIR (please also item (1) of our overall comments).

R To provide a detailed effluent stream inventory would require a confirmed plant design; consideration of the effluent streams based on current information is provided in Annex II.

S3.1.2

i) It is said that "the outfall location chosen for the study is not necessarily that which will be used for the station development" (Para 1, P.20). But surely the findings of the modelling exercise should help determine the location of the ideal outfall and not the other way round.

R The outfall locations modelled in the study represent "worst-case" locations with regard to potential effects on Deep Bay. The modelling exercise was thus not aimed at testing a preferred location, but to establish the degree of flexibility available to engineering preference for the siting of the outfalls.

ii) The cumulative effects of *all* major discharges in these waters, ie from the LTPS, CPPS and NWNTSS, should be addressed.

R Please see Section 3.17 of the Report and our response to Comment S3.1.2 (ii) above.

S3.1.7

We believe that a cumulative assessment of the impacts due to the major discharges (LTPS, CPPS, NWNTSS) in the region is *very important*. The temperature and density gradients and contours are related, and may affect the dispersion of sewage from NWNTSS.

R Please see Section 3.1.7 of the report and the Response to Comment S3.1.2(ii) above.

S3.2.2

i) **Para 2, Line 5-8**

The derivation of this information is not clear. The DBWQO for inorganic nitrogen is 0.7 mg/l for inner marine subzone and 0.5 mg/l for outer marine subzone.

R Noted, text amended.

ii) **Para 4, Line 2:**

The DBWQO does not state that DO of 2 mg/l is for industrial use. It states that the DO concentration should not be less than 2 mg/l within 2 metres of the seabed in outer marine subzone excepting mariculture subzone.

R Noted with thanks. Text amended.

S3.2.3.3

Please confirm that the domestic sewage will be treated before mixing with the main effluent streams and then discharged to the sea. What will be the levels of nitrogen and phosphorus removal achieved at the proposed sewage treatment plant?

R As stated in Section 5.2.4 of Volume 3 of the Initial Assessment Report, domestic sewage will be treated onsite. The level of nitrogen and phosphurous removal will be established at detailed design stage, but will be such that the Deep Bay WCZ WQO's are met.

S3.2.3.5

We share the same concerns of WPG on the large increase of nitrate level.

R Noted. However, although concentrations of nitrate will be elevated around the outfall, phosphate is the limiting nutrient in the area. Consequently, the scope of enhanced production resulting in entrophication will not increase above current levels.

S3.2.5

The conclusion drawn by the consultants is unsatisfactory. It is an over-simplified and generalised statement implying that "nothing would be affected and all would be well". As mentioned above, the increase in nitrate concentration alone is of grave concern. It is not the right attitude to imply that as the background ammonical nitrogen and nitrate levels have already exceeded the DBWQO's, the cooling water discharge of the LTPS will not significantly add to the existing problem of nutrient enrichment.

R The consultants disagree with the content of this comment, and reject the unsupported contention that the increase in nitrate is of "grave" concern.

S3.3.6

It is agreed that it is necessary to examine the overall ecological character of the receiving water in order to have a full picture of the likely consequences of the discharge from the LTPS (re: Para 1, P.43). Whilst the consultants say that they recognise this need, they have not set about to achieve this in action.

R Please refer to Section 3.4.3 of the report, which summarises the findings of the marine ecological surveys commissioned for the study.

S3.4.2

i) It is said that "... the levels of nutrient input involved will only result in a marginal increase above existing levels, and will certainly not reached a level where algal blooms or eutrophication could occur." (re: Line 3-5, Para 1, P.43) As commented on S3.2.3.5, the increase in nitrate concentration is considered to be very significant.

R See Response to 3.2.3.5 above.

ii) The statement "combined effects with thermal inputs are unlikely to be distinguishable from thermal inputs alone" (re: Line 5-6, Para 3, P.43) itself is not very clear. The consultants have not demonstrated this effectively.

R Temperature may have a slight influence on the rates at which metals absorb onto or desorb for particles. Potentially this could influence the partition coefficients used in extrapolating the results of the dispersion modelling results for Zn to the other metals, and in predicting metal deposition rates. However, any such effects would be limited to the area where a large temperature differential existed (eg 5°C or more). Even then other factors (such as bonding capacity of particles, metal speciation and complexation etc all of which are variable) would also act to cause variations in the partition coefficients. The Consultants have applied the partition coefficients in a conservation manner which allows for such variables.

S3.5

i) The consultants' arguments for dissolution of gypsum (re: Para 1, P.47) are not acceptable. Firstly, the figures need clarification. In Para 1, 25,000 te/yr of inert insoluble material is mentioned whereas it is stated in Para 2, 20,000 te/yr of inert insoluble material plus 3,500 te/yr of fly ash would be generated. Secondly, the fact that calcium and sulphate ions are natural components of seawater does not automatically induce that excessive anthropogenic input from the LTPS would not produce any adverse environmental effect.

R Calcium and sulphate are dominant species in seawater and the ranges indicated by monitoring and indicate no significant effect.

ii) The statement "the combined increase in SS concentrations .. are not considered significant" (re: last sentence, Para 2, P.47) is not acceptable. An increase of up to 6.5 mg/l of SS concentration is considered to be quite significant. The DBWQO of SS for marine waters is such that the natural ambient level should not be raised by 30%. Furthermore, only the levels of SS near seabed are quoted. The effect of any element/pollutant to a water body should be addressed fully in terms of its likely distribution in the water column (eg metals likely to be accumulated in the sediments) in comparison with the difference, if any, of the ambient levels of the element or pollutant.

R SS levels near the seabed are quoted as this will be the section of the water column most affected. An increase of *up to* 6.5 mg/l of SS would not raise the natural ambient level by more than 30% (natural range to 100–150 mg/l) and in any event, assumes the poorest quality limestone.

S3.6

i) The information provided so far do not adequately support the consultants' conclusion that "... the predicted maximum effluent discharges are unlikely to give rise to significant effects on marine ecology of the area." (Line 2–3, Para 1, P.47) It appears that the conclusion was first decided and then the arguments worked towards it, rather than the other way round. As such, the arguments were generally unconvincing and confusing.

R The consultants reject this accusation. Perhaps WPG could specify their inability to follow the arguments presented.

ii) The consultants' emphasis seems to be on FGD effluent. We need to have a very clear picture of all wastewater discharges, their quantities and their characteristics. The consultants should inform us which certain parameters would exceed the likely acceptable levels and then propose treatment(s) for these waste streams. The feasibility of reuse/recycling should also be examined carefully for each waste stream.

R The KIA adopted the approach of the macro view of the potential impacts from the total effluents from the power station. This is necessitated as the specific plant and streams to be provided have yet to be decided. Opportunities have been identified for reuse/recycling and will be implemented where practicable. The aim of the KIA was to establish whether total discharges from the station would produce significant impacts to the environment, so that mitigation if necessary could be directed accordingly.

iii) There is neither conclusion nor recommendation in this "Mitigation Opportunities" section. In fact, there is simply not enough information to conclude or recommend anything. The points in (ii) above are relevant.

R As pointed out in (ii) above, the mitigation applicable is related to the balance the degree needed and the overall cost, and the KIA was aimed at establishing the macro need for mitigation. The specific mitigation methods to be adopted will be finalised at the detailed design/licencing stage.

iv) In addition to toxic metals and nutrients, the pH and sulphide concentration of the treated effluent stream from the FGD process should also be mentioned.

R pH will be with the range detailed in the TM. Sulphide will only be present if added to promote precipitation to further reduce metal levels, excess sulphide levels cannot be defined at this stage.

v) The consultants should also comment on the possibility of reusing/recycling the FGD plant effluent.

R In view of the fact that FGD element is fully saturated with inorganic species, there is very little scope for its recycling/reuse.

S3.6.1

i) The consultants should further elaborate why the metal concentrations in the FGD plant effluent cannot be further reduced to levels much lower than 0.1 mg/l for Hg and Cd, and 1.0 mg/l for As, Cr, Cu, Ph, Ni and Zn. It is recognised that precipitation techniques are not expected to produce lower concentrations but have other techniques been investigated?

R As pointed out in the report, other techniques would include reverse osmosis or total evaporation. Both would be extremely expensive while yielding little benefit to the environment, since no significant impacts at the levels currently stated are anticipated.

ii) Whilst it is appreciated that it may be technically difficult (but *not* impossible) and undoubtedly costly to remove a relatively low concentration of metals from a large effluent stream, further removal is not an impossibility and therefore cannot be disregarded totally.

R See comment above

S3.6.2

i) Depending on the total nitrogen concentration acceptable to WPG, consideration should be given to divert the effluent containing up to 200 mg/l of ammonium ion from the Water Treatment Plant to the Domestic Sewage Treatment Plant. The latter plant should be upgraded to include nitrification and denitrification.

R This possibility could be investigated as part of the detailed station design.

ii) The consultants should also comment on other methods, such as stream stripping, for the removal of nitrate/ammonia present in the FGD plant effluent.

R These methods will also be investigated as part of the detailed station design.

S3.6.3

i) This section only addresses the recycling of certain effluent streams. As commented on Chapter 3, the consultants should provide a list of all effluent streams, and possible reuse/recycling of each individual stream should be addressed clearly.

R The effluents dealt with in this section cover by far the greater majority of effluents arising from the site. The primary effluent not included is FGD chloride purge stream waters. This stream is saturated with dissolved solids, including chloride levels of 20,000–80,000 mg/l (depending on the process) and would not be suitable for water recycling. It could perhaps be used for fly ash conditioning but is likely to guse significant engineering difficulties due to furring and corrosion.

ii) The consultants should also consider the use of PFA lagoon decantrate and part of FGD plant effluent for the slurrification of PFA and quenching of furnace bottom ash (FBA) instead of discharging them directly to the sea in order to minimise the pollution loading entering the marine environment.

R Present experience suggests that return decantrate volumes are relatively low. In principle, some of the seawater used for pumping ash to the lagoon would be replaced with decantrate, but to do so would require the addition of significant decantrate storage.

iii) Para 2 – Is there anything following 'Overall significant reductions in aqueous discharges are likely to be possible 30–'?

R Typo: text amended.

S4.3.2

Could the consultants indicate how they would propose to monitor the potential effect, if any, caused by the release of dissolved toxic metals from resuspended solids.

R This will be addressed in the monitoring and auditing section of the report to be produced once the broad issues of the KIA's have been agreed.

Chapter 5

i) Dredging is one of the most important aspects in the Construction Phase and this has not been addressed fully.

R The Consultants consider that given the provision of the Deep Bay Guidelines for dredging and reclamation, and the monitoring works proposed, the issue is adequately addressed.

ii) As regards the Operational Phase, the conclusions are over–simplified to advocate that "there will be insignificant effect and everything will be O.K." It is difficult for us to believe this or to give comment in any depth when we have not been provided with adequate information backed with solid.

R The consultants disagree with this statement, as the information leading to the conclusions is clearly presented in the report; the conclusions are put simply so as to be clear – complex conclusions would not be any more valid. It would appear from this comment that LCG had prejudged that effects of the LTPS would be significant.

(3) **WMPG:**

S4.2.5 (Para 3, P.52)

i) Schedule of the monitoring programme regarding frequencies, sample numbers, etc. should be provided.

R Monitoring locations and frequencies can be established once the specific works required have been identified. EPD may wish to co-ordinate the monitoring for the various projects to be undertaken in the area, and could be finalised at the licensing stage.

ii) What mitigation measures will be taken in the case of deviation from permitted statutory limits.

R If statutory limits are exceeded, mitigation will require the modification of dredging practices in terms of the working method used, the provision of screens, and the period during which dredging is carried out.

(4) SCG:

S4.3.2 & 4.4

We appreciate the Consultants' effort in obtaining some basic information about the trace metal contents in Black Point sediments. However, we would like to stress that, before the commencement of the actual dredging work, the Contractor is required to obtain a marine dumping licence form the EPD. The Contractor might be required to take samples for analysis from the area to be dredged. Without any detailed information about the sampling method adopted by Consultants and the exact locations to be dredged, we have reservations on the Consultants' conclusion that 'the dredged spoil could be disposed of at any of the government dump sites'.

Noted. Please see the results presented in Annex V; the current indications are that the contaminated guidelines will be met, but the need to allay governments reservations is noted.

(5) APG/ACG:

S1.2

i) The discussions on development scenarios did not reflect all the scenarios being studied. Apart form the "all coal" (scenario I) and the "4 gas–4 coal" (scenario II) firing options mentioned in the text, there are "oil-substitution" options in the Air Quality Key Issue Assessment, which CLP would like to study for operation flexibility.

Noted. The oil substation options however are not being studied for liquid fuels as a primary fuel. If liquid fuels were to be used in the CCGT's no additional impacts to water quality are anticipated. For coal-fired units, oil substitution for coal would result in a reduction in heavy metal and nitrate impacts due to FGD and ash handling, but potentially may increase calcium sulphate volumes requiring discharge, if a seawater scrubbing system is adopted. A note indicating these implication for oil-burning will be inserted as a new Section 3.6 Implication for Oil Firing.

ii) The last sentence of para 3 is misleading and should be deleted for the following reasons:

a) FGD is the best practicable means (BPM) for all new coal-fired (and oil-fired) power stations. It is the prerequisite for getting a license under the Air Pollution Control Ordinance (APCO);

b) the "Stack Emission EIA" has not yet established that SO_2 AQO would be maintained without FGD;

c) according to the "Stack Emission EIA", Hong Kong's natural environment has very low buffering capacity for acidic deposition has very low buffering capacity for acidic deposition and hence is sensitive to acid. The CLP, being the major source of acidic emissions with contribution over 50-60%, should have the obligation to control the acid emissions to minimal through the use of advanced technology, viz FGD, for preventing further aggravation of the situation.

R The Consultants disagree that the statement is misleading - the fact that FGD is considered BPM does not alter the validity of the statement; the "Stack Emission KIA" (not EIA) has clearly established the SO_2 AQO can be maintained without FGD at the 4 coal LTPS units. The third point, regarding what EPD consider CLP's "obligations" do not alter the facts of the statement as it stands.

Our position is that FGD scenarios are baseline scenarios and should be carried through the whole study.

R APG/ACG's position is noted.

(6) **NWNT Dev. O.**

(a) The report states on page 6 that modelling of the water quality impacts has assumed a discharge into Deep Bay rather than Urmston Road. This may not be the worst case with respect to the outfall.

R: The assumed location in the thermal modelling was selected according to the proximity of the discharge to sensitive areas in Deep Bay (eg Deep Bay Mariculture Subzone and Oyster beds in Inner Deep Bay etc). Therefore, by assuming the cooling water discharging into the more shallow Deep Bay area, the potential worst-case effect to these sensitive receivers was evaluated.

(b) Page 23, Density Effects. Details of the modelling of the temperature plume are not given. The impact of the cooling water discharge on the outfall will depend on the location of the discharge. For example if the discharge is into the lower stratified layer in the vicinity of the outfall the additional turbulence caused by the cooling water (which would be at a higher temperature and lower density than the receiving water) could bring the sewage effluent to the surface. Modelling of the plume discharge would indicate whether or not this impact is likely to be significant.

R: Details of the hydrothermal modelling are given in Section 3.1.2 (page 19) which indicates the cooling water flow rates; temperature at the outfall; the assumed intake and outfall locations.

(c) Page 23, paragraph 3.2, Nutrients Dispersion. This paragraph states that "The degree of nutrient enrichment ... requires assessment". These are no details of this assessment in the section of the report given to us. [Mott MacDonald]

R: The "Nutrient Dispersion" assessment is reported in subsections 3.2.2 - 3.3.5.

(d) Page 59. The second bullet seems to conflict with the previous statement that the cooling water was modelled discharging into Deep Bay.

R: The cooling water discharge was modelled assuming the outfall location at the entrance of Outer Deep Bay just north of Black Point. However, modelling results revealed that the thermal plume is unlikely to extend further into Inner Deep Bay but restricted to Outer Deep Bay with a range less than 0.2–0.5°C above ambient. The Consultants do not think there is any conflict in this statement with previous discussions (see Figure 3.1(a), 3.1(d)–(i) for details of discharge location and the dispersion pattern of cooling water discharged).

(e) There does not appear to be any assessment of sedimentation from dredging around the diffusers of the NWNT outfall. This issue is also not addressed in the monitoring section.

R: Sedimentation from dredging activities was reported in Section 4 and water quality monitoring in the construction phase of the station was recommended in Section 4.2.6. One of the recommended water quality monitoring stations is at the north–east of Lung Kwu Chau near the NWNT outfall (see Figure 4.2(b) for reference). Therefore, although the NWNT outfall has not been directly referred to in the assessment, any effect of sedimentation on the outfall will be detected by the recommended monitoring programme.

2. **Section 3.4.2 – Potential Impacts (on Marine Biota)**

2.1 The report notes that fish and other mobile species would either avoid the thermal plume (created by the effluent discharged from the proposed LTPS outfall) or be attracted to it and that the most likely effect on the non–swimming biota will be some zonation around the outfall according to temperature tolerances. In view of the size of the zone predicted to have temperature 2°C above ambient as illustrated in Figures 3.1(e), 3.1(g) and 3.1(i) of the report, I query the conclusion that "any zonation effects or changes in species structures will be limited to an area within a few hundred metres of the outfall at most" (also in Section 5.1.2 of the report).

R: The point regarding the anticipated limited zonation effects produced by the thermal discharge from the LTPS outfall is based upon previous experience at CPPS and associated marine studies, as pointed out in the report. Species distribution evidence from these studies and those specifically commissioned for the LTPS EIA, suggests that for the waters off the western NT species diversity was higher during the summer, and that since none of these organisms were living close to their southern limit, their survival was unlikely to be threatened by modest thermal inputs. It is plausible to suggest that slight warming of winter waters will lead to an increase in species diversity, since Hong Kong waters exhibit rather low winter temperatures for their latitude. We would welcome sight of any evidence on which GEO's query is based.

2.2 It is not clear whether the effluent discharged from the Castle Peak Power Station (CPPS) has been included as an external loading in the modelling. If not included, the cumulative effect of discharges from both power stations should be assessed.

R: The temperature dispersion modelling included the contribution from Castle Peak Power Station, and hence the cumulative effect of discharges has been addressed.

3. **Section 4.1.1 - Volume of (Dredged) Marine Sediments**

3.1 Please note that marine disposal of mud is becoming problematic because of the limited capacity of existing dumping grounds and because special means are required for the disposal of any contaminated mud. Justification of the need to dredge more than 500,000 m^3 of uncontaminated mud or any quantity of contaminated mud will have to be reviewed by the GEO in accordance with Works Branch Technical Circular No.6/92.

R: Noted.

3.2 In addition to the well established method of foundation improvement using vertical drains, recent studies have shown that direct ground improvement techniques, such as deep mixing with cement, can be used to improve seawall foundations to the extent that mud dredging can be avoided. Detailed foundations should be given to minimising the amount of mud dredging for the project.

R: Noted.

4. **Section 4.3.2 - Metal Concentrations of Sediments**

4.1 As a general comment, there are significant discrepancies between some of the figures given in Table 4.3(b) and the interpreted figures given in the text which obscure the overall significance of the data in relation to the critical 'action levels' for contaminated mud.

R: A comparison between the CAD and MPD metal concentrations in sediment samples from Black Point with Government's action limits for Cd, Cr, Cu, Hg, Ni, Pb and Zn (see Table 4.3(b)) shows that the following sediment samples exceed acceptable criteria (see Table 4.3(a)):

Sample Sites	**Test Method**	**Cd**	**Cu**
D1	MPD	1.9	80.4
D2	MPD	2.4	-
D5	MPD	3.1	-
Action Limits	-	1.5	65

Since only 6% of the sediments sampled (see the seven metals defined above) exceed Government "action limits", the Consultants consider the general interpretation of the metal concentrations in sediment samples to be justified.

4.2 The implication of footnote (2) in Table 4.3(b) is not clear. If "the second D4 sample containing large amount of sand grains" noted in the footnote refers to the sample tested in February, 1992 by Conventional Acid Digestion (CAD) analysis, this presumably accounts for the much greater differences between the CAD and MPD metal values for site D4 than for other sites. As such, the validity of comparing the test results on two sets of samples, collected at different times and subjected to different method of analysis, is highly questionable. This is acknowledged in the text (first paragraph on page 55). It appears that the MPD results are included to emphasise the fact that the metal values are generally below the action levels. The assertion that the CAD results are "generally more representative of the biologically available fraction" (first paragraph on page 56) is possibly true, but as the definition of the recommended 'action levels' and 'trigger levels' are based on the *total* metal contents, this is really immaterial and the MPD results are more appropriate in the assessment of contamination.

R: As Sample D4 contains a high percentage of sand grains, it is surprising that 71% of seven metals (noted above) analysed by MPD are higher than CAD for Sample D4. Actually, the reverse trend is expected as large sand grains (generally lower in POC) usually contain proportionally lower concentrations of anthropogenic metals (eg Cd, etc).

As GED correctly noted the MPD and CAD results shown in Table 4.3(b) are not comparable, which is clearly pointed out in the text (paragraph 1 of pp.55).

MPD results are often referred to in the text because MPD is more a severe digestion procedure than CAD, thus an upper limit for metals is assumed and a precautionary approach is adopted throughout Section 4. For instance, for seven metals (ie Cd, Cr, Cu, Hg, Ni, Pb and Zn), 70% of the MPD results are higher than CAD results and 10% of MPD and CAD results are in agreement to within ±7% (on average) with a range of ±1–20%. For remaining, 20% metal analyses, surprisingly CAD results exceed MPD results for the metals given earlier. This result is partially due to the large sand grains present in Sample D4.

CED's point that MPD results are possibly more relevant than CAD in the content of the Government's definition of sediment criteria are true. This is why MPD results are discussed as explained in line 7–11 paragraph 1 in pp.55. Nevertheless, CAD analyses are closer to Government procedures than MPD and therefore both data sets are included in this report. However, it must be emphasised that baseline metal concentrations and sampling methodology from which the contaminated sediment criteria are derived, do not account for regional differences and geological factors which affect the bioavailability of trace metals in sediments. Forstner, V. and Wittman G.T.W., Metal Pollution in the Aquatic Environment, Springer-Verlag, Berlin, 1979. For these reasons, the Consultants understand that Government is currently re-examining the contaminated sediment criteria as the financial implications of dumping large amounts of contaminated mud from HK territory are significant.

Typo, line 2, paragraph 1, pp56, delete "45% and 9% respectively" insert "24%". The "trigger levels" were used previously as a baseline for Cu in Sample D1 since these "trigger levels" are more stringent than "action levels", thereby again adopting a precautionary approach in the original text. However, if "action levels" are used as a criteria for Cu contamination in Sample 4, an upper Cu limit (ie MPD results) an exceedance of only 24% is obtained for Cu, which underlines the point made in line 2–4, paragraph 1, pp.56.

4.4 The dismissal of the "exceedances" of copper concentrations of no "undue concern" and as being well within sampling and analytical uncertainties is not acceptable without these errors being specified. A 45% 'exceedance' over the 'action level' can hardly be dismissed on the basis of it being within experimental error. If it is, in fact, within the error due to sampling and analytical method, the entire data set and the procedures by which it was obtained are questionable. I note that the difference between the 'trigger' and 'action' levels for copper is 10 mg/kg (the difference between 55 and 65 mg/kg) or 15% of the 'action' level. Clearly, a sampling and analytical method which involves errors which would appear to preclude this distinction is not valid or acceptable.

R: The exceedances of Cu concentrations of considered to be within *realistic* sampling and analytical errors. The Consultants point out that throughout the text, upper limits (ie MPD analyses) for Cd and Cu are compared with the most stringent criteria (ie trigger levels) thus again adopting a precautionary approach. Furthermore, a ±24% error bar (based on action levels for Cu) is commonly acceptable in data interpretation. In addition, only one Cu analysis (ie 8.4 mg/kg; D1; CAD) out of ten (ie 10% of total CAD and MPD Cu results) actually exceeds the action limits of 6.5 mg/kg for Cu.

This later point emphases the importance of analysing the whole data set with a sense of proportion and objectivity.

The Consultants totally agree that the different analytical and sampling methodologies are not comparable, as noted in paragraph 1 of pp.55. Please note that the analyses were conducted in August '91 and February '92 (see Table 4.3(b)). The DRAFT "Technical circular - Marine Disposal of Dredged Mud" which states sampling and analytical guidelines was not available until after the sediment analyses had been carried out. A more fundamental question is the validity of the contaminated sediment criteria as noted in 4.2(c) (see above).

Annex H

Water Quality KIR Consultants' Response to Comments EPD Consolidated Comments Annex to Position Statement

WPG:

Overall Comments:

a) Throughout the EIA study, the consultants only focus on the "worst case" in which it is assumed that all the wastewater discharges arising from scenario 1 would be mixed and discharged with the cooling water after little or no treatment. All along, the consultants try to demonstrate that, despite large quantities of pollutants that would be generated by the plant, it will be environmentally safe to discharge these pollutants to Outer Deep Bay. The consultants have also made it clear in the draft responses to government comments that no consideration has been given to the reduction of wastes in the production processes and that the mitigation measures proposed are not mandatory and, therefore, will not necessarily be implemented.

b) Such an approach is not helpful from an environmental standpoint. What the consultants should do is to look into individual potential waste arising processes and consider the feasibility of reducing or even eliminating the pollutants at source. Emphases should always be placed on replacement, minimization, recycling and reuse, whereas treatment and disposal should be seen as the last resort when no better alternative is feasible. The consultants should note that the government, in making joint attempts with the PRC to protect the waters of Deep Bay, has committed itself to the long term aim of achieving zero discharge. The government therefore will be very reluctant to consider permitting further discharges into Deep Bay unless it is convinced that the best technology has been adopted in minimizing the wastes and that the impact of residual discharges on receiving water bodies is insignificant.

c) Little mention has been made of the statutory requirements of the Water Pollution Control Ordinance (WPCO). S2.3 of the WQKIA tends to suggest that the effluent standards in the TM can be disregarded. There is no dispute that because the total discharge flow rate of the "worst case" falls outside the largest flow band stipulated in the TM, the effluent standards should be set according to its impacts. However, it does not follow that the standards referred to in the TM can be totally ignored. In fact, it would be absurd if effluent standards set for a discharge are much more relaxed than those specified in the TM. In setting terms and conditions for a licence for the LTPS discharges under the WPCO, it will still be necessary to make reference to the TM. In particular, the general principle of not permitting standards to be met by dilution must be taken into account.

Specific Issues

a) Effluent Streams

i) Individual effluent streams should be considered separately. If the effluent streams cannot be eliminated, recycled or reused, they must be treated to a high standard before mixing with the cooling water for discharge into the Deep Bay waters. The impact should then be assessed on the basis the residual loads. It also follows that the proposed mitigation measures should not be treated as simply opportunities.

ii) PFA lagoon decantrate should not be discharged to the CW system. As suggested in S1.6 of Annex 1, transport of ash in conditioned form would eliminate arisings of decantrate and should, therefore, be adopted.

iii) It is noted that effluent arising from the boiler bottom ash system and coal stockyard can be recycled or reused. This should be included as a firm recommendation.

iv) The seawater scrubbing process is not considered acceptable from a water quality viewpoint as not only would it result in substantial increases in nitrogen, TSS and heavy metal levels, but also there is no mitigation measure available to reduce the pollution loads. We find it difficult to reconcile the WQKIR's findings that the discharge from the FGD process will constitute a significant input of nitrate with the consultants' conclusion that the effects are fairly small. The consultants also concede that the total metal loads from the LTPS are substantial and the FGD plant is the main source of these heavy metals. While the consultants cite the conclusions of Langston's study to support their view that the effects of the heavy metals can cause significant ecological harm. Since the long term build-up effects of these persistent toxic substances are uncertain, a conservative approach should be taken to avoid irreversible damage. The Limestone/gypsum process is therefore considered to be the preferred option as the removal of pollutants is possible. It is noted that the consultants are considering the possibility of dissolving the solid gypsum in cooling water. But if the effect is a substantial increase the pollutant loads as in the case of seawater scrubbing process and the assessment cannot confirm that the impacts are acceptable, this dissolution of gypsum in cooling water will not be acceptable. This option requires detailed assessment.

b) Hydrothermal Modelling

i) The consultants' response to our request for a +5°C above ambient zone is noted. However, given the large volume and high temperature of the discharge, the thermal impacts at and around the outfall can be very great. The consultants have already pointed out in S3.4.2 that effects on marine biota will occur within the >2°C above ambient zone. The nature and extent of the impacts, especially in areas close to the outfall, should be elaborated. An indication of the extent of the >5°C above ambient zone will be very useful in this regard.

ii) The consultants should explain how the thermal input from the CPPS has been taken into account in the temperature assessment.

c) Cumulative Effects

i) The consultants should clarify the cumulative effects due to various discharges in the nearby receiving waters, as promised in their response to comment.

ii) The consultants promise that further information/documents will be provided. These include monitoring report, model calibration report, baseline monitoring results and the paper by Ball. Furthermore, it is noted that the consultants will further discuss the metal sampling and analysis methods in the final report. Comments will be provided when these information/documents are received.

d) Phase 1 development

With regard to the gas/distillate oil fired combined cycle plant, the consultants should confirm that all the waste streams have been summarised in Annex 1, Part 2 and that mitigation measures will be taken to ensure full compliance with the TM. It should be pointed out that as the total flow is less than 6000 m^3/d, the standards in the TM will apply. We however cannot see any difficulty in achieving these standards.

LCG:

Overall Comments

a) Dissolution of gypsum:

The solubility of gypsum is of concern because of the likely effect of high SS to the marine environment. Gypsum should be recycled as far as possible. The environmental impact of gypsum, whether in solution or suspension, should be fully assessed.

b) Cumulative effects of discharges in respect of temperature, metals, nutrients etc. from the existing Castle Peak Power Station, NWNT Sewage outfall on the receiving waters:

The cumulative effects have not been adequately addressed. Although the consultants have indicated that this will be clarified in the final report, it is appropriate to have this resolved at an early stage. The assessment in this area should provided now.

c) Large increase in nitrate level:

The effect of increased nitrogen level on the water quality is of concern. The consultants should demonstrate to the satisfaction of EPD that phosphate is the limiting nutrient such that eutrophication will not increase above current levels even with this increase of nitrate. The DBWQO must be achieved and the concept of "zero discharge" into Deep Bay must be taken into consideration.

d) Mitigation measures:

Pollution load must be reduced as much as possible. All aspects of waste minimization, reuse/recycle, treatment must be fully explored.

e) Further reduction of ammonium concentration for WTP:

Effluent from the WTP containing up to 200 mg/l of ammonium should be diverted to the domestic STP and the latter upgraded to include nitrification and identification. This should be investigated as part of the detailed design.

f) In general, Annex 1 (Response to Comments) is useful and gives a clearer picture than before of the different effluent streams generated separately under the 8 x 680MW coal fired scenario and the 4 gas/distillate oil fired combined cycle. However, mitigation measures in some cases are too brief and need to be expanded should that particular scenario be implemented. Although the impact on water quality is significantly less for a gas fired scenario than for a coal scenario, the summary in Annex 1, Part 2 is too brief in some areas. For example, there is no mention of ammonium concentration under the heading of Water Treatment Plant or oil removal under Oil Separators. A flow chart of water cycle 8 x 680 coal/HFO fired units was included; a similar flow chart based on the gas fired scenario would be very useful.

WMPG:

We have no further comment on the WQKIR except on the disposal of FGD gypsum. While the environmental acceptability of discharging FGD gypsum via cooling water to the marine environment needs to be established, beneficial use of FGD gypsum is the preferred option. Dissolution of FGD gypsum in cooling water should not be the preferred solution. We do not agree that "the focus of the management strategy for gypsum by-products is prevention of arising via discharge of dissolved gypsum to sea in preference to utilisation or disposal of solid gypsum" (re: Para 1, Page viii, Executive Summary, SKIR) as FGD gypsum is itself a usable resource and should therefore be used rather than disposed of (dissolution in cooling Water is a disposal route) whenever possible.

Annex I

Effluent Stream Breakdown

EFFLUENT STREAMS

1. 8 x 680 MW COAL FIRED

The detail of the effluent streams for this case are uncertain but other than the FGD plant effluent are unlikely to be substantially different from Castle Peak Power Station.

1.1 Cooling Water System

Seawater is drawn by pumps to cool the condensors. The water is dosed with sodium hypochlorite generated by the electrochlorination of the water itself and ferrous sulphate is added for corrosion inhibition if the condensor tubes are not fabricated from Titanium.

(A) Period and Duration

Continuous

(B) Discharge Quantity and Rate

Up to 22 cubic metres/second/unit
15×10^6 m^3/day total

(C) Effluent Quality

(i) Discharge temperature up to 12°C above ambient when unit on full load

(ii) Continuous Hypochlorite injection of up to 1.5 PPM of Chlorine which decays to around 0.3 PPM on discharge.

(iii) Ferrous sulphate addition (if used) of 1 PPM for up to 1 hour/day.

(D) Discharge Point

Cooling Water Outfall(s) located at seawall in N.E. corner of site and c. 400 m offshore (see fig. 32).

(E) Mitigation

None possible.

1.2 Boiler Blow Down

The water in the boilers exist in a largely "closed loop" condition except for losses in the system due to drains and some heaters. In order to maintain the very high quality of the circulating water sodium hydroxide is added to maintain pH and hydrazine is added to scavenge oxygen. Some water must be bled from the system occasionally to maintain the chemistry and this is called "blow down".

(A) Period and Duration

Carried out on an as needed basis to maintain water quality.

(B) Discharge Quantity and Rate

Up to 3 m^3/minute/unit
Typically 150 m^3/day/unit or 1,200 m^3/day total

(C) Effluent Quality

Boiler water is demineralised, maintained at a pH of 9 - 10 and contains low levels of ammonia originating from the hydrazine dosing. Ammonia levels are of the order of 1 PPM.

(D) Discharge Point

To Cooling Water stream.

(E) Mitigation

Neutralisation by acid addition is possible but to add more chemicals before the CW stream is undesirable as the buffering effect of the CW flow is more than adequate.

Collection of the water into the central wastewater plant (CWP) is possible and will be examined.

1.3 Water Treatment Plant

Water fed to the boilers is demineralised in a Water Treatment Plant (WTP) by filtration, anion exchange, cation exchange and mixed resin beds. The plant effectively concentrates any pollutants in towns water adding only small quantities of sulphuric acid and sodium hydroxide. Three primary effluent streams are produced, one acidic, one alkaline and one containing filter backwash which are mixed and neutralised.

(A) Period and Duration

4-8 hours per day.

(B) Discharge Quantity and Rate

Resins and filters are backwashed only when needed and this is dependent upon towns water quality.

Typically	100 m^3/unit/day
or	1000 m^3/day total

This can be discharged rapidly over the space of 4 - 8 hours or more steadily. Seventy-five to ninety percent of the effluent originates from the filter backwashing.

(C) Effluent Quality

Filter Backwash - mean TSS 50 - 150 PPM

Resin Regeneration (after mixing) pH 6 - 9

Towns Water Impurity concentration factor 10 to 20 : 1 overall

(D) Discharge Point

Effluent suitable for direct discharge to CW system or storm water drains after settling.

(E) Mitigation

Sedimentation of suspended solids with recycling of filter water desirable together with adjustment of pH if necessary. Resin flush effluents may be recycleable to CWP.

1.4 Condensate Polishing Plant

Leakage of saline cooling water into the circulating boiler water and dissolution of steel leads to an accumulation of cations and anions. In order to reduce the volume of blowdown needed a mixed cation/anion exchange resin bed is integrated into the circuit and a proportion of the water is passed through it. In addition to the ions from the seawater ammonium ion is also extracted and concentrated in the effluent.

(A) Period and Duration

The resins are backflushed, on average, every ten days with eight plants in existence for 8 units. The sumps can be pumped dry in the space of two hours.

(B) Discharge Quantity and Rate

Effluent Volume/regeneration	250 m^3
Discharge pump rate	100 m^3/hr
Daily discharge	250 m^3

(C) Effluent Quality

The water used for regeneration is demineralised and hence very pure. The ions extracted are those originating from seawater leakage and are typical of that water, together with sodium and sulphate ions from the alkali and acid used for backflushing the resins. The ammonia concentration is variable but can be expected to be in the range of 200 - 500 PPM. Ammonia load is approximately 50 kg/regeneration and pH is 6 - 9 after adjustment if necessary.

(D) Discharge Point

To CW Outfall or direct to the central wastewater plant (CWP) for recycling.

(E) Mitigation

pH adjustment can be carried out if necessary, although to do so prior to discharge to the CW system would appear to be inadvisable. Ammonium (N) can be reduced prior to discharge by air or steam stripping or biological treatment. In the first case substantial quantities of alkali are needed to be added to raise the pH to 11-12, the ammonia stripped and discharged to atmosphere and the effluent neutralised with more acid. In the second case a dedicated biological treatment plant is feasible but would require substantial tankage and the addition of nutrients to the effluent in the form of organic carbon and phosphorus from methanol and phosphoric acid. This would increase the phosphorus load to the sea which is considered worse than adding nitrogen. It could be possible to handle the effluent through an expanded sewage plant system but there are significant doubts about the workability of this in view of the large increase in sewage plant sizing required for a small effluent flow and whether the process would work effectively on saline effluents.

The alternative approach is to divert the effluent to the CWP for recycling.

1.5 Boiler Bottom Ash System

Ash agglomerating in the furnace falls to the base of the boiler where it is quenched by water and removed by chain conveyor. Clean water is required for the cooling sprays and a portion of the overflowing water is returned, after simple cleaning and cooling, to the system as make up. There is a net outflow of water. In emergencies seawater can be used.

(A) Period and Duration

Discharge from the boiler is continuous but is directed to a sump from which it is pumped intermittently to a settling pond.

(B) Discharge Quantity and Rate

The rate of make up water is about 30 m^3/hr/unit. Effluent quantities will be less than this due to evaporation and water lost to the ash. The maximum rates are expected to be

750 m^3/day/unit or
3000 m^3/day/4 boilers or
6000 m^3/day total

Two separate system would be used.

(C) Effluent Quality

The effluent produced has been exposed to hot ash some part of which tends to dissolve. The effluent quality is expected to be :-

pH	8 - 12
T.S.S.	20 - 100 PPM
Hg, Cd	< 10 PPB
Other TMs	< 100 PPB
Fe	< 10 PPM

(D) Discharge Point

C.W. Outfall after settling.

(E) Mitigation

Removal of suspended solids is the primary requirement and this can be carried out in a static tank or inline settling system with, or without flocculation. Consideration will be given to recycling this effluent to the CWP. Treatment for Toxic metal removal is ineffective at these levels.

1.6 P.F.A. Lagoon Decantrate

PFA not sold directly will be stored in the Tsang Tsui ash lagoons. Transport of the ash could be in conditioned form by road truck or in pumped slurry form. In the latter case seawater is used to convey the ash and some of this will be returned as decantrate.

(A) Period and Duration of Discharge

Pumping of ash to the lagoons would not normally occupy more than 12 hours a day when firing at full load and with high ash coal. Decantrate return is found from experience to be substantially less than this even in rainy weather due to evaporation and losses.

(B) Discharge Qauntity and Rate

The decantrate return pumps are rated at 750 m^3/hr and daily quantities will not normally exceed 10,000 m^3.

(C) Effluent Quality

pH	6 - 9
T.S.S.	< 50 PPM
Hg, Cd	< 1 PPB
Other TMs	< 100 PPB

(D) Discharge Point

To CW system.

(E) Mitigation

No mitigation is possible on this effluent stream other than the possible reuse for pumping ash to the lagoon. Such a scheme would involve the installation of special pits and pumps.

Transport of ash in conditioned form would virtually eliminate arisings of decantrate.

1.7 Flue Gas Desulphurisation (FGD) Purge Stream

The FGD plant scrubs acidic gases from the waste gas with an alkaline solution. Two systems are proposed, the limestone/gypsum process and the seawater scrubbing system and variants exist for each.

The limestone gypsum plants would use approximately 100 m^3/hr/unit of water together with crushed limestone to produce 5 - 30 m^3/hr of effluent, the volume depending upon the concentration of chloride in the coal and the effluent. The effluent can have a pH of 3 - 6 and a very high COD and must be neutralised and aerated prior to discharge. Some of the water used for the process can be replaced with seawater although this will tend to increase the effluent volumes. The calcium sulphate (gypsum) produced can be handled "dry" or it may be possible to redissolve it into the C.W. stream.

The seawater scrubbing process uses a proportion of the spent cooling water together with calcium oxide (lime) to dissolve the acidic gases. The resultant liquor is combined with the balance of the cooling water and aerated prior to discharge. The gypsum remains in solution and no solid waste stream is generated.

(A) Period and Duration

FGD plant operation is continuous although the rate of effluent discharge will vary depending upon boiler firing rate and coal quality.

(B) Discharge Qauntity and Rate

For the seawater scrubbing process there is no noticeable change in C.W. quantities.

For the limestone/gypsum process the quantities would be

	5 - 30 m^3/hr/unit
typically	120 m^3/hour
or	3000 m^3/day total

(C) Effluent Quality

For the seawater scrubbing the CW outflow would be altered as follows

Component	Concentration	Annual quantity
pH	no change	N.A.
T.S.S.	+ 6.5 PPM	25,000 t
$NO_3(N)$	+ 0.25 PPM	5,400 t as NO_3^-
Hg & Cd	+ 0.16 PPB	< 1,000 kg each
Other TMs	+ 0.5 - 3 PPB	< 30,000 kg total
Ca^{2+}	+ 40 PPM	}
SO_4^{2-}	+ 100 PPM	} 550,000 t

For the Limestone/Gypsum plant discharge loads will not alter substantially with purge volumes but concentrations will. For 15 m^3/hr the concentrations and loads would be :-

Component	Concentration	Annual load
pH	6 - 9	N.A.
T.S.S.	20 g/l	25,000 t
NO_3(N)	4,500 mg/l	5,400 t as NO_3^-
Hg & Cd	0.2 PPM	< 1,000 kg each
Other TMs	< 3 PPM	30,000 kg
Ca^{2+}	saturated	
SO_4^{2-}	saturated	

(D) Discharge Point

C.W. Outfall.

(E) Mitigation

No mitigation is envisaged for the seawater scrubbing but TSS and TM removal is possible for the limestone/gypsum process yielding the following :-

Component	Concentration	Annual load
pH	6 - 9	
T.S.S.	< 30 PPM	33 t
Hg & Cd	< 50 PPB	c 50 kg
Other TMs	< 1 PPM	c 5,000 kg

Nitrate could be treated by biological means but only after massive dilution to reduce the ion concentrations and the addition of methanol and phosphorus. In view of this it would be desirable to establish whether the effluent could be used for dust suppression on the ash lagoons or a similar application.

1.8 Oil Separators

Wherever the risk of an oil spillage (particularly lighter oils) on site is present, drains from the area are directed to an oil separator. These static tanks permit the separation of oil from the rainwater etc.

(A) Period and Duration

Normally discharges only after significant rainfall.

(B) Quantity and Rate

Dependant upon area of site covered and rate of rainfall.

(C) Effluent Quality

Rainwater with < 5 PPM oil.

(D) Discharge Point

Normally storm water drains.

(E) Mitigation

The separator itself is the mitigation although it may be possible to reuse some in the C.W.P.

1.9 Coal Stockyard

The coal storage areas occupy a significant part of the site (c 50 ha) and rainfall falling here is contaminated with coal particles and any ions leached from the coal. The coal piles are therefore surrounded by drains and adjacent areas such as the coal offloading berths also drain to these facilities. Water runoff achieves primary settling in these drains as it passes to storage ponds at each end of the yard where secondary settling occurs.

(A) Period and Duration

Effluent discharge occurs during and after rainfall events.

(B) Quantity and Rate

This is dependant upon the rainfall intensity but for 50 ha

2.5 metres annual rain = $1.25 + 10^6$ m^3/annum

(C) Effluent Quality

pH	6 - 9
T.S.S.	< 50 PPM
Cd & Hg	< 10 PPB
Other TMs	< 100 PPB

(D) Discharge Point

Dedicated outfall or storm water drains.

(E) Mitigation

Improved settling is possible with the use of dynamic in line settlers but this is mainly applicable to low flow rates. Rainfall of 100 mm/hr results in a flow rate of 50,000 m^3/hr and this for exceeds the size of such plant. The strategy to be implemented is :-

(i) Reuse as much water as possible from the settling ponds. This "brown" water can be used for stockyard dust suppression and coal conveying system washing without further treatment.

(ii) Provide as much storage capacity as possible. Settling pond capacities will total between 50 and 80,000 m^3.

(iii) Install flocculation/settling plants sized for 2000-5000 m^3/day with the product passing to the CWP.

(iv) In the event of very high rainfall periods pump excess water to Tsang Tsui lagoon for settling.

In this way little discharge of untreated water should be necessary.

1.10 Precipitor/FGD Plant Drains

Spillages can occur in these areas and rainfall or washdown will require to be intercepted in a settling pond.

(A) Period and Duration

Usually after rainfall.

(B) Quantity and Rate

The area effected is around 10 ha and water flows would be

for 100 mm	10,000 m^3 effluent

(C) Effluent Quality

Largely contaminated with PFA

SS after sump	< 25 PPM

(D) Discharge Point

Normally overflow to storm drains.

(E) Mitigation

To avoid the possibility of high SS to the storm water drains the effluent can be pumped to the Tsang Tsui ash lagoons for settling. Some may be recovered to the CWP.

2. GAS/DISTILLATE OIL FIRED COMBINED CYCLE

Effluent quantities from a combined cycle plant are much lower in view of the smaller site area, the absence of outdoor fuel stocking and byproduct disposal systems but mostly due to lack of Flue Gas disulphurisation.

2.1 Cooling Water System

The boiler/steam turbine component of a combined cycle plant only delivers approximately one third of the total power output. Cooling water requirements are, therefore, significantly lower. Fouling prevention systems and condensor corrosion systems are similar for this type of plant.

(A) Period and Duration

Continuous

(B) Discharge Quantity and Rate

Up to 8 cubic metres/second/unit
5.5×10^6 m^3/day total

(C) Effluent Quality

(i) Discharge temperature up to 12°C above ambient when unit on full load

(ii) Continuous Hypochlorite injection of 1.5 PPM of Chlorine which decays to around 0.3 PPM on discharge.

(iii) Ferrous sulphate addition (if used) of 1 PPM for up to 1 hour/day.

(D) Discharge Point

Cooling Water Outfall on seawall (see fig. 35).

(E) Mitigation

None possible.

2.2 Boiler Blow Down

As work the cooling water a CCGT unit boiler requires significantly less blowdown but the chemistry is similar.

(A) Period and Duration

A few minutes at a time on an as needed basis to maintain water quality.

(B) Discharge Quantity and Rate

Estimate	1 - 2 m^3/minute/unit
	50 m^3/day/unit
	400 m^3/day total

(C) Effluent Quality

Boiler water is demineralised, maintained at a pH of 9 - 10 and contains low levels of ammonia originating from the hydrozine dosing. Ammonia levels of 1 PPM are expected.

(D) Discharge Point

To C.W. system or storm water drains.

(E) Mitigation

Neutralisation by acid is possible but is considered unnecessary for discharge.

Collection for reuse can be considered.

2.3 Water Treatment Plant

Essentially similar to the coal fired plant other than lower quantities of effluent.

(A) Period and Duration

4-8 hours per day.

(B) Discharge Quantity and Rate

Typically	40 m^3/unit/day
or	350 m^3/day total

(C) Effluent Quality

Filter Backwash 50 - 150 PPM

Resin regeneration effluent pH 6 - 9

Towns Water Impurities concentrated by 10 or 20 : 1.

(D) Discharge Point

To CW system or storm water drains.

(E) Mitigation

Removal of SS from filter backwash and reuse.

3. Condensate Polishing Plant

(A) Period and Duration

Around two hours/day

(B) Discharge Quantity and Rate

Effluent volume/regeneration	100 m^3
Daily discharge quantity	100 m^3

(C) Effluent Quality

Ions originating from leaking seawater together with 200 -500 PPM of ammonia. Daily ammonia load c. 20 kg.

(D) Discharge Point

To cooling or storm water outfalls.

(E) Mitigation

Denitrification by stripping or biological means, recycle for plant use or discharge to ash lagoons.

4. Oil Separators

(A) Period and Duration

Normally after significant rainfall.

(B) Discharge Quantity and Rate

Dependant on area covered and rainfall.

(C) Effluent Quality

Rainwater with < 5 PPM.

(D) Discharge Point

Normally storm water drains.

(E) Mitigation

None necessary.

EFFLUENT QUALITIES AND TOXIC METAL LOADS

The metals and nutrient models are based upon the contribution to the load made by the following primary effluents and annual quantities. Analysis used are conservative.

(i) FGD plant effluent for 50,000 full load hours a year. Reagent qualities and annual loads were :-

	Coal PPM	Limestone PPM	Water PPM	Annual Load kg
Hg	0.1	0.2	0.01	581
Cd	1.0	1.0	0.01	584
As	5.0	0.75	0.01	875
Cr	10.0	10.0	0.01	5010
Cu	20.0	3.0	0.02	2045
Pb	10.0	1.0	0.05	1550
Ni	20.0	5.0	0.10	4040
Zn	22.0	15.0	0.05	8105
% Contribution	27	68	5	

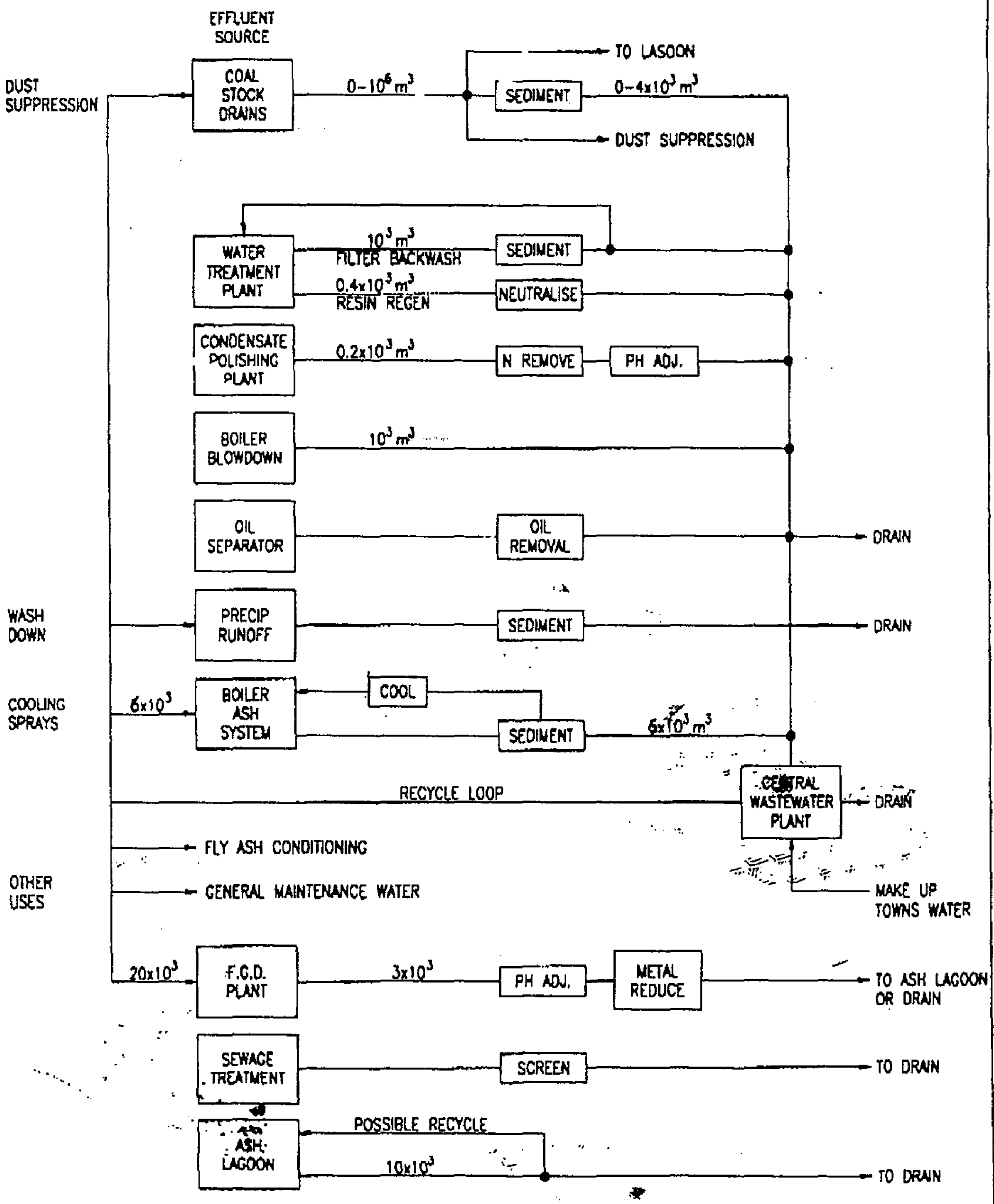
(ii) Boiler Bottom Ash effluent based on a flow of 2 x 10^6 m^3/a, Coal Stock Runoff based 1.2 x 10^6 m^3/a and lagoon decantrate based on 4 x 10^6 m^3/a. The qualities assumed are :-

	Boiler Bottom PPM	Coal Stock Runoff PPM	Lagoon Decantrate PPM
Hg	0.1	0.01	0.01
Cd	0.1	0.1	0.01
As	0.01	0.01	0.01
Cr	0.16	0.1	0.1
Cu	0.1	0.1	0.1
Pb	0.65	0.65	0.1
Ni	0.1	0.25	0.1
Zn	0.1	0.1	0.1

The contribution from other sources was considered to be insignificant. Overall annual loads in kg were :-

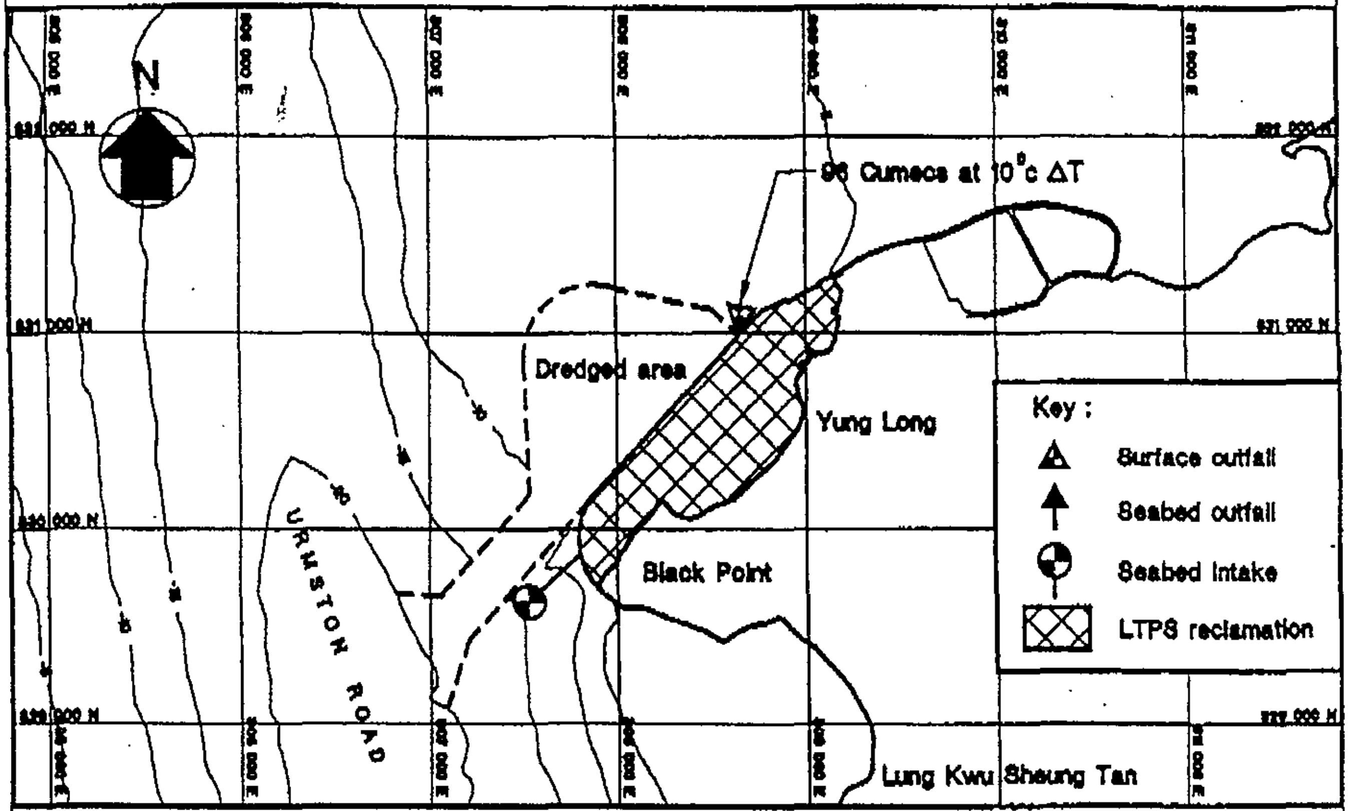
	FGD Plant kg	Boiler Bottom kg	Coal Stock Runoff kg	Lagoon Decantrate kg	Total
Hg	581	200	12	40	833
Cd	584	200	120	40	944
As	875	20	12	40	947
Cr	5010	320	120	400	5850
Cu	2045	200	120	400	2765
Pb	1550	1300	780	400	4030
Ni	4040	200	300	400	4940
Zn	8105	200	120	400	8825
% Total	78	9	5	7	

WATER CYCLE 8x680 COAL /HFO FIRED UNITS

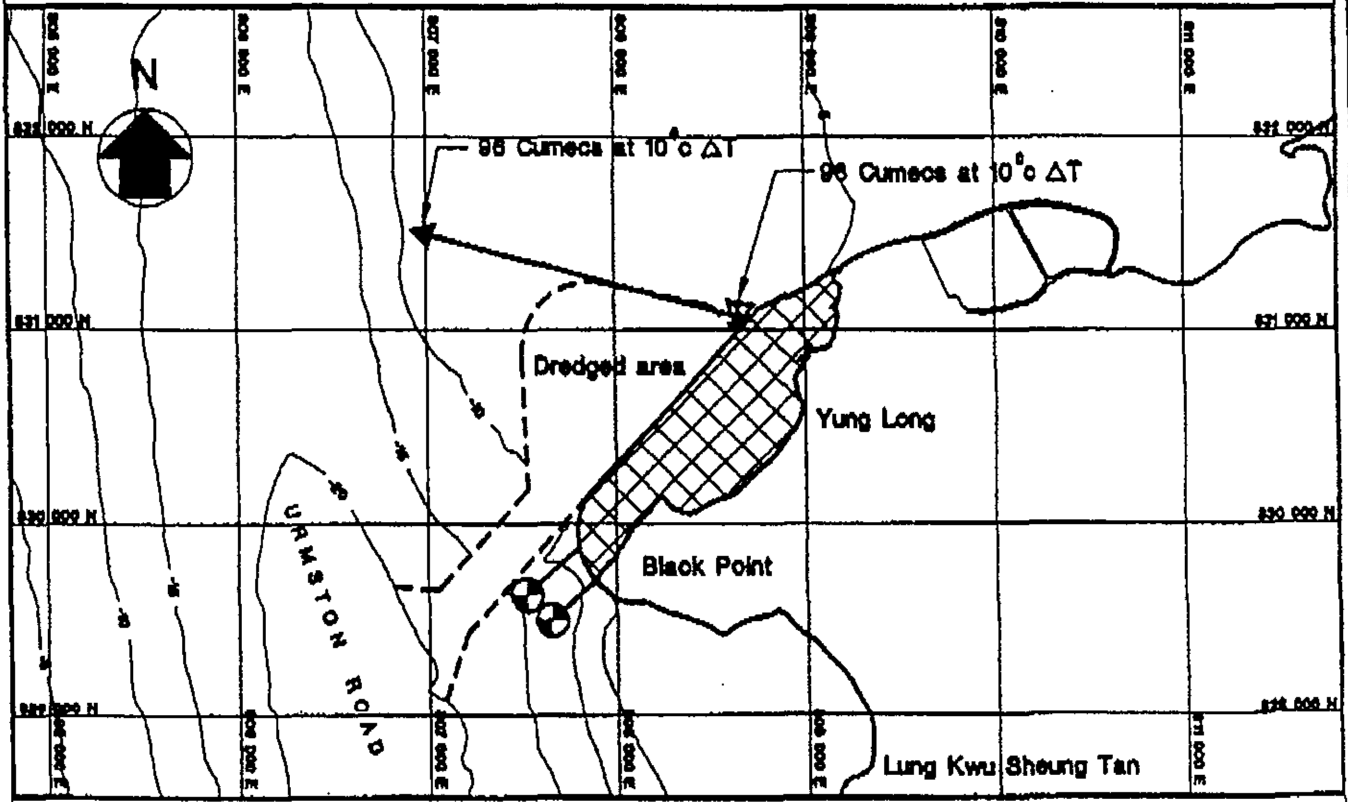


Annex II

Outfall Locations Examined



First Stage : Units 1 - 4 Coal



Final Stage : Units 1 - 8 Coal

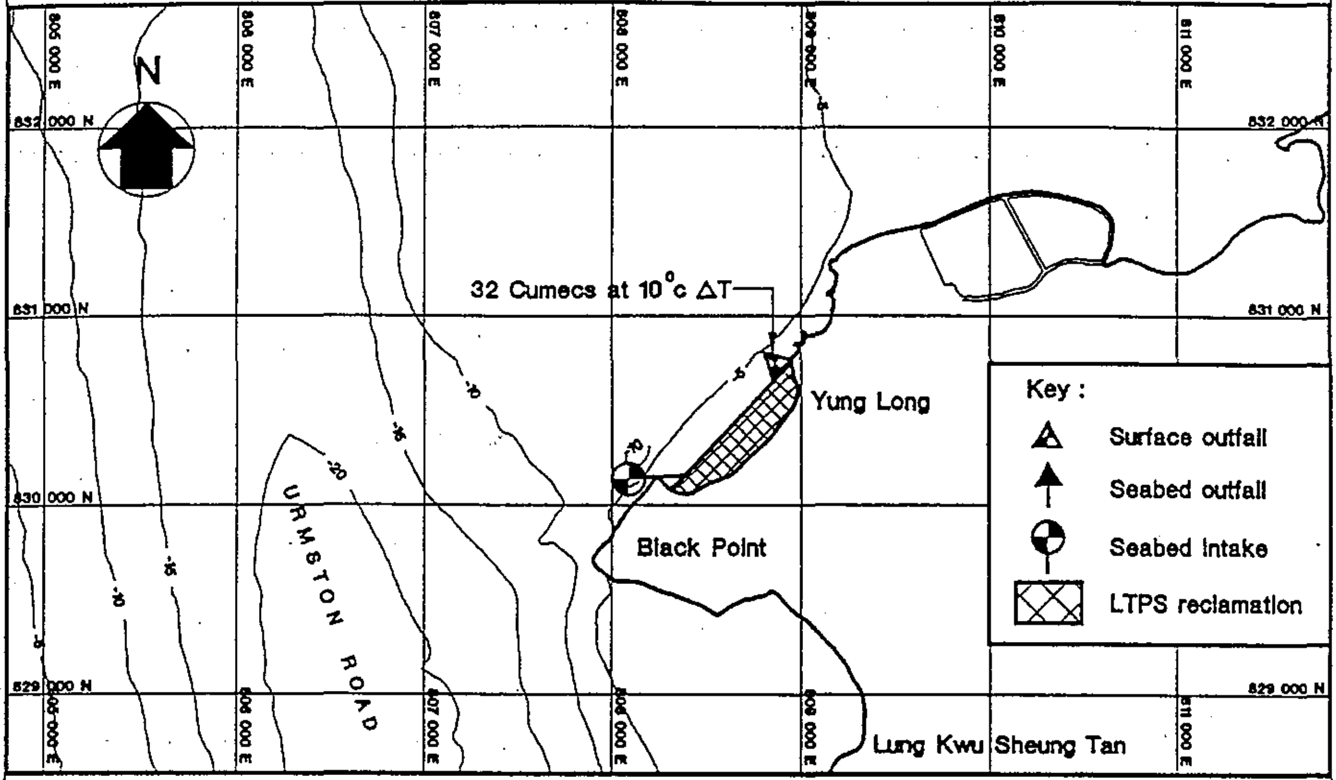
LTPS
Large Thermal Power Station

Cooling Water System

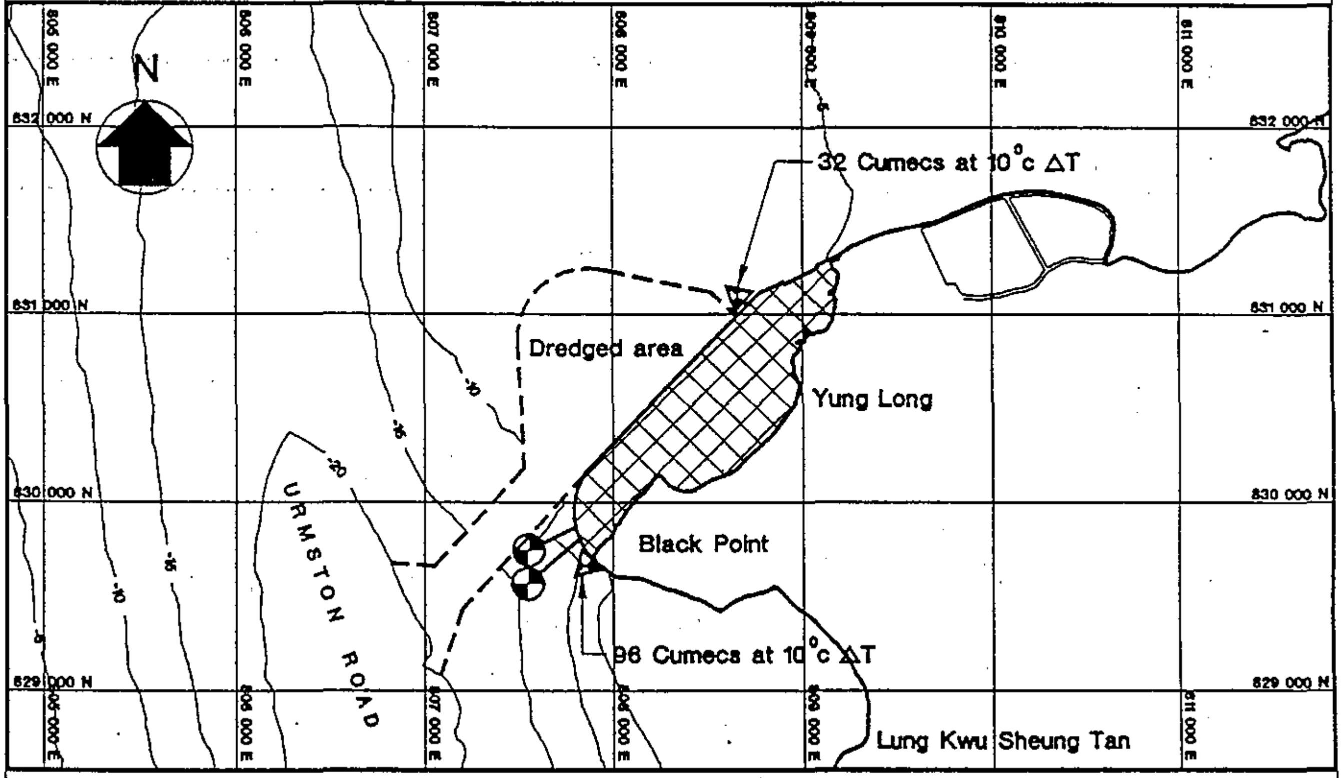
November 1991

Intake / Outfall Configurations Scenario I :
4 Coal + 4 Coal

Figure No. 32



First Stage : Units 1 - 4 CCGT



Final Stage : Units 1 - 4 CCGT & Units 5 - 8 Coal

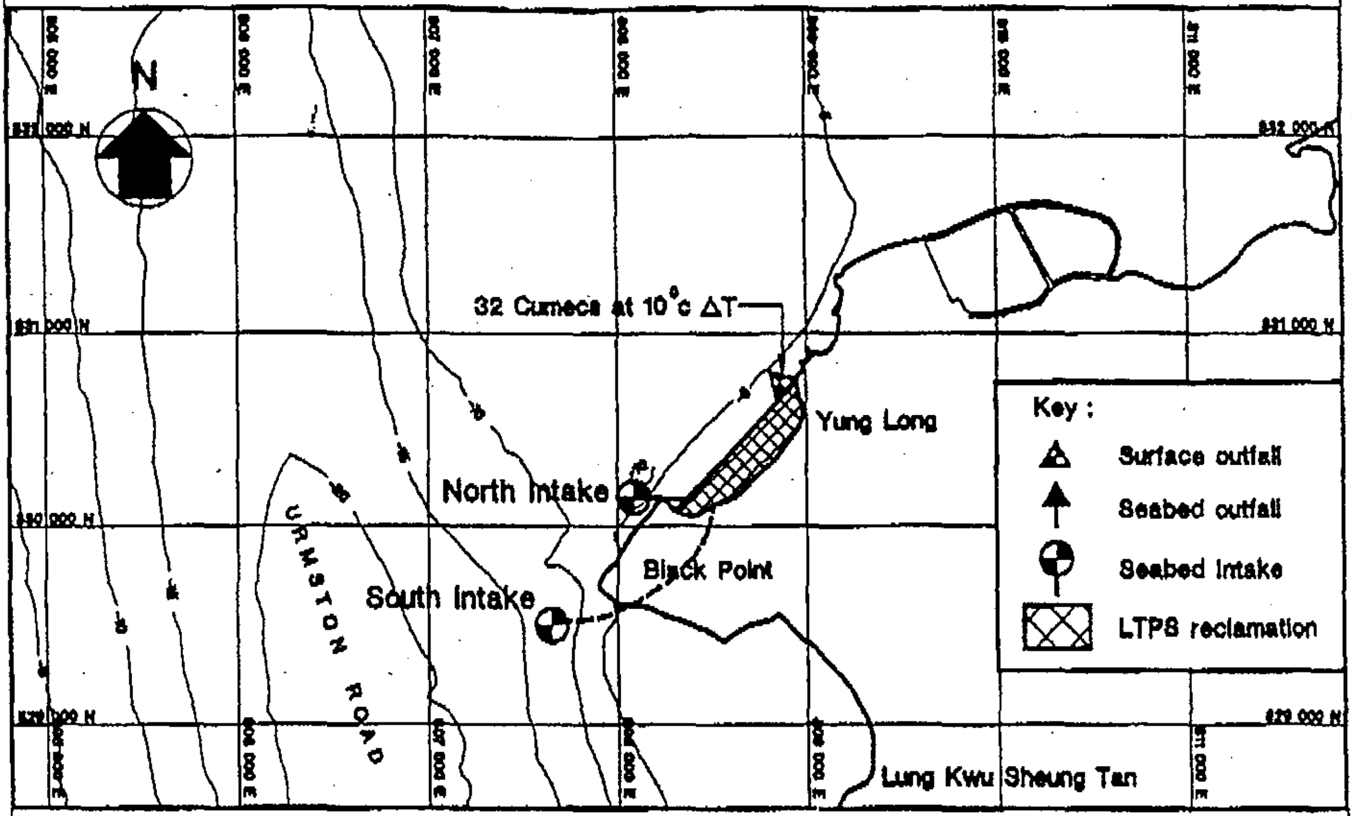
LTPS
Large Thermal Power Station

Cooling Water System

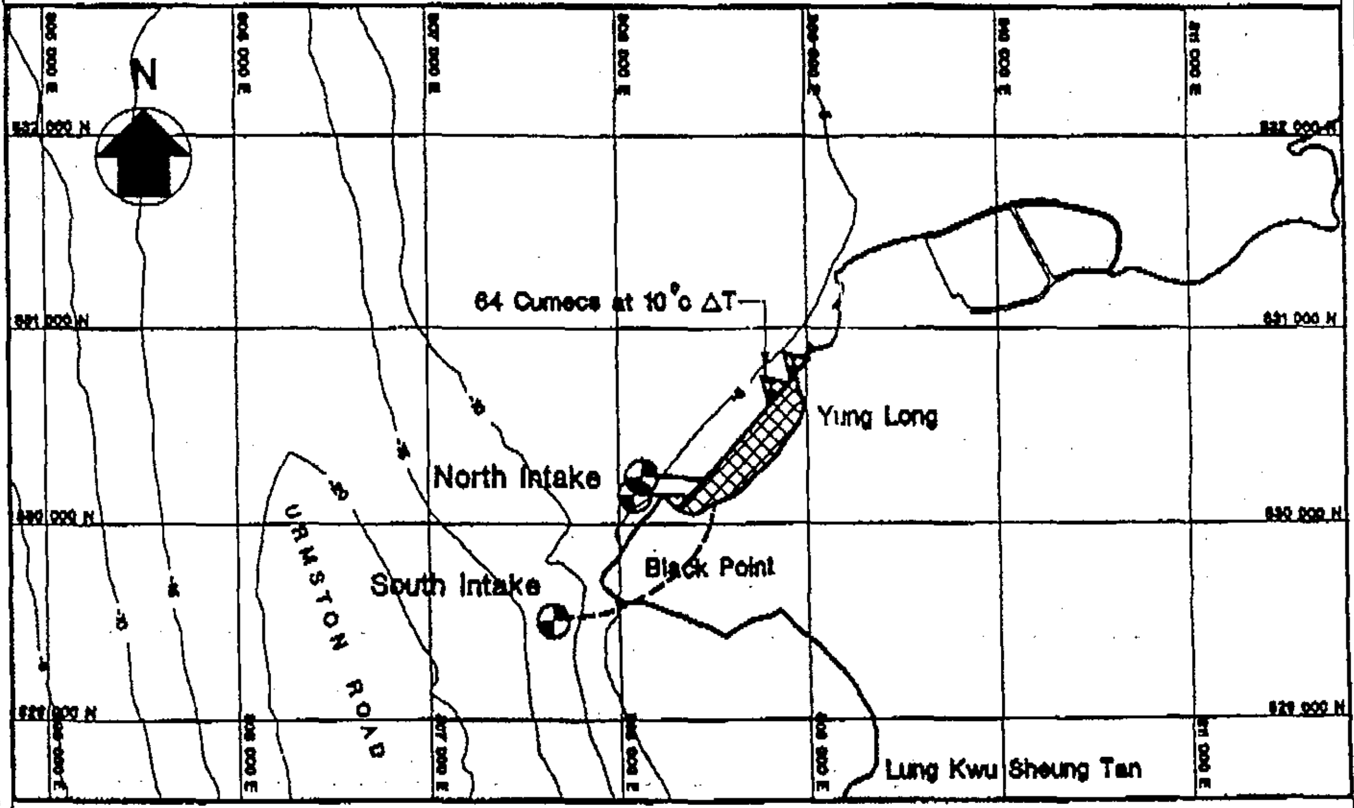
November 1991

Intake/Outfall Configurations Scenario II :
4 CCGT + 4 Coal

Figure No.
33



First Stage : Units 1 - 4 CCGT



Final Stage : Units 1 - 8 CCGT

LTPS
Large Thermal Power Station

Cooling Water System

November 1991

Intake/Outfall Configurations Scenario IV :
4 CCGT + 4 CCGT

Figure No. 35

Annex III

Toxic Effects of Metals and the Incidence of Metal Pollution in Marine Ecosystems

W.J. Langston

Library of Congress Cataloging-in-Publication Data

Heavy metals in the marine environment / editors, Robert W. Furness
and Philip S. Rainbow.
p. cm.
Bibliography: p.
Includes index.
ISBN 0-8493-5506-0
1. Heavy metals--environmental aspects. 2. Marine pollution-
Environmental aspects. I. Furness, R. W. II. Rainbow, P. S.
QH545.H42H42 1990
363.73'9463--dc20 89-34792
CIP

Direct all inquiries to CRC Press, Inc., 2000 Corporate Blvd., N.W., Boca Raton, Florida 33431.

International Standard Book Number 0-8493-5506-0

Library of Congress Card Number 89-34792
Printed in the United States

Chapter 7

TOXIC EFFECTS OF METALS AND THE INCIDENCE OF METAL POLLUTION IN MARINE ECOSYSTEMS

W. J. Langston

TABLE OF CONTENTS

I. INTRODUCTION

Metals occur naturally in seawater and many, such as Cu, Co, Fe, Mn, Ni, Se, V, and Zn, are used for essential purposes by marine organisms. In evolving mechanisms for the sequestration, transport, and utilization of these metals, the biota has developed a general capacity for metal tolerance. Once the assimilative capacity (threshold) of the system is overloaded, however, either by an excess of essential metal, or by the presence of unusually high levels of the rarer nonessential metals (such as Ag, Cd, Hg, and Pb), deleterious effects may occur.

The potential threat to marine organisms posed by metal pollution has been recognized for decades. The major concerns have focused on estuarine and nearshore waters where there are a number of examples of serious effects caused by industrial and domestic discharges. In the worst cases, the consequences have been so devastating that establishing cause-effect relationships has been relatively easy and subsequent "clean-up" procedures successfully implemented. For the majority of coastal and offshore environments, however, concentrations of metals are commonly below "effect levels" observed in field and laboratory tests and consequently the threat of chronic pollution, particularly at the ecosystem level, is still largely unresolved.

Nevertheless, in recent years, a variety of sensitive responses have been discovered in marine organisms which help to visualize the subtle effects of metal contamination. Although it is currently difficult to explain the ecological significance of many of these responses, further development and application of such indices is likely to become increasingly valuable in the assessment and prediction of damage caused by heavy metals and their compounds.

In the present chapter, we review some of the ways in which metals may exert their toxic effects, together with the methods used to establish threshold levels. Areas in the marine environment where potentially toxic metal concentrations have been found, and where biological impact is evident, are also considered.

II. TOXIC EFFECTS OF METALS

Since the most obvious manifestation of metal intoxication is death, early studies on the effects of metals were biased towards short term LC_{50}-type investigations. Such studies were useful for initial regulatory purposes in that they demonstrated the likely extent of direct contaminant-induced mortalities in the field. However, comparisons of dissolved metal concentrations from various sea areas (Table 1) with levels which are acutely toxic to marine species (reviewed for example by Mance[10]) suggest that, with the exception of a few heavily polluted sites, metals are unlikely to pose an instantaneous threat. For moderately contaminated areas, metal concentrations are considerably lower than acute thresholds and direct impact is likely to be restricted to areas immediately surrounding the site of release, such as industrial effluent pipes, mine adits, sewage outfalls, and dumpsites.

Dilution and removal processes are thus often seen as contributing to the self-cleansing process in the marine environment, but as a result, a much larger area is subjected to a moderate degree of contamination and recognition of chronic sublethal effects is clearly more relevant for practical assessments of damage. Before categorizing these effects, however, it is important to identify the parameters which influence the toxic action of metals and which may modify hazard evaluations.

A. FACTORS AFFECTING TOXICITY

Toxic effects occur when excretory, metabolic, storage, and detoxification mechanisms are no longer capable of matching uptake rates. This capacity may vary greatly between phyla, species, populations, even individuals and also may depend on the stage in the life

TABLE 1
Examples of the Range of Metal Concentrations in Various Sea Areas (μg/l)

	Offshore/coastal				Estuaries/embayments			
Metal	Oceanic[1]	North Sea and U.K. Coastal[2-5]	Baltic Sea[5]	Mediterranean[6]	Bristol Channel, U.K.[7] (industry, sewage)	Poole Harbor, U.K.[8] (industry, sewage)	Derwent estuary[a] Tasmania (refinery, chlor-alkali)	Restronguet Creek,[9] U.K. S ‰ 18-34 (mining waste)
As	1.35—2.5	1.52—2.4	0.52—7.4	—	—	0.54—1.38	1—6	3.3—65.4[a]
Cd	0.0002—0.025	0.005—0.48	0.03—0.07	<0.02—0.7	0.4—9.4	0.3—42	0.5—15	0.7—38
Cr	0.088—0.55	—	—	—	—	—	—	—
Cu	0.025—0.64	0.01—6.8	0.31—0.95	<0.04—5.8	0.6—5.4	0.2—28	10—27	3—176
Hg	0.004—0.012	0.003—0.08[a]	0.001—0.006	0.005—0.08	0.009—0.07[a]	0.002—0.13	<0.1—16	0.005—0.03[a]
Ni	0.18—0.70	0.01—4.8	0.41—1.76	—	0.2—3.0	—	—	1—18
Se	0.06—0.12	0.09—0.47[a]	—	—	0.2—1.8	0.3—29	—	0.1—0.3[a]
Pb	0.006—0.015	0.006—1.23	0.02—0.11	—	0.35—13	—	4—16	<2—4
Zn	0.0007—0.588	0.006—70	1.3—3.3	0.02—10.0	2.7—44	1—674	6—1500	22—20460

Note: Compiled from the sources indicated.

[a] Unpublished results.

history of the organism, thus explaining the range of sensitivities often observed in toxicity studies. In addition, many organisms may be better adapted to their natural environment than suggested by laboratory studies. *Metal tolerance,* either genetically based or resulting from previous exposure history can greatly influence apparent toxicity thresholds as demonstrated, for example, in the polychaete *Nereis diversicolor,* where individuals from highly metalliferous sediments (mining wastes) have become much more resistant to elevated levels of Cu and Zn than those from unpolluted sites.[11] The mechanisms which have evolved in organisms to counteract excess metals are many and varied and range from surface processes of exclusion/reduced permeability observed in *N. diversicolor* (Cu, Zn),[11] to the internal detoxification systems, including metallothioneins, lysosomes, and granules (Ag, Cd, Cu, Hg, Zn, Pb) described for representatives of many phyla.

Toxic effects are inexorably linked with bioaccumulation (since, in most cases, metals must first enter cells before exerting their influence) and many of the physical and chemical processes which control these events are identical. Metal burdens in organisms are usually a function of environmental concentrations; however, it is now widely recognized that *chemical speciation* of metals in seawater can greatly modify their bioavailability and hence toxicity. Generally, bioavailability is reduced by the presence of natural organic chelators and for metals, such as Cu and Cd, the free ion appears to be the most biologically active species. In addition, it is important to recognize that sediments represent a major source of contamination to many benthic organisms and that *partitioning* of metals among solid phases may, correspondingly, modify the bioavailability and toxicity of sediment-bound metals.[12]

As a general (though not universal) rule, high *temperature* and low *salinity* act synergistically with metals to increase mortality.[13] The higher toxicity of metals such as Cd, Cr, Pb, Hg, Ni and Zn at low salinity is usually attributable to more rapid accumulation rates and is clearly of greatest significance in estuaries.

It is usual for polluted environments to be contaminated with several, as opposed to single, metals and numerous laboratory studies, supported by residue data, point to *synergistic/antagonistic interactions.* In particular, there is consistent evidence of competition between a number of metals, such as Cd-Zn, Cu-Ag, Cu-Mn, Cd-Se, and Hg-Se.[9,14,15] In the latter case, the antagonistic effect of Se on Hg accumulation is often seen as fulfilling a detoxifying role, at least in some marine vertebrates, while in contrast, competition from Cu may result in deficiencies of essential Mn in algal cells.[14] For the majority of metal combinations, however, the consequences of their joint action under natural conditions is not understood.

Redox potentials may strongly influence speciation, availability, and thus toxicity of metals, particularly in sediments. Anoxic conditions are frequently accompanied by high metal levels (especially in pore water) at polluted sites and their effects may be synergistic as suggested, for example, by experiments with *Macoma balthica* subjected to combined oxygen and Cu stress.[16] In this study, it was suggested that the proportion of (bioavailable) Cu^{2+} ions was increased at the lower pH levels associated with low oxygen tensions, resulting in enhanced uptake and sublethal toxicity. Because of its impact on chemical speciation, it is perhaps surprising that the influence of pH on metal toxicity in marine organisms has not been studied more often. However, it is generally assumed that the buffering capacity of seawater is sufficient to resist major pH changes in most areas other than in the immediate vicinity of certain waste outfalls or mine drainage.

Bearing in mind the variety of factors which can modify toxicity, some of the ways in which metals exert their effects are now discussed.

B. MEASURING EFFECTS OF METALS

Techniques used to assess the effects of metals are varied and range across many levels of biological organization from cells to whole communities. It is worth noting, however, that effects rarely occur in isolation and impact is usually due to a combination or sequence of related events. Thus, for example, lower-order biochemical responses may be intimately linked with disturbances in essential life processes, such as growth and reproduction, which in turn may influence the health and survival of individuals, populations, and ultimately communities.

As a rule, the effects of metals take longer to develop for each increasing level of biological complexity and this has led to the concept of using stress indices (at the lower levels of organization) to predict higher-order effects.[17] However, although many of these indices have the advantage of extreme sensitivity and selectivity for metals, and undoubted potential as 'early warning systems' for metal pollution, their ecological relevance is not always evident: links between biochemical effects and physiological damage, for example, may appear obvious but are rarely demonstrated. In contrast, measurement of pollutant responses at the highest levels of organization maximizes ecological significance, but usually does so at the expense of sensitivity (thus population and community studies often fail to distinguish between natural and pollutant-induced changes in all but the most extreme cases). Consequently an integrated approach, using combinations of the techniques described below, is usually the only appropriate way of detecting the more subtle effects of metal contamination.

1. Biochemical Responses

There are a number of biochemical indices which may be used to reflect responses to specific contaminants, including metals, following their uptake by cells. Many are dealt with in greater detail in Chapter 8 of this volume, but two merit consideration here since they provide an insight into mechanisms of toxicity. Thus, both metallothionein (MT) induction and changes in lysosomal activity are frequently regarded as manifestations of the organism's effort to detoxify excess metals.

The production of MT (and other metal-binding proteins) appears to be particularly valuable as an index of stress in view of its specificity to metals (including Cd, Cu, Hg, and occasionally Ag, Zn), and a number of authors have reported that induction may be quantitatively related to metal contamination, both in the laboratory and in the field.[18,19] The detoxifying role of MT has been established in work with mussels, *Mytilus edulis*, which demonstrated that acquired tolerance to Hg was due to MT induction following pre-exposure to Hg (0.05 to 5 μg/l), Cu (5 μg/l), or Cd (50 μg/l).[20] It has been proposed that toxic effects occur as the binding capacity of MT becomes saturated, due to the interaction of excess free metal in the cell with the enzyme pool ("spillover").[21] The precise significance of this displacement, in terms of decreased performance, is still open to question, however. Further development of methods to quantify and assess the consequences of MT induction is required in a wide range of species before this technique can be routinely used to monitor effects.

Impaired lysosomal function also reflects disturbances to the detoxification system of the cell and, as with induction and saturation of MT, may be seen as a forerunner, and possibly causitive feature, of various higher order effects. This potential has been demonstrated in studies with mussels which showed that reduced latency of lysosomal hexosaminidase, (a function of membrane destabilization in lysosomes, and inducible at Cu levels as low at 20 μg/l), is quantitatively related to physiological responses in the whole organism, such as clearance rates and growth.[17,22] Furthermore, studies with the hydroid, *Campanularia flexuosa*, showed that destabilization of lysosomes occurs at concentrations of Cu (1.2 to 1.9 μg/l), Cd (40 to 75 μg/l), and Hg (0.17 μg/l), almost ten times lower than levels causing reductions in growth, highlighting the value of such indices as early warning devices of deleterious effects.[17,23]

2. Whole Organism Responses

a. *Growth*

Of all the sublethal responses investigated to date, growth and condition are probably the most intensively studied. The effect of metals on growth has been assessed in a range of marine organisms and examples of threshold levels reported in experiments with algae, hydroids, mollusks, and fish are shown in Table 2.

Growth responses in algae, especially phytoplankton, are among the most sensitive indicators of heavy metal contamination and the use of ^{14}C incorporation as a measure of production has greatly improved the capability to determine impact. Also, following the discoveries that microalgal cultures contain large quantities of metal-chelating ligands and that, generally, toxicity is determined by free ions rather than complexed metals, recent studies have focused on the use of 'natural communities', either in the laboratory or in the field, to determine effects. The role of these chelating materials is still the subject of debate and may be linked with mobilization of essential elements, such as Fe and Mn. There is no doubt, however, that such complexes reduce the availability of several metals, especially Cu and Hg, thus fulfilling a detoxifying role.[27] As a result, metal concentrations reported to inhibit growth in microalgae vary greatly depending on the complexation capacity of the seawater and, as shown, for example, by the data of Sunda and Lewis (Table 2), the value of free ions (Cu^{2+}) causing growth inhibition may be considerably lower than levels of 'total' dissolved metal. It has even been suggested that Cu at natural levels might be inhibitory if uncomplexed, particularly near metal-rich upwellings. Although this claim has yet to be proved, there is clear evidence that Cu can be toxic at levels of 0.19 to 0.3 μg/l, only marginally above those found in oceanic waters.[14] Hg also reduces algal growth at low levels (~1 μg/l, Table 2) although such concentrations would be encountered only in highly contaminated estuaries and bays. Zinc, however, may reduce growth at 15 to 20 μg/l, concentrations not uncommon in some inshore areas.[26,30] Results for Cd are conflicting and variations in thresholds may be due to differences either in complexation or in tolerance of test populations. Arsenic (V) inhibits growth at concentrations as low as 5 μg/l and may possibly result in reduced productivity in As-contaminated estuaries and coastal waters.[31] While Pb reduces growth above 20 μg/l, no effects could be detected for Se, Ni, or Cr at levels around 50 μg/l and it seems unlikely that these elements would be toxic in most areas.

In one of the few studies using mixtures of metals, Thomas et al.[28] showed that the growth of diatom/dinoflagellate assemblages was inhibited at metal concentrations five times higher than levels typically found in moderately polluted estuaries: toxicity was mainly attributed to Cu (15 μg/l) and Hg (0.75 μg/l).

Based on results described here, and in similar studies, it is evident that metal contamination could reduce growth and photosynthesis at some polluted sites, although the extent to which metals influence the productivity of inshore waters has yet to be ascertained.

Experiments with macroalgae, *Laminaria saccharina*, have shown that growth may be affected by Hg, Cu, and Zn[32] and for the most sensitive life stages (sporelings) threshold concentrations are similar to those observed in microalgae (Table 2).

Among invertebrates, growth reductions have been demonstrated at concentrations sometimes encountered in contaminated areas (Table 2). For example, exposure to 14.3 μg/l Cu, 1.6 μg/l Hg, and 0.13 μg/l TBT (tributyltin) inhibited colonial size in hydroids *C. flexuosa*.[23] Although other responses may be more sensitive, growth parameters in hydroids have, nevertheless, proved useful in bioassays to reflect water quality, as influenced by sewage and industrial wastes. Thus, Karbe and co-authors[36] demonstrated that leaching of metals from Hamburg dredge spoils reduced growth in *Eirene viridula* colonies.

Mollusks are among the most frequently used organisms in pollution studies and effects of metals on growth in oysters, mussels, and clams are included in Table 2. Concentrations

TABLE 2
Sublethal Effects of Metals — Growth

Species	Ag	As	Cd	Cu	Hg	Ni	Pb	Zn	Response	Ref.
	Metal concentration (μg/l)									
Phytoplankton										
Natural assemblage				0.3					Reduced ^{14}C fixation	14
Natural assemblage			1.0	1.0	1.0				Reduced ^{14}C fixation	24
Natural assemblage				10.0					Reduced ^{14}C fixation	25
Natural assemblage		23	112	6.4	<6.0	60[a]	20	20	Reduced growth	26
Monochrysis lutheri				21.6 (0.07 as Cu^{2+})					Reduced division	27
Natural assemblage					0.8				Reduced growth	28
Natural assemblage					1.0				Reduced productivity	29
Natural assemblage								15	Reduced photosynthesis	30
Natural assemblage		5							Reduced growth	31
Macroalgae										
Laminaria saccharina										
Sporeling				10	0.5 (0.5)[b]			100	Reduced growth	32
Sporophyte				50	50 (5.0)[b]			1000	Reduced growth	32
Hydroids										
Campanularia flexuosa			195	14.3	1.6			740	Reduced growth	23
Mollusks										
Mytilus edulis			10	3	0.3	>200[a]	>200[a]	10	Reduced shell growth	33
Mercenaria mercenaria	32			16	15	5700		195	Reduced growth[c]	34
Crassostrea virginica	25			33	12	1200			Reduced growth[c]	34
Fish										
Pleuronectes platessa			5	10					Reduced growth	25, 35

[a] No effect observed at this concentration.

[b] Methylmercury.

[c] For larvae: concentrations also represent LC_{50} values (8 to 12 d).

of dissolved metals reported to inhibit growth, and which occasionally prove toxic to larvae, may be environmentally significant for Cu, Hg, Zn, and Cd, while for Ni and possibly Pb, threshold values are seldom encountered in the field.

Various condition indices have also been used to assess the impact of pollutants in mollusks, and of these, scope for growth is advocated as a particularly valuable indicator of stress.[17] Thus, measurement of scope for growth (the energy available for growth and reproduction, calculated as the difference between energy consumed in food and that lost in respiration and excretion) showed that condition of transplanted mussels, *M. edulis*, declined along a pollution gradient in Narragansett Bay.[37] As with so many field studies, however, it was not possible to separate the effects of metals from other similarly distributed contaminants.

Marine fish are regarded generally as being less sensitive to the effects of metals than other aquatic organisms, possibly as a result of more highly developed detoxification systems. Nevertheless, inhibition of growth has been observed in plaice, *Pleuronectes platessa*, exposed to 5 µg/l Cd or 10 µg/l Cu.[25,35] In terms of environmental impact, however, it is likely that effects on reproductive success are most critical for fish stocks, as described in subsequent sections.

b. Morphology

Morphological responses to pollutants are usually mechanistically linked to growth disturbances and may be important indicators of metal exposure. For example, in studies with hydroids, *Eirene viridula*, Karbe et al.[36] have used alterations in hydranth morphology to evaluate the toxicity of As, Cd, Cu, Hg, Pb, Se, and Zn. Threshold values in these experiments were, with the possible exception of Cu, higher than concentrations present in most contaminated waters (Table 3).

Among the most important morphological and histopathological abnormalities caused by metals are those which occur in embryonic and larval stages and the implications for successful recruitment are obvious. Studies on early stages of mollusks, in particular oysters and mussels,[38,39] have shown that such effects might be expected at contaminated sites, at least for Cu, Hg, Cd, Zn, and possibly Ag, while abnormalities caused by As, Cr, Ni, Pb, and Se seem less likely (Table 3).

Some extraordinary metal-induced deformities have been discovered in stenoglossan gastropods. These include abnormalities in eyes and tentacles of *Urosalpinx cinerea* exposed to Hg (10 µg/l)[40] and mascularization of female dogwhelks, *Nucella lapillus*, exposed to TBT (1 ng/l).[41] The significance of this latter observation and evidence linking shell deformities in oysters with TBT is discussed later.

Recent suggestions that contaminants are responsible for the induction of fish lesions (skeletal and gill deformities, tumors, ulcers, and fin rot) have caused much concern. However, although a number of field studies have revealed correlations between the incidence of lesions and contaminant levels, it is frequently impossible to identify the causative agents (indeed there is considerable debate as to whether anthropogenic inputs are contributory factors at all in some areas). Evidence for the involvement of metals in the induction of gill and skeletal deformities is provided by Bengtsson and co-authors[42] who found a greater proportion of affected fish in populations from metal-polluted sites in the Baltic compared with 'clean' sites. In subsequent long-term experiments with sculpin, *Myoxocephalus quadricornis*, exposed to diluted smelter effluents,[43] effects due to metals (a mixture of As, Cd, Cu, Hg, Pb, Zn) were shown to be dose related, though significant abnormalities occurred even at the highest dilutions (Table 3). Such evidence is limited, however, and further verification is necessary before the incidence of deformity and disease in fish is widely used as an indicator of pollutant stress.

TABLE 3
Sublethal Effects of Metals — Morphology

Species	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn	Response	Ref.
	Metal concentration (μg/l)											
Hydroids												
Eirene viridula		300	100		10	3		300	3,000	1,500	Altered hydranth morphology[a]	36
Mollusks												
Crassostrea gigas	22	326	611	4538	5	7	349	476	>10,000	199	50% abnormal larvae	38
Mytilus edulis	14	>3,000	1200	4469	6	6	891	758	>10,000	175	50% abnormal larvae	38
Crassostrea virginica	24					11				206	50% abnormal larvae	39
Fish												
Myoxocephalus quadricornis		32	0.5		0.8	0.1		1.2		5.3	Increase in vertebral deformities[b]	43

[a] Lowest reported threshold concentration.

[b] Metals applied as a mixture.

c. Reproduction and Recruitment

In organisms which reproduce by both asexual and sexual means, the effect of metals may be to enhance or suppress one or other form. For example, sexual reproduction in the red seaweed, *Champia parvula,* as determined by the production of mature cystocarps, is reduced following exposure to As.[44] In contrast, hydroid colonies respond to metal intoxication by increasing the production of gonozooids (the sexual morphs), an adaptation which may help to disperse the colony away from polluted sites.[23] Threshold levels for gonozooid production in *Campanularia flexuosa* are among the lowest observed in sublethal tests with Cu and Zn (Table 4), and bioassays using this index have been used to assess water quality.[23]

For other organisms, inhibition of fertilization and embryogenesis are usually the most significant reproductive effects since they may ultimately determine the survival of the population. Thus, studies on the effects of metals on reproductive cycles in polychaetes (Table 4) have shown that reduced fecundity is likely to occur at concentrations considerably lower than levels reported to be acutely toxic in adults.[10] Based on these data, however, it seems unlikely that recruitment would be affected at all but the most severely contaminated sites. This agrees with observations from the field (described elsewhere in this chapter) that certain polychaetes are able to tolerate conditions, for example in highly metalliferous sediments, where more sensitive species are eliminated.[11] Resistance across the whole life cycle may, therefore, confer considerable adaptive advantages.

There are a number of observations of impaired fecundity in mollusks as a result of exposure to metals and their compounds and some of the most important discovered to date — those attributable to TBT — are discussed later. In experiments with mussels *Mytilus edulis,* Myint and Tyler[46] showed that oocyte development was suppressed by Cu and Zn at 50 and 200 µg/l, respectively. The sensitivity of eggs and sperm was also demonstrated in studies with the clam *Spisula solidissima* which showed that embryogenesis was affected to a far greater extent by prefertilization exposure of gametes to Ag (9.5 µg/l) than by postfertilization treatment.[47]

Germ cells and embryos of echinoderms are commonly used to assess the effects of pollutants on reproduction. Threshold concentrations associated with the arrest of fertilization and development in sea urchins range from 10 µg/l for Cu and Hg to $>$1000 µg/l for Pb, Cr, As, (Mn and Fe) as shown in Table 4. Gametes appear to be especially vulnerable and for sperm, effects are detectable at extremely low concentrations of Zn (5 µg/l). Echinoderm bioassays using fertilization, cleavage, and gastrulation as markers, have been successfully employed as indicators of water quality, demonstrating, for example, the extent of deleterious effects caused by metal refinery wastes.[51]

The incorporation of life cycle tests is an important feature of studies on crustaceans and has usually confirmed that sexual maturation and reproduction are the most sensitive stages. Threshold levels for some species (Table 4) suggest that effects might be expected at contaminated sites. Long term experiments with *Pontoporeia affinis,* for example, indicate that fecundity is reduced at around 5 µg/l Cd or Pb. Applied jointly, however, Pb appears to reduce the toxicity of Cd.[48]

Despite the relative tolerance displayed by adult fish, gametes and embryos have been identified as vulnerable to the effects of metals. Thus, fertilization and embryogenesis in spring-spawning herring are inhibited by Cu, Zn, and Cd in the range 5 to 10 µg/l, while hatching success in the eggs of *Fundulus heteroclitus* is reduced by similar levels of Hg.[52,53] Extremely low levels of free Cu^{2+} activity (Table 4) have been found to affect viability of eggs in spot, *Leiostoma xanthurus* and silverside *Menidia menidia,* prompting suggestions that natural Cu levels in sea water would, if uncomplexed, suppress hatching.[54] However, elevated metal concentrations in surface films of contaminated inshore areas, as described later, probably represent the greatest threat to the survival of free-floating fish eggs.

TABLE 4
Sublethal Effects of Metals — Reproduction and Development

Species	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn	Response	Ref.
	Metal concentration (µg/l)										
Macroalgae											
Champia parvula		60								Inhibition of sexual reproduction	44
Hydroids											
Campanularia flexuosa					0.05	0.01			500	Increase in gonozooid frequency[a]	23
Polychaetes											
Neanthes arenaceodentata			1000	50				3100	320	Reductions in reproduction	45
Capitella capitata			560	100				200	560	Reductions in reproduction	45
Ctenodrilus serratus			2500	50	100	50	500	1000	500	Reductions in reproduction	45
Bivalves											
Mytilus edulis					50				200	Development of oocytes supressed	46
Spisula solidissima (germ cells)	9.5									Impaired embryogenesis	47
Crustaceans											
Pontoporeia affinis			5.5					4.9		Fecundity reduced	48
Rhithropanopeus harrisii			50						25	Hatch time increased	49
Tigriopus japonicus			44		6.4					Generation time doubled	50
Echinoderms											
Sea urchin eggs (various spp.)		1500	600	1000	10	10	600	1000	30	Fertilization and development arrested[a]	51
Fish											
Spring-spawning herring			5		10				10	Reduced fertilization	52
Fundulus heteroclitus						10				Reduced hatch	53
Leiostomus xanthurus (eggs)					0.064[b]					Reduced hatch	54
Menidia menidia (eggs)					0.025[b]					Reduced hatch	54

[a] Lowest reported threshold concentration.

[b] Calculated as free ion (Cu^{2+}).

d. *Behavior*

Behavioral responses are often difficult to quantify in the field and except for Cu, Hg, and Cd, most information from laboratory studies suggests that threshold values are significantly above realistic environmental levels. Nevertheless, some responses, including food handling in hydroids[36] and (reduced) filtration in bivalves[17] are useful indicators of water quality and, in addition, they may be important precursors of other deleterious effects. For example, reduced filtering in bivalves during prolonged periods of metal exposure would clearly, in time, become detrimental to their condition. More importantly perhaps, complete valve closure can occur at relatively low metal levels, as observed in mussels exposed to 5 μg/l Cu.[33] Similar responses in sediment-dwelling species could lead to critical delays in burrowing and settlement. Thus in experiments with clams, *Macoma balthica*, McGreer[55] showed that inhibition in burrowing was linearly related to metal contamination in sediments and concluded that toxicity was probably due to Cd and Hg. At the highest sediment concentrations (1.4 μg/g Cd, 0.46 μg/g Hg), active avoidance was displayed by *Macoma*, demonstrating how recruitment could be affected at contaminated sites.

3. Community Responses

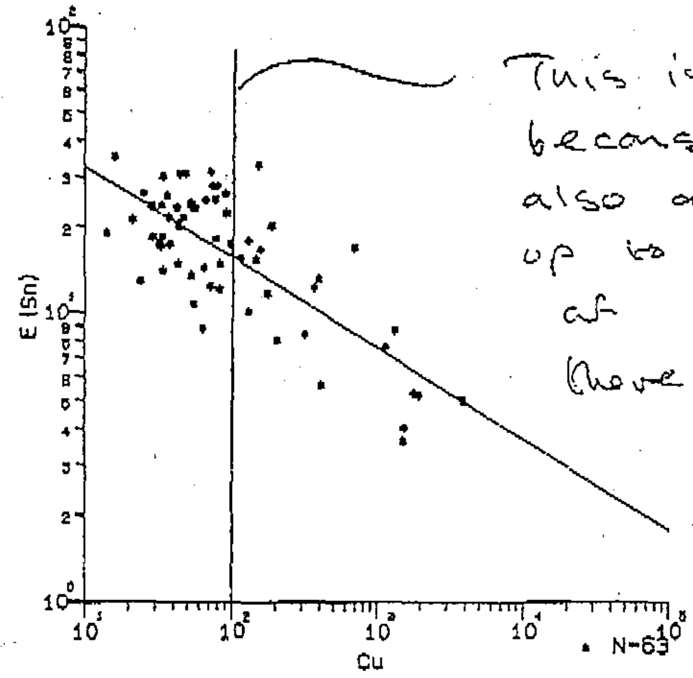
Through their effects on the previously described life processes, metals reduce the competitive ability of the most sensitive organisms and may ultimately lead to their exclusion from marine communities. Thus, one of the earliest observations of the effects of severe pollution was that opportunistic (tolerant) species became dominant at the expense of specialist species and often resulted in more simplified ecosystems.

Evidence for the impact of pollutants on plankton communities is derived largely from *in situ*, enclosure-type experiments using natural assemblages, and changes in dominance patterns of phytoplankton have been observed for several metals. As a general rule, sensitivity in algae appears to vary depending on the metal studied and it is not easy to predict resistant species. However, among diatoms, replacement of centric species by pennate forms is a consistent observation. Ibragim and Patin[24] showed, for example, that exposure of Mediterranean assemblages to Cd, Cr, Pb, or Hg resulted in a preponderance of *Nitzschia closterum* at most concentrations tested in the range 1 to 1000 μg/l. A similar transfer of dominance in favor of pennate diatoms has been observed by other workers at 5μg/l Cu,[56] 1 to 5 μg/l Hg,[29] and, perhaps most remarkably, at 5 μg/l As,[31] a concentration only five times greater than background.

Changes in the taxonomic diversity of phytoplankton communities are not necessarily the result of direct toxicity on sensitive species, however, but may be related to reduced grazing pressure.[29] Conversely, changes in phytoplankton diversity may have fundamental implications for higher trophic levels, since a change in dominant species, even if not accompanied by lowered productivity, could reduce the choice and abundance of preferred prey organisms. Sanders[57] has shown, for example, that algal population shifts from flagellates to smaller, tolerant diatoms, inducible at low levels of As (15 μg/l), may result in reduced copepod fecundity and survival, even though the copepods themselves are resistant to relatively high levels of As.

A degree of caution must be exercised when extrapolating the results of containment studies to natural ecosystems, nevertheless, they do provide valuable insights into the mechanisms of metal toxicity in plankton communities.

Despite difficulties in separating anthropogenic and naturally induced events, deleterious effects of metals in natural benthic marine communities have also been demonstrated. For example, using data from several Norwegian fjords, Rygg[58] was able to show that metal contamination in sediments (Cu, Pb, and Zn) reduces the diversity of benthic fauna. Based on the strength of (negative) correlations between species diversity and sediment metal concentrations, Cu was identified as the most likely agent responsible for the absence of



This is interesting because what is also apparent is that up to concentrations of 100 µg g⁻¹. ([illegible] there is no correlation.

FIGURE 1. Correlation between faunal diversity, E (Sn), and sediment Cu concentrations (μg/g) for benthic populations in Norwegian Fjords. Regression equation is Log_{10} diversity = −0.3 $\log_{10}$ (Cu in sediment) + 4.2 ($R = -0.76$, $p \leq 0.001$). (From Rygg, B., *Marine Ecol. Progr. Ser.*, 25, 83, 1985. With permission.)

sensitive species (Figure 1). At sediment concentrations above 200 μg/g Cu (10 × background), diversity was reduced by 50%, while effects were evident even at values five times normal. The high proportion of carnivorous polychaetes surviving at polluted sites confirms earlier observations of their higher metal tolerance.

The foregoing discussion is by no means intended as a comprehensive review of metal toxicity, but nevertheless illustrates the ways in which deleterious effects may be detected. In the remainder of this chapter, we examine further evidence, from various areas of the marine environment, which indicates that metal contamination has resulted in biological impact.

III. DELETERIOUS EFFECTS OF METALS IN THE FIELD

A. MERCURY POLLUTION

It was the incidents involving human fatalities in Japan, from Hg poisoning, which initiated concern over metal pollution in aquatic environments. These cases have been well documented elsewhere and only a brief overview is presented here as an introduction to later discoveries. In the most important example, that of Minamata Bay, some 80 tonnes of Hg (used as a catalyst in the production of acetaldehyde and vinyl chloride) were discharged over a period from 1932 to 1968, with the result that sediments in some areas of the bay contained several hundred micrograms per gram Hg and concentrations in water as high as 3.6 μg/l Hg were recorded.[59] By the early 1950s, there were mortalities in fish and invertebrates from the bay and cats, dogs, rats, and waterfowl inhabiting the waterfront displayed symptoms of poisoning. Although the first human case was recorded in 1956, it was not until the end of the decade that mobilization of methyl mercury (McHg) through the food chain was identified as the cause of the problem and by 1975, there were more than 800 verified cases of 'Minamata disease' of which more than 100 proved fatal, primarily among fishermen and their families.

Since Minamata, attention has focused on other potential Hg sources (notably discharges from chlor-alkali plants and from the use of Hg as fungicides, pesticides, and antifouling preparations) and contamination is frequently detected where the use of Hg by industry is high (Table 5).

Apart from observations of food chain magnification, however, there are surprisingly few substantiated reports of the effects of Hg contamination in marine biota. The absence of intertidal organisms has been reported near Hg inputs or where levels in sediments are high,[8,60] although in none of these studies can the presence of adverse factors other than Hg be excluded as contributing to the elimination of aquatic biota.

Widespread regulations have, in recent years, eliminated the threat of Minamata-type catastrophes; however, despite reductions in inputs, "clean-up" may take many years in some areas due to the retention of Hg by sediments. Thus, for example, sediment Hg concentrations as high as 100 μg/g were still detectable at certain sites in Minamata Bay 10 years after discharges ceased.[59]

B. METAL-POLLUTED SEDIMENTS

Most of the experimental evidence of metal toxicity is related to dissolved forms though, in estuaries and bays, sediments may trap large proportions of incoming contaminants (tragically apparent at Minamata) so that sediment metal concentrations often exceed those in overlying water by several orders of magnitude. Examples of values from polluted sites are shown in Table 5. Uptake by organisms of even a minute fraction of sediment-bound metal could have considerable toxicological significance especially where conditions favor bioavailability.[12] Elevated metal concentrations in pore water may also contribute significantly to sediment toxicity.

Evidence for deleterious effects is usually established by the absence of sensitive species or by the induction of resistance mechanisms and adaptation in tolerant forms. There are few studies, however, where effects can be related to a single contaminant and in order to confirm that pollution (as opposed to natural variation) is the cause of change, biological observations are usually backed up by chemical measurements and bioassay response. Applying this combined approach at sites in Puget Sound, Long and Chapman[63] were able to show that, where combined contaminant levels (metals plus organics) were high in sediments and subsequently induced toxicity in bioassays (amphipod lethality; oligochaete respiration; larval development in fish, oysters, and polychaetes; cytotoxicity and mutagenicity in fish cells), lowered diversity in infauna could be expected. Reduced numbers of echinoderms and arthropods and a predominance of polychaetes and mollusks, were consistent features of benthic communities at polluted stations. Although agreement between toxicological observations and sediment pollution gradients (up to 581, 2109, and 1190 μg/g for Cu, Pb, and Zn) were generally good, biological responses could not always be satisfactorily predicted from chemical data, highlighting the need to consider site-specific factors which affect bioavailability.

C. SEWAGE DISPOSAL AND SLUDGE DUMPING

The discharge and dumping of sewage and industrial spoils may release or redistribute significant quantities of heavy metals in the marine environment. In the U.K. for example, 10 million tons of sewage (25% of the U.K. total) are discharged annually to coastal waters.[10] Studies near outfalls in California[61] have shown that, locally, there may be strong enrichment of metals in sediments (up to 200 times background, see Table 5). However, although chemically, it may be easy to distinguish the presence of contamination — and for metals such as Ag, Cd, and Cu, enhanced bioaccumulation is a frequent observation — evidence of deleterious effects in biota is limited. Impact depends largely on the dispersive character of the area with problems occurring mainly at accumulative sites. McGreer[64] has shown,

TABLE 5

Examples of Metal Concentrations (µg/g) in Contaminated Sediments[a] (Compiled from Sources Indicated)

Metal	Baltic Sea[5] (various sources)	Bristol Channel/ Severn estuary, U.K.[9] (industry, sewage)	Mersey estuary U.K.[60] (sewage, industry including chlor-alkali)	Los Angeles outfall, California[61] (sewage)	Derwent estuary Tasmania[5] (refinery, chlor-alkali)	Restronguet Creek, U.K.[9] (mining)	Port Pirie, Australia[62] (smelter)
As		8	71			2520 (13)	151 (1.0)
Cd	8.1 (<0.01)	1.1	3.9	66 (0.3)	862	1.2 (0.3)	267 (0.5)
Cu	283 (1.0)	54	144	940 (8.3)	>400	2,540 (19)	122 (3.0)
Hg	9 (0.01)	0.48	6.2	5.4 (0.04)	1,130	0.22 (0.12)	8
Ni	920 (1.0)	33	44	130 (9.7)	42	32 (28)	19.4 (12)
Pb	400 (2)	88	205	580 (6.1)	>1,000	400 (2)	5,270 (2)
Zn	2,090 (6)	255	255	2,900 (43)	>10,000	2,090 (6)	16,667 (11)

[a] Maximum concentrations shown together with local background values (in parentheses), where given.

for example, that sediment-bound metals, originating from sewage discharge in the Fraser River estuary, Canada, were influencing the distribution of clams, *Macoma balthica*. Although metal concentrations (0.89 μg/g for Hg, 234 μg/g for Cu, 264 μg/g for Zn) were not exceptional, or even toxic to adults, their joint action was considered sufficient to prevent settlement and survival of juveniles near to the outfall.

In a rare demonstration in the field of the potential value of biochemical indices, Brown et al.[21] discovered an increase in Cd, Cu, and Zn binding to MT, accompanied by 'spillover' of metals into the enzyme pool, in mussels collected in the vicinity of a sewage input. Interestingly, these observations correlated with decreasing mussel population densities near to the outfall, although a direct link between the two events was not established.

D. IMPACT FROM METAL MINING AND SMELTING

Based on levels of contamination, the most significant anthropogenic releases of metals to the marine environment originate from the disposal of mine tailings and the discharge of wastes from smelters and refineries. Consequently some of these localities provide conclusive evidence of the deleterious effects of metals.

Southwest England has for centuries been the scene of widespread mining for metals, such as Sn, Cu, Zn, As, Pb, and Ag and a number of estuaries are heavily contaminated. Metal concentrations in water and sediments of Restronguet Creek, for example, exceed 'normal' values by orders of magnitude (Tables 1 and 5). Biological surveys have revealed that while some species, such as the polychaete (*Nereis diversicolor*), crabs (*Carcinus maenas*), and oysters (*Ostrea edulis*), have adapted to conditions in the creek, many others are absent from sites where metal contamination is highest.[11] Bivalves including mussels *Mytilus edulis*, cockles *Cerastoderma edule*, and clams, *Scrobicularia plana* are conspicuously absent when compared with nearby uncontaminated estuaries. Bryan and co-authors[11] considered Cu and Zn to be responsible for the impoverished fauna of Restronguet Creek, largely as a result of reduced recruitment and survival of juvenile forms.

Large reductions in clam production and a decrease in species diversity of benthic invertebrate communities were also evident in Goa estuaries heavily impacted with mine wastes,[65] though high turbidity, blanketing of bottom fauna, and lowered oxygen tensions probably contributed significantly to these effects. Similarly, in the Southeast Asia tin mining strip, secondary factors, notably increased suspended solids resulting from tailings dispersal, may exert the greatest impact. Corals in particular are highly intolerant of turbid waters.[66]

At the other end of the extraction process, wastes from smelters and refineries are potentially most hazardous since metals are usually in a more chemically active form. Studies by Ward and co-authors[62] at the site of the world's largest Pb smelter at Port Pirie in Australia (where some 600 km^2 have been contaminated with Cd, Pb, Zn, As, Cu, Mn, and Sb), have shown that metals are involved in the elimination of 20 species of fish and crustaceans from sea-grass communities. Sediments, the most appropriate measure of contamination, were considered to play a significant role in the toxicity of metals. Although effects were greatest near the effluent source, where sediment values 200 to 1000 times background were recorded (Table 5), species richness was reduced by sediment concentrations (0.5 to 0.7 μg/g Cd, 10 to 14 μg/g Pb, 62 to 92 μg/g Zn) only five times background. The authors concluded that changes in community structure were probably due to an array of sublethal effects rather than acute toxicity, and that, although Zn was probably most toxic, biological impact (observed over an area of 100 km^2) was due to the joint action of several metals.

In situ cage-culture techniques have sometimes been used to evaluate the impact of smelting and mining wastes. For example, in studies with phytoplankton assemblages transplanted along contamination gradients in Norwegian fjords (Zn, Cu, Pb, Cd, and Hg concentrations up to 610, 4, 2, 3 and 0.4 μg/l, respectively) Eide and co-authors[67] were able to demonstrate that elimination of sensitive species and growth inhibition in tolerant forms

TABLE 6
Effects of Tributyltin (TBT) on Marine and Estuarine Organisms

Species	Concentration of TBT in water (ng/l as Sn)	Effect	Ref.
Nucella lapillus, dogwhelk	1—10	Imposex, impaired reproduction	41
Crassostrea gigas, oyster[a]	8	Shell thickening	70
	20	Reduced growth, viability	71
Mytilus edulis, mussel[a]	40	Reduced viability	72
Venerupis decussata, clam[a]	40	Reduced growth, viability	73
Gammarus oceanicus, amphipod[a]	120	Reduced growth	74
Homarus americanus, lobster[a]	400	Reduced viability	75
Pavlova lutheri *Skeletonema costatum* } microalgae *Dunaliella tertiolecta*	40—400	Reduced growth	76

[a] Larvae.

were a function of reduced water quality. Evidence for the involvement of smelter discharges in the increased incidence of fish deformities has been discussed previously.

Residues from the production of titanium dioxide have been dumped in the sea or released into estuaries for many years. Possible effects could arise from high acidity, ferrous sulfate, and some trace metals (Mn, Ti, Cr, V, Cd). However, although tests show the potential for harmful effects, these are not easily demonstrated in the field. Complexation of metals with rapidly precipitating ferric oxide may help to reduce their toxicity.

E. ANTIFOULING AGENTS — METALS AND TBT

Because of their toxic properties, metals, particularly Cu, have been incorporated into antifouling paints since the beginning of this century. Following observations of Cu tolerance in some fouling organisms, a number of other biocides, including organomercury, arsenic, and lead compounds, have been used to enhance the toxic properties of Cu. The use of these 'boosters' was phased out around 1970 because of fears concerning their environmental toxicity, though there is little published information on their impact in the field.

Since 1970, TBT compounds have been used increasingly in antifouling preparations (for use on boat hulls and fish-farming gear), both in conjunction with Cu and as the sole biocidal agent. Although TBT eventually degrades in the environment, effects on nontarget organisms have recently been recognized at lower levels than was ever envisaged. Shell abnormalities and reduced growth and recruitment in oysters, *Crassostrea gigas*, sampled near marinas, were the first indications of the "TBT problem"[68] and subsequently effects have been demonstrated in a number of marine and estuarine species. TBT concentrations in inshore waters typically range from a few nanograms per liter in boat-free areas to levels in excess of 600 ng/l (as Sn) near marinas,[69] often exceeding toxic thresholds observed for aquatic organisms, especially mollusks (Table 6). The most sensitive species identified so far is the dogwhelk, *Nucella lapillus*, which exhibits 'imposex' (the imposition of male characteristics on females) at concentrations as low as 1 ng/l TBT (as Sn), and complete reproductive failure at 10 ng/l. *N. lapillus* is currently in decline along much of the south coast of England and there appear to be few populations in England where the effects of TBT are not readily observed.[41]

Following the discovery of the highly toxic nature of TBT-based paints, regulations have recently been placed on their usage on small boats in France (1982) and the U.K. (1987). In view of the reservoir of TBT in estuarine sediments and its continued application on large vessels, however, it may be some time before contamination is eliminated from many inshore localities.

The association of TBT with sediments may have important consequences for infauna, especially bivalves, which have become increasingly scarce at some highly contaminated sites in the U.K.[69] However, although laboratory experiments show that spiked sediments (1 µg/g TBT) are toxic to clams, *S. plana*,[80] further evidence is required to confirm whether or not TBT is the cause of the decline in field populations.

F. ORGANOLEAD

In addition to TBT, a number of other organometallic compounds have proved to be extremely toxic to marine life as a result of their release into the sea. For example alkyl Pb compounds, originating from the manufacture of petrol additives, were almost certainly responsible for bird kills in the Mersey estuary, U. K., during 1979 to 1982. Consumption of clams and worms which had accumulated trimethyl Pb from water was identified as the critical pathway to birds.[77] Fortunately, as a result of improved effluent standards, Pb burdens in invertebrate fauna in the Mersey have declined substantially in recent years[60] and to date no further bird kills have been reported.

G. SEA-SURFACE MICROLAYER

Metal concentrations in the surface microlayer of the sea can often exceed subsurface concentrations by orders of magnitude at inshore sites and may, therefore, threaten the survival of organisms which congregate in the upper layers.[78] Recent studies,[78,79] in Puget Sound, for example, have shown that the abundance of neustonic organisms and also numbers, chromosomal integrity, and viability of fish eggs, were reduced in surface film samples from urban areas (Σ Cd, Pb, Zn, Ag, and Cu up to 1420 µg/l) compared with samples from control sites (combined metals 58 µg/l). The most significant metal enrichments at urban sites were for Cu and Pb, the latter as a result of petrol combustion. Enrichments for Ag were attributed to sewage inputs. However, although metal-induced effects would be expected at these high concentrations, it seems likely that other contaminants which are similarly magnified in the surface film, including TBT, PCBs, and hydrocarbons, will also play a considerable role in determining overall toxicity.

IV. SUMMARY

Following the development of a wide range of criteria to assess the impact of metals on marine organisms, effects are now recognized at much lower levels than in earlier LC_{50} studies. Growth, reproduction, and recruitment are generally the processes most susceptible to metal stress and sublethal damage may be detected at concentrations more than an order of magnitude lower than in acute tests. Effects on embryonic and larval development probably have the greatest ecological significance in terms of preserving the health of marine communities. The trend towards increasingly more sensitive indices may eventually enable us to visualize effects at even lower levels; biochemical studies, related to the induction and saturation of detoxification mechanisms, seem particularly promising in this respect, providing their ecological relevance can be established.

On present evidence, Cu and Hg are potentially the most hazardous metals present in the marine environment and their harmful effects have been demonstrated in many studies. Overall, Cu is perhaps most significant and, arguably, may be toxic at levels only marginally above background. Although Hg is extremely toxic, concentrations in the field rarely exceed even the lowest experimentally derived thresholds and, despite the dangers in extrapolating data from the laboratory to nature, it would seem that recent regulations on Hg emissions have considerably reduced the direct threat of Hg pollution. Nevertheless, the consequences of food chain biomagnification of McHg residues still remain a justifiable cause for concern in a number of contaminated areas.

Recently, the impact of organic forms of several other metals has assumed increasing importance. TBT, for example, is one of the most toxic compounds released into the marine environment, directly affecting recruitment and survival of aquatic organisms, especially molluscs. In the case of organolead, effects may, as with MeHg, be most severe in top predators.

For metals such as Ag, Cd, Zn, Pb, and Cr, effects might be expected only in highly contaminated inshore areas, particularly estuaries and embayments, and then usually as a result of their joint action; the individual impact of these metals has rarely been demonstrated in the field. Because of their low toxicities, Se and Ni present few problems for aquatic organisms. Arsenic appears to be relatively harmless to marine fauna but may, surprisingly, affect phytoplankton at concentrations only five times greater than background.

However, although the temptation to generalize about pollutant effects may be great, extreme caution is warranted in view of the large number of environmental and physiological factors which influence the toxicity of metals, notably the wide range of tolerance displayed by different organisms. In addition, indirect effects caused by the elimination of sensitive species could have far greater significance for marine communities than indicated in toxicity studies with single species. Consequently, the incidents of metal pollution described in this chapter merely serve to highlight the types of change which can occur at contaminated sites and do not necessarily signify universally applicable responses. Clearly, reasonable assessment and prediction of environmental impact is best made on a regional basis, following a thorough consideration of local conditions.

ACKNOWLEDGMENTS

Parts of this work were supported by the Department of the Environment under contract PECD 7/7/226.

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Annex IV

Baseline Water Quality Results

BLACK POINT BASELINE STUDY

WATER

N1 - N5

		1990			1991											
		OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Avg	Min	Max
pH	N1	7.70	8.20	7.80	7.83	7.78	7.97	7.88	7.76	7.74	7.74	7.96	7.98	7.86	7.70	8.20
	N2	7.80	8.20	7.90	7.86	7.86	7.94	7.92	7.92	7.92	7.96	7.92	8.25	7.95	7.80	8.25
	N3	7.80	8.20	7.90		7.90	8.05	8.05	8.01	7.59	7.95	7.86	8.19	7.95	7.59	8.20
	N4	7.80	8.20			7.93		8.20	8.10	7.74	8.04	7.83	8.32	8.02	7.74	8.32
	N5	7.70	8.30	7.90			7.90	8.00	8.02	7.70	8.09	7.83	8.10	7.95	7.70	8.30
Temperature	N1	23.0	22.6	19.8	18.0	18.7	25.0	27.7	28.9	27.8	27.8	29.7		24.5	18.0	29.7
	N2	23.0	22.7	19.8	18.7	19.0	25.0	28.0	28.8		29.5	29.0		24.4	18.7	29.5
	N3	23.0	22.6	19.8	19.2	20.5	25.0	25.0	28.9	29.7	29.8	29.4		24.8	19.2	29.8
	N4	23.0	27.2	20.3	19.6	21.0	19.6	27.2	28.8		29.8	29.3		24.6	19.6	29.8
	N5	23.0	22.8	20.0	19.0	19.7	25.0	27.3	28.9		29.6	29.0		24.4	19.0	29.6
Turbidity	N1	1.3	5.6	0.6	10.0	5.0	3.3	7.5	2.4	9.0	9.0	10.4	16.7	6.7	0.6	16.7
	N2	1.7	5.2	2.0	9.5	2.4	1.3	9.0	3.7	5.3	11.7	12.2	13.2	6.4	1.3	13.2
	N3	1.7	2.5	0.8	5.2	2.0	0.5	0.5	3.1	8.4	26.4	12.5	15.4	6.6	0.5	26.4
	N4	4.1	7.1	1.2	6.4	0.6	6.4	7.1	2.3	2.8	6.3	9.5	22.4	6.3	0.6	22.4
	N5	4.3	6.0	1.7	6.2	1.7	3.5	8.5	1.4	3.6	4.5	10.0	20.0	6.0	1.4	20.0
Conductivity	N1	46.7	47.8	50.0	47.6	46.5	40.4	47.6	38.1	24.1	24.1	34.5	46.5	41.2	24.1	50.0
	N2	49.7	42.8	53.3	48.1	46.7	40.0	47.0	35.0	18.9	16.4	38.4	47.1	40.3	16.4	53.3
	N3	45.7	42.9	47.7	48.9	46.7	38.4	38.4	37.6	26.1	33.1	37.5	48.3	40.9	26.1	48.9
	N4	46.2	46.7	47.3	48.2	47.7	48.2	46.7	33.6	27.3	16.2	41.7	48.9	41.6	16.2	48.9
	N5	46.5	43.4	47.1	48.7	47.3	43.3	47.3	34.7	30.5	17.5	42.7	48.9	41.5	17.5	48.9
Salinity	N1	28.0	31.0	28.0			22.4	25.1	20.2	11.9	7.9	16.5	25.1	21.6	7.9	31.0
	N2	29.0	31.0	28.0			22.2	24.7	17.7	9.1	7.6	18.6	25.4	21.3	7.6	31.0
	N3	27.0	31.0	28.0			21.2	23.9	20.0	13.0	16.2	18.1	26.1	22.5	13.0	31.0
	N4	28.0		29.0			25.0	24.5	17.7	13.6	7.5	20.4	26.4	21.3	7.5	29.0
	N5	28.0		28.0			24.2	24.9	18.4	15.4	8.1	20.9	26.5	21.6	8.1	28.0
DO	N1	7.9	8.4	7.5	8.4	7.5	8.0	7.7	7.4	6.5	6.5	6.1		7.5	6.1	8.4
	N2	7.8	8.5	7.9	7.7	7.5	8.0	7.4	6.7		5.7			6.7	0.0	8.5
	N3	7.2	7.9	8.2	8.6	7.6	7.6	7.6	8.0	6.4		5.9		7.5	5.9	8.6
	N4	7.4	7.5	9.2	12.2	7.4	12.2	7.5	9.0	6.4		5.7		8.4	5.7	12.2
	N5	7.3	8.3	9.4	10.0	7.4	8.1	7.6	9.3	6.5		5.5		7.9	5.5	10.0
TSS	N1	2.0	2.0	2.0	195.0	3.0	2.0	3.0	2.4	0.1	76.4	4.6	12.9	25.4	0.1	195.0
	N2	7.1	2.0	2.0	198.0	1.0	0.4	2.0	0.3	4.7	78.5	4.5	7.8	25.7	0.3	198.0
	N3	2.3	2.0	2.0	211.0	2.0	1.0	1.0	1.1	1.5	171.1	11.3	9.1	34.6	1.0	211.0
	N4	1.6	1.0	2.0	196.0	3.0	196.0	1.0	0.3	5.8	85.5	5.2	13.2	42.6	0.3	196.0
	N5	7.0	3.0	2.0	235.0	4.0	1.0	1.0	2.2	2.8	88.7	19.6	12.0	31.5	1.0	235.0
Sulphate	N1		2800	2750	2280	2510	1960	2170	1507	1065	1065	1450	2077	1967	1065	2800
	N2		2800	2310	2230	2330	1910	2330	1272	1306	834	1550	2066	1903	834	2800
	N3		2500	2450	2230	2360	1750	1750	1491	1494	1445	1510	2208	1926	1445	2500
	N4		2510	2300	2310	2450	2310	2510	1263	1548	914	1710	2297	2011	914	2510
	N5		2600	2290	2320	2620	1980	2450	1304	1700	920	1800	2205	2017	920	2620

BLACK POINT BASELINE STUDY

WATER

F1 S

	Oct-90	NOV	DEC	Jan-91	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	Avg	Min	Max
pH (pH unit)	7.80	8.20	7.90	7.95	7.84	7.97	7.95	7.69	7.80	7.92	7.88	8.52	7.95	7.69	8.52
Temperature ('C)	23.0	22.7	19.9	16.2	19.0	25.0	28.0	28.8		29.5	29.0		24.1	16.2	29.5
Turbidity (NTU)	4.6	4.9	3.5	8.3	6.5	2.1	8.3	4.0	3.3	9.3	16.3	15.0	7.2	2.1	16.3
Conductivity (mS cm-1)	49.6	43.3	49.6	48.6	46.2	38.9	45.6	33.2	18.4	14.7	40.2	47.7	39.7	14.7	49.6
Salinity (g/kg)	30.0	31.0	28.0	18.6	18.3	22.5	6.6	16.1	8.8	8.7	19.4	25.8	19.5	6.6	31.0
Dissolved oxygen (mg/l)	7.0	7.8	8.2	8.1	7.6	8.0	7.8	8.3	7.3	7.7	5.6	6.5	7.5	5.6	8.3
TSS (mg/l)	3.1	2.0	1.0	265.0	4.0	13.0	1.0	0.5	2.1	95.7	5.5	15.7	32.9	0.5	265.0
BOD (5 day) (mg/l)	1.00		1.00	0.90	1.20	1.39	1.06	0.44	1.57	0.73	0.59	0.70	0.96	0.44	1.57
Organic carbon (mg/l)	4.0			1.8	1.7	2.5	1.4	0.9	8.0		8.0	8.0	4.0	0.9	8.0
Grease and oil (mg/l)	0.20	0.01	0.01	7.90	4.60	5.70	5.70	34.00	0.30	0.10	0.10	0.10	4.89	0.01	34.00
Sulphates (mg/l)	2100	2400	2250	2260	2250	1760	2410	1194	1392	824	1600	2195	1886	824	2410
Bicarbonates (mg/l)	6.0	11.0	8.0	13.2	11.0	7.9	10.9	5.8	4.6	7.9	9.7	7.2	8.6	4.6	13.2
Phosphorus (mg/l)	0.19	0.10		0.05	0.05	0.05	0.05	0.02	0.04	0.03	0.04	0.04	0.06	0.02	0.19
Nitrate-N (mg/l)	0.06	0.01	0.50	0.13	0.13	0.49	0.01	0.65	0.57	0.87	0.52	0.09	0.34	0.01	0.87
Ammonia-N (mg/l)	0.01	0.05		0.17	0.11	0.10	0.01	0.04	0.03	0.01	0.05	0.11	0.06	0.01	0.17
Organic N (mg/l)	0.10	0.06		0.23	0.12		0.73	0.50	0.31	1.51	12.30	8.40	2.43	0.06	12.30
Chlorophyll 'A' (mg/m3)	1.7	1.5		4.7	2.0		2.8	11.6	2.1	3.6	3.0	3.9	3.7	1.5	11.6
Chloride (mg/l)	15000	17000	16600	17800	17000	14600	14900	10529	6523	4874	12800	16732	13697	4874	17800
Chlorine (mg/l)	<0.1	<0.1	≤0.1	≤0.1	≤0.1	≤0.1	≤0.1	≤0.1	≤0.1	≤0.1	≤0.1	≤0.1	0.00	0.00	0.00
Detergents (mg/l)	0.05	0.05		0.13	0.03	0.01	0.01	0.05	0.02	0.05	0.03	0.01	0.04	0.01	0.13
Magnesium (mg/l)	946														
Calcium (mg/l)	310														
Potassium (mg/l)	359														
Sodium (mg/l)	7817														
Cadmium (ug/l)	0.54														
Mercury (ug/l)															
Chromium (ug/l)	0.8														
Copper (ug/l)	< 5														
Lead (ug/l)	0.9														
Nickel (ug/l)	< 5														
Zinc (ug/l)	16														
Arsenic (ug/l)	< 1														
Manganese (ug/l)	20														
Selenium (ug/l)	< 1														
Iron (ug/l)	222														
Aluminium (ug/l)	208														
Fecal coliform CFU/100ml	3000	400	10700	760	40	500	100	240	80	960	640	190	1468	40	10700
E. coli CFU/100ml	2700	350	600	100	0	200	40	100	0	800	460	120	456	0	2700

BLACK POINT BASELINE STUDY

WATER

F2 S

	Oct-90	NOV	DEC	Jan-91	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	Avg	Min	Max
pH (pH unit)	7.80	8.50	7.90	7.88	7.93	[illegible]	7.88	7.87	7.90	7.92	7.90	8.03	7.96	7.80	8.50
Temperature ('C)	23.0	22.5	19.7	18.2	18.9	25.0	28.8	28.9		29.5	29.0		24.4	18.2	29.5
Turbidity (NTU)	4.3	2.8	0.5	8.1	4.5	4.8	11.6	2.4	6.5	22.8	9.6	25.2	8.6	0.5	25.2
Conductivity (ms/cm)	49.9	43.5	48.6	48.2	47.3	39.9	46.1	33.9	24.5	17.7	31.7	45.9	39.8	17.7	49.9
Salinity (g/kg)	30.0	30.0	28.0	22.5	23.8	20.5	14.8	18.6	12.1	9.1	15.0	24.6	20.8	9.1	30.0
Dissolved oxygen (mg/l)	7.5	7.8	8.4	7.8	7.8	8.5	8.8	8.2	6.8	7.5	5.6	6.6	7.6	5.6	8.8
TSS (mg/l)	6.6	2.0	1.0	257.0	4.0	11.0	3.0	4.9	2.9	119.3	2.9	19.0	35.3	1.0	257.0
BOD (5 day) (mg/l)	1.00	1.00	1.00	1.10	1.20	1.23	0.82	0.29	1.29	0.72	0.59	0.64	0.91	0.29	1.29
Organic carbon (mg/l)	4.0			2.5	2.5	2.0	0.2	0.7	8.0	7.0	10.0	9.0	4.6	0.2	10.0
Grease and oil (mg/l)	0.20	0.14	0.26	6.20	5.70	6.80	6.80	18.00	0.10	0.10	0.10	0.10	3.71	0.10	18.00
Sulphates (mg/l)	1900	2900	2480	2260	2160	1920	2390	1196	1513	909	1260	2272	1930	909	2900
Bicarbonates (mg/l)	6.0	10.0	8.0	11.9	10.3	7.7	9.7	8.6	4.4	7.8	8.8	7.4	8.4	4.4	11.9
Phosphorus (mg/l)	0.18	0.15		0.06	0.07	0.08	0.04	0.01	0.03	0.05	0.05	0.03	0.07	0.01	0.18
Nitrate-N (mg/l)	0.05	0.03	0.50	0.35	0.15	0.51	0.14	0.63	0.88	0.80	0.69	0.08	0.40	0.03	0.88
Ammonia-N (mg/l)	0.03	0.06		0.02	0.13	0.16	0.01	0.04	0.01	0.04	0.03	0.11	0.06	0.01	0.16
Organic N (mg/l)	0.10	0.07		0.18	0.21	0.06	1.26	0.42	0.33	0.26	6.70	7.10	1.52	0.06	7.10
Chlorophyll 'A' (mg/m3)	1.5	0.9		5.5	3.2	0.4	2.8	12.9	1.7	2.5	2.8	4.1	3.5	0.4	12.9
Chloride (mg/l)	14000	17000	16800	17400	17000	13600	16000	10369	7445	6027	9960	16910	13543	6027	17400
Chlorine (mg/l)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Detergents (mg/l)	0.05			0.16	0.03	0.05	0.01	0.04	0.01	0.04	0.01	0.01	0.04	0.01	0.16
Magnesium (mg/l)															
Calcium (mg/l)															
Potassium (mg/l)															
Sodium (mg/l)															
Cadmium (ug/l)															
Mercury (ug/l)															
Chromium (ug/l)															
Copper (ug/l)															
Lead (ug/l)															
Nickel (ug/l)															
Zinc (ug/l)															
Arsenic (ug/l)															
Manganese (ug/l)															
Selenium (ug/l)															
Iron (ug/l)															
Aluminium (ug/l)															
Fecal coliform CFU/100ml	600	700	800	800	220	600	140	140	80	1080	280	210	463	80	1080
E. coli CFU/100ml	320	500	660	160	20	300	60	60	0	1000	200	180	288	0	1000

BLACK POINT BASELINE STUDY

WATER

F2 L

	Oct-90	NOV	DEC	Jan-91	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	Avg	Min	Max
pH (pH unit)	7.80	8.10	7.90	7.90	7.91		7.92	7.89	7.92	7.89	7.89	8.52	7.97	7.80	8.52
Temperature ('C)	23	22.6	19.8	18	17.8	25	28	27.9		29.6	28.9		24.1	17.8	29.6
Turbidity (NTU)	1.8	8.3	0.6	11.5	4.8	3.8	19.6	3.8	11.2	70.2	25.5	35.2	16.4	0.6	70.2
Conductivity (ms/cm-1)	49.9	43.5	49.5	48.99	48.9	40.8	46.9	42.63	29.25	11.6	41.6	49.2	41.9	11.6	49.9
Salinity (g/kg)	30	31	31	22.6	27.7		8.1	21.3	14.7	5.7	20.3	26.7	21.7	5.7	31.0
Dissolved oxygen (mg/l)	7.4	7.5	8.8	8.6	7.9	8.54	8.4	7.8	6.7	6.88	6.83	6.49	7.65	6.49	8.80
TSS (mg/l)	4.0	2.0	1.0	251.0	1.0	0.1	1.0	1.5	6.9	269.5	3.0	27.1	47.3	0.1	269.5
BOD (5 day) (mg/l)	1.00	1.00	1.00	0.90	1.33	1.63	0.74	0.22	1.43	0.73	0.59	0.77	0.95	0.22	1.63
Organic carbon (mg/l)				2.1	1.7		0.4	1	8	11	8	9	5.15	0.40	11.00
Grease and oil (mg/l)		0.14		4.60	11.10		5.70	18.00	0.10	0.10	0.10	0.10	4.44	0.10	18.00
Sulphates (mg/l)	2200	2700	2470	2300	2250	1960	2350	1765	1802	1563	1700	2347	2117	1563	2700
Bicarbonates (mg/l)	6	10	8	10.8	10.1	7.5	9.9	8.8	4.62	7.52	9.5	7.5	8.4	4.6	10.8
Phosphorus (mg/l)	0.18	0.09		0.08	0.07	0.06	0.04	0.01	0.03	0.19	0.08	0.03	0.08	0.01	0.19
Nitrate-N (mg/l)	0.05	0.01	0.50	0.25	0.12	0.46	0.17	0.36	0.78	0.56	0.51	0.08	0.32	0.01	0.78
Ammonia-N (mg/l)	0.02	0.06		0.02	0.12	0.12	0.01	0.06	0.01	0.07	0.06	0.11	0.06	0.01	0.12
Organic N (mg/l)	0.11	0.07		0.20	0.21		0.55	0.38	0.12	4.22	5.00	9.60	2.05	0.07	9.60
Chlorophyll 'A' (mg/m3)	1.5	1.76		5.5	2.17	1.24		10.7	1.68	4.68	1.93	3.03	3.42	1.24	10.70
Chloride (mg/l)	14000	17000	16900	17200	17100	13800	16200	13772	9075	11699	13420	17282	14787	9075	17282
Chlorine (mg/l)															
Detergents (mg/l)	0.05			0.05	0.01		0.01	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.05
Magnesium (mg/l)															
Calcium (mg/l)															
Potassium (mg/l)															
Sodium (mg/l)															
Cadmium (ug/l)															
Mercury (ug/l)															
Chromium (ug/l)															
Copper (ug/l)															
Lead (ug/l)															
Nickel (ug/l)															
Zinc (ug/l)															
Arsenic (ug/l)															
Manganese (ug/l)															
Selenium (ug/l)															
Iron (ug/l)															
Aluminium (ug/l)															
Faecal coliform CFU/100ml	300	800	2000	720	200	680	440	400	0	1120	400	250	609	0	2000
E. coli CFU/100ml	200	700	1600	160	20	260	200	200	0	900	320	200	397	0	1600

BLACK POINT BASELINE STUDY

WATER

F3 S

	Oct-90	NOV	DEC	Jan-91	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	Avg	Min	Max
pH (pH unit)	7.90	8.20	7.90	7.80	7.91	7.88	7.89	8.17	7.97	7.94	7.83	8.17	7.96	7.80	8.20
Temperature ('C)	23.0	22.5	19.9	19.1	19.8	25.0	28.0	29.2		30.0	28.8		24.5	19.1	30.0
Turbidity (NTU)	3.3	1.8	1.5	10.5	3.5	2.8	4.3	1.6	7.5	12.7	9.0	6.8	5.4	1.5	12.7
Conductivity (ms/cm)	49.7	42.9	48.8	48.8	49.4	39.8	45.3	34.1	25.0	15.7	42.4	47.7	40.8	15.7	49.7
Salinity (g/kg)	30.0	30.0	28.0	29.3	29.1	26.4	18.6	14.8	13.4	7.3	20.7	26.0	22.8	7.3	30.0
Dissolved oxygen (mg/l)	7.4	8.3	8.5	8.5	7.9	8.0	7.0	8.5	7.2	7.7	5.7	6.4	7.6	5.7	8.5
TSS (mg/l)	3.0	2.0	1.0	244.0	5.0	1.0	1.0	10.5	5.5	98.2	5.2	4.1	30.9	0.6	244.0
BOD (5 day) (mg/l)	1.00	1.00	1.00	1.20	1.57	1.49	0.74	0.30	1.39	1.01	0.48	0.64	0.99	0.30	1.57
Organic carbon (mg/l)	4.0			0.4	2.0	3.6	1.5	0.6	8.0	8.0	7.0	9.0	4.4	0.4	9.0
Grease and oil (mg/l)	0.10	0.01	0.03	6.80	7.90	5.70	5.70	18.00	0.30	0.10	0.10	0.10	3.74	0.01	18.00
Sulphates (mg/l)	1900	2600	2640	2230	2240	1860	2360	1273	1471	889	1670	2280	1951	889	2640
Bicarbonates (mg/l)	6.0	10.0	7.0	13.4	10.1	8.0	9.2	7.0	3.7	7.5	11.7	7.5	8.4	3.7	13.4
Phosphorus (mg/l)	0.16	0.10	[illegible]	0.07	0.06	0.07	0.03	0.02	0.03	0.03	0.04	0.05	0.06	0.02	0.16
Nitrate-N (mg/l)	0.07	0.03	0.50	0.37	0.18	0.49	0.17	0.62	0.82	0.76	0.50	0.07	0.38	0.03	0.82
Ammonia-N (mg/l)	0.03	0.06		0.02	0.11	0.11	0.01	0.04	0.01	0.02	0.04	0.07	0.05	0.01	0.11
Organic-N (mg/l)	0.09	0.06	[illegible]	0.19	0.20	0.26	0.23	0.59	0.33	1.75	9.80	7.10	1.87	0.06	9.80
Chlorophyll 'A' (mg/m3)	1.4	1.0		5.2	1.8	0.3	2.5	10.7	3.2	2.5	1.4	3.6	3.0	0.3	10.7
Chloride (mg/l)	15000	17000	16700	17400	17000	13500	15900	10582	7533	5442	13700	17229	13916	5442	17400
Chlorine (mg/l)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Detergents (mg/l)	0.05	0.05		0.03	0.01	0.05	0.04	0.05	0.01	0.02	0.01	0.01	0.03	0.01	0.05
Magnesium (mg/l)			1077	1013	1072	857	1000	710	416	301	825	1010	828	301	1077
Calcium (mg/l)			390	359	400	325	409	239	207	160	355	406	325	160	409
Potassium (mg/l)			400	333	353	274	306	183	119	160	260	319	271	119	400
Sodium (mg/l)			8559	9040	9381	6867	8090	5160	3990	3330	7280	7220	6892	3330	9381
Cadmium (ug/l)		0.05	0.05	0.05	0.05	0.13	0.08	0.11	0.18	0.09	0.10	0.04	0.08	0.04	0.18
Mercury (ug/l)				< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Chromium (ug/l)		1.4	1.7	2.1	1.2	1.2	1.4	0.5	0.3	1.2	0.2	0.5	1.1	0.2	2.1
Copper (ug/l)		5	5	5	5	5	5	7	5	5	6	5	5	5	7
Lead (ug/l)		0.3	0.7	0.6	0.9	1.7	1.4	0.6	1.7	0.7	0.9	0.6	0.9	0.3	1.7
Nickel (ug/l)			5	5	5	5	5	< 5	5	5	5	5	5	< 5	5
Zinc (ug/l)			5	6	11	6	4	11	5	4	8	1	6	1	11
Arsenic (ug/l)			1.0	1.2	1.2	1.8	1.0	1.0	1.0	1.0	1.0	1.0	1.1	1.0	1.8
Manganese (ug/l)			14	19	10	11	14	8	5	7	8	17	11	5	19
Selenium (ug/l)			< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Iron (ug/l)			94	132	115	256	366	86	264	280	231	350	217	86	366
Aluminium (ug/l)			67	186	86	284	353	110	326	239	235	261	215	67	353
Fecal coliform CFU/100ml	780		2800	280	840	460	460	240	0	920	980	210	725	0	2800
E. coli CFU/100ml	660		1600	160	0	200	220	40	0	700	840	210	421	0	1600

BLACK POINT BASELINE STUDY

WATER

F3 M

	Oct-90	NOV	DEC	Jan-91	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	Avg	Min	Max
pH (pH unit)	7.80	8.10	7.90	7.84	7.92	7.89	7.90	8.11	7.95	7.93	7.85	7.98	7.93	7.80	8.11
Temperature ('C)	23.0	22.5	19.8	18.9	19.5	25.0	25.5	28.4		30.2	28.5		24.1	18.9	30.2
Turbidity (NTU)	1.1	1.4	4.6	11.2	3.5	6.0	6.5	2.8	13.1	26.4	7.0	12.7	8.0	1.1	26.4
Conductivity (ms/cm-1)	45.8	42.7	48.8	48.5	49.4	43.4	46.7	36.5	34.5	26.6	44.4	48.3	43.0	26.6	49.4
Salinity (g/kg)	29.0	30.0	30.0	22.7	28.0	19.2	8.5	21.3	17.6	12.8	21.7	26.4	22.3	8.5	30.0
Dissolved oxygen (mg/l)	7.1	8.0	8.2	8.8	7.7	8.2	7.5	8.4	6.5	7.3	5.9	6.5	7.5	5.9	8.8
TSS (mg/l)	2	2	1	252	45	6	7	0.6	9.2	159.4	67.4	9.04	38.2	0.6	252.0
BOD (5 day) (mg/l)	1.00	1.00	1.00	0.90	1.28	1.92	0.92	0.30	1.15	0.51	0.71	0.52	0.93	0.30	1.92
Organic carbon (mg/l)	3.0			1.4	2.8	3.4	1.4	1.9	8.0	7.0	8.0	9.0	4.6	1.4	9.0
Grease and oil (mg/l)	0.05	0.01		6.20	[illegible]	8.90	7.90	39.00	0.10	0.10	0.10	0.10	6.25	0.01	39.00
Sulphates (mg/l)	2200	2400	2600	2310	2370	2280	2370	1353	2104	1108	1730	2261	2091	1108	2600
Bicarbonates (mg/l)	6.0	10.0	8.0	13.0	9.7	7.9	10.1	7.0	4.6	7.9	12.1	7.5	8.7	4.6	13.0
Phosphorus (mg/l)	0.16	0.10		0.09	0.13	0.12	0.01	0.02	0.03	0.07	0.05	0.04	0.07	0.01	0.16
Nitrate-N (mg/l)	0.07	0.03	0.50	0.34	0.16	0.37	0.09	0.55	0.61	0.68	0.39	0.07	0.32	0.03	0.68
Ammonia-N (mg/l)	0.02	0.05		0.03	0.13	0.10	0.02	0.04	0.02	0.05	0.04	0.07	0.05	0.02	0.13
Organic-N (mg/l)	0.09	0.06		0.08	1.02	0.06	1.62	0.81	0.57	3.21	8.30	3.30	1.74	0.06	8.30
Chlorophyll 'A' (mg/m3)	1.1	1.0		5.2	2.4	1.6	3.0	10.2	1.1	3.0	1.4	4.7	3.2	1.0	10.2
Chloride (mg/l)	15000	17000	16800	17200	16500	14500	16200	11291	11433	8863	14270	17282	14695	8863	17282
Chlorine (mg/l)															
Detergents (mg/l)	0.05	0.05			0.01		0.01	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.05
Magnesium (mg/l)															
Calcium (mg/l)															
Potassium (mg/l)															
Sodium (mg/l)															
Cadmium (ug/l)															
Mercury (ug/l)															
Chromium (ug/l)															
Copper (ug/l)															
Lead (ug/l)															
Nickel (ug/l)															
Zinc (ug/l)															
Arsenic (ug/l)															
Manganese (ug/l)															
Selenium (ug/l)															
Iron (ug/l)															
Aluminium (ug/l)															
Fecal coliform CFU/100ml	750	1400	3600	360	900	480	380	240	100	800	520	220	813	100	3600
E. coli CFU/100ml	500	960	3000	200	20	180	60	80	0	800	420	200	535	0	3000

BLACK POINT BASELINE STUDY

WATER

F4 S

	Oct-90	NOV	DEC	Jan-91	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	Avg	Min	Max
pH (pH unit)	7.80	8.30	8.00	7.83	7.90	7.94	7.94	8.22	7.82	8.06	7.89	8.37	8.01	7.80	8.37
Temperature ('C)	23	22.3	20	19	19.9	25	27.3	29.5		30	28.9		24.5	19.0	30.0
Turbidity (NTU)	3.8	2.4	8.3	7.7	2.8	3.8	7.8	2	14.9	7.4	5.0	21.5	7.3	2.0	21.5
Conductivity (ms/cm)	49	45.9	49.7	48.3	54.18	39.8	46.8	35.3	29.5	12.3	38.2	48.9	41.5	12.3	54.2
Salinity (g/kg)	29	30	28	22.4	23.7	22.7	5.4	19.9	14.8	6.2	18.5	26.6	20.6	5.4	30.0
Dissolved oxygen (mg/l)	7.2	8.7	8.7	8.6	7.5	9.04	8.1	8.6	6.8	7.64	6.05	6.35	7.77	6.05	9.04
TSS (mg/l)	10	20	11.0	257.0	3.0	13.0	10.0	14.2	8.6	87.9	4.0	17.1	33.0	1.0	257.0
BOD (5 day) (mg/l)	2.00	1.00	1.00	0.30	1.39	1.65	0.55	0.47	1.16	0.78	0.85	0.44	0.97	0.30	2.00
Organic carbon (mg/l)	4			1.5	2.8	2	0.2	1.1	7	7	8	8	4.2	0.2	8.0
Grease and oil (mg/l)	0.05	0.11	0.10	6.18	10.0	6.8	5.7	18	0.10	0.10	0.10	0.10	4.00	0.05	18.00
Sulphates (mg/l)	2200	2500	2410	2220	2240	1940	2260	1551	1582	889	1510	2176	1957	889	2500
Bicarbonates (mg/l)	6	10	6	12.8	9.5	7.5	9.2	4.3	7.7	8.18	9	6.8	8.08	4.30	12.80
Phosphorus (mg/l)	0.13	0.12		0.04	0.04	0.05	0.06	0.01	0.04	0.04	0.05	0.02	0.05	0.01	0.13
Nitrate-N (mg/l)	0.05	0.03	0.50	0.36	0.02	0.46	0.21	0.58	0.76	0.82	0.63	0.07	0.37	0.02	0.82
Ammonia-N (mg/l)	0.02	0.06		0.02	0.09	0.10	0.01	0.04	0.02	0.01	0.03	0.07	0.04	0.01	0.10
Organic-N (mg/l)	0.09	0.07		0.02	0.26	0.04	0.30	0.81	0.47	3.03	5.20	4.70	1.36	0.02	5.20
Chlorophyll 'A' (mg/m3)	2.1	1.23		4.7	1.27	1.7	4.1	17.1	1.24	1.65	3.03	3.3	3.77	1.23	17.10
Chloride (mg/l)	14000	18000	16800	17500	17000	14100	16200	11131	9430	5938	11960	17105	14097	5938	18000
Chlorine (mg/l)	<0.1	<0.1	<0.1	≤0.1	≤0.1	≤0.1	≤0.1	≤0.1	≤0.1	≤0.1	≤0.1	<0.1	<0.1	<0.1	<0.1
Detergents (mg/l)	0.05	0.05		0.07	0.07	0.01	0.01	0.07	0.01	0.01	0.03	0.01	0.04	0.01	0.07
Magnesium (mg/l)			1154	1038	1087	857	1060	826	502	331	827	1000	868	331	1154
Calcium (mg/l)			387	349	405	334	418	283	256	171	287	423	331	171	423
Potassium (mg/l)			511	339	346	252	313	220	137	159	226	269	277	137	511
Sodium (mg/l)			8889	8939	9513	6937	8380	6064	5340	3510	6360	8200	7213	3510	9513
Cadmium (ug/l)		0.05	0.05	0.16	0.05	0.12	0.07	0.09	0.11	0.10	0.10	0.05	0.09	0.05	0.16
Mercury (ug/l)				<1	<1	<1	<1	< 1	< 1	< 1	<1	<1	<1	<1	<1
Chromium (ug/l)		1.4	1.5	2.3	1.1	1.3	2.1	0.5	0.3	0.8	0.4	0.7	1.1	0.3	2.3
Copper (ug/l)		5	5	5	5	5	5	6	5	5	7	5	5	5	7
Lead (ug/l)		0.33	0.56	1.1	0.9	1.2	1.6	0.5	0.9	0.6	0.7	1.1	0.9	0.3	1.6
Nickel (ug/l)		< 5	< 5	<5	<5	<5	<5	<5	< 5	< 5	6	<5	6.00	<5	6.00
Zinc (ug/l)		7	7	6	4	4	5	4	4	5	5	4	5	4	7
Arsenic (ug/l)		1.0	1.0	1	1.3	2.0	1.8	1.0	1.0	1.0	1.0	1.0	1.2	1.0	2.0
Manganese (ug/l)		13	11	18	14	12	30	4	9	7	8	29	14	4	30
Selenium (ug/l)		<1	<1	<1	≤1	≤1	≤1	<1	≤1	≤1	<1	<1	<1	<1	<1
Iron (ug/l)		128	107	145	124	238	951	36	451	191	190	91	241	36	951
Aluminium (ug/l)		172	80	230	104	307	778	75	552	182	193	65	249	65	778
Fecal coliform CFU/100ml		250	3000	300	60	500	540	360	0	580	940	170	609	0	3000
E. coli CFU/100ml		230	2600	280	40	200	120	220	0	240	900	150	453	0	2600

BLACK POINT BASELINE STUDY

WATER

F4 S

	Oct-90	NOV	DEC	Jan-91	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	Avg	Min	Max
pH (pH unit)	7.80	8.30	8.00	7.83	7.90	7.94	7.94	8.22	7.82	8.06	7.89	8.37	8.01	7.80	8.37
Temperature ('C)	23	22.3	20	19	19.9	25	27.3	29.5		30	28.9		24.5	19.0	30.0
Turbidity (NTU)	3.8	2.4	8.3	7.7	2.8	3.8	7.8	2	14.9	7.4	5.0	21.5	7.3	2.0	21.5
Conductivity (mS/m)	49	43.3	49.7	48.3	54.18	39.8	46.8	35.3	29.5	12.3	38.2	48.9	41.3	12.3	54.2
Salinity (g/kg)	29	30	28	22.4	23.7	22.7	5.4	19.9	14.8	6.2	18.5	26.6	20.6	5.4	30.0
Dissolved oxygen (mg/l)	7.2	8.7	8.7	8.6	7.5	9.04	8.1	8.6	6.8	7.64	6.05	6.35	7.77	6.05	9.04
TSS (mg/l)	11.0	21.0	11.0	257.0	33.0	63.0	10.0	12.4	78.6	87.9	40	17.5	33.0	10.0	257.0
BOD (5 day) (mg/l)	2.00	1.00	1.00	0.30	1.39	1.65	0.55	0.47	1.16	0.78	0.85	0.44	0.97	0.30	2.00
Organic carbon (mg/l)	4			1.5	2.8	2	0.2	1.1	7	7	8	8	4.2	0.2	8.0
Grease and oil (mg/l)	0.05	0.11	0.10	6.18	10.0	6.8	5.7	18	0.10	0.10	0.10	0.10	4.00	0.05	18.00
Sulphates (mg/l)	2200	2500	2410	2220	2240	1940	2260	1551	1582	889	1510	2176	1957	889	2500
Bicarbonates (mg/l)	6	10	6	12.8	9.5	7.5	9.2	4.3	7.7	8.18	9	6.8	8.08	4.30	12.80
Phosphorus (mg/l)	0.13	0.12		0.04	0.04	0.05	0.06	0.01	0.04	0.04	0.05	0.02	0.05	0.01	0.13
Nitrate-N (mg/l)	0.05	0.03	0.50	0.36	0.02	0.46	0.21	0.58	0.76	0.82	0.63	0.07	0.37	0.02	0.82
Ammonia-N (mg/l)	0.02	0.06		0.02	0.09	0.10	0.01	0.04	0.02	0.01	0.03	0.07	0.04	0.01	0.10
Organic-N (mg/l)	0.09	0.07		0.02	0.26	0.04	0.30	0.81	0.47	3.03	5.20	4.70	1.36	0.02	5.20
Chlorophyll 'A' (mg/m3)	2.1	1.23		4.7	1.27	1.7	4.1	17.1	1.24	1.65	3.03	3.3	3.77	1.23	17.10
Chloride (mg/l)	14000	18000	16800	17500	17000	14100	16200	11131	9430	5938	11960	17105	14097	5938	18000
Chlorine (mg/l)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Detergents (mg/l)	0.05	0.05		0.07	0.07	0.01	0.01	0.07	0.01	0.01	0.03	0.01	0.04	0.01	0.07
Magnesium (mg/l)			1154	1038	1087	857	1060	826	502	331	827	1000	868	331	1154
Calcium (mg/l)			387	349	405	334	418	283	256	171	287	423	331	171	423
Potassium (mg/l)			511	339	346	252	313	220	137	159	226	269	277	137	511
Sodium (mg/l)			8889	8939	9513	6937	8380	6064	5340	3510	6360	8200	7213	3510	9513
Cadmium (ug/l)		0.05	0.05	0.16	0.05	0.12	0.07	0.09	0.11	0.10	0.10	0.05	0.09	0.05	0.16
Mercury (ug/l)				< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Chromium (ug/l)		1.4	1.5	2.3	1.1	1.3	2.1	0.5	0.3	0.8	0.4	0.7	1.1	0.3	2.3
Copper (ug/l)		5	5	5	5	5	5	6	5	5	7	5	5	5	7
Lead (ug/l)		0.33	0.56	1.1	0.9	1.2	1.6	0.5	0.9	0.6	0.7	1.1	0.9	0.3	1.6
Nickel (ug/l)		< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	6	< 5	6.00	< 5	6.00
Zinc (ug/l)		7	7	6	4	4	5	4	4	5	5	4	5	4	7
Arsenic (ug/l)		1.0	1.0	1	1.3	2.0	1.8	1.0	1.0	1.0	1.0	1.0	1.2	1.0	2.0
Manganese (ug/l)		13	11	18	14	12	30	4	9	7	8	29	14	4	30
Selenium (ug/l)		< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Iron (ug/l)		128	107	145	124	238	951	36	451	191	190	91	241	36	951
Aluminium (ug/l)		172	80	230	104	307	778	75	552	182	193	65	249	65	778
Fecal coliform CFU/100ml		250	3000	300	60	500	540	360	0	580	940	170	609	0	3000
E. coli CFU/100ml		230	2600	280	40	200	120	220	0	240	900	150	453	0	2600

BLACK POINT BASELINE STUDY

WATER

F4 M

	Oct-90	NOV	DEC	Jan-91	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	Avg	Min	Max
pH (pH unit)	7.80	8.10	8.00	7.85	7.93	7.84	7.92	8.12	7.89	8.00	7.93	8.29	7.97	7.80	8.29
Temperature ('C)	23.0	22.4	19.7	18.9	19.5	25.0	27.0	29.0		30.1	28.6		24.3	18.9	30.1
Turbidity (NTU)	1.1	2.3	4.7	10.5	2.3	2.0	5.0	8.1	17.2	10.5	3.2	20.3	7.3	1.1	20.3
Conductivity (mS cm-1)	48.9	43.6	49.0	49.4	54.0	42.6	46.6	39.6	30.7	28.1	39.4	49.2	43.4	28.1	54.0
Salinity (g/kg)	29.0	30.0	29.0	22.7	27.7	24.4	13.7		15.5	6.0	19.3	26.8	22.2	6.0	30.0
Dissolved oxygen (mg/l)	7.2	8.2	8.4	8.8	7.5	9.0	7.7	8.0	6.6	7.5	6.1	6.5	7.6	6.1	9.0
TSS (mg/l)	2.0	2.0	1.0	250.0	1.0	4.0	1.0	0.3	17.8	130.9	12.7	11.4	36.2	0.3	250.0
BOD (5 day) (mg/l)	1.00	1.00	1.00	0.90	1.52	1.70	0.71	0.52	1.11	0.62	0.71	0.59	0.95	0.52	1.70
Organic carbon (mg/l)	3.0			1.3	1.7	2.8	0.8		8.0	9.0	9.0	12.0	5.3	0.8	12.0
Grease and oil (mg/l)	0.05	0.10		6.8	5.7	6.8	6.8		0.10	0.10	0.10	0.10	2.67	0.05	6.80
Sulphates (mg/l)	2500	2600	2490	2330	2280	2060	2210	1642	1709	1039	1570	2216	2054	1039	2600
Bicarbonates (mg/l)	6.0	10.0	8.0	13.0	10.6	7.3	9.2	4.1	6.8	8.4	9.0	7.0	8.3	4.1	13.0
Phosphorus (mg/l)	0.13	0.11		0.03	0.05	0.06	0.10	0.01	0.07	0.07	0.04	0.02	0.06	0.01	0.13
Nitrate-N (mg/l)	0.05	0.03	0.50	0.31	0.02	0.42	0.13	0.52	0.76	0.67	0.59	0.07	0.34	0.02	0.76
Ammonia-N (mg/l)	0.02	0.05		0.02	0.10	0.10	0.02	0.07	0.02	0.04	0.03	0.07	0.05	0.02	0.10
Organic N (mg/l)	0.09	0.05		0.07	0.17	0.22	0.71		0.51	6.41	8.20	2.80	1.92	0.05	8.20
Chlorophyll 'A' (mg/m3)	1.4	0.9		3.0	1.5	1.2	2.8		0.6	1.9	2.2	2.5	1.8	0.6	3.0
Chloride (mg/l)	16000	18000	17400	17200	16600	14500	16100	12638	9749	8473	12670	17194	14710	8473	18000
Chlorine (mg/l)															
Detergents (mg/l)	0.05	0.05		0.05	0.05	0.02	0.02		0.01	0.01	0.04	0.01	0.03	0.01	0.05
Magnesium (mg/l)															
Calcium (mg/l)															
Potassium (mg/l)															
Sodium (mg/l)															
Cadmium (ug/l)															
Mercury (ug/l)															
Chromium (ug/l)															
Copper (ug/l)															
Lead (ug/l)															
Nickel (ug/l)															
Zinc (ug/l)															
Arsenic (ug/l)															
Manganese (ug/l)															
Selenium (ug/l)															
Iron (ug/l)															
Aluminium (ug/l)															
Fecal coliform CFU/100ml	2100	1200	4000	400	60	600	340	380	0	740	1180	180	932	0	4000
E. coli CFU/100ml	1600	1000	3400	340	40	260	80	240	0	300	1020	170	704	0	3400

BLACK POINT BASELINE STUDY

WATER

F4 L

	Oct-90	NOV	DEC	Jan-91	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	Avg	Min	Max
pH (pH unit)	7.90	8.10	8.00	7.86	7.92	7.87	7.94	8.07	7.83	8.04	7.92	8.27	7.98	7.83	8.27
Temperature ('C)	23	22.5	19.8	18.5	18.4	25	27	28.6		30.0	28.6		24.1	18.4	30.0
Turbidity (NTU)	1.1	3	4.5	13.8	1.6	15.1	7.2	13.5	41.0	8.4	9.0	20.6	11.6	1.1	41.0
Conductivity (mS/m)	48.9	48.3	51.1	49.6	52.7	45.1	46.4	42.3	32.3	24.2	42.8	48.9	44.0	24.2	52.7
Salinity (g/kg)	29	21	30	21.3	14.5	20.4	14.8	19.9	16.4	12.1	20.9	26.6	20.6	12.1	30.0
Dissolved oxygen (mg/l)	7.2	7.8	8.4	8.7	7.5	8.78	7.8	7.8	6.1	7.7	6.7	6.5	7.6	6.1	8.8
TSS (mg/l)	10	20	20	270	10	13.0	12.0	16.8	15.3	10.4	9.1	54.5	40.1	10	270
BOD (5 day) (mg/l)	1.00	1.00	1.00	1.20	0.87	1.75	0.69	0.38	0.97	0.76	1.01	0.60	0.94	0.38	1.75
Organic carbon (mg/l)	3			2.8	3.4	1.6	0.8	0.8	9	7		11	4.38	0.80	11.00
Grease and oil (mg/l)	0.05			4.6	[illegible]	8.9	8.9	34	0.10	0.10	0.10	0.10	6.02	0.05	34.00
Sulphates (mg/l)	2500	2600	2620	2310	2370	2250	2230	1985	1779	926	1810	2152	2128	926	2620
Bicarbonates (mg/l)	6	11	8	12.5	9.2	7.3	8.8	5.5	8.1	7.9	9.0	7.1	8.4	5.5	12.5
Phosphorus (mg/l)	0.13	0.10		0.12	0.05	0.07	0.12	0.01	0.13	0.03	0.06	0.03	0.08	0.01	0.13
Nitrate-N (mg/l)	0.05	0.02	0.50	0.32	0.02	0.34	0.21	0.50	0.67	0.74	0.51	0.07	0.33	0.02	0.74
Ammonia-N (mg/l)	0.02	0.06		0.03	0.10	0.09	0.01	0.10	0.07	0.02	0.03	0.08	0.06	0.01	0.10
Organic N (mg/l)	0.09	0.06		0.22	0.08	0.28	0.12	0.37	0.66	2.53	23.20	7.60	3.20	0.06	23.20
Chlorophyll 'A' (mg/m3)	1.4	0.85		3.0	0.74	1.49	5.0	8.3	1.13	1.93	2.75	2.48	2.64	0.74	8.30
Chloride (mg/l)	16000	18000	17700	17700	16400	15400	16400	13081	10493	6842	14270	17335	14968	6842	18000
Chlorine (mg/l)															
Detergents (mg/l)	0.05	0.05		0.05	0.05	0.13	0.02	0.05	0.01	0.01	0.04	0.01	0.04	0.01	0.13
Magnesium (mg/l)					1101	1016	1045	928	615	446	864	1000	877	446	1101
Calcium (mg/l)					405	353	424	343	294	232	365	392	351	232	424
Potassium (mg/l)					388	300	361	248	186	184	264	327	282	184	388
Sodium (mg/l)					9912	7723	8215	6915	5840	4320	7400	8080	7301	4320	9912
Cadmium (ug/l)					0.05	0.12	0.05	0.08	0.08	0.10	0.08	0.07	0.08	0.05	0.12
Mercury (ug/l)					<1	<1	<1	< 1	< 1	< 1	<1	<1	<1	<1	<1
Chromium (ug/l)					1.4	3.7	2.4	0.9	2.1	0.9	0.4	0.8	1.58	0.40	3.70
Copper (ug/l)					5	9	5	16	5	5	7	5	7	5	16
Lead (ug/l)					0.8	3.3	1.9	1.7	2.8	0.9	0.7	1.2	1.7	0.7	3.3
Nickel (ug/l)					5	5	5	9	5	5	7	5	6	5	9
Zinc (ug/l)					4	8	8	8	6	4	6	5	6	4	8
Arsenic (ug/l)					1.2	1.8	1.8	1.0	1.0	1.0	1.0	1.0	1.2	1.0	1.8
Manganese (ug/l)					13	54	42	26	43	9	13	30	29	9	54
Selenium (ug/l)					<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Iron (ug/l)					87	1714	1344	678	2224	314	237	1024	953	87	2224
Aluminium (ug/l)					106	1468	1124	463	2133	237	239	629	800	106	2133
Faecal coliform CFU/100ml	2500	4700	3200	320	40	500	460	600	0	860	1100	210	1208	0	4700
E. coli CFU/100ml	1800	410	2800	280	40	220	140	360	0	320	840	200	618	0	2800

BLACK POINT BASELINE STUDY

WATER

F5 S

	Oct-90	NOV	DEC	Jan-91	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	Avg	Min	Max
pH (pH unit)	7.70	7.70	8.00	7.90	7.88	7.94	7.95	8.13	7.83	8.04	8.00	7.98	7.92	7.70	8.13
Temperature (°C)	23.0	23.0	20.0	18.3	22.3	25.0	27.0	29.0		29.9	29.1		24.7	18.3	29.9
Turbidity (NTU)	4.0	4.0	3.0	6.7	1.9	8.7	8.0	1.5	2.8	7.7	5.8	56.5	9.2	1.5	56.5
Conductivity (mS/cm)	49.8	49.8	48.6	49.8	53.6	42.8	47.0	34.4	27.0	12.9	35.7	47.7	41.6	12.9	53.6
Salinity (g/kg)	30.0	30.0	28.0	26.7	29.0	26.5	16.0	13.3	13.4	6.7	17.5	26.9	22.0	6.7	30.0
Dissolved oxygen (mg/l)	7.2	7.2	8.5	8.8	7.6	8.2	8.6	8.4	6.8	7.7	6.3	6.3	7.6	6.3	8.8
TSS (mg/l)	4.0	4.0	2.0	248.0	4.0	8.0	2.0	6.4	17.4	134.5	5.0	101.2	44.7	2.0	248.0
BOD (5 day) (mg/l)	1.00	1.00	1.00	1.00	0.90	1.55	1.01	0.50	1.19	0.86	0.43	0.63	0.92	0.43	1.55
Organic carbon (mg/l)	3.0	3.0		3.6	3.6	2.7	0.2	0.4	8.0	7.0	9.0	10.0	4.6	0.2	10.0
Grease and oil (mg/l)	0.05	0.05		7.90	12.20	15.70	6.80	18.00	0.10	0.10	0.10	0.10	4.65	0.05	18.00
Sulphates (mg/l)	2300	2300	2370	2250	2230	2030	2240	1453	1474	844	1430	2236	1930	844	2370
Bicarbonates (mg/l)	6.0	6.0	6.0	11.2	8.6	7.3	10.1	4.3	6.6	6.5	5.5	7.7	7.1	4.3	11.2
Phosphorus (mg/l)	0.10	0.10		0.06	0.09	0.12	0.06	0.01	0.03	0.03	0.06	0.05	0.06	0.01	0.12
Nitrate-N (mg/l)	0.05	0.05	0.50	0.31	0.01	0.33	0.26	0.51	0.72	0.83	0.67	0.06	0.36	0.01	0.83
Ammonia-N (mg/l)	0.02	0.02		0.02	0.09	0.10	0.02	0.05	0.02	0.01	0.03	0.10	0.04	0.01	0.10
Organic-N (mg/l)	0.07	0.07		0.09	0.17	0.20	0.45	0.37	2.18	0.61	4.20	4.00	1.13	0.07	4.20
Chlorophyll 'A' (mg/m3)	2.0	2.0		2.8	0.7	1.5	2.8	17.6	3.0	1.9	3.0	1.9	3.6	0.7	17.6
Chloride (mg/l)	15000	15000	15900	17800	16900	14100	16400	10670	8614	5956	11610	16396	13696	5956	17800
Chlorine (mg/l)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Detergents (mg/l)	0.05	0.05		0.04	0.01	0.01	0.01	0.04	0.01	0.01	0.05	0.01	0.03	0.01	0.05
Magnesium (mg/l)															
Calcium (mg/l)															
Potassium (mg/l)															
Sodium (mg/l)															
Cadmium (ug/l)															
Mercury (ug/l)															
Chromium (ug/l)															
Copper (ug/l)															
Lead (ug/l)															
Nickel (ug/l)															
Zinc (ug/l)															
Arsenic (ug/l)															
Manganese (ug/l)															
Selenium (ug/l)															
Iron (ug/l)															
Aluminium (ug/l)															
Fecal coliform CFU/100ml	1800	1800	2000	80	40	500	240	600	0	320	720	220	693	0	2000
[illegible]	1300	1300	280	0	20	140	100	260	0	220	520	210	363	0	1300

BLACK POINT BASELINE STUDY

WATER

F5 L

	Oct-90	NOV	DEC	Jan-91	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	Avg	Min	Max
pH (pH unit)	7.70	8.10	8.00	7.93	7.89	7.95	7.90	8.03	7.80	8.08	8.04	8.44	7.99	7.70	8.44
Temperature ('C)	23	22.5	19.8	18.6	21.3	25	27.3	28.8		29	28.6		24.4	18.6	29.0
Turbidity (NTU)	2	2.2	5.6	7.7	1.8	14	25.5	3.6	23.7	8.2	8.2	92	16.2	1.8	92.0
Conductivity (ms/cm)	49.8	44.6	49.7	50.6	53.3	43.8	46.8	36.7	34.7	18.8	40	47.7	43.0	18.8	53.3
Salinity (g/kg)	30	31	30	22.9	26.4	22.9	14.8	18.6	17.7	9.7	19.4	26.8	22.5	9.7	31.0
Dissolved oxygen (mg/l)	7.2	7.5	8.4	8.8	7.6	7.8	8.8	7.5	6.2	7.31	6.02	6.47	7.47	6.02	8.80
TSS (mg/l)	1.0	2.0	2.0	27.0	3.0	16.0	4.0	2.4	3.1	8.2	17.9	9.54	[illegible]	1.0	27.0
BOD (5 day) (mg/l)	1.00	1.00	1.00	0.90	0.80	1.08	0.76	0.41	1.58	0.67	1.27	0.54	0.92	0.41	1.58
Organic carbon (mg/l)	3			4.2	4.2	1.6	0.5	0.8	7	7	9	8	4.53	0.50	9.00
Grease and oil (mg/l)	0.05	0.11		7.90	5.70	5.70	7.90	39.00	0.10	0.10	0.10	0.10	6.07	0.05	39.00
Sulphates (mg/l)	2400	2800	2430	2390	2420	2410	2270	1499	1937	934	1540	2276	2109	934	2800
Bicarbonates (mg/l)	6	11	7	10.6	9	7.3	9.9	4.1	4.84	6.82	4.8	7.7	7.4	4.1	11.0
Phosphorus (mg/l)	0.10	0.11		0.06	0.09	0.11	0.11	0.01	0.04	0.02	0.06	0.05	0.07	0.01	0.11
Nitrate-N (mg/l)	0.05	0.02	0.50	0.27	0.09	0.28	0.13	0.51	0.65	0.76	0.57	0.07	0.33	0.02	0.76
Ammonia-N (mg/l)	0.02	0.08		0.02	0.10	0.10	0.01	0.05	0.02	0.01	0.04	0.11	0.05	0.01	0.11
Organic-N (mg/l)	0.07	0.07		0.08	0.05	0.06	0.82	0.19	0.58	0.99	9.90	3.90	1.52	0.05	9.90
Chlorophyll 'A' (mg/m3)	1	0.89		3.3	1.95	1.57	3.6	12.1	2.75	2.48	1.93	4.68	3.30	0.89	12.10
Chloride (mg/l)	16000	18000	17000	18000	17100	14600	16300	11592	11415	6948	12660	17105	14727	6948	18000
Chlorine (mg/l)															
Detergents (mg/l)	0.05	0.05		0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.05
Magnesium (mg/l)															
Calcium (mg/l)															
Potassium (mg/l)															
Sodium (mg/l)															
Cadmium (ug/l)															
Mercury (ug/l)															
Chromium (ug/l)															
Copper (ug/l)															
Lead (ug/l)															
Nickel (ug/l)															
Zinc (ug/l)															
Arsenic (ug/l)															
Manganese (ug/l)															
Selenium (ug/l)															
Iron (ug/l)															
Aluminium (ug/l)															
Fecal coliform CFU/100ml	1500	400	3000	100	160	560	260	440	0	260	740	290	634	0	3000
E. coli CFU/100ml	1000	400	2800	233	20	200	120	200	0	200	640	260	506	0	2800

BLACK POINT BASELINE STUDY

WATER

CPA S

	Oct-90	NOV	DEC	Jan-91	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	Avg	Min	Max
pH (pH unit)	7.90	8.10	8.10	7.83	7.98	7.84	8.10	7.94	7.99	8.01	8.03	8.12	8.00	7.83	8.12
Temperature ('C)	23.0	22.6	20.2	18.9	21.1	25.0	27.3	31.7		31.0	29.8		25.1	18.9	31.7
Turbidity (NTU)	4.5	7.8	2.1	20.1	2.8	3.6	2.0	7.0	28.1	9.5	12.4	19.5	10.0	2.0	28.1
Conductivity (ms cm-1)	47.5	44.0	51.1	49.3	50.8	37.8	45.7	41.0	33.03	17.5	40.4	44.4	41.9	17.5	51.1
Salinity (g/kg)	29.0	31.0	30.0	28.0	28.0	23.0	24.1	18.7	16.8	9.4	20.2	24.7	23.6	9.4	31.0
Dissolved oxygen (mg/l)	7.4	7.7	9.1	8.9	7.6	7.2	8.4	8.9	7.1	7.6	6.1	6.3	7.7	6.1	9.1
TSS (mg/l)	10.0	21.0	2.0	202.0	5.0	1.0	2.0	5.1	12.0	86.4	61.0	17.4	29.2	1.0	202.0
BOD (5 day) (mg/l)	1.00	1.00	2.00		1.72	1.63	1.26	0.86	2.23	0.70	0.40	0.71	1.23	0.40	2.23
Organic carbon (mg/l)	3.0			3.6	1.6	1.8		0.4	7.0	6.0	9.0	9.0	4.6	0.4	9.0
Grease and oil (mg/l)	0.15	0.18	<0.01		10.0	8.90	4.60	66.00	<0.1	<0.1	<0.01	<0.1	11.40	0.00	66.00
Sulphates (mg/l)	2400	2700	2600	2310	2370	2020	2190	1796	1251	1425	1620	2187	2072	1251	2700
Bicarbonates (mg/l)	6.0	10.0	5.0	15.8	9.0	9.5	7.3	11.9	6.2	7.9	5.7	6.4	8.4	5.0	15.8
Phosphorus (mg/l)	0.15	0.10		0.05	0.06	0.07	0.02	0.01	0.05	0.03	0.07	0.06	0.06	0.01	0.15
Nitrate-N (mg/l)	0.04	0.06	<0.5	0.21	0.02	0.39	0.17	0.35	0.71	0.76	0.47	0.06	0.29	0.02	0.76
Ammonia-N (mg/l)	<0.01	0.07		0.02	0.11	0.09	0.01	0.05	0.02	0.01	0.06	0.07	0.05	0.01	0.11
Organic N (mg/l)	0.10	0.06		0.16	0.19	0.26	0.34	0.86	0.43	2.77	11.20	2.50	1.82	0.06	11.20
Chlorophyll 'A' (mg/m3)	1.2	3.7		3.6	1.6	0.7	4.1	7.7	3.3	1.7	2.2	2.8	3.0	0.7	7.7
Chloride (mg/l)	16000	18000	18000	18500	17000	14700	16000	13081	6558	6771	13560	17335	14625	6558	18500
Chlorine (mg/l)	<0.1	<0.1	<0.5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Detergents (mg/l)	0.01	<0.05		0.03	0.01	0.02	0.03	0.05	<0.01	0.02	<0.01	0.01	0.02	<0.01	0:05
Magnesium (mg/l)	1027	1027	1231	1050	1058	952	1017	957	374	366	800	1010	906	366	1231
Calcium (mg/l)	374	404	402	363	409	327	411	338	187	185	358	426	349	185	426
Potassium (mg/l)	392	425	547	319	361	304	336	282	107	170	256	332	319	107	547
Sodium (mg/l)	9221	10137	10167	9141	9336	7188	8007	6809	3570	3840	6960	8070	7704	3570	10167
Cadmium (ug/l)	<0.05	<0.05	<0.05	0.07	<0.05	0.14	0.09	0.16	0.09	0.11	0.11	0.04	0.10	0.04	0.16
Mercury (ug/l)				<1	<1	<1	<1	< 1	< 1	< 1	<1	<1	<1	<1	<1
Chromium (ug/l)	1.1	2.7	1.6	3.0	1.5	1.0	1.0	0.8	1.3	0.6	0.8	1.9	1.3	0.0	3.0
Copper (ug/l)	<5	<5	<5	<5	<5	<5	<5	13	<5	<5	11	9	11	9	13
Lead (ug/l)	10.5	0.7	0.8	1.2	0.8	1.3	1.3	1.2	2.0	1.0	1.3	2.6	2.1	0.7	10.5
Nickel (ug/l)	< 5	< 5	< 5	<5	<5	<5	<5	8	< 5	< 5	8	<5	8	<5	8
Zinc (ug/l)	10	7	8	8	6	4.0	4	6	8	3	7	8	7	3	10
Arsenic (ug/l)	< 1	< 1	< 1	1.2	1.1	2.5	1.5	< 1	< 1	< 1	<1	<1	2	<1	3
Manganese (ug/l)	26	30	19	32	15	9.0	17	18	26	11	21	53	23	9	53
Selenium (ug/l)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Iron (ug/l)	416	308	105	366	155	177	533	378	1350	210	551	2031	548	105	2031
Aluminium (ug/l)	349	300	97	383	131	178	489	316	1431	230	453	1236	466	97	1431
Fecal coliform CFU/100ml	1000	790	3200	320	100	0	40	420	60	880	240	550	633	0	3200
E. coli CFU/100ml	800	640	3000	100	20	0	0	280	20	460	140	400	488	0	3000

BLACK POINT BASELINE STUDY

WATER

CPA L

	Oct-90	NOV	DEC	Jan-91	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	Avg	Min	Max
pH (pH unit)	7.80	8.10	7.80	7.92	8.08	7.81	8.14	7.95	8.93	7.96	8.02	7.98	8.04	7.80	8.93
Temperature ('C)	23.0	22.6	19.9	18.9	21.1	25.0	27.3	28.9		30.7	28.6		24.6	18.9	30.7
Turbidity (NTU)	2.3	7.0	0.8	17.5	3.6	1.7	10.0	8.0	55.8	17.0	19.6	35.6	14.9	0.8	55.8
Conductivity (ms.cm-1)	46.7	44.0	52.0	49.3	50.2	39.2	46.7	44.31	33.84	32.1	44.3	51.6	44.5	32.1	52.0
Salinity (g/kg)	29.0	31.0	31.0	18.7	29.3	24.1	21.3	16.0	17.2	16.3	22.3	28.9	23.8	16.0	31.0
Dissolved oxygen (mg/l)	7.4	7.7	8.5	8.9	7.5	7.1	7.6	8.3	6.9	7.3	6.9	6.4	7.5	6.4	8.9
TSS (mg/l)	7.0	2.0	2.0	198.0	1.0	1.0	1.0	4.7	3.5	137.6	14.9	34.5	33.9	1.0	198.0
BOD (5 day) (mg/l)	1.00	< 1	1.00		1.42	1.39	0.64	0.36	2.13	0.59	0.32	0.48	0.93	0.32	2.13
Organic carbon (mg/l)	3.0			2.4	3.4	1.6	0.6	0.6	9.0	14.0	8.0	9.0	5.2	0.6	14.0
Grease and oil (mg/l)	0.16	0.18		6.80	6.80	6.80	7.90	29.00	≤0.1	≤0.1	≤0.1	≤0.1	8.23	≤0.1	29.00
Sulphates (mg/l)	2500	2600	2500	2250	2400	2080	2240	1975	1887	961	1820	2171	2115	961	2600
Bicarbonates (mg/l)	6.0	11.0	11.0	11.9	8.4	9.0	7.0	12.3	5.3	7.7	6.2	5.8	8.5	5.3	12.3
Phosphorus (mg/l)	0.15	0.11		0.03	0.07	0.05	0.06	≤0.01	0.05	0.03	0.07	0.05	0.07	0.03	0.15
Nitrate-N (mg/l)	0.05	0.07	<0.5	0.28	0.05	0.30	0.14	0.28	0.90	0.57	0.39	0.06	0.28	0.05	0.90
Ammonia-N (mg/l)	<0.01	0.07		0.02	0.12	0.09	0.03	0.08	0.05	0.03	0.06	0.10	0.07	<0.01	0.12
Organic N (mg/l)	0.10	0.06		0.10	0.13	0.18	0.73	0.34	0.39	0.51	10.70	4.60	1.62	0.06	10.70
Chlorophyll 'A' (mg/m3)	1.9	1.4		10.7	1.1	1.1	4.1	10.2	2.5	1.1	2.2	2.8	3.5	1.1	10.7
Chloride (mg/l)	15000	18000	18100	18300	16400	14700	15600	14180	10954	10741	14620	17282	15323	10741	18300
Chlorine (mg/l)															
Detergents (mg/l)	0.01	<0.05		0.06	<0.01	0.03	0.03	0.05	<0.01	0.01	<0.01	0.01	0.03	<0.01	0.06
Magnesium (mg/l)					1087	1016	1031	1029	591	576	879	1020	904	576	1087
Calcium (mg/l)					398	353	416	358	287	288	381	418	362	287	418
Potassium (mg/l)					358	290	349	272	186	186	276	323	280	186	358
Sodium (mg/l)					9292	7946	8132	7487	5300	5700	7700	7550	7388	5300	9292
Cadmium (ug/l)					≤0.05	0.14	0.06	0.08	0.09	0.06	0.06	0.06	0.08	0.06	0.14
Mercury (ug/l)					<1	<1	<1	< 1	< 1	< 1	<1	<1	<1	<1	<1
Chromium (ug/l)					1.6	1.0	0.9	0.6	0.4	0.8	0.8	2.1	0.9	0.4	2.1
Copper (ug/l)					≤5	≤5	≤5	14	≤5	≤5	12	8	7	≤5	14
Lead (ug/l)					0.9	1.5	2.1	0.9	1.4	1.7	1.3	2.6	1.6	0.9	2.6
Nickel (ug/l)					<5	<5	<5	8	< 5	< 5	7	<5	8	7	8
Zinc (ug/l)					4	4	4	5	5	4	7	9	5	4	9
Arsenic (ug/l)					1.1	2.0	1.5	< 1	< 1	< 1	<1	<1	<1	<1	2
Manganese (ug/l)					17	12	22	12	15	16	10	52	20	10	52
Selenium (ug/l)					≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1
Iron (ug/l)					138	250	655	223	877	513	1134	2065	732	138	2065
Aluminium (ug/l)					136	237	577	191	797	408	725	1287	545	136	1287
Fecal coliform CFU/100ml		530	800	280	60	20	20	200	60	1020	480	230	336	20	1020
E. coli CFU/100ml		400	1200	120	0	0	0	40	20	420	400	210	255	0	1200

BLACK POINT BASELINE STUDY

WATER

B1

	Oct-90	NOV	DEC	Jan-91	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	Avg	Min	Max
pH (pH unit)	7.80	8.10	7.90	7.74	8.03	7.84	7.90	8.02	7.98	7.78	7.85	8.37	7.94	7.74	8.37
Temperature ('C)	23.0	20.6	19.0	19.5	19.0	25.0	27.3	28.7	30.0	29.0	28.9	30.0	25.0	19.0	30.0
Turbidity (NTU)	3.5	2.0	0.7	6.7	3.3	5.0	10.0	5.5	24.2	18.2	14.8	49.2	11.9	0.7	49.2
Conductivity (ms/cm)	48.7	41.1	47.0	47.5	52.3	40.0	41.8	29.2	19.7	15.0	36.2	42.0	38.4	15.0	52.3
Salinity (g/kg)	29.0	24.0	27.0	21.0	27.8	22.7	4.5	14.5	9.5	9.2	17.9	23.3	19.2	4.5	29.0
Dissolved oxygen (mg/l)	7.8	7.7	9.0	9.2	7.9	8.9	8.0	8.3	7.3	7.2	6.1	6.1	7.8	6.1	9.2
TSS (mg/l)	3.0	2.0	2.0	207.0	2.0	5.0	3.0	2.3	13.2	70.3	27.6	42.6	31.7	2.0	207.0
BOD (5 day) (mg/l)	1.00	1.00	1.00	1.10	1.81	1.80	0.82	0.82	1.69	0.54	0.66	0.62	1.07	0.54	1.81
Organic carbon (mg/l)	4.0	3.2	2.4	1.6	5.5	3.2	0.8	0.8	5.4	10.0	8.0	8.0	4.4	0.8	10.0
Grease and oil (mg/l)	0.05	0.03	0.29	6.80	6.80	6.80	6.80	18.00	0.20	0.10	0.10	0.10	3.84	0.03	18.00
Sulphates (mg/l)	2000	2100	2250	2180	2280	1981	2000	1087	1166	839	1420	2273	1798	839	2280
Bicarbonates (mg/l)	6.0	11.0	8.0	15.8	6.6	9.5	9.5	5.7	6.6	8.6	7.0	6.8	8.4	5.7	15.8
Phosphorus (mg/l)	0.25	1.10	0.67	0.24	0.19	0.15	0.08	0.03	0.06	0.11	0.09	0.08	0.25	0.03	1.10
Nitrate-N (mg/l)	0.08	0.20	0.50	0.59	0.49	0.56	0.35	0.74	2.37	0.90	0.63	0.13	0.63	0.08	2.37
Ammonia-N (mg/l)	0.02	2.50	1.26	0.02	0.36	0.35	0.01	0.07	0.03	0.09	0.08	0.31	0.43	0.01	2.50
Organic N (mg/l)	0.16	0.62	0.41	0.19	0.06	0.02	1.93	0.29	0.60	1.09	8.20	3.10	1.39	0.02	8.20
Chlorophyll 'A' (mg/m3)	2.2	4.5	3.8	3.0	4.4	1.7	2.8	13.2	7.8	1.9	4.1	7.4	4.7	1.7	13.2
Chloride (mg/l)	14000	14000	16800	16400	15500	13700	14200	8898	5920	5229	11630	17371	12804	5229	17371
Chlorine (mg/l)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Detergents (mg/l)	0.01	0.05	0.06	0.07	0.06	0.02	0.01	0.05	0.01	0.01	0.06	0.01	0.04	0.01	0.07
Magnesium (mg/l)	731	742	1015	1013	1029	889	918	662	239	286	691	897	759	239	1029
Calcium (mg/l)	356	367	388	341	404	341	387	238	111	149	330	364	315	111	404
Potassium (mg/l)	419	426	480	298	332	267	288	186	85	149	217	289	286	85	480
Sodium (mg/l)	8000	8086	8667	8434	8717	7382	7469	4840	2150	3100	6100	6830	6648	2150	8717
Cadmium (ug/l)	0.05	0.06	0.15	0.12	0.05	0.11	0.11	0.30	0.17	0.37	0.18	0.14	0.15	0.05	0.37
Mercury (ug/l)				<1	<1	<1	<1	<1	< 1	< 1	<1	<1	<1	<1	<1
Chromium (ug/l)	0.7	2.1	1.1	1.9	1.7	0.9	1.6	0.6	0.4	0.9	0.4	0.8	1.1	0.4	2.1
Copper (ug/l)	< 5	< 5	<5	<5	<5	< 5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Lead (ug/l)	1.1	0.8	1.2	0.9	1.1	3.7	1.0	0.8	1.4	3.0	1.5	1.4	1.5	0.8	3.7
Nickel (ug/l)	< 5	< 5	< 5	<5	<5	<5	<5	<5	< 5	< 5	<5	<5	<5	<5	<5
Zinc (ug/l)	10	8	10	6	5	3	5	6	6	9	7	4	7	3	10
Arsenic (ug/l)	1.0	1.0	1.0	1.2	1.4	2.5	1.8	1.0	1.0	1.0	1.0	1.0	1.2	1.0	2.5
Manganese (ug/l)	26	116	50	53	36	25	15	11	9	17	17	23	33	9	116
Selenium (ug/l)	< 1	<1	<1	<1	<1	< 1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Iron (ug/l)	313	167	60	171	91	280	317	165	510	520	507	402	292	60	520
Aluminium (ug/l)	196	179	56	173	109	271	362	151	558	460	452	358	277	56	558
Fecal coliform CFU/100ml	250	2900	1200	120	40	40	0	540	0	380	480	110	505	0	2900
E. coli CFU/100ml	210	2900	200	20	20	0	0	240	0	340	320	70	360	0	2900

BLACK POINT BASELINE STUDY

WATER

B4

	Oct-90	NOV	DEC	Jan-91	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	Avg	Min	Max
pH (pH unit)	7.80	8.10	7.90	7.86	7.96	7.91	7.90	7.96	7.59	7.80	8.02	8.00	7.90	7.59	8.10
Temperature ('C)	23.0	21.3	19.0	19.8	19.3	25.0	27.3	29.0	29.3	28.7	28.9		24.6	19.0	29.3
Turbidity (NTU)	3.4	0.6	0.7	6.5	3.6	2.9	5.0	4.4	6.2	19.2	16.4	13.0	6.8	0.6	19.2
Conductivity (ms cm-1)	48.3	42.5	47.0	48.8	50.0	36.9	41.9	57.9	14.3	14.8	36.4	46.8	34.5	14.3	57.9
Salinity (g/kg)	29.0	27.0	27.0	17.4	25.2	24.6	9.4	13.3	6.8	7.7	18.0	26.1	19.3	6.8	29.0
Dissolved oxygen (mg/l)	7.7	7.8	9.0	9.2	7.7	8.5	7.9	8.0	6.5	7.2	6.0	6.3	7.6	6.0	9.2
TSS (mg/l)	7.0	24.0	2.0	208.0	51.0	11.0	2.0	0.1	14.7	67.2	28.7	12.9	28.9	0.81	208.0
BOD (5 day) (mg/l)	1.00	1.00	1.00	1.40	1.38	1.65	1.08	0.38	2.06	0.27	0.50	0.75	0.96	0.27	2.06
Organic carbon (mg/l)	3.0			1.9	3.6	4.2	1.4	1.5	9.0	6.0	8.0	8.0	4.7	1.4	9.0
Grease and oil (mg/l)	0.20	0.07	0.29	[illegible]	5.70	7.90	5.70	29.00	0.20	≤0.1	≤0.1	≤0.1	6.13	≤0.1	29.00
Sulphates (mg/l)	2200	2300	2250	2220	2040	2070	2040	1270	1096	775	1440	2038	1812	775	2300
Bicarbonates (mg/l)	6.0	11.0	8.0	11.7	8.4	8.8	8.8	7.9	5.7	9.0	4.6	7.0	8.1	4.6	11.7
Phosphorus (mg/l)	0.21	0.25	[illegible]	0.01	0.05	0.07	0.05	0.03	0.04	0.06	0.05	0.06	0.08	0.01	0.25
Nitrate-N (mg/l)	0.08	0.12	0.50	0.43	0.03	0.42	0.33	0.67	0.89	0.90	0.65	0.10	0.43	0.03	0.90
Ammonia-N (mg/l)	0.02	0.46		0.02	0.13	0.15	0.01	0.06	0.02	0.04	0.02	0.11	0.09	0.01	0.46
Organic N (mg/l)	0.13	0.19	[illegible]	0.29	0.21	≤0.01	0.61	0.13	0.49	0.60	6.10	3.00	1.07	≤0.01	6.10
Chlorophyll 'A' (mg/m3)	1.7	1.7		4.1	1.6	2.0	4.1	13.2	4.1	2.5	3.0	3.9	3.8	1.6	13.2
Chloride (mg/l)	14000	16000	16800	17100	15300	14100	14300	9465	4821	4910	11660	16626	12924	4821	17100
Chlorine (mg/l)	<0.1	≤0.1	≤0.1	≤0.1	≤0.1	≤0.1	≤0.1	≤0.1	≤0.1	≤0.1	≤0.1	≤0.1	≤0.1	≤0.1	≤0.1
Detergents (mg/l)	0.01	<0.05		0.07	0.05	0.01	0.02	0.04	<0.01	<0.01	0.01	<0.01	0.02	<0.01	0.07
Magnesium (mg/l)	742	796	1015	1013	957	905	889	647	291	264	654	986	763	264	1015
Calcium (mg/l)	333	371	388	319	380	348	391	239	155	142	306	392	314	142	392
Potassium (mg/l)	430	411	480	304	313	276	306	163	92	102	220	309	284	92	480
Sodium (mg/l)	9083	8902	8667	8789	8407	7339	7469	4734	2780	2950	5670	6725	6793	2780	9083
Cadmium (ug/l)	<0.05	<0.05	0.15	0.08	≤0.05	0.11	0.11	0.16	0.25	0.14	0.12	0.09	0.10	≤0.05	0.25
Mercury (ug/l)				<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chromium (ug/l)	0.9	1.5	1.1	2.1	1.4	0.7	1.2	0.6	0.4	0.8	0.3	0.9	1.0	0.3	2.1
Copper (ug/l)	<5	≤5	≤5	≤5	≤5	≤5	≤5	≤5	≤5	≤5	≤5	≤5	≤5	≤5	≤5
Lead (ug/l)	0.7	0.38	1.2	0.8	0.9	1.2	1.3	1.2	1	2.7	0.7	1.2	1.1	0.4	2.7
Nickel (ug/l)	< 5	< 5	< 5	<5	<5	<5	<5	<5	< 5	< 5	<5	<5	<5	<5	<5
Zinc (ug/l)	8	5	10	5	8	6	4	2	3	8	5	5	6	2	10
Arsenic (ug/l)	< 1	< 1	< 1	<1	1.2	2.5	1.5	<1	< 1	< 1	<1	<1	1.7	<1	2.5
Manganese (ug/l)	29	38	50	19	10	11	13	13	7	19	12	21	20	7	50
Selenium (ug/l)	<1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1
Iron (ug/l)	429	91	60	159	139	181	333	209	349	577	334	455	276	60	577
Aluminium (ug/l)	362	118	56	225	105	221	336	212	404	523	292	348	267	56	523
Fecal coliform CFU/100ml	360	200	1200	40	40	40	0	40	0	940	240	250	279	0	1200
E. coli CFU/100ml	300	200	200	20	0	0	0	0	0	440	240	110	126	0	440

BLACK POINT BASELINE STUDY

WATER

B6

	Oct-90	NOV	DEC	Jan-91	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	Avg	Min	Max
pH (pH unit)	7.80	8.10	7.90	7.83	7.92	7.98	7.87	8.03	7.88	7.77	7.88	8.06	7.92	7.77	8.10
Temperature ('C)	23.0	21.3	19.0	18.4	21.0	25.0	27.0	29.0	29.2	29.1	29.1		24.6	18.4	29.2
Turbidity (NTU)	3.4	0.6	0.7	9.3	3.8	2.6	14.3	1.2	19.3	8.4	24.2	14.2	8.5	0.6	24.2
Conductivity (ms/cm)	48.3	42.5	47.0	50.0	52.6	39.4	46.9	34.7	18.8	27.6	41.3	48.9	41.5	18.8	52.6
Salinity (g/kg)	29.0	27.0	27.0	22.7	29.1	27.2	8.5	14.8	9.1	14.6	20.7	27.4	21.4	8.5	29.1
Dissolved oxygen (mg/l)	7.7	7.8	9.0	8.9	7.6	7.2	8.2	9.5	7.4	7.3	5.7	6.3	7.7	5.7	9.5
TSS (mg/l)	7.0	2.0	2.0	221.0	1.0	2.0	5.0	3.0	1.9	85.9	25.5	15.8	31.0	1.0	221.0
BOD (5 day) (mg/l)	1.00	1.00	1.00	0.80	0.69	1.37	1.12	0.34	2.14	0.64	0.59	0.69	0.95	0.34	2.14
Organic carbon (mg/l)	3.0			2.4	1.2	3.4	0.8	0.8	6.0	8.0	9.0	8.0	4.3	0.8	9.0
Grease and oil (mg/l)	0.20	0.07	0.29	6.80	6.80	6.80	7.90	29.00	0.20	0.10	0.10	0.10	4.86	0.07	29.00
Sulphates (mg/l)	2200	2300	2250	2270	2300	2100	2240	1255	1265	1167	1650	2255	1938	1167	2300
Bicarbonates (mg/l)	6.0	11.0	8.0	14.5	8.8	8.6	10.3	4.6	5.5	8.1	10.1	5.9	8.5	4.6	14.5
Phosphorus (mg/l)	0.21	0.25		0.01	0.05	0.05	0.08	0.01	0.04	0.02	0.12	0.08	0.08	0.01	0.25
Nitrate-N (mg/l)	0.08	0.12	0.50	0.28	0.32	0.33	0.21	0.53	0.87	0.78	0.51	0.50	0.42	0.08	0.87
Ammonia-N (mg/l)	0.02	0.46		0.02	0.12	0.08	0.01	0.04	0.05	0.01	0.08	0.06	0.09	0.01	0.46
Organic-N (mg/l)	0.13	0.19		0.35	0.12	0.13	1.28	0.85	0.57	0.33	15.10	4.80	2.17	0.12	15.10
Chlorophyll 'A' (mg/m3)	1.7	1.7			1.3	1.2	2.8	22.6	2.2	2.8	2.8	2.8	4.2	1.2	22.6
Chloride (mg/l)	14000	16000	16800	17600	17000	15000	16100	11078	6204	7339	13860	17406	14032	6204	17600
Chlorine (mg/l)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Detergents (mg/l)	0.01	0.05		0.05	0.07	0.02	0.01	0.06	0.01	0.05	0.03	0.01	0.03	0.01	0.07
Magnesium (mg/l)	742	796	1015	1025	1043	1016	1060	779	361	334	806	1040	835	334	1060
Calcium (mg/l)	334	371	388	367	393	376	426	280	184	177	356	404	338	177	426
Potassium (mg/l)	430	411	480	341	363	292	318	196	110	159	268	334	309	110	480
Sodium (mg/l)	9083	8902	8667	9141	8938	8240	8339	5745	3630	3450	7170	8050	7446	3450	9141
Cadmium (ug/l)	0.05	0.05	0.15	0.06	0.05	0.13	0.07	0.09	0.23	0.11	0.10	0.05	0.10	0.05	0.23
Mercury (ug/l)				< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Chromium (ug/l)	0.9	1.5	1.1	2.1	1.5	0.8	1.5	0.5	1.1	0.9	0.6	1.0	1.1	0.5	2.1
Copper (ug/l)	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	9	< 5	0.75	0.00	9.00
Lead (ug/l)	0.7	0.4	1.2	0.6	0.5	0.7	1.5	0.7	1.5	2.1	2.2	0.9	1.1	0.4	2.2
Nickel (ug/l)	< 5	< 5	< 5	<5	<5	<5	<5	<5	< 5	< 5	<5	<5	<5	<5	<5
Zinc (ug/l)	8	5	10	6	7	4	7	2	6	7	9	5	6	2	10
Arsenic (ug/l)	< 1	< 1	< 1	<1	1.1	2.2	1.1	< 1	< 1	< 1	<1	<1	1.5	<1	2.2
Manganese (ug/l)	29	38	50	18	18	9	27	4	11	16	37	21	23	4	50
Selenium (ug/l)	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Iron (ug/l)	429	91	60	131	132	153	720	21	740	364	999	458	358	21	999
Aluminium (ug/l)	362	118	56	160	127	171	619	55	777	345	949	350	341	55	949
Fecal coliform CFU/100ml	360	200	1200	160	40	40	420	180	100	780	680	600	397	40	1200
E. coli CFU/100ml	300	200	200	140	40	20	180	20	40	280	600	500	210	20	600

BLACK POINT BASELINE STUDY

WATER

B7 S

	Oct-90	NOV	DEC	Jan-91	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	Avg	Min	Max
pH (pH unit)	7.80	8.20	8.00	7.96	7.99	8.14	8.10	8.01	7.88	7.99	7.98	7.79	7.99	7.79	8.20
Temperature ('C)	23.0	22.6	20.5	18.7	19.8	25.0	27.3	28.9	29.5	30.0	31.5	29.4	25.5	18.7	31.5
Turbidity (NTU)	5.0	6.8	1.5	18.8	3.2	2.8	4.3	2.3	11.0	8.3	16.8	19.5	8.4	1.5	19.5
Conductivity (mscm-1)	47.7	43.4	51.2	49.2	52.7	38.3	46.0	38.4	29.3	19.3	40.5	44.4	41.7	19.3	52.7
Salinity (g/kg)	29.0	31.0	30.0	26.7	30.3	26.4	26.7	18.6	14.7	10.0	20.3	24.7	24.0	10.0	31.0
Dissolved oxygen (mg/l)	7.7	7.7	9.1	8.8	7.6	7.2	8.8	8.1	7.3	7.4	6.4	6.3	7.7	6.3	9.1
TSS (mg/l)	10.0	21.0	21.0	209.0	11.0	3.0	2.0	2.3	0.9	77.0	20.1	17.4	28.9	0.9	209.0
BOD (5 day) (mg/l)	1.00	1.00	2.00	1.91	1.82	1.49	0.84	0.78	2.35	1.45	0.50	0.71	1.32	0.50	2.35
Organic carbon (mg/l)	4.0			0.9	1.3	6.0	1.2	0.7	7.0	11.0	7.0	9.0	4.8	0.7	11.0
Grease and oil (mg/l)	0.05	0.01	0.13	6.80	6.80	6.80	5.70	12.00	0.10	0.10	0.10	0.10	3.22	0.01	12.00
Sulphates (mg/l)	2400	2500	2550	-2410	2220	2000	2220	1627	1306	1023	1650	2187	2008	1023	2550
Bicarbonates (mg/l)	6.0	11.0	7.0	13.9	8.4	8.9	7.9	8.8	5.3	7.3	5.9	6.4	8.1	5.3	13.9
Phosphorus (mg/l)	0.09	0.14	0.08	0.02	0.06	0.05	0.05	0.01	0.03	0.04	0.07	0.06	0.06	0.01	0.14
Nitrate-N (mg/l)	0.05	0.05	0.50	0.30	0.03	0.37	0.19	0.42	0.88	0.79	0.45	0.06	0.34	0.03	0.88
Ammonia-N (mg/l)	0.01	0.07	0.05	0.02	0.09	0.08	0.01	0.05	0.04	0.01	0.06	0.07	0.05	0.01	0.09
Organic-N (mg/l)	0.12	0.06	0.11	0.16	0.29	0.05	0.85	0.28	0.62	1.14	10.90	2.50	1.42	0.05	10.90
Chlorophyll 'A' (mg/m3)	1.8	1.5	2.2	3.0	2.2	1.2	8.7	16.3	2.2	1.7	2.8	2.8	3.9	1.2	16.3
Chloride (mg/l)	15000	18000	17910	18100	17000	14900	15700	12319	7125	7019	13680	17335	14507	7019	18100
Chlorine (mg/l)	<0.1	0.01	≤0.1	≤0.1	≤0.1	≤0.1	≤0.1	≤0.1	0.1	≤0.1	≤0.1	≤0.1	≤0.1	≤0.01	≤0.1
Detergents (mg/l)	0.01	0.05	0.06	0.07	0.01	0.01	0.03	0.03	0.01	0.03	0.02	0.01	0.03	0.01	0.07
Magnesium (mg/l)	878	1108	1123	1088	1058	952	1030	899	369	377	794	1040	893	369	1123
Calcium (mg/l)	340	400	398	397	404	359	420	333	188	199	355	412	350	188	420
Potassium (mg/l)	373	486	556	367	344	276	315	250	119	167	262	338	321	119	556
Sodium (mg/l)	8244	11298	8889	10303	8982	7983	8256	6595	3760	3650	7080	7440	7707	3650	11298
Cadmium (ug/l)	0.05	0.05	0.05	0.07	0.05	0.16	0.07	0.08	0.11	0.08	0.14	0.03	0.08	0.03	0.16
Mercury (ug/l)				<1	<1	<1	<1	< 1	< 1	< 1	<1	<1	<1	<1	<1
Chromium (ug/l)	1.2	2.8	1.5	1.2	1.6	1.0	1.6	0.6	0.6	0.6	0.4	1.3	1.20	0.40	2.80
Copper (ug/l)	≤ 5	≤ 5	≤ 5	≤ 5	≤ 5	≤ 5	≤ 5	≤ 5	≤ 5	7	8	≤ 5	7.50	≤ 5	8.00
Lead (ug/l)	23.0	0.6	0.8	1.3	1.5	0.9	1.7	0.6	1.5	1.9	1.9	1.3	3.1	0.6	23.0
Nickel (ug/l)	< 5	< 5	< 5	<5	<5	<5	<5	<5	< 5	< 5	<5	<5	<5	<5	<5
Zinc (ug/l)	19	5	6	11	6	7	8	3	7	11	8	5	8	3	19
Arsenic (ug/l)	< 1	< 1	< 1	<1	1.2	1.7	1.0	< 1	< 1	< 1	<1	<1	0.6	0.0	1.7
Manganese (ug/l)	21	24	16	10	16	8	16	7	11	14	10	36	16	7	36
Selenium (ug/l)	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1
Iron (ug/l)	174	232	77	87	212	173	489	68	398	487	997	944	362	68	997
Aluminium (ug/l)	371	231	60	106	154	222	434	101	683	445	756	620	349	60	756
Fecal coliform CFU/100ml	1000	560	5000	500	60	80	20	240	80	420	160	550	723	20	5000
E. coli CFU/100ml	800	400	2400	240	60	0	0	120	40	300	120	400	407	0	2400

BLACK POINT BASELINE STUDY

WATER

B7 M

	Oct-90	NOV	DEC	Jan-91	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	Avg	Min	Max
pH (pH unit)	7.80	8.20	7.80	7.97	7.93	7.94	8.10	8.04	7.95	7.98	8.00	8.02	7.98	7.80	8.20
Temperature ('C)	23.0	22.7	19.9	18.8	19.6	25.0	27.3	29.0		30.0	28.8		24.4	18.8	30.0
Turbidity (NTU)	3.5	1.3	0.3	18.5	2.4	3.0	8.0	3.5	20.1	15.8	11.7	23.3	9.3	0.3	23.3
Conductivity (mS/cm)	45.9	43.5	50.0	50.1	52.5	40.1	45.8	40.3	29.7	23.9	40.7	51.0	42.8	23.9	52.5
Salinity (g/kg)	29.0	31.0	31.0	29.3	29.0	25.5	16.0	20.0	14.9	11.8	20.4	28.6	23.9	11.8	31.0
Dissolved oxygen (mg/l)	7.6	7.8	8.2	8.6	7.5	7.1	8.7	7.8	7.4	7.0	6.2	6.4	7.5	6.2	8.7
TSS (mg/l)	41.0	21.0	2.0	220.0	31.0	7.0	22.0	21.5	11.5	146.2	36.6	20.5	38.5	2.0	220.0
BOD (5 day) (mg/l)	1.00	1.00	1.00		1.03	1.65	1.29	0.73	1.87	0.52	0.34	0.73	1.01	0.34	1.87
Organic carbon (mg/l)	3.0			1.0	5.0	3.3	1.0	1.2	12.0	21.0	9.0	8.0	6.5	1.0	21.0
Grease and oil (mg/l)	0.05	<0.01		6.80	11.60	7.90	5.70	45.00	<0.10	<0.1	<0.1	<0.1	12.84	<0.01	45.00
Sulphates (mg/l)	2600	2600	2640	2360	2440	2110	2180	1822	1729	1482	1620	2233	2151	1482	2640
Bicarbonates (mg/l)	6.0	11.0	12.0	13.9	8.6	8.8	7.0	9.2	4.8	7.5	6.6	6.3	8.5	4.8	13.9
Phosphorus (mg/l)	0.13	0.12		0.05	0.06	0.05	0.04	0.01	0.04	0.03	0.09	0.05	0.06	0.01	0.13
Nitrate-N (mg/l)	0.08	0.04	0.50	0.23	0.03	0.29	0.17	0.39	0.79	0.59	0.40	0.06	0.30	0.03	0.79
Ammonia-N (mg/l)	<0.01	0.07		0.02	0.09	0.09	0.01	0.05	0.05	0.03	0.06	0.08	0.05	0.00	0.09
Organic-N (mg/l)	0.12	0.05		0.17	0.08	0.19	1.01	0.40	0.89	4.49	10.00	2.50	1.81	0.05	10.00
Chlorophyll 'A' (mg/m3)	1.5	1.4		2.8	1.8	1.4	2.8	3.0	2.8	1.1	2.2	2.8	2.1	1.1	3.0
Chloride (mg/l)	13000	18000	18100	17700	16800	15600	15600	12975	9518	11220	13510	17424	14954	9518	18100
Chlorine (mg/l)															
Detergents (mg/l)	0.01	0.05		0.07	0.04	0.04	0.03	0.04	<0.01	0.03	0.03		0.04	0.00	0.07
Magnesium (mg/l)															
Calcium (mg/l)															
Potassium (mg/l)															
Sodium (mg/l)															
Cadmium (ug/l)															
Mercury (ug/l)															
Chromium (ug/l)															
Copper (ug/l)															
Lead (ug/l)															
Nickel (ug/l)															
Zinc (ug/l)															
Arsenic (ug/l)															
Manganese (ug/l)															
Selenium (ug/l)															
Iron (ug/l)															
Aluminium (ug/l)															
Fecal coliform CFU/100ml				440	80	100	20	360	80	680	260	310	259	20	680
[illegible]				320	60	80	0	200	40	600	200	280	198	0	600

BLACK POINT BASELINE STUDY

WATER

B7 L

	Oct-90	NOV	DEC	Jan-91	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	Avg	Min	Max
pH (pH unit)	7.80	8.20	8.00	7.97	7.95	7.92	8.10	7.96	7.94	7.96	8.02	7.97	7.98	7.80	8.20
Temperature ('C)	23.0	22.7	19.0	18.8	18.4	25.0	27.4	28.4		29.8	29.7		24.2	18.4	29.8
Turbidity (NTU)	1.1	9.7	2.6	15.6	5.3	4.6	7.5	3.9	11.9	20.2	11.6	24.9	9.9	1.1	24.9
Conductivity (msiem-1)	46.5	49.3	51.5	49.6	52.3	40.9	46.5	43.50	34.1	32.2	42.5	50.7	44.5	32.2	52.3
Salinity (g/kg)	29.0	31.0	31.0	25.0	22.5	16.0	5.4	18.7	17.4	16.7	21.4	28.4	21.9	5.4	31.0
Dissolved oxygen (mg/l)	7.4	7.9	8.1	8.7	7.5	7.0	8.5	8.2	7.6	6.9	7.1	6.3	7.6	6.3	8.7
TSS (mg/l)	5.0	2.0	2.0	220.0	4.0	1.0	1.0	2.2	17.9	156.6	15.2	25.6	37.7	1.0	220.0
BOD (5 day) (mg/l)	1.00	1.00	1.00		1.00	1.51	0.66	0.62	2.07	0.51	0.21	0.66	0.93	0.21	2.07
Organic carbon (mg/l)	4.0			3.4	3.8	0.7	0.6	0.7	14.0	8.0	9.0	10.0	5.4	0.6	14.0
Grease and oil (mg/l)	0.05	<0.01		6.20	5.70	6.80	16.80	56.00	<0.1	<0.1	<0.1	<0.1	13.59	0.05	56.00
Sulphates (mg/l)	2800	2700	2490	2380	2290	2080	2230	2011	1906	1504	1750	2221	2197	1504	2800
Bicarbonates (mg/l)	6.0	11.0	6.0	12.1	9.0	8.7	6.6	12.8	4.8	6.8	5.7	6.2	8.0	4.8	12.8
Phosphorus (mg/l)	0.13	0.15		0.10	0.06	0.05	0.05	<0.01	0.05	0.03	0.06	0.06	0.07	<0.01	0.15
Nitrate-N (mg/l)	0.08	0.06	0.50	0.33	0.03	0.37	0.21	0.32	0.58	0.51	0.45	0.07	0.29	0.03	0.58
Ammonia-N (mg/l)	0.02	0.07		0.02	0.06	0.09	0.01	0.05	0.05	0.04	0.06	0.07	0.05	0.01	0.09
Organic-N (mg/l)	0.12	0.06		0.34	0.05	0.13	1.13	0.23	0.30	1.12	14.30	6.30	2.19	0.05	14.30
Chlorophyll 'A' (mg/m3)	1.3	1.4		3.0	2.0	0.6	3.3	8.0	1.3	1.7	2.2	3.3	2.5	0.6	8.0
Chloride (mg/l)	17000	18000	18000	17100	17200	15100	15800	13879	10990	12230	14320	17264	15574	10990	18000
Chlorine (mg/l)															
Detergents (mg/l)	0.02	<0.05		0.04	0.05	0.05	0.02	0.05	<0.01	0.02	<0.01	0.02	0.02	<0.01	0.05
Magnesium (mg/l)					1043		1017	1029	633	669	812	1040	892	633	1043
Calcium (mg/l)					402		433	360	313	328	365	409	373	313	433
Potassium (mg/l)					365		336	307	183	207	260	330	284	183	365
Sodium (mg/l)					9027		8256	7234	5870	7500	7300	7400	7512	5870	9027
Cadmium (ug/l)					<0.05		0.07	0.07	0.10	0.06	0.10	0.05	0.06	<0.05	0.10
Mercury (ug/l)					<1		<1	< 1	< 1	< 1	<1	<1	<1	<1	<1
Chromium (ug/l)					2.4		0.6	0.7	0.5	1.0	0.4	1.4	1.0	0.4	2.4
Copper (ug/l)					<5		<5	<5	<5	<5	5	<5	5.00	<5	5.00
Lead (ug/l)					1.0		1.7	0.6	1.2	2.5	1.3	1.7	1.4	0.6	2.5
Nickel (ug/l)					<5		<5	<5	< 5	< 5	<5	<5	0.00	0.00	0.00
Zinc (ug/l)					10		7	4	7	7	7	28	10	4	28
Arsenic (ug/l)					1		1.0	< 1	< 1	< 1	<1	<1	<1	<1	1
Manganese (ug/l)					31		34	9	12	26	11	41	23	9	41
Selenium (ug/l)					<1		<1	<1	<1	<1	<1	<1	<1	<1	<1
Iron (ug/l)					302		859	135	601	760	527	1242	632	135	1242
Aluminium (ug/l)					308		764	139	630	644	529	687	529	139	764
Fecal coliform CFU/100ml	900	550	8400	440	100	100	20	460	100	580	360	510	1043	20	8400
	[illegible]	270	6600	300	60	80	0	360	40	520	200	510	820	0	6600

Annex V

Summary of Sediment Analysis

Gammon Construction Limited

Soil and Rock Testing Laboratory

SUMMARY OF SEDIMENT ANALYSIS

Client : China Light & Power Co. Ltd Sheet ____ of ____

Location : Large Thermal Power Station Date : 15/10/92

Job No : 1499 Works Order No : 2

VC/BH No.	Level / Sample No.	Depth (m)	Moisture %	TEST RESULT Method : AAS / Cool Vapour						Unit : mg/kg
				Copper	Cadium	Chromium	Lead	Nickel	Zinc	Mercury
A1	-5.20	0.1	18.74	18.91	0.11	12.37	26.71	0.39	57.28	0.11
A1		1.0	22.69	16.66	0.11	10.56	30.09	3.77	51.38	0.15
A1		2.0	24.71	6.10	0.09	12.41	25.83	15.36	55.28	0.15
A1		3.0	21.38	7.55	0.11	11.58	24.82	7.61	52.15	0.15
A1		6.0	20.08	1.93	0.02	2.11	23.56	4.23	18.72	0.03
A2	-5.00	0.1	18.36	10.05	0.05	14.72	35.14	4.12	70.92	0.07
A2		1.0	20.17	6.97	0.09	15.84	24.33	1.45	59.52	0.17
A2		2.0	25.44	7.30	0.11	15.48	28.45	11.47	61.94	0.15
A2		3.0	28.27	6.58	0.05	13.71	24.69	5.06	62.08	0.11
A2		5.0	20.11	6.71	0.01	1.31	20.09	1.01	14.68	0.13

Prepared By ....

Checked By ....

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Gammon Construction Limited

Soil and Rock Testing Laboratory

SUMMARY OF SEDIMENT ANALYSIS

Client : China Light & Power Co. Ltd   Sheet ___ of ___

Location : Large Thermal Power Station   Date : 15/10/92

Job No : 1499   Works Order No : 2

VC/BH No.	Level / Sample No.	Depth (m)	Moisture %	TEST RESULT Method : AAS / Cool Vapour Copper	 Cadium	 Chromium	 Lead	 Nickel	 Zinc	 Unit : mg/kg Mercury
A 3	-2.50	0.1	21.79	15.53	0.07	14.16	31.37	1.95	67.76	0.15
		1.0	24.58	4.35	0.03	14.10	24.53	13.15	49.19	0.11
		2.0	26.78	5.34	0.09	14.38	31.55	5.15	58.03	0.17
		3.0	24.55	5.06	0.11	13.53	32.64	18.26	55.01	0.15
		6.0	23.16	6.45	0.09	13.72	33.42	0.74	56.45	0.13
A 4	-2.30	0.1	31.71	6.53	0.07	13.64	34.42	4.66	56.79	0.15
		1.0	24.31	22.14	0.03	12.76	44.60	3.59	66.94	0.17
		2.0	20.16	6.18	0.05	11.47	34.89	0.85	54.93	0.19
		3.0	26.16	6.41	0.03	10.14	33.58	1.67	53.36	0.17
		6.0	18.26	4.69	0.03	12.24	36.97	8.01	57.19	0.15

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Gammon Construction Limited

Soil and Rock Testing Laboratory

SUMMARY OF SEDIMENT ANALYSIS

Client : China Light & Power Co. Ltd Sheet ___ of ___

Location : Large Thermal Power Station Date : 15/10/92

Job No : 1699 Works Order No : 2

VC/BH No.	Level / Sample No.	Depth (m)	Moisture %	TEST RESULT Method : AAS / Cool Vapour						Unit : mg/kg
				Copper	Cadium	Chromium	Lead	Nickel	Zinc	Mercury
A5	-2.60	0.1	34.11	26.33	0.05	30.87	67.93	9.32	56.52	0.15
		1.0	20.66	6.27	0.11	18.55	35.94	13.51	65.24	0.13
		2.0	22.61	28.41	0.13	2.86	54.22	7.06	82.79	0.15
		3.0	19.66	6.22	0.07	19.12	42.47	4.78	61.10	0.15
		6.0	18.74	1.92	0.01	7.67	37.33	1.04	7.71	0.17
A6	-2.40	0.1	20.24	17.92	0.03	18.94	49.84	1.83	54.09	0.15
		1.0	21.34	3.86	0.03	14.81	40.42	2.76	30.84	0.13
		2.0	19.24	4.82	0.01	16.34	39.85	7.88	31.48	0.24
		3.0	21.34	6.63	0.09	19.40	53.58	18.95	66.83	0.23
		6.0	19.31	1.75	0.01	2.22	45.00	4.87	5.55	0.19

5oct/10/92

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Soil and Rock Testing Laboratory

SUMMARY OF SEDIMENT ANALYSIS

Client : China Light & Power Co. Ltd. Sheet ____ of ____

Location : Large Thermal & Power Station Date : 14/10/92

Job No : 1499 Works Order No : 2

VC/BH No.	Level / Sample No.	Depth (m)	Moisture %	TEST RESULT Method : AAS / Cool Vapour Copper	Cadium	Chromium	Lead	Nickel	Zinc	Unit : mg/kg Mercury
A7	-1.60	0.1	36.18	28.30	0.11	21.05	63.57	6.82	76.98	0.13
		1.0	23.16	4.82	0.01	18.25	50.49	7.32	49.12	0.09
		2.0	20.17	6.17	0.03	17.22	49.54	16.49	55.63	0.13
		3.0	21.77	6.46	0.03	15.54	54.47	12.12	52.57	0.15
		4.5	20.01	1.97*	0.01	3.96	52.46	8.55	4.76	0.15
A8	-1.05	0.1	26.28	13.37	0.09	17.09	67.49	7.23	62.08	0.17
		1.0	21.19	3.78	0.05	15.27	59.47	9.58	47.03	0.19
		2.0	22.17	5.14	0.05	17.70	65.27	17.78	58.63	0.19
		3.0	20.36	5.97	0.07	20.14	57.77	10.23	48.29	0.21
		4.5	21.74	1.01	0.01	3.78	57.48	0.70	12.35	0.19

[illegible]/10/92.	Prepared By	Checked By ....

Annex VI

Schematisation of WAHMO Model

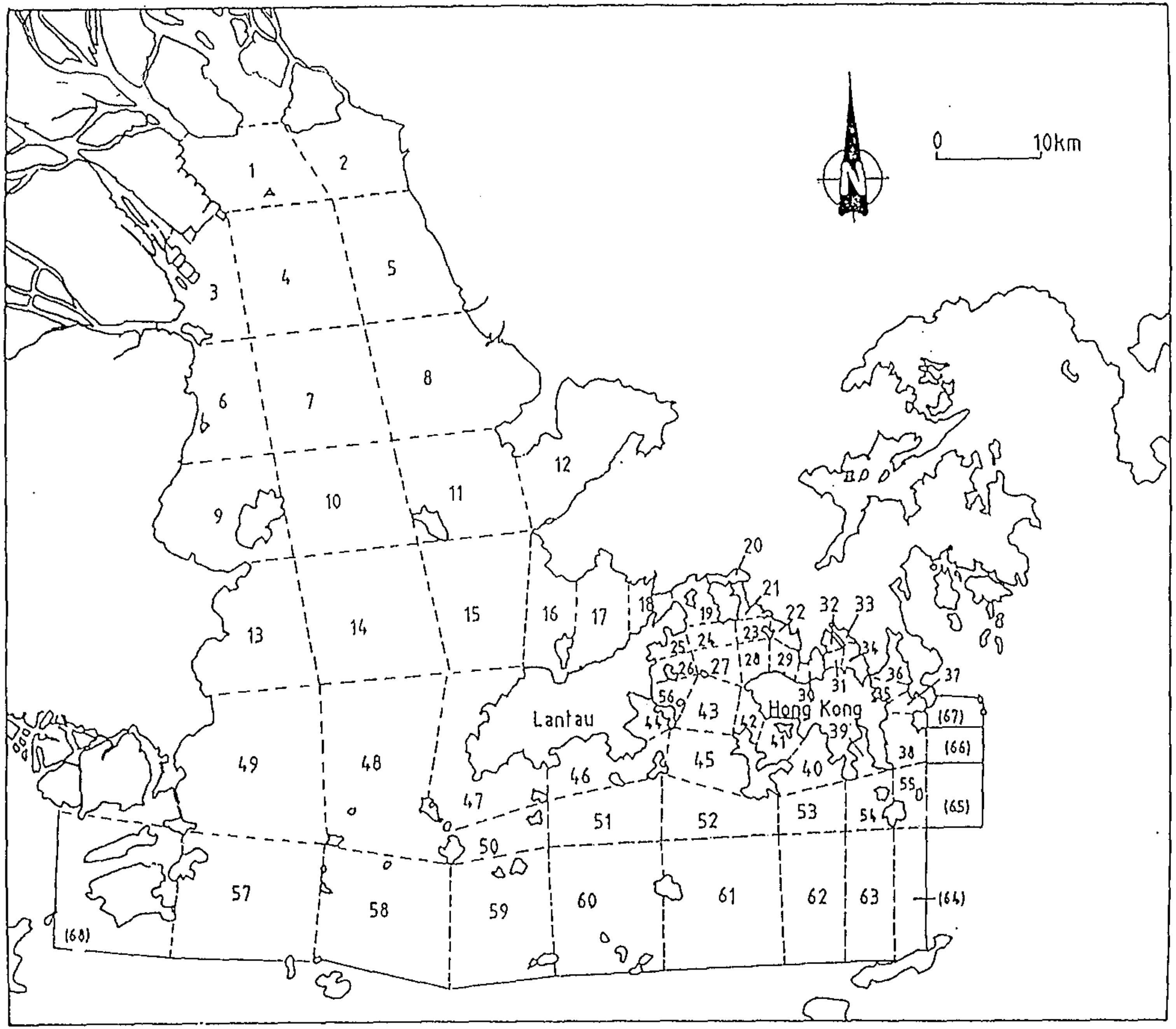

Fig 1 Schematisation of WAHMO seasonal flow model

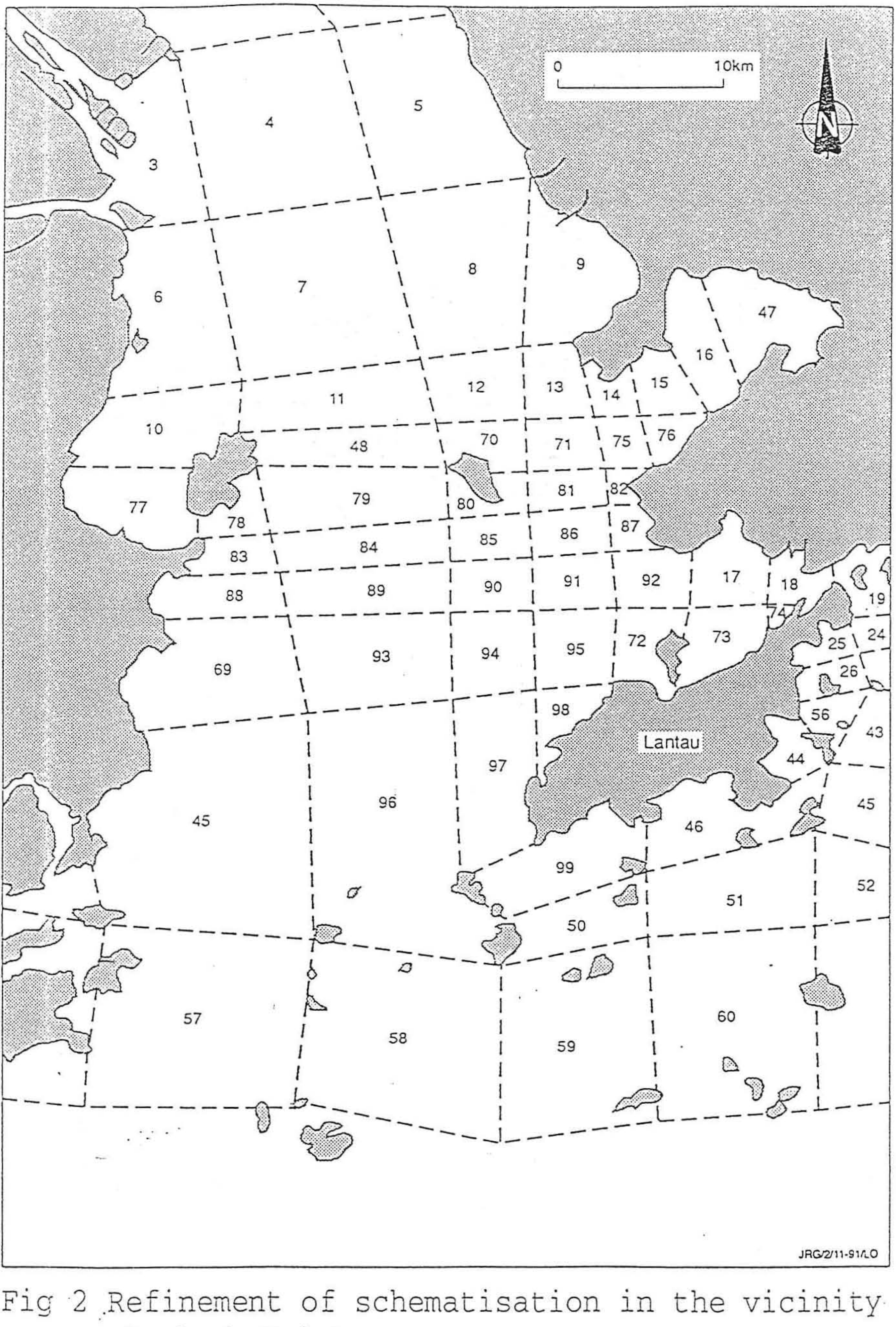

Fig 2 Refinement of schematisation in the vicinity of Black Point