MANAGEMENT OF ENVIRONMENTAL ISSUES RELATED TO CAPITAL DREDGING WORKS AT PORT KLANG, MALAYSIA

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ABSTRACT

Port Klang is Malaysia's leading port with two main navigational entrances / exits. The Northern Pulau Angsa Approach is via the dredged North Channel, 153 meters wide with maintained declared depth of 11.3 meters below Chart Datum (m CD). The Southern approach lies adjacent to the North bound lane of the Malacca Straits Traffic Separation. The South Channel has a width of 365 meters with a maintained declared depth of 15.5 m below CD.

Capital dredging work is proposed in order to upgrade the North access channel to the same width and a declared depth of 365 meters & 15.5 m below CD respectively as that of the Southern approach. The capital dredging volume involved is approximately 39 million cubic meters.

The mainland bordering the port is the most developed region in the country. Mangrove forests cover the undeveloped coastal zones within and at areas bordering the port. Inter tidal mud flats and natural islands off the port provide protection and environmental buffer zones. The gazetted port area and its surroundings also include numerous fishing villages, cage fish farms, cockle breeding farms and artificial reefs to promote natural fish breeding.

The port area is a multi user environment with significant natural buffer zones. Hence implementation of this major capital dredging project requiring relocation of very large quantities of dredged materials will cause multi-user conflicts, socio-economic impacts as well as concerns for environmental protection.

Adequate studies, investigations and planning have been carried out to identify and address all issues on environmental impacts, environmental monitoring and mitigation measures to be adopted for the successful implementation of the project with minimal impact. This paper addresses at macro level, the management of environmental issues related to the successful implementation of the capital dredging project at Port Klang.

Keywords: Port Klang, capital dredging, mangroves, socio-economic impacts, environmental issues

INTRODUCTION

Port Klang which was formally known as Port Swettenham is the major port of Malaysia. It is strategically located on the West coast of Peninsular Malaysia facing the Straits of Malacca which is the busiest navigation waterway in the world. It has trade connections with over 120 countries and dealings with more than 500 ports around the world. Its ideal geographical location makes it the first port of call for ships on the eastbound leg and the last port of call on the westbound leg of the Far East-Europe trade route. It was ranked 13th busiest port in the world for container traffic in the year 2005.

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Figure 1. Location of Port Klang on the world map.

Port Swettenham was established by the British in the 1893 at the present day South Port area. Northport was developed in the early 1960's and subsequently expanded to Westport in the late 1980's.

Figure 2. Locations of West Port, North Port & South Port.

Port Klang is administered by the *Port Klang Authority* (PKA) which is under the purview of the Ministry of Transport Malaysia (MoT). Port operations were privatised in the late nineteen eighties. North Port & South Port terminals are managed & operated by *Northport Malaysia Berhad* while West Port terminal is managed & operated by *Klang Multi Terminal Sendirian Berhad*.

Existing Infrastructure

The port is sheltered by a group of islands and inter-tidal mud flats on the Western side. Marine infrastructure of the port comprises two access channels, the North Channel and the South Channel, together with fairways, basins and anchorages. The South channel is 365 meters wide and has a declared depth of 15.5m below CD while the North Channel has a minimum width of 153 meters and declared depth of 11.5m below CD.

Proposed Developments

Deep draught vessels entering or exiting the port via the North Channel need to wait for sufficient tide. Alternatively they enter through the South approach. Transit for deep draught vessels from the North to enter Northport / South port terminals via the South approach takes an additional 3 hours. Any waiting time or additional transit time for shipping has commercial implications.

In order to improve the marine infrastructure of the port, capital dredging works to deepen and widen the North access channel, so as to be consistent with the South channel, was proposed and commenced, as scheduled, in 2006.

Table 1. Dredging zones and requirements:

ITEM	DREDGING AREA	PRE-DREDGE DEPTH	CAPITAL DREDGE DEPTH	DIMENSION
1	Fairway Opposite Northport Terminal	13.2 m CD	15.5 m CD	750 m Wide X 7.1 Km Long
2	North Channel	11.3 m CD	15.5 m CD	365 m Wide X 20.6 Km Long

The capital dredging works involved dredging and the disposal of approximately 39 million cubic meters of material, mainly soft silty marine clay. This relocation of such a huge quantity of material would definitely have impacts on the environment and the socio-economy of the surrounding areas.

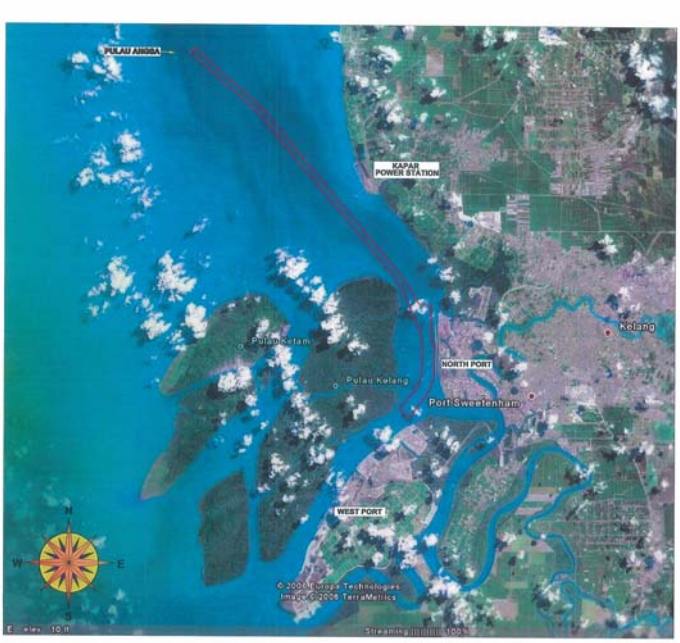

Figure 3. Capital dredging area.

The Capital dredging project proponent is the Ministry of Transport Malaysia (MoT) and the task of implementing the project was assigned to the Port Klang Authority (PKA), as the project's Superintending Officer (S.O.)

ENVIRONMENTAL SENSITIVITIES & SOCIO-ECONOMIC ACTIVITIES

The islands sheltering Port Klang are uninhabited; except for one. They are comprised of natural mangrove forests providing buffer zones and breeding grounds for marine life. The undeveloped coastal zones bordering the port are comprised of similar mangrove vegetation**.** These mangroves provide protection against wave action and act as erosion buffers as well as natural bio-filters for storm water runoff. They also act as a sanctuary for several species of migratory birds from other continents. The mangroves comprise 25 species belonging to 13 families. The coastal zones and the islands cluster also include inter-tidal mud-flats on the western borders, created over a long period of time by silt loaded discharges mainly from the ***Klang River*** and to a lesser extent by the ***Selangor River*** in the North and ***Langat River*** in the South.

These mangrove forests and inter-tidal mud flats are very significant to fisheries. A total of 162 species of fish and 18 species of prawns are found to inhabit these zones. In addition, 36 species of fish and 11 species of prawns have been found to enter these zones during high tide. This indicates the importance of mangrove and mud-flat ecosystems in supporting the food chain and being the natural breeding grounds for fish, prawns and crabs.

Figure 4. Mangrove forests at the inter-tidal coastal Zzones.

Socio –Economic Activities

Cage fish breeding farms are prevalent and located on the waterways between the islands sheltering the ports. Fishing communities comprising of coastal and deep sea fisherman are located on the only inhabited island as well as along coastal villages located to the North and South of the port.

Figure 5. Caged fish breeding farms near Pulau Ketam.

Cockle farming for commercial purposes is prevalent along the coastal zones bordering the North Channel.

Artificial reefs are also present in the area north of the North Channel entrance. These reefs have been laid in place by the *Malaysian Fisheries Development Board* in order to successfully provide fish breeding grounds.

Pulau Ketam (Crab Island), the only inhabited island located off Port Klang is a tourist attraction. Ferry services are available for tourists to visit the island which offers fresh sea food restaurants and fishing villages located at the fringes of the mangrove forests within the inter tidal zone. Buildings are constructed on raised platforms and stilts above the high water levels and are inter connected by wooden walkway platforms. The ferry ride from South Port to the island offers scenic views of North Port, mangrove forested islands and aquaculture sites along the way.

Figure 6. Fishing boats and houses on stilts at "Pulau Ketam".

Figure 7. Aerial photograph of "Pulau Ketam" and nearby islands.

Figure 8. Fishing village at "Pulau Ketam".

Figure 9. Aerial photograph of Port Klang.

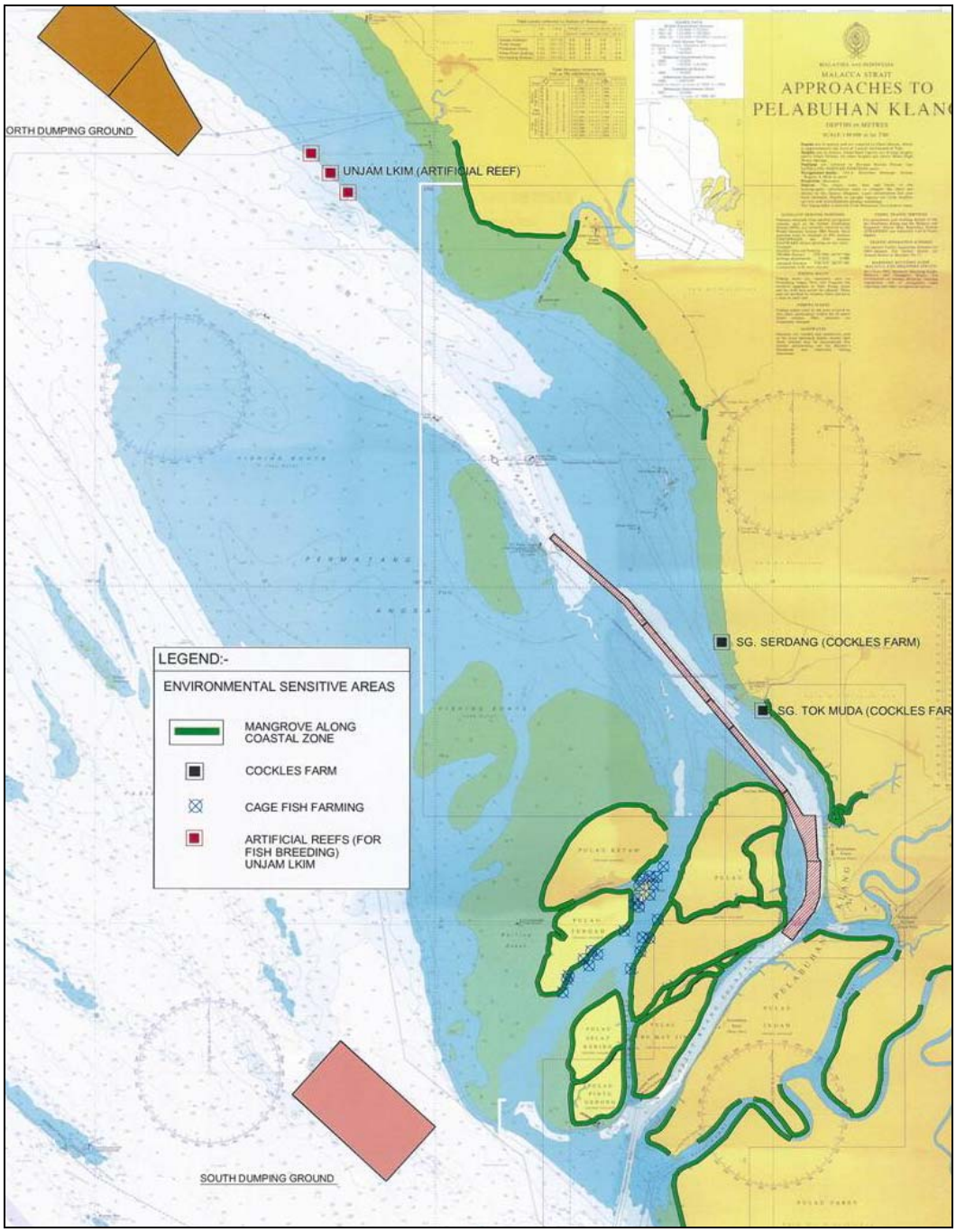

Figure 10. Environmental sensitive areas.

INVESTIGATIONS AND STUDIES

In order to identify in detail all the environmental & socio-economic issues related to implementing the capital dredging project within a busy operating port with multi-user interests and environmental sensitivities, various studies and investigations were carried out as outlined below;

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- Detailed hydraulic studies covering the dredging area as well as the dumping grounds;
- Soil Investigations;
- Bathymetry surveys;
- Marine water quality & biological samplings;
- Detailed Environmental Impact Assessment (EIA)
- Socio-economic studies

The investigations and studies were carried out by independent specialist consultants engaged by the Government (MoT) over a six month period.

ENVIRONMENTAL EVALUATION AND APPROVALS

Reports on the studies & investigations were submitted to an Integrated Team or One Stop Agency, headed by the Department of Environment Malaysia (DoE), for evaluation and approvals.
The Integrated Team comprised of:

I. Department of Environment Malaysia (DoE);
II. Drainage & Irrigation Department;
III. Marine Department of Malaysia;
IV. Fisheries Department of Malaysia;
V. Fisheries Development Board;
VI. Archaeology & Museum Department
VII. Malaysian Economic Planning Unit;
VIII. Port Klang Authority;

The evaluation process took three months and conditional approval was granted to the project proponent (MoT) thereafter.

The conditions of approval that were of significance included:

1. The project proponent was required to prepare and submit to the DoE a detailed Environment Management Plan (EMP);

2. Periodic environmental monitoring works throughout the duration of the project to be carried out by an independent specialist consultant registered with the DoE (the Consultant) who should be engaged by the project proponent. The monitoring works shall include water quality, marine biological samplings, coastal monitoring works, hydrographic surveys etc. which must cover the dredging areas, disposal areas and the environmentally sensitive areas;

3. All testing on water quality & marine biological samples must be carried out by DoE accredited laboratories;

4. In the event of signs of environmental degradation or pollution happening in the environmental sensitive areas, all dredging works must be stopped at once and remedial action instituted immediately;

5. Environmental Compliance Audits must be carried out at three month intervals by the Consultant engaged by the project proponent. The periodic audit reports together with project progress reports must be submitted to the DoE for its review;

6. All dredging vessels working on the project must report to the Marine Department of Malaysia on their daily activities. The dredgers will also be monitored by the Port Klang Vessel Traffic Monitoring Control Station (VTMS) on a 24 hour basis;

7. Disposal of domestic waste, solids waste, stocks and disposal records of oil sludge, grease, oily water and other scheduled waste generated by the dredgers must be in compliance with DoE requirements. All stock records and disposal records for the above mentioned pollutants generated by the dredgers must be made available on request during audit checks;

8. An Emergency Response Plan (ERP) for oil spills incorporating contingency action plans, control measures, cleaning of coastal areas and all other consequential effects resulting from possible oil spills must be prepared and submitted to the Marine Department and DoE for approval;

AREAS OF CONCERNS AND BASELINE VALUES IDENTIFIED IN THE INVESTIGATIONS AND STUDIES

Sediment Plume

One significant area of concern identified in the hydraulic studies is the worst case scenario relating to the extent of sediment plumes due to the dredging activity reaching the environment sensitive areas as well as any socio-economic sensitive areas.

The worst case scenario coincides with spring tides with the full fleet of 4 Trailing Suction Hopper Dredgers (TSHD), proposed for the project, working simultaneously.

Marine biological organisms

Other less significant aspects include the presence of the marine biological organisms that support the local ecological chain found within both the dredging and disposal areas.

- Phytoplankton which is the primary producer in the marine food web, makes up the first marine trophic level. It is in high abundance and diversity which indicates a good ecological character for the areas in terms of primary productivity.
- Zooplankton which feeds on the Phytoplankton makes up the second trophic level and those that feed on other Zooplankton make up the third trophic level. These are found to be of average density & diversity in the dredging areas and much lower at the disposal areas;
- Macrobenthos are macrofauna which feed on zooplankton make up the fourth level and form the most essential link in the marine food chain. These have a low count & diversity probably due to the disturbed nature of the sea bed, the periodic maintenance dredging activities and relatively deep waters.

Nature and Types of Dredge Materials

The Soil Investigation results indicate that the dredge material to be of:

- Sandy silty marine clay at the Southern Section;

- Very soft silty marine clay at the Northern Section.

Marine Water Quality

The baseline water quality analyses indicated

- Total Suspended Solids (TSS) to be within acceptable level (< 50 mg/l)
- Turbidity levels within acceptable limits
- E-coli well below the standard levels

However, this marine water quality is subject to tidal, seasonal and climatic fluctuations as well as being dependent on the physical processes in the dynamic zone affected by hinterland developments. It therefore may not be representative of the seasonal fluctuations.

Chemical Analyses

Metal analyses on several layers of bed profiles indicated that the concentrations were within acceptable limits and classified as of non pollution origin.
Heavy metal concentrations are on the high side but about 80% to 99% are of the resistant or lithogenous fraction which are unavailable to the environment.

SELECTION OF SPOILS DISPOSAL GROUNDS

There are two traditional dredged spoil disposal areas; one each at the North and the South. Catering mainly for maintenance dredging activities they were located outside of the two channel entrances respectively.

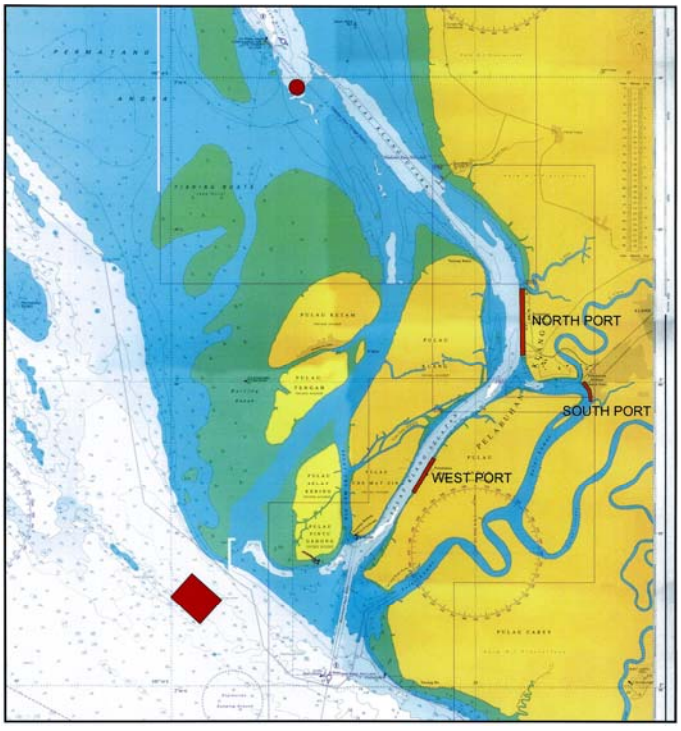


Figure 11. Locations of traditional dumping grounds (used for periodic maintenance dredging).

Annual maintenance dredging volumes average one million cubic meters of mainly silt material contributed by the Klang River and the tidal currents. The traditional dredged spoil disposal areas do not have the capacity to accommodate any capital dredging volume. There would be adverse effects on the environment and socio-economy if the traditional dumping grounds were to be used for capital dredging.

Two new disposal areas; one each at North and South respectively were proposed and adopted. The locations and sizes of the dumping grounds were chosen so as to provide sufficient capacity to accommodate the dredged spoil, have minimal impacts on the environment and be at optimal distances in relation to the dredging areas in terms of economic viability for the project.

Table 2. Dumping ground capacities:

ITEM	DUMPING GROUND	SURFACE AREA	DISPOSAL VOLUME	AVERAGE DEPTH REDUCTION
1	South Dumping Ground	28 Million m^2	18 Million m^3	643 mm
2	North Dumping Ground	35 Million m^2	18 Million m^3	541 mm

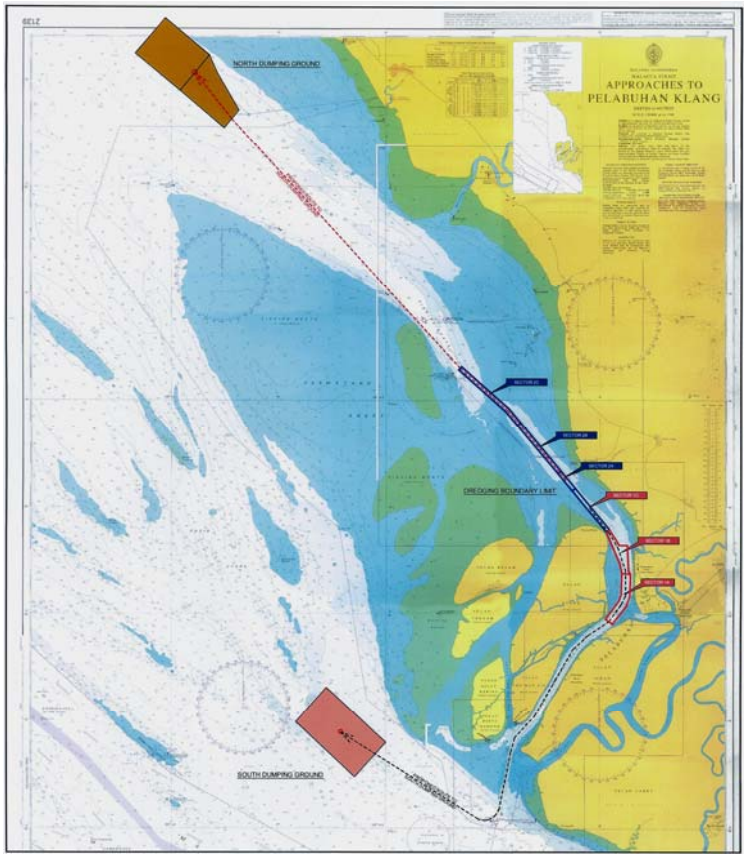


Figure 12. Dumping grounds & dredging areas.

The selection of dumping grounds was based on the following important criteria:

- The dumping areas are where there is deep water (more than 23 meters deep);
- The areas are sufficiently far away from the influence of riverine discharges;
- The areas are not classified as critical fishing areas;
- The areas are not within the deep water international shipping route;
- The areas do not contain any natural or artificial reefs;
- The areas are in good proximity to the dredging areas;
- The areas will allow an acceptable sediment dispersion rate and smallest plume possible;
- The areas do not specifically have any major or critical ecological importance in terms of marine life or habitat;
- The areas are far enough away so as not to cause detrimental impacts on the coastal processes.

PROJECT PLANNING AND IMPLEMENTATION

The implementation of the project was carefully planned and executed, incorporating and accommodating all the environmental sensitive issues identified in the EIA, the conditions of approvals by the DOE and the EMP.

The dredging area is divided into two main sectors which are further sub-divided into 3 sub-sectors each. **Sector 1**, located at the South comprises the fairway opposite the North Port berths and southern section of the North Channel. Sector 2 comprises the middle and northern section of the North Channel. Dredged materials from Sector 1 are disposed of at South dumping ground while the dredged materials from Sector 2 are disposed of at the North dumping ground.

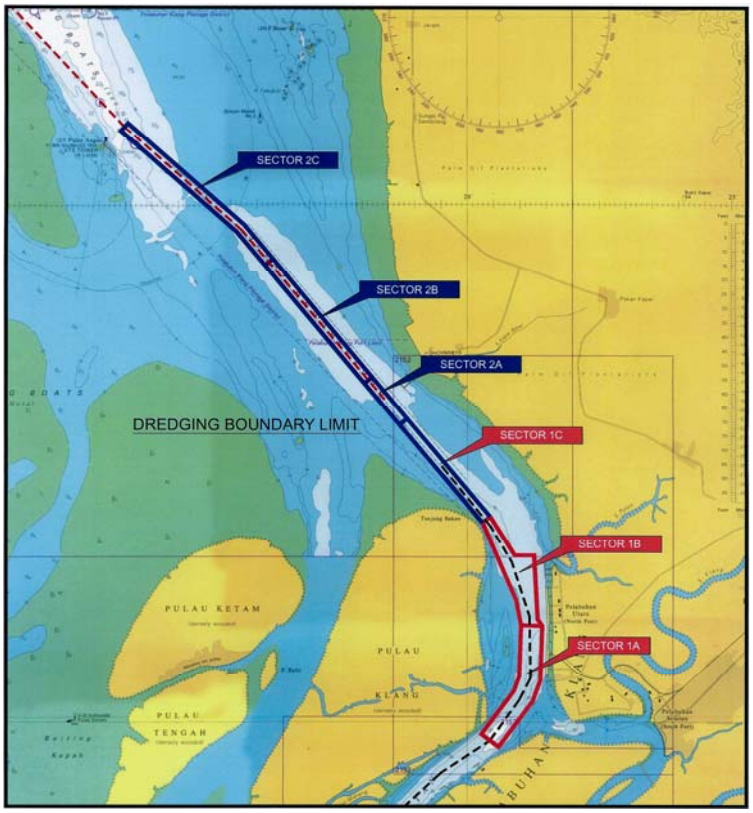


Figure 13. Dredging sectors.

Planning for sector division is based on:

- Distances to the dumping grounds from the dredging areas. The dumping grounds for both sectors have approximately similar minimum and maximum distances. The distances ranged between 16 nautical miles to maximum of 25 nautical miles.
- Approximately equal proportions of the dredged volume are to be distributed between the two dumping grounds.
- Consistency in the nature of in-situ materials and receiving materials at the respective dumping grounds;
  - ✓ Sector 1 dredged materials is sandy silty clay & in-situ materials at the South dumping ground is silty clayey sand;
  - ✓ Sector 2 dredged materials is very soft silty marine clay & in-situ materials at the North dumping ground is soft silty marine clay.

Proposed Dredging Plant

Dredging plant utilised on the project comprised of four locally owned Trailing Suction Hopper Dredgers (TSHDs) ranging from 10,700 cubic meters to 5,250 cubic meter hopper capacities.

Table 3. Proposed dredging plant.

ITEM	DREDGING PLANT	HOPPER CAPACITY
1	TSHD “Inai Selasih”	10,700 m3
2	TSHD “Inai Anggerik”	8,125 m3
3	TSHD “Inai Tulip”	6,800 m3
4	TSHD “Inai Siantan”	5,250 m3

Phases of Implementation

The project is to be implemented over two phases consistent with budget allocations.

- Phase 1 of the project involving approximately twenty three (23) million cubic meters is currently in progress, on schedule and nearing seventy percent (70 %) completion as of February, 2007. The scheduled duration is 14 months.
- Phase 2 of the project involving the balance of approximately sixteen (16) million cubic meters is planned to be executed following the completion of Phase 1.

Phase 1 implementation is coordinated and controlled to be on schedule based on the following reasons:

- ❖ Dredging plant resources allocation is greater than needed for the contract duration. The actual number of TSHDs allocated to the project averaged only 3 of the units at any one time. The remaining TSHD was assigned on a rotational basis to carry out periodic maintenance dredging works at other Malaysian ports;
- ❖ This helps in reducing the extent of sediment plumes during the worst case scenario which is at spring tides;
- ❖ Idling of dredging plant is minimised.

- ❖ Dredging work is executed and completed while being confined to sub-sector levels at any one time. This helps in localising environmental concerns to the active dredging area and its related dumping ground only.
- ❖ Minimising environmental monitoring costs. Monitoring activities are limited to the active dredging sub-sector, the corresponding dumping ground and the control stations at those particular environmentally sensitive areas only.

ENVIRONMENTAL MONITORING WORKS AND ENVIRONMENTAL AUDITS

An independent consultant registered with the DoE was appointed by the project proponent to carry out the related works in compliance with the condition of approval.

Sampling parameters for the various monitoring activities were:

- ➢ **Marine Water Quality:**
  - ~ Total Suspended Solids (TSS) & Turbidity
  - ~ Oil & Grease
  - ~ Heavy Metals [Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Mercury (Hg), Nickel (Ni).
  - ~ Water Appearance

- ➢ **Marine Biological Organisms & Communities**
  - ~ Phytoplankton
  - ~ Zooplankton
  - ~ Macrobenthos

- ➢ **Coastal Monitoring**
  - ~ Cross-Section & Long Section Surveys (Hydrographic & Topographic)
  - ~ Visual inspections of any erosion / accretion along coastlines
  - ~ Inspections of any changes to coastline vegetation
  - ~ Satellite image comparison (pre & post project)

Table 4. Periodic monitoring & audits and their respective frequencies.

ITEM	ACTIVITY	FREQUENCY	REMARKS
1	Marine Water Quality	Twice Monthly	Spring Tide & Non-Spring Tide
2	Marine Biological Organism Samplings	Three Monthly interval	
3	Coastal Monitoring	Monthly	
4	Environmental Audits	Three Monthly interval	
5	Visits to Sensitive Areas	Monthly	

Figure 14. Environmental monitoring works in progress.

Figure 15. Environmental monitoring works in progress.

QUALITATIVE SUMMARY OF RESULTS OF MONITORING ACTIVITIES TO-DATE

The monitoring activities to-date has indicated that there are no major concerns.

- ✓ **Marine Water Quality**:

  The Malaysian Interim Marine Water Quality Standards is used as the applicable standard to compare the water quality monitoring. The compliance requirements for some of the parameters are as per the tabulation below.

Table 5. The Malaysian interim marine water quality standards:

PARAMETER	UNIT	INTERIM STANDARD
Escherichia Coli (E.coli)	MPN/100 ml	100
Oil & Grease	mg/l	0
Total Suspended Solids	mg/l	50
HEAVY METALS		
Arsenic (As)	mg/l	0.1
Cadmium (Cd)	mg/l	0.1
Chromium (Cr) Total	mg/l	0.5
Copper (Cu)	mg/l	0.1
Lead (Pb)	mg/l	0.1
Mercury (Hg)	mg/l	0.001

With the exception of total suspended solids (TSS) and *E. coli*, the marine water quality parameters complied with the Malaysian Interim Marine Water Quality Standards.

Generally, elevated TSS and turbidity levels were observed at all sampled stations during spring tide periods. The observed readings during spring tide periods were about 2 to 5 times the measurements taken during non-spring tides periods.

Besides the capital Dredging works being in progress, the affected sites are also subject to normal dynamic conditions, undergoing constant change governed by various factors ranging from:

- ~ Physical processes (such as the strength of currents, waves, tidal changes and up welling events in the coastal zone, and from fresh water inputs from rivers and streams),
- ~ Geographical and topographical factors such as location (sheltered or unsheltered) and bottom bathymetry (underwater contouring),

These factors would influence the sites in some way or another. The actual extent of such influences may vary substantially according to location and from one particular time to another.

A long-term monitoring programme is necessary in order to establish result trends (to assess whether any detected changes represent short-term or long-term phenomena).

The *E. coli* measurements exceeding the Malaysian Interim Marine Water Quality Standards (of 100 counts/100 ml) were localized and limited to a few stations. The most likely source of the *E. coli* contamination was due to partially treated or untreated domestic sewage and animal waste.

- ✓ **Marine Biological Organisms & Communities reports indicated**:
  - ~ No changes in density of Phytoplankton & Zooplankton levels at the dredging & disposal areas.
  - ~ Decrease in the density of Macrobenthos at the dredging areas and an increase of the same at the disposal area.
  - ~ The diversity index:
    - Phytoplankton - Decrease ,
    - Zooplankton - Increase
    - Macrobenthos - Decrease at dredging areas and increase at disposal areas.

These changes are considered temporary and of no major concern in regard to environmental damage. They are also in line with anticipated results in consideration of the dredging activity and relocation of materials involved.

- ✓ **Coastal Monitoring Works**:

A preliminary observation is that the site is an active estuary with high prevailing sediment loads. Based on physical observations carried out to-date, it is noted that within the North Port area some vegetation debris is observed especially within areas which are relatively calm. In addition, along the northern shores of Pulau Kelang (Kelang Island), some signs of erosion were noted. This situation was also noted in the EIA studies prior to the project commencement. These observations are of no serious concern and continuous monitoring, progressing with the project, is in place to check on any possible effects on the coastlines.

- ✓ **Visits & Inspections at the Sensitive Areas**:
  - ~ The scheduled visits to all the sensitive areas identified in the EIA indicated there were no significant concerns affecting either the environment or the socio-economy of the local population as a result of the project.

- ✓ **Scheduled Environmental Compliance Audits:**
  - ~ Scheduled Environmental Compliance Audits included visits to dredgers, project site office and the project site.
  - ~ Disposal of domestic waste and other scheduled waste from the dredging plant was found to be in compliance with the DOE requirements.
  - ~ All records are kept in order and made available to the audit team upon request.

- ✓ **Unscheduled Environmental Compliance Audits:**
  - ~ Unscheduled Environmental Compliance Audits are also carried out by the DOE which includes visits to dredgers, project site office and the project site.

OTHER ENVIRONMENTAL IMPACTS AND MITIGATION MEASURES

Besides the issues identified above, other potential significant causes on environmental impacts and related mitigation measures include:

Navigation Safety

Dredging operations involving physical dredging and transits to and from dumping grounds are carried out within the main shipping lanes. These operations can pose threats to other vessels plying the area. Primary hazards include collisions (with other vessel), impacts (due to drifting on to immovable objects such as a jetty), and grounding and striking (with floating objects such as dislodged logs, pontoons, etc). These primary hazards can lead to catastrophic environmental disasters. However, any dredgers proposed for the works are equipped with Global Positioning Systems (GPS), Electronic Navigation Charts, electronic update of hydrographic survey information on alternate days and 24 hour radar surveillance, all of which enable safe working and navigation.

A Notice to Mariners is issued and updated progressively by the Marine Department of Malaysia, providing information and awareness on the dredging activities among the shipping communities.

All vessels' movements, including dredging plant are constantly monitored by the Port Klang Vessel Traffic Monitoring System by means of radar surveillance and Automatic Identification System (AIS) surveillance.

Solid Waste and Scheduled Waste

Besides the domestic waste generated by the dredgers other wastes include solid waste such as rubbish, wood, cables, etc. that are found at the drag heads of TSHDs after each cycle of the dredging exercise.
This is disposed off properly through the designated waste collection agents. Solid waste disposal records are made available to the independent Audit team upon request. These are in compliance with the *Malaysian Environmental Quality Act (1974) – Environmental Quality (Schedule Waste) Regulation.*

Scheduled Waste includes spent oil & grease, spent hydraulic oil, oily water and discarded or off-specification batteries. Stock and disposal records for the scheduled wastes are kept on board the dredgers and are made available to the audit team on request.

Figure 16. Garbage removed from TSHD's drag head.

Risks due to Discarded Bombs.

Remnants of Second World War bombs which were discarded off-shore during and at the end of the war have been encountered during previous maintenance dredging exercises. There was one encounter with these bombs during the capital dredging works. The bombs were found to be lodged to the bomb grids of TSHD drag-heads with the help of clay material.

Figure 17. Second world war bomb found at TSHD's drag head during maintenance dredging.

Standard operating procedures established previously through experience were adopted. These procedures include:

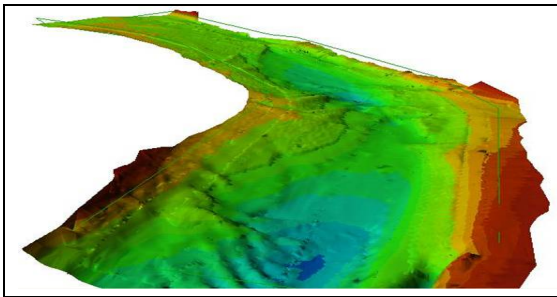
- Securing the bomb with nets to the drag-head to prevent it from falling on to the deck.
- Positioning the dredger away from the area to avoid obstructions to shipping traffic.
- Requesting the Malaysian Navy Bomb Disposal Unit to remove the bomb from the dredger.

Figure 18: Second world war bomb found at TSHD's drag head during capital dredging.

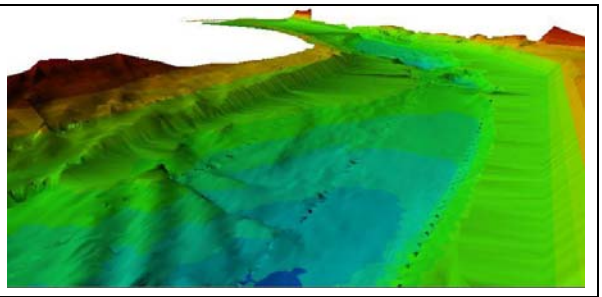
Sea Bed Stability

Multi beam hydrographic surveys were conducted from time to time in order to map the sea bed as well as the progress of works. 3-D images are generated based on the surveys and analysed for possible sea bed instability or slope failures.

The coastal zones were also inspected periodically to identify any mud waves and erosion / accretion.



3-D Image of Multibeam Survey of Fairway opposite Northport Terminal



3-D Image of Fairway opposite Northport Terminal with simulated dredging

Figure 19. Multi beam survey images.

CONCLUSION

The development dredging involving the widening and deepening of the North Channel and Fairway opposite North Port terminals was very essential to meet Port Klang's growth needs. This was also inevitable in order to keep up with the need for improvements to the marine infrastructure of the port with ever increasing ship sizes world wide.

The port area encompasses natural environment providing very essential natural buffer zones and a catalyst for numerous socio-economic activities besides the port operation. The capital dredging project with the main objective of bringing about the necessary development to Port Klang is being implemented in parallel with the consideration of environmental sensitivities and matters of socio-economic importance.

This has been successfully achieved through considerable collective efforts and close cooperation amongst the various parties involved in the project especially in the areas of:

- Reconnaissance Surveys, Investigations & Studies;
- Environmental & Socio-economic Assessments;
- Compliances With The Laws & Regulations;
- Careful Planning & Implementation;
- Environmental Monitoring & Audits;
- Responsibility & Concern for Environmental Preservation.

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ABBREVIATIONS

DoE - Department of Environment Malaysia
MoT - Ministry of Transport Malaysia
PKA - Port Klang Authority
S.O. - Superintending Officer
EIA - Environmental Impact Assessment
EMP - Environmental Management Plan
TSHD - Trailing Suction Hopper Dredger
m CD - Meters below Chart Datum
TSS - Total Suspended Solids
GPS - Global Positioning System