Green Valley Landfill, Ltd

South East New Territories (SENT) Landfill

Supplementary Environmental Impact Assessment (SEIA)

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er ENVIRONMENTAL

Section 13.5 RISK ASSESSMENT OF LINER LEAKAGE

Page 13-7, Paragraph 1, Sentence 8, Line 10

An average seepage rate of 0.25 litres/hectare/day through the liner was calculated for the following 3 components:

Thickness	Material	Hydraulic Conductivity
2.0 mm	HDPE Geomembrane	$K = 10^{-15}$ m/s
6.0 mm	Bentonite Matting	$K = 10^{-11}$ m/s
1.5 mm	HDPE Geomembrane	$K = 10^{-15}$ m/s

Page 13-7, Paragraph 3, Sentence 1, Line 1

Giroud and Bonaparte (Ref 3) independently evaluated leaks in geomembrane liners.

Section 13.7 IMPLICATIONS FOR GROUNDWATER QUALITY

Page 13-9, Paragraph 4, Sentence 2, Line 2

Theoretically, the maximum amount of leachate that could leak from liner defects into the environment in this manner could be 1.05 litres/hectare/day through the basal liner system when seepage through the actual membranes is taken into account.

Page 13-9, Paragraph 4, Sentence 3, Line 6

This figure represents the maximum theoretical leakage rate under a 1 meter head of leachate.

Page 13-9, Paragraph 4, Sentence 4, Line 6

The maximum theoretical leakage rate of 1.05 litres/hectare/day is 11% of the USEPA's guideline for de minimis leakage of 1 gallon/acre/day (9.35 litres/hectare/day).

Page 13-9, Paragraph 4, Sentence 5, Line 7

Given that the basal area of the landfill upon completion of installation of the entire liner system is 94.68 hectares, the maximum potential leachate leakage through the liner at the SENT Site could be 99.4 litres/day.

Page 13-10, Paragraph 1, Sentence 1, Line 1

Therefore, with the incorporation of the groundwater collection blanket, any leakage that does occur from the landward part of the landfill would be intercepted and treated, and therefore have little or no impact on the groundwater quality beneath the SENT Site.

Page 13-10, Insert between Paragraph 1 and Paragraph 2

If any leachate seeps through the seaward liner system in the reclaimed area, it will be detected in the groundwater quality in the downgradient monitoring wells. This will allow an assessment to be made of the possible degradation of the groundwater quality and action taken, such as interception and treatment through the downgradient monitoring wells. The groundwater quality assessment would be detailed in a corrective action programme.

Section 13.8 CONCLUSIONS AND RECOMMENDATIONS

Page 13-11, Paragraph 2, Sentence 5, Line 4

As discussed, a maximum theoretical leakage rate of 1.05 litres/hectare/day calculated using a 1 metre head of leachate, is below the USEPA guideline for de minimis leakage of 1 gallon/acre/day (9.35 litre/hectare/day).

Page 13-11, Paragraph 2 addition at end of paragraph

Any leachate seepage from the landward part of the basal liner system will be intercepted by the groundwater drainage blanket and treated. The potential impact of leachate seepage from the reclaimed area will be assessed through the routine monitoring of groundwater quality at the downgradient monitoring wells, and if necessary intercepted and treated. Any action to be taken in response to degradation of groundwater quality will be detailed in a corrective action programme.

Section 14.4.3 Liner Leakage

Page 14-3, Paragraph 1, Sentence 3, Line 4

In summary, the theoretical maximum potential leakage of leachate (1.05 litres/hectare/day) through the liner system could be 99.4 litres/day for the whole Site of SENT Landfill following the completion of installation of the liner system (94.68 hectares), which is 11% of USEPA's guideline for de minimus leakage of 1 gallon/acre/day (9.35 litre/hectare/day), assuming a 1 metre head of leachate.

Section 14.5.3 Liner Leakage

Page 14-5, Paragraph 1, Sentence 1, Line 1

The small quantity of leachate seepage (99.4 litres/day) which could occur will be spread over the whole landfill base (94.68 hectares). This quantity would be distributed with some entering the groundwater collection blanket and being tested and treated if necessary, and the rest being detected in the downgradient monitoring wells, and if necessary intercepted and treated.

SENT LANDFILL

SUPPLEMENTARY EIA

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Non-Technical Summary

NON-TECHNICAL SUMMARY

1. INTRODUCTION

SENT Landfill is one of three strategic landfills being developed and operated to meet present and future solid waste disposal needs for Hong Kong for the next 20 to 30 years. The contract to develop and manage SENT Landfill was awarded to Green Valley Landfill, Ltd (GVL) in August 1993 and the site is due to receive waste within one year of this date.

A comprehensive and detailed Environmental Impact Assessment has already been prepared for SENT Landfill (the Conceptual Environmental Impact Assessment, or CEIA), based on a conceptual design developed for EPD. However there are a number of differences between the design produced by GVL and the conceptual design, with consequential differences in the potential environmental impacts of the project compared to those identified in the CEIA. An independent environmental review of the GVL design was undertaken as part of the Tender process. The review identified design changes between GVL design and the conceptual design and supplementary issues which required further study. The aim of this Supplementary Environmental Impact Assessment (SEIA) is to assess the impacts of these design changes and to complement the CEIA by addressing those issues arising since production of the CEIA.

2. THE SENT LANDFILL SITE

SENT Landfill is located on the western edge of Clear Water Bay Peninsula in the south eastern corner of the New Territories. The site covers an area of about 95 hectares, half of which is being reclaimed from Shek Miu Wan (Junk Bay). At present part of the site has been reclaimed and the access road D6 is complete. To the north and east of the site lies Clear Water Bay Country Park; to the west, a reclamation started in 1991 for the Tseung Kwan O (TKO) Third Industrial Estate (TIE) and to the south a proposed reclamation for potentially hazardous installations and deep water-front industries (Tseung Kwan O Area 137).

3. PROJECT BACKGROUND

SENT Landfill will receive approximately 40 million tonnes of waste over a period of 15 to 17 years at current predicted waste generation rates. Municipal, commercial, industrial and chemical wastes will be accepted, together with the types of construction waste which cannot be recycled for use as fill material in reclamations. The site has been designed to incorporate extensive means to collect, contain, transfer and treat landfill by-products, including leachate and landfill gas. Unlike the other two strategic landfills (WENT and NENT), SENT Landfill is a direct replacement for an existing facility TKO Landfill Stages II/III, which is located to the north.

A "conceptual" design was produced by consultants employed by EPD in 1990. Its development was an iterative process involving many inputs from the environmental assessment work being carried out simultaneously. The design incorporated extensive measures to protect ground water and marine waters from contamination during both preparation of the site, and filling with waste. Full containment of the deposited waste was stipulated, by low permeability liners over the base and sides, and a low permeability cap over the top of the site.

Since the CEIA was carried out, further environmental monitoring and assessment work including an Environmental Review has been undertaken; this has been reviewed as part of the SEIA, and incorporated where appropriate. A number of Site Investigations have been carried out with boreholes drilled to establish the depth, nature and characteristics of the geology of both land and marine areas. An Advance Works contract was carried out from June 1992 to August 1993, which included dredging muds and silts from the marine area, to give a stable base for the reclamation work; construction of seawalls and reclamation of parts of the site; construction of a temporary access road and surface water drainage system; and provision of advance landscape planting around the boundary of the site to screen the works from the Clear Water Bay Country Park, and particularly the High Junk Peak Hiking Trail. In addition environmental monitoring has been undertaken.

4. GVL Project Design

Prior to the start of landfilling, reclamation of the remainder of the marine parts of the site will be completed, using marine sands dredged from a licensed area (just south of Tung Lung Chau Island) and rock from on-site excavations. Preparation of the site for waste will also include blasting of rock slopes to provide a suitable base for the landfill, and installation of the site liner system. Four different liner systems will be used in different parts of the site, all of which are high technology "composite" systems using the latest synthetic impermeable materials to provide exceptionally high levels of integrity. Rigorous Construction Quality Assurance (CQA) checks will be adopted during installation of the liner.

Access to the site will be gained from the west via Road D6. A site infrastructure area at the extreme south of the site will house the landfill business office, the independent consultants, and offices for EPD. Weigh bridges, waste examination area, waste examination, environmental and soils laboratory, a waste recycling area, a maintenance building, and plant to treat the landfill byproducts, landfill gas and leachate will be carefully collected and removed from the waste mass. State-of-the-art Leachate treatment facility will be used on site, prior to discharge via forcemen to TKO5W for ultimate disposal as effluent discharge to inland waters. Stringent environmental controls will ensure impact on the environment is minimised. Each component of the site has been designed to accommodate the initial projected waste input rate of 3,000 tonnes per day, while allowing for a possible emergency waste intake of up to 30,000 tonnes per day.

The site will be developed and operated in 21 areas, with phased construction, operation and restoration. Areas filled to final levels will be restored as soon as feasibly possible, with low permeability caps, a special drainage layer and at least 1.5m depth of soil. Areas will then be landscaped with a mixture of native trees, shrubs and grasses. Following completion of the site and restoration of all areas, the site will be closely managed for an "aftercare" period of about 30 years. Safe removal of landfill gas and leachate will continue over this period, as well as environmental monitoring. The site will be restored as an informal recreational area with footpaths, pavilions and sitting out areas. In both terms of topography and landscape it will integrate attractively with the Country Park.

5. SEIA SUPPLEMENTARY ISSUES

Eleven specialist environmental studies of "Supplementary Issues" have been undertaken as part of the SEIA. These have evolved through an Environmental Review of the project, discussions with EPD and other Government Departments, and variations between the GVL design for SENT Landfill and the Conceptual Design. The conclusions of each of the Supplementary Issue studies are summarised in the following paragraphs.

6. WASTE RECYCLING

Waste recycling at SENT Landfill has been proposed for both construction waste and combustible materials that can be used to make refuse derived fuel. Recycling is both environmentally preferred and in accordance with the Government's stated policies. Recycling proposals will be finalised following a waste characterisation study during the first year of waste disposal at the site, and following a review of the effects of the Government's plans for a number of centralised construction waste recycling centres, one of which may be located in the TKO area.

A preliminary assessment has been made of the impacts of a construction waste recycling plant. On the basis of current intentions and available information it is not anticipated that the plant will cause either noise or dust impacts. However, it is recommended that when decisions have been made regarding the recycling processes and proposed plant details are available, then predictive modelling for potential noise and dust impacts should be undertaken.

7. LANDFILL GAS UTILISATION

Landfill gas is produced by decomposing waste and will be collected and transferred to a treatment plant where it will be burnt off in enclosed flares, which have very low air and noise emissions. More than 98% of the harmful compounds in the gas will be destroyed. When the volumes of gas produced reach a level at which it is practical and economically viable, a gas utilisation plant will be installed. This will use the latest turbine technology to produce electricity to supply all the needs of the site, and possibly for sale to other users off-site.

Computer modelling of air and noise emissions from the plant has been carried out. The very low emissions, and comparatively large distances to Sensitive Receivers (SRs) result in very low concentrations at the SRs, well within the noise and air quality standards. No significant odour or visual impacts are predicted.

8. SOURCES AND AVAILABILITY OF CONSTRUCTION MATERIALS

During preparation of the site, there is potential for environmental impact from the large quantities of soil and rock required, and from activities such as blasting, excavation, material handling, transport, processing and stockpiling. The impacts will be minimised by maximising the use of materials from the site excavation into the reclamation and site formation fill materials. Extensive mitigatory measures have been incorporated into the design and their effectiveness will be checked by the Environmental Monitoring Plan (EMP).

A number of alternative materials may be used to cover the waste at the end of each day to minimise odour, rodents, flies and litter. Soil is routinely used, but the utilisation of other materials can preserve soil supplies and reduce the use of valuable landfill spaces. Materials under consideration include foams, geotextile, tyre chips and foundry slag. All of these materials have been used at landfills in the USA, without adverse results. It is recommended that trials should be carried out, however, of the intended materials, including testing of the likelihood for them leaching toxic chemicals. In addition, monitoring should be undertaken on-site to assess the effectiveness of the performance of the alternative cover materials.

9. LEACHATE PRODUCTION AND MANAGEMENT

"Leachate" is the term used to describe the highly polluting liquid formed within waste by the seepage of water through it, and the chemical and biological reactions taking place as the waste decomposes, together with any liquids already present in the waste when landfilled. The leachate will be collected at the base of the landfill, extracted and treated at the leachate treatment facility (LTF). The LTF will use chemical and biological processes to reduce the amounts of organic chemicals, ammonia and metals in the raw leachate to specified concentrations prior to discharge to a sewer leading to TKO sewage treatment works (TKO STW). From 1998, it is planned that TKO STW will be connected into Hong Kong's Strategic Sewage Disposal Scheme (SSDS). Prior to this, treated effluent from TKO STW is discharged to the Tathong Channel through a long sea outfall. During this interim period, significant impacts on water quality are not expected due to the advanced processes which will be provided at the LTF (including almost total ammonia removal) and the good tidal flushing characteristics in the Tathong Channel which will disperse any residual contaminants along with sewage from TKO.

The LTF uses a series of air-strippers to remove ammonia. The ammonia gas removed will be passed over a hot catalyst material prior to discharge, to convert it to harmless nitrogen gas and water vapour. Computer modelling of ammonia emissions from the LTF indicate very low ambient concentrations, and no adverse impact. It is recommended however that the performance of the catalyst is closely monitored; an additional ammonia monitoring location in the close vicinity of the LTF equalisation tank is included in the EMP; and an Emergency Procedures Plan is produced. Construction and operation of the LTF is not predicted to have any significant adverse impacts.

10. SURFACE WATER RUN-OFF AND OPERATIONAL EFFLUENT DISCHARGES

The surface water management system at SENT Landfill has been designed such that clean surface water is segregated from leachate producing parts of the landfill and does not come into contact with waste. Run-off from slopes surrounding the site is intercepted and discharged at controlled, monitored locations to Junk Bay and Clear Water Bay. The design and operational procedures of the surface water management system are such that no significant adverse impacts on water quality are expected to occur. The EMP will show if contamination of surface water is occurring, and subsequent investigations will identify the source to establish where remediation measures are required.

11. GROUNDWATER

Monitoring data show that the groundwaters within the SENT Landfill catchment are uncontaminated. The higher standards of the GVL liner system above the conceptual design will result in higher levels of protection to the groundwater. However, some seepage of leachate through the liner system is inevitable, and calculations indicate a maximum rate of 0.07 litres per hectare per day. This is below the US EPA's allowable leakage rate of 1 litre per hectare per day. Given the small amounts of leachate that may escape from the site, and the provisions to deal with them, it is considered that there is very little risk of groundwater quality being adversely affected by the project.

The groundwater levels will reduce, but as groundwater is not considered a resource in the area, this will have little noticeable impact, and the reduction in groundwater levels should have little effect on stream discharges in Clearwater Bay and Joss House Bay.

It is recommended that an Action Plan for dealing with a major liner rupture be prepared by GVL within 12 months from commencement of landfilling operations.

12. MARINE DISCHARGES

Prior to the finalisation of the specific methodology for the reclamation of the marine infill area, it is not possible to quantify the associated impacts. It is expected, however, that mitigation measures, including the use of sediment traps, will be required to prevent any adverse impacts on the receiving marine water quality in Junk Bay. The sediment traps will have to be designed so that sufficient settling time is allowed to ensure that the effluent water complies with Government standards.

The potential impact of leachate seepage on marine water quality is considered negligible.

13. LANDSCAPE AND ECOLOGY

Advance landscape planting was carried out under the Advance Works Contract and its effectiveness will be assessed during preparation of the Landscape Masterplan. The selected tree and shrub species will be made up of a mix of indigenous and introduced species with proven local adaptability. It is recommended however that consideration be given to not using Acacia trees, since they are neither native nor have significant wildlife value in Hong Kong. It is also recommended that exotic species should not be used in coastal areas and that species which attract fruit-eating birds should be introduced.

Landscaping will also be provided adjacent to the access road, along the western boundary of the site; in the site infrastructure area, to screen the LTF and landfill gas plant; and in adjacent areas of the Country Park. Planting trials will be undertaken during the first phase of the restoration, to determine the most appropriate seed and plant mixes and methods of implementation.

Monitoring of flora and fauna will be carried out six-monthly under the EMP. Additional surveys of rodents, burrowing animals and birds are proposed. Which additions have already been incorporated into the EMP.

14. VISUAL IMPACT

The key areas of potential visual impact as a result of the development and operation of SENT Landfill are users of the High Junk Peak Hiking Trail adjacent to the site, and residential properties across Junk Bay. Extensive mitigatory measures have been incorporated by GVL into the design of the site, including the hydroseeding of soil slopes with grass; provision of landscaping around the periphery of the site; and the phasing of filling and restoration. These measures, combined with the screening effect of Junk Island, mean that visual intrusion to residential areas will be low.

Medium to high levels of visual impact will be experienced, however, in the early years of the project, to users of the Hiking Trail and the part of Clear Water Bay Country Park adjacent to the site. These will be mitigated over time by trees planted around the site boundary. The presence of the TIE and Area 137 industrial developments will detract from the quality of mid to long range views, but the restored landfill will partly hide these developments. Following restoration the visual impact of SENT Landfill will be negligible, providing an attractively landscaped area of recreational open space between the Country Park and adjacent developments.

15. EXCEPTIONAL TRAFFIC IMPACTS

If a situation should occur when one (or even both) of the other strategic landfills (NENT and WENT) were unable to accept waste, significant additional waste inputs to SENT Landfill would be necessary. This has been termed an exceptional waste situation (EWS). Although an EWS is a possibility, it would be expected to be of a maximum of about two weeks duration. It would lead to a maximum predicted road traffic flow of 454 lorry arrivals at the peak hour of 17:00-18:00. Although some traffic congestion would be experienced, following completion of the Western Coast Road to TKO, minimal traffic disruption is anticipated. Where possible, waste would be transferred by barge, to reduce road congestion.

Mitigation measures have been identified which would deal with an EWS. These include the development of extra tipping faces, which would speed up the input and output rate of the lorries. A major aim is to avoid fly tipping causing disturbance to the neighbouring sensitive receivers. It is recommended, however, that a Management Plan be drawn up for handling containers at both the SENT Landfill and TKO(I) marine access points, based on the marine traffic arrival patterns predicted under the EWS.

16. ADJACENT DEVELOPMENTS

Of the planned adjacent developments to the SENT Landfill site, none have been identified as potentially incompatible. Any future development should be planned taking due cognisance of the presence of the SENT Landfill and its permitted threshold emissions.

17. ENVIRONMENTAL MONITORING

An Environmental Monitoring Plan (EMP) has been developed for SENT Landfill. This is designed not only to detect any adverse environmental impacts and help to ensure compliance with the required standards, but to gauge the effectiveness of the mitigation measures adopted in the GVL design and to provide data for on-going environmental audit of the project. The range of environmental and operational variables and parameters to be monitored includes:

- Leachate
- Landfill gas
- Groundwater
- Surface water
- Marine water
- Noise
- Dust
- Organic emissions and odour
- Volatile organic carbons (VOCs) and ammonia
- Meteorological data
- Volume and density of waste
- Settlement
- Waste type
- Flora and fauna

18. CONTINUOUS ASSESSMENT PROGRAMME

Since there are environmental issues to be addressed during the early life of the landfill which cannot be undertaken during the limited period of time available for the preparation of the SEIA, a Continuous Assessment Programme (CAP) is planned and will include the following studies:

- EIA of refuse derived fuel recycling plant;
- dust assessment of construction waste recycling;
- alternative cover materials trials;
- on-going groundwater assessment; and
- input advice to EPD in the production of a Management Plan for handling marine traffic and containers during an EWS.

Section 1

Environmental Background

Contents

Introduction & Terms of Reference

Chapter 1

1 INTRODUCTION AND TERMS OF REFERENCE

1.1 THE ENVIRONMENTAL ASSESSMENT PROCESS

This report is a Supplementary Environmental Impact Assessment (SEIA) for the South East New Territories (SENT) Landfill, being developed and managed for the Hong Kong Government Environmental Protection Department (EPD) by Green Valley Landfill, Ltd (GVL). It has been prepared by Acer Environmental, environmental consultants to GVL, and meets the requirements of Sections 1.3.3 and 33.10 of Tender Document: Volume 3 : Part A, the Specification for the Development and Management of SENT Landfill, Contract EP/SP/10/91 (Ref 1.1). The SEIA has been prepared in consultation with the Environmental Assessment and Planning Group (EAPG) of EPD, and a number of other interested groups, including other relevant specialist groups within EPD and other government departments. The scope of the SEIA, and the assessment methodologies used, have been agreed with these parties.

A comprehensive Environmental Impact Assessment (EIA) has already been completed for the SENT Landfill, based on a conceptual landfill design prepared by consultants engaged by EPD. This comprises two reports:

- Environmental Impact Assessment - Initial Assessment Report, July 1990 (The Conceptual EIA [CEIA-IAR] (Ref 1.2)); and

- Environmental Impact Assessment - Key Issues Report [CEIA-KIR], September 1990 (Ref 1.3).

The principal objective of the CEIA-IAR was to provide an initial evaluation of the environmental impacts likely to arise from the proposed development of the SENT Landfill and identify those issues of key concern. It was not possible to resolve all of these within the CEIA-IAR so detailed assessment work continued in parallel to the landfill design, and the CEIA-KIR was produced. In conjunction, the two reports provide a comprehensive assessment of all the impacts of the project and contain extensive mitigation measures and monitoring.

Environmental assessment work has been, and is being, carried out at every stage of the progressive planning, tender and design of the site, from initial site selection to the preparation of final construction documents. As part of the tender for the contract to develop and operate the SENT Landfill, it was a requirement to undertake an Environmental Review (ER) of the project, reporting the predicted impacts of all aspects of the tender design. A key role of the ER was to audit the GVL design against the baseline of the CEIA-IAR and CEIA-KIR, and identify those issues not fully mitigated in the CEIA-IAR which would be assessed in the SEIA. The scope of this SEIA was thus initially defined.

1.2 OBJECTIVES OF THE SEIA

The SEIA has the following objectives:

- to address any issues identified in previous studies as requiring further EIA work;

- to review the differences between the successful GVL project design and the conceptual design used in the CEIA-IAR, and assess the environmental impacts of these design changes; and

- to identify whether the environmental performance criteria and standards, mitigation measures and environmental monitoring are appropriate.

1.3 TERMS OF REFERENCE

The Terms of Reference of the SENT Landfill SEIA comprise the following:

- Contract Specification Sections 1.3.3 and 33.10;
- The conclusions of the ER carried out by Acer Environmental;
- Additional issues raised by EPD during the tender negotiation process; and
- Comments from EPD and other Government departments on the scope of the SEIA.

For ease of reference, the Terms of Reference are included as Appendix 1 to this report. The SEIA has also been compiled in accordance with the Hong Kong Government's "Advice Note 2/90 - Application of the Environmental Impact Assessment Process to Major Private Sector Projects", produced by the EAPG of EPD (Ref 1.4), and sections 1 to 5 of Appendix 4 of the UK Department of Environment's "Environmental Assessment - A Guide to the Procedures" (Ref 1.5).

1.4 STRUCTURE OF THE SEIA

The SEIA is structured in three sections. Section 1 sets out the environmental background to the SENT Landfill Project in terms of the history and evolution of the project, the site, its surroundings and sensitive receivers to possible impacts; and the detailed GVL project design, with particular emphasis given to the effects of any variations from the conceptual design. Those environmental effects, unchanged from the CEIA-IAR, and which have already been assessed and mitigated to the satisfaction of EPD, are then listed. Since the GVL design complies fully with the mitigation measures recommended in the CEIA, no further consideration of these issues is given in this report. The identification and scoping of the supplementary issues, afforded detailed consideration in the SEIA, is then described.

Section 2 presents eleven "Supplementary Issues" chapters. These describe the results of detailed additional assessment work carried out on those issues identified as consequent on the GVL design proposals, or identified as omissions which were omitted from the CEIA-IAR and CEIA-KIR Report or which arose from the GVL project design proposals. The 11 areas addressed are:

- Waste Recycling;
- Landfill Gas Utilisation;
- Sources of Construction Materials;
- Leachate Treatment Plant;
- Surface Water;
- Hydrogeology;
- Marine Discharges;
- Landscape and Ecology;
- Visual Impact;
- Exceptional Traffic Impacts; and
- Adjacent Developments.

Section 3 of the SEIA contains a summary of the environmental impacts of the SENT Landfill throughout all phases of the project (Works, Operations, Restoration and Aftercare); drawing on the conclusions of the CEIA-IAR, CEIA-KIR Reports and Sections 1 and 2 of the SEIA. The full inventory of mitigation measures is then presented, together with the programme of implementation. Monitoring proposals are summarised, together with any requirements identified as additional to the existing Environmental Monitoring Plan (EMP) (Ref 1.6). A brief review of the assessment methodologies used in the SEIA is also included here, together with recommendations for the issues to be addressed as part of the Continuous Assessment Programme (CAP). The CAP covers environmental issues which need addressing during the early life of the landfill, but which cannot be undertaken during the initial period of the contract allowed for the preparation of the SEIA.

A summary, in non-technical language of this SEIA has also been prepared by Acer Environmental and is presented as the preface to this report.

REFERENCES

1.1 Environmental Protection Department, Hong Kong Government. Development and Management of SENT Landfill, Contract EP/SP/10/91, Tender Document: Volume 3, Part A, Specification (June 1992).

1.2 Scott Wilson Kirkpatrick & Partners. SENT Landfill Environmental Impact Assessment, Initial Assessment Report (July 1990).

1.3 Scott Wilson Kirkpatrick & Partners. SENT Landfill Environmental Impact Assessment, Key Issues Report (September 1990).

1.4 Hong Kong Government Environmental Protection Department. Advice Note 2/90 - Application of the Environmental Impact Assessment Process to Major Private Sector Projects (February 1990).

1.5 Department of the Environment. Environmental Assessment: A Guide to the Procedures (HMSO, 1989)

1.6 Woodward Clyde International. Environmental Monitoring Plan, SENT Landfill, Hong Kong (August 1993).

Site Context

Chapter 2

2 SITE CONTEXT

2.1 SITE DESCRIPTION

SENT Landfill is located on the western edge of Clear Water Bay Peninsula in the south eastern corner of the New Territories see Figure 3.1. Clear Water Bay Peninsula is an extremely attractive part of the New Territories located near the developing community of Tseung Kwan O New Town and metropolitan areas of Hong Kong. The rocky, cliff-edged coast and high peaks and ridges create a spectacular landscape, making the area popular for informal recreational activities such as swimming, boating and walking. The site itself comprises approximately 100 hectares (ha) with an area of 94 ha being used for filling waste. The site extends from just below the ridge of Clear Water Bay Peninsula to Fat Tong Chau (Junk Island), part of which is incorporate into the site.

Much of the site (about 50 ha) represents land reclaimed from Shek Miu Wan (Junk Bay), with the remainder comprising the natural undeveloped western slopes of the Clear Water Bay Peninsula and a number of small fishing villages at the base of the slopes. The three villages, Tin Ha Wan, Sheung Lau Wan and Tin Wan Tsai, with a total population of 149 (in 1989) were relocated to a new site in 1993 and all buildings within the site boundary are now derelict.

Following completion of the Advance Works Contract, two areas (at the extreme north and south of the site) have been reclaimed. The Third Industrial Estate (TIE) reclamation to the west is already well advanced, with Fat Tong Chau (Junk Island) joined to the mainland at the north, and access road D6 already in place.

A detailed site description is given in the CEIA.

2.2 SURROUNDING LANDSCAPE AND LAND USE

The topography, landscape and land use of the SENT Landfill site and surrounding areas is described in detail in the CEIA. The following sections are provided as summaries to set the scene for the SEIA.

2.2.1 Topography

SENT Landfill is situated at the south western end of the Clear Water Bay Peninsula. The landmass is rugged and mountainous and is dominated by a pronounced north-south ridgeline which rises into a series of peaks from Sheung Yeung Shan (260m) in the north to Tin Ha Shan (273m) in the south. Tiu Yue Yung (344m) (High Junk Peak) to the north east of the site is the highest point on the peninsula, its conical shape forming a distinctive landmark.

The slopes to the east and west of these peaks are generally steep, descending unbroken into the sea and forming a series of sharply inclined high-sided valleys and secondary ridges with upper slopes having average gradients of 1:2 and lower slopes between 1:2 and 1:3.

The landward boundary extends to the mid slopes of the peaks of Ha Shan Tuk (187m) and Tin Ha Shan (273m). From these peaks the steep rocky slopes descend sharply to the sea enclosing the site to the north, south and east. A distinctive saddle runs east-west between the two peaks from which a series of gullies extend, opening out into the narrow coastal valley of Shek Miu Wan.

Facing the bay, previously separated from the peninsula by a 300m channel but now joined to the mainland by the TIE reclamation, lies Fat Tong Chau (Junk Island), which comprises a series of rounded ridges, the highest rising to 99m. Fat Tong Chau has been partially excavated to provide reclamation material for the TIE.

2.2.2 Landscape

The area is of high scenic quality characterized by a series of steep, boulder strewn peaks and ridges which descend dramatically into the sea below. The upper slopes of these peaks support little vegetation other than grassland which further accentuates their rugged beauty.

A pronounced ridge links the peaks and forms a distinct feature in the overall landscape; the saddle between the peaks of Ha Shan Tuk and Tin Ha Shan is also a noticeable landmark.

There are localised areas of mixed broadleaf woodland which spread along the sheltered damp valley floors into the foothills. Woodland is replaced by scrub at higher elevations.

2.2.3 Surrounding Land Use

To the north and east, the Clear Water Bay Country Park (as shown on Figure 2.1) abuts the site following the north-south ridge-line along the peninsula. There are also small areas of land designated as Countryside Conservation Areas. To the south of the site, a reclamation for Deep Waterfront Industries in Tseung Kwan O Planning Area 137 has been proposed as part of the Port and Airport Development Strategy (PADS). To the west of the site, a reclamation started in August 1991 for the development of the TIE in Tseung Kwan O Planning Area 87 managed by The Hong Kong Industrial Estates Corporation (HKIEC). These two latter developments will eventually land lock the Site. Details of the types of development planned for these adjacent reclamations are described in Chapter 18.

2.3 SENSITIVE RECEIVERS

As part of the CEIA all potentially sensitive receivers within the Study Area were identified. This analysis included planned future developments in the Tseung Kwan O area. The same sensitive receivers have been used, where appropriate, in the SEIA. These are identified and described in the relevant sections of Chapters 8 to 18.

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FIGURE 2.1

LOCATION PLAN

Project Background

Chapter 3

3 PROJECT BACKGROUND

3.1 BACKGROUND AND HISTORY

SENT Landfill is one of three strategic landfills which will be designed, constructed, operated and restored by the private sector. The three landfills, West New Territories (WENT), SENT, and North East New Territories (NENT) will be developed and operated to meet present and future solid waste disposal needs for Hong Kong for the next 20 to 30 years. SENT Landfill has been designed and will be operated as a co-disposal landfill where various types of waste will be accepted including municipal, industrial, commercial, and chemical waste.

SENT Landfill contributes to meet the disposal strategy set out by the Hong Kong EPD, it has been designed to operate in a cost efficient manner while at the same time providing means to minimize or eliminate potential impacts to the surrounding environment. SENT Landfill will incorporate extensive means to collect, contain, transfer, and treat landfill byproducts, including leachate and landfill gas.

Presently, currently active landfill sites within Hong Kong, including Tseung Kwan O Landfill (TKO) Stages II/III, are at or near design capacity. Commissioning of the three strategic landfills is necessary as soon as possible to avoid a problem situation resulting from insufficient waste disposal facilities. Delays in development of the strategic landfills could result in an overall degradation of public health, safety, and the surrounding environment.

The contract to develop and manage WENT Landfill was awarded in Spring 1993 and acceptance of waste at the site is due to commence in November 1993. The contract for SENT Landfill was awarded to GVL in August 1993, and initial works at the site are progressing. Filling of waste is programmed to commence in August 1994.

3.2 CONCEPTUAL DESIGN

An outline or "conceptual" design for waste disposal at the identified site, located at the south western end of Clear Water Bay Peninsula, was prepared by consultants Scott Wilson Kirkpatrick for EPD in 1990 (Ref 3.1). Its development was an iterative process involving many inputs from the environmental assessment work being carried out simultaneously. The CEIA was based on the conceptional design.

3.2.1 Design Parameters

As a result of the CEIA, and the iterative design process running in parallel with it, a series of design criteria were developed, specifically for issues which could not be finalised at the conceptual design stage.

Table 3.1 SENT Landfill Design Criteria

Objective	Design Criteria
Protection of groundwater	* prevent groundwater entering leachate producing waste * prepare and line site prior to landfilling * do not drain clean water through leachate producing waste * prevent leachate migration towards Clear Water Bay
Protection of marine waters	* no visible or measurable deterioration in water quality of Junk Bay adjacent to site * marine infill to have minimal pollution potential * secondary protection of sea water from potential contamination of marine infill leachate (e.g. by attenuation in permeable sea wall) * leachate collection, on site treatment and discharge via TKO STW outfall in Tat Hong Channel
Leachate minimisation	* surface water interception at site boundary * direction of clean surface run-off away from operational areas of landfill * segregation of contaminated and clean waters within landfill * start new phases in dry season whenever possible * minimise working areas, and utilise progressive restoration, optimising run-off and capping
Leachate collection	* construct low permeability liner beneath leachate producing waste * liner not to be compromised by settlement of underlying marine infill materials * collection of leachate above liner to avoid single drainage sumps where liner failure could be catastrophic * leachate heads to be controlled and minimised within the leachate management objectives * prevent surface seepages of perched leachate (e.g. by drainage system within wastes) * prevent surface ponding of leachate
Leachate treatment	* pipe leachate to treatment plant * pre-treat leachate to remove ammonium * treatment at TKO STW * provision for denitrification/nutrient removal

Table 3.1 SENT Landfill Design Criteria (cont'd)

Objective	Design Criteria
Prevent risks from explosive, asphyxiating or toxic gases	* provide a positive extraction system for landfill gas collection with adequate back-up facilities * relieve positive pressures of landfill gas at the landfill boundary and near the surface * prevent off site migration of landfill gas and demonstrate the achievement of this objective * prevent landfill gas migration via pipes, services or other pathways into any enclosed spaces on or off site * provide adequate gas protection measures for any temporary or permanent structures or chambers on the landfill * establish safe working practices at any location liable to be affected by hazardous concentrations of landfill gas (e.g. gas extraction system, boreholes) * ensure a high standard of capping and covering to minimise surface emissions of landfill gas and specify a maximum surface emission rate * flare or burn in an engine the collected gas efficiently * minimise noise and visual intrusion associated with the landfill gas disposal system

3.2.2 Summary of Conceptual Design

The project design on which the CEIA is based is presented in full in the SENT Landfill Outline Design Report (Ref 3.1) and summarised within the CEIA itself. The full details are not reproduced within this report, however the main features of the design are set out below.

Sea wall

A permeable sloping sea wall was proposed, to define the seaward boundaries of the landfill until the adjacent reclamations to the west and south were carried out. A section of vertical sea wall would be constructed if barge unloading facilities were required. A 10m layer of completely decomposed volcanic (cdv) fill was proposed, along the inner side of the seawall, to facilitate interception of landfill gas and leachate, in the event of liner failure.

Marine Infill

The marine part of the site would be reclaimed with approximately 4 million m^3 of fill. Only inert fill would be permitted below the primary leachate containment, probably comprising a combination of the following materials:

- suitable inert construction waste material;
- soft fill, from within or outside the site;
- rock, from within or outside the site; and
- marine fill from a suitable dredging ground.

Initial reclamation would be in the north western and southern sectors of the site, to accommodate site administration/waste reception facilities and the first tipping phase respectively.

Liner System

The base and sides of the site would be lined with a low permeability barrier to contain leachate and landfill gas. Four distinct zones were identified, requiring different liner systems. Over the marine area, a multi-layer flexible membrane liner was proposed, incorporating drainage and protection layers above and below. HDPE membranes were proposed for the primary low permeability layers. It was considered that, over the land area, less flexibility would be required, and hydraulic asphalt (possibly incorporating an HDPE membrane) could be used as the primary low permeability layer, again in combination with drainage and protection layers. For the rock slopes, it was proposed to use sprayed concrete, with a wire mesh reinforcement,and a groundwater drainage layer beneath. An HDPE flexible membrane based liner was proposed for lining of the upper soil slopes.

Leachate Treatment and Disposal

Leachate would be contained, collected and conveyed to Tseung Kwan O sewage treatment works for treatment. Direct discharge of leachate from SENT Landfill for treatment in a mixture with general sewage was not recommended. Pre-treatment of leachate on-site would be required and a treatment process comprising extended aeration (with a retention time of 30 to 40 days) in lagoons, followed by denitrification was proposed.

Landfill Gas Management

The risk of off-site migration of landfill gas was considered to be low. However, in light of the proposed adjacent developments, active gas management and control would be essential. This would be installed progressively and gas actively pumped from the site. The possibility of gas utilisation was raised, but no firm proposals for a gas utilisation plant generating electrical power were evaluated.

Phasing

A provisional phasing layout for the site was proposed, with tipping in sixteen phases on three levels, each phase of approximately one year duration. Landfilling would start on a landward area at the southern end of the site.

Surface Water Drainage

The proposed design and operation of SENT Landfill would prevent the ingress of surface water as far as practicable. The Agriculture and Fisheries Department (AFD) concerns were recognised over the possible early construction of catchwaters within the Clear Water Bay Country Park.

Restoration Capping

The conceptual design proposed a cap comprising at least 2m of completely decomposed granite (cdg), incorporating a synthetic membrane to reduce water ingress and thus decreased volumes of leachate and landfill gas emissions.

3.3 WORK CARRIED OUT SINCE THE CONCEPTUAL DESIGN

Following completion of the Outline Landfill Design Report (September 1990), CEIA (July 1990) and EIA-Key Issues Report (November 1990) design work continued with the production of a number of working papers and a Final Report (in January 1991).

A number of other environmental studies were undertaken by EPD's consultants prior to the preparation of contract documentation for the SENT Landfill, namely :

- leaching trials on PFA (Ref 3.2);
- leachate treatment and denitrification trials (Ref 3.3); and
- analysis of marine sediments (Ref 3.4).

These have been reviewed during the preparation of the SEIA.

The CEIA identified the need for extensive background monitoring of a number of key areas prior to the commencement of construction work on site. The background monitoring programme, undertaken over the period September 1991 to March 1993 (Ref 3.5) covered the following environmental media :

- groundwater;
- marine water;
- sediments;
- dust; and
- volatile organic compounds (VOCs).

This data, where appropriate, has been incorporated into the SEIA studies.

Further Site Investigation work has been carried out since the CEIA with the marine area being covered in May/June 1991 and the landward part of the site drilled in January 1992. Laboratory testing of soil samples was undertaken in March 1992. This data has been reviewed, and used where appropriate, as part of the SEIA.

The Advance Works Contract, administered by the Civil Engineering Department (CED) of the Hong Kong Government, included the following major works :

- Dredging of soft marine deposits from Shek Miu Wan Bay and disposal at designated marine disposal areas at Ninepins and South Cheung Chau;
- Dredging of marine sand from the designated marine borrow area in the Tathong Channel for fill to form the northern and southern reclamations;
- Construction of seawalls and reclamation toe protection walls;
- Provision, deposition and compaction of materials to form the northern and southern reclamations;
- Construction of a temporary road access to Shek Miu Wan Bay;
- Excavation of soft and hard materials on Fat Tong Chau;
- Construction of temporary surface water drainage systems;
- In-situ monitoring and laboratory analysis of seawater; and
- Advance landscaping including forestry planting around the boundary of the High Junk Peak Hiking Trail and relocation of portions of the existing alignment.

The Advance Works were carried out over the period June 1992 to September 1993.

REFERENCES

3.1 Scott Wilson Kirkpatrick & Partners. SENT Landfill, Outline Design Report (September 1990).

3.2 Scott Wilson Kirkpatrick & Partners. Privatisation of SENT Landfill, Results of PFA Leaching Trials (December 1991).

3.3 Scott Wilson Kirkpatrick & Partners. Privatisation of SENT Landfill, Leachate Treatment and Denitrification Trials (March 1992).

3.4 Scott Wilson Kirkpatrick & Partners. Privatisation of SENT Landfill, Analysis of Marine Sediments (April 1992).

3.5 Scott Wilson Kirkpatrick & Partners. SENT Landfill, Environmental Monitoring Final Report (October 1993).

3.6 Scott Wilson Kirkpatrick & Partners. SENT Landfill Study, Report R7, Final Report (January 1991).

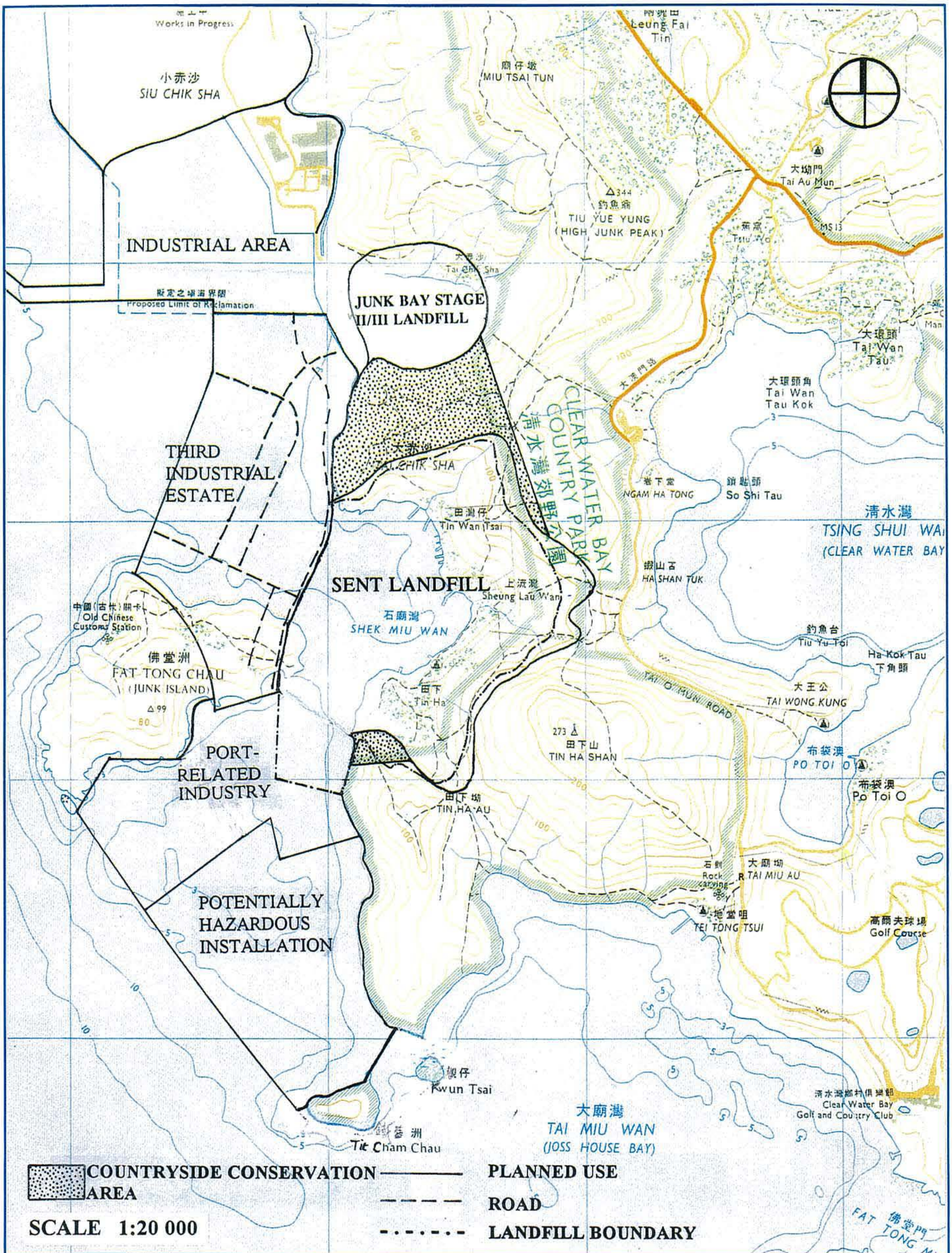

FIGURE 3.1

LAND USE

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GVL Project Design

Chapter 4

4 GVL PROJECT DESIGN

4.1 INTRODUCTION

The design of SENT Landfill, as submitted to EPD by GVL in their successful tender, and further developed since, is based upon the CEIA and Outline Landfill Design by Scott Wilson Kirkpartrick (1990), numerous site investigations and the past experience of the Waste Management Inc. Group (part of GVL)at over 250 landfills worldwide. The intent of the design is to provide long term protection of the environment while providing an economic solution for disposal of waste generated in Hong Kong.

4.2 SITE FORMATION AND MARINE RECLAMATION

Site formation consists of developing an area of approximately 94 ha, over which the base liner is installed, with almost half this area being reclaimed from Shek Miu Wan. Partial dredging of marine sediments, and reclamations of 2 ha at the north end and 4 ha at the south end of the site, have been accomplished during the Advance Works contract. The remaining marine works being undertaken by GVL comprise :

- dredging the remaining soft marine sediments to provide a stable base for the reclamation;
- disposal of the sediments at a designated dumping ground at Ninepins;
- construction of a rubble mound seawall between Fat Tong Chau (Junk Island) and the southern reclamation;
- construction of an additional vertical seawall to provide facilities for future marine barge access;
- reclamation of Shek Miu Wan using marine sands (from a marine borrow area, south of Tung Lung Chau) and rock fill from on-site excavations.

The marine part of the site will initially be reclaimed with marine sands up to an elevation of approximately -5 to -6mPD. Site formation fill, between this level and +2.5mPD will comprise graded rock and soil material.

Site formation grades on the land area are generally 1V:50H and the marine area 1V:33H. There will be a single rock cut slope of 4V:1H, and an upper soil slope design of 1V:1H.

Slope stability analyses have been performed to evaluate the slopes created by both the site formation and landfill operation. The analyses indicate that the stability of all slopes, including the design restoration slopes, will be adequate.

4.3 LANDFILL LINER

SENT Landfill has been designed, and is being constructed, as a secure containment facility incorporating multilayer composite liner systems covering the entire surface area of the site where waste will be deposited. Four different liner systems are being used for the different areas of the site as follows:

- land area;
- marine area;
- rock cut slopes; and
- upper trimmed soil slopes.

The liner systems are detailed in Chapter 5 below, and illustrated in Figure 5.1. Comprehensive Construction Quality Assurance (CQA) measures will be adopted during the installation, to ensure protection of the liner systems.

4.4 LEACHATE MANAGEMENT

Leachate management at SENT Landfill is described in Chapter 11 of the SEIA. The main features are:

- leachate collection system comprising aggregate and synthetic drainage layers;
- leachate collection sumps;
- HDPE sideslope risers;
- leachate transmission system;
- leachate treatment facility;
- treated leachate disposal to TKOSTW via pressure main alongside road D6.

4.5 LANDFILL GAS MANAGEMENT

Collection, treatment and utilisation of landfill gas are described in Chapter 9 of the SEIA. In summary, the main features of the gas management system at SENT Landfill are:

- vertical gas extraction wells;
- horizontal gas extraction zones and sideslope risers;
- gas transmission system;
- centrifugal blowers to actively extract gas;
- enclosed gas flares; and
- gas utilisation plant

4.6 SURFACE WATER MANAGEMENT

The surface water management system at SENT Landfill has been designed to control surface water run-on from upgradient areas and run-off from final restoration and temporary slopes to minimise soil erosion and maintain water quality. The system consists of a series of temporary and permanent storm water channels, culverts, sand traps, drop inlets and separation lagoons, designed both to efficiently manage surface water and cause minimal visual impact to the natural landscape surrounding the site.

There are four major surface water management systems:

(i) temporary/construction system;
(ii) intermediate system;
(iii) permanent system; and
(iv) off-site system.

The features of each are described in Chapter 12 of the SEIA. Surface water flows will be discharged at 6 designated locations. Four of these discharges will be culverted beneath the adjacent reclamations (Third Industrial Estate and Area 137) into Tseung Kwan O (Junk Bay). The remaining two will be to Clear Water Bay.

The surface water system addresses the important issue of segregating clean water from leachate. The cut-off channel system will be constructed upgradient of the waste disposal areas and will divert surface water around the area to the surface water discharge points.

Several measures will be used in the active disposal areas to provide surface water/leachate segregation. This system maximises segregation of leachate while allowing progressive construction of the liner system.

4.7 GROUNDWATER MANAGEMENT

Groundwater will be managed throughout the life of the site to prevent a hydrostatic build-up of water below the base liner and to prevent contamination by leachate. A geocomposite drainage layer below the primary base liner will collect and transport groundwater away from the liner. On the rock cut slopes, a geonet drainage layer will perform the same function. The drainage layers provides a means for groundwater to leave the site without coming in contact with leachate and provide a monitoring system to detect leakages through the base liner. Groundwater will flow to a collection trench and pipe, for eventual discharge to Tseung Kwan O with surface water. If the EMP identifies contamination in the groundwater, it will be pumped to the LTF for treatment. Further details on groundwater management are given in Chapter 13.

4.8 SITE INFRASTRUCTURE

The site infrastructure at SENT Landfill will provide maximum operational efficiency while minimising the environmental impact to the site and surrounding areas. The site infrastructure will provide for efficient transportation and disposal of waste while maximising facility security, safety, and control. The layout of roads, structures, and ancillary facilities will take advantage of the site's natural characteristics while incorporating the Advance Works contracts. The following infrastructure components will be provided:

- access to the site from the public highway network and marine transfer areas;
- internal haul roads;
- contractor's office and Visitors' centre;
- gantry for initial waste investigations;
- waste segregation area for unpermitted wastes (including vehicle impoundment area);
- soils testing laboratory;
- waste examination laboratory;
- environmental laboratory;
- material storage area (northern and southern reclamations);
- waste recycling area;
- maintenance building including fuel storage;
- site services, communications and lighting;
- meteorological station;
- leachate treatment building and plant;
- EPD office;
- weighbridges (four permanent and one temporary near the marine drop-off area);
- wheel washing facility;
- potential gas utilisation building;
- gas flares;
- landscaping of the site infrastructure area;
- permanent perimeter access road and waste reception area; and
- rock crushing plant

Each of the proposed components will be designed to accommodate the initial projected waste input rate of 3,000 tonnes per day while allowing for emergency waste intake rates of around 30,000 tonnes per day (see Chapter 17).

4.9 RECYCLING

Recycling and reprocessing of waste materials brought to SENT Landfill will prolong site life by diverting waste material away from disposal areas. A waste characterization study will be conducted during the first year of operations, to determine the appropriateness of different recycling and processing systems. Recycling proposals are described and assessed in SEIA Chapter 8.

4.10 SITE DEVELOPMENT

SENT Landfill will be developed and operated in 14 phases, with a total life of approximately 15-17 years (based on latest estimates of waste intake rates). While the active phase is being filled, the next phase to receive waste will be developed.

Phases will include lined disposal areas to accommodate waste intake rates and allow construction in a single season to avoid possible problems caused during periods of high precipitation. Phase 1 will include the construction of Area 1, 2, 3 and 4 (12.52 hectares) during the Initial Works, and Phase 2 consists of Areas 5 and 6, giving approximately 8.34 hectares of disposal area. Phase 3 consists of Areas 7, 8 and 9 (14.77 hectares). Phase 4 consists of Areas 10 and 11 (8.01 hectares) and Phase 5 consists of Areas 12 and 13 (6.9 hectares). Phase 6 consists of Areas 14 and 15 (8.04 hectares) and Phase 7 consists of Areas 16 and 17 (6.96 hectares). Phases 8 and 9 consist of Areas 18, 19, 20, 21, 22 (24.47 hectares), Phases 9 and 10 continues waste disposal over areas 18 through 22, and Phase 11 includes Area 23 (4.67 hectares). Phases 12, 13 and 14 continue waste disposal in previously constructed areas 18 through 23.

Landfill operations are programmed to commence in August 1994.

4.11 OPERATIONS

Waste disposal operations will be carried out to maximise use of void space and thus extend site life. Good compaction procedures in combination with waste recycling and recovery, where appropriate, will make efficient use of void space, minimise use of daily cover, control vectors and reduce odour problems.

Daily cells for waste disposal will be marked off and contained with bunds to keep filling in as small an area as possible. Daily cover material will consist of soil placed in a layer 150mm thick at the end of each day's fill. As an alternative to soil, other daily cover materials may also be used (see Chapter 10). Use of alternative cover materials will increase the amount of void space available for waste disposal.

The proposed waste disposal operations include a traffic pattern to follow phased development, designed to minimise on-site travel and waste disposal time. In combination with the surface water management programme, waste traffic routing and disposal methods will minimise the amount of leachate generated.

The site Operation Plan has been developed to meet the required performance criteria for both the Hong Kong Government and internal requirements set by GVL. It will be updated on a regular basis to provide the best available techniques for landfill operations.

4.12 RESTORATION

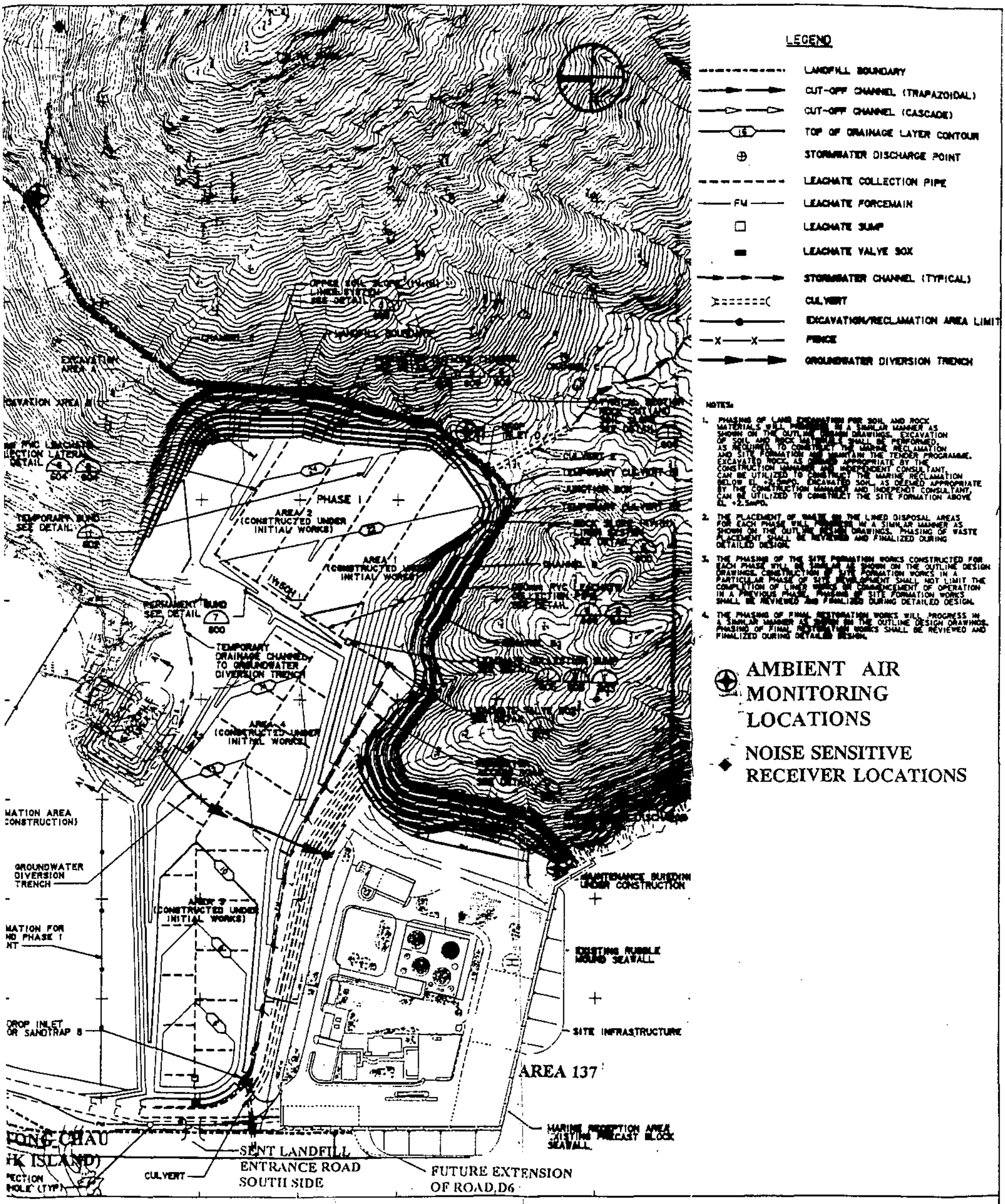
Areas filled to final grades will be restored as soon as feasibly possible. Restoration of areas will be carried out in stages as phases are progressively filled with waste. After final levels are reached within a given phase, a 300mm protective soil layer will be placed over the waste. The final cap will then be placed, comprising a 360g/m^2 non-woven geotextile, a 1.0mm textured HDPE geomembrane, a high permeability geocomposite drainage layer and a 1500mm soil layer see Figure 4.2.

The first 1200mm of soil directly above the drainage layer will be compacted to reduce surface water infiltration. The thickness of the soil layer will be increased in some planting areas to provide depth sufficient to prevent damage to the liner from vegetation rooting. After placement of the final cover system, the areas will be landscaped in accordance with the Landscape Master Plan (see Chapter 15).

4.13 AFTERCARE

Upon completion of final filling and site restoration, the period of aftercare will begin and last for approximately 30 years. During this period, by-products from waste disposal will continue to be generated including leachate and landfill gas. The established methods for controlling these by-products will continue after operation are completed.

Regular site maintenance will be continued during the aftercare period to keep incorporated systems functioning as designed. Site monitoring during the aftercare period will continue under the EMP, but may be decreased if warranted and approved. Leachate management, landfill gas management, monitoring, and site maintenance will continue until the Certificate of Final Closure is awarded to GVL by the Hong Kong Government.



SITE LAYOUT PLAN

Differences Between GVL Design and Conceptual Design

Chapter 5

5 DIFFERENCES BETWEEN GVL DESIGN AND CONCEPTUAL DESIGN

5.1 INTRODUCTION

A specific requirement of the SEIA is that it assess the environmental effects of the SENT Landfill project with particular reference to the extent and implications of any differences, variations, additions or deletions between GVL's design and the conceptual design assessed in the CEIA.

Where these are considered substantive or potentially adverse in terms of net environmental impact, detailed supplementary EIA studies have been undertaken and are presented in Section 2 of this SEIA report. The differences between the GVL design and conceptual design are described in detailed in the ER (Ref 5.1). This chapter presents a summary of the most important differences.

5.2 VARIATIONS IN SITE FORMATION GRADIENTS

The site formation gradients in the GVL design have been increased from those specified in the conceptual design, for both the marine reclamation area and the rock cut slopes. The former incorporate leachate collection pipes at a minimum gradient of 1 (vertical) in 50 (horizontal) [1(V): 50(H)] as opposed to 1(V): 150(H) in the conceptual design.

In the marine area the effect will be to increase the speed at which leachate flows to the leachate collection sumps and therefore reduce the leachate head build-up on the base liner. This should reduce the risk of leakage of leachate through the liner. The rock cut slopes are to be at an angle of 56° and as such will provide increased volumes of fill material and give an increased void space for waste disposal.

5.3 VARIATIONS IN SITE LINER

As for the conceptual design, four different liner systems will be used for different areas of the site. These all differ from the systems proposed in the conceptual design, but provide a higher degree of environmental protection and an increase in void space. Table 5.1, below, presents details of the 4 liner systems.

The GVL design includes the complete removal of all marine sediments underlying the site to minimise the risk of failure of the liner due to settlement or potential structural instability as experienced at TKO (I) landfill.

Table 5.1 Differences Between GVL Design Liner Systems and those Proposed at Conceptual Design Stage

Area of Site	Conceptual Liner Design	GVL Design	Comments
Marine area	1000mm drainage blanket 500mm low permeability barrier HDPE flexible membrane bentonite mat or 300mm bentonite/soil admixture HDPE flexible membrane 500mm low permeability barrier (cdv or similar) selected fill material	Woven geotextile 500mm high permeability drainage stone 540g/m^2 non-woven geotextile 2mm textured HDPE flexible geomembrane bentonite mat 1.5mm textured HDPE flexible geomembrane 540g/m^2 non-woven geotextile 300mm selected fill	Design is similar to conceptual design with the exception of not having a 500mm layer of cdv. In place of this will be a 300mm layer of fine grained soil, which in conjunction with the geotextile, will provide equal or better protection to the liner system. Accepted design ensures stability, resistance to clogging, rapid removal of leachate, flexible membrane protection and conservation of void valuable space (compared to Conceptual Design).
Land area	1000mm drainage blanket 150mm sand (if required) HDPE flexible membrane (if required) 250mm hydraulic asphalt 300mm sub-base material 600mm groundwater drainage material site formation level	woven geotextile 500mm high permeability drainage stone 540g/m^2 non-woven geotextile 2mm textured HDPE flexible geomembrane bentonite mat 1.5mm textured HDPE flexible geomembrane textured geocomposite drainage layer for groundwater diversion 300m selected fill	Design does not include hydraulic asphalt which is replaced by a bentonite mat and secondary HDPE flexible membrane. Hydraulic asphalt has been shown to be less compatible with leachate and could deteriorate over the expected life of the site.

Table 5.1 Differences Between GVL Design Liner Systems and those Proposed at Conceptual Design Stage (cont'd)

Area of Site	Conceptual Liner Design	GVL Design	Comments
Rock slopes	1000mm drainage layer 50mm sprayed concrete wire mesh reinforcement no fines concrete or geodrains with impermeable protection sheeting rock face	1300g/m^2 non-woven geotextile geocomposite drainage layer (for leachate collection) 2mm smooth HDPE flexible membrane geocomposite drainage layer (for groundwater diversion) 100mm sprayed concrete (with weepholes) rock face	The addition of a HDPE flexible membrane to this liner system gives an significantly increased level of protection than the conceptual design, and one which is comparable to the liner applied to other parts of the site.
Upper soil slopes	600mm drainage blanket 300mm protective layer of soil material 2mm HDPE flexible geomembrane geodrain layer with impermeable protection sheeting 1000mm lower protective layer of soft material soil cut slope	540g/m^2 non-woven geotextile 2mm textured HDPE geomembrane bentonite mat 1.5mm textured HDPE flexible membrane geocomposite drainage layer (for groundwater diversion) 300mm selected fill	The accepted design incorporates 2 HDPE flexible membrane layers rather than one, and ensures landfill stability, resistance to clogging, flexible membrane protection, conservation of void space, rapid removal of leachate and efficient groundwater diversion.

The GVL design uses woven geotextile over the drainage media to prevent clogging, and non-woven geotextiles around the HDPE membranes to afford them a high degree of protection. Except for the rock slope liner, the HDPE flexible membranes are textured on both sides. As this contorts the non-woven geotextile, a high degree of friction is maintained, ensuring the landfill stability.

5.4 VARIATIONS IN LEACHATE MANAGEMENT

The main variation in terms of the leachate collection, treatment and disposal systems for SENT Landfill is the different leachate treatment plant design. In the conceptual design, aerobic treatment lagoons and a denitrification reactor were proposed. These components have been replaced with more compact, sophisticated plant which have been designed to meet the stringent post-treatment contaminant levels stipulated by EPD. The design now incorporates the following:

- a metal precipitation unit;
- ammonia-stripping towers;
- a thermal catalytic unit, for the removal of ammonia from the stripper offgas;
- a sequencing batch reactor; and
- a dewatering sludge filter press.

A review of the predicted efficiency, robustness and suitability of the plant for handling the projected volumes and strengths of leachate is presented in Chapter 11 of this SEIA, together with an assessment of the environmental impacts of the plant itself.

The GVL landfill design also incorporates a number of minor changes from the conceptual design in terms of leachate management:

- drainage layer gradients altered in line with site formation gradient (see 5.1 above);
- addition of highly permeable stone to leachate collection system;
- leachate sumps with side-slope risers instead of "man-hole" type collection system;
- use of PVC and HDPE drainage pipes instead of concrete, which may deteriorate; and
- additional liner protection underneath leachate sumps.

These will generally lead to reduced environmental risks, by means of more rapid and efficient removal of leachate; reduced liner stress and the use of materials less susceptible to leachate attack; concrete in landfills will deteriorate, use of PVC/HDPE will be much better; sideslope risers instead of vertical reduces chance of disruption/settlement significantly; additional liner protection.

5.5 VARIATIONS IN LANDFILL GAS MANAGEMENT

GVL propose to install a gas utilisation plant at SENT Landfill within the first few years of operations, to generate electricity for use on-site and possible export to off-site users. This was not included in the conceptual design or the CEIA. The environmental effects of gas utilisation at SENT Landfill are assessed in Chapter 9 of the SEIA. Following installation of the gas utilisation plant, flares will be retained as a secondary gas treatment method, should maintenance or shutdown of the plant be required.

Other minor design changes in terms of landfill gas management are:

- condensate will either be drained back into gas wells or removed by condensate traps and treated as leachate, rather than being discharged into the waste mass via soakaways;

- horizontal permeable gas collection bunds will be used, instead of radial trenches;

- gas wells will not be based directly on top of the liner;

- combined gas and groundwater monitoring wells will not be used; and

- stainless steel bolts, valves and flanges will be used instead of non-metallic components.

It is considered that these changes will be beneficial in ensuring efficient and effective operations and environmental performance.

5.6 VARIATIONS IN SURFACE WATER MANAGEMENT

The following design modifications have been made to the conceptual design:

- provision of additional culverts on the final cover;
- addition of gabions and stone pitching in areas with the potential for erosion;
- diversion of flows from southern slope catchments to the north, for final discharge to Clear Water Bay (see SEIA Chapter 12);
- extensive use of surface water diversion channels and bunds to segregate run-off from active fill areas; and
- diversion of the Joss House Bay flows to TKO Bay.

These variations should reduce soil erosion and the last measure will reduce the volume of leachate produced.

5.7 VARIATIONS IN GROUNDWATER MANAGEMENT

The GVL design uses a geocomposite groundwater drainage layer instead of the granular type layer proposed in the conceptual design. The geocomposite layer will provide a higher drainage capacity (when incorporated with the additional drainage channels and pipes) and also conserve void space due to its smaller diameter.

5.8 VARIATIONS IN PHASING

SENT Landfill will be filled in 14 phases, in a different sequence to that described in the conceptual design. The first phases to be developed will not now be in the marine reclamation area but in the landward area. This will increase the length of time available for completion of the marine reclamation works and permits the complete removal of the marine sediments thereby providing a stable foundation for the landfill. The potential visual impact of the phasing of the site is assessed in Chapter 16. Figure 5.3 gives the development program for SENT Landfill.

5.9 VARIATIONS IN SITE INFRASTRUCTURE

As a result of the different phasing sequence, a number of slight changes have been made in the layout of access and haul roads, to minimize cross-traffic between waste vehicles and construction vehicles. In addition, separate site offices will now be provided for the contractor and the Independent Consultant, and the government, together with an equipment maintenance building. To promote the public image of the landfill, a visitors centre will be provided, with extensive landscape planting around the visitors centre and reception area.

5.10 VARIATIONS IN OPERATIONS

A number of measures have been built into the design to conserve void space, recycle waste materials and reduce the shortfall in fill material at the site:

- use of alternative daily cover materials to soil;
- proposed recycling of waste containing combustible materials using the "Brini Fuel Process", following a thorough waste characterisation study; and
- possible construction waste recycling plant.

These issues, and the potential environmental impacts pertaining to them, are described in Chapters 8 and 10.

5.11 VARIATIONS IN RESTORATION AND AFTERCARE

As a development from the conceptual design, a textured HDPE membrane is included in the final cover system, to control water infiltration and gas migration.

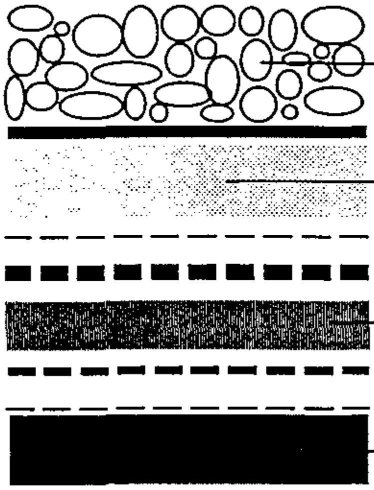
Reduced maintenance and monitoring during the aftercare period have been proposed by GVL. These would only be approved by EPD if there were a demonstrable justification, due to reduced levels of leachate and landfill gas production. If this were the case, these variations should have no adverse environmental impact.

The GVL design will also allow for greater provision of maintenance access.

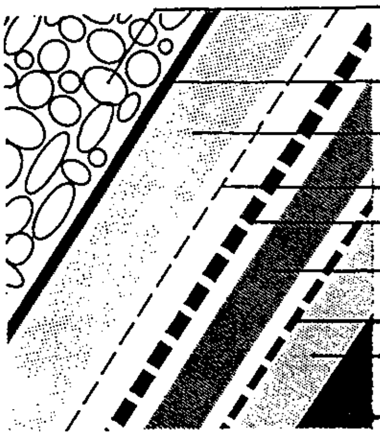
REFERENCES

5.1 Acer Environmental. Environmental Review for the Proposed Development and Management of the South East New Territories (SENT) Landfill, Hong Kong (October 1992).

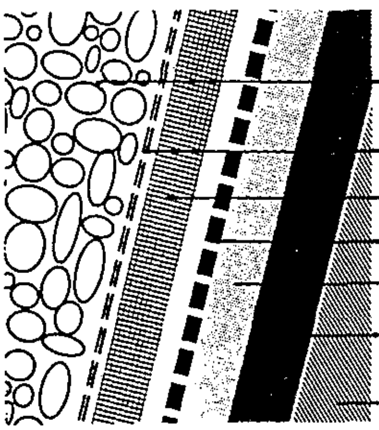
TYPICAL PROPOSED LINER SYSTEM
MARINE AREA COMPOSITE LINER DETAIL



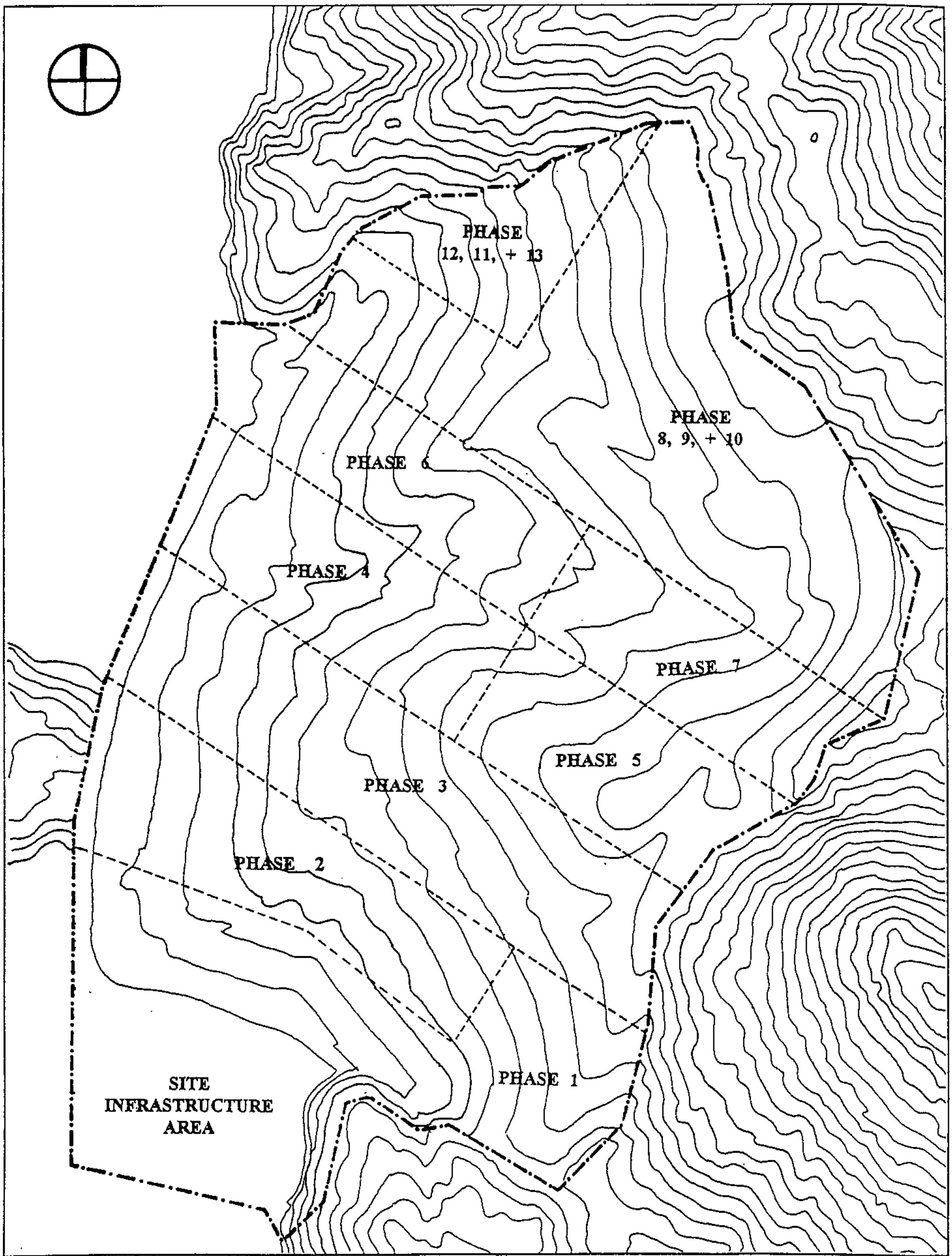
TYPICAL PROPOSED LINER SYSTEM
LAND AREA COMPOSITE LINER DETAIL
AND UPPER SOIL SLOPE COMPOSITE LINER DETAIL



TYPICAL PROPOSED LINER SYSTEM
ROCK SLOPE LINER DETAIL



acer/ENVIRONMENTAL 7	**FIGURE 5.1** **SITE LINER SYSTEM DESIGN**



acer ENVIRONMENTAL

FIGURE 5.2

PHASING PLAN

ACTIVITY	YEAR
Initial Works Phase 1 Development	
- Detailed Design	0.0 - 0.5
- Construction	0.1 - 0.9
- Mile Stone No. 1	0.9
Phase 1 Operation/Phase 2 Development	
- Design	0.9 - 1.6
- Construction	0.6 - 2.8
- Operation of Areas 1 & 2	0.9 - 1.7
- Intermediate Cap	1.0 - 1.8
- Mile Stone No. 2	1.8
- Mile Stone No. 3	3.4
- Mile Stone No. 4	2.2
Phase 2 Operation/Phase 3 Development	
- Design	1.5 - 2.0
- Construction	2.4 - 4.1
- Operation of Areas 3,4,5 & 6	1.7 - 3.0
- Intermediate Cap	1.8 - 3.1
- Final Rstoration Phase 2	2.4 - 3.2
- Mile Stone No. 5	3.2
- Mile Stone No. 6	4.7
- Mile Stone No. 7	4.2
Phase 3 Operation/Phase 4 Development	
- Design	3.0 - 4.0
- Construction	4.0 - 5.2
- Operation of Areas 7,8 & 9	3.0 - 5.2
- Intermediate Cap	3.1 - 4.1
- Final Rstoration Phase 3	4.6 - 5.4
- Mile Stone No. 8	5.4
- Mile Stone No. 9	5.6
Phase 4 Operation/Phase 5 Development	
- Design	4.0 - 4.7
- Construction	4.7 - 8.2
- Site Formation Areas 14 & 15	4.9 - 6.2
- Operation of Areas 10, 11	5.2 - 6.0
- Intermediate Cap	5.3 - 6.1
- Final Restoration Phase 4	5.7 - 6.6
- Mile Stone No. 10	6.6
- Mile Stone No. 11	7.4
Phase 5 Operation/Phase 6 Development	
- Design	4.7 - 5.6
- Construction	6.2 - 7.5
- Operation of Areas 12, 13	6.0 - 7.6
- Intermediate Cap	6.1 - 7.7
- Final Restoration Phase 5	7.4 - 7.9
- Mile Stone No. 12	7.9
- Mile Stone No. 13	8.0
Phase 6 Operation/Phase 7 Development	
- Design	5.8 - 6.5
- Construction	6.5 - 9.0
- Operation of Areas 14, 15	7.6 - 8.3
- Intermediate Cap	7.7 - 8.4
- Final Restoration Phase 6	7.4 - 7.9
- Mile Stone No. 14	8.5
- Mile Stone No. 15	9.8

Figure 5.3

Landfill Development Programme

Source GVL Tender Documents, April 1993

Figure 5.3

Landfill Development Programme

Page 2 of 2

Source : GVL Tender Documents, April 1993

ACTIVITY	YEARS
Phase 7 Operation/Phase 8 Development	
- Design	6.5 - 7.5
- Construction	8.1 - 10.7
- Operation of Areas 16 & 17	8.3 - 10.0
- Intermediate Cap	8.4 - 10.1
- Final Restoration Phase 7	9.9 - 10.4
- Mile Stone No. 16	10.4
- Mile Stone No. 17	10.8
Phase 8 Operation/Phase 9 Development	
- Design	8.0 - 10.0
- Construction	10.8 - 11.1
- Operation of Areas 18,19,20,21 & 22	10.0 - 11.6
- Intermediate Cap	10.1 - 11.7
- Mile Stone No. 18	11.4
- Mile Stone No. 19	11.7
Phase 9 Operation/Phase 10 Development	
- Design	9.0 - 10.0
- Construction	10.1 - 11.6
- Operation of Areas 20,21 & 22	11.6 - 12.2
- Intermediate Cap	11.7 - 12.3
- Mile Stone No. 20	12.1
Phase 10 Operation/Phase 11 Development	
- Design	10.0 - 10.5
- Construction	10.3 - 11.6
- Operation of Areas 20,21 & 22	12.2 - 12.7
- Intermediate Cap	12.3 - 12.8
- Mile Stone No. 21	12.8
Phase 11 Operation	
- Design	10.5 - 11.2
- Operation of Areas 22 & 23	12.8 - 13.7
- Intermediate Cap	12.9 - 13.8
Phase 12 Operation	
- Design	11.2 - 11.9
- Operation of Areas 22 & 23	13.6 - 14.8
- Intermediate Cap	13.7 - 14.9
- Final Restoration Phase 12	14.4 - 14.9
- Mile Stone No. 22	13.7
- Mile Stone No. 23	14.9
Phase 13 Operation	
- Design	11.2 - 11.9
- Construction	11.8 - 13.1
- Operation of Areas 22 & 23	14.8 - 15.6
- Intermediate Cap	14.9 - 15.7
- Final Restoration Phase 13	14.4 - 14.9
- Mile Stone No. 24	15.4
- Mile Stone No. 25	15.8
Phase 14 Operation/Final Restoration	
- Design	12.0 - 14.0
- Operation	15.6 - 15.9
- Construction	14.1 - 15.7
- Final Restoration	15.8 - 16.3
- Mile Stone No. 26	15.4
- Mile Stone No. 27	16.3
Monitoring	0.0 - 46.0
Aftercare	3.2 - 46.3

Environmental Impacts Unchanged from CEIA

Chapter 6

6 ENVIRONMENTAL IMPACTS UNCHANGED FROM CEIA

The Specification for the Contract for the Development and Management of SENT Landfill requires that the SEIA should describe the likely significant impacts of the Design, Works, Operation, Restoration and Aftercare on :

- human beings;
- flora;
- fauna;
- soil;
- water;
- air;
- climate;
- landscape;
- interaction between any of the foregoing;
- material assets; and
- cultural heritage

The CEIA for SENT Landfill used a matrix based Activity/Receiver analysis to identify the potential impacts of the project with reference to these receiver groups. This analysis formed the basis for the impact quantification which followed.

Many impacts identified at CEIA stage. These include the following:

- relocation of three village settlements (CEIA, Section 6(i));
- relocation of fish culture zone (CEIA, Section 6(i));
- clearance of agricultural activities (CEIA, Section 6(i));
- relocation of a clan grave and temple (CEIA, Section 6(i));
- loss of an area of Clear Water Bay Country Park and diversion of hiking trail. (CEIA, Section 6(ii));
- discharge of treated leachate, diluted with industrial effluent and sewage via a main outfall to Tathong Channel (CEIA, Section (iv));
- impacts of winning marine fill (CEIA, Section 6(iv));
- loss of diverse littoral and marine flora and fauna from Shek Miu Wan, associated shoreline and Junk Island (CEIA, Section 6(v));
- loss of all terrestrial habitats and associated communities within site boundary (CEIA, Section 6(v));
- disruption within Clear Water Bay Country Park (CEIA, Sections 6(ii) and 6(v));
- loss of locally potentially unique freshwater wetland (CEIA, Section 6(v));
- increased road traffic on Road D6 and through Tseung Kwan O (CEIA, Sections 4(ii) and 6(vii));
- dust, odours and other organics from landfill operational and post closure phases (CEIA, Sections 6(vi) and 6(vii)); and
- noise from site construction and operational phases (CEIA, Section 6(viii)).

The scope and intent of the SEIA is not to describe all of the impacts of SENT Landfill in detail, as this has been done by the CEIA.

Impacts which were not possible to assess in detail at the conceptual design stage, and impacts consequent on the GVL design for SENT Landfill are described in detail in Chapters 8 to 18 of the SEIA.

Scoping of the SEIA

Chapter 7

7 SCOPING OF THE SEIA

7.1 INTRODUCTION

The scope of the SEIA has been determined by a number of stages and in close consultation with the EPD specialist groups including the Solid Waste Project Management Group, RAPG and APG.

7.2 ENVIRONMENTAL REVIEW

Tenderers for the Development and Management of SENT Landfill were required to submit an ER for the landfill, based on their proposed Design, construction, Operation, Restoration and Aftercare of the site. The ER included a proposal for further detailed environmental assessment investigations of the key issues which would supplement the ER and be carried out under the SEIA.

The issues identified in the ER to be further investigated in the SEIA were:

- impacts of waste recycling plant;
- environmental appraisal of landfill gas utilisation;
- availability and suitability of raw materials required from off-site, assessment of alternative cover materials;
- impacts of leachate treatment plant;
- impacts of changed surface water catchments;
- hydrogeological impacts;
- marine impacts of reclamation;
- landscape assessment;
- visual intrusion of rock cut slopes;
- traffic impacts due to exceptional waste delivery scenarios; and
- sensitivity of planned adjacent developments to threshold emissions.

7.3 ADDITIONAL ISSUES RAISED BY EPD

Following their review of the GVL tender and the ER, a number of further issues were raised by EPD during the tender negotiation stage. These supplementary issues were considered by GVL and incorporated within the SEIA scope where appropriate. The issues were as follows:

- monitoring of flora;
- monitoring of fauna;
- surface water quality and quantity;
- quality of water emanating from operational areas;
- groundwater flow;
- the impact of liner leakage on groundwater quality;
- the impact of liner leakage on marine water quality;
- the impact of dredging on marine water quality;
- the impact of run-off from the site on marine water quality;
- the impact of discharge of treated leachate from Tseung Kwan O sewage treatment works (TKO STW); and
- the impact on air quality associated with landfill gas flaring and leachate treatment.

Monitoring of flora and fauna has been included in the Environmental Monitoring Plan (EMP) for SENT Landfill, with surveys being carried out every six months at 5 marine and 3 terrestrial sites. Since the first flora and fauna survey is to be carried out after the completion of the SEIA, the ecological assessment within the SEIA is based on previously collected data and reviews the environmental monitoring proposals presented in EMP, providing recommendations for modification where appropriate.

The issue of discharges of treated leachate from TKO STW was assessed in some depth in the CEIA. The assessment of this impact in the SEIA has been confined to a brief review of previous studies.

7.4 SEIA SCOPING REPORT

On the basis of the issues identified by the ER, EPD's responses, and a further detailed review of GVL's proposed design for SENT Landfill, Acer Environmental produced a scoping report for the SEIA which was submitted to EPD in August 1993. This set out the items to be included in the SEIA, the assessment methodologies to be used and the structure of the SEIA. EPD made comments on this Scoping Report and ACER Environmental provided responses to these comments. The Scoping Report and the comments and responses are included in Appendix 1.

The SEIA will also make recommendations for any modifications or additions to the EMP considered necessary, and for further assessment work to be carried out under the CAP.

SECTION 2

SUPPLEMENTARY ISSUES

Waste Recycling

Chapter 8

8 WASTE RECYCLING

8.1 INTRODUCTION

8.1.1 Background

The Government's policy and objectives for waste management include ensuring that proper disposal facilities are available, (either through the private or public sector), for the disposal of all wastes in a cost effective and environmentally satisfactory manner, and waste volumes are minimised by encouraging waste reduction, reuse and recycling. In recent years these objectives have been challenged by a continuing rise in waste production and a resulting shortfall of landfill capacity. One of the main causes of this problem is the increasing use of landfill capacity by waste producers to dispose of large quantities of inert construction waste.

Construction wastes, which are presently disposed of at public dumps (sites requiring reclamation and land formation), landfill and marine dumps, can be described as *'the by-products generated and removed from construction, renovation and demolition work places or sites of building and civil engineering structures'*. In 1991, an average daily total of 25,800 tonnes of such waste material (excluding dredged material) was produced. Forecasts for the next five years predict of the order of 22,370 tonnes construction waste produced per day. Government are addressing the problems associated with the disposal of such large quantities of essentially inert waste by introducing and implementing a number of measures including the encouragement of reduction of waste at source and provision of recycling or sorting facilities.

Although SENT Landfill will receive municipal, commercial, construction and industrial waste, it is however intended that it (along with other landfills in the Territory) be used predominantly for the disposal of putrescible biodegradable wastes. Consequently, a construction waste recycling plant has been proposed for SENT Landfill which would effectively prolong the landfill site's life by diverting inert construction waste from the disposal areas, thus slowing down utilisation of disposal capacity.

It is understood that the Government propose to develop a number of centralised construction waste sorting plants to be operated by the private sector. Two such plants are currently under consideration, one of which would be located in the TKO area. Should this plant be commissioned, the volumes and types of construction waste received at SENT Landfill would be significantly altered.

At this stage, however, recycling at SENT Landfill remains a viable option, and this Chapter therefore addresses the issue of recycling waste at the site, and is structured to provide:

- an overview of the relevant Government policy and objectives;
- a review of the scope for recycling at SENT Landfill; and
- a preliminary environmental assessment of proposed recycling plant and operations.

Should recycling or sorting occur as planned at two pilot scheme elsewhere in TKO, then GVL would receive the non-reusable fraction at SENT Landfill.

8.2 GOVERNMENT POLICY

Continuing programmes of development within Hong Kong have led to a substantial increase (of the order of 50% since 1986) in construction waste arisings in the Territory. In parallel, construction waste disposed of to landfill has increased significantly (Ref 8.1) such that in 1991 it comprised more than 70% of the total waste intake at landfills.

As a result of this trend and a resulting shortfall of disposal capacity, a Government inter-departmental working Group was established to review the situation. The Group implemented a number of remedial measures which have gone some way to alleviating the problem. However, the costly disposal of construction wastes at landfill sites has continued and in October 1992 a scheme entitled "New Disposal Arrangements for Construction Waste" was introduced. Under the new arrangements, construction waste should be sorted at source to enable disposal either at landfills or public dumps. Construction waste containing more than 20% by volume of "inert material" will not be accepted for disposal at both Tseung Kwan O and Shuen Wan Landfill. However, it is understood that these arrangements have been kept in abeyance due to the strong opposition from the dump truck drivers.

Consequently the Government is continuing to review the Territory's arrangements for construction waste disposal, and plans to introduce a charging system for disposal to landfill to act as a disincentive are currently under review and consideration. In order to determine the viable alternatives for waste producers wishing to dispose of such waste, the Government commissioned a study (Ref 8.2) to assess the practicality of construction waste sorting (which has previously served as a deterrent for waste producers to seek alternatives to landfill disposal) as part of a move to encourage recycling. A recycling pilot scheme was subsequently implemented at Tseung Kwan O landfill in 1992. The scheme involved waste characterisation and assessed the effectiveness of recycling construction waste. The scheme established that construction waste can be recycled and that the majority of the processed waste can be diverted from landfills to public dumps. In addition, the Hong Kong Construction Association has drawn up guidelines to encourage its members to sort waste prior to disposal, thus facilitating the re-use of material.

8.3 THE SCOPE FOR AND BENEFITS OF RECYCLING CONSTRUCTION WASTES

Construction waste in Hong Kong is predominantly derived from roadworks, excavations, building demolition, renovation and mixed site clearance. It has been estimated (Ref 8.3) that of the order of 97% by weight of these wastes are recoverable such that approximately 86% comprises inert granular materials, 8% wood wastes and 3% metals. However, data collected by EPD (Ref 8.4) indicates that the percentage of construction waste which is reusable varies from about 60 to 80% (see Table 8.1). However, it should be noted that, since the EPD survey was carried out over a relatively short period of time, the data could be considered as indicative only and may not accurately reflect the current situation.

With the exception of ferrous material it has been estimated that as much as 50-60% (by weight) of the construction waste may be diverted for beneficial reuse on the landfill site, thus conserving significant quantities of landfill disposal space. The ferrous metal will be exported off-site for reuse by scrap metal dealers or others, which could be located on the nearby TIE, (Table 8.2.).

Recycling and reuse will greatly minimise the costly importing of soft fill and granular materials required to support normal day to day landfill operations. It is therefore considered unnecessary to import fill material to the site during the operational life should a recycling plant be established on site.

Table 8.1 Composition of Construction Waste Received at Landfills

Reusable/Recyclable Waste Type	% by weight	
	1991	1992
Asphalt	1.7	0.2
Brick/Tiles	5.1	9.3
Concrete/Mortar	15.6	17.1
Reinforced Concrete	3.8	1.7
Rock/rubble	7.7	5.5
Sand/Soil	48.0	27.6
Sub-total	81.9	61.4
Non-Reusable/Recyclable Waste Type	**% by weight**	
	1991	**1992**
Bamboo	1.1	0.4
Ferrous Metal/Non-ferrous Metal	1.8	3.5
Glass	0.4	0.3
Junk/Fixtures	0.3	0.4
Plastic	3.1	0.6
Slurry & Mud	—	18.4
Trees	0.5	0.2
Wood	6.0	9.4
Other Organic & Garbage	4.9	5.4
Sub-total	18.1	38.6
TOTAL	100.0	100.0

Source : Municipal Waste Arising 1991-2 EPD, (Ref 8.4)

Table 8.2 Examples of Recycled Materials and their Potential Uses on the Sent Landfill Site

Recycled Material	Potential Use
Soft Fill, Granular Fill	Landfill daily and final cover Landfill temporary access roads Base and subbase for permanent landfill access roads Cover and bedding for landfill liners, leachate collection systems, gas recovery system vents or wells Aggregate for drainage filter layers in lined cell areas French drains (site retention areas)
Wood Chips	Landfill daily cover Soil enhancement for final cover and other landscaped site areas

8.4 WASTE RECYCLING OPTIONS

8.4.1 Introduction

For the purposes of conceptual design and planning of the recycling system, two strategies have been proposed for effective processing and material recovery, and are based on categorisation of the incoming construction waste into two types according to processing requirements (Table 8.3). Selection of the appropriate system will therefore to a large extent depend on the composition of the construction waste stream, and hence the ability of the system to deal with these materials.

Table 8.3 Two Treatment Strategies for Recycling Construction Material

MATERIAL TYPE	CONSTITUENTS	PROCESSING STRATEGY
Type I:	**Road work, Excavation Material:** predominantly clean dirt and rubble with limited quantities of wood and residue.	Granular Material Crushing/Screening
Type II:	**Building Demolition, Renovation, and Mixed Site Clearance Material:** a mixture of material with significant volumes of wood residue etc.	Mixed Construction Waste Processing System

Another method of recycling waste material is also currently being considered, known as the Brini Fuel Energy Recovery system and, in conjunction with the other recycling programmes, this is discussed in the following subsections.

8.4.2 Granular Material Crushing/Screening System

This is a portable self contained system which can be moved as necessary to meet landfill operational phasing requirements and to take advantage of end product transportation and storage needs. The granular material crushing and screening system is commonly used in many locations for concrete and rubble crushing. This system is designed to accept essentially "clean" granular material and can produce soft, fine and coarse fill material.

The system comprises a self contained jaw and impact crusher. The jaw crusher is intended to be a primary crusher for granite and other virgin rock. Use of the jaw crusher on the virgin rock material should extend the life of, and reduce maintenance requirements for, the rest of the crushing system. The end product from the crusher is generally suitable for use as fill for the reclamation. Alternatively it can be fed to the impact crusher for further treatment.

The impactor of the system can be used as a secondary crusher in accepting material from the jaw crusher, or as a primary crusher for materials such as reinforced concrete and asphalt. A hydraulic breaker can be mounted above the vibrating feeder of the impactor in order that large pieces of concrete, rubble etc. can be initially fractured before feeding to the crusher. A grizzly screen is mounted in the feeder to remove fine soft fill products prior to crushing. The soft fill product is transported by transfer conveyors to portable stackers for stockpiling and use as daily cover material.

Material discharged from the impactor is conveyed past an overhead belt magnet that removes ferrous material, granular material continues on to a vibrating triple deck screen. The screen separates two sized materials, the coarse and fine granular aggregate products, and returns a third oversize product stream to the impactor for further crushing.

Stacking conveyors transport the product from the deck screen and impactor grizzly screen for stockpiling. With potentially large volumes of material requiring storage, a series of transfer conveyors (from 1 to 5 units) can convey the initial stockpile away from the crushing screening equipment. When the initial pile is formed, the last transfer conveyor can be removed so that a second stockpile can be formed inside the first and so on. As stockpiles are created, a bulldozer can be used to flatten the piles out as necessary to meet stockpile height requirements. The proposed location of this plant is shown on Figure 4.1.

8.4.3 Mixed Construction Waste Processing System

The mixed waste processing system (see Figure 8.1) is designed to be flexible and semi-portable. The major components (impactor, waste reducer, trommel and horizontal wood hog) and end product stacking/transfer conveyors are trailer-mounted, self-contained (diesel powered) units capable of road travel. The picking belt and flotation tank/clarifier are self contained, skid mounted and can be moved via flatbed, low boy trailer.

The system can treat mixed construction waste material containing large amounts of wood waste and rubber material. Three material in-feed locations are provided: the waste reducer for bulky wood waste and other material; the compactor for concrete mixed with wood; and the trommel for small mixed material (less than 150 mm).

The *impactor* in this system provides the flexibility to process rubble material mixed with wood/residue. The compressible wood and residue material does not create a problem for the impactor as long as friable material is intermixed with it. The undersize soft fill that falls through the grizzly screen in the vibrating feeder rejoins the impactor discharge product stream. Discharge material is conveyed past an overhead belt magnet which removes ferrous material; granular material continues on through the trommel and the rest of the system.

The *waste reducer* is a slow speed unit designed to reduce the size and volume of bulky materials such as telephone poles, railroad ties, stumps, large structural timber, pallets, demolition debris, furniture and steel drums. A grapple crane is mounted on the waste reducer which removes such items as carpeting and rolls of plastic. The mixed construction waste can be fed to the waste reducer. Discharge from the waste reducer flows past an overhead belt magnet where ferrous material is removed.

The *trommel* receives material from the conveyer and screens out a less than 19mm soft fill product. The oversize materials that flow through the trommel drop into a picking belt. Sorters manually remove the non-ferrous metals, paper, plastic, small boulders (200-300mm in size), and any other contaminants. Contaminants are chuted into roll-off containers located under the picking belt platform that can be replenished as needed. A residue 'plough' (a steel plate with a rubber bottom skirt so that the belt is not damaged) can be located above the picking belt and manually lowered when large quantities of residue are on the belt and removal by hand is undesirable. The plough knocks the material into a roll-off container or onto the ground for handling with a front end loader.

The system can operate with the picking stations unmanned or with a highly concentrated labour force depending on end product quality requirements. Material remaining on the belt after picking continues into the flotation tank. An optional air classifier can be installed prior to the flotation tank to mechanically remove materials such as small paper from the wood and rock products.

Material entering the flotation tank should only be wood and rock, greater than 20mm in size. The rock penetrates the jet-stream of water in the tank and exits to the left on a rubber cleated chain conveyor where it is carried to a sizing screen or directly stockpiled. The wood product caught in the jet-stream floats over to the wire mesh belt that conveys it out of the tank. A mud removal drag bar chain conveyor removes some of the sediment from the bottom of the tank. A clarifier cleans the tank water by removing sediment and other solids centrifugally allowing a large portion of the water to be reused thus minimising the consumption of fresh water. The sediment should be dewatered prior to landfilling, and the surplus water treated as leachate.

The wood from the flotation tank is conveyed to a horizontally fed hammermill for reduction to a less than 75mm sliver product. The screens in the hammermill chamber determine the product size and throughput. The discharge conveyor is equipped with a magnet to remove nails and other small ferrous material. The infeed conveyor is equipped with a metal detector to protect the hammermill from large pieces of ferrous material. Clean wood material is tipped near the wood hog and fed directly to it, bypassing the rest of the processing system.

Soft fill material mixed with wood and rock, or pre-crushed construction waste smaller than 150mm can be fed directly into the feed hopper of the trommel thus bypassing the waste reducer and impactor. Fines are removed and over-size material flows out of the trommel and is processed through the rest of the system.

If tyres, white goods, carpeting, plastic rolls and similar materials are to be reduced prior to disposal, the portable waste reducer can be pulled back from the processing line and set up so that the discharge material will feed directly into a truck or container.

If tonnages do not warrant a dedicated impactor for the mixed material system, rubble mixed with wood can be stockpiled until it is convenient to bring the impactor over from the clean crushing system. The advantage of using an impactor over a jaw crusher in the mixed material system is that a jaw crusher cannot accept rubble mixed with wood and other residues as the compressible material jams the slow moving jaw plates.

8.4.4 Brini Fuel - Energy Recovery System

The Brini Fuel process is a system designed and developed for energy recovery from solid waste. The system separates out combustible material from the waste stream for use as fuel in fluff or densified form. Significant environmental and economic advantages can be realised through utilisation of this process.

8.4.5 Capacity

The proposed granular material crushing /screening system has the capacity to process up to 300 tonnes of granular construction waste material per hour and 150 tonnes per day of mixed materials. The combined capacities of the systems is in excess of 5,000 tonnes per day. If necessary, additional parallel systems could be added to increase capacities. The potential capacity of a Brini plant could be in the order of 80 tonnes per hour.

8.5 ENVIRONMENTAL IMPACTS

8.5.1 Introduction

Key environmental issues associated with the operation of a recycling plant at SENT Landfill comprise noise emissions and potential impacts on air quality as a result of dust. The potential environmental impacts have been identified and practical mitigation measures recommended. The findings of the preliminary assessment are presented below.

8.5.2 Methodology

As a preliminary assessment, the analysis is essentially a qualitative desk study and draws upon existing data and information. Following the finalisation of recycling processes to be undertaken, firm decisions regarding plant type, location, size and throughput can be made and then a more detailed, quantitative assessment of any noise and dust related impacts could be made.

A review of the SENT Landfill CEIA has confirmed the potential sensitive receivers (Table 8.4) in relation to both dust and noise emissions.

Table 8.4 Potential Sensitive Receivers

Issue	Potential Sensitive Receivers
Dust	Adjacent Industrial Premises • Area 137 • Area 87 Clear Water Bay County Park TKO New Town
Noise	TKO New Town Clear Water Bay Country Park

8.5.3 Noise

Emission Sources

Typical noise levels (e.g. impact crushers, hammermills etc) when measured 1 metre from the source were typically 80 to 95 dB(A).

Impact Assessment

The processing equipment will be located in the vicinity of active areas and will be some distance from the site boundary. Noise Sensitive Receivers (NSRs) are located approximately 4km from the site. The land immediately adjacent to the site will be occupied by industrial premises, and these are therefore not considered to be NSRs. The visitors to the Clear Water Bay Country Park could be considered as sensitive recievers however given the transient nature of such recievers and the generally short term nature of visits to the Country Park it is unlikely that any impacts would be significant.

Consequently noise attenuation over this distance is predicted to be sufficient to successfully reduce emissions to an acceptable level. However, in order to ensure minimum noise emissions from the recycling plant on site the following measures should be considered:

- use of stockpiles as barriers;
- ensure that the processing plant is positioned away from site boundaries; and

- use of rock crushers and other noisy items of plant should be restricted on Sundays and Public Holidays.

8.5.4 Air Quality (Dust)

Emission Sources

In general terms dust will be generated from SENT Landfill by the movement of vehicles and equipment handling fill and cover materials on the site itself. The operation of a recycling plant will contribute to these dust emissions as well as giving rise to emissions from specific elements of its operation.

The extent of dust emissions will be directly influenced by the system chosen. For both systems described above, dust will be generated as a result of wind erosion from stockpiles of recycled material (particularly soft fine fill material), waste tipping areas and in the vicinity of in-feed points where material is dumped with front end loaders. Specific emission sources are:

- Granular Material Crushing/Screening System:

  Jaw crusher (primary crusher);
  Impactor (secondary crusher);
  Conveyor system; and
  Screening.

- Mixed Construction Waste Processing System:

  Conveyor System;
  Concrete Impactor; and
  Screening/Trommel.

Impact Assessment

Potential sensitive receivers to dust are presented above in Table 8.4. Considering the patterns of local windflows described in the CEIA, it is possible that during the summer months Tseung Kwan O may be affected by dust from the site activities, during the winter the port related industries (Area 137) could be affected and when easterly winds occur, the Third Industrial Estate (Area 87) may similarly receive dust emissions from the site. However, given the controls and operations in place to minimise dust entrainment, impacts on Tseung Kwan O are unlikely.

The CEIA established that, provided the recommended mitigation measures are implemented, emissions can be maintained at an acceptable level. However, due to the nature of landfill operations, some residual nuisance potential is possible for the adjacent industrial sites.

Due to the preliminary and uncertain nature of the recycling proposals, it is not possible to either quantify potential dust emissions from the plant or determine the contribution of these emissions to overall dust levels resulting from site operations. However, it is proposed that recycling plant is located as far away from the site boundary as possible.

In 1993 EPD issued a draft guidance note: *Best Practicable Means Requirements for Mineral Works [Stone Crushing and Screening Plant] (Ref 8.5)*, which it is intended will become a Technical Memorandum under the Air Pollution Control Ordinance. The Notes state emission limits from stone crushing plants and provide guidance on control measures with respect to crushers, vibratory screens, belt conveyors, stockpiles and material transportation, to ensure dust emissions are maintained at an acceptable level.

The guidance notes are proposed to effectively control emissions of dust from stone crushing plant such as the potential recycling plant. Consequently, provided the recommended measures are observed, dust contributions from the recycling plant should not affect identified sensitive receivers. Provided that the recycling plant is constructed and operated in accordance with the requirements of EPD's guidance note, it is not expected that dust emissions from the recycling plant will contribute significantly to overall emissions from the site.

Mitigation

Most of the mitigation measures which should be adopted for the recycling plant have already been recommended in the CEIA for SENT Landfill. Specific measures necessary to mitigate potential dust impacts from the recycling plant are detailed in the aforementioned note on Best Practicable Means and include the following:

Crushers

- The outlet of all primary crushers could be enclosed and a dust extraction system installed. The particulate concentration at the exhaust outlet of the dust collection system should not exceed the limiting value 50 mg/m^3.

- The inlet hopper of the primary crusher could be enclosed on top and 2 sides to contain the emissions during dumping of rocks from trucks. It is preferred that aggregates are wetted while still on the trucks and before dumping.

- For the secondary crusher, both the crusher material feeding inlet and the crusher outlet could be totally enclosed and the air extracted and ducted to a dust collection system to meet the particulate limiting value 50 mg/m^3.

- Sufficient water sprayers with chemical suppressant could be installed and operated in strategic locations at the feeding inlet of all crushers to cover the entire feeding inlet areas.

- Crusher enclosures could be rigid and be fitted with self-closing doors and close-fitting entries and exits. Where conveyors pass through the crusher enclosures, flexible covers should be installed at entries and exits of the conveyors in the enclosure.

Vibratory Screens

- All vibratory screens could be enclosed.

- Screenhouses could be rigid and reasonably dust tight. Where conveyors pass through the screenhouse, flexible covers could be installed at entries and exits of the conveyors in the housing.

Belt Conveyors

- Conveyors could be enclosed with windshields, and be provided with metal boards at the bottom.

- Scrappers could be provided near the end of the conveyor. The scrapped material should not be let fall directly.

- All transfer points to and from conveyors could be totally enclosed and water sprayed. Openings for the passages of conveyors could be fitted with flexible seals.

Storage Piles and Bins

- All free falling transfer points from conveyors to stockpiles could be enclosed with chutes and water sprayed.

- The surface of all surge piles and stockpiles of blasted rocks or aggregates could be kept sufficiently wet by water spraying.

- Stonefines and other fine materials could be stored in totally enclosed storage bins or storage silos and water sprayed during discharge to trucks.

- Stockpiles of aggregates (other than certain specified materials) of size less than or equal to 10 millimetres should be enclosed on top and 3 sides.

- Scattered piles gathered beneath belt conveyors, inside and around enclosures should be cleared on a weekly basis.

Material Transportation

- Roadways from the entrance of the Works to the product loading points, and/or any other working areas where there are regular movements of vehicles, should be paved.

- All roads inside the Works should be adequately wetted with water and/or chemical suppressants by water trucks.

- Vehicle exhausts, wherever possible, should be directed upward.

- Wheel cleaning facilities should be provided for vehicles leaving the Works. All trucks should use this wheel cleaning facility before leaving the premises.

- Transportation of crushed or screened products should be carried out with closed tankers or covered with tarpaulin sheets before leaving the premises.

- The handling and storage of the dust collected by the dust collection system should be carried out without fugitive particulate emissions.

Housekeeping

- A high standard of housekeeping should be maintained. As stated, any piles of materials accumulated on or around the relevant plant should be cleaned up on a weekly basis and dust suppression or extraction systems should be in use whenever the related equipment are in use.

8.6 ENVIRONMENTAL MONITORING PROGRAMME

Appropriate records and documentation concerning weight, destination and receipt of recycled material used off site should be maintained. Parameters and sampling frequency will be determined by EPD. However, it is recommended that the following parameters should be monitored regularly. the dust monitoring protocol under the EMP is summarised in Chapter 20.

(a) Process Monitoring

Total monthly raw input, product output and material stock (by manual recording), and other essential operating parameter(s) which may significantly affect the emission of air pollutants.

(b) Ambient Monitoring

Total suspended particulates and respirable suspended particulates are monitored under the EMP for SENT Landfill.

8.7 CONCLUSIONS AND RECOMMENDATIONS

Recycling of waste at SENT Landfill is environmentally preferred for a number of reasons and is compatible with Hong Kong Government's stated policies.

Production of refuse derived fuel at the Brini plant will provide valuable energy recovery from waste material.

A decision on recycling of construction waste at SENT Landfill will depend on the Government's intention regarding a construction waste sorting plant in the Tseung Kwan O area.

On the basis of current intentions and available information it is not anticipated that the recycling operations will cause either noise or dust impacts. However it is recommended that when decisions have been made regarding the recycling processes and proposed plant details are available, then predictive modelling for potential dust impacts should be undertaken.

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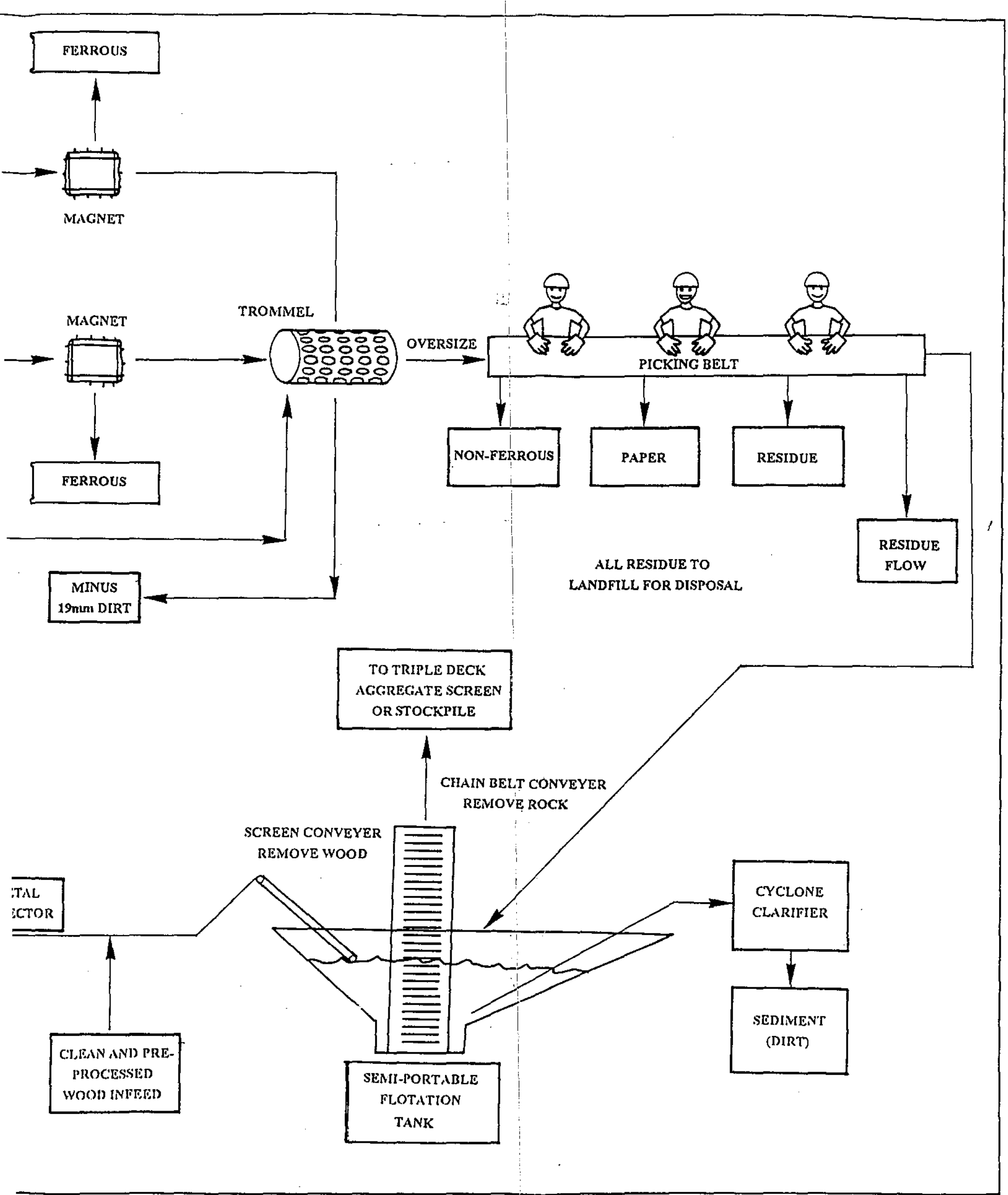

ONSTRUCTION WASTE RECYCLING PLANT
PROCESS FLOW DIAGRAM

EXTERNAL VIEW OF SIMILAR BRINI PLANT IN SWEDEN

INTERNAL VIEW OF BRINI PLANT SHOWING SHREDDED WASTE CLASSIFIERS

acer ENVIRONMENTAL

FIGURE 8.2

PHOTOGRAPHS OF PROPOSED BRINI PLANT

Landfill Gas Flaring & Utilisation

Chapter 9

9 LANDFILL GAS UTILISATION

9.1 INTRODUCTION

The active landfill gas collection system, flares and utilisation (recovery) plant to be installed at SENT Landfill have been designed based on past experience and known site conditions. Landfill gas generation rates have been calculated, and will be refined as gas extraction wells is become active in the first few years of landfilling operations.

The objectives of this Chapter are to review the proposals for both the flaring and utilisation of landfill gas and to assess the environmental impacts of both activities, particularly in terms of air quality, odour, noise and visual intrusion.

Landfill gas quality and quantity will be monitored under the EMP (Ref 9.1) to determine physical and chemical characteristics. Data obtained from this will reinforce the forecasted quantities and aid in the economic viability of the proposed gas utilisation plant or other beneficial use.

In addition to meeting on-site power requirements, it is possible that electricity produced by the gas utilisation plant will be of sufficient quantities to sell to local power companies or nearby industries (in Area 137 or the Third Industrial Estate). China Light and Power Company, Limited and K. Wah Stones Company have both expressed an interest in either purchasing the generated power or the medium BTU landfill gas from SENT Landfill.

9.2 GVL LANDFILL GAS MANAGEMENT

9.2.1 Predicted Landfill Gas Volumes

Design of the gas management system at SENT Landfill has been based on volumes predicted by a computerised landfill gas modelling programme, which incorporates an extensive landfill gas production assessment database (over 75 Waste Management Inc. landfill gas recovery assessments).

The following parameters were input into the model:

- total estimated intake mass of 32,780,000 tonnes over approximately 18 years;
- average weekly waste input of 36,000 tonnes; and
- average in-place waste density of 0.9 tonnes/m^3.

It is possible that the build up of the refuse waste stream and the quantity of inert construction waste will vary considerably from the projected "worst case" input rates, particularly in the early and final years of the landfill. Table A.3.14.3 of the ER sets out GVL's assumptions based on the EPD predictions to 2001.

The starting data and initial volumes of waste will determine how quickly and how much gas is generated for in the 1st year of operations. A longer variability in gas flow is probable at the initial stages due to operational uncertainties.

To determine a gas generation rate suitable for SENT Landfill, several characteristics of the site were compared to a database of existing Waste Management Inc. landfill assessments.

Since SENT Landfill is located in a subtropical area subject to high annual rainfall, the sites most closely related were considered to be in the southeastern United States. Landfill size and waste stream characterisation aided in the comparison. It is expected that the methanogenic process will be mostly thermophilic with microbial activity generating landfill gas temperatures exceeding 45°C and a slightly higher gas generation rate than the average mesophyllic landfill environment of North American. This has been observed in several large landfills in the southeastern United States comparable to SENT Landfill. As a result, a gas generation rate of 0.0078 cubic metres/kilogram-year (m^3/kg.yr) most closely approximates the rate anticipated for SENT Landfill.

Also input into the computer model was the theoretical maximum yield of landfill gas. This is extremely difficult to estimate without an accurate characterisation of the organic fraction of the waste stream. Several published reports have concluded that the Hong Kong waste stream has a similar biodegradability to that of the USA, so based on past experience and an extensive literature review, a theoretical gas yield of 0.280 m^3/kg of refuse was derived for SENT Landfill. This closely approximates observed gas production in similar sites in the southeastern United States.

The recoverability (the quantity of landfill gas that can be expected to be successfully extracted) for SENT Landfill was assumed to be 65 percent.

The results of the gas production analysis are presented in Table 9.1.

Recoverable gas volumes at SENT Landfill are projected to increase steadily from approximately 35,661 m^3/day in 1995 to approximately 339,841 m^3/day in 2011 (see Table 9.1). To accommodate these volumes of gas over a long period of time, the gas management system at SENT Landfill will be developed in phases in coordination with the operational constraints and completion of areas.

9.2.2 Landfill Gas Collection, Treatment and Utilisation

The SENT Landfill gas collection system has 2 basic components:

- vertical extraction wells; and
- horizontal extraction zones and sideslope risers.

The integrated system will also work in conjunction with the liner and cover systems to significantly reduce or eliminate the potential for gas to migrate off site or for gas to be emitted through the landfill cover to the atmosphere.

The landfill gas collected in the system will be burned in an enclosed flare with a documented destruction efficiency exceeding 99 percent. In addition, a gas utilization plant may supply efficient, economical electrical power to the site by burning the gas in reciprocating engines or turbines.

Condensate formed in the gas collection system will be treated on site with the collected leachate at the Biological Treatment Facility prior to sewer discharge. Liquid in gas collection wells can reduce the efficiency of the gas system, but this should be minimise through the low leachate head levels maintained above the liner.

The proposed gas probe/gas piezometer monitoring system around the landfill perimeter (Ref 9.1) will ensure gas migration is detected before it becomes an environmental, health, and safety problem. The current gas management design also includes a gas trench extraction system at the westerly perimeter of the site, adjacent to the Third Industrial Estate and site infrastructure area, to control gas migration to these sensitive areas. Closely spaced vertical gas extraction well can provide the same conservative approach to ensure no possibility of gas migration.

Table 9.1 Predicted Landfill Gas Production

Year	Annual Refuse (tonnes)	Gas Produced (m^3/d)	Recoverable Gas Produced (m^3/d)	Fuel Equivalent (mmBTU/hour)
1994	1793000	18287	11887	6.3
1995	1843000	54862	35661	19.0
1996	1832000	90616	59031	31.4
1997	1860000	125942	81862	43.5
1998	1928000	161068	104694	55.7
1999	1928000	195910	127341	67.7
2000	1816000	228638	148615	79.0
2001	1843000	259588	168732	89.7
2002	1843000	289951	188468	100.2
2003	1858000	319621	207754	110.5
2004	1860000	348639	226615	120.5
2005	1872000	376990	245044	130.3
2006	1799000	403930	262554	139.6
2007	1885000	430251	279663	148.7
2008	1842000	456278	296581	157.7
2009	1840000	481121	312729	166.3
2010	1815000	504997	328248	174.6
2011	1313000	522833	339841	180.7
2012	0	521660	339079	180.3
2013	0	507128	329633	175.3
2014	0	493000	320450	170.4
2015	0	479267	311523	165.7
2016	0	465916	302845	161.1
2017	0	452937	294409	156.6
2018	0	440319	286208	152.2
2019	0	428053	278235	148.0
2020	0	416129	270484	143.8
2021	0	404537	262949	139.8

Detailed design of the gas treatment and utilisation plants is not yet complete and the size of flares and turbines to be used has not been finalised at the time of producing this SEIA. The impacts assessment, therefore, has been based on the following preliminary plant installation schedule. The gas flares which are currently proposed, meet the same performance criteria and combust approximately double the volume of gas, but are slightly larger than those originally anticipated. Their locations are shown on Figure 9.1.

The initial phase of the gas treatment works will consist of a single fan-type centrifugal blower and an enclosed landfill gas flare. The blower will provide a stable, flexible vacuum source for the gas extraction system. The flare will be a 3.5m diameter by 15.2m high unit manufactured by the John Zinc Co., capable of combusting up to 179,000 m^3/day. Emissions tests have never reported less than a 98% destruction efficiency of VOCs in a John Zinc Co. flare (or equal). The anticipated start-up date for the first flare is 1st Quarter 1995.

It should be noted that the flare system will not be utilized if gas can be burned at the utilization plant.

A gas utilisation facility, generating electrical power for import to other users as well as on-site requirements, may be installed, following discussions between GVL and EPD and a review of its economic viability. The economic appraised of gas utilisation proposals is not within the scope of the SEIA. The gas utilisation facility could generate approximately up to 12,000 KW of electricity with four SOLAR Centaur gas turbines (or numerous reciprocating engines) installed progressively, the first preliminarily scheduled for late 1996.

The proposed phased installation of the gas treatment and utilisation plants are as detailed in Table 9.2.

Table 9.2 Phasing of Gas Flares and Utilisation Plant

Year	Equipment to be installed	
1994	No. 1	enclosed gas flare
1996	No. 1	gas utilisation plant turbine
2001	No. 2	gas utilisation plant turbine
2002	No. 2	enclosed gas flare
2006	No. 3	gas utilisation plant turbine
2011	No. 4	gas utilisation plant turbine

It is envisaged that the phasing out of turbines would begin in 2014.

9.3 DESIGN OF LANDFILL GAS FLARES

Landfill gas at SENT Landfill will be combusted using enclosed flares which are designed specifically for the efficient, intrinsically safe thermal destruction of landfill gas. The type of flare that will be used is the John Zinc Co. Model ZTOF 11 x 50, 3.5 metres in diameter by 15.2 metres high (illustrated in Figure 9.2). This type of flare has the following advantages over other systems:

- no visible flame;
- virtually no radiation;
- very low noise;
- high destruction rates; and
- long service life.

Flares of this nature are extremely efficient in terms of thermal destruction of landfill gas and associated volatile organic compounds (VOCs). Measurements of emissions from enclosed flares in the United States have indicated that destruction efficiencies of a minimum of 98% are routinely achievable. The ZTOF 11 x 50 flare will combust up to approximately 7,450 m^3/hour (179,000 m^3/day) of landfill gas with an associated heat release of 120 million BTU/hour. In practice, however, the flare will be operated under widely varying conditions throughout the operational and aftercare periods of the site, ranging from about 850 m^3/hour (initial condition) to 7,050 m^3/hour (ultimate condition).

The flares will have an operating temperature of between 870°C and 1100°C and a residence time of 0.8 to 1.7 seconds, to ensure the destruction of VOCs. They are also designed to maintain a 20:1 flame stability turndown ratio, which ensure flame stability over a wide range of landfill gas concentrations as long as the methane content of the gas exceeds 30 percent by volume. Gas concentrations less than 30% methane require other fuels to maintain proper flare operations.

The flare has a number of built-in safety features to control operating temperatures, fuel supply and plant shutdown. These are standard for modern flare systems in the United States and Europe. The flare system will operate safely complying with the relevant construction codes utilised for gas service, ensuring that the treatment works is designed to operate in an explosive environment. An operating, maintenance and safety manual and programme will be developed for the treatment works to ensure safe operation and optimum efficiency. The system is expected to operate 24 hours a day, except while the gas utilisation plant is in operation.

After the main flare station is constructed, it is expected that a second enclosed flare unit will be required and installed around 2002, according to current predicted gas production rates. In the event that sufficient quantities of landfill gas are generated during Phase 1 such that a potential environmental concern is realised, GVL will install a temporary gas blower and flare station on the plateau of phase 1. In order to alleviate any potential public concern over an open flare being visible at the SENT Landfill site, the temporary flare will be fitted with a screen shroud.

Temporary flares may be set up on individual well heads to control odours and gas migration prior to installation of the collection system piping. This is necessary part of operations since there will be time lags between installation of wells (and riser pipes) and the availability of finished contours to place collection piping in.

In the event operational filling patterns temporarily prevent economical transmission of this gas to the enclosed flare station on gas utilization plant, a temporary flare may be set up on the landfill with piping manifolded from a group of wells. This would also be done as a proactive to control odours and prevent potential migration prior to completion of the gas collection system in that area.

9.4 DESIGN OF GAS UTILISATION PLANT

The landfill gas proposals will not be finalised until GVL has conducted a more thorough gas generation evaluation to refine the total and yearly potential generated and recoverable landfill gas volumes. The results of this will be the basis for the estimation of the power output that will be generated and the feasibility of selling electricity to China Light and Power Company, Ltd. or other customers.

The landfill gas utilisation plant will be phased in when sufficient gas volumes are present to sustain full capacity operation of each proposed unit. The system will utilise fuel gas compressors to compress, dry and filter the landfill gas prior to combustion in turbine generators or reciprocating engines. The proposed location of the utilisation plant is shown on Figure 9.1 and Figures 9.3 and 9.4 show the appearance of the building.

9.4.1 Fuel Gas Compressor (FGC) System

The FGC for the turbines draws gas from the landfill, filters it with an inlet scrubber to remove dirt particles and liquid droplets, then compresses the gas in two stages to a maximum of 1275 kPa pressure at an average temperature of 50°C. The FGC will deliver 51 m^3/minute of landfill gas at the above conditions.

The production of landfill gas by refuse decomposition results in water saturated gas, which requires some dehydration prior to combustion in the turbines. The two stages of compression, which raise the temperature of the gas, are followed by subsequent cooling stages. The combination of increased gas pressure and cooling results in water condensation; the condensate being treated at biological treatment facility and transmitted through the leachate treatment system to the plant.

9.4.2 Gas Turbines

Gas is delivered from the FGC to a "Centaur" Model GSC 4500 simple cycle combustion turbine manufactured by Solar Turbines Incorporated. As described above (9.2.2) ultimately 4 turbines may be used, to be phased in as gas production increases. Each turbine will generate approximately 3,300 kilowatts of power from 40,000 joules/hour of fuel consumption.

9.4.3 Safety Features

The entire plant is equipped with a methane detection system to monitor combustible gas leaks from the equipment and initiate emergency measures. The plant also has an automatic fire detection system. An extensive training programme will be provided to plant operators to ensure the safe operation of the unit.

9.4.5 Alternative Types of Utilisation Plant Considered

Turbine technology has been selected for the gas utilisation plant at SENT Landfill because of:

- reliability of operation (>95% on-line time);
- minimum maintenance requirements;
- adaptability of plant size; and
- low air emissions.

Other types of facility were evaluated on economic, engineering and environmental grounds. These are summarised in Table 9.3 below, together with the reasons for their rejection.

Table 9.3 Alternative Gas Utilisation Options

Type of Facility	Advantages and Disadvantages Compared to Turbines
High BTU gas processing	Requires >283,270 m^3/day of gas to operate effectively Operates best at full capacity, so not practically constructed before 2005 Odour emissions and maintenance requirements excessively high
Internal Combustion Reciprocating Engines	Very effective and plant size readily adaptable Higher maintenance requirement Slightly Higher emissions of nitrogen oxides and carbon monoxide
Transporting and utilising medium BTU gas in a boiler or space heater	Very effective and easily accommodates phased gas production Cheapest option Customers must be available in proximity to the landfill who can increase their consumption of the gas as it increases over time Preferable to have customers who can use the gas 24 hours a day

9.5 AIR QUALITY AND ODOUR ASSESSMENT

The gas treatment and utilisation plant construction will proceed in different phases (Table 9.2). The works will mainly involve the installation of equipment such as turbines and compressors and will not involve any major dust emitting activity. The associated construction dust impact is expected to be minimal.

The non-odorous gaseous emissions due to the plant's operation could give rise to impact to the neighbouring receivers. The combined effect of the emissions from the gas treatment and utilisation plant and the leachate treatment plant (based on projected maximum loadings) have been investigated and the details are as follows.

9.5.1 Immediate Neighbours of the Station

The plant is bounded to the east by the Clear Water Bay Country Park, to the north-west by the proposed TKO Third Industrial Estate and to the south-west by the Tseung Kwan O Planning Area 137, which will be comprised of deep water frontage industries, potentially hazardous installations and associated industry.

The nearest air sensitive receiver (SR) from the plant will be the deep water frontage industrial area within Area 137, and this is about 40m from the edge of the site.

9.5.2 Background Air Quality

The site is situated on the eastern fringe of the Tseung Kwan O confined airshed which has only limited ability to disperse pollutants generated within the airshed. Emissions from the area have the potential to introduce pollutants into the airshed and therefore impact on air quality.

EPD has a fixed air quality monitoring station at the Haven Of Hope Sanatorium in Junk Bay. A previous study (Ref 9.2) indicated that the air quality at Area 137 and the EPD monitoring station were similar and emissions from Area 137 would enter the TKO airshed. The same conclusions can be drawn for the SENT Landfill site which is situated further into the airshed.

The annual average concentrations of SO_2 and NO_2 measured during 1992 were about 10 $\mu g/m^3$ and 20 $\mu g/m^3$ respectively and are well below the limits as set in the Hong Kong Air Quality Objectives (HKAQO, Ref 9.3). With the recent increase in construction activities in this area, the air quality is however deteriorating.

9.5.3 Assessment Methodology

To analyze the air quality impacts due to the plant operation, the computer model ISCST (Industrial Source Complex Short Term Model) was used. This is a steady-state Gaussian plume model developed by the United States Environmental Protection Agency (USEPA) for calculating the pollutant concentrations arising from a wide range of sources associated with an industrial source complex.

Given the source and meteorological parameters, the model calculates the pollutant concentrations at the receiver locations. Concentrations (1 hour average) for the key pollutants are then computed by the model.

The pollutants investigated included SO_2 and NO_2 which are of the main concern for the stack emissions. The maximum emission rates of pollutants and the emission parameters of each plant are based on the installed capacity, type and rate of fuel consumed, manufacturer's information and the USEPA Compilation of Air Pollutant Emission Factors (AP 42). The derivation of these factors are summarised in Appendix 2.

Two worst case scenarios have been investigated:

i) Full Loads of catalytic oxidizer (Qty:1) and gas flares (Qty:2); and
ii) Full Loads of catalytic oxidizer (Qty:1) and gas turbines and compressors (Qty:4).

Typical worst case meteorological parameters are assumed for the modelling and are listed in Table 9.4.

Table 9.4 Input Meteorological Parameters for the ISCST Model

Parameter	Input Value
Wind speed:	2 m/s
Wind direction:	36 wind angles (from 0 to 350 degrees)
Stability class:	D
Mixing height:	1000 m
Temperature:	25 °C

The calculated maximum pollutant concentrations are summarised in the pollutant plots, presented as Figures 9.5 to 9.10. From the contour plots, the worst affected location is identified. At this point, the variation of pollutant concentrations were then plotted against height. As shown in Figures 9.7 to 9.10, calculations have also been carried out based on the meterological conditions of stability class F and wind speed 1 m/s (IF). These take into account of the anticipated worse night time conditions although from the Royal Observatory information, the chance of occurence of IF is comparatively small (probability was 0.06 based on year 1991 Hong Kong International Airport Station's data). Existing background pollutant levels are expected to be low due to the remoteness of the site and they are not included in the plots.

9.5.4 Assessment Criteria

Table 9.5 presents the HKAQO for different pollutants. The air quality at the SRs should meet these criteria.

Table 9.5 Hong Kong Air Quality Objectives

Pollutant	Concentration in micrograms per cubic metre (i) Averaging Time				
	1 hr (ii)	8 hrs (iii)	24 hrs (iii)	3 mths (iv)	1 yr (iv)
Sulphur Dioxide	800	n/a	350	n/a	80
Total Suspended Particulates (v)	n/a	n/a	260	n/a	80
Respirable Suspended Particulates (v)	n/a	n/a	180	n/a	55
Nitrogen Dioxide	300	n/a	150	n/a	80
Carbon Monoxide	30000	10000	n/a	n/a	n/a
Photochemical Oxidants (as ozone (vi))	240	n/a	n/a	n/a	n/a
Lead	n/a	n/a	n/a	1.5	n/a

Notes
(i) Measured at 298K (25°C) and 101.325 kPa (one atmosphere).
(ii) Not to be exceeded more than three times per year.
(iii) Not to be exceeded more than once per year.
(iv) Arithmetic means.
(v) Respirable suspended particulates means suspended particles in air with a nominal aerodynamic diameter of 10 micrometres and smaller.
(vi) Photochemical oxidants are determined by measurement of ozone only.
n/a not applicable

9.5.5 Air Quality Impact

From Figures 9.7 and 9.8, with the full loads of catalytic oxidizer and gas flares, the maximum pollutant concentrations will occur at about 76 m.A.G. at the nearest receptor.

From Figures 9.9 and 9.10, with the full loads of catalytic oxidizer and gas turbines and compressors, the maximum SO_2 and NO_2 (assumed to be 20% of total NO_x) concentrations will occur at about 76 m.A.G. and at higher than 100 m.A.G. respectively at the nearest receptor.

In all the above cases, the predicted maximum pollutant concentrations are all less than the corresponding criteria under the various meterological conditions. As the height of the surrounding buildings are unlikely to exceed 20 m.A.G. and the background concentrations are low, the perceived hourly averaged pollutant concentrations, as well as the daily and annual averaged pollutant concentrations are unlikely to exceed the standards and therefore the impacts are considered to be insignificant.

9.5.6 Odour

The limits for the VOC emissions have been defined in the Government Tender Document (Ref 9.4). The concentration of any VOC measured at any on-site monitoring station shall not exceed the OEL (Occupational Exposure Limit as stipulated in the current version of "UK Health and Safety Executive EH 40/91 Occupational Exposure Limits"). The concentration of any VOC attributable to the landfill measured at any off-site monitoring station or at the boundary of the site shall not exceed 1% of the OEL, or the Odour Threshold, whichever is the lower.

Flaring of landfill gas is an effective method of destroying odorous components. As discussed above, measurements of emissions from enclosed flares in the United States have indicated VOC destruction efficiencies of a minimum of 98% are routinely achievable. For the gas utilization plant, data from turbine facilities in the United States also indicated a greater than 99.5% destruction efficiency of volatile organics.

The high VOC destruction efficiencies of the above units imply that the odour nuisance due to the landfill operation will depend to a large extent on the other processes such as the remaining surface emissions of landfill gas and thus the quantity of odorous compounds escaping to atmosphere. Success of odour control will therefore depend very much on the site practices such as use of cover materials and the effective control of landfill gas venting and escape, quick implementation/construction of permanent and temporary flares.

9.6 NOISE ASSESSMENT

9.6.1 Noise Sensitive Receivers

The SENT Landfill area is at present a rural setting but with increasing construction activities. There are no noise sensitive receivers (NSRs) in the immediate vicinity. The nearest NSRs are located within the Tseung Kwan O (TKO) New Town at about 4.7km away. Selected locations within the Country Park have been identified by the Government as NSRs in the Tender Document (Ref 9.4). They are shown in Figure 4.1 and the nearest one (NSR-3) is about 0.9km from the site.

9.6.2 Assessment Criteria

The noise criteria have been defined in the Tender Document, and have basically followed the "Technical Memorandum on Noise from Construction Work other than Percussive Piling". As discussed in the Environmental Monitoring Plan, August 1993, the Area Sensitivity Rating is B and the corresponding noise criteria are summarized in Table 9.6.

Table 9.6 Noise Criteria

Time Period	Noise Criteria, $Leq_{(5min)}$, [dB(A)]
0700 - 1900 hrs (excluding general holidays)	75
1900 - 2300 hrs (all days) & 0700 - 2300 hrs (general holiday including Sundays)	65
2300 - 0700 hrs (all days)	50

9.6.3 Construction Noise Impact

It is expected that the plant construction will only involve day time works. In the event that construction work is needed during restricted hours, the contractor would have to apply for a Construction Noise Permit (CNP) which would regulate the noise levels caused by the operation.

The numbers and types of powered mechanical equipment allowed to be used at the site can be estimated by using the following equation (neglect the barrier effect):

Sound Power Level = Sound Pressure Level (free field) + 20 log R + 8

By taking the separation of the receiver from the plant (R) as 0.9km and based on the 75 dB(A) daytime criterion, the permissible overall sound power level of the noise sources would be 139 dB(A). At the moment, details of the construction equipment to be used at site are not available, the following equipment listed in Table 9.7 is generally used at construction sites and is quoted for comparison purposes.

Table 9.7 List of Typical Construction Equipment

Equipment	Quantity	Sound Power Level [dB(A)]
1. Excavator	1	112
2. Mobile Crane	1	112
3. Bulldozer	1	115
4. Dump truck	1	117
5. Generator	1	108
Combined Sound Power Level		121 dB(A)

It can be seen that the above level is well below the 139 dB(A) limit. Even with the increase in the numbers and types of equipment, the contribution is still insignificant.

9.6.4 Operational Noise Impact

The main noise emitting components in the gas treatment and utilisation plant include the turbine station (with turbines and compressors) and the blower station.

To mitigate the noise from the turbine house, exhaust silencers will be provided for the turbines. The building will be of block or concrete construction to maximize building life and minimize noise. Noise levels measured at comparable facilities indicate that less than 50 dB(A) can be expected at 150m from the building and the corresponding noise level at 0.9km from the site will be less than 40 dB(A).

Within the blower station (the centrifugal blowers ensure sufficient gas flow is delivered to each flare), noise levels are expected to be far less than 60 dB(A). There will be fencing around the flare station.

With the low noise levels being emitted from the turbine house and blower station and the remoteness of the site from the NSRs (at least 0.9km), it is concluded that the operation noise impact associated with the gas utilisation plant is negligible.

9.6.5 Cumulative Noise Impact

It is understood that construction of the gas treatment and utilisation plant will proceed in different phases. There will be occasions that the plant will operate in parallel with the plant construction during daytime. The combined noise impact, however, is expected to be minor with insignificant contributions from the operation and construction of the plant and the hour of operation.

9.7 VISUAL IMPACT

The visual impact of the gas flares and utilisation plant is being assessed as part of the overall visual assessment of the SENT Landfill project (see Chapter 16). The 2 enclosed landfill gas flares (see Figure 9.2) will each be 15.2m high and as such be moderately intrusive. They will be sited in the far eastern corner of the site infrastructure area, close in to the rock slopes. The combination of screening from distant views across Junk Bay by Junk Island and the other buildings and landscape planting in the site infrastructure area, and the screening from views down into the site from Clear Water Bay Country Park by the steep rock slopes and cliffs, make the flares hardly visible from any location. If necessary, additional screen planting will be provided around the perimeter of the flare compound to mitigate an unusual the visual impact. The use of enclosed flares, however, means that no flame will be visible at any time from any location, so visual impact is already minimized.

The gas utilisation plant is a low building (see Figures 9.3 and 9.4) an approximate height 11m, and will be screened by landscape planting as necessary.

9.8 CONCLUSIONS AND RECOMMENDATIONS

A quantitative assessment of the atmospheric and noise impacts of the landfill gas flares and utilisation plant has been carried out using computer models based on worst case scenarios. The very low emissions of the plant, and the comparatively large distances to the SRs result in very low concentrations at all SRs, which are well within the noise and air quality standards.

Because the levels are significantly below the relevant standards, it is considered that the enclosed flares and gas utilisation plant could be located elsewhere within the site infrastructure area, should this be required or desired, without any cause for concern.

In conclusion, the use of enclosed gas flares, with long residence time and high temperature combustion, leads to extremely high efficiency destruction of VOCs, methane and other landfill gas constituents. Furthermore, utilisation of landfill gas for electricity generation using turbine technology provides a beneficial use of a waste product, with very low noise and air emissions.

It is recommended, however, that two further mitigative measures be incorporated into the design to ensure that the flares operate with no significant environmental impacts throughout the life of the site. These are:

- provision of additional screen planting and/or bunding around the landfill gas flare compound if necessary;
- should temporary flares be required siting of the flare, in the least visually intrusive location possible.

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9.2 APH Consultants. Engineering Feasibility Study of Development of Tseung Kwan O Area 137 (March 1993).

9.3 Hong Kong Government. Hong Kong Planning Standards and Guidelines (1990).

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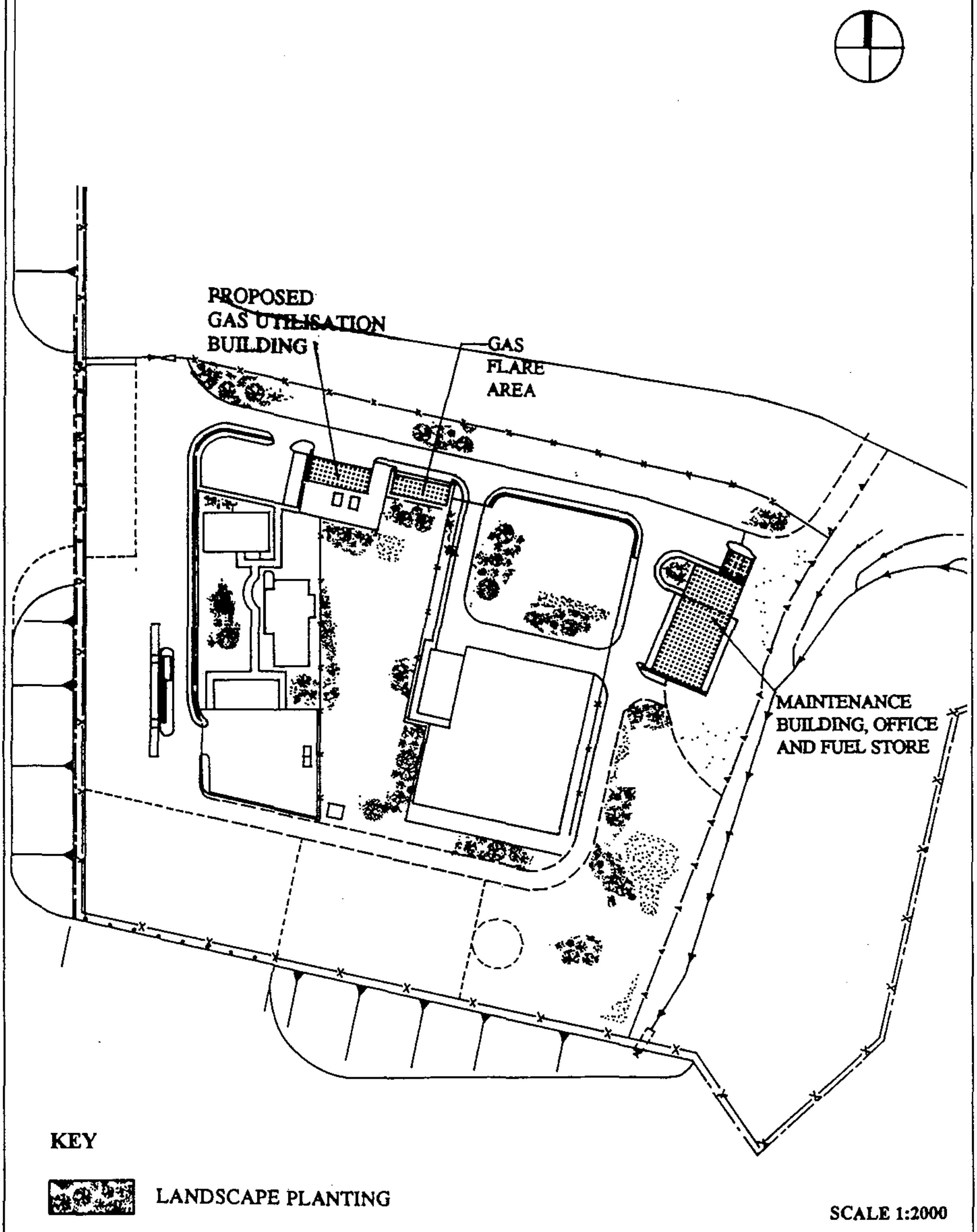

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FIGURE 9.1

LOCATION OF GAS FLARES AND UTILISATION PLANT

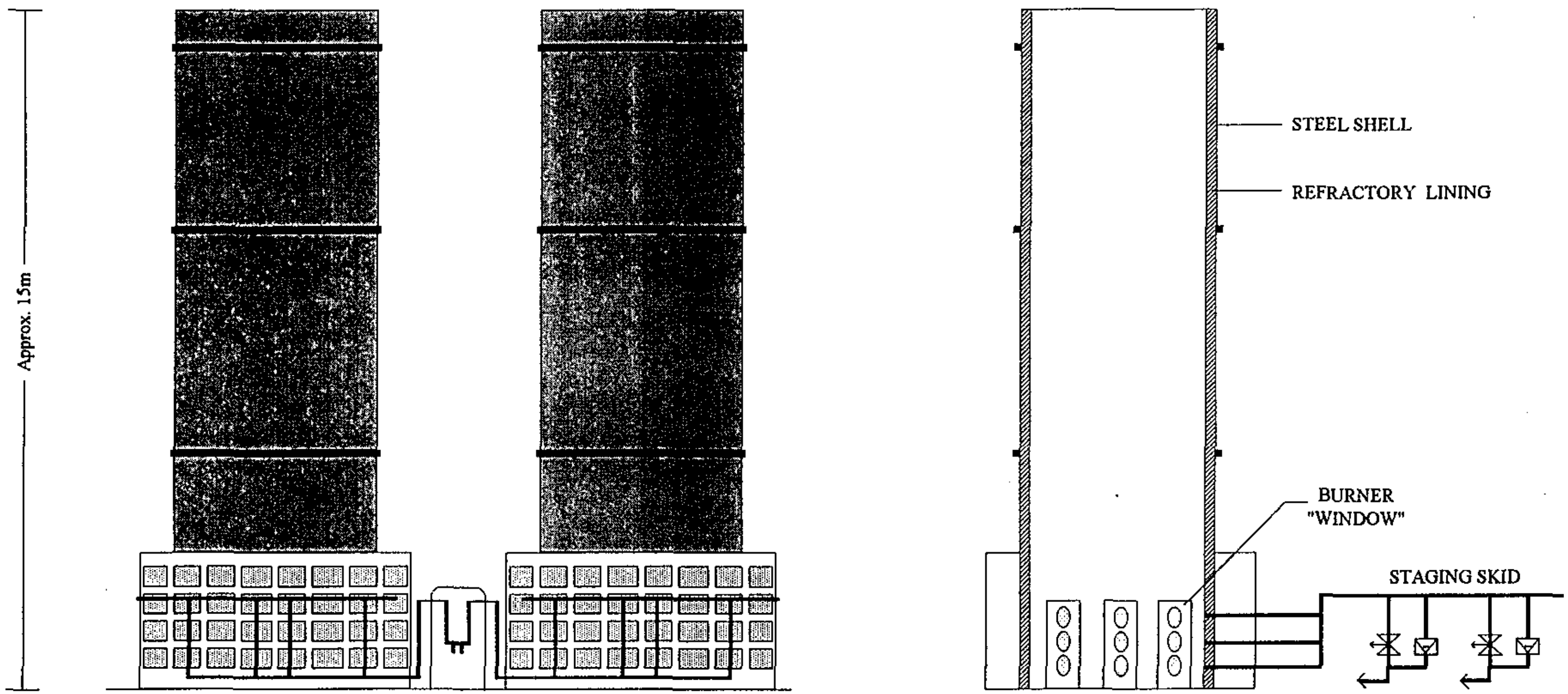

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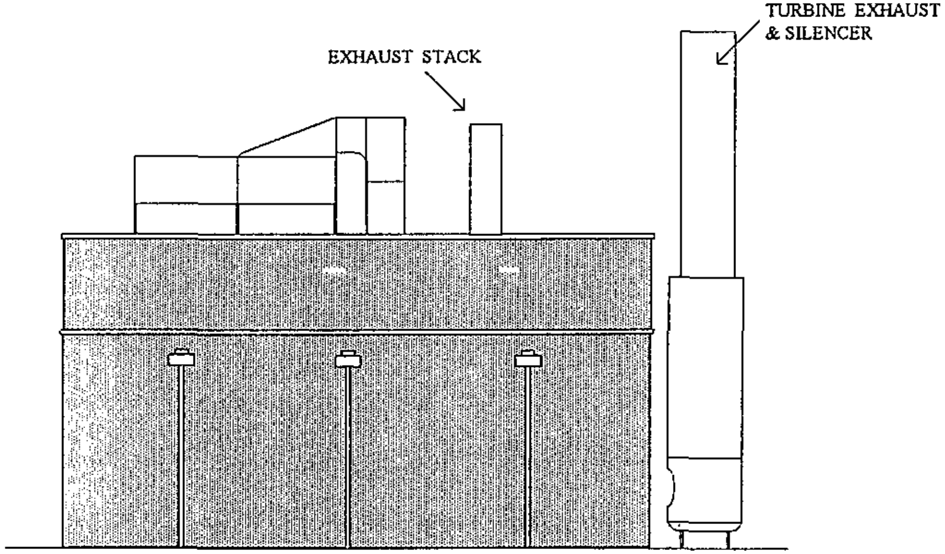
FIGURE 9.2

APPEARANCE OF GAS FLARES (ZTOF ENCLOSED FLARES)

SOUTH ELEVATION

N.T.S.



NORTH ELEVATION

N.T.S.

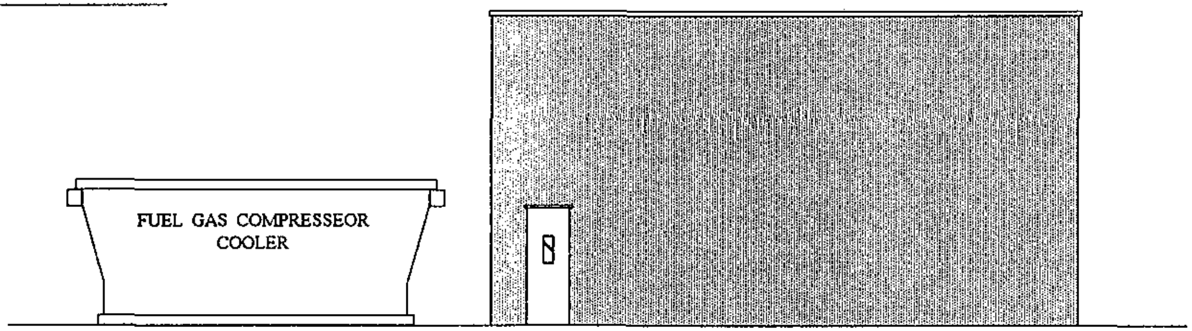


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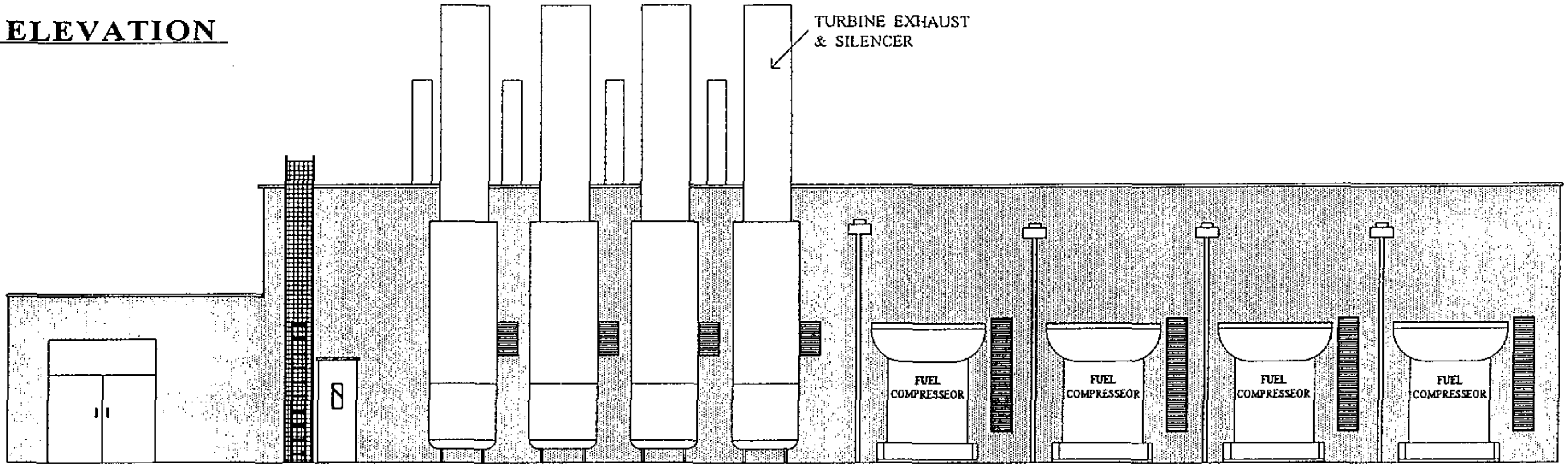
FIGURE 9.3

SENT LANDFILL GAS UTILISATION PLANT; NORTH & SOUTH ELEVATIONS

EAST ELEVATION

N.T.S.



WEST ELEVATION

N.T.S.

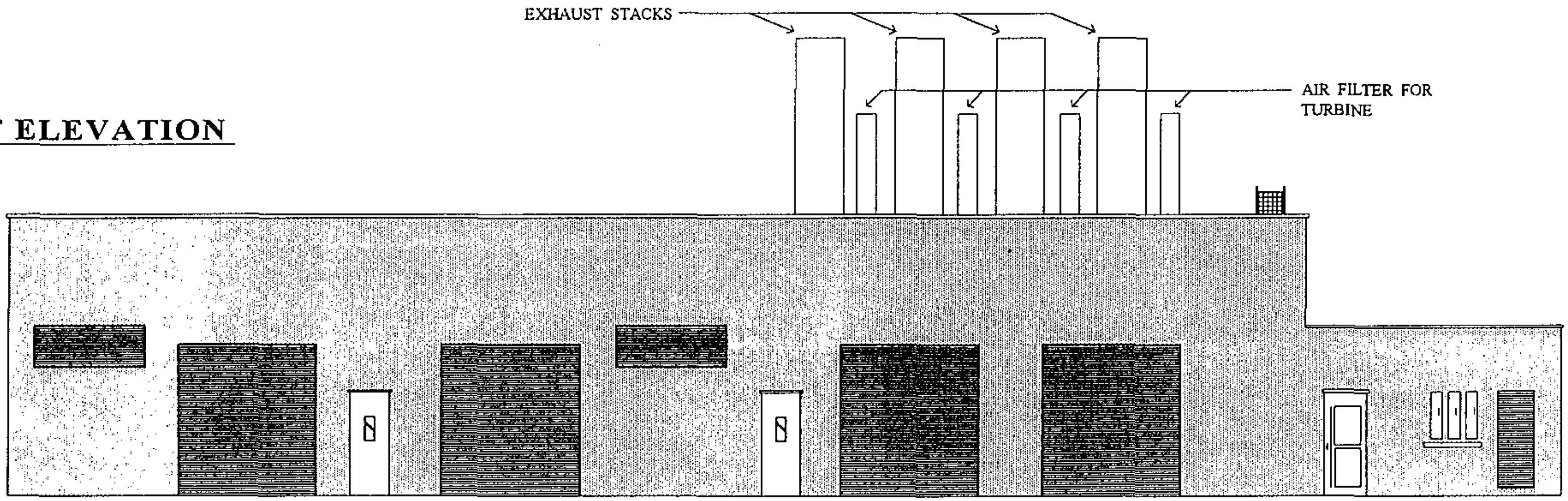


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FIGURE 9.4

SENT LANDFILL GAS UTILISATION PLANT: EAST & WEST ELEVATIONS

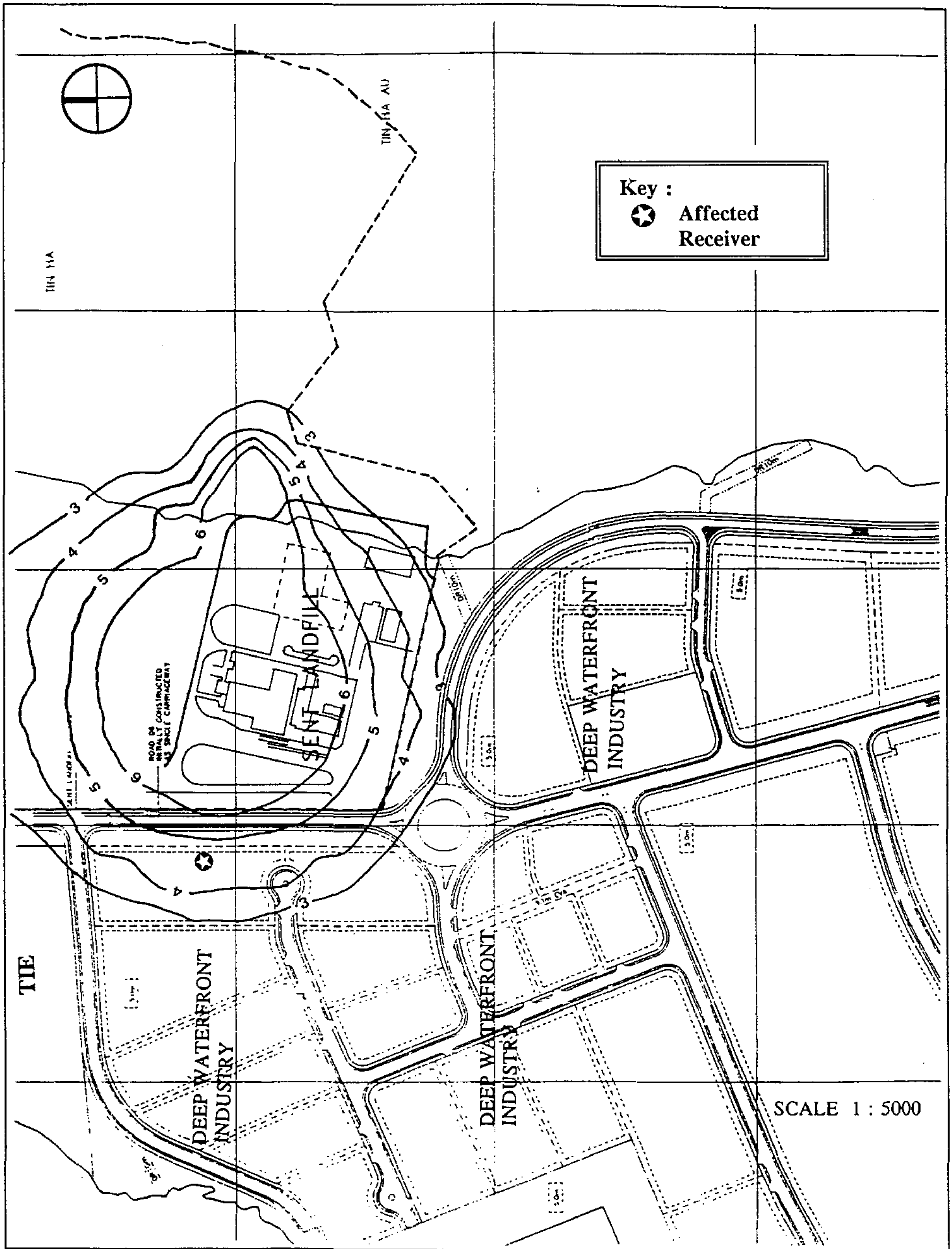

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FIGURE 9.5

SO_2 EMISSION FROM CATALYTIC OXIDISER AND GAS FLARES : HIGHEST 1 HOUR SO_2 CONCENTRATION CONTOURS AT 20mAG ($\mu g/m^3$)

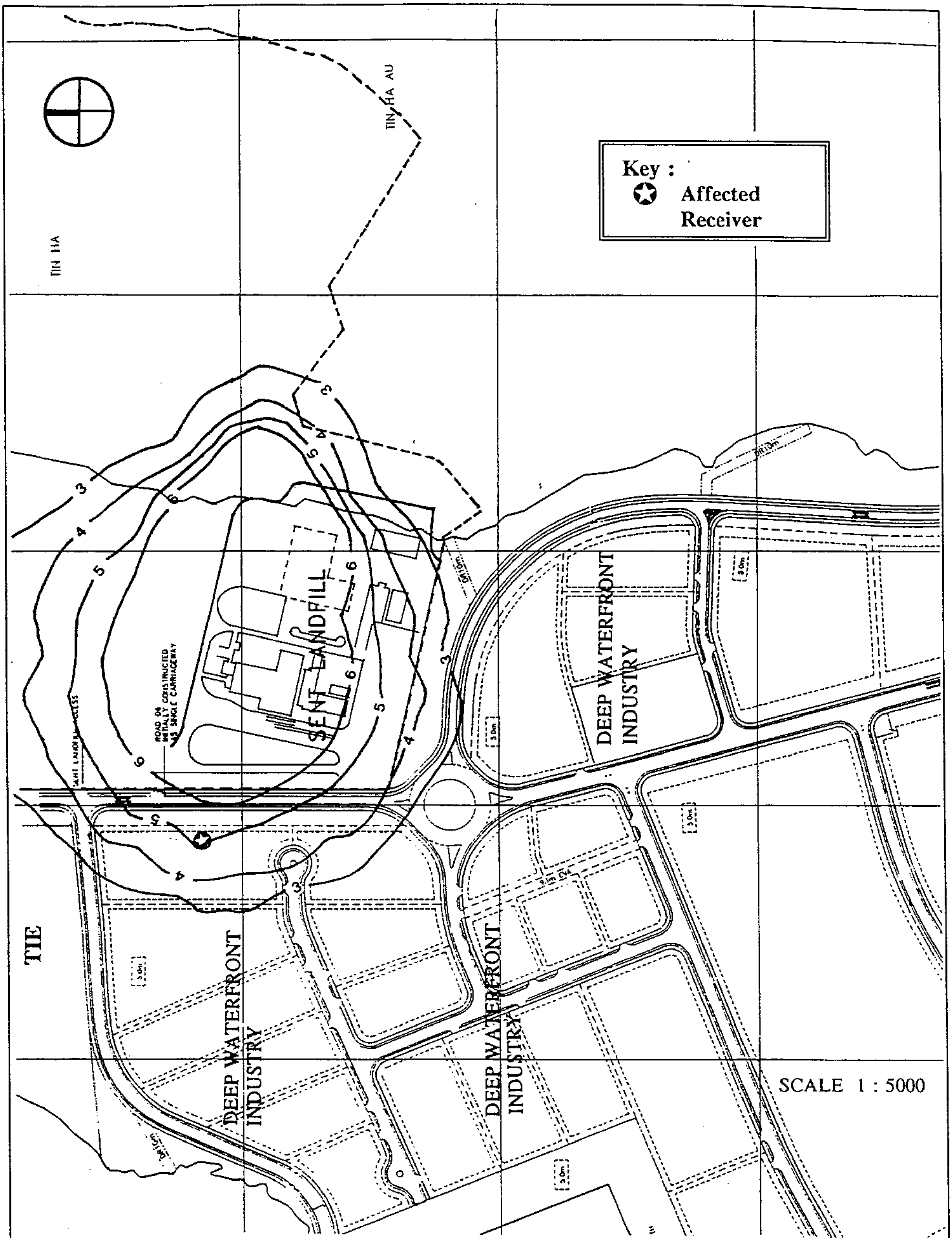

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FIGURE 9.6

SO_2 EMISSION FROM CATALYTIC OXIDISER AND TURBINE UNITS : HIGHEST 1 HOUR SO_2 CONCENTRATION CONTOURS AT 20mAG ($\mu g/m^3$)

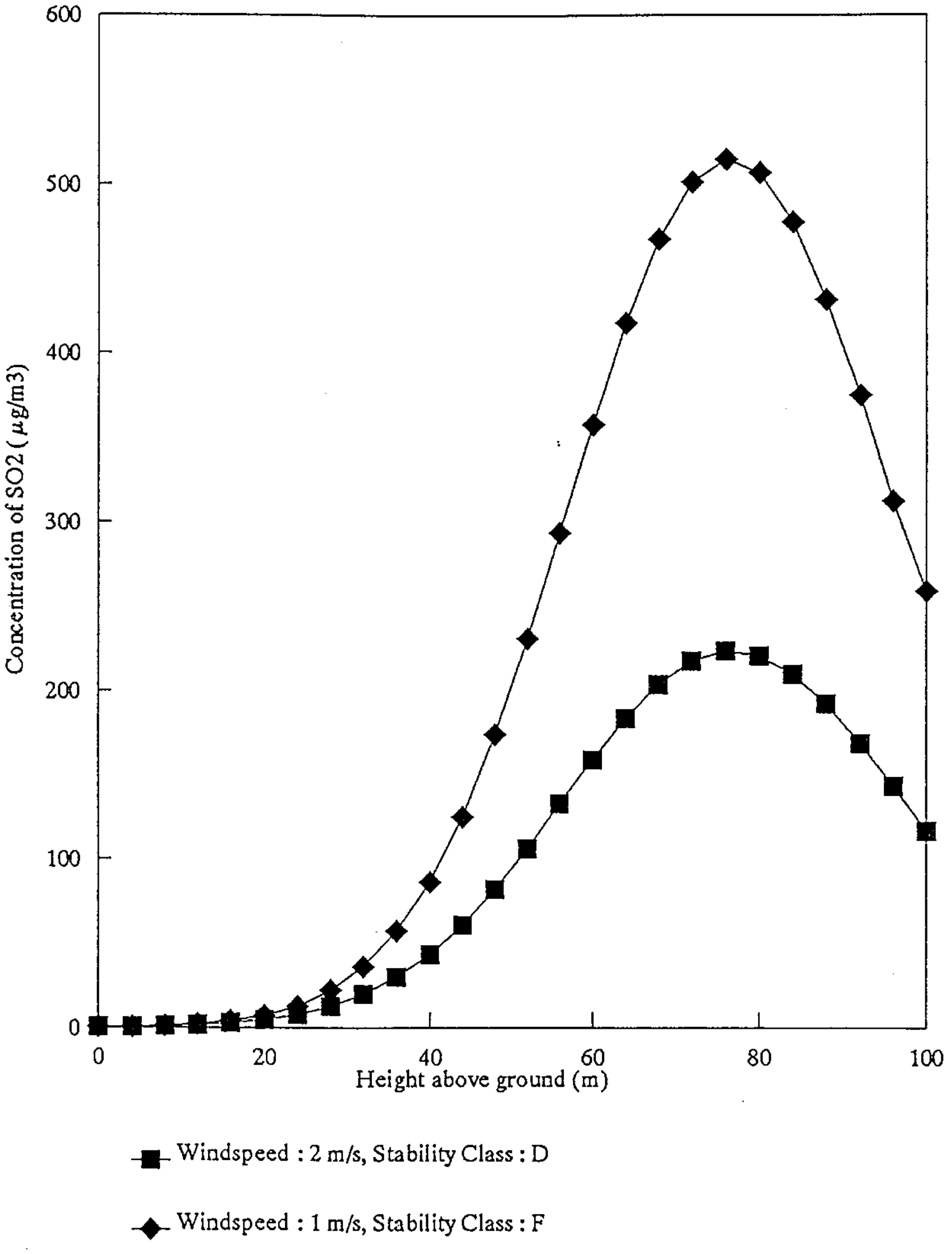

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FIGURE 9.7

EMISSIONS FROM CATALYTIC OXIDISER AND GAS FLARES: HIGHEST 1 HOUR AVERAGE SO_2 CONCENTRATION PLOTTED AGAINST HEIGHT

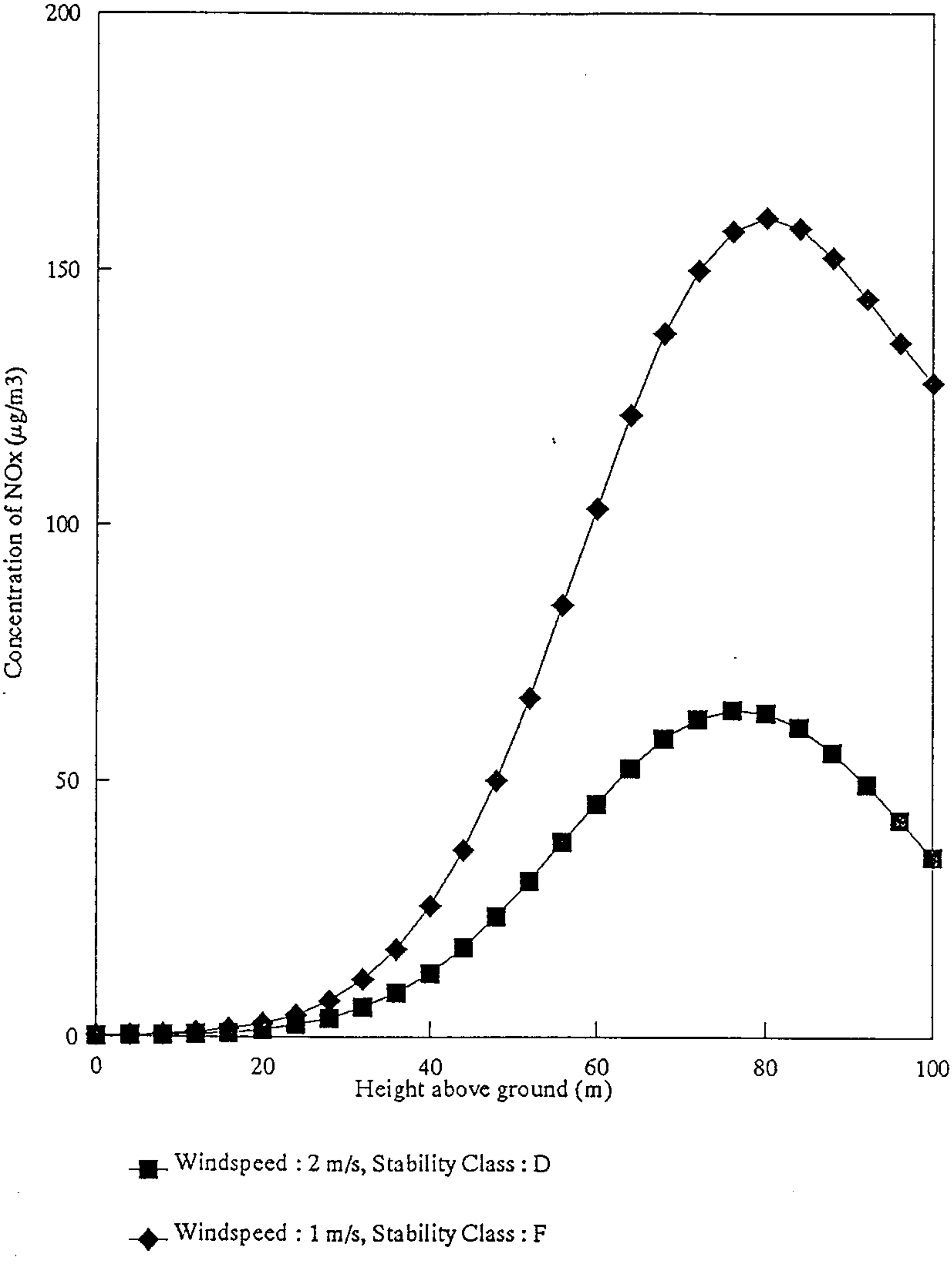

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FIGURE 9.8

EMISSIONS FROM CATALYTIC OXIDISER AND GAS FLARES: HIGHEST 1 HOUR AVERAGE NOx CONCENTRATION PLOTTED AGAINST HEIGHT

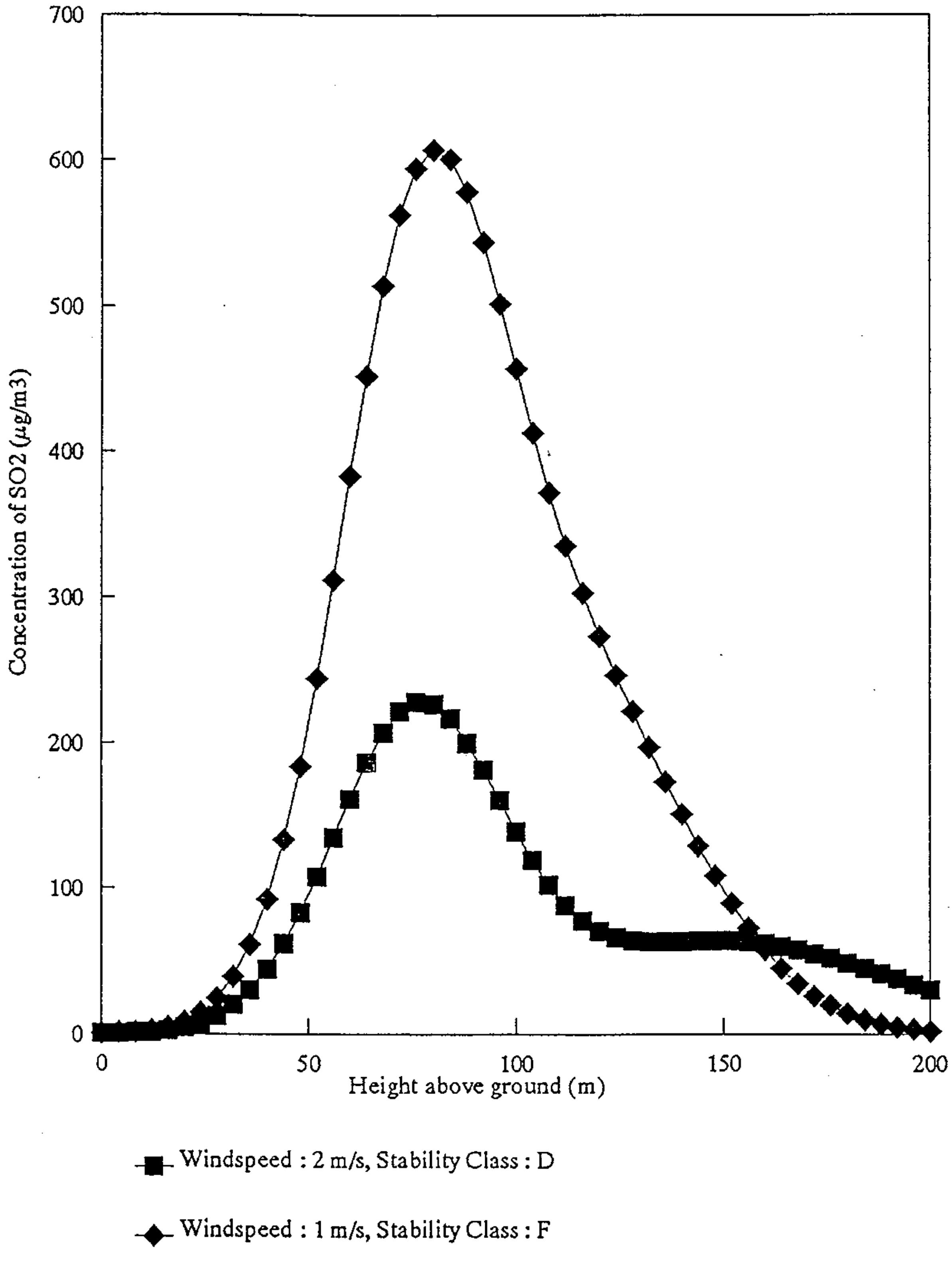

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FIGURE 9.9

EMISSIONS FROM CATALYTIC OXIDISER AND TURBINE UNITS: HIGHEST 1 HOUR AVERAGE SO_2 CONCENTRATION PLOTTED AGAINST HEIGHT

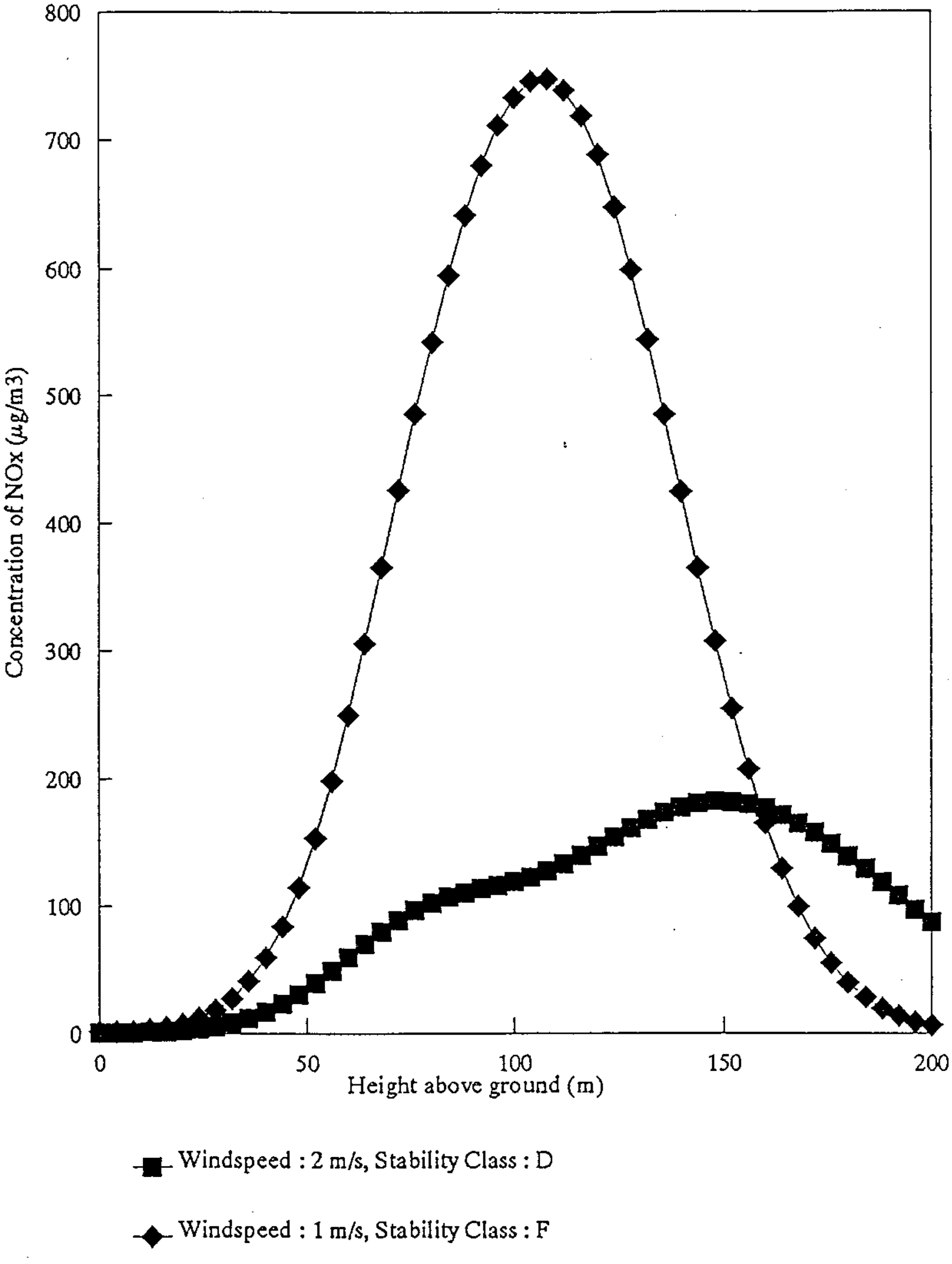

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FIGURE 9.10

EMISSIONS FROM CATALYTIC
OXIDISER AND TURBINE UNITS:
HIGHEST 1 HOUR AVERAGE NOx
CONCENTRATION PLOTTED AGAINST HEIGHT

Materials Availability and Suitability

Chapter 10

10 MATERIALS AVAILABILITY AND SUITABILITY

10.1 INTRODUCTION

This Chapter reviews the materials that will be required for SENT Landfill, both during reclamation works, site formation and for use as daily cover on top of the landfilled waste. Alternative materials are discussed, and their availability and suitability investigated.

The potential environmental impacts of the different materials are then considered and compared (including their compatibility with landfill leachate) and recommendations are made.

10.2 FILL MATERIALS

10.2.1 Background

SENT Landfill will occupy approximately 100 hectares, half of which presently lies in Shek Miu Wan Bay, and requires dredging, reclamation and extensive borrowing and quarrying (as much of the existing site has slopes up to 100 metres high). The site formation procedure will maximise usage of materials excavated from the site development for incorporation into the reclamation and formation fills.

The following site formation materials are required:

- Marine Sand;
- Rock Fill;
- Rock Fill Formation Borrow;
- Select Formation Borrow; and
- General Structural Fill.

10.2.2 Site Formation Materials

Marine Sand Borrow

This will be used for reclamation filling. All material (2 million m^3) shall be obtained from a designated marine borrow area, site, which is a 50 hectare site located approximately 6km south of SENT Landfill. All marine sand borrow shall correspond to Underwater Fill Material (Type 1) and be classified as sand under BS1377 (1990) and BS5930 (1981). The marine sand borrow will be hydraulically placed into the reclamation area. The marine impacts of the reclamation are detailed in Chapter 14.

Rock Fill Reclamation Borrow

This shall be used for reclamation. All material shall be well graded hard and durable volcanic rock (100% < 1 metre).

Rock Fill Reclamation Borrow will be deposited by bottom dump barge and by end tipping methods.

Rock Fill Formation Borrow

This will be used for formation filling. This material will be utilized to construct the formation grades to a level not higher than 300mm below the facility liner system in the land and marine areas. All rock fill formation borrow material shall be well graded hard and durable volcanic rock (100% < 0.45 metre).

Select Formation Borrow

This will be used to construct site formation grades for the 300mm (minimum) thickness that will be the uppermost surface of the formation on the land and marine areas. This layer will form the sub-base on which the liner systems will be installed. The select formation borrow shall be well graded material (100% < 0.375 metre).

General Fill

This will be used for construction of the SENT Landfill facility as directed or allowed by the Engineer or as required by the plans. All general fill shall be well graded material (100% < 0.2 metre).

10.2.3 Site Formation

The site will be developed in grouped area. The site formation procedure will maximise usage of materials excavated from the site development for incorporation into the reclamation and formation fills. For the first Areas of the site formation, the site will probably only use fill material generated from site excavation activities. The site may operate a material deficit and import of material from off-site could be required at later stages.

More than 11 million m^3 of material (rock & soil) is required for the reclamation and site development of SENT Landfill (excluding marine borrow); more than 80% of this requirement will come from the site.

Soil stockpiles may be generated from time to time. Stockpile development and operation will be a dynamic operation and actual locations and dimensions will vary during the programme.

10.2.4 Site Formation Activities

During site formation, excavation and blasting will occur on site; these activities will only occur off-site following completion of the later areas. When importing fill materials from off-site, transportation from the borrow area to SENT Landfill has the potential to cause adverse impacts, as with other construction projects in Hong Kong.

Rockfill used for the various components will require processing such as crushing and screening to meet the various material specifications, such as the 20mm specification for the 300mm liner sub-base (Select Formation Borrow). Rock use will be maximised by on-site processing.

10.3 POTENTIAL IMPACTS OF FILL MATERIALS

The potential environmental impacts associated with the various types of fill depend on many factors which include:

- quantity of fill;

- location;
- fill balance;
- method of excavation (e.g. blasting/excavation etc);
- method of handling/transport etc;
- proximity of sensitive receivers; and
- environmental monitoring and audit (EM&A).

and these are discussed below.

10.3.1 Potential Impacts of Off-Site Activities

Marine Sand Borrow

All activities at the marine borrow area should be in accordance with "General Allocation Conditions for Marine Borrow Areas and Mud Disposal Sites" (Appendix 1.7.2 of the Specification for the Development and Management of SENT Landfill). Impacts upon the marine environment in borrow areas can be minimised providing standard mitigation measures are employed.

Rockfill Borrow

Rock will be required from off-site quarrying, which has associated noise and air quality impacts, from blasting, handling and transport. Standard mitigation measures (such as restricted hours for blasting, water sprays, wheel washing and restricted hours of transport) will be required to ensure that the impacts are acceptable. No import of material will be required until after the completion of the Phase 7; assessment of the potential impacts should be addressed in more detail when information is available, such as quarry location, proximity of SRs and transport routes. It is recommended that this should form part of the CAP.

Soil Borrow

Soil might will also be required from off-site, which also has associated potentially significant environmental impacts, particularly when considering the large volumes involved. Again, measures such as water sprays, wheel washing and restricted hours of transport will be applied to ensure no significant environmental impact. No import of material will be required until after the completion of the Phase 7; assessment of the potential impacts should be addressed in more detail when specific information is available, possibly as part of the CAP.

10.3.2 Potential Impacts of On-Site Activities

Environmental impacts can potentially result from blasting, excavation, processing, and stockpiling activities, with implications for noise levels, air and water quality.

The nearest sensitive receivers (SRs) to SENT Landfill during site formation are :

- Clear Water Bay Country Park footpaths used by ramblers or hikers. These SRs would be sensitive to noise, dust, air quality and visual intrusion;

- Tseung Kwan O New Town; this is a significant distance from SENT Landfill; and

- Shek Miu Wan Bay.

Impacts can be minimised by restricting periods of noise and dust generating activities such as blasting and processing and avoiding Sundays and Public Holidays.

Care should be taken in management of stockpiles to ensure dust is not generated; also, surface water run-off from stockpiles will be carefully managed, by the use of silt fences around stockpile areas (see Chapter 12).

10.4 MATERIALS FOR DAILY COVER

At the end of each day, an inert daily cover will be placed over the exposed landfill waste. Daily cover will be transported from the stockpile area, weighed and placed at the active working area by trucks. Following the placement of further waste over the cover layer, the daily cover should be permeable to reduce the risk of perched leachate levels forming within the landfill. It should not contain free liquid to create a dust or odour problem, attract or harbour rodents, insects, birds or impede compaction by standard landfill equipment.

Intermediate cover is also required at landfill sites for placement on each completed lift and phase.

The volumes of Daily Cover required during the different site formation phase are detailed in Appendix 3, Materials Balance.

Soil is the typical daily cover used, although alternative daily cover materials are available, and may be used during the life of SENT Landfill. These are:

- foam product;
- geosynthetics;
- tyre chips;
- foundry sand, slag and refractory material; and
- other material acceptable to EPD (i.e. wood)

10.4.1 Soil

The various different soil grades that are typically acceptable for use as daily and intermediate cover are sandy loam, loam, silt loam, sandy clay loam and silty clay loam. Clay loam may also be suitable, and it will allow for a more thorough use of a borrow area.

10.4.2 Foam

Foam is composed of components such as urea, urethane, formaldehyde and other non-hazardous chemicals and when mixed with air and water forms a stable mixture that has been used to cover the daily working area on landfills. The non-toxic foam is applied by a self propelled or trailer drawn spray box. Two foam products are currently being marketed and used as daily cover by the 3M Company. One foam product sets up like a thick shaving cream, the other in a hard foam. Each product is applied in a 50-mm-thick layer over the waste at the end of each working day. The foam functions the same as the specified daily cover soil material. It can be applied in moderate winds up to 15m/s (with handheld equipment only) and during light to moderate rainfall. Once applied and set up, it can withstand moderate to heavy rain, depending on the thickness and method of application used.

The applied foam sets up within seconds to a durable, solid state with a consistency similar to a crushable expanded polystyrene. A skin is formed on the surface that promotes run-off and controls erosion. The foam's very low water permeability is critical in minimising water penetration into the cell and the production of leachate. The next layer of waste compacts and destroys the foam cover, making it part of the daily fill. The destroyed cover permits unimpeded movement of methane gas and leachate.

The foam has negligible chemical reactivity and does not contribute to leachate production.

10.4.3 Geosynthetics

Geosynthetics, which consist of geomembranes or geotextiles, can also be used as an alternative to soil materials as daily cover. Geomembranes are relatively impermeable flexible extruded polymeric sheets; geotextiles are generally fabric polymers. Geosynthetics are tarpaulin type materials that are placed over the waste at the end of each working day and either removed at the start of work the next day, or specifically left in place.

Geomembranes can be:

- Poly Vinyl Chloride (PVC); and
- Chlorosulphonated Polyethylene (CSPE).

Geotextiles that may be used include knitted, woven and non-woven materials of:

- High Density Polyethylene (HDPE);
- Polypropylene;
- Polyester;
- Polyethylene; and
- Polyamide.

These geosynthetics are used to cover the daily working area on the landfill. Generally, the geosynthetic material is stored adjacent to the disposal area and is placed with the aid of construction equipment and labourers at the end of the working day. The geosynthetic material is anchored with sand bags, tyres or other weighted material at regular intervals. Prior to the start of the landfilling the next morning, the geosynthetic is pulled off the waste, to an adjacent area, with the aid of construction equipment and labourers. Certain thin geosynthetics are used only once and are punctured by the heavy equipment the following morning and left with the refuse. The geosynthetic used will be chosen for its durability and ease of handling. Some geosynthetics currently being used and the landfill facilities using them include:

- AMOCO 2006 (Woven Polypropylene) at Colorado Springs Landfill in Colorado Springs, Colorado, USA;

- COVERTECH C-44 (Woven HDPE) at Pottstown Landfill in Pottstown, Pennsylvania, USA; and

- AMOCO EPR-NO95 (Woven Polypropylene) at Woodland Meadows Landfill in Canton, Ohio, USA.

10.4.4 Tyre Chips

Tyre chips can also be used as an alternative to soil materials as daily cover. Discarded tyres can be processed into approximately 50mm x 50mm sized tyre chips. These tyre chips can be placed in a 100-200mm thick layer over the waste at the end of each working day. They have been used as daily cover on landfills and are placed in the same manner as soils materials. They cannot however be used during periods of high winds.

At present, worn tyres in Hong Kong are understood to be re-treaded or exported to China for further use. However, the numbers of worn tyres available in Hong Kong is unlikely to be sufficient for all the daily cover requirements. Tyres could be shredded at Refuse Transfer

Stations and utilised to cover a portion of the daily cover requirements.

10.4.5 Foundry Sand, Slag and Refractory Materials

Foundry sand consists of moulding sand and baghouse dust which are by-products of the casting industry (as is refractory material) and are typically disposed to landfill as waste.

Another daily cover alternative that is used is slag, a by-product of steel manufacturing. Presently, there are approximately 50 tonnes of slag per day available from Shiu Wing steel mill. Slag is placed like soil daily cover over the waste at the end of each working day and functions similarly.

10.5 POTENTIAL IMPACTS OF ALTERNATIVE DAILY COVER MATERIALS

From an environmental point of view, the daily cover should:

- prevent vectors (such as rodents, flies, mosquitoes, rats or other vermin), odours, blowing litter and other nuisances;
- be non-combustible;
- be aesthetically acceptable;
- not introduce hazardous chemicals or excessive moisture into the landfill;
- not present a health hazard to landfill employees or the general public; and
- not cause any significant environmental impacts during its transport and handling.

Daily cover sufficient for 5 working days minimum should be stored on site. Around the stockpiles, temporary erosion and sedimentation control measures should be installed, if appropriate.

Generally, soil is used as daily and intermediate cover at landfills. However, the use of soil has certain disadvantages associated with it. The major disadvantages are:

- occupation of valuable landfill void space by daily cover soil (typically 10%);
- requirement for soil borrow areas which have associated environmental impacts;
- requirement for handling and transport of soil, which have associated environmental impacts; and
- use of soil as daily cover means that many of the alternative daily cover materials (eg. tyres, recycled construction waste) take up valuable landfill space as wastes.

Soil can be obtained from construction wastes (but would need careful sorting/segregation), which would be a more preferable source of soil, as it is already destined for landfill. The availability of soil (presently anticipated after completion of the phase 7) for import requires assessment once detailed information is available.

This subsection looks at the merits and potential environmental impacts of the various alternative daily cover materials.

10.5.1 Impacts of Foam

The foam products described above have been extensively used at landfills since 1987 and have been found to be equal or superior to soil materials for daily cover. The foam prevents insects, rodents and other nuisances from entering the waste; prevents odours; prevents blowing litter; is non-combustible; and increases the landfill void space.

Foam concentrate would be stored in drums, as would stabiliser. Hence the possibility of dust or odour nuisance would be significantly reduced. The products would need storage and handling in a well ventilated building; no special respiratory equipment would be necessary.

There is no significant potential for leaching of toxic chemicals from the foam when in the landfill.

10.5.2 Impacts of Geosynthetics

These products have been used effectively at many landfills and have been found to be equal or superior to daily cover soil materials. The geosynthetics prevent insects, rodents and other nuisances from entering the waste; prevent odour; prevent blowing litter; improve leachate and gas management by eliminating additional soil barrier layers within the landfill; are non-combustible when treated with a fire retardant; reduce the time associated with application and high wind periods when additional personnel and anchorage may be required.

Geosynthetics can be re-used and this is considered to be an environmental advantage.

Geosynthetics would have no potential air quality impact during transport or handling.

10.5.3 Impacts of Tyre Chips

The tyre chips would form an overlapping layer when placed in a 100-200mm compacted cover. This cover prevents birds, rodents, flies, mosquitoes, and rats harbouring in the refuse. The overlap would also inhibit odours and blowing litter. In addition, airborne dust and dirt would be reduced by using tyre chips instead of soil. Tyre chips do not ignite spontaneously, although precautionary fire protection measures would be necessary. In the unlikely event of a serious underground landfill fire, tyre chips would supplement smoke and fume emissions.

Tyre chips would have no potential air quality impact (dust) during handling or transportation.

Toxicity Characteristic Leaching Procedure (TCLP) testing should be conducted on tyre chips prior to use, in order to assess the likelihood for leaching of toxic chemicals from the tyre chips; previous studies have indicated that this would not be a problem.

10.5.4 Impacts of Foundry Sand, Slag and Refractory Material

Foundry sand and refractory material are essentially inert and similar to those soils typically used as daily and intermediate cover. These are not combustible materials, and if placed in 150mm compacted layers as daily cover, foundry sand, slag and refractory material will prevent rats, flies and other vermin from harbouring in the refuse. Likewise odour, blowing litter and other nuisances will be prevented.

TCLP testing should be conducted on foundry sand, slag and refractory materials prior to use.

These waste products have some potential for air quality impacts (dust) during transportation and handling and mitigation measures will be necessary to ensure that no significant environmental impacts result. Typical mitigation measures will include the use of water sprays when handling the materials and tarpaulin covers during transportation.

10.6 SUMMARY AND CONCLUSIONS

10.6.1 Fill Materials

During site formation, there is potential for environmental impact from the large quantities of soil and rock required, from activities such as blasting, excavation, material handling, transport, processing and stockpiling. The impacts will be minimised by maximising usage of materials excavated from site development for incorporation into reclamation and formation fills. On-site impacts will be less significant than those off-site owing to the lack of SRs, although mitigation measures will still be required. The material required from off-site will require assessment of its potential environmental impact during blasting, excavation, transport and handling once specific information is available.

10.6.2 Daily Cover

If soil is to be used as daily cover, the opportunities for obtaining soil from construction wastes should be further investigated.

All the alternative daily covers discussed above prevent rodents, flies, mosquitoes, odours, blowing litter and other nuisances. The use of these alternative covers will extend the landfill life by reducing the amount of void space consumed. Foundry sand, slag and refractory materials are presently placed in landfill as waste materials consuming valuable space. If used as daily cover, they will have been beneficially used. The use of these alternative materials will promote soil conservation by reducing the amount of soil required from borrow areas. It will also reduce the environmental impacts associated with the handling, transport and storage of soil.

It would be environmentally preferable to use a waste product (for example slag or tyre chips) as daily cover compared to a manufactured product such as foams or geosynthetics.

Landfills in the U.S.A. have used all of these materials, with the possible exception of foundry sand, slag and refractory materials, as daily and intermediate covers (foam only as daily cover). As a part of recent investigations for a new steel mill in Hong Kong extensive leachate tests for slag were undertaken; the conclusion was that it was acceptable to dispose of slag to landfill owing to the small degree of heavy metals leaching. Assumedly, this would mean it would also be acceptable as daily cover. However, potential air quality impacts would need addressing owing to the dusty nature of slag. The acceptability of the pH of slag leachate would also require investigation.

TCLP tests would only be undertaken for materials which are not permissible wastes or if specifically requested by EPD.

Landfill Leachate Production & Management

Chapter 11

11 LANDFILL LEACHATE PRODUCTION AND MANAGEMENT

11.1 INTRODUCTION

This Chapter reviews the proposals for the treatment and discharge of leachate from SENT Landfill, with the objectives of assessing their environmental impacts and identifying whether further mitigation measures and/or environmental monitoring are required.

The process design of the leachate treatment facility (LTF) to be provided at SENT Landfill is significantly different to that proposed by Scott Wilson Kirkpatrick in the Outline Design Report (Ref 11.1) and its environmental impacts may therefore be different to those described in the CEIA.

The purpose of the LTF is to pretreat leachate, so that the effluent can be discharged to the TKO sewage treatment works for final disposal. EPD has specifically requested that the impacts of the discharge of treated leachate from TKO be assessed as part of the SEIA. Although this impact was covered in depth in the CEIA, it is assessed below in terms of compliance with the relevant discharge standards and reviewed in the context of the short, medium and long term waste water treatment strategies at TKO.

11.2 OVERVIEW OF LEACHATE MANAGEMENT

The leachate management system incorporated into the GVL design for SENT Landfill will act to rapidly remove the leachate above the liner system and to significantly reduce or prevent the release of leachate to the surrounding environment. Water ingress will be reduced and therefore leachate quantities will be minimized by the installation of daily, intermediate and final cover systems during the phasing of the landfill and by surface water run-off from active areas of fill. In line with the requirements of the specification, condensate from the landfill gas system and any surface run-off which becomes contaminated by waste or other materials will be discharged to the LTF.

Leachate will be removed from the landfill by use of an integrated system including components for collection, removal, on-site treatment and off site disposal. The leachate collection system contains a highly permeable aggregate drainage layer placed above the land area, marine area and upper slope liner systems and a synthetic drainage layer above the rock slope liner system. The site formation and liner systems will be sloped at a drainage gradient of collection pipes and trenches located in low areas of the base of the site. Leachate will be collected in internal sumps located in seven low areas around the westerly perimeter of the landfill. The internal sumps have submersible pumps that transmit leachate to the on-site treatment facility. The internal sumps are provided to prevent pipe penetrations at the low areas of the site where a potential leak in the liner could occur. The leachate design for SENT Landfill has no pipes penetrating the liner system at the low areas. The sumps connect with HDPE sideslope risers which penetrate the top cover and link in with the leachate transmission system which removes leachate to the LTF. The internal sump design will have three bentonite liners and two HDPE liners in the low area. These low permeability barriers will provide enhanced environmental protection to any potential leachate leakage from the sump.

Several treatment technologies can be used to reduce contaminants in leachate. The method of treatment to be used at SENT Landfill will be based on physical and biological processes, and includes an equalization tank, sequencing batch reactor, and a treatment sludge processing system consisting of a storage tank and a filter press. The resulting dewatered sludge will be disposed of as required in the landfill.

The LTF will be brought into operation prior to waste disposal in Area 1 to reduce contaminant levels prior to discharge off site. The proposed treatment facility will reduce the amounts of organics, ammonia, and metals in the raw leachate to specified concentrations prior to discharge to the foul sewer. The required standards are those set by EPD for effluents discharged into drainage and sewerage systems, inland and coastal waters (Ref 11.2).

Treated effluent is discharged via a force main to the TKO STW for further treatment prior to discharge via a long sea outfall to the Tathong Channel, see Section 11.4 for a review of this operation.

These standards are summarised in Table 11.1, together with the anticipated influent leachate quality and the stringent GVL design objectives, which are set to ensure that the facility operates at standards considerably higher than the prescribed environmental standards and those for the existing sewage treatment works at TKO. This will ensure that the facility is in full compliance with the effluent discharge standards.

TABLE 11.1 SENT Landfill Leachate Characterisation and Discharge Standards

Parameter	Predicted Influent Concentration	GVL Design Objectives	Standard For Discharge to TKO STW
BOD* (Biochemical Oxygen Demand)	4500 mg/l	0 mg/l	800 mg/l (for flows $>200m^3/day$)
COD (Chemical Oxygen Demand)	6700 mg/l	500 mg/l	2000 mg/l (for flows $>200m^3/day$)
NH_4-N (Ammoniacal Nitrogen)	3000 mg/l	0 mg/l	-
NO3-N (Nitrate Nitrogen)	0 mg/l	100 mg/l	-
TOTAL N (Total Nitrogen)	3000 mg/l	100 mg/l	200 mg/l (for flows $\leq 1000m^3/day$)
TOTAL P (Total Phosphorous)	25 mg/l	0 mg/l	50 mg/l (for flows $\leq 1000m^3/day$)

Notes * BOD/COD ratio is estimated to be 0.7 for landfill leachates.

Other discharge parameters, such as suspended solids, metals and phenolics are a function of discharge flow rate. These are given in full in the EPD Technical Memorandum "Standards for Effluents Discharged into Drainage and Sewerage Systems, Inland and Coastal Waters (Ref 11.2) (TMES).

11.3 THE LEACHATE TREATMENT FACILITY

11.3.1 Plant Design

Since GVL was awarded the contract to develop and manage SENT Landfill, the LTF design has been modified to incorporate additional measures to further reduce emissions, in the light of comments raised by EPD during the tender negotiation process.

The plant consists of the following operations:

- equalisation system consisting of one air-mixed equalisation tank;
- pH adjustment followed by clarification for metals and suspended solids removal, using a metals precipitation tank and a flocculating clarifier;
- ammonia stripping, and thermal catalytic treatment of the off-gas from the air-strippers;
- pH adjustment to facilitate biological treatment;
- nitrification/denitrification through a sequencing batch reactor biological treatment system; and
- collection and dewatering of sludge using a sludge surge tank, thickener and filter press.

Initially the facility will be installed to handle an average leachate flow of 250m^3/day. The plant can be readily expandable to 800m^3/day, which is the maximum predicted leachate production rate over the lifetime of SENT Landfill.

Equalization System

The equalization system consists of an air mixed vessel with a volume of 1500m^3. Influent waste water will be pumped via a force main from the landfill into the tank. In addition, truck unloading pumps will be provided to accommodate hauled leachate, if required. The tank features an ultrasonic level instrument with secondary alarms to prevent tank overfilling.

pH Adjustment/Metals Precipitation/Clarification

Waste water will be pumped from the equalization tank into a Metals Precipitation Tank where lime will be added to raise the leachate pH to effect metals precipitation and facilitate ammonia stripping. The system is designed to remove metals from the leachate with an efficiency of 99.2 to 99.4% depending on the flow rate of leachate. The pH adjusted waste water will then fall via gravity into a flocculating clarifier where polymer flocculant will be injected to enhance solid/liquid separation. Solids will be removed via pumping to the solids dewatering system. The clarified liquid will overflow to a sump from which it will be pumped to the air-stripper.

Ammonia Removal/Destruction System

Clarified, pH adjusted waste water will be pumped to an air-stripper, which will remove approximately 90% of the ammonia from the leachate and transfer it to the off-gas.

The air stripper allows for an internal liquid recycle loop to allow for variable flow processing and maximized treatment efficiency. Liquid effluent from the ammonia stripper will drain by gravity to a pH adjustment tank. Treated off-gas from the strippers will ultimately be discharged to the atmosphere.

The off-gas from the air-stripper is to be preheated and passed through a thermal catalytic unit. The off-gas from the stripper will be heated by the burner to 600-800°F prior to entering the catalytic bed. The thermal catalytic unit burner is designed to operate either on No.2 fuel oil or landfill gas. As the off-gas passes across the catalyst bed, ammonia is converted to nitrogen, water, and a small fraction of nitrogen oxides. The unit is designed to destroy at least 97% of the inlet ammonia with minimal conversion to NO_x (1-2%). The combustion gases then pass through two air-air heat exchangers. The first exchanger preheats the off-gas from the stripper to minimize fuel consumption. The second exchanger preheats the air to the stripper which improves stripping efficiency. The process also combusts any volatile organic compounds that are present in the off-gas.

As leachate production rates increase and ultimately two additional stripper units are brought on-line, an ammonia concentrator unit will be added to the facility. The ammonia concentrator unit consists of a rotating disk of a sodium zeolite material.

The thermal unit has a stand-by operational feature to minimize energy use (in the event of a short-term process shut down).

pH Adjustment System

The effluent from the ammonia stripper flows to a pH Adjustment Tank where it is mixed with a small amount of hydrochloric acid to lower the waste water pH to facilitate biological treatment.

Sequencing Batch Reactor (SBR) System

The SBR system is utilized to destroy organic and nutrient constituents in the waste water and will be operated with an approximate 10 day hydraulic residence time and a approximate 25 day sludge age to promote thorough biological treatment. Mass balance calculations indicate that the volumes of sludge produced will range from 78.5 kg/hour at (at 250m^3 of leachate per day) to 251 kg/hour (at 800m^3/day of leachate) at 40% solids. This equates to a maximum rate of 6.0 tonnes per day which will cause neither operational problems, nor adverse environmental impacts.

Phosphoric acid will be added to the leachate to provide phosphorous nutrient. A polymer flocculant feed system will be utilized to promote rapid settling and separation of the biomass from the treated effluent. Effluent will be removed from the SBR at a rate of approximately 6.5 m^3/min. Sludge will be pumped from the SBR to the sludge surge tank for dewatering.

Solids Dewatering System

Sludge from the SBR and metals precipitation unit will be dewatered by a Sludge Thickener and Filter Press to facilitate handling and disposal within the SENT Landfill site.

11.3.2 Emissions to Air

GVL's original LTF design involved the emission of ammonia directly to the atmosphere following its removal from the leachate in an air-stripper. The acceptability of this procedure from a health and safety point of view was questioned citing a potential concern that ammonia concentrations in the vicinity of the plant could exceed the Occupational Exposure Level. Although the likelihood of this was considered to be extremely low, GVL subsequently revised their design proposals to incorporate a Thermal Catalytic Unit designed to break down the ammonia in the off-gas from the air stripper to nitrogen gas. Initially, the catalytic oxidiser will receive off-gases directly from a single air-stripper, however ultimately the facility will be expanded to 3 air-strippers. In this case, the off-gases from the air-strippers will be concentrated in a zeolite concentrator unit with the concentrated stream being sent to the catalytic oxidiser.

The Environmental Monitoring Plan (Section 14.4.3) contains a provision for ammonia monitoring specifying a trigger level of 0.2 mg/m^3 (30 minute average) that must be attained as a maximum at 8 fixed locations on the landfill boundary (see Figure 4.1). Four monitoring stations are selected from the eight on each monitoring visit. The closest monitoring point is located approximately 250m from the centre of the LTF. Ammonia monitoring will be undertaken quarterly and the off-site and site boundary trigger levels have been set at 0.2 mg/m^3.

Dispersion of ammonia from the vent of the thermal catalytic unit has been analyzed using similar methodology and meteorological parameters to those detailed in Section 9.5.3. Calculations of the emission parameters are detailed in Appendix A.9.A. The receptors are assumed to be downwind from the emission source. At different receptors' altitudes, the predicted variation of ammonia concentrations have been plotted against the distance from the source (Figure 11.2).

The ammonia concentrations at ground level(1.5 mAG) are less than 0.02 mg/m^3 which are an order of magnitude less than the 0.2 mg/m^3 criterion.

The proposed deep water industrial area to the west is at a distance of about 150m from the emission source. The corresponding ammonia concentrations are less than 0.1 mg/m^3 for receptors at 40m AG or below (Figure 11.2).

Data on background ammonia concentrations is not available, but these are expected to be low without any major industrial operation in this area. The associated aerial emissions of ammonia are therefore unlikely to exceed either the above limit or the corresponding odour threshold (35 mg/m^3 as discussed in the EPA Design Manual for Nitrogen Control). However, the performance of the Thermal Catalytic Units as the flow to the Leachate Treatment Facility builds up to a maximum should be monitored.

It is difficult to determine the emission of ammonia from the plant and if it presents any risk to the health and safety of the operators. Although we believe the risk to be low, prudent risk management warrants and some monitoring (described below). It is clear, however, that if any risk exists, the Metals Precipitation Tank and Clarifier present the greatest potential exposure. This is because the tanks contain leachate with a pH >10.8, to precipitate heavy metals and permit the ammonia to be readily removed in the air-strippers. The potential for ammonia to be emitted to the atmosphere is, therefore, increased. To ensure that any potential risk to operators is detected, it is proposed that ammonia concentrations in the atmosphere be monitored regularly following commissioning of the plant. This will show whether the Occupational Exposure Levels for ammonia are being approached or exceeded. If there are elevated levels approaching the threshold in the vicinity of either the Metals Precipitation Tank or the Clarifier, then appropriate measures would have to be taken such as:

(1) restricting access to the areas around these units;

(2) limiting the length of time operators can spend in those areas; or

(3) requiring respirators to be worn by operators.

11.3.3 Odour Impacts

Odour problems other than the emission of ammonia from the operation of the air-strippers, could arise in the following ways:

(1) from the storage of dewatered sludge cake held on site following its removal from the filter press;

(2) from spillage of process liquors in the course of leachate treatment and poor housekeeping; and

(3) from the emission of gases and vapours from the leachate and process liquors in the vicinity of the treatment facility.

Sludge cake which is dewatered using polymers as proposed by GVL is liable to generate unpleasant odours and create a fly nuisance. Odours from the storage of sludge on site can be avoided by strictly limiting the length of storage of dewatered sludge cake on site and removing it promptly to landfill.

The chance of spillage of process liquors can be reduced by ensuring:

(1) the thorough training of all operators in the proper procedures for the running of each unit process; and

(2) that the operators are carefully supervised.

The emission of gases and vapours from the leachate and process liquors will be dependent on the concentrations of volatile compounds in the leachate, which is not known at the present time. The contents of leachate will depend in turn on the nature of the material that has been placed in the landfill. A reduction in the concentrations of volatile substances in the atmosphere emitted from the leachate and process liquors should be brought about in the Equalisation System, which consists of an air mixed vessel, 1500 m^3 in volume. Experience will show whether or not this vessel is large enough if the maximum flow of leachate anticipated is generated by the site. Section 11.3.7 below discusses the provision that has been made, should the latter volume prove inadequate. The aeration of the equalisation tank should help to disperse toxic and inflammable volatile substances into the atmosphere.

Calculations have been produced to estimate the potential VOC emissions from the treatment processes at SENT Landfill LTF. The influent VOC concentrations used in the calculations were based on average leachate values reported by the US EPA (Ref 11.4). These VOC concentrations are likely to be overestimates of those which will be experienced at SENT Landfill, due to:

- less restrictive landfill operational practices prior to 1988 when the data was gathered; and
- the concentrations assume maximum air contact and no removal of volatile organics by biodegradation.

The majority of VOCs will be released in the equalisation tank and the air stripping units. The gases from these will be directed through the thermal catalytic unit, which destroys VOCs. The remaining volatile and semi-volatile compounds will be removed by biodegradation in the SBR. Any VOC emissions from the SBRs should be negligible. Total VOC emissions will be far less than for the lagoon design assessed in the CEIA because of the use of the thermal catalytic unit and fine-bubble diffusion aeration in the LTF.

The use of an enclosed facility will also significantly reduce the odour and visual impact of the LTF compared to the conceptual design.

11.3.4 Operational Noise Emissions

The LTF will comprise of the following:

- Equalization System;
- pH Adjustment/Metals Precipitation Clarification;
- Ammonia Removal/Destruction System;
- pH Adjustment System;
- Sequencing Batch Reactor (SBR) System; and
- Solids Dewatering System.

The major noise emitting elements are the pumps and motors which have relatively low noise levels compared to the other equipment and activities on the SENT Landfill. Structures within the site will screen off some of these small noise sources from the NSRs, and with the remoteness of the site the associated noise impact will be negligible. The cumulative noise impact due to the operations of the LTF and the gas treatment and utilisation plant (Section 9.6.4) will therefore be expected to be insignificant.

11.3.5 Visual Impact

The LTF is to be located in the site infrastructure area in the extreme southern corner of the site. The plant is sited between the main building and gas recovery facility. The visual impact of the LTF, as one component of the infrastructure area, is addressed as part of the overall visual impact assessment of the development, described in Chapter 16. As can be seen from Figure 11.1, landscaping is to be provided after construction. The facility is screened on almost all sides.

It is considered that the visual impact of the LTF, and other infrastructure buildings, will be most significant following final restoration. This situation will occur approximately 15 years after the start of operations (at current predicted infilling rates), by which time the planting will have reached semi-maturity and an average height of at least 10m.

11.3.6 Construction Phase Impacts

The LTF will be constructed during the initial development phase of the site, prior to the start of landfilling in Summer 1994. Construction activities will be carried out under the terms of the Contract and compliance with this will be monitored as part of the EMP.

The number of construction equipment is expected to be limited and the associated traffic during construction is only about one-tenth of the traffic during operation. There are only a few large components involved, the traffic impact will be minimized with most of them broken down into smaller components during transportation.

Details of the construction activities, and the noise levels likely to be generated, are not available at this stage. However, based on the calculation as detailed in Section 9.6.3 (Construction Noise Impact of the Gas Utilisation Plant), the construction noise impact will be insignificant with the typical construction activities.

Measures can be introduced to further attenuate the noise levels. The local topography, however, implies that the common means of using hoardings around the construction site would be relatively ineffective for the NSRs within the Country Park. The feasible measures include:

- use of silenced equipment and operation; and

- careful scheduling of works, e.g. avoid the operation of noisy activities at the same time.

11.3.7 Risks of Plant Failure and Likely Impacts

Failure of the LTF could potentially occur in the following 4 principal ways:

(1) Failure of primary and backup electricity supply;

(2) Fire;

(3) Operator error;

(4) Malfunction or breakdown of specific pieces of equipment; and

(5) Sewerage Plan inoperable.

Section 34.1.9 of the Specification (Reference 11.5) states that:

(1) the Contractor shall prepare an Emergency Procedures Plan; and

(2) that this shall state the non routine Operational procedures to be adopted during emergencies, and that these shall include but not be restricted to certain points, which are listed.

The operation of the leachate treatment plant is not specifically mentioned but clearly should be included. It is recommended that a set of procedures be drawn up by GVL specifying the actions to be taken in the event of plant failures arising from the above four types of event. This should be prepared by GVL and submitted to EPD prior to the LTF being commissioned.

The exact consequences of each of these four types of failure are difficult to specify, and it is not possible, therefore, to describe their specific environmental impacts in this report. Their significance is, however, likely to be mitigated by:

(1) The existence of the Equalisation System (capacity 1500 m^3) which is sized to provide 3-7 days storage capacity during the first 10 years of operation. In addition, the landfill liner system will hold up to in excess of 1 metre of leachate head and provision can be made to haul leachate to an off-site facility as an interim measure, in the event that the existing storage is insufficient. Finally, space has been reserved to double the equalisation volume if necessary later in the life of the site, as leachate production increases.

(2) The presence of well trained and supervised staff, fully conversant with the emergency procedures drawn up by GVL.

(3) The provision of an alternative power supply from back up generators already provided at the site.

(4) The regular servicing and planned maintenance programme which will reduce the incidence of plant breakdown.

11.3.8 Maintenance Requirements

Much maintenance work can be carried out while the plant is in operation. However, a few tasks will probably require plant shutdown. Given careful planning it should be possible to divide each of them into a series of stages, each of which can be completed within 24 hours (one notable exception being the air-strippers). During this 24 hour period, the leachate would be stored in the Equalisation System and its flow to the LTF stopped.

It is considered likely, however, that the air-strippers, which are liable to the build up of scale through the deposition of calcium carbonate, will have to be shut down from time to time for considerably longer than 24 hours so that the scale can be removed. However, the LTF will be provided with three strippers at maximum flow, and so the removal of ammonia from the leachate can continue using two units, while maintenance work is performed on the third.

Maintenance of the Thermal Catalytic Unit involves raising the temperature of the catalyst to burn off organics which are deposited on the catalyst. At this stage it is uncertain as to how often this procedure has to be performed and how long it takes. It is expected that the decomposition of ammonia will continue during this process and it may in fact proceed even more efficiently at higher temperatures.

11.3.9 Performance of Thermal Catalytic Unit

It is not possible to predict from the information available (Ref 11.3) whether the efficiency of the thermal catalyst will be significantly reduced by poisoning with substances adsorbed from the air stream passing over it or by other changes resulting from prolonged operations (15-17 years) at a high temperature (600°F). The catalytic unit will use a catalyst enhancement grid which traps heavy molecular weight organics and solid inorganic particulates and prevents the catalyst from deactivating. Organics will then be burnt off by raising the reactor temperature from time to time.

It is apparent, therefore, that some contamination of the catalyst is anticipated but it is believed that the substances involved can be driven off by the simple expedient of raising the temperature. This does not constitute proof, however, that the catalyst will sustain the required level of performance. Furthermore, the proposed life of the plant, and hence of the Thermal Catalytic Unit (15-17 years), is at the limit of the normal maximum for conventional mechanical and electrical equipment, and may be considered long for novel equipment of this kind.

It is therefore proposed that two further mitigatory measures be incorporated into the LTF design:

(1) The performance of the catalyst should be closely monitored on a regular basis from the time that the leachate treatment facility is commissioned.

(2) The design of the facility should be modified so that a second Thermal Catalytic Unit can be installed at short notice, to share the load of the first Unit, if it appears necessary, and permit the latter to be shut down for maintenance.

11.3.10 Recommendations for Additional Mitigation and Monitoring

The performance of the Equalisation System in the LTF should be closely monitored as the quantity of leachate begins to approach the maximum predicted flow (800 m^3/day). The results from this exercise will provide the information needed to decide whether or not to double the volume of the system.

Similarly, the performance of the Thermal Catalytic Unit, which decomposes ammonia to nitrogen, should be monitored closely as the ammonia load passed to it approaches the anticipated maximum. The monitoring programme implemented should be capable of detecting any marked reduction in the efficiency of the Unit, which might indicate the deterioration or poisoning of the catalyst. Specifically, the gas entering and leaving the Unit should be monitored for ammonia concentration.

In view of the lack of information on the long term performance of the Thermal Catalytic Unit, design work should be carried out to permit a second Unit to be installed to share the load of the first Unit if required, and permit the latter to be shut down for maintenance.

A programme of plant operator training should be implemented during commissioning of the plant and continued throughout the operating life of the plant (prior training is also recommended).

The Emergency Procedures Plan for the site should include actions in the event of failure of the electricity supply, fire, operator error, and the malfunction or breakdown of specific pieces of equipment. The plant operators should be trained to perform these actions when appropriate.

A comprehensive plant maintenance programme should be implemented from the time that the LTF is commissioned to minimise the chance of the breakdown or malfunction of all the equipment involved.

A programme of monitoring atmospheric ammonia concentrations in the close vicinity of the LTF should be implemented following its commissioning to determine whether or not there is any risk to the health and safety of the operators.

11.4 IMPACTS OF TREATED LEACHATE DISCHARGES

11.4.1 Leachate Quality and Standards

The design of the LTF has been based on the anticipated average leachate quality set out in Table 11.1 earlier in this Chapter.

A review of all the available data on the quality of landfill leachates in Hong Kong (Ref 11.6) concluded that leachate quality would rapidly stabilise within a range of values, from which the average contaminant levels in Table 11.1 have been derived.

The LTF has been designed to meet the standards for waste water suitable for discharge to sewer (given in TMES), which have been established as limits by Tseung Kwan O Sewage Treatment Works (TKO STW). These are also given in Table 11.1. Assuming that these standards are met at all times during the life of the site, the maximum loadings which will be discharged to TKO STW can be evaluated. These estimates are presented in Table 11.2.

Table 11.2 Predicted Contaminant Loadings to TKO STW

Phase	Estimated Start Date of Phase	Maximum Estimated Leachate Generation (m^3/d)	Maximum Daily BOD Loading (kg)	Maximum Daily COD Loading (kg)	Maximum Daily Total N Loading (kg)	Maximum Daily Total P Loading (kg)
1	Jun 94	106	85	212	21	5.3
2	Apr 95	400	320	800	80	20
3	Aug 96	525	420	1050	105	26
4	Oct 98	300	240	600	60	15
5	Aug 99	397	318	794	79	20
6	Mar 01	414	331	828	83	21
7	Dec 01	419	335	838	84	21
8	Sep 03	816	653	1632	163	41
9	Apr 05	645	516	1290	129	32
10	Nov 05	645	516	1290	129	32
11	May 06	716	573	1432	143	36
12	Apr 07	710	568	1420	142	36
13	Jun 08	457	366	914	91	23
14	Apr 09	311	249	622	62	16

11.4.2 Assessment of Impacts of Treated Leachate Discharged from TKO STW

As stated previously in this Chapter, the SENT Landfill LTF is designed to treat the leachate to a much higher standard than that stipulated in TMES for the discharge of effluents to foul sewers leading to Government sewage treatment plants.

At present the effluent from the TKO STW is discharged into the Tathong Channel south west of Junk Island. Stage 1 (the Kowloon System) of the Strategic Sewage Disposal Scheme (SSDS) is currently undergoing detailed design. The system is scheduled to be operational in 1998 and will collect and transport the sewage from various STWs in Kowloon, including Tseung Kwan O, to Stonecutters Island STW where it will undergo chemical treatment prior to discharge off the South West of Stonecutters Island through the SSDS Interim Outfall.

Filling of SENT Landfill is scheduled to start in August 1994 and it is expected that leachate production will start almost immediately; predicted leachate production rates are given in Table 11.2.

The connection of TKO STW to SSDS will mean that the discharge of leachate from SENT Landfill via the TKO STW outfall will only occur during the period August 1994 to 1998. During these 4 years leachate production increases from $106m^3$/day in August 1994 to $240m^3$/day in October 1998, with a peak of $525m^3$/day during Phase 3, which starts in August 1996. Table 11.3 gives some effluent standards required by TMES for discharge rates of up to $600m^3$/day.

Table 11.3 Effluent Standards

pH	Temp	SS	BOD	COD	Oil & Grease	Fe	Bo	Ba	Hg	Cd	Cu
6-9	43	800	800	200	50	15	4	4	0.001	0.001	1.5
Ni	**Cr**	**Zn**	**Ag**	**CN**	**Total Toxic Metals**	**Total N**	**Total P**	**Phenols**	**Sulphide**	**Sulphate**	
1.5	1	1.5	1.5	0.7	3	200	50	0.7	5	1000	

Note :- All units are mg/l, except pH which is in pH units.

A review of the existing water quality in the Junk Bay area is given in Chapter 14, Marine Discharges. The Chapter noted that the waters in this area are organically enriched, and have relatively high levels of nitrogenous compounds and bacterial concentrations. The construction of the TKO STW outfall to the Tathong Channel removed some of the nutrient loading from Tseung Kwan O, however the general water quality remains poor. In view of the increasing degradation of the water around Tseung Kwan O, the projected increases in population of the new town, and delays in the implementation of the upgraded sewage treatment facilities at the TKO STW, Interim measures are to be implemented. The Interim measures will comprise primary settlement tanks followed by chemical treatment using lime. It is expected that construction of these Interim facilities will begin in December 1993 and the plant become operational by mid 1995. The continued upgrading of TKO STW after implementation of the Interim measures is not expected, as the SSDS Stage 1 system will include TKO STW.

As identified in the CEIA, the major concern to the water quality of Junk Bay and the Tathong Channel is the discharge of an effluent containing high levels of nutrients, especially nitrogenous species. It was noted in the SENT Landfill EIA-Key Issues Report that "Water [Policy Group of EPD] have indicated that, due to good tidal flushing at the sewage treatment works outfall located in the Tathong Channel, they are prepared to accept the interim discharge of fully nitrified effluents from the leachate treatment works via TKO STW in the limited period between the need to discharge effluent and the availability of extended treatment facilities at TKO STW (1994-1995)."

Stage 1 of the SSDS System has a target commissioning date of February 1998. This will mean that the discharge of a partially nitrified leachate effluent from the SENT Landfill LTF via the TKO STW will occur for approximately $3^1/_2$ years, provided no delays in the development of either SENT Landfill or the SSDS System are encountered.

In conclusion significant impacts on water quality in the area are not expected, although this interim discharge period is somewhat longer than that initially envisaged for the fully nitrified effluent from SENT Landfill. This is especially true given the advanced processes which will be provided at the LTF, including almost total ammonia removal, and the good tidal flushing characteristics encountered at the TKO STW's outfall site in the Tathong Channel.

11.5 CONCLUSIONS AND RECOMMENDATIONS

The results of computer modelling of emissions from the LTF indicate that the quantity of ammonia emitted from the leachate treatment facility will not be sufficient to exceed the trigger level of 0.2 mg/m^3 set for the monitoring locations. This assumes, however, that the design performance of the Thermal Catalytic Unit is sustained through the period of 15-17 years when the LTF is receiving substantial flows of leachate.

Construction and operation of the LTF will have no significant adverse noise impacts.

While the design performance of the Thermal Catalytic Unit is fully adequate, no evidence is available to demonstrate that such a Unit is capable of sustaining this performance for 15-17 years and replacement equipment would then be likely.

Sludge cake produced from the filter press may give rise to an unpleasant odour unless it is promptly removed from site to landfill.

The following recommendations are made:

- close observation of the performance of the Thermal Catalytic Unit by monitoring of the ammonia concentrations of the gas entering and leaving the Unit;
- accommodation to be made for a second Catalytic Unit, to enable it to be added in the future if required;
- Emergency Procedures Plan and plant maintenance programmes for the LTF to be prepared by GVL and submitted to EPD during commissioning of the facility; and
- an additional ammonia monitoring location should be incorporated into the EMP, in the close vicinity of the air-strippers, within the LTF, to determine whether there is any risk to the health and safety of the plant operators.

REFERENCES

11.1 Scott Wilson Kirkpatrick. SENT Landfill Outline Design Report (September 1990).

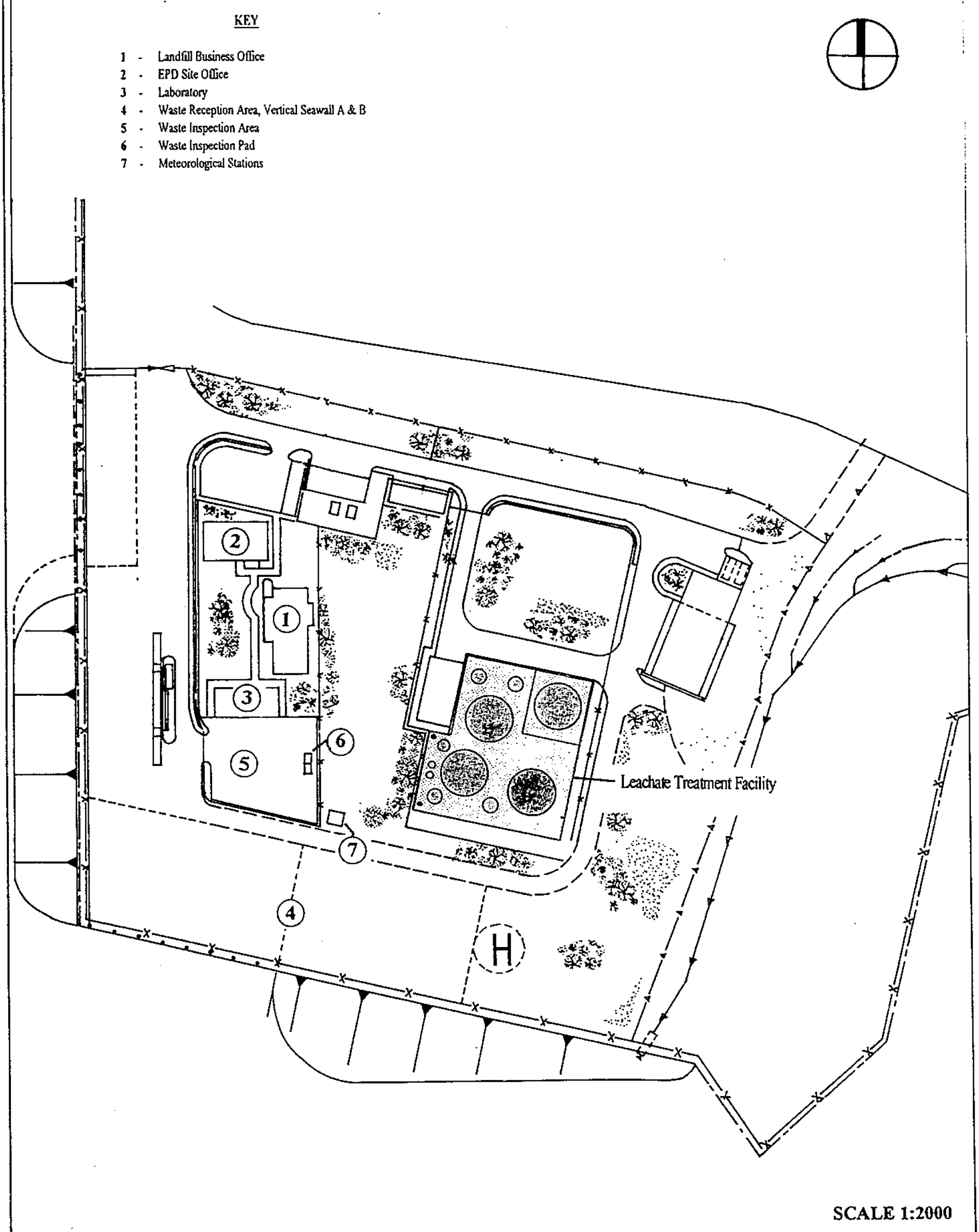
11.2 Environmental Protection Department, Hong Kong Government. Technical Memorandum: Standards for Effluents Discharged Into Drainage and Sewerage Systems, Inland and Coastal Waters (November 1992).

11.3 RUST Environment and Infrastructure Design Memorandum: SENT Landfill Leachate Treatment Facility. (1993)

11.4 USEPA. Summary of Data on Municipal Solid Waste Landfill Leachate Characteristics (Draft Background Document). (1988)

11.5 Environmental Protection Department, Hong Kong Government. Development and Management of SENT Landfill, Contract EP/SP/10/91, Tender Document: Volume 3: Part A, Specification (June 1992).

11.6 LG Mouchel and Partners (Asia), Aspinwall and Company and Balfours International Asia. NENT Landfill Leachate Disposal Study, Draft Final Report. (1989)



acer7 ENVIRONMENTAL

FIGURE 11.1

LOCATION AND LAYOUT OF LEACHATE TREATMENT FACILITY

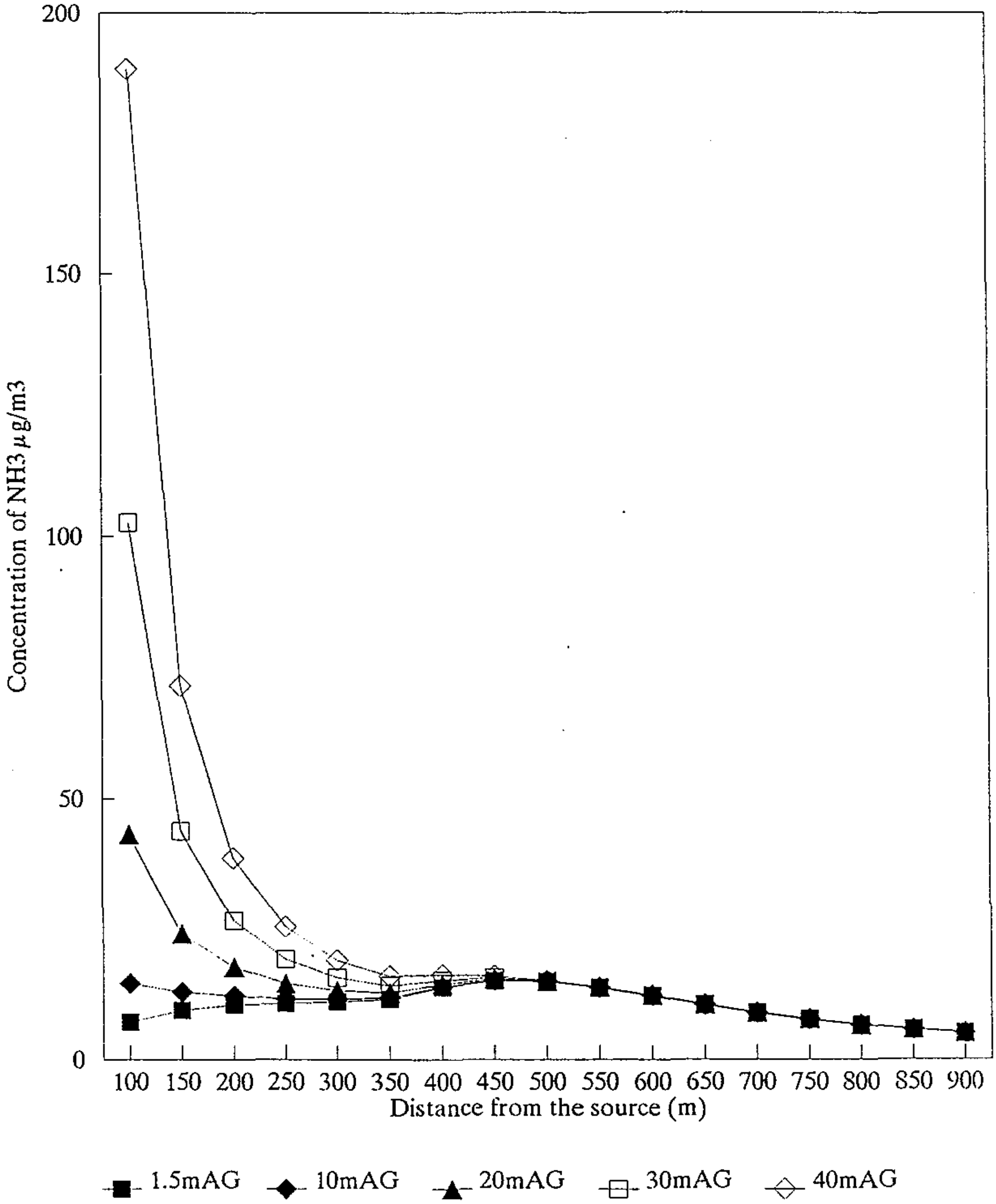


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FIGURE 11.2

HIGHEST 1 HOUR NH_3 CONCENTRATION PLOTTED AGAINST DISTANCE FROM THE SOURCE

Surface Water Run-off and Operational Effluent Discharges

Chapter 12

12 SURFACE WATER

12.1 INTRODUCTION

As discussed in the CEIA the stream catchments for SENT Landfill are bounded to the east by the ridge running approximately north to south along the Clear Water Bay peninsula.

Surface water flow will be a result of rapid surface run-off and groundwater baseflow. The groundwater base flow component supports streamflow in the perennial streams within SENT Landfill, since groundwater will emerge at the surface as springs and seepages. The location of such seepages varies depending on the bedrock structure, season and climatic conditions.

12.2 SURFACE WATER MONITORING

A weir was installed in one subcatchment of SENT Landfill in March 1992 as part of the environmental monitoring being carried out before the privatisation of SENT Landfill. The purpose of this was to quantify the rainfall run-off characteristics for the site. The position of the weir is shown in Figure 12.1.

The incident rainfall over the sub-catchment area was compared to the discharge over the weir in order to examine the rainfall/run-off relationship. The results shown in Table 12.1 indicate that over the whole monitoring period, 21% of incident rainfall flowed over the weir, the remainder being lost to evapotranspiration, groundwater flow, soil storage and on-site usage along with any surface run-off that may flow to the monitored stream. The data demonstrated substantial differences in flow between the wet and dry seasons.

The loss to evapotranspiration was calculated using rainfall data for Tseung Kwan O (adjacent to SENT Landfill) for the period 1979 to 1991, source ref 12.1. The annual data for these 13 years indicated that on average the effective rainfall is some 57% of actual rainfall, (coefficient variable of 16%). Assuming this percentage of effective rainfall, then the effective rainfall for this period is in the order of 1,208mm. During the period for which discharge data for the SENT site is available (Table 12.1), the effective rainfall was some 1,023mm, which is equivalent to approximately 174,000m^3 of rain water over the sub-catchment. Of this only 37% was measured flowing over the weir, the remainder being lost to the other sources which are listed above.

The discharge data demonstrates that the streams within SENT Landfill catchment have a strong seasonality. During the wet season 10-30% of incident rainfall becomes run-off, whilst during the dry season discharge often exceeds rainfall for several weeks at a time. This emphasises the importance of soil water storage in maintaining dry season discharges.

12.3 PROPOSED SURFACE WATER MANAGEMENT

The surface water management system at SENT Landfill will be designed to control surface water run-on from up-gradient areas and run-off from final restoration and temporary slopes to minimise soil erosion and maintain water quality. This system consists of a series of temporary and permanent storm water channels, culverts, sand traps, drop inlets and temporary separation lagoons designed both to efficiently manage surface water and to provide a "natural" appearance to the landscape for aesthetics, and to meet the following goals and objectives:

- provide adequate hydraulic capacity for the climatological regime of Hong Kong;
- provide adequate durability to accommodate the landfill environment including potential settlement;
- ensure minimal maintenance requirements particularly during the aftercare period;
- ensure the elimination to the extent practicable of surface water run-on to active areas of the landfill, reducing leachate formation potential;
- ensure the segregation of clean surface water run-off from leachate generating portions of the landfill;
- ensure the establishment of controlled, monitorable surface water discharge points;
- provide a minimisation of soil erosion on final and developing surfaces;
- ensure minimisation of visual intrusion and maximisation of natural appearance for permanent surface water control structures;
- ensure avoidance of confined entry points and incorporation of appropriate safety methods where confined entry points exist;
- provide a staged development and during operations and the facility permanent surface water control facilities upon stabilisation of the waste mass; and
- ensure the adequate consideration for safety during construction, implementation and utilisation of temporary and permanent surface water management structures. Safety considerations will address both active life and aftercare periods.

Table 12.1 Calculation of Rainfall/Run-off Relationship

Period	Stream Q (m^3)	Total Rainfall (mm)	Rainfall x Area (m^3)	Run-off/ Rainfall (%)
21/03/92 to 29/04/92	23,739	470	80,920	29
22/05/92 to 09/06/92	13,929	241.5	41,055	34
09/06/92 to 13/06/92	2,720	212.5	36,125	8
06/07/92 to 13/07/92	3,279	144	26,180	13
13/07/92 to 20/07/92	3,277	100.0	17,000	19
20/07/92 to 24/07/92	663	31.0	5,270	13
07/08/92 to 04/09/92	4,678	112.5	19,125	24
04/09/92 to 22/09/92	1,736	68.0	11,560	15
22/09/92 to 08/10/92	1,335	4.0	680	196
08/10/92 to 24/10/92	1,110	15.0	2,250	49
24/10/92 to 10/11/92	1,073	1.0	170	631
10/11/12 to 30/11/92	1,014	3.0	510	199
30/11/92 to 10/12/92	508	0.0	0	

Period	Stream Q (m^3)	Total Rainfall (mm)	Rainfall x Area (m^3)	Run-off/ Rainfall (%)
10/12/92 to 06/01/93	1,803	73.5	12,495	14
28/01/93 to 23/02/93	711	0.0	0	
23/02/93 to 31/03/93	976	55.5	9,435	10
31/03/92 to 21/05/93	2,308	262.0	44,625	5
Total	**64,859**	**1,794**	**304,980**	**21**
21/03/92 to 22/09/92	54,021	1,380	234,515	23
22/09/92 to 23/02/93	7,554	97	16,490	46

Source : SENT Landfill Environmental Monitoring Final Report November 1993 (Ref 12.1)

There will be four major surface water management systems:

i) Temporary System;
ii) Intermediate System;
iii) Permanent System; and
iv) Off-site System.

12.3.1 Temporary System

A temporary surface water drainage system to manage run-on will be used during construction and operation. This system will consist of a concrete U-channel or grass lined channel as constructed around the perimeter of the construction area. This system will collect surface water from the up-gradient areas. Erosion will be minimised because the water will be removed from the area in an efficient and controlled manner.

Temporary separation lagoons will be used to collect surface water run-off from active construction areas. Sediment laden surface water run-off will be allowed to remain in the lagoon until the sediment falls out of suspension. After settling the "clean" water is pumped to surface Discharge Points such as Discharge Point No.4 which is located at the North Western corner of SENT Landfill. It will be necessary for the GVL Design Team and the Contractor to ensure that the lagoons are of sufficient volume to allow the settlement of solids so that the effluent discharged to the sea at Discharge Point No. 1 is within the requirements of the Water Pollution Control Ordinance (WPCO) and the Technical Memorandum on Effluent Standards (TMES), Table 12.2 gives the standards for effluents discharged into the surface waters of the Junk Bay Water Control Zone.

Table 12.2 **Standards for Effluents Discharged into the Inshore Waters of Junk Bay Water Control Zone, For Selected Parameters.**

Flow Rate(m^3) → Determinand ↓	<10	>10 & <200	>200 & <400	>400 & <600	>600 & <800	>1000 & <1500	>1500 & <2000	>2000 & <3000	>3000 & <4000	>4000 & <5000	>5000 & <6000	>6000
pH	6-9	6-9	6-9	6-9	6-9	6-9	6-9	6-9	6-9	6-9	6-9	Seek EPD Advice
Colour	1	1	1	1	1	1	1	1	1	1	1	
Suspended Solids	50	30	30	30	30	30	30	30	30	30	30	

Note: Reference should be made to TMES for complete effluent standards.
Source: Technical Memorandum on the Standard of Effluents Discharged into Drainage and Sewerage Systems, Inland Waters and Coastal Waters.

Table 12.3 gives the quiescent settlement rates for various sized particles for lagoons which are 2m and 3m in depth.

Table 12.3 **Settlement Rates of Suspended Particles**

Particle Size	Falling Speed (cm/sec)	Settlement Times	
		2m Depth	3m Depth
0.2	2.1	2 min	2.4 min
0.1	0.74	4.5 min	6.8 min
0.05	0.17	19.6 min	29.4 min
0.01	0.007	7.9 hrs	11.9 hrs
0.005	0.0017	32.7 hrs	49 hrs

Initial work has been carried out on the design and sizing of the lagoons, this data is given in Table 12.4 below. As can be seen the lagoons required are of a significant size, during phases 1-3 the lagoons have an area of some 12,500m^2. A potential method to reduce the size of the lagoon is to construct the temporary drainage system so that settlement of solids is promoted along the whole length of the system and not just at the lagoons, this can be achieved by constructing the temporary drainage network at shallow or even flat gradients.

Table 12.4 **Settling Lagoon Sizes**

Lagoon	Area(m^2)	Capacity(m^3)	Phase of Operation
1	12,500	25,000	1-3
2	11,500	23,000	4-5
3	8,000	16,000	6-8

Source: RQs, Stage 3 Tender Evaluation, Response to Question 2.8.1

The lagoons have been sized so that they are capable of storing the run-off from a 1 in 2 year storm event with no out-flow and the lagoons will hold a volume equivalent to a 1 in 10 year storm event assuming that the out-flow is equivalent to the in-flow from a in 2 year storm event.

Given the lagoon design criteria above and considering the operational life span of the lagoons, it is very unlikely that any adverse water quality impacts will occur.

The temporary surface water management system will include the use of a silt fence around the soil stockpile areas to prevent sediment from entering the system.

Surface water that comes into contact with the waste is considered contaminated and will be diverted to the leachate collection system. Ingress of surface water into the active area will be minimised by carefully planning and constructing the waste slopes. If possible all areas that have intermediate cover will be sloped away from the active disposal area wherever possible for collection of surface water on temporary slopes. This water will then be collected along with water from the final cover areas and discharged off site as surface water at one of the designated discharge points. The site will be operated to assure that the volume of contaminated water that is generated on site is minimised, and that it is treated appropriately and released in a controlled manner. The slope away from the active operating area will minimise ingress of water into the working area, thus helping to minimise leachate and prevent infiltration.

An integral part of the temporary surface water management system is a technique to minimise leachate production through the control of the surface water which falls on the active phase below the lowest U-channel. This technique will be used on areas of completed base construction. Waste filling will begin in the low area of the phase, and will proceed up-slope. The liner will be constructed ahead of filling. An HDPE flap placed over a mound of drainage stone and welded to the base liner will be used to create a temporary interim bund to prevent the surface water from running into the active fill area. The clean surface water collected by the bund will be removed from the inactive fill area by pumping or gravity drainage into a surface water diversion channel, for discharge offsite as surface water at one of the designated discharge points.

12.3.2 Intermediate System

After each area is filled an intermediate cover will be placed over the area and hydroseeded if the final cap work does not commence for 1 full growing season does not commence for 1 full growing season. The major purpose of the intermediate drainage system is to prevent the clean surface water run-off from the filled phases, which have intermediate cover, coming into contact with the waste-mass in the active cell/phase and to prevent excessive surface water in-flow through the intermediate cover, which would thus contribute to an increase in the volume of leachate.

The intermediate drainage system will comprise a series of channels, possibly lined with a flexible membrane, which will collect the clean surface water run-off and divert it, away from the active areas, to the permanent perimeter channels which discharge to Junk Bay.

An intermediate drainage system will be used during the whole lifetime of SENT Landfill, after the filling of each phase/cell the intermediate drainage system for the particular phase will be constructed and become operational. As the filling of SENT Landfill continues, the intermediate drainage system will be superseded by the permanent drainage system, which will be completed near the end the final filling work.

12.3.3 Permanent System

Multiple options have been evaluated for the design of the surface water management system for SENT Landfill. The on-slope drainage channels which have been adopted are half-circle channels constructed in chunam and lined with low permeability membrane and rock or stone pitching. These channels intercept sheet flow from the final restored surface and discharge to the landscape valley channels, which convey the water downslope. The on-slope drainage channels are typically 0.5 metre deep depending on the amount of water it is designed to carry. The fall on these channels is typically 0.02 metre/metre. Chevron drains will be constructed between these on-slope channels. The chevron drains are spaced 7.5 metres up the slope and are lined with gabions to divert drainage to the on-slope channels and prevent erosion from the sheet flow.

The landscape valley channels are proposed as trapezoidal channels constructed in chunam and lined with impermeable membrane, rock and boulders. Due to the steeper slopes of these channels, the rock may have to be cemented in place. These channels accept flow from the on-slope drainage channels and convey the water down the final cover and off the landfill. The side slopes will be 1(V) on 2(H) and the bottom widths will vary from 1.0 to 3.0m. Channel depth will vary from 0.6 to 0.8m depending on the amount of water it is designed to carry. The fall on these channels varies from 0.10 to 0.20 metre/metre. Due to the steep slope of these channels, large diameter rock will be utilised as channel lining to dissipate the energy of the water flowing downslope. The valley channels discharge directly into the perimeter road channel, a drop inlet or a sand trap. The channel flow velocity and energy are dissipated by a gabion stepped spillway prior to discharging into the perimeter channel, drop inlet or sand trap.

The permanent surface water drainage system is designed to convey the water off the site restoration slopes and into the perimeter channel as quickly as possible.

The valley channels have been designed to have a curving and bending course to simulate the winding pathway of a natural stream in the existing landscaped topography. The system has been designed to collect surface water which runs off the final restoration slopes and convey it into the engineered diversion channels as quickly as possible to minimise infiltration while maintaining an efficient collection system and preserving the aesthetic qualities of the area. The diversion channels generally follow the contours of the final restoration. The step spillways are placed in the low areas of the cover terrain, just as the natural waterways would occur in the lower areas of natural terrain. The valley and on-slope channels will be constructed with the geosynthetic cap recessed below the channel and the gabion spillways will be recessed into the cover soil. The steps in the gabion spillway will cause a cascading effect to any water in the valley channel, thus creating aesthetic interest. The final stone pitching will create a natural stream-bed appearance.

The gabion spillways will drain into a perimeter collection channel which is a rectangular concrete channel.

Due to the passive recreational nature of the proposed afteruse, many people may be on the landfill cover after landfill closure. Therefore, safety is of the utmost importance. The outline design surface water management system does not incorporate any enclosed spaces. All outfalls or long culverts will be screened to prevent entry. Temporary fencing of an acceptable standard will be used where appropriate for protection. Any bridges over drainage channels will have adequate safety factors to withstand anticipated dead, live, and impact loadings and to withstand any water pressures or erosion which may occur during maximum flood conditions. All designated or commonly used access points into open water courses for environmental monitoring sampling or maintenance will have warning and safety notices, lifebelts, fencing and other appropriate safety measures.

The design of the diversion channels located on the final cover is such that their construction involves no disturbance below the cap cover soil. The construction of the valley channels will have the final cap recessed under the channel. This avoids any disturbance of the components of the final cap system or any mounding of soil above the final restoration grades. The gabion spillways will be in the soil layer, but constructed in such a way that the final cap system is not damaged. The cap cover soils will be thickened in the vicinity of the gabion spillways to accommodate a minimum soil thickness of 0.5 metre between the step channel and underlying cap geosynthetic components.

12.3.4 Perimeter Cut-Off Channel

In order to prevent off-site surface water from running onto the landfill, a perimeter cut-off channel will be constructed. On slopes less than 1(V) on 5(H), these channels are proposed as rectangular concrete channels. Fall on these channels ranges from 0.03 to less than 0.20 metre/metre.

On slopes greater than or equal to 1(V) on 5(H), the interceptor channels are proposed as step channels constructed of concrete.

The perimeter cut-off channels will ultimately discharge to six points, four of the discharges are to Tseung Kwan O and are at the following locations:

- A point at the north western corner of the site;
- A point mid way along the western side of the site;
- A point at the south western corner of the site; and
- A point at the south of the site and discharges into Tsueng Kwan O.

The remaining two discharge points comprise two culverts which run from the eastern side of the site under the ridge and discharge to Clear Water Bay. The sections within the Country Park will have landscaped channels. These two discharge points may not be necessary if stormwater is managed completely within the site boundary. The detailed design of these discharge points are currently under review.

12.3.5 Monitoring

Monitoring of the surface water discharges is part of the EMP. The results of the monitoring will show if contamination of the surface water by leachate is occurring. If surface water is found to be contaminated further monitoring will be undertaken to locate the source of contamination, and remediation measures will then be carried out. Once the source of contamination has been identified the various remediation measures would be considered, these would include as an ultimate option the classification of the surface water runnoff as leachate which would be directed to the LTF for treatment and the disposal via the TKO STW.

12.4 POTENTIAL IMPLICATIONS ON SURFACE WATER CATCHMENTS

The construction and operation of the surface water management system will permanently alter the existing surface water regime in the vicinity of the SENT Landfill site. As described previously all surface water run-off will be collected by the drainage system and discharged to the sea via a number of culverts and channels. Surface water inflow to SENT Landfill will be prevented by a perimeter drain. Surface water from within the landfill site will be, where possible, segregated from the active phases of the landfill, thereby eliminating potential contamination with leachate.

The surface water drainage system has been designed so that only surface water inflow and the run-off from the SENT Landfill is collected and discharged in a controlled manner and as such no impacts on the surrounding surface water catchments are expected.

12.5 POTENTIAL IMPACTS ON CLEAR WATER BAY COUNTRY PARK

Any construction within Country Parks has potentially significant impacts on ecology, visual and aesthetic appeal and water quality. It will therefore be necessary to ensure that the construction works within the Country Park are carried out in a careful and sympathetic manner with importance placed on the landscaping and revegetation work after construction has been completed. Construction within the Country Parks will be avoided, wherever possible.

Currently, the surface water system design incorporates two surface water drainage channels which will be constructed from the top elevations of SENT Landfill and carry drainage water to marine discharge points 6 and 7 located in Clear Water Bay. Each of the drainage channels will comprise a series of tunnelled culverts and open channels. At present the specific construction methodology for the channels and culverts has not been finalised and it is not possible to carry out a detailed assessment of the works. However, it is possible to identify a number of impacts which may occur and propose mitigation measures which would need to be incorporated into the design and construction works.

Visual impact during the construction stage can be minimised through the use of trenchless technology; this would also lead to a reduction in impacts associated with run-off containing high levels of suspended solids. The use of trenchless technology will also preserve the natural landscape and ecology of the Country Park and negate the need for extensive landscaping and revegetation work. Careful consideration of the application of trenchless technology for the culvert construction is recommended.

Run-off from the construction sites is likely to contain high levels of suspended solids; this has the potential to cause water quality impacts in Clear Water Bay. It will be necessary to incorporate measures such as silt fences and settlement lagoons to reduce suspended solids concentrations to acceptable levels, prior to discharge to sea or the stream courses in the area.

Since the design and construction methodology are not yet finalised, it is recommended that a EIA emphasising landscape, visual and ecological aspects and a review of the method statement be prepared when detailed design information is available. This should be undertaken as part of the CAP.

12.6 POTENTIAL IMPACTS ON CLEAR WATER BAY

The surface drainage management system is designed to collect, carry and discharge the clean surface water run-off from SENT Landfill and its immediate surroundings to the sea. The discharge of surface water from the landfill drainage system to the marine environment will not have any adverse impacts on the water quality of Clear Water Bay.

Contamination of the surface water with leachate or other pollutants will be detected by monitoring undertaken as part of the EMP. If a degradation in the quality of the surface water discharged occurs, the monitoring frequency would be increased and investigations carried out to identify the pollutant source. Once it has been identified, remediation work would be carried out. If contamination levels exceed present trigger levels, see Table 20.3, the run-off would be treated as leachate and diverted for treatment at the LTF and disposal to TKO STW.

During the dry season, silt, dust and soil will tend to accumulate in the channels. The first rain after an extended dry period will tend to wash accumulated sediment out of the channels. The channels will be periodically maintained to remove any accumulated silt and sediment to prevent adverse impacts associated with the discharge of run-off with high suspended solids concentration. Sand traps will also be used to take sediment out of the surface water before it is discharged to the sea. The sand traps will be regularly maintained to remove any accumulated sediment.

12.7 CONCLUSIONS

The design and operational procedures associated with the surface water management system is such that no significant adverse impacts on water quality are expected. GVL have taken a number of steps to ensure that where impacts are predicted they are either reduced to acceptable levels or removed completely. This overall approach to the design and future operation of SENT Landfill is demonstrated by the diversion of the proposed marine discharge in Joss House Bay to Tseung Kwan O Bay. This measure removes any potential impact on the marine of Joss House Bay. The EMP results will show if contamination of the surface water is occurring and subsequent investigations will identify the source as well as where remediation measures are required.

The construction of the drainage system in the Country Park has the potential for significant impact, an environmental review and review of the method statement should be carried out when the design and construction methodologies have been finalised.

References

12.1 Scott Wilson Kirkpatrick & Partners. SENT Landfill, Environmental Monitoring Final Report (October 1993).

12.2 WCI EMP. November 1993.

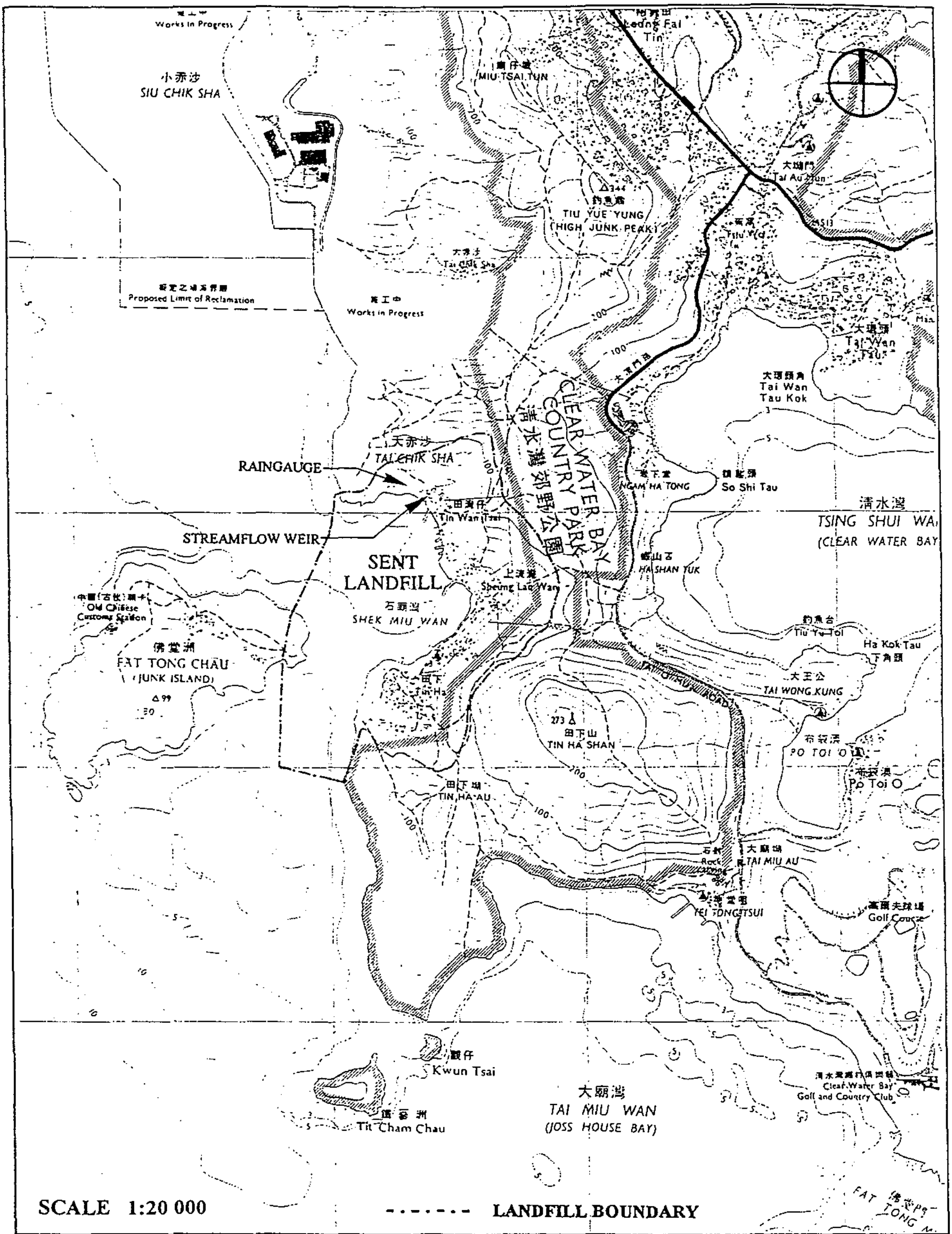

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FIGURE 12.1

STREAMFLOW WEIR LOCATION

Hydrogeology

Chapter 13

13. HYDROGEOLOGY

13.1 INTRODUCTION

The aims of this section are to assess the impacts on the groundwater regime of the excavation activities which will take place during the development of SENT Landfill, and the risks to groundwater of leakage of leachate through the site liner. Further groundwater monitoring has taken place since the CEIA and this is reviewed below. Furthermore, GVLs liner system offers greater protection to the aquifer than the liner assessed as part of the CEIA and this is also described.

There are three principal ways in which the groundwater regime within the area will be potentially altered as a result of the SENT Landfill project:

- the proposed excavation and the provision of a groundwater collection blanket which will alter the flow patterns of groundwater;
- a reduction in groundwater recharge due to the provision of a low permeability landfill cap; and
- the alteration of surface water drainage patterns for the site and the surrounding environment, with a surface water drainage plan that enables water to run off the landfill as soon as possible, the installation of surface water cut off drains around the site and increased flows of stormwater and groundwater to Clear Water Bay.

13.2 GEOLOGY

The geology of the SENT area is described in detail in the CEIA. The main points of this are as follows.

The geology of the land bordering Shek Miu Wan and surrounding areas is dominated by Mesozoic volcanic rocks, and intrusive igneous rocks. The volcanic rocks are of the Upper Jurassic Repulse Bay Volcanic Group. Variable thicknesses of weathered rock often mask the solid bedrock and in turn can be covered by recent superficial deposits usually in lower lying areas and offshore.

Solid Geology

Figure 13.1 shows the distribution of sedimentary and volcanic rocks in the proposed SENT landfill area and Table 13.1 indicates their relationships.

Ap Lei Chau Formation

Within the Repulse Bay Volcanic Group, the oldest division is the Ap Lei Chau Formation, comprising mainly tuffs. Nowhere in the study area are these rocks exposed, but they are up to 2000m in thickness and originated as large scale ash flows.

Silverstrand Formation

Overlying these deposits are rocks of the Silverstrand Formation which form the solid geology of the southern part of the study area and outcrop on Junk Island. They are mainly eutaxites (volcanic tuffs with pumice fragments), relatively hard rocks that tend to form relief features such as Tin Ha Shan, and are generally thicker than the eutaxitic tuffs within the underlying Ap Lei Chau formation. The northerly contact with the lavas of the Tai Miu Wan member of the younger Clear Water Bay Formation is fault bounded and represents a downthrow to the north of perhaps more than 200m. At Shek Miu Wan isolated outcrops of eutaxite are apparently overlain by tuffaceous sediments and tuffs of the Mang Kung Uk Formation. The Silverstrand Formation is thought to have originated in a similar manner to the Ap Lei Chau Formation, from massive ash flow eruptions related to a large caldera located to the east of Clear Water Bay.

Mang Kung Uk Formation

Rock types of this formation represent a change in the volcanic environment from the thick pyroclastic flow deposits below, to a lava dominated sequence above. To the north of the study area, on the coast between the Tseung Kwan O Stage I and II landfill sites, interbedded sandstones, tuffaceous siltstones, volcanogenic conglomerates and bedded tuffs are exposed and dip eastwards between 18° and 25°. Further south on the coast around Shek Miu Wan, pale greenish-grey tuffs and tuffites and associated tuff breccias of the same formation, less than 100m thick, are exposed. These are soft in comparison with underlying and overlying strata and tend to form topographical 'lows' along the coastal fringe at Shek Miu Wan and further north (along the rocks' strike and outcrop) to the east of Pak Shin Kok. Similar soft weathered tuffites and tuffs are found on the Clear Water Bay side of the peninsula, north-east of the study area on the coastal area of the southern side of Clear Water Bay Second Beach.

Table 13.1 Sedimentary and Volcanic Rocks of the SENT area

MESOZOIC (UPPER JURASSIC) REPULSE BAY VOLCANIC GROUP	
Volcanic Divisions	Principal Rock Types
Clear Water Bay Formation	Banded lavas and tuffs
Mang Kung Uk Formation	Well bedded tuffite, breccia, conglomerate, siltstone and sandstone layer
Silverstrand Formation	Eutaxites
Ap Lei Chau Formation	Fine ash welded tuffs interlayered with pyroclastic flow deposits

Clear Water Bay Formation (Tai Miu Wan Member)

Rocks of this formation form most of the eastern boundary of the study area and comprise mainly banded lavas and tuffs. The lavas are more resistant to erosion and can form isolated crags on the steep west-facing slopes. They dip in similar fashion to the underlying Mang Kung Uk formation.

The lava flows are of a type that are typically restricted in their lateral extent to within 10km of their source. They have been deposited upon a sequence of waterlain mudstones and tuffites (Mang Kung Uk Formation) which may have been deposited within a caldera. If the south easterly dip of the strata were a result of downsagging of the caldera floor then this suggests that the vent or vents were located to the south-east, as indicated earlier.

Intrusive Igneous Rocks

At the northern end of the study area a north-eastern south-western tending intrusion of fine-grained (<2mm) granite cuts through the tuffs, mudstones, siltstones and breccias of the Mang Kung Uk Formation and the lavas of the Clear Water Bay Formation, and extends across the bay to the northern tip of Junk Island.

Geological Structure

Figure 13.1 shows the main faults identified during geological survey of the SENT area, and from aerial photographs. The main fault patterns in the area are either north-northwest to south-southeast or east to west. The fault running east-northeast at the north of Shek Miu Wan was probably caused by the granitic intrusion to its west resulting in an upthrow to the north of the order of 30-40m.

Superficial Deposits

Over the Hong Kong area, the two main types of superficial deposits that occur are colluvium and alluvium.

Colluvium

Colluvium deposits are formed by gravity transport of rock and soil debris down slope and are very heterogeneous in their physical properties. Older deposits may be weathered and consolidated but most recent ones are loose and unconsolidated. Most deposits are thin and result from accumulation of landslip debris from higher levels. At SENT, colluvium has been identified primarily in valley features in the north and central parts of the study area.

Alluvium

The only alluvial deposits identified in the geological survey are in the extreme south of the SENT area, near Tin Ha Wan. Other deposits are noted near the coastline at Seung Lau Wan, but alluvium occurs over only small areas within the study area, and volumes will consequently be small. Other small areas near the coast are covered with beach deposits, usually composed of coarse well sorted sands. Again at SENT, these deposits are very limited in extent, along the northern part of the shoreline and small areas near the issues of streams into the sea.

13.3 GROUNDWATER LEVELS

The groundwater regime within the SENT site is principally dictated by the amount of rainfall available to the aquifer. Potential pathways for rainfall incident upon the site are:

- surface water runoff;
- interception by vegetation and loss to the atmosphere by evapotranspiration;
- infiltration into the soil to satisfy any soil moisture deficit;
- infiltration through sedimentary deposits of the northern part of the site;
- infiltration through weathered bedrock; and
- infiltration through unweathered bedrock via faults and fractures.

Extensive groundwater monitoring (Ref 2) has been undertaken prior to the privatisation of SENT Landfill by EPD. Groundwater levels have been measured by piezometers and are reproduced as Figure 13.3. As discussed in the Final Environmental Monitoring Report, groundwater levels show a distinct seasonal pattern for the majority of boreholes, with an increase in standing water levels in the wetter months of the year. Some of the boreholes were found to be more sensitive to seasonal variations than others. It is considered that the differences are likely to be due to local variations and drainage characteristics within the SENT catchment.

Groundwater levels have been found to be reasonably predictable with a groundwater mound in the centre of the Clearwater Bay peninsula, with the levels approximating the topography to some degree.

Impacts of SENT Landfill on Groundwater Levels

The installation of a groundwater collection blanket will considerably decrease the travel time for groundwater towards Tseung Kwan O. In addition, the progressive installation of a low permeability cap will result in the loss of recharge areas. The average effective rainfall for the SENT site is calculated to be 1208mm/year (Ref.2). Given that the land surface area is approximately 520,000 m^2, this will result in a loss of 630,000 m^3/year of recharge to the aquifer. The expected result of these activities will be to lower the level of the groundwater mound within the peninsula and displace the divide eastwards, towards Clearwater Bay. This infers that any leachate that may migrate from SENT landfill will remain within the catchment of the Shek Miu Wan (Junk Bay) side of the groundwater divide, rather than migrate towards Clearwater Bay.

The CEIA (Ref 1) noted that the east west ending faults crossing the peninsula provide a potential migration pathway for leachate. However, it was considered unlikely that there was connection of the faulted strata at depth across the peninsula, and hence the existence of the pathway was unlikely. Further ground investigation work and baseline monitoring carried out since the CEIA have shown that these faults appear to have no significant impact on the groundwater regime and are considered to be closed, and therefore highly unlikely to be pathways for leachate migration into Clearwater Bay. In addition, the movement of the groundwater divide discussed above will also apply within any fault zones.

In conclusion, therefore, investigations carried out to date have not identified any potential leachate migration pathways into Clearwater Bay or the surrounding area. Groundwater flow is presently away from Clearwater Bay and will continue to be towards Shek Mui Wan.

13.4 GROUNDWATER QUALITY

Monitoring and Analysis

Groundwater monitoring has been undertaken at regular intervals prior to the commencement of the SENT Landfill Privatisation Contract. The monitoring was carried out by the Hong Kong Government's consultants and is discussed in detail in their report (Ref 2). Groundwater samples were taken from a series of monitoring boreholes around the perimeter of the site as shown in Figure 13.2.

Table 13.2 Ground Water Quality

Parameter	Units	UK Water Supply (Water Quality) Regulations (1989)	Water Quality Sampling (March 1993)				
			D437	D450	D458A	D458B	D458C
Conductivity	μs/cm	< 1500 @ 20°C	83	115	200	210	215
Chloride	mg/l	<400	10	21	16	14	14
Calcium	mg/l	<250	4	4	30	28	27
Sulphate	mg/l	<250	<5	7	<5	<5	<5
Magnesium	mg/l	<50	<2	<2	<2	<2	<2
Sodium	mg/l	<150	9	15	18	16	15
Potassium	mg/l	<12	2.2	2.9	2.5	2.6	2.4
Nitrate	mg/l	<50	<0.2	<0.2	<0.2	<0.2	<0.2
Nitrite	mg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Ammonium (ammonia & ammonium ions)	mg/l	<0.5	<0.2	<0.2	<0.2	<0.2	<0.2
Kjeldahl nitrogen	mg/l	<1	<0.2	<0.2	0.7	<0.2	<0.2
Total Organic Carbon	mg/l	No significant increase over normal level	0.8	0.7	1	0.3	0.6
Iron	μg/l	<200	110	<20	<20	<20	<20
Manganese	μg/l	<50	90	250	50	50	40
Copper	μg/l	<5000	<20	<20	<20	<20	<20
Zinc	μg/l	<5000	20	40	10	10	10
Phosphorous	μg/l	<2200	<100	<100	<100	<100	<100
Arsenic	μg/l	<50	-	-			
Cadmium	μg/l	<5	<1.0	<1.0	<1.0	<1.0	<1.0
Lead	μg/l	<50	<10	<10	<10	<10	<10
Nickel	μg/l	<50	<7	19	<7	<7	<7
pH		<9.5, >5.5	6.6	6	6.8	6.8	6.6
Sulphur	mg/l	-	<0.01	<0.01	<0.01	<0.01	<0.01

Source : SWK&P, SENT Landfill, Final Monitoring Report (Ref 13.2)

Groundwater sampling was undertaken in November 1991, March 1992, June 1992, September 1992, December 1992 and March 1993. The samples were analysed for the following determinands:

- suspended solids
- COD
- Electrical conductivity
- Ammonia
- BOD
- Nitrate
- Chloride
- Sulphate
- Potassium
- Magnesium
- Manganese
- Cadmium
- Copper
- TOC
- pH
- Iron
- Zinc
- Nitrite
- Sulphide
- Carbonate/alkalinity
- Sodium
- Calcium
- Nickel
- Phosphate
- Lead
- Kjeldhal Nitrogen

The results of the last chemical analysis are reproduced in Table 13.2 along with the UK standards for groundwater abstracted for drinking water, as prescribed under the UK Water Supply (Water Quality) Regulation (1989).

Discussion of Water Quality Monitoring

This discussion is taken from the Final Monitoring Report (Ref 2).

Measurements of the majority of determinands including inorganic and total nitrogen, BOD, COD, sulphate, sulphide and phosphate were all below detection limits. TOC concentrations were low and levels of chloride, calcium carbonate and electrical conductivity were below typical levels for groundwater. Concentrations of alkali metals (calcium, magnesium, sodium and potassium) were low.

Elevated concentrations of iron were measured in samples taken from borehole D437 only (110mg/l) and for manganese in boreholes D437 (83μg/l) and D450 (115μg/l). Concentrations of other heavy metals were low and indicative of uncontaminated conditions, with the possible exception of borehole D450 where nickel concentrations were elevated (19μg/l) compared to other samples. However, measured nickel concentrations were below the UK drinking water standard (50μg/l).

Overall, it is apparent that groundwater quality is indicative of uncontaminated conditions and is within UK and WHO water quality standards for the majority of analytical determinands. Elevated concentrations of iron and manganese are considered to be a geochemical characteristic of the volcanic geology of the area rather than a result of any groundwater contamination. Determinands measured at high levels in the initial two monitoring rounds were a result of high suspended solid concentrations in unfiltered samples which were derived from the ingress of decomposed volcanic material during borehole drilling. It is considered that significant pollution sources are absent from the SENT Landfill catchment area and are restricted to localised and minor impacts associated with the village developments.

13.5 RISK ASSESSMENT OF LINER LEAKAGE

Since the composite liner system designed by GVL for SENT Landfill is a critical component of the design, it is appropriate to discuss in more detail the rationale behind the system to protect groundwater and the surrounding environment. The liner system consists of four different types for different areas of the site. These are described above, in Section 5.2. A major upgrade that the liner system has over the conceptual design. The use of HDPE in all parts of the site is this, and the steep side slope gradients, make liner leakage at the slopes very unlikely given that the preferential path for leachate will be down the leachate collection blanket (a geodrain) to the basal liner. It is at the basal liner, particularly over the marine part of the site, where leakage would be most likely to occur, if at all. Calculations have been undertaken in relation to seepage through the liner system for the marine area. An average seepage rate of 0.07 litres/hectare/day through the liner was calculated for the following 3 components:

Thickness	Material	Hydraulic Conductivity
2.0mm	HDPE Geomembrane;	$K = 10^{-15}$m/s
6.0mm	Bentonite Matting;	$K = 10^{-11}$m/s
1.5mm	HDPE Geomembrane;	$K = 10^{-15}$m/s

Although geomembranes provide a very low permeability barrier to leachate, certain types of defect can still occur, such as pinholes or tiny flaws in seams. The size and number of holes will be minimised by the construction methodology and high degree of construction quality assurance that has been proposed by GVL.

Giroud and Bonaparte (Ref 5) independently evaluated leaks in geomembrane liners. They concluded that 1 defect per 300m of field seam can be expected with reasonably good installation practice and independent quality assurance. For typical panel widths, seam defects are likely to result in 3-5 leaks/ha with good quality assurance.

The composite liner system overcomes the problem of occasional defects associated with a single geomembrane liner. If there is a hole in a geomembrane liner, liquid will easily move through the hole. With the bentonite matting alone, seepage would take place over the entire area of the basal liner. With a composite liner, incorporating a geomembrane and bentonite matting, liquid moves easily through any hole in the geomembrane but will then encounter low permeability soil. The liquid front remains localized at the defect hole and does not migrate and cause total sheet saturation. Similarly leakage through the bentonite matting is reduced by placing it in contact with a geomembrane, which despite occasional holes or defects in seams, greatly reduces the area of flow through the bentonite matting and thereby significantly decreases the rate of flow through the bentonite matting.

Seepage rates through geomembrane liner, bentonite and composite liners may be calculated using equations published by Giroud and Bonaparte (Ref 3) and Giroud at al (Ref 4). The following example is presented to compare calculated flow rates through different lining systems.

Table 13.3 Example Calculations of Flow Rates of Leachate Through Different Liner Systems

Type of Liner	Flow Rate (l/ha/day)		
	Best Case	Average Case	Worst Case
Geomembrane alone	2,500	25,000	75,000
holes/ha	2	20	60
Compacted soil alone	115	1150	11,500
K(m/s)	10^{-10}	10^{-9}	10^{-8}
Composite	0.8	47	770
holes/ha	2	20	60
K(m/s)	10^{-10}	10^{-9}	10^{-8}

From Table 13.3 it can be seen that the calculated flow rates through the composite liner are typically at least 100 times less than through a geomembrane or bentonite matting alone.

The performance in practice of composite liners has been good. Bonaporte and Gross (Ref 5) report leakage rates measured in leak detection layers for double-liner systems. Analysis of the data is complicated by the fact that most, if not all, of the liquid collected initially in a leak detection system beneath a composite primary liner is the result of consolidation of the clay-liner component of the primary composite liner. For example, if a 0.6m thick layer of saturated soil compresses 3% in thickness over a period of two years, the average flow rate due to consolidation would be 270 L/ha/day, which is likely to be far greater than the long-term leachate leakage rate.

Bonaparte and Gross (Ref 5) report that bentonite matting was used as the lower component in seven liner systems. For these systems, there was no consolidation water produced and interpretation of the leak rate through the composite liner was unambiguous. No flow was detected in the leak detection system of any of the seven composite liners, confirming the very high integrity that is achieved with a composite liner system.

13.6 LEACHATE QUALITY

Leachate is the product of the infiltration into the waste mass of rainfall, surface or groundwaters which dissolves products from the biological and physical breakdown of the solid wastes. It can contain high concentrations of inorganic and organic components, the concentrations of ammonia, biochemical oxygen demand (BOD) and chemical oxygen demand (COD) being of greatest concern.

The CEIA (Ref 1) has made predictions on the quality of leachate expected from SENT, in order to help define the treatment requirements. These are set out in Table 13.4. The same predicted leachate parameter levels can be used to assess the risks to groundwater quality.

Table 13.4 Anticipated Leachate Quality at SENT Landfill (mg/l, except pH value)

Parameter	Year 1	Year 2 - 5	Year 5 +
COD	20,000	4,000	3,000
BOD	12,000	500	300
Ammonia - N	1,500	3,000	2,000
pH value	7.0	8.0	8.5

13.7 IMPLICATIONS FOR GROUNDWATER QUALITY

As already noted given the anticipated quality of leachate, GVL are, with the proposed liner system, providing the highest possible level of groundwater protection.

Very stringent Construction Quality Assurance and Construction Quality Control procedures that will be implemented will insure that the liner system is not compromised in any major way. It is therefore considered unlikely that any leachate will "breakout" of the landfill and the risk to the groundwater regime from liner leakage incidents is minimal.

However, it is potentially feasible, albeit unlikely, that a major failure or rupture of the base liner could occur, allowing significant volumes of leachate to leak from the contained waste mass. While the action taken in response to this situation will depend on the nature and location of any such leakage, it is considered important that an Action Plan and contingency arrangements should be prepared in advance to deal with this situation in a timely manner. The Action Plan should be completed and approved by EPD prior to commencement of tipping operations. The issues which will need to be addressed in such an Action Plan include:-

1. An increased monitoring programme targeted to detect the presence of leachate or appropriate indicators and provide information to help develop corrective/mitigation measures.

2. Possible actions available to minimise leachate leakage, such as reducing the head of leachate in the cell/phase through early closure of cells or implementation of alternate extraction methods.

3. Establish a list of persons/organisations to be notified in the event of a major release.

Nevertheless, as discussed, a small amount of leachate may escape through the liner system by both permeating through the liners and through isolated defects. The maximum amount of leachate that would leak into the environment in this manner would be 0.87 L/ha/day through the basal liner system once seepage through the actual membranes is taken into account. This figure represents the maximum theoretical leakage rate under a 1 metre head of leachate and a factor of safety of 3. This is a highly conservative value that is within the USEPA's allowable leakage rate of 1 L/Ha/day. Given that the basal area of the landfill is 94.68 hectares, the maximum potential leachate leakage through the liner would be 82.4 L/day. That which escapes through the landward basal part of the system will enter the groundwater collection blanket. Monitoring of the water quality within the groundwater collection layer will allow an assessment to be made of the possible degradation of groundwater quality. In accordance with the contract, if the groundwater fails to meet the discharge standards it will be treated as leachate.

Therefore with the incorporation of the groundwater blanket, any leakage that does occur from the landfill should have little or no impact on the groundwater quality beneath the SENT site.

The rigorous groundwater monitoring regime that has been set up within the Environmental Monitoring Plan (EMP) (Ref 6), makes provisions for groundwater pollution, should it ever occur. These provisions are designed to further protect the groundwater regime and can be summarised as follows.

Within 14 days of receiving a result which indicates that a particular environmental parameter has exceeded the designated trigger value, a Special Environmental Monitoring Plan (SEMP) will be established to determine:

- the likely cause or reason for non-compliance;
- any alterations or modifications to the Works, Operations or Aftercare which would reduce the likelihood of such violations; and
- the anticipated outcome of any corrective action programme.

Within a further 28 days, GVL will either:

- demonstrate that a source other than the landfill caused the exceedance;
- demonstrate that the increase resulted from error in sampling, analysis or evaluation;
- implement a corrective action programme where the exceedance is shown to have been caused by the landfill; and
- notify in writing all persons who own the land or reside on land where unacceptable pollution concentrations have been detected.

The SEMP will be terminated, and the normal Environmental Monitoring Plan will be reinstated, only with the Employer's consent; which shall be forthcoming if it can be demonstrated that a corrective action programme has been implemented and a successful outcome achieved.

Any proposed corrective action programme will be assessed in terms of the following criteria:

- the degree of protection afforded to human health and the environment;
- the degree to which contaminant releases can be controlled so as to reduce or eliminate to the maximum extent practicable, further releases that may pose a threat to human health or the environment;
- the degree of certainty proposed for the short-term and/or long-term solution; and
- the ease or difficulty of implementing a potential corrective action programme in the light of technological, operational, and/or other practical difficulties.

It is therefore considered that with the high levels of protection, monitoring and contingency plans in place, that there is little risk of groundwater quality suffering degradation by the landfilling activities at SENT.

13.8 CONCLUSIONS AND RECOMMENDATIONS

Overall it can be concluded that the groundwaters within the SENT Landfill catchment are representative of uncontaminated conditions. Despite large variations in standing water levels in some monitoring boreholes, groundwater quality remained similar throughout the site. High concentrations of iron and manganese in samples can be attributed to the geochemical characteristics of the volcanic geology of the area.

A multiple, composite liner system has been designed for the landfill. There are four different liner systems. Each of the liner systems have been designed for specific areas of the site. The upgrades in the liner system from the conceptual design will insure better environmental protection. As discussed a maximum theoretical leakage rate of 0.87 L/Ha/day calculated using a 1 metre head of leachate and a factor of safety of 3, is below the US EPA allowable leakage rate of 1 L/Ha/day even including for defects that the QA/QC and independent checking will seek to avoid.

Given the small amounts of leachate that may escape from the site and the provisions to deal with them it is considered that there is little risk of groundwater quality suffering degradation due to the landfilling activities at SENT.

The levels of groundwater will decline, but as groundwater is not considered a resource in the area, this will have little noticeable impact, and the reduction in groundwater levels should have little effect on stream discharges in Clearwater Bay and Joss House Bay.

It is recommended that an Action Plan for dealing with a major liner rupture should be prepared by GVL, and approved by EPD, within 12 months from the commencement of waste tipping operations.

Early warning signs of a major rupture in the liner would initially become apparent in the results from the monitoring and analysis of the groundwater collected and discharged from SENT. The early warning signs would allow a sufficient time period for the implementation of the action plan to prevent any significant loss of leachate from the landfill and subsequent contamination of local environment.

The Action Plan would include procedures for the development of proposals for:

- The diversion of leachate contaminated groundwater to the LTF for treatment and disposal,
- An increase in the extent and intensity of the groundwater monitoring works,
- The installation of additional downgradient wells for monitoring and extraction purposes,
- The cessation of tipping activities of cells/areas considered to have a major liner rupture, and
- The early closure of landfill areas, including "capping off" of areas considered to have a major liner rupture.

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13.5 Bonaparte, R. and Gross, BA (1990). Field behaviour of double liner systems. Waste Containment System: Construction, Regulation and Performance (ed R. Bonaparte), American Society of Civil Engineers, New York pp 52-83.

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FIGURE 13.1

SITE GEOLOGY

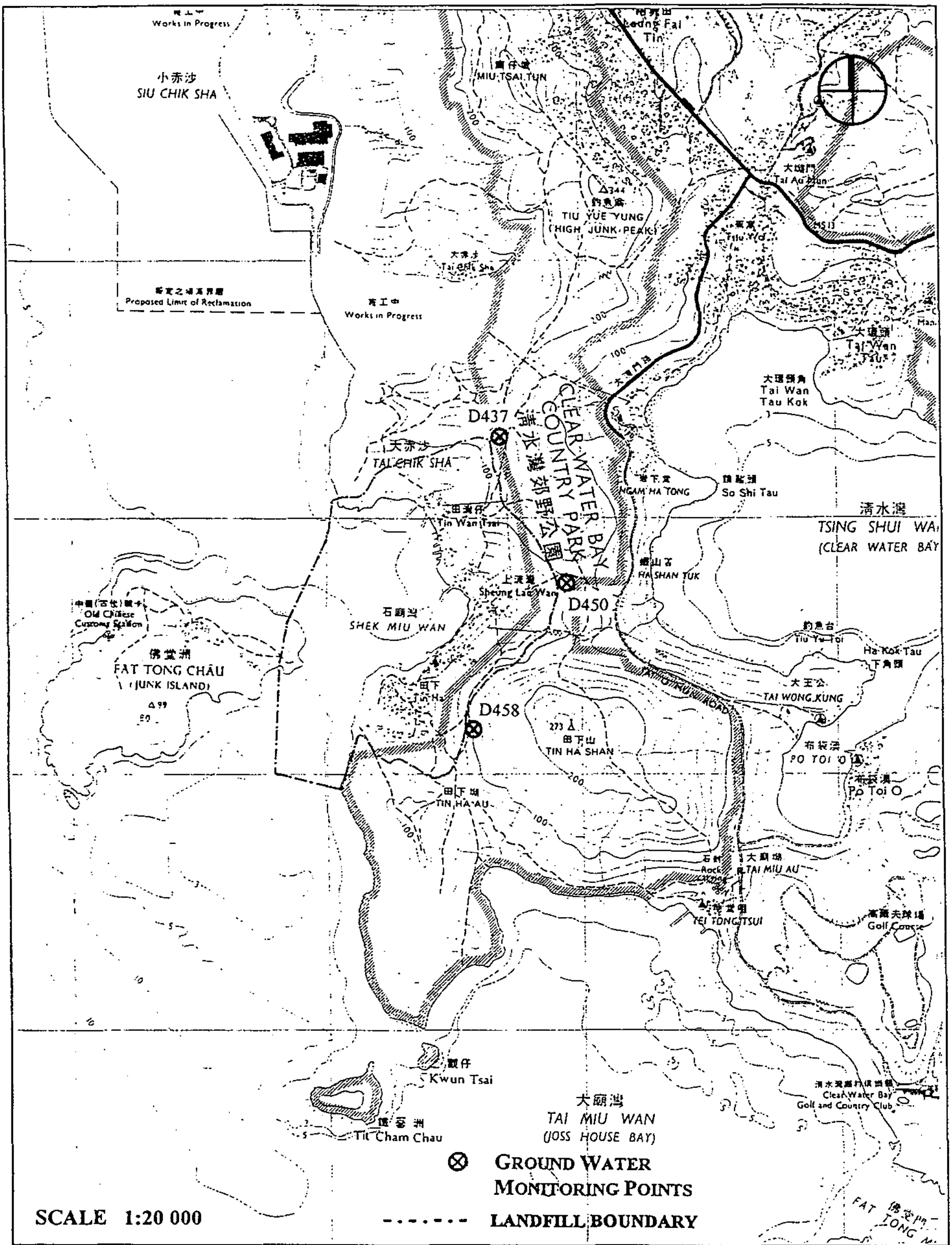

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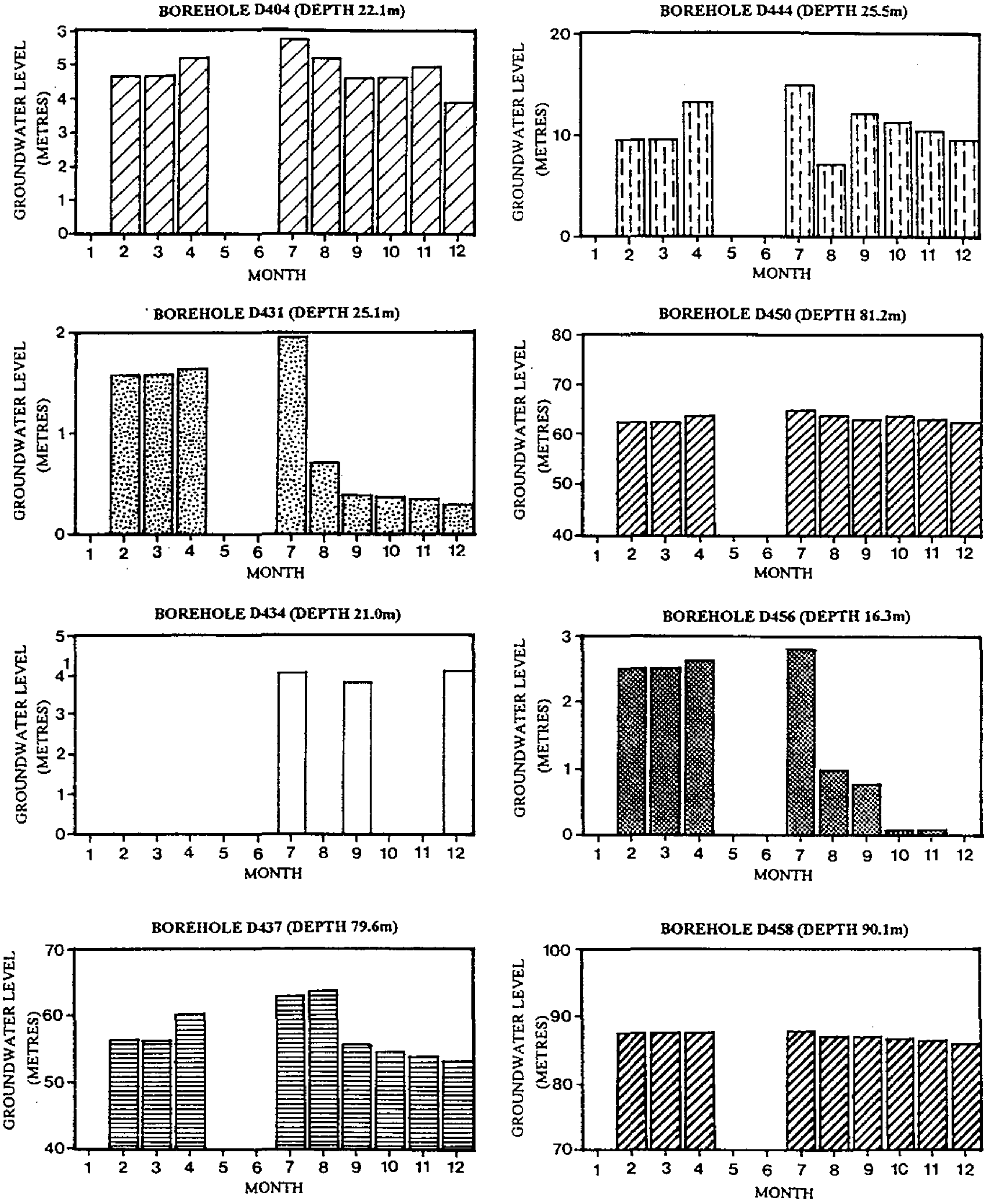
FIGURE 13.2

LOCATION OF GROUND WATER WELLS MONOTORED DURING ADVANCE WORKS



Reference - Scott Wilson Kirkpatrick and Partners,
SENT Landfill Environmental Monitoring Final Report November 1993

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FIGURE 13.3

MEASURED GROUNDWATER LEVELS IN MONITORING BOREHOLES, 1992

Marine Discharges

Chapter 14

14. MARINE DISCHARGES

14.1 INTRODUCTION

This Chapter examines the potential impacts associated with the reclamation of the marine fill area and routine liner seepage from the SENT Landfill on the existing water body within the Junk Bay Water Control Zone.

14.2. DESCRIPTION OF THE ACTIVITIES

During the initial stages of the development of SENT Landfill a seawall has been constructed at the western end of the site between Junk Island and the Clearwater Bay peninsula. This seawall will define the site's seaward boundary; the area inside the seawall, the "marine reclamation area", is to be filled with marine sands and rockfill. Prior to filling the marine area it is necessary to remove the existing soft marine sediments to prevent uneven settlement within the landfill, which if left in-situ could have significant effects on the integrity of the landfill liner.

The marine fill area will be open to the sea allowing marine access to the site by the grab dredgers and barges which are removing the soft marine muds. Also during this early stage some limited filling will occur where the marine muds have already been dredged. The fill material of marine sands will be dredged from a gazetted fill borrow area by a Suction Hopper Dredger and supplied to the site by a floating pipeline from the dredger which would anchor nearby to the site. Rockfill material will be obtained from on-site excavation. Once all the soft marine muds have been removed, the seawall will be completed impounding a large body of water behind it in the marine fill area.

The area will then be filled using an inert marine fill. It has been estimated that it will take upwards of 12 months to complete the filling operations, with approximately 3.9 million m^3 of fill material required to reclaim the marine area up to an elevation of +2.5 mPD. A further 4 million m^3 of fill material will be required above elevations of +2.5 mPD to obtain the required site formation levels. The filling operations below +2.5 mPD will be carried out by placing the marine fill material hydraulically or in the case of rock fill by end tipping. The dredged fill material will be pumped directly from the Suction Hopper Dredger to the reclamation site using floating and land based pipelines.

The water contained within the marine fill area will be removed from the lagoon by a combination of mechanical pumping and natural displacement as the fill is placed into the marine fill area. The water will be discharged to the sea through two discharge points along the south side of the SENT Landfill.

14.3 BACKGROUND WATER QUALITY MONITORING DATA

EPD has carried out all of the Hong Kong Government's marine water and sediment monitoring throughout the Territory as a regular programme since at least 1986. The measured parameters and pollution indicators are reviewed by EPD particularly in terms of compliance with the key Water Quality Objectives (WQO) for the gazetted Water Control Zones (WCZ). The SENT Landfill SEIA Study Area lies within the boundaries of the Junk Bay Water Control Zone. EPD prepare an annual publication which details the quality of the waters of Hong Kong. A summary of the latest data from EPD and a discussion of the compliance with the WQOs for Junk Bay WCZ during 1991 is given below and in Appendix 4.

The results of the EPD monitoring work show that the water quality within Junk Bay was good with almost 100% compliance with the WQOs, however the nutrient concentrations have increased significantly over the previous years levels, and are considered to be approaching critical levels.

Further background marine water quality data is available for the area from the monitoring works carried out by Scott Wilson & Kirkpatrick, during the SENT Landfill Study, and Green Valley Landfill, as a part of the Environmental Monitoring Plan (EMP) and the Marine Works Pollution Control Requirements (MWPCR) for SENT. Monitoring for the EMP was carried out on one occasion in October 1993 at three sites adjacent to SENT, while monitoring for the MWPCR was carried out at 9 locations in Shek Mui Wan and the Tat Hong Channel, during the period 18th September to 4th October 1993. The monitoring was for a total of 32 sampling occasions with subsequent analysis for a number of water quality parameters. A brief discussion of the report (ref: Background Marine Water Quality; Woodward-Clyde International Ltd, December 1993) and results of the monitoring is given below.

Dissolved Oxygen Generally the results were lower than those of EPD, overall the results showed both seasonal and year-to-year variations at the locations monitored and occasionally, for significant periods, the DO levels in the surface layer fell below the 4mg/l standard.

Suspended Solids The results of the monitoring showed that the mean levels were slightly higher in the Shek Mui Wan than in the Tat Hong Channel, significant short term variations of Suspended Solids (SS) levels were noted, these events usually coincided with rougher than usual sea conditions. A large number of exceedances of the "130% of ambient" water quality standard (WQS). This was due to the fact that although mean levels were similar at all stations in the same zone, there was a significant random variation in results between stations on the same day.

Nitrate & Phosphate The results were similar to those of the EPD but showed a slightly wider range for both parameters. Generally the levels in Shek Mui Wan were higher than in the Tat Hong Channel. There were a large number of Exceedances of the water quality standard for nitrate, with fewer exceedances of the phosphate water quality standard.

14.4 POTENTIAL IMPACTS

14.4.1 Fuel Stores

During the construction stage there will be storage areas for materials such as fuels and oils, used to service the plant equipment. Potentially significant impacts on water quality can arise through the leakage or spillage of these compounds. Through the adoption of good site practice it is possible to minimise the potential for impacts to occur.

14.4.2 Dredging and Reclamation Works

During the removal of the marine muds water quality impacts could occur from the high suspended solids and reduced Dissolved Oxygen levels. Dredging of a large quantity of the marine muds has already been carried out during the Advance Works Contract, this includes complete removal below and adjacent to the northern and southern reclamations, removal to -15 mPD in the central part of Shek Mui Wan, and to -10 mPD in an area just north of the southern reclamation. A marine access channel was dredged to -5.15 mPD in the shallow waters between Fat Tong Chau and the peninsula.

The complete removal of the remaining marine sediments is called for in the GVL design for SENT Landfill and this work is currently underway. The dredging is being carried out using grab dredgers. Various measures including the planned sequential removal of marine sediment from the Bay, adoption of careful and clean operations including restricted working areas and barge/dredger movements, minimal disturbance, restricted marine transport during the dredging activity and the use of a silt curtain to restrict the movement of sediment laden water through the opening in the seawall. The silt curtain will be opened to allow the barges to leave Shek Mui Wan and transport the muds to the Ninepins Dumping Ground. Before the silt curtain is opened, it is recommended that the dredging and filling operations temporarily cease to allow settlement of solids suspended in the water column. It is also recommended that the silt curtain is only opened during slack tides or on flood tides.

In parallel with the removal of the marine sediments filling operations will begin. Filling will be carried out using Suction Hopper Dredgers supplying the marine sand fill material to the site through floating pipes from a nearby anchorage. As discussed above, the impounded water will be discharged to the marine waters of Junk Bay. It is likely that the filling operations will increase the suspended solids in the lagooned water and will cause a reduction in the Dissolved Oxygen level, this in itself will not create any significant water quality impacts. However, if this water to be discharged to the marine environment it has the potential to impact on the receiving water quality through an increase in suspended solids and turbidity levels with a consequent reduction in Dissolved Oxygen.

14.4.3 Liner Leakage

Some seepage of leachate from SENT Landfill is inevitable however this is a very small quantity; but it does nevertheless represent a chronic impact on the local ground and marine water quality. A detailed discussion on the likelihood and risks associated with leakage of leachate through the liner is given in Chapter 13; Hydrogeology. In summary it is estimated that the maximum potential leakage of leachate through the liner system is 82.4 L/day for the whole (approximately 100 Ha) of SENT Landfill, which is some 20% below the USEPA's allowable leakage rate of 1 L/Ha/day, assuming a 1 metre head of leachate and a factor of safety of 3.

Any leakage of leachate would pass into either the groundwater drainage blanket (for the currently land based area of site) or into the site formation materials (for the currently marine based area of site). In the former case this would enter the groundwater and after testing as part of the EMP either be discharged with the surface water drainage or to the leachate treatment facility. In the latter case it would be significantly attenuated during its passage through the site base materials and gradually flow towards the sea.

14.5 MITIGATION MEASURES

14.5.1 Fuel Stores

A spill prevention plan for on-site fuel and oil storage areas should be devised, this would include a spill management plan which will include measures to cater for the containment, and clean-up, of inadvertent leaks or spills. Additionally all fuel and oil storage areas should be bunded and lined with an impermeable barrier to hold any leakage and prevent contamination of the surrounding areas and waterways.

14.5.2 Reclamation Works

It is understood that at present the actual filling method is still to be decided, however it will be necessary for the filling method to incorporate a number of measures to minimise the impacts as the lagooned water is discharged to the marine environment. As stated previously in the GVL tender design submission to EPD, discharges will comply with the Technical Memorandum on Effluent Discharges (TMES). An extract of the TMES is given below in Table 14.1. However, it is not expected that any pollutants other than high suspended solids levels and possibly some floatables will be present in the lagooned water.

Table 14.1 Standards for Discharged Effluents

Determinand	Flow Rate (m^3/day)		
	≤10	>10 and ≤6000	≥6000
Suspended Solids (mg/l)	50	30	Seek EPD advice

Note: Refer to TMES for complete set of Effluent Standards for Junk Bay WCZ
Source: TMES, Table 10a; Standards for effluents discharged into the inshore waters of Southern, Mirs Bay, Junk Bay, North Western, Eastern Buffer and Western Buffer Water Control Zones, EPD.

Methods of ensuring compliance with TMES and the Water Pollution Control Ordinance (WPCO) may include the use of lagoons and/or sand traps which will allow the settlement of solids, and the use of nets if required to catch any floatable materials. However where possible lagoon would be avoided and water discharged via sand traps.

Four sand traps will be positioned strategically along the perimeter cut-off channels the location of sand trap number one will be at approximately N 815222 and E 846746. Sand trap number two will be located at approximately N 815084 and E 846490. Numbers three and four sand traps will be located at approximately N 815350 and E 846315. The sand traps are designed to operate via induced hydraulic flow over a designed fall. This will cause water containing suspended solids to meet mechanical apparatus. The apparatus will consist of a perforated slab which is located at the end of the fall at the base of the trap this will contain 150mm diameter holes filled with a filter media. The filter media will be used to trap suspended solids, directly above this will be a bar screen which trap floating debris. The surface water will then be discharged to the marine water. Maintenance to avoid blockages and the resultant circumvention of the apparatus will need to be carried out on a periodic basis, particularly after storm events when floatables could block the bar screen.

The rate of filling of the marine infill area will have an effect on the quality of the water discharged. If the filling rate is increased, less settlement within the lagoons or sand traps will occur and the displaced water will contain a higher sediment loading therefore requiring more treatment (i.e. longer settling times), prior to discharge. The quality of the fill material will also affect the quality of the water discharged. If the fill material contains high levels of fine material then longer settling times will be required. The fill material already identified for the SENT Landfill site contains less than 10% fines and as such will require lower settlement times prior to discharge. For the finer material very long settling times are required, i.e. for a particle size of 0.01mm the settling velocity is 0.42cm per minute, and for complete settlement in a lagoon of 2m depth, a settling time of 7.9hrs would be required (see Table 14.2).

It is recommended that monitoring of the water quality in the lagoons should be included in the EMP in terms of suspended solids concentration. Also monitoring of the quality of the water discharged from the lagoons and sand traps should be carried out.

Table 14.2 Settlement Rates of Suspended Particles

Particle Size (mm)	Falling Speed (cm/sec)	Settlement Times	
		Lagoon of 2m Depth	Lagoon of 3m Depth
0.2	2.1	2 min	2.4 min
0.1	0.74	4.5 min	6.8 min
0.05	0.17	19.6 min	29.4 min
0.01	0.007	7.9 hrs	11.9 hrs
0.005	0.0017	32.7 hrs	49 hrs

14.5.3 Liner Leakage

The small quantity of leachate seepage (82.4 l/day) will be spread ever the whole landfill base. This quantity will be divided, with some entering the groundwater drainage blanket and being tested and treated if necessary, and the rest being gradually attenuated during its flow to Junk Bay. The extent of attenuation will increase when the adjacent reclamations are completed. Given the above, no additional mitigation measures are considered necessary to deal with the routine seepage of leachate.

14.6 CONCLUSIONS

At present the specific methodology for the reclamation of the marine infill area is not finalised and it is not possible to quantify the impacts associated with the reclamation work. It is expected that mitigation measures, in the form of settlement lagoons, will be required to prevent any adverse impacts on the receiving marine water quality. The settlement lagoons will have to be designed so that sufficient settling time is allowed for the effluent water to become in compliance with TMES. The final design of the lagoons can only be carried out when more information regarding the particle size distribution of the fill material, the rate of filling and the detailed method of filling are available, it is therefore recommended that the design of the lagoons is carried out as part of the CAP.

The calculated quantity of routine leachate seepage is small and this combined with the protective monitoring system in the EMP and the natural ground attenuation reduces any potential impacts from routine seepage to acceptable levels.

Landscape & Ecology

Chapter 15

15 LANDSCAPE AND ECOLOGY

15.1 INTRODUCTION

This section provides an assessment of the preliminary landscape proposals put forward by GVL and illustrates how landscape restoration works will be achieved throughout phased operations over a 15-17 year period and an aftercare period of approximately 30 years. The main intention of landscape restoration is to return the landfill site to as natural a form as possible, providing both natural scenic areas for walking and informal recreation and to create a physical and visual buffer between Clear Water Bay Country Park and the adjacent industrial developments (TIE & Area 137).

The sections below briefly explain the proposed layout and landscape features in terms of topography, drainage and vegetation (see also the Landscape Master Plan, Figure 15.1) assessing their suitability upon existing ground conditions and local vegetation. In this way, it can be seen how landscape areas will be created which blend into the surrounding natural landscape. General comments are made on GVL's proposals, together with further recommendations, for elements which should be considered as the scheme progresses.

A review of the baseline terrestrial ecology of the site is then presented, together with an updated ecological assessment, based on that provided at the CEIA stage. The landscape planting proposals are then assessed on ecological terms.

15.2 LANDSCAPE PROPOSALS

15.2.1 Topography and Ground Modelling

The rocky, cliff-edged coast and high peaks and ridges create a spectacular landscape along the Peninsula which will be reflected in the proposed landform. Gradients to restored slopes will blend into existing contours where possible, mainly set at 1(V):5(H) although some are set at 1(V):4(H) to improve the site's natural appearance.

15.2.2 Drainage

The efficient management of surface water drainage is most important to prevent environmental and operational problems. Drainage on the restored landfill will accommodate progressive settlement and be designed as an attractive addition to the landscape. The permanent drainage channels will use rock and boulders to simulate a natural stream bed.

All drainage collection channels will be integrated into the contours of the final cap as much as possible. The channels will generally follow the contours of the final cap in order to collect and convey water efficiently whilst being aesthetically pleasing. The downslope drainage channels are located within the incorporated valleys of the proposed landform, most of which will drain into the perimeter channel, much like a natural waterway feeding the main stream of a catchment area. Surface water drainage proposals are described in detail in Chapter 12.

15.2.3 Soils

The levels of the waste will be overtopped during filling operations to allow for settlement, which will occur after restoration. The maximum height of the completed landfill will be approximately 135mPD. The areas will be overtopped to an approximate magnitude of 10%

to accommodate expected settlement, thus leaving a maximum finished height of 125mPD.

Upon reaching final grades in an area, waste will be covered with a cap (as described in 4.11 above). The soil layer will be a minimum of 1.5 metres thick and is designed to sustain a grass sward and low shrubs. Medium (5 to 12 metres) to tall (> 12 metres) shrubs and trees will be planted in soil depths conducive to their root types.

15.2.4 Phasing of Operations

The site will be filled in phases to minimise the visual impact of landfilling operations and be progressively restored, with a vegetation cover established as early as possible. This will also reduce erosion of the capping layer and infiltration of water into the waste.

Each phase of the landfill will be hydroseeded in order to establish a good grass cover and provide a quick method of reducing the visual impact of the landfill. Hydroseeding will also be used as a temporary slope cover on intermediate slopes during site operations and as a cover for the excavated slopes above the surface water cut off channel.

During the initial stages of the development, the planting of trees and shrubs and seeding operations will form part of a series of trials to determine species success and suitability. Further details of these trials are outlined in Section 15.3.

15.2.5 Planting

The proposed woodland and scrubland areas are designed alongside areas of open grassland, used for passive recreation as well as screening the on-going landfill operations. Irregular swathes of woodland and scrubland planting are proposed, in keeping with the existing landscape pattern and to enable planting to continue throughout the various stages of site development. Within the site, woodland areas will generally occur along valleys. Adjacent to these, and within woodland plantings, shrubs and scrubland will feature, both as an understorey and as a transition between grassland and woodland habitats (see Figure 15.1).

Screen planting will be provided in the site infrastructure area, particularly around the gas and leachate treatment facilities (see Figures 9.1 and 11.1). The initial infrastructure plan places Government and Contractor's offices near the coastline, provides windows looking out to the shore and enhances the view with landscaping. These landscaped areas will help the site to blend in visually with the Country Park, and remain as a buffer after the site is landlocked.

Once established, planting will not only assist in control of erosion, but also provide important wildlife habitats and enclose and enhance views to and from the site.

A preliminary survey of existing vegetation has been carried out and species present on the landfill site recorded. Plant mix composition and choice of species reflects this information, along with knowledge both of the typical vegetation of the area and the various topographical and climatic factors affecting the site. For detailed information with regard to choice of species see Section 15.3 and Table 15.1.

Table 15.1 Landscape Planting Species Lists

PROPOSED SPECIES FOR WOODLAND AREAS	
Trees	*Acacia spp., including confusa, mangium & auriculaeformis* *Celtis sinensis* *Ficus microcarpa* *Ficus virens* *Litsea virens* *Machilus spp* *Murraya paniculata* *Schefflera octophylla*
Shrubs	*Ardisia crenata* *Clerodendrum fortunatum* *Ilex pubescens* *Lantana camara* *Ligustrum sinense* *Melastoma sanguineum* *Microcos paniculata* *Phyllanthus emblica* *Rhodomyrtus tomentosa* *Rhus chinensis*
SPECIES PROPOSED SPECIALLY FOR COASTAL AREAS	
	Eucalyptus torrelliana *Cerbera manghas* *Hibiscus tiliaceous* *Macaranga tanarius*
PROPOSED SPECIES FOR SHRUB/SCRUBLAND AREAS	
Shrubs	*Clerodendrum fortunatum* *Diospyros vaccinioides* *Gordonia axillaris* *Ilex pubescens* *Ligustrum sinense* *Melastoma sanguineum* *Mussaenande pubescens* *Phyllanthus emblica* *Rhaphiolepis indica* *Rhodomyrtus tomentosa*
PROPOSED SPECIES FOR GRASS MIXES	
	Cynodon dactylon *Paspalum notatum* *Lolium perenne* *Chloris gayana* *Eremochloa ophuroides* *Cenchrus ciliaris*

15.2.6 Site Features, Access and Circulation

A permanent access road located parallel to Road D6 will be developed during the course of landfill operations. This access road is designed and constructed in accordance with Tender Specifications with a carriageway width of 10 metres over operational areas (reduced to 4m on completion of works) and 4m in other areas.

A landscape buffer zone will be provided in the area between Road D6 and the site access road. This will consist of evergreen, or other coastal plantings, which are suitable for screening.

The permanent maintenance vehicle and pedestrian access track across the landfill will be designed and constructed to create minimum visual intrusion. In addition to providing access for maintenance personnel and equipment, the roads will be situated to increase access to recreational footpaths and focal points, and be constructed of materials such as gravel and stone, in keeping with the character of the site. In addition to the access track, footpaths for hiking will provide access into all areas of the site.

Several nearby existing trails and footpaths are affected by the development. The High Junk Peak Hiking Trail is of particular note and is to be temporarily diverted during certain phases of the landfill development. The low-intensity informal recreational activities proposed for the site, such as hill walking, sitting out and picnic areas, will complement the existing pedestrian facilities available in the surrounding area. Pedestrian routes on the restored landfill are designed to link with adjacent existing footpaths, to provide a variety of routes up and down the hillside and along contours and to be compatible with the rural setting of the site.

In certain locations sporadic outcrops of boulders will feature, to create microclimates and natural-looking areas to sit, view and rest.

At strategic viewpoints along footpaths, lookout pavilions styled in the local architecture command vistas of the surrounding coastline. In adjacent areas away from footpaths quiet informal spaces are to be set aside for seating, and landscaped with specimen plantings and natural planting beds. A system of directional and informational signing will be developed to guide and inform the public throughout the site and adjacent areas. The signs and site fixtures will be developed in a particular style to provide the site with its own unique identity.

The GVL design has important beneficial features over the conceptual design, these include:

- the removal of surface water discharge point No. 5 (Joss House Bay), this reduces the overall impact on the Country Park as the need for excavation, construction works and subsequent replanting is removed in this area,
- the rock face/slope located eats of the site infrastructure area will remain intact reducing the overall visual impact of SENT Landfill form the Country Park. Previously this slope was to be excavated and enlarged.

15.2.7 Landscape Planting Within Clear Water Bay Country Park

The landscape planting will be extended into those areas of Clear Water Bay Country Park affected by the project. As can be seen from both Figures 15.1 and 15.2, Advanced Planting has been carried out adjacent to the surface water drainage channels through the Park, and final restoration planting will be provided around the boundary of SENT Landfill.

15.2.8 Landscape Maintenance

A Management Plan and accompanying document should be provided as part of the restoration proposals. These should clearly describe a maintenance regime for landscape works over an agreed number of years on completion of landfill works and also include operations to landscaped areas at the end of each particular phase of development. The documents should detail operations to be carried out in each year; such as grass trimming, replanting, thinning, pest and disease control and regular litter collection. These are all essential factors to be considered for the overall success of the landscape restoration proposals.

15.3 SPECIES & PLANTING TRIALS

15.3.1 Species Proposed

In order to provide a good vegetation cover for the completed landfill, the selected shrub and tree species will be made up of a mix of indigenous species, and introduced species with proven adaptability to Hong Kong that are readily available (see also Section 15.3.2 below). Shrubs are included in the woodland mix in order to provide an understorey layer to the structure of the woodland. A list of proposed tree and shrub types provides a basis from which various planting mixes will be formed (see Table 15.1).

Some pioneer species have been included in the list to ensure immediate and effective cover. It is proposed that these will be planted at a ratio of approximately 60 pioneers to 40 climax species. However this will be subject to approval of the detailed landscape plan for each of the areas.

Tree and shrub seedlings are to be hand planted during the growing season following hydroseeding. For the mixed woodland areas, planting will consist of approximately 75 percent trees to 25 percent shrubs.

Planting will be undertaken during the accepted planting seasons with every effort made for this to be carried out at the beginning of the season to aid tree/shrub establishment.

15.3.2 Species Suitability

Tree and shrub species will be selected based on their known adaptability to the site's harsh conditions, particularly on the upper, more exposed hillslopes. These conditions include windblow, thin poor soils, drought and susceptibility to fire. Salt spray could also be a problem near to the sea, although it is likely that the site will be sheltered by the adjacent reclamations, and marine tolerant species will be planted in this area.

As hill fires are a major problem in Hong Kong and the SENT area is particularly prone to fires, firebreaks will be established on the site. Planting areas will be split into fire control blocks by firebreaks formed by roads, drainage channels and species of trees and shrubs fairly tolerant to fire, in 'rows' of at least five deep. Tree species include *Acacia confusa, Tristanis conferta* and *Melaleuca leucodendron*, with shrubs such as *Gordonia, Rhodomyrtis* and *Coprosma*. Where possible, trees in firebreaks will be high pruned to prevent grass fires becoming crown fires.

Although eucalyptus and pines may be used on the site, they are known to be susceptible to fire and will only be used as specimen plantings or small open groups. It is proposed that Eucalyptus species be included within the restoration planting for Phase I which will act as the planting trial. If the planting is successful it will also be used in subsequent phases.

As addressed in the CEIA, the Masterplan should include the possibility of coastal type vegetation which could be reflected in the edges between the park, shoreline and adjacent roads. Although this is mentioned briefly in the tender design plant lists (in Table 15.1), the concept of strand type vegetation typical to Hong Kong shores could be expanded and referenced on the Masterplan drawing.

Careful selection should be made of plant materials for specimen planting beds within pavilion and picnic areas, as well as throughout the site to ensure the use of proven low maintenance materials. Since the restored landfill surface is expected to settle over time, and due to the size and topography of the area, a piped irrigation system would be impractical and is not recommended. For this reason regionally local native plants that withstand drought and that can utilize natural precipitation patterns have been recommended.

Species chosen also have predominantly shallow rooting systems which are therefore less likely to damage the membrane cap. Where deeper rooting species are required, additional depths of soil should be provided to increase the depth of cover for the membrane layer.

15.3.3 Monitoring of Advanced Planting and Planting Trials

The Advanced Landscape Planting (shown on Figure 15.2) has not yet been included in a regular monitoring programme. It is recommended that these plantings be monitored and the sampling results be used to guide the remainder of the revegetation programme. In addition to quantification of survival, data on growth rates should be recorded by species. Photographic records of the restoration from fixed points should also be maintained.

Restored and revegetated plots should be sampled using procedures to estimate total plant cover by species per unit area. Depending on the type of vegetation which becomes established on re-seeded sites, line intercept and/or circular plot methods may be considered. For tree species, total height and breast-height diameter should be recorded. Again, statistical rigor should be a primary consideration to facilitate comparison with undisturbed sites and baseline conditions.

As discussed briefly above (Section 15.2.4), planting trials will be undertaken during the first phases of development to determine the most appropriate seed and plant mixes for the area and methods of implementation. Trials should experiment with both single species and combinations of species in trial plots on the site. Tests should be controlled and certain factors such as grass seed rate should be kept as constants to maintain a standard of comparison. Tests should also be conducted using a variety of ground preparation methods such as fertilisers and soil manufacture and improvement techniques, including the use of refuse and sludge composting techniques. The possible effects of landfill by-products on new and existing vegetation should be investigated and any effects over time monitored. The results from these trials will then help determine species and methods most successful with regard to specific site conditions. Planting mixes and methods of implementation will be amended and updated to reflect these findings during the on-going phases of landscape works.

15.4 REVIEW OF LANDSCAPE PROPOSALS AND RECOMMENDATIONS

15.4.1 Review of Preliminary Landscape Design

Prior to finalising the choice of species for tree and shrub mixes, a more detailed study of the existing vegetation pattern on the site and immediate surroundings will be carried out under the EMP, and results incorporated into the final design and written documentation. The landscape plans should be annotated with further details of the proposed pioneer species.

Planting species have been chosen reflecting the site's location and restrictions, namely fire risk, drought and exposure. In general species appear suitable for their chosen designation, though the growth of *Lantana camara* should be monitored to ensure it does not oust other species and become rampant. Ongoing maintenance and planting trials should establish whether this species would prove invasive.

Landscape management and maintenance is essential to the overall success and maturity of the proposed design. Considering for instance that topsoil depths should be sufficient for the growth of shrubs and trees, there will also be much competition from weeds and faster growing species. Constant attention, with spraying, thinning and similar operations will be required to ensure that the original investment in trees, shrubs and hard structures will achieve and maintain the desired effect of the restoration in the minimum amount of time.

15.4.2 Review of Other General Aspects

Government may wish to give consideration to extending the landscape policy throughout and within areas adjacent to the Country Park, such as the proposed TIE and Area 137 industrial developments. This would achieve the benefits of consistency and visual compatibility within the constraints of appropriate species selection, and further the integration of any proposed structures with their green surrounds, avoid a harsh juxtaposition of hard and soft environments and improve views to and from the viewing areas.

15.5 ECOLOGICAL ASSESSMENT

15.5.1 Impacts on Terrestrial Flora

The baseline terrestrial ecology of the SENT Landfill site is shown on Figure 15.3. Of the flora present within the site, one species of plant, *Gardenia jasminoides*, was listed as protected under the Forestry Regulations (Forests and Countryside Ordinance Cap. 96, Sec. 3) in the CEIA. This plant has since been removed from the list of protected species according to the ordinance revision gazetted in May 1993.

The only other protected plant known to occur in the general vicinity of SENT Landfill is the sulphur orchid. This plant was not recorded during baseline surveys of the study area, therefore is not predicted to be impacted by the project.

The macro-habitats found on the site are common in the general area, and many are largely the result of human use of the area for agriculture, residence, and managed woodland. Therefore, the impact of the loss of these habitats is predicted to be of no conservation significance.

One habitat of potential ecological interest is the fresh water marsh south of the former settlement of Tin Ha. The relative rarity of this habitat was noted in the CEIA and based on that report's recommendations, this area was studied further, and results were presented in the Terrestrial Ecology Survey (Ref 15.1).

The marsh proved to be relatively species poor, and the conservation value of the wetland was considered to be minor. No rare or endangered species were recorded. Therefore, the impact of the loss of this wetland is likely to be minimal.

The landfill project will encroach on areas within Clear Water Bay Country Park. Because there were no features of the flora within the Country Park which were of special conservation significance, the impact of the project operation will be loss of vegetation and alteration of topography. Loss of vegetation will be a medium-term impact which will be addressed through implementation of a comprehensive re-vegetation plan.

15.5.2 Impacts on Terrestrial Fauna

During the baseline and supplementary surveys, no records were made of features such as nest sites, burrows, or trails which would indicate high levels of wildlife use of the site. The wildlife recorded on the site was typical of Clear Water Bay peninsula. The only avian species of particular note was the grey bushchat, which was recorded as a winter visitor. Because of the high mobility of the avian community and the absence of noteworthy nesting or feeding sites which would link birds closely with specific habitats or locales, it is expected that impacts to birds from development of the project would be minimal.

Use of the area by small to mid-sized mammals including civets was recorded (civet presence documented by recovery of scats only). The larger mammals are protected by the Animals and Plants Protection Ordinance, Cap. 187. These would be expected to continue using the area during construction of the landfill site and during the operational and restoration stages. However, it is possible that disturbance of soils and subsoils during site preparation could cause mortality among smaller burrowing mammals such as the ferret badger.

There were no components of the local fauna which were endemic to the proposed disturbance areas within the Country Park. Therefore the impacts on the Country Park are not considered to be more significant than on the surrounding areas which support similar habitat types.

15.5.3 Mitigation of Impacts to Flora

Of the plant species recorded during the baseline studies, eleven species and one genus (*Machilus* spp.) included in the landscape planting species list are native plants which attract frugivorous birds in Hong Kong (Ref 15.2). Because some species of bird which winter in Hong Kong may be subject to dietary stress due to lack of fruit bearing shrubs and trees (Ref 15.3) re-planting such trees is considered to be an important means of enhancing post-disturbance habitats. These species (and one genus) are listed below in Table 15.2. Use of these species in revegetation should be encouraged to restore a native plant community to the site and promote long-term mitigation of the loss of the baseline vegetation.

Table 15.2 Species proposed for use in SENT revegetation which attract frugivorous birds in Hong Kong.

Celtis sinensis	*Melastoma sanguineum*
Ficus microcarpa	*Microcos paniculata*
Ficus virens	*Rhaphiolepis indica*
Ilex pubescens	*Rhodomyrtus tomentosa*
Macraranga tanarius	*Rhus chinensis*
Machilus spp.	*Schefflera octophylla*

Other plant species recorded on the site, and of known utility to frugivorous birds on Hong Kong, are not included in GVL's proposed restoration plan. These species are listed in Table 15.3, and, because they are native to Hong Kong, it is recommended that they should be included in the final restoration plan. Use of these species in revegetation will promote re-establishment of a native plant community on the restored landscape. This will partially mitigate loss of baseline vegetation during the construction phase.

Table 15.3 Native plant species recorded on the study area and attractive to frugivorous birds in Hong Kong, but not proposed for use in SENT revegetation.

Bridelia tomentosa	*Mallotus paniculatus*
Eurya japonica	*Psychotria rubra*
Ficus superba	*Rhus hypoleuca*
Litsea rotundifolia	*Sapium sebiferum*
Sterculia lanceolata	

Some of the species currently proposed by GVL for use in restoration of mixed woodland are not native to Hong Kong. These are three species of Acacia tree (*A. confusa, A. mangium*, and *A. auriculaeformis*). These species have been used in revegetation throughout Hong Kong, yet they are neither native nor do they provide abundant forage or habitat for wildlife. Therefore, it is recommended that consideration be given to not using Acacia, following consultation with AFD.

Similarly, some of the tree species proposed for coastal area revegetation are exotic (*Acacia confusa, Casuarina stricta*). Although these species readily establish on disturbed sites and grow quickly, it is recommended that they be deleted from the revegetation plant list in favour of native species.

Due to the long duration of SENT Landfill, it should be possible to order supply of some currently unavailable plant species from the Agriculture and Fisheries Department (AFD) nursery. Orders should be placed at least 24 months (and in many cases even longer) in advance of need to allow AFD adequate time to collect seed or root stock and develop seedlings. Greater supply of native plant species for use in revegetation in Hong Kong may result from a long-term programme such as SENT Landfill which will generate a sustained demand for seedlings. This would benefit other revegetation projects throughout Hong Kong.

15.5.4 Mitigation of Impacts to Fauna within Clear Water Bay Country Park

Although all habitats within the site will be lost during the construction phase, many of the more mobile terrestrial animal species will suffer only slight impacts. These animals are likely to move away from the affected area. Some animals will however be destroyed during construction, in particular any burrowing animals unable to quickly escape the site of disturbance.

The only means of mitigating loss of habitat for burrowing animals is to conduct thorough pre-disturbance surveys to identify and mark active burrows. Immediately prior to disturbance of the site the burrows should be hand dug and any captured animals should be released in protected areas distant from the disturbance area.

Impacts of habitat destruction on birds will be mitigated over the long term by replanting with native plant species of documented value to wildlife (Ref 15.2, as discussed above). Effective use of such species has the potential to enhance local habitats for some migratory birds over the long term.

15.6 RECOMMENDATIONS FOR SURVEYS, MONITORING AND HABITAT RESTORATION

15.6.1 Baseline Survey Methods

Although activities on site are already in progress, where habitats have not been disturbed the first survey carried out under the EMP should be considered as the "baseline survey".

Time limitations during production of the CEIA dictated that baseline surveys be conducted only during November 1989. Additional baseline surveys during other seasons would increase the species lists for most groups, and for birds in particular. The resulting description of pre-disturbance use of the site would be more complete, and would provide a more useful comparison with monitoring data from restored sites. In contrast to birds, mammal records may not be greatly enhanced by additional surveys.

It would not be unusual for rodent numbers and species representation to increase during operation of the landfill. It is possible that introduction of pest species could adversely impact terrestrial ecology within Clear Water Bay Country Park. Therefore, it may be useful to document baseline rodent community composition for later comparison with the post-restoration rodent communities. This would also provide an index of the extent to which rodents were introduced to the area by operation of the landfill and would allow monitoring of changes in community composition or population dynamics which might result from landfill operation.

Baseline rodent data should be collected using live capture, mark, and release methods. Grids of live traps should be placed in representative undisturbed habitats and run for a minimum of three consecutive nights during each of the two EMP flora and fauna surveys which are to be completed prior to landfilling. Captured rodents should be toe-clipped or ear-tagged and released. Captured rodents should be identified to species level, and should be sexed and aged where possible. Species richness, relative abundance, and species diversity indices should be calculated and reported.

Additional baseline surveys should be conducted of breeding and wintering bird communities. Data from such surveys would be useful for comparison with post disturbance survey results. Based on the assumption that the post-restoration habitats will be relatively open for some time, it is suggested that belt transects be run rather than the suggested 0.25ha circular plots. Circular plots are typically used for the census of closed habitats where the observer can remain hidden from birds using the plot and where there is no sampling advantage to flushing birds from the habitat. Belt transects are typically used where the open habitat allows a line of sight to the edge of the belt and where flushing the bird from the sample plot is desired to achieve a total count.

Care should be exercised in sampling design to select a methodology which will lead to use of rigorous statistical testing of results. This is particularly true of the marine and avian sampling where species richness and community diversity indices may be high. Useful quantitative comparisons of pre-disturbance and post-restoration indices will rely entirely on a rigorous approach to selection and implementation of sample methodology.

15.6.2 Monitoring Survey Methods - Terrestrial Flora and Fauna

Terrestrial flora and fauna will be monitored under the EMP. The proposed monitoring schedule, at 6 month intervals, will be adequate to assess the progress of restoration of plant and animal communities. Fauna monitoring personnel should select weather conditions which represent the season of sampling, and are similar to those prevailing during the previous sampling periods. This will facilitate the comparison of data between sample periods with minimal requirement for allowances for weather-induced variation.

Monitoring of bird communities may also require belt transects to sample the open habitats expected to colonize the restored landfill. Belt transects are expected to provide a more accurate index of total species occurrence and relative abundance. Accuracy of these data will be critical to calculation of diversity indices, and to future comparisons with baseline or undisturbed sites. It is recommended that belt transects be used for bird sampling rather than the circular plots proposed in the EMP. As discussed above, circular plots have proven to be more useful in closed habitats than in open habitats.

It is recommended that rodent monitoring be included in the EMP until the commencement of operations and during the aftercare. Rodent communities on restored landfill sites may also be monitored to determine rate of recolonization and species diversity in restored habitats. Live capture, mark, and re-capture sampling procedures should be used as described above in 15.6.1. A grid layout should be used, and traps should be run for three or more consecutive nights during each sample period.

Should rodent infestation become a problem, it is recommended that rodenticides be used only on the active, non-restored portions of the landfill. Rodenticides should not be used within the Country Park or near the edge of the landfill boundary, as this may result in destruction of non-target mammals or birds.

Linear transects should be run across restored and revegetated sites to census burrowing activity and determine species presence. Burrow locations should be mapped and descriptions of burrow sites should be included in the sampling reports.

15.6.3 Recommendations for Habitat Restoration and Management

As mentioned above (in 15.5.1), it is important to plant native species which occurred on the site or on nearby areas prior to disturbance, and to select plant species which are of documented utility to local wildlife. It will be necessary for GVL to work closely with AFD plant nursery personnel to ensure that an adequate supply of seedlings is available. It is important to note that up to 2 years lead time will be required in some cases for AFD to collect seed or cuttings and to culture plant material for use in restoration. In the case of grass seed to be used in hydroseeding, it will also be important to work with local seed suppliers to ensure availability of native mixes.

Restored areas should be monitored after each period of heavy rain or typhoon to document problems with erosion or loss of replanted vegetation. Eroded areas should be repaired immediately using erosion control matting, replacing topsoil, and re-seeding or re-planting as needed. Photographic records should be maintained of all eroded areas and repair operations. Allowance should be made for repaired sites should they fall within the areas designated for sampling on six-month intervals.

Photographic records should be maintained from fixed points of all restored parts of the site. Photographs should be taken on a six-month interval at the time of vegetation sampling. Photographs from fixed points should be included in the sampling reports to visually document the progress of revegetation.

GVL's preliminary landscape proposals suggest that landscaping chemicals may be used on the site to control vegetative diseases or infestations. It is recommended that such chemicals be used strictly on an as-needed basis, and that no preventive, scheduled, or prophylactic treatments be applied. In the case of herbicides, it is recommended that glyphosate, or a similar compound be used as it is approved for use in or near water or wetlands, its toxicity to non-target organisms is limited, and it breaks down rapidly. Selection of pesticides should be made based on the same criteria.

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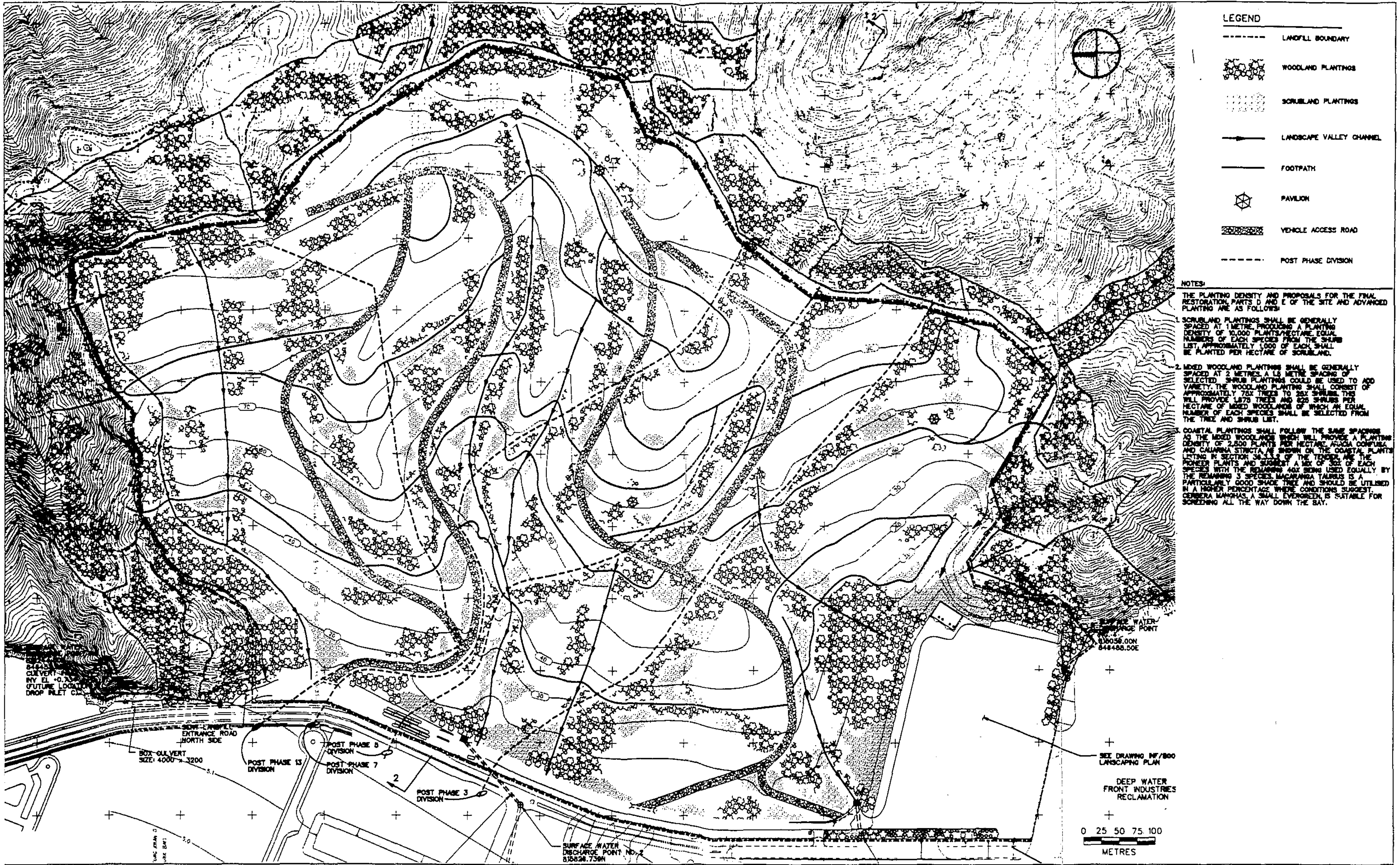

FIGURE 15.1

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LANDSCAPE MASTERPLAN

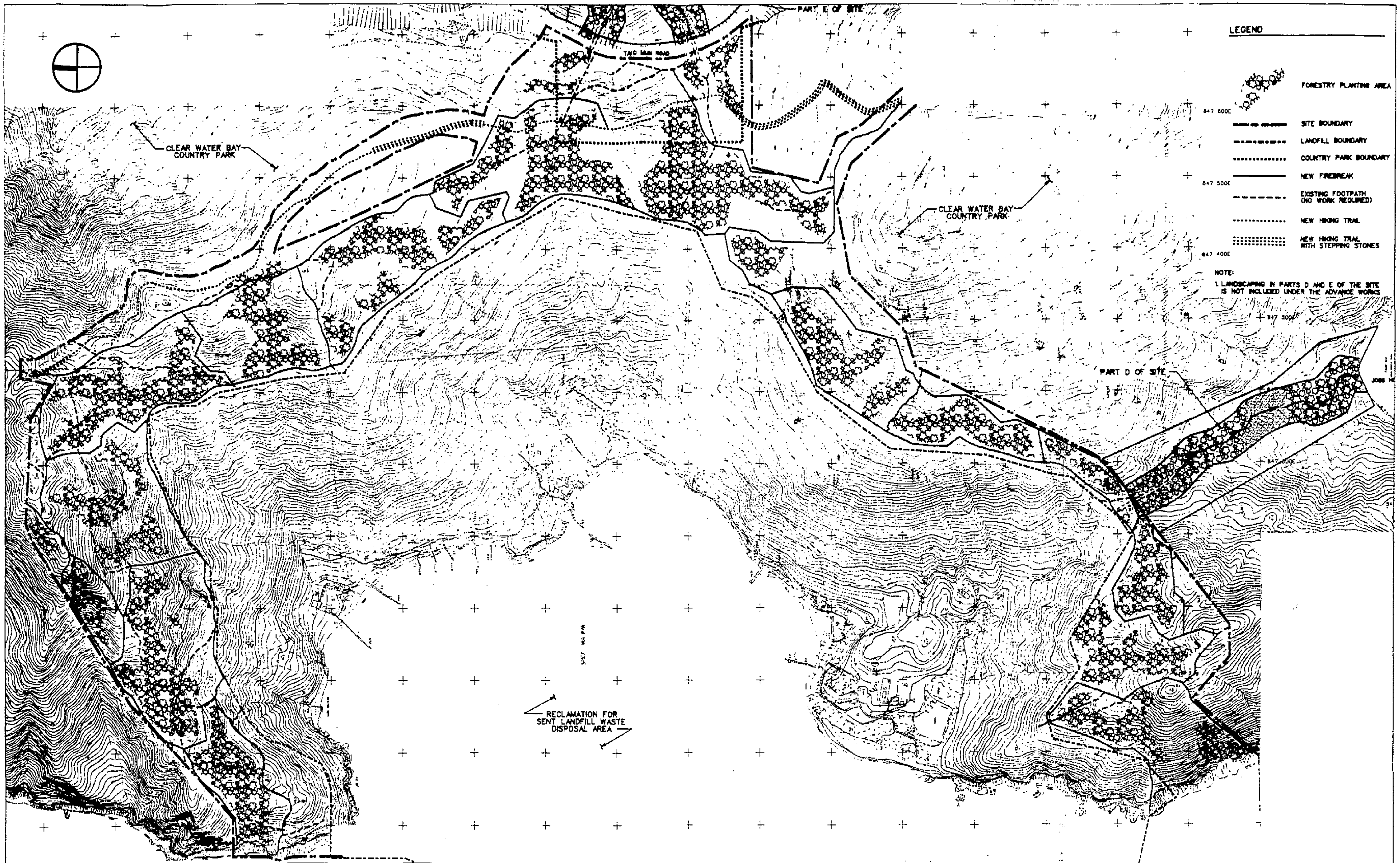

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FIGURE 15.2

ADVANCED WORKS PLANTING

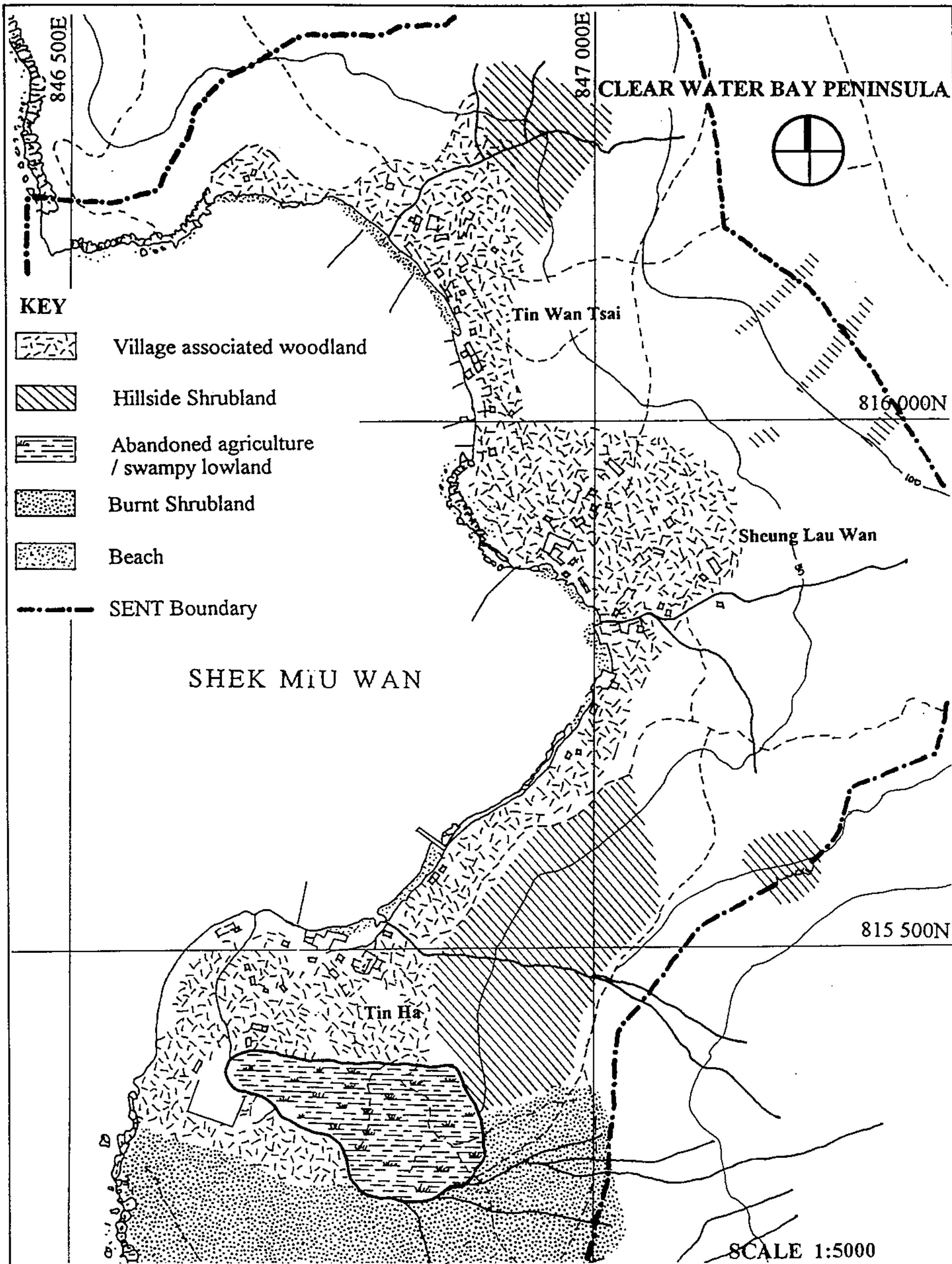

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FIGURE 15.3

BASELINE FLORA AND FAUNA

Source : Scott Wilson Kirkpatrick & Partners, CEIA

Visual Impact

Chapter 16

16 VISUAL IMPACT

16.1 INTRODUCTION

This Chapter is concerned with the visual impacts arising from the development, operation and restoration of SENT Landfill. The two key issues which were identified in the CEIA (Ref 16.1) visual assessment are:

(i) Impact of rock cut slopes; and

(ii) Impact to users of the Clear Water Bay Country Park.

The CEIA defined the zone of visual influence of the site, identified the key visual receivers and made an initial assessment of the magnitude and significance of the visual impact at each receiver location.

Since the GVL design for SENT Landfill incorporates a different phasing plan (see Figure 5.2) and rockface construction programme to the conceptual design, the visual impact at certain locations will be different to the CEIA. The GVL phasing plan has been adopted as complying with the specification. The aim of this visual assessment is therefore to illustrate, by means of a series of photomontages, the appearance of the site at different stages in its life, from a number of potentially critical visual receivers. The effectiveness of mitigative measures such as advanced planting and hydroseeding of soil slopes are then assessed, together with the appearance of the restored site following the completion of landfilling operations.

Due to their size all of the figures associated with this Chapter are enclosed in Volume II of the SEIA.

16.2 VISUAL CONTEXT

Located on the south eastern tip of Tseung Kwan O, on the west side of the Clear Water Bay Peninsula, the SENT Landfill site is visible from many locations across Junk Bay, Hong Kong Island (across the Tathong Channel) and the higher peaks of Kowloon. Figure 16.1 shows the visual envelope, the area of land from which the site can be seen at ground level. Taking into account views from high rise blocks, the visual envelope is in fact even larger.

The topography and landscape of the Study Area are described in Chapter 2.2 above. In summary, this is an extremely attractive area of the New Territories which is well used for recreational pursuits. The rocky coastline and high peaks create a spectacular landscape and overall the area is generally of a rural nature.

The site is surrounded by high steep-sided hills to the north, east and west, which form an almost continuous ridgeline providing a dramatic backdrop to the site. The hill sides are well vegetated with scrub and some localised wooded areas. The land to the east of SENT Landfill forms part of the extensively used Clear Water Bay Country Park.

The high visibility of the site from the Country Park will potentially lead to a significant reduction in the visual amenity of the area from the perspective of the park's transient users, if adequate measures to mitigate visual impact are not adopted. However, the topography of the peninsula restricts views of the site to a fairly small area of the Country Park (Figure 16.1).

Visual amenity of the site from more distant receivers will only be significantly affected by the high visibility of rock cut slopes. This is somewhat exacerbated by the light-coloured nature of the underlying bedrock found in the area. However the visibility of these faces will be attenuated by the relatively long distance from most SRs and the presence of numerous other visual detractors, including adjacent reclamations and TKO Landfill Stages II/III (TKO II/III). The appropriate use of phasing, in terms of both landfilling operations and landscape restoration, will additionally assist in the minimisation of impacts.

16.3 CRITICAL VISUAL RECEIVERS

Visible elements of the site will include rock cut slopes, stockpiles, the leachate treatment facility and gas plant, construction/operation equipment, lighting, access roads, surface water drainage channels, screen planting and transportation to/from the site.

The CEIA identified a number of SRs which are given in Table 16.1 below together with the receiver group, distance from the SENT Landfill site and importance of the visual impact.

The first stage of the SEIA visual assessment was to review the below SRs and identify those sites which could be affected by views of the landfill development and operations. Views from Clear Water Bay Country Park were determined to be of key importance and two locations along the High Junk Peak hiking trail were selected for detailed analysis. Three SRs across Junk Bay were also chosen: Chai Wan, Shau Kei Wan and Tiu Keng Leng.

Table 16.1 Visual Receivers

Receiver Group	Receiver	Distance from SENT Landfill	Importance of Visual Impact
Residential	Tseung Kwan O	3 km	Medium
Residential	Tiu Keng Leng (Rennies Mill)	3 km	Medium
Residential	Sai Wan Ho	5 km	Low
Residential	Heng Fa Chuen	3 km	Low
Residential	Chai Wan	3.5 km	Low
Residential	Siu Sai Wan	3 km	Medium
Residential	Shek O	5.5 km	Low
Commercial and industrial	Tseung Kwan O (Area 137 and TIE planned developments)	0-2 km	High
Commercial and industrial	Sai Wan Ho Ferry	4 km	Low
Commercial and industrial	Chai Wan Cargo Handling Basin	3.5 km	Medium
Recreational	Clear Water Bay Country Peak	1 km	High
Recreational	Tai Tam Country Park	5.5 km	High
Recreational	Shek O Country Park	3.5 km	Low
Recreational	Ma Wai Shan to Ng Kwai Shan (open space)	4.5 km	Medium
Recreational	Chiu Keng Wan Shan to Pan Tao Shan (open space)	3.5 km	Medium
Recreational	Boats in Junk Bay and the Tathong Channel	varies	Medium
Road users	Tseung Kwan O - P2 and D6	0-3 km	Low
Road users	Po Lam Road South	3.5 km	Low
Road users	Tai Tam Road	4.5 km	Low
Road users	Cape Collinson Road	3.5 km	Low
Road users	Shek O Road	7 km	Low

16.4 MEASURES TO MITIGATE VISUAL IMPACT

The design and operational plan for SENT Landfill include extensive measures to mitigate the visual impact of the site. These include the following:

- Restoration and landscaping will be performed in phases as the final levels are reached and the cap installed;
- The sequencing of the site development maximises the use of final restored and intermediate waste slopes to minimise visual impact caused by landfilling and related activities. Outer slope areas of the waste fill will be developed first so that operations remain behind the operational bunds;

- Temporary vegetation cover will be provided on the upper soil slopes and all intermediate slopes by hydroseeding with a grass mix;

- Landscape planting will be provided adjacent to the access road D6 to in time ameliorate close range views of the site from the west, and form a visually attractive buffer between the site and adjacent developments;

- The restoration design and final contours will preserve all the adjacent ridgelines, minimising the effect on long term views from the Country Park;

- Provision of extensive landscape planting around the site infrastructure area, especially in the vicinity of the leachate treatment facility and the landfill gas utilisation plant. This will be particularly important in screening the buildings retained following restoration of the site; and

- Advanced planting around the northern, eastern and western perimeters of the site to mitigate views into the site from the Country Park, specifically users of the High Junk Peak Hiking Trail.

The visual assessment which follows illustrates how the above mitigation measures will serve in reducing the adverse impact of the project and enhancing the integration of the site with the surrounding landscape.

16.5 VISUAL ASSESSMENT

The visual assessment has been based on the five key viewpoints identified in 16.3 above. Photographs were taken at each location from representative positions. Photomontages were then produced for each of three stages in the life of the landfill, selected because they represent potentially "worst case" visual impacts, due to the extent of visible rock cut slopes and unrestored areas:

- phase 1 operation/phase 2 development;
- phase 6 operation/phase 7 development; and
- final restoration.

16.5.1 Viewpoint 1 - Shau Kei Wan

The residential area of Shau Kei Wan lies on the top northeast tip of Hong Kong Island and, although ground level positions are not within the visual envelope, long distance views of the site are possible from upper floor properties (see Figure 16.2). Long range views from this point are currently dominated by TKO II/III. The large expanse of exposed rock and soil slopes represent a significant existing visual detractor. The TIE is also a visual detractor from this viewpoint.

Phase 1 of SENT Landfill (1994-5, according to current programme) will be barely visible from this location (Figure 16.3) with the majority of activities screened by Junk Island. The visual impact at this stage is considered to be low as SENT Landfill is not a dominant element in the view from these properties.

By Phase 6 (2001), it is assumed that TKO II/III will be restored and visually integrated into the Clear Water Bay Peninsula. By this stage, SENT Landfill will be a more prominent element in the field of view (Figure 16.4). However, the use of hydroseeding on all intermediate slopes will mean that only the rock cut slopes at the north of the site are visually intrusive. The planned development of TIE will partially screen the northern part of the site hence the impact magnitude is considered to remain low.

Following final restoration (after 2009), the site will integrate aesthetically into the slopes of the peninsula behind (Figure 16.5), with Junk Island completely screening the leachate and gas treatment plants which will remain during the aftercare period. The long term visual impact from this location is considered therefore to be slight.

16.5.2 Viewpoint 2 - Chai Wan

Residents of the high rise blocks adjacent to the cargo basin, and other nearby housing, have existing mid-range views of parts of the site (Figure 16.6). TKO II/III is also visible, to the left of Junk Island, however it forms a less dominant element of the view from this location than viewpoint 1.

During Phase 1 (1994-5) the visual impact from this viewpoint will be of medium magnitude (Figure 16.7) with rock cut slopes in the southern part of the site forming a prominent element of long range views. Much of the site, however, is screened by Junk Island and reclamation activities to the north will also be visible.

By Phase 6 (2001) the visual impact will be reduced with the majority of the visible part of the site restored or hydroseeded (Figure 16.8). By this time it is anticipated that TKO II/III will be restored and adjacent developments (TIE and Area 137) at least partially completed. The latter will provide some screening of activities (particularly the site infrastructure area) from lower floor windows and itself be a visual detractor. The visual impact is considered to be low.

The restored site (Figure 16.9, after 2009) will be hardly noticeable from this location, with the remaining site infrastructure screened by the planned Area 137 reclamation and development. The visual impact is considered to be negligible.

16.5.3 Viewpoint 3 - Tiu Keng Leng

A number of properties at Tiu Keng Leng, or Rennies Mill, will have clear mid to long range views of the site (Figure 16.10). Almost all of the site is visible from these properties with Junk Island affording little screening. TKO II/III is a less dominant visual detractor from this viewpoint. The TIE reclamation is a visual detractor in the foreground of the site.

During Phase 1 (1994-95) rock and soil slopes will be visible, however the impact magnitude is considered to be low given the distance to the site from this viewpoint (Figure 16.11).

By Phase 6 of the landfill (2001) the majority of visible slopes will have been restored or hydroseeded. Potentially intrusive rock cut slopes will be concealed behind the ridge along the north of the site (Figure 16.12). The TIE development is likely to be more intrusive than SENT Landfill by this stage. The impact magnitude is considered to be low.

Following final restoration of the whole site (after 2009) there will be a slight potential residual impact from this area, since the landfill will appear to link Junk Island to the Clear Water Bay Peninsula when viewed from these properties (Figure 16.13). By this stage, however, it is anticipated that the TIE development will be complete. This will be a visual detractor which will partially block views of SENT Landfill. The residual impact is therefore considered to be negligible.

16.5.4 Viewpoint 4 - Clear Water Bay Country Park: Peak of Spur Tai Chik Sha

This viewpoint is located at a prominent viewing position on the High Junk Peak hiking trail at an elevation of approximately 180 metres. Virtually the entire site is visible from this point, with the peaks of Hong Kong Island in the background (Figure 16.14). The quality of the existing view is reduced by the adjacent reclamation (TIE), temporary access roads to the SENT Landfill site and dredgers removing sediments from the marine part of the site.

Following filling of Phase 1 of the site (Figure 16.15, 1994-5) a large expanse of reclaimed land will be visible. By this stage the advanced planting will not have matured sufficiently to screen site activities. The impact magnitude is considered to be high with no further scope for mitigation, since the nature of mid-range views has been changed with the loss of the bay.

By phase 6 (2001) the majority of visible slopes will be either restored or hydroseeded, giving the site a softer, greener character. Landscaping around the site periphery will have matured enough to provide partial screening at this stage (Figure 16.16). By this stage Area 137 and the TIE are likely to be significant visual detractors in the background. The impact of SENT Landfill is considered to be of medium magnitude.

Following final restoration (after 2009) the site will appear as attractive rolling open space, dotted with wood and scrubland areas, extending westward to join Junk Island (Figure 16.17). Although the view will be significantly different to the existing situation, the restored site will form a buffer between the Country Park and the planned adjacent industrial estates. The long term impact is therefore considered to be positive.

16.5.5 Viewpoint 5 - Clear Water Bay Country Park - Saddle Between Tai Chik Sha and Tin Ha Shan

Most of the site is visible from this location which is located on the High Junk Peak Hiking Trail at approximately 100m elevation (see Figure 16.18). Part of the site infrastructure area (the existing southern reclamation) is not visible. The dominant elements in the view are Junk Island and the TIE reclamation.

At Phase 1 (1994-95) the visual impact will be moderate to high with a large extent of reclaimed land visible (Figure 16.19). Advanced planting will, at this time, provide very little visual screening.

By Phase 6 (2001) the northern part of the site will have been developed and this will be highly visible from this position (Figure 16.20). Landscape planting should however provide moderate screening by this stage. The use of hydroseeding and phased restoration will reduce the area of soil and rock visible. The impact magnitude is considered to be moderate to high.

Following final restoration (after 2009) the view from this location will be extremely attractive (Figure 16.21) with the restored landfill stretching into the distance and integrating the peninsula with Junk Island. Landscape planting around the site periphery will have reached maturity, allowing filtered views across the site and Junk Bay beyond. The TIE will, however, be visually prominent from this location and may detract from the quality of long range views.

16.6 POTENTIAL IMPACTS OF LIGHTING GLARE

Some evening operations will be required at the site and lighting will be provided at the tipping face, site infrastructure area and permanent access road. Wherever possible, exterior lighting will be directed downward to minimise glare impacts.

General recommendations for the enforcement of mitigation of glare include:

- the use of low level lighting wherever possible and still be consistent with safety requirements;
- the design and location of lighting should ensure that light is directed only where needed; and
- the strength of light should be kept to a level at which the site can operate safely.

The proposed landscape planting would, when the trees reach sufficient height and maturity, help reduce the impact especially from low level sources along the access road and in the site infrastructure area.

No significant glare impact is anticipated, given the above mitigation measures.

16.7 IMPACTS OF WORKS OUTSIDE THE SITE BOUNDARY

The visual impact of the surface water channels and discharge points has been reduced by the removal of the need to discharge through discharge point No. 4, Joss House Bay. If the discharges to Clear Water Bay are not required then the visual impact will be considered as part of the assessment of more works (see Chapter 12).

16.8 SUMMARY AND CONCLUSIONS

The visual impact of the SENT Landfill is considered to be low to residential areas across Junk Bay. Some periods of medium to high visual impact will be experienced from viewpoints in Clear Water Bay Country Park during certain phases of the project. These will be partially mitigated by the landscape planting provided around the site periphery, but further mitigation is not practicable.

Given the extensive mitigation measures incorporated by GVL into the project design the visual impact of the development is considered to be acceptable.

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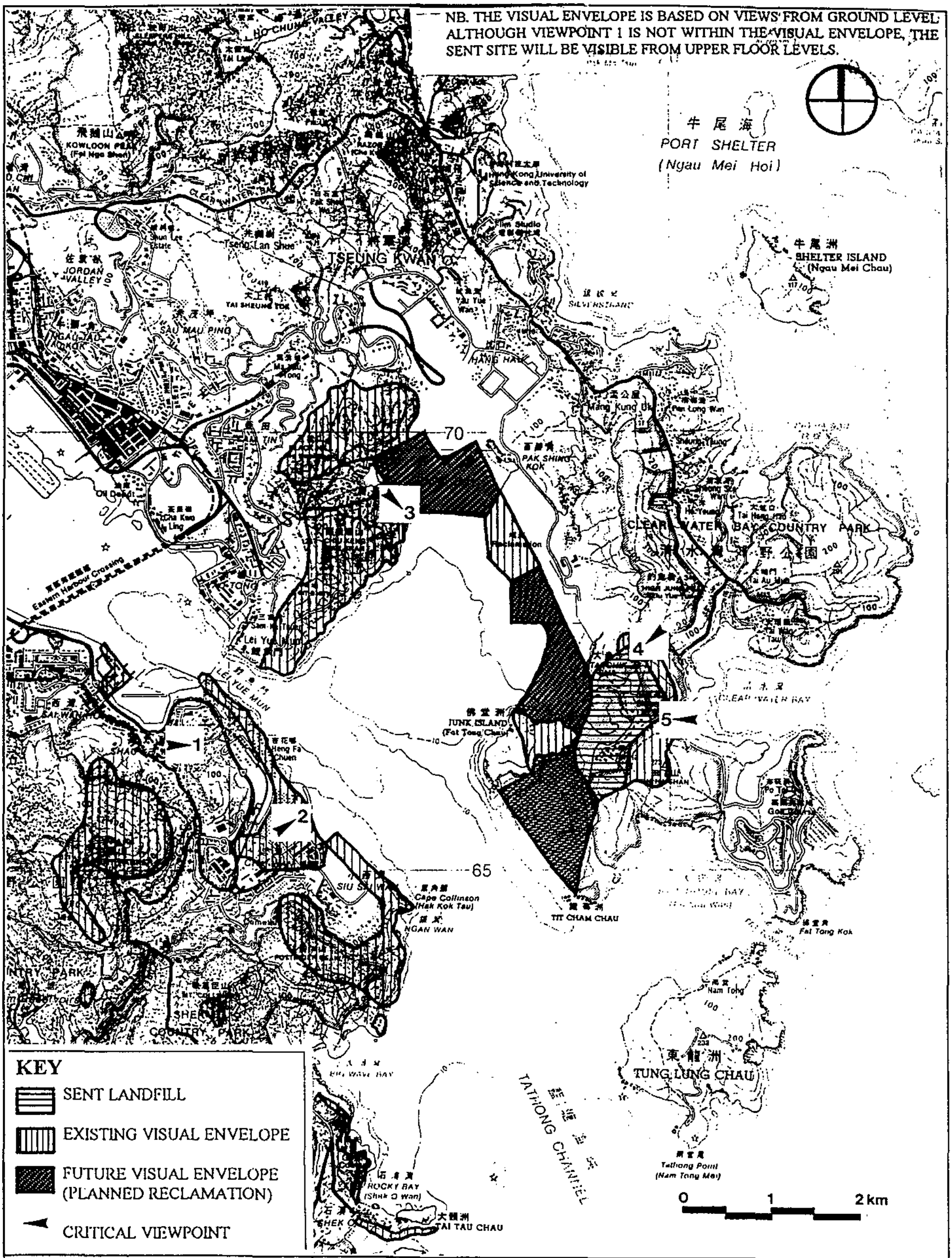

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FIGURE 16.1

VISUAL ENVELOPE AND LOCATIONS OF CRITICAL VIEWPOINTS

Execptional Traffic Impacts

Chapter 17

17 EXCEPTIONAL TRAFFIC IMPACTS

17.1 INTRODUCTION

This chapter identifies and assesses the potential impacts which are likely to arise during an exceptional waste input period and discusses practical mitigatory measures which would be required to prevent or reduce these potential impacts to acceptable levels.

17.2 THE EXCEPTIONAL WASTE SITUATION

During the Environmental Review stage of the planning of SENT Landfill, it was recognised that a situation could occur when one (or even both) of the strategic landfills (North Eastern New Territories (NENT) or Western New Territories (WENT)) could be unable to accept waste. This could result in significant additional waste inputs to SENT Landfill, and has been termed an Exceptional Waste Situation (EWS).

The priority under the above scenario is to ensure that SENT Landfill can still operate in accordance with the Specification and that environmental impacts off-site are minimised.

An assessment has been made of the "worst case" situation which might require exceptional extra quantities of waste to be accepted at SENT Landfill. This involves severe restrictions on or total closure of WENT and NENT Landfills necessitating redirection of Containerised Waste from the transfer station network, at full capacity in 1996/97, from each of the marine based, or marine capable, transfer stations:

HK Island East	1,200 tonnes/day
HK Island West	1,000 tonnes/day
West Kowloon	2,000 tonnes/day
North Lantau and Islands	1,200 tonnes/day
TOTAL	**4,800 tonnes/day**

Transfer of waste in containers by barge to SENT would require barge off-loading and container reception and handling facilities for a total of some 375 standard containers delivered by 4 separate barging operations involving 8 to 10 dumb lighters (ie. towed) or self propelled barges.

Provision is to be made for reception of marine transferred waste to SENT Landfill in the Tseung Kwan O Area 137 planning layout. APH Consultants (Ref 17.1) reported that 3500 SENT Landfill related vessel calls per year could be accommodated at the Northern Marine Basin. No marine traffic congestion problems are therefore anticipated. Barge traffic delivering landfill engineering materials and sludges from the SSDS treatment works at Stonecutters Island may be adversely affected by the temporary presence of the barges delivering waste under an EWS. Should congestion of marine traffic be anticipated with consequent disruption to river trade traffic then a proportion of waste from West Kowloon transfer station could be delivered by road with minimal disruption to traffic in TKO (40 vehicle trips per day would be required to reduce the number of barge movements by one). Alternatively, marine traffic could make use of the existing TKO(I) marine access point, which has available capacity.

The high capacity of the Area 137 Northern Marine Basin facility (due to an available quay length of 250 metres and associated handling area) is sufficient to meet the needs of the EWS with no significant adverse impact. However, it will only be possible to manage this traffic with the correct container handling plant in place.

Prior to construction of the Northern Marine Basin in Area 137, a seawall incorporating 150m of quay will be available for barges delivering sludges. It is probable that before completion of the Area 137 basin (possibly by 1997), this restricted length of available seawall would be inadequate to meet the needs of an EWS. In the interim it is recommended that the existing barge off-loading facility at TKO(I) be retained to act as an emergency back up facility.

As regards waste delivered by road to SENT Landfill under the EWS, this would be limited to that transferred from the following transfer stations:

North West NT	800 tonnes/day
Shatin	1,000 tonnes/day
Kowloon Bay	1,800 tonnes/day
TOTAL	**3,600 tonnes/day**

The total is equivalent to an additional containerised waste transfer operation of approximately 200 vehicle arrivals per day.

In addition it can be assumed that a proportion of the construction waste arising throughout the Territory would be delivered to SENT Landfill for disposal after processing of the primary waste stream at each of the two possible construction waste recycling centres being considered in the Territory in addition to the facility planned for TKO.

Assuming that between 20% and 40% of construction waste is unrecyclable (see Table 8.1) then assuming 32,000 tonnes/day of construction waste arising in the territory in 1996 there will be the following additional traffic delivering waste to SENT Landfill . This will be between 5,000 and 10,000 tonnes/day in 1996. The total likely increase in vehicle traffic accessing SENT Landfill is between 700 and 1200 vehicle trips per day.

Following implementation of the proposed Government controls on construction wastes and diversion of suitable materials to public dumps and recycling, the total wastes for disposal at SENT in the event of total closure of NENT and WENT is summarised in Table 17.1.

Table 17.1 Summary of Exceptional Waste Situation (EWS)

WASTE INPUT	Tonnes/day In 1996	Vehicles/day In 1996
Domestic waste by sea in container	4,800	-
Domestic waste by road container (1)	1,079	64
Commercial waste by road (1)	2,395	480
Construction waste by road (2)	17,900	3,580
TOTAL	**26,174**	**4,124**

Notes : (1) Ref 17.2, Figure 25.
(2) Ref 17.2, Figure 13.

The maximum delivery rate is projected to be during the afternoon peak hour between 17.00 and 18.00hrs when approximately 450 vehicles per hour are anticipated to access the site via roads D6, P1, D4, D3 and P2 from TKO Tunnel T1. The peak hour arrival patterns are based on surveys carried out at TKO Landfill Stages II/III in 1988-89.

The maximum delivery rate in 2006 is projected to be approximately 380 vehicles per hour via D6, D9, P1 and P2 (Western Coast Road to East Kowloon).

The duration of an EWS is difficult to determine as it would be greatly dependent on the cause of the closure of WENT and/or NENT. It is considered that in the event of a catastrophic failure such as an underground fire at WENT or NENT causing long term disruption, special consideration and appraisal would be necessary based on the situation at the time. The EWS is therefore only considered to involve a period of a few days up to a maximum of about 2 weeks.

17.3 POTENTIAL IMPACTS

During an EWS, it will be preferable to bring as much waste as possible by barge. This is because barge transfer is generally accepted as environmentally preferred when compared with lorry transfer due to reduced impacts stemming from larger load, quieter operation and the fact that road routes tend to involve closer proximity to sensitive receivers.

It is expected that road traffic will go through Tseung Kwan O Tunnel, Tseung Kwan O Tunnel Road (T1) and then Hang Hau Road (D6), that is, when the construction of P1 (Road connecting T1 and D6) is completed. If not, traffic will have to go through Po Hong Road (D1), Po Lam Road (D2), Po Lam North Road (D3) and Po Ning Road (D4) before reaching D6. During an EWS this will impose additional loads on the roads, particularly prior to P1 completion, roads going through populated areas such as D1, D2, D3 and D4 will be seriously affected. Following completion of road P1, there would be some relief to congestion in the TKO area, and following completion of the Western Coast Road (allowing traffic to bypass the TKO tunnel), minimal traffic disruption is anticipated.

The key potential problem will be queuing to access the site and associated potential fly tipping. If the turn around time for lorries (time to take from arrival at the site to weigh bridge check in, travel to the tipping face, tip the waste, weigh out and exit the site) is such that a backlog occurs then lorries will begin queuing at the entrance and approaches to the SENT Landfill. This queuing is time consuming and often viewed by drivers as intolerable. This situation will potentially lead to fly tipping (illegal disposal of waste at a location which is not a licensed disposal site) at the side of the road etc. Particularly vulnerable areas will be along the access roads to SENT Landfill (especially D6) and other areas of vacant land in the vicinity. GVL will be responsible for any fly tipping outside the landfill.

17.4 MITIGATION

Mitigation measures planned include the following:

- Marine based delivery of waste to minimise road traffic congestion.
- Use all 4 weighbridges to weigh vehicles in and use previous records to calculate weight of outgoing vehicles. This will speed up access and throughput and all vehicles could exit by the bypass road.
- Extra active tipping faces could be opened up to accommodate increased waste intake.

- Patrols may need to be initiated by GVL as a deterrent to ensure no fly tipping occurs. It is suggested that GVL could arrange a reciprocal agreement with the operators of WENT and NENT Landfills that any vehicle proven to have fly tipped will not be employed again.

- Initiate a program with the waste transfer operators to ensure that a regular inflow of waste is achieved and avoid different operators arriving at the same time.

- Phase delivery of construction waste recycling residuals to off peak times and control the opening hours of the landfill to accommodate the intake.

Vehicle arrival rates and projected maximum rates of input based on current forecasts of arisings are less than the maximum intake of 900,000 tonnes per month for which the site is capable, so no significant operational problems are anticipated.

17.5 CONCLUSIONS AND RECOMMENDATIONS

An EWS involving the diversion of waste from the other strategic landfills is a possibility although it would be expected to be of a maximum of about 2 weeks duration. This would result in a sudden increase of traffic to and from the SENT Landfill and would lead to:

- A maximum predicted road traffic flow of 454 lorry arrivals per hour;
- Queuing of vehicles on the public road;
- Capacity problems on roads and at junctions; and
- Need to add extra handling facilities at marine access area.

Mitigation measures have been identified which would deal with an EWS. These include opening up of extra tipping faces, speeding up the input and output rate of the lorries. A major aim is to avoid fly tipping causing disturbance to the neighbouring sensitive receivers. It is recommended, however, that an integrated Management Plan be jointly drawn up by GVL, the operators of TKO I,II/III and EPD for handling containers at SENT Landfill and TKO marine access points, based on the marine traffic arrival patterns predicted under the EWS prior to filling operations commencing.

REFERENCES

17.1 APH Consultants. Engineering Feasibility Study of Tseung Kwan O Area 137, Final Report (March 1993).

17.2 Hong Kong Government Environmental Protection Department. Monitoring of Municipal Solid Waste, 1991-92.

Adjacent Developments

Chapter 18

18 ADJACENT DEVELOPMENTS

18.1 INTRODUCTION

In order to determine the compatibility of adjacent developments in relation to both the construction and operation of SENT Landfill, the extent and nature of planned landuse in the study area has been identified. This Chapter reviews and assesses the relevant planned development proposals in terms of their sensitivity to the SENT Landfill development, particularly in terms of threshold emissions of odours, noise, dust and gases from the landfill.

18.2 SOURCES OF INFORMATION

Planned development adjacent to the site was identified through consultation with the Hong Kong Government Planning Department and Hong Kong Industrial Estates Corporation (HKIEC), together with a review of current development plans, maps and previous studies as follows:

- Tseung Kwan O Outline Zoning Plan, S/TKO/1
- Tseung Kwan O Development Plan, D/TKO/1[c]
- Layout Plan for Area 87 Tseung Kwan O, L/TKO - 87/1
- Tseung Kwan O Feasibility Study of Opportunities for Further Development (Ref 18.1).
- Engineering Feasibility Study of the Development of Tseung Kwan O Area 137 (Ref. 18.2).
- Junk Bay New Town Feasibility Study of Opportunities for Further Development (Ref 18.3).

18.3 IDENTIFICATION OF ADJACENT DEVELOPMENTS

18.3.1 Background

The study site and surrounding area was identified as a potential location for industrial development as early as 1957. In 1962, the Junk Bay Outline Development Plan was issued which allowed for approximately 60 ha of industry to be constructed on reclaimed land. In 1982, the Junk Bay New Town Study established the feasibility of developing a new town with industrial development located towards the south east of the area. The new town has been planned in three stages, the initial and second stages planned for the development of a population of up to 325 000. Phase III comprises an extension to this capacity of 115 000 and includes land adjacent to SENT Landfill. The latest Tseung Kwan O Outline Development Plan was approved by the Development Progress Committee in November 1990.

18.3.2 Adjacent Developments

Introduction

Proposed landuse immediately adjacent to SENT Landfill comprises a mixture of Deep Water Frontage Industry (DWI), Potentially Hazardous Installations (PHI) and high to medium technology industry (Figure 18.1). The planned development areas identified are:

- Area 87, Tseung Kwan O Industrial Estate (Hong Kong Third Industrial Estate) currently under construction; and

- Area 137, Port Facilities (DWIs, PHIs).

By definition DWI developments comprise industrial or warehousing operations which by virtue of their nature require access to deep water berths. PHIs are defined according to the storage of materials in equal quantity or greater than those specified in the U.K. Notification of Installations Handling Hazardous Substances Regulations, 1982. The remaining industrial developments are categorised according to the activities listed in Table 18.1 below.

TABLE 18.1 INDUSTRY CATEGORIES

Industry Category	Landuse/Activity
1A	Electrical & Electronics Food Processing General Industries Metallurgical
1B	**Chemical and Allied Industries:** • *Chemicals and Chemical Product Manufacturing* • *Oil Refining, Petroleum and Coal Products Works* **Food and Beverage:** • *Slaughtering, Preparation of Meat* **Metallurgical Industries:** • *Basic Metal Industries (e.g. aluminium, copper, iron, steel, lead, metal recovery)* • *Motor Vehicle Building/Assembly Repair* • *Ship Building/Repair*
1C	**General Warehousing:** • Oil Storage • Open Storage • Sand Storage

Area 87 (Hong Kong Third Industrial Estate)

Area 87 is located along the length of the western boundary of SENT landfill (Figure 18.1). The Area comprises approximately 95 hectares of land which will ultimately provide for 75 ha of industrial lots. It is proposed that the Area is developed in two phases to be completed by 1993/94 and 1995 respectively.

The site is zoned for Category 1B developments (see Table 18.1), however the detailed Area layout is still in the planning stage and specific industrial occupants have not yet been identified. However, consultation with HKIEC established that selection criteria will preclude multi storey operations, offensive trades and heavy users of fuel and water from occupying the site.

Area 137

Approximately 100 ha in size, Area 137 is located to the south of SENT Landfill site (see Figure 18.1). The Area is zoned to cater for Category 1B and 1C industrial purposes (which will allow for the development of land extensive industry and premises for warehousing and storage) and will be developed to accommodate port facilities supporting DWIs and PHIs.

An Engineering Feasibility Study of the planned development was completed in 1992 by APH Consultants (Ref 18.2) and a preferred concept identified in relation to the nature and layout of industrial units. The preferred concept was endorsed by the project Steering Group and EPCOM (Environmental Pollution Advisory Committee) in January and July 1993 respectively, and is expected to progress to the detailed design stage shortly.

The preferred concept recommended four sites towards the south of the Area (of the order of 40 ha) be reserved for PHIs, with an additional three sites (approximately 8 hectares) allocated for PHI related industry. The remaining northern component of the Area was recommended to provide for twenty two sites of DWI developments. Twenty per cent of these sites have been zoned for Category 1C purposes with the balance allocated for Category 1B purposes, which complies with the intentions of the Outline Development Plan.

Supporting development and facility areas were also identified and include:

- recreational facilities;
- two sewerage pumping stations;
- drainage reserves; and
- a buffer zone along the site boundary.

At this stage of the Area 137 development, specific industries have not been selected as occupants for the site. Industries which fall into the relevant categories are presented in Table 18.1, positive demand for the early provision of a bulk chemical storage facility has already been identified and it is known that the Hong Kong and China Gas Company are considering the potential of the site within their current planning exercise. It is anticipated that selection of appropriate industries for Area 137 will be according to HKIEC selection criteria. During the selection of industries for Area 137 the close proximity of SENT with its associated power generation and waste recycling facilities should be taken into account.

Construction Waste Sorting Plant

It is understood that Government plan to develop a construction waste sorting plant within the Tseung Kwan O area. This would not be affected by any emissions from the SENT Landfill site but could contribute to the local noise and air quality (particularly dust) levels.

18.4 COMPATIBILITY OF ADJACENT DEVELOPMENTS

Environmental concerns arising from the construction and operation of SENT Landfill comprise potential impacts on air quality in terms of dust and odour, and possibly noise and vibration.

As indicated above, industry category types 1B and 1C will occupy the surrounding land. Potential impacts are therefore a combination of health effects, nuisance and adverse effects on particularly sensitive industries (e.g. interfering with production, processes etc.). SENT Landfill will operate in accordance with the Air Quality Objectives (AQOs), and the subsequent control of emissions and compliance with the Objectives during construction, operation and aftercare will be achieved through implementation of a comprehensive environmental monitoring and audit programme (EMP) (Ref 18.4). The EMP covers noise, dust, organic emissions and odour, with Trigger Levels having been set to eliminate exceedance of environmental standards or occupational exposure limits. Consequently health and nuisance effects should not be of concern.

Industrial uses are not classified as sensitive receivers for noise or vibration (Ref 18.5). In any case, since the site access roads will be built to a high standard, no discernible vibrations are anticipated in any adjacent industrial units. Noise levels off-site will be controlled by the EMP.

With regard to the operation of industries particularly sensitive to air emissions, details pertaining to potential site occupants are not currently available, however, none of the potential industry types which may occupy the site (Table 18.1) have been identified as being particularly sensitive to air pollution (Ref 18.5).

In the event that a specific industry which is considered to be especially sensitive to air pollution should propose to occupy the adjacent development areas, the onus should be on the industry operators of concern to consider the presence of SENT Landfill and the Trigger and Action Levels to which the landfill will operate. It will then be the responsibility of the specific industry to determine the suitability of operating in close proximity to such a landfill site.

Conversely these future developments could contribute to the background concentrations in the Tseung Kwan O area, and might affect the Trigger Levels for the Environmental Monitoring Plan of the SENT Landfill site. The Specifications require that in the event of a Trigger Level exceedance GVL initiate a Special Environmental Monitoring Plan (SEMP) to investigate the cause of exceedance.

18.5 CONCLUSION

Of the planned adjacent developments in the area of the SENT Landfill none have been identified as potentially incompatible. Any future development should be planned taking due cognisance of the presence of the SENT Landfill.

REFERENCES

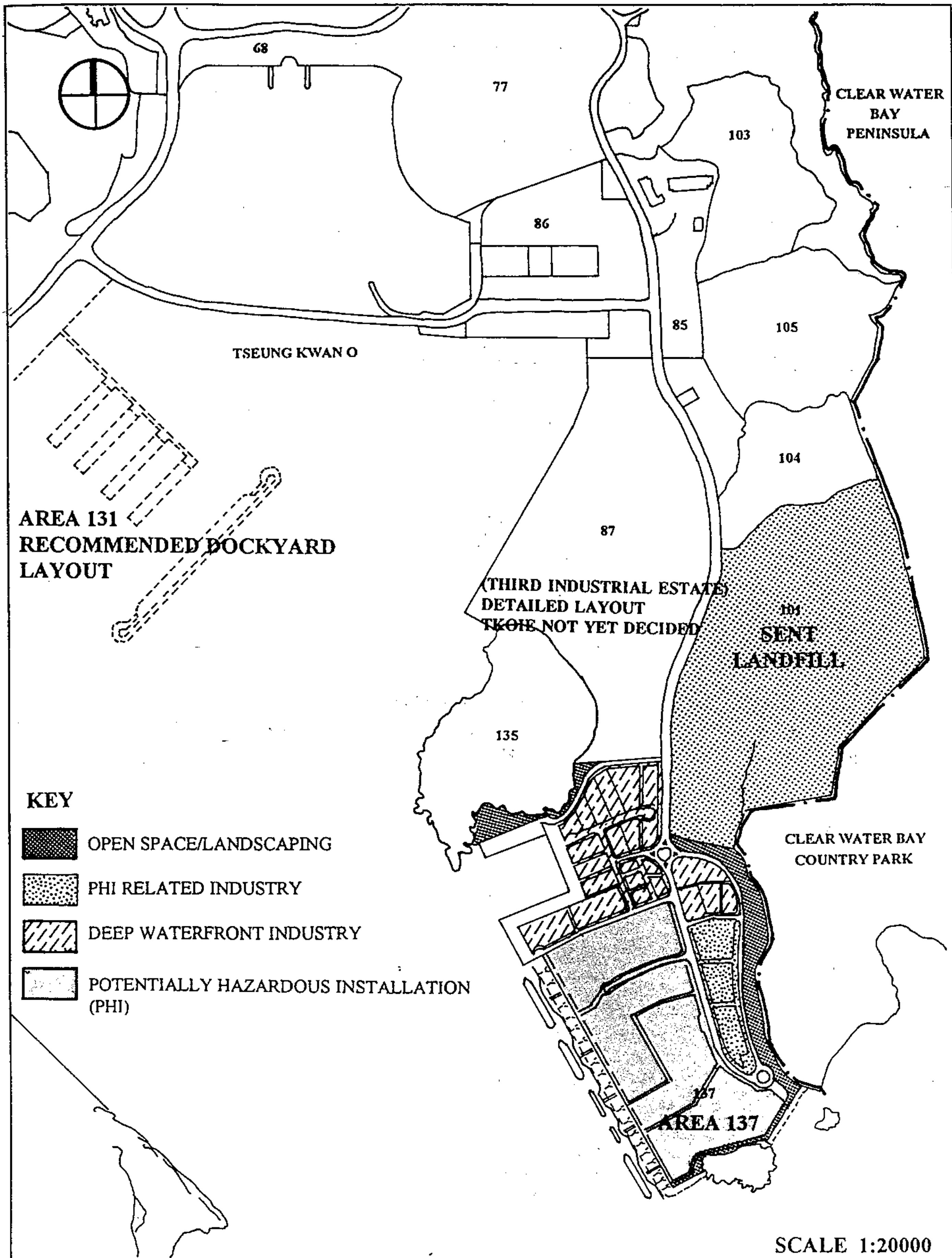
18.1 Maunsell Consultants Asia Ltd, Tseung Kwan O Feasibility Study of Opportunities for Further Development, Final Report (May 1990).

18.2 APH Consultants, Engineering Feasibility Study of Development Tseung Kwan O Area 137, Preferred Concepts Report (September 1992).

18.3 Maunsell Consultants Asia Ltd, Junk Bay New Town Feasibility Study of Opportunities for Further Development, Final Report (November 1989).

18.4 Woodward Clyde International, SENT Landfill, Hong Kong : Environmental Monitoring Plan (November 1993).

18.5 Hong Kong Government Environmental Protection Department and Planing Department, Environmental Guidelines for Planning in Hong Kong (April 1991).



acer ENVIRONMENTAL

FIGURE 18.1

ADJACENT DEVELOPMENTS TO SENT LANDFILL

SECTION 3

Operational Controls & Audit

19 INVENTORY OF MITIGATION MEASURES

19.1 INTRODUCTION

The GVL design for SENT Landfill incorporates a great many features to mitigate the potentially adverse environmental impacts of landfilling. Many of these were identified by the CEIA (see list of design criteria, Table 3.1). It is intended that the SEIA should not reiterate these mitigation measures which have already been incorporated into the design and EMP. However, since GVL were awarded the contract to develop and manage SENT Landfill a number of further mitigatory measures have been identified, and these are listed below. Also, during the detailed SEIA studies the requirement for further mitigation measures has been identified in certain cases, and these recommendations are also included.

For ease of cross reference between Chapters the mitigative actions scheduled in the following sections are ordered in terms of the 11 SEIA Supplementary Issues Chapters. It is recommended that all the measures detailed below be adopted by GVL and incorporated into construction and operational plans for the site.

19.2 WASTE RECYCLING

Mitigation Measures for Construction Waste Recycling Plant

Noise :

- site processing plant kept away from site boundaries and screen it by stockpiles; and
- restricted use of noisy plant on Sundays and Public Holidays.

Dust :

- maximise distance of plant from adjacent industrial developments; and
- apply mitigation measures from EPD Draft Guidance Note "Best Practicable Means Requirements for Mineral Works (Stone Crushing and Screening Plant)" where appropriate for the recycling plant at SENT Landfill.

Flotation tank residues:

- silt and mud from the flotation tank should be dewatered prior to landfilling; and
- contaminated water should be treated as leachate.

19.3 LANDFILL GAS

- provision of screen planting around landfill gas flare compound;
- if a temporary gas blower and flare are required during phase 1, consideration will be given to the siting, to minimise visual impact (possibly by bunding or screening);
- condensate from fuel gas compressor disposed of to leachate treatment system;

- methane detection system in gas utilisation plant to monitor any combustible gas leaks;
- exhaust silencers provided for gas turbines; and
- use of noise absorbent bricks in the construction of the gas utilisation plant building.

19.4 MATERIALS

- mitigation measures at marine fill borrow area should include conformance with the Fill Management Committee's General Allocation Conditions for Marine Borrow Areas and Mud Disposal Sites;
- apply mitigation measures from EPD Draft guidance note "Best Practicable Means Requirements for Mineral Works (Stone Crushing and Screening Plant)" as in 19.2 above, for rock quarries;
- where fill materials are transported from off-site locations, use of water sprays, wheel washing and restricted hours of transport should be applied;
- restrict periods of blasting and materials processing and avoid Sundays and Public Holidays;
- water spraying of materials stockpiles and provision of silt fences around stockpile areas;
- if foam is to be used as a daily cover material, drums should be stored and handled in a well ventilated building; and
- undertake Toxicity Characteristic Leaching Procedure (TCLP) testing on materials which are not permitted wastes and if specifically requested by EPD.

19.5 LEACHATE MANAGEMENT

- at the LTF, monitor atmospheric ammonia concentrations in the vicinity of the metals precipitation tank and clarifier and take measures to protect workers' health and safety (eg. restrict access, limit time spent in area, ensure respirators are worn by workers);
- strictly limit length of time that dewatered sludge cake is stored at the LTF;
- import large items of plant by marine transport wherever possible;
- use silenced construction plant and provide hoardings around active construction site;
- GVL to prepare Emergency Procedures Plan for event of LTF failure;
- provision of a second equalisation tank if and when required at the LTF;
- close monitoring of the performance of the thermal catalytic unit, by the periodic sampling and analysis of inlet and outlet gas streams;

- modify design of LTF so that a second Thermal Catalytic Unit could be installed at short notice, if required;

- implement intensive programme of training for LTF operators; and

- prepare a comprehensive plant maintenance programme.

19.6 SURFACE WATER

- additional mitigative measures will be proposed, if required, following an assessment of the detailed surface water design and method statements when available.

19.7 HYDROGEOLOGY

- develop an Action Plan, covering the contingency arrangements and emergency measures to be taken in the event of a major failure of the liner system.

19.8 MARINE DISCHARGES

- ensure the correct sizing of lagoons during the reclamation works to ensure settling of sediments from water before discharge to Junk Bay;

- ensure the correct sizing of lagoons/sand traps during the operational stage to ensure settling of sediments from surface run off water before being discharged to Junk Bay; and

- devise a spill prevention plan for on-site fuel and oil storage areas.

19.9 LANDSCAPE AND ECOLOGY

- prepare a Landscape Management Plan, describing the maintenance regime for landscape works over an agreed number of years on completion of the landfill, and operations to landscaped area at the end of each phase of development,

- careful selection of plant materials, especially for specimen planting beds within pavilion and picnic areas, to ensure use of proven low maintenance materials;

- maintain photographic records of the restoration from fixed points, to monitor success of planting;

- carefully monitor growth of *Lantana camera* to ensure it does not prove invasive;

- include larger numbers of species which attract frugivorous birds in planting lists;

- consider not using *Acacia spp.* in planting lists, following consultation with AFD;

- delete exotic species (*eg Acacia confuse, Casuarina stricta*) from planting lists for coastal areas;

- place plant orders 24 months in advance of need with AFD nursery;

- before carrying out construction works in Country Park, survey burrowing animals, hand dig any affected burrows and release captured animals in safe areas;
- ensure any areas of planting eroded by heavy rains or typhoons are repaired as soon as possible; and
- only use landscape chemicals on a strict as-needed basis and prohibit the use of preventive, scheduled and prophylactic treatments.

19.10 VISUAL IMPACT

- provide additional screen planting around the landfill gas flare compound.

19.11 EXCEPTIONAL TRAFFIC IMPACTS

- investigate feasibility of using existing barge off-loading facility at TKO (I) as an emergency back-up for periods of high marine traffic to SENT Landfill;
- GVL should consider arranging a reciprocal agreement with the operators of WENT and NENT Landfills that any vehicle proven to have fly-tipped, along the approach road, in the vicinity of SENT Landfill or elsewhere within the Territory, will not be employed again; and
- produce a Management Plan for landing containers at both TKO (I) and SENT Landfill marine access points during an EWS.

19.12 ADJACENT DEVELOPMENTS

- No additional mitigation measures proposed.

Environmental Monitoring

Chapter 20

20 ENVIRONMENTAL MONITORING

20.1 ENVIRONMENTAL MONITORING PLAN

All environmental monitoring at SENT Landfill is covered by the EMP (Ref 20.1)

The objectives of environmental monitoring at the landfill are:

- To provide a data-base against which to determine any short or long-term environmental impacts of the landfill;
- To confirm the validity of any assumptions made in the design of the landfill;
- To provide an early indication that any of the environmental control measures or other operational practices are failing to achieve the required standards;
- To provide data to determine the effectiveness of any mitigation or control measures implemented through amendments in procedures during the life of the landfill;
- To provide data to enable an environmental audit of the Works, Operation and Aftercare to be undertaken; and
- To assess compliance with the Environmental and Pollution Control Requirements, and Operational Requirements (where appropriate).

This Chapter provides a description of the environmental and operational variables and parameters which are to be monitored, and the purpose for which each is to be monitored, eg. as an indication of general background conditions or as an indicator of unacceptable environmental impact. The range of environmental and operational variables and parameters to be monitored includes:

- Leachate;
- Landfill gas;
- Groundwater;
- Surface water;
- Marine water;
- Noise;
- Dust;
- Organic emissions & odour;
- Volatile organic carbons (VOCs) and ammonia;
- Meteorological data;
- Volume and density of waste;
- Settlement;
- Waste type; and
- Flora and fauna.

It is considered that the most appropriate way to present the monitoring information is in tabular format and Tables 20.1 to 20.15 provide outline monitoring schedules, based upon information provided in the EMP.

Table 20.1 Leachate - Outline Monitoring Schedule

OBJECTIVE	PARAMETER	ACTION LEVEL	LOCATION	FREQUENCY/TIMING
Baseline Monitoring (6 - 8 weeks)	Leachate Level		Leachate Collection Sumps	Level & Flow volumes measured continuously;
	Leachate Flow & Volume		Entry & Exit of Leachate Treatment Works	
	Suite 1 Analyses *		Leachate Collection Sumps & Entry & Exit from Leachate Treatment Works	Suite 1 analyses undertaken on weekly samples
	pH, EC, Leachate & Ambient Air t°		As above	In-situ at same time as Suite 1 analyses
Compliance Monitoring	Leachate Level		Leachate Collection Sumps	Level & Flow Volumes measured continuously
	Leachate Flow Volume		Entry & Exit to Leachate Treatment Works	
	Suite 2 Analyses **	COD - 2,000mg/l Total N - 200mg/l (to sewer)	Entry & Exit to Leachate Treatment Works and Leachate Collection Sumps	Monthly
	Suite 3 Analyses ***		Leachate Treatment Works	Monthly
	pH, EC, Leachate & Ambient air t°		All locations	In situ at same time as Suite 2 & 3 sampling.

Notes * Suite 1 Analyses : COD, BOD, TOC, SS, Ammoniacal N, Nitrate (as N), Nitrite (as N), Total Kjeldhal Nitrogen (TKN), Sulphate, Phosphate, Chloride, Alkalinity, Volatile Fatty Acids, Sulphide, Na, Mg, Ca, K, Fe, Zn, Mn, Cu, Pb, Cr & Ni.

** Suite 2 Analyses : pH, COD, BOD, TOC, Ammoniacal N, Nitrate (as N), Nitrite (as N), Cl, Alkalinity, Mg, Ca, K, Fe, Zn.

*** Suite 3 Analyses : SS, Volatile Suspended Solids, TKN.

Table 20. 2 Landfill Gas - Outline Monitoring Schedule

OBJECTIVE	PARAMETER	ACTION LEVEL	LOCATION	FREQUENCY/TIMING
Baseline	O_2 CO_2 CH_4 Gas Pressure Water Level		Gas monitoring holes, Piezometers & wellheads	Monthly intervals at commission of monitoring locations until start of operation.
	O_2 CO_2 CH_4		Site Building	Continuously
	Flammable Gas Vegetable Stress		Surface Walkover	Quarterly basis
Compliance	Gas Pressure CH_4 Flammable Gas O_2 CO_2 Water Level	 1% 30ppm 1%	Gas Monitoring Holes & Piezometer locations	Monthly (weekly for those close to buildings)
	CH_4 CO_2 O_2 Flammable Gas N Flammable Gas (VOCs if Trigger levels exceeded)	1% v/v 1% v/v 30 ppm	As above	Annual (Bulk Gas Sampling)
	Vegetation Stress		Surface Walkover	Quarterly
	Flammable Gases	30 ppm	Where vegetation stress is identified & on-site enclosed spaces.	Quarterly
	Hazardous/Explosive Gas	30 ppm CO_2	Buildings	Continuous
	Gas Pressure CH_4 Flammable Gas O_2 CO_2 Flow rates	 1% 30 ppm 1%	Wellheads	Quarterly
	CH_4/CO O_2/N_2 CO/C_2H_6 C_3H_8 C_4H_{10} VOCs	1%	Wellheads	Quarterly from Wellhead with highest CH_4 concentration (Bulk Gas Sampling)
	Efficiency of Gas Plant • Pump rate, pressure, temperature • Vinyl Chloride Benzene Non-methane organic compounds Visible Emissions Exhaust t° Exhaust Gas Retention Time $CH_4/CO_2/O_2/N_2/CO$ Flammable Gas	 10 ppm 10 ppm 20 ppm 20% capacity 815 °C 0.6 seconds	Landfill Gas Treatment Works Exhaust Gases Inlet & outlet streams	 Continuous Quarterly

Table 20.3 Groundwater - Outline Monitoring Schedule

OBJECTIVE	PARAMETER	ACTION LEVEL	LOCATION	FREQUENCY/TIMING
Baseline	Water level		Monitoring Holes	Upon commission of Monitoring Holes following contract award. Monthly intervals. For selected wells, for one occasion, monitor every ½hour for 12 hour tidal cycle.
	Water Quality		Monitoring Holes	Quarterly
Compliance	Water Levels		Monitoring Holes	Monthly. Monitoring for selected wells, for one occasion, monitor every ½hour for 12 hour tidal cycle
	Water Quality pH, EC, t° Ammonia - N COD BOD, TOC, Na, K, Ca, Mg, Carbonate, Bicarbonate, $Ni_{(aq)}$, Mn, Nitrate (N), Nitrite (N), Sulphate, Chloride, Sulphide, $Cr_{(aq)}$, $Cd_{(aq)}$, $Cu_{(aq)}$, $Pb_{(aq)}$, $Fe_{(aq)}$, $Zn_{(aq)}$, Phosphate.	 0.2 mg/l 15 mg/l	Monitoring Holes	Quarterly

Table 20.4 Surface Water - Outline Monitoring Schedule

OBJECTIVE	PARAMETER	ACTION LEVEL	LOCATION	FREQUENCY/ TIMING
Baseline	Na, K, Ca, Mg, Carbonate, Bicarbonate, Ni, Mn, Nitrate (N), Nitrite (N), Sulphate, Phosphate, Chloride, Sulphide, Cr, Cd, Cu, Pb, Fe, Zn NH_3-N SS COD	 0.5mg/l 20 mg/l 30 mg/l	Three sites to be determined	Monthly
	PH, EC, DO, t°, flow			Monthly In-situ
Compliance	As above	As above	All proposed discharge points.	Quarterly

Table 20.5 Marine Water - Outline Monitoring Schedule

OBJECTIVE	PARAMETER	ACTION LEVEL	LOCATION	FREQUENCY/ TIMING
Baseline	COD BOD TOC Nitrate-N Ni, Cr, Cd, Cu, Ammonia-N Pb, Zn, Phosphate, Arsenic, selenium, Hg, SS pH, EC, D.O., t° turbidity,		3 Monitoring Stations 846,215E 815,250N 846,340E 815,045N 846,218E 815,025N at 3 depths	Monthly
	SS, Zn, Nitrate Phosphorus turbidity D.O., t°		11 Monitoring Stations mid-ebb and mid-flood	4 days/week 4 weeks
Compliance	COD BOD TOC Phosphate Nitrate - N Ammonia - N Ni, Cr, Cd, Cu, Pb, Zn, Hg As, Se pH, EC, D.O., turbidity.	20mg/l 0.2mg/l	3 Monitoring Stations 846,215E 815,250N 846,340E 815,045N 846,218E 815,025N at 3 depths	Quarterly
	SS	150 mg/l	5m seaward of any pipe constructed in a seawall through which marine water is displaced during marine reclamation.	Quarterly
	SS Zn Nitrate Phosphate Turbidity D.O. D.O. saturation t°	30% above ambient subject to absolute maximum of 150 mg/l } } 30% above } ambient 70% of ambient Subject to absolute minimum of 4mg/l surface Subject to absolute minimum of 2mg/l bottom	11 Monitoring Stations at mid-ebb and mid-flood	2 days/week during marine works and for additional 6 weeks.

Table 20.6 Marine Sediment - Outline Monitoring Schedule

OBJECTIVE	PARAMETER	ACTION LEVEL	LOCATION	FREQUENCY/ TIMING
Baseline	PCB, PAH Total N Total P Sulphide Sulphate Cr, Cu, Pb, Hg, Zn, Ni, As, Cd		846,180E 815,050N(M11) 846,160E 815,190N(M12) 846,160E 815,330N(M13) 846,320E 815,000N(M14) 846,450E 814,960N(M15)	Monthly
Compliance	As above; in addition while sampling, monitor water parameters pH EC, D.O., t°, salinity		As above	Every 6 months

Table 20.7 Noise - Outline Monitoring Schedule

OBJECTIVE	PARAMETER	ACTION LEVEL	LOCATION	FREQUENCY/TIMING
Baseline	LAeq		847,145E 816,530N 847,450E 815,900N 847,335E 815,530N	Weekly from contract award until commencement of initial works
Compliance	LAeq	(0700-1900) 75dB(A) (1900-2300) 62dB(A) Sundays & general holidays (2300-0700) 47dB(A)	As above	Weekly

Table 20.8 Dust - Outline Monitoring Schedule

OBJECTIVE	PARAMETER	ACTION LEVEL	LOCATION	FREQUENCY/TIMING
Baseline	High Volume Air Sampler		At landfill boundary: 816,250N 846,500E 816,400N 846,850E 816,235N 847,155E 815,875N 847,380E 815,535N 847,180E 815,120N 846,960E 815,050N 846,533E 815,690N 846,175E	One 24 hour sample every 6 days for 7 weeks prior to commencement of Initial Works
Compliance	24 hour High Volume Air Sampler TSP RSP	 260μg/m³ 180μg/m³	As above	4 out of the 8 monitoring stations once every 6 days
	4-8 hour Low Flow Sampling TSP RSP	 10mg/m³ 5mg/m³	1m above ground surface 50-60m from dust generating activity	Once every 6 days

Table 20.9 Organic Emissions & Odour - Outline Monitoring Schedule

OBJECTIVE	PARAMETER	ACTION LEVEL	LOCATION	FREQUENCY/TIMING
Baseline	40 volatile organic compounds (VOCs) plus ammonia [see Table 20.10]		Landfill Boundary 816,250N846,500E 816,400N846,850E 816,235N847,155E 815,875N847,380E 815,535N847,180E 815,120N846,960E 815,050N846,533E 815,690N846,175E 1.5 metres above ground surface.	Once during construction between April to July inclusive.
Compliance	40 VOCs plus ammonia [see Table 20.10]	[see Table 20.10]	As above and at one wellhead	Once every 3 months at 4 of the 8 Monitoring Stations.

Table 20.10 Trigger Levels For VOCs And Ammonia

VOC	Action Level ($\mu g/m^3$)	VOC	Action Level ($\mu g/m^3$)
Methane	350,000.0(1)	Undecane	1,300.0
Methyl Mercaptan	0.04(2)	Limonene	57.0
Ethanethiol	0.032(2)	Terpenes	57.0(4)
Butanethiol	1.6(2)	Ethanol	342.0
Trichloroethylene	1,130.0	Methanol	2,600.0
Vinyl Chloride	78.0	Butan-2-ol	3,000.0
Methylene Chloride	3,500.0	Dimethyl Sulphide	2.5
Chloroform	98.0	Methyl Propionate	36.0(5)
1,2 Dichloroethane	400.0	Ethyl Propionate	36.0(5)
1,1,1 Trichloroethane	19,000.0	Propyl Propionate	33,133.0
Carbon Tetrachloride	126.0	Butyl Acetate	7,100.0
Tetrachloroethylene	3,350.0	Ethyl Butanoate	36.0
1,2 Dibromoethane	40.0	Methyl Butanoate	8.0
Benzene	160.0	Dichlorobenzene	1,500.0
Toluene	1,880.0	Dipropyl Ether	2,700.0
Xylenes	348.0	Heptanes	16,000.0
Ethyl Benzene	4,350.0	Octanes	14,500.0
Propyl Benzenes	196.0	Nonanes	2,100.0
Butyl Benzenes	196.0(3)	Dichlorodifluoromethane	49,500.0
Carbon Disulphide	24.0	Ammonia	200.0
Decanes	1,000.0		

Notes:
(1) Based on 1% of the lower explosive limit for methane.
(2) Trigger Level is less than the required analytical detection limit.
(3) Trigger Level determined by analogy with propyl benzenes.
(4) Trigger Level determined by analogy with limonene.
(5) Trigger Level determined by analogy with Ethyl Butanoate.

Table 20.11 Meteorological Data - Outline Monitoring Schedule

OBJECTIVE	PARAMETER	LOCATION	FREQUENCY/TIMING
Meteorological Data	Atmospheric Pressure Air t° Dew Point Relative Humidity Rainfall Wind direction Wind Speed Max Gust Speed	Meteorological Station SW of Landfill, in site infrastructure area	Continuously

Table 20.12 Volume & Density of Waste - Outline Monitoring Schedule

OBJECTIVE	PARAMETER	FREQUENCY/TIMING
To determine the bulk volume and general range of densities of Permitted Waste deposited on site to enable the landfill filling rate to be determined and consequently the remaining life of the landfill	Weight of waste Type of waste Bulk waste volume and density	Continuously Continuously Annually & upon completion of any milestone

Table 20.13 Settlement - Outline Monitoring Schedule

OBJECTIVE	PARAMETER	LOCATION	FREQUENCY/TIMING
To obtain information on settlement, & use to: • estimate the amount of overfill to use above the restoration contour level to achieve final restoration grades • verify design criteria and construction methods • verify that positive drainage is being maintained	Permitted Waste Settlement	On any restored part of landfill & on any portion where no waste will be deposited for 6 months or more.	Monthly
	Formation Settlement	300mm below landfill liner at grid spacing <200 metres	Monthly

Table 20.14 Waste Type - Outline Monitoring Schedule

OBJECTIVE	PARAMETER	LOCATION FREQUENCY/TIMING
To • ensure only Permitted Waste which complies with contract is landfilled • check nature of Permitted Waste loadings • fulfill GVL's duty of care through taking all reasonable measures to demonstrate the Permitted Waste is adequately described	Waste Examination: Liquid visual pH, EC, t° Free CN Sg, μ, flammability, reaction with water, NaOH and HCl. Solid visual pH, EC, Free CN, reaction with water; NaOH, HCl.	Laboratory staff to use all available information as well as common sense in the selection of screening tests and the interpretation of the results. 5% of waste deliveries to be examine.

Table 20.15 Flora & Fauna - Outline Monitoring Schedule

OBJECTIVE	PARAMETER	LOCATION	FREQUENCY/TIMING
Flora and fauna	Marine Biota	Monitoring Sites: 846,180E 815,050N 846,160E 815,190N 846,160E 815,330N 846,320E 815,000N 846,450E 814,960N	6 monthly from 3 of the 5 Monitoring Stations. Taken in conjunction with marine sediment samples.
	Terrestrial Biota	3 0.25ha sites: - 1 on north side of SENT - 2 within landfill boundary	6 monthly

20.2 RECOMMENDATIONS FOR ADDITIONAL ENVIRONMENTAL MONITORING

In the course of preparation of the SEIA, a number of additional requirements for environmental monitoring have been identified, which are not currently covered by the EMP. It is recommended that consideration be given by GVL and EPD to incorporation of these elements within the EMP.

Recommendations for additional monitoring (identified in Chapters 8 to 18) are:

- process monitoring of construction waste recycling plant: total monthly raw input, product output and material stock, and other essential operating parameters which may significantly effect dust emissions (Section 8.6);

- monitoring of the effectiveness of the performance of any alternative daily cover materials which are used: visual inspection; checking against criteria listed in section 10.5;

- monitoring of atmospheric ammonia concentrations in the vicinity of the LTF Metals Precipitation Tank, Air-Strippers and Clarifer, to detect any potential risk to plant operators (Section 11.3.10);

- monitoring of performance of LTF Thermal Catalytic Unit, by determining ammonia concentration of gas stream entering and leaving the Unit (Section 11.3.10);

- monitoring of quality of water (in terms of suspended solids concentration) leaving settlement lagoons for discharge to Junk Bay during marine reclamation and site formation works (Section 14.5.2);

- monitoring Advanced Landscape Planting in terms of survival rates and growth rates by species, and maintenance of photographic records (Section 15.3.3);

- carry out pre-disturbance surveys of burrowing animals in Clear Water Bay Country Park prior to construction works (Section 15.5.4);

- baseline flora and fauna surveys: baseline rodent data (using live capture, mark and release methods) over period of at least 3 months; breeding and wintering bird survey (using belt transects) (Section 15.6.1);

- flora and fauna monitoring: use belt transects rather than circular plots for bird monitoring; incorporate rodent monitoring into the EMP; survey burrowing activity on restored and revegetated areas (Section 15.6.2); and

- monitor restored areas after heavy rain or typhoons to assess extent of erosion/damage and remedial actions required (include photographic records) (Section 15.6.3).

Recommendations for Scope of the Continuous Assessment Programme (CAP)

Chapter 21

21 RECOMMENDATIONS FOR THE SCOPE OF THE CONTINUOUS ASSESSMENT PROGRAMME

21.1 INTRODUCTION

It is recognised by all parties that there are a number of limited environmental issues to address during the early life of the landfill which cannot be undertaken during the limited period of time available for the preparation of the SEIA. For this reason GVL, in their successful tender, proposed that a Continuous Assessment Programme (CAP) be developed.

The CAP would be an ongoing assessment of the environmental impacts of the SENT Landfill project, building on the results of environmental monitoring (carried out under the EMP). As the EMP progresses, much more detailed assessments will be possible of certain aspects, such as hydrogeology, where the current database is insufficient for a fully quantitative assessment to be made. It is important that these elements should form part of the CAP, together with EIAs of aspects of the project where the design is not yet finalised, such as the Brini plant or the surface water drainage system. The EMP's role is to monitor environmental parameters and compare these to trigger levels and performance criteria; prediction and assessment of impacts is not a requirement of the EMP. This is the role of the CAP.

21.2 ISSUES TO BE INCLUDED IN THE CAP

The issues listed to be included in the CAP should not be considered a final and complete list. The development of new technologies, materials and increased knowledge of site specific conditions will make it necessary for future items to be included in the design; some of these will need to be assessed by the CAP.

During the course of production of this SEIA, a number of issues have evolved for inclusion in the CAP. These are as follows.

(i) EIA OF BRINI RDF FACILITY

Following a thorough waste characterisation programme, to be undertaken by GVL during the first year of operations, it will be decided whether to develop a Brini RDF facility at SENT Landfill. The Brini plant will then be designed and an EIA undertaken covering: noise, air quality (including dust), visual impact, construction impacts, water and residuals.

(ii) DUST AND NOISE ASSESSMENT OF CONSTRUCTION WASTE RECYCLING

As discussed in Chapter 8, it has not been feasible to undertake a quantitative dust and noise assessment of the construction waste recycling plant due to uncertainties and lack of emissions data. A decision on whether such a plant is installed at SENT Landfill, and its size and throughput, will not be made until the Government's deliberations on a centralised construction waste sorting plant in TKO are finalised and the effects of the decision assessed. EPD's view that dust emissions and noise impact from the plant should be modelled is accepted, this should be carried out under the CAP, once details of the plant are made available.

(iii) ALTERNATIVE COVER MATERIALS TRIALS

A number of alternative daily cover materials have been described and assessed in the SEIA (Chapter 10). The CAP should report the trials which would be carried out on these prior to their use and assess potential environmental problems. Particularly detailed assessment should be given to the results of the proposed TCLP testing.

(iv) SOIL AND ROCK BORROW AREAS

In the later stages of the SENT Landfill there will be a significant materials deficit which will be (at least partially) made up from rock and soil imported from quarries and borrow areas elsewhere in Hong Kong. Firm decisions on these will clearly depend on market forces and the availability of suitable materials at the time. When these decisions have been made, an environmental review should be carried out on the sources, particular reference should be made to the potential traffic impacts along the haul routes to SENT Landfill.

(v) ONGOING HYDROGEOLOGICAL ASSESSMENT

As more detailed data on groundwater levels, flow and quality becomes available from the monitoring work. Under the CAP an on-going assessment will be made of the effects of the project. This will allow remedial actions to be designed and implemented, if required.

(vi) LANDSCAPE ASSESSMENT

The CAP will report on and assess the results of the landscape planting trials which will be carried out following the filling of phase 1 of the site, to provide guidance to the design of the restoration and aftercare. The detailed landscape design and Masterplan will also be reviewed and assessed.

It is further proposed that under the CAP at regular intervals (probably annually) the landscaping be reviewed in terms of:

- success of different species;
- utilisation by fauna and habitat value; and
- effectiveness in mitigating the visual impact of the site.

(vii) WASTE DENSITY AND COMPACTION MEASURES

In-place waste density and volume of void space remaining will be determined by comparing regular topographical surveys of the site to records from the "DUMP" database of waste intake. This will enable the best compaction methods specific to waste accepted at SENT Landfill to be assessed.

(viii) SURFACE WATER DRAINAGE SYSTEM IN CLEAR WATER BAY COUNTRY PARK

At the time of preparing the SEIA, the detailed surface water management design work was in progress and detailed designs and method statements were not available. Since the drainage works in Clear Water Bay Country Park may have adverse impacts (both short and long-term), an assessment will be made under the CAP when the design and method statements are available.

(ix) MANAGEMENT PLAN FOR HANDLING MARINE TRAFFIC

During the analysis of the traffic impacts of an Exceptional Waste Situation (EWS), potential problems with handling the additional incoming marine barges have been identified. It is recommended that a marine traffic management plan be produced by the government, in conjunction with the operators of the territories strategic landfills. The plan would as a minimum, identify the handling plant, operational practices and possible additional facilities needed to deal with exceptionally large waste inputs to SENT Landfill.

21.3 PROGRAMME AND REPORTING

It is recommended that the CAP should be undertaken in a number of stages, as the design and baseline information becomes available. The issues would be reported to EPD as technical working papers. It is also recommended that the CAP be reviewed annually by GVL and EPD and the scope of the following year's work decided. The first of these reviews should be held in August 1995.

Review of Assessment Methodologies

Chapter 22

22 REVIEW OF ASSESSMENT METHODOLOGIES

The Specification for the Development and Management of SENT Landfill (Ref 22.1) requires that the SEIA include a description of:

- the forecasting methods used to assess any impacts on the environment about which information is given; and
- any difficulties, such as technical deficiencies or lack of know-how, encountered in compiling any specified information.

This Chapter therefore reviews the assumptions and methodologies used in the eleven supplementary issues Chapters in Section 2 and explains the difficulties encountered in compiling certain elements of the specified information.

22.1 METHODOLOGIES

The assessment methodologies used in the SEIA supplementary issues studies are as detailed in Table 22.1.

Table 22.1 Summary of Assessment Methodologies

CHAPTER	ISSUE	ASSESSMENT METHODOLOGY	CHAPTER REF.
Waste Recycling	Impacts of construction waste recycling plant	Preliminary assessment as a qualitative desk study reviewing existing data and information. Identification of distances to SRs and recommendations for mitigation.	8.5
Landfill Gas	Prediction of landfill gas volumes	WMI in-house computer model based on database of over 75 WMI landfill gas recovery assessments.	9.2.1
Landfill Gas	Atmospheric impacts of flaring and utilisation	ISCST model with "worst case" meteorological parameters. Prediction of SO_2 and NO_2 contour plots and variations with height. Comparison with HKAQOs.	9.5.3
Landfill Gas	Construction noise impacts of gas plant	Calculation of combined sound power level of typical construction equipment. Assessment of attenuation over distance to nearest NSR; comparison with noise criteria.	9.6.3
Landfill Gas	Operational noise impact of flares/turbines	Assessment based on documented levels measured near similar plant.	9.6.4
Construction Materials	Potential impacts of fill and daily cover materials	Preliminary environmental review based on manufacturer's information and studies of previous applications.	10.3 & 10.5
Leachate Treatment	Atmospheric impact of ammonia discharge from LTF	ISCST model with "worst case" meteorological parameters (as above).	11.3.2
Leachate Treatment	Noise impacts	(as above)	11.3.4 & 11.3.6

Table 22.1 Summary of Assessment Methodologies (cont'd)

CHAPTER	ISSUE	ASSESSMENT METHODOLOGY	CHAPTER REF.
Leachate Treatment	Impact of discharge of treated leachate from TKO STW	Review of TKO STW upgrading and SSDS proposals. Desk study assessment of significance of discharges from SENT LTF.	11.4.2
Surface water	Impacts of surface water discharges	Review of design. Assessment of likely compliance with Technical Memorandum on Standard of Effluents Discharged into Drainage and Sewerage Systems, Inland Waters and Coastal Waters (TMES).	11.3 - 12.6
Hydrogeology	Risk of liner leakage	Evaluation of leaks in geomembrane based on Ground and Bonaparte equation. Comparison to USEPA standard for acceptable liner leakage.	14.5
Marine Discharge	Impacts of dredging and reclamation works	Review of contractor's method statements; identification of mitigation; assessment of discharge quality vs TMES.	14.4
Landscape and Ecology	Landscape assessment	Review of GVL preliminary landscape design; recommendations for issues to be included in final design.	15.4
Landscape and Ecology	Ecological assessment	Review of baseline flora and fauna survey; review of EMP proposals; recommendations for further surveys, monitoring and ecological enhancement.	15.5
Visual impact	Visual impact of landfill development and restoration	Identification of visual envelope and critical view points. Production of photomontages of critical views at different stages of development of site.	16.3
Exceptional Traffic	Traffic Impact of Exceptional Waste Situation	Identification of waste arisings to be transferred to SENT Landfill during an EWS. Calculation of additional traffic generated.	17.2
Adjacent Developments	Compatibility with SENT Landfill	Review of development plans and SR status of industry types.	18.4

22.2 ASSUMPTIONS USED

During the course of production of the SEIA it has been necessary to make a number of assumptions, relating to both project and environmental parameters. These have arisen principally due to gaps in the baseline data set and design details not yet finalised. The main assumptions made are as follows:

- construction waste recycling at SENT Landfill assumed still to be viable;
- construction waste recycling plant assumed to be located in the vicinity of the active areas of the site;
- landfill gas volume predictions assumed correct (based on: waste in-take rate of 36,000 tonnes/week; in-place waste density of 0.9 tonnes/m^3; gas generation rate of 0.0078 m^3/kg.year and theoretical maximum yield of 0.280m^3/kg refuse);
- landfill gas recoverability assumed to be 65%;

- enclosed gas flares assumed to be the 3.5m by 15.2m type, not the smaller ones described in the GVL tender;
- implementation schedule for gas flares and turbines assumed to be as in Table 19.2;
- meteorological parameters for ISCST model assumed to be as in Table 9.4;
- construction activities assumed to take place only in daytime;
- typical construction plant assumed for noise assessment, as in Table 9.7;
- siting of LTF and gas plant within site infrastructure area assumed to be as on tender drawings;
- for ammonia modelling from LTF, receivers assumed to be downwind of emission source;
- background atmospheric ammonia concentrations in the area assumed to be low (since no baseline data available);
- performance of thermal catalytic unit assumed to be as per LTF design report over whole life of facility;
- for loadings to TKO STW, LTF assumed to meet discharge standards in TMES;
- SSDS scheme assumed to be operational in 1998;
- surface water assumed to be discharged to Junk Bay and Clear Water Bay, but not Joss House Bay;
- landscape planting assumed to achieve average growth rates;
- under EWS, maximum use of marine waste transfer assumed; and
- under EWS, 20-40% of Territory's construction waste arisings assumed to be taken to SENT Landfill by road.

22.3 DIFFICULTIES ENCOUNTERED IN COMPILING SPECIFIED INFORMATION

The principal difficulty encountered in the production of the SEIA was that certain parts of the assessment have had to be based on design assumptions and preliminary proposals. At the current time, detailed designs for the surface water management system and landfill gas utilisation plant are not complete; also the landscape design and initial flora and fauna surveys have not been completed within the SEIA period. However, given the assumptions detailed above, impact assessments have been completed on the basis of the available information for the various aspects of the project. It is the intention that the CAP carries out further assessment of the few remaining issues when design is finalised and confirmed data is available. These difficulties were recognised at the start of the study and are inherent in a project of such duration where all the design work is not necessarily completed in the first few months.

APPENDICES

SEIA Scoping Report and Comments and Responses

Appendix 1

SENT LANDFILL

SCOPE OF SEIA

August 1993

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SENT LANDFILL : SEIA

SCOPE OF WORK

1.0 THE SEIA FORMAT

1.1 Introduction

Acer Environmental (AE) has been commissioned by Green Valley Landfill (GVL) to carry out the Supplementary Environmental Impact Assessment (SEIA) of GVL's proposals for the South-East New Territories (SENT) Landfill. This report details the work elements of the SEIA in terms of:

- individual issues and their aims;
- proposed methodology; and
- deliverables.

1.2 Structure of SEIA

The SEIA will be structured in three sections to meet the requirements of Section 33.10.2 of the specification.

Section 1 will contain an Introduction to the SEIA, a review of the Conceptual Environmental Impact Assessment (CEIA) and the Environmental Review (ER) with specific reference to the effects of any variations from the tender design in the detail design. This section will draw extensively on the work carried out for the ER and will include, as a Preface, the Non-Technical Summary of the SEIA. The scope of any detailed supplementary ER is dependent on the extent of design changes identified.

Section 2 will contain reports on the key issues identified during the Environmental Review as consequent on the GVL design proposals or identified as omissions from the CEIA. The subsequent round of comments from, and negotiations with, EPD resulted in identification of further issues, some of which are considered for inclusion in Section 2. All 12 issues considered for evaluation have been scoped and the information requested in Applied Geology memo of 26/7/93 is provided in this proposal (pages 2 to 16). The key issue reports will be submitted to GVL, ICE and EPD in an integrated form, as Section 2 of the SEIA.

Section 3 of the SEIA will contain an inventory of mitigation measures; a summary of monitoring proposals, with appropriate references to the EMP; a summary of recommendations for the CAP and a summary of the predictive methodologies employed in preparing the SEIA.

KEY ISSUE REPORTS

2.0 WASTE RECYCLING

2.1 Issues

- impacts of possible recycling plant.

2.2 Methodology

- obtain existing raw data from EPD on waste composition, and assess likely scope for recycling (with reference to Responses to Questionnaires (RQs) 3rd Round Questionnaire, 2.4.1 and EPD report "Study on Recycling of Construction Waste Received at Landfills");

- establish Hong Kong policy on construction wastes; and

- undertake preliminary assessment of impacts (noise, dust, traffic, disposal of rejects) of likely recycling plant, throughout life of landfill. This would be restricted to a desk study based on measurements at similar facilities, and the development of an outline programme of mitigation measures.

2.3 Deliverables

- EIA on possible recycling plant; and

- recommendations for ongoing monitoring; possible modifications to EMP.

2.4 Notes

- since design of recycling plant will not be specified until at least the end of Phase 1, the SEIA will be limited to broad likely design parameters;

- SEIA strictly limited to recycling at SENT landfill only and not to consider strategic issues; and

- economic, design and commercial viability issues are outside the scope of the SEIA.

3.0 GAS COLLECTION AND UTILISATION

3.1 Issues

- review of landfill gas utilisation proposals;
- environmental appraisal of utilisation options; and
- impacts of likely flaring and utilisation plant.

3.2 Methodology

- AE to evaluate plant options on environmental terms and report;

- AE to review and assess impacts of gas flaring plant and utilisation plant (for preferred option).

- assess visual impact of plant and flare, taking account of screened type of flare proposed;

- construction noise assessment based on the Technical Memorandum of the Noise Control Ordinance, using criteria in Technical Memorandum on Noise from Construction Work Other than Percussive Piling;

- produce computer model of operational noise levels, with comparison against criteria in Hong Kong Planning Standards and guidelines, and Technical Memorandum for Assessment of Noise from Places other than Domestic Premises, Public Places or Construction Sites;

- undertake assessment of predicted odours from gas flaring; and

- assess atmospheric impacts using ISCST (Industrial Source Complex Short Term) computer model developed by the US EPA, to determine pollutant concentrations at receiver locations, and compare to local and WHO standards.

3.3 Deliverables

- report on environmental considerations of different plant options;

- EIA on selected flaring plant and utilisation plant; and

- recommendations for ongoing monitoring.

3.4 **Notes**

- detailed design information for Phase 1 gas management system and site power facility will not be available from RUST until week 16, therefore the SEIA will be based on design parameters only;

- GVL to undertake discussions with China Light and Power on export of electricity; and

- economic assessment of gas utilisation is outside the scope of the SEIA.

4.0 MATERIALS AVAILABILITY AND SUITABILITY

4.1 Issues

- availability of materials on-site and extraction programme;
- off-site materials sources, quantities and transportation requirements; and
- impacts of raw material usage, extraction, dredging and transportation.

4.2 Methodology

- review dredging activities and assess impacts of dredging; study contaminated muds in the area;
- review and assess impacts of other material sources (traffic impacts, noise and dust) at both point of abstraction and along transportation route to SENT throughout whole lifetime of site;
- review and assess impacts of quarry programme and on-site materials extraction; and
- review use of other construction materials and assess potential impacts.

4.3 Deliverables

- EIA of material sources encompassing impacts of quarrying/dredging; raw materials consumption; transport and depositing of material; and
- recommendations for ongoing monitoring.

4.4 Notes

- on-site extraction designed to have least impact on the Country Park; and
- if RUST are considering the use of alternative materials for daily cover (e.g. spraying with synthetic materials) the SEIA will assess the proposals.

5.0 LEACHATE PRODUCTION AND MANAGEMENT

5.1 Issues

- impacts of discharges of treated leachate from TKO STW and associated outfalls are outside the scope of the SEIA and constitute the responsibility of the Hong Kong government. Although EPD has specified that the impact of treated leachate discharges should be assessed, that study would have to be commissioned separately by EPD; and

- impacts of leachate treatment plant.

5.2 Methodology

- assess the impacts and effectiveness of the proposed leachate treatment plant;

- assess construction and operational noise impacts using methodology outlined in Section 3.2 above;

- assess odour and other atmospheric impacts using methodology outlined in Section 3.2 above, with particular emphasis on ammonia emissions (RQs 1st and 2nd Round Questionnaires, 1.2.1 and 3rd Round Questionnaire, 1.4.1);

- assess quality of discharges with respect to compliance with trigger levels defined by EPD;

- review fate of treated leachate in the context of short, medium and long term TKO STW effluent treatment strategies; and

- clarify, through discussions with EPD, their requirements regarding assessing the marine/aquatic impacts of discharge of treated leachate.

5.3 Deliverables

- EIA of leachate treatment plant; and

- brief overview of impacts of treated effluent discharges (limited scope, desk study only);

- recommendations for ongoing monitoring.

5.4 **Notes**

- early discussions with EPD required to determine how leachate discharge issues is addressed; and

- level of sophistication of odour/atmospheric impact assessment to be discussed with EPD.

6.0 SURFACE WATER RUN-OFF

6.1 Issues

- impacts of modifications to surface water catchments on streams to the east and south-east and the country park; and
- impacts of surface water regime on Clear Water Bay marine environment.

6.2 Methodology

- collect baseline water quality and flow data from EPD;
- review and assess baseline conditions for the site and impact of modifications to the surface water drainage regime in terms of quantity and quality of surface run-off;
- assess impacts on immediate marine environments (Clear Water Bay);
- review and assess construction methods especially proposals to tunnel under the ridge, particularly with respect to potential impacts on the Country Park; and
- assess adequacy of measures to reinforce and/or enlarge drainage channels within the Country Park in terms of effectiveness and acceptability.

6.3 Deliverables

- EIA of changes in surface water regime, construction of watercourses and effects of surface run-off on the Country Park; and
- recommendations for on-going monitoring.

7.0 SURFACE WATER DISCHARGES FROM OPERATIONAL AREAS

7.1 Issues

- impact of discharges of surface water from operational areas.

7.2 Methodology

- review surface water management proposals and impacts of discharges in context of any design modifications. As stated in RQs (1st Round Questionnaire, 2.7.6), both groundwater and surface water discharges will meet the standards specified in Technical Memorandum: Standards for Effluents Discharged into Drainage and Sewerage Systems, Inland and Coastal Waters.

7.3 Deliverables

- revised EIA of operational surface water discharges; and
- recommendations for on-going monitoring.

8.0 HYDROGEOLOGY

8.1 Issues

- impacts on groundwater regime of excavation proposals; and
- reduced risks to groundwater quality, since GVL's proposed liner offers greater degree of protection than the conceptual design.

8.2 Methodology

- obtain groundwater monitoring results and any other available information on the hydrogeological regime from EPD;
- review and assess baseline and predicted groundwater regime, including data from Wallace Evans Asia (WEA) site investigation;
- assess reduced risk of liner leakage on the aquifer and unsaturated zone (compared to conceptual design);
- assess the potential for both "pollution incidents" and "chronic pollution"; and
- particular regard will be made to impacts on the Country Park both in terms of groundwater levels and groundwater quality.

8.3 Deliverables

- report on WEA's further investigations with regard to risks to/potential impacts on groundwater and interpretation of environmental implications;
- report on present and predicted hydrogeological regimes (particularly with respect to impacts on the Country Park); and
- report on mitigation measures proposed.

8.4 Notes

- the GVL liner design affords a considerably greater degree of protection to the site than the conceptual design proposals, and the existing TKO Landfill. The GVL liner design is fixed unless environmental monitoring during the operational phase identifies problems.

9.0 MARINE DISCHARGES

9.1 Issues

- impact of reclamation plan/construction materials on marine water quality.

9.2 Methodology

- obtain marine water quality data from EPD;
- investigate quality of seawater which will be impounded;
- assess impacts on marine water quality. As noted in Section 7.2 above, both groundwater and surface water discharges will meet the standards specified in Technical Memorandum: Standards for Effluents Discharged into Drainage and Sewerage Systems, Inland and Coastal Waters;
- assess potential of reclamation/construction materials to impact on marine water quality, given existing pollutant levels;
- assess potential impacts of liner leakage on marine water quality; and
- investigate need for further elements to be included in the EMP.

9.3 Deliverables

- report to GVL on implications regarding discharge consents;
- SEIA section on impacts and mitigation measures; and
- recommendation for amendments/additions to the EMP.

10.0 LANDSCAPE AND ECOLOGY

10.1 Issues

- feasibility and practicality of proposed final landscaping plan; and
- impacts on flora and fauna.

10.2 Methodology

- review all existing baseline information, and receive results of initial baseline flora and fauna survey from Woodward Clyde, if available;
- review and assess proposed landscaping measures;
- assess and report the design of the landscape planting trials;
- review suitable materials for use as topsoil supplements / replacements and design testing programme;
- assess impacts of the project on flora and fauna, with particular emphasis on the Country Park, and considering impacts of the introduction of alien species and vermin; and
- assess management of the planting.

10.3 Deliverables

- report assessing practicality of landscape proposals;
- ecological impact assessment;
- recommendations for protocol for further monitoring of flora and fauna;
- recommendations for restoration and aftercare; and
- recommendations for ongoing landscape monitoring;

10.4 Notes

- EPD has specifically requested monitoring of flora and fauna. This element of work will be undertaken by the Monitoring Consultant, Woodward Clyde.

11.0 VISUAL IMPACT

11.1 Issues

- impact of rock cut slopes; and
- impacts to Country Park.

11.2 Methodology

- review rockface construction proposals and timing;
- establish overall visibility of site and define zone of visual influence;
- identify critical receptors and analyse their views of the site in terms of distance zones, dominant elements and impacts of views;
- assess visual impact of all stages of the project by analysing the effect on the critical views identified; quantify significance of impacts; describe how phasing designed to minimise visual impact (RQs 1st Round Questionnaire, 2.10.4-6, 2nd Round Questionnaire, 2.7.5);
- assess any visual impact on the Country Park in the same way; and
- assess potential mitigative measures (such as hydroseeding soil slopes) and evaluate their likely effectiveness.

11.3 Deliverables

- visual analysis and impact assessment;
- visualisations of development at different stages of its life from key receptors; and
- proposals for mitigative works.

11.4 Notes

- the visual impact of the development is currently considered a key issue by EPD. However, the scope of mitigation measures available is limited by the phasing design which has already been fixed, following agreement between GVL and EPD; and
- the visual assessment will be separate and distinct from the landscape work since it is concerned with the effects on individual "receptor groups" rather than the landscape in

general. It is proposed, however, that the landscape design be reviewed as the visual assessment nears completion in order to identify whether modifications can be made to further mitigate any significant adverse visual impacts.

12.0 TRAFFIC

12.1 Issues

- impact of both vehicular and marine traffic during periods of "exceptional waste input";
- viability of marine transport option; and
- impacts of emergency operational regimes.

12.2 Methodology

- discuss issues with EPD before commencing work, to define "exceptional waste input";
- review existing traffic assessment in context of "exceptional waste input" (with particular emphasis given to impacts on Tseung Kwan O urban development);
- review traffic growth predictions, and assess whether road capacity may limit input rates;
- review scope for importing waste by sea;
- assess stockpiling and emergency operational requirements of "exceptional waste inputs" in terms of environmental implications and nuisance parameters; and
- assess cumulative effect of traffic generated by SENT in conjunction with traffic generated by adjacent developments.

12.3 Deliverables

- EIA of traffic and operational impacts of "exceptional waste input" scenario.

12.4 Notes

- SENT site may become landlocked by adjacent reclamation and development removing the possibility of marine waste transportation; and
- "exceptional waste input" scenario to be defined during early discussions with EPD.

13.0 ADJACENT DEVELOPMENTS

13.1 Issues

- effect of incompatible adjacent developments being approved, which are potentially sensitive to threshold emissions.

13.2 Methodology

- review and assess land use and development plans, and existing planning applications, to identify any developments potentially sensitive to threshold emissions.

13.3 Deliverables

- report on current planning issues and implications to GVL; and
- identification of adjacent developments sensitive to threshold emissions to include in SEIA.

COMMENTS	RESPONSES
Reference : EP 20/03/184W	
1. FPG	
Section 2.0 Waste Recycling	
i) It appears that the emphasis of the 'Waste Recycling' proposed by the Contractor is likely to be concentrated on recycling of construction wastes (please refer to section 2.2 of the proposal).	The section of the SEIA on recycling will concentrate on construction waste recycling and the proposed Brini plant, although more emphasis will be given to construction wastes since the Brini proposals are only outline at this stage. A more detailed assessment of the Brini plant will be included in the CAP if GVL decide to install the plant.
ii The Government (mainly, SPEL, S for W, EPD and CED) has been discussing with the HKCA on the disposal of construction waste in Hong Kong environment and it was acknowledged that on-site sorting is a cost-effective means to handle construction waste, and an intermediate sorting plant will be set up to provide a practical alternative to these sites where on-site sorting is difficult due to physical site constraints. A construction waste management strategy paper is now being finalized. Therefore, the Green Valley Landfill Ltd's proposal to establish Hong Kong policy on construction wastes under a SEIA study is unacceptable.	EPD has misunderstood our intentions here. We are not intending in any way to define EPD policy, rather ascertain the current EPD position. This has been achieved by our meeting with S·H Wong, 7th September.
iii) The SEIA on recycling of construction waste should be divided into two parts, one for Type I waste containing less than 20% by volume of inert materials, and the other part for Type II waste containing more than 20% by volume of inert materials.	Agreed.

COMMENTS		RESPONSES
2.	**WPG**	
a)	Section 3.0 'Gas Collection and Utilization'	
i)	WPG has no particular comment to make on the scope of SEIA from the landfill gas utilization point of view.	Fine.
ii)	However, as mentioned in Section 3.2 (second bullet point), AE is to review and assess impacts of gas flaring plant and utilization plant (for preferred option). Regarding the preferred option of utilization plant, if the preferred option is selected only based on environmental appraisal, it may not necessarily be the same preferred option judging from the ground of economic assessment which is outside the scope of the SEIA, as mentioned in Section 3.4 (last bullet point). In view of the above, it is recommended that the preferred option be selected by taking into consideration both factors of environmental appraisal and economic assessment.	This is the approach being taken. Part of this section will describe how GVL has selected the gas utilisation plant, based on both economic and environmental considerations.
3.	**APG**	
i)	The scope of the SEIA presented by the consultants is considered acceptable. However APG has the following specific comments on the details of the SEIA.	Fine.

COMMENTS	RESPONSES
ii) Sections 3.2 and 5.2. APG has no objection in principle for the Consultants to use ISCST model in evaluating the air pollutants impacts. In the assessment, the consultants should take into account the background air pollutants concentrations and evaluate the cumulative air impacts. In comparing whether the predicted air impacts are acceptable, the local standard to be used should be in Hong Kong Air Quality Objective (HKAQO). For odour and air pollutants that are not in the list of the HKAQO, the Consultants should propose established international air quality standards and seek agreement from EPD (APG) for the use of the proposed standards.	This is accepted; our proposed standards for odour and other parameters not covered by the HKAQO will be submitted to APG for approval. Methodologies for assessing odour and VOCs will be agreed with APG. Meeting has been set for Friday 15 October 1993.
iii) Section 2.2 and 4.2. To assess the dust impact from the construction, operation and recycling activities, APG recommends the consultants to use the Fugitive Dust Model (FDM) and one year meteorological data obtained from the nearest meteorological station.	Modelling of dust levels is outside the scope of the SEIA.
iv) Section 5.2. For ammonia emissions from leachate treatment plant, their recommended standard is the concentration of ammonia in ambient air at immediately outside the landfill site boundary not to exceed 0.2 mg/m^3 (30 minute average).	Confirmed.
v) Section 12.2. The cumulative traffic emission impact on the environment during the periods of 'exceptional waste input' should also be addressed. Caline 4 model is suitable for the assessment.	Modelling exceptional waste traffic emissions is outside the scope of the SEIA. The CEIA included extensive traffic emissions modelling (using the PREDCO rather than the CALINE 4 model), and the conclusion was that the effect of SENT traffic is relatively low. Since these traffic flows would only occur in very rare circumstances, and for limited durations, we do not believe modelling is necessary.
vi) The Consultants are requested to discuss and agree on the air quality impact assessment methodology with EPD (APG) beforehand. Our technical contact is Mr H.L. Ching at 5946317.	

COMMENTS		RESPONSES
4.	**LPG**	
a)	Section 5.0 'Leachate Production and Management'	
i)	It is stated in Section 5.1 that the impact of treated leachate discharges from TKO STW would be assessed by EPD. However, the Consultant's Response to Question 6.1 indicates that the impact assessment will be included in SEIA. LPG considers that the impact of such discharge <u>must be assessed in the SEIA</u>.	The SEIA will incorporate a desk study review of leachate from TKO STW.
5.	**WSP**	
a)	Section 5.0 'Leachate Production and Management'	
i	WSP believes that the impact of "treated leachate discharge to the marine environment" was previously assessed in the report, "TKO Sewage Treatment and Disposal - Environmental Assessment, May 1993". The Consultants should examine this previous study when reviewing the fate and impact of the treated leachate.	We believe the report referred to here is in fact the May 1992 Mott MacDonald EA. Please advise whether this is correct.
b)	Section 6.0 'Surface Water Runoff'	
i)	WSP has no major comment on the scope of SEIA but have a query regarding the surface water runoff. The scope of SEIA for this part seems to cover the impacts on Clear Water Bay only. Will there be any surface water directed to Junk Bay? If positive, the impacts on the Junk Bay marine environment should also be assessed.	The impacts of discharges to the adjacent waterbodies will be covered following finalisation of the drainage proposals.
6.	**SAG**	
a)	Section 11.0 'Visual Impact'	

COMMENTS		RESPONSES
i)	Please add 'recommendations for ongoing monitoring and control' to sub-section 11.3.	Recommendations for monitoring will comprise determination of the effectiveness of mitigation measures.
7.	**LCO (TE)**	
	They have no comment on the scope of SEIA except that they are not sure whether the SEIA will address the key issues during construction and operation phases.	Construction and Operational phases will be covered, where appropriate.
8.	**PMG**	
i)	Section 3.4, 1st bullet point - the SEIA should be updated when the detailed design information on gas management system and site power facility is available.	Part of the CAP, not the SEIA.
ii	Section 6.1, 2nd bullet point - as surface water will also be discharged to Tseung Kwan O Bay and Joss House Bay, the impacts of surface water on the two marine environment should also be addressed.	Confirmed. See A.5 (b) above.
iii)	Section 11.4, 1st bullet point - in accordance with Specification Clause 1.7.3.3, the Design in respect of phasing shall be subject to approval by the Country Park Authority.	Confirmed.
B.	**Comments from Various Departments**	
1.	**AFD**	
	Please include recommendations for mitigation measures under section 10.3.	Confirmed.
2.	**DPO/SK & TKO**	
	They suggest that the financial viability assessment should be included in the waste recycling report and gas collection and utilisation report because their operation in practice will very much depend on the financial situation.	Economic aspects are outside the scope of our work and we do not believe they should form part of the SEIA, as specified in section 2.4 bullet 3 of the scope.

COMMENTS	RESPONSES
3. D of Industry	
Since the Tseung Kwan O Industrial Estate and some other industrial land are adjacent to the SENT Landfill, they would like to be kept informed of the development of the study, in particular, the assessment on 'Adjacent development'.	Confirmed subject to EPD PMG approval.
4. DSD	
They wish to be kept informed of the findings of the ESMG especially on leachate management and surface water runoff doing the course of the study.	Confirmed subject to EPD PMG approval.

Calculation of Emission Parameters

Appendix 2

APPENDIX 2 CALCULATION OF EMISSION PARAMETERS

A.2.1 Emissions From the Leachate Treatment Plant

From GVL's "SENT Leachate Treatment Facility (LTF) 50% Design Submittal" (Ref 1), the catalytic oxidizer will be designed to destroy ammonia in an air steam. In the worst case, the catalytic oxidizer will receive off-gases from three air strippers. The off-gases from the air strippers will be concentrated in a zeolite concentrator unit with the concentrated stream being sent to the catalytic oxidizer. The burner may use No.2 diesel fuel and heat the off-gas from the strippers to the required catalyst inlet temperature.

Stack Parameters

From the design calculations of the Oxidizer as contained in the above report (Page 14 of 15), the vent gas temperature
= 127 °F
= 53 °C

Mass flow rate of the vent gas
= (76,395 + 205,217) kg/hr
= 281,612 kg/hr

At 53 °C, density of air (dry) approximately
= 1.088 kg/m^3

Volume flow of vent gas
= 281,612/1.088 m^3/hr
= 258,906 m^3/hr
= 71.9 m^3/s

At present, details of the vent have not been determined. Assuming that the height of the emission point is 10m A.G. and with 2m diameter, the corresponding efflux velocity
= 71.9/ $(2/2)^2\pi$ m/s
= 22.9 m/s

Pollutant Emission Parameters

The maximum and average ammonia loadings are 268.6 kg/hr and 88.2 kg/hr respectively and the minimum requirement of ammonia destruction is 97%. Hence the maximum emission rate of ammonia from the vent
= 268.6 kg/hr x 3%
= 8.06 kg/hr
= 2.24 g/s

Fuel consumption (#2 distillate oil)
= 5.12 kg/hr
= 512 kg/hr / 800 kg/m^3 (density)
= 0.64 m^3/hr

From USEPA, Compilation of Air Pollutant Emission Factors (AP-42, 1985), emission factor of SO_2
= 17S kg/m^3 where S is the % by weight of the sulphur content
= (17) (0.5) kg/m^3
= 8.5 kg/m^3

Therefore, emission rate of SO_2
= (8.5) (0.64) kg/hr
= 5.44 kg/hr
= 1.51 g/s

Similarly, emission factor of NO_x
= 2.4 kg/m^3

Emission rate of NO_x
= (2.4) (0.64) kg/hr
= 1.536 kg/hr
= 0.43 g/s

A.2.2 Emissions From The Gas Treatment Plant

Initially, one (1) enclosed gas flare will be installed. It is a John Zinc Co. Model ZTOF 11x50 ft, 3.5m diameter x 15.2m high with 120 MMBTU Total Rated Capacity (or equal). Flares of this nature are extremely efficient in terms of thermal destruction of landfill gas and associated volatile organic compounds (VOCs). Emissions tests have never reported less than a 98% destructive efficiency of VOC's in a John Zinc, Co. enclosed flare.

Under the ultimate condition, the calculated exhaust velocity is 13.17 m/s and the gas temperature is 870 °C and is based upon a stack internal diameter of 3.33m.

In the event that a supplemental enclosed flare is required at a future date, it will be sized according to the actual extracted gas flow rates. In the present modelling, two enclosed gas flares and with the above size each have been assumed to simulate the "Worst Case" situation. Emissions from each of the flares were estimated using the information available for a smaller flare which is about half the size of the above. Again this represents a "Worst Case" estimate based on available data.

The calculated emission rate of NO_x
= 5.68 kg/hr
= 1.58 g/s

Emission rate of SO_2
= 3.16 kg/hr
= 0.88 g/s

A.2.3 Gas Utilisation Plant

The major air pollutant emitting plant will consist of turbines and fuel gas compressor systems. The Gas Turbine, the "Centaur" Model GSC 4500 is 3.3MW simple cycle combustion turbine which is manufactured by Solar Turbines Incorporated.

Emission from each unit the are guaranteed by the manufacturer less than 4 kg/hr (1.11 g/s) nitrogen oxides (NO_x). Actual measurements from facilities in the United States indicated emissions much lower than the guarantee are achievable.

Based on previous measurements, very low sulphur emissions are expected (less than 1.4 kg/hr, i.e. 0.04 g/s of SO_2).

Under full-load conditions, manufacturer's data indicates an exhaust temperature of 450 °C. Considering a stack with 1.2m internal diameter, a velocity of 32.72 m/s is realised. The estimated stack height is about 11 m above ground level.

A total of up to four units might be required during the peak year of operation.

The stack emission parameters are summarized in Table A.2.1.

Table A.2.1 Summary of Emission Parameters

Item	Qty'	Emission Parameters for Each Stack						
		Diameter (m)	Height (mA.G.)	Gas Velocity (m/s)	Gas Temp' (°C)	Emission Rates (g/s)		
						NH_3	SO_2	NO_x
Catalytic Oxidizer (Leachate Treatment Facility)	1	2	10	22.9	53	2.24	1.51	0.43
Enclosed Flare (Landfill Gas Treatment Plant)	2	3.33	15.2	13.17	870	-	0.88	1.58
Gas Turbine & Compressor (Landfill Gas Utilisation Plant)	4	11	11	32.72	450	-	0.39	1.11

REFERENCES

1. Rust Environment and Infrastructure (1993). Design Memorandum: SENT Landfill leachate Treatment Facility.

Formation Material & Stockpile Balance

Appendix 3

APPENDIX 3 SITE FORMATION MATERIAL AND STOCKPILE BALANCE

The Development Phase	MATERIALS AVAILABILITY: Soil Utilisation: Availability: Total Bank Volume (cu m)	Soil Utilisation: Availability: Total Fill Volume (cu m)	Soil Utilisation: Utilised: Total Fill Volume (cu m)	Rock Utilisation: Availability: Total Bank Volume (cu m)	Rock Utilisation: Utilised: Total Bank Volume (cu m)	Rock Utilisation: Utilised: Total Fill Volume (cu m)	Marine Borrow Area (cu m)	SITE DEVELOPMENT CONSTRUCTION REQUIREMENTS: Soil Requirements: Intermediate/ Daily Cover Volume (cu m)	Soil Requirements: Final Restoration Volume (cu m)	Rock Requirements: Land Site Formation Volume (cu m)	Rock Requirements: Marine Site Reclamation Volume (cu m)	Rock Requirements: Marine Site Formation Volume (cu m)	Rock Requirements: Drainage Layer Volume (cu m)	STOCKPILE VOLUMES: Stockpile: Soil Bank Volume (cu m)	Stockpile: Rock Bank Volume (cu m)
1 (Initial Works)	480,634	471,021	441,021	911,878	395,000	364,746	(2,000,000)	N/A	N/A	83,210	584,798	347,602	64,000	30,000	0
					—	—									
					48,000	64,000									
				Sub Totals	443,000	526,7651									
2	568,021	848,701	878,701	977,016	454,000	848,340	N/A	424,000	145,000	82,048	646,340	550,566	42,000	549,000	0
					263,000	330,901									
					32,000	42,000									
				Sub Totals	748,000	1,021,241									
3	N/A	N/A	921,172	N/A	1,298,000	1,861,604	N/A	618,000	260,000	43,172	1,861,804	896,247	73,000	0	0
					711,000	996,247									
					68,000	73,000									
				Sub Totals	2,081,000	2,919,861									
4	1,290,000	1,265,172	334,000	3,066,884	804,000	863,163	N/A	244,000	80,000	N/A	863,183	418,967	41,000	334,000	0
					333,000	418,987									
					31,000	41,000									
				Sub Totals	988,000	1,323,140									
5	N/A	N/A	274,000	N/A	—	—	N/A	495,000	145,000	N/A	N/A	544,947	34,000	0	0
					433,884	544,947									
					300,000	400,000									
				Sub Totals	733,884	944,947									
6	N/A	N/A	N/A	N/A	—	—	N/A	226,000	80,000	81,300	N/A	217,000	40,000	0	0
					246,000	308,408									
					259,000	346,000									
				Sub Totals	505,000	654,409									
7	267,229	274,000	N/A	1,301,994	—	—	N/A	586,000	160,000	20,528	N/A	155,417	36,000	0	72,000
					141,000	175,945									
					584,000	781,000									
				Sub Totals	725,000	956,945									
8	N/A	N/A	589,000	N/A	72,000	(90,000)	N/A	688,000	N/A	25,820	N/A	N/A	122,000	IMPORT	REQUIRED
9	N/A	N/A	181,000	N/A	N/A	N/A	N/A	181,000	N/A	N/A	N/A	N/A	N/A	IMPORT	REQUIRED
10	N/A	N/A	212,000	N/A	N/A	N/A	N/A	212,000	N/A	N/A	N/A	N/A	N/A	IMPORT	REQUIRED
11	N/A	N/A	377,000	N/A	N/A	N/A	N/A	377,000	N/A	N/A	N/A	N/A	23,000	IMPORT	REQUIRED
12	N/A	N/A	774,000	N/A	N/A	N/A	N/A	504,000	270,000	N/A	N/A	N/A	N/A	IMPORT	REQUIRED
13	N/A	N/A	559,000	N/A	N/A	N/A	N/A	340,000	210,000	N/A	N/A	N/A	N/A	IMPORT	REQUIRED
14	N/A	N/A	487,000	N/A	N/A	N/A	N/A	137,000	360,000	N/A	N/A	N/A	N/A	IMPORT	REQUIRED
TOTALS	2,823,884	2,943,894	6,027,894	6,257,772	8,267,772	8428,230	(2,000,000)	4,842,000	1,710,000	356,183	3,827,895	3,137,864	474,000		

NOTES:
1) The available bank volume for the initial works includes 171,000 cubic metres from Tseung Kwan O.
2) Total available volume represents the bulk volume excavated by the end of a phase. Bank volume utilized is the amount excavated and placed as per the development phase construction requirements.
3) The placed soil fill is the excavated bank volume multiplied by a 2% shrinking factor as shown in APPENDIX 33.9-B.
4) The placed rock fill is the excavated bank volume multiplied by building factors shown in APPENDIX 33.9-B:
Marine site reclamation (<2.5 mPD) bank volumes are multiplied by a 43% building factor.
Marine site formation (<2.5 mPD) bank volumes are multiplied by a 26% building factor.
Land site formation and drainage layer bank volumes are multiplied by a 34% building factor.
5) Rock is crushed to meet the gradation requirements of the drainage layer and for intermediate, daily, and final restoration soil volumes when the available on-site soil volume is exhausted.
6) Stockpile volumes are computed as bank material volumes.

Existing Water Quality - Junk Bay WCZ, Compliance with Water Quality Objectives

Appendix 4

APPENDIX 4 EXISTING WATER QUALITY - JUNK BAY WCZ, COMPLIANCE WITH WATER QUALITY OBJECTIVES

A.4.1 Introduction

Junk Bay was declared a water control zone (WCZ) in August 1989. Water quality in Junk Bay WCZ was satisfactory and the majority of the objectives were achieved during 1991, the annual mean level of inorganic Nitrogen exceeded the WQO at two of the 3 stations within Junk Bay.

The marine water quality programme adopted and maintained by EPD since 1989 includes 66 water quality monitoring stations in the Hong Kong coastal waters and 3 of these stations are located within or close to the Study Area. These sampling points are shown in Figure A.4.1. At each of the monitoring stations, a range of water quality parameters are measured and these are listed in Table A.4.1. Water samples are collected and analyzed on a monthly basis and the results obtained. A summary of the results for 1991 is given in Table A.4.2.

A.4.2 General Oceanography

The coastal waters of Hong Kong are influenced by the fresh water flow of the Pearl River and the ocean current from the South China Sea. As a result, there is a general shift from estuarine to oceanic conditions in a west to east direction. The effect of the Pearl River flow is more pronounced during the wet seasons. During the wet seasons, the salinity and pH of the surface waters are lower in the western waters than in the east.

The oceanography of the marine waters, especially the inshore waters, is also affected by other factors such as stream run-off and coastline shape. Due to the indented nature of the coastline, the current in an enclosed bay, such as Junk Bay is weak and the turbulent mixing of the water body within the bay is poor. During the summer, surface waters are heated up rapidly while the bottom water remains cool. This, as well as the influx of fresh water from the Pearl River results in the stratification of water layers, which further reduces mixing in the water column. Warm, surface water run-off also contributes to the stratification in inshore waters. In open marine waters, currents are strong and the waterbody is better mixed with only slight stratification.

Temperature

The surface sea temperature in Hong Kong reflects the seasonal variation in air temperature. Owing to the intrusion of cool oceanic currents from the South China Sea, cooler bottom waters are detected in the Southern Waters.

In winter, the strong northeast monsoon causes good turbulent mixing within the water column and a homogeneous waterbody is found over the coastal waters of Hong Kong. No temperature stratification in the water column is found at this time of the year.

Salinity

Due to the influence of the Pearl River, the coastal waters of Hong Kong showed prominent geographical and seasonal variations in salinity. Wider ranges are recorded in the western waters with a decreasing range towards the east. In summer, low salinity levels are usually recorded. In winter, the influence of the Pearl River is diminished and marine waters are generally homogeneous with salinity approaching that of oceanic water (33 to 34 ppt).

pH

The pH in the coastal waters of Hong Kong ranges from 7.6 to 9.3. The pH levels are lower in the west and increase towards the eastern waters. The pH pattern reflects the shift from estuarine to oceanic conditions from west to east.

The pH values are also affected by the activities of organic decomposition and algal photosynthesis in the water. A considerable amount of carbon dioxide, which lowers the pH of water is generated during to the decomposition of organic matter. Therefore, in Victoria Harbour where organic pollution is serious, pH values are low (annual mean below 8.3).

A.4.3 Transparency And Light Penetration

The transparency and light penetration of seawater are affected by suspended particles such as clay and silt, finely divided organic and inorganic matter, plankton and other microscopic organisms. The parameters which are used to indicate these properties include Secchi disc depth, turbidity and suspended solids content. The greater the Secchi disc depth, the more transparent the surface layer of the water is.

Inner Junk Bay exhibits smaller Secchi disc depths (annual mean 2.4m), and hence lower transparency than Outer Junk Bay (annual mean of 2.6m). The lower transparency found in inner Junk Bay is mainly due to the eutrophic conditions present with consequent active algal growth.

Turbidity and Suspended Solids

Turbidity in water is caused by the presence of suspended matter. During 1991 Inner Junk Bay had a mean Turbidity of 3.1, Outer Junk Bay was slightly higher with a mean value of 3.6. Outer Junk Bay enjoys a higher amount of flushing than Inner Junk Bay and consequently experienced lower annual mean SS levels.

A.4.4 Organic Pollution

When organic matter is discharged into marine water, a substantial portion of it decomposes. During this process, oxygen is consumed, lowering the dissolved oxygen content of the water. Thus the dissolved oxygen content reflects the level of organic pollution in a waterbody.

Dissolved oxygen

It is noted that the waters of Junk Bay exhibit conditions of supersaturation of dissolved oxygen, in 1991 the DO reached maximums of 140% in inner Junk Bay. Super-saturation of dissolved oxygen, caused by the active growth of algae, indicates eutrophication. While algal blooms result in high dissolved oxygen content in water, oxygen depletion occurs at night and when the algae die and decay. This phenomenon indicates a water pollution problem.

Biochemical Oxygen Demand

Organic pollution was detected in inner Junk Bay where relatively high BOD levels, a maximum of 3mg/l were recorded. Lower BOD levels were recorded at Outer Junk Bay, a maximum of 2mg/l was attained.

A.4.5 Bacterial Conditions

Escherichia coli

The bacterial conditions of much of the coastal waters of Hong Kong, using the indicator of *E.coli*, were unsatisfactory in 1991, with most of the marine waters affected by faecal pollution.

E.coli levels in Junk Bay have decreased since the domestic sewage loadings were diverted outside of the WCZ by a submarine outfall. Annual geometric means of *E.coli* for Junk bay are below 400 *E.coli*/100ml, lower levels were recorded in inner Junk Bay.

A.4.6 Eutrophication

Eutrophication can be simply defined as nutrient enrichment that results in a high biological productivity in a waterbody. The increase in biological productivity may lead to algal blooms. When an algal bloom declines, the decay of the dead microscopic algae (phytoplankton) consumes oxygen, and thus depletes the water of oxygen. Under serious conditions, there waterbody can become anoxic, leading to the die-off of the aquatic organisms. Therefore, when a waterbody becomes eutrophic, the water quality can deteriorate to a very poor state.

Nutrients

Junk Bay WCZ was one of a number of marine areas including the Eastern Buffer zone exhibited high eutrophic potential with annual mean inorganic nitrogen levels in the range 0.1 to 0.3mg/l. In Junk Bay there were peaks of inorganic nitrogen above 4.5mg/l recorded at all water quality stations, which shows the high eutrophic potential exhibited by this area.

Chlorophyll-a

The measurement of chlorophyll-a, which is the biomass indicator of microscopic algae (phytoplankton), can indicate the intensity of algal blooms and can reflect the extent of eutrophication.

In general a mean chlorophyll-a level of 10 μg/l can be taken as an acceptable limit for eutrophication, above 10 μg/l the eutrophic state is considered unacceptable. Junk Bay has acceptable levels of chlorophyll-a with an annual mean ranging between 1.02 and 2.43μg/l.

Red Tides

Red tides are created by the discolouration of seawater brought about by the rapid growth in numbers of certain microscopic algae (dinoflagellates). Red tides are harmful to marine life and can be hazardous to man. Some red tides are toxic and the toxins produced can kill fish. While shellfish are unaffected, they can accumulate the toxins.
There has been a general decline in the number of red tides in Hong Kong due to the successful implementation of the WPCO and Livestock Waste Control Scheme. However, there are still isolated incidents and during 1991 fourteen red tides occurred through out the territory, of which none occurred inside Junk Bay.

Table A4.3 gives the key Water Quality Objectives for Junk Bay WCZ.

Table A4.1 Summary of Marine Water Quality Determinands

Determinands	Purpose	Sampling Depth
1. Physico-chemical		
a) D.O.	to study the oceanographic conditions of marine water.	profiling
Salinity		profiling
Conductivity		profiling
Temperature		profiling
pH		S, M, B
b) Secchi disc depth	to study the transparency and light penetration of marine water which relate to the appearance and aesthetic value of a waterbody.	S, M, B
Turbidity		S, M, B
SS		
c) BOD_5	to study the organic pollution of marine water.	S, M, B
2. Bacterial Faecal coliform *Escherichia coli*	to study the bacterial condition of marine water and to indicate faecal pollution.	S, M, B
3. Nutrients and Chlorophyll NO_2-N, $NO_3$0N, NH_3-N, TKN (filtered and unfiltered) ortho PO_4-P, Total PO_4-P (filtered and unfiltered) SiO_2-Si, Chlorophyll-a phaeo-pigment	to study the eutrophic condition of marine water as a consequence of pollution by sewage, livestock wastes, industrial wastes and stream/urban runoff.	S, M, B

Note : S - 1 m below water surface
M - mid-depth of water column
B - 1 m above seabed

Table A4.2 Summary Statistics of 1991 Water Quality of Junk Bay

Determinand		Inner Junk Bay	Outer Junk Bay	
		JM2	JM3	JM4
Temperature (°C)	Surface	22.3 (16.1 - 26.8)	22.1 (16.1 - 26.9)	22.0 (15.9 - 26.8)
	Bottom	21.9 (15.8 - 25.9)	21.1 (15.8 - 25.2)	21.0 (15.8 - 25.2)
Salinity (ppt)	Surface	31.6 (27.6 - 33.2)	31.6 (27.3 - 33.3)	31.7 (27.5 - 33.4)
	Bottom	31.8 (28.1 - 33.6)	32.6 (31.5 - 33.4)	32.8 (31.5 - 33.7)
D.O. (% Saturation)	Surface	92 (69 - 140)	87 (54 - 130)	89 (56 - 132)
	Bottom	82 (47 - 103)	70 (33 - 84)	75 (47 - 88)
pH value		8.1 (7.6 - 8.4)	8.1 (7.9 - 8.3)	8.1 (7.9 - 8.4)
Secchi disc (m)		2.4 (1.4 - 4.8)	2.6 (1.6 - 4.0)	2.6 (1.5 - 4.0)
Turbidity (NTU)		3.1 (1.1 - 4.8)	3.6 (1.4 - 9.8)	3.6 (1.3 - 7.6)
S.S (mg/l)		6.6 (1.0 - 16.3)	4.7 (2.0 - 9.5)	4.5 (2.0 - 14.2)
BOD_5 (mg/l)		1 (<1 - 3)	1 (<1 - 2)	1 (<1 - 2)
Inorganic Nitrogen (mg/l)		0.34 (0.18 - 0.51)	0.34 (0.16 - 0.57)	0.26 (0.12 - 0.42)
Total N (mg/l)		0.76 (0.47 - 1.67)	0.74 (0.50 - 1.74)	0.63 (0.25 - 1.42)
PO_4-P (mg/l)		0.03 (0.01 - 0.05)	0.04 (0.02 - 0.05)	0.03 (0.02 - 0.05)
TP (mg/l)		0.10 (0.05 - 0.20)	0.11 (0.05 - 0.22)	0.10 (0.04 - 0.22)
Chlorophyll-a (μg/l)		2.43 (0.20 - 10.0)	1.95 (0.20 - 6.77)	1.02 (0.20 - 3.40)
E.coli (no./100ml)		30 (6 - 180)	82 (19 - 370)	400 (110 - 800)

1. Except as specified, data presented are depth averaged data
2. Data presented are annual arithmetic means except for *E.coli* data which are annual geometric means
3. Data enclosed in brackets indicate ranges
4. Source: Marine Water Quality in Hong Kong for 1991, EPD

Table A4.3 Key Water Quality Objectives, Junk Bay Water Quality Control Zone

Determinand	Objective	Part(s) of Zone
E.coli	annual geometric mean not to exceed 610/100ml	secondary contact recreation subzone, fish culture zones
D.O. within 2m of Bottom	not less than 2mg/l for 90% of the samples	marine waters
Depth Average D.O.	not less than 4mg/l for 90% of the samples	marine waters except fish culture zones
	not less than 5mg/l for 90% of the samples	fish culture zones
Ph value	to be in the range 6.5 to 8.5, change due to waste discharge not to exceed 0.2	marine waters except bathing beach subzones
Salinity	change due to waste discharge not to exceed 10% of natural ambient level	whole zone
Temperature Change	change due to waste discharge not to exceed 2°C	whole zone
Suspended Solids	waste discharge not raise the natural ambient level by 30% nor cause the accumulation of SS which nay adversely affect aquatic communities	marine waters
Toxicants	not to be present at levels producing significant toxic effects	whole zone
Unionised ammonia	annual mean not to exceed 0.021mg/l	whole zone
Nutrients	not to be present in quantities that cause excessive algal growth	marine waters
	annual mean depth average inorganic nitrogen not to exceed 0.3mg/l	

A.4.7 Marine Sediment Quality

There are a number of sources of data concerning marine sediment quality within the Study Area, these are :

- EPD's annual report Marine Water Quality in Hong Kong (which includes details of the marine sediment monitoring programme and discussion of results);
- the Contaminated Spoil Management Study Report June 1991; and
- the previous SENT Landfill EIA Study carried out by Scott Wilson Kirkpatrick.

The information from the above sources is discussed below:

EPD's routine sampling programme in Hong Kong takes place at 54 selected monitoring stations with 3 close to the Study Area. The sediment characteristics are studied by measuring a range of pollution indicators which are listed in Table A4.4. Sediment samples are collected and analyzed at six monthly intervals.

Table A4.4 Summary of Bottom Sediment Determinands

A. Physio-chemical		B. Heavy Metals	
1.	Particle size fractionation	1.	Arsenic (As)
2.	Specific gravity	2.	Boron (B)
3.	pH	3.	Cadmium (Cd)
4.	Total solids (TS)	4.	Chromium (Cr)
5.	Total volatile solids (TVS)	5.	Copper (Cu)
6.	Total nitrogen (TN)	6.	Mercury (Hg)
7.	Total phosphorus (TP)	7.	Lead (Pb)
8.	Polychlorinated biphenyls (PCB)	8.	Zinc (Zn)
9.	Polycyclic aromatic hydrocarbons (PAH)	9.	Nickel (Ni)
10.	Cyanide (CN)	10.	Manganese (Mn)
11.	Total sulphide (S)	11.	Iron (Fe)
12.	Chemical oxygen demand (COD)		
13.	Total organic carbon (TOC)		
14.	Electrochemical potential (Eh)		

A.4.8 Summary of Sediment Quality Results

Table A4.5 shows a summary of the results of EPD's sediment sampling program for the Junk Bay area.

Table A4.5 Summary of EPD Marine Sediment analysis for Junk Bay

Determinand	Inner Junk Bay	Outer Junk Bay	Units
Eh - Electrochemical Potential	> -50	> -50	mv
TOC - Total Organic Carbon	1.5 → 2.0	1.5 → 2.0	% dry solids
TN - Total Nitrogen	1,000 → 2,000	1,000 → 2,000	mg/kg dry solids
TP - Total Phosphorus	400 → 600	400 → 600	mg/kg dry solids
Cr - Chromium	25 → 50	75 → 100	mg/kg dry solids
Cu - Copper	< 50	200 → 400	mg/kg dry solids
Zn - Zinc	100 → 150	> 250	mg/kg dry solids
Ni - Nickel	10 → 20	20→ 30	mg/kg dry solids
Pb - Lead	50 → 75	> 125	mg/kg dry solids
Hg - Mercury	0.6 → 0.9	0.9 → 1.2	mg/kg dry solids

Table A4.6 gives the class A, B and C limits, Target, Trigger and Action levels.

Table A4.6 Target, Trigger and Action Levels for Pollutants

Metal	Class Limits		
	A	B	C
Cadmium (Cd)	0.4	1.0	1.5
Lead (Pb)	35.0	65.0	75.0
Nickel (Ni)	20.0	35.0	40.0
Zinc (Zn)	75.0	150.0	200.0
Chromium (Cr)	25.0	50.0	80.0
Mercury (Hg)	0.2	0.8	1.0
Copper (Cu)	20.0	55.0	65.0

It can be noted that the sediments from Junk Bay, especially Outer Junk Bay, are heavily contaminated with copper, lead and zinc.

A.4.9 Contaminated Spoil Management Study

In the vicinity of the SENT site is a disused spoil dumping ground, Tseung Kwan O, Area 137 overlies part of the site. Data relating to this dumping ground has been obtained from the Contaminated Spoil Management Study (CSM). The results are summarized in Table A4.7.

The CSM study checked metallic contamination at 4 sampling station adjacent to the Study Area.

Table A4.7 Contaminated Data for Sampling Locations Adjacent to the Study Area

Metal →	Cu		Cr		Cd		Pb		Zn		Ni		Hg	
Site ↓	bulk	<63μm	bulk	<63μm	bulk	<63μm	bulk	<63μm	bulk	<63μm	bulk	<63μm	bulk	<63μm
100	34	48	17	23	.66	.66	45	56	115	122	22	24	.85	
101	39	-	19	-	.55	-	42	-	95	-	20	-	.10	.07
102	18	28	13	27	.57	.44	31	52	49	86	12	19	.71	
1	11	-	12	-	.50	-	35	-	73	-	15	-	.64	.33

Note Results expressed in mg/kg bulk sample and the < 63μm fraction.

For the all the samples taken it can be seen that the sediments can be classified as Class A material requiring no special precautions during dredging and disposal except for those which would normally be applied to minimise the effects of dredging on the environment. However site 100 shows elevated levels of mercury and falls within Class B levels, and so may require more specialised dredging and disposal methods.

Further sediment quality analysis was carried out during the EIA. Four drillholes were made into the seabed, five samples from four of the drillholes were submitted for analysis. The results are given below in Table A4.8.

Table A4.8 Results of Seabed Sediment Analysis for the SENT EIA

Metal	M1/a	M2/a	M3/a	M4/a	M4/b
Cadmium	<1	<1	<1	<1	3.5
Chromium	<1	7.0	7.6	4.54	<1
Copper	<1	<1	<1	<1	<1
Mercury	<0.05	<0.05	<0.05	<0.05	<0.05
Lead	<1	44	6.2	<1	11.5
Zinc	20.6	8.6	16.6	6.6	22.4

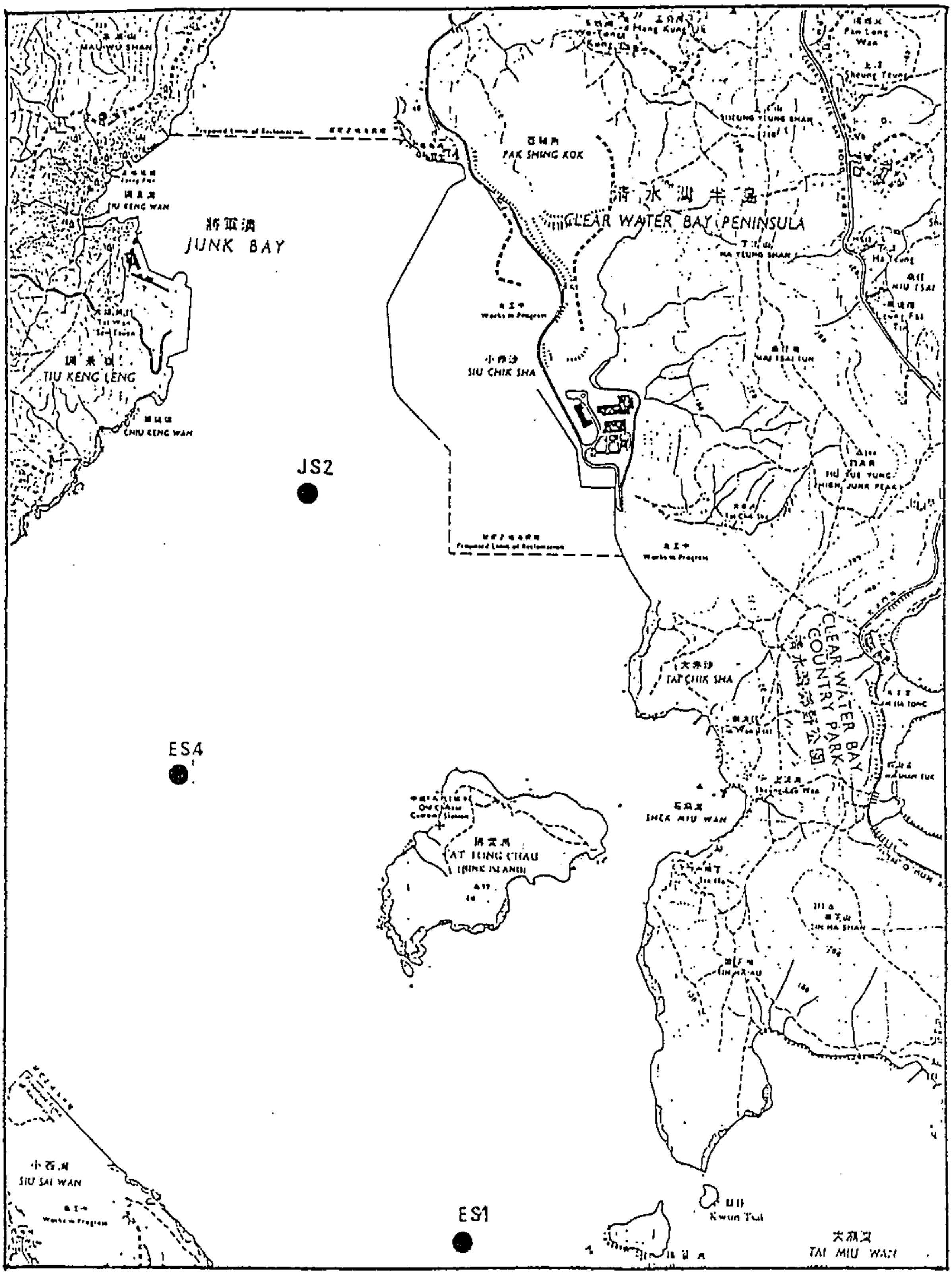
Source : SENT Landfill Study, Report R5; EIA, Key Issues Report. Scott Wilson Kirkpatrick

From the above results the majority of sediments are Class A, clean, sediments. However the results from drillhole M4/b show that there is Class C contamination of the sediment at this point with Cadmium.

Conclusions

The amount of contamination in the sediments is on the whole very low, with only a few 'hotspots' of heavy metal contamination recorded within the site boundary. Given this and the monitoring controls which will be enforced during the dredging works no significant impacts from the dredging are expected. A summary of the monitoring works to be carried out during dredging works is given below:

Determinand	Limit	Zone Applicable
D.O.	minimum of 70% of ambient value at both surface and bottom layers, subject to an absolute minimum value of 5mg/l at surface layer and 2mg/l at bottom layer	All monitoring stations
S.S.	maximum of 30% above ambient, and absolute maximum of 150mg/l	all monitoring stations more than 100m from site, 100m from dredging site
Turbidity, Nitrate, Zinc and Phosphorus	maximum of 30% above ambient values	all monitoring stations more than 100m from site



acer/ENVIRONMENTAL

FIGURE A4.1

EPD WATER QUALITY SAMPLING SITES