The management of fuel ash originating from power generation

Environmental Impact Assessment
Stage III
Report on Ash Lagoon

January 1993

Binnie Consultants Limited   The Hongkong Electric Co Ltd

The management of fuel ash originating from power generation

Environmental Impact Assessment
Stage III
Report on Ash Lagoon

January 1993

The management of fuel ash originating from power generation

Environmental Impact Assessment
Stage III
Report on Ash Lagoon

CONTENTS

Chapter		Page
1	**INTRODUCTION**	1
2	**THE SITE**	5
3	**LAGOON FORM**	9
3.1	INTRODUCTION	11
	Requirements	12
	Constraints	12
3.2	SEA LEVEL AND WAVES	13
3.3	FOUNDATION CONDITIONS	14
3.4	OPTIONS FOR THE LAGOON PERIMETER	15
	Embankment perimeter	15
	Caisson perimeter	16
	Caisson with revetment	17
	Concrete block quaywall	18
	Steel piles perimeter	19
	Tubular steel pile wall	20
	The preferred option	21
3.5	THE EMBANKMENT OPTION	24
	The typical section	26
	The power station perimeter	27
	The cooling water intake extension	29
3.6	THE CAISSON WITH REVETMENT OPTION	32
3.7	SEEPAGE	33
3.8	CONSTRUCTION	43
	Construction materials	47
	Rock	47
	Sand	48
3.9	COST ESTIMATES	49
3.10	CONCLUSIONS	50

Chapter		Page
4	**LAGOON CONSTRUCTION**	55
4.1	INTRODUCTION	57
4.2	CONSTRUCTION OPERATIONS	59
	Operation 1 Foundation preparation	59
	Operation 2 Bulk filling	61
	Operation 3 Placing of intake culvert units	61
	Operation 4 Quay wall construction for front pond	62
	Operation 5 Closure of lagoon	62
	Operation 6 Construction of perimeter road and wave wall	63
4.3	DETAILED ASSESSMENT	64
	Marine biota	64
	Sea water quality	64
	Visual impact	66
	Noise	67
	Community reaction	69
	Employment opportunity	70
	Tourism	70
4.4	CONCLUSIONS	71
5	**CONSTRUCTION ENVIRONMENTAL MONITORING AND AUDIT**	75
5.1	INTRODUCTION	77
	Environmental monitoring	77
	Environmental audit	77
5.2	ENVIRONMENTAL EFFECTS	78
5.3	MONITORING PARAMETERS AND PROGRAMME	79
	Sea water quality	79
	Noise	82
	Tourism	82
5.4	ACCEPTANCE CRITERIA	83
	Sea water quality	83
	Noise	83
	Tourism	83
5.5	CONTROL PROCEDURES	86
5.6	ENVIRONMENTAL AUDIT	87
	Environmental auditor	87
	Auditing frequency	87
	Scope of the audit	87
	Reporting procedures	88
5.7	CONCLUSIONS	89
	APPENDIX 1 TERMINOLOGY	90

Chapter		Page
6	**LAGOON OPERATING SYSTEMS**	91
6.1	INTRODUCTION	93
	Existing ash handling system	93
	Lagoon operating proposal	93
6.2	THE FILLING SYSTEM	96
	Conveyor system	96
	Types of conveyors	102
	Capacity of conveyors	102
	Ancillary equipment	103
	Lagoon filling	104
6.3	LANDSCAPING	110
6.4	DECANTRATE PUMPING SYSTEM	111
	Draw-off tower	112
	Pumps	112
	Delivery pipework	112
6.5	FLOATER COLLECTION SYSTEM	116
6.6	EMERGENCY SLUICING SYSTEM	118
	Option 1 Pipeline Extension	118
	Option 2 In-Line Booster	118
	Option 3 Intermediate Pumping	118
6.7	HARVESTING SYSTEM	122
6.8	DUST SUPPRESSION SYSTEM	123
6.9	IMPLEMENTATION	124
6.10	COST ESTIMATE	126
6.11	CONCLUSIONS	127
7	**LAGOON OPERATING EFFECTS**	129
7.1	INTRODUCTION	131
7.2	SEEPAGE AND DISPERSION IN HA MEI WAN	132
7.3	LAGOON WATER QUALITY ESTIMATION	135
7.4	DECANTRATE	139
7.5	RELEASE OF SUSPENDED SOLIDS FROM THE LAGOON	140
7.6	pH IN THE LAGOON	141
7.7	DUST	142
7.8	NOISE	143
7.9	VISUAL IMPACT	146
7.10	COMMUNITY REACTION	146
7.11	TOURISM	146
7.12	EMPLOYMENT OPPORTUNITY	146
7.13	CONCLUSION	147
	REFERENCES	148

Chapter		Page
8	**OPERATING ENVIRONMENTAL MONITORING AND AUDIT**	149
8.1	INTRODUCTION	151
	Environmental Monitoring	151
	Environmental Audit	152
8.2	ENVIRONMENTAL EFFECTS	153
8.3	PROPOSED MONITORING PROGRAMME	154
	Lagoon and Sea water quality	154
	Marine biota	157
	Dust monitoring	158
	Noise monitoring	159
	Testing standards	159
8.4	ACCEPTANCE CRITERIA	161
	Lagoon water quality	161
	Marine biota	163
	Dust	163
	Noise	164
8.5	CONTROL PROCEDURES	165
	Decantrate pumping	165
	Dust suppression	166
	Reporting procedure	166
8.6	ENVIRONMENTAL AUDIT	167
	Environmental auditor	167
	Auditing frequency	167
	Scope of the audit	167
	Reporting procedures	168
8.7	CONCLUSIONS	169
	APPENDIX 1 TERMINOLOGY	170
9	**CONCLUSIONS**	171
	TABLES	
Table 3.1	Summary of sample test results for the lagoon site	51
Table 3.2	Embankment construction methods	51
Table 3.3	Rock sizes proposed	52
Table 3.4	Cost estimates (1990) for the embankment option	53
Table 3.5	Cost estimates (1990) for the caisson with revetment option	54
Table 4.1	Estimated noise levels from principal operations	72
Table 4.2	Estimated peak construction noise levels	73
Table 4.3	Attendance at gazetted beaches on Lamma Island	74
Table 5.1	Proposed water testing specification	80
Table 5.2	Proposed test methods	80
Table 5.3	Expected sea water quality	84

		Page
Table 7.1	Estimate of seepage flows through the life of the lagoon	133
Table 7.2	Daily tidal exchange across lagoon perimeter	133
Table 7.3	Lagoon water quality estimation	138
Table 7.4	Operation corrected noise levels	144
Table 8.1	Proposed water testing schedule	157
Table 8.2	Proposed shrimp testing schedule	158
Table 8.3	Expected sea water quality	162
Table 8.4	Permitted metal levels in shellfish	163
	FIGURES	
Figure 2.1	The Site	8
Figure 3.1	Lagoon Location	11
Figure 3.2	Borehole Locations	14
Figure 3.3	Embankment Perimeter	15
Figure 3.4	Caisson Perimeter	16
Figure 3.5	Caisson with Revetment Perimeter	17
Figure 3.6	Quay Wall Perimeter	18
Figure 3.7	Steel Pile Perimeter	19
Figure 3.8	Tubular Steel Pile Perimeter	20
Figure 3.9a	Comparative Profiles for Options	22
Figure 3.9b	Comparative Profiles for Options	23
Figure 3.10	Lagoon Layout with Embankment Perimeter	24
Figure 3.11	Embankment Cross Section	26
Figure 3.12	Power Station Existing Perimeter - Typical Section	27
Figure 3.13	Interface of Embankment and Station Perimeter	28
Figure 3.14	Northern Perimeter - Proposed Typical Section	29
Figure 3.15	Front Pond Typical Section	30
Figure 3.16	Interface of Quay Wall and Station Perimeter	31
Figure 3.17	Caisson with Revetment Section	32
Figure 3.18	Seepage Flownet Through Typical Embankment Section (From Sea To Lagoon)	34
Figure 3.19	Seepage Flownet Through Typical Embankment Section (From Lagoon To Sea)	35
Figure 3.20	Seepage Flownet Through Quay Wall Section	36
Figure 3.21	Seepage Flownet Through Quay Wall Section (Foundation Sealed)	37
Figure 3.22	Seepage Through Power Station Section (Before Placing PFA)	38
Figure 3.23	Seepage Through Power Station Section (After Placing 2mPFA Layer)	38
Figure 3.24	Seepage Quantities Out of Lagoon Before Placing PFA	39
Figure 3.25	Seepage Quantities Out of Lagoon After Placing 2 m PFA Layer	40
Figure 3.26	Seepage Quantities Out of Lagoon After Complete Placement of PFA	41
Figure 3.27	Seepage Flownet Through Caisson with Revetment Section	42
Figure 3.28	Construction Programme for Embankment Option	44
Figure 3.29	Construction Sequence for Embankment	45
Figure 3.30	Construction Programme for Caisson with Revetment Option	46
Figure 3.31	Quarries in PRC Supplying Hong Kong	47
Figure 3.32	Grading of PFA and Appropriate Filters	48

Page

Figure 4.1	Lagoon Layout Plan	57
Figure 4.2	Cross-section Lagoon Perimeter	58
Figure 4.3	Estimated Construction Programme	60
Figure 4.4	Findings of Initial Assessment Report	65
Figure 4.5	Noise Sensitive Receiver	68
Figure 5.1	Sea Water Sampling Stations	81
Figure 5.2	Noise Sensitive Receiver	85
Figure 6.1	Layout of Existing PFA Handling System	94
Figure 6.2	Completed Lagoon and Mound (Including Drainage Plan)	95
Figure 6.3	Proposed Conveyor Routes - Option 1	97
Figure 6.4	Details of Proposed Conveyor Routes - Option 1	98
Figure 6.5	Proposed Conveyor Routes - Option 2	100
Figure 6.6	Details of Proposed Conveyor Routes - Option 2	101
Figure 6.7	Typical Enclosed Deep Troughed Conveyor	102
Figure 6.8	Typical Arrangement of a Drag Link Conveyor with Multiple Outlets	103
Figure 6.9	Typical Pneumatically Actuated Slide Gate	104
Figure 6.10	Filling Method at Lagoon	106
Figure 6.11	Proposed Filling Sequence - Stages 1 to 3	107
Figure 6.12	Proposed Filling Sequence - Stages 4 to 6	108
Figure 6.13	Cross Section of Mound Showing Granular Drain	109
Figure 6.14	Landscaping	110
Figure 6.15	Draw Off Tower Location	113
Figure 6.16	Cross Section of Draw Off Tower	114
Figure 6.17	Draw Off Tower Plans	115
Figure 6.18	Floater Screening	117
Figure 6.19	Emergency Sluicing System - Option 1 Pipeline Extension	119
Figure 6.20	Emergency Sluicing System - Option 2 In-Line Booster	119
Figure 6.21	Emergency Sluicing System - Option 3 Intermediate Pumping	120
Figure 6.22	Emergency Sluicing System - Option 3 Intermediate Pumping	121
Figure 6.23	PFA Harvesting System	122
Figure 6.24	Typical Sprinkler System for Dust Suppression	123
Figure 6.25	Proposed Works Programme for Lagoon Operating Systems	125
Figure 7.1	Noise Sensitive Receiver	145
Figure 8.1	Water Sampling Locations	156
Figure 8.2	Noise Sensitive Receiver	160

APPENDIX A HYDRODYNAMIC MODEL

CHAPTER 1

INTRODUCTION

1.0 INTRODUCTION

1.0.1 The Hongkong Electric Company Limited (HEC) is carrying out an environmental impact assessment (EIA) of various options for the long term disposal of pulverised fuel ash (PFA) arising from its power station on Lamma Island. The EIA follows a feasibility study of ash disposal options which was presented to Government in February 1987. The recommendations of the feasibility study were accepted by Government as providing an outline strategy able to meet the long term disposal needs for PFA and as a basis for more detailed consideration.

1.0.2 The EIA has 3 stages. Stage 1 comprised a review of the feasibility study in the context of possible power station expansion and was completed in November 1987. The review conclusions, endorsed by the Government's Study Management Group were that the preferred strategy would need to evolve from:

(i) the marketing of PFA for industrial uses

(ii) the use of PFA as fill for land formation

(iii) the use of PFA as fill to restore the Lamma Quarry site

(iv) the formation of an ash lagoon located next to the east or southeast side of the power station

1.0.3 Stage 2 of the EIA culminated in the Initial Assessment Report (IAR). The Study Management Group advised that the EIA need not include the principal option of using PFA in industry so the study was tailored accordingly. The objectives of the Stage 2 study were:

(i) to identify and describe the key elements of the total human environment likely to be affected by the various options

(ii) to predict the environmental impacts which might arise from the disposal options and to outline the requirements for effective environmental protection measures

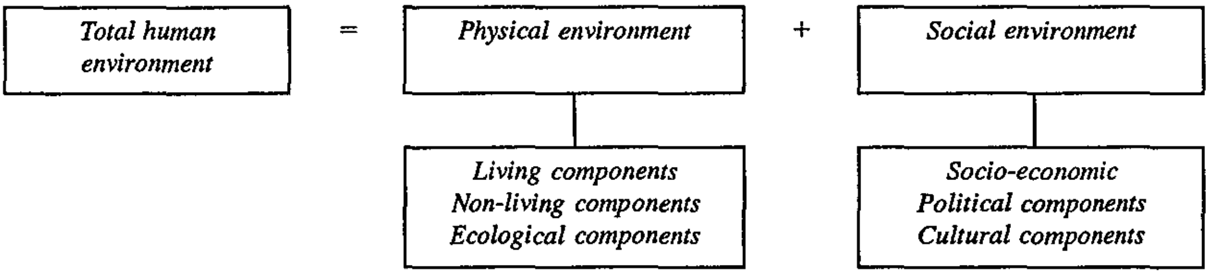
(iii) to evaluate the various implementation options with regard to environmental and operational requirements and recommend a preferred scheme

1.0.4 The second stage identified a preferred strategy, although a number of key elements in the study required further study. One of these was the proposed ash lagoon to be constructed on the sea frontage to the existing power station platform.

1.0.5 The third stage of the EIA consisted of the preparation of preliminary designs for the various elements in the strategy. These were developed in conjunction with assessments of expected environmental impacts and how they can be mitigated. The proposals were propounded in a series of working papers. A number of working papers were prepared for the study of the lagoon, which were submitted to Government for comment and approval.

1.0.6 These working papers, along with comments and responses have been compiled in this single volume. They were issued as separate volumes and inevitably a degree of repetition in descriptions of procedures becomes inherent. These repetitions have been rationalised with appropriate cross referencing where necessary.

1.0.7 The term "environment" occurs frequently in this report and some consideration of what is meant by the word is needed to provide a context for the ensuing discussion. We are concerned with the total human environment, which comprises a physical and a social aspect. The physical environment is a combination of living components such as plants and birds, non-living components such as geology and climate, and interactions between these components, which in broad terms may be referred to as ecological components. These concepts do not however cover personal, inter-personal or institutional components of the human environment. The social environment, which does cover these can be seen as a combination of socio-economic, political and cultural components:



1.0.8 Many of the environmental aspects of the lagoon were discussed in detail in the IAR. These have been expanded in the working papers to cover specific aspects of the lagoon construction and operation.

CHAPTER 2

THE SITE

2.0 THE SITE

2.01 The power station is on a platform, in part reclaimed from the sea, on the northern side of Ha Mei Wan bay (Figure 2.1). The IAR (1988) recommended that a lagoon be built at either site P or Q. Site Q is on the southern boundary of the power station, whilst site P is immediately to the east of the station. Both sites would require reclamation from the sea, Lagoon P was to have a capacity of 2.5 Mm^3, and Q about 3.7 Mm^3. The IAR expressed an overall preference for P based on an assessment of both environmental and operational advantages.

2.02 Subsequent to the issue of the IAR 1988 lagoon, P site was rejected in favour of Q. Also the proposed storage capacity of Lagoon Q was reduced from 3.7 Mm^3 to 1.5 Mm^3. This was possible following the understanding reached with Government that subsequent phases of the ash management strategy could be brought forward to alleviate the necessity for the further 2.2 Mm^3. Thus the site of the lagoon is to be on the southern seaward boundary of the power station platform. It is to be some 529 m long, stretching from the eastern edge of the platform to halfway along the platform, opposite the main control room. It will extend some 250 m into the sea, requiring an extension to the second cooling water intake.

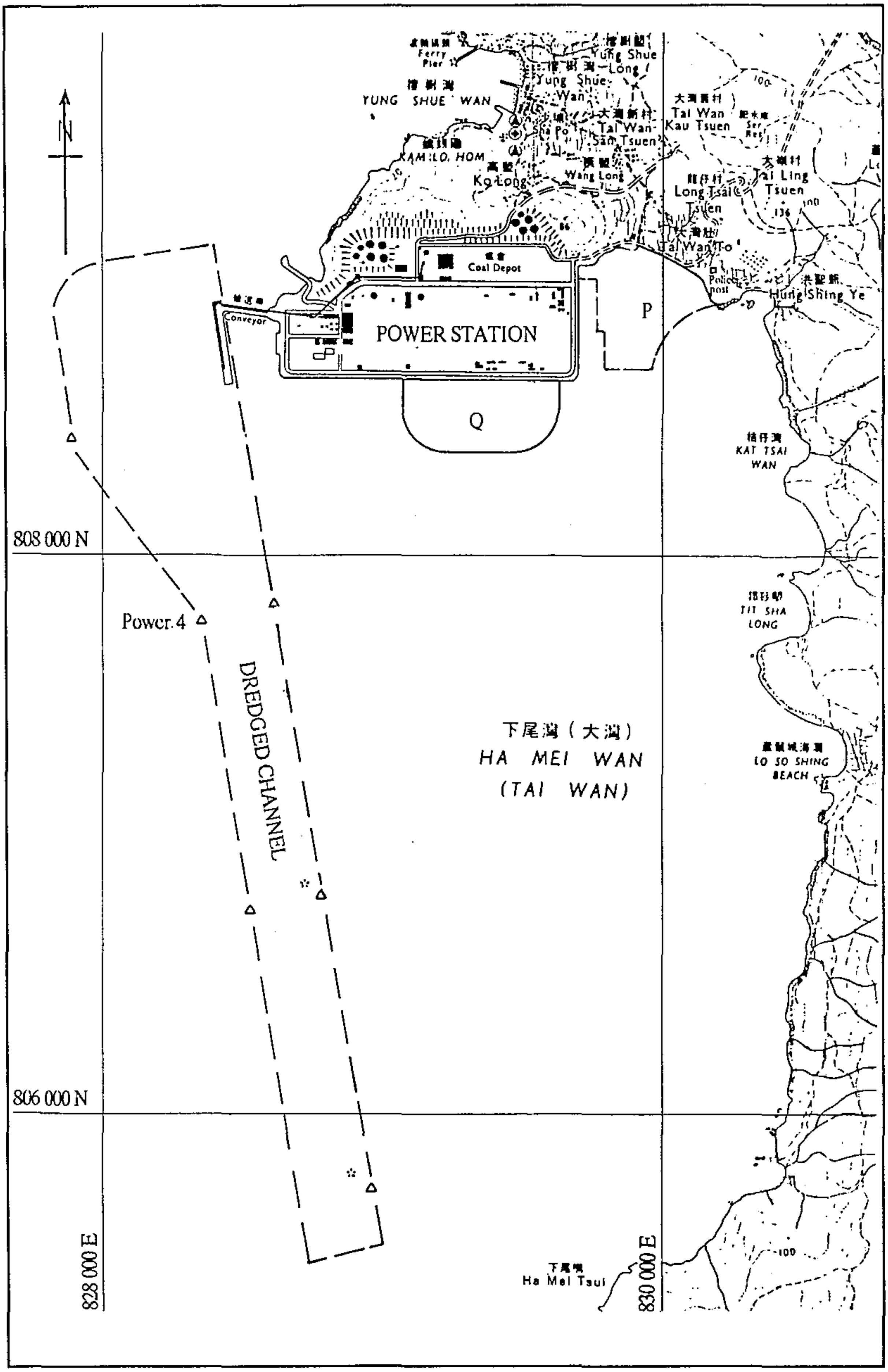


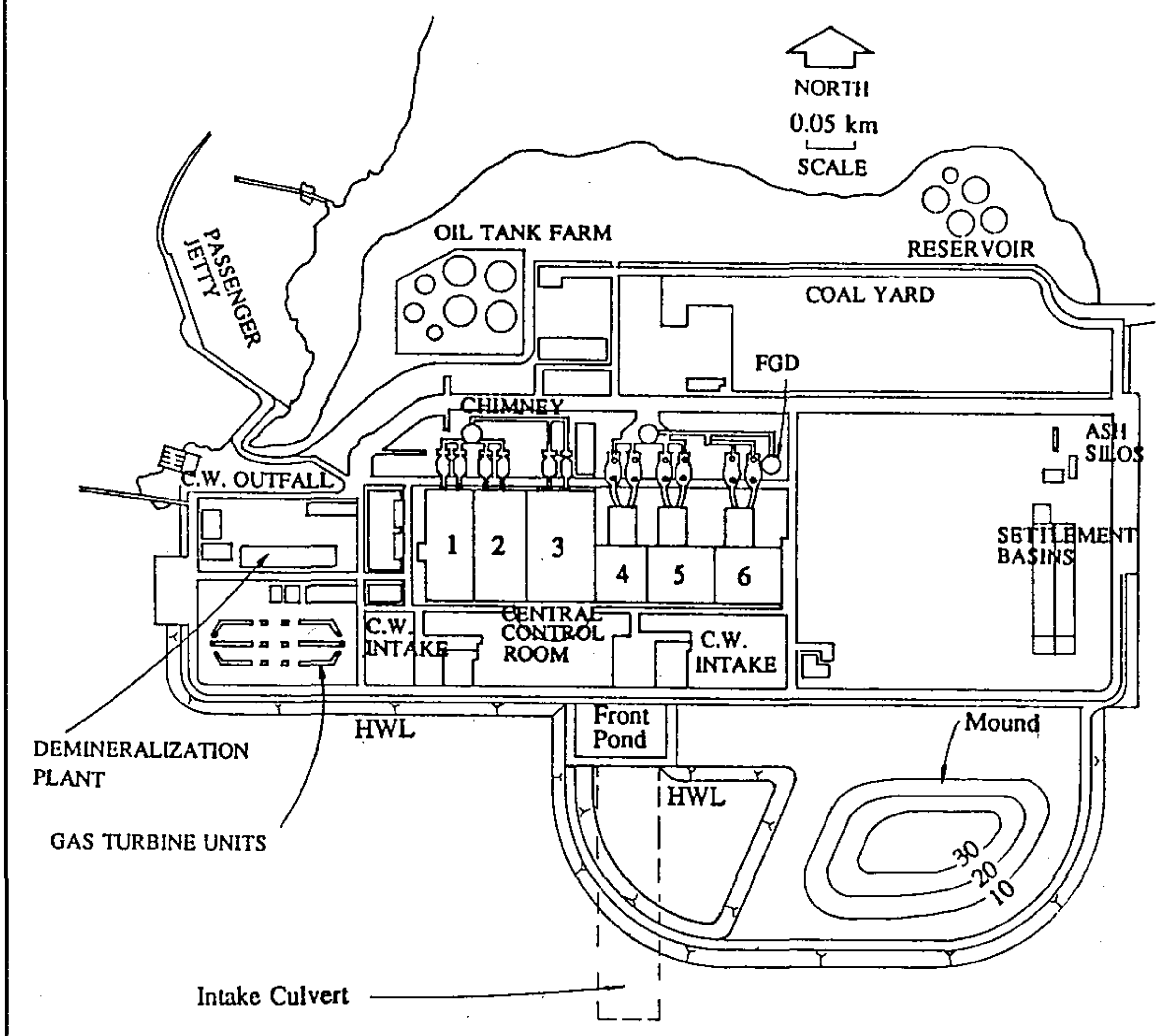
Figure 2.1 The Site

CHAPTER 3

LAGOON FORM

3.1 INTRODUCTION

3.1.1 The IAR demonstrated the need for an ash lagoon at Lamma Power Station and a site at the south east side of the station was approved by Government as the optimum location; site Q (Figure 3.1). The proposals for the lagoon form are derived from a more detailed assessment of the engineering and environmental considerations. An intergrated approach to the preliminary design has been adopted, incorporating environmental measures and identifying specific environmental impacts.



NOTES:

PFA STORAGE CAPACITY PROVIDED BY THE LAGOON

CAPACITY OF PFA IN LAGOON TO LEVEL 5.5 mPD IS 1.37 Mm^3

CAPACITY RETAINED FOR EMERGENCY SLUICING TO LEVEL 5.5 mPD IS 0.25 Mm^3

CAPACITY OF MOUNDING TO LEVEL 30 mPD IS 0.42 Mm^3

Figure 3.1 Lagoon Location

Requirements

3.1.2 Initial assessments of options for the lagoon at site Q were based on a total lagoon capacity of about 3.7 Mm^3 of PFA. While approving the lagoon location, Government felt that the lagoon capacity needed to be kept to the minimum possible and directed that a review of the requirements be carried out. The review demonstrated the need for a capacity of not less than 1.5 Mm^3, plus additional space for emergency sluicing. This smaller capacity having been endorsed by Government, has been the focus of the preliminary design. A second fundamental requirement is that the lagoon must retain all the placed PFA under all weather conditions.

3.1.3 A key Government requirement has always been that the water quality in the bay next to the power station should not be adversely affected by the lagoon construction. The initial evaluation concluded that the proposed lagoon will not significantly affect the local hydrodynamics and that local water quality will not suffer. Nevertheless, in view of the importance of this issue HEC commissioned a computer model of the local hydrodynamics to provide further analytical support to the expert assessments. In addition, the model has been used to predict the dilution and dispersion of the seepage that will take place from the lagoon (Appendix A).

Constraints

3.1.4 Key engineering and environmental constraints have been considered and incorporated with in the preliminary design. The engineering constraints are:

(i) The site has a water depth of about 8 m and the foundation comprises a layer of very soft marine mud averaging 12 m thick, underlain by firmer alluvium at a level of approximately -18 mPD

(ii) The site is susceptible to strong waves because of its exposure and local water depth. As a result, high perimeter levels and heavy armouring for shore protection are required

(iii) Speedy construction is desirable to minimize local disturbance. This calls for a simple structure, built from readily available materials

(iv) The lagoon site envelops the power station's No. 2 cooling water intake which is a concrete culvert about 40 m wide and 6.25 m high

3.1.5 The environmental constraints are:

(i) The lagoon must not significantly affect the local hydrodynamics (Appendix A)

(ii) Seepage from the lagoon must not significantly affect the local water quality (Chapter 7)

(iii) The lagoon must not be visually intrusive (Chapter 4)

3.2 SEA LEVEL AND WAVES

3.2.1 The formation level of the lagoon perimeter and the nature of its construction is to be designed to withstand strong storm conditions. Abnormal sea water levels in Hong Kong occur as surges during tropical cyclones. One method commonly used for predicting maximum sea levels is an analysis of the maximum water levels recorded during each historical event. This is the method used in the Civil Engineering Manual but it has the drawback that surge effects may be obscured by tidal effects and extrapolation to rarer events is difficult with a limited data set. A second approach is to carry out a combined probability analysis of either the maximum storm surge residual (the amount the recorded sea level differs from the normal tide level) or the high water surge (the storm surge at high tide) together with high tides. The latter of these gives a slightly higher value and this is the approach that has been used to calculate the following:-

Return period *years*	**Maximum sea water level** *mPD*
20	3.75
50	3.95
100	4.25

3.2.2 The study for the project has considered both offshore and locally generated waves including refraction modelling in each case. The locally generated waves likely to affect the lagoon site are found to be higher than the offshore waves and the significant wave height for the 50 year event will be 4.8 m with a corresponding wave period between 6 and 7 seconds (Appendix A). Thus the lagoon perimeter is intended to experience minimal overtopping during the combined effects of sea water level and waves. Though the form of the sea wall presented in this EIA is based on a 1 in 50 year event, an event of 1 in 100 years or higher can be used for the detailed design. Differences between the two events have no significant effect on the EIA.

3.3 FOUNDATION CONDITIONS

3.3.1 The typical geology beneath the proposed area for the lagoon is as follows:

(i) marine mud

(ii) alluvial deposits

(iii) decomposed rock

(iv) rock

3.3.2 The base of the lagoon perimeter structure will be founded on the alluvial deposits. These are interbedded clays, silts and sands and are typical of similar alluvial deposits found elsewhere in Hong Kong. Borehole information exists for the lagoon site and the area immediately surrounding the lagoon (Figure 3.2). Strength parameter tests have been carried out for samples taken from these boreholes and the results of these tests for the lagoon area are summarised in Table 3.1. This information has been adequate for preliminary design.

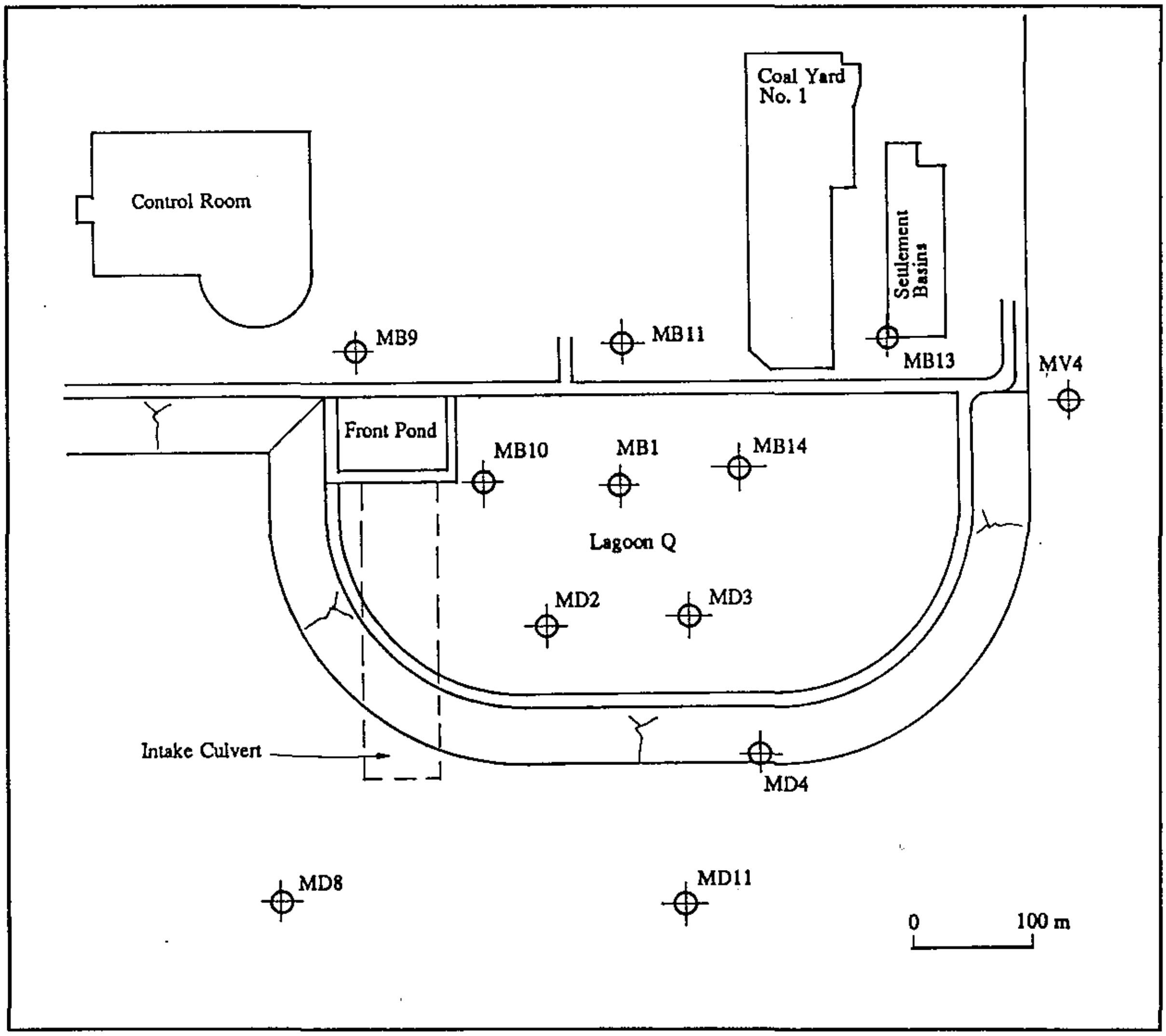


Figure 3.2 Borehole Locations

3.4 OPTIONS FOR THE LAGOON PERIMETER

3.4.1 The existing edge of the power station site comprises a rock embankment to a level of +7.5 mPD, with a slope gradient of 1 on 3. The embankment is topped by a 10 m wide perimeter road and a wave wall about 2 m high on the inner side of the road. The run-up to be expected from the 4.8 m significant wave on this 1 on 3 slope is 2.85 m. Adding this to the extreme water level of 3.95 mPD indicates an appropriate embankment crest level of 6.8 mPD, to which an allowance for settlement and freeboard must be added. The run-up from about 13% of the waves will exceed that of the significant wave for the design event. However, the perimeter road helps dissipate the energy of the overtopping waves and the 2 m wave wall gives additional security, so there should be no overtopping in the design event. Since this level of protection is also appropriate for the lagoon, the proposals for the lagoon perimeter use a similar geometry to that of the existing station and the following options have been considered.

Embankment Perimeter

3.4.2 A conventional embankment option is shown in Figure 3.3. The marine mud would be removed to provide a firm foundation for the embankment. In doing this, a relatively, small quantity of mud would remain within the lagoon site, the removal of which would provide increased lagoon capacity. The design proposes, therefore, that all marine mud be removed from the lagoon site.

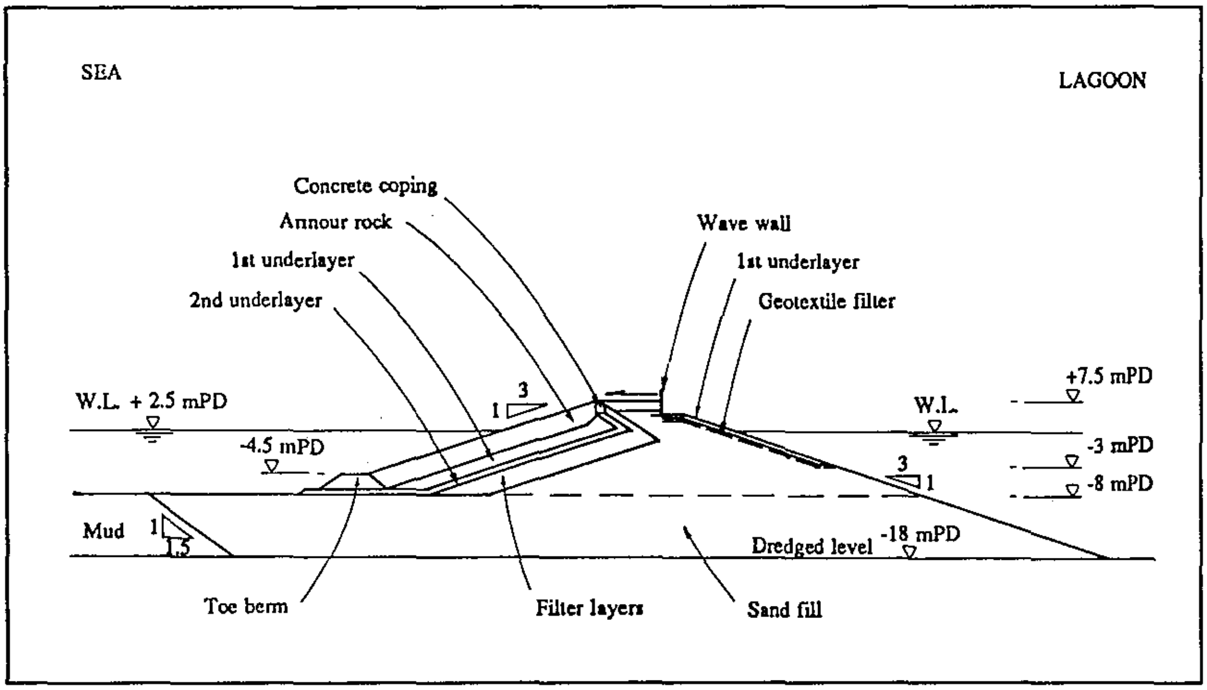


Figure 3.3 Embankment Perimeter

3.4.3 Hearting material for the embankment could be sand, rock or decomposed rock. The use of decomposed rock is not favoured because its relatively high fines content would probably lead to turbidity during placing. Although rock fill is commonly used in marine construction it is not proposed for the lagoon perimeter because it is relatively expensive and has very high permeability. Therefore marine fill (sand fill) is proposed for the hearting material for the embankment because it will be:

(i) readily available at a competitive price

(ii) speedily placed and compacted

(iii) placed with minor environmental effects

(iv) an effective filter to prevent PFA escaping

Caisson Perimeter

3.4.4 Having removed the weak mud from the foundation and backfilled with sand, contiguous pre-fabricated caissons could be used to form the perimeter (Figure 3.4). In view of the deep water and strong wave exposure the caissons would need to be about 20 m wide and sand-filled to be stable.

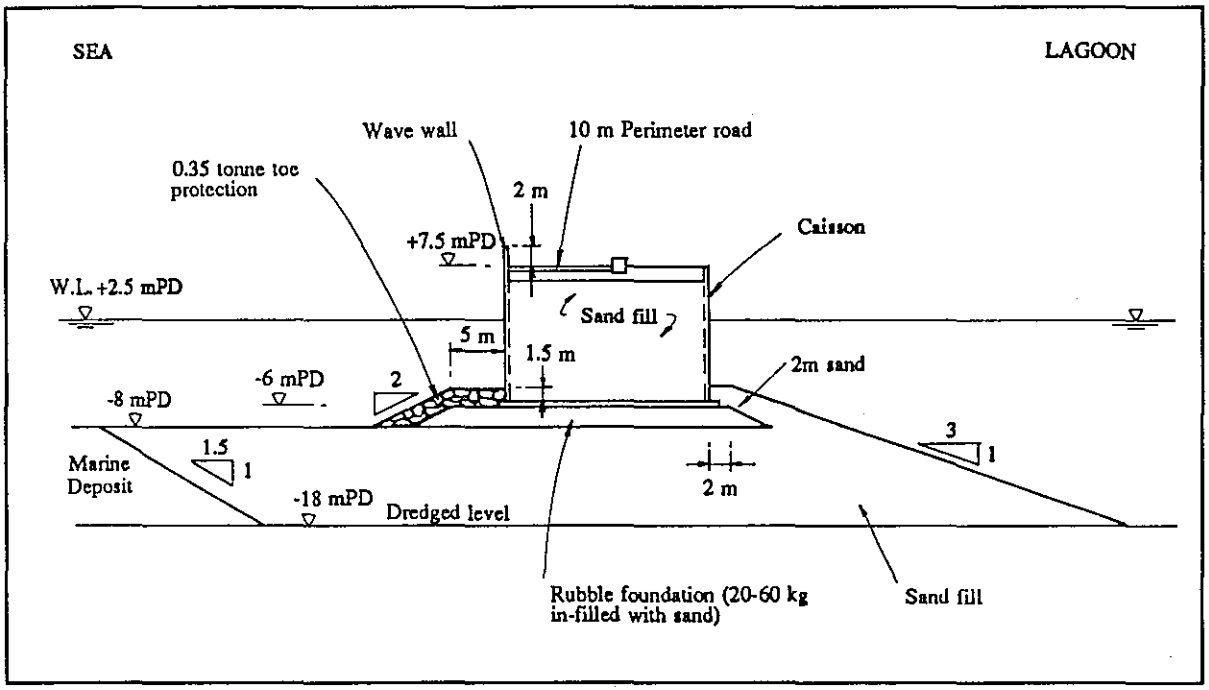


Figure 3.4 Caisson Perimeter

3.4.5 A rubble foundation would provide adequate bearing capacity and filters would be necessary to prevent loss of PFA through this layer. Similarly, filters or seals would be needed to prevent loss of PFA through vertical joints between caissons. However, such caissons would require specialist fabrication facilities and transportation facilities. The principal advantages of the caisson option are:

(i) saving of space at the perimeter

(ii) reduced quantity of construction fill

(iii) increase in lagoon capacity

Caisson with Revetment

3.4.5 The embankment and caisson options could be combined to give the caisson with revetment option (Figure 3.5). This would reduce the space taken by the perimeter and would present some increase in lagoon capacity relative to the embankment option. The caissons required for this option would be much smaller than the single caisson option and would be more appropriate for local construction. As with the former option, a rubble foundation would be necessary to provide adequate bearing capacity and this. Also the joints between caissons would require filters or seals, as appropriate, to prevent PFA loss.

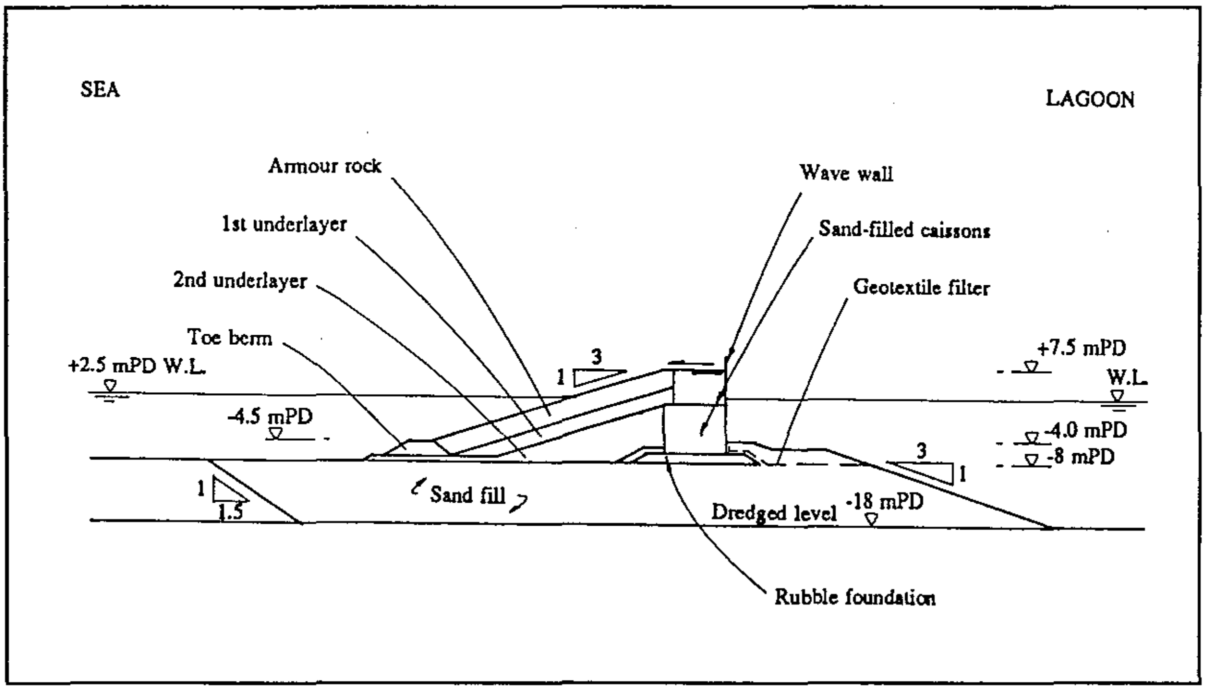


Figure 3.5 Caisson with Revetment Perimeter

Concrete Block Quay Wall

3.4.6 Seawalls built from concrete blocks are common in Hong Kong and these built in a back to back fashion could be adopted for the perimeter (Figure 3.6). The construction would require pre-cast concrete blocks produced off-site and transported by barge to the site. Sand fill would be used to fill the area remaining between the walls.

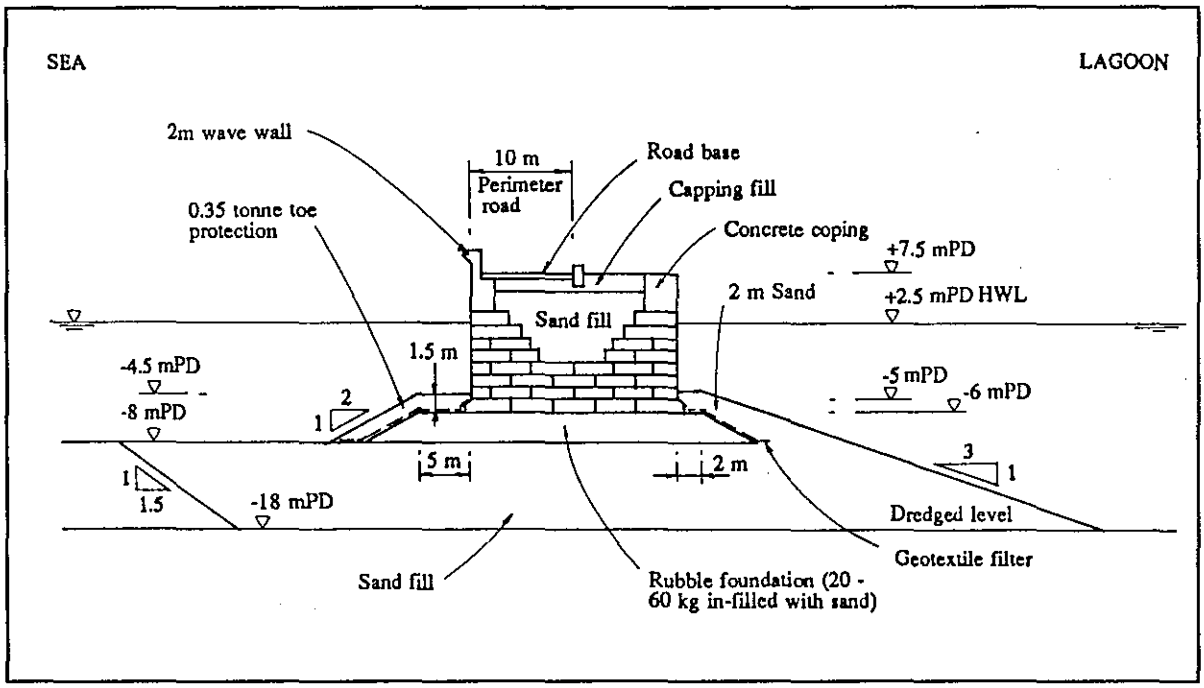


Figure 3.6 Quay Wall Perimeter

Steel Pile Perimeter

3.4.7 Ash lagoons in Japan have been constructed with two rows of steel H-piles and connecting sheet piles, separated by sand fill. This arrangement adapted for the lagoon at Lamma would involve a geometry similar to that illustrated in Figure 3.7.

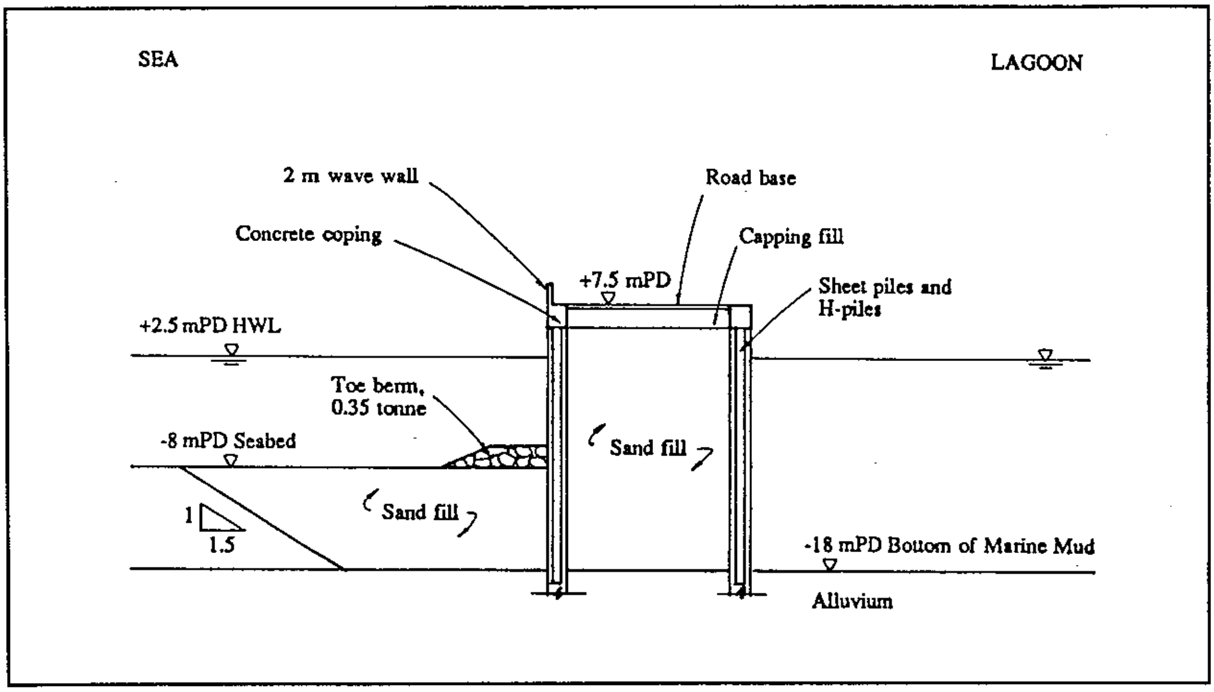


Figure 3.7 Steel Pile Perimeter

Tubular Steel Pile Wall

3.4.8 The existing perimeter of the Lamma Power Station typhoon shelter is formed by interlocking tubular steel piles capped by a reinforced concrete platform. Raking tubular piles are provided for lateral support. This arrangement can be adapted for the lagoon perimeter (Figure 3.8).

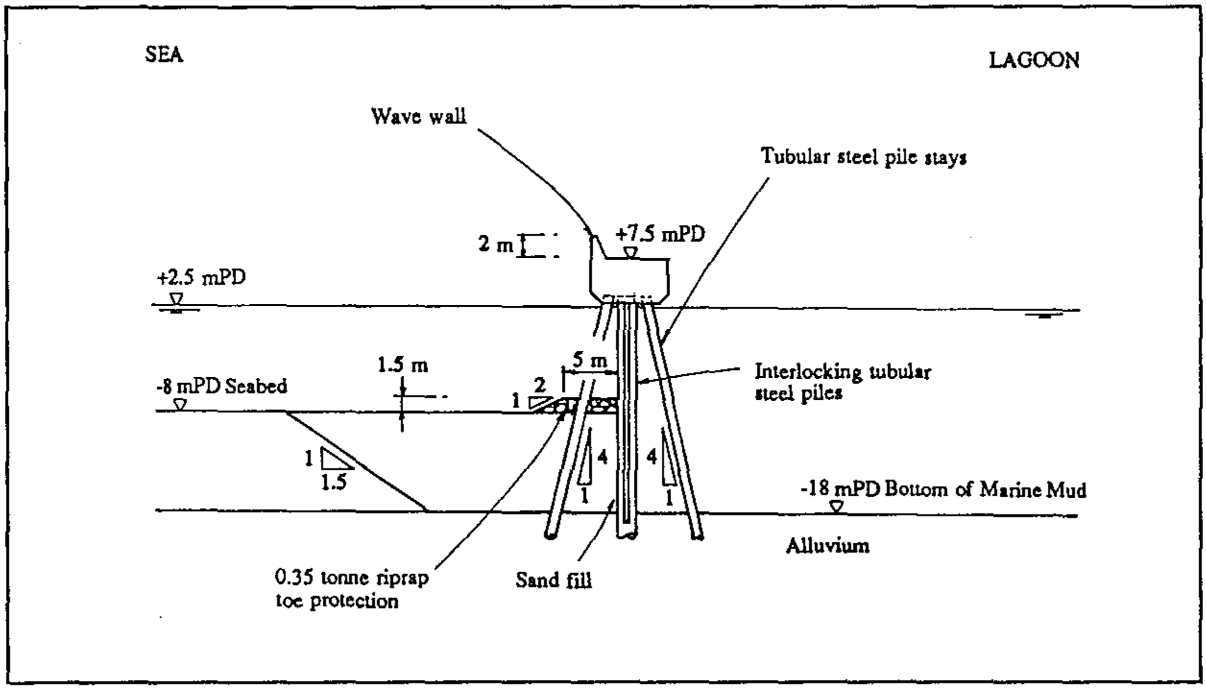


Figure 3.8 Tubular Steel Pile Perimeter

The Preferred Option

3.4.9 A comparison of the cross-sectional profiles of the options considered is given in Figure 3.9. From an environmental viewpoint, the embankment option has a number of advantages:

(i) it will blend visually with the existing power station embankment whilst those options presenting a vertical seaward face which would present a less attractive view

(ii) the marine fauna associated with the existing power station perimeter will re-establish on the same rocky perimeter of the embankment

(iii) being the most substantial structure of the options reviewed, the embankment is likely to offer most reassurance to those local residents that have expressed concern for the perimeter stability

(iv) the perimeter could accommodate substantial storm or accident (collision) damage without risk of PFA escape. Similarly there would be no risks from failure of corrosion protection systems that would be present in the steel pile perimeter options

(v) the construction period would be relatively short because the operation would be principally excavation and bulk filling using high capacity modern equipment. Moreover, because the construction techniques are relatively straightforward, there will be a relatively low risk of construction delays

3.4.11 From an engineering viewpoint, the embankment option is preferred because:

(i) it is a straight forward construction, capable of being built from readily available materials and plant

(ii) it requires only nominal land based working area

(iii) it is relatively insensitive to unforeseen ground conditions and foundation settlements

(iv) under normal operating conditions, it is effectively maintenance free (unlike the steel piled perimeter options, where corrosion would be an important issue)

3.4.12 The foregoing discussion of advantages and disadvantages, demonstrates that an embankment perimeter is likely to be the best option for the lagoon; alternatively the second choice would be the caisson with revetment option, on the basis that it would offer a marginally higher PFA holding capacity albeit with a less attractive inside face. Therefore both these options are described further.

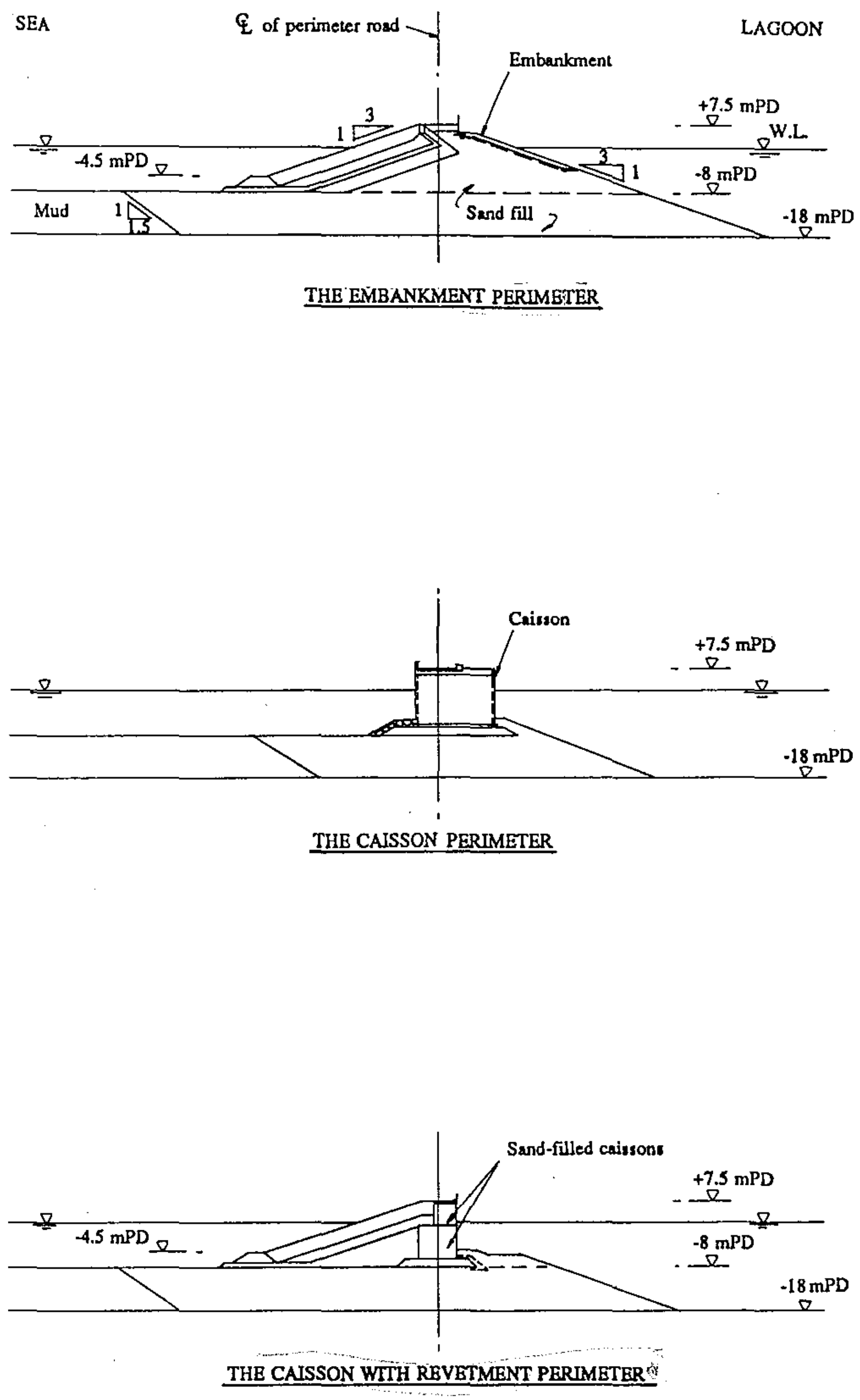


Figure 3.9a Comparative Profiles for Options

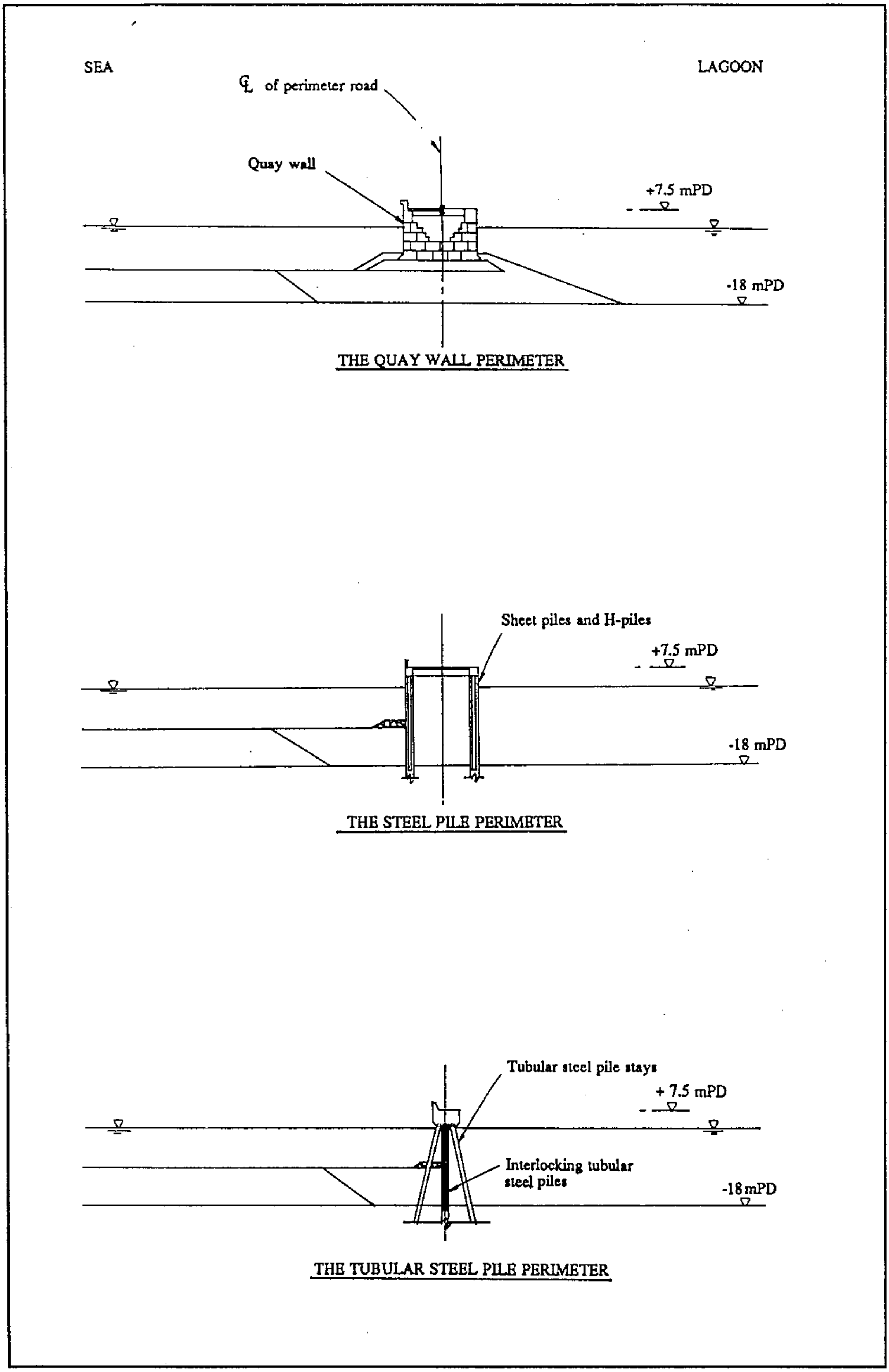


Figure 3.9b Comparitive Profiles for Options

3.5 THE EMBANKMENT OPTION

3.5.1 The proposed lagoon layout, based on an embankment perimeter is shown in Figure 3.10. In addition to its smaller size, it differs in two other principal areas from the initial concept presented in the Initial Assessment Report. Firstly, the perimeter mounding is to be developed on the east side of the lagoon rather than the west, and conversely, the emergency lagoon facility will be located to the west, rather than the east of the site. The reasons for this are:

(i) so that the landscaped mounding will be more effective in screening the lagoon operations from public view

(ii) the floater collection facility can be located at the most appropriate downwind western edge of the site

3.5.2 The second principal change is that the existing cooling water intake No. 2 will be extended out from the present sea wall. A front pond will connect the present intake structure with the new structure (Section 3.5.6).

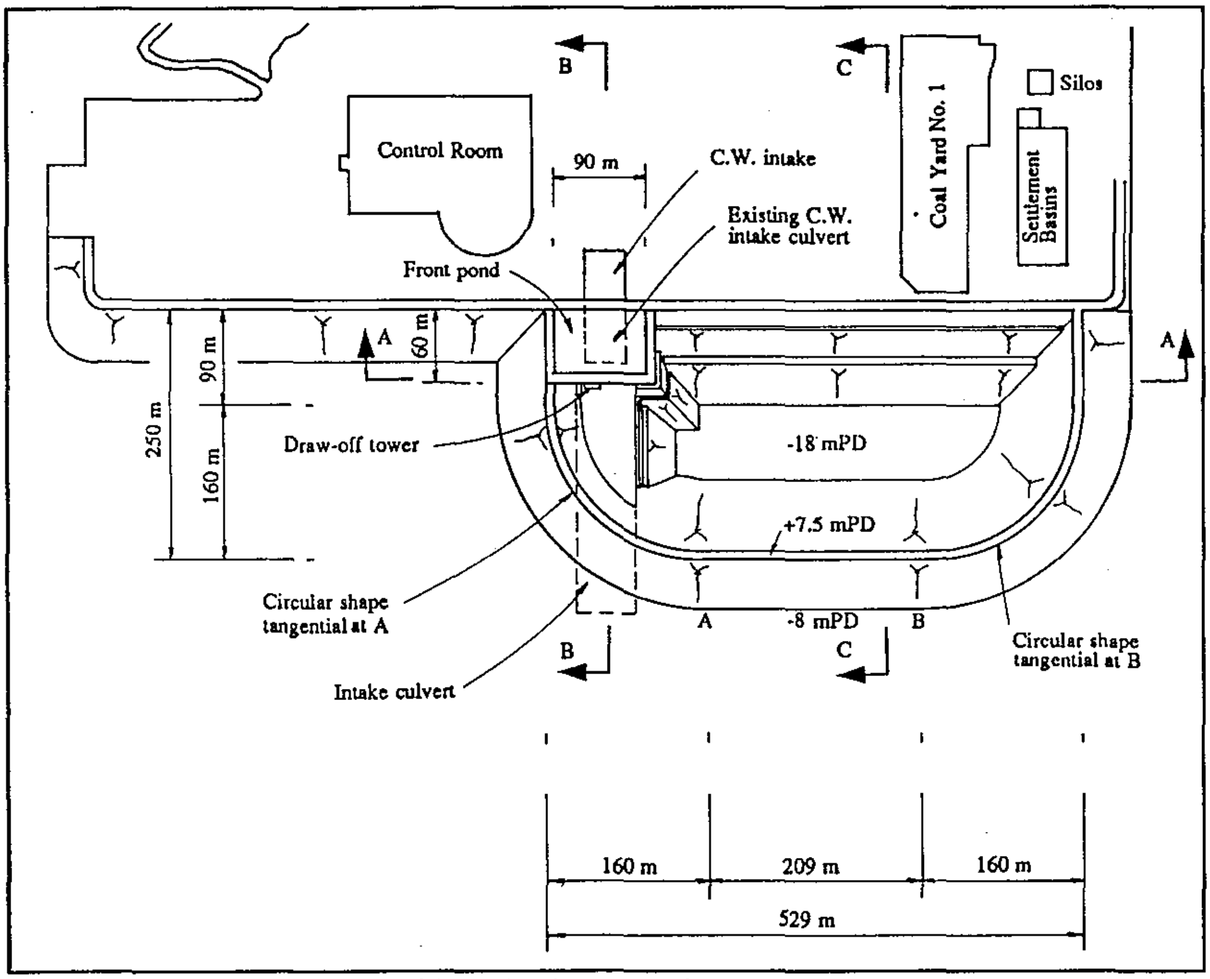
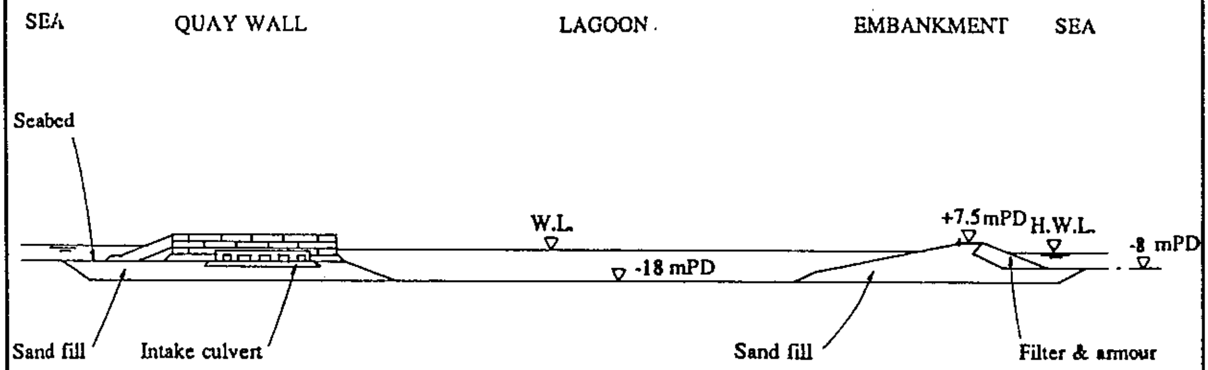
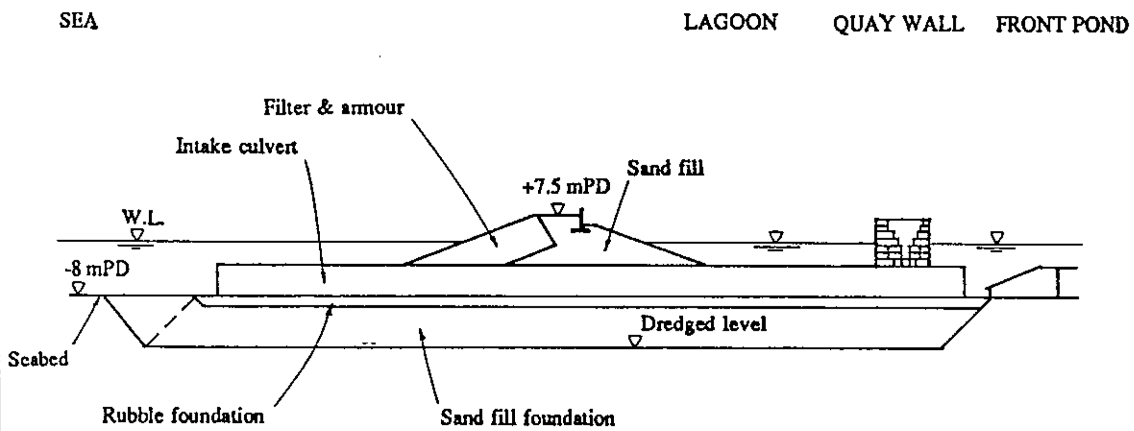


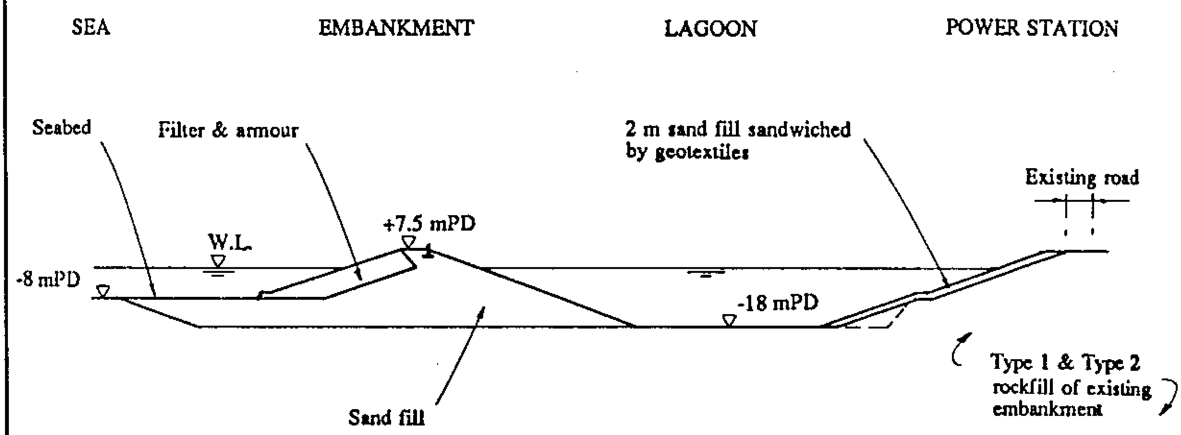
Figure 3.10 Lagoon Layout with Embankment Perimeter



SECTION A-A



SECTION B-B



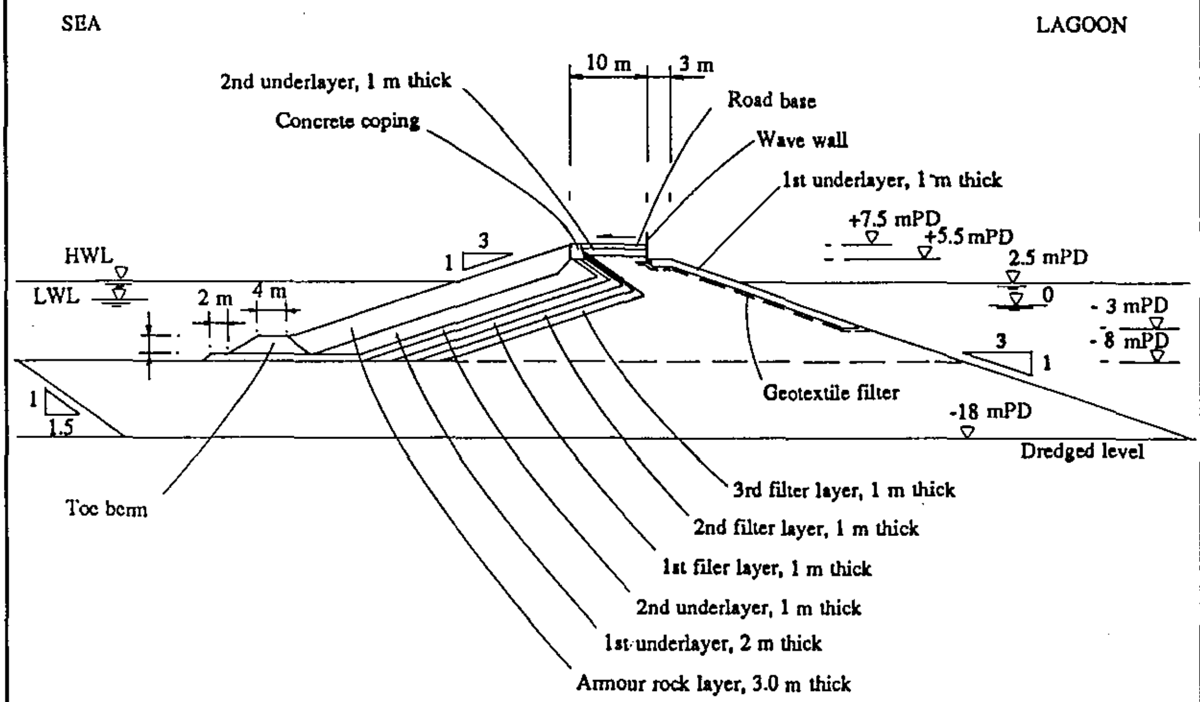
SECTION C-C

Figure 3.10 Continued Sections

The Typical Section

3.5.3 A typical section of the embankment is shown in Figure 3.11. An embankment crest width of 10 m has been adopted to be consistent with the existing power station site, this offers additional benefits such as the provision of working space during construction and additional protection against overtopping waves during storms. The principal construction material will be marine sand and the seaward face of the structure will be protected by a conventional rock revetment. The revetment will be separated from the sand fill by a conventional layered filter, or alternatively, by an appropriate geotextile which is now a common practice.

3.5.4 The inner face of the embankment will be protected by a combination of geotextile and stone which will provide surface protection until the slope is covered with PFA. The system will prevent erosion of the sand during rainstorms and will protect the body of the embankment against the choppy waves which may develop within the lagoon.



Layers	Rock size gradation	
Armour rock layer	6000 kg	- 12000 kg
Toe berm	3000 kg	- 5000 kg
1st underlayer	560 kg	- 1040 kg
2nd underlayer	20kg	- 60 kg
1st filter layer	0.41 kg	- 23 kg
2nd filter layer	7.5×10^{-3} kg	- 42.5×10^{-3}kg
3rd filter layer	0.375×10^{-3} kg	- 2.125×10^{-3} kg
Core material	Marine Sand (fine to medium)	

Figure 3.11 Embankment Cross Section

The Power Station Perimeter

3.5.5 The existing power station perimeter is constructed of coarse rock-fill (Figure 3.12). The northern perimeter of the lagoon will be formed along part of the existing southern power station perimeter. The north east end of the lagoon embankment will be matched with the existing power station boundary (Figure 3.13). To prevent PFA escaping through the rock fill of the power station's perimeter, it is to be sealed with the following treatment (Figure 3.14):

(i) removing the existing armour rock to expose the type 2 rock-fill

(ii) screeding of the type 2 and laying of geotextile separator

(iii) providing a 2 m thick sand layer as PFA filter

(iv) providing a rock and geotextile layer to give the same erosion and wave protection as remainder of the embankment perimeter

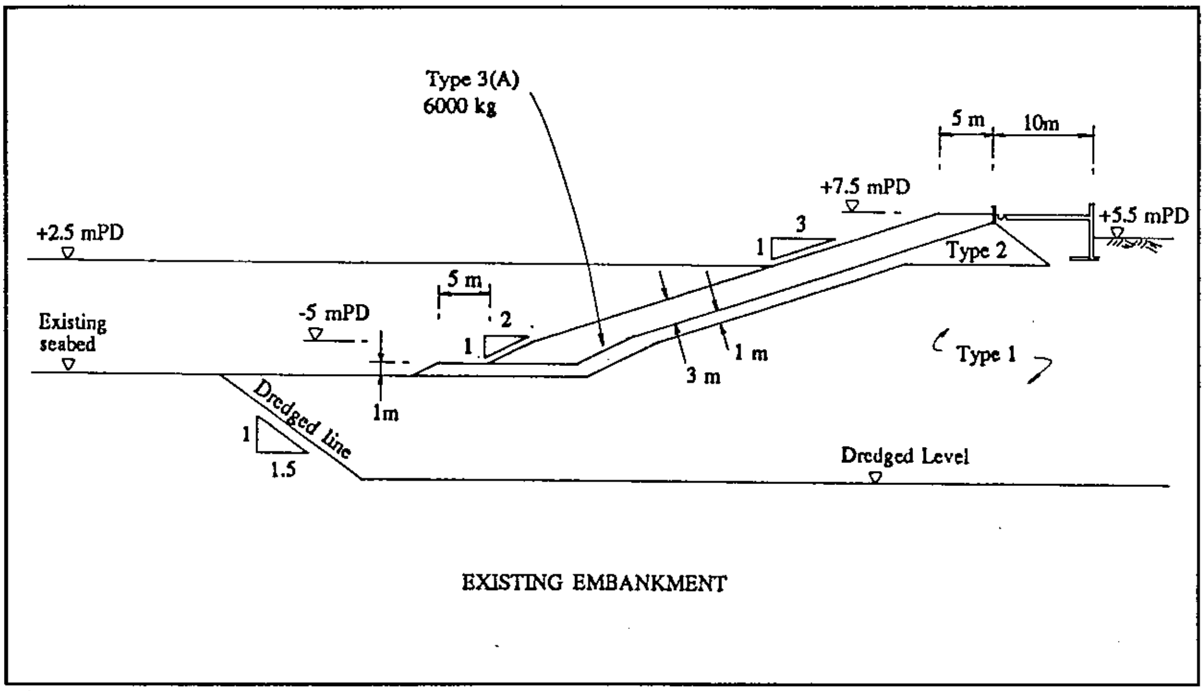


Figure 3.12 Power Station Existing Perimeter - Typical Section

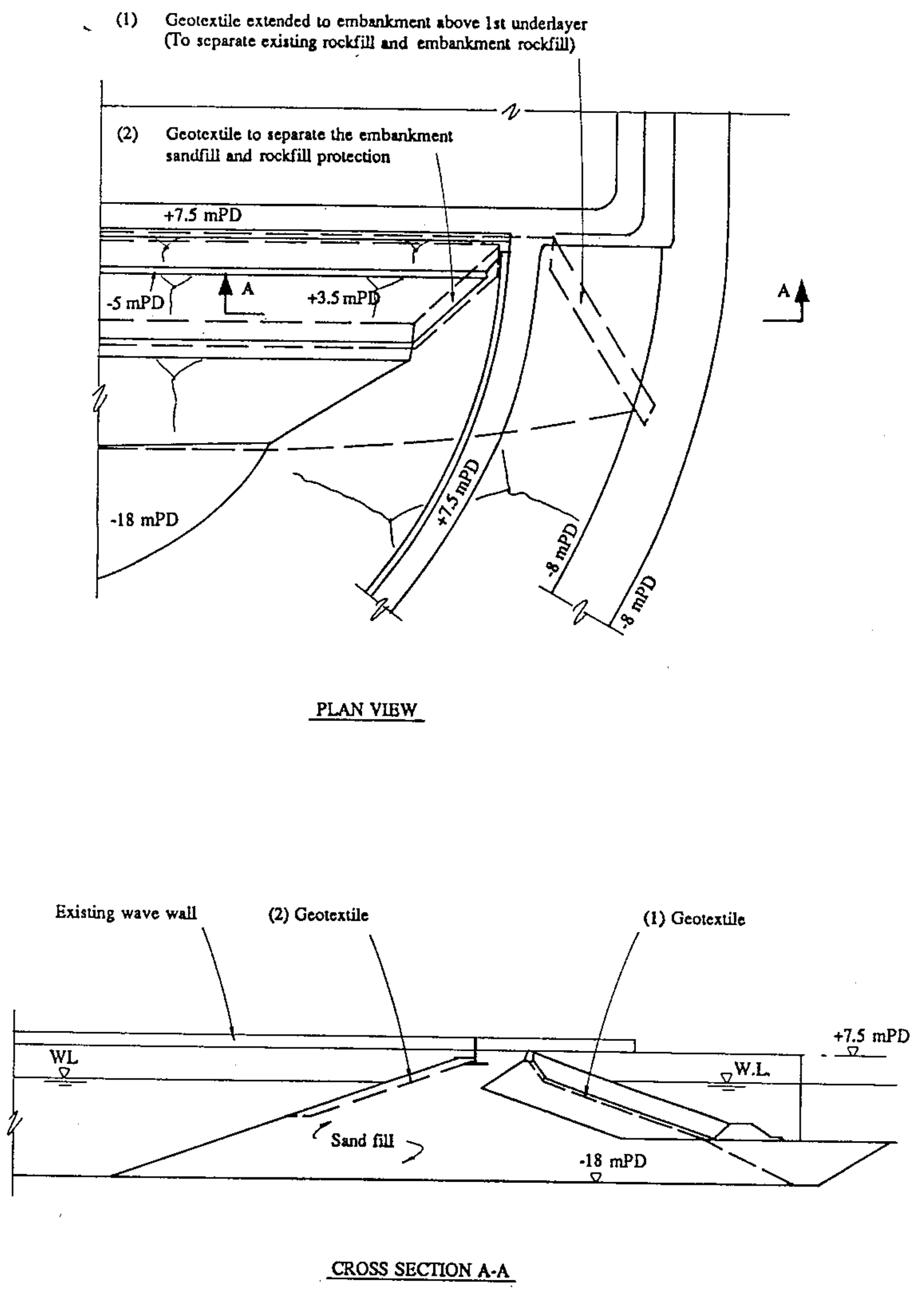


Figure 3.13 Interface of Embankment and Station Perimeter

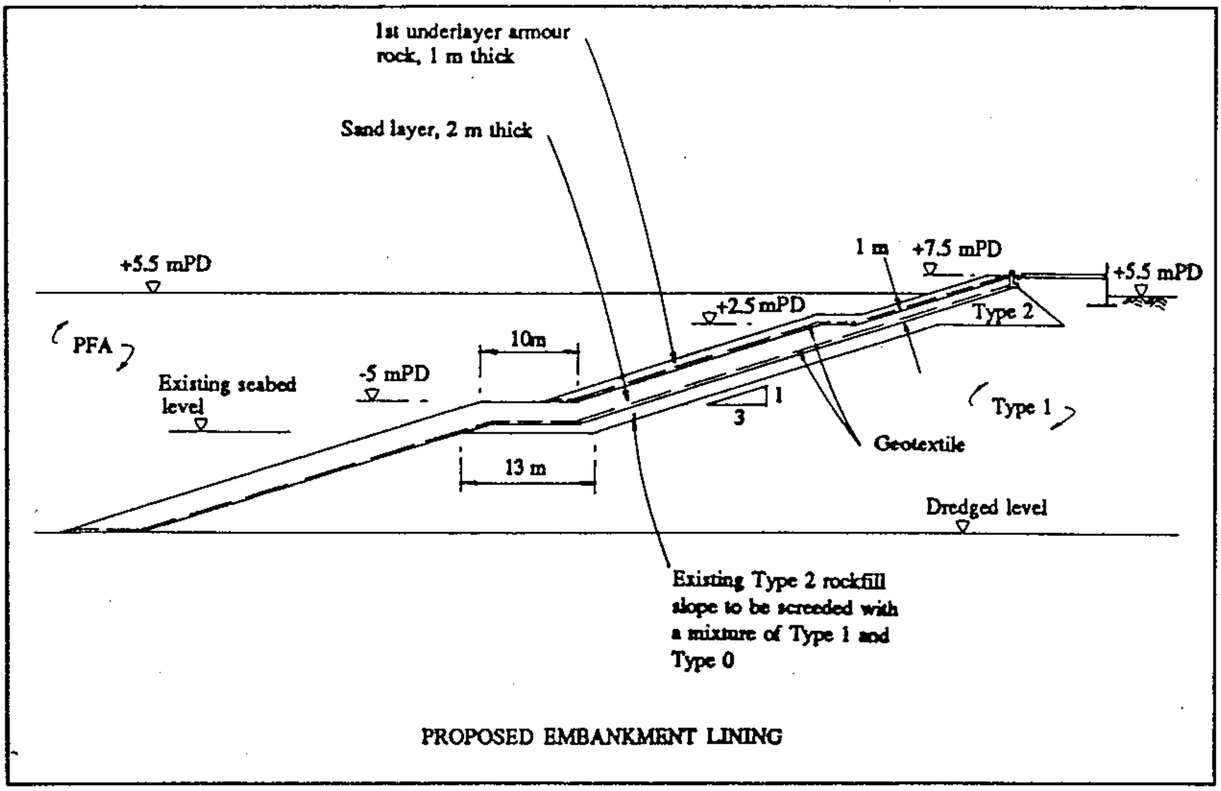


Figure 3.14 Northern Perimeter - Proposed Typical Section

The Cooling Water Intake Extension

3.5.6 The existing cooling water intake No. 2 will be extended (Figure 3.15) to ensure uninterrupted flow of sea water into the power station. The extension will consist of a precast concrete culvert which will draw sea water from the area to the south west corner of the lagoon. A front pond will connect the new culvert to the existing intake structure. The proposed form of construction is a double back-to-back conventional quay, built from precast concrete blocks and the area between filled with sand. A rubble foundation would be provided for the works, and this being a potential path of escape for PFA, it will be either covered, or preferably, filled with sand. The front pond walls will be keyed into the existing power station embankment with a stepped foundation (Figure 3.16).

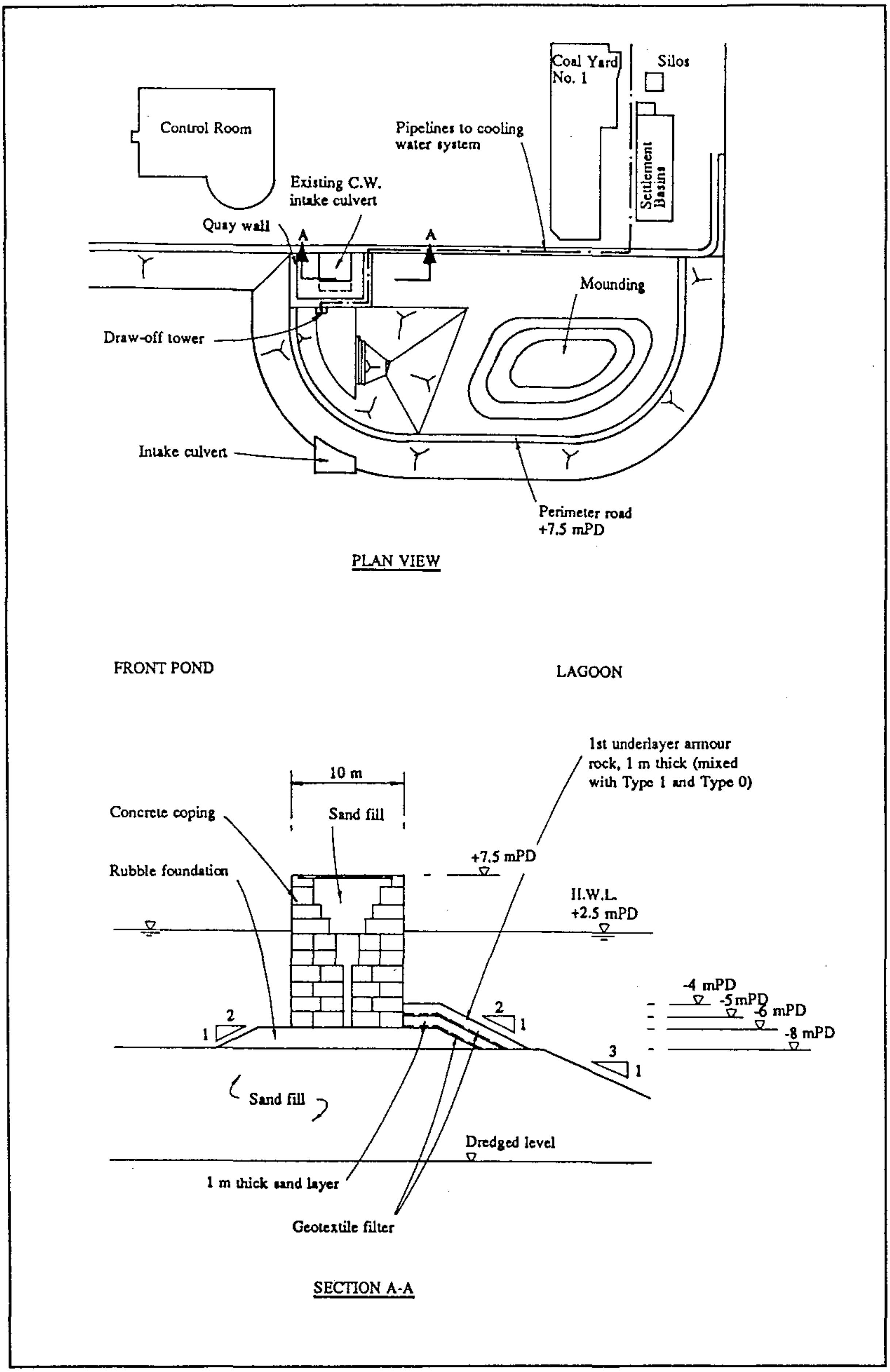


Figure 3.15 Front Pond Typical Sections

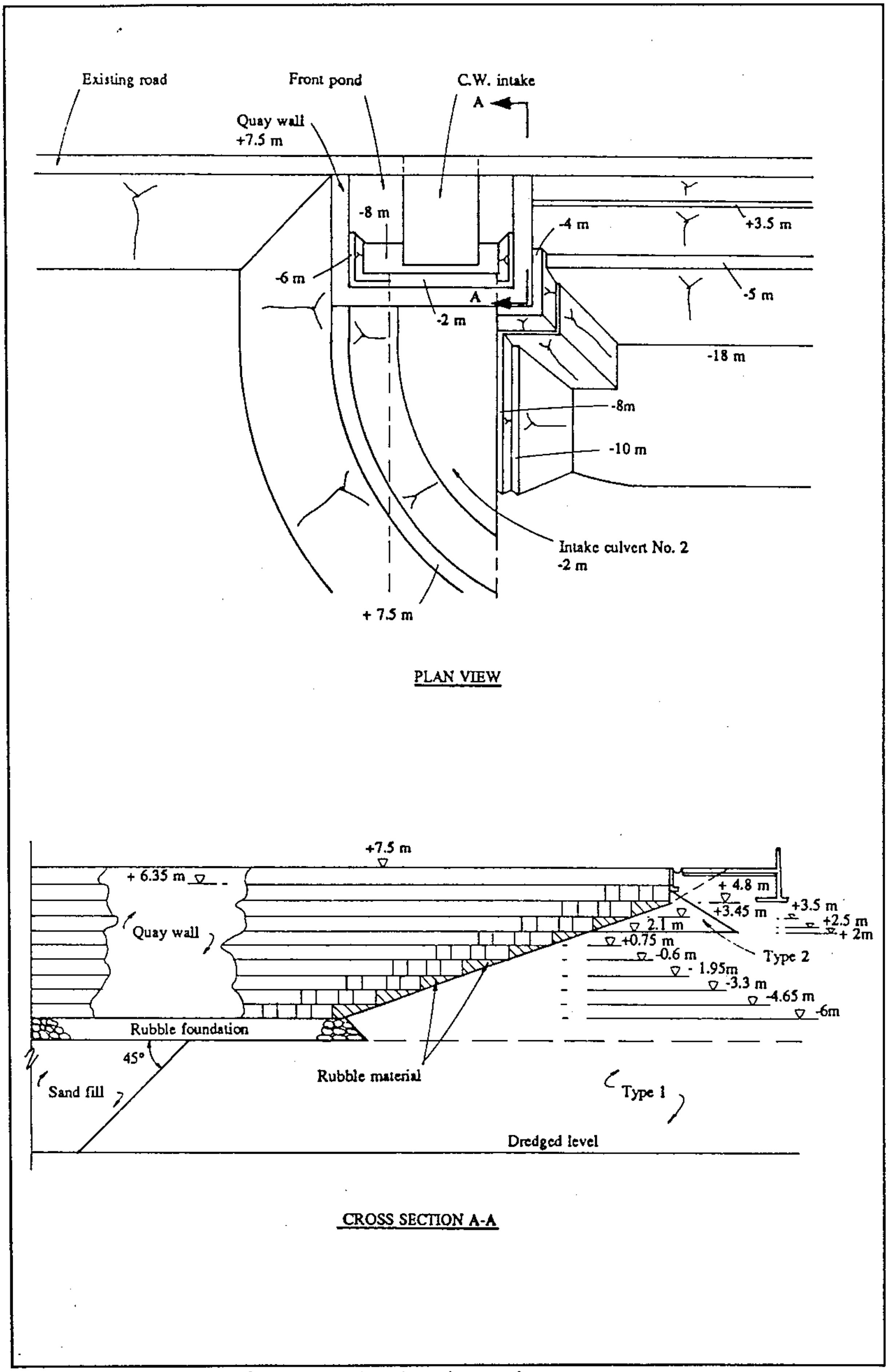
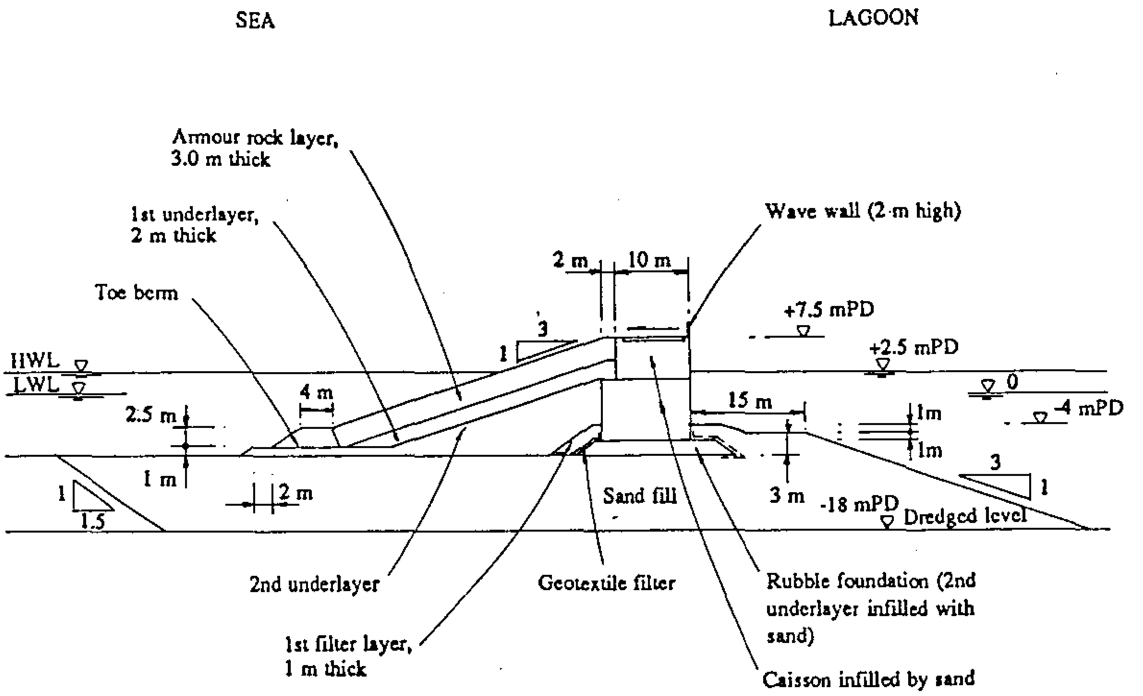


Figure 3.16 Interface of Quay Wall and Station Perimeter

3.6 THE CAISSON WITH REVETMENT OPTION

3.6.1 The typical section for a caisson with revetment perimeter is shown in Figure 3.17. Its seaward form is very similar to the embankment option but on the inside, caissons provide a vertical face and give the lagoon a marginally higher PFA storage capacity. Precast caissons would be transported to site, sunk into position and then filled with sand. The joints between units, and the rubble foundation layer would require filters or seals to prevent loss of PFA from the lagoon.

3.6.2 The profile of the perimeter, the details of the northern perimeter which interfaces with the power station and intake culvert details would be the same as those for the embankment perimeter option (Sections 3.5.3, 3.5.5 and 3.5.6 respectively).



Layers	Rock size gradation
Armour rock layer	6000 kg - 12000 kg
Toe berm	3000 kg - 5000 kg
1st underlayer	560 kg - 1040 kg
2nd underlayer	20 kg - 60 kg
1st filter layer	0.41 kg - 23 kg
Core material	Marine sand (fine to medium)

Figure 3.17 Caisson with Revetment Section

3.7 SEEPAGE

3.7.1 The design philosophy is to ensure that the lagoon perimeter will retain all PFA particles and the previous discussion and Figures have shown how this will be done. However, another issue that has been carefully considered is the likely rate of seepage away from the lagoon, the locations of this seepage and its fate when mixed and dispersed with the tidal flow. The magnitude and location of the perimeter seepage has been estimated with the aid of seepage flownets, and based on the following assumptions:

(i) The existing power station site, being formed from rock fill is highly permeable

(ii) The sand fill when placed (and, where necessary, compacted) has a permeability coefficient, (k), of about 1×10^{-4} m/s

(iii) The alluvial foundation at the site has a k value of about 1×10^{-6} m/s (it is, therefore, effectively impermeable relative to the sand fill)

(iv) Tidal exchange across the perimeter takes place under an average head difference (tidal lag) of 0.5 m to 1.0 m.

3.7.2 Flownets have been constructed for the three different types of perimeter section associated with the embankment option, each of which has its own permeability characteristics:

(i) the typical embankment section (Figures 3.18 and 3.19)

(ii) the section through the quay walls (Figures 3.20 and 3.21)

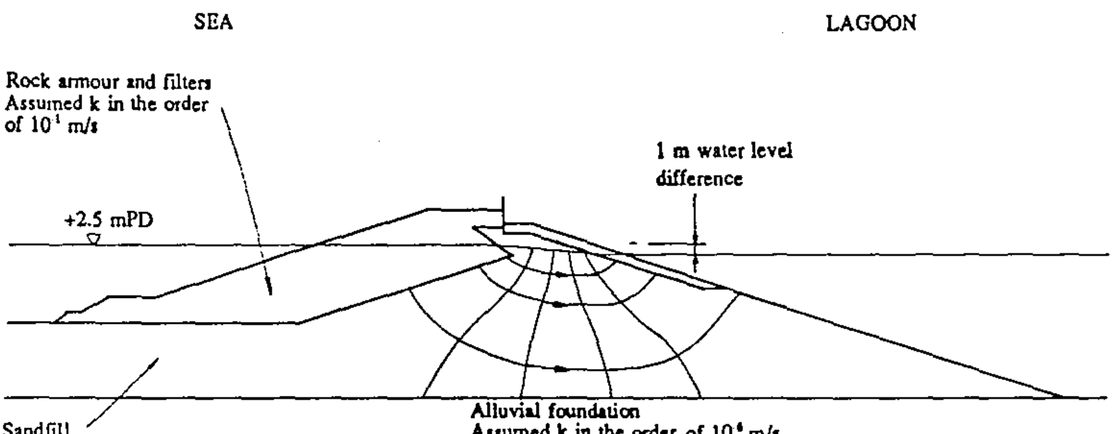
(iii) the existing power station section (Figures 3.22 and 3.23)

(The calculated seepage quantities under various conditions are summarised in Figures 3.24 to 3.26)

3.7.3 Initially, most water exchange will occur through the existing power station embankment because of the short flow path and relatively high hydraulic gradient which will develop. If the first PFA placed in the lagoon is used to form a layer across this section (say 2 m thick), the permeability and consequently the seepage will be much reduced. On completion of the PFA placing the emergency sluicing area will be at the western end of the lagoon (Figure 3.26). As shown, the western perimeter of the sluicing area does not include a layer of PFA to reduce the seepage from the lagoon. However the proposals for the filling sequence (Chapter 6) do include a layer of PFA around the whole lagoon. Thus the seepage flows presented in Figure 3.26 are higher than expected. The estimation of the seepage water quality (Chapter 7) takes account of the layer and is compatible with the filling sequence proposals.

3.7.4 The flownet through the caisson with revetment section is shown on Figure 3.27 together with a calculated seepage that would occur through it. The seepage is substantially higher than that of the embankment section, principally because of the highly permeable flow path offered by the rubble foundation. Should the permeability of this rubble be reduced by, for example, filling the rubble voids with sand, the seepage would become similar to that of the embankment section.

3.7.5 The approach to the lagoon design has been an iterative process whereby the environmental significance of the proposals have been assessed as the preliminary design has evolved. Accordingly, the significance of the lagoon seepage has been assessed with respect to its quality and eventual dilution in the bay. These issues are described in Chapter 7, which includes a description of the seepage dispersion modelling that has been carried out. However for completeness here, the environmental effect of seepage released from the lagoon can be summarised as being low and within acceptable criteria.



ASSUMED CONDITION:- WATER AT LAGOON AT +1.5 mPD
SEA WATER LEVEL AT +2.5 mPD
1 m WATER HEAD DIFFERENCE

No. of flow channels, $N_f = 3.33$

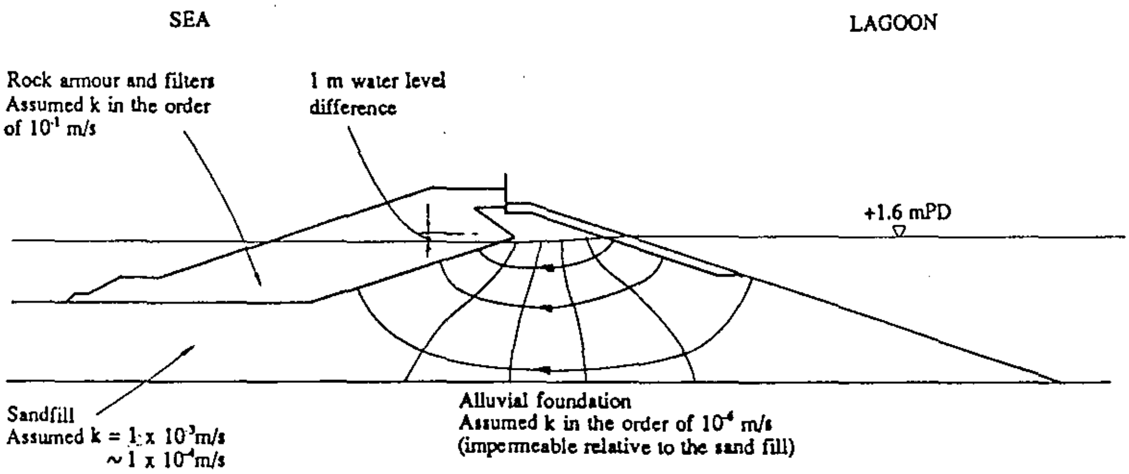
No. of head intervals, $N_d = 5$

Seepage quantity, $q = k.h.\frac{N_f}{N_d}$

For $k = 1 \times 10^{-3}$ m/s: $q = 1 \times 10^{-3}\text{ m/s} \times 1\text{ m} \times \frac{3.33}{5} = 6.66 \times 10^{-4}\text{ m}^3\text{/s per m length}$

For $k = 1 \times 10^{-4}$ m/s: $q = 1 \times 10^{-4}\text{ m/s} \times 1\text{ m} \times \frac{3.33}{5} = 6.66 \times 10^{-5}\text{ m}^3\text{/s per m length}$

Figure 3.18 Seepage Flownet Through Typical Embankment Section (From Sea To Lagoon)



ASSUMED CONDITION:- WATER AT LAGOON AT +1.6 mPD
SEA WATER LEVEL AT +0.6 mPD
1 m WATER HEAD DIFFERENCE

No. of flow channels, $N_f = 3.22$

No. of head intervals, $N_d = 5$

Seepage quantity $q = k.h.\frac{N_f}{N_d}$

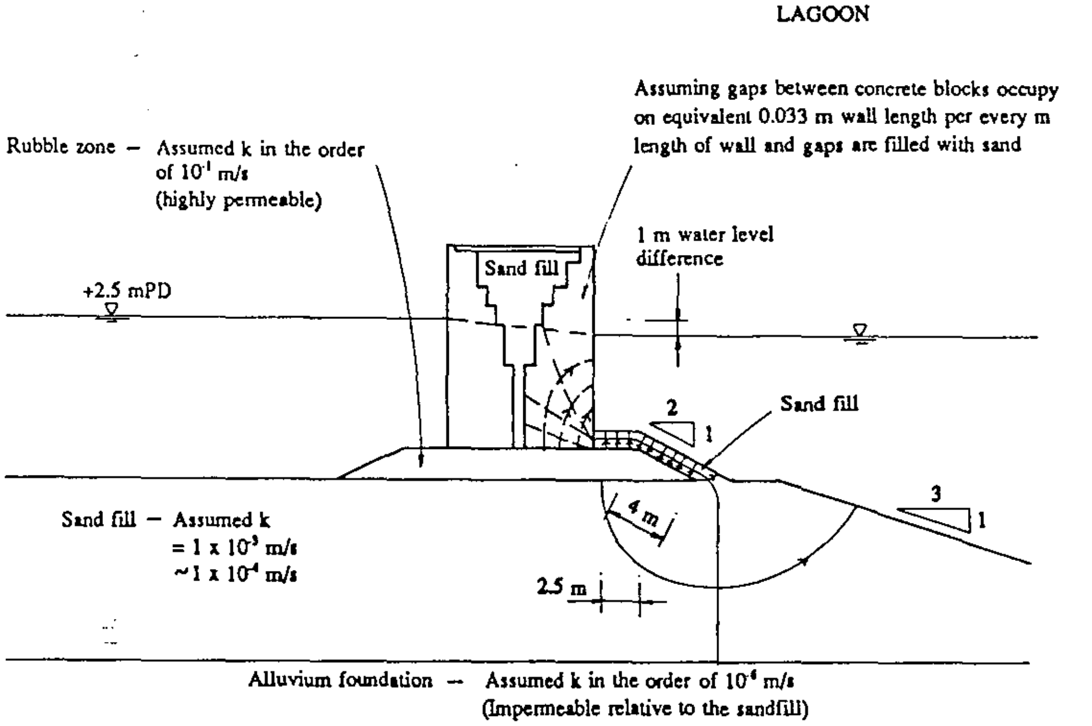
For $k = 1 \times 10^{-3}$m/s $q = 1 \times 10^{-3}\text{m/s} \times 1\text{ m} \times \frac{3.22}{5}$

$= 6.44 \times 10^{-4}\text{m}^3/\text{s}$ per m length

For $k = 1 \times 10^{-4}$m/s $q = 1 \times 10^{-4}\text{m/s} \times 1\text{ m} \times \frac{3.22}{5}$

$= 6.44 \times 10^{-5}\text{m}^3/\text{s}$ per m length

Figure 3.19 Seepage Flownet Through Typical Embankment Section (From Lagoon To Sea)



ASSUMED CONDITIONS:- SEA WATER LEVEL AT +2.5mPD
WATER IN LAGOON AT +1.5mPD
1 m WATER HEAD DIFFERENCE

For solid line flownet

No. of flow channels, $N_f = 11.5$

No. of head intervals, $N_d = 2$

Seepage quantity $q = kh.\frac{Nf}{Nd}$

For $k = 1 \times 10^{-3}$ m/s $\quad q = 1 \times 10^{-3}$ m/s x 1 m x $\frac{11.5}{2}$

$= 5.75 \times 10^{-3}$ m^3/s per m length

For $k = 1 \times 10^{-4}$ m/s $\quad q = 5.75 \times 10^{-4}$ m^3/s per m length

The seepage quantities are the same into and out of the lagoon

Assuming seepage flows through the sand in gaps between concrete blocks (the dotted-lined flownet)

$Nf = 4$

$Nd = 4$

$q = k.h.\frac{Nf}{Nd}$

For $k = 1 \times 10^{-4}$ m/s

$q = 1 \times 10^{-4}$ m/s x 1 m x $\frac{4}{4}$

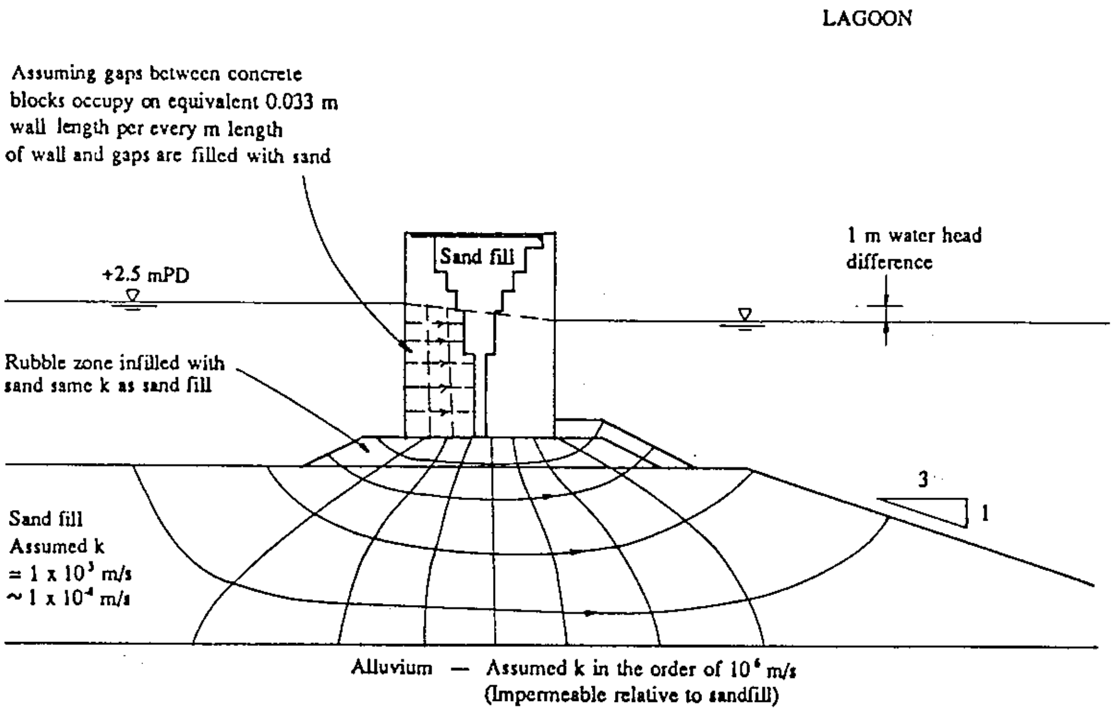
$= 1 \times 10^{-4}$ m^3/s per m length of sand

$Q = 1 \times 10^{-4}$ m^3/s x 0.033 m/m per m length of wall

$= 3.3 \times 10^{-6}$ m^3/s per m length of wall

This is small compared with the other figures and is neglected

Figure 3.20 Seepage Flownet Through Quay Wall Section



For flownet below base of concrete wall blocks,

No. of flow channels, $Nf = 4.5$

No. of head intervals, $Nd = 8$

Seepage quantity $q = kh.\frac{Nf}{Nd}$

For $k = 1 \times 10^{-3}$ m/s $\quad q = 1 \times 10^{-3}$ m/s $\times 1$ m $\times \frac{4.5}{8}$

$= 5.63 \times 10^{-4}$ m/s per m length

For $k = 1 \times 10^{-4}$ m/s $\quad q = 5.63 \times 10^{-5}$ m^3/s per m length

Total seepage quantity $= 5.63 \times 10^{-5}$ m/s $+ 3.3 \times 10^{-6}$ m^3/s

$= 5.96 \times 10^{-5}$ m^3/s per m length of wall

Considering seepage flows through the sand gaps between concrete blocks (dotted-lined flownet)

$Nf = 6$

$Nd = 3$

$q = k.h.\frac{Nf}{Nd}$

For $k = 1 \times 10^{-4}$ m/s and assuming $h = \frac{1}{2}$ m $= 0.5$ m

(ignoring the effects of the sandwiched sand fill)

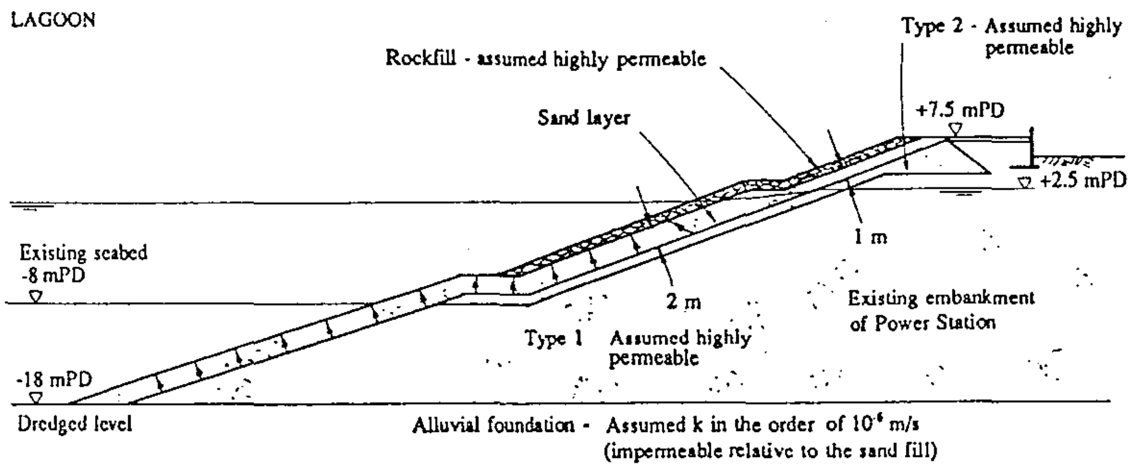
$q = 1 \times 10^{-4}$ m/s $\times 0.5$ m $\times \frac{6}{3}$

$= 1 \times 10^{-4}$ m^3/s per m length of sand

$Q = 1 \times 10^{-4}$ $m^3/s \times 0.033$ m/m per m length of wall

$= 3.3 \times 10^{-6}$ m^3/s

Figure 3.21 Seepage Flownet Through Quay Wall Section (Foundation Sealed)



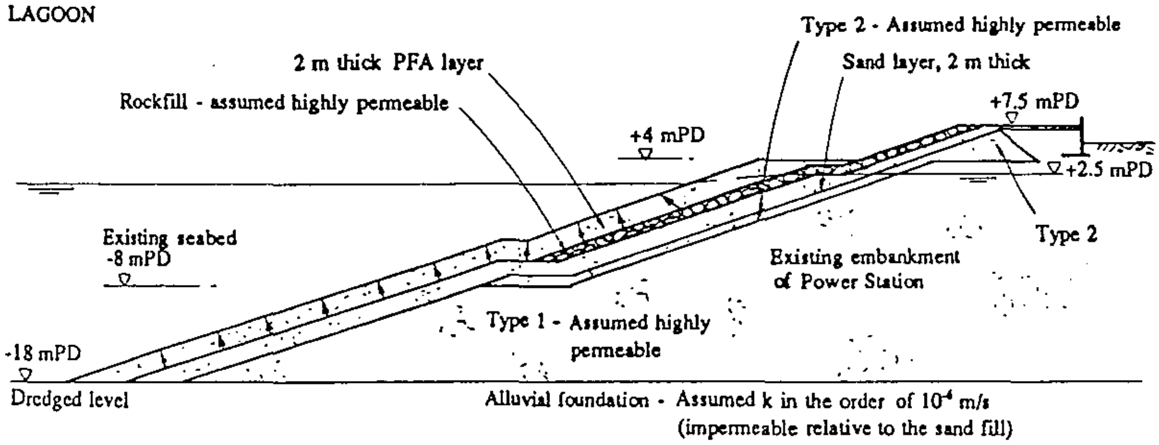
ASSUMED CONDITIONS:- WATER LEVEL WITHIN THE EXISTING ROCKFILL EMBANKMENT CHANGES IN PHASE WITH TIDE
1 m WATER HEAD DIFFERENCE
STEADY STATE SEEPAGE
k FOR SAND FILL = 1×10^{-4} m/s

$q = A.k.i.$

$= (70.0 \text{ m} \times 1 \text{ m}) \times (1 \times 10^{-4} \text{ m/s}) \times \frac{1 \text{ m}}{2 \text{ m}}$

$= 3.5 \times 10^{-3}$ m^3/s per m length of embankment

Figure 3.22 Seepage Through Power Station Section (Before Placing PFA)



ASSUMED CONDITIONS:- WATER LEVEL WITHIN THE EXISTING EMBANKMENT CHANGES IN PHASE WITH TIDE
1 m WATER HEAD DIFFERENCE
STEADY STATE SEEPAGE
k FOR SAND FILL = 1×10^{-4} m/s
k FOR PFA = 1×10^{-6} m/s

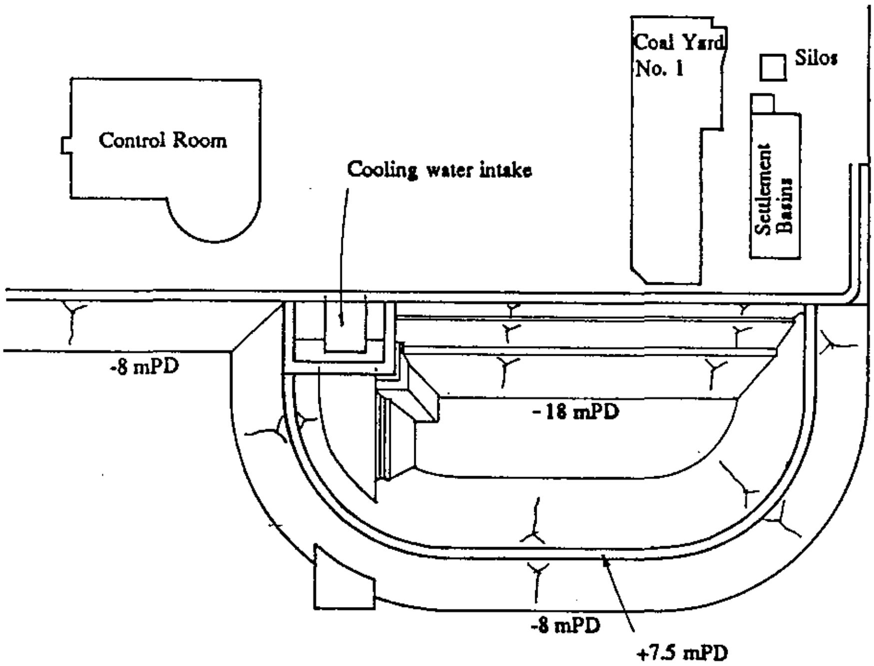
Compared with PFA, the 2 m sand is highly permeable and its effects are neglected in the calculation

$q = A.k.i.$

$= (70.0 \text{ m} \times 1 \text{ m}) \times (1 \times 10^{-6} \text{ m/s}) \times \frac{1 \text{ m}}{2 \text{ m}}$

$= 3.5 \times 10^{-5}$ m^3/s per m length of embankment

Figure 3.23 Seepage Through Power Station Section (After Placing 2m PFA Layer)



ASSUMPTIONS : Existing embankment of Power Station highly permeable and water level in it in phase with tide

Sand permeability $= 1 \times 10^{-4}$ m/s

<u>1 m Water head difference</u>

(1) Embankment typical section
$6.44 \times 10^{-5} m^3/s.m. \times 645\ m = 0.042 m^3/s$

(2) Quay wall section
$5.75 \times 10^{-4} m^3/s.m. \times 145\ m = 0.084 m^3/s$

(3) Embankment lining between lagoon and power station
$3.5 \times 10^{-3} m^3/s.m. \times 400m = 1.4\ m^3/s$

Total of (1) + (2) + (3) = $1.526\ m^3/s$

<u>0.5 m Water head difference</u>

Flownets for 1.0 m head difference also apply for 0.5 m head difference

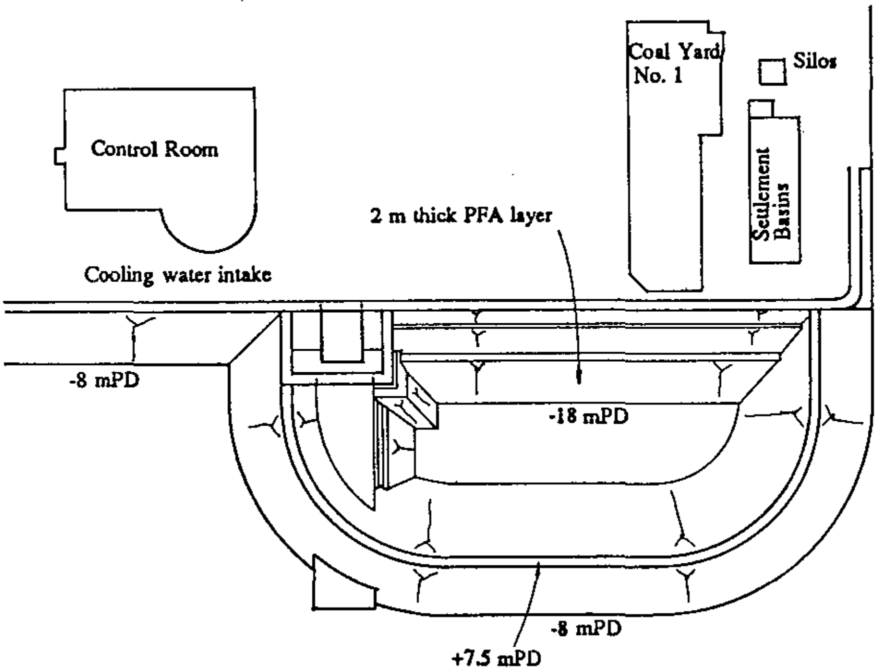
(1) Embankment typical section
$6.44 \times 10^{-5} m^3/s.m. \times \frac{0.5m}{1.0m} \times 645\ m$
$= 0.021 m^3/s$

(2) Quay wall section
$5.75 \times 10^{-4} m^3/s.m. \times \frac{0.5m}{1.0m} \times 145\ m$
$= 0.042 m^3/s$

(3) Embankment lining between lagoon and power station
$3.5 \times 10^{-3} m^3/s.m. \times \frac{0.5m}{1.0m} \times 400\ m$
$= 0.7 m^3/s$

Total of (1) + (2) + (3) = $0.763\ m^3/s$

Figure 3.24 Seepage Quantities Out of Lagoon Before Placing PFA



ASSUMPTIONS : Existing embankment of Power Station highly permeable and water level in it in phase with tide

Sand permeability $= 1 \times 10^{-4}$ m/s

PFA permeability $= 1 \times 10^{-4}$ m/s PFA layer 2 m thick

<u>1 m Water head difference</u>

(1) Embankment typical section

$6.44 \times 10^{-5} m^3/s.m. \times 645\ m = 0.042 m^3/s$

(2) Quay wall section

$5.75 \times 10^{-4} m^3/s.m. \times 145\ m = 0.084 m^3/s$

(3) Embankment lining between lagoon and power station

$3.5 \times 10^{-5} m^3/s.m. \times 400m = 0.014\ m^3/s$

Total of (1) + (2) + (3) = $0.140\ m^3/s$

<u>0.5 m Water head difference</u>

Flownets for 1.0 m head difference also apply for 0.5 m head difference

(1) Embankment typical section

$6.44 \times 10^{-5} m^3/s.m. \times \frac{0.5m}{1.0m} \times 645\ m$

$= 0.021 m^3/s$

(2) Quay wall section

$5.75 \times 10^{-4} m^3/s.m. \times \frac{0.5m}{1.0m} \times 145\ m$

$= 0.042 m^3/s$

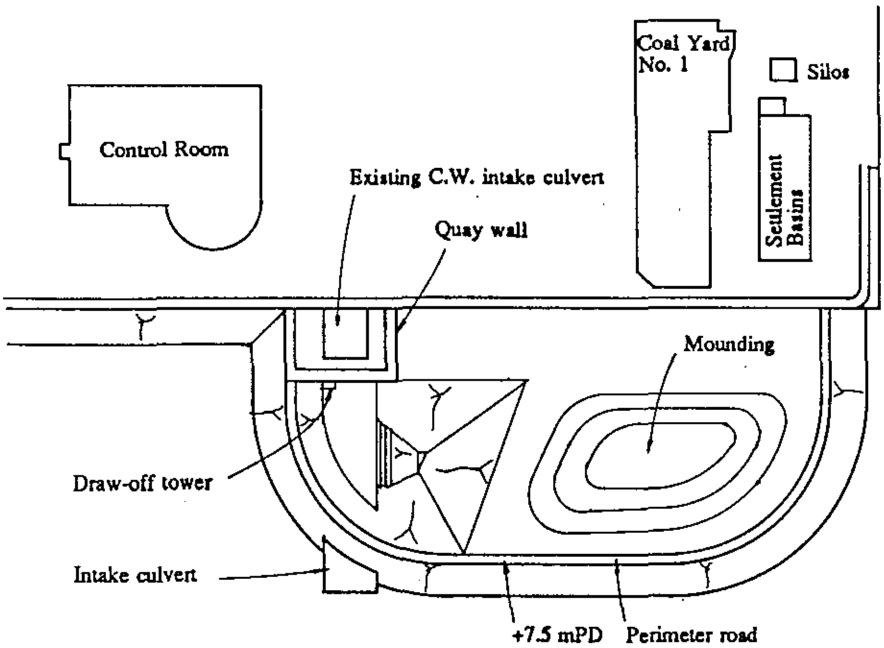
(3) Embankment lining between lagoon and power station

$3.5 \times 10^{-5} m^3/s.m. \times \frac{0.5m}{1.0m} \times 400\ m$

$= 0.007 m^3/s$

Total of (1) + (2) + (3) = $0.07\ m^3/s$

Figure 3.25 Seepage Quantities Out of Lagoon After Placing 2m PFA Layer



ASSUMPTIONS: Existing embankment of Power Station highly permeable and water level in it in phase with tide

Sand permeability = 1×10^{-4} m/s

PFA permeability = 1×10^{-6} m/s

<u>1 m Water head difference</u>

(1) Embankment typical section

$6.44 \times 10^{-5} m^3/s.m. \times 200 m = 0.013 m^3/s$

(2) Quay wall section

$5.75 \times 10^{-4} m^3/s.m. \times 85 m = 0.049 m^3/s$

(3) Embankment lining between lagoon and power station

$3.5 \times 10^{-5} \times \frac{2m}{70m} m^3/s.m. \times 130 m$

$= 1.3 \times 10^{-4} m^3/s$

(negligible)

Total of (1) + (2) + (3) = $0.062 m^3/s$

<u>0.5 m Water head difference</u>

Flownets for 1.0 m head difference also apply for 0.5 m head difference

(1) Embankment typical section

$6.44 \times 10^{-5} m^3/s.m. \times \frac{0.5m}{1.0m} \times 200 m$

$= 0.006 m^3/s$

(2) Quay wall section

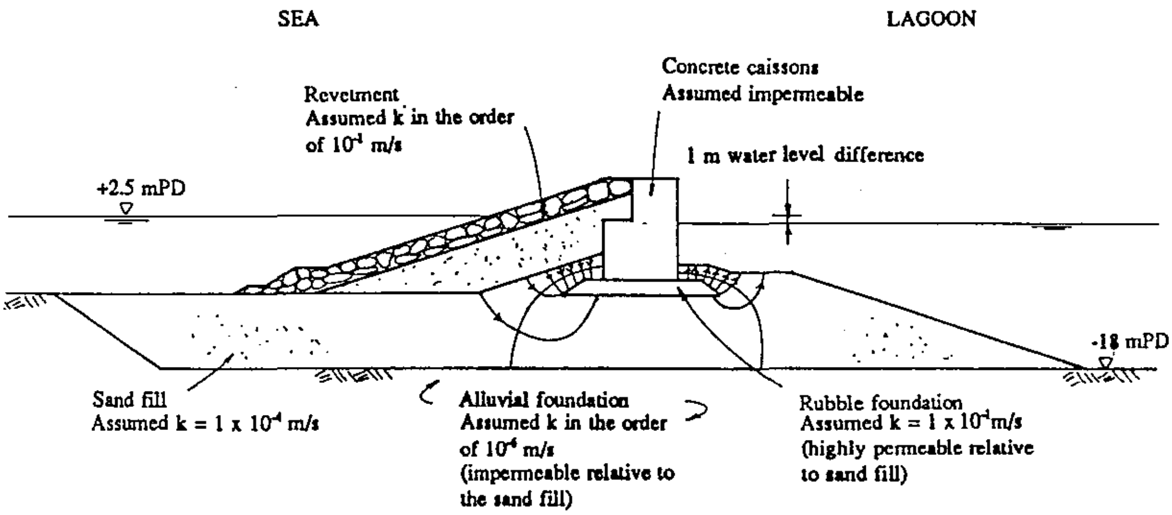
$5.75 \times 10^{-4} m^3/s.m. \times \frac{0.5m}{1.0m} \times 85 m$

$= 0.025 m^3/s$

(3) Embankment lining between lagoon and power station (negligible)

Total of (1) + (2) + (3) = $0.031 m^3/s$

Figure 3.26 Seepage Quantities Out of Lagoon After Complete Placement of PFA



ASSUMED CONDITIONS:- SEA WATER LEVEL AT +2.5 mPD
WATER IN LAGOON AT +1.5 mPD
1 m WATER HEAD DIFFERENCE
STEADY STATE SEEPAGE
THE SANDFILL IS HOMOGENEOUS
(THE SEEPAGE QUANTITIES ARE THE SAME INTO AND OUT OF THE LAGOON WHEN THE WATER HEAD DIFFERENCE IS REVERSED)

Nf = No. of flow channels
Nd = No. of head intervals
$k_1 = k_2$ = coefficient of permeability of sand
$h_1 + h_2 = 1$ m = water head difference

Flow into rubble foundation

$$q_1 = k_1 . h_1 . \frac{Nf^1}{Nd^1} = 1 \times 10^{-4} \text{ m/s} \times h_1 \times \frac{7.2}{2}$$

Flow out of rubble foundation

$$q_2 = k_2 . h_2 . \frac{Nf^2}{Nd^2} = 1 \times 10^{-4} \text{ m/s} \times (1-h_1) \times \frac{8}{2}$$

For continuity,

$$q_1 = q_2$$

$$h_1 \times \frac{7.2}{2} = (1 - h_1) \times \frac{8}{2}$$

$$15.2\, h_1 = 8$$

$$h_1 = 0.53 \text{ m}$$

$$\therefore \text{Flow through the section} = q_1 = k_1 h_1 \frac{Nf^1}{Nd^1}$$

$$= 1 \times 10^{-4} \text{m/s} \times 0.53 \text{ m} \times \frac{7.2}{2}$$

$$= 1.908 \times 10^{-4} \text{ m}^3\text{/s per m length}$$

Figure 3.27 Seepage Flownet Through Caisson with Revetment Section

3.8 CONSTRUCTION

3.8.1 The embankment perimeter formed of sand as the principal fill can be constructed relatively quickly. The estimate of the shortest practicable construction programme is shown on Figure 3.28 which is based on the construction sequence illustrated on Figure 3.29. This assumes that any densification of the sand that is required, is carried out using a relatively quick vibrocompaction technique that is able to keep pace with the rate of filling.

3.8.2 Following the preparation stages, involving the removal of marine mud and replacement with sand to form the foundation (Stages (a) and (b) in Figure 3.29), construction would start in the west and advance eastward to ensure that the initial works provide some measure of protection for those on going. A gap would be left at the north east corner of the embankment to permit marine access during construction (Figure 3.29(e)). This gap would be closed when construction is almost complete.

3.8.3 Most of the work will be carried out as a marine based operation. However quay wall construction for the front pond may take place on two fronts concurrently, one as a land based operation from the power station perimeter and the other as a marine based operation. The intake culvert extension would be positioned prior to construction of the front pond. Table 3.2 summarises the embankment construction methods envisaged and indicates the material quantities involved.

3.8.4 The foregoing comments relate to construction of an embankment perimeter, but the estimated shortest practicable construction period for the caisson with revetment perimeter is similar (Figure 3.30). However, a critical factor with this option will be the availability of an adequate caisson casting area with sea frontage.

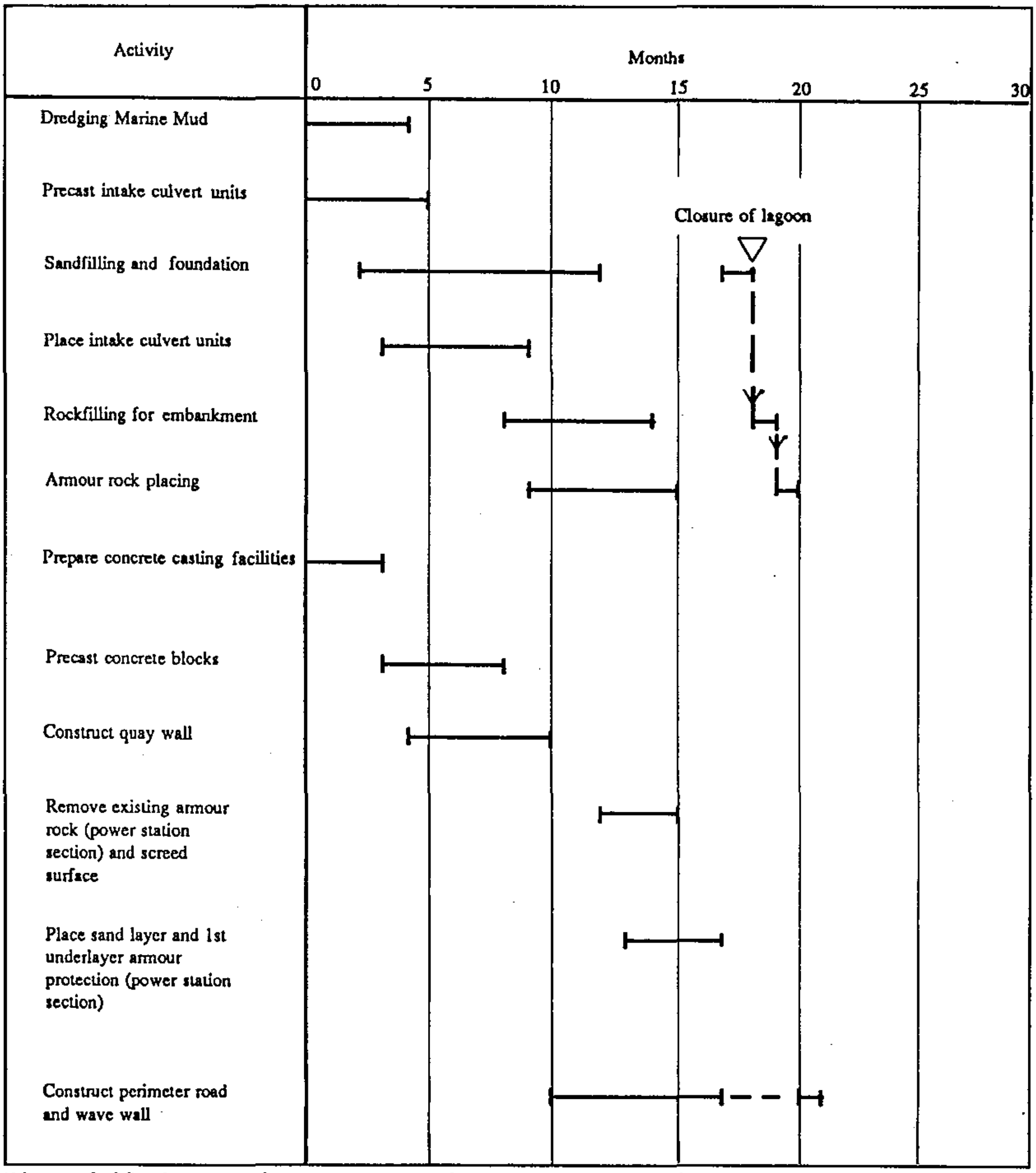


Figure 3.28 Construction Programme for Embankment Option

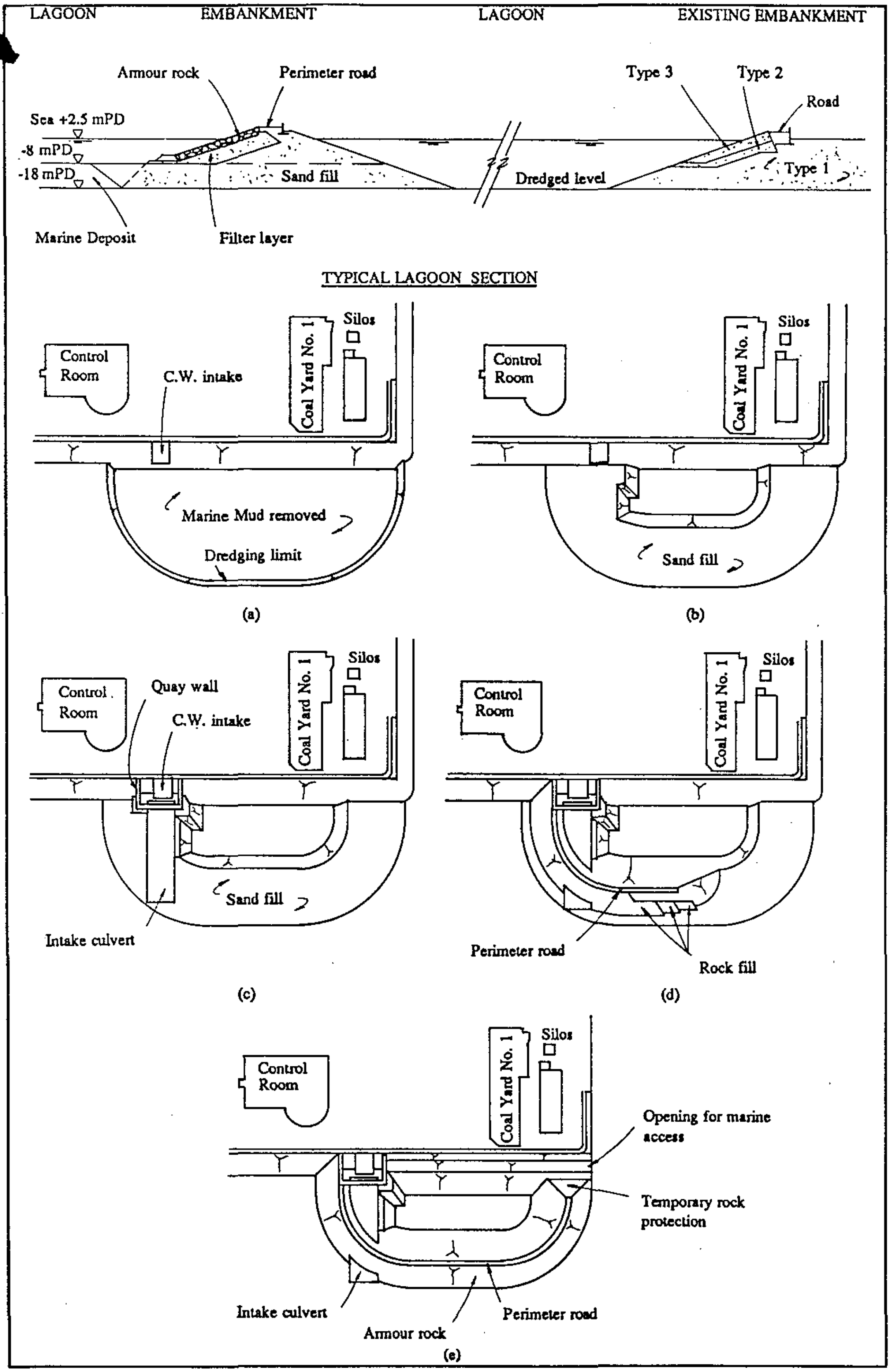


Figure 3.29 Construction Sequence for Embankment

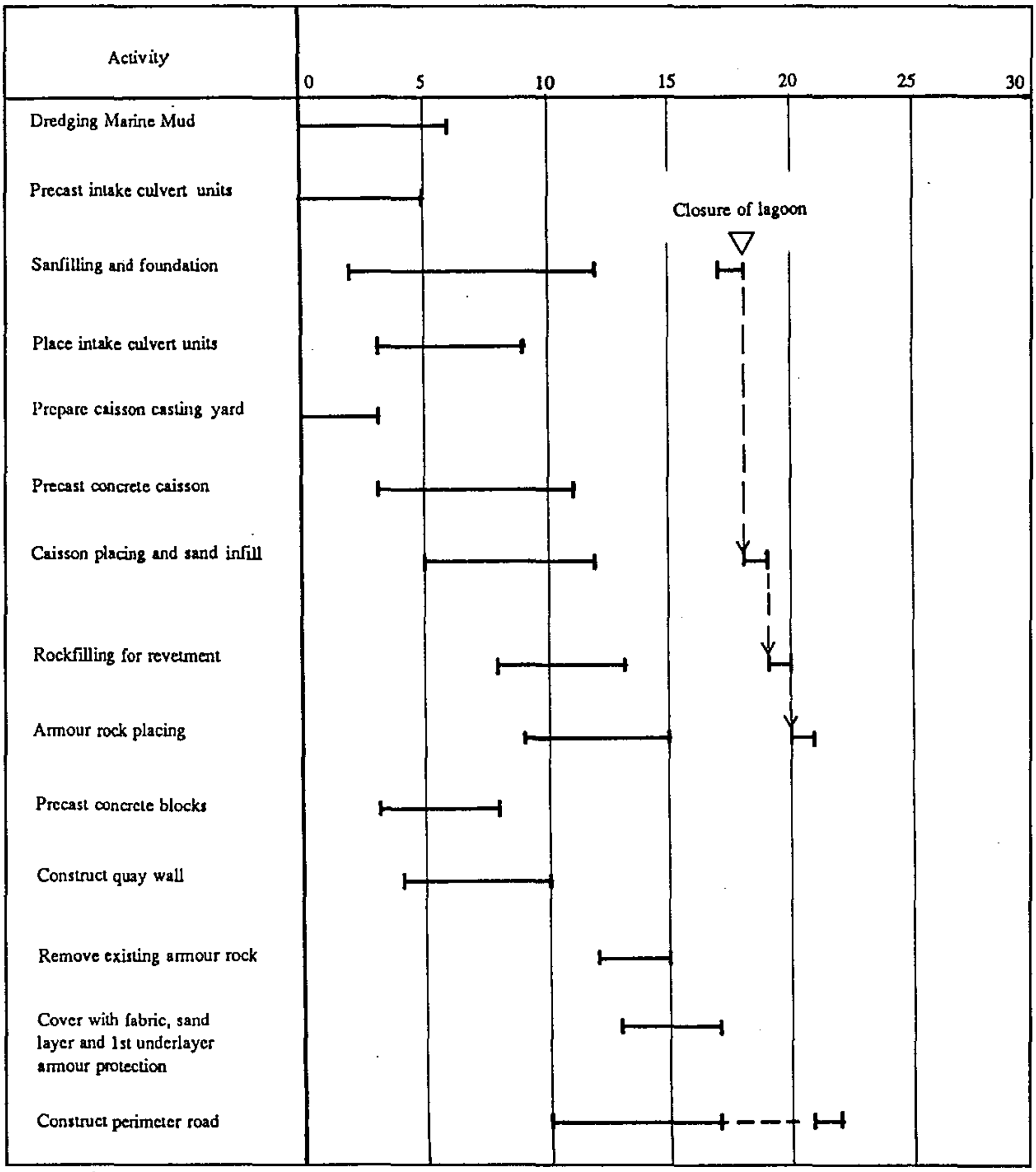


Figure 3.30 Construction Programme for Cassion with Revetment Option

Construction Materials

3.8.5 The principal materials proposed for the lagoon construction are rock for the revetment and sand as the bulk fill. Both material types can be supplied from existing sources with minimal environmental impact.

Rock

3.8.6 The rock gradings envisaged (Table 3.3) assumes that a conventional granular filter is adopted beneath the rock armour and underlayers. In addition to the existing Hong Kong based quarries there are now a number of quarries on neighbouring PRC islands which are supplying the Hong Kong construction industry (Figure 3.31), consequently supply of these materials is not thought to be a problem.

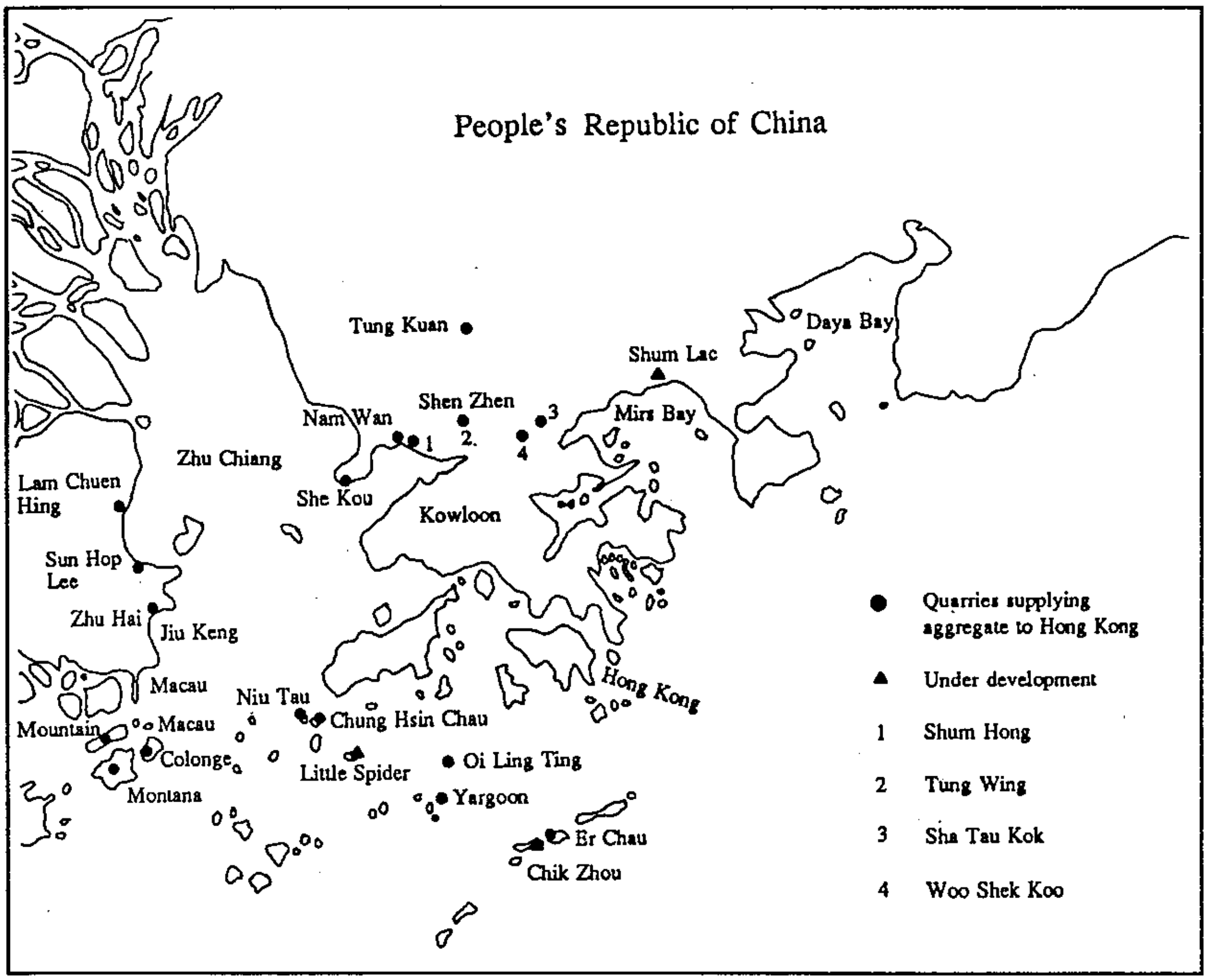


Figure 3.31 Quarries in PRC Supplying Hong Kong

Sand

3.8.7 Recent studies in Hong Kong have proven the existence of substantial reserves of marine sand around Hong Kong. Successful large scale projects such as the Tin Shui Wai land formation and the Kwai Chung Container Terminals 6 and 7 have shown how the sand can be won and placed cost effectively and at a faster rate than conventional materials.

3.8.8 An important criteria for the lagoon perimeter is the filter relationship between the sand used for the embankment and the PFA to be retained by it. Government's Geotechnical Manual of Slopes gives a particle size envelope for a granular filter that is suitable for all silts and finer soils (PFA has a similar grading to that of a silt) and this is reproduced as Figure 3.32, together with some typical gradings of marine sand from around Hong Kong. Figure 3.32 indicates that locally available marine sands should perform as a suitable filter for PFA. When a specific source has been allocated for the sand fill, its grading and variability should be checked to ensure that differing types, if any, are appropriately located in the works.

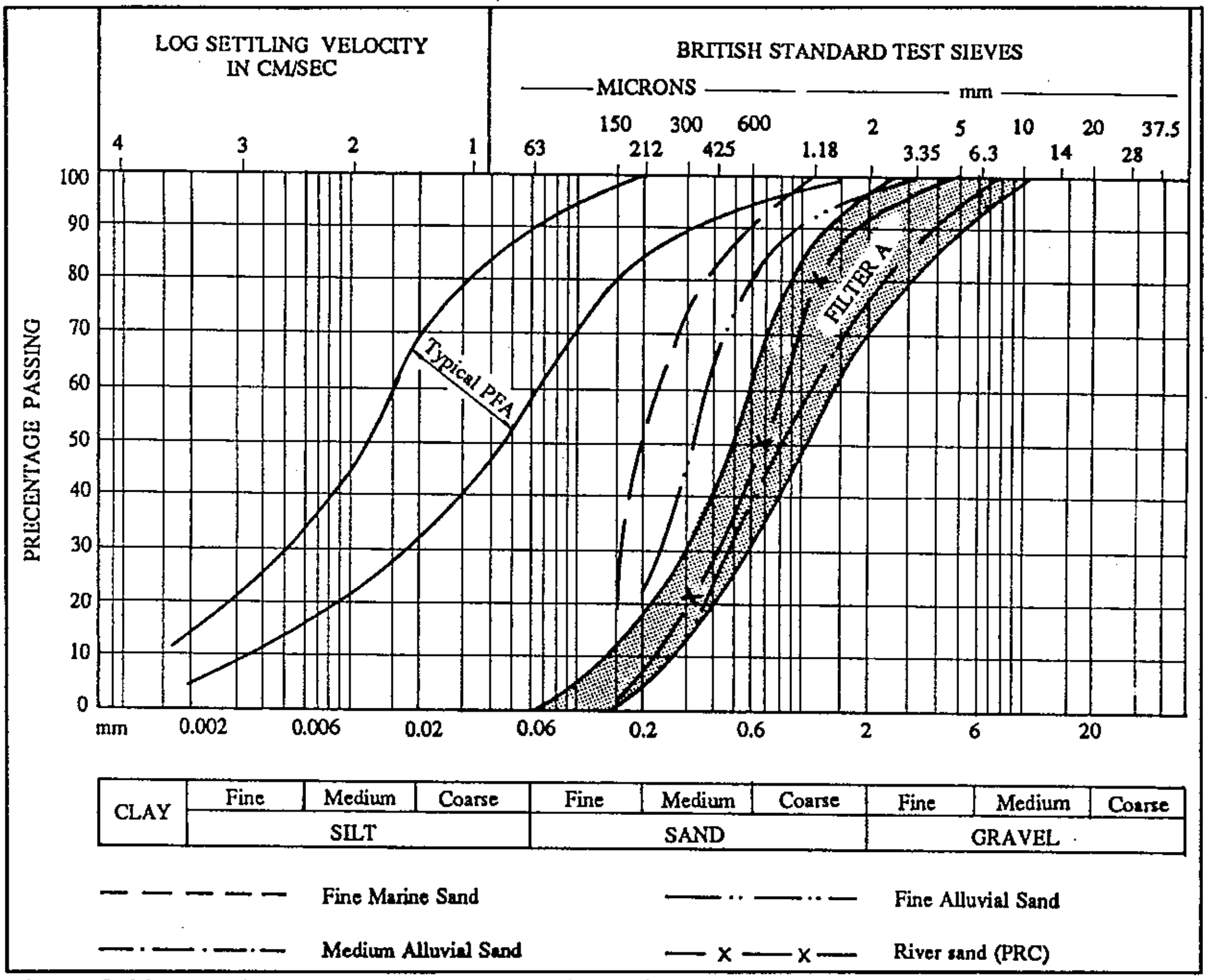


Figure 3.32 Grading of PFA and Appropriate Filters

3.9 COST ESTIMATES

3.9.1 Cost estimates (1990) for forming the lagoon site with an embankment perimeter and with a caisson revetment perimeter are given in Tables 3.4 and 3.5, both exclude any costs associated with land acquisition. Excluding any land costs, there is a clear cost benefit to be derived from the embankment option.

3.10 CONCLUSIONS

3.10.1 The options for forming the ash lagoon at Lamma Power Station has been reviewed bearing in mind and the environmental, technical and economic issues involved, the conclusions from this are:-

(i) an embankment construction (Figure 3.11) will be most appropriate. This offers a very effective barrier which will retain all PFA placed behind it, and in addition economy of construction

(ii) an embankment crest level, width and wave wall the same as those of the existing station site which will provide an appropriate level of coastal protection for the site

(iii) a lagoon plan as shown on Figure 3.10 with a curved form, coupled with the natural stone revetment will blend visually with the existing station site. The effect of the lagoon on the local hydrodynamics is insignificant (Appendix A).

Borehole No.	Depth of sample (m)	Bulk density (Kg/m³)	Grading (%)				One dimensional consolidation		Compressive strength (KN/m²)	Phi angle ϕ (degrees)
			Grl	Snd	Slt	Cly	e_o	Cc		
MD2	12.45		4	73	18	5				
MB10	12.45	1846	0	55	33	12	0.773	0.146	36	11
MB10	15.45	1707								
MB10	21.00	1805	0	11	48	41	1.123	0.355		
MB10	33.45	1971							13	26
MB14	15.00	1959	0	20	63	17	0.736	0.116		
MB14	18.00	1977	0	41	39	20	0.690	0.189		
MB14	21.00	1832	0	28	52	20	1.144	0.352		
MB14	24.00	1838	0	22	52	26	1.000	0.262		
MB14	33.45	1959	0	50	45	5	0.732	0.199		

Table 3.1 Summary of sample test results for the lagoon site

Activity	Method	Plants	Approx. material quantity
Dredging marine mud N.B. Marine mud would be disposed at the designated dumping area off Cheung Chau	Grab and pumping	Trailer dredgers and support barges	1.6 Mm³
Sandfilling and foundation + vibro flotation	Dumping by barges	Bottom-dump barges or side-dump barges and vibro flotation probes	1.62 Mm³
Intake culvert	Sink precast units on to prepared foundation	Derrick lighters	-
Rockfilling for embankment	Placing by barges	Derrick lighters and backhoes	0.31 Mm³
Armour rocks for embankment	Placing by barges	Derrick lighters and backhoes	0.12 Mm³
Constructing quay wall	Placing by barges	Derrick lighters	3,100 units
Remove existing Armour rocks and placing lining	Grab by barges	Derrick lighters and backhoes	0.09 Mm³
Constructing perimeter road	Concreting	Grader + compactor and concrete mixer	10,500 m²
Constructing wave wall and drainage	Concreting and pipe laying	Concrete mixer and backhoes	Along the perimeter road

Table 3.2 Embankment construction methods

Layer		Weight	Gradation	D15	D85	Layer thickness
Armour layer	W	8 t	6 t - 10 t	1.545 m		3.2 m
Toe berm	$\frac{W}{2}$	4 t	3 t - 4 t			2.5 m
1st underlayer	$\frac{W}{10}$	0.8 t	0.56 t - 1.04 t	714 mm	826 mm	2 m
2nd underlayer	$\frac{W}{200}$	40 kg	20 kg - 60 kg	250 mm	330 mm	1 m
Filter layer	$\frac{W}{6000}$	1.34 kg	0.41 kg - 2.3 kg	71 mm	110 mm	1 m
Filter layer	$\frac{W}{320000}$	0.025 kg	7.5×10^{-3} - 0.0425 kg	19 mm	28 mm	1 m
Filter layer	$\frac{W}{6.4 \times 10^6}$	1.25×10^{-3} kg	$0.374 \times 10^{-3} - 2.125 \times 10^{-3}$ kg	7 mm	10.3 mm	1 m
Core material		10×10^{-6} kg	Marine sand	0.2 mm	3 mm	
Toe protection for quay wall		0.35 t				1.5 m
		For $D15_{(cover)} \leq 5D85_{(under)}$				

Table 3.3 Rock sizes proposed

Description		Quantity	Unit	Rate HK$	Amount HK$
Dredging marine mud		1.6M	m^3	12	19.2M
Foundation and sandfilling (including vibro-flotation)		1.62M	m^3	45	72.9M
Armour rock	8 t	0.12M	m^3	150	18.00M
Toe berm	4 t	0.018M	m^3	150	2.70M
1st underlayer	0.8 t	0.106M	m^3	120	12.72M
2nd underlayer	40 kg	0.091M	m^3	145	13.2M
1st filter layer	1.34 kg	0.032M	m^3	120	3.84M
2nd filter layer	0.025 kg	0.030M	m^3	120	3.60M
3rd filter layer	1.25×10^{-3} kg	0.030M	m^3	120	3.60M
Intake Culvert		1	no.	66M	66M
Quay wall		3,100	no.	4300	13.33M
Remove existing armour rocks and cover with fabric, sand and rock		580	lin.m	4900	2.85M
Reuse of 70% existing armour rocks		0.063M	m^3	150	-9.45M
Perimeter road		1,050	lin.m	5130	5.39M
				Total	227.88M

Note : The unit rates of all activities include material costs as well as construction/installation costs. Preliminary and contingencies are also allowed for the unit rates.

Table 3.4 Cost estimates (1990) for the embankment option

Description		Quantity	Unit	Rate HK$	Amount HK$
Dredging marine mud		1.6M	m^3	12	19.2M
Foundation and sandfilling (including vibro-flotation)		1.47M	m^3	45	66M
Precast r.c. caissons		80	no.	0.75M	60M
Armour rock	8 t	0.115M	m^3	150	17.25M
Toe berm	4 t	0.018M	m^3	150	2.70M
1st underlayer	0.8 t	0.086M	m^3	120	10.32M
2nd underlayer	40 kg	0.180M	m^3	145	26.1M
1st filter layer	1.34 kg	0.005M	m^3	120	0.6M
Intake culvert		1	no.	66M	66M
Quay wall		3,100	no.	4300	13.33M
Remove existing armour rocks and cover with fabric, sand and rock		580	lin.m	4900	2.85M
Reuse of 70% existing armour rocks		0.063M	m^3	150	-9.45M
Perimeter road		1,050	lin.m	5130	5.39M
				Total	280.29M

Note : The unit rates of all activities include material costs as well as construction/installation costs. Preliminary and contingencies are also allowed for the unit rates.

Table 3.5 Cost estimates (1990) for the caisson with revetment option

CHAPTER 4

LAGOON CONSTRUCTION

4.1 INTRODUCTION

4.1.1 There are a number of environmental and technical advantages (Chapter 3) to the proposals for an embankment perimeter (Figures 4.1 and 4.2), although an alternative of caissons with revetment is also appropriate. Thus discussion of the construction activities concentrate on those for the preferred option of an embankment.

4.1.2 The water depth at the lagoon site is about 8 m and the sea bed consists of about 12 m of very soft marine mud underlain by firmer alluvium. These conditions coupled with the form of the perimeter, an embankment, predetermine the methods to be employed for the construction. The outline assessment of various options presented in the IAR, it was not possible to detail the effects of the Lagoon Construction, and this was one of the items having a potential environmental impact. Thus, these activities are discussed here.

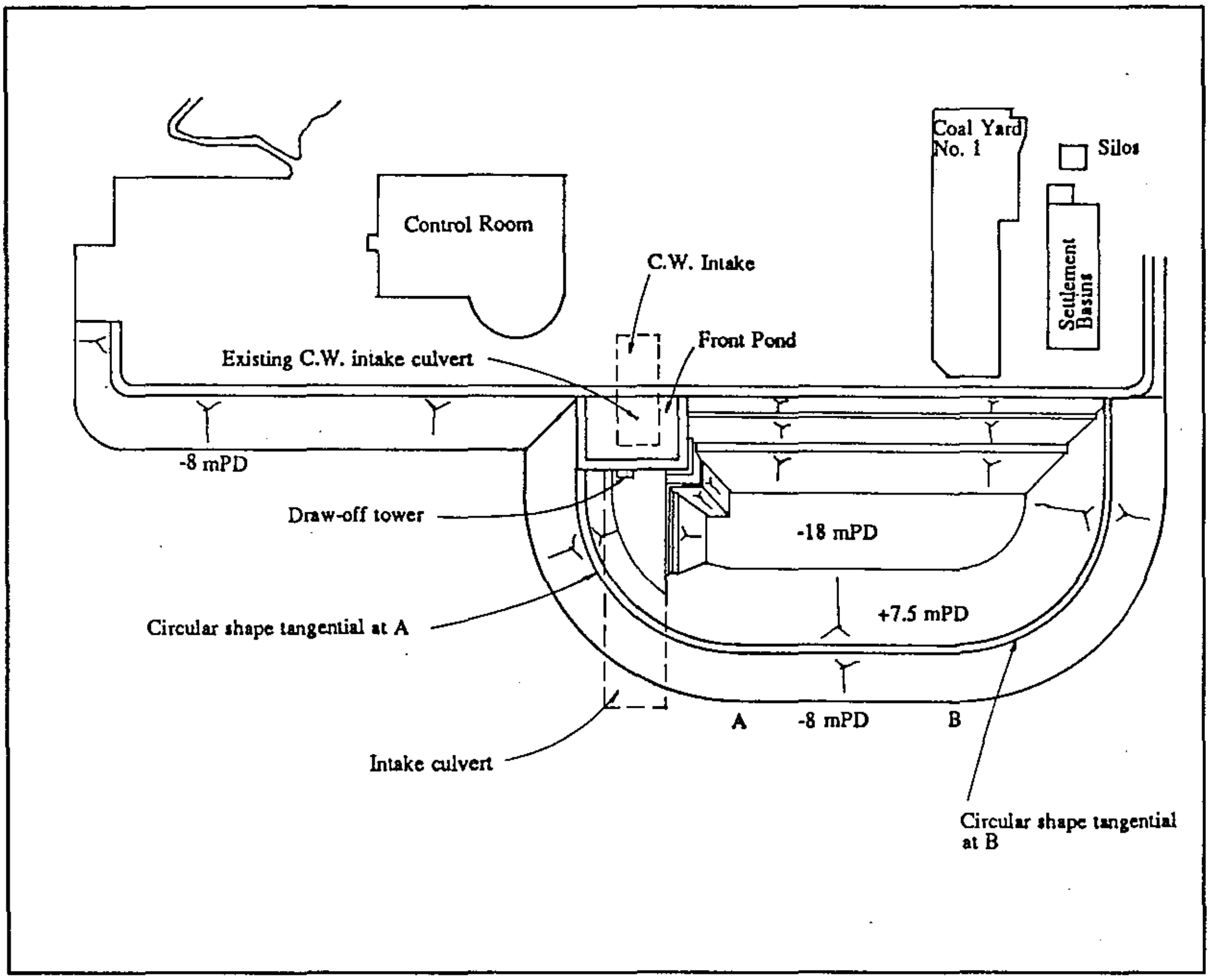


Figure 4.1 Lagoon Layout Plan

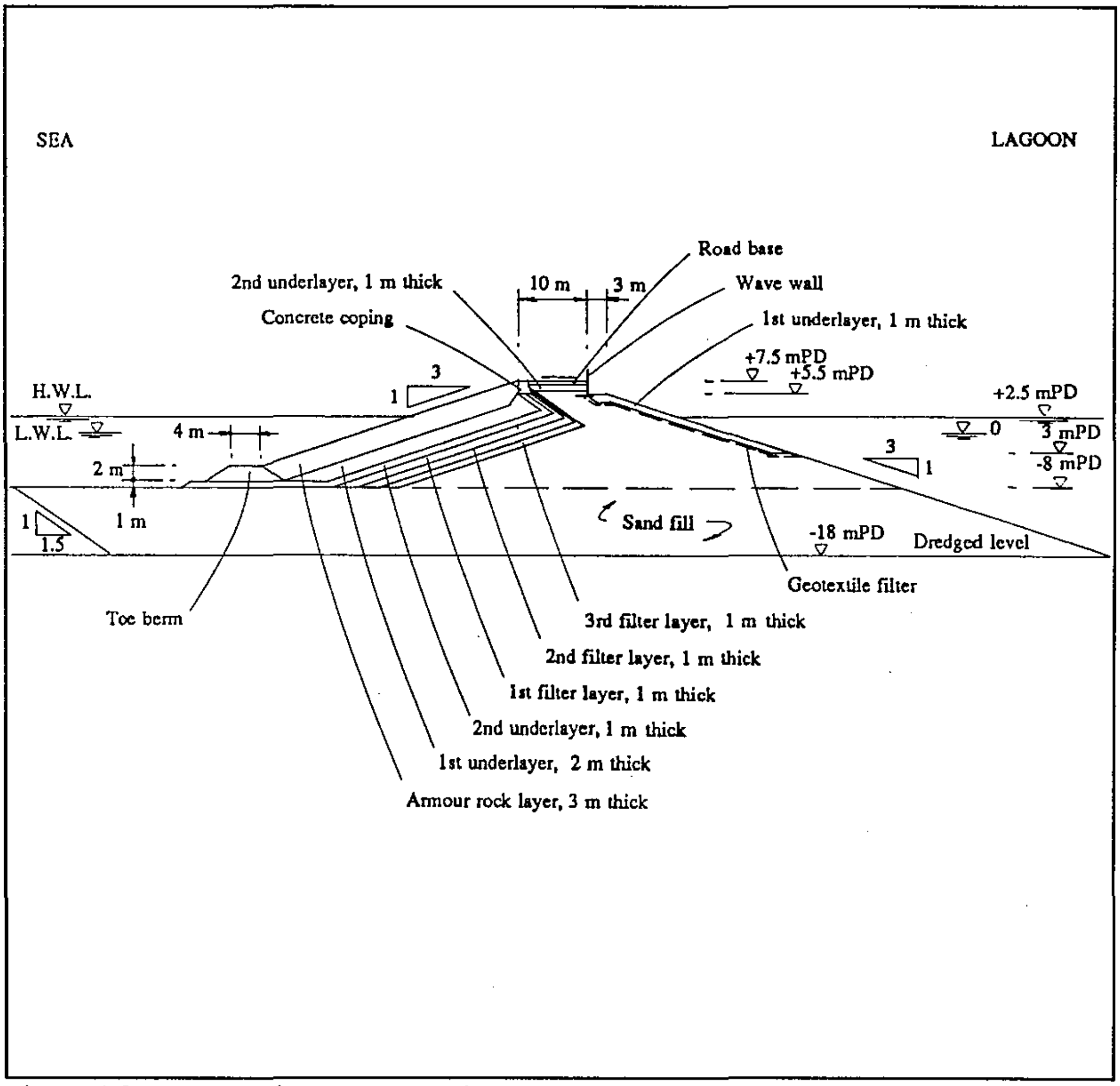


Figure 4.2 Cross-section Lagoon Perimeter

4.2 CONSTRUCTION OPERATIONS

4.2.1 The precise working methods that any one contractor may chose to use during construction cannot be predetermined, and will vary between contractors. However the type of work to be undertaken is not uncommon and an estimate of the likely working methods can be based on previous experience. Lagoon construction will involve six principal operations which are summarised below. For each operation the total number of each equipment type required for the task and also the total number likely to be at the lagoon site at any one time has been estimated. The latter estimate is particularly relevant to noise assessment.

4.2.2 Embankment construction is likely to commence at the west side of the lagoon, and progress in an easterly direction, thus providing progressive protection to the works from prevailing wave conditions. Marine access inside the lagoon will be maintained by leaving a temporary gap at the eastern end of the embankment until operations on the existing power station embankment are finished. The programme for lagoon construction and closure is shown in Figure 4.3.

4.2.3 In addition there will be the construction of a small decantrate draw-off tower and the provision of the conveying and pumping systems to and from the lagoon. However, the activities associated with providing these are of no environmental significance in comparison with the perimeter construction works so they have not been detailed here.

Operation 1 - Foundation Preparation (4 Months)

4.2.4 Approximately 1.6 Mm^3 of soft marine mud will be dredged from the site to provide a suitable foundation for the perimeter embankment and provide the required lagoon capacity. The disposal of the mud will be subject to the normal regulations, and will require approval from EPD. Although there is a registered area off Cheung Chau for the disposal of such dredged mud, the eventual location for it's disposal will be dependent on an agreement between EPD and the contractor at the time of construction. Not withstanding these considerations the plant to be used is likely to be:

Total no. of equipment		Equipment operated on site at any one time	
The dredging of 1.6 Mm^3 of soft marine mud (4 months) using:			
1	Grab dredger	1	Grab dredger
1	Trailer dredger (small/medium)	1	Trailer dredger (small/medium)
4	Support barges	2	Support barges

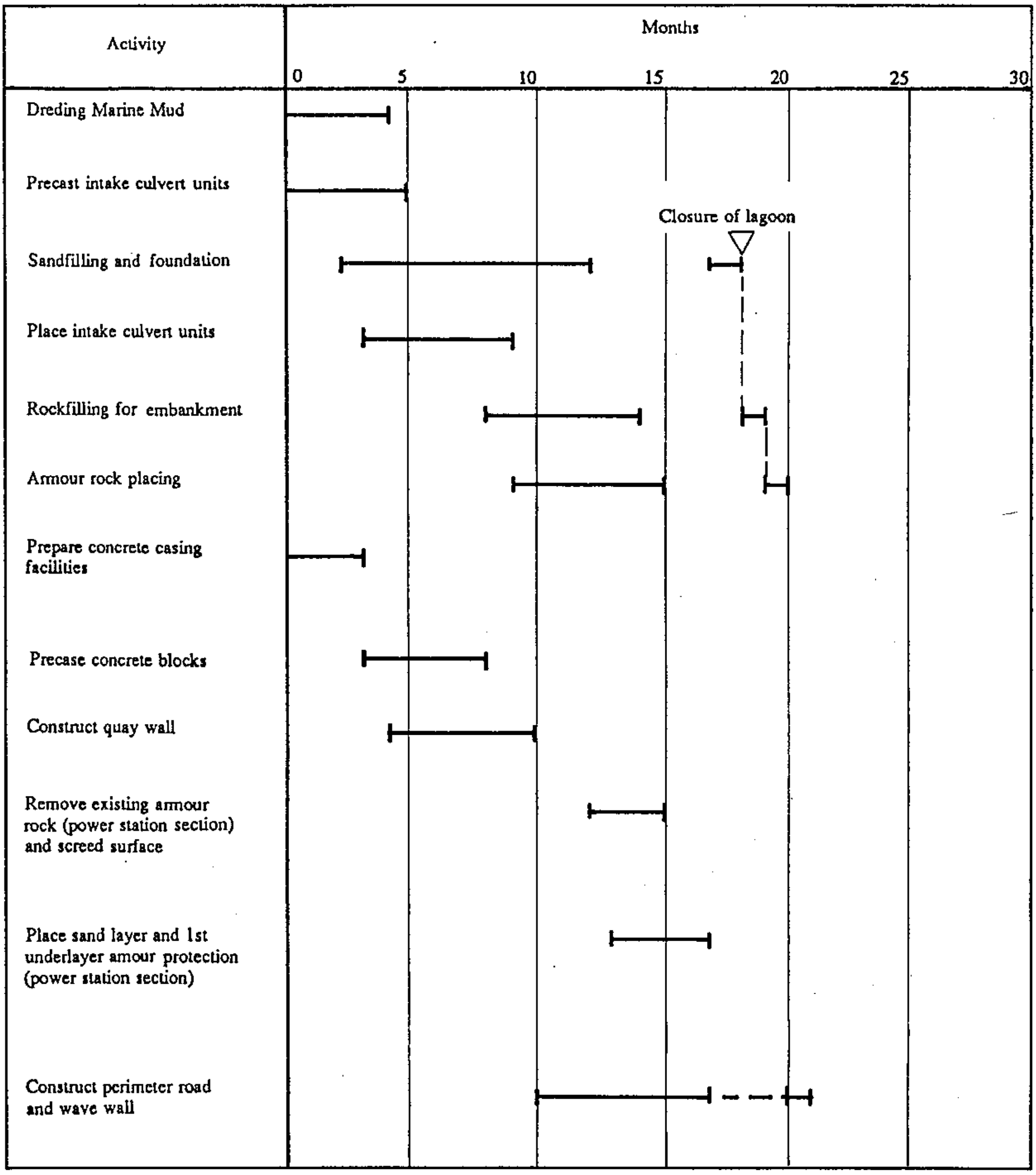


Figure 4.3 Estimated Construction Programme

Operation 2 - Bulk Filling (13 Months)

4.2.5 Bulk filling for the embankment will involve the transportation to site and placing of about 2 Mm^3 of sand and rock fill which will probably require the following equipment:-

Total no. of equipment		Equipment operated on site at any one time	
1.62 Mm^3 of sand fill for foundation and embankment hearting (10 months) using:			
6	Bottom dump or side-dump barges	3	Bottom dump or side-dump barges
3	Grab dredgers	3	Grab dredgers
6	Vibro compaction probes	6	Vibro compaction probes
		4	Derrick lighters
		5	Backhoes
0.30 Mm^3 of rock fill for embankment (6 months) using:			
4	Derrick lighters		
4	Backhoes		
0.116 Mm^3 of armour rocks for embankment (6 months) using:			
3	Derrick lighters		
3	Backhoes		

Operation 3 - Placing of Intake Culvert Units (7 Months)

4.2.6 The intake culvert will be formed in precast sections, transported to site by submersible barge and sunk into position. The foundation for the culvert will have been formed as part of operation 1. The majority of the equipment is associated with the manoeuvring and placing of the units. The operation will involve the following equipment:

Total no. of equipment		Equipment operated on site at any one time	
1	Submersible barge	1	Submersible barge
2	Floating cranes	2	Floating cranes
2	Tug boats	2	Tug boats

Operation 4 - Quay Wall Construction for Front Pond (6 Months)

4.2.7 This operation will involve the placing of about 3100 pre-cast concrete blocks to form the quay wall. The construction will probably be achieved in part from land and part as a marine operation. Thus the following equipment will probably be used:

Total no. of equipment		Equipment operated on site at any one time	
2	Derrick lighters	1	Derrick lighter
2	Land-based cranes	2	Land-based cranes

Operation 5 - Closure of Lagoon (9 Months)

4.2.8 This operation will involve completion of a number of activities within the lagoon before closure of the perimeter prevents marine access. About 0.07 Mm^3 of armour rocks will be removed from the enclosed power station revetment and will be transferred by derrick barge to the seaward side of the new perimeter. The slope exposed after armour rock removal will then be covered with a combination of geotextile, sand and rock to form a filter. Finally, the remaining length of the embankment will be formed to close the lagoon. The following equipment will probably be used during the closure operations:

Total no. of equipment		Equipment operated on site at any one time	
Removal of existing armour rocks (3 months) using:			
3	Derrick lighters	3	Derrick lighters
3	Backhoes	4	Backhoes
		1	Bottom dump or side-dump barge
		1	Vibro compaction probe
Placing and protection filter lining with 0.07 Mm^3 sand and 0.018 Mm^3 rock (4 months) using:			
2	Derrick lighters		
2	Backhoes		
Completion of embankment with 0.017 Mm^3 sand, 0.009 Mm^3 rockfill and 0.004 Mm^3 armour rock (3 months) using:			
1	Bottom dump barge or side-dump barge		
1	Derrick lighter		
1	Vibro compaction probe		
1	Backhoe		

Operation 6 - Construction of Perimeter Road and Wave Wall (7 Months)

4.2.9 About 7 months will probably be required for the construction of the perimeter road, wave wall and surface drainage system. The nature of the construction activities will depend greatly upon the contractor's working methods and to an extent on construction details, for example whether or not pre-cast wave wall units are used. The following is thought to be representative of the likely equipment involved:

Total no. of equipment		Equipment operated on site at any one time	
Construction of perimeter road using:			
1	Grader	2	Compactors
2	Compactors	1	Grader
1	Concrete batching system	1	Concrete batching system
		2	Backhoes
Construction of wave wall and drainage using:			
2	Backhoes		
1	Concrete batching system		

4.3 DETAILED ASSESSMENT

4.3.1 The formulation of a preliminary design for the lagoon and judgements of the likely associated construction activities has enabled a review of the initial assessment of construction effects. The findings of the IAR, with respect to the effects of lagoon construction, are summarised in Figure 4.4. This detailed assessment reinforces the findings of the IAR in that the only effects relate to:

(i) marine biota

(ii) sea water quality

(iii) noise

(iv) visual impact

(v) community reaction

(vi) employment opportunity

(vii) tourism

Marine Biota

4.3.2 Previous sampling in the lagoon area demonstrate that the very soft marine sediments support a relatively diverse community of infauna and epifauna such as Echinoderms, Molluscs, Crustacea and Polycheates which are common in Hong Kong's shallow coastal waters. The area provides no unique habitats, nor is it a nursery ground and is therefore considered to be of low conservation value. As construction involves sea bed excavation and sea bed filling there will be an inevitable loss of some benthic animals in the limited area of the site.

4.3.3 Free swimming organisms, mainly fish are commonly trapped at the power station's cooling water inlet. The assemblage is not unusual and there is no reason to believe that it will be significantly affected by the temporary effects of the lagoon construction.

Sea Water Quality

4.3.4 Lagoon construction activities will have no permanent effects on the local sea water quality. Two possible temporary effects will be the release of nutrients or toxic substances when the marine mud is dredged, and a very localised increase in turbidity next to the dredging and filling operations. Since the local marine biota are of no special significance, any turbulence which does occur is unlikely to be of concern. Similarly, the visual impact of the turbulence need not be a real concern since it will be short-lived and will be distant from the swimming areas off Hung Shing Ye and Tai Wan To beaches.

PRINCIPAL ACTIVITIES	SOCIAL EFFECTS													PHYSICAL EFFECTS									
	SOCIO-ECONOMIC						PSYCHOLOGICAL						POLI-TICAL	BIOTIC		ABIOTIC							
	Land-use	Employment Opportunity	Agriculture	Mariculture	Tourism	Property Values	Visual Impact	Noise	Smell	Lights	Community Reaction	Fung Shui	Planning	Marine Biota	Terrestrial Biota	Air Quality	Sea Water Quality	Groundwater	Land Drainage	Sedimentation	Micro-climate	Archeology	Radioactivity
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
CONTRUCTION Formation of:-																							
Embankments		Δ			O		O	O			O			O			O			O			

Notes:-

1. Judgements assume that all practicable mitigatory measures would be implemented.
2. Where there is no symbol at an intersection believe there will be no effect.
3. Judgements of potentially adverse effects although of low significance are illustrated as O
4. Judgements of beneficial effects are illustrated as Δ

Figure 4.4 Findings of Initial Assessment Report

4.3.5 The sea bed sediments around the Power Station are in a healthy state (IAR) and there need be no concern with respect to releases of nutrients or toxic substances. However, further tests on the marine mud will be carried out to confirm this prior to dredging activities commencing.

4.3.6 There are two reasons for limiting the turbidity during the construction period, the first being the environmental impact, secondly the power station's intakes are close by and excessive turbidity adversely affects the station's performance. Apart from good working practices, there are two natural factors at the site which will aid this objective. The depth of water (8 m) is sufficient to suppress turbidity rising to the surface and secondly the water in the area is not turbulent (Appendix A), so it has a low capacity for sustaining suspended solids. Recent works in Hong Kong have demonstrated that the amount of suspended sediment can be effectively controlled by a good contract specification and working procedures. For example, the specification would require that:

(i) mechanical grabs shall be designed and maintained to avoid spillage and seal tightly while being lifted. Closed grabs shall be used.

(ii) ladders of bucket dredgers shall be designed to minimise disturbance of the sea bed.

(iii) the cutters of cutter suction dredgers shall be suitable for the materials being excavated and shall be designed to minimise overbreak and sedimentation around the cutter.

(iv) washing out or overflowing of hoppers of hopper dredgers or barges while dredging and loading material will not be permitted in Ha Mei Wan.

(v) the decks of all vessels shall be kept tidy and free of oil or any other substances or articles which may be washed overboard. Rubbish shall not be dumped in the sea.

Visual Impact

4.3.7 The construction works and the completed structure will be visible to a small number of dwellings at Tsai Tsuen and Hung Shing Ye, from the beaches at Tai Wan To, Hung Shing Ye and Lo So Shing and from Ha Mei Wai bay and the slopes abutting it.

4.3.8 Concern to minimise the visual impact of the lagoon has been a key factor in influencing the form of the proposed lagoon perimeter. As a result the proposals include:

(i) an embankment structure for the perimeter

(ii) a curved layout plan

(iii) a crest width and wave wall details to match the existing formation

(iv) a rock revetment for wave protection on the seaward and inside embankment slopes to match that of the existing station site

4.3.9 The visual impact of the construction will be kept to the minimum practicable, principally by limiting the construction period to the minimum possible. Moreover, the lagoon construction will take place next to existing materials movements to and from the eastern side of the power station and the increase in marine traffic will not give a significant increase in visual impact.

4.3.10 Construction works for the relatively small scale ash conveying systems will probably not be discernible against the routine power station activities.

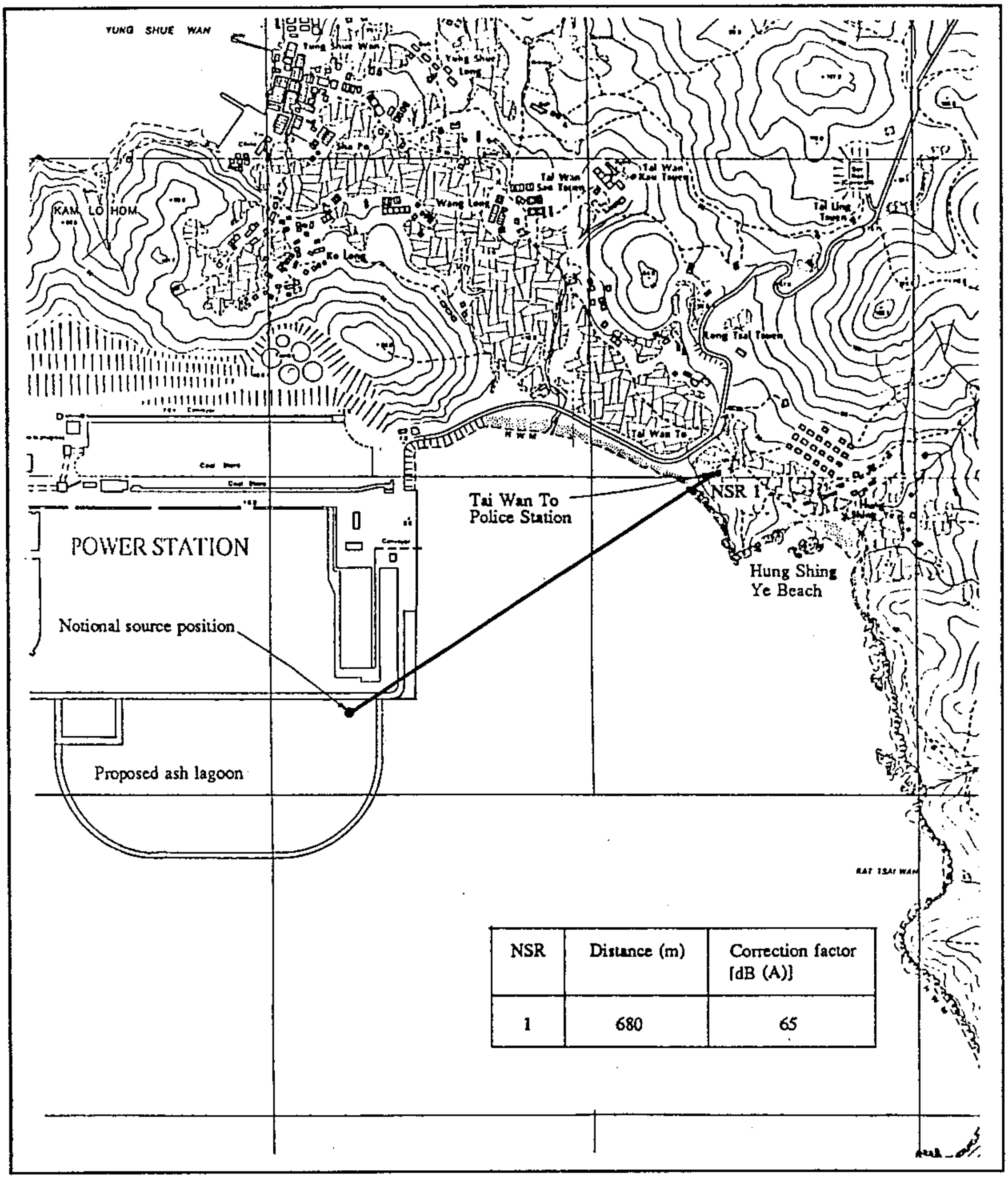
4.3.11 Permanent works will be detailed to match and compliment existing works. The architectural detailing of the conveyors and associated junction towers will match the existing station systems. Similarly, the small decantrate draw-off tower to be located inside the western edge of the lagoon will be designed with architectural expression relating to the existing station buildings design.

4.3.12 Upon construction completion, therefore, the lagoon will appear as an extension to the power station site which blends with it in landscape terms. The structure will not block any sea views although it must necessarily impinge on some. However visual impact has not featured as a public concern and we conclude that the proposed lagoon form is visually acceptable. Visual aspects of the landscaped mound within the lagoon are discussed in Chapter 7.

Noise

4.3.13 Construction noise will affect the Tai Wan To and Hung Shing Ye areas. The principal noise sensitive receiver (NSR) that could be affected by the works is the Tai Wan To police station (Figure 4.5). The noise assessment for the site has been carried out, using the principles and assumptions set out in the IAR.

4.3.14 In considering the likely significance of construction noise the procedures set out in the 1988 Noise Control Ordinance for noise from construction work other than percussive piling have been used. The Area Sensitivity Rating will be "A" during the day-time, evening and night-time periods. Since corrections are not necessary for construction duration and number of construction sites, the Acceptable Noise Level (ANL) is exactly the same as the Basic Noise Level (BNL) for the NSR (Figure 4.5). The ANL would be 60 dB(A) during the evenings (1900 to 2300 hours), and general holidays (including Sundays) during the day-time and evening (0700 to 2300 hours). The ANL would be 45 dB(A) at night (2300 to 0700 hours). These figures give some perspective in assessing the noise levels expected to result from construction.



NSR	Distance (m)	Correction factor [dB (A)]
1	680	65

Figure 4.5 Noise Sensitive Receiver

4.3.15 The Corrected Noise Level (CNL) likely to be received at a NSR is a function of distance as well as the type of equipment producing the noise and any corrections for effects such as acoustic screens and reflectors. The source of noise from a site is taken as a point mid way between the geographical centre of the site and the site boundary nearest to the NSR, this is termed the Notional Source Position (NSP). Where the construction site is large such that the NSP is greater than 50 m from the point on the site boundary nearest to the NSR the position is taken to be a point 50 m inside the site boundary along the same line, and this is the approach adopted here to indicate the worst case scenario (Figure 4.5).

4.3.16 The distance between the noise source and the nearest Noise Sensitive Receiver (NSR) is 680 m. The correction factor for distance attenuation is 65 dB(A) derived from equation (4.1). Also the NSR is partially screened and therefore receives a negative correction factor of 5 dB(A); it is also a building and so receives a 3 dB(A) positive correction.

$$K = 20 \log_{10} R + 8 \quad (4.1)$$

where K is the correction factor dB(A) for distance attenuation
R is the distance in meters

4.3.17 The estimated construction noise levels are based on the Total Sound Power Levels (TSPL) to be expected from the principal operations described in Section 3 (Table 4.1). The cumulative effects of all these TSPLs have been considered, and indicate an upper bound noise level (Table 4.2).

4.3.18 The CNLs from individual operations will be low [49 - 55 dB(A)]. The upper bound CNLs [57 - 58 dB(A)] for likely combinations of construction operations are still acceptable for working even in the evenings and on general holidays. Construction noise therefore, is not expected to be significant. A permit will be required to carry out construction during restricted hours.

Community Reaction

4.3.19 The Lamma community gives the impression that the rational and plans for the lagoon have now been accepted, albeit reluctantly in some cases. This is reinforced by the discussions held during the ash management exhibition held on Lamma from 13.10.89 to 15.10.89 when all the proposed ash management works were presented and explained to Lamma residents. Subsequently, the Lamma Conservation Society have publicly announced their acceptance of the ash management plans. Consequently significant adverse community reaction as a result of the lagoon construction works is not expected. However, some local residents are not confident that the lagoon will be able to retain the ash placed in it and are not fully convinced that the ash will not be dusty. These issues are addressed in Chapter 7.

Employment Opportunity

4.3.20 The principal lagoon construction works of dredging and bulk filling will be undertaken by specialist marine contractors whose demand for local labour will not be great. However, the concreting works needed to cap the structure will require a land-based skilled and semi-skilled workforce. The local workforce requirements will depend upon the Contractor's method of working, but a minimum of 20 persons may be required for the duration of the works.

Tourism

4.3.21 The principal tourist attractions near the ash lagoon site are the Lo So Shing, Tai Wan To and Hung Shing Ye beaches (plus the restaurants at Hung Shing Ye), and Ha Mei Wan Bay itself are a recreational facilities.

4.3.22 The popularity of the beaches at Lo So Shing and Hung Shing Ye is indicated by Government's attendance figures which, for 1985 to 1989 are summarised in Table 4.3. Although the data set is too small for reliable statistical analysis, the figures do suggest a trend of rising attendance over the three summers since 1987 and indicate that about 60% to 70% of the total annual attendance is during the three months of June, July and August.

4.3.23 Lo So Shing beach is about 1.5 km from the lagoon site so the construction activities are unlikely to have any effect in the area of the beach. Tai Wan To and Hung Shing Ye beaches may be less attractive to some tourists while the lagoon construction works are in progress but since the works will have no significant effect on the water quality and will not restrict the swimming or sailing facilities, it seems highly unlikely that many beach users will be discouraged.

4.3.24 Ha Mei Wan bay is a picnic anchorage for private pleasure boats in the summer months. There is no data to indicate how many pleasure boats use the bay, but local observers report that the numbers have increased in recent years with the most popular anchorage being off Lo So Shing beach and the area to the south of it. The temporary construction works are unlikely to have any significant effect on pleasure boat usage of the bay.

4.4 CONCLUSIONS

4.4.1 Environmental considerations have had a major influence in preliminary design of the ash lagoon location, its plan form, its cross section, the materials to be used in its construction, the construction methods and the construction programme. The iterative approach to engineering design and environmental assessment has minimised the effects of lagoon construction leaving only those temporary and permanent effects which are unavoidable. However, the temporary effects resulting from the construction of the ash lagoon will have minor environmental impact.

4.4.2 The construction period is to be approximately two years. The temporary effects during construction are:

(i) local short-lived turbidity - kept to a minimum by good working practices.

(ii) visual intrusion from the coming and going of construction craft - kept to a minimum by providing a short construction programme.

(iii) construction noise - kept within the limits of the Noise Control Ordinance.

4.4.3 The permanent effects resulting from lagoon construction are:

(i) loss of a small area of sea bed

(ii) local deflection of tidal flow

(iii) visual intrusion from the structure

4.4.4 These are minor environmental effects and are acceptable disadvantages when weighed against the overall environmental benefits to be provided by the lagoon facility, forming as it does an integral part of the Ash Management Strategy for Lamma Power Station.

	Noise [dB(A)]						TSPL [dB(A)][1]	CNL [dB(A)][2] at NSR
Operation 1 (4 months):	- Dredging Marine Mud							
1 Grab dredger	112	> 115	> 115.5	>			)	
1 Trailer dredger	112	>		> 116			)	
2 Support barges	104	> 107	>	>			) 116	116-67[3] = 49
	104	>		>			)	
Operation 2 (13 months):	- Sandfilling for foundation							
	- Rockfilling for embankment							
	- Armour rock placing							
3 Bottom dump barges	104	> 107	>				)	
	104	>	> 110	>			)	
	104	> 107	>	> 115	>		)	
4 Derrick lighters	104	>		>	>		)	
	104	> 107	>	>	>		)	
	104	>	> 113.5		>		)	
	104	> 112.5	>		>		)	
3 Grab dredgers	112	>			> 122	>	)	
	112	> 115	> 118	>	>	>	)	
	112	>	>	>	>	>	)	
5 Backhoes	112	> 115	>	> 120.5	>	>	)	
	112	>		>		>	) 122	
	112	> 115	>	>		> 122	)	122-67[3] = 55
	112	>	> 117			>	)	
	112	> 112	>			>	)	
6 Vibro compaction probes	80	>		>		>	)	
	80	> 83	>	>		>	)	
	80	>	> 86	> 87	> 87	>	)	
	80	> 83	>	>			)	
	80	>					)	
	80	> 80	> 80	>			)	
Operation 3 (7 months):	- Placing of intake culvert units.							
1 Submersible barge	104	> 104	>				)	
2 Floating cranes	112	>	> 115.5	>			)	
	112	> 115	>	>			)	
2 Tug boats	110	>		> 117.5			) 118	118-67[3] = 51
	110	> 113	> 113	>			)	
							)	
Operation 4 (6 months):	- Quay wall construction for front pond							
1 Derrick lighter	104	> 104	>				)	
		>	> 115.5	>			)	
2 Land-based cranes	112	> 115	>	> 116			) 116	116-67[3] = 49
	112	>	>	>			)	
Operation 5 (9 months):	- Remove existing armour rock and screed surface							
	- Place sand layer and 1st underlayer armour protection							
	- Sandfilling and foundation							
	- Rockfilling for embankment							
	- Armour rock to placing							
3 Derrick lighters	104	> 107	>				)	
	104	>	> 113.5	>	>		)	
	104	> 112.5	>	> 118.5	>		)	
4 Backhoes	112	>		>	>		)	
	112	> 115	>	>	> 118.5		) 119	119-67[3] = 52
	112	>	> 117	>	>		)	
	112	> 112	>		>		)	
1 Vibro compaction probe	80	>					)	
1 Bottom dump barge	104	> 104	> 104	> 104	>		)	
Operation 6 (7 months):	- Construct perimeter road and wave wall							
1 Graders	113	> 113.5	>				)	
			> 115	>			)	
2 Compactors	105	>	>	>			)	
	105	> 110	>	> 118			) 118	
1 Concrete batching system	108	>		>			)	118-67[3] = 51
2 Backhoes	112	> 115	> 115	>			)	
	112	>					)	

Remarks:
(1) Total Sound Power Level
(2) Corrected Noise Level
(3) Correction Factor for Distance Attenuation between the NSR and the construction site [-65 dB(A)], partial screening of NSR [-5 dB(A)] and NSR being a building [+ 3 dB(A)]

Table 4.1 Estimated noise levels from principal operations

	TSPL [dB(A)]					CNL [dB(A)]
Operation 1	116	>				
		>	123	>		
Operation 2	122	>		>		
				>	125	58
Operation 3	118	>		>		
		>	120	>		
Operation 4	116	>				
Operation 2	122	>				
		>	135.3	>		
Operation 3	118	>		>	124	57
		>	116	>		
Operation 4	116	>				
Operation 2	122	>				
		>	124	>		
Operation 5	120	>		>	125	58
		>	118	>		
Operation 6	118	>				

Table 4.2 Estimated peak construction noise levels for operations carried out simultaneously (refer Figure 4.3)

Month	Lo So Shing beach				
	1985	*1986*	*1987*	*1988*	*1989*
April	700	2,900	3,100	400	1,100
May	13,100	13,300	4,900	6,000	14,400
June	21,800	37,400	12,300	9,800	26,400
July	34,300	33,200	19,500	31,700	28,600
August	44,600	40,300	23,100	19,200	27,300
September	22,600	14,600	9,000	15,000	11,200
October	8,900	5,300	5,800	12,900	4,500
Total	146,000	147,000	77,000	95,000	113,500

Month	Hung Shing Ye beach				
	1985	*1986*	*1987*	*1988*	*1989*
April	1,100	3,800	5,700	17,000	3,400
May	10,900	10,200	11,800	9,500	6,100
June	16,900	31,700	19,300	24,500	25,700
July	30,000	21,700	18,300	33,500	39,100
August	30,400	30,600	28,200	28,200	53,900
September	11,800	19,200	14,100	23,900	19,000
October	7,000	8,400	14,600	14,100	7,300
Total	108,100	125,600	112,000	135,400	154,500

Source : Regional Services Department

Table 4.3 Attendance at gazetted beaches on Lamma Island

CHAPTER 5

CONSTRUCTION ENVIRONMENTAL MONITORING AND AUDIT

5.1 INTRODUCTION

5.1.1 Detailed studies (Chapters 3 and 4) have considered both civil engineering and environmental aspects of the project and led to a proposal for the lagoon which will have minimal effect on the environment. To confirm this, the lagoon construction will be subject to environmental monitoring and audit procedures.

5.1.2 Environmental monitoring involves the measurement of a range of physical and chemical parameters which may be influenced by lagoon construction. Environmental auditing is the methodical examination of a project in a manner designed to establish whether the activities are complying with the previously defined criteria and that remedial measures are identified to remedy any unacceptable impacts.

Environmental Monitoring

5.1.3 Monitoring is required to provide the necessary data for an informed assessment of the environmental impacts of the various activities, and to what extent these persist beyond the end of the activities. This can only be achieved by measuring the relevant parameters before, during and after the activities. For the Lagoon construction the monitoring programme will consist of the following:

- (i) determine the environmental effects arising from the project
- (ii) identify the parameters to be used for measuring the effects
- (iii) define acceptance criteria for the parameters where possible
- (iv) collect the necessary data

Environmental Audit

5.1.4 The environmental audit consists of a series of procedures controlling the monitoring programme and other functions that ensure that the environmental impact of activities are measured consistently and that the correct procedures are implemented if the environmental effects are found to be outside the acceptable criteria. The purpose of the audit is to:

- (i) access the quality of the monitoring data
- (ii) compare the measured effects with the acceptance criteria
- (iii) initiate control procedures to mitigate identified effects outside the acceptance criteria

5.2 ENVIRONMENTAL EFFECTS

5.2.1 The potential environmental effects of lagoon construction have been discussed in the IAR, which recommended that the following areas be monitored:

(i) sea water quality

(ii) noise

(iii) tourism

5.2.2 Lagoon construction will also have some effect on marine biota, visual impact, community reaction and employment opportunities, however these aspects will not be specifically monitored (Chapter 4).

5.2.3 The environmental monitoring programme is expected to confirm that the above areas will not adversely affected to any significant degree by lagoon construction.

5.3 MONITORING PARAMETERS AND PROGRAMME

5.3.1 Environmental effects associated with lagoon operating should, where possible, be measured by quantifiable scientific methods.

5.3.2 The monitoring programme will be influenced by the timing of construction activities (Figure 4.3). The proposed monitoring programme is based on an assumed construction sequence which may need to be revised when construction commences.

Sea Water Quality

5.3.3 Sea water quality will be regularly measured at three locations around the site to monitor any changes arising from construction (Figure 5.1). Location ST1 will monitor water quality entering cooling water intake no. 2. Location ST2 will monitor water quality close to the construction site and location ST3 will monitor water quality near the public beaches in Ha Mei Wan. A fourth location ST4, will be used to determine "ambient" sea water properties. ST4 is to be in an area which will not be effected by lagoon construction activities (e.g. near the Power 4 navigation light).

5.3.4 Samples are to be collected at 14 day intervals for 3 sampling occasions before construction to form the baseline monitoring. During the construction period samples will be taken at 14 days intervals for the first 3 months of construction, becoming 28 day intervals for the rest of the construction period. Three sampling occasions will be taken at 28 days intervals after construction to provide data for assessment of the extended effects of the construction and the data for the post project analysis.

5.3.5 On each sampling occasion the following general observations should be recorded:

(i) tide level

(ii) tidal condition (e.g. ebb or flood conditions)

(iii) weather (e.g. wind, rain)

5.3.6 On each sampling occasion, sea water will be sampled at locations ST1, ST2 and ST4 at the surface (1 m below surface), mid-depth and bottom (1 m above the bottom). The water at location ST3 is approximately 4-5 m deep, hence only surface and bottom water samples will be taken.

5.3.7 The physical parameters (Table 5.1) will be determined on water samples from locations ST1, ST2 and ST3. Chemical parameters will be determined on the mid-depth water samples from locations ST1 and ST2 and the bottom sample at location ST3. Location ST4 is intended to measure the ambient parameters referred to in Table 5.3 which may be affected by lagoon construction. Temperature and salinity will not be affected hence only total suspended solids need be measured. Proposed analytical methods for measuring the parameters listed in Table 5.1 are given in Table 5.2. The methods quoted may be replaced by alternatives which would give results of comparable accuracy.

	Testing parameter
Physical parameters	Water depth of sampling station (m) Temperature (°C) Dissolved Oxygen (mg/l) pH (Unit) Salinity (0/00) Turbidity (NTU) Total Suspended Solids (mg/l)
Chemical parameters	Total Ammonia Nitrogen (NH_3-N), mg/l Nitrate (NO_3^--N), mg/l Nitrite (NO_2^--N), mg/l Orthophosphate (PO_4^{-3}-P), mg/l BOD_5 (mg/l) COD (mg/l)

Table 5.1 Proposed water testing specification

	Parameter	Analytic method	Reference
Physical parameters	Water depth (m)	Sounding lines method (with angle correction if necessary)	a
	Temperature (°C)	Mercury thermometer of 0.1°C scale	212
	Dissolved Oxygen (mg/l)	D.O. meter measurement	421F
	pH (Unit)	pH - meter measurement	423
	Salinity (0/00)	Conductivity - meter measurement	210A
	Turbidity (NTU)	Nephelometric method	214A
	Total Suspended Solids (mg/l)	Gravimetric method, dried at 103°-105°C	209C
Chemical parameters	Total Ammonia Nitrogen (NH_3-N), mg/l	Colorimetric - phenate method	417C
	Nitrate (NO_3^--N), mg/l	Colorimetric - cadmium reduction method	418C
	Nitrite (NO_2^--N), mg/l	Colorimetric - diazotization method	419
	Orthophosphate (PO_4^{-3}-P), mg/l	Colorimetric - ascorbic acid method	424F
	BOD_5 (mg/l)	D.O. meter measurement, 5 days incubation at 20°C	507
	COD (mg/l)	Dichromate - open reflux method	508A

References Ref: Reference quoted (except for, a, b and c) is the part number of the "Standard Methods for the Examination of Water and Wastewater", 17th edition, APHA- AWWA - WPCF

a) Tait, R.V. (1972). Elements of Marine Ecology, London Butterworths : 42-43

Table 5.2 Proposed test methods

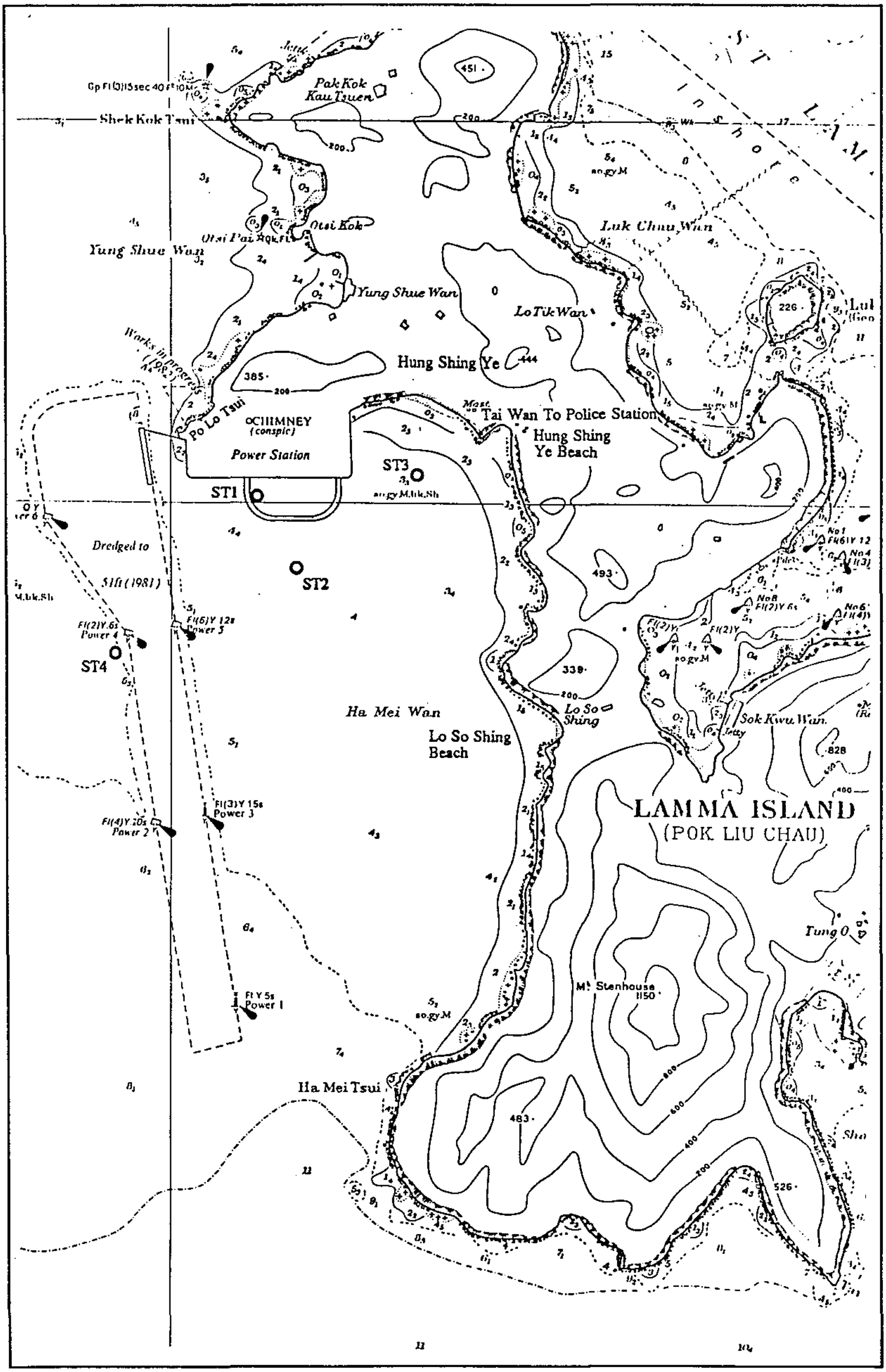


Figure 5.1 Sea Water Sampling Stations

Noise

5.3.8 The noise levels produced by lagoon construction will be acceptable at the nearest Noise Sensitive Receiver (NSR), which is taken to be the Tai Wan To police station (Chapter 4).

5.3.9 Noise levels will be monitored continuously at the two existing HEC sites at Ching Lam and Hung Shing Ye, using the present equipment and methodology. This equipment will record noise produced on the power station site as a whole and not just from lagoon construction.

Tourism

5.3.10 Initial estimates indicate that there should not be any adverse effect on tourism in the Ha Mei Wan area as a result of lagoon construction (Chapter 4). In order to confirm this estimate the number of tourists frequenting the area should be monitored.

5.3.11 Lo So Shing and Hung Shing Ye are both gazetted beaches at which the Hong Kong Government record the number of visitors. This information can be obtained from the Regional Services Department. Tourism will be monitored by considering the number of tourists attending Lo So Shing and Hung Shing Ye beaches during the tourist season from April to October. Tai Wai To is not a gazetted beach, so attendance figures are not available.

5.4 ACCEPTANCE CRITERIA

5.4.1 Acceptance criteria against which the measured environmental parameters (Section 5.3) are to be judged, are wherever possible those specified by the Hong Kong Government. However in several cases Hong Kong standards do not exist, and criteria from other sources, or even judgements are necessary. These are described in more detail where appropriate.

Sea Water Quality

5.4.2 There are few standards against which to judge acceptability of sea water quality in Hong Kong. Those applicable to the present programme are listed in Table 5.3 and they will help to put into perspective the monitoring results. The typical ranges quoted are not absolute limits but rather an indication of the values which can occur naturally in sea water. By comparing water quality before, during and after construction, the impact of the project on the environment, if any, can be assessed.

5.4.3 The values given in Table 5.3 can be compared with measured results to determine whether site conditions are within the expected ranges. Table 5.3 does not define criteria for acceptable or unacceptable conditions, hence a judgement will be necessary when interpreting field data.

Noise

5.4.4 Construction noise will affect the Tai Wan To and Hung Shing Ye areas. The principal noise sensitive receiver (NSR) that could be affected by the works is the Tai Wan To police station (Figure 5.2), so the noise assessment is with respect to this site, using the principles and assumptions set out in the IAR.

5.4.5 In considering the likely significance of construction noise we have used the procedure set out in the 1988 Noise Control Ordinance for noise from construction work other than percussive piling. The Area Sensitivity Rating will be "A" during the day-time, evening and night-time periods. Therefore the Acceptable Noise Level (ANL) for the NSR at the Tai Wan To police station would be 60 dB(A) during the evenings (1900 to 2300 hours), and general holidays (including Sundays) during the day-time and evening (0700 to 2300 hours). The ANL would be 45 dB(A) at night (2300 to 0700 hours). These figures give some perspective in assessing the noise levels expected to result from construction.

5.4.6 The estimate (Chapter 4) of Corrected Noise Levels (CNLs) from individual operations is within the range of 49 to 55 dB(A) and an upper bound noise level of 57 to 58 dB(A) for likely combinations of operations. The latter are lower than the ANL for evenings and general holidays. Construction noise therefore is not expected to be significant.

Tourism

5.4.7 There are no criteria against which to judge the impact of lagoon construction on tourism. We recommend that a comparison be made of the number of visitors to the two gazetted beaches before, during and after construction. In this way an indication of its impact can be derived, although outside factors, such as weather conditions, may distort the findings.

Parameters	Typical range			Acceptable range
Temperature (°C)	17.3	-	29.5	< ± 2°C from ambient
Dissolved Oxygen (mg/l)[d]				> 4
pH (unit)	8.04	-	8.60	6.5 - 8.5
Salinity (0/00)	25.2	-	34.1	< ± 10% from ambient
Turbidity (NTU)	1.8	-	15.7	< 75[c]
Total Suspended Solids (mg/l)	1.8	-	16.7	< +30% from ambient
Total Ammonia nitrogen (NH_3-N), mg/l				< 0.050[c] < 0.021 (annual average)
Nitrate (NO_3^--N), mg/l				< 0.1
Nitrite (NO_2^--N), mg/l				< 0.03[a], [b]
Orthophosphate (PO_4^{3-}-P), mg/l	0.005	-	0.02[c]	< 0.16[b]
BOD_5 (mg/l)	0.3	-	2.6	< 5
COD (mg/l)				< 30

References

1. The acceptable range is based on the Southern Water Control zone statement of Water Quality Objectives [Laws of Hong Kong Vol. 22 (CAP 358), 1988] except (a), (b), (c) and (d).

2. The typical range is based on the water quality of West Lamma Channel in 1988 (EPD, Marine Water Quality in Hong Kong 1989).

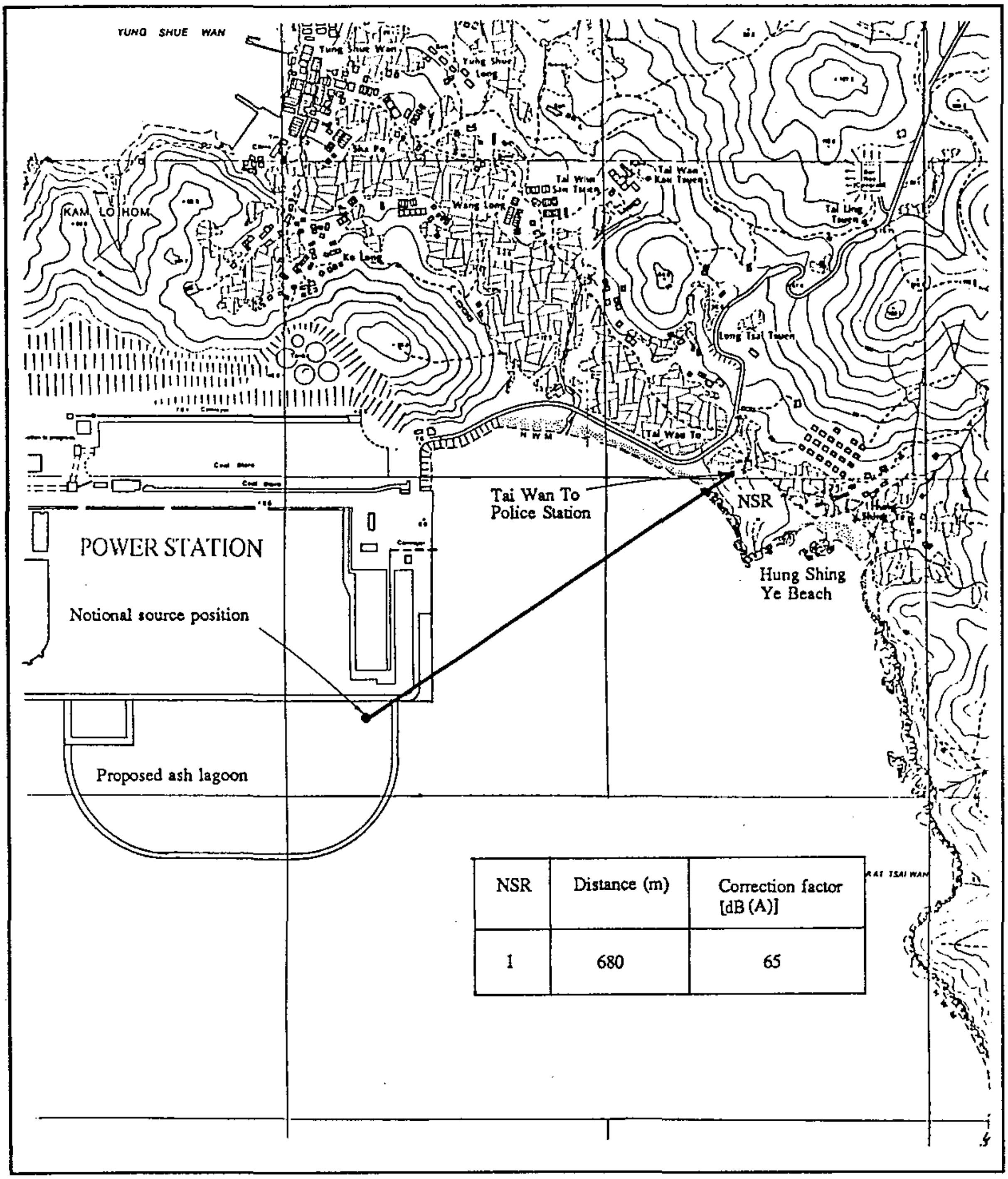
a. Chen, K.C. (1965). Analytical Chemistry of Sea Water. Scientific Publications, Peking : 130 and 140.

b. Goldberg E,D. (1972). A guide to Marine Pollution. Gordon and Beach Science Publishers, London.

c. Mok, M.H. (1979). "Discussions on the Standardization of Water Qualities - summary report".:91 in Conference on the Standardization of Methodology of Water Pollution (edited by Chung, M.T. and Chui, V.) Note: NTU approximate JTU but not exactly the same.

d. Arithmetic mean of at least 3 measurements at 1 metre below water surface, mid-depth and 1 metre above seabed.

Table 5.3 Expected sea water quality



NSR	Distance (m)	Correction factor [dB (A)]
1	680	65

Figure 5.2 Noise Sensitive Receiver

5.5 CONTROL PROCEDURES

5.5.1 Sea water quality is the major environmental impact that may arise due to lagoon construction, and can to some extent be controlled by adjusting construction procedures. Noise is not expected to be significant, as described earlier.

5.5.2 The sea bed sediments around the Lamma Power Station are in a healthy state (IAR), hence there need be no concern with respect to releases of nutrients or toxic substances during dredging operations. Regarding turbidity, recent works in Hong Kong have demonstrated that the amount of suspended sediment can be effectively controlled by a good contract specification and working procedures. For example, the specification would require that:

(i) mechanical grabs shall be designed and maintained to avoid spillage and seal tightly while being lifted. Closed grabs shall be used

(ii) ladders of bucket dredgers shall be designed to minimise disturbance of the sea bed

(iii) cutters of cutter suction dredgers shall be suitable for the materials being excavated and shall be designed to minimise overbreak and sedimentation around the cutter

(iv) washing out or overflowing of hoppers on hopper dredgers or barges while dredging and loading material will not be permitted in Ha Mei Wan

(v) the decks of all vessels shall be kept tidy and free of oil or any other substances or articles which may be washed overboard. Rubbish shall not be dumped in the sea

5.6 ENVIRONMENTAL AUDIT

5.6.1 The environmental audit system is intended to check methodically that the activities of the project are complying with previously defined environmental requirements and predictions, and that the necessary measures are identified to remedy any unacceptable or unforeseen environmental impacts. Environmental auditing is a check to reassure management and regulatory agencies, that the facilities are being operated in an environmentally acceptable manner. It also enables a post project analysis to be carried out to examine the accuracy of the original environmental impact assessment.

Environmental Auditor

5.6.2 HEC staff have satisfactorily monitored the power station's operations under the auspices of EPD for a number of years. The staff have the necessary expertise to review the methods and philosophy behind the monitoring programme, consequently HEC are the proposed environmental auditor for the construction phase and are to operate under the auspices of EPD.

Auditing Frequency

5.6.3 Auditing frequency will be related to a number of factors, such as the rate of data collection and construction activities. Audits would be carried out at 6 monthly intervals for the first year after construction commences and thereafter at 12 monthly intervals so that the monitoring programme can be updated to take account of any changing environmental impacts. One audit should be carried out some time after construction completion to determine the long term environmental impact of the facility. The frequency will be reviewed and revised as necessary as part of the audit process.

Scope of the Audit

5.6.4 The following points will be considered, as appropriate, for each of the environmental impacts, namely, sea water quality, noise and tourism (Section 5.2). The audit will:

(i) check that the approved sampling procedures and analytical techniques are used to assess the quality of the collected data

(ii) consider tidal, wind and weather conditions where appropriate at the time of sampling. These factors may influence sea water quality and noise monitoring respectively

(iii) ascertain whether any extraneous activities, unrelated to lagoon construction, may have influenced the data. Factors such as building works adjacent to monitoring sites will be considered

(iv) ascertain what activities or operations take place at the lagoon site before or during the sampling period

(v) review the collected data, in the light of the preceding information, to identify any events which create unacceptable impacts. In many cases deciding whether an impact is acceptable or not would be a matter of judgement since there are few clearly defined acceptance criteria

(vi) recommend measures to change unacceptable impacts, so that they become acceptable

(vii) review impacts that cannot be quantified and for which there are no absolute acceptance criteria, such as visual impact

(viii) review actions taken to deal with complaints from the general public and consider whether any fundamental changes are necessary. A clearly defined system should be established to respond promptly to public complaints without waiting for the next audit

(ix) review the overall monitoring philosophy, in terms of sampling location, frequency, parameters measured, test methods, acceptance criteria and control procedures. Revise if necessary

(x) revise the scope and frequency of the auditing system to reflect changes in environmental impacts and lagoon construction procedures

(xi) carry out a post project analysis to compare the environmental impacts predicted in the EIA, with actual impacts. Comment on any discrepancies and make recommendations as appropriate

Reporting procedures

5.6.7 A report will be produced by the auditors after each inspection. The report will provide HEC management and EPD with information on the environmental impacts arising from lagoon construction and will review the earlier stages of the Environmental Impact Assessment. It will, in addition, indicate any changes which should be made to monitoring and control procedures.

5.7 CONCLUSIONS

5.7.1 The proposals for the lagoon have been devised with due consideration to not only the operating effects but also the likely environmental effects during construction. During construction the most relevant effects are likely to be those on marine water quality, tourism and noise.

5.7.2 Although the effects on these parameters are not expected to be significant, they will be monitored before during and after the construction period. Changes and significant impacts, should they occur, will be identified by the monitoring and audit process. The regular audits will also initiate remedial measures should these be necessary and following the construction period it will report on the accuracy of the EIA.

APPENDIX 1 TERMINOLOGY

Definition of the terminology used :

Baseline monitoring	-	the measurement of environmental parameters during a representative pre-project period in order to determine the nature and ranges of natural variation and to establish the nature of change.
Environmental monitoring	-	the systematic measurement of parameters during project implementation so as to detect changes in those parameters which can be attributed to the project. The parameters monitored are those which were identified during the Environmental Impact Assessment (EIA) stage as being likely to be affected by the project.
Environmental auditing	-	the methodical examination of procedures and practices to verify compliance with predetermined environmental requirements or accepted practices.
Post project analysis	-	the comparison of the predicted environmental impact of a project, as described in the Initial Assessment Report and Detailed Assessment Report, with the observed impacts monitored in the field. This analysis can improve the scientific and technical understanding of EIA, and the effectiveness of the methodologies.

CHAPTER 6

LAGOON OPERATING SYSTEMS

6.1 INTRODUCTION

6.1.1 The proposed lagoon operating system has seven key elements, relating to the ash handling system, final land form and landscaping, water quality control, the collection of floaters, the emergency sluicing system, PFA harvesting and dust suppression. These are described in the following sections.

Existing Ash Handling System

6.1.2 The existing ash handling system (Figure 6.1) in the Lamma power station handles furnace bottom ash (FBA) in a wet form, and handles PFA in a dry or conditioned (moist) form. In emergencies, the PFA can also be handled by sluicing to the settlement basin as a slurry. PFA is moved by conveyors or pipes to barges for off-site transport. FBA is dug from the settlement basin by grab crane for transportation to the ash barges by the conveyor system.

Lagoon Operating Proposal

6.1.3 PFA will be transported and placed in the lagoon in conditioned form, so that the lagoon will be able to accommodate about 15% more ash relative than that possible if slurrying were used. The increased ash capacity arises because conditioned PFA can be placed at a higher density than sluiced PFA. Slurrying will only be used in emergencies.

6.1.4 To achieve the desired capacity of 1.5 Mm^3 in the limited site the PFA will be built up as a landscaped mound above the level of the perimeter (Figure 6.2). The ash forming the permanent outer layer to the mound will be mixed with decomposed granite soil and organic matter and will be progressively planted with selected species. Each filling level and the completed crest of the mound will be landscaped to prevent surface erosion and enhance the visual appearance. The temporary inner slopes formed by PFA filling will be given temporary erosion protection before the next stage of mounding.

6.1.5 During all stages of the mound construction surface runoff from the stabilised inside slopes will be directed to the lagoon. The quality of the water within the lagoon will be monitored and, if necessary, regulated by controlled pumping from the draw-off tower and discharging directly to the cooling water outfall.

6.1.6 Some storm water drains presently discharge into the sea between CW Intake No. 2 and the south east corner of the station site. These cannot discharge into the ash lagoon when constructed, and will be diverted so that they discharge directly to the sea outside the lagoon, or to the front pond (Figure 6.2).

6.1.7 The filling operations will be carried out in a manner which prevents the PFA from becoming dusty, but, in addition, the easily blown lightweight particles or "floaters" will be collected and a sprinkler system will be provided to keep exposed areas moist, and dust-free.

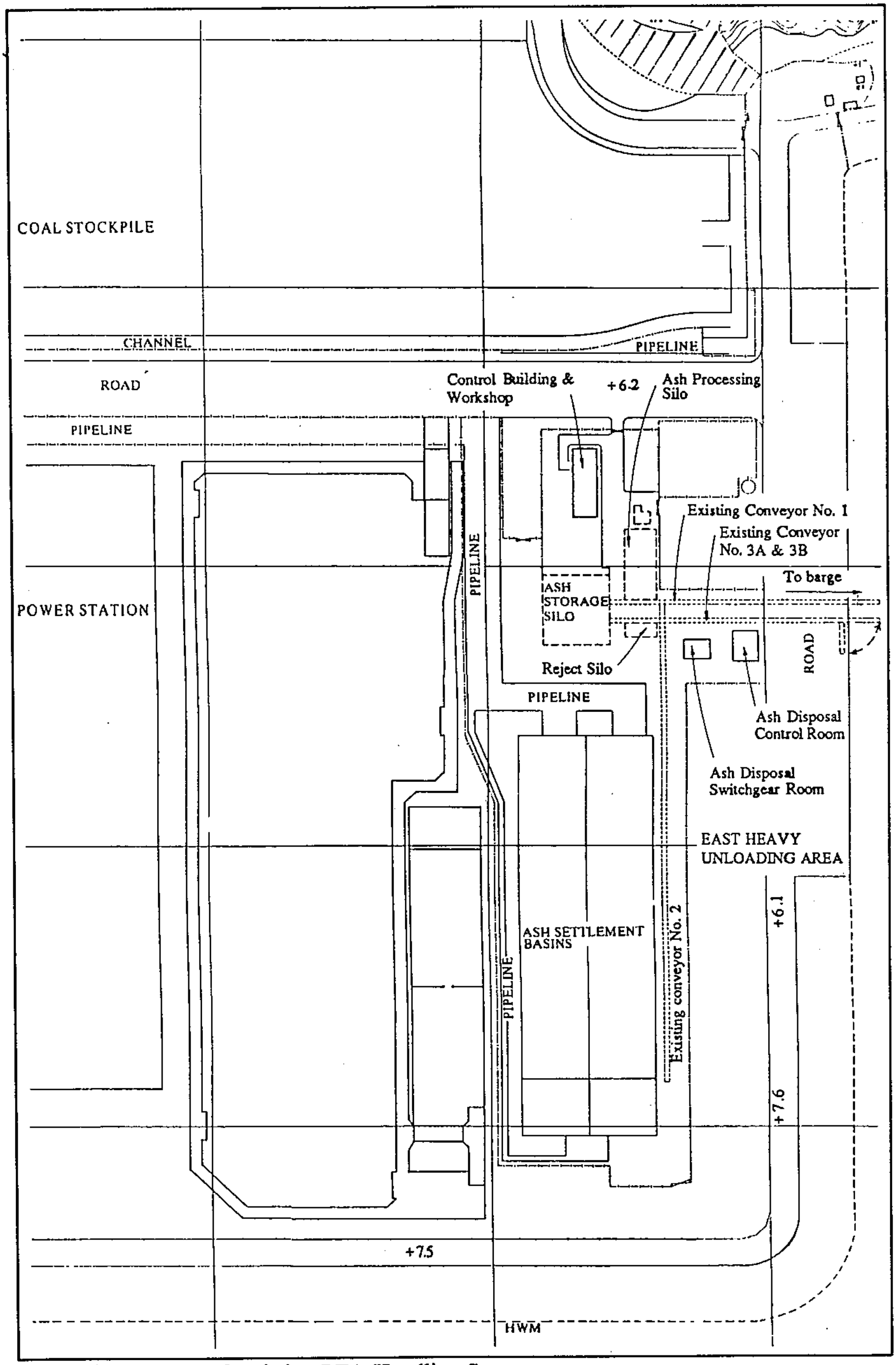


Figure 6.1 Layout of Existing PFA Handling System

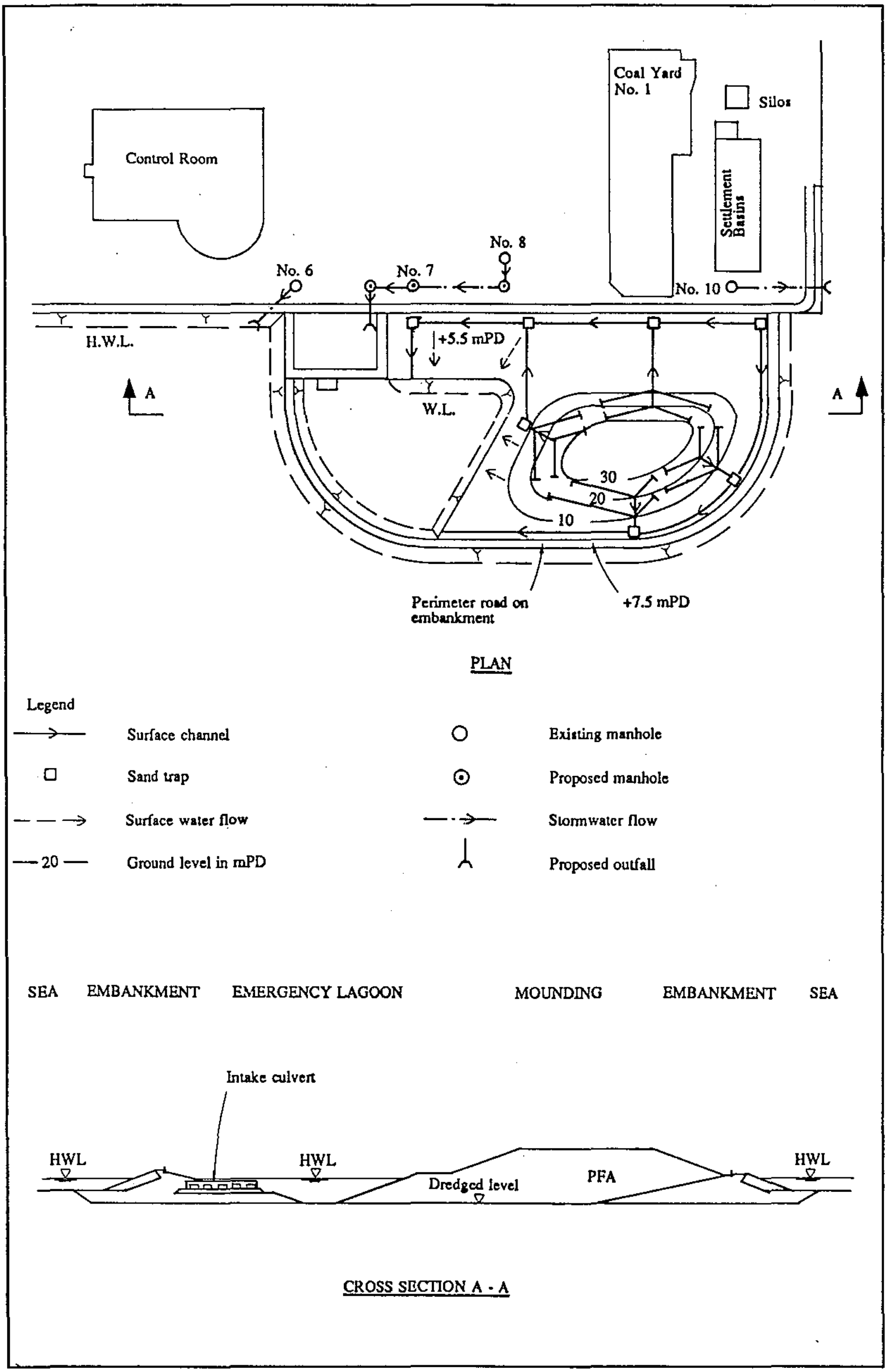


Figure 6.2 Completed Lagoon and Mound (Including Drainage Plan)

6.2 THE FILLING SYSTEM

6.2.1 Ash will be placed in the lagoon only when it is not possible to transport it off-site for industrial use or for land fill material. The lagoon filling system must therefore be compatible with the existing system, and the facility must be available for directing conditioned PFA to either system. In considering the system layout, the provision of an additional system for transporting conditioned PFA to the Lamma quarry has been included. The IAR identified conveyors as the best means of transporting the conditioned ash to the lagoon and this more detailed review has found no reason to disagree with those initial findings.

Conveyor System

6.2.2 A new conveyor system will be provided to convey conditioned PFA to any of the three destinations, the lagoon, the quarry or the existing quay. The system will make maximum use of the existing PFA handling silos and associated PFA conditioning plant (Figure 6.1), and will involve modification of the existing conveyors. Two options have been considered for the system and to provide a more secure transportation system for the quarry restoration, two lines to the quarry have been adopted when considering these options.

6.2.3 **Option 1** involves the use of chain conveyors (drag link conveyors) with multiple in-line outlets (Figures 6.3 and 6.4). The proposed layout uses drag link conveyors with multiple in-line outlets, and the following modification to the existing conveyor system would be required:

(i) Conveyor 3B to be modified to incorporate three additional outlets

(ii) A section of belt conveyor no. 1 to be replaced by a drag link conveyor with four outlets

(iii) All outlets of the new drag link conveyor will be fitted with isolating gates. These gates can be actuated pneumatically or electrically

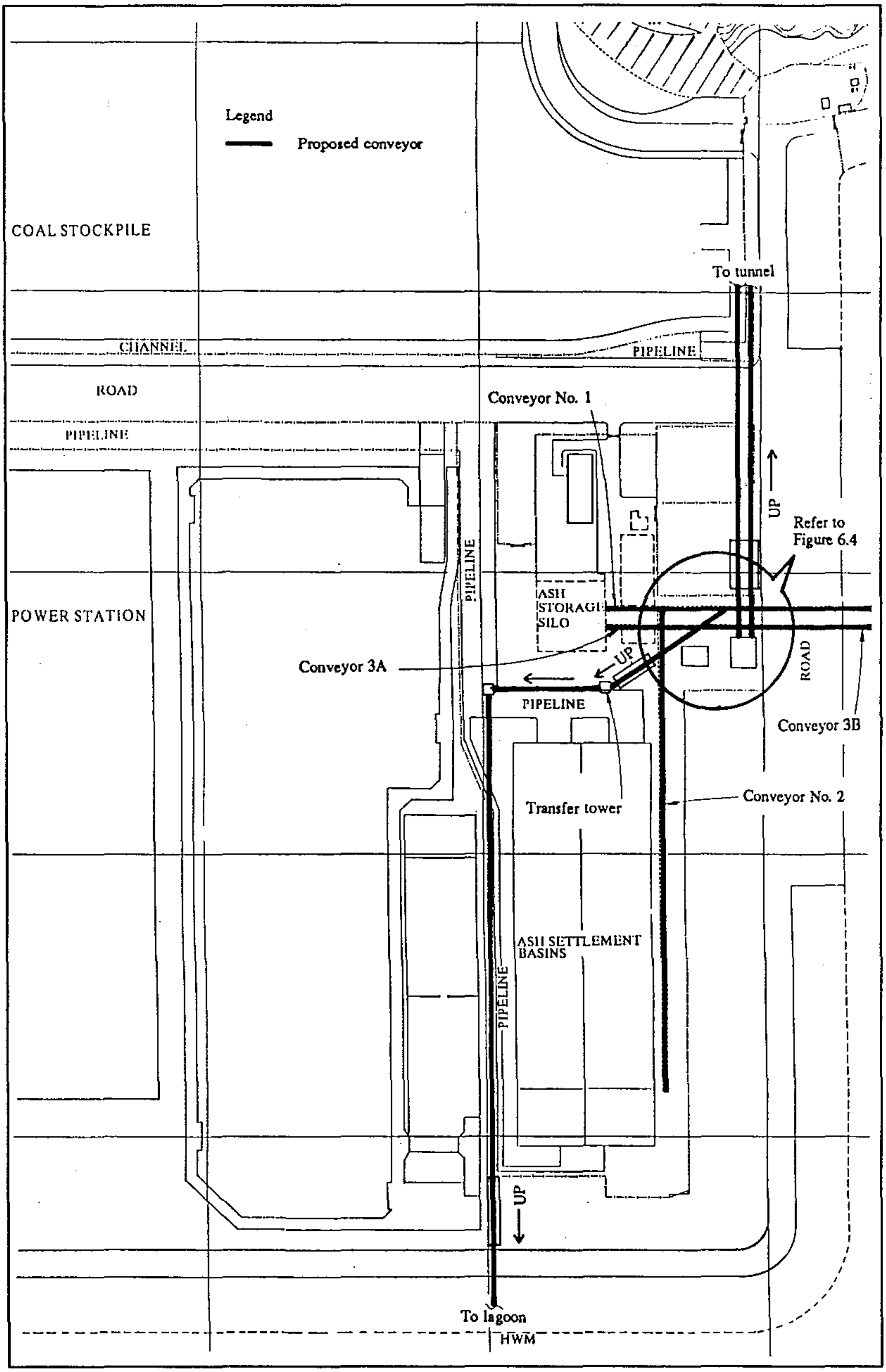


Figure 6.3 Proposed Conveyor Routes - Option 1

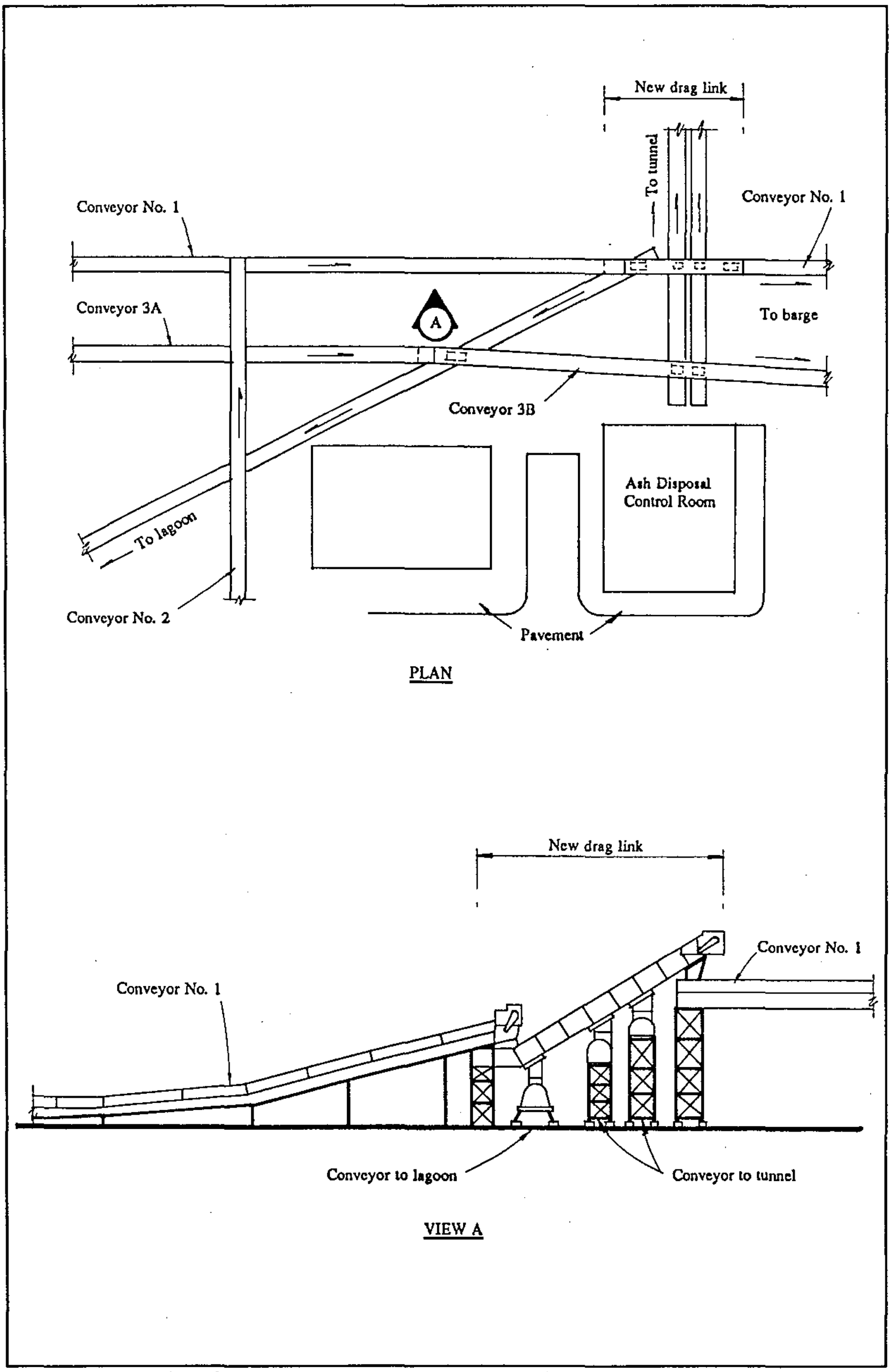


Figure 6.4 Details of Proposed Conveyor Routes - Option 1

6.2.4 **Option 2** involves the use of belt conveyors only. This is believed to be preferable, since drag link conveyors incur higher capital and maintenance costs. The only modification required to the existing system is to replace sections of conveyors no. 1 and 3A underneath the silos by 2-way belt conveyors (Figures 6.5 and 6.6).

6.2.5 Option 2 has less operational flexibility than Option 1. Ash from one silo can only be delivered to one of the tunnel conveyor systems. A similar situation exists at present between the ash silos and barge loading conveyors. We believe such limitations are acceptable, since at all times during and after conveyor modifications for Option 2, the emergency sluicing system will be available.

6.2.6 Option 2 is recommended, principally because it will allow more space for operation and maintenance. Since there are no drag link conveyors in the system, it should also be cheaper to maintain and more reliable.

Advantages of Option 2	Disadvantages over Option 1
less congested layout	longer route
more operational and maintenance space	less flexibility
lower maintenance costs	

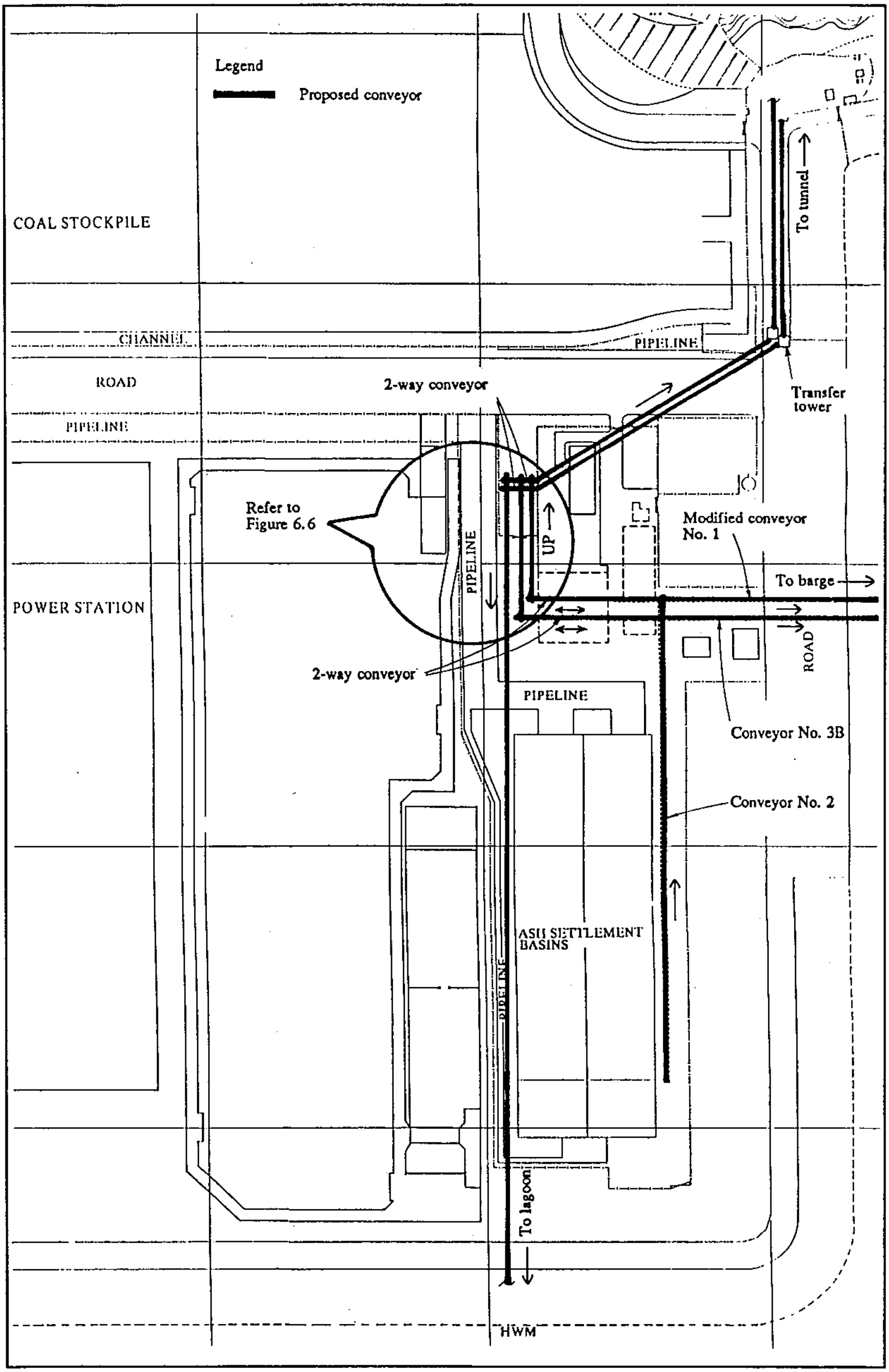


Figure 6.5 Proposed Conveyor Routes - Option 2

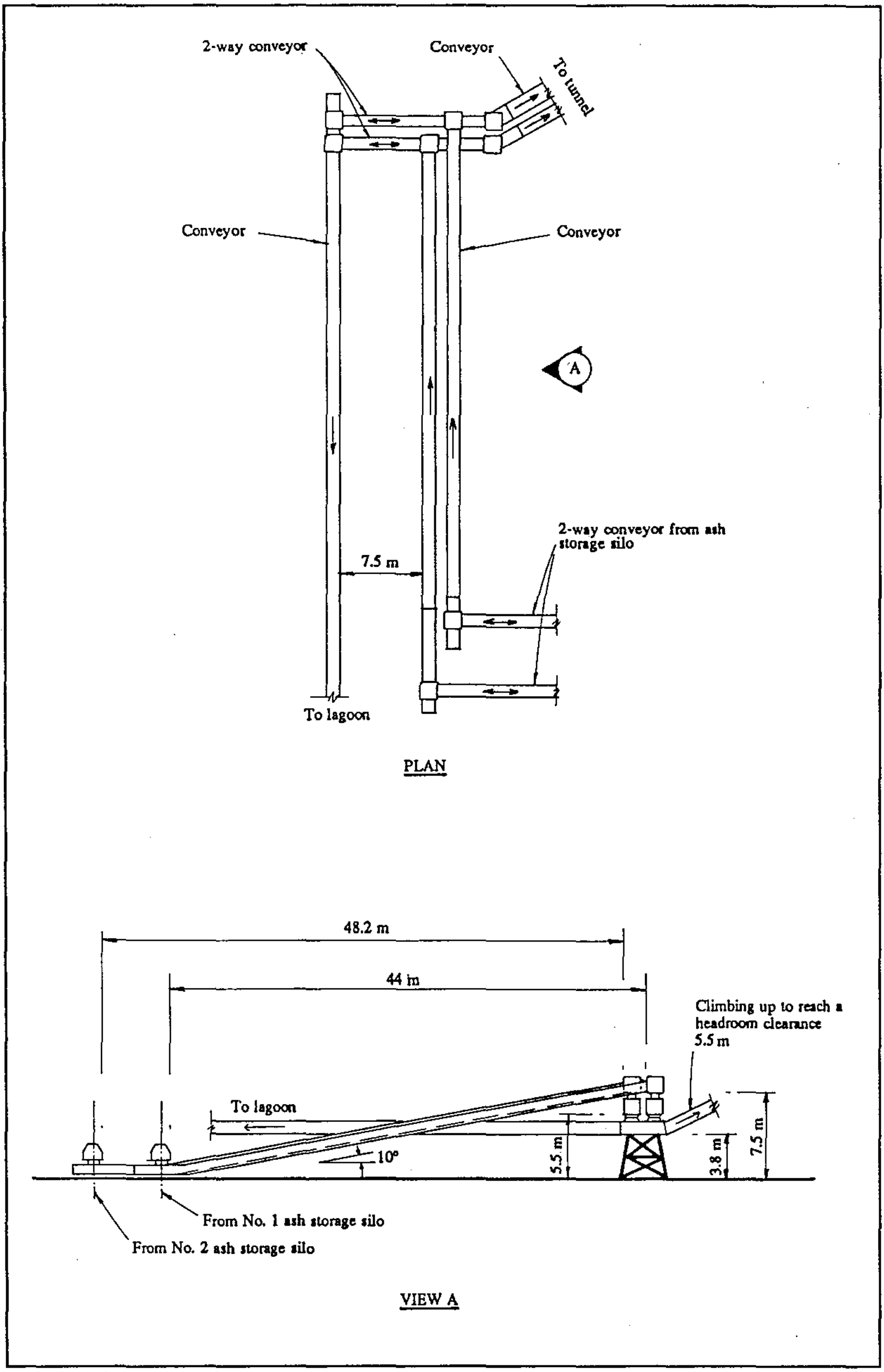


Figure 6.6 Details of Proposed Conveyor Routes - Option 2

Types of Conveyors

6.2.7 A belt conveyor, deep troughed to reduce spillage and enclosed for dust control, is recommended for transporting the PFA to the lagoon (Figure 6.7). The following factors have been considered in selecting the type of conveyor to be used:

(i) length of transportation route

(ii) power requirement

(iii) type of material to be handled (conditioned PFA and occasionally FBA)

(iv) spillage

(v) dust

(vi) maintenance cost

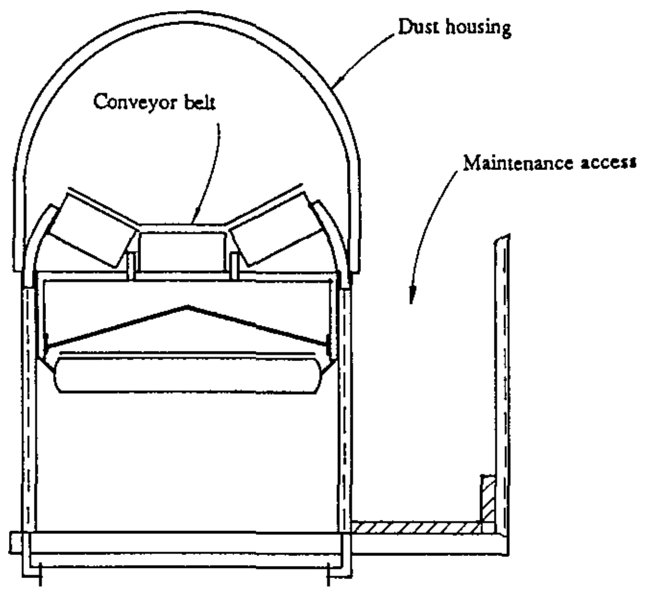


Figure 6.7 Typical Enclosed Deep Troughed Conveyor

Capacity of Conveyors

6.2.8 The existing ash conveyors C1 and C3 are each of a capacity of 220 Te/hr. The maximum capacity of the new conveyor to the lagoon which will collect PFA from both conveyor C1 and conveyor C3, would therefore be 440 Te/hr. The capacity of the dual line conveyors for transporting the PFA to the quarry would be 220 Te/hr each.

Ancillary Equipment

6.2.9 Since the new conveyor system will be installed in an outdoor coastal environment, drive assemblies will be weatherproof and materials and painting systems will be selected to suit the application. Terminals and drive machinery will be guarded to prevent accidental access from operation personnel. An important component of a belt conveyor system is the chute used to load or discharge material onto or off the belt. Chutes will be enclosed to reduce spillage and dust, and, if required, vibrators will be fitted to promote even flow.

6.2.10 Should Option 1 for the conveyor system be adopted (Section 2.6.6) the slide gates would be fitted at the outlets of the drag link conveyors to provide unrestricted flow at the openings (Figure 6.8). The gates would be pneumatically actuated. Alternatively, the gates could be driven by electric motors through threaded spindles (Figure 6.9).

6.2.11 Suitable interlocks and controls will be provided for the operation of individual components of the conveyor system. The system will be automated by the use of programmable logic controllers (PLC).

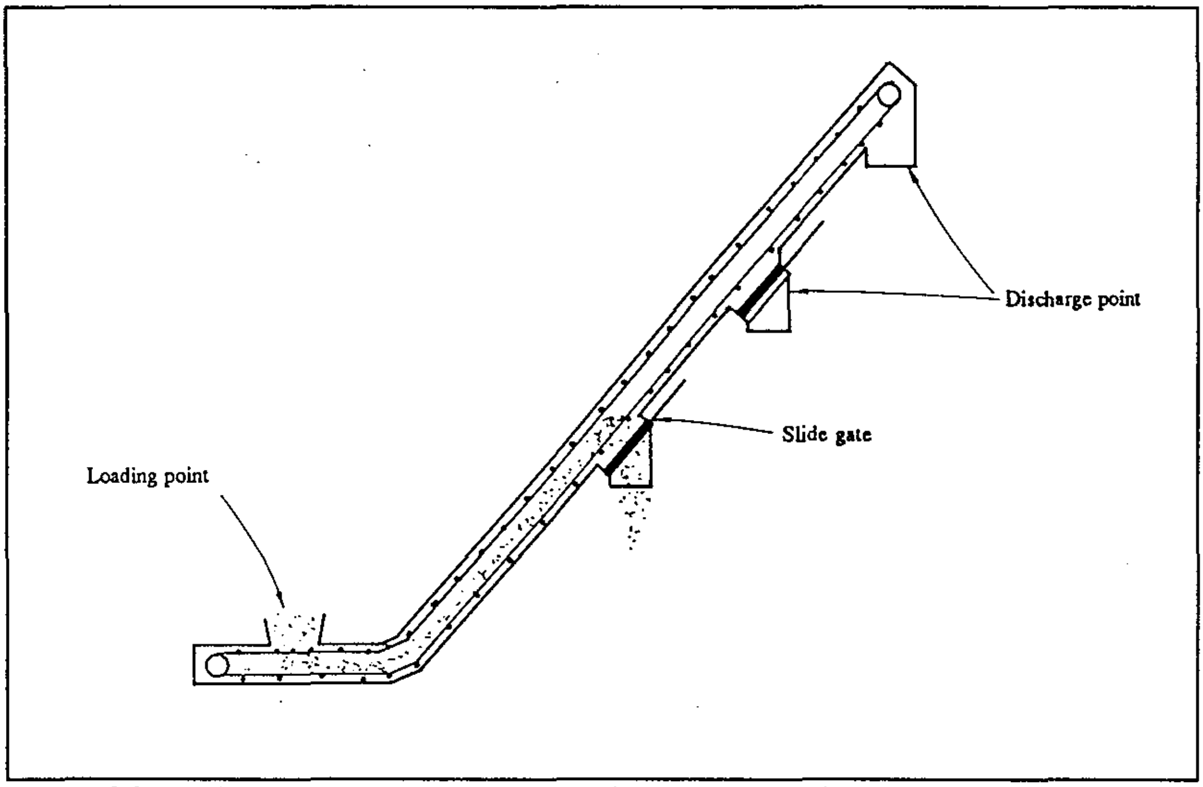


Figure 6.8 Typical Arrangement of a Drag Link Conveyor with Multiple Outlets

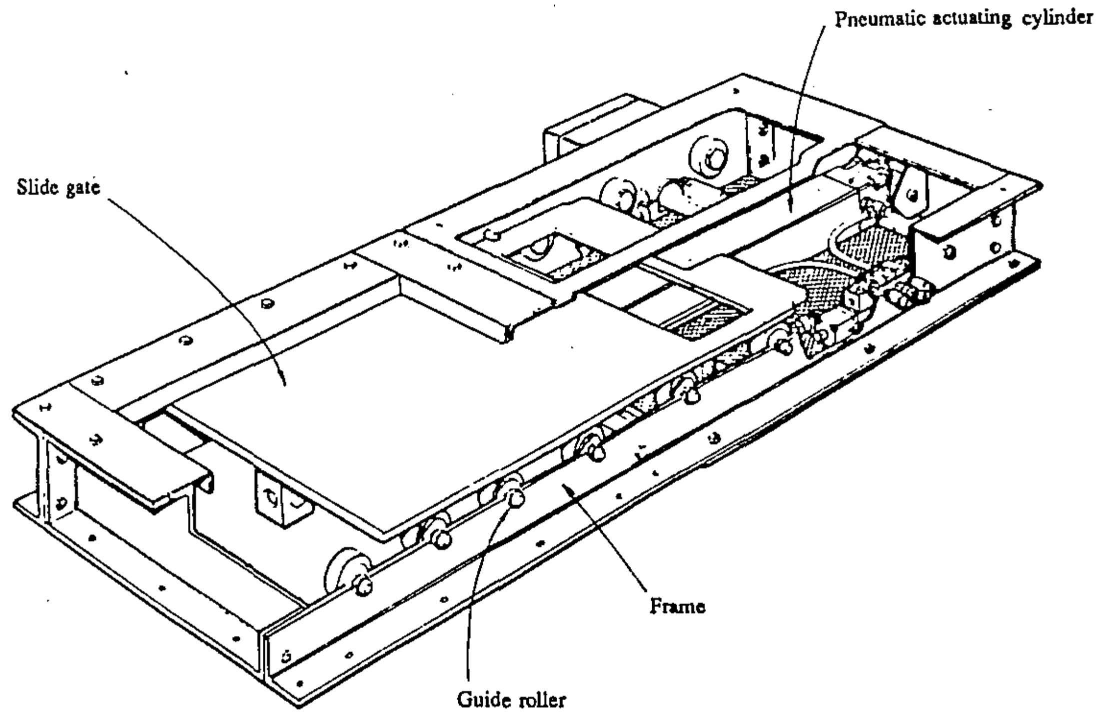


Figure 6.9 Typical Pneumatically Actuated Slide Gate

Lagoon Filling

6.2.12 The lagoon filling proposal has been formulated to derive maximum environmental benefit. The landscaped PFA mound at the eastern end of the lagoon will be formed as early as PFA supply permits. The PFA will be placed in the lagoon in a conditioned form using normal earth moving equipment to haul and compact the ash. The principal environmental benefits given by this approach are:

(i) the available lagoon space will be utilized to the best advantage by compacting the PFA wherever possible to a relatively high density

(ii) the initial mounding will provide attractive landscaped to screen subsequent filling works

6.2.13 The lagoon filling will progress in a number of stages. In **Stage 1** the PFA will be discharged directly into the lagoon from the end of the conveyor (Figure 6.10). A platform will be formed around the foot of the conveyor at about +4.0 mPD, sufficiently large to accommodate and operate working vehicles, such as lorries, a loading shovel and a bulldozer (Figure 6.11). A loading shovel will be used to load PFA from a stockpile if the conveyor cannot load the lorries directly. Stage 1 will take about 2 months to complete, assuming use of all PFA produced at the station.

6.2.14 **Stage 2.** Once the initial platform has been established the filling operation will move along the existing embankment towards the west. A 15 m wide strip of PFA be placed to about +4.0 mPD (Figure 6.11). This will substantially reduce seepage to and from the lagoon and it will provide a storage area for materials to be used in the landscaping works. The width of the platform will increase towards the north west corner of the lagoon, where it will be moulded to fill the corner of the lagoon, and prevent floaters collecting there. The filling will be carried out using a loading shovel, lorries, bulldozer and a vibrating roller. It will take about 8 months from commencement of PFA placing to complete Stage 2 of the filling operation.

6.2.15 **Stage 3.** The Stage 3 operation will be to fill the north east corner of the lagoon to +4.0 mPD. This will further reduce seepage to and from the lagoon and will also produce a working area for future mounding of PFA. Once the northern and eastern sections of the perimeter have been lined, the lining will continue around the southern section to reduce the seepage egress to the bay in the shortest viable time. It will take about 15 months, to complete Stage 3 filling from commencement of PFA placing.

6.2.16 **Stage 4.** The platform at the east end of the lagoon will be raised to +5.5 mPD and then mounded up to 15 mPD (Figure 6.12). The mound will be landscaped on the outer slope. Temporary inner slopes will be protected against erosion by a combination of measures including cement stabilisation, benching, covering in granular material, water spraying or hydroseeding. The PFA will be loaded at the conveyor into lorries by loading shovel and hauled to the mound where it will be spread and compacted by a bulldozer and vibrating roller. A granular layer, probably FBA, will be included at the base of the mound, this will collect any leachate which percolates down through the landscaped slope and will direct it to the perimeter stormwater drain for discharge into the lagoon (Figure 6.13). An irrigation system, probably comprising buried polythene pipes and sprinklers will be included with the landscaped slope. The Stage 4 works will be completed about 21 months after filling commencement.

6.2.17 **Stages 5 and 6** (Figure 6.12). As mounding continues the PFA platform will extend towards the west end of the lagoon. The PFA will be placed using a loading shovel, lorries, a bulldozer and a roller.

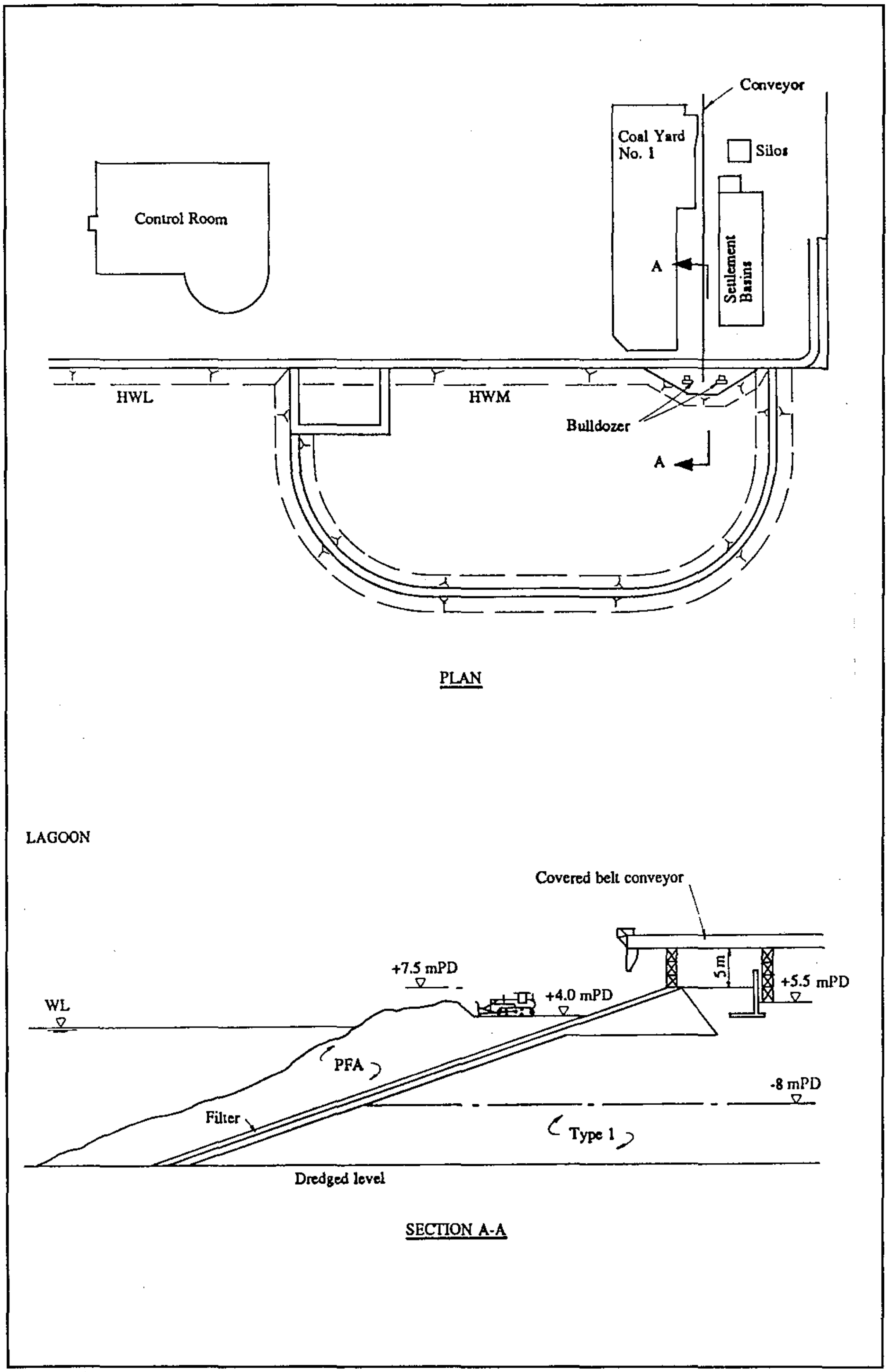


Figure 6.10 Filling Method at Lagoon

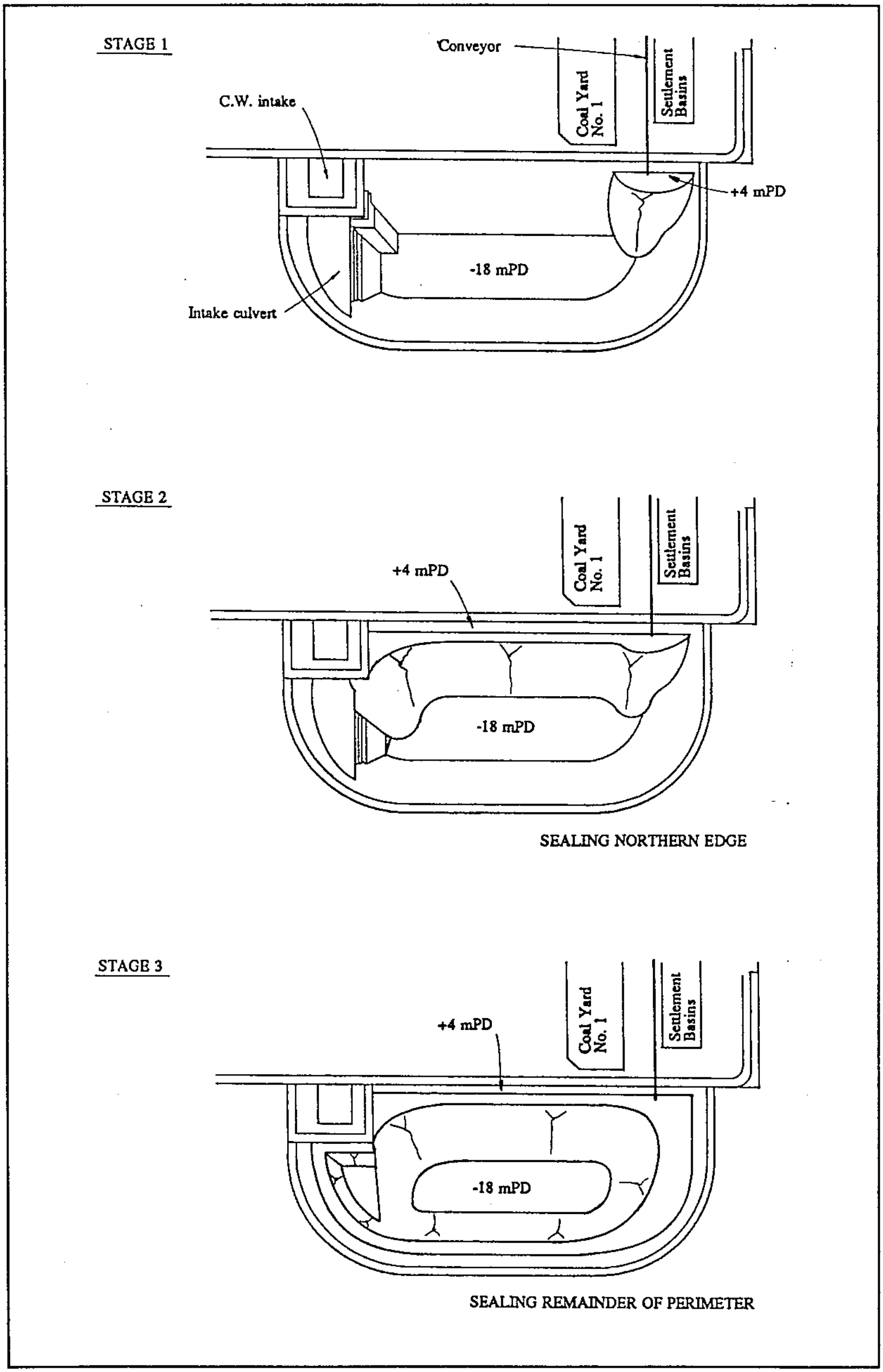


Figure 6.11 Proposed Filling Sequence - Stage 1 to 3

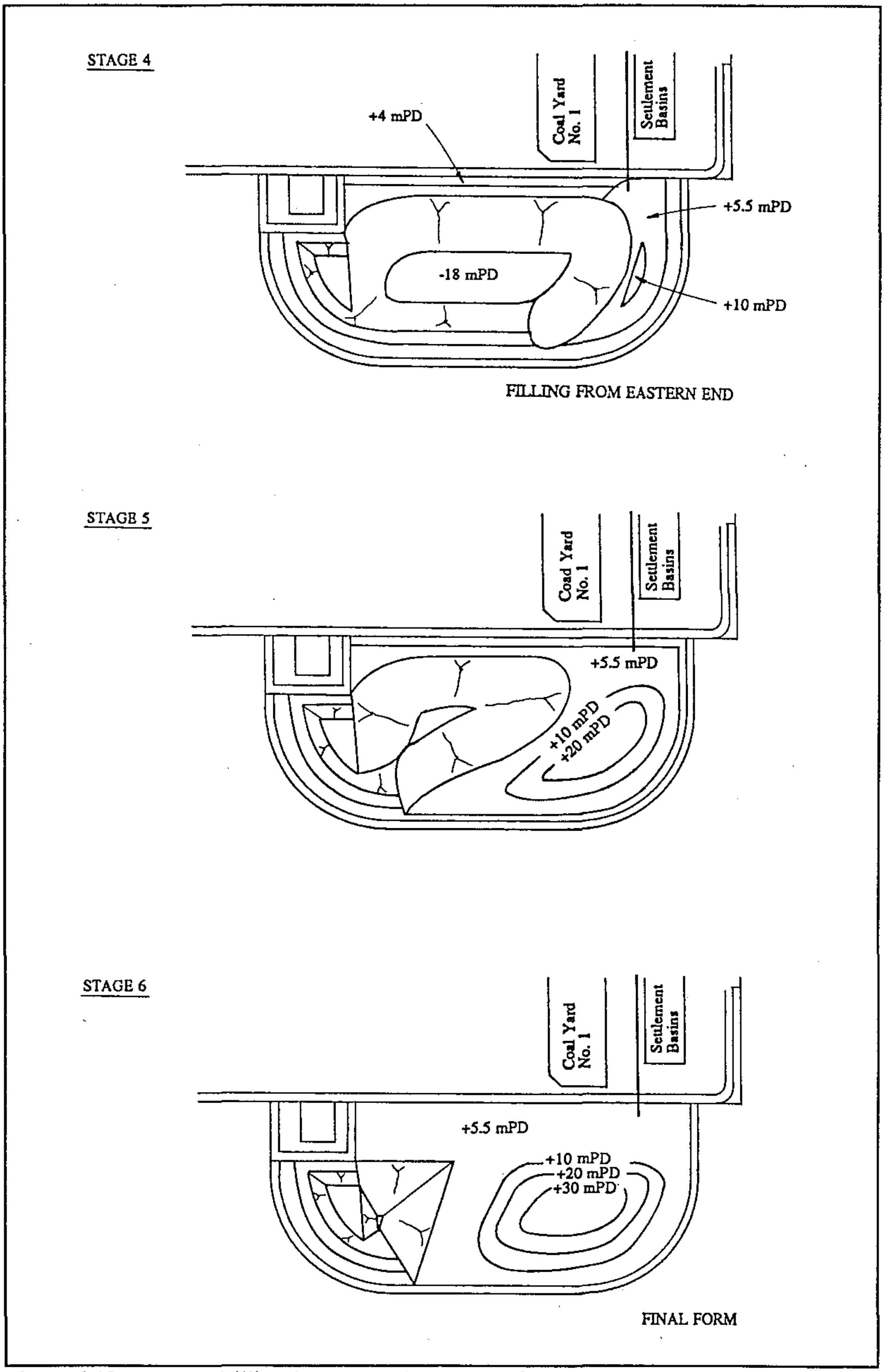


Figure 6.12 Proposed Filling Sequence - Stages 4 to 6

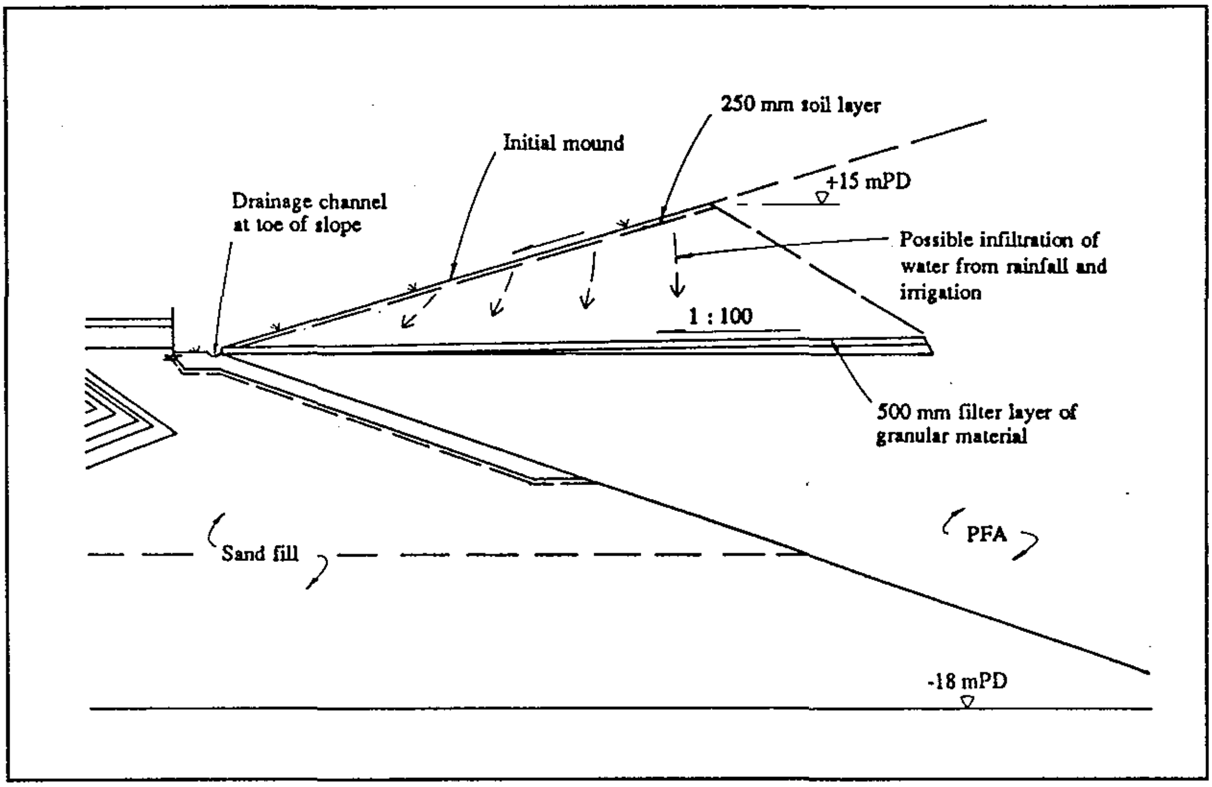


Figure 6.13 Cross Section of Mound Showing Granular Drain

6.3 LANDSCAPING

6.3.1 The outer slope of the landscaped mound will be formed at a gradient of about 1 on 2 and a system of concrete "j" channels will be provided progressively as the mound is raised, arranged in a herringbone fashion (Figure 6.2). Concurrently a 250 mm thick layer of completely decomposed granite mixed with organic material will be spread over the completed surfaces (Figure 6.14). This layer will provide the soil structure, nutrients and moisture retention potential necessary to sustain healthy vegetation on the slopes.

6.3.2 The prime objective of the planting which will follow the provision of the soil medium, is to provide an ecologically suitable ground cover similar to that which occurs on the nearby natural hillsides, but with more shrubs and small trees to provide visual variety and interest. The detailed landscape design and planting schedule will ensure that the mound will merge with the Landscaping Master Plan developed for the power station and will reinforce the fundamental lagoon design concept of providing visual harmony with the existing site.

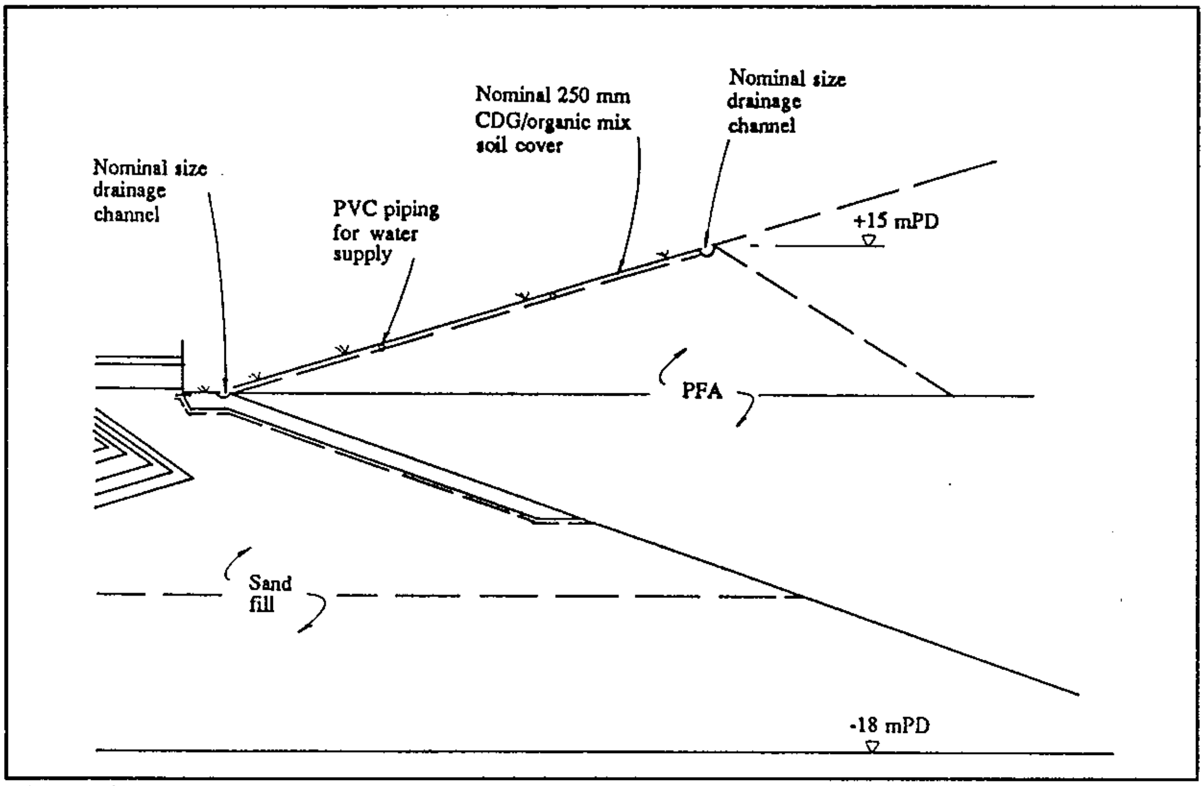


Figure 6.14 Landscaping

6.4 DECANTRATE PUMPING SYSTEM

6.4.1 All PFA particles will be retained within the lagoon by the filtering action of the perimeter but trace of metals dissolved from the PFA will be present in the lagoon water (Section 7.3).

6.4.2 The principal function of providing a pumping facility would be to transfer some of this lagoon water to the station's existing cooling water outfall. The term 'decantrate' is used to describe water pumped from the lagoon. This transfer would have two effects. Firstly the decantrate would be dispersed by the cooling water flow to the West Lamma channel away from Ha Mei Wan and secondly, the water seeping into the lagoon to replace the decantrate, redressing the balance of the water quality remaining in the lagoon.

6.4.3 Although regular monitoring of the lagoon water quality would indicate when decantrate pumping would be required, the proposals are to pump decantrate 20,000 m^3 each day throughout the life of the lagoon to maintain the water quality well within acceptable criteria (Section 7.4). However pumping is anticipated to be unnecessary until placed PFA has effectively sealed the lagoon perimeter in the later stages of the filling operation, at which time tidal exchange will be small.

6.4.4 The system can also be used to maintain a low lagoon water level (particularly during the later PFA filling stages), during heavy rainstorms and when emergency sluicing into the lagoon has been necessary. Maintenance of a low lagoon water level will facilitate lagoon filling works and will, in addition reduce the amount of seepage leaving the lagoon.

6.4.5 The decantrate pumps in the draw-off tower should have sufficient capacity to cope with all events without an unacceptable situation developing. Therefore ultimately the pumping capacity will be large enough to handle the maximum daily rainfall which may be collected by the lagoon and also the maximum emergency ash sluicing flows.

6.4.6 The maximum recorded daily rainfall is 534 mm. Assuming the lagoon perimeter is totally impermeable, this represents a volume of 54,000 m^3/day to be pumped from the lagoon. The maximum emergency ash sluicing flow into the lagoon is 46,000 m^3/day.

6.4.7 The provision for 6 pumps in the draw-off tower is recommended, each pump with a capacity of 700 m^3/hr. Practical experience will be needed to determine the rate of pumping necessary to maintain the quality of the lagoon water. However, this is unlikely to exceed the installed pumping capacity of 4,200 m^3/hour. (This is more than 7 times the maximum rate of seepage into the lagoon that is likely after initial PFA placing.) Initially half of this capacity would be provided, pending practical experience of the lagoon operation.

Draw-off Tower

6.4.8 A draw-off tower with intakes at different levels will be provided so that water can be abstracted selectively from different parts of the water column. Also floating PFA particles (floaters) drawn to the tower will be collected by a floater collection system housed within the draw-off tower (Section 6.5).

6.4.9 The proposed location of the draw-off tower is at the western end of the Lagoon, adjacent to the front pond (Figure 6.15). The wet well of the draw-off tower consists of two compartments, each with intakes at three different levels and fitted with electrically actuated penstocks (Figures 6.16 and 6.17). Each of the compartments can be isolated for cleaning and maintenance, while the other one is in service.

6.4.10 The superstructure of the draw-off tower will consist of the pipe floor and the main entrance floor. The switchboard for the power supply and control of the pumps and the floater micro-screen (Section 6.5) will be housed on the main entrance floor. An overhead crane will also be provided in the superstructure to facilitate installation and maintenance.

Pumps

6.4.11 The wet well suspended bowl mixed-flow pump is recommended for this pumping application. The following factors have been considered in selecting the type of pump:

(i) Pump duties

(ii) Type of fluid to be pumped (decantrate will be relatively free from debris and fibrous matter)

(iii) Operation and maintenance requirements

(iv) Construction cost

Delivery Pipework

6.4.12 The main delivery pipe from the lagoon draw-off tower could be merged with the existing delivery main from the settlement basin effluent discharge pumps for discharge to the cooling water outfall, which would provide some pipework saving. However, the existing delivery main from the ash settlement basin is fully utilised, consequently the decantrate from the lagoon will be pumped to the station cooling water outlets via a new main.

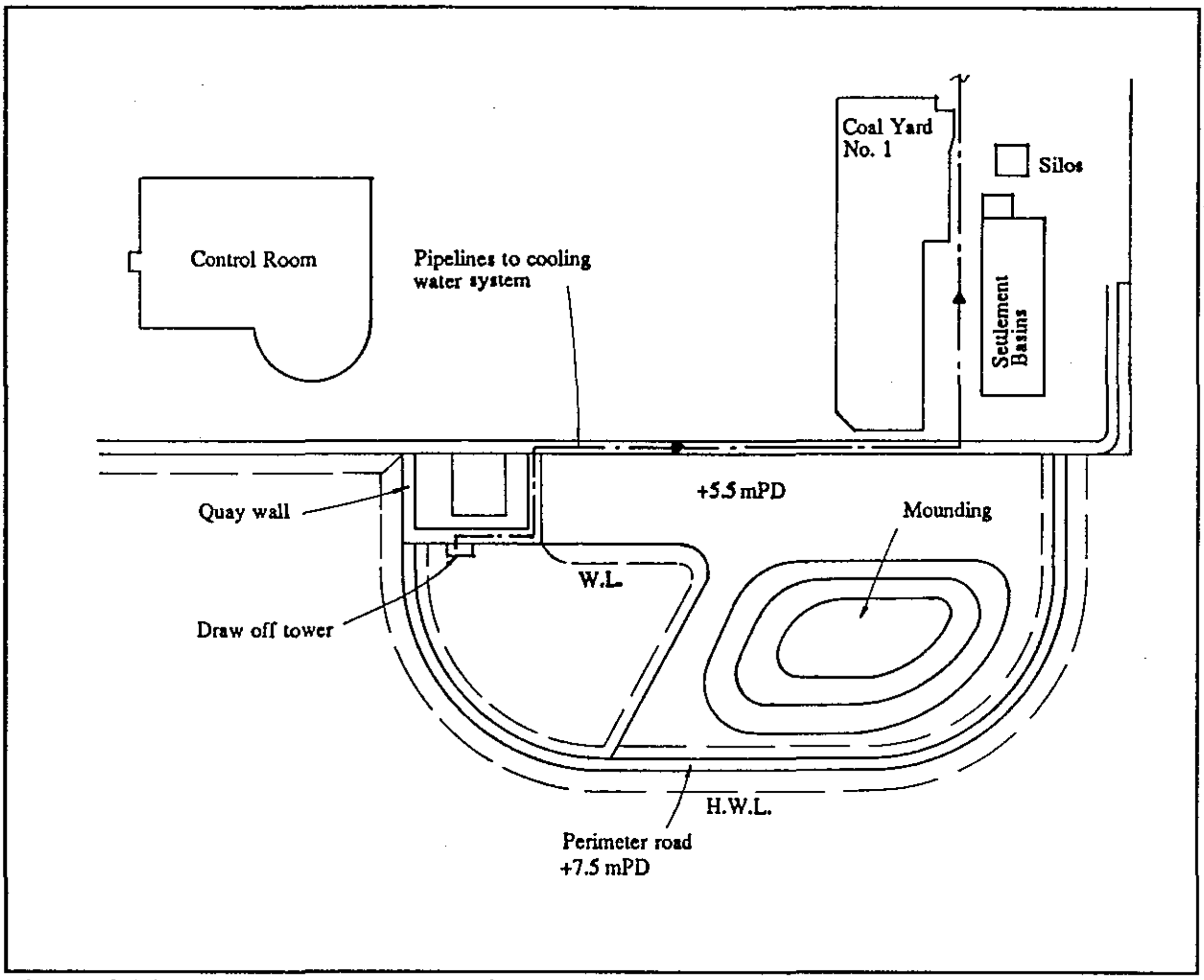


Figure 6.15 Draw Off Tower Location

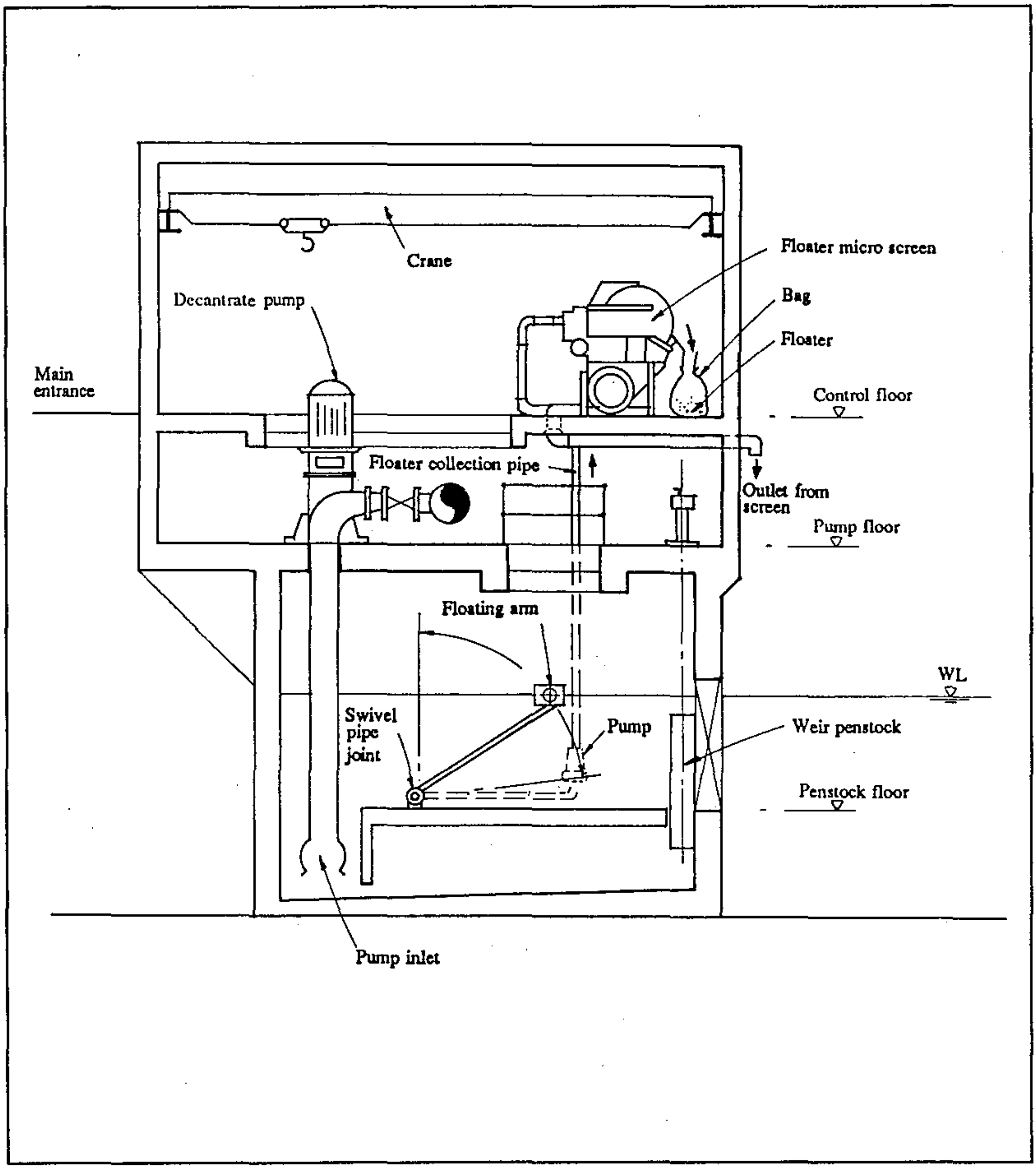


Figure 6.16 Cross Section of Draw Off Tower

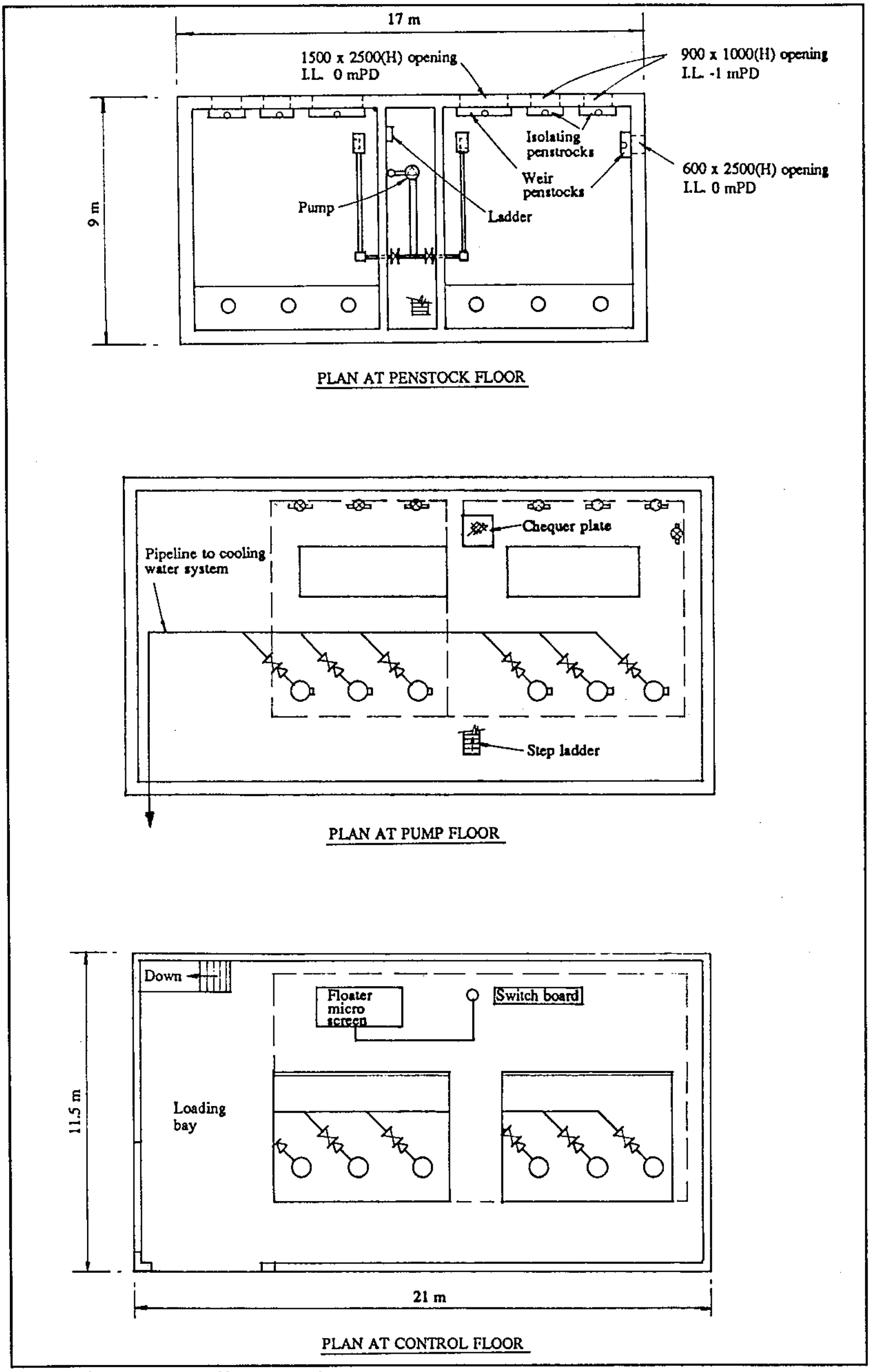


Figure 6.17 Draw Off Tower Plans

6.5 FLOATER COLLECTION SYSTEM

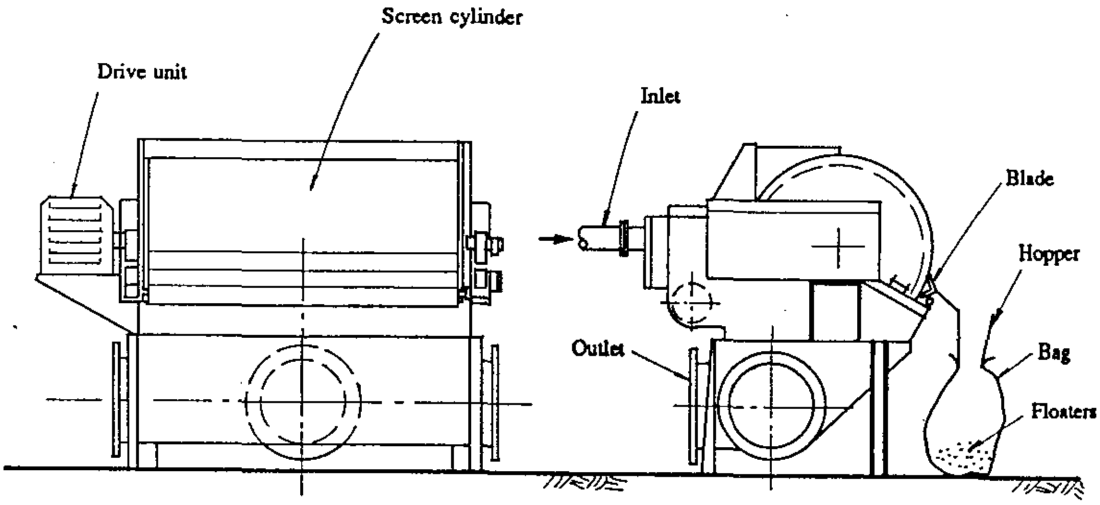
6.5.1 Overseas experience has shown that hollow PFA particles which float on the water surface can build up into rafts, dry out then become dusty. These particles, known as 'floaters', usually represent less than 1% of the PFA. Where the PFA is deposited into water the floaters will separate and float to the surface. To prevent an accumulation of floaters on the lagoon surface and perhaps the development of a dust nuisance, a collection system is proposed.

6.5.2 Floaters will be blown across the lagoon surface by the wind and as the prevailing wind direction is from the east, the collection system will be at the west edge of the lagoon where the particles will usually accumulate. The proposed floater collection system located in the draw-off tower where the decantrate pumps are housed so that the operation of the pumps will introduce currents in the lagoon in addition to wind to attract the floaters to the collection system. Should the effects of wind and current not be strong enough to move floaters to the draw-off tower, a contingency measure may be necessary. For this we recommend a boat equipped with a floating boom which would be used to push floaters to the collection point.

6.5.3 The floater collection system in the draw-off tower will comprise three elements; a floating arm (Figure 6.16), a pump and a micro screen (Figure 6.18). The floating arm is designed to draw-off of floaters continuously from the water surface with the water level inside the lagoon varying between 0 mPD to 2.5 mPD. It consists of a float, a collection pipe and a swivel bend.

6.5.4 The inlet to the collection pipe will always be kept at the water surface by the float and the swivel action of the bend. The collection pipe and the bend will lead to a pump (Figure 6.16). Weir penstocks, adjustable between 0 mPD and 2.5 mPD in the wall of the draw-off tower will ensure that the surface water can be skimmed to collect floaters effectively when the submersible pump is activated. The floaters will then be delivered to the micro-screen by the pump which will have a vortex impeller or a single-channel open impeller to minimise the breaking up of small rafts of floaters and thereby facilitate screening.

6.5.5 A micro-screen (Figure 6.18) will be installed in the draw-off tower to screen the floaters. The common commercially available micro-screens provide screening down to 0.25 mm. This size should be adequate for the purpose, but trials will be needed to confirm this. Mesh size down to 0.10 mm is available, if required, although this requires a specially designed screen. The effluent from the micro-screen will be piped back to the lagoon and floaters collected from the micro-screen will be bagged by machine for sale or disposal.



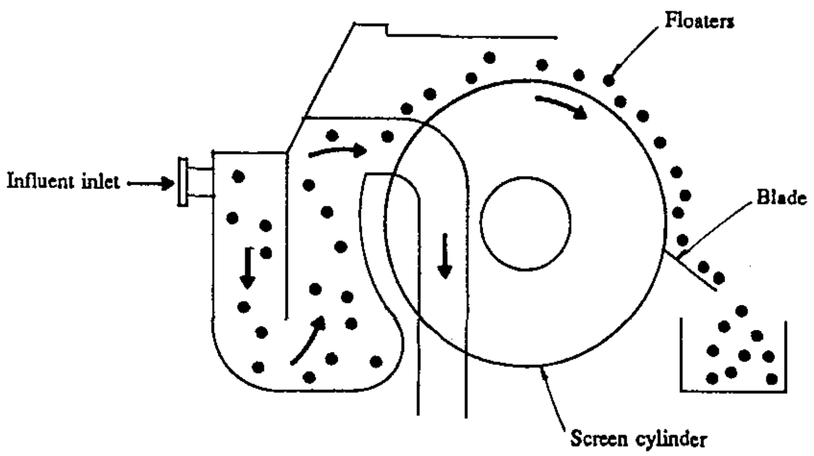


Figure 6.18 Floater Screening

6.6 EMERGENCY SLUICING SYSTEM

6.6.1 The existing ash handling system incorporates an emergency PFA handling system, which collects PFA from individual ash hoppers using exhausters. From these exhausters, PFA is conveyed to the settlement basins in a slurry form.

6.6.2 Options have been considered for extending the existing emergency PFA handling system so that it will be suitable for PFA emergency sluicing to the ash lagoon. There are three options, the first is a direct connection to extend the existing delivery system and the other two include additional pumping capacity at the ash settlement basins to provide further energy to discharge the PFA to the lagoon. However, the option selected will primarily depend on the capacity of the existing system to convey slurry the longer distance to the lagoon. The first option is preferred because it requires minimum modification to the existing facilities in the confined area of the ash settlement basins. However should this not be possible option 2 is recommended as the alternative.

Option 1 Pipeline Extension

6.6.3 The connection of a pipeline extension (Figure 6.19) to the existing pipeline would require the minimum space of all the options for the transfer of PFA to the lagoon. However the additional length of pipe would put further load on to the pumping facility, an additional capacity which is not as yet proven. Any additional available capacity is likely to be limited thus the pipeline would probably discharge to the lagoon at the closest point i.e. at the end of separation road.

Option 2 In-Line Booster

6.6.4 Option 2 is an in-line booster arrangement (Figure 6.20). Additional controls will have to be incorporated to link the new equipment with the existing system. The in-line booster pumps will probably have variable speed drives so that the flow handled by the pumps can match closely with that of the exhausters.

Option 3 Intermediate Pumping

6.6.5 Option 3 is an intermediate pumping arrangement installed in a new pump pit, to which the existing PFA slurry pipeline will discharge (Figures 6.21 and 6.22). The existing ash settlement basin would be modified to incorporate the new pump pit and the original FBA slurry discharge pipelines rerouted at the settlement basin. Three pumps are proposed to provide operational flexibility (Figure 6.22). This option requires minimal control coordination between the existing and the new pumping system. However, it is important that the new pump pit be flushed after every operation to ensure that no PFA remains in it.

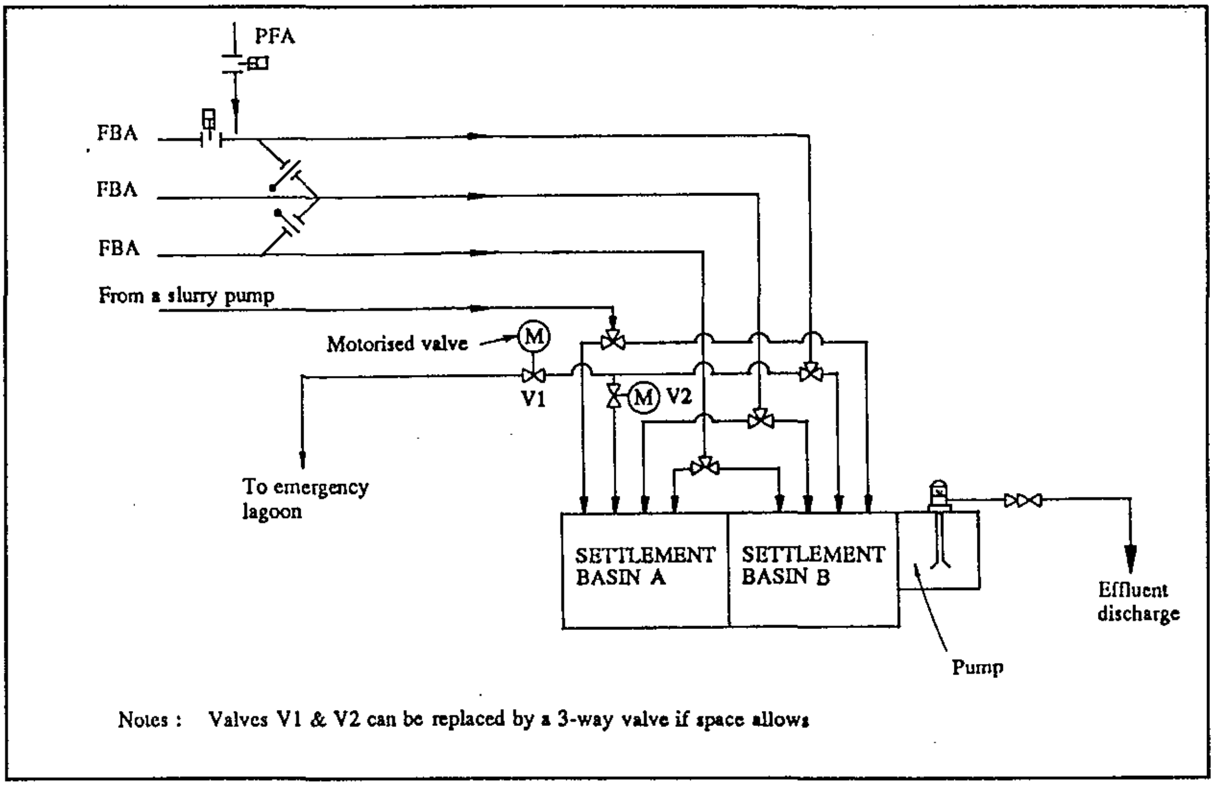


Figure 6.19 Emergency Sluicing System - Option 1 Pipeline Extension

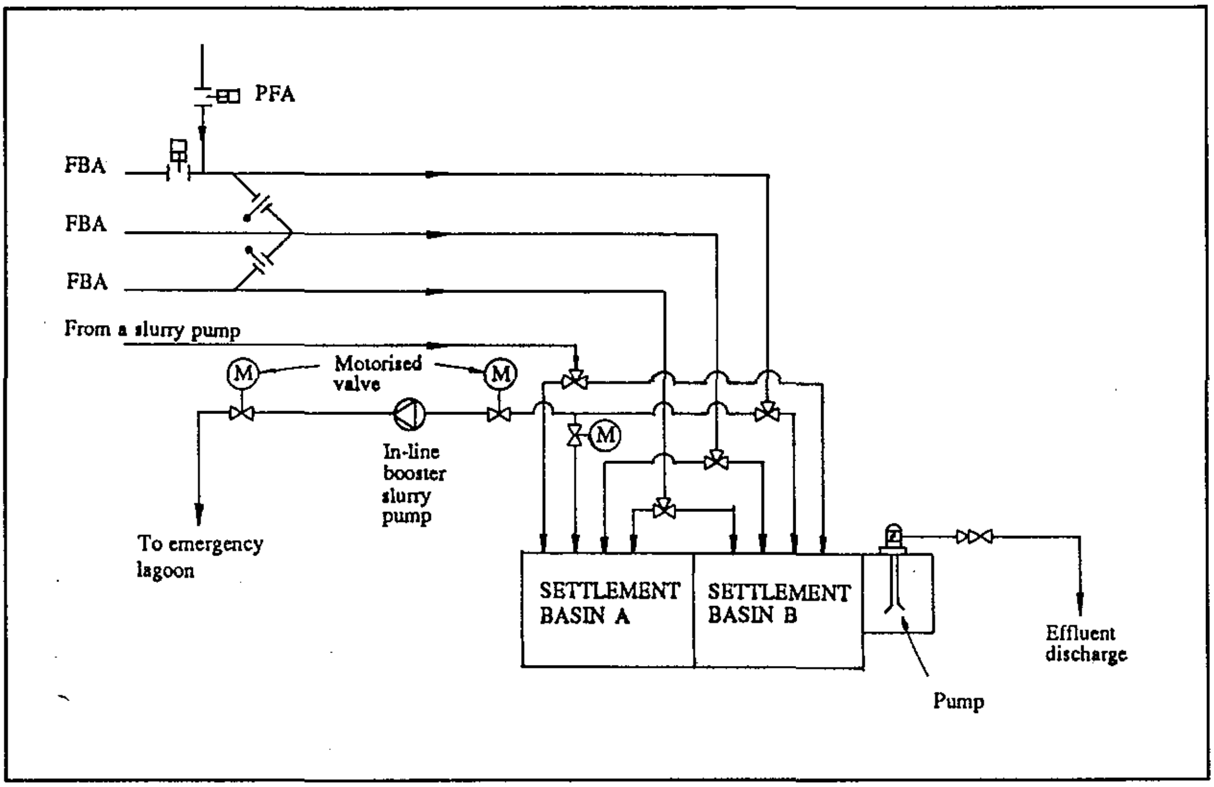


Figure 6.20 Emergency Sluicing System - Option 2 In-Line Booster

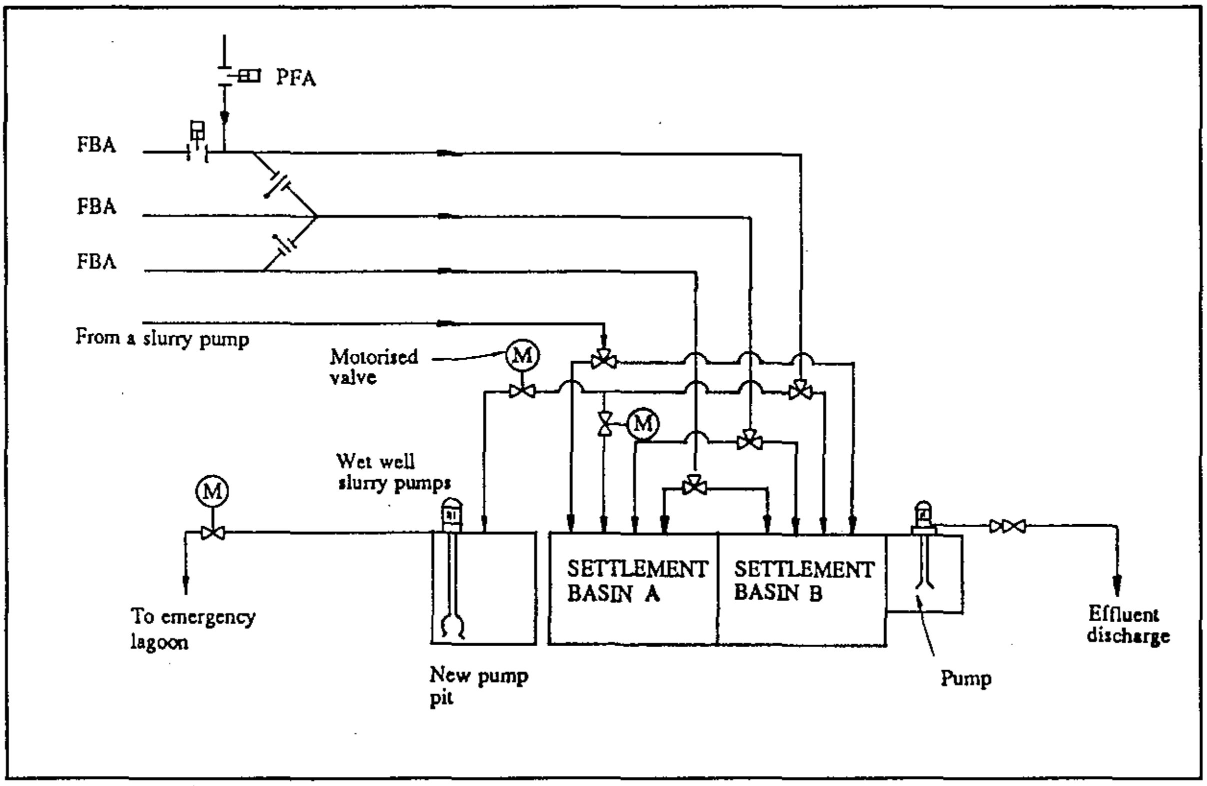


Figure 6.21 Emergency Sluicing System - Option 3 Intermediate Pumping

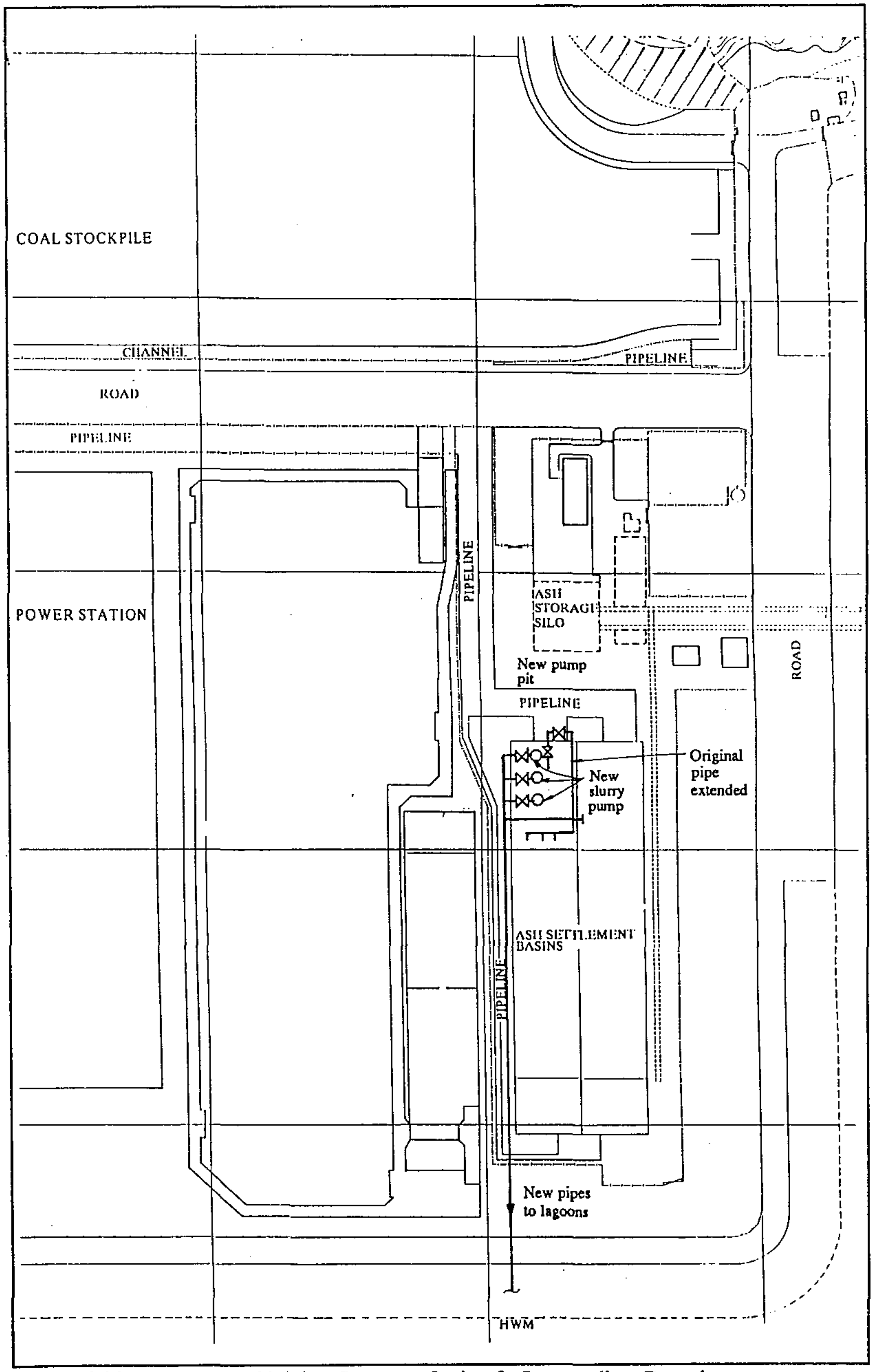


Figure 6.22 Emergency Sluicing System - Option 3 Intermediate Pumping

6.7 HARVESTING SYSTEM

6.7.1 If there is sufficient demand for PFA from industrial or landfilling operations, the excavation or 'harvesting' of material previously placed in the lagoon may prove viable. Harvesting of PFA from the lagoon could recover material from both below and above the water level.

6.7.2 PFA below water level would be removed by a crawler crane with a clam-shell grab (Figure 6.23). The PFA would be stock piled to reduce the moisture content to that of a moist, conditioned PFA before transportation by lorries to the station's barge loading area. PFA above water level would be excavated by backhoes and would be loaded directly into lorries for delivery to the barge loading quay (Figure 6.23).

6.7.3 A wheel washing system will be installed at the vehicle entrance to the lagoon. This will prevent PFA being dropped on the power station roads by vehicles leaving the lagoon site.

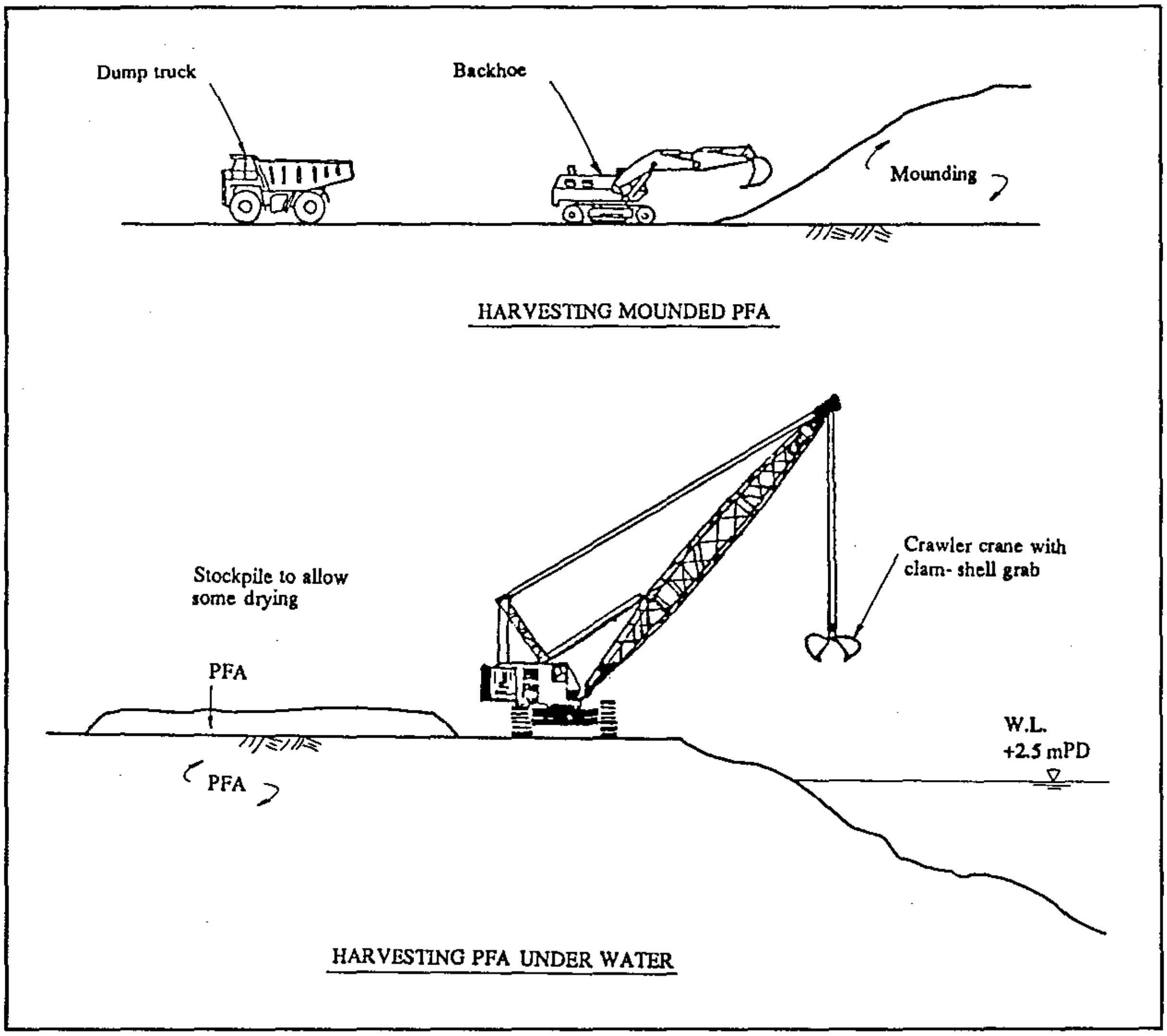


Figure 6.23 PFA Harvesting System

6.8 DUST SUPPRESSION SYSTEM

6.8.1 A dust suppression system will be provided to ensure there is no dust problem. A simple seawater spraying system will be provided to sprinkle any potential problem areas. The system will consist of a submersible pump and a delivery main with outlets for incorporating fixed sprinklers or hose reels (Figure 6.24). The water spraying system will be designed so that it can be dismantled easily and relocated to a new works area to follow phases of PFA filling or harvesting. Areas which have been landscaped and vegetated will be irrigated with fresh water. A possible source of supply is the coal yard storm water catchment pit.

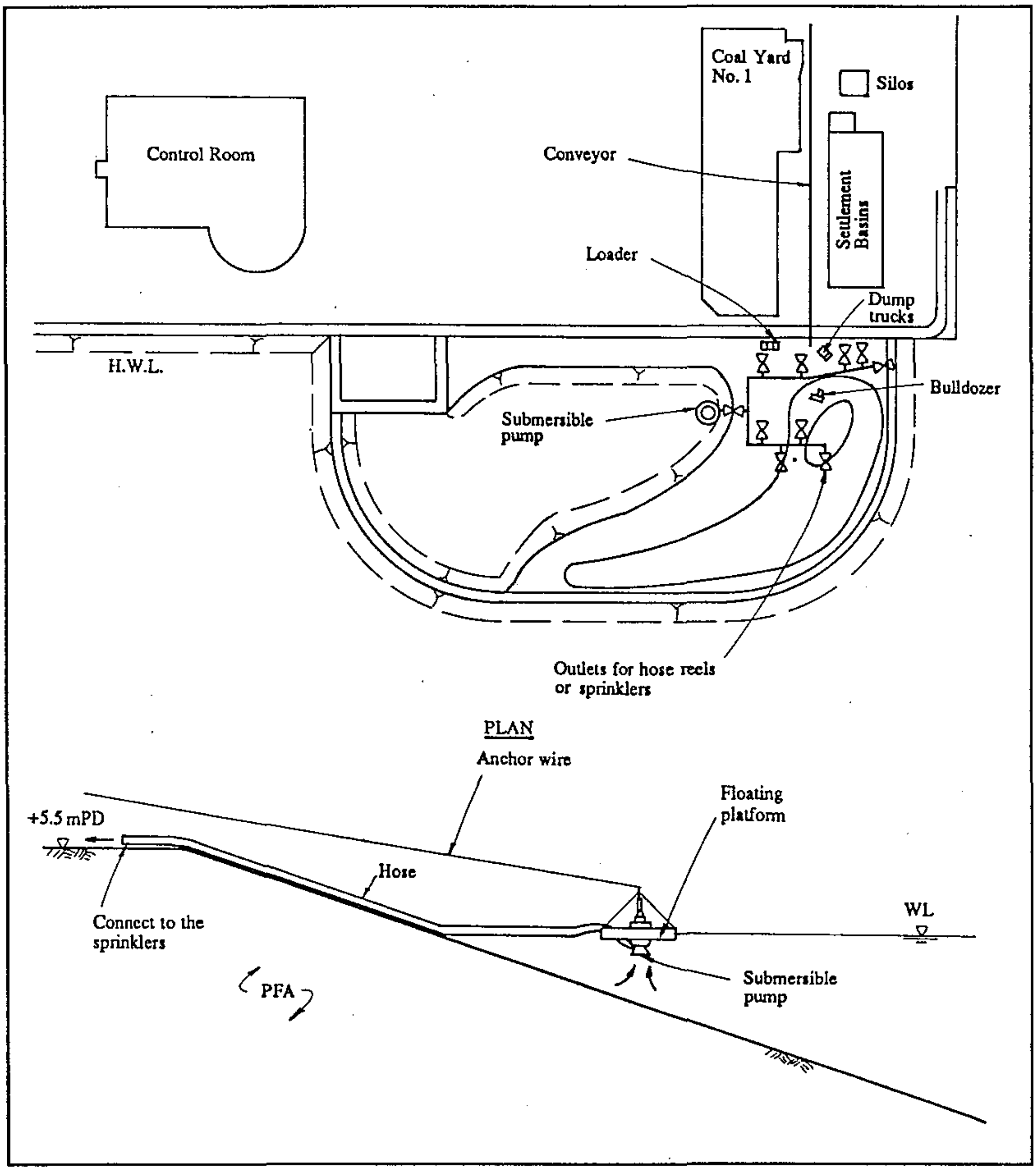


Figure 6.24 Typical Sprinkler System for Dust Suppression

6.9 IMPLEMENTATION

6.9.1 The construction of the conveyor system for PFA filling at the lagoon and the emergency sluicing system will require some modification of the existing installations at the power station. Other systems, namely systems for the decantrate pumping, floater collection, harvesting and dust suppression are independent of the existing installations.

6.9.2 Construction of the new conveyor system requires partial shutdown of the existing PFA transportation system to the ash barges. However, the programme will be scheduled to ensure that the emergency sluicing system to the ash lagoon is available before the existing conveyor system is shut down.

6.9.3 With the emergency sluicing system, the modification work required on the existing systems is to provide tee-off branches from the existing pipework. This will require only partial shutdown as each system has two delivery pipes. Modifications can be carried out on one pipe at one time. It is expected that the work could be completed in a few days and would not require further shutdown of the existing systems when the new systems are installed and commissioned. The emergency sluicing system will be completed and commissioned before the existing ash conveyors are modified. This can only take place after the lagoon embankment is completed.

6.9.4 The ash lagoon decantrate pumping system will be completely new and will not require any alterations to the existing ash settlement basin system.

6.9.5 The estimated works programme for the lagoon operating systems, (Figure 6.25) takes into consideration the timing of relevant lagoon construction activities, such as lagoon embankment completion.

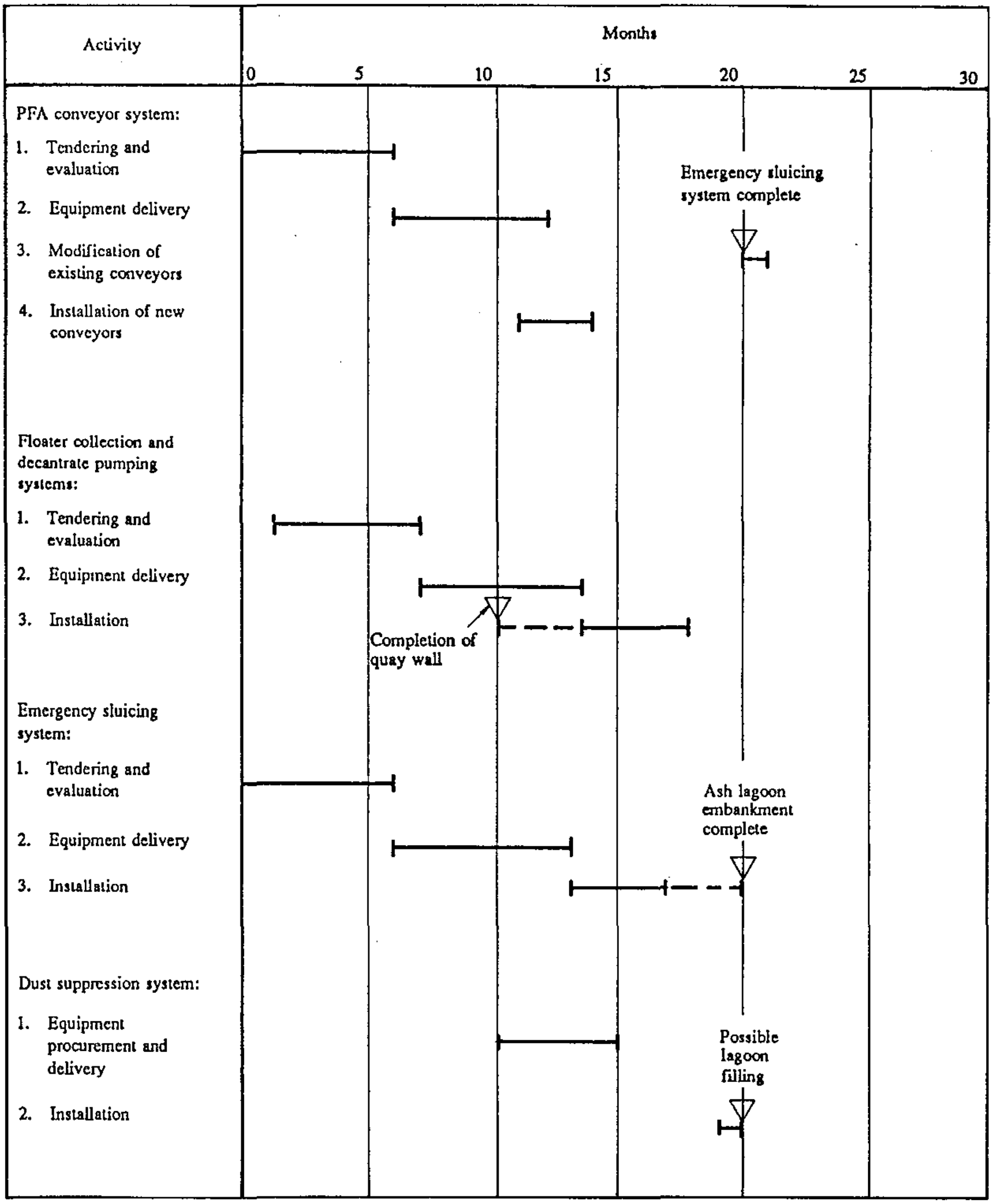


Figure 6.25 Proposed Works Programme for Lagoon Operating Systems

6.10 COST ESTIMATE

6.10.1 The cost estimate for establishing the six key systems required for the lagoon operation is as follows:

	Description		Estimates (HK$M) (1990)
(i)	Filling system		
	(a)	conveyors	18.0
	(b)	lagoon filling	25.0
(ii)	Decantrate pumping system		
	(a)	pumping plant	7.0
	(b)	draw-off tower	5.0
(iii)	Floater collection system		1.0
(iv)	Emergency sluicing system		3.0
(v)	Harvesting system		included in (i)(b)
(vi)	Dust suppression system		0.5
	TOTAL		59.5

This estimate excludes running costs.

6.11 CONCLUSIONS

6.11.1 Throughout the preparation of these proposals for the lagoon operating systems relevant environmental issues have been addressed. Thus the proposals represent a practical operating system, reducing the environmental impact to a minimum and fall within acceptable levels. Detailed discussion of environmental impacts are given in Chapter 7 and the criteria for their acceptance are discussed in Chapter 8.

CHAPTER 7

LAGOON OPERATING EFFECTS

7.1 INTRODUCTION

7.1.1 At the time of the IAR, the lagoon and its operating procedures had not be sufficiently well defined to permit a detailed assessment of the effects of the operations involved. Subsequent studies have resolved these issues (Chapters 3 and 6) and the operation can be discussed in greater detail. The activities will include the placing and harvesting of the PFA, water quality control in the lagoon, and other measures relating to the reduction of specific environmental impacts. Despite the implementation of these measures some residual impacts will remain irrespective of the mitigation measures adopted. These are discussed in detail where necessary to demonstrate that they fall within acceptable criteria.

7.1.2 Lagoon operation will involve a number of activities and their duration will depend on the rate of PFA supply. The supply will vary according to industrial demand and the requirements for quarry restoration, either can vary during the life of the lagoon and are unpredictable at this time. However the duration of active PFA filling is envisaged to be between 6 to 8 years. The activities envisaged during the lagoon operation are:

(i) PFA filling

(ii) floater collection

(iii) decantrate pumping

(iv) emergency sluicing

(v) harvesting

(vi) dust suppression

(vii) landscaping

7.1.3 Despite the unknown factors various conservative assumptions have been made to derive the "worst case" estimations of water quality both within the lagoon and outside. The main assumption is that the PFA will be placed at a constant high rate of 700 m^3/day in order to fill the lagoon within the minimum 6 year life of the lagoon. Also the leaching of the various determinands is assumed to be complete and wholly dispersed by seepage or through the decantrate system. In practice the determinands will be dispersed by both means, thus the estimates of water quality for both that of seepage dispersion in the Ha Mei Wan bay and through the cooling water outfall are both highly conservative. The discussions on water quality relate to the determinands specified in the Technical Memorandum on Effluent Standards 1991 (TM).

7.2 SEEPAGE AND DISPERSION IN HA MEI WAN

7.2.1 The IAR described the occurrence of heavy metals in PFA and discussed current international research findings with respect to the solubility and release of these metals in water. This demonstrated that even assuming a "worst case scenario" the significance of dissolved metals released via the power station's cooling water stream would be insignificant. The discussion can now amplify the view that the significance of metals released with seepage through the perimeter would also be small.

7.2.2 Chapter 3 describes the proposed structure of the lagoon perimeter and explains that it will retain all PFA placed within it effectively whilst permitting seepage in and out in response to tidal movements. When PFA has been placed within the lagoon, the small soluble fraction that is dissolved will be dispersed throughout the lagoon water. This lagoon water will then be progressively diluted and dispersed, at least in part, to the sea by the tidal exchanges through the perimeter. The resulting water quality will depend upon:

(i) the chemistry of the PFA

(ii) the existing concentrations in the sea water

(iii) the rate of sea water exchange through the perimeter (which will reduce as filling progresses)

(iv) amount of rainfall

(v) interaction between PFA and lagoon water

(vi) the volume of lagoon water (which will reduce with time)

(vii) chemical attenuation as the seepage traverses the long flow lines through the perimeter

7.2.3 The processes involved are interrelated and the resulting complexity does not lend itself to quantitative analysis. However, various estimates of water quality and quantity have been derived by making a number of conservative assumptions.

7.2.4 Once PFA is placed in water the soluble fractions on the surface of the PFA particle substrate can be released. The means by which this is dispersed is dependent on the hydrodynamic regime within the lagoon. There are to be two means of dispersing these soluble fractions beyond the lagoon environment. Firstly, the decantrate pumps which will discharge water to the cooling water outfall, and secondly the embankment is to be permeable which will permit seepage to pass, and disperse in the bay of Ha Mei Wan.

7.2.5 The relative magnitude of the flows that are likely to be discharged by either means is to a large extent dependant on the extent of PFA deposition within the lagoon. In the later stages of PFA deposition, as the lagoon is filled with PFA, the seepage flow will decrease and the decantrate pumping system will be required to discharge and disperse a greater proportion of the soluble fraction of PFA.

7.2.6 At each stage (Chapter 6) the PFA is to be placed in such a manner to minimise the seepage through the embankment towards the beach area to the east. Due to the construction of the existing platform for the station the northern perimeter of the lagoon will be the most permeable. Thus a layer of PFA is to be placed along this edge in the first and second stage of PFA deposition. This will drastically reduce the seepage from 1.442 m^3/s to 0.056 m^3/s (Table 7.1). The subsequent stage involves the lining of the remaining perimeter with PFA, further reducing the seepage to about 0.034 m^3/s, the seepage will then progressively drop throughout the filling process to a final value of about 0.014 m^3/s. There will also be some seepage under the quay wall forming the extension to the cooling water intake, which will be carried through the cooling water stream to the outfall at the western end of the station. Table 7.1 demonstrates the relative proportions of seepage and where the egress from the lagoon will probably occur.

Stage	Seepage To Cooling Water Intake (m^3/s)	Seepage to Ha Mei Wan Towards West (m^3/s)	Towards East (m^3/s)	Total (m^3/s)
1	0.084	0.721	0.721	1.442
2	0.084	0.028	0.028	0.056
3	0.049	0.017	0.017	0.034
6	0.049	0.007	0.007	0.014

Table 7.1 Estimated seepage flows through the life of the lagoon

7.2.7 The flows given in Table 7.1 are the estimated maxima during an ebb tide and are assumed to be a applicable for 12 hours each day, corresponding to two tidal cycles. Thus the daily tidal exchange of water across the perimeter for the various stages can be estimated (Table 7.2). However the processes of tidal exchange and factors determining water quality are not the same for all the stages. Following the construction of the lagoon embankment (stage 1) but prior to the completion of the lining of the lagoon with PFA (end of stage 3), the water quality of the seepage will be governed largely by the direct exchange of lagoon water across the lagoon perimeter. Following stage three the tidal exchange will be governed by the exchange between the PFA and the marine waters around the perimeter. During a rising tide marine water will penetrate the PFA at the perimeter. Due to the low permeability of the placed PFA, the depth of penetration is likely to be a matter of about one metre. On the ebb tide this same water will be flushed out. Thus the water quality will be determined by this process (i.e. the PFA around the perimeter to a depth of about one metre will be washed with each tidal cycle).

Stage	Flow to Bay m^3/day	Seepage Quality
1	62,294	Lagoon Water
2	2,419	Lagoon Water
3	1,468	Washed PFA
6	605	Washed PFA

Table 7.2 Daily tidal exchange across lagoon perimeter

7.2.8 Once the lagoon leachate has migrated through the lagoon perimeter, it will disperse with the tidal currents throughout Ha Mei Wan and beyond. Studies (Appendix A) have investigated the hydrodynamic regime and estimated the dispersion characteristics based on a linear dispersion model. This makes the conservative assumption that there is no decay or deposition of the determinands in time or space. Such a model has the added advantage that it can be used to investigate the dispersion resulting from varying daily seepage loads from the lagoon. Thus the sensitivity to varying methods of water quality estimation or the stage of lagoon filling can be investigated by linear interpolation.

7.2.9 The water quality of the two forms of seepage water, lagoon water and washed PFA are estimated in section 7.3, the section also demonstrates a sensitivity analysis on the method of water quality estimation. However a conservative estimate of the effect of dispersion within the adjacent Ha Mei Wan bay is a daily load of 14.46 kg of total metals. This corresponds to a seepage water quality with a concentration of 20.667 ppm of total metals (or 2.176 ppm total toxic metals) in a constant seepage flow during the ebb tide of 1.442 m^3/s has been used for the study (Appendix A). Since a linear dispersion model has been used, which assumes no decay of the determinands, the results of the model can be used to examine the sensitivity of the results to the different daily loads associated with different stages. From this the elevations in concentration of total metals or total toxic metals can be derived for each stage for different positions in the bay.

7.2.10 The dispersion model shows that the metals would probably disperse to less than 5 μg/l within one grid square (83.33 m by 83.33 m) of the lagoon boundary. The equivalent total toxic metal elevation is 0.7 μg/l. On completion of stage 3 (Section 6.2.15) the seepage flow will be reduced to 0.034 m^3/s, which would give an equivalent total toxic metal concentration elevation of about 0.03 μg/l.

7.2.11 Following stage three the daily load of determinands dispersed in Ha Mei Wan will be solely determined by the washing action of the flood and ebb tide around the perimeter of the lagoon. The quantity of washing seawater will progressively decrease and availability of various determinands on the PFA particles will decay. However due to the complexity of the processes and number of unknown factors a realistic estimate of this cannot be attempted. Thus overriding criteria have been chosen for the estimate which negate the necessity for such considerations (Section 7.3.14). Consequently the maximum estimated elevated concentration of total metals at the extremity of one grid square from the lagoon perimeter will not exceed 15 μg/l, with a corresponding elevation in Total Toxic Metals of 2.1 μg/l (Section 7.3.15).

7.2.12 Apart from the tidal exchange by seepage, the lagoon decantrate will provide an important means of dispersing the soluble determinands. This will become increasingly important in the latter stages of the scheme as the seepage decreases. The water quality and load of the decantrate is discussed in section 7.4.

7.3 LAGOON WATER QUALITY ESTIMATION

7.3.1 The extent of leaching of metals and other determinants from PFA to water is a complex relationship of various processes and parameters, related to the chemical constituents of both the PFA and the receiving water. Van der Sloot's work (1986) indicates that the degree of leaching is also dependent on the ratio of the volumes of PFA and water with which it is mixed as well as the time of contact with the water. Van der Sloot studied 7 determinands in detail, or five of the thirteen defined as toxic metals in the TM. Environment Canada (1986) collected data on PFA leachate quality from around the world. The water quality in these leachates varied considerably, which were concluded to be due to differences in water quality, proportions of mixing, the length of time for mixing and the PFA constituents. These conclusions are in agreement with Van der Sloot's work. Environment Canada did not attempt to separate or quantify the various effects (unlike Van der Sloot) but presented the ranges that have been found to exist in all the variations. The work by both Environment Canada and Van der Sloot has been summarised in the IAR.

7.3.2 Various studies have been carried out into the effect of time on the extent of leaching. Environment Canada reported on work by Reed et al 1976, Talbet et al 1978 and others. The data from both laboratory and field studies indicate that most leaching occurs within one hour of contact with water, except for Potassium and Magnesium where leaching may continue for several days. The data presented by Van der Sloot concurs with this for the determinands studied, except those of Selenium and Molybdenum, this is particularly pronounced with a neutral PFA in seawater.

7.3.3 The PFA which is placed in the lagoon will be mixed with seawater through two main processes. PFA placed below water level will be mixed directly with the lagoon seawater. Various determinands will be leached out and then dispersed throughout the lagoon water. Van der Sloot describes methods of estimating the resulting concentrations of the determinands studied, accounting for the various means of deposition, i.e. dumping from barges, sluicing into lagoons, and placing dry into lagoons.

7.3.4 Van der Sloot's recommended approach has been used to estimate the concentration in the initial lagoon contact water which is given in column C of Table 7.3. However, where this is exceeded by the world data presented by Environment Canada (Column D) the latter concentration is used. The world data exceeds all these estimates given by Van der Sloot, only the Molybdenum concentration is retained since Environment Canada do not present data for this element. In order to investigate the sensitivity of the Van der Sloot analysis the figures are reworked in Columns (G) to (J) for a dilution in 20 parts of seawater. Again the estimate is governed by the maximum values of the Environment Canada work, except for Molybdenum as before.

7.3.5 The lagoon water quality will be established in much the same way as that for the CLP ash lagoon at Tsang Tsui, which is presented for comparison in Column (K). None of the parameters investigated exceed the estimate given in Column (E, E_2, E_3).

7.3.6 Although the processes forming the leachate from the quarry trial at Sok Wku Wan are not directly comparable, the maximum concentration in any sample is presented in Column (F). Although the estimated concentrations are exceeded for Antimony, Cadmium, Chromium, Lead, Mercury and Molybdenum, usually by small margins, the total metal and the total toxic metal concentration is less than the estimate (Column E).

7.3.7 The foregoing indicates that the estimate of concentrations for the water quality (Column E) of the initial contact water in the lagoon is realistic, and for the lagoon water as a whole it will be conservative.

7.3.8 Once the lagoon has been lined with PFA (Stage 3) the seepage flow across the lagoon boundary will be much reduced (Table 7.1). Indeed the only seepage will be the marine waters carried into a limited depth of PFA at the perimeter by the flood tide which will be flushed out on the ebb tide. Thus further leaching, and flux to marine waters can only occur through this mechanism. Although leaching will already have occurred due to the method of placing, the analysis presented here presumes that the PFA is fresh ash that has not been leached. The porosity of placed PFA will probably be of the order of 0.25, giving a solids volume to pore ratio of 3 : 1.

7.3.9 The contact time for the marine water is only a maximum of one tidal cycle, i.e. 12 hours. For the purpose of this analysis a conservative contact time of 50 hours and a PFA to water ratio of 1 : 1 has been taken. The estimated water quality of the seepage can be estimated in the same way as for the lagoon water. Indeed the quality can be taken as the same as Column (E) which is conservative.

7.3.10 Between the PFA and open marine waters there are to be granular filters and the lagoon embankments, which will promote ion exchange, chemisorption, precipitation, adsorption and microbiological processes. All of these will attenuate the concentrations of the seepage prior to dispersion in the bay. Quantification of the effects are not attempted and are ignored in order to provide a conservative assessment of the water quality in the bay.

7.3.11 The lagoon water quality (Section 7.3.7) is applicable to the hydrodynamic model for stages 1 to 3 and the PFA seepage quality (Section 7.3.9) is applicable to stages thereafter.

7.3.12 Although these studies indicate likely qualities in seepage water they do not estimate the total load of determinands for the life of the scheme. The total load is limited to the total of leachable determinands in the 1.5 Mm^3 of PFA to be deposited. The load to the bay is made up of two parts, the lagoon water that seeps out to the bay prior to the completion of stage 3, and the PFA seepage from the 1 m depth of PFA around the lagoon perimeter thereafter.

7.3.13 Van der Sloot recommends that the leachate be assumed to disperse in the whole lagoon. Until the end of stage 3 this would represent a dilution of about 1,600 times, giving a rise in total metals concentration of about 0.012 mg/l each day in the lagoon. Although some dispersion will occur it is difficult to predict the extent of dispersion, or the extent of concentration gradients that may exist. By ignoring these effects, and assuming that the whole leachate load is carried out of the lagoon each day by seepage (62,294 m^3/day) a very conservative assessment is assured. This represents a dilution of about 100 times, for stage 1. Until the end of stage 3 the water quality of the seepage is assumed to remain the same, and hence the leachate load per day to the bay will be reduced by a factor of 40 by the end of stage 3.

7.3.14 Following the completion of stage 3, the lining of the lagoon with PFA, the seepage concentration will be purely determined by PFA washing at the perimeter of the lagoon. The international research and the quarry trial demonstrate that the leachable determinands will be greatly reduced by this time, by orders of magnitude. However the quantification of this reduction is difficult to determine with any certainty. Thus a conservative assumption is made, that the ash at the perimeter is fresh and no leaching has occurred on each and every day of the lagoon's life. Consequently the water quality of the seepage (1,468 m^3/day) will be that of Column E in Table 7.3. This implies that the leachate load per day will be about 2.6 times that estimated for the initial stages, which is a conservative assumption.

7.3.15 Following this line of reasoning the concentration elevations implied by the dispersion model for the determinands in the bay would be 2.6 times those of stage 1, i.e. a maximum in the bay of 14 μg/l for total metals. However as has be outlined above this is unrealistically high, and would probably be a magnitude less than this. Thus a maximum elevation of 15 μg/l for the total metals would be more than conservative for the life of the scheme with a corresponding maximum 2.1 μg/l for the total toxic metals.

			A	B	B2	C	C2	D	E	E2
			Concentration in Tatung Coal FPA	% released when placed in lagoon (1:1 dilution)	% released when placed in lagoon (1:1 dilution)	Estimated release from 1:1 dilution (A) x (B)	Estimated release from 1:1 dilution (A) x (B2)	Alternative estimate of concentration	Concentration used for Estimation	Higher value of (C2) or (D)
Element	TM	Symbol	(ppm)	Neutral Ash in Seawater	Alkaline Ash in Seawater	Neutral Ash (ppm)	Alkaline Ash (ppm)	(ppm)	(ppm)	(ppm)
Antimony	*	Sb	8	2.5	0.02	0.2	0.0016	<0.1 - 0.2	0.2	0.2
Arsenic	*	As	40	0.04	0.4	0.016	0.016	<0.002 - 0.03	0.03	0.03
Boron		B	98	-		-		4 - 8.2	8.2	8.2
Cadmium	*	Cd	2	-		-		<0.001 - 0.037	0.037	0.037
Chromium	*	Cr	-	1.1	1.3	-		0.02 - 0.98	0.98	0.98
Copper	*	Cu	10	-		-		<0.01 - 0.31	0.31	0.31
Iron		Fe	-	-		-		<0.05 - 1.93	1.93	1.93
Lead	*	Pb	10	-		-		<0.01 - 0.06	0.06	0.06
Mercury	*	Hg	4	-		-		<0.0002-0.001	0.001	0.001
Manganese		Mn	-	-		-		<0.01 - 0.48	0.48	0.48
Molybdenum		Mo	30	18	4	5.4	1.2	-	5.4	1.2
Selenium	*	Se	10	10	0.33	1	0.03	0.002 - 0.058	1	0.058
Vanadium	*	V	80	0.66	0.001	0.53	0.0008	0.1 - 0.5	0.53	0.5
Zinc		Zn	80	-		-		0.02 - 1.51	1.51	1.51
								Total Metals	20.668	15.496
								Total Toxic Metals	3.148	2.176

(A) Tatung coal is commonly used at the Lamma Power Station
(B) From H.A. van der Sloot et al,1986
(D) From Report EPS 3/PG/5, Environment Canada, May 1986
* Those metals listed as Toxic in the TM
\- no data available
(1) with permission of China Light & Power Co. Ltd

			F	G	H	I	E3	J	K
			Quarry trial Highest Concentration in any sample	% released from 1:20 dilution (Alkaline Ash)	Estimated release from 1:20 dilution (A) x (G)	Concentration in 1:20 release water (H) / 20	Concentration usable for estimate 1:20	Estimated release per tonne of PFA (1:20) dilution	Max recorded in Tsang Tsui(1) Lagoon Jan 88 to Sep 88
Element	TM	Symbol	(ppm)		(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
Antimony	*	Sb	0.9	16	1.28	0.64	0.2	1.28	
Arsenic	*	As	<0.0005	0.43	0.172	0.0086	0.03	0.172	0.0061
Boron		B	7.6				8.2	8.2	
Cadmium	*	Cd	0.05				0.037	0.037	0.00043
Chromium	*	Cr	1.2	6.2			0.98	0.98	
Copper	*	Cu	0.03				0.31	0.31	0.0076
Iron		Fe	0.4				1.93	1.93	
Lead	*	Pb	0.3				0.06	0.06	0.0071
Mercury	*	Hg	0.05				0.001	0.001	
Manganese		Mn	0.19				0.48	0.48	
Molybdenum		Mo	5.5	9.6	2.88	0.144	0.144	2.88	
Selenium	*	Se	0.015	13	1.3	0.065	1	1.3	0.54
Vanadium	*	V	0.53	0.13	0.104	0.0052	0.5	0.104	
Zinc		Zn	0.06				1.51	1.51	0.035
Total Metals			16.83				15.382	19.244	g / tonne
Total Toxic Metals			3.075				3.118	4.244	g / tonne

Table 7.3 Lagoon water quality estimation

7.4 DECANTRATE

7.4.1 By assuming that no leachate load is lost through seepage, conservative estimates can be made for the yield of determinands to the decantrate and hence dispersed through the cooling water outfall. Then the total yield during the period of PFA disposal, perhaps a minimum of 6 years, is likely to be 23.5 tonnes of Total Metals or 4.7 tonnes of Total Toxic Metals. To discharge and disperse this at a water quality with an elevation of no greater than 0.1 mg/l, 47 Mm^3 of water would be required, which equates to a discharge of some 20,000 m^3/day. This rate is a fraction of the available pumping capacity in the decantrate system (100,800 m^3/day).

7.4.2 In the absence of stormwater pumping or emergency sluicing, the daily discharge would be 20,000 m^3/day. If a rainfall event does occur then the discharge may exceed this, to give a discharge up to the maximum expected discharge of 54,000 m^3/day (Section 6.4.6). Similarly emergency sluicing may require 46,000 m^3/day. However these discharges will not be compounded, consequently the maximum daily flow will be 54,000 m^3/day with an elevated Total Toxic Metal concentration lower than that for the normal daily flow.

7.4.3 To put this into perspective, consider that the station's cooling water discharge is an average 50 m^3/second, or 180,000 m^3/hr. This is a conservative average since the design flow for the station cooling water is 260,000 m^3/hr. The decantrate pumping system will be capable of discharging lagoon water at a rate of about 4,200 m^3/hr. If, for example, the metals content of the lagoon water has reached 0.1 mg/l when decantrate pumping commences, this will elevate the metals content of the cooling water stream by about 2 μg/l. This will disperse imperceptibly when the cooling water stream mixes with the deep tidal stream in the west Lamma Channel.

7.5 RELEASE OF SUSPENDED SOLIDS FROM THE LAGOON

7.5.1 The criterion for TSS (Total Suspended Solids) for effluent set in the TM is 30 ppm for discharges to inshore waters in the area of Lamma. There are two processes that might be considered to be effluent derived from the lagoon water, firstly seepage water that permeates the lagoon perimeter, and secondly the decantrate water that is to be discharged to the cooling water outfall. Suspended solids in the lagoon water will derive from the action of depositing PFA in the lagoon and from the occasional emergency sluicing of PFA. A similar process occurs in the ash settlement basins of the existing station, although they differ in important respects:

(i) the PFA is to be deposited dry and not as a slurry. Thus less material is likely to go into suspension (excepting occasions of emergency sluicing)

(ii) the size of the lagoon will initially be considerably larger than the ash settlement basins, although this discrepancy will diminish with time. Also the detention time will be longer in the lagoon, thus there will be considerably longer time in the lagoon for the solids to settle out

(iii) the extraction of decantrate need not be continuous in the lagoon and the power station operations would not be affected by detaining the decantrate for extended periods on occasions

(iv) the water in the lagoon is essentially quiescent in comparison to that in the ash settlement basins, thus the lagoon water will have less capacity to sustain suspended solids

(v) although the ash settlement basins are intended primarily for the extraction of FBA, which has a higher course material content than PFA, the TSS in the ash settlement basins is ostensibly determined by the fines content

7.5.2 The correct design of filter layers on the inside of the perimeter embankment will prevent the egress of PFA particles in the seepage. Thus the TSS of the seepage will be well within the TM criterion.

7.5.3 Given the current performance of the ash settlement basin, the TSS in the lagoon is expected to be comparable, or better. In the early stages of the lagoon operation the performance might be expected to be considerably better, and fall within the criterion that would permit the pumping of the decantrate. Any deterioration in the performance of the lagoon with respect to TSS will be gradual as the volume of water in the lagoon slowly decreases. This will allow sufficient time for alterations in the operating practice should this be required. Early operational experience will determine whether or not operational procedures would have to be altered to comply with the criteria in the later stages of lagoon operations.

7.5.4 The TSS level of the decantrate will be reduced approximately fifty fold when mixed with the station cooling water flow. The combined flow will disperse imperceptibly when mixed with the open sea of the west Lamma Channel.

7.6 pH IN THE LAGOON

7.6.1 When PFA is placed within the lagoon, the small soluble fraction that is dissolved will be dispersed throughout the lagoon water, resulting in a change in pH. The number and complexity of the variables involved (Section 7.2.2) makes the prediction of the magnitude of this change impossible to any degree of accuracy. However monitoring results from the existing ash settlement basins give a general indication of the behaviour of ash in sea water. Values of pH measured to date typically range from approximately 7.0 to 8.5. The sea water in the ash lagoon will probably behave in a similar manner and hence pH will not be a critical parameter needing to be controlled. The dilution of lagoon decantrate by a factor of approximately fifty when discharged into the cooling water stream will reduce any changes in pH to insignificant levels.

7.6.2 During the initial period of lagoon filling, the ash to water ratio will be low and any changes in pH which do occur will be gradual. Routine monitoring of lagoon water quality will detect any changes in pH at an early stage and enable control procedures, if necessary, to be developed. However we do not expect such procedures will be necessary.

7.7 DUST

7.7.1 A principal concern of Lamma residents has always been that the PFA will be dusty. The lagoon operating proposals have taken full account of the need to prevent dust. Consequently a suite of measures is to be provided to prevent a dust nuisance arising from known causes and to be able to react to any occasion of unexpected causes through control procedures (Section 8.5). The suite of preventative measures is:

(i) PFA will never be handled in a dry state - it will always be moist

(ii) PFA conveyors will be deep troughed to avoid spillage

(iii) PFA conveyors will be enclosed

(iv) the operating procedure will avoid leaving large areas of PFA exposed to air

(v) completed areas of the mound will be landscaped as soon as practicable

(vi) areas which must be left exposed will be well compacted (and will develop a characteristic non-dusty surface if not disturbed)

(vii) a flexible sprinkler system will always be on standby

(viii) tracks and wheels of lagoon operating plant will be sluiced clean daily

(ix) a wheel washing system will be installed at the entrance to the lagoon

(x) a floater collection system will be provided

7.8 NOISE

7.8.1 To evaluate the significance of noise arising from lagoon operations, we have used the procedures set out in the Noise Control Ordinance published by the Environmental Protection Department (EPD) of the Hong Kong Government.

7.8.2 The placing of PFA in the lagoon, and harvesting, may take place intermittently over a considerable number of years depending on several indeterminable factors (Section 7.1.2). Lagoon operations have therefore been considered to be an industrial operation rather than a construction activity.

7.8.3 Discussions with the Noise Control Group of EPD revealed that the placing of PFA in the lagoon would be considered as two operations. PFA placed below sea level would be classified as construction work, and above sea level as an industrial operation. The procedures presently proposed for operating the lagoon will always involve placing conditioned PFA above sea level and at times below it also, hence it will be considered as an industrial operation.

7.8.4 Noise arising from lagoon filling operations has been assessed using the procedures set out in the 'Technical Memorandum for the Assessment of Noise from other than Domestic Premises, Public Places or Construction Sites'. The Area Sensitivity Rating (ASR) will be "A". Therefore the Acceptable Noise Level (ANL) for a Noise Sensitive Receiver (NSR) is 60 dB(A) during the day-time (0700 to 1900 hrs) and evening (1900 to 2300 hrs) and 50 dB(A) at night (2300 to 0700 hrs). The Tai Wan To police station is considered as the NSR.

7.8.5 The Hong Kong Planning Standards and Guidelines state that the level of intruding noise at the facade of the nearest noise sensitive receiver should be at least 5 dB(A) below the appropriate ANL (Table 3 of the 'Technical Memorandum'), or the prevailing background noise level, whichever is lower.

7.8.6 Background noise at the NSR will mainly originate from the power station. Any further installation of coal fired generating units will affect the background noise level. As such, measurement of background noise at the present time is unlikely to be representative of the future long term background noise. Therefore the acceptance criterion of ANL minus 5 dB(A) for planning purposes has been adopted. The revised ANL is therefore 55 dB(A) during the day time and evening and 45 dB(A) at night.

7.8.7 The Corrected Noise Level (CNL) likely to be received at the NSR is a function of distance and the Total Sound Power Levels (TSPL) of the equipment producing the noise. Corrections must also be applied for the effects of acoustic screens, type of receiver etc.

7.8.8 The distance from the noise source position, taken to be the end of the conveyor belt in the lagoon, to the NSR is 680 m (Figure 7.1). The correction factor for distance attenuation is 65 dB(A) derived from equation (7.1). Also the NSR is partially screened and therefore receives a negative correction factor of 5 dB(A) and being a building receives a positive correction factor of 3 dB(A) (IAR).

$$K = 20 \log_{10} R + 8 \tag{7.1}$$

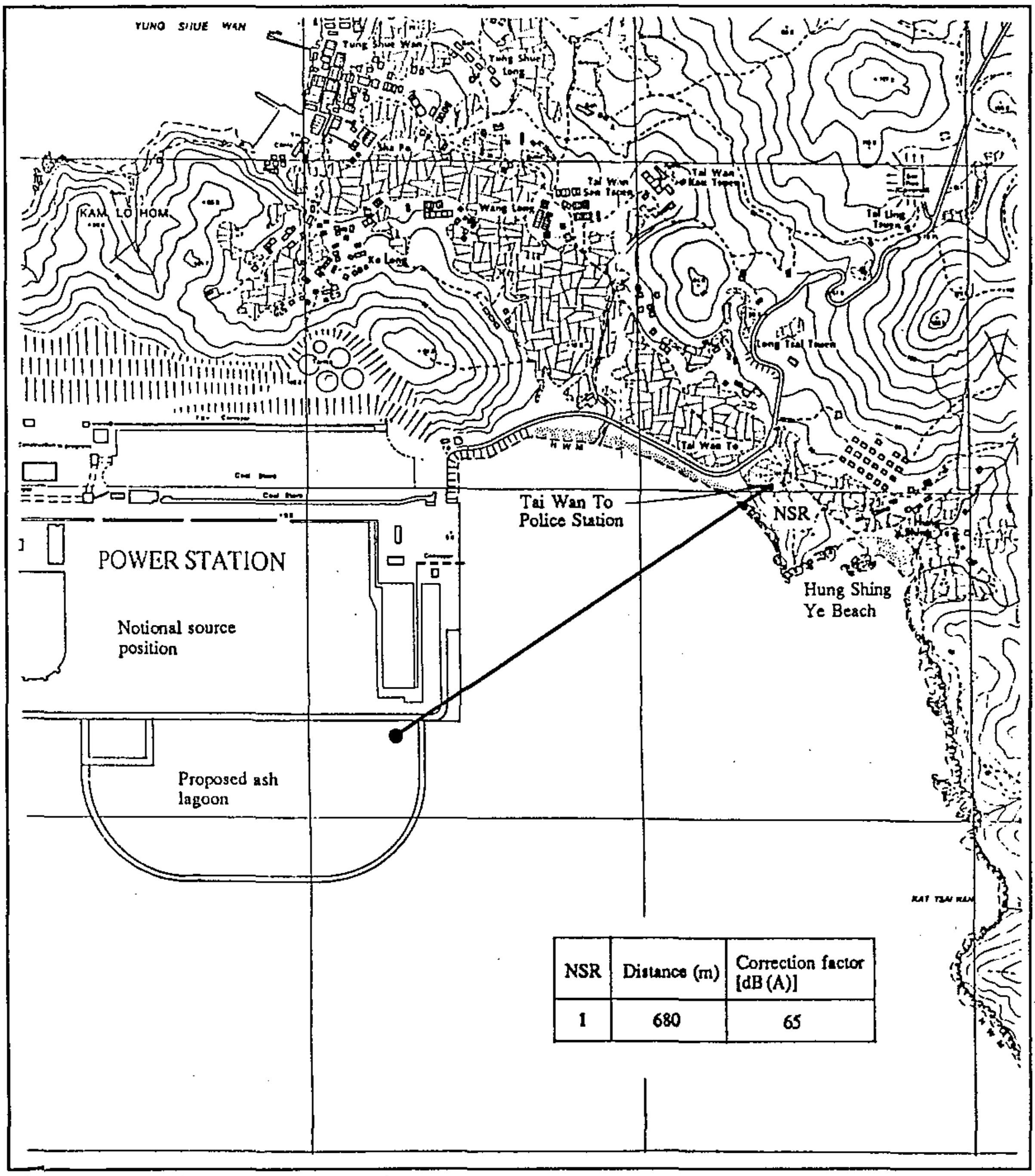
where K is the correction factor dB(A) for distance attenuation
R is the distance in metres

7.8.9 The Corrected Noise Level (CNL) at the NSR can be calculated from the TSPL by applying the appropriate correction factors (Table 7.4). The CNL of 53 dB(A) is less than the ANL of 55 dB(A) during the day time and evening and therefore the noise impacts will be acceptable. However the operations will not be carried out at night.

Equipment	Noise [dB(A)]										TSPL[1]	CNL[2] for NSR
3 conveyors	90	>								)		
	90	>	93	>						)		
	90	>		>	115	>				)		
1 bulldozer	115	>	115	>		>				)		
1 vibratory compactor	105	>				>	119	>		)		
1 loader	112	>	113	>		>		>		)	120 dB(A)	120-65[3]-5[4]+3[5] = 53
3 lorries	112	>		>	117	>		>		)		
	112	>	115	>				>	120	)		
	112	>						>		)		
1 pump (electrical)	88	>	112	>	112	>	112	>		)		

Remarks:
(1) Total Sound Power Level
(2) Corrected Noise Level
(3) Correction factor for noise attenuation
(4) Negative correction factor for partial screening
(5) Positive correction factor for being a building

Table 7.4 Operation Corrected Noise Levels



NSR	Distance (m)	Correction factor [dB (A)]
1	680	65

Figure 7.1 Noise Sensitive Receiver

7.9 VISUAL IMPACT

7.9.1 The majority of the lagoon operating activities will not be visible from the dwellings near the power station or from the nearby beaches at Hung Shing Ye and Tai Wan To. Some of the works will be visible from the high hill slopes bordering Ha Mei Wan. When the perimeter mounding and landscaping have begun, the vegetated foreground view will merge visually with the vegetated natural slopes next to, and behind the power station. This will offer some softening of the industrial scene. The location of the principal mounding to the east of the site (rather than the west as indicated in the IAR) offers additional benefit in this respect.

7.10 COMMUNITY REACTION

7.10.1 The ash management exhibition held on Lamma Island in October 1989 appears to have allayed local concerns with respect to lagoon operation. Some measures in this respect has been given by letters to the press and leading articles in the small periodical produced on Lamma. Therefore further significant community reaction to the lagoon is not anticipated.

7.11 TOURISM

7.11.1 Lagoon operations will have no physical effect on the local tourist facilities (the beaches and restaurants) thus any significant effect on tourism is not envisaged.

7.12 EMPLOYMENT OPPORTUNITY

7.12.1 The lagoon operations may afford some local employment opportunity, principally in connection with the implementation and maintenance of the landscaping works. However the opportunity is not great, comprising only a few additional labourers working under the direction of the existing station landscape supervisor. The principle activities will be the operation and manipulation of the sprinkler system, the placing of the top soil and planting vegetation on the landscaped mound.

7.13 CONCLUSION

7.13.1 The lagoon operation activities will persist for a number of years, the duration is dependent upon alternative demands for PFA from industry and the availability of the Lamma Quarry for PFA disposal. At present the PFA filling operation in the lagoon is anticipated to last for between 6 and 8 years, although emergency sluicing and harvesting operations are likely to persist longer than this. Not withstanding this, the operations have been considered as an industrial operation, and as such falls within the ambit of various relevant Government Ordinances and regulations. A number of aspects, such as the effect on tourism, do not fall under such regulations, but have also been appreciated, assessed and discussed. In each case the effects are likely to fall within the various relevant criteria, although necessarily some judgements are subjective; such as the perception of tourists visiting the area. However the environmental impact of the lagoon operations is not foreseen as a determining factor in the adoption of the project.

REFERENCES

Binnie & Partners Hong Kong (1988) "The Management of Fuel Ash Originating from Power Generation - Environmental Impact Assessment, Initial Assessment Report".

Binnie & Partners (September 1990) "Lamma Island Power Station Ash Lagoon - Hydrodynamic Model".

Environment Canada (1986) "Contaminant Solubilization in bench-scale recirculating ash transport systems" Report EPS 3/PG/5.

Van der Sloot H.A. & Nieuwendizk B.J.T. (1986)
"Release of Trace elements from Surface-enriched fly ash in seawater" Netherlands Energy Research Foundation.

CHAPTER 8

OPERATING ENVIRONMENTAL MONITORING AND AUDIT

8.1 INTRODUCTION

8.1.1 This chapter describes the proposed environmental monitoring and audit programme for the lagoon operating systems. The environmental monitoring proposals for the lagoon help ensure it is operated in an environmentally acceptable manner, and the auditing system is proposed to confirm compliance with appropriate standards and operating procedures. Monitoring will involve the measurement of certain physical and chemical parameters, that could be influenced by the placing of PFA in the lagoon. The measured parameters will be compared with preset environmental standards to decide whether control measures are necessary. Routine implementation of standard control procedures, when necessary, will form part of the audit process.

8.1.2 Environmental auditing is the methodical examination of a project in a manner designed to check whether the activities are complying with previously defined environmental requirements, and that the necessary remedial measures are identified to remedy any unacceptable or unforeseen environmental impacts. Technical terms are defined in Appendix 1.

Environmental Monitoring

8.1.3 Monitoring is required to provide the necessary data for an informed assessment of the performance of the lagoon, the identification of any environmental impact, and how these vary throughout the life of the facility. This can only be achieved by measuring the relevant parameters throughout the operational life of the lagoon and for a while after. The monitoring programme will consist of:

(i) determine the environmental effects relevant to the project

(ii) identify the parameters to be used for measuring the effect

(iii) define acceptance criteria for the parameters

(iv) collect the necessary data

8.1.4 Environmental monitoring of lagoon operations will be necessary for the life-time of the facility. Details of the parameters and properties to be measured, as a means of reviewing the perceived environmental impact of the lagoon, are described in subsequent sections.

Environmental Audit

8.1.5 The environmental audit will consist of a series of procedures controlling the monitoring programme and other functions that ensure that environmental impacts are measured consistently and the correct procedures are implemented if the environmental effects are found to be outside the acceptable criteria. The purpose of the audit is to:

(i) assess the quality of the monitoring programme

(ii) compare the measured effects with the accepted criteria

(iii) initiate control procedures to mitigate identified effects outside the acceptance criteria

8.1.6 These procedures will be carried out on two-levels. The first will determine the routine running of the Lagoon operations, where the monitoring will be fed back into the procedures for control. This will be apart from the regular reporting procedures under the audit which will identify long term trends and the need for changes in monitoring or control procedures.

8.2 ENVIRONMENTAL EFFECTS

8.2.1 The potential environmental effects of operating the lagoon have been discussed in the IAR and Chapter 7, which recommended that the following areas be monitored; the monitoring programme will provide information in each of these areas:

(i) sea water quality inside and outside the lagoon

(ii) marine biota outside the lagoon

(iii) dust

(iv) noise

8.3 PROPOSED MONITORING PROGRAMME

8.3.1 Environmental effects associated with lagoon operating will be measured wherever possible by quantifiable scientific methods. The results can then be judged against predetermined environmental standards.

8.3.2 The monitoring programme will be influenced by the timing of PFA placing. Before ash has been placed in the lagoon, monitoring will determine baseline values. Once ash is placed in the lagoon, even if only intermittently, monitoring of sea water quality and marine biota will be carried out on a regular basis. However, noise monitoring of the lagoon operating system need only be undertaken when relevant activities are occurring. Dust monitoring, on the other hand, will be necessary when PFA is being handled or placed above water level.

8.3.3 A monitoring programme cannot be fully specified at the present time, because the operation of lagoon systems will depend on the timing of ash placing, which is indeterminate. Ash will be placed in the lagoon only when other industrial and land reclamation uses are not available. Subject to these timing variables, the following monitoring programmes are recommended for each of the potential environmental effects identified (Section 8.2).

Lagoon and sea water quality

8.3.4 Sea water quality will be regularly monitored inside and outside the lagoon to detect any changes resulting from operating the facility. Hydrodynamic modelling (Appendix A) has shown that no significant changes in local water quality are to be expected, although water exchange and dispersion of seepage from the lagoon may slightly affect the area to the east adjacent to the nearest public beaches (Figure 8.1). The proposed monitoring programme is intended to detect the changes that may result from the lagoon's operation.

8.3.5 Baseline conditions will be established by analysing water samples from two locations at monthly intervals over the three months prior to placing ash in the lagoon. The two locations are to be ST3 and ST4 (Figure 8.1). ST3 will measure ambient conditions in the Ha Mei Wan bay, close to the beaches and ST4 will measure ambient condtions at the edge of the bay, adjacent to the West Lamma Channel.

8.3.6 While the lagoon is in operation there are to be four sampling locations (Figure 8.1). Two locations are within the lagoon, ST1 and ST2. The sampling location ST3 is to be in the bay to the east of the lagoon and ST4 is to be at Power 4 navigation light to determine the ambient conditions. On each sampling occasion one sample is to be taken at ST1, three from ST2 and two from each of ST3 and ST4. At each of the locations ST3 and ST4 the samples are to be taken 1 m below the surface and 1 m above seabed level. The proposed testing specification for the water samples is given in Table 8.1.

8.3.7 The concentrations of metals within the lagoon should be an average of samples taken at regular intervals. Two sampling sites are proposed, one adjacent to the decantrate tower, ST1, and one at a far extremity of the lagoon, ST2. These samples may well have to be depth integrated to arrive at a representative concentration.

8.3.8 The water quality will be controlled by daily discharges of the decantrate, supplemented with regular monitoring of the lagoon waters. During the first 12 months of operation the daily discharge for water quality control will be 20,000 m^3/day (Section 5.3) and the sampling interval will be one calendar month. Should the pumping rate prove to be inappropriate in the light of the monitoring results it can be adjusted. The samples (Section 4.1) will be tested for all 13 total Toxic Metal determinands (TM paragraph 3.2). After the first 12 months of operation of performance will be reviewed and adjusted where required, in particular the monitoring interval might reasonably be extended to 2 months. Also the number of determinands for monitoring should be those that form the largest portion of the Total Toxic Metal concentration and can be deemed to represent the overall concentration of Total Toxic Metals. At present these are thought to be:

(i) Arsenic

(ii) Cadmium

(iii) Chromium

(iv) Copper

(v) Lead

(vi) Mercury

(vii) Selenium

8.3.9 The samples will be analysed by HEC or their appointed subcontractor and the results presented as Total Toxic Metals.

8.3.10 In addition to the chemical parameters identified for measurement the following physical parameters will be recorded when water samples are taken to permit the identification of influencing factors:

outside the lagoon

(i) tide level

(ii) tidal condition

(iii) weather

inside the lagoon

(i) lagoon water level

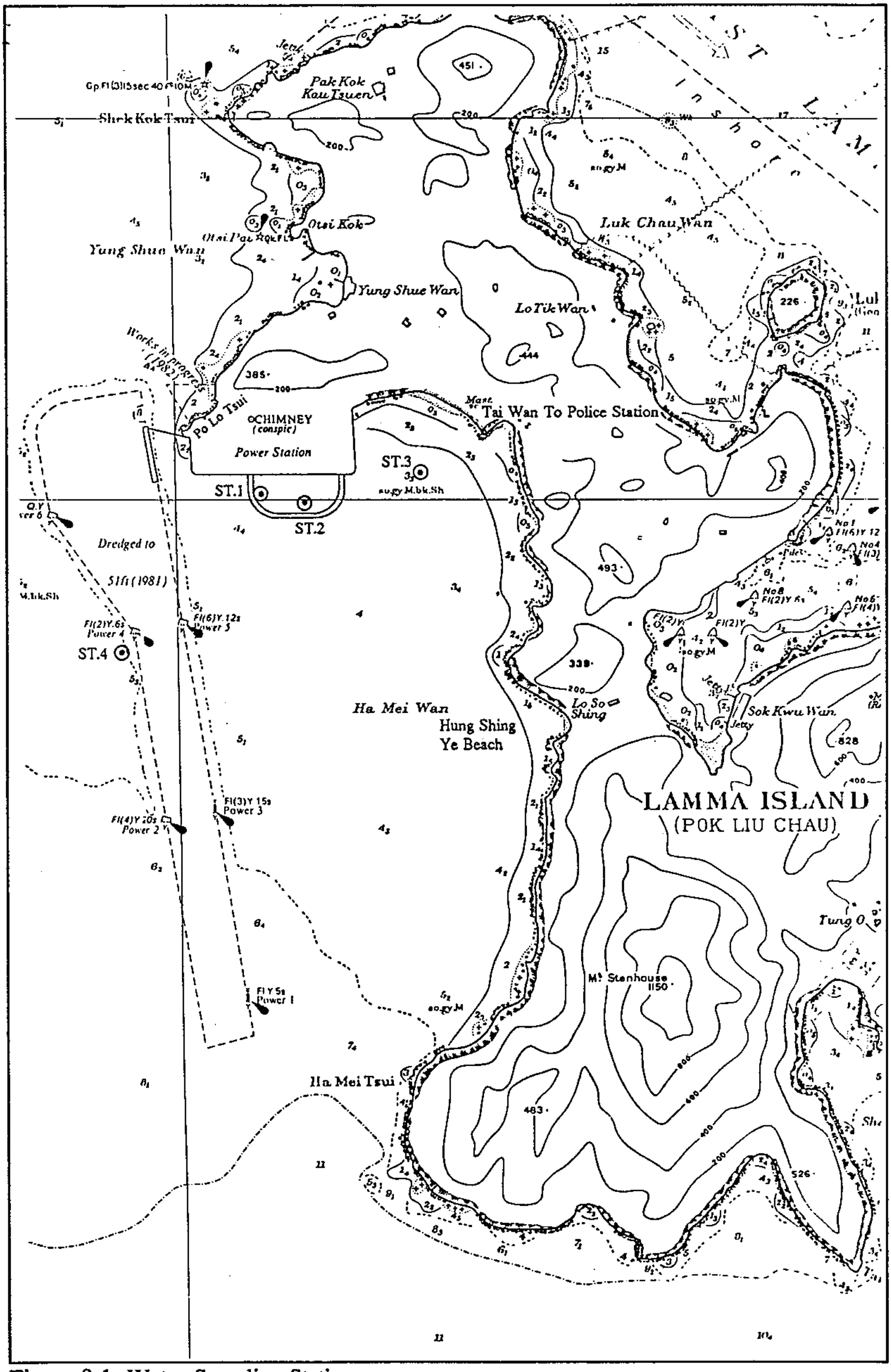


Figure 8.1 Water Sampling Stations

	Sea Water Outside Lagoon	Sea Water Inside Lagoon
Physical parameters	Water depth of sampling station (m)	Water depth (m)
	Temperature (°C)	
	Dissolved Oxygen (mg/l)	pH
	pH (Unit)	
	Salinity (0/00)	
	Turbidity (NTU)	Total Suspended Solids
	Total Suspended Solids (mg/l)	
Chemical parameters	Nitrate (NO_3^--N), mg/l	
	Nitrite (NO_2^--N), mg/l	
	Orthophosphate (PO_4^{-3}-P), mg/l	
	Sulphate (SO_4^{2-}), mg/l	
	BOD_5 (mg/l)	
	COD (mg/l)	
Heavy metals (all units in μg/l)	Antimony	Antimony
	Arsenic	Arsenic
	Beryllium	Beryllium
	Boron	Boron
	Cadmium	Cadmium
	Chromium	Chromium
	Copper	Copper
		Iron
	Lead	Lead
	Mercury	Mercury
	Molybdenum	Molybdenum
	Nickel	Nickel
	Selenium	Selenium
	Silver	Silver
	Tin	Tin
	Zinc	Zinc

Table 8.1 Proposed water testing schedule

Marine biota

8.3.11 The proposed sea water monitoring programme will measure water quality near the lagoon thereby providing data for the impact assessment review. Despite this water quality monitoring, samples of shrimps are also to be caught in Ha Mei Wan to demonstrate that the lagoon does not adversely affect the local marine biota.

8.3.12 Shrimps trawled from the area are used to make shrimp sauce, thus forming a link in the food chain ultimately leading to humans. Testing of the shrimps caught in Ha Mei Wan will therefore give a measure of the impact, if any, of the ash lagoon on these organisms. Measuring heavy metal concentrations in shrimp tissue will show the extent to which the organisms are contaminated, in a manner easily understood by the general public. Since shrimps bio-accumulate heavy metals to a much lower degree than mussels, the results are expected to show that they are fit for human consumption before and during lagoon operations. Interpreting the results of monitoring shrimps is discussed in section 8.5.

8.3.13 Shrimps will be collected by trawling in Ha Mei Wan at 3 monthly intervals on two occasions before, and for the first year after PFA is placed in the lagoon. Sampling frequency after this period will depend upon the initial findings. It is proposed that each shrimp sample will be tested following the schedule shown in Table 8.2.

	Parameter of Shrimp
Physical parameter	Whole body weight (gm) Body length (mm) Moisture content (gm)
Heavy metals (all units are in μg/g and based on dry weight)	Antimony Arsenic Boron Cadmium Chromium Lead Mercury Selenium Tin

Table 8.2 Proposed shrimp testing schedule

8.3.14 Both wet and dry weights of shrimp tissue will be recorded for each shrimp before any metals analysis is carried out. The wet weights will be used for comparison with Government guidelines for acceptable metal levels in sea food which are expressed as a function of the wet weight (Food Adulteration (Metallic Contamination) Regulations Cap 132, Section 55(1)). The metals Boron and Selenium will be analysed in addition to those included in the above Regulations, because they can be released by PFA and can be used as an impact indicator.

Dust monitoring

8.3.15 A concern frequently expressed by local residents is that PFA will be dusty. Chapter 7 describes the measures designed to prevent a dust nuisance at all stages of handling and storage.

8.3.16 High volume air samplers will be used to measure total suspended particulates (TSP). These instruments draw approximately 1.5 m^3/min through a filter which collects airborne particulates. The particulates can be weighed and, if necessary, microscopically examined to ascertain whether any PFA is present.

8.3.17 At present there are two high volume air samplers associated with the power station, one is located at the east gate (about +6.0 mPD) and the other on top of reservoir road (about +48 mPD). The existing instruments and monitoring methodologies are suitable for monitoring dust emissions from the ash lagoon. Additional equipment to specifically monitor the lagoon is not considered necessary.

Noise monitoring

8.3.18 Estimates of the increase in noise levels associated with the lagoon operating system indicate that it will be insignificant at the nearest Noise Sensitive Receiver (NSR), taken to be the Tai Wan To police station (Figure 8.2).

8.3.19 The baseline noise level and any noise arising from the lagoon filling operation will be continuously measured using the equipment and methodology already employed by HEC at the Tai Wan To police station.

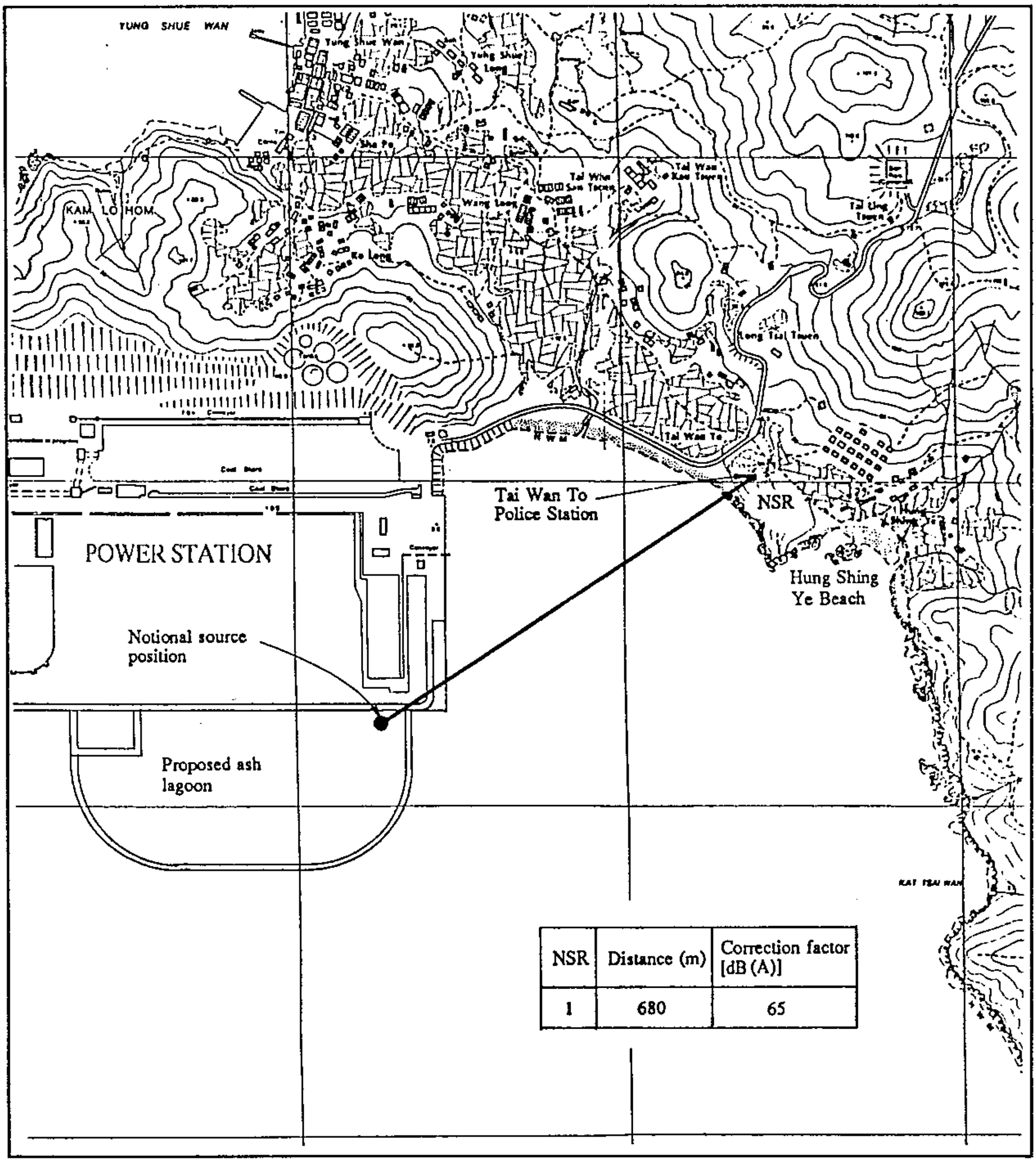
Testing Standards

8.3.20 The proposed monitoring programme involves measuring a large number of different physical and chemical parameters. The standards will be where possilble, those set down in government technical memoranda:

(i) Sound level measurements will be in accordance with the " Technical Memorandum on Noise from Construction work other than Percussive Piling. Annex - General Calibration and Measurement Procedures."

(ii) Total suspended particulates will be monitored using currently installed high volume air samplers to the standards in USEPA Standard Method 40, CFR Part 50, Appendix B

(iii) The water quality will be measured in accordance with "Technical Memorandum on Effluent Standards (Annex 1)". The sea water samples may have to be pretreated, so that the presence of large concentrations of ions in normal sea water do not mask or distort the results



NSR	Distance (m)	Correction factor [dB (A)]
1	680	65

Figure 8.2 Noise Sensitive Receiver

8.4 ACCEPTANCE CRITERIA

8.4.1 Acceptance criteria against which the measured environmental parameters (Section 8.3) will be judged, are generally those specified by the Hong Kong Government. Where local standards do not exist, criteria from other sources are proposed and are described in more detail where appropriate.

Lagoon water quality

8.4.2 There are few standards against which to judge acceptability of sea water quality in Hong Kong, and none relating to heavy metal concentrations. Some of those applicable to the monitoring programme are listed in Table 8.3 and they will help to put into perspective the results from the proposed monitoring programme. By comparing concentrations before and during lagoon operations, the impact of the facility on the environment, if any, can be assessed.

8.4.3 Although there are a number of criteria in the TM that have to be met for the discharge of effluents, a single critical criterion is proposed for monitoring, to provide a clear appreciation of the water quality in the lagoon. The nature of PFA and the solution of the soluble fractions suggest that the Total Toxic Metals would be the most critical criterion and thus form a suitable basis for control. The other determinands and criteria set in the TM could be established from samples at intervals to ensure that the system is performing well, but would not form part of the control mechanism.

8.4.4 A Total Toxic Metals upper limit criterion is proposed for the water quality that should be permitted within the lagoon. It is to be 0.1 mg/l elevation over the background ambient concentration of the seawater around Lamma. This has been chosen to mimic the criterion set in the TM (Table 10a).

8.4.5 The definition of the ambient background concentration in the sea water surrounding Lamma is to be defined as an average of the data gathered from the analysis of samples from ST4 averaged over a length of time. Although the site ST4 will be regularly flushed by the ocean waters it is likely to be stratified during certain parts of the year and will have to be accounted for in arriving at representative base line concentrations.

8.4.6 Acceptable values for the physical parameters of pH and total suspended solids (TSS) are discussed in Chapter 7. We believe that the pH of lagoon decantrate will not exceed the range 6-9 quoted in the TM (Table 10a), and therefore will not present a problem. The monitoring and auditing process will determine whether or not these limits are met, and whether the operating procedures have to be changed following the initial experience of operation.

Parameters	Typical range	Acceptable range
Temperature (°C)	17.3 - 29.5	$< \pm 2$°C from ambient
Dissolved Oxygen (mg/l)[e]		>4
pH (unit)	8.04 - 8.6	6.5 - 8.5
Salinity (0/00)	25.2 - 34.1	$< \pm 10\%$ from ambient
Turbidity (NTU)	1.8 - 15.7	<75[d]
Total Suspended Solids (mg/l)	1.8 - 16.7	$< +30\%$ from ambient
Nitrate (NO_3^--N), mg/l		<0.1
Nitrite (NO_2^--N), mg/l		<0.03[b][c]
Orthophosphate (PO_4^{3-}-P), mg/l	0.005 - 0.02	<0.16[c]
Sulphate (SO_4^{2-}), mg/l		<2710[a]
BOD_5 (mg/l)	0.3 - 2.6	<5
COD (mg/l)		<30

References

1. The acceptable range is based on the Southern Water Control Zone statement of Water Quality Objectives [Laws of Hong Kong Vol 22 (CAP 358), 1988] except (a), (b), (c), (d) and (e).

2. The typical range is based on the water quality of the west Lamma Channel in 1988 (EPD Marine Water Quality in Hong Kong, 1989).

a. Tait, R.V. (1972). Elements of Marine Ecology. London Butterworths : 73 and 81.

b. Chen, K.C. (1965). Analytical Chemistry of Sea Water. Scientific Publications, Peking : 130 and 140.

c. Goldberg E.D. (1972). A guide to Marine Pollution. Gordon and Beach Science Publishers, London.

d. Mok, M.H. (1979). "Discussion on the Standardization of Water Qualities - summary report".:91 in Conference on the Standardization of Methodology of Water Pollution (edited by Chung, M.T. and Chui, V.). Note : NTU approximate JTU but not exactly the same.

e. Arithmetic mean of at least 3 measurements at 1 metre below water surface, mid-depth and 1 metre above seabed.

Table 8.3 Expected sea water quality

Marine biota

8.4.7 The Hong Kong Government provides standards for acceptable metal levels in sea food as shown in Table 8.4. These standards are applicable to the shrimp monitoring. Samples of shrimps will be digested before analysis, according to the procedure described in "Standard Methods for the Examination of Water and Waste Water" 17th Edition, APHA, AWWA, WPCF or similar international standard method.

Metal	Concentration (ppm)
Antimony	1
Arsenic	10
Cadmium	2
Chromium	1
Lead	6
Mercury	0.5
Tin	230

Notes: All units expressed as wet weight

Table 8.4 Permitted metal levels in shellfish

Dust

8.4.8 Acceptable levels for total suspended particulates are specified by the Hong Kong Government in the Air Pollution Control Ordinance. The limits for total suspended particulates are as follows:

(i) the concentration of total suspended particulates in air averaged over any 24 hour period shall not exceed 260 microgrammes per cubic metre more than once a year

(ii) the concentration of total suspended particulates in air averaged over a year shall not exceed 80 microgrammes per cubic metre

8.4.9 Measuring dust concentrations at the existing monitoring locations will provide details of general dust emissions from the power station site as a whole and not specifically from the ash lagoon. It is not possible to monitor the lagoon alone, since wind changes could carry dust from outside sources to a monitoring instrument placed anywhere around the lagoon perimeter.

Noise

8.4.10 Acceptable noise levels arising from lagoon filling, classified as an industrial operation, are governed by the 1988 Noise Control Ordinance. Following the procedures set out in this ordinance the Acceptable Noise Levels (ANLs) for the principal Noise Sensitive Receiver (NSR), the Tai Wan To police station, are listed below for working days. For planning purposes, a negative correction factor of 5 dB(A) has been applied to the ANL because the NSR is a building.

Time Period	ANL dB(A)
All days during the night-time (2300 to 0700 hours)	45
All days (0700 to 1900 hours) and evenings (1900 to 2300 hours)	55

8.5 CONTROL PROCEDURES

8.5.1 A clearly defined reporting procedure is necessary to ensure the monitoring results are available as soon as possible to personnel controlling the operating systems. The main aspect of lagoon operation which needs to be controlled is the decantrate pumping system, although changes will occur slowly. The other possible effect is that of dust which may arise rapidly but can also be rectified rapidly through the sprinkler system.

Decantrate pumping

8.5.2 The decantrate pumping system has been proposed to control the lagoon water level and water quality. Decantrate will be discharged via the cooling water outlet to the open sea, and must therefore comply with the criteria given the TM.

8.5.3 Initially the rate at which water quality in the lagoon will discharged is to be 20,000 m^3/day and any change will occur relatively slowly during the early life of the lagoon.

8.5.4 Decantrate pumped out of the lagoon and discharged with the cooling water, would normally be replaced by seepage through the embankment. Should this prove an insufficient means of replacing the lagoon water particularly in the later stages of the lagoon operation, sea water could be pumped into the lagoon through the emergency sluicing system. Sufficient water will be exchanged to ensure that the decantrate quality will not exceed the maximum permitted levels before the next sampling occasion, due consideration being given to past and future rates of ash placement. Commissioning trials and operations in the early life of the lagoon will be carried out to optimise the use of the decantrate system.

8.5.5 It should not be necessary to control pH within the ash lagoon by operating the decantrate pumps (Chapter 7).

8.5.6 Total suspended solid concentrations will not be regulated by pumping since this parameter, unlike pH or metal concentrations, is not influenced solely by the ash to water ratio. Increases in TSS will occur due to emergency sluicing of ash to the lagoon and then decrease when sluicing ceases due to sedimentation. The daily discharge can be suspended until the TSS decreases.

8.5.7 Should the seawater quality outside the lagoon prove to be outside the criteria set and unacceptable the decantrate system will be used to improve the quality of the seepage and therefore reduce the load of determinands to the bay. The general flushing action of the currents around the bay, and particularly the gyre (Appendix A) which takes waters out to the West Lamma Channel, will restore the water quality in the bay.

Dust suppression

8.5.8 The various dust suppression techniques (Section 7) are intended to prevent a dust nuisance arising. However the measures are also sufficiently comprehensive and flexible to mitigate an impact should it arise from the handling and storing of PFA. These measures range from water sprinkler systems to soil cover and vegetation, and are intended to prevent any form of dust nuisance occurring, rather than suppressing one which has developed.

Reporting procedure

8.5.9 Results from the environmental monitoring will be available soon after sampling, a reporting period of less than 2 weeks will be aimed at. This data will pass quickly through clearly defined channels to the person responsible for the lagoon operating system. In this way, any potentially unacceptable situations will be detected at an early stage, and preventive measures can be taken. Regular monitoring and operating summaries will be submitted to EPD.

8.6 ENVIRONMENTAL AUDIT

8.6.1 The environmental audit system is intended to check methodically that the activities of the project complying with previously defined environmental requirements and predictions, and that the necessary remedial measures are identified to remedy any unacceptable or unforeseen environmental impacts. Environmental auditing is a check to reassure management and regulatory agencies, that the facilities are being operated in an environmentally acceptable manner. It also enables a post project analysis to be carried out to examine the accuracy of the original environmental impact assessment.

Environmental auditor

8.6.2 HEC staff have satisfactorily monitored their own operations under the auspices of EPD for a number of years. They have the necessary expertise to review the methods and philosophy behind the monitoring programme, consequently HEC are proposed as the environmental auditor, to operate under a similar arrangement with EPD.

Auditing frequency

8.6.3 Auditing frequency will be related to a number of factors, such as rate of data collection and ash deposition. Audits will be carried out at 6 monthly intervals for the first year after ash is placed in the lagoon and thereafter at 12 monthly intervals so that the monitoring programme can be updated to take account of any changing environmental impacts. This frequency will be reviewed and revised as necessary as part of the audit process.

8.6.4 Environmental audits will be necessary throughout the operating life of the lagoon and for a period after operations have ceased . Environmental auditing will be considered as a long term exercise, but the auditing system would propose that the monitoring be suspended when the monitored environmental effects are within acceptable limits and are stable or decreasing.

Scope of the audit

8.6.5 The auditors will be familiar with the philosophy behind the lagoon operating system design, environmental impacts and control procedures. The following points will be considered, as appropriate, for each of the four environmental impacts identified in Section 8.3, namely, sea water quality inside and outside the lagoon, marine biota, dust and noise. The audit will:

(i) check that the approved sampling procedures and analytical techniques were used to assess the quality of the collected data

(ii) consider tidal, wind and weather conditions where appropriate at the time of sampling. These factors may influence sea water quality, dust monitoring and noise monitoring respectively

(iii) ascertain whether any extraneous activities, unrelated to lagoon operating, may have influenced the data. Factors such as dredging, or building works for example adjacent to monitoring sites will be considered

(iv) ascertain what activities or operations were taking place at the lagoon before or during the sampling period. For example whether was decantrate being discharged, or the operational status of the dust suppression system

(v) review the collected data, in the light of the preceding information, to identify any events which did not comply with the acceptance criteria, or the identification of trends which may lead to non compliance and why they did not comply

(vi) recommend measures to change any unacceptable impacts, so that they become acceptable and identify trends which may result in an unacceptable impact

(vii) review impacts that cannot be quantified and for which there are no absolute acceptance criteria such as visual impact

(viii) consider any complaints or reactions from the general public relating to the lagoon operating system. If appropriate, recommend suitable actions which could be taken

(ix) review and revise if necessary the monitoring philosophy, in terms of sampling location, frequency, parameters measured, test methods, acceptance criteria and control procedures

(x) revise the scope and frequency of the auditing system to reflect changes in environmental impacts and lagoon operating procedures

(xi) carry out a post project analysis to compare the environmental impacts predicted in the EIA, with actual impacts. Comment on any discrepancies and make recommendations as appropriate

Reporting procedures

8.6.6 A report will be produced by the auditors after each inspection. The report will provide HEC management and EPD with information about compliance status of the lagoon operating system and will review the earlier stages of the Environmental Impact Assessment. It will, in addition, indicate any operational changes which should be made to monitoring and control procedures.

8.7 CONCLUSIONS

8.7.1 The environmental audit process is to be a methodical framework within which the environmental monitoring and control procedures can be assessed and altered where necessary, to ensure that environmental criteria for the lagoon operations are maintained. The form of the audit is intended to be flexible such that it can be altered through the life of the of the project to addresses relevant issues or trends as they became apparent.

8.7.2 The monitoring programme is an integral part of the audit process providing information for decisions and procedures within the audit. The monitoring programme will be controlled by the audit and will also be flexible to allow it to adapt to the requirements of the audit. The proposed monitoring programme covers those criteria that will be used for the assessment of the effectiveness of the installed environmental measures and for the correct application of control procedures. The programme is to monitor water quality, dust and noise.

8.7.3 The monitoring of water quality within the lagoon, the decantrate and in Ha Mei Wan is based on the concentrations of Total Toxic Metals (TM) which is to be used as part of the control mechanism for the water quality control. This does not obviate the need for monitoring other parameters for compliance with effluent licence agreements to be entered into with regulatory authorities. The water quality within the lagoon is to be controlled by regular pumping through the decantrate system to the cooling water outfall. The effectiveness of this procedure is to be assessed within the audit process and should the regular flow be inappropriate, the rate can be adjusted to redress the balance.

8.7.4 Other effects to be monitored are those on dust and noise levels. Various preventative measures have been included in the proposals to mitigate impacts and the assessments of the effects indicate that they should fall within the relevant criteria. Should the audit process prove that they, in the event fall outside the criteria the working practices can be adjusted to redress the balance.

8.7.5 The monitoring of the shrimps in Ha Mei Wan has been included in the proposals to provide a bio-indicator of the water quality which is easily appreciated by the public.

8.7.6 Two audits will be carried out in the first year and annually thereafter. The regular audits will be carried out following the cessation of the PFA filling operation and are expected to identify trends in which impacts will stabilise or progressively reduce. Once this status has been reached the audit may recommend the reduction in frequency or suspension of monitoring procedures and the eventual suspension of the environmental audit process. At this time the accuracy of the environmental impact assessment can be appraised.

Appendix 1 TERMINOLOGY

Definition of the terminology used:

Baseline monitoring - the measurement of environmental parameters during a representative pre-project period in order to determine the nature and ranges of natural variation and to establish the nature of change.

Environmental monitoring - the systematic measurement of parameters during project implementation so as to detect changes in those parameters which can be attributed to the project. The parameters monitored are those which were identified during the Environmental Impact Assessment (EIA) stage as being likely to be affected by the project.

Environmental auditing - the methodical examination of procedures and practices to verify compliance with predetermined environmental requirements or accepted practices.

Post project analysis - the comparison of the predicted environmental impact of a project, as described in the Initial Assessment Report and Detailed Assessment Report, with the observed impacts monitored in the field. This analysis can improve the scientific and technical understanding of EIA, and the effectiveness of the methodologies.

CHAPTER 9

CONCLUSIONS

9.0 CONCLUSIONS

9.0.1 Prior to this third stage of the environmental impact assessment of the Ash Management Study for The Hongkong Electric Company Limited, various options for the disposal of PFA were explored in the Initial Assessment Report (1989) (IAR). The IAR concluded that a lagoon adjacent to the power station should be an integral, and key, element of the strategy. The preferred sites were designated P and Q, subsequent to this a 1.5 Mm^3 capacity lagoon on site Q was adopted.

9.0.2 The third stage of the EIA has developed a preliminary design of the Lagoon structure and its operating systems. These proposals have taken due regard of the environmental effects of both the likely construction techniques and the operational activities throughout the facility's life. Various measures have been incorporated into the design to reduce the expected impacts to within environmental criteria. Where possible these criteria are quantified and measurable. Many derive from Government Ordinances, regulations or standards. However where none exist, others from around the world have been suggested, or subjective judgements made where necessary.

9.0.3 Of all the options considered for the form of the Lagoon perimeter, the embankment has the greater number of advantages, although the caisson wall with revetment is comparable. Thus the majority of the discussion centres around this option although much of it is equally applicable to the alternative.

9.0.4 All the issues identified for this third stage of the EIA have been addressed and the effects are likely to fall within generally accepted criteria for the environment. The local community on Lamma give the impression that the need for a lagoon is accepted although some concerns remain. This report has readdressed these concerns, relating to subjects such as dust control and effects on tourism.

9.0.5 The construction of the lagoon will take about two years and environmental audits will be carried out at 6 month intervals. The capacity of the lagoon is suitable for about six to eight years of PFA production. However the eventual period of active PFA filling will be determined by the demand for PFA from industry and land filling sites. Two environmental audits will be carried out in the first year and then annually for the period of the filling operation. Following the cessation of the filling operation the regular audits will continue until the impacts are stable or are steadily reducing, at which point an appraisal of the environmental impact assessment can be carried out.

9.0.5 Given that a lagoon has been found to be necessary for the provision of an element in the PFA disposal strategy, the proposals for an embankment present the least impact and various measures are to be instituted to reduce to a minimum those that do exist. A methodical assessment of the EIA and the performance of the lagoon is to be provided by instituting an environmental monitoring and audit system. This is to be carried out during both the construction and operational phases of the lagoon. The auditing system will not only provide affirmation of the expected performance of the lagoon, but also identify transgressions of criteria and institute remedial measures to rectify the situations should they arise.

APPENDIX A

HYDRODYNAMIC MODEL

LAMMA ISLAND POWER STATION ASH LAGOON HYDRODYNAMIC MODEL

CONTENTS

SECTION		PAGE
1	INTRODUCTION Introduction Scope of the study	A 1
2	LAMMA ISLAND Topography Flow patterns	A 2
3	FLOW SIMULATION DIVAST model WAHMO models Extent of the DIVAST model	A 3
4	DATA EXTRACTION Bathymetric data Boundary conditions	A 4
5	MODEL CALIBRATION Method of calibration Comparison with WAHMO results Observed data	A 5
6	FLOW SIMULATION RESULTS Existing flow patterns Hydrodynamic effects of lagoon construction	A 10
7	SEDIMENTATION EFFECTS Bed composition Method of simulation Sedimentation results	A 12
8	LEACHATE SIMULATIONS Modelling of leachates Leachate results	A 13
9	CONCLUSIONS	A 16
REFERENCES		A 17
APPENDIX 1	DESCRIPTION OF THE DIVAST MODEL	A 18

FIGURES

Figure 1 Lamma Island

Figure 2 Location of Model Boundaries and Calibration Points

Figure 3 Velocity Calibration Curves - Neap Tide - Point 1

Figure 4 Velocity Calibration Curves - Neap Tide - Point 2

Figure 5 Velocity Calibration Curves - Neap Tide - Point 3

Figure 6 Velocity Calibration Curves - Spring Tide - Point 1

Figure 7 Velocity Calibration Curves - Spring Tide - Point 2

Figure 8 Velocity Calibration Curves - Spring Tide - Point 31

Figure 9 Flow Patterns at Times of Maximum Flow (by WAHMO)

Figure 10 Maximum Ebb Flows - Spring Tide

Figure 11 Maximum Flood Flows - Spring Tide

Figure 12 Maximum Ebb Flows - Neap Tide

Figure 13 Maximum Flood Flows - Neap Tide

Figure 14 Gyre as Reproduced by DIVAST Model

Figure 15 Flow Residuals - No Lagoon - Spring Tide

Figure 16 Flow Residuals - Lagoon - Spring Tide

Figure 17 Flow Residuals - No Lagoon - Neap Tide

Figure 18 Flow Residuals - Lagoon - Neap Tide

Figure 19 Maximum Shear Stress - No Lagoon - Spring Tide

Figure 20 Maximum Shear Stress - Lagoon - Spring Tide

Figure 21 Maximum Shear Stress - No Lagoon - Neap Tide

Figure 22 Maximum Shear Stress - Lagoon - Neap Tide

Figure 23 Seepage of Leachate from Lagoon Q

Figure 24 Envelope of Maximum Leachate Concentrations - Spring Tide

Figure 25 Envelope of Minimum Leachate Concentrations - Spring Tide

Figure 26 Envelope of Maximum Leachate Concentrations - Neap Tide

Figure 27 Envelope of Minimum Leachate Concentrations - Neap Tide

Figure 28 Envelope of Average Leachate Concentrations - Spring Tide

Figure 29 Envelope of Average Leachate Concentrations - Neap Tide

1. INTRODUCTION

Introduction

1.1 Lamma Island is situated immediately south-west of Hong Kong Island, in the South China Sea. On the west coast of the island, the construction of Hongkong Electric Company's power station has involved the reclamation of an area at the northern end of Ha Mei Wan Bay. It is proposed that an ash lagoon is constructed adjacent to the original reclamation. The selection of this site, 'Q', has followed detailed environemtnal impact assessment. The location of Lagoon site 'Q' is shown in Figure 1.

1.2 The flow patterns observed at Lamma Island are complex. There is a strong nrotherly longshore drift throughout the bay. A gyre forms during the ebb tide in the northern part of the bay, limiting the flushing of the bay.

1.3 The proposed lagoon will affect the hydrodynamic conditions within the adjacent waters. As a result, sedimentation patterns within the bay may be altered. In addition, any seepage of leachates through the lagoon embankments may cause some pollution in the area.

1.4 To review these effects, a detailed assessment of the hydrodynamic conditions along the west coast of Lamma Island has been carried out. A two-dimensional mathematical model was constructed to simulate the flow characteristics encountered in the area. This model used boundary conditions derived from the WAHMO hydrodynamic model. In the following report, the results of the study are summarized.

Scope of the Study

1.5 The main aims of the study have been:

(i) to simulate the existing flow patterns along the western coast of Lamma Island, using boundary conditions derived from the WAHMO hydrodynamic model

(ii) to determine the hydrodynamic effects of introducing a coastal ash lagoon at the proposed site

(iii) to predict the distribution of leachates as they are diluted and dispersed

(iv) to evaluate any potential deposition or erosion of sediment caused by modified flow conditions in the bay

2. LAMMA ISLAND

Topography

2.1 Typical of the islands around Hong Kong, Lamma Island has a relatively abrupt shoreline. The sea bed slopes away steeply, with water depths exceeding 20 metres commonly encountered within 500 metres of the shoreline. However, deposition of sediments has occurred in the relatively slack waters of Ha Mei Wan Bay, and a small beach has formed at the northern end of the bay.

Flow Patterns

2.2 The tidal range is of the order of 2 metres during an average spring tide, and 1 metre for a neap tide. In common with the rest of Hong Kong, the tides are mixed diurnal and semi-diurnal tides.

2.3 The flow patterns observed at Lamma Island are complex. The flood tide advances from the south-east, filling the bay and causing a strong northerly longshore drift throughout the bay. During the ebb tide, a gyre forms in the northern part of the bay, causing circulation of the water within the bay. The presence of a dredged channel to the west of the bay further complicates flow patterns.

3. FLOW SIMULATION

DIVAST Model

3.1 A hydrodynamic model of the flow patterns in the area was developed using the DIVAST (Depth Integrated Velocities and Solute Transport) flow simulation model (Reference 1).

3.2 The program was originally developed by Professor Falconer at Birmingham University. Since 1981, Binnie and Partners have used the model extensively, being involved in further development work. The program uses two-dimensional modelling techniques to predict the depth-averaged flow patterns encountered in estuaries, lakes and coastal waters. A flow field is modelled by constructing a grid of data, representing the bed topography. The initial conditions and boundary conditions are specified using preselected hydrodynamic data, for example, tidal records at a given location. The model then computes the water level and discharge in each cell, as these values vary throughout the tidal cycle. For the defined flow field, the program can be used to predict:

(i) circulation in and flushing from harbours and reservoirs

(ii) water temperature rise due to discharge of cooling water

(iii) dispersion of pollutants, resulting from discharge of sewage and industrial effluent

(iv) sediment transport characteristics

(v) eddy shedding from obstructions

3.3 A more detailed description of the DIVAST program is included in Appendix 1 of this report.

3.4 The program has been continuously developed, and was updated in November 1989 for the purpose of the present study. Modifications were made to the method of input of boundary data, for both hydrodynamic conditions and discharge of pollutants.

3.5 B&P have used the DIVAST model for a wide range of flow and quality simulations. Some recent studies have included:

(i) Poole Harbour, UK, simulation of sewage works outfalls

(ii) Humber estuary, UK, simulation of tidal power barrage, with sedimentation effects and power generation

(iii) Deep Bay, Hong Kong, simulation of water movement and pollution due to dredged spoil

(iv) R. Indus, Pakistan, simulation of water movement and sedimentation at major irrigation intake barrage

In all cases, successful calibration and validation of the models have been carried out, giving high confidence in the formulation and performance of the DIVAST model.

WAHMO Models

3.6 The WAHMO suite of computer programs were developed by Binnie & Partners, Hydraulics Research Limited and the Water Research Centre for the Urban Area Development Office of the Territory Development Department. The programs reproduce the existing hydraulic and water quality conditions in Victoria Harbour and can simulate the effects of proposed future developments (Reference 2).

3.7 The area covered by the WAHMO models includes the west Lamma area, which is of particular interest to this study. Results from the WAHMO models were obtained from the Environmental Protection Department for use as boundary conditions to the DIVAST model.

3.8 The WAHMO model used to obtain these boundary conditions was the Global Intertidal water movement model (Reference 3). This is a depth averaged 2-D flow model of similar formulation to DIVAST. This model includes all Hong Kong Territorial waters and the whole of the Pearl river estuary. The calculations are performed on a 750 m grid in the outer area and a 250 m grid on the inner area. The two grids are dynamically linked together. The west Lamma area lies within the 250 m grid portion of the WAHMO model.

3.9 The calibration of the WAHMO model is reported in detail in Reference 3. Although the degree of correspondence between model and observations varied, good simulations of tidal flows were achieved in the East and West Lamma Channels and to the west of Hong Kong Island. These areas are of particular interest to this study, and the good calibration achieved indicates that the WAHMO results may be used with confidence.

Extent of the DIVAST Model

3.10 The extent of the model constructed for this study was limited to an area of approximately 50 square kilometres along the western coast of the island, as illustrated in Figure 2. Results from the WAHMO model indicated that the predominant flow direction along the western coast of Lamma Island runs approximately from north to south. It was considered that the chosen location of the model boundaries was not likely to produce undue constraints on the flow patterns within the model, since they were located far enough from the area of interest around Ha Mei Wan Bay.

3.11 A grid size of 83.33 metres was adopted throughout the model. This value was chosen to give good definition of the coastline, the dredged channel and the proposed lagoon. The grid size is a reduced by a factor three from the WAHMO 250 m grid used to generate the boundary conditions; this procedure is considered good modelling practice for nested models.

3.12 The advantages of aligning the model grid with the dredged channel were investigated. It was concluded that the grid adopted would correctly model water movements across the channel whatever grid alignment was chosen, due to the small size of the grid compared with the width of the channel. A grid orientation of 30 degrees from north was finally adopted, since it:

(i) gave best flow conditions at the main flow boundaries

(ii) was identical to that used in the WAHMO model, simplifying data transfer

4. DATA EXTRACTION

Bathymetric Data

4.1 The bathymetry of the area was digitized into a digital terrain model using the industry standard MOSS computer program, with depth readings from Admiralty Charts of the area as data. Details of the dredged channel were confirmed using an as-built plan supplied by HEC. Details of the dredging carried out early in 1990 in the channel were not available for the study. The position of the grid was determined in UTM (Universal Transverse Mercator projection) co-ordinates and transformed to Hong Kong grid co-ordinates using triangulation data.

4.2 Depth data at the grid nodes were produced by interpolation from the digitized bathymetric model.

Boundary Conditions

4.3 Before the equations for the mathematical model can be solved, the boundary conditions around the edge of the model must be known. There are three possible ways of defining the limits of the model, these being closed boundaries, known discharge open boundaries and known level open boundaries.

4.4 For the present study the boundary conditions were compiled from tidal data generated by the WAHMO model. The data available consists of simulated velocities and water surface elevations for typical repeating spring and neap tides. For the area under investigation, data were available at 250 metre intervals, and at 20 minute intervals throughout the tidal cycle. Tests were carried out from low water to low water, with a 12.67 hours simulation for the neap tide, and 25 hours for the spring tide, as in the WAHMO model.

4.5 In view of the predominant flow directions, the boundary conditions were initially applied as follows:

(i) a water surface elevation was imposed along the north-western boundary, as the flow was, in general, approximately parallel to the boundary

(ii) the flow normal to the boundary was imposed at the north-eastern and south-western limits of the model. In this case, the remaining component of flow was computed within the model. The flow parallel to the boundary was considered to be of secondary importance

(iii) on the south-eastern boundaries, water surface elevation was initially imposed. However, problems due to numerical instabilities close to the boundary prompted a change in boundary conditions. By replacing the elevation data with flow normal to the boundary, the instabilities were eliminated. No alternation was made to the original position of the boundaries

4.6 The locations of the open flow and elevation boundaries are shown in Figure 2.

4.7 For all open boundaries, the appropriate value of flow or elevation was computed by linear interpolation between the WAHMO output data. Similarly, boundary conditions at each timestep were determined by linear interpolation throughout the tidal cycle.

4.8 The initial conditions were also determined using output from the WAHMO model. The average value of water surface elevation was calculated at the beginning of the tidal cycle, and imposed across the entire model. The model was then allowed to run through an initial tidal cycle, in order to achieve a dynamic starting condition for the predictive runs.

5. MODEL CALIBRATION

Method of Calibration

5.1 The accuracy of the simulations was primarily assessed by comparison with those generated in the WAHMO model, and some float tracks and observed data. No tidal records were available for the area immediately off the coast of Lamma Island. However, the calibration of the WAHMO model against recorded data from nearby locations indicates that a reasonable level of accuracy was achieved by the WAHMO models and that the reliability of the results adjacent to Lammo is similarly acceptable.

5.2 After a number of tests, a bed friction factor of k_s = 200 mm and an eddy viscocity of 10 m^2/s were adopted throughout the model. These values were identical to that used in the WAHMO model of the surrounding area. The DIVAST model was found to be relatively insensitive to changes these parameters.

5.3 Using the Courant condition for stability, a timestep of 24 seconds was found to be suitable for computations. In an attempt to reduce computation time, the possibility of increasing the timestep was investigated. However, the results were not acceptable, due to the production of numerical instabilities within the model.

Comparison with WAHMO Results

5.4 Calibration points were chosen at three locations within the model, as shown in Figure 2. Two of these points lay outside of the bay and the deep water dredged channel; the third lay within the shallow bay.

5.5 For the neap tide, the simulated velocities at points 1 and 2 are very similar to those predicted by the WAHMO model. This is seen to be the case for both components of velocity. For point 3, located within Ha Mei Wan Bay, some differences are evident, especially towards the end of the tidal cycle. Some minor irregularities in the graphical output are due to rounding effects in the veloctiy outputs, and do not indicate any major disagreement between the models. the velocity calibrations are shown in Figures 3 to 5.

5.6 Similar agreement is found in the spring tide calibrations at points 1, 2 and 3. Again, the comparison for point 3 shows some differences. The velocity calibrations are shown in Figires 6 to 8. For both the neap and spring tides, differences between the two models are primarily due to the increased grid resolution, and hence the accuracy of the DIVAST model. In the model constructed for the present study, the representation of the dredged channel and the bay are significantly more accurate than the WAHMO data. Simulated flows in this area are sensitive to any changes in bathymetry. Current refraction, which aligns the tidal current with the deep water zone of the dredged channel, is more pronounced in the DIVAST model than in the WAHMO output. In the bay, large changes in flow direction occur over a small distance. Phase lags also differ between the two models. It is considered that, in general, the new values are more accurate than those computed in the WAHMO model.

5.7 Water surface elevations compared well between models throughout the area modelled for both tidal conditions investigated.

5.8 A comparison of velocities near the boundaries was also carried out. These agreed less well, especially in the velocity component parallel to the boundary. These effects die out within several grid cells of the boundary, and appear to be non-existent in the area of interest. The existence of irregularities close to the boundaries is associated with nested models and is also observed in the linked models of the WAHMO suite. The effect is illustrated on the south-western boundary of the Lamma model, where the boundary conditions are affected by the proximity of the transition, in the WAHMO model, from a 250 metre grid to a 750 metre grid.

5.9 A further check against the WAHMO results was carried out by plotting flow snapshots at peak flows in the flood and ebb, and comparing them with the results presented in the WAHMO reports. The WAHMO model results are presented in Figure 9, and the DIVAST results in Figures 10 to 13. Despite the small scale of the WAHMO plots, it can be seen that there is a close correspondence between the two models.

Observed Data

5.10 Observations and aerial photographs show that during the ebb tide, a gyre forms in the northern end of the bay, causing circulation of the water within the bay. The DIVAST model was found to reproduce this gyre, as shown in Figure 14.

5.11 Float track data were also available from earlier studies of the area. These tracks were examined closely to see whether they could be directly used as part of the calibration process. However, they could not be used, since corresponding tide data were not available. It was noted that the model water movement results were generally consistent with the float tracks, showing a main north-south track on both ebb and flood, but a tendency for flows close the shore line at the power station to curl into the northern part of the bay during the ebb tide. The best guide to model performance was, however, still considered to be the close correspondence with the validated WAHMO models.

6. FLOW SIMULATION RESULTS

Existing Flow Patterns

6.1 The flow simulations carried out have revealed the predominant flow patterns along the western shore of Lamma Island. The main features may be summarized as follows:

(i) the predominant flow direction is approximately north-south, with considerable velocities generated close to headlands

(ii) the circulation in the northern part of the bay has been reproduced by the model

(iii) flows at the upper northern end of the bay are small in magnitude, irrespective of the phase in the tidal cycle

(iv) in the vicinity of the dredged channel, the deep water exerts a refractive effect on the flow

Hydrodynamic Effects of Lagoon Construction

6.2 In order to assess the hydrodynamic effects of introducing a coastal lagoon, the following test conditions were examined:

(i) neap tide, with and without lagoon included

(ii) spring tide, with and without lagoon included

6.3 The changes in hydrodynamic conditions were assessed both by comparison of time snapshots and by consideration of flow residuals before and after lagoon construction. The comparison of flow snapshots at a particular time had to be interpreted with care, since the lagoon was found to have some small effect on the phasing and timing of flows, as well as their absolute values. However, it could be generally concluded that:

(i) flow patterns in the north of the bay were changed by the lagoon reclamation partially enclosing this area, velocities being slightly reduced

(ii) some minor changes in flow patterns were seen in the inner centre of the bay, but were not of sufficient magnitude to be of concern

(iii) no significant pattern changes were found in the south and outer bay areas

6.4 The results from flow residual calculations are shown in Figures 15 to 18. Again, it can be seen that the only significant changes are in the immediate vicinity of the lagoon, particularly in the north of the bay.

6.5 Some concern had been expressed that the presence of the lagoon could constrict flow to the eastern cooling water intake to the power station. The DIVAST model cannot predict any localised effects at the intake that are of smaller definition than the model grid size. However, it was concluded that the patterns of flow off shore of the intake were little changed, and should not affect its operation.

7. SEDIMENTATION EFFECTS

Bed Composition

7.1 The WAHMO studies (Reference 4) and the earlier Ash Lagoon Environmental Impact Study (Reference 5) give the following information concerning sediment in the west Lamma and Ha Mei Wan bay areas:

(i) the predominant supply of sediment is silt from the Pearl River

(ii) within Ha Mei Wan bay, silt and clay are overlayed in places by fine sands

(iii) the beach in Ha Mei Wan bay is a deposited ribbon of sand

Method of Simulation

7.2 In view of the above details of bed composition, a method of simulation was required that reflected the high percentage of fine silts and clays. It was therefore decided to use maximum shear stress as the indicator for changes in the sediment regime. After running the model spring and neap tides, with and without the lagoon, the results were examined for areas of high and low shear stress. In general, stresses above 0.3 N/m^2 indicate areas of potential erosion, whilst stresses below 0.1 N/m^2 indicate areas of potential deposition.

Sedimentation Results

7.3 The results from the simulation showed that the potential areas of erosion within the model lay in the main flow channels off shore from the island. All of inner Ha Mei Wan bay, and some of the outer bay, is a potential deposition zone. This conclusion is in agreement with findings of the WAHMO sediment models (Reference 4). It should also be noted that there are major seasonal variations of sediment load from the Pearl river.

7.4 The simulation further showed that the changes in shear stress in the bay due to construction of the lagoon would be restricted to its immediate area. Figures 19 to 22 show the results from the shear stress runs for this area at the northern head of the bay. It should be noted that in the area of change, most shear stresses are less than 0.2 N/m^2.

7.5 It is concluded that the only changes to sedimentation of the bay will occur at its northern head, where shear stresses are reduced. This will marginally increase deposition in the area partially enclosed by the lagoon. However, flow velocities and shear stresses in the bay are so small that any such change will be very gradual.

7.6 The build up of sediments in the bay will continue to be influenced by storm wave activity. Changes to the sedimentation patterns in the bay will be more closely linked to any changes in wave climate brought about by construction of the lagoon, than to changes in tidal current.

8. LEACHATE SIMULATIONS

Modelling of Leachate

8.1 The dispersion of solutes from the proposed lagoon was modelled using the predicted flow patterns from the DIVAST model. The convection and dispersion processes taking place within the solute model are generally slower than the equivalent hydrodynamic processes. The timestep for analysis may therefore be increased to an upper limit of the time for flow to traverse any grid cell in the model. For the Lamma model, a timestep of 2 minutes was used.

8.2 For the conditions under investigation, it was assumed that no sources of pollutants exist other than that at the lagoon. The leachate was assumed to be a conservative substance, undergoing no decay or chamical change, in the model. At the model boundaries, dispersion was permitted in the outward direction only, with no return of solutes from outside the model. The model results indicated that concentrations at boundary were minimal and that this assumption was adequate.

8.3 Figure 23 illustrates the estimated flow of pollutants from the lagoon. It has been assumed that seepage will occur only on the ebb tide, and also that seepage will take place purely as a function of the hydrostatic head across the embankment. For the purpose of the model, several simplifying assumptions were made:

(i) no phase lag exists between the ebbing of the tide outside the lagoon, and the onset of seepage through the embankment

(ii) seepage continues as a discharge of effluent at a constant rate throughout the ebb tide

(iii) the concentration of effluent is constant, any may be represented by introducing a mass of pollutant into the model

(iv) the majority of seepage occurs at either end of the lagoon, and that the quantity of solute released into Ha Mei Wan Bay from other sources is negligible

Further details are given in a separate working paper entitled "Lagoon shape and form".

8.4 The accumulation and dispersion of pollutants was therefore modelled by introducing two leachate sources, one at either end of the lagoon. The quantity of solute released was adjusted to give the estimated daily discharge. Further details are given in an accompanying working paper entitled "The effects of lagoon operating". Dispersion coefficients used were either consistent with the WAHMO model or proven values used within DIVAST during previous studies. Parameters used in the simulation of the conservative leachate were:

(i)	Mass of heavy metals released daily:	14.46 kg
(ii)	Total metal concentration in leachate:	0.23 mg/l
(iii)	Longitudinal dispersion coefficient:	5.93 m^2/s
(iv)	Lateral turbulent dispersion coefficient:	0.15 m^2/s
(v)	Wind induced dispersion coefficient:	1.40 m^2/s

8.5 The leachate model was allowed to run for a number of tidal cycles until the concentrations had converged. This was normally achieved after a period of four days had been modelled.

Leachate Results

8.6 The envelope of maximum and minimum leachate concentrations during spring and neap tide cycles are shown in Figures 24 to 27. The leachate is flushed from the bay better by the stronger flows of the spring tide than the neap tide. It can be seen that concentrations in the north of the bay are mostly below 5 microgram/litre at all stages in the tide. For both spring and neap tides some accumulation of leachate is likely to occur, but only within the northern head of the bay. Typical leachate levels are summarized in Table 1.

8.7 Envelopes of tidal average leachate concentrations during spring and neap tide cycle are shown in Figures 28 and 29. These values represent the continuing pollutant levels in the bay that may be absorbed by marine life. Typical levels are again summarized in Table 1. The average levels in the northern part of the bay represent a dilution of about 50 times from that of the leachate released from the lagoon. This dilution is only about 20 times immediately adjacent to the lagoon, but as much as 1000 times in the centre of the bay.

8.8 Since the leachate has been modelled as a conservative substance, the model results are linear in nature. The concentrations in the bay due to a lower or higher leachate release may therefore by directly proportioned from the results presented in this chapter.

	Concentrations in microgram/litre	
	Spring tide	Neap tide
Adjacent to lagoon		
Maximum	8	10
Minimum	2	5
Average	4	8
At north of bay		
Maximum	3	4
Minimum	2	3
Average	2	3
In centre of bay		
Maximum	0.3	0.2
Minimum	< 0.1	< 0.1
Average	0.1	0.1

Table 1 - Typical Leachate Levels in Ha Mei Wan Bay

9. CONCULSIONS

9.1 This study has shown that:

(i) flow patterns in the north of the bay will be changed by construction of the lagoon; only minor changes will occur elsewhere

(ii) the only changes to sedimentation of the bay will occur at its northern head, where a maringal increase of deposition will occur in the area partially enclosed by the lagoon

(iii) leachate concentrations in the bay are mostly below 1 microgram/litre at all stages in the tide. For both spring and neap tides, accumulation of leachate will only occur within the northern head of the bay, at levels of below 5 micrograms/litre

REFERENCES

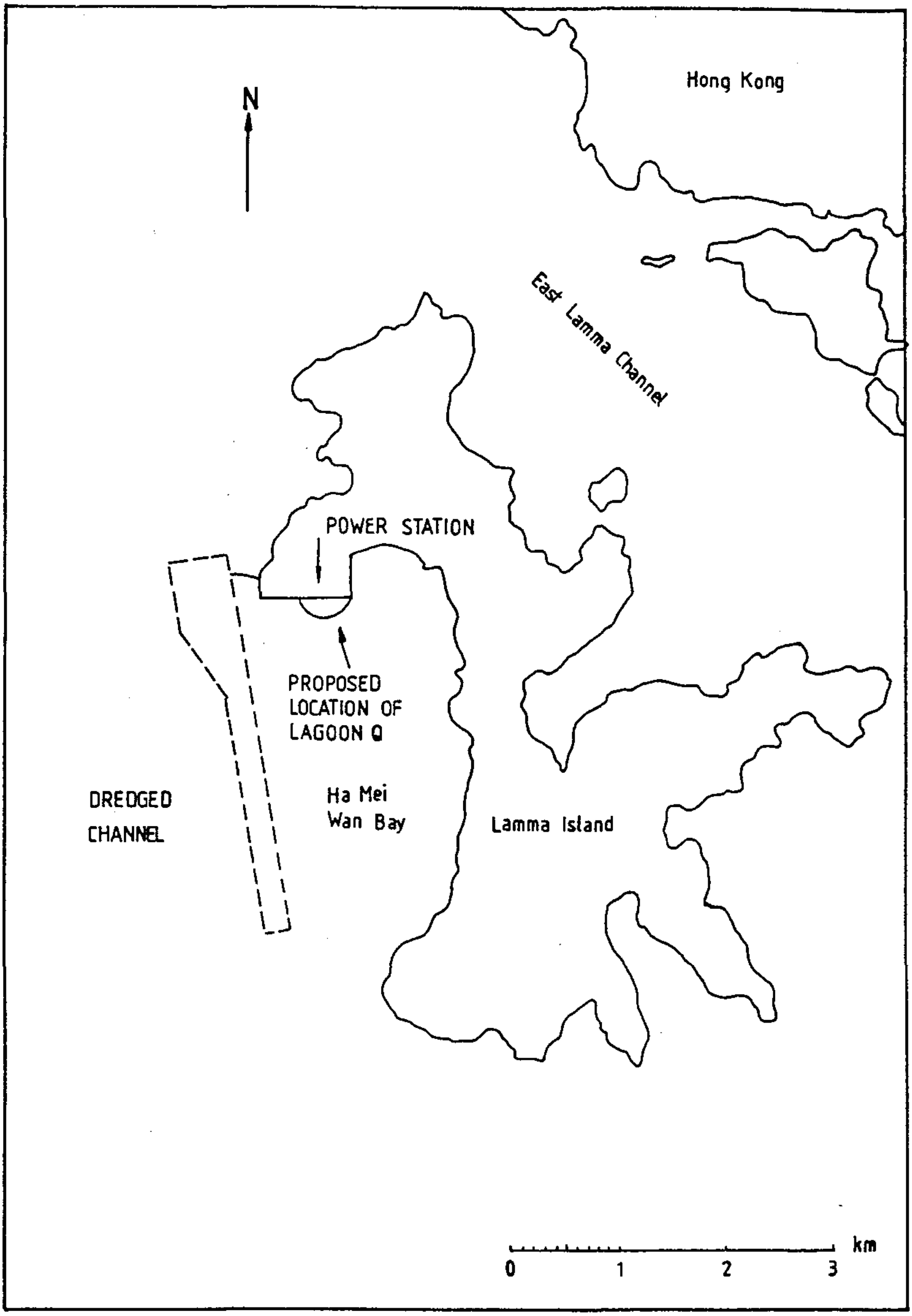
1. Falconer, R.A. (September 1981). Numerical modelling of flushing and mixing in Holes Bay. Report for Wessex Water Authority et al.

2. Binnie & Partners (Hong Kong) (January 1989). Hydraulic and Water Quality Studies in Victoria Harbour. Mathematical Model Report, Part 1 - Overview. Report for Government of Hong Kong Territory Development Urban Area Development Office.

3. Binnie & Partners (Hong Kong) (June 1988). Hydraulic and Water Quality Studies in Victoria Harbour. The Global Intertidal Depth Averaged Model - Calibration and Validation report. Report for Government of Hong Kong Territory Development Urban Area Development Office.

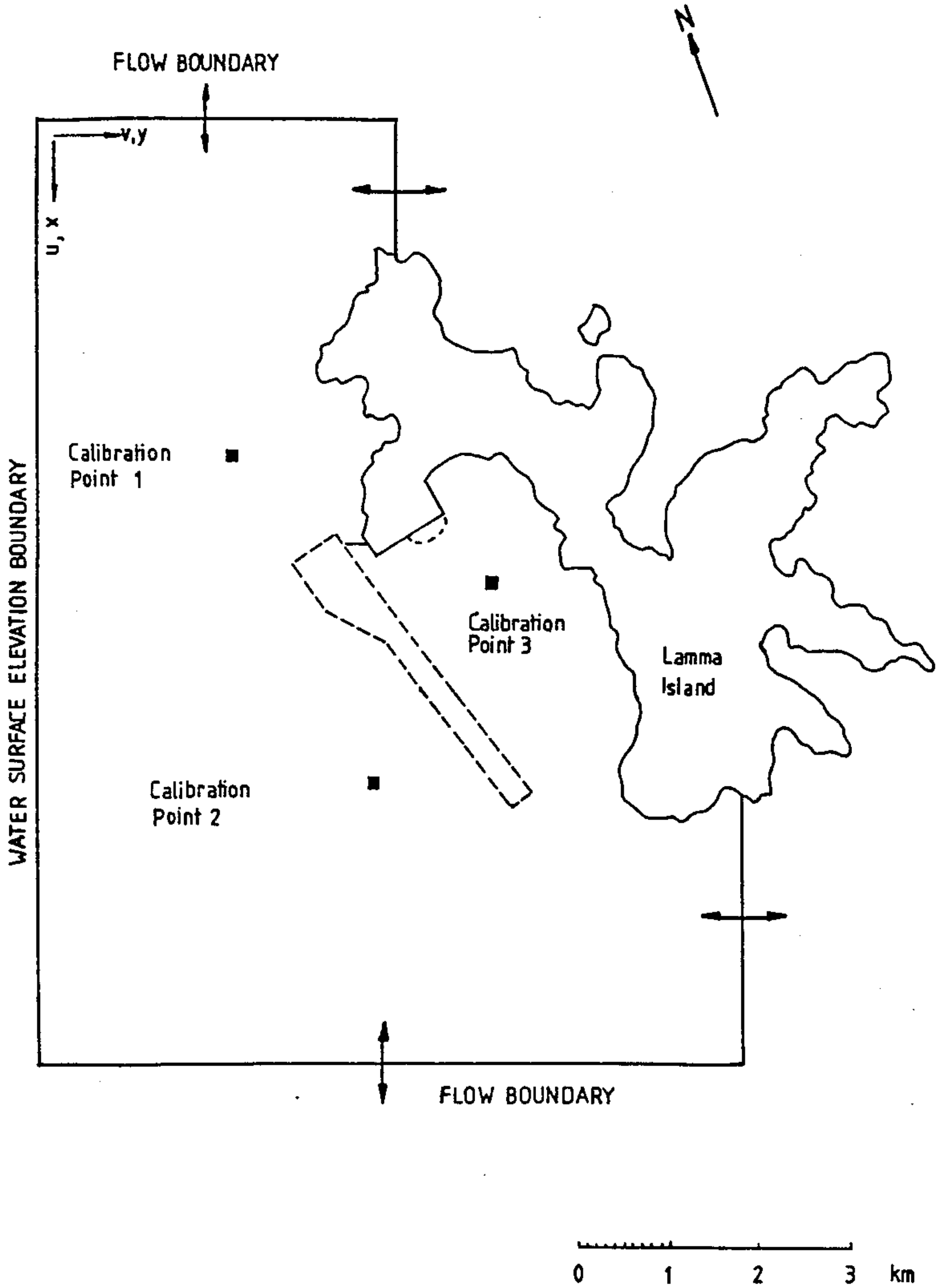
4. Binnie & Partners (Hong Kong) (April 1989). Hydraulic and Water Quality Studies in Victoria Harbour. The Sediment Movement Model - Calibration and Validation report. Report for Government of Hong Kong Territory Development Urban Area Development Office.

5. Binnie & Partners (Hong Kong) (November 1989). The Management of Fuel Ash Originating from Power Generation. Environmental Impact Assessment, Initial Assessment Report. Report for the Hong Kong Electric Company.



LAMMA ISLAND

FIGURE 1



LOCATION OF MODEL BOUNDARIES AND CALIBRATION POINTS

FIGURE 2

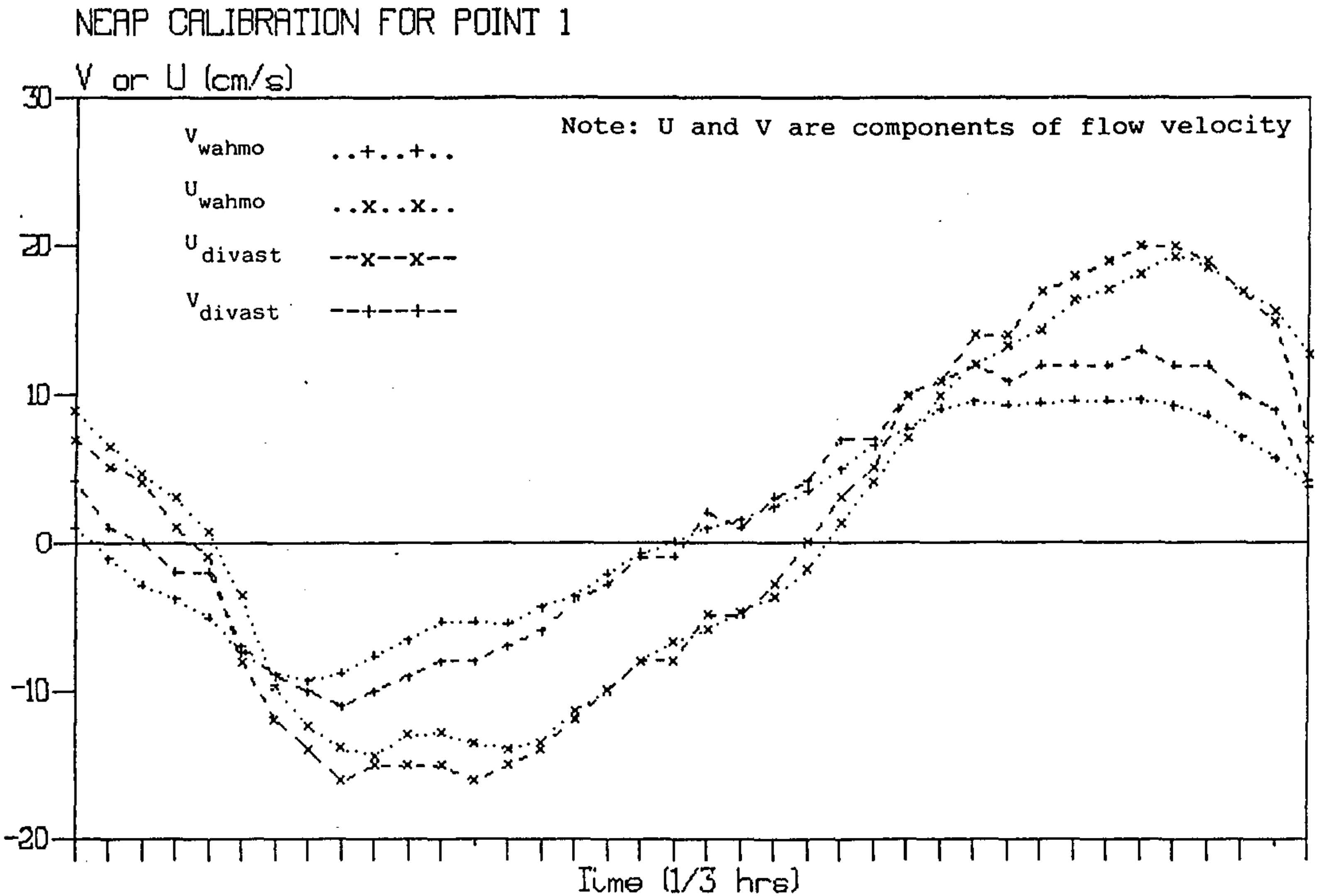
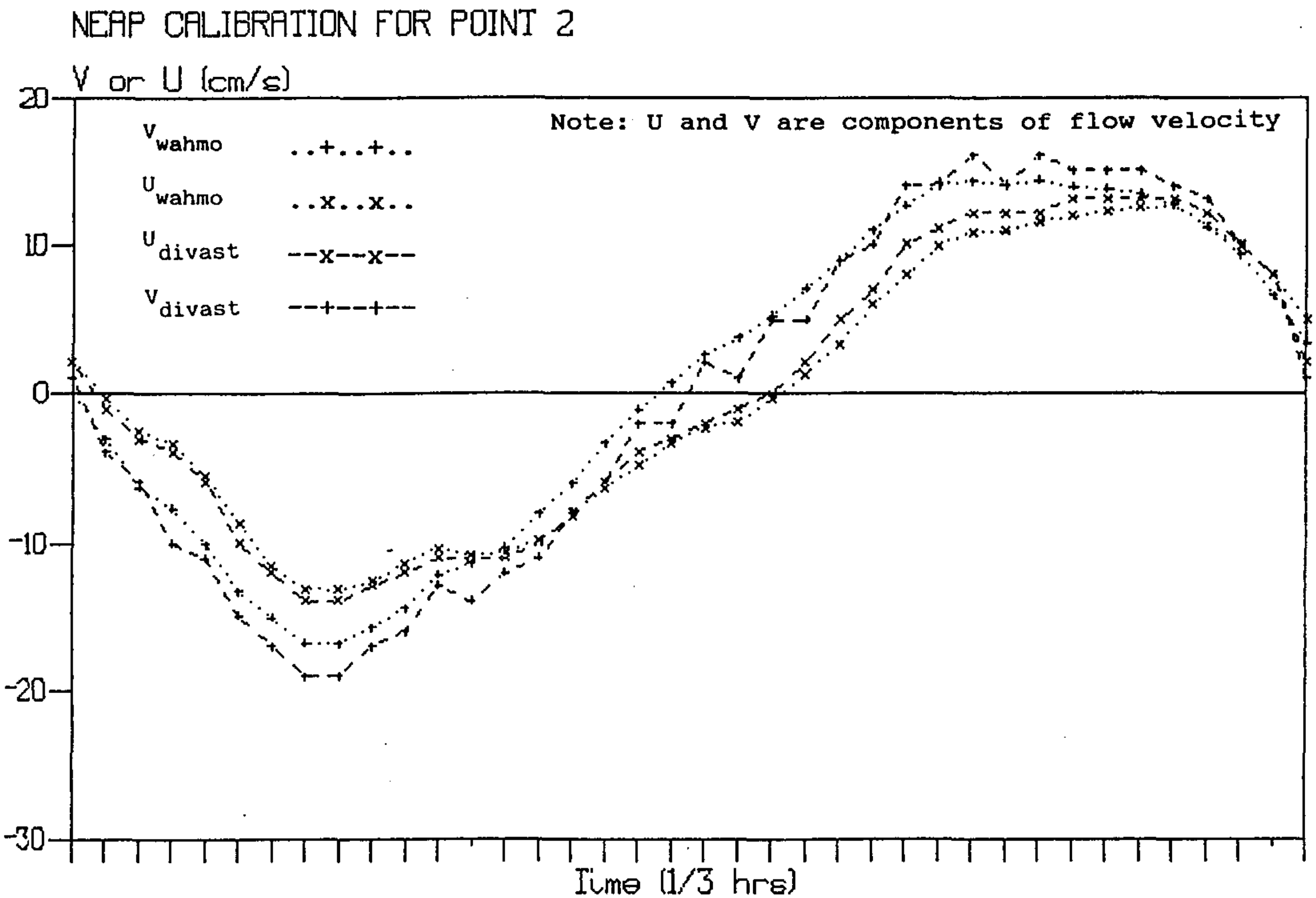


Figure 3. Velocity calibration curves - neap tide - point 1



Velocity calibration curves
- neap tide - point 2

Figure 4.

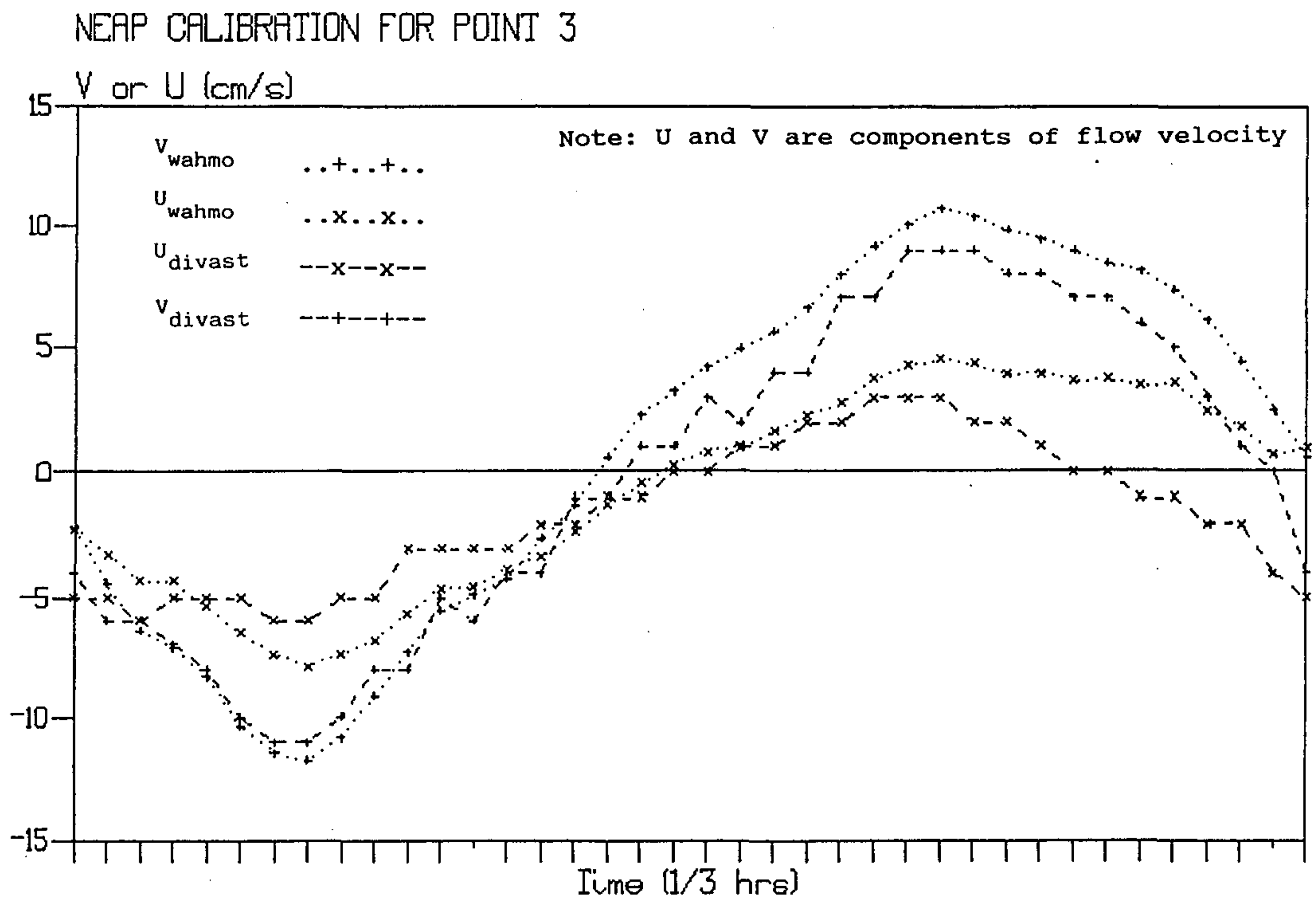


Figure 5. Velocity calibration curves - neap tide - point 3

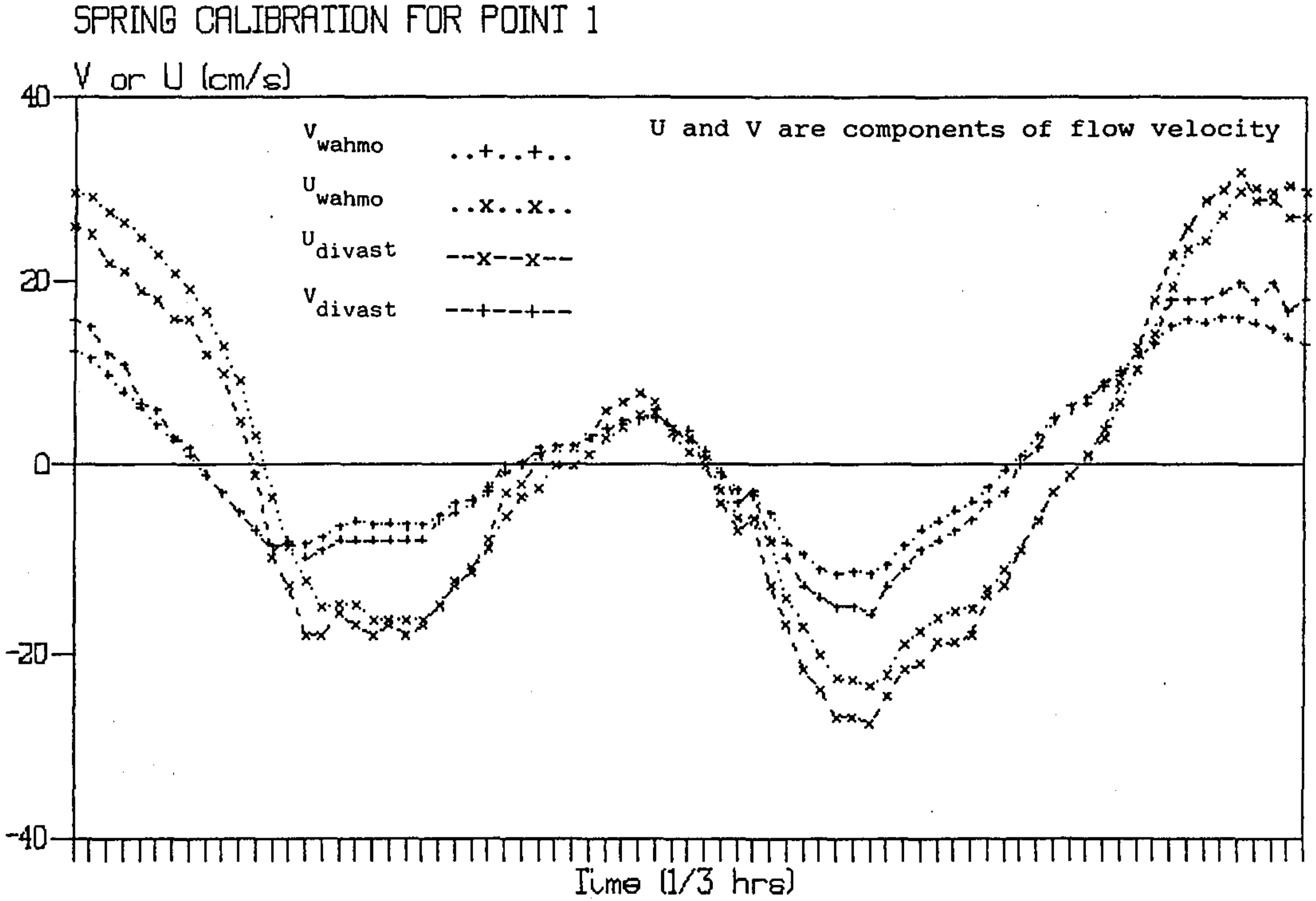
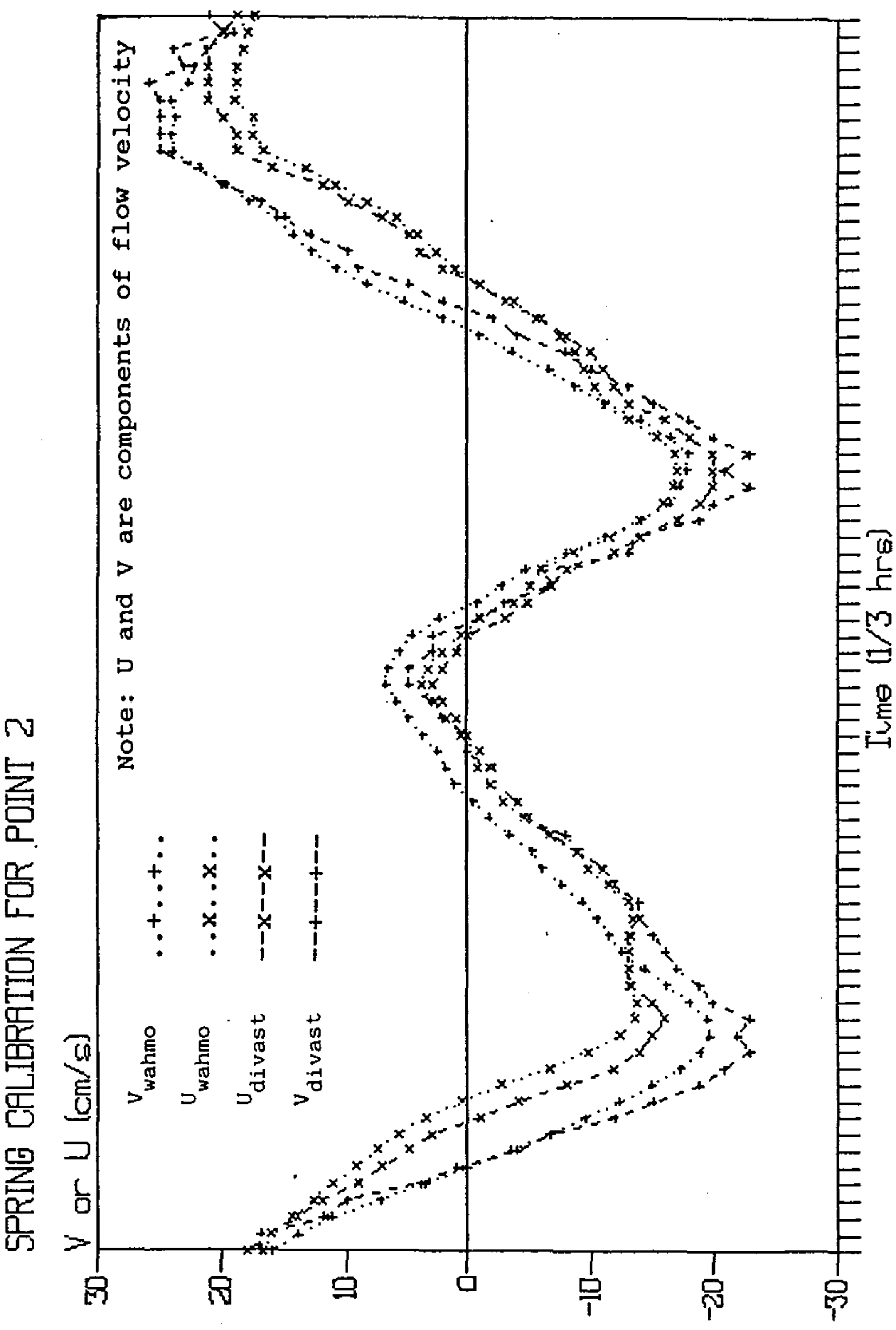
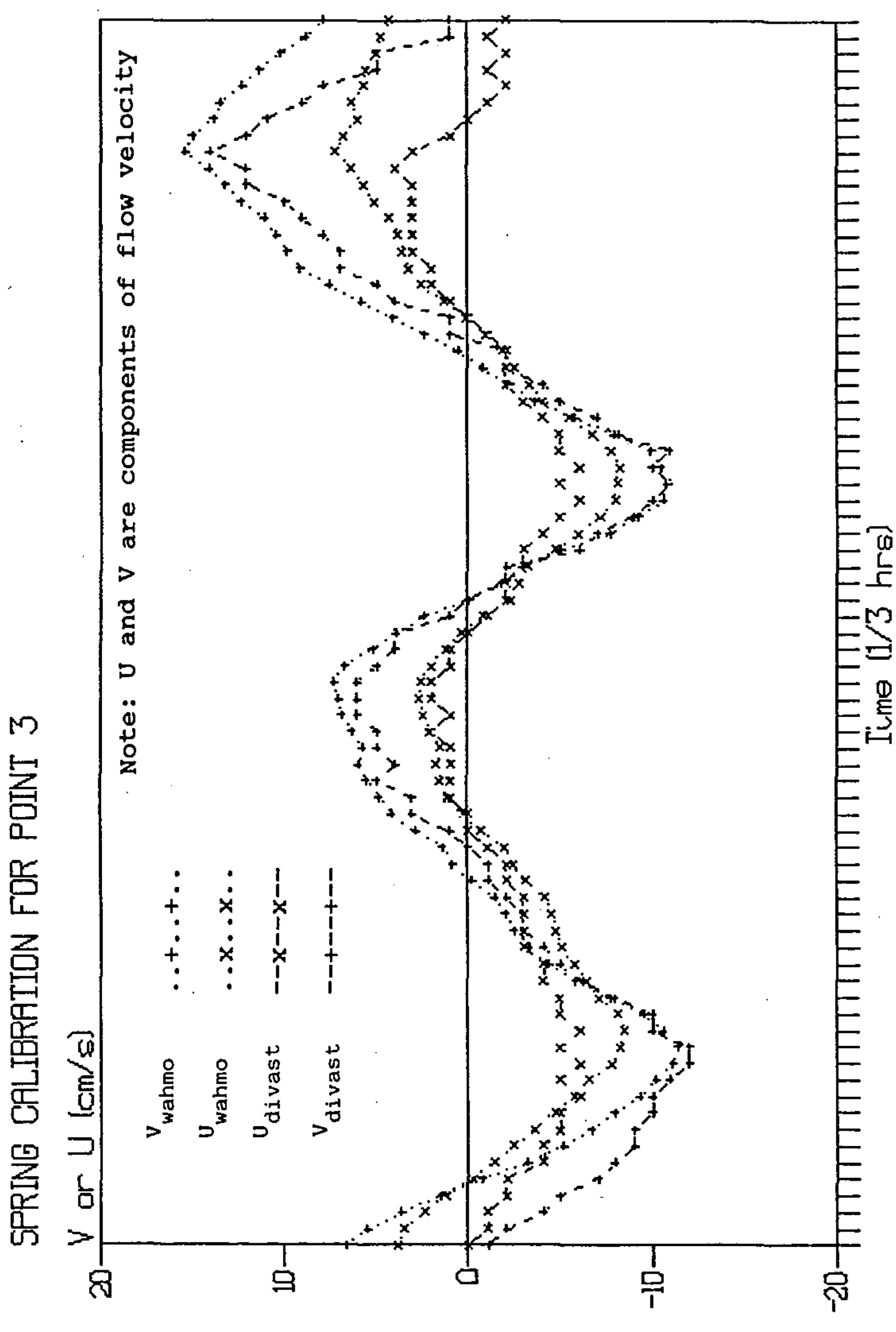


Figure 6. Velocity calibration curves - spring tide - point 1



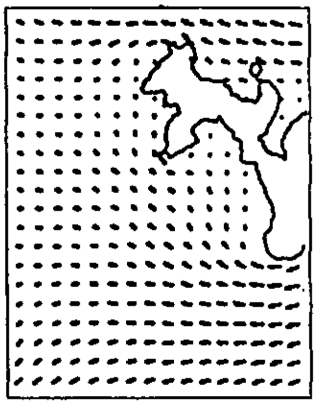
Velocity calibration curves
- spring tide - point 2

Figure 7.

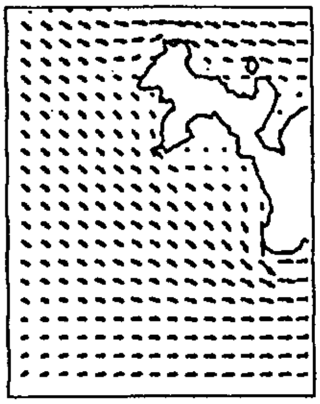


Velocity calibration curves
- spring tide - point 3

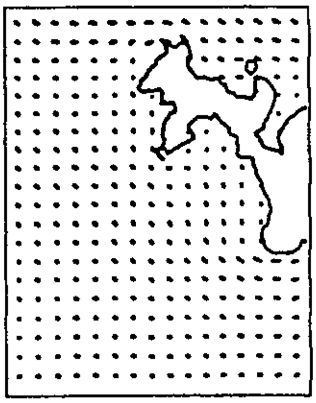
Figure 8.



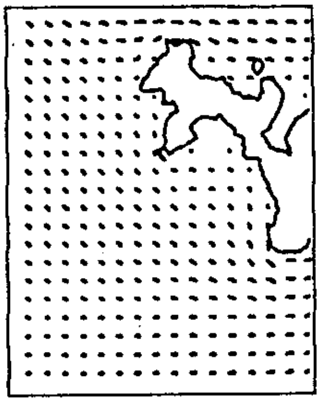
Spring Tide
Peak Flood
HW North Point -13hr



Spring Tide
Peak Ebb
HW North Point +4hr



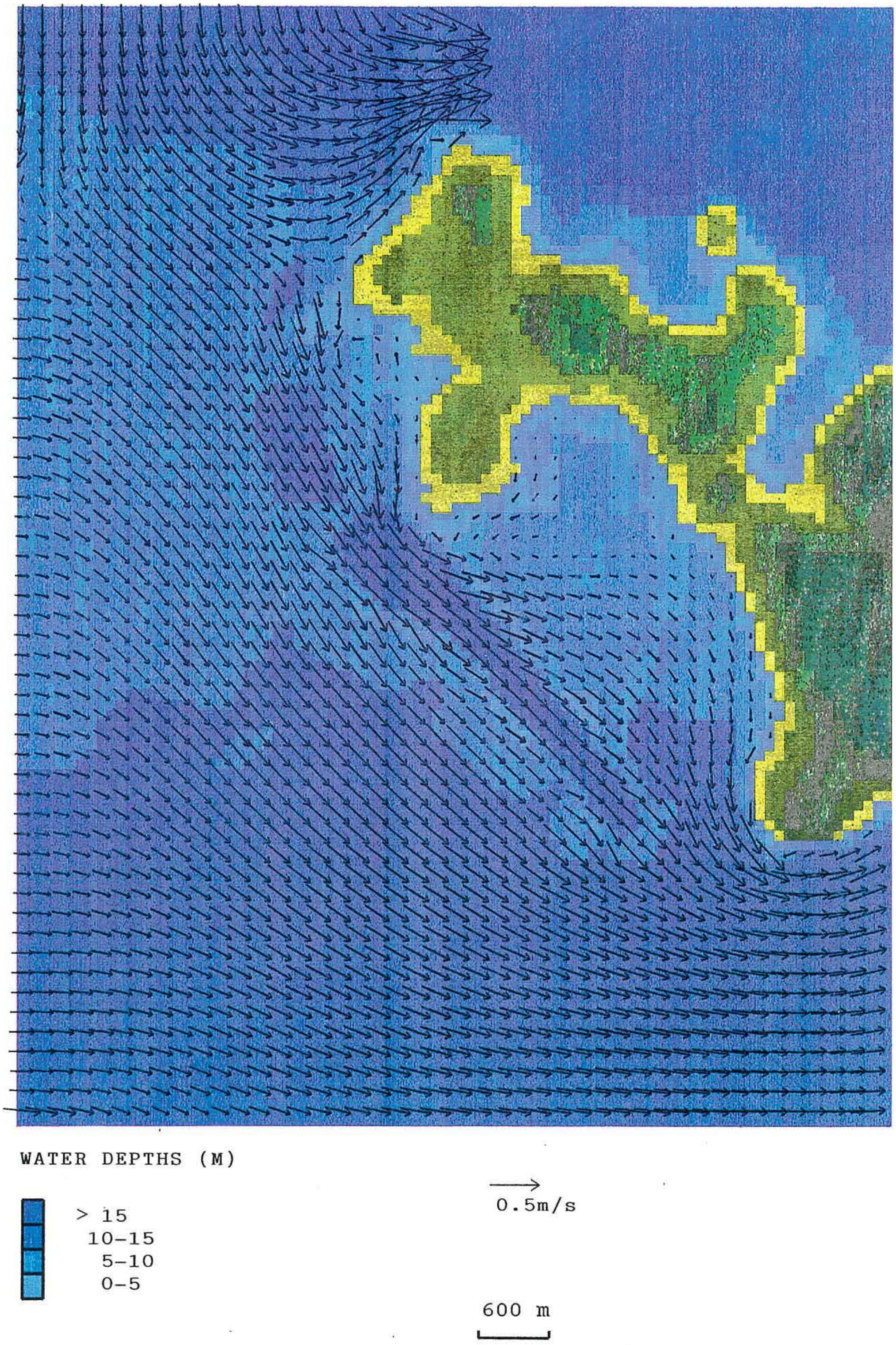
Neap Tide
Peak Flood
HW North Point -3hr



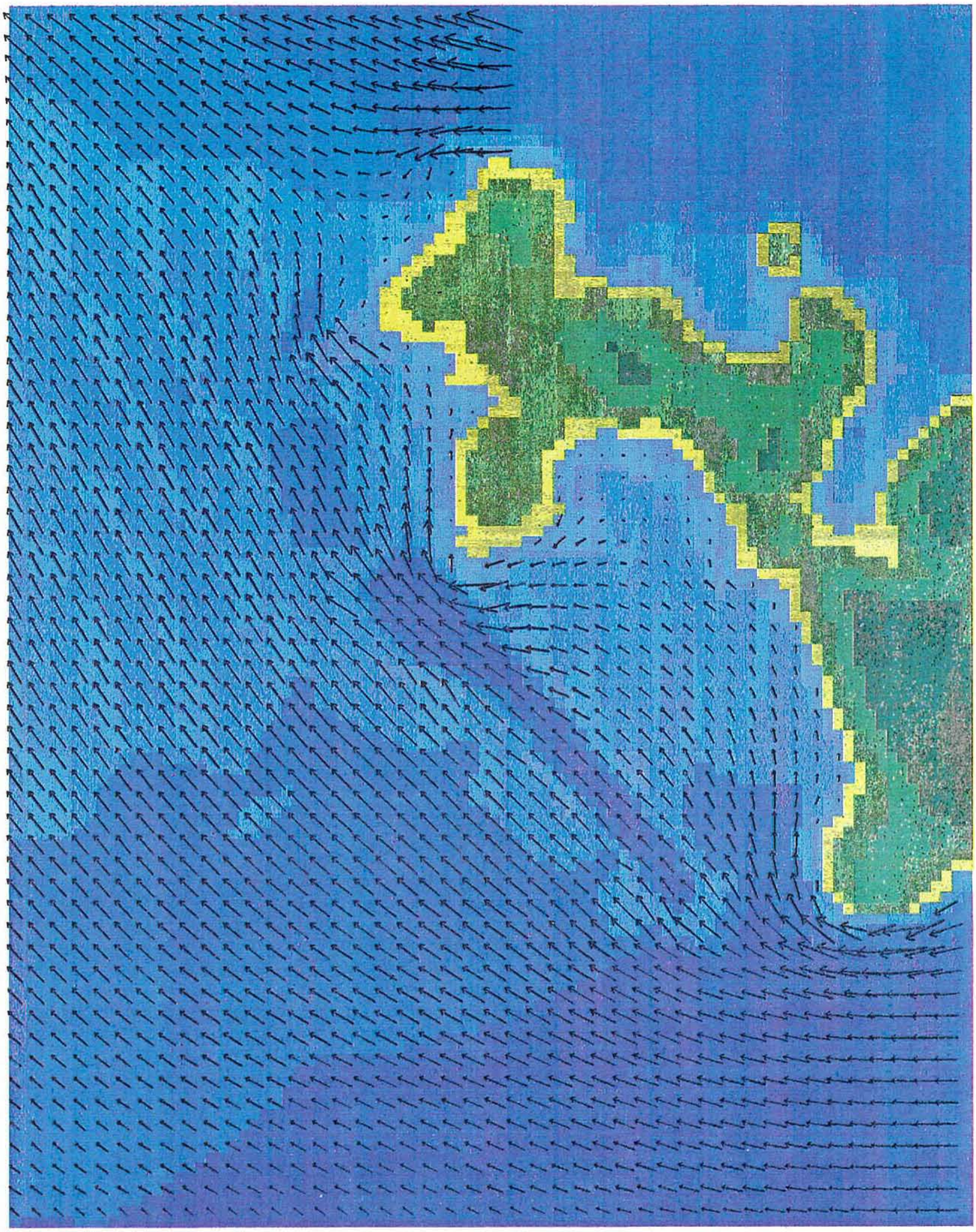
Neap Tide
Peak Ebb
HW North Point +5hr

⟼ 1 Kilometre → 0.5 m/s

Flow Patterns at Time of Maximum Flow (by WAHMO). Figure 9.



MAXIMUM EBB FLOWS - SPRING TIDE FIGURE 10



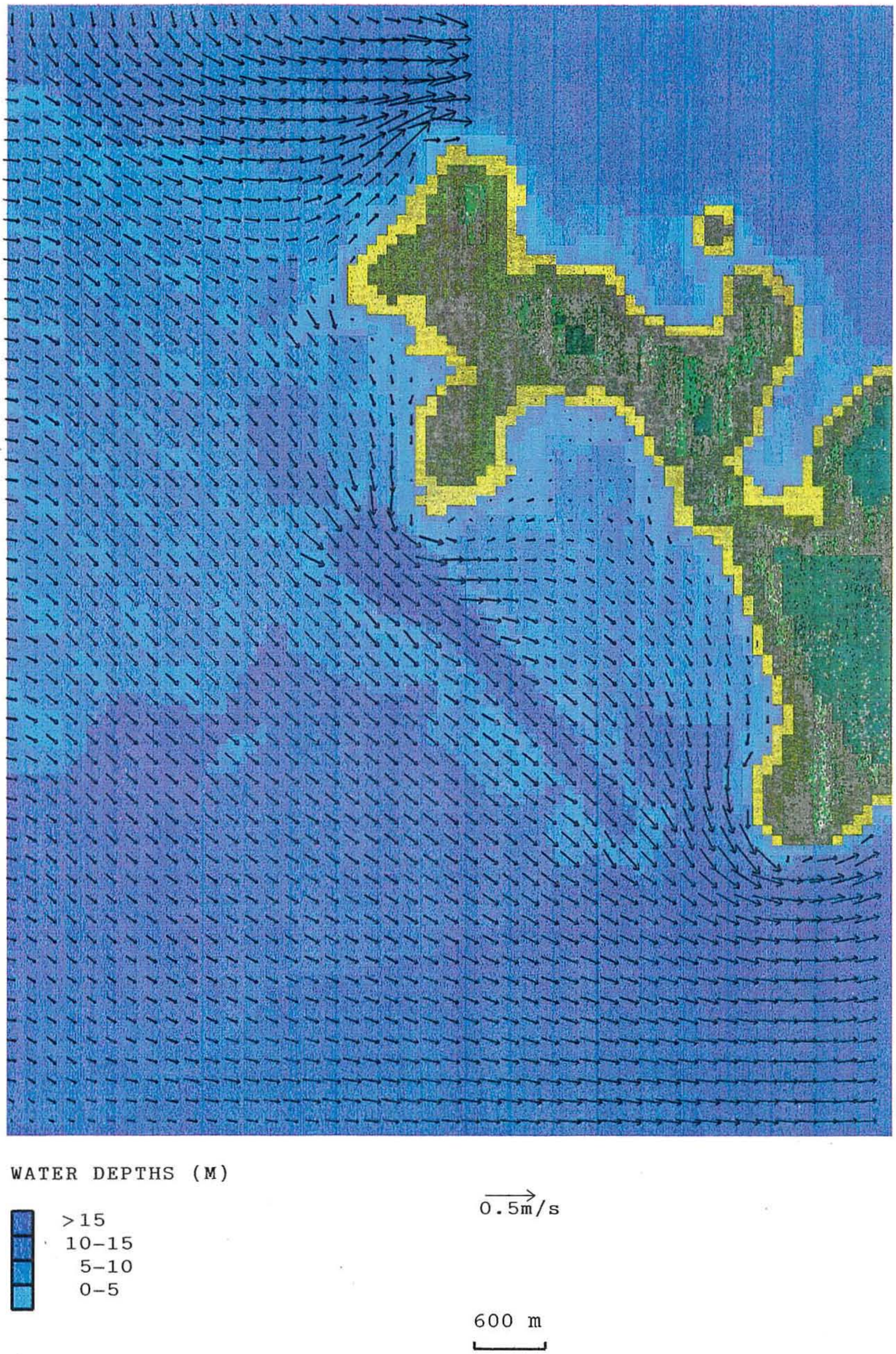
WATER DEPTHS (M)

> 15
10-15
5-10
0-5

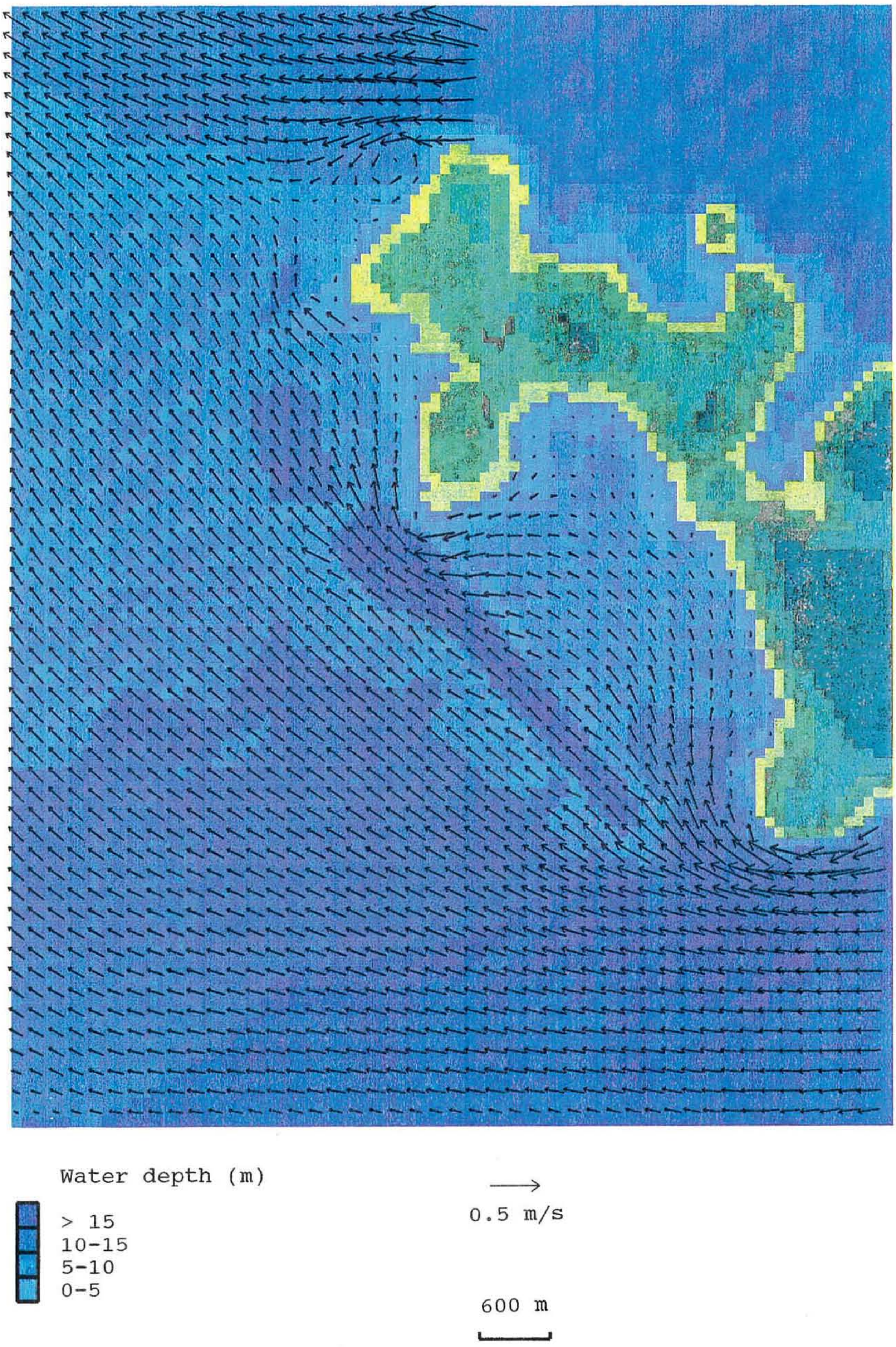
0.5m/s

600 m

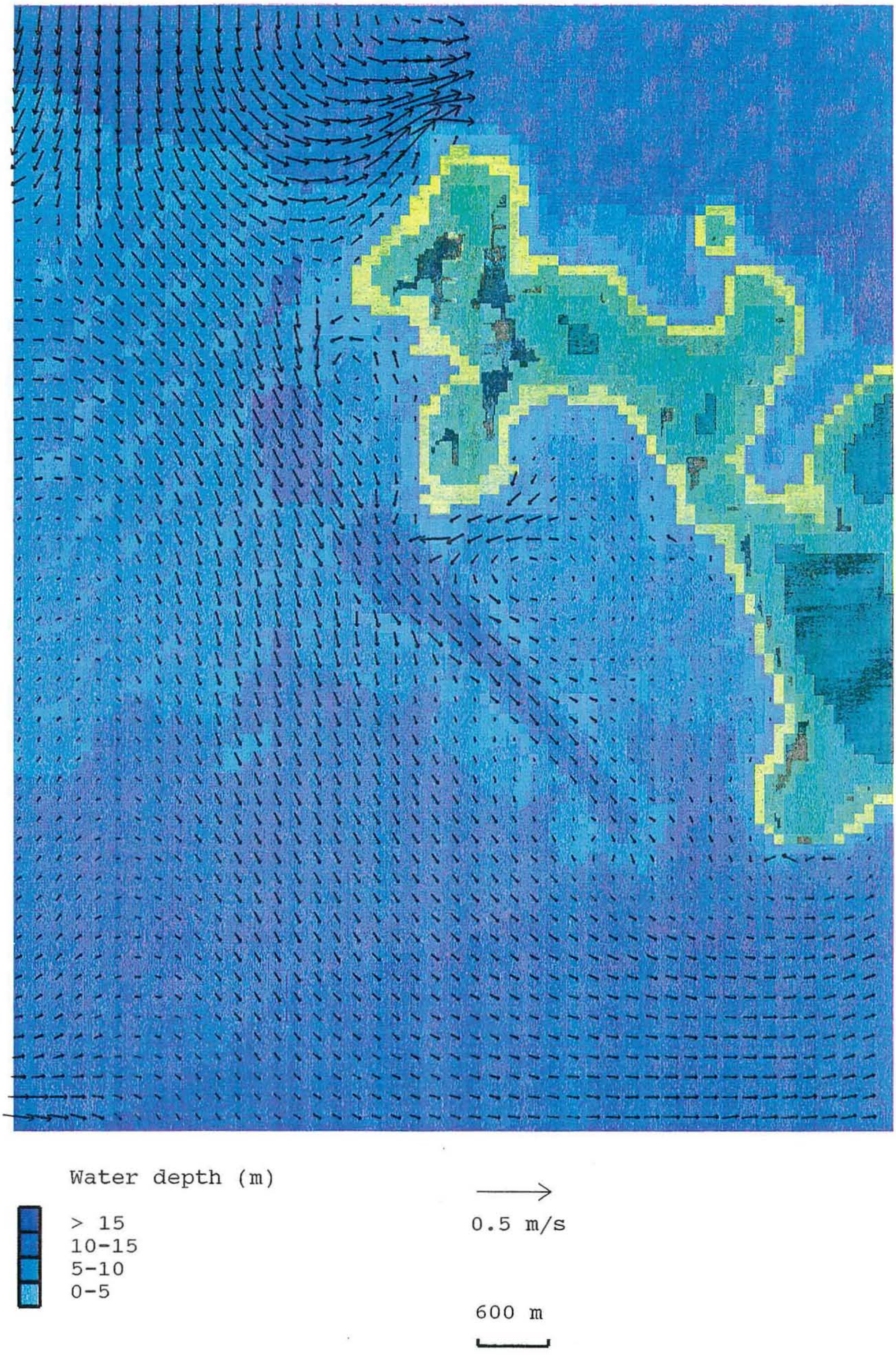
MAXIMUM FLOOD FLOWS - SPRING TIDE FIGURE 11



MAXIMUM EBB FLOWS - NEAP TIDE FIGURE 12

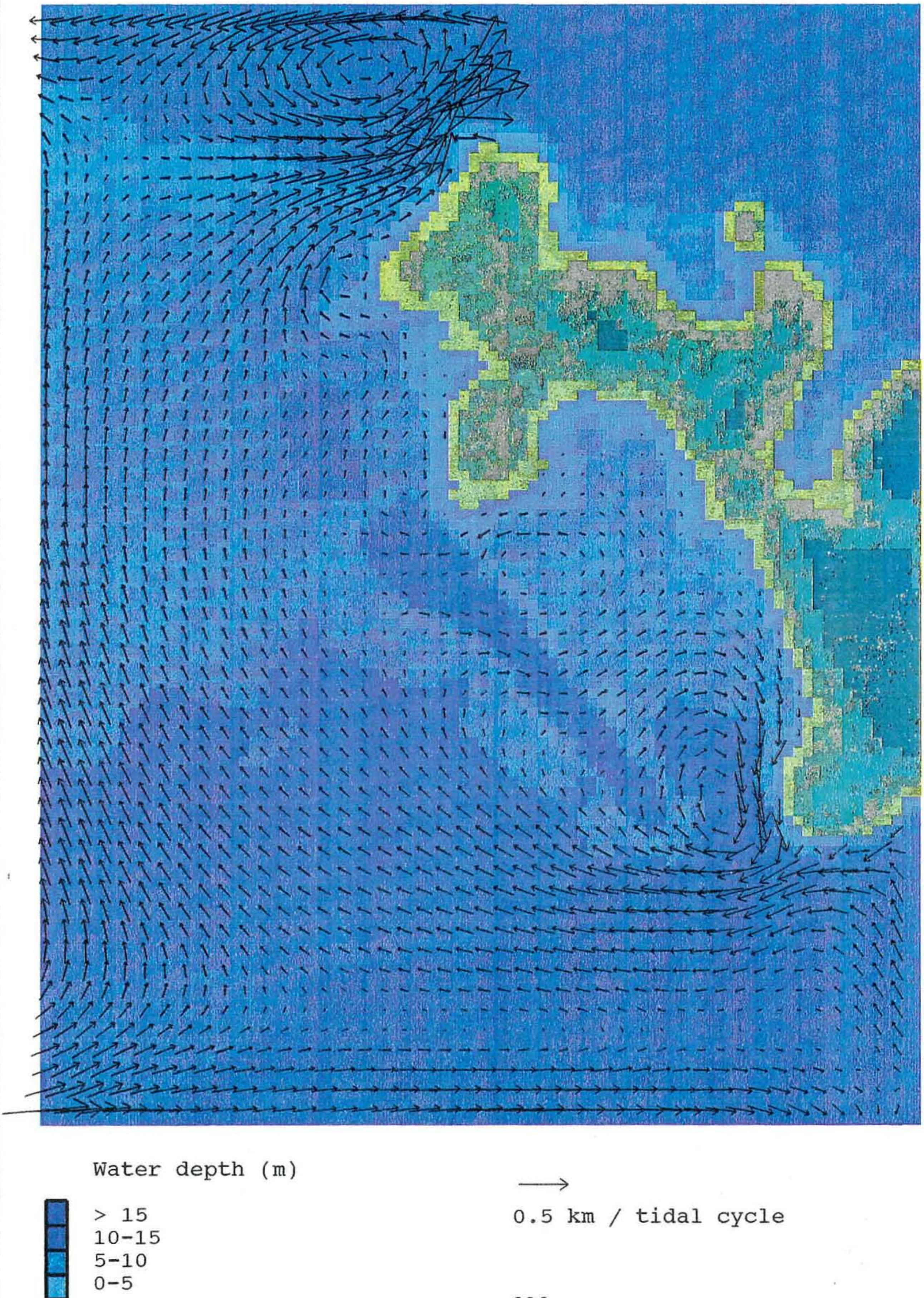


MAXIMUM FLOOD FLOWS - NEAP TIDE **FIGURE 13**

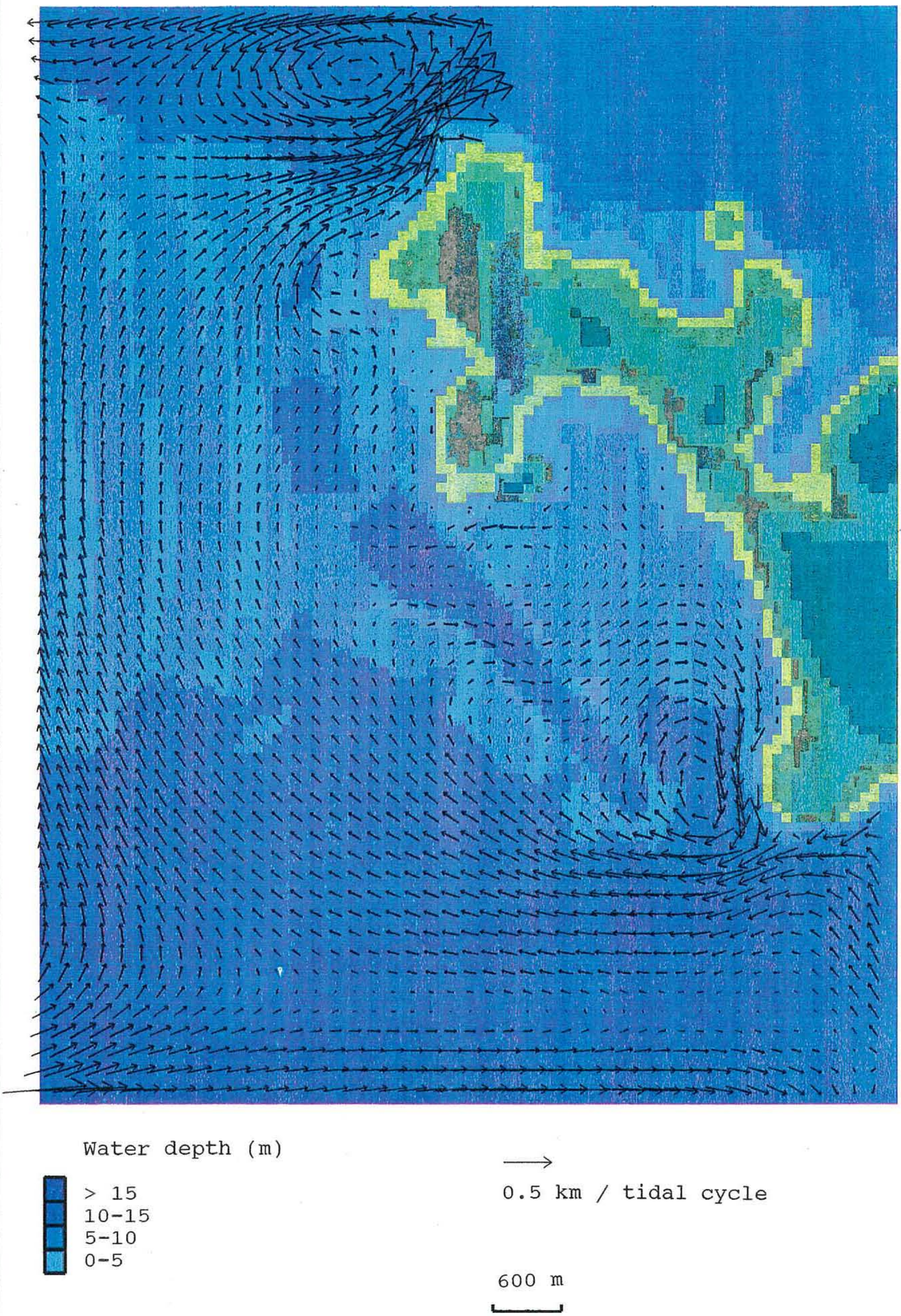


GYRE AS REPRODUCED BY DIVAST MODEL

FIGURE 14

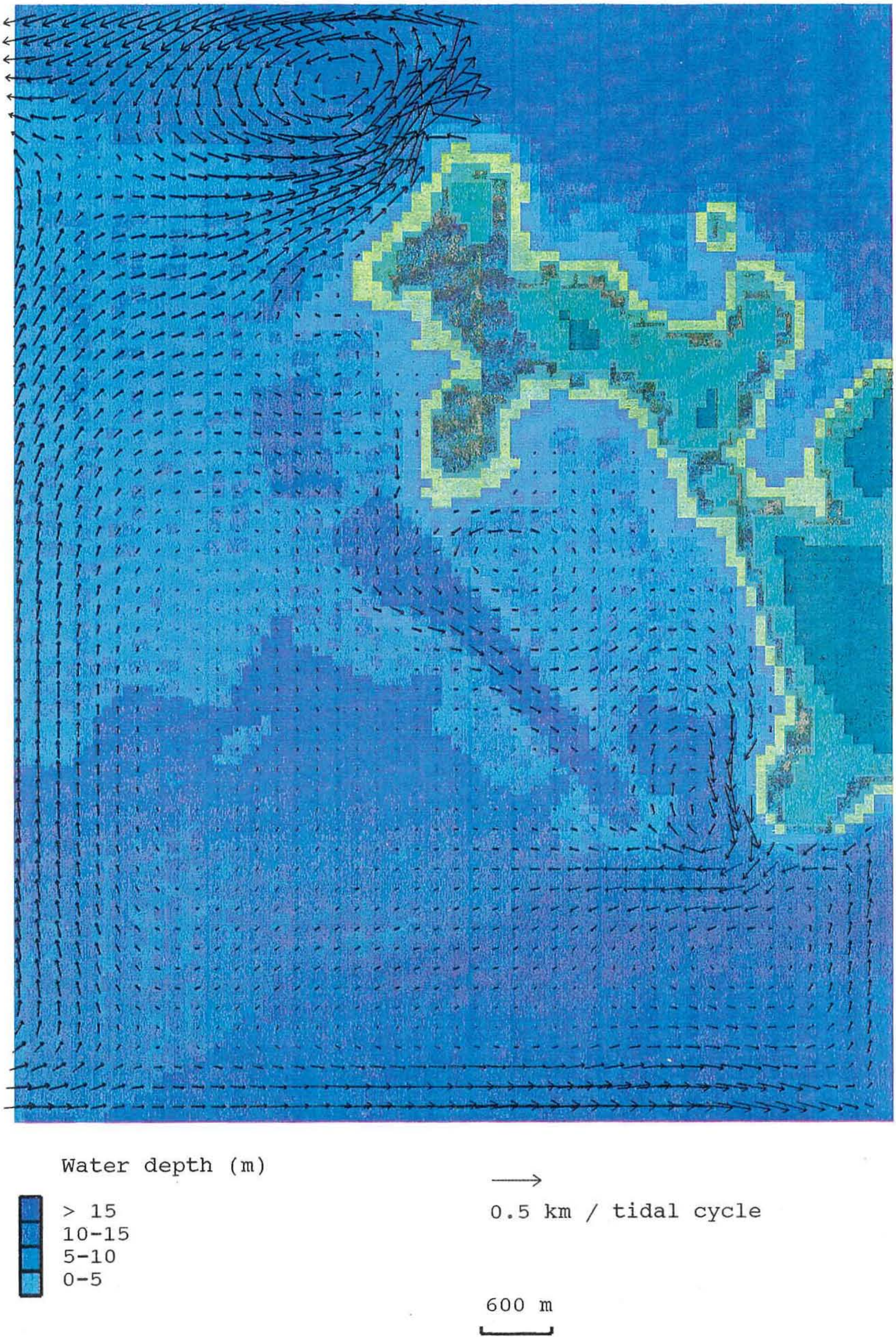


FLOW RESIDUALS - NO LAGOON - SPRING TIDE **FIGURE 15**

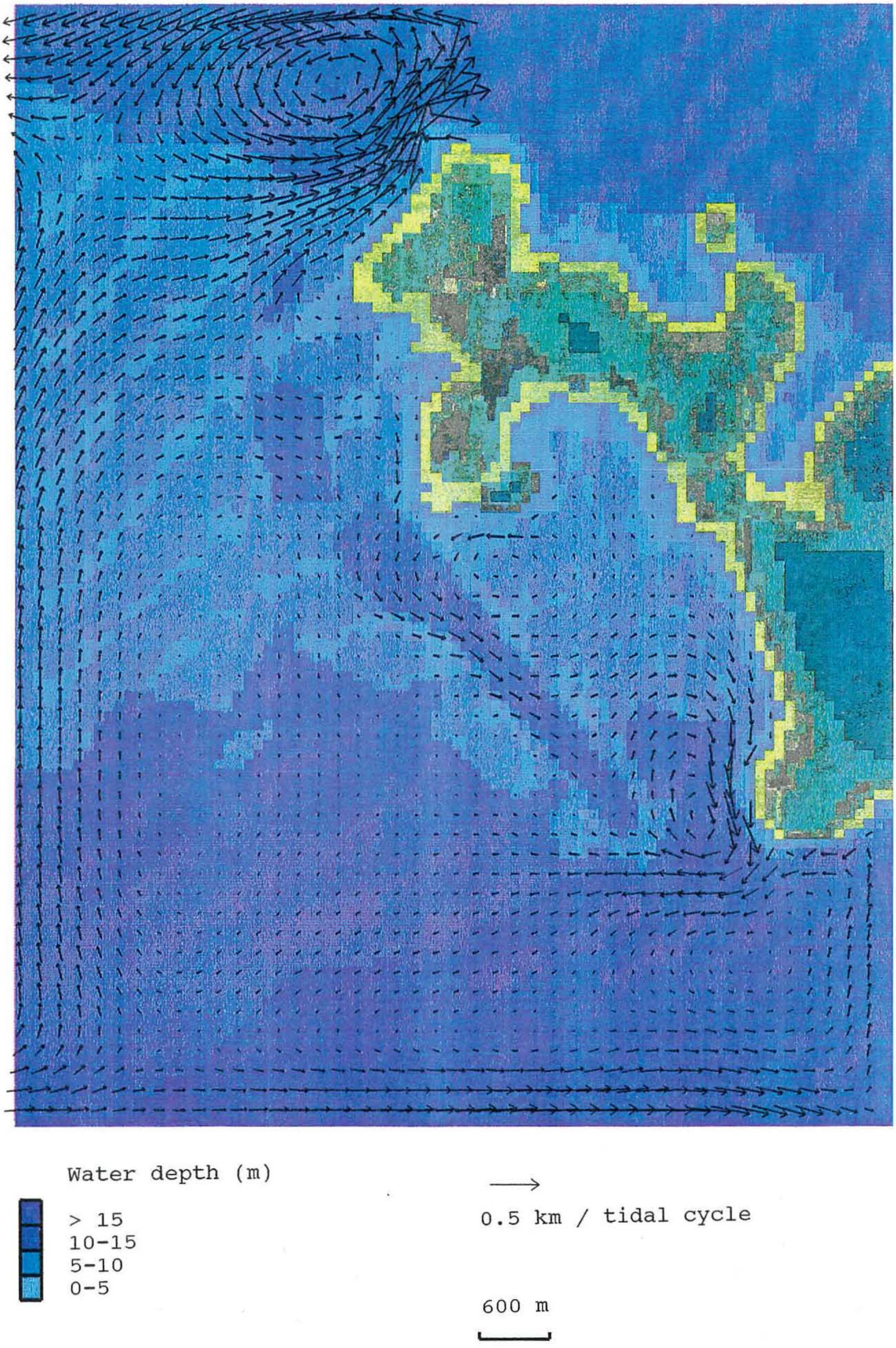


FLOW RESIDUALS - LAGOON - SPRING TIDE

FIGURE 16



FLOW RESIDUALS - NO LAGOON - NEAP TIDE **FIGURE 17**



FLOW RESIDUALS - LAGOON - NEAP TIDE

FIGURE 18

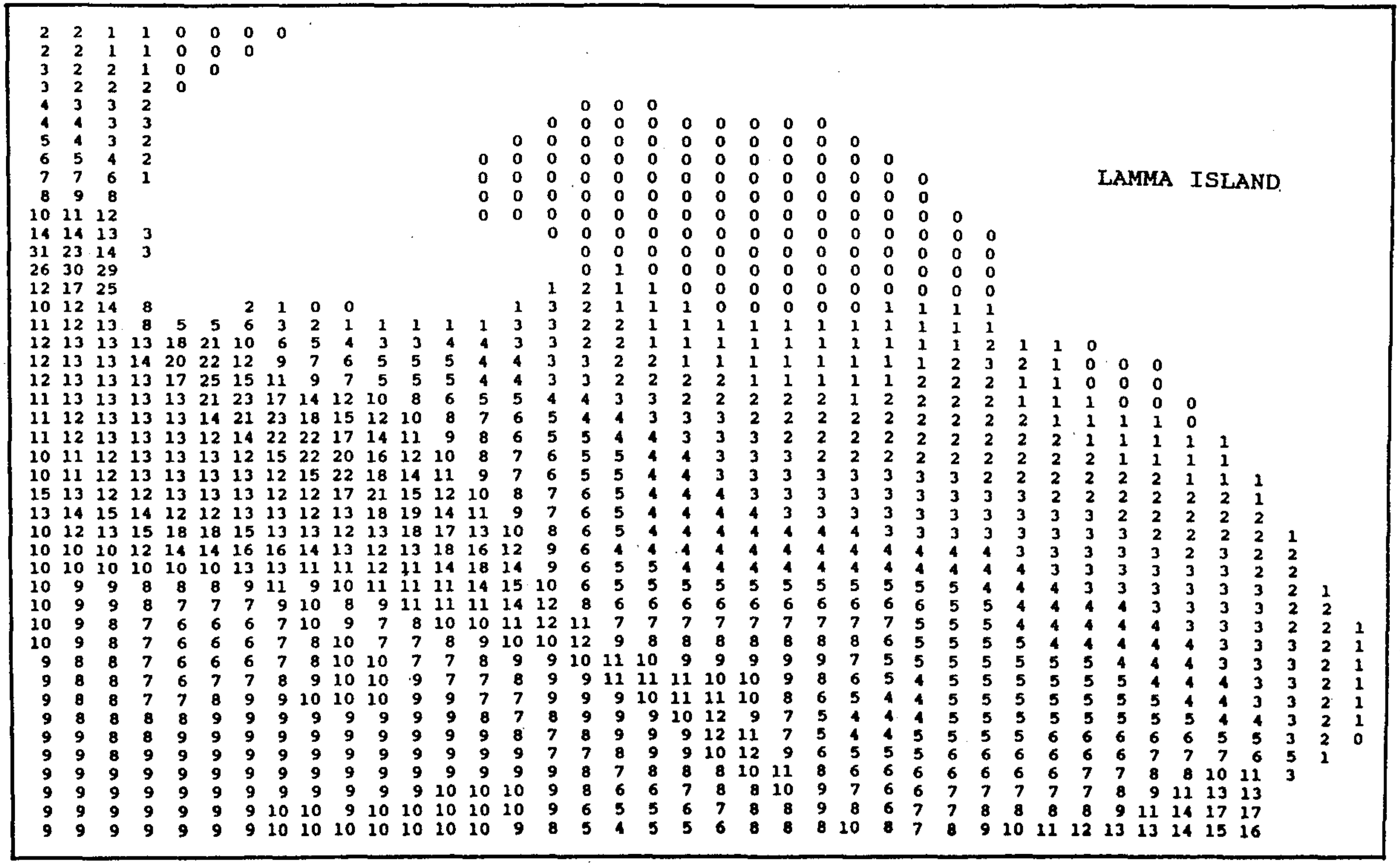
Maximum Shear Stress - No Lagoon - Spring Tide

LAMMA ISLAND

2	2	1	1	0	0	0	0																																
2	2	1	1	0	0	0																																	
3	2	2	1	0	0																																		
3	2	2	2	0																																			
4	3	3	2													0	0	0																					
4	4	3	3												0	0	0	0	0	0	0	0	0																
5	4	3	2											0	0	0	0	0	0	0	0	0	0	0															
6	5	4	2										0	0	0	0	0	0	0	0	0	0	0	0	0														
7	7	6	1										0	0	0	0	0	0	0	0	0	0	0	0	0	0													
8	9	8											0	0	0	0	0	0	0	0	0	0	0	0	0	0													
10	11	12											0	0	0	0	0	0	0	0	0	0	0	0	0	0	0												
14	14	13	3										1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0											
31	23	14	3										1	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0											
26	30	29										1	2	2	2	1	1	0	0	0	0	0	0	0	0	0	0	0											
12	17	25								1	1	2	2	2	2	1	1	1	0	0	0	0	0	0	0	0	0	1											
10	12	14	8			3	3	1	2	2	2	2	3	3	2	2	1	1	1	0	0	1	1	1	1	1	1	1											
11	12	13	8	4	6	8	6	5	3	3	3	3	3	3	2	2	1	1	1	1	1	1	1	1	1	1	1	1											
12	13	13	13	17	21	11	7	6	5	3	3	3	3	3	3	2	2	1	1	1	1	1	1	1	1	1	1	2	1	1	0								
12	13	13	14	20	22	13	10	7	6	4	4	4	3	3	3	2	2	2	1	1	1	1	1	1	1	1	2	3	2	1	0	0	0						
12	13	13	13	17	25	15	11	9	7	5	4	4	3	3	3	2	2	2	2	1	1	1	1	1	1	2	2	3	1	1	0	0	0						
11	13	13	13	13	21	22	17	14	12	10	8	6	5	5	4	3	3	3	2	2	2	2	2	2	2	2	2	2	1	1	1	0	0	0					
11	12	13	13	13	14	21	23	18	15	12	10	8	7	6	5	4	4	3	3	2	2	2	2	2	2	2	2	2	2	1	1	1	1	0					
11	12	13	13	13	12	14	22	22	17	14	11	9	7	6	5	5	4	4	3	3	2	2	2	2	2	2	2	2	2	2	1	1	1	1	0				
10	11	12	13	13	13	12	15	22	20	16	12	10	8	7	6	5	4	4	3	3	3	3	2	2	2	2	2	2	2	2	2	1	1	1	1				
10	11	12	12	13	13	12	12	15	22	18	13	11	9	7	6	5	5	4	4	3	3	3	3	3	3	3	3	3	2	2	2	2	2	1	1	1			
15	13	12	12	12	13	13	12	12	17	21	15	12	10	8	7	5	5	4	4	4	3	3	3	3	3	3	3	3	3	2	2	2	2	2	1	1			
13	14	15	14	12	12	13	13	12	13	18	19	14	11	9	7	6	5	4	4	4	4	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2			
10	12	13	15	18	18	15	13	13	12	13	18	17	13	10	8	6	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	2	2	2	2	1		
10	10	10	12	14	14	16	16	14	13	12	13	18	16	12	9	6	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	2	2		
10	10	10	10	10	10	13	13	11	11	12	11	14	18	14	9	6	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3	3	3	2	2		
10	9	9	8	8	8	9	11	9	10	11	11	11	15	15	10	6	5	5	5	5	5	5	5	5	5	5	5	4	4	4	4	3	3	3	3	3	2	1	
10	9	9	8	7	7	7	9	10	8	9	11	11	11	14	12	8	6	6	6	6	6	6	6	6	6	6	5	5	4	4	4	4	3	3	3	3	2	2	
10	9	8	7	6	6	6	7	10	9	7	8	10	10	11	13	11	7	7	7	7	7	7	7	7	7	6	5	5	4	4	4	4	4	3	3	3	2	2	1
9	8	7	7	6	6	6	7	8	10	7	7	8	10	10	10	12	10	8	8	8	8	8	8	8	6	5	5	5	5	4	4	4	4	4	3	3	3	2	1
9	8	7	7	6	6	6	7	8	10	10	7	7	8	9	9	11	12	10	9	9	9	9	9	7	5	5	5	5	5	5	5	4	4	4	3	3	3	2	1
9	8	8	7	6	7	7	8	9	10	10	9	7	7	8	9	9	11	11	11	10	10	9	8	6	5	4	5	5	5	5	5	5	4	4	4	3	3	2	1
9	8	8	7	7	8	9	9	10	10	9	9	9	7	7	9	9	9	10	11	11	10	8	6	5	4	4	5	5	5	5	5	5	5	4	4	3	3	2	1
9	8	8	8	8	9	9	9	9	9	9	9	9	8	7	8	9	9	9	10	12	9	7	5	4	4	4	5	5	5	5	5	5	5	5	4	4	3	2	1
9	9	8	8	9	9	9	9	9	9	9	9	9	9	8	7	8	9	9	9	12	11	7	5	4	4	5	5	5	5	6	6	6	6	6	5	5	3	2	0
9	9	8	9	9	9	9	9	9	9	9	9	9	9	9	7	7	8	9	9	10	12	9	6	5	5	5	6	6	6	6	6	6	7	7	7	6	5	1	
9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	8	7	8	8	8	10	11	8	6	6	6	6	6	6	6	7	7	8	8	10	11	3		
9	9	9	9	9	9	9	9	9	9	9	9	10	10	10	9	8	6	6	7	8	8	10	9	7	6	6	7	7	7	7	7	8	9	11	13	13			
9	9	9	9	9	9	9	9	9	9	10	10	10	10	10	9	6	5	5	6	7	8	8	9	8	6	7	7	8	8	8	8	9	11	14	17	17			
9	9	9	9	9	9	9	10	10	10	10	10	10	10	9	8	5	4	5	5	6	8	8	8	10	8	7	8	9	10	11	12	13	13	14	15	15			

Shear Stresses in N/m² x 10

Figure 19.



Shear Stresses in N/m² x 10

Figure 20. Maximum Shear Stress - Lagoon - Spring Tide

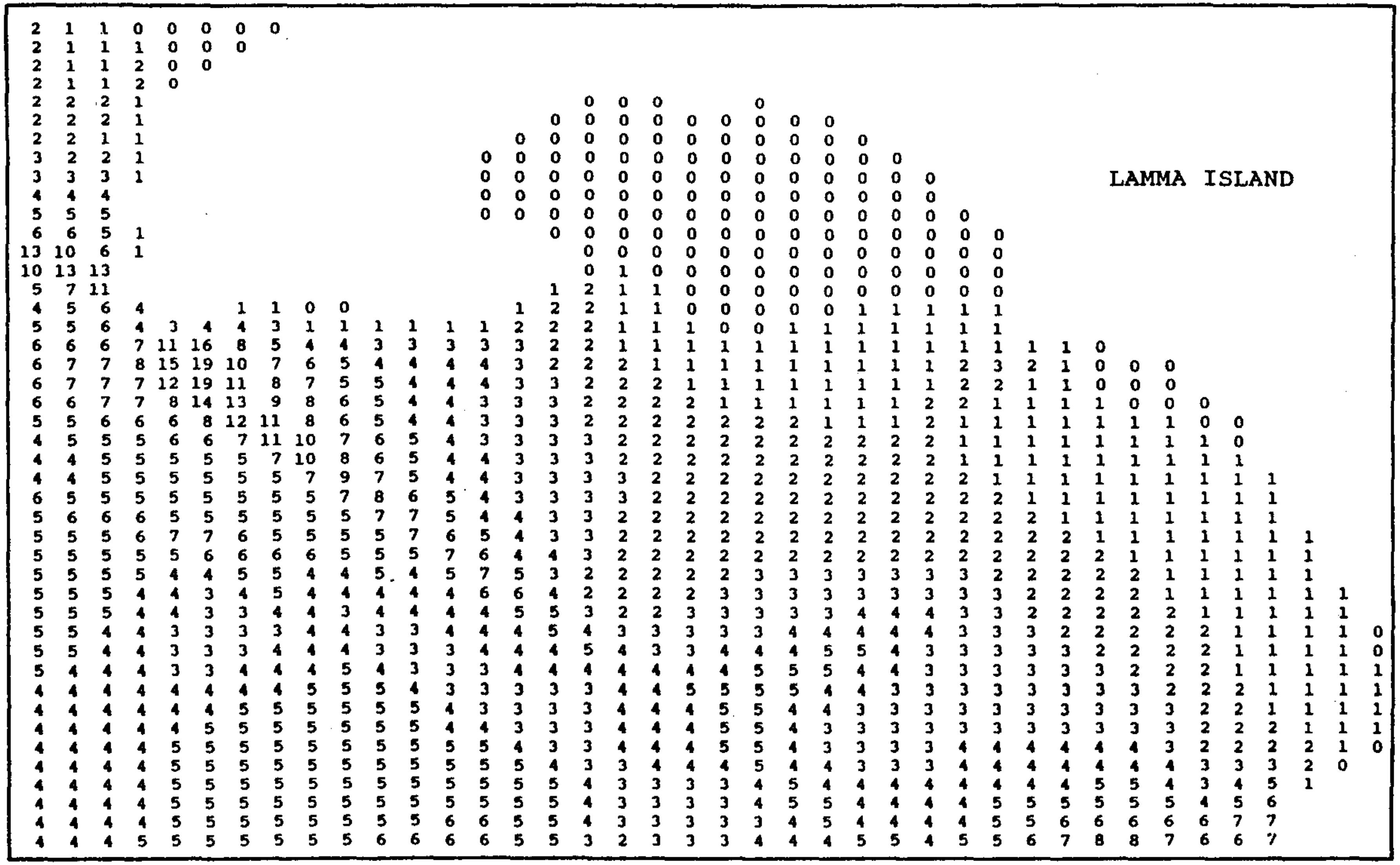
Maximum Shear Stress - No Lagoon - Neap Tide

LAMMA ISLAND

1	1	1	0	0	0	0	0																															
2	1	1	1	1	0	0																																
2	1	1	1	1	0																																	
2	1	1	2	0																																		
2	2	2	1												0	0	0			0																	
2	2	2	1											0	0	0	0	0	0	0	0	0															
2	2	1	1										0	0	0	0	0	0	0	0	0	0	0														
3	2	2	1									0	0	0	0	0	0	0	0	0	0	0	0	0													
3	3	3	1									0	0	0	0	0	0	0	0	0	0	0	0	0	0												
4	4	4										0	0	0	0	0	0	0	0	0	0	0	0	0	0												
5	5	5										0	1	0	0	0	0	0	0	0	0	0	0	0	0	0											
6	6	5	1									0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0										
12	9	6	1									1	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0										
10	13	12									1	2	2	2	1	1	0	0	0	0	0	0	0	0	0	0	0										
5	7	11								0	1	2	2	2	2	1	1	0	0	0	0	0	0	0	1	0	0	0										
4	5	6	3			2	2	1	1	1	2	2	2	2	2	2	1	1	0	0	0	1	1	1	1	1	1	1										
5	5	6	4	2	4	6	5	4	3	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1										
6	6	6	7	11	17	9	6	5	4	3	3	3	3	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0								
6	6	6	8	15	19	11	8	6	5	4	3	3	3	2	2	2	2	1	1	1	1	1	1	1	1	1	2	3	2	1	0	0	0						
6	7	7	7	13	20	12	9	7	5	4	3	3	3	3	2	2	2	2	1	1	1	1	1	1	1	2	2	2	1	1	1	0	0						
6	6	7	7	8	15	14	9	8	6	4	4	3	3	3	2	2	2	2	2	2	1	1	1	1	1	2	2	1	1	1	1	0	0	0					
5	5	6	6	6	8	13	11	8	6	5	4	3	3	3	3	2	2	2	2	2	2	2	2	1	2	2	2	1	1	1	1	1	1	0	0				
4	5	5	5	6	6	7	11	9	7	5	4	4	3	3	3	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	0				
4	4	5	5	5	5	5	7	10	8	6	5	4	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1				
4	4	5	5	5	5	5	5	7	9	7	5	4	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	0			
6	5	5	5	5	5	5	5	5	7	8	6	4	4	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	0			
5	6	6	6	5	5	5	5	5	5	7	7	5	4	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1			
5	5	5	6	7	7	6	5	5	5	5	7	7	5	4	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1		
5	5	4	5	6	6	6	6	6	5	5	5	7	6	4	4	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1		
5	5	5	4	4	4	5	5	4	4	5	4	5	7	5	3	2	2	2	2	2	3	3	3	3	3	3	3	2	2	2	2	2	1	1	1	1	1	1	
5	5	5	4	4	3	4	4	4	4	4	4	4	6	6	4	2	2	2	2	3	3	3	3	3	3	3	3	3	2	2	2	2	2	1	1	1	1	1	
5	5	5	4	4	3	3	4	4	3	4	4	4	4	5	5	3	2	2	3	3	3	3	4	4	4	4	3	3	2	2	2	2	2	1	1	1	1	1	
5	5	4	4	3	3	3	3	4	4	3	3	4	4	4	5	4	3	3	3	3	4	4	4	4	4	4	3	3	3	2	2	2	2	1	1	1	1	1	0
5	5	4	4	3	3	3	3	4	4	3	3	3	4	4	4	5	4	3	3	4	4	5	5	5	4	3	3	3	3	3	2	2	2	2	1	1	1	1	0
5	4	4	4	3	3	4	4	4	5	4	3	3	3	4	4	4	4	4	4	4	5	5	5	4	4	3	3	3	3	3	3	2	2	2	1	1	1	1	1
4	4	4	4	4	4	4	4	5	5	5	4	3	3	3	3	4	4	4	5	5	5	5	4	4	3	3	3	3	3	3	3	3	2	2	2	1	1	1	1
4	4	4	4	4	4	5	5	5	5	5	5	4	3	3	3	3	4	4	4	5	5	4	4	3	3	3	3	3	3	3	3	3	2	2	2	1	1	1	1
4	4	4	4	4	5	5	5	5	5	5	5	4	4	3	3	3	4	4	4	5	5	4	3	3	3	3	3	3	3	3	3	3	3	2	2	2	1	1	1
4	4	4	4	5	5	5	5	5	5	5	5	5	5	4	3	3	4	4	4	5	5	4	3	3	3	3	4	4	4	4	4	3	3	3	2	2	2	1	0
4	4	4	4	5	5	5	5	5	5	5	5	5	5	5	4	3	3	4	4	4	5	4	4	3	3	3	4	4	4	4	4	4	3	3	3	3	2	0	
4	4	4	4	5	5	5	5	5	5	5	5	5	5	5	5	4	3	3	3	4	4	5	4	4	4	4	4	4	4	5	5	4	4	3	4	5	1		
4	4	4	4	5	5	5	5	5	5	5	5	5	5	5	5	4	3	3	3	3	4	5	5	4	4	4	4	5	5	5	5	5	5	4	5	6			
4	4	4	4	5	5	5	5	5	5	5	5	6	6	6	5	4	3	3	3	3	3	4	4	4	4	4	4	5	5	6	6	6	6	6	7	7			
4	4	4	4	5	5	5	5	5	5	6	6	6	6	5	5	3	2	3	3	3	3	4	4	5	5	4	5	5	6	7	8	8	7	6	6	7			

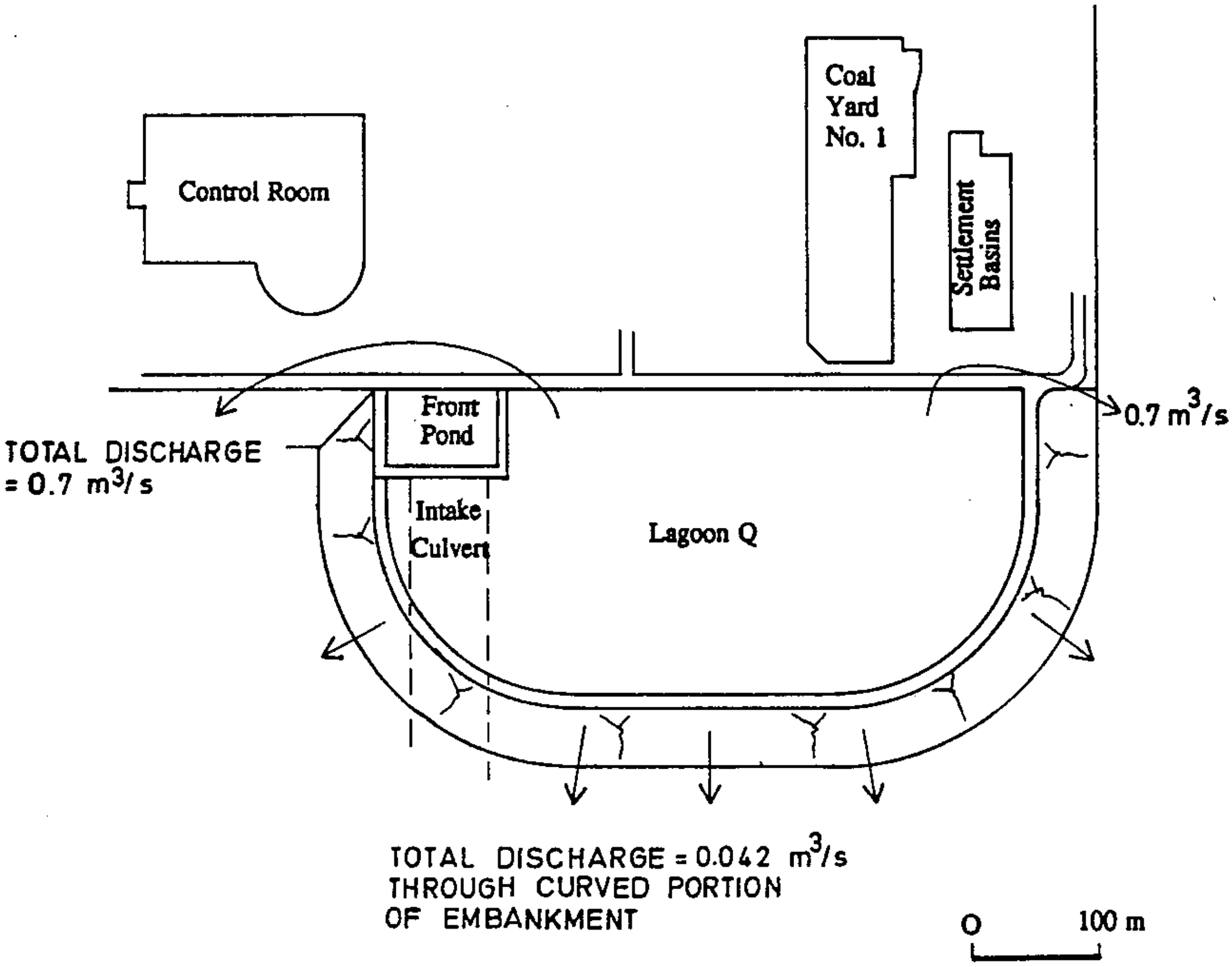
Figure 21.

Shear Stresses in N/m² x 10



Shear Stresses in N/m² x 10

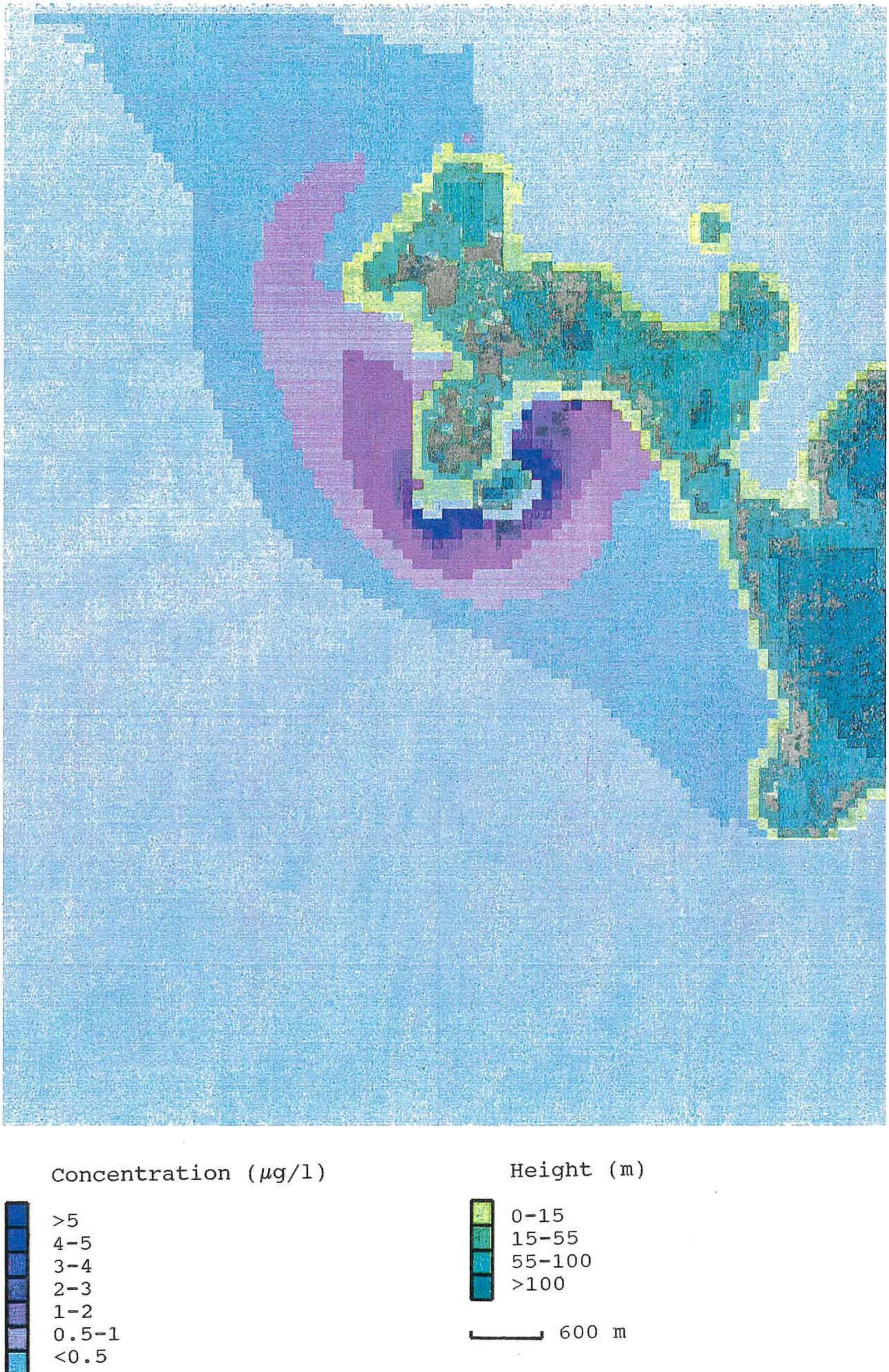
Figure 22. Maximum Shear Stress - Lagoon - Neap Tide



NB. Seepage calculations presented in a seperate working paper entitled "Lagoon shape and form".

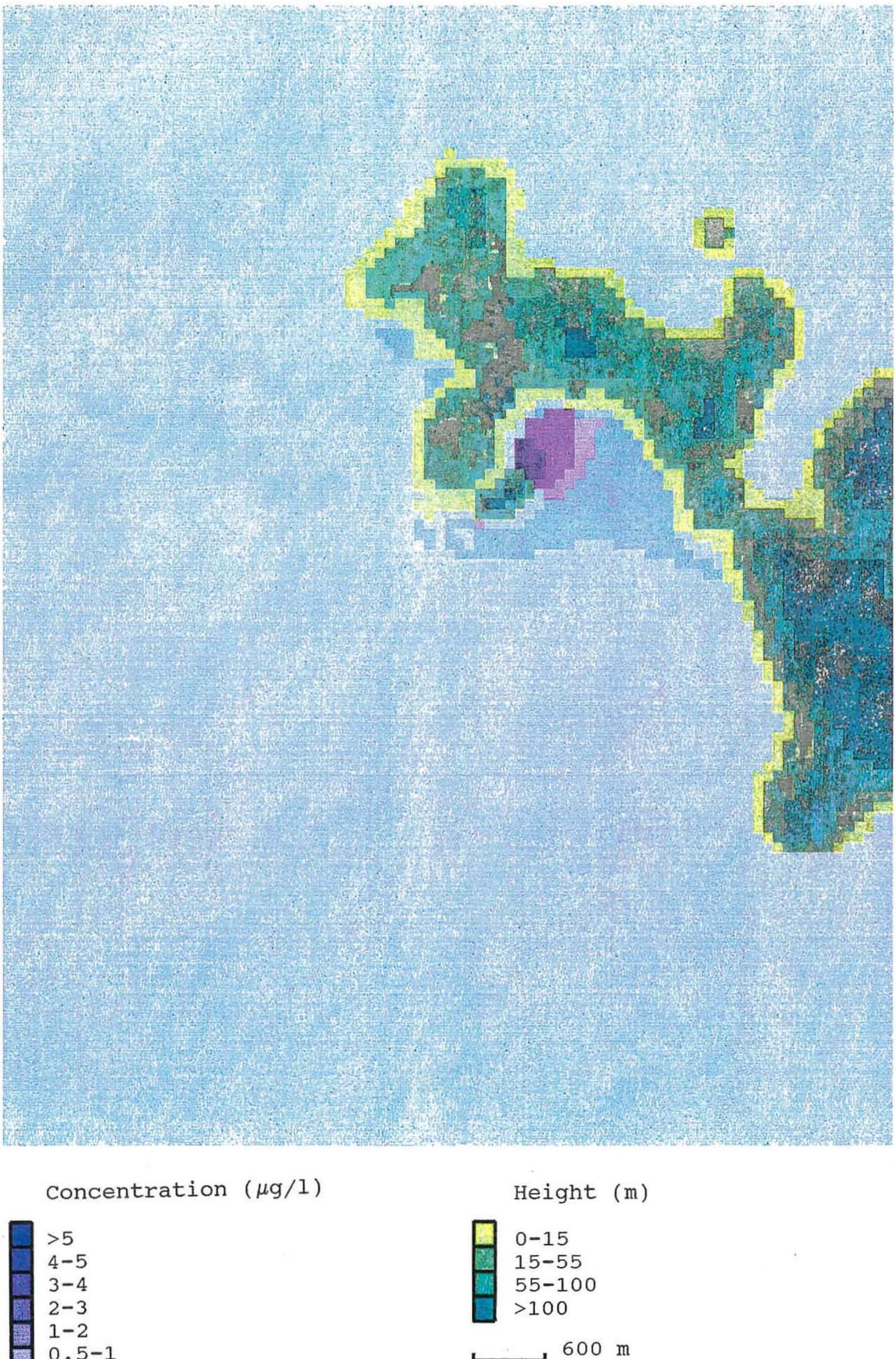
SEEPAGE OF LEACHATE
FROM LAGOON Q

Figure 23



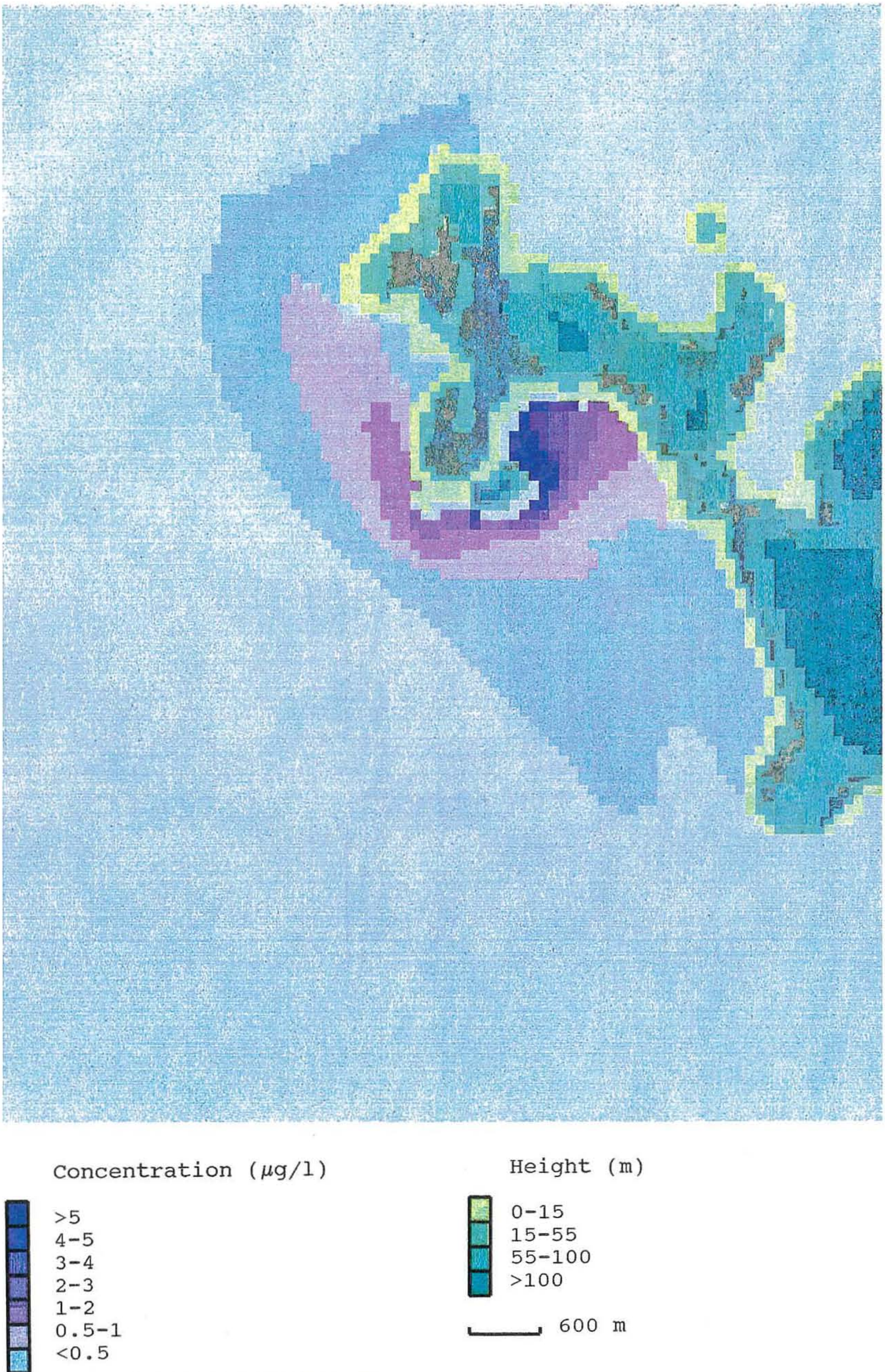
ENVELOPE OF MAXIMUM LEACHATE CONCENTRATIONS - SPRING TIDE

FIGURE 24



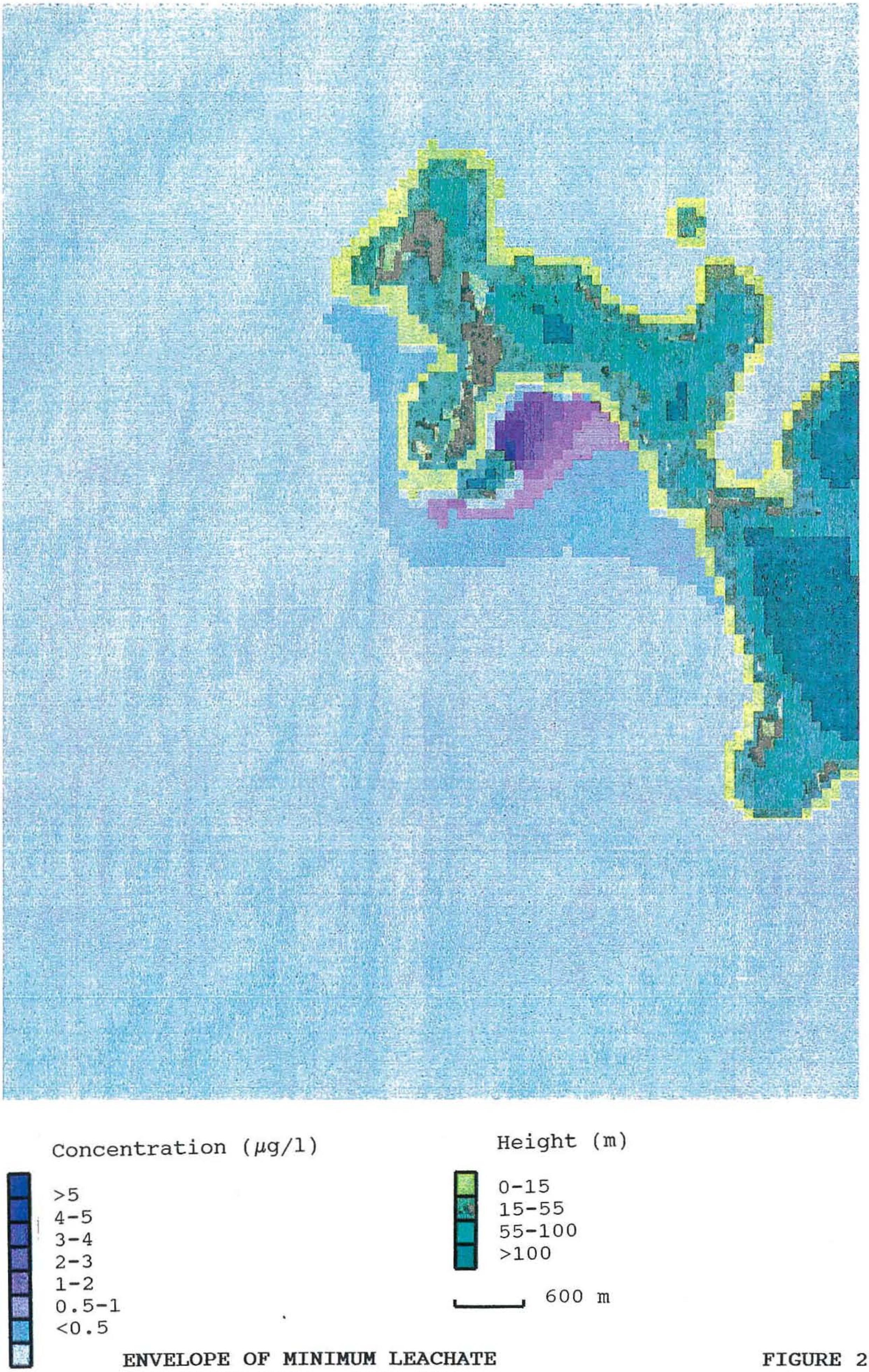
ENVELOPE OF MINIMUM LEACHATE CONCENTRATIONS - SPRING TIDE

FIGURE 25



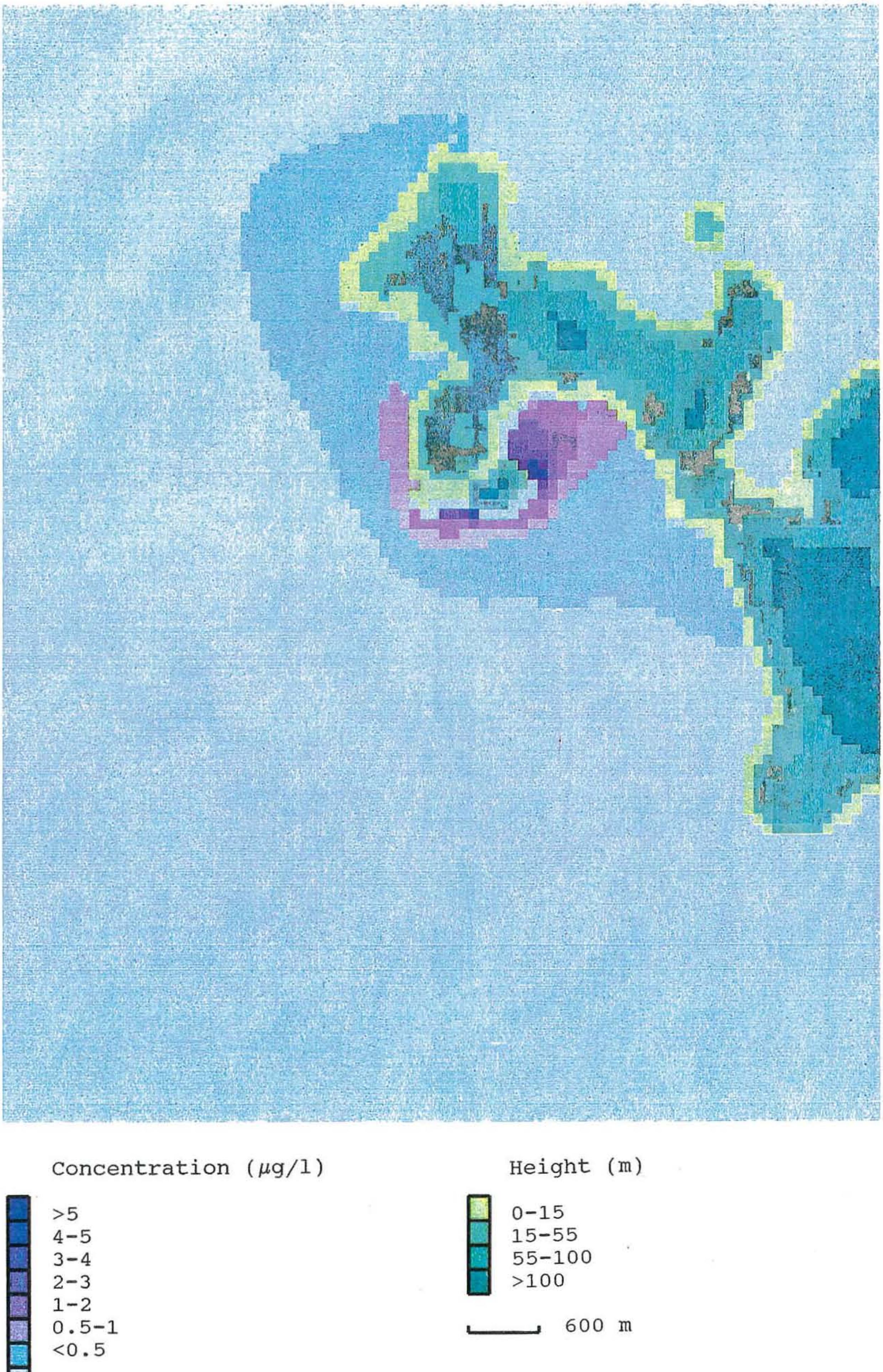
ENVELOPE OF MAXIMUM LEACHATE CONCENTRATIONS - NEAP TIDE

FIGURE 26



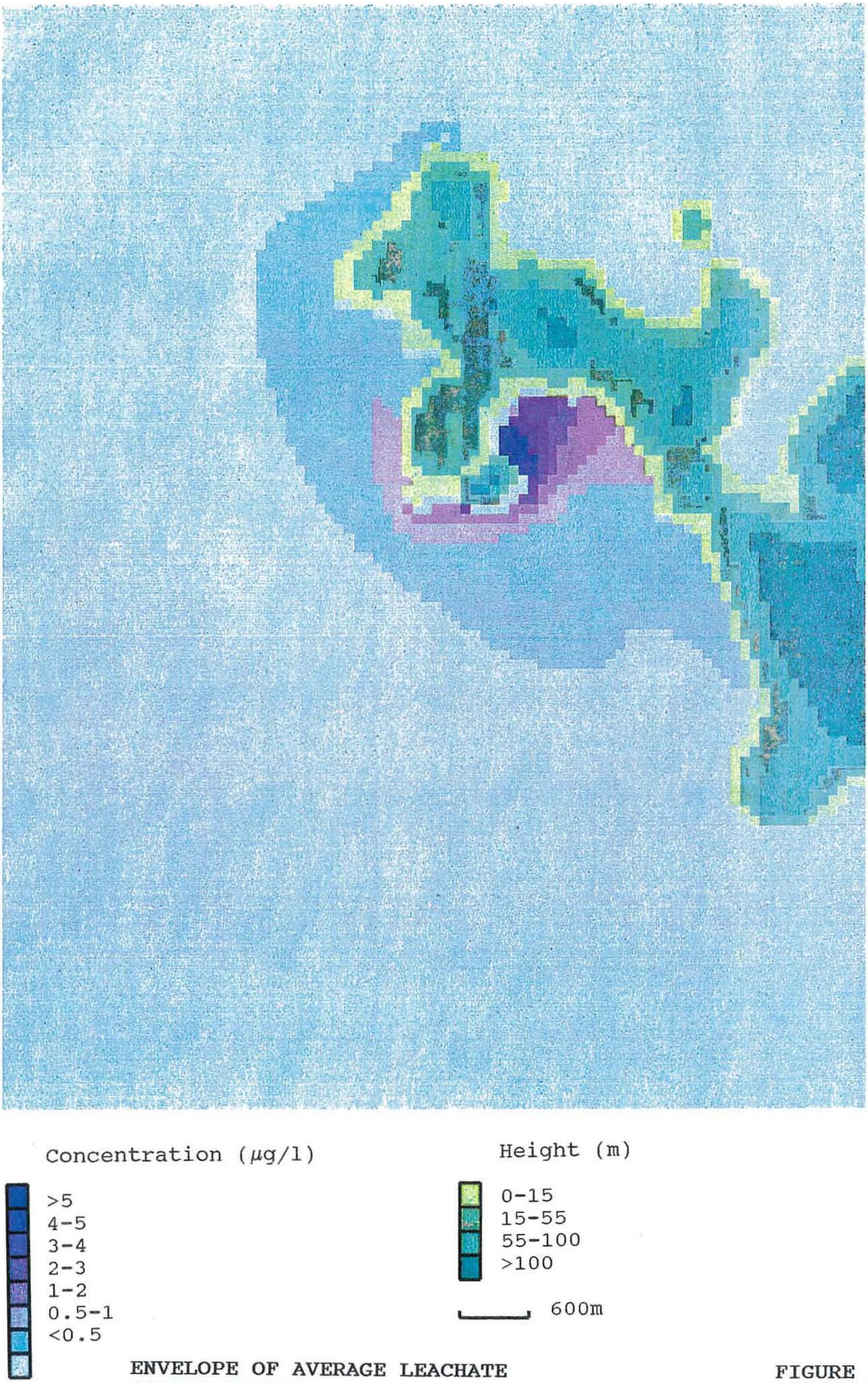
ENVELOPE OF MINIMUM LEACHATE CONCENTRATIONS - NEAP TIDE

FIGURE 27



ENVELOPE OF AVERAGE LEACHATE CONCENTRATIONS - SPRING TIDE

FIGURE 28



ENVELOPE OF AVERAGE LEACHATE CONCENTRATIONS - NEAP TIDE

FIGURE 29

APPENDIX 1

DESCRIPTION OF THE DIVAST COMPUTER MODEL

A.1 Computer Model - DIVAST

A.1.1 The program DIVAST is a two-dimensional flow and pollutant model. The model simulates flow patterns in rivers, lakes, estuaries, bays and coastal areas. Currents and water levels are calculated as a function of time, taking into account the hydraulic characteristics of the seabed, and the boundary currents and water-levels. The model also predicts the movement, decay and reactions of pollutants within the calculated flow field.

A.2 Features of DIVAST

A.2.1 The model was developed by Professor R.A. Falconer, now of Bradford University, and is based on a programming technique similar to that used in the Leendertse (Rand Corporation) model, with enhancements to the solution technique and program capabilities that allow modelling of:

(i) contractions and jetting

(ii) islands and breakwaters

(iii) sand banks that can dry out at low water

(iv) pollutant sources and sinks

A.2.2 The program is structured in a very general form and project specific requirements can be easily added. Hence the program is highly versatile. DIVAST has been successfully used to model:

(i) circulation in and flushing from harbours and reservoirs

(ii) water temperature rise caused by cooling water

(iii) solute distributions, resulting from discharge of sewage and industrial effluent

(iv) sediment transport characteristics

(v) eddy shedding from obstructions

A.2.3 The developments carried out by B&P include structuring the program into a modular form and making the model fully data driven. The type of problem and the layout of the area simulated are defined by the input data file rather than being specified inside the program. The operation of the program has also been altered to allow:

(i) simplified specification of the flow field

(ii) starting a simulation with the end conditions from a previous run

(iii) running the water movement model without the solutes model

(iv) routing of pollutants through a steady state flow field, which is not recalculated at each time step

(v) modelling several water quality parameters which can interact, decay and have sources or sinks either from the bed or the water surface

(vi) calculation of net current residuals, for instance over a tidal cycle

(vii) calculation of bed shear stresses and plotting of maximum shear stress maps

(viii) calculation of sediment transport rates and plotting of net sediment movement

(ix) creation of artificial float tracks

(x) modelling of barrage hydraulics

A.3 Solution Techniques

A.3.1 The model simulates the time-history of water levels, flows, and solute concentrations, throughout an area of interest. The study area is represented by a 2-dimensional grid in a horizontal plane one the earth's surface. The different properties of this body of water, such as land/water boundaries, bed topography, and bed roughness, are described on this grid system. Time is considered at a series of points during the period being simulated. At each point in time, the continuity and momentum equations are solved to give the water-levels, velocities, and concentrations, throughout the grid.

A.3.2 The model DIVAST solves the general form of the momentum and continuity equations for flow and solutes using an Alternating Direction Implicit finite difference technique. The boundary conditions and the solution grid are defined by the input data. The model is therefore capable of being applied to a wide variety of problems in its current state. However if necessary the governing equations can readily be changed to include the peculiarities of the problem in hand.

A.3.3 The dydrodynamic equations which govern the behaviour of the body of water are:

(i) *Continuity Equation* -

The equation for the conservation of mass of water, integrated over depth. It includes terms for flux and storage.

(ii) *Momentum Equation* -

The equation for the conservation of momentum of water, integrated over depth. Since momentum is a vector quantity, there are two of these equations, one for the x-, and one for the y-, directions. It includes terms for local and convective accelerations, Coriolis force, hydrostatic pressure gradient, wind stress, bed friction, and turbulent transfer of momentum.

(iii) *Solute Mass Balance Equation* -

The equation for the conservation of mass of solute in the water, integrated over depth. It includes terms for local effects, advective effects, turbulent diffusion/dispersion, decay, aeration, benthic uptake and interaction of pollutants.

A.3.4 The continuity and momentum equations are solved for the first half-time step in the x-direction. Variables in the y-direction are assumed to be explicitly known. The variables in the x-direction are solved for implicitly, using a Gaussian Elimination technique for solving simultaneous equations.

A.3.5 The equations are then solved for the second half-time step in the y-direction. Variables in the x-direction are known from the previous half-time step, and are assumed not to change during the second half-time step. That is, the variables in the x-direction are known explicitly. The variables in the y-direction are solved for implicitly, using the Gaussian Elimination technique.

A.3.6 This is then repeated in the x-direction, then the y-direction, then the x-direction, and so on, with time moving by a full-time step for each x-/y- sweep. This method is known as the Alternating Direction Implicit (ADI) method. This method is supplemented by an improved solution technique, the 'QUICK' solution, which uses Quadratic Interpolation to give better representation of concentration fronts.

A.4 Model Assumptions

A.4.1

(i) The bed topography is known.

(ii) The bed topography may change rapidly, but water-levels change gradually.

(iii) The bed roughness is known.

(iv) The curvature of the earth across the study area is ignored.

(v) The Coriolis force is constant over the whole area.

(vi) The atmospheric pressure is uniform across the study-area.

(vii) The water-levels, or discharges, at the open boundaries are known.

(viii) The water behaviour can be represented by the shallow water wave equations.

A.5 Boundary Conditions

A.5.1 Before the simultaneous equations for a reach can be solved, the boundary conditions at the lower and upper bounds must be known. There are three possible ways of defining the limits of the model. These are as follows:

(i) CLOSED BOUNDARIES, which occur when the end of the reach is adjacent to dry land.

(ii) KNOWN DISCHARGE OPEN BOUNDARIES, where the discharge is known at all times during the simulation period. For example, the hydrograph of a river, or the discharge through an outfall, might be known.

(iii) KNOWN WATER-LEVEL OPEN BOUNDARIES, where the water-levels are known at all times during the simulation period. For example, the boundary between the study area and the open sea might be prescribed by a curve or the boundary might be a lake or reservoir of known level. The level is specified by either a series of water levels at constant or varying time intervals or by one or more tidal harmonic constituents.

Binnie Consultants Limited
11/F New Town Tower
Pak Hok Ting Street
Shatin N.T.
Hong Kong

The Hongkong Electric Co Ltd
Electric House
44 Kennedy Road
Hong Kong